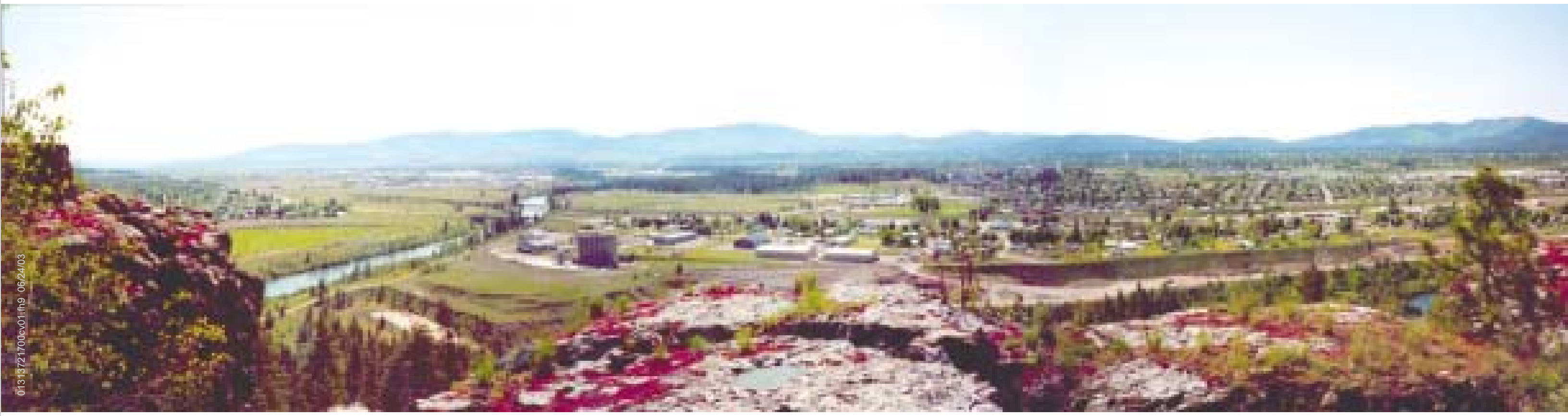
Report to
Spokane County and the
WRIA 55 and 57 Planning Unit
Spokane, WA

Little Spokane (WRIA 55) and Middle Spokane (WRIA 57) Watershed Planning
Phase II - Level 1 Assessment
Data Compilation and Preliminary Analysis



June 2003

Submitted by

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December 30, 2003

Spokane County ref: P2960
Golder ref: 013-1372

Spokane County Utilities Division
Mail Stop PWB-4
1116 W Broadway
Spokane, WA 99260

ATTENTION: Stan Miller, Program Manager, WQMP

RE: WRIA 55 AND 57 WATERSHED LEVEL 1 TECHNICAL ASSESSMENT

Dear Stan:

Enclosed are twelve copies of the Level 1 Technical Assessment for the Little and Middle Spokane watersheds (Water Resource Inventory Areas [WRIAs] 55 and 57). We believe that this Level 1 Assessment is the most comprehensive conducted in this state to date and was developed with the assistance of the WRIA 55/57 Planning Unit, and in particular, with significant assistance from yourself and Reanette Boese of Spokane County.

Although there are water resource management issues in need of solutions in these watersheds, members of the Planning Unit have individually demonstrated their willingness to work hard and cooperatively toward resolving them. It has been a pleasure to work with such a good Planning Unit, and we very much appreciate the opportunity to have conducted this work with you.

Sincerely,

GOLDER ASSOCIATES INC.

Chris V. Pitre, P.G.
Associate, Water Resources

cc: Bryony Stasney

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LITTLE SPOKANE (WRIA 55) AND MIDDLE SPOKANE (WRIA 57) WATERSHEDS

PHASE II – LEVEL 1 ASSESSMENT

DATA COMPLIATION AND PRELIMINARY ANALYSIS

Prepared under grant # 9800300
from the Washington Department of Ecology

Prepared for:
The WRIA 55 and 57 Planning Unit
Spokane, WA

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June 2003

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EXECUTIVE SUMMARY

Watershed planning under RCW 90.88 is being jointly conducted in the Little and Middle Spokane River Basins. These basins are part of the Spokane River System that is tributary to the Columbia River. Water Resource Inventory Area (WRIA) 55 is comprised of the drainage basin of the Little Spokane River. WRIA 57 is comprised of the portion of the drainage basin of the Spokane River from the Washington-Idaho border to its confluence with Hangman Creek. Watershed planning for WRIAs 55 and 57 were combined because of the significant movement of groundwater from WRIA 57 into WRIA 55.

This report presents a compilation of data for WRIA 55 and WRIA 57 for Level 1 of Phase II of the watershed planning process. Spokane County and Golder Associates Inc. (Golder) coordinated the compilation of this data, much of which already existed. Spokane County acted as a clearinghouse for the transfer of information from the watershed Planning Unit members to Golder. The information was compiled in one of four formats: hardcopy; bibliography; GIS data layers; or other electronic data (e.g., spreadsheets, databases, etc.). A listing of the information compiled is presented in Appendix A.

The hydrologic processes in the basins are well understood. The Planning Unit has decided to proceed in Level 2 of Phase II (data analysis) with the development of a computer simulation model of the hydrologic processes. With this in mind, the Level 1 compilation was conducted such that the data is formatted for incorporation into such a model and that parameters needed for model development are addressed. This model will be used to support development of the watershed plan in Phase III.

Background

The current watershed planning effort was initiated in 1998 when funding was made available from the Washington State Department of Ecology (Ecology). Spokane County is the lead agency for this effort and is one of the initiating governments. Members of the watershed Planning Unit include broad representation of interests within the basins and hold monthly meetings that are open to the public. Although there are no tribal reservations within WRIAs 55 and 57, most of WRIA 55 and the lower reach of WRIA 57 are contained within the ancestral lands of the Spokane Indian Tribe, who were invited to participate. The initiating agencies for WRIA 55 and 57 chose to address water quality as it relates to flow in addition to addressing quantity issues. In addition, application for additional funds to study instream flows was submitted to Ecology in October 2001.

WRIA 55 (the Little Spokane River basin) and WRIA 57 (the Middle Spokane River Basin) are located on the eastern boundary of Washington State where the climate is affected by both the Cascade and Rocky mountain ranges. In both basins, precipitation is relatively low, particularly during the summer months. The basins rely on spring snowmelt from the upland areas and groundwater discharge to the rivers to maintain stream flows during the drier months. Water is needed to supply a growing population, agriculture, industry, power generation, wildlife and recreation. Watershed planning offers a tool for citizens, businesses, and local governments, as well as state and federal agencies, to come together to make water resource management decisions.

Watershed-related work has been conducted for many years in both WRIA 55 and WRIA 57. The first basin-wide WRIA 55 was completed by Ecology to assess the availability of water for further appropriation (Chung, 1975). As a result of this study, an instream flow rule was adopted for the Little Spokane River and the tributaries to the Little Spokane River were closed to further appropriation. In 1995, a draft Initial Watershed Assessment of the Little Spokane River Basin was completed for Ecology (Dames and Moore and Cosmopolitan, 1995). The primary purpose of the assessment was to evaluate the status of surface and groundwater resources within WRIA 55. The conclusions of the 1995 study included:

(1) Flows in the Little Spokane River did not meet regulatory minimum instream flow requirements (established by rule in 1978 in WAC 173-555) 53 days per year on average between 1970 and 1991, and went below the MISF at least one day in 16 of 21 years between 1970 and 1991;

(2) Non-point pollution is increasingly affecting water quality; and,

(3) Development and population growth in the lower part of the watershed are steadily increasing the demand for water.

Additional watershed related work that has been completed within WRIA 55 includes a hydrogeologic characterization of the Deer Park Basin (EMCON, 1992) and an aquifer delineation and groundwater quality investigation of a portion of north Spokane County (Boese and Buchanan, 1996). The Pend Oreille Conservation District completed a water quality assessment throughout all of WRIA 55 in 2000. This assessment indicated that water temperatures on the Little Spokane River in the West Branch and below Chattaroy are higher than anticipated for a system so highly dependant on groundwater discharge to the stream (POCD, 2000). The Spokane County Conservation District is continuing this study with on-going water quality monitoring and stream gaging within WRIA 55.

This Level 1, Phase II assessment represents the first integrated basin-scale study of WRIA 57. In 1978 the United States Environmental Protection Agency (EPA) designated the Spokane Valley Rathdrum Prairie (SVRP) Aquifer a "Sole Source Aquifer”. Currently, the SVRP Aquifer is the drinking water source for more than 400,000 people living in Spokane County, Washington and Kootenai County, Idaho. Due to the unique characteristics of the SVRP Aquifer, most of the previous work within WRIA 57 has focused on this aquifer. The important categories of work include:

- Research level studies and papers on the formation of the SVRP Aquifer (Bretz, 1930; Bretz, 1959; Purves, 1969; Baker, 1973; Kiver and Stradling, 1985; and, Jensen and Eckart, 1987);
- A series of sequential groundwater flow modeling studies (Pluhowski and Thomas, 1968; Drost and Seitz, 1978; Bolke and Vaccaro, 1979; Bolke and Vaccaro, 1981;

Vaccaro and Bolke, 1983; Buchanan and Olness, 1994; CH2M Hill, 1998; and, CH2M Hill, 2000);

- Aquifer sensitivity and wellhead protection studies (MacInnis and others, 2000; CH2M Hill, 1998; and, CH2M Hill, 2000); and,
- Hydraulic continuity studies (McDonald and Broom, 1951; Broom, 1951; Miller, 1996; and, Gearhart and Buchanan, 2000).

To date, an instream flow rule has not been set for the Spokane River in WRIA 57. However, a recommended minimum flow target for the Spokane River was set by Ecology at 2,000 cfs in 1999 at the United States Geologic Survey (USGS) gage 12422500 (Spokane River at Spokane). This flow target was recommended by the Washington Department of Fish and Wildlife (WDFW) based on the 50% exceedance flow for the period of record pre-installation of the Post Falls Dam (i.e., 1891 to 1906).

Although Ecology has not completed a basin-scale study of WRIA 57, the WRIA 55/57 Planning Unit has identified a number of issues based on its understanding of the area:

1) The 2,000 cfs Spokane River target flow is met only 86% of the time and only 55% of the time in the summer (June through October) and the target flow was met every day in only five years in the period of record;
2) Interactions between the SVRP Aquifer and the Spokane River are important seasonally and spatially to maintain flows and good water quality in the Spokane River; and,
3) A better understanding of how Spokane River flows are impacted by human activities (e.g., land use changes, pumping wells, and dam operations) is required to plan the future of water management in WRIA 57.

Regional Setting

The Little and Middle Spokane Basins are located in Northeastern Washington on the border with Idaho. The natural drainage of the Little Spokane River Basin is almost entirely within the WRIA 55 boundary. WRIA 57 contains less than 10% of the contributing natural drainage of the Middle Spokane Basin, most of which lies in Idaho. The two basins are located on the eastern edge of the Columbia River Basalt Plateau, in the foothills of the Rocky Mountain Range. Annual precipitation ranges from about 15 inches per year in the lower elevations of the basins to over 45 inches in the mountainous parts of the basins. Approximately 25-40% of the precipitation falls as snow, depending on elevation, with accumulations on the order of 18 inches around the City of Spokane.

The subsurface geology is comprised of crystalline basement rocks of granite and gneiss, which outcrop on the uplands surrounding the basins. Columbia River Basalt rocks cover parts of the lower elevations of the basins. Rivers eroded valleys in these deposits, and filled them with unconsolidated sediments. These sediments form the primary aquifers, but the basalts are also tapped as productive aquifers.

Land use and land cover vary in the two basins. In WRIA 55, the dominant land uses are forest (70%), agriculture (25%) and urban/suburban development (5%). In WRIA 57, the dominant land uses are forest (60%), urban/suburban development (23%), and agriculture (16%; USGS Land Use and Land Cover). Land use changes in the future are expected to result in the conversion of agricultural land to urban land use in both WRIAs.

Surface Water

The major drainage in WRIA 55 is the Little Spokane River. The headwaters of the Little Spokane River are split approximately evenly between the West Branch of the Little Spokane River and the mainstem. Dames and Moore and Cosmopolitan (1995) hypothesized that the mainstem receives baseflow from the Pend Oreille River system in the form of inter-basin underflow. The West Branch includes several large shallow lakes (i.e., Eloika, Sacheen and Diamond Lakes). The upper reaches of the Little Spokane River are relatively undeveloped and provide good wildlife habitat.

Flow in the upper reaches of the Little Spokane River increases primarily through the contribution of tributaries such as Deadman and Dragoon Creeks. In the lower reaches, flow increases significantly as a result of groundwater discharge from WRIA 57. The river is dominantly gaining throughout its length. Although annual variations and long-term streamflow trends are affected by water diversions and withdrawals, large-scale weather patterns (e.g., decadal patterns affected by the Pacific Decadal Oscillation [PDO]) are believed to be the dominant influence affecting streamflows. The Little Spokane River has few artificial controls on its flow and the hydrograph shows sharp responses to seasonal effects such as snow pack melt. Minimum instream flows were established in 1976 at four points on the Little Spokane River (Ch. 173-555 WAC). The minimum flows were set at the 20% exceedance level based on the historical record. As part of the current watershed planning process, an instream flow needs study on the Little Spokane River is being completed in 2003, in part to review the applicability of the established minimum instream flows to aquatic biota needs.

The major drainage of WRIA 57 is the Spokane River. The Post Falls Dam, located nine miles downstream from the outlet of Lake Coeur d'Alene, a natural lake, regulates flow in the Spokane River about half the year. In the fall, the lake is drawn down to provide capacity for runoff from the upper watershed. Peak flows in the mainstem Spokane River are not as sharp as for the Little Spokane River and are attenuated as a result of the larger drainage basin size (i.e., a dampened response of the system overall) as well as having storage that buffers changes in flow. Several run-of-the-river dams along the mainstem have minor effects on the Spokane River hydrograph. There is a high degree of hydraulic continuity between the Spokane River and groundwater of the SVRP Aquifer that strongly affects seasonal and annual flows. Between the Idaho-Washington border and the river's confluence with Hangman Creek, there are several defined gaining or losing reaches. Water flowing through the Spokane River Valley flows out of the WRIA through the Spokane River and as groundwater through the Hillyard and Trinity Troughs. The SVRP Aquifer and its overlying soils are permeable to the extent that streams running off of the adjacent uplands completely infiltrate into the subsurface at the margins of the aquifer. As a result, there are no perennial tributaries to the Spokane River in WRIA 57 between the state line and Latah (Hangman) Creek, west of downtown Spokane.

An instream flow target of 2,000 cfs at Spokane Falls was agreed to by Ecology and the Washington Department of Fish and Wildlife in 1999. This target was based on 50% of natural flows using flow data from before the installation of the Post Falls Dam (1891-1906). The seven-day low flow fails to meet the instream flow target most every year. The frequency and duration of non-attainment of these target flows correlates to wet and dry PDO periods. Recent studies suggest that the 1891-1906 period may have been within a wet PDO period. If so, the instream flow target may not be representative of 50% of natural flows on average over different climatic periods.

Groundwater

Important groundwater resource aquifers occur primarily within the unconsolidated sediments that include glacial flood deposits and recent alluvium. Important local sources of domestic water supply are also found within glacial lake deposits, fractured and weathered basalt, and crystalline basement rocks. Dense and unweathered crystalline basement rocks as well as glacial lake clays act as important local aquitards, restricting vertical and lateral groundwater movement. The crystalline basement aquitard represents the lower hydrogeologic boundary of the region.

There are eight principal aquifer areas delineated in WRIAs 55 and 57. Three of these areas (Five Mile Prairie, Orchard Prairie and Green Bluff) contain basalt aquifers. Four of these areas (the SVRP Aquifer, the Little Spokane River aquifer area, Peone Prairie, and the Diamond Lake aquifer area) are unconsolidated sediment aquifers. One of these areas (the Deer Park Basin) is comprised of an upper unconsolidated sediment aquifer and a lower basalt aquifer. The Diamond Lake Aquifer area, in the northeast corner of WRIA 55, may be a conduit for groundwater flow from the Pend Oreille Basin into the headwaters of the Little Spokane River, though this has not been substantiated. The SVRP Aquifer, which occurs within the central portion of WRIA 57 and the southern portion of WRIA 55 as well as extending into Idaho, is one of the most productive aquifers in the United States and serves as the primary water source for more than 400,000 people in Washington and Idaho. The SVRP Aquifer acts a conduit for flow from the Spokane River through the Hillyard Trough to the Little Spokane River, and to a lesser extent through the Trinity Trough to lower reaches of the Spokane River.

Information on groundwater monitoring was compiled and reviewed to determine the spatial distribution of groundwater elevation data for WRIA 55 and WRIA 57. Two types of data were compiled: groundwater elevations for well networks monitored over one time period (i.e., snapshot data); and, groundwater elevations monitored at single well locations over a continuous time period (i.e., hydrograph data). The majority of the groundwater data compiled is for the SVRP Aquifer. Some data (predominantly snapshot data) was also available for the Deer Park Basin and the Little Spokane Aquifer area.

Three types of groundwater level fluctuations were observed in hydrograph data from WRIA 55 and WRIA 57:

1) Groundwater levels in close hydraulic continuity with surface water exhibit quick response (e.g., hours or days) to river stage fluctuations, with the response becoming more muted and the time lag becoming longer with increasing distance from surface water bodies;
2) Seasonal fluctuations in response to rainy and dry seasons; and,
3) Long-term (decadal) fluctuations as a result of extended periods of below or above average precipitation.

These variations of response may be important for developing water resource management options. For instance, the lag time of influence between surface water and groundwater may allow for development of groundwater extractions in areas of the aquifer system such that impacts to surface water occur during times of the year with higher flows.

A series of groundwater flow models for the SVRP Aquifer have been constructed over the last 30 years. These models have been developed primarily in support of land development (i.e., groundwater supply), to designate groundwater quality protection areas over aquifer zones that provide water to large water supply wells (i.e., wellhead protection), and academic research purposes. The development of these models has prompted studies that have resulted in improved understanding of the SVRP Aquifer.

Water Quality

The lower reaches of the Little Spokane River are listed under Section 303(d) of the Clean Water Act, including the area around the confluence with Deadman Creek (temperature [T], pH, and coliform) and near the confluence with the Spokane River (polychlorinated biphenyls [PCBs] and coliform). The largest contributing sub-basin to the Little Spokane River is Dragoon Creek, where the City of Deer Park is located. The Dragoon Creek sub-basin has several reaches that are water quality impaired (dissolved oxygen [DO], coliform) and listed under Section 303(d) of the Clean Water Act. The water quality problems in the Little Spokane system are probably related to agricultural activities (dissolved oxygen [DO] and coliform), maintenance of residential lawns (DO and T), loss of riparian vegetation (T), and industrial activities (PCBs), among other potential factors.

Groundwater quality is generally good to excellent throughout WRIA 55. However, localized areas with elevated nitrate concentrations exist and are thought to be related primarily to agricultural activities. Groundwater discharge to Dragoon Creek during low flow periods is believed to contribute nitrate to surface water (Anderson, 1986; and, EMCON, 1992). Significant groundwater discharge from the SVRP Aquifer in the lower reaches of the Little Spokane River is important in maintaining flows and maintaining good surface water quality, which in turn supports aquatic habitat.

In WRIA 57, Newman Lake is listed under Section 303(d) of the Clean Water Act for high total phosphorus concentrations. The Spokane River is on the 303(d) list for high levels of PCBs, heavy metals, DO, pH, and sediment. Heavy metal concentrations are related to the influx of heavy metals from mining activities in Idaho's Coeur d'Alene River Basin. Metals are in the river both bound with sediments and in a dissolved form. Concentrations of both total and dissolved metals generally correlate directly with river flow. Suspended sediment load and associated total metals concentrations are larger at high flows. Groundwater quality has a higher hardness, which decreases the solubility of metals. Therefore, dissolved metal concentrations are decreased during low flow conditions as a result of both less suspended sediment and lower metal solubilities where there is groundwater seepage to the river. The remaining water quality issues may be related to waste water treatment plant effluents (DO), industrial activities (PCBs), land use activities, and possibly other factors.

Water quality in the SVRP Aquifer (the dominant aquifer in WRIA 57) is good to excellent. However, water quality trends from the 1970s and 1980s indicate a gradual increase in nitrate concentrations within the aquifer. The SVRP Aquifer is highly susceptible to contamination because it is unconfined and the aquifer materials overlying sediments are very permeable. The high potential for contamination to this Sole Source Aquifer is perhaps the most critical groundwater quality issue in the basin.

Water Rights

A version of Ecology's Water Rights Application Tracking System (WRATS) database was queried to provide a synoptic assessment of the current status of water allocation. The results of this assessment are summarized in the tables below. The database is incomplete with respect to the quantities associated with all permits and certificates and no quantities are given for claims. Therefore, a number of assumptions were made to quantify all rights. Water rights where the purposes of use are listed as fish propagation, fire suppression and power are excluded because they are generally non-consumptive, or, in the case of fire suppression, rarely used.

It is likely that some of the rights registered in the WRATS database are not valid and may be subject to relinquishment due to non-use. There have been three periods since the water code was implemented for users of surface water (1917) and groundwater (1945) to register claims to water rights. The methodology used to quantify water rights and claims indicates that claims may constitute approximately 15% of the total amount. A review of the claim records reveals apparent duplicate and triplicate records for similar claims. These apparent replications are probably due to individuals registering the same claim during each claim registry period and likely do not actually represent unique claims. Therefore, the number of valid claims may be significantly less than indicated. An adjudication of surface water rights in the Deadman Creek sub-basin (the only legal way to determine validity of water rights and claims) validated only about 40% of the rights and claims previously registered.

Estimated Allocation of Water Rights by Type
(1,000s of AF/yr; excluding rights for fish propagation, fire suppression and power purposes of use)

		WRIA 55	WRIA 57	Total
Certificates & Permits				
	Groundwater	128	472	600
	Surface Water	15	16	31
	Subtotal:	**143**	**488**	**631**
Claims				
	Groundwater	21	14	35
	Surface Water	23	11	34
	Subtotal:	**44**	**25**	**69**
	TOTAL:	**187**	**513**	**700**

The distribution of water rights among various purposes of use is shown below. The amount estimated for exempt wells based on per capita use in water districts outside of the City of Spokane, the Spokane County Comprehensive Plan and census population outside of purveyor service areas.

There are 23 applications in WRIA 55 for new water rights, 16 of these for groundwater, and 16 change applications. In WRIA 57, there are 37 applications for new water rights, 27 of these for groundwater, and 46 change applications. The average size of applications for new groundwater rights is approximately 1,370 gpm in WRIA 55 and 1,270 in WRIA 57. The average size of applications for new surface water rights is approximately 117 gpm (0.26 cfs) in WRIA 55 and 9 gpm (0.02 cfs) in WRIA 57.

Spokane County recently established a Water Conservancy Board as an available avenue for processing change applications. The board can consider change applications to valid water rights. Changes may not result in an enlargement of the water right or impairment of other water rights including streamflows. Therefore these proposed changes are not anticipated to have a significant impact on water resource management.

Estimated Allocation of Water Rights by Purpose of Use
(1,000s of AF/yr)

	WRIA 55	**WRIA 57**	**Total**
Municipal & Domestic			
Permits & Certificates	81	404	485
Claims	8	2	10
Subtotal:	**89**	**406**	**495**
Irrigation			
Permits & Certificates	39	28	67
Claims	34	23	57
Subtotal:	**73**	**51**	**124**
Commercial/Industrial			
Permits & Certificates	**21**	**51**	**72**
Other	**4**	**5**	**9**
Exempt Wells			**~10**
Total:	**187**	**513**	**700**

Water Use

Actual water use estimated for the categories of agricultural irrigation, water systems, commercial/industrial use, and exempt wells is presented in the following summary table. The largest uses of water for the combined WRIAs 55 and 57 are: municipal/domestic (~128,500 AF/yr); commercial/industrial (~38,000 AF/yr); exempt wells (~16,600 AF/yr); and, agricultural irrigation (~7,500 AF/yr).

Municipal and domestic use and commercial/industrial use data was compiled by Spokane County and includes the major water distribution systems. Exempt well use is estimated based on water system data provided by Spokane County, 2000 census data, and per capita use provided by Spokane County.

The estimate of agricultural irrigation use is based on United States Department of Agriculture land use census Natural Resource Conservation Service data and USGS land use mapping. The estimate of actual use incorporates only the crop irrigation requirement.

Summary Comparison of Estimated Allocated Water and Actual Use
(excluding fire, fish and power uses; all quantities in AF/yr)

Purpose of Use	Allocated	Actual Withdrawal	Unused Allocation
WRIA 55			
Agricultural Irrigation	73,337	6,398	66,939
Municipal and Domestic	88,996	24,553	64,443
Commercial / Industrial	21,428	3,929	17,499
Exempt Wells	-	11,000	-
Subtotal	183,761	45,880	148,881
WRIA 57			
Agricultural Irrigation	51,151	1,278	49,873
Municipal and Domestic	405,703	103,962	301,741
Commercial / Industrial	50,996	34,254	16,742
Exempt Wells	-	5,600	-
Subtotal	426,103	145,094	368,356
Total	**609,864**	**190,974**	**517,237**

[a] Allocated use based on a duty of 3-4 feet/acre/year. Actual use based on a duty of 1.6 feet/acre/year. Application efficiencies, conveyance losses and stock watering are not included and may result in higher actual use estimate.

Based on these estimates, approximately 6% of water allocated for agricultural irrigation is actually being used. However, this estimate does not account for conveyance losses irrigation or application efficiencies. The distribution of irrigation rights being exercised is expected to vary widely and it is expected that many irrigation rights are being used to the full extent of validity. Approximately 43% of water allocated to municipal and domestic use is being used. However, the availability of allocated water rights is not evenly distributed among purveyors. In fact, there are communities that are considering development moratoriums because there is no available permitted water. The estimate of municipal and domestic actual use does not include small domestic systems that do not need a water right and are included with the exempt wells. Most of the water in WRIA 57 allocated for commercial/industrial applications is being used, while approximately 20% of the water allocated in WRIA 55 for this purpose is being used.

A water balance of actual use is as follows:

Actual withdrawal:		179,974	AF/yr
Irrigation use:	92,327		AF/yr
Waste water discharge:	78,819		AF/yr
Septic system recharge:	12,000		AF/yr
Actual use accounted:		183,146	AF/yr
Actual difference:		(3,172)	AF/yr

There is a discrepancy of approximately 1.8% between the estimated quantity of water pumped and accounting for where that water ends up. Multiple assumptions were used in preparing each component of this tabulation and changes may occur by improving the methods of estimation.

Watershed Modeling

The Planning Unit has decided to develop a computer simulation model in order to evaluate future water resource management options. An objective of watershed planning in the Little and Middle Spokane Basins is to maintain surface water flows for multiple benefits. Because of the high degree of interaction of surface water with the meteorological and groundwater components of the hydrologic cycle, a computer software package that adequately simulates the processes and their interactions is needed. The capabilities of a wide range of available software packages were reviewed and presented to the Planning Unit for consideration. The MIKE suite of software packages was selected to conduct computer simulation in Level 2 of Phase II, primarily because it was considered the best package currently available to simulate hydraulic continuity processes. The model will be calibrated to the 1999 hydrologic year, which is considered to be representative of current average conditions.

The model domain will be selected to conform to natural hydrologic boundaries and will approximate WRIA boundaries. The model domain will extend into Idaho to Post Falls Dam where a historical surface water record is available to be used as a model boundary condition. The model domain will also cover a portion of WRIA 54 (Lower Spokane) including the reach of the Spokane River downstream of WRIA 57 to Long Lake, and the confluences of Hangman (Latah) Creek and the Little Spokane River with the Spokane River. The lake level of Long Lake will be used as a model boundary condition. Southeastern and northeastern portions of WRIA 57 where surface water drains to Idaho will be excluded from the model domain.

Data Gaps

Identification of data gaps focused on the minimum requirements for developing a computer simulation model of the hydrologic system that include:

- Geo-referenced river cross-sections;
- Characterization of dam and stream flow control structures including location, pool and outlet elevation, operating information, stream flow and river stage;
- Geology, soils, hydrogeology and land use information for portions of the model domain within Idaho;

- Distribution of agricultural irrigated acres and representative application efficiencies; and,
- Distribution of irrigated landscaping within purveyors service areas.

Additional data needs may be identified after sensitivity analysis of a calibrated model. Such data will be prioritized on the basis of need to refine analysis to the resolution required to support development of a watershed plan.

Summary and Future Direction

This Level 1 Assessment fulfills all watershed planning technical assessment requirements except estimates of future water need and availability. The technical assessment presented in this report will be further refined through development of a computer simulation model in the Level 2 Analysis. A technical memorandum will be delivered to the Planning Unit in January 2002 addressing estimation of future water needs.

A computer model simulating the hydrology of WRIAs 55 and 57 has been completed and being used by the Planning Unit to evaluate alternative water resource management scenarios. This model is calibrated to the period 1993-1999 that includes relatively wet, dry and average hydrologic years and recent actual water use patterns.

Application has been made to Ecology to obtain additional funding for conducting instream flow studies in both WRIAs 55 and 57. The work has recently been completed for the Little Spokane River, and is being developed for the mainstem Spokane River.

The Planning Unit is initiating the preliminary conceptual framework of a watershed plan. On-going technical work will focus on the technical and geographic areas identified by the Planning Unit as important for making decisions in preparing the plan.

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APPENDICES

1. INTRODUCTION

This section presents the objective and purpose of this study, the location of the study area, an outline of the watershed issues and the scope of work for this project. A list of acronyms used within the text is presented as Table 1.1.

1.1 Objective

The objective of this report is to compile, characterize and provide a preliminary assessment of existing information for Water Resource Inventory Area #55 (WRIA 55) and Water Resource Inventory Area #57 (WRIA 57). The area encompassed by WRIA 55 (Figure 1.1) includes all the land within the Little Spokane River watershed and comprises of lands in Spokane (62%), Stevens (13%) and Pend Oreille (25%) Counties. The area encompassed by WRIA 57 (Figure 1.1) includes all the land within the Spokane River watershed, from the Washington-Idaho state line westwards to the Hangman Creek confluence and small adjacent areas in Washington State that flow into Idaho. WRIA 57 lies within Spokane (92.6%) and Pend Oreille Counties (7.4%). A summary of the approximate areas within the WRIAs and Counties are provided in the table below.

	Acres	**Square Miles**
Total WRIA 55	**433,000**	**675**
Spokane County in WRIA 55	267,000	415
Pend Oreille County in WRIA 55	108,000	170
Stevens County in WRIA 55	58,000	90
Total WRIA 57	**183,000**	**285**
Spokane County in WRIA 57	170,000	265
Pend Oreille County in WRIA 57	14,000	21

This report is designed to accomplish the following:

- Provide an inventory of existing information relevant to watershed planning in WRIAs 55 and 57;
- Organize the existing information into categories based on major technical disciplines (e.g., climate, hydrology, land use etc.);
- Interpret the existing information and describe the major characteristics of the watersheds;
- Provide a preliminary assessment of information gaps;
- Partially fulfill the requirements of the Phase II, Level I Assessment of the 1998 Watershed Planning Act (RCW 90.82);

- Provide a foundation for Level 2 Assessment of Phase II; and,
- Provide data to support development of a Watershed Plan under Phase III.

1.2 Purpose

Watershed planning is funded by the State of Washington under the direction of the Department of Ecology (Ecology). Watershed planning is a tool for developing water resources management strategies in the context of current laws and policies. As the human population increases and land use activities change, so may the demands for water. Watershed planning incorporates the knowledge of those who live within a watershed with science to develop an inventory of water inflows into and outflows from the watershed. A wide variety of local interest groups have an opportunity to voice their needs and concerns. For WRIAs 55 and 57, the interest groups involved in the watershed planning process are listed in Section 2.2 of this report. Watershed planning attempts to incorporate the perspectives of these groups into a framework for water resource allocation within the watersheds.

1.3 Location and Background

WRIAs 55 and 57 are located on the eastern boundary of Washington State, where the climate is affected by both the Cascade and Rocky mountain ranges (Figure 1.1). The Washington State Department of Natural Resources (DNR) has defined sub-basins within the two WRIAs known as Watershed Administrative Units (WAUs; Figure 1.2). Precipitation is relatively low in both WRIAs, particularly during the summer months. The WRIAs rely on snowmelt from the upland areas and groundwater recharge to the rivers to maintain river flows throughout the drier months. Groundwater and surface water are used to supply water to a growing population, for domestic water supply, agriculture, industry, power generation, wildlife and recreation. Given that water resources in the basins are limited by climate, watershed planning offers a tool for citizens, businesses, local governments as well as state and federal agencies to come together to make water resource management decisions.

1.4 Watershed Planning Issues

The following sections describe watershed planning issues within WRIA 55 and WRIA 57. The information presented is based on a review of existing information and on communication with the WRIAs 55 and 57 Planning Unit.

1.4.1 WRIA 55 – The Little Spokane River Basin

The first basin-wide study of WRIA 55 was completed by Ecology to assess the availability of water for further appropriation (Chung, 1975). As a result of this study, an instream flow rule (WAC 173-555) was adopted in 1978 for the Little Spokane River (see Section 5.1 and Appendix C4 for more detail). In addition, eleven cubic feet per second (cfs) was identified as available for further appropriation for specified uses along some reaches of the main stem of the Little Spokane River. The tributaries to the Little Spokane River were closed to further appropriation.

In 1995, a draft initial watershed assessment of the Little Spokane River Basin was completed for Ecology (Dames and Moore and Cosmopolitan, 1995). The primary purpose of the assessment was to evaluate the status of surface and groundwater resources within WRIA 55 to help Ecology make appropriate water resource management decisions. The issues identified in the 1995 initial assessment of WRIA 55 included:

- Water flows in the Little Spokane River and its tributaries did not meet instream flow requirements, established by rule in 1978 in WAC 173-555, 53 days per year on average between 1970 and 1991, and went below the MISF at least one day in 16 of 21 years between 1970 and 1991;
- Declines in stream flows and groundwater levels are due in part to the consumptive water uses in the basin and below average precipitation in recent years;
- Non-point pollution is increasingly affecting water quality in the watershed;
- The lower eight-mile reach of the Little Spokane River is a state-designated Scenic River Corridor; and,
- Development and population growth in the lower part of the watershed are steadily increasing the demand for water.

Activities in the basin since the 1995 assessment have resulted in identification of additional issues. These issues are briefly described in the points below.

- As a result of better understanding and acknowledgement of surface water – groundwater continuity between the Little Spokane River and adjacent aquifers, Ecology started denying applications for groundwater rights as of 1996. Although the 11 cfs of surface water defined as available in 1975 (Chung, 1975) had not been allocated, 20 cfs of groundwater rights had been granted by Ecology between 1975 and 1996.
- Recent developments located in close proximity to the river are serviced by septic systems that have the potential to impact the water quality of groundwater and surface water.
- The upper portion of the watershed does not meet Washington State’s fresh water temperature criteria for the protection of aquatic life.
- Recent geologic information suggests that there may be a deeper aquifer zone within the Spokane Valley Rathdrum Prairie aquifer within WRIA 55 that is separated from the upper zone by a semi-continuous clay and silt layer.

1.4.2 WRIA 57 – The Middle Spokane River Basin

In contrast to WRIA 55, this study represents the first integrated study of the Middle Spokane WRIA. The movement and availability of water within WRIA 57 is dominated by the Spokane Valley Rathdrum Prairie (SVRP) Aquifer and the interactions between the Spokane River and the SVRP Aquifer. Most of the studies completed to date within WRIA 57 have focused on understanding and protection of the SVRP Aquifer. Sources of recharge to the aquifer include infiltration of precipitation and irrigation, seepage from perimeter lakes and hillside subbasins and recharge from the Spokane River.

To date, an instream flow rule has not been set for the Spokane River. However, a recommended minimum flow target for the Spokane River was set by Ecology at 2,000 cfs in 1999 at the United States Geologic Survey (USGS) gage 12422500 (Spokane River at Spokane). The 2,000 cfs target was recommended by the Washington Department of Fish and Wildlife (WDFW) and represents the 50% exceedance flow for the period of record pre-installation of the Post Falls Dam (i.e., 1891 to 1906). The letter from the WDFW to Ecology recommending the 2,000 cfs target is included within Appendix C4.

The issues described in brief below for WRIA 57 are based on review of a number of study reports and on discussions with the WRIA 55 and WRIA 57 Planning Unit (PU) members.

- Across the period of record for the Spokane River at Spokane gage (1891 to 1999), the 2,000 cfs target flow is met only 86% of the time and the flow did not fall below the target in only five years in the period of record. Analysis of summer (June to October) flows, indicate that 45% of the flow record is below 2,000 cfs.
- The SVRP Aquifer is highly vulnerable to contamination from activities on the ground surface because it is an unconfined, coarse-grained aquifer.
- Interactions between the SVRP Aquifer and the Spokane River are important seasonally and spatially to maintain flows and good water quality in the Spokane River.
- If water demands continue to increase, the average daily withdrawal of water from the SVRP Aquifer may exceed the inflow to the aquifer from sources other than the Spokane River. This may result in increased leakage from the Spokane River to the SVRP Aquifer, thereby reducing flows in the Spokane River.
- Lower Spokane River flows may compromise the ability of the river to dilute contaminants.
- Discharge from the SVRP Aquifer to the Little Spokane River is important to maintain flows in the lower reaches of the Little Spokane River.
- The impacts on water flow and quality of the Spokane River from changes in water use and application (e.g., if treated wastewater is applied to crops in the summer rather than directly discharged to the Spokane River) are not well understood nor quantified.

- A better understanding of how river flows are impacted by human activities (e.g., land use changes, pumping wells, and dam operations) is required to plan future water management in the Spokane River Valley; and,
- A better understanding of the quantity of water flowing through the Trinity and Hillyard Troughs is needed.

1.5 Report Organization

This report is organized into two main sections: the main text, tables and figures that are organized by chapter and the appendices that follow the main text.

The main text is organized in to ten sections as follows:

- Section 1 outlines the report objectives, scope and organization.
- Section 2 provides background information on the Watershed Management Act including past and present planning activities.
- Section 3 explains the hydrologic cycle and its important components at the watershed scale.
- Section 4 describes the regional setting of the WRIAs including physiography, climate, geologic setting, soils, land cover and land use.
- Section 5 describes the surface water flows and groundwater of the Little Spokane and Middle Spokane Basins.
- Section 6 characterizes and describes water quality issues that relate to stream flow.
- Section 7 compiles and characterizes the existing water rights and water use.
- Section 8 describes the approach to computer simulation modeling the water resources of the Little Spokane and Middle Spokane Basins
- Section 9 identifies data gaps that need to be filled to adequately quantify the surface water and groundwater resources of the Little Spokane and Middle Spokane Basins.
- Section 10 summarizes the key findings of the data compilation and characterization for both WRIAs 55 and 57 and presents an overview of resource management considerations.

1.6 Scope, Authorization, Limitations and Acknowledgements

This report is prepared in fulfillment of Task 1000 of the November 7, 2000 scope of work entitled “Phase II – Data Compilation and Assessment, WRIA 55-57: The Middle Spokane and Little Spokane Rivers”. This scope of work was agreed to in a contract signed between Spokane County and Golder Associates Inc. (Golder) in December 2000 under Spokane County contract #P2960, funded by a Washington Department of Ecology grant (number 9800300). This report is designed to compile information relevant to watershed planning for WRIAs 55 and 57. It is not designed to address all the WRIA 55 and WRIA 57 issues outlined in Section 1.4.

The following main elements are included in the scope of work:

- Task 1100: Existing Data Collection and Compilation
- Task 1200: Preliminary Assessment of Data Gaps
- Task 1300: Model Options
- Task 1400: Estimation of Recharge/Discharge of Used Water
- Task 1500: Estimation of Water Conservation Impacts on Water Use
- Task 1600: Model Discretization
- Task 1700: Characterization Report

Several individuals contributed significantly to the preparation of this report. Stan Miller, Water Quality Section Manager for the Utilities Division of Spokane County Public Works, is the project manager on behalf of Spokane County. Reanette Boese, Bea Lackaff, and Erin Cunningham of Spokane County participated in the data collection and review of the report. Susan McGeorge of Whitworth Water District provided staff time for collection of water use data. Spokane County staff provided significant insights into the dynamics of the natural hydrologic system.

Chris Pitre, senior project manager, water resources, is the project manager on behalf of Golder Associates Inc. Bryony Stasney was the local project coordinator and with Sara Marxen, Michael Klisch and Philip Beetlestone of Golder participated in data collection, analysis and report preparation.

This work has been completed in accordance with generally accepted professional practices at the time of preparation within the limitations of available data and budget.

TABLE 1.1
Acronym List

°F	Degrees Fahrenheit
7Q10	7-day low flow with a recurrence interval of 10 years
7Q20	7 day low flow with a recurrence interval of 20 years
abv	above
af/yr, AF/yr	acre-feet per year
amsl	above mean sea level
ASCII	American Standard Code for Information Interchange
AVISTA	Power company
blw	below
CBOD	Carbonaceous Oxygen Demand
CD	Cumulative Departure
CE-QUAL-W2	Surface water quality model developed by the US Army Corps of Engineers
cfs	cubic feet per second
cfs/af/yr	cubic feet per second per acre-feet per year
CID	Consolidated Irrigation District
CIR	Crop Irrigation Requirement
CORPS	United States Army Corps of Engineers
CRB	Columbia River Basin
CU	Consumptive Use
degrees C	Degrees Celsius
DEM	Digital Elevation Model
DEQ	Department of Environmental Quality
DNR	Department of Natural Resources
DO	Dissolved Oxygen
DOE, WaDOE, Ecology	Washington Department of Ecology
DP	Deer Park
e.g.	For example
EES	Economic and Engineering Services (a company name)
EIS	Environmental Impact Statement
EMCON	Company name
EPA	United States Environmental Protection Agency
ESA	Federal Endangered Species Act
ESHB	Engrossed Substitute House Bill
ET	Evapotranspiration
ET_{rc}	evapotranspiration for refrence crop
FERC	Federal Energy Regulatory Commission
ft	feet
ft/gpm	feet per gallons per minute
FSA	Farm Service Agency

TABLE 1.1
Acronym List

ftp	File Transfer Protocol
gcd	gallons per capita per day
GIS	Geographic Information Systems
GMA	Growth Management Act
gpd/ft	gallons per day per foot
gpm/af/yr	gallons per minute per acre-feet per year
gpm/ft	gallons per minute per foot
HUC	Hydrologic Units Codes
ID	Idaho
IDEQ	Idaho Department of Environmental Quality
IFIM	Instream Flow Incremental Methodology
ISFs	Instream Flows
JISAO and SMA	Joint Institute for the Study of the Atmosphere and Ocean and School of Marine Affairs
K	Hydraulic Conductivity
Kh	Horizontal Hydraulic Conductivity
Kv	Vertical Hydraulic Conductivity
LSR	Little Spokane River
LSRA	Little Spokane River Aquifer Area
LULC	Land Use and Land Cover
m.y.	million years
m/s	meters per second
max	Maximum
mg/L	milligrams per liter
mi^2	square miles
MIKE	Group of Software Products developed by DHI Water and Environment. MIKE refers to the suite of software modeling packages selected for use in this Watershed Inventory Assessment
mL	Milliliters
mm/h	millimeters per hour
MSL	Mean Sea Level
MSR	Middle Spokane River
n	Porosity
NAM	Acronym for how rainfall/run-off is simulated by MIKE software. A lumped, conceptual rainfall-runoff model simulating overland flow, interflow and baseflow as a function of the moisture content in four mutually interrelated storages.
NASA	National Aeronautics & Space Administration
NAWQA	National Water-Quality Assessment Program
NE	North East
NEPA	National Environmental Policy Act

TABLE 1.1
Acronym List

NGVD	National Geodetic Vertical Datum
NID	National Inventory of Dams
NOAA	National Oceanic and Atmospheric Administration
nr	Near
NRCS	National Resource Conservation Service (formerly the Soil Conservation Service)
NROK	Northern Rockies Intermontain Basins (NAWQA study area)
NTU	Nephelometric Turbudity Units
NW	North West
OWD	on-site waste-disposal
OWDS	on-site waste-disposal systems
PDO	Pacific Decadal Oscillations
P_{ET}	Potential Evapotranspiration
PHD	Panhandle Health District
PNRBC	Pacific Northwest River Basins Commission
POCD	Pend Oreille Conservation District
POD	Point of Discharge
ppb	parts per billion
ppt	Precipitation
PRISM	**P**arameter-elevation **R**egressions on **I**ndependent **S**lopes **M**odel
PU	Planning Unit
Qa	Permitted Annual Water Use
Qa/Qi	ratio for non-irrigation groundwater and surface water rights
Qal	Recent Deposits of Alluvium
Qfs/Qfg/Qfcg	Lower Sand and Gravel Unit, Flood Sand and Gravel Units
Qgl	Glacial Deposits
Qi	Instantaneous Water Use
Ql	Loess
Qmw	Mass Wasting Deposits
Qp/Qla	Recent Deposits of Lacustrine
R	Runoff
RCD	Rescaled Cumulative Departure
RCW	Revised Code of Washington
SAJB	Spokane Aquifer Joint Board
SCCD	Spokane County Conservation District
SCS	Soil Conservation Service (now the Natural Resource Conservation Service)
SDWA	Safe Drinking Water Act
SEPA	State Environmental Policy Act
SNOTEL	**SNO**wpack **TEL**emetry, snowpack and related climatic data collected in the Western United States by the NRCS through an automated system.

TABLE 1.1
Acronym List

SR	Spokane River
S_s	Specific Storage
SSA	Sole Source Aquifer
stn	Station
SVA	Spokane Valley Aquifer
SVRP	Spokane Valley – Rathdrum Prairie
SVRPA	Spokane Valley - Rathdrum Prairie Aquifer
SW/GW	Surface Water-Groundwater
SWE	Snow Water Equivalent
S_y	Specific Yield
T	Transmissivity
TCE	Trichloroethlyene
TEM	Transient electro-magnetics
TIR	Total Irrigation Requirement
Tl	Lacustrine silts and clays, Latah Formation
TMDL	Total Maximum Daily Load – a part of the federal Clean Water Act
TRS	Township, Range, Section
Tw/Tgr	Columbia River Basalts WRIA 55/57
UofW	University of Washington
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UTM	Universal Transvere Mercator
v	Linear Velocity
w/o	without
WA, Wa, Wash.	Washington
WAC	Washington Administrative Code
WAUs	Watershed Administrative Units
WMA	Watershed Management Act
WQMP	Water Quality Management Program
WRATS	Water Rights Application Tracking System
WRIA	Water Resource Inventory Area
WRIA 54	Lower Spokane River Watershed
WRIA 55	Little Spokane Watershed
WRIA 57	Middle Spokane River Watershed
WRIA 62	Pend Oreille River Watershed
WRIS	Water Resources Information System

2. WATERSHED PLANNING

Watershed planning within Watershed Resource Inventory Areas (WRIAs) recognizes the large scale and complexity of water resources and the wide variety of factors that influence the amount of water available for use. Although the geographic area contained in a WRIA rarely corresponds with political/jurisdictional boundaries, water resource issues such as water supply, water quality, and habitat for fish and wildlife are closely linked together within watersheds.

From an assessment perspective, the watershed (or basin) scale is appropriate because the hydrologic processes that occur within WRIA boundaries can be approximated by a basin scale hydrologic cycle or equation. This equation can be expressed generally as "water inflow to the basin is equal to water outflow from the basin plus / minus changes in water storage within the basin". With a conceptual understanding the hydrologic cycle within a basin, planners can gain an intuition on how future actions within the watershed may impact water resources.

2.1 Washington State Watershed Planning Process

The 1998 Washington State legislature passed House Bill 2514, codified into **RCW 90.82**, to set a framework for addressing the State's water resources issues. RCW 90.82 states:

> *"The legislature finds that the local development of watershed plans for managing water resources and for protecting existing water rights is vital to both state and local interests. The local development of these plans serves vital local interests by placing it in the hands of people: Who have the greatest knowledge of both the resources and the aspirations of those who live and work in the watershed; and who have the greatest stake in the proper, long-term management resources. The development of such plans serves the state's vital interests by ensuring that the state's water resources are used wisely, by protecting existing water rights, by protecting instream flows for fish and by providing for the economic well-being of the state's citizenry and communities. Therefore the legislature believes it necessary for units of local government throughout the state to engage in orderly development of these watershed plans."*

Twelve State agencies signed a Memorandum of Understanding identifying roles and responsibilities for coordination under the Watershed Planning Act. This memorandum commits these agencies to work through issues in order to speak with one governmental voice when sitting at local planning unit tables. The following agencies signed this document:

- The Department of Agriculture
- The Conservation Commission
- The Department of Community, Trade and Economic Development
- The Department of Ecology
- The Department of Fish and Wildlife

- The Department of Health
- The Department of Natural Resources
- The Department of Transportation
- The Interagency Committee for Outdoor Recreation
- The Puget Sound Water Quality Action Team
- The Salmon Recovery Office, within the Governor's Office
- The State Parks and Recreation Commission

The purpose of the 1998 Watershed Management Act (WMA) is to provide a framework for local government, interest groups and citizens to collaboratively identify and solve water related issues in each of the 62 Water Resource Inventory Areas (WRIAs) of Washington State.

The WMA does not require watershed planning but instead enables a group of initiating agencies to:

- Select a lead agency;
- Apply for grant funding;
- Define the scope of the planning; and,
- Convene a local group called a planning unit for the purpose of conducting watershed planning.

The initiating agencies include all the counties within the WRIA, the largest city and water purveyor within the WRIA. Indian tribes with reservation lands within the watershed must be invited to participate as an initiating government. Although their participation is optimal, participation is not required for watershed planning to proceed. Although there are no treaty reservation lands in WRIAs 55 and 57, the Spokane Indian Tribe's ancestral land (also referred to as ceded territories) covers a large portion of WRIA 55 and a smaller portion of WRIA 57 (Figure 1.1). The ancestral land is the original land area occupied and used by the Spokane Tribe. The boundary of the ancestral lands shown on Figure 1.1 is based on information provided by the Spokane Tribe's Department of Natural Resources. The Spokane Tribe was invited to participate but has chosen to only monitor progress through minutes and agendas.

Upon successful completion of Phase I, the State may grant funds to the planning unit to conduct watershed planning. Under the law, the Planning Unit (PU) has considerable flexibility to determine the planning process, focus on areas or elements of particular importance to local citizens, assess water resources and needs, and recommend management strategies. The WMA identifies four topics that can be addressed within the watershed assessment plan: water quantity, water quality, habitat, and instream flow. Water quantity must be addressed if grant funds are accepted and is a required component. Water quality, habitat and instream flows may be addressed but are optional. The law specifies certain types of information that must be gathered and a range of water resource management strategies that need to be addressed.

The law also includes constraints on the activities of planning units. For example, the PU does not have the authority to change existing laws, alter water rights or treaty rights, change treaties, or require any party to take an action unless that party agrees.

Four phases of watershed planning are identified in the WMA:

- Phase I - Organization ($50,000)
- Phase II - Assessment ($200,000)
  - ⇒ Level 1 Assessment: A compilation and review of existing data (within time and budget limitations) relevant to defined objectives. If the Planning Unit decides that the existing data is sufficient to support the management requirements of all or some of the issues, the Planning Unit may choose to skip Level 2 and move on to Level 3 for these issues.
  - ⇒ Level 2 Assessment: Collection of new data or conduct additional analysis of existing data within the time frame of the planning process to fill data gaps and to support decision needs.
  - ⇒ Level 3 Assessment: Long term monitoring of selected parameters following completion of the initial watershed plan to improve management strategies.

  Supplemental assessments may be conducted in the following focused areas

  - ⇒ Multipurpose Storage ($100,000): To conduct a detailed assessment of multipurpose water storage opportunities or for studies of specific multipurpose storage projects which opportunities or projects are consistent with and support the other elements of the planning unit's watershed plan developed under RCW 90.82.
  - ⇒ Instream Flow Assessment ($100,000): To establish new minimum instream flow regulations, or amend existing regulations; and,
  - ⇒ Water Quality Assessment ($100,000): To conduct water quality assessment in fulfillment of RCW 90.82.090 and to support development of watershed plan.
- Phase III – Planning ($250,000)

  The WMA calls for a consensus approval of the watershed plan by all members of the PU, or a consensus of the initiating governments and a majority vote by the remaining members of the PU. Following approval by the PU, the WMA calls for a joint session of the legislative session bodies of all counties in the watershed to consider the plan. The counties can recommend changes to the plan but the PU must agree to make the changes for them to be effective. Once the plan has been approved by the county legislative bodies and the PU, the county and state agencies are required to implement the plan. Phase III must be completed within four years of initiating Phase II work.
- Phase IV – Implementation ($400,000)

The PU must provide a detailed implementation plan to provide water for agriculture, commercial, industrial and residential use, and instream flows, including timelines and milestones. The plan must clearly define coordination, oversight responsibilities, needed regulations (ordinances, interlocal agreements or rules), and funding sources. The funds are distributed over up to five years of implementation, and require 10% matching funds, which may consist of in-kind goods and services.

2.2 The WRIA 55 and 57 Planning Unit

WRIAs 55 and 57 each have compelling issues for watershed planning and were combined for the planning effort because of a unique hydraulic connection between the two river systems via groundwater. The initiating agencies for the Little Spokane (WRIA 55) and the Middle Spokane (WRIA 57) Planning Unit are listed below. The initiating agencies accepted Spokane County as the lead agency. The role of the lead agency is to take responsibility for administering watershed assessment grant monies and to be a point of contact through which information is channeled.

	Contact	Department
Initiating Agency		
Spokane County	Ms. Terry Liberty	Planning
Pend Oreille County	Mr. Neil White	Planning
Stevens County	Mr. Dennis Sweeney	Planning
City of Spokane	Mr. Lloyd Brewer	Environmental Programs
Vera Water and Power	Mr. Steve Skipworth	Operations Director
Whitworth Water District	Ms. Susan McGeorge	Manager
Lead Agency		
Spokane County	Mr. Stan Miller	Utilities

In 1998, the initiating agencies formed a planning unit by asking various agencies, organizations and businesses to appoint a member. In addition, interested members of the public were invited to join. In October 2001, the invited members of the planning unit were:

Other Government or Regulatory Agencies
- City of Deer Park
- Town of Millwood
- Spokane Tribe
- Spokane Regional Health District
- Washington State Department of Ecology

Purveyors
- City of Spokane Water Department
- Stevens County PUD #1
- Spokane Aquifer Joint Board

Industry
- Kaiser Aluminum and Chemical Company
- Inland Empire Paper
- WFPA
- Central Premix
- Avista Utilities

Agriculture
- Washington State Dairy Federation
- General Agriculture

Community Development
- Spokane Area Chamber of Commerce
- Spokane Economic Development Council
- Spokane Valley Chamber of Commerce

Citizen Representation
- Friends of the Little Spokane River
- Community Assembly and Neighborhood Services
- Spokane Area League of Women Voters
- Water Quality Advisory Committee
- Citizens at Large

Environmental
- Washington Environmental Council
- The Lands Council

Development
- Spokane Home Builders Association
- Association of Realtors

River Users
- Spokane Fly Fishing Club
- Spokane Canoe and Kayak Club

Technical Support Agencies
- Spokane County Conservation District
- Pend Oreille County Conservation District
- Stevens County Conservation District
- Spokane Aquifer Joint Board
- Washington State Department of Natural Resources

- Washington State Department of Health
- Washington State Department of Ecology
- Washington State Department of Fish and Wildlife
- U.S. Geological Survey
- U.S. Environmental Protection Agency
- Eastern Washington University

2.2.1 Phase II Watershed Planning Optional Components

The WMA requires that the initiating agencies use Phase II grant monies to address water quantity issues. The law provides that grant money may be requested to address water quality, fish habitat, and instream flows, at the option of the initiating agencies. The initiating agencies for WRIA 55 and 57 chose to address water quality as it relates to flow in addition to addressing quantity issues. The Planning Unit has submitted applications for funding to support instream flow studies in both WRIAs 55 and 57. Requests for funding to support water quality and storage considerations studies were made in the application for a Phase III grant.

2.2.2 Planning Unit Goals and Objectives

The WRIA 55 and 57 PU have defined the following six objectives. It is important to appreciate that these objectives may be modified in the future and that the list below represents the objectives as of October 2001. The scope of work for this report (Level 1, Phase II of Watershed Planning) is to compile the information that will be used in Level 2, Phase II to address these objectives.

1. Determine the impact of groundwater recharge from the SVRP Aquifer on flows in the Little Spokane River at and near Dartford including recharge from water purveyed from the SVRP Aquifer.
2. Refine data for evaluating the effect of surface water and groundwater withdrawals on flows in the Little Spokane River.
3. Determine the effect of the interaction between the Spokane River and the SVRP Aquifer on the quantity and quality of groundwater and surface water at varying river flow conditions.
4. Refine estimates of recharge to the SVRP Aquifer from adjacent sub-basins.
5. Evaluate the effect of increased withdrawals on recharge to the Spokane and Little Spokane Rivers using a groundwater model which incorporates refined surface water / groundwater exchange information.
6. Develop a tool for evaluating water quality impacts (resulting from changes in river flow) of point source discharges on the Spokane and Little Spokane Rivers.
7. Evaluate the impact of Post Falls Dam operations on surface water and groundwater quality and quantity.

2.2.3 Phase II, Level 1 Assessment Process

A listing of the information types and strategies for the watershed planning elements selected for the Little Spokane and Middle Spokane Basins are provided in Table 2.1. The assessment activities described in this document were defined and overseen by the WRIA 55 and 57 PU. Members of the PU were asked to submit relevant information to Spokane County staff. Spokane County staff also compiled needed information (such as climatic data and river flows) from governmental and educational organizations. Decisions on the information to be assessed were made by the PU members during scheduled meetings. Effort was made by Spokane County staff to compile the information to a manageable form. The information was supplied to Golder in electronic format where possible, and if not, hard copy information was supplied. A listing of the information compiled for the Level 1 assessment is included in Appendix A as a bibliography (Appendix A1), a directory of spreadsheet, text and database files (Appendix A2) and a directory of Geographic Information System (GIS) files (Appendix A3). Draft materials produced by Golder were provided to the PU for review. Review comments were discussed and incorporated prior to preparation of the final document.

2.3 Related Planning and Regulatory Programs

The Watershed Management Act recognizes that water resources planning by federal, state, city, county and district entities and others occur under a variety of authorities. To take advantage of existing work and to avoid duplication, planning units are required to consider all existing plans and related planning activities. Relevant plans and programs should be looked at as sources of: 1) existing information; 2) water resources impact and mitigation studies; and, 3) authority to implement watershed plan recommendations.

The following lists federal, state and local programs and plans relevant to watershed planning in WRIAs 55 and 57:

Federal Programs

- National Environmental Policy Act (NEPA).
- The Federal Clean Water Act;
- The Federal Safe Drinking Water Act;
- United States Environmental Protection Agency’s (EPA’s) Sole Source Aquifer Designation;
- The Federal Clean Water Act (CWA) Section 303(d);
- The Federal Total Maximum Daily Load (TMDL) process;
- The Federal Endangered Species Act (ESA);

State Programs

- State Environmental Policy Act (SEPA);
- Washington State Water Quality Guidelines;

- The Washington Department of Health's Wellhead Protection Program;
- Washington State Department of Health (DOH) Water Quality Monitoring;
- The Washington Department of Ecology's (Ecology's) Shorelands and Water Resources Program;
- State-designated Scenic River Corridor program;

Local Programs

- Local Comprehensive Planning and the Growth Management Act (GMA);
- Critical Area Ordinances and the Growth Management Act (GMA);
- Groundwater Management Areas;
- Spokane Water Quality Management Program;
- Spokane County Utilities Sewer Service Area Expansion;
- Spokane County and City Stormwater Management / Underground Injection;
- Local Agricultural Programs; and,
- Adjacent Watershed Planning Efforts.

2.3.1 Federal Programs

2.3.1.1 National Environmental Policy Act (NEPA)

National Environmental Policy Act (NEPA) is triggered by various actions including the investment of federal funds or watershed planning actions by federal agencies. If it is anticipated that NEPA will be invoked during the watershed planning process, NEPA requirements should be reviewed so that they can be incorporated early in the watershed planning process.

2.3.1.2 The Federal Clean Water Act

The Federal Clean Water Act (CWA) is the primary legislation controlling water quality in the United States. The goals of the CWA are:

- To develop technology to eliminate the discharge of pollutants;
- To achieve water quality high enough to be protective of fish and recreation;
- To prohibit the discharge of toxic pollutants; and,
- To construct publicly owned waste treatment facilities and to develop area-wide waste treatment management planning processes.

Three facets of the CWA are described below.

2.3.1.2.1 Federal Clean Water Act (CWA), NPDES

A National Pollutant Discharge Elimination System (NPDES) Permit is required for all point discharges to surface waters. Although the EPA is responsible for implementing this act, states may elect to develop and regulate their own programs providing their programs are at least as stringent as the federal program. Washington State has elected to assume responsibility for invoking the Federal Clean Water Act. The Department of Ecology (Ecology) has the primary responsibility for enforcing the CWA.

2.3.1.2.2 Federal Clean Water Act (CWA), Section 303(d)

The Federal Clean Water Act (CWA), Section 303(d), requires States to develop a list of water bodies that are not expected to meet water quality standards after implementation of technology-based pollution controls. These controls include enforceable best management practices for non-point sources. The EPA requires that these controls be completed or scheduled for completion within two years of the waterbody's listing. The 303(d) list contains all those water bodies that require some additional management activities.

2.3.1.2.3 Total Maximum Daily Load (TMDL) Process

The Federal Clean Water Act (CWA) directs that a Total Maximum Daily Load (TMDL) be established for all water bodies listed under Section 303(d). The EPA defines a TMDL as the sum of all pollution loads allocated to various sources and/or reserves after a public participation process. The TMDL is established so that pollution does not exceed the loading capacity of the waterbody segment. The TMDL also includes recommendations on how to control the pollution impairing the water as well as a monitoring program to ensure the effectiveness of these pollution controls.

2.3.1.3 The Federal Safe Drinking Water Act

The Federal Safe Drinking Water Act (SDWA) ensures public water systems meet national standards for the protection of public health. This act establishes primary and secondary drinking water standards. Primary standards are established for those contaminants that pose a human health risk. Secondary standards are based on aesthetic factors such as color and taste. The Washington State Department of Health (DOH) has responsibility for implementing the Federal Safe Drinking Water Act.

2.3.1.4 Sole Source Aquifer Designation

The Sole Source Aquifer (SSA) Protection Program is authorized by Section 1424(e) of the Safe Drinking Water Act of 1974 (Public Law 93-523, 42 U.S.C. 300 et. Seq). It states that:

> *"If the Administrator determines, on his own initiative or upon petition, that an area has an aquifer which is the sole or principal drinking water source for the area and which, if contaminated, would create a significant hazard to public health, he shall publish notice of that determination in the Federal Register. After the publication of any such notice, no commitment for federal financial assistance (through a grant, contract, loan guarantee, or*

> *otherwise) may be entered into for any project which the Administrator determines may contaminate such aquifer through a recharge zone so as to create a significant hazard to public health, but a commitment for federal assistance may, if authorized under another provision of law, be entered into to plan or design the project to assure that it will not so contaminate the aquifer."*

The EPA defines a sole or principal source aquifer as one that supplies at least 50 percent of the drinking water consumed in the area overlying the aquifer. These areas have no alternative drinking water source(s) that could physically, legally, and economically supply all those who depend upon the aquifer for drinking water.

The EPA designated the Spokane Valley Rathdrum Prairie (SVRP) Aquifer a sole source aquifer in 1978 in response to the concern of area residents. The SVRP Aquifer was the second aquifer in the United States to receive this designation. The SVRP Aquifer is the sole source of drinking water for most of the people living in Spokane County (Washington) and Kootenai County (Idaho). At present, aquifer protection efforts are managed by Spokane County's Water Quality Program in Washington and by the Idaho Department of Environmental Quality (IDEQ) and the Panhandle Health District (PHD) in Idaho.

Proposed projects with federal funding which have the potential to contaminate a designated sole source aquifer are subject to EPA review. Proposed projects that are funded entirely by state, local, or private concerns are not subject to EPA review. EPA does not endorse using SSA status as the sole or determining factor in making land use decisions that may impact ground water quality. However, it does recommend that site-specific hydrogeological assessments be considered along with other factors such as project design, construction practices, and long-term management of the site.

2.3.1.5 Endangered Species Act (ESA)

There are no species listed under the Endangered Species Act in WRIAs 55 and 57. Grand Coulee Dam blocks anadromous salmonids from the Upper Columbia. ESA issues are therefore not considered as a component of watershed planning in WRIA 55 and WRIA 57.

2.3.2 State Programs

2.3.2.1 State Environmental Policy Act (SEPA)

The State Environmental Policy Act (SEPA) was adopted in 1971 to ensure that environmental values were considered during decision-making by state and local agencies. Adoption of the watershed plan and any associated implemented projects will invoke SEPA for cities, counties and other agencies subject to SEPA. The methodology for watershed planning is similar to that for a SEPA programmatic Environmental Impact Statement (EIS). Therefore, it may streamline the planning process and reduce SEPA requirements in subsequent implementation of watershed plan recommendations if the watershed planning process is structured in a similar way to that of an EIS (see Section 11.3.1 and Table 11-1 of EES's 1999 Guide to Watershed Planning and Management).

Although this Level 1, Phase II data compilation report is not directly subject to SEPA review, it does follow the SEPA structure by summarizing existing conditions within WRIAs 55 and 57 using best available science. This Level 1, Phase II data compilation report is completed in support of the Phase III Watershed Plan. The Phase III Watershed Plan is subject to SEPA review.

2.3.2.2 Washington State Water Quality Guidelines

Ecology has broad authority over surface water and groundwater quality (WAC 173-200 and WAC 173-201). Effective implementation of Ecology's water quality programs is a key component of watershed planning. Watershed planning in WRIAs 55 and 57 must incorporate Ecology's standards and implementation guidance for surface water and ground water quality in any land-use or development issues.

2.3.2.3 Wellhead Protection

All Group A public water systems relying on groundwater (WAC 246-290) are required by the state of Washington to have a wellhead protection program. The City of Spokane prepared a protection plan for its wells, and the Spokane Aquifer Joint Board (SAJB) prepared a wellhead protection plan on behalf of the other purveyors withdrawing groundwater from the Spokane Valley portion of the SVRP Aquifer (i.e., the SVRP Aquifer within Washington State). This area is within WRIA 57 and the southern portion of WRIA 55 (Figure 5.8). The individual water purveyors, land use regulators, and the Washington State Department of Health (DOH) are responsible for these wellhead protection programs.

2.3.2.4 Washington State Department of Health (DOH) Water Quality Monitoring

The Washington State DOH oversees compliance of public water systems with water quality monitoring requirements. Based on the source water assessment classifications given by DOH, public water systems are required to monitor various parameters at various frequencies at each of their water sources. The water quality monitoring results are reviewed by DOH to ensure compliance with water quality standards and with monitoring requirements. In addition, Washington DOH oversees the Consumer Confidence Report (CCR) federal rule (40 CFR 141 Subpart O) which was adopted as a state rule (WAC Chapter 246-290 Part 7 Subpart B) in June 2000. It became effective as a state requirement on August 21, 2000. This state regulation requires Group A community water systems to provide their customers with a report each year about the quality of water being served by the system. Group A water systems serve 15 or more connections or 25 or more people. This regulation does **not** apply to transient non-community (TNC), non-transient non-community (NTNC) or Group B water systems. The Consumer Confidence Report is required to be delivered to water system customers and the State Department of Health before July 1 of each year.

2.3.2.5 Ecology's Shorelands and Water Resources Program

Ecology's Shorelands and Water Resources program is charged with managing Washington State's water resources to ensure that the waters of the state are protected and used beneficially. An important component of water management relies on permitting and enforcement of water rights. The authority of Washington State and Ecology over water rights is outlined in the Revised Code of Washington (RCW) 90.03 and 90.44. In order to make water management decisions (for example granting or declining a permit for water use), Ecology must determine that the proposed water use passes four statutory tests (RCW 90.03.290): 1) the use will be beneficial; 2) the use will be in the pubic interest; 3) the water is available; and, 4) the use will not impair senior water users.

In addition to the four statutory tests listed above, Ecology must also consider other water management issues mandated by State and Federal Law including:

- Washington State water quality guidelines (WAC 173-200 and WAC 173-201)
- Preservation of instream flows (WAC 173-500);
- Preservation of aquatic habitat for endangered species (Environmental Species Act)

2.3.2.6 State-Designated Scenic River Corridor Program

In 1991, the Washington State Legislature designated the lower eight-mile reach of the Little Spokane River as a State Scenic River corridor. A river management plan is being developed to preserve the unique qualities of this portion of the river, which includes a diverse and biologically rich riparian wetland zone. The Washington State Parks Department is the lead agency.

2.3.3 Local Programs

2.3.3.1 Local Comprehensive Planning and the GMA

Future land use designation efforts under the Growth Management Act (GMA) require participating counties to accommodate a proportionate share of the state's projected 20-year population growth. The GMA identifies thirteen broad goals to guide local governments in the planning process. Included in the goals is encouragement of development in urban areas with existing or planned public facilities and services, reduction of urban sprawl, conservation of natural resources, protection and enhancement of the environment, and adequate provision of necessary public facilities and services.

City and county comprehensive plans are important to consider within the context of watershed planning because cities and counties: 1) govern land use within their corporate boundaries; and 2) have a great deal of responsibility for choosing and financing infrastructure that both effect and mitigate impacts on water resources. Historically, water resources have been addressed through a variety of focused means (e.g., sewer plans, storm water plans and shoreline management programs). City and county comprehensive plans are a means to coordinate more narrowly focused efforts over a broader jurisdictional area and at a watershed scale. Comprehensive plans define existing conditions, provide a forum for evaluating and making important public decisions, and provide authority to implement many potential watershed plan recommendations.

The Growth Management Act (GMA, Chapter 36.70A RCW)) has provided the mechanism to coordinate comprehensive plans for a variety of purposes, including achieving water resources goals. The most significant provision of the GMA bearing on the power and importance of city and county comprehensive plans is the requirement that all government decisions, including capital budget decisions, must be consistent with the comprehensive plan. The plan provides the policy basis and the authority for both short-term actions (e.g., infrastructure investments) and long-term solutions to water resource issues (e.g., shifts in land use configurations). Under GMA, local governments must make sure services are available prior to development. Theoretically, this includes examining the availability of water rights.

2.3.3.2 Critical Area Ordinances and the GMA

The GMA combined with Article 11 of the Washington State Constitution mandates every county and city in Washington to adopt policies and development regulations that designate and protect critical areas. Critical areas are defined as: wetlands; areas with a critical recharging effect on aquifers used for potable water; frequently flooded areas; geologically hazardous areas; and, fish and wildlife habitat conservation areas (WAC 365-190-080). Spokane County set forth the goals and policies in the Natural Environment Element of the Generalized Comprehensive Plan to guide the County in carrying out its mandate to designate and protect critical areas (Spokane County, 2001). The goals and policies related to critical areas will be implemented by updating the Spokane County Critical Areas Ordinance (Spokane County, 1996), including adoption of critical aquifer recharge areas designation and regulations, and updating the Spokane County Shoreline Master Program (Spokane County, 1975).

2.3.3.3 Groundwater Management Areas

The concept of a groundwater management area is embedded in Washington Administrative Code. Under the provisions of the code, Ecology designates a groundwater management area after petition by local government. The community then develops a management plan for groundwater protection based on existing data and any new data collected. Funding for developing groundwater management area plans has been available through the CWA.

In Spokane County and WRIA 55, the Deer Park basin has been designated a Groundwater Management Area. A groundwater management plan for the basin was developed in 1992 but has not been formally adopted. Portions of the plan have been molded into the Spokane County Conservation District’s Dragoon Creek Watershed management plan.

2.3.3.4 Spokane Water Quality Management Program

Spokane's Water Quality Management Program (WQMP) is set up as a joint County-City effort to direct the implementation of the Water Quality Management Plan. The plan (Spokane County, 1979) was approved as the guidance document for protection of the SVRP Aquifer within Washington by the Spokane City Council and the County Commissioners in the spring of 1979. The WQMP recommended that planning activities for the aquifer sensitive area recognize that the aquifer has a limited capacity to accept pollutants without degradation of the aquifer's water quality. The water quality management plan recognized the importance of the aquifer as a drinking water resource, recommended a goal of nondegradation; and, except to the extent that the Spokane River could impact the aquifer, placed a premium on aquifer water quality over river water quality. The WQMP also recommended mitigation for pollutant loading so as to allow for additional development without increasing the total pollutant load to the aquifer. Over the last 20 years, the WQMP has provided a wide variety of services and administered a number of regulation adoption efforts.

2.3.3.5 Spokane County Utilities Sewer Service Area Expansion

Spokane County has an on-going program of sewer interceptor construction within the designated urban area. To date, about half the residents within that area have been connected to the system. The current construction schedule will result in completion of the County sewer system by 2015. At that time, it is expected that at least 90% of the homes and businesses within the urban area will be connected.

2.3.3.6 Spokane County and City Stormwater Management / Underground Injection

Increased emphasis on underground injection control (UIC) and compliance with TMDLs by EPA and Ecology are having a significant impact on the City and County stormwater management programs. The UIC program is forcing both the City and County to evaluate the need for pre-treatment in the more than 10,000 stormwater injection wells that were installed prior to the passage of pretreatment requirements in 1980. The UIC program may require higher levels of stormwater treatment than current practice. The water quality standards for discharge and the amount of water subject to treatment may increase.

2.3.3.7 Local Agricultural Programs

The Farm Service Agency (FSA), the Natural Resources Conservation District (NRCS), the Washington State Department of Natural Resources (DNR), and the Spokane County Conservation District (SCCD) oversee local agricultural programs. Current programs include:

- The Environmental Quality Incentive Program – a cost share program that assists with installation of environmental practices such as dairy waste facilities and reduced or no-till management systems (NRCS).
- The Production Flexibility Contract – which supports program crop (wheat, barley, oats and corn in WRIAs 55 and 57) production (NRCS).

- The Conservation Reserve Program – which provides an annual rental payment to farmers willing to plant wildlife habitat. This program includes support for installation of filter strips and riparian buffers adjacent to streams (FSA).
- The Stewardship Incentive Program – which helps forestry landowners establish management plans and provides assistance for plan implementation (DNR).
- The Spokane County Buffer program – which helps farmers protect and replant the shoreline buffers to protect water quality (SCCD).

2.3.3.8 Wetland and Riparian Programs

- Wetland Reserve Program – administered by the NRCS, which gives financial incentives to enhance wetlands in exchange for retiring marginal land from agriculture.
- Forestry Riparian Easement Program – managed by the Small Forest Landowner Office within the DNR, which partially compensates small forest landowners in exchange for a 50-year easement on qualifying timber next to streams or rivers.
- Spokane Riparian Inventory and Assessment Project – an SCCD project to inventory and assess riparian areas throughout Spokane County.

