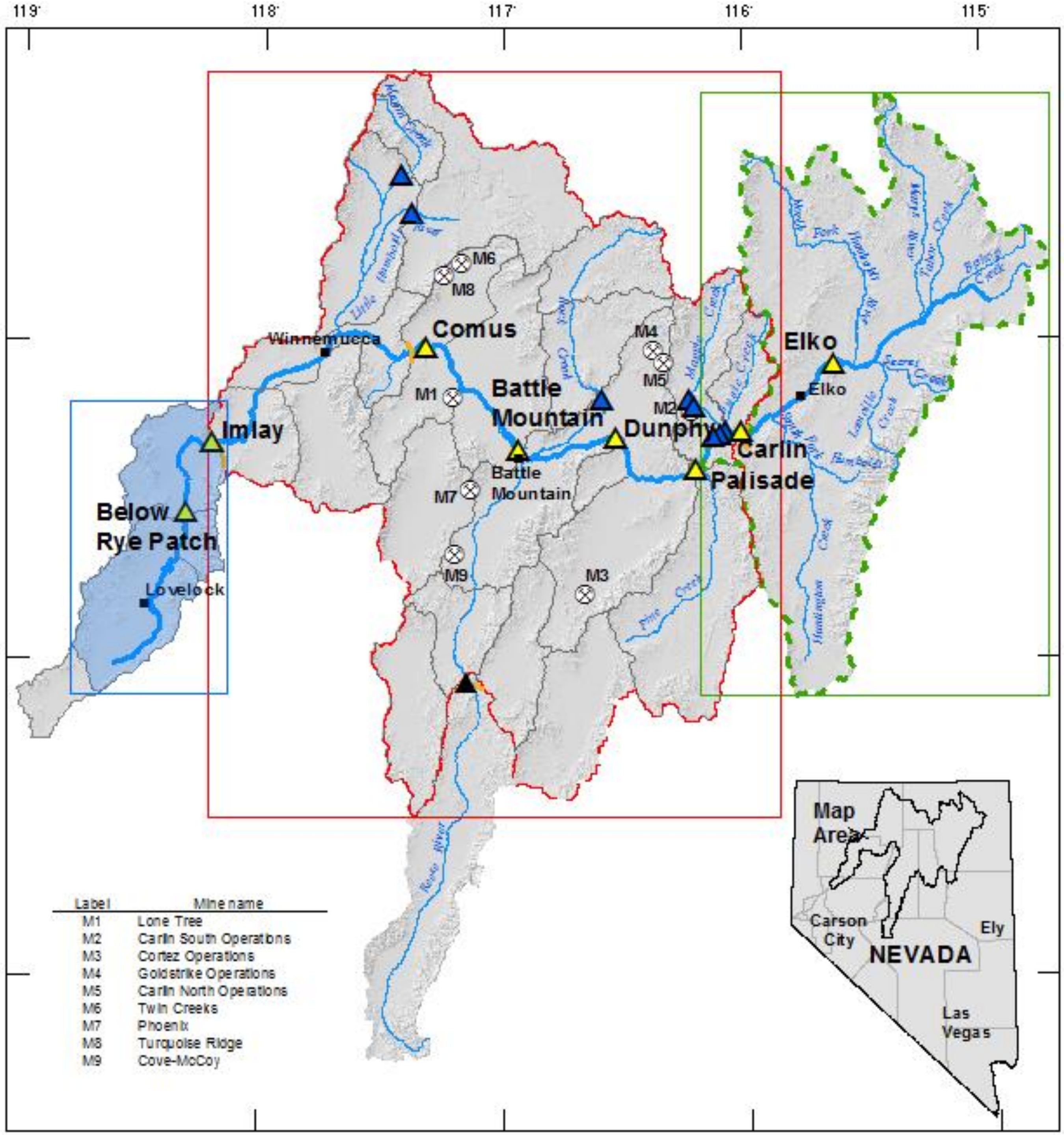
HUMBOLDT RIVER BASIN MODELING UPDATE

Lovelock & Winnemucca
January 15, 2019
Elko
January 16, 2019

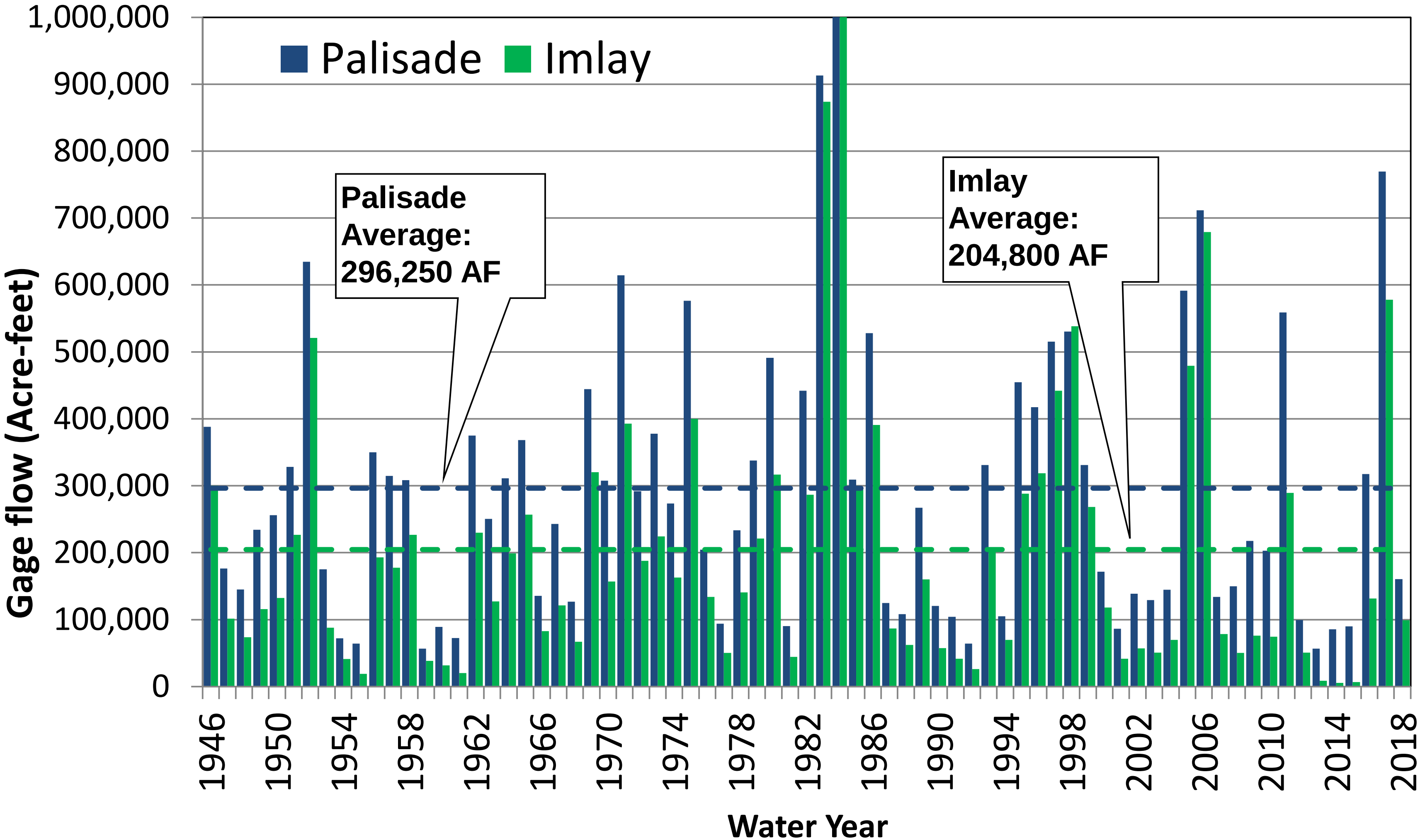
DEPARTMENT OF
CONSERVATION & NATURAL RESOURCES



Humboldt River Basin Modeling Update - Outline

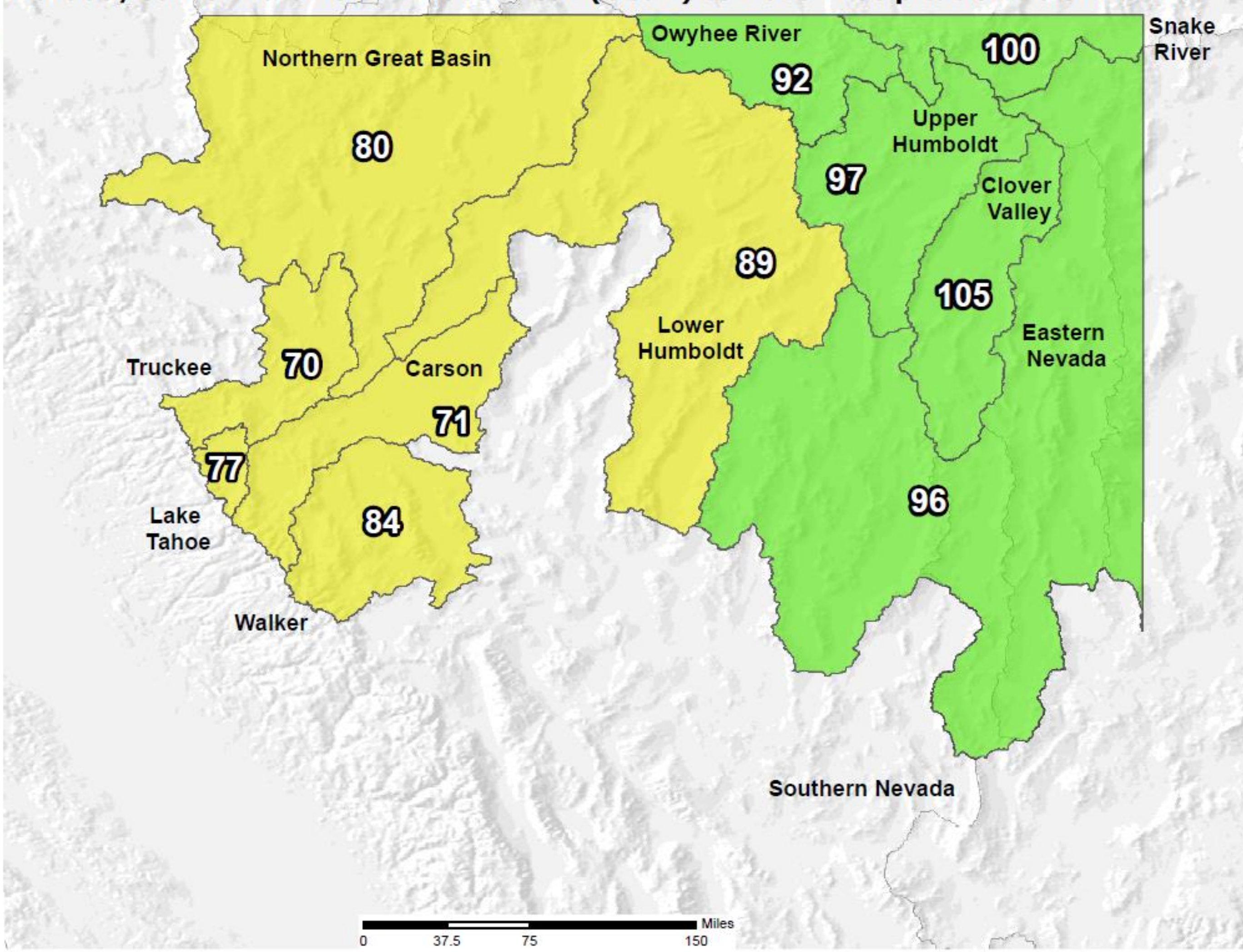
- Water supply forecast
- Water use and overview of modeling effort
- Ongoing modeling and hydrologic studies
  - Hydrology General Overview
  - ET Studies
  - Upper Basin Model
  - Middle Basin Model
  - Lower Basin Model
- Q & A

Humboldt River Flow, 1946-2018



Nevada/California SNOTEL Water Year (Oct 1) to Date Precipitation % of Normal

Jan 12, 2019



Water Year (Oct 1) to Date Precipitation Basin-wide Percent of 1981-2010 Average

- unavailable *
- <50%
- 50 - 69%
- 70 - 89%
- 90 - 109%
- 110 - 129%
- 130 - 149%
- >=150%

** Data unavailable at time of posting or measurement is not representative at this time of year*

Provisional data subject to revision

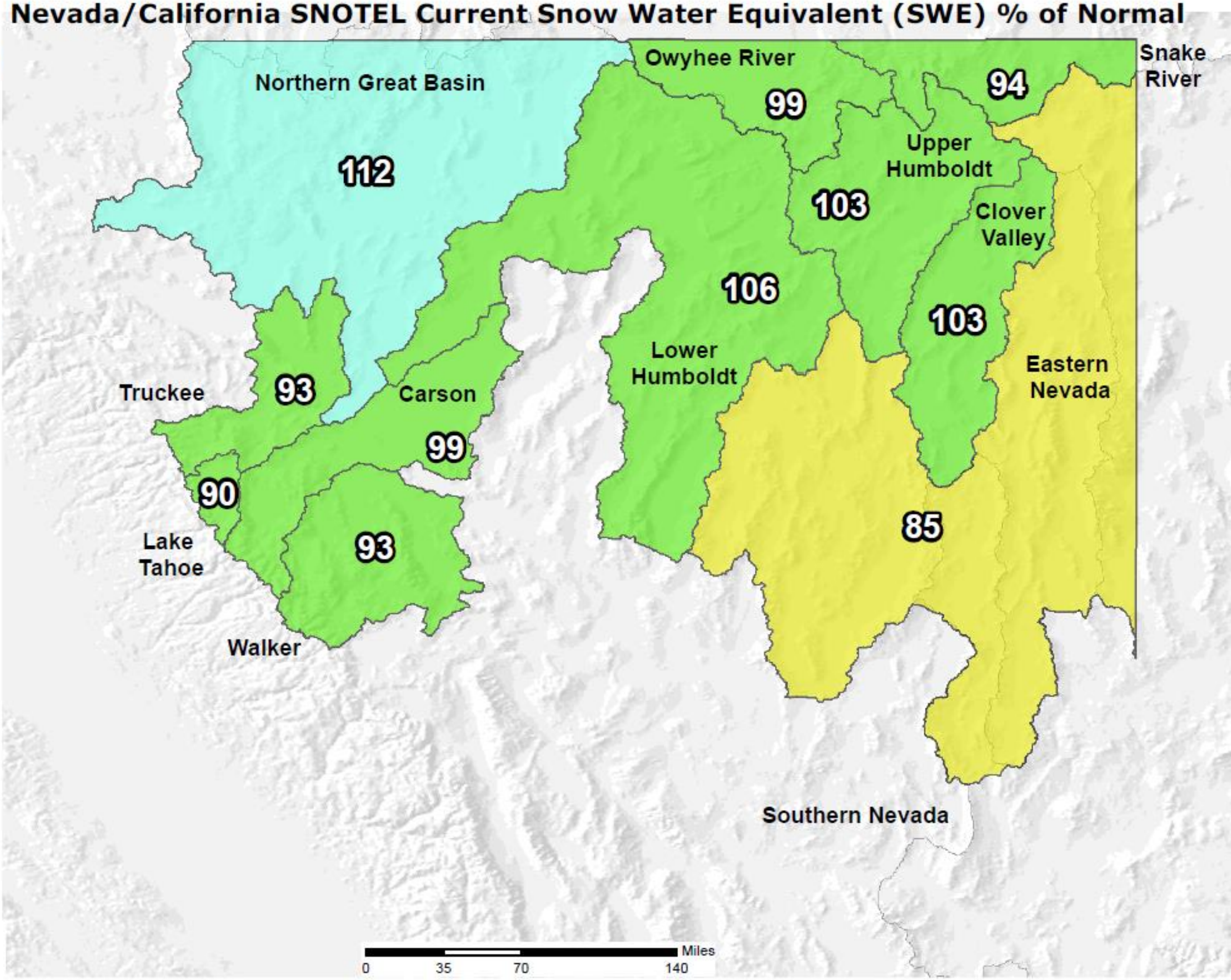
USDA NRCS

The water year to date precipitation percent of normal represents the accumulated precipitation found at selected SNOTEL sites in or near the basin compared to the average value for those sites on this day. Data based on the first reading of the day (typically 00:00).

Prepared by:
USDA/NRCS National Water and Climate Center
Portland, Oregon
http://www.wcc.nrcs.usda.gov

Nevada/California SNOTEL Current Snow Water Equivalent (SWE) % of Normal

Jan 12, 2019



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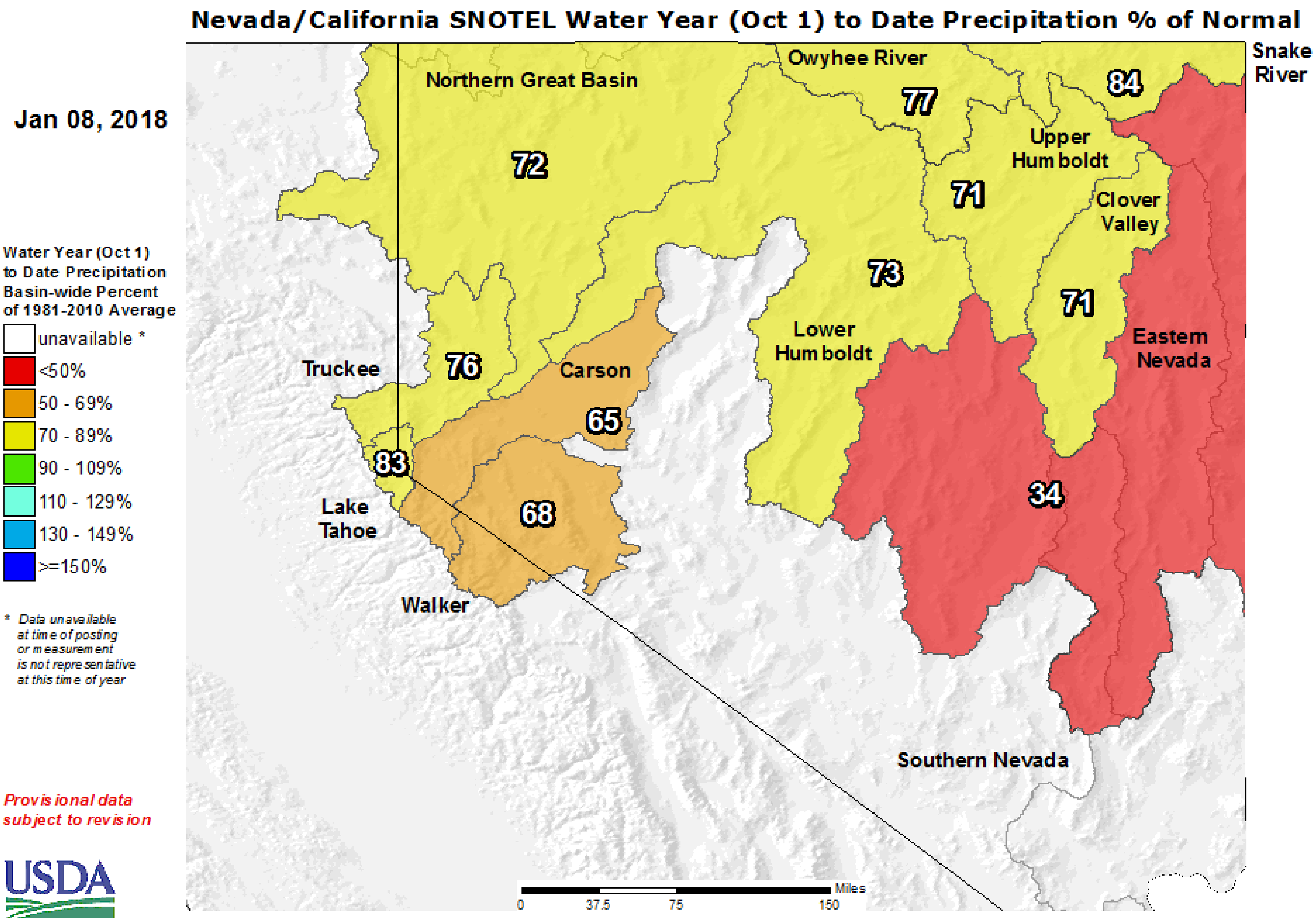

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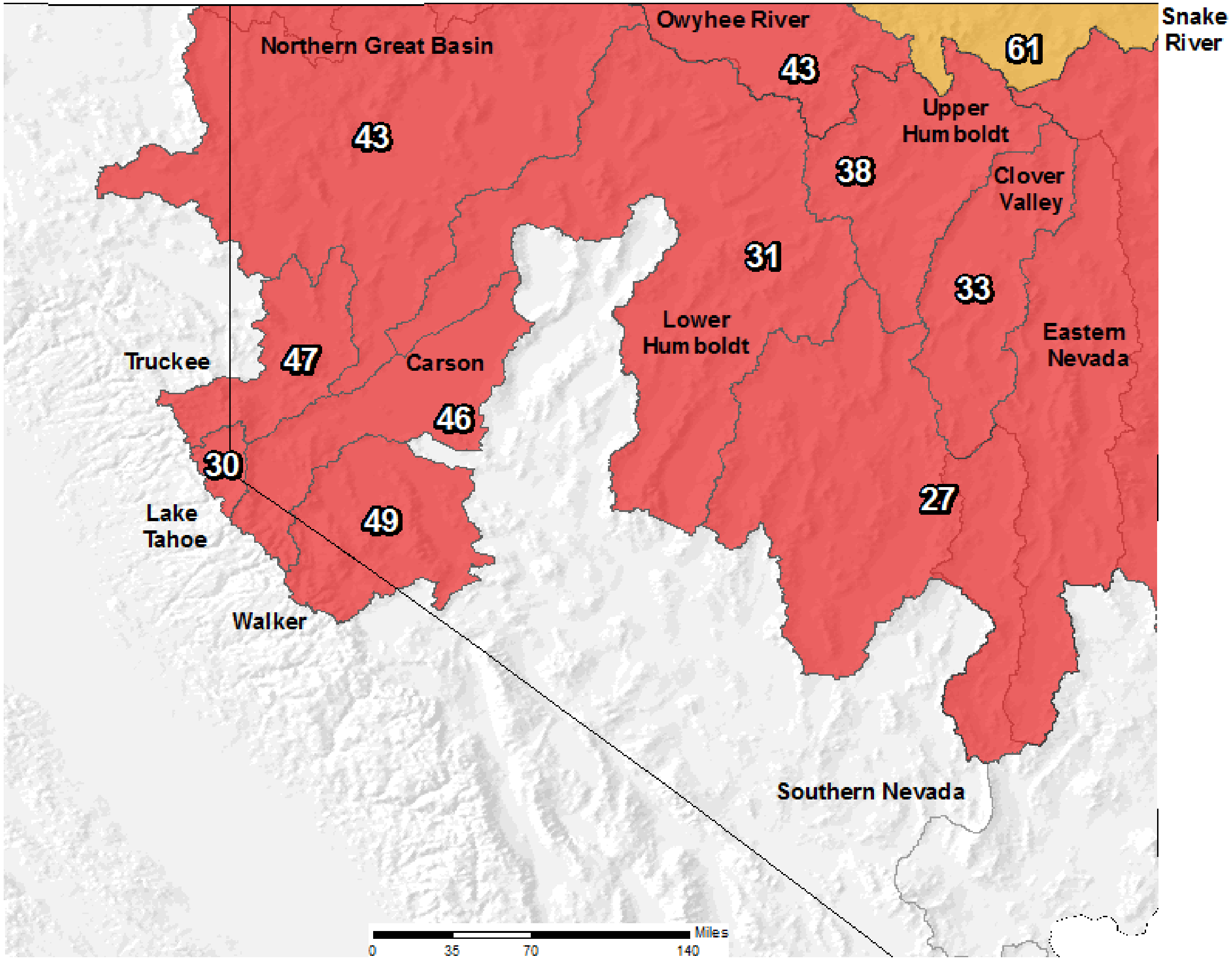

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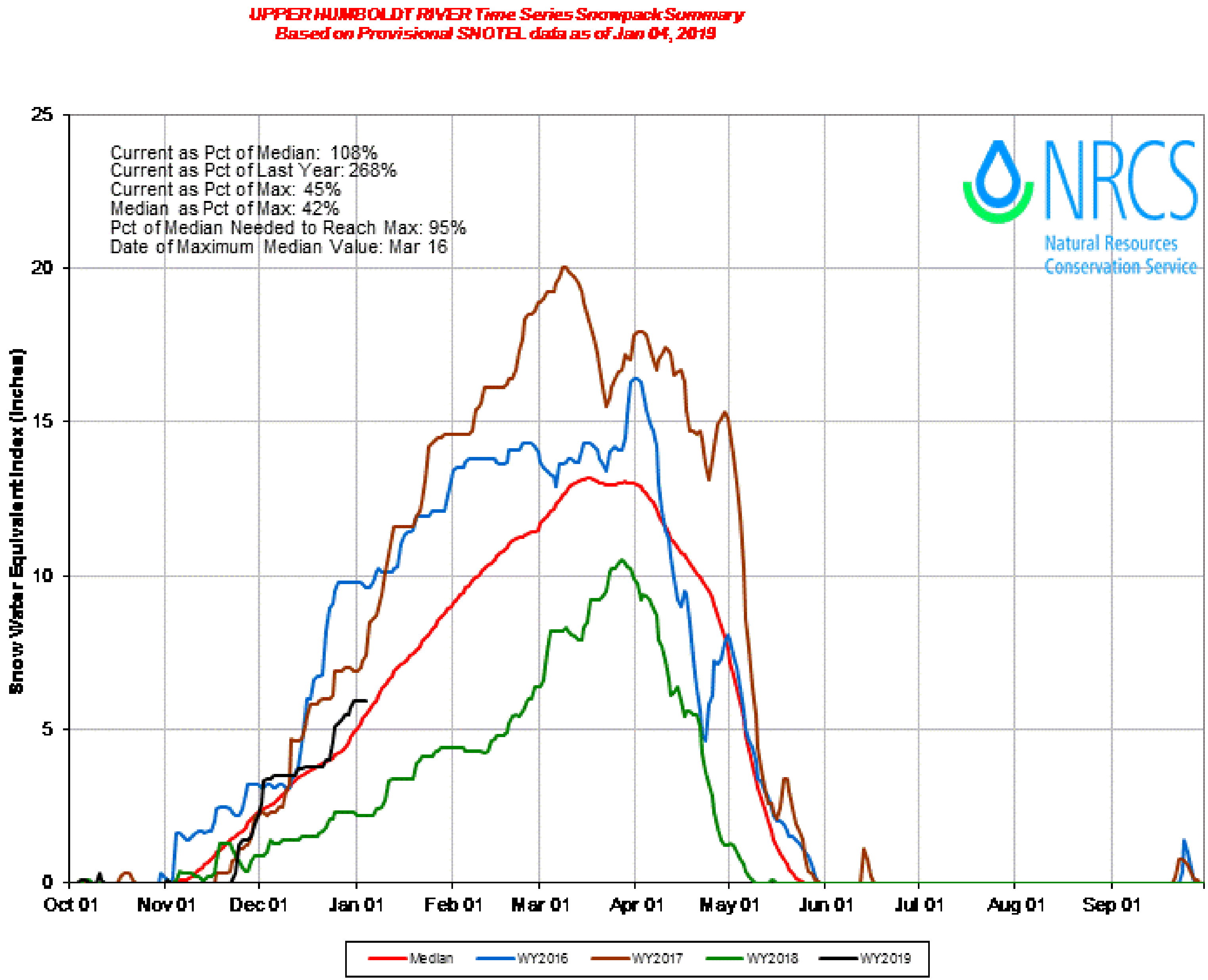

UPPER HUMBOLDT RIVER Time Series Snowpack Summary
Based on Provisional SNOTEL data as of Jan 04, 2019
Current as Pct of Median: 108%
Current as Pct of Last Year: 268%
Current as Pct of Max: 45%
Median as Pct of Max: 42%
Pct of Median Needed to Reach Max: 95%
Date of Maximum Median Value: Mar 16
NRCS
Natural Resources Conservation Service
Snow Water Equivalent Index (Inches)
25
20
15
10
5
0
Oct 01
Nov 01
Dec 01
Jan 01
Feb 01
Mar 01
Apr 01
May 01
Jun 01
Jul 01
Aug 01
Sep 01
Median
WY2016
WY2017
WY2018
WY2019

Jan 4, 2019

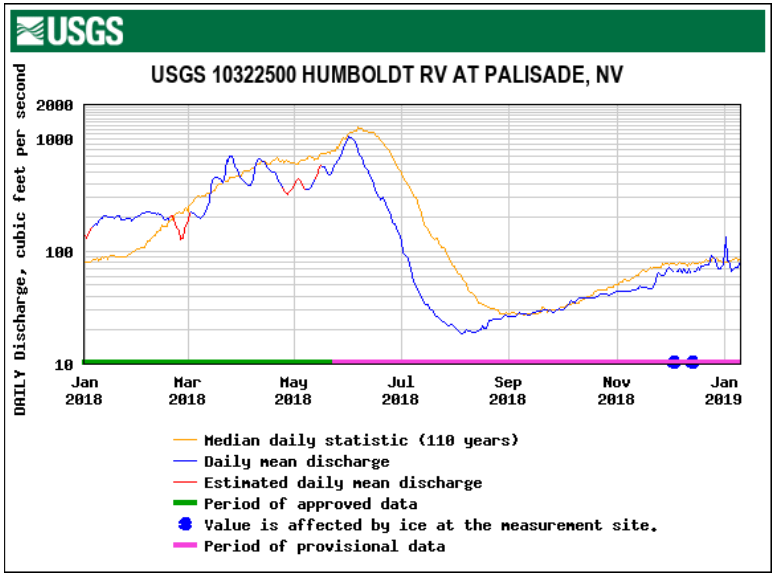
JAN 1, 2019: Humboldt River Forecast

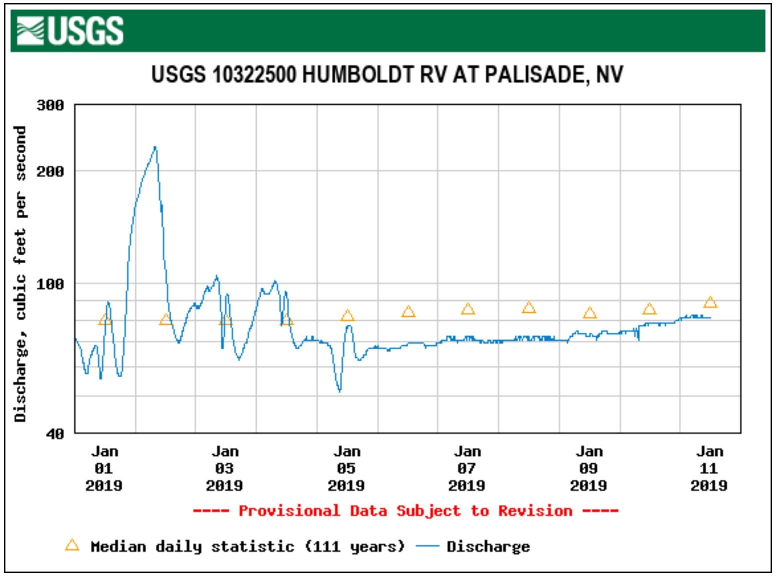
NO RIVER FORECASTS PUBLISHED BY NRCS FOR JANUARY

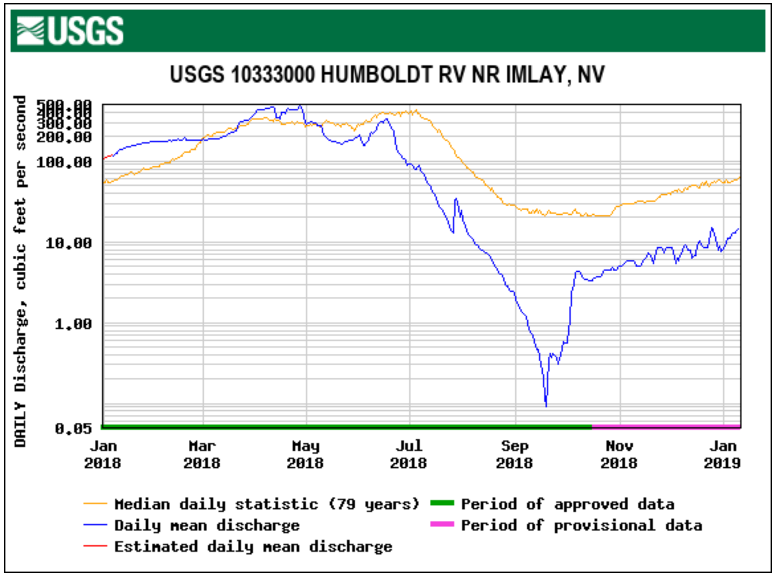
	Current		**Last Year**	**Average**
	(KAF)	**% of Capacity**	**(KAF)**	**(KAF)**
Rye Patch Reservoir	***79.4***	***41***	157.3	69.2

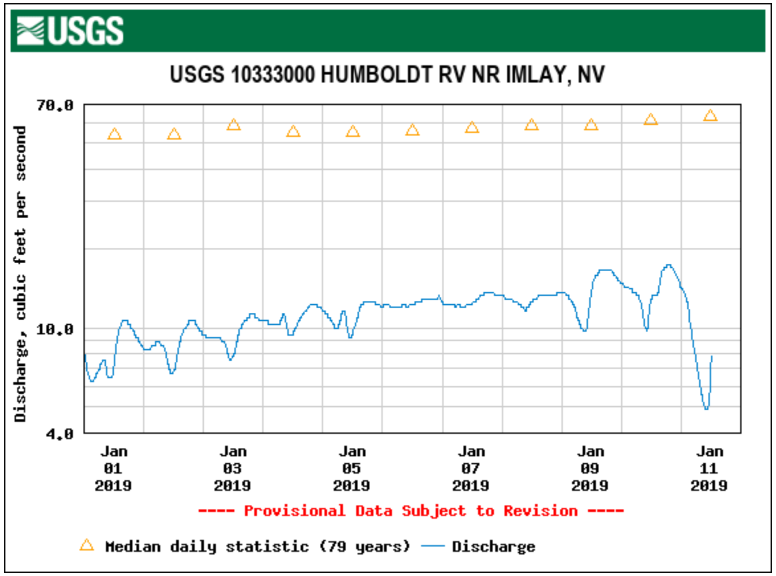
Source: NRCS

Humboldt River Flow, 2018-2019

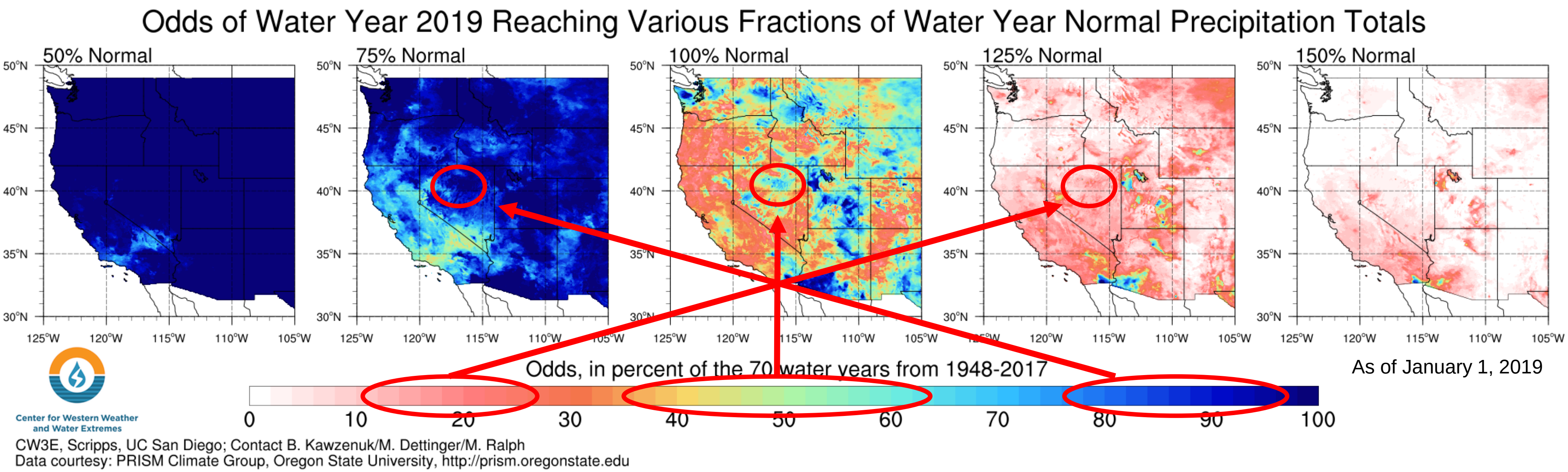








Precipitation Odds for Water Year 2019

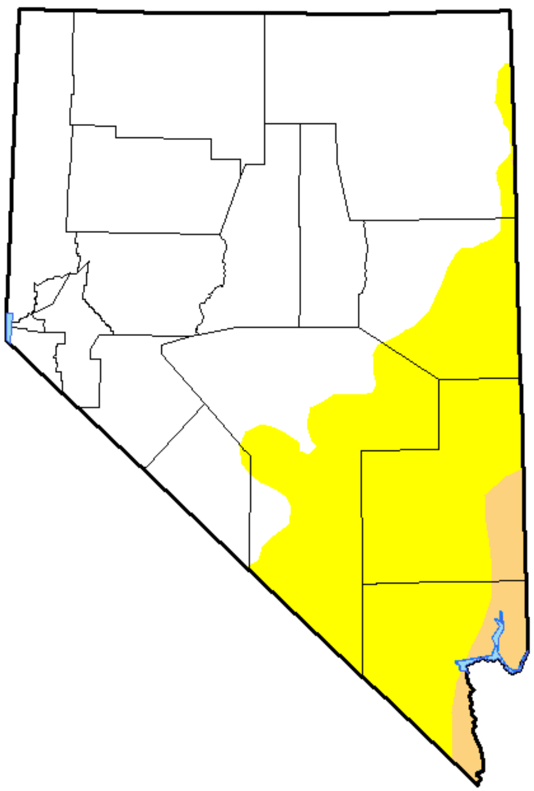


50:50 Odds for 100% year

January 9, 2018

U.S. Drought Monitor

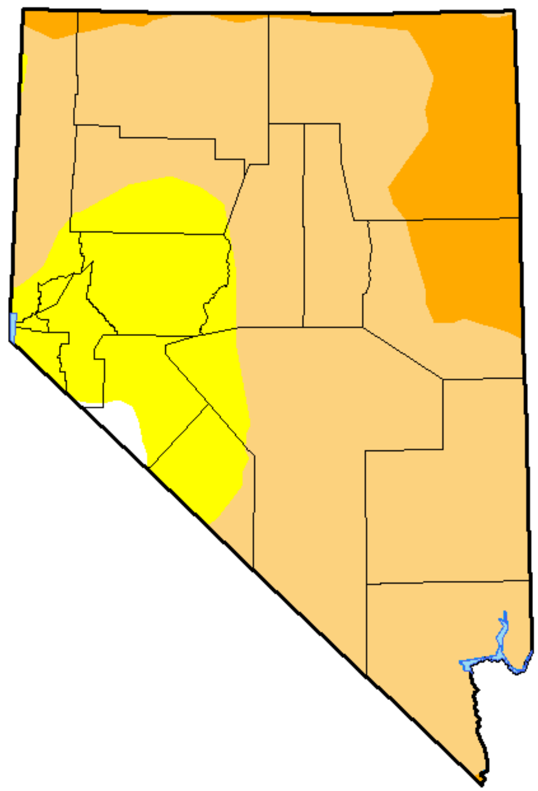
Nevada



January 1, 2019

U.S. Drought Monitor

Nevada



January 1, 2019

(Released Thursday, Jan. 3, 2019)

Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	0.71	99.29	81.09	12.84	0.00	0.00
Last Week *12-25-2018*	0.71	99.29	81.09	12.84	0.00	0.00
3 Months Ago *10-02-2018*	5.54	94.46	47.76	13.11	0.00	0.00
Start of Calendar Year *01-01-2019*	0.71	99.29	81.09	12.84	0.00	0.00
Start of Water Year *09-25-2018*	5.54	94.46	47.76	13.11	0.00	0.00
One Year Ago *01-02-2018*	68.23	31.77	3.41	0.00	0.00	0.00

Intensity:

D0 Abnormally Dry
D1 Moderate Drought
D2 Severe Drought
D3 Extreme Drought
D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

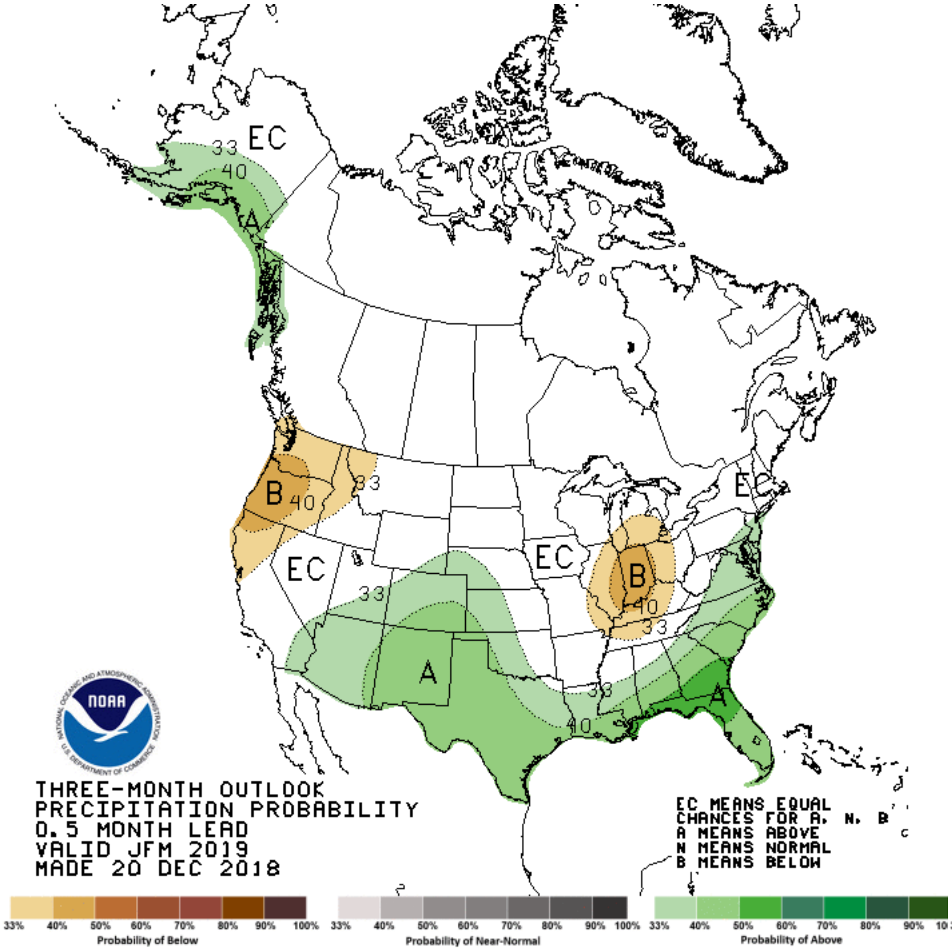
Author:

David Miskus
NOAA/NWS/NCEP/CPC

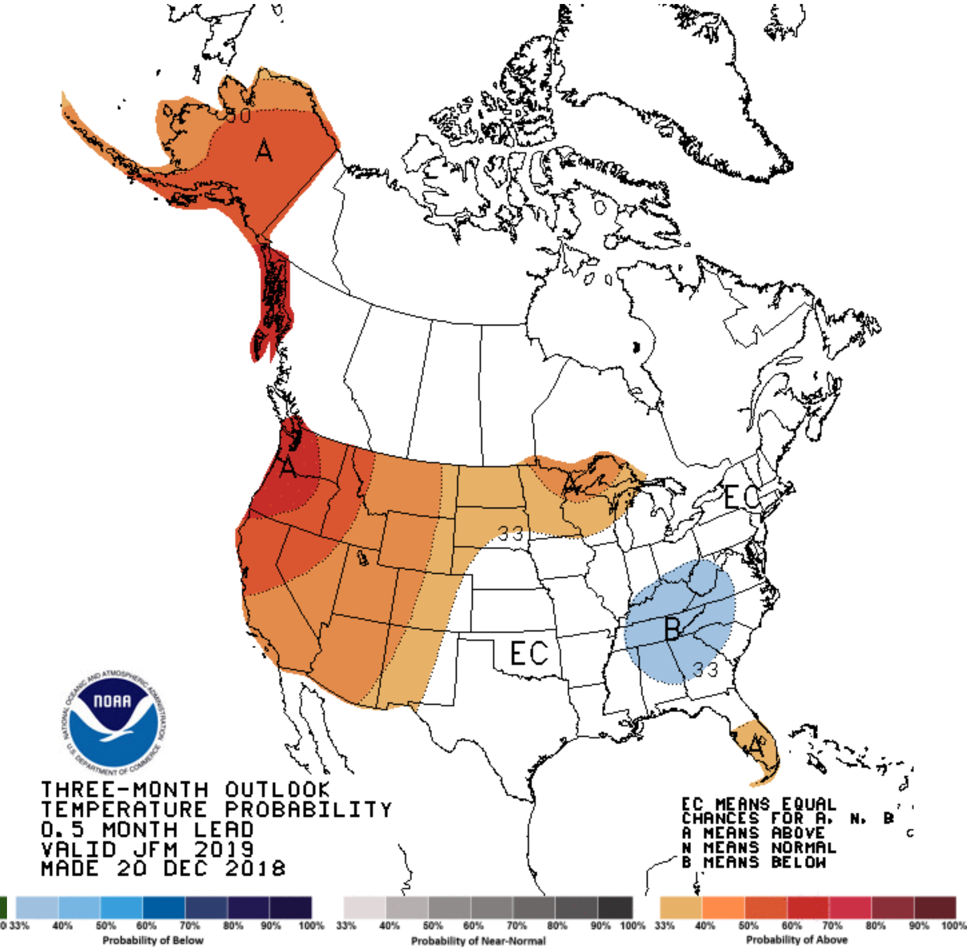
http://droughtmonitor.unl.edu/

3 – Month Outlook

Precipitation

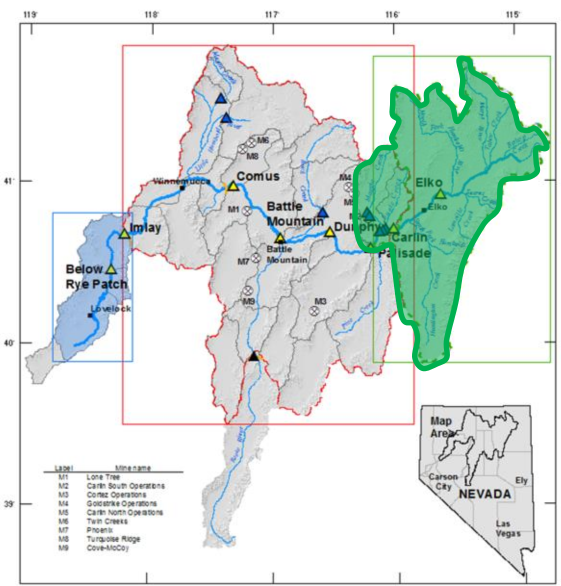


Temperature



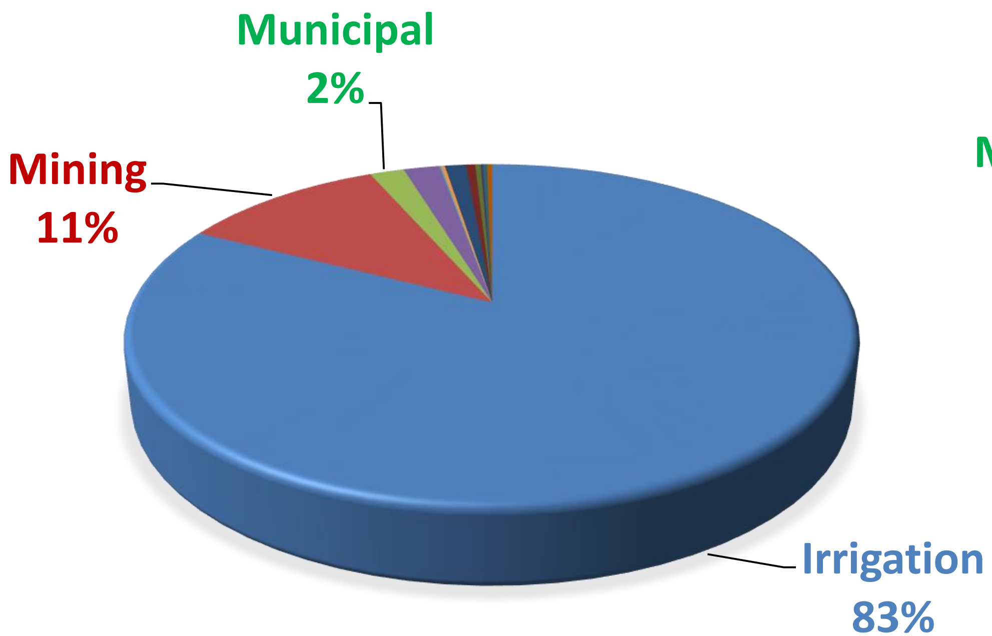
Water Use

- Humboldt River adjudication finalized in 1930's
- 275,450 acres irrigated under the decree, rights total ~661,200 af
  - 399,200 af above Palisade
  - 261,900 af below Palisade, plus ~135,400 af storage rights
- Groundwater development began in 1950's
- Current groundwater appropriations = 667,100 af
- Perennial yield = 429,100 af
  - 133,000 af above Palisade
  - 296,100 af below Palisade
- 2017 Annual pumping ≈ 300,000 af
  - ~46,000 af above Palisade
  - ~254,000 af below Palisade



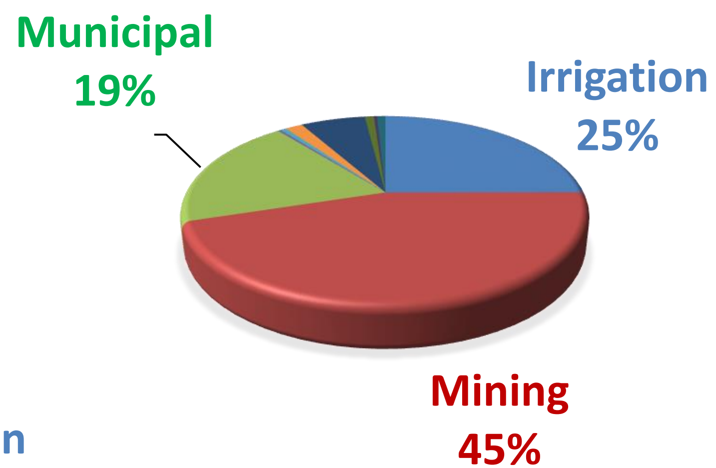
Preliminary 2017 Pumpage Inventory Results

MIDDLE & LOWER BASINS



~254,000 AF

UPPER BASIN: ABOVE PALISADE



~46,000 AF

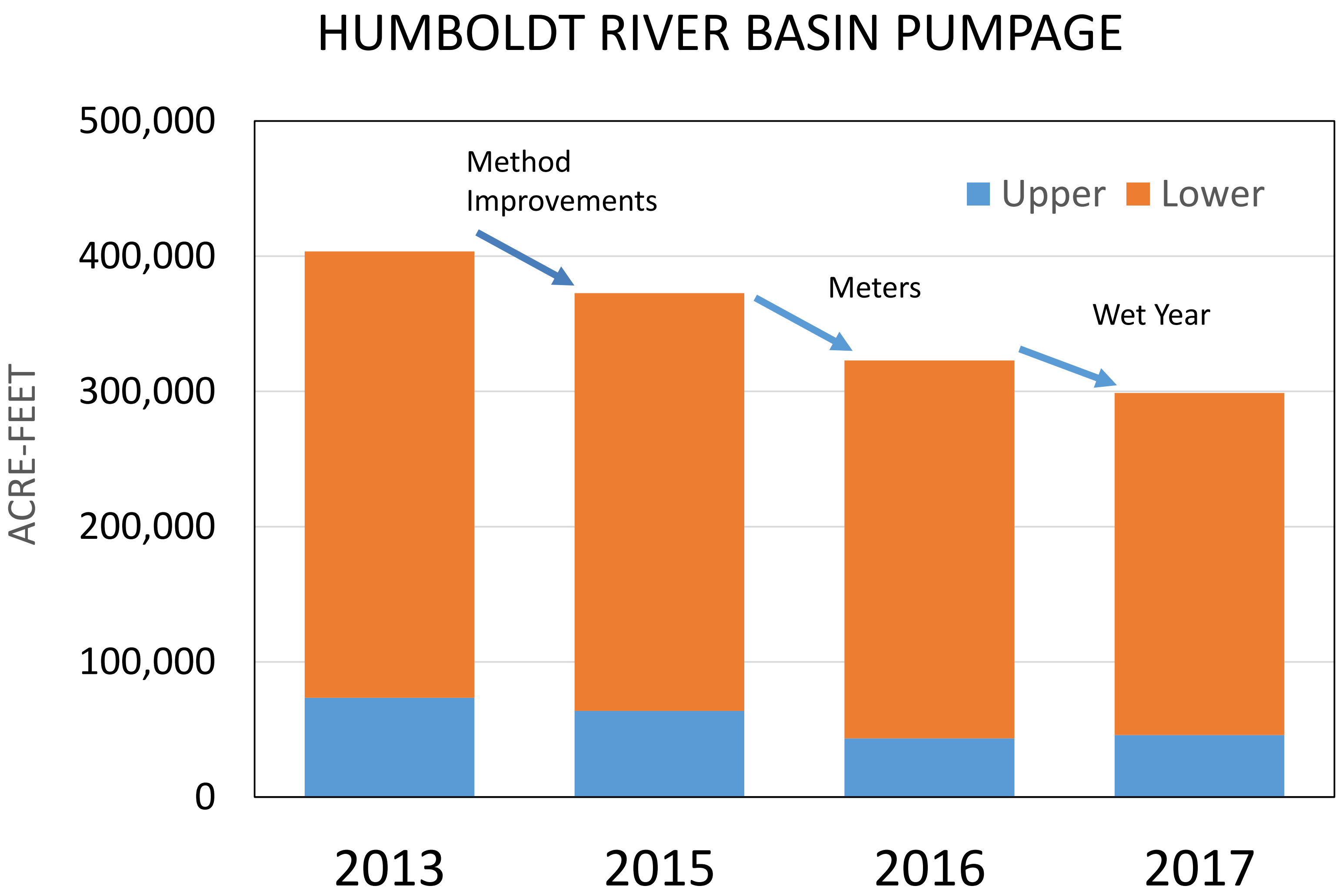
Order 1251: Required metering of all groundwater wells in HRB

2018 Compliance Statistics:

- 1,142 sites with meters
- 1,086 sites reported pumpage in 2018
- 95.1% compliance by sites
- 5% that did not report are very small users
- Very similar to 2017

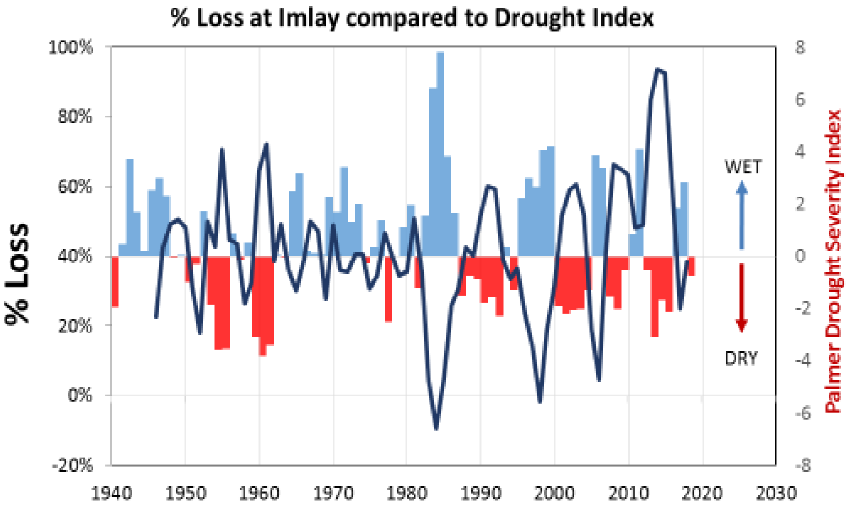
Compliance measured in terms of pumped water is ~ 99%

Recent Pumpage Inventories



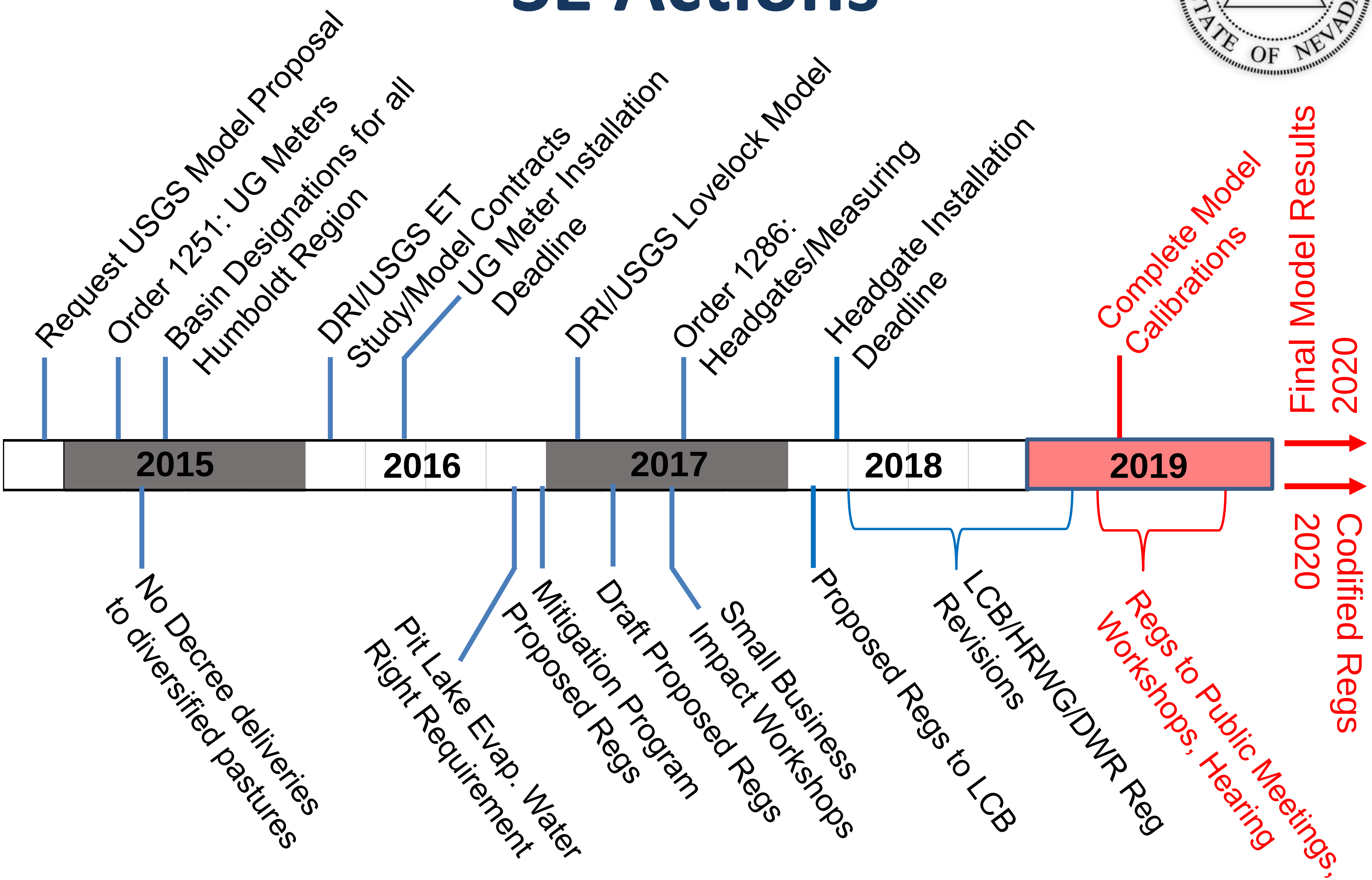
Problem

- Humboldt River is fully appropriated, surface water rights are senior to groundwater rights
- Downstream senior surface water right holders got very little water in 2013-2015 period and point to groundwater pumping as causing conflict
- Existing studies indicate that junior groundwater pumping can cause depletion of Humboldt River
- Extent of depletion caused by pumping and magnitude of conflict with senior surface water rights is not known



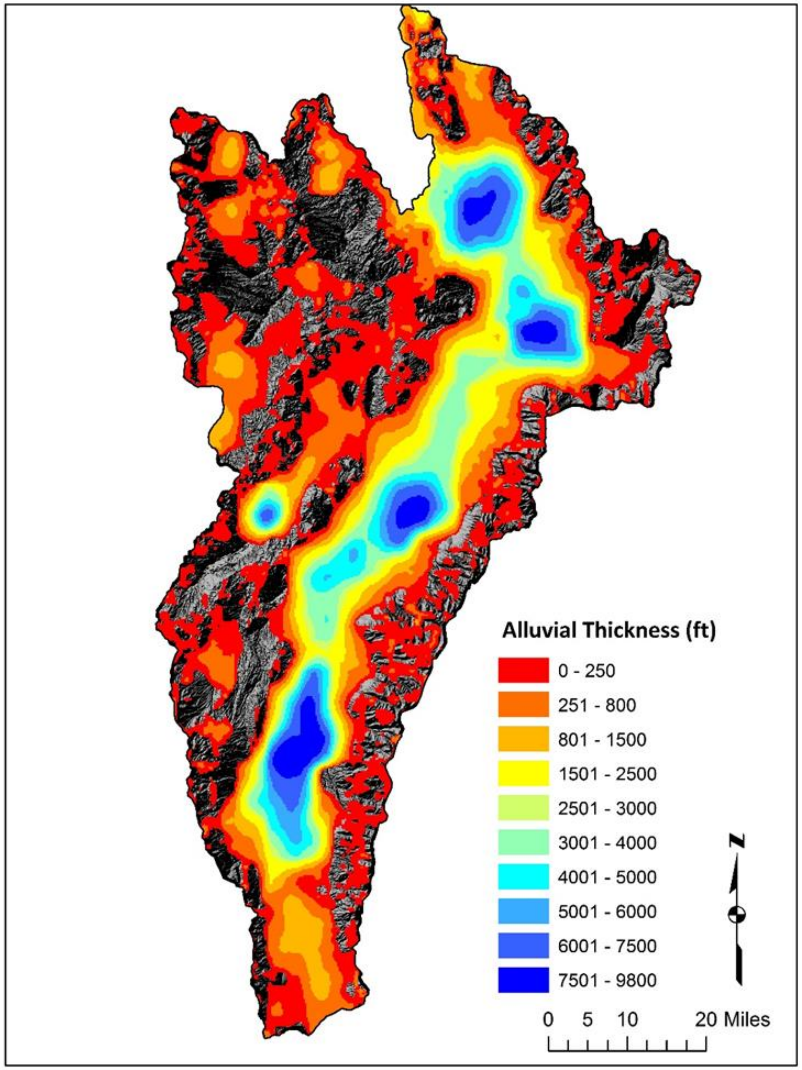
… NEED APPROPRIATE TOOLS AND SUPPORTING DATA TO MEASURE/MANAGE CONFLICT

SE Actions


Request USGS Model Proposal
Order 1251: UG Meters
Basin Designations for all Humboldt Region
DRI/USGS ET Study/Model Contracts
UG Meter Installation Deadline
DRI/USGS Lovelock Model
Order 1286: Headgates/Measuring
Headgate Installation Deadline
Complete Model Calibrations
Final Model Results 2020
2015
2016
2017
2018
2019
No Decree deliveries to diversified pastures
Pit Lake Evap. Water Right Requirement
Proposed Regs
Mitigation Program
Draft Proposed Regs
Small Business Impact Workshops
Proposed Regs to LCB
LCB/HRWG/DWR Reg Revisions
Regs to Public Meetings, Workshops, Hearing
Codified Regs 2020

Ongoing Modeling

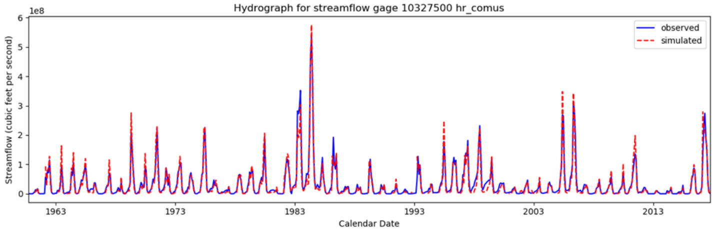
- In order for SE to manage the resource and enforce water law, must be able to determine amount and source of conflict
- SE contracted with USGS and DRI to develop groundwater models to quantify amount of river depletion caused by groundwater pumping
- $2.8M cost ($1.75M DWR/$1.1M USGS JFA)
- 4-year project, completion date = end of 2019

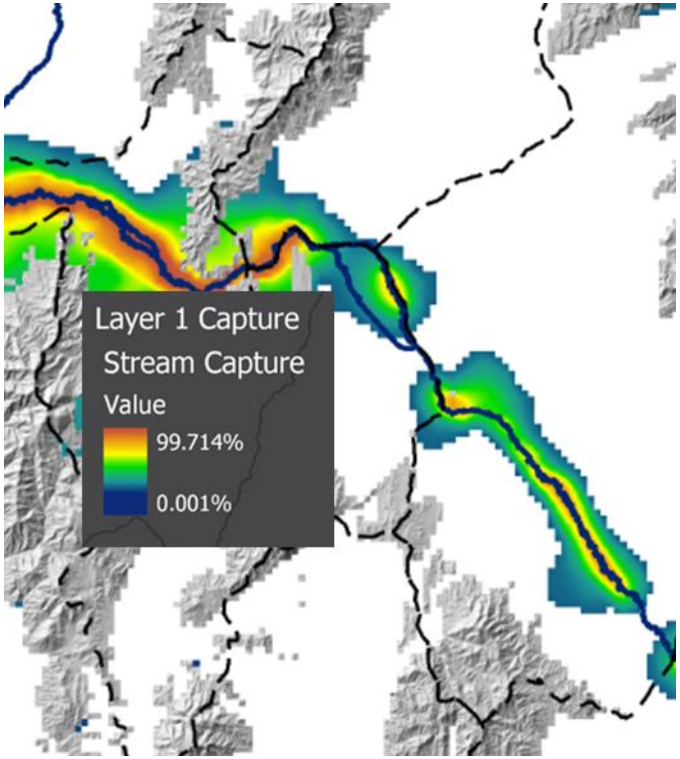


Hydrogeologic Model of the Humboldt River Basin

- Simulate the natural system
- Use existing models and geology data
- Calibrate to historical flow records, water levels, and pumpage
- Quantify how much surface water is actually captured by groundwater pumping
- Develop capture map showing distribution of capture % (potential capture) for model area
- Use models as tool to manage problem

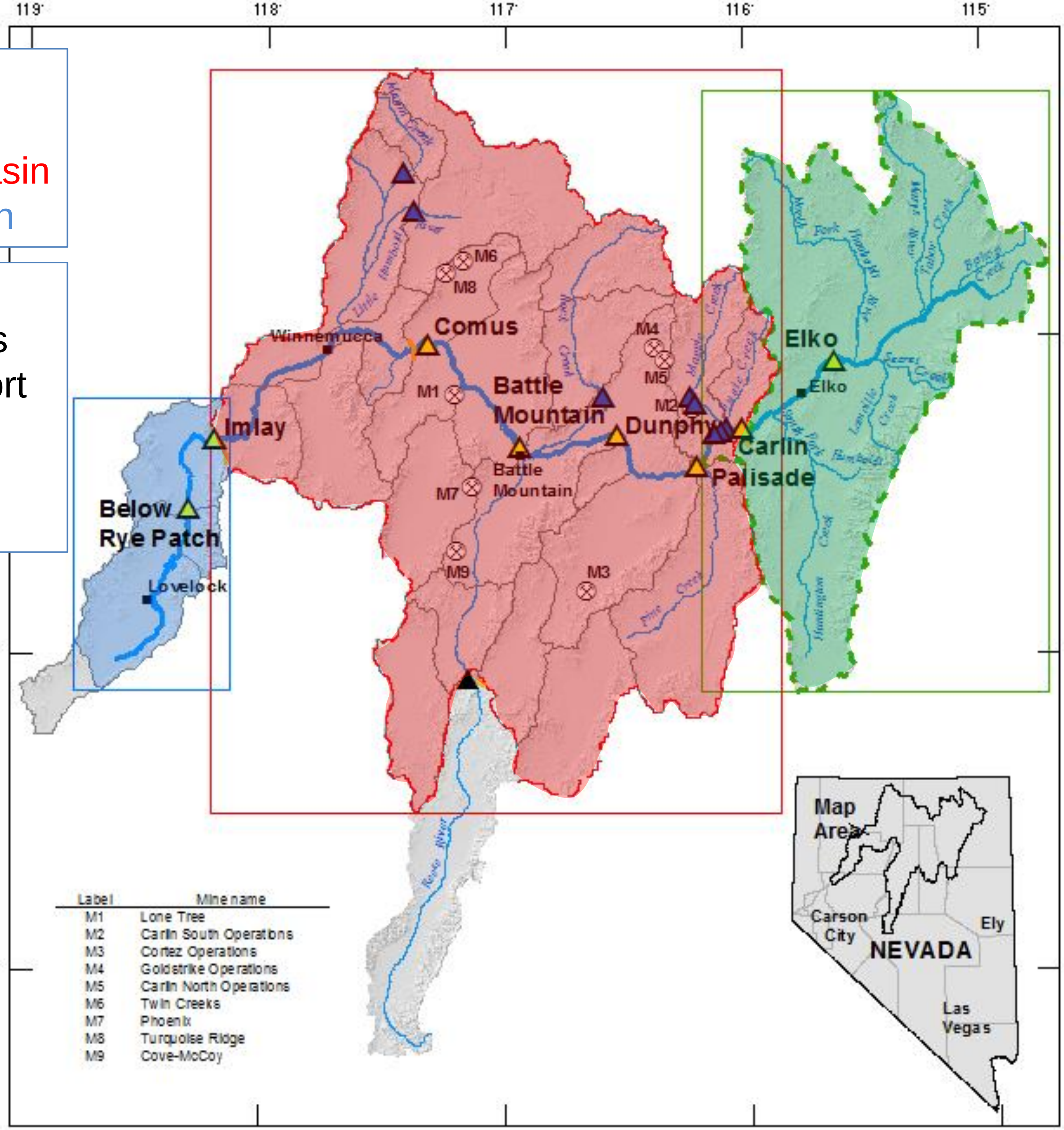
Humboldt River at Comus





Model Areas
- DRI Upper Basin
- USGS Middle Basin
- Joint Lower Basin

DRI ET Study
- Covers all Basins
- Needed to support model water budgets and calibrate models



Groundwater 101

Greg Pohll – DRI

Kip Allander - USGS

Groundwater Hydrology Principles

- Groundwater and surface water, how are these connected or related?

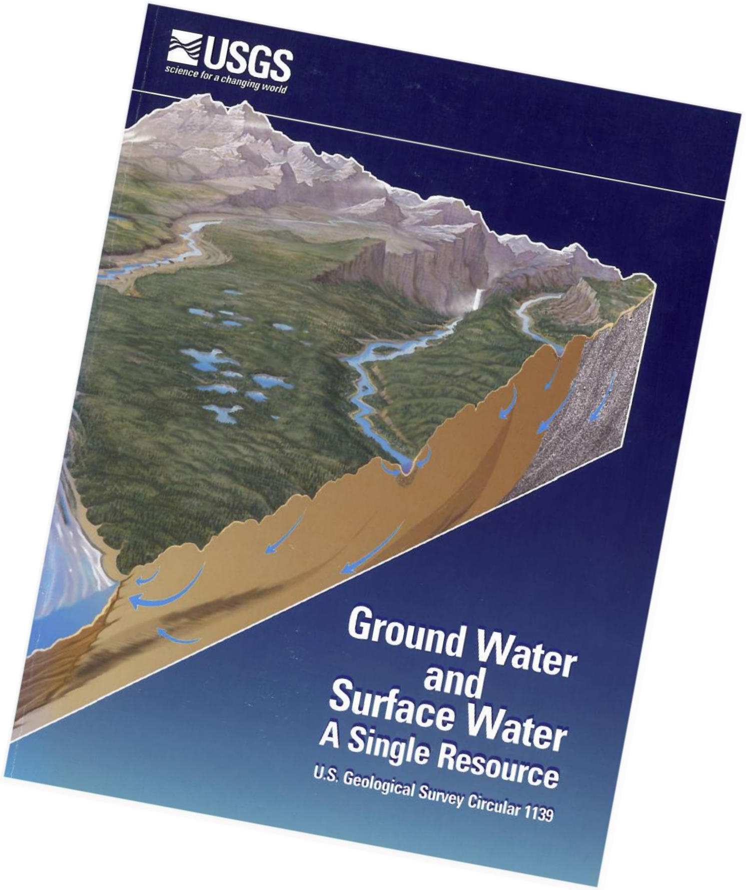
- Where does water come from when pumping a well?

- What are groundwater models and why are they needed?

Groundwater and Surface Water, how are these connected or related?

Important concept for understanding how groundwater works.

Understanding is necessary for proper management of Nevada's water resources.



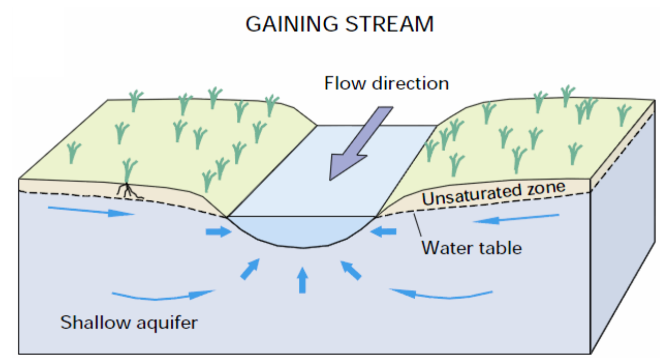
Winter, T.C., Harvey, J.W., Franke, O.L., and Alley, W.M., 1998, Ground water and surface water—A single resource: U.S. Geological Survey Circular 1139, 79 p. https://pubs.usgs.gov/circ/circ1139/

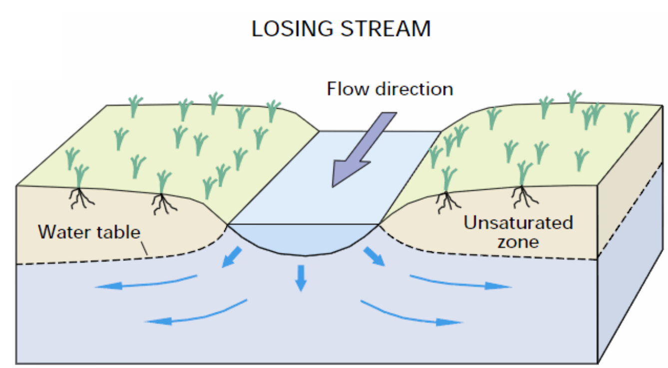
Groundwater and Surface Water are a single resource

- Streams flowing year-round are connected with groundwater.

- Groundwater can:
  - Discharge to a stream (gaining stream).
  - Receive water from a stream (losing stream).

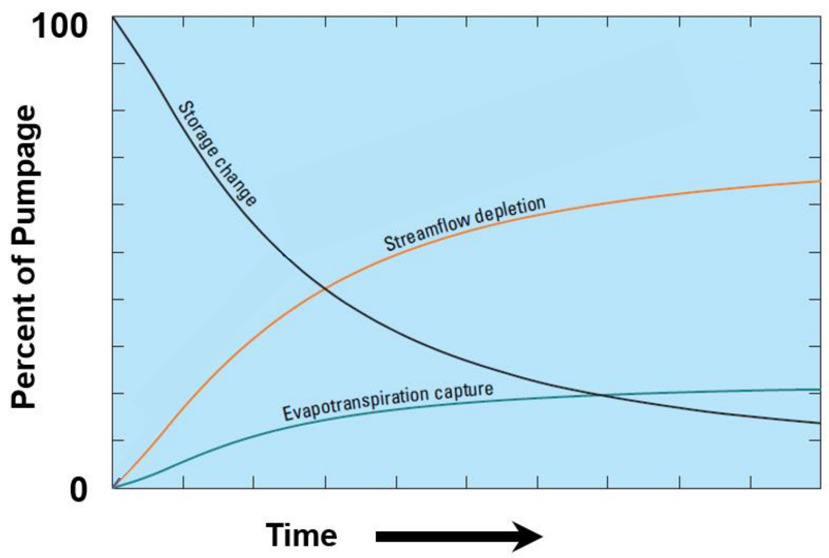
- Streams can:
  - Lose water to groundwater (losing).
  - Gain water from groundwater (gaining).

