Gold King Mine Release –
Analysis of Fate and Transport in the Animas and San Juan Rivers

Session 4

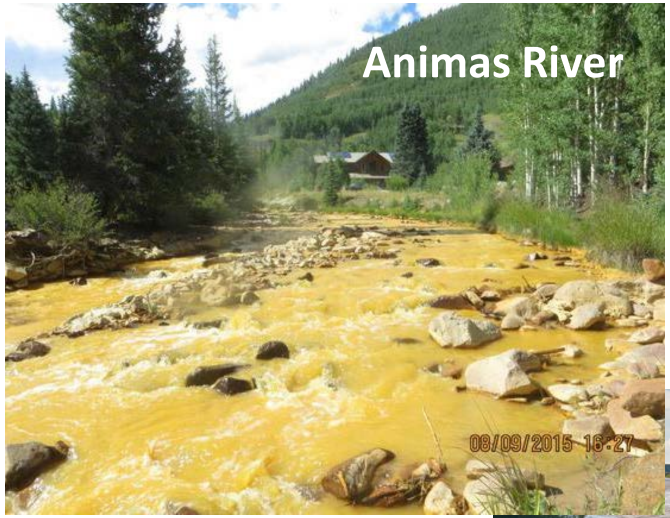
Gold King Mine Team
National Exposure Research Lab/ORD

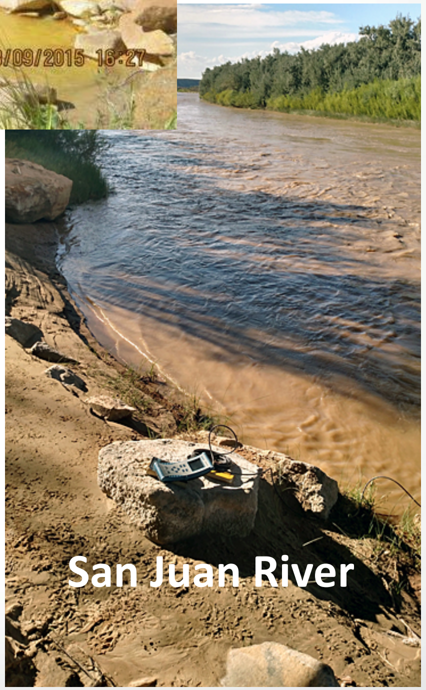
June 30, 2016

Review Outline—Session 4

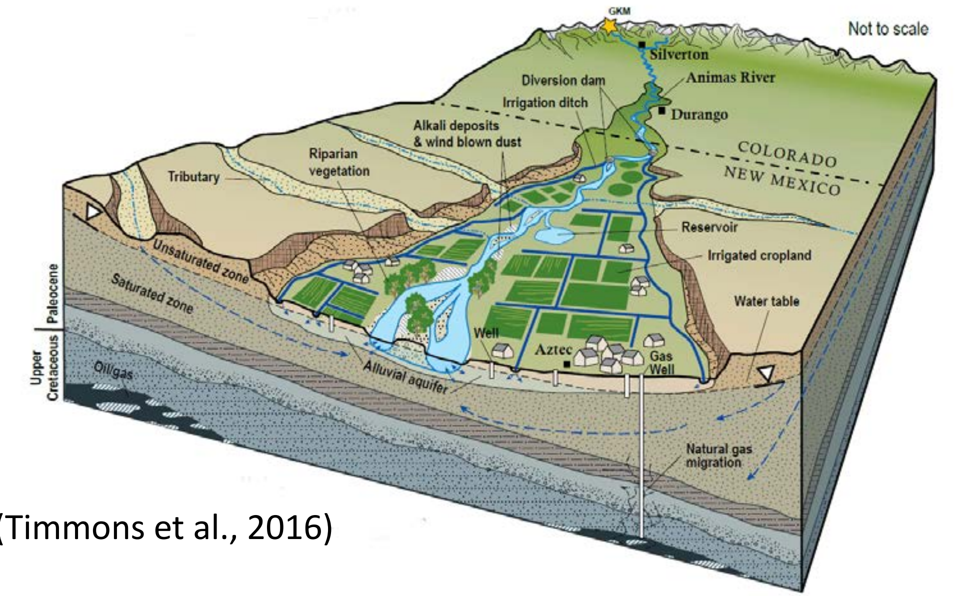
- **Groundwater assessment of potential for contamination of wells in river alluvium**
  - goals and objectives
  - step-wise and progressive groundwater modeling approach, regional to local to regional, building understanding
  - groundwater modeling methods, including baseflow assessment, capture zone delineation, particle tracking for solute breakthrough
  - initial assessment of wells located in the floodplain deposits of the mid Animas River given proximity to GKM source and understanding of plume river transport
  - preview of assessment for wells located in lower Animas River floodplain

- **Summary of GKM Findings and Wrap-up**





Surface Geology Animas River Watershed

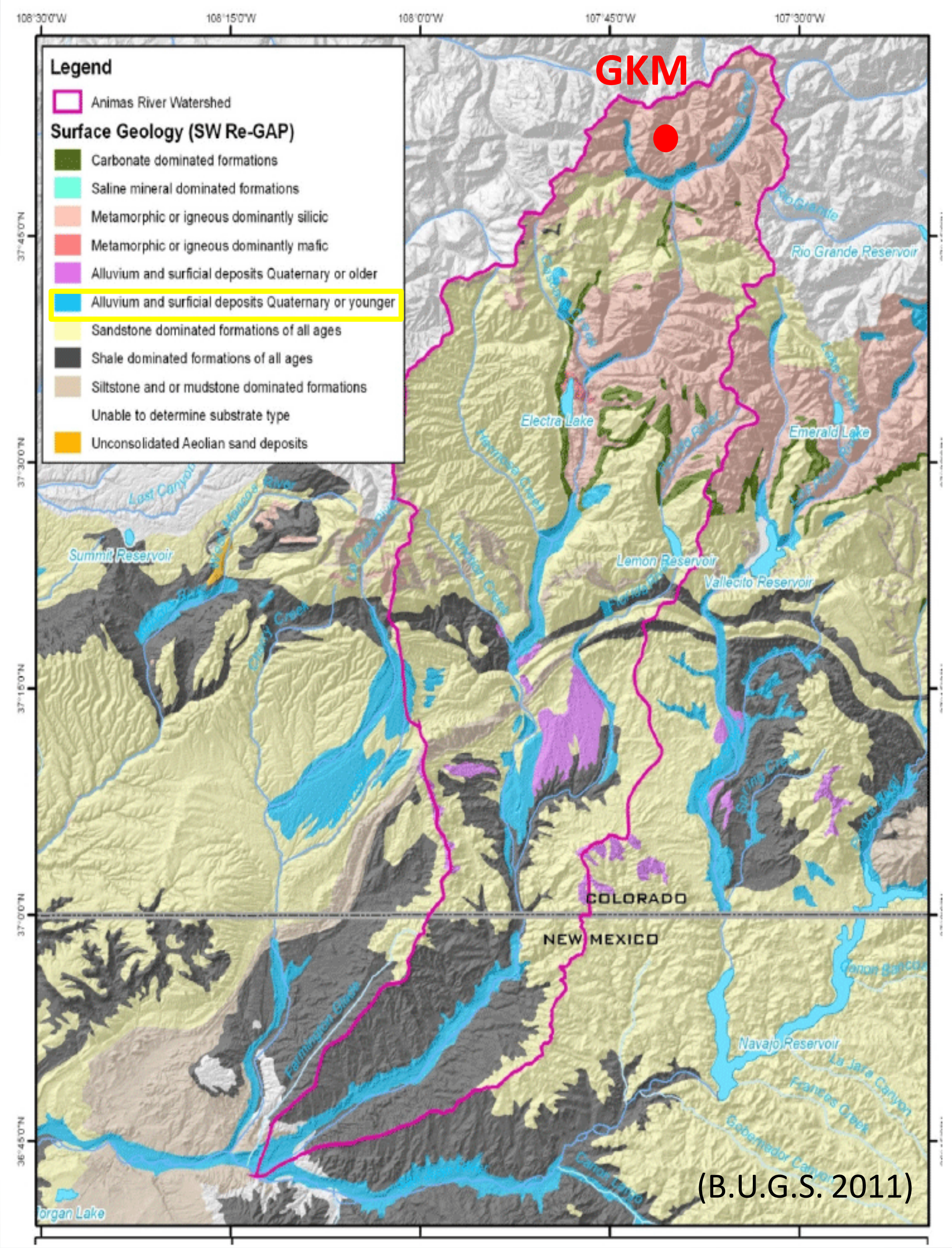


(Timmons et al., 2016)

The thin *ribbon* unconfined unconsolidated alluvial aquifers source are an important water source supplied by wells (community, domestic, irrigation, other)

Geology and geomorphology have an influence on gw/sw interactions and water quality

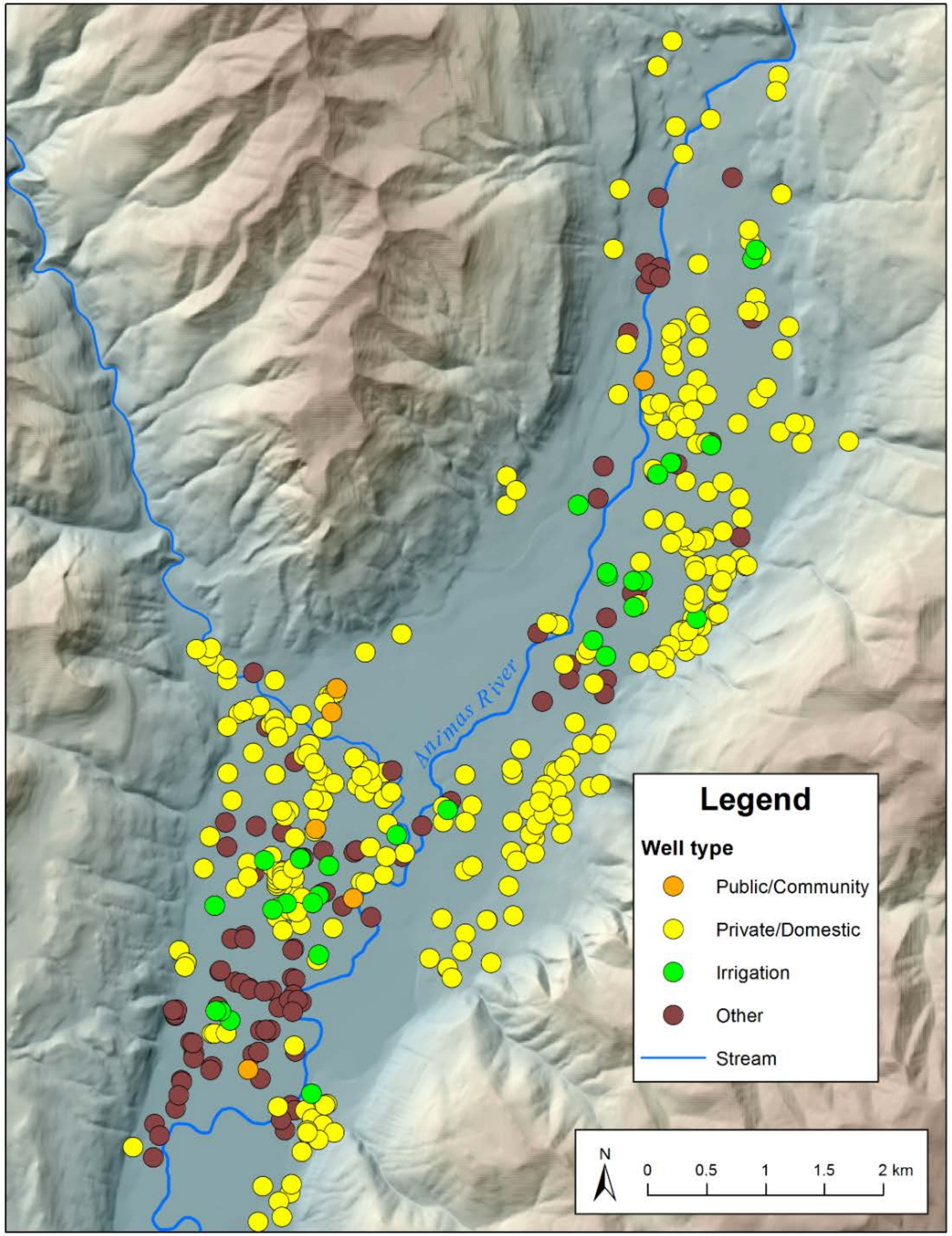
- **Upper drainage through metamorphic-igneous rocks**
- **Mid Animas drainage through sandstone rocks**
- **Lower Animas drainage through shale dominated rocks (also presence of human-made irrigation ditches)**



(B.U.G.S. 2011)

Water supply well types in the mid Animas River floodplain

- large number of wells, variable distance from river, variable pumping volumes
- Public/Community wells more likely to have year-round pumping and higher volumes.
- Private/Domestic wells are widely distributed, including
  - seasonal irrigation purposes
  - low volume household use
- other, commercial



(Colorado DWR well permit search)

(map courtesy Lourdes Prieto, EPA)

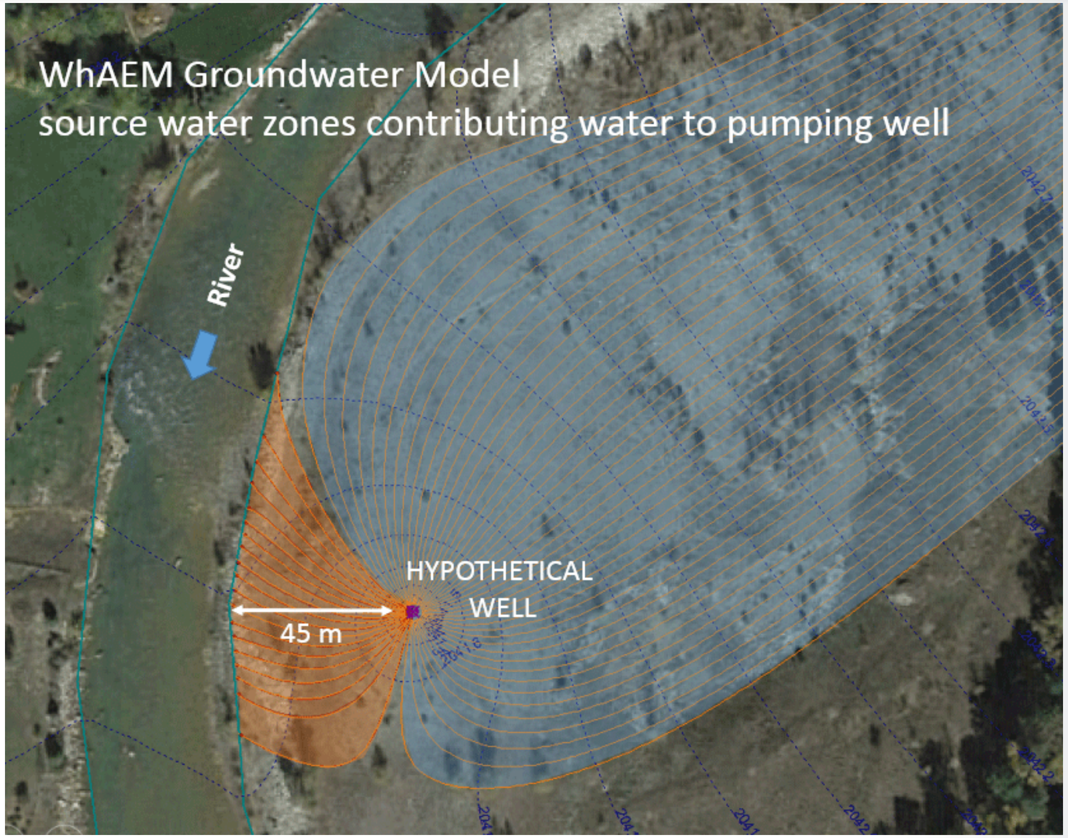
Potential Impacts on Wells

Do wells located in the floodplain have the potential to draw water from the river, especially along the Animas where concentrations were highest?

- Rivers and groundwater in alluvial floodplains exchange water
  - most of the time, groundwater feeds rivers
  - sometimes, in some places, the river loses water to groundwater
  - pumping wells located in the floodplain can draw in river water (low pumpers near naturally losing river sections; high pumpers creating their own losing sections)

Could those sourcing wells have acquired GKM contaminated water from the river?

- the GKM plume passed location during a specific time window
  - most metals passed in about 12 hours
  - left deposited metals in the streambed
  - a well sourcing from river water could have drawn in dissolved metals

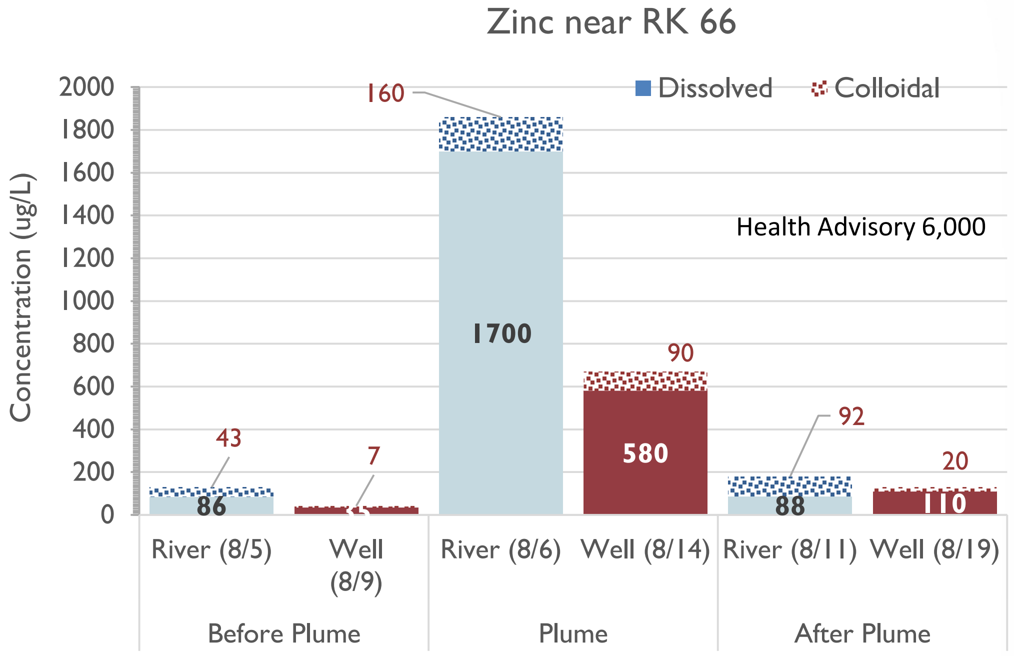


Influencing Factors:

- *Proximity to gaining or losing river reaches*
- *Pumping volume (we tested for typical annual diversions, measured rates, and maximum rated yield)*
- *Pumping schedule (municipal wells pump more consistently than seasonal irrigation wells)*

Is there any empirical evidence of communication?