2.3.3.9 Adjacent Watershed Planning Efforts

Watershed planning is currently being conducted in WRIA 59 (Colville River), WRIA 62 (Pend Oreille River) and WRIA 56 (Hangman Creek). All three of these adjacent WRIAs are also within Phase II of the Watershed Planning process. The lead agencies for WRIAs 59, 62 and 56 are Stevens County Conservation District, Pend Oreille Conservation District and Spokane County Conservation District, respectively.

2.4 Technical Information Development

Continued research to improve understanding of local water resources is being completed with grant funds focused on specific information needs or public utility funds to develop information for drinking water, stormwater and wastewater management. Currently, there are several on-going programs (in addition to the WRIA 55 and WRIA 57 assessments) to collect technical information. These additional programs are briefly described below.

2.4.1 Spokane Aquifer Coordinated Monitoring Program

This program is managed by Spokane County and involves:

- Collection and interpretation of regional aquifer quality data from quarterly sampling;
- Incorporation of purveyor drinking-water-compliance monitoring data into regional interpretations; and,

- Preparation of annual water quality reports.

2.4.2 USGS Stream Gaging Program

The USGS operates the most extensive network of stream gaging stations in the state. In the WRIA 55 and WRIA 57 area, the USGS has been collecting stream flow data since 1895 with the Spokane River at Spokane streamflow gage. The USGS currently operates eight satellite stream gaging stations within WRIAs 55 and 57 that provide readily available data that can be downloaded from the Internet. The USGS stream gaging sites within WRIAs 55 and 57 that are currently or have been monitored in the past are listed on Table 5.2 and located on Figure 5.2a.

2.4.3 Spokane County Conservation District Little Spokane River Studies

The Spokane County Conservation District (SCCD) is currently completing a number of water quality and quantity studies on the Little Spokane River. Summaries of these studies are provided below.

2.4.3.1 Nitrogen Sampling

As a result of recent land development within the Little Deep Creek and Deadman Creek sub-basins (Figure 1.2), the SCCD is currently evaluating the nitrogen levels in Little Deep Creek and Deadman Creek. Sampling began January 2001 and will continue through September 2002.

2.4.3.2 Macro Invertebrate Sampling

Benthic macro invertebrate samples are being collected in a fall 2000 to fall 2002 study. Samples are collected during the fall and spring from approximately 25 sites within WRIA 55. Dr. Lang of the Eastern Washington University Biology Department will identify samples. Sampling follows the Washington State Department of Ecology protocols developed by Rob Plotnikoff.

2.4.3.3 Water Quantity

The SCCD operates five stream flow monitoring stations within WRIA 55 (Figure 5.2a). All stations were installed September 1999 in conjunction with the Pend Oreille Conservation District study (POCD, 2000) and record stream depth and water temperature at one-hour intervals. Water depths will be converted to mean daily stream depths followed by mean daily stream flows. SCCD is currently compiling the 2000 water year's stream flow data. The stations monitored are:

- LS-1 Little Spokane River, Scotia Road near Newport WA.
- LS-3 Otter Cr., Elk to Hwy Road near Elk WA.
- LS-4 Little Spokane River, Deer Park-Milan Rd. near Riverside, WA.
- LS-5 Dragoon Cr., Crescent Road, Chattaroy

- LS-6 Deadman Cr., 15628 North Little Spokane Drive Spokane, WA.

With the exception of LS-1, all depth recorders were removed for repair by May 2001, and replaced between July and November of 2001.

2.4.4 Ecology / Army Corps of Engineers Spokane River Water Quality Modeling

Ecology and the Army Corps of Engineers are developing a 2D longitudinal / vertical, laterally averaged, hydrodynamic water quality model in support of TMDLs for the Spokane River. Ecology will be providing the Corps with groundwater inflows to and outflows from the river based on spreadsheet calculations that compare flow records in a downstream direction from the Post Falls Gage to the Long Lake outlet. Differences in flows between successive gaging stations in a downstream direction (including significant discharge to or withdrawals from the river by industry) represent a loss to or gain from the aquifer. The spreadsheet model is based primarily on 1991-1992 water year data. The model will be capable of predicting how water quality in the Spokane River will be impacted by groundwater and watershed changes only if the flows and concentrations entering and leaving the model resulting from these changes can be provided as input to the model. The model output predicts water surface elevations, velocities, temperatures and water quality for up to 21 constituents. The model is UNIX & PC compatible.

2.4.5 USGS Northern Rocky Mountain Water Quality Assessment

To address water resources protection at a national level, Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA program builds upon an existing base of USGS water quality studies as well as those of other Federal, State and local agencies. The objectives of the NAWQA program are to:

- Describe current water quality conditions for a large part of the Nations' freshwater rivers and aquifers;
- Describe how water quality is changing over time;
- Improve understanding of the primary natural and human factors that affect water quality conditions.

The Northern Rockies Intermontane Basins (NROK) study area (which includes areas in eastern Washington, northern Idaho and western Montana) is one of 59 study units selected by the USGS for full-scale implementation of the NAWQA program. The NROK study area includes the SVRP Aquifer (see Figure 5.8 and 5.9). Biological, hydrological and hydrogeological (on-going) studies of the SVRP Aquifer area are planned within the NROK study area.

In 2000, 18 wells were drilled by the USGS within 0.6 miles of the Spokane River between Post Falls, Idaho and Harvard Bridge near Spokane, Washington. These wells, and an additional 7 wells drilled for Ecology and Spokane County, were sampled 8 times from August 2000 to August 2001. Samples were analyzed for major ions, trace elements and stable isotopes (oxygen / deuterium). Ten of the wells were instrumented with continuous data loggers that recorded temperature and pressure. Continuous measurements of temperature, stage and specific conductance were also recorded at the USGS gage on the Spokane River at Post Falls. Elevations of the wells and elevations along cross-sections of the river channel were surveyed. This data will be summarized and interpreted in a USGS Water Resources Investigations Report. The USGS data and results (if available) will be incorporated into the water resources management model for WRIA 57.

2.4.6 Washington Department of Natural Resources Geologic Mapping

During the last ten years, the Washington Department of Natural Resources (DNR) has completed several studies to improve the geological mapping of the 14 USGS map quads that encompass the Spokane area. These studies include:

- Remapping the Quaternary geology of the Missoula Flood deposits;
- Refining areas of bedrock geologic mapping; and,
- Reconciliation of bedrock and Quaternary geology in conjunction with the Natural Resources Conservation Service.

Some of the geologic cross-sections completed as a component of this effort are included within this report as the Figure 4.14 series.

2.4.7 Soil Survey Update

The Natural Resources Conservation Service (NRCS), with support from the Spokane County Conservation District (SCCD) and Spokane County, is collecting data to update the 1968 Soil Survey for Spokane County. The project, which started in 1998, is expected to be completed by 2004. The soils information within this report is based on the 1968 Spokane County Soil Survey, as more up to date information is not yet available.

2.4.8 Stormwater Basin Planning

Spokane County's Stormwater Utility has recently completed the Chester Creek Basin and the Glenrose-Moran Prairie Basin Plans and is currently working on plans for the West Plains, North Spokane Plains and Spokane Valley. These plans include information on the quantity of water flowing out of the basin to the aquifer under various development scenarios. Spokane County is beginning a two-year study of stormwater quality and the efficiency of several treatment options.

2.4.9 Avista Dam Relicensing

Avista's license for its Spokane River Hydroelectric Project from the Federal Energy Regulatory Commission (FERC) expires in 2007. The license, FERC #2545, includes five hydroelectric developments. Avista must initiate the relicensing process in 2002, which is likely to include information collection in 2003 and 2004. Although this process is scheduled to occur after the development of a watershed management tool for WRIA 55 and 57, any relevant information collected and analyzed by Avista may be incorporated into the watershed management process and the watershed management tool updated as needed.

TABLE 2.1

Watershed Management Act Technical Assessment Requirements for WRIA 55 and WRIA 57

Component	Technical Assessment Requirements of the Watershed Management Act (WMA)	Status
Water Quantity RCW 90.82.070(1)	(a) An estimate of the surface water and groundwater present in the management area;	Complete.
	(b) An estimate of the surface water and groundwater available in the management area, taking into account seasonal and other variations;	
	(c) An estimate of the water in the management area represented by claims in the claims registry, water use permits, certificated rights, existing minimum instream flow rules, federally reserved rights, and any other rights to water;	
	(d) An estimate of the surface water and groundwater actually being used in the management area;	
	(e) An estimate of the water needed in the future for use in the management area;	
	(f) Identification of the location of areas where aquifers are known to recharge surface water bodies and areas known to provide for the recharge of aquifers from the surface; and	
	(g) An estimate of the surface water and groundwater available for further appropriation, taking into account the minimum instream flows adopted by rule or to be adopted by rule under this chapter for streams in the management area including the data necessary to evaluate necessary flows for fish.	To be completed within Phase III.
Water Quality RCW 90.82.090	(1) An examination based on existing studies conducted by federal, state and local agencies of the degree to which legally established water quality standards are being met in the management area;	Complete.
	(2) An examination based on existing studies conducted by federal, state and local agencies of the causes of water quality violations in the management area, including an examination of information regarding pollutants, point and non-point sources of pollution, and pollution-carrying capacities of water bodies in the management area. the analysis shall take into account seasonal stream flow or level variations, natural events and pollution from natural sources that occurs independent of human activities;	Complete as per WRIA 55/57 Ecology grant agreement.
	(3) An examination of the legally established characteristic uses of each of the nonmarine water bodies in the management area;	Complete.
	(4) An examination of any total maximum daily load established for nonmarine water bodies in the management area, unless a total maximum daily load process has begun in the management area as of the date the watershed planning process is initiated under RCW 90.82.060;	
	(5) An examination of existing data related to the impact of fresh water on marine water quality;	Not applicable.
	(6) A recommended approach for implementing the TMDL established for achieving compliance with water quality standards for the nonmarine water bodies in the management area, unless a TMDL process has begun in the management area as of the date the watershed planning process is initiated under RCW 90.82.060; and	To be completed within Phase III.
	(7) Recommended means of monitoring by appropriate government agencies whether actions taken to implement the approach to bring about improvements in water quality are sufficient to achieve compliance with water quality standards.	

3. THE HYDROLOGIC CYCLE

The hydrologic cycle provides the conceptual basis for a technical evaluation of a watershed. At a global scale, the hydrologic cycle describes the circulation of water between the oceans, atmosphere and land. At the watershed scale, the hydrologic cycle focuses in on the land-based hydrologic system that is bounded by surface water divides. For WRIA 55, the watershed area is defined as the area of land within Washington State that contributes surface water flow to the Little Spokane River (i.e., the contributing land area between headwaters of the Little Spokane River and the Little Spokane River – Spokane River confluence). For WRIA 57, the watershed area is defined as the area of land within Washington State that contributes surface water flow to the Spokane River above the confluence with hangman Creek (i.e., the contributing land area between the Idaho State Line and the Hangman Creek–Spokane River confluence).

A watershed must be viewed as a combination of both the surface drainage area and the subsurface soils and rocks that underlie the watershed (Figure 3.1). A good understanding of the hydrologic cycle at the watershed scale involves an inventory of the water inputs, outputs and storage within the watershed. Knowledge of the dynamic processes of a watershed hydrologic cycle provides an understanding of what effects various resource management approaches will have on the natural system.

In order to inventory and ultimately model a watershed, it is useful to also represent the hydrologic cycle as a systems diagram. Figure 3.2 illustrates the systems approach to the basin scale hydrologic cycle and differentiates between those terms that involve rates of movement (hexagonal boxes) and those that involve storage (rectangular boxes).

The hydrologic cycle, illustrated in Figures 3.1 and 3.2, is a network of inflows and outflows that may be expressed as a water balance or water budget by equating the primary variables (input, output and change in storage):

$$\text{Input} = \text{Output} +/- \text{Change In Storage}$$

This equation is a conservative statement that assures that all the water within the watershed is accounted for and that water cannot be lost or gained.

The main input to the hydrologic system is precipitation, in the form of rainfall and snowmelt. The amount of precipitation is the primary control on the amount of water that may be available within the watershed. Secondary inflows to the hydrologic system include groundwater recharge and surface water recharge into the watershed. For the Little Spokane WRIA, groundwater recharge from the Middle Spokane WRIA through the Hillyard Trough into the Little Spokane River is an important inflow. For the Middle Spokane WRIA, groundwater inflow and surface water inflow into the watershed at the Idaho State Line are important. The inflow of water across the state line comes from the rest of the watershed that lies outside of the State of Washington, an area much larger than the Middle Spokane WRIA.

Outflow from a watershed occurs naturally as streamflow or runoff, groundwater discharge and as evapotranspiration. Evapotranspiration is the combination of evaporation from open bodies of water, evaporation from soil surfaces and transpiration from the soil by plants. Outflow from a watershed also occurs as a result of human consumption and redirection of flows

Movement of water within a watershed occurs naturally through a number of processes. Overland flow delivers precipitation to stream channels. Infiltration results in movement of water at the land surface downward into the subsurface. Groundwater flow results in movement of water within the subsurface. Baseflow delivers groundwater to stream channels. Streamflow or surface water flow results in movement of water within stream channels. Infiltration rates and groundwater flow rates are controlled by the nature of the land surface and subsurface. Infiltration rates and groundwater flow rates in turn influence the timing and spatial distribution of surface water flows. Groundwater flows and surface water flows are linked by the relationships between infiltration, groundwater recharge, baseflow and streamflow generation.

Movement and outflow/inflow of water within a watershed is also impacted by a number of human factors including groundwater pumping, extraction of surface water, stormwater generation and discharge, wastewater generation and discharge, and agricultural and land use practices.

The hydrologic cycle at a watershed scale is most commonly analyzed on an annual basis over the water year, defined as the October 1 through September 30 (i.e., the beginning of autumn through to the end of summer). Successive years are compared so that changes in the water budget (and its components) over successive years can be assessed. The primary variables are affected by seasonal, interannual, interdecadal and decadal variability (e.g.: snowpack accumulation and melting; dry versus wet years; El Nino / El Nina; and, Pacific Decadal Oscillations, respectively).

The data compilation completed and documented in this report collects, describes and assesses the existing information that may be used to develop a conceptual and numerical watershed model for WRIA 55 and 57. In broad categories, this information includes: topography and drainage; climate; land cover; geology; groundwater; surface water; hydraulic continuity between groundwater and surface water; and, water use.

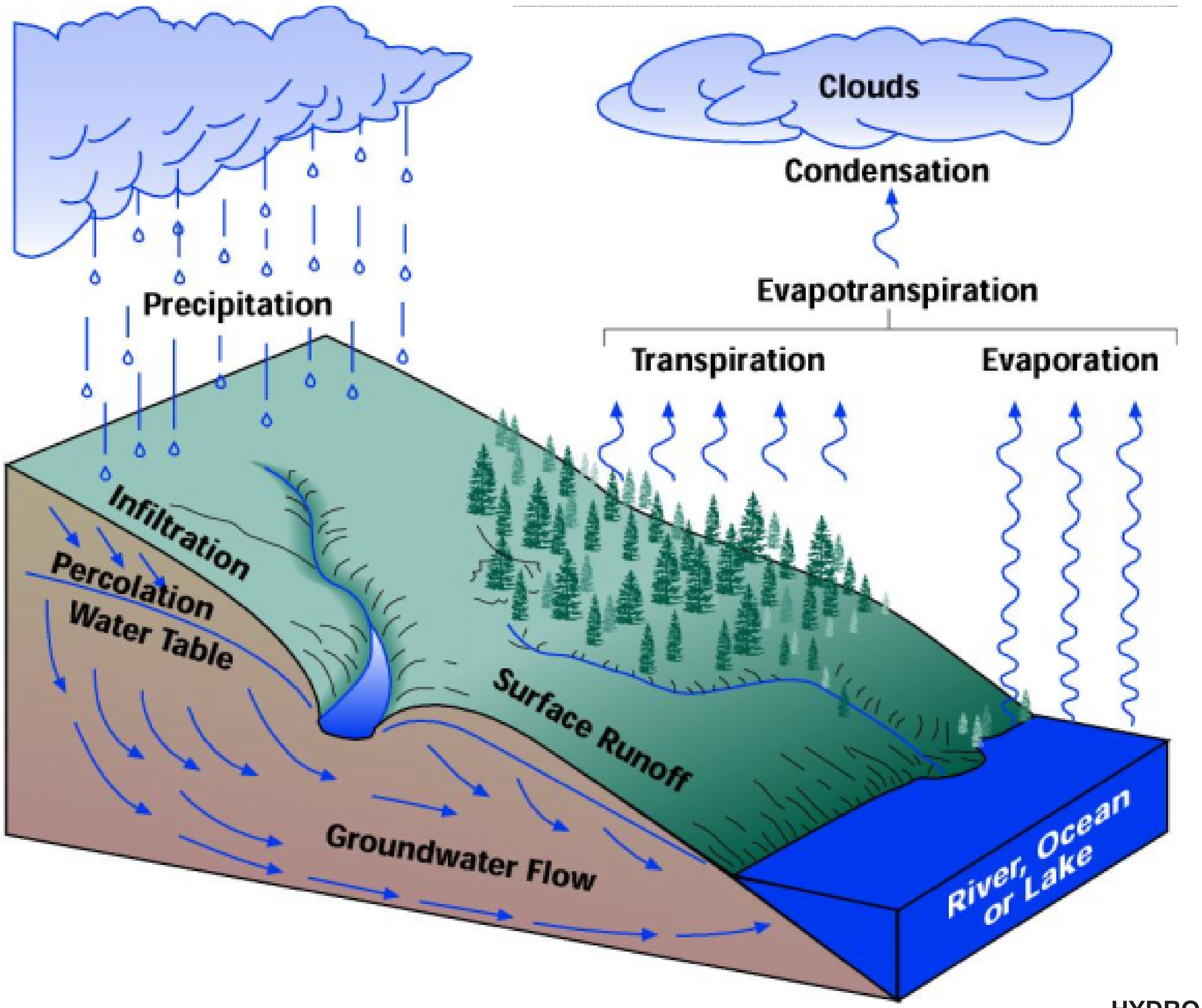


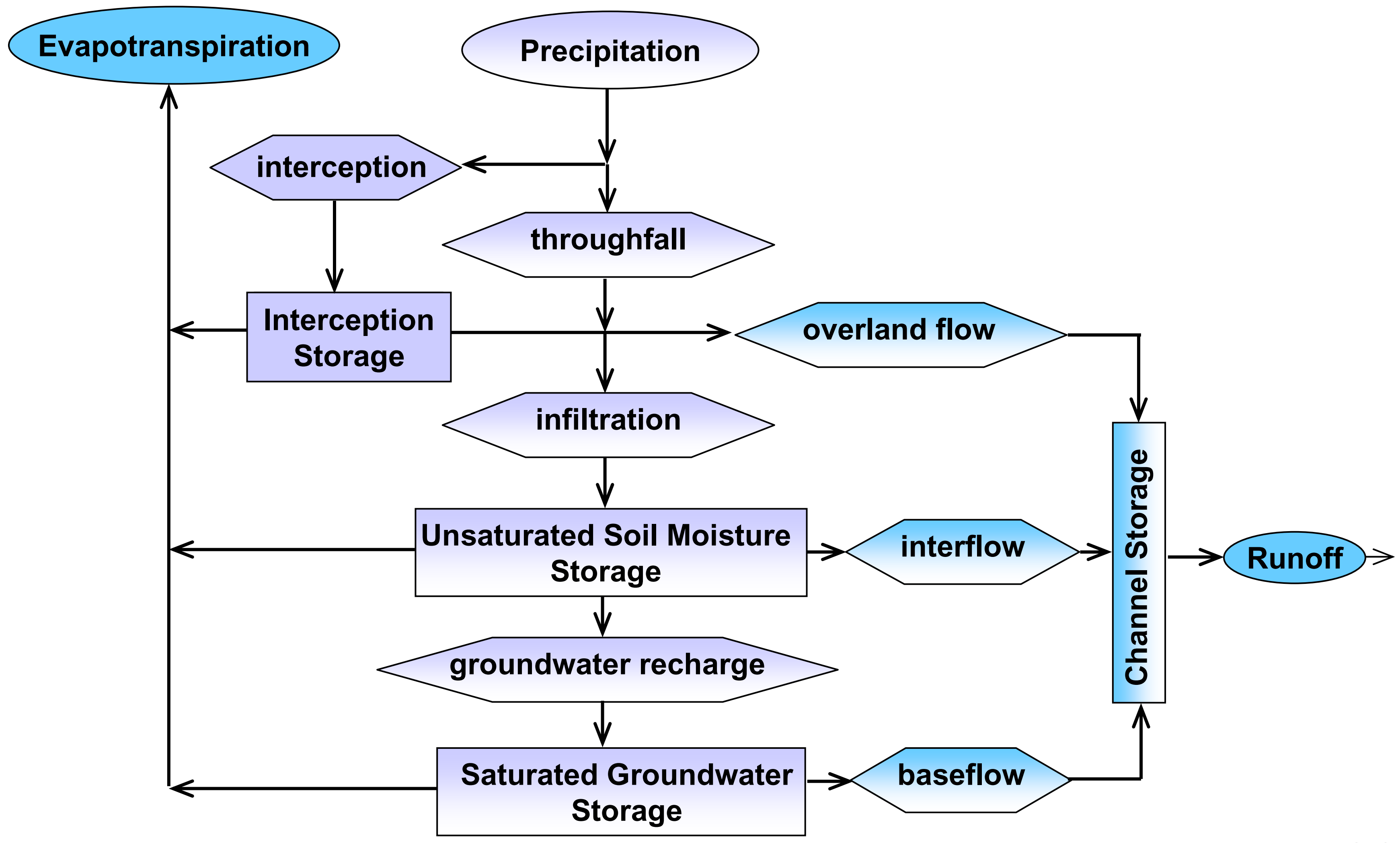
FIGURE **3.1**

HYDROLOGIC CYCLE

SPOKANE COUNTY/LEVEL I ASSESSMENT/WA

PROJECT NO. 013 1372_1700 DRAWING NO. 92886 DATE 10/15/01 DRAWN BY ETF

Golder Associates



Adapted from Freeze and Cherry, 1978.

FIGURE **3.2**

SYSTEMS REPRESENTATION OF THE HYDROLOGIC CYCLE

SPOKANE COUNTY / LEVEL 1 ASSESSMENT / WA

PROJECT NO. 013-1372.1700 DRAWING NO. DATE 10/15/01

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4. REGIONAL SETTING

This section places the study area within a regional setting and describes the climate, geology, soils, land cover, land use and population of WRIA 55 and WRIA 57. The purpose of this section is to characterize the distribution of precipitation within the WRIAs and the physical and human facets of the WRIAs that influence the fate of precipitation on land and within the subsurface. The movement of water on the surface (i.e., the hydrology) and the movement of water within the subsurface (i.e., the hydrogeology) of WRIAs 55 and 57 are described in Section 5.

4.1 Overview

WRIA 55 and WRIA 57 are located within northeastern Washington, on the Washington-Idaho border (Figure 1.1). The WRIAs are bounded by WRIA 56 (the Hangman Creek basin) to the south, WRIA 54 (the Lower Spokane basin) to the east, WRIA 59 (the Colville River basin) to the northwest and WRIA 62 (the Pend Oreille River basin) to the northeast (Figure 1.1). Watershed planning is ongoing in all of these WRIAs with the exception of WRIA 54 (Lower Spokane Basin, the Spokane River downstream of the Hangman Creek confluence).

Topographic elevations range from 1,640 feet above mean sea level where the Little Spokane River discharges into the Spokane River to 5,878 feet above mean sea level on the summit of Mount Spokane. The climate ranges from high plains desert to temperate. Annual precipitation ranges from less than 20 inches to over 40 inches. Between 12 and 15 feet of snow accumulates on Boyer Mountain in the northwest corner of WRIA 55, and on Mount Spokane on the eastern border of WRIA 55 with WRIA 57. Otherwise snow accumulation is less than three feet in the area of the City of Spokane and the Spokane Valley.

The watersheds lie at the boundary between two major physiographic provinces of North America (Fenneman, 1931; Figure 1.1). The north of WRIA 55 and the east of WRIA 57 are characterized by landforms typical of the Northern Rocky Mountains Province. The Northern Rocky Mountains are characterized by north-south trending mountains and valleys and comprise predominantly crystalline basement rocks that rise steeply from the Columbia Plateau. In WRIA 55, the mountains are rounded and are located on the west (the Huckleberry Range), the east (Mount Spokane) and the north (the Selkirks) of the watershed. In WRIA 57 the mountains are rounded and are located to the north (Antoine Peak) and the south (Mica Peak) of the Spokane Valley. The south of WRIA 55 and the west of WRIA 57 comprise landforms typical of the Columbia Plateau Province. These include flat-topped basalt plateaus (Half Moon Prairie, Wild Rose Prairie, Orchard Prairie, Green Bluff, Orchard Bluff and Five Mile Prairie).

In both WRIA 55 and WRIA 57, there are areas of subdued topography that represent areas of basement and basalt rocks that were scoured and infilled by peri-glacial processes, including the Missoula Floods. The Spokane Valley represents the main Missoula Flood channel. The primary aquifers in WRIA 55 and WRIA 57 comprise these glacial flood unconsolidated sediments (e.g., the highly productive SVRP Aquifer). Less productive aquifers occur within the basalts (e.g., Green Bluff).

Natural land cover ranges from scrub brush in the lower portions of the basins to mixed coniferous and deciduous forests in the uplands. Land use is primarily urban with residential development in the Spokane Valley and around the City of Deer Park. Substantial suburban development is occurring in the lower reaches of the Little Spokane River north of the City of Spokane. Agricultural land use is concentrated in the Dragoon Creek sub-basin of the Little Spokane Basin, and in the Deadman Creek sub-basin (Figure 1.2), and scattered in lower density throughout the rest of the lower elevations of the basins. Minor amounts of land are used for rangeland.

4.2 Climate

The climate of the Little Spokane and Middle Spokane WRIAs is generally warm and dry in the summer and cool and moist in the winter. Large variations in climate occur across the basin from a sub humid mountain climate in the north to semiarid in the south (Dames and Moore and Cosmopolitan, 1995). Annual precipitation also varies considerably over the region increasing from an average of 16 inches annually in the southwest areas to more than 35 inches in the north and east.

There are 18 meteorological stations in and around WRIAs 55 and 57 that can aid in understanding climate patterns in the region (Figure 4.1 and Table 4.1a). Hydrographs of annual precipitation at selected stations are included in Appendix B. Spokane County staff provided most of the climate station data to Golder. Additional station data and summaries (not whole periods of record) were obtained for stations in the area that could aid in evaluating the local climate. These stations are identified in Table 4.1a as having periods of record that are “not supplied”.

Outputs from the Parameter-Elevation Regressions on Independent Slopes Model (PRISM) are used to represent climate data for the basins. PRISM is a model that uses point data and a digital elevation model (DEM) to generate gridded estimates of climate parameters (Daly and others, 1994). Unlike other statistical methods in use today, PRISM was written by a meteorologist specifically to address climate. PRISM is well suited to mountainous regions because the effects of terrain on climate play a central role in the model’s conceptual framework. Data input to the model consisted of 1961-1990 mean monthly precipitation from over 8000 National Oceanic and Atmospheric Administration (NOAA) Cooperative sites, Snowpack Telemetry (SNOTEL) sites, and selected state network stations. PRISM is used to estimate mean annual, mean monthly and event-based precipitation, temperature, and other variables. The model grid resolution is 4-km (latitude and longitude). The outputs used in this study are re-sampled to 2-km resolution using mathematical filtering procedures (Daly and others, 1994).

Due to the vast amount of data used in the analysis and the high degree of peer review since publication, PRISM precipitation data are considered high quality. Other PRISM outputs for the state of Washington, such as mean monthly temperature, are more preliminary and have not yet benefited from the same level of peer review.

4.2.1 Precipitation

Precipitation includes all water that falls from the atmosphere to the earth's surface. Precipitation occurring in the liquid phase (rainfall) and the frozen phase (snow, hail, sleet and freezing rain) are the phases that are of interest for this watershed analysis. Rainfall has the potential to run off into streams (though not all rainfall runs-off immediately due to infiltration, evaporation, etc.). Frozen precipitation may remain where it falls for a long time before melting and producing run-off.

Snowfall in the study area is an important component contributing to streamflow and aquifer recharge. In order to estimate the amount of water available in frozen precipitation it is often defined by the amount of liquid that would be produced if melted; called the snow water equivalent or SWE. SWE can be measured at gages using specialized sensors or it can be estimated by conversion of snowfall to SWE. Only three stations in the vicinity of the WRIAs collect SWE data (Figure 4.1): Bunchgrass Meadow, Quartz Peak and Spokane International Airport. The average of the peak annual snowpack in SWE measured for these stations is 28.5 inches, 22.3 inches and 0.6 inches, respectively. Established conversion values can be used to estimate SWE of other snowfall gages. Lindsay and others, (1997) state that 1 inch of snowfall is usually equivalent to 0.1 inch of SWE (i.e., water).

4.2.1.1 Precipitation and Snowpack in WRIA 55

In contrast to WRIA 57, the watershed area that contributes precipitation to WRIA 55 is essentially delineated by the WRIA 55 boundary. Precipitation variability across WRIA 55 is primarily a function of elevation and proximity to upland areas (Figure 4.2). Based on average annual PRISM data (Figure 4.2), annual precipitation within WRIA 55 ranges from:

- 15 to 20 inches in southern, low-lying area of WRIA 55.
- 20 to 25 inches across the moderate elevations of the Deer Park Basin (central western WRIA 55).
- 25 to 30 inches across the moderate elevations of the Diamond Lake area (northeastern WRIA 55).
- Between 30 to over 40 inches in the uplands along northern and eastern boundaries of WRIA 55.

In order to confirm if PRISM precipitation data adequately approximates the actual precipitation within the WRIA 55, a comparison was made between average annual PRISM precipitation (Figure 4.2) and average annual precipitation for representative WRIA 55 climate station data (Figure 4.1 and Table 4.1a). The following stations were selected as representative of WRIA 55's precipitation variability. The locations of these stations are shown on Figure 4.1.

- The Spokane International Airport station (at 2,355 ft amsl) represents southern, low-lying area of WRIA 55.

- The Deer Park 2 E station represents (at 2,201 ft amsl) the moderate elevation climate of central and western WRIA 55.
- The Newport station (at 2,134 ft amsl) represents the moderate elevation climate of northeastern WRIA 55.
- The Mt. Spokane Summit station (at 5,280 ft amsl) represents the northeastern high mountainous regions of WRIA 55.

The summary table below compares the average annual PRISM precipitation data to the average annual precipitation recorded at the representative climate stations.

Comparison of PRISM and WRIA 55 Climate Station Data

Station	**Station Elevation** (ft amsl)	**Avg. Annual Station Precipitation** (inches)	**Avg. Annual PRISM Precipitation Range** (inches)
Spokane International Airport	2,355	16.25	15 – 20
Deer Park 2 E	2,201	21.8	20 – 25
Newport	2,134	26.5	25 – 30
Mt. Spokane Summit	5,280	41.4	>35

As indicated on the summary table above, PRISM data adequately represents average annual precipitation data for WRIA 55 climate stations.

The average monthly PRISM precipitation for WRIA 55 (Figure 4.3) illustrates that the majority of the WRIA 55 precipitation occurs between November and March. The monthly PRISM data is supported by the average monthly precipitation for representative climate stations (Figure 4.1 and Figure 4.4).

Significant snow pack (Figure 4.5) accumulates mostly in the eastern and northern portions of the basin at relatively high elevations. Up to 60% of the total precipitation falls as snow during the winter months over the higher elevations (Figure 4.6). For example, at the Quartz Peak station, located on the eastern boundary of WRIA 55 (Figure 4.1), SWE is between 25% and 60% of total precipitation. A daily representation of SWE and precipitation is shown in Figures 4.7a and b. A monthly representation of SWE (calculated from snow depth) is presented on Figure 4.8. These figures indicate that spring snowmelt originating from the higher elevation areas in the north and east of WRIA 55 represent an important component of run-off to streams. However, the spring snowmelt contribution to streamflow from the lower-lying central and southern portions of WRIA 55 is often reduced in stages throughout the winter by the frequent mid-winter thaws (Figure 4.8).

4.2.1.2 Precipitation and Snowpack in WRIA 57

Precipitation variability across WRIA 57 is also a function of elevation and proximity to upland areas (Figure 4.2). Based on average annual PRISM data (Figure 4.2), annual precipitation within WRIA 57 ranges from:

- 15 to 20 inches in the western and central, low-lying area of WRIA 55.
- 20 to 25 inches across the southeastern (Mica Peak) and western (Hauser Lake) moderate elevations of WRIA 57.
- Between 35 to over 40 inches across the uplands of northwestern WRIA 57.

The following stations were selected as representative of WRIA 57's precipitation variability. The locations of these stations are shown on Figure 4.1.

- The Spokane International Airport station (at 2,355 ft amsl) represents the western and central, low-lying area of WRIA 57.
- The Coeur d'Alene 1 E station (at 2,132 ft amsl) represents the low to moderate elevation climate southeastern and western WRIA 57.
- The Mt. Spokane Summit station (at 5,280 ft amsl) represents the northeastern high mountainous regions of WRIA 55.

The summary table below compares average annual PRISM precipitation (Figure 4.2) and average annual precipitation for representative WRIA 57 climate station data (Figure 4.1 and Table 4.1a). As indicated on the summary table above, PRISM data also adequately represents average annual precipitation within WRIA 57.

Comparison of PRISM and WRIA 57 Climate Station Data

Station	**Station Elevation** (ft amsl)	**Avg. Annual Station Precipitation** (inches)	**Avg. Annual PRISM Precipitation Range** (inches)
Spokane International Airport	2,355	16.25	15 - 20
Coeur d'Alene 1 E	2,132	26.49	20 - 25
Mt. Spokane Summit	5,280	41.4	35 - > 40

As for WRIA 55, the average monthly PRISM precipitation for WRIA 57 (Figure 4.3) illustrates that the majority of the WRIA 57 precipitation (38% [Dames and Moore and Cosmopolitan, 1995]) falls between November and March. The lowest precipitation occurs from July through September (approximately 12 % of the annual total [Dames and

Moore and Cosmopolitan, 1995]). The monthly PRISM data is supported by the average monthly precipitation for representative climate stations (Figure 4.1 and Figure 4.4).

Winter snowfall (Figure 4.5 and Figure 4.6) frequently accumulates to depths of a foot or more over the lower elevation areas of WRIA 57, but usually melts within a few days (MacInnis and others, 2000). This is supported by the fact that the average monthly temperature at the Spokane International Airport station falls below freezing only in December and January. At the Spokane International Airport station, the maximum average monthly snowfall is 13 inches and occurs in January. In comparison, the maximum average monthly snowfall recorded at the Mount Spokane Summit station is about 38 inches in January. Average annual snowfall at the Spokane International Airport is 41.8 inches. Average annual snowfall at the Mount Spokane Summit station is 170.4 inches. Using the ratio of 1 inch of snowfall to 0.1 inches of SWE, the average annual snowfall at the Spokane International Airport and the Mount Spokane Summit stations are equivalent to about 4 and 17 inches, respectively.

4.2.1.3 WRIA 57 Contributing Watershed Area

As described in more detail in Section 5.1 of this report, the watershed area that contributes water to the Middle Spokane River in WRIA 57 is large (greater than 3,700 square miles) and extends to the Idaho-Montana border (Figure 5.1). Precipitation falling within WRIA 57 has less importance in sustaining streamflow and aquifer recharge than precipitation and snowmelt that falls in the portion of the basin in Idaho (i.e., the Bitterroot Mountains). The Bitterroot Mountains, east of Coeur d’Alene, are an important recharge area for both the SVRP Aquifer and the Spokane River due to the relatively high elevation of the mountains in comparison to the WRIA 57 area. Average annual precipitation in the Bitterroot Mountains is more than 70 inches a year (MacInnis and others, 2000). About 60% of this precipitation falls during the five-month period between November and March. Much of this falls as snow, especially in the mountains. It is the resulting snowmelt that is responsible for the spring peak in the streamflow hydrographs (see Chapter 5).

4.2.2 Temperature

Temperature varies considerably across WRIAs 55 and 57 from an annual average of 48 degrees Fahrenheit (°F) in the lower-lying areas to 36 °F in the mountains. Deviations in temperature within the Spokane Valley of WRIA 57 are very small, varying no more than 2 or 3 °F (MacInnis and others, 2000). Average temperatures in WRIA 55 vary by more than 10 °F from the low-lying areas in the south to the mountains in the north and east. Table 4.1b details annual monthly average maximum and minimum temperature for representative stations. Mean monthly temperatures at these same stations are presented in Figure 4.9.

4.2.3 Evaporation

Evaporation and transpiration from plants (water lost through plant uptake and release to the atmosphere) are combined together and referred to as evapotranspiration.

Evapotranspiration occurs year round, but is highest during the summer months (May to September) when it is estimated that 80% of total transpiration and evaporation occurs. Potential evapotranspiration (P_{ET}) is the amount of evapotranspiration that would occur if water were always available. P_{ET} is estimated to range from 20 to 25 inches at lower elevations (PNRBC, 1970). Actual evapotranspiration depends on many factors including land cover, temperature, precipitation, surface water, growing season, etc. It is especially important in irrigated areas and is discussed further in Section 7 (Water Use). Actual evapotranspiration has been estimated to range between 10 and 12 inches annually (PNRBC, 1970) over much of the area. Annual evapotranspiration at Deer Park (elevation 2,214 feet amsl) was estimated as 23 inches for P_{ET} and 14 inches for actual evapotranspiration (Chung, 1975).

4.2.4 Long Term Climatic Variations

Long term climatic variations (including natural climate variability and human induced climate change) are identified by assessing historic climatic trends and extrapolating these trends to predict future climates.

4.2.4.1 Natural Climate Variability

Natural climate variability in the Pacific and Inland Northwest is associated primarily with changes in the surface temperature and winds of the Pacific Ocean (JISAO and SMA, 2001). The two main Pacific climatic patterns that influence the Pacific Northwest are the El Nino Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). The ENSO recurs on a 2 to 7 year time scale. The PDO is a pattern that reverses on a 20-30 year time scale.

El Nino (also called a warm phase ENSO) is an unusual warming of the equatorial Pacific sea surface temperatures that generally causes unusually warm and dry weather in the Inland Northwest. La Nina (also called a cool phase ENSO) is an unusual cooling of the equatorial Pacific sea surface temperatures that generally causes unusually cool and wet weather in the Inland Northwest. ENSO phases usually last 6 to 18 months with particularly strong impacts of the climate of the Inland Northwest in October and March. Good understanding of the ENSO phases and triggers has resulted in the ability of climate research groups to predict these events up to one year in advance. Currently (2001), the Inland Northwest is being impacted by an ENSO neutral period. The forecast for the winter 2001 and 2002 predicts a weak El Nino developing over the winter or late spring.

The PDO, recognized initially in the early 1990s, also has warm and cool phases that impact the Inland Northwest over 20 to 30 year cycles. A warm phase PDO, which occurs as a result of unusual warming of sea surface temperatures in the central north Pacific, brings cooler sea surface temperatures to the coast of the Pacific Northwest. A cool phase PDO, which occurs as a result of unusual cooling of sea surface temperatures in the central north Pacific, brings warmer sea surface temperatures to the coast of the Pacific Northwest. Because the PDO triggers are not well understood, they cannot be predicted at this time. Based on the climatic record of the Pacific Northwest, cool, wet

PDO regimes are predicted to have lasted from 1890-1924 and again from 1947-1976. Warm, dry PDO regimes have spanned 1925-1946 and from 1977-1994 (Miles, 2000). It is believed that the PDO phase may have shifted to a cool period in the late 1990s. The estimated PDO changes in the climate of the Pacific Northwest as a percentage of average (except for temperature) are presented in the summary table below (JISAO and SMA, 2001).

Climatic Changes as a result of PDO Phases

(adapted from Figure 4, JISAO and SMA, 2001).

Climatic Factors	**WARM PDO** (1925-45 and 1977-1995)	**COOL PDO** (1890-1924, 1946-1976 and 1996-?)
Temperature	+ 0.3 °F	- 0.2 °F
Precipitation	+ 2%	- 4%
Snow Depth	- 15%	+ 17%
Streamflow	- 10%	+6%
Forest Fires	+65%	-49%

Note: Temperature averaged over the Pacific Northwest for October – March.
Total annual precipitation averaged over the Pacific Northwest.
Snow depth averaged from Jan 15 to Apr 15 at Snoqualmie Pass.
Streamflow at The Dalles corrected for dam regulation.
Areas burned by forest fires in Washington and Oregon.

4.2.4.2 Human Induced Climate Change

The Pacific Northwest has become on average 1.4 °F warmer and 2.9-inches wetter over the last 100 years. Carbon dioxide in the atmosphere has increased by more than 30% since the beginning of the Industrial Revolution, mainly because of the burning of fossil fuels. Although it has not been confirmed that increasing levels of carbon dioxide in the atmosphere has caused this change, these changes are consistent with the results of computer models used to simulate the effects that increases in atmospheric carbon dioxide will have on climate (JISAO and SMA, 2001). Studies completed indicate that temperatures in the Pacific Northwest will increase between 3.1 to 6.3 °F by the 2050s, resulting in wetter winters and drier summers (JISAO and SMA, 2001). The most significant change in the Inland Northwest is likely to be a shift from winter snow to rain, snow pack reduction, higher winter streamflows, earlier streamflow peaks and less water availability in the summer.

4.2.4.3 Assessment of Climate Variations in WRIA 55 and WRIA 57

Generally, it is difficult to identify long-term climatic changes from hydrograph data. Rescaled Cumulative Departure (RCD) analysis provides a method for assessing long-term, cyclic precipitation trends. An RCD plot displays whether a system is exhibiting above or below average precipitation, how severe current conditions are (i.e., how far from average conditions) and the duration of the wet or dry period.

RCD analysis involves determination of mean-monthly values of the hydrologic variable (e.g., precipitation) for a selected base period. The difference between the monthly value in that year minus the mean-monthly value is calculated as the departure. The cumulative departure is calculated as the sum of the monthly departure over the entire period of record. Standardization (or rescaling) is completed by dividing the cumulative departure by the standard deviation of the cumulative-annual departure.

In order to calculate the cumulative departure it is necessary to first determine a base period. The base period should be a period of record that is representative of a normal cycle of wet and dry seasons. The base period could be the entire period of record or a shorter representative period. In a study completed by the USGS (Kresch, 1999) it was determined that a base period of 1937-1976 accurately reflected long-term average conditions in Washington. The USGS study involved an RCD evaluation of precipitation and stream gaging stations across Washington and parts of Oregon and Idaho in order to identify geographic regions of similarity. The study objective was to determine areas where the severity and duration of dry and wet periods was similar. Spokane International Airport was the only station available in the vicinity of the WRIA 55 and WRIA 57 study area that had a long enough period of record to analyze using cumulative departure methods. The Spokane International Airport is located about 5 miles west of WRIA 57 and 10 miles south of WRIA 55 (Figure 4.1). Another station analyzed in the USGS report, Colfax 1 NW, is located about 50 miles south of WRIA 57 (Figure 4.1) but is relevant to analysis of the cyclic nature of precipitation in WRIAs 55 and 57.

RCD curves for precipitation at the Spokane International Airport and Colfax 1 NW stations are presented as Figures 4.10a and 4.10b, respectively. A declining RCD plot slope, such as the slope between 1932 and 1947 for Spokane International Airport (Figure 4.10a) and Colfax 1 NW, indicates that precipitation was below average during much of the interval. The slope of the RCD trend and duration of the cycle indicate the relative severity of the drought. For example, the steep declining RCD slope of the 1932 to 1947 dry period in the vicinity of the Spokane International Airport (Figure 4.10a) indicates that the drought was significantly more severe in this area in relation to Colfax. The Colfax data (Figure 4.10b) indicates a slightly declining slope overall with short-term periods of increasing slope.

Between 1947 and the mid 1960s, both the Spokane International Airport area (Figure 4.10a) and the Colfax area (Figure 4.10b) experienced a period of above average precipitation which is indicated on the figures by an increasing slope to the early 1960s followed by a decline to more average conditions. This wet period is followed by a period of below average precipitation, indicated by the declining RCD slope between the mid-1960s and 1994 (Figures 4.10a and 4.10b). Based on the climate station data, this below average precipitation period was more severe in the Colfax area (Figure 4.10b) than the Spokane area (Figure 4.10a) as indicated by the steeper declining slope for the Colfax 1 NW data. After 1994, there appears to be a slight increasing trend in precipitation (Figures 4.10a).

The PDO shifts (see Section 1.2.4) are also included on Figures 4.10a and 4.10b. Cool, wet PDO regimes are predicted to have lasted from 1890-1924 and again from 1947-1976, and from 1994 to present. Warm, dry PDO regimes spanned 1925-1946 and from 1977-1994 (Miles, 2000). Spokane International Airport and Colfax 1 NW generally follow these shifts except for a period between the mid-1960s to 1976 when precipitation at these stations declined to below average.

4.2.5 Watershed Planning and WRIA 55 / 57 Climatic Setting

In terms of watershed planning, it is important to understand the impacts that climatic change may have on the future water resources of WRIAs 55 and 57 so that appropriate watershed management decisions can be made and so that the watershed plan is resilient to the impacts of climatic change. Based on a review of available information on the climatic setting of WRIAs 55 and 57 and on the predicted climatic changes of the future, climatic warming as a result of increased greenhouse gases within the atmosphere has the greatest potential to impact water resources management over the next 50 years. Due to the near freezing winter temperatures experienced within the mountains of WRIA 55 and WRIA 57 (indicated by winter thaws), the overall increase in annual temperatures as a result of warming is likely to cause a shift from winter snow to winter rain, snow pack reduction, higher winter streamflows, earlier streamflow peaks and less water availability in the summer. The El Nino / La Nina cycles (which can be predicted up to a year in advance) and the PDO shifts, have the potential to exacerbate or alleviate this human induced change.

4.3 Geologic Setting

This section presents the geologic framework for WRIAs 55 and 57, including the geologic history of the watersheds, stratigraphy and description of geologic units. The purpose of this section is to present the background information necessary to formulate a conceptual hydrogeologic model for the WRIAs.

The information presented within this section is based primarily on:

- USGS, DNR and Geological Society of America publications (Pardee and Bryan, 1926; Bretz, 1930; Newcomb, 1953; Bretz, 1959; Baker, 1973; Weisenborn and Weis, 1976; Molenaar, 1988; Boleneus and Derkey, 1996; Derkey, 1997; Derkey, Gerstel and Logan, 1998; DNR, 2001 unpublished);
- Research theses and papers (Kiver and Stradling, 1985; McKiness, 1988; Robinson, 1991; Boese and Buchanan, 1996);

- Work completed for the private sector (Boleneus, 1978); and,
- Work completed within the basins by local, state and federal agencies (Landau Associates, Inc., 1991; EMCON, 1992; Dames and Moore and Cosmopolitan, 1995; CH2M Hill, 1998; CH2M Hill, 2000;MacInnis and others, 2000).

4.3.1 Geologic Mapping and Stratigraphy

The simplified geologic stratigraphy of the study area (Figure 4.11) describes the layered sequence of geologic units from the land surface downward and the age relationships between the units. The expression of these units on the land surface is illustrated as the surficial geology (Figure 4.12). This surficial geologic map was published by the DNR and was provided to Golder by Spokane County GIS.

The stratigraphic relationships between the geologic units are most easily explained by geologic cross-sections. A geologic cross section represents a vertical slice though the ground that is drawn based on well log or seismic information and the correlation of unit contacts between points or areas of known geology. The location of available geologic cross-sections for WRIAs 55 and 57 are shown as traces on Figure 4.12 and include sections constructed by Emcon (1992), Boese & Buchanan (1996), CH2M Hill (1998) and DNR (2001, unpublished). Fifteen geologic cross-sections are included with this report and are presented as Figure 4.14A through 4.14O. An explanation of symbols used on the cross-sections is provided as Figure 4.13. The locations of the cross-sections included within the report (Figures 4.14A through 4.14O) are denoted on Figure 4.12 with a letter symbol at either end of the section trace. These cross-sections were selected to illustrate specific features that are important to the formulation of the conceptual hydrogeologic model for WRIAs 55 and 57.

4.3.2 Geologic History

The geologic history of WRIA 55 and 57 can be summarized by: 1) formation of basement rocks; 2) the basalt flows and interbedded sedimentary deposition; 3) glaciation and outburst flooding events; and, 4) recent processes.

The crystalline basement rocks that are exposed over the upland areas of the WRIA 55 and WRIA 57 (denoted as B on Figure 4.12) also underlie the valleys. These rocks were originally deposited as sediments within a shallow marine environment. These sediments were heated and uplifted and intruded by igneous rocks during the mountain building continental plate activity that created the Rocky Mountains.

The Columbia River Basalts within WRIAs 55 and 57 (denoted as Tw/Tgr on Figure 4.12) are remnants of flows that extended northwards past the present location of Spokane and eastward into Idaho. A lull in volcanic activity after the Grande Ronde Basalt extrusion and prior to the Wanapum Basalt extrusion allowed for the formation of lakes in areas where the basalt had dammed existing streams. Significant thicknesses of lacustrine silts and clays (known in the Spokane area as the Latah Formation and denoted as Tl on Figure 4.12) collected in these lakes. Resurgence of volcanic activity resulted in flow of the Priest Rapids Member of the Wanapum Basalt into the Little Spokane area. Although most of the Wanapum has been eroded, thin veneers of this basalt cap plateaus such as Green Bluff, Orchard Bluff, Pleasant Prairie, Orchard Prairie and Five Mile Prairie at elevations between 2,250 and 2,350 feet above mean sea level (Boese and Buchanan, 1996).

After the formation of the Columbia River Basalt flows and prior to the recent glaciation, the Spokane River flowed westwards from Idaho through the Spokane Valley, northwards around Beacon Hill in what is known today as the Hillyard Trough. At this time, the ancestral Spokane River probably entered the Little Spokane River between Waikiki and Griffith Springs. The Spokane River would have flowed on a basement and basalt surface at an elevation of about 500 feet lower than that of today. The ancestral Little Spokane is likely to have flowed within the same general area as it does today, also on a predominantly basement and basalt surface and at a lower elevation than that of the present river elevation.

Geologic evidence suggests that at least two major Ice Ages have left a clear record in the landscape of the Northern Rockies. The most recent Ice Age, known as the Wisconsin, climaxed about 15,000 years ago and ended about 10,000 years ago. This glacial period had the most significant effect on the present landscape of WRIAs 55 and 57. Glaciers covered most of British Columbia and moved south into Northern Idaho and Washington (down the Purcell and Pend Oreille Valleys), filling the basalt and basement valleys and covering all but the higher mountains. Glacial till (very poorly sorted clay to boulder sized material that is pushed and carried by a glacial ice) and outwash (clay to gravel sized material deposited by meltwater) were deposited over and infilled the valley floors as the glaciers advanced and retreated.

During the last major Ice Age, it has been postulated that the Purcell Ice Lobe of the Cordilleran Ice Sheet dammed the Clark Fork River at the site of present-day Pend Oreille Lake. Water ponded behind the dam, forming Glacial Lake Missoula. At its highest level, the lake covered 3,000 square miles in the valleys of northwestern Montana. During the same period, ice dams to the west created Glacial Lake Columbia that may have extended eastwards across the Spokane Valley to Coeur d’Alene and northwards into the Little Spokane watershed valleys. Glacial Lake Clark in the Pend Oreille River Valley north of Newport formed as glaciers retreated.

As the water level rose behind the Clark Fork dam, it is believed that the ice dam was floated and undermined. An enormous torrent of water rushed first southwestwards across the present day Rathdrum Prairie in western Idaho and then turned westwards at the present site of Lake Coeur d’Alene and continued in a westerly direction through the Spokane Valley and then across the Columbia Plateau of eastern Washington. Some of the floodwaters were also deflected through the Blanchard Channel into the Deer Park Basin resulting in deposition of flood sands and gravels within the central and southern parts of the WRIA 55 (Figure 4.12). Terraces near the Spokane – Little Spokane River confluence suggest that the last of the larger Wisconsin floods may have used the Little Spokane River valley as the flow course (Kiver and Stradling, 1985). The spillway for

Glacial Lake Clark was through the Scotia Channel (the location of today's Little Spokane River headwaters) into the Little Spokane River valley.

There is strong evidence to support dozens of successive breechings of the Clark Fork ice dam. After each dam breaching, Lake Missoula would have been partially drained before the water started to build up behind the dam again. It has been estimated that the maximum discharge across the Columbia Plateau may have been as high as 750 million cubic feet per second (cfs). This is equivalent to twenty times the combined flow of all the rivers of the world today (Baker, 1973; Molenaar, 1988).

The outbursts of water scoured the ground along the major flow courses and picked up large quantities of sediment (earlier glacial and flood deposited sediments) ranging from boulder to clay size particles (denoted as Qfs/Qfg/Qfcg on Figure 4.12). As the energy of the flow dissipated, the floods deposited sediment within the scoured valleys. Larger particles such as boulders and cobbles were deposited in the valleys closer to the site of the dam breach. Smaller particles such as sand and silt were carried in suspension and were either deposited in side valleys or carried out onto the Columbia Plateau. With each successive filling of Lake Missoula and breach of the ice dam, the floodwaters would have likely taken a slightly difference course, reworking earlier glacial and flood deposited sediments along the course of the flow.

Deposition of fines (silts and clays) within the glacial lakes would have resulted in layers of fine-grained material (denoted as Qgl on Figure 4.12) overlying earlier flood and glacial deposits. These fine-grained sediments would have been washed out along the main flood courses but would have been preserved in areas of lower energy flows by a blanket of overlying flood deposits. Coarse grained (sand, gravel and boulder sized) flood deposited sediments up to 500 feet thick within the Rathdrum Prairie of western Idaho and the Spokane Valley, now form the SVRP Aquifer, one of the world's most productive groundwater resources (see Figure 5.9). Less coarse (sand and gravel sized) flood deposited sediments also occur within the central and northeastern parts of the Little Spokane basin (Figure 4.12).

After the final draining of Lake Missoula, the climate became warmer and the Cordilleran Ice sheet retreated northwards. The Spokane River resumed its course westward to Spokane. However, instead of flowing northwards through the Hillyard Trough (as it did prior to the Missoula Flood events), the Spokane River continued westward through what is now downtown Spokane, then turned northwards, to join the Little Spokane River at the western toe of Lookout Mountain. The course of the Spokane River likely changed because the flood sediments within the Hillyard Trough area were deposited to a higher elevation relative to those deposited within the lower Spokane Valley. As a result, the Spokane River formed the falls in downtown Spokane, and possibly the Trinity Trough, instead of resuming its prior course within the Hillyard Trough.

During the early stages of glacial retreat, the flow rates of the Little Spokane and Spokane Rivers would have been much greater than those of today because they would have been fed year round by glacial melt water. The large valley occupied by the Lower

Spokane River between the Hangman Creek confluence and Nine Mile Dam provides evidence that the Spokane River was, at one time, a much larger river than it is today.

In some of the lower tributary watersheds, small lakes formed where glacial moraines and flood deposits dammed streams and creeks. Hauser Lake, Newman Lake and Liberty Lake (and their associated peat deposits) are examples. Outlets from these lakes flow towards the Spokane River but do not reach the river. Instead the outflows recharge the SVRP Aquifer before reaching the river because of the high permeability of the flood deposited sediments.

The Palouse Formation (denoted as Ql on Figure 4.12) comprises a thin veneer of windblown silt and sand that formed after the last glaciation as the river flows and water levels decreased and the sparsely vegetated glacial deposits dried.

Finally, along the present river and stream drainages, the glacial materials were reworked and deposited as sand and gravel alluvium (denoted as Qal on Figure 4.12).

4.3.3 Geologic Units

The geologic units that occur within WRIA 55 and WRIA 57 can be divided from oldest to youngest into three major terrains (McKiness, 1988; Cline, 1969): 1) crystalline basement; 2) basalt flows and intercalated sediments; and, 3) unconsolidated deposits. In general, the geology comprises vertically stratified and laterally discontinuous geologic units that have been modified at the surface by erosional processes. The nature and occurrence of the three major terrains is described below, beginning with the oldest unit. The geologic cross-sections presented as Figure 4.14A through 4.14O illustrate how these units are likely to occur within the sub-surface. The locations of these cross-sections are shown in plan on Figure 4.12.

4.3.3.1 Crystalline Basement

The crystalline basement comprises Precambrian (pre 570 my ago) metamorphics (e.g., quartzite, schist and gneiss) in addition to Mesozoic and early Cenozoic (245 to 37 m. y. ago) plutonic rocks (e.g., granite). Uranium is associated with the plutonics on the west flank of Mount Spokane (Weisenborn and Weis, 1976) and springs enriched in uranium occur in this area.

As indicated on Figure 4.12, the crystalline basement is generally exposed on the higher ground above the valleys, including the western, northern and eastern portions of WRIA 55 and in the southeastern and northeastern uplands of WRIA 57. In the central areas of WRIA 55 and WRIA 57, where later units blanket the basement rocks, the depth to the basement rocks is illustrated on the geologic cross-sections. In general, the depth to the basement rocks increases in a southerly direction within the valleys of WRIA 55 (Figures 4.14C, 4.14D, 4.14E and 4.14F) to a depth of up to 700 feet below grade in the Hillyard Trough area. Depth to basement rocks within WRIA 57 increases towards the axis of the Spokane Valley (see cross-sections 4.14G through 4.14O) and is generally within 400 to 700 feet below grade. A notable exception is the Pines Road Knoll, illustrated on Figures

4.14L and 4.14M. At this location, the bedrock extends to surface as an erosional remnant left after the Missoula floods.

The surface of the crystalline basement has significant topographic relief. For example, Mount Spokane, on the WRIA 55 – WRIA 57 boundary, reaches an elevation of 5,878 feet above mean sea level. In contrast, a drill hole on Peone Prairie (Township 26, Range 44, Section 6, SW ¼ SW ¼), located about 12 miles southwest of Mount Spokane, indicates the basement surface at 1,070 feet above mean sea level.

4.3.3.2 Basalt and Intercalated Sediments

The basalt rocks comprise Miocene age Columbia River Basalt Group flows intercalated with fluvial and lacustrine deposits of the Latah Formation.

4.3.3.2.1 Basalts

Because WRIA 55 and WRIA 57 are located at the northeastern extent of the Columbia River Plateau, only two of the Columbia River Basalt flows extend into these basins. The basalt flows belong to the Grande Ronde Basalt and the Priest Rapids Member of the Wanapum Basalt. The Grande Ronde is between 15.6 and 16.6 m.y. old (Reidel and others, 1980). The Priest Rapids Member is between 15.3 and 14.5 m.y. old (Reidel and others, 1980). The basalt flows are believed to have flowed in an easterly direction into the Spokane Valley from the Columbia Plateau. The basalts are gray to black, massive, fractured, sometimes with columnar joints, and often vesicular rocks.

As indicated on Figure 4.12 and on cross-sections 4.14D and 4.14E, the basalt rocks resist erosion and tend to form flat-topped prairies (e.g., Valley Prairie, Five Mile Prairie, Orchard Prairie, Pleasant Prairie, Halfmoon Prairie and Wildrose Prairie) or bluffs (e.g., Green Bluff).

Within WRIA 55, the basalts occur primarily on the west side of the Little Spokane River, within the southern portion of the basin (see Figure 4.12). As illustrated on Figures 4.14A and 4.14B, the basalts occur within 100 feet from surface and are exposed as a series of erosional remnants following last glaciation and the Missoula Floods. Within the northern portion of cross section 4.14A, the basalts thin and lap on top of the crystalline basement surface. This represents the northern extent of the Columbia River Basalts within WRIA 55.

In WRIA 57, the basalts occur in the northern, western and southern parts of the basin. Two important geologic features of the basalt are noted:

- Firstly, the Grande Ronde Basalt, which forms the base of Five Mile Prairie, extends southwards, forming a continuous subsurface ridge between Five Mile Prairie and downtown Spokane (see cross section 4.14H). As illustrated on Figure 4.12 and Figure 4.14H, the basalt ridge contains a channel filled with flood channel gravels. The channel, known as the Trinity Trough, is believed to be an ancient channel of the Spokane River (CH2M Hill, 1998). Based primarily on seismic data, the Trinity Trough is about a mile wide and up to 300 feet deep.

- Secondly, the Grande Ronde Basalt rises to within 50 feet of ground surface in the central portion of the Spokane Valley, below Greene Street (CH2M Hill, 1998). Although not apparent from the surficial geology presented on Figure 4.12, this feature is illustrated in section on Figure 4.14J.

4.3.3.2.2 Latah Formation

The Latah Formation consists of lacustrine silt and clay beds containing some fluvially deposited sand and gravel. Latah sediments have been described as orange where oxidized, off-white to dark-gray where not oxidized, very stiff to hard, silt and clayey silt to silty fine sand (Boleneus, 1978; Landau Associates, 1991) with minor sand and gravel beds. Robinson (1991) characterized the Spokane County Latah Formation as comprising 60% clay or silty clay, 30% silt and 10% sand and gravel. The sand and gravel beds ranged up to 20 feet in thickness (Robinson, 1991).

Stratigraphically, Latah Formation sediments may underlie or overlie (i.e., may be both older and younger than the Grande Ronde) and underlie (i.e., are older than) the Priest Rapids Member of the Wanapum Basalt. As indicated on Figure 4.12, Latah Formation sediments are associated with the basalt exposures and occur in the south and central portions of WRIA 55 and in the northern, western and southern parts of WRIA 57. The Latah Formation is generally exposed along the steep bluffs that define the edges of the prairies (see Figure 4.12).

4.3.3.3 Unconsolidated Quaternary Deposits

Quaternary (2 m.y. ago to the present) unconsolidated deposits comprise predominantly sands and gravels with minor amounts of silt and clay. Quaternary sediments within the study area have been deposited during glacial advances and retreats up to the present day alluvial system. As indicated on Figure 4.12, the unconsolidated Quaternary sediments (denoted with a Q prefix in the Figure 4.12 legend) occur within the valleys of WRIA 55 and WRIA 57.

Three important features dominate the Quaternary units of WRIA 55 and WRIA 57:

- The pre-Quaternary buried valley that was eroded by the ancestral Spokane and Little Spokane Rivers into the basement and basalt rocks;

- The glacial flood derived sand and gravel deposits that partially fill the early valleys and the lower reaches of the tributary valleys; and,

- The combined erosional / depositional surface of the present valley floors.

The present day thickness of the unconsolidated sediments is a function of these three Quaternary features. A map presenting the approximate thicknesses of the unconsolidated units is presented as Figure 4.15. This information was compiled from a number a sources (DNR, 2001; CH2M Hill 2000; CH2M Hill 1998; Boese and Buchanan, 1996; EMCON, 1992) and represents the approximate thicknesses of all Quaternary units from the ground surface down to the contact with the basalts, Latah Formation sediments and crystalline basement rocks. The purpose of this map is to provide an indication of the vertical extent of the unconsolidated sediments within WRIA 55 and WRIA 57 because it is these sediments (when saturated) that have the greatest potential to supply water to wells and to hydraulically interact with surface water. As illustrated on Figure 4.15, the unconsolidated deposits range in thickness as follows:

- 700 feet or more within the Hillyard Trough area of southern WRIA 55 and northern WRIA 57;
- About 400 to 600 feet within the central portion of the Spokane Valley in WRIA 57;
- Up to 200 feet within the Deer Park basin of WRIA 55; and,
- In general between 50 to 100 feet within the valleys of WRIA 55.

The main units that make up the unconsolidated Quaternary deposits are described below, generally from oldest to youngest.

4.3.3.3.1 Lower Sand and Gravel Unit (Qfs/Qfg/Qfcg)

This unit overlies the Latah, basalt and basement rocks in the southern part of WRIA 55. It occurs in the northern portion of the Hillyard Trough and is overlain by locally continuous glacial lake deposits (Landau Associates, 1991; CH2M Hill, 2000). It comprises medium dense to very dense, fine to coarse sand with some gravel and occasional gravel and silty sand zones (Landau Associates, 1991). Meltwater streams draining major glacial ice lobes likely deposited these sediments. The lower sand and gravel unit is depicted in section on Figure 4.14F and Figure 4.14G. The thickness of the unit is estimated to range between 100 to 300 feet thick with an average thickness of about 200 feet.

4.3.3.3.2 Glacial Deposits (Qgl)

The glacial deposits within WRIA 55 and WRIA 57 (denoted as Qgl on Figure 4.12) are generally well-laminated fine sands, silts and clays that contain some interbeds of fluvial gravel (Cline, 1969). Within WRIA 55, stratified clay, silt and fine sand sequence appears to extend from the northern end of the Hillyard Trough beneath the Little Spokane River, northward to the Colbert area. Depicted in section on Figure 4.14F and Figure 4.14G, these glacial deposits overlie the lower sand and gravel unit described above and may be up to 200 feet thick. These deposits have been described in the Colbert Landfill area as comprising 30 to 50 % dense to very dense sand with 50 to 70 % very stiff to hard silt and clay layers (Landau Associates, 1991). As indicated on Figure 4.12, glacial deposits are exposed at surface interbedded with flood sediments along Dragoon Creek in WRIA 55 and along the eastern portion of the Spokane River in WRIA 57.

4.3.3.3.3 Flood Sand and Gravel Units (Qfs/Qfg/Qfcg)

The flood sands and gravels infill the Spokane valley in WRIA 57 and blanket the valleys of WRIA 55. This unit is composed primarily of loose to dense, well-graded sand and gravel with cobbles, boulders and zones of silty gravelly sands. The proportion of cobbles and boulders within this unit decreases in a westerly direction across the Spokane Valley and the unit tends to be finer grained within WRIA 55 than within WRIA 57. The flood sands and gravels are generally overlain and laterally bounded by crystalline basement, basalt or relatively fine-grained Latah or glacial sediments.

Within WRIA 55, the thickness of the flood sands and gravels ranges from less than 50 feet to 200 feet adjacent to the Little Spokane River channel and within the central portion of the Deer Park Basin. The flood deposits include bars and terraces of poorly-sorted sand and gravel up to several hundred feet thick in the center of the channel, generally thinning towards the west and east (Figures 4.14C, 4.14D and 4.14E). In the Hillyard Trough area of WRIA 55 (see cross-sections4.14F and 4.14G) up to 200 feet of flood sands and gravels are thought to overlie the glacial deposits.

Within WRIA 57, the flood sands and gravels infill the Spokane Valley and range up to 700 feet in thickness. The geometry of the Spokane Valley, including the flood sediments that fill the valley, is illustrated on Figures 4.14H through 4.14O.

4.3.3.3.4 Loess (Ql)

As illustrated on Figure 4.12, eolian (wind blown) loess caps the basalt plateaus in the southern portion of WRIA 55. Known as the Palouse Formation, these eolian deposits comprise angular fragments of fine sand to silt sized grains of quartz, feldspar and mica derived from alluvium, flood sediments and glacial outwash deposits. Because WRIA 55 occurs at the northern edge of the Palouse deposition area, the loess particles are relatively fine and the depth of the unit thin. Well logs from Green Bluff indicate loess thicknesses of less than 25 feet (Boese and Buchanan, 1996).

4.3.3.3.5 Recent Deposits (Qal/Qp/Qla)

Recent deposits include alluvium and lacustrine (lake) deposits:

- Alluvium (denoted as Qal on Figure 4.12) occurs in present stream channels and includes primarily reworked glacial sediments and flood deposits and gravel, sand and silt alluvial fans (denoted as Qaf on Figure 4.14M) that have formed where steep drainages enter lower gradient drainage. As shown on Figure 4.12, alluvium is generally lined on either side by glacial deposits in the stream channels of WRIA 55.

- Lacustrine Deposits (denoted as Qp/Qla on Figure 4.12) occur in and around lakes such as Newman and Hauser and comprise fine sand, silt, clay and peat in post-glacial lakes.

4.3.3.3.6 Mass Wasting Deposits (Qmw)

Mass wasting deposits (denoted as Qmw on Figure 4.12) range in age from 5 million years old to present and comprise landslide debris with lesser amounts of debris-flow and rockfall deposits. Most mass wasting deposits occur where soft sediments of the

Latah Formation underlie basalt along the southern side of the Spokane River valley and the edges of Peone Prairie.

4.4 Land Surface Cover

This section summarizes the existing and available land surface cover information for WRIAs 55 and 57. Information sources include: National Resource Conservation Service (NRCS), Spokane County, Pend Oreille County, Stevens County, the City of Spokane and the USGS. Land surface cover information presented within this report is divided into:

- Land use / land cover mapping (Figure 4.16); and
- Soils cover mapping (Figure 4.17).

Soil types and vegetative cover in conjunction with topography are the primary components that affect how rainfall runs off the surface of watersheds. In addition, land cover / land use information is used to assess water use and water discharge spatially across the watersheds.

4.4.1 Land Use / Land Cover

Land Use and Land Cover (LULC) mapping combines information on land development by people (i.e., land use) and natural vegetative cover (i.e., land cover). Two main sources of LULC mapping were identified for this study:

- Gap Analysis Program (GAP) Mapping funded by the Biological Resources Division of the USGS through the Washington Cooperative Fish and Wildlife Research Unit at the University of Washington; and,

- Land Use and Land Cover (LULC) Mapping developed by the USGS as part of its National Mapping Program.

The object of the GAP analysis program is to identify areas of high conservation priority. The analysis relies on current land cover and terrestrial vertebrate distributions. The vegetative land cover mapping is developed at a 100-hectare (247 acre) resolution from 1991 satellite Thematic Mapper images. After a preliminary assessment, it was determined that the GAP land cover mapping was not applicable to the WRIAs 55 and 57 study area due to the large area (about 57,000 acres) defined as irrigated land. Based on communication with Spokane County staff, it was confirmed that this area is about 10 times greater than the actual area of irrigated land within the two WRIAs.

The USGS's National Mapping Program Land Use / Land Cover (LULC) mapping for WRIAs 55 and 57 (Figure 4.16) was obtained via an Internet anonymous File Transfer Protocol (ftp). The LULC data files are also based on 1991 Thematic Mapper images and describe vegetative cover, areas of open water, natural surface and cultural features on the land surface. The data files were created by the USGS using a series of processing steps:

1. Manual interpretation of NASA high altitude aerial photographs.
2. Incorporation of existing land use survey data.
3. Digitization of the LULC maps to create a national LULC database within a UTM projection.

All LULC features are represented as polygons with a minimum size of 10 acres with a minimum width of 660 feet. Attribute codes assigned to the LULC features along with the LULC areas in each of the counties and WRIAs are detailed in Table 4.2 for WRIA 55 and Table 4.3 for WRIA 57. A summary table is provided below.

USGS Land Use / Land Cover Summary for WRIA 55 and WRIA 57

Land Use /	**WRIA 55**		**WRIA 57**	
Land Cover	**Acres**	**% WRIA 55**	**Acres**	**% WRIA 57**
Urban or Built Up Land	19,181	4.4	42,318	23.1
Agricultural Land	110,293	25.5	29,665	16.2
Rangeland	6,391	1.5	3,505	1.9
Forest Land	292,051	67.5	105,191	57.4
Water	2,498	0.6	1,807	1.0
Wetland	1,023	0.2	0	0
Barren Land	903	0.2	769	0.4

As for the GAP data, an assessment of irrigated acreage was made to determine the applicability of the coverage to WRIAs 55 and 57. Because irrigated acreage is not defined, United States Department of Agriculture (USDA) 1997 agricultural census data was used to determine the ratio of total agricultural land to irrigated agricultural land for Spokane, Pend Oreille and Stevens Counties. These ratios were determined as 0.27 for Spokane County, 0.59 for Pend Oreille County and 0.81 for Stevens County. By multiplying the total area of agricultural land within each of the counties by the appropriate ratio, a total agricultural irrigated acreage of about 4,710 acres was determined (3,903 acres in WRIA 55 and 807 acres in WRIA 57). Because this area, along with the other LULC areas (see summary table above), appear to reasonably reflect the LULC conditions in WRIAs 55 and 57, the USGS's National Mapping Program Land Use / Land Cover (LULC) mapping was determined as the most suitable LULC coverage for the study area (Figure 4.16).

As illustrated on Figure 4.16 and indicated on the tables (Table 4.2 and 4.3), the majority of the land in both WRIA 55 (67.5%) and WRIA 57 (57.4%) is forestland. The forestland occurs predominantly across the northern and eastern portions of WRIA 55 and across the northern portion of WRIA 57. For WRIA 55, the second largest land use category, covering 25.5% of the WRIA, is agricultural. In contrast, the second largest land use category in WRIA 57 is urban or built up land, covering about 23.1% of the WRIA.

Agricultural land within WRIA 57 covers about 16.2 % of the watershed. Urban or built up land makes up about 4.4% of WRIA 55.

Spokane County is approximately 1,760 square miles in area, of which approximately 5% is incorporated and 95% is unincorporated. Approximately 417 square miles of that comprises 62% of WRIA 55, and 265 square miles comprises 93% of WRIA 57 (Table 4.2). The urban growth areas cover about 33 square miles in WRIA 55 and 78 square miles in WRIA 57 (Table 4.3). Outside of the urban growth area, there are approximately 105 square miles in WRIA 55 and 19 square miles in WRIA 57 of designated natural resource lands. The remaining land outside the urban growth area is designated rural. Land uses in the rural area are predominantly large-lot residential, along with ranching and farming. Near the urban area, residential parcels generally range in size from 1 acre to 5 acres, although there are areas that are subdivided into lots of 10,000 square feet (~¼ acre) and smaller. With greater distance from the urban area, residential parcel sizes increase, ranging from 10 acres to 40 acres and greater. Most commercial and industrial uses in the rural area are associated with natural resource activities.

Urban development is concentrated in the area within and adjacent to the City of Spokane. Residential development generally follows the Spokane River Valley to the east and the Little Spokane River to the north. Commercial development in these river valleys is generally located directly adjacent to, or within a few blocks of, principal arterials, state highways, or major intersections. To the east, these corridors extend to the Washington/Idaho state line along I-90 and portions of Sprague Avenue, Broadway Avenue and Trent Avenue. To the north, development follows Division Street/U.S. 395 and U.S. 2/Newport Highway.

Industrial activity is generally located in the metropolitan area around the City of Spokane. Immediately northeast of the city, Kaiser Aluminum Mead, the Bonneville Power Administration Bell Substation and the R.A. Hanson Company occupy a large industrial area. Extending east from the city, industrial areas are associated with the Burlington Northern and Union Pacific Railroad Lines. Other industrial uses in this area include Kaiser Trentwood, the Spokane Industrial Park and the area north and west of Liberty Lake.

Pend Oreille County comprises approximately 25% of WRIA 55 with about 87% forestry and about 8% agricultural land uses (Table 4.2). The remaining 5% includes single-family residences, commercial, and recreational uses. Pend Oreille County makes up approximately 7% of WRIA 57 with approximately 86% of that being forested and the remainder split evenly between agricultural and rangeland.

