Monitoring storage change and recharge

- BLUF:
  - Repeat microgravity is a method for measuring mass (water) change in the subsurface.
  - A groundwater storage-change (gravity) network was established ca. 2015. This could be re-observed to determine storage changes since then. Approximate cost $30-50k.
  - Mountain block recharge – especially interannual variation – is a hard research problem ($300-500k for gravity instrumentation).

Relevance to the water budget

- The water budget approach attempts to estimate total change in storage as the sum of individual storage changes

Table 2. Groundwater-budget values calculated for 2002 and 2012, change in values, and uncertainty for natural aspects of the system, groundwater pumping, active-management measures, and unintentional recharge in the Sierra Vista Subwatershed, southeastern Arizona.

[acre-ft, acre-foot; NA, not applicable]

Groundwater budget element, in acre-ft	2002	2012	Change	Estimated uncertainty
1. Natural recharge	13,500	13,500	NA	±4,700
2. Groundwater inflow	3,000	3,000	NA	±800
3. Groundwater outflow	−1,200	−1,200	NA	±400
4. Stream base flow discharge	−2,600	−2,600	NA	±1,100
5. Riparian evapotranspiration	−12,200	−12,200	NA	±900
Subtotal: Natural aspects of system	500	500	NA	NA
6. Municipal and water-company pumping	−10,700	−9,500	1,200	±1,000
7. Rural/exempt well pumping	−1,200	−1,400	−200	±700
8. Industrial pumping	−1,600	−1,200	400	±300
9. Irrigation pumping	−2500	−50	2,450	±100
Subtotal: Groundwater pumping	−16,000	−12,150	3,850	NA
10. Effective impact of mesquite and tamarisk treatment	400	100	−300	±70
11. Municipal-effluent recharge	1,300	3,000	1,700	±200
12. Detention basin recharge	200	100	−100	±100
Subtotal: Active-management measures	1,900	3,200	1,300	NA
13. Total incidental recharge	900	1,000	100	±700
14. Urban enhanced recharge	1,900	2,400	500	±1,000
Subtotal: Unintentional recharge	2,800	3,400	600	NA
Total water-budget balance	−10,800	−5,000	$\boxed{5,800}$	±5,500
Sierra Vista Subwatershed population	69,942	80,866	10,924	NA

Gravity surveys provide this number

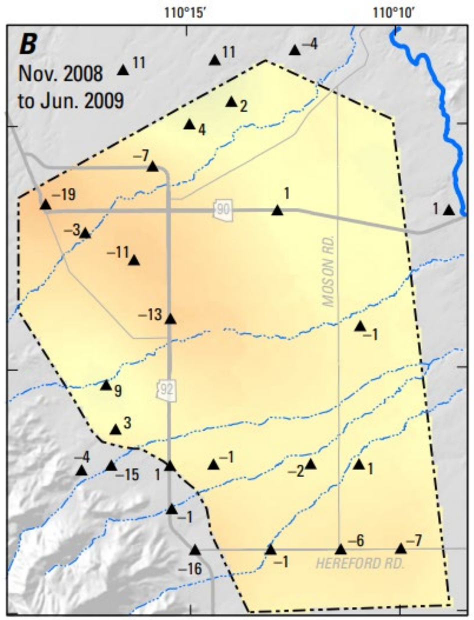
Which could also be determined from groundwater-level changes, but that requires:

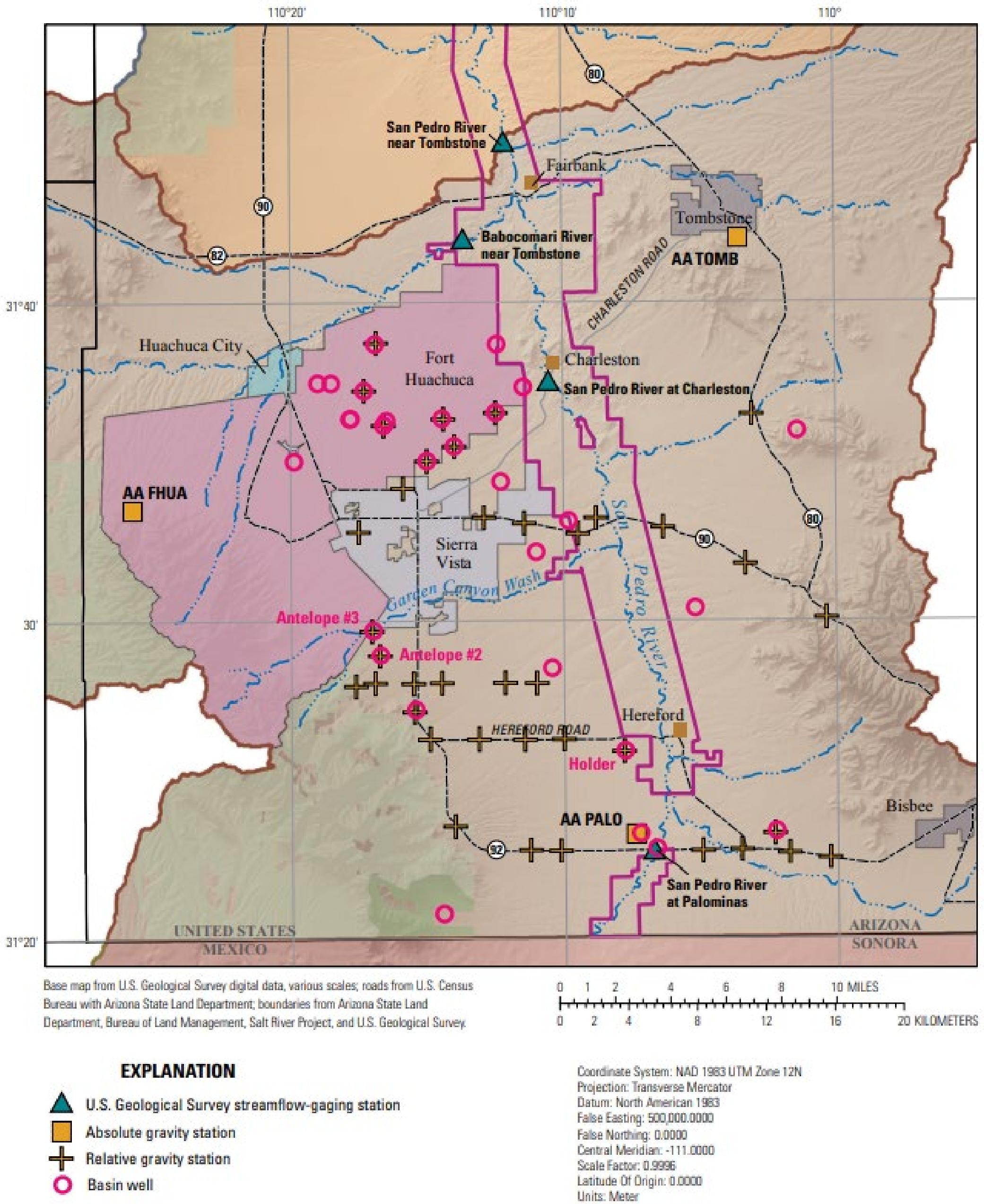
- Adequate well coverage
- Knowledge of the aquifer storage coefficient (specific yield)

2003-2011 Gravity network

- The initial gravity network had stations spaced far apart, attempting to cover the entire basin.
- This provided individual site estimates of *1-dimensional storage change*

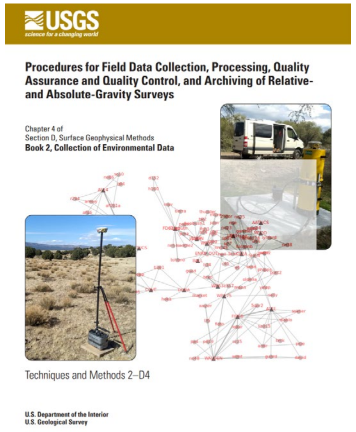
To calculate a *volume* of storage change (e.g., acre-feet), we need sufficient data to interpolate a surface

