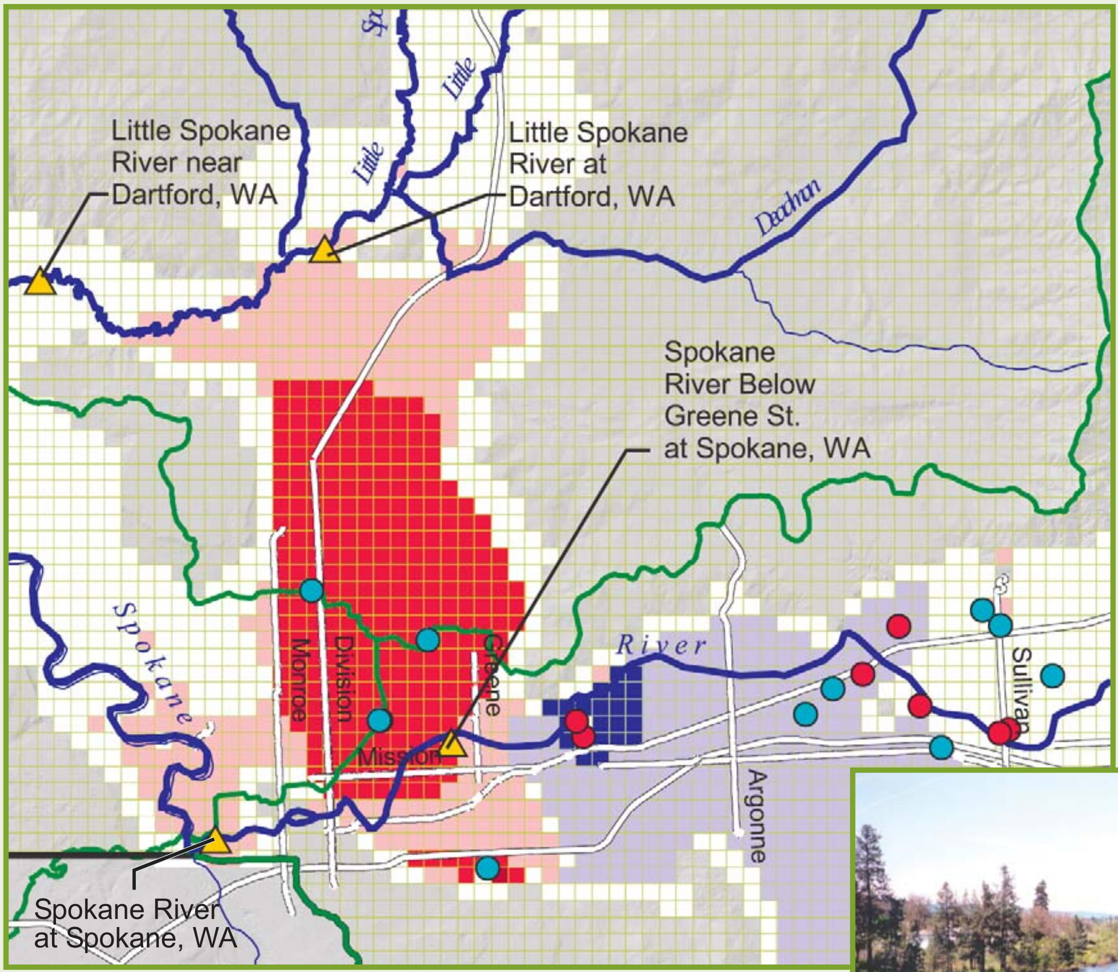
REPORT TO THE

Little and Middle Spokane Watershed WRIA 55 and 57 Planning Unit:

Watershed Model Scenario Analysis



Spokane River

Little Spokane River

Golder Associates

March 9, 2005

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March 9, 2005

Our Ref.: 013-1372

Spokane County
1026 W Broadway Ave.
Spokane, WA 99201-2002

Attention: Rob Lindsay

RE: WRIA 55 AND 57 WATERSHED MODEL SCENARIO ANALYSIS REPORT

Dear Rob:

Please find enclosed seven hardcopies and 10 CDs of the report presenting the findings of the model scenarios conducted for the Little and Middle Spokane Basin (WRIA 55 and 57).

The scenarios include assessing the effects of the following on streamflows and groundwater:

- Predevelopment conditions
- 20-year growth
- Aquifer injection of Spokane River water
- Relocation of groundwater supply wells
- Full exercise of municipal inchoate water rights

We also include in an appendix a preliminary assessment of global warming predictions on flows of the Little Spokane River, and updated some portions and improved the calibration of the model.

It has been a real pleasure conducting this work for you and the WRIA 55/57 Planning Unit. We feel that it provides significant insights on how the watersheds will respond to various conditions, and should be useful in developing water resource management policies.

Sincerely,

GOLDER ASSOCIATES INC.

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

Chris V. Pitre

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REPORT ON

WRIA 55 AND 57 WATERSHED MODEL

SCENARIO ANALYSIS

Prepared under Grant G9800300
from the Washington State Department of Ecology

Submitted to:

WRIA 55 and WRIA 57 Planning Unit
Spokane, Washington

Submitted by:

Golder Associates Inc.
Seattle, Washington

for Sara Marxen, E.I.T.
Water Resources Engineer

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

Distribution:

7 Copies - Spokane County (10 CD)
4 Copies - Golder Associates Inc.

March 9, 2005

State of Washington
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013-1372.3100

EXECUTIVE SUMMARY

A watershed simulation model of the Little and Middle Spokane Watersheds (Water Resources Inventory Areas [WRIAs] 55 and 57, respectively) was developed during Phase II, Level 2 of watershed planning under RCW 90.82. The model was developed using was the MIKE suite of software provided by DHI, Inc. The purpose of the model was to evaluate alternative management options and their effects on the hydrology of the watersheds, including streamflows.

After initial construction of the model, several updates were incorporated before running alternative management scenarios. These included modifications to groundwater abstraction and irrigation schedules, and increasing the evapotranspiration crop coefficient. This resulted in between 25% and 50% better agreement between actual and simulated mean annual streamflows. Simulated flows remain slightly too low in the Spokane River at Spokane, and too high in the Little Spokane River. Improved model calibration may be possible by refining and reducing groundwater flow through the Hillyard Trough.

The scenarios evaluated are:

- Pre-development (i.e., natural conditions);
- 20-year growth projections;
- Diversion of Spokane River flow to aquifer recharge;
- Relocation of groundwater abstraction wells;
- Full exercise of municipal inchoate water rights; and,
- Effects of predicted climate change.

Predevelopment: This scenario removed all anthropogenic effects on the hydrology of the watershed (i.e., groundwater withdrawals, irrigation, wastewater returns and dry wells) except for land use (e.g., deforestation and vegetation changes). Anthropogenic effects from the Idaho side of the state border are not considered.

Under predevelopment conditions, Spokane River at Spokane August flows (currently the month of peak pumping) are increased from current conditions by approximately 14%. This is equivalent to approximately 57% of the WRIA 57 August groundwater withdrawals. The remaining portion of groundwater withdrawals may be realized as reduced flows through the Hillyard and Trinity Troughs, and/or other effects. Return flows from the City of Spokane Waste Water Treatment Plant reduce the combined effects of groundwater withdrawals and use in WRIA 57 to approximately a 9% increase in streamflow over current conditions in August. This is consistent with an estimate of approximately 50% consumptive use through landscape irrigation practices, combined with the mitigating effects of dry wells.

The principal groundwater effects (e.g., greater than one foot difference in groundwater elevation at the end of the summer) were observed in the primary groundwater abstraction areas, in the western half of the Spokane Valley Rathdrum Prairie (SVRP) Aquifer, and in the Hillyard Trough. Localized effects of limited extent were also observed around Liberty Lake. Groundwater levels seasonally recovered during the winter in most areas, and no areas were identified as having been developed to an unsustainable level as defined by continued inter-annual decreases in water levels.

<u>20-Year Growth:</u> The 20-year growth scenario was designed to gauge watershed impacts based on projected 20-year population growth and water demands. The population and water requirements were calculated based on individual water districts, and those portions of WRIA 55 and 57 outside district boundaries as reported in the Golder Phase II – Level 1. Total purveyor water use is estimated to increase by 30% in WRIAs 55 and 57 by 2020. August flows are predicted to decrease on the order of 54 cfs, equivalent to a 4% decrease, on the Spokane River, and 13 cfs, equivalent to a 7% decrease, on the Little Spokane River at Dartford. In WRIA 57 approximately Groundwater elevations in the SVRP Aquifer are lower by up to a foot during the summer, although winter levels appear to be relatively unaffected. Groundwater levels in localized areas of the headwaters of WRIA 55 drop by up to a foot even though the level of groundwater withdrawals in these areas is relatively low, reflecting the sensitivity of headwater areas to groundwater withdrawals. Changes in groundwater levels most strongly affect (i.e., reduce) gaining reaches of streams. The losing reaches are slightly affected locally.

<u>Diversion of Spokane River Flow to Aquifer Recharge</u>: This scenario simulated the diversion of 100 cfs of water from the Spokane River during peak flows and injection of that water into the aquifer with the expectation the lag time of return flow would augment streamflow during low flow periods. Recharge of water to the aquifer near Barker Road resulted in an almost immediate increase in baseflow to the Spokane upstream of Greene Street. No significant lag time was observed, and only slight residual effects of increased baseflow (e.g., 5-10 cfs) persisted into the two months after cessation of recharge.

<u>Relocation of Groundwater Abstraction</u>: Selected wells close to the Spokane River were shut down and their withdrawal quantities assigned to existing groundwater wells located further from the river. Summer low flows were increased by up to 31 cfs at Greene Street, and up to 12 cfs at Spokane and the City of Spokane Waste Water Treatment Plant. This represents less than 1% of the total low flow at Spokane. Slight decreases in streamflow were observed during the late winter and early spring, though this is not considered a significant impact to habitat because this is the high flow period.

Flows in the Little Spokane River were unaffected at Dartford, but decreased by between 1 cfs and 2.5 cfs near Dartford, which is mostly downstream of the influence of the Hillyard Trough. This in interpreted to be a result of lowered groundwater elevations in the Hillyard Trough, and concurrent lower spring discharge to the Little Spokane River.

<u>Scenario 5 Full Municipal Water Rights Use</u>: This scenario simulates the full use of perfected and inchoate municipal/domestic water rights, which represent approximately twice the current water use for these purposes. Model set-up includes associated increases in wastewater discharge and expanded lawn irrigation.

Portions of the model aquifer system were not able to support the specified groundwater withdrawals either as a result of limitations in the model set up and/or the actual ability of the hydrologic system to yield the specified quantities. As a result, only 91% of the specified withdrawal was achieved by the model, and predicted impacts may be slightly greater than presented.

Full exercise of inchoate municipal water rights is predicted to reduce Spokane River streamflows by approximately 215 cfs in August below current flows during the summer low flow period, equivalent to a 15% decrease in average August streamflow. There is no significant lag time between groundwater withdrawals from the SVRP Aquifer and impacts on Spokane River streamflows, and impacts are realized during the period of lowest streamflows. Average August flows in the Little

Spokane River at Dartford are predicted to decrease by an average of 11 cfs, equivalent to a 6% reduction in streamflow. The lag time between groundwater withdrawals and impacts on the Little Spokane River is may be as much as 5 months.

Groundwater levels were approximately one foot lower in most of the model domain, although seasonal decreases of up to five feet are predicted in portions of the Hillyard Trough. Predicted impacts in the Diamond Lake Aquifer appeared to not converge during the model run, and the cause of this is predicted to be an artifact of the model which is being investigated by the software vendor.

Appendix A: Model Predicted Effects of Climate Change in WRIA 55: The Climate Impacts Group at the University of Washington has predicted future climate conditions (temperature and precipitation) in the Pacific Northwest based on the average of seven climate models. These conditions were input to the 20-year growth scenario to assess potential impacts of climate change imposed on future water use predictions. Analysis is presented only for WRIA 55 because this watershed is wholly contained within the model domain. In this way, the effects of changes of snowpack and groundwater storage on streamflows can be reasonably simulated. The headwaters of WRIA 57 extend into Montana where changes in the effects of snowpack cannot be simulated because this area is outside of the model domain.

Maximum mean monthly winter flows are predicted to be on the order of 400 cfs higher, and to occur one monthly earlier than current flows. The change in magnitude and the shift in timing of the peak flow is a result of diminished snow pack, and more closely tracks actual precipitation patterns as rain. Summer flows are predicted to be on the order of 5 cfs lower than current low flows. Because there is little perennial snow pack that sustains current summer low flows, the reduction of summer low streamflows reflects a decrease in the groundwater storage that supports streamflow through baseflow.

Limitations

The model was developed to simulate general hydrologic conditions across almost 1,000 square miles. The model cells are one-quarter mile square. Interpretation of phenomenon at the local scale may be limited.

Precipitation is distributed across the domain using PRISM data and meteorological stations. The model includes two hydrologically active geologic strata (a sand and gravel aquifer overlying basalt) simulated by two model layers. A clay lens known to exist in the Hillyard Trough area is implicitly included in the model by vertically averaging aquifer parameters with those of the sand and gravel aquifer.

Numerical instabilities exist in this portion of the model as a result of the high rate of groundwater discharge through springs, and oscillation between simulated subsurface and overland flow in the Hillyard Trough area. Therefore, confidence is limited in the simulated flows in the Little Spokane River downstream of the Hillyard Trough (e.g., at the near Dartford stream gage), and may partially affect simulated flows at the upstream end of this reach (i.e., at Dartford stream gage).

Hydrologic data is very limited in the upper Little Spokane watershed. Simulated groundwater levels in the Deer Park area are decreasing over the six-year model run in all scenarios, including the baseline condition, while simulated groundwater levels in the Diamond Lake Aquifer increase in all scenarios including the baseline condition. These are considered artifacts of the model and calibration can be improved in these areas.

Additional limitations of the model are described in the original model report (Golder, 2004). This work was conducted according to professionally accepted standards of this time and place within the constraints of available budget.

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1.0 INTRODUCTION/BACKGROUND

Watershed planning under RCW 90.82 is being jointly conducted in the Little and Middle Spokane River Basins (Water Resources Inventory Area [WRIA] 55 and 57 respectively). A Phase II – Level 1 Technical Assessment was completed as part of the watershed planning process (Golder, 2003), and a numerical simulation model was built to evaluate the effects of alternative water resources management options (Golder, 2004). The MIKE SHE model of the Little and Middle Spokane Watersheds was presented to the planning unit on November 13, 2002. Details of the model set-up, calibration and results are in a report titled "Level 2 Technical Assessment: Watershed Simulation Model," Golder Associates, dated February 13, 2004.

Subsequent to model development the Planning Unit directed Golder to run five model scenarios. The scenarios covered a range of watershed planning strategies and concerns, including: continued municipal growth and development, streamflow augmentation plans in an effort to meet the Washington Department of Fish and Wildlife minimum instream flow requirements, and full exercise of all municipal "paper rights" (inchoate). The impacts of projected climate change were also evaluated. All scenarios are simulated using the model calibrated to conditions between October, 1993 and September, 1999 (Water Years, 1994 through 1999) (e.g., precipitation and temperature patterns and streamflow boundary conditions at the Idaho-Washington Stateline). The scenarios were run and results presented to the Planning Unit in brief memos and at several meetings in early 2004. This report presents scenario results in a cohesive report but should be used in conjunction with the Level 2 Technical Assessment in order to fully understand the model set-up, calibration, and limitations.

1.1 Report Overview

This report is organized into the following chapters.

Chapter 2: Model Updates

Changes made to the baseline model set-up as a result of additional information received from DHI regarding software function and corrections in model set-up are summarized. Baseline conditions represent WRIA 55 and WRIA 57 in the period October, 1993 to September, 1999 (Water Year 1994 – 1999). This baseline model set-up is referred to as the updated baseline run, whereas the previous model set-up is referred to as the original baseline run. The original baseline run (presented in the Level 2 Technical Assessment) is only included in this report for comparison purposes.

Chapter 3: Scenario 0 – Predevelopment: The predevelopment scenario assesses streamflow and groundwater levels under natural conditions in order to evaluate impacts of current water use.

Chapter 4: Scenario 1 – 20-Year Growth: The 20-year growth scenario was designed to gauge watershed impacts based on projected 20-year population and associated water demand growth. The population and water requirements were calculated based on individual water districts, and those portions of WRIA 55 and 57 outside of those district boundaries, and reported in the Golder Phase II – Level 1.

Chapter 5: Scenario 2 – River Diversion and Groundwater Injection: This scenario simulates the diversion of water from the Spokane River during peak flows and injection of that water into the aquifer with the expectation the lag time in the return flow would augment streamflow during low flow periods. The scenario provides a prediction of when and where injected water may discharge back to the Spokane River.

Chapter 6: Scenario 3 – Relocation of Groundwater Abstraction: This scenario simulates the relocation of wells which pump groundwater near the Spokane River to locations that are further from the river. This scenario predicts the change in impacts to Spokane River and Little Spokane River discharge during low flow periods.

Chapter 7: Scenario 5 – Full Municipal Water Rights Use: This scenario simulates full use of perfected and inchoate municipal/domestic water rights. Model set-up includes the expected resulting increases in wastewater discharge and expanded lawn irrigation. The results provide a prediction of the projected distribution and magnitude of impact to stream flow and groundwater elevations throughout the watershed.

Appendix A: Model Predicted Effects of Climate Change in WRIA 55: Results from a scenario which predicts the effects of climate change, as described by the University of Washington Climate Impacts Group, on streamflows in WRIA 55.

Appendix B: Conversion of the Spokane model from Mike 2001 to Mike SHE 2003: A summary of a 2003 version of the watershed simulation model completed as a combined effort between DHI and Golder (Appendix B).

1.2 Model Output

Scenario Output is generally displayed for the following river locations. Individual scenarios may not display results for monitoring points for which the scenario has no effect and/or are not the focus of the simulation.

Spokane River Monitoring Points (from upstream to downstream):

- The Spokane River above Liberty Bridge near Otis Orchard (USGS station 12419500, Mike 11 river chainage 31,901). This point is indicative of a losing reach of the river just downstream of the Stateline.

- Spokane River below Greene Street (USGS station 12422000, Mike 11 river chainage 53,716). This point is downstream of the gaining reach between Flora Road and Greene Street.

- Spokane River at Spokane (USGS station 12422500, Mike 11 river chainage 61,417). This point is at the outlet of WRIA 57 and is downstream of a losing reach of the river.

- Spokane River downstream of the City of Spokane Wastewater Treatment Plant (WWTP; no USGS gage exists in this specific area, Mike 11 river chainage 71,153). This monitoring point is downstream of WRIA 57. It includes return flow from the CITY OF SPOKANE WWTP to the river as well as additional gains from the SVRP that occur downstream of WRIA 57.

Little Spokane River Monitoring Points (from upstream to downstream):

- Little Spokane River at Dartford (USGS station 12431000, Mike 11 river chainage 62,731). This point is downstream of Dragoon and Deadman Creek but considered to be mostly upstream of influence from the SVRP.

- The USGS gage on the Little Spokane River near Dartford (USGS station 12431500, Mike 11 river change 70,625) was presented in previous reports but instabilities in river flows at this location make it difficult to interpret the resulting change in flow from one scenario run to the baseline conditions. Therefore this location on the Little Spokane River is no longer presented.

Streamflow results are presented in two manners: as a monthly average change in streamflow from baseline conditions and as the predicted monthly average streamflow. The monthly average change in streamflow is calculated as the scenario discharge minus the baseline model discharge. Therefore, a negative change in streamflow indicates a reduction in streamflow under scenario conditions while a positive change in streamflow indicates an increase in streamflow under scenario conditions. The predicted monthly average streamflow is calculated as the actual measured average monthly streamflow (from water year 1994 – 1999) plus the relative (percent) change in simulated monthly average streamflow. For the Spokane River at the City of Spokane WWTP measured data is not available, therefore only simulated conditions are presented.

Groundwater is presented as groundwater elevations comparing baseline to the scenario conditions.

2.0 MODEL UPDATES

A completed Mike SHE model was presented to the WRIA 55 and57 Planning Units in the Level 2 Technical Assessment Watershed Simulation Model (Level 2 Assessment) dated February 13, 2004. In that report several potential improvements and/or model limitations were discussed, and some of these issues were addressed prior to scenario analysis. This section describes modifications to the irrigation, groundwater abstraction and evapotranspiration inputs, and the impact of those modifications on the baseline results.

2.1.1 Irrigation

Irrigation (lawn and agricultural irrigation) input was designed to apply irrigation for 3 hour intervals on specified days. The model did not apply the full designated amount because the time step, which varies automatically throughout a run, would sometimes exceed 3 hours and overstep an application period. The end result was that the model did not apply the full estimated irrigation water use to the land surface. To correct this problem, irrigation rates were evenly distributed over the course of a full day. While this does not reflect actual practice, the model better simulates the effects.

The updated irrigation input resulted in the model applying the full amount of water, increased total irrigation by an average of 81%, an increase of 118,321 AF over the 6 year simulation. Most of the additional irrigation water was supplied by municipal wells (74,785 AF) and the remaining portion was supplied by exempt wells (43,535 AF). Figure 2.1 displays the resulting change in applied irrigation between the original and the updated model. This component can vary from year to year depending on the availability of water for pumping.

2.1.2 Groundwater Abstraction

Groundwater abstraction is supplied as a monthly average abstraction rate to the model, and does not vary from year to year. It was discovered that the groundwater abstraction input was offset by one month during the original simulation. This misunderstanding was caused by incomplete software documentation. The dates in the input file were adjusted for the updated baseline simulation (Figure 2.2).

2.1.3 Evapotranspiration

Total streamflow in the original simulation was significantly higher than actual. The evapotranspiration crop coefficient (Kc) was increased by 33% in an effort to better calibrate the model, particularly the Little Spokane River discharge during the summer. The crop coefficient modifies the percentage of the potential evapotranspiration applied for each land cover, based on the growth stage and type of vegetation. The parameter increase remained within an acceptable range of coefficient values. Model results indicate this change resulted in an average 11% increase in evapotranspiration (617,913 AF) over the model run. The majority of this increase occurred during summer months, when the crop coefficients and potential evapotranspiration are highest. Figure 2.3 shows the difference between average monthly evapotranspiration results in the original and updated model for WRIA 55 and WRIA 57.

2.1.4 Net Changes in Simulated Baseline Streamflow

The net changes to streamflows resulting from changes in evapotranspiration, groundwater withdrawal and irrigation inputs improved the model calibration (Table 2.1). The effects of changes to evapotranspiration dominated in the Little Spokane River watershed and resulted in a decrease in simulated flows, closer to actual flows. The effects of evapotranspiration and irrigation inputs on Spokane River discharge more equally balance each other, and results in an increase in discharge compared to the original model for most years.

TABLE 2-1

Actual and Simulated Mean Annual Flows

Water Year	Mean Annual Flow (cfs)								
	Spokane River at Spokane			Little Spokane River near Dartford			Little Spokane River at Dartford		
	Measured	Original Model	Updated Model	Measured	Original Model	Updated Model	Measured	Original Model	Updated Model
1994	3,013	3,126	3,175	--	569	562	152	300	286
1995	6,322	6,071	6,248	--	826	798	328	558	516
1996	9,854	9,904	9,851	--	809	738	346	516	452
1997	10,349	9,890	10,020	--	989	915	626	682	618
1998	5,432	5,188	5,178	625	851	770	348	562	498
1999	7,537	7,435	7,403	689	879	770	446	565	498
Average deviation		-2%	-1%		32% [1]	17% [1]		52%	38%

Note: [1] Calculated based on 1998-1999 water years only.

The relative differences between mean annual flows in the original and updated models show a reduction by up to half in the deviation from the original model (Table 2-2). Simulated flows on the Spokane River at Spokane are slightly lower than actual while simulated flows on the Little Spokane River are higher than actual. Further constraining flow through the Hillyard Trough would both increase flows in the Spokane River and reduce flows in the Little Spokane River and improve model calibration.

Stream flow analyses in the scenarios are presented as average monthly flow calculated over the model run period, from October, 1993 through September, 1999. Groundwater results are also plotted over this period.

TABLE 2-2

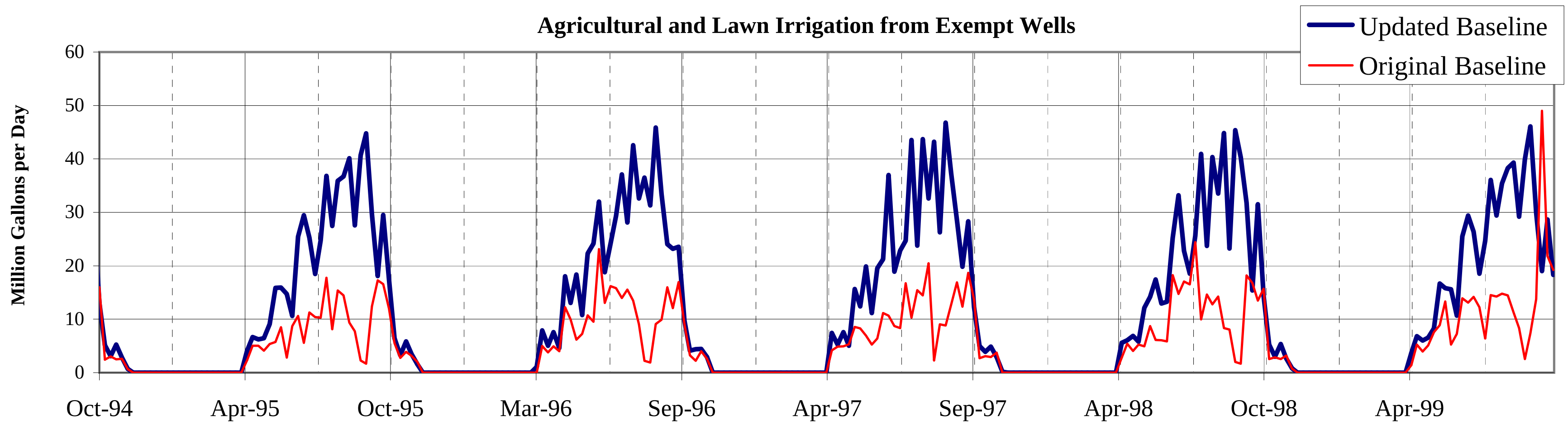
Deviation from Actual to Simulated Mean Annual Flows

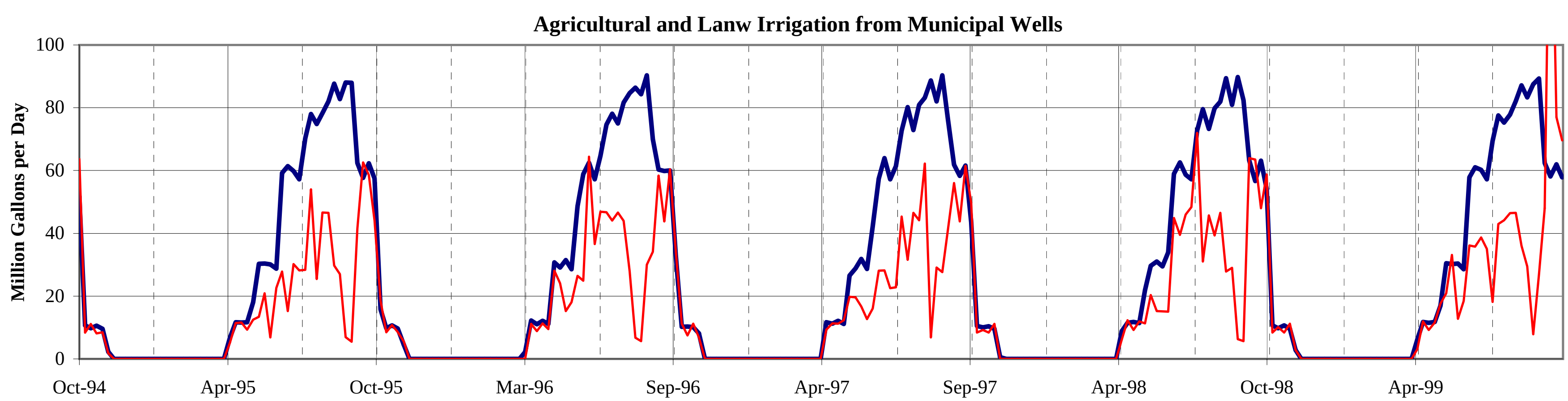
Water Year	Average Annual Flow (cfs)					
	Spokane River at Spokane		Little Spokane River near Dartford		Little Spokane River at Dartford	
	Original Model	Updated Model	Original Model	Updated Model	Original Model	Updated Model
1994	3.8%	5.4%	-	-	97.4%	88.2%
1995	-4.0%	-1.2%	-	-	70.1%	57.3%
1996	0.5%	0.0%	-	-	49.1%	30.6%
1997	-4.4%	-3.2%	-	-	8.9%	-1.3%
1998	-4.5%	-4.7%	36.2%	23.2%	61.5%	43.1%
1999	-1.4%	-1.8%	27.6%	11.8%	26.7%	11.7%
Average (%)	-1.7%	-0.9%	32%	17%	52%	38%
Average (cfs)	-118	-64	209	115	196	143

2.2 Instabilities in the Lower Little Spokane River

Numerical instabilities are present in the area surrounding the Little Spokane River near Dartford where there is significant discharge from the Spokane Valley Rathdrum Prairies (SVRP) Aquifer through the Hillyard Trough to the Little Spokane River. Discussions with DHI suggest that this may be due to software limitations in complex areas such as this where a large amount of discharge (as springs and seeps) occurs from groundwater to the river, as well as the large topographic gradient that occurs near the river channel. Attempts were made in the initial model set-up to reduce these instabilities through modifications of overland flow and riverbed leakage coefficients, but the instability, visible as oscillations in the discharge results, could not be fully eliminated.

It was speculated in the Level 2 Assessment that regardless of the oscillations in this area, the relative change of the results for each scenario was useful for understanding system effects. However scenario modeling as reported in this report has indicated that the instabilities in this area provide inconsistent results that should not be used to infer the total impact to streamflow at the near Dartford gage from the scenario inputs. Therefore results of this monitoring point are not presented.





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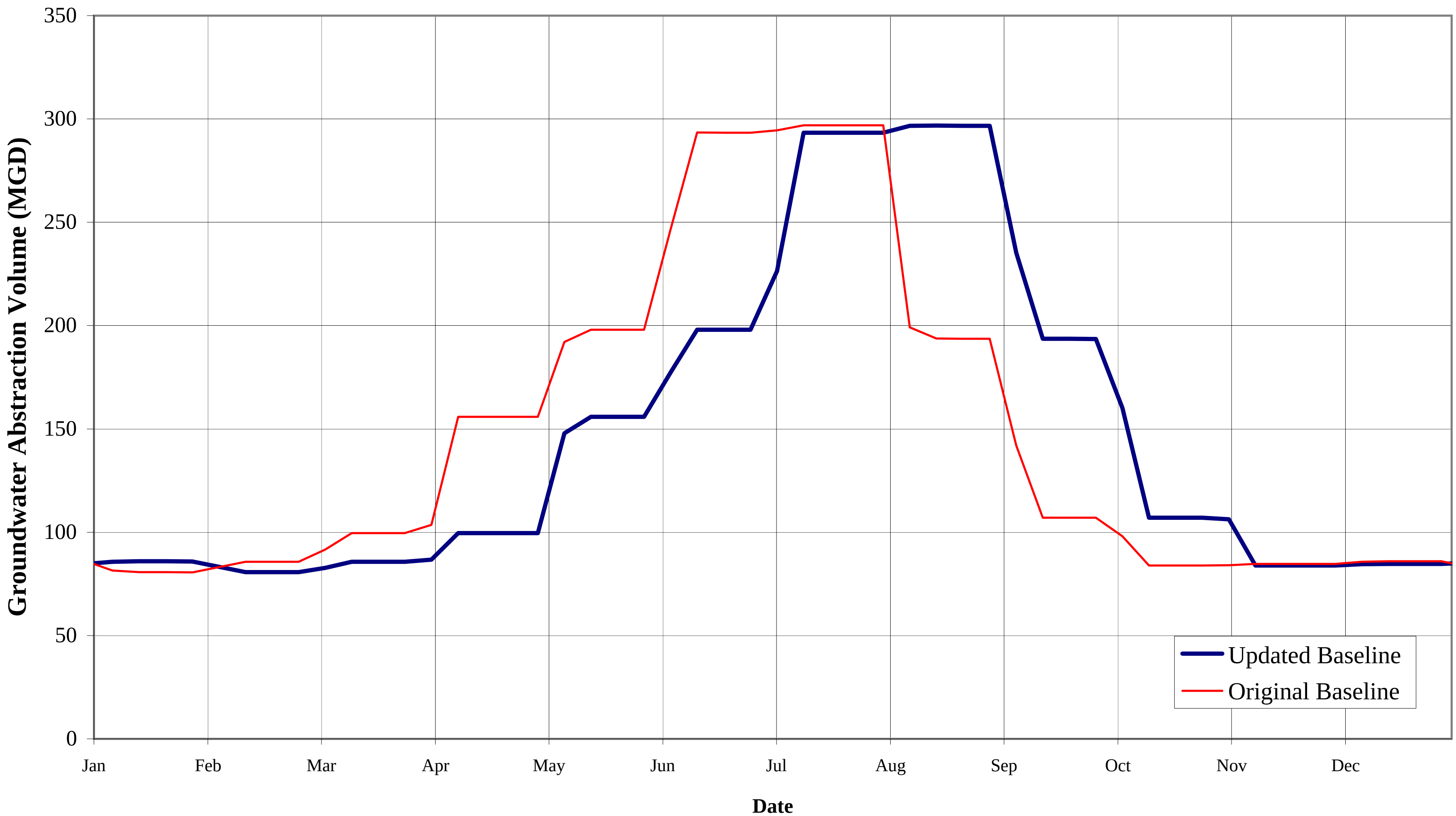
TITLE

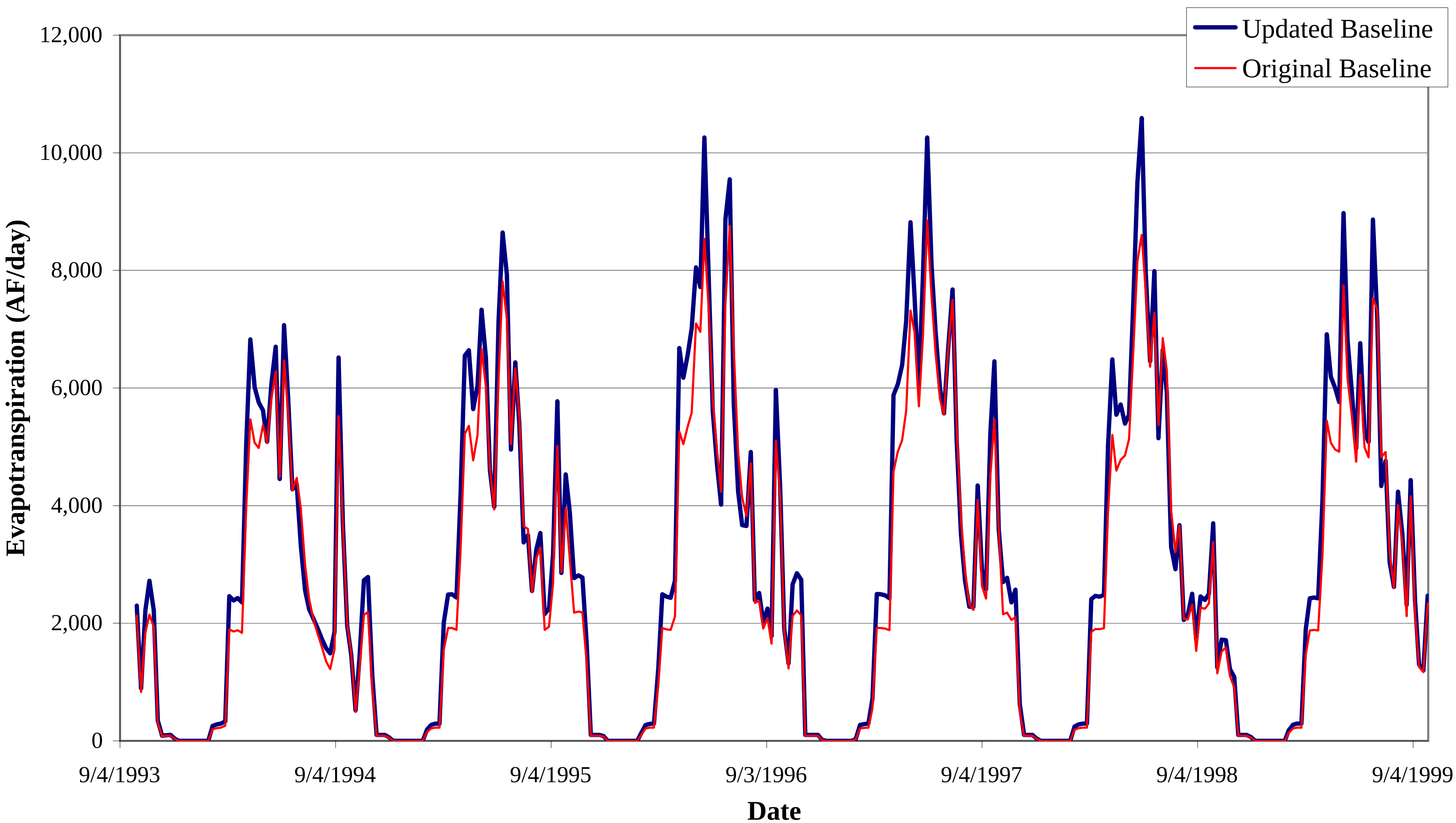
Applied Irrigation Output Comparison: Updated vs. Original Baseline Model

WRIA 55 & 57/ WATERSHED PLANNING/ WA

DRAWN	JM	DATE	June 2004	JOB NO.	013-1372
CHECKED		SCALE		DWG. NO.	
REVIEWED		FILE NO.	rum # 032704	FIGURE NO.	2.1



Golder Associates	TITLE **Abstraction Input Correction: Baseline Model Updated versus Original**		
WRIA 55 & 57/ WATERSHED PLANNING/ WA	DRAWN JM	DATE June 2004	JOB NO. 013-1372
	CHECKED	SCALE	DWG. NO.
	REVIEWED	FILE NO. RUN # 032704	FIGURE NO. 2.2



Golder Associates	TITLE **Total Evapotranspiration Output Comparison: Updated vs. Original Baseline Model**		
WRIA 55 & 57/ WATERSHED PLANNING/ WA	DRAWN JM	DATE June 2004	JOB NO. 013-1372
	CHECKED	SCALE	DWG. NO.
	REVIEWED	FILE NO. Basline Water Balance.xls	FIGURE NO. 2.3

3.0 SCENARIO 0: PREDEVELOPMENT

The predevelopment scenario predicts natural groundwater and surface water conditions without the influence of current human water use related activities.

3.1 Model Setup

Pre-developed conditions are simulated in the model by "turning off" the following processes:

- Groundwater abstraction (baseline abstraction is shown in Figure 3-1);
- Agricultural and lawn irrigation;
- Wastewater discharge to surface water and land surface; and,
- Drywell recharge.

Groundwater abstraction is simulated in two ways by the model: purveyor withdrawals for which specific withdrawal schedules were used (Figure 3-1); and, exempt well withdrawals that were simulated as the source of consumptive water use for irrigated acres outside of purveyor service areas (Figure 6.3 of the Level 2 Technical Assessment: Watershed Simulation Model, Golder, 2004).

There was no surface water diversions modeled under baseline conditions. These components entail all the watershed processes representative of development within the model domain, except for hydroelectric dams, land use (e.g. changes in paved areas or deforestation), and changes to aquifer inflow across the Idaho-Washington state line. Hydroelectric dams on the Spokane River in WRIA 57 have little effect on downstream flows because they are run-of-the-river and are not used to regulate flows. While land cover changes to a watershed can be significant in terms of hydrologic response, natural conditions are difficult to predict. Therefore direct hydrologic changes are considered a good surrogate for land use change effects on hydrology.

3.2 Results

The results of the Pre-Development Scenario are shown for surface water and groundwater in Figures 3.2 through 3.14 and are discussed in this section. In general the figures show an overall increase in streamflow and groundwater elevations under pre-development conditions, particularly during the late summer. Annual periods listed are for water years (e.g., 1994-1999).

Surface water results are presented in two frames on each figure. The upper frame of each figure shows the measured monthly hydrograph for the location (shown as a dashed line) and the measured monthly hydrograph with the predicted change in streamflow added (shown as a solid line). This provides a visual of the relative impact of the change in streamflow to actual streamflow. The change in discharge is displayed as a separate graph in the lower frame along with total pumping for each WRIA.

3.2.1 <u>Spokane River</u>

The monthly average change in flow on the Spokane River near Greene Street, at Spokane, and below the wastewater treatment plant along with the average monthly groundwater pumping rates under developed conditions are shown in Figure 3.2 through 3.4. The change in streamflow is displayed as pre-developed conditions minus developed conditions; a positive change in streamflow indicates that pre-developed conditions have higher discharge. Although pumping is turned off throughout the full model domain of WRIAs 55 and 57, only pumping in WRIA 57 is plotted in these figures because groundwater withdrawals in WRIA 55 are not expected to affect streamflows of the Spokane River in WRIA 57.

The **Otis Orchards gage** is approximately 6 miles from the model boundary and little groundwater abstraction within WRIA 57 occurs upstream of this reach (see Figure 3-1). Therefore, little response to a change in abstraction would be expected. The Spokane River at Otis Orchards shows little to no response to predevelopment conditions and therefore is not presented.

The **Spokane River at Greene Street** correlates well to the timing of groundwater pumping with the greatest monthly average change in streamflow occurring in August (approximately 165 cfs), when peak pumping occurs in baseline runs (Figure 3.2). The minimum change in flow occurs from February through April and is approximately 14 cfs. The magnitude of average annual streamflow change is approximately 38% of the annual abstraction.

The change in streamflow of the **Spokane River at Spokane** correlates well to groundwater pumping (Figure 3.3). Peak groundwater pumping is on the order of 360 cubic feet per second (cfs), whereas maximum monthly average changes in streamflow are on the order of 205 cfs. There is not a significant lag time between the two peaks, which suggests there is little lag time between peak pumping and river affects.

The magnitude of average annual streamflow change at Spokane is approximately 72% of the annual abstraction, a greater response than observed at Greene Street. This is attributed to the concentration of pumping that occurs downstream of Greene Street. Impacts of groundwater withdrawal not realized at Spokane might be accounted for by reduced flow through the Trinity and Hillyard Troughs, and/or other effects. Abstraction reduced the average annual streamflow at Spokane over the run (October, 1993 to September, 1999) by approximately 2%.

Change in flow in the **Spokane River downstream of the City of Spokane WWTP** is shown in Figure 3.4. The magnitude of average annual streamflow change is approximately 41% of the annual abstraction. The peak streamflow increase is predicted in August and is approximately 151 cfs. The smaller change in streamflow below the City of Spokane WWTP, relative to the Spokane River at Spokane, is partially explained by the return of non-consumptive water from the wastewater treatment plant (between 60 and 70 cfs). The withdrawal of groundwater from the SVRP Aquifer and discharge at the wastewater treatment plant creates a bypass reach between points of withdrawal and the wastewater treatment plant.

The model contains uniform inter-year pumping rates; therefore a change in pumping due to varying climatic years may result in different effects of pumping on streamflows. In reality, groundwater withdrawal rates may be lower in wet years and higher in dry years. Higher groundwater withdrawals in dry years will increase the impact on streamflows.

3.2.2 Little Spokane River

Figure 3.5 shows the change in streamflow on the Little Spokane River at Dartford (differences are displayed as pre-developed conditions minus developed conditions), along with monthly groundwater pumping rates in WRIA 55. Although only pumping in WRIA 55 is plotted in this figure groundwater withdrawals in WRIA 57 are expected to have some effect on streamflows of the lower Little Spokane River in WRIA 55 at the USGS stream gage near Dartford due to the hydraulic continuity between the two basins through the Hillyard Trough. Simulated effects of streamflow changes near Dartford are not shown due to numerical instability causing the results to be of limited validity.

Figure 3.5 displays monthly average streamflow differences for the Little Spokane River at Dartford. Water year 1994 was not included in averages due to model equilibrating. The average annual increase in stream flow under predevelopment conditions is 8.5 cfs. Peak monthly increases of streamflow are on the order of 11 cfs in October while minimum increases are seen in June and July (approximately 7 cfs).

There is a time lag of approximately two months between the period of peak groundwater withdrawals in August, and maximum change in stream flow in October. This suggests that a buffering effect is present either in the form of indirect hydraulic continuity, the disperse nature of groundwater withdrawals in WRIA 55, and/or by the natural groundwater storage buffering.

3.2.3 Groundwater

Figure 3.6 shows the difference in groundwater levels at a single point in time (September 1, 1999) between pre-developed and developed conditions. The distribution of groundwater abstraction wells is shown in Figure 3.1. In general, the largest change in groundwater head is seen in the central segments of the SVRP Aquifer and Hillyard Trough where pre-developed conditions raise aquifer levels by between 1 foot and 3.5 feet, with specific areas near the Little Spokane River and Deadman Creek showing the increase in water levels between 4 and 5.5 feet. Other areas of pronounced groundwater level increases in the pre-development period are in the Deer Creek area of WRIA 55, and north of Liberty Lake in WRIA 57.

Spokane Valley Rathdrum Prairie (SVRP) Aquifer

Groundwater levels near the Idaho-Washington state line show little change in pre- and post-development groundwater levels (Figure 3.7). This is primarily an artifact of the model only considering the effects of pumping in WRIA 57 – influences of groundwater withdrawals in Idaho are not considered in the model.

Groundwater levels throughout the SVRP Aquifer from west of Liberty Lake to downtown Spokane exhibit a progressive impact to groundwater levels of between 1.5 feet to 5 feet during the summertime (Figures 3.8 through 3.10). The relatively small change in groundwater elevations reflects the highly transmissive nature of the SVRP Aquifer. Winter groundwater levels under post-development conditions mostly recover to pre-development conditions as a result of increased seasonal recharge (presumably both naturally from precipitation and higher stream flows, and enhanced recharge from dry wells), and decreased groundwater withdrawals during the winter. The magnitude of response generally increases from east to west, consistent with the increasing volume of groundwater withdrawals in the western part of the aquifer under post-development conditions (Figure 3.1).

Throughout all groundwater level simulations, the natural hydrograph fluctuations are maintained reflecting the seasonal influences of rising water levels in response to recharge during the winter, and dropping water levels in response to regional drainage during the summer. At the temporal scale evaluated, the magnitude of impacts from groundwater withdrawal appears to stabilize and “mining” of groundwater does not appear to be occurring (i.e., continued decline of groundwater levels that would indicate depletion of aquifer storage and an unsustainable degree of aquifer development).

Spokane Valley Rathdrum Prairie Aquifer near Little Spokane River

Whitworth Well #4 is located in the Hillyard Trough (Figure 3.11). It shows seasonal impacts on the order of 3.3 feet during the summer from groundwater withdrawal, and regularly fully recovers during the winter to pre-development conditions. The high transmissivity of the SVRP Aquifer probably contributes to the seasonal recovery of water levels. Inflection points in the pre-development curve during the summer may be related to the presence of the clay lens in this area affecting the pattern of seasonal groundwater level fluctuations.

The Dakota Well shows a moderate impact of groundwater pumping on the scale of 3.5 feet that is sustained year-round (Figure 3.12). The sustained drop in groundwater levels is probably a result of slow recharge to this portion of the aquifer system. However, the level of impact is relatively constant (after an initial two-year period in which the model is converging), and does not display an unsustainable degree of development that may be indicated by a continued drop in aquifer levels. The equilibration of groundwater levels under developed conditions relative to pre-development conditions suggests that induced recharge as a result of decreased groundwater levels is offsetting the effects of groundwater withdrawals.

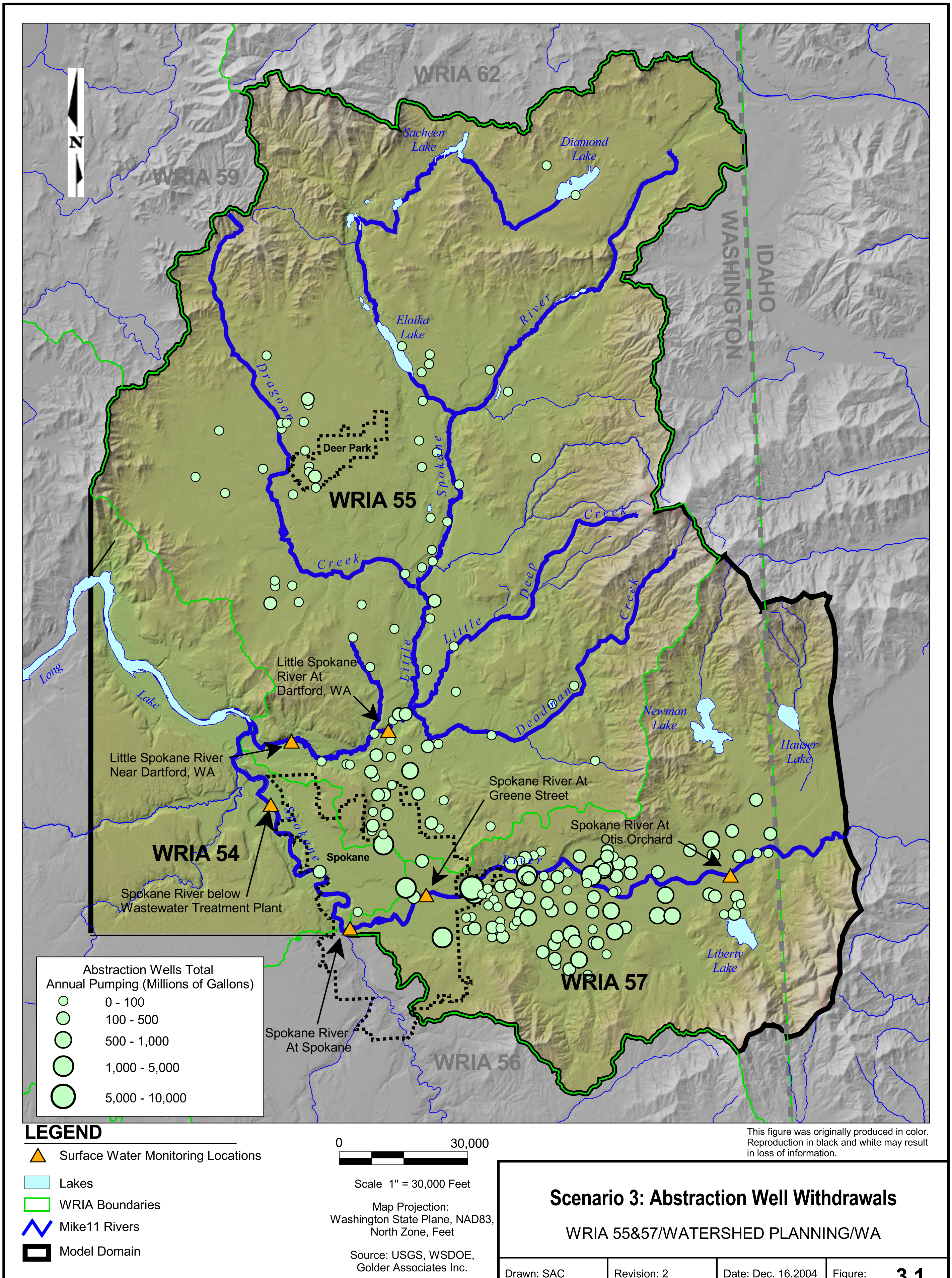
Whitworth Well #8A1 is in an isolated portion of the highly transmissive SVRP Aquifer of the Hillyard Trough and shows a greater seasonal variation of impact to groundwater levels on the order of 10 feet (Figure 3.13). However, groundwater levels recover to near pre-development levels occurs every year, suggesting that this part of the aquifer system has a recharge component that has a response time of less than a year.

Deer Park Aquifer Area

Groundwater levels in the Deer Park aquifer show small changes under predevelopment conditions (Figure 3.14). The impacts of groundwater withdrawal (e.g., typically less than 0.2 ft.) are smaller than the natural seasonal fluctuations (approximately 1 ft.).

Diamond Lake Aquifer

Groundwater levels in the Diamond Lake Aquifer area show a year-round impact from groundwater withdrawals (Figures 3.15). This area is a headwater region, typically most sensitive to groundwater withdrawals. Regardless, the scale of impact is small, on the order of 0.5 feet, and is relatively constant over the simulation period which does not indicate an unsustainable degree of groundwater development, as would be indicated by increasing impacts over time.



