Estimating Change in Groundwater in Storage Using Groundwater Level Data

California Water Plan Update 2013 Appendix E

5th California Water Plan Update 2013 Webinar - September 9th, 2015

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First Things First

- This presentation covers:
  - The estimation of the change in groundwater in storage using groundwater level data
  - The methods and use of the Groundwater GIS tool
  - Much of this information is covered in more detail in the California Water Plan Update 2013, Change in Groundwater in Storage - Appendix E

Overview of Presentation

- Introduction
  - Background, Goals, and Objectives
  - What is Change in Groundwater in Storage?
  - Data Types and Availability
- Methodology
  - The importance of data management and GIS
  - Assumptions and Key Concepts
  - Workflow Process
- Conclusions

Introduction

- Background
  - Previous efforts to estimate change in groundwater were inconsistent
- Goals and Objectives
  - Develop a Transparent, Repeatable, Reliable Process
  - Create Standardized Reports
  - Applicable Statewide

Introduction

- Change in Groundwater in Storage

In general, the change in groundwater storage is calculated by multiplying the difference in groundwater elevation between two monitoring periods, by the area overlying the groundwater basin, and by the average storativity (specific yield in an unconfined aquifer).

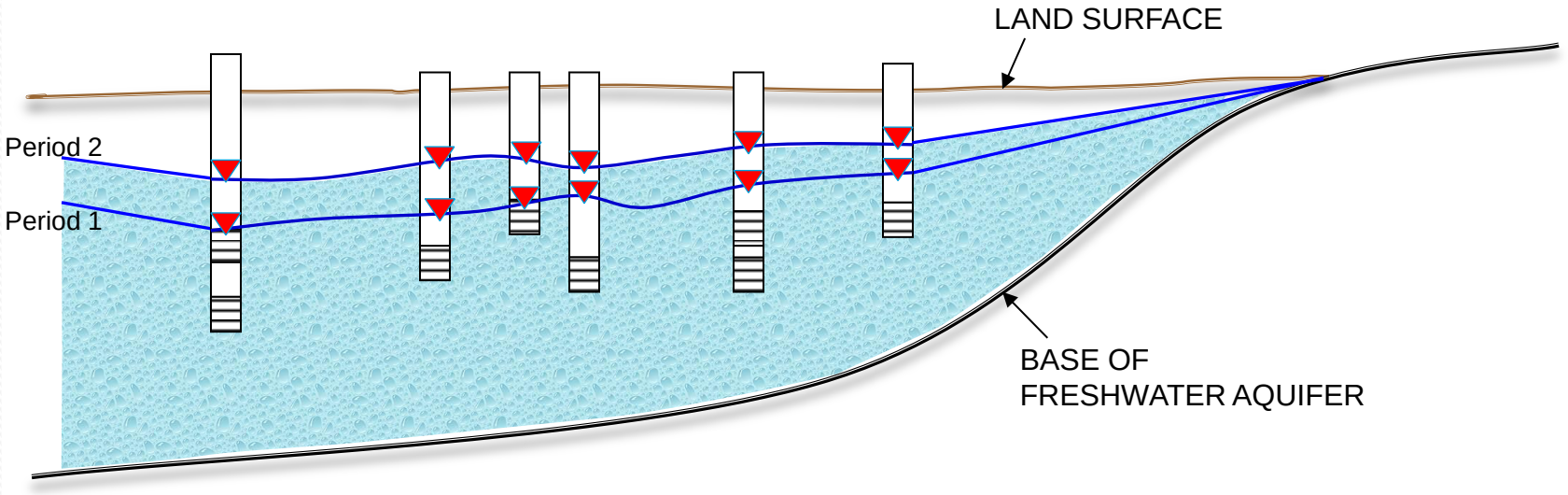
Change in Groundwater in Storage = (GWE_{t0} – GWE_{t1}) x Overlying Area x Specific Yield

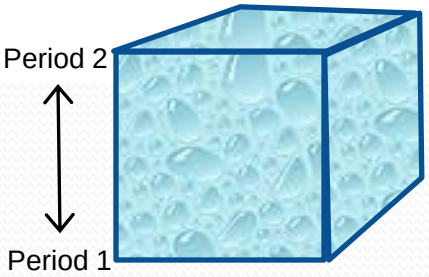
Where:

GWE_{t0} = Groundwater elevation monitoring period one
GWE_{t1} = Groundwater elevation monitoring period two

Introduction

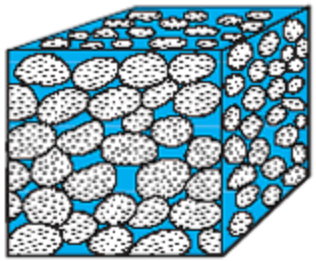
- Change in Groundwater in Storage





Total Change Volume

X



Specific Yield
(range 0.07 to 0.17)

=>

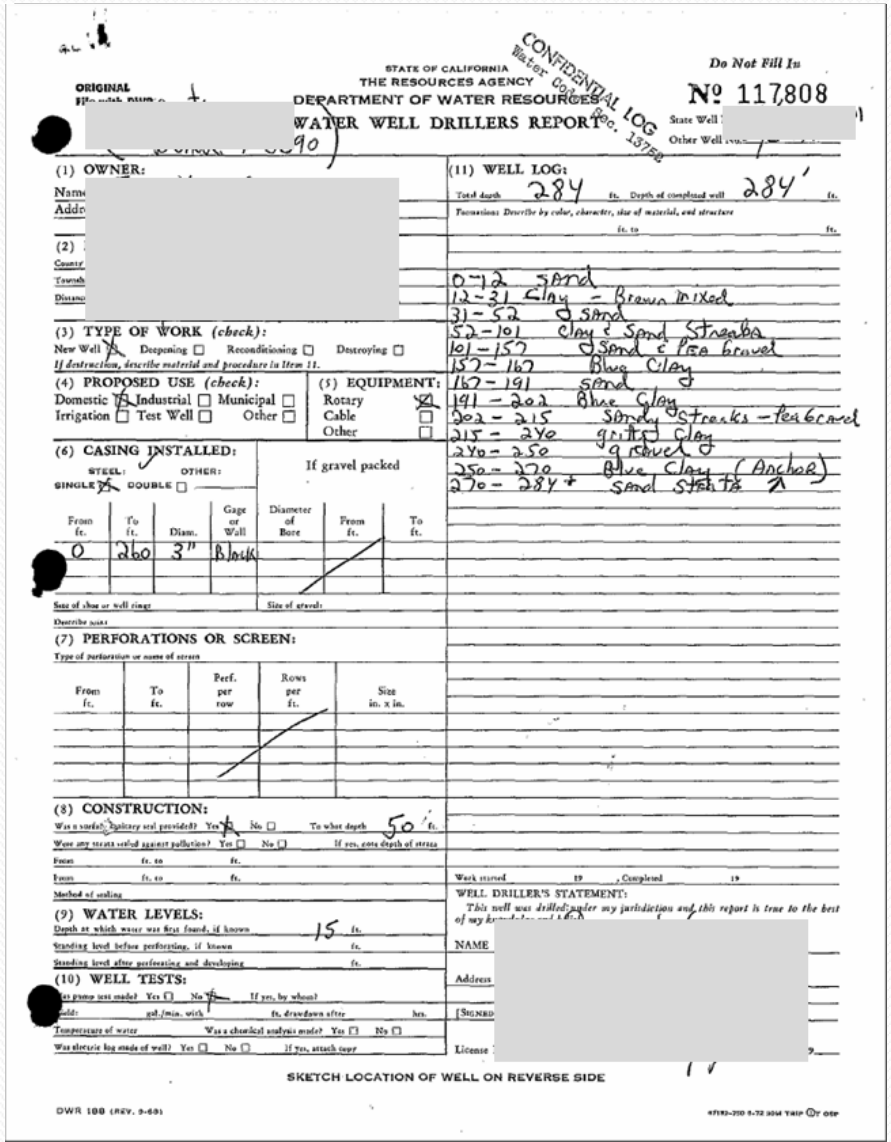
Estimated Change in GW in Storage

Data Types and Availability

- Estimating the change in groundwater in storage requires three types of data
  - Well Data
  - Groundwater Level Data
  - Hydrogeologic Data

Data Types and Availability

- Well Data
  - Information about the monitoring well
  - Well completion reports (and other well data)
  - The quality is highly variable



STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
WATER WELL DRILLERS REPORT

CONFIDENTIAL LOG Water Co. Co. 13758

Do Not Fill In
№ 117808

ORIGINAL

(1) OWNER:

(2)

(3) TYPE OF WORK (check):
New Well ☒ Deepening ☐ Reconditioning ☐ Destroying ☐

(4) PROPOSED USE (check):
Domestic ☒ Industrial ☐ Municipal ☐
Irrigation ☐ Test Well ☐ Other ☐

(5) EQUIPMENT:
Rotary ☒
Cable ☐
Other ☐

(6) CASING INSTALLED:
STEEL: OTHER:
SINGLE ☒ DOUBLE ☐

From ft.	To ft.	Diam.	Gage or Wall
0	260	3"	Black

If gravel packed

Diameter of Bore	From ft.	To ft.

(7) PERFORATIONS OR SCREEN:

From ft.	To ft.	Perf. per row	Rows per ft.	Size in. x in.

(8) CONSTRUCTION:
Was a sanitary seal provided? Yes ☒ No ☐ To what depth 50 ft.
Were any strata sealed against pollution? Yes ☐ No ☐ If yes, note depth of strata
From ft. to ft.
From ft. to ft.
Method of sealing

(9) WATER LEVELS:
Depth at which water was first found, if known 15 ft.
Standing level before perforating, if known ft.
Standing level after perforating and developing ft.

(10) WELL TESTS:
Was pump test made? Yes ☐ No ☒ If yes, by whom?
gal./min. with ft. drawdown after hrs.
Temperature of water Was a chemical analysis made? Yes ☐ No ☐
Was electric log made of well? Yes ☐ No ☐ If yes, attach copy

(11) WELL LOG:
Total depth 284 ft. Depth of completed well 284' ft.
Formations: Describe by color, character, size of material, and structure

ft. to	ft.	
0	12	Sand
12	31	Clay - Brown Mixed
31	52	Sand
52	101	Clay & Sand Streaks
101	157	Sand & Fine gravel
157	167	Blue Clay
167	191	Sand
191	202	Blue Clay
202	215	Sandy Streaks - fine Gravel
215	240	gritty Clay
240	250	Gravel
250	270	Blue Clay (Anchor)
270	284+	Sand Streaks

Work started 19 , Completed 19

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
NAME
Address
[Signed]
License

SKETCH LOCATION OF WELL ON REVERSE SIDE

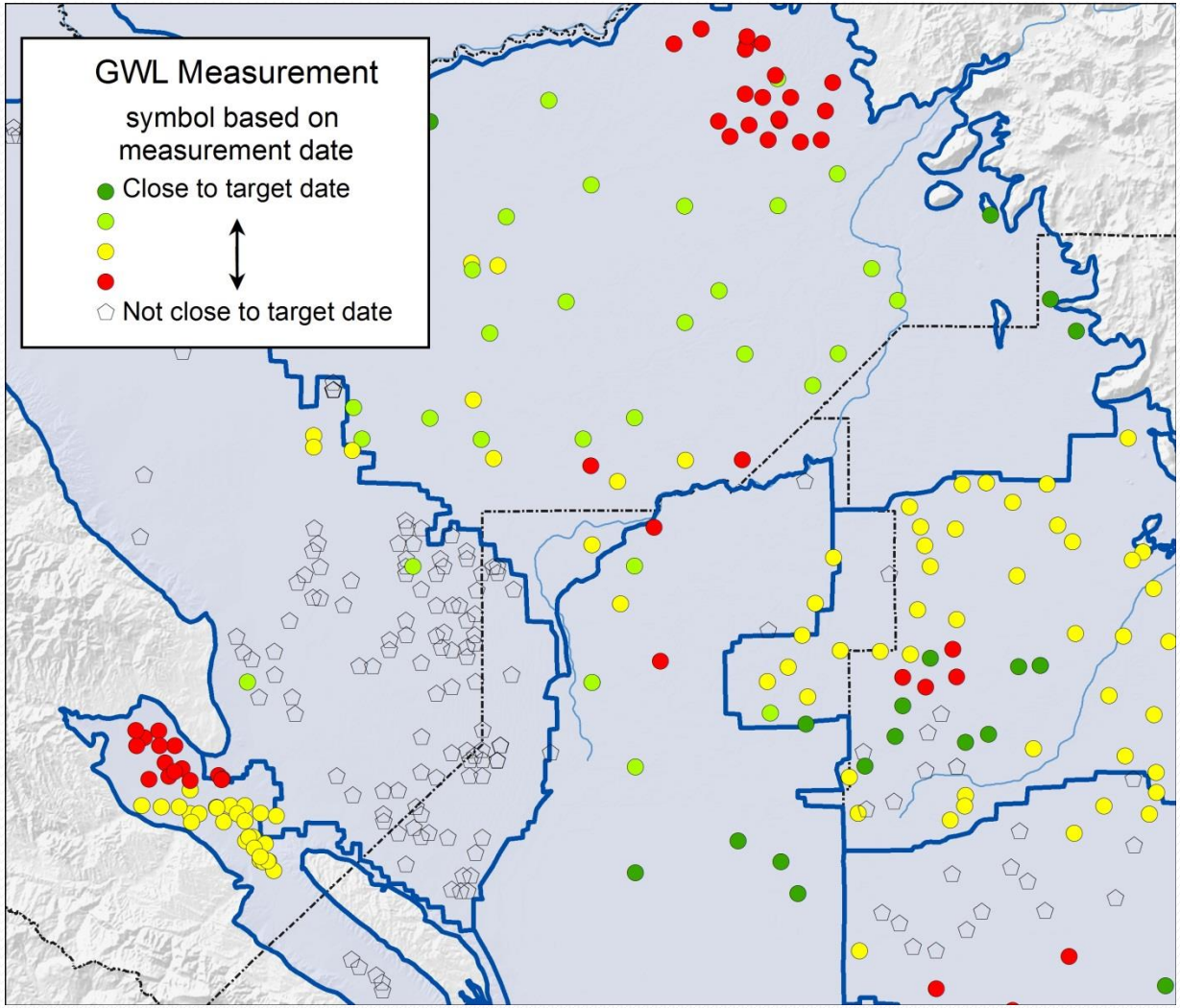
DWR 188 (REV. 9-69)

