

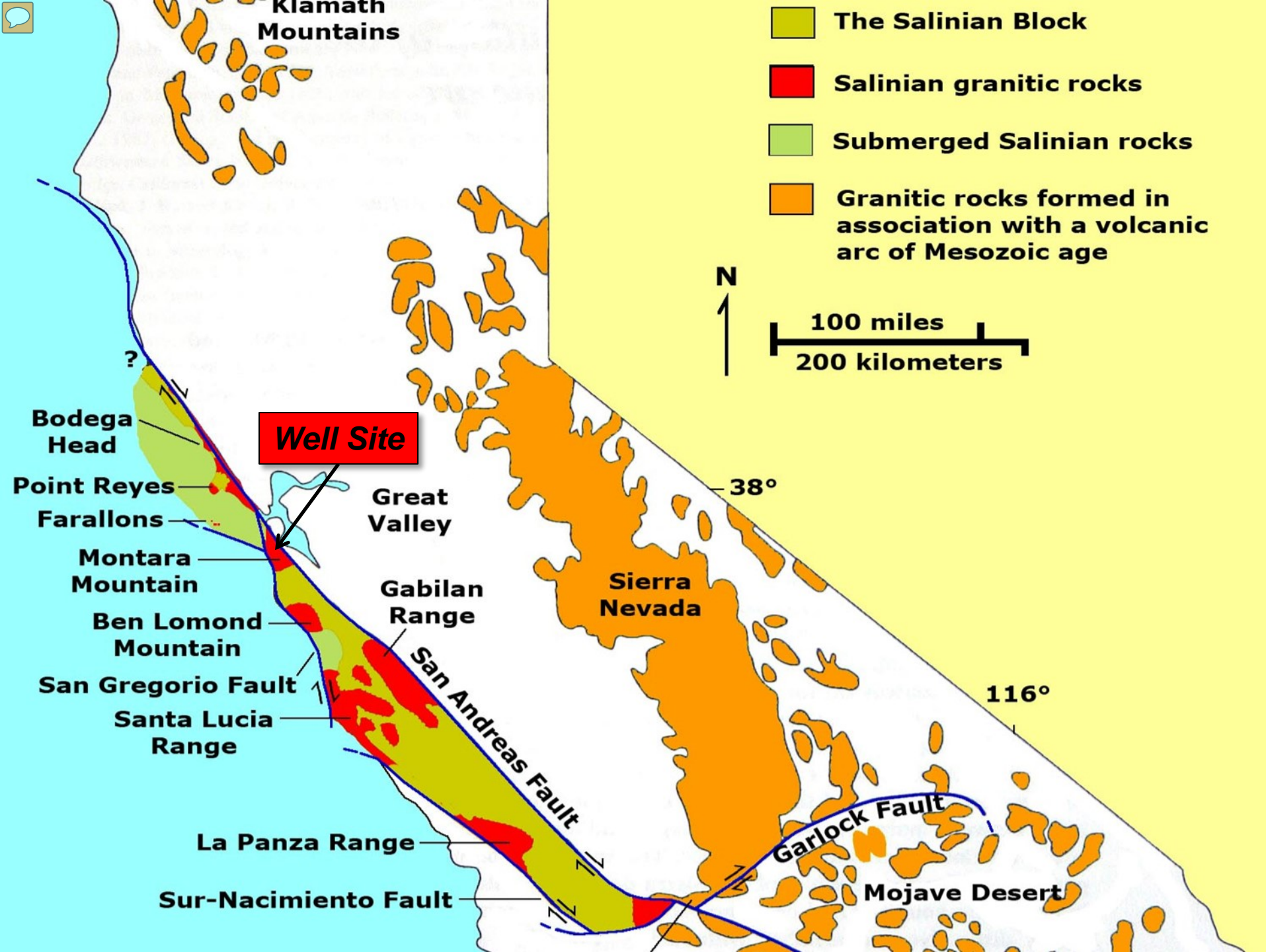


**Assessing natural recharge and managing  
withdrawals from a fractured granitic  
aquifer in coastal California during a  
multi-year drought to wet-year cycle.**

## **Balancing Pumping with Recharge**

Mark Woyshner, Clemens Heldmaier,  
Gustavo Porras and Barry Hecht







A scenic landscape photograph showing a coastal area. In the foreground, there are rolling green hills with some utility poles. In the middle ground, a coastal town is visible, followed by a sandy beach and the ocean. The sky is clear and blue.