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Scenario 3: Abstraction Well Withdrawals

WRIA 55&57/WATERSHED PLANNING/WA

Drawn: SAC	Revision: 2	Date: Dec. 16,2004	Figure: 3.1

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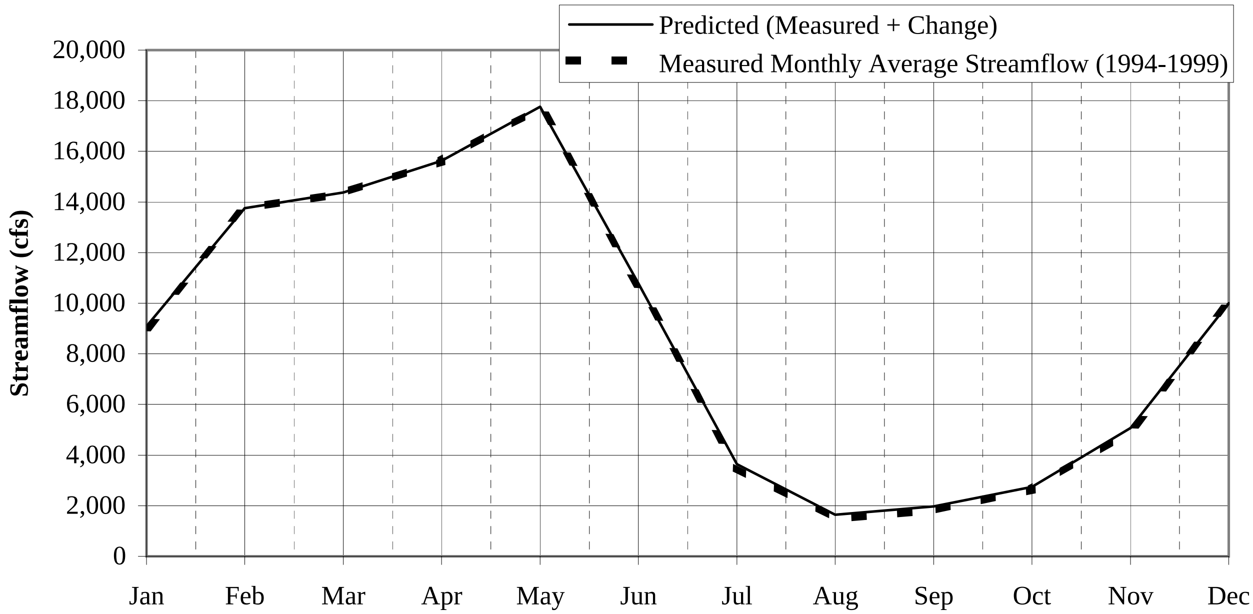
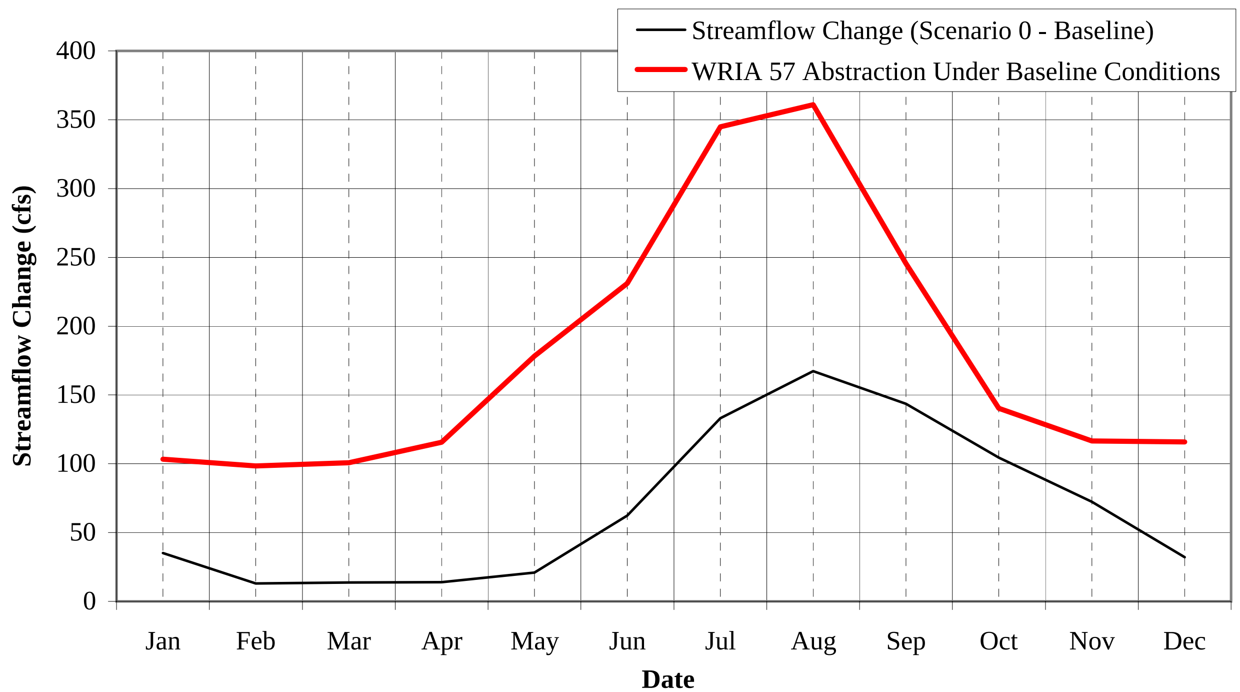
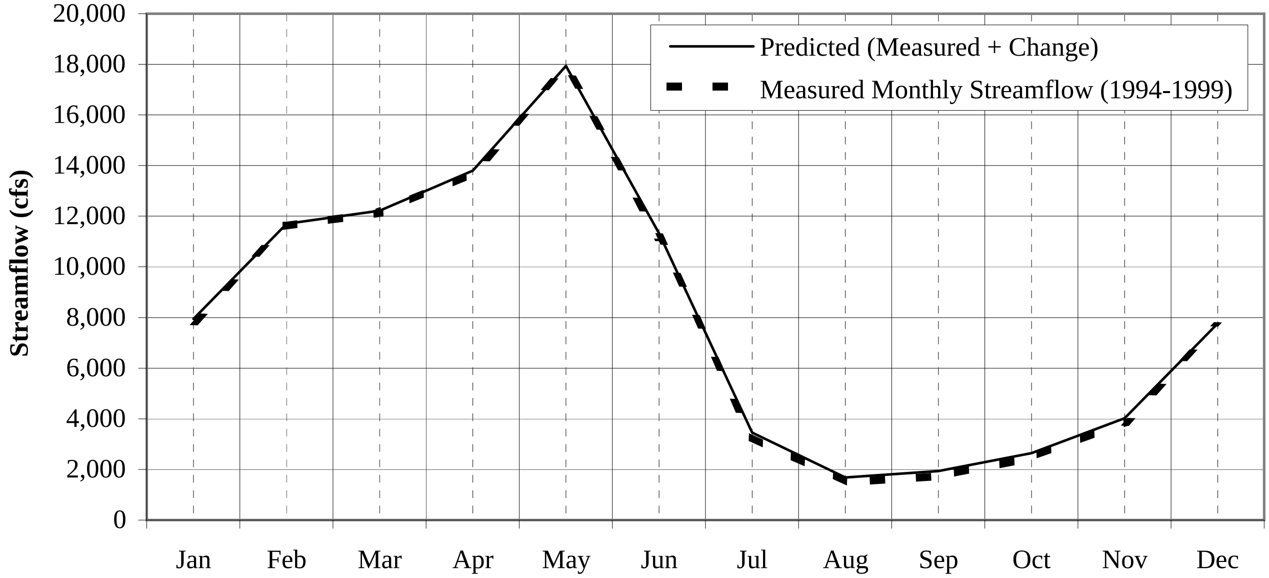
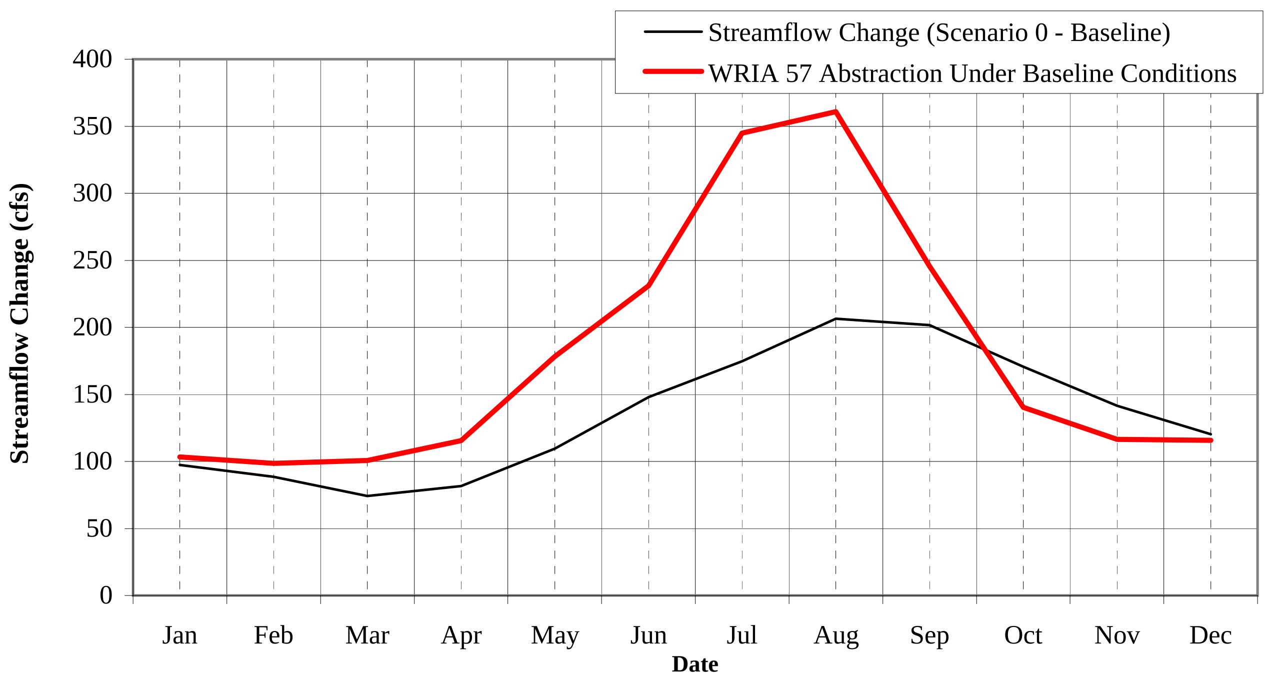
Golder Associates





Golder Associates	TITLE **Scenario 0: Spokane River below Greene St. Change in Monthly Streamflow**		
WRIA 55 & 57/ WATERSHED PLANNING/ WA	DRAWN JM	DATE December	JOB NO. 013-1372
	CHECKED	SCALE	DWG. NO.
	REVIEWED	FILE NO. Run # 061004	FIGURE NO. 3.2





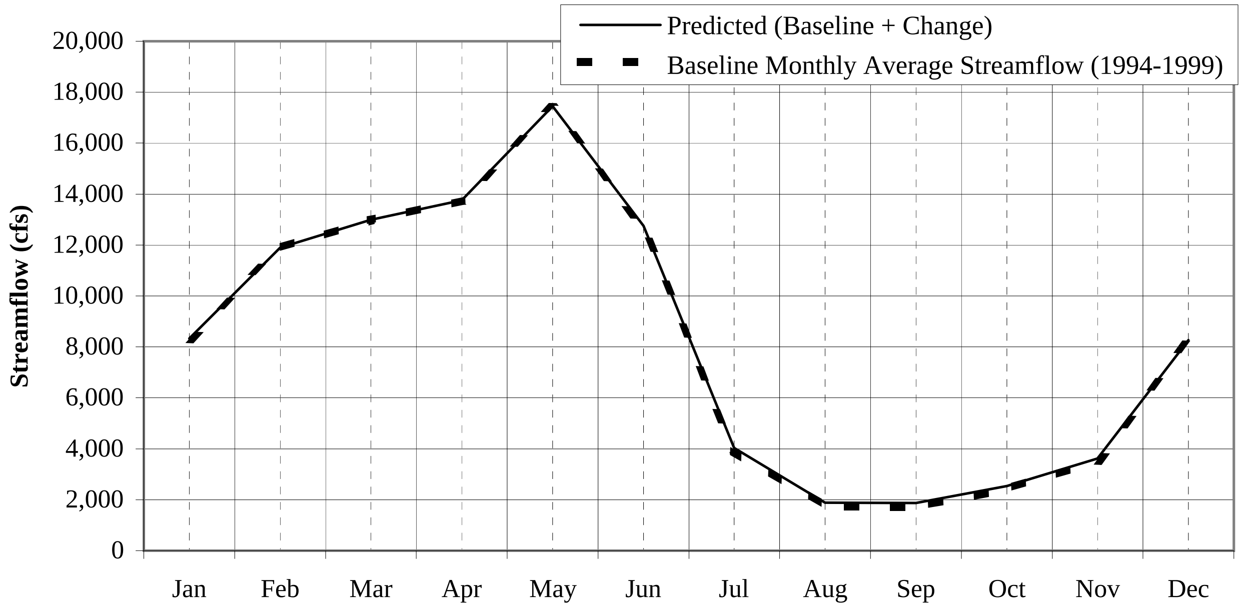
Golder Associates

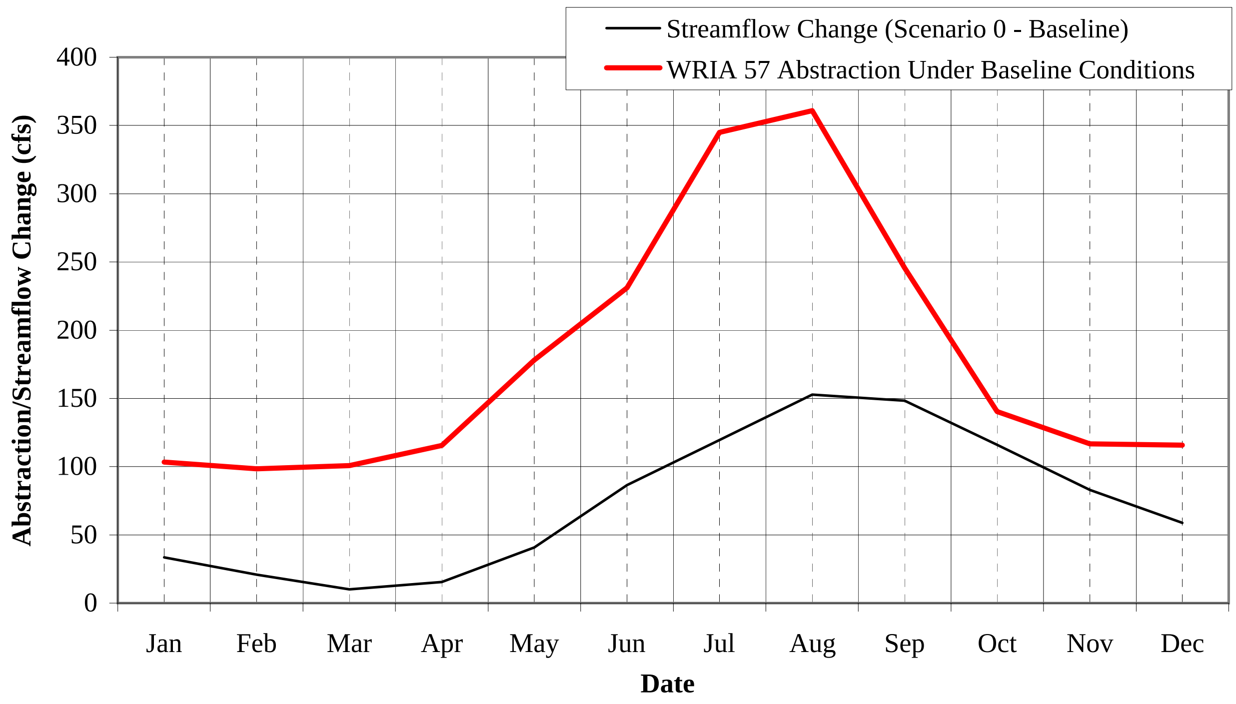
TITLE

Scenario 0: Spokane River at Spokane
Change in Monthly Streamflow

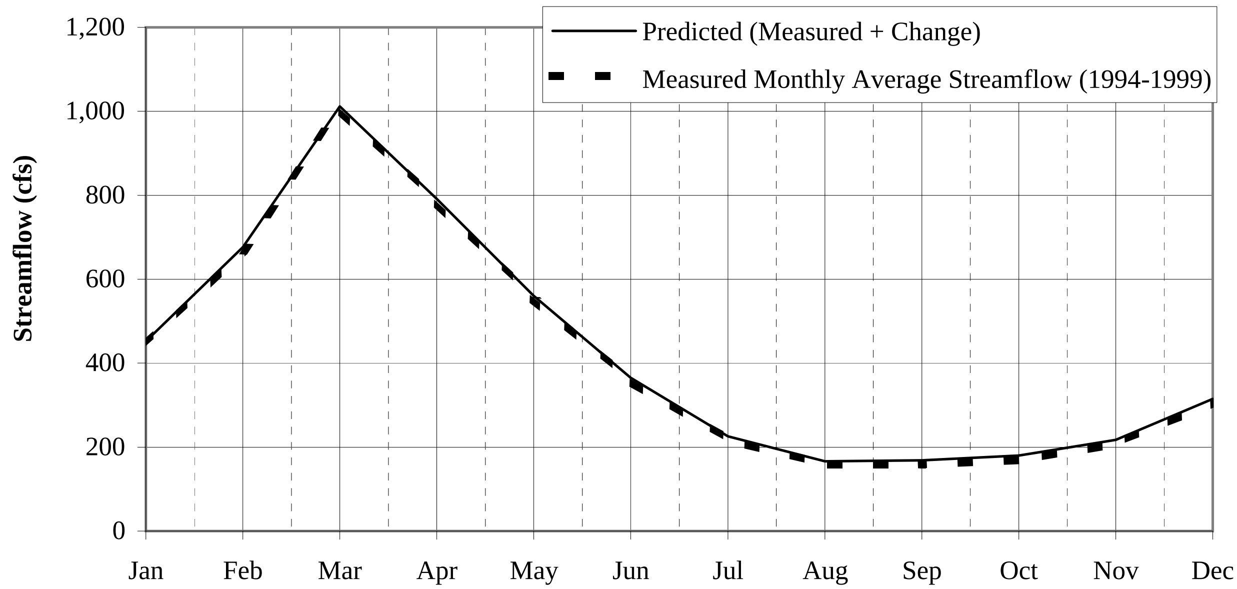
WRIA 55 & 57/ WATERSHED PLANNING/ WA

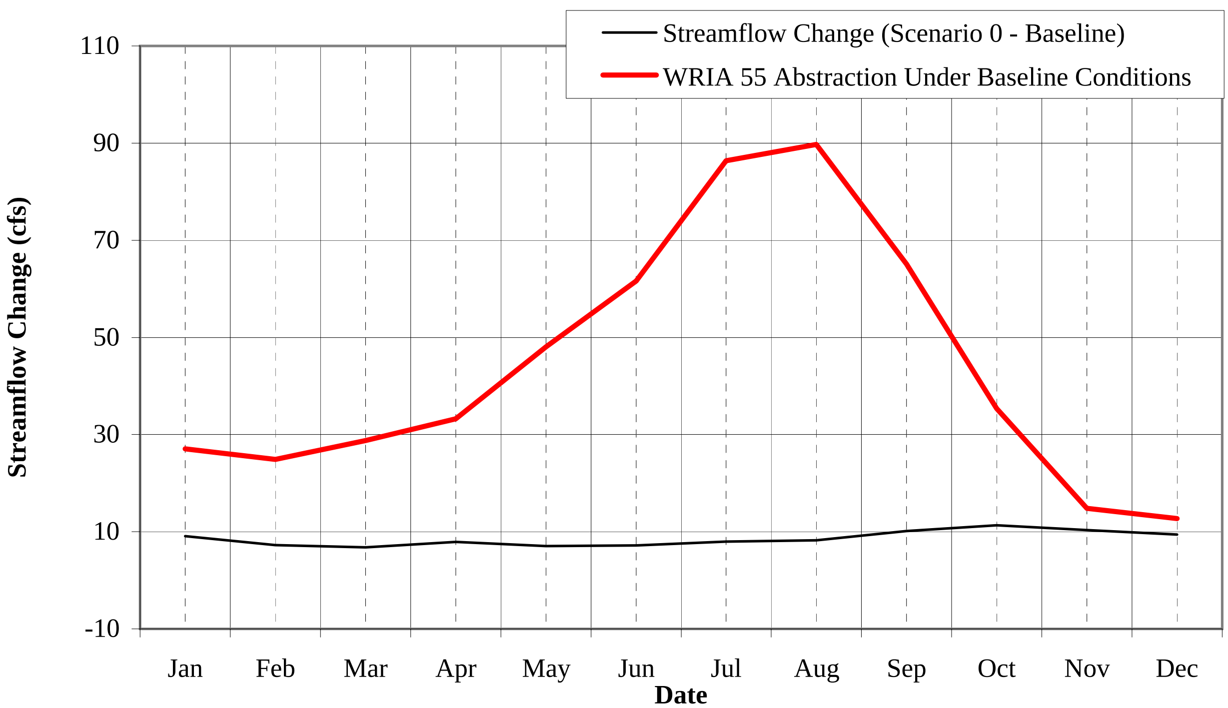
DRAWN	JM	DATE	December 2004	JOB NO.	013-1372
CHECKED		SCALE		DWG. NO.	
REVIEWED		FILE NO.	Run #061004	FIGURE NO.	3.3





Golder Associates	TITLE **Scenario 0: Spokane River downstream of Wastewater Treatment Plant Change in Monthly Streamflow**		
WRIA 55 & 57/ WATERSHED PLANNING/ WA	DRAWN JM	DATE December 2004	JOB NO. 013-1372
	CHECKED	SCALE	DWG. NO.
	REVIEWED	FILE NO. Run # 061004	FIGURE NO. 3.4





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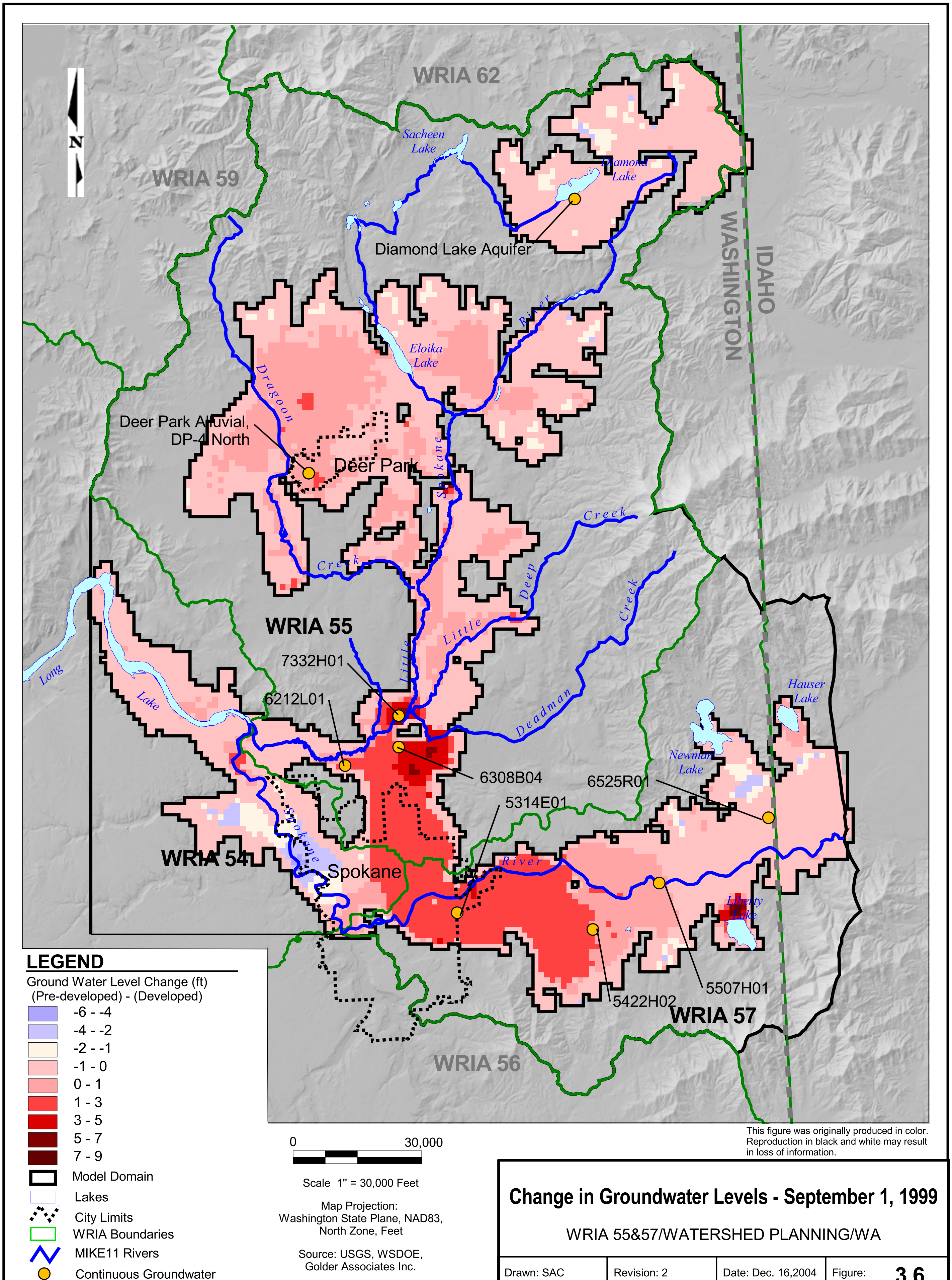
TITLE

Scenario 0: Little Spokane River at Dartford
Change in Monthly Streamflow

WRIA 55 & 57/ WATERSHED PLANNING/ WA

DRAWN	JM	DATE	December 2004	JOB NO.	013-1372
CHECKED		SCALE		DWG. NO.	
REVIEWED		FILE NO.	Run # 061004	FIGURE NO.	3.5



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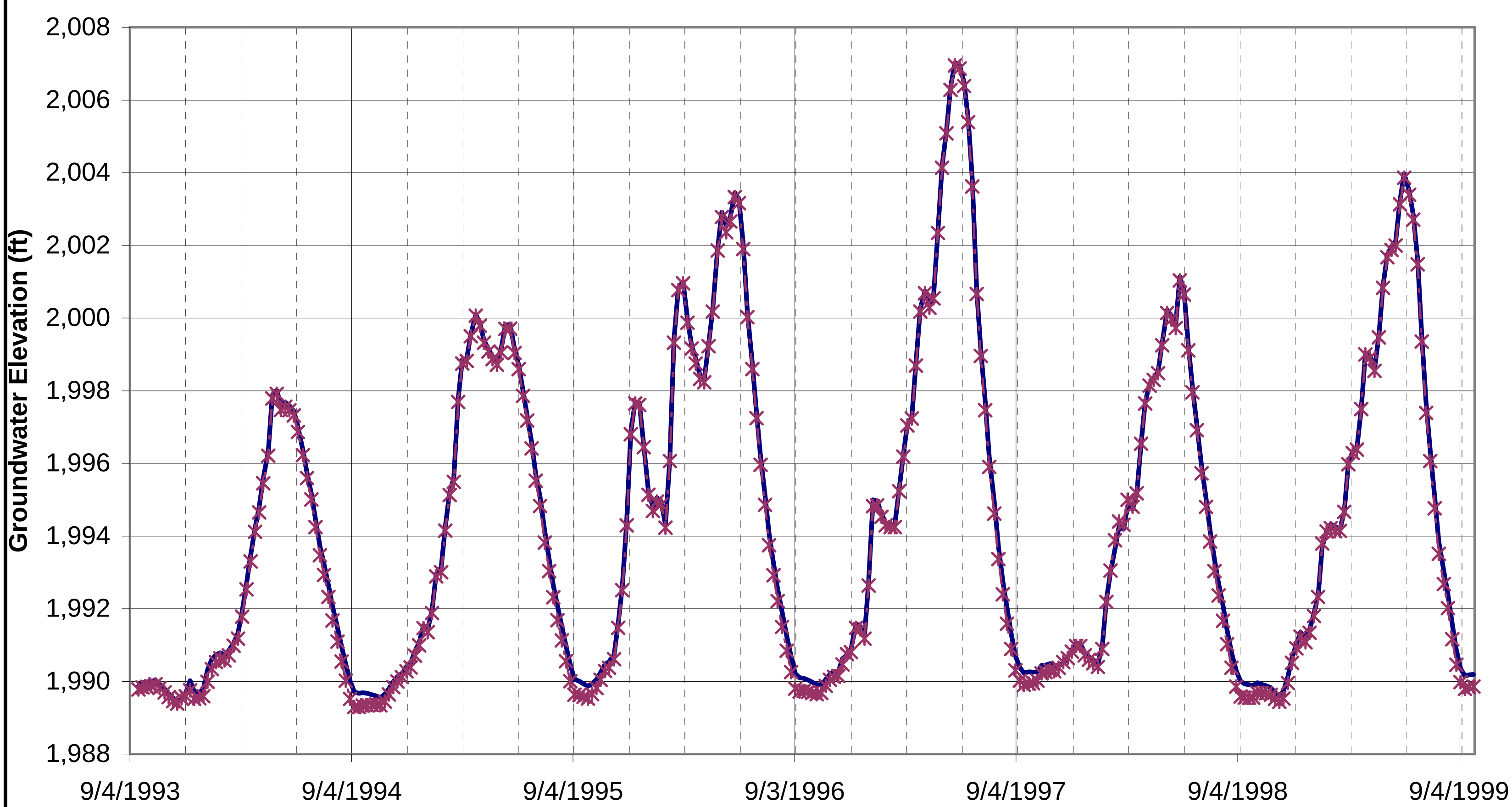
Golder Associates



Legend

Scenario 0, Predevelopment

Baseline

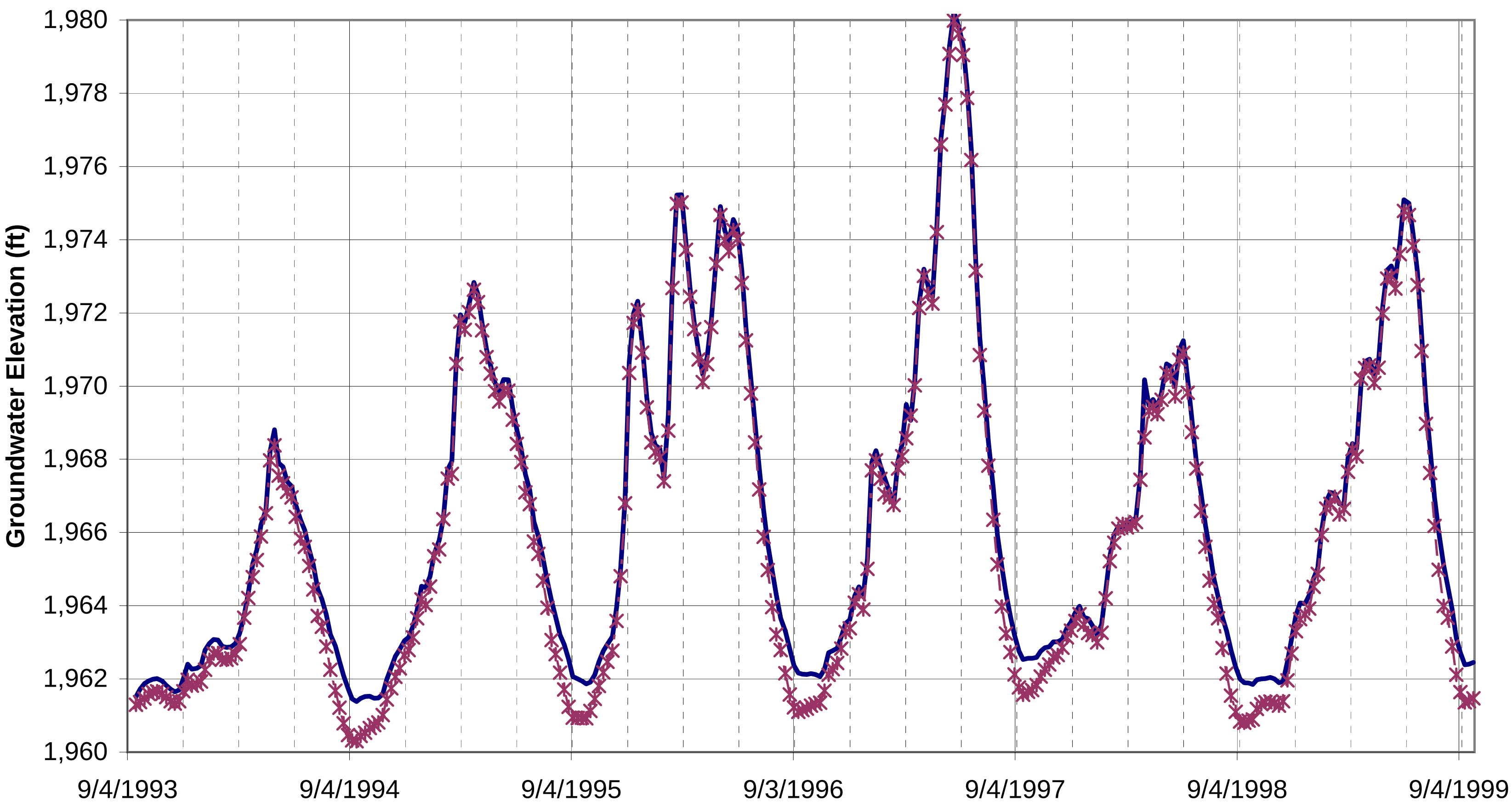
FIGURE 3.7: Scenario 0: Idaho Rd near Pipeline (6525R01) Change in Groundwater Elevation

Spokane County
Watershed Assessment

Run # 061006

Golder Associates

Fig 3.7-15 Scenario 0 Baseline Groundwater.xls,Fig 3.7



Legend

Scenario 0, Predevelopment

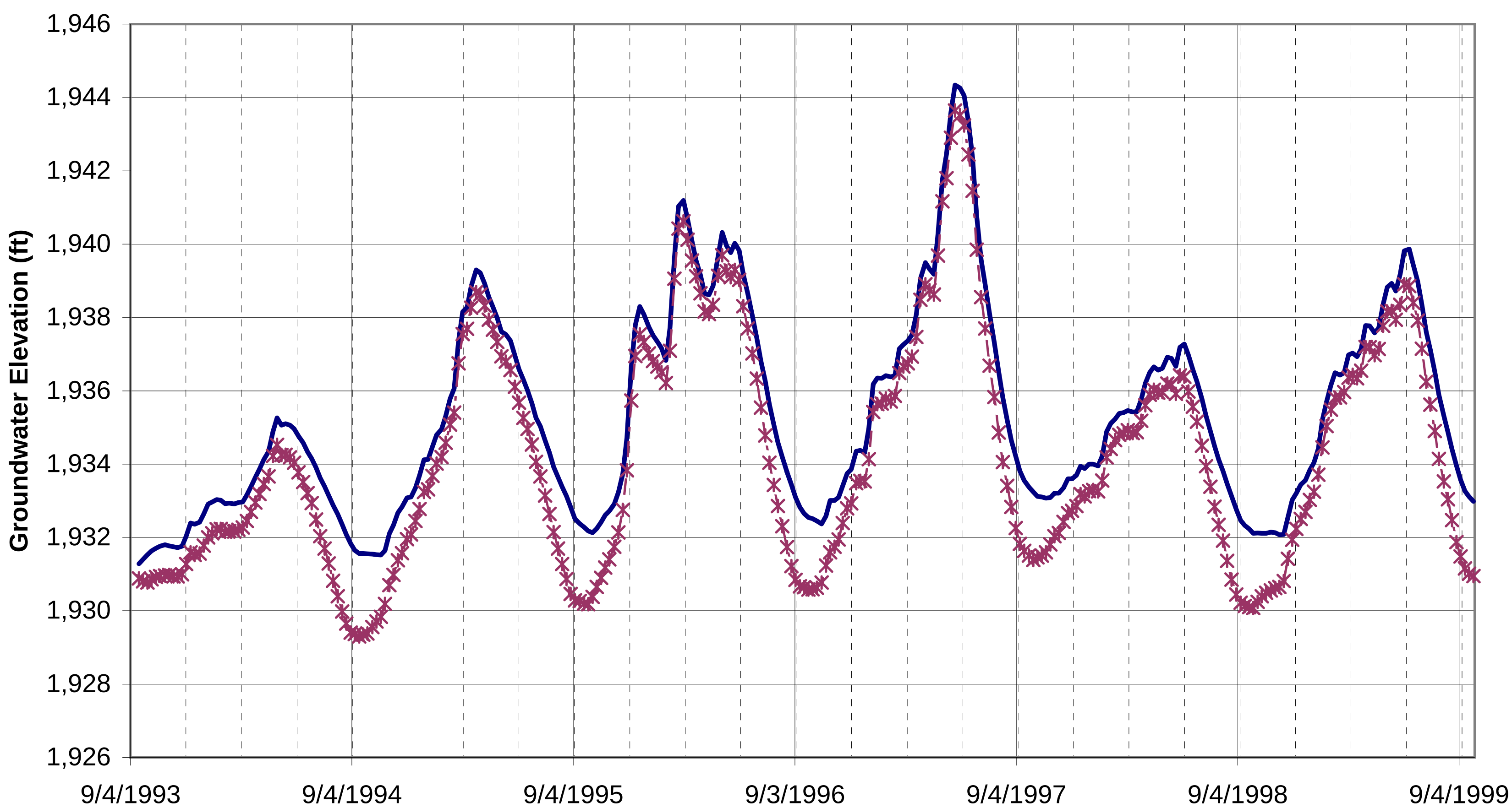
Baseline

FIGURE 3.8: Scenario 0, Barker-North (5507H01) Change in Groundwater Elevation

Spokane County
Watershed Assessment

Golder Associates

Run # 061004



Legend

Scenario 0, Predevelopment

Baseline

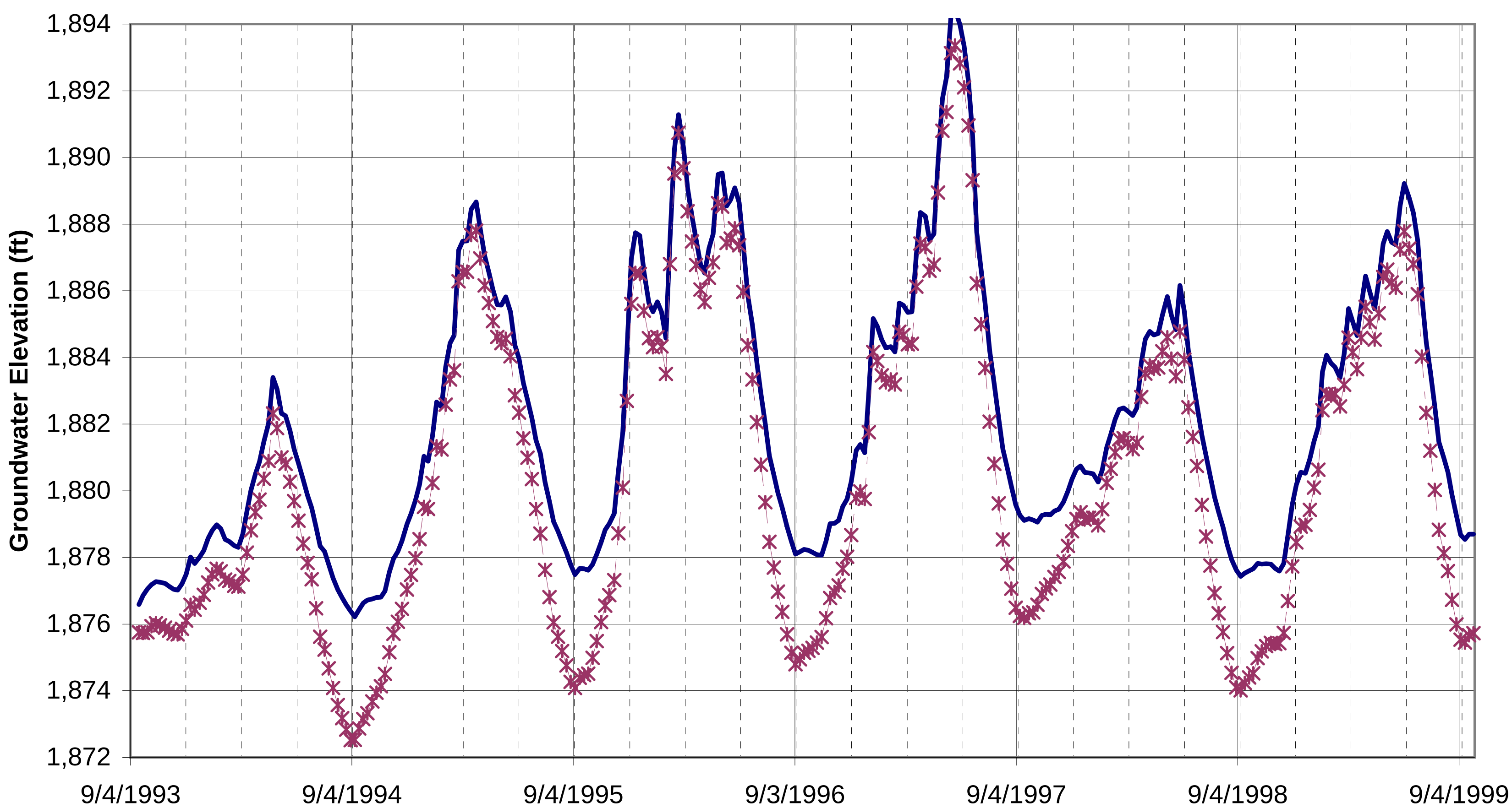
FIGURE 3.9: Scenario 0, Vera #6 (5422H02)
Change in Groundwater Elevation

Spokane County
Watershed Assessment

Golder Associates

Run # 061004

Fig 3.7-15 Scenario 0 Baseline Groundwater.xls,Fig 3.9



Legend

Scenario 0, Predevelopment

Baseline

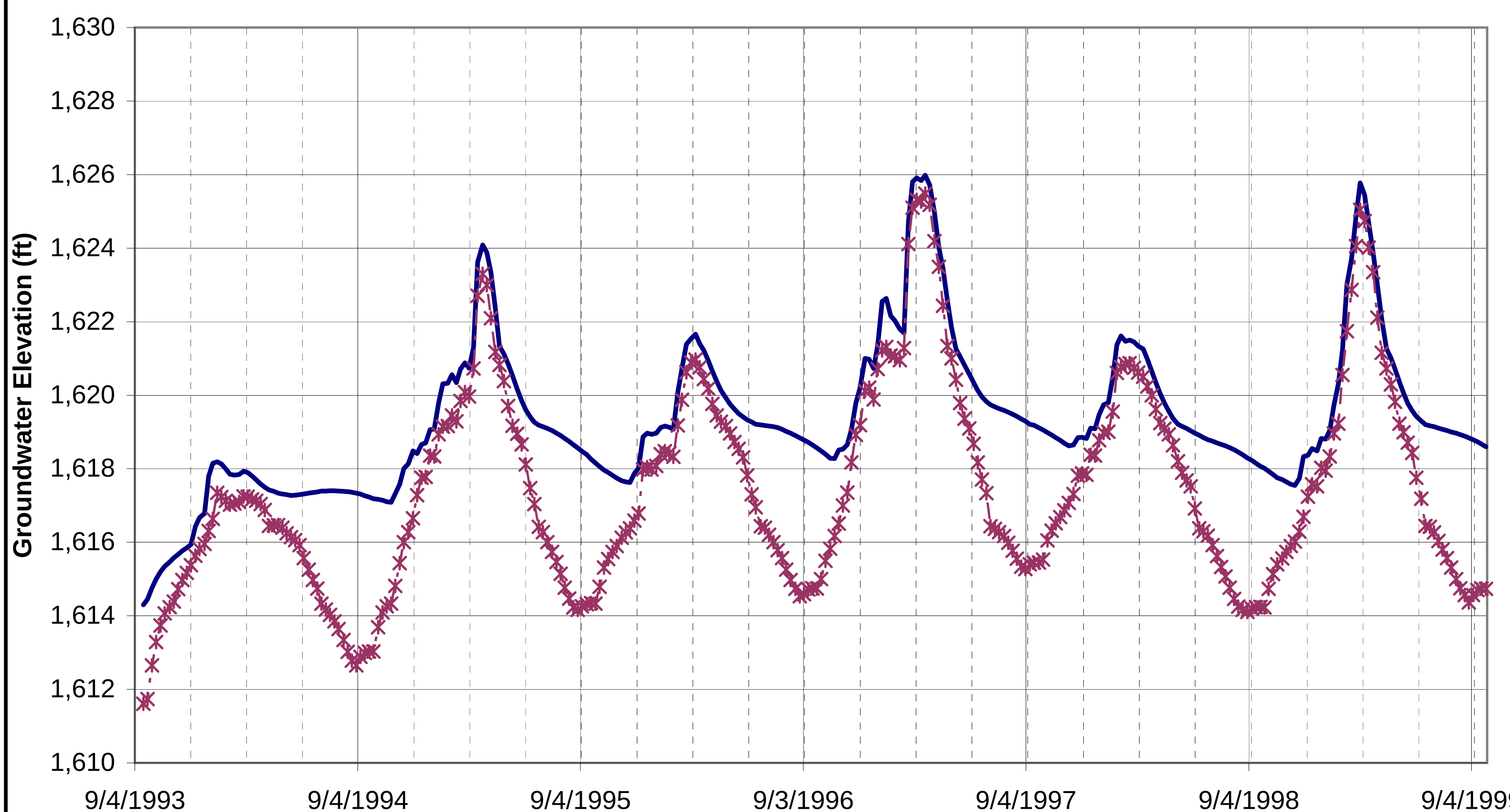
FIGURE 3.10: Scenario 0, City Central PreMix (5314E01) Change in Groundwater Elevation

Spokane County
Watershed Assessment

Golder Associates

Run # 061004

Fig 3.7-15 Scenario 0 Baseline Groundwater.xls,Fig 3.10



Legend

Scenario 0, Predevelopment

Baseline

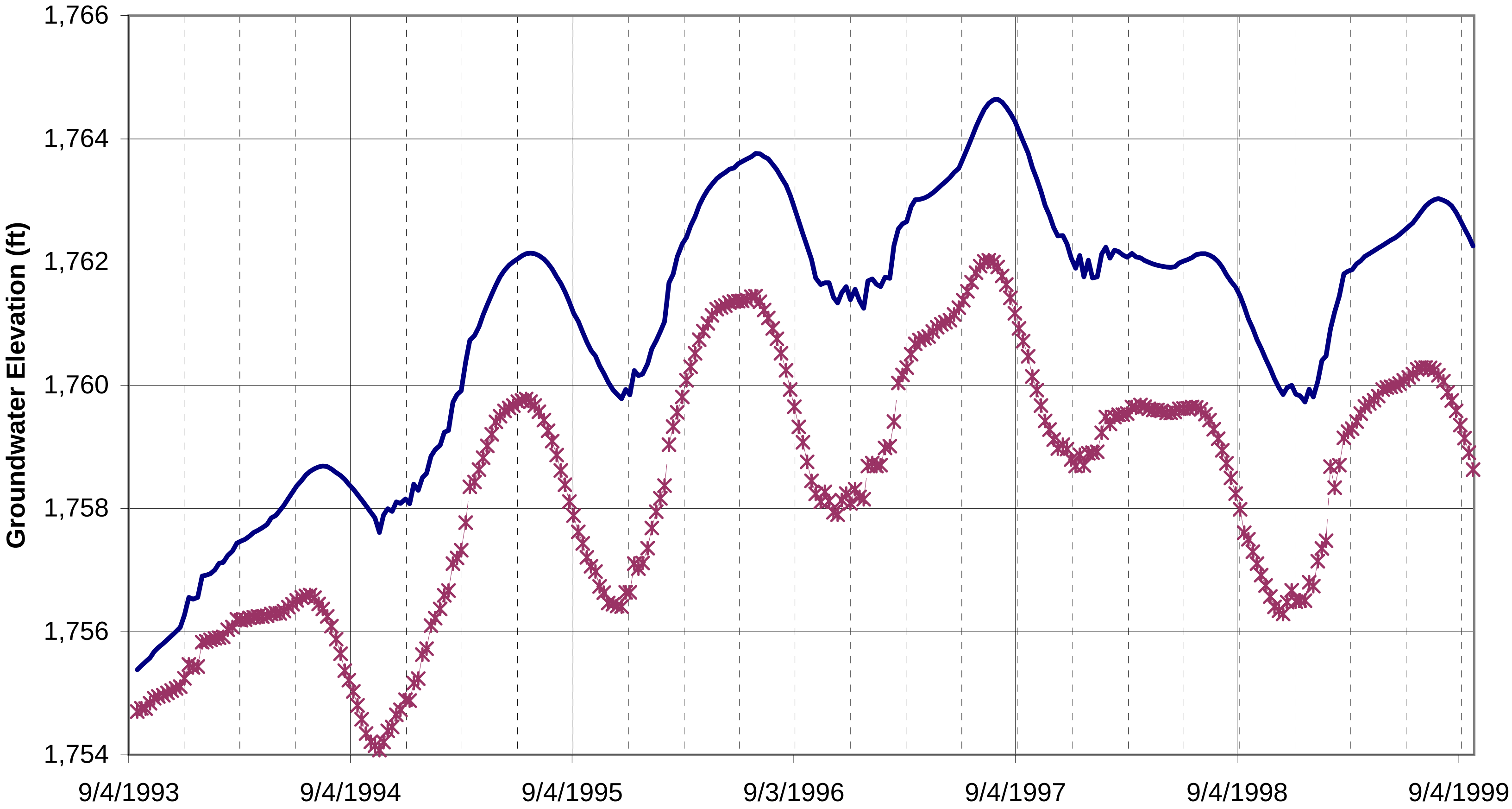
FIGURE 3.11: Scenario 0, Whitworth #4 (6212L01) Change in Groundwater Elevation

Spokane County
Watershed Assessment

Golder Associates

Run # 061004

Fig 3.7-15 Scenario 0 Baseline Groundwater.xls,Fig 3.11



Legend

Scenario 0, Predevelopment

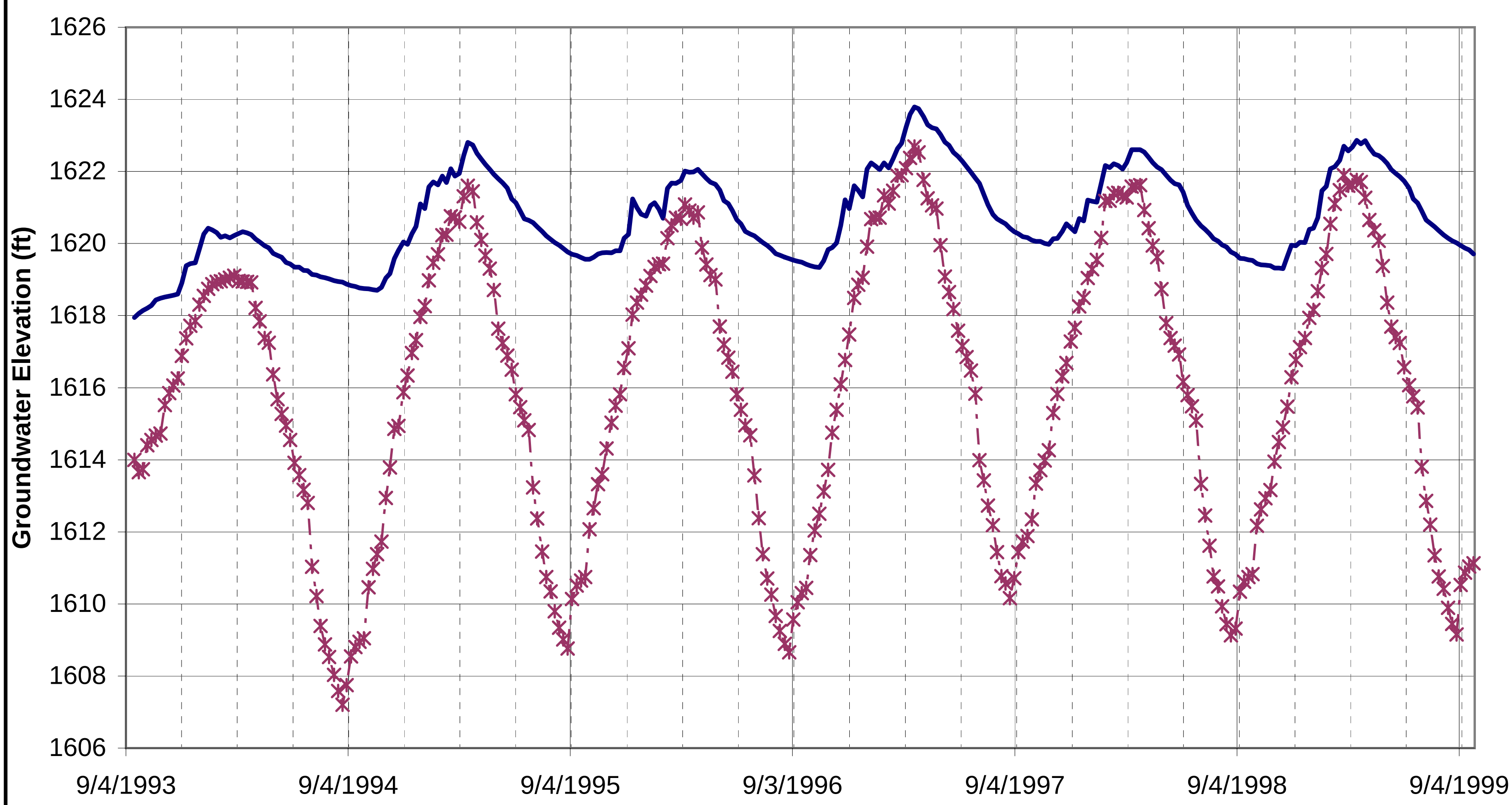
Baseline

FIGURE 3.12: Scenario 0, Dakota (6308B04)
Change in Groundwater Elevation

Spokane County
Watershed Assessment

Run # 061004

Fig 3.7-15 Scenario 0 Baseline Groundwater.xls,Fig 3.12



Legend

Scenario 0, Predevelopment

Baseline

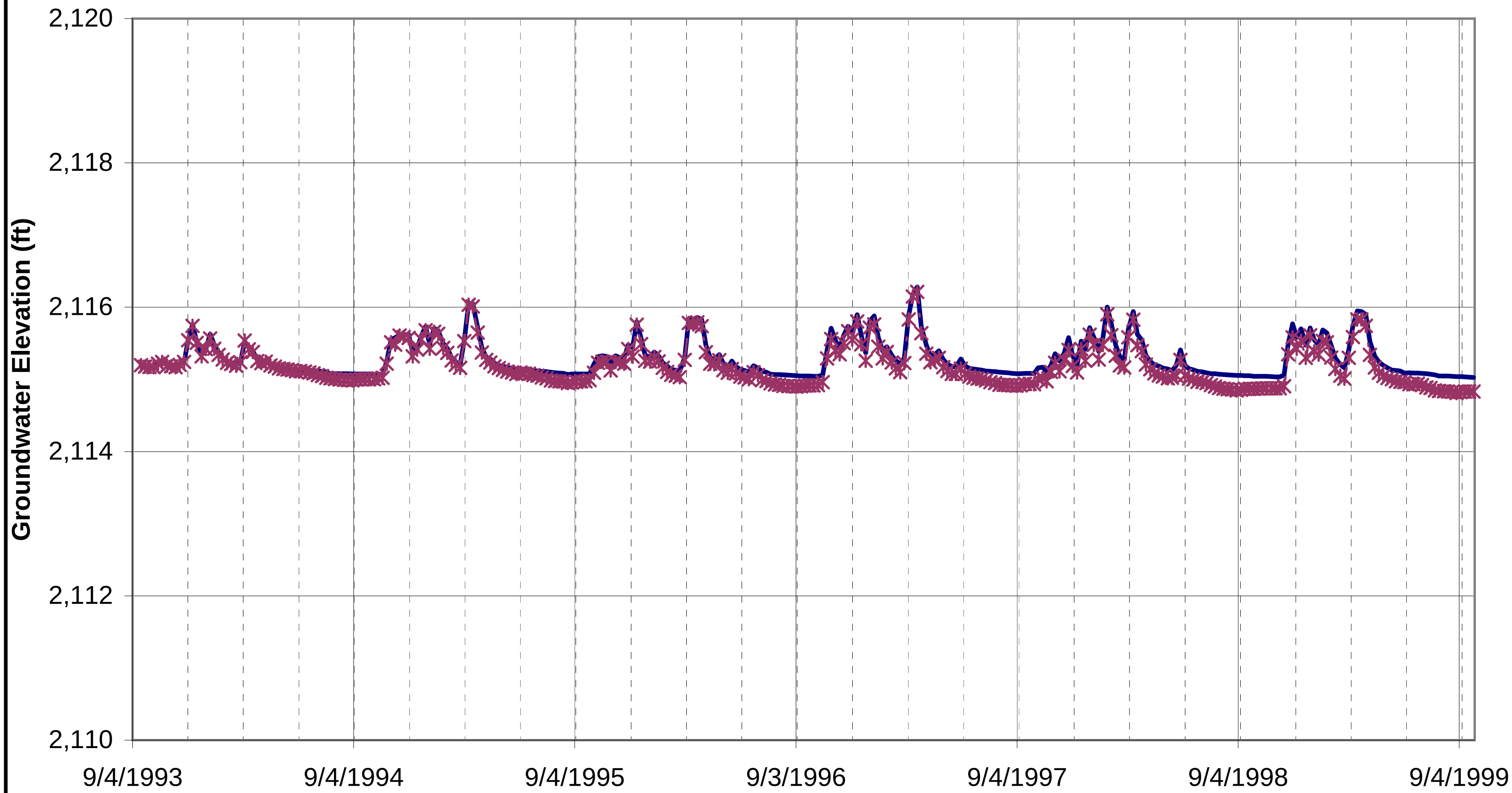
FIGURE 3.13: Scenario 0, Whitworth #8A1 (7332H01) Change in Groundwater Elevation

Spokane County
Watershed Assessment

Golder Associates

Run # 061004

Fig 3.7-15 Scenario 0 Baseline Groundwater.xls,Fig. 3.13



Legend

Scenario 0, Predevelopment

Baseline

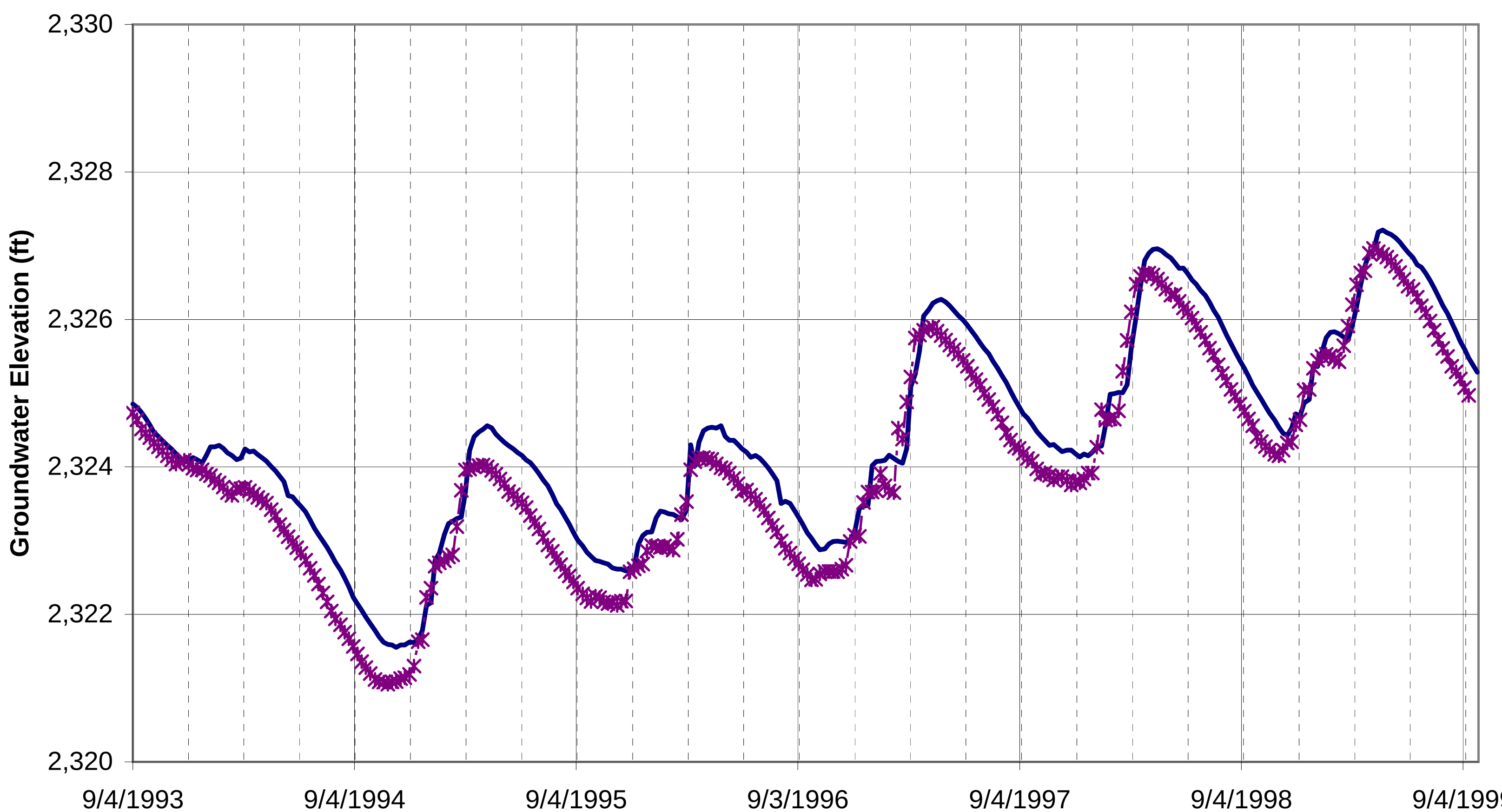
FIGURE 3.14: Scenario 0, Deer Park, DP-4
Change in Groundwater Elevation

Spokane County
Watershed Assessment

Golder Associates

Run # 061004

Fig 3.7-15 Scenario 0 Baseline Groundwater.xls,Fig 3.14



Legend

Scenario 0, Predevelopment

Baseline

FIGURE 3.15: Scenario 0, Diamond Lake Aquifer Change in Groundwater Elevation

Spokane County
Watershed Assessment

Golder Associates

Run # 061004

Fig 3.7-15 Scenario 0 Baseline Groundwater.xls,Fig 3.15

4.0 SCENARIO 1: 20-YEAR GROWTH

The 20-year Growth Scenario simulates the projected changes in municipal and domestic water use, wastewater discharge and lawn irrigation for the year 2020. The purpose of this scenario is to develop an understanding of how the projected distribution and volume of increased groundwater withdrawals may affect the watershed streamflow and groundwater levels.