Data Types and Availability

- Groundwater Level Data
  - GW level measurements collected from wells
  - A groundwater measurement is:
    - A point in space (x, y, z)
    - A point in time
    - Metadata about the measurement

Data Types and Availability

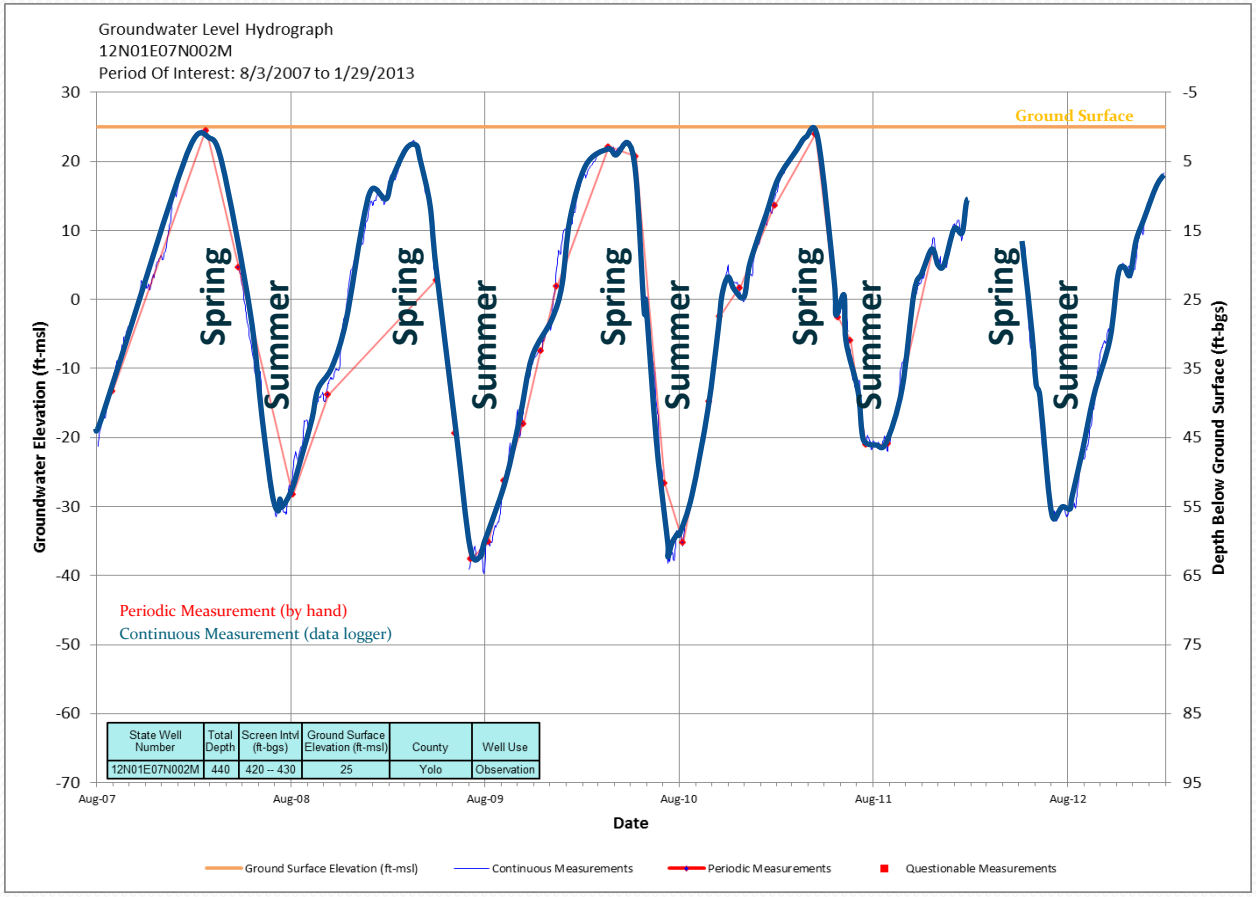
- GWL data is collected at different locations and a different times



Data Types and Availability

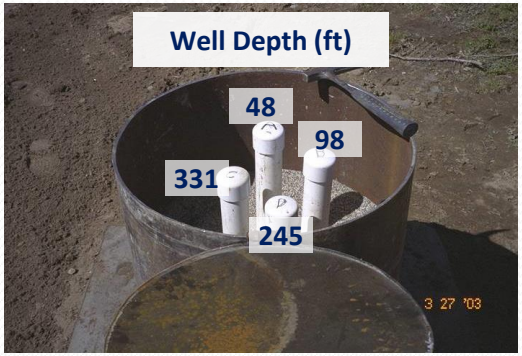
- Groundwater Level Data
  - Hydrograph…groundwater levels over time

Groundwater levels vary over time!

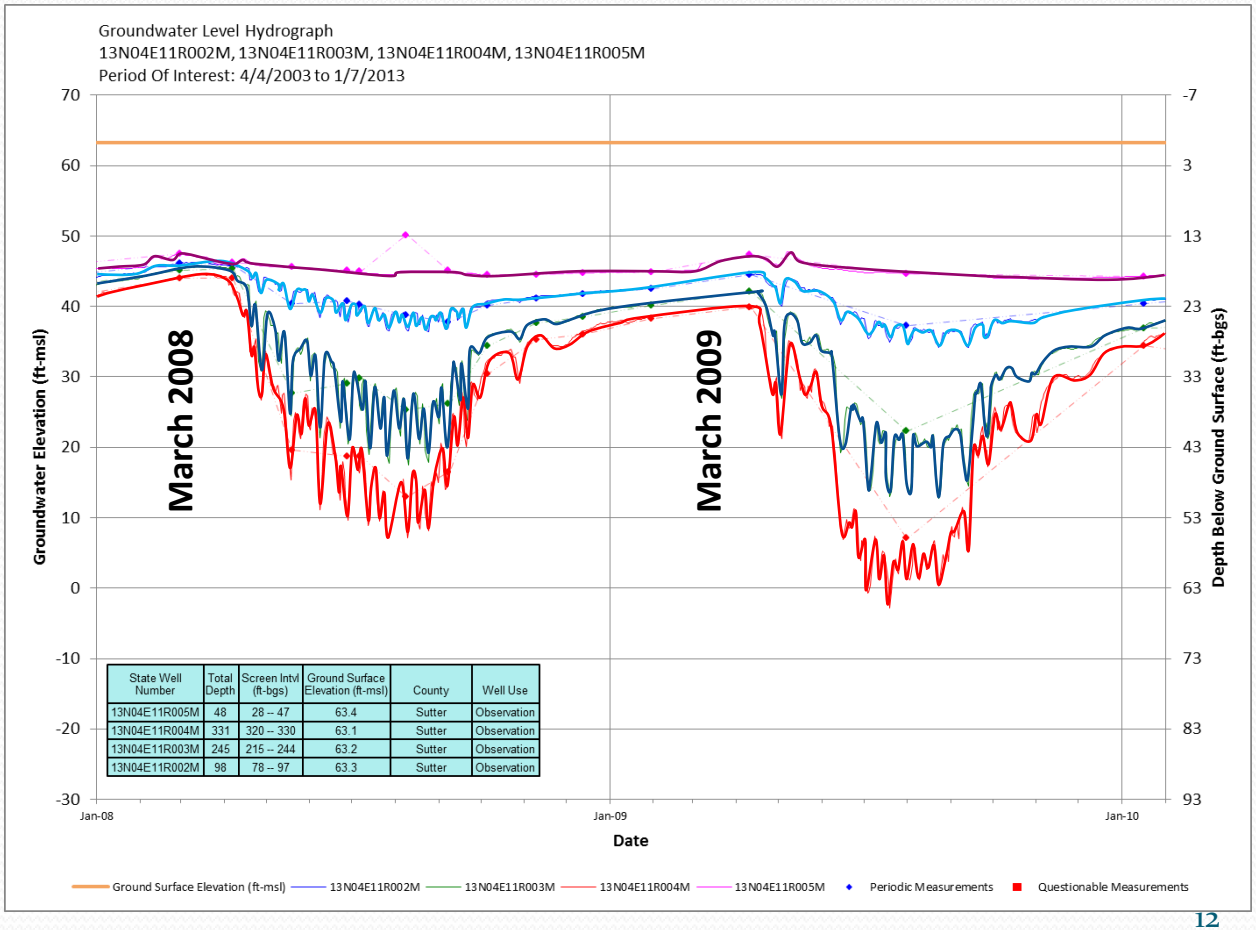


Data Types and Availability

- Groundwater Level Data
  - Multi-completion well hydrograph



Groundwater levels vary because of well construction!



Data Types and Availability

- Groundwater Level Data Availability
  - There is an abundant amount of GW level measurement data – over 1.4 million records in the DWR database
  - GW level measurement is often unavailable when applying x, y, z, and time constraints

Data Types and Availability

- Hydrogeologic Data
  - Aquifer Properties
    - Unconfined aquifer system
  - Storage Coefficients
    - Specific Yield (S_y) is used in unconfined systems
- Hydrogeologic data is available for many groundwater aquifers, but not in a consistent format
- Specific Yield range of 0.07 to 0.17 is used

Data Types and Availability

- Groundwater data is widely availably, **but…**
- Varies in location, time, and quality, **so…**
- In some areas groundwater data is not available to estimate the change in groundwater in storage

?? QUESTIONS ??

Overview of Presentation

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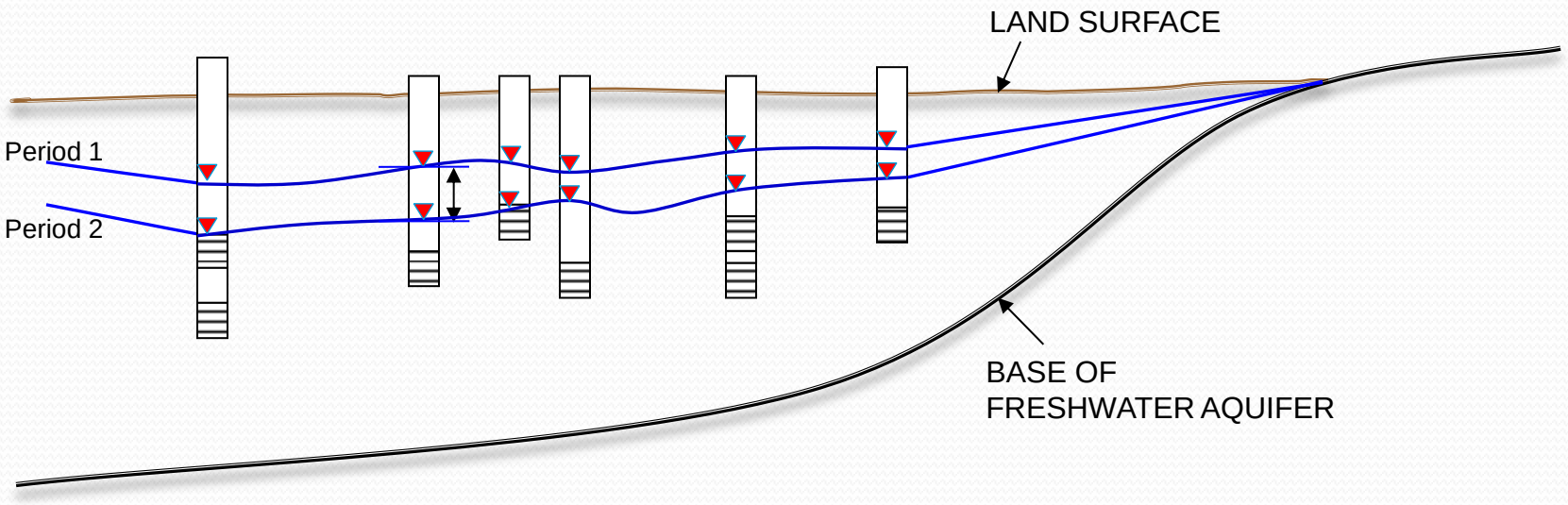
  - Data Types and Availability
- Methodology
  - The importance of data management and GIS
  - Assumptions and Key Concepts
  - The Groundwater GIS tool

