Spokane Valley-Rathdrum Prairie Aquifer Storage and Recovery for Summer Flow Augmentation

Dr. Michael Barber[1], Mr. Colt Shelton[2], Mr. Matt McDonald[2], Dr. Akram Hossain[3], Dr. Cara Poor[1]

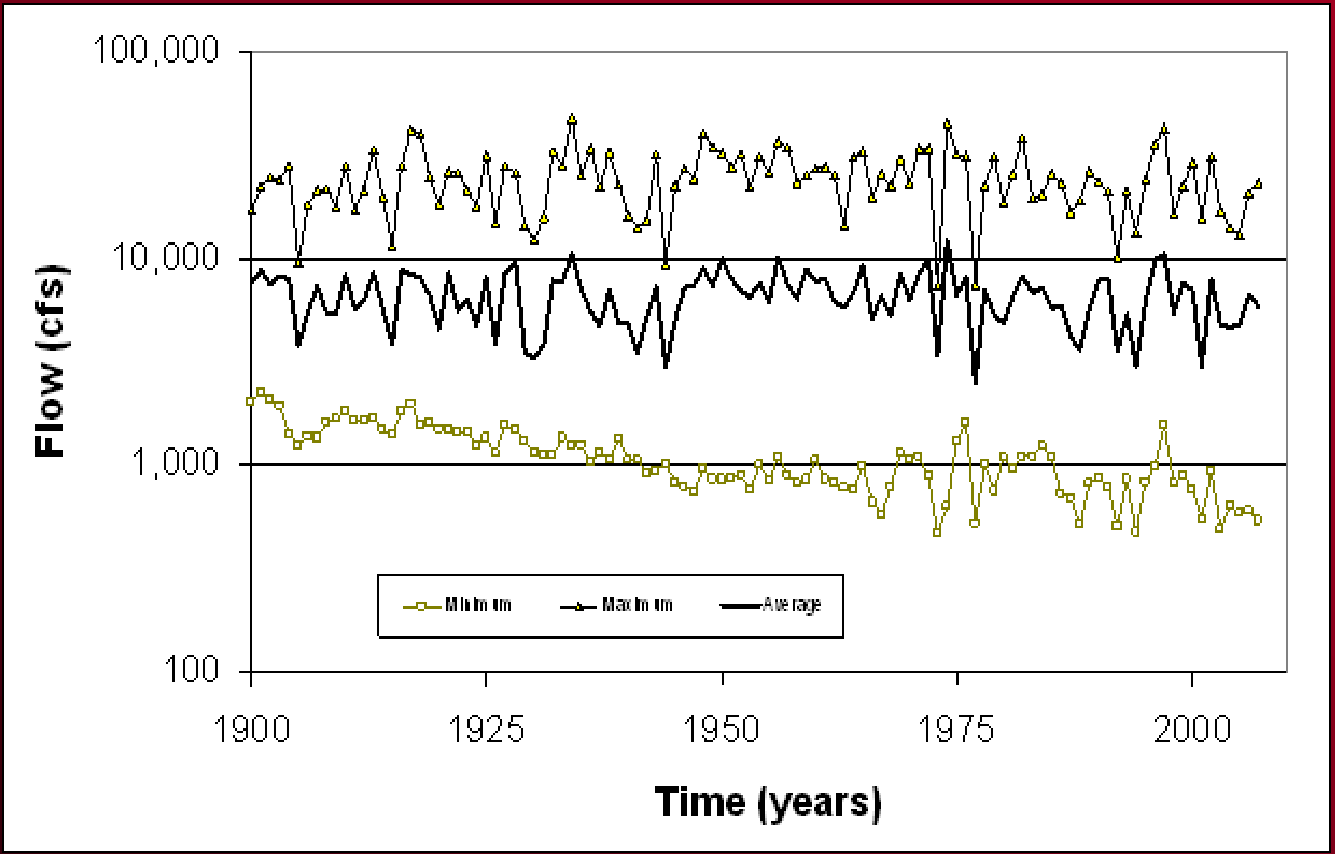
[1]State of Washington Water Research Center, WSU
[2]Civil and Environmental Engineering, WSU
[3]Environmental Engineering, WSU-Tri Cities

May 10, 2013

Presentation Outline

- Problem Overview
- Project Objective
- Study/Project Area
- Discussion of Results
  - MODFLOW
  - EPANET
  - CE-QUAL-W2
  - ECONOMIC ANALYSIS
- Conclusions

Problem Overview



Declining low flows in late summer and early fall and project regional growth in demand.