# GRA 2013 Posters

Deep weathering promotes recharge,  
provides storage, and sustains baseflows.

**Deeply weathered granitics: Resilient storage for a changing climate.**

*Hecht, Woyshner, Brown, Donaldson, Richmond, Owens*

**Planning for increased climate extremes and strategies for managing groundwater withdraws from high-yielding bedrock wells in Coastal California.**

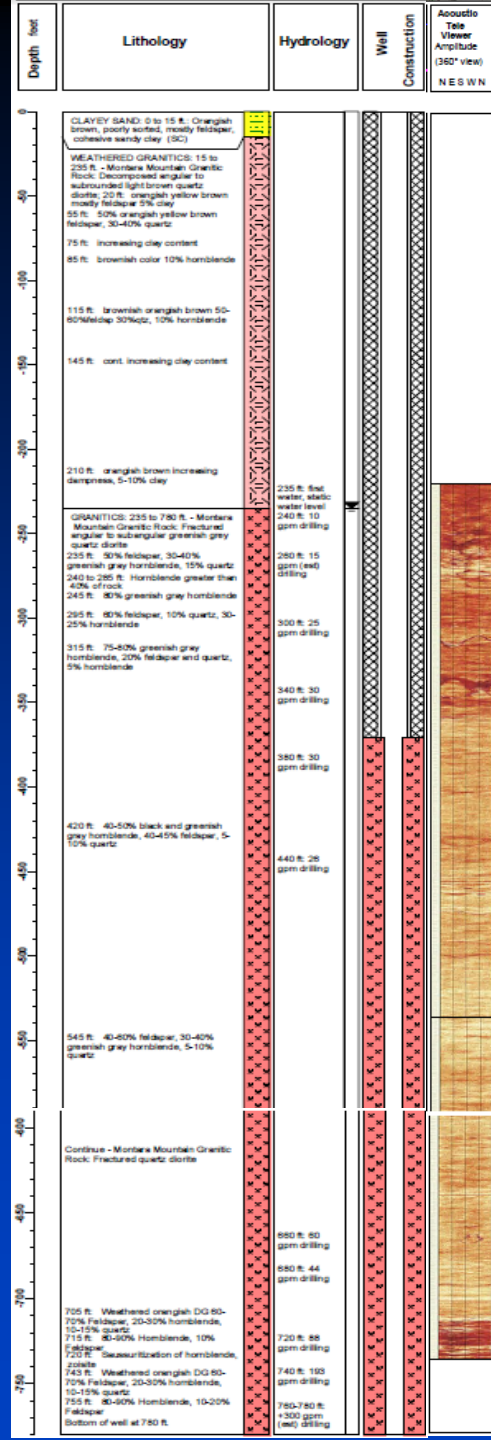
*Woyshner, Heldmaier, Porras and Hecht*





# Well Characteristics

- Completed July 2004 to a depth 780 feet below ground-surface elevation of 530 feet
- Draws groundwater primarily from deep, regional joints below a depth of 700 feet bgs in unweathered granitic rock of the Montara batholith.
- Weathered granitic rock was found to a depth of 235 ft. bgs, with primarily unweathered, fractured granitic rock below this depth.
- The well was completed in a manner that isolates the deep ground water source from shallow sources.