Data Management and GIS



GW level measurement at a single location:
provides some information about current conditions

Repeated measurements at a single location:
provides information about water level changes

Measurements at multiple locations:
provides GWL information for a region

Repeated measurements at multiple locations:
provides GWL **change** information for a region

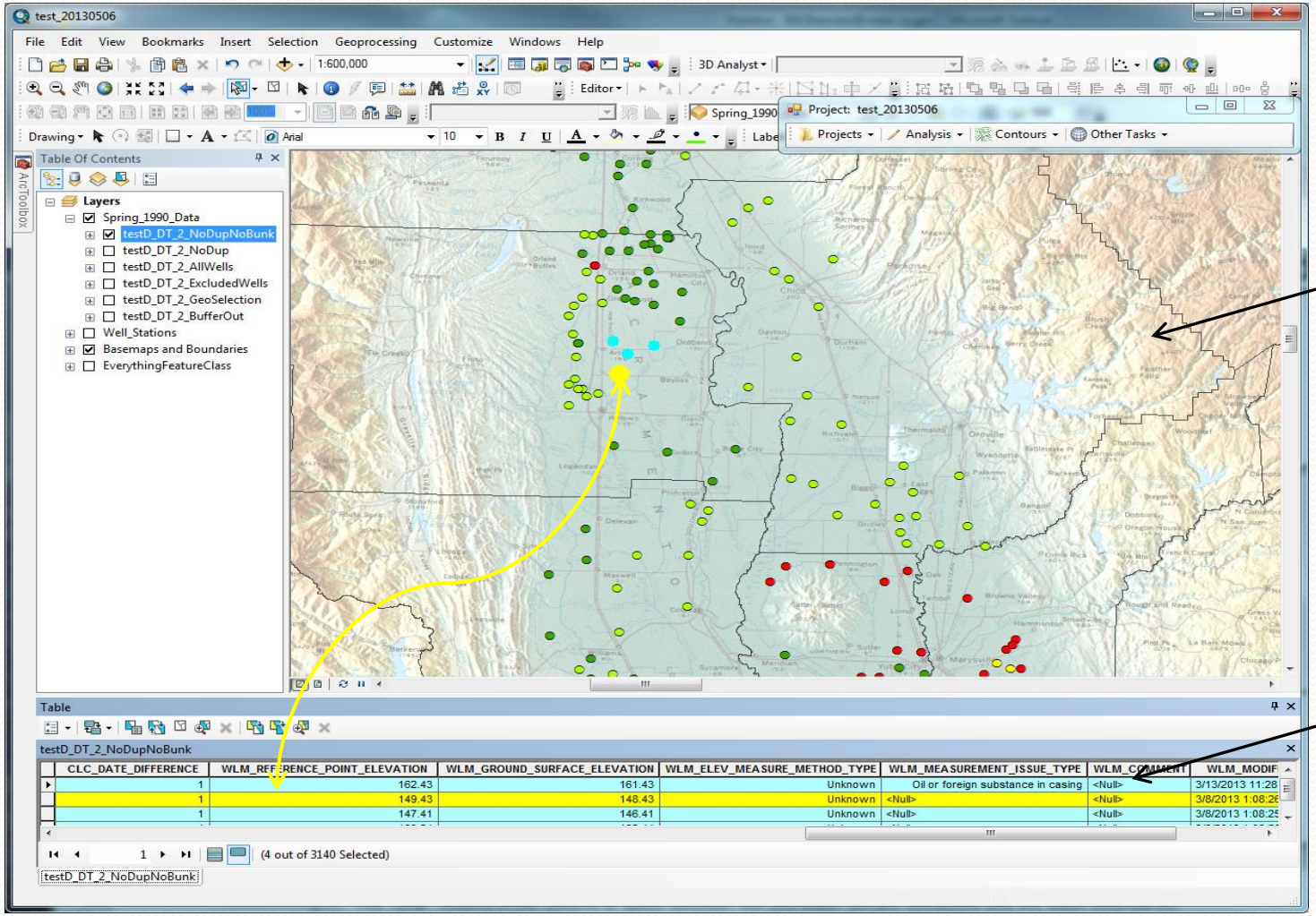
Data Management and GIS

- GIS workflows are used to provide structure to data management and analysis
- Workflows are repeatable, reliable, transparent

DWR Water Data Library, CASGEM, and other Data Collection Programs

GIS workflow elements used to estimate change in groundwater in storage

Data Management and GIS



In a map...

and,
in a table.

- GIS provides a flexible way of looking at the data

Assumptions and Key Concepts

- **Assumptions** are used to simplify complex systems
  - Eight Assumptions
- **Key Concepts** are used to apply rules to geoprocessing workflows
  - Seven Key Concepts

- A few of these are reviewed in the next few slides
- These are discussed in more detail in the CWP 2013 Change in Groundwater in Storage - Appendix E

Assumptions

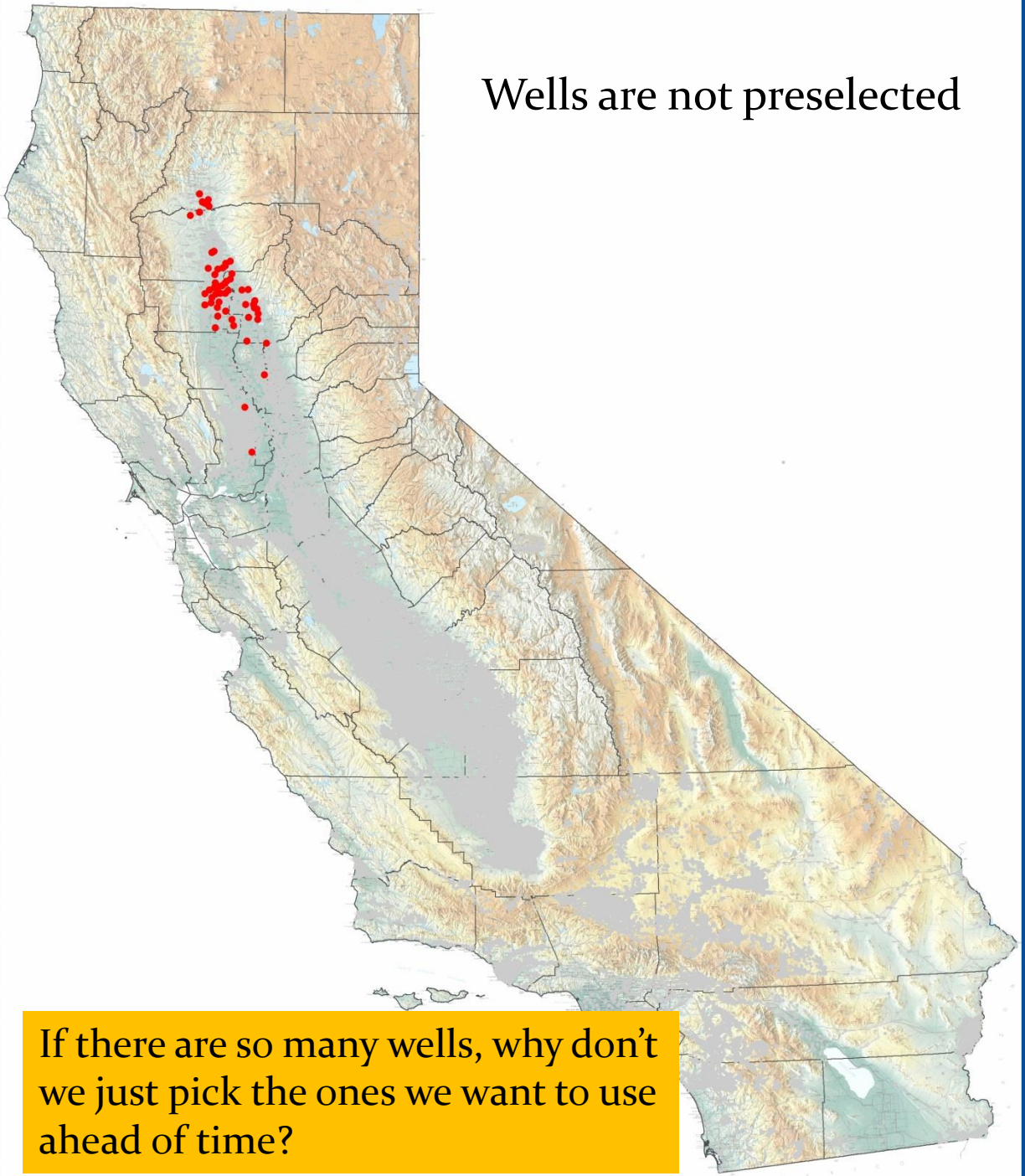
- There are eight (8) assumptions
  1) All data must reside in the DWR Water Data Library*
  2) Wells are not preselected and all available groundwater level data is initially considered to be good data
  3) Groundwater levels represent unconfined, static, aquifer conditions
  4) Only "spring to spring" changes in groundwater storage are estimated
  5) Groundwater level change is calculated from two water level measurements in the same well**
  6) The geographic limit the groundwater basin is delineated and no changes in groundwater elevations occur at this boundary
  7) The geographic limit of available groundwater level data is delineated
  8) Specific Yield values are applied as an average for an entire Reporting Area**

*As of 2011 groundwater level data is maintained as part of the CASGEM database
**DWR is currently revising and updating this process

Key Concepts

- There are seven (7) key concepts
  1) Groundwater Basin and Subbasin Boundaries
  2) Reporting Areas and Non-Reporting Areas
  3) Depth to groundwater and groundwater elevation
  4) Selecting unique groundwater level measurements
  5) Groundwater level surfaces (WSEL and DBGS)
  6) Change in groundwater level
  7) Change in groundwater storage

Wells are not preselected



If there are so many wells, why don't we just pick the ones we want to use ahead of time?

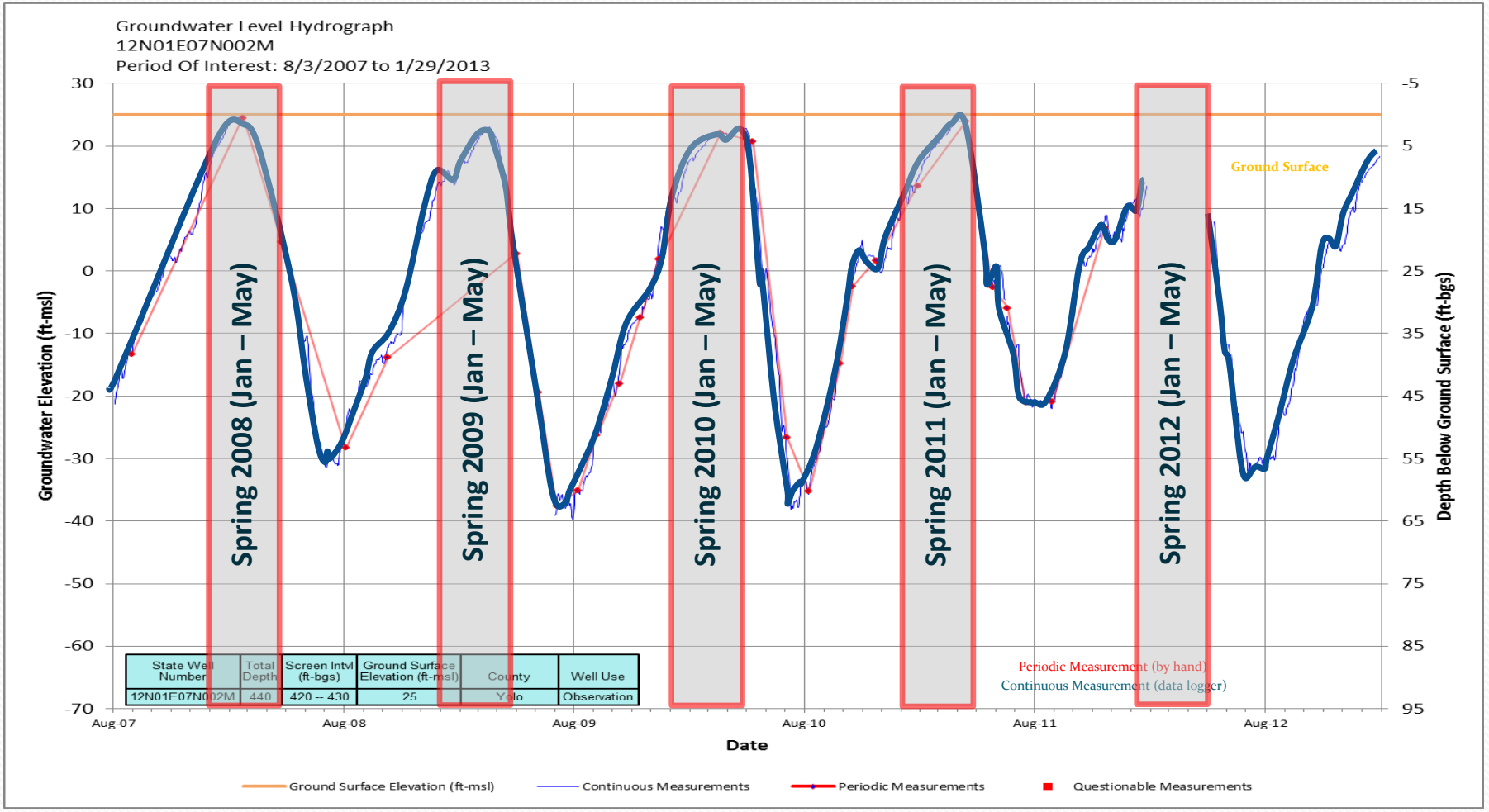
SELECTION CRITERIA	WELL COUNT
Number of wells in the database	**39,995**
wells that have depth and screen information	3,989
...and Well Completion Reports	2,484
And were measured	
...between 2005 and 2010	893
...in spring	824
...of 2010 only	719
And are located in the Central Valley	419
...With perforations in the unconfined aquifer	296
...And are dedicated Observation wells	**89**