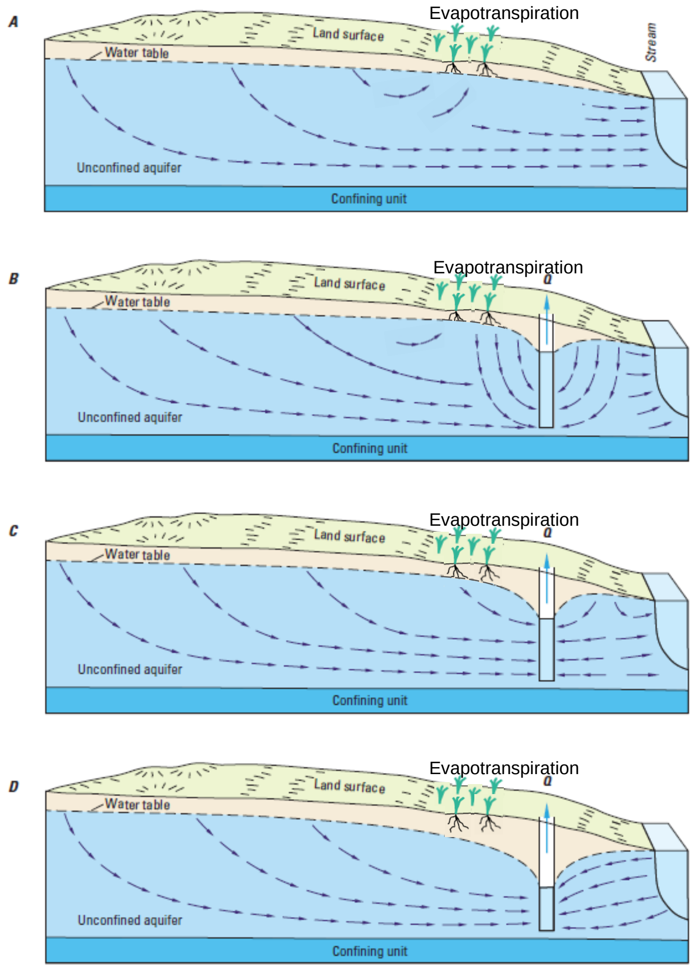




Where does water come from when pumping a well?

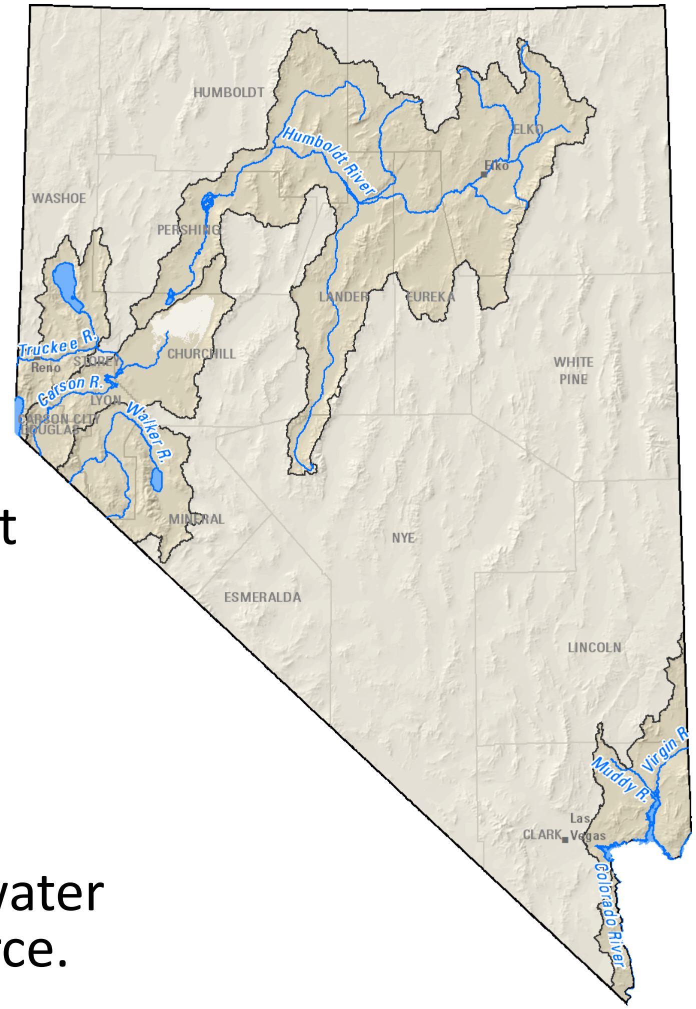
- Storage change – water from ground near well.
- Streamflow capture – diversion from stream.
- Evapotranspiration capture – water intercepted from plant use and evaporation.





Barlow, P.M., and Leake, S.A., 2012, Streamflow depletion by wells—Understanding and managing the effects of groundwater pumping on streamflow: U.S. Geological Survey Circular 1376, 84 p. http://pubs.usgs.gov/circ/1376/

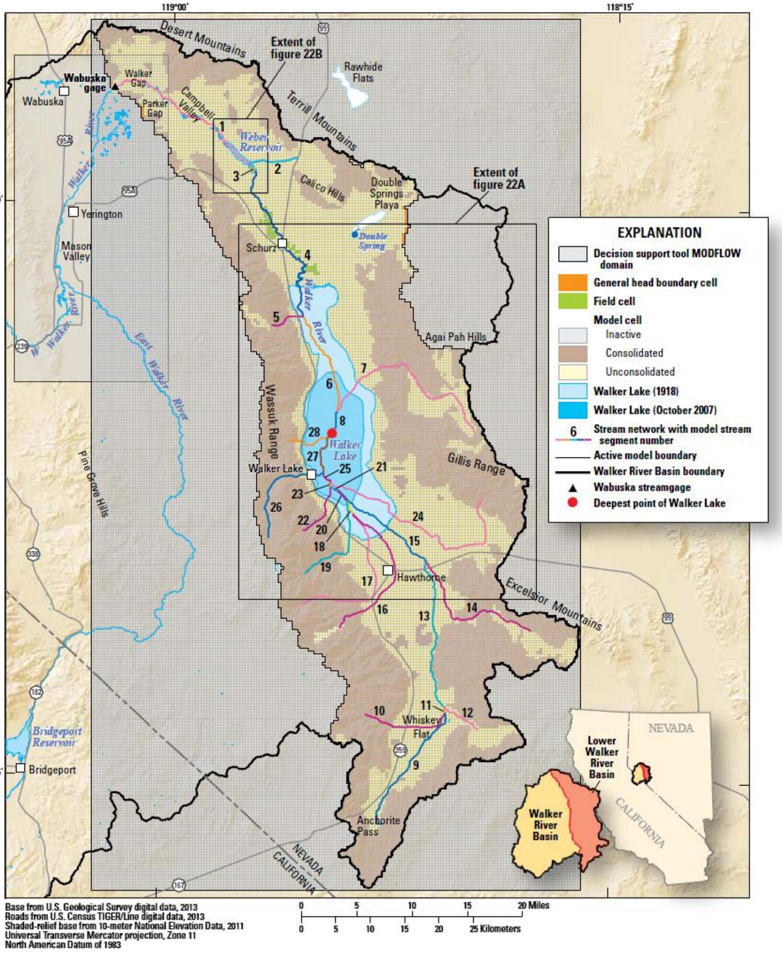
River Connected Groundwater Systems in Nevada



- River connected flow systems.
  - Much of the groundwater movement between Hydrographic areas is by streamflow.
  - 25 percent of Nevada's groundwater systems.
  - Substantial potential for conflict between groundwater and surface water users due to shared nature of resource.

What are Groundwater models?

- Mathematical representations of complex hydrologic systems.
- Simulate hydrologic systems based on principles, aquifer properties, and boundary conditions.

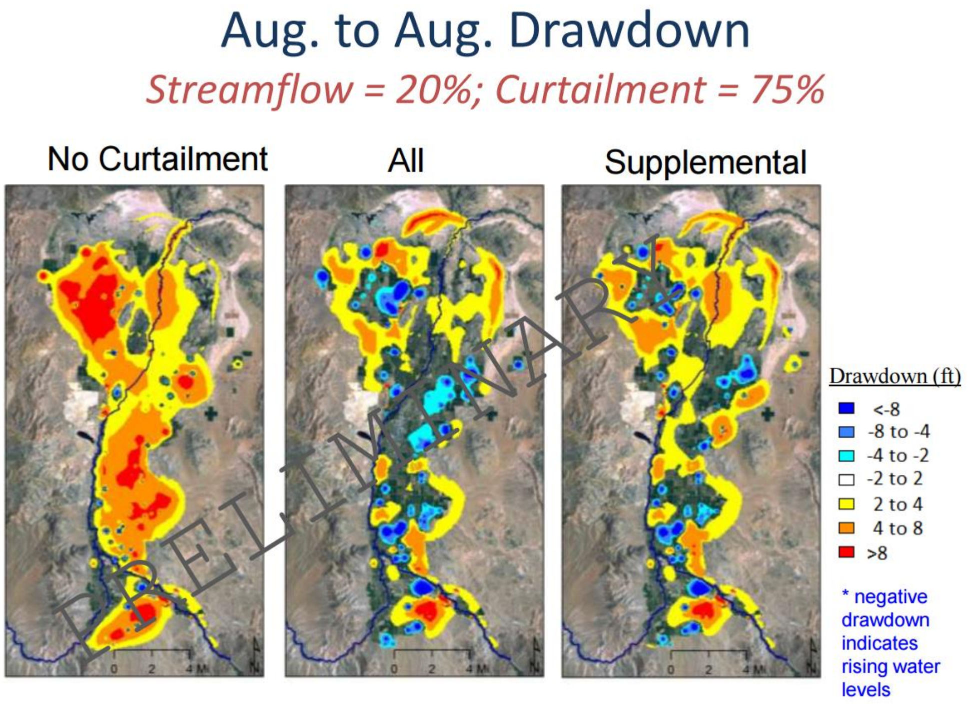


Groundwater flow equation:

$$\frac{\partial}{\partial x}\left[K_{xx}\frac{\partial h}{\partial x}\right]+\frac{\partial}{\partial y}\left[K_{yy}\frac{\partial h}{\partial y}\right]+\frac{\partial}{\partial z}\left[K_{zz}\frac{\partial h}{\partial z}\right]+W=S_S\frac{\partial h}{\partial t}$$

Why are Groundwater models needed?

- Use existing information and understanding to estimate properties that govern flow.
  - Referred to as calibration.
- Needed to understand complex system interactions and to inform results of management actions.

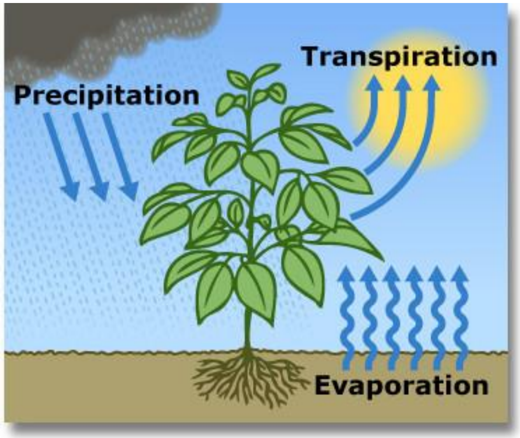


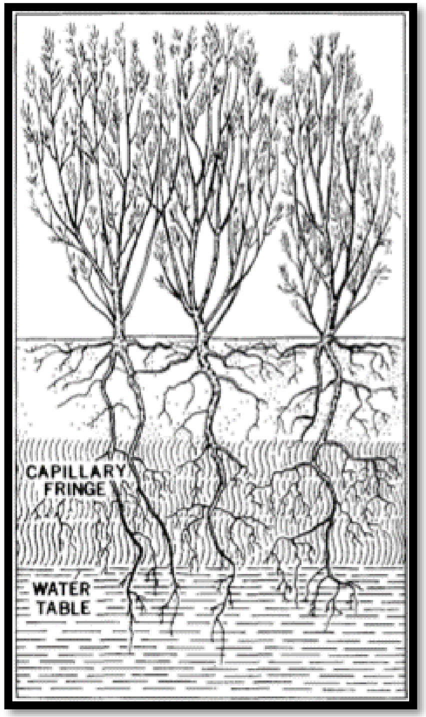
Evapotranspiration

Matt Bromley - DRI

Evapotranspiration

- Water recharged in the Humboldt River Basin is naturally discharged through:
  - Evaporation from Open Water
  - Evaporation from Playas
  - Transpiration from Phreatophytes (plants that access and use groundwater)
- Evaporation + Transpiration = **ET** (EvapoTranspiration)
- DRI ET Task: Estimate annual groundwater ET for each HA of the Humboldt River Basin in order to support groundwater modelling efforts





Subtasks

- Review previous groundwater ET estimates and develop a database of:
  - Groundwater Discharge (Phreatophyte) Boundaries
  - ET rates
  - ET volumes
- Modify discharge area boundaries based on satellite/aerial imagery and field investigations
- Apply new remote sensing and gridded weather data techniques to update ET rates and volumes

Where are plants discharging groundwater and how much groundwater is being discharged?

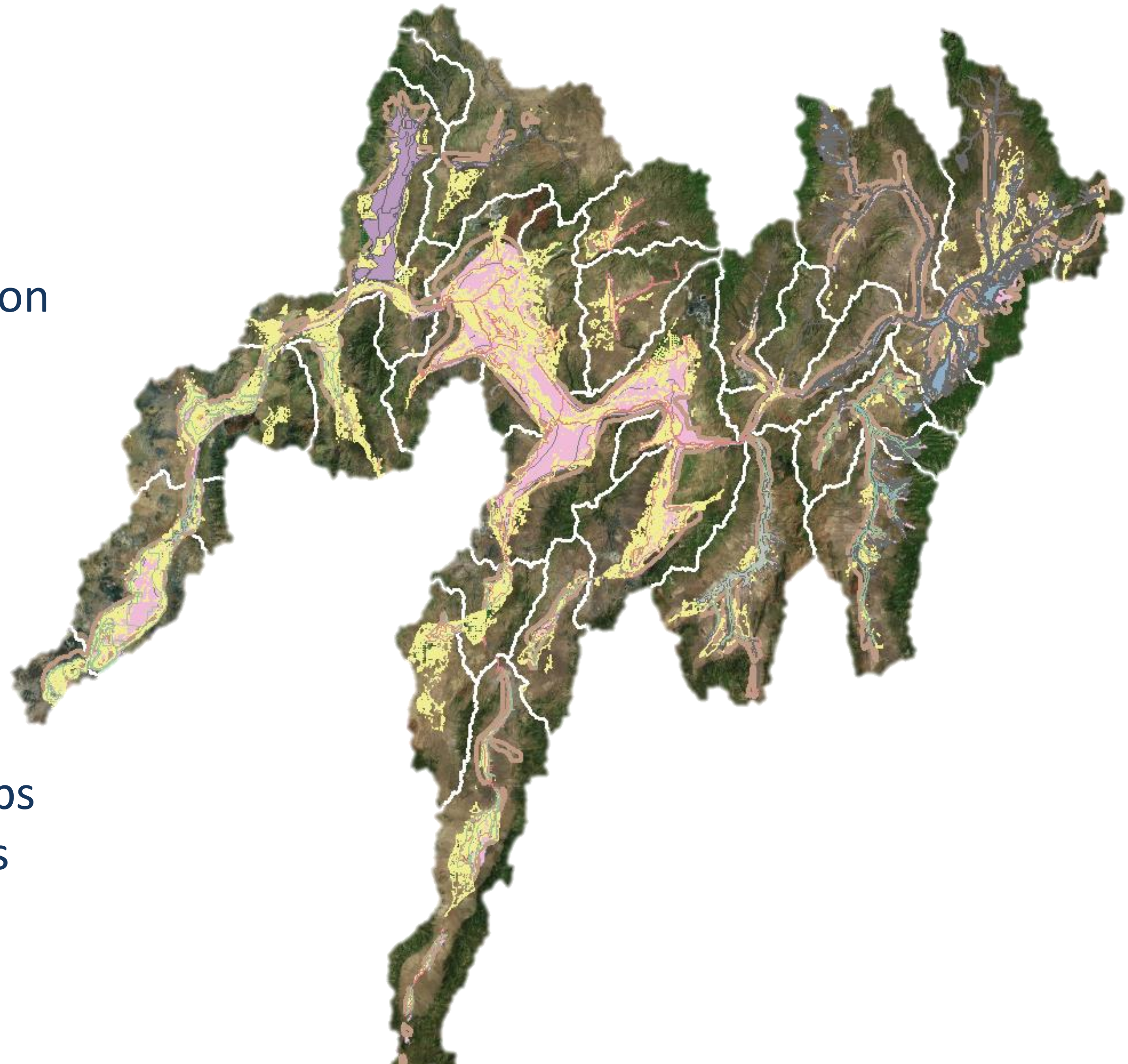
Established Discharge Boundaries

Previous Studies

- Reconnaissance Reports
- Water Resource Bulletins
- Water-Resource Investigation Reports
- Other reports

Sources of Error in Previous Boundaries

- Limitations in data
- Some studies used specific assumptions or relationships to estimate discharge areas
- Changes over time

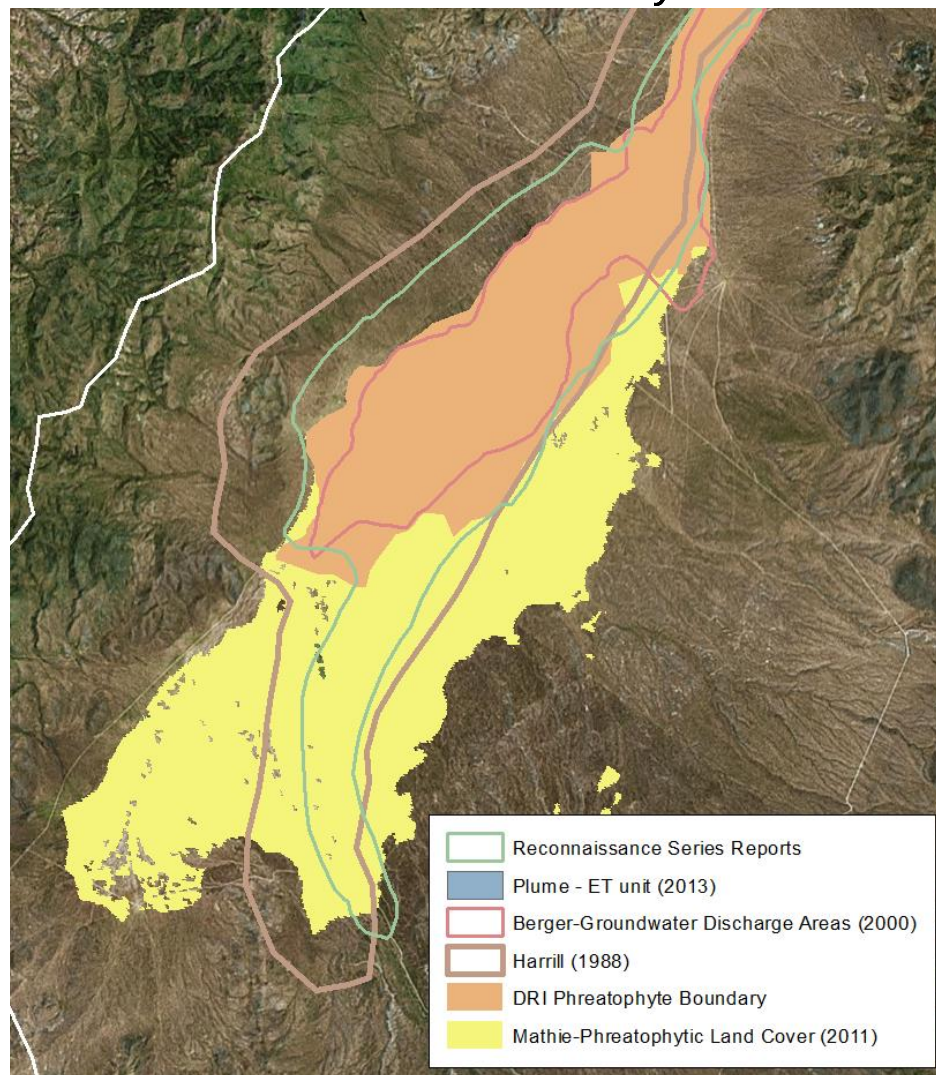


Development of Hybrid Boundaries

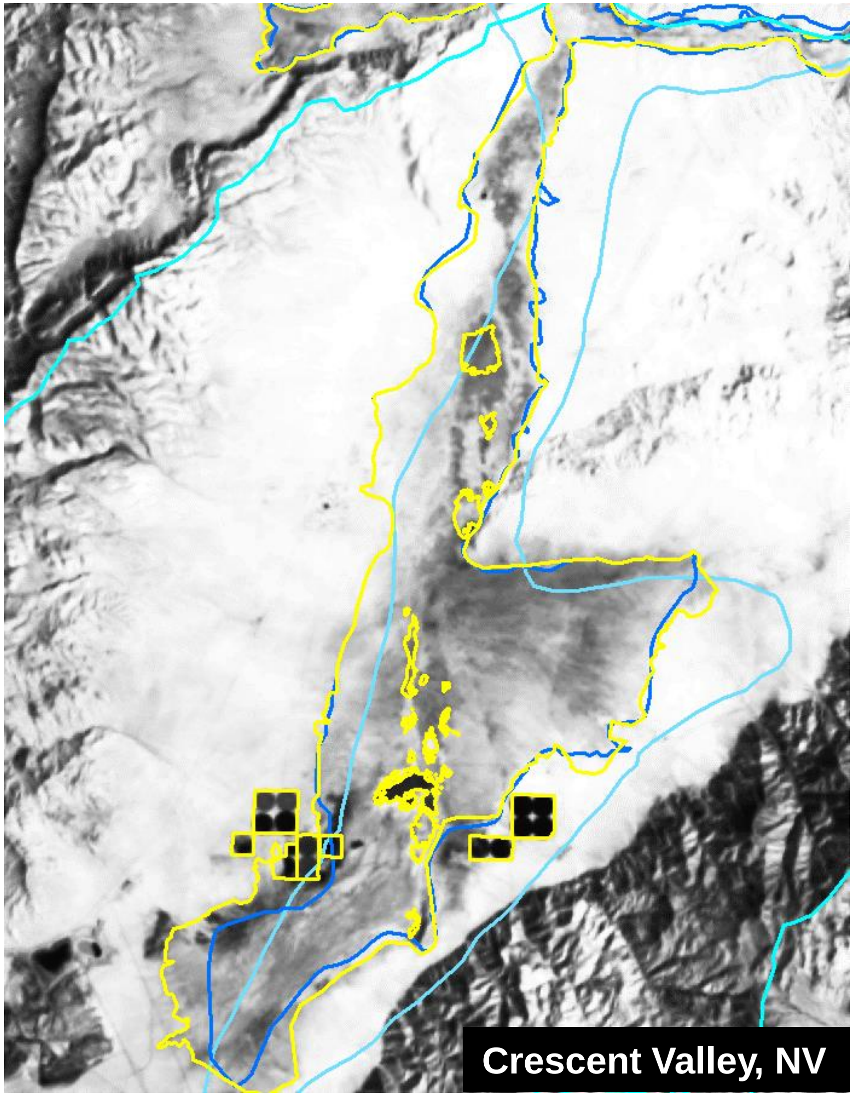
- Assess previous boundaries
  - Historical Landsat satellite imagery
  - High resolution aerial imagery
  - Digital elevation
  - Field investigations
- Create new DRI boundaries based on multiple datasets

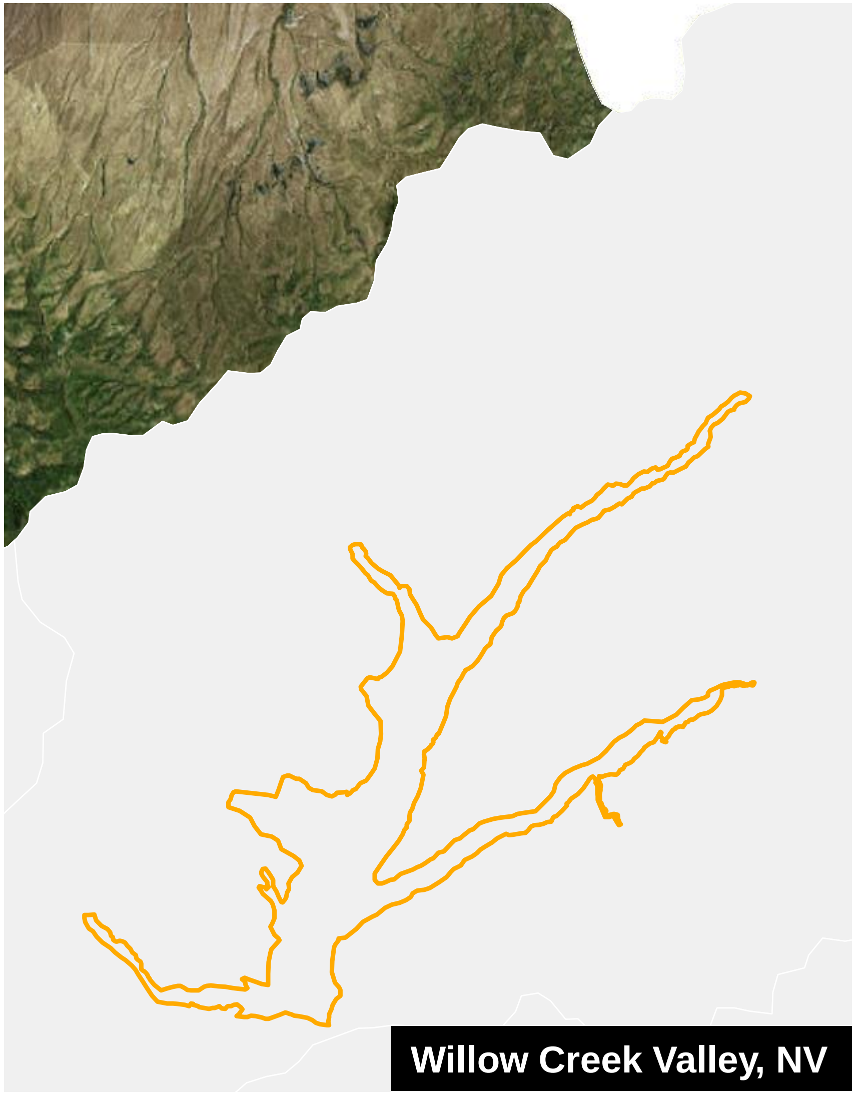
NOTE: Area is an important component in calculating volume, so correctly defining the discharge area in each basin is important

Carico Lake Valley

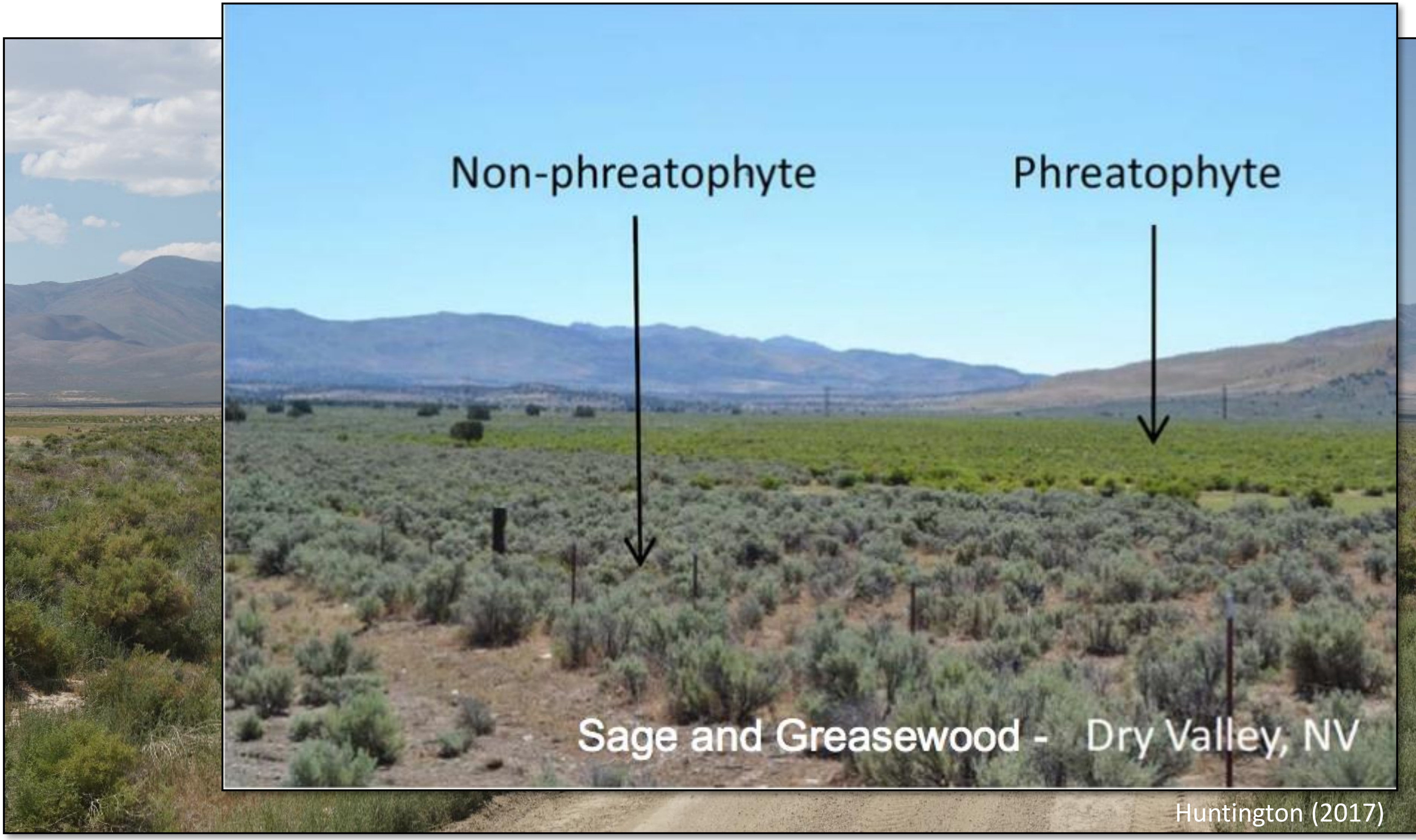


Satellite and Aerial Images

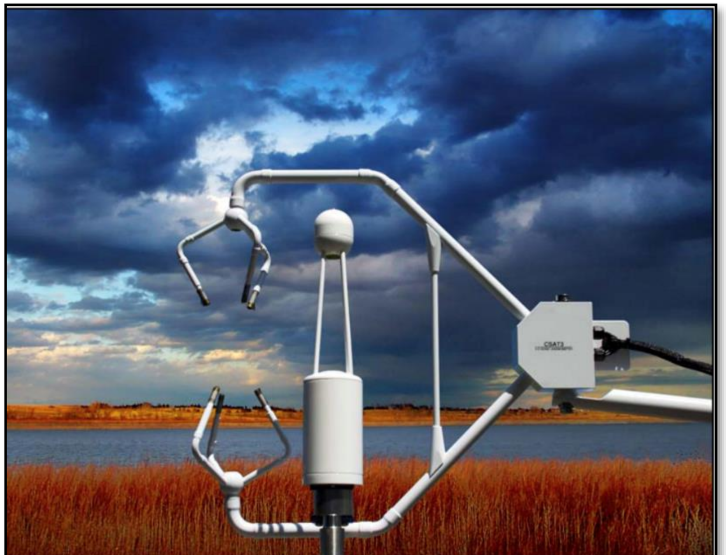




Field Investigations

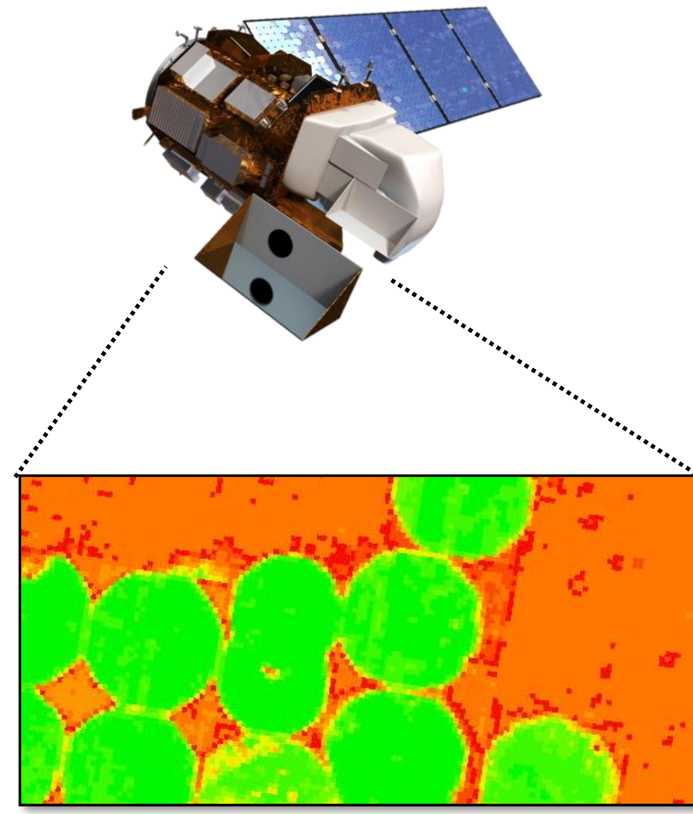


Recent groundwater ET studies



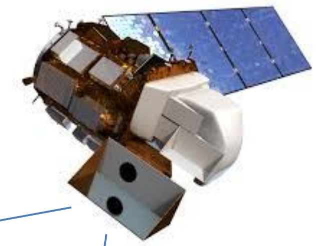
ET measured with sensors

Relate



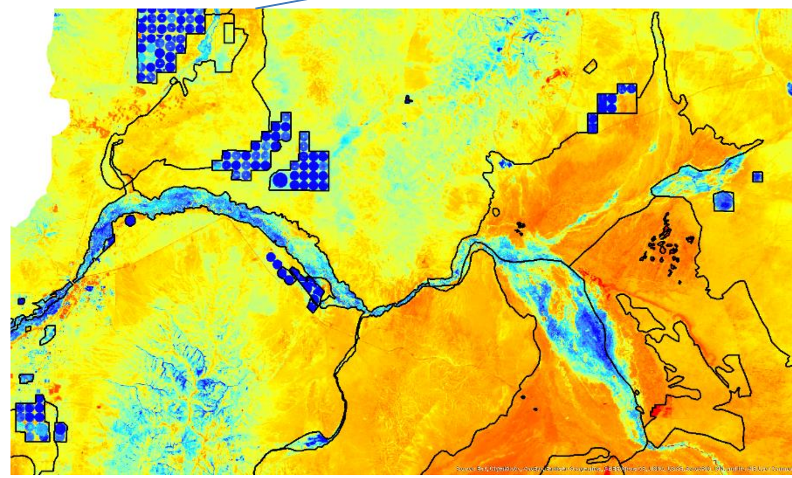
Mid-summer
Landsat imagery
(Vegetation Indices)

Remote Sensing of ET

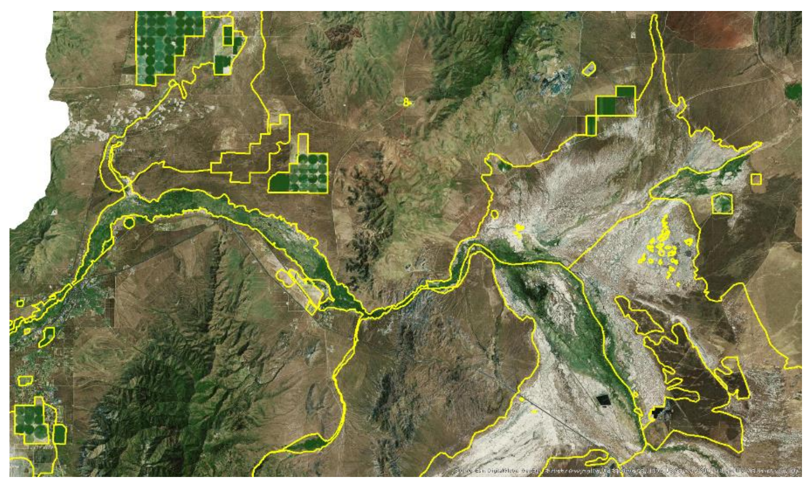


Groundwater ET rates based on:

- Published regression model Based on 40 site years of measured ET from phreatophytes in Nevada
- Landsat satellite images of vegetation vigor (greenness) from 1985-2015
- Gridded weather data from 1985-2015
  - Potential ET (PET)
  - Precipitation (PPT)



Vegetation Index (30m)

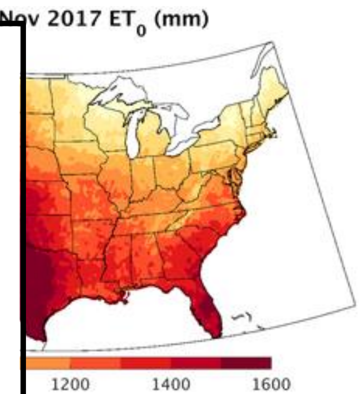


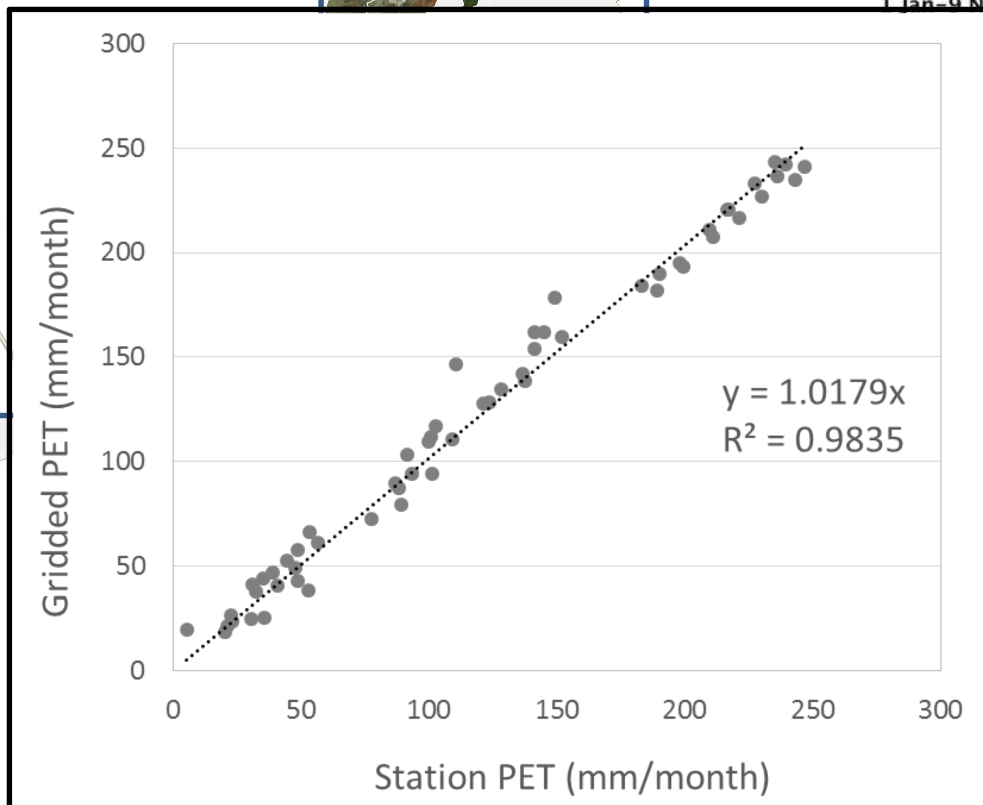
True Color

Meteorological Data

Weather station data
(Represents some areas for some periods of time)