4.1 Model Setup

Changes to the model setup to simulate 20-year growth conditions include increased groundwater pumping from defined wells, increased spatial distribution of irrigated lawns, and increased wastewater discharge.

Projected growth rates used to simulated increased groundwater abstraction were reported in the Phase 2 – Level 1 Technical Assessment for WRIA 55 & 57 (Golder, 2003), and are presented in Figure 4.1. The effect of these percentage increases on monthly abstraction rates, combined for each WRIA, is shown in Figure 4.2 along with Baseline pumping conditions for comparison. Figure 4.3 displays the spatial distribution of projected 20-Year Growth pumping. This scenario assumes there is no change in water use designated primarily for agriculture, commercial and industrial, or exempt well use.

Changes to wastewater discharge and lawn irrigation model set-up were also implemented. Wastewater dischargers currently modeled in the system include the cities of Deer Park, Liberty Lake, Spokane and Diamond Lake. Discharge from each of these entities was increased by the respective percentage of growth (shown in Figure 4.1) or by the average WRIA increase projected if increases for specific waste water districts were not available. Increased lawn irrigation was provided by Spokane County (Figure 4-4). The rate of water applied to lawns was not changed and all additional lawn areas are served by purveyor wells.

4.2 Results

Summer flows during peak groundwater pumping in August are predicted to decrease as much as 50 cfs on the Spokane River at Spokane, and 13 cfs on the Little Spokane River at Dartford. Results are presented in Figures 4.5 through 4.17, and discussed below.

4.2.1 <u>Surface Water</u>

<u>Change in Spokane River Flows</u>

The increase in groundwater abstraction for Scenario 1 in WRIA 57 equates to an increase of approximately 20 cfs (13 mgd) during minimum winter pumping period, and approximately 85 cfs (56 mgd) during peak summer pumping. There is no significant lag time between when peak pumping occurs (Figure 4.2) and when the greatest decrease in flows occurs (Figure 4.5 through 4.7).

Under 20-year growth conditions the model predicts that streamflow of the Spokane River may decrease by the following amounts:

Monthly Average Streamflow Reduction

	February ***WRIA 57 Change in Abstraction ~ 20 cfs***	**August** ***WRIA 57 Change in Abstraction ~ 85 cfs***
Greene Street	18 cfs	47 cfs
At Spokane	20 cfs	54 cfs
Near City of Spokane WWTP	6 cfs	42 cfs

The difference in discharge between Greene Street and the Spokane River at Spokane is primarily due to increases in pumping immediately upstream of the gage at Spokane which increase the magnitude of river discharge to groundwater in this loosing reach. The difference in discharge between Spokane River at Spokane and downstream of the City of Spokane WWTP reflects the influence of return flow from the treatment plant.

Change in Little Spokane River Flows

The Little Spokane River streamflow at Dartford displays a peak change in streamflow of approximately 18 cfs between November through January and a minimum change in streamflow of approximately 13 cfs in the July to September time frame (Figure 4.8).

The average increase in pumping in WRIA 55 equates to between 1.6 cfs (1 mgd) in the winter months and 15 cfs (10.4 mgd) in the summer months. Therefore the change in streamflow at Dartford lags that of maximum pumping increases by 3 to 5 months and is also larger than the change in pumping. The reason for a larger streamflow response than change to abstraction in WRIA 55 is not understood; further investigation of model results and inputs in this area may uncover the cause. Though the change in flow at the near Dartford streamflow gage are not quantified it's expected that pumping in WRIA 57 would decrease groundwater flow through the Hillyard Trough and therefore groundwater discharge into the Little Spokane River upstream of the near Dartford gage.

4.2.2 Groundwater

Groundwater elevations throughout the model domain are shown as an average change in groundwater elevation between June and September, 1999 (Figure 4.9). The year 1999 is considered an average hydrologic year. In general groundwater elevations show a decrease throughout the model domain of between 0.25 and 1.0 ft (Figure 4.9). The largest widespread change in groundwater elevation is seen in the Hillyard Trough in WRIA 55 with groundwater elevation decreasing by up to 1.0 ft. Similar drops in water levels in the northern portions of WRIA 55 are likely a result of the sensitivity of headwater areas to groundwater withdrawals.

Water level results for five groundwater locations in WRIA 55 & 57 are compared to the groundwater elevations produced during present hydrologic, baseline, conditions (Figures 4.10 through 4.14).

Two locations in the SVRP Aquifer, Vera #6 and City–Central PreMix, show similar seasonal and pumping water level responses relative to baseline groundwater levels. The 20-year growth levels show slightly lower groundwater levels of between 0.5 ft and 1 ft during the peak summer withdrawal period. Winter groundwater levels appear to be unaffected by the higher pumping rates.

The Dakota Well, which is near the at Dartford gage, and the Deer Park area show a general decrease of groundwater elevations throughout the year of approximately 0.25 ft to 0.5 ft (Figures 4.12 and 4.13).

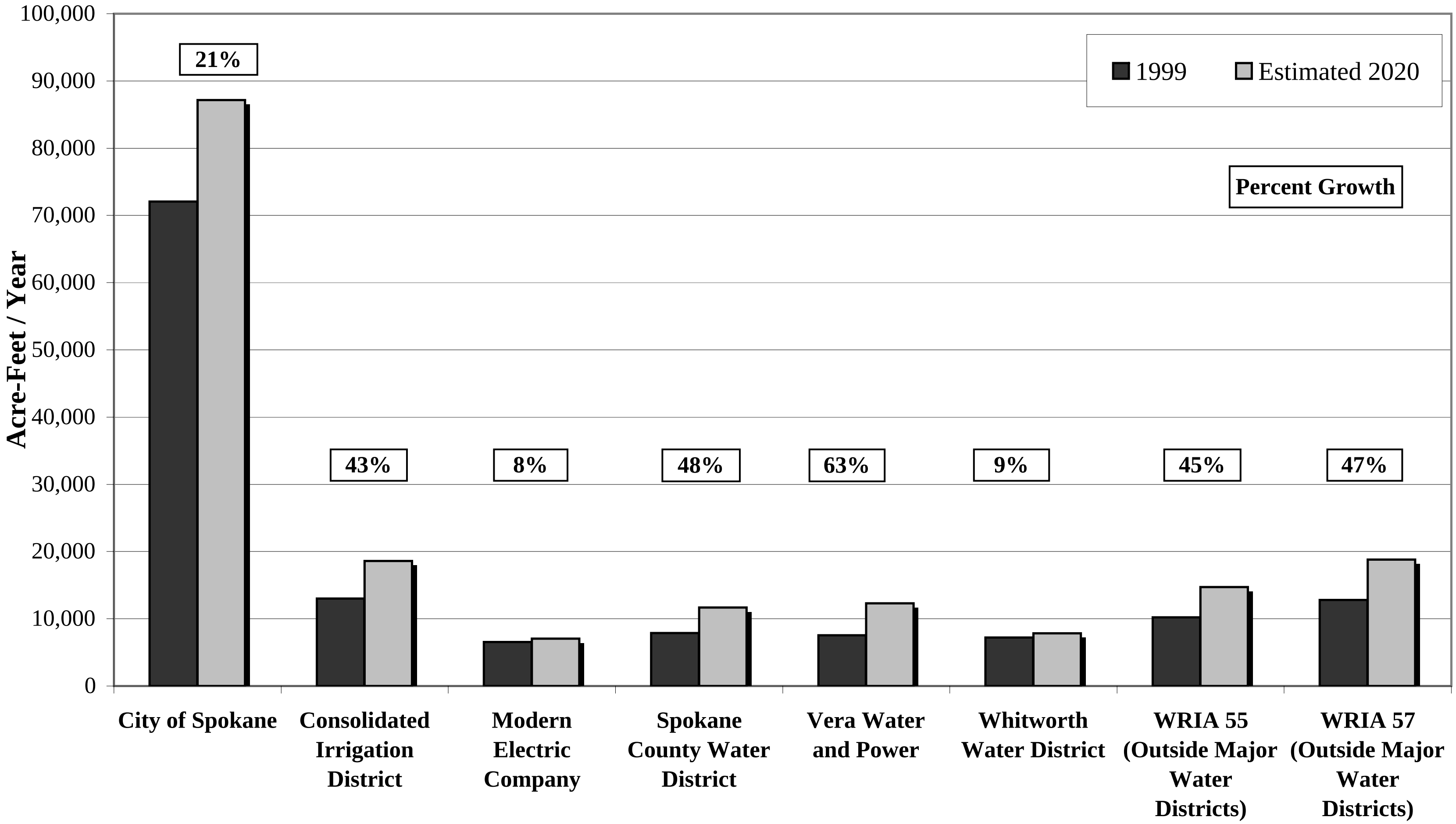
The Diamond Lake Aquifer has a minimal impact from increased groundwater withdrawals on groundwater levels of around 0.2 ft (Figure 4.14).

4.2.3 Groundwater – Surface Water Interactions

The predicted impacts on groundwater surface water interactions are presented in Figure 4.15 (Spokane River) and 4.16 (Little Spokane River). These figures illustrate the impacts to baseflow during the peak pumping period (August). The increased pumping primarily predicts a reduction of groundwater discharge to gaining reaches in both the Little Spokane River and Spokane River.

Results show that the largest decrease in groundwater discharge to the Spokane River under 20-year growth conditions occur in the gaining reaches around Sullivan Road and just upstream of Greene Street (Figure 4.15). A slight increase in river recharge to the aquifer occurs in the losing reach downstream of Greene Street to Trent Road Bridge.

The largest decreases in groundwater discharge to the Little Spokane River under 20-year growth conditions occur in the gaining reach between Dragoon and Deadman Creeks as well as the reach downstream of Dartford Creek which includes inflow from the SVRP Aquifer through the Hillyard Trough.



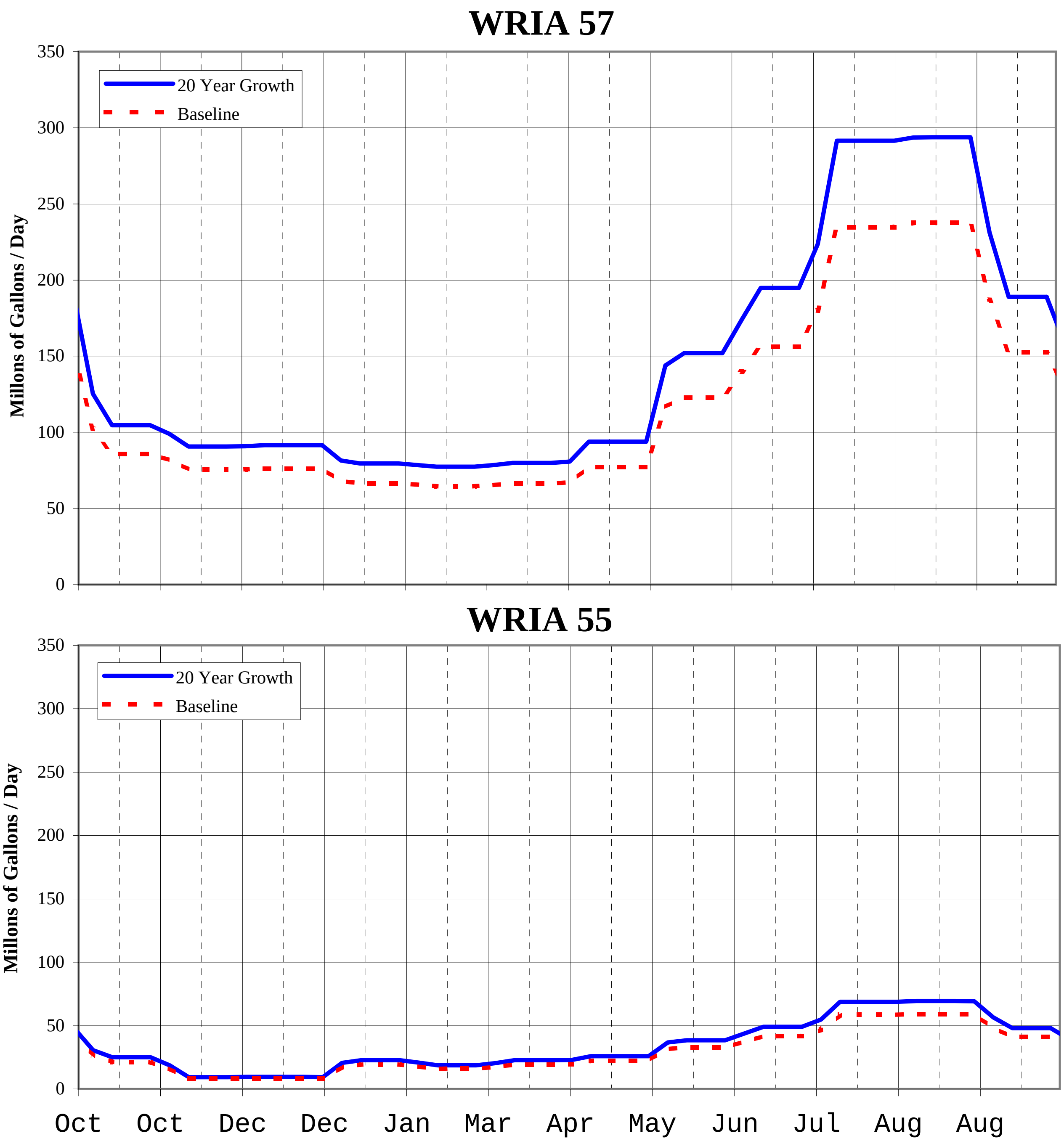
Golder Associates

TITLE

Projected Demand Increase for Scenario 1

WRIA 55 & 57/ WATERSHED PLANNING/ WA

DRAWN	JM	DATE	December 2004	JOB NO.	013-1372
CHECKED		SCALE		DWG. NO.	
REVIEWED		FILE NO.	Run # 043004	FIGURE NO.	4.1



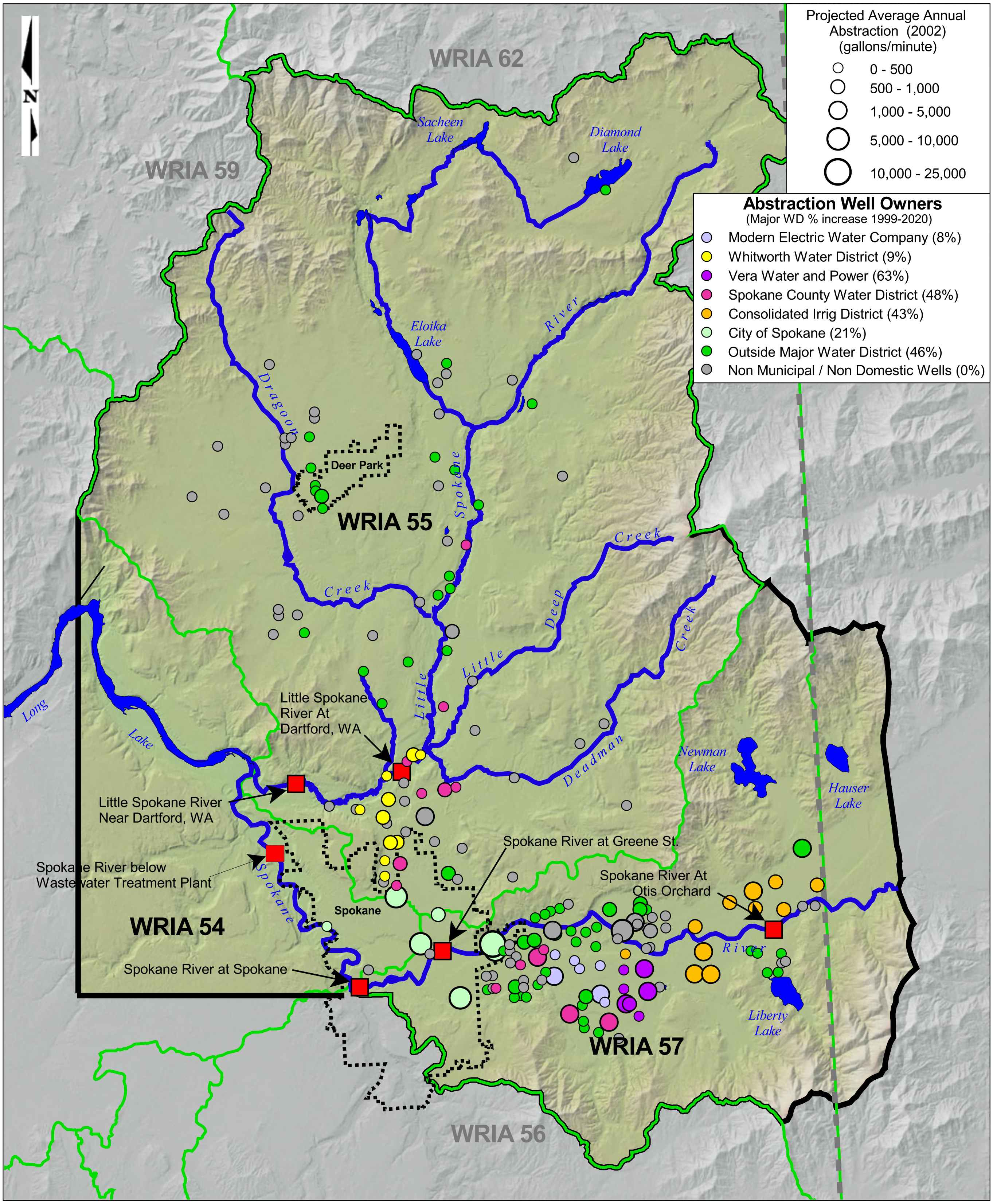
Golder Associates

TITLE

Comparison of Monthly Groundwater Pumping for Baseline and Scenario 1

WRIA 55 & 57/ WATERSHED PLANNING/ WA

DRAWN	JM	DATE	December 2004	JOB NO.	013-1372
CHECKED		SCALE		DWG. NO.	
REVIEWED		FILE NO.	Run # 043004	FIGURE NO.	4.2



LEGEND

- Surface Water Monitoring Locations
- Lakes
- WRIA Boundaries
- Mike11 Rivers
- Model Domain

0 30,000

Scale 1" = 30,000 Feet

Map Projection:
Washington State Plane, NAD83,
North Zone, Feet

Source: USGS, WSDOE,
Golder Associates Inc.

This figure was originally produced in color. Reproduction in black and white may result in loss of information.

Scenario 1: Projected Abstraction Well Withdrawals

WRIA 55&57/WATERSHED PLANNING/WA

Drawn:GKL	Revision: RMT	Date: Mar. 8, 2005	Figure: 4.3

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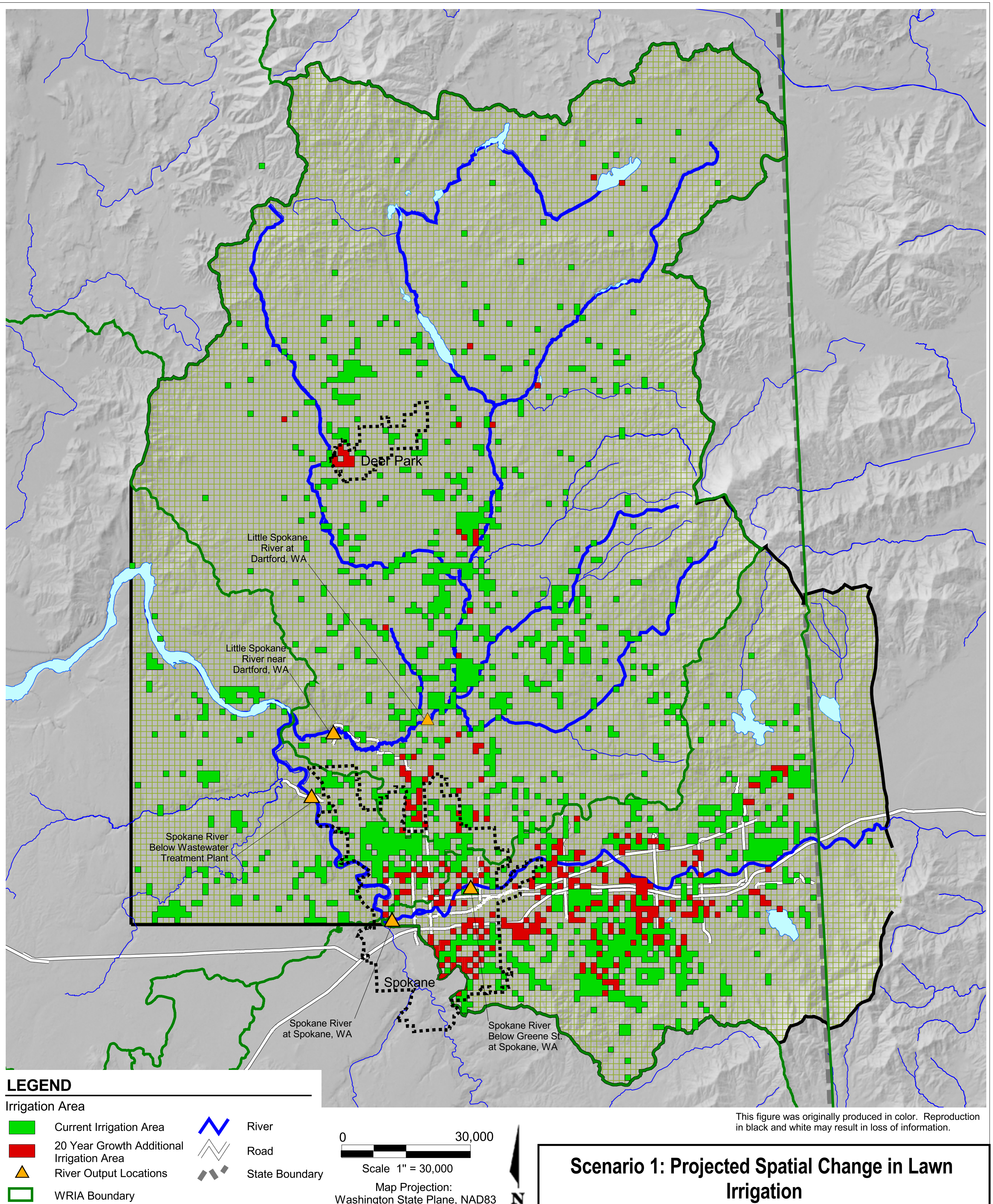
Golder Associates



Map Projection:
Washington State Plane, NAD83
North Zone, Feet

Source: USGS, WSDOE,
Golder Associates Inc.

This figure was originally produced in color. Reproduction in black and white may result in loss of information.

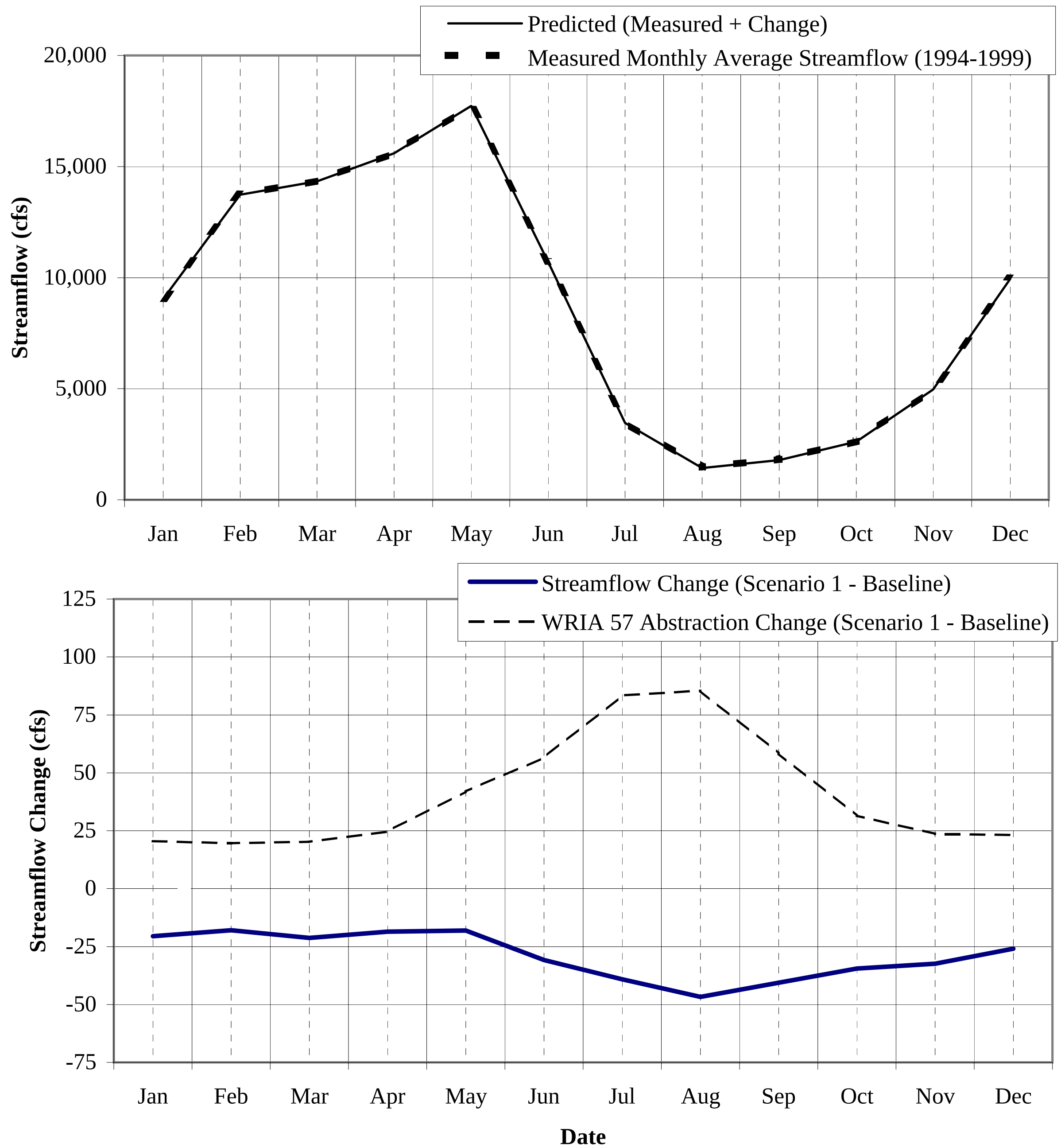
Scenario 1: Projected Spatial Change in Lawn Irrigation

WRIA 55&57/WATERSHED PLANNING/WA

Drawn: RMT	Revision: 1	Date: May 11, 2004	Figure: 4.4

01313722100_042004.apr

Golder Associates



Golder Associates

TITLE

Scenario 1: Spokane River below Greene St.
Monthly Streamflow Comparison

WRIA 55 & 57/ WATERSHED PLANNING/ WA

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CHECKED	SCALE	DWG. NO.
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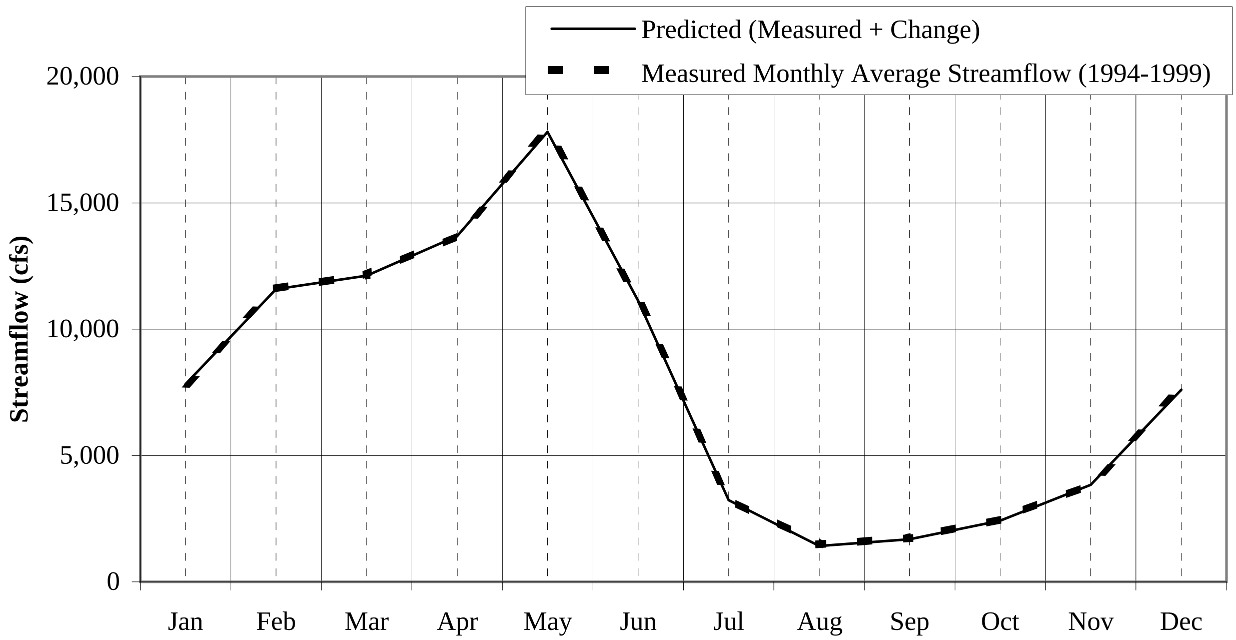
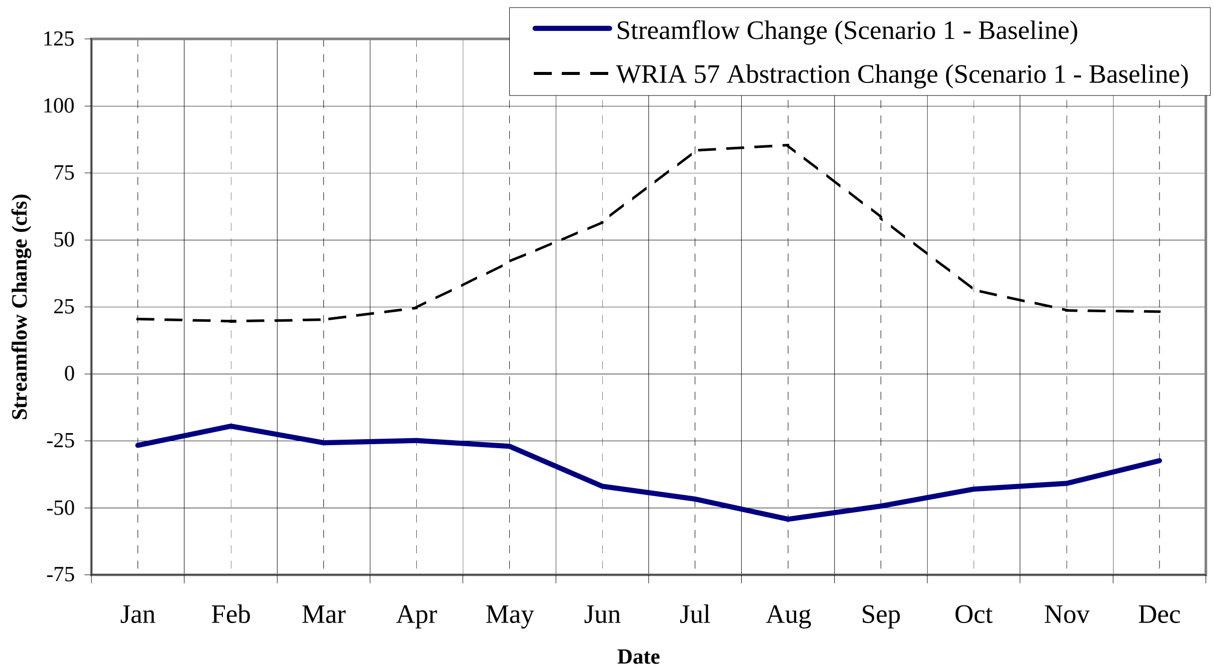




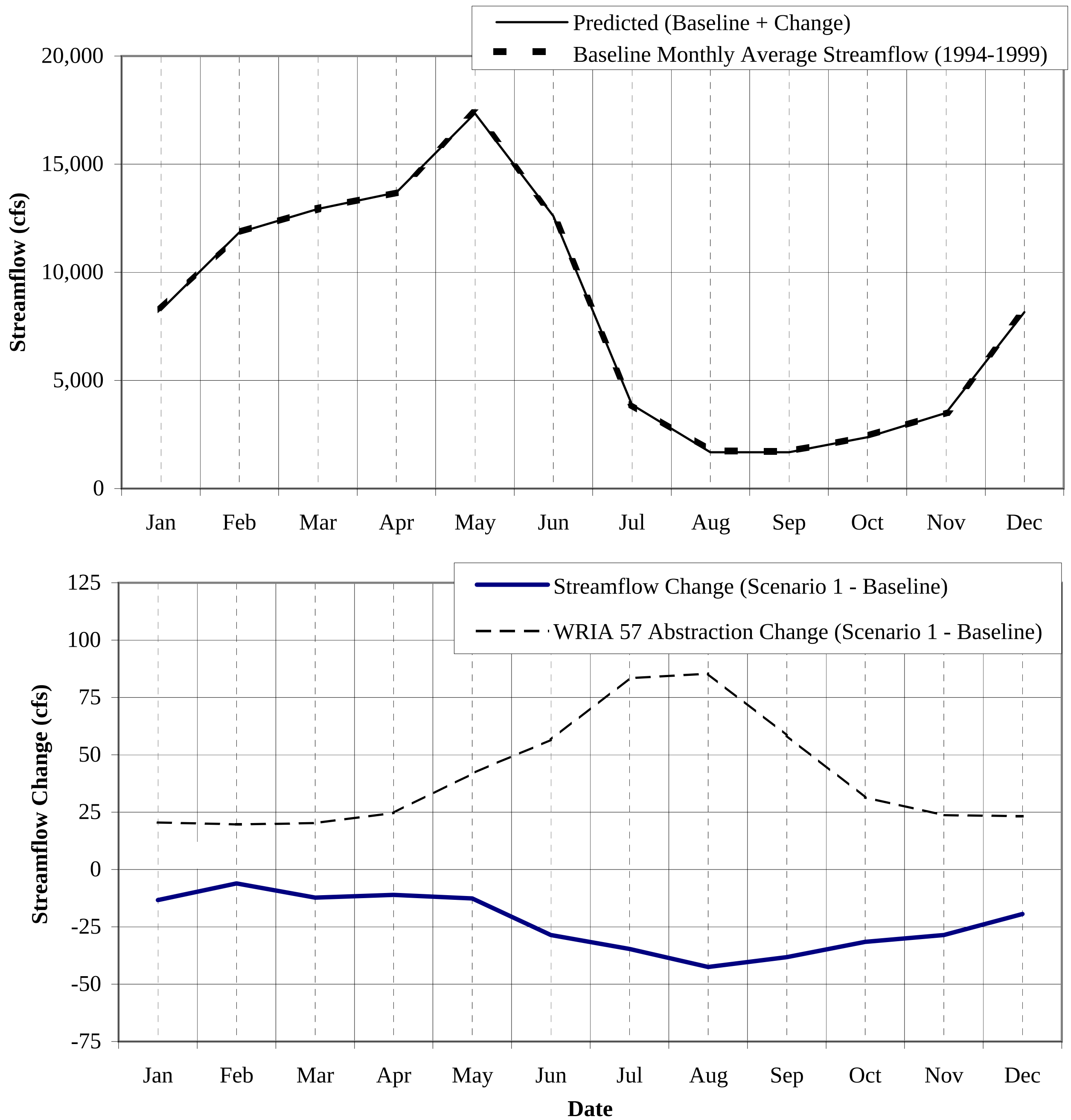
Golder Associates

TITLE

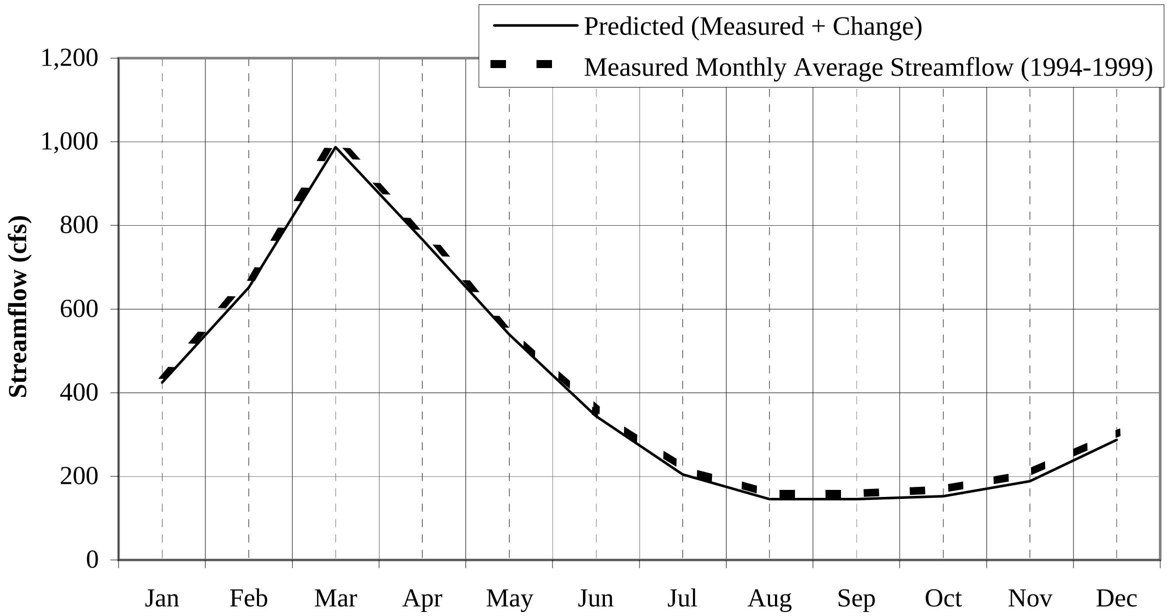
Scenario 1: Spokane River at Spokane
Monthly Streamflow Comparison

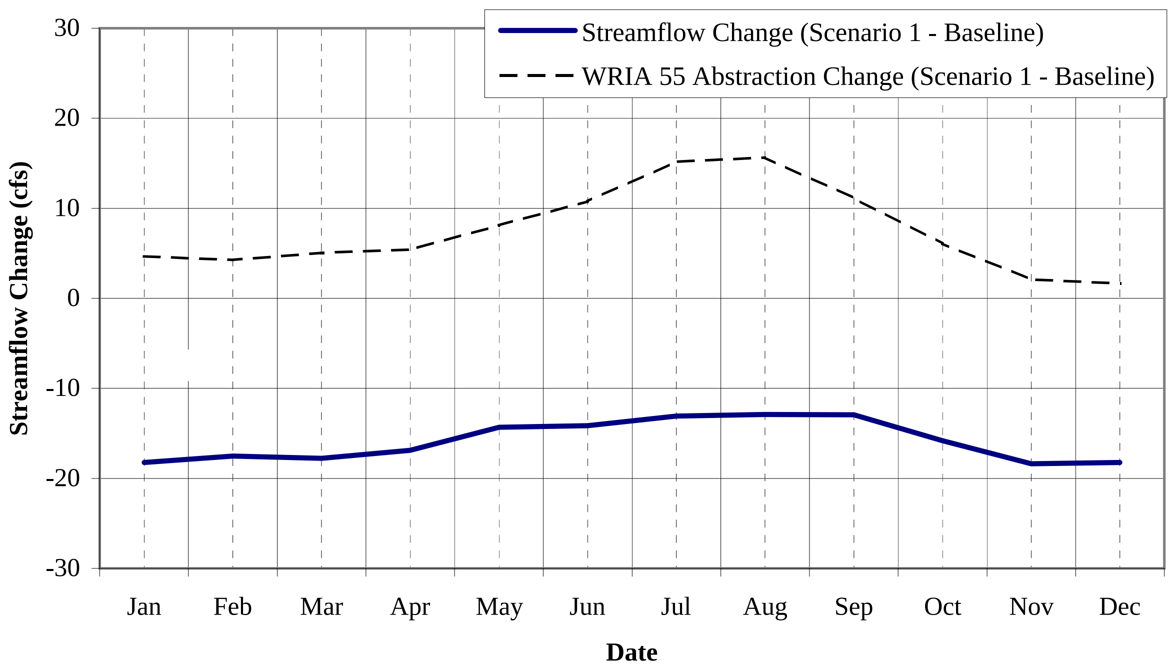
WRIA 55 & 57/ WATERSHED PLANNING/ WA

DRAWN JM	DATE December 2004	JOB NO. 013-1372
CHECKED	SCALE	DWG. NO.
REVIEWED	FILE NO. Run # 043004	FIGURE NO. 4.6



Golder Associates	TITLE **Scenario 1: Spokane River near Wastewater Treatment Plant Monthly Streamflow Comparison**				
WRIA 55 & 57/ WATERSHED PLANNING/ WA	DRAWN JM	DATE December 2004	JOB NO. 013-1372		
	CHECKED	SCALE	DWG. NO.		
	REVIEWED	FILE NO. Run # 043004	FIGURE NO. 4.7		





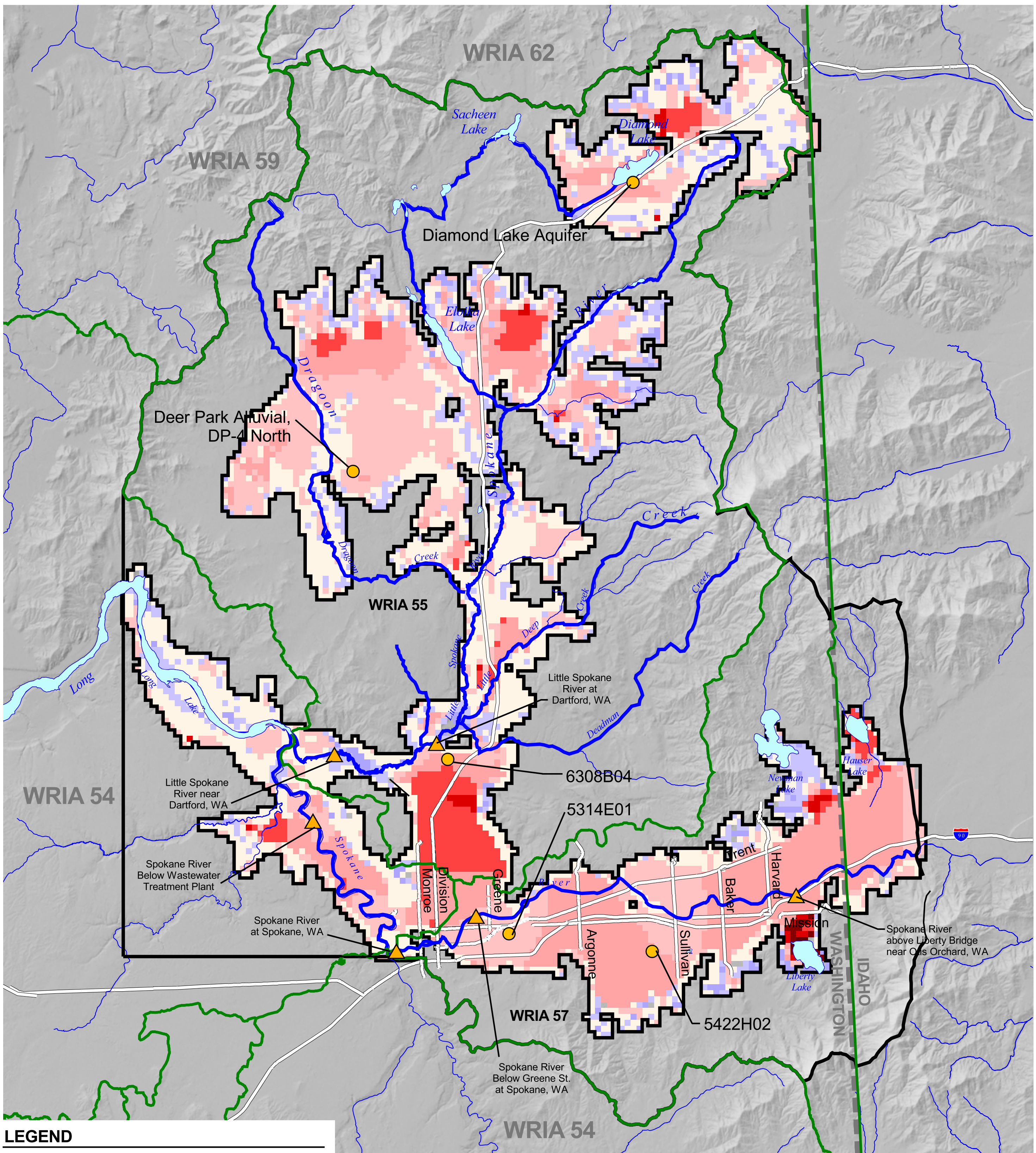
Golder Associates

TITLE

Scenario 1: Little Spokane River at Dartford
Monthly Streamflow Comparison

WRIA 55 & 57/ WATERSHED PLANNING/ WA

DRAWN	JM	DATE	December 2004	JOB NO.	013-1372
CHECKED		SCALE		DWG. NO.	
REVIEWED		FILE NO.	Run # 043004	FIGURE NO.	4.8



LEGEND

Change in Groundwater Elevation in Qfg (ft.)

- -1.5 - -1.25
- -1.25 - -1
- -1 - -0.75
- -0.75 - -0.5
- -0.5 - -0.25
- -0.25 - -0.001
- -0.1 - 0.1
- 0.001 - 0.25
- 0.25 - 0.5
- Qfg Extent
- River Output Locations
- WRIA Boundary
- Model Domain
- Lakes
- River
- Road
- State Boundary
- Continuous Groundwater

0 30,000

Scale 1" = 30,000

Map Projection:
Washington State Plane, NAD83
North Zone, Feet

Source: USGS, WSDOE,
Golder Associates Inc.