Project Objective

Use bi-state MODFLOW model to investigate alternatives associated with aquifer storage and natural recovery in the SVRP including examining:

1) raw water source,

2) location of extraction and injection points,

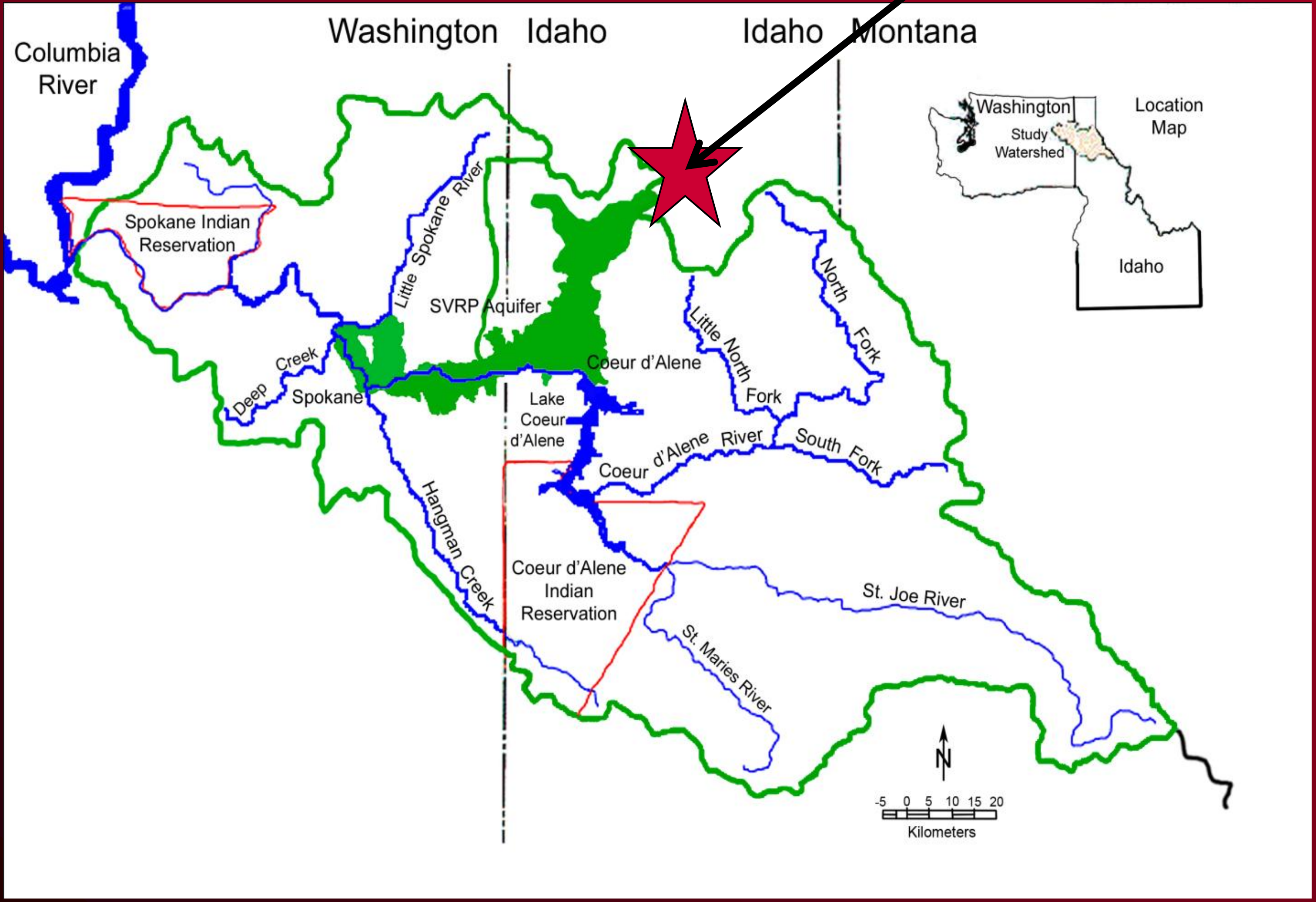
3) pipeline routes, and

4) costs

with ultimate goal of increasing low flow river conditions.

