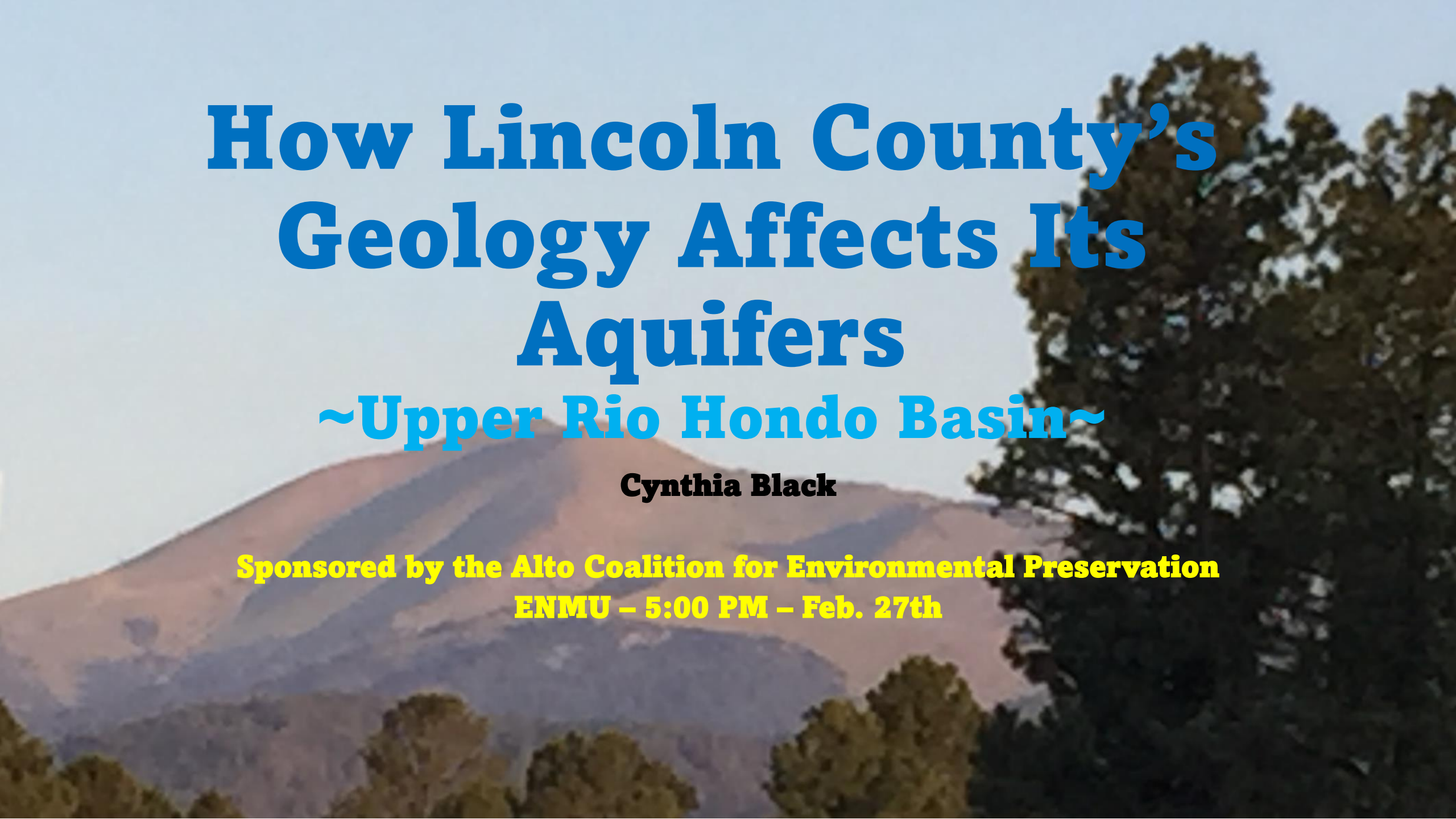


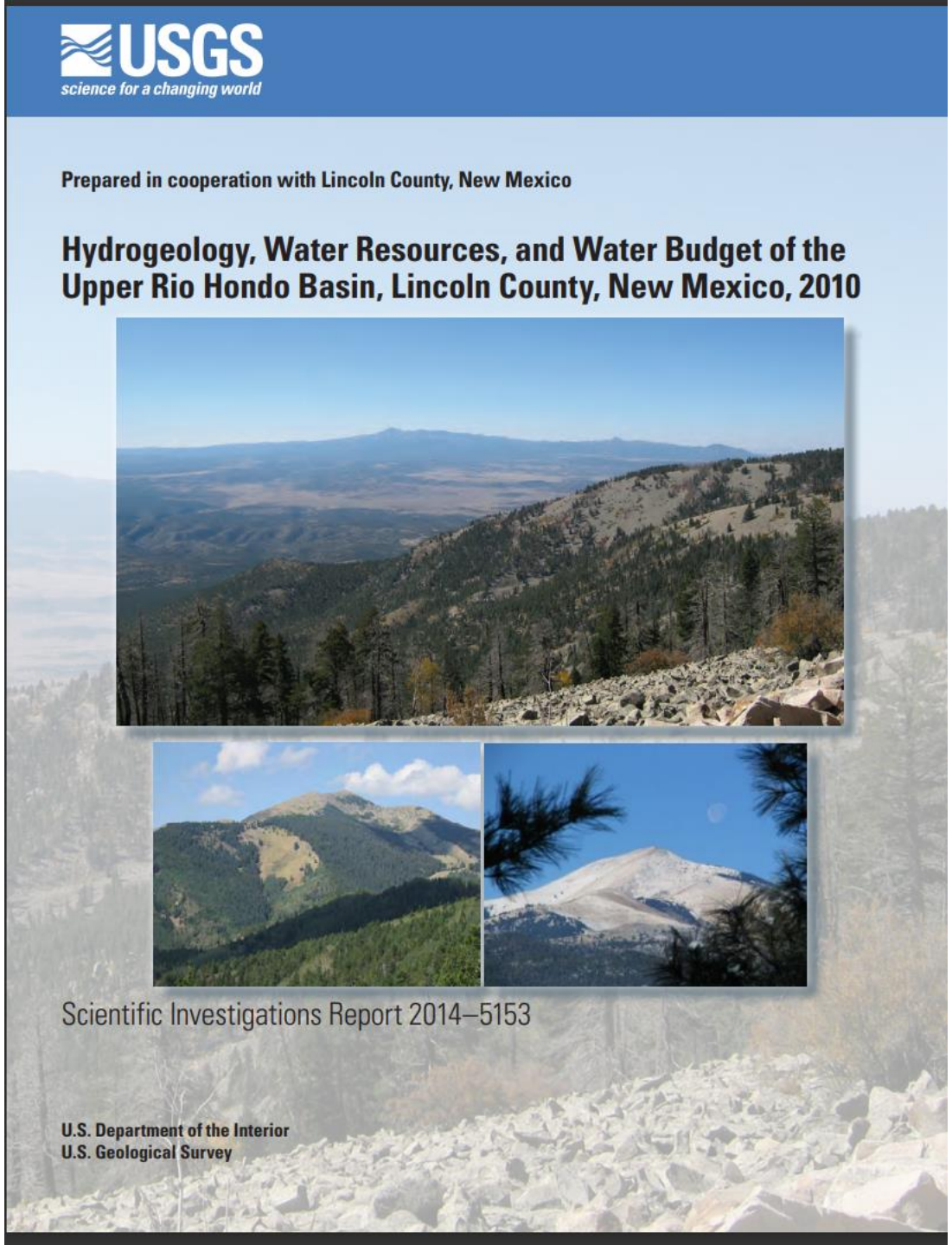
How Lincoln County's Geology Affects Its Aquifers

~Upper Rio Hondo Basin~

Cynthia Black

Sponsored by the Alto Coalition for Environmental Preservation

ENMU – 5:00 PM – Feb. 27th



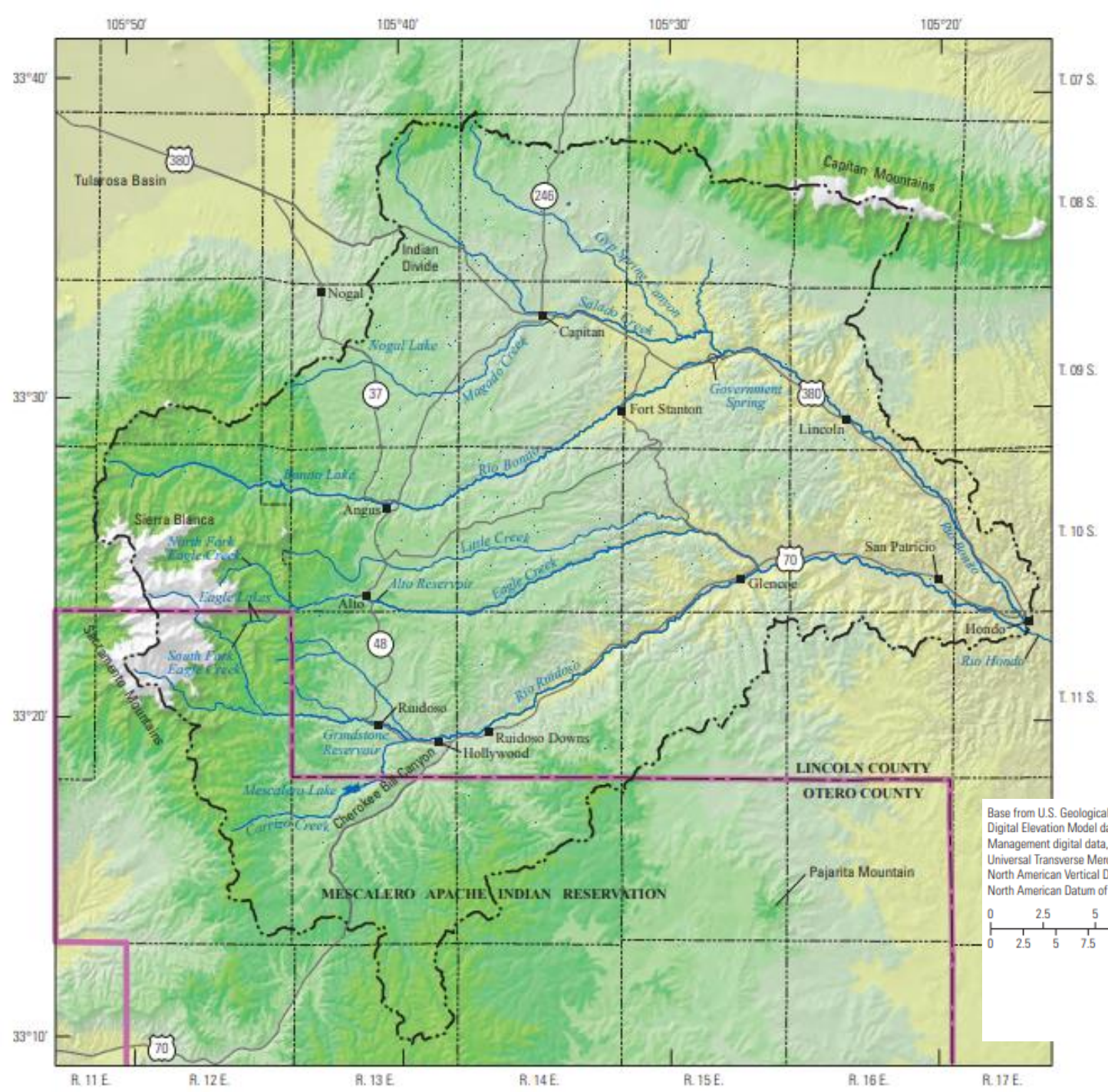
Acknowledgements

USGS Report 2014-5153 – Hydrogeology, Water Resources, and Water Budget of the Upper Rio Hondo Basin, Lincoln County, New Mexico, 2010