‘Gridded’ weather data
(Covers the continental U.S. from 1979-yesterday)





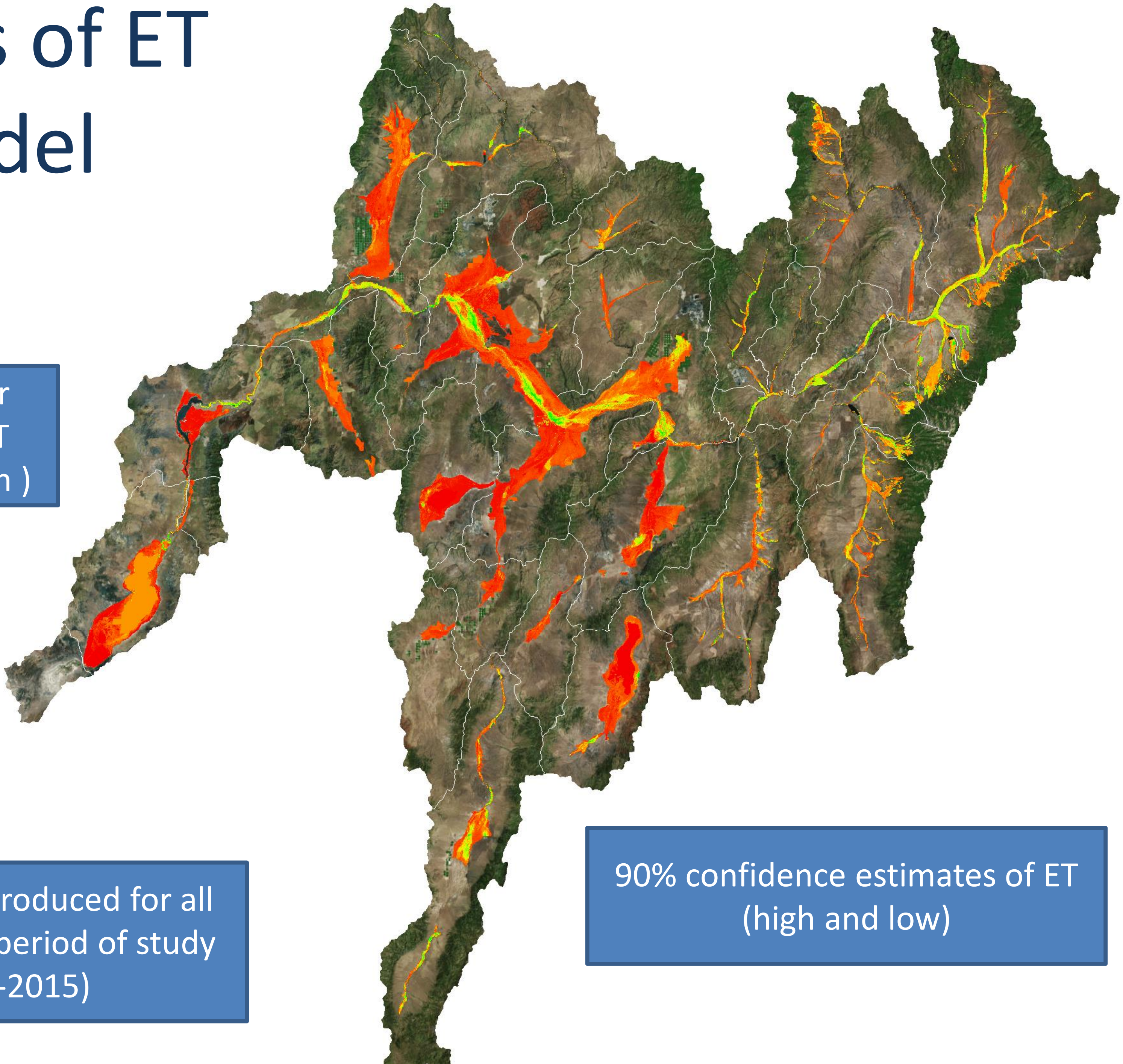
Data Processing

- Google Earth Engine, a massively parallel cloud-computing platform, was used to process the data
- Processed all areas contained in the DRI discharge boundaries
- Model applied to the Landsat image archive (years 1985-2015)

Google Earth Engine

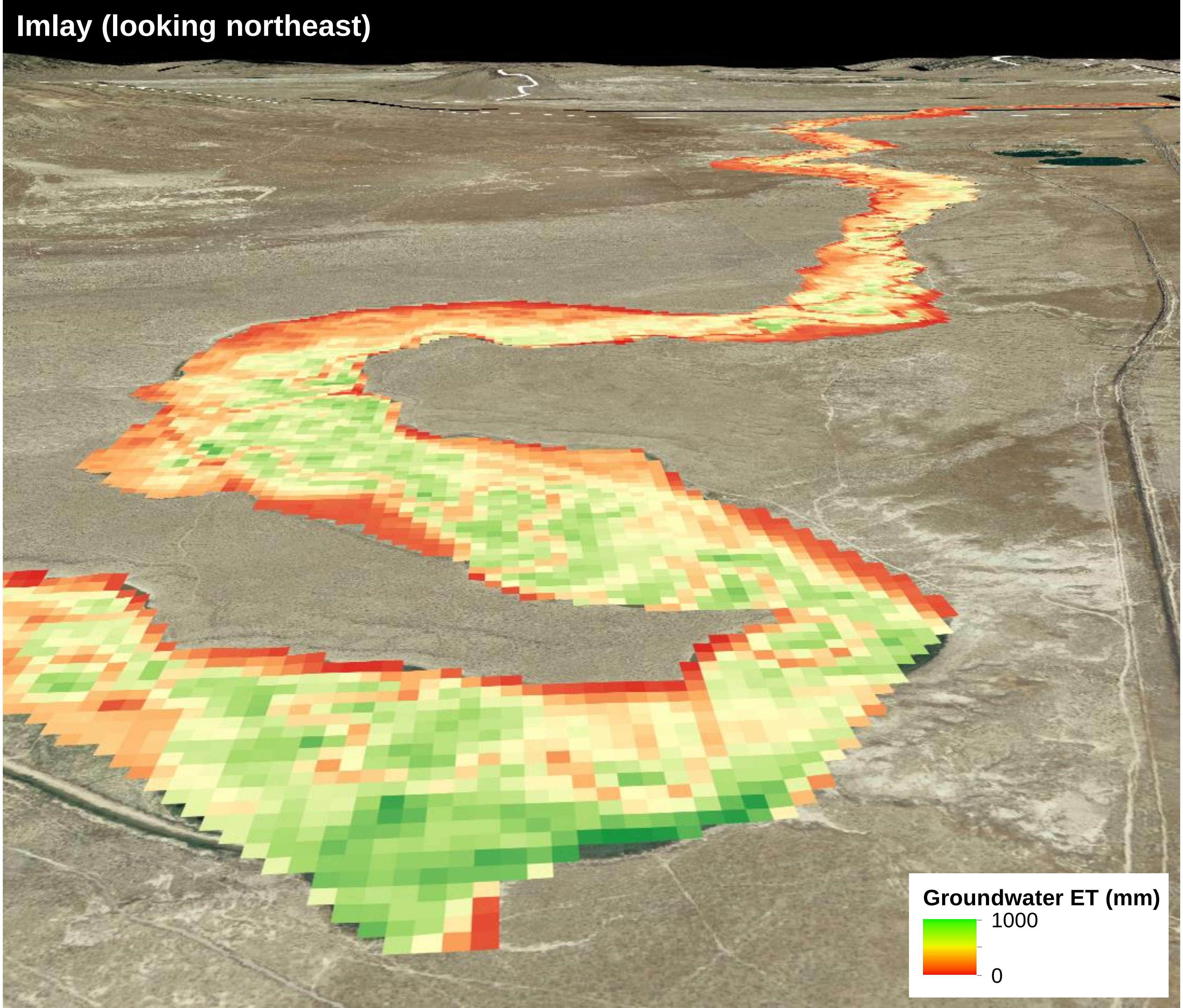
Results of ET Model

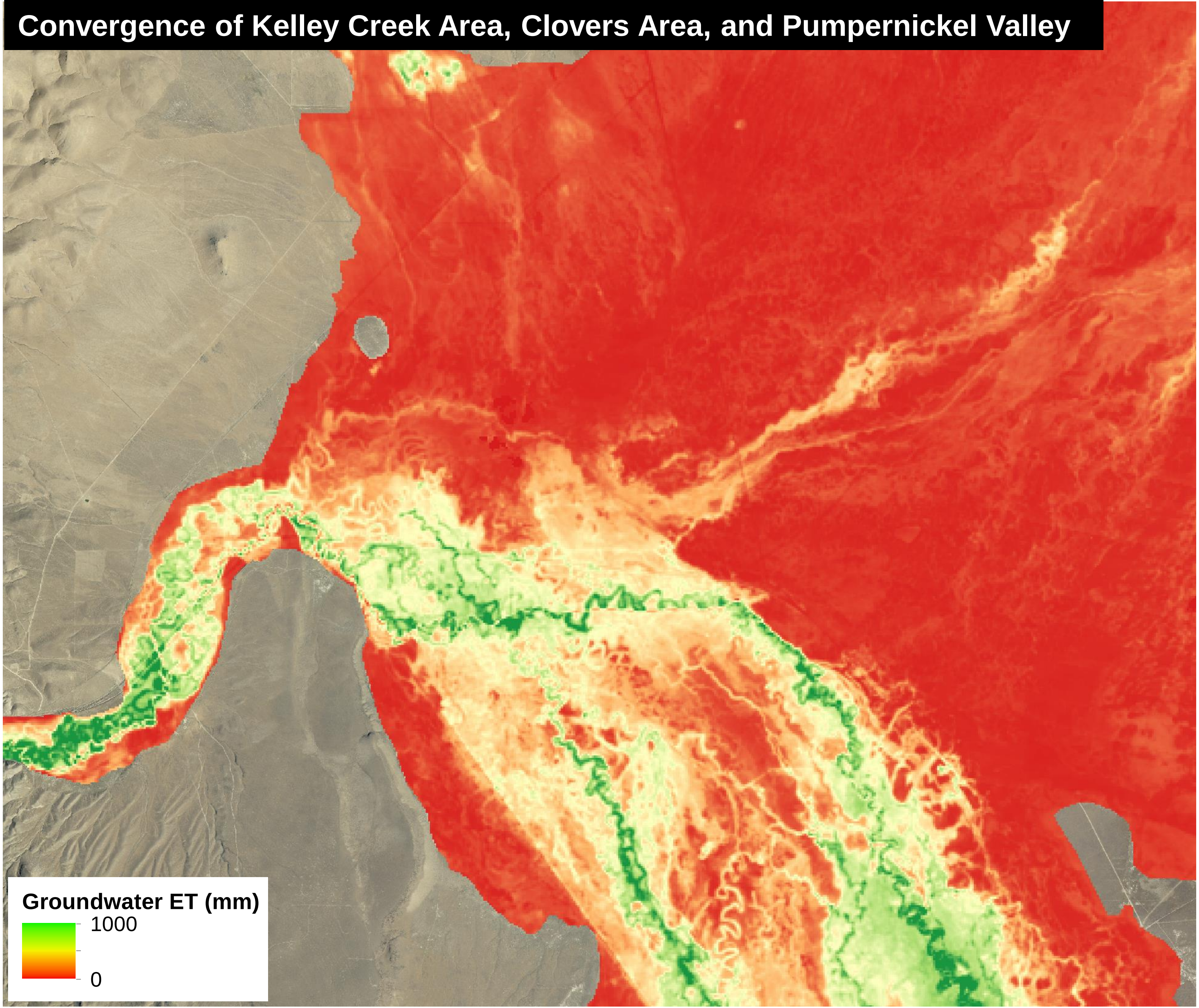
The groundwater component of ET (ET – precipitation)

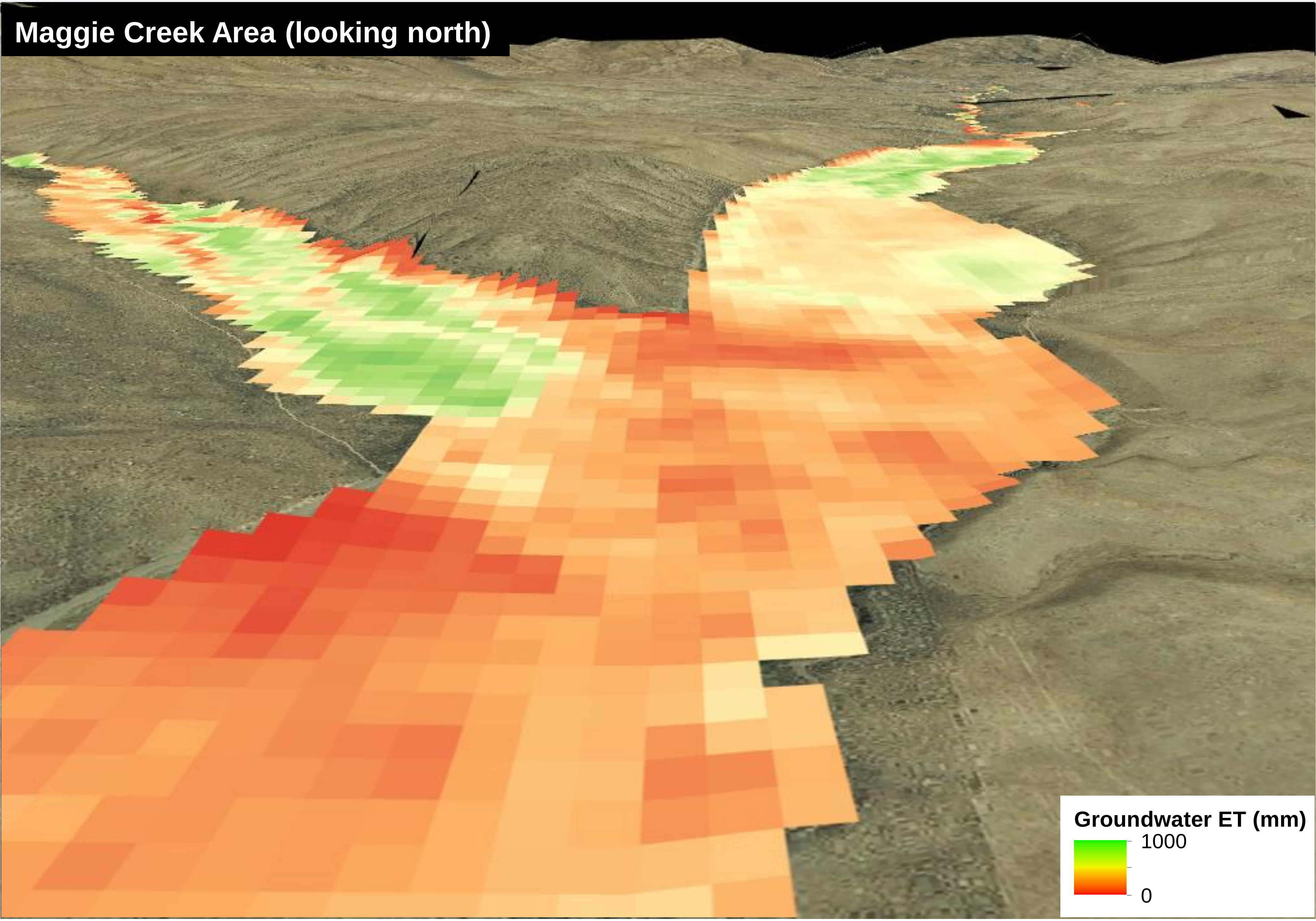


Annual rates produced for all basins for the period of study (1985-2015)

90% confidence estimates of ET (high and low)


Imlay (looking northeast)
Groundwater ET (mm)
1000
0

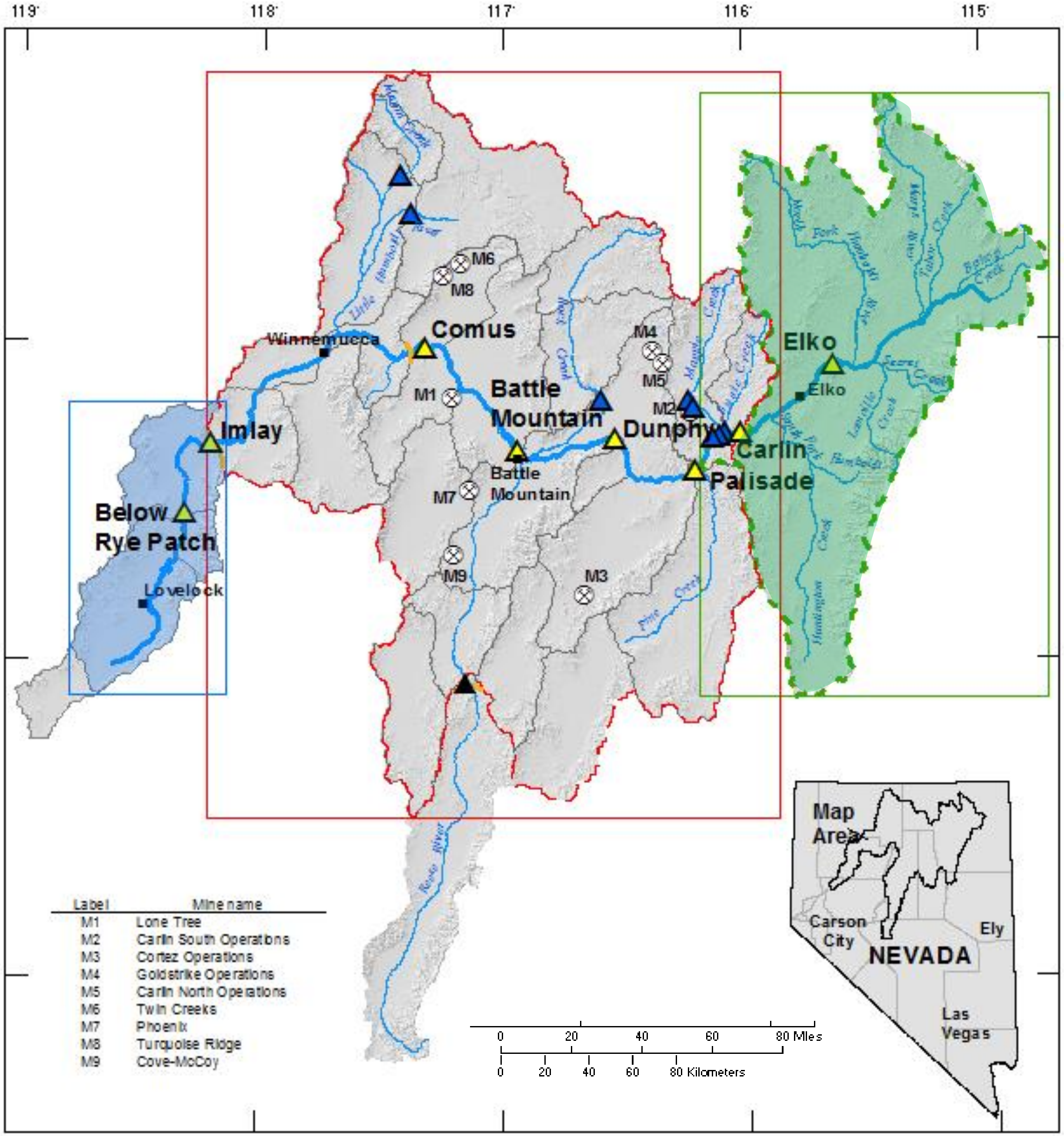

Convergence of Kelley Creek Area, Clovers Area, and Pumpernickel Valley
Groundwater ET (mm)
1000
0


Maggie Creek Area (looking north)
Groundwater ET (mm)
1000
0

Groundwater Models

Upper Basin Model

Greg Pohll - DRI

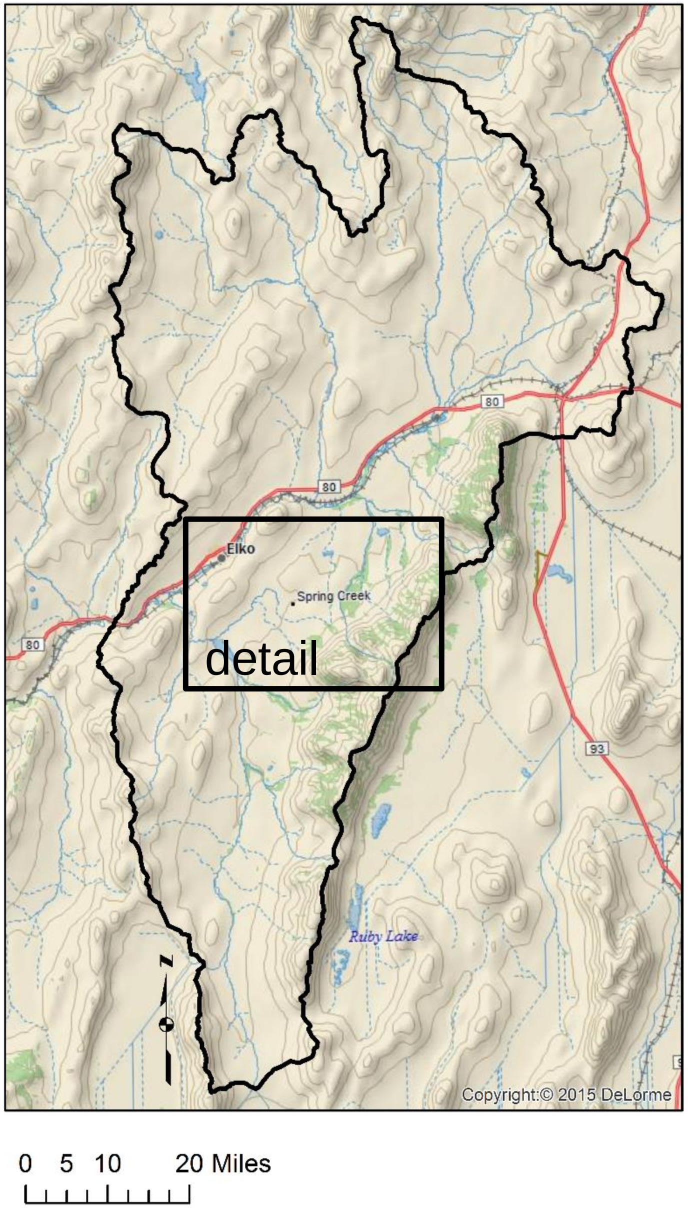


- Upper basin model – DRI
- Middle basin model – USGS
- Lower basin Model – USGS/DRI

Outline

- Model grid
- Steady-state calibration
- Transient calibration
- Capture map
- Uncertainty analysis

Model Grid



(cell dim. 900 ft)

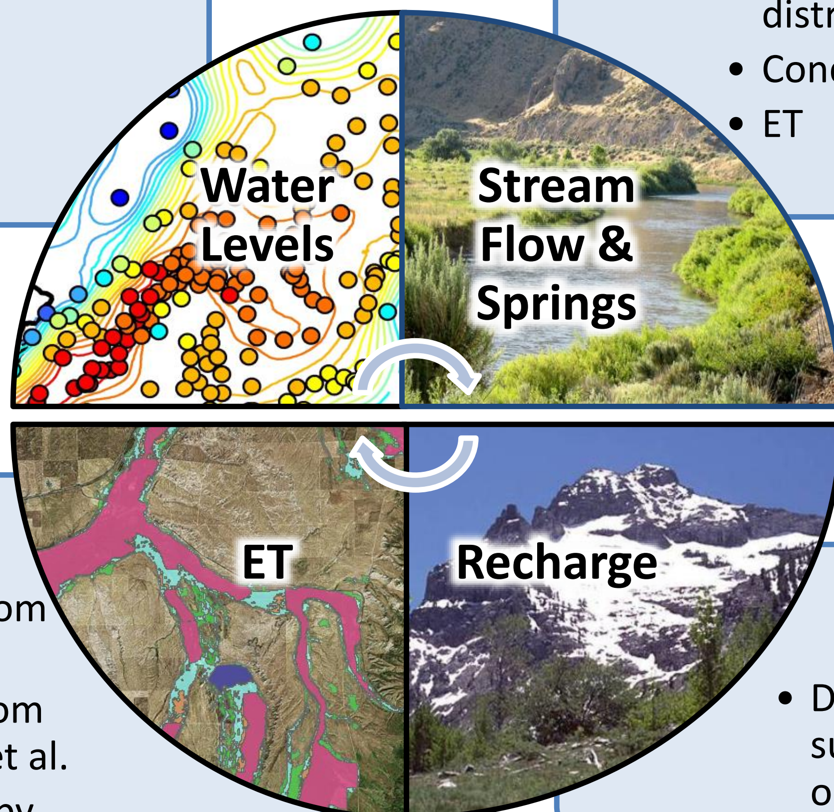
<u>NWT Grid Improves over USG</u>:

- Numeric stability
- Computational speed
- Wet/dry & unconfined conditions

Calibration Strategy

- Horizontal K
- Recharge distribution

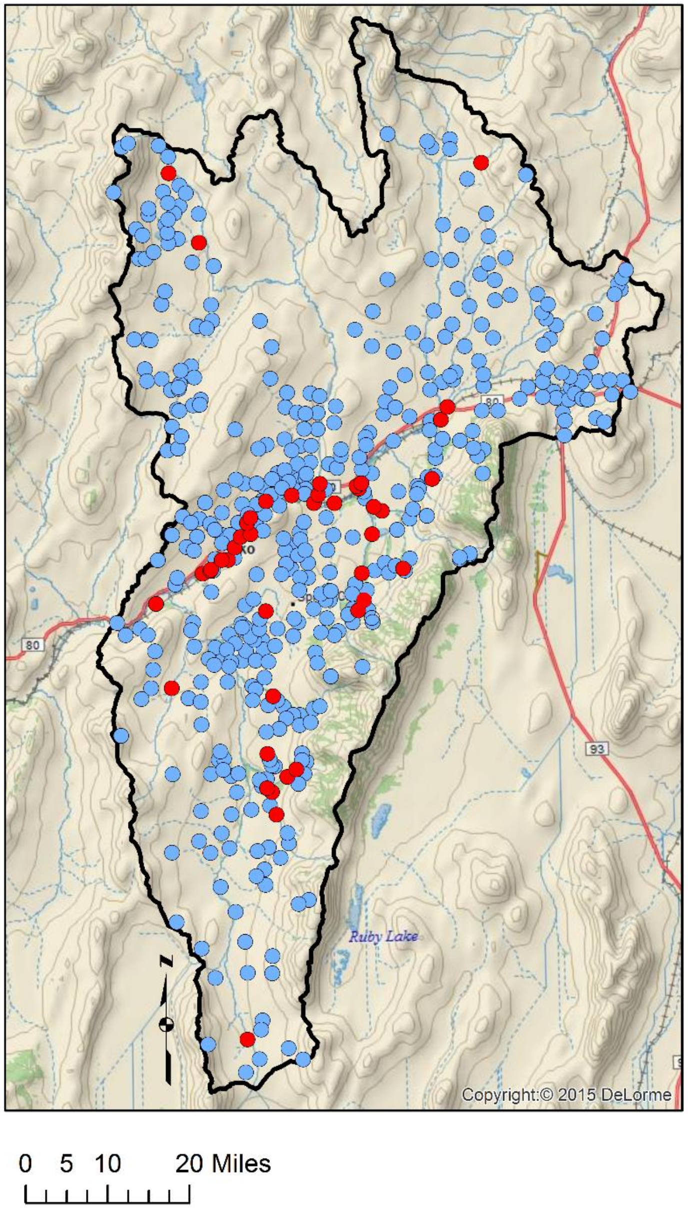
- Recharge distribution
- Conductance
- ET

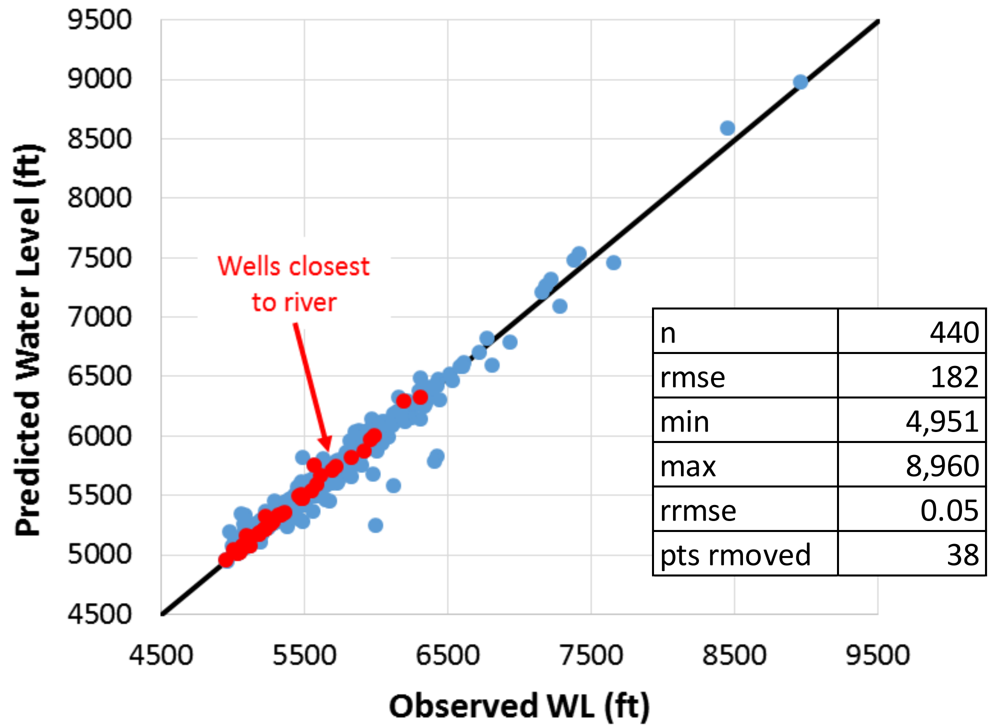


- Ext. depth from Walsh, 2007
- Adjust ET_0 from Huntington et al.
- ET provided by Huntington et al.