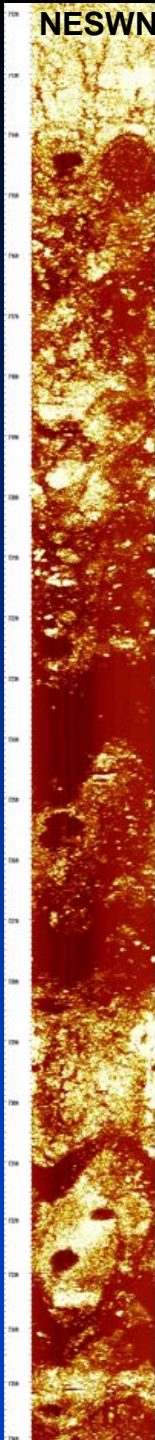
0 ft

235 ft

370 ft

724 ft

780 ft



715 ft

720 ft

725 ft

730 ft

735 ft

Acoustic Televiewer  
(360° view)

2 ft open joint  
dip 58 deg N087E

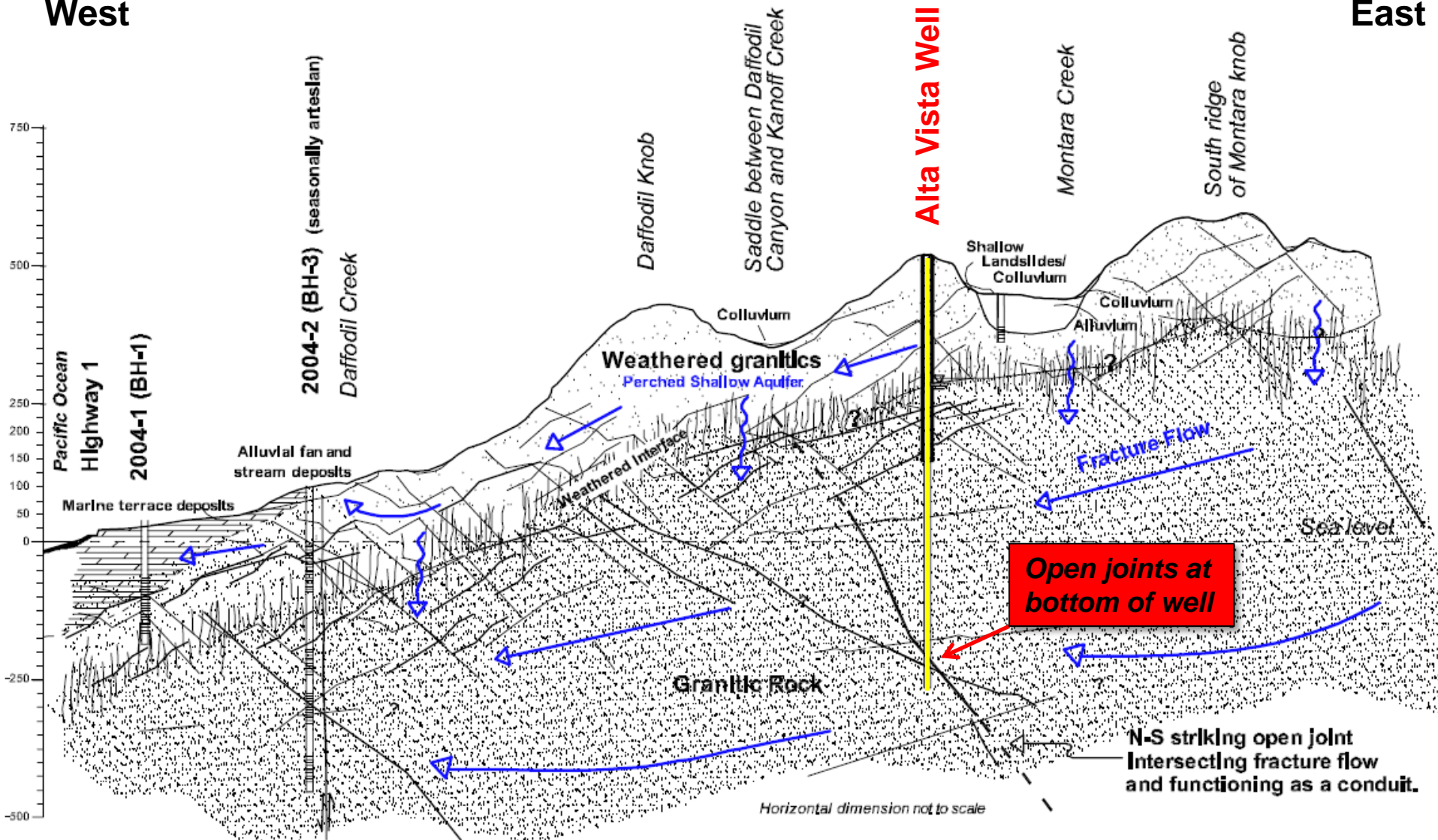
1 ft open joint  
dip 40 deg N111E

Air-rotary hammer drilling  
after intersecting open joints



West

East







# Pumping Tests

- Following well completion, an 8-hour test at 300 gpm.
- Then a 5-day yield test at 300 gpm