- Early in our the investigation there was publically released drinking water quality data for community wells in the mid Animas River of Colorado, around Durango
- Sampling suggests this well may be in equilibrium with the river water quality
- One of the wells, located 35 m from the river, may have had an apparent water quality signal for dissolved metals
- Note: observed concentrations of dissolved metals in well water were below federal drinking water action levels
- Can we use computer models to try to understand this potential river to well exchange and time frame for these communications?



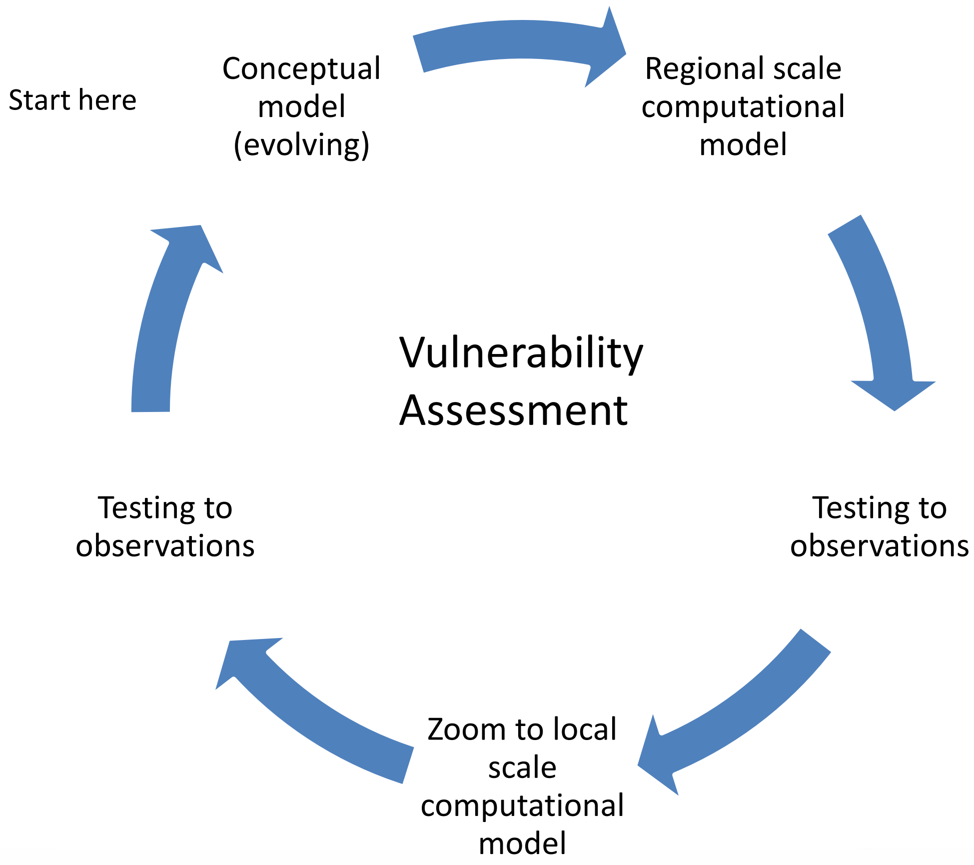
(CDPHE, 2015)

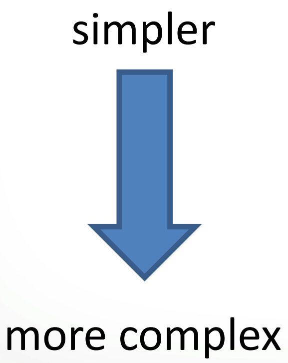
Community well near Durango within 35 m of river

GW Modeling Flow Chart

"A model should be as simple as possible, but not simpler."

-- Albert Einstein



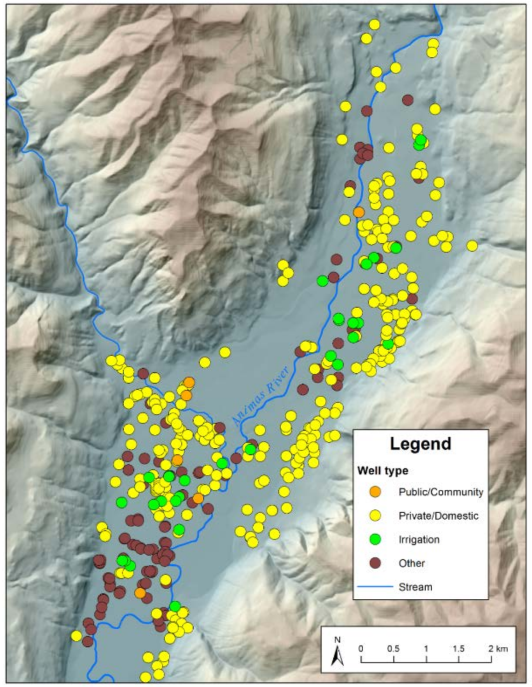


Ideally, complete the model and evaluate vulnerability when additional complexity does not change the answer as expressed in the objective of the study

Step-wise progressive GW modeling

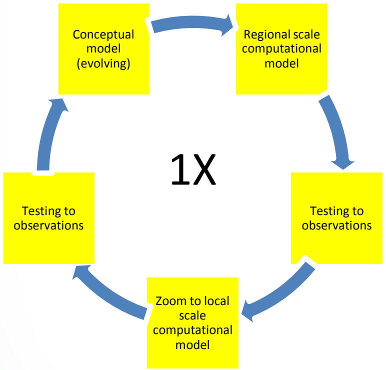
* **Groundwater modeling* techniques used to inform:**
  - **source water or capture zone of pumping wells**
  - **particle tracking representing solute movement from river to well**
  - **break-through from Animas River to well given pumping**
  - **likely time frame and strength of signal**

*** modeling for understanding (not necessarily prediction for any individual well)**

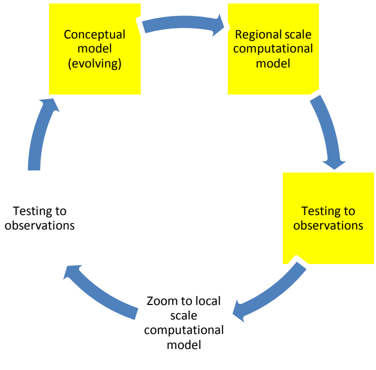


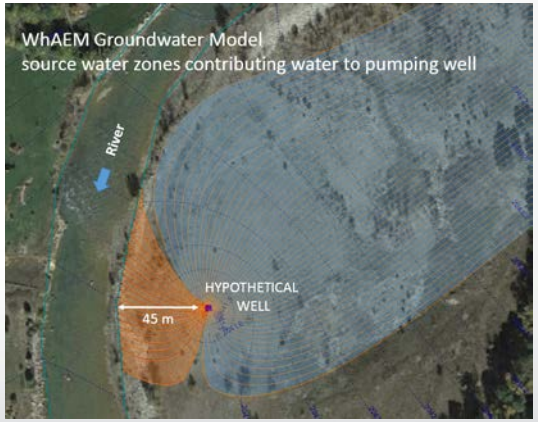
Progress to date:

mid Animas River floodplain wells



lower Animas River floodplain wells





mid Animas, starting regional scale, focus on local, return to regional, what are some important things to explore? gw-sw interactions; pumping schedule and volume of the pumping wells; the regional influences of geology alluvial floodplain surrounded by rock/mountains,; local heterogeneity such as location of the river bank; presence of buried channels; importance of irrigation ditches.

lower Animas conceptual and regional model being tested with field observations.

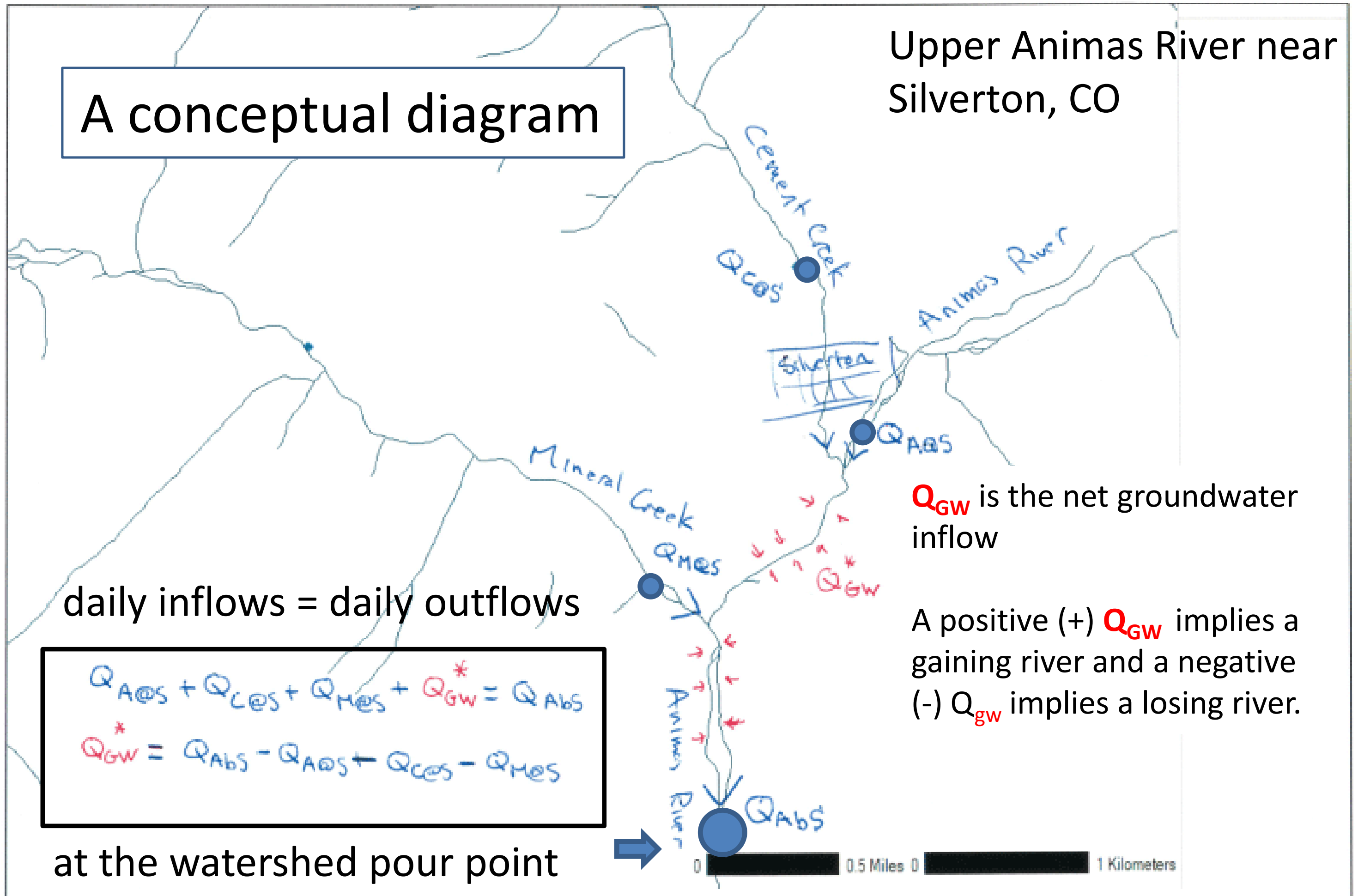
Groundwater/surface water interactions in the upper Animas River floodplain

The upper Animas River can be a gaining or losing stream

An empirical investigation is presented for a segment of the upper Animas River where data exists supporting a water flow balance assessment

- **Given four USGS gage stations near Silverton, CO**
- **A daily water balance analysis calculated at the USGS gage below Silverton can provide insight into the net lateral diffuse groundwater contribution along the Animas River**
- **Results in following slide**

$Q_{A@S}$ = streamflow Animas R at Silverton
$Q_{C@S}$ = streamflow Cement Cr at Silverton
$Q_{M@S}$ = streamflow Mineral Cr @ Silverton
Q_{AbS} = streamflow Animas R below Silverton
Q_{GW} = lateral groundwater inflow



* The net groundwater inflow for this segment Q_{GW} includes diffuse subsurface inflow and spring contributions.

Upper Animas River Water Balance Analysis

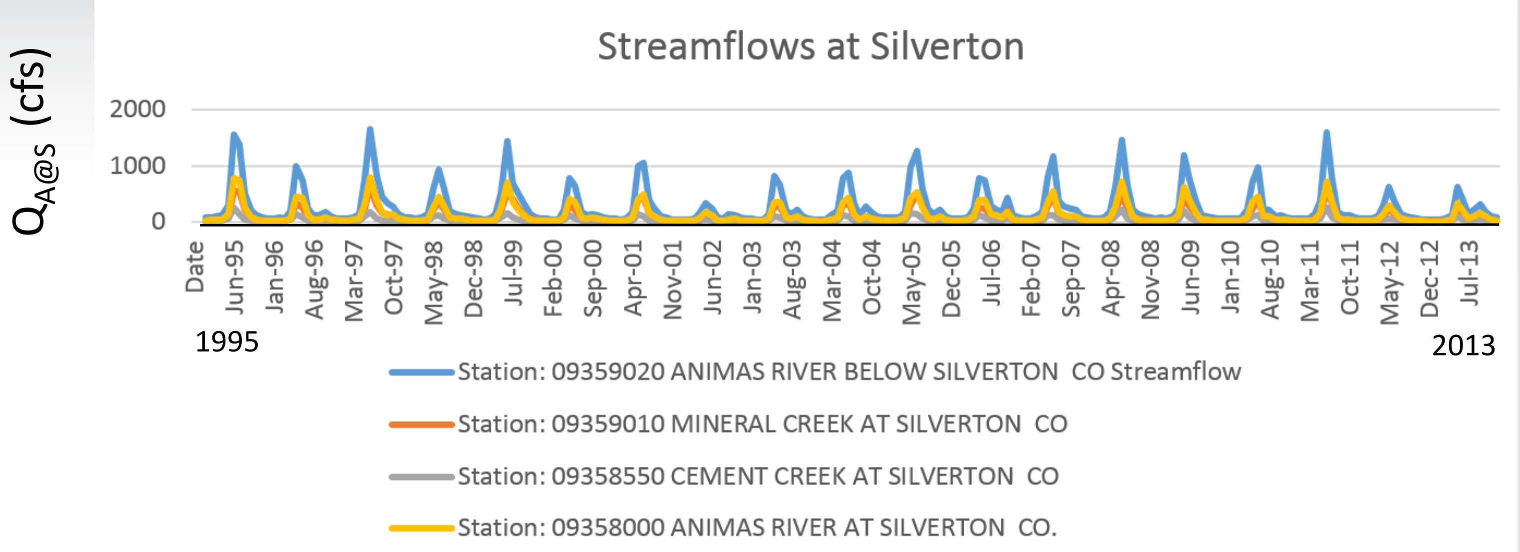
used the USGS Groundwater Toolbox

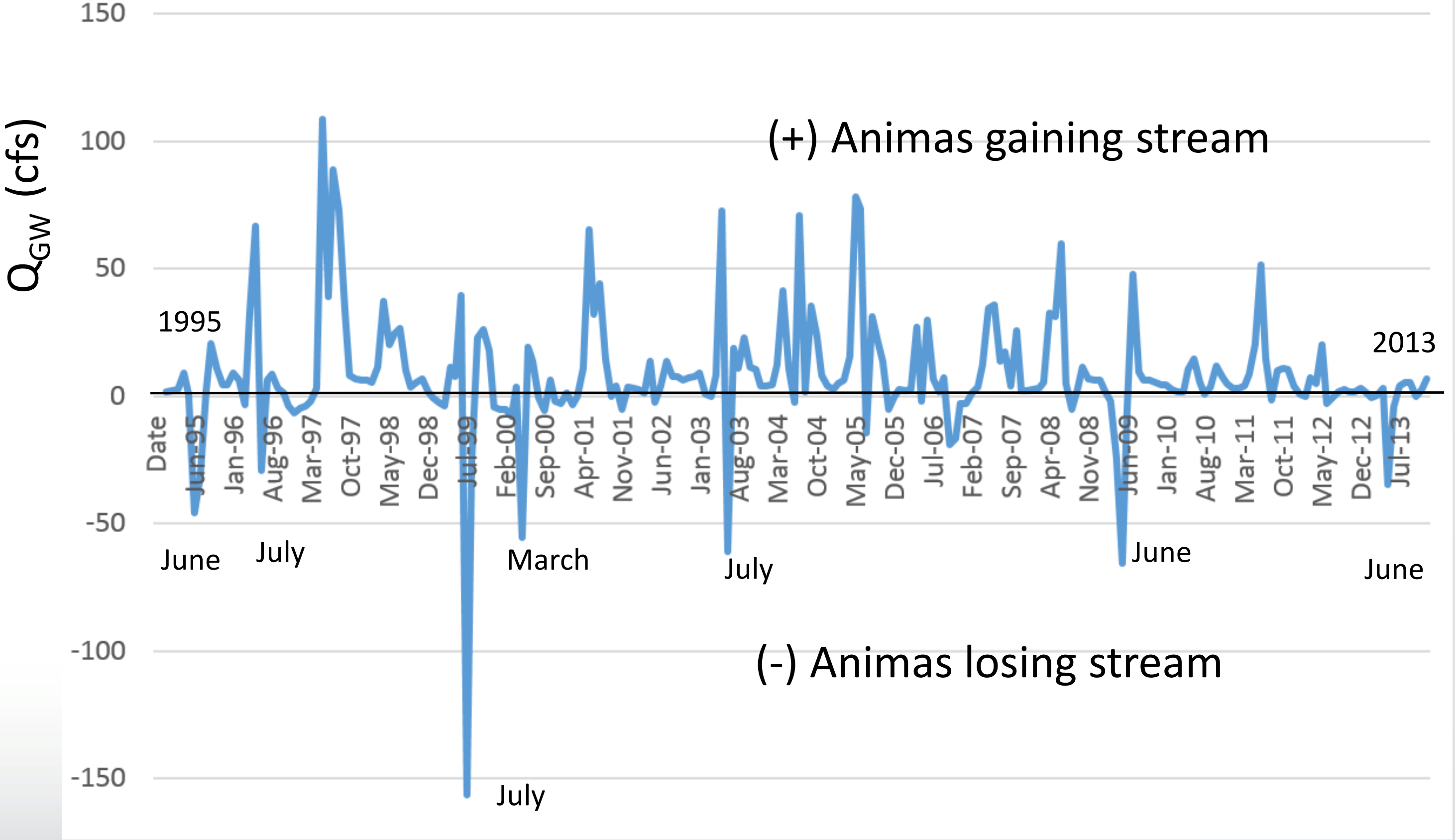
late spring---early summer snowmelt drives the annual river hydrograph