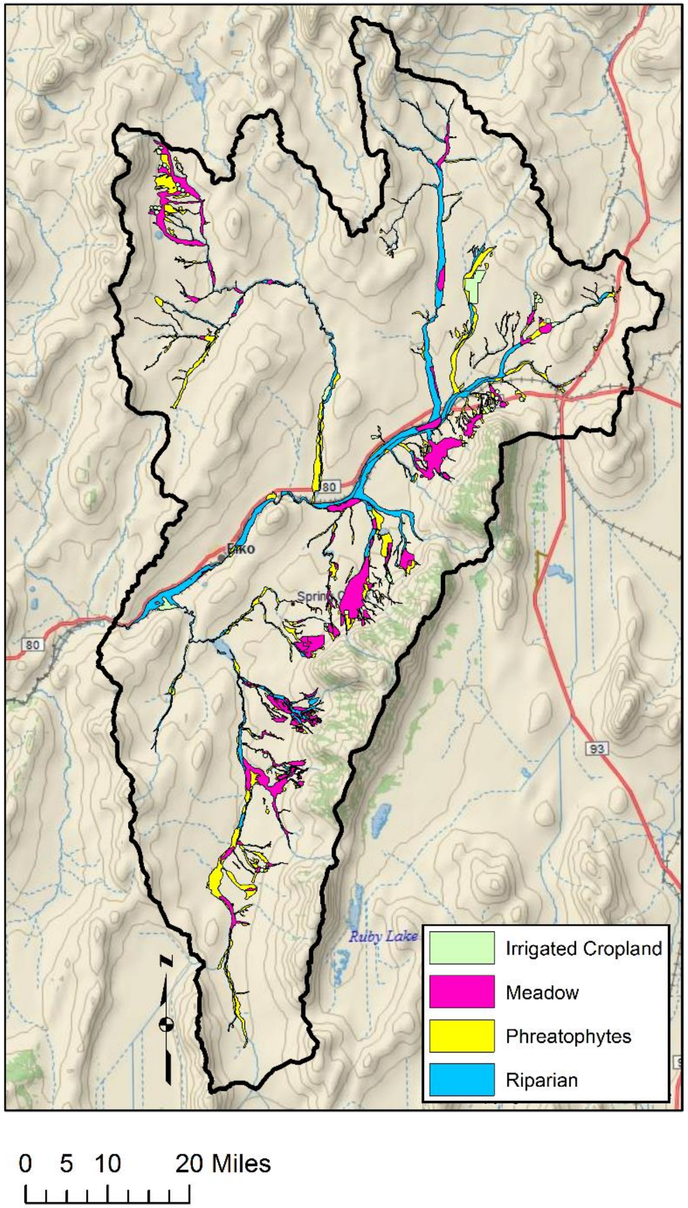
- Define as sum of outflows

Steady State Water Levels

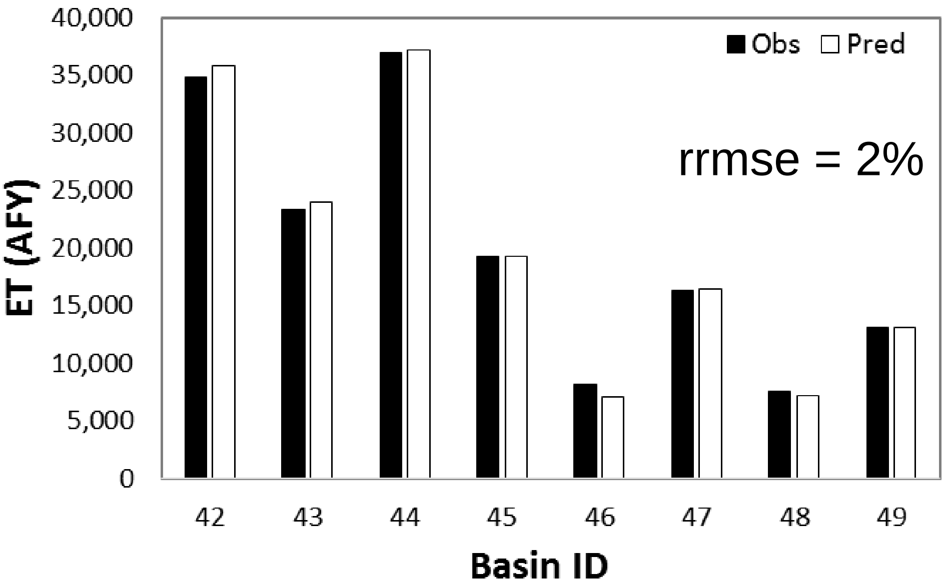




ET Calibration

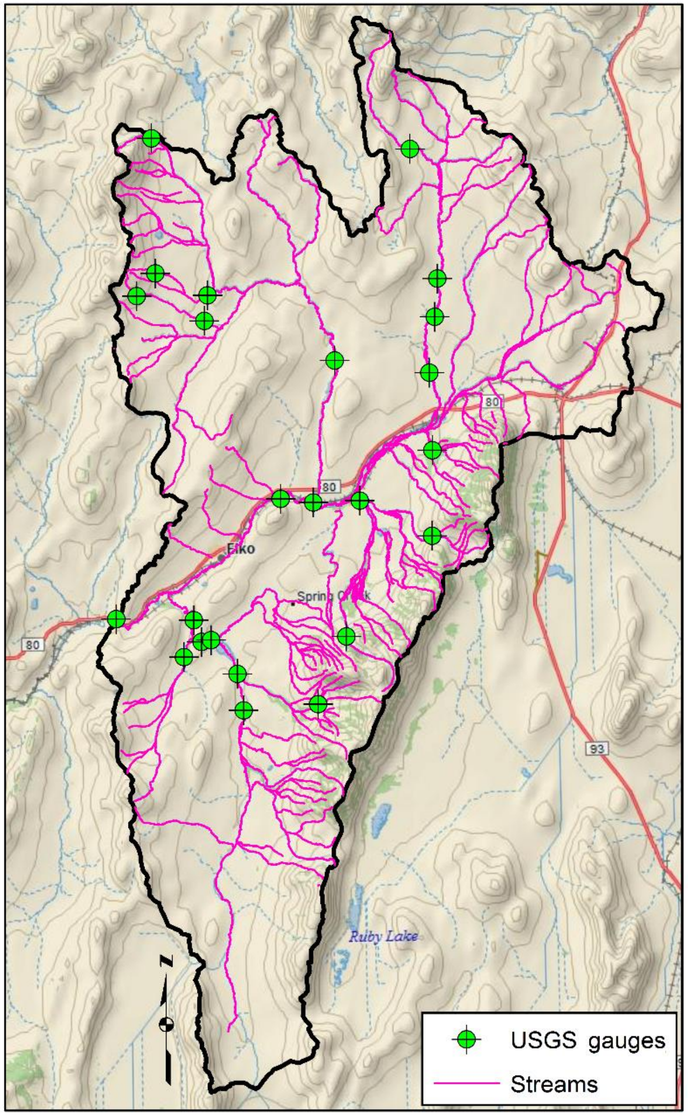


Total Observed: 159,592 AFY
Total Predicted: 159,927 AFY

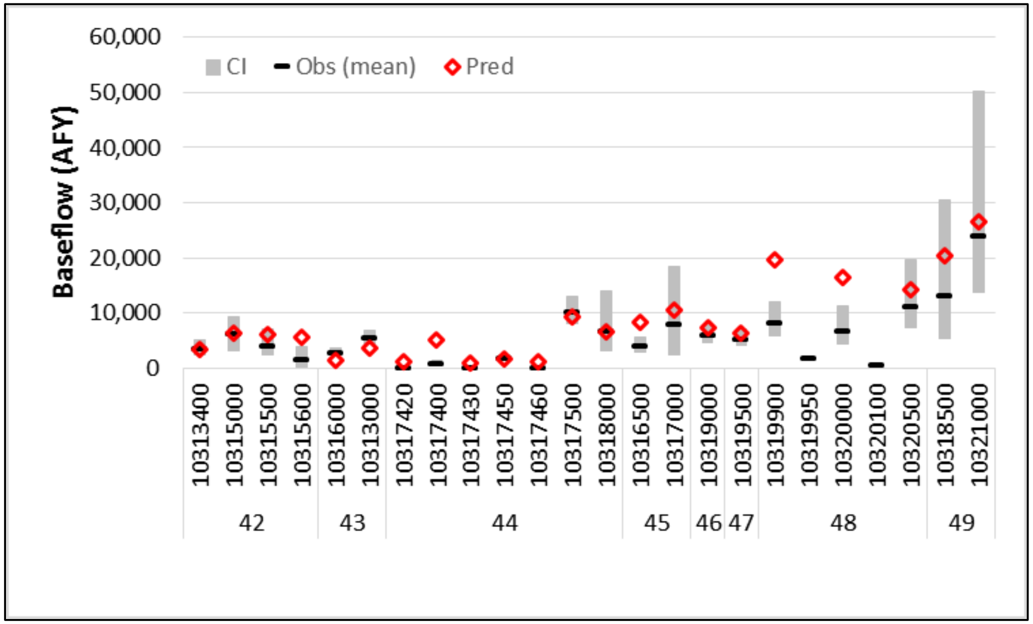


Adjusted ETo by vegetation type for each sub-basin to best match net ET

Stream Calibration

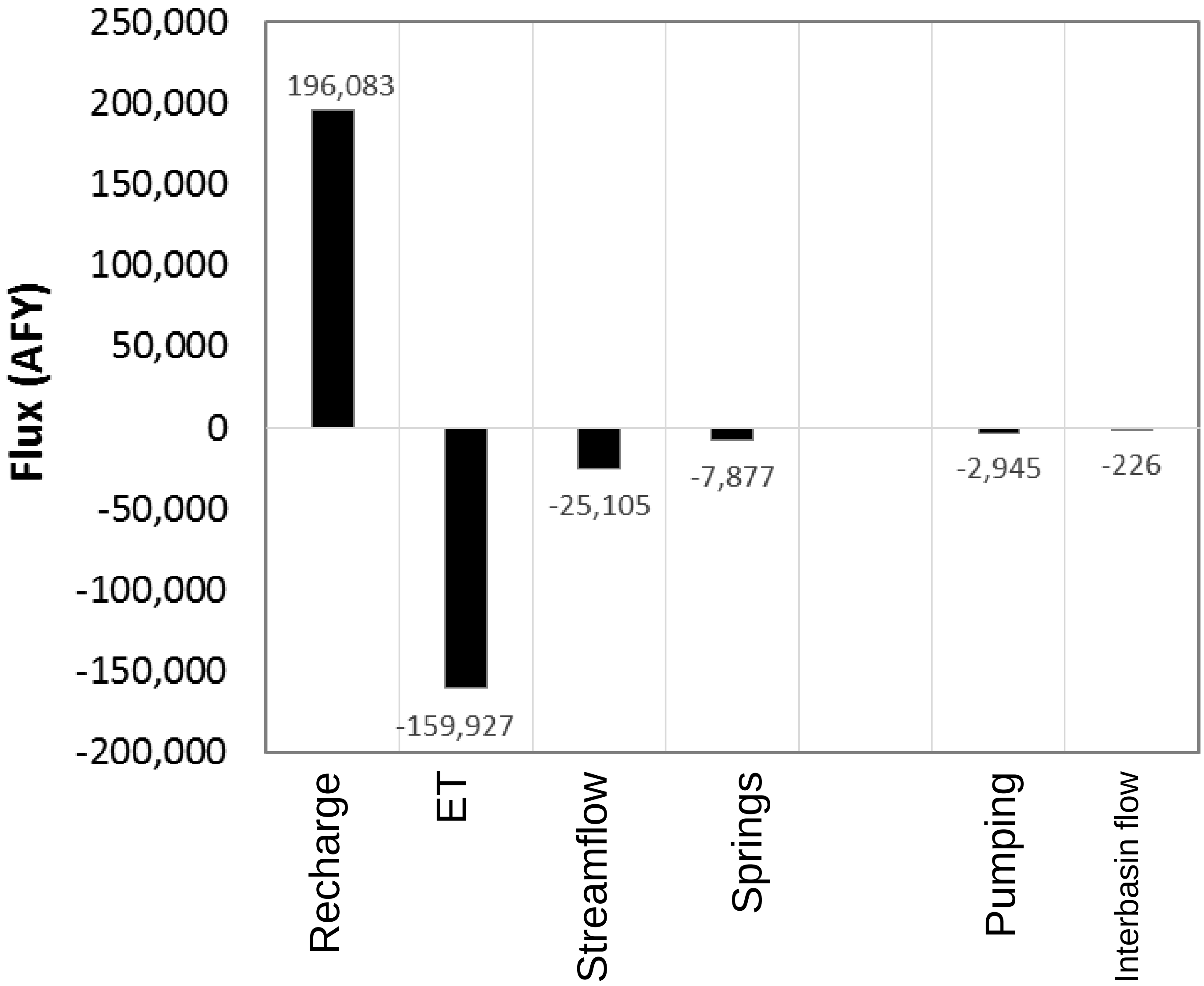


0 5 10 20 Miles

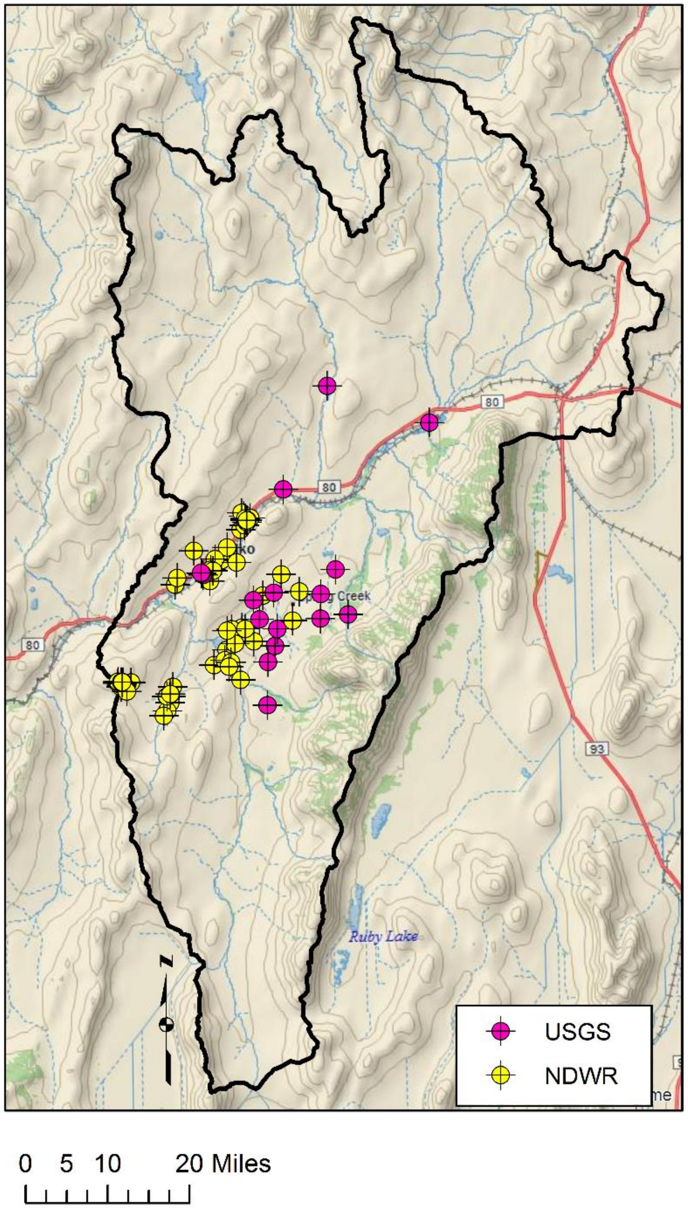


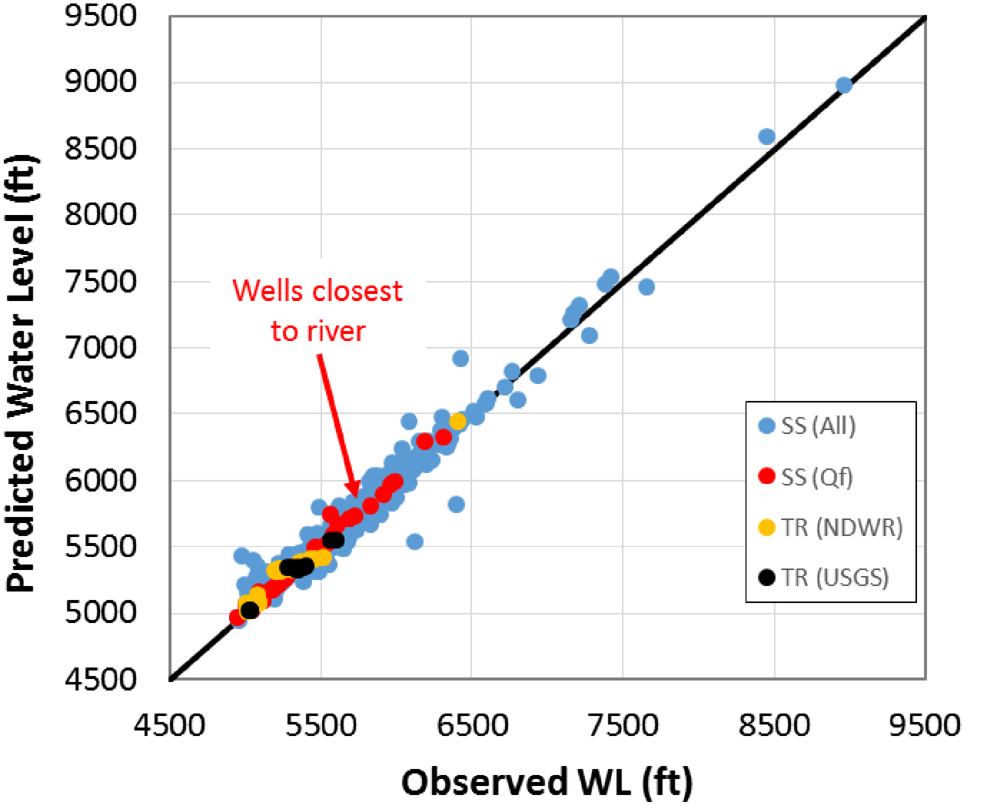
Recharge adjusted to best match observed October and November stream discharge. CI = 25th and 75th confidence intervals for period of record at each gage

Steady-State Water Budget



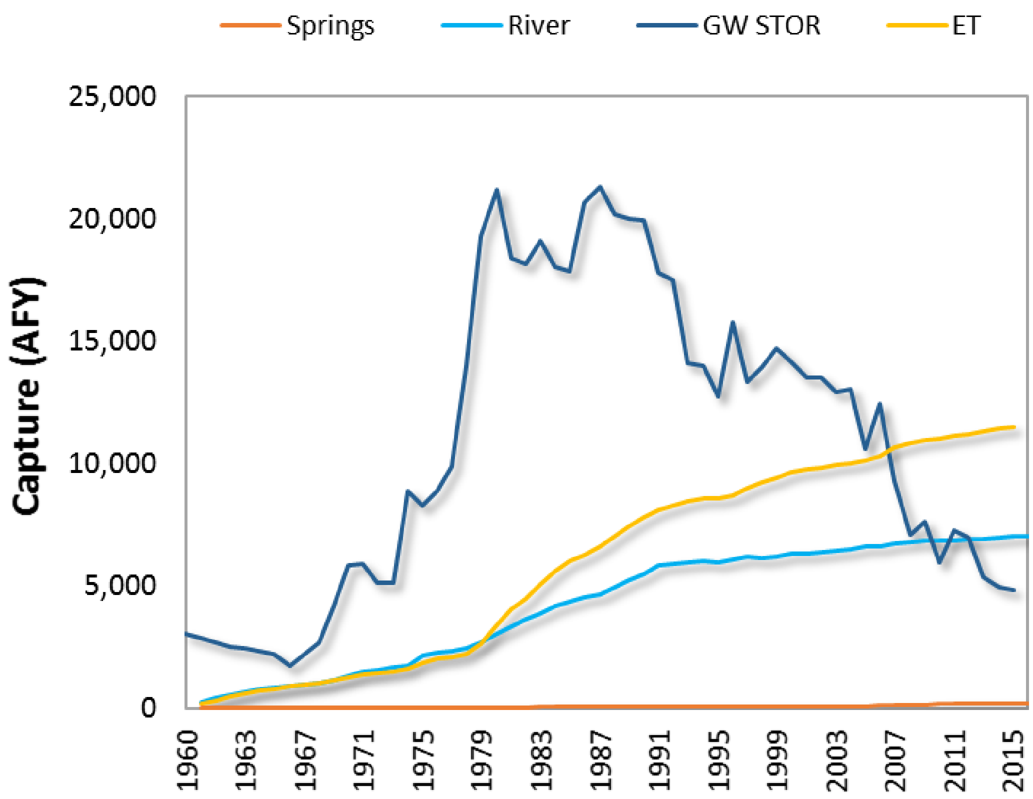
Transient Water Levels





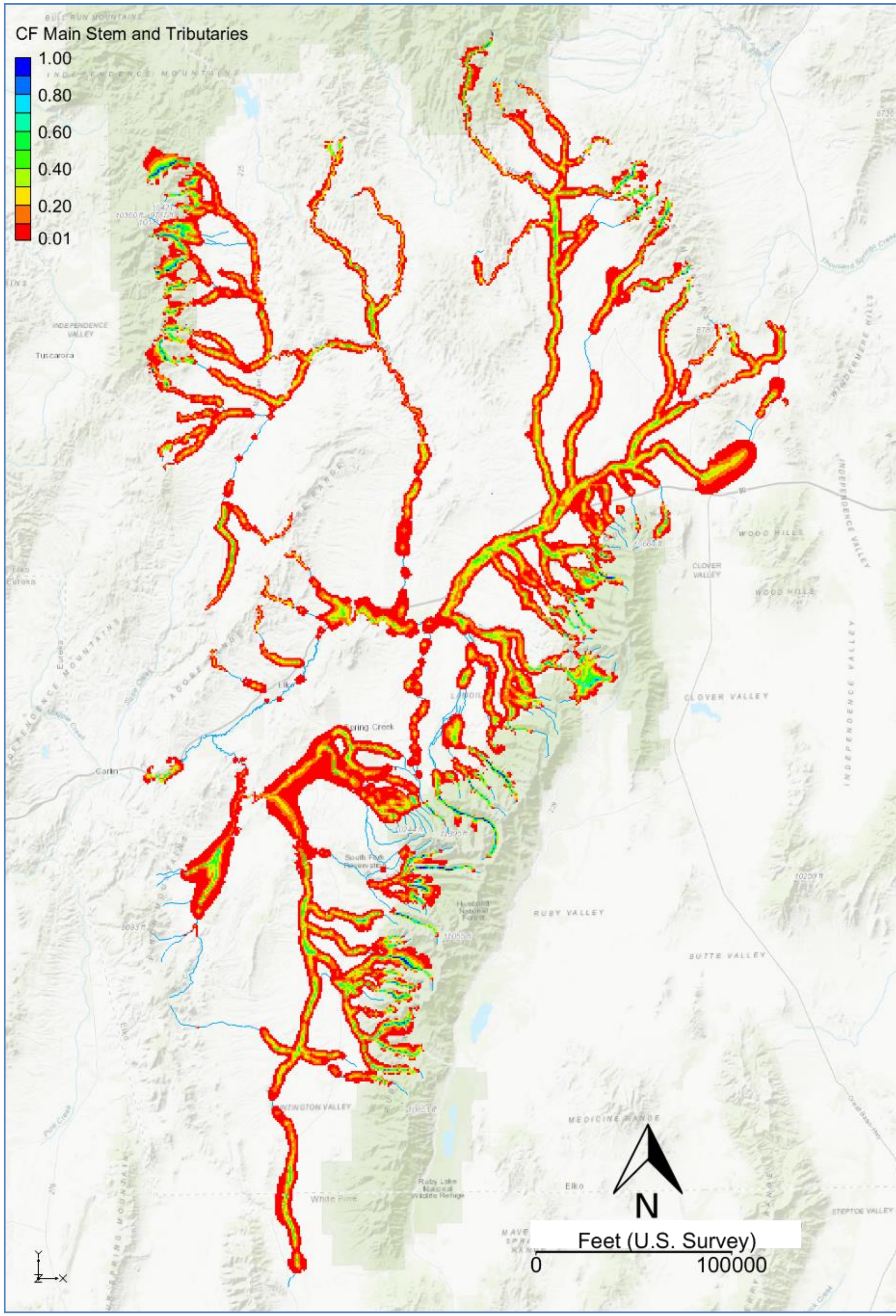
A comparison between steady state (SS) and transient (TR) water levels

Basin-Scale Capture



	Sim. End AFY	CFS
Wells	-23,560	-32.54
Springs	203	0.28
River	7,022	9.70
ET	11,456	15.82
GW Storage	4,828	6.67

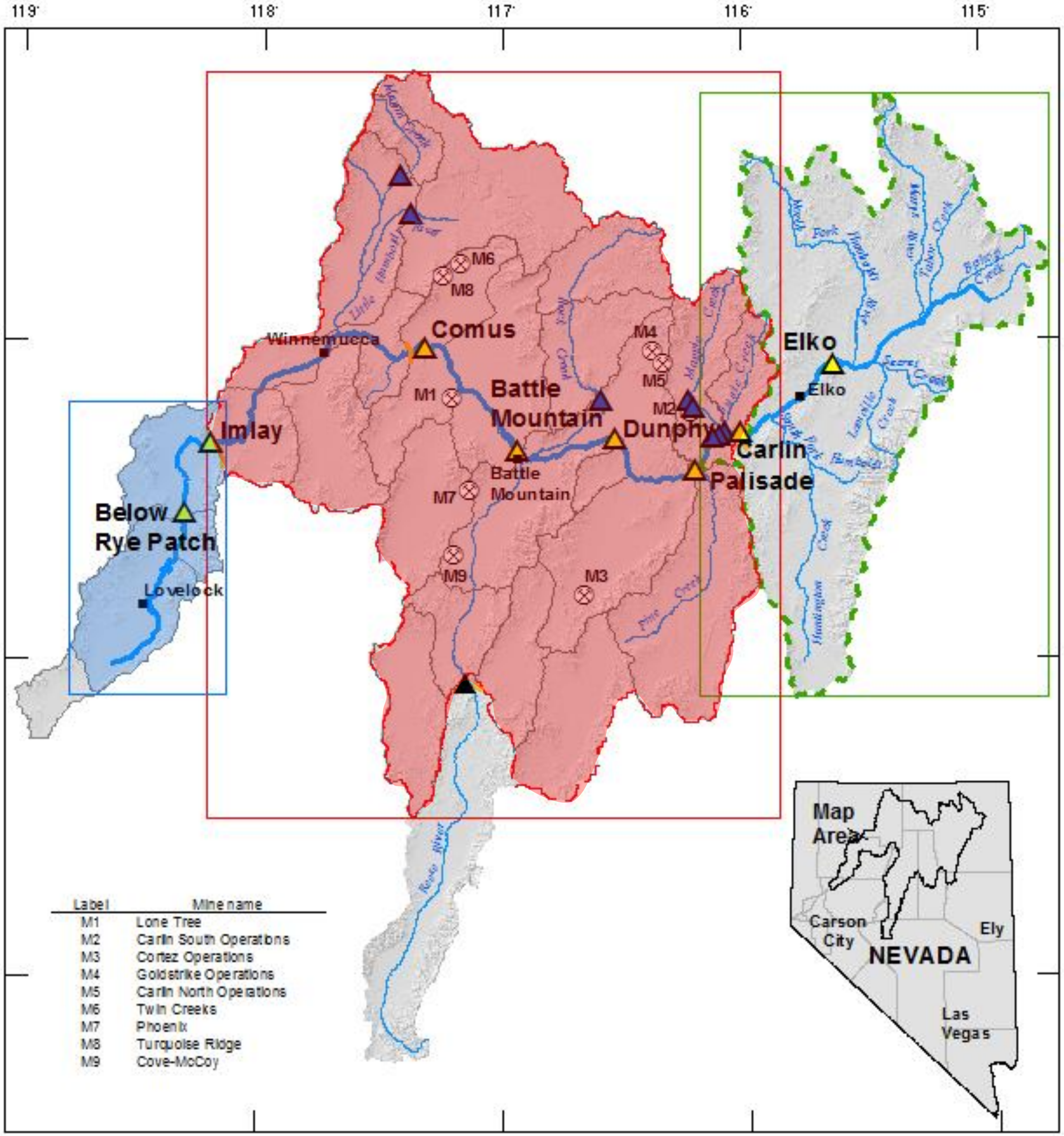
Two-Year Capture Map



Groundwater Models

Middle Basin Model

Kip Allander – USGS



- Upper basin model – DRI
- Middle basin model – USGS
- Lower basin Model – USGS/DRI

Review

- Groundwater flow model being developed to understand capture of Humboldt River by pumping.
- Major tasks:
  - Assemble datasets: Pumping, water-levels, mine-water management, hydrogeology, stream network, etc. ***~DONE***
  - Develop method for understanding limitations of capture maps. (Capture Map Bias) ***DONE***
  - Estimate recharge distribution. ***DONE***
  - Develop and calibrate model. ***ONGOING***
  - Use model to estimate capture and impact of mine-dewatering. ***ONGOING***

Dataset progress through 2018

Completed or mostly completed:

2017

- Humboldt gage datums surveyed
- Depth to basement (basin fill)
- Humboldt River cross-sections
- Groundwater levels – USGS and NDWR data; data from historic reports digitized
- ET discharge areas

2018

- **Pitt-Taylor diversion**
- **N NV Rift**
- **Irrigation pumping**
- **Paradise Valley datasets**
- **Gumboot Lake dataset**
- **Additional water level contour data**

Dataset progress through 2018

- USGS requires all data used in analysis be publicly available.
- Datasets published as they are completed.
- Following datasets released in 2017-2018:

Damar, N.A., 2018, Geospatial Data for the Northern Nevada Rift: U.S. Geological Survey data release, https://doi.org/10.5066/F7SN0869.

Hess, G.W., Plume, R.W., and Arthur, J.M., 2018, River Channel Cross-Sections, Middle Humboldt River, North-Central Nevada: U.S. Geological Survey data release, https://doi.org/10.5066/F73X85WM.

Nadler, C., Allander, K.K., Pohll, G., Morway, E., Naranjo, R., 2017, Evaluation of bias associated with capture maps derived from nonlinear groundwater flow models: Groundwater, vol. 56, no. 3, p 458-469. https://doi.org/10.1111/gwat.12597.

Ponce, D.A., and Damar, N.A., 2017, Depth to pre-Cenozoic bedrock in northern Nevada: U.S. Geological Survey data release, https://doi.org/10.5066/F75B01DD . (Bulletin 2218 2-km pre-cenozoic basement)

Smith, J.L., Warmath, Eric, and Medina, R.L., 2017, Groundwater discharge areas for the 14 hydrographic areas in the middle Humboldt River Basin, north-central Nevada: U.S. Geological Survey data release, https://doi.org/10.5066/F72805TT . (WRIR 2000-4168: Groundwater discharge areas.)

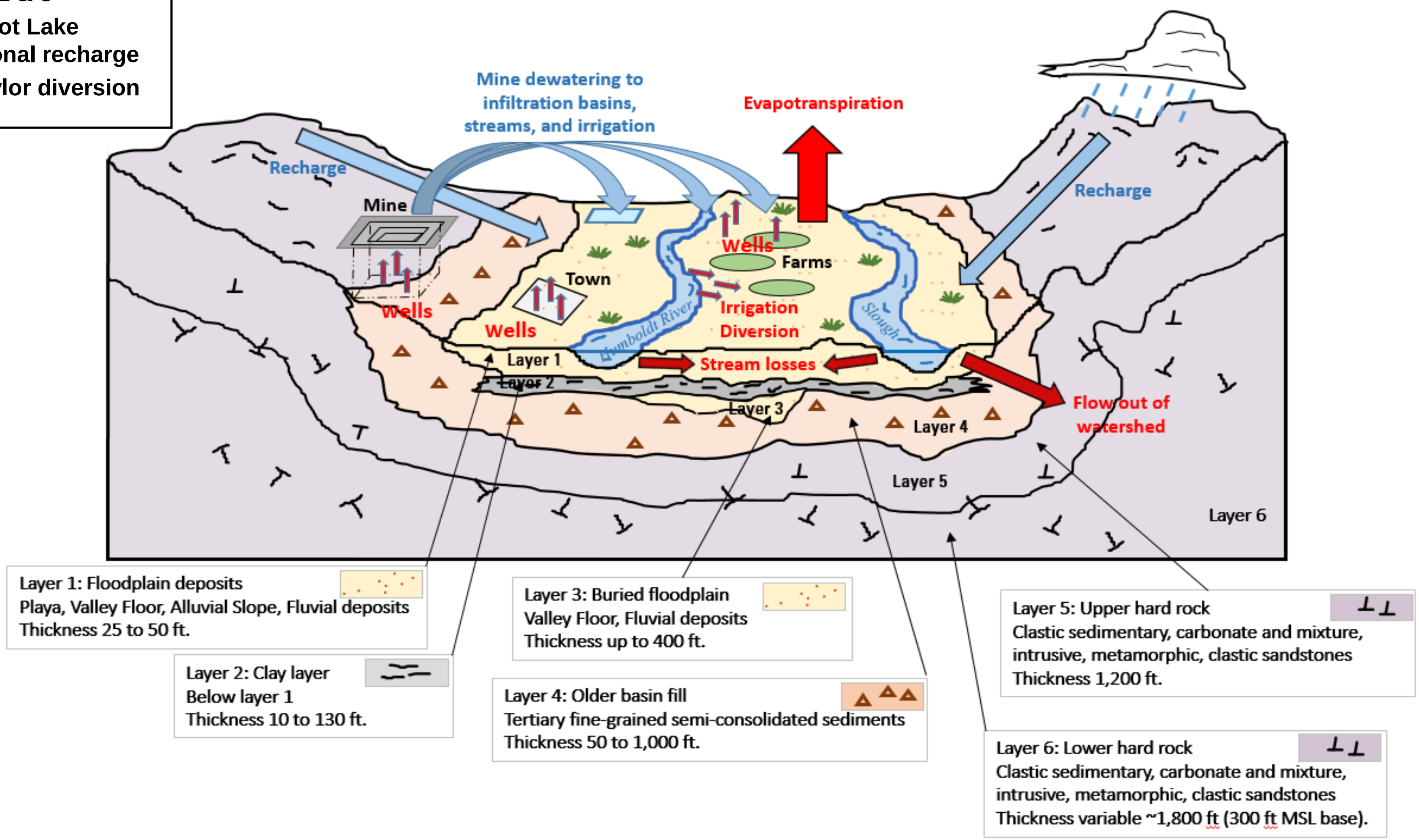
Smith, J.L., Welborn, T.L., and Medina, R.L., 2017, Evapotranspiration units and potential areas of groundwater discharge delineated July 20–24, 2009 in the upper Humboldt River Basin, northeastern Nevada: U.S. Geological Survey data release, https://doi.org/10.5066/F7668BN7 . (SIR 2013-5077).

Welborn, T.L., and Medina, R.L., 2017, Depth-to-water area polygons, isopleths showing mean annual runoff, 1912-1963, and water-level altitude contours for the Humboldt River Basin, Nevada: U.S. Geological Survey data release, https://dx.doi.org/10.5066/F7XW4GXC . (Bulletin 32 datasets: water levels, water level altitude, isopleths of mean annual runoff.)

Model Development and Calibration – Conceptual Model

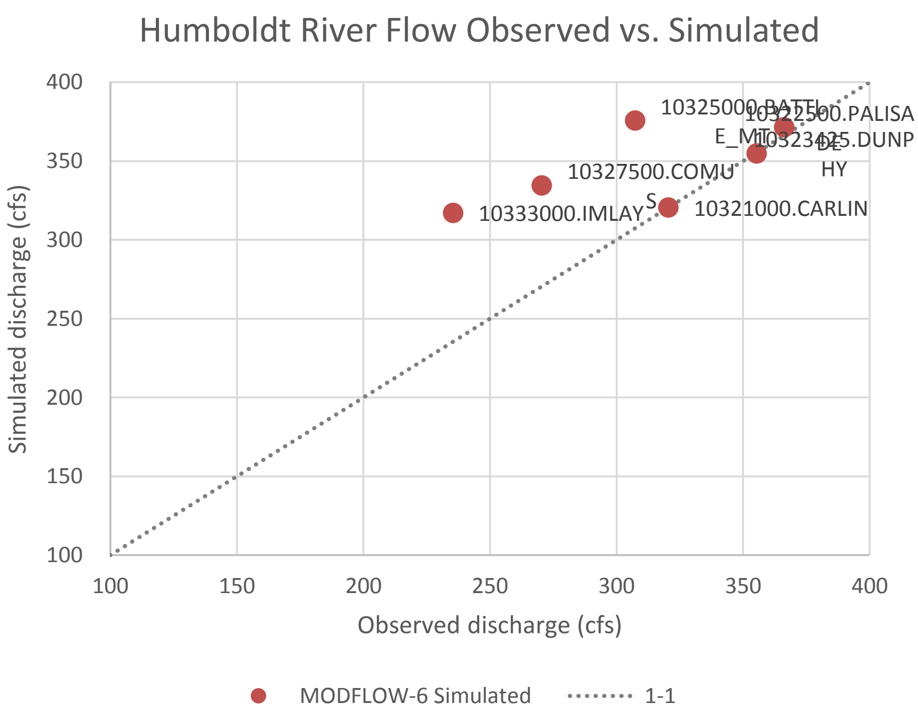
2018 Model additions:

- **Defined irrigated areas to better account for ETg**
- **Layers 2 & 3**
- **Gumboot Lake occasional recharge**
- **Pitt-Taylor diversion**

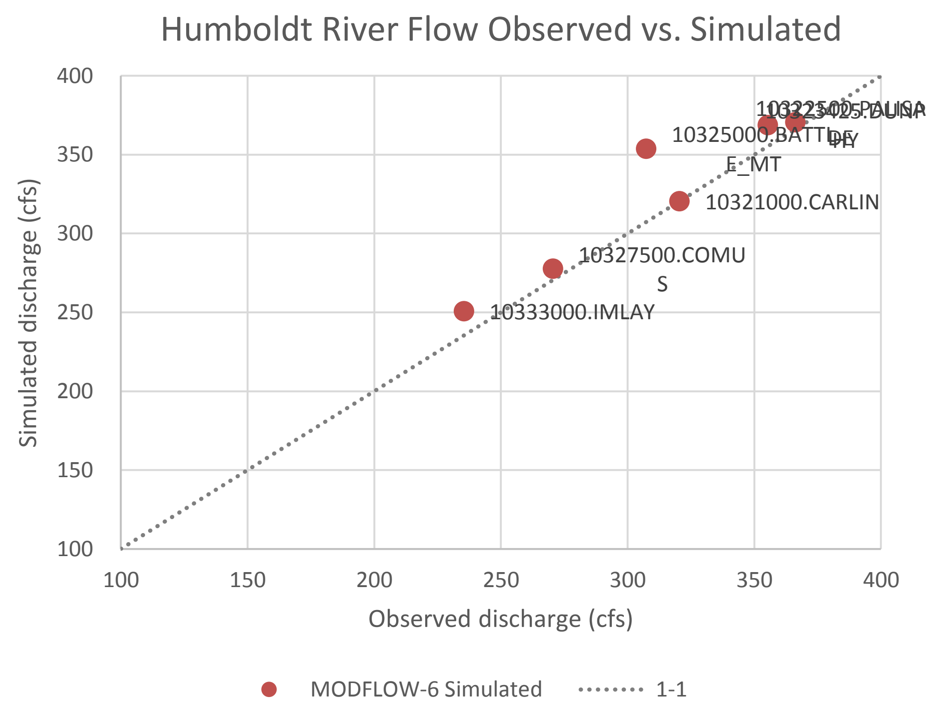


Model Development and Calibration – Steady-State Flow Calibration

Prior calibration



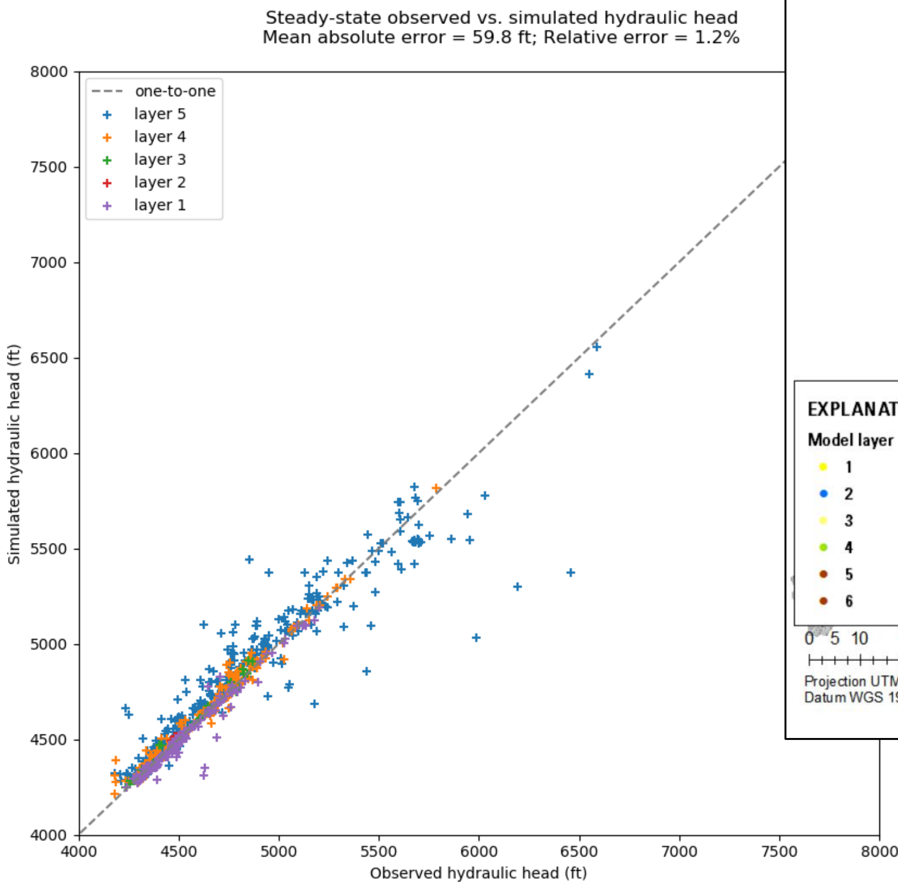
Current

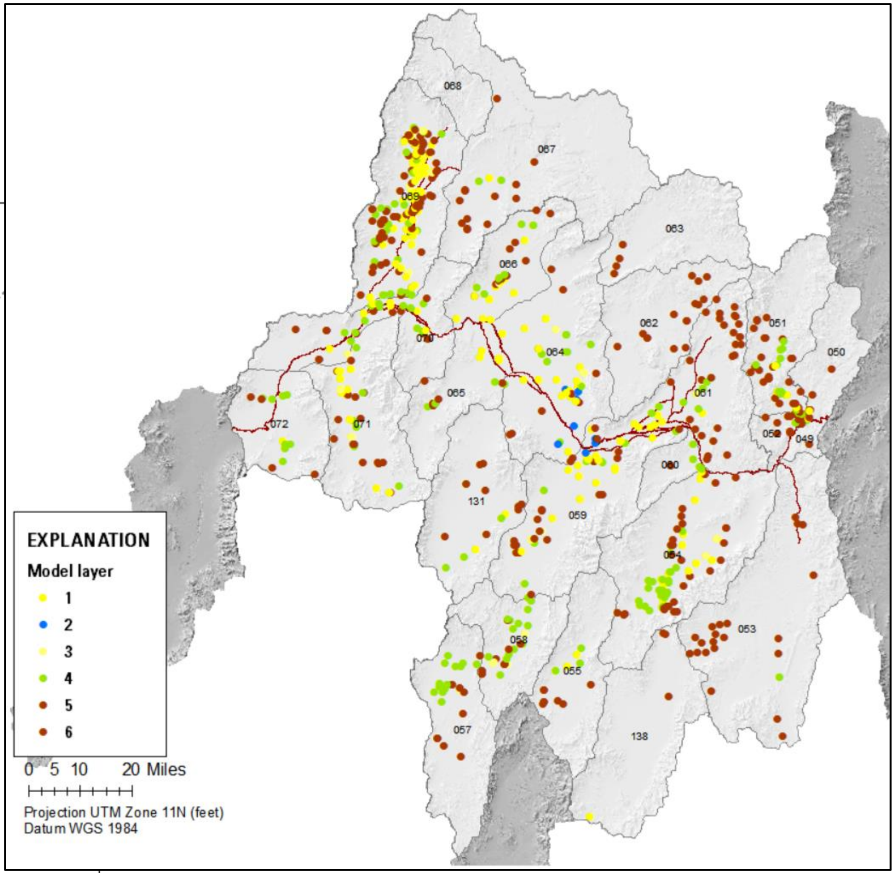


Steady State Water Level Calibration

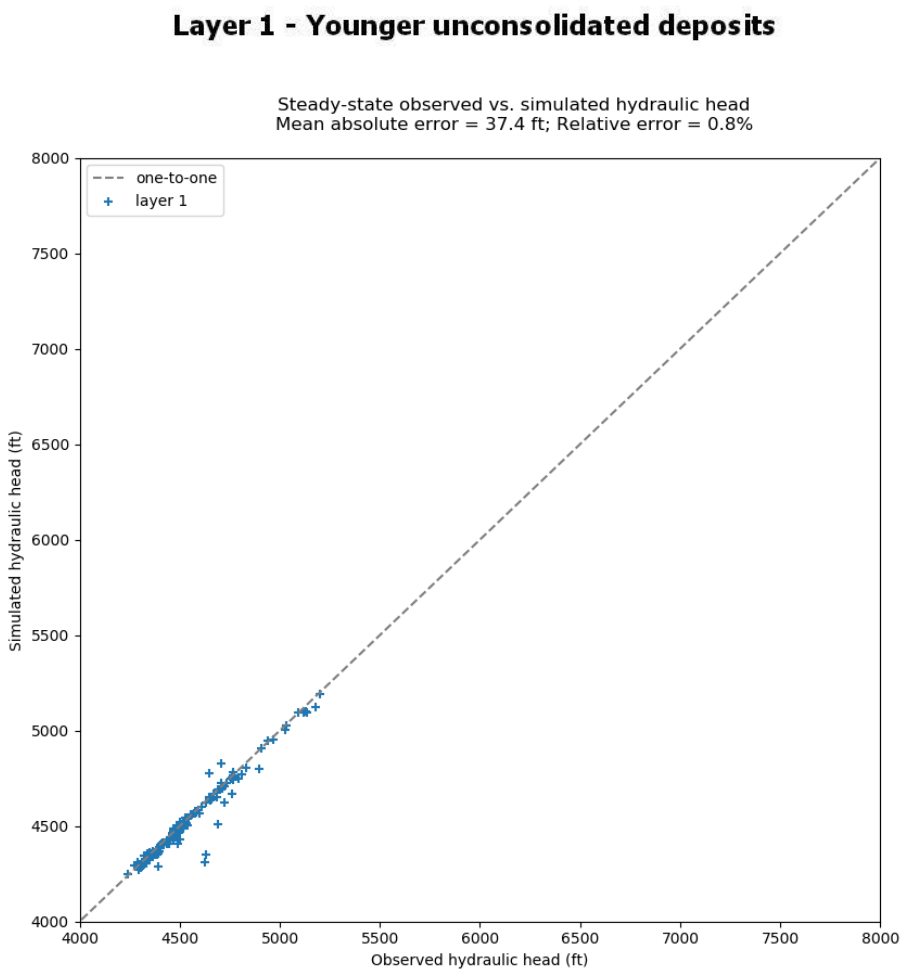
One to one plots of observed vs. simulated hydraulic head for the entire model