The Stevens County comprises 13% of WRIA 55 of which about 72% is forestry and 25% agricultural land use (Table 4.2).

4.4.2 Soils

Detailed GIS coverages of soil types within WRIA 55 and WRIA 57 were provided to Golder as shape files from Spokane County GIS. The original coverages were created by digitizing the soil survey county maps (USDA SCS, 1968; USDA SCS, 1978; USDA SCS, 1980). Soils coverage is an important component of a watershed assessment because the nature of the soil cover determines the fate of incident precipitation, as evapotranspiration, runoff, or infiltration to groundwater.

The detailed GIS coverages provided by Spokane County include separate mapped areas for over 177 soil types within Spokane County, 66 soil types within Stevens County and 100 soil types within Pend Oreille County. A listing of all the soil types within Spokane, Stevens and Pend Oreille Counties is presented on Table 4.4, Table 4.5 and Table 4.6, respectively (NRCS, 1996). In order to simplify the soils coverage, the land surface was reclassified into four main National Resource Conservation Service (NRCS) hydrologic soil classes A, B, C and D and into areas of open water. These classes are used in equations that estimate runoff from rainfall, for example the Soil Conservation Service (SCS) runoff method. The hydrologic classification for each of the soil types within Spokane, Stevens and Pend Oreille Counties is also presented on Table 4.4, Table 4.5 and Table 4.6, respectively (NRCS, 1996).

The NRCS define a soil hydrologic group as a group of soils having similar runoff potential under similar storm and vegetative cover conditions. Runoff potential is a function of infiltration rate and transmission rate. The infiltration rate is the rate at which water enters the soil at the surface and is controlled by surface conditions. The transmission rate is the rate at which water moves in the soil and is controlled by soil properties. The NRCS classification system is based on the use of rainfall-runoff data from small watersheds and infiltrometer plots. From these data, the NRCS established relationships between soil properties and hydrologic group. Wetness characteristics, permeability after prolonged wetting, and depth to very low permeability layers are properties that assist in estimating hydrologic groups.

The hydrologic groups defined by NRCS soil scientists are as follows (NRCS, 1996):

Group A soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist mainly of sands and gravels that are deep, well drained to excessively drained, and have a high rate of water transmission (greater than 0.30 inches / hour).

Group B soils have moderate infiltration rates when thoroughly wetted. They consist mainly of soils that are moderately deep to deep, moderately well drained to well drained, and have moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15 to 0.30 inches / hour).

Group C soils have low infiltration rates when thoroughly wetted and consist mainly of soils having a layer that impedes downward movement of water and soils of moderately fine to fine texture. These soils have a slow rate of water transmission (0.05 to 0.15 inches / hour).

Group D soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist mainly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay pan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0 to 0.05 inches / hour).

By classifying the soils according to hydrologic group, the soils of WRIA 55 and WRIA 57 were simplified into a coverage of soil types according to hydrologic characteristics. This coverage is presented as Figure 4.17. The areas and percentages of soils with similar hydrologic characteristics are provided on Table 4.7 and are summarized below:

NRCS Hydrologic Classification of Soils in WRIA 55 and WRIA 57

Soil Hydrologic Group	WRIA 55		WRIA 57	
	Acres	%	Acres	%
Group A (high infiltration, low run-off)	33,854	7.8	10,415	5.7
Group B	225,644	52.2	85,359	46.9
Group C	95,275	22.0	62,036	34.1
Group D (low infiltration, high run-off)	75,225	17.4	21,522	11.8
Open Water	2,589	0.6	2,611	1.4

As illustrated on Figure 4.17 and indicated on the summary table above, low run-off potential soils (Group A soils) are relatively rare within both WRIA 55 and WRIA 57 and occur within valley areas that are underlain by coarse flood gravel deposits (Figure 4.12). The most apparent Group A soil areas occur in small isolated areas lying east-southeast from downtown Spokane within WRIA 57 and along the southern valley of the Little Spokane River and in the southern portion of the Deer Park Basin within WRIA 55. In total 33,854 acres (7.8 %) of WRIA 55 and 10,415 acres (5.7 %) of WRIA 57 comprise soils that possess a low run-off potential.

Moderate infiltration soils (Group B soils) are the most common soil type within both WRIA 55 and WRIA 57 and predominate within the valley areas underlain by flood deposits (see Figure 4.12). Group B soils also occur over upland areas on the western side of WRIA 55 and in WRIA 57, within WRIA 57 over the upland area of the Spirit Lake drainage northeast of Mount Spokane. These upland areas are underlain by crystalline basement rocks (see Figure 4.12). In total 225,644 acres (52.2 %) of WRIA 55 and 85,359 acres (46.9 %) of WRIA 57 comprise soils that possess a moderate infiltration.

Low infiltration soils (Group C soils) predominate across the northern and eastern upland areas of WRIA 55 and the northeastern upland areas of WRIA 57, within areas underlain by crystalline basement rocks (see Figure 4.12). These soils are likely to be a thin veneer overlying the bedrock. In total 95,275 acres (22.0 %) of WRIA 55 and 62,036 acres (34.1 %) of WRIA 57 comprise soils that possess a low infiltration.

High run-off potential soils (Group D soils) occur along the flanks of upland areas in both WRIA 55 and 57 and also in WRIA 55 along the southern portion of the Little Spokane River. On the upland flanks, these soils occur as a thin veneer on steep slopes. Within the southern portion of the Little Spokane drainage, these soils have a high permanent water table. In total 75,225 acres (17.4 %) of WRIA 55 and 21,522acres (11.8 %) of WRIA 57 comprise soils that possess a high run-off potential.

4.5 Population

The table below presents Census population data for Spokane, Stevens and Pend Oreille Counties. As indicated, Spokane County is about 10 times more populated than Stevens County and about 40 times more populated than Pend Oreille County. The 2000 Census data indicates that the populations of WRIAs 55 and 57 are 95,201 and 188,872, respectively.

County	Population		% Change
	1990	2000	1990-2000
Spokane	361,364	417,939	16%
Stevens	30,948	40,066	29%
Pend Oreille	8,915	11,732	32%

The major incorporated areas in WRIAs 55 and 57 are the City of Spokane (in both WRIAs), the City of Deer Park (within the Dragoon Creek sub-basin of WRIA 55) and the Cities of Millwood and Liberty Lake (in WRIA 57). The City of Spokane is located to the north and south of the Spokane River within the western portion of WRIA 57 and the southern portion of WRIA 55. Millwood is located to the east of Spokane. The City of Liberty Lake is located within the southeastern portion of WRIA 57, in the vicinity of Liberty Lake. The table below summarizes the 1990 and 2000 population information for these cities as well as projected 2020 population.

WRIA	City	Actual			Projected	
		Population		% Change	Population	% Change
		1990	2000	1990-2000	2020	2000-2020
55	Deer Park	2,278	3,017	32	5,767	91%
55, 56, & 57	Spokane	177,196	195,629	9.5	246,529	26%
57	Millwood	1,559	1,649	5.8	1,821	10%
57	Liberty Lake	600	3,265	444	7,253	122%

Residential growth generally follows the Spokane River Valley to the east and the Little Spokane River to the north. Much of the population growth in Spokane County is occurring outside of the incorporated areas with the exception of Liberty Lake. The Town of Millwood is small in both population and actual land area. Any growth will most likely occur as infill or re-development. In Deer Park there are several residential subdivision commitments plus a manufactured home park that includes a preliminary 95-unit project. Recently recorded and planned developments would increase the current residential accommodations by a minimum of 55% when complete. Liberty Lake has been the fastest growing area in Spokane County for the past ten years and it is expected to continue to lead the County in growth for the next ten years. The City of Liberty Lake is approximately four square miles in area with approximately 1,306 existing residential units with another 1,595 residential lots approved. The City of Spokane population is projected to grow by 50,400 entirely by use of vacant lots within the incorporated boundary.

The total population of the unincorporated areas of Spokane County in 2000 was approximately 199,135, with about 56,500 of that in WRIA 55 and about 88,000 of that in WRIA 57. The projected population for 2020 is 288,732, or an addition of 89,597 people. Most of the growth should occur within the Urban Growth Area, which is divided into several smaller subareas, each with an allocated population projection for 2020. The following areas and population allocations are in WRIAs 55 and 57:

- Approximately 28,363 acres of unincorporated land located east of the City of Spokane and referred to as the Valley/Liberty Lake Urban Growth Area has a population allocation of 39,431.
- Approximately 1,670 acres of unincorporated land located adjacent to the south and southeast corporate limits of the City of Spokane referred to as the Moran/ Glenrose Joint Planning Area. The population allocation for this area is 4,108.
- Approximately 458 acres of unincorporated land located adjacent to the east corporate limits of the City of Spokane referred to as the Alcott Joint Planning Area has a population allocation of 1,013.
- Approximately 962 acres of unincorporated land located adjacent to the east corporate limits of the City of Spokane referred to as the Yardley Joint Planning Areas has an allocation of 9.
- Approximately 368 acres of unincorporated land located adjacent to the east corporate limits of the City of Spokane referred to as the Upriver Joint Planning Area has a population allocation of 282.
- Approximately 103 acres of unincorporated land located contiguous with the northeast incorporated boundary of the City of Spokane. This area has no population allocation.

Pend Oreille County’s Planning Department estimates their portion of the population within the Little Spokane Watershed to be approximately 2,750. The population growth trend is expected to continue in this area as substantiated by the number of subdivision applications, building permits and vacant tracts of land for sale, with the most desirable tracts of land being adjacent to the Little Spokane River and its tributaries. Areas around Diamond Lake, Chain Lakes, along the major State Route Highway 2 and Scotia Road have the highest population densities in southern Pend Oreille County. In Stevens County, residences are generally located near Highway 395.

The population in southeastern Stevens County is estimated to be equal to or less than the 2,750 of Pend Oreille County. Projected population numbers for Stevens County were not collected; a logical assumption is populations will increase in a similar fashion to the Pend Oreille County population. (POCD, 2000).

TABLE 4.1a

Meterological Stations and Periods of Record

Station ID	Name	Data Source	Period of Record	Record Length (Years)	Data Type	Temp	PRCP	SNOW	WIND	EVAP	SNWD	SWE	Elevation (above MSL)	WRIA	County	State
10000	Ragged Ridge	Snow Course	01/01/1982-04/30/2000	18	monthly						X	X	3333.0	57	Spokane	WA
10041	Mica Creek	Snotel	not supplied	N/A	daily	X	X					X	4750.0	N/A	Kootenai	ID
101956	Coeur D'Alene 1 E	NCDC	10/01/1960-12/31/2000	40	daily	X	X	X			X		2132.3	N/A	Kootenai	ID
45004	Bunchgrass MDW	Snotel	10/01/1983-09/30/1999	15	daily	X	X					X	5000.0	62	Pend Orielle	WA
45031	Quartz Peak	Snotel	10/01/1985-09/30/1999	13	daily	X	X					X	4700.0	57	Spokane	WA
451362	Cheney	NCDC	Not Supplied	N/A	daily	X	X						2040.0	56	Spokane	WA
451395	Chewelah	NCDC	Not supplied	N/A	hourly,daily	X	X						1660.0	59	Stevens	WA
451586	Colfax 1 NW	NCDC	Not supplied	N/A	daily	X	X						196.3	34	Whitman	WA
452066	Deer Park 2 E	NCDC	01/01/1960-09/03/1977	17	daily	X	X	X					2200.6	55	Spokane	WA
455674	Mount Spokane Summit	NCDC	01/01/1960-12/09/1972	12	daily	X	X	X					5280.8	55	Spokane	WA
455844	Newport	NCDC	01/01/1960-08/09/2000	40	daily	X	X	X					2134.3	62	Pend Orielle	WA
457180	Rosalia	NCDC	Not supplied	N/A	daily	X	X						240.0	34	Whitman	WA
457933	Spokane	NCDC	01/01/1960-10/09/1983	23	daily	X	X	X					1879.4	57	Spokane	WA
457938	Spokane International AP	ASOS-NWS	01/01/1960-08/09/2000	40	daily	X	X	X		X		X	2355.4	56	Spokane	WA
457941	Spokane WFO	NCDC	07/30/1996-08/09/2000	4	daily	X	X	X		X			2386.5	54	Spokane	WA
459058	Wellpinit	NCDC	Not supplied	N/A	daily	X	X						2460.0	54	Stevens	WA
727856	Spokane Felts Field	ASOS-FAA	12/31/1972-12/31/2000	28	daily	X							1952.6	57	Spokane	WA
999999	Fairchild AFB	NWS-FAA	01/01/1960-12/09/1970	10	daily	X	X	X					2437.4	54	Spokane	WA

Note: Record Lengths equal to N/A indicate data not supplied by Spokane County
PRCP - Precipitation
SNOW - Snowfall
EVAP - Evaporation
SNWD - Snow Depth

TABLE 4.1b

Temperature Summary (in degrees F)

Station Name		January	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual	Winter	Spring	Summer	Fall
Coeur d'Alene 1 E	Max.	34.4	40.5	48.3	58.5	68.3	75.2	85.1	85	73.9	60.4	44.2	36.6	59.2	37.1	58.4	81.8	59.5
	Mean	28	32.4	38.4	46.4	54.9	61.7	68.9	68.3	59.2	48.9	37.1	30.9	47.9	30.4	46.6	66.3	48.4
	Min.	21.5	24.3	28.5	34.3	41.5	48.1	52.6	51.7	44.5	37.2	30	25.2	36.6	23.7	34.7	50.8	37.2
Deer Park 2 E	Max.	31.6	39.1	46.6	57.7	68.3	74.9	85	82.9	73.5	59.1	41.9	33.9	57.9	34.9	57.6	80.9	58.2
	Mean	23.8	30.1	36	44.7	53.7	60	66.7	64.9	56.6	45.2	34.3	27.1	45.3	27	44.8	63.9	45.4
	Min.	16.1	21.1	25	31.5	39.2	45	48.5	46.5	39.7	31.3	26.8	20.8	32.6	19.3	31.9	46.7	32.6
Felts Field	Max.	35.9	42.3	50.9	59.4	67.5	75.7	84	83.9	74.6	60.6	43.7	35.7					
	Mean	30.4	34.7	40.9	48.2	55.7	63.3	70	69.2	59.9	48	37.3	30.6					
	Min.	24.9	28	31.8	37.1	43.6	50.1	55.1	54.6	46.6	37.4	31	25.2					
Mt Spokane Summit	Max.	23.1	27.6	30.3	38.2	49	57.4	66.5	66	56.4	43.1	32.5	26.4	43	25.7	39.1	63.3	44
	Mean	18.1	22.8	24.8	31.7	41.9	49.3	57.8	57.5	48.7	37	27.5	21.6	36.6	20.8	32.8	54.9	37.7
	Min.	13.1	18.4	19.4	24.9	35	41.1	49.3	48.8	40.9	30.8	22.5	16.9	30.1	16.1	26.4	46.4	31.4
Newport	Max.	31.6	38.6	48.4	59.5	69.2	75.8	85.2	84.4	73.9	58.4	40.8	33.2	58.3	34.5	59	81.8	57.7
	Mean	24.7	29.8	37.1	45.3	53.6	59.9	65.8	64.4	56.2	45.4	34	27.4	45.3	27.3	45.3	63.3	45.2
	Min.	17.9	20.9	25.6	31.1	38	43.9	46.3	44.4	38.4	32.5	27.3	21.7	32.3	20.2	31.6	44.8	32.7
Spokane	Max.	34.5	42.5	49.6	59.2	68.8	76.8	85.8	84.5	74.4	60.3	44	37.1	59.8	38	59.2	82.3	59.6
	Mean	29.3	35.6	40.4	48	56.5	64	70.9	69.6	60.8	49.4	37.8	32.1	49.5	32.3	48.3	68.2	49.3
	Min.	23.9	28.8	31.2	36.8	44.3	51.2	56	54.7	47.2	38.4	31.5	27.2	39.3	26.6	37.4	54	39.1
Spokane International Airport	Max.	32.9	39.1	48.2	58.3	67.1	74.3	83.9	82.7	72.5	59.3	43	34.8	58	35.6	57.9	80.3	58.2
	Mean	27.2	32.1	39.4	47.4	55.4	62.2	69.8	68.6	59.5	48.5	36.5	29.6	48	29.6	47.4	66.9	48.2
	Min.	21.5	25.2	30.5	36.5	43.7	50.1	55.8	54.5	46.6	37.7	30.1	24.4	38	23.7	36.9	53.5	38.1

TABLE 4.2

Land Use in WRIA 55

	SPOKANE COUNTY			STEVENS COUNTY			PEND OREILLE COUNTY			TOTALS	
	Acres in WRIA	% County	% of WRIA	Acres in WRIA	% County	% of WRIA	Acres in WRIA	% County	% of WRIA	Acres	% of WRIA
Totals:	**266,959**	**100**	**62**	**57,726**	**99**	**13**	**107,655**	**100**	**25**	**432,340**	**100**
1 - URBAN OR BUILT UP LAND											
11 Residential	12,562	4.71	2.90	221	0.38	0.05	1,613	1.50	0.37	14,396	3.33
12 Commercial	1,801	0.67	0.42	12	0.02	0.00	125	0.12	0.03	1,938	0.45
13 Industrial	834	0.31	0.19	0	0.00	0.00	12	0.01	0.00	846	0.20
14 Transportation, Communications	978	0.37	0.23	15	0.03	0.00	0	0.00	0.00	992	0.23
15 Industrial & Commercial	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00
16 Mixed Urban or Built-Up Land	188	0.07	0.04	0	0.00	0.00	224	0.21	0.05	412	0.10
17 Other Urban or Built-Up Land	596	0.22	0.14	0	0.00	0.00	0	0.00	0.00	596	0.14
Totals	**16,959**	**6.35**	**3.92**	**247**	**0.42**	**0.06**	**1,974**	**1.83**	**0.46**	**19,181**	**4.43**
2 - AGRICULTURAL LAND											
21 Cropland and Pasture	85,729	32.11	19.80	13,990	24.01	3.23	7,264	6.75	1.68	106,983	24.71
22 Orchards, Groves, Vineyards, Nurseries	562	0.21	0.13	0	0.00	0.00	0	0.00	0.00	562	0.13
23 Confined Feeding Operations	31	0.01	0.01	0	0.00	0.00	0	0.00	0.00	31	0.01
24 Other Agricultural Land	1,372	0.51	0.32	402	0.69	0.09	943	0.88	0.22	2,717	0.63
Totals	**87,693**	**32.85**	**20.26**	**14,392**	**24.70**	**3.32**	**8,208**	**7.62**	**1.90**	**110,293**	**25.48**
3 - RANGELAND											
31 Herbaceous Rangeland	4,344	1.63	1.00	688	1.18	0.16	966	0.90	0.22	5,997	1.39
32 Shrub and Brush Rangeland	74	0.03	0.02	0	0.00	0.00	0	0.00	0.00	74	0.02
33 Mixed Rangeland	106	0.04	0.02	0	0.00	0.00	214	0.20	0.05	321	0.07
Totals	**4,523**	**1.69**	**1.04**	**688**	**1.18**	**0.16**	**1,180**	**1.10**	**0.27**	**6,391**	**1.48**
4 - FOREST LAND											
41 Deciduous Forest Land	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00
42 Evergreen Forest Land	155,438	58.23	35.91	42,184	72.40	9.74	94,429	87.72	21.81	292,051	67.47
43 Mixed Forest Land	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00
Totals	**155,438**	**58.23**	**35.91**	**42,184**	**72.40**	**9.74**	**94,429**	**87.72**	**21.81**	**292,051**	**67.47**
5 - WATER											
51 Streams and Canals	79	0.03	0.02	2	0.00	0.00	0	0.00	0.00	82	0.02
52 Lakes	62	0.02	0.01	83	0.14	0.02	1,644	1.53	0.38	1,789	0.41
53 Reservoirs	597	0.22	0.14	0	0.00	0.00	29	0.03	0.01	627	0.14
54 Bays and Estuaries	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00
Totals	**739**	**0.28**	**0.17**	**86**	**0.15**	**0.02**	**1,673**	**1.55**	**0.39**	**2,498**	**0.58**
6 - WETLAND											
61 Forested Wetlands	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00
62 Unforested Wetlands	983	0.37	0.23	0	0.00	0.00	40	0.04	0.01	1,023	0.24
Totals	**983**	**0.37**	**0.23**	**0**	**0.00**	**0.00**	**40**	**0.04**	**0.01**	**1,023**	**0.24**
7 - BARREN LAND											
71 Dry Salt Flats	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00
72 Beaches	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00
73 Sandy Areas Other Than Beaches	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00
74 Bare Exposed Rock	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00
75 Strip Mines, Quarries & Gravel Pits	542	0.20	0.13	129	0.22	0.03	150	0.14	0.03	822	0.19
76 Transitional Areas	81	0.03	0.02	0	0.00	0.00	0	0.00	0.00	81	0.02
77 Mixed Barren Land	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00
Totals	**623**	**0.23**	**0.14**	**129**	**0.22**	**0.03**	**150**	**0.14**	**0.03**	**903**	**0.21**

Notes: % County = % of county area within WRIA 57
Land Use Classification Codes - First and Second Level Categories
Data Source - USGS Land Use and Land Cover 1:250,000 Scale

TABLE 4.3

Land Use in WRIA 57

	SPOKANE COUNTY			PEND OREILLE COUNTY			TOTALS	
	Acres in WRIA	**% County**	**% of WRIA**	**Acres in WRIA**	**% County**	**% of WRIA**	**Acres**	**% WRIA**
Totals:	**169,632**	**100**	**92.57**	**13,622**	**100**	**7.43**	**183,254**	**100**
1 - URBAN OR BUILT UP LAND								
11 Residential	27,505	16.21	15.01	51	0.37	0.03	27,555	15.04
12 Commercial	4,761	2.81	2.60	0	0.00	0.00	4,761	2.60
13 Industrial	6,083	3.59	3.32	0	0.00	0.00	6,083	3.32
14 Transportation, Communications	1,490	0.88	0.81	0	0.00	0.00	1,490	0.81
15 Industrial & Commercial	0	0.00	0.00	0	0.00	0.00	0	0.00
16 Mixed Urban or Built-Up Land	58	0.03	0.03	69	0.51	0.04	127	0.07
17 Other Urban or Built-Up Land	2,301	1.36	1.26	0	0.00	0.00	2,301	1.26
TOTALS	**42,198**	**24.88**	**23.03**	**120**	**0.88**	**0.07**	**42,318**	**23.09**
2 - AGRICULTURAL LAND								
21 Cropland and Pasture	28,597	16.86	15.61	704	5.17	0.38	29,301	15.99
22 Orchards, Groves, Vineyards, Nurseries	71	0.04	0.04	0	0.00	0.00	71	0.04
23 Confined Feeding Operations	0	0.00	0.00	0	0.00	0.00	0	0.00
24 Other Agricultural Land	150	0.09	0.08	143	1.05	0.08	294	0.16
Totals	**28,818**	**16.99**	**15.73**	**847**	**6.22**	**0.46**	**29,665**	**16.19**
3 - RANGELAND								
31 Herbaceous Rangeland	1,358	0.80	0.74	878	6.45	0.48	2,236	1.22
32 Shrub and Brush Rangeland	670	0.39	0.37	0	0.00	0.00	670	0.37
33 Mixed Rangeland	599	0.35	0.33	0	0.00	0.00	599	0.33
Totals	**2,626**	**1.55**	**1.43**	**878**	**6.45**	**0.48**	**3,505**	**1.91**
4 - FOREST LAND								
41 Deciduous Forest Land	0	0.00	0.00	0	0.00	0.00	0	0.00
42 Evergreen Forest Land	93,477	55.11	51.01	11,713	85.99	6.39	105,191	57.40
43 Mixed Forest Land	0	0.00	0.00	0	0.00	0.00	0	0.00
Totals	**93,477**	**55.11**	**51.01**	**11,713**	**85.99**	**6.39**	**105,191**	**57.40**
5 - WATER								
51 Streams and Canals	0	0.00	0.00	0	0.00	0.00	0	0.00
52 Lakes	1,768	1.04	0.96	39	0.29	0.02	1,807	0.99
53 Reservoirs	0	0.00	0.00	0	0.00	0.00	0	0.00
54 Bays and Estuaries	0	0.00	0.00	0	0.00	0.00	0	0.00
Totals	**1,768**	**1.04**	**0.96**	**39**	**0.29**	**0.02**	**1,807**	**0.99**
6 - WETLAND								
61 Forested Wetlands	0	0.00	0.00	0	0.00	0.00	0	0.00
62 Unforested Wetlands	0	0.00	0.00	0	0.00	0.00	0	0.00
Totals	**0**	**0.00**	**0.00**	**0**	**0.00**	**0.00**	**0**	**0.00**
7 - BARREN LAND								
71 Dry Salt Flats	0	0.00	0.00	0	0.00	0.00	0	0.00
72 Beaches	0	0.00	0.00	0	0.00	0.00	0	0.00
73 Sandy Areas Other Than Beaches	0	0.00	0.00	0	0.00	0.00	0	0.00
74 Bare Exposed Rock	0	0.00	0.00	0	0.00	0.00	0	0.00
75 Strip Mines, Quarries & Gravel Pits	745	0.44	0.41	24	0.18	0.01	769	0.42
76 Transitional Areas	0	0.00	0.00	0	0.00	0.00	0	0.00
77 Mixed Barren Land	0	0.00	0.00	0	0.00	0.00	0	0.00
Totals	**745**	**0.44**	**0.41**	**24**	**0.18**	**0.01**	**769**	**0.42**

Notes: % County = % of county area within WRIA 57
Land Use Classification Codes - First and Second Level Categories
Data Source - USGS Land Use and Land Cover 1:250,000 Scale

TABLE 4.4

Spokane County Soils

Map Unit Symbol	NRCS Map Unit Name	Slope, %	Hydrologic Group
AaA	Athena silt loam	0 to 5	B
AaC	Athena silt loam	5 to 30	B
AaD	Athena silt loam	30 to 55	B
AaE	Athena silt loam	55 to 70	B
AlC	Athena-Lance silt loams	0 to 30	B
AlD	Athena-Lance silt loams	30 to 55	B
BaB	Bernhill silt loam	0 to 20	B
BaC	Bernhill silt loam	20 to 30	B
BaD	Bernhill silt loam	30 to 55	B
BbB	Bernhill silt loam, moderately shallow	0 to 20	C
BbD	Bernhill silt loam, moderately shallow	30 to 55	C
BeB	Bernhill gravelly silt loam	0 to 20	B
BfB	Bernhill very stony silt loam	0 to 20	B
BfD	Bernhill very stony silt loam	20 to 55	B
BhD	Bernhill soils	20 to 55	B
BkC	Bernhill very rocky complex	0 to 30	D
BkD	Bernhill very rocky complex	30 to 55	D
BoB	Bong coarse sandy loam	0 to 8	A
BpB	Bong and Phoebe fine sandy loam	0 to 8	A
BrB	Bong and Phoebe coarse sandy loam	0 to 20	A
BrC	Bong and Phoebe coarse sandy loam	20 to 30	A
BsB	Bong and Phoebe loamy sand	0 to 20	A
BtB	Bonner silt loam	0 to 8	B
BuB	Bonner gravelly silt loam	0 to 20	B
BvB	Bonner loam	0 to 20	B
BwB	Bonner fine sandy loam	0 to 20	B
BxD	Brickel stony loam	20 to 55	C
By	Bridgeson silt loam		D
Bz	Bridgeson silt loam, drained		C
Ca	Caldwell silt loam		C
CeA	Cedonia silt loam	0 to 5	B
CeB	Cedonia silt loam	5 to 20	B
CeC3	Cedonia silt loam, severely eroded	20 to 30	B
CgB	Cheney gravelly silt loam	0 to 8	B
ChB	Cheney stony silt loam	0 to 20	B
CkC	Cheney very rocky complex	0 to 30	D
CmC	Cheney extremely rocky complex	0 to 30	D
CnB	Cheney & Uhlig silt loam	0 to 8	B
CoB	Cheney-Uhlig complex	0 to 8	B
CsA	Clayton fine sandy loam	0 to 5	B
CsB	Clayton fine sandy loam	5 to 20	B
CtA	Clayton loam	0 to5	B
CtB	Clayton loam	5 to 20	B
CuB	Clayton sandy loam	0 to 8	B
Cw	Cocolalla silty clay loam		D

Spokane County Soils

Map Unit Symbol	NRCS Map Unit Name	Slope, %	Hydrologic Group
Cy	Cocolalla silty clay loam, drained		C
DaA	Dearyton silt loam	0 to 5	C
DaB	Dearyton silt loam	5 to 20	C
DaC	Dearyton silt loam	20 to 40	C
DeB	Dearyton silt loam, thin solum variant	0 to 20	C
DrC	Dragoon silt loam	0 to 30	C
DsC	Dragoon stony silt loam	0 to 30	C
DsD	Dragoon stony silt loam	30 to 55	C
DvD	Dragoon very rocky complex	20 to 55	D
EkB	Eloika silt loam	0 to 20	B
ElC	Eloika very stony silt loam	0 to 30	B
ElD	Eloika very stony silt loam	30 to 55	B
Em	Emdent silt loam		D
FaB	Freeman silt loam	5 to 20	C
FaB3	Freeman silt loam, severely eroded	5 to 20	C
FaC3	Freeman silt loam, severely eroded	20 to 30	C
Fm	Fresh water marsh		D
GaC3	Garfield silty clay loam, severely eroded	0 to 30	C
GgA	Garrison gravelly loam	0 to 5	B
GgB	Garrison gravelly loam	5 to 20	B
GmB	Garrison very gravelly loam	0 to 8	B
GnB	Garrison very stony loam	0 to 20	B
GpA	Glenrose silt loam	0 to 5	B
GpB	Glenrose silt loam	5 to 20	B
GpC	Glenrose silt loam	20 to 30	B
GpD	Glenrose silt loam	30 to 55	B
GrB	Glenrose gravelly silt loam	5 to 20	B
GrD	Glenrose gravelly silt loam	20 to 55	B
GsD	Glenrose stony silt loam	20 to 55	B
GtA	Green Bluff silt loam	0 to 5	B
GtB	Green Bluff silt loam	5 to 20	B
HfC	Hagen loamy fine sand	0 to 30	A
HgB	Hagen sandy loam	0 to 20	A
HhA	Hardesty silt loam	0 to 5	B
HmA	Hardesty silt loam moderately shallow	0 to 5	C
HnB	Hesseltine silt loam	0 to 10	B
HoB	Hesseltine silt loam, moderately deep	0 to 8	B
HrB	Hesseltine gravelly silt loam	0 to 10	B
HsB	Hesseltine stony silt loam	0 to 20	B
HtB	Hesseltine stony silt loam, mounded	0 to 8	B
HvC	Hesseltine very rocky comlex	0 to 30	D
HvD	Hesseltine very rocky comlex	30 to 55	D
HxC	Hesseltine extremely rocky comlex	0 to 30	D
Kc	Konner silty clay loam		D
Kd	Konner silty clay loam, drained		C

TABLE 4.4

Spokane County Soils

Map Unit Symbol	NRCS Map Unit Name	Slope, %	Hydrologic Group
LaB	Lakesol silt loam	0 to 20	B
LaD	Lakesol silt loam	20 to 55	B
LeA	Laketon silt loam	0 to 5	C
LeB	Laketon silt loam	5 to 20	C
LfA	Laketon fine sandy silt loam	0 to 5	C
LmC	Lance silt loam	0 to 30	B
LmC3	Lance silt loam, severely eroded	0 to 30	B
LnA2	Larkin silt loam, eroded	0 to 5	B
LnB2	Larkin silt loam, eroded	5 to 20	B
LnD2	Larkin silt loam, eroded	20 to 55	B
Lt	Latah silt loam		C
MaC	Marble loamy sand	0 to 30	A
MbC	Marble loamy coarse sand	0 to 30	A
McB	Marbe sandy loam	0 to 8	B
Md	Mondovy silt loam		B
MmC	Moscow silt loam	0 to 30	C
MmD	Moscow silt loam	30 to 55	C
MoC	Moscow silt loam, shallow	0 to 30	D
MoD	Moscow silt loam, shallow	30 to 55	D
MsC	Moscow very rocky complex	0 to 30	D
MsE	Moscow very rocky complex	30 to 70	D
NaA	Naff silt loam	0 to 5	B
NaA2	Naff silt loam, eroded	0 to 5	B
NaC	Naff silt loam	5 to 30	B
NaC2	Naff silt loam, eroded	5 to 30	B
NaC3	Naff silt loam, severely eroded	0 to 30	B
NaD2	Naff silt loam, eroded	30 to 45	B
NcA	Narcisse silt loam	0 to 5	B
NpA	Nez Perce silt loam	0 to 5	C
NpB	Nez Perce silt loam	5 to 20	C
NpB3	Nez Perce silt loam, severely eroded	5 to 20	C
PaB	Palouse silt loam, moderately shallow	0 to 20	C
PaC	Palouse silt loam, moderately shallow	20 to 30	C
PbC2	Palouse silt loam, eroded	5 to 30	B
PcC	Palouse very rocky complex	0 to 30	D
PcE	Palouse very rocky complex	30 to 70	D
PeA	Peone silt loam	0 to 5	D
PoA	Peone silt loam, drained	0 to 5	C
PsA	Phoebe sandy loam	0 to 5	B
PsB	Phoebe sandy loam	5 to 20	B
RdA	Reardon silt loam	0 to 5	C
RdB	Reardon silt loam	5 to 20	C
RdB2	Reardon silt loam, eroded	5 to 20	C
RdC2	Reardon silt loam, eroded	20 to 30	C
Rh	Riverwash		D

TABLE 4.4

Spokane County Soils

Map Unit Symbol	NRCS Map Unit Name	Slope, %	Hydrologic Group
Ro	Rock outcrop		D
SaB	Schumacher silt loam	0 to 20	B
SaB2	Schumacher silt loam, eroded	0 to 20	B
SaC	Schumacher silt loam	20 to 30	B
SaC2	Schumacher silt loam, eroded	20 to 30	B
SaD	Schumacher silt loam	30 to 55	B
ScC	Schumacher gravelly silt loam	5 to 30	B
ScC2	Schumacher gravelly silt loam, eroded	5 to 30	B
ScD	Schumacher gravelly silt loam	30 to 55	B
ScD2	Schumacher gravelly silt loam, eroded	30 to 55	B
Se	Semiahmoo muck		D
Sk	Semiahmoo muck, drained		C
Sm	Semiahmoo muck, moderately shallow, drained		D
SnA	Snow silt loam	0 to 5	B
SnC	Snow silt loam	5 to 30	B
SoE	Speigle very stony silt loam	30 to 70	B
SpC	Spokane loam	0 to 30	C
SpD	Spokane loam	30 to 55	C
SrC	Spokane stony loam	0 to 30	C
SrE	Spokane stony loam	30 to 70	C
SsC	Spokane complex	0 to 30	C
SsE	Spokane complex	30 to 70	C
StC	Spokane very rocky complex	0 to 30	D
StE	Spokane very rocky complex	30 to 70	D
SuE	Spokane extremely rocky complex	20 to 70	D
SwB	Springdale gravelly sandy loam	0 to 20	A
SxB	Springdale gravelly sandy loam, deep	0 to 20	A
SyB	Springdale cobbly sandy loam	0 to 20	A
SzE	Springdale gravelly loamy sand	30 to 70	A
TeB	Tekoa gravelly silt loam	5 to 20	B
TeC	Tekoa gravelly silt loam	20 to 30	B
TeD	Tekoa gravelly silt loam	30 to 55	B
TkD	Tekoa very rocky complex	25 to 55	D
UhA	Uhlig silt loam	0 to 5	B
UhB	Uhlig silt loam	5 to 20	B
UmC	Uhlig silt loam, moderately shallow	5 to 30	B
VaC	Vassar silt loam	0 to 30	B
VaD	Vassar silt loam	30 to 55	B
VsD	Vassar very rocky silt loam	20 to 55	B
We	Wethey loamy sand		C
Wh	Wethey loamy sand, drained		B
Wo	Wolfeson very fine sandy loam		C

TABLE 4.5

Stevens County Soils

Map Unit Symbol	NRCS Map Unit Name	Slope, %	Hydrologic Group
13	AQUOLLS, SLOPING		D
19	BERNHILL VERY STONY LOAM	0 to 40	B
21	BERNHILL SILT LOAM	0 to 15	B
22	BERNHILL SILT LOAM	15 to 25	B
23	BERNHILL SILT LOAM	25 to 40	B
23	BERNHILL SILT LOAM	25 to 40	B
24	BERNHILL SILT LOAM	40 to 65	B
25	BERNHILL-ROCK OUTCROP COMPLEX	0 to 25	D
26	BERNHILL-ROCK OUTCROP COMPLEX	25 to 60	D
27	BESTROM SILT LOAM	0 to 15	B
28	BESTROM SILT LOAM	15 to 25	B
29	BESTROM SILT LOAM	25 to 40	B
30	BISBEE LOAMY FINE SAND	0 to 15	A
35	BONNER SILT LOAM	0 to 10	B
38	BRICKEL STONY LOAM	20 to 60	B
39	BRIDGESON SILT LOAM		D
40	BRIDGESON SILT LOAM, DRAINED		C
46	CEDONIA SILT LOAM	5 to 15	B
56	CLAYTON FINE SANDY LOAM	0 to 5	B
57	CLAYTON FINE SANDY LOAM	5 to 15	B
60	DART LOAMY COARSE SAND	0 to 8	A
61	DEARYTON SILT LOAM	0 to 5	C
62	DEARYTON SILT LOAM	5 to 15	C
80	ELOIKA SILT LOAM	0 to 15	B
82	ELOIKA VERY STONY SILT LOAM	25 to 40	B
88	HAGEN SANDY LOAM	0 to 15	B
90	HARDESTY SILT LOAM		B
91	HARTILL SILT LOAM	0 to 15	B
92	HARTILL SILT LOAM	15 to 25	B
93	HARTILL SILT LOAM	25 to 40	B
94	HARTILL SILT LOAM	40 to 65	B
98	HISTOSOLS, PONDED		D
121	KONNER SILTY CLAY LOAM		D
122	KONNER SILTY CLAY LOAM, DRAINED		C
126	LAKETON SILT LOAM	0 to 5	C
127	LAKETON SILT LOAM	5 to 15	C
142	MARBLE LOAMY SAND	5 to 25	A
151	MOBATE GRAVELLY LOAM	0 to 30	D
152	MOBATE GRAVELLY LOAM	30 to 65	D
159	MOSCOW SILT LOAM	0 to 25	B
160	MOSCOW SILT LOAM	25 to 40	B
161	MOSCOW SILT LOAM	40 to 65	B
162	MOSCOW-ROCK OUTCROP COMPLEX	0 to 30	D

TABLE 4.5

Stevens County Soils

Map Unit Symbol	NRCS Map Unit Name	Slope, %	Hydrologic Group
163	MOSCOW-ROCK OUTCROP COMPLEX	30 to 65	D
164	NARCISSE SILT LOAM		C
172	PEONE SILT LOAM		D
173	PEONE SILT LOAM, DRAINED		C
176	RAISIO SHALY LOAM	0 to 20	B
177	RAISIO SHALY LOAM	20 to 40	B
178	RAISIO SHALY LOAM	40 to 65	B
195	ROCK OUTCROP-MOSCOW COMPLEX	30 to 65	D
196	ROCK OUTCROP-SPOKANE COMPLEX	30 to 65	D
201	SALTESE MUCK		D
202	SALTESE MUCK, DRAINED		D
209	SKANID LOAM	0 to 25	D
210	SKANID LOAM	25 to 40	D
211	SKANID LOAM	40 to 65	D
218	SPOKANE LOAM	0 to 25	B
219	SPOKANE LOAM	25 to 40	B
220	SPOKANE LOAM	40 to 65	B
221	SPOKANE STONY LOAM	0 to 40	B
222	SPOKANE STONY LOAM	40 to 65	B
223	SPOKANE-ROCK OUTCROP COMPLEX	0 to 40	D
224	SPOKANE-ROCK OUTCROP COMPLEX	40 to 65	D
238	VASSAR SILT LOAM	30 to 65	B
247	WOLFESON VERY FINE SANDY LOAM		C

TABLE 4.6

Pend Oreille County Soils

Map Unit Symbol	NRCS Map Unit Name	Slope, %	Hydrologic Group
4	Aits loam high precipitation 0 to 15 percent slopes	0 to 15	B
5	Aits loam high precipitation 15 to 25 percent slopes	15 to 25	B
6	Aits loam high precipitation 25 to 40 percent slopes	25 to 40	B
7	Aits loam high precipitation 40 to 65 percent slopes	40 to 65	B
8	Aits stony loam high precipitation 0 to 40 percent slopes	0 to 40	B
9	Aits stony loam high precipitation 40 to 65 percent slopes	40 to 65	B
10	Aits high precipitation - Rock outcrop complex 0 to 40 percent slopes	0 to 40	D
11	Aits high precipitation - Rock outcrop complex 40 to 65 percent slopes	40 to 65	D
14	Aquolls silt loam 0 to 7 percent slopes	0 to 7	D
19	Blueslide silt loam		D
20	Bonner silt loam 0 to 10 percent slopes	0 to 10	B
21	Bonner gravelly silt loam 0 to 10 percent slopes	0 to 10	B
22	Borosaprists ponded		D
25	Brickel stony loam 20 to 60 percent slopes	20 to 60	C
27	Buhrig very stony loam 25 to 40 percent slopes	25 to 40	C
28	Buhrig very stony loam 40 to 65 percent slopes	40 to 65	C
29	Buhrig - Rock outcrop complex 25 to 40 percent slopes	25 to 40	D
30	Buhrig - Rock outcrop complex 40 to 65 percent slopes	40 to 65	D
31	Clayton fine sandy loam 0 to 5 percent slopes	0 to 5	B
32	Clayton fine sandy loam 5 to 15 percent slopes	5 to 15	B
38	Cusick silt clay loam		D
39	Dalkena fine sandy loam 0 to 7 percent slopes	0 to 7	C
40	Dalkena fine sandy loam 7 to 15 percent slopes	7 to 15	C
41	Dalkena fine sandy loam 15 to 25 percent slopes	15 to 25	C
42	Dalkena fine sandy loam 25 to 40 percent slopes	25 to 40	C
43	Dufort silt loam 0 to 15 percent slopes	0 to 15	B
44	Dufort very stony silt loam 0 to 40 percent slopes	0 to 40	B
45	Eloika silt loam 0 to 15 percent slopes	0 to 15	B
46	Hartill silt loam 0 to 15 percent slopes	0 to 15	C
47	Hartill silt loam 15 to 25 percent slopes	15 to 25	C
48	Hartill silt loam 25 to 40 percent slopes	25 to 40	C
49	Hartill silt loam 40 to 65 percent slopes	40 to 65	C
50	Hartill - Rock outcrop complex 40 to 65 percent slopes	40 to 65	D
51	Hoodoo silt loam		D
53	Huckleberry silt loam 40 to 65 percent slopes	40 to 65	C
54	Huckleberry - Rock outcrop complex 25 to 65 percent slopes	25 to 65	D
56	Inkler gravelly silt loam 20 to 40 percent slopes	20 to 40	B
58	Inkler - Rock outcrop complex 20 to 40 percent slopes	20 to 40	D
59	Inkler - Rock outcrop complex 40 to 65 percent slopes	40 to 65	D
60	Kaniksu sandy loam 0 to 15 percent slopes	0 to 15	B
61	Kaniksu sandy loam 15 to 45 percent slopes	15 to 45	B
62	Kegel loam		D
63	Kiehl gravelly silt loam 0 to 10 percent slopes	0 to 10	B
70	Martella silt loam 0 to 5 percent slopes	0 to 5	C
72	Martella silt loam 15 to 25 percent slopes	15 to 25	C

Pend Oreille County Soils

Map Unit Symbol	NRCS Map Unit Name	Slope, %	Hydrologic Group
74	Merkel stony sandy loam 0 to 40 percent slopes	0 to 40	B
76	Merkel - Rock outcrop complex 10 to 65 percent slopes	10 to 65	B
77	Mobate - Rock outcrop complex 0 to 40 percent slopes	0 to 40	D
78	Mobate - Rock outcrop complex 40 to 65 percent slopes	40 to 65	D
79	Moscow silt loam 0 to 25 percent slopes	0 to 25	C
80	Moscow silt loam 25 to 40 percent slopes	0 to 25	C
81	Moscow silt loam 40 to 65 percent slopes	40 to 65	C
82	Moscow - Rock outcrop complex 0 to 40 percent slopes	0 to 40	D
83	Moscow - Rock outcrop complex 40 to 65 percent slopes	40 to 65	D
84	Moso silt loam 0 to 25 percent slopes	0 to 25	B
85	Moso silt loam 25 to 40 percent slopes	25 to 40	B
86	Newbell silt loam 0 to 25 percent slopes	0 to 25	B
87	Newbell silt loam 25 to 40 percent slopes	25 to 40	B
88	Newbell silt loam 40 to 65 percent slopes	40 to 65	B
89	Newbell stony silt loam 0 to 40 percent slopes	0 to 40	B
90	Newbell stony silt loam 40 to 65 percent slopes	40 to 65	B
91	Newbell very bouldery silt loam 25 to 40 percent slopes	25 to 40	B
93	Newbell - Rock outcrop complex 15 to 40 percent slopes	15 to 40	D
94	Newbell - Rock outcrop complex 40 to 65 percent slopes	40 to 65	D
97	Orwig sandy loam 0 to 20 percent slopes	0 to 20	B
98	Orwig sandy loam 20 to 65 percent slopes	20 to 65	B
99	Pits		
104	Pywell much		D
105	Raisio channery loam 10 to 40 percent slopes	10 to 40	C
106	Raisio channery loam 40 to 65 percent slopes	40 to 65	C
107	Raisio - Rock outcrop complex 25 to 40 percent slopes	25 to 40	D
108	Raisio - Rock outcrop complex 40 to 65 percent slopes	40 to 65	D
109	Rathdrum very fine sandy loam		B
110	Riverwash		D
113	Rock outcrop		D
114	Rock outcrop - Aits high precipitation complex 30 to 65 percent slopes	30 to 65	D
115	Rock outcrop - Huckleberry complex 30 to 65 percent slopes	30 to 65	D
117	Rock outcrop - Moscow complex 30 to 65 percent slopes	30 to 65	D
118	Rock outcrop - Newbell complex 30 to 65 percent slopes	30 to 65	D
119	Rock outcrop -Orthents complex 50to 90 percent slopes	50 to 90	D
121	Rock outcrop - Usk complex 30 to 65 percent slopes	30 to 65	D
122	Rubbleland		A
123	Rufus channery loam 30 to 65 percent slopes	30 to 65	D
124	Rufus - Rock outcrop complex 30 to 65 percent slopes	30 to 65	D
125	Sacheen loamy fine sand 5 to 15 percent slopes	5 to 15	A
126	Sacheen loamy fine sand 15 to 25 percent slopes	15 to 25	A
129	Scotia fine sandy loam 7 to 15 percent slopes	7 to 15	B
130	Scotia fine sandy loam 15 to 25 percent slopes	15 to 25	B
134	Skanid - Rock outcrop complex 0 to 40 percent slopes	0 to 40	D
135	Skanid - Rock outcrop complex 40 to 65 percent slopes	40 to 65	D

Pend Oreille County Soils

Map Unit Symbol	NRCS Map Unit Name	Slope, %	Hydrologic Group
145	Typic Xerorthents 30 to 65 percent slopes	30 to 65	B
146	Uncas muck		D
148	Usk loam 0 to 20 percent slopes	0 to 20	C
149	Usk loam 20 to 40 percent slopes	20 to 40	C
150	Usk loam 40 to 65 percent slopes	40 to 65	C
151	Usk stony loam 0 to 40 percent slopes	0 to 40	C
152	Usk - Rock outcrop complex 0 to 40 percent slopes	0 to 40	D
153	Usk - Rock outcrop complex 40 to 65 percent slopes	40 to 65	D
154	Vassar silt loam 30 to 65 percent slopes	30 to 65	B
155	Vassar silt loam shaly substratum	30 to 65	B

TABLE 4.7

Distribution of Soil Types Classified by NRCS Hydrologic Code

WRIA 55 (includes areas of Spokane, Stevens and Pend Oreille Counties)

	Acres	% WRIA 55
Total acres in WRIA 55 =	432,619	100%
Spokane County Acres =	265,667	61%
Pend Oreille County Acres =	108,025	25%
Stevens County Acres =	58,927	14%

County	NRCS Soil Hydrologic Group								Open Water	
	Group A		Group B		Group C		Group D			
	Acres	% WRIA	Acres	% WRIA	Acres	% WRIA	Acres	% WRIA	Acres	% WRIA
Spokane	27,944	6.46	139,947	32.35	68,560	15.85	28,330	6.55	887	0.20
Stevens	96	0.02	46,982	10.86	2,980	0.69	8,789	2.03	80	0.02
Pend Oreille	5,814	1.34	38,715	8.95	23,736	5.49	38,107	8.81	1,622	0.38
Total	33,854	7.83	225,644	52.16	95,275	22.02	75,225	17.39	2,589	0.60

WRIA 57 (includes areas of Spokane and Pend Oreille Counties)

	Acres	% WRIA 57
Total acres in WRIA 57 =	181,953	100%
Spokane County Acres =	168,501	93%
Pend Oreille County Acres =	13,452	7%

County	NRCS Soil Hydrologic Group								Open Water	
	Group A		Group B		Group C		Group D			
	Acres	% WRIA	Acres	% WRIA	Acres	% WRIA	Acres	% WRIA	Acres	% WRIA
Spokane	7,999	4.40	80,682	44.34	58,321	32.05	18,948	10.41	2,540	1.40
Pend Oreille	2,416	1.33	4,677	2.57	3,715	2.04	2,574	1.41	70	0.04
Total	10,415	5.72	85,359	46.91	62,036	34.09	21,522	11.83	2,611	1.43

5. WATER QUANTITY

Water quantity is the primary focus of watershed planning in WRIAs 55 and 57. This section presents a characterization of the flow of surface water and groundwater. These two domains are interconnected through hydraulic continuity and it is acknowledged throughout the text. A final section in this chapter focuses on specific hydraulic continuity issues, as they are currently understood.

5.1 Surface Water

Watershed planning for WRIA 55 and 57 is primarily being conducted to manage surface water flows. Previous studies and planning efforts in the basin have focused on single issues, such as groundwater flow through the state boundary or transport of specific contaminants into the aquifer and are discussed in the Groundwater section (5.2) below. The purpose of this study is to quantify, characterize and present an initial building block for planned future efforts by looking at the watershed as a whole.

This section will begin with a brief overview of each watershed and the data currently available then go on to discuss streamflow characterization and the factors affecting streamflow and conclude with an analysis of streamflow in each basin including hydrograph analysis, low flows, base flows and instream flow requirements.

5.1.1 WRIA 55 Watershed Overview

The Little Spokane watershed encompasses just under 700 square miles along the eastern border of Washington including areas in Spokane, Pend Oreille and Stevens Counties. Elevations in the watershed range from more than 5,300 feet amsl (NGVD 1929) in the north and east sides of the WRIA to approximately 1,540 feet amsl (NGVD 1929) at the junction of the Little Spokane River (LSR) and Spokane River (SR). WRIA 55 can be broadly split into two regions the Columbia Plateau Province, and the Northern Rocky Mountains Province (see Figure 4.1; Fenneman, 1931). Broad and relatively flat topographic features with deeply incised river drainages characterize the Columbia Plateau Province of the southern portion of the watershed. Steep-sided canyons and relatively straight river courses, characterize the Rocky Mountains province to the north. Evergreen forests are the primary land cover in the mountainous areas to the north and east. Agricultural lands are interspersed throughout the watershed but the majority are found on the south and east sides of the WRIA. The remaining portions of WRIA 55 are composed of urban areas, rangeland, wetlands and barren land (USGS, 1992; Figure 4.16).

Streams in WRIA 55 originate in the northern part of the basin and all feed the Little Spokane River. The river flows 48.6-miles from just south of Newport, Washington to its discharge into the Spokane River, approximately 5 miles north of Spokane city limits. Mean annual flow in the Little Spokane River At Dartford (stun 12431000) is 306 cfs and ranges from 626 cfs to 128 cfs. Peak flows have been recorded at 4,110 cfs and minimum flows as low as 62 cfs (USGS, 2001).

Groundwater is also directly connected to river flows, especially in the alluvial and glacial flood aquifers along Dragoon Creek, at the southern end of the Little Spokane River near the Spokane River, and near the outlet of Deadman Creek. The SVRP Aquifer is closest to the surface near the confluence of the Little Spokane River and Spokane River and many springs can be seen along the southern edge of the Little Spokane River (Jenson and Eckhart, 1987). Inter-basin groundwater flow from the Pend Oreille drainage into the Little Spokane River basin may occur in the northeast corner of WRIA 55, but this is not substantiated (Dames and Moore and Cosmopolitan, 1995; Section 5.2.3.4 for more detail).

There are approximately 22 dams within WRIA 55 the majority of which are small private dams located on tributaries of the Little Spokane River. All of these dams are classified for one of the following purposes: irrigation, recreation and water quality. There are no dams on the main stem Little Spokane River (Ecology, 1998).

5.1.2 WRIA 57 Watershed Overview

The Middle Spokane Watershed (WRIA 57) bounds an area of approximately 290 square miles and includes less than 30 miles of the 100-mile long Spokane River. The Spokane River originates at the outlet of Lake Coeur d’Alene approximately 9 miles upstream of the Post Falls Dam in Idaho and discharges into the Columbia River upstream of Grand Coulee Dam. Lake Coeur d’Alene is fed by the drainages of the St. Maries River, the St. Joe River and the Coeur d’Alene River. The location of the watershed near the border of Washington and Idaho dictates that WRIA boundaries, delineated by the Washington Department of Natural Resources, artificially end at the state line. In reality, the WRIA boundary encompass only a fraction of the contributing area to the Spokane River, with most of the surface water originating in the more mountainous regions of Idaho. The Spokane River is fed by a drainage that extends from the WRIA 57 boundaries to the border of Idaho and Montana, more than 3,700 square miles (Figure 5.1; Bennett and Underwood, 1988).

WRIA 57 varies in elevations from more than 5,400 feet amsl in the northeast to approximately 1,600 feet amsl at the discharge of the Little Spokane River into the Spokane River. Land cover in WRIA 57 is comprised mainly of urban, agricultural, and forested land. Urban Land comprises most of the area to the north and south of the river, with portions to the east interspersed with agricultural land. Forests comprise most of the rest of the watershed, primarily in the northern and southern areas.

Several streams originating within the WRIA do not drain directly to the Spokane River but rather drain across the state line to Idaho or into the SVRP Aquifer. The Blanchard Creek sub-basin in the northeast portion of WRIA 57 is not connected through surface water channels to the Spokane River. Rather, water flowing out of this sub-basin drains via groundwater into Rathdrum Prairie portion of the SVRP Aquifer. Also, in the southern portion of the watershed on the southeast side of Mica Peak, Lake Creek flows southeast and eventually reaches Lake Coeur d’Alene. Mean annual flow in the Spokane River at Spokane (stn 12422500) is 6760 cfs and ranges from 2507 cfs to 12,306 cfs. Extreme flows have been recorded at a minimum of 466 cfs to a peak of 49,000 cfs.

The Spokane River flows over (in areas where the river elevation is above the aquifer groundwater level) and within (in areas where the river elevation is below the aquifer groundwater level) the SVRP Aquifer. The Spokane River is the only river that flows for an extended distance over the aquifer (MacInnis and others, 2000). Most of the streams that feed the Spokane River within WRIA 57 "disappear" into the aquifer as they flow towards the river. These streams recharge the aquifer at its boundaries. The aquifer in turn alternately recharges or drains the Spokane River. The northern and southern boundaries of the SVRP Aquifer and the Spokane River Valley occur at the contact between the aquifer gravels and the crystalline rocks bordering the valley.

There are a total of 11 dams recorded within WRIA 57, the majority of these are small, private dams used for irrigation or recreation. Only 3 of these are on the mainstem Spokane River within the WRIA: the Upriver Dam, the Upper Falls Dam, and the Monroe Street Dam.

5.1.3 Previous studies

Though there have been many studies done on various and distinct components of the hydrologic regime within WRIAs 55 and 57 including habitat analysis, water quality and groundwater flow; few studies have focused on the watershed as a whole. The watershed scale studies completed to date have all occurred within WRIA 55 (referenced in Appendix A1) and include:

- Cline's 1969 study of groundwater resources within north central Spokane and south east Stevens Counties;

- Chung's 1975 water resources management study of the Little Spokane River Basin to support instream flow policy; and,

- Dames and Moore and Cosmopolitan's 1995 Initial Watershed Assessment of WRIA 55 completed for Ecology as a precursor to full scale watershed planning.

Habitat studies have been completed to determine instream flow requirements and habitat availability on both the Little and Middle Spokane Rivers. Water quality studies have been completed within both WRIAs to examine pollutant levels, surface water / groundwater continuity and streamflow effects on water quality. Multiple groundwater studies have been completed on portions of the SVRP Aquifer (see Section 5.2).

5.1.4 Available Data

The primary surface water data necessary for a watershed assessment are streamflow-gaging records. Spokane County has made data available to Golder for more than 80 streamflow-gaging stations within WRIAs 55 and 57. There are 13 continuous USGS gaging stations in and around the study area. Most of the remaining records are bimonthly or random measurements (i.e., "snap-shot" in time) that have been collected by local, state, and federal agencies for various water quality or groundwater studies.

The locations of all surface water stations within the study area are shown on Figure 5.2 a. A table of all stations, their data type, source and period of record is included within Appendix C. While random or less frequent values can be useful for streamflow analysis, streamflow records that are continuous for at least 5 years or more are most useful for surface water analysis and modeling. Table 5.2 summarizes the location, data source, contributing area, river mile, elevation and period of record of continuous streamflow gages with 5 years of record or more. These stations are also distinguished on Figure 5.2a with name call-outs. The reliability and accuracy of USGS data are considered high, based on the internal quality control used by the USGS in recording and maintaining the gages. Monitoring of several gages in this list was initiated or continued temporarily by the Spokane Community College surface water program. This data has been merged with USGS data and is assumed to be of similar quality. Several of the gaging stations, while having a period of record that is useful, do not have a recent period of record or are missing large periods of time and this limits their value.

Other types of data aid in characterizing a surface water system including significant river features, cross-sections, river profile elevations, structures, and impoundments and their operating procedures. A large amount of data was collected for this report and is summarized in Appendix C. Data specific to surface water characterization includes:

WAU Boundaries - WRIA boundaries are subdivided into smaller divisions called Watershed Administrative Units (WAUs). These divisions are developed to further to aid in understanding watershed characteristics. Ideally, a WAU outlines a boundary within which precipitation falls, feeds surface water and is withdrawn and/or discharged without crossing the boundary. WAU boundaries were obtained from the Washington DNR and are illustrated on Figure 1.2 and summarized in Table 5.1. Sub-basin boundaries developed by the USGS, referred to as fifth field Hydrologic Unit Code basins (HUC-5s), closely match WAU boundaries. For purposes of this report WAU boundaries are used to represent individual stream drainage basins within the WRIA.

Minimum Instream Flow Reaches and Control Stations - Minimum instream flow reach outlets and control stations defined under Ch. 173-555 WAC for the Little Spokane watershed are shown in Figure 5.2b. Control stations are used to monitor an affected stream reach. However, three of the control stations are several miles upstream or downstream of the outlet of the affected stream reach. Figure 5.2b shows how the locations of the gaging stations affect the contributing area to the stream reach.

Dam Location and Summary - GIS coverage of distribution of dams was obtained from Ecology (1998) and the National Inventory of Dams (Figure 5.3). A summary of dam facts can be found in Appendix C. Some dam operating data was supplied for the Monroe Street and Post Falls Dams.

5.1.5 Factors Affecting Streamflow

Streamflow is affected by many factors including climate, physical characteristics of the watershed, land use/cover in the watershed and regulation. This section briefly states how these factors can affect streamflow the following sections discuss how these factors are displayed in general streamflow analysis and finally in the study area.

Climate is often considered the driving factor for streamflow. The climate is spatially and seasonally variable in WRIA 55 and 57. Precipitation falling as rain usually has a direct, relatively immediate affect on streamflow, depending on basin characteristics. Precipitation falling as snow can be held in snow pack for long periods of time and can be released in a relatively short period (freshet) causing seasonal variations in flow. Snowmelt can increase flows in the Little Spokane River by as much as 300% and in the Spokane River by as much as 10,000%.

Physical characteristics of the watershed include soils, geology, topography and areal extent. Soils and geology affect whether water flows on the surface of the ground or infiltrates and how this water then moves towards the river. Areas with highly permeable geologic material may show little response to storm events because much of the water is infiltrated and released slowly over time. Elevation and size of the watershed also influences how much and how quickly water reaches the river. Steep sloped basins often have quick response to precipitation events while a flat basin would not. Basins that are wide with many varying length tributaries would likely have several peak flow periods in response to a storm event or snow melt while a narrow watershed would only show one peak response to an event.

Land use and land cover also affect run-off from snow and precipitation. Developed areas have greater percentages of impervious area, causing rainfall to flow more quickly, and sometimes, directly into surface water. In forested areas some water is intercepted and used (evapotranspirated) by trees and shrubs, reducing the total amount of water that reaches the stream. Forested areas also slow the rate at which runoff reaches the stream, decreases peak flows and increases base flows.

Lastly regulation of flows, including dams, withdrawals and discharges, can change a flow regime through changes in timing, size and location of flows. Dam storage and release practices influence streamflows down and up river of the impoundment as well as increase the pressure head, which can affect ground water flows. The same effects apply for any structure on the river (e.g., weirs, bridges and natural obstructions). Withdrawals can change in timing and/or location of flows. For example, waters withdrawn and used for irrigation may infiltrate back to the river but it may take weeks and it may return to the river at a different location from where it was withdrawn.

5.1.6 Surface Water Regulation

WRIA 55 has 22 dams, which are operated for a number of purposes including recreation, irrigation and water quality. The total normal storage available in these dams is approximately 2,100 AF, with a total contributing area recorded to be 32 square miles (Ecology, 1998). Approximately 78% of total storage is held within the 5 structures summarized in the table below.

Dams within WRIA 55 with Large Normal Storage Volume
(Ecology, 1998)

Name	Normal Storage (AF)	Location
Reflection Lake Dam (North and South)	860	Sheets Creek, Tributary of Dry Creek, near confluence with LSR
Ponderosa Lake Dam	357	Beaver Creek, Tributary of W. Branch LSR
Deer Park Waste Water Storage Lagoon	176	Tributary of Dragoon Creek, near Deer Park
Dragoon Lake Dam	157	Dragoon Creek near Deer Park
Kettwig Wildlife Dam	100	Spring Heel Creek, Tributary W. Branch LSR

Operating procedures were not available for dams within WRIA 55. Information on dams is summarized within Appendix C and locations are shown on Figure 5.3.

Within WRIA 57, Spokane River flow is used by three hydroelectric dams (Upriver Dam, Upper Falls Dam, and Monroe Street Dam) with a combined normal storage of approximately 1,030 AF (Ecology, 1998). An additional 8 dams are located on tributaries within the WRIA. The largest of these is the Newman Lake Flood Control Dam (8700 AF). The combined normal storage of all dams within the WRIA is approximately 10,000 AF with a total drainage area recorded to be more than 4,000 square miles (Ecology, 1998). Upstream of WRIA 57, the natural constriction at the outlet of Lake Coeur d'Alene and the Post Falls Dam control the flow in the Spokane River. Downstream of WRIA 57 are Nine Mile Dam and Long Lake Dam. Nine Mile Dam is located on the Spokane River about one mile upstream of the confluence with the Little Spokane River. Long Lake Dam is 23.7 miles downstream and impounds a normal volume of 105,000 AF in a 23-mile long reservoir. Each of these dams is operated for both electric generation and recreation. Dams on the mainstem Spokane River are summarized in the table on the following page.

Upriver, Upper Falls, Monroe Street and Nine Mile Dams are all "run of river" hydroelectric facilities. Run-of-river dams, in this case, are used for hydropower and preferably operate so that outflow is virtually the same as inflow. Reservoir levels at run-of-river projects vary only a few feet in normal operations. Avista Corporation (Avista) operates every dam on the Spokane River, except for the Upriver Dam. The Upriver Dam is operated by the City of Spokane. A summary of dams in and around the study area can be found in Appendix C-1.

Dams Operating on the Mainstem of the Spokane River

(Avista, 2001)

Dam Name	**Normal Elevation** (ft, Avista Datum*)	**Normal Storage** (AF)	**Approximate River Mile**
Post Falls Dam	2128.0	225,000	102
Upriver Dam	1909.9 (amsl)**	200***	79.9***
Upper Falls Dam	1870.5	800	
Monroe Street Dam	1806.0	30	74.2****
Nine Mile Dam	1606.6	3,130	58.1
Long Lake Dam	1536.0	105,000	33.9
Little Falls Dam	1362.0	2,220	29.3

* Subtract 3 feet for the elevation in the datum used in the rest of this document.
** Not Avista datum. (personal communication Mark Cleveland, 2001).
*** Ecology (1998).
**** 74.7 at Control Works

Avista operates its five dams in a coordinated manner to "maximize electricity generation while meeting other upstream and downstream interests" (Avista, 2001).

- Post Falls Dam releases just enough water to provide flow and, typically, maintain summer Coeur d'Alene lake elevations at 2,128 feet (2,125 feet amsl) through at least Labor Day. The Lake can be drawn down during the winter to provide capacity for runoff from the upper watershed by as much as 7.5 feet to the height of the natural outlet of the lake (Avista, 2001).

- The Upriver Dam powerhouse can use approximately 7,500 cfs. When flows exceed this value the powerhouse is bypassed and flow is released.

- The hydroelectric power plant at Upper Falls Dam has a capacity of 2,500cfs.

- Avista uses the Spokane River at Spokane gage (USGS stn 12422500) data to calculate flow through and over the Monroe Street Dam. The Monroe Street Dam is approximately 1 mile upstream of the gage. The powerhouse has a capacity of 2,400 cfs and the storage capacity is 30 acre feet. The dam at the lower falls is 24 feet high.

- Nine Mile Dam is the next dam downstream, immediately upstream of the confluence of the Little Spokane River with the Spokane River. It has a hydraulic capacity of 6,500 cfs. Flashboards raise the height of the dam when flows are low enough, typically in the summer, and are removed as flows increase, usually sometime in the winter. Avista supplied discharge records for 1986-1999. Average discharge from this facility was 6,800 cfs, with maximum flows recorded at 42,194 cfs and minimum flows at 571 cfs.

- Beyond Nine Mile Dam is Long Lake Dam. The elevation of the water behind this dam can theoretically vary by more than 24 feet. During the summer and fall reservoir elevation varies little from normal elevation, less than 1 foot. While during the winter and spring it can be drawn down as much as 24 feet to provide generation and storage capacity. Typically, it is drawn down less than 24 feet.

The Federal Energy Regulatory Commission (FERC) license for the Avista dams on the Spokane River expires in 2007. Avista is beginning to work on this relicensing effort, which requires a formal filing between 5 and 5 1/2 years prior to license expiration.

5.1.7 Streamflow Characterization Methodology

Goals of this project include determining the affect of withdrawals, quantifying aquifer and river exchange flows, and determining how various factors (snow, dams and climate) affect streamflow. Because hydrologic data are highly variable, dynamic, and often come in large data sets, it is common to use some form of aggregation to manage and condense large data sets. There are a few common methods that we have used in this report including correlation, average flows, hydrographs, exceedance curves, and representative years.

5.1.7.1 Correlation

Correlation is a check of the relationship or dependence of two parameters to each other on a defined time step. This report evaluates the interdependence of precipitation and flow on an annual basis. On an annual basis it is expected that any snow falling as precipitation would have melted and reached the river and that any withdrawals would have been discharged. If this were the case, a one-to-one relationship would be expected, or a 45 degree angle if the two parameters were plotted against each other. Generally river flows are not directly responsive to precipitation due to watershed characteristics and surface water and groundwater storage. Groundwater can delay precipitation reaching the river for periods longer than a year, as can surface water storage. Also withdrawals for irrigation are often a net loss from the system because of loss through evaporation. Though a one-to one response may not be seen this analysis is still useful to understand how well correlated the system is, how different tributaries vary and if there are losses of water from the system.

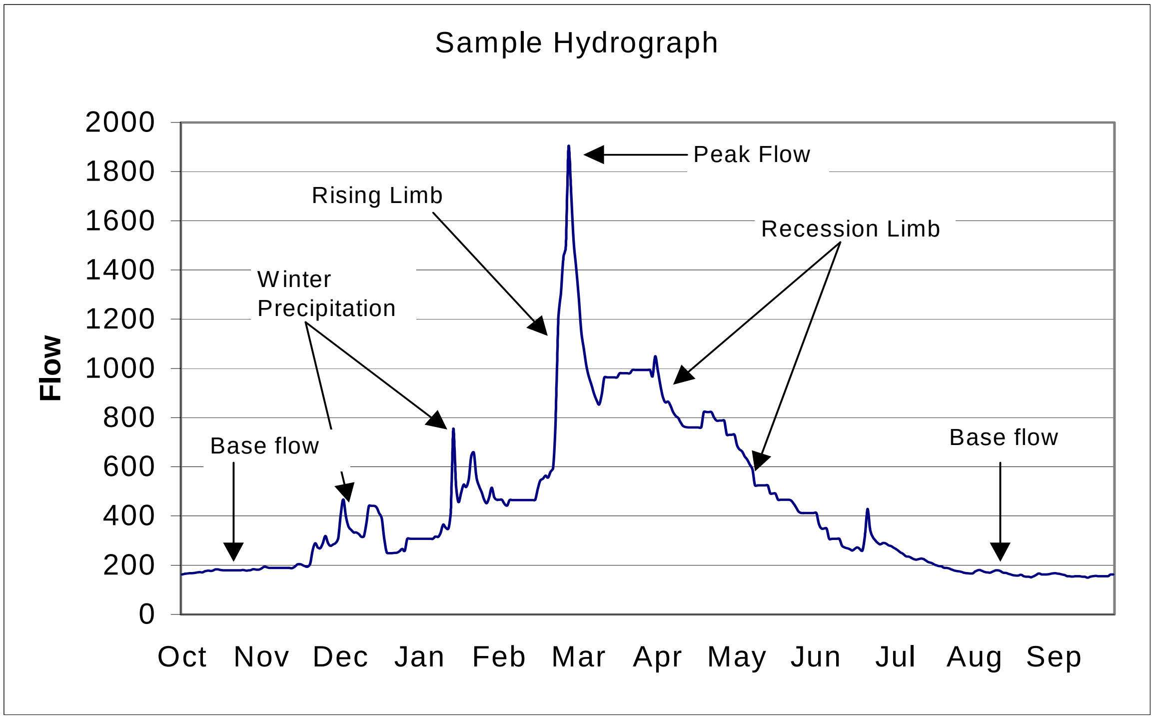
5.1.7.2 Average Flows

Average flows aid in general characterization of the river and evaluation of long-term trends. Comparison of mean annual flows of multiple rivers can indicate their relative size or indicate a wet or dry year. Mean monthly flows may indicate when peak periods occur and how large peaks are, in a simple and compact format. The use of average flows is very general; specific assumptions regarding watershed characteristics should generally not be inferred from this data.

5.1.7.3 Hydrographs

A hydrograph of streamflow (or stage) versus time can provide very detailed information on a watershed depending on its time scale. Hydrographs are used in this report to describe each watersheds response to precipitation, run-off and groundwater inflows. A drawback of hydrograph analysis is that the data is so detailed that it can be impossible to determine long-term trends or be sure that the hydrograph being used is representative of a normal year.

It is important to understand both the elements that a hydrograph illustrates and the driving factors that cause each element's response (discussed in Section 5.1.5). The basic elements of a hydrograph include base flow, rising limb, peak flow and recession limb. All of these elements can be seen in the sample hydrograph.



- Base flow represents streamflow, or runoff, which results from discharge from the groundwater system. It is also referred to as groundwater inflow. It is often the primary source of water during dry periods when there is little or no surface water run-off. The rate and volume of base flow can also be influenced by dam storage and release, well operations, and withdrawals (particularly in the summer). Without analysis, it would be incorrect to consider the total flow during the indicated time (on the sample hydrograph) as base flow because some of it may be run-off from small storm events, discharges and late snowmelt.

- The rising limb represents the period of time when run-off (from snowmelt or rain) begins to reach the stream after flowing overland to the stream and downstream to the gage. The rising limb can be a steep or gradual incline representing a quick or slow response (run-off period) of the watershed to a storm or snowmelt event. For example if the watershed had high infiltration rates or impoundments in the watershed, the rising limb might be expected to be more gradual.

- Peak streamflow represents the largest volume of streamflow in a certain time period. Peak flows can be dampened by retention of run-off or streamflow in an impoundment and withdrawals or they can be magnified if there is little natural or man-made storage in the basin.

- Finally, the recession limb represents the time it takes for all run-off to reach the stream and ultimately the gaging station. A steeply descending falling limb can also indicate there is little storage in the watershed (quick run-off), dam releases or a radical change in temperature that results in melt of snow pack.

5.1.7.4 Exceedance Curves

Exceedance curves are often used to represent or provide analysis of hydrologic data. These curves present a return period or exceedance probability of a flow or flow volume. The return period signifies the average length of time that elapses between observances of a particular level of flow. Exceedance probability represents the probability that a particular flow will occur in any one year. Exceedance curves are used to set minimum instream flows and water quality criteria. For example, exceedance curves are used in this report to indicate how often a certain low flow can be expected to occur.

5.1.7.5 Representative Years

Representative years are used as a form of aggregation. Rather than aggregating data statistically, data is merged logically with actual data being used to represent each logical group. In this report data from three water years was chosen to represent wet (i.e., 1997), dry (i.e., 1994) and average years (i.e., 1999). Representative years were specifically chosen from the 1990s because there is a reasonable amount of data available for this period for many watershed parameters. Streamflow data for the Elk gaging station is not available for these years and so alternate years were chosen for average (1959) and dry (1968) years based on the magnitude of annual flow volume. No representative wet year was identified within the available period of record for the Elk gage.

5.1.8 Correlation of Streamflow to Precipitation

Flows in WRIA 55 At Dartford and Elk were compared to precipitation data from Deer Park 2 E and Newport respectively (see Figure 4.1 for locations). This correlation is displayed in Figure 5.4a.

Flows at the USGS Elk gage appear to be insensitive to annual precipitation indicating that precipitation in the area is either captured and released slowly or captured and withdrawn from the basin. A rainfall-runoff model of this area will aid in answering this question. Dames and Moore and Cosmopolitan (1995) indicated the possibility of inflow from the Pend Oreille River in this area and this could explain the lack of responsiveness of the river to precipitation variations, but this base flow source has not been confirmed by a comprehensive evaluation. Section 5.2.3 outlines this area, referred to as the Diamond Lake Aquifer Area, more clearly.