max groundwater inflow about 10% max streamflow

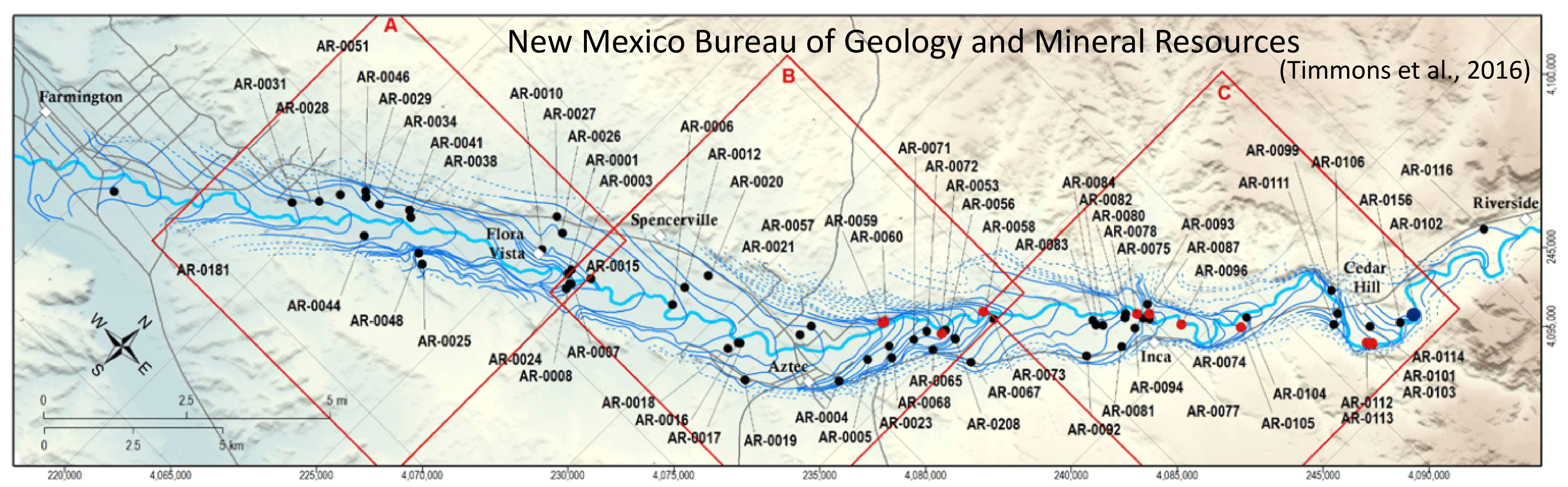
most of the time this region of the Animas River is a gaining stream, receiving inputs from groundwater along its length.

Note: occasional summer shift to net losing segment as aquifer fills and drains





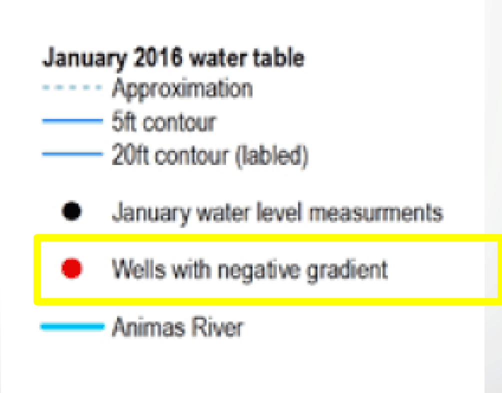
Groundwater/Surface Water interactions of the Lower Animas River



Lower Animas River can be a gaining or losing stream

Evidence of localized and transient losing sections of the Lower Animas River between Riverside and Farmington based on high resolution synoptic mapping of well water levels and river water levels during "baseflow" conditions of January 2016

The wells with negative gradient located close to the river



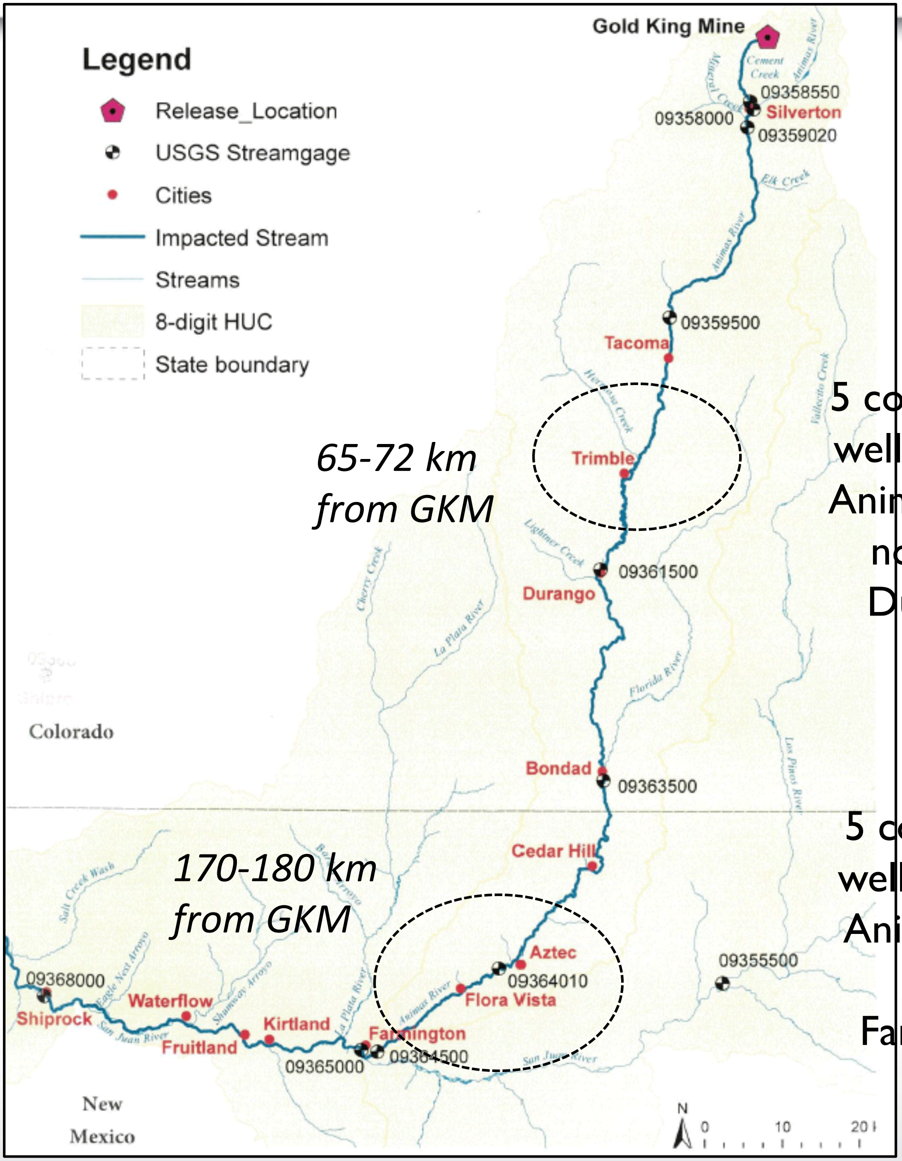
Computer Simulation for Understanding Potential Vulnerability of Water Supply Wells to River Chemicals

Initially looked for consistent *larger pumper* floodplain wells (the community wells) since considered more vulnerable and had publically available data (drillers logs, pump test)

Two clusters emerged, mid-Animas and lower Animas ---- no community wells in the upper Animas below GKM even though that is close to the source

Continued with the mid-Animas and extended the population of wells to include the *smaller pumper* floodplain wells (the domestic/household wells)

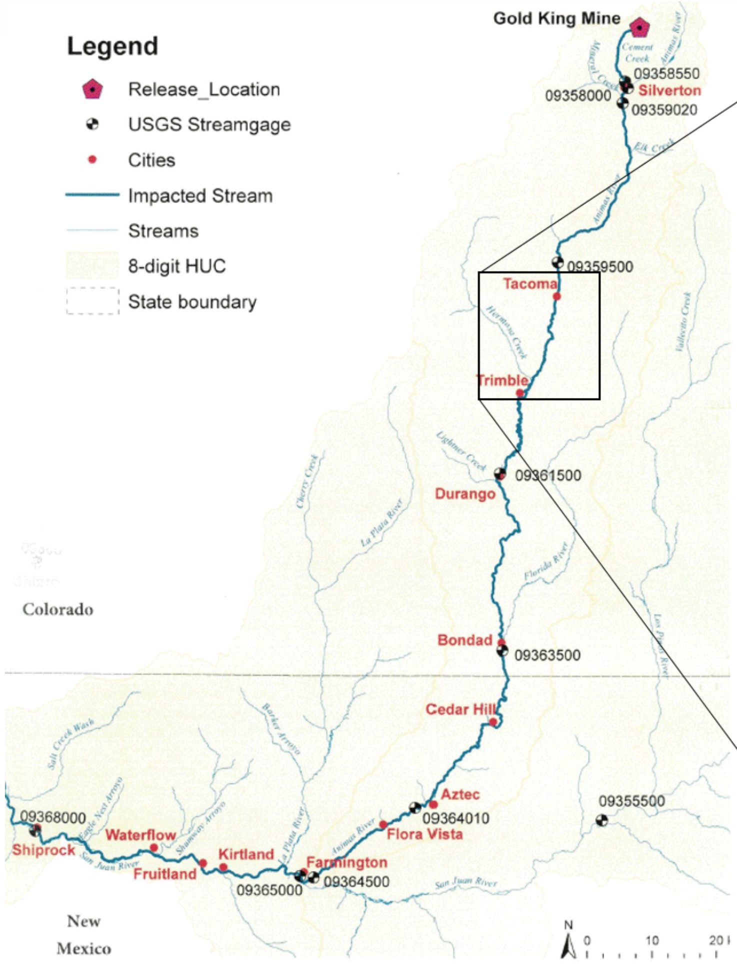
After completion of the mid Animas analyses will repeat in the Lower Animas.

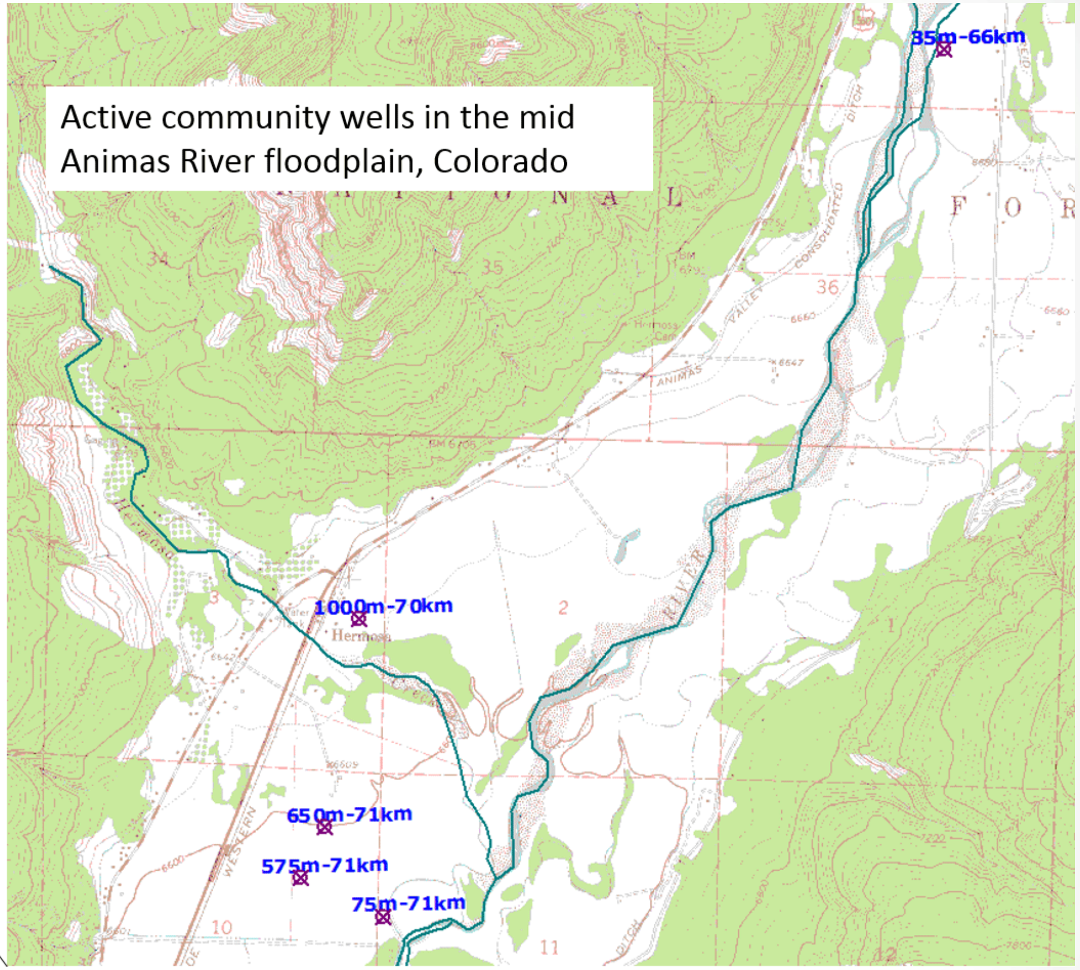


5 community wells in mid-Animas River north of Durango

5 community wells in lower Animas River Aztec, Farmington area

Community wells expected to be the larger and more consistent pumpers

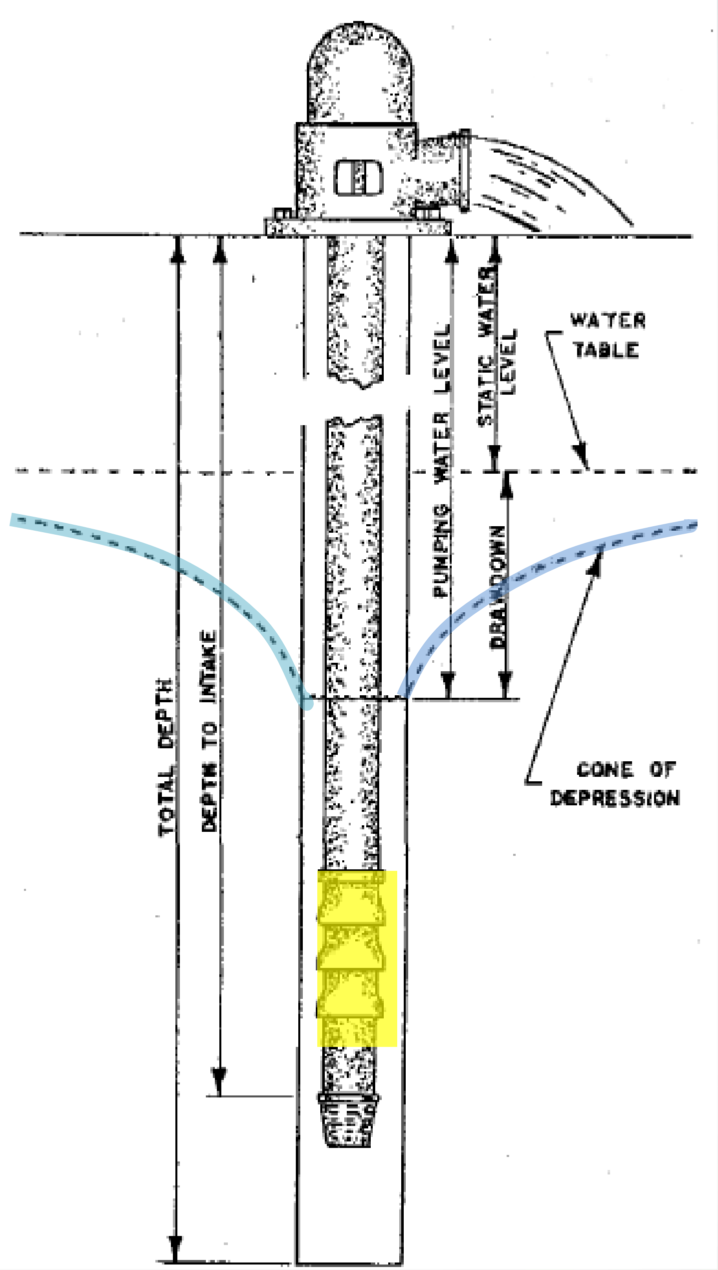




* Our project ID for the public water system wells embeds distance from river in meters and downstream from GKM in kilometers, as estimated using publically available UTM (x,y) location information.

