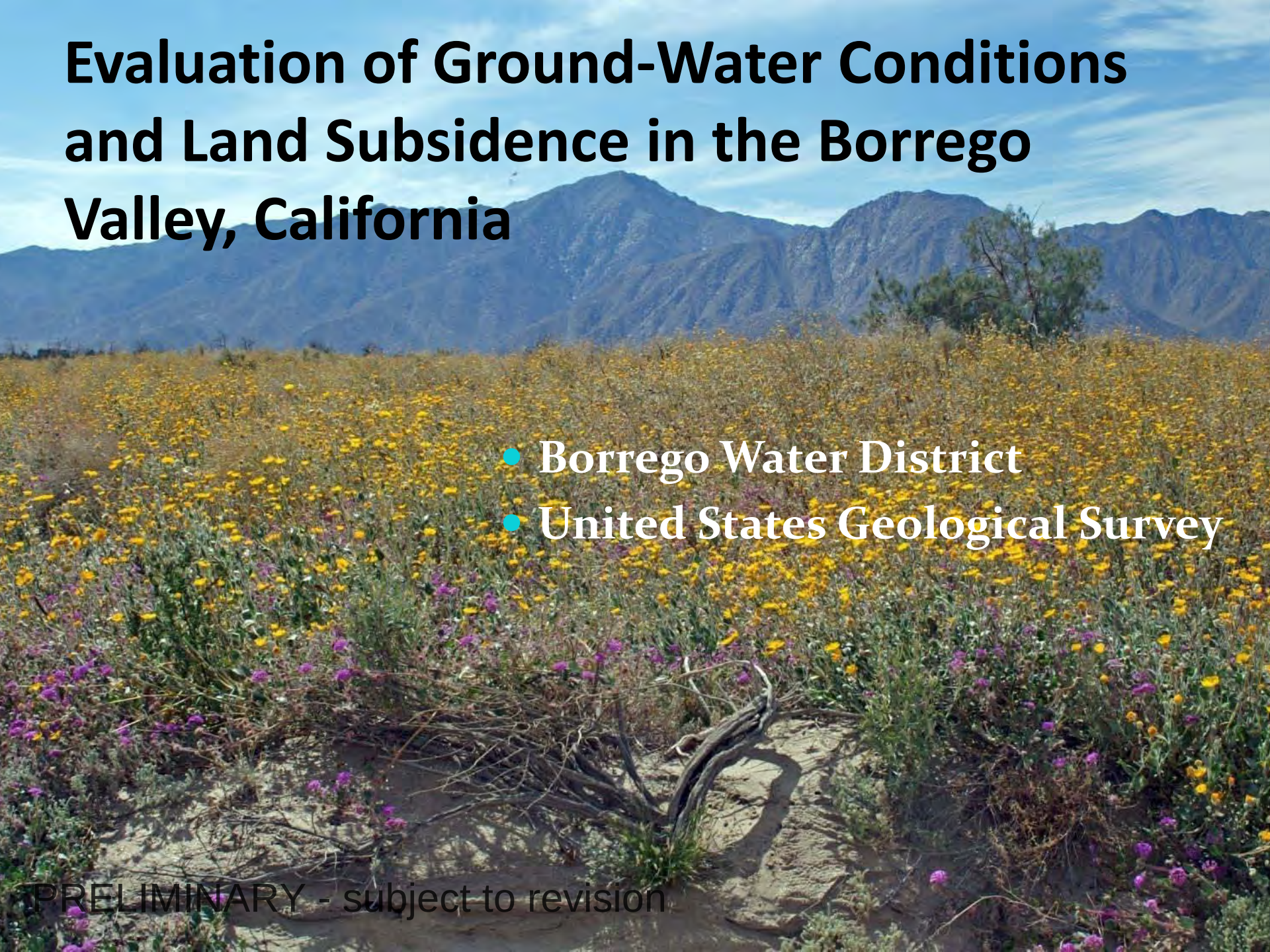
Evaluation of Ground-Water Conditions and Land Subsidence in the Borrego Valley, California



- Borrego Water District
- United States Geological Survey

PRELIMINARY - subject to revision

USGS Borrego Study Team

- Peter Martin: Program chief
- Claudia Faunt: Project chief, model development
- Michelle Sneed: Land subsidence
- Matt Burgess: Model development
- Joseph Nawikas: High precision GPS, water levels
- Andy Morita: High precision GPS, water levels
- Chris Stamos: Model development
- Steve Predmore: GIS support
- Donald Martin: GIS support

PRELIMINARY - subject to revision

Problem:

- Groundwater is virtually the sole source of water supplies in Borrego
- Annual groundwater pumping exceeds natural recharge by about four times
- Pumping has resulted in water levels dropping over two feet per year for the past twenty years
- Water-level declines in areas with significant clay deposits could result in land subsidence
- As the more permeable upper aquifer is dewatered, water-level declines may accelerate and water quality may deteriorate

PRELIMINARY - subject to revision

Objectives:

- (1) improve the understanding of groundwater conditions and land subsidence and
- (2) incorporate this improved understanding into a groundwater flow and land-subsidence model that will help to better manage the groundwater resources in the Borrego Valley.

PRELIMINARY - subject to revision

Approach:

(1) compilation of available hydrogeologic data,

(2) collection and analysis of new data,

(3) update and refine existing groundwater flow model, and

(4) preparation of an interpretive report.

PRELIMINARY - subject to revision

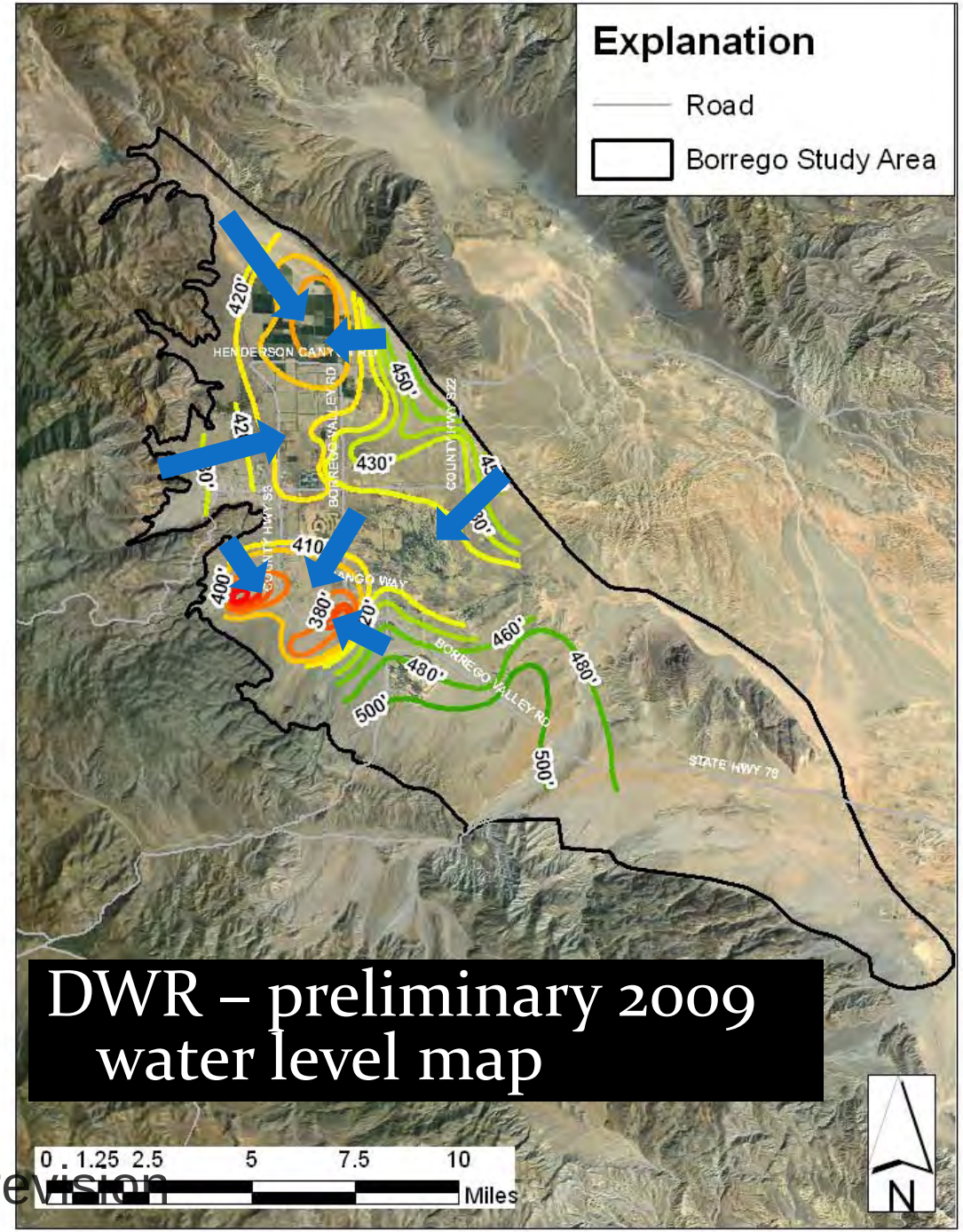
Overview:

- Water level observations
  - data interpreted and gathered by CA-DWR
- Recharge
- Hydrogeologic framework model
- Groundwater model
- Chemistry

PRELIMINARY - subject to revision

Water levels:

- Compiled >2,000 historical measurements
- USGS surveyed 79 wells
- DWR constructed water-level map using available measurements and updated altitudes



DWR – preliminary 2009 water level map

PRELIMINARY - subject to revision

Recharge

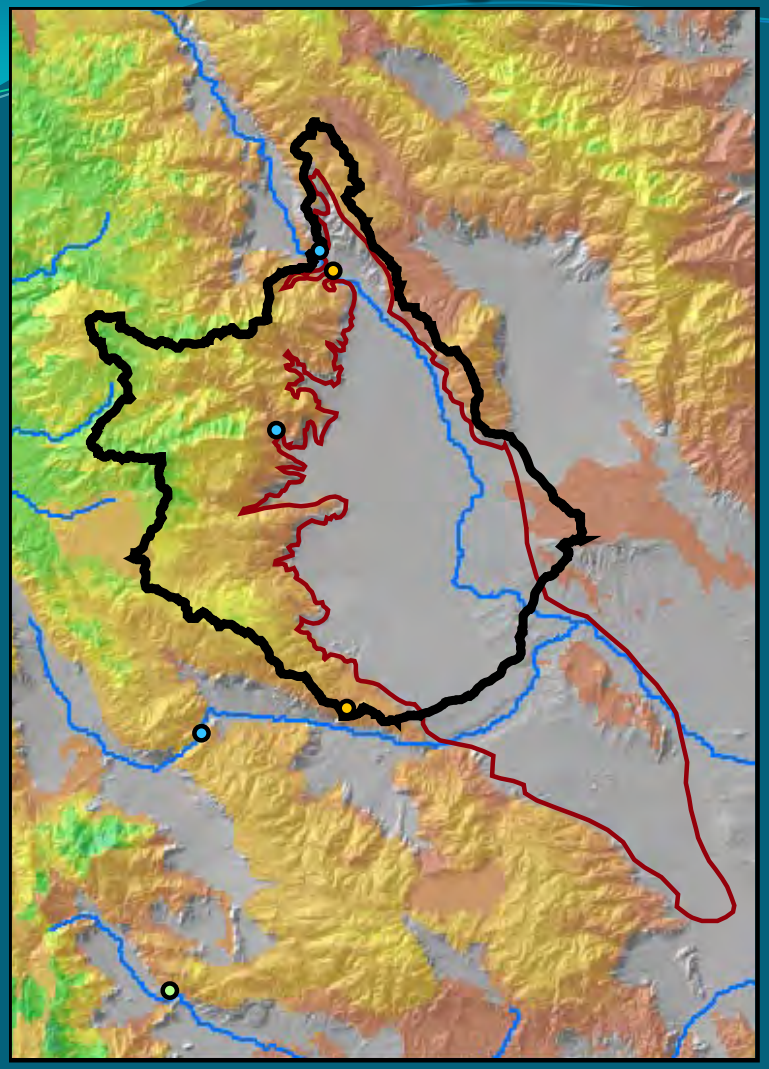
- Preliminary calculations done using a regional recharge model

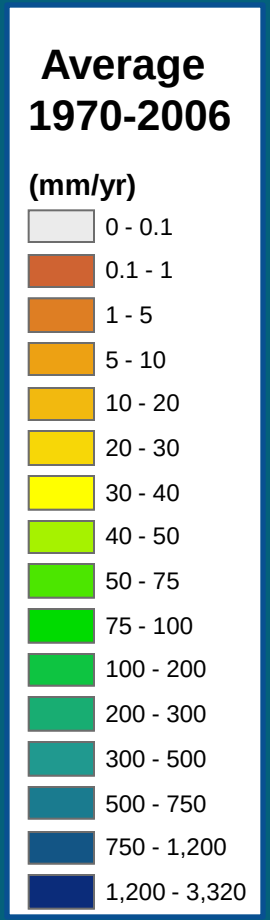
  - Basin Characterization Model (BCM)

- BCM provides estimates of recharge and runoff to the groundwater basin
- Monthly precipitation and potential evapotranspiration for 1940-2007