- Prior to source-water use, 60-day yield test at 40 gpm (from November 10, 2007 to January 10, 2008)
- Results showed drawdown in fractured bedrock aquifer but no discernible drawdown in the overlying weathered granitic aquifer and alluvial aquifers, and no effect on streamflow.



# What pumping rate is sustainable?

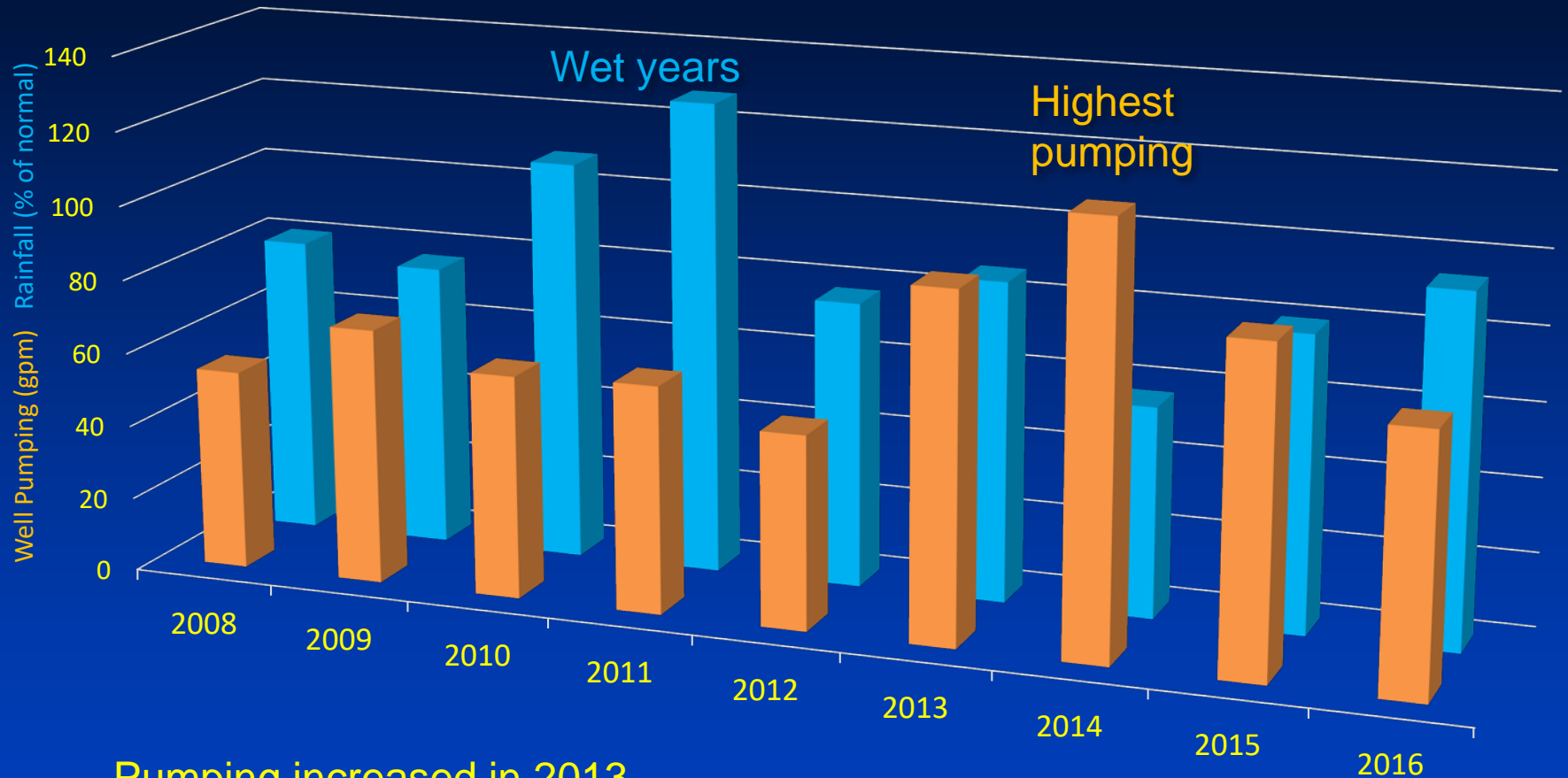
**We estimate 60 to 70 gpm based on monitoring across a cycle of major recharge years and drought years.**

