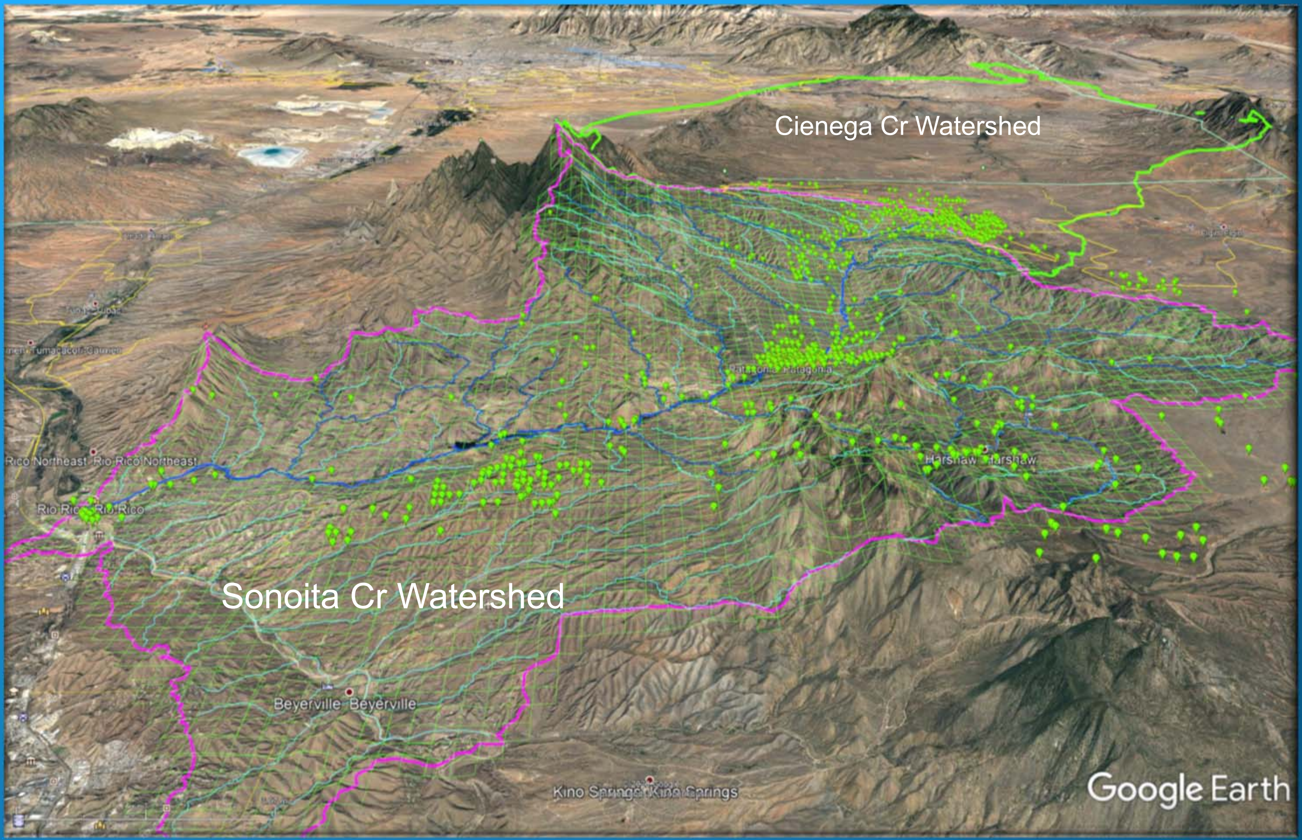
Hydrologic Evaluation of Proposed Hermosa Mine Water Treatment Plant (WTP2) Discharge

Presentation to PARA
November 12, 2020

Patagonia Area Resource Alliance



Laurel Lacher, PhD, RG, *Lacher Hydrologic Consulting, Tucson, AZ*

Bob Prucha, PhD, PE, *Integrated Hydro Systems, LLC, Boulder, CO*

Integrated Hydro Systems, LLC

Lacher Hydrological Consulting

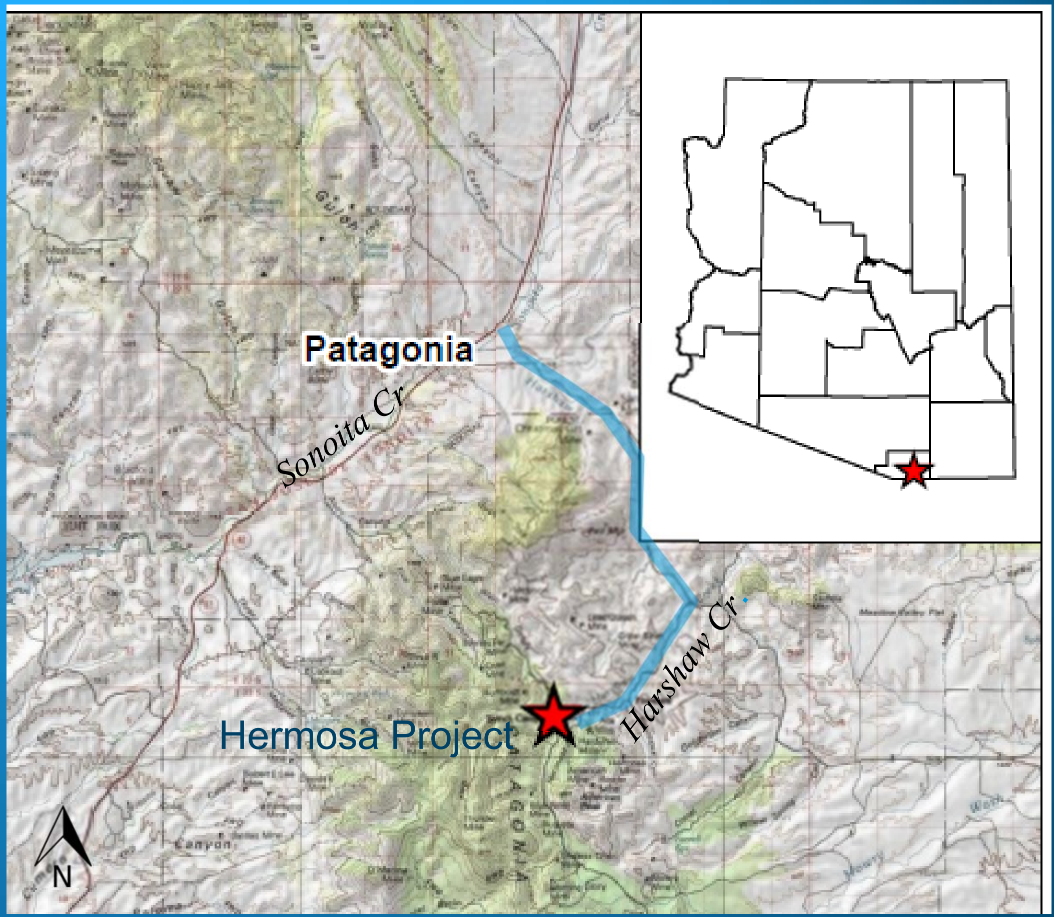
Study Commissioned by PARA

- Purpose of Study:
  - To evaluate potential hydrologic impacts of South32's proposed discharge of treated water from the Hermosa Project to Harshaw Creek as described in August 2020 AZPDES and APP applications.

South32's Proposed Action

- South32 (parent company to Arizona Minerals, Inc.) proposes dewatering of Hermosa Project area ~ 5 miles south of the Town of Patagonia to facilitate underground mining.
    1) Taylor Deposit (zinc, lead, silver)
    2) Clark Deposit (zinc, manganese, silver)

- ❑ Initial dewatering rate up to 4500 gpm
- ❑ Treated water discharged to Harshaw Cr.



Modified from Clear Creek Assoc., Aug 2020, APP Significant Amend. Applic P-512235, fig. 1.

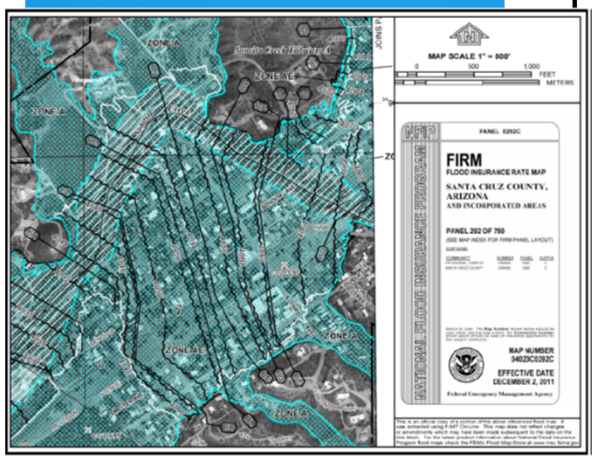
Motivating Factors for PARA

- ❖ **Existing Flood Potential on Harshaw Creek and in Town of Patagonia**
- ❖ **South32's conclusion of no surface water impact in Sonoita Cr.**

History of Flooding in Patagonia


Figure 3 – Highway 82, Sonoita Creek, Oct 1983


Figure 4 – Patagonia, Oct 1983

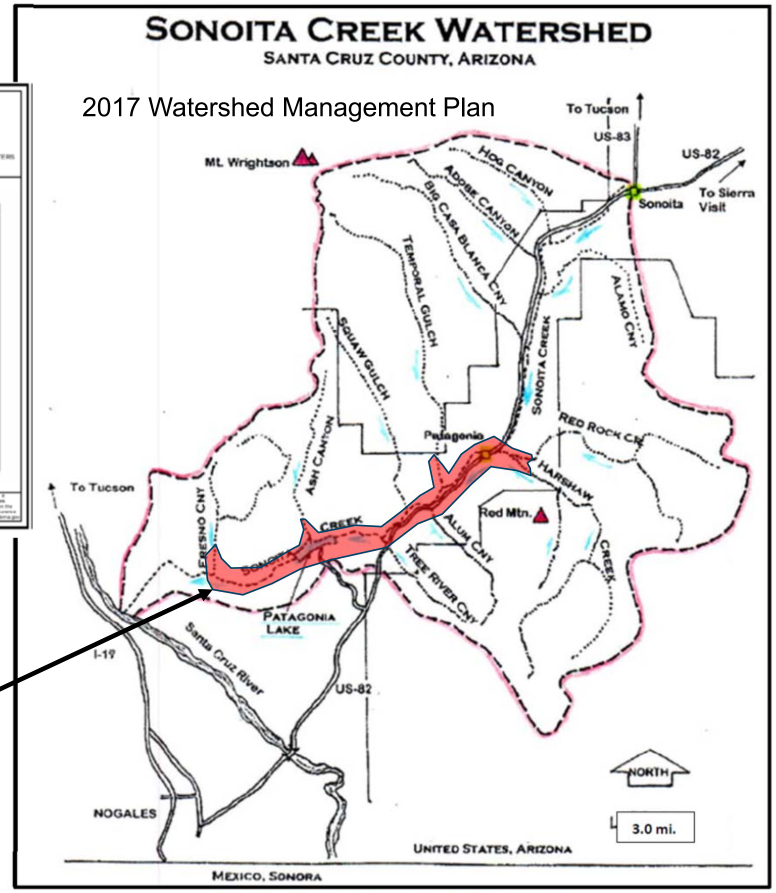


Perennial flows along Sonoita and lower parts of tributaries shown

Sonoita = is the local Indian name *Şon 'Oidag*, which may be best translated as "spring field" (Wikipedia).

Mountains = Sonoita Creek is bounded by the Santa Rita Mountains on the north and the Patagonia Mountains on the east and the south.

Perennial flow reaches = the rock narrows at the Nature Preserve at the south edge of the Town of Patagonia, keeping the flow near the surface, then downstream to Lake Patagonia, about 7 miles. From the Lake downstream toward Rio Rico, the perennial flow reach is approximately 5 miles. Coal Mine Canyon, Fresno Canyon, Temporal Gulch, Harshaw Canyon, Red Rock Canyon, Ash Canyon, Cottonwood Spring and Cott Tank Drainage all contain small perennial flow sections.



Sonoita Creek Watershed (Jim Davidson)

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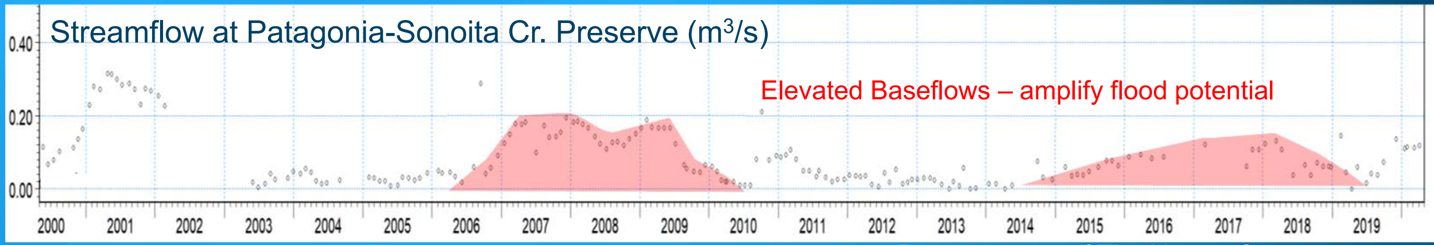
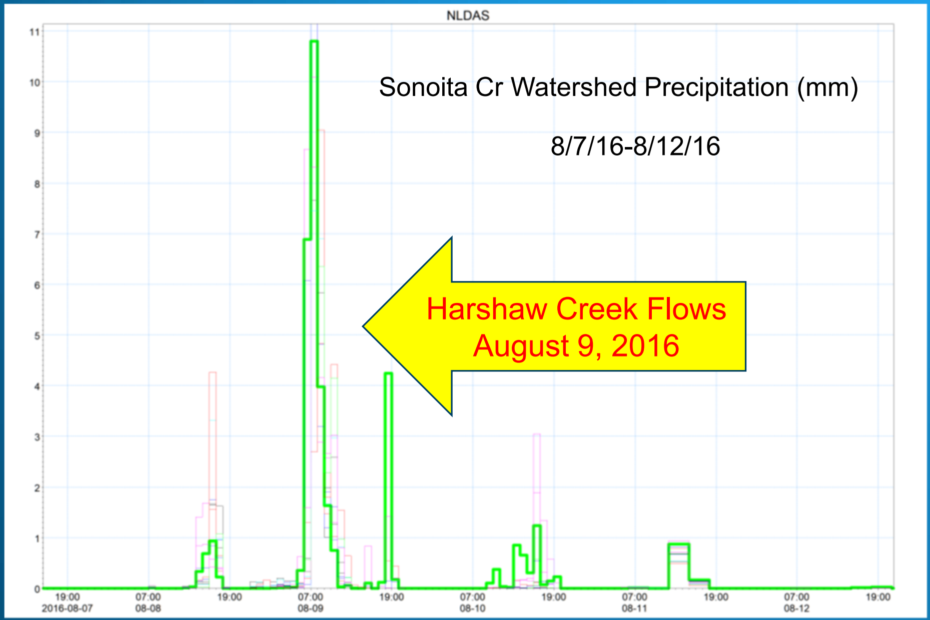
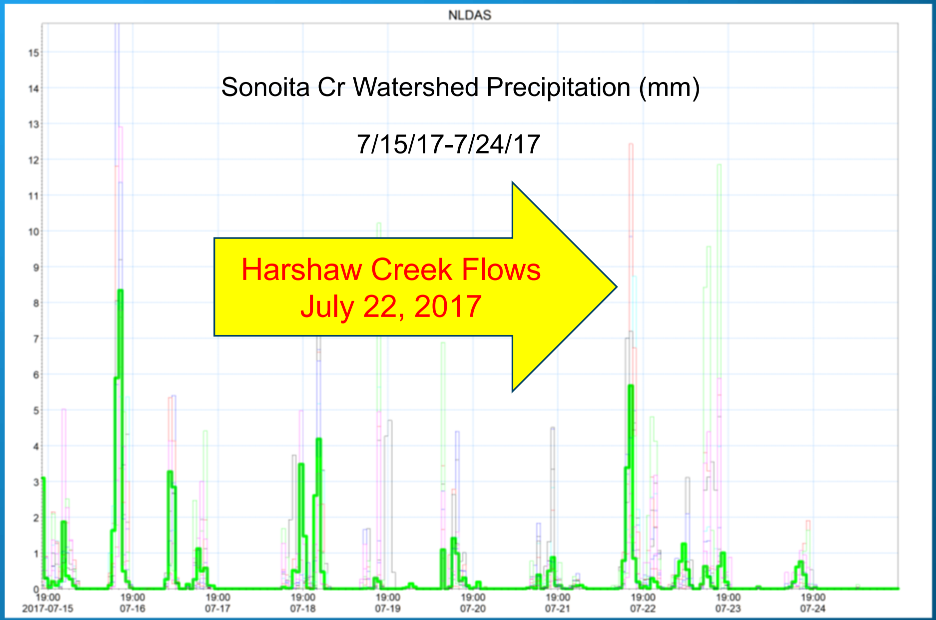
Recent Harshaw Creek Flooding



Data courtesy of The Nature Conservancy





Key Points →

- Monsoonal storms leading to Discharge on Harshaw Cr → relatively typical annual monsoon storm events
- Preceding storms → increase surface saturation and runoff

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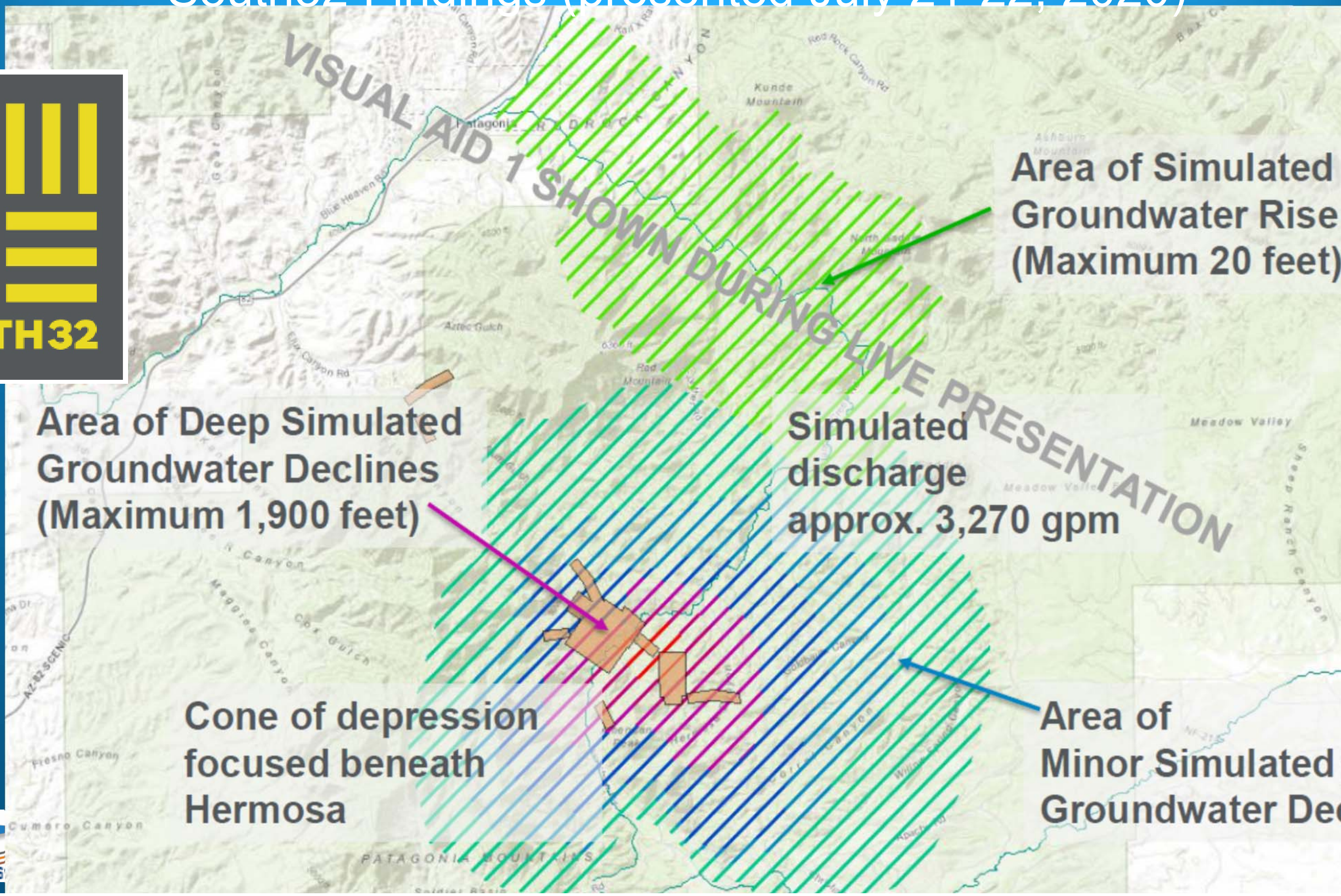
South32 Findings (presented July 21-22, 2020)



Literature Review

Documents Reviewed

- 1996_Book_RunoffInfiltrationAndSubsurfac.pdf
- 2019 1204 USFS Harshaw Mine Fact Sheet.pdf
- 2020.08.17_APP Signif Amend Application_AMI.pdf
- 2020-july-continued-exploration-and-permitting.pdf
- 2020-september-hermosa-exploration-and-water-stewardship-graphic.pdf
- AMI - Application for Amendment of AZPDES Permit No.AZ0026387.pdf
- An-Update-on-Patagonia's-Water-StrategiesPRTapril2015.pdf
- AZDEQ_2003_santacruz_harshaw_tmdl.pdf
- Bradbeer1978_UoA_MS_hydrogeoSonoitaCreek.pdf
- Brady2001_of01-267.pdf
- Davis_1977_Watermanagement_development.pdf
- Final-Phase-1-Sonoita-Creek-WMP-5-12-17.pdf
- Floods_1977_Aldridge_Eychaner_USGS2223report.pdf
- Harshaw Creek Channel Morphology.pdf
- HermosaProject2014_M3_pre-feasibiltyTRWS20131210.pdf
- hermosa-project---mineral-resource-declaration.pdf
- Honan2019_RiskAssmt_SantaCruz.pdf
- Map of Tailings Storage Facility.pdf
- Mayor's Letter to FS.pdf
- menges-mcfadden-1981_miocenelandscapeEVOL.pdf
- Nassereddin1967_hydrogeo_SonoitaCreek.pdf
- Norman2008_Article_TrackingAcidMine-drainageInSou.pdf
- NRC_1991_DAMmanagement_1832.pdf
- Patagonia-water-study-October-1964.pdf
- PatgoniaRegionalTimes-template-10.20finalforweb.pdf
- Schrag-Toso_MS_UoA_2020.pdf
- Seeps & Springs Catalog.pdf
- Simons_1972_Stratigraphyreport.pdf
- Tracing-Ground-Water-Input-to-Base-Flow-Using-Sulfate-Isotopes.pdf
- UoA_AZwellownerguideaz1485-2017_0.pdf
- USFS Harshaw-EECA Report_Final Aug 2020.pdf

Hermosa Project – Trench Camp Property

Aquifer Protection Permit
SIGNIFICANT Amendment Application

P-512235

Santa Cruz County, Arizona

ARIZONA MINERALS

Prepared for:
ARIZONA MINERALS, INC.
2210 E. Ft. Lowell
Tucson, AZ 85719

Prepared by:
CLEAR CREEK ASSOCIATES, LLC
221 N. Court Avenue
Tucson, AZ 85719

August 14, 2020

Application for Amendment of AZPDES Permit No. AZ0026387

Water Treatment Plant 2 - Hermosa Project

Santa Cruz County, Arizona

ARIZONA MINERALS

Prepared for:

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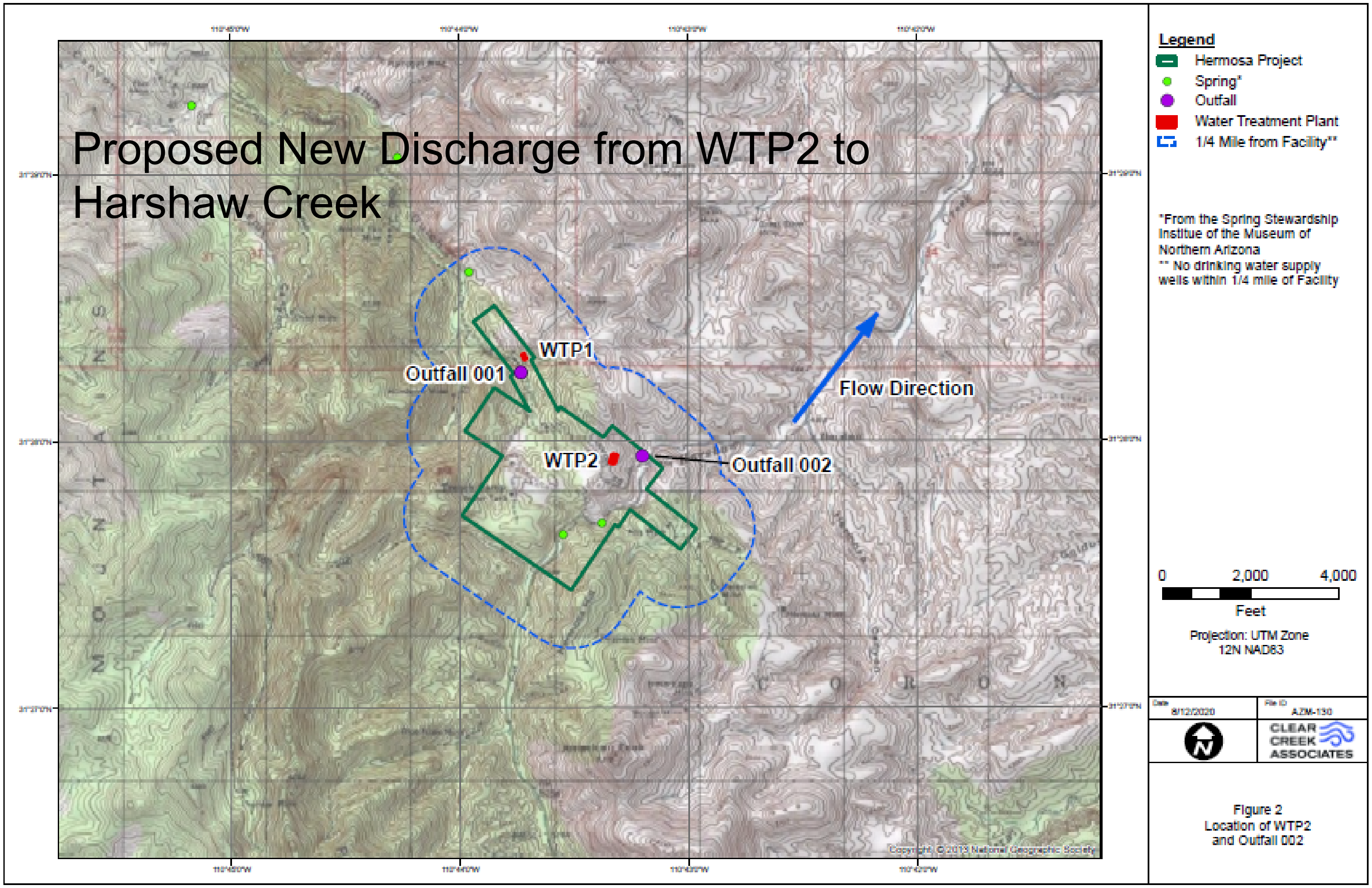
Tucson, Arizona 85719

Prepared by:

CLEAR CREEK ASSOCIATES, LLC
221 North Court Avenue Suite 101
Tucson, Arizona 85719

August 14, 2020

Proposed New Discharge from WTP2 to Harshaw Creek



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Study Objectives

1. Evaluate effects of 4500 gpm mine dewatering discharge from WTP2 on:

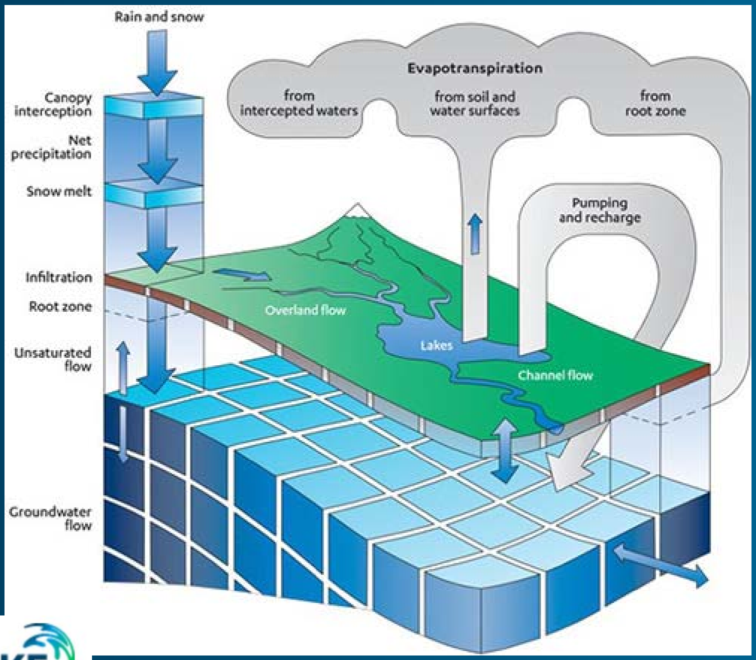
- Streamflow
  - Harshaw Cr
  - Sonoita Cr
- Conveyance of Mine Discharge
  - Natural regime PLUS mine dewatering
  - Along Harshaw Cr
  - Through town of Patagonia
- Groundwater
  - Groundwater-dependent ecosystems
  - Aquifer storage changes

2. Assess baseline hydrologic conditions and controlling factors

3. Develop a robust numerical model of Sonoita Cr watershed → applicable to other problems

Integrated Modeling

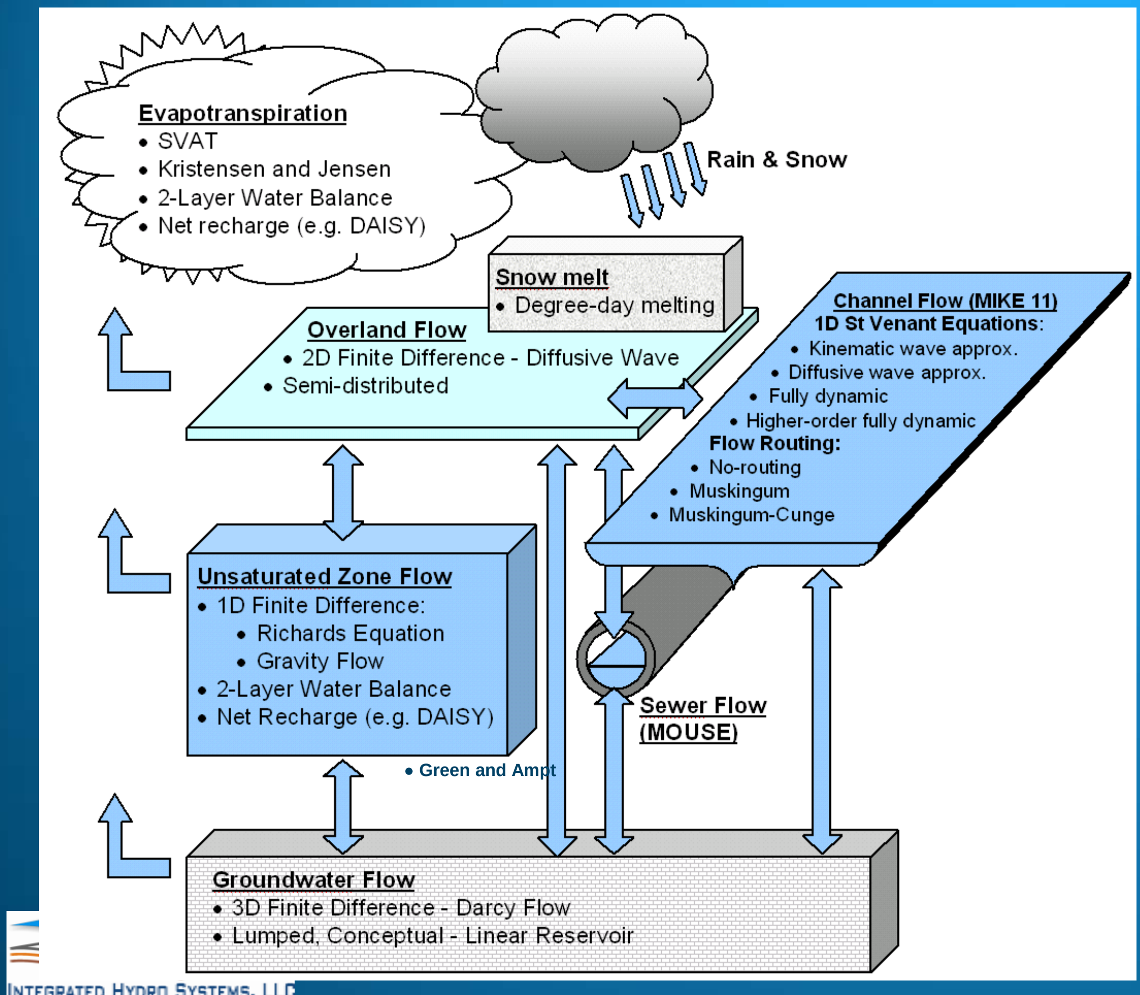
MIKESHE by DHI



https://www.mikepoweredbydhi.com/products/mike-she

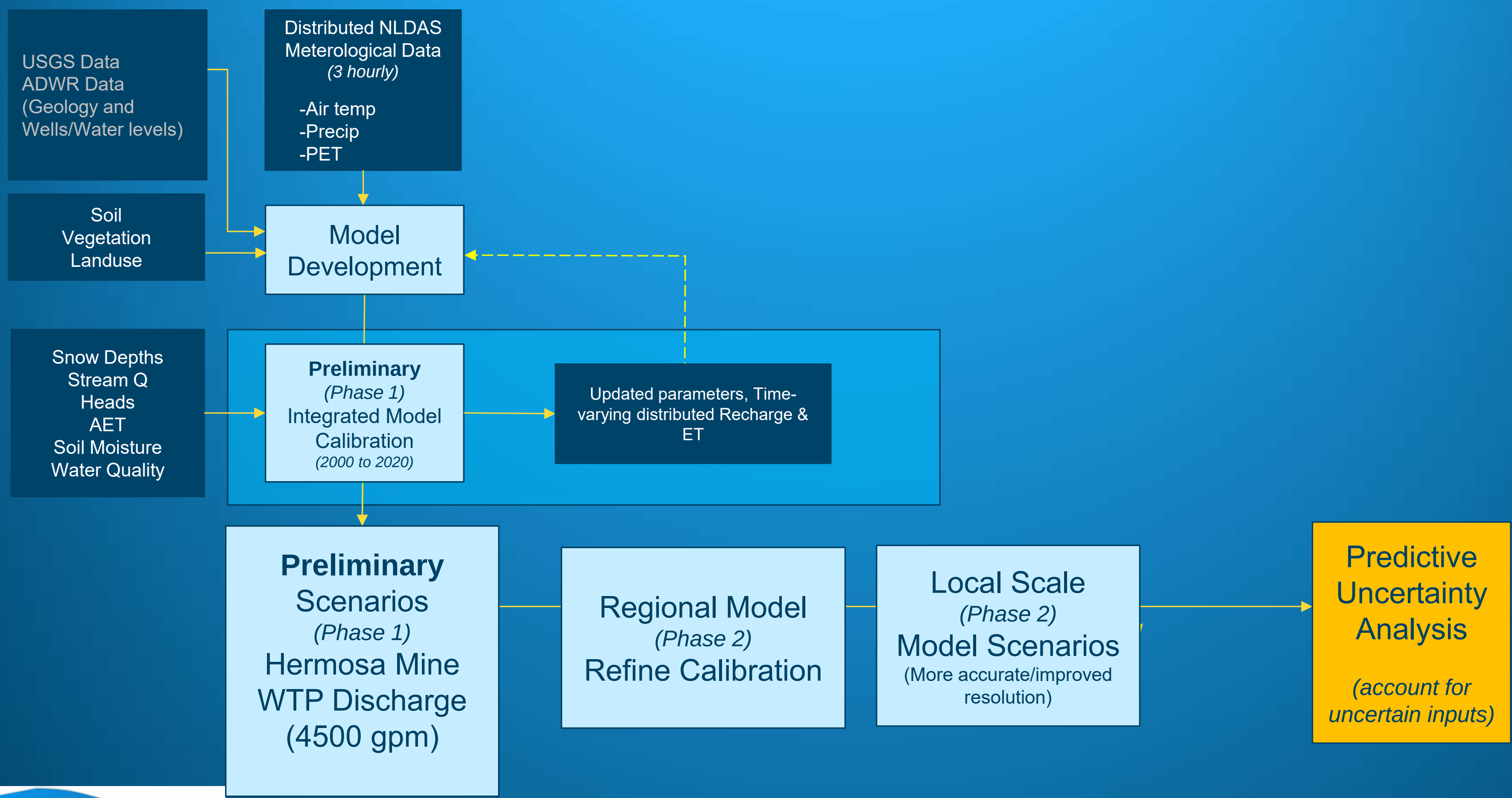
MIKESHE / MIKEHydro

flexible process descriptions



- Choice of spatial and temporal scales (depends on processes):
  - *Groundwater (days to years)*
  - *Surface water (seconds to hours)*
  - *Unsaturated flow (seconds to years)*
- Process time scales independent and automatically controlled
- Choice of processes to include in model
- Choice of simple to complex solutions
- Groundwater flow virtually identical to MODFLOW.
- FEMA-approved fully hydrodynamic, surface water hydraulic model

MIKESHE Model Development Approach



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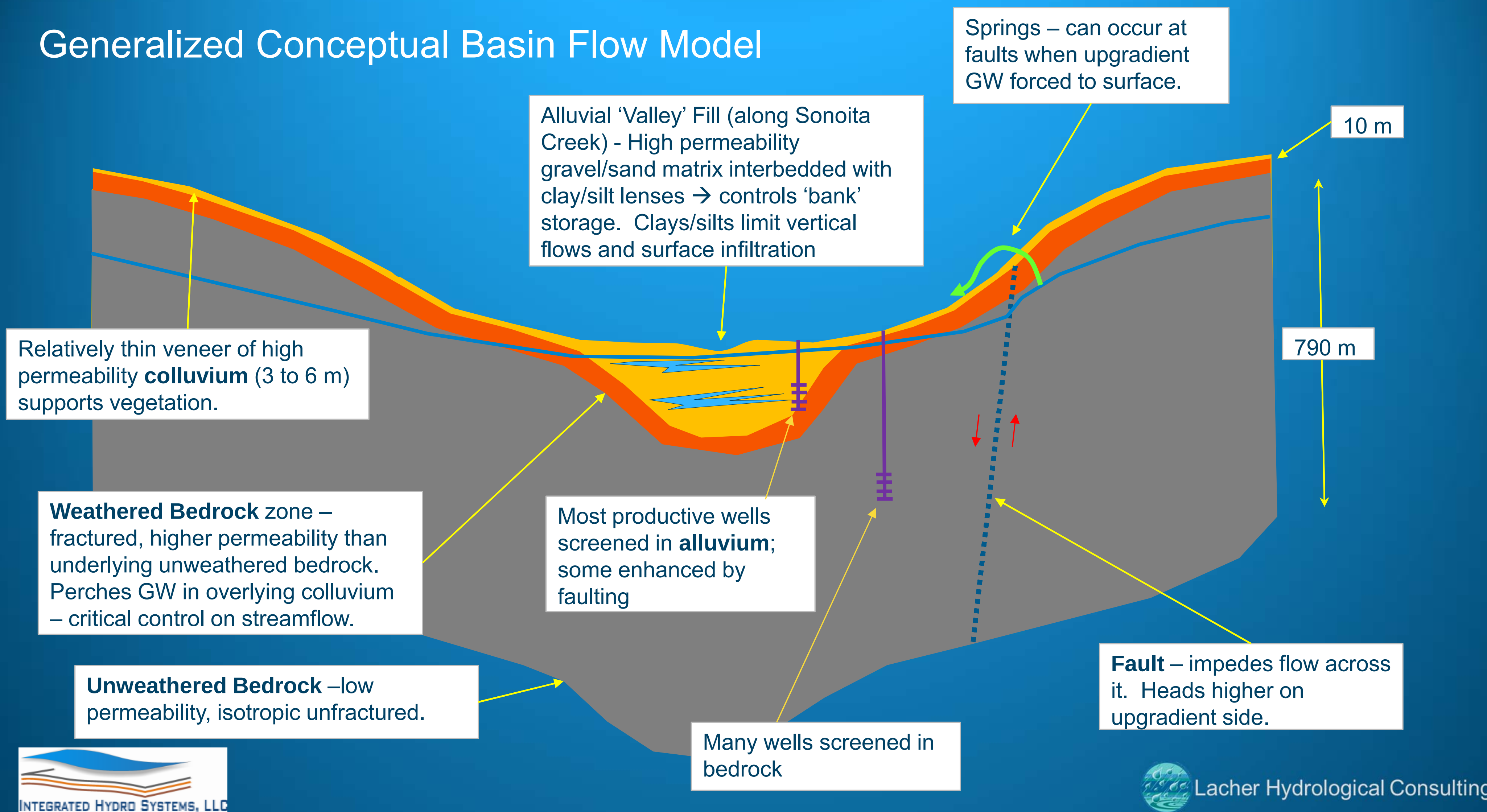
Conceptual Model

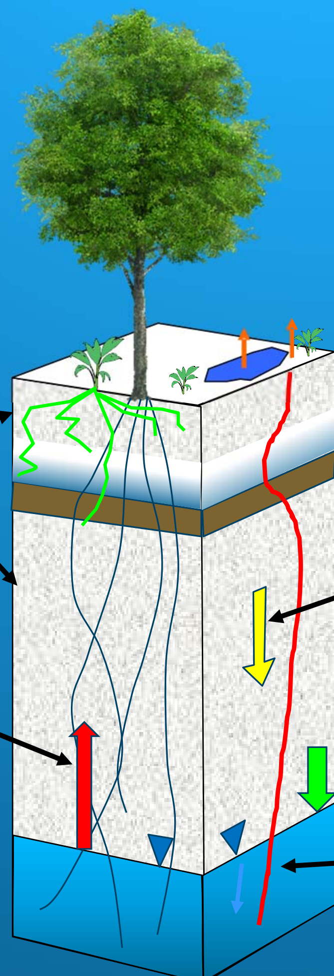
Generalized Conceptual Basin Flow Model



Conceptualization of Unsaturated Zone Flow

Variable soil types
→ Strongly control ET dynamics, infiltration & recharge to aquifer

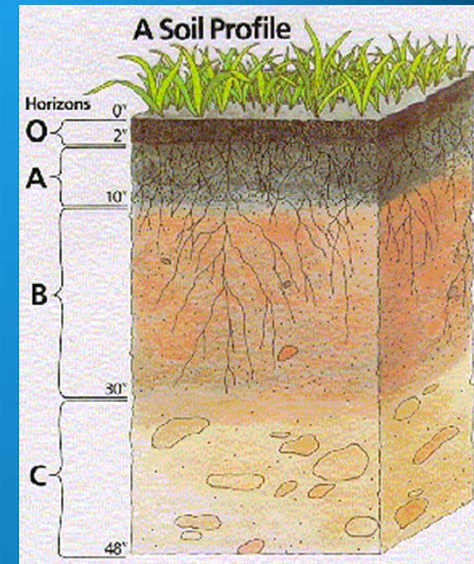
Unsaturated Zone Moisture Deficit → draws water UPWARD from water table (capillary draw).