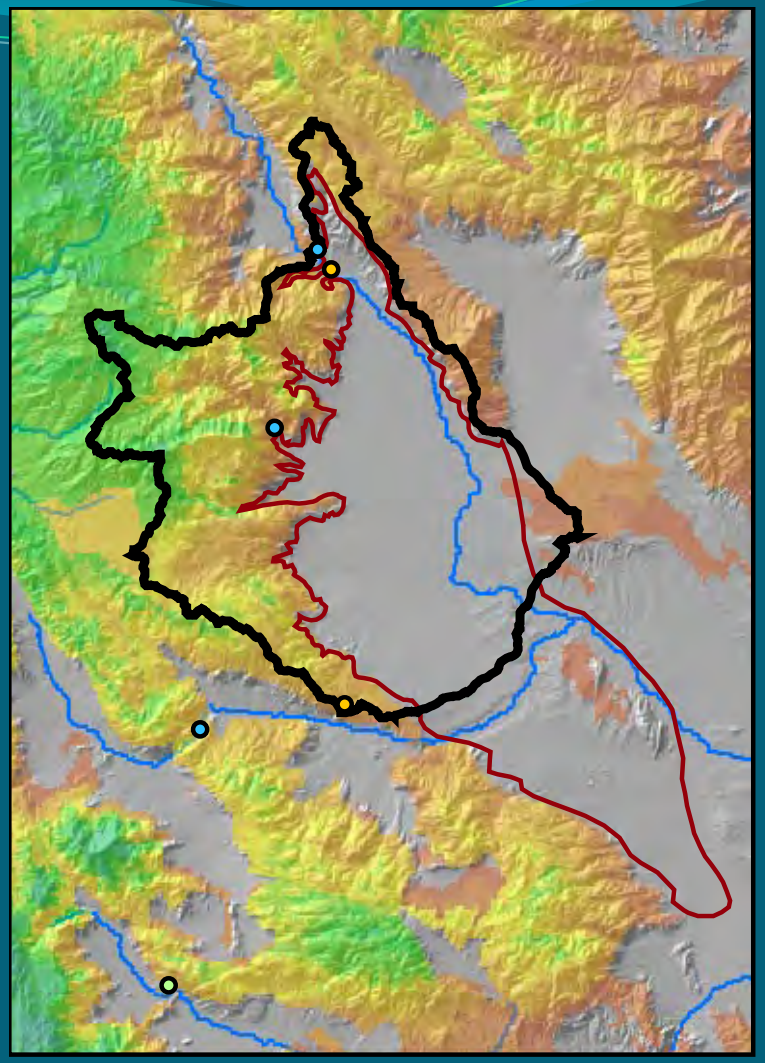
PRELIMINARY - subject to revision

Recharge





Runoff

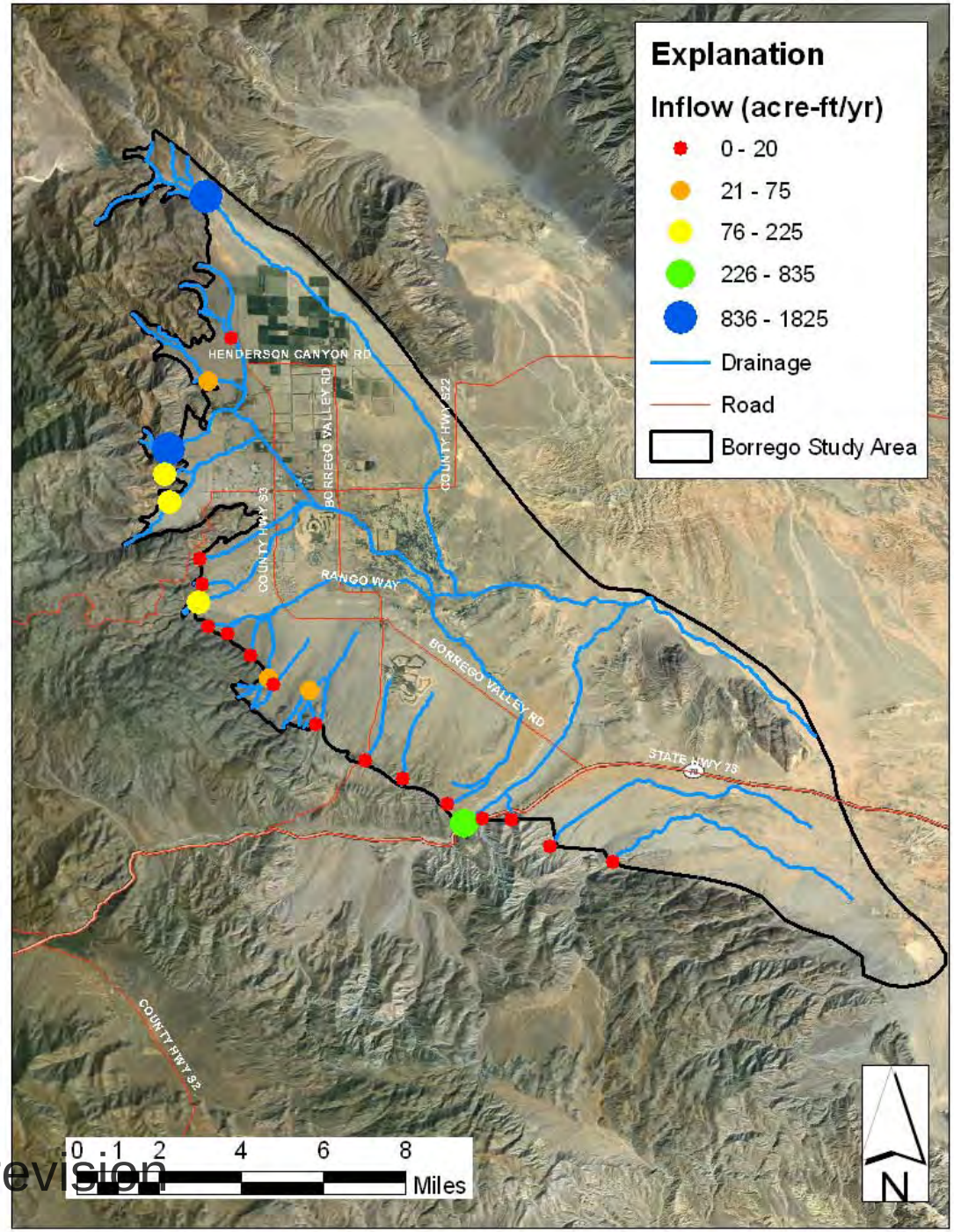


Ave. annual	m3	ac-ft
Runoff	5.6 million	4,590
Recharge	4.2 million	3,370

PRELIMINARY - subject to revision

Within Borrego watershed
Approx 25% of runoff becomes recharge (~1150 ac-ft)
~4,500 ac-ft total recharge

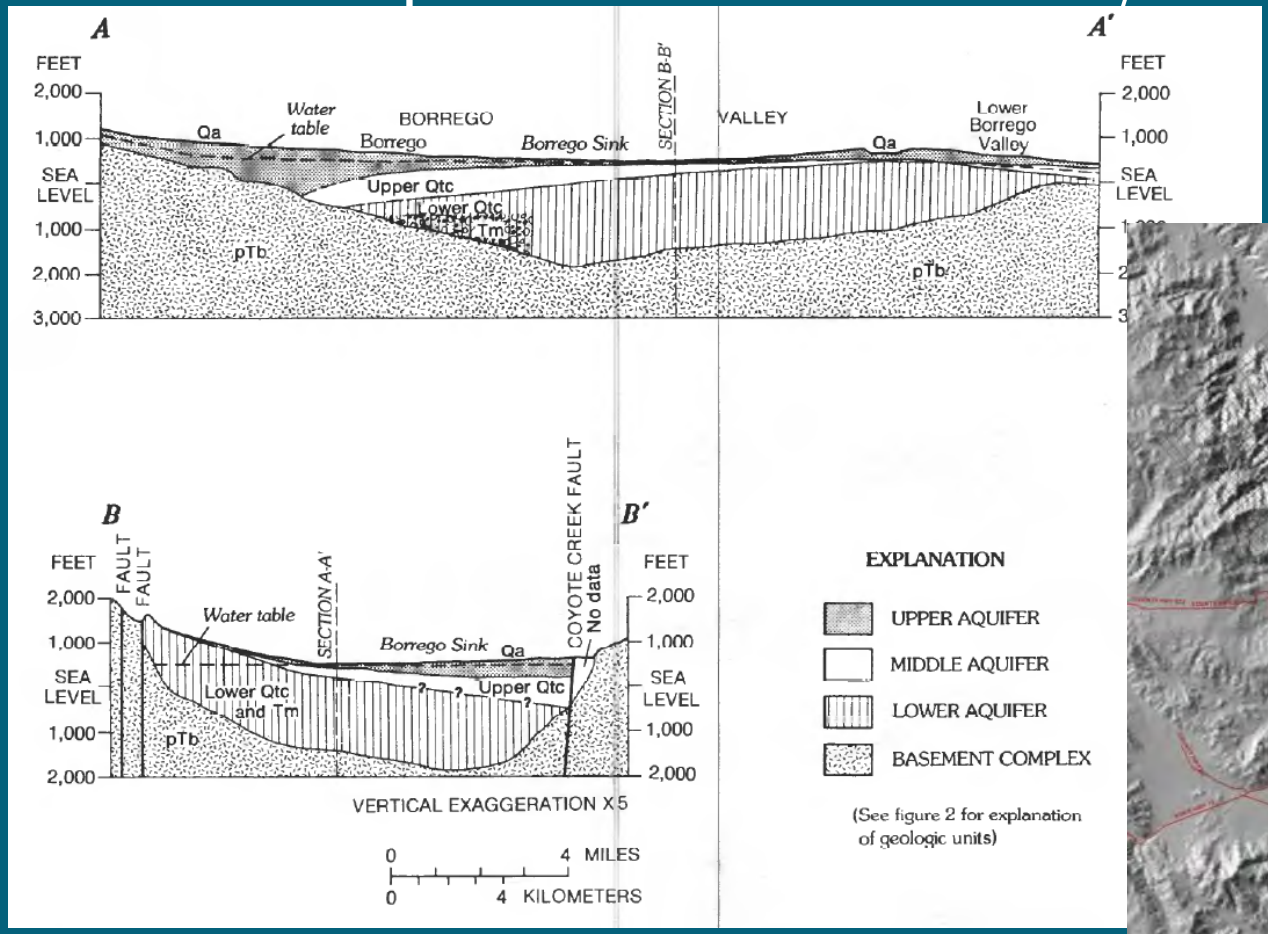
Recharge Model Inflow

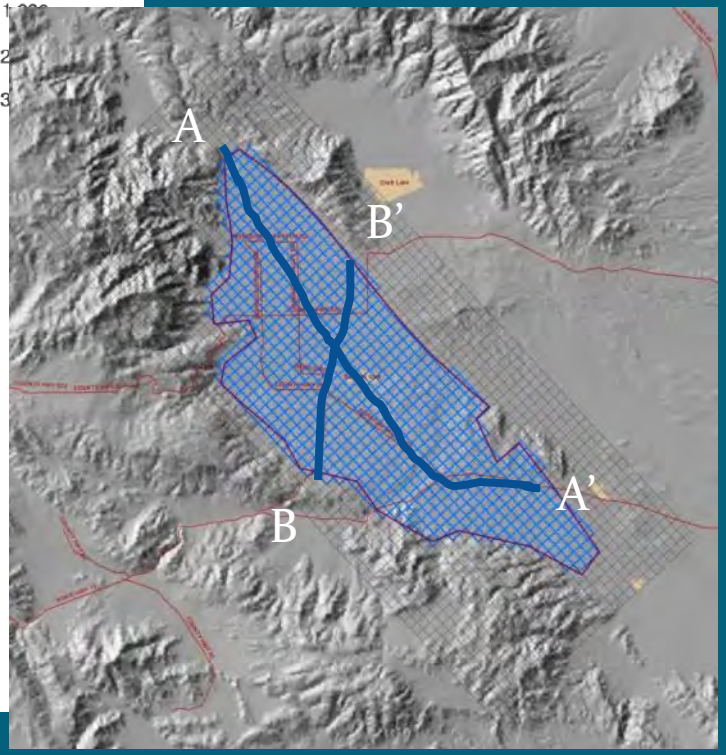


PRELIMINARY - subject to revision

Schematic geologic section

- Aquifers modified from Mitten and others (new well logs)
- Basement updated from Henderson/Netto