Flows at the USGS gage At Dartford in Figure 5.4a are more responsive to precipitation but still display a low correlation. This area is also underlain by aquifers and this could cause a lag in precipitation reaching the stream from year to year. Also, this site is much further downstream from the Elk gage and the drainage area is much greater and more variable in terms of land cover, urbanization and geology. Areas of the watershed between Dartford and Elk are more highly urbanized, which typically improves the response of flows to precipitation. Also several tributaries reach the Little Spokane River which are not underlain by an aquifer but rather flow down from the more mountainous regions where snowmelt acts as primary water storage.

A correlation plot for WRIA 57 is displayed in Figure 5.4b. This correlation plots Spokane River at Spokane flows against data from the Coeur d'Alene weather gage. The relationship is stronger in this plot than the previous two but still weak. There are several influential factors in this basin that would affect this plot. The SVRP Aquifer underlies the entire river, which could cause a delay in river flow response longer than a year. The drainage basin feeding the river is very large and the precipitation gage used does not likely reflect precipitation falling on the entire basin. Also the basin is highly developed which would increase the response of flows to precipitation. Conversely, the fact that Lake Coeur d'Alene regulates the river could improve the correlation through releases that are in response to rainfall, if the rainfall gage is representative of the basin. Additional modeling of the basin will likely help understand the drivers of this system better.

5.1.9 Hydrograph Analysis

Hydrographs discussed in this section were developed for 8 gages in the study area. Figures include daily data for the wet, dry and average year as well as average, maximum and minimum daily flows from the period of record. These gages are represented in the Figure series 5.5 a-h from upstream to downstream.

(a) Little Spokane River at Elk, Washington
(b) Little Spokane River, Chattaroy Road, Chattaroy, Washington
(c) Little Spokane River At Dartford, Washington
(d) Little Spokane River Near Dartford, Washington
(e) Spokane River near Post Falls, Idaho
(f) Spokane River above Liberty Bridge near Otis Orchards, Washington
(g) Spokane River below Greene Street at Spokane, Washington
(h) Spokane River at Spokane, Washington (Cochran Street gage)

Detailed gage information and locations are included within Appendix C, and locations are shown on Figure 5.2a.

Gages on the Little Spokane River show many similar characteristics. The rising limb is visible generally from late October or November through winter. The rising limb is interspersed with small peaks that are likely the result of storm events or possibly early winter snowfall and melt cycles. A strong seasonal peak is most visible in March, but can vary from March through early May. Flows recede (recession limb) from the peak through July to base flow levels, generally by late July or August. Lowest flows occur during late summer (August and September). This pattern is reflective of a snow driven water cycle.

Low flows during the dry summer period from July through November appear to relate to spring peak flows, with higher peak flows indicating higher summer flows. The ratio of peak to low flows (using March 30 and September 15 as peak and low flow respectively) is shown in the following table. This data, with the exception of the Elk gage, suggest that the ratio of low to peak flows is relatively constant except during dry years. Driving factors for this pattern likely include large snowmelt volumes that are infiltrating and being released throughout the summer as base flows. Dry year low summer flows are likely totally supported by groundwater inflows, implying that groundwater reserves are large and can support base flows even during dry years when little precipitation is available to recharge aquifers.

Low Summer Flows as a Percentage of Peak Flows for Representative Years

Year	Elk (stn 2427000)*	Chattaroy (stn 8327Q)	At Dartford (stn 12431000)	Near Dartford (stn 12431500)
Wet Year, 1997		15%	11%	
Average Year, 1999	64%	14%	8%	31%
Dry Year, 1994	90%	29%	35%	

*Using representative years

Comparing flows between the gages provides some perspective of how the river changes downstream. Flows increase steadily downstream from Elk to the Near Dartford station (RM 3.9) due to tributary and groundwater inflows. It should be noted that the data from the station Near Dartford has a short period of record so max daily flows shown to be lower than those At Dartford are not likely to be representative of the actual relationship but more likely reflective of the lack of data at this gage. Comparison of monthly differences between the Dartford station (RM 10.3) and the station Near Dartford indicate that flows Near Dartford during the period of record are on average approximately 1000 cfs greater than flows At Dartford.

The hydrograph for the Elk gage, while showing a similar trend to the other gages, has much smaller peaks as compared to low flows. This is another indication (see Section 5.1.8) that this basin may be less affected by snowmelt and direct run-off than by base flows. The river in this upper reach also has few tributaries and the mountainous areas to the east and west feed the Dry Creek and West Branch Little Spokane, which contribute to the Little Spokane River further downstream.

The Spokane River is also dependent on snowfall for flows but has a slightly different response than that of the Little Spokane River as displayed in the hydrographs. The hydrograph for the Spokane River is not as “spiky” as the Little Spokane River for individual events. This suggests a dampened system with storage effects and is consistent with the known factors on this river, including: interactions with the SVRP Aquifer, a higher altitude snowpack, and a large drainage area for the Spokane River (see Figure 5.1 for drainage area).

Flows in the Spokane River generally begin to rise in early to mid November, rising slowly throughout the winter. This slowly increasing flow is interspersed with prominent, yet smooth peaks that are likely the response to runoff from storm events within the basin that pass through Lake Coeur d'Alene. These peaks are visible at all four gages downstream indicating that there is little inflow from other sources, relative to the high winter flows (there is inflow from other sources, namely the SVRP Aquifer it is just not big enough to have a spreading or dampening affect on the peaks). Peak flows on the Spokane river system occur later in the year than on the Little Spokane River, generally in April or May. Flows quickly recede from their peak to base flows by late June or early July. Flows are at their lowest for a period, generally in August, and then increase in September and remain relatively constant through October.

Evaluation of flows downstream (comparing multiple graphs) indicate that flows at Post Falls are generally higher than the flow volume near Otis Orchards, indicating a loss of water from the river into the SVRP Aquifer. Data for Greene Street are sparse but indicate that flows in this area are higher than flows near Otis Orchards, indicating SVRP inflows to the river upstream of Greene Street. The net effects of the gains and losses between Post Falls and Spokane are lower flows at Spokane in the winter and spring and higher flows at Spokane during the rest of the year.

These four hydrographs also show a pronounced increase in low flows during the late summer, generally in September. Based on operating data obtained from Avista this is due to releases of water from Post Falls Dam beginning after Labor Day.

5.1.10 Trend Analysis

For an increasingly populated watershed, it is important to determine if streamflow is declining due to over allocation. Previous efforts compared declines in annual streamflow in the Little Spokane River to declines in annual precipitation to postulate that over allocation may be occurring (Dames and Moore and Cosmopolitan, 1995). However, analysis in this report indicates that there may not be a strong enough correlation between streamflow and precipitation to support this comparison. Because streamflow is affected by many factors, including withdrawals, climate and regulation, it is difficult to identify direct cause and effect relationships between these two elements. Annual precipitation and annual flow graphs in Appendix C show a visible increasing trend in annual values since the mid-1990s. Recent studies in climate trends indicate a climate pattern in the mid-1990s that would switch us from a warm-dry period to a cool-wet period (see Section 4.2 for more discussion on this).

5.1.11 Low Flows

Low flow periods generally occur during the late summer after the snow pack has melted and before fall precipitation has begun. Low flow analysis is important for habitat, water quality, water use, recreation, and power generation, among other things. However, the time period of analysis of low flow that is considered important varies among regulatory and interest groups. For example, when calculating effluent discharge permits, Ecology uses the 7-day low flow with a recurrence interval of 20 years (7Q20). For habitat instream flow analysis the 7-day low flow with a recurrence interval of 10 years (7Q10) is generally of more interest. Seven-day low flows are the lowest average of flows over 7 consecutive days in a year. Low flows can vary across a watershed due to precipitation, geologic/hydrogeologic factors, and water use variations in the basin.

The 7Q10 for the Little Spokane River is approximately 35cfs at Elk and about 82 cfs At Dartford (Figure 5.6a). Chung (1975) estimated 7Q10 flows for the West Branch of the Little Spokane River at 2.8 cfs. These differences are likely indicative of differing base flow contributions. The West Branch of the Little Spokane is underlain, in large part, by metamorphic bedrock with low groundwater storage and discharge capacity. Alternatively, the main stem is underlain largely by alluvial and glacial flood deposit aquifers, as well as fed by several springs along its length, that can supply larger base flows.

The 7-day low flows over time for the Spokane River for the gages at Post Falls (ID), Liberty Bridge and Spokane (Figure 5.6b). The 7Q10 is 161 cfs at Post Falls, 117 cfs at Liberty Bridge, and 847 cfs at Spokane. These low flows provide a quick glimpse at how the Spokane River flow is affected and supported by base flows from the SVRP Aquifer. The Spokane River from Post Falls to between Barker Road and Flora Road is a losing reach, where water from the river seeps through the riverbed into the unsaturated sediments above the SVRP Aquifer. Downstream of Flora Road, the Spokane River generally gains flow from the aquifer. However, within this overall gaining reach there are smaller reaches that may seasonally lose water to the aquifer. Low flows per square mile of watershed are not calculated due to the large contributing area and the extensive aquifer contribution to flows.

5.1.12 Base Flows

Base flow is defined as the component of streamflow derived from groundwater inflow. Base flow can have varying importance to streamflow levels. Flow in rivers located in basins with very low snowfall (no water storage in snowfall) and little regulation is derived largely from two components; runoff during precipitation events and slower, sustained discharge of base flow (groundwater). During dry periods, base flow can be the main supply of water to such rivers. In other rivers, snowmelt and regulation have a much larger influence than base flow on sustaining streamflows throughout the year. In these rivers, estimating total base flow effects can be very difficult, requiring more information such as snow pack, snow water equivalent and temperature as well as operating procedures of regulating elements.

In 1999, the Washington Department of Ecology completed an evaluation of base flow contributions to total streamflow at 582 gauging stations across the Washington State, three of which are in WRIA 55. Ecology used several criteria to determine which stations were appropriate to analyze using standard base flow estimation procedures. Criteria included that the station must have:

- At least 3 complete water years of daily mean streamflow;
- A low degree of flow regulation; and,
- Low snowmelt influences.

Both WRIA 55 and 57 have base flow or groundwater contributions affecting streamflow. WRIA 57, while heavily affected by groundwater, does not lend itself to traditional base flow separation techniques as used in the Ecology study due to the summertime use of Post Falls Dam to maintain the elevation of Lake Coeur d'Alene. Base flow analysis of the Spokane River is better suited for focus in the next phase of this project. WRIA 55 on the other hand, is less influenced by anthropogenic sources, barring some irrigation usage, and though snow pack does influence streamflow during the spring thaw, during the rest of the year streamflow is mainly influenced by base flow and direct precipitation run-off. Hydrographs of representative dry, wet and average years have been plotted with average base flows on Figures 5.7 a, b and c (Elk, Chattaroy and At Dartford stations respectively). Base flows for the Elk gage are estimated to comprise between 95 and 98 percent of mean monthly streamflows, 79 to 97 percent for the At Dartford gage, and 84 to 99 percent of mean monthly streamflows for the Near Dartford gage.

Base flow estimates completed by Chung (1975) and Cline (1969) corroborate these percentages with estimates that base flows At Dartford comprise almost all streamflows occurring during summer months. Chung (1975) and Cline (1969) report that 234 cfs are added to the streamflow of the lower Little Spokane River in a four-mile reach of the river up to the confluence with the Spokane River. In addition, the USGS estimates flow, usually within 10 percent accuracy, in the Little Spokane River at its confluence with the Spokane River by multiplying the flow At Dartford by 1.9 and adding a constant of 252 cfs (Dames and Moore and Cosmopolitan, 1995). The constant in this equation represents a large inflow that is independent of the streamflow at any time. This inflow can nearly double the discharge At Dartford considering the average annual discharge measured At Dartford of approximately 300 cfs (Dames and Moore and Cosmopolitan, 1995).

5.1.13 Relation of Actual Flows to Instream Flow Requirements and Base Flows

Instream flows describe the volume of flow required to meet fish needs and other factors (Ecology, 2001; RCW 90.54, Water Resources Act of 1971). Minimum instream flows (MISFs) were set for the mainstem of the Little Spokane River from the headwaters to the confluence with the Spokane River in 1976 and are detailed in Chapter 173-555 WAC (included in Appendix C). MISFs have been established for four points on the Little Spokane River System at the 20% exceedance curve of historical data. The Dartford gage has the longest record (approximately 60 years). Regression analysis between other stations with the Dartford gage was conducted to create representative records.

MISFs are specified for each month of the year at four compliance points (control stations) including the reach from the headwaters to the abandoned Elk gaging station, Elk to Chattaroy, Chattaroy to Dartford, and Dartford to the confluence with the Spokane River. MISFs are summarized in Table 5.3. Currently there are 135 of the water rights that are junior to the MISFs of the Little Spokane River are regulated by the flow at the gage Near Dartford. Junior water right holders were directed by Ecology to not exercise their water rights in 1989, 1994, 1995, and 2001. The pumping of domestic exempt wells is not regulated by Ecology.

Three control stations on the Little Spokane River currently have continuous flow gaging stations nearby; Little Spokane River At Dartford (station 12431000) managed by the USGS, Little Spokane River at Chattaroy Road, managed by Spokane Community College, and the Little Spokane River Near Dartford (station 124315000) managed by the USGS. The Elk control station had a USGS gage collecting continuous records from 1949-1971. Although the gage has been retired, there are more recent bimonthly measurements taken at the Elk gage between 1987 and 1990. The Confluence control station (USGS gage 12431500, Little Spokane River Near Dartford) had monthly flow measurements collected by Ecology and SCCD at periods throughout the 1990's and has been gaged continuously since 1997 by the USGS in cooperation with Spokane County. Figures 5.7a-d display the current instream flow requirements as compared to flows during a reference dry, wet and normal year of precipitation where continuous gage data was available.

Each control station on the Little Spokane River was analyzed for MISF exceedance statistics based on the entire period of record as well as only the summer months. Table 5.4 summarizes the results of this analysis for each control station. A summary is provided here.

- The average exceedance length, in days, at all control stations, ranges from 12 to 22 days.

- The control station at Chattaroy has the highest percent of record below MISF levels with more than 42% of dry season flows below MISF levels.

- Chattaroy also recorded the longest exceedance length, which infringed on more than just the generally accepted "dry season", lasting for 262 days.

- An extremely long exceedance is visible in Figure 5-7 a, b and c (Elk, Chattaroy, and Dartford) for the "dry" year. At Dartford, it can be seen that although estimated average base flows are higher than MISF requirements that flows in a dry year can be well below MISF levels (Figure 5.5c).

- The discrete measurements taken near the Elk Control station (station 9408K) were collected between 1987 and 1990 during the summer months (May - September). During this period there were 39 days recorded, 30 of these days did not meet instream flow levels and instream flows were not met during each year data was collected.

- Discrete measurements collected near the Confluence control station (LSR near mouth @ Hwy 291, station 6205E) show that of 47 days collected year round from 1993-1997, there are 10 exceedances. Most of these exceedances occurred in the summer or fall of each year.

Instream flows have not, at this time, been set for the Middle Spokane River Basin. However, the Washington Department of Fish and Wildlife recommended a minimum flow target of 2,000 cfs at USGS gage station 12422500, Spokane River at Spokane, based on the minimum streamflows recorded at the Spokane gage prior to the construction of the Post Falls Dam. The communication regarding this recommendation is included in Appendix C.

Across the period of record at the Spokane River at Spokane gage (1891-1999) there are flows below the temporary 2,000 cfs level 14% of the time and only 5 years had no flows below 2,000 cfs. The longest continuous exceedance was 231 days beginning in July of 1930. The average length of an exceedance is 22 days. Analysis of the summer months only (June-October) shows that 45% of the record does not meet suggested instream flow minimums and that the average length of an exceedance is 19 days with a maximum length of 132 days. The period from 1920-1946 had the largest number of days below 2,000 cfs. This correlates to a dry period influenced by the Pacific Ocean (Pacific Decadal Oscillation; PDO). Also, after the construction of Post Falls Dam until 1941, Lake Coeur d'Alene was held at an elevation of 2123.5 feet during the summer months. The summer lake elevation has been 2125 feet since 1941. In recent years and in the early 1900's (before 1920) the number of days of exceedances was lower.

5.1.14 Conclusion

Surface water flow within WRIA 55 and 57 is complicated by aquifer interactions, highly variable climate and watershed characteristics. In WRIA 55, an examination of existing data indicates that base flows are very important along almost every stretch of the river, especially during the summer months. Hydrograph analysis indicates that the volume of these base flows varies with the volume of water stored in winter snow pack. Although the average base flows are higher than the MISF, flows below instream flow requirements are frequent. This suggests that the cumulative effects of water use are affecting streamflows, or that minimum instream flows are established at a level inconsistent with natural streamflows. Additional research should be completed to better understand the volume and timing of base flows on the mainstem and tributaries and the factors that affect them. In addition better estimates or continuous gaging on tributaries within the basin could help to better pinpoint where problems originate. The original MISF studies were based on historical streamflow data and did not consider the habitat needs of fish. The Planning Unit has received an instream flow supplemental grant to do evaluate the relevance of existing regulatory flow levels on Little Spokane River flows to the biological needs of fish.

WRIA 57 is also highly supported by base flows, but has many other affects including periodic regulation, a large drainage area, and a high degree of urbanization. The Spokane River flow is regulated by the Post Falls dam during the summer to keep Lake

Coeur d'Alene at 2125 feet, but is also highly supported by the SVRP Aquifer. Surface flow measurements along the Spokane river indicate that flow from Post Falls to Otis Orchards decrease slightly, followed by an increase from Otis Orchards to Greene Street and a decrease from Greene Street to Spokane. The net effects of the gains and losses between Post Falls and Spokane are lower flows at Spokane in the winter and spring and higher flows at Spokane during the rest of the year. Instream flows have not been formally set for the Spokane River but analysis of suggested MISFs indicate that even in wet years the suggested MISF is violated.

5.2 Groundwater

Groundwater is an important water resource within both WRIA 55 and WRIA 57. Because the availability of surface water resources is limited, sources of high quality groundwater are important to maintain the water supply to the existing population and to support community growth. In addition, where groundwater and surface water are in hydraulic continuity, groundwater recharge to surface water as baseflow provides a year round supply of water to maintain instream flows.

Useful quantities of groundwater occur within aquifers, defined as geologic units that are sufficiently permeable to transmit economically viable volumes of water to wells or to springs. Aquitards are low permeability geologic units that transmit water slowly. Aquifers can be confined or unconfined. A confined aquifer is bounded above and below by an aquitard or confining unit. An unconfined aquifer is bounded only at its base by an aquitard.

Within both WRIA 55 and WRIA 57 important groundwater resource aquifers are found in a variety of different geologic units including the crystalline basement rocks, the basalts, and the unconsolidated deposits. A detailed description of these units is included in Section 4.3 of this report. Of these three main water-bearing units, the unconsolidated sediments, and in particular the flood sands and gravels (depicted as Qfs, Qfg and Qfcg on Figure 4.12 and Figures 4.14A though 4.14O) are the most important in terms of water supply. The Spokane Valley – Rathdrum Prairie (SVRP) Aquifer, the main groundwater supply for the southern portion of WRIA 55 and for WRIA 57, occurs within the flood sands and gravels of the Spokane River Valley and Hillyard Trough. The EPA designated the SVRP Aquifer a Sole Source Aquifer in 1978 because it is the water source for most of the residents of Spokane County in Washington and Kootenai County in Idaho.

5.2.1 Previous Studies

Previous hydrogeologic studies relevant to WRIA 55 include:

- A regional study of the north-central portion of Spokane County and southeastern portion of Stevens County based on well and stream flow data (Cline, 1969);
- A detailed study of the Colbert Landfill Superfund site by Landau Associates (1991);

- A groundwater characterization study of the Deer Park area (EMCON, 1992; Anderson, 1986);
- The Phase I wellhead protection plan for the City of Newport, Washington and West Bonner Water District No. 1, Idaho (Welch, Comer and Associates, Inc. and Riley, J.A., 1994).
- An inventory of groundwater, surface water and climate information for WRIA 55 (Chung, 1975; Dames and Moore and Cosmopolitan, 1995);
- A hydrogeologic study of the Green Bluff area for the Washington State Department of Ecology (Ader, 1996);
- A groundwater resource study of Five Mile Prairie (Olson, 1979);
- A uranium mining feasibility study of Peone Prairie (Boleneus, 1978; Boleneus and Derkey, 1996);
- An aquifer delineation study of a portion of north Spokane County (Boese and Buchanan, 1996); and,
- A series of studies of the Spokane Aquifer system (Bolke and Vaccaro, 1979; Bolke and Vaccaro, 1981; Vaccaro and Bolke, 1983; Jensen and Eckart, 1987; Molenaar, 1988; Buchanan and Olness, 1994; CH2M Hill, 1998; CH2M Hill, 2000).

Due to the unique characteristics of the SVRP Aquifer, most of the previous work on the hydrogeology of WRIA 57 has focused on this aquifer. The important categories of work include:

- Research level studies and papers on the formation of the SVRP Aquifer (Bretz, 1930; Bretz, 1959; Purves, 1969; Baker, 1973; Kiver and Stradling, 1985; Jensen and Eckart, 1987; Molenaar, 1988);
- A series of sequential groundwater flow modeling studies (Pluhowski and Thomas, 1968; Drost and Seitz, 1978; Bolke and Vaccaro, 1979; Bolke and Vaccaro, 1981; Vaccaro and Bolke, 1983; Buchanan and Olness, 1994; CH2M Hill, 1998; CH2M Hill, 2000);
- Documents for public education (MacInnis and others, 2000)
- Aquifer sensitivity and wellhead protection studies (MacInnis and others, 2000; CH2M Hill, 1998; CH2M Hill, 2000);
- Hydraulic continuity studies (McDonald and Broom, 1951; Broom, 1951; Miller, 1996; Gearhart and Buchanan, 2000); and,
- On-going aquifer studies (USGS and Spokane County).

5.2.2 Hydrogeologic Units

Important groundwater resource aquifers in WRIA 55 and WRIA 57 occur primarily within the unconsolidated sediments that include the glacial flood deposits and recent alluvium. Important local sources of domestic water supply are also found within glacial lake deposits, the fractured and weathered basalt and crystalline basement rocks. Dense and unweathered crystalline basement rocks and basalt as well as glacial lake clays and dense Latah sediments act as important local aquitards, restricting vertical and lateral groundwater movement. The crystalline basement aquitard represents the lower hydrogeologic boundary of the region.

The following sections describe the hydrogeologic units of WRIA 55 and WRIA 57.

5.2.2.1 Flood Sand and Gravel Aquifers

The most productive hydrogeologic unit within both WRIA 55 and WRIA 57 are the unconfined and semi-confined aquifers comprising flood deposited sands and gravels. These deposits can be expected to yield hundreds to thousands of gallons per minute (Dames and Moore and Cosmopolitan, 1995). Where unconfined, these aquifers are recharged by infiltration of precipitation and irrigation, by groundwater discharge from adjacent units and by discharge from streams. Groundwater from the flood deposits may also recharge underlying units and streams.

In WRIA 55, the greatest thickness (up to 700 feet or more) of flood sand and gravel deposits (Figure 4.15) occurs on the south side of the Little Spokane River, within the Hillyard Trough. Thick deposits of flood sands and gravels also occur adjacent to the Little Spokane River and within the Deer Park Basin. In the vicinity of the Colbert Landfill (located just east of Green Bluff) and just east of the northern portion of Five Mile Prairie, the flood sands and gravels are over 200 feet thick (Boese and Buchanan, 1996). Within the central portion of the Deer Park Basin, the flood sands and gravels also reach thicknesses of 200 feet. The static groundwater level is often less than 25 feet below ground surface and subject to seasonal fluctuations on the order of 5 feet.

Within WRIA 57 and WRIA 55 south of the Little Spokane River, the flood sands and gravels form the Spokane Valley portion of the SVRP Aquifer. As illustrated on Figure 4.15, the thickness of the flood sands and gravels is greatest (300 to over 700 feet thick) just east of downtown Spokane, within the Hillyard area and within the central portions of the Spokane Valley. The flood sands and gravels thin to a few feet in thickness on the valley sides.

5.2.2.2 Basalt Aquifers

Groundwater flow in the basalts occurs mainly within fractured flow top and flow bottom zones that generally run parallel to the basalt surface. To a lesser extent, groundwater in the basalts flows within vertical fractures and joints. Where the basalts overlie low permeability sediments (such as crystalline basement, Latah or glacial lake silts and clays) groundwater tends to flow along the slope of the contact, either emerging at the surface as springs or recharging downgradient units. These aquifers are recharged by infiltration of precipitation and irrigation in areas where the basalts are exposed at surface, by stream discharge and from underlying and overlying hydrostratigraphic units. Groundwater elevation contours in the north Spokane area indicate that the basalts in this area discharge mainly to surface streams with some leakage to lower units (Boese and Buchanan, 1996).

The basalt aquifers are important locally within WRIA 55 as a source of water for domestic, agricultural and industrial uses. To the west of the Little Spokane River, the aquifer comprises confined and unconfined flows of Grande Ronde Basalt. In the Deer Park Basin of WRIA 55, the Grande Ronde Basalt underlies a large portion of the flood sand and gravel units. Basalt well yields range from very low to sufficient volumes for domestic and stock watering needs and may be artesian. The City of Deer Park well DP-5 yields up to 350 gpm.

To the east of the Little Spokane River, less productive basalt aquifers occur within the Wanapum Basalt of Orchard Bluff (located between Deer Creek to the north and Little Deep Creek to the south), Green Bluff (located between Little Deep Creek to the north and Deadman Creek to the south) and Orchard Prairie (located south of Deadman Creek). Declining water levels in wells led Ecology to complete a hydrogeologic study of Green Bluff (Ader, 1996). The study concluded that a combination of groundwater pumping and precipitation trends were responsible for static groundwater level changes.

In contrast, basalt occurs only in limited areas within the south and central portions of WRIA 57, to the north and south of the Spokane River Valley. The ancestral Spokane River and the Missoula floodwaters eroded the flow basalts that once filled the ancestral Spokane River Valley in WRIA 57. Because of the limited extent of basalt deposits and the high productivity of the SVRP Aquifer, the basalts of WRIA 57 do not supply significant amounts of water. However, the basalt deposits in WRIA 57 may supply sufficient water for domestic wells.

5.2.2.3 Latah and Glacial Lake Aquitards

Latah Formation and glacial lake deposits are usually defined as aquitards and are comprised mainly of silt and clay with minor sands and gravels. Because they are generally fine grained, these units are not tapped for water production (EMCON, 1992). Domestic wells that do extract water from the Latah Formation typically have yields of less than 35 gpm (Cline, 1969). Yields to wells tapping the glacial lake deposits vary widely from 5 gpm to as high as 600 gpm (Cline, 1969). The 600 gpm yield was noted by Cline (1969) for a well located to the south of the Deer Park Basin. The Latah and glacial lake deposits are potentially recharged from three sources: 1) direct infiltration of precipitation and surface run-off; 2) groundwater leakage from overlying units; and 3) groundwater recharge from underlying units.

5.2.2.4 Crystalline Basement

Crystalline basement rocks underlie WRIA 55 and WRIA 57. Groundwater is found generally in fractures and weathered zones near the top of the unit. Where exposed at surface, the crystalline basement rocks are recharged by infiltration of precipitation and steam discharge. Where overlain by other units, the overlying units recharge the basement rocks. Groundwater wells within the basement rocks are typically low yields and tend to be of varying quality. Because well yields range from negligible to 35 gpm (Cline, 1969), basement rock wells are used most often for domestic supply and not for agriculture or industry.

5.2.3 Aquifer Delineations

A schematic illustrating the location of the main aquifers within WRIA 55 and WRIA 57 is presented as Figure 5.8. This figure was originally prepared as a component of Spokane County's Water Quality and Water Quantity report (Spokane County, 1996). For this study, the figure was updated to include the Diamond Lake aquifer area. In terms of population served, the three most important aquifers within WRIA 55 and WRIA 57 are the SVRP Aquifer, the Deer Park groundwater basin and the Little Spokane aquifer area. The Green Bluff, Peone Prairie, Orchard Prairie and Five Mile Prairie aquifer areas provide less volumes of water but are nevertheless important locally.

The following paragraphs present a synopsis of reviewed information on these aquifers.

5.2.3.1 The Spokane Valley – Rathdrum Prairie Aquifer

The Spokane Valley – Rathdrum Prairie (SVRP) Aquifer, shown on Figure 5.8 and in more detail on Figure 5.9, covers a total area of about 320 square miles, 200 square miles of which occur within Idaho and 120 square miles of which occur within Washington. Most of the SVRP Aquifer in Washington occurs within WRIA 57 although the northern portion of the aquifer extends into WRIA 55 and the western portion into WRIA 54. The aquifer is one of the most productive in the United States and serves as the primary water source for more than 400,000 people in Idaho and Washington with more than 180 large purveyor wells pumping water from the aquifer (MacInnis and others, 2000). Because it supplies water to more than 80 % of the population living above and in the vicinity of the aquifer, the EPA designated the SVRP Aquifer as a Sole Source Aquifer in 1978.

As illustrated on Figure 5.9, the SVRP Aquifer extends from the western end of Lake Pend Oreille and from the northern arm of Lake Coeur d'Alene in Idaho, westwards and southwards beneath the Rathdrum Prairie and westwards down the Spokane River Valley to the City of Spokane. On the western side of the City of Spokane, the aquifer is split into an eastern and a western area by the Five Mile Prairie basalt plateau. On the eastern side of the plateau, the aquifer extends northwards beneath the Hillyard neighborhood, to the Little Spokane River. To the west of the plateau, the aquifer continues northwards within the Lower Spokane River valley to Nine Mile Dam. At Nine Mile Dam the aquifer narrows to span the 400-foot gap trough in the basement rock. A small amount of flow from the aquifer continues as groundwater down the valley past Nine Mile Dam. Between downtown Spokane and the Lower Spokane Valley, the aquifer to the south of Five Mile Prairie is restricted to a one mile wide, 300-foot deep channel known as the Trinity Trough. The Trinity Trough is illustrated in Figure 4.14H.

The principle sources of recharge to the SVRP Aquifer are:

- Groundwater inflow from Idaho;
- Direct infiltration of precipitation and irrigation water;
- Seepage from lakes along the perimeter of the aquifer (e.g., Hauser Lake, Newman Lake, Liberty Lake);

- Surface waters that originate in the surrounding uplands and flow onto and infiltrate into the aquifer; and,
- Recharge from the Spokane River.

The SVRP Aquifer in WRIA 57 receives a large percentage of its water from surface and subsurface flow from the high ground immediately adjacent to the Aquifer. Land uses and human activities within these aquifer recharge areas have significant impact on the quantity and quality of water in the Aquifer. The total contribution of water to the SVRP Aquifer from these recharge areas around the Aquifer is estimated by modeling to be about 300 cubic feet per second (cfs; MacInnis and others, 2000). In comparison, the amount of water crossing the Washington – Idaho State Line is estimated by modeling to be about 390 cfs (MacInnis and others, 2000).

The SVRP Aquifer occurs within porous and permeable flood deposited sands and gravels that are bounded by low permeability basalt and crystalline basement rocks. As illustrated in Figure 4.15, this unit ranges in thickness from over 700 feet thick within the central portion of the Hillyard Trough to 500 and 600 feet within the Spokane Valley (DNR, 2001; CH2M Hill, 2000). Within the Trinity Trough area, the flood sands and gravels are up to 300 feet in thickness over a trough cross sectional length of about 1 mile. Pump tests completed by CH2M Hill (1998) support a general decrease in aquifer permeability in a downgradient direction, westwards from the state line and northwards through the Hillyard Trough.

The thickness and subsurface characteristics of the SVRP Aquifer have been investigated using a number of different geophysical methods including gravity (Purves, 1969), seismic refraction (Newcomb, 1953; Hart-Crowser, 1994) and seismic reflection (WA State DNR, 1994; CH2M Hill, 1998; CH2M Hill, 2000). Where available, the thickness of the SVRP Aquifer has been confirmed using well log data. Power company grounding wells that extend though unconsolidated sediments to the bedrock have provided important geologic information on the characteristics of the sediments and depth to bedrock.

In the Hillyard Trough area, recent seismic studies and a review of well logs provide evidence to support the presence of a clay/silt aquitard (CH2M Hill, 2000). The trough is estimated to be between 50 feet and 200 feet thick. It is believed to be relatively continuous across the northern portion of the Hillyard Trough to just north of the Little Spokane River and into the western reaches of the Little Spokane River Valley. This aquitard separates the aquifer system into an upper unconfined portion of the SVRP Aquifer and a lower confined sands and gravel aquifer that is 50 to 150 feet thick (Figures 4.14F and 4.14G). A stratified silt, clay and fine sand layer has also been observed between upper and lower sand and gravel units in the vicinity of the Colbert Landfill (Landau Associates, 1991). The consistent elevation of the silt/clay aquitard unit supports its deposition within a glacial lake environment (CH2M Hill, 2000).

Because the clay/silt confining unit (that divides the Hillyard Trough arm of the SVRP Aquifer into upper and lower units) pinches out to the south, the lower unit below the confining layer receives most of its recharge from the SVRP Aquifer. Confirmation of the presence of the lower sand and gravel aquifer in this vicinity may have important implications for water rights decisions and for the development of this groundwater resource in the future. At present however, the water quality, hydraulic properties and hydraulic connection of this lower aquifer with the Little Spokane River are not well understood (CH2M Hill, 2000). During pump tests at wells near the Colbert Landfill (Landau Associates, 1991) no response in the upper sands and gravels was observed during pumping from the lower sands and gravels, indicating that the glacial lake sediments act as a vertical hydraulic barrier between the upper and lower sand and gravel units in this area.

The majority of the SVRP Aquifer is unconfined. Groundwater generally flows within the aquifer in an east to west direction, from Idaho and into Washington, discharging into the Little Spokane River and Long Lake (Figure 5.9). At the Idaho – Washington state line, the groundwater table elevation (USGS datum) is about 1,980 feet above mean sea level (amsl). At the discharge of the SVRP Aquifer along the Little Spokane River, located about twenty miles downgradient of the state line, the water elevation is about 1,600 feet amsl. Based on groundwater monitoring completed by CH2M Hill in September 1994, the approximate hydraulic gradient (the slope of the water table surface) within the central portion of the Spokane Valley is 0.002. The approximate hydraulic gradient within the southern portion of the Hillyard Trough is 0.004. The approximate hydraulic gradient within the northern portion of the Hillyard Trough is 0.01. The approximate hydraulic gradient across the Trinity Trough is 0.04.

Within the SVRP Aquifer, the static groundwater level ranges from over 200 feet below ground surface in the Hillyard Trough, to about 150 feet below ground surface at the Washington-Idaho State line, to 40 feet at the eastern Spokane City limits (Spokane County, 1996), to within 20 feet of ground surface in areas within City of Spokane and close to the Spokane River. The depth to groundwater (based on well log data) is illustrated on the geologic cross-sections Figures 4.14G through and including 4.14N. Seasonal changes in the static groundwater level may be minimal in some areas and may reach up to 15 feet or more in other areas. The greater changes in groundwater levels are noted within the western portion of the valley and in the vicinity of the Spokane River.

5.2.3.2 Deer Park Groundwater Basin

As illustrated on Figure 5.8, the Deer Park Groundwater Basin is located within the central and eastern portion of WRIA 55. This groundwater basin comprises two aquifers: 1) a shallow aquifer within the unconsolidated sediments; and, 2) a deeper aquifer system contained within the basalts, Latah sediments and crystalline basement rocks (EMCON, 1992). Geologic cross-sections illustrating the basin are presented as Figures 4.14A, 4.14B and 4.14D.

The thickness of the unconsolidated sediments within the Deer Park Basin (illustrated on Figure 4.15) ranges from less than 50 feet at the margins of the basin to over 200 feet just east of the City of Deer Park. In general, groundwater in the unconsolidated sediments flows from the northwest to the southeast across the basin, discharging into the Little Spokane River to the east and Dragoon Creek to the south. The static water level is shallow (often within 10 feet of surface) and is subject to seasonal fluctuations (EMCON, 1992). Groundwater elevations range from 2,320 feet amsl in the northern portion of the basin to 2,000 feet amsl in the vicinity of Dragoon Creek.

Groundwater within the deeper aquifer system generally flows from the northwest to the southeast from a groundwater elevation of about 2,040 feet amsl to about 1,200 feet amsl in the vicinity of Dragoon Creek (EMCON, 1992).

5.2.3.3 Little Spokane River Aquifer Area

The Little Spokane River Aquifer Area is located within WRIA 55 and covers the area south and east of the Deer Park Groundwater Basin and north of the Little Spokane River and the Spokane Valley Aquifer (Figure 5.8). The aquifer materials are comprised of unconsolidated sediments that range locally up to 400 feet. The most productive units are the flood sands and gravels that range in thickness from 50 feet to 200 feet. In localized areas (e.g., in the vicinity of the confluence of Little Deep and Deadman Creeks with the Little Spokane River, and south to Wandermere Lake) the sand and gravel unit is divided into an upper and lower aquifer by a silt and clay aquitard (Figures 4.14F and 4.14G). Although very limited information is available on groundwater flow elevations and directions, it is likely that groundwater within this aquifer area flows in a southerly direction, discharging to major streams such as Dartford Creek, Deadman Creek and the Little Spokane River. The vicinity of the former Colbert Landfill is the most studied portion of the area and demonstrates the complexity of the aquifers in the Little Spokane area (Landau Associates, 1991). Sand and gravel layers separated by a discontinuous silt and clay aquitard underlie it. The water in the upper unit flows in a southeastern direction while groundwater in the lower unit is divided by lobe of Latah sediments so some flows north and the rest flows south.

A focused assessment of the Pine River Park and lower Dartford Creek areas (in the southern portion of the Little Spokane River Aquifer Area) was completed by CH2M Hill (2000) in support of the Spokane Aquifer Joint Board’s (SAJB) wellhead protection plan. Groundwater levels from five Whitworth Water District #2 wells (Rivilla, #8A1, #8A2, #8B and the Shady Slope well) and one Spokane County Water District #3 well (Pine River Park) were measured along with water levels in the Little Spokane River to estimate the localized groundwater flow pattern. This assessment indicated that the Whitworth Water District #2 wells (#8A1, #8A2, #8B) and the Spokane County Water District #3 (Pine River Park well) draw groundwater from a sand and gravel unit that is overlain by 100 feet or more of silt and clay. The groundwater system in this area of the Little Spokane River Aquifer area is believed to have limited hydraulic connection with the aquifer units within the northern portion of the Hillyard Trough. This conclusion is based on apparent differences in hydraulic head, basement rock highs and comparison of stratigraphic relationships between the aquifer units (CH2M Hill, 2000).

5.2.3.4 The Diamond Lake Aquifer Area

The Diamond Lake aquifer area, located within Pend Oreille County, in the northeastern portion of WRIA 55 has not been defined prior to this study (Figure 5.8). The aquifer area comprises sedimentary deposits (primarily flood deposited sands and gravels) located in the vicinity of Diamond Lake and includes the sediments of the Diamond Lake basin and the Scotia Valley (Figure 4.12). This aquifer area borders the Newport / West Bonner aquifer described in the City of Newport / West Bonner Water District No. 1 Phase I wellhead protection plan (Welch, Comer and Associates, Inc. and Riley, 1994). The western boundary of the Newport / West Bonner aquifer is inferred to run in a southerly direction just west of Newport. However, the Scotia Valley channel, which represents a Pleistocene flood channel, extends in a southwesterly direction from Newport. Because this channel is infilled with unconsolidated alluvial and flood sediments, it may connect the Diamond Lake aquifer area and the Newport / West Bonner aquifer. This groundwater connection has not been confirmed by investigations to date.

Although no information was available on the thickness of the sediments within this area, it is likely that the sediments range between a few feet thick at the aquifer margins to 100 feet thick or more in the central Diamond Lake basin and Scotia Valley. The aquifer area is bounded by crystalline basement bedrock exposures to the south, west and north (Figure 4.12). The unconsolidated deposits of the aquifer extend east toward Lake Pend Oreille, the elevation of which is controlled by the Albeni Falls Dam at about 2,060 ft amsl (immediately upstream of the SR 2 crossing of the Pend Oreille River; Figure 5.3). It is possible that groundwater flows from the Pend Oreille River watershed (WRIA 62) into WRIA 55 in a southwesterly direction through the sediments of the Diamond Lake basin and the Scotia Valley. However, this has not been confirmed by hydrogeological studies.

5.2.3.5 Green Bluff Aquifer Area

Information on the Green Bluff aquifer area is based primarily on an Ecology report describing the hydrogeology of the Green Bluff Plateau (Ader, 1996). The hydrogeologic study was initiated following a report of water level declines. Green Bluff is a four square mile topographic high located in WRIA 55, within the northeastern extent of the Columbia River Plateau, 15 miles north of Spokane (Figure 5.8). Green Bluff rises 400 to 500 feet above the surrounding lowlands and is partially bisected by an unnamed stream that flows into Deadman Creek. The geology is comprised of up to 15 feet of loess overlying up to 50 feet of basalt, which in turn overlies up to 200 feet of Latah sediments (Figure 4.14E; Ader, 1996). The Green Bluff Aquifer occurs within the basalts and is unconfined.

Ader (1996) estimated that 918 AF/yr of precipitation recharges the Green Bluff Aquifer. Groundwater flows downward within the basalts and towards the unnamed creek. Because the sediments below the basalts have a relatively low permeability, about 798 acre-feet of the 918 acre-feet per year of the water that recharges the aquifer, discharges to the stream. Approximately 120 AF/yr of the 918 AF/yr of recharge is estimated to leak down into the deeper Latah sediments (Ader, 1996). Following the 1988 Deadman Creek surface water rights adjudication, 148 acre-feet per year of water from the unnamed tributary were allocated.

5.2.3.6 Orchard Prairie Aquifer Area

Orchard Prairie (located partially in WRIA 55 and partially in WRIA 57) has similar hydrogeologic characteristics to that of Green Bluff. The stratigraphy comprises loess, overlying basalt, which in turn overlies Latah sediments and crystalline basement. This aquifer area has limited groundwater resources (Spokane County, 1996) and recharge, similar to Green Bluff, occurs primarily via precipitation.

5.2.3.7 Five Mile Prairie Aquifer Area

Information on the Five Mile Prairie aquifer area is based primarily on an Ecology report evaluating the ground water resources of Five Mile Prairie (Olson, 1979). Five Mile Prairie is a four square mile topographic high located partially in WRIAs 55, 56 and 57 (Figure 5.8). Five Mile Prairie rises 375 to 400 feet above the surrounding lowlands and is an erosional remnant of the Missoula Floods. From the ground surface downwards, the geology is comprised of: 1) up to 15 feet of loess; 2) up to 50 feet of Wanapum Basalt; 3) up to 150 feet of Latah sediments; and, 4) up to 250 feet of Grande Ronde Basalt (Figure 4.14H). Groundwater occurs primarily as unconfined and confined aquifers within the basalt flows. Based on well log data, well specific capacities ranged on average between 0.5 to 1.0 gpm per foot of drawdown (gpm/ft). Transmissivity was estimated to range between 1,000 to 2,000 gallons per day per foot (gpd/ft). Storage was estimated at 0.0025. The study concluded that groundwater recharge over Five Mile Prairie was approximately equivalent to withdrawals (wells and spring flows).

5.2.3.8 Peone Prairie Aquifer Area

The stratigraphy of Peone Prairie (located within WRIA 55) comprises up to 300 feet of sediment, including flood deposited sands overlying glacial and pre-glacial lake sediments, which in turn overlie crystalline basement rocks. This aquifer area has limited groundwater resources (Spokane County, 1996) and recharge, similar to Green Bluff, occurs primarily via infiltration of precipitation. Peone Prairie discharges to Deadman Creek, which is closed to consumptive appropriations June 1 through October 31 each year.

5.2.4 Conceptual Hydrogeology

This section of the report presents conceptual models that simplify the hydrogeology of WRIA 55 and WRIA 57. The conceptual models are based on review of existing information and are presented as schematics in Figures 5.10a and 5.10b. These schematics illustrate the hydrogeology of typical sections within WRIA 55 and WRIA 57, respectively. Simplification of the hydrogeology is necessary to aid construction of a groundwater flow model for the WRIAs.

As illustrated on Figures 5.10a and 5.10b, groundwater occurs primarily within the units overlying the crystalline basement. Surficial groundwater within the fine-grained Latah and glacial sediments flows slowly downwards to the basalt contact. The groundwater may flow along the sediment-basalt contact and appear at the ground surface as a spring. Similarly, groundwater that flows downwards into the basalts travels along vertical and lateral fracture surfaces and may exit the exposed face of the basalt as a spring. Mass wasting deposits occur on the relatively steep valley sides and are often lubricated by groundwater that flows along the lower contact between the in-situ unit and the slide deposits. Groundwater within the crystalline basement occurs mainly in the upper weathered zone and within major fractures.

The upper unconfined sand and gravel aquifer within WRIA 55 (Figure 5.10a) occurs mainly adjacent to river channels, above finer grained fluvial and lake deposits. Groundwater within this upper aquifer flows rapidly along the groundwater flow gradient to recharge the river. If the contact between the sands and gravels and the finer grained fluvial and lake deposits is above the river level, a spring may form. Groundwater within the finer grained fluvial and lake deposit flows relatively slowly downwards from higher elevations and may ultimately recharge the river. Groundwater will preferentially flow in the sand and gravel layers that occur within the finer grained sediments. Except where they are in direct contact with stream channels, these lower, discontinuous sands and gravel lenses represent small, confined aquifers. However, because the occurrence of these sand and gravel lenses is difficult to predict, these units are not deliberately targeted for water supply.

The upper unconfined sand and gravel aquifer within WRIA 57 (Figure 5.10b) dominates the groundwater flow system. Over the areas where the level of the Spokane River is higher than that of the aquifer, the river recharges the aquifer. The rate at which the surface water recharge to groundwater takes place is controlled primarily by the thickness and permeability of the finer grained sediments that line the riverbed. In areas where the level of the Spokane River is lower than that of the aquifer, the aquifer discharges to the river, often as springs along the river bank or seeps within the river bed. Though water flows between the river and aquifer near the river, the majority of the aquifer flows under the river, perpendicular to the section (i.e., out of the page in Figure 5.10b), along the regional groundwater flow gradient that runs east-west down the valley.

5.2.5 Hydraulic Properties

An understanding of the hydraulic properties of hydrogeologic units is needed to assign the most appropriate values for these properties to the hydrogeologic units within the study area. These properties may be used to simulate the behavior of these hydrogeologic units within a conceptual or numeric groundwater flow model.

Based on the information reviewed, a compilation of aquifer property information is presented on Table 5.5 and Table 5.6. A brief description of the aquifer properties compiled is included as Appendix D1. The original data sources range from local to regional scale studies. A summary of the transmissivity and hydraulic conductivity ranges for local hydrogeologic units is provided below.

Summary of Transmissivity and Hydraulic Conductivity Data

Hydrogeologic Unit	**Aquifer Area**	**Transmissivity** (feet^2/day)	**Hydraulic Conductivity** (feet/day)
Flood Sand & Gravel	SVRP	4,320 – 11,000,000	500 – 12,000
Flood Sand & Gravel	Little Spokane River	10,000 – 518,400	530 - > 640
Flood Sand & Gravel	Deer Park	722 – 267,400	16 – 6,077
Lower Flood Sand & Gravel	Little Spokane River	10,000 – 40,000	100 - 230
Basalt	West Plains, Little Spokane River, Five Mile Prairie, Deer Park	25 - 193	0.18 – 12.1
Basement	North End of Five Mile Prairie		1 - 86

The large ranges in transmissivity and hydraulic conductivity are due to the large variations in grain size within the aquifers. The larger and more homogeneous the grain size, the larger the transmissivity and hydraulic conductivity. Within the SVRP Aquifer, grain sizes tend to be largest in the east and smallest to the northwest.

Vertical anisotropy is the ratio of the horizontal hydraulic conductivity to the vertical hydraulic conductivity (Appendix D1). Direct measurements have not been made for the Spokane Valley Aquifer. Previous studies on the SVRP Aquifer (Bolke and Vaccaro; 1981; CH2M Hill, 1998) have assumed that the ratio is between 3:1 and 10:1. Bolke and Vaccaro (1981) assumed that for the SVRP Aquifer the horizontal hydraulic conductivity is approximately equal to the vertical hydraulic conductivity because vertical stratification is absent throughout most of the aquifer. CH2M Hill (1998) assumed a vertical anisotropy of 10:1 to provide conservative wellhead capture zone delineations. Lower vertical anisotropy values would tend to produce smaller and deeper wellhead capture zones.

5.2.6 Groundwater Monitoring

Information on groundwater monitoring was compiled and reviewed to determine the coverage of groundwater elevation data for WRIA 55 and WRIA 57. Groundwater elevation data is required to define groundwater flow directions (because groundwater flows from a high groundwater elevation, or hydraulic head, towards a lower groundwater elevation). In addition, groundwater elevation data is needed to calibrate groundwater flow models both spatially and over time (e.g., seasonally). Two types of data were compiled:

- Groundwater elevations from numerous wells measured over a snapshot in time; and,

- Groundwater elevations monitored at single well locations over a continuous time period.

The compilation of groundwater monitoring points is summarized on Figure 5.11. The snapshot data is presented on Tables 5.7 through 5.11. The continuous water level data is summarized on Table 5.12. A brief summary of the data is provided in the two sections below.

5.2.6.1 Snapshot Groundwater Data

Discrete water level monitoring events are performed to provide a "snapshot" of groundwater elevations within an aquifer. The snapshot data reviewed for this study is summarized in the table below. The data is included as Tables 5.7 through and including 5.11. Additional data and available contour maps from the original reports are included within Appendix D2. A brief summary of the data by source is provided in the bullets below.

- EMCON (1992) – groundwater level data collected at 36 wells between September 1991 and April 1992 for the hydrogeologic characterization of the Deer Park Basin (Table 5.7).
- Boese & Buchanan (1996) – groundwater level data collected at 36 wells between April 23 and June 4, 1996 in support of the aquifer delineation and baseline groundwater monitoring investigation of a portion of north Spokane County (Table 5.8).
- CH2M Hill (1998) – groundwater level data collected at 119 wells between September 12 and 16, 1994 and at 114 wells between April 10 and 14, 1995. The data was collected to calibrate the Spokane Aquifer groundwater flow model that was created to delineate well capture zones for the City of Spokane wellhead protection program (Table 5.9).
- CH2M Hill (2000) – additional groundwater level data was collected on October 30, 1996 within approximately fives miles of the state line, both in Washington and Idaho. This information was used to refine the 1998 groundwater flow model to allow delineation of the Spokane Aquifer Joint Board (SAJB) wells (Table 5.10).
- USGS (2000) – groundwater level data collected at about 140 wells in March and August 2000 in support of the on-going USGS NAQWA study on the hydraulic continuity between the Spokane Aquifer and the Spokane River. This groundwater level data was collected to provide indications of groundwater level elevations and flow directions during river high and low flow periods (Table 5.11).

Summary of Snapshot Groundwater Elevation Data

Data Source	Monitoring Periods	Aquifers
EMCON, 1992	September 1991 – April 1992	52 wells – West and central LSRA (basalt, sands and gravels, crystalline basement)
Boese & Buchanan, 1996	April – June, 1996	36 wells – Northern SVRP, south and central LSRA (basalt, lower and upper sands and gravels, crystalline basement)
CH2M Hill, 1998	September 12-16, 1994 April 10 – 14, 1995	119 wells – SVRP and 31 sites LSR & MSR 114 wells – SVRP and 31 sites LSR & MSR
CH2M Hill, 2000	October 30, 1996	35 wells – Eastern SVRP
USGS, 2000	March – August, 2000	140 wells – Central and eastern SVRP

SVRP – Spokane Valley Rathdrum Prairie Aquifer
LSRA – Little Spokane Aquifer Area
LSR – Little Spokane River
MSR – Middle Spokane River

The bullets below summarize the important observations made based on a brief review of the snapshot groundwater elevation data.

- Groundwater within the Deer Park Basin unconsolidated (shallow) aquifer flows generally in a southerly direction, discharging to Dragoon Creek, with a component of flow in an easterly direction towards Eloika Lake (EMCON, 1992).
- Groundwater within the Deer Park Basin basalt and basement (deep) aquifer flows generally in a southerly direction with a component of discharge to Dragoon Creek (EMCON, 1992).
- Groundwater from the Deer Park Basin shallow aquifer recharges the deep aquifer (EMCON, 1992).
- Groundwater within the Spokane Aquifer flows in a westerly direction within the Spokane Valley and through the Trinity Trough and in a northerly direction within the Hillyard Trough (CH2M Hill, 1998; CH2M Hill, 2000).
- The hydraulic gradient of groundwater flow with the Spokane Aquifer increases along the flow path. Based on groundwater monitoring completed by CH2M Hill in September 1994, the approximate hydraulic gradient (the slope of the water table surface) within the eastern and central portions of the Spokane Valley is 0.002. The approximate hydraulic gradient within the southern portion of the Hillyard Trough is 0.004. The approximate hydraulic gradient within the northern portion of the Hillyard Trough is 0.01. The approximate hydraulic gradient across the Trinity Trough is 0.04.

- Based on comparison of September 1994 and April 1995 data, groundwater levels in the Spokane Aquifer fluctuate between less than 5 feet to 15 feet seasonally. The highest seasonal fluctuations (greater than 10 feet) were noted within the central and eastern portions of the Spokane Valley and the Trinity Trough. The lowest fluctuations (less than 5 feet) were noted within the northern part of the Hillyard Trough (CH2M Hill, 1998).

5.2.6.2 Groundwater Hydrograph Data

Continuous monitoring information includes data for sixty-five wells provided by Spokane County staff. As indicated in the summary table below, the City of Spokane, Vera Water and Power, Whitworth Water District, Spokane Water District #3, Ecology, USGS and Spokane County collected the original data. A listing of the wells, data periods of records and aquifers is presented as Table 5.12. Hydrographs of the data are included within Appendix D2.

Summary of Hydrograph Groundwater Elevation Data

Original Data Source	Monitoring Points	Monitoring Periods	Aquifer
Spokane County	16 monitoring wells	1998 – 2001	Western, central and eastern SVRP
Vera Water and Power	8 water supply wells	January 1967 – December 2000	Central SVRP
City of Spokane	9 monitoring wells	November 1994 – January 2001	Western SVRP
USGS	18 monitoring wells 1 monitoring well	June, 2000 – March, 2001 1929 – 2001	Central and eastern SVRP Central SVRP
Whitworth Water District	8 water supply wells	1955 – 2001	Northwestern SVRP and southern LSRA
Ecology	4 monitoring wells	1978 – 2000	Northwestern SVRP and central LSRA
Spokane Water District #3	1 monitoring well	February 1998 – September, 1998	Central LSRA

SVRP – Spokane Valley – Rathdrum Prairie Aquifer

LSRA – Little Spokane River Aquifer area

All hydrograph data provided by Spokane County Staff

Based on an overview of the hydrographs (included as Figures D2-1 though D2-54 in Appendix D2), the bullets below summarize the important observations. A more detailed description of the data follows these points and is organized according to the source of the data.

- Groundwater levels in the SVRP Aquifer change in response to yearly and seasonal changes in recharge and discharge of the aquifer.
- Groundwater level changes in the SVRP Aquifer correspond to changes in the flow (and stage) of the Spokane River, indicating that the river and the aquifer are hydraulically connected.
- There has been no net groundwater level change in the Spokane Valley Aquifer over a long period of record (as indicated by the 1967 to 2001 period of record for the Vera Water and Power wells and the USGS Inland Empire Paper Well).
- The seasonal changes in groundwater elevations of the Spokane Valley aquifer are generally higher in the western and central part of the aquifer. The magnitude of the seasonal groundwater level changes decrease with: 1) increasing distance from the Spokane River; and, 2) increasing thickness of the unsaturated zone.
- Water level changes in the Hillyard Trough do not respond as closely to discharge in the Spokane River due to the greater distance from the river and due the decrease in the hydraulic conductivity of the aquifer materials in a northerly direction through the Hillyard Trough.
- There is good groundwater elevation data coverage for the Spokane Aquifer within both WRIA 55 and 57 and very sparse data coverage (3 wells) for the aquifer areas (other than the Spokane Aquifer) within WRIA 55.

5.2.6.2.1 Spokane County Hydrograph Data

The data collected by Spokane County comprises the Spokane Valley Aquifer Monitoring network. Since the spring of 1977, Spokane County has been tracking the quality of the Spokane Valley portion of the SVRP Aquifer by sampling a network of public water supply wells (Spokane County, 1998). During the first year of monitoring, the wells were monitored on a monthly basis (Esvelt, 1978). Between the fall of 1978 and the summer of 1983, monitoring occurred generally on a quarterly basis with a number of breaks in the data record. Since the fall of 1983, the network has been monitored consistently on a quarterly basis.

The data provided by Spokane County includes wells located within two miles of the Spokane River from the Mission Street Bridge within the City of Spokane eastwards to Idaho Road (0.25 miles west of the Washington-Idaho state line). The data covers periods from October 1998 through September 2000 and includes: 1) wells monitored by transducers as a part of the regular aquifer monitoring program; and, 2) wells monitored weekly (Gearhart and Buchanan, 2000) in support of a study on the hydraulic connection between the Spokane River and the Aquifer. All of the wells are completed within the flood sands and gravels of the Spokane Valley Aquifer.

The Spokane County aquifer monitoring program data is included as hydrographs on Figure D2-1 through Figure D2-10 in Appendix D2. The information comprises average daily groundwater elevations for the wells listed below and is plotted along with flow in the Spokane River near Post Falls.

Summary of Spokane County Hydrograph Data

Well ID	Well Name	Period of Record	Figure #, Appendix D2
6525R01	Idaho Road near Pipeline	5/1999 – 9/2000	Figure 1
6631M07	CID 11 / Idaho Road	5/1999 – 9/2000	Figure 2
5507H01	Barker Road North / Barker North	11/1998 – 9/2000	Figure 3
5507A04	Barker & Euclid / CID Barker North	5/1999 – 8/2000	Figure 4
5508M02	Barker & Centennial S / Barker South 1	11/1998 – 9/2000	Figure 5
5508M01	Barker & Centennial N / Barker South 2	11/1998 – 9/2000	Figure 6
5517D05	Barker & Mission / CID Barker South	5/1999 – 9/2000	Figure 7
5411R04	Sullivan South	11/1998 – 9/2000	Figure 8
5411R03	Sullivan Park South / Sullivan North 2	11/1998 – 9/2000	Figure 9
5411R02	Sullivan Park North / Sullivan North 1	11/1998 – 9/2000	Figure 10

Data collected by Christina Gearhart (Gearhart and Buchanan, 2000) is included as Figure D2-11 (Barker Road Wells), Figure D2-12 (Sullivan Road Wells) and Figure D2-13 (Upriver Wells) in Appendix D2. The information comprises weekly manual measurements for the following fourteen wells listed below and is plotted along with flow in the Spokane River near Post Falls.

Summary of Gearhart and Buchanan (2000) Hydrograph Data

Well ID	Well Name	Period of Record	Figure #, Appendix D2
5505D01	Trent at Barker Road	12/1998 – 8/1999	Figure 11
5507A04	CID Barker North	12/1998 – 8/1999	Figure 11
5507H01	Barker North	12/1998 – 8/1999	Figure 11
5508M02	Barker South 1	12/1998 – 8/1999	Figure 11
5508M01	Barker South 2	12/1998 – 8/1999	Figure 11
5517D05	CID Barker South	12/1998 – 8/1999	Figure 11
5412M01	Central Pre-Mix Sullivan	12/1998 – 8/1999	Figure 12
5411R02	Sullivan North 1	12/1998 – 8/1999	Figure 12
5411R03	Sullivan North 2	12/1998 – 8/1999	Figure 12
5411R04	Sullivan South	12/1998 – 8/1999	Figure 12
5311H01	USGS @ Upriver Dam	12/1998 – 8/1999	Figure 13
5311D03	Upriver Greenhouse	12/1998 – 8/1999	Figure 13
5311E03	Avista @ Beacon	12/1998 – 8/1999	Figure 13
5309M04	Avista @ Mission	12/1998 – 8/1999	Figure 13

The following key points are noted based on review of the hydrographs presented as Figures D2-11 through D2-13 in Appendix D2:

- The Idaho Road near Pipeline well (located about 1.2 miles north of the Spokane River) had an 8-foot seasonal water level rise between October 1999 and April 2000. The CID 11 Idaho Road well (located about 0.5 miles north of the Spokane River) had an 8.5-foot seasonal water level rise between October 1999 and April 2000. Both wells had similar hydrograph patterns as that of the Spokane River flow at the gage near Post Falls. The groundwater elevation in the Idaho Road near Pipeline well was about 1.5 feet higher than that in the CID 11 Idaho Road well, indicating groundwater flow southwards towards the Spokane River.
- The Barker Road wells also had similar hydrograph patterns to that of the Spokane River flow at the gage near Post Falls. The wells are located between 1.5 miles north and 0.5 miles south of the Spokane River. All the Barker Road wells had an 11-foot seasonal water level rise between September / October 1999 and April 2000.
- The Sullivan Road wells also had similar hydrograph patterns to that of the Spokane River flow at the gage near Post Falls. The wells are located within 0.25 miles north and south of the Spokane River. The Sullivan Road south well (located on the south bank of the Spokane River) had a 13.5-foot groundwater level rise between September 1999 and April 2000. The Sullivan Road north wells (located on the north bank of the Spokane River) both had a 16-foot groundwater level change between September 1999 and April 2000.
- The Upriver wells show a similar pattern. The USGS at Upriver Dam, Upriver Greenhouse and Avista at Beacon wells showed an 8- to 9-foot groundwater level rise between December 1998 and May 1999. The Avista at Mission well showed a 6.5-foot groundwater level rise between December 1998 and May 1999. Again, the increasing and decreasing groundwater levels occurred in concert with the increasing and decreasing flow in the Spokane River at the gage near Post Falls.

5.2.6.2.2 Vera Water and Power Hydrograph Data

The groundwater water level data collected by Vera Water and Power comprises weekly measurements of static groundwater levels between 1967 and 2001 in eight of the district's water supply wells. The wells are completed in the flood sands and gravels and are located within the central portion of the Spokane Valley, between one and three miles south of the Spokane River. Hydrographs for the wells are included as Figures D2-14 through D2-29 in Appendix D2. Figure D2-14 illustrates the 1967 to 2001 hydrograph for Vera Water and Power Well #1. The hydrograph indicates no long term change in the groundwater elevation at this well and that the seasonal changes correspond very closely to the seasonal changes in the flow of the Spokane River near Post Falls. This relationship is also noted for Vera Water and Power Well #s 2 though 8 for the hydrograph periods 1967 through 2001 (see Figures D2-16 though D2-29 in Appendix D2). This indicates that the below average precipitation period that occurred between 1962 and 1995 based on climatic data recorded at the Spokane International Airport (see Section 4.2.4 and Figure 4.10), did not cause a significant reduction in the groundwater elevations of the Vera wells. This suggests that the primary influence on water levels in the wells is the flow of the Spokane River and not local climatic conditions. Seasonal water levels changes of between 8 to 15 feet were observed.

5.2.6.2.3 City of Spokane Hydrograph Data

The City of Spokane hydrograph information comprises daily average groundwater elevations for nine wells calculated by Spokane County Staff from the original transducer data. The wells are located within the City of Spokane, including the western portion of the Spokane Valley Aquifer, the Hillyard Trough and the Trinity Trough. The City of Spokane wells for which hydrograph data was provided are listed below and are plotted along with Spokane River flows near Post Falls in Figures D2-30 through D2-38 in Appendix D2.

Summary of City of Spokane Hydrograph Data

Well ID	Well Name	Period of Record	Figure #, Appendix D2
5312C01	Felts Field	11/1994 – 1/2001	Figure D30
5314E01	Central Pre-Mix at Yardley	12/1994 – 1/2001	Figure D31
5311J07	Hale's Ales Nested Mid-Well	11/1994 – 11/1999	Figure D32
5322A03	Third & Havana Nested Mid-Well	11/1994 – 11/1999	Figure D33
5308H01	Marietta Monitoring Well	11/1994 – 10/2000	Figure D34
5307M01	Trinity School	3/1995 – 1/2001	Figure D35
5304G01	NE Community Center	11/1995 – 1/2001	Figure D36
5322A03	Franklin Park	1/1996 – 1/2001	Figure D37
5202E01	Wastewater Treatment Plant	1/1995 – 1/2001	Figure D38

The hydrographs indicate that the groundwater elevation changes correspond to changes in the Spokane River flow near Post Falls and that the magnitude of the changes in the wells decreases with increasing distance from the Spokane River. For example, the Felts Field well (located about 0.5 miles south of the Spokane River) shows an 18-foot groundwater level rise between August 1996 and April 1997 whereas the Franklin Park well (located about 2.5 miles north of the Spokane River) shows a 10-foot groundwater level rise between August 1996 and April 1997.

5.2.6.2.4 USGS Hydrograph Data

The USGS hydrograph data includes the Inland Empire Paper Well that has been monitored since 1929 and a series of 18 new wells that were installed in 2000 for the NAQWA hydraulic connection study between the Spokane River and the Aquifer.

The Inland Empire Paper well is located within the eastern portion of the Spokane River Valley, about one mile south of the Spokane River. Hydrographs for this well are included as Figure D2-39 and Figure D2-40 in Appendix D2. The 1929 to 2001 hydrograph (Figure D2-39) indicates the lowest groundwater elevation years in 1929 to 1932 with an overall rise in groundwater elevations between 1932 and 1962, an overall fall in groundwater elevations between 1962 and 1995, and a rise in groundwater elevations from 1995 to 2001. A peak groundwater elevation of 1974 ft amsl is noted in the spring of 1997 and a low of 1941 ft amsl is noted in the winter of 1931.

In comparison to climatic changes (see Section 4.2.4 and Figure 4.10), the Inland Empire Well hydrograph does mirror the low precipitation levels of 1928 to 1932 but does not reflect the 1932 to 1947 period of below average precipitation. However, the well hydrograph does indicate a rise in groundwater elevation between 1945 and 1962, which correlates with the 1947 to 1965 period during which precipitation was above average. In addition, the well hydrograph shows an overall decline in groundwater elevations between 1962 and 1995 when precipitation is noted as below average.

As shown on Figure D2-40, the groundwater elevation within the Inland Empire well is strongly correlated to the Spokane River flow near Post Falls with a lag time on the order of days.

Composite hydrographs for the 18 new USGS wells are presented as Figures D2-41 through D2-46 in Appendix D2. All wells are screened in the flood sand and gravels of the SVRP Aquifer and are located along sections with wells at varying distances north and south of the Spokane River. The locations of the wells are shown on the map included within Appendix D2. The wells indicate varying interchanges between the Spokane River and the Aquifer. Because this data is part of an ongoing USGS study and is in a draft format, no further assessment of the data will be made within this compilation report.

5.2.6.2.5 Whitworth Water District Hydrograph Data

Hydrographs for eight of the Whitworth Water District wells are presented on Figures D2-47 through D2-49 in Appendix D2. Five of the wells are located within the upper sands and gravels of the Spokane Aquifer, in the northern portion of the Hillyard Trough. Three of the wells are located north of the Little Spokane River within sands and gravels that occur below an overlying clay layer. The measurements have been taken randomly, mainly between 1992 and 2001. Because of the low resolution of the data, seasonal and annual trends are not assessed. However, it is noted that the wells located north of the Little Spokane River (see Figure D2-49) show different seasonal groundwater level changes in comparison to the wells located within the northern portion Hillyard Trough. This indicates that portions of the aquifers on opposite sides of the Little Spokane River do not have a high degree of hydraulic continuity in this vicinity, possibly due to the presence of an intervening clay aquitard. However, they are believed to be in hydraulic continuity to the south where the clay layer is absent. These two aquifer areas are both presumed to be recharged by groundwater that originates within the SVRP Aquifer.

5.2.6.2.6 Ecology Hydrograph Data

Spokane County provided long-term groundwater level data for the four Ecology monitoring wells listed below. The hydrographs are included as Figures D2-50 through and including D2-53 in Appendix D2. The groundwater level information for the Dakota Well (Figure D2-51) was obtained from CH2M Hill (2000).

Summary of Ecology Hydrograph Data

Well ID	Well Name	Period of Record	Appendix D2 Figure #
6308F02	Mayfair Well (Whitworth Water District Test Well)	9/1997 – 9/2000	Figure 50
6308B04	Dakota Well (Spokane Water District #3)	5/1998 – 8/1999	Figure 51
8316D01	Chattaroy Observation Well	4/1978 – 3/2000	Figure 52
9233G01	Deer Park Observation Well	4/1978 – 3/2000	Figure 53

The Mayfair and Dakota wells are located in the northern portion of the Hillyard Trough. The Mayfair well is completed in the lower sands and gravels between 452 and 462 feet below ground surface. The Dakota well is completed in the upper sands and gravels to 89 feet below ground surface. The upper and lower sands and gravels of northern Hillyard are separated by up to 100 feet or more of silt and clay (Figure 4.14G). The Mayfair well log notes clay layers from 132 to 317 feet below grade. This silt and clay layer thins and pinches out in a southerly direction until it occurs as only remnant lenses in the central portion of the Hillyard Trough (Figure 4.14I).

Groundwater levels rose three feet in the Mayfair well between September 1998 and May 1999, and about 1.5 feet in the Dakota well over the same time frame (Figures D2-50 and D2-51 in Appendix D2). In addition, the Mayfair well hydrograph (Figure D2-50) shows peaks and troughs that can be correlated to variations in Spokane River flow near Post Falls. These peaks and troughs are not apparent on the Dakota Well hydrograph (Figure D2-51). This suggests limited vertical hydraulic connection between the upper and lowers sands and gravels in the vicinity of the two wells. However, because the clay layer that separated the upper and lower aquifer zones pinches out in an upgradient direction, both aquifer zones are recharged by groundwater flowing northwards with the SVRP Aquifer from the downtown Spokane area and believed to be in lateral hydraulic continuity.

The Chattaroy and Deer Park observation wells are completed within the sands and gravels of the Little Spokane Aquifer area and the Deer Park Basin, respectively. The Chattaroy well indicates an overall groundwater level drop from 1978 to 1994 (from 35.5 feet to 44 feet below the measuring point) followed by a groundwater level rise from 1994 to 2000 (from 44 feet to 35.5 feet below the measuring point; Figure D2-52). The Deer Park well indicates steady and slight rise in the overall groundwater level from 43 feet to 36 feet below the measuring point (Figure D2-53).

5.2.6.2.7 Spokane Water District #3 Hydrograph Data

Twelve groundwater elevation measurements are available from February 1998 to September 1998 for the Spokane Water District #3 Chattaroy Hills well. The well is located just west of the Little Spokane River, within the central portion of the Little Spokane River Aquifer area. Although there is insufficient groundwater elevation data to establish a relationship between the river flow and the groundwater elevations, it is apparent that the groundwater elevations are relatively high during times of the year when the river flows are high (Figure D2-54).

5.2.6.3 Groundwater Level Changes

Groundwater level changes within WRIAs 55 and 57 occur over three different time scales:

- Over the short term in areas where the groundwater is in direct hydraulic continuity with surface water. Direct hydraulic continuity between surface water and groundwater is indicated by short-term fluctuations in groundwater levels that can be correlated to short-term changes in river stage and flow with a lag time varying between hours and days. Short term groundwater level changes are illustrated by the Barker Road North Well hydrograph and the Mayfair Well hydrograph (Figures 5.12 and 5.13);

- Over the water year due to seasonal changes in groundwater recharge. Seasonal groundwater level fluctuations are illustrated by the Dakota Well hydrograph (Figure 5.14); and,

- Over long term wet and dry cycles associated with the impact of the Pacific Decal Oscillations on the climate of the Pacific Northwest (Section 4.2). Decadal groundwater level changes are illustrated by the Chattaroy Observation Well hydrograph (Figure 5.15).

The locations of the Barker Road North, Mayfair, Dakota and Chattaroy Observation Wells are indicated on Figure 5.11

Short-term changes in groundwater levels associated with river flows (and stage) are observed in all the wells completed within the SVRP Aquifer in the vicinity of the Spokane River. The Barker Road North Well hydrograph (Figure 5.12) illustrates this relationship for a well located just north of the Spokane River, along Barker Road in WRIA 57 (Figure 5.11). This is one of the wells monitored regularly as a part of Spokane County's WQMP and was also monitored by Gearhart and Buchanan (2000) for the recent study on the hydraulic connectivity between the Spokane River and the SVRP Aquifer. The groundwater level in the well rises rapidly with increasing Spokane River flow rates (Figure 5.12). The lag time to the groundwater level change that follows the increase in river flow rate is less than one day. Spokane County staff has observed this effect for many of the wells completed within the SVRP Aquifer in the vicinity of the Spokane River.

The Mayfair Well is located about six miles north of the Spokane River and is completed between 452 to 462 feet below ground surface within the lower sands and gravels of the

Hillyard Trough in WRIA 55 (Figure 5.11). The Mayfair Well hydrograph illustrates short-term, muted groundwater level changes associated with hydraulic continuity between the lower portion of the SVRP Aquifer and the Spokane River (Figure 5.13). Although the short-term peaks associated with short-term river flow events do not cause groundwater peaks that are as well defined as those for wells located adjacent to the river (such as the Barker Road wells), a muted response is observed. This indicates that the Spokane River influences the groundwater levels within the lower sands and gravels of the Hillyard Trough at a distance of at least six miles from the river.

The Dakota Well is also located about six miles north of the Spokane River, in the Hillyard Trough area of WRIA 55 (Figure 5.11). However, this well is completed to a depth of 89 feet below ground surface within the upper sand and gravel unit (that is separated from the lower sand and gravel unit by about 200 feet of low permeability clay and silt layers). The groundwater level changes within the Dakota Well illustrate a typical seasonal pattern of high groundwater levels in the spring and early summer, declining levels over the summer to late summer, and rising levels through the winter months (Figure 5.14). These groundwater level variations are related to annual (i.e., seasonal) precipitation changes. In contrast to the lower aquifer zone, the short-term changes in Spokane River flows are not transmitted through the upper aquifer zone (Figure 5.13). Although there is hydraulic separation in the Dakota and Mayfair wells area between the upper and lower sand and gravel units, they are believed to be in hydraulic continuity to the south where the confining clay aquitard pinches out.

Pacific Decadal Oscillations (PDO) are caused by Pacific Ocean influences on the climate of the Pacific Northwest. PDO also has an impact on groundwater levels over a timeframe of decades. The groundwater level changes are caused by changes in groundwater recharge rates during the dry and wet PDO periods. The hydrograph for the Chattaroy Observation Well (Figure 5.15), located within the eastern portion of the Deer Park basin in WRIA 55 (Figure 5.11) illustrates the PDO effect. 1974 to 1994 is characterized as a dry PDO. Groundwater levels in the Chattaroy well show a declining trend during this time period (Figure 5.15). In contrast, the years following 1994 have been characterized by a wet PDO. As illustrated in Figure 5.15, the groundwater levels in the Chattaroy well have risen between 1994 and 2000.

