Using Cross-Sectional models to Develop Measurable Objectives for Seawater Intrusion

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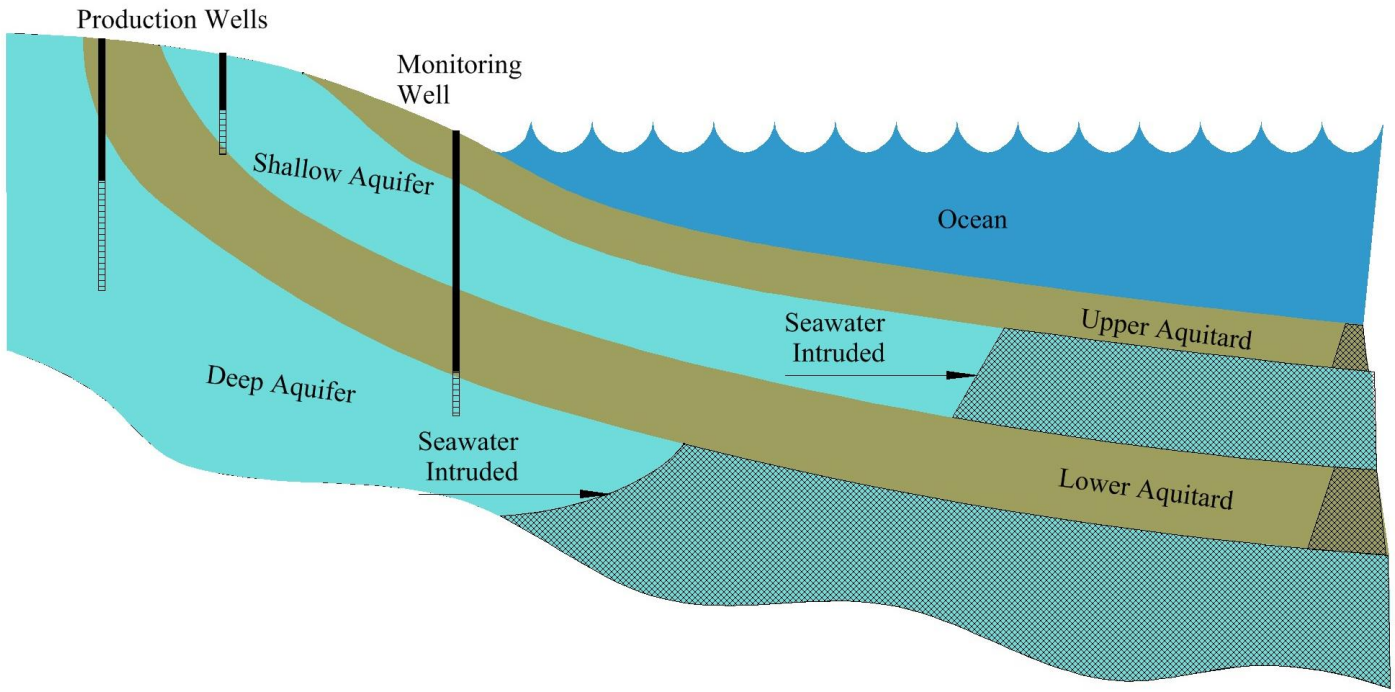
Seawater Intrusion

- Increasing Population along Coastal Zones
- Increasing Groundwater Use
- Climate Change and Sea Water Rise



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Sustainable Groundwater Management

- The 2014 California Sustainable Groundwater Management Act (SGMA)
  - Seawater intrusion = undesirable result
- Groundwater Sustainability Plans (GSPs) must define a measurable objective to prevent seawater intrusion.
  - Draft Regs: “The minimum threshold for seawater intrusion shall be the location where seawater intrusion is considered significant… defined by a numeric chloride concentration.”
  - **Long-term measurable objective: protective groundwater elevations.**