Our study relied on publically available data
Example: community wells

Project ID*	Well Type	Total depth (ft)	Static water level (ft bgs)	Pumped water elevation (ft bgs)	Well yield observed (gpm)	Average annual well diversions (acre-ft)
35m66km	Community	100	22.5	25.0	480	56.4
75m71km	Community	87	10.5	13.5	445	145.74
575m71km	Community	210	18.2	19.3	100	139.38
650m71km	Community	120	24	28.75	400	162.65
1000m70km	Community	100	31.2	35.2	425	NA

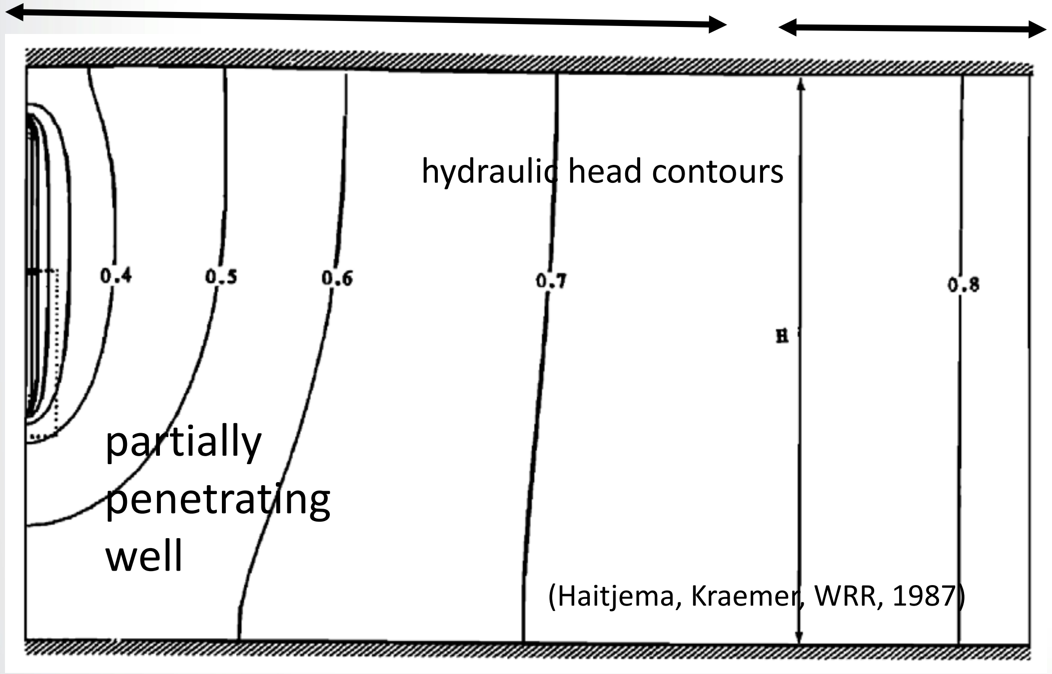


Step-wise Groundwater Modeling and Computer Codes

Evolving model complexity straightforward
Dupuit-Forchheimer deserves more explanation

- Near-field
- Heads vary with depth
- 3D flow
- Within 2H to 5H radial distance of well

- Far-field
- Heads constant with depth
- DF zone (horizontal flow)



aquifer cross section to scale

Conceptual Complexity	GFLOW	MODFLOW
Single Layer aquifer (piecewise homogeneous properties, horizontal base elevations, point sinks for wells, line-sinks for rivers, line-elements for ditches, area elements for zoned recharge and aquifer properties)	☑	
Dupuit Forchheimer assumption (neglect resistance to vertical flow; hydraulic heads constant with depth, horizontal 2D flow)	☑	
Non-time variant (steady state) stress and flow	☑	
Time-variant (transient) stress and flow		☑
Three dimensional flow		☑
Particle tracking (reverse – capture zones; forward – breakthrough response)	☑	☑

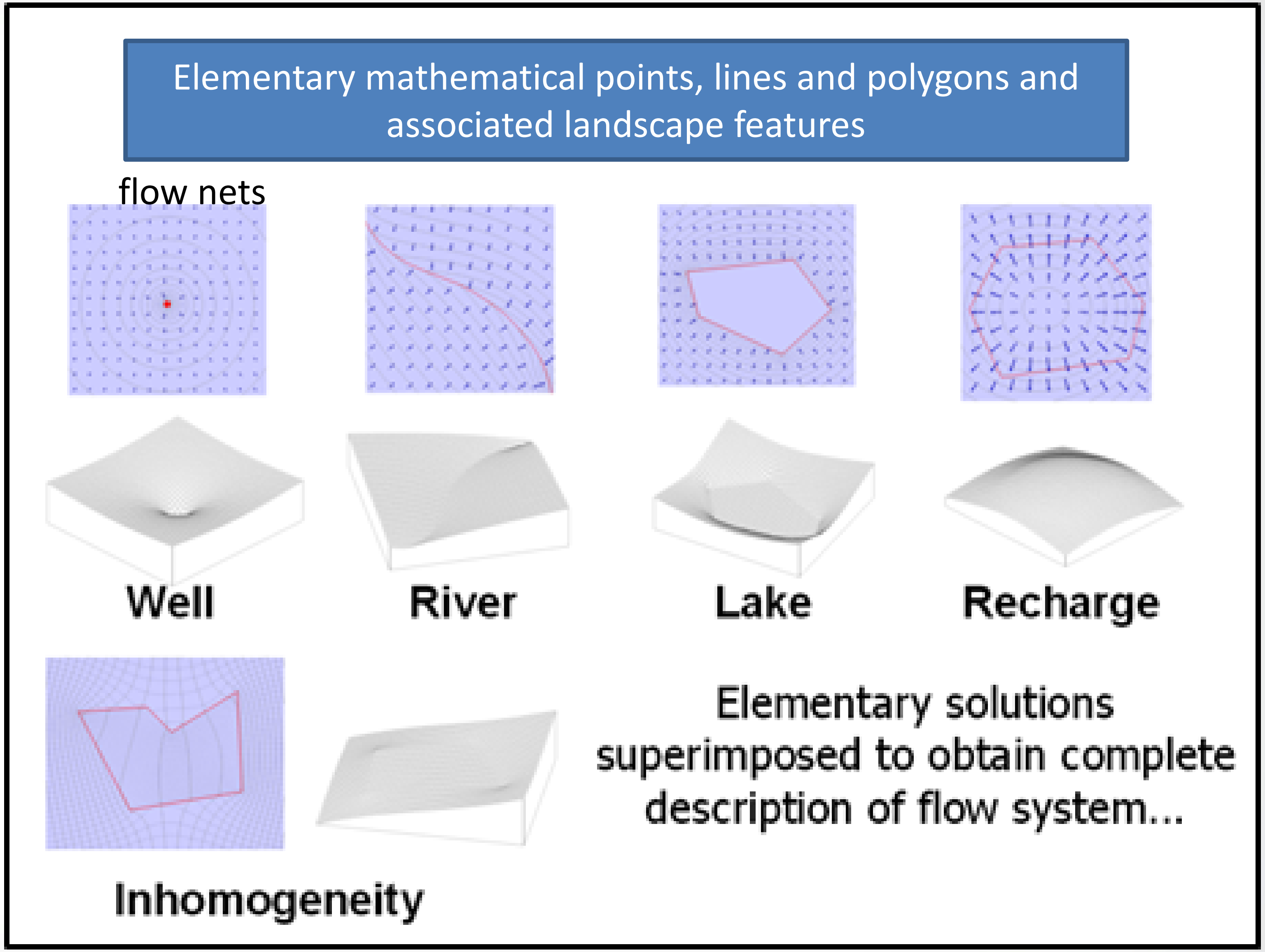
The essential elements of the regional groundwater model

We applied the software system GFLOW for groundwater modeling

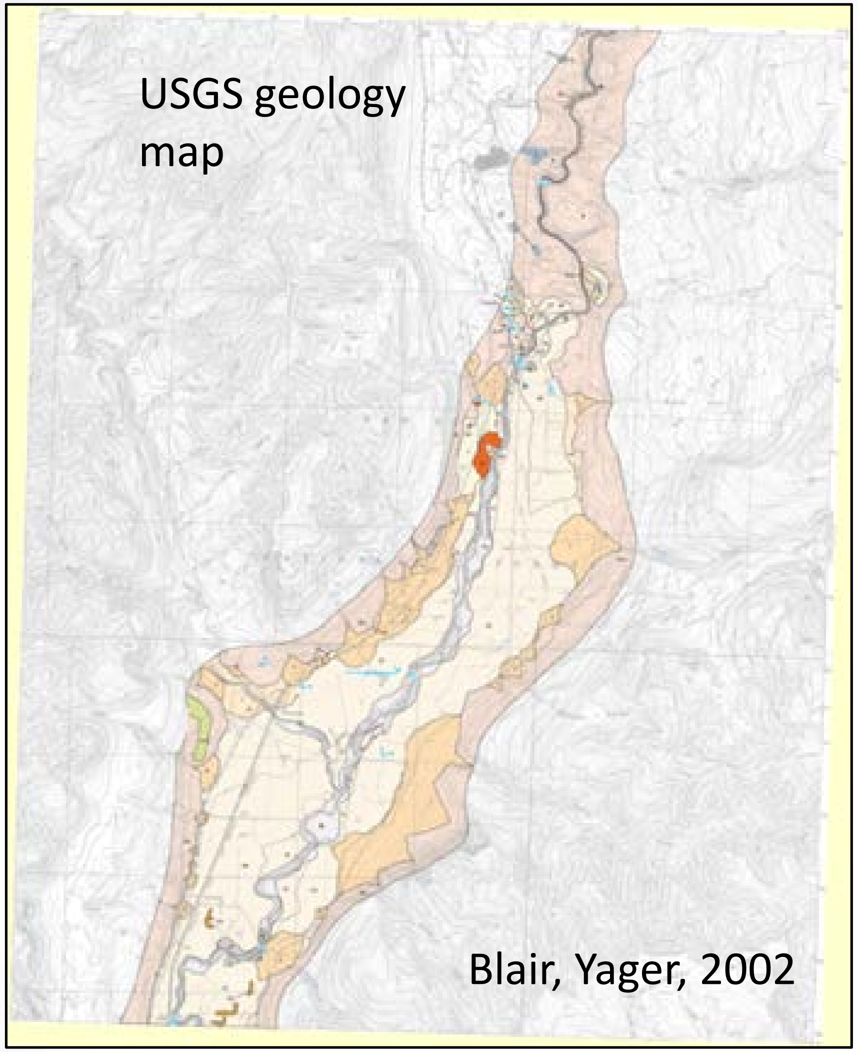
GFLOW has a package for establishing groundwater flow gradients relative to common topographic features

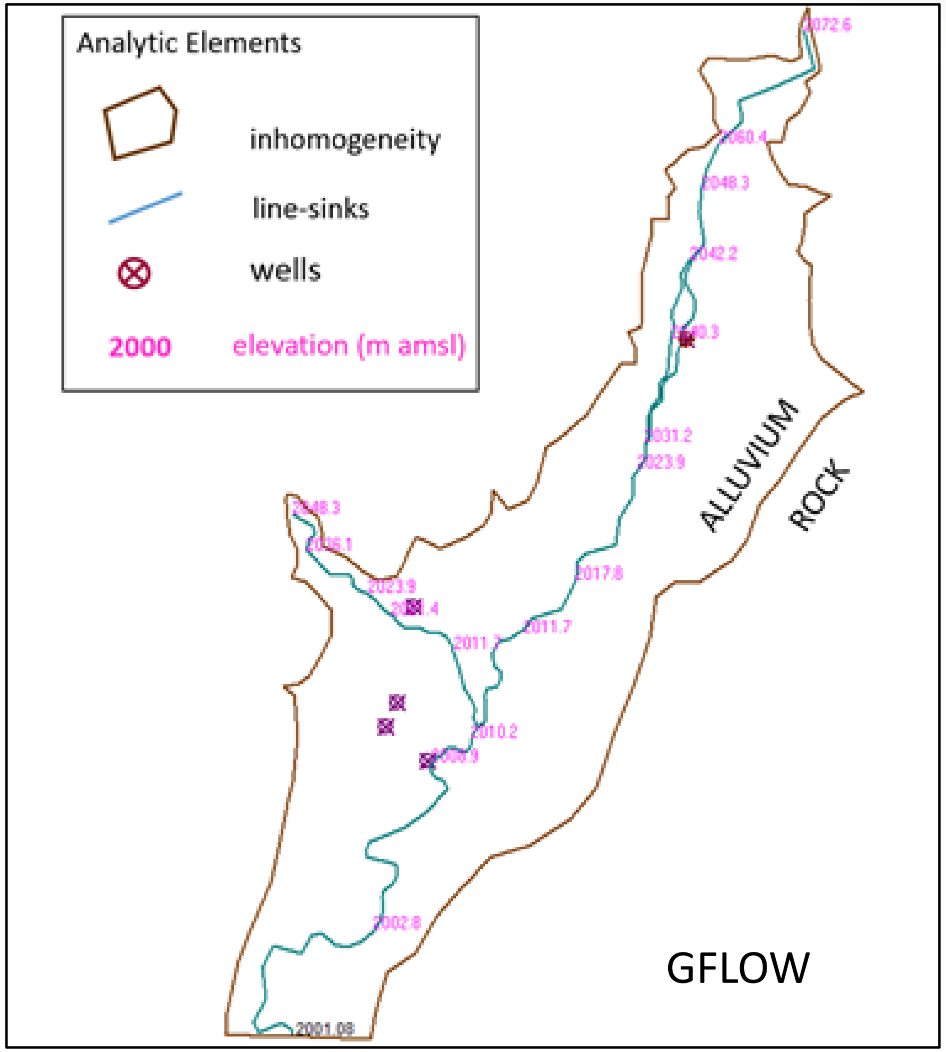
GFLOW allows for solving the groundwater-surface water interactions that helps establish gaining and losing streams as well as ephemeral and perennial streams

www.analyticelements.org



Generalized GFLOW model setup mid Animas River





The GFLOW basemap includes points of known topographic elevation to help parameterize the heads associated with the line-sink representation of the rivers.

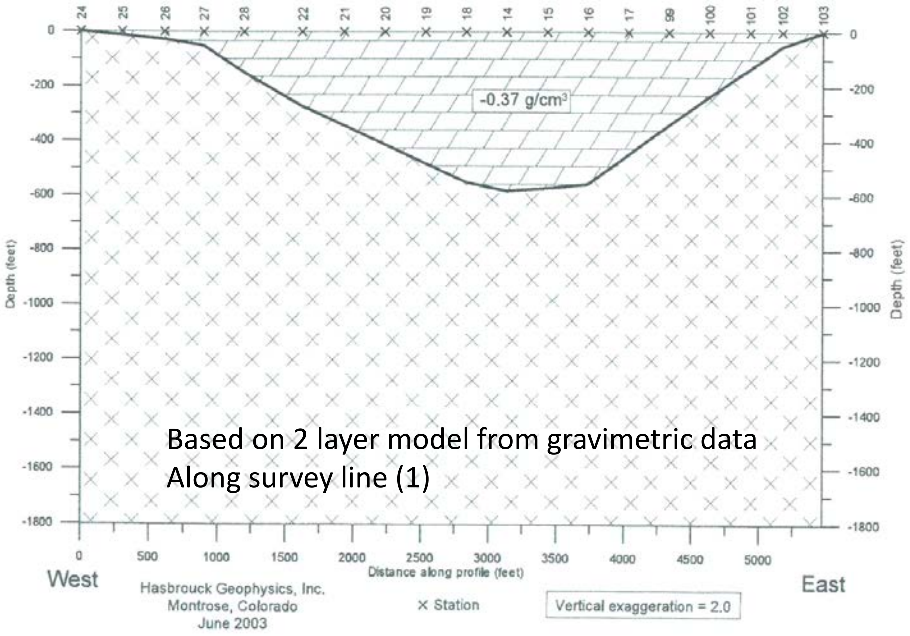
Regional groundwater model layout

Water balance is constrained by aquifer top, bottom and sides.

Top=land surface elevation, recharge boundary

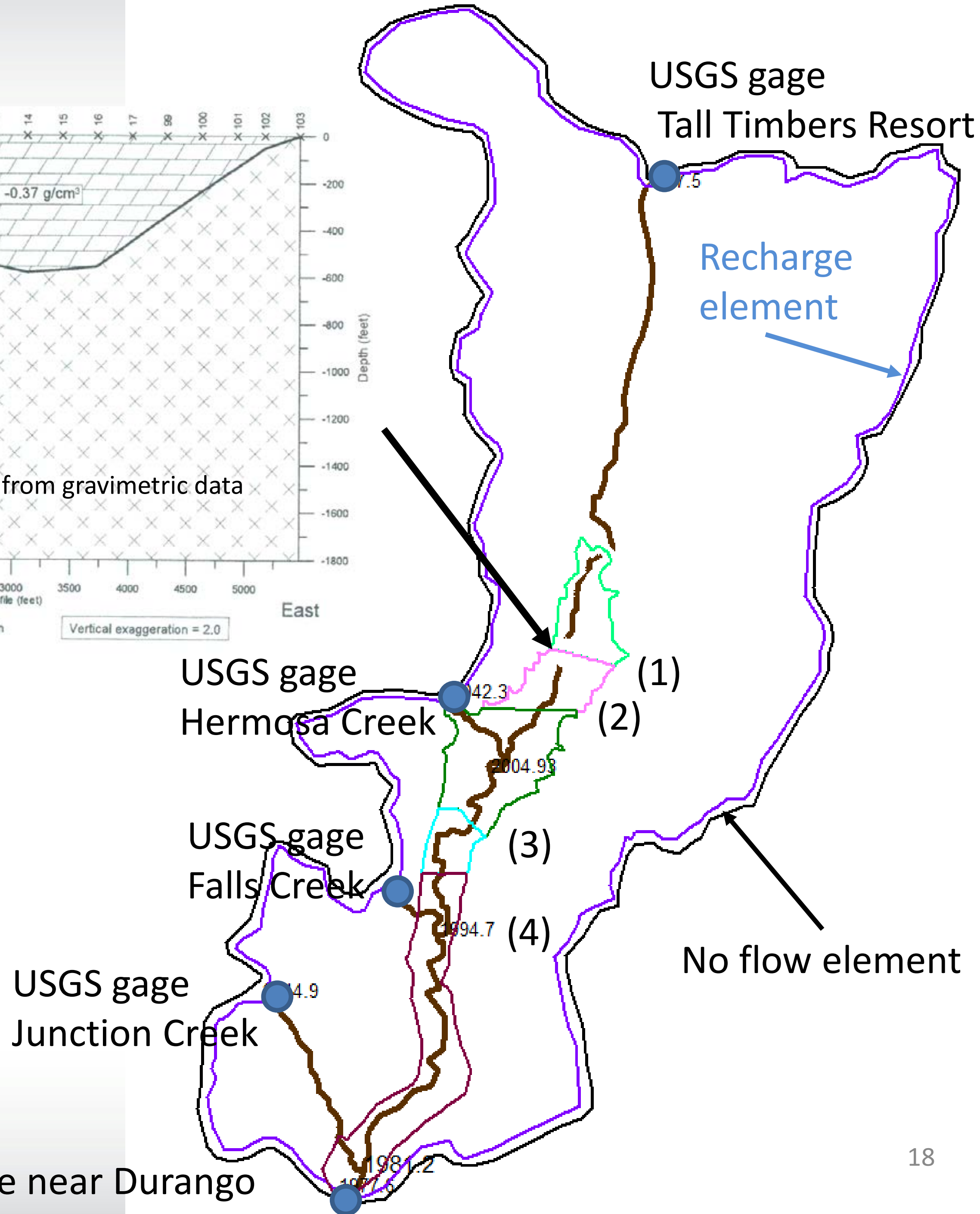
Sides= watershed boundary, no flow boundary