Assumptions and Key Concepts

- Only yearly "spring to spring" changes in groundwater storage are estimated
  - Springtime groundwater levels are most consistent year to year and typically least affected from pumping wells
  - Groundwater levels are at their yearly highs
  - Assures more consistent yearly comparisons
  - What is "Spring"?
    - Data collected prior to first irrigation of the year
    - Data collection dates range from January to May, depending on the region, year, and collecting agency

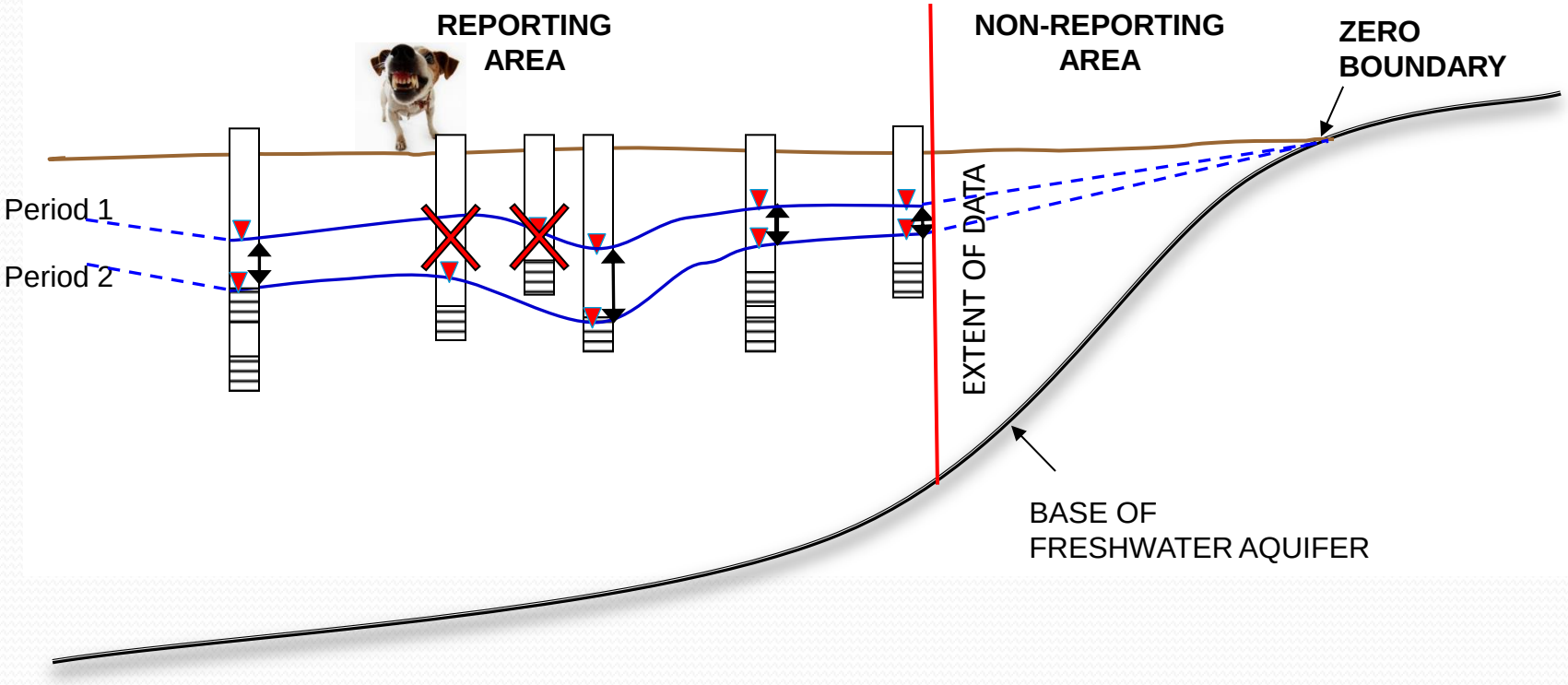
Data Types and Availability

- Using "spring" measurements

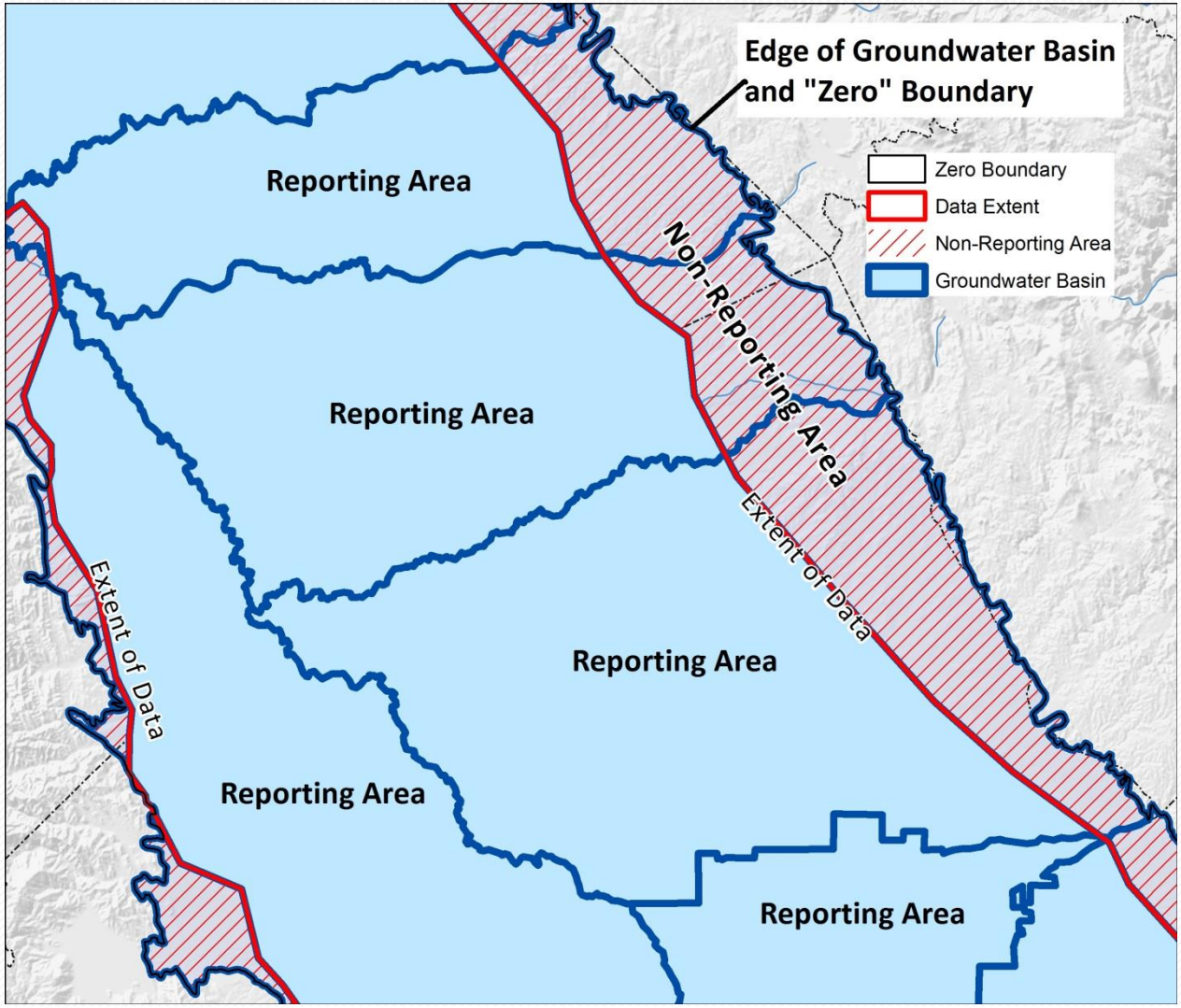


Assumptions and Key Concepts

- Groundwater level change is calculated from two water level measurements in the same well
- There is no change in groundwater levels at the edge of the groundwater basin
- Reporting Areas and Non-Reporting Areas



Assumptions and Key Concepts



Zero boundary at basin extent

The data extent is a defined boundary

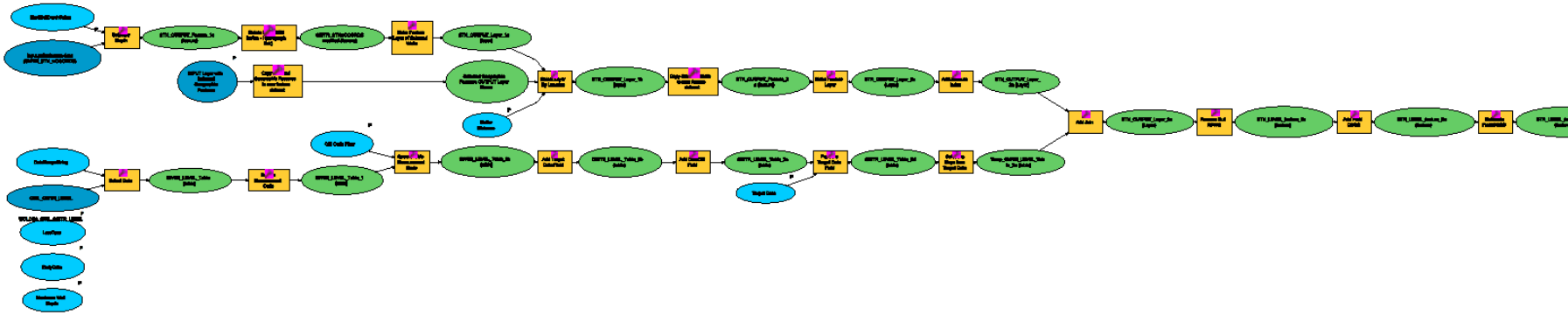
Reporting Areas are typically defined by subbasin boundaries

Non-Reporting Areas

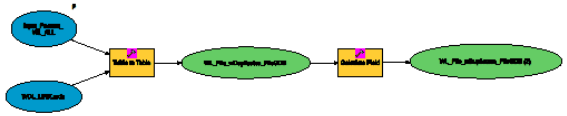
The Groundwater GIS Tool

- A custom tool was developed to estimate change in GW storage… the Groundwater GIS tool
- Basic steps (workflow)
  - Query data
  - Make groundwater elevation surfaces from two periods
  - Estimate the total volume between the two surfaces
  - Apply a storage coefficient to convert the total volume to an estimated amount of groundwater
  - Create summary reports of the analysis for each reporting area
  - QA/QC in between each step