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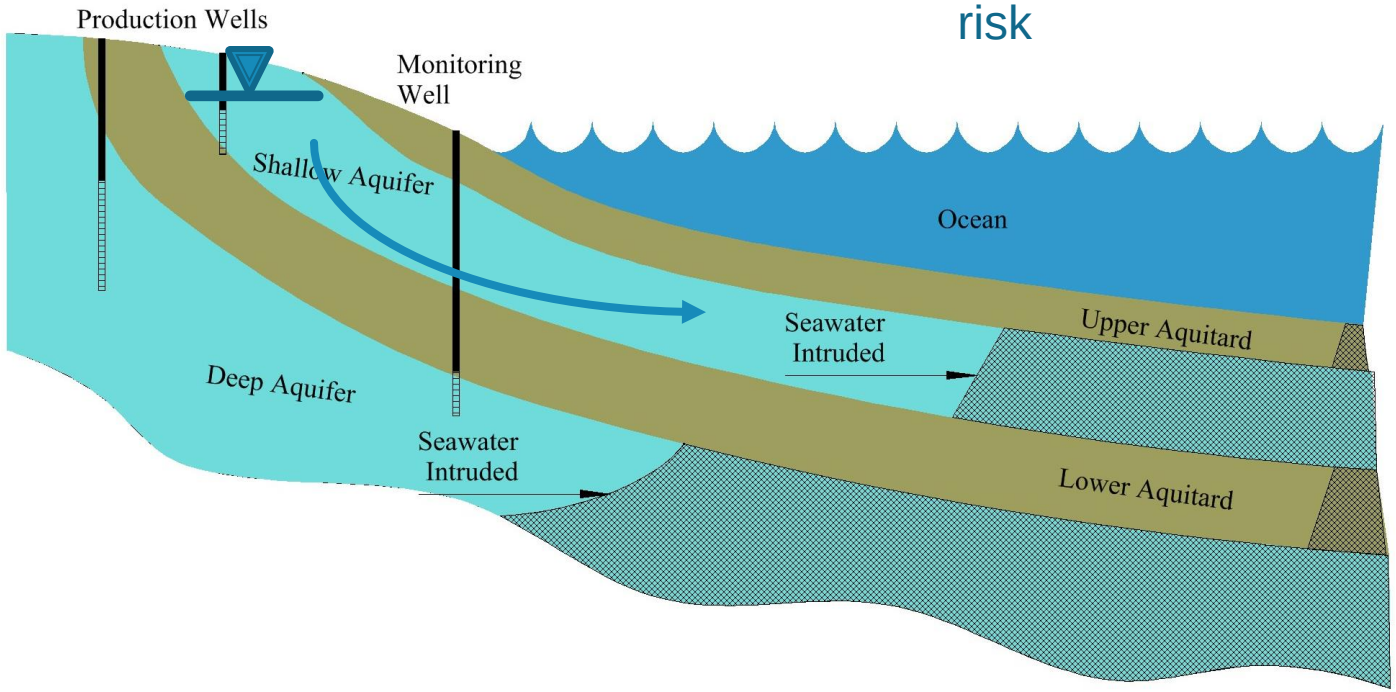
Measurable Objectives

Protectively high GW elevation inland will allow for enough discharge to prevent intrusion

Seawater/freshwater interface may be far offshore, inland water quality may not be indicative of intrusion risk