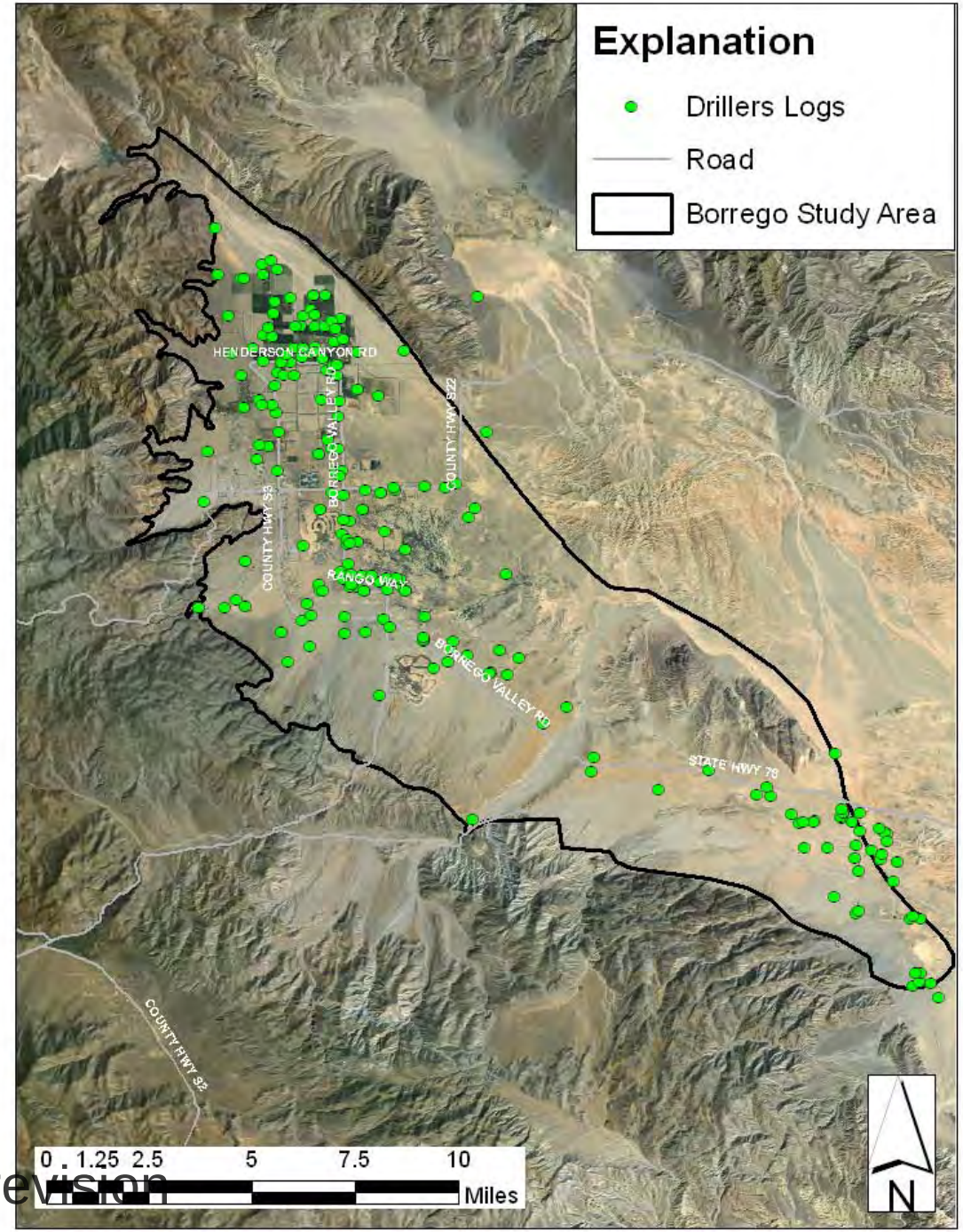


(Mitten and others, 1988)

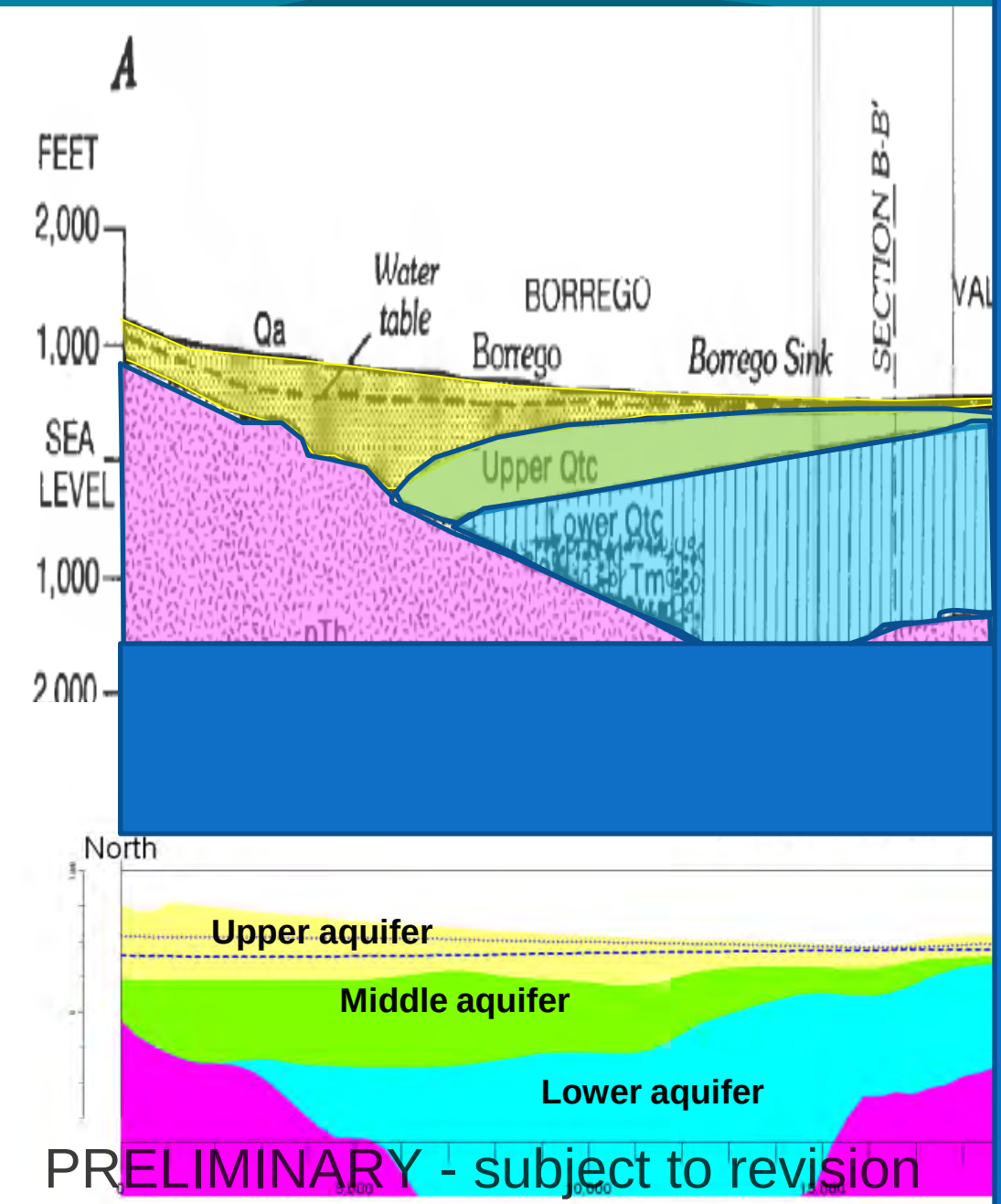
PRELIMINARY, subject to revision

Hydrogeologic characterization:

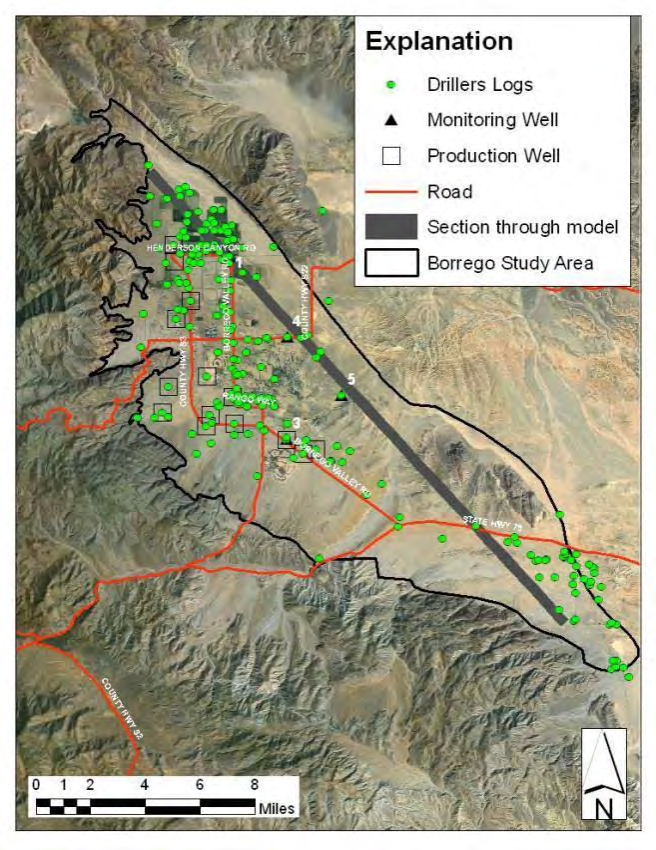
226 drillers logs
(32 outside active domain)
13 wells with GP logs



PRELIMINARY - subject to revision



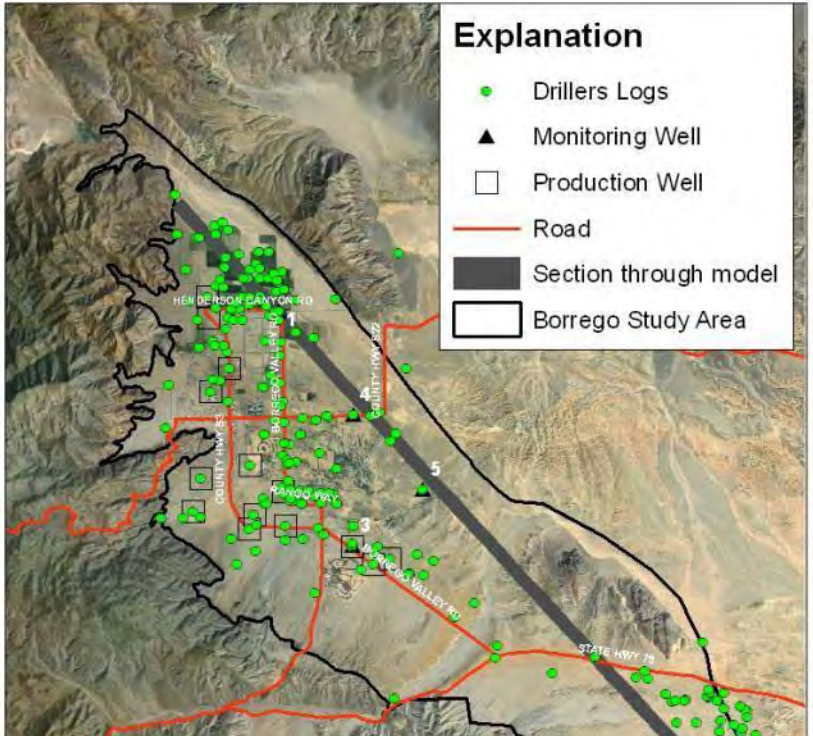
- Updates to aquifer contacts based on additional geologic and geophysical logs

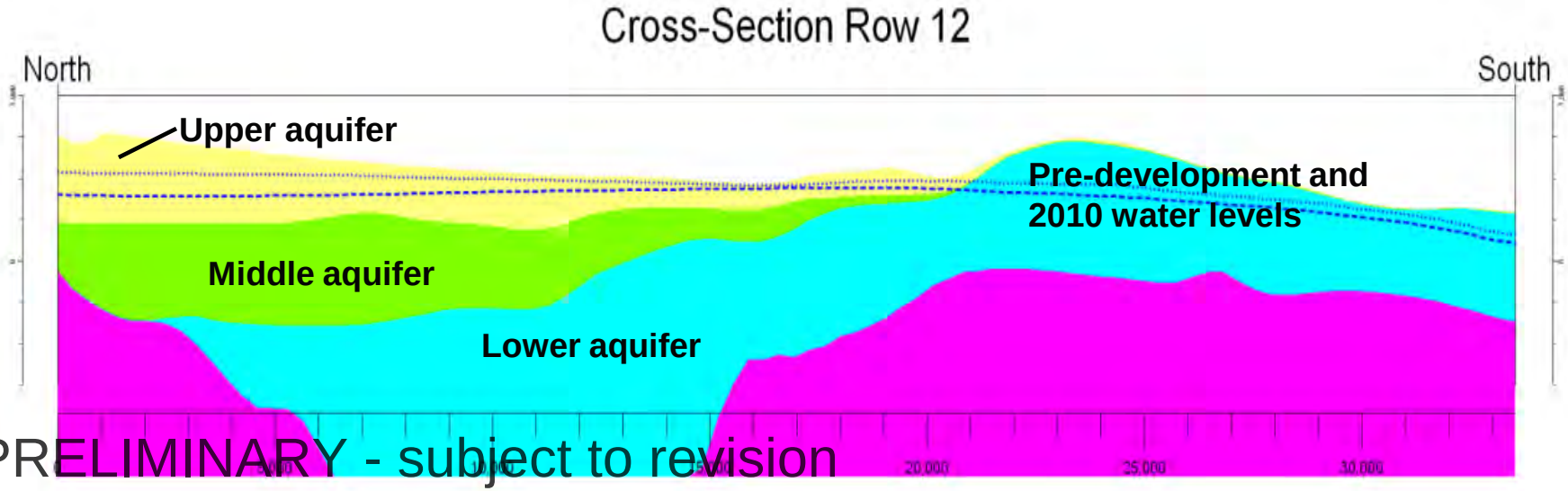


Hydrogeologic characterization:

Horizontal hydraulic conductivity (Specific Yield)

- Upper aquifer 43-81 feet/day (14%)
- Middle aquifer 5.8 feet/day (7%)
- Lower aquifer 1.4 feet/day (3%)