N

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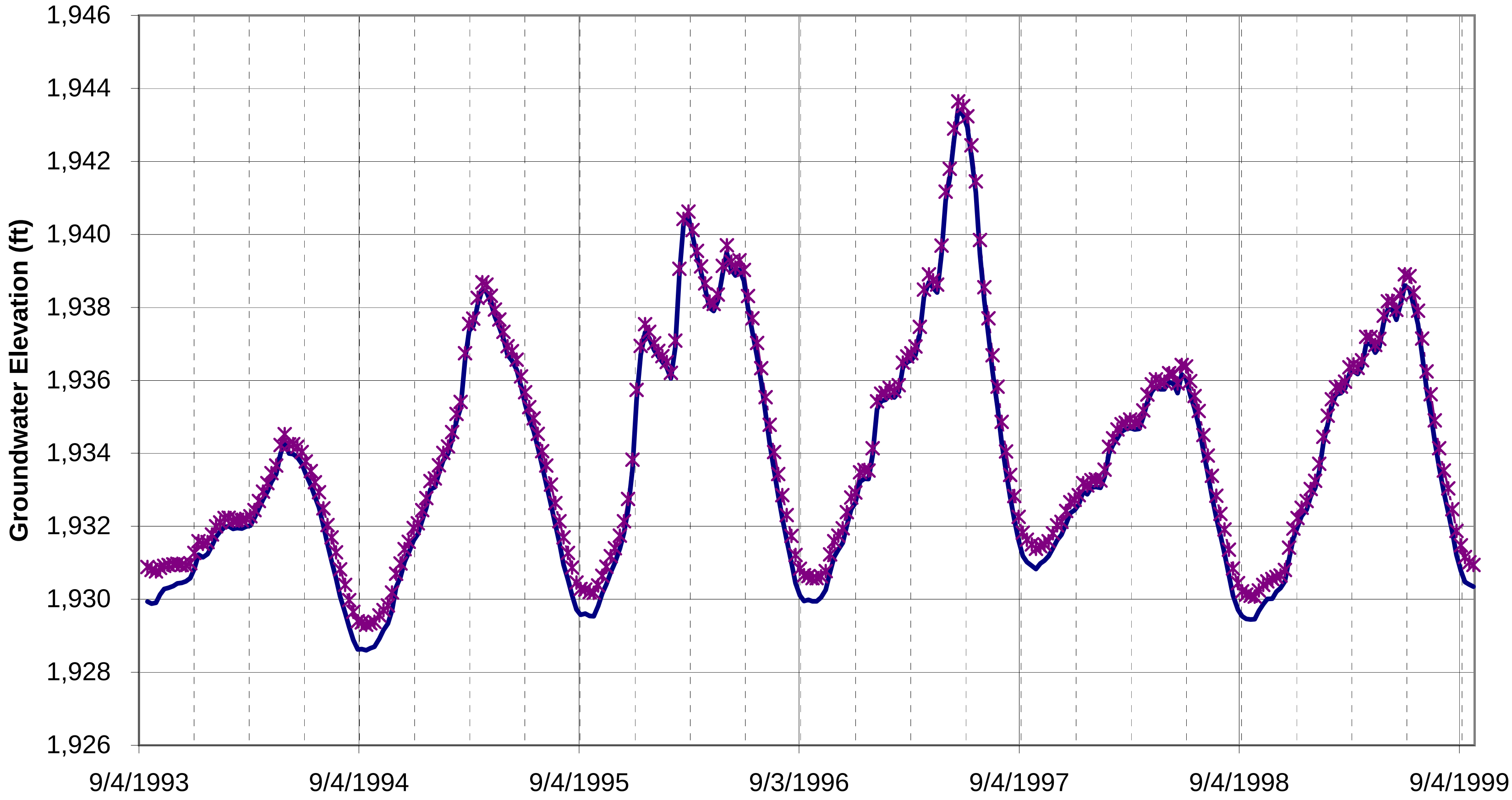
Spatial Change in Groundwater Elevations From Baseline (Averaged June - September, 1999)

WRIA 55&57/WATERSHED PLANNING/WA

Drawn: RMT	Revision: 1	Date: Dec. 15, 2004	Figure: 4.9

01313722100_121504.apr

Golder Associates



Legend

Baseline

Scenario 1, 20 Year Growth

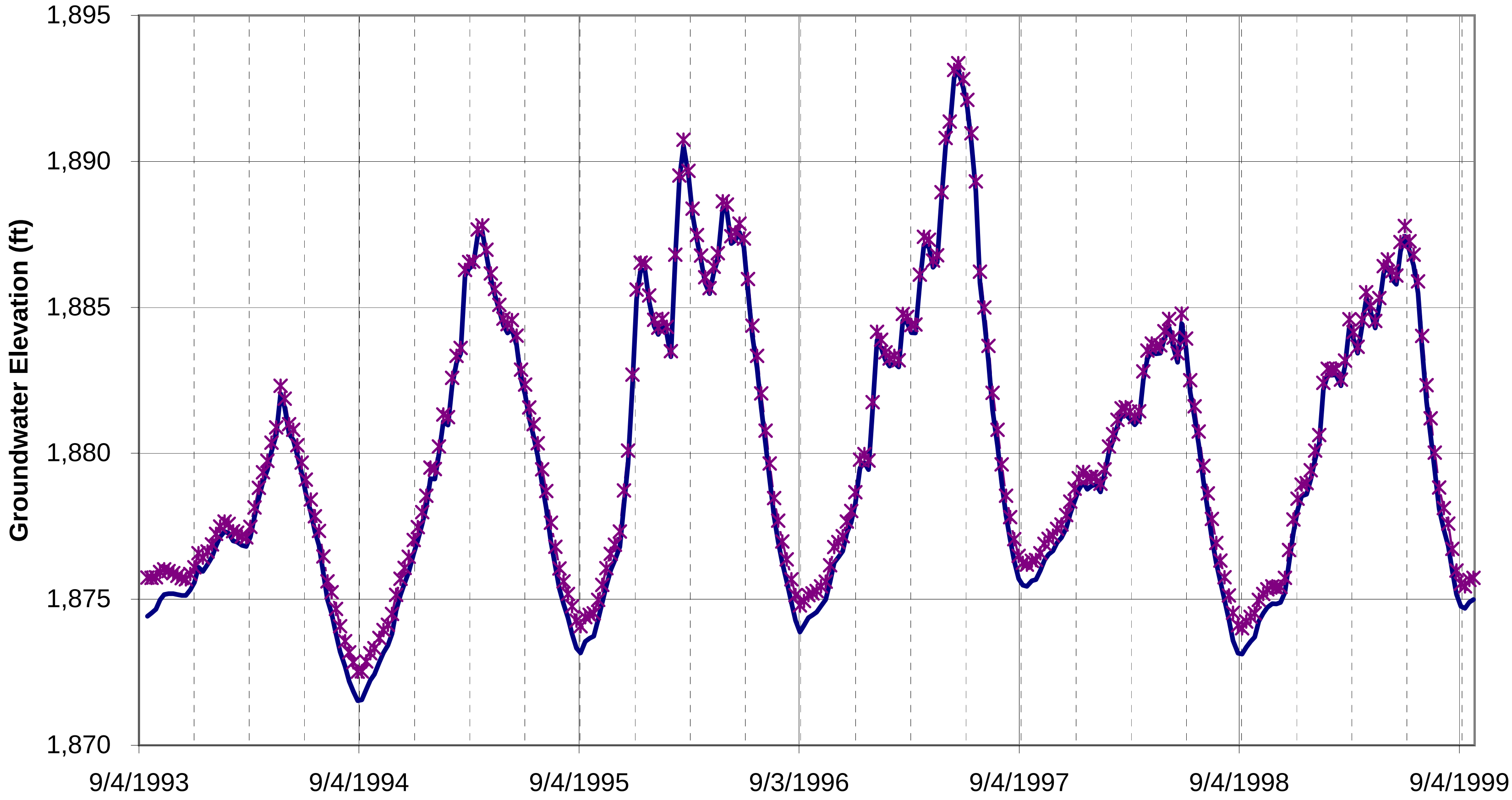
FIGURE 4.10: Scenario 1, Vera #6 (5422H02)
Change in Groundwater Elevation

Spokane County
Watershed Assessment

Golder Associates

Run # 043004

Fig Fig 4.10-15 20 Yr Gndwtr Comp.xls,template (12)



Legend

Baseline

Scenario 1, 20 Year Growth

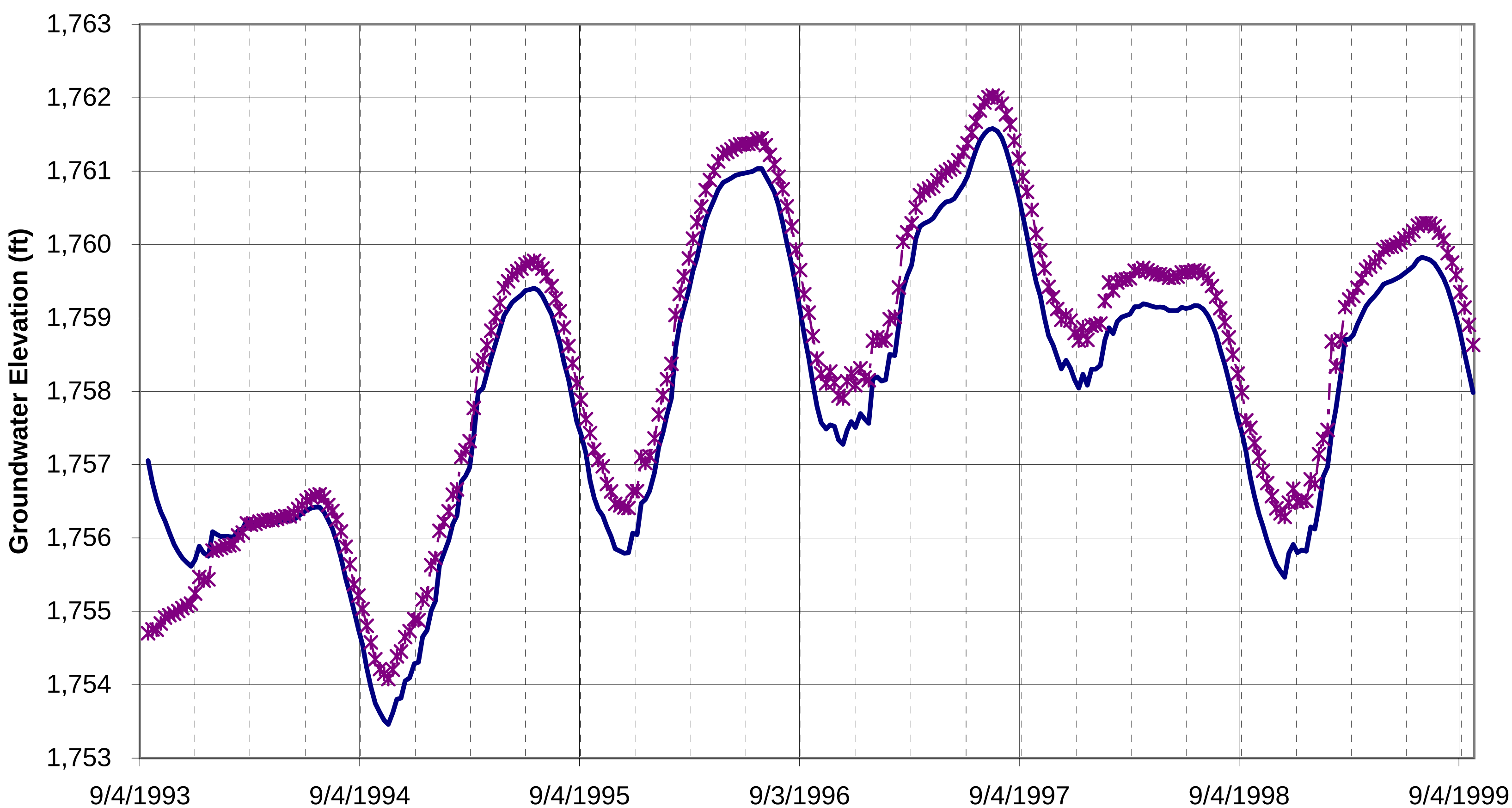
FIGURE 4.11: Scenario 1, City Central PreMix (5314E01) Change in Groundwater Elevation

Spokane County
Watershed Assessment

Golder Associates

Run # 043004

Fig Fig 4.10-15 20 Yr Gndwtr Comp.xls,template (7)



Legend

Baseline

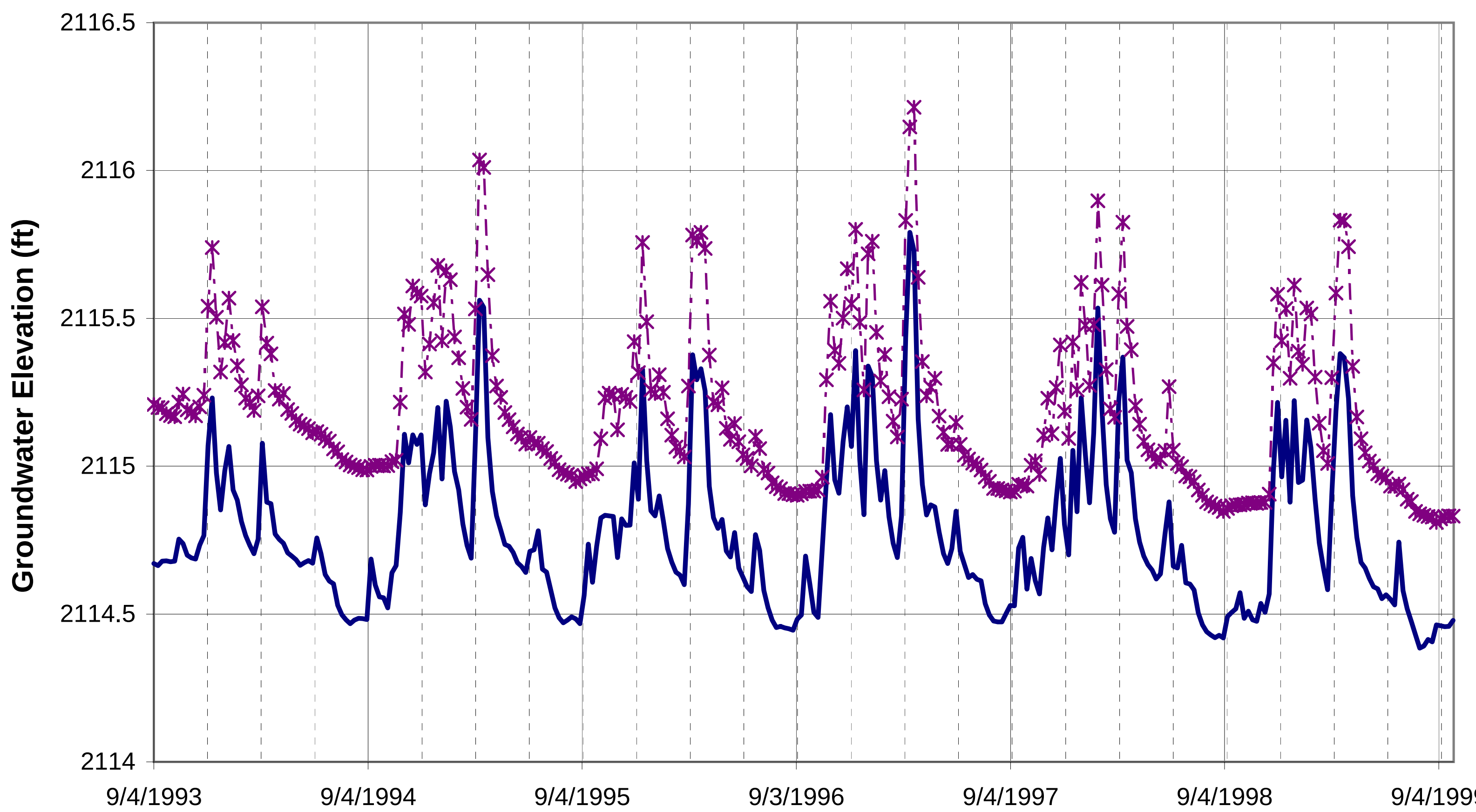
Scenario 1, 20 Year Growth

FIGURE 4.12: Scenario 1, Dakota (6308B04) Change in Groundwater Elevation

Spokane County
Watershed Assessment

Golder Associates

Run # 043004



Legend

Baseline

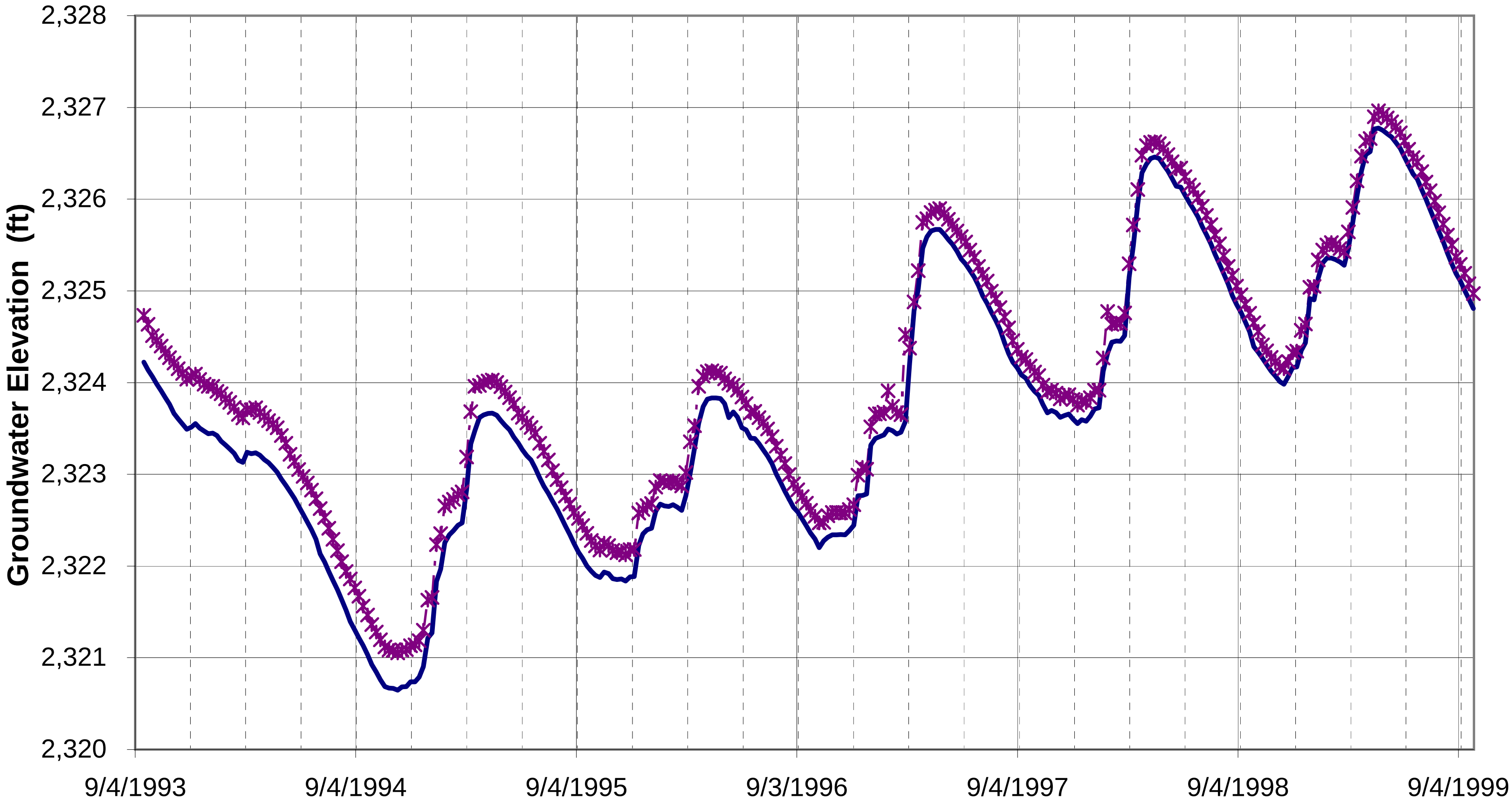
Scenario 1, 20 Year Growth

FIGURE 4.13: Scenario 1, Deer Park Alluvial, DP 4 North Change in Groundwater Elevation

Spokane County
Watershed Assessment

Golder Associates

Run # 043004



Legend

Baseline

Scenario 1, 20 Year Growth

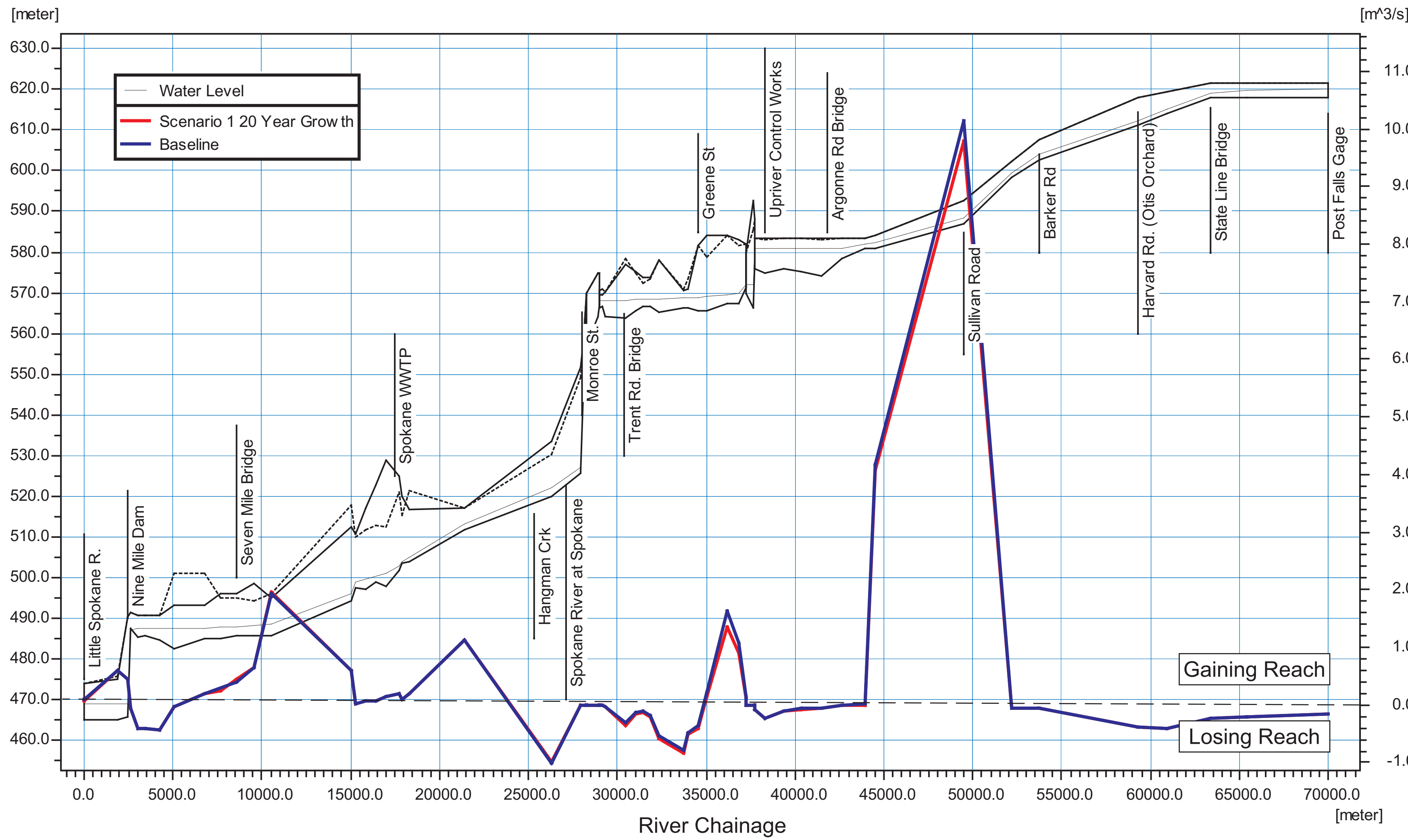
FIGURE 4.14: Scenario 1, Diamond Lake Aquifer Change in Groundwater Elevation

Spokane County
Watershed Assessment

Golder Associates

Run # 043004

20 Year - Baseline Groundwater Comparison.xls,template (28)



Colored lines indicate the range of surface water – aquifer interactions simulated as baseflow during a typical run.
A line that is below 0.0 m3/s (right side y-axis) indicates that river water is infiltrating and recharging the aquifer (losing river reach).
Lines above 0.0 m3/s indicate that groundwater is discharging to surface water (gaining river reach).

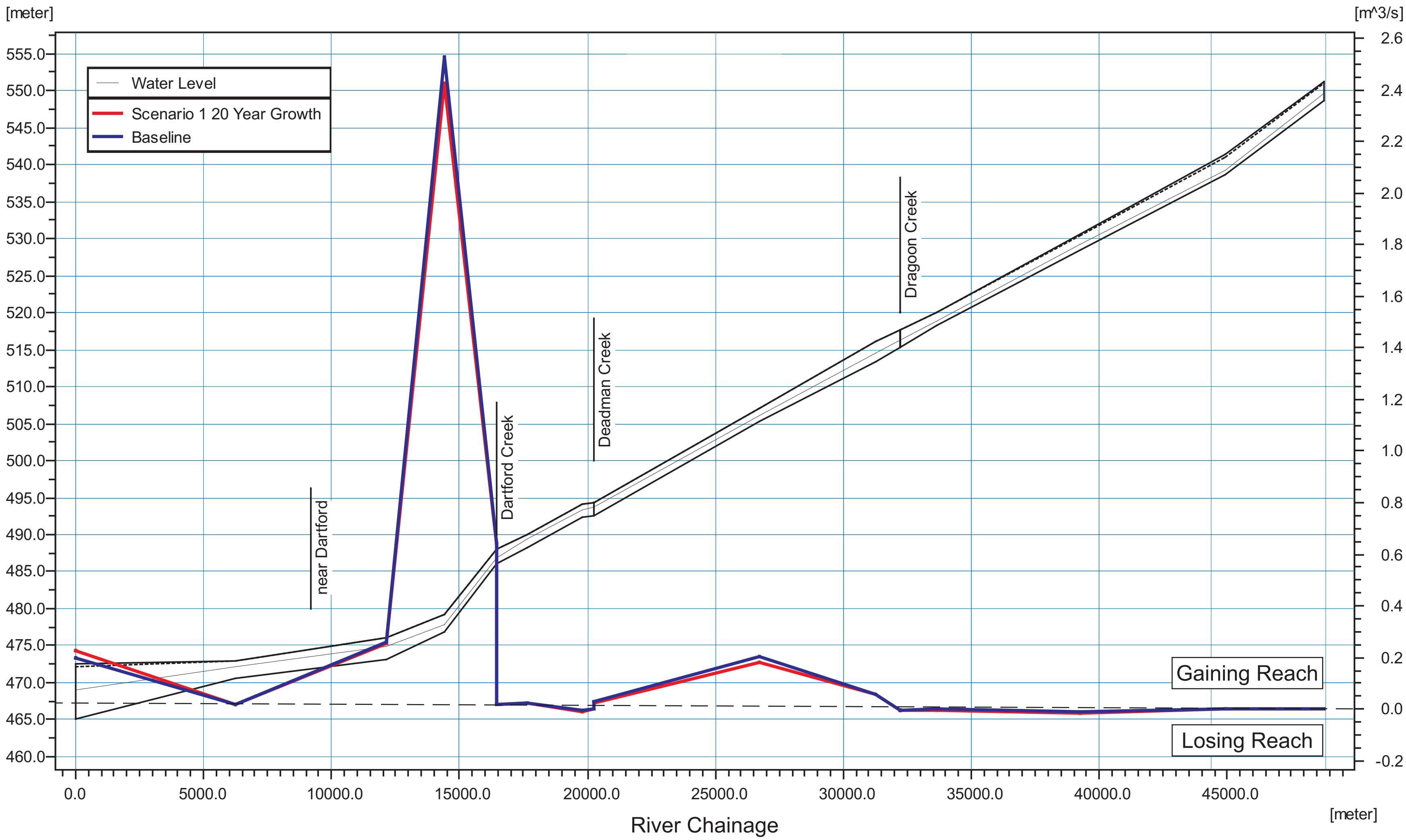
FIGURE **4.15**

BASELINE AND SCENARIO 1 GROUNDWATER CONTRIBUTIONS TO THE LOWER REACH OF THE SPOKANE RIVER

WRIA 55 & 57/WATERSHED PLANNING/WA

DRAWING NO. 01313722100fg05.fh11 DATE 12/27/04 DRAWN BY EL

Golder Associates



Colored lines indicate the range of surface water – aquifer interactions simulated as baseflow during a typical run.
A line that is below 0.0 m3/s (right side y-axis) indicates that river water is infiltrating and recharging the aquifer (losing river reach).
Lines above 0.0 m3/s indicate that groundwater is discharging to surface water (gaining river reach).

FIGURE **4.16**

BASELINE AND SCENARIO 1 GROUNDWATER CONTRIBUTIONS TO THE LITLE SPOKANE RIVER

WRIA 55 & 57/WATERSHED PLANNING/WA

DRAWING NO. 01313722100fg04.fh11 DATE 12/27/04 DRAWN BY EL

Golder Associates

5.0 SCENARIO 2: RIVER DIVERSION AND GROUNDWATER INJECTION

The purpose of the river diversion and groundwater injection scenario was to increase Spokane River flows during the low flow period (August to September) by temporarily sequestering river water in the SVRP Aquifer during peaks flows. The scenario simulates diverting water from the Spokane River and injecting it into the aquifer through a well near Barker Road approximately a mile north of the river during the peak flow period (April to May).

5.1 Model Setup

The simulation uses the baseline model with two changes to simulate diversion of water from the Spokane River and the injection of water into the SVRP Aquifer:

- Discharge at the stream gage located at Post Falls, ID, is reduced by 100 cfs from April 1 to June 1 annually; and,
- The diverted river water is injected into the aquifer at a rate of 100 cfs from April 1 to June 1 annually.

Figure 5.1 shows the location of both the diversion point and the injection point. All other model parameters (e.g. groundwater abstraction, precipitation, and boundary conditions) are identical to baseline conditions.

5.2 Results

5.2.1 Surface Water

Surface water results are presented in Figures 5.2 through 5.4. Surface water results are presented in two frames on each figure. The upper frame of each figure shows a hydrograph of monthly average measured flow from the local gage (shown as a dashed line) and a hydrograph of the monthly average measured hydrograph with the model predicted change in streamflow added (shown as a solid line). This provides a visual of the relative impact of the change in streamflow to actual streamflow. The change in discharge is displayed as a separate graph in the lower frame along with the timing and rate of the diversion/injection.

Spokane River

Results from Greene Street (Figure 5.2) show an immediate decrease in discharge when water is being diverted from the river between April 1 and June 1. However, the reduction of streamflow is less than the amount being diverted because return flow is occurring so quickly (i.e., within the resolution of the seven-day time step). Upon completion of diversion and injection, there is a sharp increase in streamflow above the baseline condition as the residual drainage of recharged groundwater back to the river. However the increase is not sustained and is less than the total injected volume. The river response period generally ends by August and adds, on average, 20 cfs in June and 5 cfs in July to river flows.

Spokane River flows at Spokane (Figure 5.3) and immediately downstream of the City of Spokane WWTP (Figure 5.4) are almost identical to that shown at Greene Street. This indicates that all influences on the Spokane River from the injection pointed are realized by Greene Street and no additional groundwater discharge to the river occurs downstream of Greene Street.

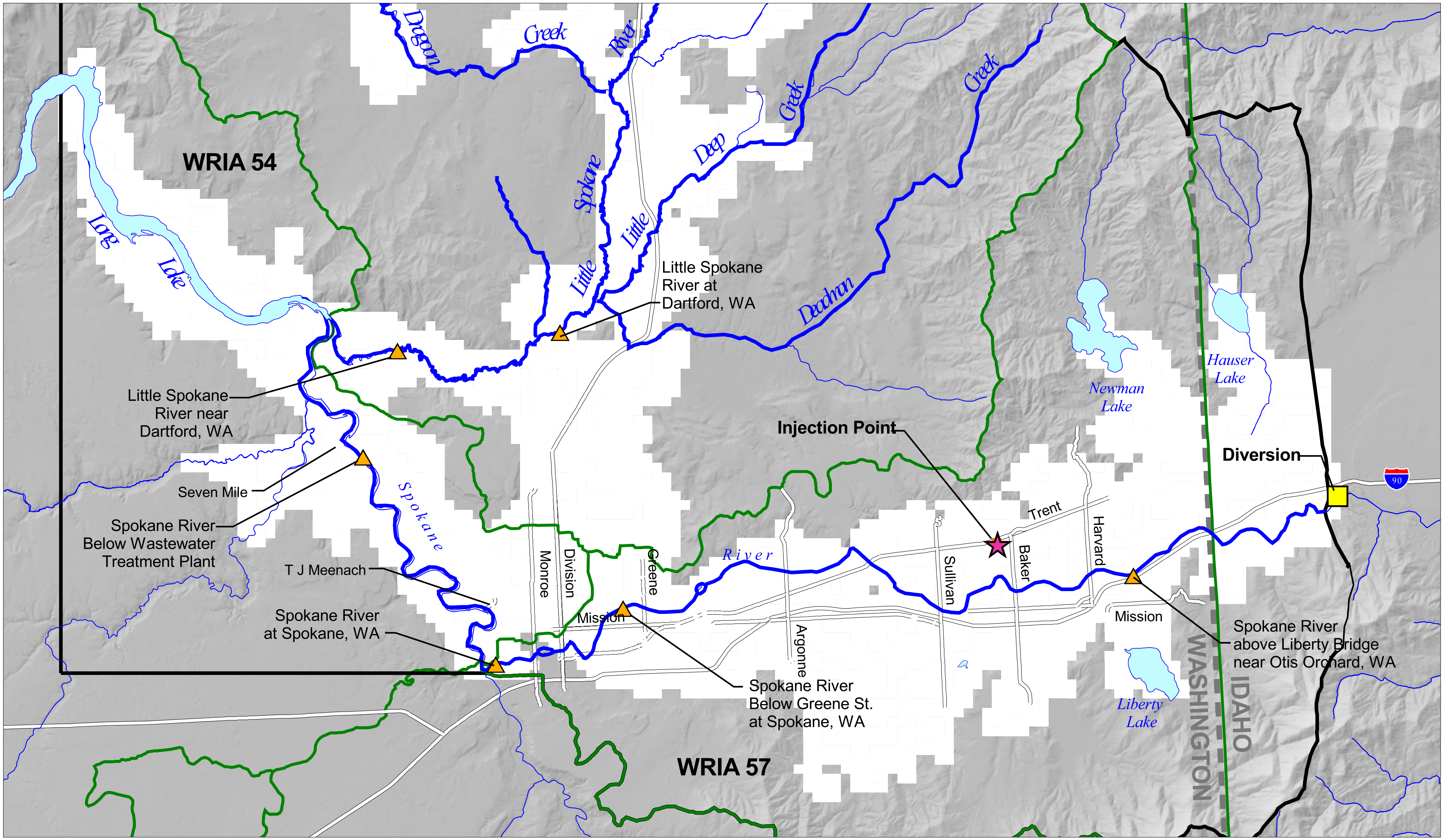
Little Spokane River

The primary effects of the groundwater injection were observed in Spokane River within WRIA 57. No consistent differences in discharge occurred along the Little Spokane River at either the at Dartford or near Dartford gage.

5.2.2 Groundwater

Figures 5.5 through 5.8 characterize the changes in groundwater during the last month of groundwater injection and the months following. The figures depict the monthly average difference (for May, June, July, and August) in groundwater elevation between Spokane River diversion scenario and baseline condition (Scenario 2 minus Baseline). Increases in groundwater elevation represent an increase in groundwater head over existing (baseline) conditions; decreases in groundwater elevation represent a decrease in groundwater head from existing conditions.

- Figure 5.5 (May): Presents system response during the injection period. The greatest increase in groundwater elevation is seen at the injection point, with widespread increases in groundwater elevations (i.e., less than 0.75 feet) above baseline conditions between Argonne Road and upgradient into Idaho. The area between the TJ Meenach Bridge and Seven Mile Bridge shows slightly decreased groundwater levels (e.g., less than -0.25 feet) probably due to the preceding period of lower streamflows downstream of the diversion point.
- Figure 5.6 (June): Presents the average system response for the month immediately after injection has ended. The groundwater mound has begun to spread and dissipate, and increased groundwater elevations (between 0.01 and 0.25 ft) are visible from Idaho to Upriver Control Works. Between the TJ Meenach Bridge and Seven Mile Bridge, there is now a head increase of between 0.01 and 0.25 ft). This downstream effect is possibly due to the increased head upstream in the aquifer changing the gradient through the Trinity Trough or increased streamflow. No change is seen in groundwater head through the Hillyard Trough.
- Figure 5.7 (July): The injected volume has further dissipated and decreased in area around the injection point, but further down from Spokane River at Spokane the area of increased head is grown in the area between the TJ Meenach Bridge and Seven Mile Bridge..
- Figure 5.8 (August): The groundwater mound has almost fully dissipated with residual effects along the edge of the aquifer and downstream of Spokane River at Spokane.



LEGEND

- River Output Locations
- Mike11 River
- WRIA Boundary
- Model Domain
- Layer 1: Surficial Aquifer (Flood Sand & Gravel)
- Lake
- Road

0 20,000
Scale 1" = 20,000

Map Projection:
Washington State Plane, NAD83
North Zone, Feet

Source: USGS, WSDOE,
Golder Associates Inc.

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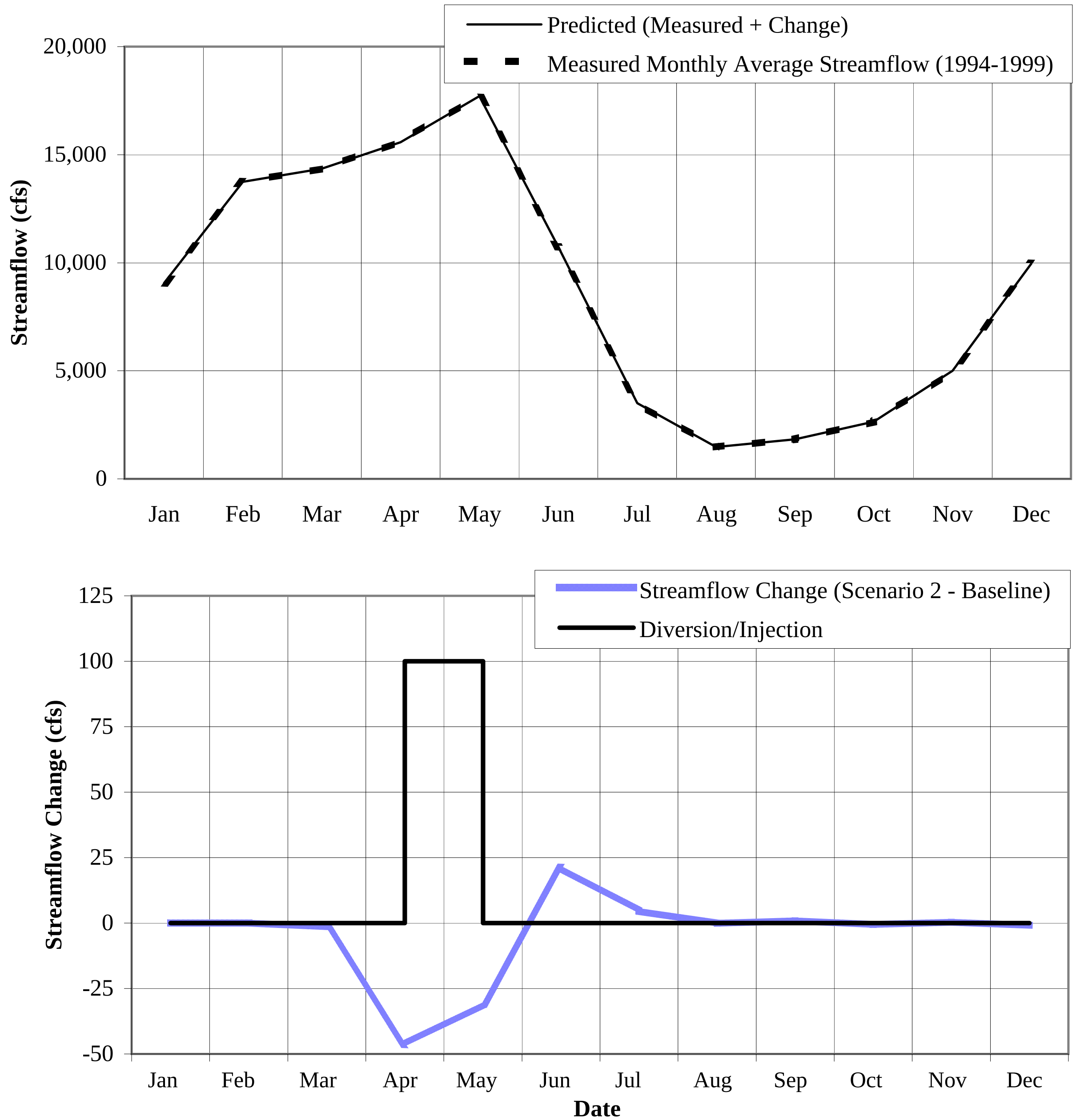
SCENARIO 2: SPOKANE RIVER DIVERSION AND INJECTION

WRIA 55&57/WATERSHED PLANNING/WA

Drawn: RMT	Revision: 4	Date: Dec. 15, 2004	Figure: 5.1

01313722100_121504.apr

Golder Associates



Note: Model Outliers Removed

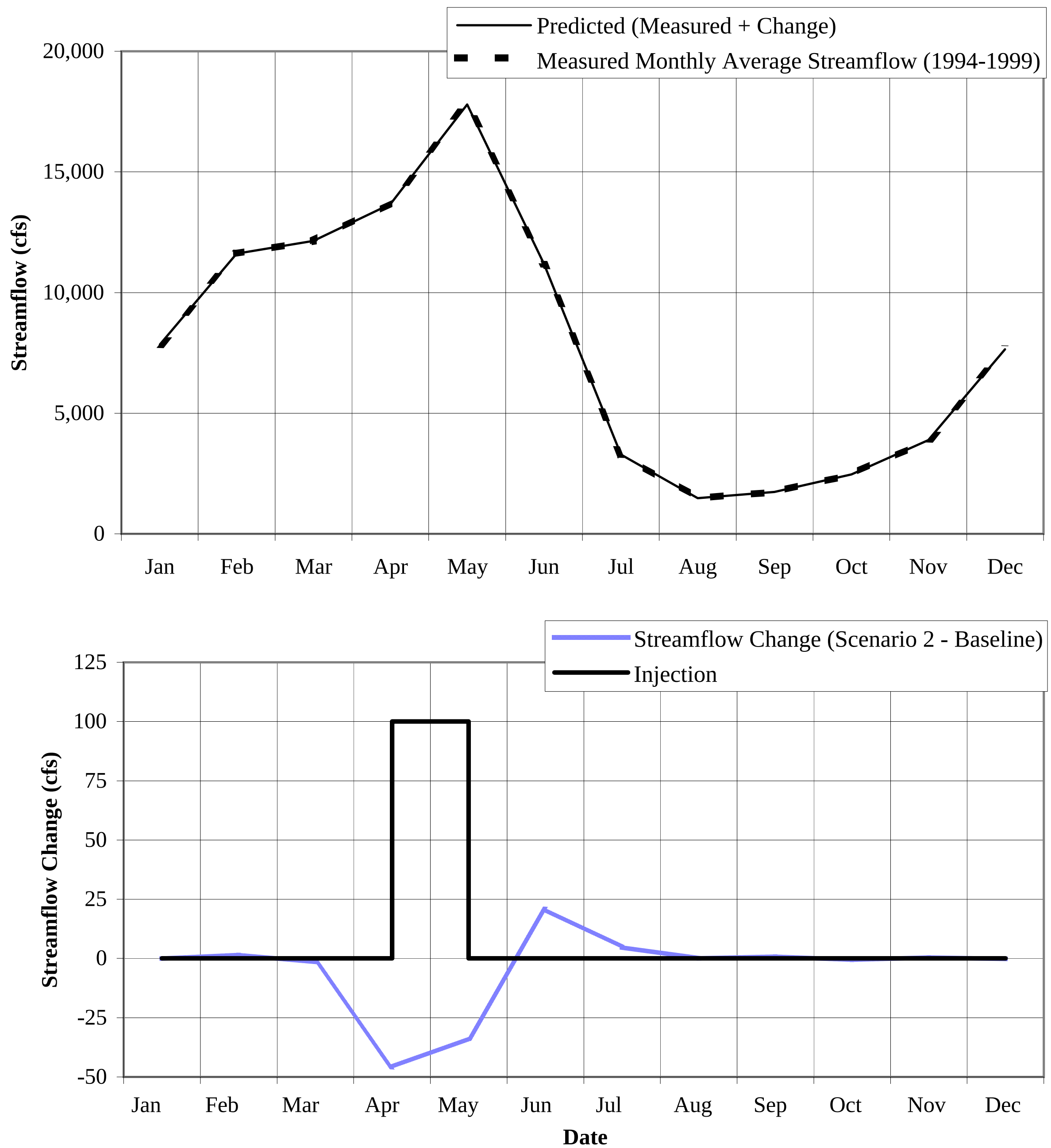
Golder Associates

WRIA 55 & 57/ WATERSHED PLANNING/ WA

TITLE

Scenario 2: Spokane River below Greene St.
Monthly Streamflow Change

DRAWN	JM	DATE	December 2004	JOB NO.	013-1372
CHECKED		SCALE		DWG. NO.	
REVIEWED		FILE NO.	Run # 033004	FIGURE NO.	5.2



Note: Model Outliers Removed

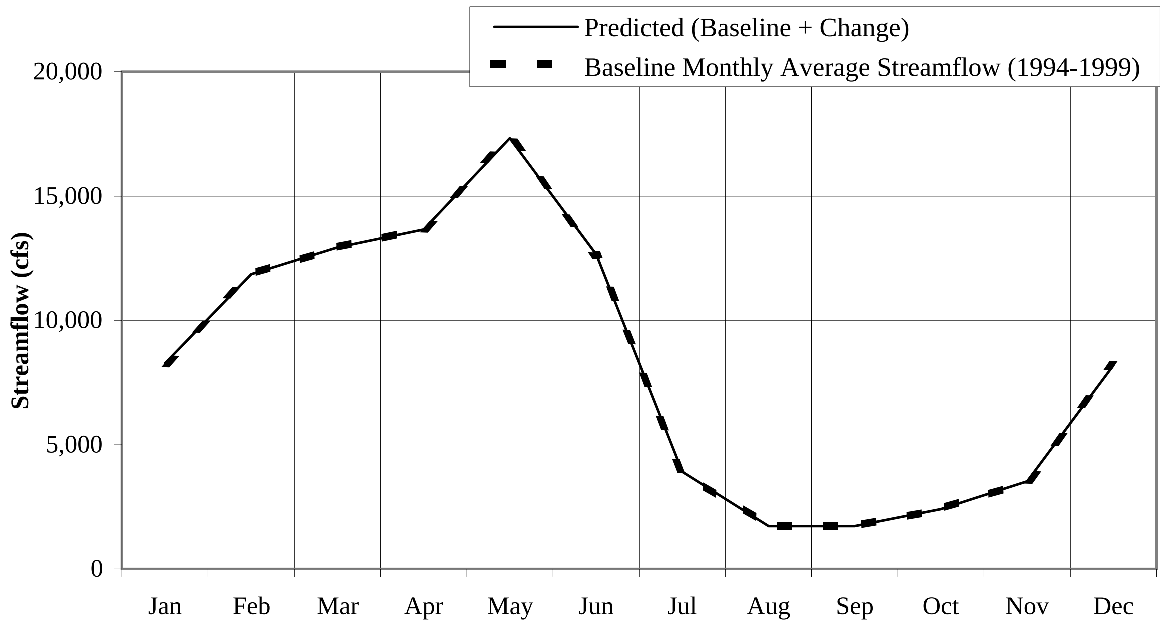
Golder Associates

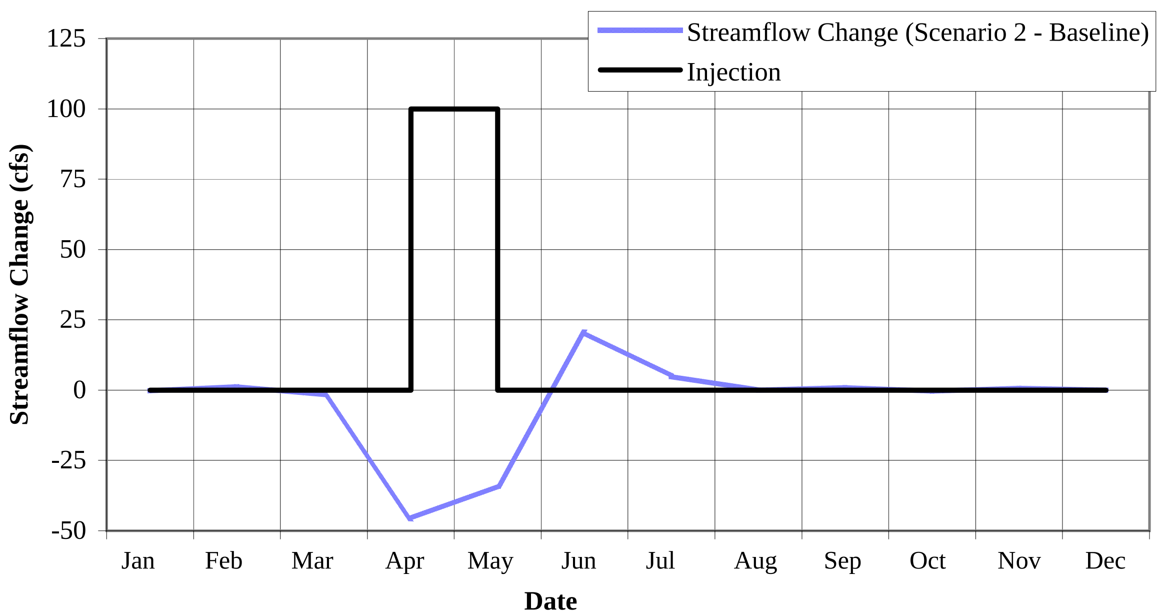
TITLE

Scenario 2 : Spokane River at Spokane
Monthly Streamflow Comparison

WRIA 55 & 57/ WATERSHED PLANNING/ WA

DRAWN	JM	DATE	December 2004	JOB NO.	013-1372
CHECKED		SCALE		DWG. NO.	
REVIEWED		FILE NO.	Run # 033004	FIGURE NO.	5.3





Note: Model Outliers Removed

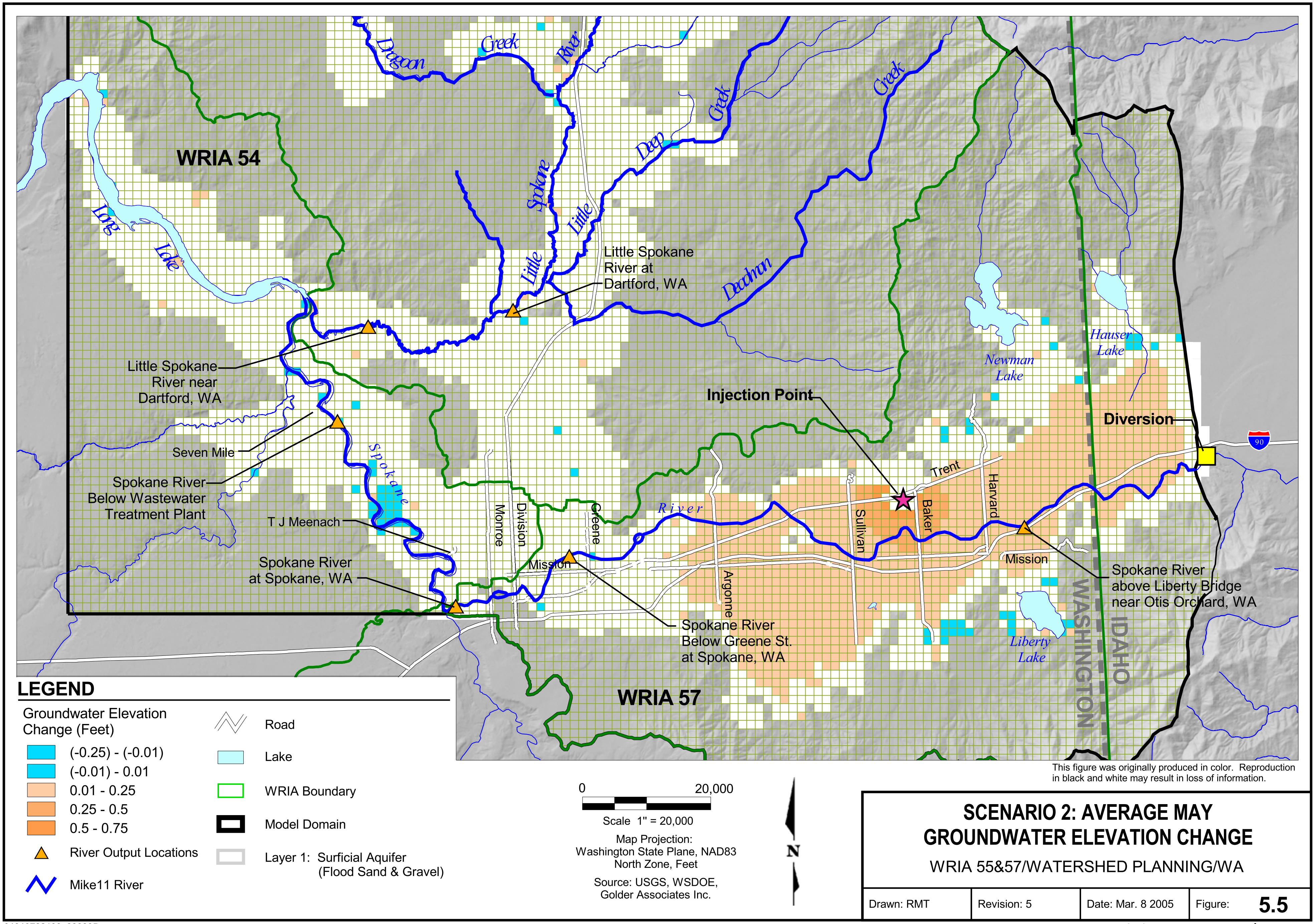
Golder Associates

TITLE

Scenario 2 : Spokane River downstream of Wastewater Treatment Plant
Change in Monthly Streamflow

WRIA 55 & 57/ WATERSHED PLANNING/ WA

DRAWN	JM	DATE	December 2004	JOB NO.	013-1372
CHECKED		SCALE		DWG. NO.	
REVIEWED		FILE NO.	Run # 033004	FIGURE NO.	5.4



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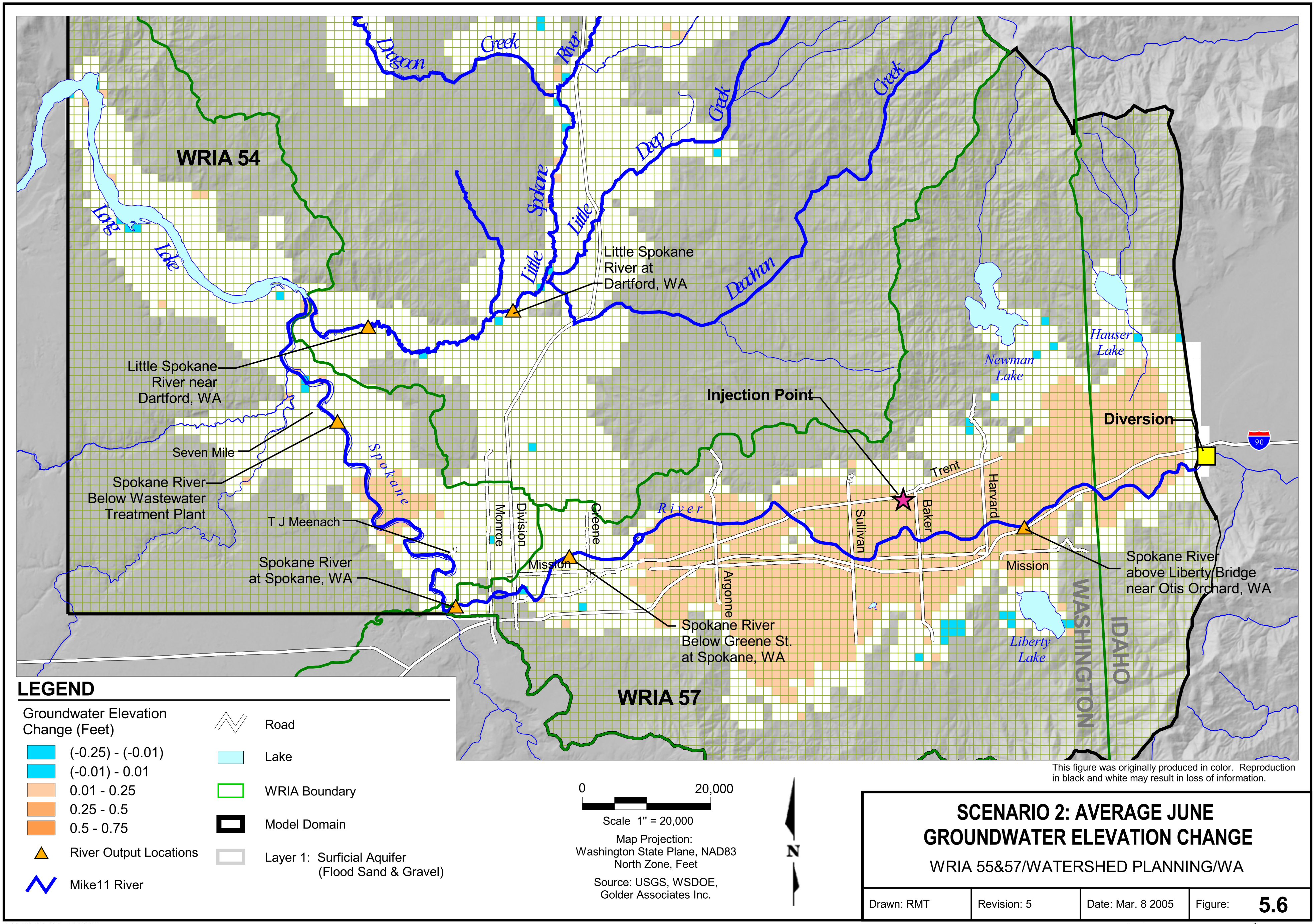
SCENARIO 2: AVERAGE MAY GROUNDWATER ELEVATION CHANGE

WRIA 55&57/WATERSHED PLANNING/WA

Drawn: RMT	Revision: 5	Date: Mar. 8 2005	Figure: 5.5

01313722100_030805.apr

Golder Associates

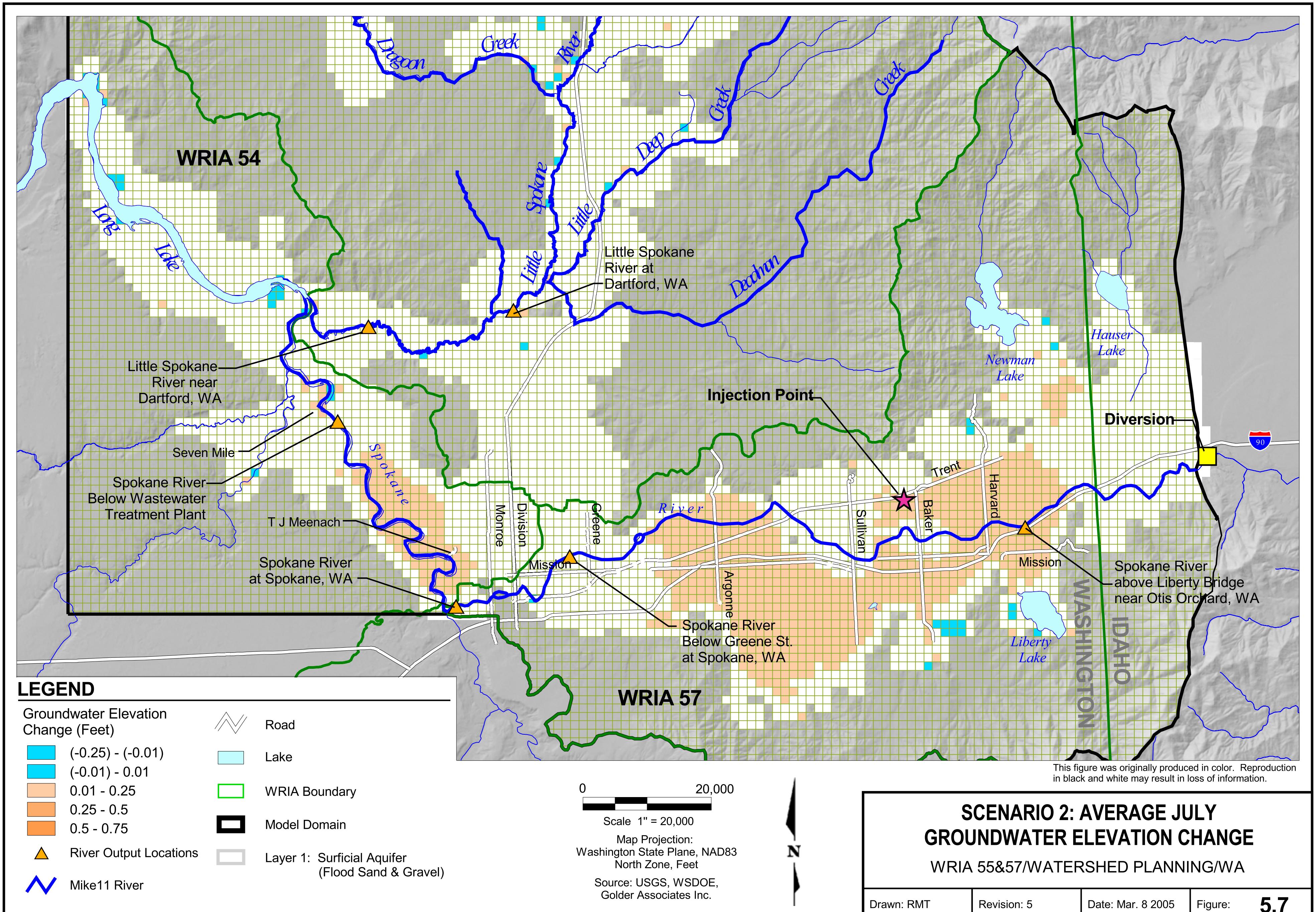


SCENARIO 2: AVERAGE JUNE GROUNDWATER ELEVATION CHANGE

WRIA 55&57/WATERSHED PLANNING/WA

01313722100_030805.apr

Golder Associates



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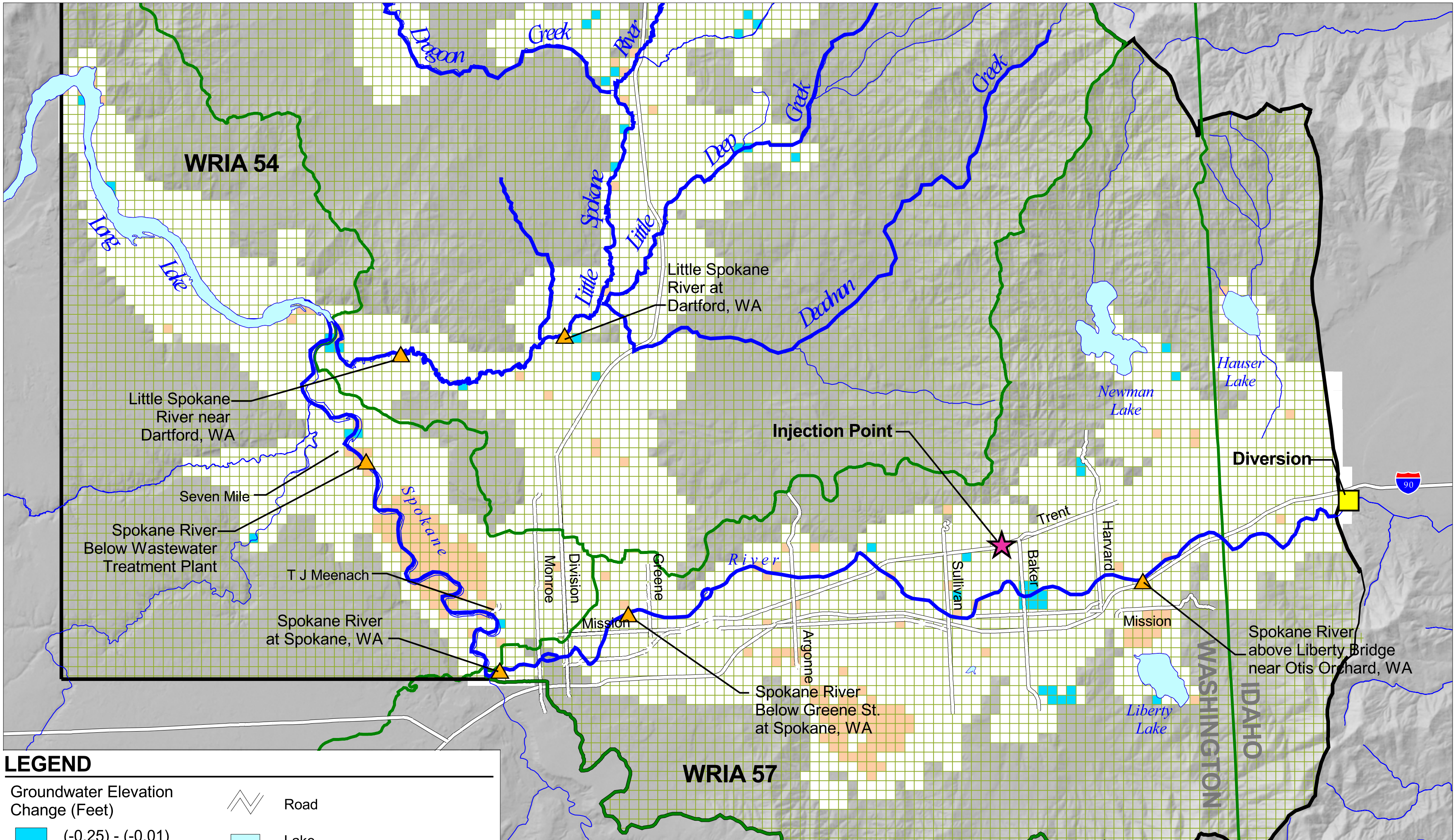
SCENARIO 2: AVERAGE JULY GROUNDWATER ELEVATION CHANGE

WRIA 55&57/WATERSHED PLANNING/WA

Drawn: RMT	Revision: 5	Date: Mar. 8 2005	Figure: 5.7

01313722100_030805.apr

Golder Associates



LEGEND

Groundwater Elevation Change (Feet)

- (-0.25) - (-0.01)
- (-0.01) - 0.01
- 0.01 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- River Output Locations
- Mike11 River
- Road
- Lake
- WRIA Boundary
- Model Domain
- Layer 1: Surficial Aquifer (Flood Sand & Gravel)

0 20,000

Scale 1" = 20,000

Map Projection:
Washington State Plane, NAD83
North Zone, Feet

Source: USGS, WSDOE,
Golder Associates Inc.