Project Area

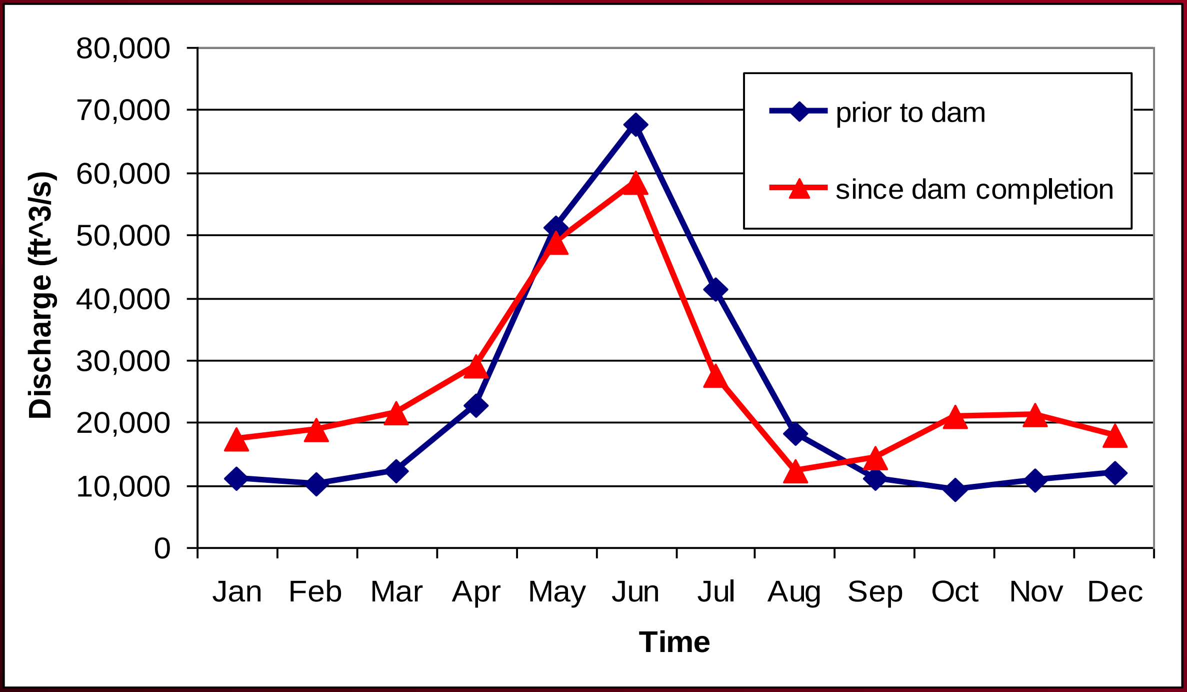
Lake Pend Oreille



Raw Water Sources

- Spokane River
- Spokane Well Field
- Lake Pend Oreille Well Field

Pend Oreille River



MODFLOW ANALYSIS

Converted model to Visual MODFLOW

- Conducted 275 runs to examine:
  - Extraction well location
  - Injection well location
  - Pumping rate
  - Pumping duration
  - Impact on river flows (quantity & timing)

Extraction/Diversion Location

Spokane River

1. Expensive water treatment needed although pipeline costs were less. Overall, too costly.

Spokane River well field

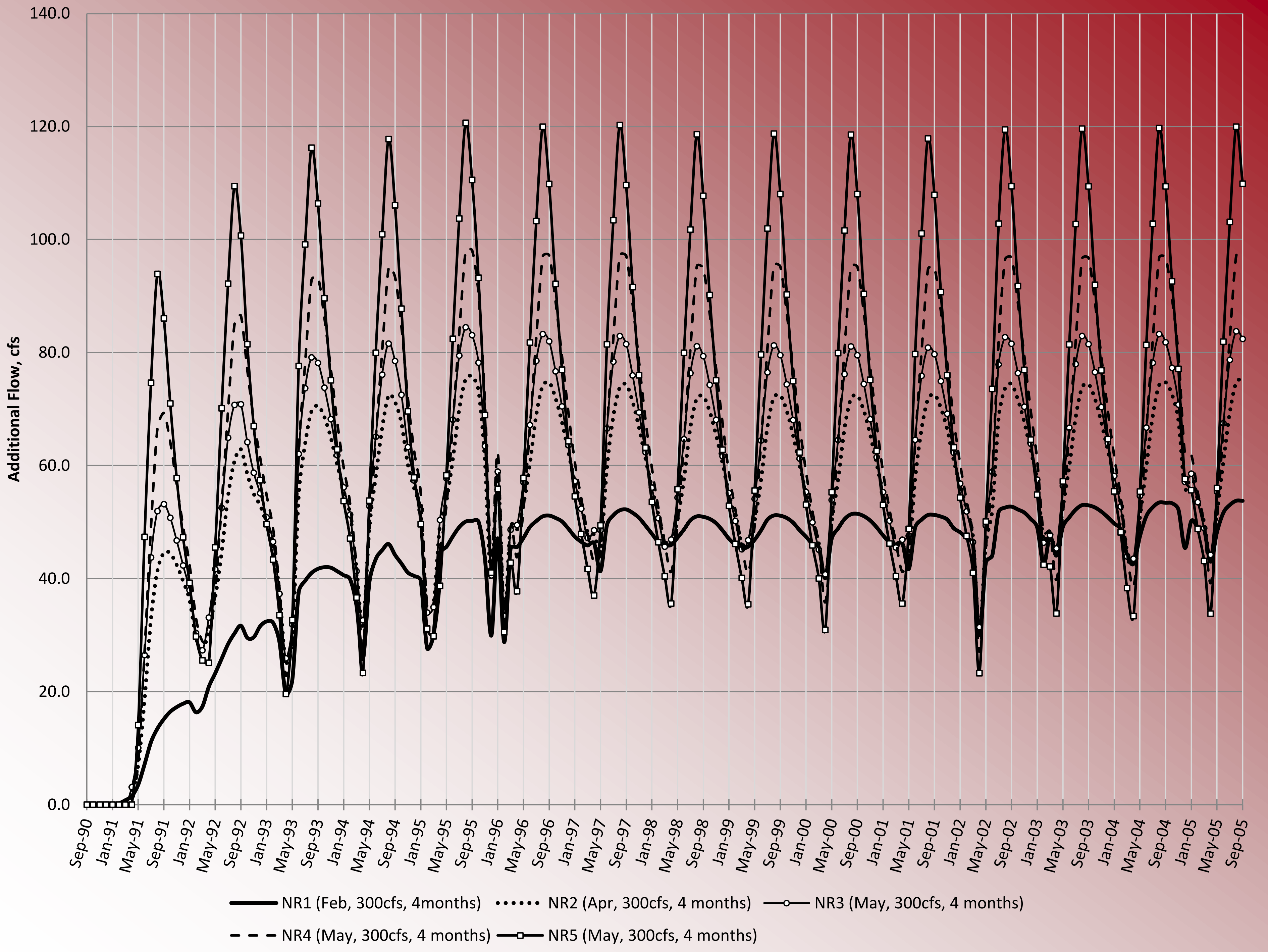
1. Created too big a “hole” and stole water from river