Bottom= bedrock basement, no flow boundary



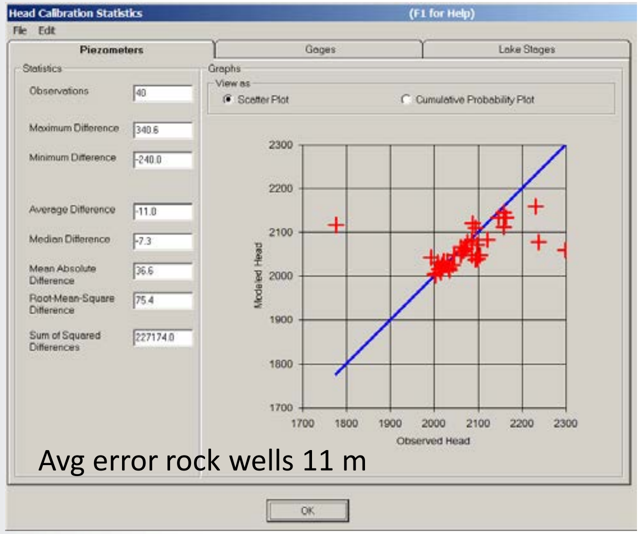
Supporting field observations:

- USGS streamflow measurements and model calibration on recharge over the catchment area
- Static water level elevations in water supply wells and model calibration on hydraulic conductivity
- Gravimetric survey of aquifer thickness at (4) cross sections and model representation of variable stepped base elevation

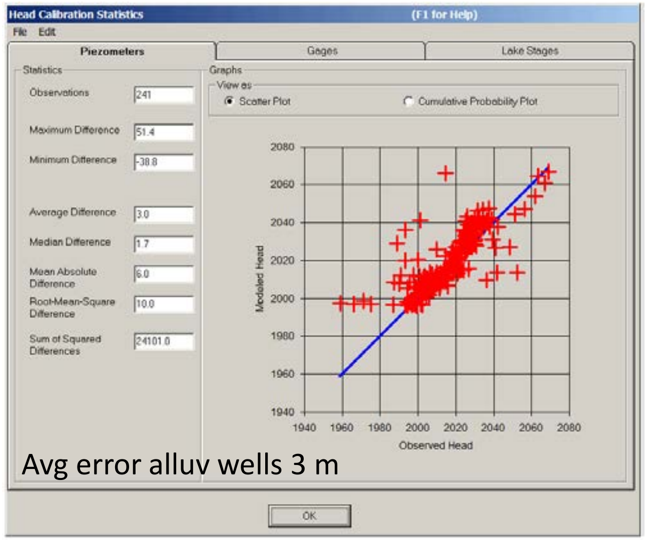


Resulting regional groundwater model parameterized to honor the field observations

Result of Calibration:
Hydraulic conductivity k_rock=0.2 m/d, k_alluv = 60 m/d
Areal recharge N = 0.000463 m/d = 6.6 in/yr



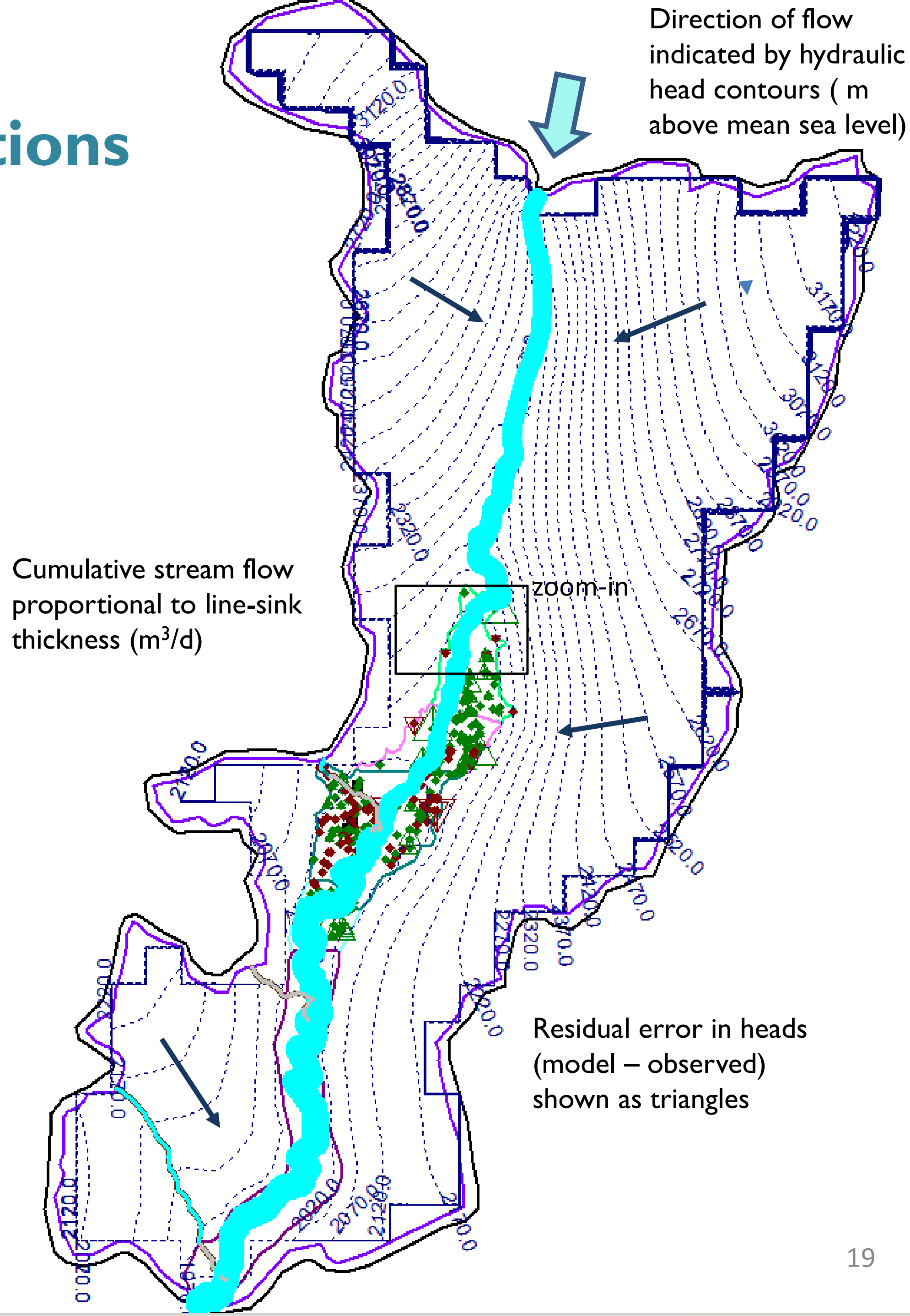
Avg error rock wells 11 m



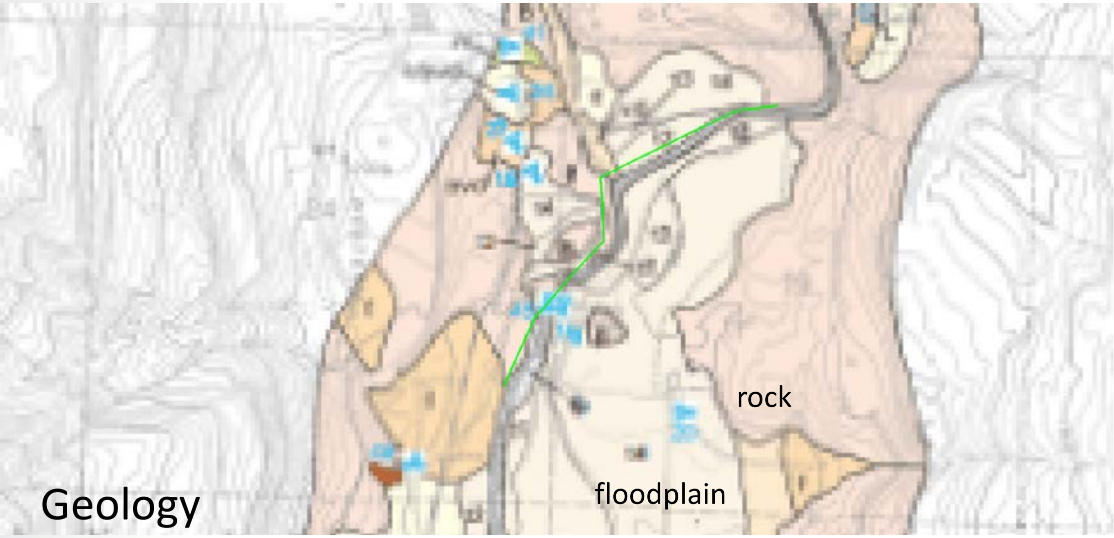
Avg error alluv wells 3 m

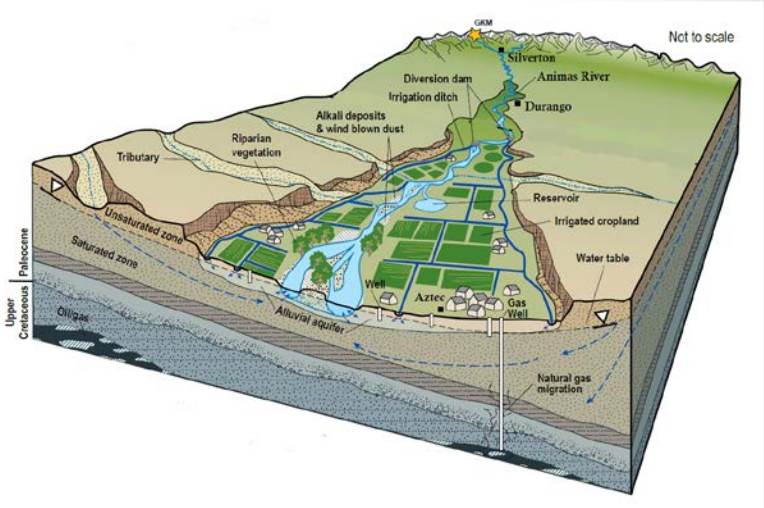
Some sources of uncertainty:

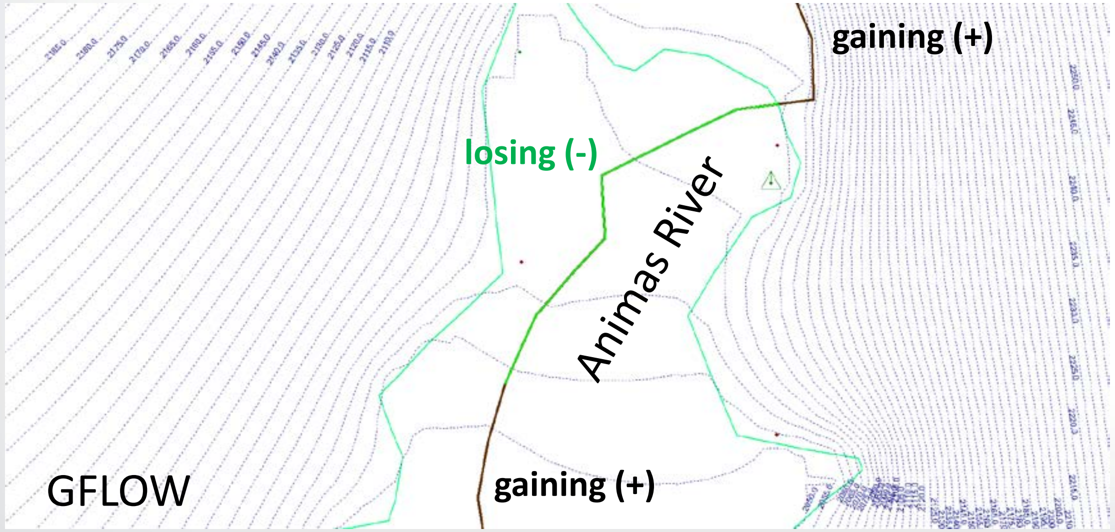
- Limitations in accuracy of the land surface elevation contributes to error.
- Non synoptic water level measurements in wells
- Location of wells



Zoom-in to regional groundwater solution mid Animas floodplain





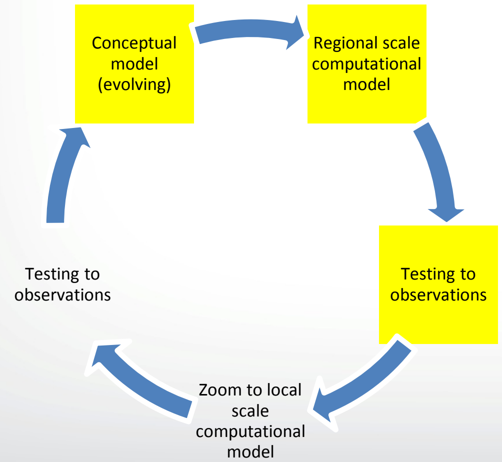


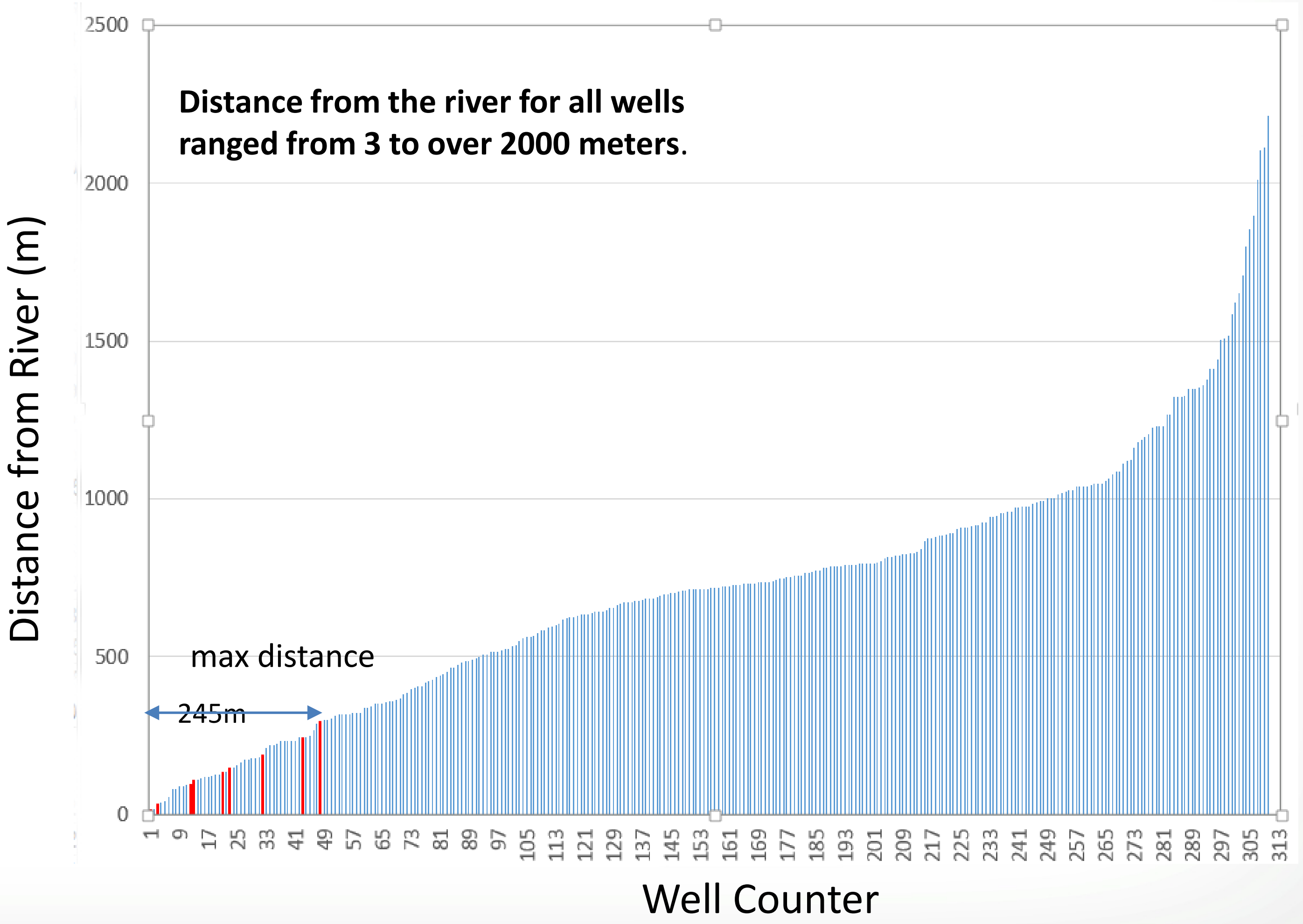
In this geomorphic setting the model suggests the Animas River water spills into and fills the subsurface alluvial floodplain aquifer

This hypothesized scenario has significant impact on the potential for wells to source river water.