Geological maps by

Geoffrey C. Rawling

NM Bureau of Geology & Mineral Resources, NM Tech, Socorro, NM



Upper Rio Hondo Basin Generalized Topographic Map

- **Major drainages, mountains**
- **Highways, villages**

- **Timeframe data through 2010**

Base from U.S. Geological Survey, 2005, 10-meter Digital Elevation Model data and Bureau of Land Management digital data, 2004, 1:100,000
Universal Transverse Mercator projection, zone 13
North American Vertical Datum of 1988 (NAVD 88)
North American Datum of 1983 (NAD 83)

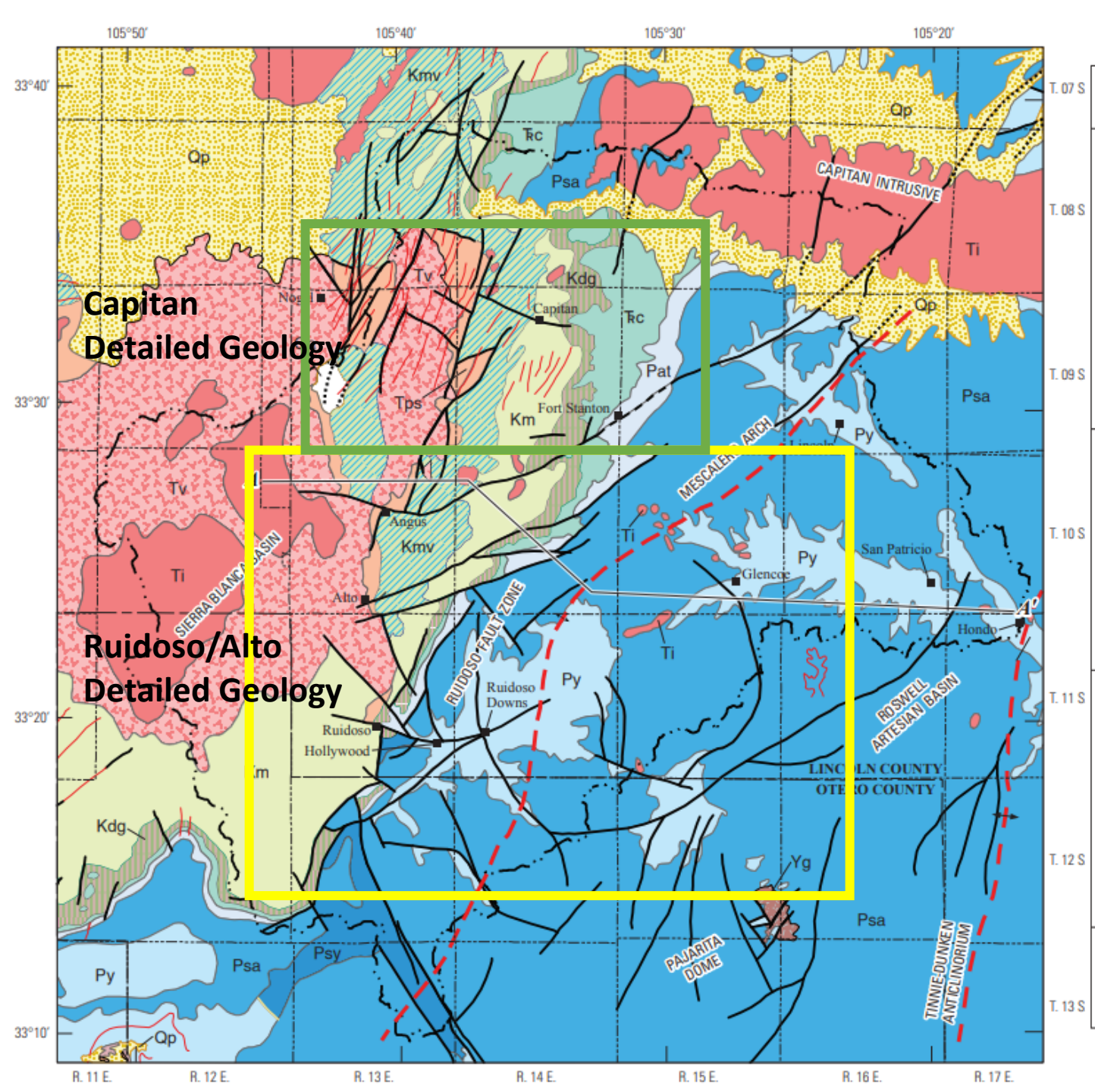
0 2.5 5 7.5 10 MILES
0 2.5 5 7.5 10 KILOMETERS

EXPLANATION

Elevation, in feet above North American Vertical Datum of 1988 (NAVD 88)

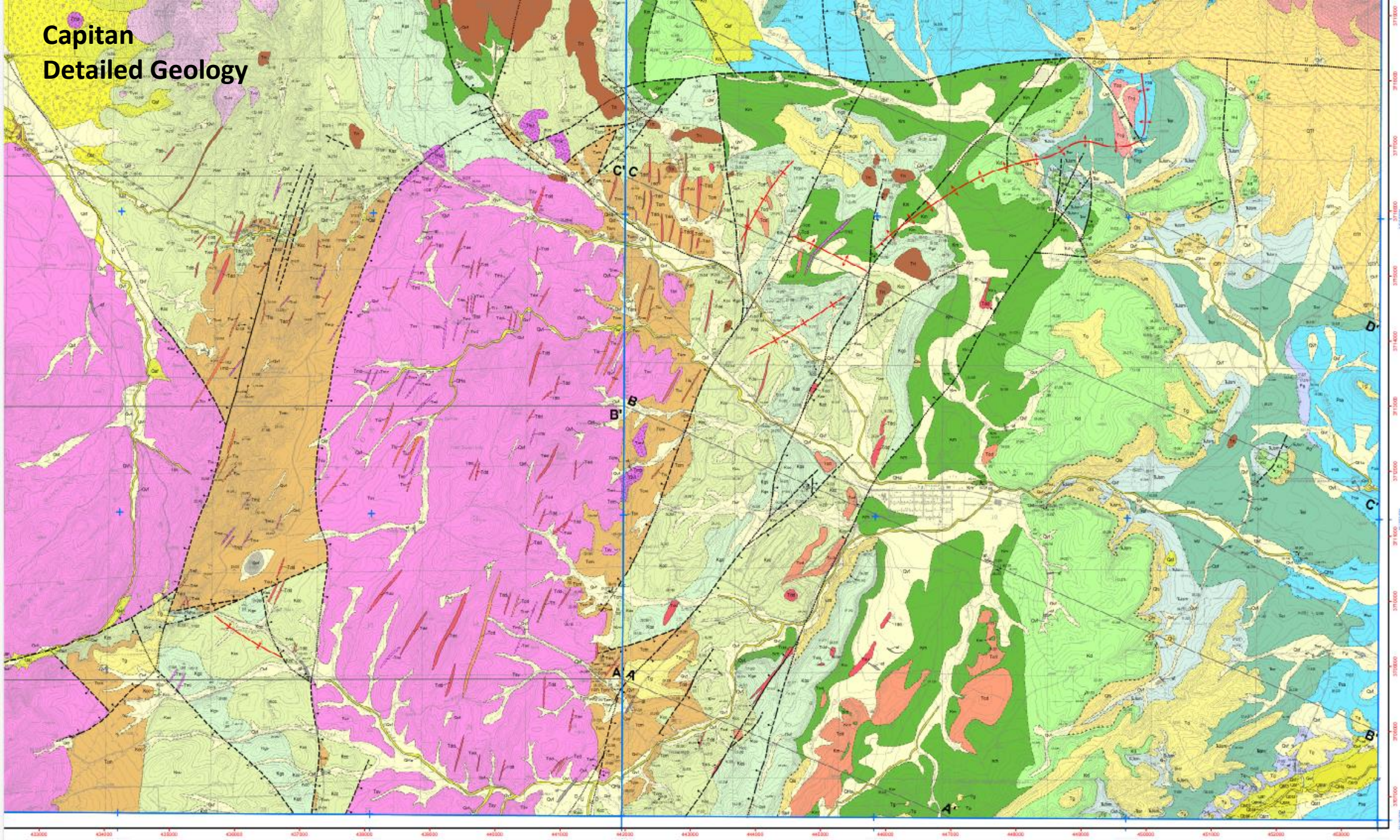
- 5,000 to 5,700
- 5,701 to 6,400
- 6,401 to 7,100
- 7,101 to 7,800
- 7,801 to 8,500
- 8,501 to 9,200
- 9,201 to 10,000

- **Study area boundary**
- **County boundary**
- **Mescalero Apache Indian Reservation boundary**



Geologic age		Geologic map units	Hydrologic characteristics
Cenozoic	Quate	**Pleistocene-Quaternary 1 my - present**	s in river valleys and at foot of ntains.
	Ter	**Oligocene Volcanic Complex Intrusive Dykes 50-40 my**	Typically not water bearing, except where heavily fractured. Modest to good aquifers in Mountain Block terrane.
Mesozoic	Cretaceous	**Cretaceous Mesaverde Group (Coals) Dakota Sandstone 70-65 my**	
	Triassic	**Triassic, Chinle/Santa Rosa**	ifer at foot of onal system.
Paleozoic	Permian	**Permian Grayburg (Artesia Gp) San Andres Yeso 250+ my**	r or aquiclude in north part of Central ne. ional aquifer system. San Andres forms uifer in north part of Central Basin nd localized perched aquifers e. Yeso forms a moderate to good the Hondo Slope terrane and localized aquifers elsewhere.
Precambrian	Proterozoic	Yg Precambrian rocks	Not water bearing (hydrologic bedrock) except where heavily fractured.