Lake Pend Oreille well field

1. Realistic costs and water supply

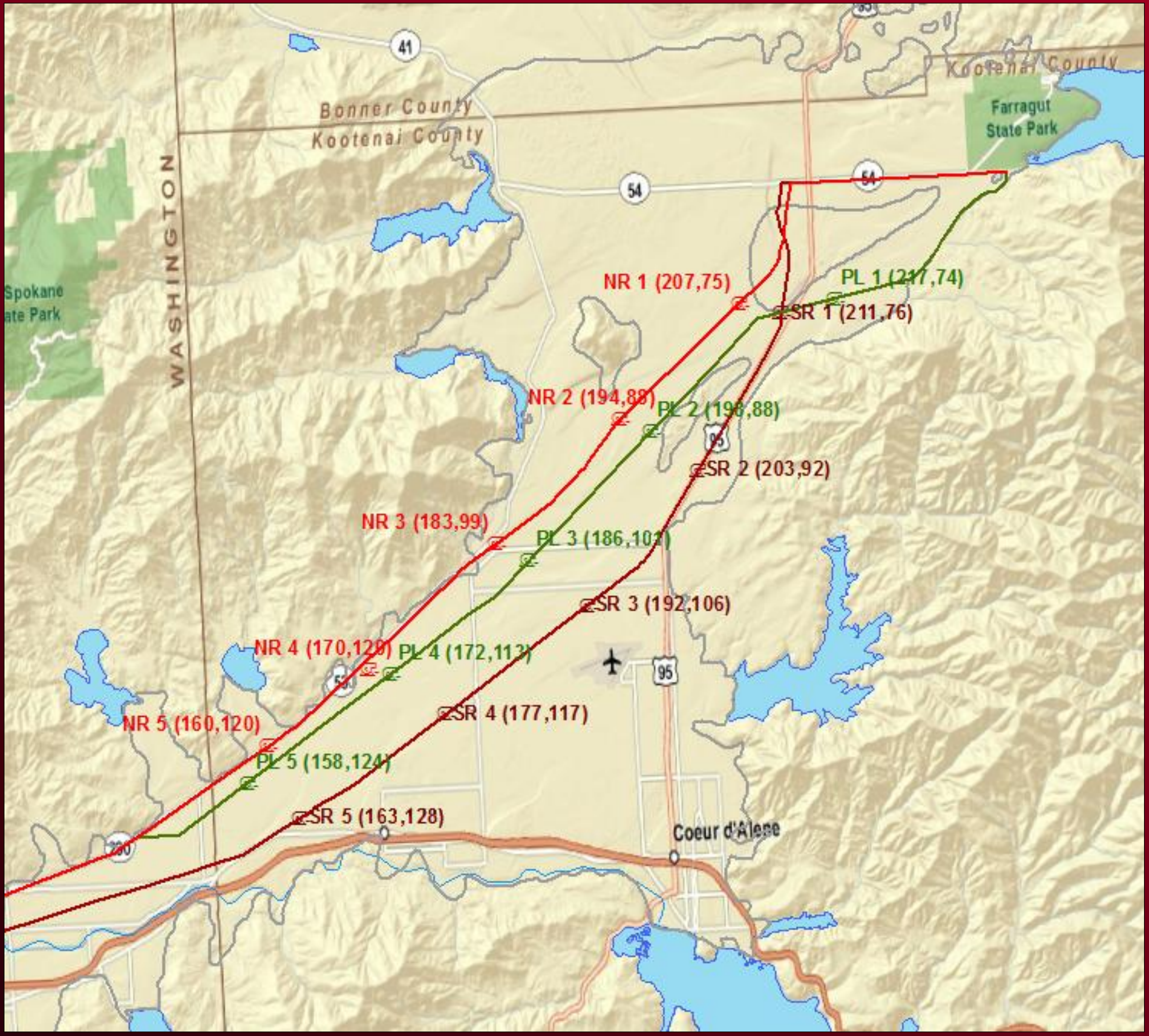
MODFLOW Results

Location	Starting Month	Rate (ft^3/s)	Length of Injection (Months)	Peak Monthly Return (ft^3/s)	Peak Monthly % Return	Average Yearly Return	Max Month	2nd Highest	3rd Highest
NR1	Jan	25	3	3.26	4.49%	47.35%	August	July	October
NR1	Feb	25	3	3.52	4.86%	51.56%	August	October	July
NR1	Mar	25	3	3.37	4.45%	47.15%	October	August	July
NR1	Apr	25	3	3.26	4.44%	46.98%	October	December	August
NR1	May	25	3	3.26	4.39%	46.88%	December	N/A	N/A
NR1	Dec	25	3	3.27	4.50%	47.40%	July	August	May
NR1	Jan	50	3	6.53	4.50%	47.33%	August	July	October
NR1	Jan	75	3	9.82	4.51%	47.37%	August	August	October
NR1	Jan	100	3	13.11	4.51%	47.37%	July	August	October
NR1	Jan	150	3	19.69	4.52%	47.34%	July	August	October
NR1	Jan	200	3	26.27	4.52%	47.32%	July	August	October
NR1	Jan	300	3	40.67	4.67%	48.71%	July	August	October