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Two Case Studies

Santa Cruz Mid-County Basin

Seaside Basin, Monterey County

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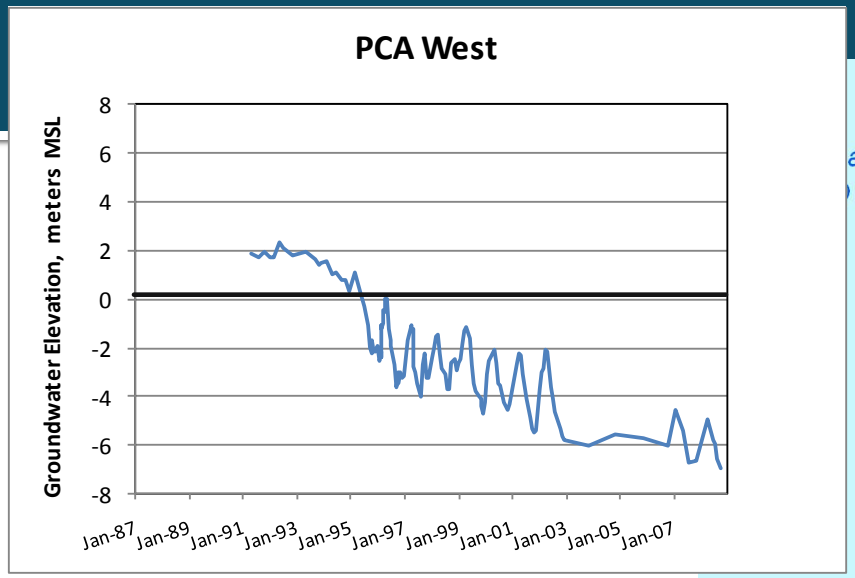
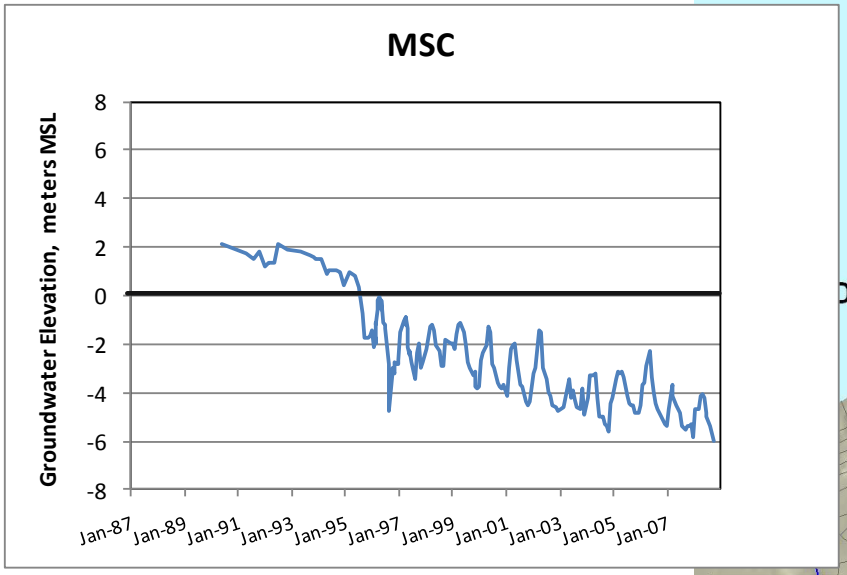
