# ESPA TRIBUTARY BASIN UNDERFLOW ESTIMATION

Preliminary Investigation Update

Mike McVay

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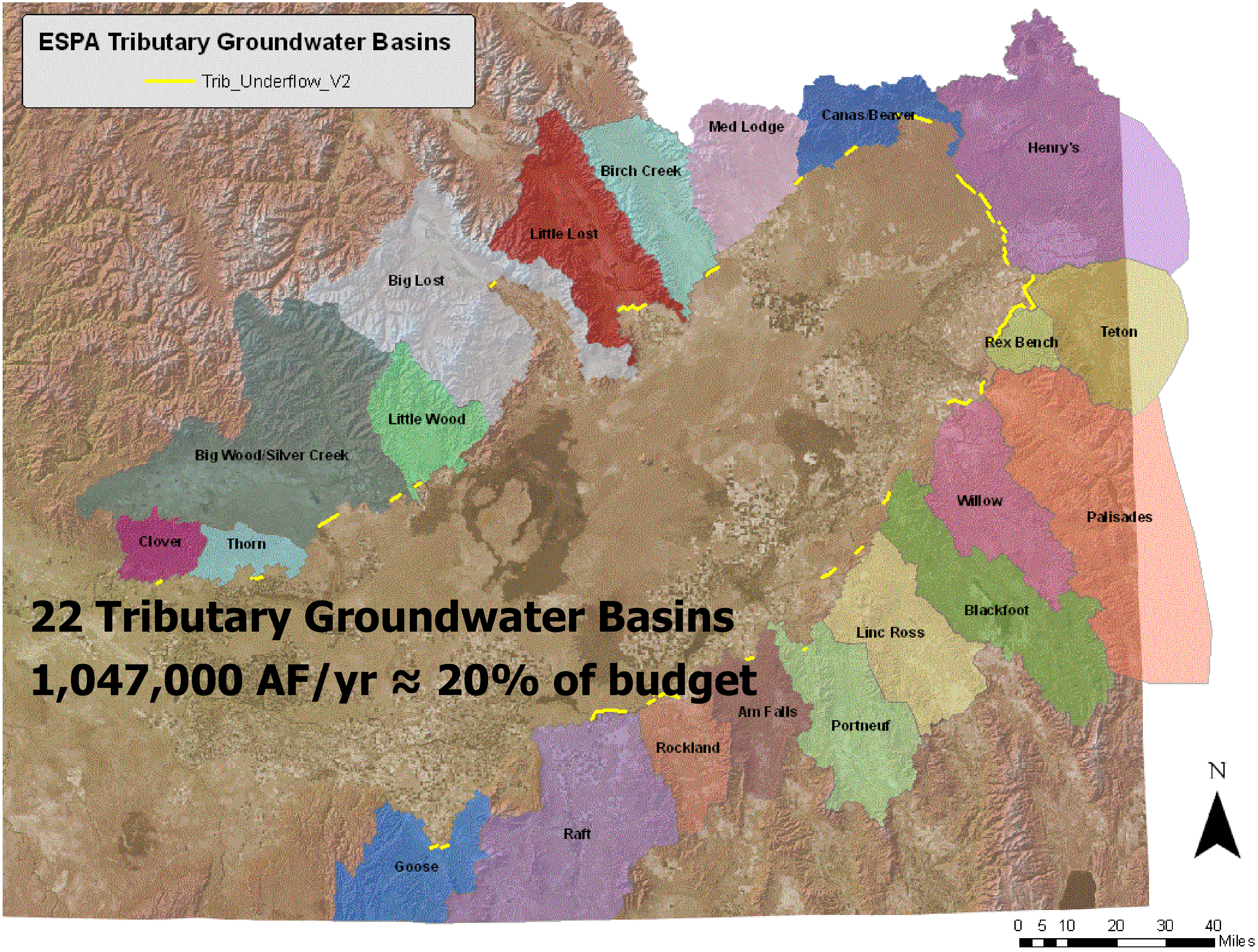
# Objectives

- Re-introduce myself
- Review for committee
- Present my level of understanding
- Summary of Dr. Welhan's 2006 report
- Looking for input on a way forward




# 22 Tributary Groundwater Basins

# 1,047,000 AF/yr ≈ 20% of budget

# Current Method to Calculate Tributary Underflow into ESPA

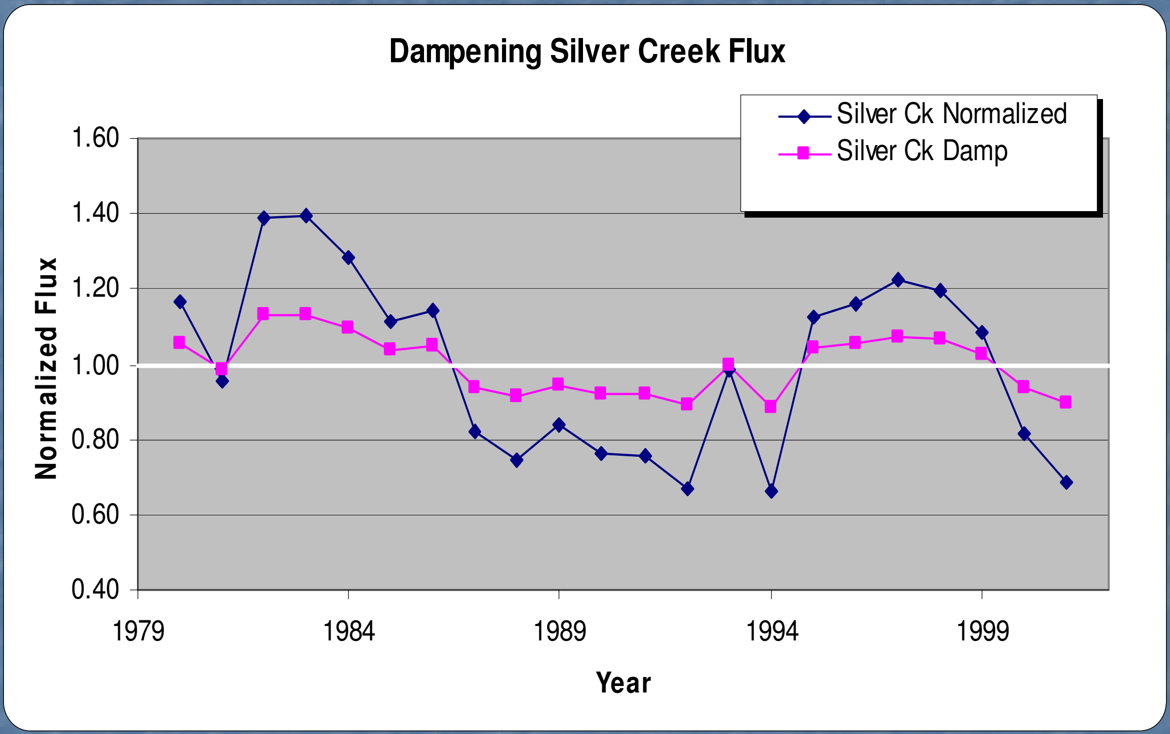
- Based on Kjelstrom 1986 values.
- Use Garabedian 1992 underflow values.
  - Adjusted to represent new model boundaries.
- Annual flux is shaped using Silver Creek as a proxy.
  - Silver Creek is spring fed.
  - Silver Creek is assumed to reflect temporal changes in underflow from an average groundwater basin.