Capitan
Detailed Geology



certain geologic contact,
certain geologic contact,
uncertain geologic contac
headscarp of landslide o
fault decorations indicating app
dip-slip movement, bar a
dip-slip movement on co
fault,
axis of anticline
axis of syncline
cross-section line
quadrangle boundary

af/daf artificial fill and hea
QHa Alluvium
Qvf Valley fill
Qaf Alluvial fan deposits
Qbtd Bajada and fan toe
Qls Landslide deposits
Qbt4 Lowest terrace dep
Qbt3 Intermediate terrac
Qbt2 Intermediate terrac
Qbt1 Highest terrace dep
QTf Alluvial fan deposit
Tg Pediment gravel de
Tiu Undetermined igne
Tdd Diabase/diorite and
Tml Monzonite/latite an
Tcd Diorite of Champ H
Trt Rhyolite/trachyte a
Monzonite
Intrusion of Vera C
Tcg Capitan granite
Tsv Sierra Blanca volca
Tcm Cub Mountain Form
Kcc Crevasse Canyon F
Kgs Gallup Sandstone
Km Mancos Shale
Kd Dakota Sandstone
TrJsm Morrison Formation
Tsr Santa Rosa Sandst
Pg Grayburg Formatio
Psa San Andres Formal

Sedime
surfi

US Hwy 70 - Hondo Valley
Permian Yeso & San Andres Fm.

San Andres formation (middle Permian)

Thickness – 1000 ft, extremely important regional aquifer
It consists of gray limestone, dolomite, and is thin to massively bedded. Gypsum beds may be present.
The unit has been thinned by dissolution and exhibits karst features, sinkholes, and collapse breccias, particularly where gypsum has been removed. Wells drilled in the formation encounter cavities, enlarged solution fractures, and joints.
The Snowy River Cave, Ft. Stanton, is the named & discovered part of an extensive underground cave & ephemeral stream.

Yeso formation (Lower Permian)

Thickness – 1300 ft, major aquifer in eastern part of Upper Rio Hondo Basin
The upper two-thirds of the formation are composed of yellow-to-red sandstone and siltstone interbedded with gray-to-tan silty limestone and dolomite; the lower one-third is mainly composed of gray-to-white gypsum and anhydrite and interbedded siltstone.

Secondary porosity & permeability caused by dissolution along fractures, bedding planes; tight intraformational folding may be a barrier to groundwater flow, but may assist in creating fractures, bringing water to surface as springs (Tinnie-Dunken Ant.).

Permian – major aquifers in Lincoln Co.

San Andres Formation

Note flat-lying beds capping hills

Yeso Formation

Tight folds, steep dips in limestone beds; intense fracturing may help water storage and transmissivity. It definitely creates "damming" that impedes GW flow.

Chinle/Dakota contact – East of Capitan

Dakota Sandstone (Cretaceous) – big ridge-former

Jurassic Chinle/Morrison equivalent (According to Rawling)

Cretaceous Dakota Sandstone
Lookout Tower - Midtown

Country Club Drive at Bridge over Rio Ruidoso

Dakota Sandstone

Thickness - 300 ft

Regional aquifer
Gray, tan, to purple sandstones & siltstones, and produces best when fracture-enhanced, and close to faults.

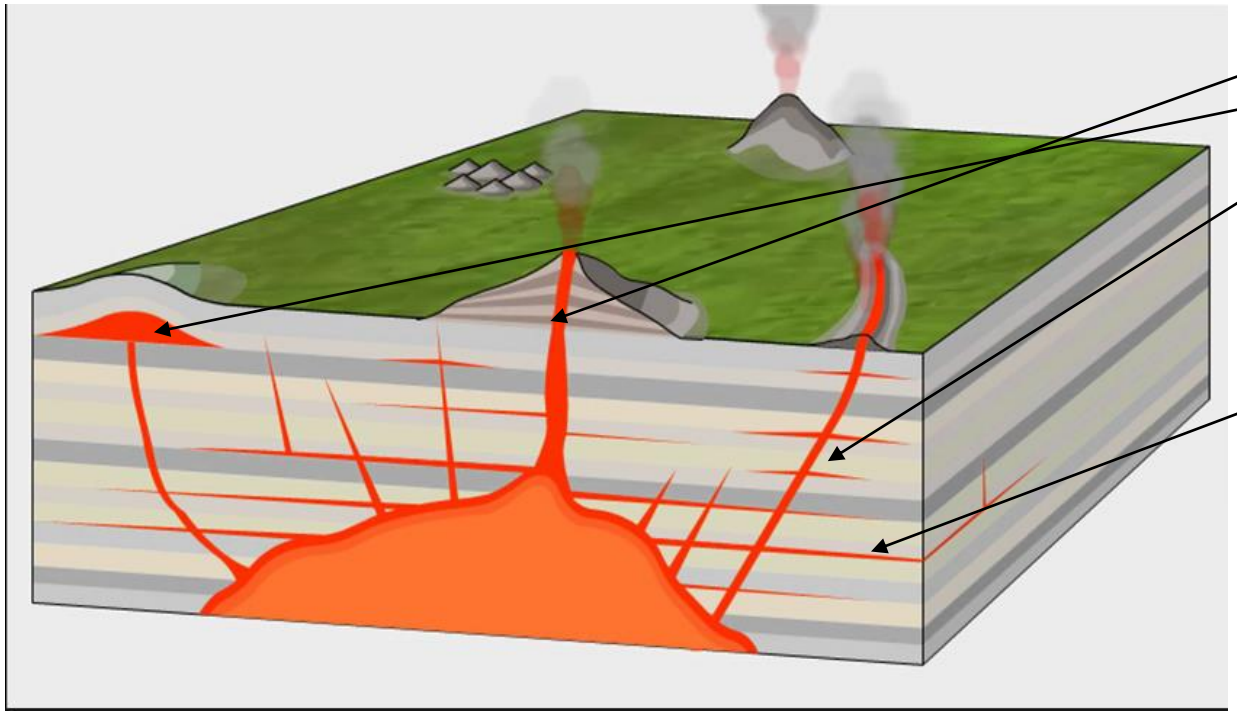
Mancos Shale – behind Skate Park in Ruidoso

Hwy 220 Ft Stanton Road
U. Cretaceous Mesaverde Fm.

Mesaverde Group
Thickness – 1500 ft – Alternating sandstones and shales. The shales are usually black (coaliferous) with plant fossils. Is a poor reservoir except where sandstones are faulted or fractured, but even then, proximity to Mancos Shale can cause problems.

Mesaverde Sandstones & Shales intruded by an igneous dyke, West of Capitan

Igneous Rocks – Volcanoes
Lava & Ash flows; intrusive dykes, sills, laccoliths



Stock – visible high on Baldy, Monjeau
Laccolith - (Capitan Mts.)
Dykes – numerous examples – these intrude previously deposited lavas or sedimentary rocks, exploiting pre-existing zones of weakness, and may be preferentially fractured
Sills – usually don't see them unless exposed by erosion

Mt. St. Helen's 1980 eruption

Swiss Chalet Hill – Many volcanics are explosion breccias & pyroclastic flows

Ski Run Road, Horseshoe Bend – Explosion Breccia cut by igneous dykes

Ski Run Road across from Eagle Creek turnoff – major dykes cut by later dykes

Red & maroon feldspar porphyry cut by later dyke

Hwy 70 – Ruidoso→Mescalero near Casino

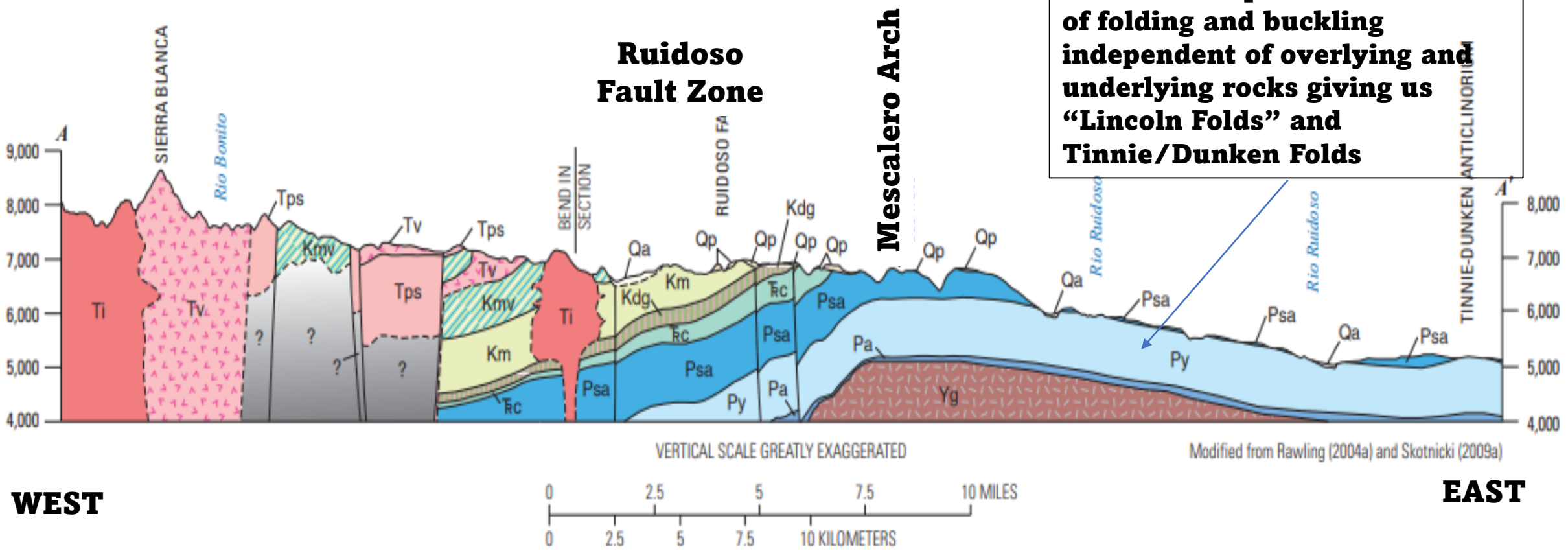
Shaping our mountains by intense erosion after last ice age

A Layer Cake with Issues

- Regional dip to the east
- Ruidoso Fault Zone
- Mescalero Arch (Anticline)
- Local dips to the west
- Variable hydrological properties (porosity & permeability)