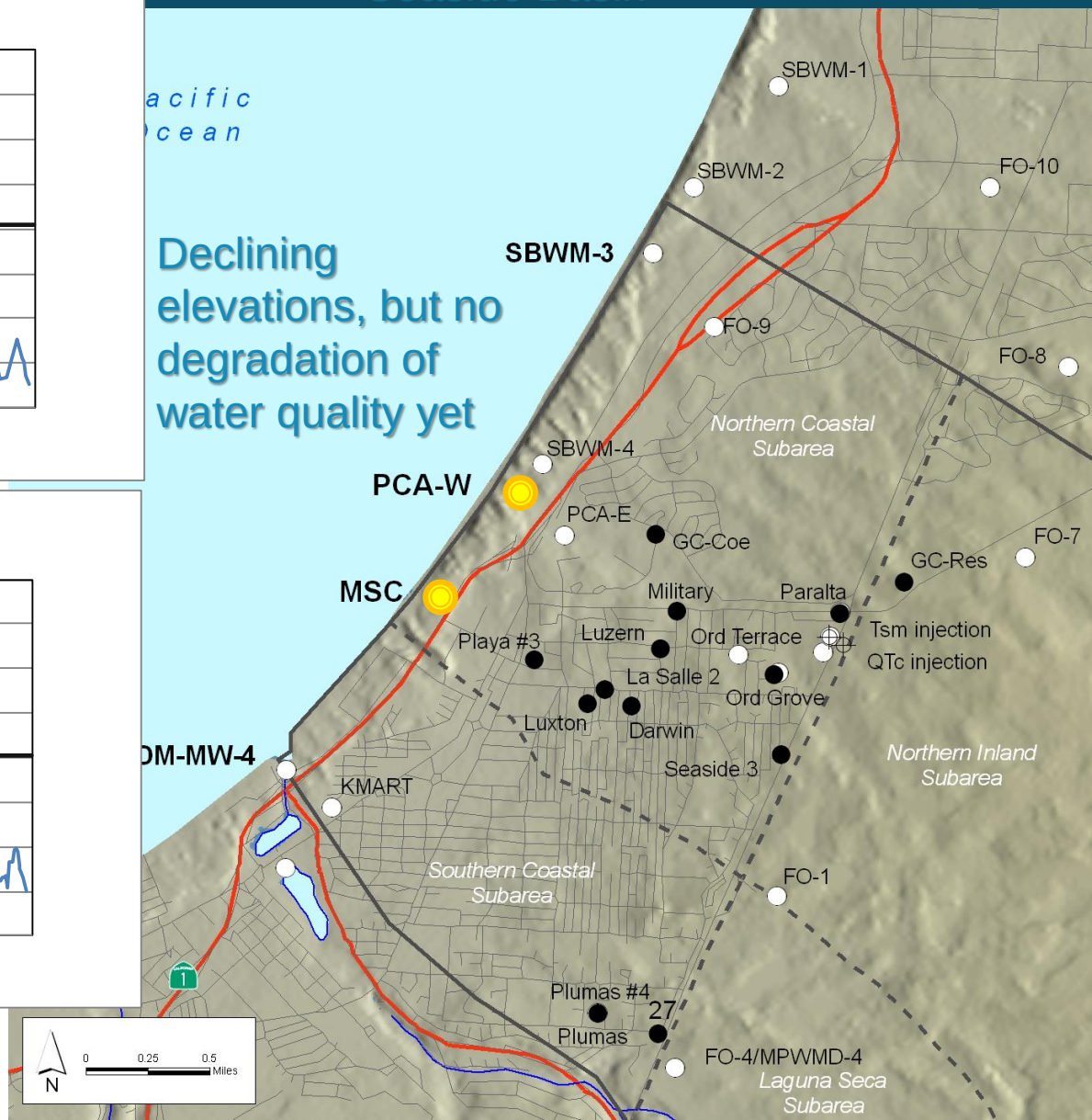
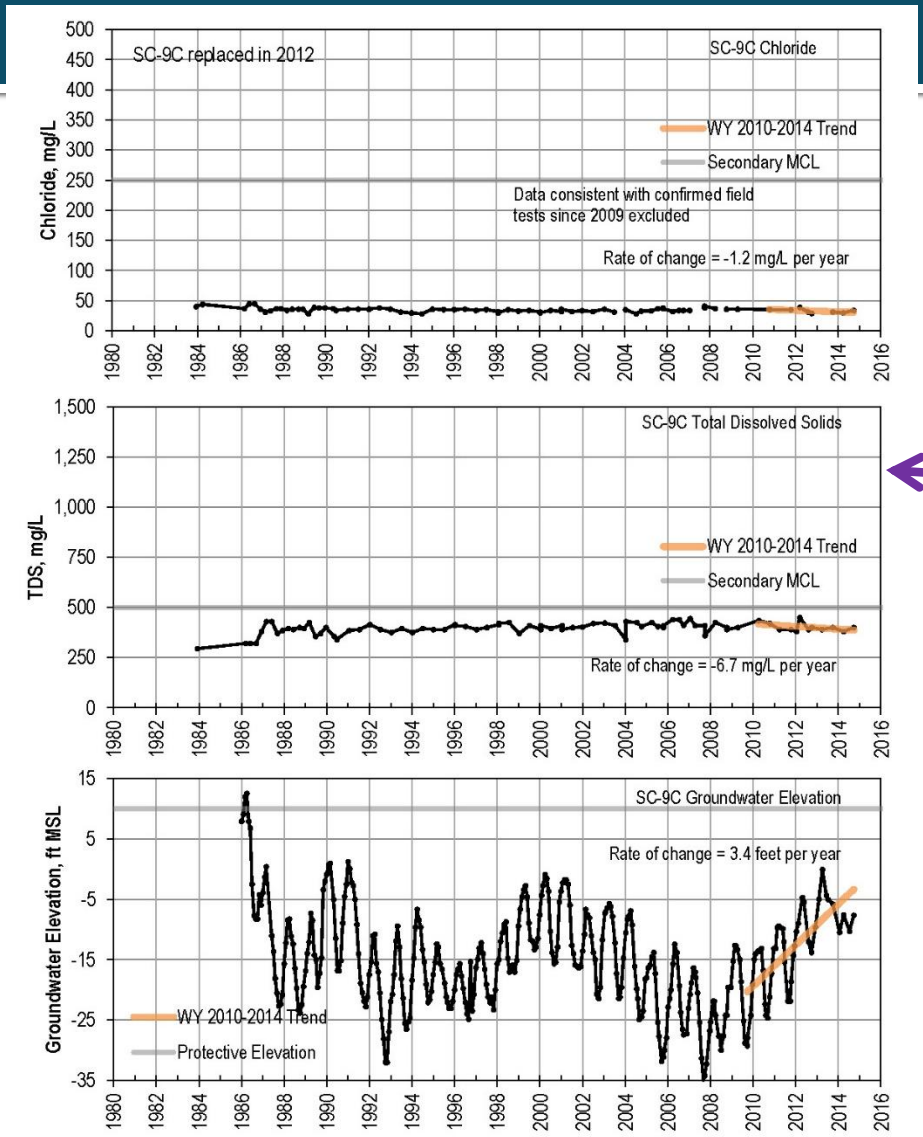
Seaside Basin: Declining Groundwater Elevations