# Shaping Tributary Underflow Using Silver Creek

- Compute Normalized Flux.
  - Divide annual flow by mean flow (1980-2001).
- Normalized values are above 1 during wet years and below 1 during dry years.
- Values adjusted to dampen year-to-year variation.
  - Dampened to simulate general aquifer behavior because springs are at the aquifer top (1/3 amplitude).
- Scaled to balance the water budget.
  - Underflow values multiplied by 0.96.

# Dampening Procedure

- Goal is to reduce the variation (bring down highs and bring up lows).
- Example – Normalized value of 1.17.
  - Subtract the normalized value from 1.0
  - 1.0 – 1.17 = -0.17
  - Multiply the difference by 2/3
  - -0.17 x 2/3 = -0.11
  - Add the product to the original normalized value
  - 1.17 + -0.11 = 1.06
- Result is Dampened Normalized value.

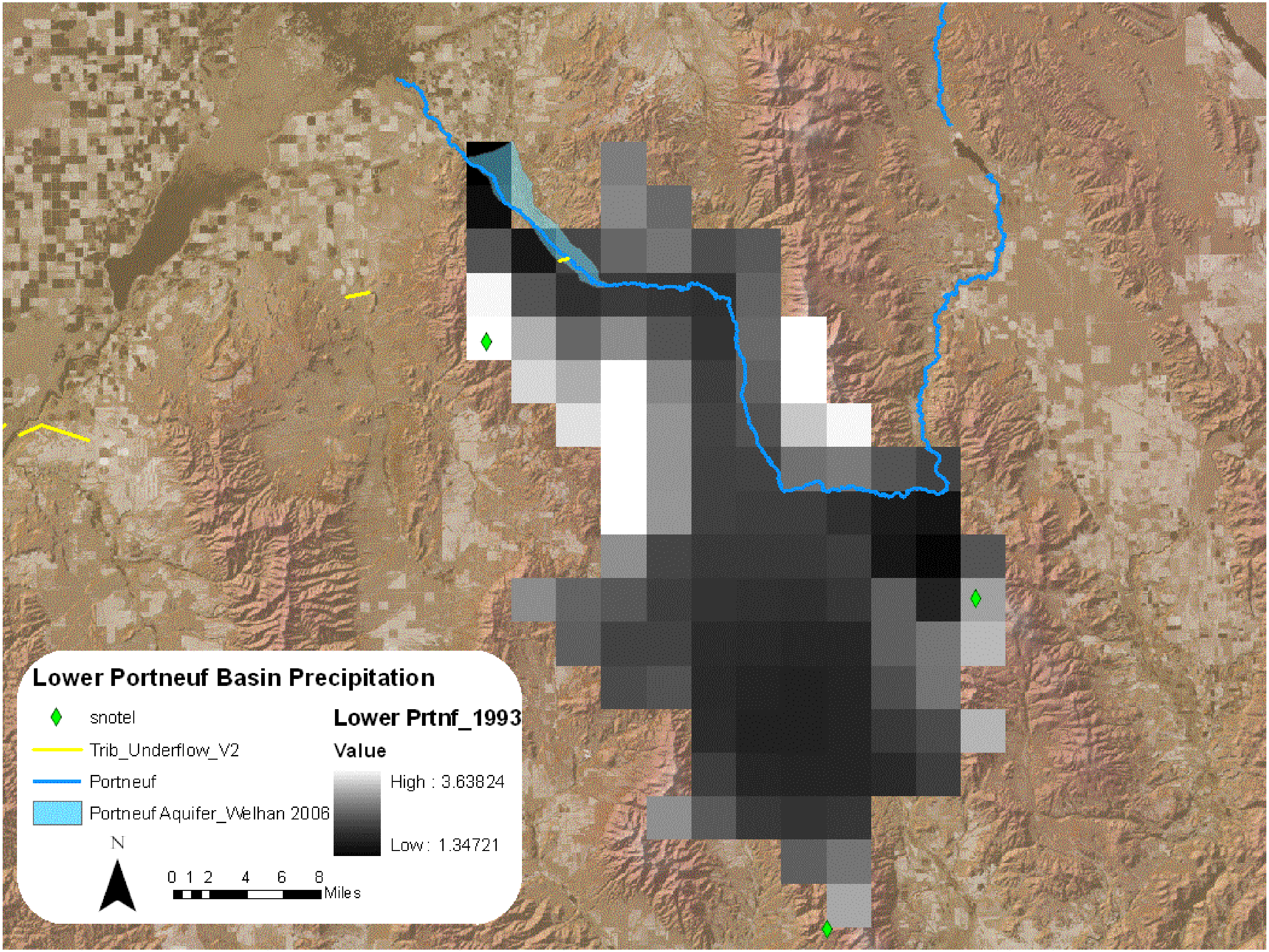


# Is the current method acceptable?

- Great deal of uncertainty associated with current method.
- True apportionment of underflow to each basin is unknown.
- Is Silver Creek an adequate proxy for 22 basins?
- What are the options?