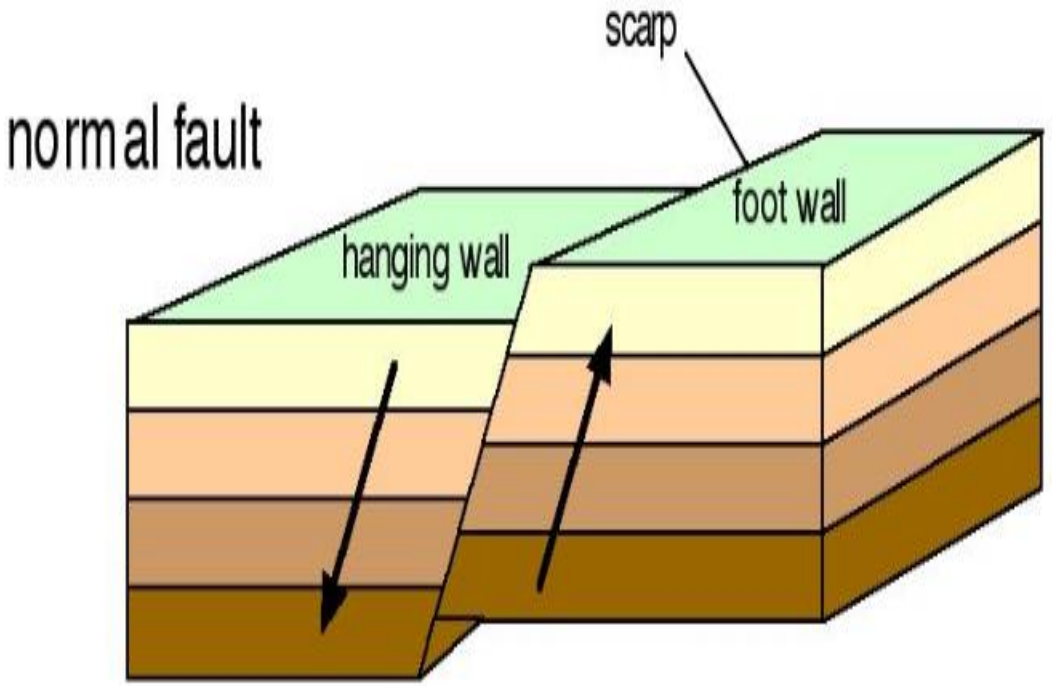
Cross section from West (Sierra Blanca Peak) to East (Tinnie)

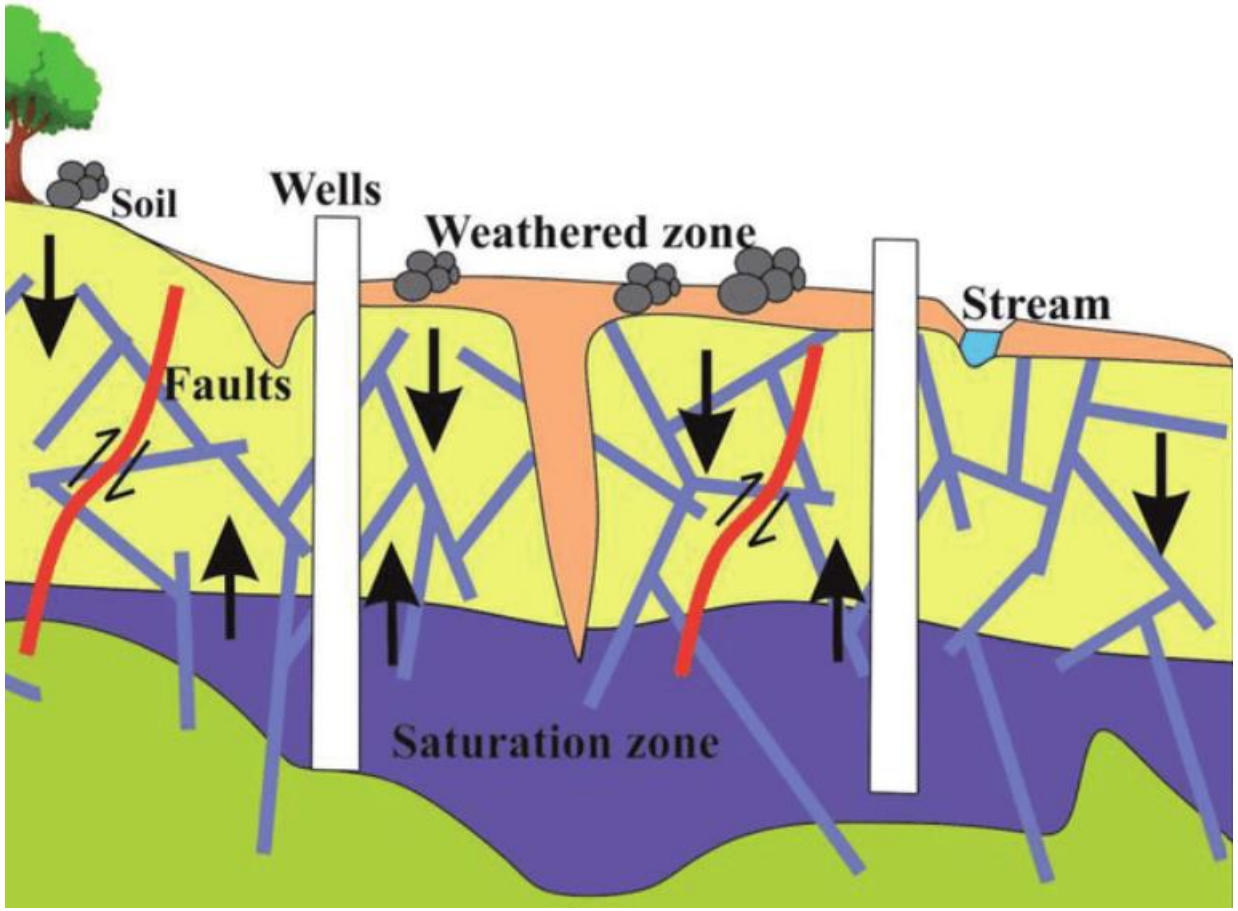
Yeso has the peculiar character of folding and buckling independent of overlying and underlying rocks giving us "Lincoln Folds" and Tinnie/Dunken Folds