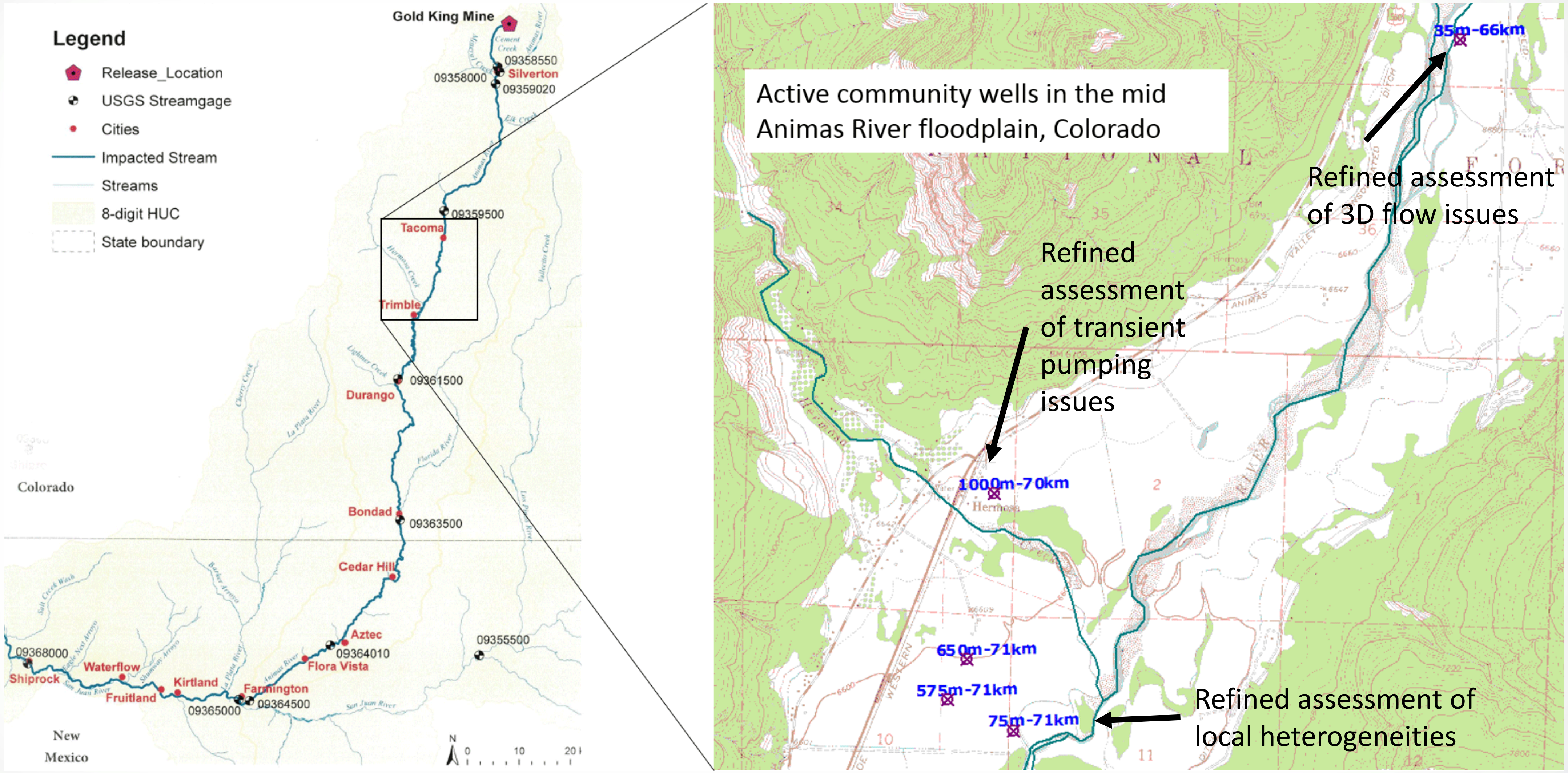
Well communication with the river

- not all factors considered by GFLOW modeling to date, results subject to change
- preliminary results suggest some wells closer to the river source from the river, but not always
- proximity not necessarily a determining factor
- influence of local scale irrigation ditches not accounted for yet





Selected community wells will be used for investigation of influence of complexity (3-D, transient, heterogeneities)



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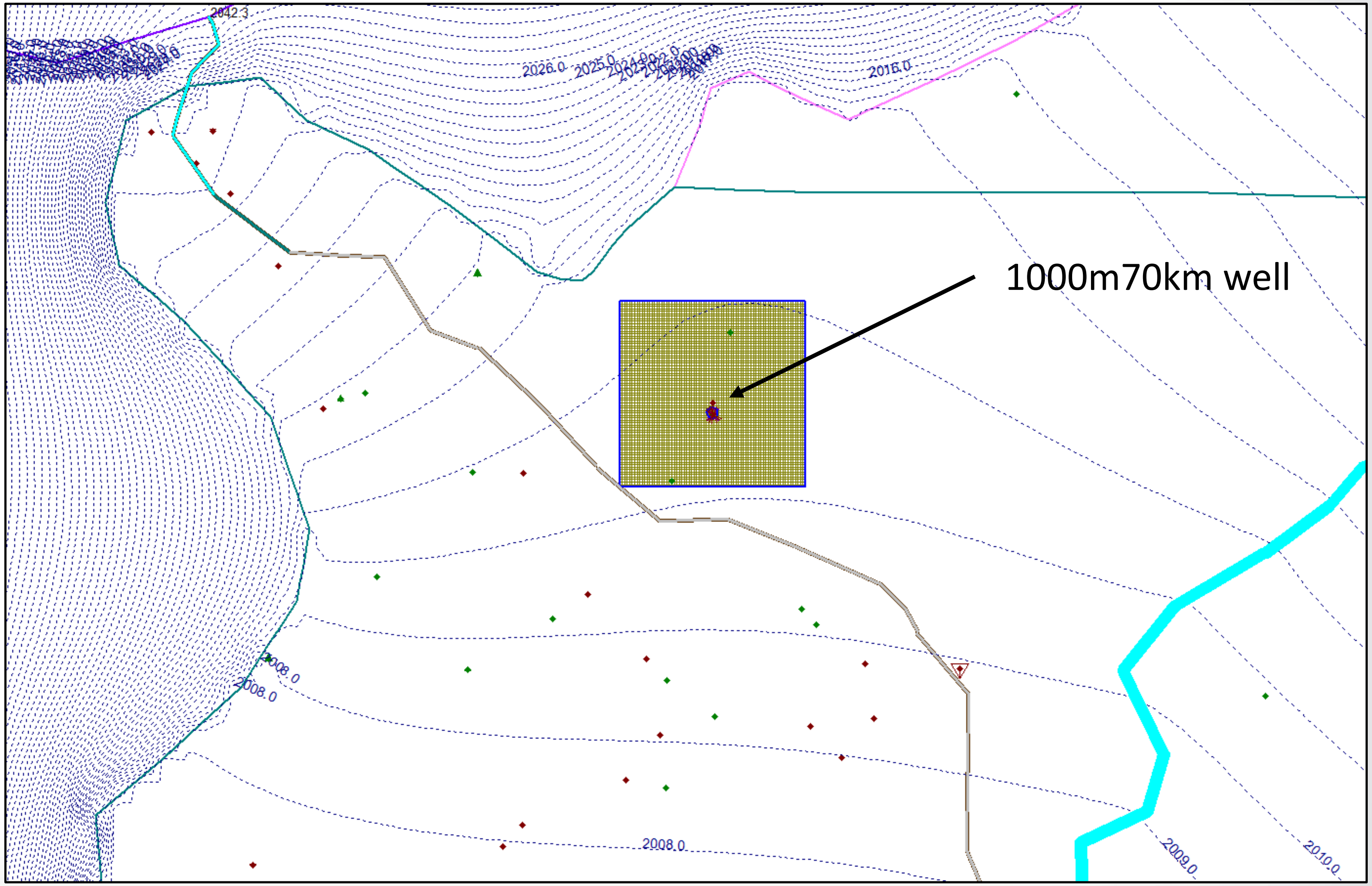
Preparation for transient analysis



GFLOW to MODFLOW
Grid Extract
Fixed heads on outer boundary
Initial condition heads for internal cells

Community Well Transient Pumping

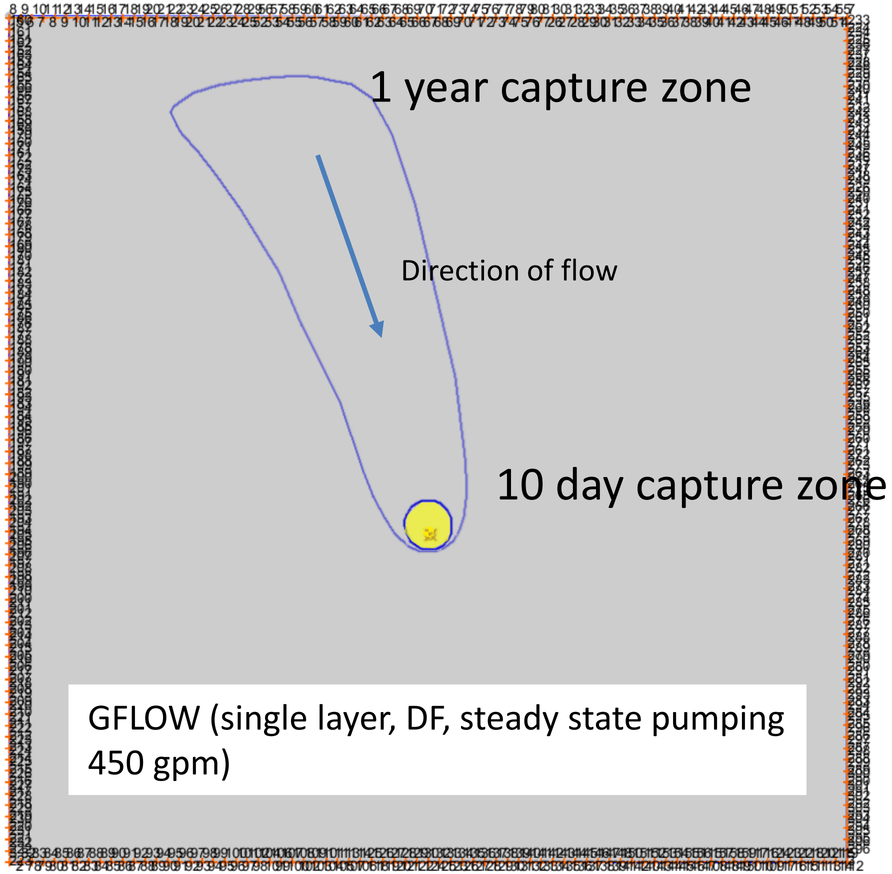
Local MODFLOW m
community well 1000
calibrated based on 7
test data

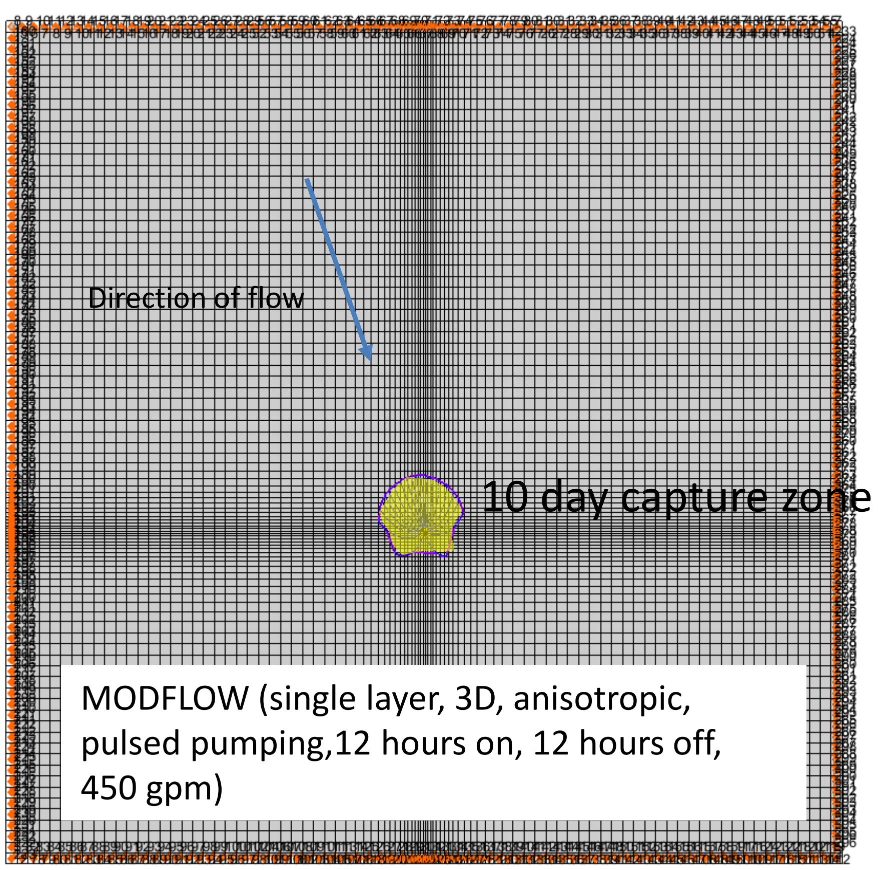
Variables were the lo
anisotropic hydraulic
specific yield

Representative pump
simulated, 10 days of
on 8am-8pm, off rest

table

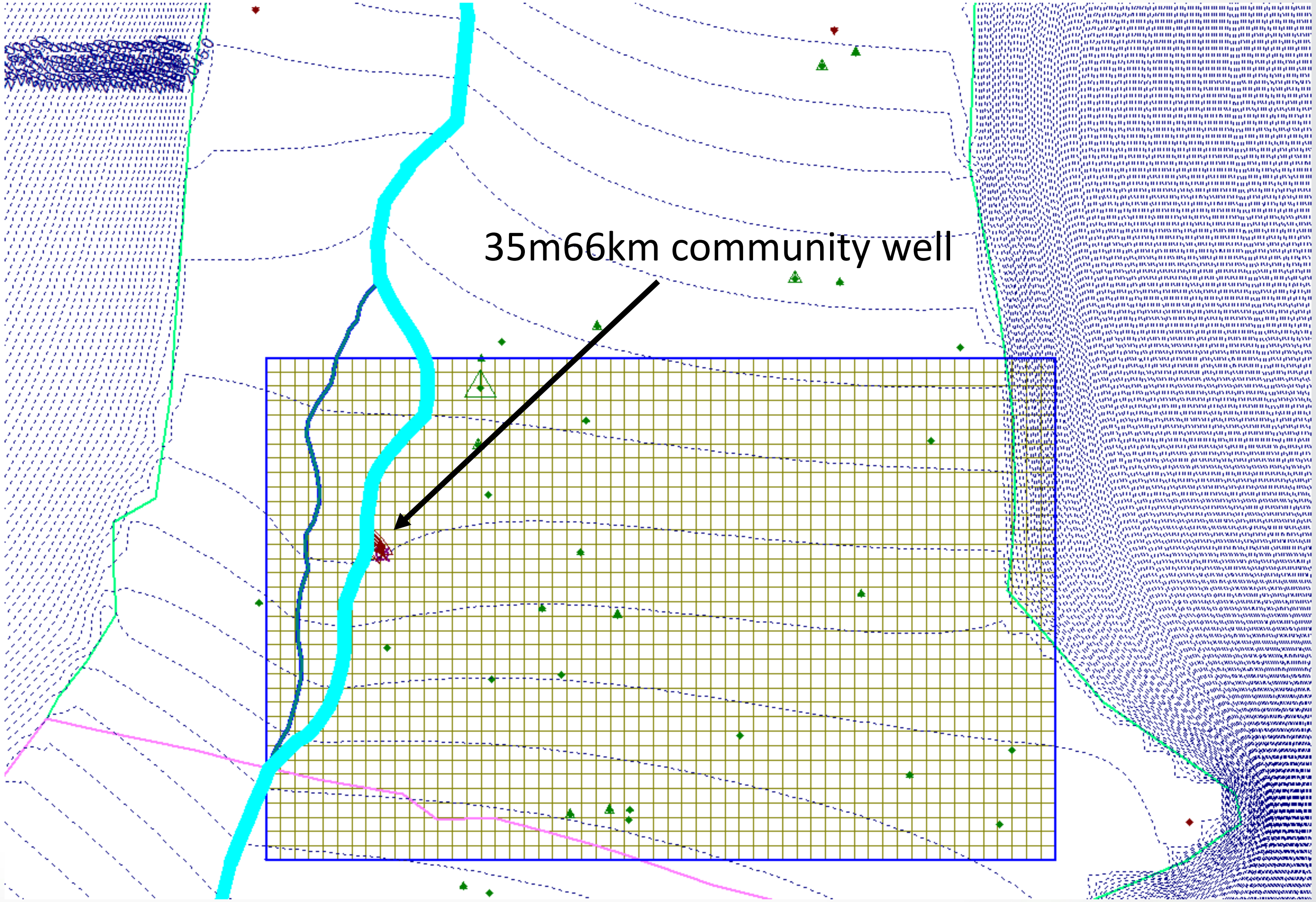
Influence of transient pumping on the capture zone





The preliminary model suggests the influence of pulsed pumping exists, and that the pulsed capture zone may be larger than the steady pumped area. In this case the pulsed upgradient radius is 1.8 X longer; the pulsed area is 2.9 X larger. The reason is not understood; possibility of numerical dispersion.