Saturation increases above **clay layers** → Influences infiltration and recharge to groundwater

Groundwater Recharge
Response to stream stage

Macropores → rapid recharge



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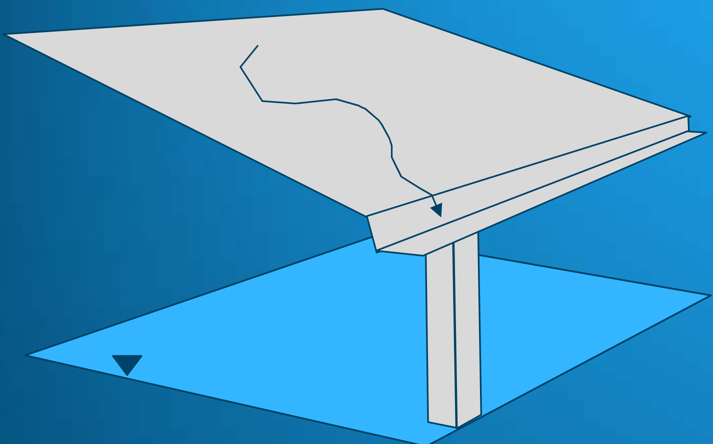
Surface Water Runoff Mechanisms

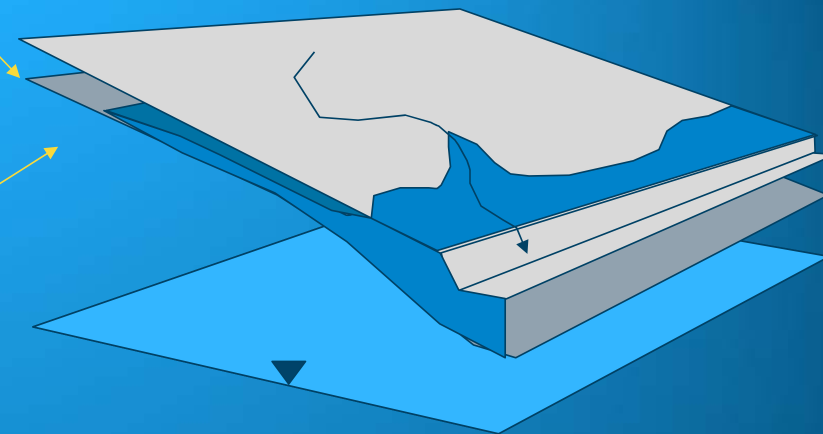


Low permeability soils with deeper GW table & bedrock

- Runoff occurs as 'Hortonian Flow' (i.e., rainfall rate exceeds infiltration capacity).
- Unlikely in most storms

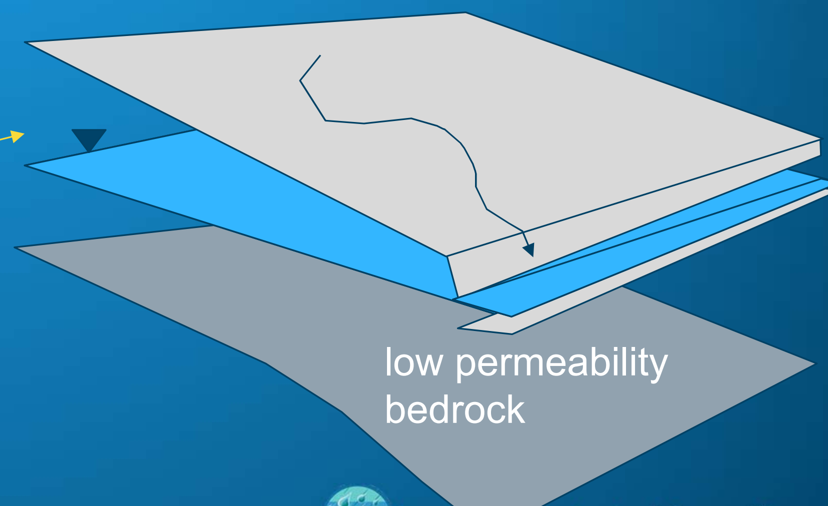
Shallow, low permeability bedrock

Perched Flow – above shallow bedrock



Shallow bedrock

- Causes rapid surface saturation, increasing runoff
- True in many areas



Shallow groundwater table

- Limits aquifer storage capacity
- "Rejects" infiltrating water, increasing runoff

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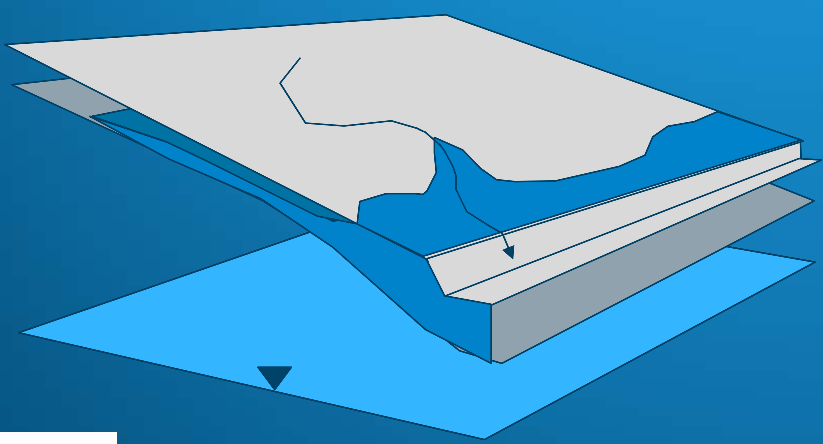
Evidence for Runoff Mechanism

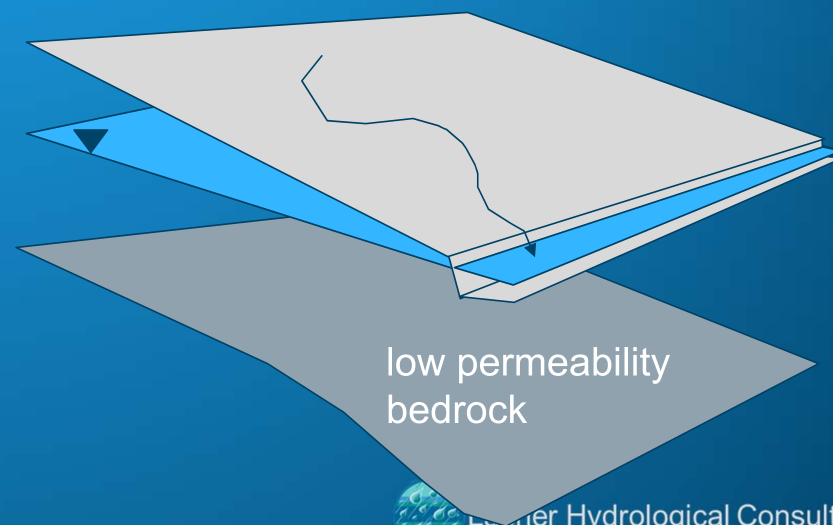
Surface water discharge appears strongly controlled by **shallow GW table** (locally-perched or connected to regional aquifer) for several reasons:

- *Reported range of soil permeability → doesn't produce peaky discharge (i.e., Hortonian runoff)*
- *Aquifer storage effects apparent in surface discharge at Preserve gage*
- *Relatively shallow GW beneath town/Sonoita Cr*
- Perennial flow along lower reaches of most tributaries and downstream of Town where shallow bedrock forces GW to surface. (eg, TNC preserve)

Shallow bedrock



Shallow groundwater



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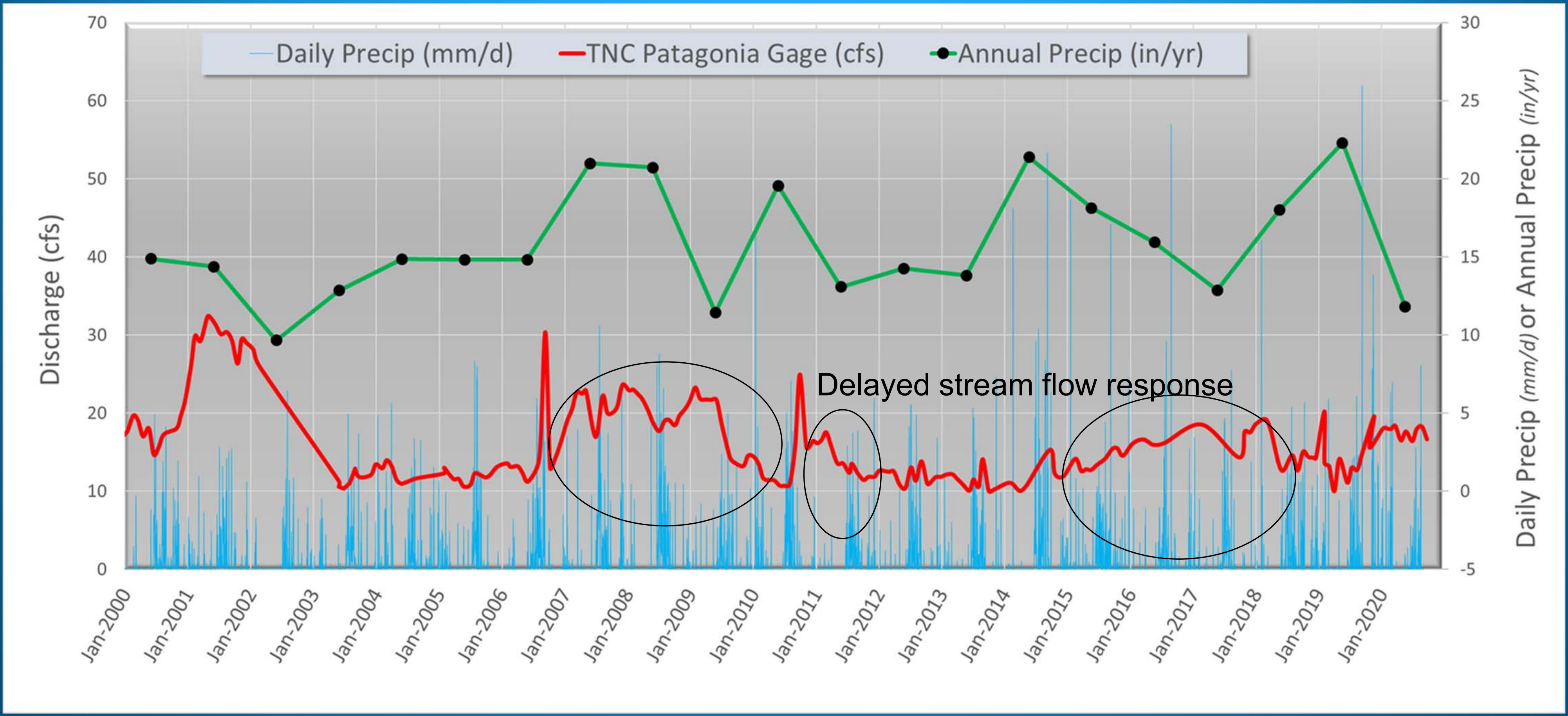
Streamflow at Precipitation at Patagonia-Sonoita Cr Preserve*



* Data courtesy of The Nature Conservancy

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REGIONAL Model Setup/Assumptions

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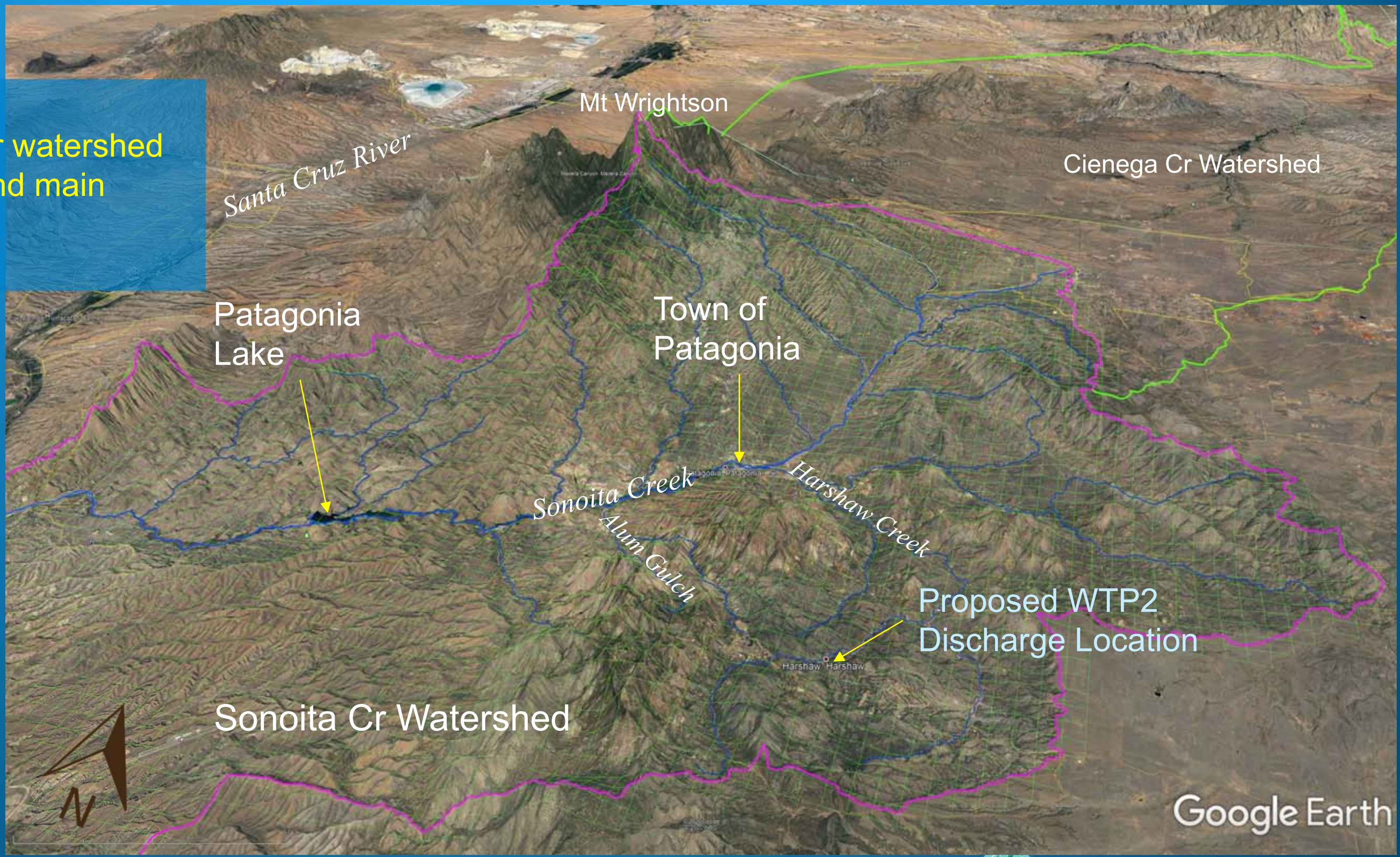
Model Domain, Discretization, and Hydraulic Network

- 500 m grid cells
- Entire Sonoita Cr watershed
- Sonoita Creek and main tributaries
- Patagonia Lake



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Climate Data

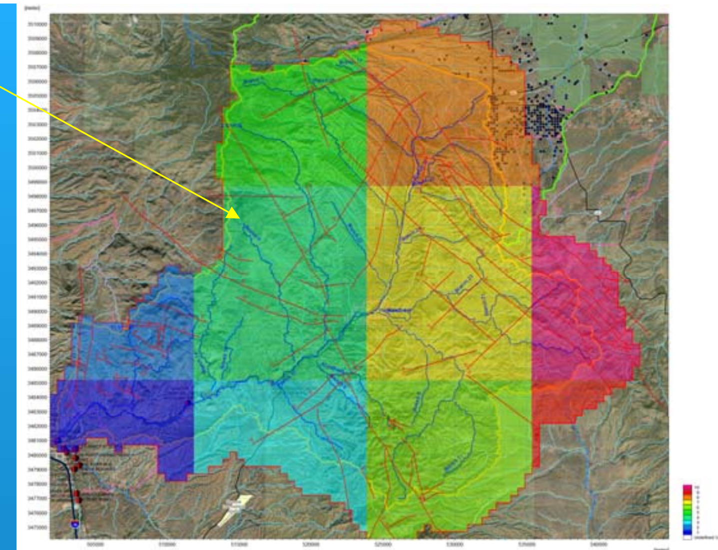
NLDAS Zones (11.4 km x 13.8 km spacing)

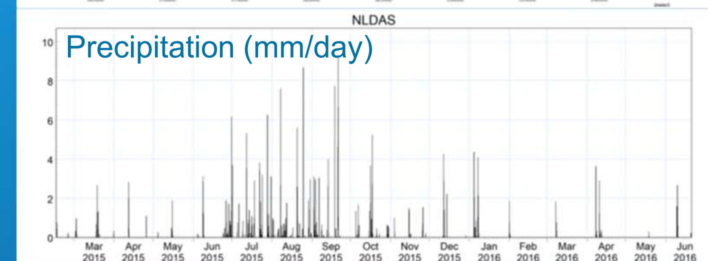
- NASA's National Land Data Acquisition System (NLDAS) data
- Hourly Rainfall, Potential Evapotranspiration (PET), and Air Temperature (2000 through 2020)
- Benefits of NLDAS dataset:
    - spatially distributed (~11.4 x 13.8 km grid)
    - no data gaps
    - hourly consistency between rain, PET and air temperature.

➡ *These data 'drive' the hydrologic and snowmelt response*.

- Elevation lapse rates adjust rain and air temp → account for orographic effects.

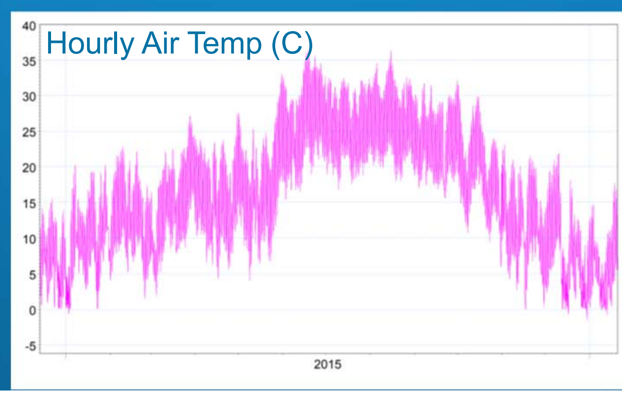
Can supplement with local weather station data

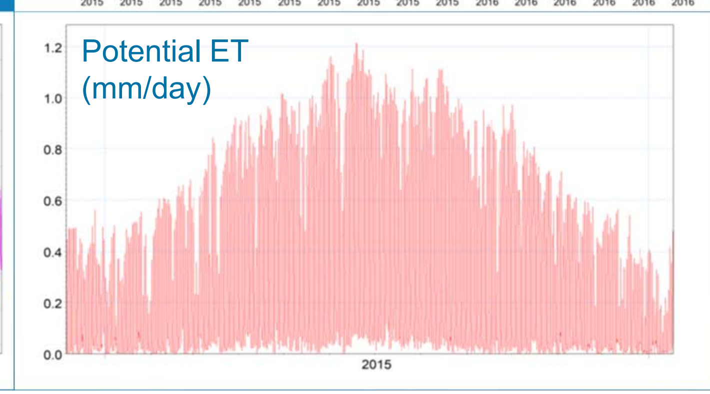




SNOWMELT PARAMETERS

- Melting Temperature – 0° C (uniform)
- Degree Day Coeff – 4 mm/C/day
- Maximum Wet Snow Fraction – 0.1
- Thermal melting (from rain heat on snow) included – Melt Coeff – 0.131/C





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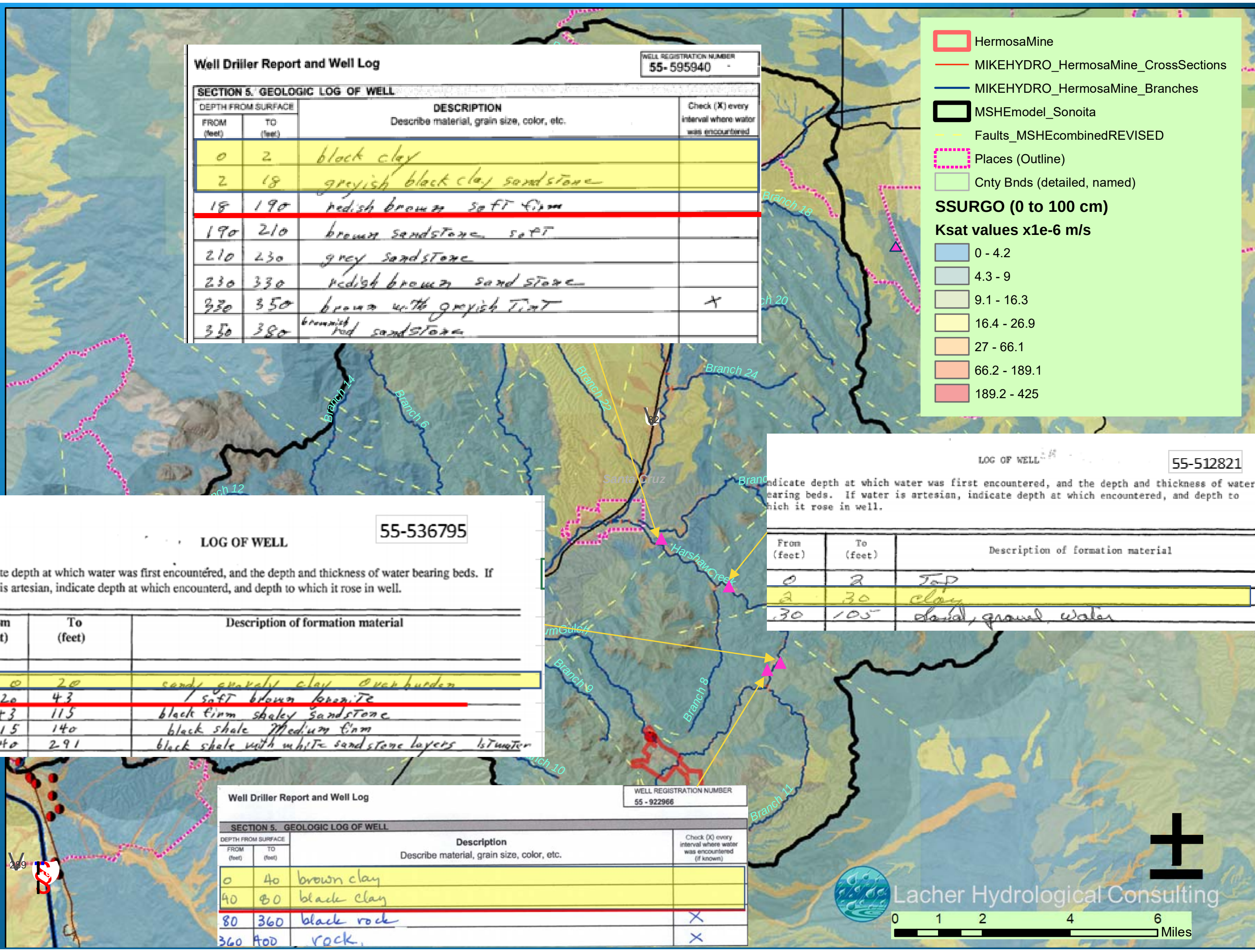
Unsaturated Zone

- USDA - SSURGO Soil Survey data
- Similar to AZGS Surficial Geology and supported by well logs
- Saturated hydraulic conductivity values shown for top 100 cm.
- These data → converted into MIKESHE soil types.
- Assumed uniform to higher elevation of either groundwater table or bedrock surface.



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ERC

WTP2 Discharge – PMA Evaluation
August 2020

Figure 4 – Sample Bed Material at East Branch of Site 3

Middle Harshaw Cr.

Clays present in Harshaw Creek and Valley Alluvium

Alluvial unit No. 1 is unconsolidated poorly sorted, fine to coarse grained, and weakly cemented. A size analysis made on a sample collected from the creek near Patagonia shows 71.74 percent sand; 21.01 percent silt and clay; and 7.27 percent gravel (Table 2).

Most exposures of unit No. 1 have medium permeability which is due to the presence of fine material filling part of the pore spaces which helps in decreasing the permeability. This unit ranks second to unit No. 4

(Nassereddin, 1967)

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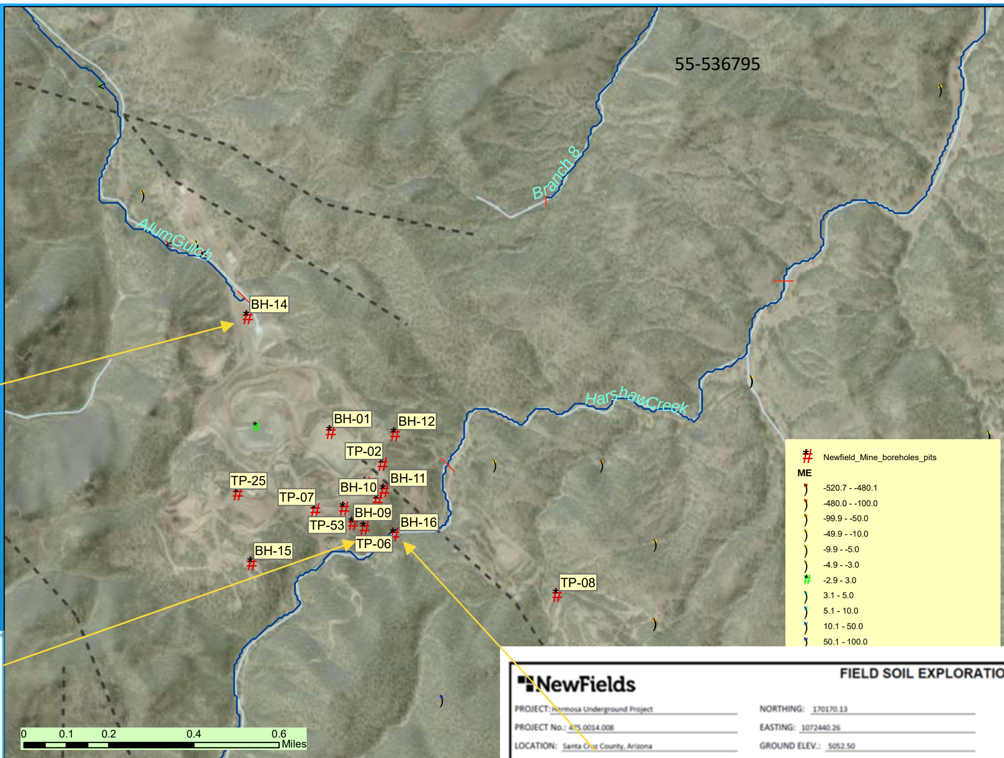
Hermosa Project Borehole Logs

FIELD CORE LOG

NewFields

Project: Hermosa Uunderground Project	Total Depth (ft): 16.7	Borehole ID: BH-14
Project No.: 475.0014.008	Core Size: HQ3	Borehole Location: Under drainage pond
Drilling Contractor: Yellow Jacket Drilling	Azimuth: NA	Logged By: J. Roberts
Drilling Equipment: CME 850	Inclination: -90	Ground Water Depth (ft): NA
Drill Operator: Roger	Easting: 1070596.40	Circulation Loss: NA
Date Started: 1/7/2017	Northing: 172850.27	Datum: NAD83 State Plane Arizona Central US feet
Date Completed: 1/7/2017	Elevation: 4929.69	Page: 1 of 1

Depth (ft)	Run No.	Run Length (ft)	REC (%)	RQD (%)	Weathering	Hardness	Material Description	Graphic Log	Water Table	Remarks
0							GRAVEL (GC), clayey, some silt and sand, medium plastic, fine to coarse grained gravel, angular, reddish brown, moist			Auger refusal at 1.7ft, switch to HQ3 coring methods with compressed air
	1	5	18%	1%	MW	R3	Andesite, plagioclase, porphyritic, fine grained, moderately weathered, fracture at 60deg with Mn oxide			Core fell from inner barrel during barrel removal - only able to retrieve 0. 4ft of rubble and 0.5ft of whole core
5										
							Intensely fractured with hematite and limonite alteration and limonite staining on			



NewFields

Pit ID: TP-06

Project: Hermosa Underground		Project No.: 475.0014.008
Project Location: Sant Cruz County, Arizona		Date: 1/19/2017
Equipment: Deere 180G LC	Contractor: DM Engineering & Excavating	Logged by: J. Roberts
Coordinates: 170244.73N 1072068.89E	Elevation: 5094.13	Total Pit Depth: 10.5ft
Datum: NAD 83 Arizona Central State Plane US feet	Surface Conditions: Edge of road	Backfilled: Yes

Depth (ft)	Sample (depth & type)	Pit Wall Profile	Description	Additional Notes
2.5	LD-1 @ 1-3ft		CLAY (CH), sandy, some silt, medium to high plastic, brown, moist Red, orange, and light gray	Test pit placed in road Clay thickens to the North Residual soil
5.0			4.0	
7.5	SD-1 @ 7-8ft		GRAVEL (GP), sandy with some silt, coarse, angular, MPS=6.0in, reddish gray, moist, Andesite bedrock	Hard digging at 9.0ft
10.0			10.5	
12.5			TD = 10.5ft, refusal on competent bedrock Water table not encountered at time of excavation.	