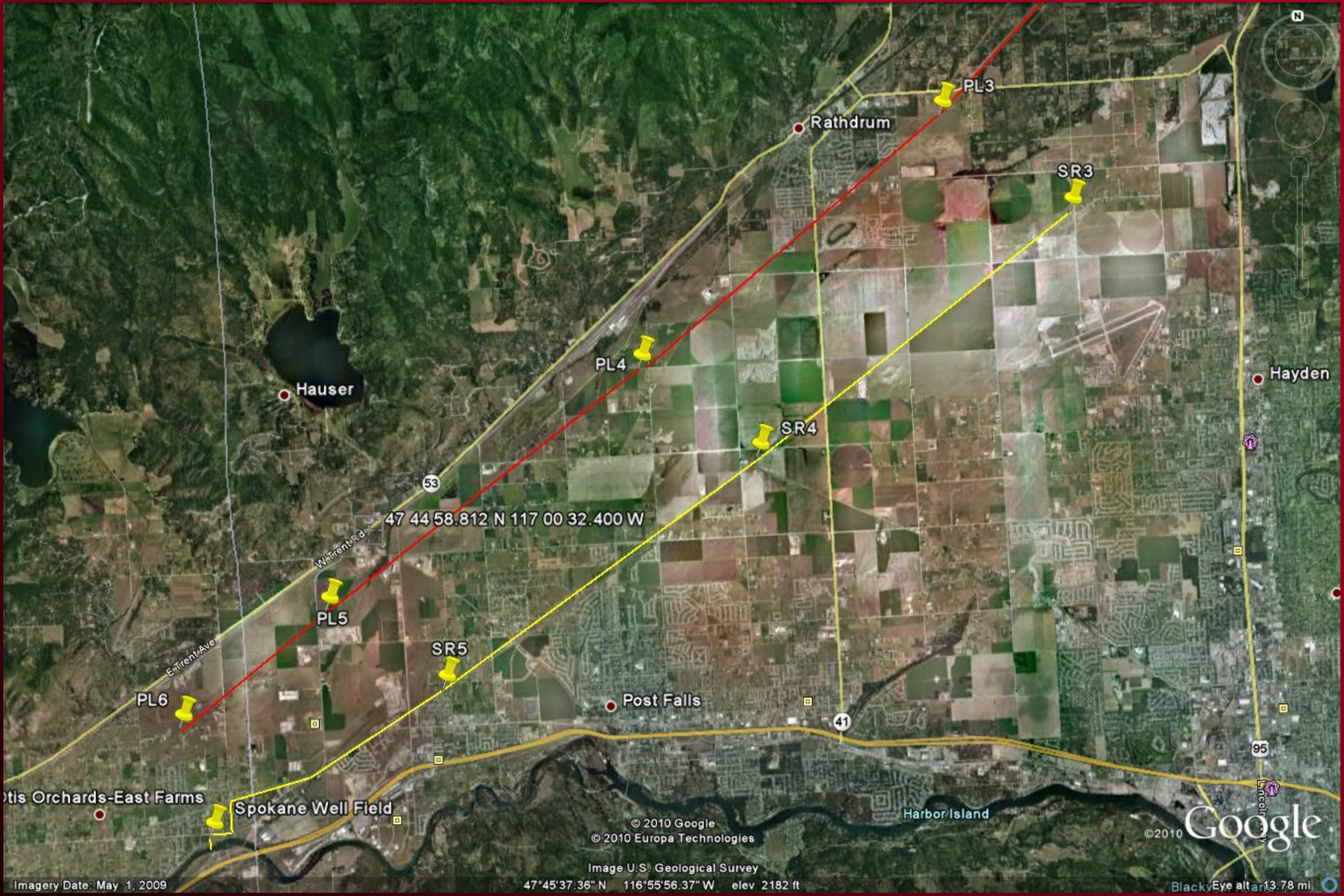


Additional Flow, cfs
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
Sep-90 Jan-91 May-91 Sep-91 Jan-92 May-92 Sep-92 Jan-93 May-93 Sep-93 Jan-94 May-94 Sep-94 Jan-95 May-95 Sep-95 Jan-96 May-96 Sep-96 Jan-97 May-97 Sep-97 Jan-98 May-98 Sep-98 Jan-99 May-99 Sep-99 Jan-00 May-00 Sep-00 Jan-01 May-01 Sep-01 Jan-02 May-02 Sep-02 Jan-03 May-03 Sep-03 Jan-04 May-04 Sep-04 Jan-05 May-05 Sep-05
NR1 (Feb, 300cfs, 4months)
NR2 (Apr, 300cfs, 4 months)
NR3 (May, 300cfs, 4 months)
NR4 (May, 300cfs, 4 months)
NR5 (May, 300cfs, 4 months)