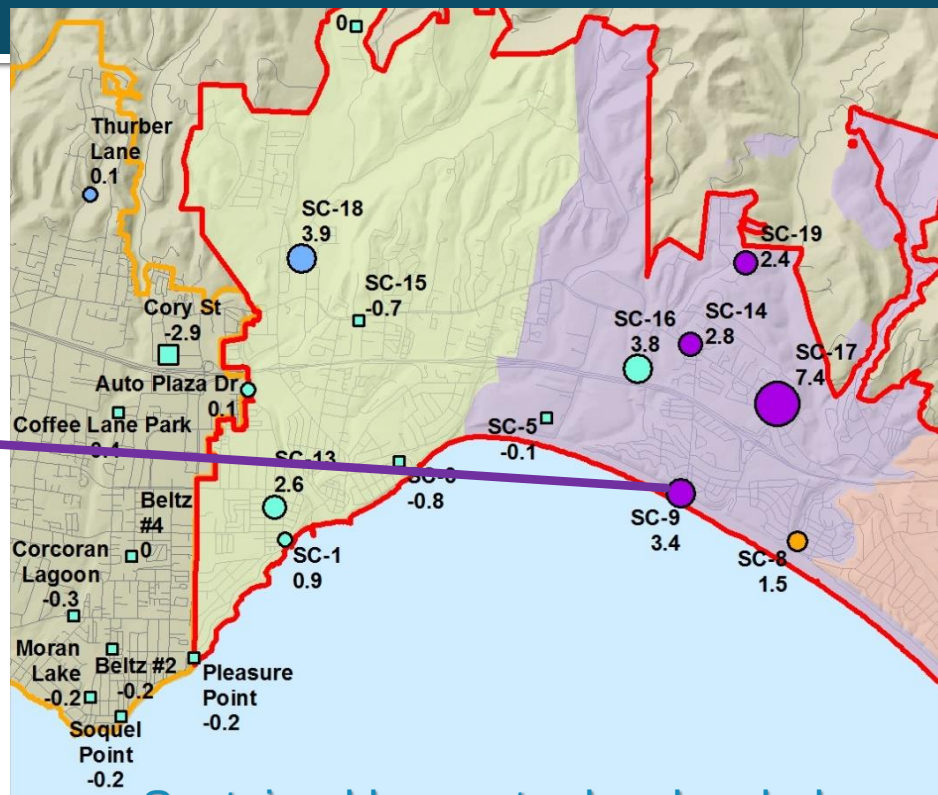






Santa Cruz Mid-County Basin



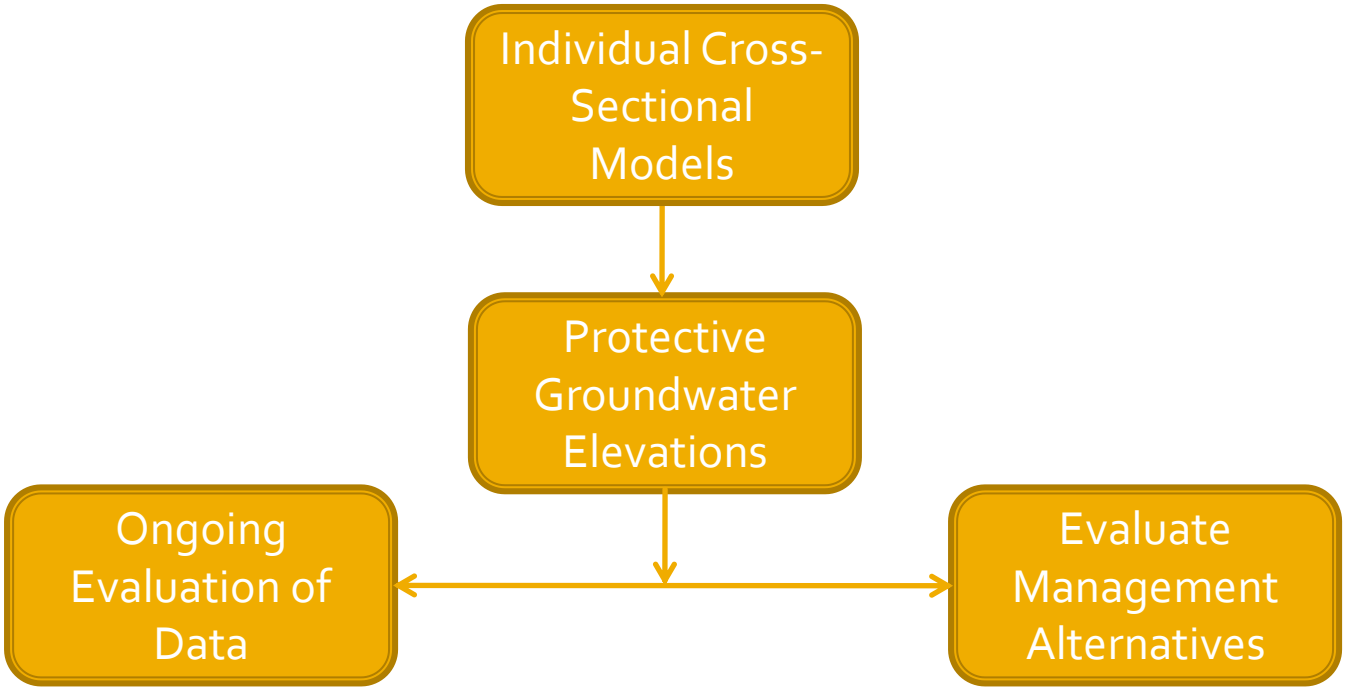


Sustained low water levels – below sea level – increase risk of impact to groundwater quality.

Risk not identifiable from salinity.

Model Challenges and Approach

- Approach:

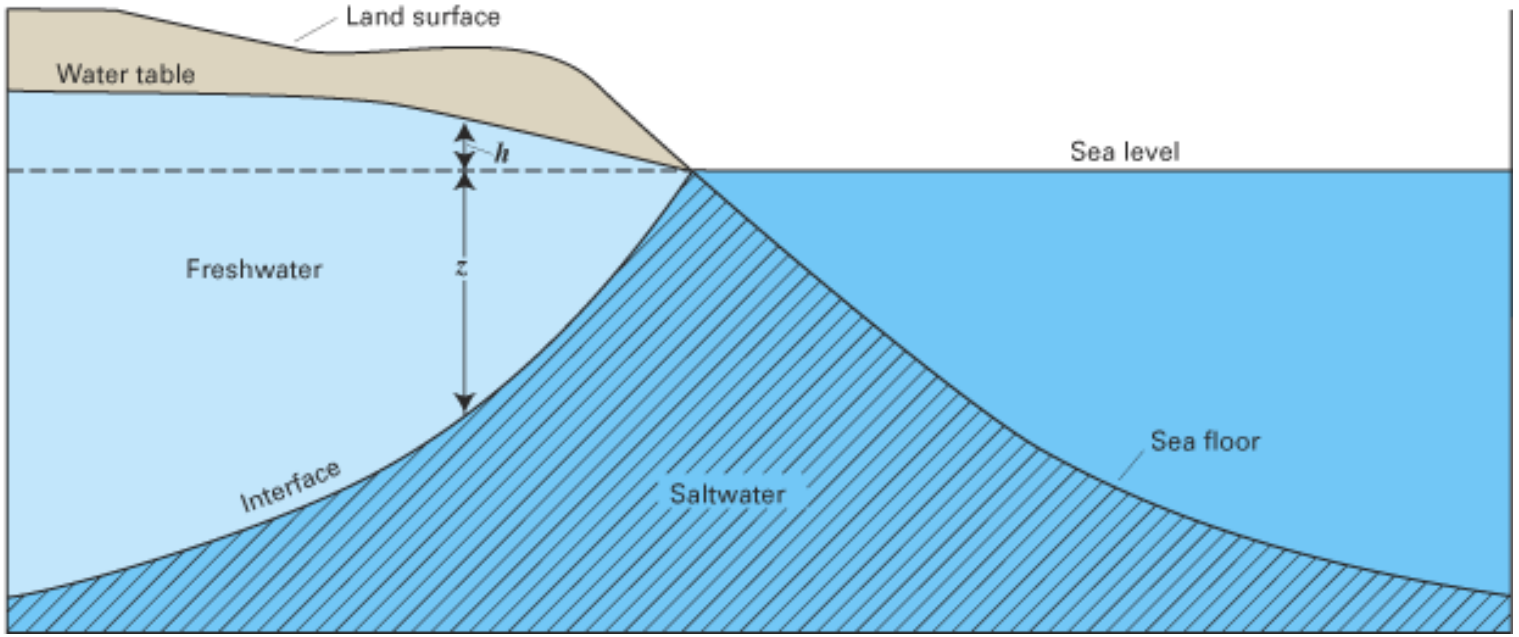


Model Challenges and Approach

- Modeling density dependent flow is numerically intensive
- Unknown location of freshwater-salt water interface
- Model discretization limitations
- Lack of offshore data

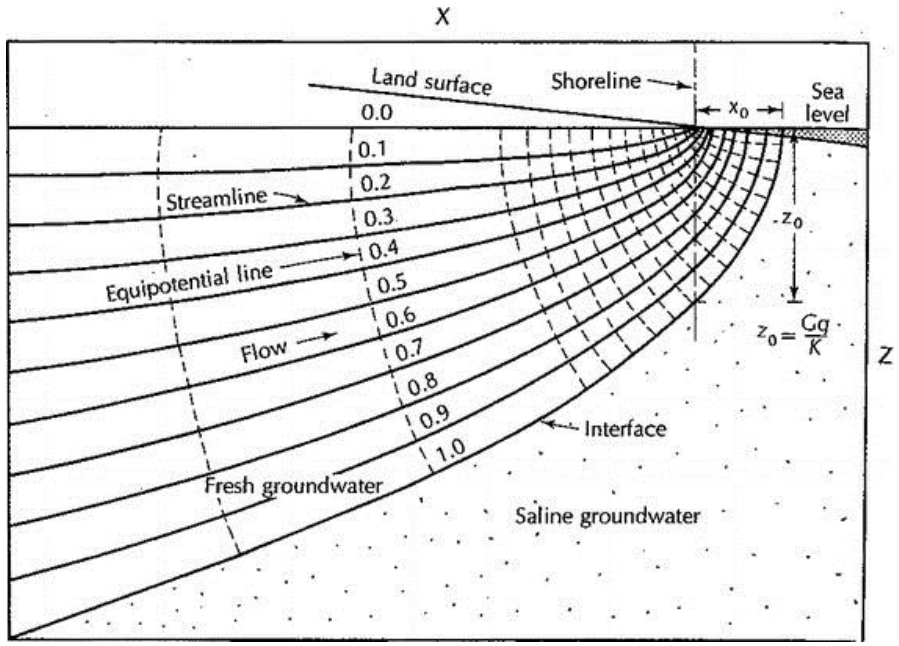
Calculating Protective Elevations

- Ghyben-Herzberg
  - Does not account for outflow from aquifer



Calculating Protective Elevations

- Glover Equation
  - Corrects for outflow
  - As in Ghyben-Herzberg, does not account for hydrostratigraphy, bathymetry