Most logs show soils overlying bedrock have significant **clays & silts** – even within Harshaw Creek.

FIELD SOIL EXPLORATION LOG

NewFields

BOREHOLE ID: BH-16

Page 1 of 1

PROJECT: Hermosa Underground Project	NORTHING: 170170.13	
PROJECT No.: 475.0014.008	EASTING: 1072440.26	
LOCATION: Santa Cruz County, Arizona	GROUND ELEV.: 5052.50	
LOGGED BY: J. Roberts	DATUM: NAD83 AZ State Plane Central US feet	
START DATE: 1/18/2017	EQUIPMENT: CME 850	BACKFILLED: 20% Solids Bentonite Grout
END DATE: 1/18/2017	DRILLING METHOD: 4 1/4" HSA	OPERATOR: Roger

GROUNDWATER LEVEL		
DATE	DEPTH (ft)	ELEV. (ft)

Depth (ft)	Sample Type	SPT 6 Inch Increments	Graphic Log	USCS	Water Table	Material Description	Remarks
0	SS	10-13-18		SC		SAND (SC), clayey, with gravel, dense, medium plastic, brown, moist	
3.5	MC	6-24-23				Hard	
6.0	SS	5-20-25				With gravel, low plastic	
8.0	MC	42-50/3"		GC		GRAVEL (GC), clayey, with sand, some silt very dense, low plastic, brown and gray, moist Auger refusal at 8.4ft depth - switch drill method to HQ3 core	Log continues on core log (next page)
10							

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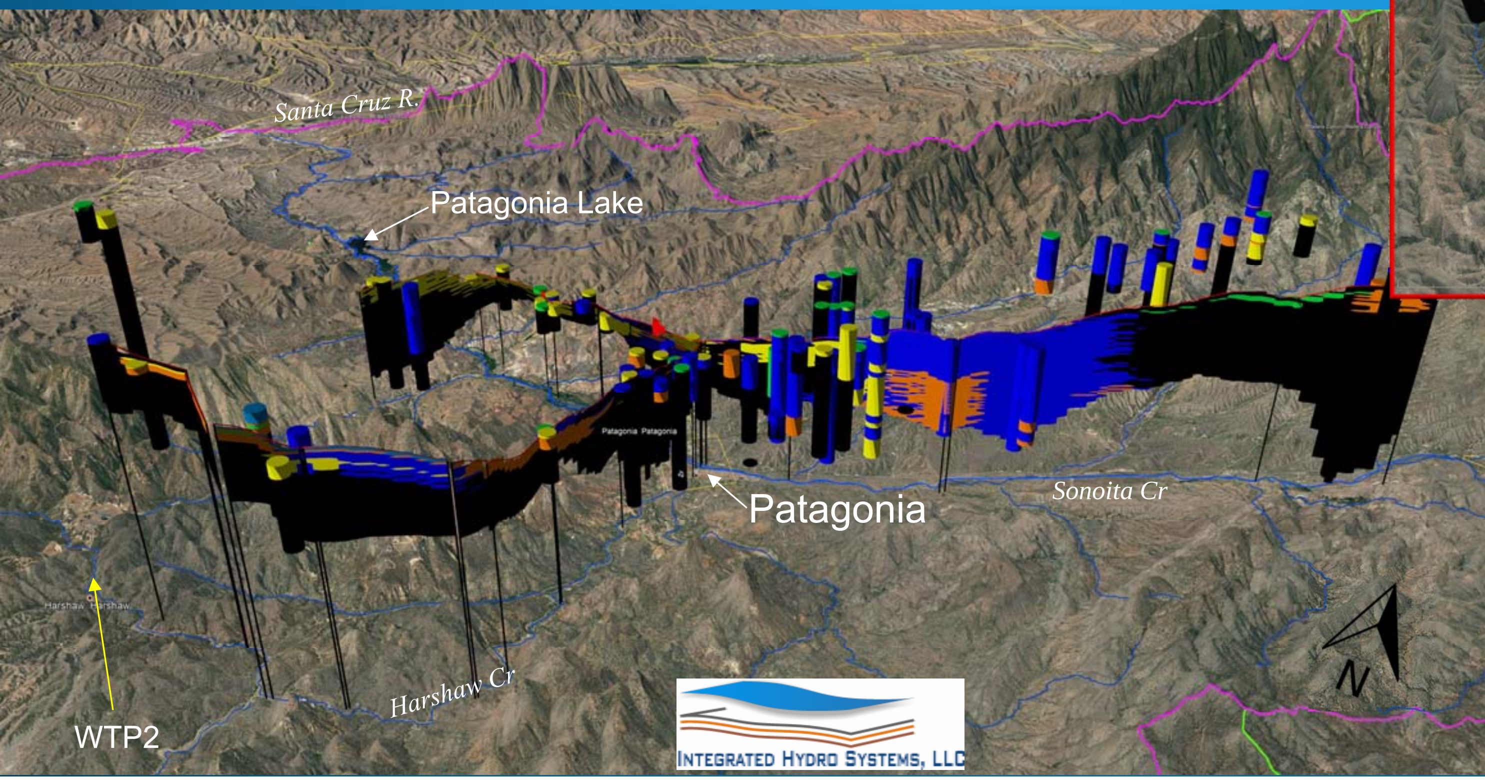
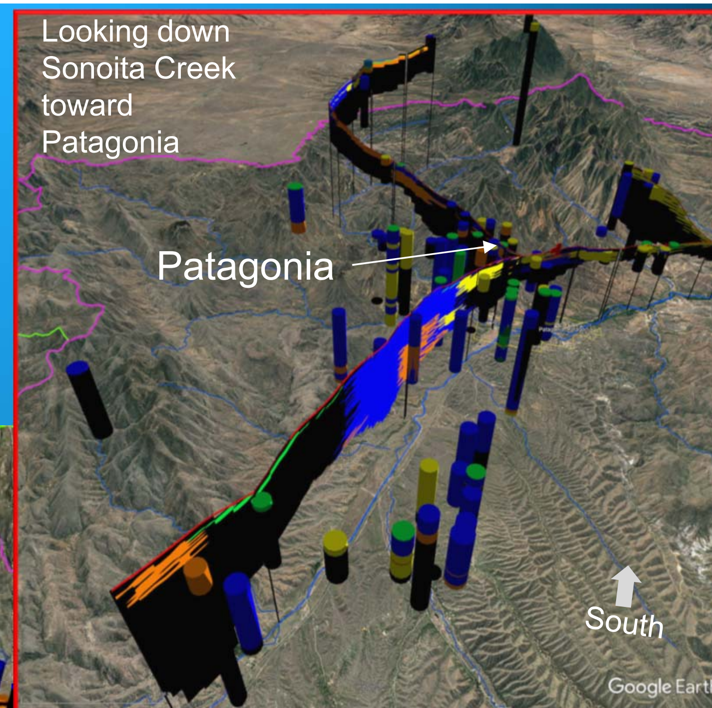
3D Lithologic Model – Deposits Overlying Bedrock

Borehole Lithology from ADWR's Well55 Registry Driller's Logs





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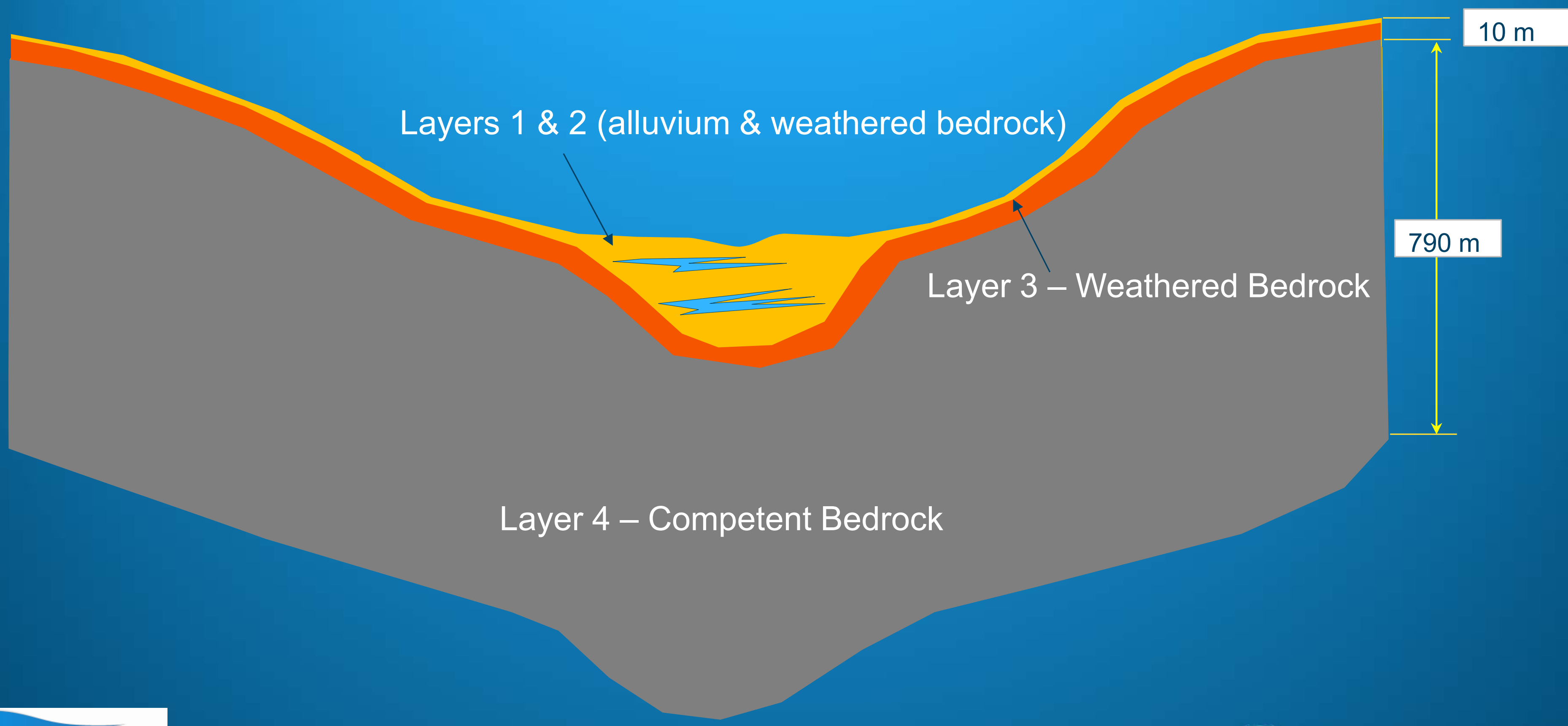
Saturated Zone

4 model layers



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Unconsolidated Material Thickness - Isopach

Depths to bedrock increase rapidly into Cienega Creek watershed to north

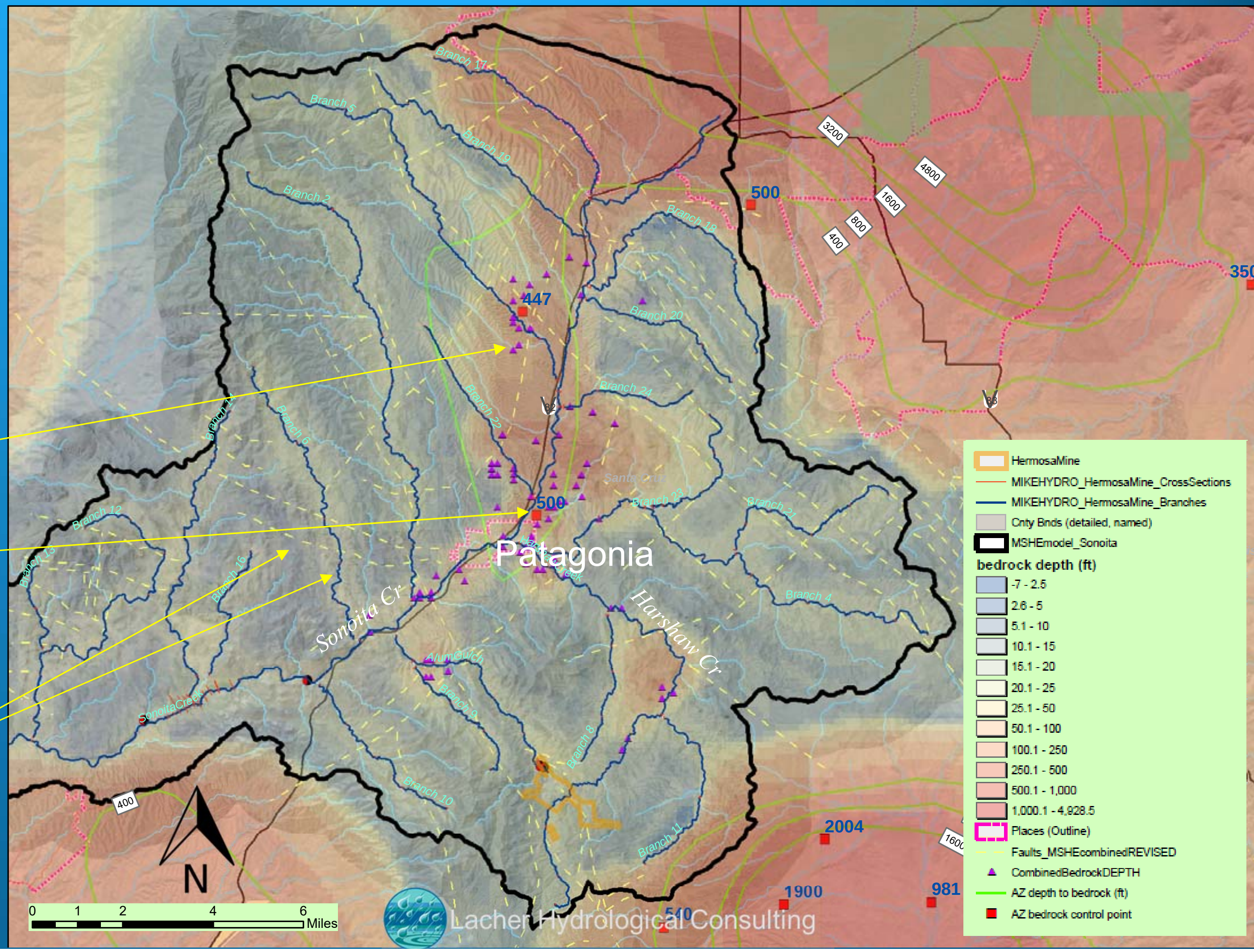
Thickness data shows →

- 100s of feet thick from Patagonia to ~7.5 miles north along Sonoita Creek
- Shallows at/south of Patagonia, along Sonoita (~20-30 feet)
- Harshaw depth variable (~150 to 10 feet)

ADWR well log locations

Arizona State Depth to Bedrock – borehole location (ft)

Assumed thickness ~3 m hilltop areas, and ~6 m along drainages (where data lacking)



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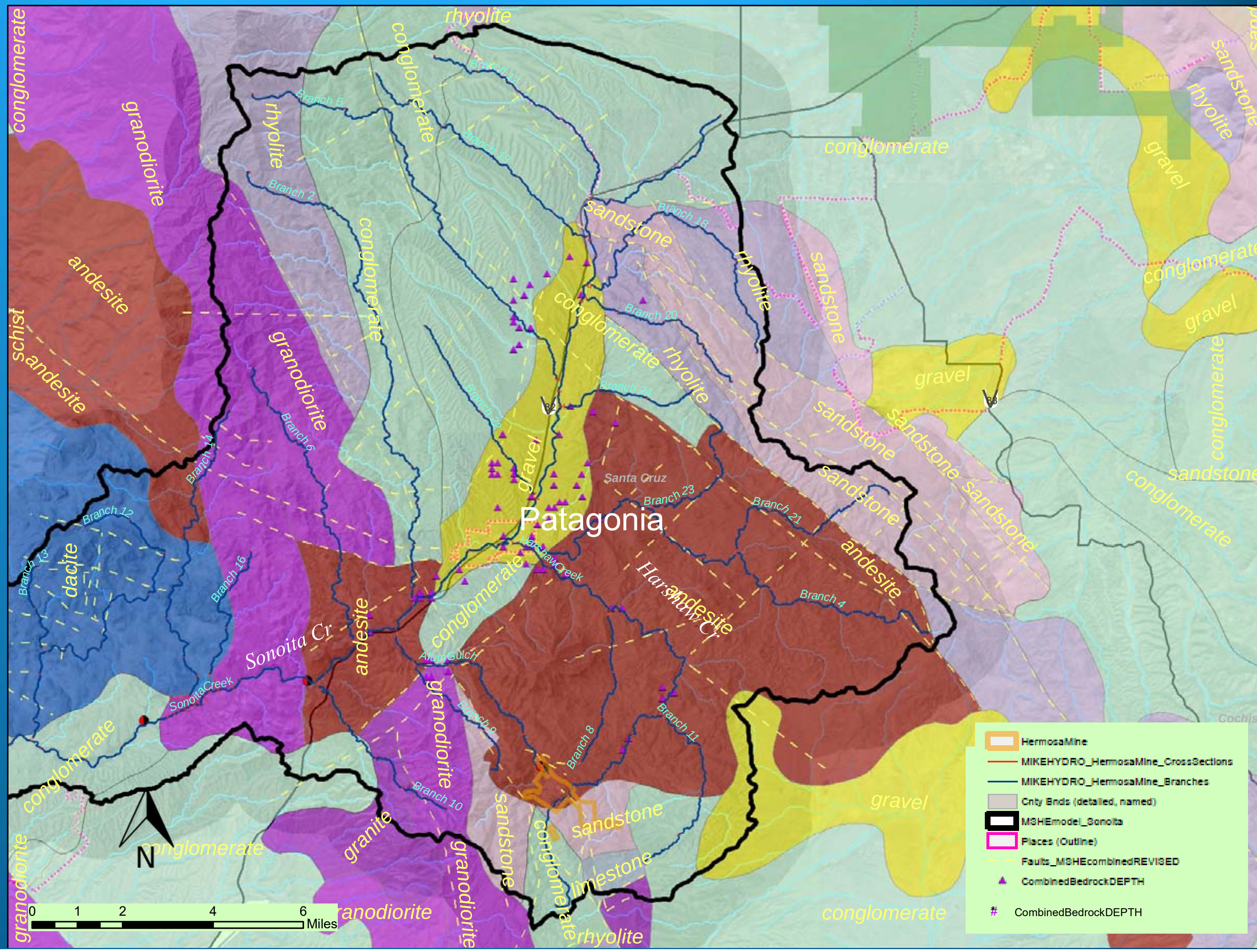
Saturated Zone Hydraulic Properties

Utilized hydraulic properties (conductivity and storage) from modeling associated with Rosemont Mine EIS

Refinement of hydraulic property distributions guided by AZGS surficial geologic zones



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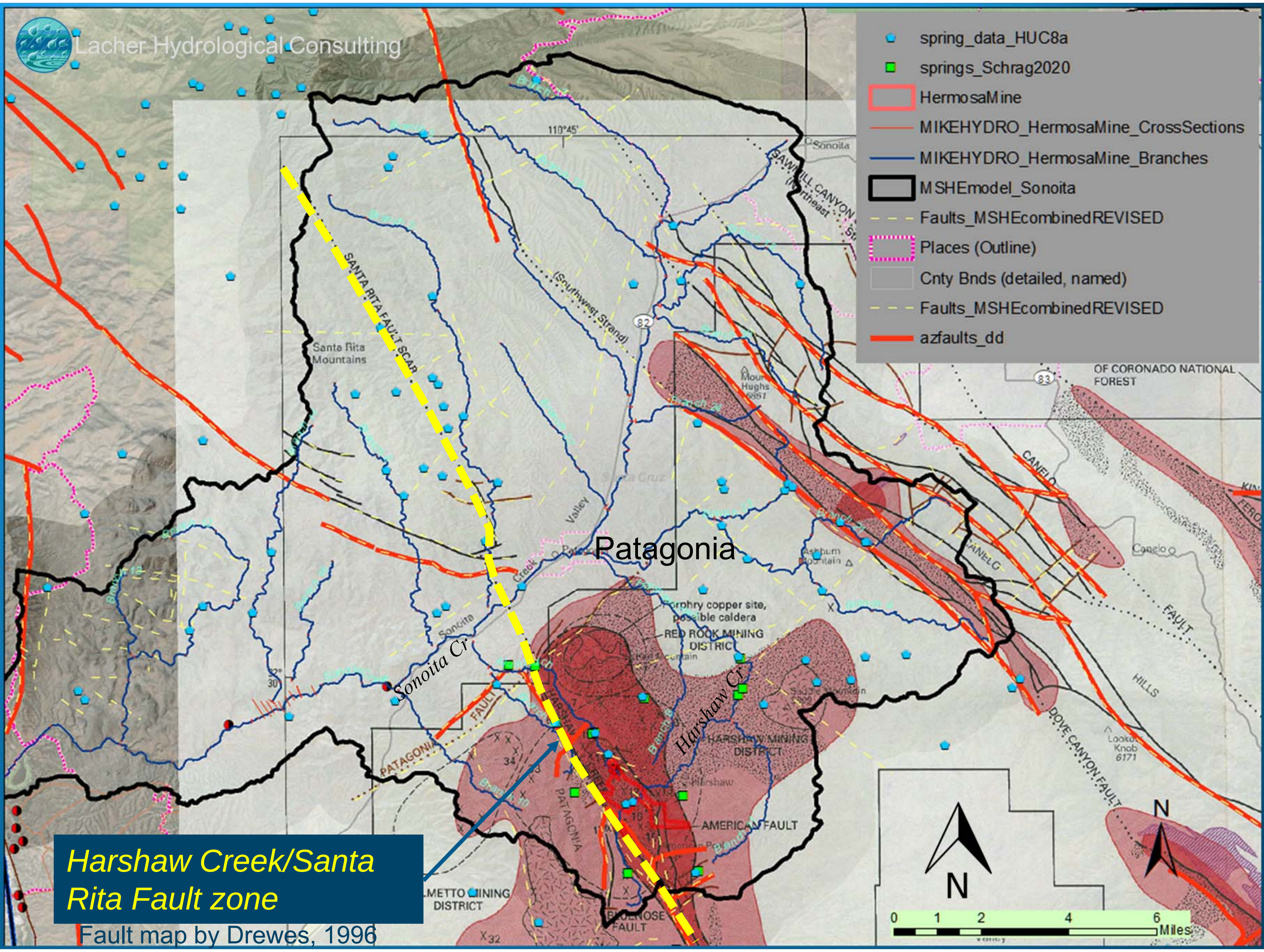
Faults and Springs

Faults can either impede flow across OR facilitate flow along them.