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SCENARIO 2: AVERAGE AUGUST GROUNDWATER ELEVATION CHANGE

WRIA 55&57/WATERSHED PLANNING/WA

Drawn: RMT	Revision: 6	Date: Mar. 8 2005	Figure: 5.8

01313722100_030805.apr

Golder Associates

6.0 SCENARIO 3: RELOCATION OF GROUNDWATER ABSTRACTION

The purpose of this scenario was to evaluate the impact to the Spokane River of redistributing groundwater withdrawals to wells further from the river for the purpose of enhancing discharge during low flow periods.

6.1 Model Setup

Spokane County staff identified wells near the Spokane River where pumping could be reduced. Withdrawal rates were reduced in wells close to the Spokane River, and increased in wells further from the Spokane River (Table 6-1). The greatest annual decreases in pumping were implemented in the City-Well Electric, City-Parkwater, and Trentwood #4 wells, the greatest annual increases were in the City – Nevada, City-Grace, and City-Ray wells. The total groundwater withdrawal remained the same, with only a shift in their distribution. Figure 6.1 shows the change in monthly groundwater pumping of each well.

TABLE 6-1

Groundwater Pumping Relocation Rate Changes
(average annual gpm)

WELL NAME	ORIGINAL RATE	SCENARIO 3 RATE
Central Pre Mix Sullivan Road	14	0
CID#1	229	229
City-Central	7,912	9,281
City-Grace	1,602	7,067
City-Hoffman	508	913
City-Nevada	6,410	13,897
City-Parkwater	5,011	0
City-Ray	5,699	13,128
City-Well Electric	17,143	0
Industrial Park	221	301
IWD #1	209	315
IWD #3	188	0
IWD #4	313	395
Spo Co Mirabeau Park	0.11	0
Spo Co Sullivan Park	3	0
Trentwood #3	343	518
Trentwood #4	351	0
Trentwood #5	186	361
TOTAL	**46,342**	**46,404**

A total of 12,000 million gallons of annually pumped water was redistributed to wells located further from the river. The spatial distribution of pumping changes are displayed in Figure 6.2. The generalized gaining and losing reaches of the river from the baseline model run (Golder, February 2004) are also displayed on this figure. All other model parameters (e.g. groundwater abstraction of non relocated wells, precipitation, and boundary conditions) are identical to baseline conditions.

6.2 Results

6.2.1 Surface Water

Surface water results are presented in Figures 6.3 through 6.6. The upper frame of each figure shows the measured monthly hydrograph for the location (shown as a dashed line) and the measured monthly hydrograph with the predicted change in streamflow added (shown as a solid line). This provides a visual of the relative impact of the change in streamflow to actual streamflow. The change in streamflow is displayed as a separate graph in the lower frame.

Spokane River

Hydrographs of the Spokane River at Greene Street, Spokane, City of Spokane WWTP and Little Spokane River near Dartford are shown in Figures 6.3 through 6.6 respectively.

Spokane River flow at Greene Street (Figure 6.3) is greater throughout the run adding as much as 31 cfs during August and approximately 10 cfs in February. Most of the wells that have been shut off are located upstream of the Greene Street gage (Figure 6.2). The City-Parkwater and City-Well Electric wells located upstream have a combined decrease in pumping of 89 cfs in the summer. Approximately 35% of this decreased pumping is represented in increased streamflow at Greene Street.

Spokane River flows at Spokane and below the City of Spokane WWTP (Figures 6.4 and 6.5), are higher during the summer months by as much 12 cfs but there is a decrease in flow of almost 2 cfs during the late winter and spring. The model predicts an increase in recharge to the aquifer from the river between Greene Street and Spokane. The increase of streamflow at Spokane during the summer represents less than 1% of the total low flow. Decreases in flow during the late winter and spring are not as critical for habitat purposes because that is a high flow period.

Little Spokane River

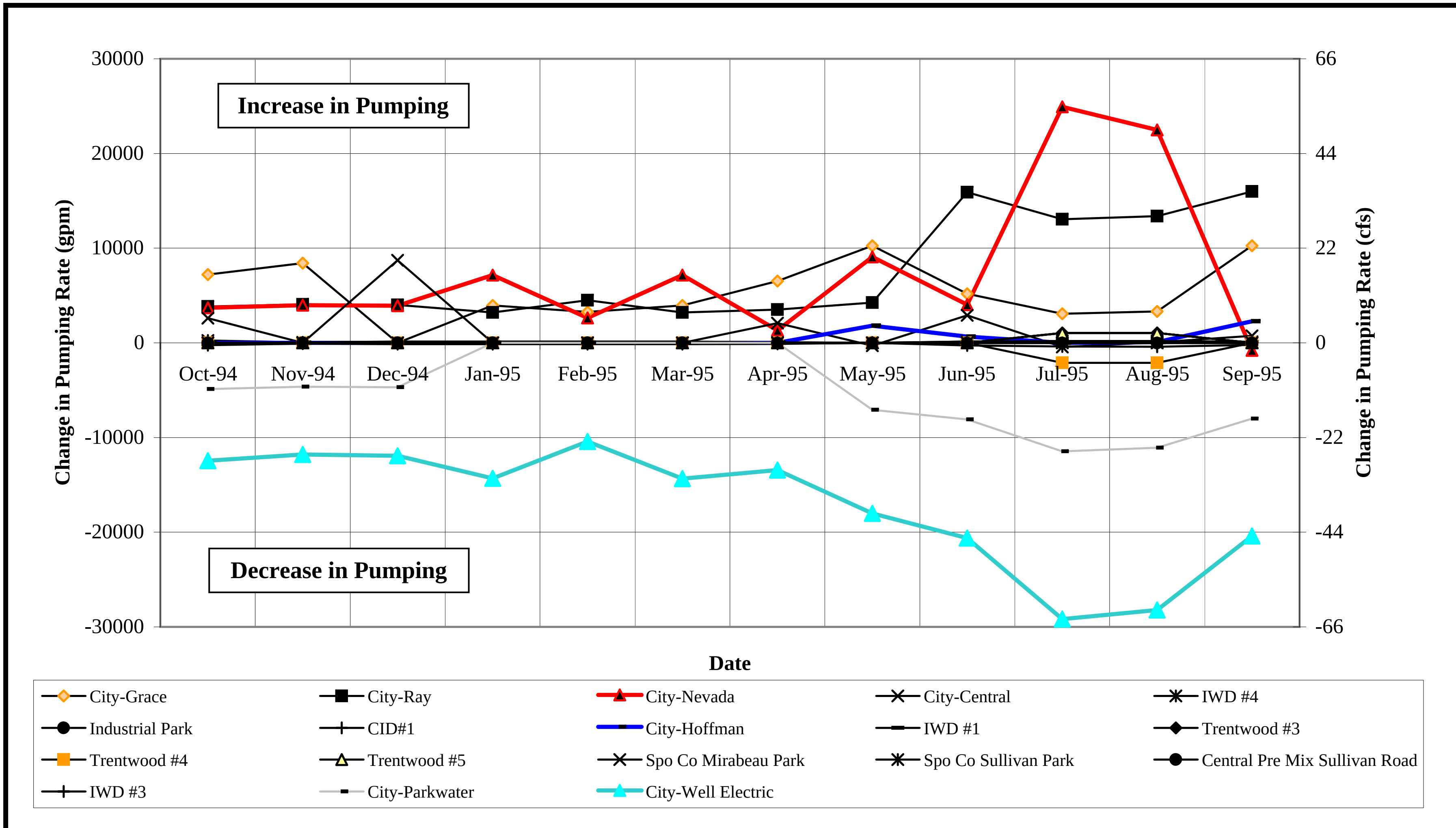
No change in discharge was observed in the Little Spokane River at Dartford (results not shown), presumably because it is located upgradient of the majority of the influence from the Hillyard Trough. There is a small decrease of between 1 cfs and 2.5 cfs in Little Spokane River flow near Dartford (Figure 6.6). This is most likely due to decreases in groundwater elevations in the Hillyard Trough attributed to increased pumping north of the Spokane River in the Trough. The largest impact occurs from November to February, while the smallest impact occurs from May to August.

6.2.2 Groundwater

The average change in groundwater elevations during the summer period (May through September) is shown in Figure 6.7. Positive numbers indicate an increase in groundwater head over Baseline conditions, while negative number indicates a decrease in groundwater head. Downstream of Sullivan Road to just upstream of Greene Street there is an increase in average groundwater elevations. Two of the largest decreases in groundwater pumping, peaking at a combined rate of almost 40,000 gpm (~89 cfs) occur upstream of Greene Street at the City-Parkwater and City-Well Electric wells. There is a general decrease in groundwater levels downstream of Greene Street, through the Hillyard Trough to the Little Spokane River, and through the Trinity Trough downstream of Spokane. This is an area to which additional pumping has been transferred, especially to the City-Nevada and City-Ray wells, as well as some additional abstraction to the City-Central and City-Hoffman wells.

6.2.3 Groundwater Surface Water Interaction

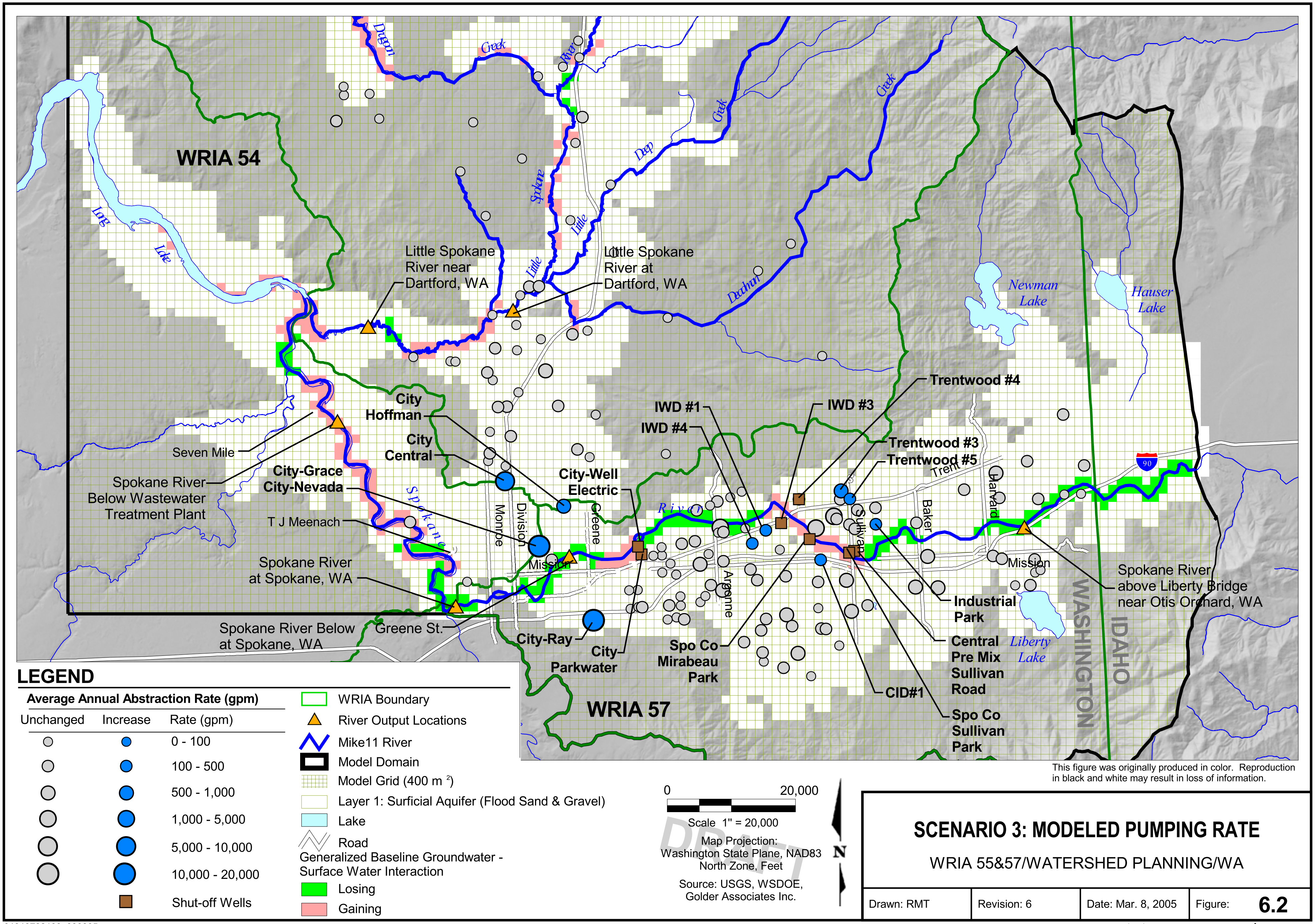
A snapshot profile of the Spokane River from Post Falls to the mouth of the Little Spokane River with baseflow results for Baseline and Scenario 3 is shown in Figure 6.8. Baseflow represents river-aquifer interactions. This figure shows that changes in groundwater-surface water interactions primarily occur between Upriver Control Works and the Trent Road Bridge. With the altered pumping state, discharge to the river is increased in the gaining reach between Upriver and Greene Street and recharge to the aquifer increases in the losing reach between Greene St. and Trent Rd. Bridge.



Golder Associates

WRIA 55 & 57/ WATERSHED PLANNING/ WA

TITLE	Scenario 3: Change in Groundwater Pumping				
DRAWN	JM	DATE	December 2004	JOB NO.	013-1372
CHECKED		SCALE		DWG. NO.	
REVIEWED		FILE NO.	Run # 031004	FIGURE NO.	6.1



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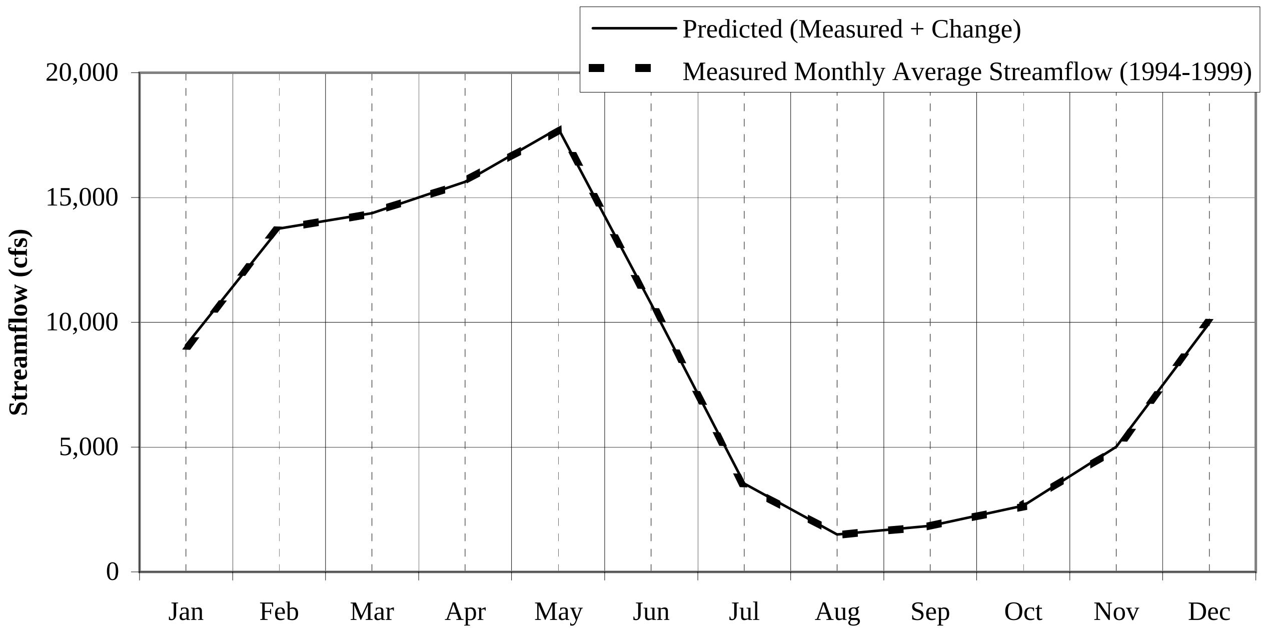
SCENARIO 3: MODELED PUMPING RATE

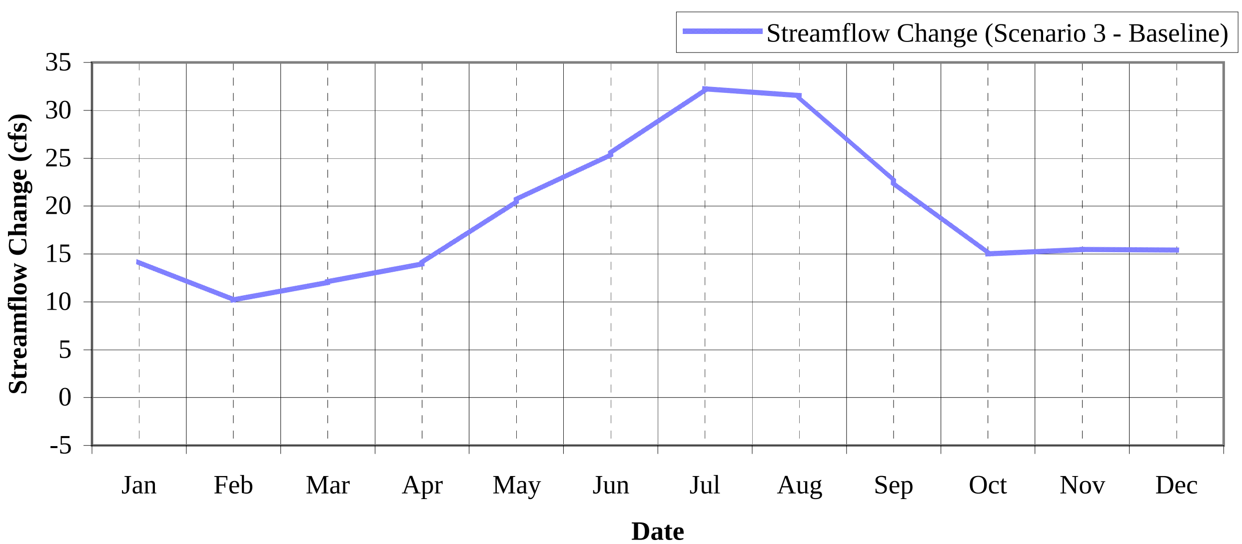
WRIA 55&57/WATERSHED PLANNING/WA

Drawn: RMT	Revision: 6	Date: Mar. 8, 2005	Figure: 6.2

01313722100_030805.apr

Golder Associates





Note: Model Outliers Removed

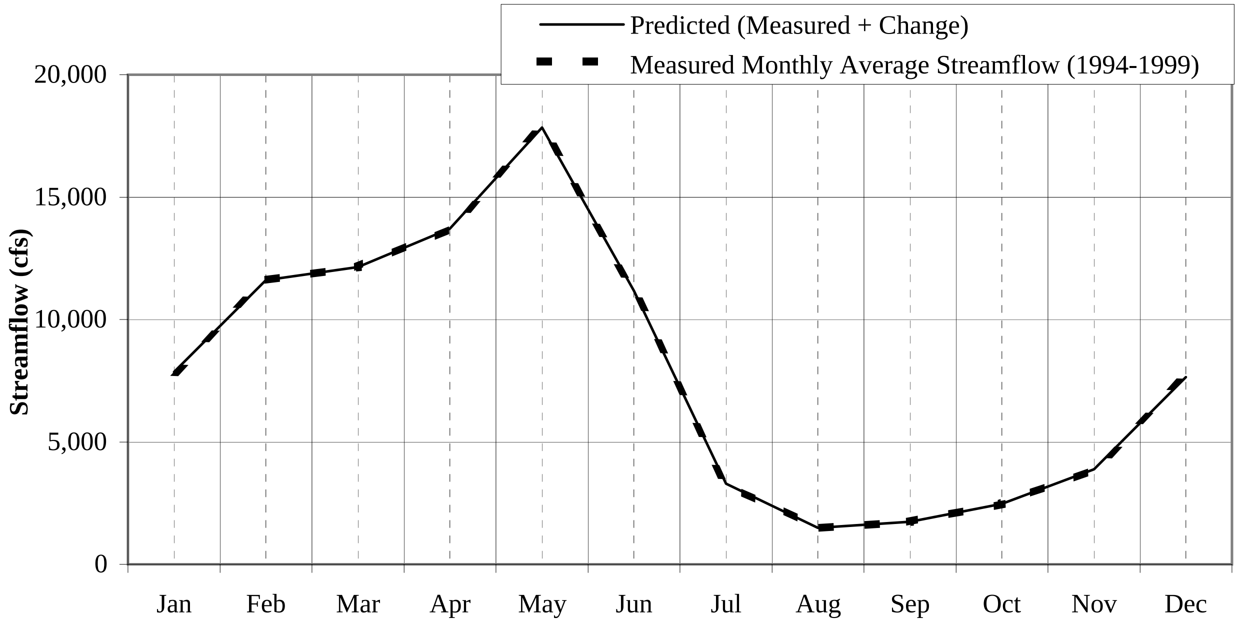
Golder Associates

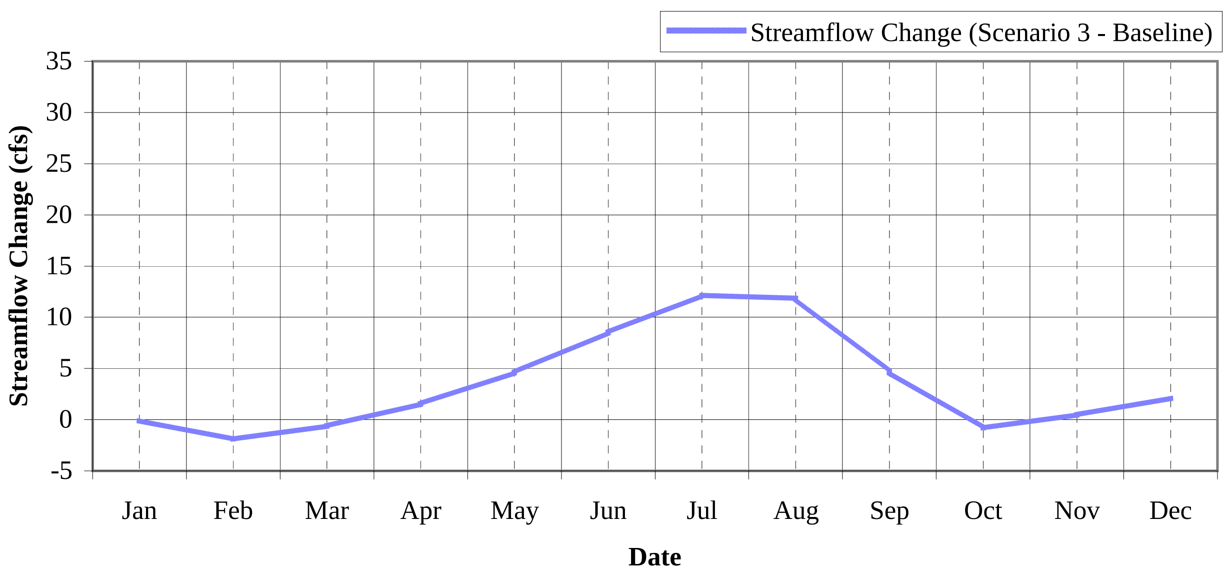
TITLE

Scenario 3: Spokane River below Greene St.
Monthly Streamflow Comparison

WRIA 55 & 57/ WATERSHED PLANNING/ WA

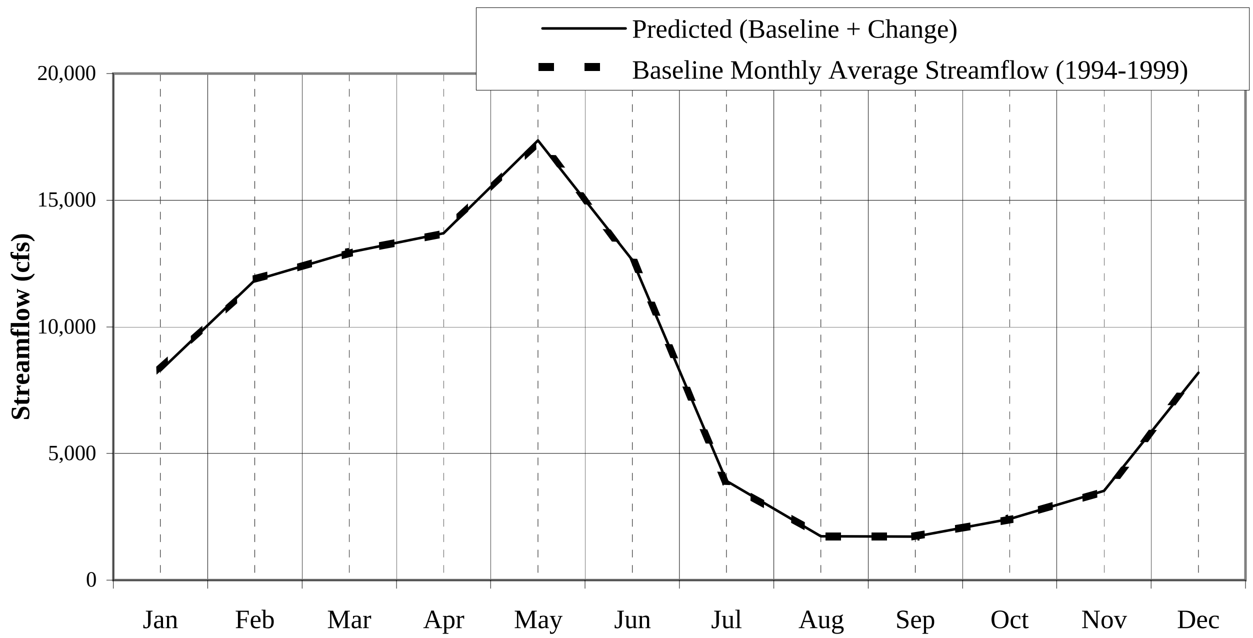
DRAWN	JM	DATE	December 2004	JOB NO.	013-1372
CHECKED		SCALE		DWG. NO.	
REVIEWED		FILE NO.	Run # 031004	FIGURE NO.	6.3

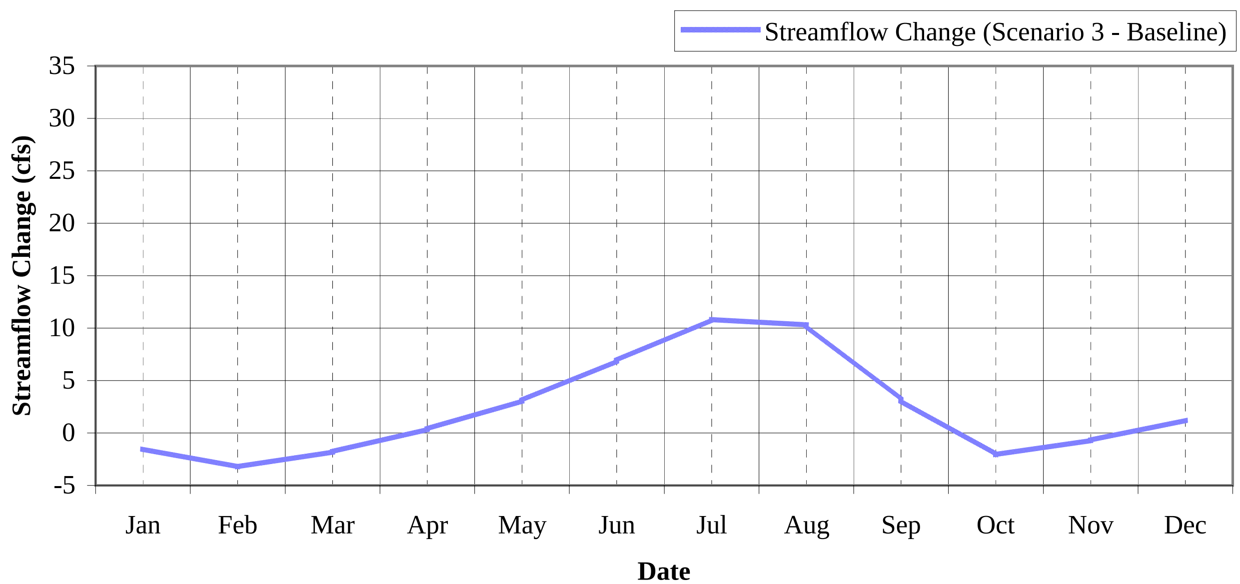




Note: Model Outliers Removed

Golder Associates	TITLE **Scenario 3: Spokane River at Spokane Monthly Streamflow Comparison**		
WRIA 55 & 57/ WATERSHED PLANNING/ WA	DRAWN JM	DATE December 2004	JOB NO. 013-1372
	CHECKED	SCALE	DWG. NO.
	REVIEWED	FILE NO. Run # 031004	FIGURE NO. 6.4





Note: Model Outliers Removed

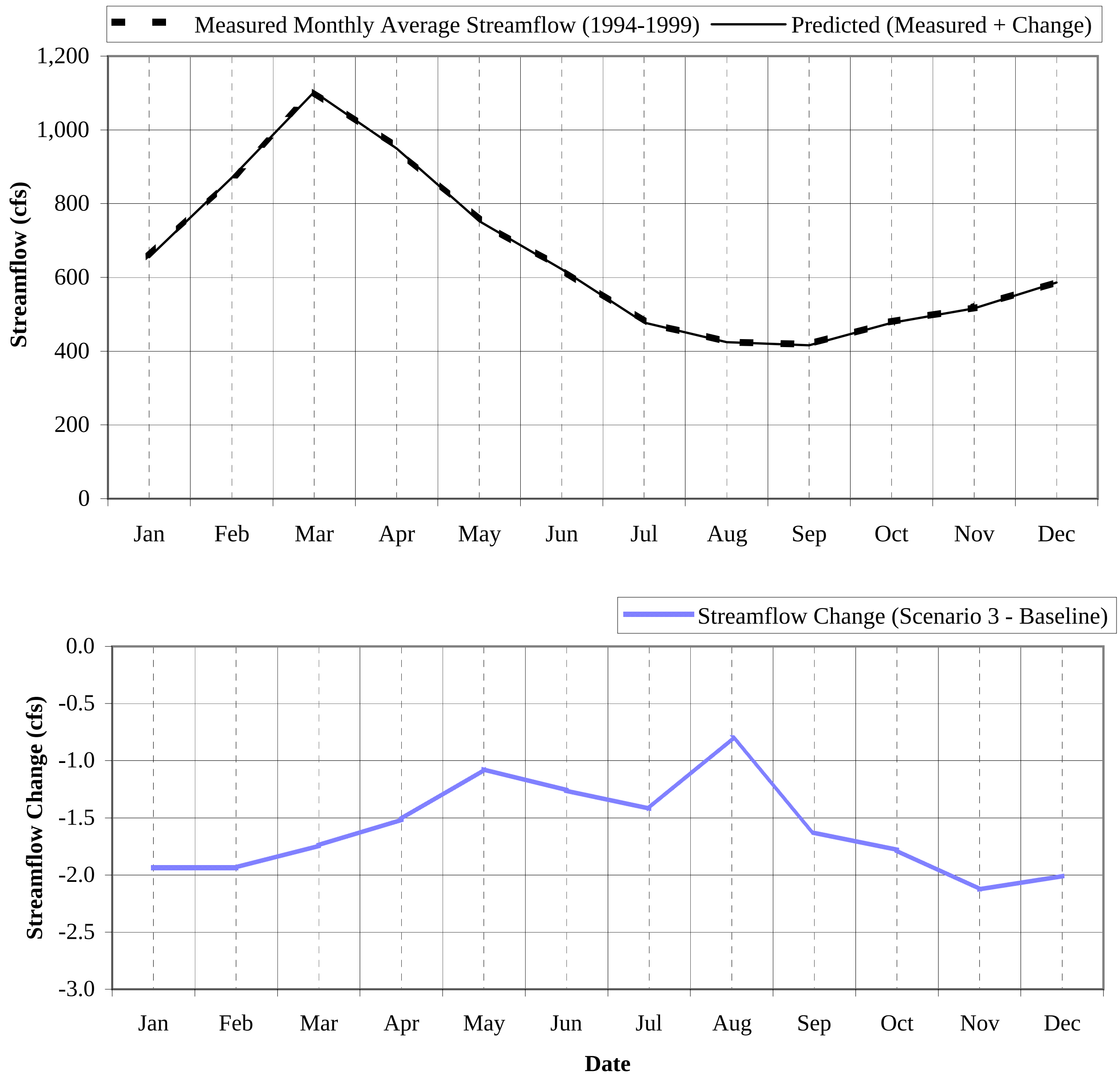
Golder Associates

TITLE

Scenario 3: Spokane River downstream of Wastewater Treatment Plant
Monthly Streamflow Comparison

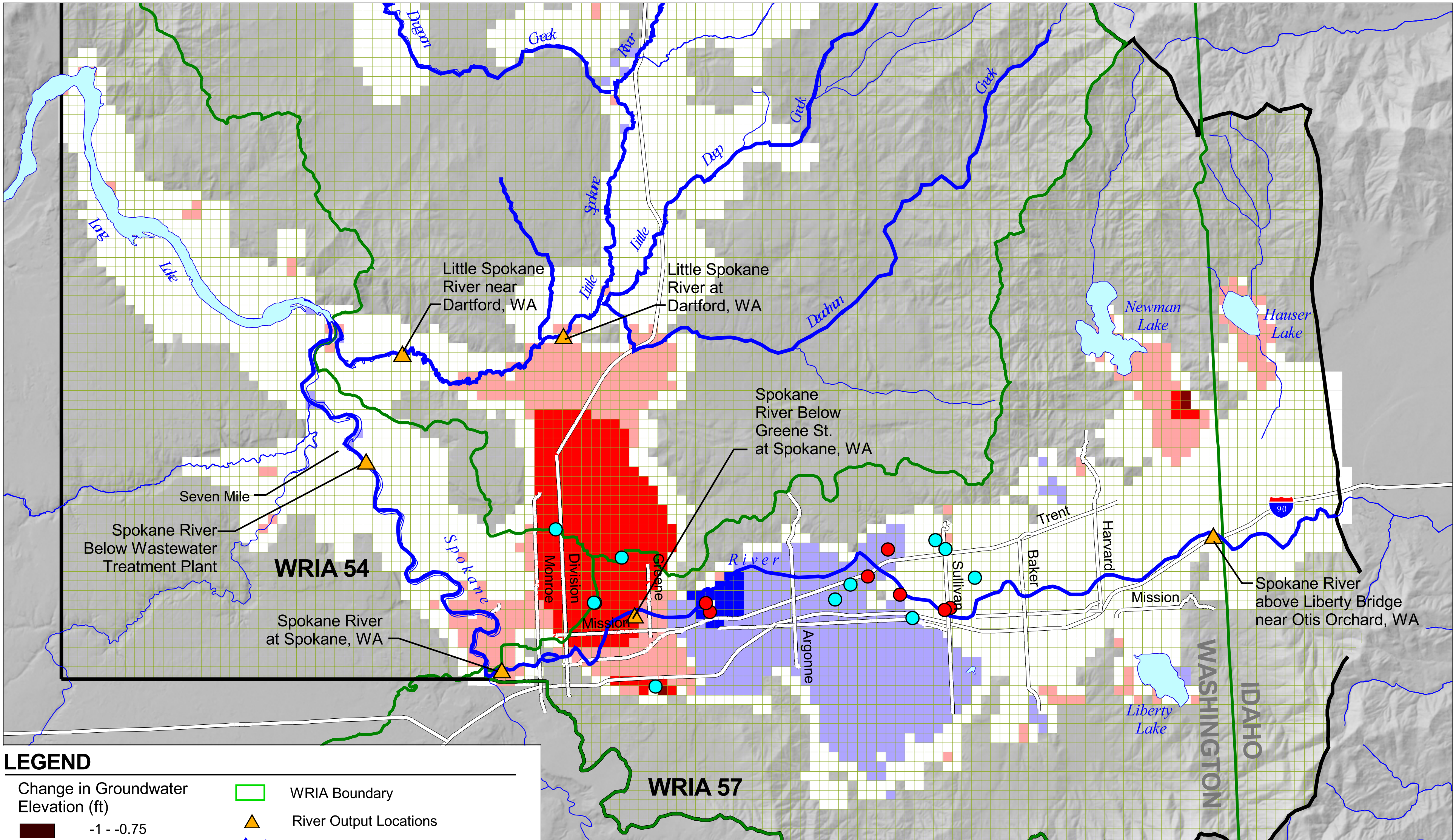
WRIA 55 & 57/ WATERSHED PLANNING/ WA

DRAWN JM	DATE December 2004	JOB NO. 013-1372
CHECKED	SCALE	DWG. NO.
REVIEWED	FILE NO. Run # 031004	FIGURE NO. 6.5



Note: Model Outliers Removed

Golder Associates	TITLE **Scenario 3: Little Spokane River near Dartford Monthly Streamflow Comparison**		
WRIA 55 & 57/ WATERSHED PLANNING/ WA	DRAWN JM	DATE December 2004	JOB NO. 013-1372
	CHECKED	SCALE	DWG. NO.
	REVIEWED	FILE NO. Run # 031004	FIGURE NO. 6.6



LEGEND

Change in Groundwater Elevation (ft)

- -1 - -0.75
- -0.75 - -0.5
- -0.5 - -0.25
- -0.25 - -0.01
- 0.01 - 0.25
- 0.25 - 0.5
- Decreasing Abstraction
- Increasing Abstraction
- WRIA Boundary
- River Output Locations
- Mike11 River
- Model Domain
- Model Grid (400 m²)
- Layer 1: Surficial Aquifer (Flood Sand & Gravel)
- Lake
- Road

0 20,000

Scale 1" = 20,000

Map Projection:
Washington State Plane, NAD83
North Zone, Feet

Source: USGS, WSDOE,
Golder Associates Inc.

N

This figure was originally produced in color. Reproduction in black and white may result in loss of information.

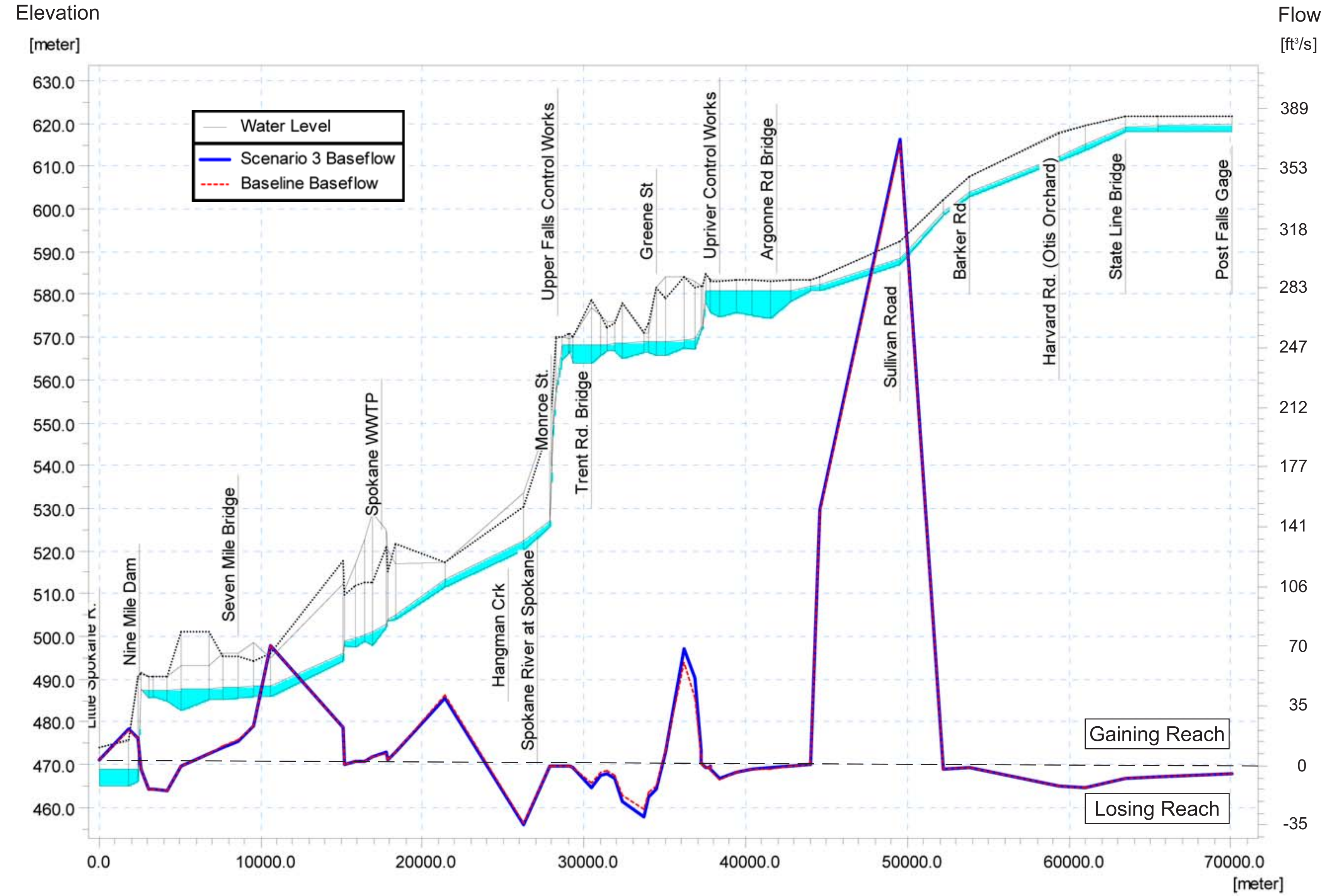
SCENARIO 3: AVERAGE CHANGE IN GROUNDWATER ELEVATION (MAY 1 TO SEP 31)

WRIA 55&57/WATERSHED PLANNING/WA

Drawn: RMT	Revision: 4	Date: Dec. 15, 2004	Figure: 6.7

01313722100_121504.apr

Golder Associates



Colored lines indicate the range of surface water – aquifer interactions simulated as baseflow during a typical run.
A line that is below 0.0 m3/s (right side y-axis) indicates that river water is infiltrating and recharging the aquifer (losing river reach).
Lines above 0.0 m3/s indicate that groundwater is discharging to surface water (gaining river reach).

Note: Results shown are from 8/24/1998. Run # SCEN3_031004C

FIGURE **6.8**

SCENARIO 3: PROFILE OF GAINING/LOSING REACHES
SPOKANE RIVER

WRIA 55 & 57/WATERSHED PLANNING/WA

DRAWING NO. 01313722100fg02.fh11 DATE 12/07/04 DRAWN BY EL

Golder Associates

7.0 SCENARIO 5: INCHOATE WATER RIGHTS

There is more water allocated than actually being used in WRIAs 55 and 57. The unused portions of water rights are referred to as inchoate water rights. In Scenario 5, the full future use of water rights are simulated, including the associated effects of wastewater discharge and expanded lawn irrigation, in order to assess the projected distribution and magnitude of impact to stream flow and groundwater elevations throughout the watershed.

Municipal and domestic water users in WRIA 55 and 57 use approximately 145,000 AF/yr, or less than half of their administratively issued water rights (~300,000 AF/yr). Legislation passed in 2003 (House Bill 1338, the "Muni Bill") allows the full development of inchoate water rights held by municipal purveyors under certain conditions. The definition of municipal purveyors includes water systems with 15 or more connections.

Portions of water rights for non-municipal purposes of use may not be valid if they have never been used, or have not been used for any continuous five-year period. Such rights may be considered relinquished. Therefore, non-municipal water rights issued for other purposes of use are assumed to be valid only to the degree that they are currently used. To simulate possible maximum future water use under currently issued water rights, the full volume of water rights issued for municipal and domestic purposes of use plus all other current uses of water was modeled. This is the same as the baseline simulation of current use (Scenario 1) plus the exercise of inchoate municipal water rights.

Comparison of annual quantities of water used under current, 20-year projections (Scenario 1), and full exercise of municipal inchoate water rights is presented in Figures 7.1 and 7.2.

7.1 Model set-up

Water rights were summed on the basis of the township, range, and section from information provided from the Washington Department of Ecology Water Rights Application Tracking System (WRATS) database. The database contains information about water right permits and certificates, including maximum annual amount of water allowed to be withdrawn (expressed in acre-feet) and the maximum instantaneous allowable pumping rate (expressed in gpm). Comparison of the ratios of the annual quantities to instantaneous quantities confirmed that most of the annual quantity would still be withdrawn within the limitations of instantaneous quantity of the water rights and their monthly demand patterns. Therefore, the annual quantities of water rights were used in simulating future extraction volumes. Water rights were correlated by Spokane County staff to approved water plans in order to more accurately simulate the location of abstraction (Figure 7.3).

The monthly distribution of water production by major municipal purveyors was used (Figure 7.4) to represent monthly residential water demand. This pattern of use reflects constant year round total demand by residential indoor use and other users (e.g., non-seasonal commercial and retail uses), as well seasonal landscape irrigation. Residential use patterns used in the baseline scenario have slightly higher summer demand and lower winter demand because it does not account for the more constant year-round use by non-residential uses. Although municipal demand patterns are considered more representative of total water use, the refinement is minimal and use of the baseline scenario to evaluate the inchoate scenario is considered valid for comparison purposes.

The modeled groundwater abstraction input is shown in Figure 7.5. Groundwater pumping to full allocated municipal and domestic water rights in WRIA 57 results in increased pumping of approximately 160 mgd (250 cfs) above baseline conditions during the summer, and between 64 and 100 mgd (100 cfs and 150 cfs) during the winter.

The modeled increase in municipal and domestic water use is accompanied by increased wastewater discharge and increased lawn irrigation. Wastewater dischargers currently modeled in the system include Deer Park, Liberty Lake, City of Spokane and Diamond Lake. Discharge was increased proportionally to the increase in the associated municipal systems and discharged into the river from the City of Spokane WWTP at Liberty Lake and Spokane, and applied to the ground by Deer Park and Diamond Lake Sewer Districts. Increased lawn irrigation is accounted for by an enlargement in the spatial extent of irrigated lawns (Figure 7.6). Added irrigation areas were located in the closest proximity possible of the corresponding water right within the limitations of the spatial resolution of the model. The rate of water applied to lawns was not changed and it is assumed that all additional lawn areas are served by purveyor wells (not individual private exempt wells).

7.2 Results

The water balance results indicate the model withdrew 91% of the groundwater demand specified in the model input files. The majority of the wells that ran dry at some time during the model run are located outside the boundaries of the primary aquifers, where the model layers are a relatively shallow veneer above the crystalline basement (Figure 7.7). The greatest percentage of unfulfilled groundwater demand occurs during the summer when the pumping rates are the larger and groundwater levels lowest (Figure 7.8). Therefore, predicted impacts may be slightly lower than if all requested abstraction was fulfilled.

There are 3 possible explanations for the failure of the model to fully extract the specified withdrawal. This may be an artifact of the model setup, the aquifer system may not be able to yield the specified quantities, or there may be errors in the registration of water right locations in the WRATS database. The locations of the wells were selected based on the registered points of withdrawal in Ecology's Water Rights Application Tracking System (WRATS) database, modified by Spokane County to reflect the actual current points of withdrawal where actual locations were know to be different from the database.

7.2.1 Surface Water

Surface water results are presented in Figures 7.9 through 7.11. The upper frame of each figure shows the measured monthly hydrograph for the location (shown as a dashed line) and the measured monthly hydrograph with the predicted change in streamflow added (shown as a solid line). This provides a visual of the relative impact of the change in streamflow to actual streamflow. The modeled change in discharge is displayed in the lower frame along with the change in abstraction.

Spokane River

Figure 7.9 and 7.10 show the influence of groundwater abstraction on the Spokane River at Spokane, and downstream of the City of Spokane WWTP. Results of the model simulation predict a model-run average discharge reduction of approximately 150 cfs to the Spokane River at Spokane. The most substantial streamflow reduction coincides with peak groundwater abstractions during the mid to late summer, resulting in a reduction of approximately 215 cfs. During the winter off-peak groundwater use, the Spokane River discharge is reduced by approximately 105 cfs.

The model predicts a significant portion of the increase in groundwater pumping is reflected by a reduction in river flow. Spokane River flow at Spokane is reduced by approximately 80% of the peak use and 64% of off-peak groundwater use. These results are consistent with the findings of the 20-year growth simulation and the known hydrogeologic connection of the Spokane River and the SVRP Aquifer. The remaining groundwater abstraction not observed in river discharge change may be accounted for by buffering of impacts by groundwater storage, losses due to evapotranspiration from landscape irrigation, and changes to groundwater flow through the Hillyard and Trinity Troughs.

The impacts to the Spokane River downstream of the City of Spokane WWTP are predicted to be less than at Spokane as a result of return flows from the WWTP. River discharge below the WWTP is reduced from the baseline condition by an average of 83 cfs. During peak, summer, groundwater pumping, the river discharge decreases approximately 153 cfs. During off-peak, winter, groundwater pumping, the river discharge decreases approximately 34 cfs. Comparing the river discharges between Spokane and downstream of the City of Spokane WWTP, the return flow from the treatment plant and groundwater contributions along the stretch in between the two points, restores approximately 50 cfs to the streamflow.

There is no significant lag between the time periods of maximum groundwater withdrawal and peak differences in river discharge (Figures 7.9 and 7.10). The majority of groundwater abstraction occurring within WRIA 57 is located within the boundaries of the SVRP Aquifer. The lack of significant lag time between the time of withdrawals and observed impacts on streamflow is a result of the high conductivity of the aquifer, and the high degree of hydraulic continuity between the river and the aquifer.

Little Spokane River

The increase in groundwater pumping in WRIA 55 (presented in the lower frame of Figure 7.11) shows a dip in pumping rates between August and October. This is believed to due to modeled wells going dry during this period. Further investigation could clarify this issue. Full exercise of inchoate water rights is predicted to reduce the average annual flow of the Little Spokane River at Dartford by approximately 13 cfs (Figure 7.11). Groundwater withdrawal rates peak in July, while impacts on the Little Spokane River peak between November and January; a lag time of three to five months. Maximum changes in river discharge in the Little Spokane River occur between November and January, reducing streamflow by as much as 18 cfs, whereas minimum streamflow reductions occur during August and result in reduced streamflow of approximately 11 cfs.

The streamflow monitoring point at Dartford is mostly upstream of influence of the Hillyard Trough. Therefore the assessment of impacts from groundwater withdrawals on streamflow at Dartford represents impacts from increased withdrawals from upstream points throughout WRIA 55, with minimal influence from groundwater development in WRIA 57 and downstream portions of WRIA 55. The lag time between peak withdrawals and associated peak reduction of streamflows is interpreted to be a result of the diffuse distribution of the points of withdrawal throughout the upstream portion of the WRIA 55 watershed, and the buffering effects of groundwater storage.

Although the timing of discharge changes do not directly coincide with peak groundwater abstraction at Dartford, the changes in volume between groundwater and river discharge reasonably correspond, with peak pumping changes and peak river flow changes of approximately 17 cfs.

7.2.2 Groundwater

Groundwater elevations were averaged from June 1 to September 30, 1999 for both the inchoate and baseline scenarios. The averaged groundwater elevations from the baseline scenario were subtracted from the averaged inchoate scenario to calculate the change in groundwater levels (Figure 7.12). The largest impacts occur in the SVRP Aquifer west of Sullivan Road and extending through the Hillyard Trough.

East of Sullivan Road, the results show a minimal increase (about 2 inches) in groundwater elevation; this is counterintuitive because of the increase in pumping volume within this area. Using data from the same four month period in 1998 actually shows an expected groundwater level decrease. The fluctuation between years suggests that the aquifer is relatively insensitive to the different levels of development, and that the results reflect numerical noise of the model simulation. The relative insensitivity of this portion of the aquifer is attributed to the very high hydraulic conductivity of the aquifer, and the model boundary condition on the east side of this area, which is a fixed, seasonally varying head. The boundary condition reflects current conditions and does not reflect future conditions that may exist as a result of development on the Idaho side of the state boundary. The boundary condition in the future may be lower, which would be expected to result in a general decrease in groundwater levels in this area.

Smaller areas of larger impacts occur near Hauser and Liberty Lakes, near the confluence of Deadman Creek with the Little Spokane River, and in the Upper Dragoon drainage. These areas are generally within the vicinity of wells that have significant unused portions of inchoate water rights. Groundwater levels for five groundwater locations in WRIA 55 & 57 under the baseline and inchoate scenarios are compared below.