3 Possible Pipeline Routes – NR, PL, SR

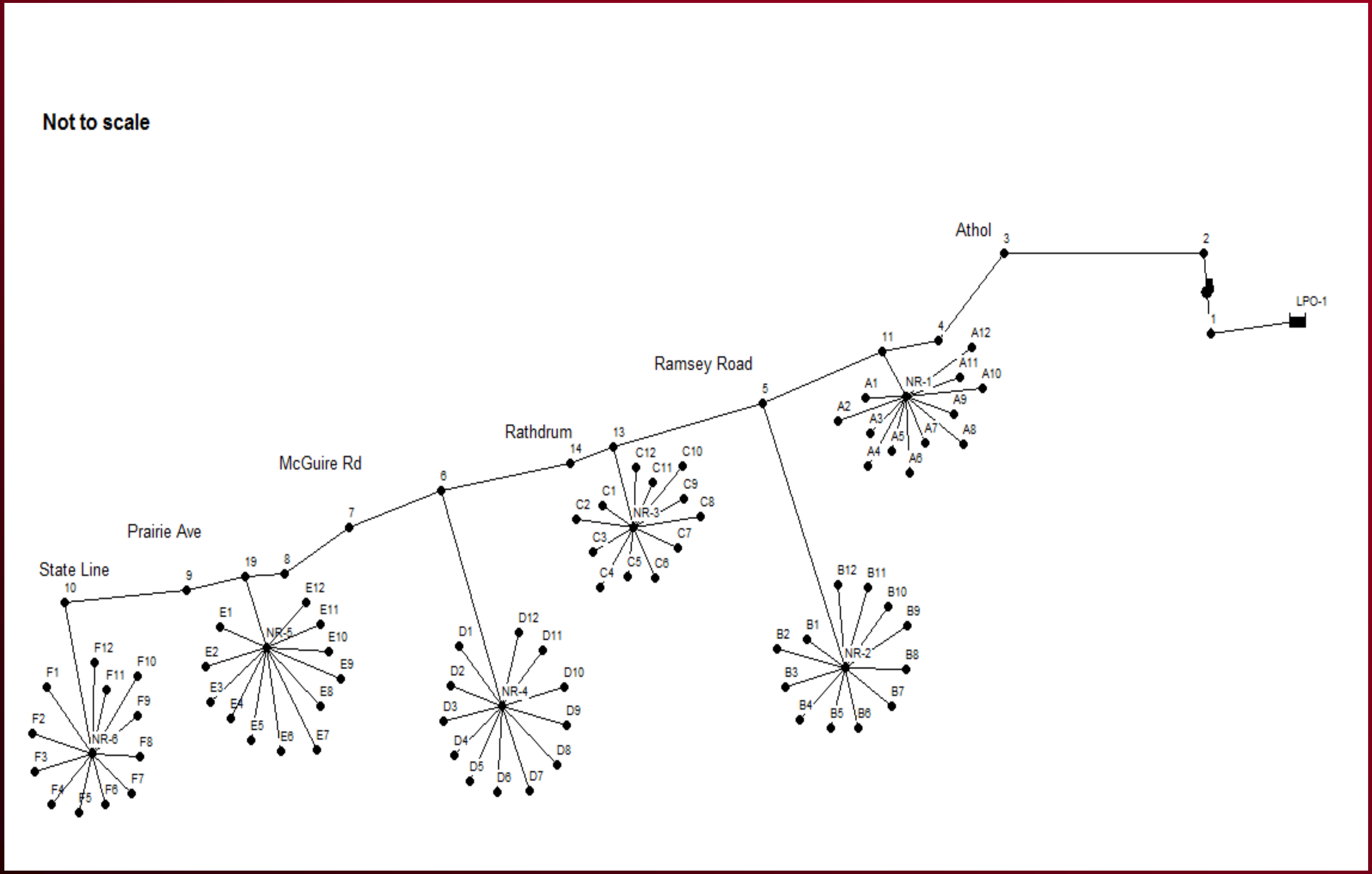


Close-up of Routes & Injection Points



EPANET Analysis

Pipeline and Injection Well Size versus Head Loss



PL3 Head versus Size

Pipe Diameter (inches)	Injection Well Diameter (inches)	Flow Rate to PL3 Location (ft^3/s)						
		25	50	75	100	150	200	300
24	12	915.9						
	18	842.2						
	24	833.2						
30	12	365.6	1,096.4					
	18	291.9	1,022.7					
	24	282.9	1,013.8					
36	12	200.8	501.5	966.9				
	18	127.1	427.8	893.2	1,504.2			
	24	118.1	418.8	884.2				
48	12			302.6	455.4	869.1		
	18		105.4	228.9	381.6	795.4	1346.7	
	24			220.0	372.7	786.4	1337.8	
60	12					349.8	535.8	1,039.5
	18				136.6	276.1	462.0	965.8
	24				127.6	267.2		
72	12							478.1
	18					111.6	188.2	404.4
	24							395.4