5.2.7 Groundwater Flow Modeling

Groundwater flow modeling within the study area has been limited to the SVRP Aquifer. The driving force behind these models is the need to predict groundwater flow directions and the amounts of groundwater that flow within the aquifer. These models have been developed primarily in support of land development (i.e., groundwater supply), to designate protection areas over aquifer zones that provide water to large water supply wells (i.e., groundwater quality protection), and for academic research purposes.

Groundwater flow models simulate the processes of groundwater flow. Groundwater flow models can be created at different levels of complexity. An analytical equation, such as a water balance calculation, is a relatively simple type of groundwater flow model that aims to estimate the amount of water that passes a certain point or cross section.

Computer code that mathematically represents the aquifer and solves groundwater flow and contaminant transport equations is a more complex type of groundwater flow model. Due to the large number of input variables and the need to predict "what if" scenarios across the Spokane Aquifer, groundwater flow modeling of the aquifer has progressed over time from relatively simple models to complex computer models.

A sequential list and brief description of the SVRP Aquifer groundwater flow models that have been created are provided in the summary table below. Detailed descriptions of the models are provided in Appendix D3.

Summary of Spokane Valley Rathdrum Prairie Groundwater Flow Modeling

Author	Date	Model Type
Pluhowski and Thomas, USGS	1968	Water balance spreadsheet
Drost and Seitz, USGS	1978	Water balance spreadsheet
Bolke and Vaccaro, USGS	1981	2D, finite element groundwater flow model
Painter, IDEQ	1991	Water balance spreadsheet
Buchanan and Olness, Eastern Washington University	1994	3D, finite difference, MODFLOW groundwater flow model
CH2M Hill (for City of Spokane wellhead protection)	1998	3D, finite element, MICRO FEM groundwater flow model
Buchanan	2000	3D, finite difference, MODFLOW groundwater flow model
CH2M Hill (for SAJB wellhead protection)	2000	3D, finite element, MICRO FEM groundwater flow model

5.2.7.1 Groundwater Inflow at the Eastern Model Boundary

An important component of the water balance for WRIA 57 will be to provide an estimate of the quantity of groundwater that flows into WRIA 57 across the eastern (i.e., the upgradient) boundary of the WRIA. The table below provides a summary of the groundwater inflows at the eastern boundary for the SVRP Aquifer modeling efforts completed to date.

Summary of Groundwater Inflow at Eastern Model Boundary

Source	**Approx. Location of Eastern Model Boundary**	**Estimated Groundwater Flow Across Eastern Model Boundary** (cfs)
Pluhowski and Thomas (1968)	3 miles west of WA-ID state line	950
Drost and Seitz (1978)	WA-ID state line	800
Bolke and Vaccaro (1981)	WA-ID state line	396[1]
Bolke and Vaccaro (1981)	3.5 miles east of WA-ID state line	453[2]
Painter (1991)	WA-ID state line	753
Buchanan and Olness (1994)	WA-ID state line	320
CH2M Hill (1998)	WA-ID state line	380
Buchanan (2000)	WA-ID state line	390
CH2M Hill (2000)	WA-ID state line	400

Note: 1. Calculated by subtracting north and south groundwater inflow from the total groundwater inflow to the model with WA-ID line as the eastern model boundary (i.e., 668 – 145 (north) – 127 (south).

2. Calculated by subtracting north and south groundwater inflow from the total groundwater inflow to the model with Post Falls Dam as the eastern model boundary (i.e., 668 – 108 (north) – 107 (south).

As illustrated in the summary table above, recent studies, which are likely to be more accurate because of additional data, indicate that the groundwater flow across the Washington-Idaho state line is approximately 400 cfs.

5.2.7.2 Groundwater Flow Through the Trinity Trough

As illustrated on Figure 5.9, groundwater within the SVRP Aquifer flows in a westerly direction towards the City of Spokane. From about Division Street westwards in downtown Spokane, the Spokane River flows over a basalt outcrop. The basalt diverts most groundwater flow in a northerly direction, towards Hillyard. However, a proportion of the groundwater within the Spokane Valley aquifer flows in a westerly direction through the Trinity Trough. Based on groundwater flow modeling results, Buchanan (2000) and CH2M Hill (1998) estimated that approximately 10 cfs of groundwater flows through the Trinity Trough into WRIA 54.

Using the geologic cross section that runs perpendicular to the Trinity Trough (presented as Figure 4.14H), an estimate of the annual average groundwater flux through the Trough can be made based on an appropriate range of values for aquifer parameters. The range in estimated values is shown in parentheses and are based on the compilation of existing hydraulic property data for the western portion of the SVRP Aquifer presented on Table 5.6. The hydraulic gradient of groundwater flow across the Trinity Trough was estimated from CH2M Hill's (1998) groundwater monitoring data.

- Saturated cross sectional area (approximately 600,000 square feet);
- Porosity (10-30 %);
- Hydraulic conductivity (500 to 2,000 feet / day); and,
- Hydraulic gradient (approximately 0.044).

Using the equation:

$$Q = K * \frac{dh}{dl} * A * n * \frac{1}{24 * 60 * 60}$$

Where,

Q = flux (cubic feet per second)
K = hydraulic conductivity (feet per day)
dh/dl = hydraulic gradient
A = cross sectional area (square feet)
n = porosity

The estimated annual average flow through the Trinity Trough ranges from 15 to 182 cfs. This suggests that the 10 cfs of groundwater flow modeled across the Trinity Trough may underestimate the actual flows because it falls outside the low end of the estimated range.

5.2.7.3 Groundwater Flow Through the Hillyard Trough

Groundwater flow though the Hillyard Trough can be estimated by: 1) the increase in discharge of the Little Spokane River downstream of the SVRP Aquifer because the SVRP Aquifer discharges to the Little Spokane River; and, 2) groundwater model simulations. A summary of the estimated flow through the Hillyard Trough from previous groundwater modeling studies is provided below.

Summary of Estimated SVRP Aquifer Discharge to Little Spokane River

Source	**Estimated Annual Average SVRP Aquifer Discharge to Little Spokane River** (cfs)
Bolke and Vaccaro, 1981	254
CH2M Hill, 1998 (Spring 1995)	335
CH2M Hill, 1998 (Fall 1994)*	300
CH2M Hill, 2000 (Fall 1994)*	182

*CH2M Hill used additional data in the northern SVRP Aquifer area to recalibrate the model in 2000, resulting in a lower estimate of this value.

Using the same equation as for the Trinity Trough above, along with CH2M Hill's (1998) groundwater monitoring data and the following values for hydraulic parameters:

- Saturated cross sectional area (approximately 4,800,000 square feet);
- Porosity (10 – 30 %);
- Hydraulic conductivity (500 to 3,000 feet / day); and,
- Hydraulic gradient (approximately 0.013).

Using these approximate values and ranges provides a large estimated flow range through the Hillyard Trough of 36 to 650 cfs. Because the modeled flows in the summary table above) fall within the center of this calculated range, it is likely that the 182 cfs to 335 cfs of groundwater flow modeled across the Hillyard Trough simulates actual flows. The increased flow of the Little Spokane River between the At Dartford gage and the Near Dartford gage (Figure 5.2a) is about 250 cfs, which also supports the groundwater model results listed above.

5.2.7.4 Improved Understanding of the Spokane Aquifer

In addition to improving the estimated values for the quantities of water flowing within the aquifer across the state line, groundwater flow modeling has resulted in an improvement in the understanding of the geometry of the aquifer. At the time of Molenaar's 1988 publication on the SVRP Aquifer, it was believed that westerly groundwater flow into the lower Spokane River (WRIA 54) occurred from WRIA 57 across a five-mile wide channel from the southern basalt exposure of Five Mile Prairie to Spokane Falls. Because groundwater elevations simulated by Bolke and Vaccaro (1981) within the Hillyard Trough were significantly lower than the monitored elevations, the model suggested that less volumes of water than those modeled were actually able to flow westwards into WRIA 54. This resulted in additional geologic studies (CH2M Hill, 1998; CH2M Hill, 2000) that identified the Trinity Trough as only a one-mile wide (north-south), 300 feet deep channel through which groundwater within the aquifer could flow in a westerly direction from WRIA 57 to WRIA 54. Also as a result of this work, a deep, confined portion of the Spokane Aquifer in the northern portion of the Hillyard Trough was identified.

Based on review of the groundwater models completed to date for the SVRP Aquifer, the CH2M Hill groundwater flow models (CH2M Hill, 1998; CH2M Hill, 2000) and Bolke and Vaccaro's 1981 groundwater flow model are considered the most accurate. However, the main objectives of the models (and all of the other models described above) were to characterize the SVRP Aquifer for groundwater resource studies and protection. The interaction between surface water and groundwater was not modeled dynamically, partially because surface water impacts were not the primary focus of the projects and partially because the surface water – groundwater interaction program algorithms were at an early stage of development. As a result, these models do not accurately predict changes in the flow of the Spokane River as a result of varying groundwater withdrawals or varying groundwater recharge to the SVRP Aquifer. Because streamflow prediction is a primary focus of the WRIAs 55 and 57 Watershed Planning process, the Planning Unit chose to select the MIKE suite of programs (see Section 8 for a detailed discussion) as a tool to compare the effects of different water resources management strategies on the surface water and groundwater regimes of the two WRIAs. MIKE is one of the first available packages that includes a module that dynamically couples groundwater and surface water. This attribute along with its ability to take GIS data as input will build upon the modeling efforts of the past and continue to improve the understanding of the system.

5.3 Groundwater and Surface Water Interactions

The continuity of water flow between surface water and groundwater is an important consideration when assessing water availability (for example, the impact that groundwater withdrawals may have on surface water flows) and also in protecting the quality of both surface water and groundwater resources.

Surface water recharge from a river to an aquifer may occur when the surface water level in the stream is higher than the groundwater level in the aquifer. Discharge of groundwater to a stream may occur when the surface water level in the stream is lower than the groundwater level in the aquifer. The rate at which the interchange takes place is dependent on the magnitude of the water level difference and the permeability of the riverbed sediments.

Aquifers that are separated from surface water by depth or distance, are confined and/or are composed of low permeability materials, require longer periods of time for water exchange to occur. This results in attenuation or dampening of the seasonal variability in groundwater and surface water interactions.

Hydraulic continuity occurs between the Spokane River, SVRP Aquifer and Little Spokane River system of WRIA 57 and southern WRIA 55 and has been documented along the alluvial and flood deposited sediments of the Little Spokane River in WRIA 55 (Dames and Moore and Cosmopolitan, 1995). The following sections summarize the available information on these river-aquifer interactions.

5.3.1 Spokane River and Spokane Valley Aquifer Interactions

Along the reach of the Spokane River, from the Coeur d’Alene Lake outflow in Idaho to the Hangman Creek confluence, there are sections of the river that lose water to or gain water from the SVRP Aquifer. In general, the reach from the beginning of the Spokane River at Coeur d’Alene Lake loses water to the SVRP Aquifer until about Flora Road in the Spokane River Valley (MacInnis and others, 2000). From Flora Road to about Greene Street, the Spokane River generally gains flow from the SVRP Aquifer (MacInnis and others, 2000). From Greene Street to the Hangman Creek confluence, the Spokane River generally loses water to the SVRP Aquifer. Although these three reaches can be defined generally as losing and gaining reaches, the two downstream sections (Flora Road to the Hangman Creek confluence) exhibit complex interactions involving variation in magnitude and direction of flow (i.e., gaining or losing). Seasonal and decadal climatic variations affect both the Spokane River and the SVRP Aquifer.

The locations of losing and gaining reaches of the Spokane River and the volumetric interchanges between the river and the aquifer have been investigated for a number of years. Although knowledge of the hydrology of this connected system is improving, considerable uncertainty remains as to the quantities of water exchanged and the seasonal variations in the reaches and quantities of the exchanges.

Appendix D4 presents a summary of the main technical studies that have been completed to describe the relationship between the Spokane River and the SVRP Aquifer. The information is based on a summary of previous investigations presented in Gearhart and Buchanan's 2000 report on the hydraulic connection between the Spokane River and the Spokane Aquifer prepared for the Spokane County Water Quality Management Program. Copies of figures from the Gearhart and Buchanan (2000) report are included within Appendix D4. A compilation of simulated losses and gains in the Spokane River flow based on these previous studies is presented as Table 5.13.

With reference to Table 5.13, the most accurate representations of the interaction between the Spokane River and the SVRP Aquifer include the results of CH2M Hill (1998) and Gearhart and Buchanan (2000). Both these studies place the change in the Spokane River from a generally losing to generally gaining stream between Barker Road and Sullivan Road (Flora Road runs north-south parallel to and between Barker and Sullivan Roads). This has been confirmed by Spokane County based on field observations of springs along the Spokane River bank beneath the Sullivan Bridge. The CH2M Hill (1998) results are based on a steady-state groundwater flow model (described in Appendix D3). The Gearhart and Buchanan (2000) investigation compiled flow, stage and groundwater level data to assess the changes in the location of the losing and gaining reaches with seasonal changes in the flow of the Spokane River and groundwater levels in wells adjacent to the river. Both these studies provide a snapshot of the system at instances in time (CH2M Hill, 1998) and over a period of time (Gearhart and Buchanan, 2000) and do not provide information on how the system may behave dynamically.

The MIKE suite of modeling software includes a groundwater flow modeling module with a coupled surface water – groundwater interaction algorithm and is described in more detail in Section 8 of this report. One of the reasons the Planning Unit selected this tool over others is that it has the ability to dynamically model surface water – groundwater interactions. Details on the model selection process are included in Appendix E of this report.

The USGS is currently working on a Spokane River – Aquifer hydraulic connection study as a component of their National Water-Quality Assessment Program (NAWQA). The purpose of the study is to further improve the understanding of the groundwater / surface water interactions along the losing reach of the Spokane River between Pleasant View Road in Idaho and Harvard Road in Washington. The study also aims to investigate the impacts of the river on the water quality of the aquifer.

To date, the USGS NAWQA study has involved:

- Compilation of a well inventory database;
- Installation of 18 new wells;
- Monitoring at the 18 new wells and 7 pre-existing wells;
- Assessment of pressure and temperature responses in the wells as a result of flow changes in the Spokane River; and,
- Investigation of the water quality differences between groundwater within the aquifer and the surface water of the Spokane River.

Because the work is ongoing, further description of the study and the study results will not be included within the Level 1 Watershed Assessment. However, the study results may be used within the model development stage of this assessment (i.e., Level 2, Phase II).

5.3.2 Groundwater and Surface Water Interaction in WRIA 55

Most of the natural groundwater discharge within WRIA 55 occurs as baseflow to the Little Spokane River. During late summer, when flows in the Little Spokane River At Dartford average about 150 cfs, most of this flow (up to 110 cfs) is derived from groundwater inflow (Chung, 1975). The rest is supplied by tributaries, which also receive most of their water from groundwater inflow. Based on stream gaging at the Elk station (see Figure 5.2a), groundwater inflow (baseflow) is also high in the Little Spokane River upstream of its confluence with the West Branch (Chung, 1975).

Along the Little Spokane River to the north of the Hillyard Trough, the groundwater table is at a higher elevation than the river stage so that the aquifer discharges water to the stream. Based on river flows between Dartford and the confluence with the Spokane River, it is estimated that between 234 cfs (Dames and Moore and Cosmopolitan, 1995) and 310 cfs (Drost and Seitz, 1978) of groundwater from the SVRP Aquifer recharges the Little Spokane River. Groundwater flow models indicate between 182 cfs (CH2M Hill, 2000) and 335 cfs (CH2M Hill, 1998) of groundwater from the SVRP Aquifer recharges the Little Spokane River. Up to 45 cfs of this occurs from five springs (Cline, 1969). Although it is thought that most of this inflow is derived from the SVRP Aquifer, the source of up to 25 % of this inflow may be groundwater originating in the upper portion of WRIA 55 (Cline, 1969). The Little Spokane River baseflow from groundwater nearly doubles the average annual discharge in the Little Spokane River gaged At Dartford (Dames and Moore and Cosmopolitan, 1995). Groundwater inflow along this lower section maintains wetlands and rich riparian vegetation.

TABLE 5.1

Drainage Summary

WAU Name	Average Elevation (ft amsl)	Acres*
WRIA 55 - Little Spokane		
Beaver Creek	2900	47,172
Branch, W	3400	65,972
Dartford Creek	2200	18,679
Deadman Creek	2200	54,047
Deer Creek	3300	66,899
Dragoon Creek	2800	61,899
Ft Spokane	2000	20,924
Little Deep Creek	3100	29,029
Scotia	2800	67,200
	Total Acreage of WRIA 55:	431,821
WRIA 57 - Middle Spokane		
Blanchard Creek	3900	41,430
Liberty Creek	3400	22,228
Spokane Urban	3200	89,682
Thompson Creek	3400	30,272
	Total Acreage of WRIA 57:	183,612

*Acreage obtained from GIS coverage supplied by the Washington Department of Natural Resources.

TABLE 5.2

Continuous Streamflow gaging Stations with greater than Five Years of Record

Station Name	Source	Period of Record (water year)	River Mile	Drainage Area (square miles)	Mean Elevation (ft amsl, NGVD 29)
Spokane River near Post Falls, ID	USGS	1913 – 2000	100.7		
Spokane River at Liberty Br near Otis Orchard, WA	USGS/ SCC	1930 - 1983,	93.8	388	
		1994 – 1999*			
Spokane River below Trent Brg Near Spokane, WA	USGS	1949 - 1954	85.3	42	
Spokane River Below Green St at Spokane, WA	USGS/ SCC	1949 - 1952,			
		1993 - 1998*			
Spokane River At Spokane WA	USGS	1892 – 1999	72.9	429	
Spokane River at Long Lake, WA	USGS	1940 – 1999	33.8		
Hangman Creek At Spokane, WA	USGS	1948 – 1999	0.8	689	
Little Spokane River At Elk, WA	USGS	1949 – 1971	~37.5	115	
Little Spokane River, Chattaroy Rd., Chattaroy, WA	SCC	1976 – 1996,	23.2	312	
		1998 - 1999			
Little Spokane River At Dartford, WA	USGS	1930 - 1932,	11.4	665	1585.62
		1948 – 1999			
Little Spokane River Near Dartford, WA	USGS	1949 – 1951	4.4	698	
		1998 – 1999			

* SCC monitored from 1993-1998

TABLE 5.3

Minimum Instream Flows (MISFs) at Control Points in the Little Spokane River Basin (cfs).

Month	Day	Elk	Chattaroy	Dartford	Confluence
January					
	1	40	86	150	400
	15	40	86	150	400
February					
	1	40	86	150	400
	15	43	104	170	420
March					
	1	46	122	190	435
	15	50	143	218	460
April					
	1	54	165	250	490
	15	52	143	218	460
May					
	1	49	124	192	440
	15	47	104	170	420
June					
	1	45	83	148	395
	15	43	69	130	385
July					
	1	41.5	57	115	375
	15	39.5	57	115	375
August					
	1	38	57	115	375
	15	38	57	115	375
September					
	1	38	57	115	375
	15	38	63	123	380
October					
	1	38	70	130	385
	15	39	77	140	390
November					
	1	40	86	150	400
	15	40	86	150	400
December					
	1	40	86	150	400
	15	40	86	150	400

TABLE 5.4

Minimum Instream Flow Excursion Summary for WRIA 55

	Elk		**Chattaroy**		**Dartford**	
Period Of Record	7/1949 - 10/1971	June – October Only	10/1975 - 09/1996	June – October Only	5/1929 - 9/1932, 1/1947 - 9/1999	June – October Only
Days in Record	8415	3633	7671	3213	20515	8659
Days of Instream Flow Violations	813	416	2521	1352	3135	1909
Number of Continuous Excursions of Instream Flow Levels	71	22	162	62	205	94
Percent of Record below Instream Flow Levels	10%	11%	33%	42%	15%	22%
Max Continuous Days below Instream Flow Levels	153	92	262	153	245	181
Average Continuous Days below Instream Flow Levels	12	19	16	22	15	20

TABLE 5.5

Spokane Valley Aquifer Specific Capacity Data

Well ID	Owner	Well Name	Reported Yield (gpm)	Specific Capacity (gpm/ft)	Aquifer Saturated Thickness (ft)	Transmissivity (millions ft^2/day)	Hydraulic Conductivity (ft/day)
6317J01	NW Pipeline Co.		55	11	150	0.00	0
5406J03	Pasadena Park Irr. Dist.	#5 (New well)	1500	34	250	0.02	100
6432Q02	Pleasant Prairie WD		100	19	250	0.03	100
5418J01	Hutchinson Irr. Dist.	Broadway and Sergent	550	73	400	0.10	300
5510F01	Delp Place		125	63	400	0.10	300
6318B01	Whitworth College	New Well #2	1000	100	120	0.03	300
6320D01	Whitworth Water Dist. #2	2B	1800	200	175	0.05	300
5401R01	Spokane Industrial Park	Well #4	2500	141	300	0.13	400
6234N03	Fairmont Cemetery	Fairmont Cemetery Well	1500	115	100	0.04	400
6321J01	Acme Materials	Acme Crestline well (B 041)	200	67	150	0.06	400
5505H01	C & L Farms		600	150	250	0.13	500
5402B01	Trentwood Irr. Dist.	Progress #6	1500	341	150	0.09	600
6319A02	Whitworth Water Dist. #2	2A	2250	250	175	0.12	700
5214J01	Fairmont Cemetery Assoc.	Riverside Cemetery	2280	507	150	0.15	1,000
5503N01	Coen		750	375	400	0.50	1,300
6330H02	Holy Cross Cemetery	New Well	1000	500	250	0.33	1,300
5408B01	Millwood WD	Old Park Well	500	500	350	0.52	1,500
6631M06	Consolidated Irr. Dist. (CID)	East Farms, 11C	3008	1,003	400	0.77	1,900
5428M02	Model Irr. Dist.	#5	1150	575	250	0.50	2,000
6535F02	Consolidated Irr. Dist. (CID)	East Farms, 10B	3190	1,063	400	0.80	2,000
5414J01	Vera Irr. Distr #15	New #2 well	5000	1,852	400	1.11	2,800
5415E01	Modern Electric	#5	4000	833	400	1.10	2,800
5502G02	Consolidated Irr. Dist. (CID)	Otis Orchards, 9A	3400	1,700	400	1.13	2,800
5402P01	Kaiser Trentwood	Extraction Well (OH-EW1)	1065	619	200	0.57	2,900
5213B01	Inland Empire Cold Storage		400	667	200	0.60	3,000
5416E01	Modern Electric	#2	4500	900	400	1.20	3,000
5223B01	City of Spokane	Indian Canyon Golf Course	450	450	100	0.40	4,000
5504D01	Consolidated Irr. Dist. (CID)	Otis Orchards, 9A	4500	2,647	250	1.09	4,400
5411N02	Consolidated Irr. Dist. (CID)	Carder, 1B	1600	1,600	250	1.23	4,900
5517D04	Consolidated Irr. Dist. (CID)	Greenacres, 4D	1800	4,500	450	2.67	5,900
5426D01	Vera Irr. Dist #15	#5	1400	1,400	300	1.85	6,200

Note: Data compiled from CH2MHill, 1998.

TABLE 5.6

Compilation of Aquifer / Aquitard Hydraulic Properties Properties

Hydrogeologic Unit	Aquifer Area	Locality	Well	Saturated Thickness	Pump Rate / Well Yield	Specific Capacity	Transmissivity	Hydraulic Conductivity	Storage	Porosity	Linear Velocity	Source
				(feet)	(gpm)	(gpm/ft)	(ft2/day)	(ft/day)		(%)	(ft/day)	
Alluvium				0 - 40	5 - 600							Cline, 1969.
Flood Sand & Gravel	SVRP							0.1 - 10,000	0.1 - 0.2	10 - 20	30.00	Spokane County, 2001 Draft
Flood Sand & Gravel	Deer Park		TW-1	45	90		722	16				EMCON, 1992.
Flood Sand & Gravel	Deer Park		TW-2	50	106		6,685 - 20,055	134 - 401				EMCON, 1992.
Flood Sand & Gravel	Little Spokane River	Colbert Landfill					10,000 - 12,000	530 - 640	0.2		3.5 - 6.4	Landau, 1991. Boese & Buchanan, 1996.
Flood Sand & Gravel	SVRP	N Spokane, Francis & Market	N Spokane ID #3	200	800	198	100,000 - 700,000	500 - 3,500				CH2MHill, 2000
Flood Sand & Gravel	SVRP	Kaiser Trentwood - Central Spokane Valley	OH-EW-1	175	1,065		160,000 - 350,000	650 - 1,400				Hart Crowser, 1994 cited in CH2MHill, 1998
Flood Sand & Gravel	SVRP	Hillyard						864	0.10 - 0.15			Bolke & Vaccaro, 1981
Flood Sand & Gravel	SVRP	Valley, Sullivan & Broadway	Vera #2-1	400	2,500		380,000	950				CH2MHill, 2000
Flood Sand & Gravel	SVRP	Below Spokane Falls	Northside Landfill					1,200 - 2,100				CH2MHill, 1998
Flood Sand & Gravel	SVRP	Kaiser Mead North - North Hillyard Trough	Well No. 6					1,100 - 2,500				Hart Crowser, 1980 cited in CH2MHill, 1998
Flood Sand & Gravel	SVRP	Whitworth - North Hillyard Trough	7G2					1,100 - 2,500				Hart Crowser, 1980 cited in CH2MHill, 1998
Flood Sand & Gravel	SVRP	North Hillyard Trough					4,320 - 172,800		0.05 - 0.15			Boese & Buchanan, 1996.
Flood Sand & Gravel	SVRP	Hillyard					130,000					Drost & Seitz, 1978.
Flood Sand & Gravel	SVRP	Hillyard		160			400,000	2,500		30	47.00	Drost & Seitz, 1978.
Flood Sand & Gravel	Little Spokane River	West WRIA 55					172,800 - 518,400					Boese & Buchanan, 1996.
Flood Sand & Gravel	SVRP	Central Hillyard Trough	Central Well No. 2	250 - 300	8,225	1,443	630,000 - 750,000	2,500				CH2MHill, 1998
Flood Sand & Gravel	SVRP	Downtown Spokane						2,592	0.10 - 0.15			Bolke & Vaccaro, 1981
Flood Sand & Gravel	SVRP	Idaho Road & Wellesley	CID #11A	400	3,400	1,889	800,000 - 1,700,000	2,000 - 4,200				CH2MHill, 2000
Flood Sand & Gravel	SVRP	South Hillyard Trough	Nevada Well	400	18,200	2,563	1,300,000	3,000				CH2MHill, 1998
Flood Sand & Gravel	SVRP	Central Spokane Valley						4,320	0.15 - 0.20			Bolke & Vaccaro, 1981
Flood Sand & Gravel	SVRP	State Line to Pines Knoll						6,048	0.15 - 0.20			Bolke & Vaccaro, 1981
Flood Sand & Gravel	Deer Park		Olsen (west)	44	620		267,400	6,077	0.001			EMCON, 1992.
Flood Sand & Gravel	SVRP	Valley, nr Barker & Mission	CID #4B	450	1,975	2,821	1,900,000 - 2,500,000	4,200 - 6,200				CH2MHill, 2000
Flood Sand & Gravel	SVRP	State Line		280			3,400,000	12,000		25	64.00	Drost & Seitz, 1978.
Flood Sand & Gravel	SVRP	State Line					11,000,000					Drost & Seitz, 1978.
Flood Sand & Gravel				0 - 700	600 - 20,000							Cline, 1969.
Lower Flood Sand & Gravel	Little Spokane River	Colbert Landfill	CP-E1		200		10,000 - 14,000	100 - 140	0.16	30	0.30	Landau, 1991. Boese & Buchanan, 1996.
Lower Flood Sand & Gravel	Little Spokane River	Colbert Landfill	CP-W1		220		30,000 - 40,000	170 - 230	0.0004	30	0.60	Landau, 1991. Boese & Buchanan, 1996.
Glacial Lake Deposits	Deer Park			0 - 300	5 - 600							Cline, 1969.
Grande Ronde Basalt	Columbia Plateau							0.005 - 2,522				Boese & Buchanan, 1996.
Wanapum Basalt	Columbia Plateau							0.007 - 5,244				Boese & Buchanan, 1996.
Wanapum Basalt	West Plains							0.18 - 12.1				Boese & Buchanan, 1996.
Basalt	Little Spokane River	Colbert Landfill	CP-E2				25	0.7 - 1.0	0.01	10	0.40	Landau, 1991. Boese & Buchanan, 1996.
Basalt	Five Mile Prairie	Five Mile Prairie		80		0.5 - 1	134 - 267	1.7 - 3.3	0.0025			Olson, 1979
Basalt	Deer Park	City of Deer park	DP-5		350							EMCON, 1992.
Basalt					< 35							Cline, 1969.
Wanapum Basalt	Five Mile Prairie						134.8 - 192.5					Boese & Buchanan, 1996.
Latah					< 35							Cline, 1969.
Basement					< 35							Cline, 1969.
Basement	West Plains						38					Boese & Buchanan, 1996.
Basalt & Basement	Five Mile Prairie	N. Five Mile Prairie						1 - 86	< 0.05			Olson, 1979

Note: Where an upper flood sand and gravel unit occurs over a lower sand and gravel unit with an aquitard separating the (e.g. in the Hillyard area), the upper unit is referred to as "Flood Sand and Gravel" and the lower unit as "Lower Flood Sand and Gravel".

TABLE 5.7

Groundwater Monitoring Wells with Snapshot Data (EMCON, 1992)

WELL_ID	WELL_NAME	X_WSP_N	Y_WSP_N	STATE	AQUIFER	T	R	S	DATE	GROUND_ELEV _(USGS)	GW_ELEV _(USGS)	GW_FT_BGS
8222N01	ANDERSON	2458962.56018	352657.08784	WA	deep	28N	42E	22	09/04/91	2020	1991	29.00
8222N01	ANDERSON	2458962.56018	352657.08784	WA	deep	28N	42E	22	11/01/91	2020	1991	28.80
8222N01	ANDERSON	2458962.56018	352657.08784	WA	deep	28N	42E	22	01/30/92	2020	1992	27.70
8222N01	ANDERSON	2458962.56018	352657.08784	WA	deep	28N	42E	22	04/03/92	2020	1990	29.50
8203G01	BLY	2460194.26064	364891.97907	WA	deep	28N	42E	3	10/03/91	2110	2093	16.90
8203G01	BLY	2460194.26064	364891.97907	WA	deep	28N	42E	3	10/31/91	2110	2093	16.80
8203G01	BLY	2460194.26064	364891.97907	WA	deep	28N	42E	3	01/28/92	2110	2094	15.80
8203G01	BLY	2460194.26064	364891.97907	WA	deep	28N	42E	3	04/02/92	2110	2094	16.10
8307M01	BOOHER	2475877.91317	362839.14497	WA	deep	28N	43E	7	06/14/91	2151	2119	31.60
8307M01	BOOHER	2475877.91317	362839.14497	WA	deep	28N	43E	7	10/29/91	2151	2120	31.30
8307M01	BOOHER	2475877.91317	362839.14497	WA	deep	28N	43E	7	01/27/92	2151	2119	32.20
8307M01	BOOHER	2475877.91317	362839.14497	WA	deep	28N	43E	7	04/01/92	2151	2118	32.90
8211K01	BROWN	2465285.28921	360622.08415	WA	deep	28N	42E	11	06/20/91	2087	2080	6.65
8211K01	BROWN	2465285.28921	360622.08415	WA	deep	28N	42E	11	11/01/91	2087	2077	9.90
8211K01	BROWN	2465285.28921	360622.08415	WA	deep	28N	42E	11	01/29/92	2087	2079	7.60
8211K01	BROWN	2465285.28921	360622.08415	WA	deep	28N	42E	11	04/02/92	2087	2081	6.10
8213C01	BUNKE	2472593.37861	356187.96249	WA	deep	28N	42E	13	10/10/91	2071	2039	32.20
8213C01	BUNKE	2472593.37861	356187.96249	WA	deep	28N	42E	13	11/04/91	2071	2039	32.40
8213C01	BUNKE	2472593.37861	356187.96249	WA	deep	28N	42E	13	01/30/92	2071	2038	32.80
8213C01	BUNKE	2472593.37861	356187.96249	WA	deep	28N	42E	13	04/03/92	2071	2039	32.10
8203P01	CHRISTCHURCH	2457812.97309	366205.79290	WA	deep	28N	42E	3	06/21/91	2157	2072	84.87
8203P01	CHRISTCHURCH	2457812.97309	366205.79290	WA	deep	28N	42E	3	10/29/91	2157	2096	61.00
8203P01	CHRISTCHURCH	2457812.97309	366205.79290	WA	deep	28N	42E	3	01/28/92	2157	2063	94.00
8203P01	CHRISTCHURCH	2457812.97309	366205.79290	WA	deep	28N	42E	3	04/01/92	2157	2103	54.20
8307C01	COOPER	2478259.20072	361771.67124	WA	deep	28N	43E	7	06/14/91	2075	2020	54.55
8307C01	COOPER	2478259.20072	361771.67124	WA	deep	28N	43E	7	11/01/91	2075	2024	50.90
8307C01	COOPER	2478259.20072	361771.67124	WA	deep	28N	43E	7	01/27/92	2075	2024	51.10
8307C01	COOPER	2478259.20072	361771.67124	WA	deep	28N	43E	7	04/01/92	2075	2024	51.20
9227C01	D_REITER	2460604.82746	376552.07676	WA	deep	29N	42E	27	06/03/91	2138	2132	5.80
9227C01	D_REITER	2460604.82746	376552.07676	WA	deep	29N	42E	27	10/28/91	2138	2128	9.50
9227C01	D_REITER	2460604.82746	376552.07676	WA	deep	29N	42E	27	01/28/92	2138	2130	8.00
9227C01	D_REITER	2460604.82746	376552.07676	WA	deep	29N	42E	27	04/02/92	2138	2131	6.70
8316N01	DOE-16	2484499.81639	357255.43622	WA	deep	28N	43E	16	02/04/92	2012	1971	40.70
8316N01	DOE-16	2484499.81639	357255.43622	WA	deep	28N	43E	16	04/01/92	2012	1971	40.70
9233F01	DOE-33	2453789.41825	370557.80119	WA	deep	29N	42E	33	02/04/92	2170	2129	40.80
9233F01	DOE-33	2453789.41825	370557.80119	WA	deep	29N	42E	33	04/02/92	2170	2127	43.30
9226M01	DP(OLSEN)	2463232.45511	378030.11732	WA	shallow	29N	42E	26	10/03/91	2145	2131	14.00
9226M01	DP(OLSEN)	2463232.45511	378030.11732	WA	shallow	29N	42E	26	10/28/91	2145	2131	13.80
9226M01	DP(OLSEN)	2463232.45511	378030.11732	WA	shallow	29N	42E	26	01/28/92	2145	2132	13.40
9226M01	DP(OLSEN)	2463232.45511	378030.11732	WA	shallow	29N	42E	26	04/01/92	2145	2133	12.20
9331J01	DP/M-10	2474399.87261	369490.32746	WA	shallow	29N	43E	31	06/20/91	2180	2127	52.85
9331J01	DP/M-10	2474399.87261	369490.32746	WA	shallow	29N	43E	31	11/01/91	2180	2128	52.20
9331J01	DP/M-10	2474399.87261	369490.32746	WA	shallow	29N	43E	31	01/27/92	2180	2127	53.00
9331J01	DP/M-10	2474399.87261	369490.32746	WA	shallow	29N	43E	31	04/01/92	2180	2127	53.10
8201B01	DP/M-2	2471197.45142	368012.28691	WA	shallow	28N	42E	1	06/20/91	2189	2129	60.23
8201B01	DP/M-2	2471197.45142	368012.28691	WA	shallow	28N	42E	1	10/29/91	2189	2129	60.30
8201B01	DP/M-2	2471197.45142	368012.28691	WA	shallow	28N	42E	1	01/27/92	2189	2129	60.20
8201B01	DP/M-2	2471197.45142	368012.28691	WA	shallow	28N	42E	1	04/01/92	2189	2129	60.30
8201D01	DP/M-3	2468241.37031	364235.07216	WA	shallow	28N	42E	1	06/20/91	2188	2147	40.53
8201D01	DP/M-3	2468241.37031	364235.07216	WA	shallow	28N	42E	1	10/29/91	2188	2147	41.00
8201D01	DP/M-3	2468241.37031	364235.07216	WA	shallow	28N	42E	1	01/27/92	2188	2147	41.30
8201D01	DP/M-3	2468241.37031	364235.07216	WA	shallow	28N	42E	1	04/01/92	2188	2147	41.10
9332P01	DP/M-5	2478012.86063	372692.74865	WA	shallow	29N	43E	32	06/20/91	2190	2163	27.44
9332P01	DP/M-5	2478012.86063	372692.74865	WA	shallow	29N	43E	32	11/01/91	2190	2163	27.40
9332P01	DP/M-5	2478012.86063	372692.74865	WA	shallow	29N	43E	32	01/27/92	2190	2162	27.90
9332P01	DP/M-5	2478012.86063	372692.74865	WA	shallow	29N	43E	32	04/01/92	2190	2162	27.80
9331N01	DP/M-6	2473496.62561	373021.20211	WA	shallow	29N	43E	31	06/20/91	2202	2146	55.94
9331N01	DP/M-6	2473496.62561	373021.20211	WA	shallow	29N	43E	31	11/08/91	2202	2145	56.90
9331N01	DP/M-6	2473496.62561	373021.20211	WA	shallow	29N	43E	31	01/29/92	2202	2143	59.00
9331N01	DP/M-6	2473496.62561	373021.20211	WA	shallow	29N	43E	31	04/01/92	2202	2145	56.70
8306P01	DP/M-9	2473578.73897	367355.37999	WA	shallow	28N	43E	6	06/20/91	2165	2113	52.26
8306P01	DP/M-9	2473578.73897	367355.37999	WA	shallow	28N	43E	6	10/29/91	2165	2112	52.90
8306P01	DP/M-9	2473578.73897	367355.37999	WA	shallow	28N	43E	6	01/27/92	2165	2112	53.10
8306P01	DP/M-9	2473578.73897	367355.37999	WA	shallow	28N	43E	6	04/01/92	2165	2112	53.40
9234A01	DP-1(34SES)	2461508.07447	368587.08045	WA	shallow	29N	42E	34	10/03/91	2117	2102	15.40
9234A01	DP-1(34SES)	2461508.07447	368587.08045	WA	shallow	29N	42E	34	11/01/91	2117	2101	15.50
9234A01	DP-1(34SES)	2461508.07447	368587.08045	WA	shallow	29N	42E	34	01/29/92	2117	2102	15.10
9234A01	DP-1(34SES)	2461508.07447	368587.08045	WA	shallow	29N	42E	34	04/03/92	2117	2102	15.10
8202D01	DP-2(2N1)	2463807.24866	365466.77262	WA	shallow	28N	42E	2	10/03/91	2113	2094	18.60

TABLE 5.7

Groundwater Monitoring Wells with Snapshot Data (EMCON, 1992)

WELL_ID	WELL_NAME	X_WSP_N	Y_WSP_N	STATE	AQUIFER	T	R	S	DATE	GROUND_ELEV_(USGS)	GW_ELEV_(USGS)	GW_FT_BGS
8202D01	DP-2(2N1)	2463807.24866	365466.77262	WA	shallow	28N	42E	2	11/01/91	2113	2094	18.70
8202D01	DP-2(2N1)	2463807.24866	365466.77262	WA	shallow	28N	42E	2	01/29/92	2113	2095	18.20
8202D01	DP-2(2N1)	2463807.24866	365466.77262	WA	shallow	28N	42E	2	04/03/92	2113	2094	18.70
9235J01	DP-4	2463560.90857	369736.66755	WA	shallow	29N	42E	35	01/29/92	2136	2105	31.10
9235J01	DP-4	2463560.90857	369736.66755	WA	shallow	29N	42E	35	04/03/92	2136	2105	31.00
8213D01	EDWARDS	2472100.69842	358569.25005	WA	shallow	28N	42E	13	06/18/91	2113	2070	43.15
8213D01	EDWARDS	2472100.69842	358569.25005	WA	shallow	28N	42E	13	10/31/91	2113	2068	44.50
8213D01	EDWARDS	2472100.69842	358569.25005	WA	shallow	28N	42E	13	01/29/92	2113	2068	44.90
8213D01	EDWARDS	2472100.69842	358569.25005	WA	shallow	28N	42E	13	04/02/92	2113	2068	45.10
8222K01	FAHLAND	2460358.48737	349783.12010	WA	deep	28N	42E	22	06/18/91	2020	1978	41.50
8222K01	FAHLAND	2460358.48737	349783.12010	WA	deep	28N	42E	22	11/01/91	2020	1978	41.80
8222K01	FAHLAND	2460358.48737	349783.12010	WA	deep	28N	42E	22	01/30/92	2020	1979	41.40
8222K01	FAHLAND	2460358.48737	349783.12010	WA	deep	28N	42E	22	04/03/92	2020	1978	41.80
8210E01	FLUGEL	2461261.73437	362018.01133	WA	deep	28N	42E	10	06/26/91	2130	2106	23.50
8210E01	FLUGEL	2461261.73437	362018.01133	WA	deep	28N	42E	10	10/29/91	2130	2104	26.00
8210E01	FLUGEL	2461261.73437	362018.01133	WA	deep	28N	42E	10	01/29/92	2130	2107	23.10
8210E01	FLUGEL	2461261.73437	362018.01133	WA	deep	28N	42E	10	04/02/92	2130	2111	19.20
9215M01	GLEASON	2457648.74636	388951.19473	WA	deep	29N	42E	15	09/11/91	2230	2198	31.90
9215M01	GLEASON	2457648.74636	388951.19473	WA	deep	29N	42E	15	10/28/91	2230	2207	22.70
9215M01	GLEASON	2457648.74636	388951.19473	WA	deep	29N	42E	15	01/28/92	2230	2209	21.40
9215M01	GLEASON	2457648.74636	388951.19473	WA	deep	29N	42E	15	04/02/92	2230	2209	20.60
9215R01	HARPER	2455842.25235	384188.61962	WA	deep	29N	42E	15	10/03/91	2160	2156	4.30
9215R01	HARPER	2455842.25235	384188.61962	WA	deep	29N	42E	15	10/28/91	2160	2156	4.30
9215R01	HARPER	2455842.25235	384188.61962	WA	deep	29N	42E	15	01/28/92	2160	2156	4.30
9215R01	HARPER	2455842.25235	384188.61962	WA	deep	29N	42E	15	04/02/92	2160	2153	6.80
9226F01	HASTINGS	2464299.92884	376305.73667	WA	shallow	29N	42E	26	09/03/91	2170	2131	39.30
9226F01	HASTINGS	2464299.92884	376305.73667	WA	shallow	29N	42E	26	10/28/91	2170	2130	39.80
9226F01	HASTINGS	2464299.92884	376305.73667	WA	shallow	29N	42E	26	01/28/92	2170	2130	39.70
9226F01	HASTINGS	2464299.92884	376305.73667	WA	shallow	29N	42E	26	04/01/92	2170	2131	39.00
8213N01	HELM	2469473.07077	358487.13668	WA	deep	28N	42E	13	06/18/91	2110	2046	63.95
8213N01	HELM	2469473.07077	358487.13668	WA	deep	28N	42E	13	11/01/91	2110	2056	53.70
8213N01	HELM	2469473.07077	358487.13668	WA	deep	28N	42E	13	01/29/92	2110	2062	47.60
8213N01	HELM	2469473.07077	358487.13668	WA	deep	28N	42E	13	04/02/92	2110	2059	51.00
8210B01	HYTEIN	2462493.43483	360539.97078	WA	deep	28N	42E	10	06/20/91	2115	2073	42.46
8210B01	HYTEIN	2462493.43483	360539.97078	WA	deep	28N	42E	10	11/01/91	2115	2059	56.00
8210B01	HYTEIN	2462493.43483	360539.97078	WA	deep	28N	42E	10	01/30/92	2115	2071	43.90
8210B01	HYTEIN	2462493.43483	360539.97078	WA	deep	28N	42E	10	04/01/92	2115	2079	35.90
8223B01	KEIFEL	2467502.35004	349783.12010	WA	deep	28N	42E	23	09/09/91	2053	2007	45.60
8223B01	KEIFEL	2467502.35004	349783.12010	WA	deep	28N	42E	23	10/28/91	2053	2011	41.80
8223B01	KEIFEL	2467502.35004	349783.12010	WA	deep	28N	42E	23	01/29/92	2053	2016	37.10
8223B01	KEIFEL	2467502.35004	349783.12010	WA	deep	28N	42E	23	04/02/92	2053	2017	36.30
8305F01	LOSHBAUGH	2481379.50855	366862.69981	WA	shallow	28N	43E	5	10/03/91	2169	2104	64.60
8305F01	LOSHBAUGH	2481379.50855	366862.69981	WA	shallow	28N	43E	5	10/29/91	2169	2104	64.50
8305F01	LOSHBAUGH	2481379.50855	366862.69981	WA	shallow	28N	43E	5	01/29/92	2169	2104	64.60
8305F01	LOSHBAUGH	2481379.50855	366862.69981	WA	shallow	28N	43E	5	04/01/92	2169	2104	65.00
8212D02	LOVE	2473168.17215	362674.91825	WA	deep	28N	42E	12	06/25/91	2147	2103	44.10
8212D02	LOVE	2473168.17215	362674.91825	WA	deep	28N	42E	12	10/29/91	2147	2103	44.00
8212D02	LOVE	2473168.17215	362674.91825	WA	deep	28N	42E	12	01/29/92	2147	2103	44.20
8212D02	LOVE	2473168.17215	362674.91825	WA	deep	28N	42E	12	04/01/92	2147	2103	44.30
8308C01	MCCANN	2483268.11593	362592.80488	WA	deep	28N	43E	8	6/14//91	2125	1976	148.94
8308C01	MCCANN	2483268.11593	362592.80488	WA	deep	28N	43E	8	10/29/91	2125	1975	149.50
8308C01	MCCANN	2483268.11593	362592.80488	WA	deep	28N	43E	8	01/27/92	2125	1976	149.40
8308C01	MCCANN	2483268.11593	362592.80488	WA	deep	28N	43E	8	04/01/92	2125	1975	149.70
8212M01	MCLEMORE	2470540.54451	363742.39198	WA	deep	28N	42E	12	06/14/91	2163	2116	47.21
8212M01	MCLEMORE	2470540.54451	363742.39198	WA	deep	28N	42E	12	11/01/91	2163	2115	48.20
8212M01	MCLEMORE	2470540.54451	363742.39198	WA	deep	28N	42E	12	01/29/92	2163	2116	47.00
8212M01	MCLEMORE	2470540.54451	363742.39198	WA	deep	28N	42E	12	04/02/92	2163	2111	51.60
9222A01	MICKAVICZ	2460686.94083	384024.39289	WA	deep	29N	42E	22	09/11/91	2203	2169	33.60
9222A01	MICKAVICZ	2460686.94083	384024.39289	WA	deep	29N	42E	22	10/28/91	2203	2173	30.40
9222A01	MICKAVICZ	2460686.94083	384024.39289	WA	deep	29N	42E	22	01/28/92	2203	2174	29.40
9222A01	MICKAVICZ	2460686.94083	384024.39289	WA	deep	29N	42E	22	04/01/92	2203	2174	29.00
9214N01	MILLER	2462000.75465	388294.28782	WA	deep	29N	42E	14	09/11/91	2250	2194	56.00
9214N01	MILLER	2462000.75465	388294.28782	WA	deep	29N	42E	14	10/28/91	2250	2194	55.50
9214N01	MILLER	2462000.75465	388294.28782	WA	deep	29N	42E	14	01/28/92	2250	2195	54.80
9214N01	MILLER	2462000.75465	388294.28782	WA	deep	29N	42E	14	04/02/92	2250	2194	55.90
8212D01	MINDEN	2473168.17215	363249.71179	WA	deep	28N	42E	12	06/14/91	2148	2104	43.61
8212D01	MINDEN	2473168.17215	363249.71179	WA	deep	28N	42E	12	10/29/91	2148	2104	44.30
8212D01	MINDEN	2473168.17215	363249.71179	WA	deep	28N	42E	12	01/29/92	2148	2104	44.00
8212D01	MINDEN	2473168.17215	363249.71179	WA	deep	28N	42E	12	04/01/92	2148	2131	17.00

TABLE 5.7

Groundwater Monitoring Wells with Snapshot Data (EMCON, 1992)

WELL_ID	WELL_NAME	X_WSP_N	Y_WSP_N	STATE	AQUIFER	T	R	S	DATE	GROUND_ELEV _(USGS)	GW_ELEV _(USGS)	GW_FT_BGS
8215D01	NEFF	2462247.09474	357009.09613	WA	deep	28N	42E	15	10/03/91	2138	2065	73.40
8215D01	NEFF	2462247.09474	357009.09613	WA	deep	28N	42E	15	10/01/91	2138	2066	72.00
8215D01	NEFF	2462247.09474	357009.09613	WA	deep	28N	42E	15	01/30/92	2138	2069	69.40
8215D01	NEFF	2462247.09474	357009.09613	WA	deep	28N	42E	15	04/02/92	2138	2069	69.00
9212H01	OSTRANDER	2469390.95741	384517.07307	WA	shallow	29N	42E	13	09/11/91	2205	2171	34.20
9212H01	OSTRANDER	2469390.95741	384517.07307	WA	shallow	29N	42E	13	11/01/91	2205	2170	34.80
9212H01	OSTRANDER	2469390.95741	384517.07307	WA	shallow	29N	42E	13	01/30/92	2205	2170	35.20
9212H01	OSTRANDER	2469390.95741	384517.07307	WA	shallow	29N	42E	13	04/08/82	2205	2170	35.00
8317J01	PLUNKETT	2481133.16846	354217.24175	WA	shallow	28N	43E	17	06/18/91	1998	1913	85.46
8317J01	PLUNKETT	2481133.16846	354217.24175	WA	shallow	28N	43E	17	10/29/91	1998	1910	87.90
8317J01	PLUNKETT	2481133.16846	354217.24175	WA	shallow	28N	43E	17	01/30/92	1998	1912	86.00
8317J01	PLUNKETT	2481133.16846	354217.24175	WA	shallow	28N	43E	17	04/08/92	1998	1912	86.00
8305N01	PUTNAM	2480065.69473	367930.17354	WA	deep	28N	43E	5	06/25/91	2163	2094	68.70
8305N01	PUTNAM	2480065.69473	367930.17354	WA	deep	28N	43E	5	10/29/91	2163	2093	69.80
8305N01	PUTNAM	2480065.69473	367930.17354	WA	deep	28N	43E	5	01/27/92	2163	2094	69.00
8305N01	PUTNAM	2480065.69473	367930.17354	WA	deep	28N	43E	5	04/01/92	2163	2094	69.30
9317F01	RAMSEY	2479573.01455	387719.49427	WA	deep	29N	43E	17	09/05/91	2240	2129	111.00
9317F01	RAMSEY	2479573.01455	387719.49427	WA	deep	29N	43E	17	10/28/91	2240	2133	107.08
9317F01	RAMSEY	2479573.01455	387719.49427	WA	deep	29N	43E	17	01/28/92	2240	2133	106.80
9317F01	RAMSEY	2479573.01455	387719.49427	WA	deep	29N	43E	17	04/01/92	2240	2132	107.60
9318P01	REMINGTON	2471690.13160	388047.94772	WA	shallow	29N	43E	18	09/11/91	2220	2184	36.10
9318P01	REMINGTON	2471690.13160	388047.94772	WA	shallow	29N	43E	18	10/28/91	2220	2184	36.10
9318P01	REMINGTON	2471690.13160	388047.94772	WA	shallow	29N	43E	18	01/?/92	2220	2153	67.00
9318P01	REMINGTON	2471690.13160	388047.94772	WA	shallow	29N	43E	18	4/?/92	2220	2183	37.00
8317P01	SALTZ	2479655.12791	356844.86940	WA	shallow	28N	43E	17	06/14/91	2021	1961	59.54
8317P01	SALTZ	2479655.12791	356844.86940	WA	shallow	28N	43E	17	10/29/91	2021	1955	66.30
9317A01	SMETHERS	2481543.73528	386159.34035	WA	shallow	29N	43E	17	09/05/91	2220	2066	153.90
9317A01	SMETHERS	2481543.73528	386159.34035	WA	shallow	29N	43E	17	10/28/91	2220	2066	153.90
9317A01	SMETHERS	2481543.73528	386159.34035	WA	shallow	29N	43E	17	01/28/92	2220	2066	154.10
9317A01	SMETHERS	2481543.73528	386159.34035	WA	shallow	29N	43E	17	04/01/92	2220	2066	154.20
9214C01	STATEMA	2464710.49566	388047.94772	WA	shallow	29N	42E	14	09/11/91	2210	2171	38.70
9214C01	STATEMA	2464710.49566	388047.94772	WA	shallow	29N	42E	14	10/28/91	2210	2192	17.80
9214C01	STATEMA	2464710.49566	388047.94772	WA	shallow	29N	42E	14	01/28/92	2210	2195	14.70
9214C01	STATEMA	2464710.49566	388047.94772	WA	shallow	29N	42E	14	04/02/92	2210	2197	13.20
9234J01	STENZEL	2458387.76663	368422.85373	WA	deep	29N	42E	34	09/03/91	2162	2131	30.90
9234J01	STENZEL	2458387.76663	368422.85373	WA	deep	29N	42E	34	10/28/91	2162	2130	31.80
9234J01	STENZEL	2458387.76663	368422.85373	WA	deep	29N	42E	34	01/28/92	2162	2131	30.90
9234J01	STENZEL	2458387.76663	368422.85373	WA	deep	29N	42E	34	04/02/92	2162	2133	29.30
9223R01	TW2	2461918.64129	379836.61132	WA	shallow	29N	42E	23	10/10/91	2155	2138	16.70
9223R01	TW2	2461918.64129	379836.61132	WA	shallow	29N	42E	23	10/28/91	2155	2138	16.60
9223R01	TW2	2461918.64129	379836.61132	WA	shallow	29N	42E	23	01/28/92	2155	2138	16.60
9223R01	TW2	2461918.64129	379836.61132	WA	shallow	29N	42E	23	04/01/92	2155	2140	15.40
9332E01	VEILLETTE	2480558.37491	372939.08875	WA	deep	29N	43E	32	09/21/91	2198	2121	76.90
9332E01	VEILLETTE	2480558.37491	372939.08875	WA	deep	29N	43E	32	10/28/91	2198	2121	76.70
9332E01	VEILLETTE	2480558.37491	372939.08875	WA	deep	29N	43E	32	01/27/92	2198	2121	76.70
9332E01	VEILLETTE	2480558.37491	372939.08875	WA	deep	29N	43E	32	04/01/92	2198	2122	76.10
8224H01	WILLARD	2472429.15188	347976.62609	WA	deep	28N	42E	24	06/18/91	1988	1935	53.09
8224H01	WILLARD	2472429.15188	347976.62609	WA	deep	28N	42E	24	11/01/91	1988	1938	50.40
8224H01	WILLARD	2472429.15188	347976.62609	WA	deep	28N	42E	24	01/29/92	1988	1938	50.00
8224H01	WILLARD	2472429.15188	347976.62609	WA	deep	28N	42E	24	04/02/92	1988	1938	50.40
9330F01	WILSON	2476042.13989	376880.53022	WA	deep	29N	43E	30	09/11/91	2220	2118	101.80
9330F01	WILSON	2476042.13989	376880.53022	WA	deep	29N	43E	30	10/28/91	2220	2118	101.90
9330F01	WILSON	2476042.13989	376880.53022	WA	deep	29N	43E	30	01/29/92	2220	2118	102.30
9330F01	WILSON	2476042.13989	376880.53022	WA	deep	29N	43E	30	04/01/92	2220	2118	102.40
9223N01	WOLF	2462575.54820	382628.46570	WA	deep	29N	42E	23	6/?/91	2200	2183	16.80
9223N01	WOLF	2462575.54820	382628.46570	WA	deep	29N	42E	23	10/28/91	2200	2182	18.00
9223N01	WOLF	2462575.54820	382628.46570	WA	deep	29N	42E	23	01/28/92	2200	2182	18.30
9223N01	WOLF	2462575.54820	382628.46570	WA	deep	29N	42E	23	04/01/92	2200	2182	18.10
9215D01	WORKMAN	2459701.58046	389279.64818	WA	shallow	29N	42E	15	10/29/91	2245	2223	21.90
9215D01	WORKMAN	2459701.58046	389279.64818	WA	shallow	29N	42E	15	01/28/92	2245	2222	23.00
9215D01	WORKMAN	2459701.58046	389279.64818	WA	shallow	29N	42E	15	04/02/92	2245	2224	21.00

Groundwater Monitoring Wells with Snapshot Data (Boese and Buchanan, 1996)

WELL_ID	X_WSP_N	Y_WSP_N	GROUND_ELEV_(USGS)	GW_ELEV_(USGS)	GW_FTBGS	DATE
6204N02	2456429.83279	299616.56125	1720	1549.44	170.56	Apr-Jun,1996
6211K01	2470517.86609	296434.30873	1600	1594.08	5.92	Apr-Jun,1996
6301J01	2507958.17880	302653.82128	1820	1784.00	36.00	Apr-Jun,1996
6303K02	2495124.25829	301833.57738	1860	1750.30	109.70	Apr-Jun,1996
6311B01	2501036.80323	300166.41206	1875	1750.70	124.30	Apr-Jun,1996
6312M01	2503124.73268	297700.74839	1875	1795.04	79.96	Apr-Jun,1996
6404F01	2520552.84395	304517.01911	1870	1808.70	61.30	Apr-Jun,1996
6404N01	2518989.91563	301392.94071	1865	1802.00	63.00	Apr-Jun,1996
7205C01	2450229.22059	335033.13226	2180	2172.83	7.17	Apr-Jun,1996
7212J02	2475150.77384	328099.32120	2145	2068.57	76.43	Apr-Jun,1996
7224R01	2475797.67115	315776.09373	1960	1907.12	52.88	Apr-Jun,1996
7304N01	2485664.37438	335122.98133	2010	1722.57	287.43	Apr-Jun,1996
7305C03	2479522.54809	336446.78657	2040	1825.00	215.00	Apr-Jun,1996
7312P01	2503519.30780	328556.75140	1895	1701.10	193.90	Apr-Jun,1996
7314C01	2498325.25020	326950.63047	1850	1681.60	168.40	Apr-Jun,1996
7315F02	2494007.83954	324238.08979	1847	1686.04	160.96	Apr-Jun,1996
7317E01	2482420.69521	323986.00839	1995	1962.79	32.21	Apr-Jun,1996
7319R01	2480769.25862	316043.52802	1900	1845.65	54.35	Apr-Jun,1996
7320K01	2483968.15505	317132.87063	1970	1890.29	79.71	Apr-Jun,1996
7321C02	2488667.32817	321086.82247	1680	1665.53	14.47	Apr-Jun,1996
7321C01	2488173.12652	320717.16224	1740	1665.35	74.65	Apr-Jun,1996
7324B01	2504939.75809	321483.67426	2050	2027.99	22.01	Apr-Jun,1996
7326N01	2497633.96673	311412.61495	1900	1704.10	195.90	Apr-Jun,1996
7327J01	2495354.34402	313241.07630	1825	1693.23	131.77	Apr-Jun,1996
7407P02	2509092.11698	328101.68891	2030	1987.60	42.40	Apr-Jun,1996
7420A	2516827.73229	321898.67289	2330	2313.19	16.81	Apr-Jun,1996
7427F01	2525933.87229	315757.37771	2010	1941.40	68.60	Apr-Jun,1996
7432L01	2515191.11742	309109.91359	1985	1939.20	45.80	Apr-Jun,1996
7433P01	2522004.48474	274068.17966	1840	1812.90	27.10	Apr-Jun,1996
8222Q01	2462106.98338	346859.81192	2030	1972.60	57.40	Apr-Jun,1996
8225C01	2471782.35554	345974.98021	2035	1974.80	60.20	Apr-Jun,1996
8332G01	2483937.94495	340159.85950	2055	1958.92	96.08	Apr-Jun,1996
8333E02	2485446.90342	340146.33417	1950	1892.94	57.06	Apr-Jun,1996
8335B01	2498522.96514	343292.08215	1875	1818.55	56.45	Apr-Jun,1996
8419P01	2507714.35342	348955.24227	1930	1888.18	41.82	Apr-Jun,1996
8429R01	2515434.26155	346099.97193	2330	2003.46	326.54	Apr-Jun,1996

TABLE 5.9

Groundwater Monitoring Wells with Snapshot Data (CH2MHill, 1998)

WELL_ID	X_WSP_N	Y_WSP_N	STATE	DEPTH	WL_DATE_1994	GW_ELEV_(FT_USGS)_1994	WL_DATE_1995	GW_ELEV_(FT_USGS)_1995
6306H01	2480633.55436	303449.29758	WA	136	09/13/94	1595.79	04/12/95	1597.37
6221K01	2459165.00111	285531.13365	WA	121	09/12/94	1599.72	04/11/95	1603.74
6221C05	2458422.24951	288881.21984	WA	100	09/12/94	1600.2	04/11/95	1604.04
6221D04	2456624.67884	287803.51209	WA	66	09/12/94	1600.38	04/11/95	1604.03
6227F01	2463540.48767	280265.60924	WA	126	09/13/94	1612	04/11/95	1625.77
6219A01	2449413.12751	286934.63989	WA	303	09/13/94	1615.5	04/11/95	1619.55
6234N03	2462612.85380	274358.61628	WA	71	09/16/94	1627.75	04/13/95	1632.03
5203H02	2467934.04718	271449.02318	WA	121	09/13/94	1645.43	04/13/95	1655.01
5203Q01	2464043.00333	269196.60314	WA	217	09/13/94	1645.46	04/11/95	1654.57
5203H01	2467040.02639	271904.00751	WA	124	09/15/94	1647.27	04/13/95	1647.15
5214C02	2469513.36983	261746.16664	WA	140	09/16/94	1677.77	04/13/95	1684.34
5214J01	2471742.42241	260437.40298	WA	160	09/16/94	1685.89	04/13/95	1692.82
5223B01	2470498.51932	257893.14543	WA	59	09/15/94	1687.61	04/13/95	1697.87
5213B01	2475681.88644	262521.48578	WA	208	09/14/94	1690.92	04/12/95	1700.37
6307G04	2480035.94737	299133.10287	WA	200	09/14/94	1700.56	04/12/95	1706.02
6308C02	2483172.01290	300699.81536	WA	< 100	09/13/94	1711.02		
6303N01	2492500.42008	301126.99293	WA	180	09/13/94	1742.47	04/12/95	1745.22
6318B01	2480195.91182	294049.87330	WA	282	09/13/94	1745.35	04/12/95	1748.58
5307M01	2478271.06370	266319.84038	WA	254	10/07/94	1748.1	04/11/95	1767.41
6309N01	2488446.59258	296922.28797	WA	< 175	09/13/94	1760.59	04/12/95	1761.24
6317J01	2486018.91452	292871.77569	WA	248	09/14/94	1776.27	04/12/95	1779.04
6316Q01	2490704.26483	293559.65267	WA	165	09/13/94	1787.68	04/12/95	1788.43
6319A02	2482012.94165	289743.43531	WA	228	09/14/94	1792.14	04/12/95	1796.99
6320D01	2480709.85625	289940.36253	WA	286	09/14/94	1792.58	04/12/95	1797.82
6310K01	2495380.36257	298083.63912	WA	116	09/13/94	1803.58	04/12/95	1815.58
6321J01	2490180.49499	287466.83815	WA	238	09/14/94	1815.53	04/12/95	1820.04
6330H02	2481302.37178	282901.91114	WA	310	09/15/94	1825.83	04/12/95	1837.58
6322N03	2492989.89751	285259.59546	WA	275	09/14/94	1830.63	04/12/95	1835.89
6331A02	2481870.91529	278325.18267	WA	272	09/15/94	1832.82	04/11/95	1845.98
6328M02	2487861.74711	282105.72267	WA	250	09/14/94	1836.14	04/12/95	1842.14
6330P03	2478623.67976	279486.40351	WA	234	09/15/94	1839.03	04/12/95	1845.98
6327H01	2498353.08362	281256.76151	WA	225	09/15/94	1848.6	04/12/95	1856.23
6331J01	2483412.48121	275612.36375	WA	222	09/13/94	1849.6	04/11/95	1856.72
5304B01	2490873.08798	274428.33289	WA	231	09/15/94	1851.87	04/11/95	1862.82
5304B02	2490873.08798	274428.33289	WA	216	09/15/94	1853.57	04/11/95	1862.28
5308A02	2487089.24771	268156.31067	WA	126	09/15/94	1854.37	04/11/95	1862.19
5308D01	2484242.94029	267804.76561	WA	77	09/13/94	1856.43	04/13/95	1862.88
5304G01	2492115.02195	272370.47073	WA	195	09/21/94	1857.04	04/11/95	1864.92
5308A01	2487334.24888	268152.31408	WA	124	09/15/94	1858.38	04/11/95	1866.03
5309E04	2488310.92123	267534.29739	WA	101	09/14/94	1859.57	04/11/95	1866.94
5304R01	2493520.39468	270642.18475	WA	185	09/14/94	1861.08	04/11/95	1869.21
5322F01	2495575.59669	256578.47969	WA	77	09/15/94	1863.45	04/12/95	1875.68
5316K01	2491965.57144	260684.98269	WA	65	09/15/94	1864.55	04/12/95	1871.96
5316R01	2494049.68276	260081.49448	WA	100	09/12/94	1866.13	04/12/95	1874.21
5310P02	2495260.65352	264712.27558	WA	96	09/15/94	1869.2	04/13/95	1876.85
5311E01	2499656.25387	268452.82765	WA	80	09/15/94	1870.77	04/11/95	1878.77
5311N01	2500025.81677	265454.27662	WA	70	09/13/94	1870.98	04/12/95	1878.17
5314E01	2499166.88297	262536.61178	WA	211	09/12/94	1872.05	04/11/95	1881.28
5311G01	2502193.07466	267756.50312	WA	46.7	09/14/94	1872.55	04/13/95	1881.39
5311G06	2502864.31115	268229.52820	WA		09/15/94	1872.67	04/13/95	1881.44
5322A02	2499279.66504	257859.94989	WA	79	09/16/94	1873.13	04/12/95	1881.83
5322A01	2499118.89036	257862.86808	WA	62	09/16/94	1873.15	04/12/95	1881.85
5322A03	2499217.27102	257857.61838	WA	103	09/16/94	1873.18	04/12/95	1881.87
5311H01	2502237.62669	267857.86883	WA	< 100	09/14/94	1873.65	04/12/95	1882.16
5314Q01	2502737.97330	260693.29782	WA	< 120	09/12/94	1876.8	04/11/95	1886.09
5311R01	2503428.38516	265978.98377	WA	104	09/13/94	1877.62	04/11/95	1887.12
5311J05	2504030.99681	266569.26971	WA	80	09/16/94	1878.04	04/12/95	1887.44
5312E01	2505571.04053	267292.76794	WA	103	09/14/94	1879.69	04/13/95	1888.58
5313E01	2504827.64895	261968.00430	WA	81	09/12/94	1880.67	04/11/95	1890.17
5312L03	2505699.46743	265992.68970	WA	90	09/12/94	1881.27	04/11/95	1890.87
5324G01	2508653.66880	257170.61074	WA	147	09/13/94	1882.46	04/12/95	1892.43

TABLE 5.9

Groundwater Monitoring Wells with Snapshot Data (CH2MHill, 1998)

WELL_ID	X_WSP_N	Y_WSP_N	STATE	DEPTH	WL_DATE_1994	GW_ELEV_(FT_USGS)_1994	WL_DATE_1995	GW_ELEV_(FT_USGS)_1995
5312C01	2505617.57511	267908.47120	WA	80	09/14/94	1883.82	04/12/95	1892.93
5312H01	2509307.27225	268521.88185	WA	96	09/13/94	1887.35	04/11/95	1897.01
5418F01	2512052.81181	262648.24743	WA	110	09/15/94	1889.26	04/11/95	1899.1
5409E01	2520577.34695	268739.12983	WA	141	09/14/94	1890.89	04/11/95	1901.25
5406J03	2511221.50286	273621.21332	WA	180	09/13/94	1892.49	04/11/95	1902.74
5406A02	2513778.74754	274540.35514	WA	160	09/13/94	1893.58	04/11/95	1904.66
5407R01	2514579.95572	266535.29797	WA	120	09/13/94	1893.74	04/10/95	1904.04
6432Q02	2516967.82531	275735.13532	WA	139	09/13/94	1897.49	04/11/95	1907.99
5417M01	2515721.43601	261197.43489	WA	114	09/14/94	1898.6	04/11/95	1909.21
5408B01	2515993.42094	270384.35456	WA	120	09/13/94	1899.18	04/11/95	1909.15
5404K03	2523631.32026	272766.82218	WA	< 40	09/13/94	1900.16	04/11/95	1910.73
5404Q01	2525218.46922	271287.82455	WA	< 125	09/12/94	1905.31	04/11/95	1913.98
5416E01	2521032.46020	262788.89477	WA	128	09/14/94	1906.06	04/11/95	1917.16
5409Q01	2524676.54693	266989.12114	WA	< 125	09/13/94	1910.46	04/10/95	1921.64
5421N01	2521944.84287	255138.13275	WA	183	09/13/94	1910.77	04/11/95	1922.28
5428M02	2521856.67801	251513.16808	WA	160	09/13/94	1911.94	04/11/95	1923.95
5428P01	2522261.93703	250206.96353	WA	167	09/13/94	1912.75	04/11/95	1925.45
5415E01	2525578.39591	263432.86282	WA	158	09/14/94	1914.55	04/11/95	1925.49
5421J01	2525815.48972	257628.58231	WA	122	09/14/94	1915.19	04/11/95	1926.4
5428R01	2526190.79988	249977.00325	WA	132	09/14/94	1916.87		
5422R01	2531236.18900	255547.75223	WA	257	09/15/94	1919.72	04/11/95	1931.22
5426D01	2532058.79258	255259.23628	WA	170	09/15/94	1920.21	04/11/95	1931.74
5426L01	2533722.56142	252678.49808	WA	163	09/15/94	1920.97	04/11/95	1932.94
5411J01	2531155.12012	270166.53679	WA	85	09/13/94	1921.16	04/11/95	1927.8
5411N02	2531280.61897	265934.89631	WA	176	09/14/94	1922.08	04/10/95	1933.38
5423C01	2532595.78211	260022.63850	WA	97	09/15/94	1922.45	04/11/95	1933.61
5402N01	2531140.49217	271640.56403	WA	< 125	09/13/94	1923.35	04/11/95	1932.12
5423J03	2535791.65974	258049.58725	WA	210	09/15/94	1923.41	04/11/95	1935.11
5403B01	2527606.97653	275468.17453	WA	120	09/12/94	1925.09	04/11/95	1932.86
5411G01	2534246.36227	269624.48814	WA	< 125	09/13/94	1928.45	04/11/95	1938.59
5414J01	2535716.78303	263154.80312	WA	265	09/15/94	1928.5	04/11/95	1938.57
5402R01	2535120.94932	271783.41045	WA	< 125	09/13/94	1929.55	04/11/95	1940.32
5402B01	2534240.06969	275362.76908	WA	236	09/13/94	1930.05	04/11/95	1941.27
5412M01	2536057.56461	267372.04097	WA	< 150	09/12/94	1930.8	04/10/95	1942.34
5401D01	2535553.09496	275521.69608	WA	159	09/13/94	1931.83	04/11/95	1943.51
5401R01	2539719.02372	271899.34128	WA	150	09/12/94	1936.49	04/11/95	1948.51
5506D02	2540820.64639	276324.43811	WA	177	09/12/94	1938.35	04/11/95	1951.27
5517Q01	2550083.19574	261478.73562	WA	287	09/12/94	1941.62	04/10/95	1954.02
5516C01	2554976.91702	266365.20717	WA	129	09/12/94	1944.05	04/10/95	1956.42
5517D04	2547628.11055	266603.42472	WA	229	09/14/94	1944.25		
6532J02	2550990.14928	280325.51112	WA	152	09/12/94	1947.05	04/11/95	1959.84
5509B02	2554743.99944	271281.10680	WA	147	09/12/94	1947.42		
5503N01	2557969.23618	273902.99408	WA	138	09/12/94	1949.3	04/11/95	1961.78
5511M01	2564961.49279	268903.17326	WA	186	09/12/94	1949.38	04/10/95	1961.88
5515R01	2561481.49329	261938.38803	WA	155	09/12/94	1949.47	04/10/95	1970.49
5503D02	2556773.98299	277652.25056	WA	137	09/12/94	1949.52	04/12/95	1961.92
5510F01	2559487.74015	270984.36281	WA	85	09/14/94	1949.89	04/10/95	1962.34
5514F01	2564394.56736	265998.22675	WA	238	09/12/94	1950.45	04/10/95	1963.89
5511G01	2563387.21097	270009.17052	WA	< 150	09/12/94	1950.7	04/10/95	1963.68
6536N02	2566943.88164	278712.47703	WA	< 150	09/12/94	1955.85	04/11/95	1968.15
5501H03	2570332.09163	276321.76178	WA	165	09/12/94	1956.82	04/11/95	1969.42
6526H03	2566591.64835	286525.49703	WA	< 150	09/12/94	1958.42	04/11/95	1970.89
6619N01	2571755.12277	288728.03064	WA	263	09/12/94	1963.17	04/11/95	1976.04
6525J01	2571844.11757	287923.38255	WA	190	09/12/94	1964.52	04/11/95	1976.48
5311J06	2504030.99681	266569.26971	WA	98			04/12/95	-61.22
5311J07	2504030.99681	266569.26971	WA	120			04/12/95	-60.85
5313K01	2508932.98560	260933.12642	WA	125	09/16/94		04/10/95	1894.62
6331A03	2481870.91529	278325.18267	WA	272	09/15/94		04/11/95	1846.82

Groundwater Monitoring Wells with Snapshot Data (CH2MHill, 2000)