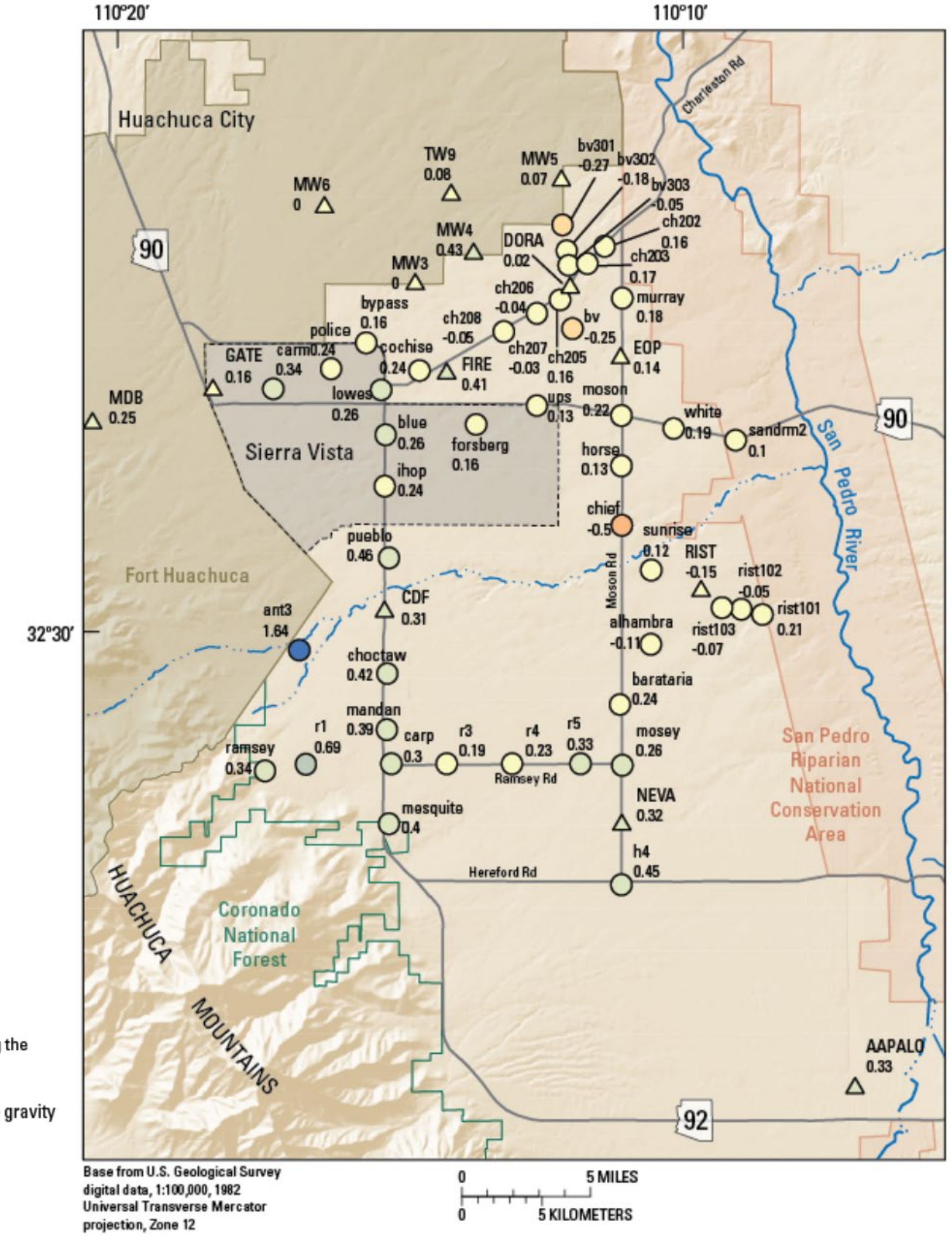




2015 Gravity network

- 7 years since last visit – stations in unknown condition
- A good GPS survey was carried out last time, thanks to TNC volunteers. We should be able to tell if stations have changed elevation
- Usually, data interpretation is straightforward – subtract one time period from another
- Instrumentation, data collection, and processing have improved since the last survey