WEST **EAST**

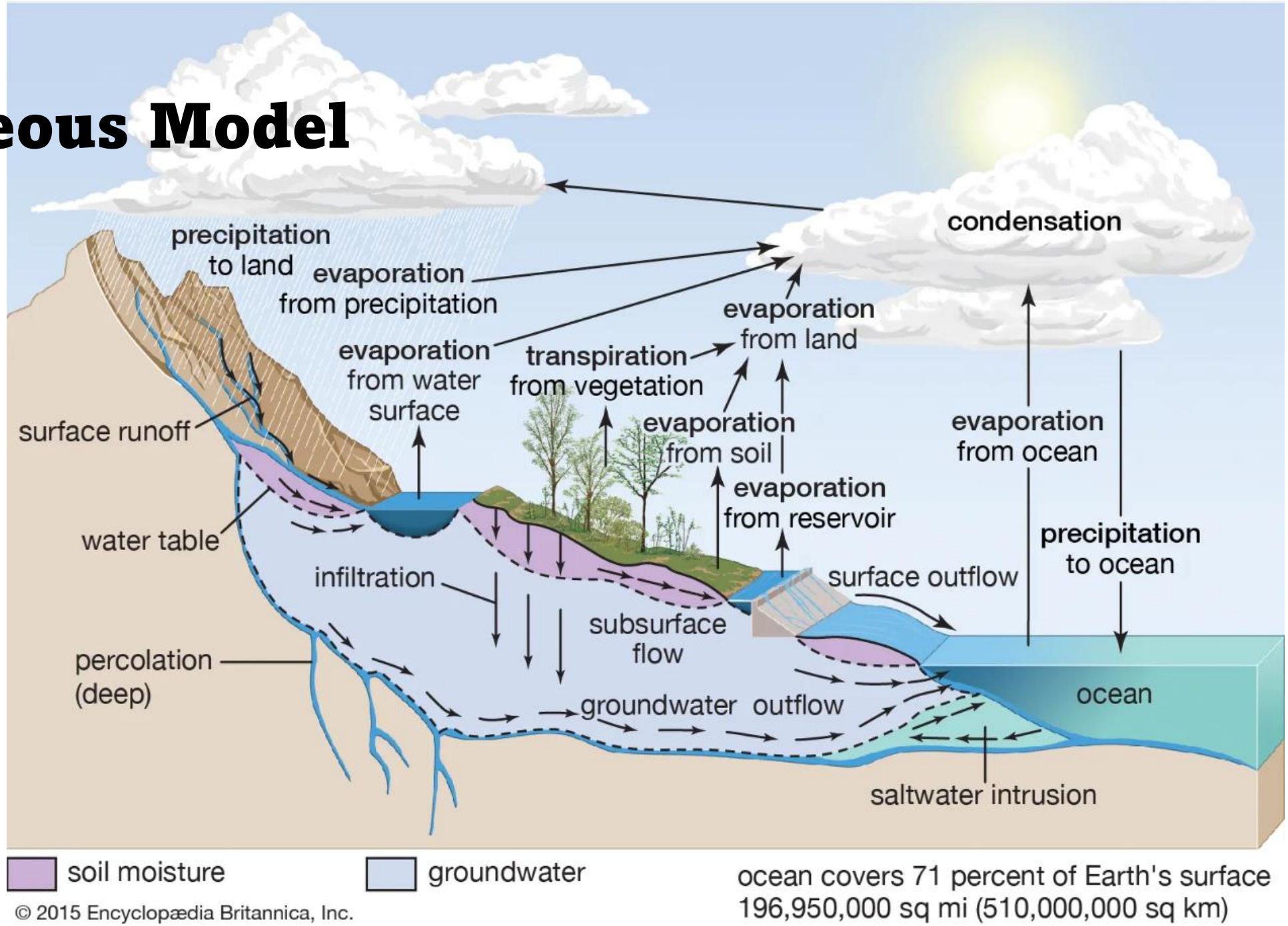
Faults & Fractures





Dissolution & Karsting

Homogeneous Model



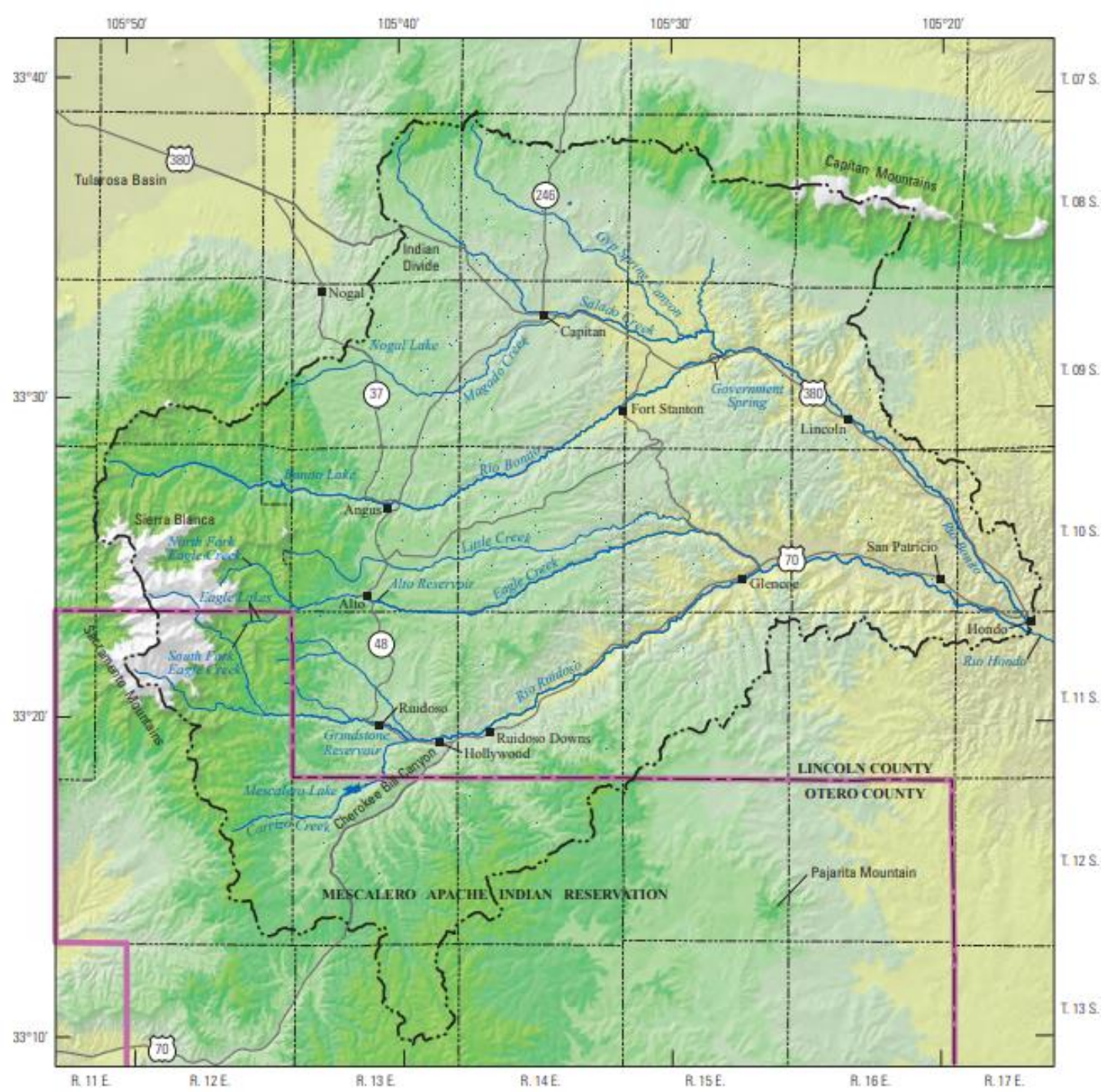
Let's talk about water....

Table 1. Distribution and sources of water on Earth.

Water source	Water volume (cubic miles)	Percentage of fresh water	Percentage of total water
Oceans	321,000,000	–	96.5000
Glaciers and permanent snow	5,773,000	68.700	1.7400
Groundwater	5,614,000	–	1.6900
Saline	3,088,000	–	0.9300
Fresh	2,526,000	30.100	0.7600
Ground ice and permafrost	71,970	0.860	0.0220
Lakes	42,320	–	0.0130
Fresh	21,830	0.260	0.0070
Saline	20,490	–	0.0060
Soil moisture	3,959	0.050	0.0010
Atmosphere	3,095	0.040	0.0010
Swamp water	2,752	0.030	0.0008
Rivers	509	0.006	0.0002
Biological water (plants and animals)	269	0.003	0.0001

Adapted from Shiklomanov (1993).

All other things being equal, groundwater storage represents 4-5 orders of magnitude more volume than rivers/streams.



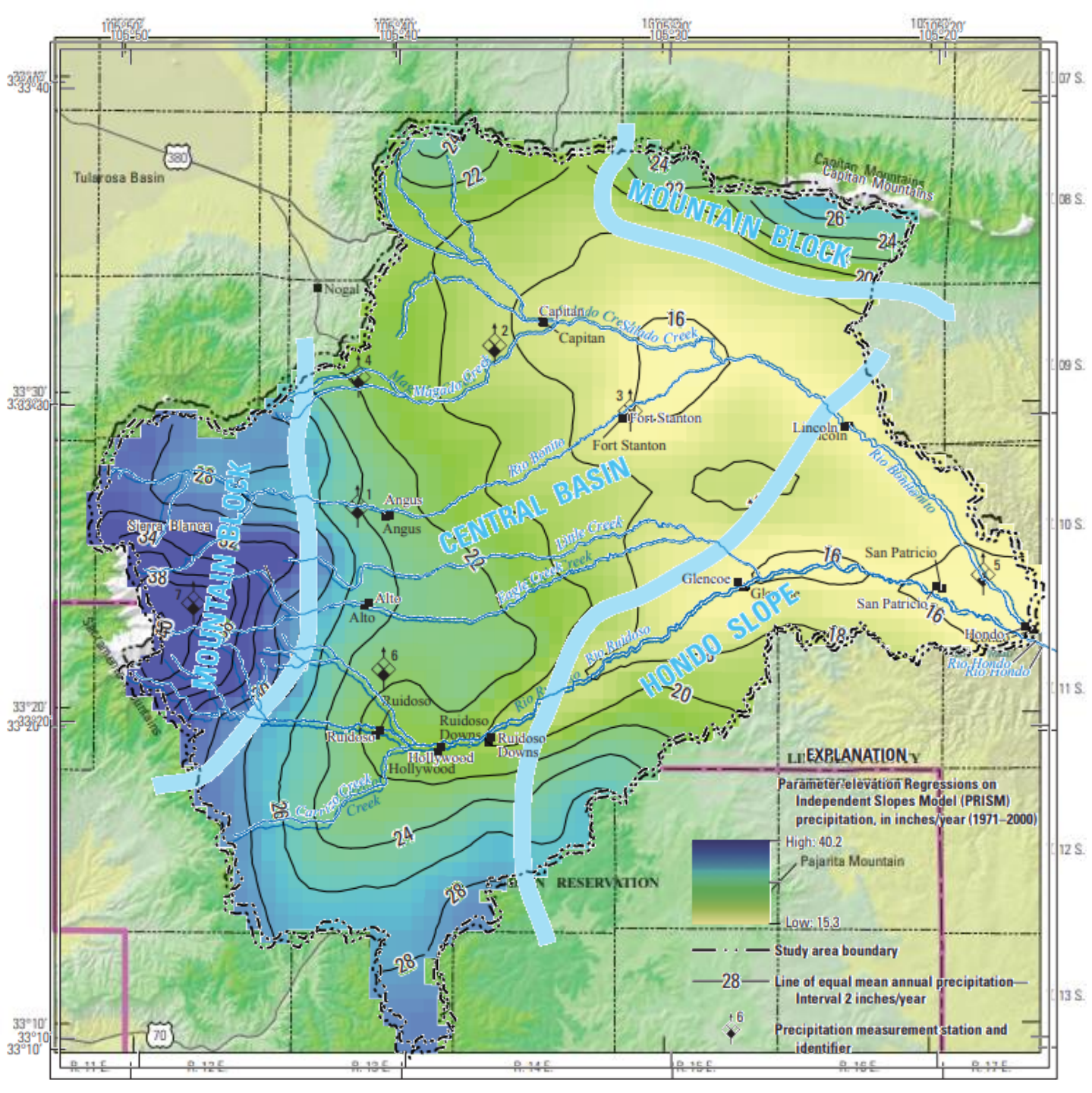
UPPER RIO HONDO BASIN

- **Where does the water come from?**
  - **Rain**
- **Where does the water go?**
  - **Evaporation & Transpiration**
  - **Stream flow**
  - **Aquifers (groundwater), including underflow**
  - **Human use**

The answers to these questions varies depending on where you are:

Three areas are defined by geology, aquifer characteristics and hydrologic behavior:

1. **Mountain Block**
2. **Central Basin**
3. **Hondo Slope**



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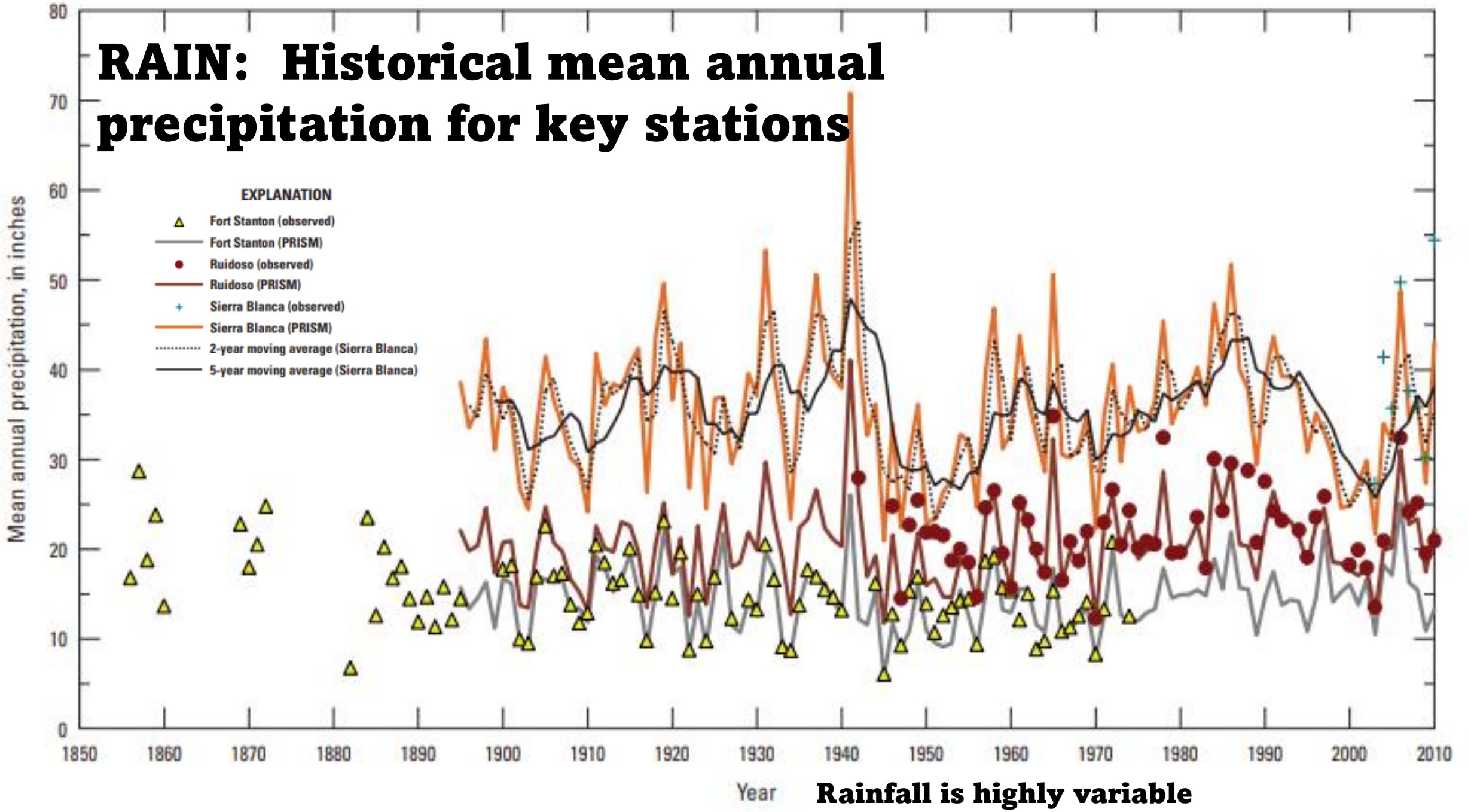
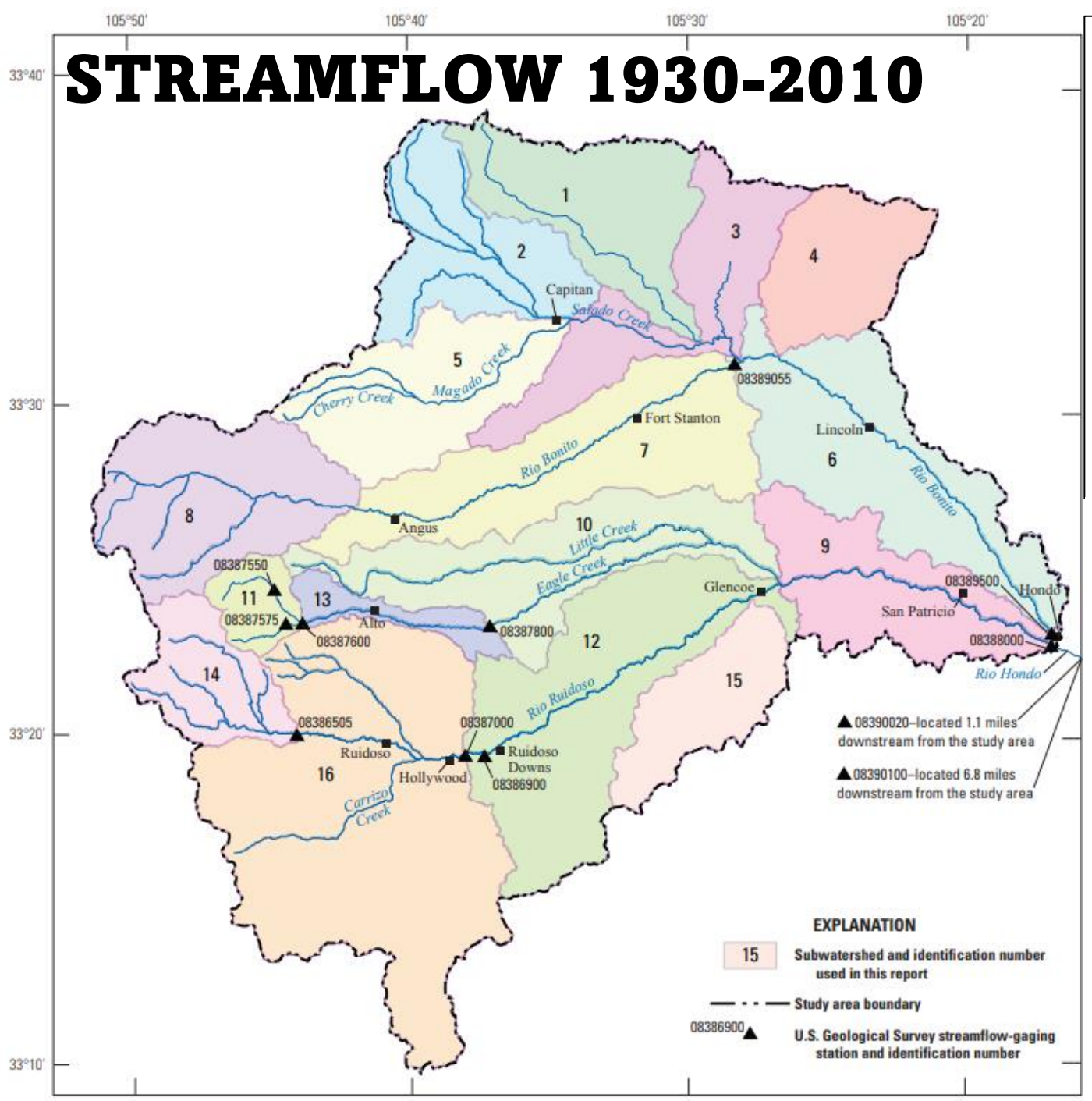
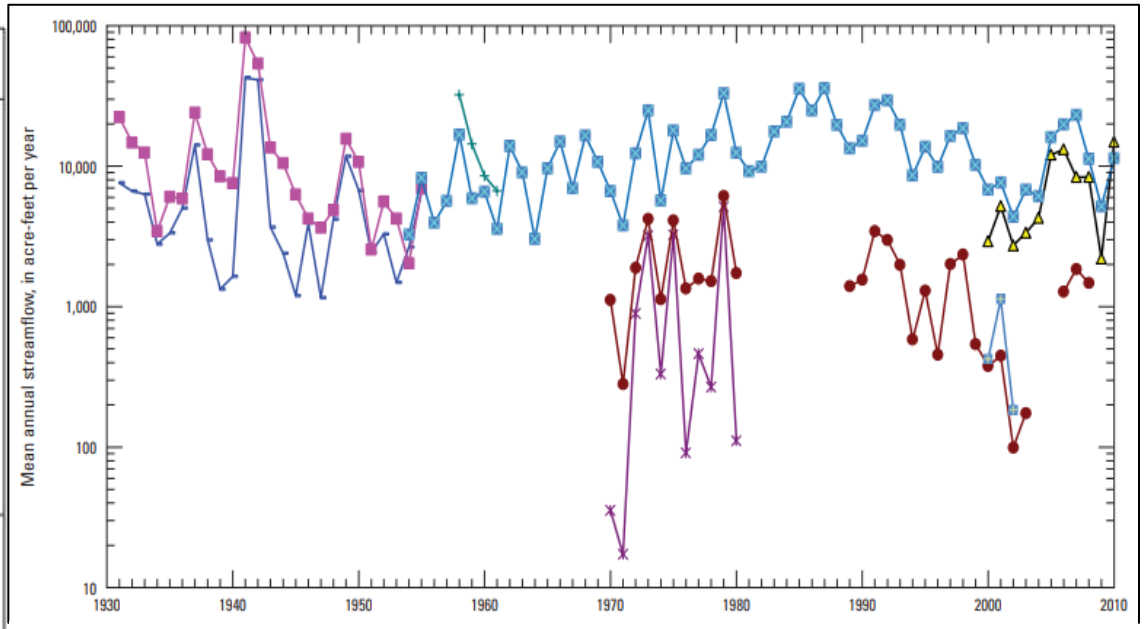
RAIN: Historical mean annual precipitation for key stations