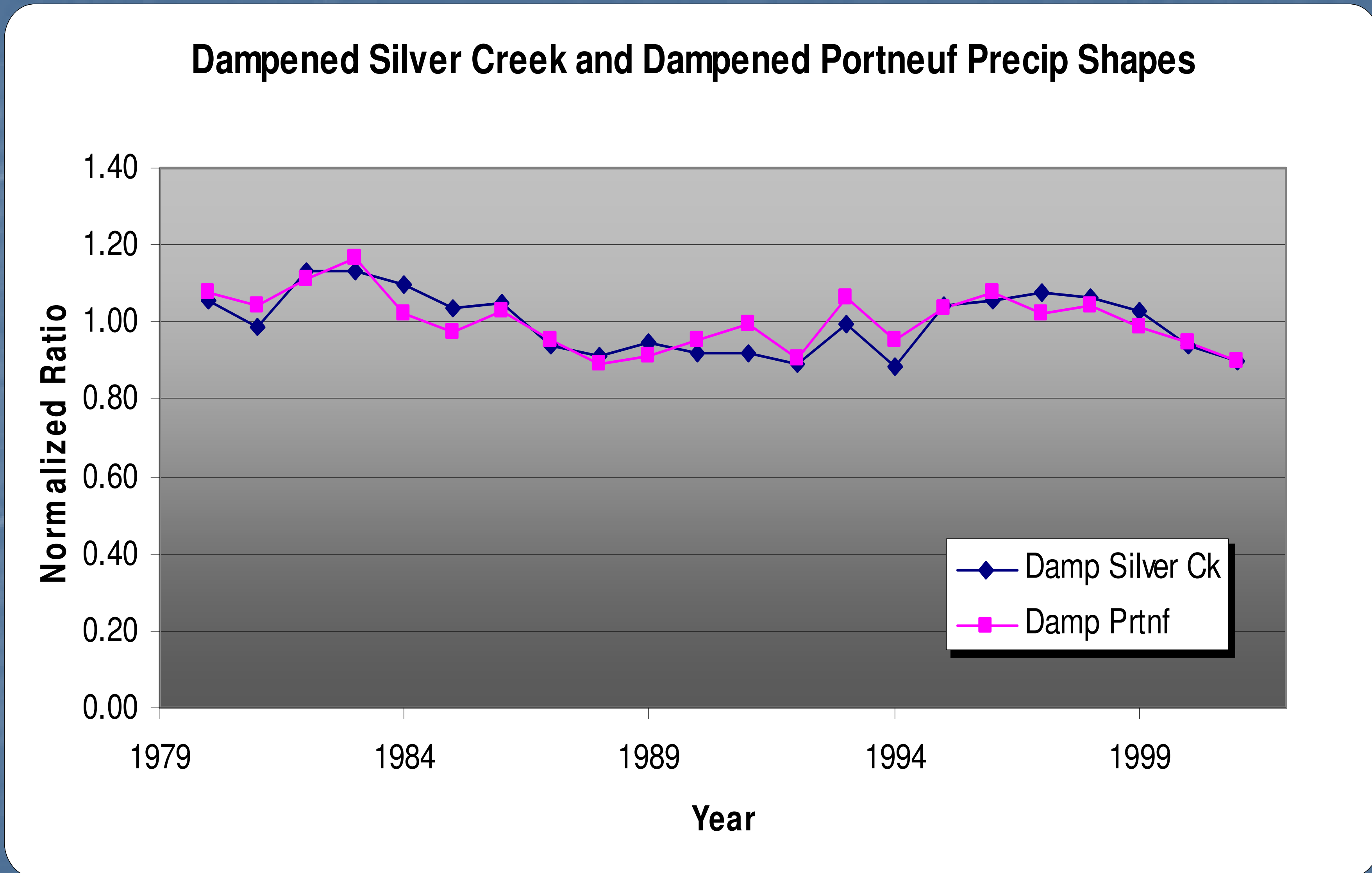
# Is it OK to shape tributary underflow using Silver Creek flow?

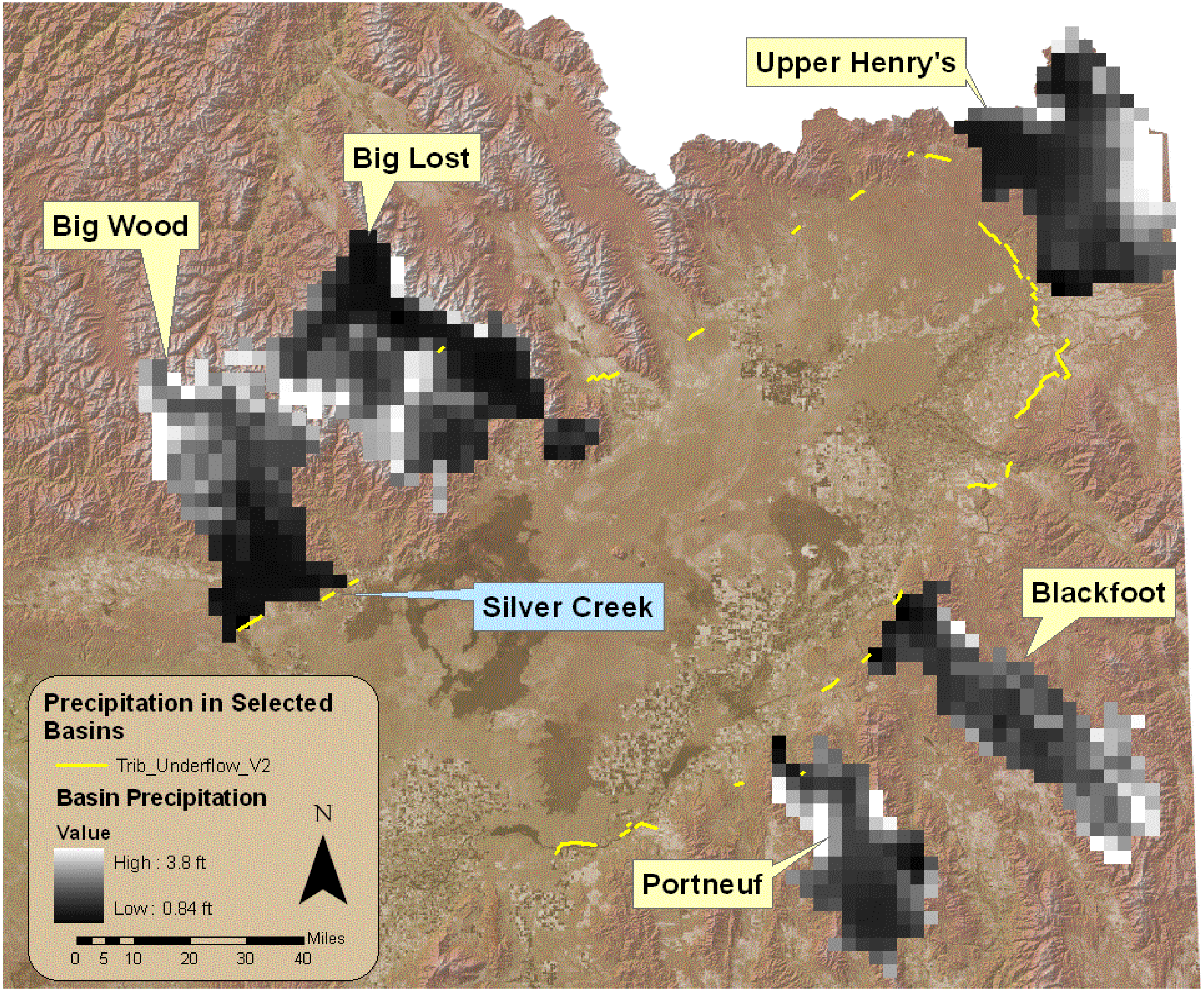
- How to assess if the flow in Silver Creek represents underflow from other basins?
- Look at precipitation in the individual basins to shape underflow
- First - Portneuf