2a Select_GWTR_wells_ByDATE

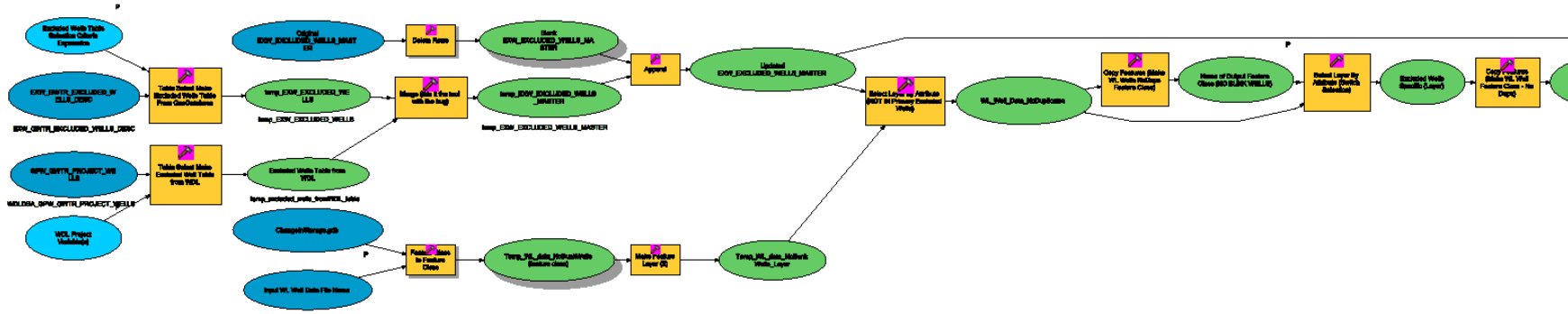


2B1 Remove_Duplicates_begin



2B3 Remove_Duplicates_finish

2C Remove_Excluded_Wells



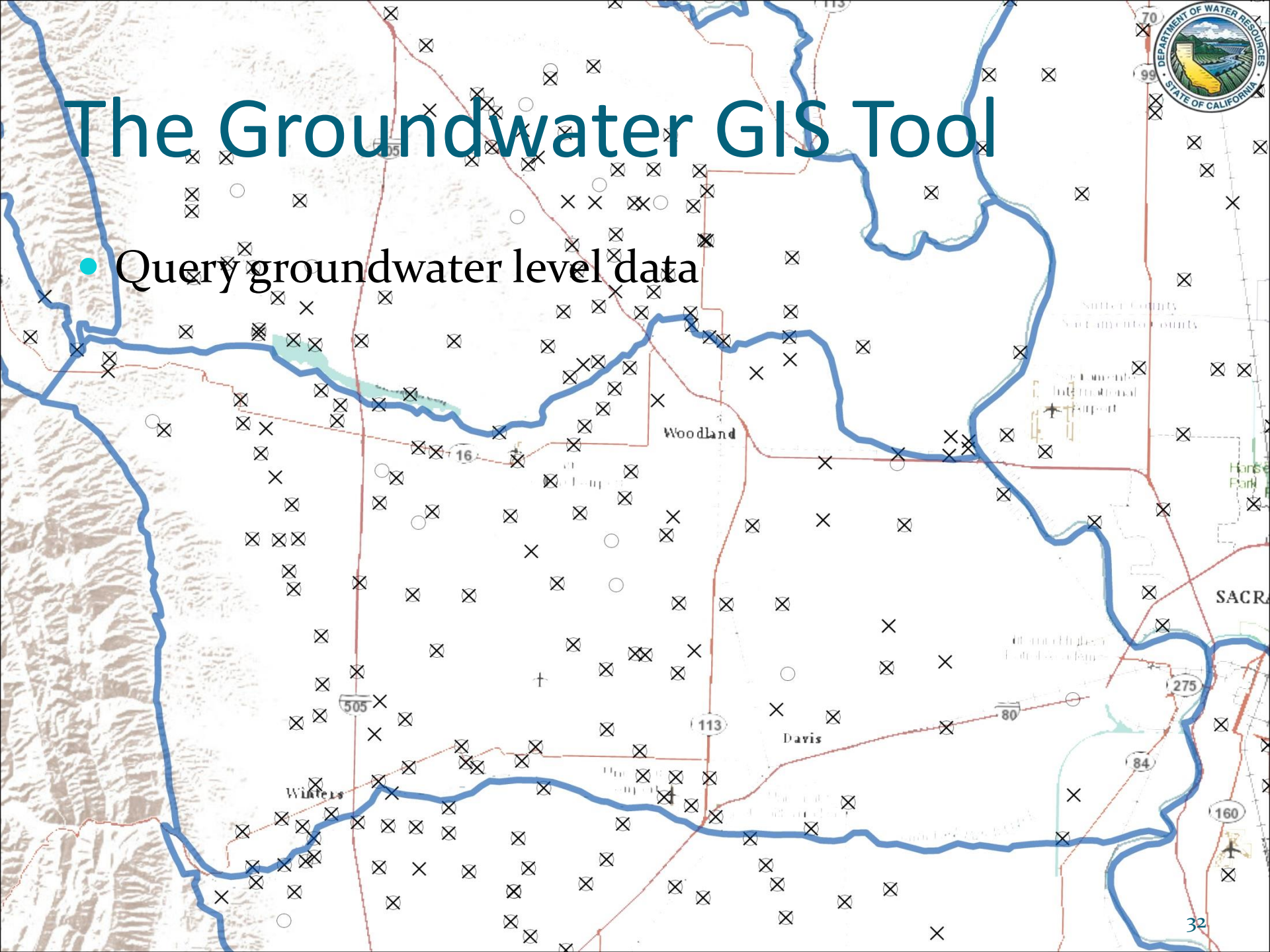
The Groundwater GIS Tool

- Query data using GIS based on specific parameters

Parameter	Data Description	Purpose
Geographic Region	Polygon feature	Limits the geographic scope of the query
Date Range	Minimum date value and maximum date value	Selects only well data within a specific date range
Target Date	Date	Selects the water level measurement nearest the specified target date
Well Depth	Depth, in feet	Filters wells by depth
Questionable Measurement Code	Coded values (alphanumeric)	Filters out measurements with specific measurement quality codes (such as "well is pumping" or "pumping well nearby")
Excluded Wells	Table identifying selected wells in groups using well group codes	Enables filtering wells by group, as listed on the Excluded Wells table