PRELIMINARY - subject to revision

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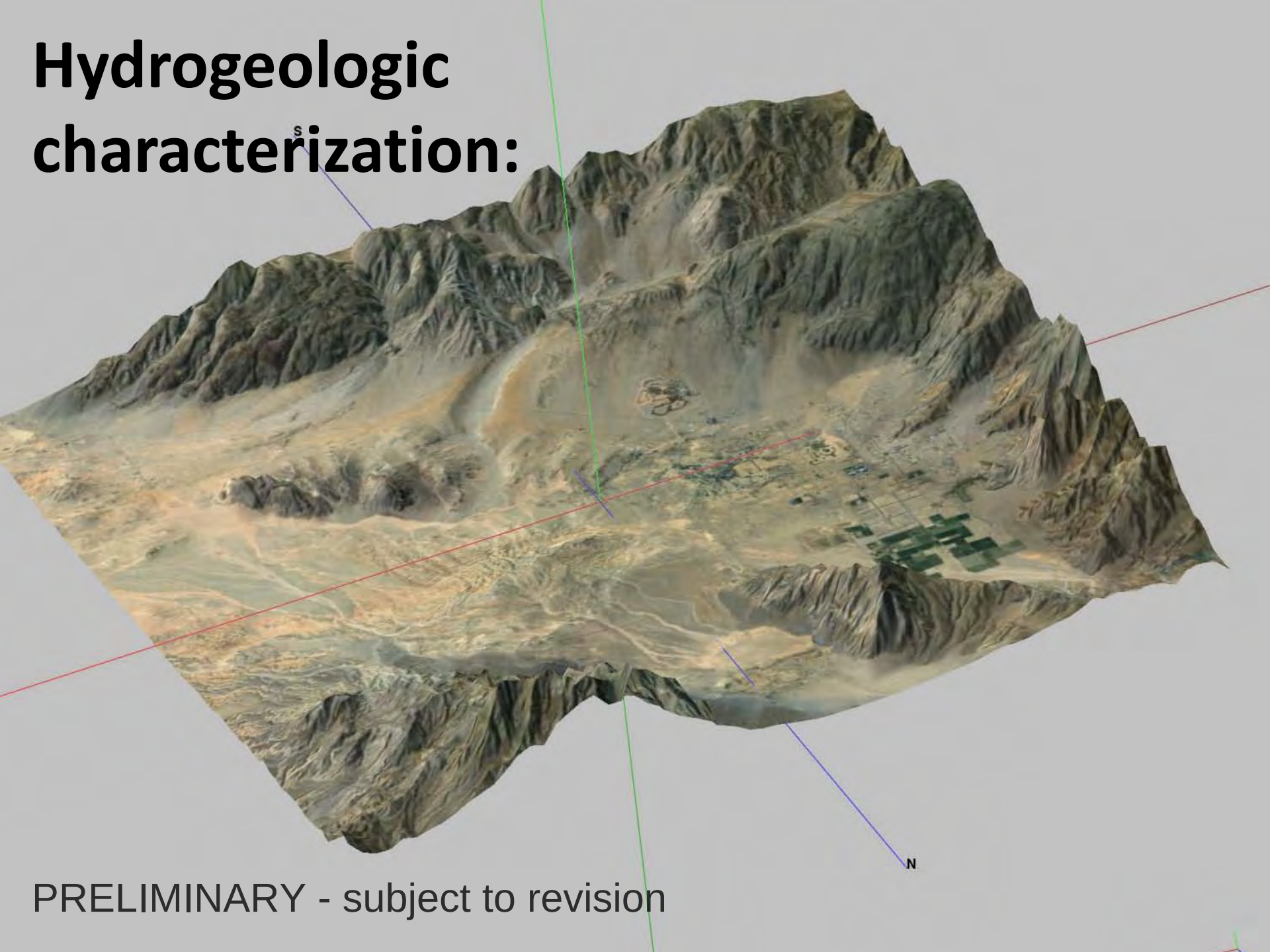
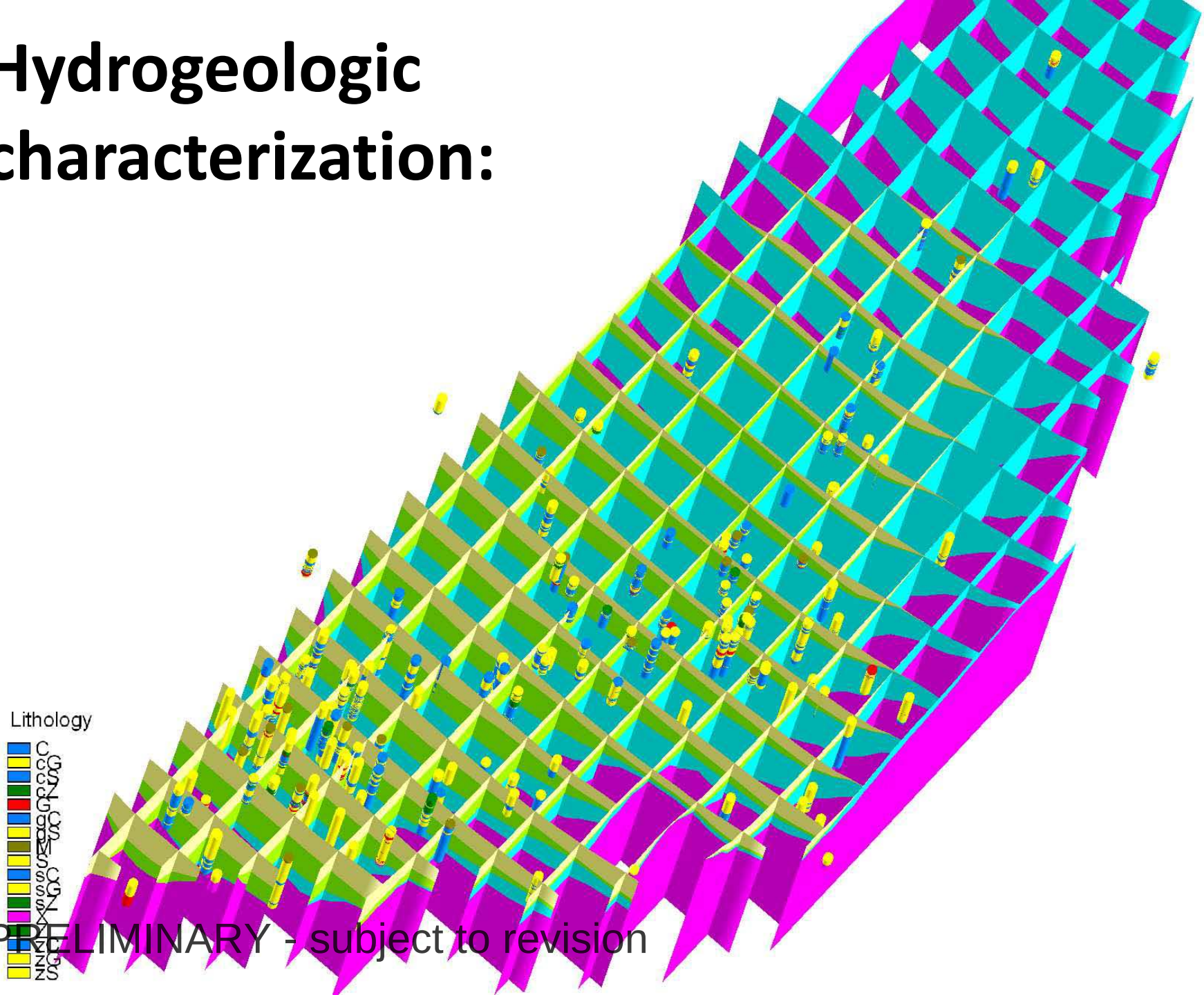


PRELIMINARY - subject to revision

Hydrogeologic characterization:

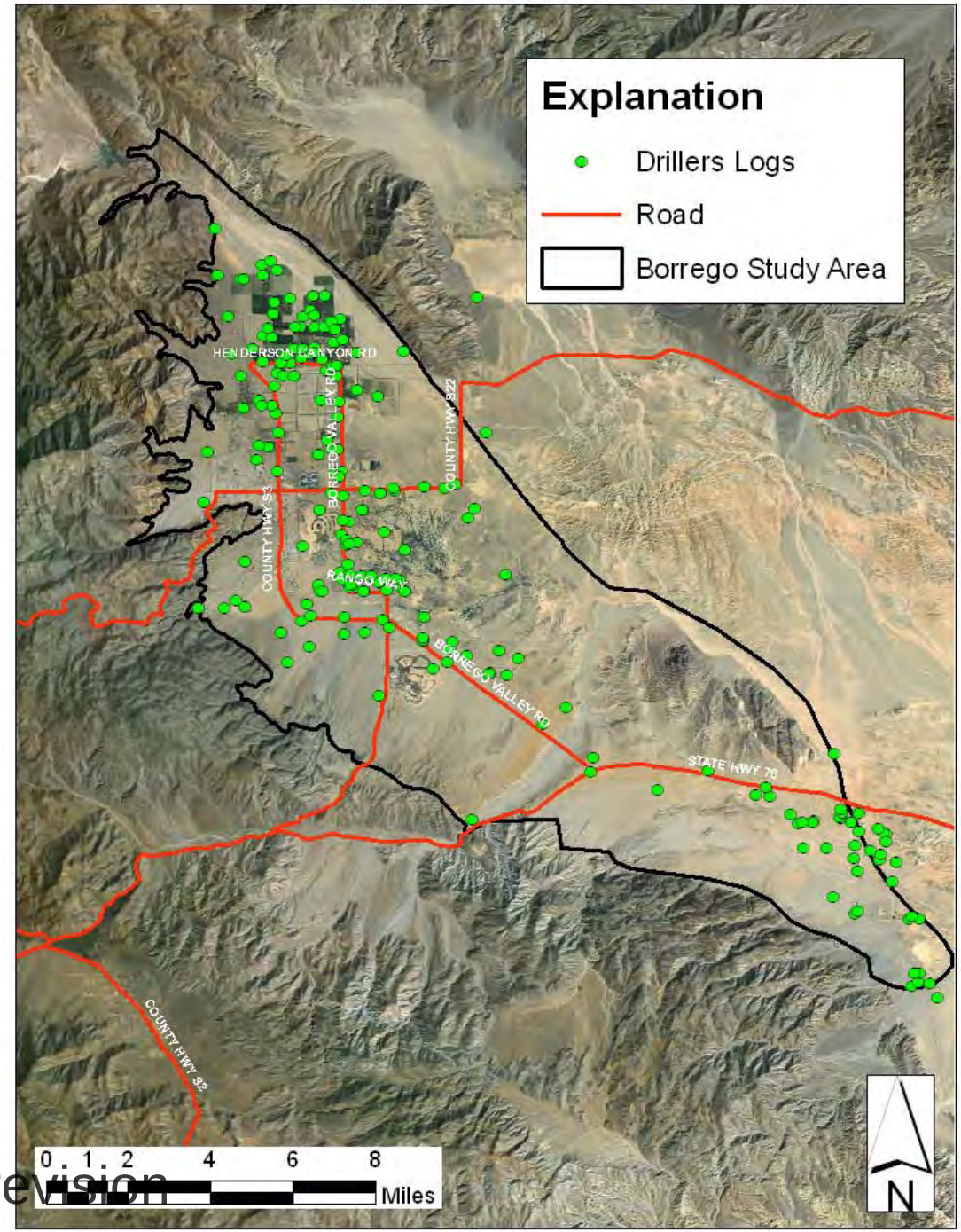


PRELIMINARY - subject to revision

Hydrogeologic characterization:

226 drillers logs

Dominant Texture	Texture	Abbrev.	Coarse
Soil	Soil	M	NA
Clay	Clay	C	Fine
Clay	Silty_clay	zC	Fine
Clay	Sandy_clay	sC	Fine
Clay	Gravelly_clay	gC	Fine
Silt	Silt	Z	Fine
Silt	Clayey_silt	cZ	Fine
Silt	Sandy_silt	sZ	Fine
Silt	Gravelly_silt	gZ	Fine
Sand	Sand	S	Coarse
Sand	Clayey_sand	cS	Fine
Sand	Silty_sand	zS	Fine
Sand	Gravelly_sand	gS	Coarse
Gravel	Gravel	G	Coarse
Gravel	Clayey_gravel	cG	Fine
Gravel	Silty_gravel	zG	Fine
Gravel	Sandy_gravel	sG	Coarse
Rock	Rock	X	NA