MIKESHE modeling assumed they all impede flow. Further evaluation is needed.

Groundwater flow could be enhanced along the *Harshaw Creek/Santa Rita Fault zone or similar faults*.



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2014 Existing Vegetation Types

Leaf Area Index (LAI) from 8-day MODIS satellite (from 2000 to 2020) drives Actual ET. Consistent with wet/dry climate periods.

3 main types:

- Conifer
- Shrubland
- Grassland

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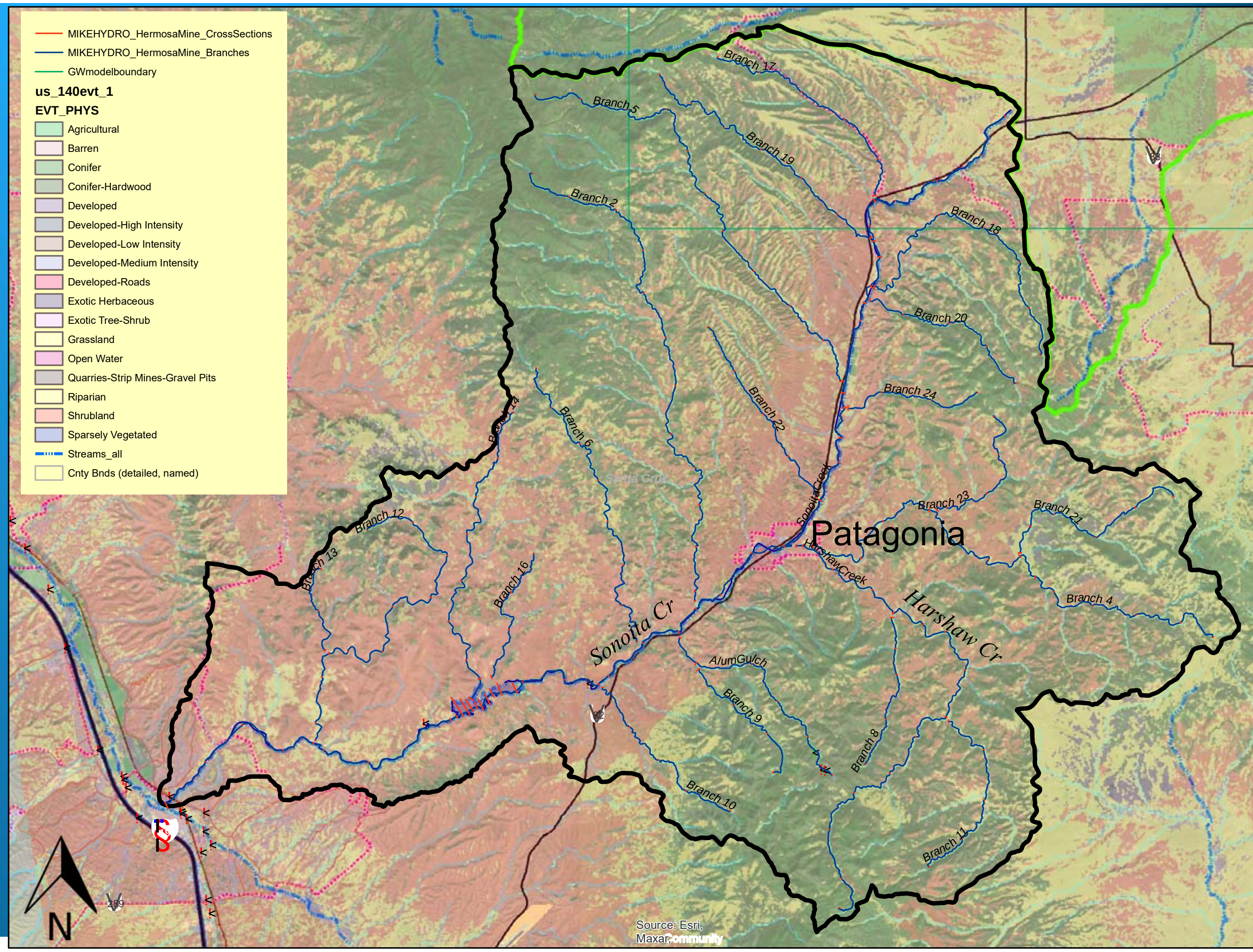
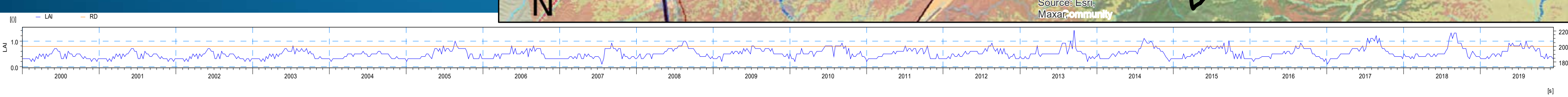


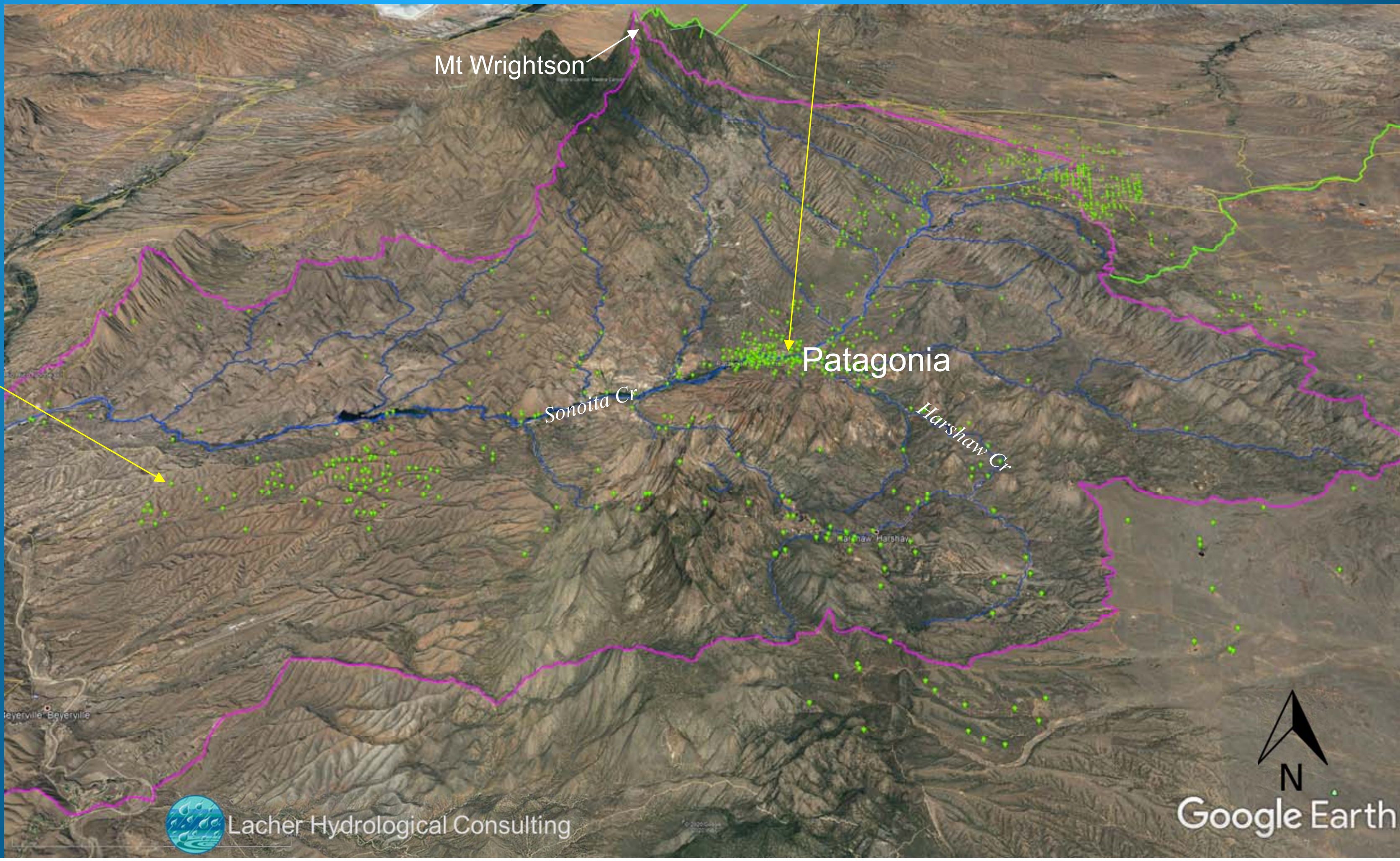


Boundary Conditions

Groundwater Pumping

Includes Patagonia Community Water System Pumping by year (2 wells)

Assumed 0.5 ac-ft/yr net pumping from all ADWR Wells.



Groundwater Level Data

ADWR GWSI and Well-55 Registry data used to create a time-averaged groundwater 'potentiometric' surface map.

Initial condition for the integrated model.

Transient water level data are used as calibration data in the model.

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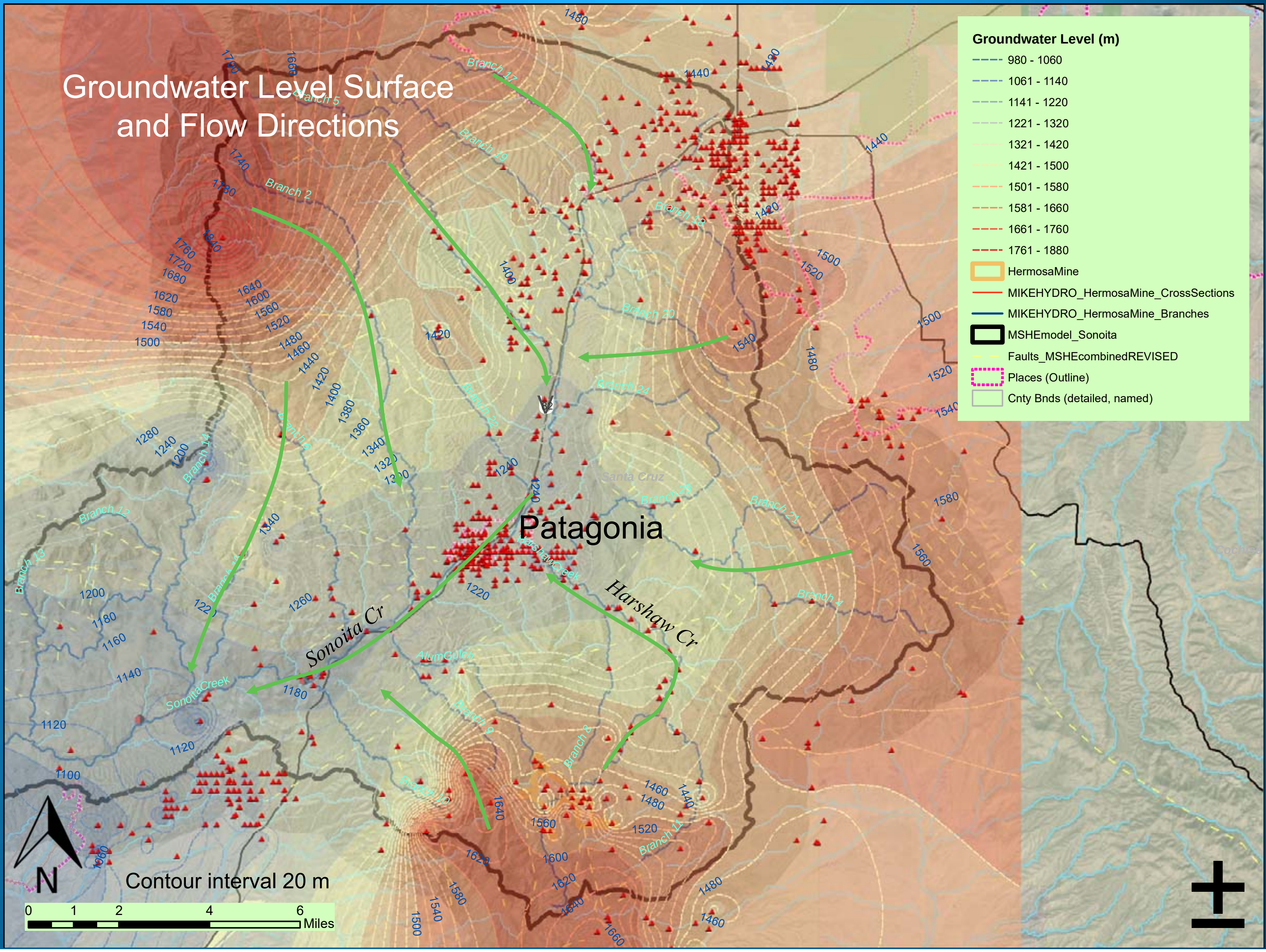
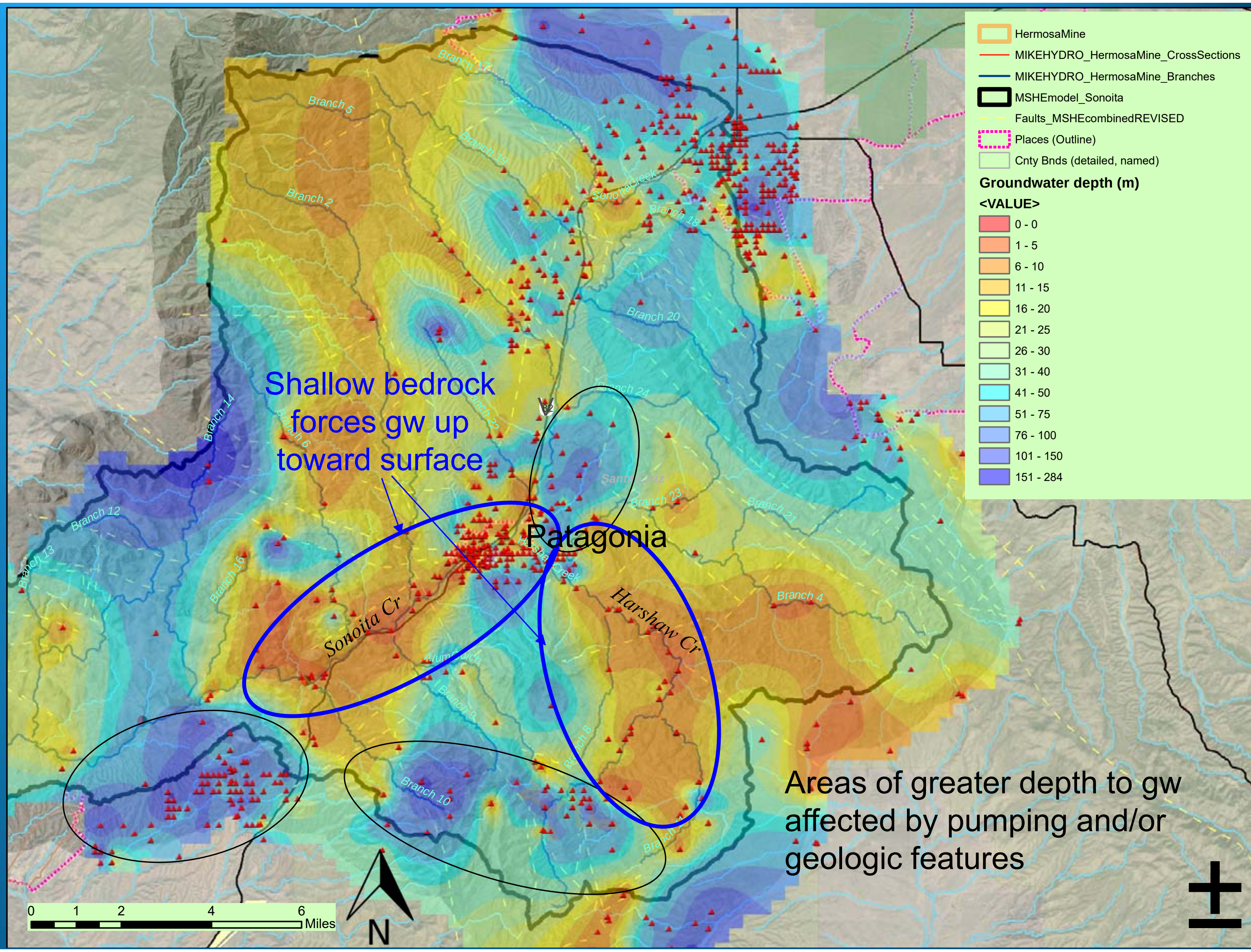


Depth to Groundwater

Estimated depth to groundwater below ground surface:

- increases in deeper bedrock areas
- shallow along most of Harshaw Creek (~2 to ~15 m) →

Shallow groundwater limits surface infiltration



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Preliminary Model Performance/Calibration

Snowmelt

Streamflow

Groundwater

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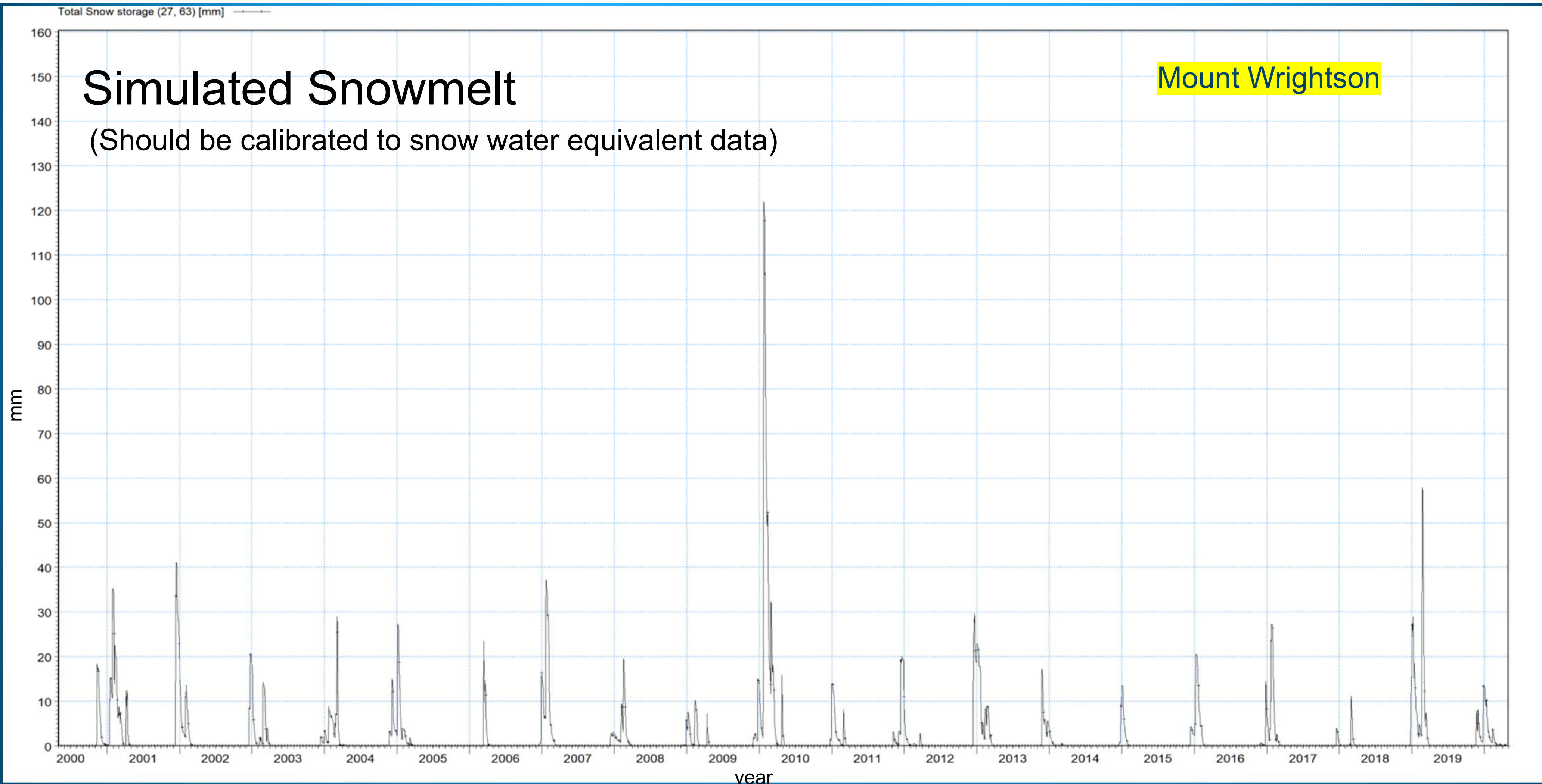
Simulated Snowmelt

(Should be calibrated to snow water equivalent data)

Mount Wrightson



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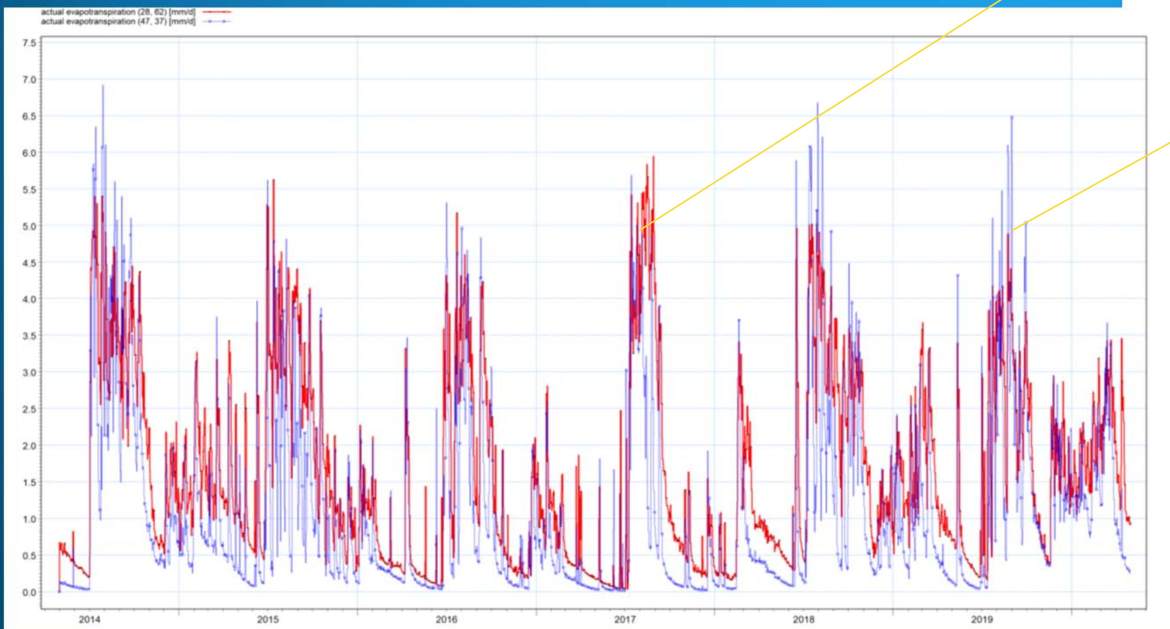
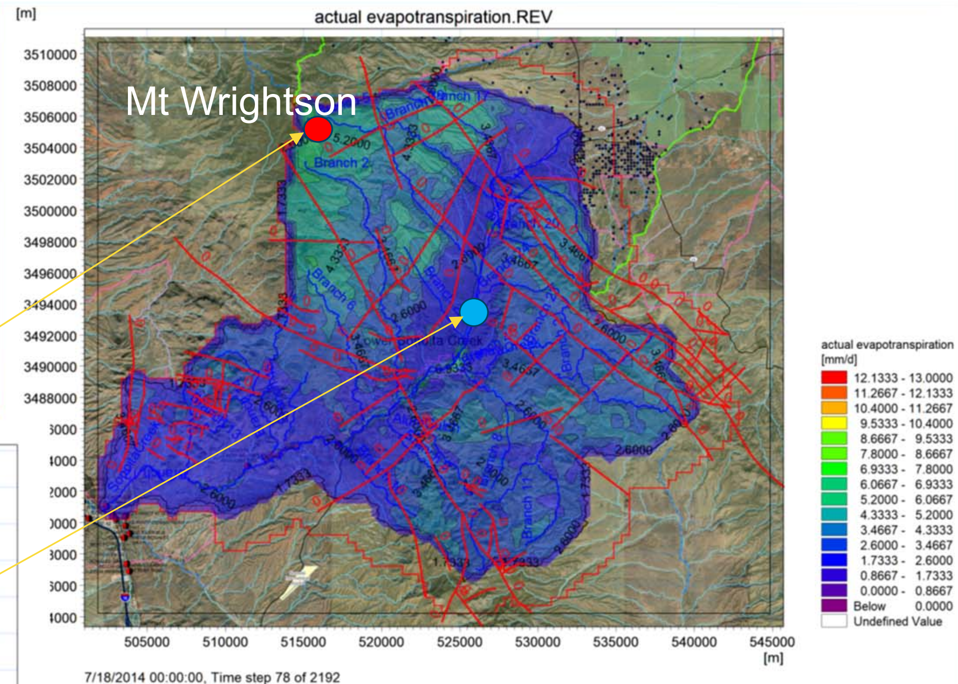
Simulated Actual Evapotranspiration (AET)

Higher Altitudes → produce more AET, mostly due to increased precipitation with elevation.