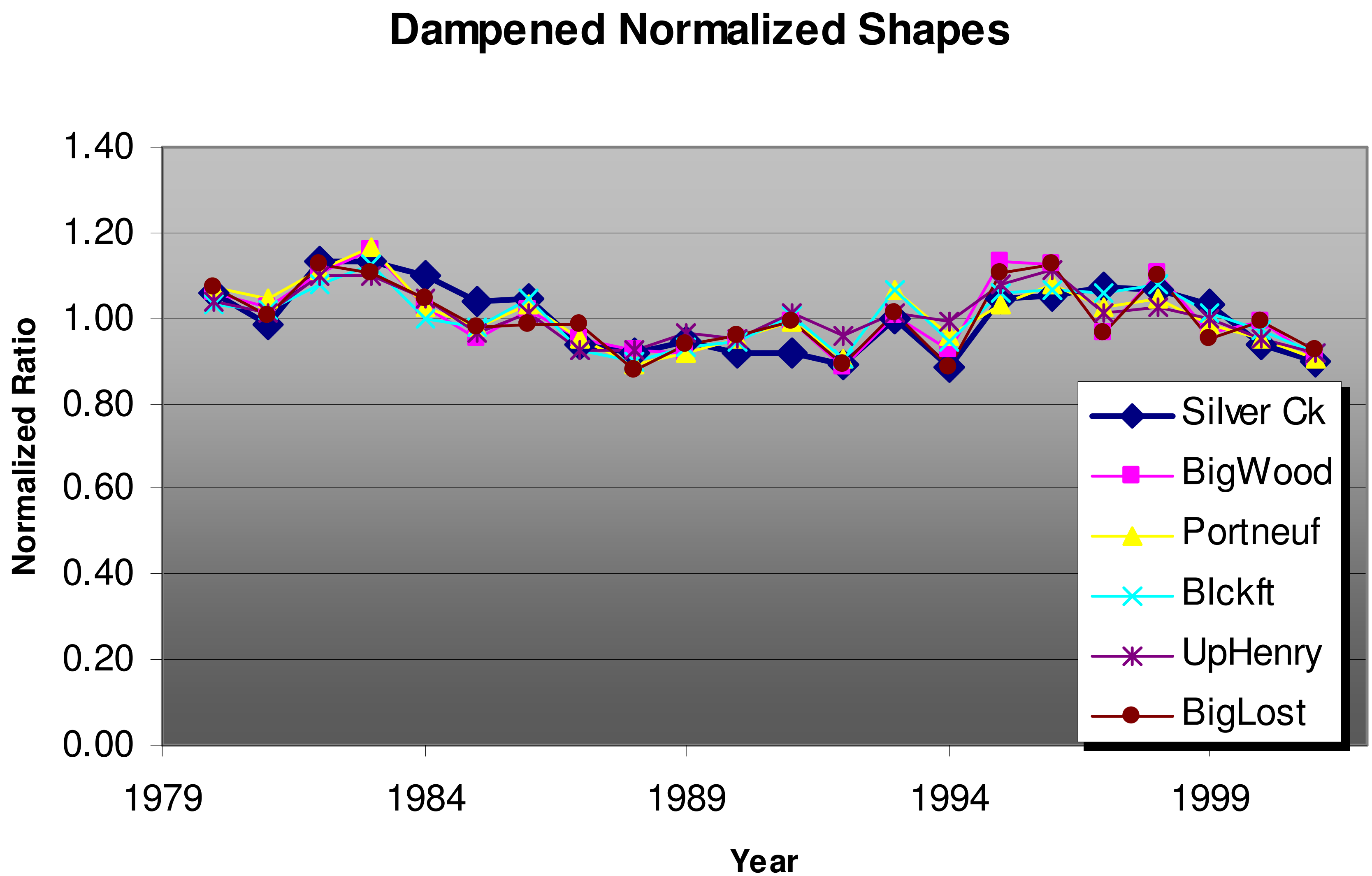

Lower Portneuf Basin Precipitation
snotel
Trib_Underflow_V2
Portneuf
Portneuf Aquifer_Welhan 2006
Lower Prtnf_1993
Value
High : 3.63824
Low : 1.34721
N
0 1 2 4 6 8
Miles

# Shaping Tributary Underflow Using Basin Precipitation

- Compute Normalized Precipitation.
  - Divide annual precipitation by mean precipitation (1980-2001).
- Normalized values are above 1 during wet years and below 1 during dry years.
- Adjust values to dampen year-to-year variation.
  - Dampened to simulate general aquifer behavior because it is assumed precipitation variation will be greater than underflow variation (1/3 amplitude).


Dampened Silver Creek and Dampened Portneuf Precip Shapes
Normalized Ratio
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1979
1984
1989
1994
1999
Year
Damp Silver Ck
Damp Prtnf


Upper Henry's
Big Lost
Big Wood
Silver Creek
Blackfoot
Portneuf
Precipitation in Selected Basins
Trib_Underflow_V2
Basin Precipitation
Value
High : 3.8 ft
Low : 0.84 ft
N
Miles
0 5 10 20 30 40


Dampened Normalized Shapes
1.40
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0.20
0.00
Normalized Ratio
1979
1984
1989
1994
1999
Year
Silver Ck
BigWood
Portneuf
Blckft
UpHenry
BigLost

# Conclusions about Basin Precipitation vs. Silver Creek

- Shapes are similar for the basins used and Silver Creek
- Implies similar climate for the region
- Silver Creek may be a acceptable proxy for shaping underflow – for now

# Options for Calculating Underflow

- Darcy’s approach
- Water Balance approach

# Darcy's Approach

- Attractive due to simplicity
  - Q=-KA (dh/dl)
- Drawbacks
  - Limited and questionable data
    - Well logs
  - Big $$
    - Drilling
    - Testing
    - Geophysics
  - Uncertainty in parameters

# Mass Balance Approach

- Seemingly simple, truly complicated
- Data needs
  - Basin boundaries
  - Volume of applied surface water
    - Water Rights
    - Land Use, Crop Ratings, Land Cover
    - Direct measurement
  - Groundwater Production
    - Water Rights
    - Land Use, Crop Ratings, Land Cover
    - Direct measurement
  - Stream Flow
  - Precipitation
    - PRISM
  - Evapotranspiration
    - METRIC and ET Idaho
  - Basin Data from Other States
  - Streamstats