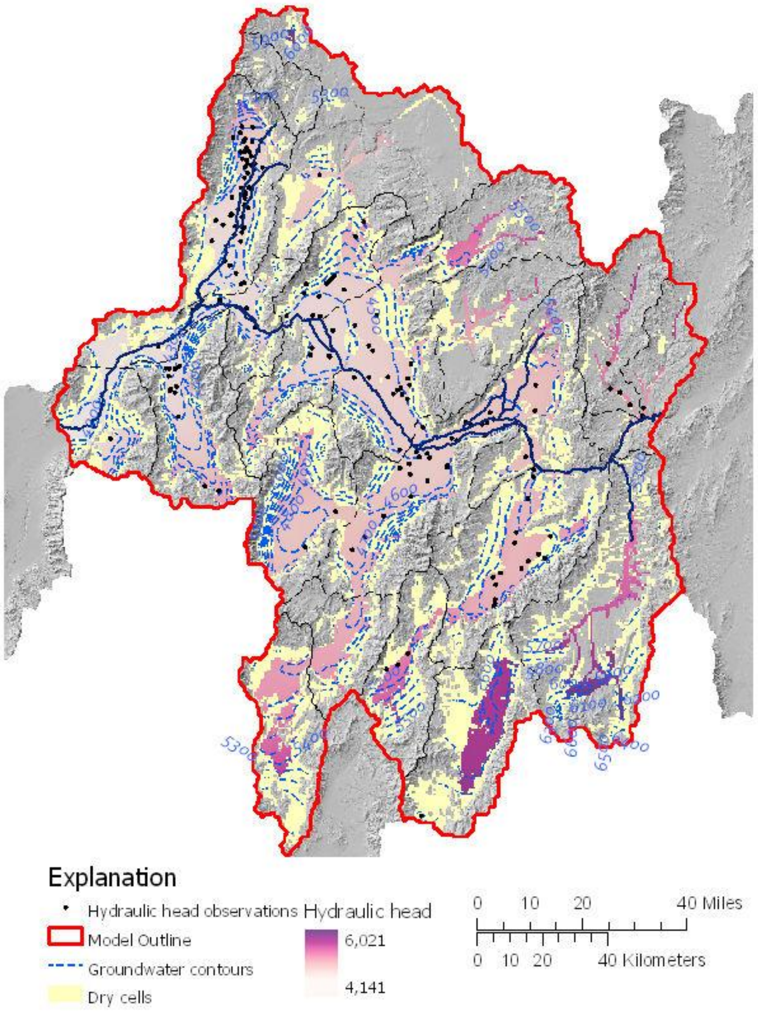
Current



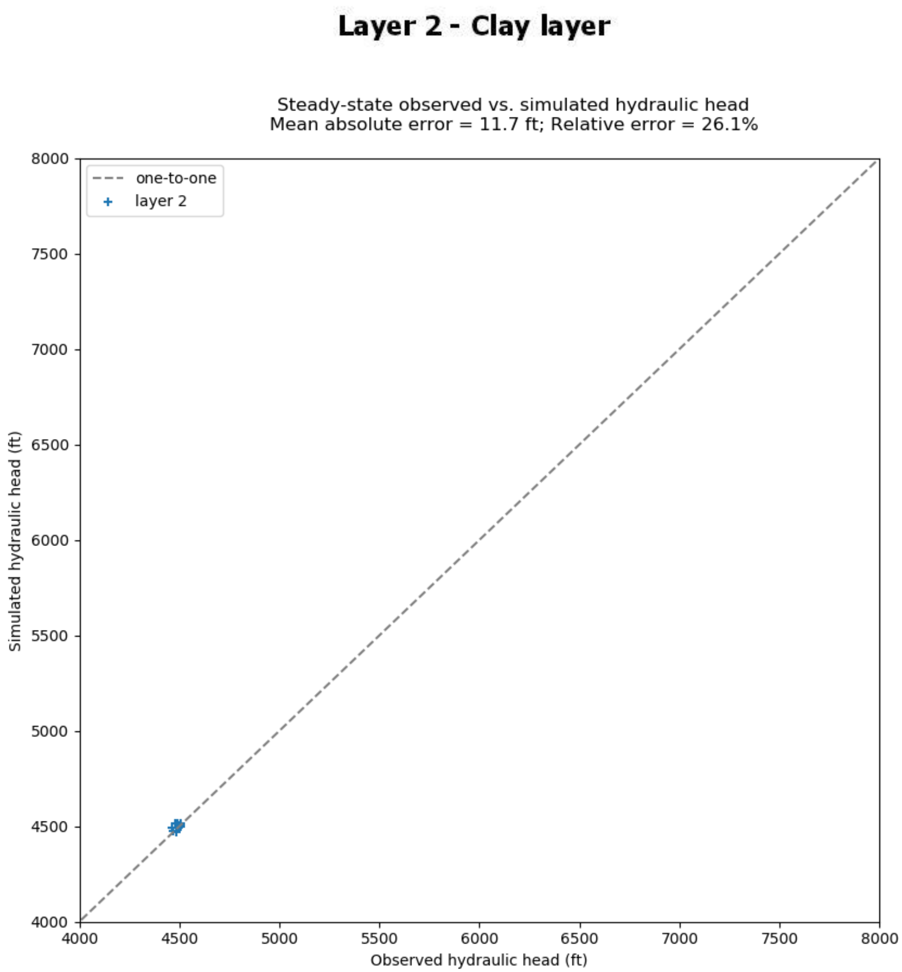


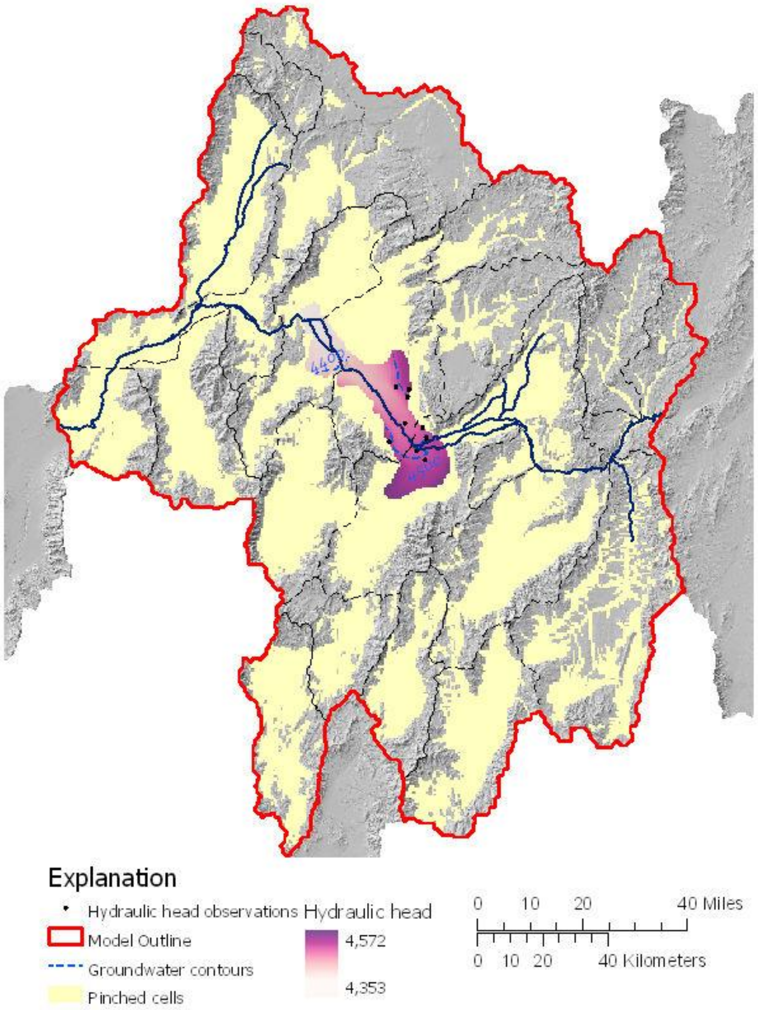
Steady State Water Level Calibration



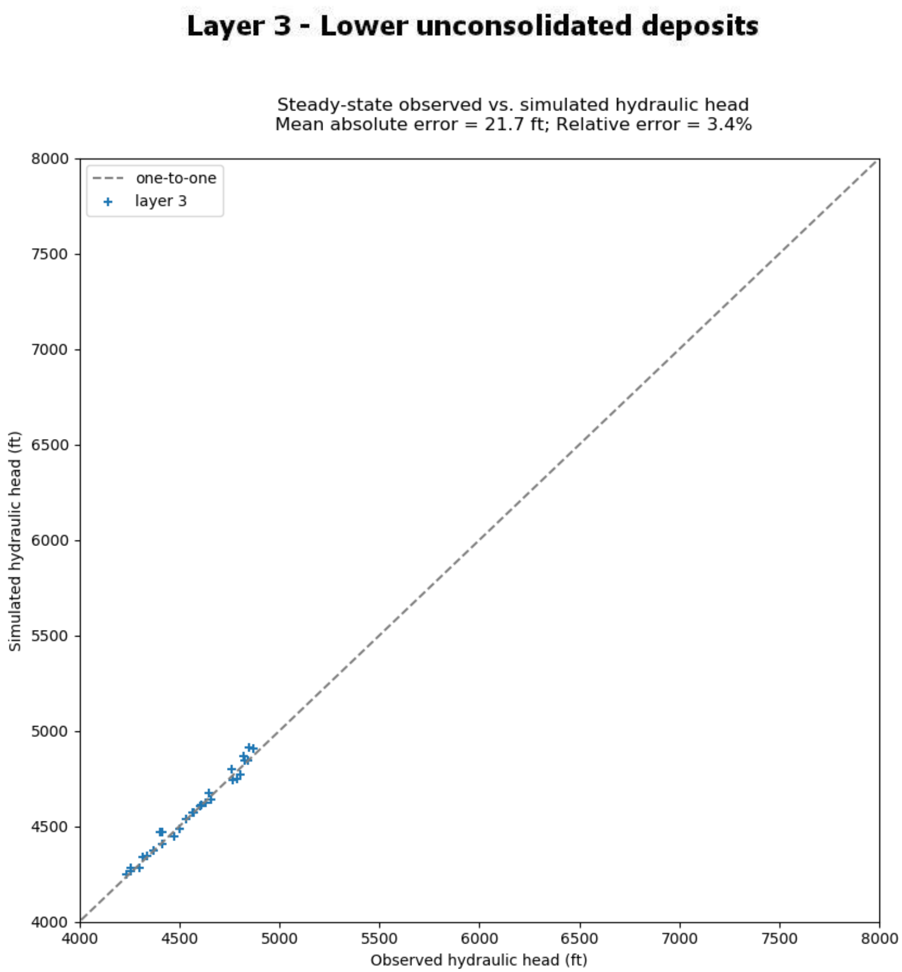


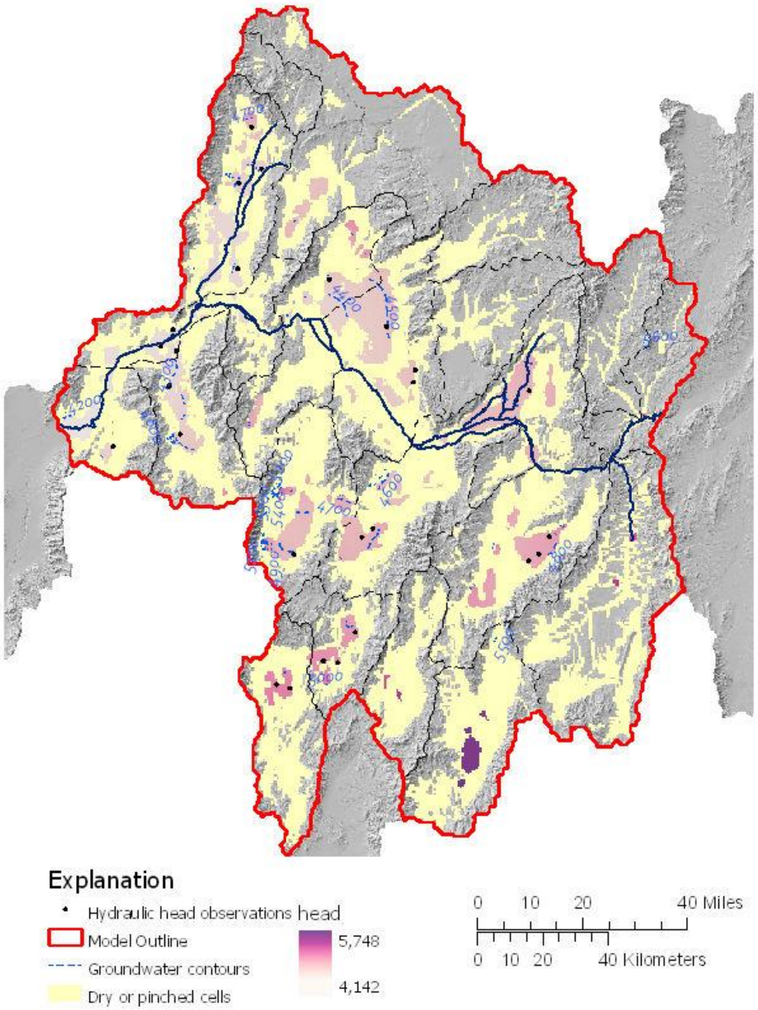
Steady State Water Level Calibration



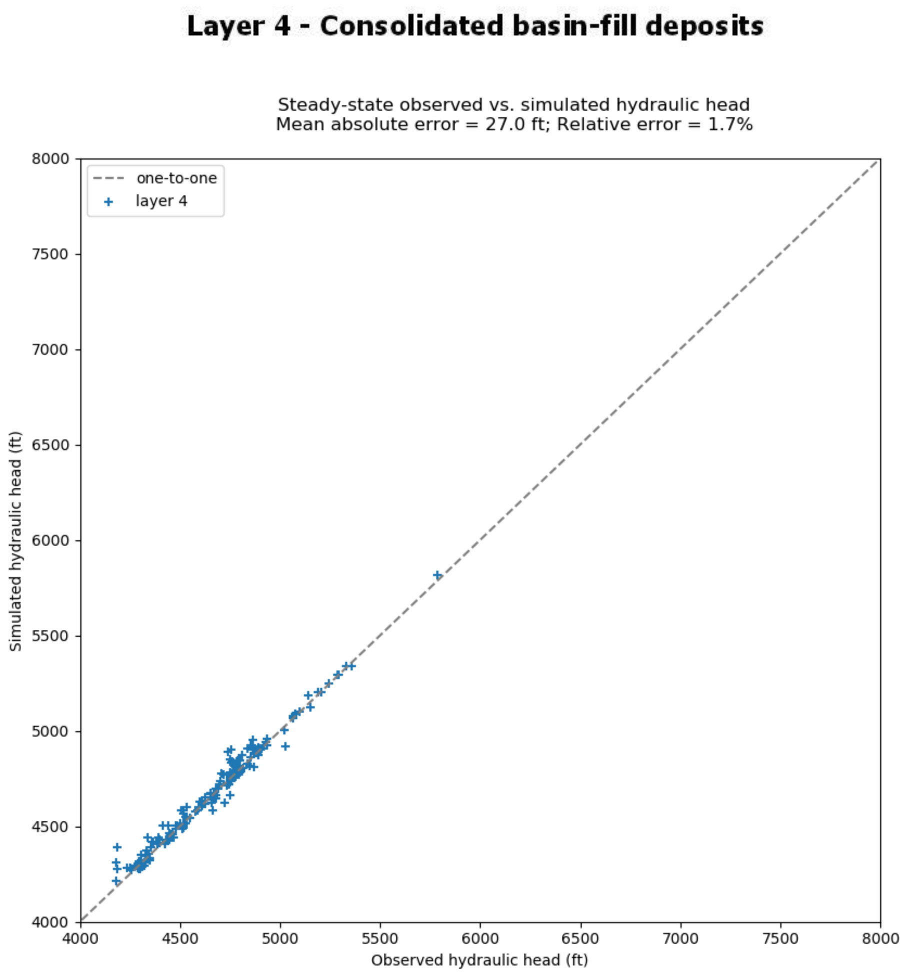


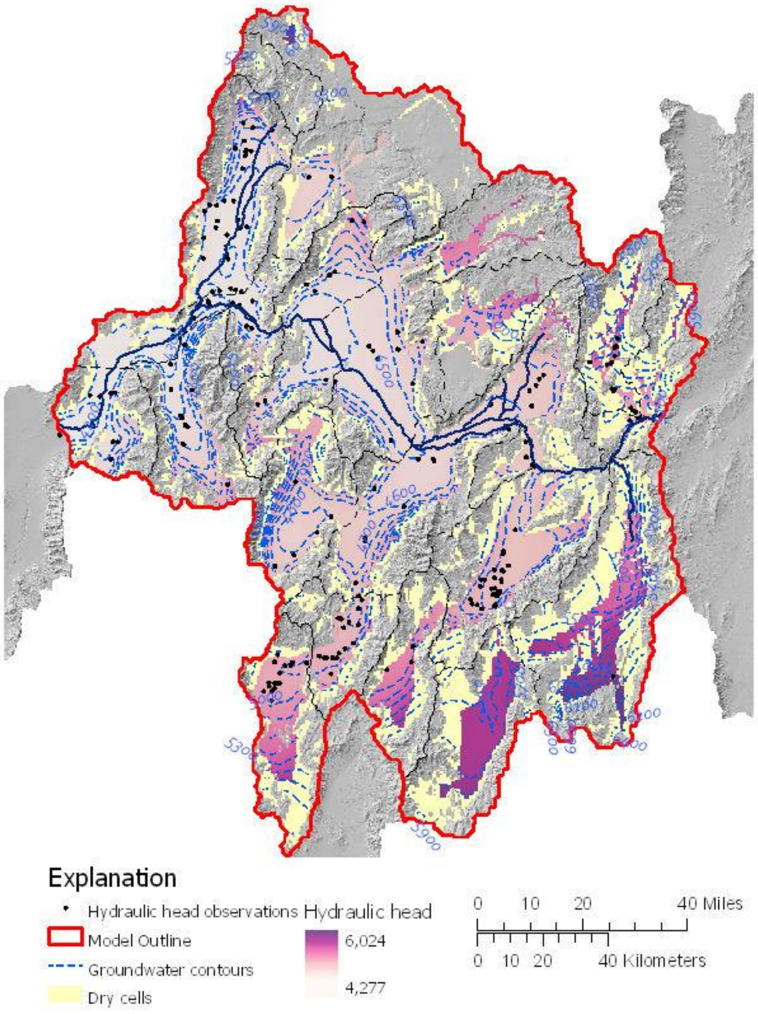
Steady State Water Level Calibration



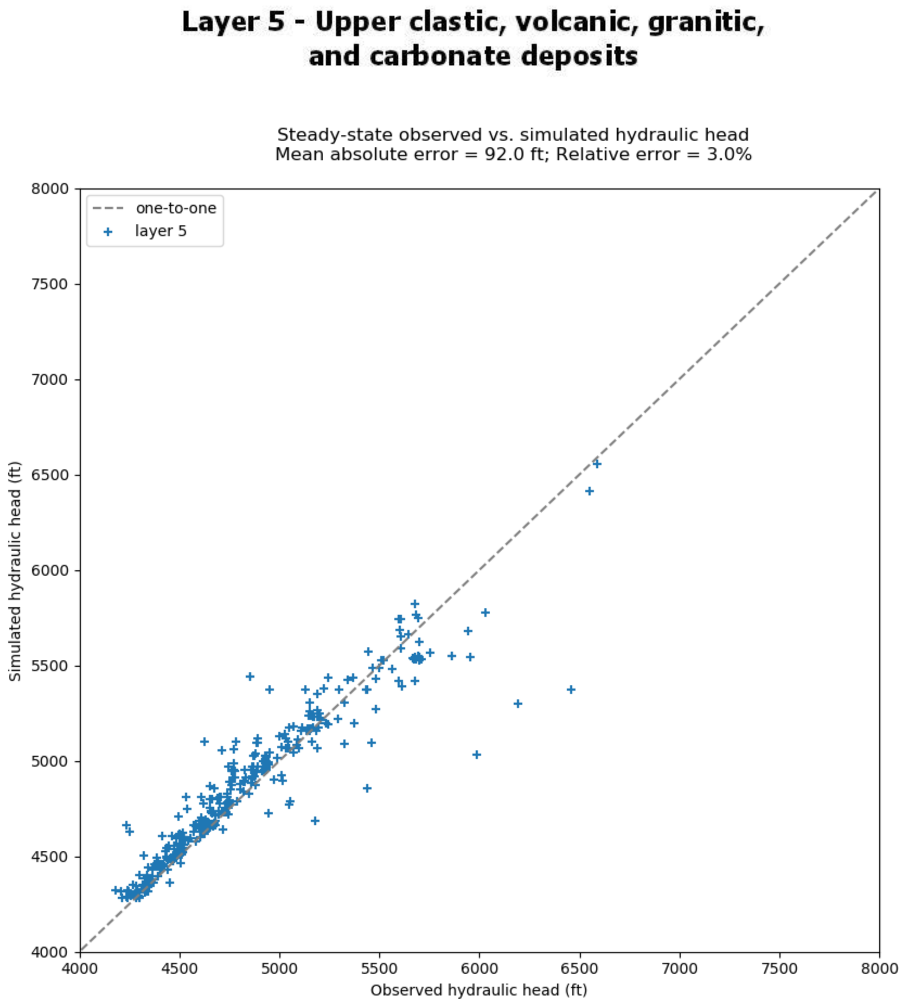


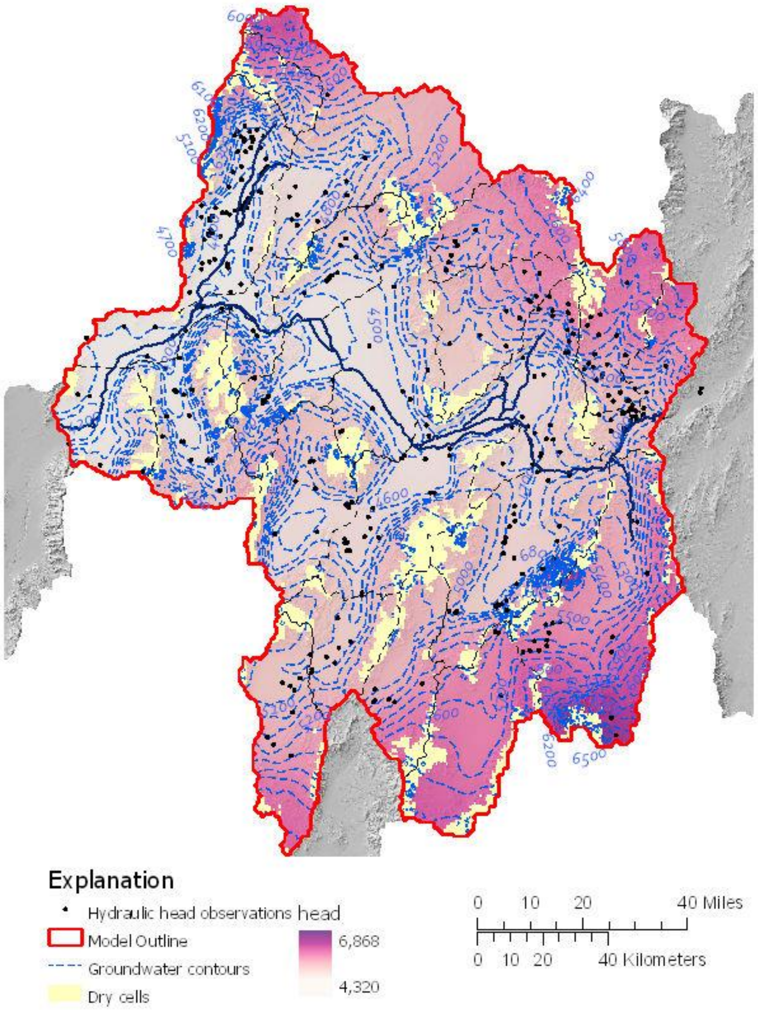
Steady State Water Level Calibration



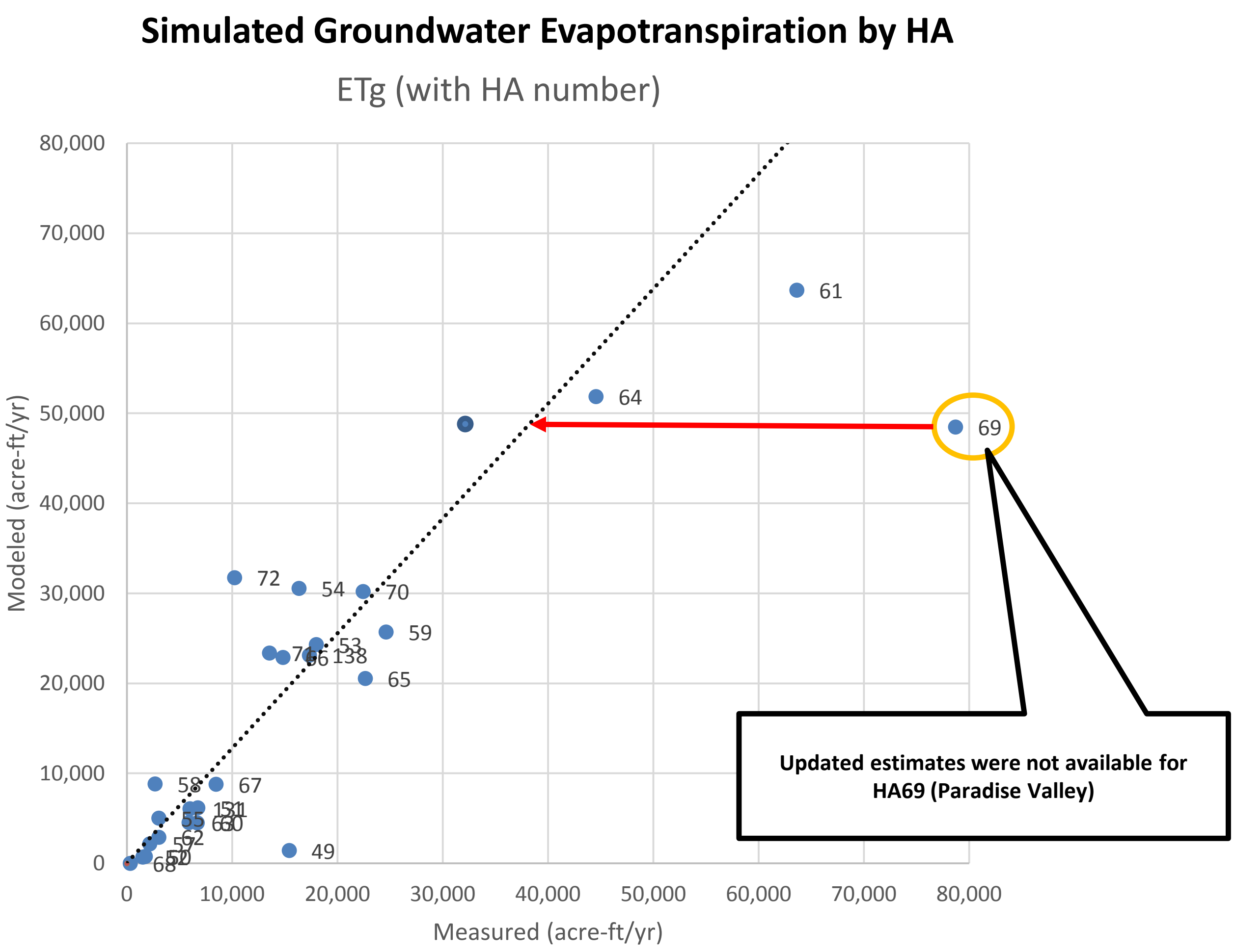


Steady State Water Level Calibration



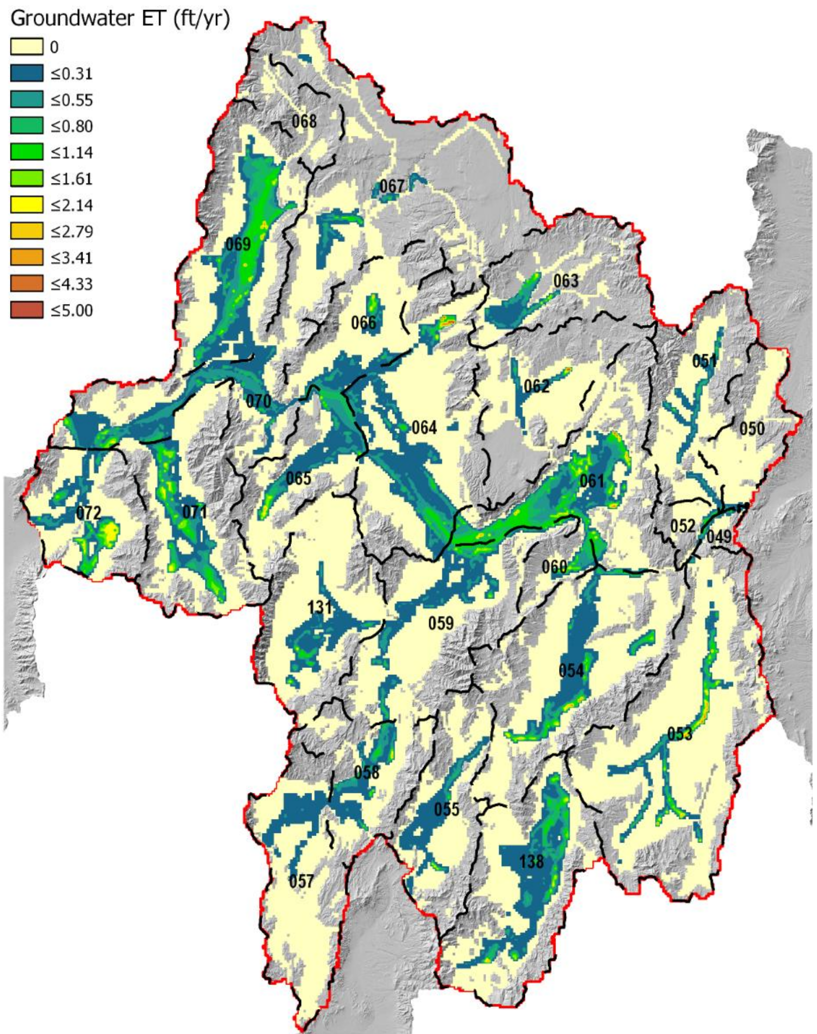


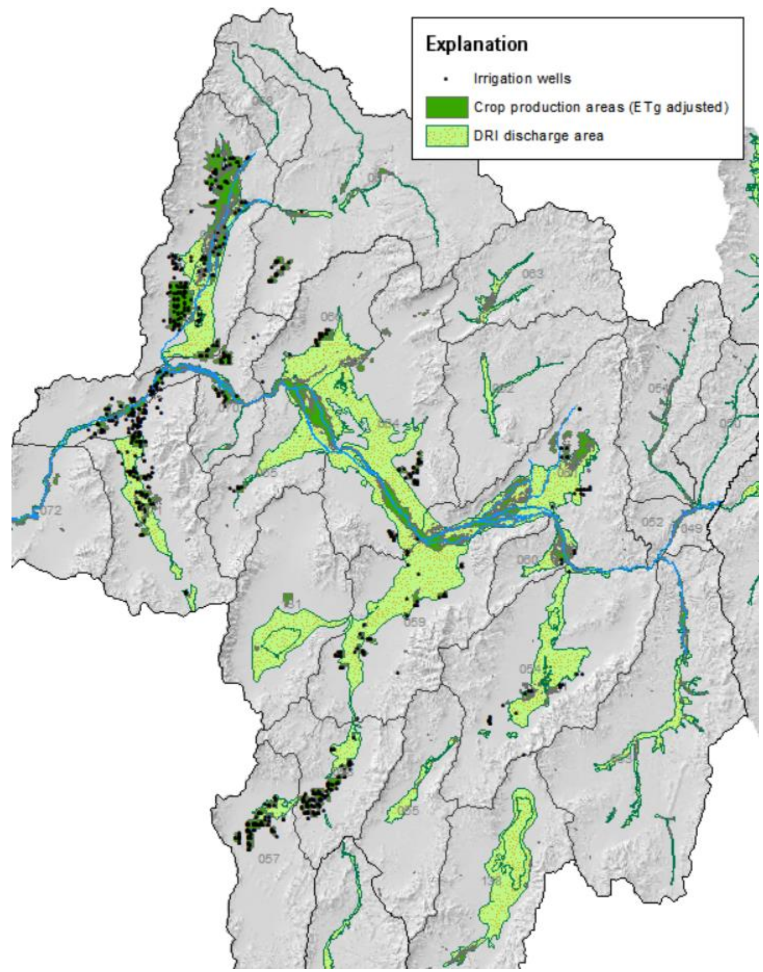
Evapotranspiration Calibration



HA Number	HA Name
49	Elko Segment
50	Susie Creek Area
51	Maggie Creek Area
52	Marys Creek Area
53	Pine Valley
54	Crescent Valley
55	Carico Lake Valley
57	Antelope Valley
58	Middle Reese River Valley
59	Lower Reese River Valley
60	Whirlwind Valley
61	Boulder Flat
62	Rock Creek Valley
63	Willow Creek Valley
64	Clovers Area
65	Pumpernickel Valley
66	Kelley Creek Area
67	Little Humboldt Valley
68	Hardscrabble Area
69	Paradise Valley
70	Winnemucca Segment
71	Grass Valley
72	Imlay Area
131	Buffalo Valley
138	Grass Valley

Evapotranspiration Distribution

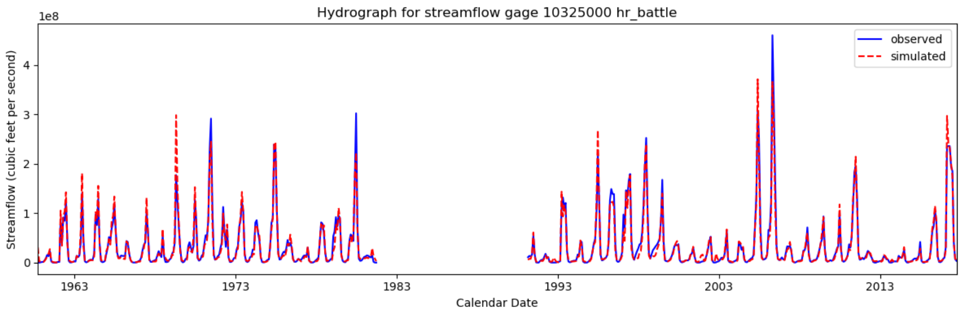




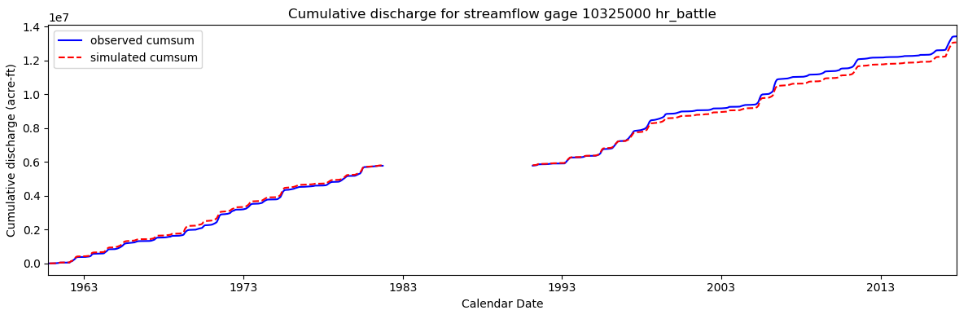
Model Development and Calibration – Transient Flow Calibration

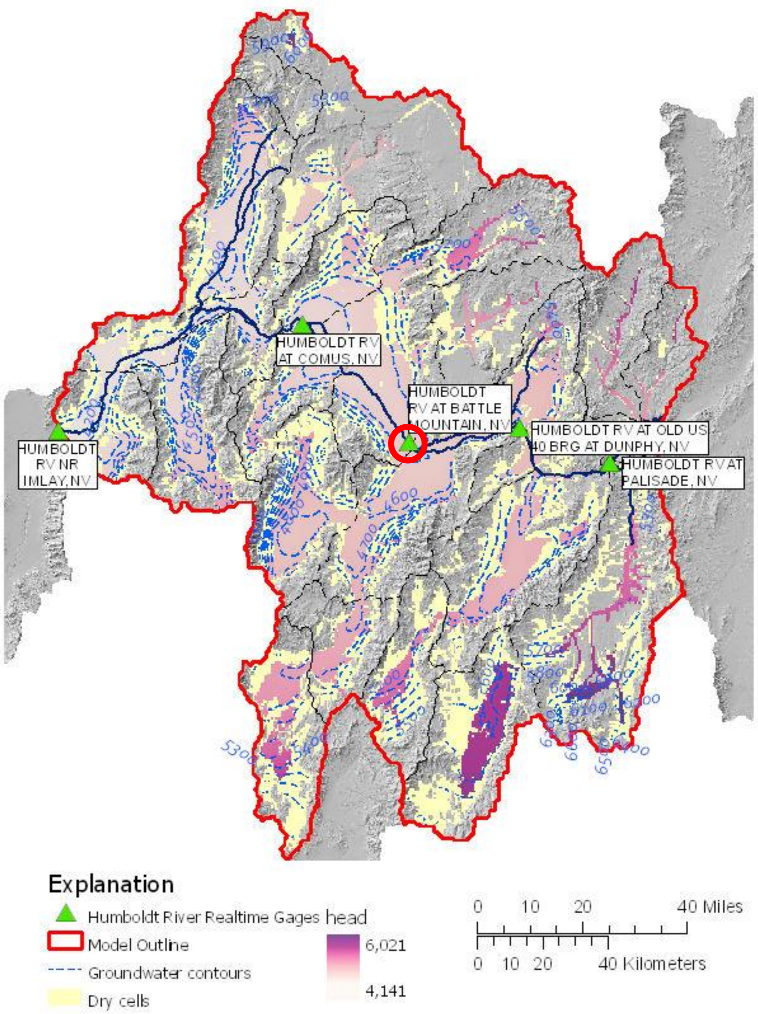
Humboldt River at Battle Mt.