The Groundwater GIS Tool

- Query groundwater level data

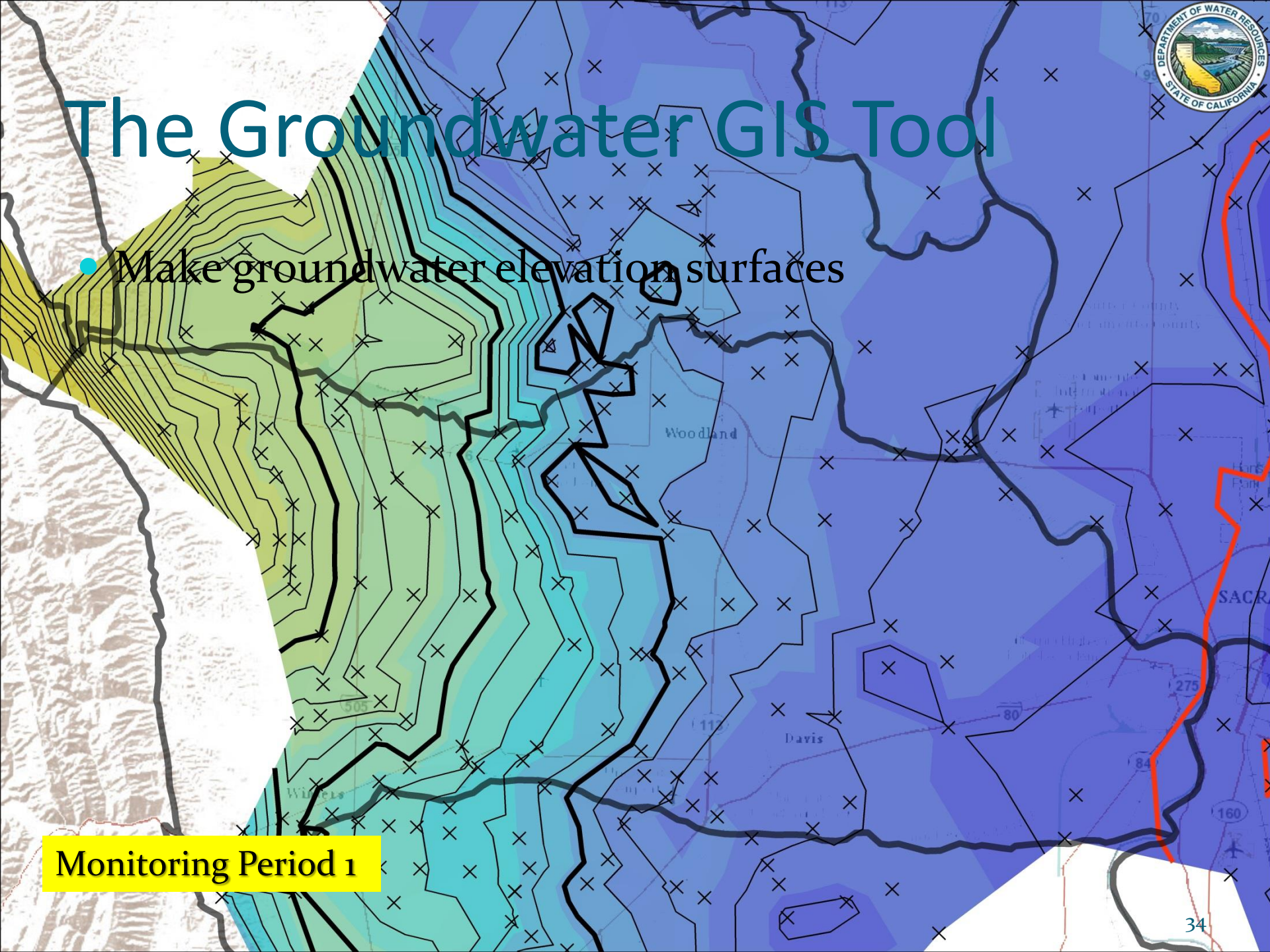


The Groundwater GIS Tool

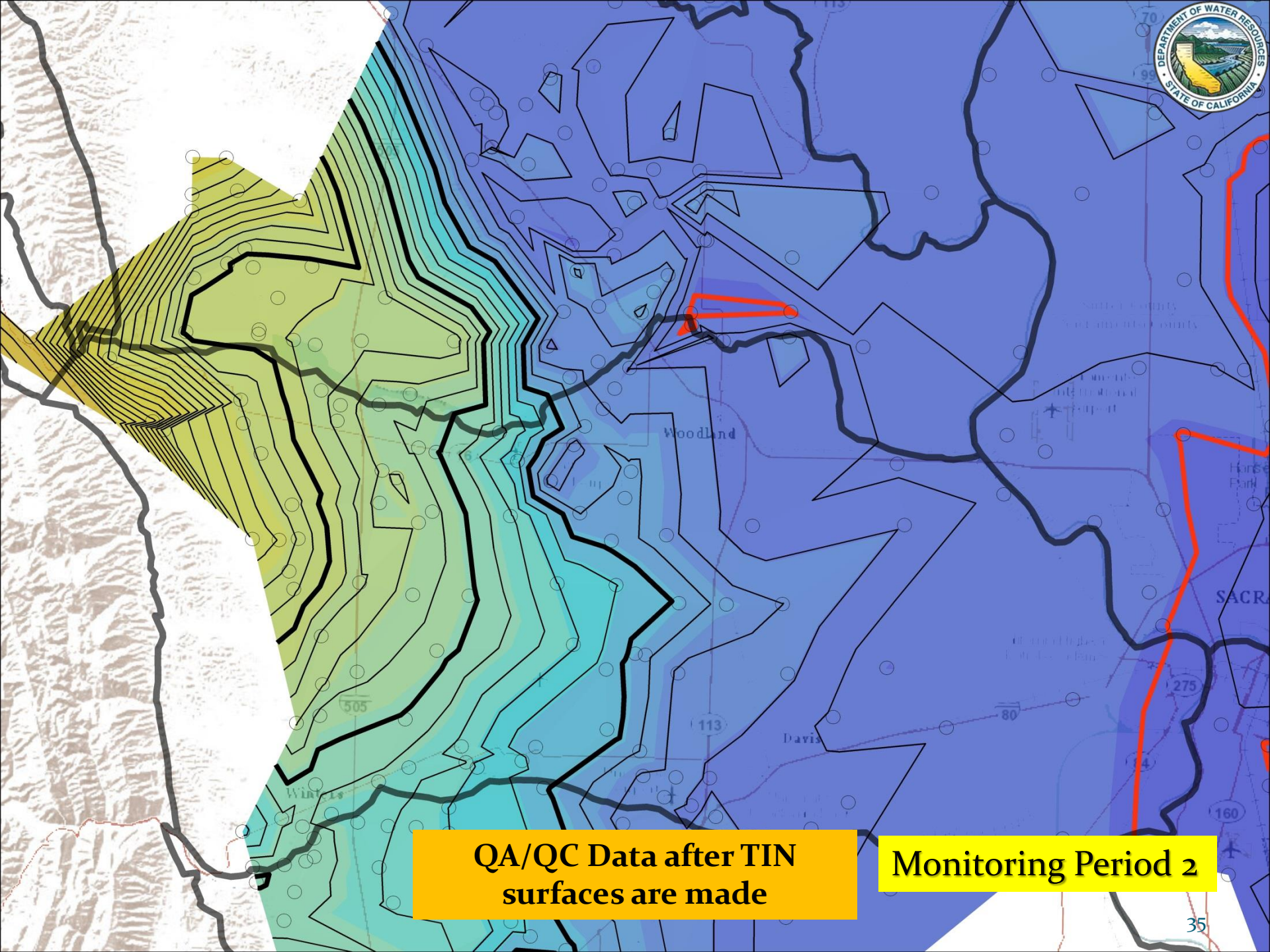
- Make groundwater elevation surfaces

The Groundwater GIS Tool

- Make groundwater elevation surfaces



Monitoring Period 1

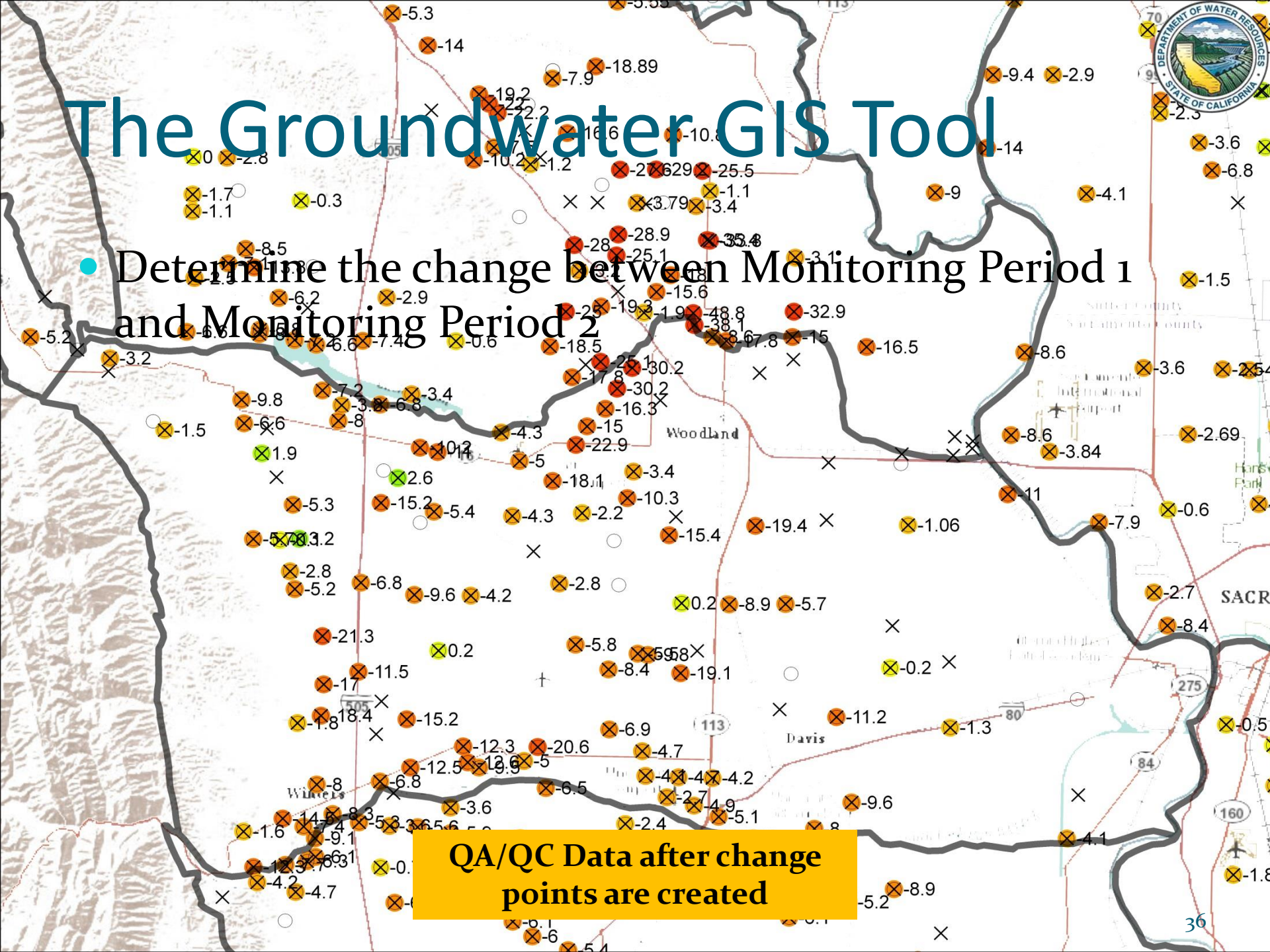


QA/QC Data after TIN surfaces are made

Monitoring Period 2

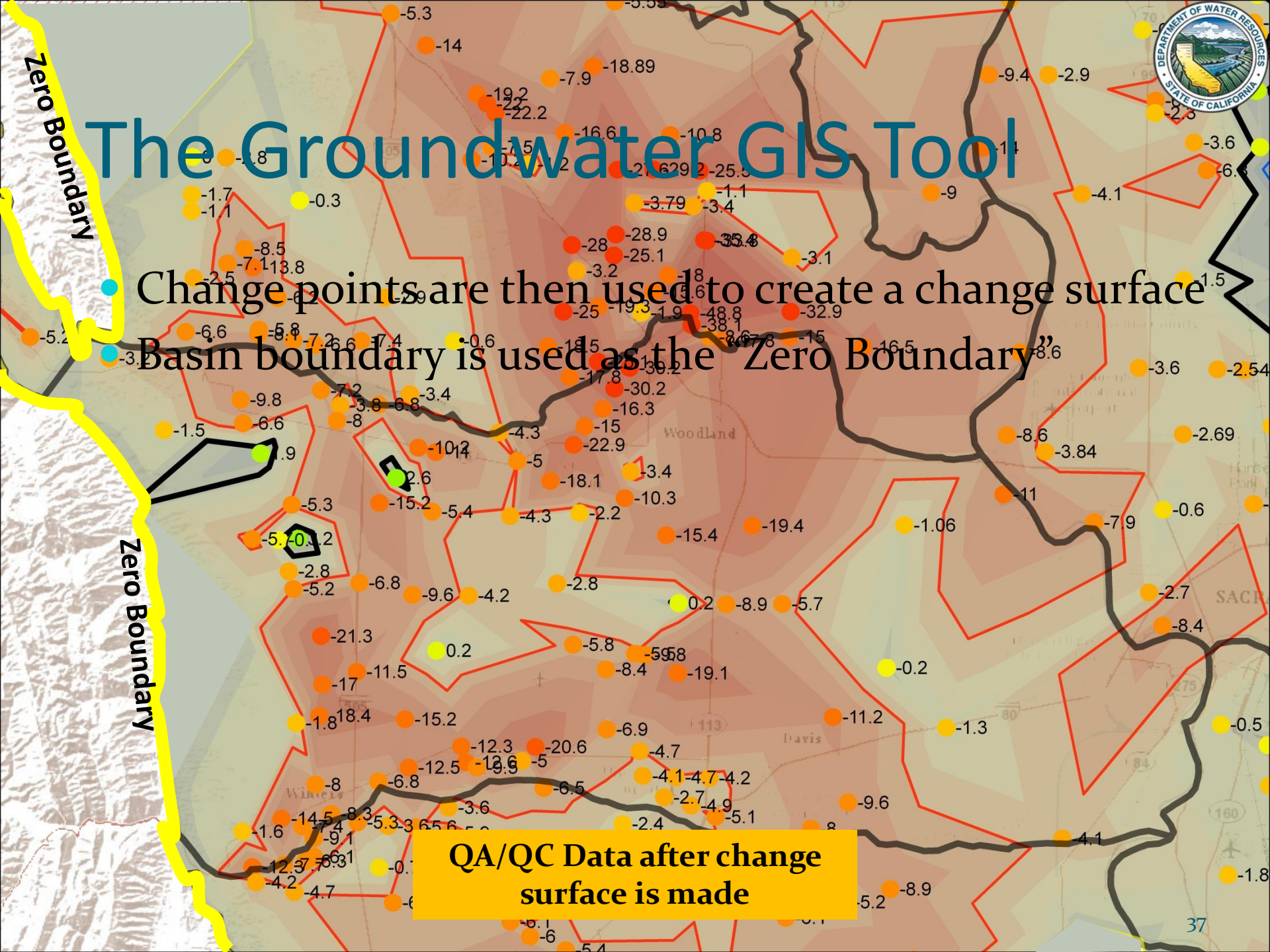
The Groundwater GIS Tool

- Determine the change between Monitoring Period 1 and Monitoring Period 2



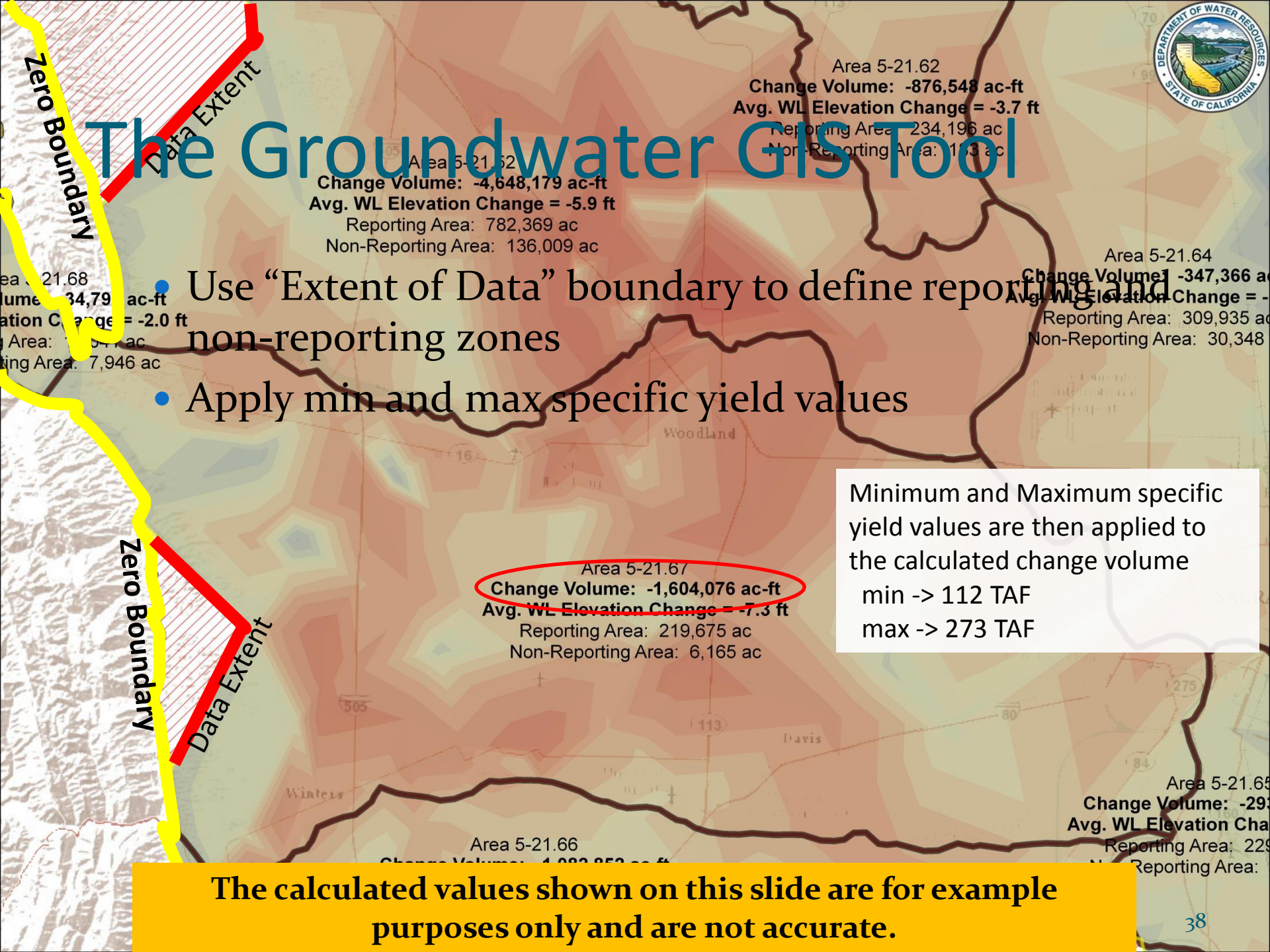
The Groundwater GIS Tool

- Change points are then used to create a change surface
- Basin boundary is used as the "Zero Boundary"



The Groundwater GIS Tool

- Use "Extent of Data" boundary to define reporting and non-reporting zones
- Apply min and max specific yield values