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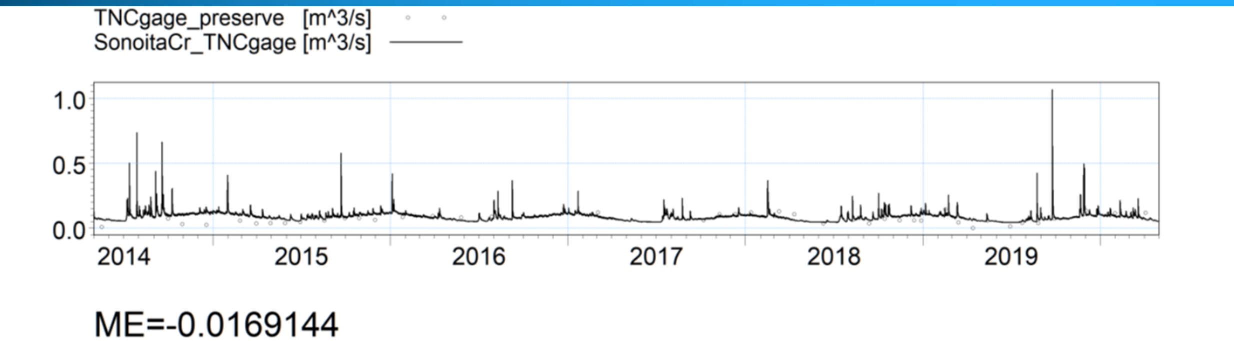
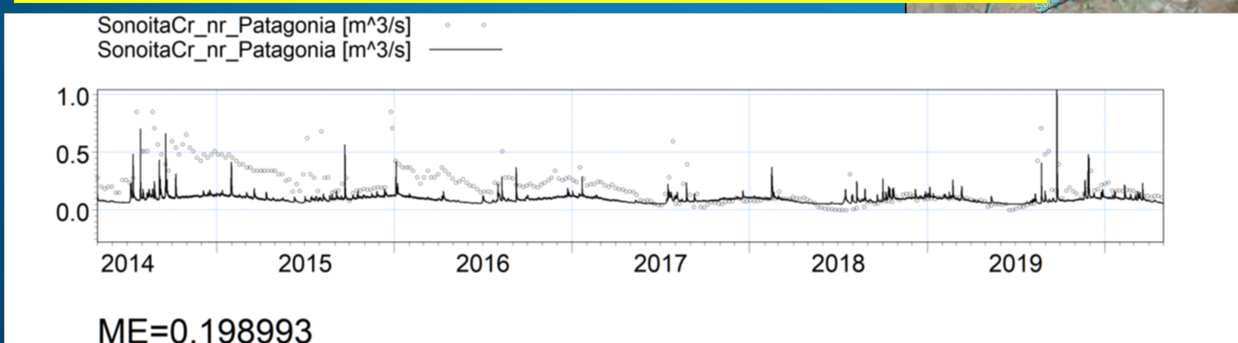
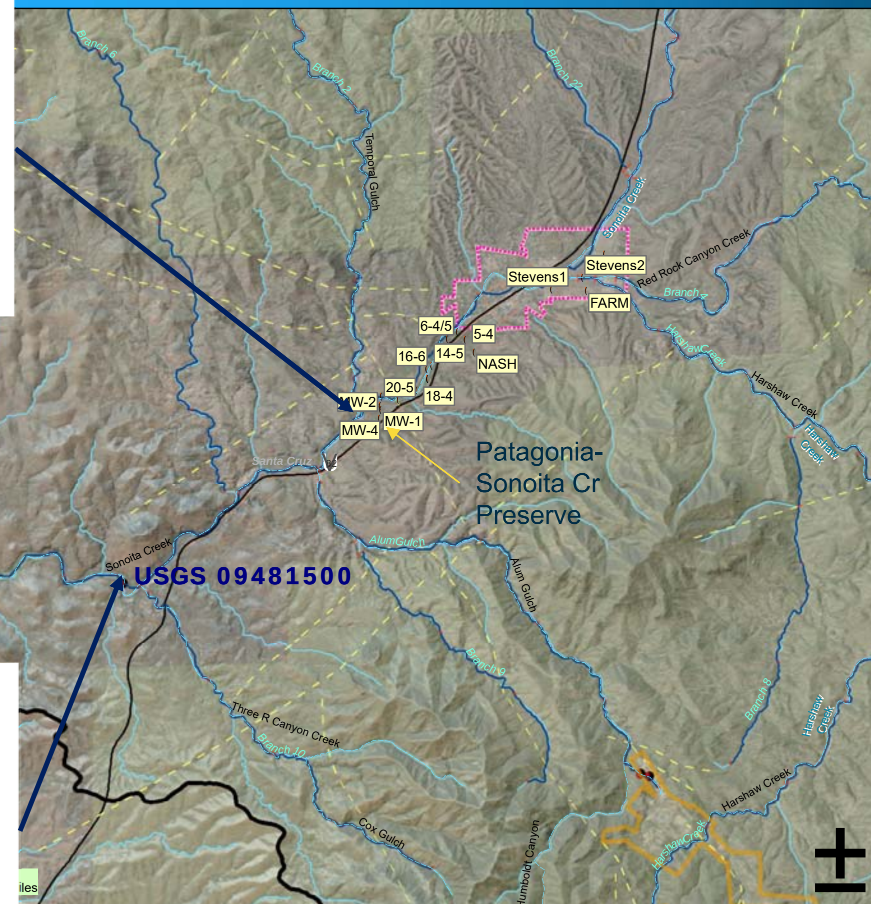
Simulated Discharge – USGS Patagonia Gage (1930-1972)



Seasonal variations in baseflow realistic at Preserve gage. Hourly measurements are required to confirm short-term 'storm-event' peak flows.

Observed discharge (dots on lower plot) are from 1960s-early 1970s <u>only</u> for comparison. Baseflows and range of peak flows are reasonable – but need actual data.





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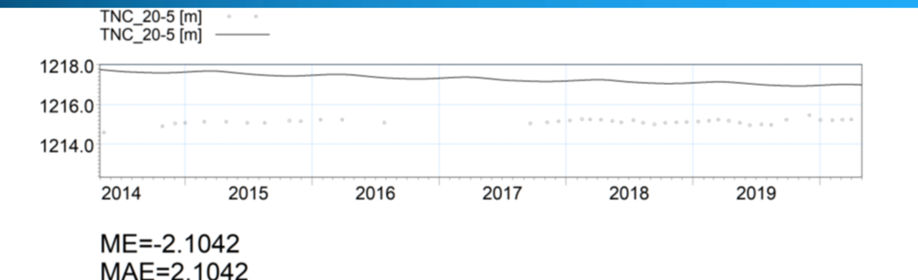
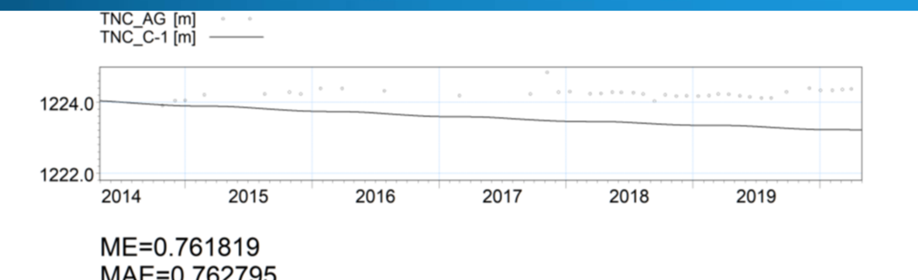
Preliminary Simulated Transient Heads





Many potential reasons for deviations:

- *Relatively <u>coarse model grid</u> → a finer grid will better simulate local flows/heads*
- *<u>Assumed pumping</u> (0.5 ac-ft/yr) at all wells*
- *Variations in local geology*
- *Faulting assumptions (some faults facilitate flow)*
- *Water level measurements (ADWR)*
  - *Old/outdated*
  - *Influenced by pumping*
  - *Assumed screened depths*
- *Upstream diversions (stock ponds, etc)*
- *Upstream AG-irrigation*
- *Legacy mining dewatering*
- *Current/recent mining dewatering*
- *Inaccuracy in initial heads*

→ Further calibration required

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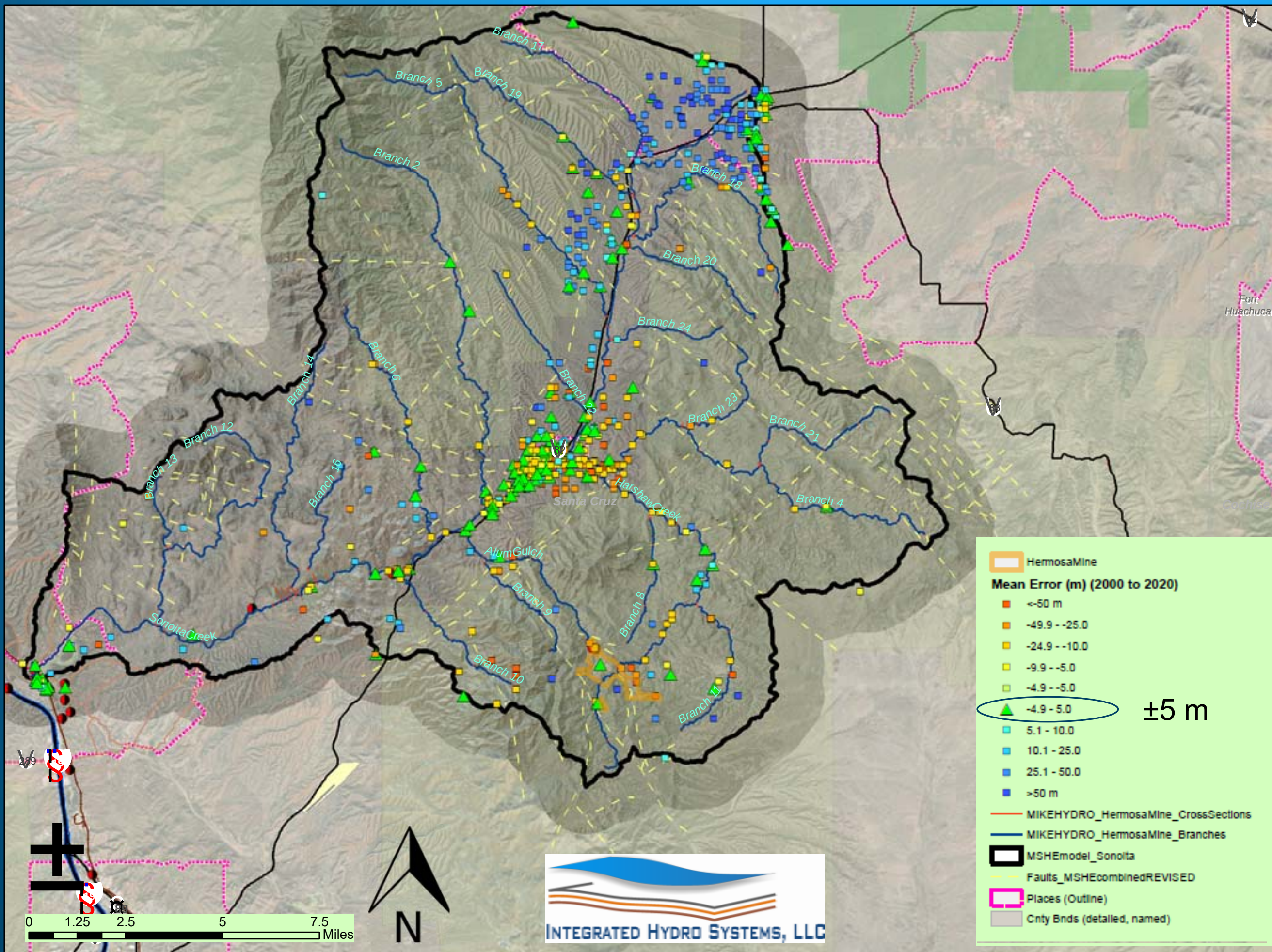
Simulated vs. Observed Heads (all ADWR wells)



<u>Preliminary results</u> – identify areas needing further refinement.

- Green triangles indicate reasonable calibration.
- 822 wells – multiple depths
- Spatial coverage limited outside of main drainages

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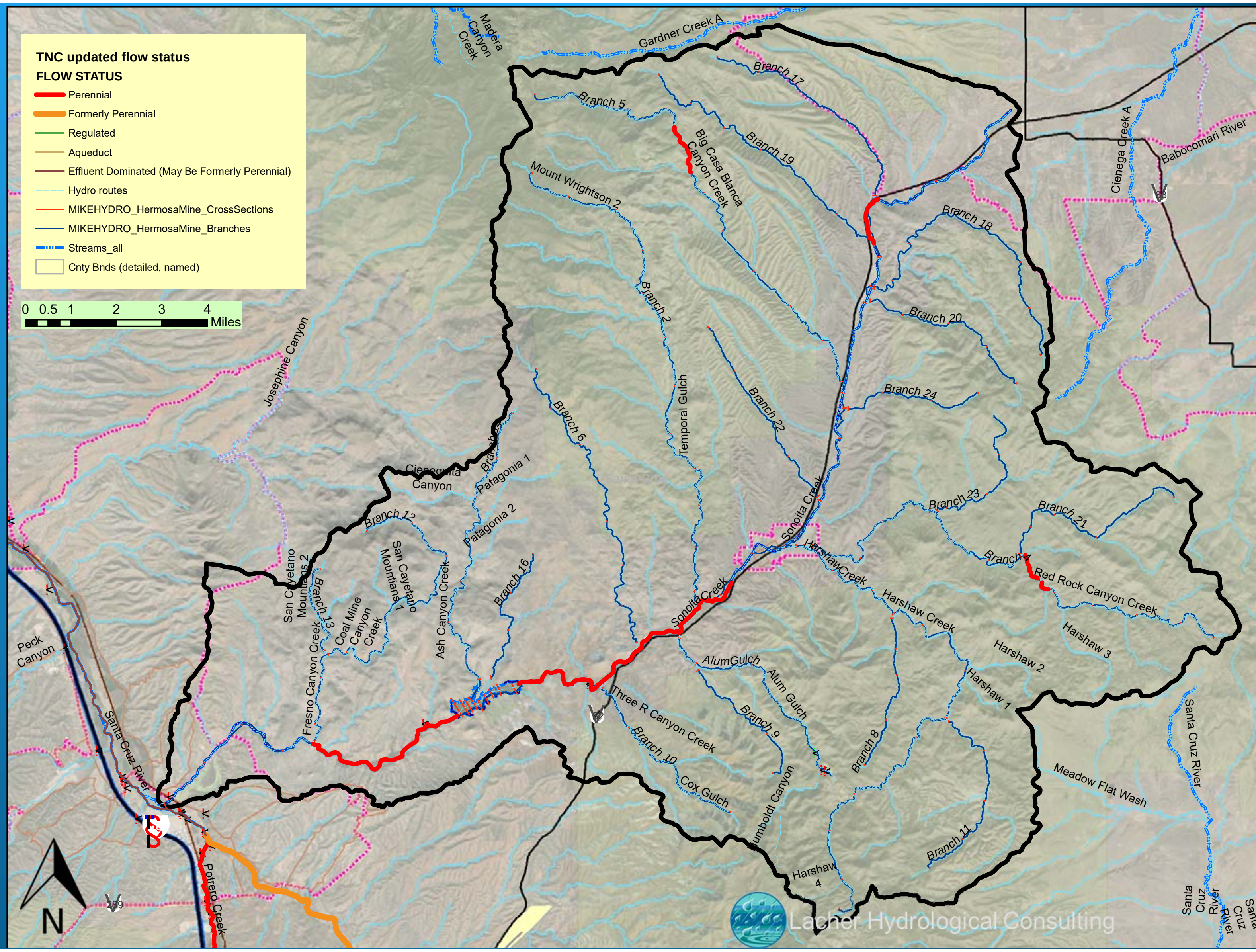
Perennial Flow Reaches – TNC

Important calibration data in lieu of gaging stations



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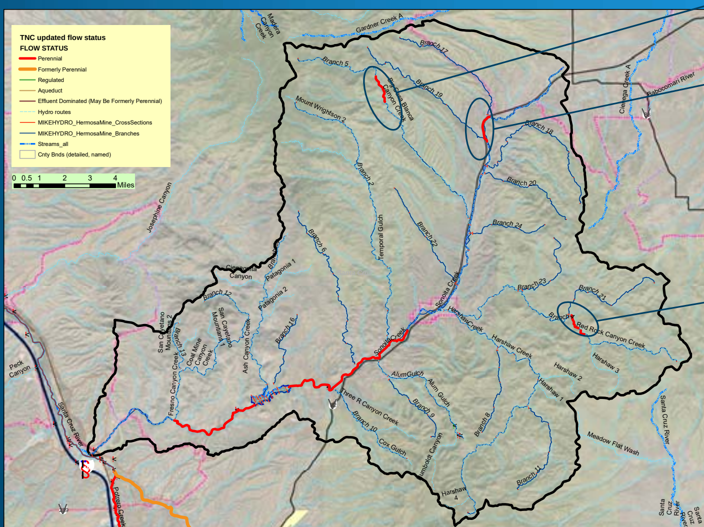
Simulated Gaining and Losing Reaches

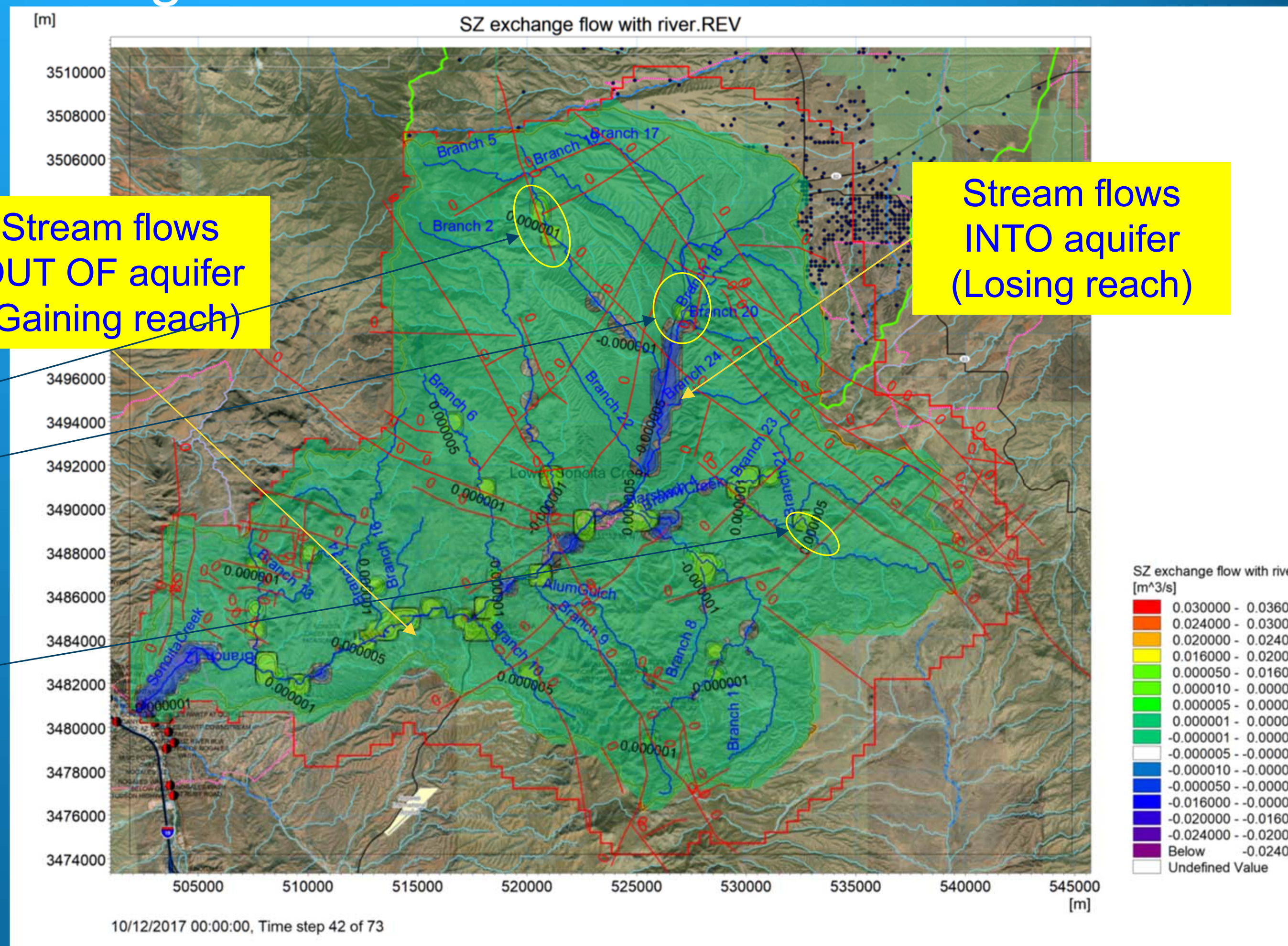
General agreement between MIKESHE and Perennial stretches.