Simulated vs. observed streamflow (cubic feet per second)



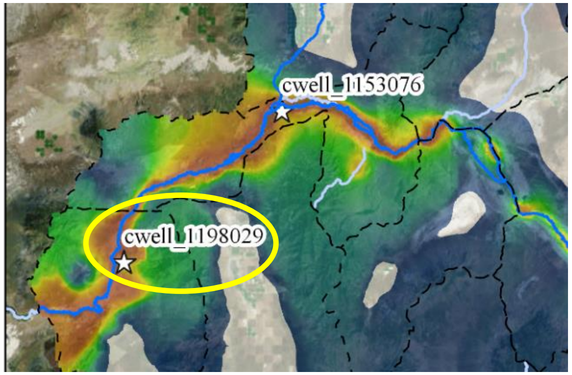
Simulated vs. observed cumulative discharge (acre feet)



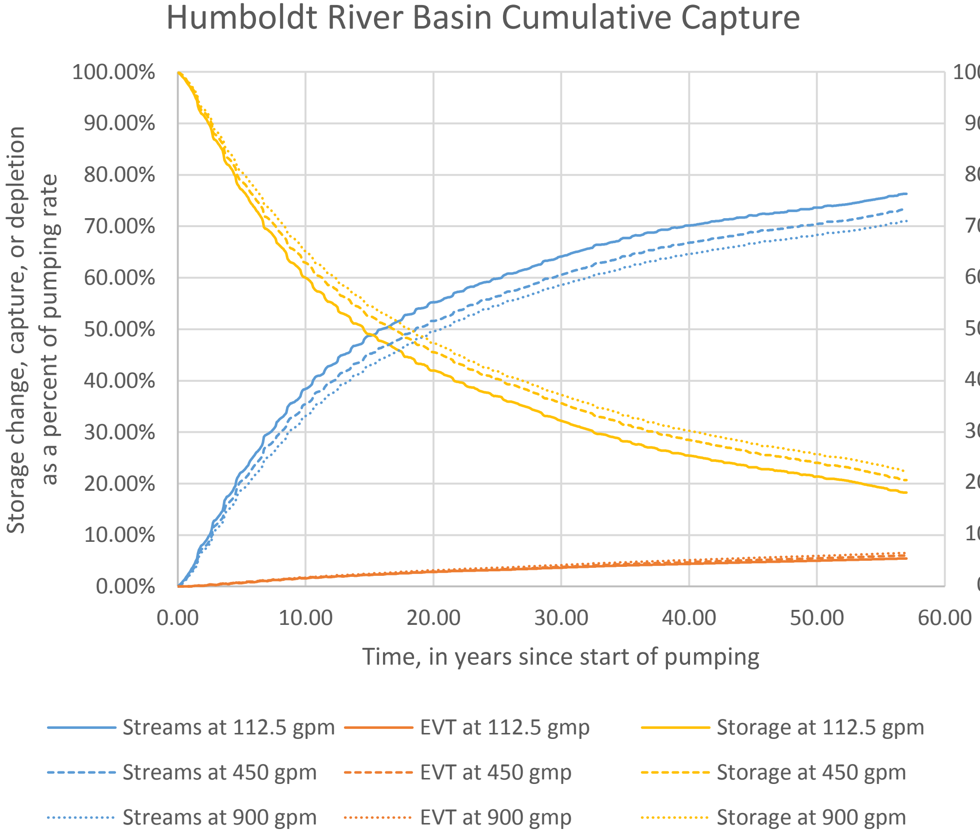


Transient streamflow capture (hypothetical well #1198029)

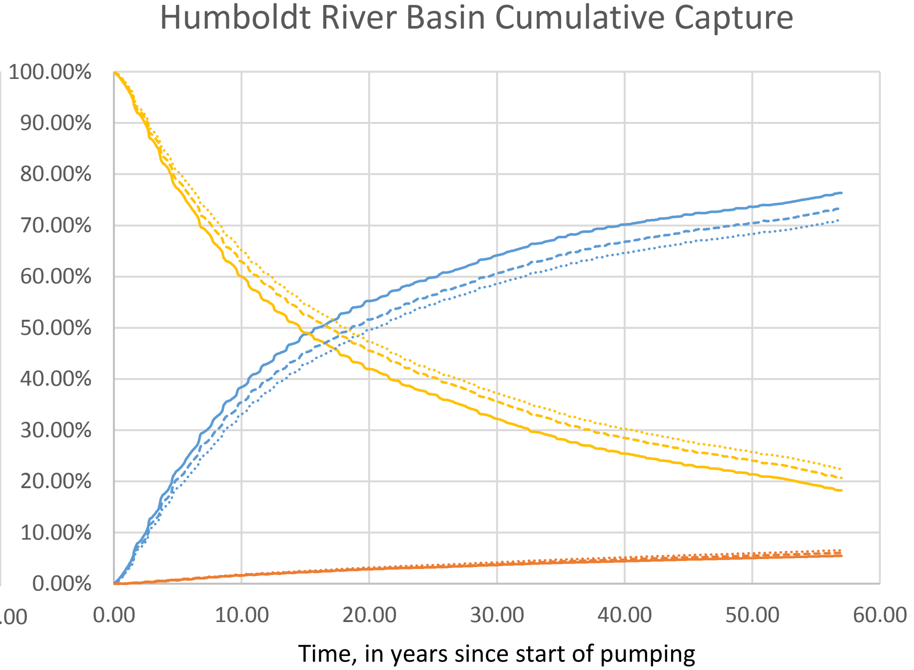
- 5,800 ft from Humboldt River
- Near Imlay gage



Layer 1



Layer 4



Humboldt Capture Query Tool

- In development
- Extracts capture output from model results based on location, years of pumping, and well depth.
- Example capture report

Humboldt Depletion Project

Enter Parameters

Latitude (NAD83 DD)

40.80557

Longitude (NAD83 DD)

-118.08499

Depth Below Surface (1-10,000 feet)

65

Years of Pumping (1-100 years)

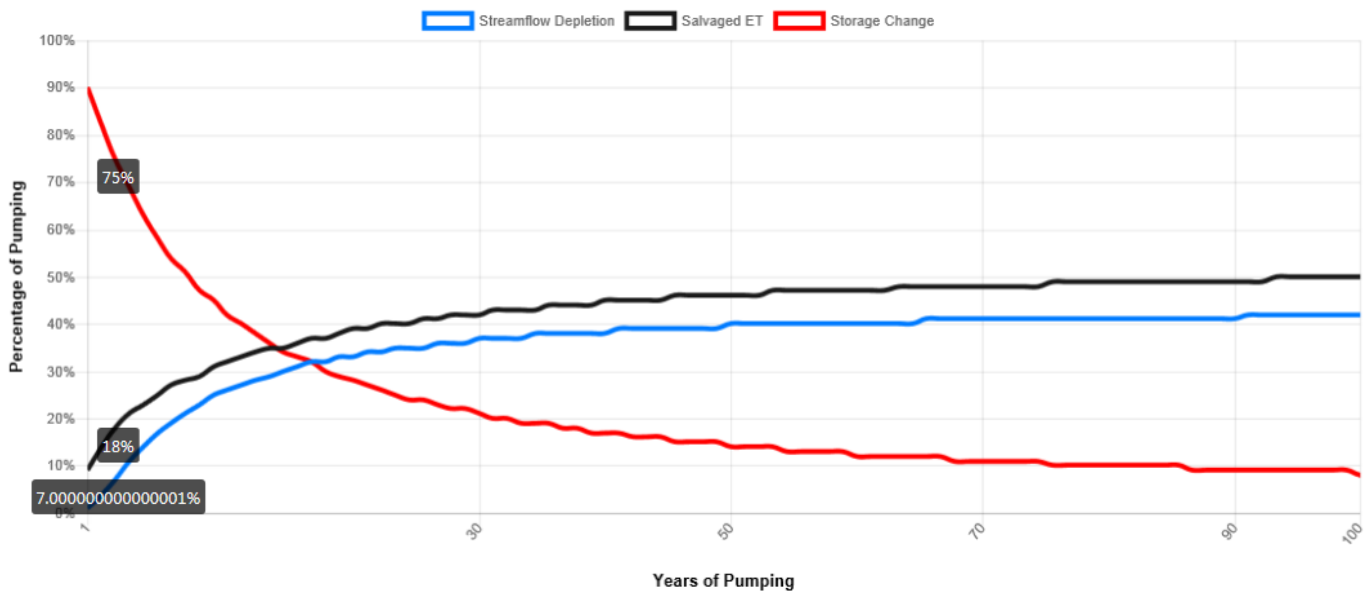
22

Plot

Results

Export

After 22 years of pumpng at Latitude 40.80557, Longitude -118.08499 and a a depth of 65 ft below landsurface, groundwater is dervived from the following sources: 34.4% streamflow depletion, 39.6% salvage ET, and 26.1% storage change.



Output

Years of Pumping	Streamflow Depletion	Salvaged ET	Storage Change
1	1.0%	9.2%	89.8%
5	14.0%	22.9%	63.1%
10	24.7%	30.6%	44.6%
22	**34.4%**	**39.6%**	**26.1%**
25	35.5%	40.9%	23.6%
50	39.8%	46.6%	13.7%
100	42.0%	50.2%	7.8%

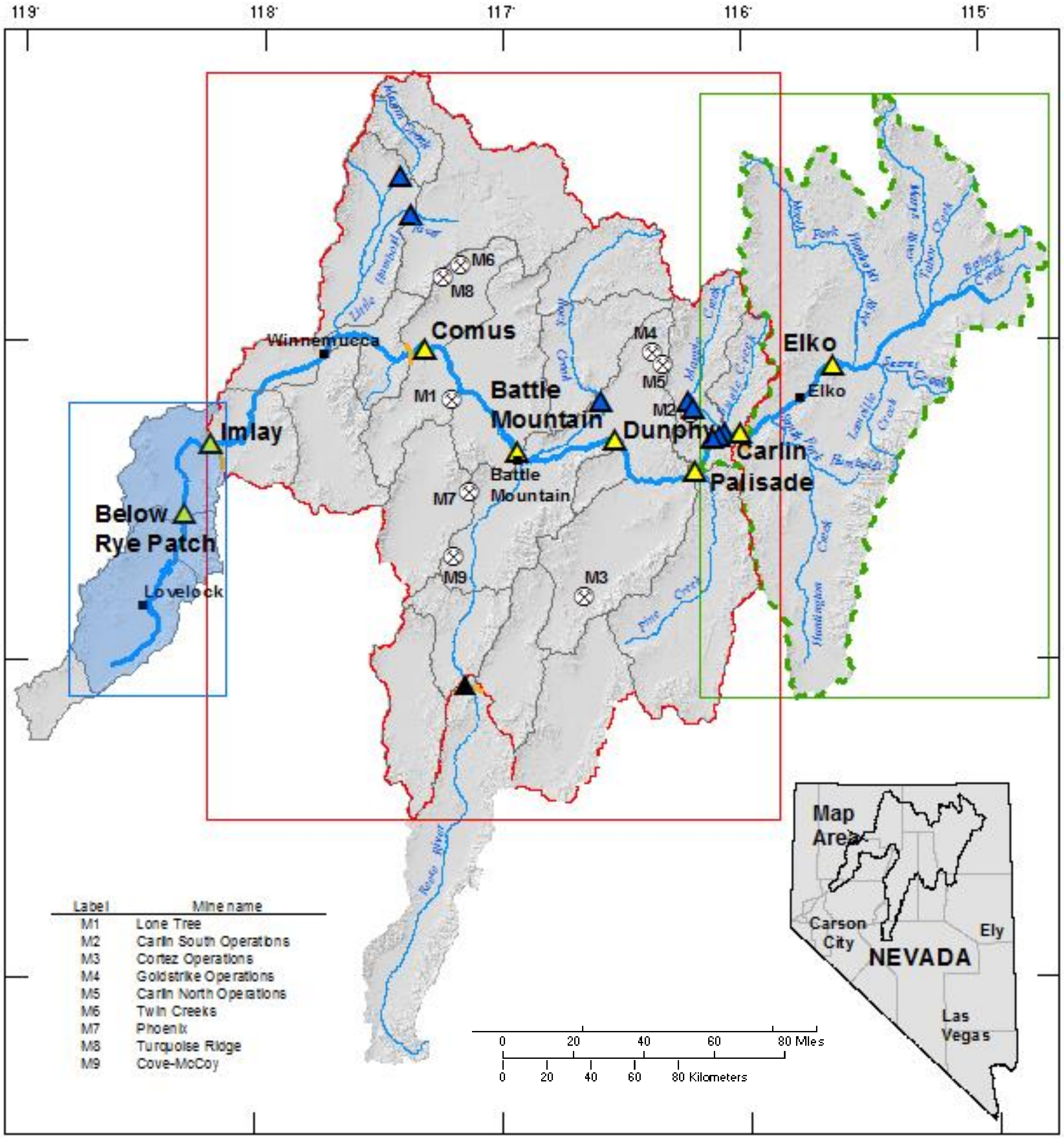
Model Development and Calibration – Plans for 2019

- Continue calibrating Steady State and Transient models.
- Refine calibrations by Hydrographic Area.
- Achieve satisfactory calibration by Spring 2019.
- Produce preliminary capture analysis for developing conjunctive use regulation by Spring 2019.
- Complete capture analysis by end of 2019 or early in 2020

Groundwater Models

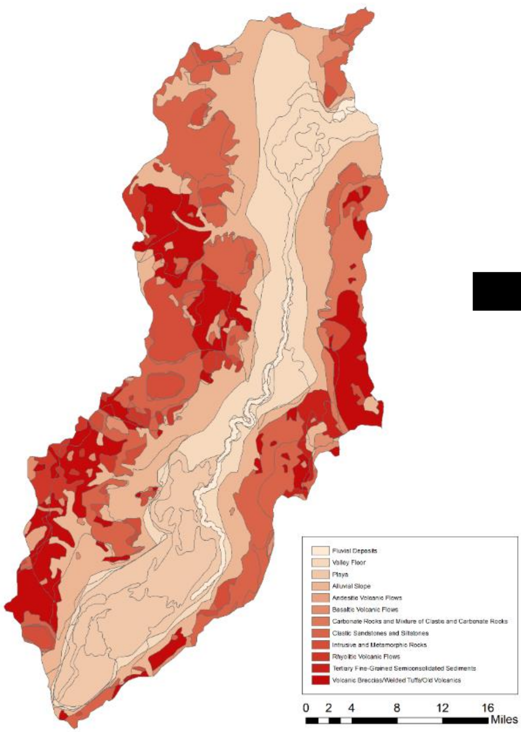
Lower Basin Model

Susan Rybarski - DRI

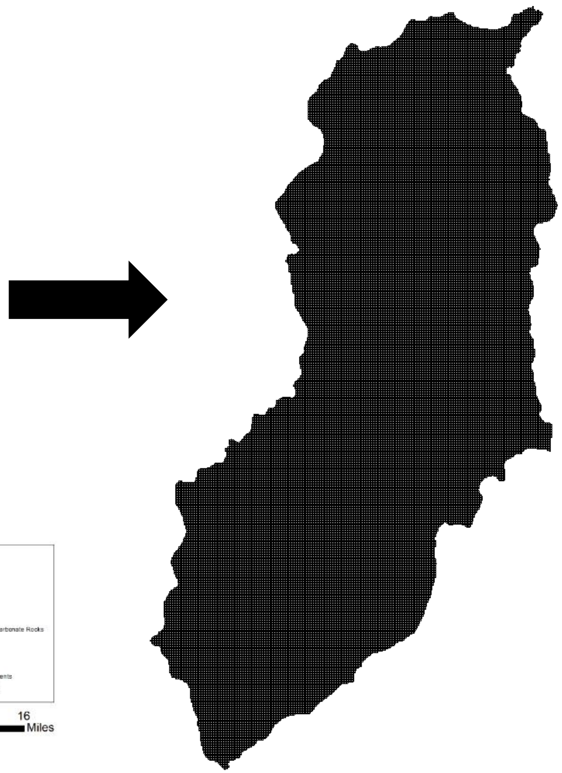


- Upper basin model – DRI
- Middle basin model – USGS
- Lower basin Model – USGS/DRI

Model Domain



Modified from Maurer and others (2004)



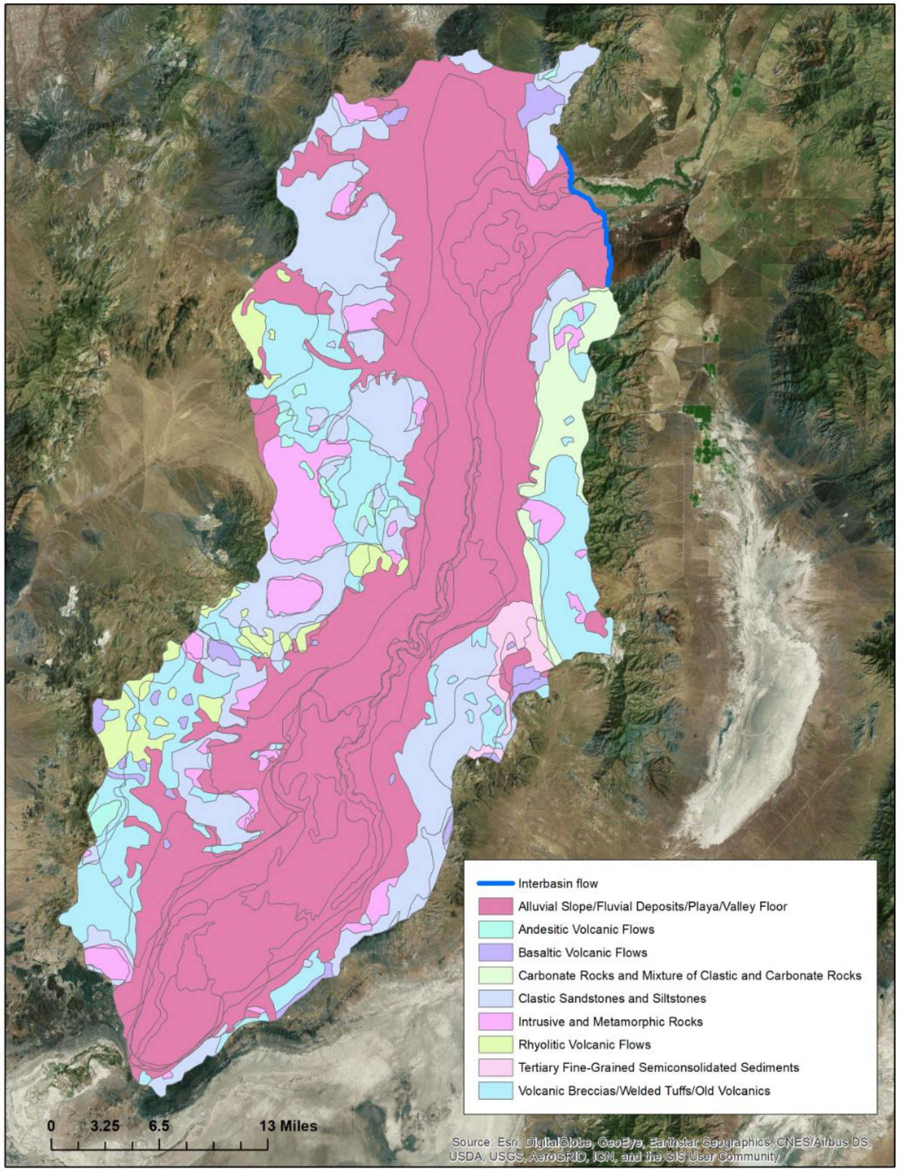
- 500 ft grid cell resolution
- Includes mountain block/bedrock
- 3 layers, generally representing clay (layer 1), alluvium/valley fill (layer 2), bedrock (layer 3)
- Thickness of clay layer set to 50 feet
- Depth to basement defined by Justin Mayers (USGS), and used to define elevation of top of layer 3, with a minimum depth of 20 feet bls.

Lakes and River

- Humboldt River simulated using River package (RIV), in two segments to prevent overlap with Rye Patch Reservoir.
- Rye Patch Reservoir simulated as a constant head boundary (CHD), using mean stage for SS model.
- Pitt-Taylor Reservoirs, Toulon Lake, and Humboldt Lake not simulated as they are frequently dry and heads are unknown.
- Mean annual stages applied to transient model.
- River conductance calibrated to estimated steady-state river loss of 7,300 AFA
- 6,000-14,000 AF mean annual reservoir loss to bank storage; loss to aquifer unknown (Eakin, 1962; Fereday and Nash, 2017). Simulated loss of 900 AFA determined by model given calibration to ET in Imlay area and local heads.

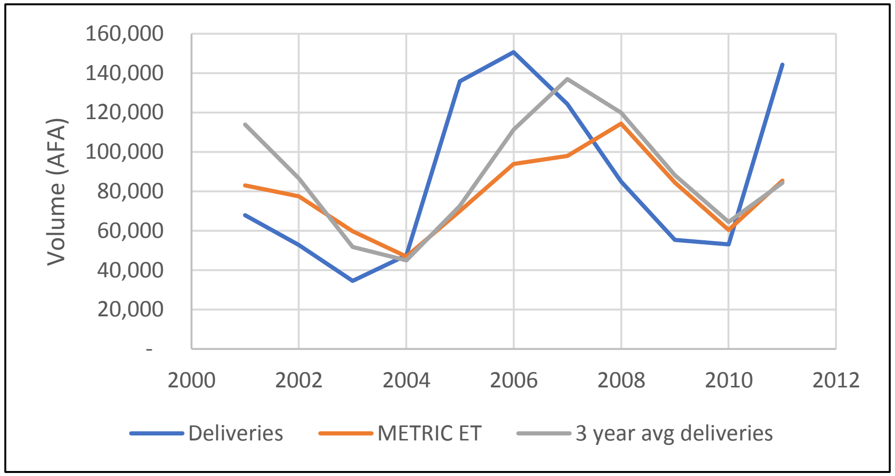
Interbasin Flow

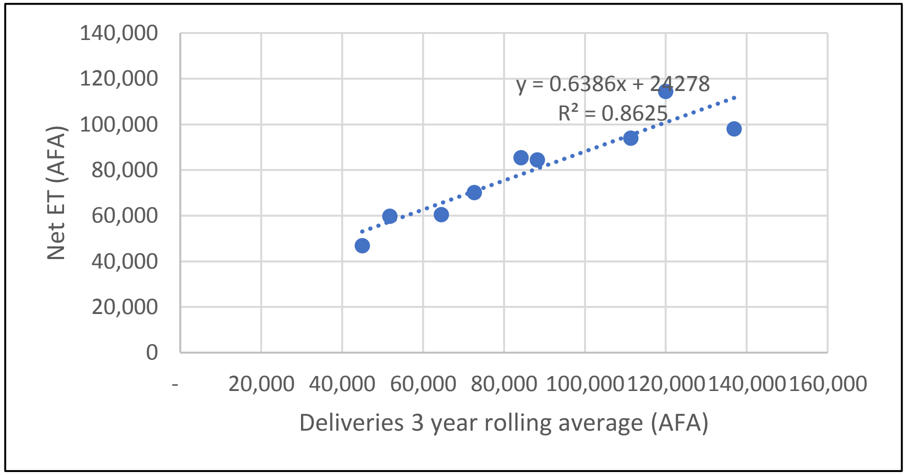
- Specified flux boundary applied along shared boundary with Middle Humboldt model
- Limited to extent of alluvial slope/fluvial deposits/playa/valley floor
- SS flux of 771 AFA based on current outflow from Middle Humboldt model



Estimate Ag ET

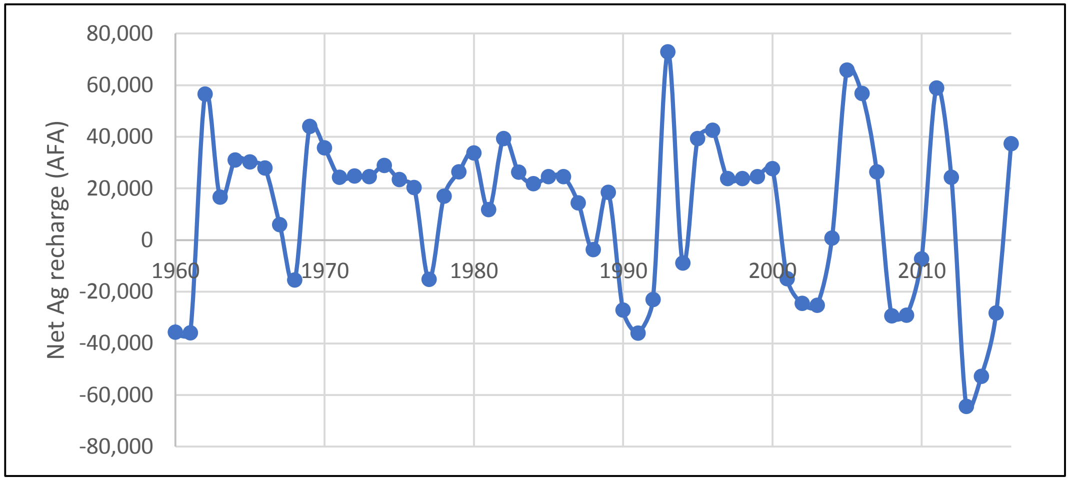
- Use METRIC ET for 2001-2011
- ET correlates poorly to delivery rates; correlates well to 3-year rolling average
- Relate METRIC ET to 3-year rolling average of delivery rates for all other years

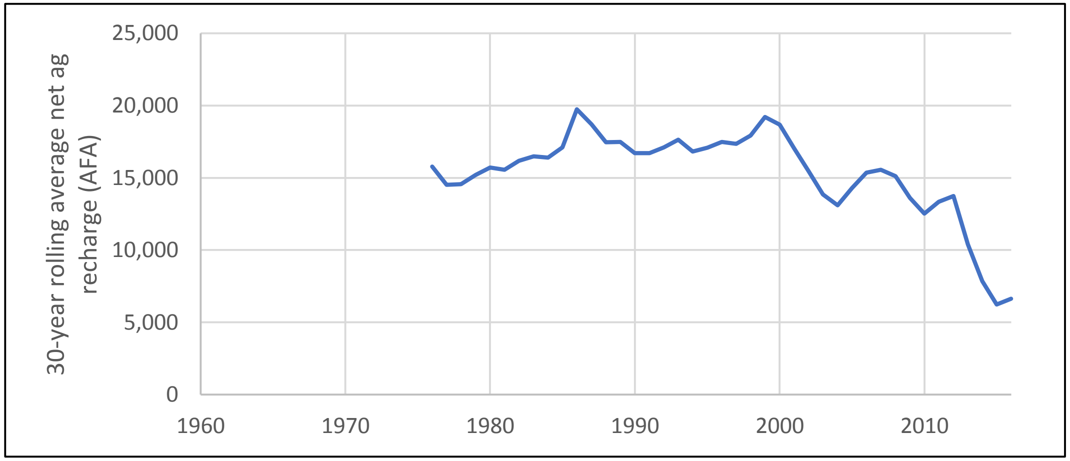




Ag Recharge

- Streamflow applied to fields less Net ET = Ag Recharge
- Mean ag recharge value for 1960-1990 applied to steady state model (16,700 AFA)
- ET applied as negative recharge for years where ET is greater than net recharge

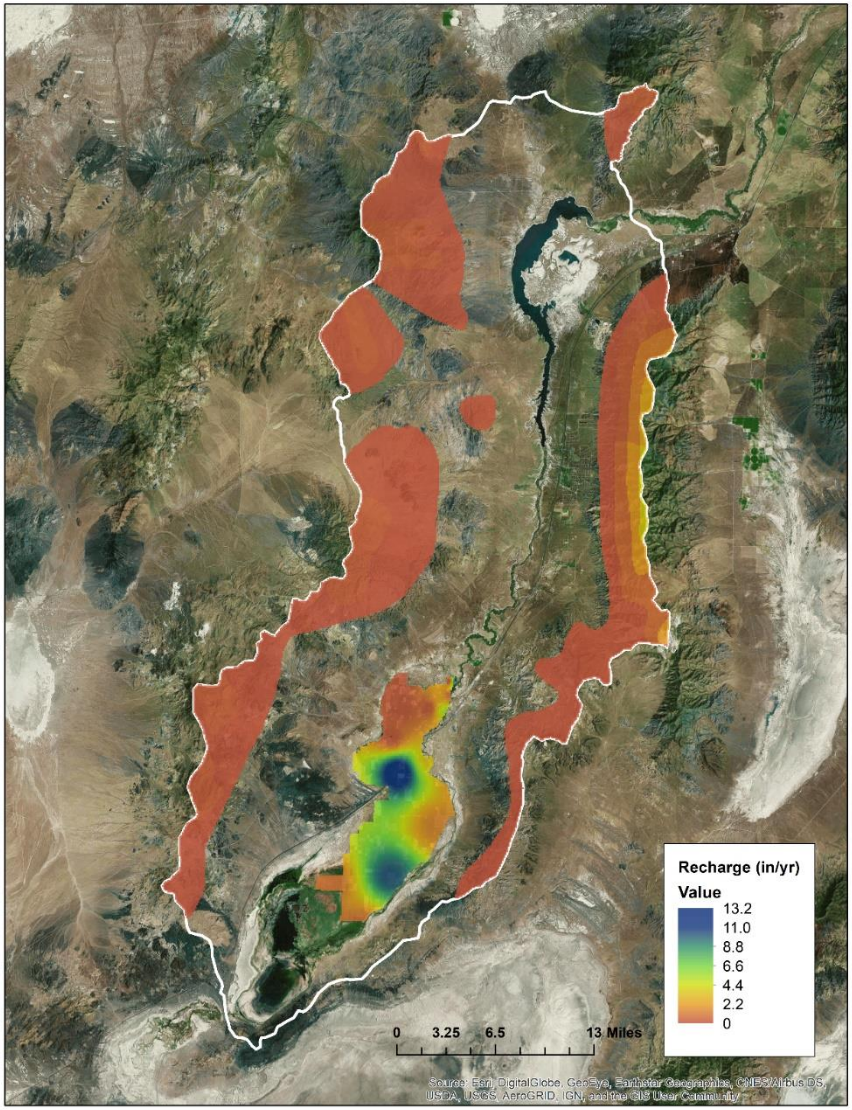




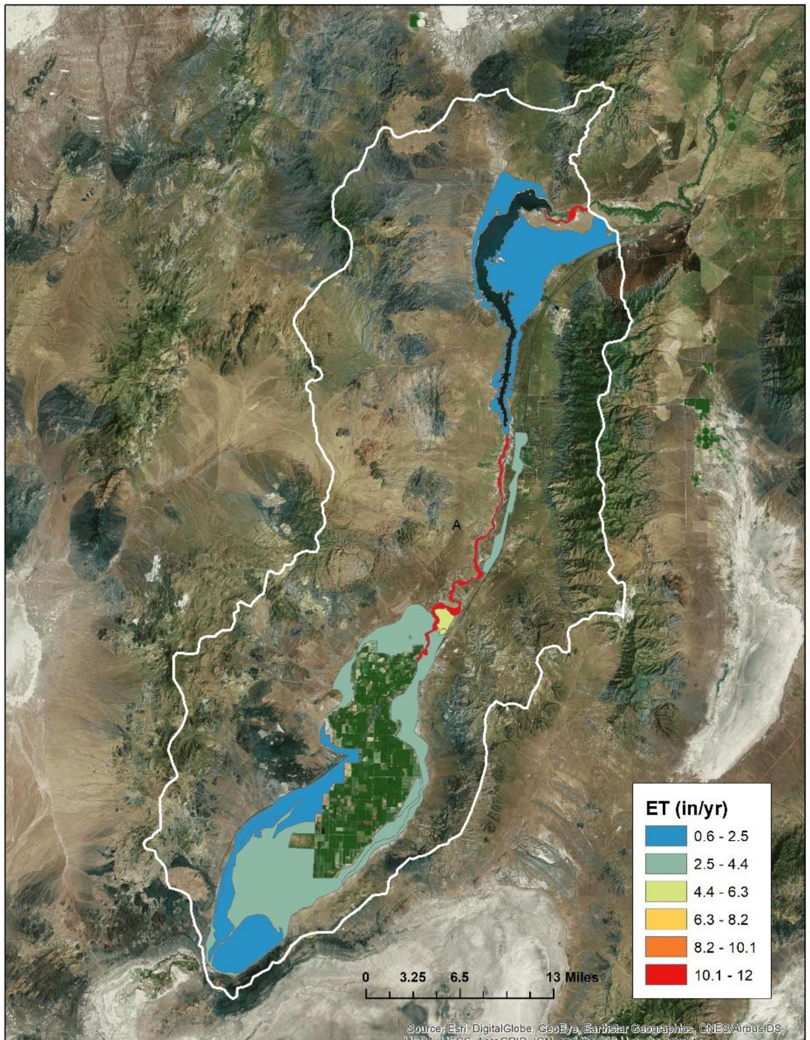
Steady State Recharge

	Mountain Block Recharge (afy)				
Reference	Lovelock	Oreana	Imlay	Model Domain	Methodology
Everett and Rush, 1965	1,200	2,000	--	--	Maxey-Eakin, 1949
Eakin, 1962	--	--	4,000	--	Maxey-Eakin, 1949

- Mountain block recharge estimates from Recon Reports distributed proportionally over Hardman map intervals
- Ag recharge rate applied as average of 1960-1990 regression
- Mountain block recharge = 5,700 AFA
- SS Ag recharge = 16,700 AFA, applied proportionally to layer 1 hydraulic conductivity



Evapotranspiration

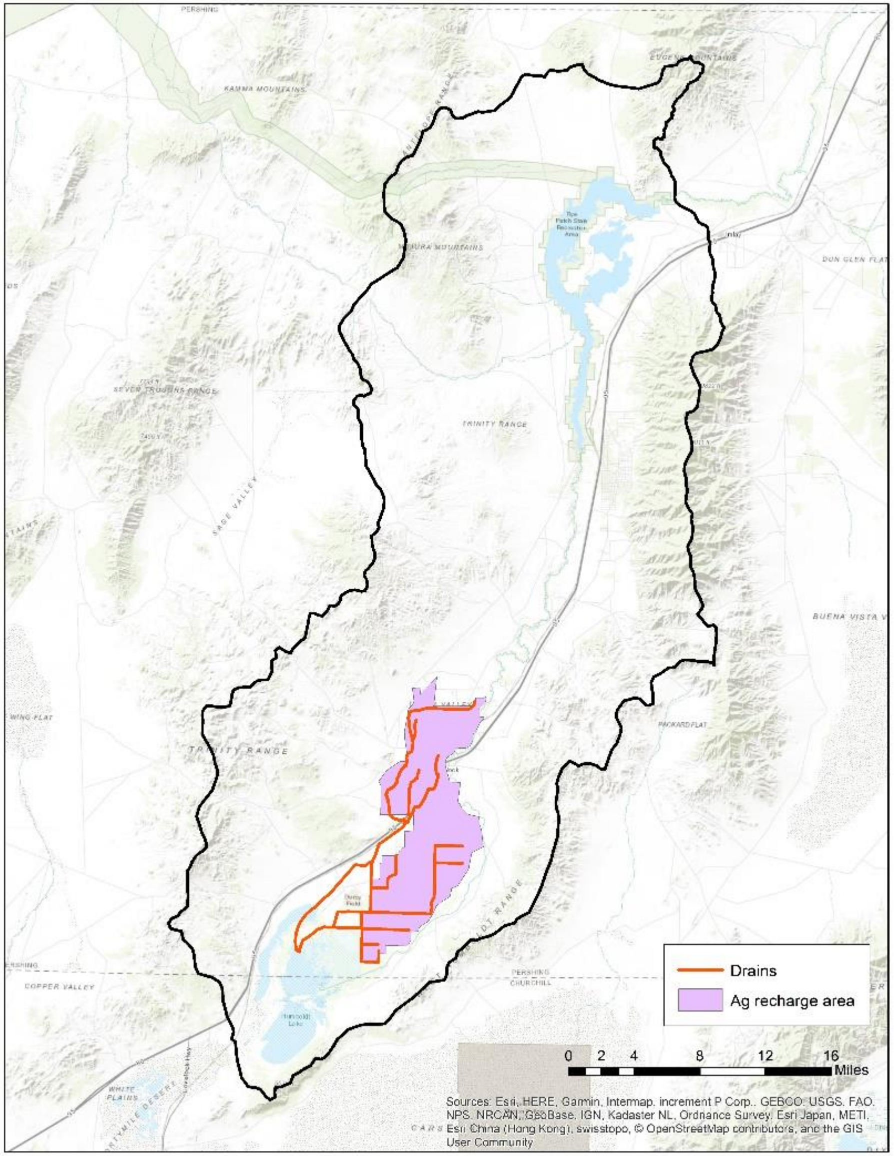


- ET zones applied over DRI polygons, total phreatophyte and bare soil ET estimated at 22,400 AFA

- Ag ET incorporated in net ag recharge estimate, not explicitly simulated

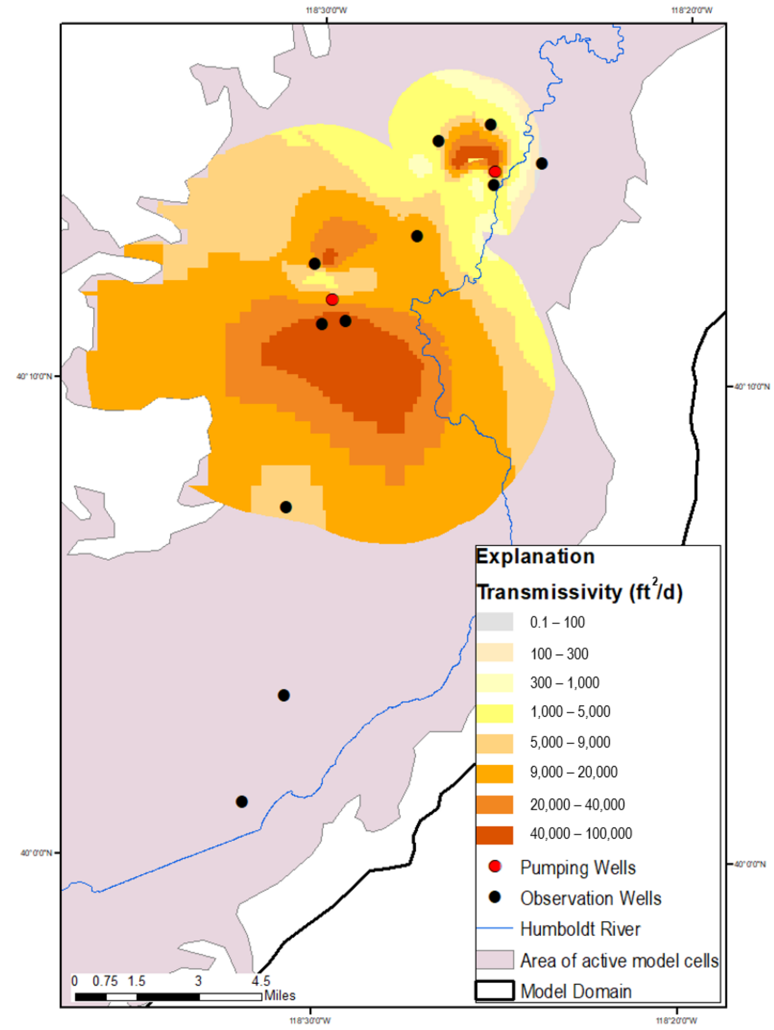
Drains

- Represents ag runoff/recharge lost to sink; simulated using Drain (DRN) package
- Drain bottoms set to 9 ft bls
- Drain outflow estimated to be 9,500 AFA