Rainfall is highly variable

STREAMFLOW 1930-2010



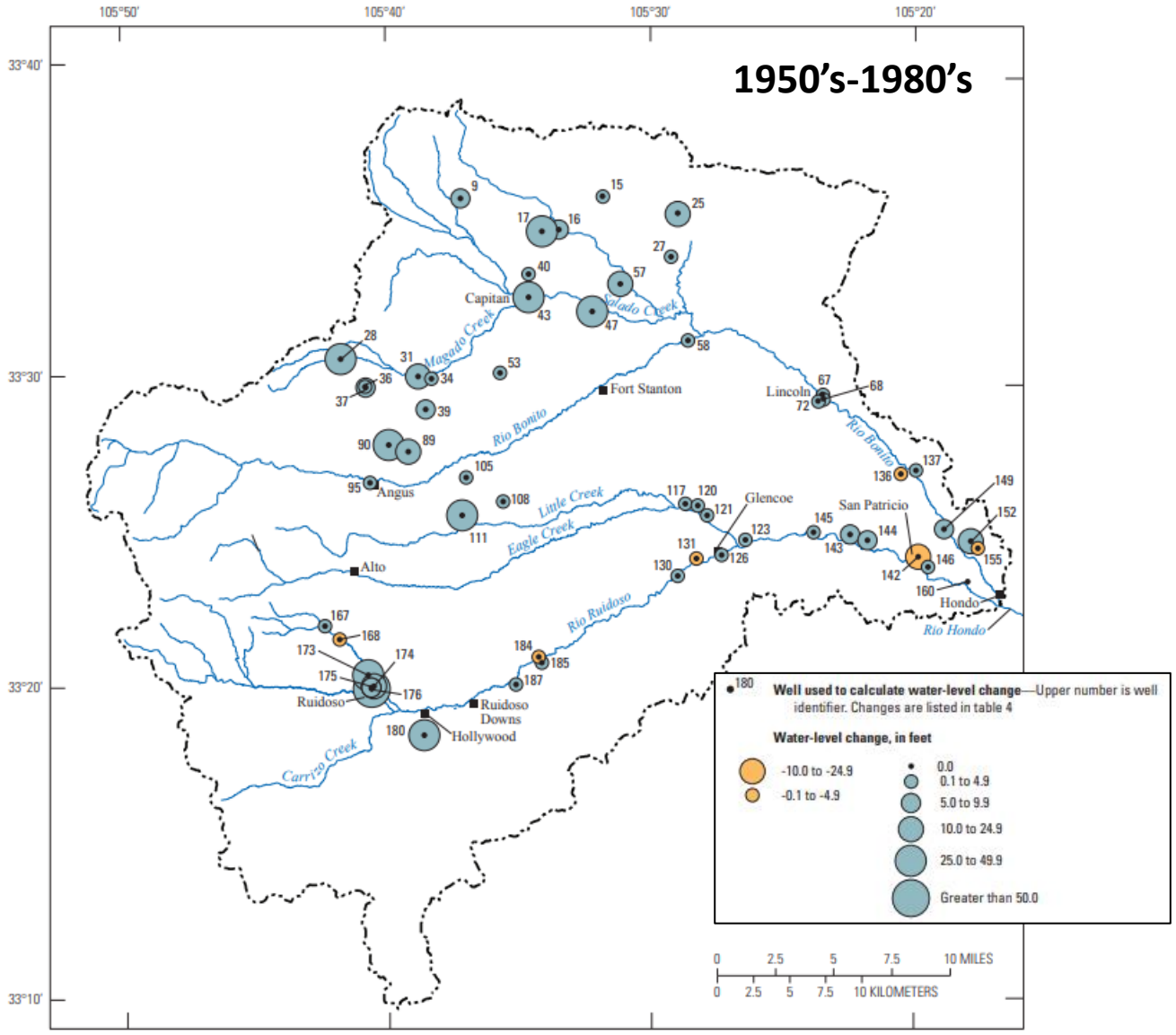


EXPLANATION

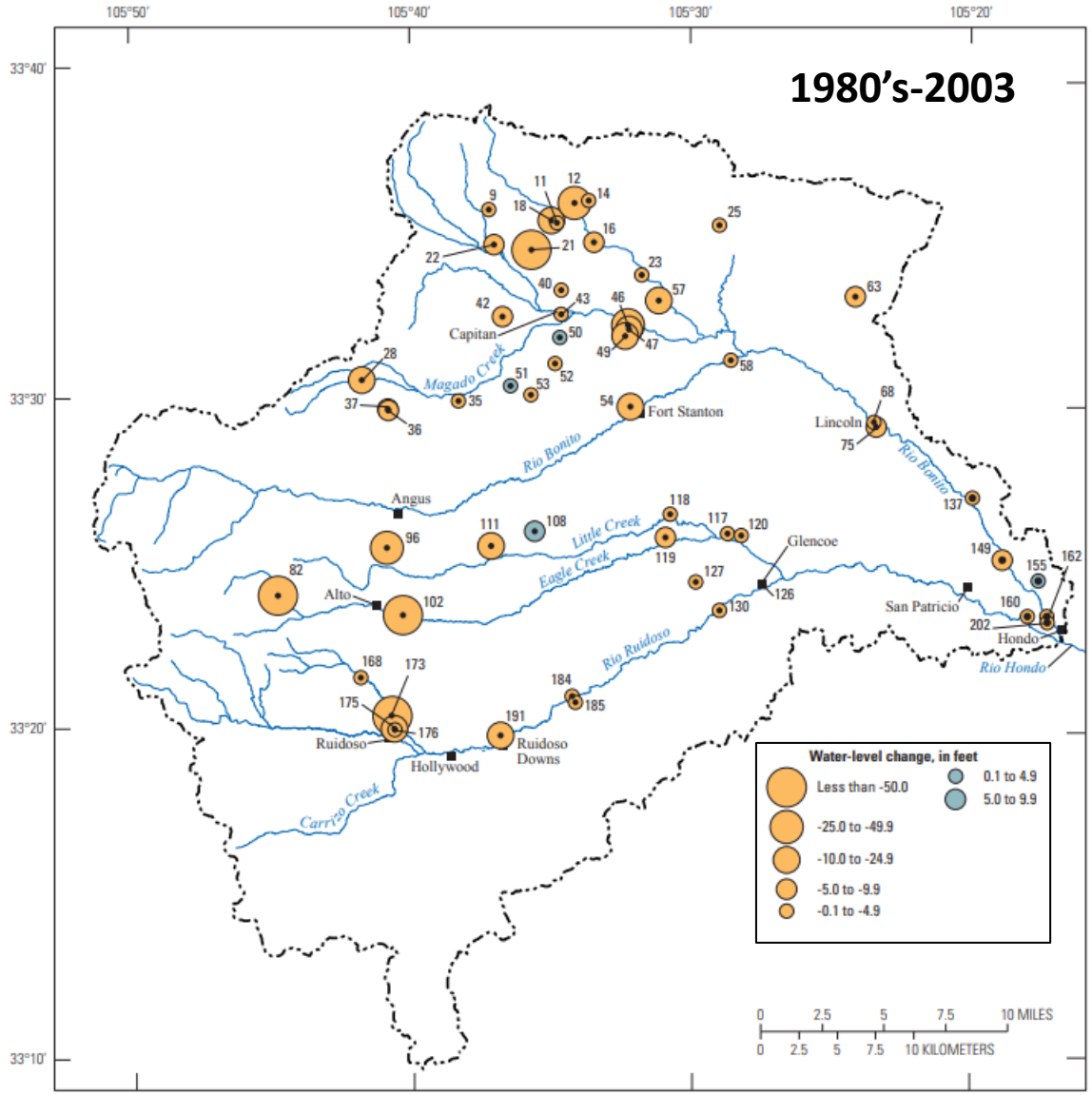
U.S. Geological Survey streamflow-gaging station number and name

- 08389500–Rio Bonito at Hondo
- 08388000–Rio Ruidoso at Hondo
- 08386505–Rio Ruidoso at Ruidoso
- 08387000–Rio Ruidoso at Hollywood
- 08387800–Eagle Creek near Alto
- 08387600–Eagle Creek below South Fork near Alto
- 08390100–Rio Hondo at Picacho
- 08389055–Rio Bonito near Lincoln

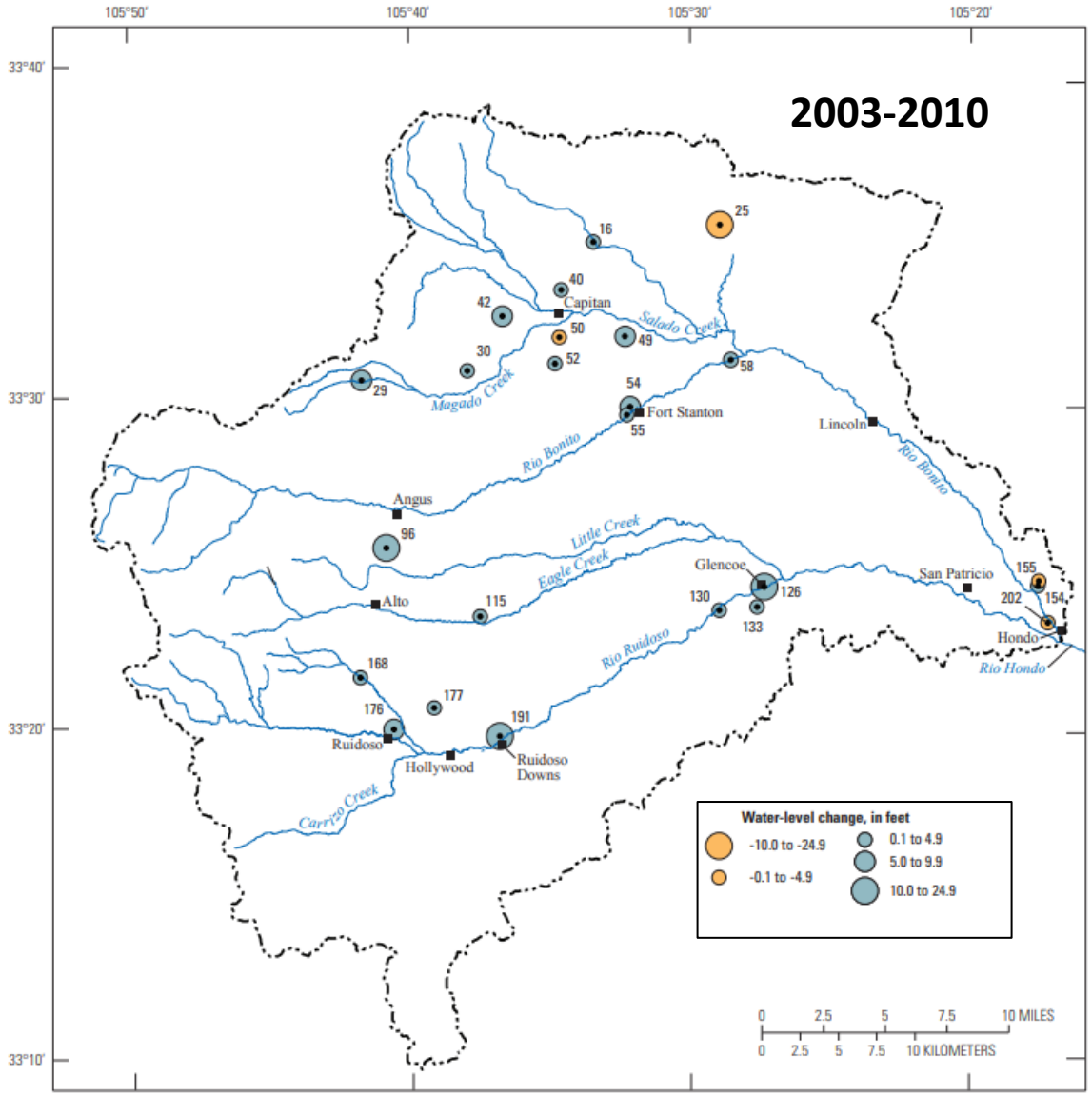
Generalized Long-Term Water Table Elevations Using Selected Wells



Generalized Long-Term Water Table Elevations Using Selected Wells



Generalized Long-Term Water Table Elevations Using Selected Wells



Human Use – Municipalities, private wells, major diversions & depletions

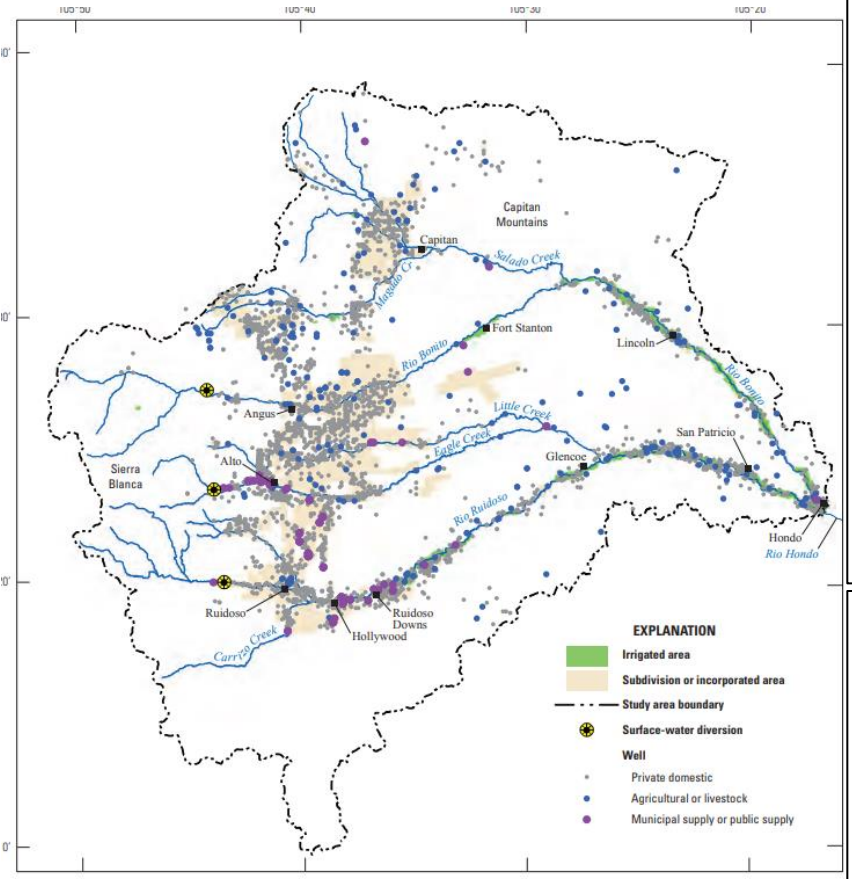


Table 5. Estimated 2005 water diversions and depletions from the upper Rio Hondo Basin study area, Lincoln County, New Mexico.