Minimum and Maximum specific yield values are then applied to the calculated change volume

min -> 112 TAF

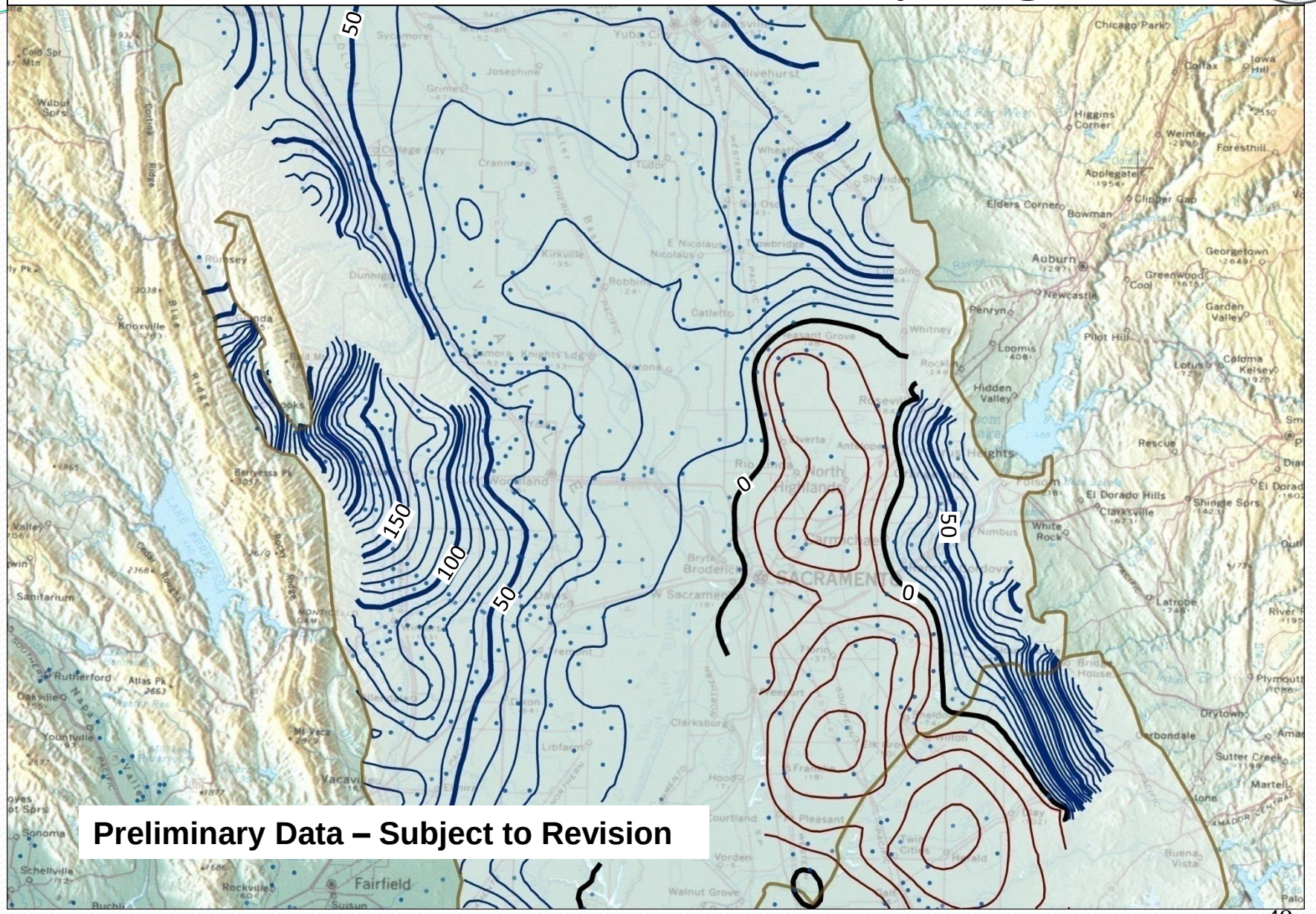
max -> 273 TAF

The calculated values shown on this slide are for example purposes only and are not accurate.