Note → MIKESHE indicates gaining/losing reaches vary throughout the year

Stream flows OUT OF aquifer (Gaining reach)

Stream flows INTO aquifer (Losing reach)





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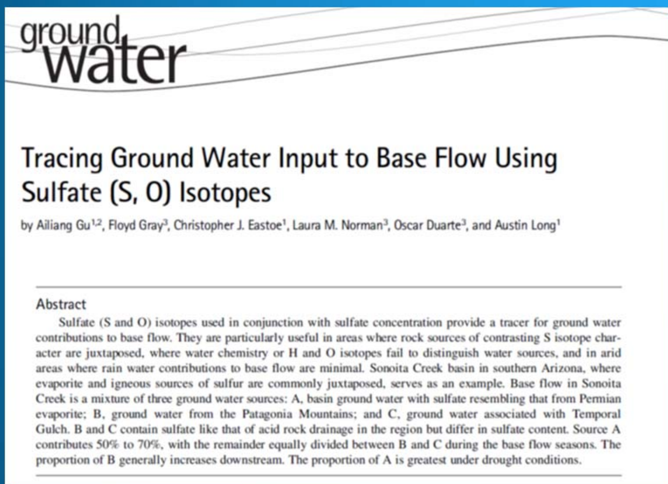
Utilize WQ/Isotopes to refine MIKESHE flow calibration

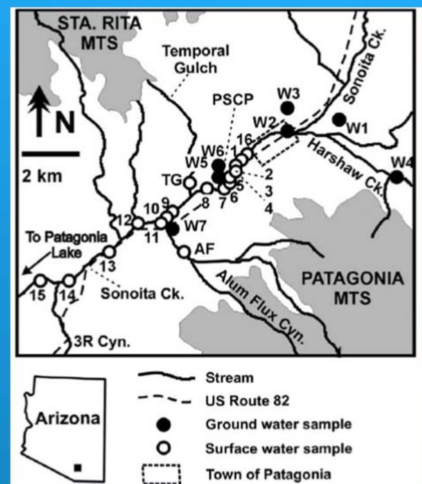

ground water

Tracing Ground Water Input to Base Flow Using Sulfate (S, O) Isotopes

by Ailiang Gu[1,2], Floyd Gray[3], Christopher J. Eastoe[1], Laura M. Norman[3], Oscar Duarte[3], and Austin Long[1]

Abstract

Sulfate (S and O) isotopes used in conjunction with sulfate concentration provide a tracer for ground water contributions to base flow. They are particularly useful in areas where rock sources of contrasting S isotope character are juxtaposed, where water chemistry or H and O isotopes fail to distinguish water sources, and in arid areas where rain water contributions to base flow are minimal. Sonoita Creek basin in southern Arizona, where evaporite and igneous sources of sulfur are commonly juxtaposed, serves as an example. Base flow in Sonoita Creek is a mixture of three ground water sources: A, basin ground water with sulfate resembling that from Permian evaporite; B, ground water from the Patagonia Mountains; and C, ground water associated with Temporal Gulch. B and C contain sulfate like that of acid rock drainage in the region but differ in sulfate content. Source A contributes 50% to 70%, with the remainder equally divided between B and C during the base flow seasons. The proportion of B generally increases downstream. The proportion of A is greatest under drought conditions.



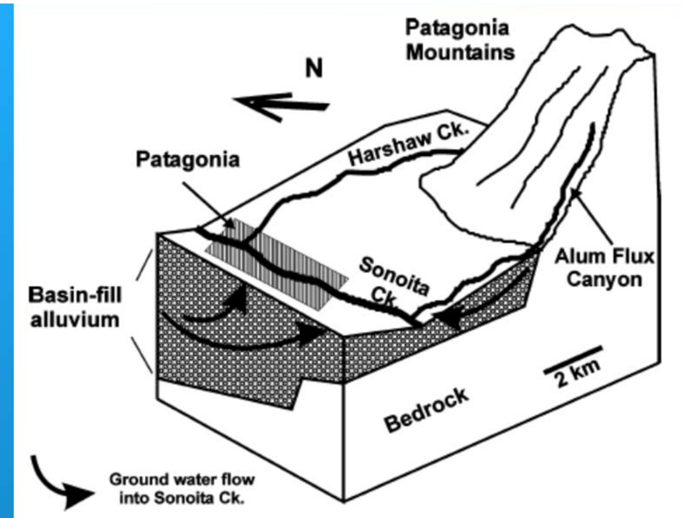
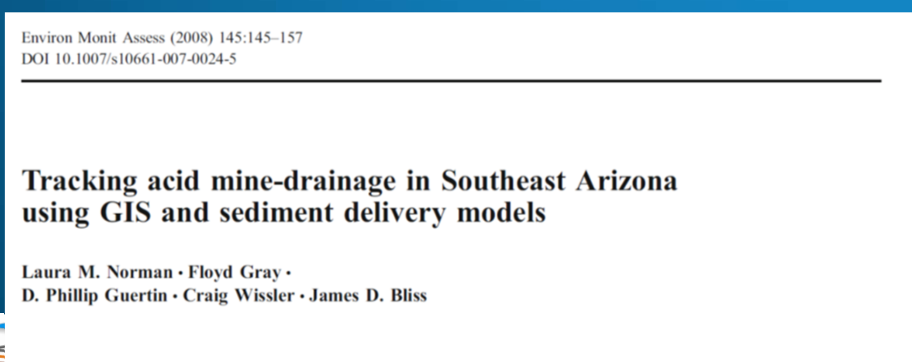


Figure 3. Conceptual block diagram showing relevant elements of geology and suggested ground water flow directions. Vertical scale is unspecified and horizontal scale is approximate. Flow from the Patagonia Mountains to the aquifer below Sonoita Creek is also present north of Alum-Flux Canyon. The diagram does not show ground water flow from the northwest side of Sonoita Creek.


Environ Monit Assess (2008) 145:145–157
DOI 10.1007/s10661-007-0024-5

Tracking acid mine-drainage in Southeast Arizona using GIS and sediment delivery models

Laura M. Norman · Floyd Gray · D. Phillip Guertin · Craig Wissler · James D. Bliss

"The use of extreme events such as 100-year floods, or droughts, or the input of management practices targeting erosion (vegetation, contouring, etc.) into these models would allow management to test outcomes and solutions to a wide variety of potentially damaging conditions with the goal of preventing costly loss or injury to lives or properties." *(Norman et al, 2008)*

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Scenarios

1. Baseline Conditions (no mine dewatering) - 2014 to 2020
2. WTP2 discharge – 2014 to 2020 (7 years)
3. Dewatering Scenario (*assumptions based on South32 presentation July 2020*)

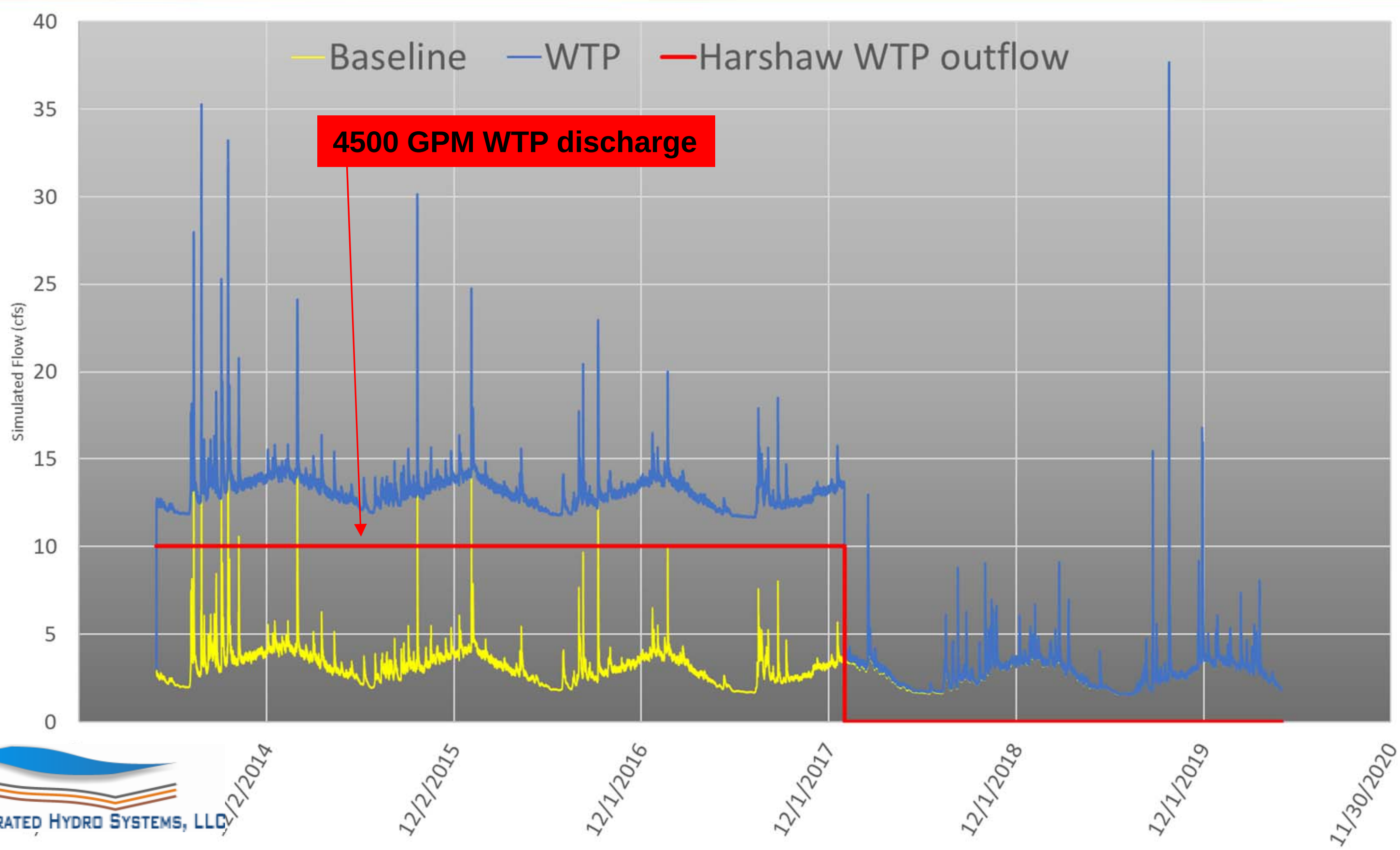

South32 Continued Exploration and Permitting

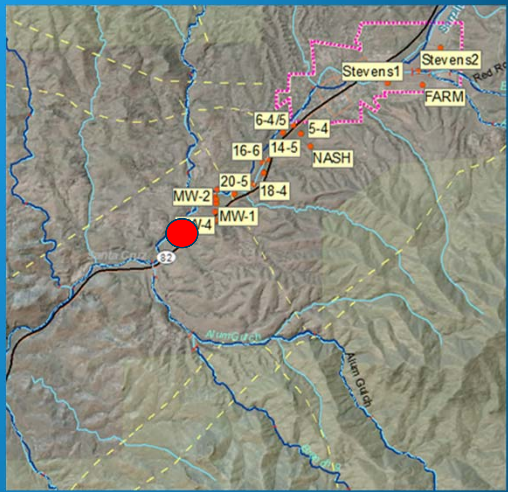
Santa Cruz County Board of Supervisors & Town of Patagonia
July 21 & 22, 2020

Assumptions:

- 4500 gpm discharged to Harshaw Cr from WTP2
- Continuous flow for 3.5 years, then off for 3.5 years
- Includes hourly distributed weather and runoff

Simulated Effects of WTP Discharge to Upper Harshaw Creek at Patagonia-Sonoita Cr. Preserve





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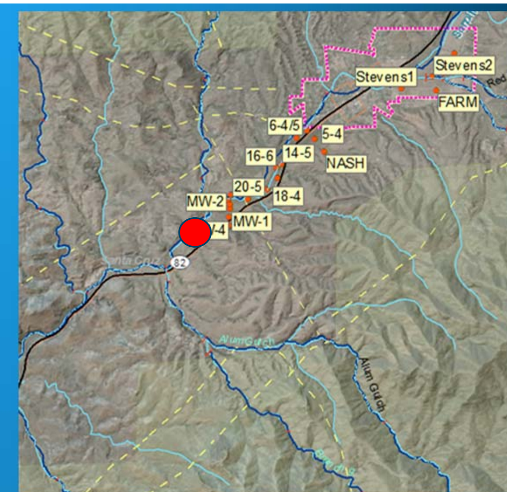
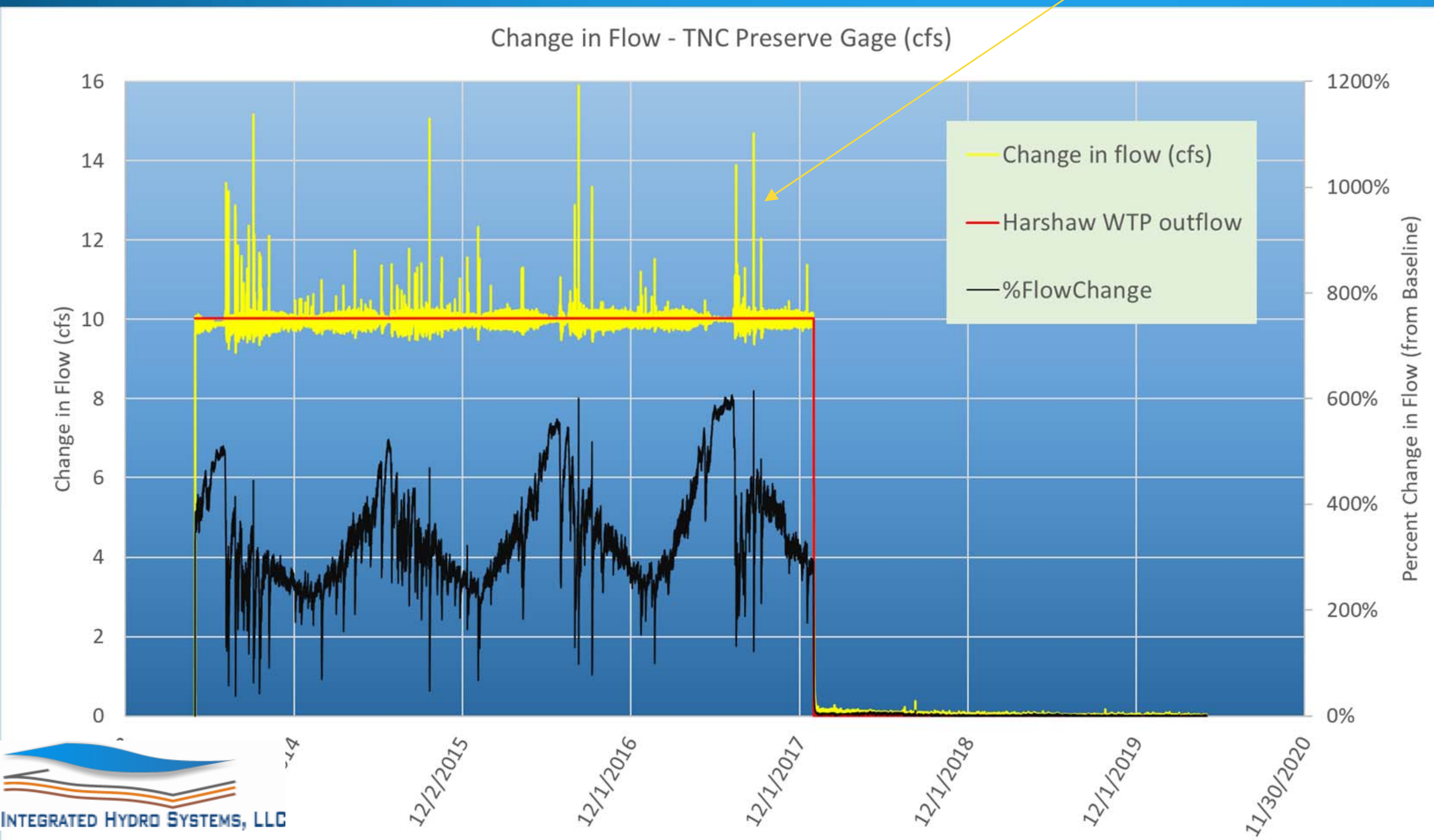
Simulated Change in Flow at Patagonia-Sonoita Cr. Preserve

Virtually all peak storm flows increase – significantly amplifying flood potential through town.





Flows at TNC preserve increase 200 to 600%.

Modeling shows → discharge at preserve increases baseline surface flows MORE than WTP 4500 gpm (10 cfs). **Precip from typical storm events runs off instead of infiltrating**
Nearly all of WTP discharge translates past Town.

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WTP Discharge Effects

<u>South32 Evaluation</u> of WTP discharge impacts on Harshaw and Sonoita Creek:

- Shows no/minimal impacts on Sonoita Creek
- Simulated Groundwater rise ~3 miles across Harshaw Cr:
  - MIKESHE shows impact along Harshaw Cr. limited to channel alluvium and bedrock just around creek (hundreds of feet – not 3 miles)
- "Steady State" analysis doesn't account for effects of subsurface saturation and storm events on streamflow.

Area of Groundwater Rise extends nearly 3 miles around Harshaw Creek - Unrealistic

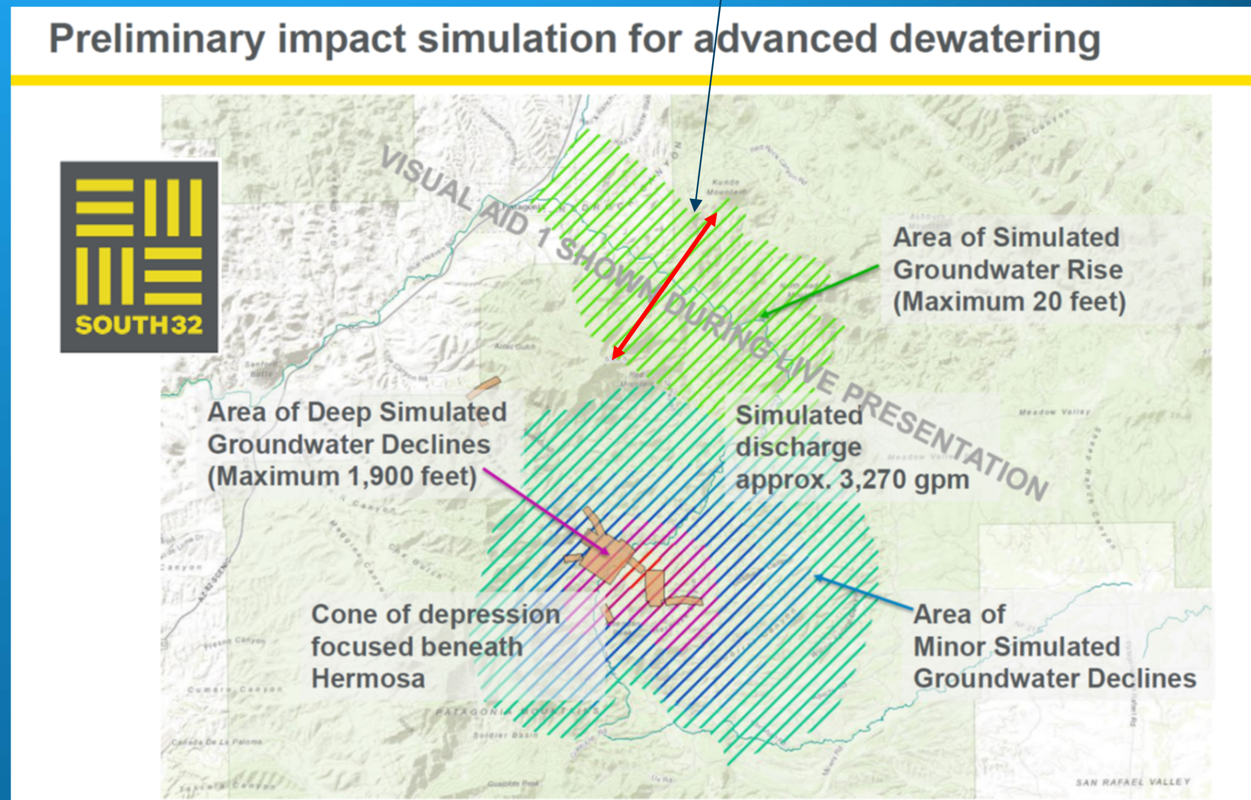
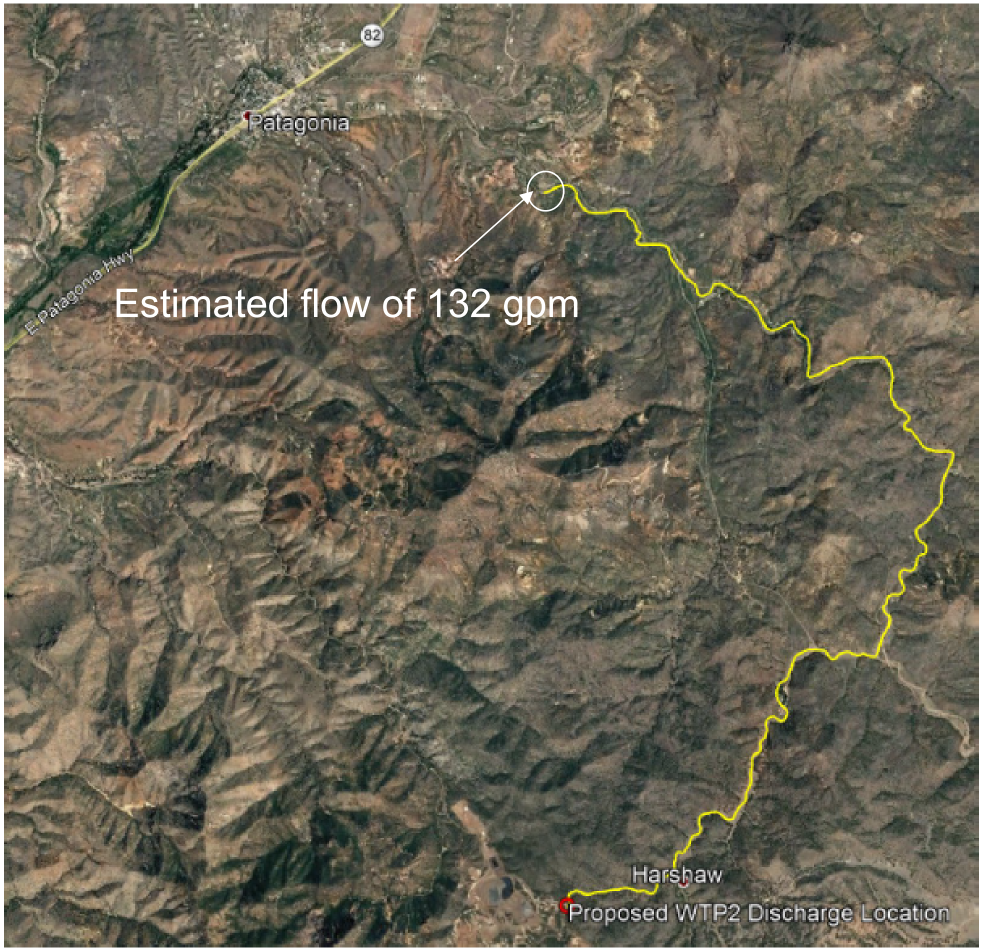


Figure 11 – Extent of Calculated PMA in Harshaw Creek (yellow) Resulting from Maximum 4,500 gpm Discharge from WTP2