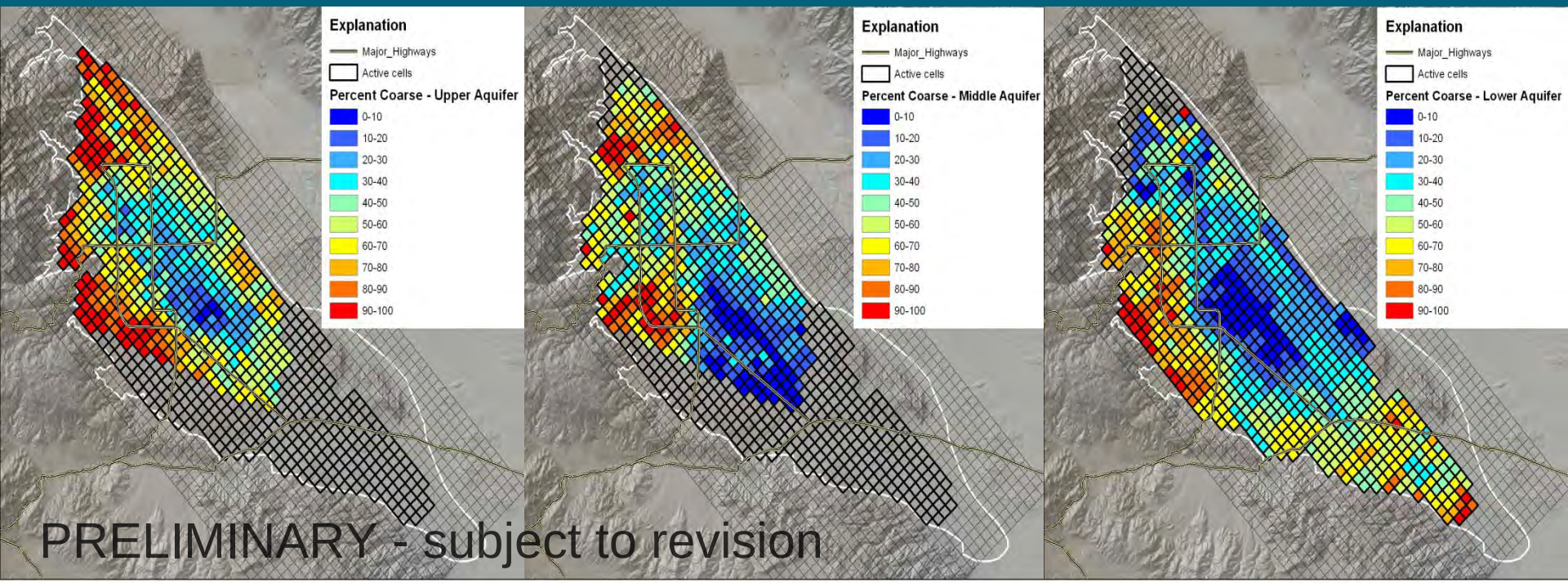
PRELIMINARY - subject to revision

Hydrogeologic framework:

Percent coarse-grained deposits in each aquifer:

- Red – coarser grained and relatively more permeable
- Blue – finer grained and relatively less permeable

- Average by aquifer:
  - Upper – 58%
  - Middle – 45%
  - Lower – 44% (40% in main area of interest)



PRELIMINARY - subject to revision

Predictive simulations:

Identify areas

- Coarse-grained deposits above water table
- Landuse restrictions?

4 Scenarios

(1) No action 50 years (2010-2060)

(2) Agricultural production cut in half for 50 years (2010-2060)

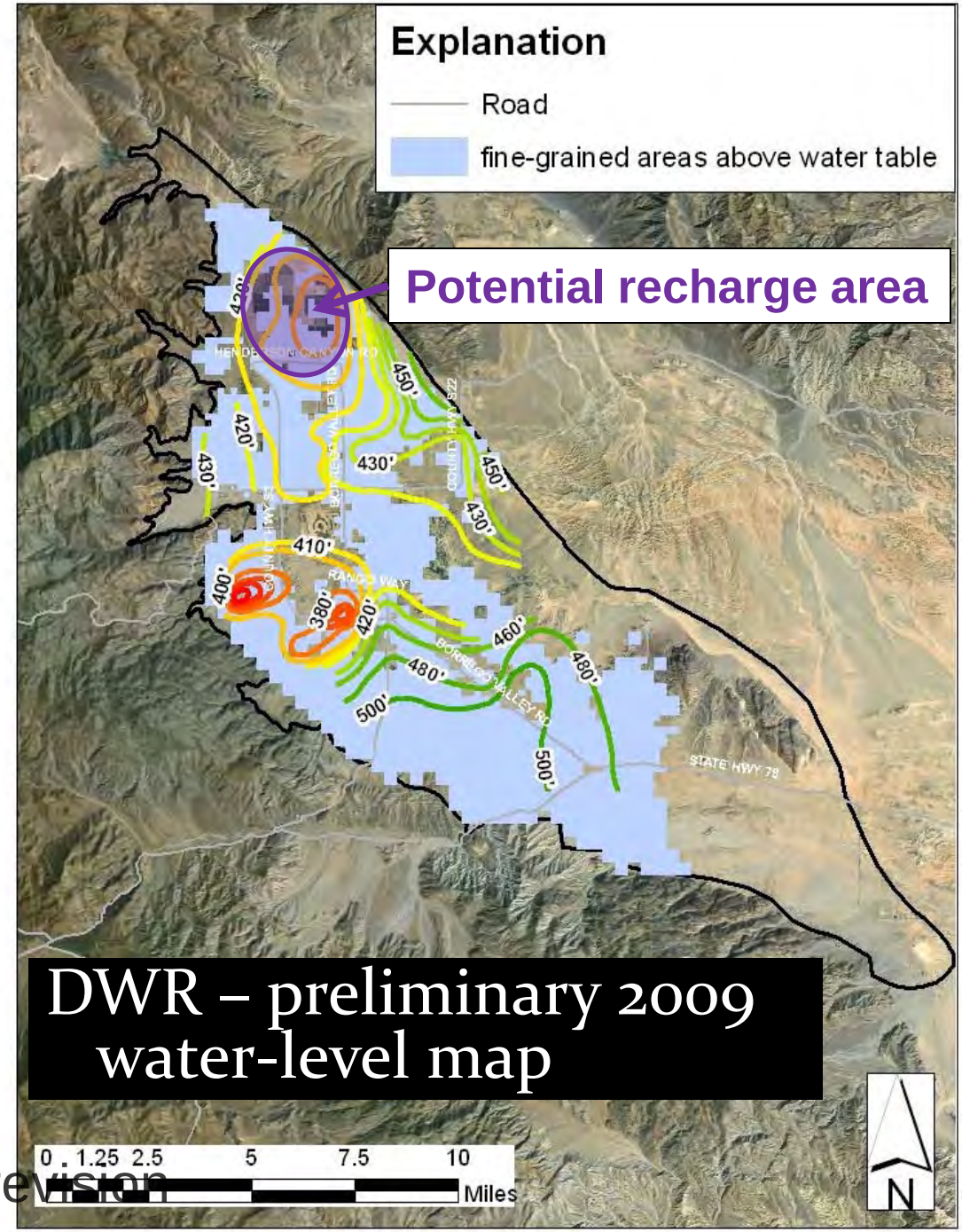
(3) Cessation of agriculture, 50% more recreational pumping, and 25% more municipal pumping (over first 10 years)

(4) Cessation of agriculture and recreational pumping with doubling of municipal pumping (over first 10 years)

PRELIMINARY - subject to revision

Potential areas:

Extent of fine-grained deposits above water table (too restrictive, thickness?)



DWR – preliminary 2009 water-level map

PRELIMINARY - subject to revision

Predictive simulations:

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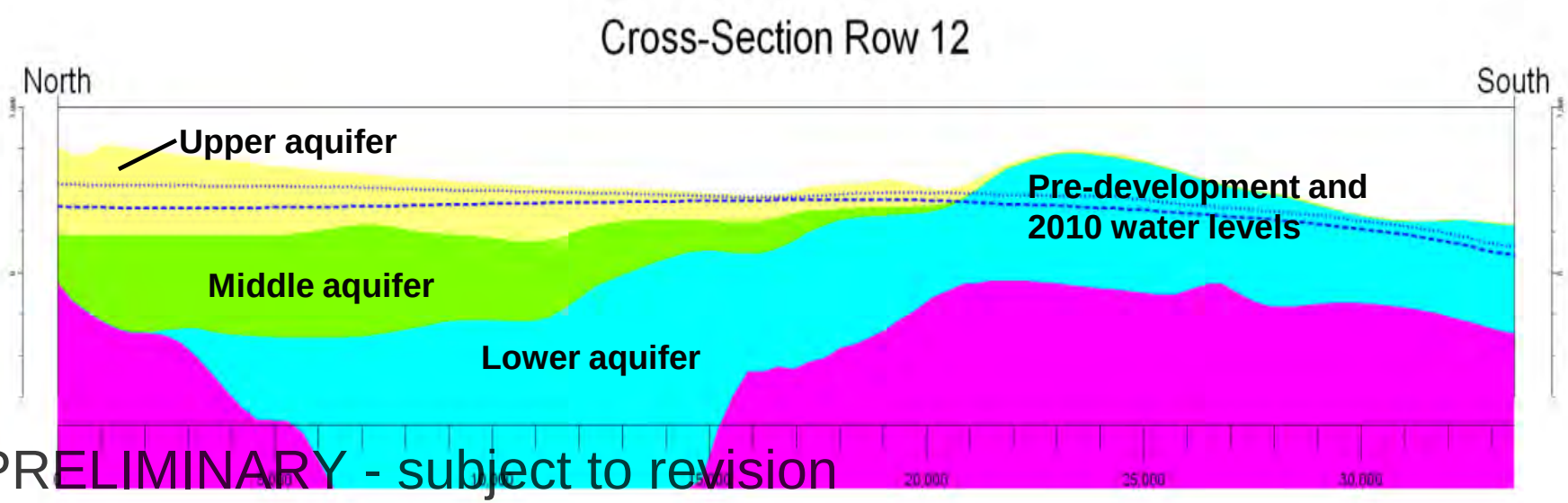
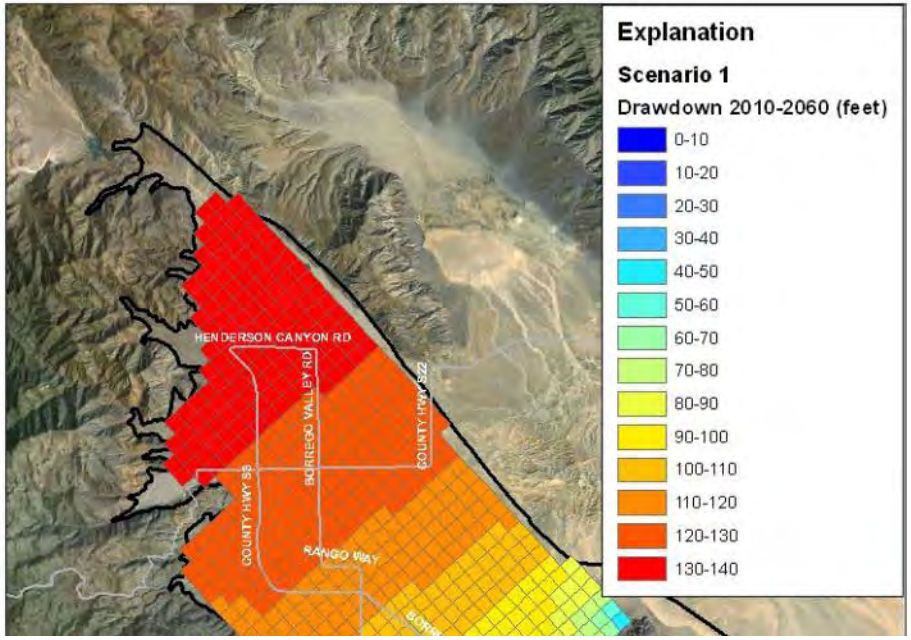


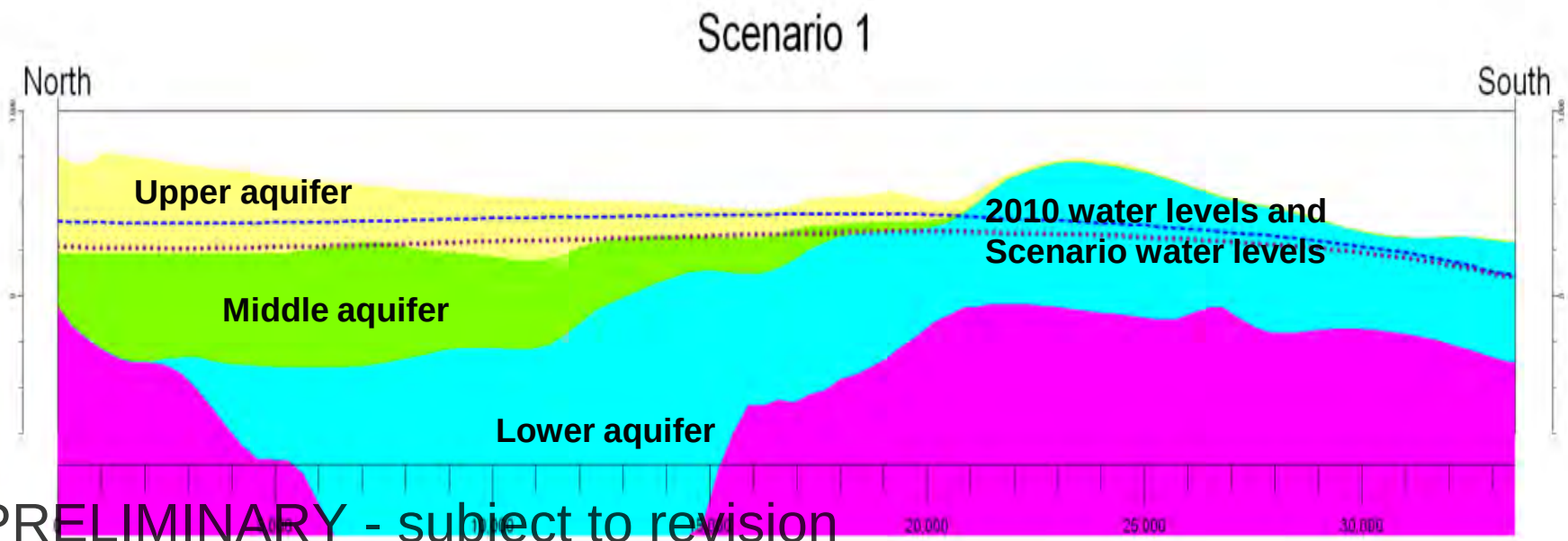
PRELIMINARY - subject to revision

Scenario 1:

No action 50 years (2010-2060)

Continue current pumping rates 20,000 acre-feet/year

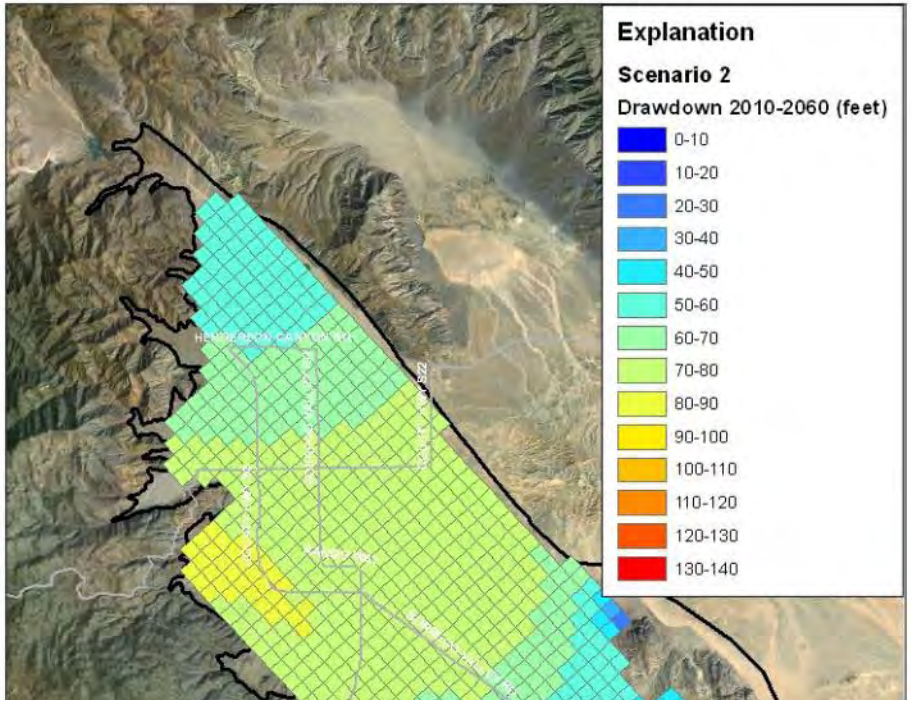


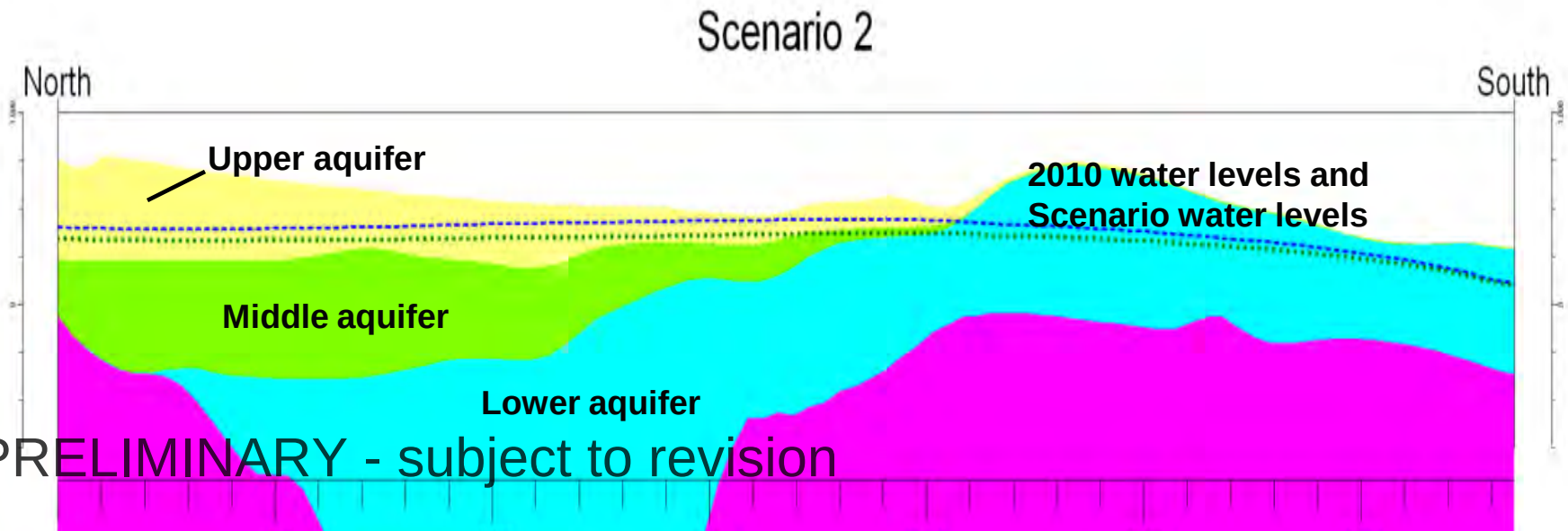


PRELIMINARY - subject to revision

Scenario 2:

Agricultural production cut in half for 50 years (2010-2060)

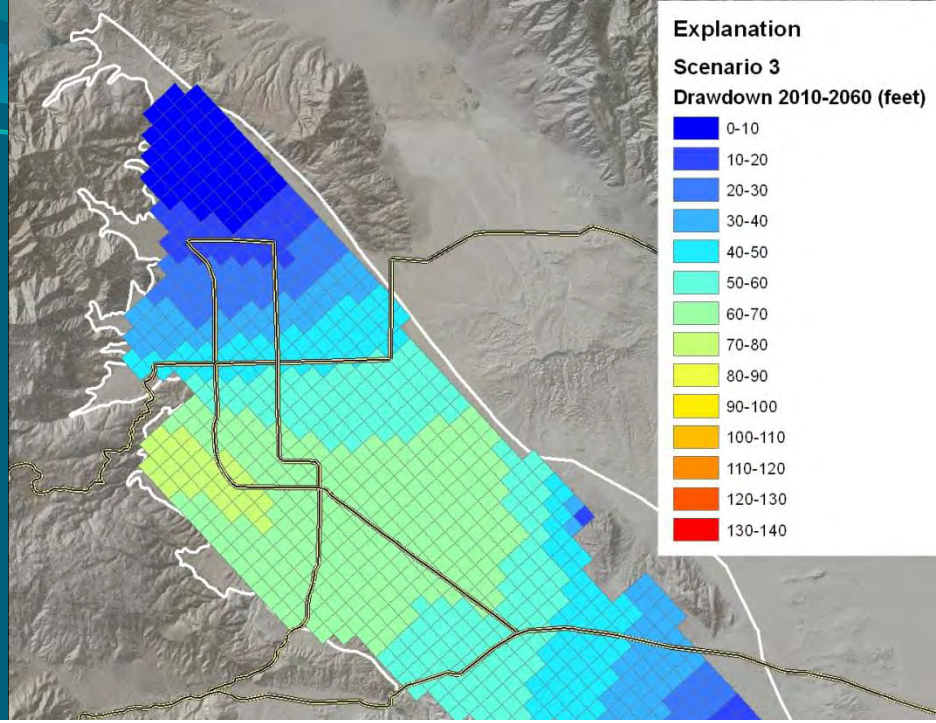




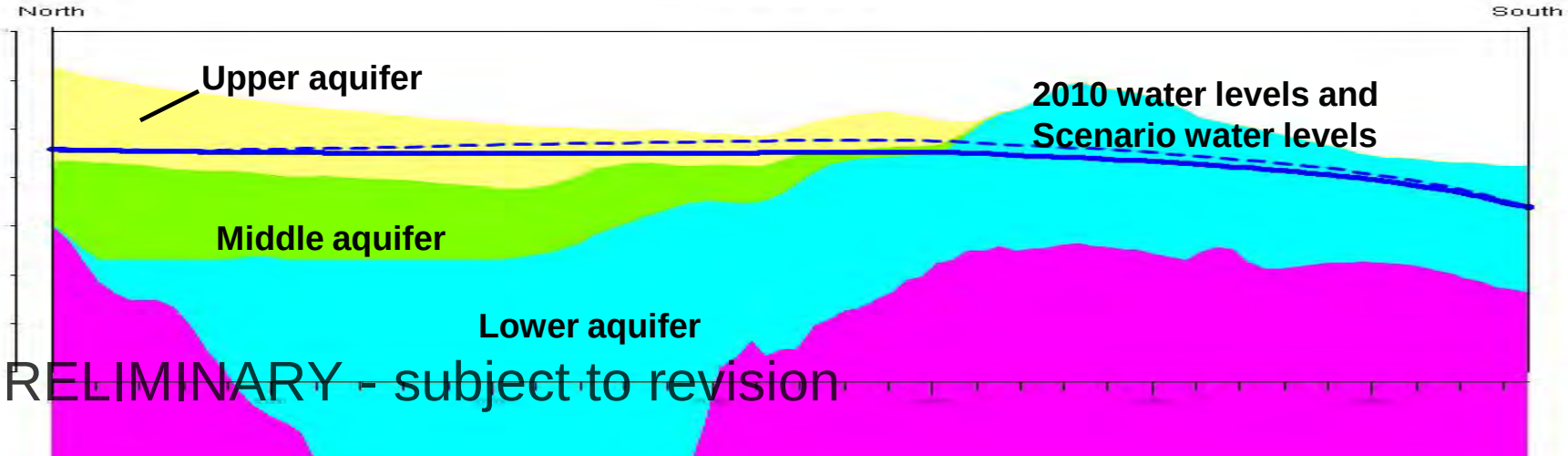
PRELIMINARY - subject to revision

Scenario 3:

Cessation of agriculture, 50% more recreational pumping and 25% more municipal pumping (over first 10 years)



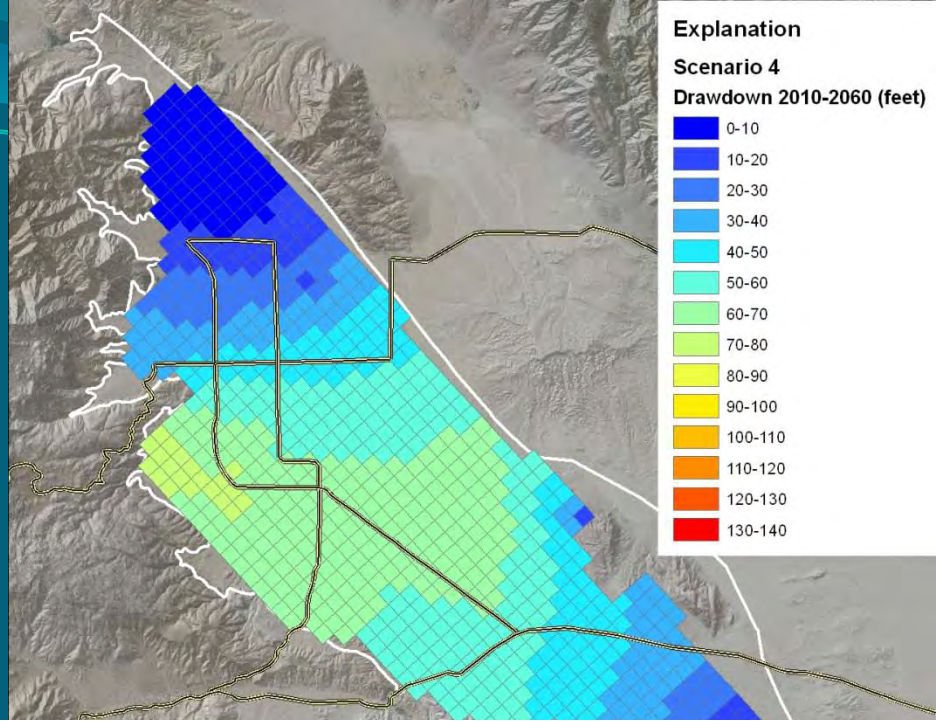
Scenario 3



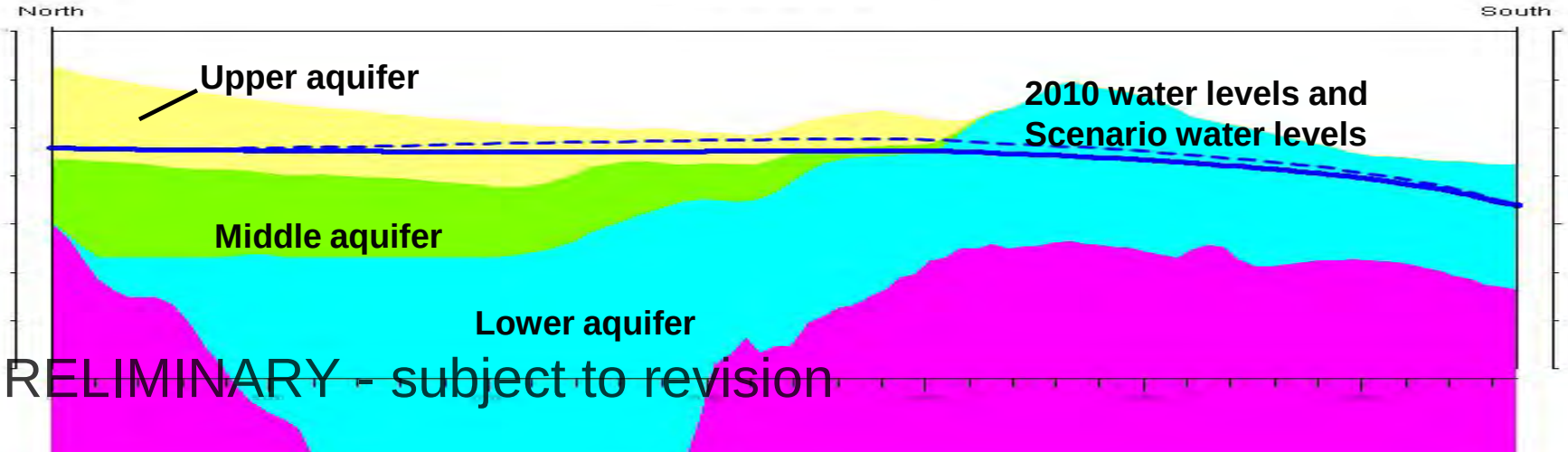
PRELIMINARY - subject to revision

Scenario 4:

Cessation of agriculture and recreational pumping with doubling of municipal pumping (over first 10 years)



Scenario 4



PRELIMINARY - subject to revision

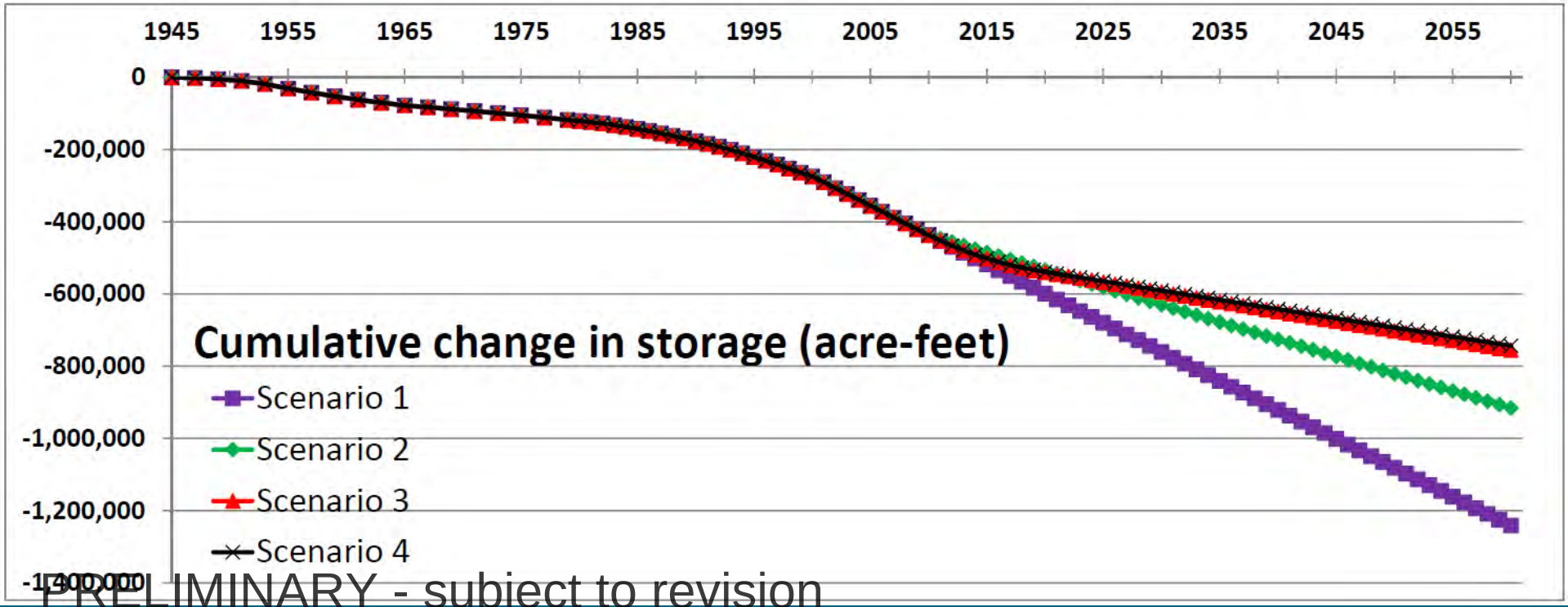
Change in storage through time

(1) No action 50 years (2010-2060)

(2) Agricultural production cut in half for 50 years (2010-2060)

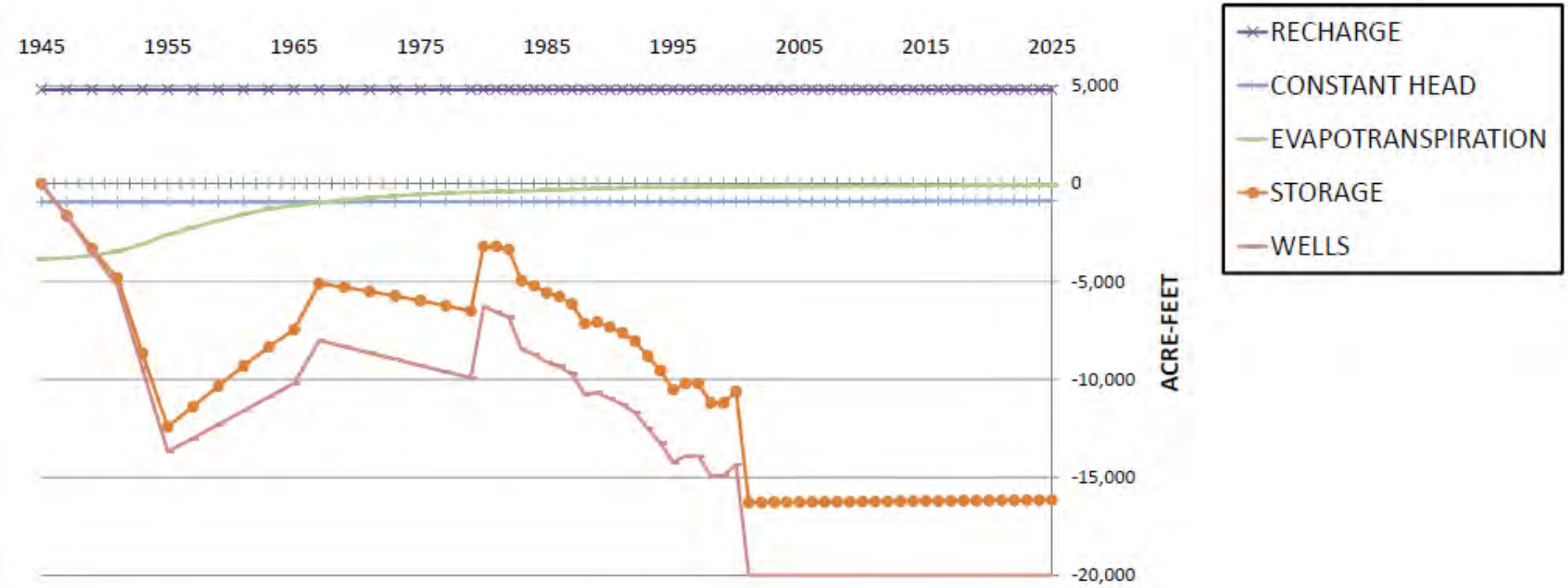
(3) Cessation of agriculture, 50% more recreational pumping, and 25% more municipal pumping (over first 10 years)

(4) Cessation of agriculture and recreational pumping with doubling of municipal pumping (over first 10 years)



PRELIMINARY - subject to revision

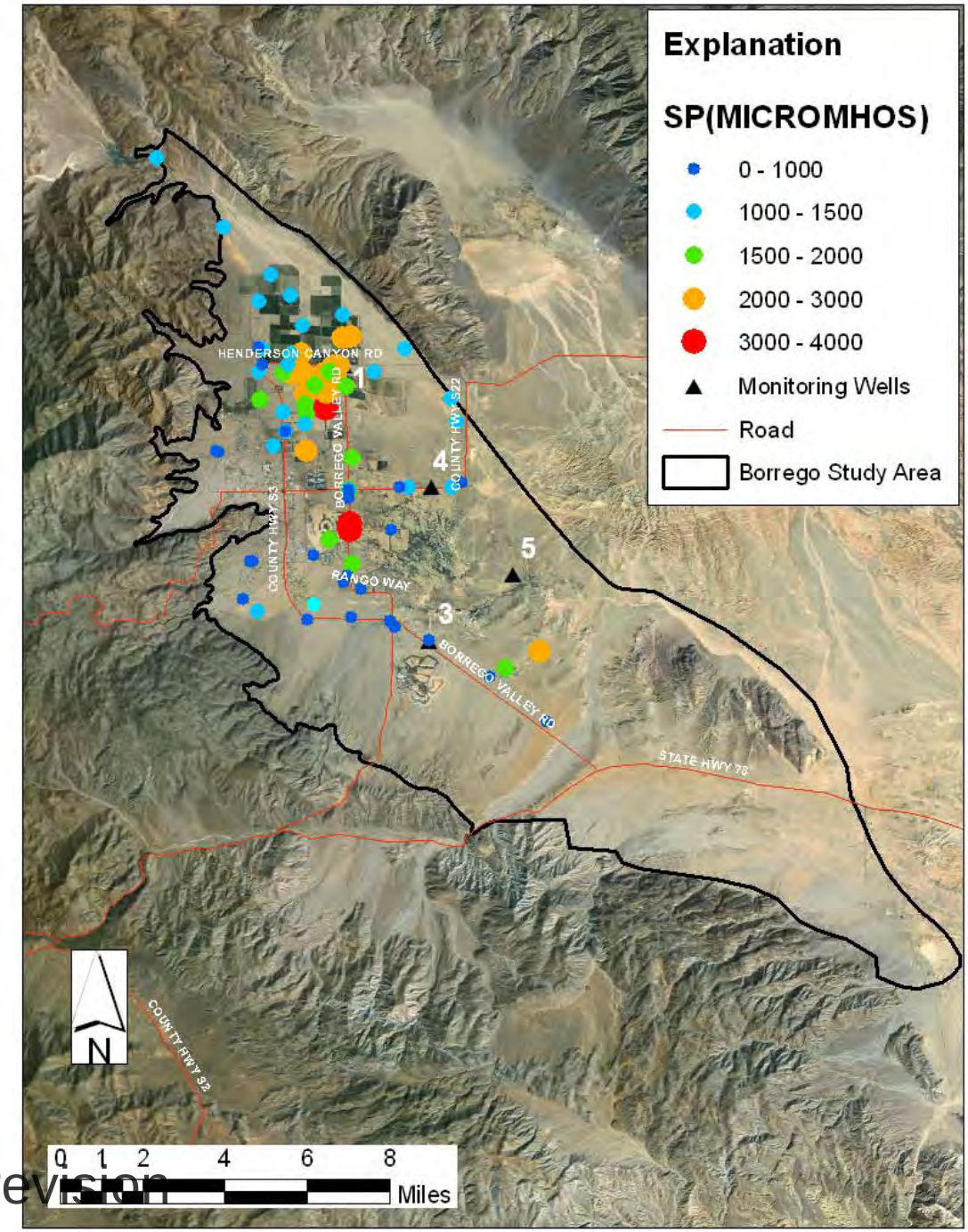
Basic water budget through time



PRELIMINARY - subject to revision

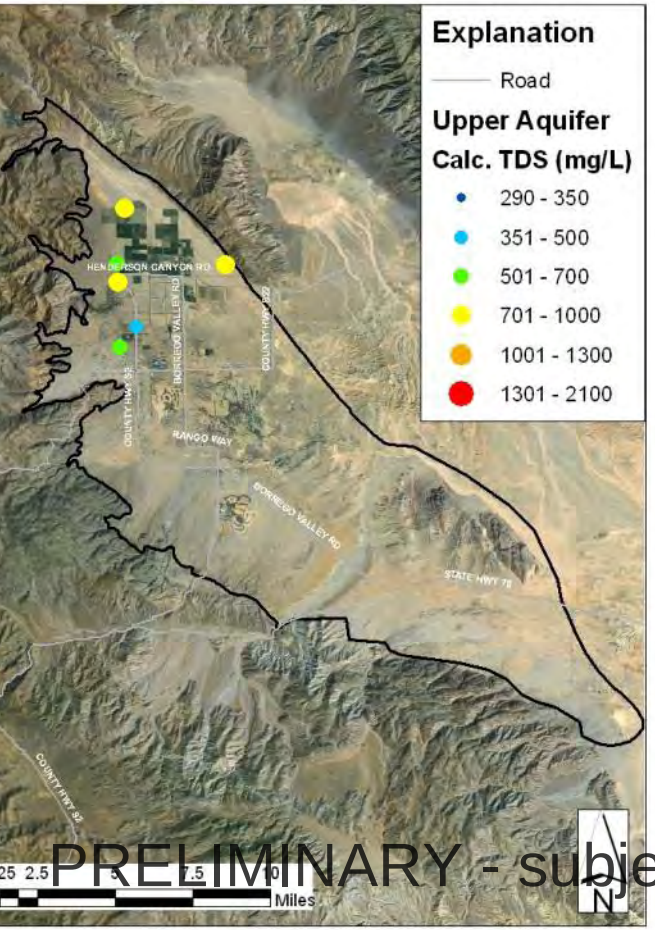
Chemistry:

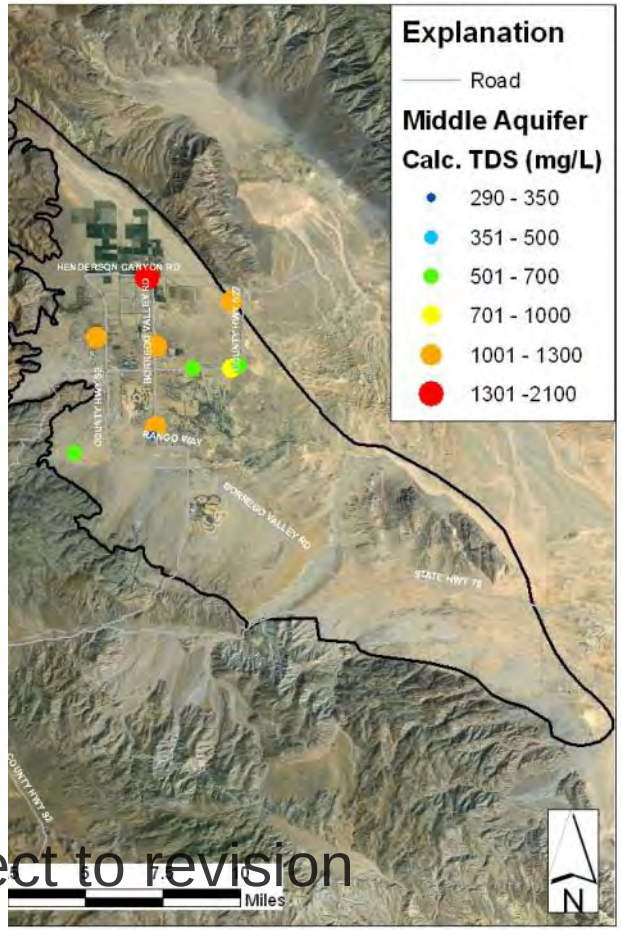
> 1500 analyses
from > 150 wells

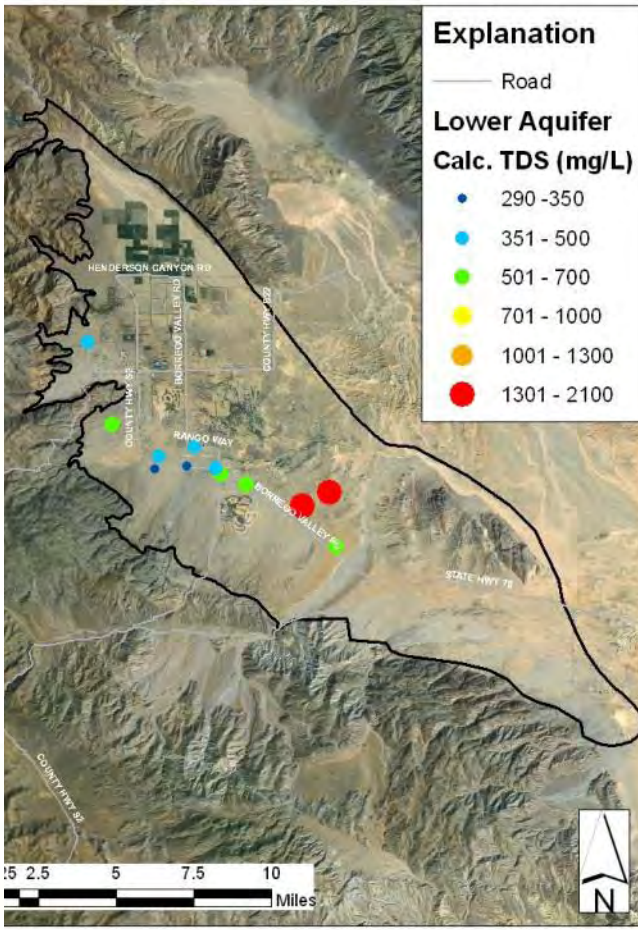


PRELIMINARY - subject to revision

Chemistry by aquifer:

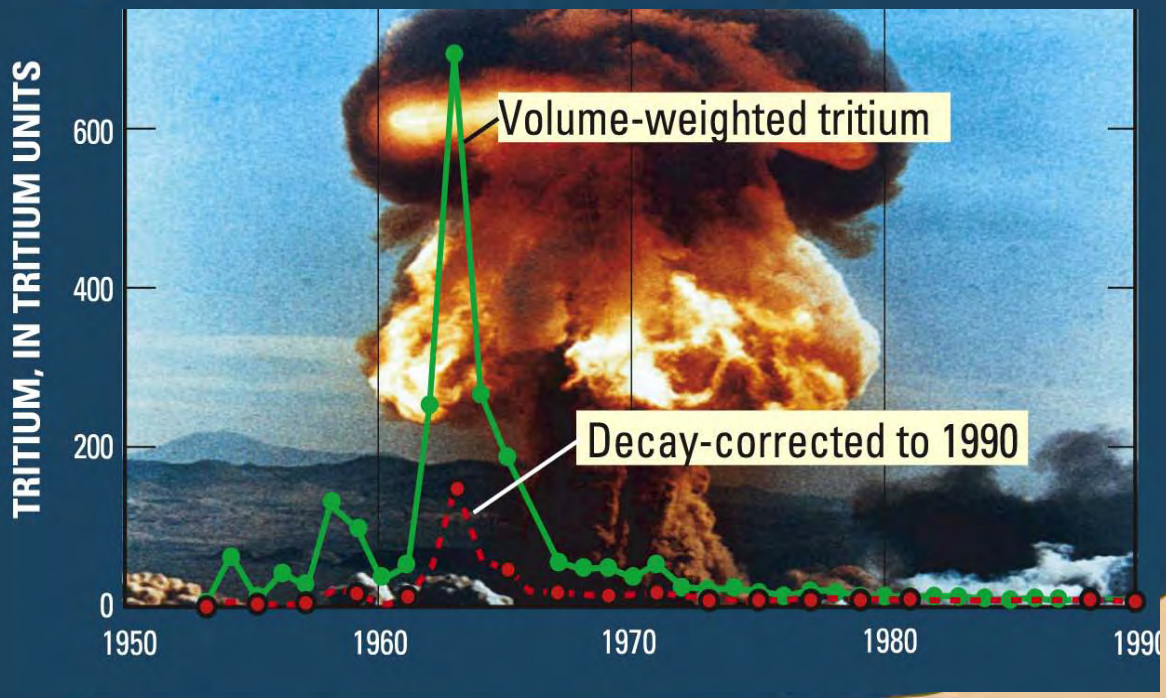


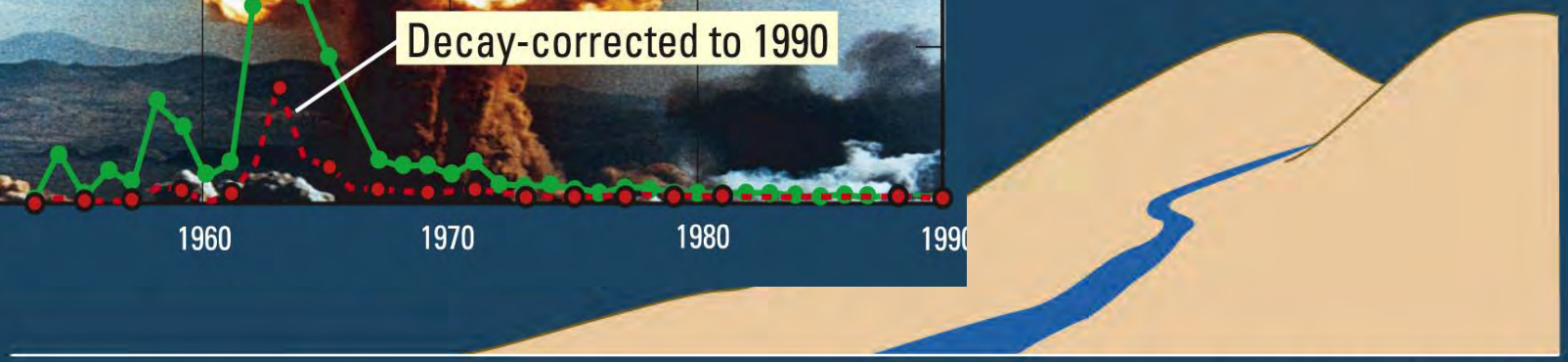




PRELIMINARY - subject to revision

Age Dating Ground Water (Time Since Recharge)





Infiltration

Tritium, Helium-3, Chlorofluorocarbons

<50 YBP

Old

Carbon-14, Helium-4

Ancient

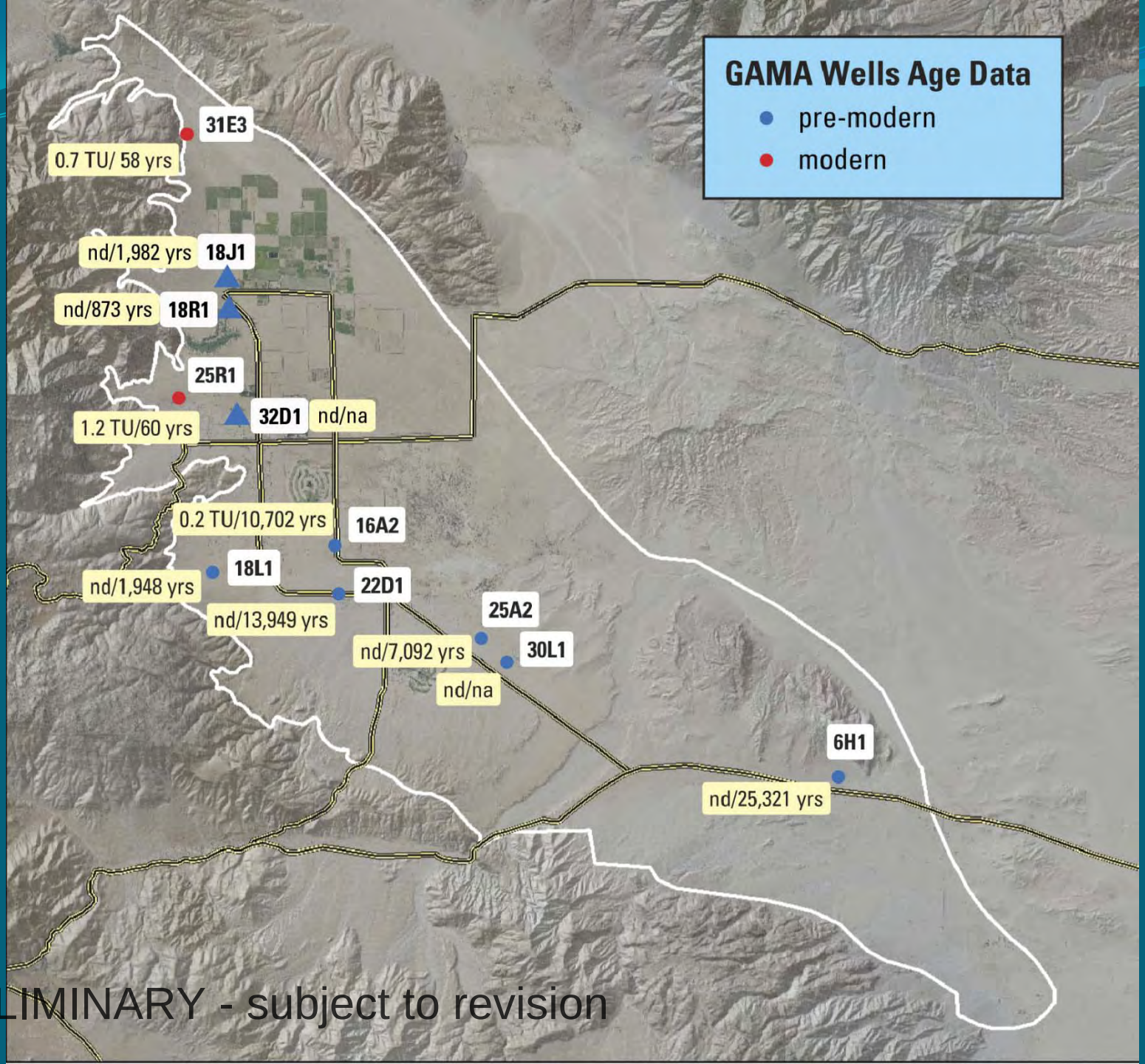
Very Old

<20,000 YBP

CHEMICAL REACTIONS

Dissolution
Precipitation
Oxidation of organic material
Sulfate reduction
Chemical and isotopic exchange

PRELIMINARY - subject to revision



PRELIMINARY - subject to revision

Plans:

(1) Complete updating and calibrating MODFLOW,

(2) Construct and analyze predictive simulations identified by Borrego Water District such as, and

- Artificial recharge
- Reduced municipal or recreational pumpage
- Fallow agriculture land
- Import water and change pumping patterns

(3) Obtain and analyze additional water quality data

(4) Complete interpretive report

PRELIMINARY - subject to revision