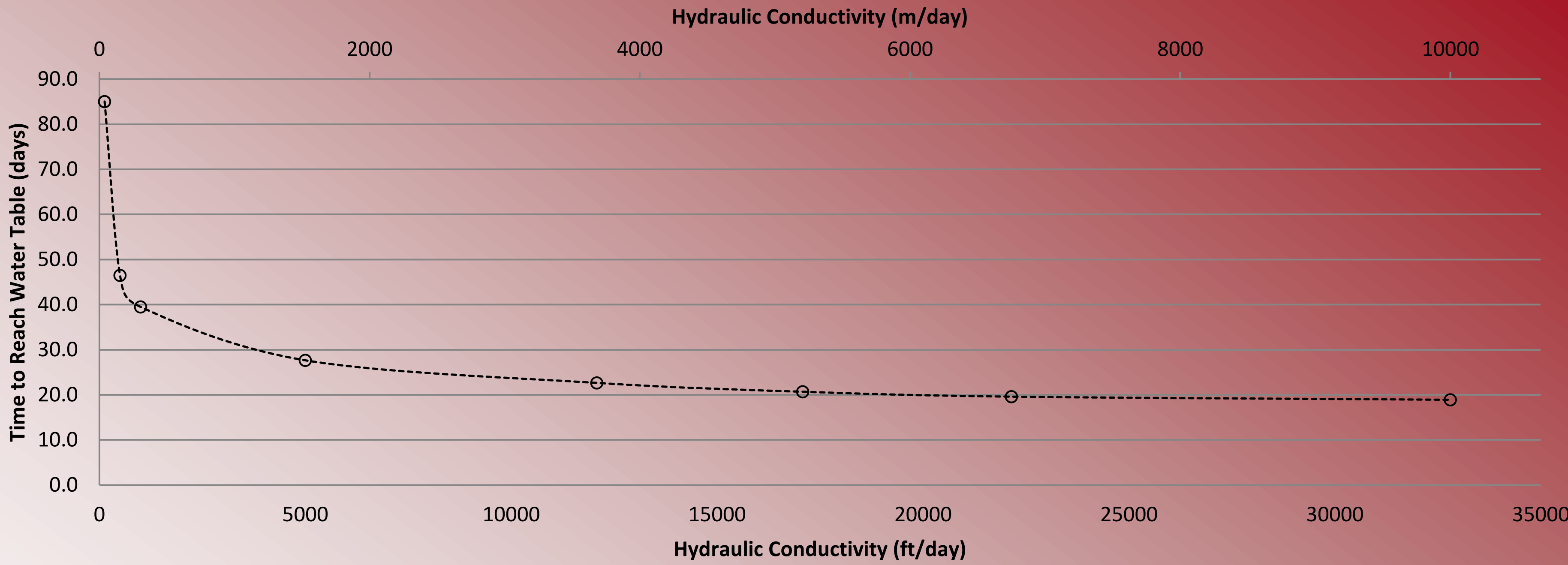
Examined Infiltration v. Injection

Used HYDRUS2D/3D Model

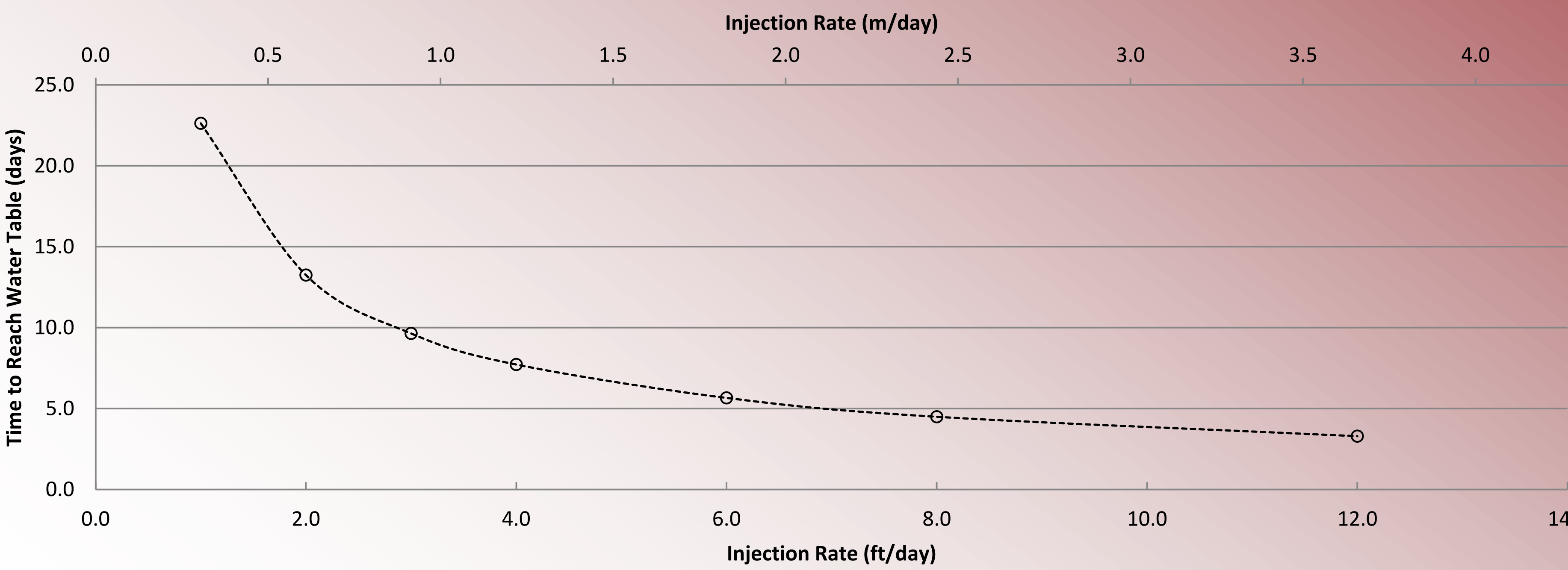
High Hydraulic Conductivity throughout aquifer