WRIA 57

SVRP Aquifer

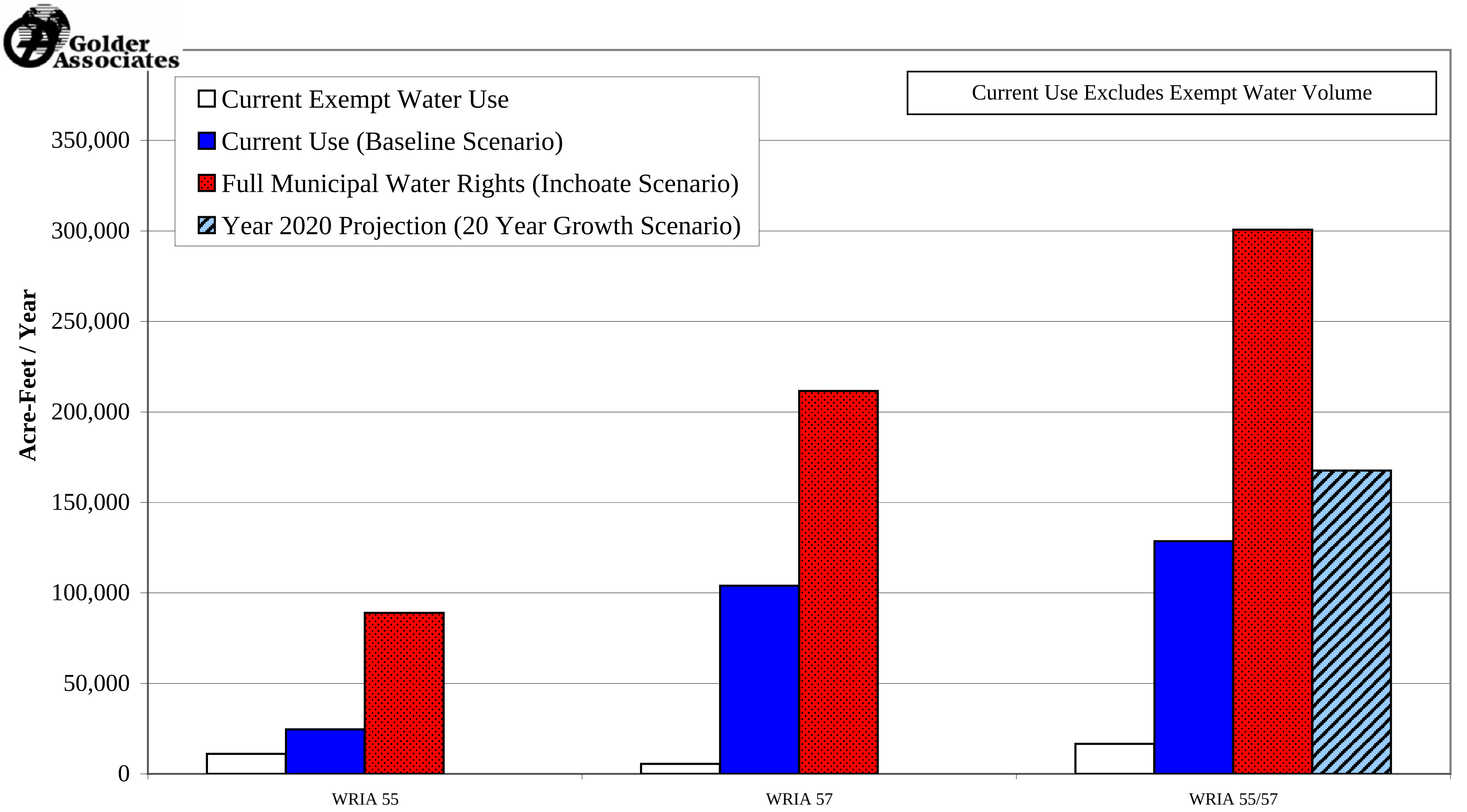
Groundwater levels in the City-Central PreMix and Vera #6 wells show similar seasonal and pumping responses to baseline groundwater levels; except that groundwater levels in the inchoate scenario are lower (Figures 7.13 and 7.14). The most pronounced differences in groundwater elevation coincide with the summer peak groundwater demand. In general, the increased pumping lowers groundwater elevation by approximately 2 to 5 feet during the summer months. (These water levels represent average aquifer groundwater levels across a model cell, which is 400 m by 400 m.) Aquifer groundwater levels recover quickly during the winter to within one foot of baseline levels.

The Dakota Well is located at the northern end of the HIllyard Trough portion of the SVRP Aquifer near the at Dartford gage (Figure 7.12). Groundwater elevations for this location show a general decrease in elevations throughout the model simulation, though not as pronounced as in the upgradient portions of the SVRP Aquifer. Groundwater levels decrease a little over two feet during the summer months, and recover to approximately one foot below baseline groundwater levels during the winter (Figure 7.15).

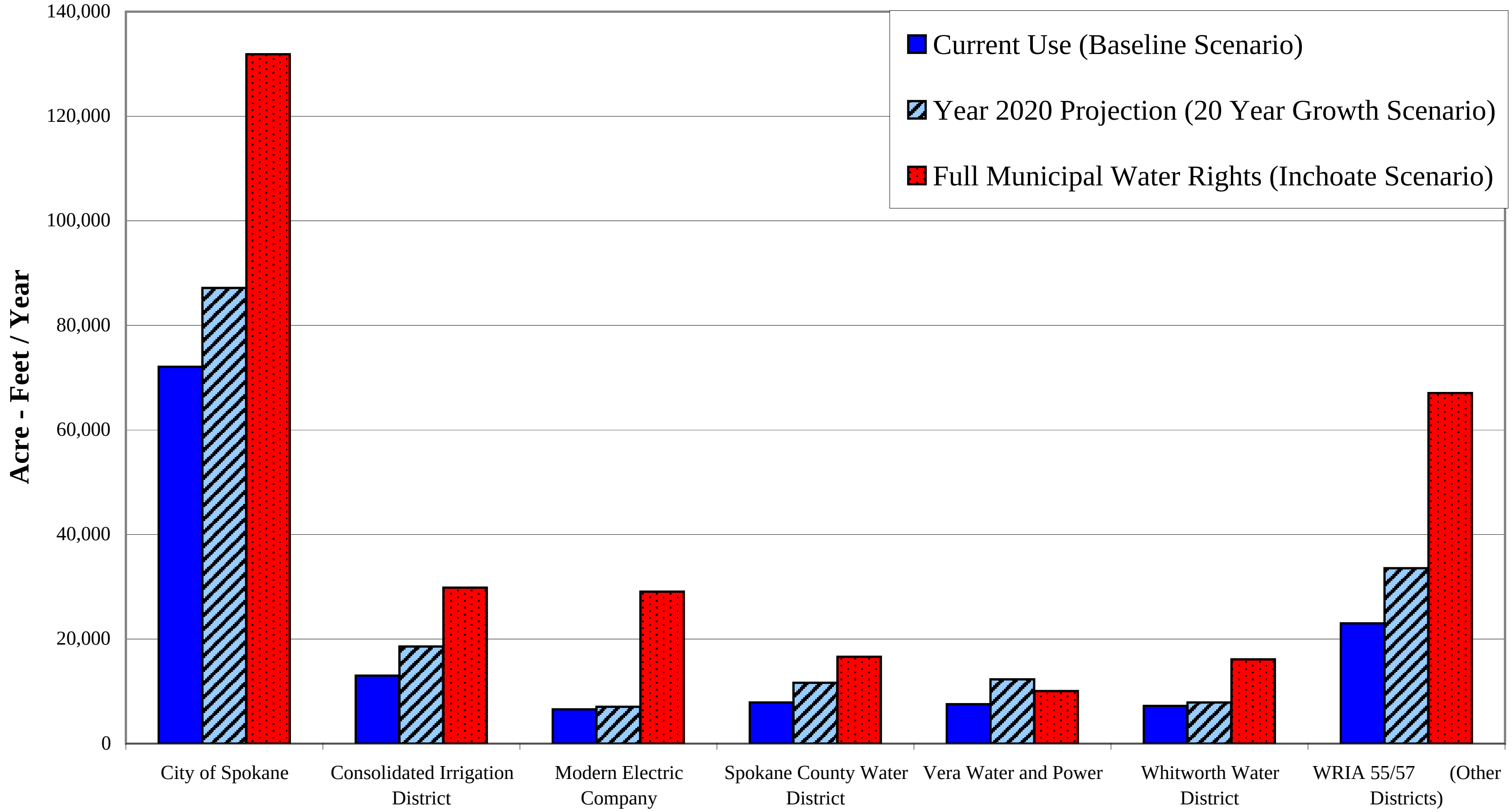
The trend of groundwater levels across the full simulation period in the Deer Park and Diamond Aquifer wells in both the baseline and inchoate scenarios is interpreted to be a result of continuing model convergence, as discussed in the original Model Simulation Report (Golder, 2004). Therefore, interpretations between the baseline and inchoate scenarios are based on the relative change between the scenarios.

Groundwater levels in pumping well in the Deer Park aquifer are lower year-round by approximately one foot in the inchoate scenario relative to the baseline scenario (Figure 7.16). The results indicate that the level of development is sustainable relative to current development because there is not an increasing impact over time.

Groundwater levels in the Diamond Lake Aquifer are on the order of one foot below baseline groundwater elevations (Figure 7.17). However, the difference between the inchoate and baseline simulations decreases through the progression of the simulation. This is interpreted to be an artifact of the model, and was also recognized in the pre-development simulation. This point was not calibrated in the baseline scenario because time series data were not available. The software developer (DHI, Inc.) is examining possible causes of these artifacts.



Golder Associates	TITLE **WRIA Municipal/Domestic Water Use Comparison**		
WRIA 55 & 57/ WATERSHED PLANNING/ WA	DRAWN JM	DATE June 2004	JOB NO. 013-1372
	CHECKED	SCALE	DWG. NO.
	REVIEWED	FILE NO.	FIGURE NO. 7.1



Golder Associates	TITLE				
	Major Water Districts Municipal/Domestic Water Use Comparison				
WRIA 55 & 57/ WATERSHED PLANNING/ WA	DRAWN JM	DATE June 2004	JOB NO. 013-1372		
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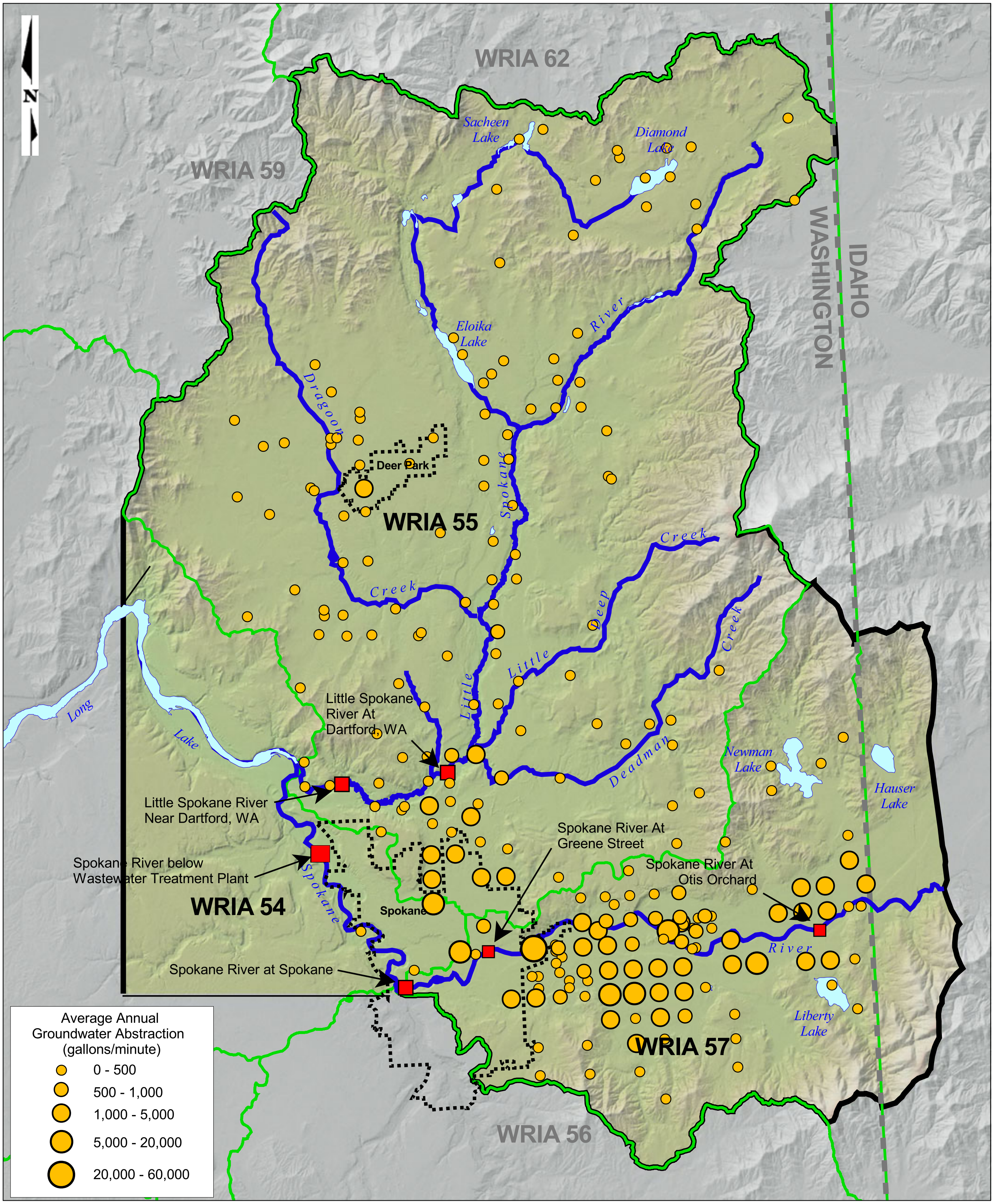
	REVIEWED	FILE NO.	FIGURE NO. 7.2		



LEGEND

- Surface Water Monitoring Locations
- WRIA Boundaries
- Lakes
- Mike11 Rivers
- Model Domain

0 30,000

Scale 1" = 30,000 Feet

Map Projection:
Washington State Plane, NAD83,
North Zone, Feet

Source: USGS, WSDOE,
Golder Associates Inc.

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Scenario 5: Abstraction Well Withdrawal Input

WRIA 55&57/WATERSHED PLANNING/WA

Drawn:GKL	Revision: 2	Date: Dec. 16, 2004	Figure: 7.3

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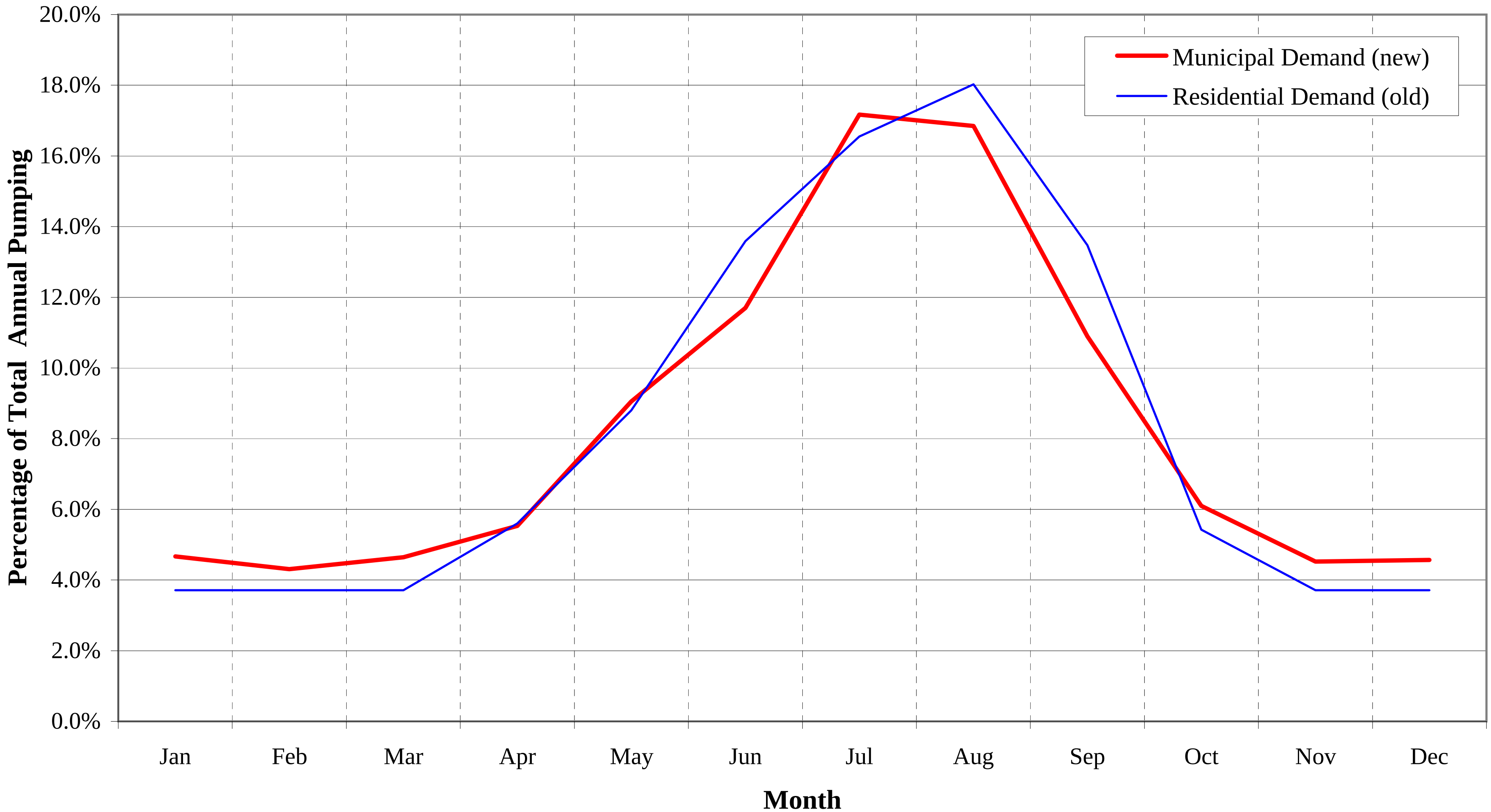
Golder Associates



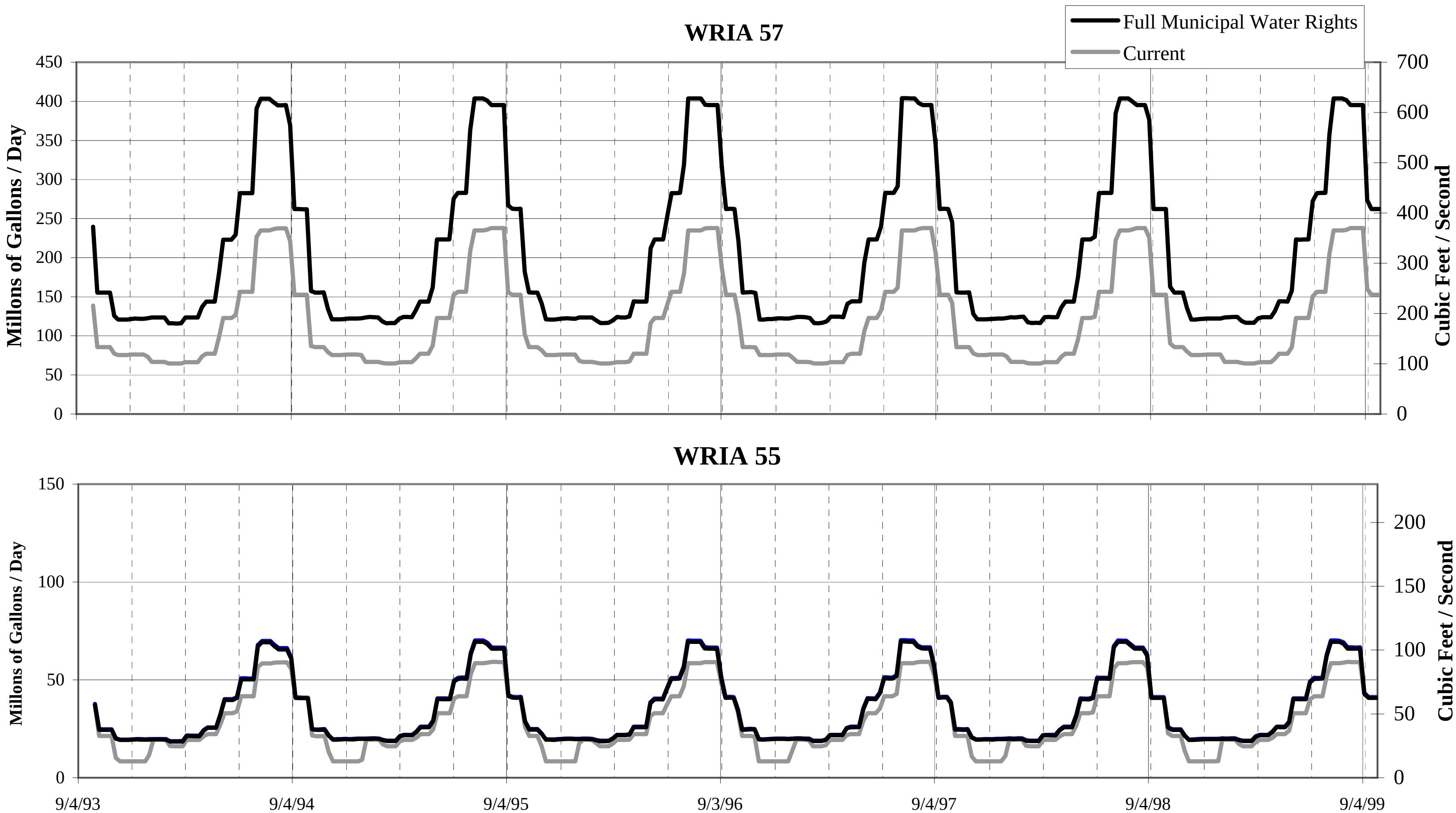
Golder Associates

TITLE

Monthly Water Demand Schedule Comparison

WRIA 55 & 57/ WATERSHED PLANNING/ WA

DRAWN	JM	DATE	June 2004	JOB NO.	013-1372
CHECKED		SCALE		DWG. NO.	
REVIEWED		FILE NO.		FIGURE NO.	7.4



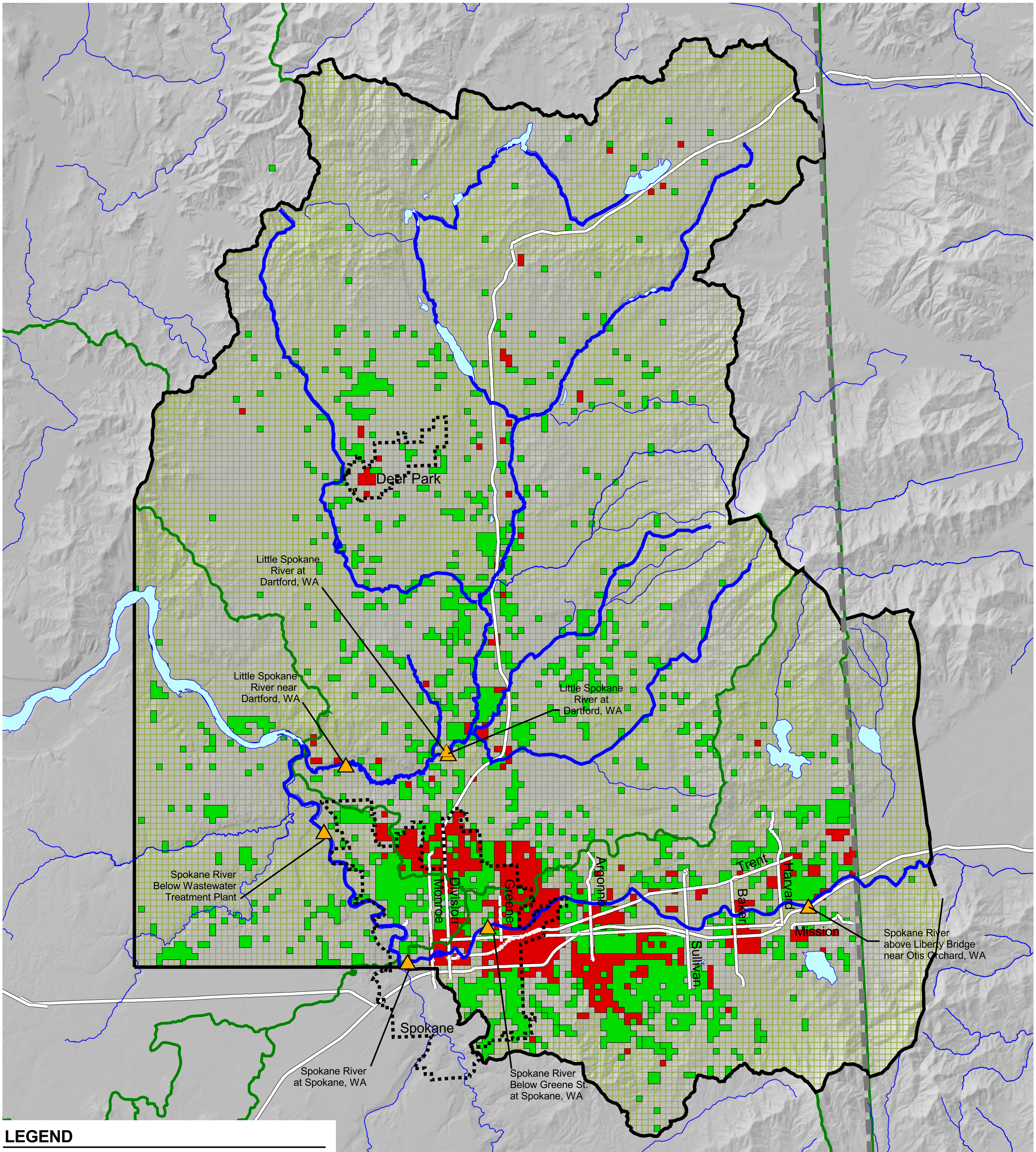
Golder Associates

TITLE

Comparison of Groundwater Abstraction Output for Baseline and Scenario 5

WRIA 55 & 57/ WATERSHED PLANNING/ WA

DRAWN	JM	DATE	December 2004	JOB NO.	013-1372
CHECKED		SCALE		DWG. NO.	
REVIEWED		FILE NO.	Run # 060804	FIGURE NO.	7.5



LEGEND

Irrigation Area

- Current Irrigated Area
- Full Water Rights Additional Irrigated Area
- River Output Locations
- WRIA Boundary
- Model Domain
- Model Grid (400 m^2)
- Lakes
- Mike 11 River
- Road
- State Boundary

0 30,000

Scale 1" = 30,000

Map Projection: Washington State Plane, NAD83 North Zone, Feet

Source: USGS, WSDOE, Golder Associates Inc.

N

This figure was originally produced in color. Reproduction in black and white may result in loss of information.

Scenario 5: Projected Spatial Change in Lawn Irrigation

WRIA 55&57/WATERSHED PLANNING/WA

Drawn: RMT	Revision: 1	Date: Dec. 16, 2004	Figure: 7.6

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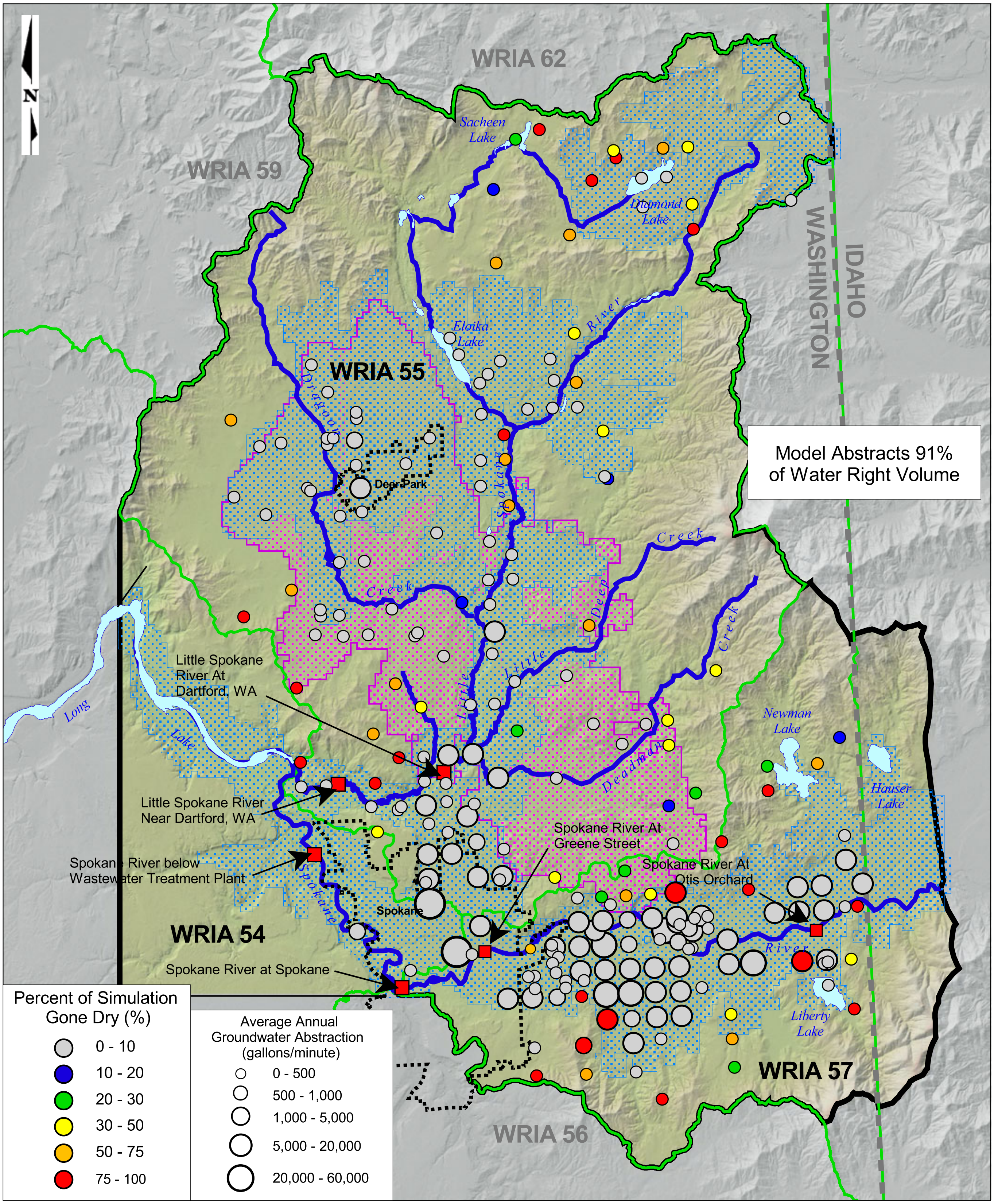
Golder Associates



LEGEND

- Surface Water Monitoring Locations
- WRIA Boundaries
- Lakes
- Mike11 Rivers
- Qfg Aquifer Boundary
- Tgr Aquifer Boundary
- Model Domain

0 30,000

Scale 1" = 30,000 Feet

Map Projection:
Washington State Plane, NAD83,
North Zone, Feet

Source: USGS, WSDOE,
Golder Associates Inc.

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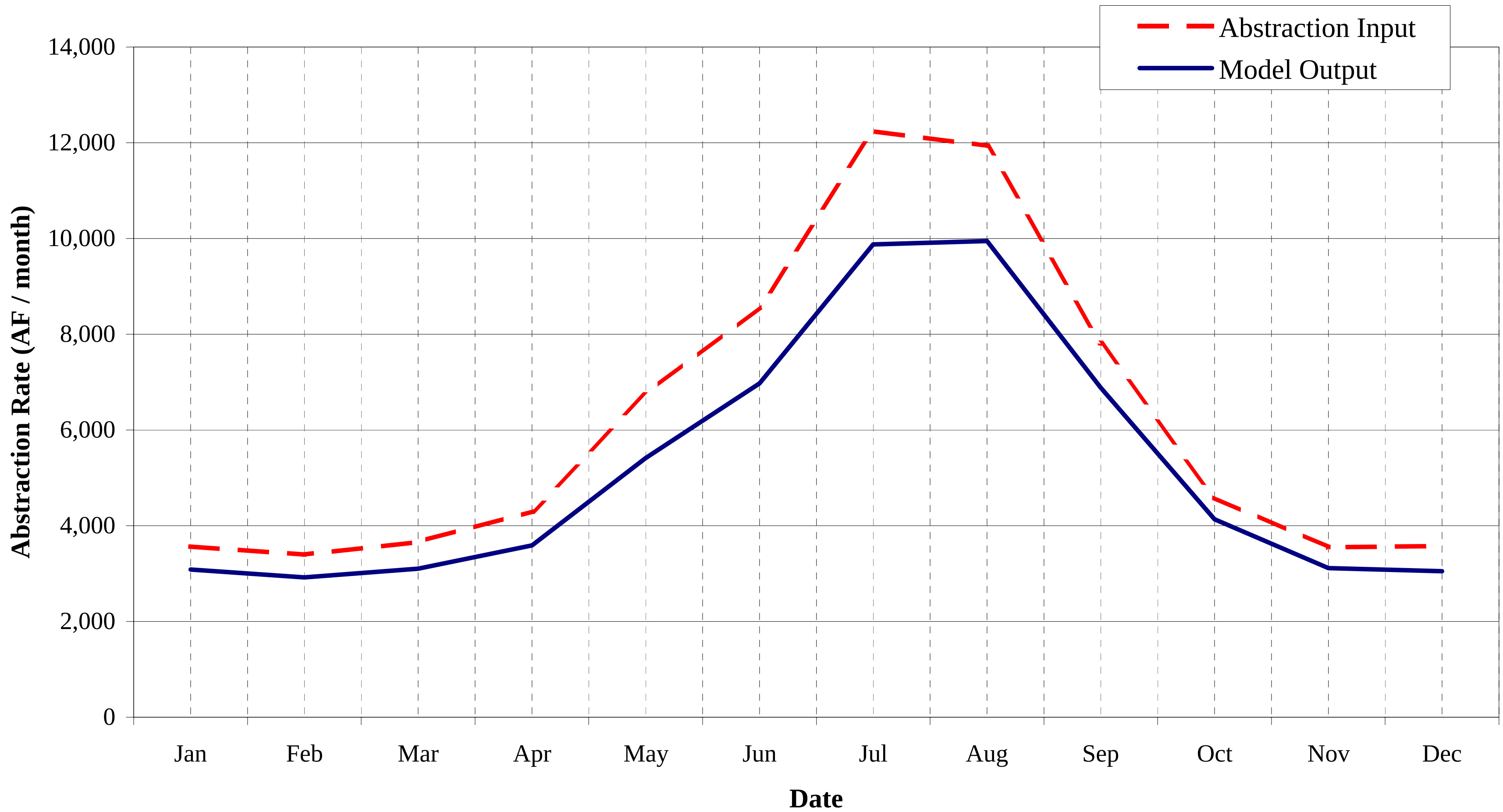
Scenario 5: Volume of Water Not Abstracted

WRIA 55&57/WATERSHED PLANNING/WA

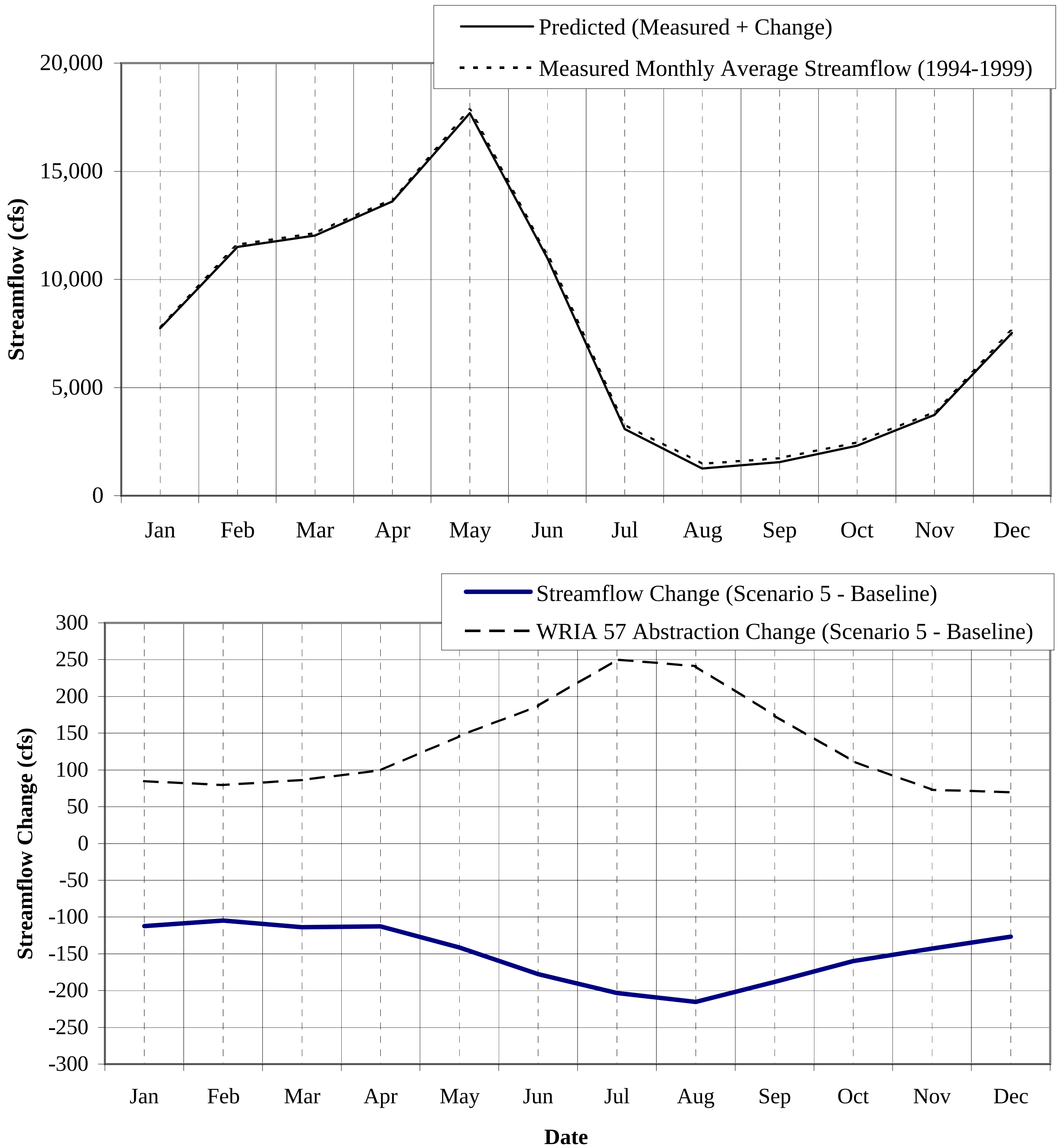
Drawn:GKL	Revision: RMT	Date: Dec. 16, 2004	Figure: 7.7

01313722100_121504.apr

Golder Associates



Golder Associates	TITLE **Comparison of Groundwater Pumping: Model Output vs Input**					
WRIA 55 & 57/ WATERSHED PLANNING/ WA	DRAWN JM		DATE December 2004		JOB NO. 013-1372	
	CHECKED		SCALE		DWG. NO.	
	REVIEWED		FILE NO. Run # 060804		FIGURE NO. 7.8	



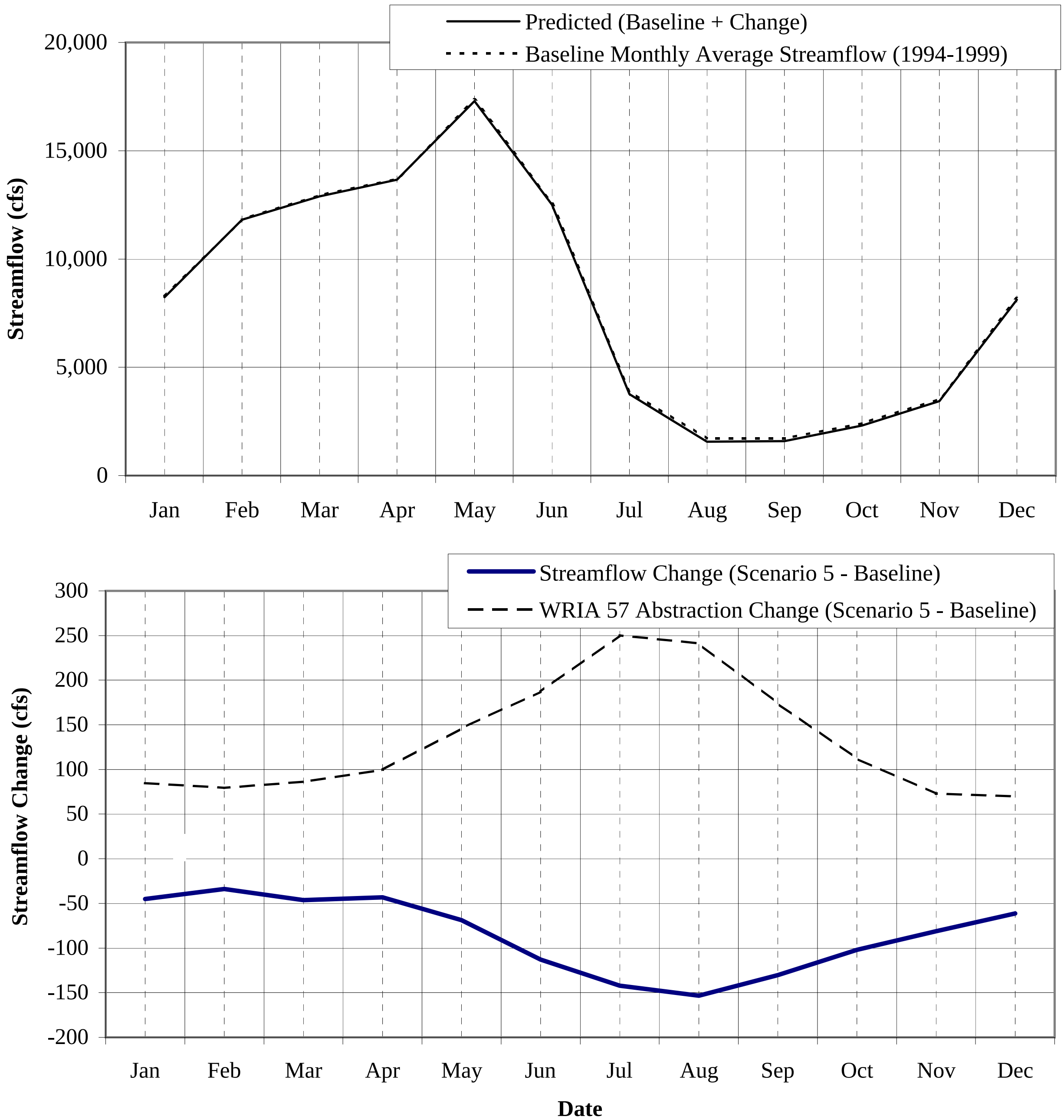
Golder Associates

TITLE

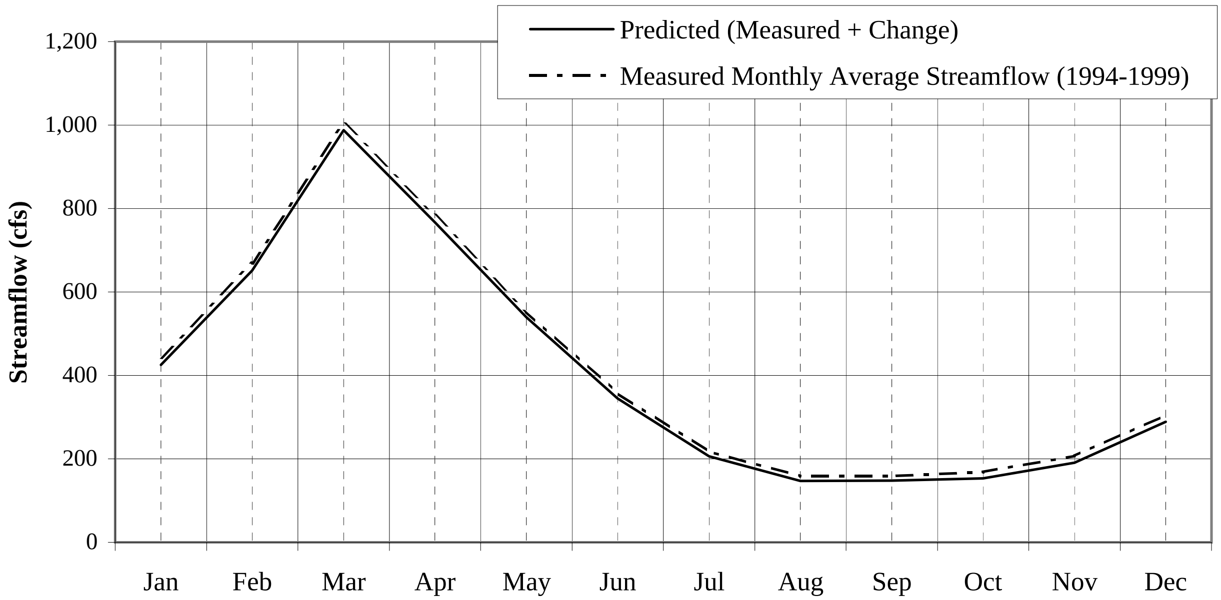
Scenario 5: Spokane River at Spokane
Monthly Streamflow Comparison

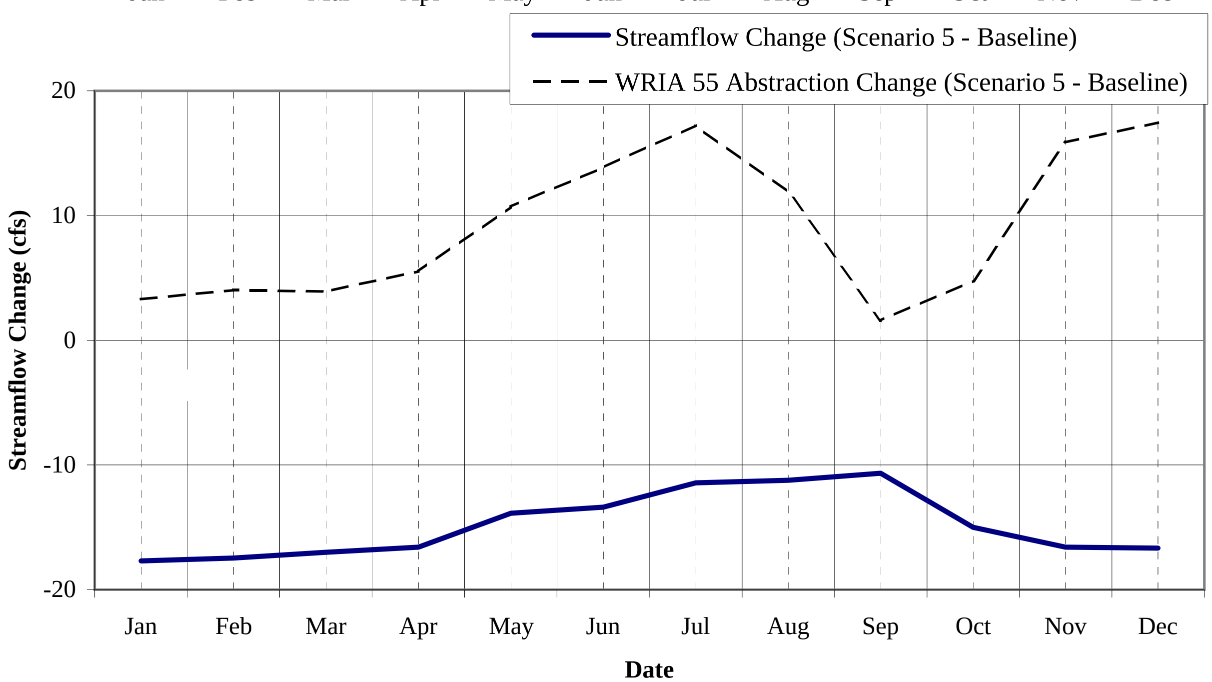
WRIA 55 & 57/ WATERSHED PLANNING/ WA

DRAWN	JM	DATE	December 2004	JOB NO.	013-1372
CHECKED		SCALE		DWG. NO.	
REVIEWED		FILE NO.	Run # 060804	FIGURE NO.	7.9



Golder Associates	TITLE **Scenario 5: Spokane River downstream of Wastewater Treatment Plant Monthly Streamflow Comparison**		
WRIA 55 & 57/ WATERSHED PLANNING/ WA	DRAWN JM	DATE December 2004	JOB NO. 013-1372
	CHECKED	SCALE	DWG. NO.
	REVIEWED	FILE NO. Run # 060804	FIGURE NO. 7.10





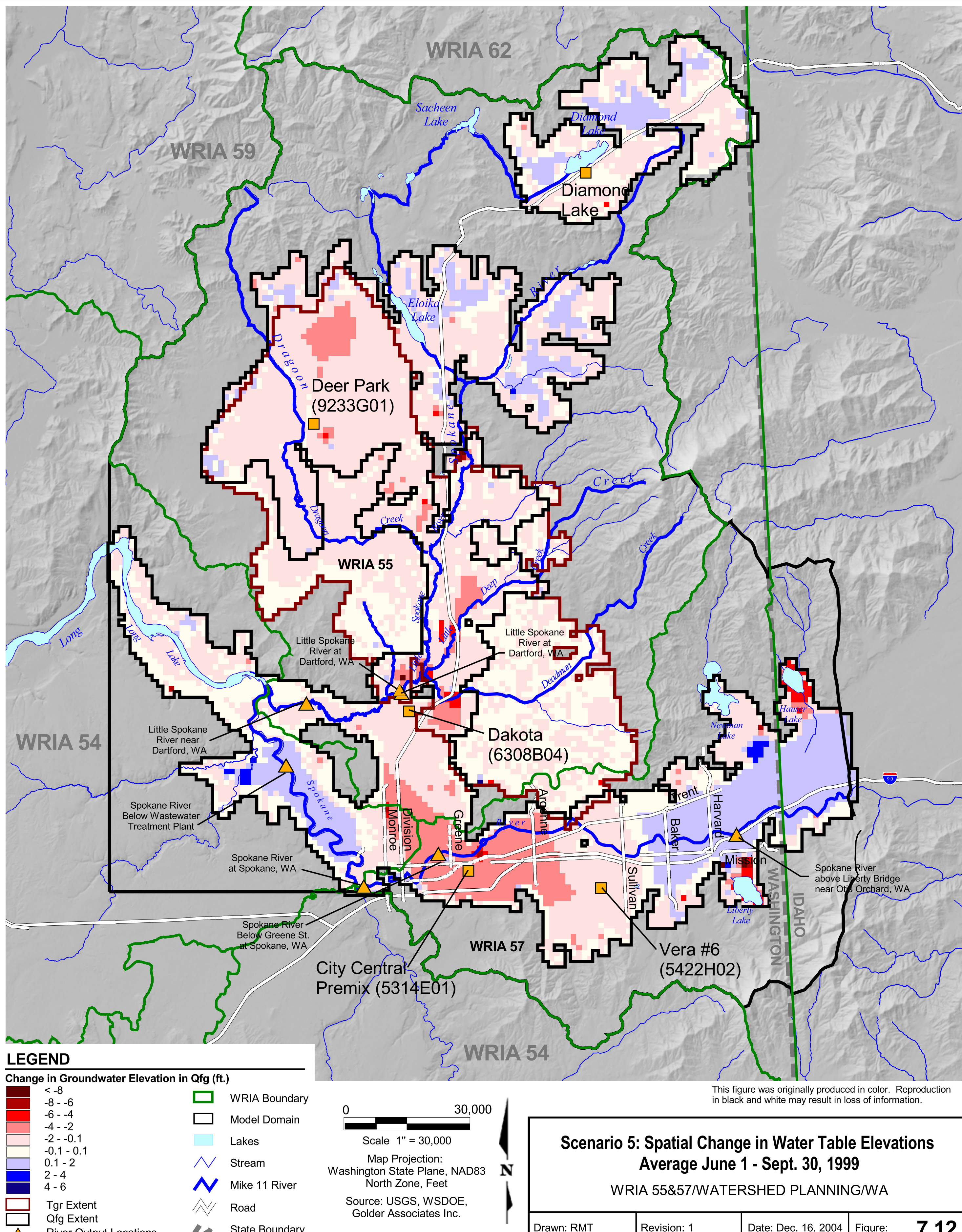
Golder Associates

TITLE

Scenario 5: Little Spokane River at Dartford
Monthly Streamflow Comparison

WRIA 55 & 57/ WATERSHED PLANNING/ WA

DRAWN JM	DATE December 2004	JOB NO. 013-1372
CHECKED	SCALE	DWG. NO.
REVIEWED	FILE NO. Run # 060804	FIGURE NO. 7.11



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Scenario 5: Spatial Change in Water Table Elevations
Average June 1 - Sept. 30, 1999

WRIA 55&57/WATERSHED PLANNING/WA

Drawn: RMT	Revision: 1	Date: Dec. 16, 2004	Figure: 7.12

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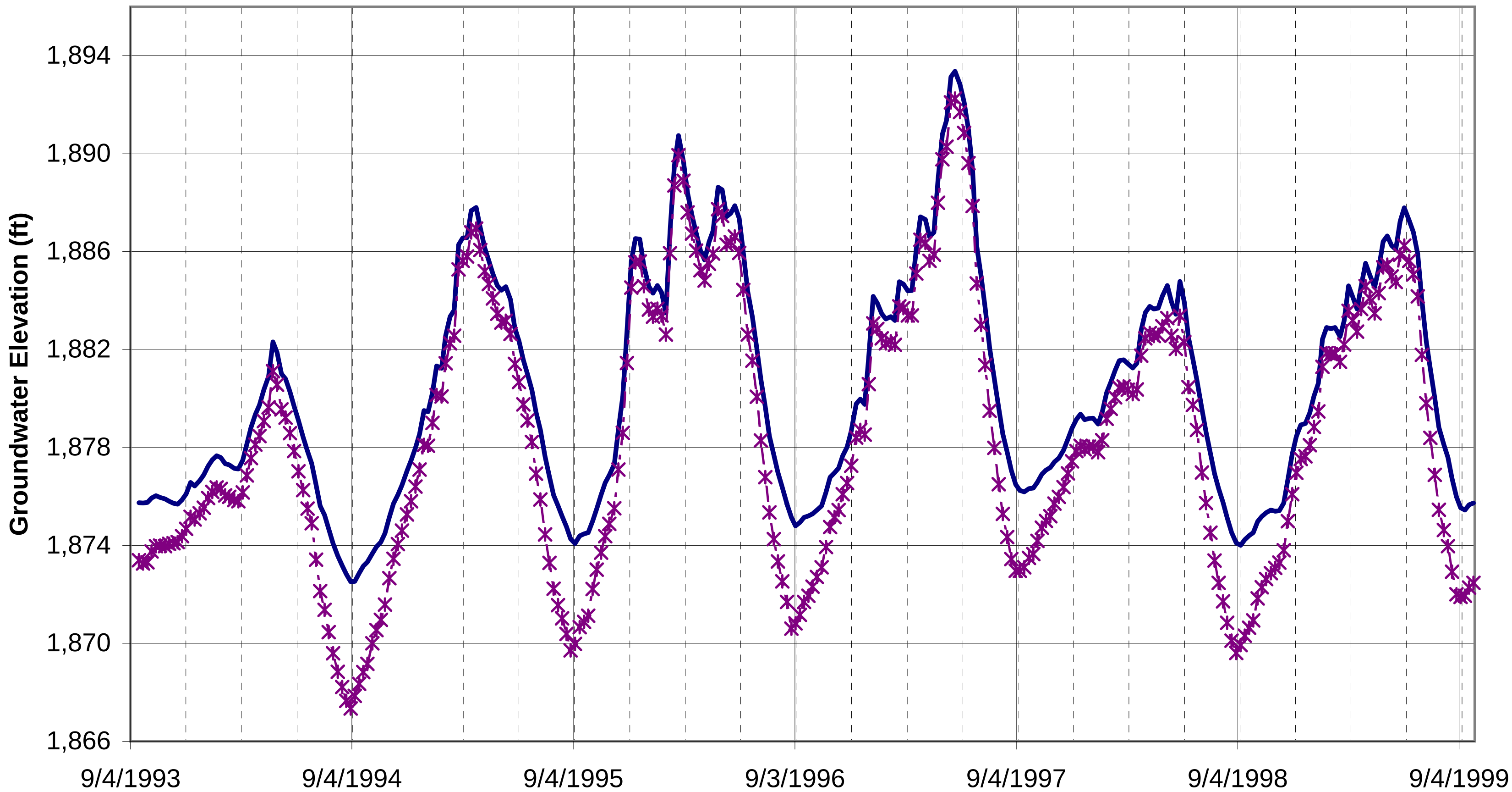
Golder Associates