# Mass Balance Approach (cont'd)

- MASS BALANCE APPROACH
  - **NON-IRRIGATED LANDS**

    $TU_{ni}$ = ppt - ET - SW – GW

    Where:

    $TU_{ni}$ = tributary underflow from non-irrigated basins

    ppt = precipitation on non-irrigated land

    ET = evapotranspiration from non-irrigated land

    SW = surface water flow out of the basin

    GW = groundwater pumping

# Mass Balance Approach (cont'd)

- MASS BALANCE APPROACH
  - **IRRIGATED LANDS**

    $TU_{irr} = AW_{irr} + ppt_{irr} - ET_{irr} - returns_{sw}$

    Where:

    $TU_{irr}$ = tributary underflow from basins with irrigated land

    $AW_{irr}$ = applied water on irrigated land

    $ppt_{irr}$ = precipitation on irrigated land

    $ET_{irr}$ = evapotranspiration from irrigated land

    $returns_{sw}$ = returns to surface water

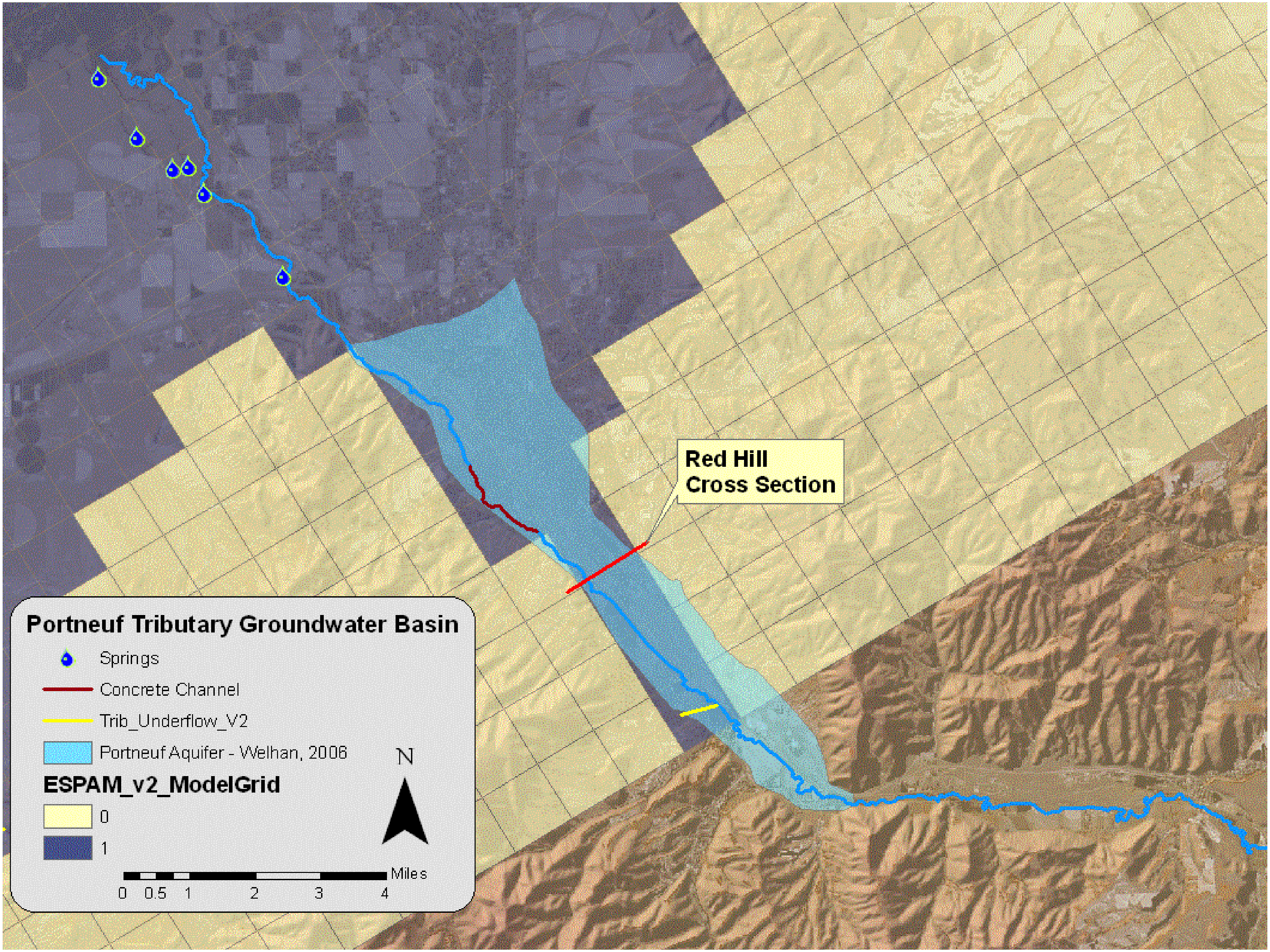
# Mass Balance Approach (cont'd)

- Mass Balance will cost money too
- Leg work may produce usable results
  - More data available