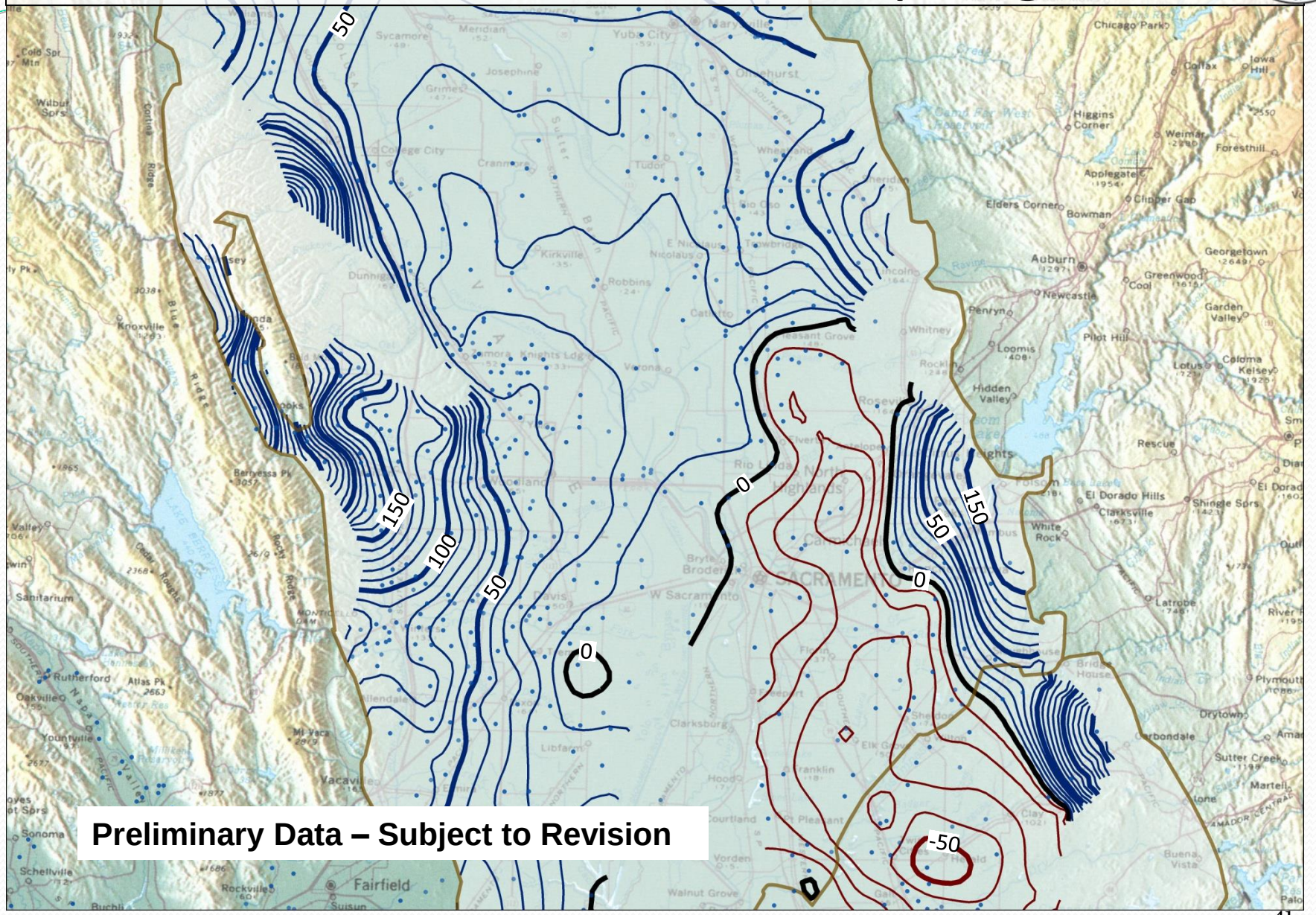
Another Example

- Spring 2005 to Spring 2010

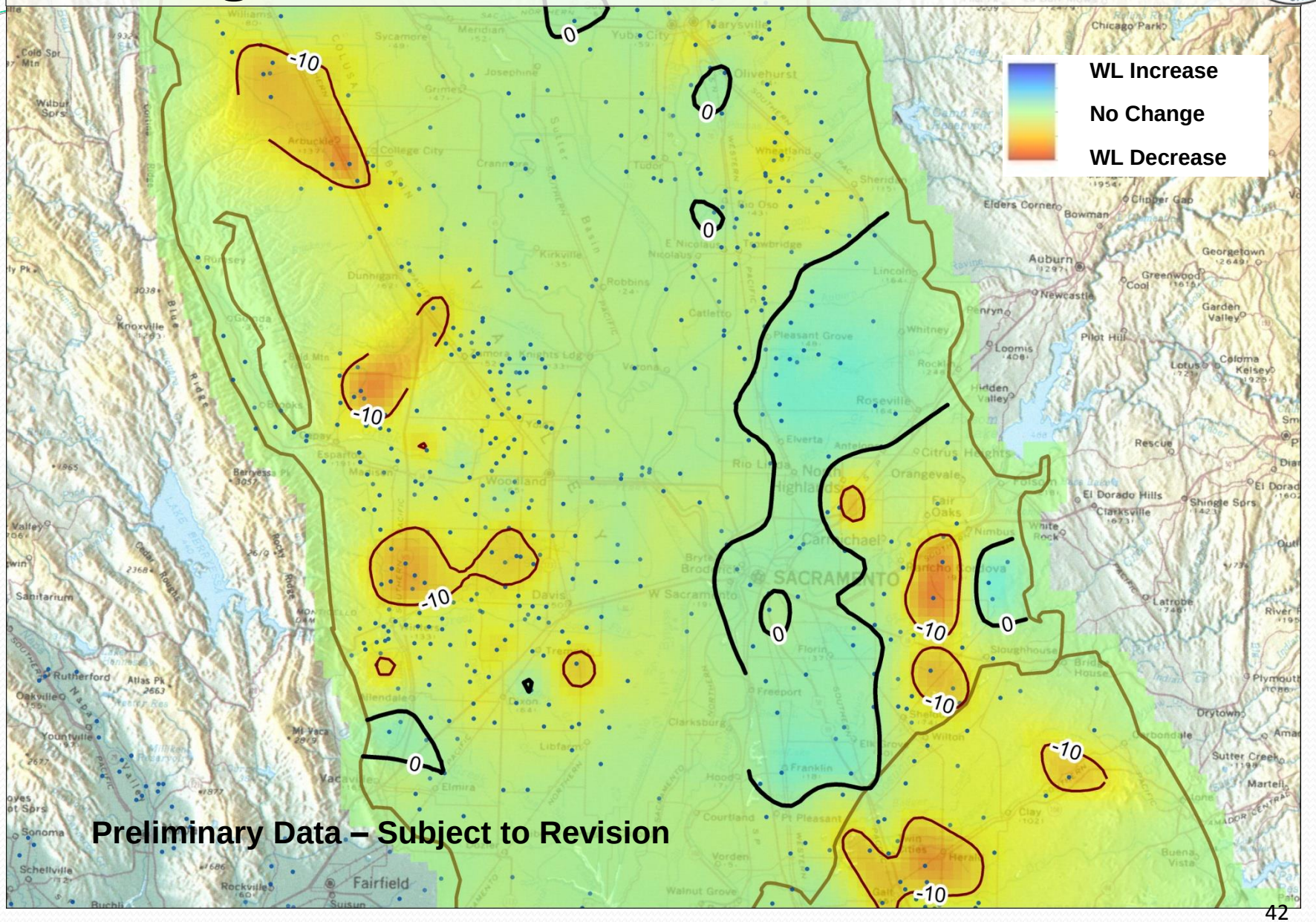
Groundwater Elevation – Spring 2005



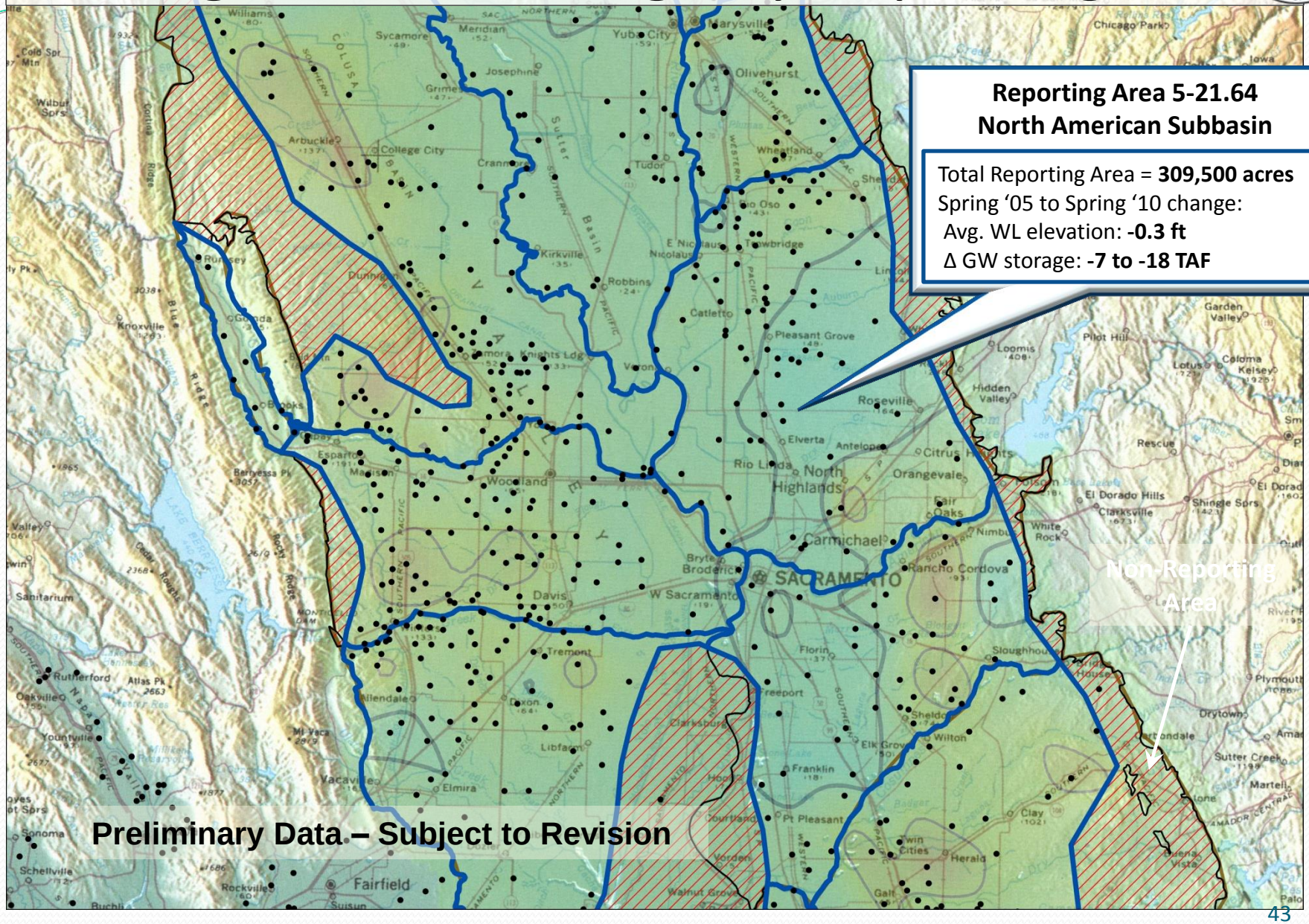
Groundwater Elevation – Spring 2010



Change in GW Elevation – 2005 to 2010

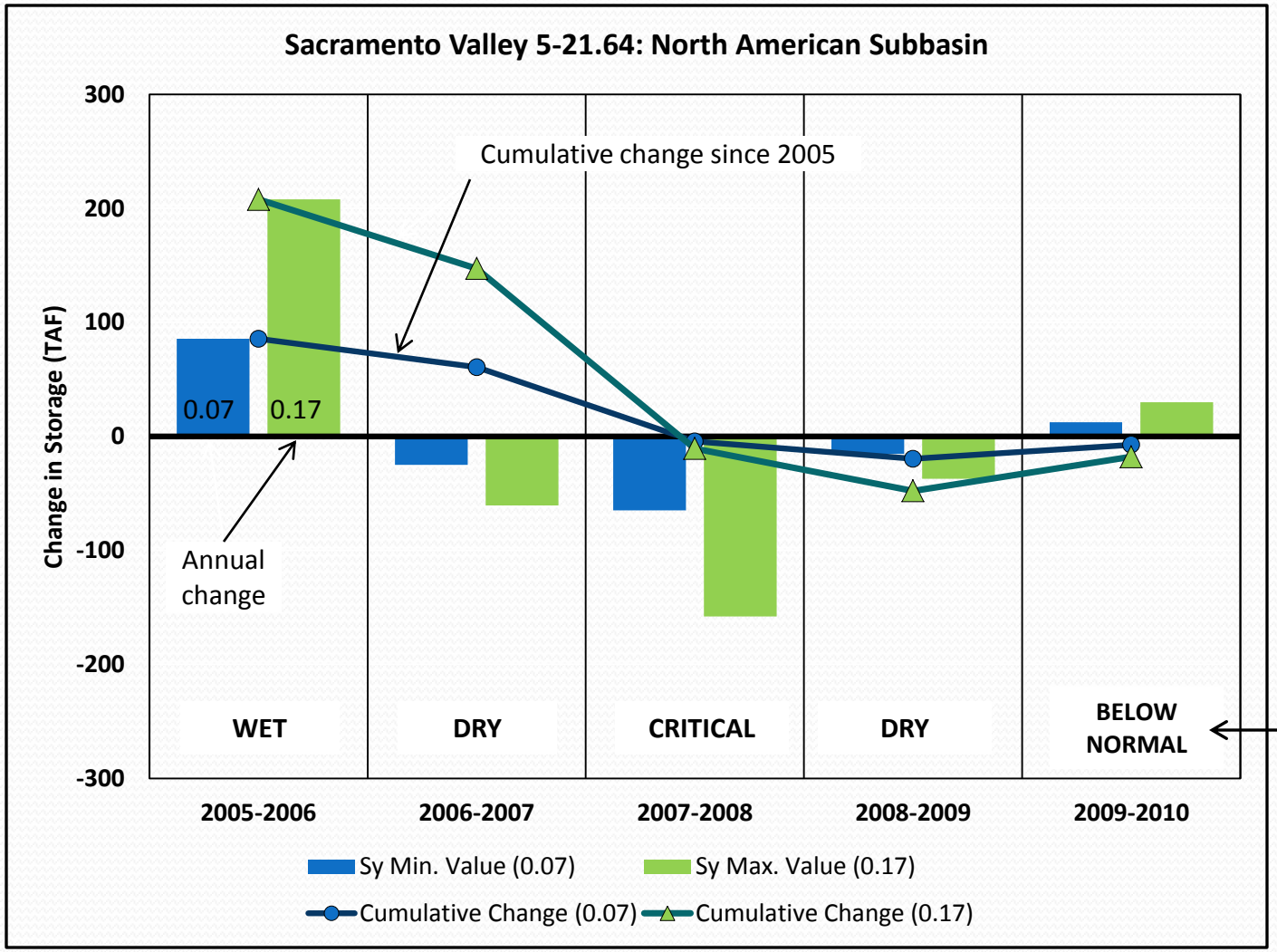


Change in GW Storage by Reporting Area



Annual Change in GW Storage

Preliminary Data – Subject to Revision



Annual Change in GW Storage

Preliminary Data – Subject to Revision

Sacramento Valley 5-21.64: North American Subbasin

Reporting Area: **309,500 acres**
Non-Reporting Area: **30,800 acres**

Period Spring - Spring	Average Change in GW Elevation (feet)	Estimated Change in Storage in TAF	
		Assuming S_y= 0.07	Assuming S_y = 0.17
2005-2006	4.0	85.6	207.8
2006-2007	-1.2	-25.0	-60.6
2007-2008	-3.0	-65.0	-157.9
2008-2009	-0.7	-15.3	-37.1
2009-2010	0.6	12.3	29.8
2005-2010 (total)	-0.3	-7.4	-17.9

Note: GW elevation and change in storage estimates are calculated within reporting area only.

QUESTIONS?

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Conclusions

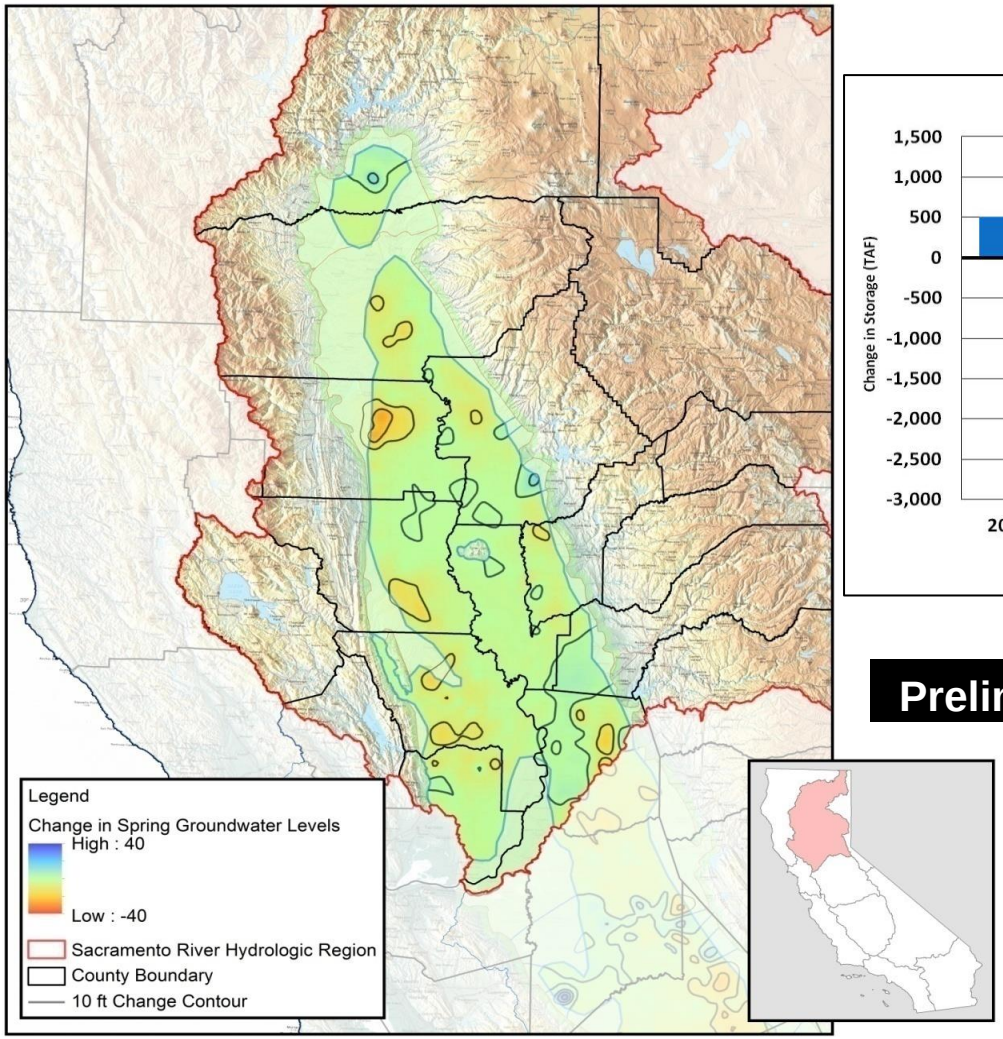
- To meet the goals of estimating the change in GW in storage, it was necessary to build custom tools
- The GW GIS tool:
  - uses a transparent workflow
  - effectively queries groundwater level data,
  - and can provide complex reports including the change in groundwater in storage
  - is versatile, and can be used for a wide variety of analysis

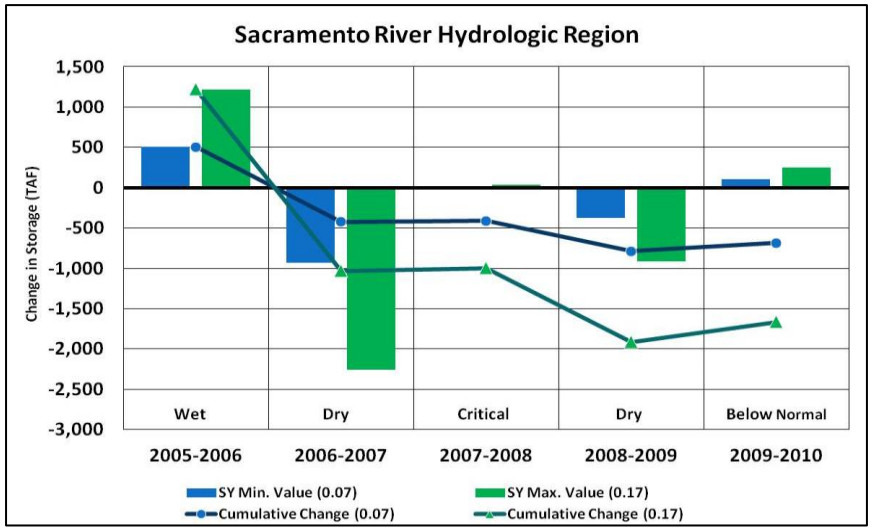
Conclusions (cont.)

- Data quality and availability is the most important aspect of estimating the change in GW in storage
- The timing of data collection by cooperating agencies is highly variable
- The quality of available data is highly variable
- DWR is refining the process of applying storage coefficients
- This project has resulted in many “spin-off” reports

Depth to Groundwater Contours

Well Type Distribution for 2010 Well Data - Sacramento Valley





Preliminary Data – Subject to Revision

Bulletin 118 Groundwater Subbasin

QUESTIONS ?