Legend

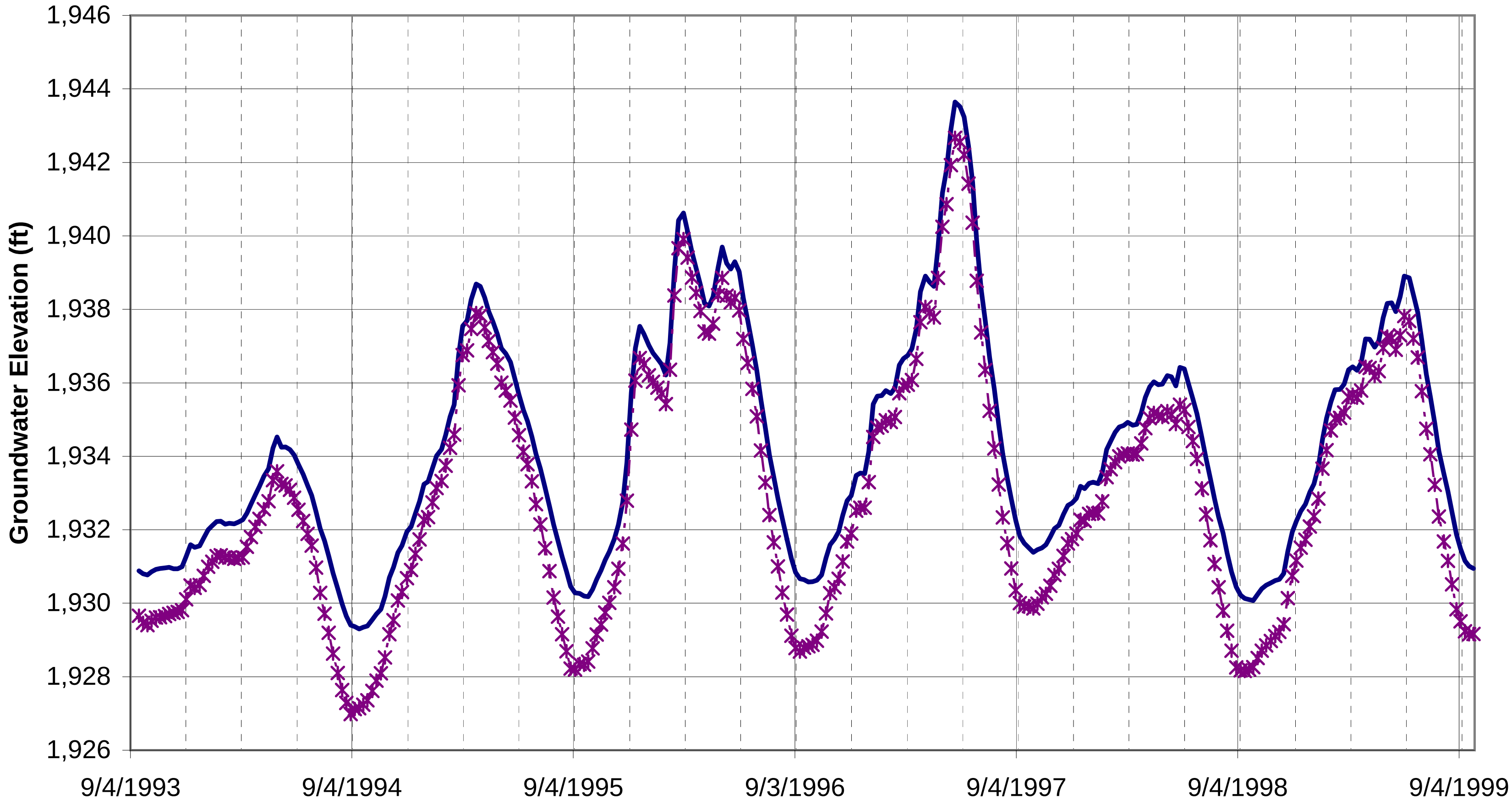
Baseline

Scenario 5, Inchoate Water Rights

FIGURE 7.13: Scenario 5, City Central PreMix (5314E01) Change in Groundwater Elevation

Spokane County
Watershed Assessment

Golder Associates



Legend

Baseline

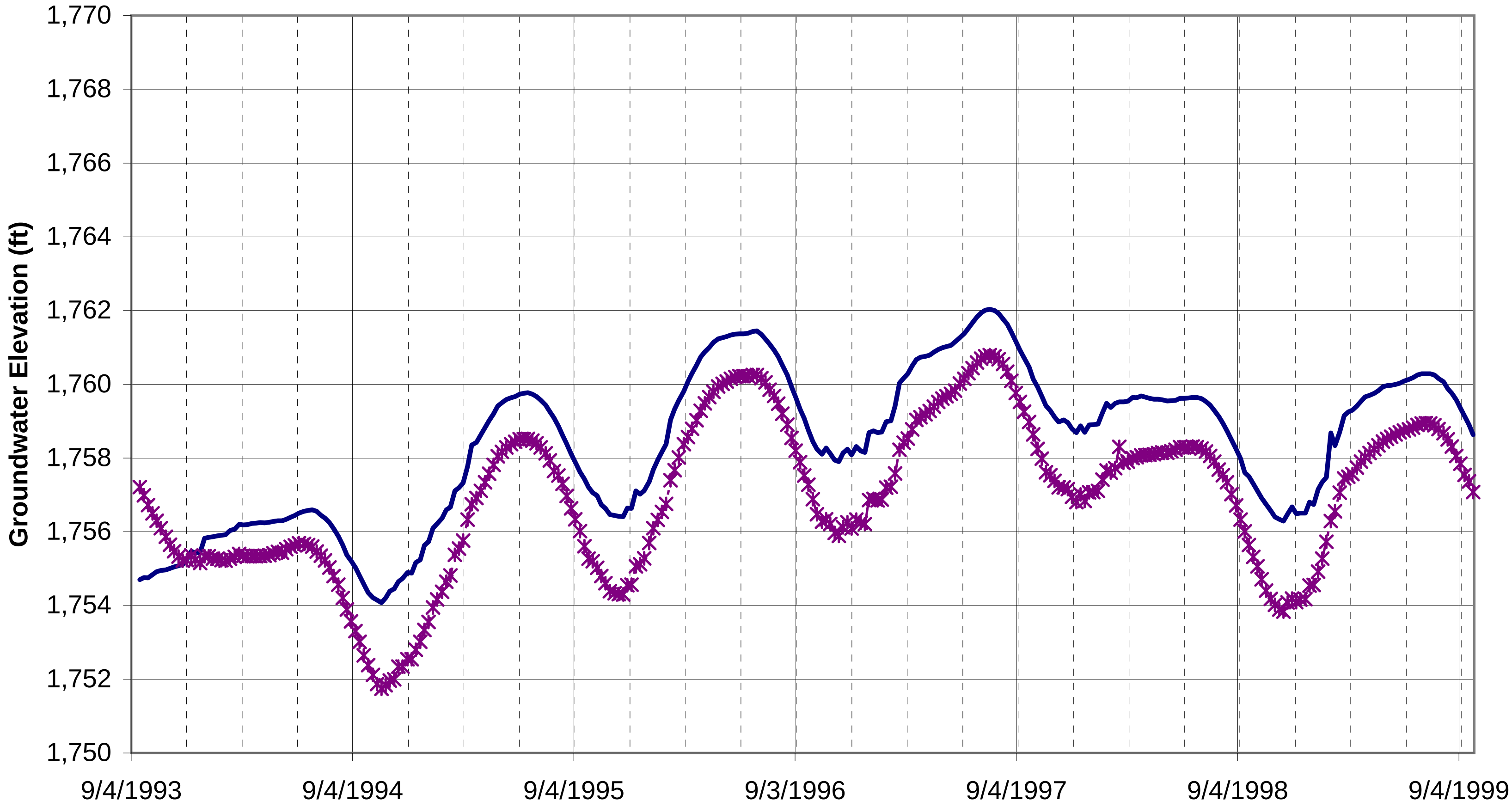
Scenario 5, Inchoate Water Rights

FIGURE 7.14: Scenario 5, Vera #6 (5422H02)
Change in Groundwater Elevation

Spokane County
Watershed Assessment

Golder Associates

Fig 7.13 - 17 Scen 5 Grndwtr Comp.xls,template (12)



Legend

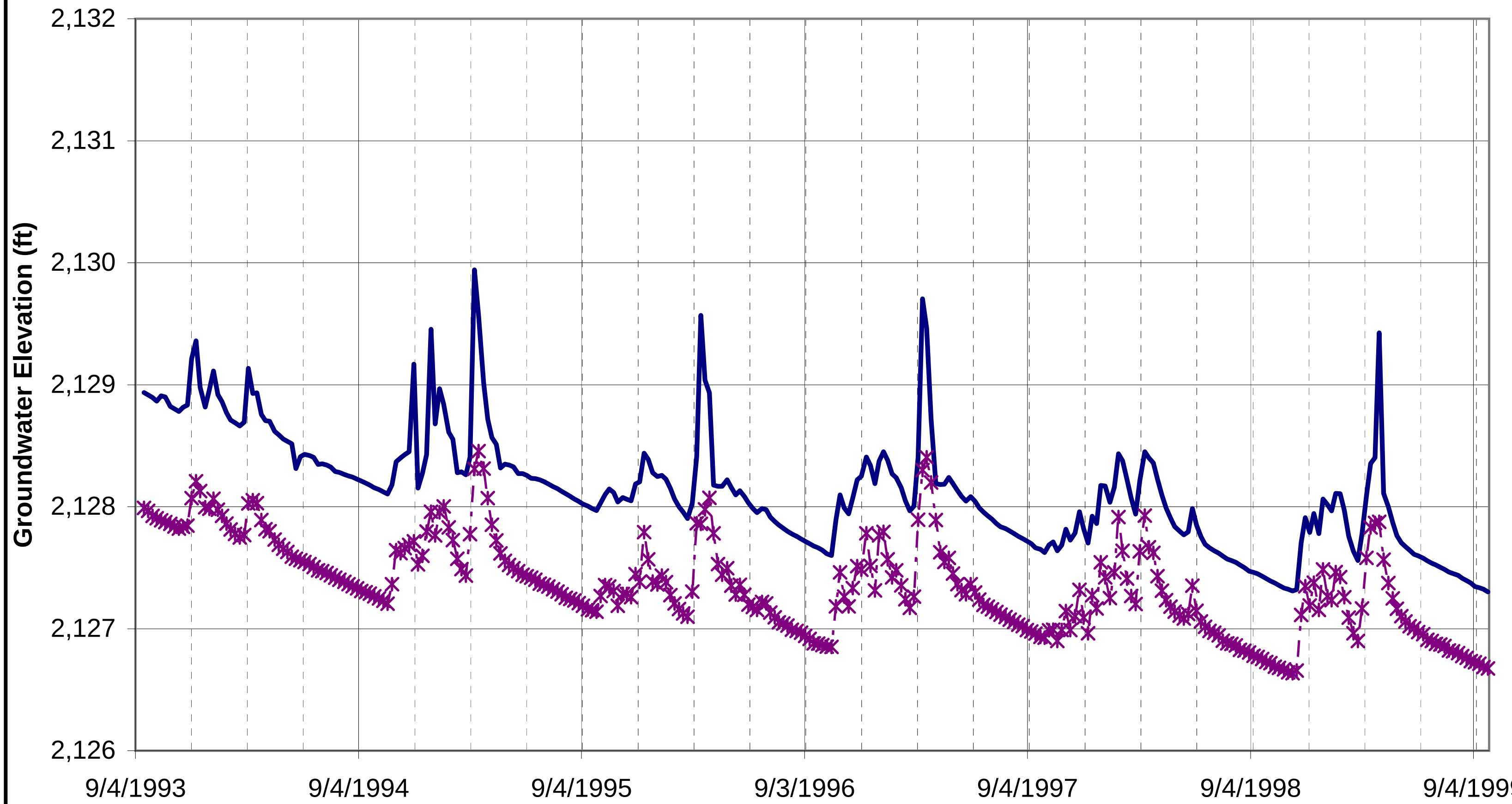
Baseline

Scenario 5, Inchoate Water Rights

FIGURE 7.15: Scenario 5, Dakota (6308B04) Change in Groundwater Elevation

Spokane County
Watershed Assessment

Golder Associates



Legend

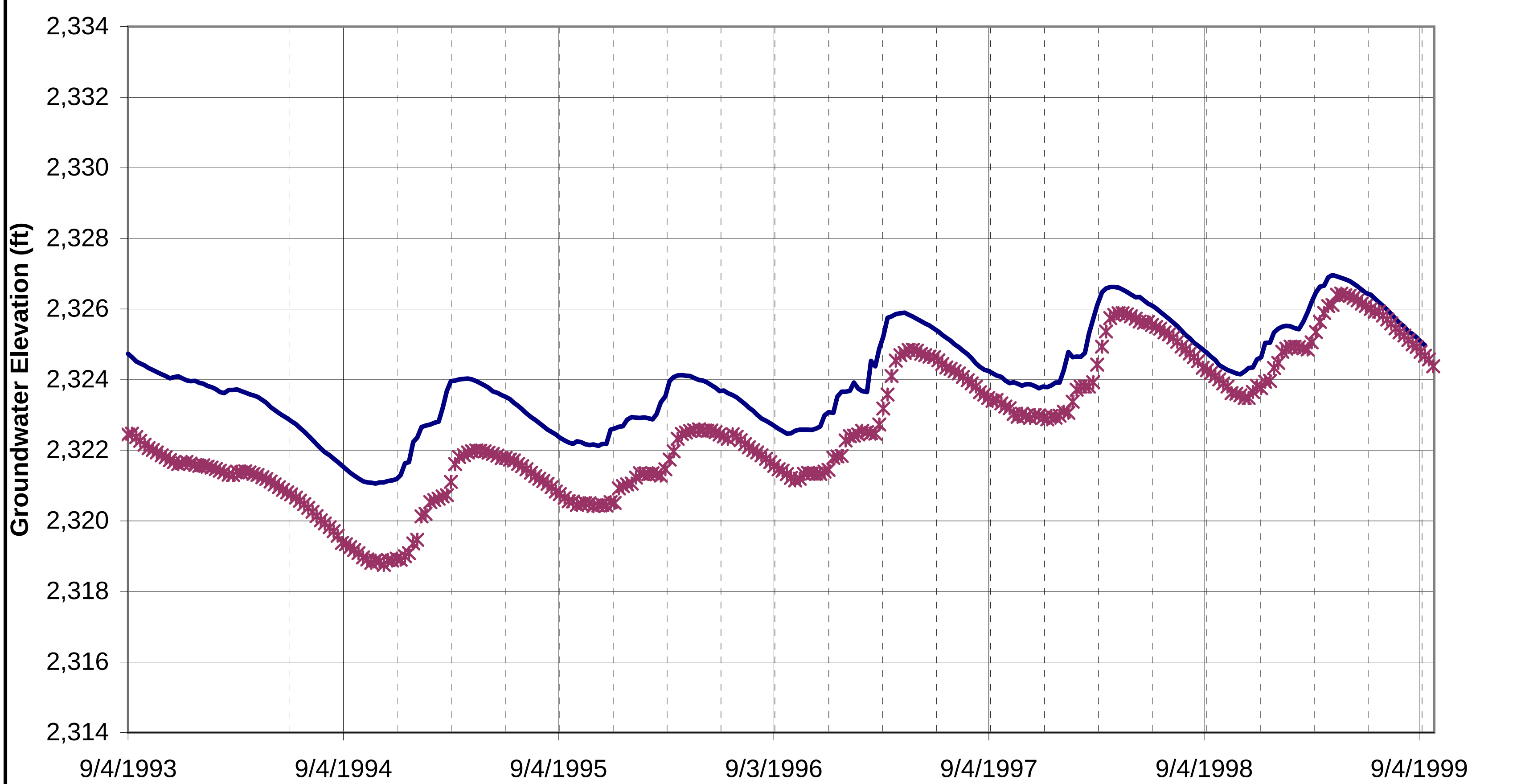
Baseline

Scenario 5, Inchoate Water Rights

FIGURE 7.16 : Scenario 5, Deer Park (9233G01) Change in Groundwater Elevation

Spokane County
Watershed Assessment

Golder Associates



Legend

Baseline

Scenario 5, Inchoate Water Rights

FIGURE 7.17: Scenario 5, Diamond Lake Aquifer Change in Groundwater Elevation

Spokane County
Watershed Assessment

Golder Associates

8.0 REFERENCES

DHI, 2001. Mike SHE Water Movement Use Manual (for Version 2001b).

Golder Associates, Inc., June, 2003. Little Spokane and Middle Spokane Watershed Planning Phase 2 – Level 1 Watershed Assessment.

Golder Associates, Inc., February, 2004. Level 2 Technical Assessment: Watershed Simulation Model.

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APPENDIX A

MODELED IMPACTS OF CLIMATE CHANGE IN WRIA 55

TABLE OF CONTENTS

LIST OF TABLES

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1.0 MODEL PREDICTED IMPACTS OF CLIMATE CHANGE IN WRIA 55

An additional model scenario was run by Golder to simulate the affect of climate change on streamflow in WRIA 55 and 57. This scenario was not requested from the WRIA 55 and 57 Planning Unit but was completed by Golder for research purposes, and watershed planning funding was not used. The results were considered by Golder to be useful and therefore are included here as an appendix. This write-up does not include a full analysis of results and impacts, but rather a brief presentation of the effects of climate change on streamflow in WRIA 55.

Climate change is being studied by the Climate Impacts Group (CIG), an interdisciplinary research group at the University of Washington. The CIG conducts research on the impacts of climate variability and climate change in the Pacific Northwest. The CIG developed a memo for use by watershed planning units dated April 15, 2004. That memo provides an overview of research completed by the CIG on the impacts of climate variability and climate change on the Pacific Northwest environment as well as basic language on the predicted hydrologic impacts of these processes. Climate variability refers to natural variability which occurs in part in response to natural cycles in Pacific Ocean sea surface temperatures and related ocean/atmosphere dynamics. Climate change as referred to here is the response in the climate to future greenhouse gas and aerosol emissions.

Climate change is reported in terms of changes in precipitation and temperature. The surface drainage of the Little Spokane River (WRIA 55) is completely contained within the domain of the MIKE SHE model. However, the majority of the WRIA 57 catchment extends outside of the MIKE model domain to the Idaho-Montana border. This portion of the catchment in Idaho is the primary source of snow pack and melt and therefore primary determinant of flow for the Spokane River including almost all of the snow pack influences on the Spokane River flow. Therefore, the effects of changes in precipitation and temperature on streamflow cannot properly be evaluated for the Spokane River. Therefore only climate change impacts on the Little Spokane River are presented.

1.1 Model Setup

The CIG memo describes projected changes due to climate change in terms of average precipitation and temperature based on the evaluation of seven global warming scenarios. These projected changes are described in Table A-1.

This model scenario was set-up using the 20-year growth scenario (Scenario 1, Chapter 4) as the base with additional changes to the set-up to reflect predicted climate change to 2040. Temperature, precipitation and potential evapotranspiration input files were modified.

- Precipitation was increased by 9% between October and March and increased by 2% between April and September.

- Temperature was increased by 2.1 ^{o}C year round.

- Potential evapotranspiration was recalculated using the new temperature input file.

Therefore this model predicts the effects of climate change predicted for 2040 in addition to the already projected changes of 20-year growth.

TABLE A-1

Projected Changes in Average Annual Pacific Northwest Temperature and Precipitation for the Decades of the 2020s and 2040s
(Whitely, 2004)

Decades	Temperature Change	Precipitation Change	
	Average Annual (°C)	**Oct – Mar**	**Apr – Sept**
2020s			
Low	0.4	+ 2%	-4%
Average	**1.4**	**+ 8 %**	**+ 4%**
High	1.8	+ 18%	+ 14%
2040s			
Low	1.5	+ 2%	- 7%
Average	**2.1**	**+ 9%**	**+ 2%**
High	2.7	+ 22%	+ 9%

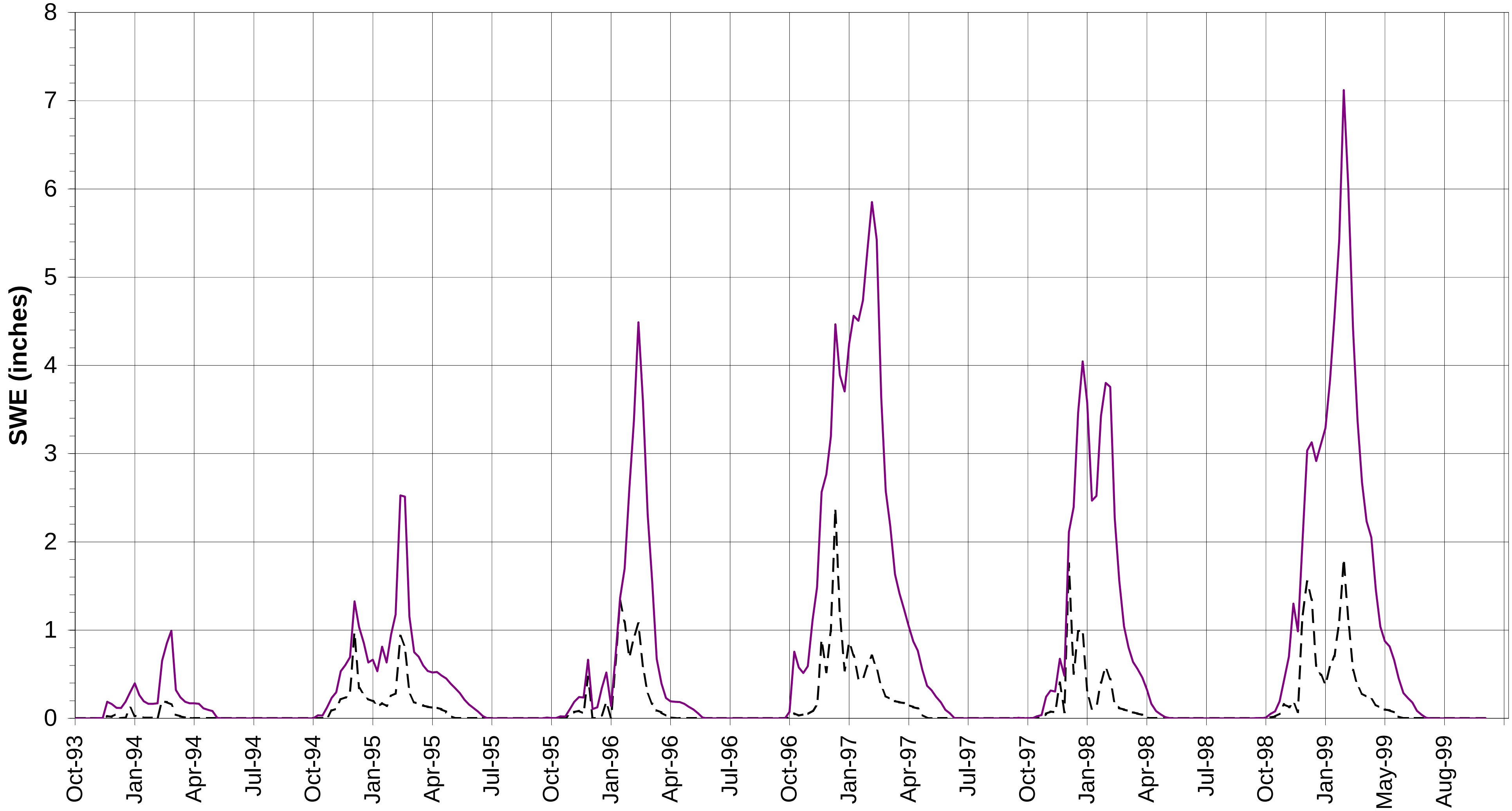
1.2 Results

A comparison of climate change results to Baseline and 20-year growth conditions is shown in Figures A-1 through A-3.

Climate change in a snowmelt dominant basin is expected to cause a change in the characteristics of snow pack accumulation and melt. Warmer temperatures results in less snow accumulation and earlier snow pack depletion in the spring (Figure A-1). The model predicts a 27% to 75% reduction in peak snow pack from baseline conditions.

Streamflow response to climate change in WRIA 55 is depicted at the Little Spokane River at Dartford (Figure A-2). The top graphic displays the predicted streamflow changes applied to measured data for the Little Spokane River at Dartford. This figure shows an increase and shift in the peak mean monthly flow from approximately 900 cfs March to 1,000 cfs in February (Figure A-2). These shifts are consistent with a transformation from a system that is transitional between rain-dominated and snow-dominated, to one that is more rain-dominated. The descending limb of the hydrograph from peak winter flows to low summer flows also falls at a much faster rate resulting in lower summer low flows. The bottom frame of Figure A-2 shows the monthly average change in streamflow calculated as the difference between the climate change and baseline scenarios, and as the difference between the climate change and 20-year growth scenario (this was also displayed in Chapter 4).

During the baseflow period, from August through October the average difference in streamflow between projected 20-year growth conditions and projected 20-year growth under climate change conditions ranges from 2 to 7 cfs (Figure A-3).



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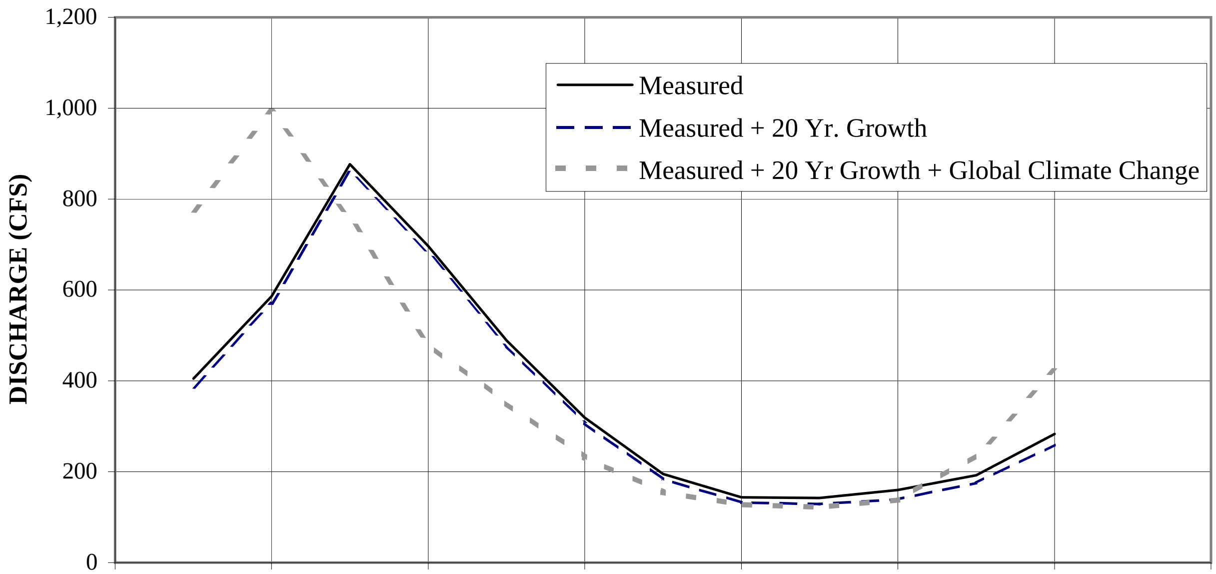
WRIA 55 & 57/Watershed Planning/WA

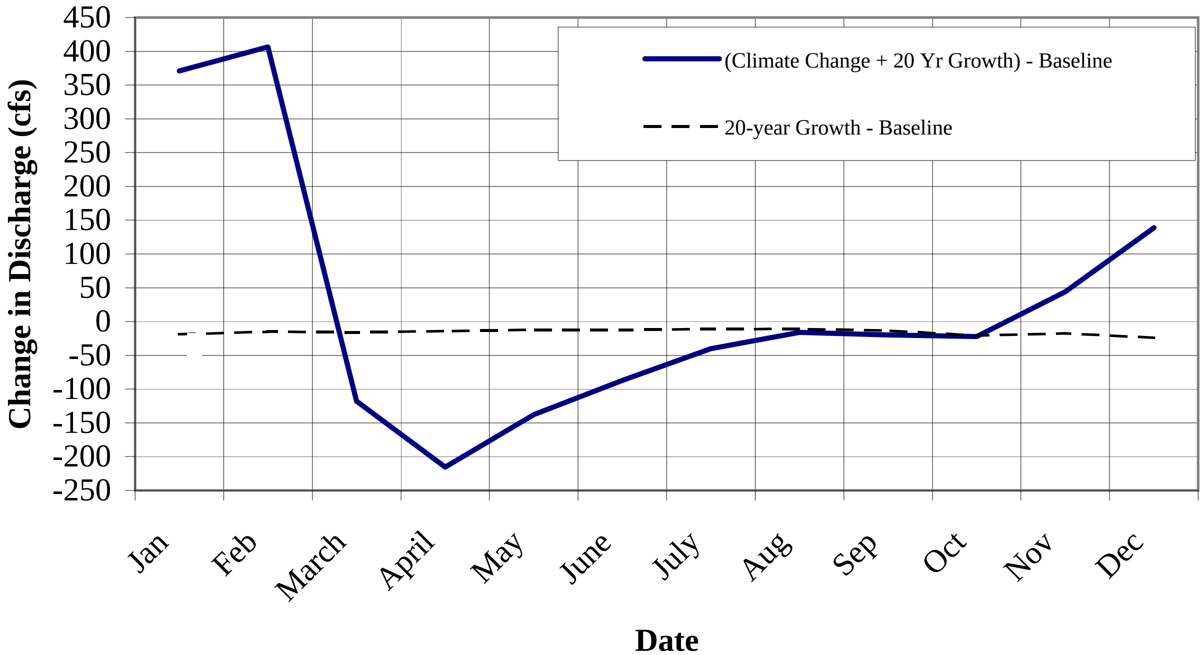
Global Climate Change + 20 Yr Growth

Baseline

Climate Change: Comparison of Snow Water Equivalent from Baseline to Climate Change Conditions

DRAWN		DATE	Dec-04	JOB NO.	013-1372
CHECKED	SM	SCALE	na	DWG. NO.	na
REVIEWED	CVP	FILE NO.	1993	FIGURE NO.	A-1





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WRIA 55 & 57/ WATERSHED PLANNING/ WA

TITLE

Global Climate Change: Little Spokane River at Dartford, Change in Streamflow

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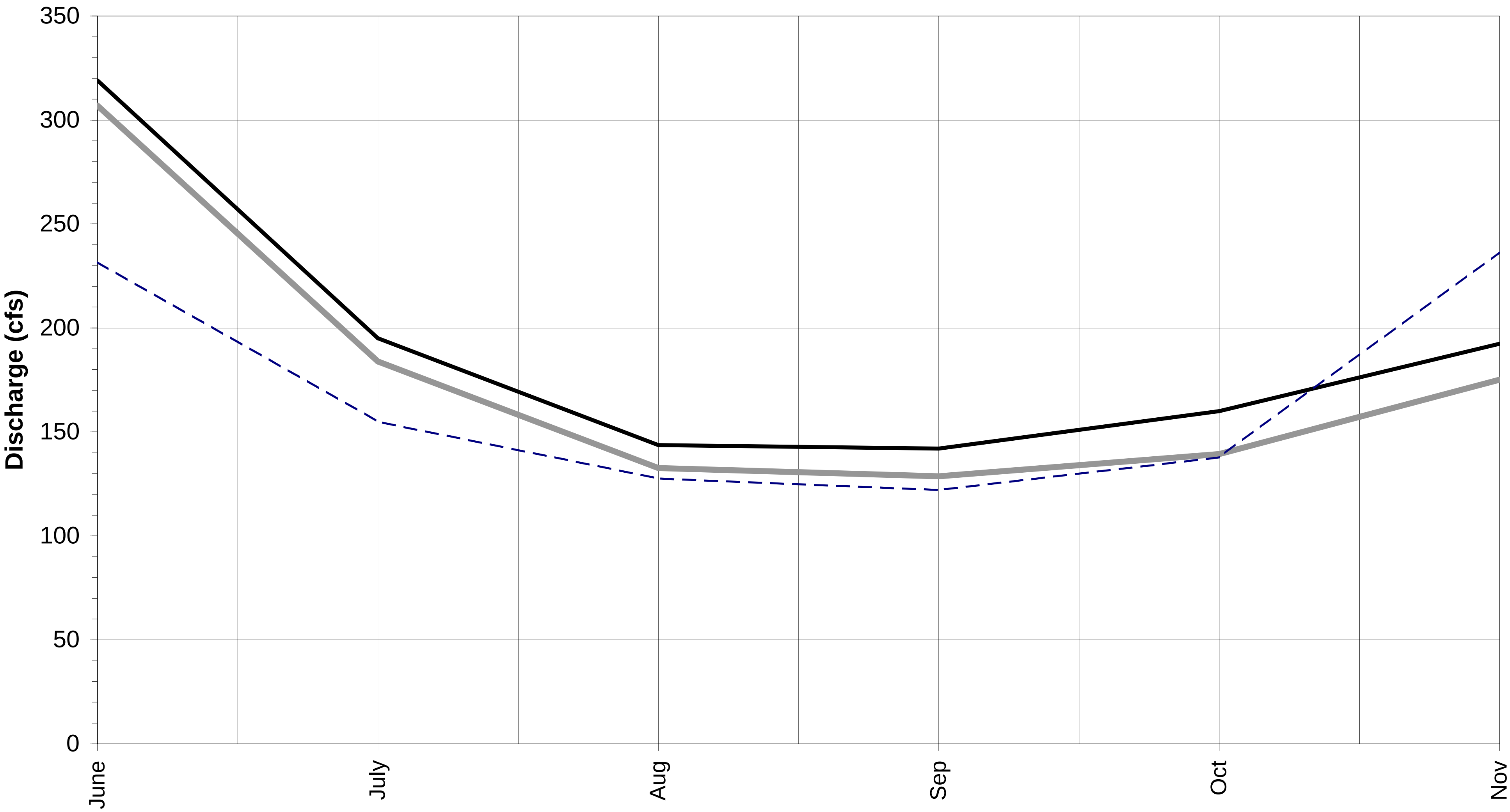
REVIEWED		FILE NO.		FIGURE NO.	A-2



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WRIA 55 & 57/Watershed Planning/WA

Measured

Measured + 20 Yr. Growth

Measured + 20 Yr Growth + Global Climate Change

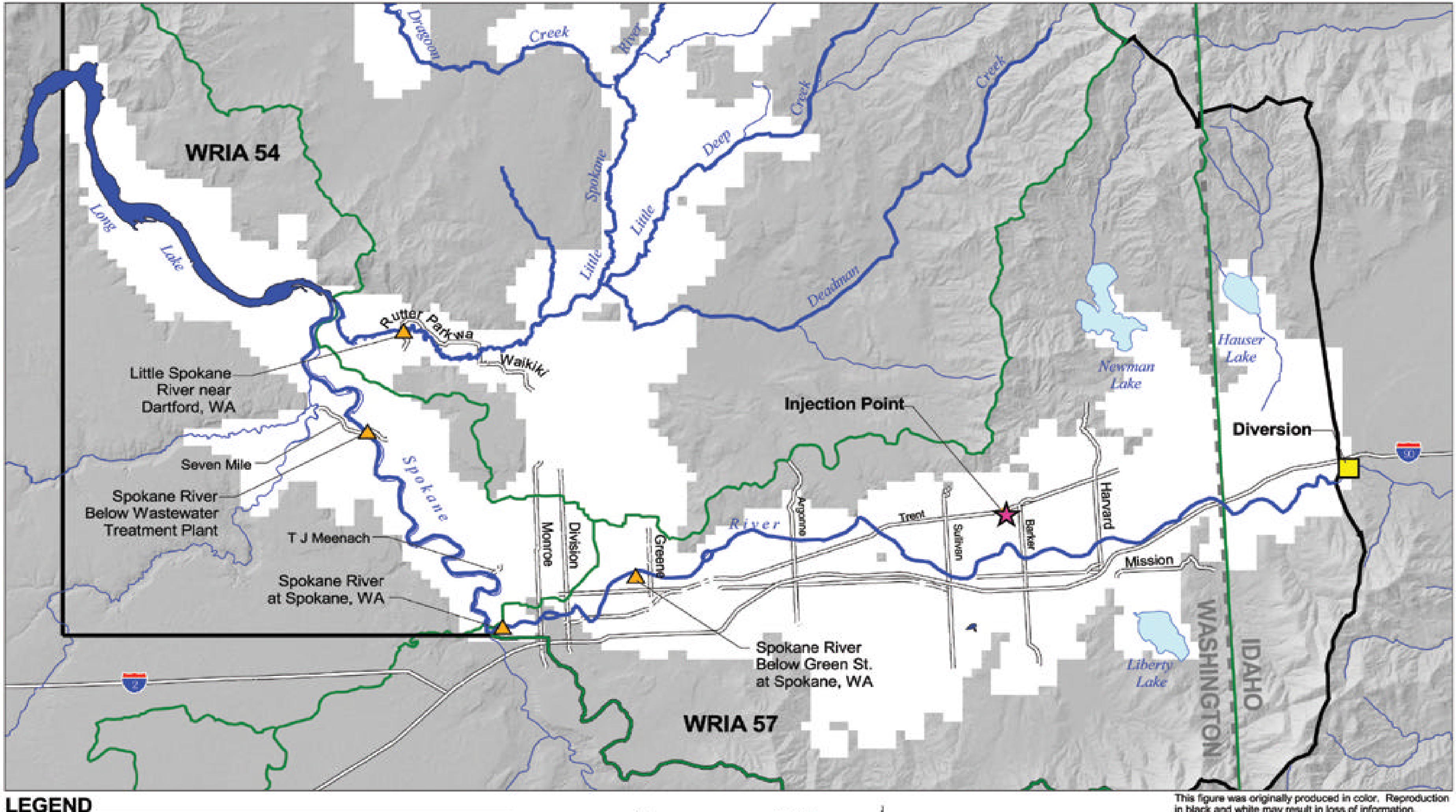
Global Climate Change: Little Spokane River at Dartford, Change in Streamflow

DRAWN		DATE	Dec-04	JOB NO.	013-1372
CHECKED	SM	SCALE	na	DWG. NO.	na
REVIEWED	CVP	FILE NO.	1993	FIGURE NO.	A-3

APPENDIX B

CONVERSION OF THE SPOKANE WATERSHED SIMULATION MODEL FROM MIKE SHE 2001 TO MIKE SHE 2003

(Provided under separate cover)



SCENARIO 2: SPOKANE RIVER DIVERSION AND INJECTION

WRIA 55&57/WATERSHED PLANNING/WA

Drawn: RMT	Revision: 4	Date: Apr. 20, 2004	Figure: 1

01313722100_042004.apr

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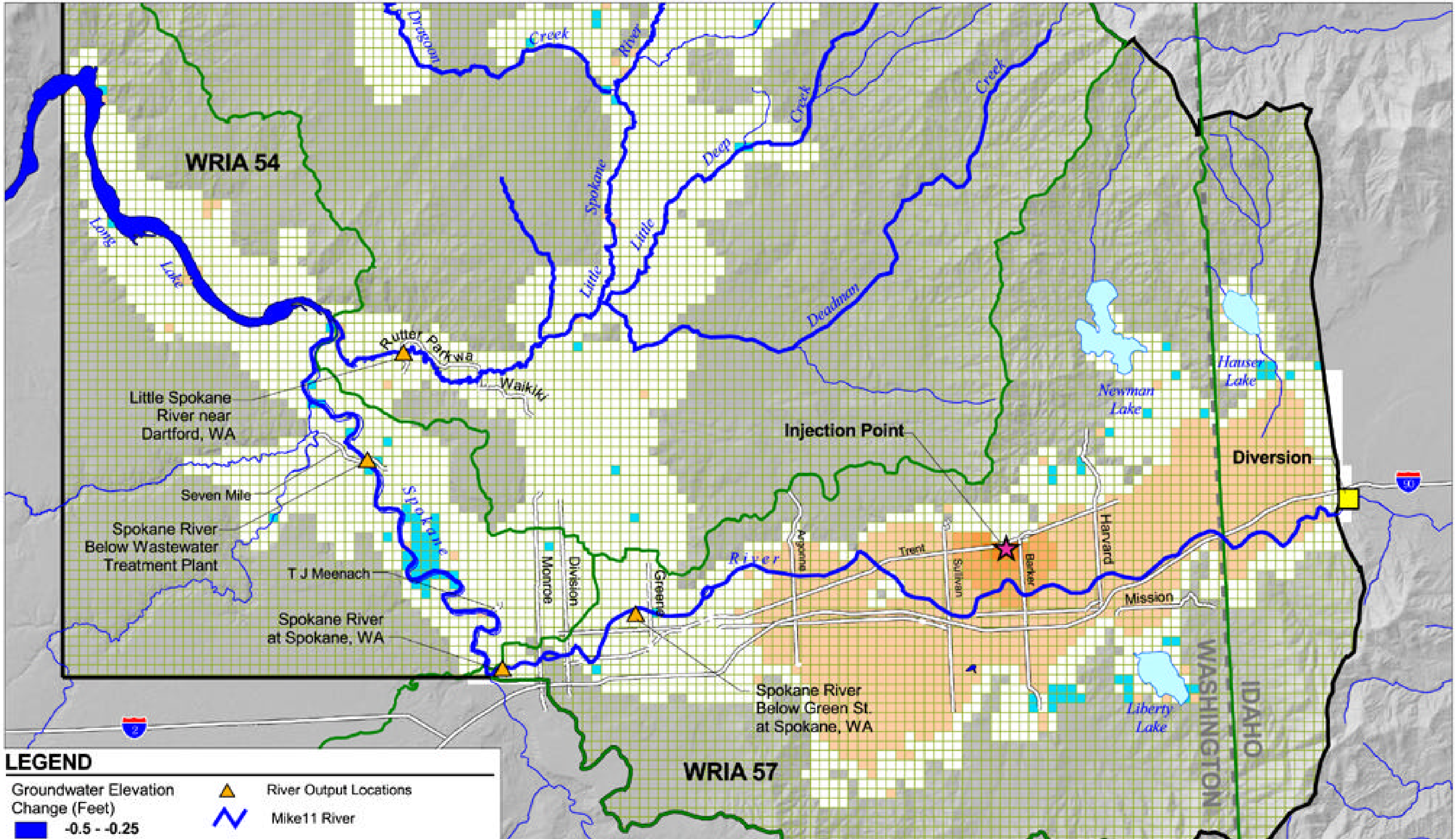

LEGEND

Groundwater Elevation Change (Feet)

- -0.5 - -0.25
- -0.25 - -0.01
- 0.01 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.25
- 1.25 - 1.5
- 1.5 - 1.75
- 1.75 - 2
- 2 - 2.25

- River Output Locations
- Mike11 River
- WRIA Boundary
- Model Domain
- Layer 1: Surficial Aquifer (Flood Sand & Gravel)
- Lake
- Road

0 20,000

Scale 1" = 20,000

DRAFT

Map Projection: Washington State Plane, NAD83 North Zone, Feet

Source: USGS, WSDOE, Golder Associates Inc.

N

This figure was originally produced in color. Reproduction in black and white may result in loss of information.

SCENARIO 2: AVERAGE MAY GROUNDWATER ELEVATION CHANGE

WRIA 55&57/WATERSHED PLANNING/WA

Drawn: RMT	Revision: 4	Date: Apr. 20, 2004	Figure: 2

01313722100_042004.apr

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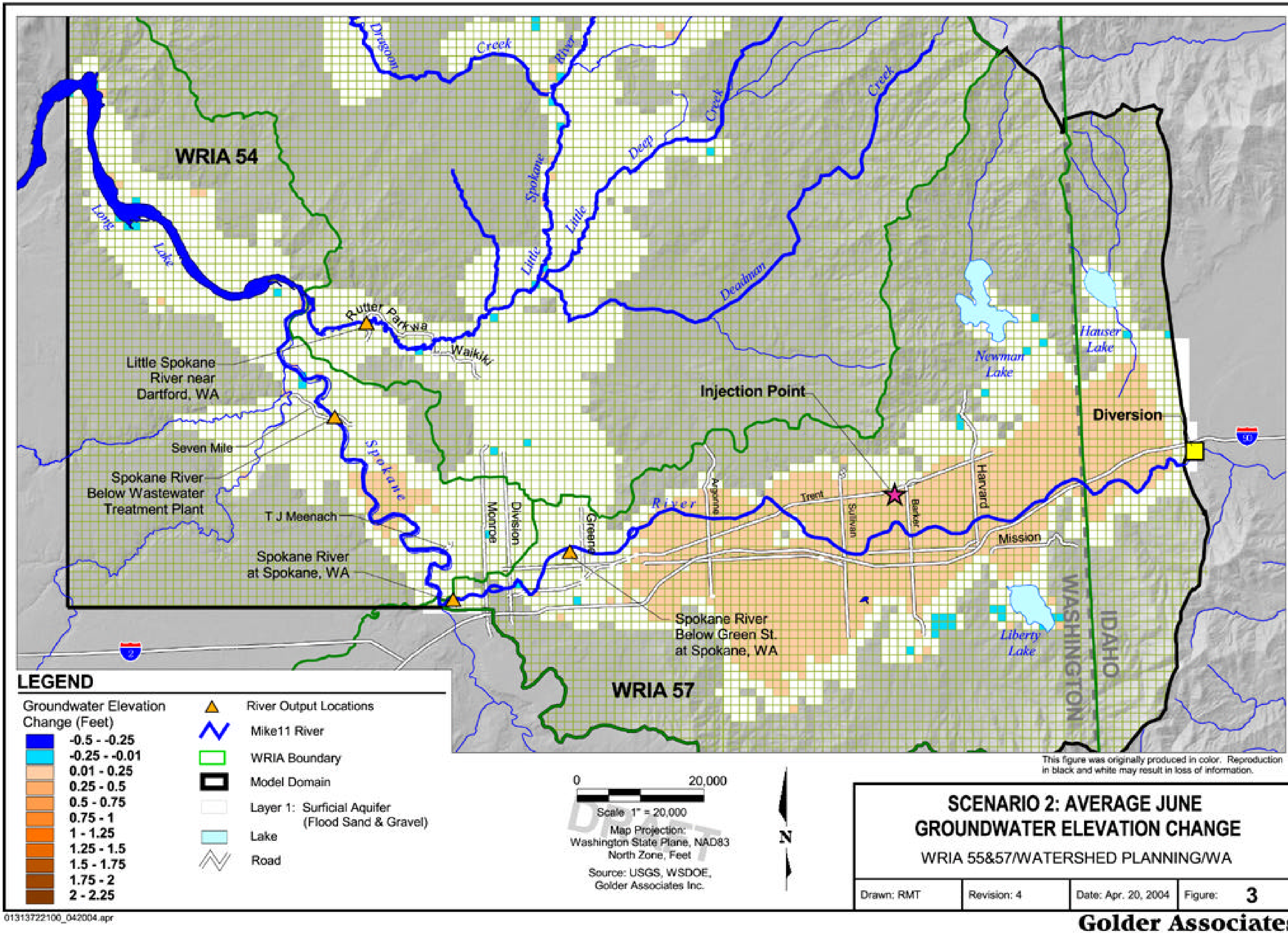
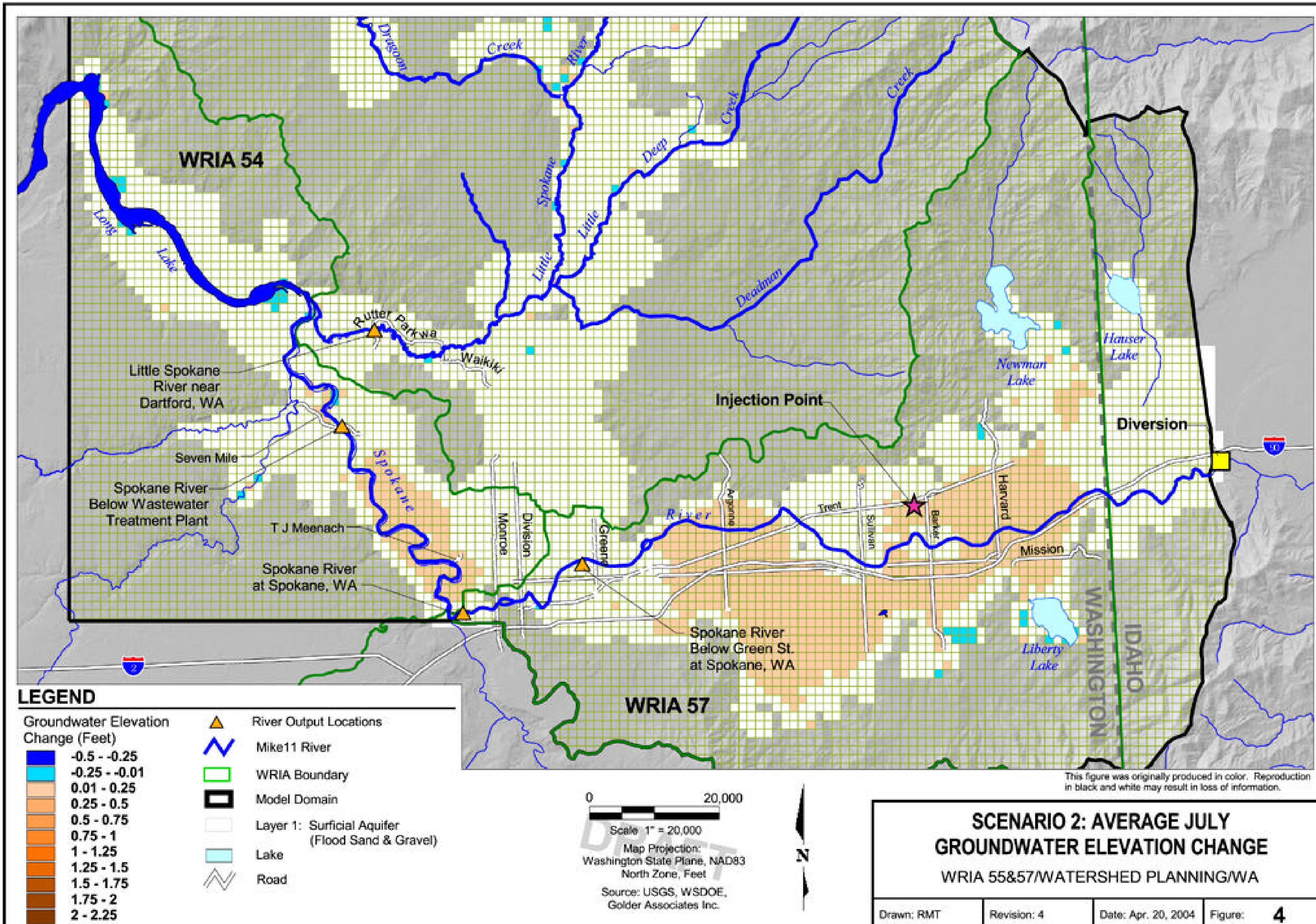

WRIA 54
WRIA 57
Long Lake
Dragoon Creek
Spokane River
Little Spokane
Little
Deep Creek
Creek
Deadman
Rutter Parkwa
Waikiki
Little Spokane River near Dartford, WA
Seven Mile
Spokane River Below Wastewater Treatment Plant
T J Meenach
Spokane River at Spokane, WA
Spokane
River
Monroe
Division
Green
Argonne
Trent
Sullivan
Barker
Harvard
Mission
Injection Point
Spokane River Below Green St. at Spokane, WA
Newman Lake
Hauser Lake
Liberty Lake
Diversion
WASHINGTON
IDAHO
90
2
LEGEND
Groundwater Elevation Change (Feet)
-0.5 - -0.25
-0.25 - -0.01
0.01 - 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1 - 1.25
1.25 - 1.5
1.5 - 1.75
1.75 - 2
2 - 2.25
River Output Locations
Mike11 River
WRIA Boundary
Model Domain
Layer 1: Surficial Aquifer (Flood Sand & Gravel)
Lake
Road
0
20,000
Scale 1" = 20,000
Map Projection: Washington State Plane, NAD83 North Zone, Feet
Source: USGS, WSDOE, Golder Associates Inc.
DRAFT
N
This figure was originally produced in color. Reproduction in black and white may result in loss of information.
SCENARIO 2: AVERAGE JUNE GROUNDWATER ELEVATION CHANGE
WRIA 55&57/WATERSHED PLANNING/WA
Drawn: RMT
Revision: 4
Date: Apr. 20, 2004
Figure: 3
01313722100_042004.apr
Golder Associates



This figure was originally produced in color. Reproduction in black and white may result in loss of information.