WELL_	WELL_NAME	X_WSP_N	Y_WSP_N	STATE	WL_DATE_ 1996	REF_ELEV_ (CITY)	GW_ELEV_ (CITY)	GW_ELEV_ (FT_USGS)
1625H0	Yung	2577550.04563	291822.88643	ID	10/30/96	2125.07	2001.51	1984.58
0606Q0	Jacklin Seed	2581597.25116	279685.01808	ID	10/30/96	2129.34	2002.34	1985.41
1534B03	City of Post Falls #5	2596324.37145	290905.02924	ID	10/30/96	2246.12	2015.62	1998.69
1533E01	Schneidmiller(USGS)	2589533.27359	288114.64295	ID	10/30/96	2160.26	2008.13	1991.20
1531Q0	Greenacres Plant Food Ctr. #1	2581747.16034	284749.31779	ID	10/30/96	2146.97	2003.09	1986.16
1531E01	Beck, Don #1	2578062.13508	287542.40596	ID	10/30/96	2123.86	2000.87	1983.94
1530N0	POE Asphalt	2577779.88138	290138.69497	ID	10/30/96	2127.88	2001.49	1984.56
1528R03	East Greenacres ID #3C	2593100.22651	292047.68411	ID	10/30/96	2170.96	2012.21	1995.28
1528N0	East Greenacres ID #1C	2588630.21068	291112.62576	ID	10/30/96	2164.42	2009.37	1992.44
1527F01	Guy	2594766.00578	293847.00346	ID	10/30/96	2176.59	2013.49	1996.56
1522D02	East Greenacres ID #2B	2593071.16997	300770.69202	ID	10/30/96	2180.23	2015.28	1998.35
1521M0	Wolkenhaur	2588464.89855	297022.41336	ID	10/30/96	2156.39	2011.59	1994.66
1519K02	Hauser Lake Water Assoc. #1	2580072.00645	296670.45646	ID	10/30/96	2146.78	2006.61	1989.68
6631M0	Spokane County (SAJB MW#3)	2572296.74657	280712.64247	WA	10/30/96	2112.72	1994.22	1977.29
6619N0	Spokane County (208) Idaho Rd	2571755.08707	288728.01784	WA	10/30/96	2120.65	1994.23	1977.30
6536N02	Boshears	2566943.87684	278712.48672	WA	10/30/96	2086.38	1984.18	1967.25
6532J02	Schmidt	2550990.12768	280325.51452	WA	10/30/96	2115.72	1973.57	1956.64
6526H0	Pentler	2566591.62465	286525.46743	WA	10/30/96	2083.57	1987.38	1970.45
5517Q0	Spokane Gun Club	2550083.16174	261478.71272	WA	10/30/96	2062.95	1966.42	1949.49
5517D05	Spokane County (SAJB MW#1)	2547867.12523	266405.54148	WA	10/30/96	2058.29	1970.42	1953.49
5516C01	Inland Empire Paper	2554976.86802	266365.24967	WA	10/30/96	2073.36	1969.48	1952.55
5515R01	Liberty Lake Sewer District (Sprague)	2561481.48049	261938.34523	WA	10/30/96	2090.25	1977.49	1960.56
5514F01	Liberty Lake Sewer District (Schultz)	2564394.56276	265998.22595	WA	10/30/96	2160.83	1977.28	1960.35
5511M0	Kennert (North Well)	2564961.51989	268903.13936	WA	10/30/96	2127.41	1974.91	1957.98
5511G0	Bryant Motors	2563387.16787	270009.19191	WA	10/30/96	2074.00	1977.60	1960.67
5510F01	Delp	2559487.77185	270984.37631	WA	10/30/96	2040.47	1976.37	1959.44
5507A04	Spokane County (SAJB MW#2)	2546101.58964	271765.18247	WA	10/30/96	2044.08	1970.73	1953.80
5506D02	Borjessan	2540820.59859	276324.42091	WA	10/30/96	2081.61	1963.21	1946.28
5503N0	Coen	2557969.18708	273903.02817	WA	10/30/96	2065.11	1976.40	1959.47
5503D02	Otis Orchards School	2556773.99329	277652.28836	WA	10/30/96	2075.75	1976.55	1959.62
5501H0	Washington State Patrol	2570332.08893	276321.78918	WA	10/30/96	2067.92	1985.74	1968.81
5414J01	Vera Water and Power (#2 Test)	2535716.74313	263154.79092	WA	10/30/96	2061.20	1949.27	1932.34
5412M0	Central PreMix	2536057.57081	267371.99457	WA	10/30/96	2015.00	1953.48	1936.55
5401R01	Spokane Industrial Park #4	2539719.05932	271899.29508	WA	10/30/96	2034.94	1960.34	1943.41
5401D0	Trentwood ID #5	2535553.10796	275521.66738	WA	10/30/96	2068.47	1954.79	1937.86

TABLE 5.11

Groundwater Monitoring Wells with Snapshot Data (USGS, 2000)

WELL_ID	X_WSP_N	Y_WSP_N	GW_ELEV _(USGS)_ MAR_2000	GW_ELEV _(USGS)_ AUG_2000
25N44E01BBCC01	2535648.50236	275495.82209	1944.45	
25N44E01CBBA01	2536796.22980	273800.94758		
25N44E01DBDD01	2539598.20111	272998.97084		
25N44E01DCDD01	2539728.44688	271606.52780	1951.63	1947.34
25N44E11DDAC01	2535731.38015	267067.88145	1940.17	1932.11
25N44E11DDAD01	2535679.20837	266919.34577	1940.31	1932.62
25N44E11DDDD01	2536064.59531	266280.25544		1931.75
25N44E12BBBD01	2536415.83680	270898.06261		
25N44E12CBCD01	2536629.86914	267782.29987	1949.25	1943.66
25N44E12CCAB01	2536958.04144	267414.40022	1947.87	1940.64
25N44E12DABB01	2540185.37425	268944.18078	1952.78	1948.30
25N44E24BDAA01	2538914.25272	259345.42927	1943.61	
25N45E01ABDD01	2570961.65537	277260.96058		1976.58
25N45E01ABDD02	2570961.65537	277260.96058		1981.91
25N45E01ABDD03	2570924.00994	277123.98337		1976.78
25N45E01ACAD01	2570770.60406	276583.24089		1976.10
25N45E01ADBB01	2571161.85401	276799.68683	1975.62	1973.83
25N45E01ADCD01	2571620.74261	275741.24292		
25N45E01BBAA01	2568347.49930	277979.89778	1976.28	1974.74
25N45E01CBBD01	2567790.58256	275005.40804		2000.02
25N45E01CBBD02	2567790.58256	275005.40804		2016.88
25N45E01CBBC01	2567461.59866	275076.94313		1988.67
25N45E02AACD01	2565023.20662	275476.27372		
25N45E02DDDD01	2567139.08600	273001.40729		
25N45E03BDDA01	2559165.36740	275618.34090		1966.84
25N45E03BDDA02	2559044.09976	275729.31815		
25N45E03CBDD01	2557960.15189	273777.73561	1964.69	
25N45E03CDDA01	2559365.23557	273075.32464		1966.94
25N45E03CDDD01	2559212.34576	272516.45908		1966.39
25N45E04BAAC02	2553516.41231	276955.50410		
25N45E05BBBC01	2545967.78324	276541.74211		1953.70
25N45E05DDBA01	2550551.69290	273190.05832	1962.61	1959.63
25N45E06BBCA01	2541147.30437	276249.66500	1955.11	1951.51
25N45E07AAAA02	2546070.66865	271813.88785		
25N45E07AAAA04	2546135.17886	271857.14387	1955.05	1951.92
25N45E07ADDD01	2546403.11765	269452.44925	1955.06	1952.64
25N45E08BDAA01	2548810.13876	270429.60463	1960.50	1957.47
25N45E08CBBC01	2546637.82024	268722.35768	1954.72	1951.21
25N45E08CBBC02	2546566.42094	268616.68962	1953.63	1950.33
25N45E09ABCD01	2554901.62445	271193.92067	1962.44	1959.00
25N45E09ADAB01	2556499.17266	270745.26966		1970.04
25N45E09ADAD01	2556848.95402	270448.12988		1967.42
25N45E10BAAA01	2559282.91420	272180.25210		1989.18
25N45E10BAAA02	2559280.42342	272282.38594		1981.18
25N45E10BAAA03	2559266.91510	272205.03931		
25N45E10BDAD01	2559461.00146	270797.50097	1957.66	1955.63
25N45E10CBDA01	2558058.82085	268790.31326		1964.82
25N45E10DBCB01	2559816.94120	268952.28283	1968.58	1966.43
25N45E11CCAA01	2563371.90218	268683.32782	1969.86	1967.09
25N45E14BACD01	2564474.85254	266096.72205	1970.30	
25N45E14CABB01	2564283.90487	264498.78872	1973.95	

TABLE 5.11

Groundwater Monitoring Wells with Snapshot Data (USGS, 2000)

WELL_ID	X_WSP_N	Y_WSP_N	GW_ELEV _(USGS)_ MAR_2000	GW_ELEV _(USGS)_ AUG_2000
25N45E14CCDD01	2563802.15047	262083.24386		
25N45E15BADA01	2559529.98853	266276.07945	1963.54	
25N45E15BADC01	2559230.88870	265932.89108	1962.06	
25N45E15DDCC01	2561463.50267	261973.04317	2014.24	
25N45E16ACAB01	2555274.05481	265525.88263		
25N45E17BBAA01	2547777.78551	266549.32118		
25N45E17BBAA05	2547852.64484	266479.87100	1954.86	1951.80
25N45E17CDDD01	2549407.39019	261631.72767		
25N45E17DCCB01	2549816.75376	261790.14558	1956.96	1953.56
25N45E18DDCB01	2545735.35644	261802.80859		
25N45E23BBAA01	2563846.50796	261983.15045	1971.09	
25N46E06BBCB01	2572451.76337	277542.44526	1978.90	1977.80
25N46E06BCDD01	2573796.78628	275815.54599	1985.43	1984.98
25N46E06CBBD01	2573052.58215	275055.75207		
25N46E06CCDD01	2573910.46967	273209.90486	1987.23	1987.73
25N46E07BCAC01	2573822.37270	271445.25341		
25N46E07BCAD01	2573710.72391	271158.53880	1988.05	1988.88
25N46E07BCDA01	2573952.11121	270914.79236		
25N46E07CACC01	2574094.10981	269935.72918		
26N45E24DDDA01	2571652.28290	289324.88040	1959.24	1957.50
26N45E25ABBC01	2569459.23917	288424.54562		
26N45E25BAAA01	2568966.67204	288670.61363	1981.87	
26N45E25BAAA02	2568937.66595	288709.36251		
26N45E25BCCC01	2566667.83479	286253.47579	1979.43	1977.64
26N45E25CCAC01	2567563.39616	284321.58665	1980.34	1978.83
26N45E25CCBB01	2566912.62823	284424.83492	1969.61	
26N45E25DAAB01	2571526.30032	285977.02180	1979.61	
26N45E25DAAC01	2571280.84034	285756.77458	1984.61	1983.37
26N45E25DAAC02	2571302.07023	285776.07953	1979.30	
26N45E25DDAA01	2571898.30169	284728.05989	1979.82	1979.39
26N45E26ACDD01	2565039.91124	286334.53387		
26N45E27CBAC01	2556644.11249	284965.61341		
26N45E27CBDA01	2556973.83560	284568.91359		
26N45E27CBDA02	2556988.34900	284828.90473		
26N45E32ADAA01	2550832.91682	281080.68587	1965.48	
26N45E32DBDA01	2549681.74660	279082.54362	1960.50	
26N45E32DCBC01	2548681.45154	278044.85869	1962.12	1959.05
26N45E32DCCD01	2549074.46587	277355.26070	1959.88	
26N45E33ACAB01	2554259.78853	281318.89717		
26N45E34CADB01	2558483.88938	279704.67936	1961.90	
26N45E34CADB02	2558455.99893	279568.20415		
26N45E35BDBD03	2563333.03437	281415.93897		
26N46E31CBBC01	2572339.79159	280867.63186	1978.15	1977.60
26N46E31DBAD03	2572240.38125	280683.78460		
50N04W05CBAA01	2616408.17981	283396.00986		
50N04W06BADA01	2612269.14005	285312.36415		
50N05W01ACBB01	2607406.28383	284288.88829	2050.46	
50N05W01CBBB01	2604667.49685	282936.52026		
50N05W04ACDA01	2592387.44926	282862.58604		
50N05W04CACB01	2590327.37537	281473.46308	2014.02	

Groundwater Monitoring Wells with Snapshot Data (USGS, 2000)

WELL_ID	X_WSP_N	Y_WSP_N	GW_ELEV _(USGS)_ MAR_2000	GW_ELEV _(USGS)_ AUG_2000
50N05W04CABD01	2590443.84420	282001.58277		
50N05W04CACC02	2590241.89609	281260.99390	1996.98	1997.48
50N05W06DCDC01	2581598.57147	279682.36884	1992.82	
50N05W07ADDD01	2583334.30443	277106.32336	1994.80	
50N05W07BCCC01	2578377.05031	276933.06837	1987.70	1987.63
50N05W07CBBD01	2578471.39955	276273.05462		
50N05W07DABC01	2582555.31043	276161.79327		2009.95
50N05W07DABC02	2582558.59791	276194.82649		
50N05W07DBBA01	2581250.98262	276557.09220	2055.83	2047.53
50N05W07DBBA02	2580124.38154	277297.29893		
50N05W07DCCB01	2580835.50759	274695.75704		
50N05W08BBBB01	2583699.54586	279524.01076		
50N05W10BAAA01	2596609.73387	279748.21635		
50N05W12BBBD02	2605300.56758	279948.25411	1999.87	
50N05W12BBAB01	2605652.96843	280145.19195		
50N05W12BBBD01	2605130.78599	280038.21356		
50N05W12BBDA01	2605762.68252	279734.41376		
50N05W12BBDA02	2605803.37477	279758.40385		
50N05W12BCAD01	2605851.55828	278668.79240	2014.60	
50N05W12BCDA01	2606065.78004	278336.39467	2067.21	
50N05W12CCCC01	2605186.91757	275453.66321		
50N06W12BDAC01	2575029.69494	277213.04980		
50N06W12CABA01	2574789.09977	276193.19071		
50N06W12CACA01	2574913.08027	275479.84644	1986.68	1986.33
50N06W12CBDB01	2574015.50017	275530.51192	1986.84	1986.56
50N06W12CCAD01	2574359.44066	274506.62985	1982.81	
50N06W12CCAD02	2574271.66956	274586.29813	1986.71	
50N06W12DBAD01	2576989.17607	275980.53154	1987.33	1986.76
50N06W12DBCD01	2576288.47155	275390.75365	1986.77	1986.65
50N06W12DCDD01	2577122.15253	274040.52890		
50N06W12DDAB01	2578001.68301	275103.01300	1987.32	1987.46
50N06W12DDCD01	2577733.77112	274238.79928	1987.51	1982.46
50N06W12DDDB02	2577987.65247	274539.88966	1987.26	1986.68
50N06W13ACDB01	2576648.90376	271891.58596		
50N06W13CAAD01	2575913.63798	270799.78255		
50N06W13CABA01	2575293.26687	271075.91871	1988.40	1989.54
51N04W20CBCD01	2614459.27144	298256.23612	2005.32	
51N05W19DBC3	2580073.96817	296669.52938		
51N05W26AAA1	2603507.77341	296026.07463		
51N05W26BBDA01	2599794.28994	295026.47928		
51N05W27DCCC01	2596314.59440	290905.75095		
51N05W28DAD1	2593095.49578	292149.47143		
51N05W31BCCB01	2577872.06259	287670.90439	1992.35	1991.90
51N06W36DAAA01	2577506.85576	286984.46853	1991.19	1991.03
51N06W36DDAA01	2577684.10159	285495.87119	1987.33	
25N44E12CCDC01	2536888.46404	266279.06598		

TABLE 5.12

Groundwater Monitoring Wells with Extended Periods of Record

WELL_ID	WELL_NAME	DATA_SOURCE	DATA_TYPE	DATA_RES	POR_DATES	POR_YRS	AQUIFER	X_WSP_N	Y_WSP_N	STATE
0507J01	USGS_15	SPOKANE_CO2001	WL_HYDRO	RANDOM	6/2000-3/2001	<1	E_SVRP	2582555.31043	276161.79327	ID
0507J02	USGS_15	SPOKANE_CO2001	WL_HYDRO	RANDOM	6/2000-3/2001	<1	E_SVRP	2582558.59791	276194.82649	ID
5202E01	CITY_WWTP	SPOKANE_CO2001	WL_HYDRO	DAILY_AVG	1/1995-1/2001	1-10	W_SVRP	2467934.04718	271449.02318	WA
5304G01	CITY_NE_COMMUNITY	SPOKANE_CO2001	WL_HYDRO	DAILY_AVG	1/1995-1/2001	1-10	W_SVRP	2492115.02191	272370.47069	WA
5307M01	CITY_TRINITY	SPOKANE_CO2001	WL_HYDRO	DAILY_AVG	3/1995-1/2001	1-10	W_SVRP	2478271.06371	266319.84041	WA
5308H01	CITY_MARIETTA	SPOKANE_CO2001	WL_HYDRO	DAILY_AVG	11/1994-10/2000	1-10	W_SVRP	2488310.92127	267534.29735	WA
5309M04	AVISTA_MISSION	SPOKANE_CO2001	WL_HYDRO	WEEKLY	12/1998-7/1999	<1	W_SVRP	2499839.13009	269122.27885	WA
5311D03	UPRIVER_GREENHOUSE	SPOKANE_CO2001	WL_HYDRO	WEEKLY	12/1998-7/1999	<1	W_SVRP	2499183.73683	266719.12921	WA
5311E03	AVISTA_BEACON	SPOKANE_CO2001	WL_HYDRO	WEEKLY	12/1998-7/1999	<1	W_SVRP	2502956.20628	268084.58939	WA
5311H01	UPRIVER_USGS	SPOKANE_CO2001	WL_HYDRO	WEEKLY	12/1998-7/1999	<1	W_SVRP	2488927.65849	264467.70504	WA
5311J07	CITY_HALES	SPOKANE_CO2001	WL_HYDRO	DAILY_AVG	11/1994-11/1999	1-10	W_SVRP	2504030.99680	266569.26975	WA
5312C01	CITY_FELTS_FIELD	SPOKANE_CO2001	WL_HYDRO	DAILY_AVG	11/1994-1/2001	1-10	W_SVRP	2505617.57510	267908.47122	WA
5314E01	CITY_CENTRAL_PREMIX	SPOKANE_CO2001	WL_HYDRO	DAILY_AVG	12/1994-1/2001	1-10	W_SVRP	2499166.88296	262536.61183	WA
5322A03	CITY_THIRD_HAVANNA	SPOKANE_CO2001	WL_HYDRO	DAILY_AVG	12/1994-1/1999	1-10	W_SVRP	2499279.66501	257859.94993	WA
5411R02	SULLIVAN_N(SULLIVAN_N_1)	SPOKANE_CO2001	WL_HYDRO	DAILY_AVG	11/1998-9/2000	1-10	C_SVRP	2535679.20837	266919.34577	WA
5411R03	SULLIVAN_S(SULLIVAN_N_2)	SPOKANE_CO2001	WL_HYDRO	DAILY_AVG	11/1998-9/2000	1-10	C_SVRP	2535731.38015	267067.88145	WA
5411R04	SULLIVAN_S	SPOKANE_CO2001	WL_HYDRO	DAILY_AVG	11/1998-9/2000	1-10	C_SVRP	2536064.59531	266280.25544	WA
5412M01	CENTRAL_PREMIX	SPOKANE_CO2001	WL_HYDRO	WEEKLY	12/1998-7/1999	<1	C_SVRP	2536629.86914	267782.29987	WA
5414J01	VERA_2	SPOKANE_CO2001	WL_HYDRO	WEEKLY	1/1967-12/2000	1-10	C_SVRP	2535716.78300	263154.80313	WA
5415J01	VERA_1	SPOKANE_CO2001	WL_HYDRO	WEEKLY	1/1967-12/2000	20-50	C_SVRP	2530783.66572	262549.97788	WA
5422H02	VERA_6	SPOKANE_CO2001	WL_HYDRO	WEEKLY	1/1967-12/2000	20-50	C_SVRP	2530890.84168	258624.70707	WA
5422R01	VERA_3	SPOKANE_CO2001	WL_HYDRO	WEEKLY	1/1967-12/2000	20-50	C_SVRP	2531236.18898	255547.75226	WA
5423C01	VERA_7	SPOKANE_CO2001	WL_HYDRO	MONTHLY	5/1967-12/2000	20-50	C_SVRP	2532595.78208	260022.63853	WA
5423J03	VERA_8	SPOKANE_CO2001	WL_HYDRO	MONTHLY	5/1987-12/2000	1-10	C_SVRP	2535791.65976	258049.58721	WA
5426D01	VERA_5	SPOKANE_CO2001	WL_HYDRO	WEEKLY	1/1967-12/2000	20-50	C_SVRP	2532058.79259	255259.23632	WA
5426L01	VERA_4	SPOKANE_CO2001	WL_HYDRO	WEEKLY	1/1967-12/2000	20-50	C_SVRP	2533722.56138	252678.49810	WA
5501B01	USGS_1	SPOKANE_CO2001	WL_HYDRO	RANDOM	6/2000-3/2001	<1	E_SVRP	2570961.65537	277260.96058	WA
5501B02	USGS_2	SPOKANE_CO2001	WL_HYDRO	RANDOM	6/2000-3/2001	<1	E_SVRP	2570961.65537	277260.96058	WA
5501B03	USGS_3	SPOKANE_CO2001	WL_HYDRO	RANDOM	6/2000-3/2001	<1	E_SVRP	2570924.00994	277123.98337	WA
5501G01	USGS_4	SPOKANE_CO2001	WL_HYDRO	RANDOM	6/2000-3/2001	<1	E_SVRP	2570770.60406	276583.24089	WA
5501M01	USGS_9	SPOKANE_CO2001	WL_HYDRO	RANDOM	6/2000-3/2001	<1	E_SVRP	2567790.58256	275005.40804	WA
5501M02	USGS_8	SPOKANE_CO2001	WL_HYDRO	RANDOM	6/2000-3/2001	<1	E_SVRP	2567790.58256	275005.40804	WA
5501M03	USGS_10	SPOKANE_CO2001	WL_HYDRO	RANDOM	6/2000-3/2001	<1	E_SVRP	2567461.59866	275076.94313	WA
5503F04	USGS_13	SPOKANE_CO2001	WL_HYDRO	RANDOM	6/2000-3/2001	<1	E_SVRP	2559165.36740	275618.34090	WA
5503P01	USGS_7	SPOKANE_CO2001	WL_HYDRO	RANDOM	6/2000-3/2001	<1	E_SVRP	2559365.23557	273075.32464	WA
5503P02	USGS_17	SPOKANE_CO2001	WL_HYDRO	RANDOM	6/2000-3/2001	<1	E_SVRP	2559212.34576	272516.45908	WA
5505D01	TRENT_BARKER	SPOKANE_CO2001	WL_HYDRO	WEEKLY	3/1999-7/1999	<1	E_SVRP	2545967.78324	276541.74211	WA
5507A04	BARKER_EUCLID(CID_BARKER_N)	SPOKANE_CO2001	WL_HYDRO	DAILY_AVG	5/1999-8/2000	1-10	E_SVRP	2546135.17886	271857.14387	WA
5507H01	BARKER_N	SPOKANE_CO2001	WL_HYDRO	DAILY_AVG	11/1998-9/2000	1-10	E_SVRP	2546403.11765	269452.44925	WA
5508M01	BARKER_CENTENNIAL_N(BARKER_S_2)	SPOKANE_CO2001	WL_HYDRO	DAILY_AVG	11/1998-9/2000	1-10	E_SVRP	2546637.82024	268722.35768	WA
5508M02	BARKER_CENTENNIAL_S(BARKER_S_1)	SPOKANE_CO2001	WL_HYDRO	DAILY_AVG	11/1998-9/2000	1-10	E_SVRP	2546566.42094	268616.68962	WA
5509H01	USGS_5	SPOKANE_CO2001	WL_HYDRO	RANDOM	6/2000-3/2001	<1	E_SVRP	2556848.95402	270448.12988	WA
5509H02	USGS_6	SPOKANE_CO2001	WL_HYDRO	RANDOM	6/2000-3/2001	<1	E_SVRP	2556499.17266	270745.26966	WA
5510C01	USGS_11	SPOKANE_CO2001	WL_HYDRO	RANDOM	6/2000-3/2001	<1	E_SVRP	2559282.91420	272180.25210	WA
5510C02	USGS_12	SPOKANE_CO2001	WL_HYDRO	RANDOM	6/2000-3/2001	<1	E_SVRP	2559280.42342	272282.38594	WA
5510C03	USGS_18	SPOKANE_CO2001	WL_HYDRO	RANDOM	6/2000-3/2001	<1	E_SVRP	2559266.91510	272205.03931	WA
5510M01	USGS_14	SPOKANE_CO2001	WL_HYDRO	RANDOM	6/2000-3/2001	<1	E_SVRP	2558058.82085	268790.31326	WA
5516C01	INLAND_EMPIRE	SPOKANE_CO2001	WL_HYDRO	MONTHLY	7/1929-01/2001	>50	E_SVRP	2475549.45864	263131.38056	WA
5517D05	BARKER_MISSION(CID_BARKER_S)	SPOKANE_CO2001	WL_HYDRO	DAILY_AVG	5/1999-9/2000	1-10	E_SVRP	2547852.64484	266479.87100	WA
6212L01	WHITWORTH_4	SPOKANE_CO2001	WL_HYDRO	RANDOM	1997-2001	1-10	N_SVRP_U	2473630.44089	296700.07176	WA
6307G01	WHITWORTH_3B	SPOKANE_CO2001	WL_HYDRO	RANDOM	1979-2001	20-50	N_SVRP_U	2480035.52107	299133.20876	WA
6308B04	ECOLOGY_DAKOTA	SPOKANE_CO2001	WL_HYDRO	DAILY	5/1998-8/1999	1-10	N_SVRP_U	2484914.30239	300581.82455	WA
6308F02	ECOLOGY_MAYFAIR	SPOKANE_CO2001	WL_HYDRO	DAILY_AVG	9/1997-9/2000	1-10	N_SVRP_L	2482486.83892	299057.26794	WA
6319A01	WHITWORTH_2B	SPOKANE_CO2001	WL_HYDRO	RANDOM	1979-2001	20-50	N_SVRP_L	2482012.57286	289743.12250	WA
6320D01	WHITWORTH_2A	SPOKANE_CO2001	WL_HYDRO	RANDOM	1979-2001	20-50	N_SVRP_L	2480709.55345	289940.10123	WA
6330F01	WHITWORTH_1	SPOKANE_CO2001	WL_HYDRO	RANDOM	1955-2001	20-50	N_SVRP_L	2479373.76912	282470.12269	WA
6331J01	CITY_FRANKLIN	SPOKANE_CO2001	WL_HYDRO	DAILY_AVG	1/1996-1/2001	1-10	W_SVRP	2483412.48151	275612.36375	WA
6525R01	IDAHO_RD_PIPELINE	SPOKANE_CO2001	WL_HYDRO	DAILY_AVG	5/1999-9/2000	<1	E_SVRP	2571898.30169	284728.05989	WA
6631M07	CID_11(IDAHO_RD)	SPOKANE_CO2001	WL_HYDRO	DAILY_AVG	5/1999-9/2000	<1	E_SVRP	2572339.79159	280867.63186	WA
7332H01	WHITWORTH_8A1	SPOKANE_CO2001	WL_HYDRO	RANDOM	1997-2000	1-10	S_LSR	2486001.30116	308535.97188	WA
7332H02	WHITWORTH_8A2	SPOKANE_CO2001	WL_HYDRO	RANDOM	1992-2001	1-10	S_LSR	2486001.30116	308535.97188	WA
7333E01	WHITWORTH_8B	SPOKANE_CO2001	WL_HYDRO	RANDOM	1988-2001	10-20	S_LSR	2487671.13266	309706.17192	WA
8316D01	ECOLOGY_CHATTEROY	SPOKANE_CO2001	WL_HYDRO	QUARTERLY	4/1978-3/2000	20-50	LSR	2484190.17458	357784.77231	WA
8323C01	SCWD3_CHATTEROY_HILLS	SPOKANE_CO2001	WL_HYDRO	RANDOM	2/1998-9/1998	<1	LSR	2497240.25134	353590.07039	WA
9233G01	ECOLOGY_DEER_PARK	SPOKANE_CO2001	WL_HYDRO	QUARTERLY	4/1978-3/2000	20-50	DP	2454676.87647	370689.61788	WA

Note:
E_SVRP - Eastern portion of the Spokane Valley Rathdrum Prairie Aquifer
C_SVRP - Central portion of the Spokane Valley Rathdrum Prairie Aquifer
W_SVRP - Western portion of the Spokane Valley Rathdrum Prairie Aquifer
N_SVRP_U - Northern portion of the Spokane Valley Rathdrum Prairie Aquifer, Upper Sands and Gravels
N_SVRP_L - Northern portion of the Spokane Valley Rathdrum Prairie Aquifer, Lower Sands and Gravels
LSR - Little Spokane Aquifer Area
S_LSR - Southern portion of the Little Spokane Aquifer Area
DP - Deer Park Groundwater Basin

TABLE 5.13

Summary of Estimated Spokane River Gains and Losses

Spokane River Stage Measurement Station			Broom (1951)	Drost & Seitz (1978)	Bolke & Vaccaro (1981)		Miller (unpublished 1996)		CH2MHill (1998)					Gearhart & Buchanan (2000)
Upstream	Downstream	Average River Width (ft)	Gain / Loss	Gain / Loss	Leakage Coefficient (sec^{-1})	Gain / Loss	Gain / Loss at Low Flow	Gain / Loss at Medium Flow	Leakage Coefficient (sec^{-1})	Gain / Loss Fall 1994		Gain / Loss Spring 1995		Gain / Loss Dec 1998 to Jul 1999
State Line	Harvard Rd	350	-78	-80	6.20E-07	-50	-207	-319	5.0E-07	-45	-136	-71	-171	-307 to -47
Harvard Rd	Barker Rd	300												- 137 to -29
Barker Rd	Sullivan Rd	200	370	330					2.0E-06	-91		-100		-28 to +126
Sullivan Rd	Kaiser	150			1.00E-04	240	206	160	1.0E-06	-7		-5		-88 to +50
Kaiser	Trent Ave Brg	150							5.0E-04	22		64		
Trent Ave Brg	Plantes Ferry	200	566	230	6.20E-07	-40			5.0E-06	1	16	12	71	-53 to +30
Plantes Ferry	Argonne	250							5.0E-07	-12		-4		
Argonne	Upriver Dam	400					Unquantified loss		5.0E-08	-6	-18	-4	-8	
Upriver Dam	Green St	100			2.00E-04	270	209	377	1.0E-03	149	149	194	194	
Green St	Mission St Brg	250	-39		6.20E-07	-200	63	122	5.0E-06	-38	-75	-32	-42	
Mission St Brg	Sirti	300							5.0E-06	-22		-9		
Sirti	Monroe St	300		120					5.0E-06	-15		-1		
Monroe St	Cochrane St	200			1.00E-05	130	-57	-80	5.0E-06	-42	-152	-41	-121	
Cochrane St	Meenach Brg	200	126		4.00E-06	-45			5.0E-06	-110		-80		
Meenach Brg	Albi Park	150			2.00E-06	-40			1.0E-05	50	133	56	147	
Albi Park	7 Mile	200	21	100	4.00E-06	50			1.0E-05	77		82		
7 Mile	9 Mile Falls	750			1.00E-07	-40			1.0E-05	6		9		
State Line to USGS at Cochrane St			819	580		350	214	260		-106		3		
State Line to Mission St Bridge			858	480		220	271	340		-64		44		
USGS at Cochrane St to 9 Mile Falls			147	220		-75				23		87		
Total (State Line to 9 Mile Falls)			966	700		275				-83		70		

Note: All values for flows, gains, and losses are in ft^3/second or cfs.
Adapted from CH2MHill, 1998.
WRIA 57 extends to just downstream of the USGS Cochrane St Gage (also known as Spokane River at Spokane)
Leakage Coefficient defined as the vertical hydraulic conductivity of the streambed divided by the streambed thickness

TABLE 5.14

Compilation of Vertical Riverbed Hydraulic Conductivity Estimates

STUDY	**Vertical Riverbed Hydraulic Conductivity (ft/sec)**
Spokane Aquifer	
Drost & Seitz (1978)	1×10^{-4} to 1×10^{-3}
Bolke & Vaccaro (1981)[1]	1×10^{-7} to 2×10^{-4}
Gifford Consultants, Inc. (unpublished 1995)	1.6×10^{-4} to 4.8×10^{-2}
CH2MHill (1998)[1]	7×10^{-7} to 1×10^{-3}
Other Sand and Gravel Aquifers in the US	
Duwelius (1996)	3.4×10^{-6} to 8×10^{-4}
Yager (1993)	1.2×10^{-6} to 5.8×10^{-6}
Barker and MacNish (1976)	1.55×10^{-4} to 2.5×10^{-3}
Walton, Hills & Grundeen (1967)	6.38×10^{-6}
Moore & Jenkins (1966)	2.17×10^{-5} to 2.63×10^{-5}
Weeks, Erickson & Holt (1965)	1.55×10^{-5} to 6.2×10^{-5}

Note: 1) Values given as leakage coefficients

Adapted from Gearhart & Buchanan (2000)

6. WATER QUALITY

Grant Agreement No. G9800300 between the Washington State Department of Ecology and Spokane County established the following objective for water quality evaluation in the Little Spokane and Middle Spokane watersheds:

To the extent that the Planning Unit identifies water quality, instream flows and habitat as issues to be addressed in Phase II the following objectives will be met:

- Use the best available science to make estimates of the minimum low flows required to meet water quality and habitat protection goals; and,
- Use the best available science to make estimates of the Total Maximum Daily Loading (TMDL) of contaminants throughout the watershed to ensure that the water quality standards for the designated uses of each water body are achieved.

Task 7.0 of the Planning Unit's proposed Scope of Work identified four basic water quality needs: compile existing water quality data; identify impacted waters; identify flow related water quality parameters; and, determine if existing data is adequate to assess those problems. This chapter accomplishes those tasks.

There is a great deal of existing water quality data available for the study area and there are several major water quality studies under way. This chapter separately discusses surface water and groundwater quality components of the watersheds, though the two components are highly interrelated. The bullets below describe various ways that water quality is influenced as it moves through the hydrologic cycle (Molenaar, 1988):

1. Rain and snow falling though the atmosphere may pick up some gaseous/ particulate impurities (e.g., gas and smoke emissions from cars);
2. Surface water runoff flows over the ground surface and through soils and rocks and picks up soluble minerals, organic substances and residues of human activity;
3. As the water infiltrates through the unsaturated zone, the water dissolves additional components; and,
4. As the groundwater flows within an aquifer, it may be dissolving and precipitating minerals along the flow path.

In addition to these "natural" processes, some surface water is directly impacted by discharges of "wastewater" having various levels of treatment.

6.1 Surface Water

Discussion of surface water quality is limited to previously identified parameters of concern, primarily within the context of the federal Clean Water Act. This section presents background information on water quality standards, the current status of parameters that are listed under Section 303(d) of the Clean Water Act, and a statement on the status of the Total Maximum Daily Load process. The last sub-section describes the spatial and temporal distribution of parameters of concern including a description of their relationship to stream flow.

6.1.1 Surface Water Quality Standards

Water quality standards are regulated by the Washington State Surface Water Quality Standards (Chapter 173-201A WAC). Water bodies that do not meet State Surface Water Quality Standards must be reported to the EPA every four years, in accordance with Section 303(d) of the Federal Clean Water Act. Washington Surface Water Quality Standards are designed to preserve the designated "characteristic uses" of the river. The Spokane River (SR) and Little Spokane River (LSR) have both been designated as Class A (excellent) streams with the following characteristic uses:

- Water supply (domestic, industrial, agricultural);
- Stock watering;
- Fish and shellfish;
- Wildlife habitat;
- Recreation (primary contact recreation, sport fishing, boating and aesthetic enjoyment); and,
- Commerce and navigation.

The critical time for most water quality parameters is low flow periods, characteristically observed in the summer. Therefore, the Washington Department of Ecology (Ecology) typically establishes seasonal permit limits for wastewater discharges with more stringent requirements in the summer season. For effluent limitations, Ecology typically determines allowable loading using the lowest 7-day average flow that occurs during a 20-year period (7Q20). Low flow analyses at the Little Spokane at Dartford gage (1929-1999) results in a 7Q20 of approximately 70 cfs. Low flow analyses at the Spokane gage (1941-1999) results in a 7Q20 of 618 cfs. Low flows at Spokane for the winter permit period are much higher, with flows estimated at 1,532 cfs.

Certain water quality parameters, such as metals concentrations, have elevated levels during high flows. This is primarily due to the flushing of sediments containing metals downstream during high flows.

Theoretically the lower hardness of surface water during high flows would contribute to elevated dissolved metals levels. The degree of hardness of the Spokane River is dependent on the percentage of inflow contributed by groundwater as well as the high hardness of wastewater effluent discharges. Groundwater from the SVRP aquifer is high in calcium concentrations (greater hardness) due to the flow of groundwater through rocks and sediments that contain calcium. When calcium concentrations, and therefore hardness, are high, dissolved metals such as zinc, cadmium and lead form insoluble precipitates and drop out of the water column. The reverse is true when water is soft.

Regulation of water quality on the Spokane River is complex because several authorities regulate discharges to the river. On either side of the Washington/Idaho state line, regulated discharges and parameters used for discharge permitting can vary. For example the dissolved oxygen standard for the Spokane River in Washington in 8.0 mg/L, while in Idaho the standard is 6.0 mg/L (Chapter 173-201A WAC; IDAPA 58.01.02).

Washington State Surface Water Quality Standards (Chapter 173-201A WAC) for Class A (excellent) waters, which include the Little Spokane River and the Spokane River, are summarized below. Also included are specific classifications for sections of each river as identified under (Chapter 173-201A-130).

- **Fecal Coliform** – expressed as number of colonies per 100 mL, the geometric mean shall be less than 100 with less than 10% of samples exceeding 200.

- **Dissolved Oxygen** – shall exceed 8.0 mg/L.

- **Temperature** – Temperature shall not exceed 18° C due to human activities. When natural conditions exceed 18° C no temperature increase will be allowed that will raise the receiving water temperature by greater than 0.3 °C; nor shall such temperature increases, at any time, exceed t=28/[T + 9] (Where t = maximum permissible temperature increase measured at the mixing zone boundary; and, T = the background temperature as measured at a point or points unaffected by the discharge and representative of the highest ambient water temperature in the vicinity of the discharge).

  The Spokane River, from the Nine Mile Bridge (RM 55.0) to the Idaho Border (RM 96.5) has specific requirements, which are that temperature shall not exceed 20°C due to human activities. When natural conditions exceed 20°C, no temperature increase will be allowed that will raise the receiving water temperature by greater than 0.3 C°; nor shall such temperature increases, at any time, exceed t=34/[T + 9].

  The temperature criteria are designed to help protect fish. Certain coldwater species (e.g., salmonids) are particularly at risk when higher temperatures reduce the oxygen-carrying capacity of water while at the same time increasing the oxygen uptake rate due to biodegradation.

- **pH** – shall be within a range of 6.5 to 8.5 with a human-caused variation of less than 0.5 units within that range.

- **Turbidity** – shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10 percent increase in turbidity when the background turbidity is more than 50 NTU.

- **Toxic Material** – standards vary based on the contaminant and can be found in Chapter 173-201A-040 WAC.

- **Radioactive Material** – concentrations shall be the lowest practicable concentration attainable and in no case shall exceed:
    - 1/12.5 of the values listed in Chapter 246-221-290 WAC; and,
    - USEPA Drinking Water Regulations for radionuclides.
- **Aesthetics** – shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of smell, touch or taste.
- **Metals** – standards for dissolved metals of concern in the study area are calculated based on hardness and are divided into acute and chronic levels. Acute indicates a level of toxicity that has short-term effects; measured as one-hour average concentration in micrograms per liter not to be exceeded more than once every three years. Chronic indicates a level of toxicity that has long-term effects; measured as the four-day average concentration in micrograms per liter not to be exceeded more than once every three years. Acute standards are higher than chronic because an aquatic organism can usually survive a short term high level of contamination. However a lower level of concentration must be maintained for protection over the long term. The criteria are as follows:

    Dissolved Cadmium

    $\text{Chronic} < (1.101672-((\ln(\text{hardness}))*(0.041838)))*\text{EXP}(0.7852*(\ln(\text{hardness}))-3.49)$

    $\text{Acute} < (1.136672-((\ln(\text{hardness}))*(0.041838)))*\text{EXP}(1.128*(\ln(\text{hardness}))-3.828)$

    Dissolved Lead

    $\text{Chronic} < (1.46203-((\ln(\text{hardness}))*(0.145712)))*\text{EXP}(1.273*(\ln(\text{hardness}))-4.705)$

    $\text{Acute} < (1.46203-((\ln(\text{hardness}))*(0.145712)))*\text{EXP}(1.273*(\ln(\text{hardness}))-1.46)$

    Dissolved Zinc

    $\text{Chronic} < 0.986*\text{EXP}(0.8473*(\ln(\text{hardness}))+0.7614)$

    $\text{Acute} < 0.978*\text{EXP}(0.8473*(\ln(\text{hardness}))+0.8604)$

Washington State regulations (Ch. 173-201A-070 WAC) also include an anti-degradation policy. This requires that discharges into receiving water shall not further degrade the existing water quality of the water body.

Ecology is currently working on revisions to the State Water Quality Standards in Chapter 173-201A WAC. These revisions would change Washington standards from a classification-based system to a use-based system. The key difference is the way uses are assigned for protection (Ecology, 2000):

> *"Rather than assigning waters to classes having predetermined sets of beneficial uses (regardless of what the water body can actually support) we could assign beneficial uses to water bodies independently of each other. This would provide greater flexibility to assign the most scientifically defensible combination of beneficial uses."*

For example, a river could be classified as high quality recreation without being classified as salmon spawning habitat. This type of combination is not available under the current system.

6.1.2 Section 303(d) Listed Pollutants

Section 303(d) of the federal Clean Water Act requires states to identify and submit a list of their polluted waterbodies to the EPA every four years. Water bodies submitted under Section 303(d) must meet two criteria to be placed on the list:

1) Water quality does not meet state water quality standards; and,

2) Technology-based controls are not sufficient to achieve water quality standards.

The 303(d) list was last updated in 1998, waterbodies listed for the Little Spokane River and the Spokane River are summarized in Table 6.1 and displayed in Figure 6.1. In 1998, the EPA changed its policy on monitoring waterbodies to provide a better indication of what portion is impaired. Before 1998, a few sampling stations were used to characterize the major segments of the waterbody, but in 1998 segments were limited to the portion of the waterbody in the same section (township/range/section) as the sampling region.

6.1.3 Total Maximum Daily Loads under 303(d)

The goal of a Total Maximum Daily Load (TMDL) is to ensure that water quality impaired waters will attain water quality standards. For each impaired waterbody listed under Section 303(d), the EPA requires that the states set priorities for cleaning it up and establish TMDLs for surface waters that do not meet standards after application of technology based pollution controls. The TMDL, which includes a water clean up plan, requires an analysis of how much pollution the waterbody can handle and still be used for its intended purposes, such as swimming, fishing, drinking water, or fish habitat. The TMDL includes recommendations on how to control the pollution impairing water quality as well as a monitoring program to ensure the effectiveness of pollution controls.

Thus far within WRIA 57, a voluntary phosphorus TMDL and a recent TMDL for dissolved metals (cadmium, lead and zinc; Ecology, 1999) have been established for the Spokane River. The Washington State dissolved metals TMDL, assures that water quality criteria for the metals of interest will be achieved in Washington if the criteria are met at the Washington-Idaho border. If the criteria are not met at the state line, the Washington TMDL will result in no further degradation as a result of Washington dischargers. Though the EPA and the Idaho Division of Environmental Quality are working to control metals levels in Idaho, Washington State standards and criteria are frequently violated at the state line. The Washington TMDL for dissolved metals

(Ecology, 1999) is implemented through discharge permits issued to individual dischargers. The permits require that the more stringent of the following be met:

- Metals concentrations in effluent discharges shall meet the chronic, aquatic life criteria for the hardness of the effluent (calculated based on chronic criteria for each metal and effluent hardness at the discharge point); or,

- Where adequate data exit to establish a baseline, metals concentrations in the effluent shall not exceed historic levels, plus 10%. This performance-based criterion rests on the assumption that current conditions are acceptable and that the facility is using best available technology for metals control.

Dischargers to the Spokane River currently follow a voluntary TMDL for phosphorus in the Spokane River based on a phosphorus attenuation model (P-Attenuation Model) developed in the mid 1980's for Long Lake (Lake Spokane), an impoundment of the Spokane River in WRIA 54 immediately downstream of WRIAs 55 and 57. The phosphorus TMDL was established with the assistance of the Department of Ecology, and is administered by Spokane River dischargers through the Phosphorus Technical Advisory Committee (PTAC). The basic conditions of the phosphorus TMDL are:

- Maintain a phosphorus concentration of less than 25 micrograms per liter in the euphotic zone of Long Lake (Lake Spokane) during the growing season; and,

- Limit the discharge of total phosphorus to 259 kg P/day between Coeur d'Alene and Long Lake.

The dischargers have assigned daily loads to each of their facilities by mutual consent. The PTAC, in consultation with the Department of Ecology, determines when each discharger will initiate any special phosphorus attenuation practices deemed necessary for their facilities. Work on a TMDL is being completed by Ecology to reassess the phosphorus attenuation model and to study the Biochemical Oxygen Demand (BOD) of the Spokane River (Ecology, 1999). These two studies are linked because both nutrient loading (including phosphorus) and BOD can affect Dissolved Oxygen (DO) concentrations. Nutrient loading causes an increase in plant growth, which triggers a decrease in DO levels during periods dominated by plant respiration (e.g., low sunlight conditions and night time) and by plant decay. The direct loading of organic material from point and non-point sources increases BOD, which represents the potential amount of oxygen consumed by microorganisms degrading organic matter or oxidizing inorganic chemicals.

When completed, the TMDL for BOD will provide an understanding of how pollutant sources affect DO along the Spokane River and recommendations for loading levels from point and non-point sources. The model being used for the BOD TMDL includes a groundwater component so it will allow an assessment of both groundwater and surface water flow components on the DO in the Spokane River. This will allow testing Watershed Plan recommendations for improving this flow related water quality parameter.

Dragoon Creek, a tributary of the Little Spokane River, has failed to meet state standards for DO and fecal coliform and is listed under 303(d) for those parameters. Remarks on the 303(d) listing of DO for Dragoon Creek state that a TMDL was submitted for DO in 1992 but were rejected for unknown reasons. The TMDL was based on the removal of discharge to the creek from the Deer Park Wastewater Facility during the summer. The remark states that it is expected that Dragoon Creek currently meets standards due to this discharge removal but that no recent monitoring has been completed to verify this (Ecology, 2000). Dragoon Creek 303(d) listings in 1996 for phosphorus, ammonia and chlorine were removed in 1998 based on the removal of discharge from the Deer Park Wastewater Facility. Currently, no TMDL studies have been completed for surface waters within WRIA 55.

6.1.4 Surface Water Quality in WRIA 55

The Little Spokane River (LSR) does not meet state standards on various sections of the river (Figure 6.1) for dissolved oxygen, fecal coliform, pH, temperature and PCB’s. The probable source of most of these parameters on the Little Spokane is non-point source discharges; those discharges without a specific discharge point. There are currently no permitted point source dischargers on the Little Spokane River that are known to contribute to water quality standard violations. Likely non-point source discharges that affect the Little Spokane River include agricultural activities, on-site sewage disposal contributions (e.g., septic systems), stormwater and highway run-off, forest practices, land development, landfills, and mining.

6.1.4.1 Temperature

Temperatures on the Little Spokane River vary widely from 2°C in winter to more than 22°C in summer. Figure 6.3a shows temperatures for the 1999 water year for several locations along the river. Figure 6.3b and 6.3c display temperatures along the river for dry and wet seasons respectively. The temperature measured at the West Branch of the Little Spokane River sampling point generally equals or exceeds temperatures from most of the other sampling points. However, the West Branch of the Little Spokane River is not listed under section 303(d) of the CWA for temperature. The Little Spokane River near Scotia has cool water temperatures year round due to groundwater inflow. Many of the sampling points on the mainstem Little Spokane River below Chattaroy and on the West Branch Little Spokane River exceed the state standard of 18°C during the summer (Figure 6.3a). Temperature excursions listed in the 303(d) listing occurred downstream of Deadman Creek, Dartford Creek and at the mouth of the Little Spokane River. Station abbreviations are referenced to names and river miles in Table 6.2. Station locations are referenced in Figure 6-1.

6.1.4.2 Dissolved Oxygen

Several factors affect DO levels including temperature, water movement, photosynthesis, respiration, and BOD. DO levels have an inverse relationship to temperature: as temperature decreases, gas solubility increases. Turbulent flow increases oxygen dissolution through increased surface area of water being in contact with the atmosphere. Plant photosynthesis releases oxygen into the water column during the day, while plant respiration removes oxygen during the night. Lastly, organic loadings to a waterbody remove oxygen through BOD, which is the use of oxygen by bacteria as they decompose the organic matter.

The Little Spokane River is most likely to violate standards during low-flow, summer periods. Figure 6.4a displays DO from July 1996 through November 1999. The illustration shows that DO levels are at their peak when temperatures are low and flows are high. During the summer months DO levels are lower and excursions are most likely to occur. Figure 6.4 a, b and c display several trends along the river. DO levels are lower, year round near the mouth of the Little Spokane River, and, during the summer months on the West Branch of the Little Spokane River. These locations closely correlate with locations of temperature excursions. Concentrations of DO generally increase from Chattaroy down stream until after the confluence of Deadman Creek during wet periods (Figure 6.4b), whereas concentrations of DO are at their peak during dry periods (Figure 6.4c) just before the confluence with Dartford Creek (below Deadman).

Dissolved Oxygen (DO) concentrations on the Little Spokane River were below the state standard of 8 mg/L in 1996 but had improved by 1998 and stream segments were removed from the 1998 303(d) list.

Data are available for Dragoon Creek from February 1995 through June 1995 for DO (Figure 6.7) and Fecal Coliform (Figure 6.8). Dissolved oxygen standards were not violated during this period. Fecal Coliform levels, however, did not meet state standards for DR-1 and DR-2 (upstream and near Deer Park respectively). Fecal Coliform quantities vary seasonally with higher levels occurring during the summer. Water quality tends to be worse near Deer Park (Figure 6.7 and 6.8). This suggests that DO and coliform problems are a result of anthropogenic activities.

6.1.4.3 Fecal Coliform

Fecal coliform measurements made from winter 1998 through fall 1999 are shown in Figure 6.5a. These measurements show a pronounced dip during the spring freshet period but are higher during other times of the year. Figures 6.5d and 6.5e demonstrate an inverse correlation of flow and fecal coliform levels over the period of record. Figures 6.5b and 6.5c display fecal coliform along the length of the river for both the dry (6.5b) and the wet season (6.5c). During the wet season, high concentrations of fecal coliform seem to be found near Dry Creek and Dartford Creek, this relationship is not as visible during the dry season.

6.1.4.4 pH

The pH of the Little Spokane River measured between July 1996 and September 1999 is shown in Figure 6.6a. The values range from 7 to more than 9, in comparison to state standard of 6.5 to 8.5. A slight decrease in pH was measured at all stations in February followed by a period of high pH in April. Plots of pH versus flow show a positive trend in this relationship (Figures 6.6b and 6.6c). The pH on the West Branch of the Little Spokane River shows the widest variations, but does not show a relationship to flow.

This is possibly due to its interception by several shallow lakes (Diamond Lake, Sacheen Lake, Horseshoe Lake, and Eloika Lake, among other small lakes) that have problems with algae and invasive species. The pH level of surface water is impacted by plant growth through photosynthesis, respiration, and decomposition. Photosynthesis generally increases pH (lower acidity) and is most pronounced in the summer days when plant growth is high. Respiration and decomposition lower pH values (increase acidity) and are more dominant processes during winter nights.

6.1.4.5 Polychlorinated BiPhenyls

The Little Spokane River also has 303(d) listings for PCBs near the mouth of the River. PCB samples were obtained from rainbow trout tissue; time series data are not available.

6.1.5 Surface Water Quality in WRIA 57

The Spokane River exceeds state standards on various portions of the river for DO, PCBs, lead, zinc, cadmium, arsenic, sediments, pH and temperature. The problems associated with these parameters have been identified through measurements in the water column, in river sediment, and in fish tissue (Table 6.1 and Figure 6.2). The primary source of metals in the River in WRIA 57 appears to be river-borne silt transported through Lake Coeur d'Alene Lake from contaminated sites in the Coeur d'Alene River Basin. Non-point source discharges along the river in Washington are also a concern due to the large population living along some reaches of the river. In addition, there are seven wastewater treatment facilities permitted to discharge to the river (Figure 6.2). In Idaho, the EPA permits the following discharges (proceeding downstream from Lake Coeur d'Alene):

- City of Coeur d'Alene Advanced Wastewater Treatment Plant
- Hayden Area Regional Sewer Board Publicly-Owned Treatment Works
- City of Post Falls Publicly-Owned Treatment Works

In Washington, Ecology permits discharges from:

- Liberty Lake Publicly-Owned Treatment Works
- Kaiser Aluminum Industrial Wastewater Treatment Plant
- Inland Empire Paper Company Industrial Wastewater Treatment Plant
- City of Spokane Advanced Wastewater Treatment Plant

6.1.5.1 Metals

Elevated concentrations of metals in the Spokane River have been linked to historical mining activities in the upper reaches of the watershed (Ecology, 1999). At the state line, the instream concentrations of these metals often exceed Washington State water quality standards. Concentrations of dissolved zinc almost continually violate EPA and state water quality standards (both acute and chronic fish toxicity). Dissolved lead concentrations are higher than the chronic standard during the high flow season.

Cadmium violates the chronic criteria during high flow, but only upstream of Upriver Dam. The highest concentrations of all three of these metals occur during the highest flows (Spokane County, 2000).

The toxicity of the three regulated metals (zinc, lead and cadmium) is dependent on the hardness of the water. Metals form complexes at higher hardness that are less available to fish. In addition to the problems of fish toxicity associated with dissolved metals, there are also concerns regarding metals in suspended sediments and the deposition of those sediments along some reaches of the river in Washington. Suspended sediment is primarily a concern during high flow periods.

There are several relationships of concern on the river: total metals concentrations as they relate to flow; dissolved metals concentrations as they relate to flow and hardness; hardness and metals concentrations as they relate to the dynamic aquifer/river system and associated interchanges.

Groundwater inflows contribute significantly to hardness concentrations in the river and result in a net increase in the hardness of the river water and a decrease in dissolved metal concentrations. There is a strong relationship between lower flows and higher hardness levels (Figure 6.9a). This is because groundwater inflow with high hardness comprises a larger percentage of river flow during low flow conditions. This relationship is also evident through an increase in hardness concentrations moving downstream (Figures 6.9b and 6.9c). Consequently, as the Spokane River flows downstream, its carrying capacity for dissolved metals decreases due to inflows of harder groundwater. Groundwater inflows also dilute the existing metals concentrations. The sharp increase of hardness at the springs near the Sullivan Bridge noted in the figures is due to the contribution of groundwater to stream flow in that location.

Dissolved cadmium and zinc concentrations decrease moving downriver, while lead remains relatively constant (Figures 6.10a-c). Higher total and dissolved metal concentrations are observed in May and June when flow and resuspended sediments are high, and hardness is low, while lower concentrations are observed in September and October when river flows and suspended solids are lower, hardness levels are higher (Figures 6.10d-f). The temporal correlation of total and dissolved metal concentrations with river flow is due to the scouring of metal laden sediment in the Coeur d'Alene River basin and its transport through Lake Coeur d'Alene into the Spokane River at high flow, and the lower pH due to the minimal influence of hard groundwater.

The portion of the total metals in dissolved form averages 20% dissolved for lead, 66% cadmium, and 88% for zinc (Figure 6.10g). Dissolved lead concentrations in the Spokane River between Post Falls Dam and Upper Falls Dam remain relatively constant under high or low flows (Figure 6.10c).

In the Spokane River between Post Falls Dam and Upper Falls Dam under high flow conditions (e.g., May 1999), hardness increases by almost a factor of two and cadmium and zinc concentrations decrease on the order of 30%. Over the same reach during low flow conditions (e.g., September 1999), hardness increases by more than five fold, and cadmium and zinc concentrations decrease on the order of 60%. The larger increase in hardness under low stream flow conditions is a result of the larger relative influence of groundwater. Dissolved metals concentrations generally inversely relate to water hardness. Therefore, as hardness increases moving downriver, dissolved metal concentrations decrease. Aquifer/river interchange dynamics also result in a decrease of metal concentrations. There is little change in streamflows between Post Falls Dam and Upper Falls Dam under high or low flow conditions with respect to the dilution effect that changes in flow may have on metal concentrations transported through this reach, relative to the observed concentration decreases. Therefore, changes in metals concentrations along the reach can be attributed to the influence of groundwater/surface water interaction and the associated changes in hardness.

The biggest reason for the drop in total concentration of metals at lower flows is that they are not transported out of the Coeur d'Alene basin. Total concentrations of cadmium, lead and zinc are greater during higher flows indicate that during high flows metals which are in sediments are resuspended in the water column. The decrease in dissolved metal concentrations downstream is probably a combination of increased hardness and associated reduction in metal solubility. Suspended solids dropping out would reduce the total metal concentration downstream.

6.1.5.2 Dissolved Oxygen

Dissolved Oxygen (DO) levels are listed in the 1998 303(d) listing and are currently being studied by Ecology. Multiple factors have been identified as possible causes for low dissolved oxygen concentrations, including organic loading from point and non-point sources, water temperature, and low DO concentration inflows. The 303(d) DO listing for the Spokane River indicates excursions occurred downstream of Inland Empire Paper Company and just downstream of the Washington-Idaho Stateline (Ecology, 2000). A study completed by Pelletier (1998) indicated that background DO levels near the Inlands discharge (i.e., normal DO levels not affected by Inland discharge) were already less than 8 mg/L. These low background levels were attributed to groundwater inflows with low DO levels as well as high summer temperatures. However, groundwater sampling during the summer of 1999 and 2001 showed groundwater DO in areas adjacent to river recharge zones to be above 8 mg/L for nearly all samples.

The TMDL study currently underway by Ecology is focusing mainly on organic pollutants which affect DO levels, including carbonaceous oxygen demand (CBOD) and ammonia from point and non-point loading sources as well as the indirect affect of nutrient loading on DO levels. The primary goal is to assess the assimilative capacity of the Spokane River system with respect to CBOD and ammonia sources (Ecology, 1999). Sampling for this study began in 1999 and continued through the summers of 2000 and 2001 at sites from the state line to the Long Lake Dam.

The following dischargers have NPDES permits for discharging oxygen-consuming waste (Ecology, 1999):

- Liberty Lake Publicly Owned Treatment Works;
- Kaiser Trentwood Aluminum Industrial Wastewater Treatment Plant;

- Inland Empire Paper Company; and,
- The City of Spokane WWTP.

Dissolved Oxygen data from quarterly sampling from 1973 through 1974 (Figure 6.11), and summer data for 2000 and 2001 was provided by Spokane County for this report. DO levels are higher than the required 8 mg/L for nearly the entire period of record at all stations collected.

6.2 Groundwater Quality

This section of the report characterizes groundwater quality and its relation to the quality of surface water flows within WRIA 55 and WRIA 57 based on the information provided by Spokane County for review. The following list of the references provides the basis for the information presented within this section.

- The Spokane Aquifer Cause and Effect Report, which summarizes water quality and cause and effect relationships for water quality in the SVRP Aquifer (Esvelt, 1978).
- The Spokane Water Quality Management Program (Spokane County, 1979).
- Molenaar's report on the geologic origin and physical and chemical hydrogeology of the Spokane Valley portion of the SVRP Aquifer (Molenaar, 1988). This report evaluates the groundwater quality of the Spokane Valley portion of the SVRP Aquifer based on data collected and interpreted by Vaccaro and Bolke (1983).
- EMCON's 1992 groundwater characterization of the Deer Park Basin (EMCON, 1992).
- Spokane County's water quality addendum to the Deer Park Basin Groundwater Management Plan (Spokane County, 1995).
- The initial watershed assessment for WRIA 55 (Dames and Moore and Cosmopolitan, 1995).
- A baseline groundwater quality investigation for a portion of North Spokane County (Boese and Buchanan, 1996).
- The Spokane Valley-Rathdrum Prairie Atlas (MacInnis and others, 2000).
- Water quantity and water quality summaries prepared by Spokane County (Spokane County, 1996 and 2000).

The quality of groundwater depends upon the degree to which society has impacted the water, and the geologic materials through which the water passes, either prior to the water infiltrating the ground or within the subsurface (e.g., impacts such as septic tank recharge to groundwater, fertilizer residues or leaking underground storage tanks).

The concentrations of substances that may be dissolved by groundwater are a function of the amount of water that flows through the system, the nature of the aquifer recharge water, the chemical characteristics of the aquifer materials, and the volumes, concentrations and rates at which various substances are introduced into the groundwater.

6.2.1 Groundwater Quality in WRIA 55

Groundwater in WRIA 55 is generally of good to excellent quality. Total dissolved solids (TDS) are generally less than 200 mg/L within the alluvial aquifers, 250 mg/L within the basalts and 500 mg/L from the crystalline basement rocks (Dames and Moore and Cosmopolitan, 1995). Water from the crystalline basement rocks tends to be more highly mineralized and high in calcium, magnesium and bicarbonate.

Specific studies on groundwater quality in WRIA 55 include a baseline groundwater quality investigation for a portion of north Spokane County (Boese and Buchanan, 1996) and a groundwater quality characterization of the Deer Park Basin for the Deer Park Basin Groundwater Management Plan (EMCON, 1992).

Groundwater was sampled from 44 wells in North Spokane (Boese and Buchanan, 1996). The table below summarizes the water quality results by aquifer type and compares the results to the EPA and Washington State Maximum Contaminant Levels (MCLs). The groundwater quality of the North Spokane aquifers is generally good with localized areas of elevated nitrate.

North Spokane Water Quality Summary

(adapted from Boese and Buchanan, 1996)

Aquifer (# of samples)		**$NO_3^- + N\ O_2^-$** (mg/L as N)[a]	**pH**[c]	**Hardness** (mg/L as CaCO3)	**Chloride** (mg/L)[b]	**Iron**[b] (mg/L)	**Specific Conductance** (µS/cm)[b]
MCL		10	6.5 – 8.5		250	0.3	700
Upper sand and gravel aquifer (2)	Max.	0.77	7.0	148	4.96	< 0.01	314
	Mean	0.40	6.9	121	4.26	< 0.01	278
	Min.	0.03	6.7	94	3.55	< 0.01	242
Lower sand and gravel aquifer (2)	Max.	6.7	8.2	498	235	14.9	1160
	Mean	1.2	7.4	198	17.6	2.82	392
	Min.	< 0.01	6.5	< 1	1.42	< 0.01	205
Basalt / Landslide (8)	Max.	9.9	7.8	312	9.93	10.6	635
	Mean	1.7	7.2	191	3.46	2.54	397
	Min.	< 0.01	6.5	< 1	1.06	< 0.01	217
Crystalline Basement (1)		0.62	7.4	106	3.19	0.015	308

a) Primary MCL (health concerns).
b) Secondary MCL (aesthetic concerns).
c) Surface water antidegradation guideline.

EMCON (1992) reported similar findings in their groundwater characterization study of the Deer Park Basin. The groundwater quality in the Deer Park Basin was found to be good overall with the exception of elevated nitrate levels (from agricultural activities and sewage/septic disposal). Nitrate concentrations in shallow groundwater of the Deer Park Basin Aquifer (flood deposits and alluvial) increased from less than 2 mg/L in 1975 to more than 8 mg/L by 1988. The largest grouping of wells with elevated nitrate levels occurs to the east of the City of Deer Park in Township 28N, Range 42E, Section 12 and in Township 28N, Range 43E, Sections 6 and 7. Three wells in Section 12 have had historical nitrate levels as high as 250 mg/L. These excessively high nitrate concentrations are probably due to past manure disposal practices (EMCON, 1992).

Elevated nitrate levels have also been monitored in the deeper basalt aquifer of the Deer Park Basin (EMCON, 1992). These elevated levels are attributed to agricultural practices and septic tanks. The transmission of nitrate-impacted groundwater to the deeper aquifer occurs via aquifer recharge and may also occur along the annulus of poorly sealed wells. The basalt and Latah Formation sediments within the Deer Park Basin were reported as commonly having naturally elevated levels of iron and manganese (EMCON, 1992).

The elevated nitrate levels in the Deer Park Basin have the potential to impact the water quality of Dragoon Creek and the Little Spokane River because both the shallow unconsolidated and deeper basalt aquifers discharge to Dragoon Creek (which in turn flows into the Little Spokane River) along the southern portion of the basin. High nitrate concentrations (e.g., 6 mg/L) occur in Dragoon Creek during low flow periods primarily as a result of the discharge of nitrate-laden groundwater to the creek (Stan Miller, personal communication).

At the north end of the Hillyard Trough portion of the SVRP Aquifer, groundwater from the aquifer discharges into the Little Spokane River. As described in Section 5.3.2 of this report, groundwater nearly doubles the flow of the Little Spokane River between the gaging stations at Dartford and near Dartford (see Figure 5.2a). The flow in the Little Spokane River is frequently below its required Minimum Instream Flow (MISF) during the summer months and the recharge from the SVRP Aquifer is important in maintaining flows to this river. The discharge of high quality groundwater from the SVRP Aquifer maintains good surface water quality in the lower reach of the LSR. The Section 305(b) report submitted to Congress in 2000 highlighted the Colbert Landfill as the only site within WRIA 55 as posing a critical risk to public drinking water supply. The Colbert Landfill is located about 15 miles north-northeast of Spokane, and approximately a mile east of the Little Spokane River (Figure 6.2). This site is a 40-acre inactive municipal solid waste landfill. The on-site contamination includes chlorinated organics disposed at the site from 1975 to 1980 (Landau Associates, 1991). There is a pump and treat system currently in place at the site that collects impacted water, removes the contaminants by air stripping and discharges the treated water to the Little Spokane River.

6.2.2 Groundwater Quality in WRIA 57

Discussion on the groundwater quality of WRIA 57 focuses on the SVRP Aquifer because the majority of groundwater used within the basin is extracted from this aquifer. Water quality of the SVRP aquifer is good (MacInnis and others, 2000). However, water quality trends from the 1970s and 1980s indicate a gradual increase in contaminants within the aquifer. The SVRP aquifer is highly susceptible to contamination because it is shallow and unconfined and because the sand and gravel aquifer materials are very permeable with little capacity for natural attenuation of contaminants. The high potential for contamination is perhaps the most important aquifer issue that must be addressed in order to maintain the aquifer as a regional drinking water source.

Spokane County, in cooperation with the Spokane Regional Health Districts and several local water purveyors, has conducted detailed water quality monitoring of the SVRP aquifer for over 20 years as part of the Water Quality Management Program (Spokane County, 1979 and 2000). Base line water quality for Spokane’s Water Quality Management Program was established between 1977 and 1979 (Esvelt, 1978) and has been monitored quarterly since then. During this time more than 100,000 individual water quality tests have been performed on more than 4,000 individual samples (Spokane County, 2000).

The contaminants detected within the SVRP aquifer that have prompted regulatory attention include coliform bacteria, nitrate and volatile organic compounds (VOCs). These contaminants seldom occur in concentrations high enough to exceed water quality criteria and tend to occur in limited areas for short periods of time due to the high rate of groundwater flow within the aquifer. The tables below summarize the SVRP aquifer water quality. These tables are based on the period of record for the monitoring programs in Washington and Idaho that date back to 1977 (Washington) and 1976 (Idaho).

Rathdrum Prairie Groundwater Quality Summary

(adapted from MacInnis and others, 2000)

Contaminant	**EPA MCL** (mg/L)	**Typical Aquifer Concentration** (mg/L)	**Typical Contaminant Sources**
Nitrate – Nitrogen	10	< 1 to 8	Fertilizer, septic tanks, sewage, animal waste/feed lots
Fluoride	4	< 0.12	Aluminum industry, natural deposits, fertilizer, water additives
Copper	1.3	< 0.01	Natural deposits, industrial uses, wood preservatives, plumbing
Lead	0.015	< 0.005	Industrial uses, plumbing solder, brass alloy plumbing fixtures
Chromium (total)	0.1	< 0.010	Natural deposits, electroplating, mining, paint pigments
Carbon tetrachloride	0.005	< 0.001	Solvents and their degradation products
Trichloroethene (TCE)	0.005	< 0.001	Textiles, adhesives, metal degreasers, electronic industry, dry cleaners
1,1,1-Trichloroethane (TCA)	0.2	< 0.001 to 0.005	Paints, inks, textiles, adhesives, metal degreasers
Tetrachloroethene (PCE)	0.005	Not detected	Dry cleaning and other solvents
Xylenes	10	Not detected	Gasoline, paints, inks, detergents

The list of parameters listed in the above table includes only a small number of the parameters actually examined as part of the monitoring programs. The parameters included give an overall picture of the general quality of aquifer water. It should be noted that the data for organic chemicals includes testing results from several specific contamination incidents and thus the range of data shown reflect “worse case” scenarios for the SVRP Aquifer.

The data for the Rathdrum Prairie aquifer provides an indication of the aquifer's quality as it enters Washington at the state line.

The table for Spokane Valley Aquifer groundwater quality shown below is based on over 20 years of water quality monitoring data. In most cases concentrations near the upper end of the range of observed values have occurred on only a few occasions. In some cases the upper values are related to specific contamination events, the sources of which have been removed.

Spokane Valley Aquifer Groundwater Quality Summary

(Spokane County, 2000)

Contaminant	**EPA MCL** (mg/L)	**Range of Concentrations** (mg/L)	**Median Concentration** (mg/L)	**Typical Contaminant Sources**
Nitrate – Nitrogen	10	0.01 – 48	1.55	Fertilizer, septic tanks, sewage, animal waste/feed lots
Chloride	250	0.1 - 1709	2.9	Aluminum industry, septic tanks
Fluoride	4	< 0.1 – 9	0.16	Aluminum industry, natural deposits, fertilizer, water additives
Copper	1.3	< 0.0001 – 0.080	0.01	Natural deposits, industrial uses, wood preservatives, plumbing
Lead	0.015	< 0.0001 – 0.080	0.0004	Industrial uses, plumbing solder, brass alloy plumbing fixtures
Chromium (total)	0.1	< 0.0001 – 0.070	0.0012	Natural deposits, electroplating, mining, paint pigments
Carbon tetrachloride	0.005	< 0.001 – 0.007	< 0.001	Solvents and their degradation products
Trichloroethene (TCE)	0.005	< 0.001 – 0.020	< 0.001	Textiles, adhesives, metal degreasers, electronic industry, dry cleaners
1,1,1-Trichloroethane (TCA)	0.2	< 0.001 – 0.062	0.001	Paints, inks, textiles, adhesives, metal degreasers
Tetrachloroethene (PCE)	0.005	< 0.001 – 0.020	< 0.001	Dry cleaning and other solvents

A general, gradual degradation of water quality shown by region wide increases in indicator parameters such as nitrate and chloride provides the primary indication that human activity over the aquifer creates a concern for water quality. The Spokane Aquifer Water Management Plan, using trends in and distribution of indicator contaminants, identified on-site sanitary waste disposal, stormwater injection and improperly managed chemical spills, leaks and disposal operations as the major threats to groundwater quality. Programs to address these disperse sources were initiated in the early to mid-1980's. Actions include initiating construction of a regional sewer system to eliminate septic tanks in 1985 and the prohibition of the injection of untreated stormwater over the aquifer in 1980.

In addition to the disperse sources, a number of localized contaminant sources have lead to significant groundwater degradation problems. The major localized pollution sources have been unlined landfills, large septic systems, and industrial sites with poor contaminant handling practices. Examples include an unlined 40-acre septic-tank sludge disposal area at the northern end of Argonne Road (Dion, 1987) and the Greenacres Landfill, located on the southern hillside of the Spokane Valley, about 11 miles east of the City of Spokane (Lum and others, 1986). The Argonne Road site, located on the northern hillside of the Spokane Valley, operated from the early 1970s until the Spokane County Health District confirmed elevated groundwater concentrations of chlorinated organic compounds near the site and closed the facility in 1984. The Greenacres Landfill site operated from 1951 to 1972, was designated as a Superfund site by the US EPA in 1983, and has since been capped. Numerous instances of chloride contamination from aluminum dross disposal have been documented (Drost and Seitz, 1978).

In 1985, a major effort was initiated on both sides of the Washington-Idaho state line to reduce septic system contamination of the aquifer through installation of regional wastewater collection systems. These measures have decreased the rate of nitrate contamination. Improvements in stormwater disposal practices in Washington are ongoing. However, the aquifer remains vulnerable to both legal and illegal discharges from industry, commercial and domestic activities, and underground and above ground storage tanks installed prior to adoption of secondary containment requirements and not yet upgraded.

The hydraulic connection between the Spokane River and the SVRP Aquifer is important in terms of water quality. Over the reaches of the Spokane River where groundwater discharges to the stream, the quality and quantity of the groundwater currently have a beneficial impact on river quality. During the Spokane River low flow periods (late summer), much of the water within the Spokane River downstream of the Centennial Trail Bridge near Plantes Ferry Park originates from the SVRP Aquifer. These inflows of high water quality help maintain aquatic habitat within the stream and plant life within the riparian zone, and reduce dissolved metal concentrations. In addition, the groundwater inflows help to dilute the treated effluent that discharges to the Spokane River from wastewater treatment plants in Coeur d'Alene, Hayden and Post Falls in Idaho, and Liberty Lake in Washington.

Increased extraction of water from the SVRP Aquifer has the potential to lower aquifer levels, create more wastewater and decrease the volume of groundwater that discharges to the Spokane River. These impacts would decrease the ability of the Spokane River to accept treated wastewater and still meet the federal and state water quality standards. In addition, contamination of the SVRP Aquifer has the potential to impact the water quality of the Spokane River along the reaches of the river where the aquifer discharges to the river (see Section 5.3).

Hardness (and associated calcium) concentrations in the SVRP Aquifer are significantly higher than concentrations in the river due to the flow of groundwater through rocks and sediments and dissolution of carbonate-containing minerals. These concentration differences have been used to characterize hydraulic connection between the river and the aquifer, including determining both the length of gaining and losing reaches and the volume of the surface water and groundwater interchange. These studies indicated that as much as 95% of the Spokane River summer low flows are derived from the SVRP Aquifer (Miller, 1996). Because the difference between calcium concentrations in the groundwater and the river are relatively small below the first gaining reach of the river, use of calcium does not produce rigorous results for reaches of the Spokane River below this point. The on-going USGS NAWQA study is exploring the use of lead and temperature differences between the river and the aquifer to characterize flows and interactions.