- Portneuf Example from Welhan, 2006 utilizes both methods

# Portneuf Underflow

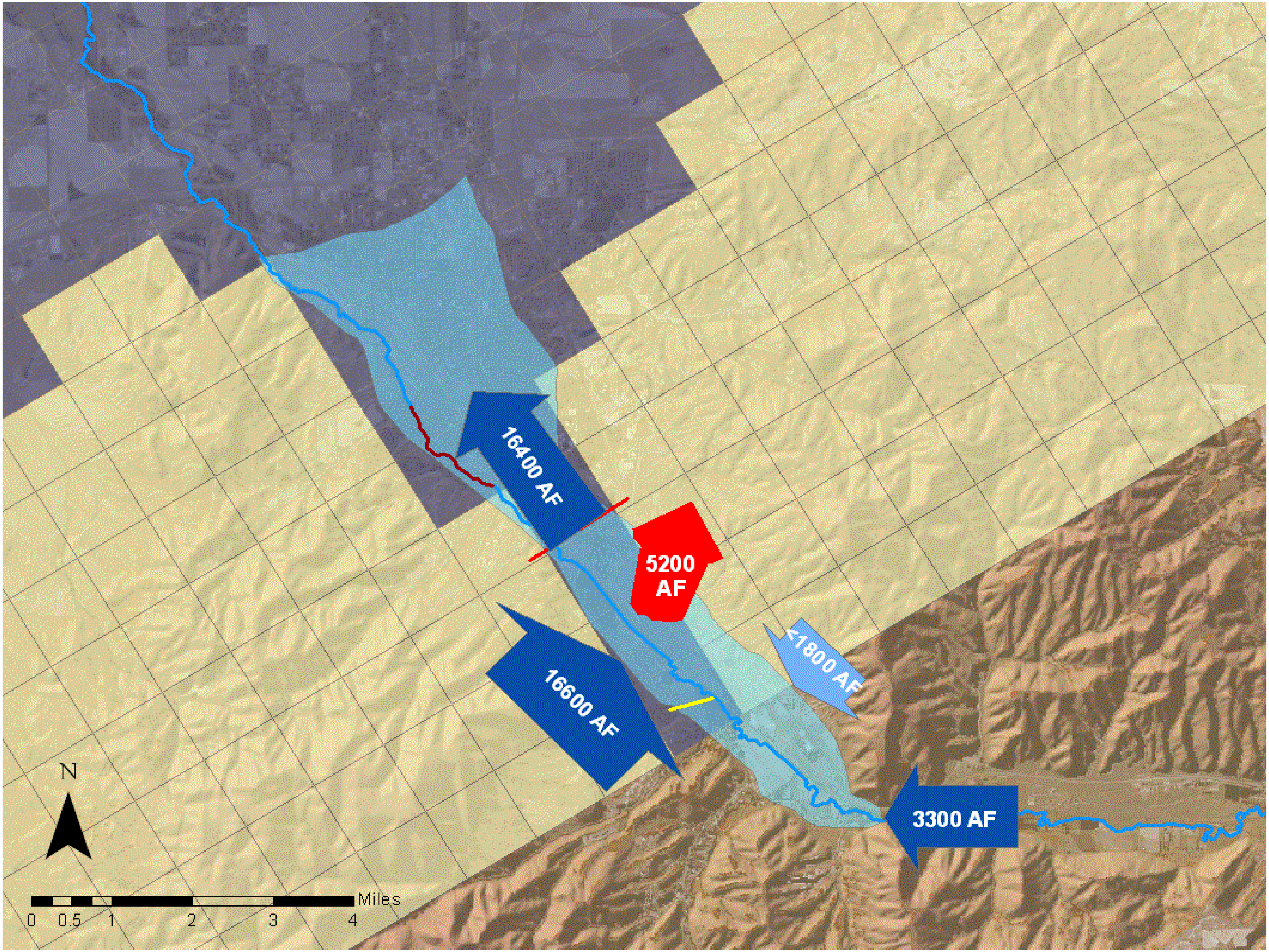
- "Water Balance and Pumping Capacity of the Lower Portneuf River Valley Aquifer, Bannock County, Idaho"
  - John Welhan, July 2006
- Report presents water balance for all of Lower Portneuf Valley Aquifer
  - The focus here is on the southern portion of the LPRV aquifer



Red Hill
Cross Section
Portneuf Tributary Groundwater Basin
Springs
Concrete Channel
Trib_Underflow_V2
Portneuf Aquifer - Welhan, 2006
ESPAM_v2_ModelGrid
0
1
N
Miles
0 0.5 1 2 3 4

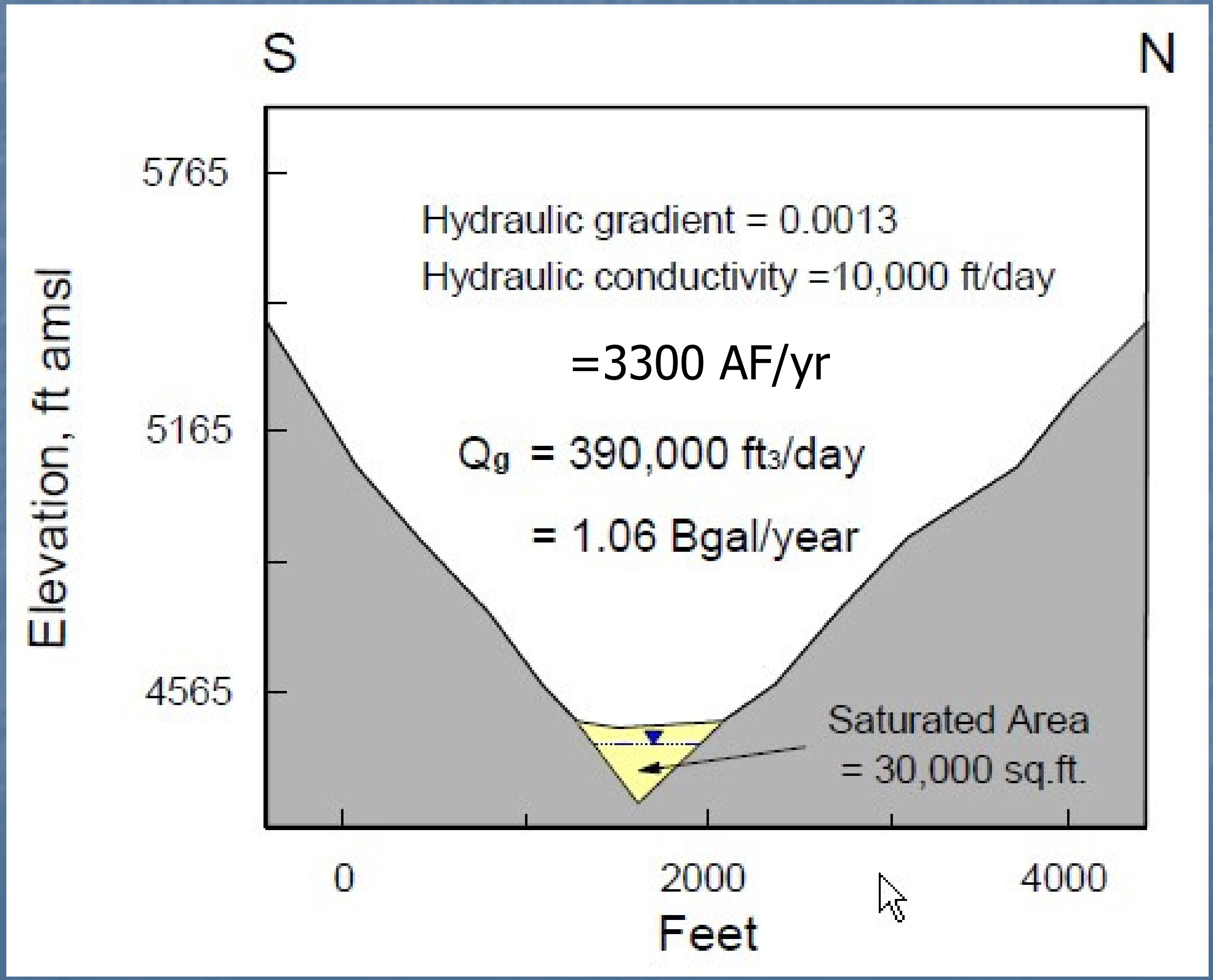
# Portneuf Underflow

- Welhan 2006 report is an update to the detailed 1993-94 study.
  - Updated with new information on recharge.
- 75% of recharge to Southern Aquifer comes from the Bannock Range.
- River leakage is <5% of Southern Aquifer water budget.
  - Leakage conceptualized to occur near Portneuf Gap, during short periods of high flow.
- Chemical mass balance inference that east-side recharge is <10% of Bannock recharge