SCENARIO 2: AVERAGE JULY GROUNDWATER ELEVATION CHANGE

WRIA 55&57/WATERSHED PLANNING/WA

Drawn: RMT	Revision: 4	Date: Apr. 20, 2004	Figure: 4

01313722100_042004.apr

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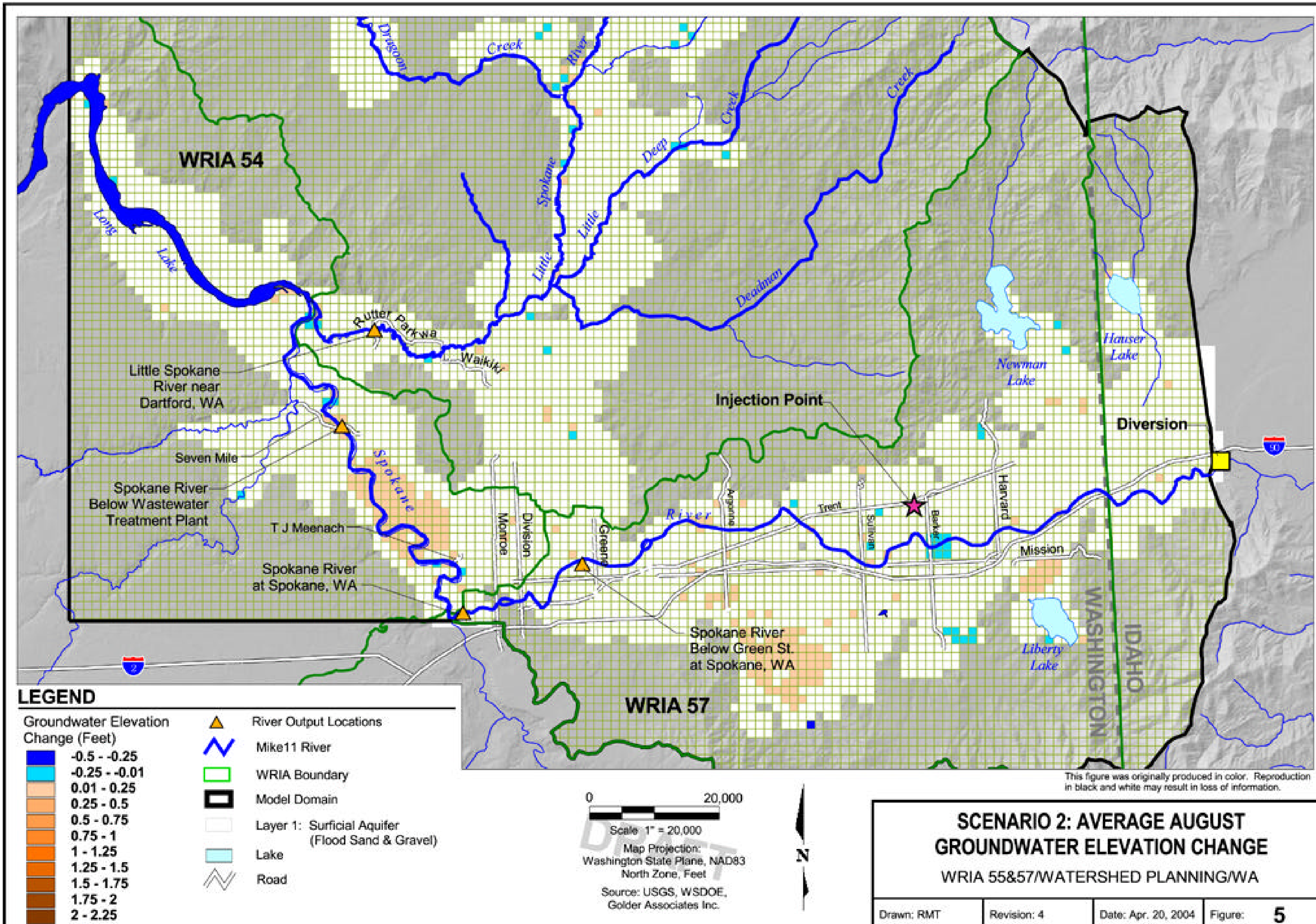

SCENARIO 2: AVERAGE AUGUST GROUNDWATER ELEVATION CHANGE

WRIA 55&57/WATERSHED PLANNING/WA

Drawn: RMT	Revision: 4	Date: Apr. 20, 2004	Figure: 5

01313722100_042004.apr

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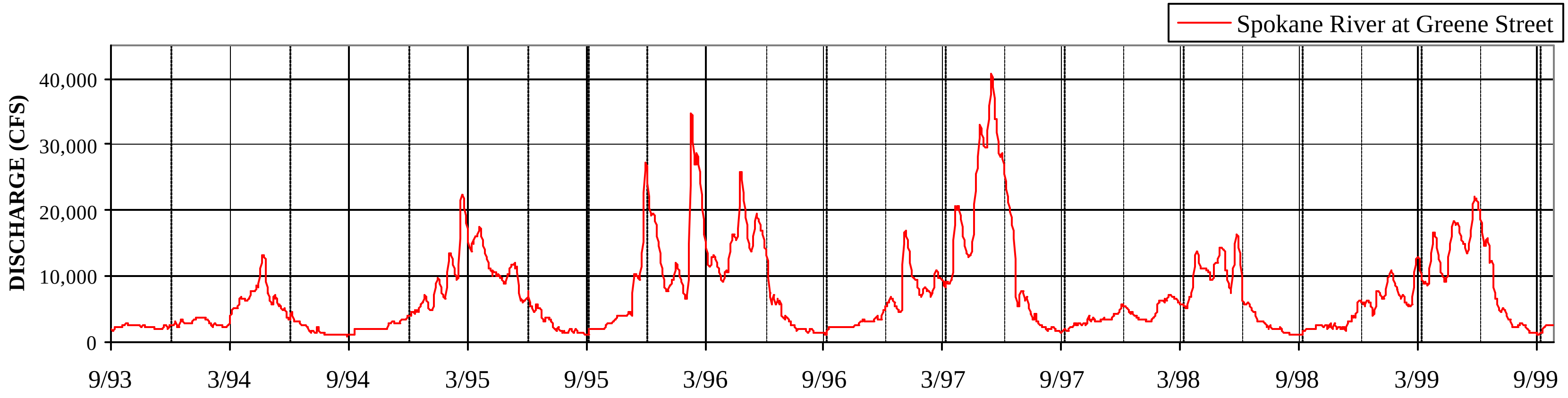

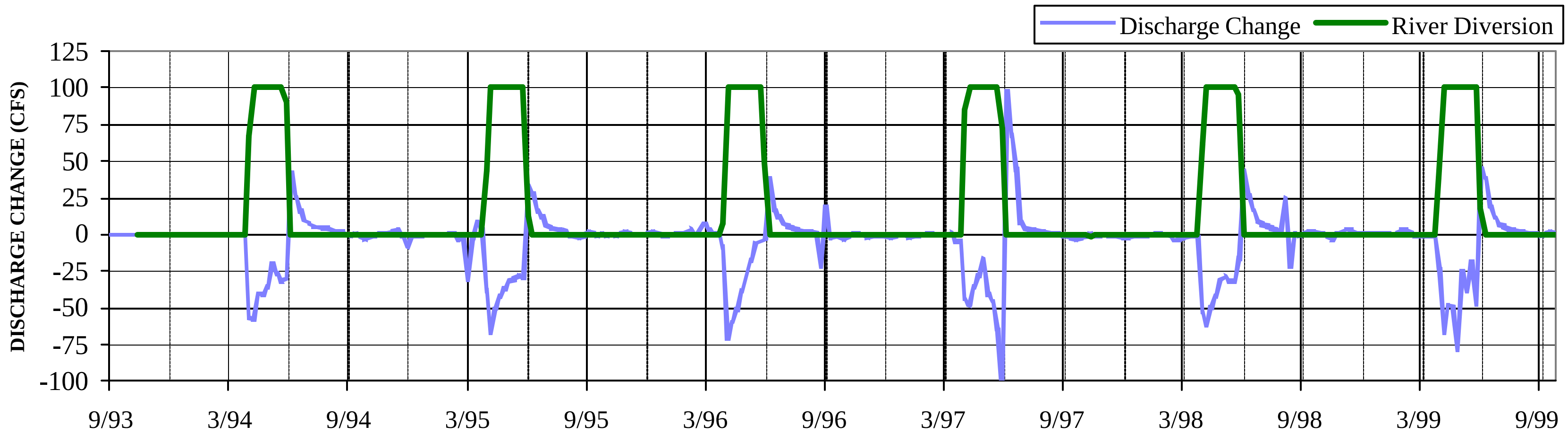

Note: Model Outliers Removed

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TITLE

SCENARIO 2: CHANGE IN DISCHARGE
SPOKANE RIVER AT GREENE STREET

WRIA 55 & 57/ WATERSHED PLANNING/ WA

DRAWN	JM	DATE	April 2004	JOB NO.	013-1372
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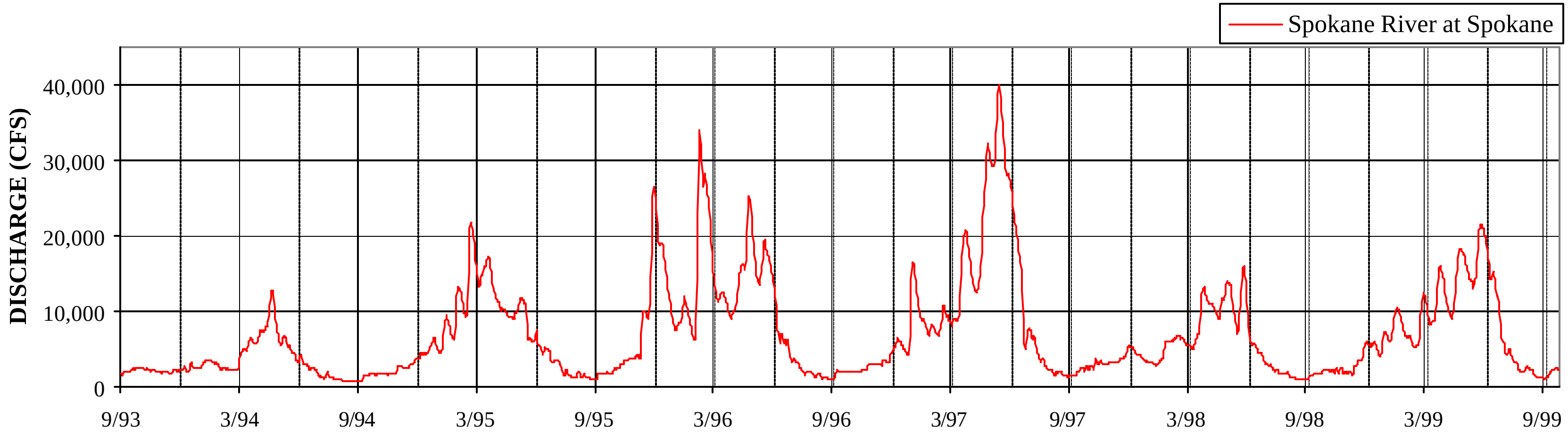

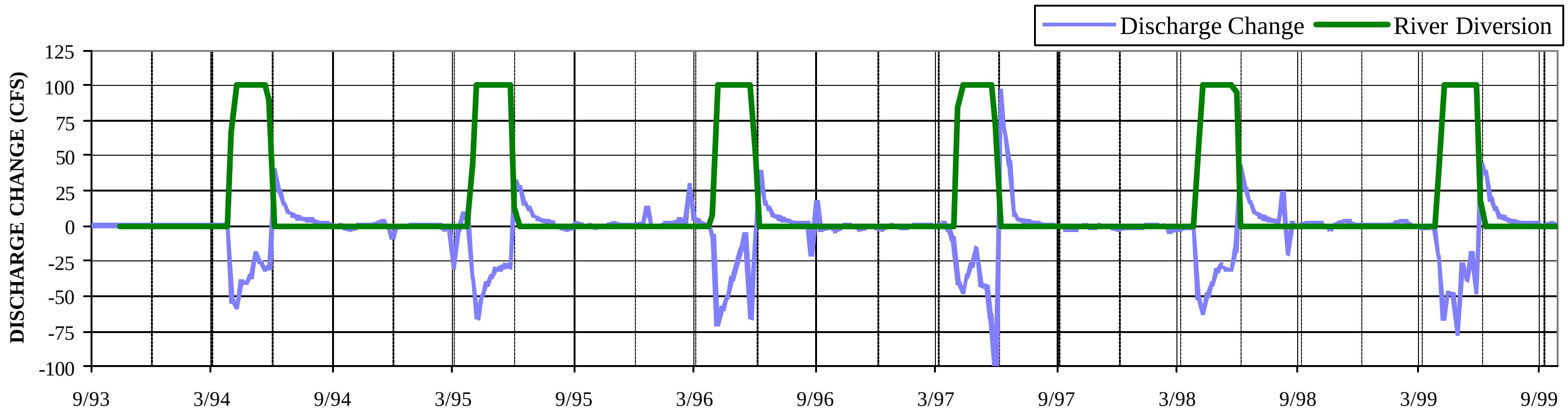

Note: Model Outliers Removed

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TITLE

SCENARIO 2 : CHANGE IN DISCHARGE
SPOKANE RIVER AT SPOKANE

WRIA 55 & 57/ WATERSHED PLANNING/ WA

DRAWN	JM	DATE	April 2004	JOB NO.	013-1372
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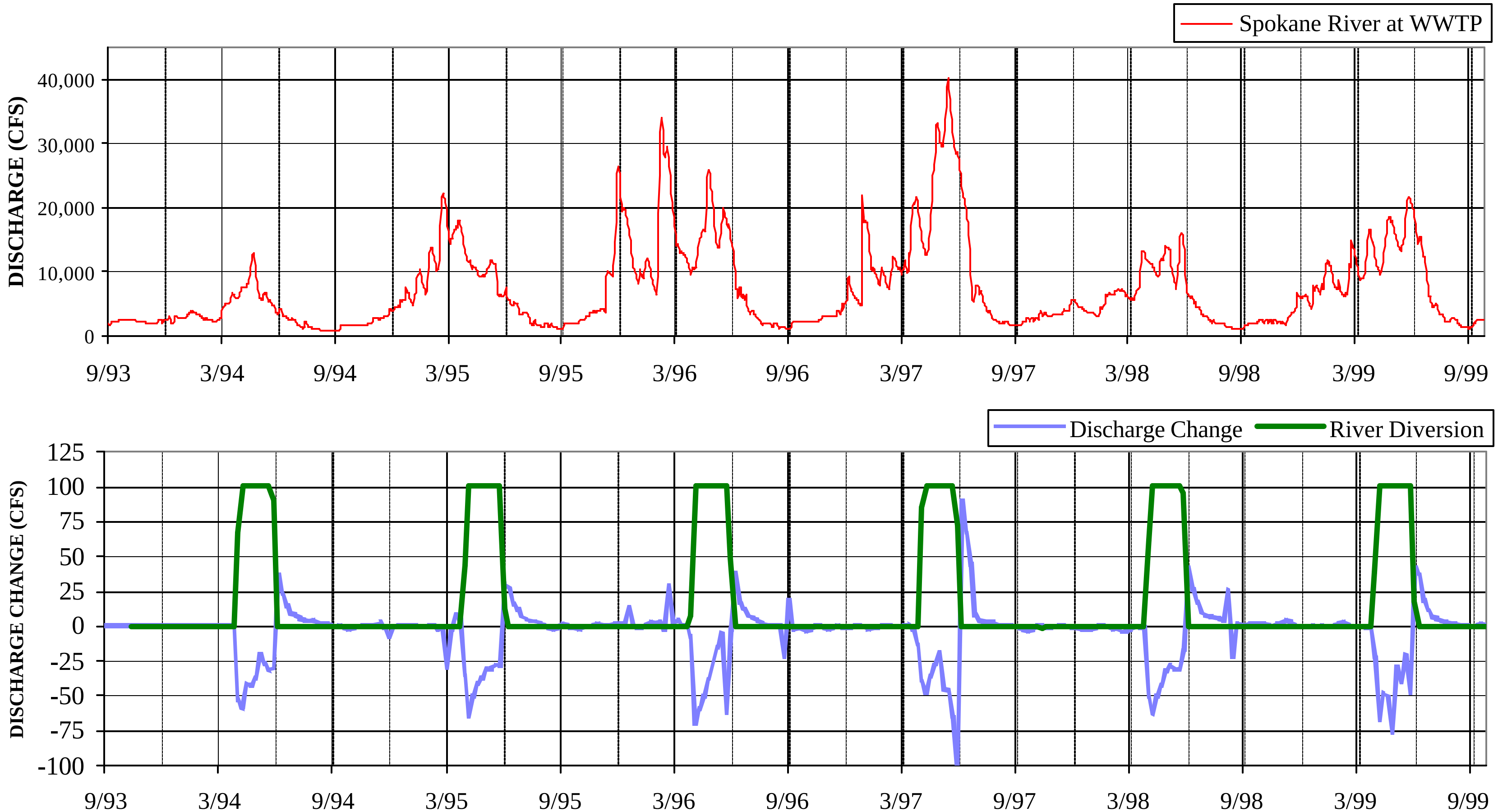
REVIEWED		FILE NO	Scen2InjWell 033004a-c.frf	FIGURE NO.	7



Note: Model Outliers Removed

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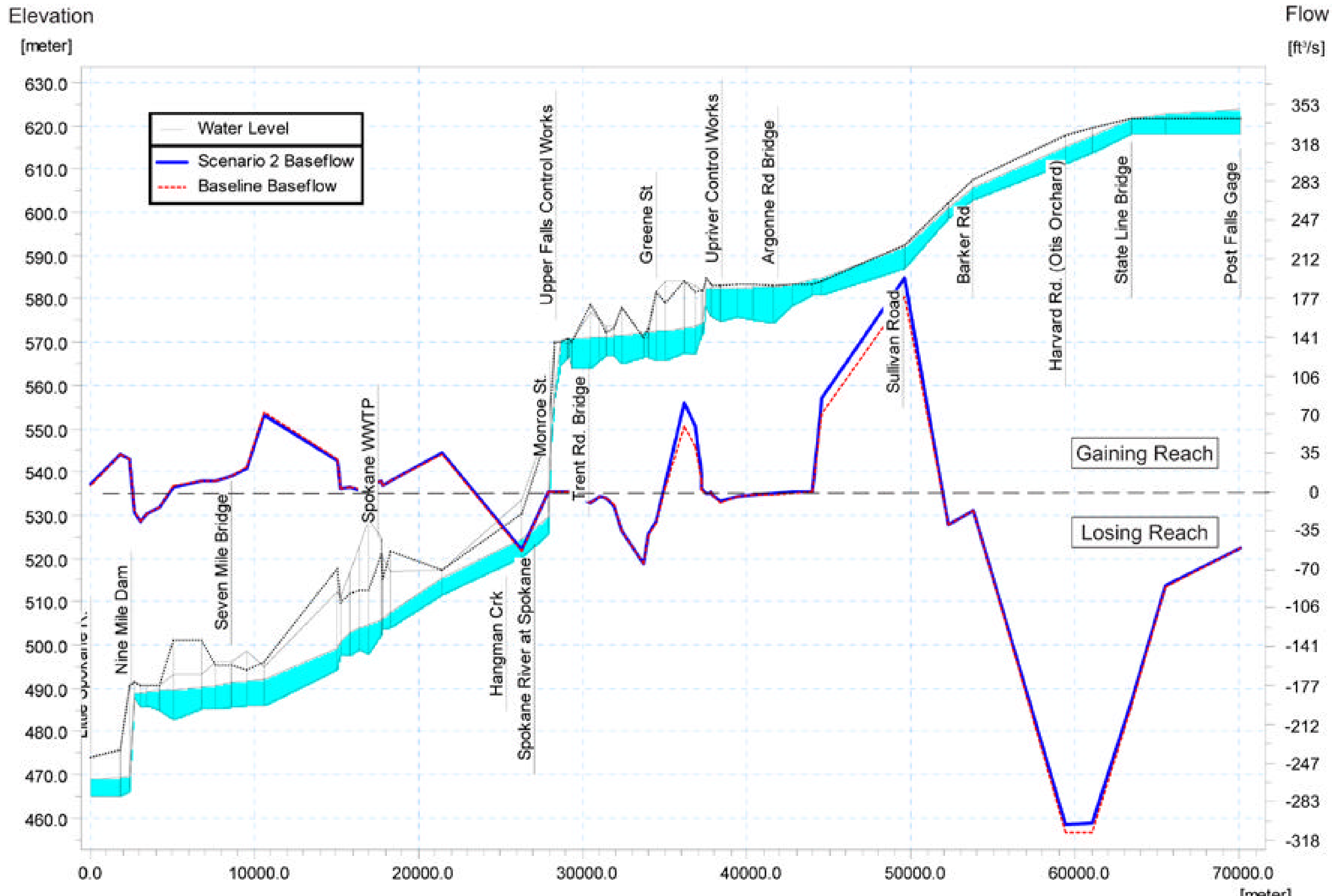
WRIA 55 & 57/ WATERSHED PLANNING/ WA

TITLE

SCENARIO 2 : CHANGE IN DISCHARGE
SPOKANE RIVER AT WWTP

DRAWN	JM	DATE	April 2004	JOB NO.	013-1372
CHECKED		SCALE		DWG. NO.	
REVIEWED		FILE NO.	Scen2InjWell_033004a-c.frf	FIGURE NO.	8



Colored lines indicate the range of surface water – aquifer interactions simulated as baseflow during a typical run.
A line that is below 0.0 m3/s (right side y-axis) indicates that river water is infiltrating and recharging the aquifer (losing river reach).
Lines above 0.0 m3/s indicate that groundwater is discharging to surface water (gaining river reach).

Note: Results shown are from run 6/05/1998. Run # SCEN2INJWELL_033004C

FIGURE 9

SCENARIO 2 : PROFILE OF GAINING/LOSING REACHES SPOKANE RIVER

WRIA 55 & 57/WATERSHED PLANNING/WA

DRAWING NO. 01313722100fg03.fh11 DATE 04/20/04 DRAWN BY EFS

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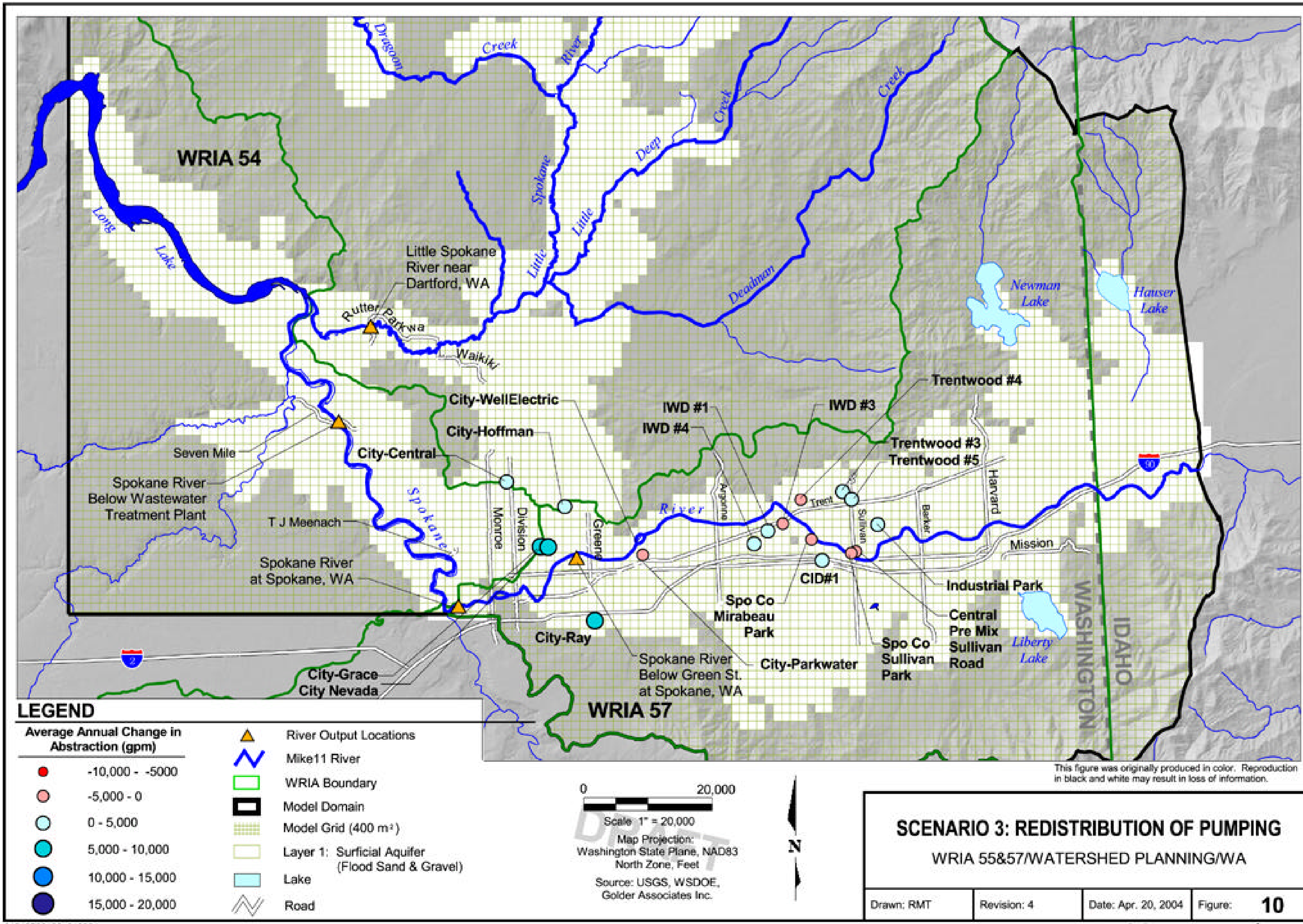

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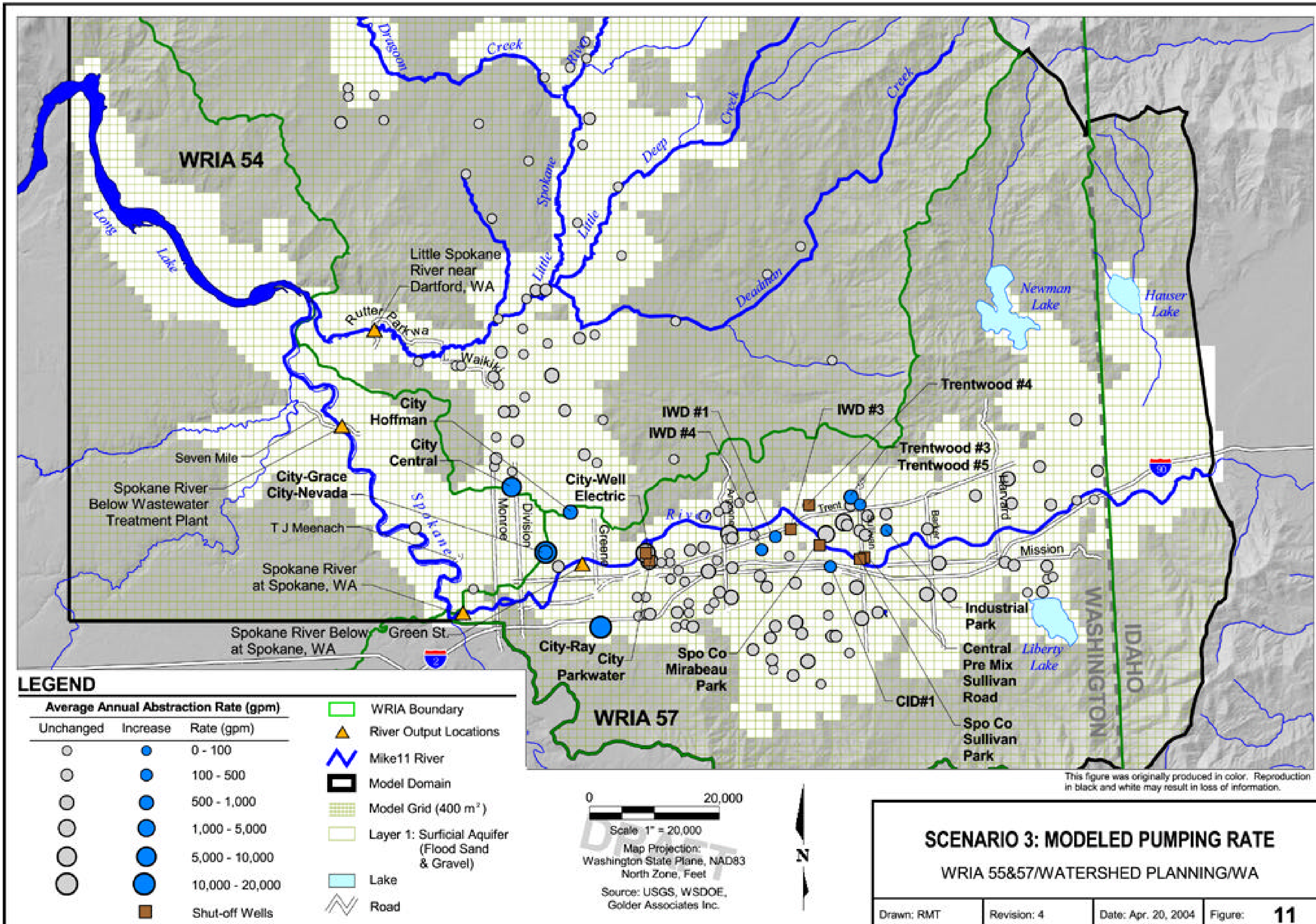
Golder Associates



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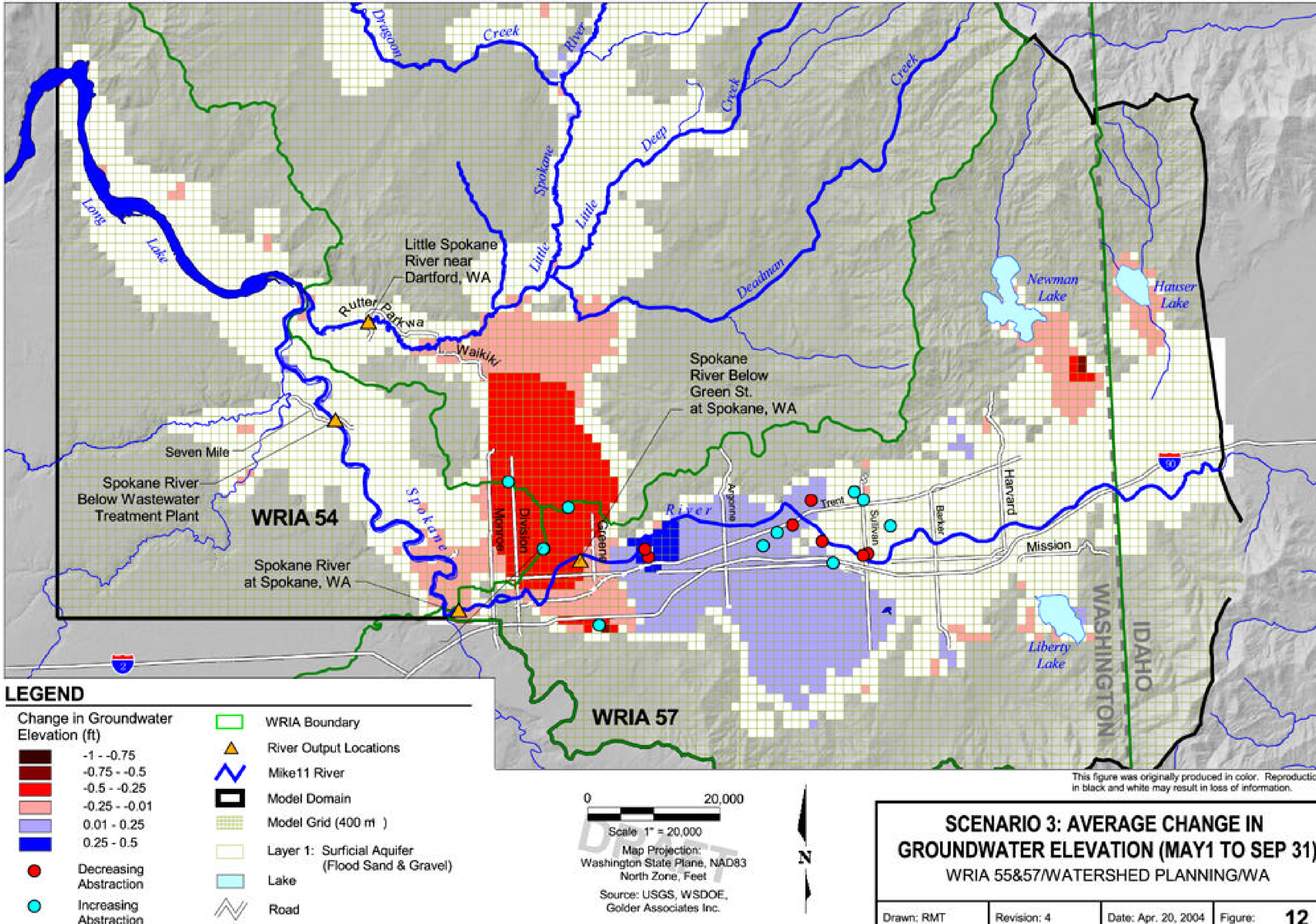

This figure was originally produced in color. Reproduction in black and white may result in loss of information.

SCENARIO 3: AVERAGE CHANGE IN GROUNDWATER ELEVATION (MAY1 TO SEP 31)

WRIA 55&57/WATERSHED PLANNING/WA

Drawn: RMT	Revision: 4	Date: Apr. 20, 2004	Figure: 12

01313722100_042004.apr

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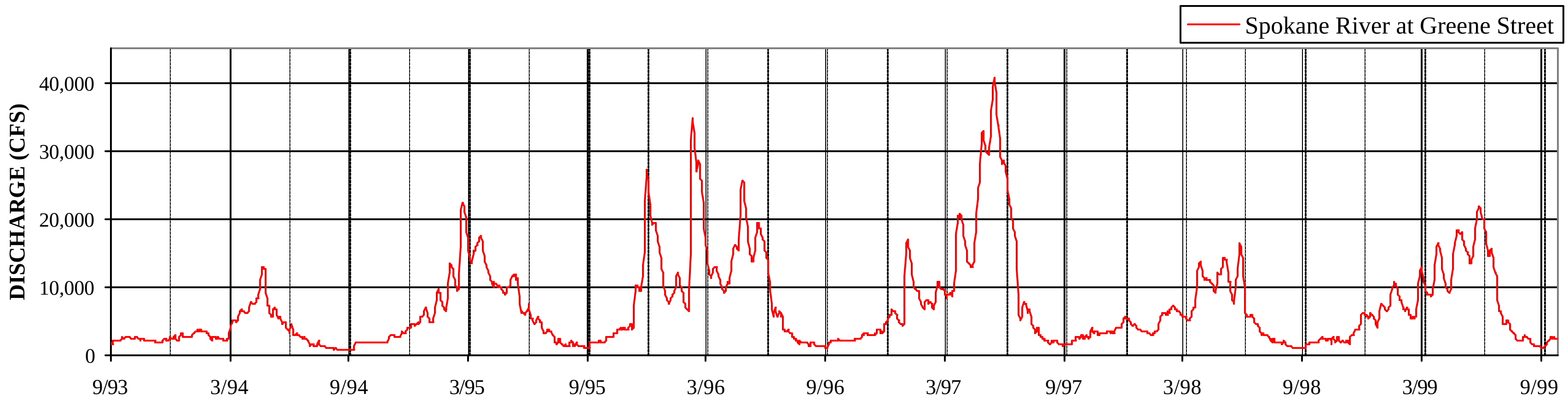

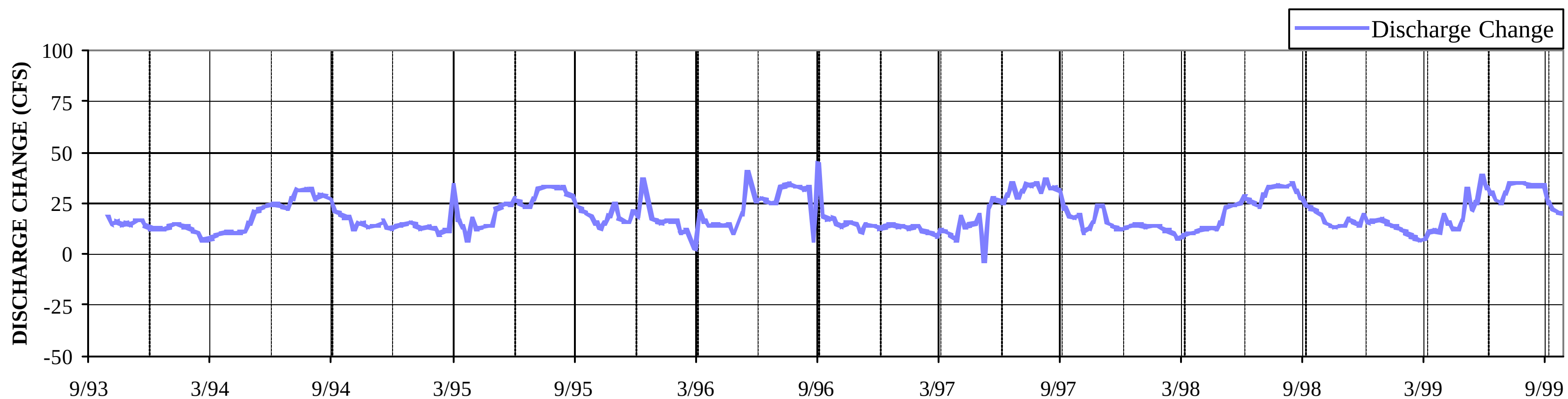

Note: Model Outliers Removed

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WRIA 55 & 57/ WATERSHED PLANNING/ WA

TITLE

SCENARIO 3: CHANGE IN DISCHARGE
SPOKANE RIVER AT GREENE STREET

DRAWN	JM	DATE	April 2004	JOB NO.	013-1372
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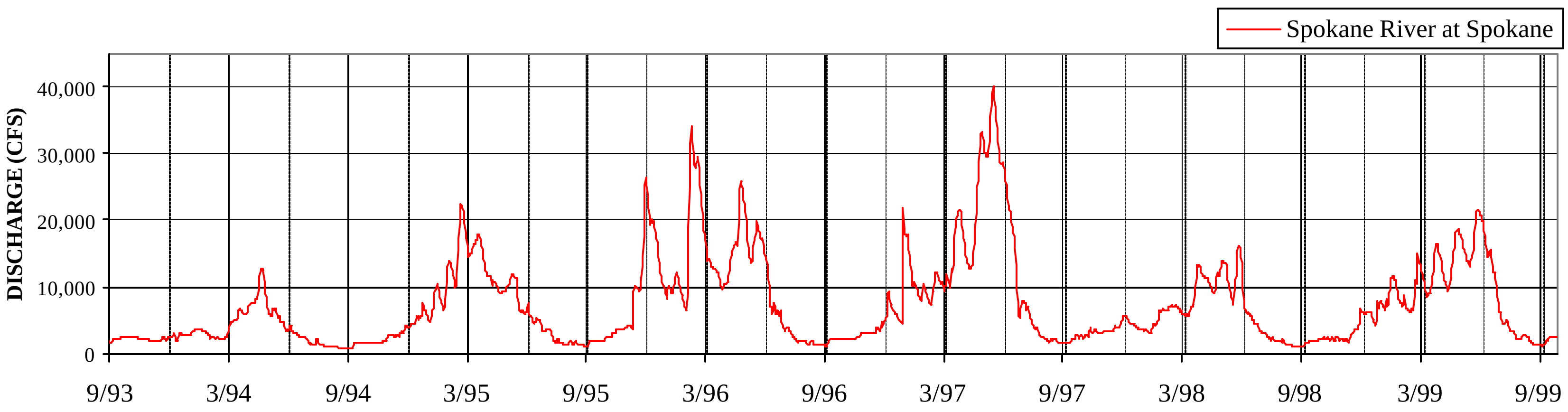

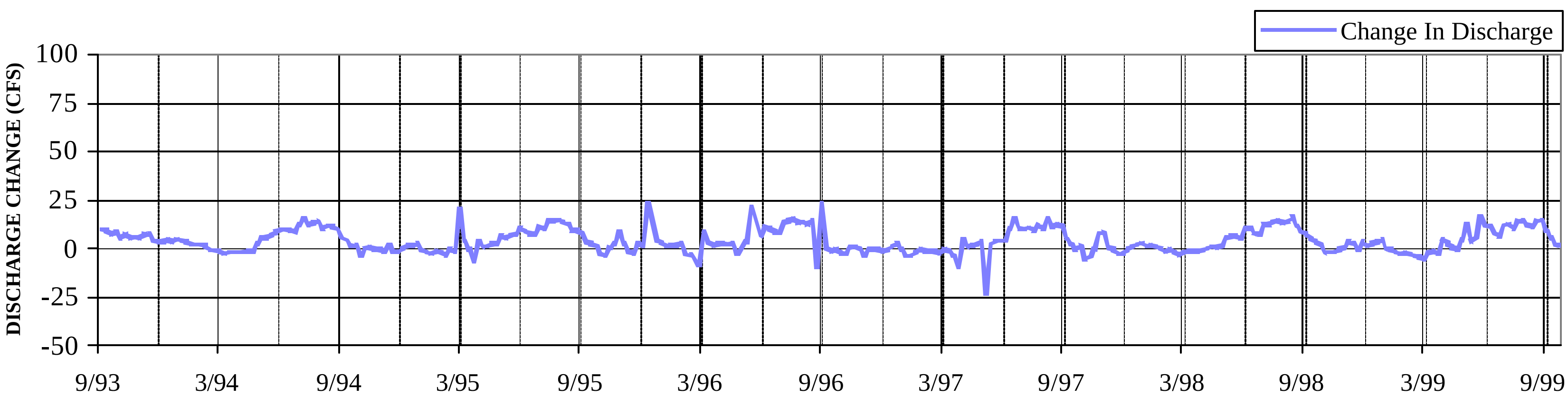

Note: Model Outliers Removed

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TITLE

SCENARIO 3 : CHANGE IN DISCHARGE
SPOKANE RIVER AT SPOKANE

WRIA 55 & 57/ WATERSHED PLANNING/ WA

DRAWN	JM	DATE	April 2004	JOB NO.	013-1372
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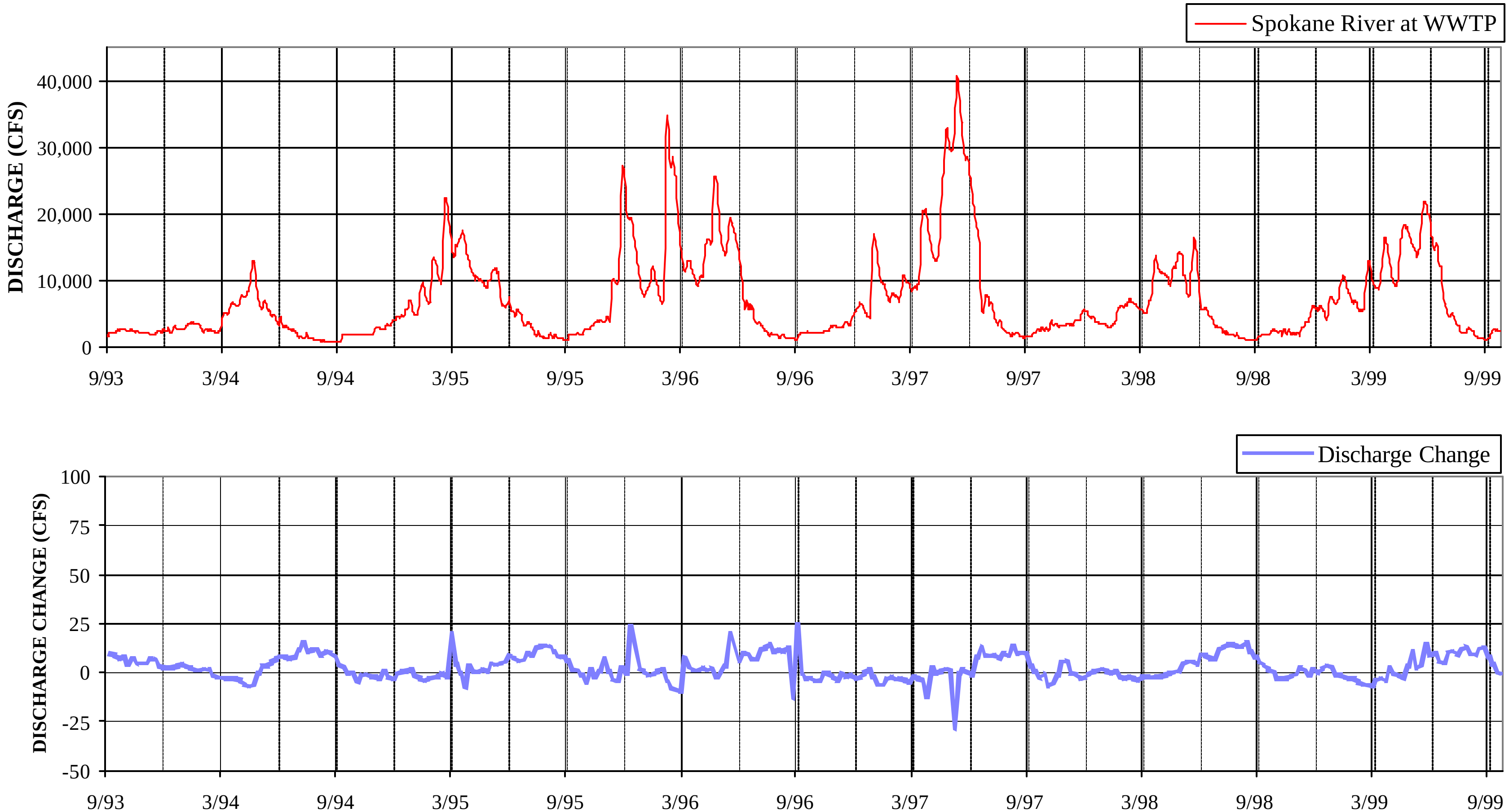

Note: Model Outliers Removed

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TITLE

SCENARIO 3: CHANGE IN DISCHARGE
SPOKANE RIVER AT WWTP

WRIA 55 & 57/ WATERSHED PLANNING/ WA

DRAWN JM	DATE April 2004	JOB NO. 013-1372
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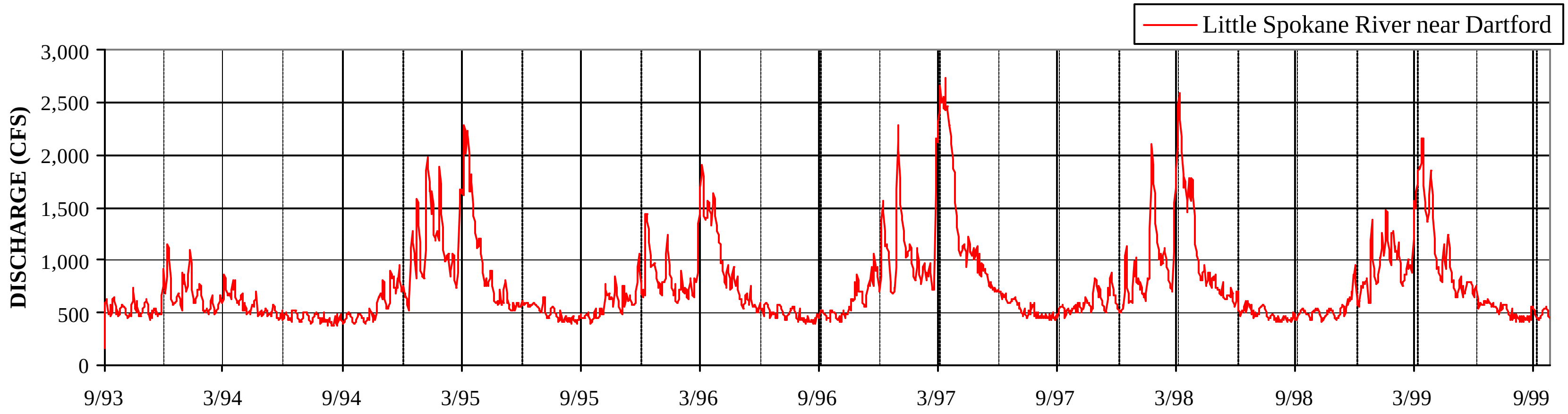
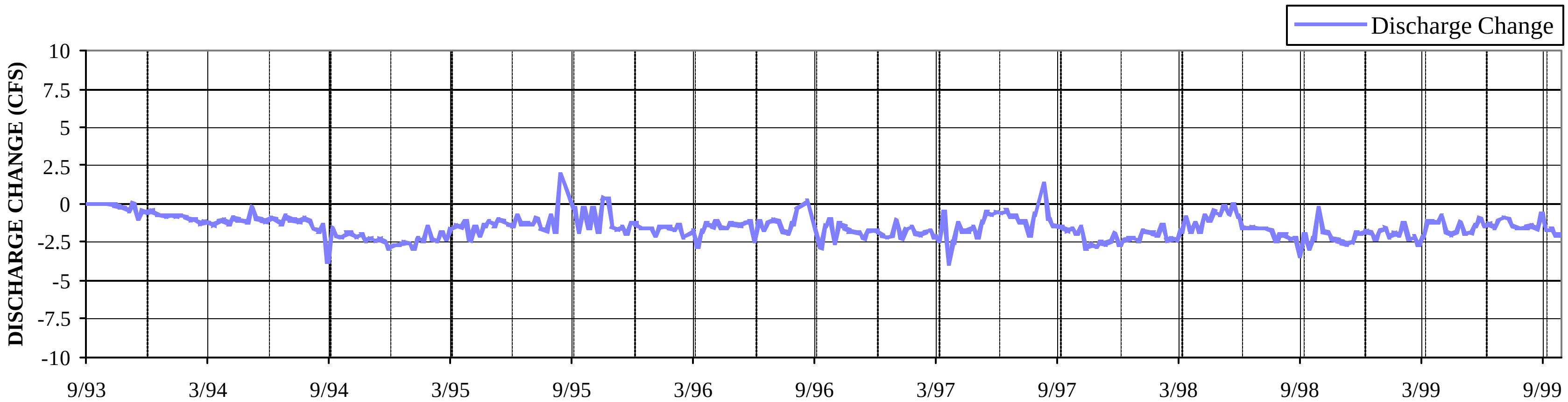
REVIEWED	FILE NO. Scen031004a-c.frf	FIGURE NO. 15





Note: Model Outliers Removed

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TITLE

SCENARIO 3: CHANGE IN DISCHARGE
LITTLE SPOKANE RIVER NEAR DARTFORD

WRIA 55 & 57/ WATERSHED PLANNING/ WA

DRAWN	JM	DATE	April 2004	JOB NO.	013-1372
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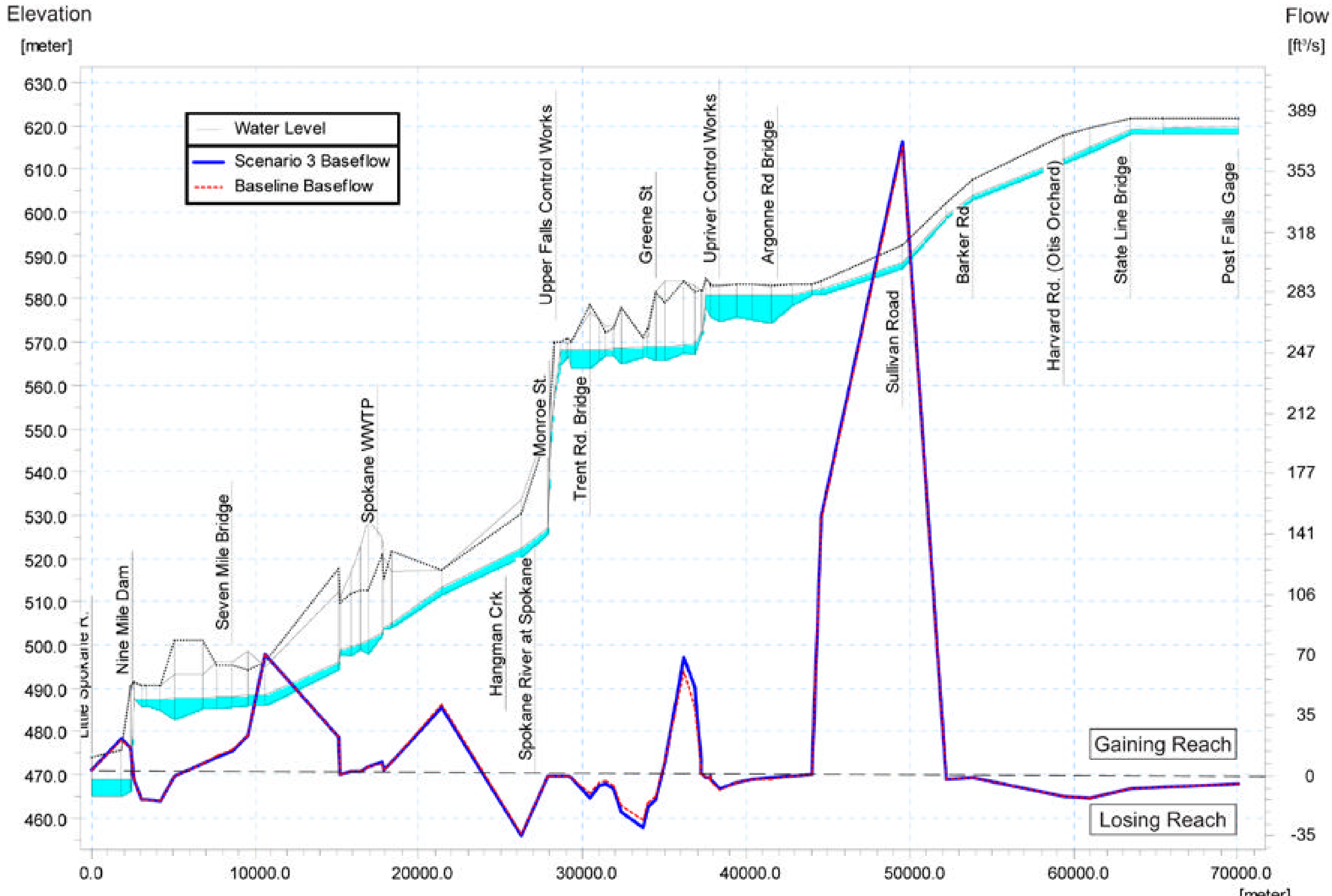

Colored lines indicate the range of surface water – aquifer interactions simulated as baseflow during a typical run.
A line that is below 0.0 m3/s (right side y-axis) indicates that river water is infiltrating and recharging the aquifer (losing river reach).
Lines above 0.0 m3/s indicate that groundwater is discharging to surface water (gaining river reach).

Note: Results shown are from run 8/24/1998. Run # SCEN3_031004C

FIGURE **17**

SCENARIO 3: PROFILE OF GAINING/LOSING REACHES SPOKANE RIVER

WRIA 55 & 57/WATERSHED PLANNING/WA

DRAWING NO. 01313722100fg02.fh11 DATE 04/20/04 DRAWN BY EFS

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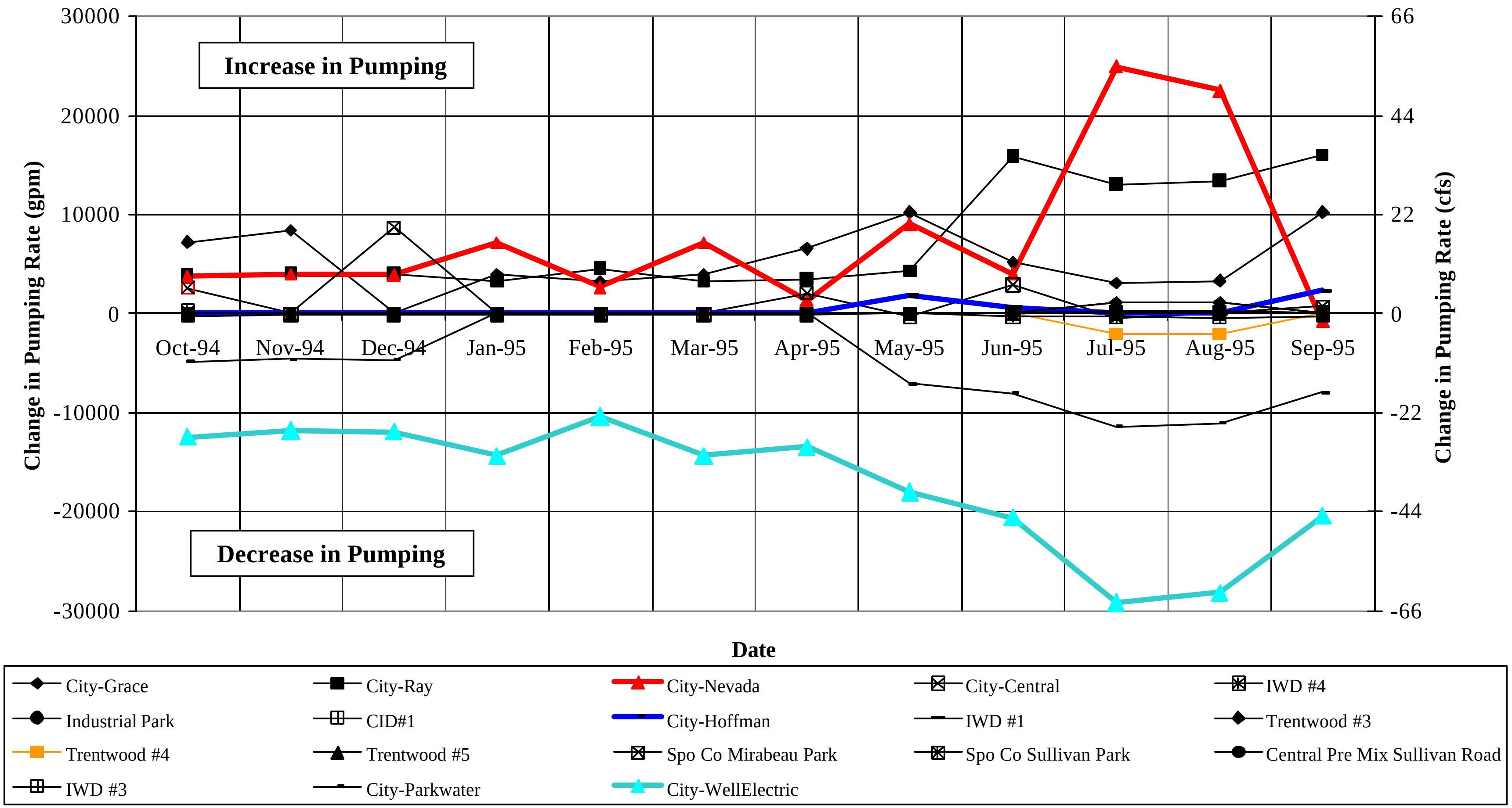

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WRIA 55 & 57/ WATERSHED PLANNING/ WA

TITLE	SCENARIO3 : CHANGE IN GROUNDWATER PUMPING				
DRAWN	JM	DATE	April 2004	JOB NO.	013-1372
CHECKED		SCALE		DWG. NO.	
REVIEWED		FILE NO.	Scen2InjWell 033004a-c.frf	FIGURE NO.	18