TABLE 6.1

Section 303(d) Listed Waterbodies

Name	Parameter	TRS	ID #
WRIA 55			
Dragoon Creek	Dissolved Oxygen	28N 42E 03	GL94EJ
	Dissolved Oxygen	29N 42E 08	GL94EJ
	Dissolved Oxygen	30N 42E 18	ST18TI
	Fecal Coliform	29N 42E 08	GL94EJ
	pH	27N 43E 33	MY92TJ
Deadman Creek	Temperature	27N 43E 33	MY92TJ
Little Spokane River	Fecal Coliform	26N 42E 11	JZ70CP
	Fecal Coliform	27N 43E 32	JZ70CP
	PCB – 1248	26N 42E 04	JZ70CP
	PCB – 1254	26N 42E 05	JZ70CP
	PCB – 1260	26N 42E 06	JZ70CP
	pH	27N 43E 32	JZ70CP
	Temperature	27N 43E 32	JZ70CP
	Temperature	27N 43E 33	JZ70CP
WRIA 57			
Newman Lake	Total Phosphorus	26N 45E 11	572HJX
Spokane River	Arsenic	25N 46E 06	QZ45UE
	Cadmium [1]	25N 46E 06	QZ45UE
	Dissolved Oxygen	25N 44E 06	QZ45UE
	Dissolved Oxygen	25N 46E 06	QZ45UE
	Lead [1]	25N 46E 06	QZ45UE
	PCB – 1242	25N 44E 04	QZ45UE
	PCB – 1248 [2]	25N 43E 09	QZ45UE
	PCB – 1248 [2]	25N 44E 05	QZ45UE
	PCB – 1254 [2]	25N 43E 09	QZ45UE
	PCB – 1254 [2]	25N 44E 04	QZ45UE
	PCB – 1254 [2]	25N 44E 05	QZ45UE
	PCB – 1260 [2]	25N 43E 09	QZ45UE
	PCB – 1260 [2]	25N 44E 04	QZ45UE
	PCB – 1260 [2]	25N 44E 05	QZ45UE
	Sediment Bioassay	25N 43E 01	QZ45UE
	Zinc [1]	25N 44E 03	QZ45UE
	Zinc [2]	25N 46E 06	QZ45UE

1. Elevated water concentrations above criteria during various samplings due primarily to upstream sources in Idaho.
2. Elevated concentrations above criterion in fish tissue from the rivers.

Water Quality Station Information

Station ID	Station Name	Station Abbreviation	River Mile
Little Spokane River			
134	Little Spokane	LSR-5	19.2
135	Little Spokane @ Milan	LSR-4	31.8
136	Little Spokane @ Scotia	LSR-1	47.0
137	Little Spokane below Deadman	LSR-6	13.0
138	Little Spokane near Mouth (Hiway 291 Bridge)	55B070	1.1
141	Little Spokane River @ Dartford Rd Bridge	55B082	10.3
144	Little Spokane River @ USGS Elk Gage	LSR-2	37.5
145	Little Spokane River near Dartford	55B075	3.9
147	Little Spokane River, Chattaroy Rd.	55B200	23.1
192	W Branch of the LSR at Rd (2 culverts)	LSR-3	
Dragoon Creek			
112	Dragoon Ck @ Crawford Rd	DR-2	
113	Dragoon Ck @ Crescent Br	DR-5	
117	Dragoon Cr @ Oregon culv	DR-1	
Spokane River			
101	Spokane River - Barker Road Bridge		90.4
125	Spokane River - Harvard Road Bridge #2		92.7
126	Spokane River - Harvard Road Bridge		92.7
149	Spokane River - Mission Ave Bridge		76.6
160	Spokane River - Plantes Ferry		84.1
161	Post St River Sample		74.1
162	Spokane River - Stateline Bridge		96.0
164	Spokane R Ab Liberty Brdge near Otis Orchard		93.8
167	Spokane River @ Greenacres		90.4
169	Spokane River @ Spokane		72.9
170	Spokane River below Green St @ Spokane		78.0
174	Spokane River - Sullivan Rd		87.7
176	Spokane River - Trent Bridge		85.3

7. WATER RIGHTS AND WATER USE

The hydrologic system consists of three principal components: the ocean, the atmosphere, and the terrestrial systems. Watershed planning typically focuses on the terrestrial component of water balance and the way that humans affect it. The water balance includes the principal components of precipitation falling as rain or snow, runoff as surface water, infiltration to the soil and groundwater, and discharge to surface water flows. Humans affect the natural hydrologic cycle in two fundamental ways: 1) removal of water from the terrestrial system (also called consumptive use); and, 2) timing of the movement of water through the terrestrial system.

Consumptive use of water results in the removal of water from the terrestrial system by evaporation and transpiration (evapotranspiration) of water to the atmosphere, thereby reducing the amount of water left either in aquifer storage and/or in stream flows. Irrigation, either as agricultural or urban landscaping applications, usually represents the largest consumptive use of water, in which between 50% to almost 100% of the applied water may be lost to evapotranspiration. Evaporative industrial cooling process is another highly consumptive water use.

Most other water uses have a considerably smaller portion of loss to consumptive use. For example, domestic use of water, such as washing and toilets, return most of the water to the terrestrial system.

Some water uses, such as routing water through a fish hatchery, are considered non-consumptive despite the large associated volumes of water. Similarly, hydropower generation uses large volumes of water but has negligible consumptive use. Evaporative loss of water from the surface of associated reservoirs may be considerable. Lake Coeur d’Alene may lose 29,280 acre feet of water to evaporation in July and 29,760 acre feet of water to evaporation in August (J.C. Stevens, 1920). The pool behind Upriver Dam would be expected to lose a smaller amount of water to evaporation due to its smaller relative size.

Characterization of water use in WRIA 55 and WRIA 57 is presented below. The allocation of water in the form of rights is described, followed by estimates of actual use. Then estimates of future demand projections are presented followed by comparison of allocated water with actual use and a discussion of the consumptive use associated with various water uses.

7.1 Water Rights

The Washington State Department of Ecology maintains a database of allocated water called the Water Rights Application Tracking System (WRATS) database. A subset of the database was used in the analysis of water allocation in the Little and Middle Spokane Basins. A version of this database current as of August 2001 was used for most of the analysis, although a version current as of June 2001 was used in the assessment of applications for new water rights and change applications. Although the database is continually updated and maintained, there are data gaps. Most of the information is based on hardcopies of water right records on file with Ecology, which are sometimes incomplete, so the database is subject to data entry errors. The WRATS subset database includes information on:

- Document type (e.g., claim, application for a new right, permit, certificate, application for change);
- Point(s) of use by township, range, and section;
- Priority date;
- Purpose of use; and,
- Permitted annual (Qa) and instantaneous (Qi) withdrawal rates.

Water law in Washington State initially was based on the riparian doctrine in which users jointly shared the resource. In times of restricted water availability, all users generally cut back on their use. In an effort to encourage development, the doctrine of prior appropriation was adopted by the state in the late 1800s. Under prior appropriation, new water users may not affect older, “senior,” water users. This encouraged development because once a water use was established it was guaranteed not to have to be restricted or impacted as a result of future development. Therefore, in times of restricted water availability, the most recent, “junior,” water users are required to stop using water. The relative seniority of water rights is based on the priority date, which is established at the time that a complete water right application is submitted to Ecology. Instream flows established by rule are considered a water right with a priority date of the effective date of the regulation (i.e., January 6, 1976 for the Little Spokane River; Ch. 173-555 WAC).

Water use in Washington State was regulated in 1917 for surface water, and 1945 for groundwater. Water rights issued after these dates are referred to as administratively issued water rights. Water use preceding these dates was “grandfathered in.” However, those water users were required to register their claim to water. In order to provide adequate opportunity to water users to register their claims, additional periods in which to register a claim were opened. These additional claim registry periods were June 1969 through June 1974, a short period in 1985 under the authority of the Pollution Control Hearings Board, and September 1997 through September 1998. A claim is not recognized as a water right by the state and its validity may only be established through a court adjudication process.

Groundwater use of less than 5,000 gallons per day for specified uses (Ch. 90.44.050 RCW) does not require a formal permit from Ecology. A valid water right is established by such use (e.g., as an “exempt well”), and is subject to conditions of availability, non-impairment and other requirements of maintaining a valid water right. All surface water uses require a formal permit from Ecology.

There are two types of claims: long and short. Short claims are equivalent to exempt well use and are generally for single home domestic use, although such claims may also be registered as a long claim. The only information required to register a short claim is a name, source of water, purpose of use and place of use. Registering a long claim requires more information including the quantity of water claimed and number of irrigated acres if the purpose of use is irrigation. The WRATS subset database does not report the quantity of water claimed.

Most water rights in Washington State are issued with a condition of "use it or lose it." In general, if a water right, or a portion of a water right, is not used for a continuous five-year period, it is no longer valid and is subject to relinquishment. A relinquished water right is permanently lost and cannot be restored. Municipal water rights have been protected from relinquishment due to non-use because of the requirement of public agencies to provide water and the understanding that communities are expected to grow. The portion of municipal water rights not currently in use and reserved for future use are known as inchoate rights.

7.1.1 Estimation of Water Right Quantities

The WRATS subset database does not define the annual quantity (Qa) for every administratively issued water right, nor for any claim. In order to provide an assessment of the volumes of water associated with water rights and claims for which Qa is not defined, an estimate of Qa can be made by using a series of assumptions. This process is as described in the following sub-sections.

The assessment and characterization of water rights was based on:

- Source type (groundwater or surface water);
- Document type (certificate, permit, claim, etc); and
- Purpose of use (municipal, irrigation, etc.).

The WRATS database was initially queried to exclude all documents listed as relinquished, rejected, cancelled, or otherwise not in good standing. The extracted data were placed in a database and further evaluated. Water rights listed in the WRATS subset database may have several purposes of use. The database is incomplete with respect to allocating portions of water rights among various uses. To characterize the purpose of use, the database was queried to extract water right documents based on the following order of extraction:

- All documents containing the "MU" (municipal) purpose of use, and any documents containing only "DG", "DM", and "DS" (domestic) purposes of use. All short claims were assumed to be for domestic use. Exempt wells are not included in this accounting and are specifically addressed in the Section 7.2 (Estimated Actual Use);
- Remaining documents containing the "IR" (irrigation) purpose of use, with the exception of those rights identified by Ecology as being municipal purpose of use. All long claims without a listed purpose of use were assumed to be used for irrigation;
- Remaining documents containing the "CI" (commercial-industrial) purpose of use;

- Remaining documents with non-consumptive or infrequently used purposes of use (power, fish, fire, and cooling); and,
- All other purposes of use.

In quantifying the municipal/domestic water rights, Ecology identified a number of water rights that were supplemental. Supplemental water rights are those that allow the diversion or withdrawal of water from alternate points, but do not expand the water right. Therefore, the total volume of supplemental water rights is not additive and was not included in the quantification of water rights.

A summary of water rights and claims by type and by purpose of use are presented in Tables 7.1 and 7.2, respectively. Tables 7-1 and 7-2 do not include reservoir rights. It is considered useful to exclude water rights for power, fish propagation and fire suppression purposes of use in the assessment of allocated water use for watershed planning purposes because they do not result in a significant impact to streamflows. A separate table of fish propagation, power, and fire suppression water rights is presented below. A calculated annual quantity based on use of the Qi 24 hours a day for 365.25 days is included for comparison purposes only.

Rights for fire suppression are rarely used, fish propagation returns water directly to streamflows, and power use in the Spokane Basins is run of the river hydroelectric generation. Ecology does not assign a Qa for power or fish propagation on rights for surface or ground water. Any reservoir created for power generation or fish propagation also requires a water right and is assigned a Qa.

Power, Fish Propagation, and Fire Suppression Water Rights
(Certificates and Permits)

	Power Rights		**Fish Propagation Rights**		**Fire Suppression Rights**	
	Qi (cfs)	**Annual** (AF/yr)	**Qi** (cfs)	**Annual** (AF/yr)	**Qi** (cfs)	**Annual** (AF/yr)
WRIA 55						
Groundwater			0.1	61.3		
Surface water	1.75	1268.1	36.8	26,692.7		
Reservoir		2,500		847.4		
Subtotal	1.75	3768	36.9	27,601		
WRIA 57						
Groundwater					0.2	138
Surface water	11,500	8,333,544	1.11	804.4		
Reservoir		4,000				
Subtotal	11,500	8,337,544	1.11	804.4	0.2	138
TOTAL	11,502	8,341,312	38	28,405	0.2	138

7.1.1.1 Estimation of Qa for claims

Most of the long claims with irrigation listed as the purpose of use also reported the number of acres irrigated. Duties typical of irrigation water rights in each WRIA used to calculate Qa for long claims with a listed number of irrigated acres are:

- 3 AF/yr per irrigated acre for WRIA 55; and,
- 4 AF/yr per irrigated acre for WRIA 57.

These duties were used based on relative soil conditions and crop requirements (James and others, 1989). Soils in the Spokane Valley are much more permeable which results in quicker infiltration thereby requiring more watering. Additionally, during the adjudication of surface water in the Deadman Creek portion of WRIA 55, a duty of 3 feet was assigned for most new certificates with irrigation acreage (Case No. 246952). The ratio of annual quantity to number of irrigated acres of water rights contained in the WRATS subset database with a purpose of use of irrigation and for which these fields are defined are as follows:

Average Irrigation Duties for Water Rights

	Arithmetic Average (ft/acre)
WRIA 55	2.46
WRIA 57	3.61

Long claims with irrigation listed as the purpose of use without an associated number of irrigated acres were assigned the average number of acres for long claims in the respective WRIAs, and the annual quantities were calculated using the method outlined in the preceding paragraph (3 feet/yr * 17.85 acres in WRIA 55 and 4 feet/yr * 23.19 acres in WRIA 57).

Long claims for non-irrigation use and all short claims were assigned a Qa of 2 AF/yr for domestic purposes, 1 AF/yr for stock purposes, and 2 AF/yr for other purposes. Short claims with only an irrigation purpose of use were assigned a Qa of 2 AF/yr. A Qa of 2 AF/yr is more than the quantity used annually by households in metered areas of both WRIAs and the maximum quantity assigned to private domestic use certificates in the Deadman Creek sub-basin surface water rights adjudication in 1985 (Case No. 246952). A Qa of 1 AF/yr was assigned to the stock watering purpose in the same Deadman Creek sub-basin adjudication.

7.1.1.2 Estimation of Qa for irrigation certificates and permits

The Qa for irrigation rights with a Qi but without a defined Qa was estimated by multiplying the number of irrigated acres by a duty of 3 AF/yr for WRIA 55 or 4 AF/yr for WRIA 57

7.1.1.3 Estimation of Qa for non-irrigation certificates and permits

The Qa for non-irrigation rights without a defined Qa is estimated by applying the Qi/Qa ratio for defined for other non-irrigation (excluding power, fish and fire purposes of use). The ratios are calculated separately for groundwater and surface water, and for WRIAs 55 and 57. The results are summarized in the table below.

Approximately 6.5 percent of the non-irrigation permits and certificates in WRIA 55 and 57 did not have a Qa listed in the WRATS database. The Qi/Qa ratio for surface water rights in WRIA 55 and 57 is generally consistent at between 7.36 and 7.76. The ratio is more variable for groundwater rights in both WRIAs, but generally consistent. Therefore, the simple arithmetic average of Qi/Qa of both WRIAs was used to estimate Qa for those certificates and permits where Qa was not listed (groundwater was calculated using the equation Qa = 6.46 * Qi. Surface water was calculated using the equation Qa = 0.0143 * Qi).

Summary of Qi/Qa Ratios Used in Estimating Undefined Qa

	Qi/Qa (gpm)/(AF/yr)	**Qi/Qa** (cfs)/(AF/yr)	**Number of Non-irrigation Rights**	**Non-irrigation Rights w/o Qa**	
				#	**%**
WRIA 55					
Certificates					
Groundwater	4.45	0.0099	195	1	0.5
Surface Water	7.76	0.0173	441	43	9.7
Permits					
Groundwater	3.92	0.0087	10	0	0
Surface Water	7.50	0.0167	4	1	25
WRIA 57					
Certificates					
Groundwater	11.94	0.026	173	4	2.3
Surface Water	7.36	0.0164	128	12	9.4
Permits					
Groundwater	2.29	0.005	3	0	0
Surface Water	-		1	1	100
TOTAL:			**955**	**62**	**6.5**
AVERAGE:	**6.46**	**0.0143**			

7.1.1.4 Estimation of Qa for permits and certificates with POD in multiple sections

Some water rights contain multiple points of diversion (POD) over several sections for a single permit or certificate. The allocation of Qa by section was made by dividing the Qa for the certificate or permit by the number of sections indicated in the WRATS database for the permit or certificate.

7.1.2 Discussion of Water Rights

The distribution of water rights by type (i.e., surface water versus groundwater, and claims versus rights) is shown on Figures 7.1 through 7.4. The distribution of water rights by type (e.g., agricultural irrigation, non-agricultural irrigation, non-irrigation) is shown in Figures 7.5 through 7.8. All figures, and discussion in general, exclude consideration of water rights for the purpose of power, fish propagation and fire suppression, and reservoir rights because: 1) power uses are generally so large that they skew comparisons; 2) fire suppression is generally not used and have little effect on the overall timing of flows through the system; and, 3) fish propagation is generally non-consumptive. Approximately 11,500 cfs of water rights are associated with power generation in WRIA 57. A much smaller quantity (39 cfs) is located in WRIA 55 and is mostly associated with a fish hatchery. All of the water rights for power production, fish propagation, and fire suppression are administratively issued. There are no claims for these purposes of use.

Typically, an assessment of water rights on a basin scale compares the estimated level of allocation to streamflows. A discussion of this comparison follows. However, the limitations of this approach of assessment must be considered. Much of the allocated water used is returned to the hydrologic system resulting in diminished impacts. In addition, all of the rights and claims included in the analysis are not exercised and/or valid. A more rigorous assessment would include consideration of these limitations and is partially addressed in Section 7.2. This issue will be further evaluated in development of a hydrologic model in Level 2 data analysis.

Little Spokane Basin (WRIA 55)

The total estimated volume in rights and claims, excluding instream flows, in WRIA 55 is about 187,419 AF/yr. The average annual flow in the LSR At Dartford is 215,121 AF/yr (based on the period of record from 1929-1999). However, the Dartford gage is at the upstream extent of the reach that receives significant groundwater discharge from the SVRP. Assuming an average annual contribution of 250 cfs from the SVRP, flow in the Little Spokane River below the Dartford gage increases by an additional 181,000 AF/yr for a total estimate average annual flow on the order of 396,000 AF/yr. A significant portion of the total annual flow of the Little Spokane River (LSR) appears to be allocated based on the comparison of total administratively issued water rights and claims

The permitted instantaneous withdrawal in WRIA 55 is 495 cfs (excluding claims) compared to average monthly low flows of the LSR At Dartford of 134 cfs (Figure 5.5c), and a 7Q10 of 93 cfs (Figure 5.6a). Although water rights are typically exercised to the greatest extent during low flow periods, full exercise of all rights is not thought to occur. The seasonal exercise of groundwater rights may not result in immediate impacts to streamflows, but may be delayed by the buffering capacity of aquifer storage coefficients. The resulting lag time between withdrawals and impacts depends on aquifer properties, geologic stratigraphy, and the relative location of wells with respect to surface water bodies.

Middle Spokane Basin (WRIA 57)

The total estimated volume in rights and claims in WRIA 57 is about 319,151 AF/yr, or approximately 7% of the average annual flow in the Spokane River at Spokane of 4,790,369 AF/yr (based on the period of record from 1960-1999). The permitted instantaneous withdrawal in WRIA 57 is 1,346 cfs (excluding claims) compared to average monthly low flows of the Spokane River at Spokane of 1,750 cfs (Figure 5.5c) and a 7Q10 of 806 cfs (Figure 5.6b). Although water rights are typically exercised to the greatest extent during low flow periods, full exercise of all rights probably does not occur. Because significant groundwater flow from WRIA 57 discharges through the Trinity and Hillyard Troughs, impacts within WRIA 57 from groundwater withdrawals is expected to be distributed between the Spokane River and groundwater flow from the basin through the troughs. The high degree of hydraulic continuity between the aquifer and river in the Spokane Valley is expected to result in relatively rapid impacts to surface water in response to groundwater withdrawals. However, the timing and magnitude of the response varies depending on the location of the well, the magnitude of the withdrawal and the distance from the river.

A more detailed consideration of water rights by type and purpose of use follows. Most of this discussion excludes consideration of rights with a purpose of use for power, fish and fire suppression.

7.1.2.1 Permits and certificates

Two thirds of the administratively issued water rights within the WRIAs are in WRIA 55, although over half of the allocated volume is in WRIA 57. Groundwater withdrawals comprise about 93% of all rights (about 95% in WRIA 57; about 90% in WRIA 55). The largest withdrawals of groundwater occur east of the City of Spokane along the Spokane River Valley, with smaller withdrawals occurring north of the City of Spokane and in the vicinity of the City of Deer Park (Figure 7.1). The majority of surface water rights is in WRIA 55 and is primarily for irrigation (about 14,307 AF/yr) with a smaller amount for domestic use (about 944 AF/yr). There are large surface water rights in WRIA 57 for hydropower (about 800,000 AF/yr). The remainder of surface water rights in WRIA 57 is for irrigation (about 12,294 AF/yr), domestic (about 262 AF/yr) and other uses (including heat exchange and wildlife about 13 AF/yr).

7.1.2.2 Claims

Although the largest number of documents are claims (about 75% of all documents), they represent only about 24% of the estimated annual quantity allocated and claimed in WRIA 55 and only about 5% of the total estimated annual quantity allocated and claimed in WRIA 57. This reflects the small actual use estimated to be associated with each claim. Groundwater and surface water claims are generally evenly distributed across the both watersheds (Figure 7.3, 7.4). An estimated total of 34,029 AF/yr of surface water diversion are claimed in the watersheds. Approximately 68% of all surface water claims are in WRIA 55, and approximately 94% of all surface water claims are for the agricultural irrigation purpose of use. Claims are evenly distributed between groundwater and surface water, while administratively issued water rights are dominated by groundwater withdrawals.

Although there are a large number of claims registered (i.e., 4,391 in WRIA 55; 1,178 in WRIA 57), a sorting of the database by registered owner showed that many individuals held two or three registered claims for near-identical properties. This may be a function of the fact that there have been three significant claim registry periods over which individuals may have registered a claim more than once. Such multiple registrations may actually only represent a single claim. Therefore, the number of unique claims may be significantly less than those recorded in the WRATS subset database.

Water rights in Washington State are issued with a condition of “use it or lose it.” In general, if a water right, or a portion of a water right, is not used for a continuous five-year period, it is no longer valid and is subject to relinquishment. A relinquished water right is permanently lost cannot be restored. To be valid, water use under a claim must have been established before 1917 or 1945, for surface water and groundwater respectively. Given the length of time that claims may have existed, it is considered likely that many valid claims are subject to relinquishment due to non-use. For these and other reasons, claims are generally considered less likely to be valid water rights than administratively issued water rights.

The validity of claims can only be established through an adjudication process. The surface water of the Deadman Creek sub-basin of WRIA 55 was adjudicated with the process completed in 1985. Therefore, there are no surface water claims shown in this subbasin in Figure 7.4. Both rights and claims were examined and either rejected or issued new certificates. The results are shown in the table below.

Deadman Creek Surface Water Adjudication Results

	Count	**Qi** (cfs)	**Acres irrigated**	**Qa** (AF/yr)*
Adjudicated claims	192	n/a	790	2370.0
Relinquished certificates	84	41.06	681	1275.5
Total – old claims & certificates	275	41.06	1471	3645.5
New certificates	120	11.28	496	1451.0
Percent of old claims & certificates	43.5%	27.5%	33.7%	39.8%

* Adjudicated claims Qa based on an irrigation duty of 3 feet per acre.

7.1.2.3 Purpose of use of rights and claims

Beyond a characterization of the types of water rights (e.g., administratively-issued permits and certificates; claims; and surface water/groundwater), an analysis of the uses of the rights and claims will help in understanding the economic and societal role that water rights and claims have in the basins. In some parts of the state, irrigation use is the largest consumptive user of water and so it was considered important to quantify these water rights separately. Population growth in the Spokane region is one of the highest in the Washington State and there is concern over the ability of existing water rights to meet the anticipated growth in water demand. Therefore, water rights for municipal and domestic water use were quantified. Commercial/industrial use was also quantified, and all other uses were lumped into “other” (which constituted only about 0.1% of all rights and claims).

Water rights by use are approximately 60% municipal/domestic, 25% agricultural irrigation and ~14% commercial/industrial, excluding rights for the purposes of use of power, fish and fire suppression. These purposes of use are plotted as non-irrigation rights and claims (Figures 7.5 and 7.6), municipal and domestic certificates and permits

(Figure 7.7), and irrigation rights and claims (Figures 7.8 and 7.9) associated with groundwater and surface water (excluding power, fish and fire). Groundwater use represents ~90% of rights and claims (Figures 7.5 and 7.8). Most of the non-irrigation rights and claims represent municipal/domestic (86%) and commercial industrial use (~13%) and is concentrated around the Cities of Spokane and Deer Park, and along the Spokane Valley. Irrigation rights and claims have a similar distribution of concentration.

Surface water rights and claims account for approximately 10% of all rights and claims, and are primarily (about 90%) for irrigation as defined above, many of which also include stock watering purpose (Figure 7.9). Non-irrigation surface water diversions account for about 10 percent of the permitted and claimed diversions in the watersheds, most of which is certificated or claimed for domestic purposes (Figure 7.6).

7.1.2.4 Applications and Changes

There are 39 applications in WRIA 55: 16 of these are for new water groundwater rights; seven are for new surface water rights; and, 16 change applications for groundwater rights (Table 7.1, Figure 7.10). In WRIA 57, there are 83 applications: 27 for new groundwater rights; 10 for new surface water rights; and, 46 change applications for groundwater rights. The average size of allocation requested on applications for new groundwater rights is approximately 1,370 gpm in WRIA 55 and 1,270 gpm in WRIA 57. The average size of the surface water allocation applications is considerably smaller at 0.26 cfs (117 gpm) in WRIA 55, and 0.02 cfs (9 gpm) in WRIA 57.

Spokane County recently established a Water Conservancy Board as an available avenue for processing change applications. The Board may only consider applications involving existing valid water rights. Changes application may be allowed if there is no enlargement of the right and there is no impairment of other existing rights. Therefore, change applications are not expected to have a significant impact on water resource management. Entities that have change applications currently filed with Ecology (62) may transfer their applications to the Water Conservancy Board for consideration for processing.

7.2 Estimated Actual Use

This section provides estimates for the amount of water used within WRIA 55 and 57. The components of water use included in this assessment are:

- Agricultural irrigation water use;
- Purveyor withdrawals;
- Commercial/industrial use;
- Exempt well use;
- Non-agricultural irrigation water use; and,
- Recharge from septic systems to groundwater.

Sources of information on actual water use incorporated within this study include the following:

- USDA (1997) agricultural land use studies and statistics;
- Water district and wastewater treatment facilities comprehensive plans;
- Water use statistics published in Metcalf and Eddy (1994); and,
- Information on the location and quantity of water withdrawals and wastewater discharge compiled by Spokane County and Whitworth Water District staff.

In addition to the aforementioned direct sources of actual water use information, the following spatial coverages were used in conjunction with appropriate water use factors to estimate the spatial distribution and volumes of varying components of actual water use.

- Agricultural land use (USGS);
- Population (2000 census data);
- Water district service areas;
- Sewer system service areas;
- Septic systems; and,
- Precipitation and temperature.

Analysis of water use data is detailed in the sections below. Although total annual water use is estimated and presented below, monthly water use has been calculated. These monthly use statistics will be used in development of a computer model in the Level 2 Assessment that will simulate the hydrologic conditions of the basin. Finer resolution to weekly or daily water use patterns will be developed after the initial model calibration.

7.2.1 Agricultural Water Use

This section presents estimates of agricultural water use. Agricultural water use can be divided into two general categories, irrigation and stock watering. Irrigation water constitutes water applied to crops, which includes conveyance losses, application losses and evapotranspiration by the crop. Stock water use refers to the amount of water used by farmers to maintain stock. Total stock water use is not precisely known in either WRIA 55 or WRIA 57. Spokane County has compiled a list of estimated stock water use for WRIA 55. Based on the compiled data, stock watering in WRIA 55 accounts for approximately 20 AF/yr. No data were available for WRIA 57. In comparison to other water uses in the watershed stock water use is not considered significant and is therefore excluded from further analysis. Full accounting of water use in dairy activities, particularly in WRIA 55, may indicate a need to include those quantities of water use.

7.2.1.1 Irrigated Acreage

In order to estimate water use for agricultural irrigation, the amount and location irrigated acreage must be identified. The more precise this data is, the more representative the water use estimate will be. The total irrigated agricultural acreage and the location of the irrigated acreage is not precisely known for either WRIA 55 or 57. Therefore, estimates of irrigated acreage were made based on data complied in the USDA 1997 Census of Agriculture, and GIS land use coverage from the USGS (LULC) interpreted from 1992 satellite imagery.

The USDA census data provides an estimate of irrigated acreage and total cropland (based on survey information) for the three counties that encompass the WRIAs, shown in Table 7.2. Using the USDA acreage data, a ratio of irrigated acreage to total cropland was established for each county. Applying the ratios to all the agricultural lands that are delineated on the land use coverage for each county (Figure 4.16), an estimate of irrigated acreage was calculated for each WRIA on a TRS resolution. Approximately 4,710 acres were estimated to be irrigated, with 3,903 acres and 807 acres in WRIAs 55 and 57, respectively. The three most prominent crops cultivated in the encompassing counties are wheat, hay-alfalfa, and barley (Table 7.3). Because the resolution of the USDS data is on a county scale, the irrigated acreage is assumed to be distributed uniformly through out each county within USGS-delineated agricultural use land. Windshield surveys of Spokane County in May of 1995 and of Stevens and Pend Oreille Counties in September of 2000 found 2,973 irrigated acres in WRIA 55 and 1,971 irrigated acres in WRIA 57. Most of these fields were planted in alfalfa with some potatoes and grass for turf.

7.2.1.2 Crop Irrigation Requirement

Crop Irrigation Requirement (CIR) is the optimal amount of water required by a crop in addition to the water provided by precipitation. The CIR and precipitation is water “lost” to the atmosphere from evaporation and transpiration, “evapotranspiration” or ET through the crop. In order for the full theoretical amount of CIR to be lost, the irrigation water must be applied at optimal timing and rates to maintain optimal soil moisture conditions for plant growth. Applying less water will result in less water being evapotranspired, while greater watering will result in return flow to groundwater. Therefore, CIR represents a theoretical maximum consumptive loss as a result of crop evapotranspiration. Higher consumptive losses may result from application irrigation efficiencies in which water evaporates between a spray nozzle and before it reaches the crop or soil. CIR is calculated using the following equation:

$$\text{CIR} = \text{ET}_{\text{crop}} - \text{precipitation}$$

Crop evapotranspiration (ET_{crop}) can be estimated by direct measurement or by calculating from empirical equations. A rigorous estimate of ET can be calculated using localized meteorological data (temperature, precipitation, wind run, solar radiation, dew point). Due to the paucity of local climate data for WRIA 55 and WRIA 57, ET was calculated based on temperature data alone and calculated to a Township Range Section

(TRS) resolution. The estimation method used was based on the Hargreaves equation, which uses only temperature and precipitation data (Maidment, 1993). The Hargreaves equation calculates the ET for an idealized reference crop (ET_{rc}) of grass clipped to a height of 0.12 meters. To calculate the ET for a specific crop, the reference crop evapotranspiration, ET_{rc}, is multiplied by a crop specific coefficient, K_c. K_c is a factor that takes into account the growth stage of the crop.

$$ET_{crop} = K_c * ET_{rc}$$

Monthly maximum, minimum and average temperature and monthly average precipitation data were obtained from PRISM for each Township Range Section. For the purposes of this analysis, an average crop coefficient for all areas and all crops was calculated and varied by month as a function of growth stage of the crop. The average crop coefficient is based on the arithmetic average of the three most prevalent crops grown in the three counties, wheat, alfalfa/hay, and barley, which account for about 95% of all agricultural crops in the region. The monthly ET_{crop} was calculated for each Township Range Section during the growing season of May through October.

The annual Crop Irrigation Requirement was calculated by aggregating the monthly CIR less precipitation for each Township Range Section (Figure 7.10). The annual CIR for WRIA 55 and WRIA 57 are approximately 6,398 AF/yr and 1,278 AF/yr, respectively.

Summary of Estimated Agricultural Irrigation Water Use

(Crop Irrigation Requirements)

	WRIA 55	**WRIA 57**	**Total**
Irrigated Acreage (acres)	3,903	807	4,710
CIR Duty (feet/yr)	1.64	1.58	
CIR (AF/yr)	6,398	1,278	7,676

7.2.1.3 Agricultural Irrigation Efficiencies

The average CIR is 1.64 feet/year and 1.58 feet/year for WRIA 55 and WRIA 57 respectively. This water duty does not account for irrigation system application losses because CIR does not include “efficiency” losses from conveyance systems such as seepage, evaporation, spillage, and application efficiency such as wind drift, surface runoff and excessive subsurface drainage. Conveyance losses are typically higher for large-scale irrigation districts that deliver surface water through extensive canal or ditch systems. Approximately 80% of the water allocated to agricultural irrigation in WRIAs 55 and 57 is groundwater. The cost associated with pumping groundwater is expected to provide irrigators with an incentive to minimize conveyance losses. Additionally, groundwater sources are typically installed close to their place of use. These factors will tend to minimize conveyance losses.

Typical values for efficiencies for various types of irrigation systems and methods are listed in Table 7.2. The irrigation application methods used predominantly in WRIAs 55 and 57 are center pivot and wheel move sprinkler systems. These methods have an average irrigation efficiency of 70 percent. A prior study (Ecology, 1975) noted irrigation efficiencies of 65 (rill irrigation) and 70 (spray irrigation) percent. These application efficiencies represent evaporative losses and return flows, and were not included in calculating agricultural irrigation water use. Actual agricultural irrigation water use may be significantly higher than presented.

The fate of water applied in excess of the CIR will follow two scenarios depending on if the irrigation water source is from surface or ground water.

1) If the irrigator's source is groundwater and the farmer over applies water, the resulting excess water will return to the ground water system resulting in no net loss to the groundwater.

2) If the irrigator's source is surface water and the farmer over applies water the resulting excess will return to the groundwater system and eventually return to the surface water system. The lag time for the excess irrigated water to return to the surface water system may result in short-term impacts to surface water flows which may be important during periods of low stream flows.

A detailed review of irrigation practices including irrigated acres and applied irrigation water could quantify the amount of irrigated water recharged to the groundwater system.

Approximately 6,400 acres were irrigated in 1976 (Ecology, 1975). Further reductions have occurred throughout the 1980s (USDA agricultural land use census) and in 1997 only 4,710 acres were estimated to be irrigated (USDA, 1997). If this trend continues, the importance of agricultural water use in the basin-wide water balance should be weighed in relation to other water uses in the Middle Spokane and Little Spokane watersheds. This may provide the opportunity to reallocate water resources among the changing social and economic activities within the basins.

7.2.1.4 Deer Park Irrigation with Wastewater

The City of Deer Park uses treated wastewater to irrigate 180 acres of alfalfa and corn at the Deer Park airport with a spray system. Rainfall, evapotranspiration, and soil moisture are tracked to insure no irrigation water recharges groundwater. The average quantity of water applied for the years 1997 to 2001 was 20.24 inches. This does not account for efficiency losses. The City of Deer Park estimates its system is 73% efficient yielding a CIR of 14.8 inches. With a 70% efficiency the CIR is 14.2 inches.

7.2.2 Purveyor Water Production

Spokane County obtained the water production data from major water purveyors for 1994 to 1999 (Tables 7.4 and 7.5). This data was presented to Golder as average monthly water production from these purveyor wells based on the 1994 to 1999 data. The average annual volume of water withdrawn by these purveyors (about 128,451 AF/yr) was aggregated by section (Figure 7.12). Water rights (certificates and claims) with a municipal or domestic purpose of use total approximately 300,630 AF/yr (Figure 7).

The largest concentration of purveyor water wells occurs in the SVRP Aquifer within the southeastern portion of WRIA 55 (in the vicinity of and south of the Little Spokane River) and within the central portion of WRIA 57. Some large water purveyor wells in the Pine River Park area north of the Little Spokane River (i.e., Whitworth Water District and Spokane County Water District #3) lie just outside of the sole source SVRP Aquifer boundary delineated in 1977 (Drost and Seitz, 1978). More recently, information collected for the SAJB Wellhead Protection Plan indicates the confined, lower portion of the SVRP Aquifer extends under the Little Spokane River to supply water to these wells (CH2M Hill, 2000). The most significant concentration of water purveyor wells outside the SVRP Aquifer occurs in the vicinity of the City of Deer Park.

The annual water withdrawn by the water purveyors in WRIA 55 is approximately 24,489 AF/yr (7,978 million gallons per year). The annual water withdrawn by the water purveyors in WRIA 57 is approximately 103,962 AF/yr (33,871 million gallons per year).

Cross-referencing the extents of water district boundaries with census population and typical residential per capita usage, approximately 64,225 AF/yr is used in residential applications. Residential use within the City of Spokane has been characterized as being equally divided between interior and exterior use. In suburban areas outside of the City of Spokane exterior water use can be as high as two thirds of total water use. Usage pattern of non-residential (e.g., commercial/industrial) water has not been characterized.

7.2.3 Commercial / Industrial Water Use

Information on average monthly water use by commercial/industrial users was provided by Spokane County. The average monthly values presented on Table 7.6 for WRIA 55 and Table 7.7 for WRIA 57 are based on data obtained by Spokane County from commercial and industrial users not using water from a public water supply system for the period of 1994 to 1999. Commercial and industrial water use is estimated at 3,929 AF/yr in WRIA 55, and 34,254 AF/yr in WRIA 57. The majority of the water withdrawn by commercial and industrial users is extracted from the SVRP Aquifer with minor quantities withdrawn from the Little Spokane Aquifer area and the Deer Park Basin (Figure 7.13).

7.2.4 Exempt Well Use

Domestic exempt well withdrawals are defined as “any withdrawal of public ground waters for stock-watering purposes, or for the watering of a lawn or of a noncommercial garden not exceeding one-half acre in area, or for single or group domestic uses in an amount not exceeding five thousand gallons a day, or for an industrial purpose in an amount not exceeding five thousand gallons a day” (Ch. 90.4050 RCW).

Exempt wells are a concern in watershed planning because the total number of wells and quantity of water withdrawn is usually not known. Although exempt wells are permitted to use up to 5,000 gallons a day for multiple purposes (maximum annual use of 5.6 AF/yr), they are usually used to provide a much smaller volume to domestic homes. An average residential connection within water districts outside of the City of Spokane uses about 800 gallons per day (0.9 AF/yr; 2.5 people per residence; year-round average daily per capita use of 320 gallons), an amount significantly less than the maximum allowed for an exempt well (see table below). The Spokane County Comprehensive Plan and the Washington State Department of Health also estimate residential water use is about 800 gallons per day. Exempt wells are an important component of overall water use in the watersheds because substantial rural development supplied by exempt wells for homes has been occurring outside of the service areas of purveyors.

Residential Water Use in Selected Water Districts Outside the City of Spokane.

System	**Year**	**Residential Use per Connection** (gallons per day)	**Residential Use per Person** (gallons per day)
SCWD#3 South Hill	1998	677	271
SCWD#3 Colbert	1995	630	252
SCWD#3 Colbert	1996	727	291
SCWD#3 Colbert	1998	741	296
SCWD#3 Colbert	1999	517	207
SCWD#3 BP	1998	602	241
SCWD#3 Mead	1998	760	304
SCWD#3 south Valley	1998	788	315
SCWD#3 Chattaroy	1998	925	370
SCWD#3 Chattaroy	1999	1,104	441
Whitworth Water District	average	943	377
Modern Electric Water Company	average	973	389
Vera Water and Power	average	825	330
Stevens Co PUD Half Moon	average	798	319
Stevens Co PUD Riverside	average	868	347
Stevens Co PUD Panorama Acres	average	1,040	416
Average:		**807**	**323**

The analysis used to estimate exempt well use assumes that the population outside of the service areas of purveyors is served by exempt wells. The 2000 U.S. Census data was obtained and GIS tools used segregate the population outside water district boundaries (Figure 7.12). This population was distributed by section, and the population was assumed to be evenly distributed within an individual section. The average per capita daily water use for this population was assumed to be 320 gallons. The resulting quantity of exempt well water use is estimated to be about 16,680 AF/yr (about 11,000 AFR/yr in WRIA 55 and about 5,600 AF/yr in WRIA 57; Figure 7.14).

7.2.5 Non-Agricultural Irrigation Water Use

The use of water supplied by purveyors and exempt wells can be generally characterized by two components; a low consumptive use component characterized by water that is returned to the hydrologic system through waste water treatment plants and septic systems, and a high consumptive use component in the form of irrigation of landscaping and home gardens. The high consumptive use component, the amount of water that is used in non-agricultural irrigation, is estimated in this section.

An average annual hydrograph of domestic use from the City of Spokane Comprehensive Water System Plan is displayed in Figure 7.14. Year-round base use is generally interior use that is returned to the system via a wastewater treatment plant or septic system. Peak summer water use is assumed to be outdoor use; including lawn watering, car washing and other outdoor uses. Approximately 50% of total annual residential water use is peak summer (outdoor) use, although this will vary across the basins. In order to estimate this quantity of water, U.S. 2000 census data was combined with typical water use rates obtained from Spokane County to calculate average monthly and annual values (Figure 15). Outdoor use is estimated to be about 70,000 AF/yr, primarily used for irrigation. This number represents an upper limit of consumptive use from non-agricultural irrigation because actual consumptive losses are likely lower as a result of over watering. When over watering occurs, a portion of the applied water is recharged to groundwater.

The amount of non-irrigation use represents all domestic water users including those supplied by domestic exempt wells and residents served by a water supply purveyor. It is assumed that non-irrigation water use does not vary across the watersheds. In reality, there is likely less water use in areas where rainfall amounts are larger. However, this uniform use assumption probably doesn’t introduce much error to this study as population decreases towards the east and north where rainfall increases.

It is recognized that significant variation in water use supplied from exempt wells may occur. Variables influencing higher or lower use of exempt wells include:

Higher use influences:

- There is no meter charge for exempt wells as there is for water supplied by purveyors, therefore there is less incentive to conserve water (other than the electrical bill associated with pump operation);
- Some large lawns are irrigated by exempt wells; and,
- People support livestock with wells.

Lower use influences:

- Many exempt wells are installed in less productive aquifers which limit the volumes of water that can be withdrawn; and,
- Many homes using exempt wells do not irrigate any lawn.

Given the restrictions of currently available data, and the off setting effects of the different variables that would result in higher or lower estimates, the method of analysis used is considered reasonable.

7.2.6 Wastewater Discharge

In developing a water balance, return flow back to the hydrologic system must be accounted for. The following section describes permitted discharges and discharges to the groundwater system via septic systems.

7.2.6.1 Permitted Discharges

Approximately 7% of the entire study area and 60% of the population (Census, 2000) in WRIA 55 and WRIA 57 resides within the boundaries of a public sewer system. Wastewater discharge data was available as both monthly data directly from the dischargers and average monthly data calculated by Spokane County staff. The locations of the wastewater discharges are shown on Figure 6.2. A listing of the wastewater dischargers for WRIA 55 and WRIA 57 and the average annual discharge rates are presented on Table 7.8.

Three of the six dischargers in WRIA 55 release wastewater to the ground (942 AF/yr) and three release wastewater to surface water including the Little Spokane River and Deadman Creek (13,885 AF/yr; Table 7.8). Of this total surface water discharge to the Little Spokane River, 9,942 AF/yr is from the fish hatchery to the Little Spokane River, with minimal consumptive use.

In contrast, four of the five dischargers in WRIA 57 release wastewater to the Spokane River. The fifth discharger releases wastewater to a dry well adjacent to the Spokane River that is presumed to be in close hydraulic continuity with the Spokane River. Therefore, the major wastewater dischargers within WRIA 57 release essentially all of their wastewater (i.e., 28,669 AF/yr) to the Spokane River.

Most of the water treated at the City of Spokane WWTP is withdrawn from the SVRP Aquifer within WRIA 57. Although the City of Spokane Waste Water Treatment Plant (WWTP) discharge is located on the Spokane River outside of WRIA 55 and WRIA 57, most of the water discharged from the WWTP originates in WRIA 57. The City of Spokane WWTP discharges 46,265 AF/yr (15,078 million gallons per year or about 104 cfs), which is almost twice that of the other five WRIA 57 dischargers combined. About 1,000 AF/yr of this discharge comes from Fairchild Airforce Base, which does not draw water from WRIAs 55 or 57. Another 390 AF/yr comes from Airway Heights, which also receives about 450 AF/yr of water from City of Spokane wells within WRIAs 55 & 57.

Target flows of 2,000 cfs on the Spokane River have been established at Spokane Falls. The majority of aquifer withdrawals within WRIA 57 occur upstream of Spokane Falls, while the discharge from the WWTP is downstream of Spokane Falls (Figures 5.2b, 6.2 and 7.11). Although flows in the intervening reach of the stream are affected by this redistribution, flows downstream of the WWTP are mitigated relative to those measured at Spokane Falls.

7.2.6.2 Septic System Recharge

Effluent from septic systems is released beneath the ground surface and is therefore mostly recharged to groundwater. A small portion of effluent from septic systems may be drawn up through root system of plants, however this phenomenon is considered insignificant within the precision of analysis conducted here.

Water quality contamination in aquifers from septic systems, specifically by nitrates, is a concern. These problems are likely to be localized to areas of high concentration of residential development. Within the study area, population is greatest along the Spokane River, and around the confluence of Deadman and Deep Creeks with the Little Spokane River. Some of these areas coincide with areas of shallow groundwater and are most susceptible to contamination from septic systems. Most of these areas are already sewered, with sewering of additional areas planned under the 20-year Comprehensive Plan (CWMP, 1996). However, there are several areas with large and growing populations that overlie susceptible recharge areas that are not scheduled for sewer hook up in the near future. These areas include the area southeast of the confluence of Little Spokane River with Deadman Creek and areas along the Spokane River Valley east of Spokane.

Different analytical methods were used to estimate the amount of wastewater recharged to groundwater from septic systems inside of sewered areas and outside of sewered areas. Outside of sewered areas, population was multiplied by a general per capita discharge rate. It was assumed that population residing outside sewage system boundaries discharges wastewater to septic systems. Census 2000 data and GIS coverage of sewered areas were used to quantify the population outside of serviced areas. The advantage of using census data is that data is available on all of the study area and it is from a highly reliable source. Because the distribution of population is know only down to a Census Block scale there is some error introduced when distributing population inside and outside of a boundary. This distribution can only be done on an areal basis, meaning that the ratio of area inside and outside of a boundary is used as the ratio of population inside and outside a boundary; this is not necessarily the case, but the error is acceptable when considering such large populations. Per capita day wastewater discharge is assumed to adequately represent total discharge from a septic system because there is little loss from physical processes during recharge from septic systems. A typical discharge per capita day base value of water use provided by Spokane County and the City of Spokane is approximately 82 gal/capita/day. No seasonal peaking factors are accounted for in this calculation because the majority of increased seasonal use does not discharge through septic systems.

For septic systems inside sewered areas, the recharge was calculated using a GIS coverage of septic systems within sewer service area and assuming 2.5 persons per septic system (Spokane County Capital Facilities Plan, March 2001). A per capita day discharge rate of 82 gallons was also used in this calculation. Based on the assumptions and data specified, total annual septic system recharge in both WRIAs is estimated to be approximately 12,000 AF/yr. An estimated 1,600 AF/yr of this occurs from septic systems within sewered areas. Average annual recharge rates per acre are shown below.

Approximately 71% of the study area is considered low population density (less than 60 people per square mile) rural residential, farm, or forestland containing approximately 13% of the population. The variation of septic system recharge will be considered in the development of a hydrologic model.

Summary of Septic System Average Recharge Rates
(inches/year/acre)

	Average	**Low Density**	**High Density**
WRIA 55	0.13	0.05	0.36
WRIA 57	0.49	0.03	1.20
Weighted average	0.22	0.04	0.67

7.3 Comparison of Allocated Water and Actual Use

A comparison of the amount of water allocated and the amount of water actually used in the basins is presented in the following summary table, which is compiled from Table 7.2 and Section 7.2.

Summary Comparison of Estimated Allocated Water and Actual Withdrawal
(excluding fire, fish and power uses; all quantities in AF/yr)

Purpose of Use	Allocated	Actual Withdrawal	Unused Allocation	Percent of Allocation Used
WRIA 55				
Agricultural Irrigation [a]	73,337	6,398	66,939	9%
Municipal/Domestic	88,996	24,553	64,443	28%
Commercial/ Industrial	21,428	3,929	17,499	18%
Exempt Wells	-	11,000	-	
Subtotal	183,761	34,880 [b]	148,881	19%
WRIA 57				
Agricultural Irrigation [a]	51,151	1,278	49,873	2%
Municipal/Domestic	211,634	103,962	107,672	49%
Commercial/Industrial	50,996	34,254	16,742	67%
Exempt Wells	-	5,600	-	
Subtotal	313,781	139,494 [b]	174,287	44%
Total	**497,542**	**174,374** [b]	**323,168**	**35%**

[a] Allocated quantities based on a duty of 3-4 feet/acre/year. Actual withdrawal based on a duty of 1.6 feet/acre/year. Application efficiencies, conveyance losses, and stock watering are not included and may result in higher actual withdrawal estimates.

[b] Excludes exempt well use.

Actual withdrawal quantities shown above are averages rather than maximum quantities, therefore some of the “unused allocations” may be exercised under higher demand conditions (e.g., hot dry years). Additional differences between allocated and actual withdrawal may be a result of: 1) assumptions made in estimating the associated volumes; 2) incomplete inventory of actual withdrawals; and/or, 3) not all allocated water is being used. A thorough understanding of the methodologies used in making these calculations is required to properly interpret the data presented above. The assumptions used in making the estimates are described in Section 7.2. Implications of the assumptions made are described below.

The assumption that likely has the largest impact on the estimate of actual use for agricultural irrigation is the assumption that the quantity applied is equal to the crop irrigation requirement (CIR). The CIR represents only the amount of water pulled from wet soil by a crop and evaporated to the air. It does not consider conveyance losses, application efficiencies, or return flows from over watering. This method of analysis also assumes that the optimal amount of water is applied to the soil and that it never dries out. Actual irrigation practices usually result in periods of less than optimal soil saturation maintained resulting in less water being evapotranspirated than the maximum amount of water that could be theoretically evapotranspired, and more return flows. Incorporation of these considerations may result in increasing the estimate for agricultural irrigation. Regardless, it appears that there is significantly more water allocated in water rights and claims than is needed for the acres actually being irrigated.

The most important variable with respect to estimating the actual withdrawal by purveyors may be the accuracy of the purveyor's inventory of withdrawal, which are average and not maximum quantities (Tables 7.4 and 7.5). The estimate of allocated water for domestic and municipal use includes all rights for all large purveyors and all other rights with a purpose of use listed as domestic, excluding any rights with an associated purpose of use for irrigation. Included in the estimate of domestic and municipal allocations are long form claims with a domestic purpose of use and all short form claims. All claims included in this estimate were assigned an annual quantity of 2 AF/yr, the total of which represents about 3% of the unused allocated water for domestic and municipal uses.

About 67% of the allocated water in WRIA 57 for commercial/industrial appears to be actually used. Only about 18% of the water allocated for this purpose of use in WRIA 55 is used. A more rigorous inventory of commercial/industrial water use in WRIA 55 may reveal a larger actual use.

7.4 Consumptive Use

Comparison of water use should also take into account the consumptive portion of water use. This is the portion of water that is evaporated through various processes and transpired by plants as opposed to the portion of water that is returned to groundwater or streams. The largest consumptive water use in the two basins may be outdoor use for irrigation of landscaping within purveyor service areas. Further discussion on each category of use is presented below, along with a summary table of estimated consumptive use.

Consumptive use based on application of water to irrigation is estimated for two categories – agricultural irrigation and landscaping irrigation. Consumptive use from agricultural irrigation is estimated based on crop irrigation requirements. This estimate of consumptive use represents the maximum consumptive use from the soil and plants. Less water may be evapotranspired from soil and plants if irrigation is applied in a pattern that does not provide the crop irrigation requirement all of the time. Alternatively, additional evaporative loss may occur in the application of water, such as through high-pressure spray irrigation and wind drift of the spray mist. Actual consumptive use may be 5% to 80% higher due to application inefficiencies depending on the method of irrigation (e.g., rill or spray irrigation).

The method of estimating consumptive loss for landscaping irrigation is through demand analysis of water provided by purveyors. Approximately 70% of the annual residential demand of the City of Spokane occurs during the summer. Most of this is assumed to be exterior use, primarily for landscape irrigation. In more suburban water districts, such as Whitworth Water, up to two thirds of the annual residential consumption is used for landscape irrigation. Approximately 64,225 AF/yr is supplied to residential uses (Table 7.9), and half to two thirds of this (about 32,112 AF/yr to 43,030 AF/yr) is primarily used in landscape irrigation. Because typical landscape irrigation practices result in over watering and resultant return flows, actual consumptive use may be smaller. Because landscape irrigation is expected to be the highest representative consumptive use of water delivered by purveyors, and may be the highest consumptive use in the basins, a more accurate estimate of consumptive use is considered important for proper calibration of a hydrologic computer simulation model.

Non-residential use and the associated use patterns have not been characterized. If non-residential use is similar to residential use, half to 67% of non-residential water is used for landscape irrigation. This means 65,000 to 86,000 AF/yr of all water delivered by purveyors may be used primarily in landscape irrigation, a portion of which will be consumptive.

Assuming a use pattern for exempt wells of an average of 800 gallons per residence per day, the total volume of withdrawals from exempt wells is estimated to be on the order of 16,600 AF/yr. One half to two thirds of these withdrawals (8,300 to 11,066 AF/yr) may be used in landscape irrigation, a portion of which will be consumptive.

Summary of Estimated Consumptive Use

Purpose of Use	**Actual Use** (AF/yr)	**Irrigation Use** (%)	**Irrigation Use** (AF/yr)
WRIA 55			
Agricultural Irrigation[1]	6,398	100%	6,398
Municipal/Domestic[2]	24,553	50% - 67%	12,276 - 16,369
Commercial/Industrial	3,929	Unknown	-
Exempt Wells[2]	11,000	50% - 67%	5,500 - 7,333
Subtotal	45,880		24,174 - 30,100
WRIA 57			
Agricultural Irrigation[1]	1,278	100%	1,278
Municipal/Domestic[2]	103,962	50% - 67%	51,981 - 69,310
Commercial/Industrial	34,254	Unknown	-
Exempt Wells[2]	5,600	50% - 67%	2,800 - 3,733
Subtotal	145,094		56,059 - 74,321
Total	**190,974**		**80,233 - 104,421**

[1] Based on Crop Irrigation Requirement. Application efficiencies may result in higher consumptive use. Actual application schedules may result in lower consumptive use.

[2] Based on exterior use of residential demand patterns for the City of Spokane. Over watering may result in a significant amount of return flow and reduced consumptive use.

7.5 Water Balance of Actual Use

Total estimates of actual withdrawal, consumptive use, septic system recharge, and wastewater discharge have been calculated for the combined WRIAs 55 and 57. A water balance of actual use is useful in indicating the completeness of accounting. This also allows a water balance of actual use to be prepared:

Actual withdrawal:		179,974	AF/yr
Irrigation use:	92,327		AF/yr
Waste water discharge:	78,819		AF/yr
Septic system recharge:	12,000		AF/yr
Actual use accounted:		183,146	AF/yr
Actual difference:		(3,172)	AF/yr

There is about a 1.8% discrepancy between the estimated quantity of water pumped (actual withdrawal) and the quantity of actual use. There are many potential explanations for this discrepancy. Actual use estimates shown above considered wastewater discharge, septic system recharge, and irrigation (assuming half of purveyor and exempt well water is used for landscape irrigation). Actual use estimates are about 2% greater than actual withdrawals if it is assumed that two thirds of purveyor and exempt well use is for landscape irrigation. Some water purveyors calculate "unaccounted water" (water that is pumped but is not metered). Water that is not metered includes that consumed by fire suppression, hydrant testing, main breaks, reservoir rehabilitation, street cleaning or other permitted hydrant use. The volume of unaccounted water can be more than 10% of the total water pumped by a purveyor.

Several assumptions, outlined in previous sections, were used in preparing each component of this tabulation. Therefore, significant changes may occur by modifying the methods of estimation. However, these changes may not alter the discrepancy between actual withdrawal and actual use estimates. For example, a more accurate estimate of the consumptive use of landscape irrigation may result in reducing the consumptive use, but would introduce a component of return flow. Similarly, increasing the amount of water used in agricultural irrigation may increase actual use, but could also increase consumptive use and/or return flows.

Further, in using the discharge from wastewater treatment plants in the water balance of actual use, it is implicitly assumed that these discharges represent return flows from water accounted for in actual use. In reality, infiltration and inflow (I & I) from and to the wastewater sewer system occurs. Infiltration represents water lost from a leaky sewer system to the aquifer. Inflow represents groundwater that seeps into sewer systems. A better characterization of I & I is being conducted. In addition, a portion of the City of Spokane has a combined wastewater and stormwater system. Most stormwater in this area is processed through the wastewater treatment plant, but sometimes stormwater and wastewater overflow into the Spokane River.

The use patterns for commercial/industrial use have not been characterized. Incorporating the consumptive portion of such use may explain a part of the difference in actual water withdrawal and accounted use.

7.6 Future Water Use Projections

Current and future water use patterns are established for six major water systems and used to extrapolate future water demand for WRIAs 55 and 57. The following water use and data collection and evaluations were conducted as part of this evaluation:

- Review and compile existing water use in the six water systems of interest:
  - City of Spokane;
  - Consolidated Irrigation District;
  - Modern Electric Water Company;
  - Spokane County Water District #3;
  - Vera Water and Power; and,
  - Whitworth Water District #2.

- Calculate per capita demands of these water districts to permit estimation of present water demand in the areas of WRIAs 55 and 57 not served by one of these six water systems.
- Obtain and review water system plans (WSPs) for the six water systems of interest in order to determine projected growth rates for each system. Scale projected water use as necessary to arrive at projected 2020 water use for each system.
- Obtain and review Spokane County Comprehensive Plan, 2001 or other data to estimate population and growth rates for areas of WRIAs 55 and 57 outside the service areas of the six water systems of interest. Although a Spokane County Capital Facilities Plan was developed in 2001, the original WSPs of each individual water system were used in the analysis presented in this section.
- Summarize projected conservation levels as obtained from the WSPs or information verbally provided by water system operators.
- Summarize water saving changes made in the 1994 Uniform Plumbing Code (UPC).
- Prepare a spreadsheet summarizing the above information.

Acronyms/Abbreviations Used in Future Water Use Projections Discussion

OWSA	Area outside the water service area of the six major water systems	Spokane	City of Spokane water system
CID	Consolidated Irrigation District #19	UGA	Urban Growth Area
GMA	Growth Management Act	UPC	Uniform Plumbing Code
OFM	Washington State Office of Financial Management	Vera	Vera Power and Water Company
Modern	Modern Electric Water Company	WSP	Water System Plan
SCWD #3	Spokane County Water District #3	Whitworth	Whitworth Water District #2

The six major water systems used as the basis of deriving future water use projections are located as described in the following table and shown in Figure 7.12:

Water System Locations

Water System	WRIA 55	WRIA 57	Comments
City of Spokane	X	X	Spokane's service area includes parts of WRIAs 55 and 57 as well as areas outside of these WRIAs.
Consolidated Irrigation District # 19		X	
Vera Water and Power		X	
Modern Electric Water Company		X	
Spokane County Water District #3	X	X	This water district is comprised of several non-contiguous areas lying within both WRIAs.
Whitworth Water District #2	X		

Total annual current and projected (2020) water use from the WSPs is summarized in Table 7.10. Current and projected monthly water use is summarized in Table 7.11. These data are based on information contained in water system plans, production data compiled by Spokane County with the assistance of the water systems, and US 2000 census data. Population distribution among the WRIAs, and within and outside of the major water systems is presented in Tables 7.12 through 7.14.

7.6.1 Description of Existing Water Use

Water use is characterized within the service areas of the six major water systems and then extrapolated to areas outside of the major water systems.

7.6.1.1 Existing Water Use Within the Six Major Water Systems

Information from Water System Plans for the six systems related to current and future water demand is summarized in Table 7.10. Most population figures in the plans were calculated by multiplying the number of residential connections by the estimated persons per connection, usually 2.5. Existing well pumping records were obtained by Spokane County with the assistance of water system operators (Table 7.11). Some of the data (e.g., population) may vary slightly between the two tables for various reasons, such as population being adjusted to different years. Approximately half of the population of the City of Spokane water service area is inside of WRIAs 55 and 57, with the rest of it in WRIA 54 and 56 (Lower Spokane and Hangman Creek watersheds, respectively).

Typical annual average per capita daily demand ranges from 274 gallons per capita per day (gpcpd) for Whitworth (based on 3 persons per connection), to 355 gpcpd for the Modern Electric Water Company (Table 7.10). The Consolidated Irrigation District # 19 (CID) water usage is consistent with other water districts during the winter, irrigation off-season (e.g., ~170 gpcpd within a range of 108-185 gpcpd; Table 7.11). However, during the summer irrigation season the CID monthly demand peaks at approximately 2,400 gpcpd, which is approximately three times the peak monthly demand of other water systems (e.g., 575-740 gpcpd; Table 7.11). This is assumed to reflect the summer agricultural irrigation demand serviced by the CID. Therefore, the annual water supply demand distribution of the CID is not considered representative of typical purveyor water supply. Average annual water demand from the major water systems considered is 320 gpcpd, excluding the CID.

The average annual water demand is calculated using total population served and total water demand. The total water demand includes commercial, industrial and retail use within the service areas of the water systems. Therefore the calculated per capita water demand is representative of total water demand (excluding agricultural irrigation), and residential per capita water demand may be less (compare Figure 7.15 for representative residential/domestic per capita use, and Figure 7.18 for total water system per capita use).

7.6.1.2 Existing Water Use For Areas Outside Service Area of Six Major Water Systems

The population for areas outside the water service area of the six major water systems (OWSAs) was estimated using 2000 US census data and water system service areas. Where a census tract crossed the WRIA or water system service area boundary, the census tract population was divided between the WRIAs or inside/outside the water system service area. In most cases, plat maps were available and were used to indicate areas of heavier population density. These density approximations were then used to estimate census tract population allocations. Where no better information existed, the census tract population was assumed to be evenly distributed across the census tract and allocated to WRIAs 55/57 and areas within and outside of the major water systems proportional to area (Tables 7.12 and 7.13).

To illustrate the above, consider census tract 011300 on the border between WRIAs 55 and 57 just north of Millwood.

- In Table 7.12, it was judged that 95% of the population within this tract was within WRIA 57 and 5% was within WRIA 55. This was based on the approximate area of the tract within each WRIA.

- In Table 7.13, it was judged that all of the tract population in WRIA 55 was in Spokane's service area.

- In Table 7.13, it was judged that 25% of the tract population in WRIA 57 was in Spokane's service area and 75% was outside of the major water service districts. This judgment was based on area and the rough population density as estimated based on plat maps of this area.

- Water use for the estimated population within the OWSA of each census tract was estimated by using the average existing (1999) per capita demand for the six major water systems (from Table 7.11) and multiplied by the population within the OWSA within each census tract. Table 7.11 summarizes water use within the OWSAs for each WRIA as a whole.

Various assumptions are shown as footnotes on the attached Tables 7.10 and 7.11, and the key ones are reiterated here:

- Water use data for the six major water systems as collected by Spokane County was an average of several years, which is representative of water pumping in 1999. Census information used to estimate population in the OWSAs was for 2000. To estimate population for the OWSAs in 1999 for which no census data exists, the projected annual population increase for these areas through 2020 was *subtracted* from the 2000 population estimate.

- All six water system plans had water use data for 1998 except the Vera and Modern systems, which had data for 1999, and Whitworth, which had data for 1997. All systems contained a projected water demand in 2020 except for Vera (2019) and Whitworth (2018). Vera and Whitworth's water demand projection to 2020 was adjusted using prorated growth projections.

Estimated total water use in WRIAs 55 and 57, based on average total per capita use, is approximately 130,260 AF/yr (42,429 million gallons per year; Table 7.11). Total per capita use includes industrial, commercial, and retail, as well as residential services provided by the purveyors of the major water systems. This compares with an estimated water use based on residential per capita use alone of approximately 125,500 AF/yr (Section 7.3).

The six water systems evaluated account for approximately 82% of the total water system and residential water use in the two watersheds (Table 7.11). The remainder of the water use is distributed among smaller water systems and exempt wells.

7.6.2 Future Water Use Projections

7.6.2.1 Projected 2020 Water Use Within the Six Major Water Systems

Each WSP contained either a direct projection of water use in 2020 or enough information to make such a projection. In order to develop a monthly water use estimate, the growth percentage was applied to 1999 data. That is, the 2020 demand curve over the year is identical (in shape) to the demand curve in 1999 for each water system (Table 7.11, Figure 7.18). Actual per capita usage may vary from 1999 to 2020 due to conservation effects, differences in the ratio of commercial/agricultural/industrial/residential, and/or other influences. Conservation effects are accounted for the Whitworth Water District No. 2 (see section 7.6.3).

7.6.2.2 Projected 2020 Water Use For Areas Outside of the Six Major Water Systems

Pend Oreille County, which forms a small part of WRIA 55, has no population projection for unincorporated areas. However, the Pend Oreille County planning department provided preliminary advance numbers it had received from Washington State Office of Financial Management (OFM) indicating a projected annual medium range growth rate for the county as a whole of 1.58%. Because no information for unincorporated areas exists, the 1.58% annual growth rate was used.

Stevens County does not have a preliminary advance projection from OFM as of the writing of this section. Therefore, the 1.58% used for Pend Oreille County was also used for Stevens County.

Spokane County's comprehensive plan contains a population growth projection of 1.87% growth for the unincorporated areas of the County. This growth rate is used to estimate population growth in areas outside of the major water district service areas in Spokane County.

The projected growth rates described above for each county were applied uniformly across each OWSA within each county. The reasonableness of these projections is supported by the following points:

- A large percentage of the projected growth in unincorporated areas of Spokane County will occur in the UGA. Similarly, a large portion of the projected growth in Stevens County will occur in the south part of the County according to the Stevens County planning department (this part of the County already being more densely populated than the north part). Because the OWSAs within the Spokane County's UGA and Stevens County's south part are already generally more densely populated than other unincorporated areas of these counties, applying a uniform growth rate to all OWSAs has the effect of directing more population into these areas (UGA and south part of Stevens County), where more population is expected.

- Spokane County Comprehensive Plan, 2001 projects 89,000± additional people in the unincorporated areas of the County. This projection compares with the projections made herein as follows.

Spokane County Inside WRIAs 55 & 57:		
Additional projected population within unincorporated water systems (per WSPs):		~32,000
Additional population within OWSA using 1.87% growth:		~29,000
	Subtotal:	**~61,000**
Spokane County Outside of WRIAs 55 & 57:		
Remaining growth projected for Spokane County outside of WRIAs 55 and 57:	~89,000-~61,000 =	~28,000
	Total:	**~89,000**

These population projections are summarized Table 7.14 by census tract. As described above, water use for the projected population within the OWSA of each census tract was estimated by using the average existing per capita use for the five major water systems and multiplied by the population within the OWSA within each census tract (excluding CID; Table 7.11). Table 7.11 summarizes water use within the OWSAs for each WRIA as a whole.

A projected increase in water demand between 1999 and 2020 within the major water systems is expected to average 25%. Average projections by water system ranges from a low of 8% for the Modern Electric Water Company, to a high of 63% for Vera Water and Power. An increase in water demand outside of the major water systems is expected to average 28% across WRIAs 55 and 57.

7.6.3 Conservation

A review of the WSPs for the six water systems considered reveals a generally non-aggressive approach to conservation (with the possible exception of Whitworth), which is expected, given traditional perceptions of the large quantity of water available in the Spokane aquifer. Generally, all systems have implemented at least some conservation measures including metering sources, metering services, bills with consumption history, locating and repairing leaks, mailing of conservation literature, consideration of rate structures that would tend to promote conservation, and other measures. One indication of the amount of conservation likely to be realized is the “targeted water savings” section of each WSP (a required section). The targeted water savings for each system along with associated comments are included below.

Reductions in fixture usage mandated in the 1994 UPC revisions would result in negligible amounts of overall water use reduction, although at least one study projects a reduction of approximately 12% in wastewater production. That study “The Effect of Efficiency Standards on Water Use and Water Heating Energy Use in the US” done by the Lawrence Berkeley Laboratory in Berkeley CA estimates domestic usage savings of 12% in the year 2010 due to 1994 UPC code revisions, which translates to roughly 2% of overall water usage.

Among the most effective conservation measures are metering of services (which has already been done for the water systems in this study) and inclining block rate structures coupled with public education.

Based on the preceding narrative, the future projected water demand was adjusted downward only for the Whitworth Water District to account for conservation (Table 7.11).

Targeted Water Savings per WSPs

System	Targeted Savings	Comments
City of Spokane	No numeric target	WSP contains qualitative target: no increase in peak demand and decrease in average demand
Consolidated Irrigation District	No numeric target	WSP describes conservation disincentives including revocation of water rights for non-use, which has occurred in the past in this state.
Vera Water and Power	No numeric target	-
Modern Electric Water Company	No numeric target	WSP describes conservation as “moderate” with a central goal of gradual permanent reduction in average demand.
Spokane County Water District #3	No numeric target	WSP describes conservation as “moderate” with a central goal of gradual permanent reduction in average demand.
Whitworth Water District #2	7%	Water use dropped 5% from 1999 to 2000 at least in part due to a large rate increase.

7.6.4 Potential Data Gaps in Future Water Use Projections

A small number of people have not been counted per the methods described above. The service areas actually represent ultimate service areas, and current infrastructure may not yet extend to the farthest reaches of the indicated service areas. Therefore, the people within a water system’s service area who are not yet connected to that water system (e.g., have their own wells or are on small water systems) are not counted. This quantity of people is judged to be relatively small because, in general, only low density areas are on private wells. That is, water systems have generally found it economical to extend service to higher density areas and, therefore, have done so for most or all such areas. These same people are accounted for in future population projections because, as the water systems expand to their ultimate service areas, it is expected that a greater proportion of the population within the service areas will be connected to the water system.

Table 7.1

Summary of Water Rights and Claims by Type

(Excluding rights for reservoirs, power, fish, and fire suppression.)

	Number of Documents		Qi		Qa [3] (AF/yr)	
	Ground Water	**Surface Water**	**Ground Water** (gpm)	**Surface Water** (cfs)	**Ground Water**	**Surface Water**
WRIA 55						
Short Claims	2,048	317	-	-	7,470	853
Long Claims	1,519	507	-	-	13,530	22,246
Sub-total	3,567	824	-	-	21,000	23,099
Total	**4,391**				**44,099**	
Permits	13	3	1,610	0.15	656	13
Certificates	478	731	170,355	72.57	127,368	15,283
Sub-total	491	734	171,965	72.72	128,024	15,296
Total: [2]	**1,225**		**456**		**143,320**	
Applications	16	7	21,790	1,421	-	-
Changes	16	-	-	-	-	-
Grand Sub-total [1]	4,058	1,558	383.48	72.72	149,024	38,395
Grand Total [2]	**5,616**		**456**		**187,419**	
WRIA 57						
Short Claims	435	126	-	-	1,687	437
Long Claims	408	209	-	-	12,703	10,493
Sub-total	843	335	-	-	14,390	10,930
Total [2]	**1,178**				**25,320**	
Permits	8	0	21,340	0	30,942	
Certificates	306	191	552,261	67.41	247,243	15,646
Sub-total	314	191	573,601	67.41	278,185	15,646
Total [2]	**505**		**1,347**		**293,831**	
Applications	27	-	34,588	0.64	-	-
Changes	46	-	-	-	-	-
Grand Sub-total [1]	1,157	526	1,279.13	67.41	292,575	26,576
Grand Total [1, 2]	**1,683**		**1,347**		**319,151**	
WRIA 55 plus WRIA 57						
Supergrand Total[1,2]	**7,299**		**1,803**		**506,570**	

(1) Excludes applications for new water rights and change applications.
(2) Total Qi in cfs.
(3) Qa estimated for claims and other rights as described in text.

Table 7.2

Summary of Annual Quantities of Water Rights and Claims by Purpose of Use

(except reservoir, power, fish, and fire; AF/yr)

		WRIA 55	WRIA 57	Total
ALL USES (except power, fish, and fire)				
Certificates and Permits	GW	128,024	278,185	406,209
	SW	15,296	15,646	30,942
	Subtotal	143,320	293,831	437,151
Long and Short Claims	GW	21,000	14,390	35,390
	SW	23,099	10,930	34,029
	Subtotal	44,099	25,320	69,419
Total:		**187,419**	**319,151**	**506,570**
IRRIGATION				
Certificates and Permits	GW	24,759	16,107	40,866
	SW	14,307	12,294	26,601
	Subtotal	39,066	28,401	67,467
Long and Short Claims	GW	12,589	12,470	25,059
	SW	21,682	10,280	31,962
	Subtotal	34,261	22,750	57,021
Total:		**73,337**	**51,151**	**124,488**
MUNICIPAL & DOMESTIC				
Certificates and Permits	GW	80,180	209,254	289,434
	SW	944	262	1,206
	Subtotal	81,124	209,516	290,640
Long and Short Claims	GW	6,810	1,618	8,428
	SW	1,062	500	1,562
	Subtotal	7,862	2,118	9,990
Total:		**88,996**	**211,634**	**300,630**
COMMERCIAL-INDUSTRIAL				
Certificates and Permits	GW	21,419	47,915	69,334
	SW	9	3,077	3,086
	Subtotal	21,428	50,992	72,420
Long and Short Claims	GW	0	4	4
	SW	0	0	0
	Subtotal	0	4	4
Total:		**21,428**	**50,996**	**72,424**
OTHER				
Certificates and Permits	GW	1,666	4,909	6,575
	SW	36	13	49
	Subtotal	1,702	4,922	6,624
Long and Short Claims	GW	1,601	298	1,899
	SW	355	150	505
	Subtotal	1,956	448	2,404
Total:		**3,658**	**5,370**	**9,028**

GW = Groundwater; SW = Surface Water

TABLE 7.3

Agricultural Water Use

Total Crop Land and Irrigated Land by County
(including lands outside of WRIAs 55 and 57; acres)

Agricultural Census	County					
	Spokane		Stevens		Pend Oreille	
	1992	1997	1992	1997	1992	1997
Total Cropland[1]	397,644	398,064	124,452	123,434	23,095	6,763
Irrigated land[2]	14,755	10,711	9,119	9,997	1,167	1,583

Source: USDA 1997 Census of Agriculture

1) Land from which crops where harvested or hay was cut, and land in orchards, citrus groves, Christmas trees, vineyards, nurseries, and greenhouses; cropland used only for pasture or grazing; land in cover crops, legumes, and soil improvements grasses; land on which all crops failed; land in cultivated summer fallow; and idle cropland
2) All land watered by any artificial or controlled means

Acreage of Crops Cultivated
(including lands outside of WRIAs 55 and 57; acres)

Crop	County		
	Spokane	Stevens	Pend Oreille
Wheat	115,324	9,530	Undisclosed
Hay – Alfalfa	52,901	48,023	14,288
Barley	43,927	7,462	105

Source: USDA 1997 Census of Agriculture

Typical Efficiencies for Various Types of Irrigation Systems

Irrigation Method		Application Efficiency[1] (%)
Surface:		
	Furrow (rill)	35 - 60
	Furrow w/ land leveling	50 - 65
	Furrow w/ automation[2]	75 - 80
	Furrow w/ tailwater re-use	75 - 90
Sprinkle:		
	Hand-move	60 - 70
	Wheel-move	60 - 70
	Center pivot / Lateral Move	60 - 85
	Precision System	80 - 95
	LEPA	85 - 98
	Traveling gun	55 - 70
	Solid set	60 - 80
Microirrigation:		
	Drip/trickle	80 - 98
	Micro-sprayers	80 - 90

Source: Evans, R. G., Irrigation Technologies for Central Washington, Washington State Univeristy, Prosser, WA.
Note:

1) Irrigation application efficiency is highly dependent on the irrigation practices of an individual farmer

2) Automated surge flow furrow irrigation.