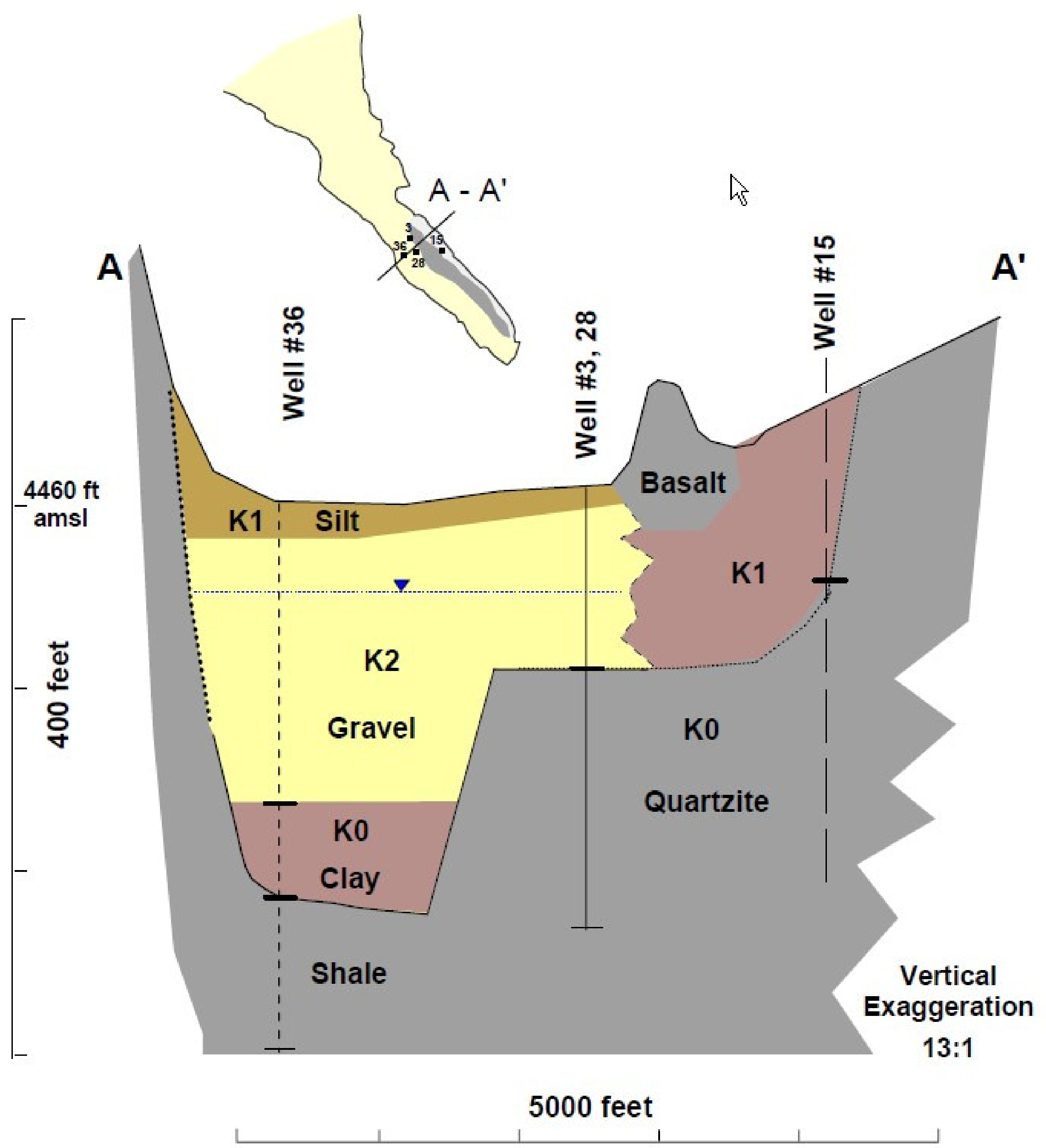

16400 AF
5200 AF
<1800 AF
16600 AF
3300 AF
N
Miles
0 0.5 1 2 3 4

# Cross Section at Portneuf Gap

(adapted from Welhan, 2006)



# Cross Section at Red Hill (adapted from Welhan, 2006)



# Underflow using Welhan and Silver Creek

- Underflow shape based on Silver Creek
  - Normalized (dampened) Flux in 1993/1994 = 1.00
  - Normalized (dampened) Flux in 2000 = 0.94
  - Suggested underflow in 93/94 = **16,600 AF**
  - Underflow in 2000 based on Silver Creek
    - Tributary Underflow = 0.94 x 5.4 = **15,700 AF**

# Underflow using Welhan and Silver Creek

| | 1993/94 | 2000 |
|---|---|---|
| ***Losses** (withdrawals + outflow)* | | |
| Pocatello municipal wells | 1.32 | 1.72 |
| Domestic wells | 0.14 | 0.18[2] |
| Agricultural wells | 0.11 ± 0.04 | 0.15 ± 0.05[2] |
| Non-metered golf courses | 0.15[1] | 0.09[2] |
| Total pumping demand | 1.72 ± 0.04 | 2.13 ± 0.05 |
| Red Hill underflow | 16400 AF → 5.33 | 5.14[3] ← 15800 AF |
| ***Gains** (recharge + inflow)* | | |
| Portneuf Gap underflow | 1.06 | 1.01[3] |
| Portneuf River losses | 0.3 | 0.3 |
| ***Change in aquifer storage*** | -0.29 | -3.35 |
| ***Calculated recharge residual*** (all unknown recharge sources) | 5.7 ± 0.1[4] | 2.9 |
| ***Bannock Range recharge*** | 5.4 ± 0.1[4] | 2.7 |

[1] Country Club golf course demand assumed equivalent to Highland's (0.1 Bgal/yr); Riverside non-metered withdrawal is about 50% of Highland's (J. Ulrich, oral comm., 2006).

[2] Proportions relative to municipal demand were assumed constant between 1993-94 and 2000; non-metered golf course use was estimated from actual demand at Highland.

[3] Hydraulic gradients were assumed not to differ substantially from 1993-94; underflow estimates were adjusted only for a decrease in cross-sectional saturated flow area due to a 5.5 foot average water table decline during 2000.