→ very large surface area required for significant lag

→ monthly time step in MODFLOW resulted in very



Hydraulic Conductivity (m/day)
0
2000
4000
6000
8000
10000
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Time to Reach Water Table (days)
0
5000
10000
15000
20000
25000
30000
35000
Hydraulic Conductivity (ft/day)



Injection Rate (m/day)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
25.0
20.0
15.0
10.0
5.0
0.0
Time to Reach Water Table (days)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
Injection Rate (ft/day)

Costs Considered

1. Pumping (Extraction) Costs
2. Pumping (Distribution) Costs
3. Treatment (Spokane Surface Water)
4. Pipeline Costs
5. Well Field Costs
6. O&M Costs

Neglected

1. Right-of-way Costs

Example of Annual Costs

	Injection Rate					
	100 ft^3/s		200 ft^3/s		300 ft^3/s	
Scenario	Aug	Aug, Sep, & Oct	Aug	Aug, Sep, & Oct	Aug	Aug, Sep, & Oct
LPO-NR2-72-18 May – 1 m			788 $11,898	2234 $4,197	1185 $10,256	3361 $3,616
LPO-NR2-60-18 May – 2 m			1531 $7,241	4442 $2,496		
LPO-NR2-72-18 May – 2 m			1531 $6,513	4442 $2,245	2337 $5,719	6789 $1,969
LPO-NR2-60-18 April – 3 m			2266 $5,275	6475 $1,846		
LPO-NR2-72-18 April – 3 m			2266 $4,663	6475 $1,632	3460 $4,213	9899 $1,473
LPO-NR2-60-18 April – 4 m			2949 $4,357	8675 $1,481		
LPO-NR2-72-18 April – 4 m			2949 $3,792	8675 $1,289	4573 $3,461	13473 $1,175

Construction v. O&M

Scenario	Construction Costs	Annual Operation Cost per Extraction Period (days)			
		30	61	91	122
LPO-NR2-72-18-200	$70,427,417	$5,032,000	$5,647,000	$6,243,000	$6,858,000
LPO-NR2-72-18-300	$87,630,000	$6,733,000	$7,985,000	$9,197,000	$10,449,000
LPO-NR3-60-18-100	$73,813,000	$4,937,000	$5,233,000	$5,519,000	$5,815,000
LPO-NR3-60-18-300	$166,676,000	$13,067,000	$15,719,000	$18,285,000	$20,937,000
LPO-NR3-72-18-300	$122,041,000	$9,099,000	$10,557,000	$11,967,000	$13,425,000
LPO-PL4-60-18-300	$198,393,000	$15,516,000	$18,634,000	$21,651,000	$24,769,000
SR-PL3-72-18-300	$464,299,000	$12,391,000	$13,008,000	$13,606,000	$14,223,000

Ancillary Benefits Considered

- **Water Quality Improvement**
  - **Lower instream temperatures**
  - **Reduced algal growth at Long Lake**
- **Increased Hydropower Production**
  - **5 dams in study area**

Ancillary Benefits: CE-QUAL-W2

- Methodology
  - Visual MODFLOW output
    - Pumping/Injection durations of 1-4 months beginning in May
    - Flow rate of 300 cfs
    - Well field: NR5
  - CE-QUAL-W2 surface water model
    - Ecology's Scenario A (background inputs)
    - Altered only the groundwater flow files
    - Examined water entering Long Lake

Ancillary Benefits

- Results
  - Changes in stream flow entering LL increase with longer pumping/injection durations

Scenario	Average Increase over Scenario A (cfs)	First Increase
A.1	25	Sept. 21
A.2	53	July 9
A.3	87	June 29
A.4	118	June 19

  - No significant change in P, N, DO, or temperature

Average constituent concentrations for all scenarios

Parameter	Scenario				
	A	A.1	A.2	A.3	A.4
Dissolved Oxygen (mg/L)	9.93	9.77	9.73	9.74	9.74
Phosphorus (mg/L)	0.0030	0.0033	0.0034	0.0035	0.0035
Nitrogen (mg/L)	0.0236	0.0214	0.0211	0.0211	0.0212
Temperature (^{o}C)	12.51	12.61	12.62	12.59	12.57

Ancillary Benefits

Incremental power production (MWh) and additional annual hydropower revenue.

Dam	Scenarios			
	A.1	A.2	A.3	A.4
Upriver	3,927	4,005	4,072	4,139
Upper Falls	2,803	3,130	3,455	3,754
Monroe Street*	381	837	1,283	1,702
Nine Mile	3,636	4,139	4,568	5,009
Long Lake	8,674	8,674	9,130	10,351
TOTAL Revenue	$1,510,000	$1,617,000	$1,751,000	**$1,941,000**

- Power generated only from March 15 to October 31 of 2001
- Based on retail energy cost of $0.078/kWh
- *Potential turbine flow used

Conclusions

A few key observations :

- It appears technically feasible to use Lake Pend Oreille water to enhance SVRP and Spokane River
- It is not viable to extract Spokane River water due to excessive water treatment costs
- NR and PL lines look most promising – SR possible
- Direct injection is preferable to infiltration
- WQ/TMDL issue hinges on groundwater concentrations which are not well understood

Questions?

WASHINGTON STATE UNIVERSITY

World Class. Face to Face.