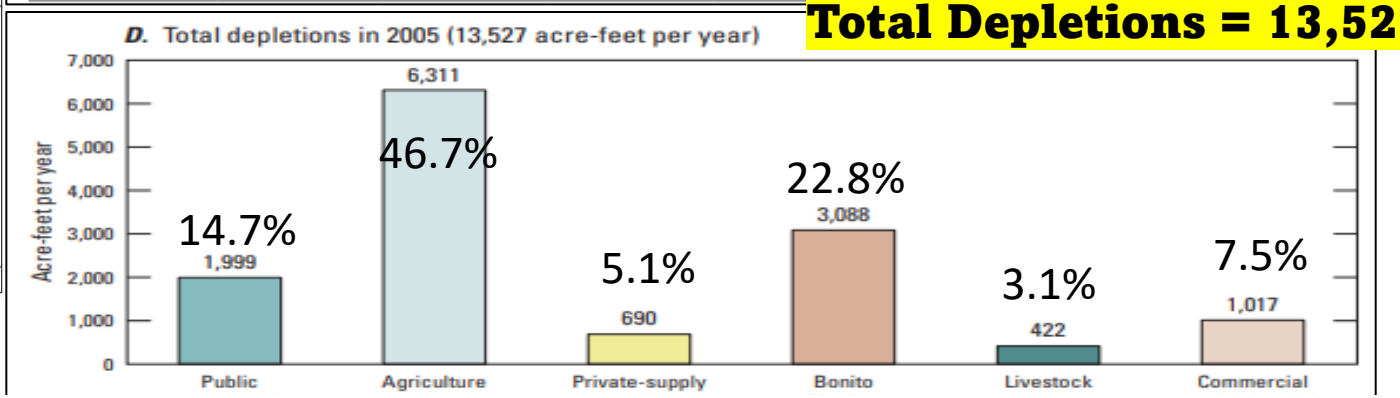
[All values in acre-ft/yr, acre-feet per year]

	2005 diversions (acre-ft/yr)								
Source	Public water supply (domestic) systems[1]	Agriculture[2]	Private supply wells[3]	Bonito Pipeline[4]	Livestock[5]	Commercial and industrial[5]	Subtotal of domestic, commercial and industrial, and pipeline	Subtotal of agriculture and livestock	Total diversions
Groundwater	1,614	3,353	920	0	228	1,605	4,139	3,581	7,720
Surface water	2,383	11,028	0	3,088	194	0	5,471	11,222	16,693
Total	3,997	14,381	920	3,088	422	1,605	9,610	14,803	24,413

Total Diversions = 24,413 ac-ft/yr

	2005 depletions (acre-ft/yr)								
Source	Public water supply (domestic) systems[6]	Agriculture[7]	Private supply wells[8]	Bonito Pipeline[4]	Livestock[8]	Commercial and industrial[9]	Subtotal of domestic, commercial and industrial, and pipeline	Subtotal of agriculture and livestock	Total depletions
Groundwater	807	1,911	690	0	228	803	2,514	2,139	4,653
Surface water	1,192	4,400	0	3,088	194	214	4,280	4,594	8,874
Total	1,999	6,311	690	3,088	422	1,017	6,794	6,733	13,527

Total Depletions = 13,527 ac-ft/yr



Assume 20,000 year-round population in study area & include municipal, private wells, & commercial/industrial, this works out to 170 gallons/day but if population is tripled to 60K, this is about 56 gall/person/day.

Watershed Yield: Available water AFTER Evapotranspiration is subtracted from total Precipitation (note that only 6 of 16 sub-watersheds have positive RPLE's)

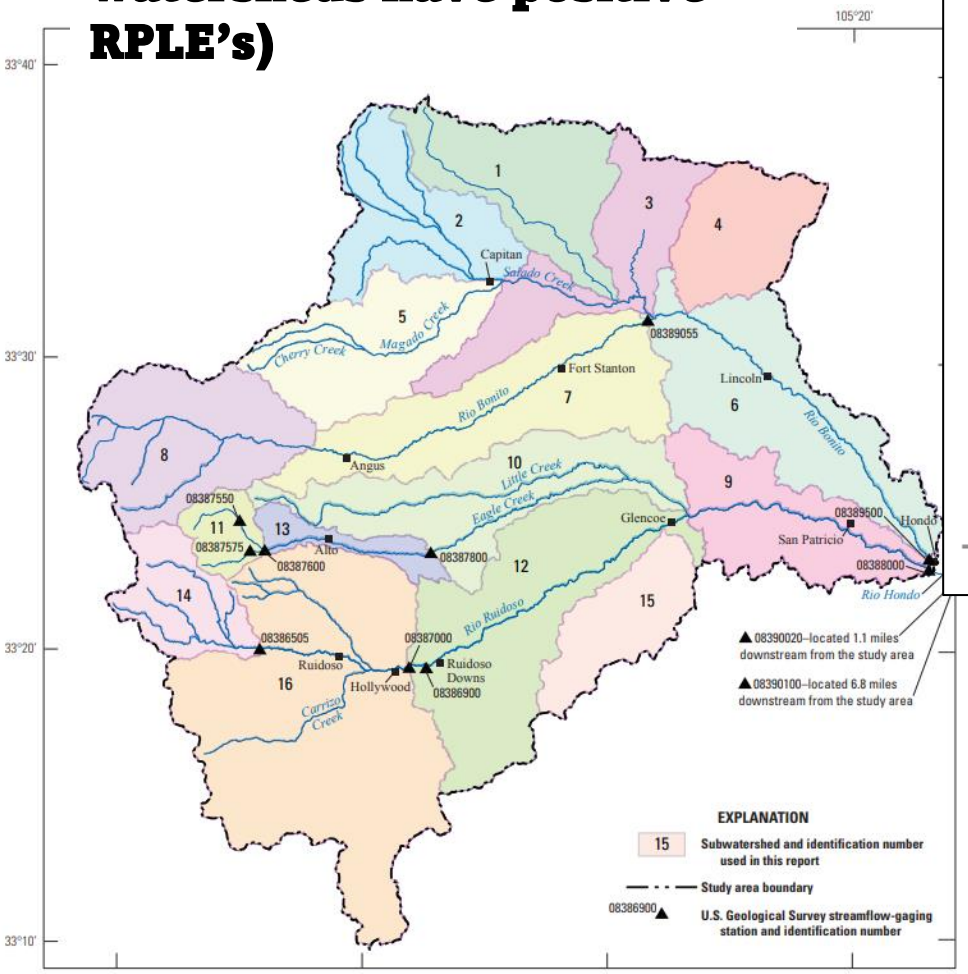


Table 8. Watershed-yield estimates from residual of precipitation less evaporation (RPLE) for the upper Rio Hondo Basin study area, Lincoln County, New Mexico.

[Source for precipitation data is PRISM (1971–2000); acre-ft/yr, acre-feet per year; –, method does not apply because mean annual precipitation is 18.1 inches or less]

Subwatershed number	Subwatershed name	A Area (square miles)	Mean annual precipitation (inches)	P Total precipitation (acre-ft/yr)	Mean annual evapo-transpiration (inches)[1]	ET Total evapo-transpiration (acre-ft/yr)[1]	RPLE precipitation less evapo-transpiration (acre-ft/yr)
1	Gyp Spring Canyon	33.4	16.8	29,934	16.8	29,934	–
2	Upper Salado Creek	31.0	17.3	28,550	17.3	28,550	–
3	Peppin and Padilla Canyons	32.4	15.9	27,505	15.9	27,505	–
4	East Salazar	23.1	17.9	22,013	17.9	22,013	–
5	Magado Creek	34.9	18.6	34,577	18.2	33,945	632
6	Lower Rio Bonito	50.4	14.4	38,614	14.4	38,614	–
7	Middle Rio Bonito	50.2	16.7	44,719	16.7	44,719	–
8	Upper Rio Bonito	40.4	26.5	57,159	20.5	44,093	13,067
9	Lower Rio Ruidoso	32.4	14.3	24,796	14.3	24,796	–
10	Lower Eagle Creek	42.1	18.1	40,673	18.1	40,673	–
11	Upper Eagle Creek	8.1	29.2	12,630	21.3	9,183	3,447
12	Middle Rio Ruidoso	58.0	17.9	55,524	17.9	55,524	–
13	Middle Eagle Creek	8.0	22.1	9,373	19.2	8,160	1,213
14	Upper Rio Ruidoso	18.3	29.7	28,923	21.4	20,804	8,119
15	Waterhole Canyon	20.6	17.7	19,508	17.7	19,508	–
16	Carrizo Creek	101.9	22.2	120,421	19.2	104,588	15,832
Total		585.3		594,918		552,608	42,310

[1]Evapotranspiration calculated by using the MacDonald and Stednick (2003) method.

Watershed yield estimates

RPLE = (P-ET) * A * 53.33 = 42,310 acre-ft/year

ET = P- (18.11 + 0.28(P-18.11))

Table 11. Regional water-budget components for the upper Rio Hondo Basin study area,

[All values rounded to hundreds of acre-feet per year (acre-ft/yr); –, no data]

Inputs (acre-ft/yr)	Total annual precipitation	Total annual evapotrans-piration	Watershed yield from precipitation less evapotrans-piration (table 8)
Watershed yield	594,900	552,600	42,300
Total inputs (range): 38,200–42,300			
Recharge (range): 10,200–13,400			
Outputs (acre-ft/yr)	**Diversions for all water uses**	**Returns from all water uses**	**Net depletion from all water uses**
Diversions and depletions	24,400	10,900	13,500
Surface-water output	–	–	–
Deep groundwater output	–	–	–
Total outputs (range): 37,000–40,400			

Residual (acre-ft/yr)	Low	High
Range in sum of input and output terms	-2,200	+5,300

1 acre-foot = 325,851.42857 gallons

Total Annual Rainfall
594,900 ac-ft = 2 x 10^{11} gallons

Total Annual Evapotranspiration
93% of total rainfall

Net depletion from ALL WATER USES
32% of Watershed Yield
13,527 ac-ft = 4.4 billion gallons

Municipal Water & Private Wells & Commercial/Industrial are
27.3% of all Net Depletion
3,693 ac-ft = 1.2 billion gallons

If there are 20,000 people living in URHB, this works out to 170 gall/person/day which is not realistic. Tripling full-time population calculates to 56 gall/person/day: Tourism results in significantly more water use!

Summary

- The study I'm summarizing only uses data through 2010! Updates should be done.
- Rio Hondo Basin – 585 mi2
- Major topographical changes: 12,003 ft (Baldy) to 5,185 ft at confluence of Rio Bonito & Rio Hondo
- Highly variable precipitation temporally & spatially
- Complex geologic history has resulted in numerous aquifers with complex flow & damming properties
- Complex faulting/fracturing has enhanced ability of recharging aquifers rapidly
- Storage capacity of the aquifers (rock units) is highly variable and probably underestimated by most studies
- Our county has thrived but could be compromised by a lack of thoughtful planning – we must understand the bounty & the limitations
- We must take care to preserve the qualities of the land, especially the water resource!
  - Use cisterns – catchments to store rainwater for household or garden use, Rainwater Roof Calculator: How Much Can You Collect? (harvestingaqua.com)
  - Educate & Inform
  - Every person and business should monitor water use!! How much water do you use/day??

A GOOD LOOK FOR MONJEAU & BALDY