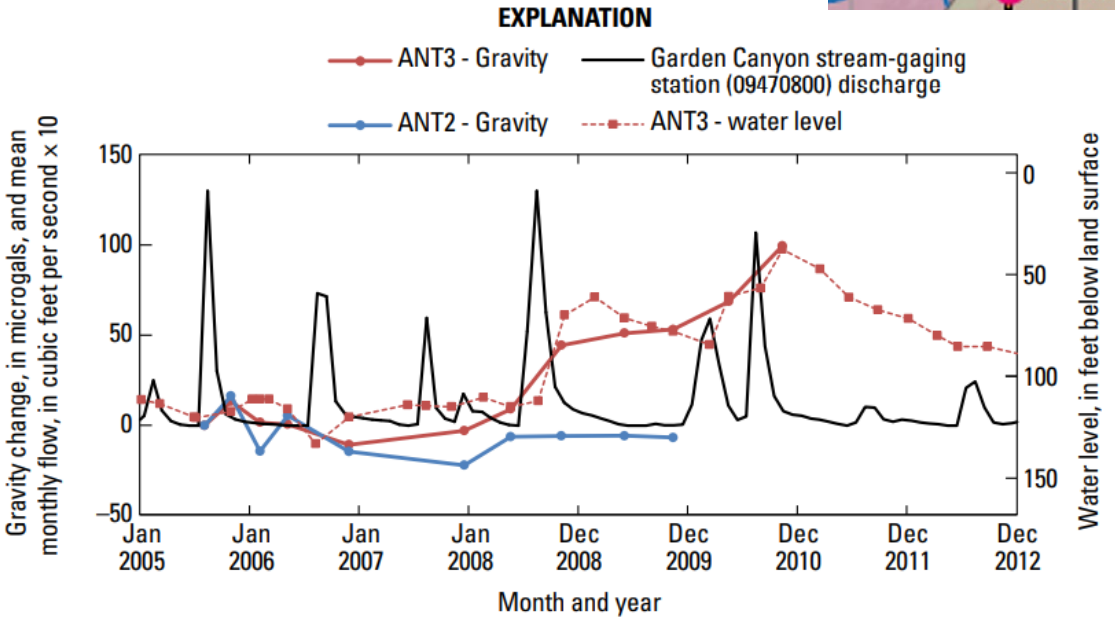
EXPLANATION

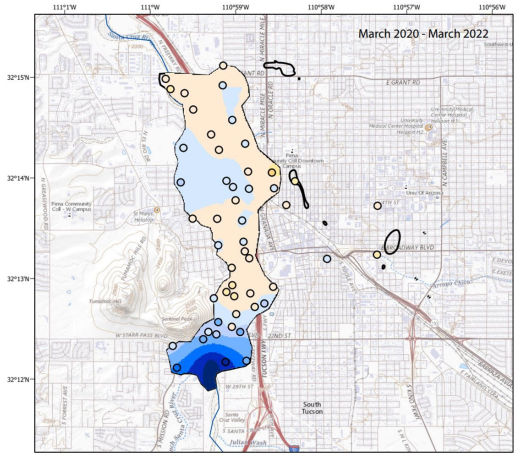
Storage change from June 2014 to June 2015 derived from gravity data using the horizontal infinite slab approximation, in meters of water

-0.74 - 0.5	0.26 - 0.5	Absolute gravity station
-0.49 - -0.25	0.51 - 0.75	
-0.24 - 0.25	1.51 - 1.75	

Mountain front recharge

- Majority occurs in the main channels
- Nearly 100% infiltration between MF and river
- Streamgaging is expensive, but the value is high relative to other methods.





Santa Cruz River network in Tucson

Mountain block recharge

- Several recent studies have sought to elevate a gravity sensor above its surroundings
- This reduces near-field (soil moisture) sensitivity, which can dominate the signal
- In effect, this creates a whole-mountain mass sensor (aka lysimeter) with a big footprint
- Data are very precise, but require AC power, and can be expensive
- How much groundwater is gained relative to the amount of precipitation? How quickly is it lost during dry periods?