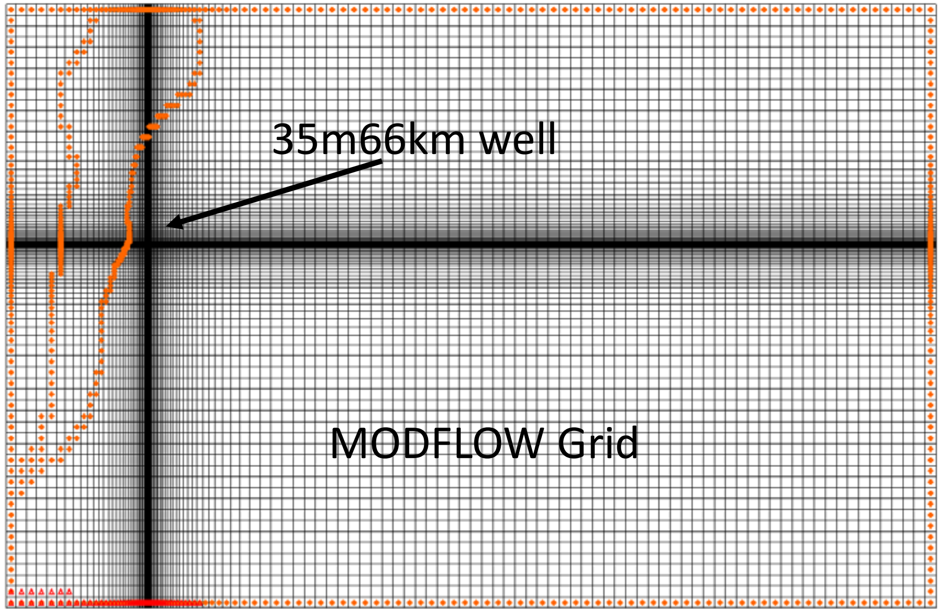
Preparation for three-dimensional flow analysis



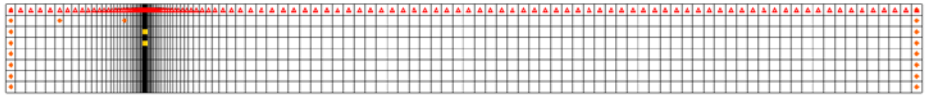
GFLOW to MODFLOW
Grid Extract
Fixed heads on outer boundary
Initial condition heads for internal cells

Discretization of space for the 35m66km community well

plan view



xsection



Refined numerical grid to capture details in nearfield pumping well

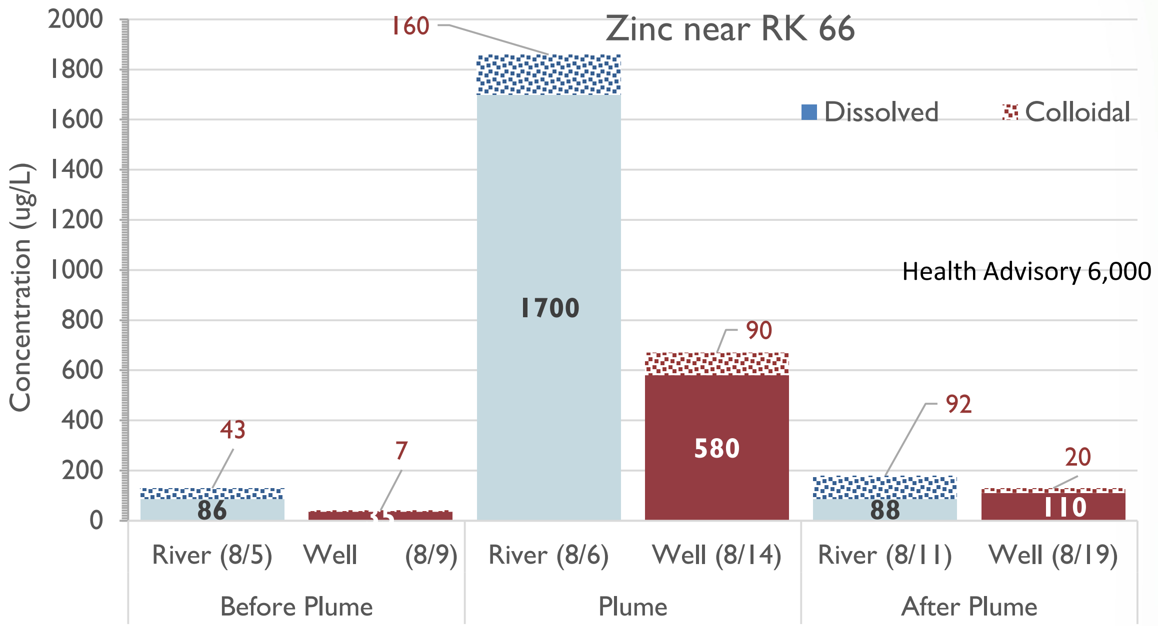
Note that for this scale of MODFLOW simulatio the aquifer is relatively thin.

10 cells in the z-direction

GMS MODFLOW

Will computer modeling be useful to understand the potential communication of wells with the plume?

- **The empirical evidence for this community well suggests capture of the river plume water with breakthrough including day-8 post plume passage**
- **This early breakthrough time has not been simulated/explained yet by preliminary modeling (modeling suggests later breakthrough).**
- **Modeling continues …**



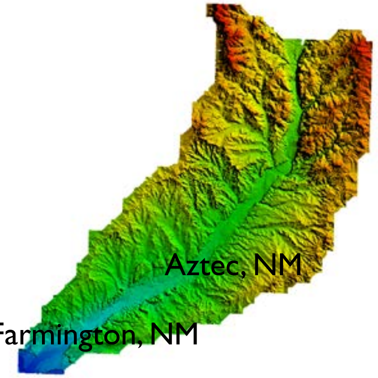
(CDPHE, 2015)

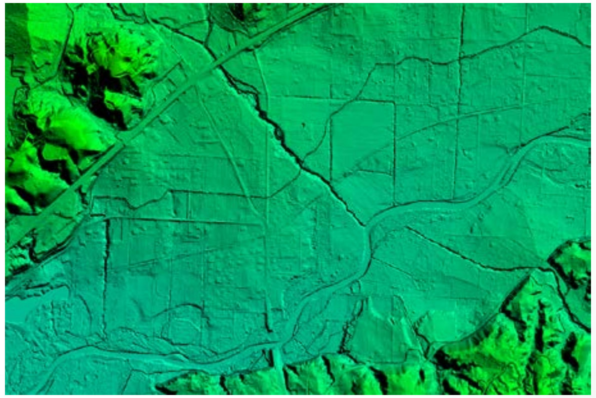
Community well near Durango within 35 m of river

Ongoing groundwater modeling work

- **Continuing to try to improve local parameterization for the 75m71km community well in the mid Animas River floodplain to refine prediction:**
  - **Exploration of influence of local heterogeneities (buried oxbow channels) on capture zone**
  - **Irrigation ditch influence**

- **Lower Animas River floodplain community wells analysis (170-180 km downstream of GKM)**
  - **Collaborating with New Mexico agencies who produced and supported the recent floodplain well and groundwater report**
  - **Continuing to refine the regional well solution to study capture zones and potential sourcing from the river (influence of ditches, influence of irrigation) using new data**





Lower Animas LiDAR elevations (1m resolution)

Summary of groundwater analysis to date

- There are hundreds of water supply wells in the floodplain aquifers of the Animas River, ranging from continuous higher volume pumpers (the community wells) to the lower volume pumpers (the domestic/household wells); there are also the seasonal intermediate pumpers (the irrigation wells)
- Animas River is overall a gaining stream; locally, some locations may be gaining or losing at any particular time or flow; floodplain geomorphology and irrigation ditches may be an important factor
- The preliminary modeling suggests that a relatively small number of mid Animas River floodplain wells source from the river during the flows that were modeled
- Analysis is continuing with an exploration of local scale heterogeneities and influence of irrigation ditches
- The recent New Mexico Bureau of Geology and Mineral Resources study may provide the type of high resolution topography and synoptic water level data that could help in calibration of lower Animas River models and contribute to overall groundwater systems understanding
- Understanding based on model testing with empirical observations

Denver Post.com

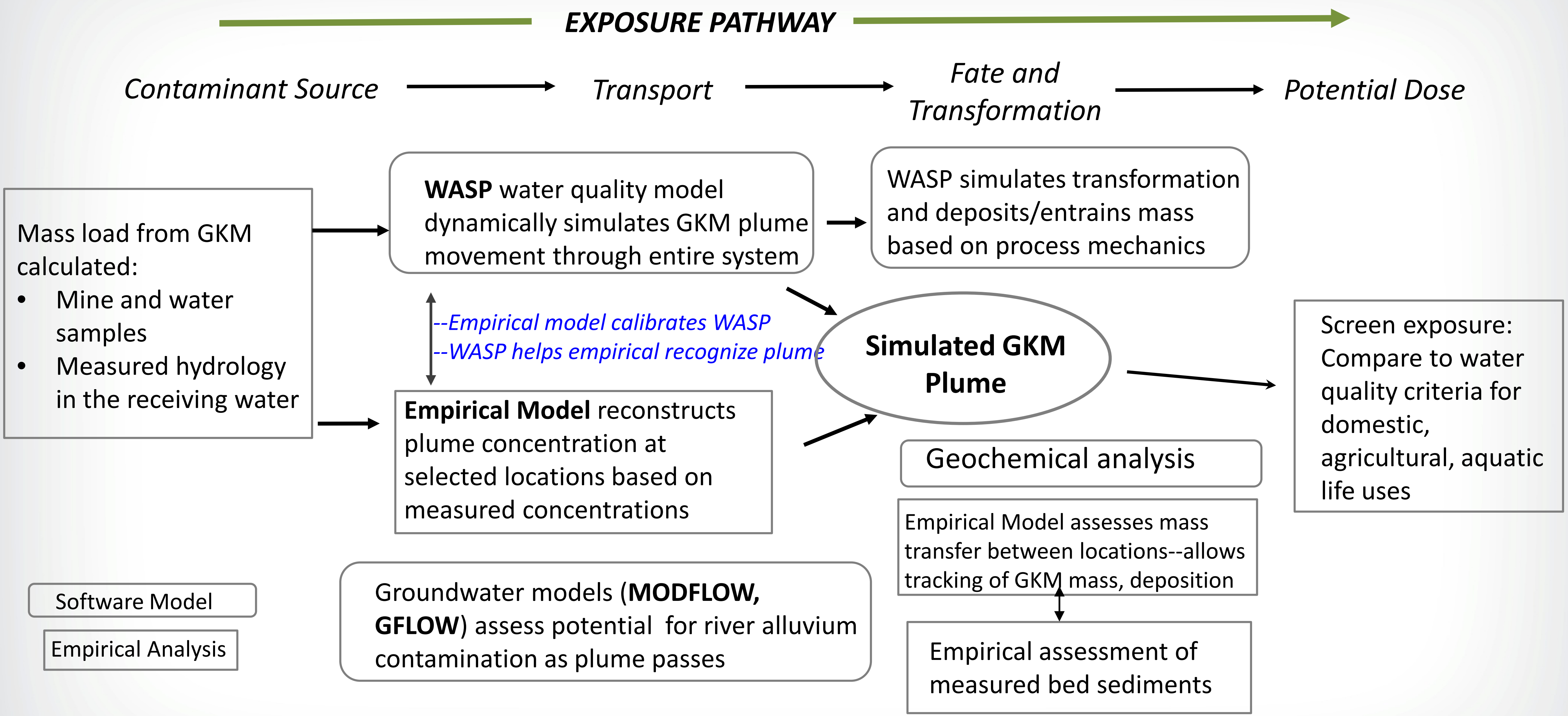
SUMMARY of Gold King Mine Project Findings

Research Objectives

Specific research objectives:

- Quantify the release from the Gold King Mine
  - Contaminants
  - Volume and timing
- Characterize transport and fate of AMD in Animas and San Juan Rivers
  - Surface water
  - Sediments
- Quantify water quality impacts
- Near term
  - Longer term
- Characterize potential exposure to AMD for various water users, including municipal wells
- Advise future monitoring priorities

GKM Analysis Road Map



Preliminary Key Findings—Animas River

- **The load of metals released from the Gold King Mine increased significantly as the mine water traveled between the mine and the Animas River;:the rate and volume of flow scoured additional metal load from the hillslope and streambed delivering about 490,000 kg of metals to the Animas.**
- **The GKM plume travelled downstream as a coherent mass at approximately 3 kilometers per hour whose maximum concentrations decreased as it travelled due to dilution, geochemical neutralization that transformed dissolved metals to solids causing the intense yellow color, and deposition.**
- **Most of the colloidal/particulate* metals (~90%) deposited in the Animas River in the river reach between Silverton and Durango. Although a large mass of metals was deposited in the Animas River, sediment concentrations in the streambed did not increase significantly due to the large pre-existing contamination from ongoing acid mine drainage throughout the Animas headwaters.**
- **Water quality returned towards background levels quickly after the plume passed, although there were some adjustments in water chemistry characteristics in the months following the release which could arise from a variety of causes; water quality criteria were not exceeded.**
- **Metals concentrations are related to streamflow, and high flow events after the GKM plume have increased medals load in the river following similar patterns as observed in USGS studies in the Animas in the 1990's. Masses carried in these storms have exceeded the GKM metals mass. On-going monitoring will target stormflow to improve understanding, but this analysis suggests it will be difficult to separate GKM from existing and ongoing contamination.**

** As pH increases, iron and aluminum oxides precipitate and clump together as solids-- we refer to as "colloids"*

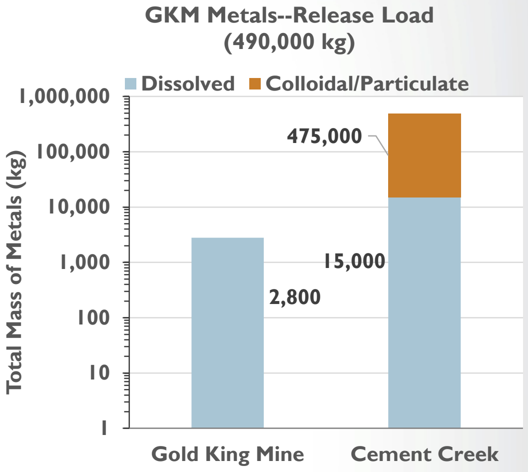
Preliminary Key Findings—San Juan River

- The GKM plume entered the sediment-rich San Juan River at Farmington where the plume metals were mixed with a large metals load in the river associated naturally with the sediments
  - 45,000 kg of colloidal/particulate metals were delivered to the San Juan River by the GKM plume
  - For most metals, the concentrations in the two rivers during plume transitions were similar or lower in the Animas
  - Background metals mass was far in excess of what GKM delivered, with the exception of colloidal/particulate lead (~420 kg) and selenium (5 kg)
- Metals concentrations in the San Juan River appear to be strongly related to sediment concentrations and increase proportionately with flow during storms
- At the same time, metals concentrations in the streambed of the San Juan are much lower than the Animas
- Analysis to date suggests that GKM metals probably did not settle in the San Juan until Lake Powell
- Masses carried during the GKM plume and in each post-event storm have exceeded the GKM metals mass
- On-going monitoring will target stormflow to improve understanding, but this analysis suggests it will be difficult to separate GKM related metals from those in existing river sediments

GKM Source

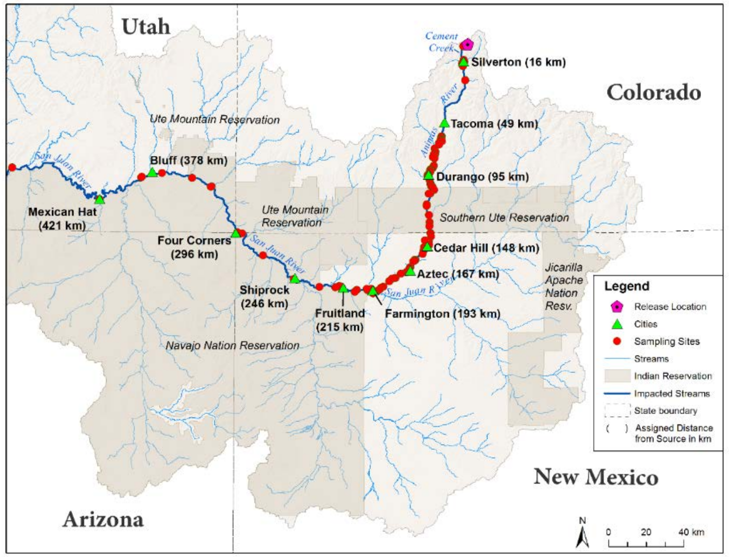
How much mine waste was released and what was its composition?

- The Gold King Mine released approximately 3 million gallons of low pH acid mine drainage and 490,000 kg of dissolved and colloidal/particulate metals into the Animas River on August 5, 2015
  - The mine itself produced a relatively small amount of metals mass (2,800 kg)
  - Most of the material was entrained between the mine entrance and in Cement Creek before reaching the Animas River in Silverton



Where did material in the release volume go?

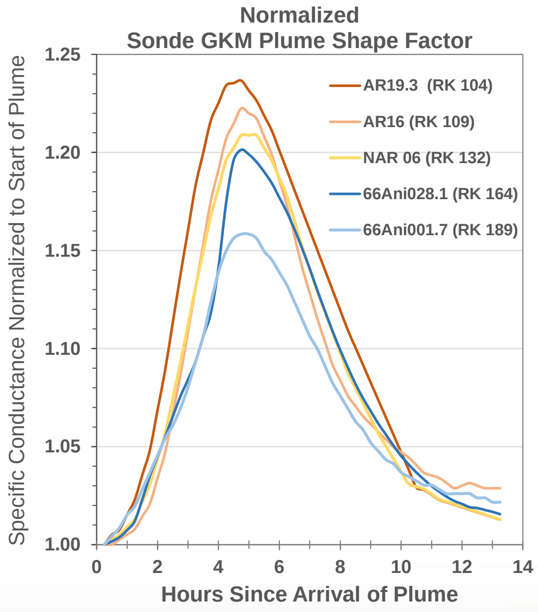
- In the subsequent days, federal and state agencies, tribes and municipalities mobilized to collect water and sediment samples for a variety of purposes to help them manage public exposure to the contaminated waters as the plume traveled 600 km through the Animas and San Juan Rivers
  - These data provided considerable information to analyze the transport and fate of metals in the affected river system
  - The study was augmented by software and analytical models to represent processes involved in transport and transformation of mine products in this lengthy zone of influence

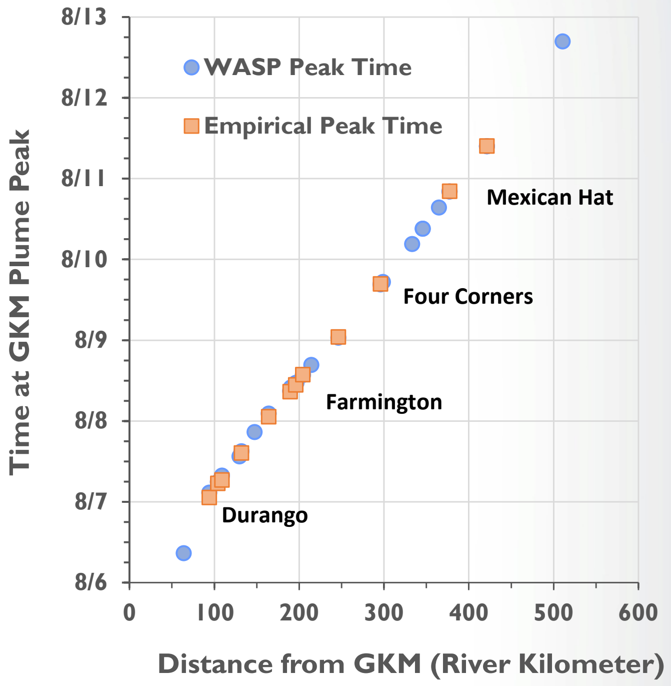


Characteristics of the Plume

Where did material in the release volume go?