Prior to drilling this bedrock well, coastal terraces and alluvial valleys were the principal sources of water.



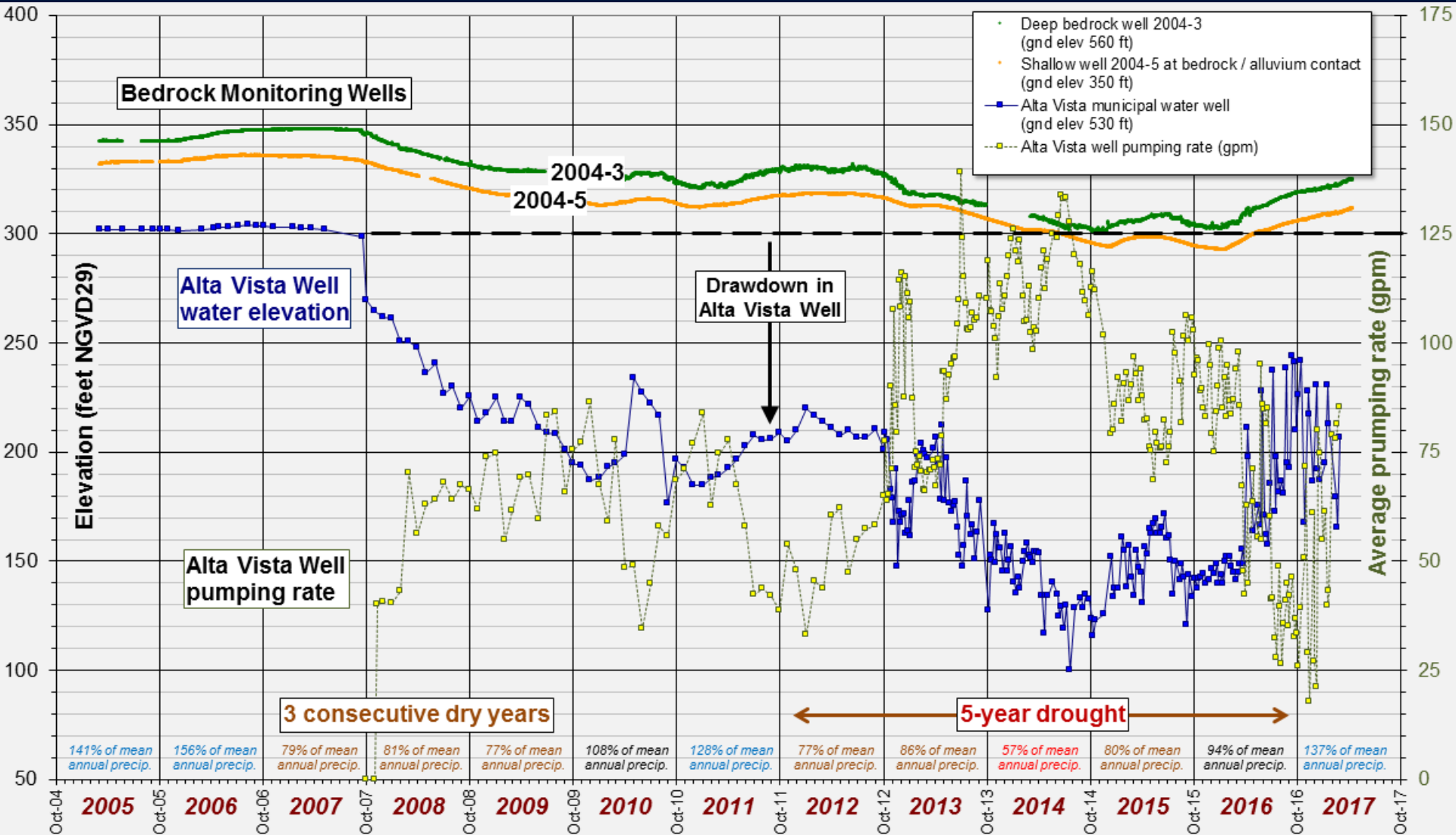


# Rainfall and Well Pumping



Pumping increased in 2013, was highest during severe dry year 2014, then returned to earlier levels in 2016 corresponding with near normal rainfall.