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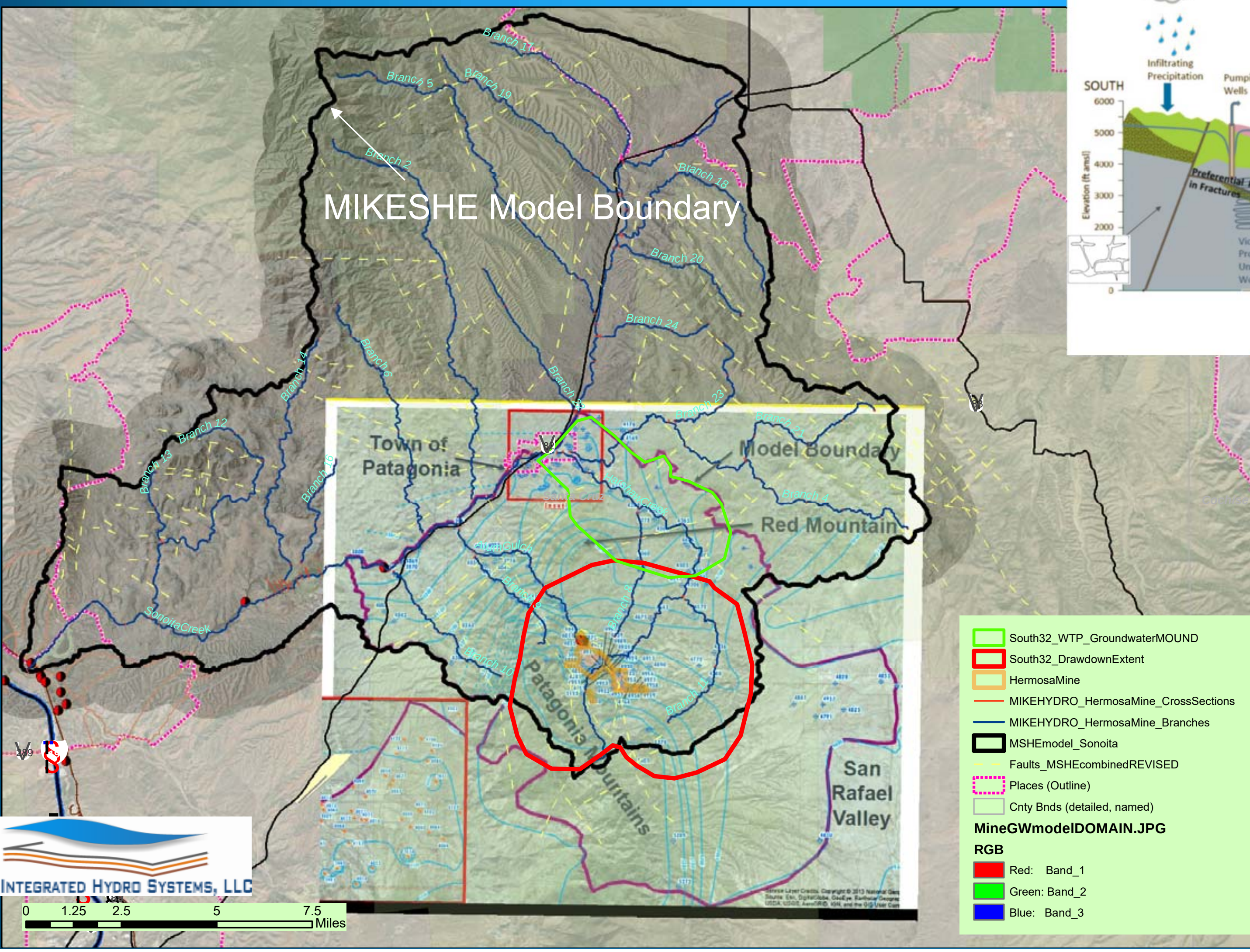
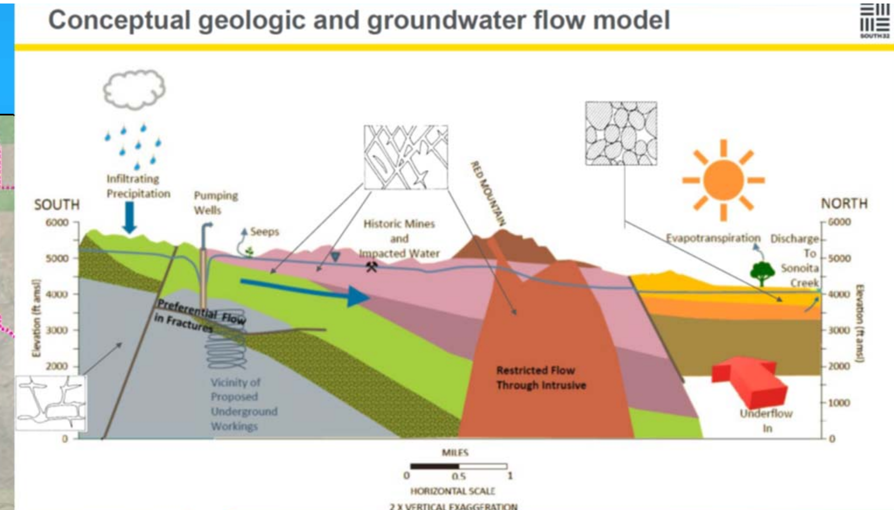
Dewatering





Suggests dewatering to at least 2000' elevation (>3000' below ground surface).

South32 Groundwater Model (purple line) only includes Harshaw Creek → can't assess impacts to Sonoita Cr upstream.

Model boundary clearly affects both drawdown (red line) and groundwater mounding (green line).

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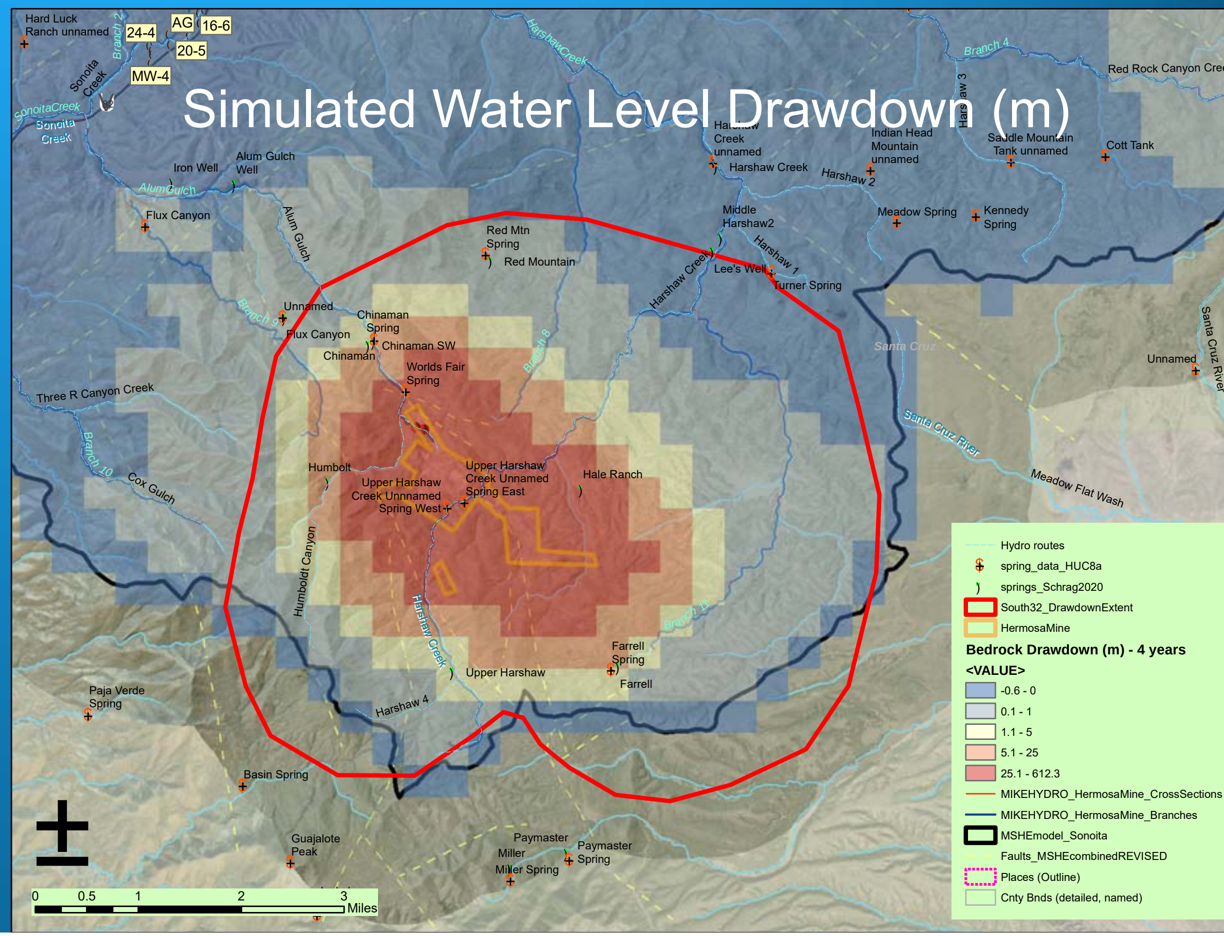
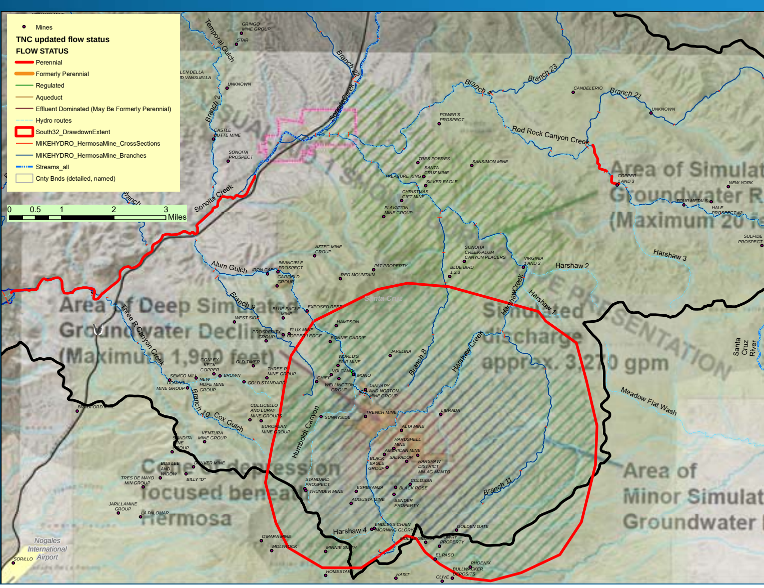
Simulated Water Level Drawdown

- Assumed 600 m (1968 ft) dewatering depth.
- Specified drains in mine footprint.
- Preliminary drawdown shows similar extent to South32 (after 4 years), but is elongated along Alum Gulch (faulting).
- Can't compare to mine drawdown levels – details unavailable.
- Predicted dewatering rate much lower





Effect of Legacy Mines on Proposed Dewatering

Dewatering and WTP discharge can facilitate movement of degraded water from legacy mines into Harshaw Creek

"A significant component of metal dispersion in these watersheds is the circulation and eventual surface discharge of waters that have absorbed metals and acidity via passage through networks of underground mine tunnels."
(Norman et al, 2008)

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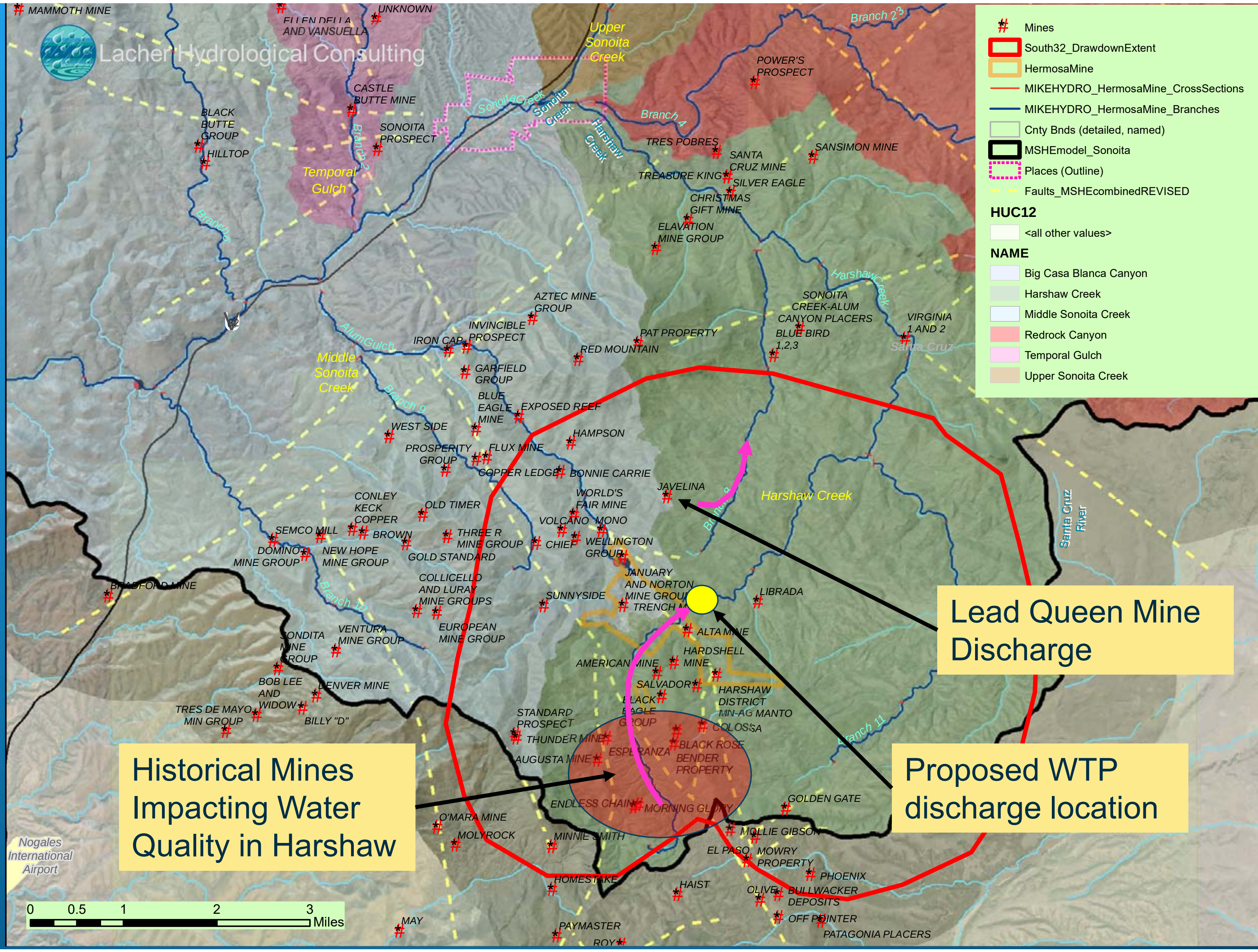

CONCLUSIONS AND RECOMMENDATIONS

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Key Findings from MIKESHE Modeling

- Important details influencing flows:
  - *transient shallow groundwater, shallow bedrock, clay in soil zone*
- MIKESHE results differ from APP → *show a range of impacts through Town.*
- Impacts derive from entire watershed upstream of Lake Patagonia
- A fully integrated modeling tool is needed to simulate:
  - the dynamically coupled GW-SW flow conditions
  - continuous response to each storm event
  - flows in ungauged watersheds

WTP2 DISCHARGE Conclusions

Proposed WTP2 discharge is likely to:

1. Quickly saturate/fill shallow alluvial aquifer along Harshaw Creek
2. Flow through Town and Preserve after initial wetting period
3. Increase PEAK flows downstream on Harshaw and Sonoita Cr. through Town and Preserve by more than WTP2 discharge
4. Facilitate transport of any contaminants above the WTP2 to downstream areas
5. Raise groundwater levels along both Harshaw and Sonoita creeks

MINE DEWATERING Conclusions

Findings from dewatering simulation in MIKESHE:

- Lateral extent similar to South32's July 2020 presentation (though uncalibrated)
- Dewatering rate much lower than South32 → details of dewatering/local geology at mine unavailable
- Numerous springs within drawdown footprint
- Faults likely influence drawdown and infiltration and could translate drawdown to Sonoita Creek

- Remaining Questions:
  1. Will mine dewatering & treatment address WQ at intercepted legacy mines inside and outside mine footprint?
  2. How will post-mining water level recovery and discontinuation of WTP discharge affect baseline conditions along Harshaw and Sonoita creeks?
  3. What will be long-term post-mining WQ impacts?

Missing in South32 analysis of WTP2 impacts

Item	Description
Variable bedrock depths	*Variable-depth low-permeability bedrock → important constraint on potential stream infiltration and saturation. Must develop geologic model based on boreholes and/or geophysical survey.*
Lithologic variations above bedrock – substantial clay layers	*Review of numerous logs → most wells show notable clay layers, which reduce stream infiltration/storage potential. Need more complete geologic model based on logs.*
Variable/dynamic GW table – beneath Harshaw and Sonoita Creeks	*Available water level data show relatively shallow water table → limits stream infiltration/aquifer storage potential. A broader model needs to be prepared to simulate groundwater flow/stream interaction.*
Sonoita Creek inflows above Harshaw Creek	*Lack of gage data at this location requires calibrated modeling of continuous, long-term coupled groundwater-surface water flow conditions – entire catchment upstream of confluence.*
Distribution and dynamics of soil moisture	*Not accounted for; should use available detailed soil survey data. Must consider transient effects (antecedent conditions).*
Storm runoff inflows along Harshaw upstream of WTP2 discharge point	*AZDEQ identified water quality issues with legacy mines upstream of WTP discharge point. Storm runoff above WTP2 may transport contaminants and add flow to area downstream of WTP2. Must model entire catchment above WTP2.*

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DATA GAPS

1) High-resolution topography (LiDAR) of Harshaw-Sonoita Creek system
2) More detailed characterization of alluvial aquifer along Harshaw Cr
3) Mapped legacy mine footprints/adits/tunnels/shafts, etc.
4) Details of mine water use throughout 30-year mine life
5) Geologic model based on well logs/geophysics
6) Continuous groundwater-level monitoring in wells along Harshaw and Sonoita creeks and in upland recharge areas
7) Continuous stream-flow measurements (every 5 minutes)
   a. upstream and downstream of WTP2 discharge point on Harshaw Cr.
   b. Sonoita Cr. upstream and downstream of Town
8) Wet/dry mapping of key ephemeral/intermittent stream reaches above and below Town
9) High-resolution meteorological data
10) Pumping/diversion data
11) More frequent/informed WQ monitoring at WTP2 and POCs
    – capture notable runoff events in Harshaw Cr
12) Hydraulic testing - aquifer testing, long term dewatering pumping

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Modeling Recommendations

- Conduct a more rigorous analysis
  - *Use "integrated' code like MIKESHE (vs single-process codes like HEC or MODFLOW) to capture highly dynamic groundwater-surface water interactions*
  - *Model full hydrologic system upstream/upgradient of Patagonia Lake*
    - *Collect additional data (data gaps list) for at least 1 year*
    - *Develop 3D geologic model for entire watershed – including bedrock depth, faulting and alluvial lithology*
    - *Improve calibration to available data (~last 20 years) to reproduce:*
      - *complete storm hydrographs, especially large events*
      - *average and transient well water levels (and springs)*
      - *actual evapotranspiration*
  - *Develop local-scale (eg, 40-m) model of Harshaw/Sonoita Cr through Town to examine:*
    - *Dewatering with WTP discharge*
    - *Mining alternatives*
  - *Conduct formal uncertainty analysis*
    - *Assess range of impacts*
    - *Identify worst case*
- Peer review work

APPLICATIONS OF INTEGRATED MODEL

1. Assessments:

- Erosion impacts from additional flows from WTP2
- Spring hydrology
- ET changes (increased flows, wetted area, vegetation)
- Long-term water quality changes
- Climate Change

2. Mitigations (examples):

- Possible reservoir on tributary upstream of town to store WTP discharge, thereby:
  - Minimizing flooding in Harshaw/Sonoita creeks
  - Providing controlled supply of water to town
  - Enhancing wetland habitat
- Passive wetland treatment system to mitigate long-term water quality impacts to Harshaw & Sonoita creeks and enhance habitat
- Erosion-control structures (single-rock dams, gabions, road swales, etc.)

Thank you!

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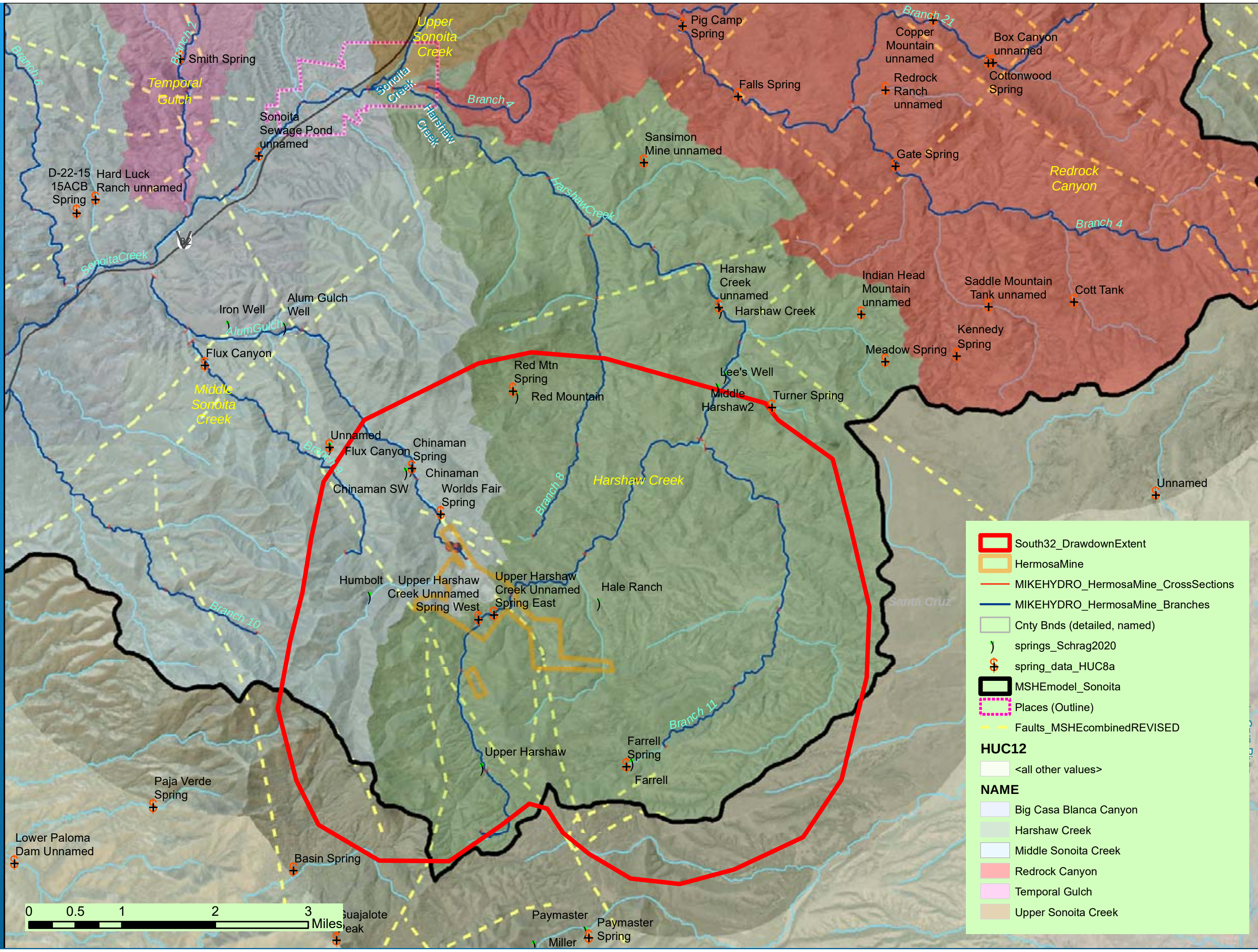
Effects of Dewatering and WTP discharge on Springs, during and post-mining



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