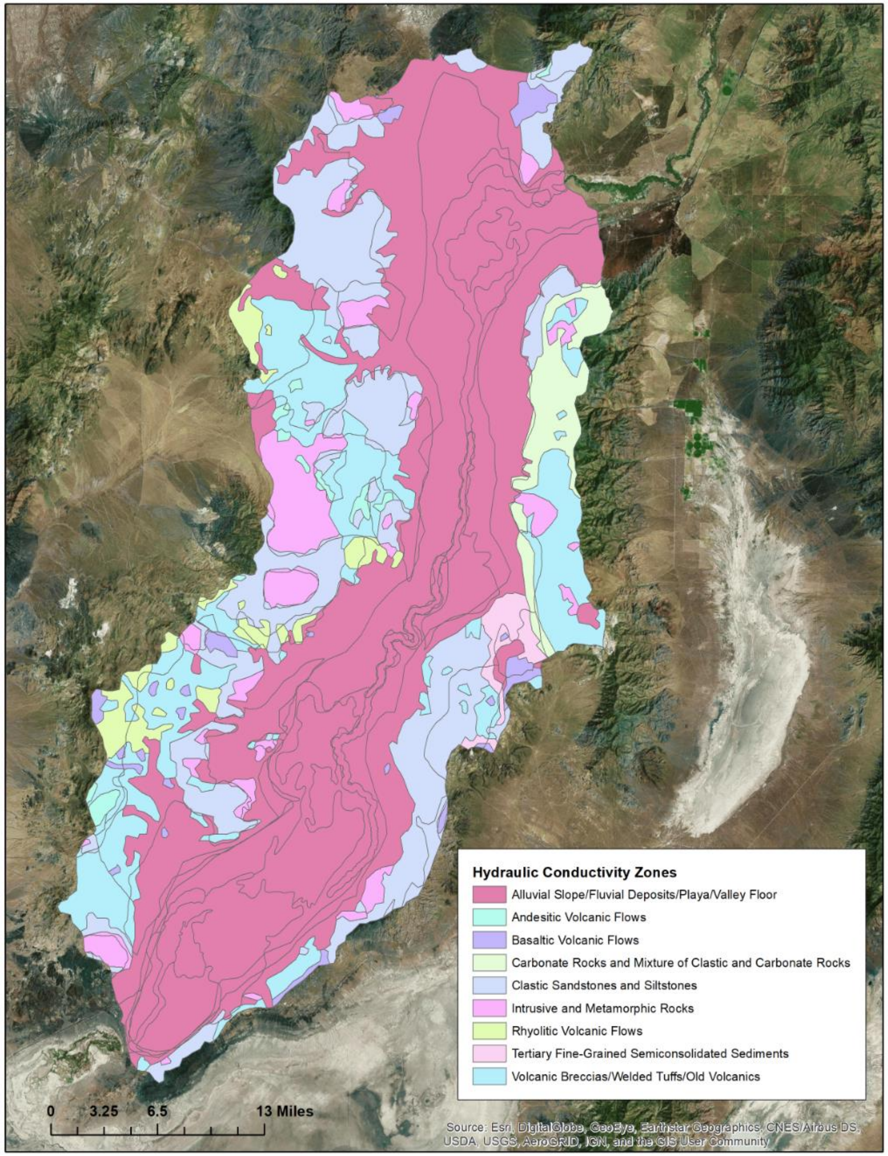
USGS Aquifer Test Results

	Lahontan Clays and Silts	Fluvial Deposits	Coarser Alluvium
Minimum Transmissivity (ft^2/d)	0.0001	2.6	0.05
Maximum Transmissivity (ft^2/d)	50	53.8	95,000
Average Transmissivity (ft^2/d)	1	14.1	11,000



Hydrogeology

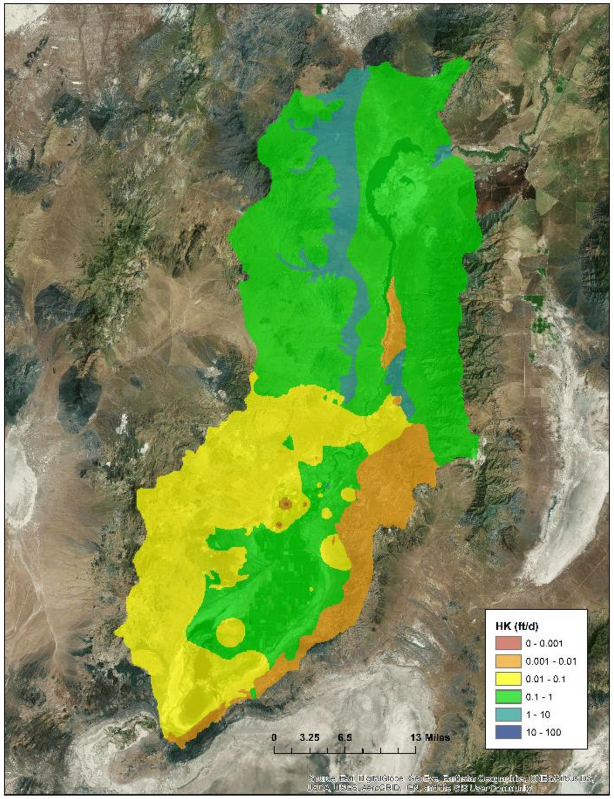
K Zone	K (ft/d)	Min (ft/d)	Max (ft/d)
Clastic Sandstones and Siltstones	0.01	2.00E-09	18
Alluvial Slope/Fluvial Deposits/Playa/Valley Floor	1 (L1), 10 (L2), 0.01 (L3)	0.0001	150
Basaltic Volcanic Flows	1	0.0002	1300
Andesitic Volcanic Flows	0.1	0.0002	60
Intrusive Metamorphic Rocks	0.001	7.00E-08	30
Rhyolitic Volcanic Flows	0.01	0.00002	260
Carbonate Rocks and Mixture of Clastic and Carbonate Rocks	5	0.00003	3300
Volcanic Breccias/Welded Tuffs/Old Volcanics	0.1	3.00E-07	600
Tertiary Fine-Grained Semiconsolidated Sediments	0.1	0.0002	20



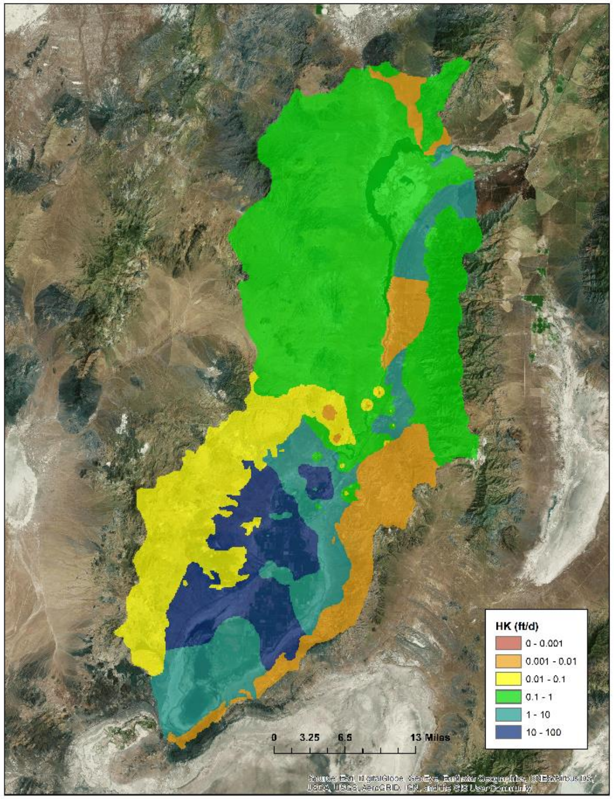
Alluvial slope/fluvial deposits/playa/valley floor located in central basin simulated using pilot points

From Maurer and others, 2004

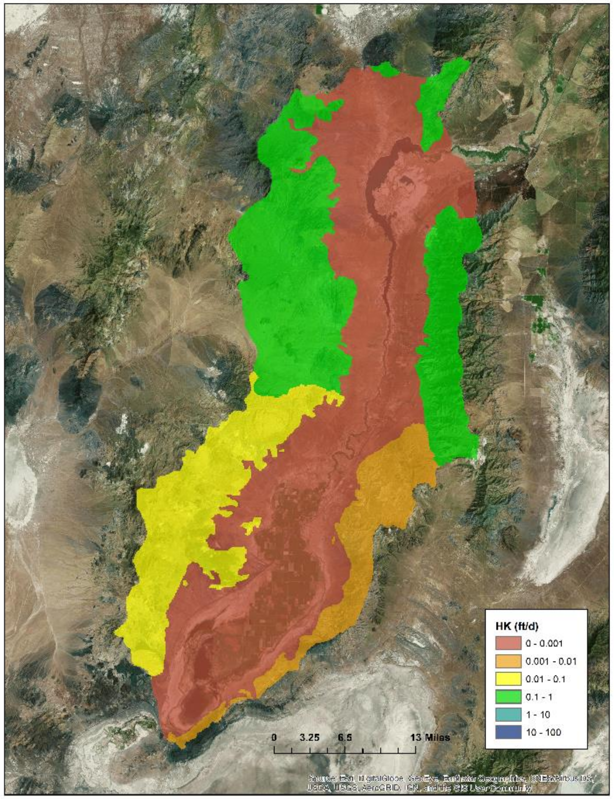
Hydraulic Conductivity



Layer 1

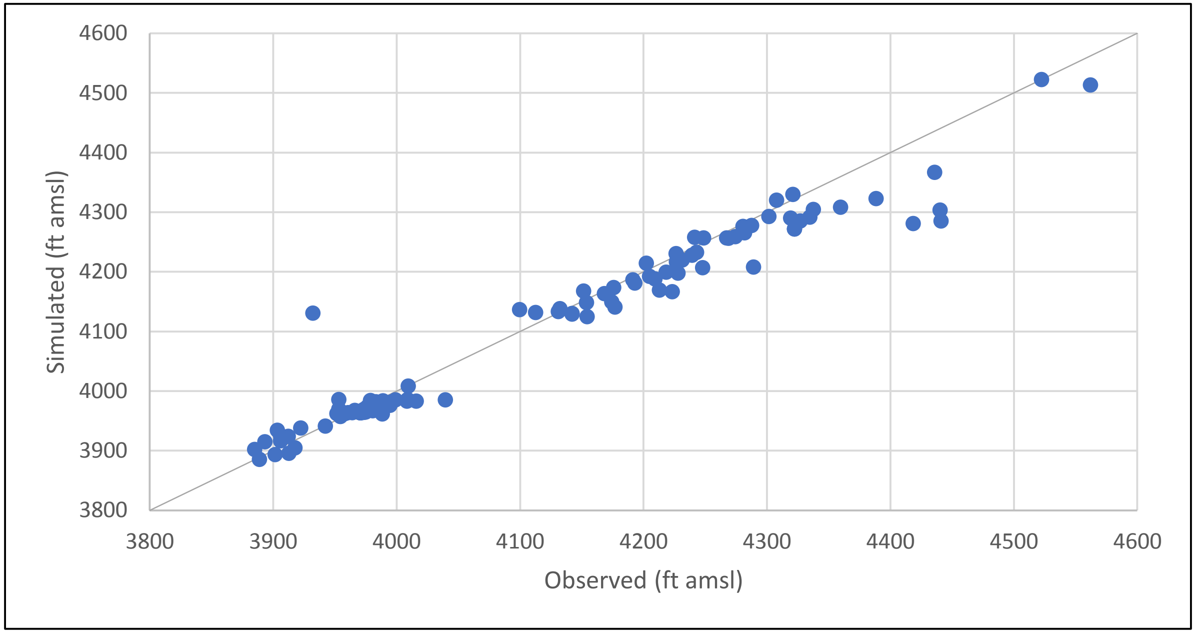


Layer 2



Layer 3

SS Model Calibration



Mean Residual (Head) (ft)	9.55
Mean Absolute Residual (Head) (ft)	23.52
Root Mean Squared Residual (Head) (ft)	40.33
Relative Error	3.5%

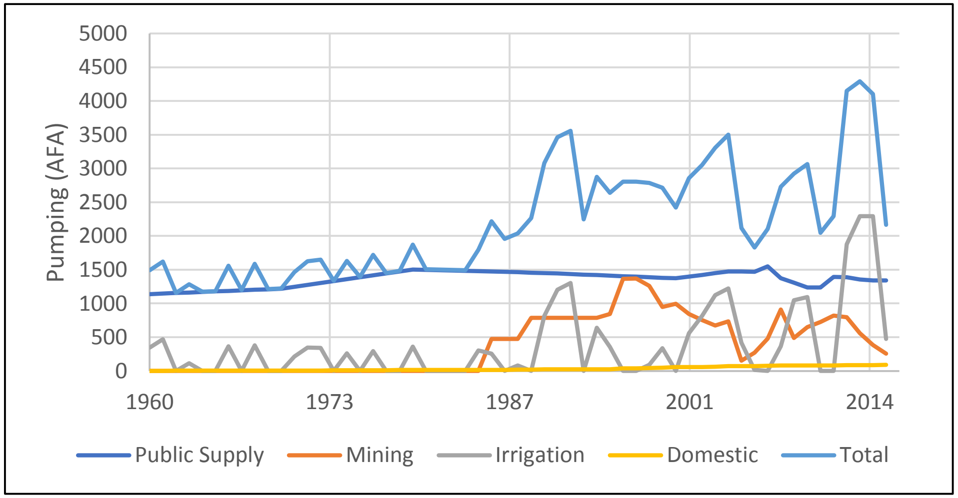
Flow Budget

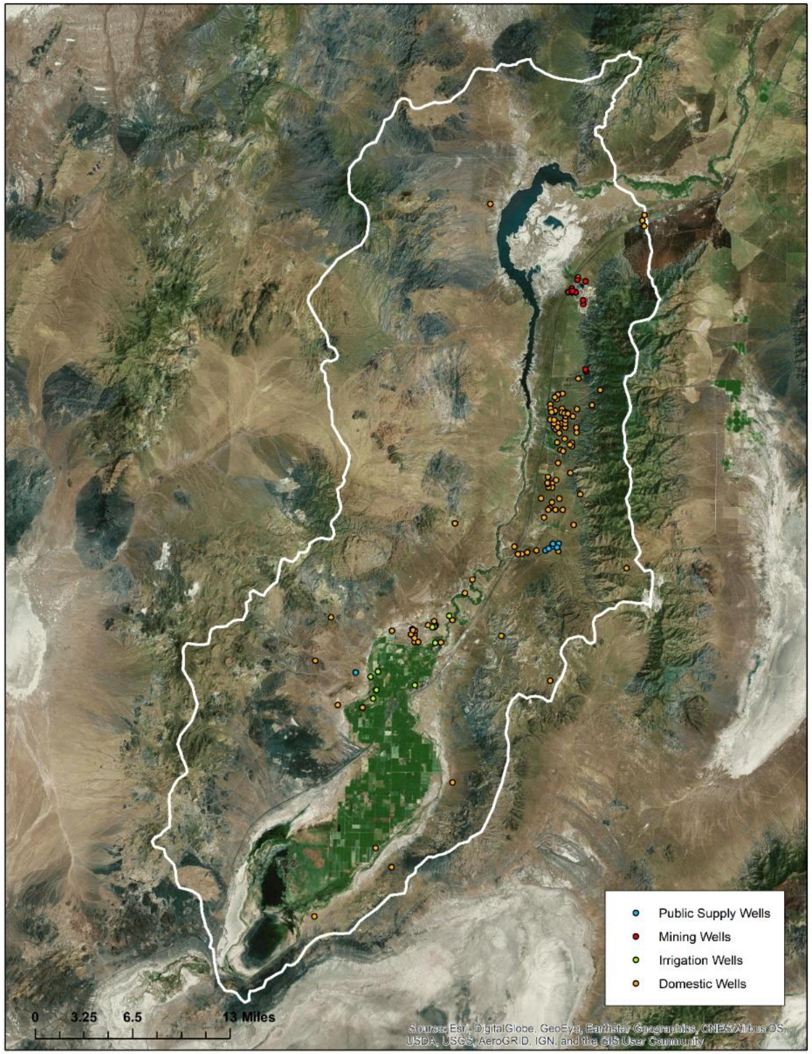
Inflows	Estimated (AFA)	Simulated (AFA)
Recharge (Mountain block + Net Ag)	22,400	22,400
Reservoir Loss	<14,000	900
River Loss	7,300	7,500
Interbasin Flow	800	800
Total	30,500 + reservoir loss	31,600

Outflows	Estimated (AFA)	Simulated (AFA)
Evapotranspiration	22,400	22,100
Drains	8,100 + reservoir loss	9,500
Total	30,500 + reservoir loss	31,600

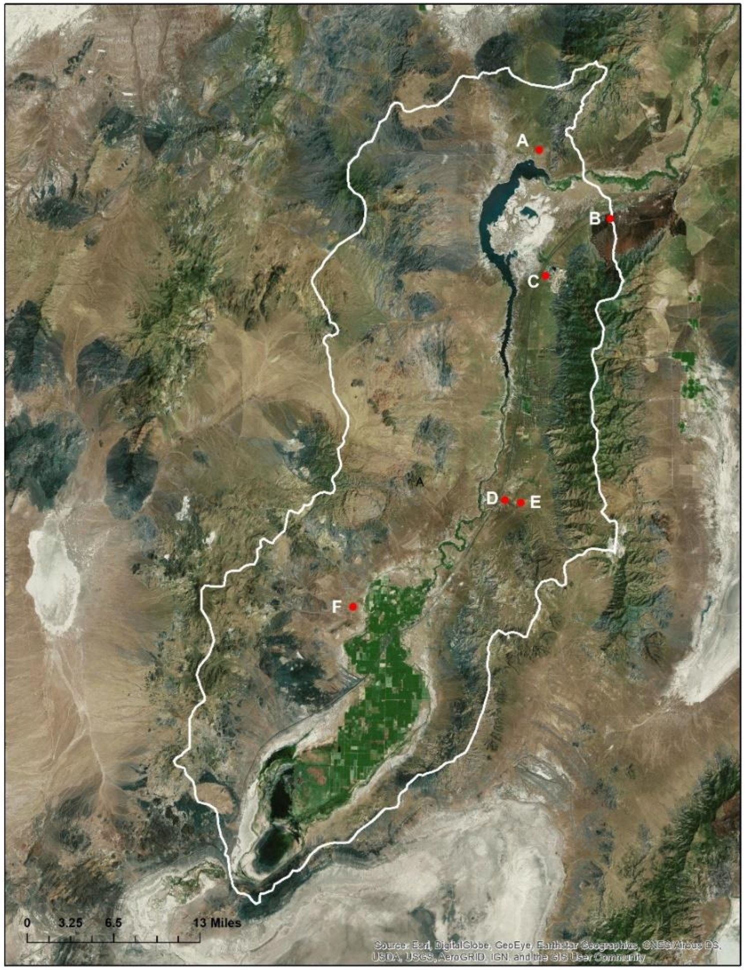
Transient Pumping

- Domestic wells pumping outside of Lovelock Meadows service area at 0.7 AFA.
- Public supply wells pumped at rates extrapolated backwards to 1960 based on population.
- Mining wells pumpage extrapolated earliest known rates backwards to 1986.
- Irrigation wells pumpage inversely proportional to the ratio of estimated ag recharge relative to the mean ag recharge 1960-1990.

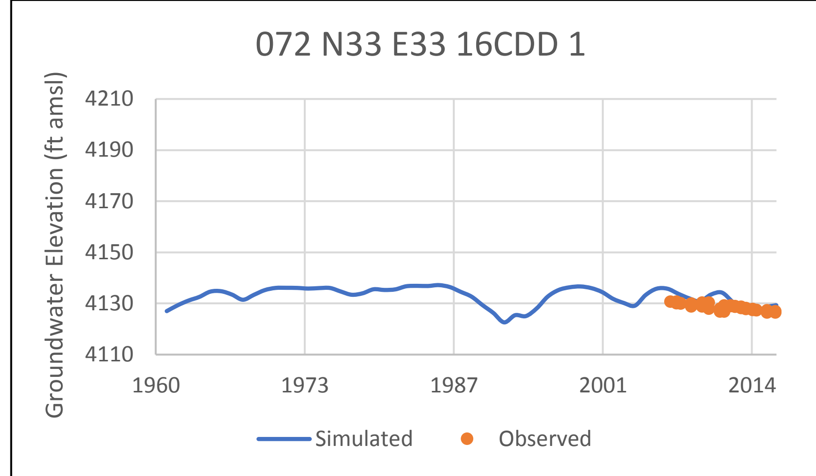




Transient Results



A



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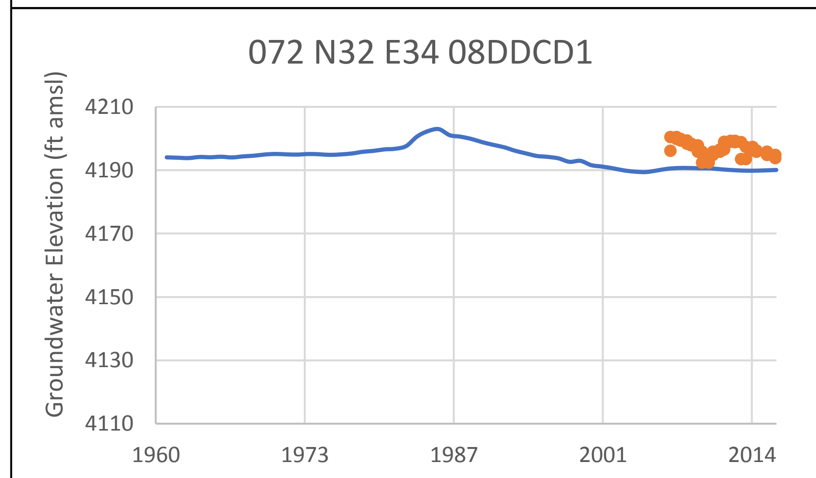

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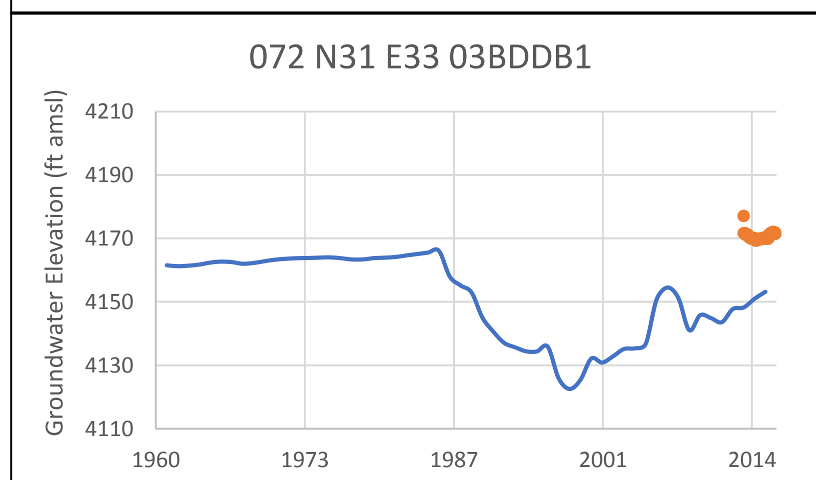
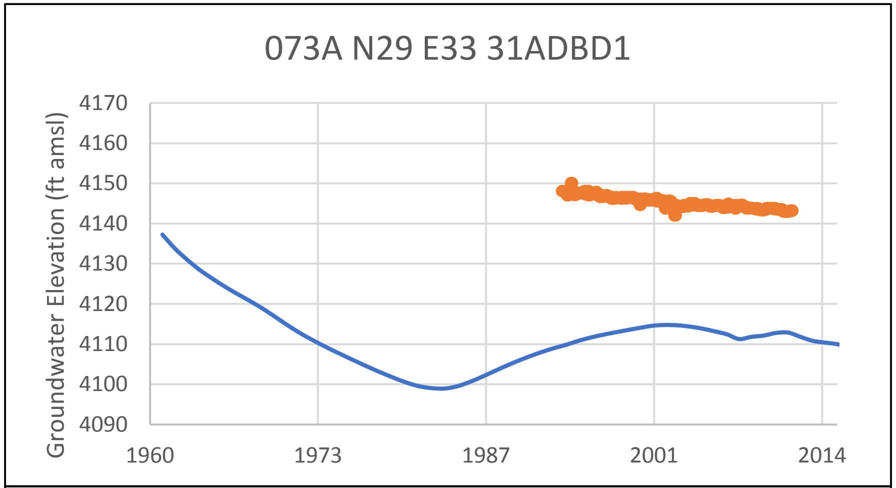


Transient Results

D



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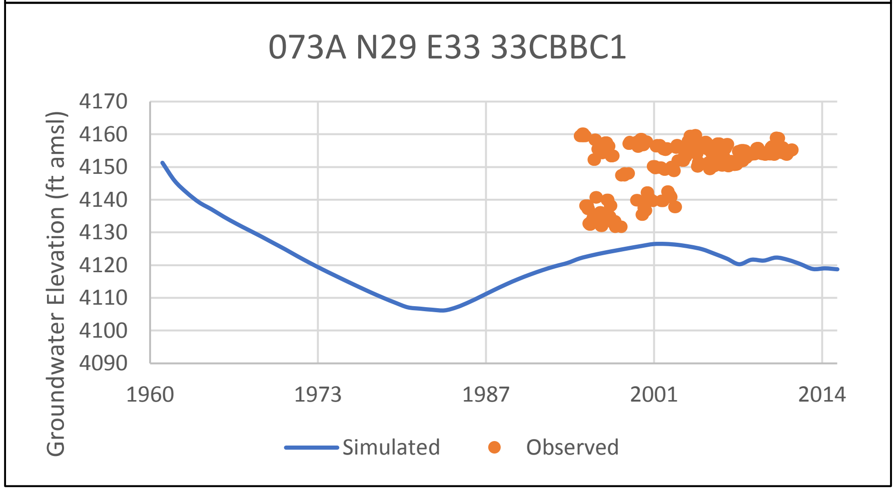
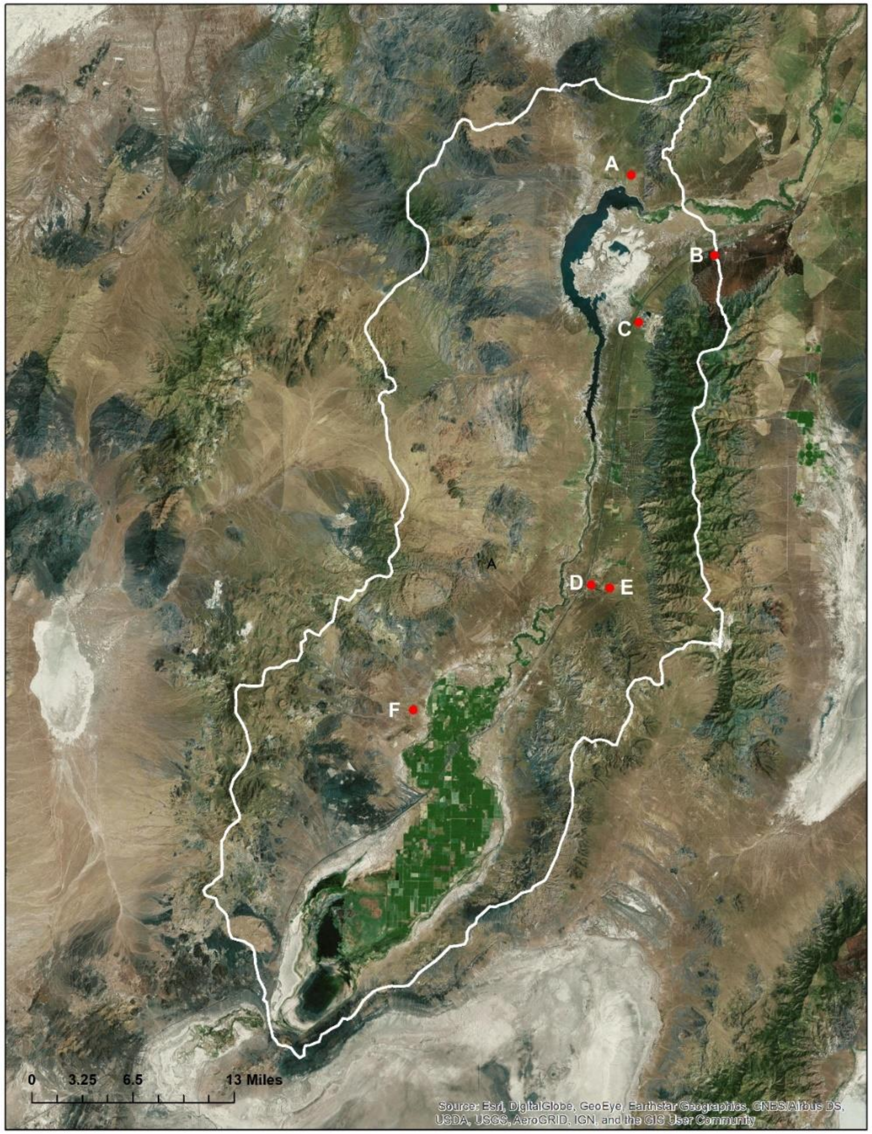
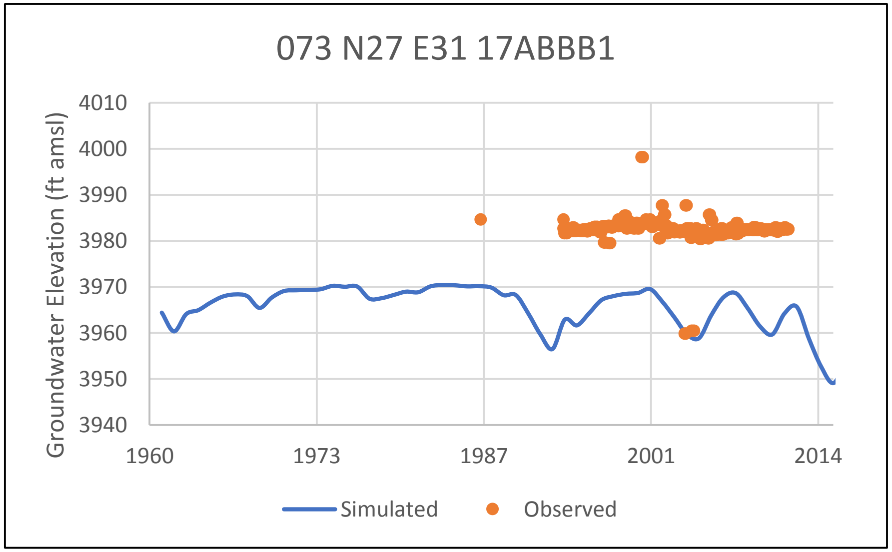
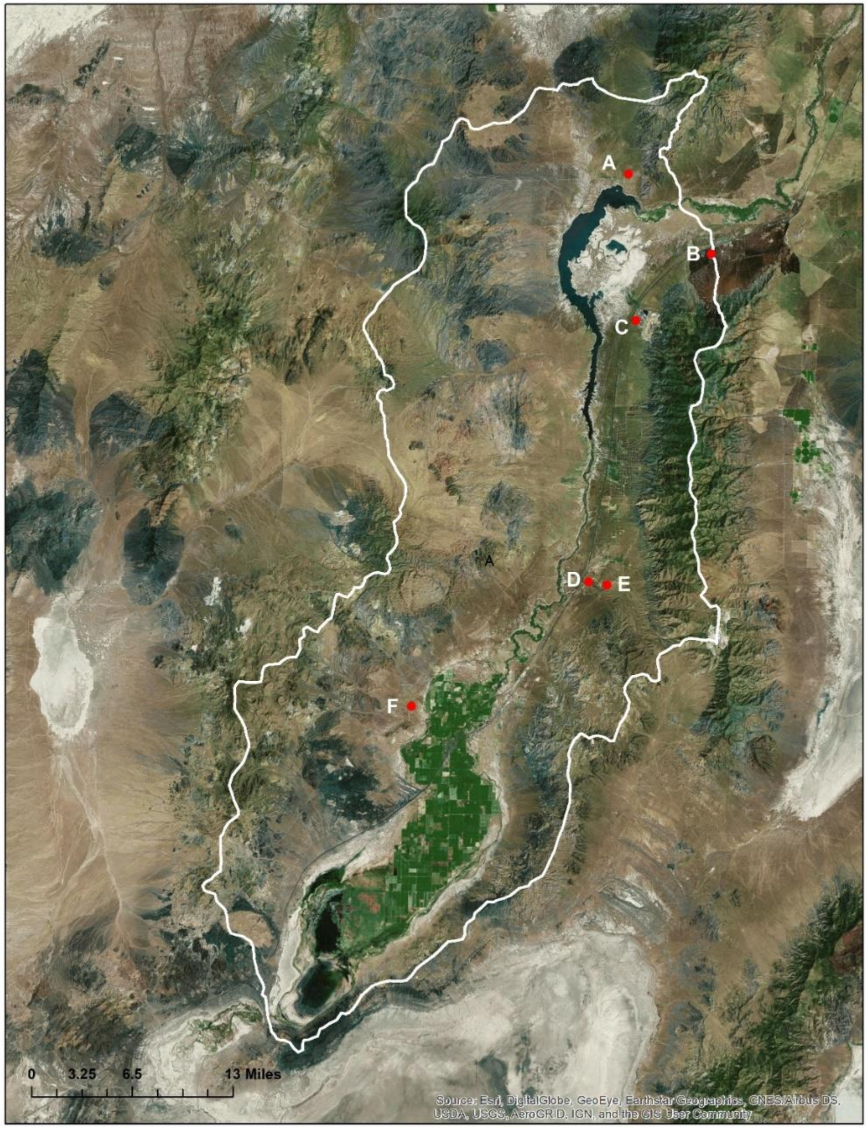




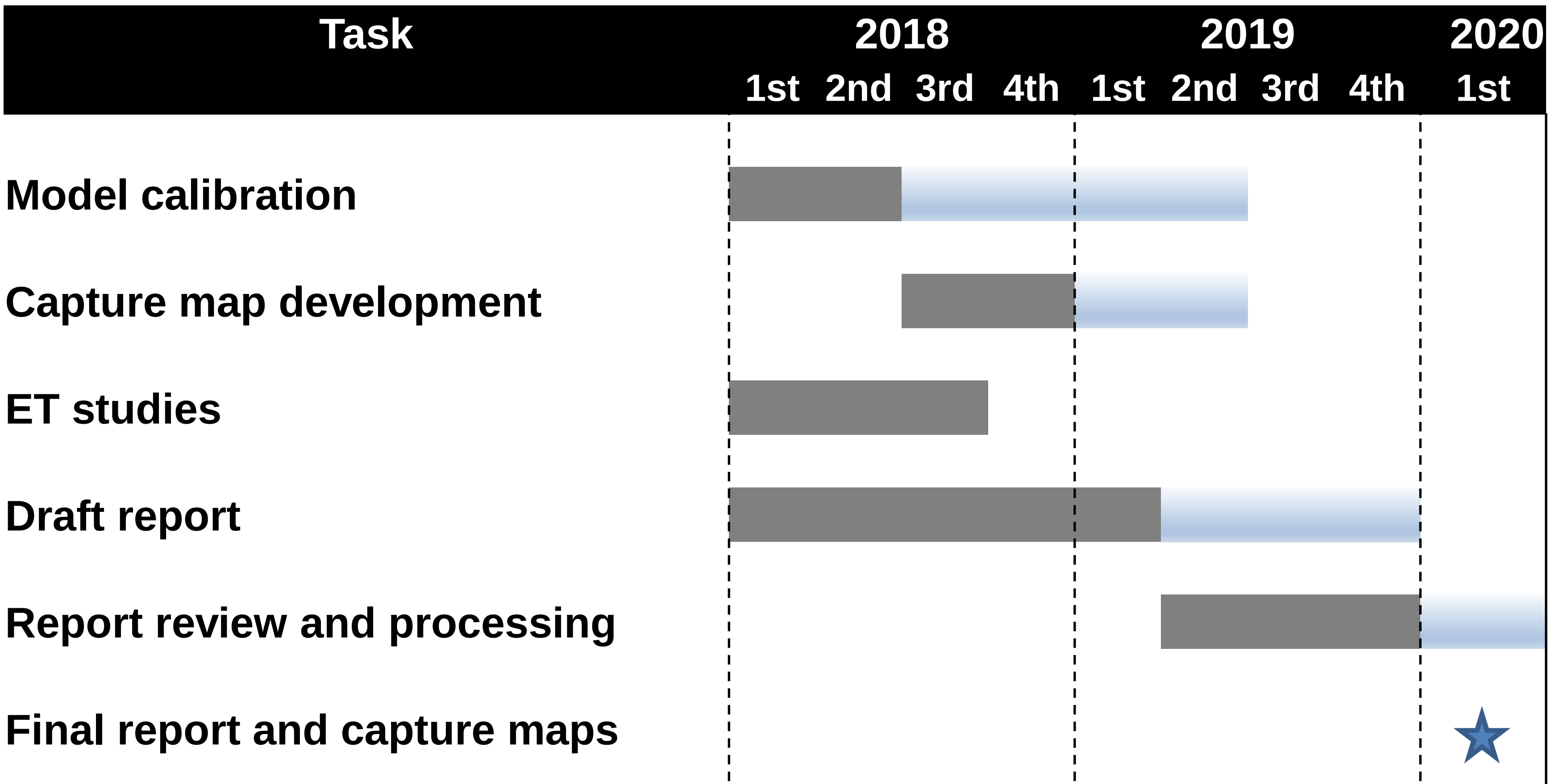
Transient Results

F





Project Schedule




Questions?