- **The Gold King Mine release traveled downstream as a coherent plume of metals over a period of 8 days traveling at approximately 3 kilometers per hour**
- **For most of the metals mass in the plume to pass a location required from 20 hours near the source to 60 hours in the lower river reaches**
- **However, the majority of the metals mass travelled within a shorter 12-hour period, a length of time that persisted through much of the length of the river**

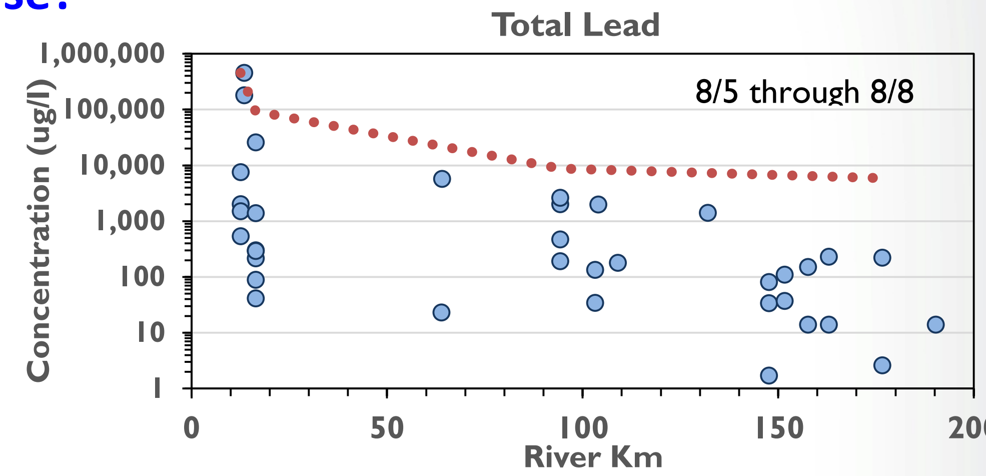


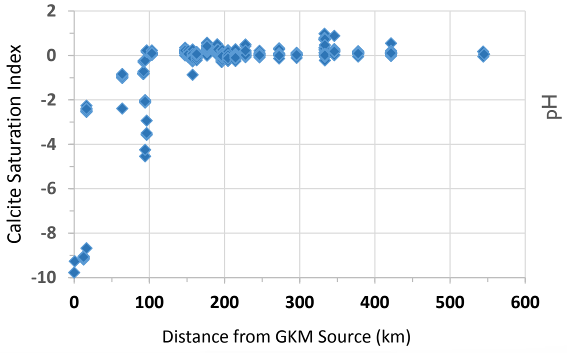


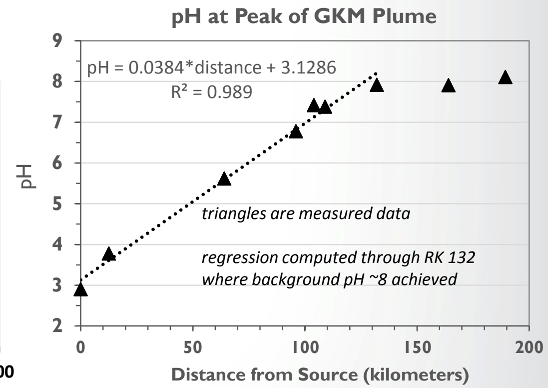
Water Quality During the Plume

How was water quality affected by the Gold King Mine release?

- **Concentrations of metals were exceptionally high near the GKM source and declined as the plume traveled down river**
  - Very high initial concentrations observed near the source generally declined by at least 2 orders of magnitude by the time the plume reached Durango (95 km from the GKM source)
  - The volume of acidity in the release carried acid mine drainage metals much farther downstream in dissolved form than typically occurs with the ongoing contamination
  - Dissolved metals reached background levels by the time the Animas joined the San Juan River
  - The rate of decline and distance of travel varied by metal
- **Decline in dissolved and total metals concentrations occurred for 3 primary reasons:**
  - Dilution from incoming flow to the river had a very significant effect, beginning almost immediately at Silverton
  - Geochemical reactions neutralized pH and transformed dissolved metals to solid forms we call colloids (sometimes called "sludge")
  - Colloidal/particulate metals were deposited in the river bed







Exposure Potential

What was the potential for water user exposure to metals released from the GKM?

- **The initial dissolved and total metals concentrations were very high near the GKM source in the Animas headwaters , creating the greatest potential exposure to adverse levels of metals as defined by the water quality criteria**
- **Decline in concentrations as the plume traveled significantly reduced potential exposure by Durango**
  - **Aquatic acute hours above criteria for several metals were potentially a problem from Silverton to Bakers Bridge**
  - **Chronic aquatic exposure levels were exceeded from the headwaters to Durango for a number of metals during the plume**
- **Metals exceedances mostly involved total rather than dissolved metals fractions**
- **Human, agricultural and livestock, exposure was minimized by agencies who curtailed water use as the GKM plume passed.**

Analysis in progress.

To date:

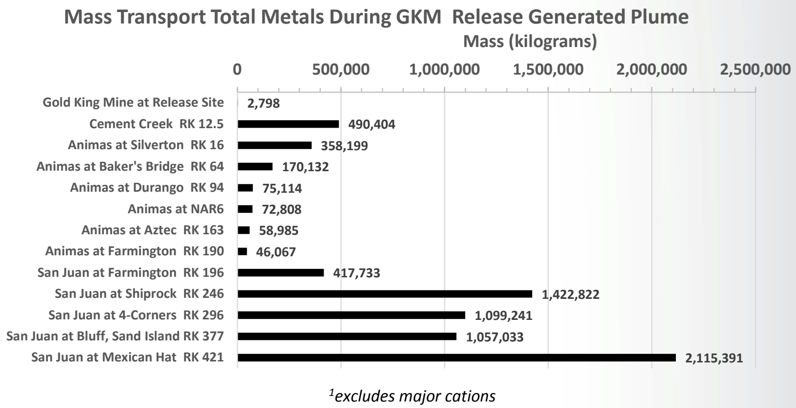
Similar results as reported in Mountain Studies Institute report on Animas River at Durango, March 2016

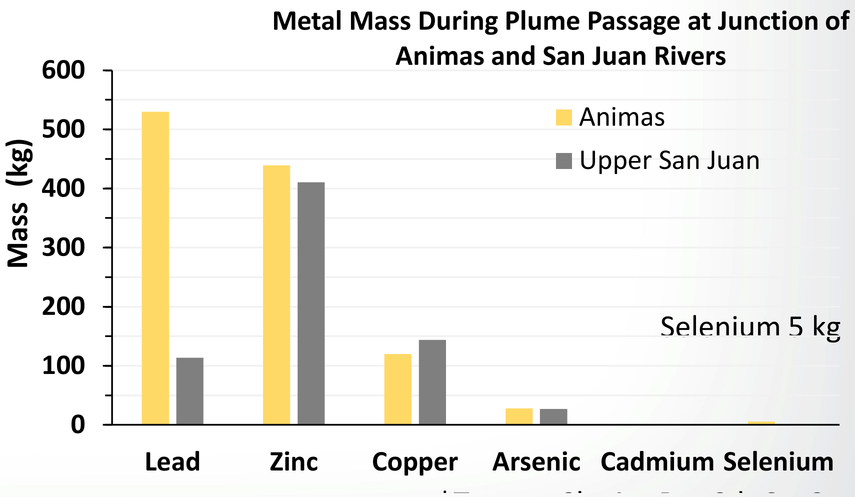
Utah DEQ Long-term Monitoring Plan, March 2016

Metal Mass Transport

Where did material in the release volume go?

- **Metals mas due to the GKM release declined as the plume moved downriver, indicating that the colloidal/particulates were deposited**
- **Most of the deposition occurred within the Animas River**
  - **Mass declined sharply in the upper and mid-Animas between Silverton and Durango**
  - **Mass continued to decline suggesting deposition through the lower Animas**
  - **The mass of metals in dissolved form was estimated to be at background levels by the time the Animas reached Farmington**
- **The GKM plume joined the San Juan River where flow and sediment concentration was high due to the release from the Navajo Dam**
  - **45,000 kg of colloidal metals were delivered to the San Juan**
  - **Due to high background of sediment concentrations, most metals in the San Juan were already elevated to similar concentrations as the GKM plume when it arrived.**
  - **Background metals mass was far in excess of what GKM delivered, with exception of colloidal/particulate lead, zinc and selenium**
  - **During the period when the plume moved through the San Juan, the river continued to gain sediment and metals mass as it travelled**

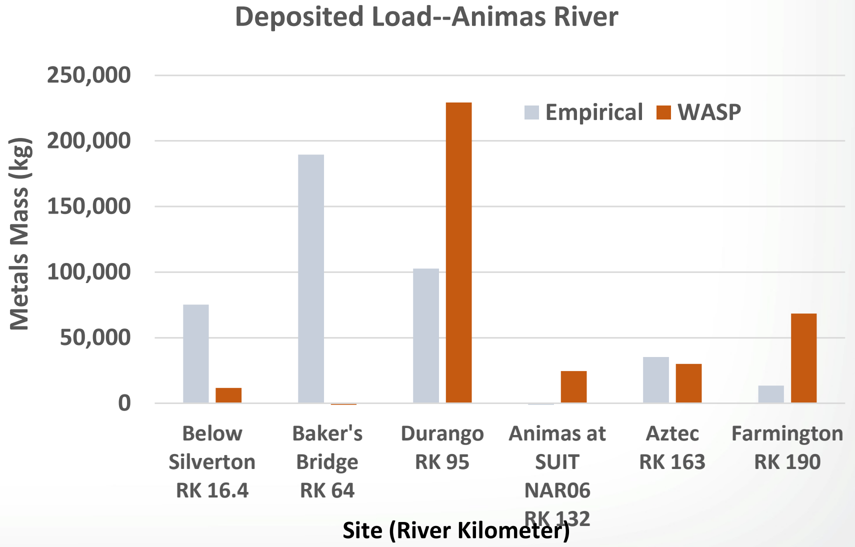




Deposition of GKM Metals Mass

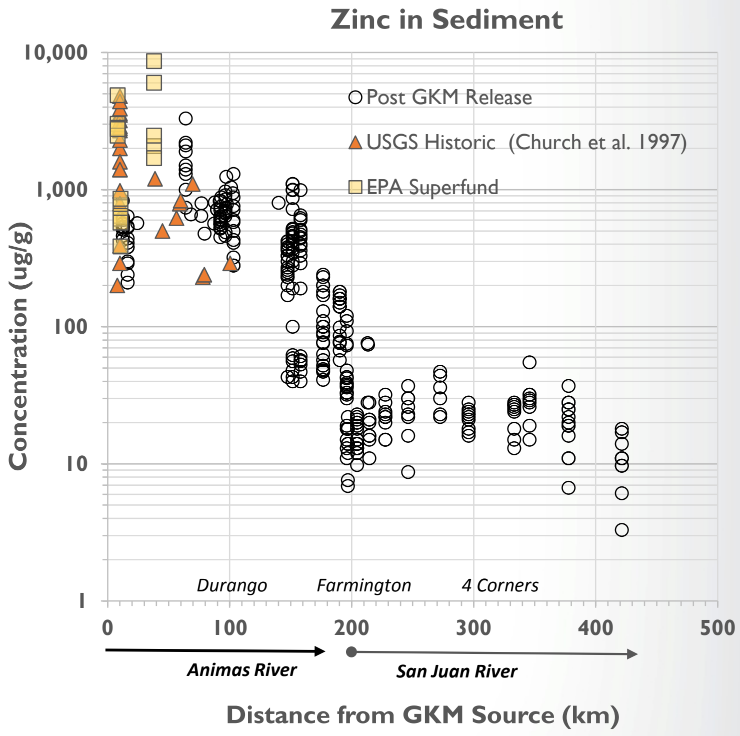
Did any of the material stay in the river system, sequester to the stream bed?

- **Most of the metals mass introduced into the Animas River during the Gold King Mine release was deposited in the Animas River**
  - **Initially comprised of dissolved metals from the mine and particulates and colloidal solids entrained or formed as the plume travelled**
  - **Most deposited in the upper Animas in the reach below Silverton, within the canyon reach and in the middle Animas between Bakers Bridge and Durango**
  - **Much smaller amounts were deposited in the lower Animas from Durango to Farmington**
- **The GKM plume delivered 45,000 kg of colloidal/particulate metals to the San Juan River that was probably made up mostly of colloidal metals**
  - **Analysis suggests that little of this mass deposited in the San Juan River**
  - **We have not compared post to pre-event samples in the San Juan at this point of analysis**
  - **Most was probably carried to Lake Powell**



Metals Concentrations in the Streambed

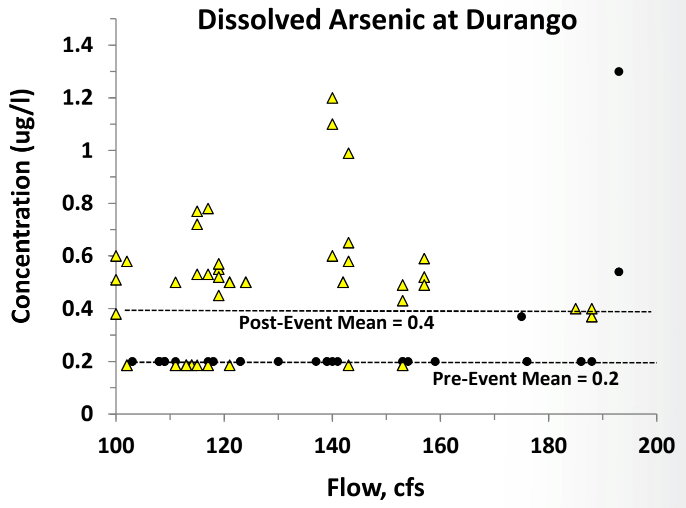
- The USGS studies of acid mine drainage in the Animas River in the 1990's found that AMD from numerous mines in the Animas headwaters contaminates the streambed with metals through much of the Animas River to Farmington
  - Concentrations decline with distance from headwaters showing the same patterns observed during and after the GKM plume
- Despite the relatively large mass of metals deposited all at once during the GKM plume, metals concentrations in the streambed were not statistically different from what they had been prior to the plume
- This result reflects the large mass of metals already in the streambed from decades of ongoing contamination from acid mine drainage
- Relative to the existing metals mass in the streambed, the GKM release was approximately equal to:
  - 10-20% of the metals mass in the Silverton reach
  - 0.4-0.8% of the metals mass in the reach between Silverton to Bakers Bridge
  - 0.2 to 0.4% of the mass in the reach between Bakers Bridge and Durango



Post-Event Water Quality

Have metals concentrations in the water and sediment returned to pre-event levels?

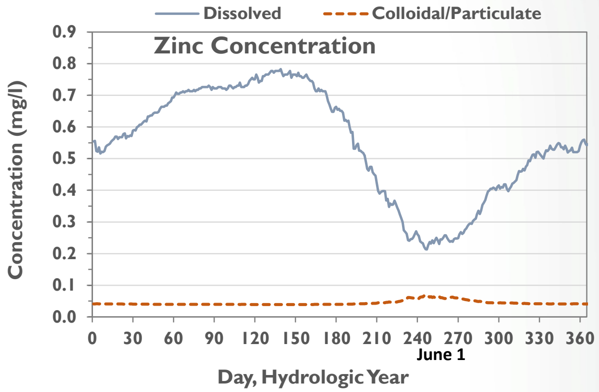
- In the Animas, metal concentrations in the water declined toward background conditions quickly after the plume passed
- The concentration of many dissolved metals is inversely related to streamflow and changes post-plume partially reflect declining flow during the fall months
- In the 3-month period after the release, there have been adjustments in metal concentrations compared to pre-event conditions after accounting for streamflow
  - Many statistically significant
  - Some metals increased, some decreased, and patterns varied between Silverton, Durango, and Farmington
  - Aluminum and Iron most involved
  - Concentrations remain below water quality criteria
- Causes of these changes are not known: could be due to changes in water chemistry, dissolution of precipitates, mineralization, other?
- In the San Juan, metals concentrations are dependent on stormflow and sediment



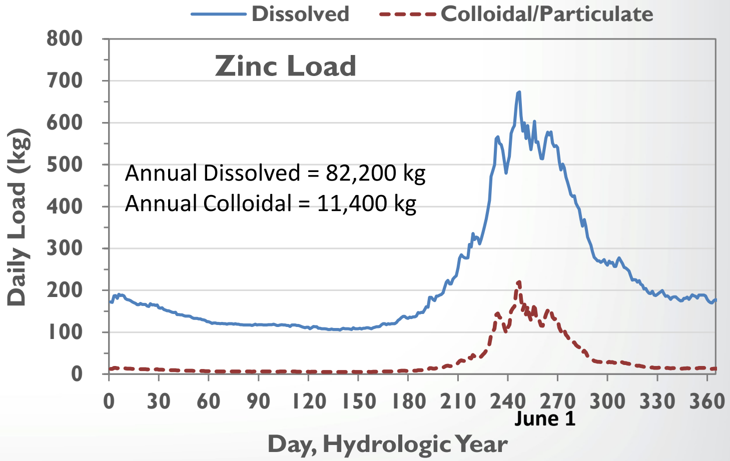
Mobilization of Metals During High Flow in the Animas

Will GKM metals released be entrained from the riverbed?

- Earlier USGS and EPA studies have shown that storms and snowmelt runoff entrain metals from the streambed along with sediment
- Water monitoring data from the Animas River shows that metal concentrations are dependent on streamflow
  - Dissolved tends to decrease with flow (dilution)
  - Colloidal/particulate tends to increase (particle mobility)
  - There is variability among metals
- Project modeling suggests that GKM metals will be mobilized in high flows, but will add small additional concentrations compared to what is usually observed
- Metals mass carried during high flows is large because of the volume of flow
- Continued post GKM monitoring during the spring snowmelt and storms should improve the reliability of these estimates of seasonal and annual metals concentrations



Silverton



ORD Project Team

Team of ORD scientists with multidisciplinary expertise in geochemistry, surface and groundwater hydrology, environmental engineering, water quality modeling, fish biology and bioaccumulation, statistics, and geographical information tools

Asked by ORD Assistant Administrator to analyze fate and transport of GKM release

ORD/NERL Subject Experts Working on the Project

- John Washington, Geochemistry
- Chris Knightes, WASP, water quality
- Mike Cyterski, Data analysis, statistics
- Kate Sullivan, Hydrology, project lead
- Craig Barber, Fish effects
- Steve Kraemer, Groundwater
- Anne Neale, Megan Mehaffey, EnviroAtlas
- Lourdes Prieto, GIS and data acquisition