[4] The range primarily reflects uncertainty in estimated non-municipal demand.

- Underflow shape based on Darcy
- More evidence that Silver Creek may be OK proxy

# Conclusions about Tributary Underflow based on Welhan

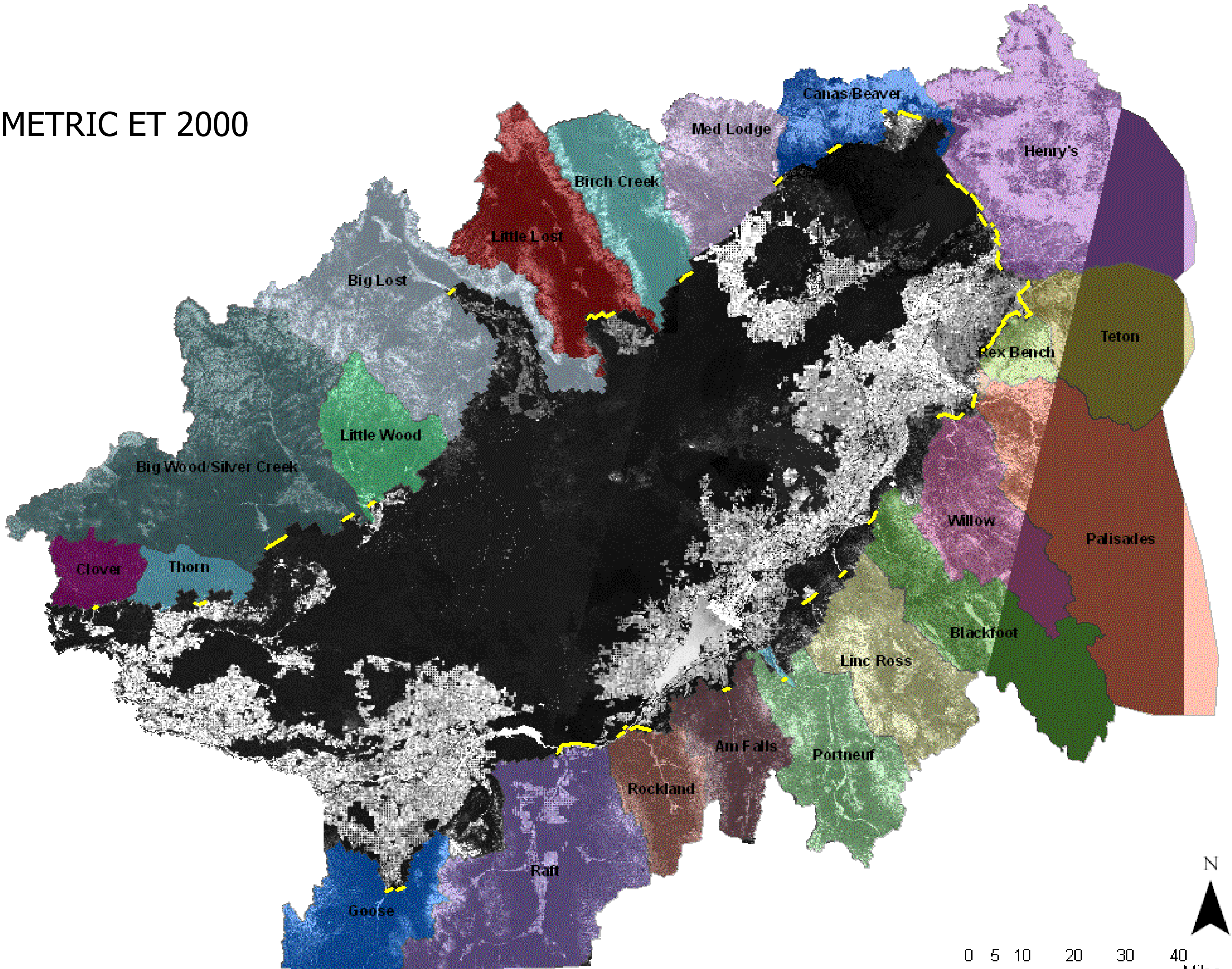
- Good example illustrating both the Darcy and Mass Balance approaches.
- Portneuf has enough data to make decisions about the volume and variation in Tributary Underflow
- Consider reducing Portneuf underflow as per Stacey and Bryce.
  - Apportion the remaining water to the other basins based on size

| Tributary Underflow Location in ESPA Model | ESPAM Simulated Ground Water Outflow (acre-feet /yr) | Re-apportioned Underflow (acre-feet/yr) | Proposed ESPAM Simulated Ground Water Outflow (acre-feet /yr) |
|---|---|---|---|
| **Clover Creek** | 10,000 | 472 | 10,472 |
| **Thorn Creek** | 6,000 | 283 | 6,283 |
| **Silver Creek** | 53,000 | 2,501 | 55,501 |
| **Big Wood** | 10,000 | 472 | 10,472 |
| **Little Wood** | 24,000 | 1,132 | 25,132 |
| **Big Lost** | 54,000 | 2,548 | 56,548 |
| **Little Lost** | 155,000 | 7,313 | 162,313 |
| **Birch Creek** | 78,000 | 3,680 | 81,680 |
| **Medicine Lodge** | 9,000 | 425 | 9,425 |
| **Camas/Beaver** | 217,000 | 10,239 | 227,239 |
| **Henrys Fork** | 110,000 | 5,190 | 115,190 |
| **Teton River** | 3,000 | 142 | 3,142 |
| **Rexburg Bench** | 18,000 | 849 | 18,849 |
| **Palisade** | 7,000 | 330 | 7,330 |
| **Willow Creek** | 29,000 | 1,368 | 30,368 |
| **Blackfoot River** | 13,000 | 613 | 13,613 |
| **Lincoln/Ross** | 4,000 | 189 | 4,189 |
| **Portneuf** | **63,000** | **-46,428** | **16,572** |
| **Bannock Creek (aka Am Falls)** | 22,000 | 1,038 | 23,038 |
| **Rock Creek (aka Lake Walcott)** | 51,000 | 2,406 | 53,406 |
| **Raft River** | 84,000 | 3,963 | 87,963 |
| **Goose Creek** | 27,000 | 1,274 | 28,274 |
| **TOTAL:** | 1,047,000 | 0 | 1,047,000 |

# Conclusions/Recommendations

- Literature Search.
  - More information available now.
- Data/tools collection.
  - Collect information by basin.
  - GIS based data preparation.
- Rank basins based on information availability and importance to model.
- Perform Darcy and or Mass Balance with available information.
- Create a range or "error bars" on tributary underflow values.

# METRIC ET 2000



PRISM Precipitation 2000