TABLE 7.4

Water Withdrawn from WRIA 55 by Water Purveyors
(Average 1994-1998)

Township N	Range E	Section	Qtr/Qtr	Annual Withdrawal (Mgal/yr)	Annual Withdrawal (AF/yr)
28	43	12		5	17
28	43	34	NW/NW	4	11
26	43	31	NE/NE	4,159	12,760
28	42	2	NW	14	43
28	42	2	SW	26	79
28	42	2	SW	182	558
29	42	35	SW	19	59
29	42	26	SE/NW	68	210
28	42	11	NE	12	36
29	43	11		8	23
26	43	27		6	18
27	43	10		5	17
27	43	19		6	18
26	43	27		236	724
29	44	20	NW	7	22
29	43	26		7	23
26	42	4		3	8
27	43	22	NW/SW	25	78
26	43	30	SE/SE	79	241
26	43	3	SW/SW	253	777
26	43	3	SE/SW	36	111
26	43	9	NW/NW	30	91
26	43	20	SW/SW	258	791
28	43	23	NE/NW	83	255
29	41	24	NW SE	22	69
27	42	12	SE	21	65
27	43	8	SE/SE	8	25
29	43	35	SW/SW	15	46
26	42	14	NE	18	56
26	43	30	SE/NW	109	336
26	43	19	SE/SW	29	90
26	43	20	NW/NW	346	1,062
26	43	19	NE/NE	403	1,237
26	43	7	SE/SW	388	1,190
26	43	7	SW/NE	273	838
26	42	12	NE/SW	0	1
27	43	32	NW/SE	108	331
27	43	32	NW/SE	469	1,440
27	43	33	NW/SW	200	614
26	43	6	SW/NE	21	63
27	42	3	NE	1	2
				7,963	24,433

Data source: Spokane County

TABLE 7.5

Water Withdrawn from WRIA 57 by Water Purveyors
(Average 1994-1998)

Township N	Range E	Section	Qtr/Qtr	Annual Withdrawal (Mgal/yr)	Annual Withdrawal (AF/yr)
25	43	23	NW	76	234
25	44	11	SW	120	369
26	45	35	NW	272	835
26	45	31	SW	389	1,193
25	45	18	SE	561	1,720
25	45	17	SW	641	1,966
25	45	17	NW	505	1,551
25	45	7	NE	394	1,210
25	45	4	NW	272	835
26	45	34	NE/SW	542	1,664
25	45	3	NW	272	835
25	45	2	NE	272	835
25	43	8	NE/NE	842	2,584
25	43	4	NW/NE	267	819
25	43	8	NE/NE	3,369	10,338
25	43	11	NE/SE	2,634	8,081
25	43	22	SE/NW	2,995	9,191
25	43	11	SW/NE	9,011	27,648
25	43	24	SW/NE	21	64
25	43	24	NE/SW	7	21
25	43	24	NE/SE	109	334
25	44	19	NE/NW	4	12
25	43	24	NW/NE	232	713
25	44	9	NW	110	337
25	44	4	SE/SE	99	304
25	44	4	SW/NW	164	504
25	45	15	NW/NW	176	540
25	45	15	NE/NW	176	540
25	45	14	SE/NW	176	540
25	45	15	SE/SE	22	67
26	45	25	NW	395	1,212
25	44	21	SW/SW	164	503
25	44	28	SE/SW	76	233
25	44	21	NE/SW	226	695
25	44	33	NE/NE	125	384
25	44	28	NW/SW	142	437
25	44	15	SW/NW	205	629
25	44	16	SW/NW	143	440
25	44	21	NE/SE	625	1,918
25	44	20	SW/NE	625	1,918
25	44	8	SW/SW	164	503
25	44	22	SW/SW	205	629
25	44	17	NE/NE	164	503
25	44	27	SW/NW	0	0
25	43	12	SE/NE	248	761
25	44	7	NE/NW	259	795
25	44	5	NW/NW	122	373
25	44	6	NE/NE	31	95
25	44	6	SE/NW	131	401
25	44	29	SE/NE	457	1,403
25	43	13	NE/NE	18	55
25	44	7	SW/SE	505	1,548
25	44	7	NE/SE	77	236
25	43	23	NE/NE	101	309
25	44	27	NE/SW	643	1,973
26	45	35	SE/SE	180	553
25	44	3	NW/NE	185	567
25	44	1	NW/NW	98	299
25	44	2	NW/NE	250	766
25	44	15	NE/SE	116	357
25	44	14	NE/SE	731	2,244
25	44	22	SE/SE	368	1,128
25	44	26	NE/SW	88	269
25	44	26	NW/NW	179	548
25	44	22	SE/NE	18	54
25	44	23	NE/SE	961	2,948
				33,753	103,568

Data source: Spokane County

TABLE 7.6

Water Withdrawn from WRIA 55 by Commercial and Industrial Users

Township N	Range E	Section	Commercial / Industrial Name	Annual Withdrawal (million gallons per year)	Annual Withdrawal (acre-feet per year)
26	43	15	C&T Truck Parts	0.43	1.33
26	43	5	Commellini Restraurant	0.43	1.33
28	42	10	Deer Park Animal Medical Center	0.43	1.33
27	43	14	Dennison Estates	7.89	24.22
27	43	6	DJ's Mini Mart	0.29	0.88
26	42	11	Fish Hatchery	1.18	3.61
27	44	33	Inland Farmers Peone Plant (Cenex)	0.34	1.04
28	44	4	Inland Power & Light Water System	0.14	0.44
29	43	9	Jerry's Landing	0.71	2.18
29	43	22	JR's Restaurant	0.45	1.38
26	43	16	Kaiser Mead North Plant	916.72	2,812.88
26	43	21	Kaiser Mead South Plant	184.09	564.85
31	44	34	Little Diamond/Thousand Trails	0.20	0.61
29	43	14	Miller's One Stop	0.43	1.33
26	43	27	Mount St Michaels	5.73	17.59
27	44	27	Mt. Spokane Golf	10.30	31.61
26	43	22	Norcan Parts & Equipment	0.72	2.21
26	43	17	Northwest Pipeline Corp	0.14	0.44
26	43	8	Pattison's North	10.39	31.89
29	43	15	Sly's Saloon	0.16	0.48
26	42	12	Spokane Country Club (assume 90 acres)	56.84	174.42
26	42	14	Vel View	18.28	56.09
26	43	5	Wandermere Golf Course	82.11	251.96
26	43	18	Whitworth College	21.00	64.44
			Total for WRIA 55	**1,319**	**4,049**

Data source: Spokane County

TABLE 7.7

Water Withdrawn from WRIA 57 by Commercial and Industrial Users

Township N	Range E	Section	Name	Annual Withdrawal (million gallons per year)	Annual Withdrawal (acre-feet per year)
25	43	13	Acme on Park	3.78	11.60
25	43	9	Avista Mech Room	111.60	342.44
25	43	12	Burger Royal	0.45	1.38
25	43	1	Camp Sekani	0.17	0.51
25	44	12	Central Pre Mix Sullivan Road	7.56	23.20
25	45	23	Eastside Liberty Lake Imp Club	128.54	394.40
25	42	13	Empire Cold Storage and Frosty Ice	0.99	3.05
25	43	23	Freightliner	0.43	1.33
25	44	11	Honeywell-Johnson Matthey Electronics	168.48	516.97
25	44	1	Industrial Park	121.14	371.72
25	44	1	Industrial Park	116.39	357.13
25	44	1	Industrial Park	148.79	456.57
25	44	12	Industrial Park	443.31	1,360.25
25	44	5	Inland Empire Paper (assuming pumping = discharge amounts)	1,444.65	4,432.79
25	44	10	Kaiser Trentwood River extraction	3,600.00	11,046.33
25	44	2	Kaiser Trentwood Well pumping	1,335.60	4,098.19
25	44	10	Kaiser Trentwood Well pumping	3,434.40	10,538.20
25	44	11	Kaiser Trentwood Well pumping	129.60	397.67
25	44	18	Levernier Construction Water System	0.14	0.44
25	45	24	MacKenzie Bay	0.22	0.69
25	43	12	Mel's Grub & Suds Saloon	0.70	2.15
25	43	13	Mercer Trucking Co Inc	0.43	1.33
25	43	12	Middco Tool & Equipment	0.14	0.44
25	43	24	Puerta Vallarta	1.26	3.87
25	43	14	Sound Tire	0.43	1.33
25	45	14	Spokane County Liberty Lake Golf Course	35.25	108.16
25	45	14	Spokane County Meadowwood Golf Course	55.98	171.76
25	45	31	Spokane County Fire Dist 8 Sta 85	0.12	0.37
25	43	14	Spokane Home Center	0.29	0.88
25	45	1	Spokane River Rest Area (DOT)	0.20	0.60
26	45	10	Sutton Bay Resort	0.16	0.48
25	44	9	Washington State Department of Transportation - Pines Road Maintenance	0.20	0.61
25	45	1	Wsahington State Patrol - Spokane Port of Entry	0.03	0.09
25	45	25	Zephyr Lodge	0.32	0.99
			Total for WRIA 57	**11,292**	**34,648**

Data source: Spokane County

TABLE 7.8

Wastewater Discharge

Township N	Range E	Section	Wastewater Discharger	Discharge Location	Average Annual Discharge (million gallons per year)	Average Annual Discharge (AF/yr)
WRIA 55						
30	44	2	Diamond Lake Sewer District	Irrigation of 25 acres	19	58
29	43	31	Deer Park Wastewater Treatment Plant	Sprayed at Deer Park airport	101	309
27	43	3	Colbert Landfill	Little Spokane River	361	1,109
26	43	3	Kaiser Mead North Plant	Deadman Creek	924	2,834
26	43	21	Kaiser Mead South Plant	Percolation basin	187	574
26	42	11	Fish Hatchery	Little Spokane River via wetland	3,240	9,942
				Total for WRIA 55	**4,832**	**14,827**
				Total for WRIA 55 (without fish hatchery)	**1,592**	**4,885**
WRIA 57						
25	43	9	Avista Heating	Spokane River	112	342
25	44	5	Inland Empire Paper	Spokane River	1,445	4,433
25	44	10	Kaiser Trentwood	Spokane River	7,605	23,337
25	44	11	Honeywell-Johnson Matthey Electronics	Drywell	6	20
25	45	9	Liberty Lake Sewer District	Spokane River	175	538
				Total for WRIA 57	**9,343**	**28,669**
City of Spokane Wastewater Treatment Plant						
25	42	2	City of Spokane WWTP	Spokane River	15,078	46,265
				Total for WRIA 57 + City of Spokane WWTP	**24,421**	**74,934**

Data Source: Spokane County

Table 7.9

Water Use Summary
(AF/yr)

	WRIA 55	WRIA 57	Total
WITHDRAWALS			
Commercial and Industrial	3,929	34,254	38,183
Stock Watering	>20	>20	>40
Agricultural Irrigation [1]	6,398	1,278	7,676
Exempt Well Use	11,000	5,600	16,600
Municipal/Domestic: Total Water Supplied	24,553	103,962	128,515
Total:	**45,900**	**145,114**	**191,014**
DISCHARGES			
Septic System Discharge	4,689	7,267	11,956
Wastewater Discharge [2]	4,885	73,934	78,819
Total:	**9,574**	**81,201**	**90,775**

1. Crop Irrigation Requirement: does not include allowances for conveyance and application efficiency.
2. Includes Spokane WWTP listed under WRIA 57 (although the discharge point is located in WRIA 54) and residential, commercial and industrial wastewater disposal.

Table 7-10

Summary of Information Obtained from Water System Plans

	Current Conditions				Projected Conditions						
	Date of Water System Plan	**Population per WSP**	**Water Use** (million gallons/year)	**Water Demand** (gpcpd)	**Date of Future Projection**	**Total Projected Population Growth**	**Annual Growth Rate**	**Projected Population**	**Conservation Goals** (total)	**Projected Water Use** (million gallons/year)	**Projected Water Demand** (gpcpd)
City of Spokane (1)	1998	198,000	23,900	331	2020	18.3%	0.77%	234,275		28,400	332
Consolidated Irrigation District No. 19	1998	16,388	4,563	763	2020	34.7%	1.36%	22,073	0%	6,059	752
-estimated non-agricultural portion(5) ⇒	1998	16,388	1,903	318	2020	34.7%	1.36%	22,073	0%	2,564	318
Modern Electric Water Co.	1999	16,482	2,136	355	2020	8.4%	0.37%	17,865	0%	2,303	353
Spokane County Water District No. 3 (2)	1998	24,887	2,955	325	2020	19.8%	0.82%	29,815	0%	3,798	349
Vera Water and Power (3)	1999	19,719	2,500	347	2020	64.6%	2.29%	32,455	0%	4,005	338
Whitworth Water District No. 2 (3, 4)	1997	20,346	2,031	274	2020	35.5%	1.39%	27,561	7%	2,559	254
Total/Average: (6)	1997-1999	**295,822**	**35,425**	**328**	**2020**	33.7%	1.33%	**395,646**		**47,529**	**329**

1. City of Spokane information from WSP 1999-2000. Total use is as reported in WSP and includes areas outside both WRIA 55 and 57. Conservation goal is to maintain peak use so as population grows, gpcd decrease. The WSP projected water use does not show the conservation effects.

2. SCWD#3 WSP does not contain population figures. Existing population estimate is based on WSP residential services (7,121) and multi-family units (2,362) @ 2.5 persons per service or unit.

3. Projections in the water system plans adjusted from 2018 for Whitworth, and 2019 for Vera.

4. WWD#2 population growth rate based on comparing existing population figure with future population figure per WSP. Future water demand was calculated by using 2,018 population figure x gpcp - 7% (total conservation goal) multiplied by 365 days for annual use.

5. Estimated non-agricultural portion of CID demand based on average gpcpd of other systems.

6. Totals/averages use non-=agricultural estimates of the CID.

Table 7-11

Existing (1999) and Projected Future (2020) Monthly Water Use [1]

	City of Spokane		Consolidated Irrigation District No.19		Modern Electric Water Company		Spokane County Water District No.3		Vera Water and Power		Whitworth Water District No.2		Total/Average of Water Systems [5]		Water Use Outside District Boundaries (million gallons)		Total Water Use (million gallons)
Date	**Mil. Gal.**	**gpcpd**	**Mil. Gal.**	**gpcpd**	**Mil. Gal.**	**gpcpd**	**Mil. Gal.**	**gpcpd**	**Mil. Gal.**	**gpcpd**	**Mil. Gal.**	**gpcpd**	**Mil. Gal.**	**gpcpd [4]**	**WRIA 55**	**WRIA 57**	
Est. 1999 Population [2]	**200,416**		**16,650**		**16,482**		**24,636**		**19,719**		**20,960**		**298,863**		**28,431**	**35,744**	**363,037**
Jan-99	1,167	188	85	164	102	200	102	133	98	161	70	108	1,630	176	155	195	1,980
Feb-99	1,047	186	85	182	102	222	102	148	98	178	70	120	1,503	180	143	180	1,826
Mar-99	1,167	188	85	164	94	185	102	133	98	161	70	108	1,623	175	154	194	1,971
Apr-99	1,351	225	93	186	105	212	127	172	123	208	117	187	1,932	215	184	231	2,347
May-99	2,122	342	314	608	178	349	229	300	221	362	235	361	3,162	341	301	378	3,841
Jun-99	2,721	453	394	790	231	467	355	481	271	457	282	448	4,087	456	389	489	4,965
Jul-99	3,956	637	1,073	2079	357	699	438	574	443	724	469	722	5,998	647	571	717	7,285
Aug-99	3,826	616	1,230	2383	378	740	439	575	443	724	469	722	5,884	635	560	704	7,147
Sep-99	2,405	400	585	1172	252	510	336	455	320	541	282	448	3,806	425	362	455	4,623
Oct-99	1,467	236	127	246	126	247	129	168	148	241	141	217	2,129	230	202	255	2,586
Nov-99	1,120	186	85	170	102	207	102	138	98	166	70	112	1,581	176	150	189	1,920
Dec-99	1,133	182	85	164	102	200	102	133	98	161	70	108	1,595	172	152	191	1,937
1999 Total	23,481	321	4,240	698	2,131	354	2,564	285	2,460	342	2,347	307	34,929	320	3,323	4,177	42,429
Est. 2020 Population [3]	**259,000**		**22,073**		**17,865**		**29,815**		**32,455**		**27,561**		**388,769**		**42,887**	**54,672**	**486,327**
Jan-20	1,411	176	121	177	111	200	151	163	160	159	77	90	2,025	168	223	285	2,533
Feb-20	1,266	175	121	196	111	222	151	181	160	176	77	100	1,871	172	206	263	2,341
Mar-20	1,412	176	121	177	102	184	151	163	160	159	77	90	2,016	167	222	284	2,523
Apr-20	1,635	210	133	201	113	211	189	211	200	205	128	155	2,401	206	265	338	3,004
May-20	2,567	320	448	655	193	348	340	368	360	358	256	300	3,940	327	435	554	4,928
Jun-20	3,291	424	564	852	250	466	527	589	441	453	307	371	5,106	438	563	718	6,387
Jul-20	4,785	596	1,533	2240	386	697	650	703	721	717	512	599	7,479	621	825	1,052	9,355
Aug-20	4,628	576	1,757	2568	408	737	651	704	721	717	512	599	7,337	609	809	1,032	9,178
Sep-20	2,909	374	836	1262	272	508	498	557	521	535	307	371	4,778	410	527	672	5,977
Oct-20	1,774	221	182	266	136	246	190	206	240	239	154	180	2,644	219	292	372	3,308
Nov-20	1,354	174	121	183	111	207	151	169	160	164	77	93	1,965	168	217	276	2,458
Dec-20	1,370	171	121	177	111	200	151	163	160	159	77	90	1,982	164	219	279	2,479
Projected 2020 Total	28,400	300	6,059	752	2,303	353	3,798	349	4,005	338	2,559	254	43,537	307	4,803	6,123	54,462
Percent Increase (1999-2020)	20.95%		42.89%		8.04%		48.14%		62.80%		9.05%		25%		45%	47%	28%

1. Water use records provided by Spokane County. gpcpd = gallons per person per day. Mil. Gal. = million gallons

2. City of Spokane population used the 1998 WSP population + 1.22% annual growth rate projected for 2000-2020. Per information supplied by Spokane County, all city wells are within WRIA 55 and 57, so using the entire City of Spokane water service population is appropriate in order to obtain an accurate per capita demand. 1999 population estimates for CID#19, SCWD#3, and WWD#2 used WSP estimates x the 1.87% the annual growth rate projected for the unincorporated areas of Spokane County for 2000-2020.

3. From Table 7-10 except for the City of Spokane. The City of Spokane water service population is estimated based on the estimated 1999 service area population x the projected annual growth rate of 1.22% for City of Spokane.

4. Per capita usage is the weighted average of all systems except CID because CID includes agricultural demand. The per capita water demand number shown on this table may vary from the per capita water use number shown on Table 7-10 because these per capita numbers reflect different data years.

5. Water use from CID is incorporated using CID population and average gpcpd of the 5 other systems because of agricultural irrigation demand influences during the summer months.

Table 7-12

Estimate of Population Inside/Outside WRIAs and Between WRIAs

Current Population by Census Tract - 2000 Census

WRIA 55: 92,721 **WRIA 57: 181,771**

Tract #	Population	WRIA		Tract #	Population	WRIA		Tract #	Population	WRIA	
		55	57			55	57			55	57
SPOKANE COUNTY											
000100	901	90%	10%	004500	3517	-	100%	011300	5018	5%	95%
000200	4571	90%	10%	004601	3667	-	100%	011400	5215	-	100%
000300	5253	100%	-	004602	2964	-	100%	011500	1443	-	100%
000400	4119	40%	-	004700	5970	-	85%	011600	1649	-	100%
000500	3334	20%	-	004800	2761	-	100%	011700	6703	-	100%
000600	3342	20%	-	004900	5289	-	70%	011800	4631	-	100%
000700	5186	15%	-	005000	2607	-	10%	011900	3887	-	100%
000800	4791	67%	-	010100	5244	33%	67%	012000	3731	-	100%
001500	5460	-	80%	010201	3468	100%	-	012100	2579	-	100%
001600	3837	-	100%	010202	5917	99%	1%	012200	2208	-	100%
001700	4317	20%	80%	010301	3525	100%	-	012300	5127	-	100%
001800	2870	-	100%	010303	2412	98%	-	012401	4090	-	100%
002300	5197	-	50%	010304	4789	100%	-	012402	5182	-	100%
002400	2880	-	65%	010305	4038	100%	-	012500	2771	-	100%
002500	7040	-	70%	010501	6764	100%	-	012600	3289	-	100%
002600	4754	-	100%	010503	5292	95%	-	012701	3191	-	100%
002800	844	-	100%	010504	3277	100%	-	012702	2166	-	100%
002900	3307	-	100%	010602	6329	5%	-	012801	4385	-	100%
003000	2513	-	100%	010700	1824	50%	-	012802	3107	-	100%
003100	4747	-	100%	010800	2234	100%	-	012901	2820	-	100%
003200	2781	-	60%	010900	4217	100%	-	012902	6567	-	100%
003300	1723	-	100%	011000	3275	100%	-	013000	4446	-	100%
003500	2203	-	80%	011101	5143	100%	-	013100	6204	-	100%
003600	3832	-	20%	011102	3497	100%	-	013201	7480	-	100%
004100	2205	-	45%	011201	4128	100%	-	013202	5450	-	100%
004400	4362	-	30%	011202	4009	98%	2%	013300	2251	-	10%
								013401	4109	-	80%
STEVENS COUNTY											
9513	3580	40%	-	9514	6217	20%	-				
PEND OREILLE COUNTY											
9703*	1021	55%	-	9704	2350	60%	-	9705	2030	65%	35%

2000 Census block data compiled by census tract.

spok.xls, pend.xls, stev.xls files downloaded from: http://www.ofm.wa.gov/census2000/download.htm

Percentages adding up to less than 100% represent census blocks with areas outside of WRIAs 55 and 57.

Table 7-13

Estimate of Population Within and Outside of the Six Major Water Systems

Census Tract		WRIA 55		WRIA 57		Water District Population					
Tract #	**Population**	**Population Within WRIA 55**	**Population Outside of Wtr. Dist. (7)**	**Population Within WRIA 57**	**Population Outside of Wtr Dist. (7)**	**Whitworth**	**SCWD#3**	**Spokane**	**Modern**	**Vera**	**CID#19**
Water District Population:						**20,346**	**23,708**	**198,000**	**16,482**	**19,719**	**16,388**
000100	901	811		90				901			
000200	4,571	4,114		457				4,571			
000300	5,253	5,253		0				5,253			
000400	4,119	1,648		0				1,648			
000500	3,334	667		0				667			
000600	3,342	668		0				668			
000700	5,186	778		0				778			
000800	4,791	3,210		0				3,210			
001500	5,460	0		4,368				4,368			
001600	3,837	0		3,837				3,837			
001700	4,317	863		3,454				4,317			
001800	2,870	0		2,870				2,870			
002300	5,197	0		2,599				2,599			
002400	2,880	0		1,872				1,872			
002500	7,040	0		4,928				4,928			
002600	4,754	0		4,754				4,754			
002800	844	0		844				844			
002900	3,307	0		3,307				3,307			
003000	2,513	0		2,513				2,513			
003100	4,747	0		4,747				4,747			
003200	2,781	0		1,669				1,669			
003300	1,723	0		1,723				1,723			
003500	2,203	0		1,762				1,762			
003600	3,832	0		766				766			
004100	2,205	0		992				992			
004400	4,362	0		1,309				1,309			
004500	3,517	0		3,517				3,517			
004601	3,667	0		3,667				3,667			
004602	2,964	0		2,964				2,964			
004700	5,970	0		5,075				5,075			
004800	2,761	0		2,761				2,761			
004900	5,289	0		3,702				3,702			
005000	2,607	0		261				261			
010100	5,244	1,731	1,731	3,513	3,232						281
010201	3,468	3,468	3,295	0		173					
010202	5,917	5,858		59		586	0				
010301	3,525	3,525	3,525	0							
010303	2,412	2,364	2,364	0							
010304	4,789	4,789	4,071	0			718				
010305	4,038	4,038	2,625	0		1,413	323				
010501	6,764	6,764		0		6,426	338				
010503	5,292	5,027	1,005	0		2,262	1,760				
010504	3,277	3,277	328	0		2,622	328				
010602	6,329	316	316	0							
010700	1,824	912	365	0		274		274			
010800	2,234	2,234		0		2,122		112			
010900	4,217	4,217	84	0		3,500	633				
011000	3,275	3,275		0		1,638	1,736	66			
011101	5,143	5,143		0				5,143			
011102	3,497	3,497		0				3,497			
011201	4,128	4,128	2,064	0				2,064			
011202	4,009	3,929	1,215	80		196	1,375	1,062			
011300	5,018	251		4,767	3,575			1,443			
011400	5,215	0		5,215	4,694						522
011500	1,443	0		1,443	1,443						
011600	1,649	0		1,649	1,649						
011700	6,703	0		6,703	2,681		3,352		335		335
011800	4,631	0		4,631					3,149	1,389	93
011900	3,887	0		3,887					3,887		
012000	3,731	0		3,731					3,731		
012100	2,579	0		2,579	1,805		774				
012200	2,208	0		2,208	883		552	773			
012300	5,127	0		5,127	3,076		1,025	1,025			
012401	4,090	0		4,090	205		3,886				
012402	5,182	0		5,182	2,332		1,296			1,555	
012500	2,771	0		2,771			1,663		1,108		
012600	3,289	0		3,289	1,316				1,973		
012701	3,191	0		3,191					1,053	2,138	
012702	2,166	0		2,166					108	2,058	
012801	4,385	0		4,385	658		2,631		1,096		
012802	3,107	0		3,107	2,175		932				
012901	2,820	0		2,820						1,692	1,128
012902	6,567	0		6,567						6,567	
013000	4,446	0		4,446						4,357	89
013100	6,204	0		6,204	310						5,894
013201	7,480	0		7,480	374						7,106
013202	5,450	0		5,450	4,469						981
013300	2,251	0		225	158		34			34	
013401	4,109	0		3,287	657		1,151	1,479			
	2000 Population	86,755	28,955	181,060	36,403	21,212	24,504	105,756	16,442	19,789	16,428
Population per Water System Plan:						20,346	23,708	198,000	16,482	19,719	16,388
Date of Water System Plan:						1997	1998	1998	1999	1999	1998
Deviation from estimated Water System Plan population:						0.2%	-1.5%	47%	0.6%	2.4%	2.9%
				(1)			(2)	(3)	(4)	(5)	(6)

1. District population per 1997 water system plan. WSP estimates approx 1.5% growth per year. Based on this growth, 2000 population est. to be 21,262.

2. Population derived from 1998 WSP reported Residential Services (7,121 @ 2.5 per) and Mult-family units (2,362 @ 2.5 per) = 24,416. @ average growth of 0.9% year results in 2000 pop of 24,855.
3. The WSP population estimate is for entire City of Spokane. The estimated population includes only those areas of the City within either WRIA 55 or 57.
4. The 1999 WSP estimates system population at 16,482 and projected growth at less than 0.5% growth to 2020. This growth rate results in 16,548 in 2000.
5. The WSP estimates 1999 system population at 19,719 with approx. 2.8% growth a year. This results in 20,271 pop in 2000.

6. System population per the 1998 WSP is derived from reported # of dwellings and assumes 2.5 persons per dwelling. The WSP estimates approx. 1.6% growth per year. This results in 16,917 pop in 2000.
7. The population shown remaining outside the water districts includes Pend Oreille Co. (3,291 WRIA 55 and 711 WRIA 57) and Stevens Co. (2,675 WRIA 55).
8. WSP population estimates were projected to year 2000 for comparison with actual 2000 census data.

Table 7-14

Population Projections Outside Service Areas of the Six Major Water Systems

		Population Outside of the Service Areas of the Six Major Water Purveyors					
2000 Census		**1999**		**2000**		**2020**	
Tract #	**Population**	**WRIA 55**	**WRIA 57**	**WRIA 55**	**WRIA 57**	**WRIA 55**	**WRIA 57**
010100	5244	**1698**	3172	**1731**	3232	**2509**	**4687**
010201	3468	**3233**		**3295**		**4777**	-
010301 (3)	3525	**3459**		**3525**		**5757**	-
10303	2412	**2320**		**2364**		**3427**	-
010304 (3)	4789	**3995**		**4071**		**6649**	-
010305	4038	**2576**		**2625**		**3806**	-
010503	5292	**987**		**1005**		**1458**	-
010504	3277	**322**		**328**		**475**	-
010602	6329	**311**		**316**		**459**	-
010700	1824	**358**		**365**		**529**	-
010900	4217	**83**		**84**		**122**	-
011201	4128	**2025**		**2064**		**2993**	-
011202	4009	**1192**		**1215**		**1761**	-
011300	5018		**3508**		**3575**	-	**5184**
011400	5215		**4606**		**4694**	-	**6805**
011500	1443		**1416**		**1443**	-	**2092**
011600 (4)	1649		**1640**		**1649**	-	**1821**
011700	6703		**2631**		**2681**	-	**3887**
012100	2579		**1772**		**1805**	-	**2618**
012200	2208		**867**		**883**	-	**1281**
012300	5127		**3019**		**3076**	-	**4460**
012401	4090		**201**		**205**	-	**297**
012402	5182		**2288**		**2332**	-	**3381**
012600	3289		**1291**		**1316**	-	**1907**
012801	4385		**645**		**658**	-	**954**
012802	3107		**2134**		**2175**	-	**3153**
013100 (5)	6204		**304**		**310**	-	**613**
13201	7480		**367**		**374**	-	**542**
013202 (5)	5450		**4385**		**4469**	-	**8835**
013300	2251		**155**		**158**	-	**228**
013401	4109		**645**		**657**	-	**953**
9513 (7)	3580	**1409**	-	**1432**	-	**1959**	-
9514 (7)	6217	**1223**	-	**1243**	-	**1701**	-
9703 (8)	1021	**554**	-	**563**	-	**770**	-
9704 (8)	2350	**1388**	-	**1410**	-	**1929**	-
9705 (8)	2030	**1299**	**698**	**1320**	**711**	**1806**	**973**
	Population	**28431**	**35744**	**28955**	**36403**	**42887**	**54672**

1. Census tract populations based on 2000 Census information. All unincorporated census tracts within Spokane County used 1.87% annual growth rate for 1999 and 2020 population projections.

2. For census tracts that included incorporated areas (Deer Park, Millwood, and Liberty Lake) the actual incorportated population was used. The remaining unincorporated population was projected by using the 1.87% annual unincorporated growth rate for Spokane

3. Includes City of Deer Park. To achieve the projected population, the 2000 Deer Park pop was subtracted from the total of the two census tracts. The remaining population was projected at 1.87% annual growth then the projected 2020 Deer Park population was added

4. Town of Millwood. Projected population per Spokane County Division of Planning

5. Includes City of Liberty Lake. To achieve the projected population, the 2000 Liberty Lake pop was subtracted from the total of the two census tracts. The remaining population was projected at 1.87% annual growth then the projected 2020 Liberty Lake population was added back in.

6. All projected populations within Spokane County are per Spokane County Division of Planning.

7. All projected populations for Stevens County used assumed 1.58% annual growth rate until more accurate figures are available.

8. All projected populations for Pend Oreille County used 1.58% annual growth rate per Pend Oreille County Planning Department.

8. WATERSHED MODELING

Water Resource planning is a difficult process due to many factors, including the high potential for conflicting interests, uncertainty of resource availability, low data reliability/longevity, varying ideals of established and emerging institutions, and the significant long and short term impacts of decisions. Models can aid in navigating through this process from start to finish if used and implemented properly.

A water resources model should:

- Define the status quo;
- Assess impacts of potential plans;
- Facilitate plan implementation and;
- Aid in assessing plan effectiveness.

Defining the status quo is important so that all stakeholders understand the current situation and have knowledge of existing problems, constraints and objectives. The model can help assess impacts of potential plans through the design and simulation of alternative situations and stakeholder involvement in this process. The model facilitates implementation through the fact that it was designed and approved by all stakeholders, not by a single group. Lastly, the model can be used to present and educate decision makers and the public of how decisions were reached, to obtain buy-in on decisions and goals and to support the movement towards those goals.

Through the process of building a model, data is collected, processes are verified, uncertainty evaluated and stakeholders are involved.

8.1 Current Modeling Objectives

In determining the type of model most suited to simulate the WRIA 55 and WRIA 57 processes, it is necessary to identify both the objectives of the project and the desired characteristics of the modeling package to achieve those objectives.

The main objectives identified during planning unit meetings and discussions for this project are as follows:

- Obtain a “wide circle of buy-in” on the decision making process through model development and use;
- Identify the actual availability of water in the basin, for purposes such as Ecology’s water rights decision-making process;
- Evaluate and predict surface water/ groundwater hydraulic continuity;
- Ascertain beneficial/detrimental impacts to downstream users due to water use or allocation changes;

- Determine how climate, snowpack, the level of Lake Coeur d'Alene and dams affect the flow of the Spokane River;
- Identify the impact of withdrawals from domestic wells along the Little Spokane River;
- Assess impacts of water pumped from the SVRP Aquifer and exported to the Little Spokane watershed;
- Evaluate alternative operating and management scenarios;
- Predict frequency and duration of low flows; and,
- Assess mitigation measures available to water rights holders who may be affected by possible water rights changes; and,
- Model minimum instream flow levels based on "natural" runoff conditions.

The Planning Unit discussed model needs extensively. Based on those discussions the following model software characteristics were identified:

- Model should support integrated hydrologic modeling of groundwater and surface water;
- The modeling software (and therefore final model) should be accepted in the technical community;
- Model should provide interfaces that allow it to be used by a technically diverse group, from consultants and Spokane County employees to the general public;
- Model should be flexible for future changes (e.g., grid resolution changes due to additional withdrawals) and able to provide scenario comparison;
- The modeling software should be widely used and supported so that software is kept current, questions can be answered and bugs can be addressed;
- Model should be commercially available (purchased or free);
- Model should provide presentation capabilities or presentation level output;
- Model should provide variable grid resolution; and,
- Model inputs and outputs should be compatible with ArcView/ArcInfo;

There are many possible users of this model with varying purposes. Model "Users" includes a wide range of use, from someone who merely pulls up data on a web site from a previous model run, to someone who actually runs the model with different scenarios. Potential users of the model and their respective interests are presented on Table 8.1.

8.2 Previous Modeling Efforts

There have been several efforts in both WRIA 55 and 57 to model portions of the watershed, but none have had a goal of modeling the watershed as a whole. Previous groundwater and surface water - groundwater interaction modeling efforts are summarized in Section 5.2.7. There currently is an ongoing effort by Ecology and the Corps to model water quality of the Spokane River. However, this model (CE-QUAL-W2) requires stream flow and groundwater recharge and discharge to the Spokane River as input values to provide an estimation of water quality parameters. Ecology has completed a TMDL study for Biological Oxygen Demand (BOD) and phosphorus attenuation for the Spokane River with assistance from the Army Cops of Engineers.

Previous modeling projects include:

Surface Water Models

- National Weather Service Flood Prediction Modeling
- Avista's hydropower model
- Ecology / CORPS Spokane River Water Quality Monitoring (being developed)

Groundwater Flow Models

- Pluhowski & Thomas (USGS, 1968 – water balance)
- Drost & Seitz (USGS, 1978 – water balance)
- Bolke & Vaccaro (USGS, 1981 – 2D numerical computer model)
- Painter (IDEQ, 1991 – Spreadsheet)
- Buchanan & Olness (EWU, 1993 – MODFLOW)
- CH2M Hill (1998 and 2000 – MicroFEM)
- Buchanan (EWU, 2000 – MODFLOW)

Most of these models were developed to answer specific questions such as the appropriate location of wellhead protection areas, groundwater recharge zones, TMDL limits, etc. These models fall short of a watershed planning tool because, while useful for their intended purpose, they are limited in both scope and process. It was determined that this project requires a model which can provide a more comprehensive picture of how the watershed functions, responds and changes over time due to various operational and natural changes. It is recognized that the model being developed is not a comprehensive model in portions of Idaho that contribute to the hydrology of the model domain are not fully accounted for.

8.3 Model Selection

The Planning Unit completed a model selection process in May 2001 and chose the MIKE Suite of software tools developed by DHI Inc. The Planning Unit model selection process involved evaluation and development of the project goals and expectations, followed by development of a list of possible model alternatives to meet these goals and finally, with evaluation of each software's pros and cons and use in the industry. DHI is a well-respected Danish corporation that has become well known throughout the water resources industry for their development of the MIKE Suite of tools.

The planning unit developed a list of variables that the model should have the ability to address. These include, but are not limited to the following:

- Frequency and duration of low flows;
- Hydraulic continuity between surface water and groundwater;
- Timing and quantity of groundwater withdrawal effects on surface water flows;
- Effects of dam operation on streamflow; and,
- Effects of flows on water quality.

Model selection was based in part upon the ability of the model to adequately address these variables (Appendix E). Although, it was recognized that the data available (existing information) for input may restrict rigorous treatment of some of these variables (data constraints/gaps are identified in Section 10 of this report).

The MIKE Suite of software is marketed as modules that can be added as needed for a project. For the Spokane Watershed Inventory Assessment the MIKE Suite software components that were deemed necessary are described in Table 8.2.

8.4 Basic Requirements for Modeling with MIKE.

This section provides a preliminary outline of the data that will be needed for each modeling component. As in any modeling process, it is anticipated that as modeling proceeds both additional data will become necessary and additional data will become available.

8.4.1 Data Collection, Data Processing and Data Analysis

The first step in modeling is to collect and characterize available field data. The second step is to process the data for input into the MIKE model. Important steps in regard to data processing are to ensure that the data do not contain major flaws, to identify driving forces of a hydrologic system, and to identify unique areas of the modeling domain where special attention should be paid. This data report contains summaries of all available data as supplied to us by Spokane County and also describes the main characteristics of that data. This characterization report represents the first step in the modeling process.

8.4.2 Data Needs for the MIKE Model

The proposed model boundaries are displayed in Figure 8.1. These boundaries were chosen based on where there is surface water continuity and where we have sufficient hydrologic information for a boundary.
It is important to note that not all data shown as needed in this section is required. The MIKE model is flexible in that it provides the ability to model complicated highly descretized processes as well as entire watershed systems. Generally, the more data

available to the model, the better and more accurate the model is, but there are methods available for estimating many of these processes or using defaults for highly discrete processes.

8.4.2.1 Basic Data Requirements

The basic data requirements for the model are:

- Boundaries and features of the study area in an X,Y Co-ordinate system;
- A digital elevation model of the entire model domain; and,
- X,Y co-ordinates of all stationed data including, but not limited to, precipitation, well levels, stream flows, and river structures.

A basin requirement is that the model area be defined with a coordinate system, preferably with an origin referring to the global coordinate system for which most data are available. The model area may be digitized and stored as X-Y data in an ASCII file or in a Microsoft Excel spread sheet. Alternatively the model area may be digitized in ArcView or ArcInfo GIS and stored as a polygon coverage. To the extent possible the model area should be confined by natural boundaries such as water divides (zero-flux boundaries) and rivers (head boundaries). In a model including both surface and sub-surface flow the water divides may not coincide. In such cases a potential head boundary or a flux boundary may be required for the groundwater. If the final extent of the model has not been established, all input data should be prepared for an area larger than the model area.

Detailed topographical contour maps (1:5000 or 1:10000 with 1-5 meter contour intervals depending on overall slope) are needed. Low-lying areas and highland areas must be represented. To build the DEM inside ArcView spot elevations can be digitized and stored as X,Y,Z in an ASCII file.

All available rainfall data for the selected period from all rainfall stations in the study area as well as the location of all the rainfall stations, periods of records and station elevations are needed. Precise location (x-y coordinates) must be known for each station. Daily data is sufficiently detailed for a MIKE SHE subbasin scale study. The coordinates are used to generate polygons, typically Thiessen polygons, for spatial distribution of rainfall data. Mean annual rainfall contour maps may be used to validate the Thiessen distribution.

8.4.2.2 Saturated Zone Flow

The saturated zone flow requirements are:

- Geo-referenced location of well locations;
- Geo-referenced borehole data;
- Hydraulic properties of aquifers and aquitards; and,

- Groundwater extraction or injection data.

Geological and hydrogeological data are required. The geologic model should be based on a conceptual understanding of the aquifer system. Different types of data may be used to describe the major geological units. Lithological classification at a number of geo-referenced boreholes can serve as basic data for the geological interpretation.

The hydraulic properties of aquifers and aquitards must be specified in terms of horizontal conductivity, vertical conductivity, confined storage coefficient and unconfined storage coefficient. These parameters are normally derived from pump test analysis and may be organized as X-Y-Z data with Z as transmissivity or storage coefficient, respectively.

Groundwater extraction data must be prepared in terms of well location (x-y coordinates) and time series of extraction data covering the simulation period. Data on a monthly basis are normally sufficient to describe the annual variation.

8.4.2.3 Unsaturated Zone Flow

The unsaturated zone flow requirements are:

- Soil map and profile information; and,
- Soil characteristics for each type of soil used in the profile.

Unsaturated flow simulation requires soil map and profile information. Based on soil profiles describing the soil types of the upper meters (from the ground surface to the ground water table) a number of characteristic soil profiles are defined. Soil maps are required to determine the distribution of characteristic soil columns within the model area.

Soil physical data must be provided for each soil type included in the soil profiles. Retention data and hydraulic conductivity data are also needed. The soil physical data required are:

- Saturated hydraulic conductivity (m/s)
- Saturated water content (%)
- Residual water content (%)
- Effective water content (%)
- Air entry water content (maximum achievable water content)
- Capillary potential at field capacity
- Capillary potential at wilting point
- Exponent of the conductivity curve: $K(\theta) = ((\theta - \theta_r)/(\theta_s - \theta_r))^n$

It is recommended that retention curve data and hydraulic conductivity data is entered into the MIKE SHE soil database. A variety of soils data collected during previous studies can be made available to supplement measured data of the model area.

8.4.2.4 Rainfall-Runoff/Overland Flow

The following information is required to simulate rainfall, runoff and overland flow:

- Topographical input map (DEM);
- Land use coverage (preferably several to account for changes over time;
- Water storage on surface and in root zone;
- Meteorological time series data including precipitation and potential evapotranspiration with temperature required to model snow;
- Any withdrawal rates that apply to the area;
- Flood Maps, potential GW head, and discharge data; and,
- Canopy drainage rates for interception of rainfall by vegetation.

Overland flow is calculated from the surface slope, which is described through the topographical input map. Data requirements includes:

- Max water content value in surface and root zone;
- Strickler roughness coefficients (equivalent to Manning's number);
- Overland flow run-off coefficient;
- Time constant for interflow;
- Time constant for routing overland flow;
- Root zone threshold value for overland flow and interflow;
- Time constant for routing baseflow; and,
- Root zone threshold value for groundwater recharge.

All sets of parameters can either be provided as default values or as 2-D maps.

Daily flow data can be used; to understand peak flows a finer resolution is necessary. Potential evapotranspiration can be input as a monthly value though daily is preferable. Temperature is required on a daily time step in order to accurately predict snow accumulation and melt. An understanding of how rainfall and temperature are distributed across the basin is necessary in order to define weighting values for missing locations. Observed discharge at the outlet of each basin for calibration and validation with simulated data is required along with groundwater extraction levels.

8.4.2.5 Channel Flow

The channel flow requirements are:

- Geo-referenced plan and profile of river reaches;
- River cross-sections;
- Bed and Flood Plain resistance;
- Wind affects;
- Geo-referenced locations of significant changes in bed slope, and channel structures;
- Geo-referenced locations and time series data for discharge and regulation structures;
- Geo-referenced locations of all major inlets and time series data for those inlets; and,
- Geo-referenced Location of major groundwater interaction locations.

Main channels, rivers and tributaries are digitized and prepared in xy ASCII format for the MIKE SHE Graphical River Editor. River bank elevations are added in a number of points along the river reaches. Data is organized from upstream to downstream of each river reach. Manning's number values are necessary.

8.4.2.6 Snowmelt

To calculate snowmelt, the model requires:

- Temperature;
- Degree-day coefficient; and,
- Other climate data affecting snow melt.

In order to simulate snowmelt, temperature data, specified on a daily basis in °C is required. Mean daily temperature values are sufficient.

A simple degree-day approach, requiring two parameters will be used:

- Constant degree-day coefficient (snow melts at rate defined by this value multiplied by temp); and.
- Base temperature (temp above which snow melts and below which snow is retained).

8.4.2.7 Irrigation Water

Time series of irrigation water applied may be required depending on sensitivity of water balance to this parameter and efficiency of irrigation in the area.

8.4.2.8 Evapotranspiration

- Pan evaporation as time series.
- Geo-referenced location of evaporation stations.
- Land use/vegetation maps (time varying if necessary) with respective evaporation rates (time varying)

Potential evaporation rate data from available stations shall be collected for the period (e.g., pan evaporation data). The data should preferably be available on daily basis. A monthly frequency is often sufficient to describe annual fluctuations. The location of the evaporation stations must be known and could be shown on the same base map as the rainfall stations. The unit (mm/h) is applied in MIKE SHE formatted files.

To simulate the actual evapotranspiration, the vegetation distribution must be specified along with time varying evapotranspiration rates for each vegetation/land use type. One or more land use map based on field surveys, aerial photos or satellite images may be applied to map the characteristic vegetation of the model area. The vegetation applied should reflect differences in evapotranspiration. The vegetation types should include crops, other types of vegetation and areas with no vegetation. The latter category may be subdivided into water bodies, urbanized areas (paved areas) and so on. Evapotranspiration (ET) rates may be estimated for input into the model, or the model can be provided with the appropriate input to calculate ET.

If significant land use changes have taken place within the simulation period, more maps of vegetation distribution should be prepared. ArcView polygon data are suitable for generating the required input maps.

8.4.3 Model Calibration Data

A number of calibration references in terms of time series are required. The model may be calibrated against the following:

- Potential head of the saturated zone. Ideally the wells should be distributed across the model area and screened to provide potential heads of all major aquifers. Coordinates and elevation of each observation well must be provided, using a consistent datum. The frequency of recorded levels should be sufficient to account for the time scale of groundwater variations.
- All available water level and river discharge data for the period from all water level and discharge stations in the study area are required.
- Water contents of the unsaturated zone.
- Floodplain maps.

A typical calibration period is in the order 3-10 years where varying hydrologic years are represented (e.g., wet and dry years). After calibration the model should be validated with data outside the calibration period (split sample test). A validation period should be of the same length as the calibration period. Thus data for a 6-20 year period is typically required in order to calibrate and validate a MIKE SHE model.

8.4.4 Coupling of MIKE SHE and MIKE 11

The coupling between MIKE 11 and MIKE SHE is made via ***river links*** (i.e., line segments between two adjacent grid points). The entire river system will always be included in the hydraulic model, but MIKE SHE will only exchange water with the user-specified coupling reaches. Figure 8.2 shows part of a MIKE SHE model grid with river links, and the corresponding MIKE 11 branches (-reaches) with H-points (where MIKE 11 calculates water levels) (DHI Inc. 2000).

During the simulation, the calculated water table elevations and flow discharges are transferred (interpolated) from MIKE 11 H-points to MIKE SHE river links. MIKE SHE calculates the exchange with the other components including, overland flow to each river link from the two neighbor grid points, river-aquifer exchange, loading and infiltration/seepage in inundation areas. The calculated source/sink terms of the river links are fed back to MIKE 11 as lateral in/out flow to the corresponding H-points.

In a normal MIKE 11 river model only the river reach lengths (dx) are important for the results. Geographic positioning of river branches and cross-sections are only important for the graphical presentation. When interfacing MIKE 11 to MIKE SHE geographic positioning is crucial, as MIKE SHE needs information on river location. A reasonably high number of river cross-sections should be included in order to ensure that the river elevations are reasonably consistent with the surface topographic features. Whenever there is a significant change in the bed slope there should, in principle, be a cross-section defined in MIKE 11. If only few cross-sections are available, it may be sufficient to estimate the cross-section shape based on neighboring cross-sections and estimate the bank/bed elevation based on the surface topographic information in MIKE SHE or other topographic maps.

8.5 Model Approach

Two main model options have been researched for the modeling approach:

1. A two model approach with MIKE 11 Rainfall Run-off and HD as one model (split approach) and integrated MIKE11 HD and MIKE SHE as the other; or,
2. A single integrated MIKE 11 HD and MIKE SHE model (unified approach).

There are benefits and detriments to each method.

The split approach is appropriate because the upper portion of WRIA 55 is not highly affected by groundwater flows. It is therefore possible to use only a surface water model for the upper portions of WRIA 55, and an integrated surface water-groundwater model for the lower portions of WRIA 55 and all of WRIA 57. It requires that the basin be separated into two models with the Mike 11 model of the upper basin providing boundary conditions to the lower, integrated model. The benefits include decreased computational time and decreased sub surface data needs. However, this option effectively splits the model in two, requiring an increased coordination of changes. Another benefit of this approach is that the Mike 11 rainfall/run-off module applies a more rigorous solution method for snow storage. However, minimal data is available for the upper basin to justify this more rigorous approach.

The unified approach, using a single, integrated, MIKE SHE/MIKE 11 approach, provides the obvious advantage of a single unified model. Also, because MIKE SHE uses a gridded method, run-off is not applied as a lump sum per delineated subbasin. Instead, run-off is calculated on a grid-by-grid basis using topographic DEM input data (among other data). The disadvantage of this is that the model is more computationally expensive. The integrated approach also allows us to specify groundwater interactions across the entire region so all subsurface storage is accounted for.

In conversations with DHI modelers, it is clear that both approaches have been applied and proven to work equally well on similar basins. Based on this information it was determined that we would move forward under the assumption that a single integrated MIKE SHE/MIKE 11 approach would be used.

The ultimate purpose of this report is to gain an understanding of the watershed as a system, the data that is available for the watershed, and how the available data can best be represented in a model for final use in watershed planning and management. This is always a cumbersome task due to the fact that as the job moves from planning-to-model, to modeling, new information arises causing unforeseen changes. This section represents how, at the end of this planning phase, it is believed the model should be developed.

8.6 Model Discretization

Discretization, in the arena of hydrologic modeling, is the process of defining and separating a watershed into distinct regions (both spatially and temporally) that respond to hydrologic stimuli in the same manner. In addition, discretization can only occur to the level for which there are data. This section establishes a minimum standard for discretization and identifies the model domain, contributing areas, temporal resolution and calibration points for both surface water and groundwater.

8.6.1 Model Domain

The preliminary model domain is presented as Figure 8.1. The domain boundaries will be controlled primarily by surface water divides and by the location of available surface water gaging information with sufficiently long periods of record (i.e., at least 6 years).

The Spokane River gage located near Post Falls, Idaho will represent the eastern or inflow surface water boundary condition for the model (Figure 8.1). This gage has a long period of streamflow record. From this gaging point, the domain boundary extends northwards to incorporate the Hauser Lake watershed in Idaho. This Idaho watershed area needs to be considered because there is no available gage at the outlet to Hauser Lake that can be used to account for the water that recharges the SVRP Aquifer from this watershed. Similarly, the model domain boundary will extend southwards to incorporate the watershed area to the south of the Spokane River that contributes flow. Groundwater levels within the SVRP Aquifer measured in wells monitored by CH2M Hill for the SAJB wellhead protection program and by the USGS as part of the ongoing NAQWA study, will be used to provide groundwater level information within the SVRP Aquifer at the eastern inflow boundary.

The northern and southern watershed areas of WRIA 57 that drain to Idaho (i.e., that are located outside the WAUs that drain into WRIA 57) will be excluded from the model domain (Figure 8.1). From a modeling perspective this is appropriate for several reasons. These areas are located outside the physiographic WAU boundaries that drain into the study area. The major hydrogeologic unit within these areas comprises relatively impermeable crystalline basement rocks. And the runoff from these areas would be included in the subsurface inflow across the Washington-Idaho state line.

The Spokane River gage at Long Lake, which has more than 60 years of record, is used as the downstream-most boundary condition, and results in the inclusion of a portion of WRIA 54 (Lower Spokane Watershed), and inflows from Hangman (Latah) Creek.

The western outflow point for WRIA 55 will be represented by the Little Spokane River gage Near Dartford. The gage is the most downstream gage on the Little Spokane River that can be used to confirm WRIA 55 flows out of the model. The Little Spokane River Near Dartford gage has approximately 6 years of data. It is possible to estimate data for additional years because there is good correlation of flows between Near Dartford and At Dartford. Flow data at the Spokane River gage at Spokane will be used for calibration of the model.

8.6.2 Contributing Areas

Areas contributing to the model domain are displayed in Figure 5.1. As discussed in Section 5 (Water Quantity), the contributing area for WRIA 55 is contained by the WRIA 55 boundaries identified by Ecology. However, the contributing area for WRIA 57 extends to the border of Idaho and Montana. Therefore boundary conditions along the east edge of WRIA 57 need to account for the entire contributing basin.

8.6.3 Temporal and Spatial Resolution

The temporal and spatial scale of available input data must reflect the purpose of the study and the detail requested of model outputs. Lack of data in a distributed model may imply assumptions on the general validity of extending existing data to the entire model area. Such assumptions affect the uncertainty associated with the model results. It is possible however, to set up a model based on limited data that may be appropriate for different purposes (DHI, Inc. 1999).

During the planning process it was determined that the desired maximum temporal resolution is one week. This was chosen, in part, to aid in modeling 7-day low flows. Therefore input data, especially precipitation, discharge and groundwater levels should at least be at a weekly time step. And benefits would be recognized if finer time scale data were available. The modeling process will start with a simplified steady state approach, then move to a monthly time step and then to a weekly time step. If the data allow, the model may ultimately be run on a daily time step.

MIKE SHE requires that a model grid cover the entire modeling domain, and, as stated before, specific sub-basin boundaries do not need to be identified. DHI documentation recommends that no more than 10,000 grid cells be used to describe the entire spatial model domain. The approximate area of the model domain is 980 square miles. Assuming the domain is divided into 5 vertical, geologic layers, the recommended minimum grid size is 0.5 square miles. We have chosen to model 1 square mile areas initially. This will provide enough detail for planning and management without causing large computational times. MIKE SHE provides the ability to easily move to a smaller grid size if more detail is necessary. It is presumed that streams will be modeled down to secondary branches of main tributaries but may vary depending on the hydrologic state of a given area. For example, because the Dragoon Creek WAU has a large number of current water rights applications, it may be important that the hydrologic response of this system is simulated at a finer resolution than the adjacent WAUs.

8.6.4 Model Calibration and Validation

The general model development approach consists of:

- Developing a saturated groundwater flow model under long-term steady-state conditions (calibrate against average annual groundwater surface contours);
- Developing a surface flow model consisting of overland flow and channel flow. This is inherently transient and will simulate various precipitation events. Results will be compared against observed values of flow for target calibration points;
- Developing an unsaturated zone model; and,
- Coupling each of the hydrologic components.

Both the groundwater and surface water components are first run separately under steady-state, average annual conditions to check for obvious errors. They are then coupled and run under steady-state conditions and, at last, with transient conditions at what time the model as a whole is calibrated.

A typical calibration period is on the order 3-10 years where varying hydrologic years are represented (e.g., wet and dry years). After calibration the model should be validated on data outside the calibration period (split sample test). A validation period should be of the same length as the calibration period. Thus data for a 6-20 year period is typically required in order to calibrate and validate a MIKE SHE model.

8.6.4.1 Groundwater Flow Model Development

The sequential stages in construction of a groundwater flow model are as follows:

1. Development of a conceptual hydrogeologic model;
2. Construction of a computer model to represent the important aspects of the conceptual hydrogeologic model;
3. Development of boundary conditions; and,
4. Identification of calibration data.

Based on the information reviewed for this study, the important aspects of the conceptual hydrogeologic models for WRIA 55 and WRIA 57 are summarized in the bullets below. A detailed description of the hydrogeologic model is presented within Section 4.3 of this report.

- Groundwater occurs primarily within the units overlying the crystalline basement (i.e., basalt and intercalated Latah sediments, and unconsolidated Quaternary units (i.e., glacial sediments, flood deposits and alluvium).
- On a basin-scale, the largest volumes of groundwater occur in the coarse grained Quaternary units (i.e., the flood sands and gravels and alluvium). Significant volumes of groundwater may also occur locally within the basalts.
- In WRIA 55, groundwater occurs primarily within a shallow, unconfined sand and gravel aquifer that occurs mainly adjacent to river channels and within the lower lying areas of the WRIA (e.g., the Deer Park Basin). The shallow aquifer occurs above finer grained fluvial and lake deposits, basalts or crystalline basement. Groundwater within this upper aquifer flows rapidly along the groundwater flow gradient to recharge rivers and lakes. If the contact between the shallow aquifer materials and the finer grained or consolidated materials occurs above the river or lake level, a spring may form. Groundwater within the finer grained or consolidated materials flows relatively slowly downwards from higher elevations and may ultimately recharge rivers and lakes. For example, within the Deer Park Basin, groundwater within the basalts below the shallow aquifer provides a significant water supply and recharges Dragoon Creek. However, this recharge contribution is small in comparison to recharge from the shallow aquifer materials.
- In WRIA 57, the unconfined sand and gravel materials of the Spokane Valley Aquifer dominate the groundwater flow system. Over the areas where the level of the Spokane River is higher than that of the aquifer, the river loses water to the aquifer. In areas where the level of the Spokane River is lower than that of the aquifer, the aquifer discharges to the river, often as springs along the river bank. “Nodes” where the river varies seasonally from gaining to losing may vary due to changes in river/aquifer elevations. The rate at which the surface water / groundwater interactions take place are controlled primarily by the thickness and permeability of the finer grained sediments that line the riverbed and the difference in the river and aquifer water levels. Close to the river, the

groundwater flows locally either down and out from the river to the aquifer or down from the aquifer to the river. However, the majority of the aquifer flow occurs along the regional groundwater flow gradient that runs westwards down the Spokane Valley and northwards through the Hillyard Trough. The majority of groundwater flow within the Spokane Valley Aquifer discharges to the Little Spokane River, across the north side of the Hillyard Trough. A small proportion of the aquifer flow discharges to the Lower Spokane River, through the Trinity Trough. A confined sand and gravel aquifer occurs below the Spokane Valley Aquifer, within the northern portion of the Hillyard Trough.

The following hydrogeologic layers, from top to bottom, may be included within the model. Due to a lack of data and relatively insignificant volumes of groundwater use, the Basalt / Latah Sediment layer may not be included.

- Soil
- Upper Flood Sands and Gravels
- Glacial Lake Sediments
- Lower Flood Sands and Gravels
- Basalts / Latah Sediments
- Crystalline Basement

The preliminary boundary conditions for the WRIA 55 and 57 groundwater flow model are summarized below. It should be noted that these boundary conditions might be modified as the model is constructed and calibrated.

- No-flow or low permeability basal boundary to represent the crystalline basement.
- No-flow or low permeability boundaries along the contacts between the unconsolidated aquifers and the basalt / basement rocks except at nodes where hillside watersheds drain into the aquifers.
- Specified flux at nodes where hillside watersheds drain into the aquifers.
- Specified flux or constant head across the eastern boundary of the Spokane Valley Aquifer.

The main model input parameters are summarized below:

- Areal recharge from effective precipitation (based on available climate and land surface data).
- Groundwater withdrawals (based on water use records).
- Groundwater return flows (based on estimates of septic recharge and recharge of irrigated water).

- Hydraulic conductivity (appropriate values for the modeled aquifers and aquitards based on existing data)
- River bed leakage coefficients (based on a review of existing data)

Initial groundwater level conditions for the major aquifers defined within the model (i.e., the SVRP Aquifer, the Little Spokane Aquifer Area and the Deer Park shallow aquifer) will be specified based on existing groundwater level data. Because the temporal coverage of data ranges between 1992 to 2000, validity of the available data will have to be made by assessing the climatic conditions for the year of the data record with the simulated wet, dry and average years.

During the calibration process, the input values will be allowed to vary and the sensitivity of the model to the varied input parameters will then be assessed.

The groundwater level snapshot and hydrograph data (presented within Section 5.2), along with information on the losing and gaining reaches of the Spokane River (presented within Section 5.2), will be used to calibrate the model along with additional USGS NAQWA data, which may become available in the near future.

Significant gaps in calibration data occur in groundwater level information for the unconsolidated materials on the eastern side of WRIA 55. There are also gaps in the coverage of groundwater levels across the entire model domain for the specified wet, dry and average years.

8.6.4.1.1 Surface Water Flow Model Development

From data provided by Spokane County there are 11 stations within WRIA 55 and 57 that meet the requirements of at least six years of continuous data. Three of these stations (Spokane River near Post Falls, Spokane River at Spokane and Little Spokane River Near Dartford) are to be used for boundary conditions, and two of them (Spokane River at Long Lake and Hangman Creek) are outside of the model domain. This leaves 6 gages with periods of record long enough for calibration (Table 8.3). The Spokane River below Trent Bridge gage is included because its period of record is close to six years and the location of this station is relevant. These calibration stations do not have the same POR, the table shows that many of the stations period of records do not even overlap. Therefore calibration must be done using discrete portions of the model. For example the Elk Creek gage was only in operation from WY 1949-1971. So the northeast portion of the watershed will have to be calibrated separately.

Other information that should be noted about these stations are provided in the bullets below:

- The LSR @ Elk gage and LSR @ Chattaroy gage provide the only continuous calibration points in the upper watershed.
- The LSR @ Chattaroy gage was initially monitored by the USGS but in recent years has been monitored by Spokane Community College (SCC).

- The LSR @ Dartford gage is considered to be upstream of the range of influence of the Hillyard Trough while the LSR Near Dartford gage reflects most of the aquifer inflow due to the Hillyard Trough (in addition to some minor tributaries).
- The Spokane River above Liberty Bridge gage is located relatively close to the State-line and will aid in providing an accurate estimate of flow across.
- The Spokane River below Trent Bridge and Spokane River below Greene Street gages are near reach boundaries defined by Gearhart and Buchanan (2000).

In addition to the stations discussed there are many other locations that have been gaged for short periods of time on less than daily increments. These values will be helpful in comparing the general range of flows encountered to modeled flows.

8.6.5 Sensitivity Analysis

Once the model is calibrated, a sensitivity analysis will be performed to estimate the amount of error due to assumptions made for model inputs. Several boundary and internal values will be varied within the previously established ranges to determine the amount of change each causes. Some of the values that may be analyzed are:

- Areal recharge from effective precipitation;
- Groundwater flow into the model;
- Groundwater withdrawals;
- Groundwater return flows;
- Hydraulic conductivity; and,
- Riverbed leakage coefficients.

TABLE 8.1

Model Users and Interests

Model users	Interests
Planning Unit	Effect of land use/cover on run-off, amount of interbasin exchange via GW (WRIA 55,57,54)
Interest Groups	Water Rights status and water availability/quality for individual purposes
Purveyors	Low flow timing, magnitude and locations
Department of Ecology	Water availability/quality data in order to process water rights, mitigation scenarios
Planning Departments/Local Government	Effect of land use/cover on run-off, water availabilities affect on growth and current and future water needs
General Public	Domestic exempt wells, water availability/quality
Development Interests	Domestic exempt wells, water availability/quality

TABLE 8.2

Model Users and Interests

Model Component Name	Purpose
MIKE SHE WM	An integrated hydrological modeling system which covers the entire land phase of the hydrological cycle, used for the analysis, planning and management of a wide range of water resources and environmental problems related to surface water and groundwater, in particular when the effect of human interference is to be assessed.
MIKE 11 HD	An implicit, finite difference computation of unsteady flows in rivers and estuaries.
MIKE 11 GIS	Developed to act as a fully integrated interface in ArcView GIS.
MIKE SHE GIS Converter	Allows for conversion between ArcView GIS and MIKE SHE formats.
MIKE SHE PP	Pre and post processor for data management and presentations.
MIKE 11 RR*	A lumped, conceptual rainfall-runoff model simulating overland flow, snowmelt, interflow and baseflow.*

TABLE 8.3

Model Users and Interests

Station Name	Source	Period of Record (Water Year)
Spokane R Ab Liberty Br Nr Otis Orchard, Wash	USGS / SCC	1930 - 1983,
		1994 – 1999*
Spokane River Blw Trent Brg Nr Spokane, Wash.	USGS	1949 - 1954
Spokane River Blw Green St at Spokane Wash	USGS / SCC	1949 - 1952,
		1993 - 1998*
Little Spokane River At Elk, Wash.	USGS	1949 – 1971
Little Spokane River, Chattaroy Rd., Chattaroy, WA	SCC	1976 – 1996,
		1998 - 1999
Little Spokane River At Dartford, Wash.	USGS	1930 - 1932,
		1948 – 1999
Little Spokane River Near Dartford, Wash.	USGS	1949 – 1951
		1998 – 1999

* SCC monitored from 93-98

9. DATA GAPS

Data compiled for the Level 1 Assessment will be used to develop a computer simulation model of the hydrologic regime in WRIAs 55 and 57. The purpose of the model is to simulate water resource management options with respect to mitigation of existing impacts and/or quantifying potential future impacts. Sufficient information currently exists to develop a preliminary model. Sensitivity analysis of the model will be used to identify the additional data or refinement of existing data that will best improve and provide the level of confidence upon which a watershed plan can be based.

Level 2 Assessment of watershed planning consists of data collection to fill gaps and data analysis to allow preparation of a watershed plan. Despite the large amount of data currently available, the MIKE model software requires several types of data that have not yet been compiled. Additionally, a more refined characterization of current water resource management practices will improve the assessment of their impacts. Additional data needs are being addressed by Spokane County and the Planning Unit and are described below. The data outlined below and the data sets and assumptions used in the Level 1 Assessment will be used in development of the model. Interpolation or regression analysis will be used to extend coverages of limited extent.

9.1 Model Requirements

One of the primary purposes of watershed planning is to manage surface water flows for multiple purposes including fisheries, allocation, water quality, and recreation, among other uses. In order for the model to properly simulate flows, the shape of the river channel, gradient, and structures that control flow must be characterized.

Accurately geo-referenced river cross-sections are needed to ensure that the river elevations are reasonably consistent with the surface topographic features. A series of cross-sections prepared in the 1940s is available, however, the profiles may have since changed. Ideally, whenever there is a significant change in the slope of the riverbed, a river cross-section should be defined in the model. If only a few cross-sections are available, interpolation on intervening cross-sections may be necessary based on neighboring cross-sections and topographic information. In on-going work by Carter Borden of the University of Idaho to develop a model of the lower reach of the Coeur d’Alene River, one cross-section every mile and at each significant change in slope is used. Although this resolution provides a higher degree of accuracy, initial model calibration can be accomplished with available data. Sensitivity analysis of the resulting model may identify reaches where additional cross-sections will be recommended to improve model accuracy. Spokane County is compiling existing river cross-section profiles.

A sensitivity analysis may reveal that riverbed leakage coefficients based on existing data are not accurate enough and need to be measured.

The relationship of dam operations on river flow along the Spokane River has to be characterized. This includes the location (x,y), pool and outlet elevation (z), operating information, and stream flow and river stage. Data is needed for the following dams:

- Post Falls (Avista)
- Upriver Dam (City of Spokane)
- Upper Falls (Avista)
- Monroe Street (Avista)
- Nine Mile (Avista)

It is assumed that there are no dams along the Little Spokane River. Similar information is needed for all man made structures or major obstructions on the rivers (e.g., falls, weirs, discharge locations etc.).

Geology, soils, hydrogeology and land use information will be required for the model domain within Idaho.

9.2 Impact Assessments

The quantity and distribution of water withdrawals for most uses is characterized relatively well based on assumptions described in Chapter 7. However, the distribution of source water for agricultural irrigation has not been characterized. The distribution of irrigated land is based on agricultural land use census on a county scale (Pend Oreille, Spokane and Stevens Counties) and land use categories. The actual distribution may be significantly different. Assuming that actual use closely correlates to consumptive use (i.e., impacts of conveyance losses and return flows are relatively small), the distribution of irrigated lands may not be significant with respect to modeling impacts. However, the distribution of source water will be significant.

A key variable to the estimation of the consumptive water use by agricultural irrigation is the evaporative component associated with the method of application (Table 7.3). The Planning Unit is currently compiling information regarding the distribution of agricultural irrigation water sources as well as representative application methods.

Summer peaking use of water delivered by purveyors comprises a significant proportion of annual water use in the basins. This summer use is assumed to be exterior use and primarily for landscape irrigation. Assuming that all of this water is lost to evapotranspiration provides an estimate of upper limit of the consumptive use portion of this water. However, actual watering patterns are expected to result in over-watering and attendant recharge back to groundwater. Accounting for application efficiencies and the actual acreage of urban irrigated land can arrive at more accurate quantification of the fate of water used for landscape irrigation.

Land use practices often have significant impacts on water balance components, particularly the treatment of storm water. In the Spokane River Valley, storm water is dominantly infiltrated via dry wells, thereby resulting in minimal impacts to the water balance and possibly an increase in water recharged to the aquifer system. In the Little Spokane Basin outside of the extents of the SVRP Aquifer (e.g., in the vicinity of the City of Deer Park), storm water management may result in an increase of runoff to streams. It is understood that the primary purpose of watershed planning in the Spokane Basin is to address water availability and, where necessary, assist in water rights allocation and mitigation. If the Planning Unit wishes to simulate land use practices, a better characterization of land use and storm water management should be incorporated into the model.

10. SUMMARY AND FUTURE DIRECTION

This Level 1 Assessment (data compilation) fulfills most of the grant requirements of Phase II Technical Assessment. The additional requirements will be fulfilled in the Level 2 Assessment (data collection and analysis). The Planning Unit is currently developing the watershed plan. This process is expected to begin with the formation of preliminary concepts, with the ultimate target of a final detailed plan being approved by the Planning Unit, presented for adoption by Counties, and submitted to Ecology in 2004. On-going technical work will be focused on providing the support needed to make decisions in the watershed plan.

10.1 Watershed Planning Grant Requirements

Watershed planning conducted under Ch. 90.82 RCW must fulfill specific requirements. Requirements for the technical assessment (Phase II) are as follows (EES, 1999):

Water Quantity:

i. Estimate of the water rights and claims;
ii. Estimate of surface water and groundwater actually being used;
iii. Estimate of surface and groundwater present;
iv. Identification of areas of exchange between surface water and groundwater;
v. Estimate of water use needed in the future; and,
vi. Estimate of future water availability.

Water Quality:

a. Review existing studies of the degree to which water quality standards are being met; and,
b. Review existing studies regarding the causes of water quality violations.

The standards required to meet these specifications are general and allow significant discretion to individual planning units for the purposes of meeting the objectives and goals for specific basins. It is anticipated that this Level 1 Assessment sufficiently satisfies all the items listed above to fulfill grant requirements, except the issues of future water use (v.) and future water availability (vi.). Model development in Level 2 Assessment will continue to refine the existing data sets. A technical memorandum addressing future water use needs will be submitted to the Planning Unit in January 2002 and used in developing future water use scenarios in the model. An estimate of future water availability will be a function of evaluating the impacts of additional allocations. Estimates of future water availability will be made by the Planning Unit upon completion of upcoming technical work, including development of a hydrologic model and instream flow studies.

10.2 Level 2 Assessment

Level 2 Assessment will include development of a calibrated model to simulate the hydrologic processes in WRIAs 55 and 57, including a quantification of impacts resulting from current water use practices. To support development of the model, information about the distribution of agricultural and non-agricultural irrigated land is being compiled by Spokane County. Future growth in water demand will be incorporated into the model assuming various management practices, including conservation and locations of water resource development.

Instream flow studies are anticipated to be conducted in 2002 on the Little Spokane River focusing on biological needs of fish along the main stem and possibly in selected critical reaches of tributaries. The study of instream flow needs on the Spokane River may be coordinated with studies which may be done by Avista Corporation, and will probably to be concentrated on critical habitat reaches.

10.3 Watershed Planning Considerations

The development of a conceptual framework for a watershed plan is essential for providing focus to the on-going technical work and data collection. The resolution and quality of existing data varies significantly. Efforts to increase the resolution of data sets should focus on those that will be used to support watershed planning decisions. In order to identify these data sets, the goals and objectives of the watershed planning process must be defined. Therefore, the Planning Unit should initiate conceptual development of a watershed plan.

Strategies for addressing the current status of water allocation may include:

- Establishing a water bank for re-allocation of existing rights;
- Identifying opportunities for water reuse and use of reclaimed water;
- Acquisition of water rights in specific reaches to improve habitat;
- Developing recommendations for the allowance of water right transfers not currently allowed by existing statute but which may have water resource management benefits;
- Development of increased storage capacity to make water available for additional uses, whether these are for habitat improvement, and consumptive or non-consumptive uses;
- Providing incentives and support for conservation practices in municipal, industrial and agricultural uses;
- Quantifying the amount of inchoate water rights and implementing an appropriate approach to further definition of these rights;
- “Cleaning up” the water rights database; and,
- Adjudication of rights and claims.

Strategies for approaching future allocation of water resources may include:

- Linking allocation to appropriate mitigation measures;
- Prioritizing beneficial uses;
- Developing land use management practices that will reduce existing impacts on water resources and reduce future impacts; and,
- Establish standards for management of development supported by exempt wells.

Historically, mitigation has typically focused on water volume impacts, where those impacts have occurred, and fully mitigating those impacts from a water balance perspective (i.e., in-kind, and in-place mitigation). Recognizing critical impacts of allocation (e.g., streamflow temperature) and mitigating for those (e.g., riparian habitat improvements) may allow additional allocation (i.e., out-of-kind, out-of-place mitigation).

Policies may be developed on a basin or sub-basin scale and should be flexible in response to changing conditions or recognition of better management approaches.