# Groundwater Elevations in Bedrock



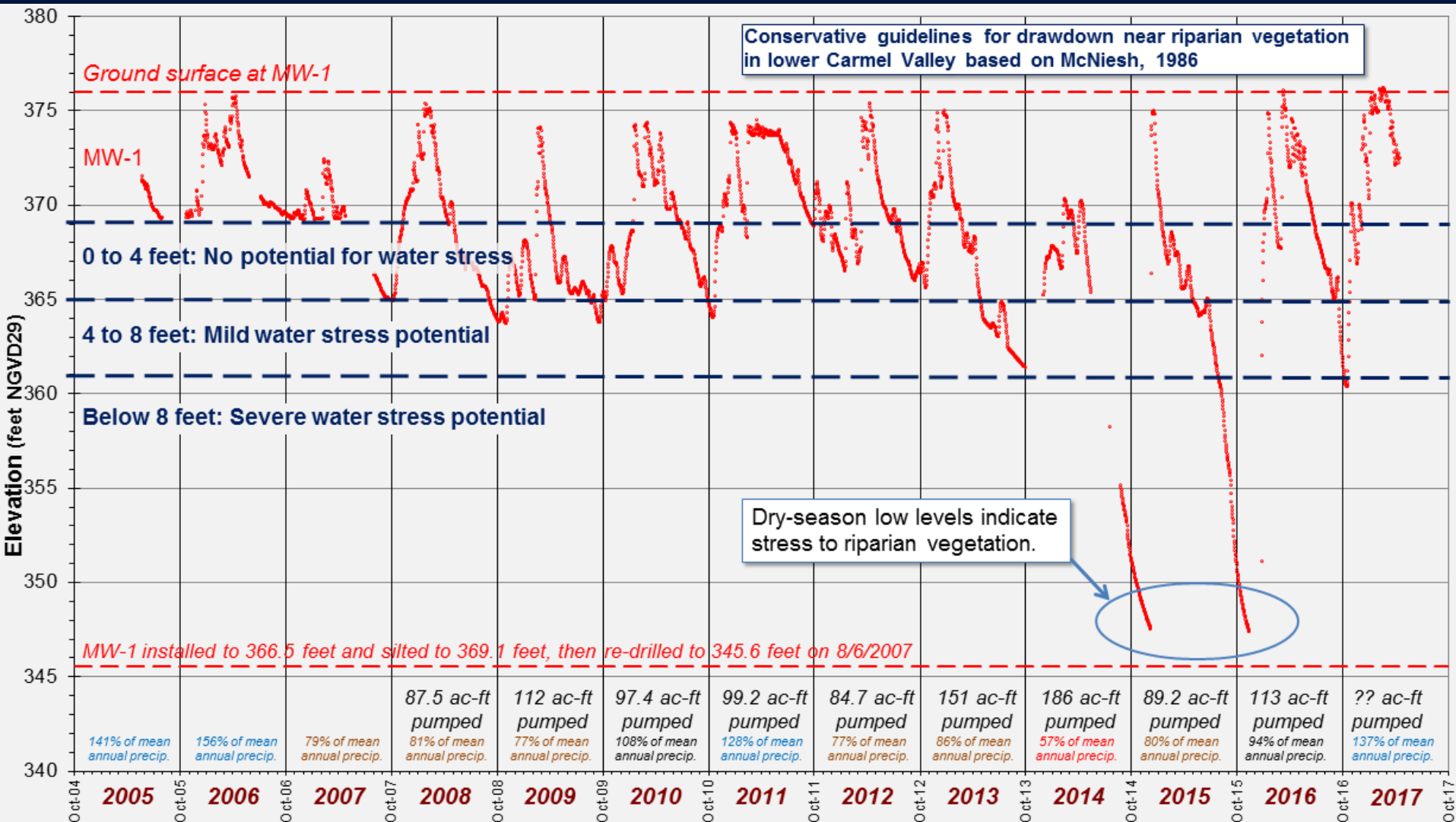




# Rainfall and Streamflow

Water Year	Rainfall (inches)	Rainfall (% of mean)	Martini Cr (no diversions) (ac-ft)	Daffodil Cyn (no diversions) (ac-ft)	Montara Cr (diversion upstream) (ac-ft)
2005	43.86	141%	678	--	--
2006	48.45	156%	1116	--	--
2007	24.45	79%	411	--	--
2008	24.99	80%	361	--	--
2009	23.75	76%	partial	15	1
2010	33.61	108%	408	37	138
2011	39.56	127%	partial	127	325
2012	23.96	77%	partial	27	71
2013	26.80	86%	356	50	40
2014	17.63	57%	226	30	0
2015	24.71	80%	213	27	23
2016	29.21	94%	410	57	151
2017	42.46	137%	na	na	na
Mean	31.07	--	488	46	93

# Shallow Groundwater near North Fork Montara Creek







# Groundwater Age Techniques

- **Modern water** (recharged over recent years and decades)
  - Tritium-helium
  - Chlorofluorocarbons (CFCs)
- **Pre-modern water** (hundreds to thousands of years old)
  - Radiogenic helium
  - Carbon-14
- **Paleoclimate indicators**
  - Stable isotopes of oxygen and hydrogen
  - Noble gases (recharge temperature)

# Groundwater Age Results

Sample Date	Modern water		Pre-modern water	
	Average Recharge year	Method	Result	Method
3/28/2011	na	Tritium	absent	Carbon-14, Radiogenic helium
10/30/2014	1991	Tritium	absent	Radiogenic helium
10/27/2015	1969	CFC	present	Carbon-14
10/20/2016	1989	CFC	absent	Carbon-14

Paleoclimate indicators were similar to modern times.





# Qualitative Check

- Since 2007, the Alta Vista well has been pumped at an average (continuous) rate of 74 gpm, similar to local stream baseflows.
- Assuming a conservative estimate of an average of 4 inches/year recharge, approximately 360 acres ( $\sim 1/2$  square mile) of open-space land on Montara Mountain can sustain this pattern of pumping observed since 2007.

# Conclusions

- A strategy of monitoring hydrologic characteristics across a cycle major recharge years and of drought years was successful to evaluate a sustainable pumping rate at a high-yielding bedrock well. We monitored:
  - Streamflow;
  - Shallow groundwater levels near riparian vegetation, and applied conservative drawdown guidelines from Carmel Valley;
  - Bedrock groundwater elevations; and
  - Groundwater age.
- When monitoring indicated a recharge limit, pumping was modified.
- We believe this is a successful habitat-responsible adaptive-management approach to managing a complex fractured bedrock aquifer.



A wide-angle landscape photograph showing rolling hills in the foreground and middle ground, covered in dense green vegetation. In the distance, a coastal town is visible, followed by a sandy beach and the ocean under a clear blue sky. The text "Thank you!" is overlaid in the center in a bold, yellow font.

Thank you!