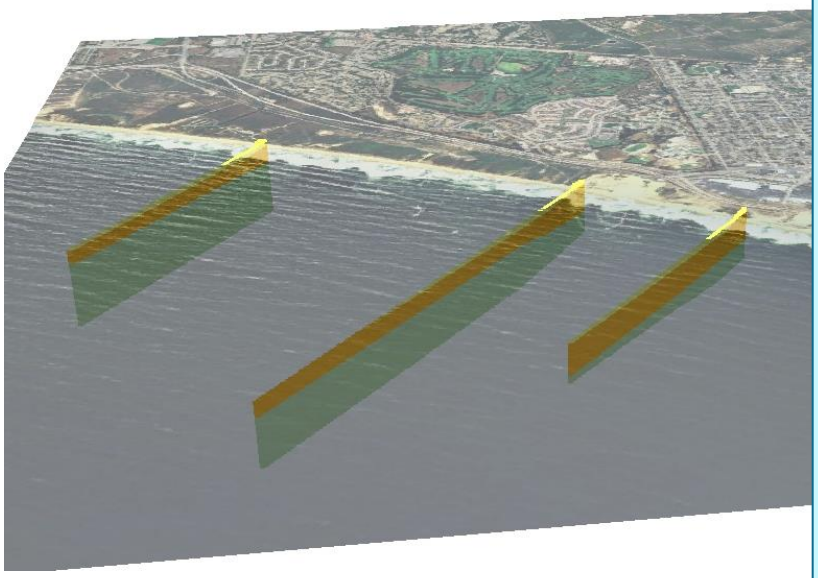


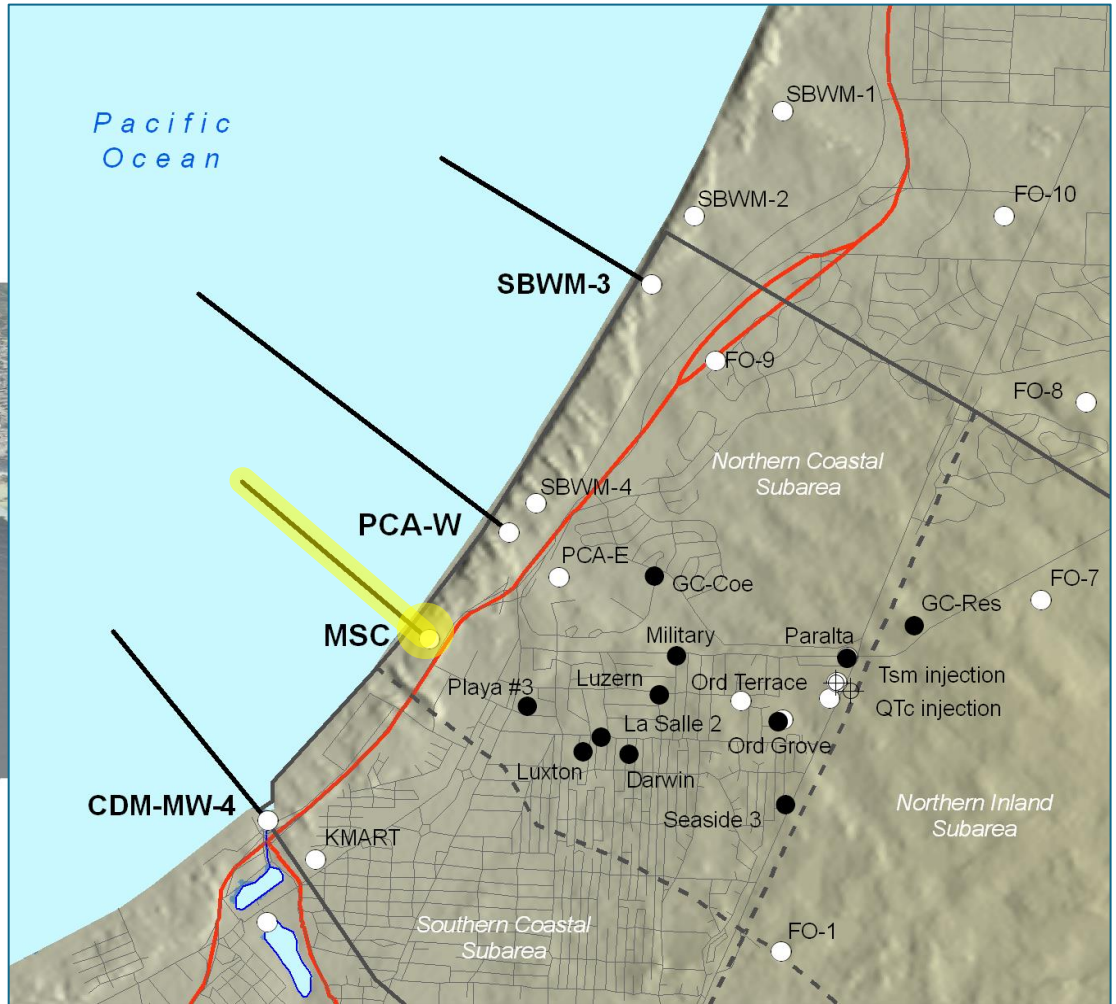
- Cross-Sectional models have been used to provide more accurate protective elevation calculations in complex layered systems

-Summarized from Todd Groundwater peer review of model results

Cross-Sectional Models

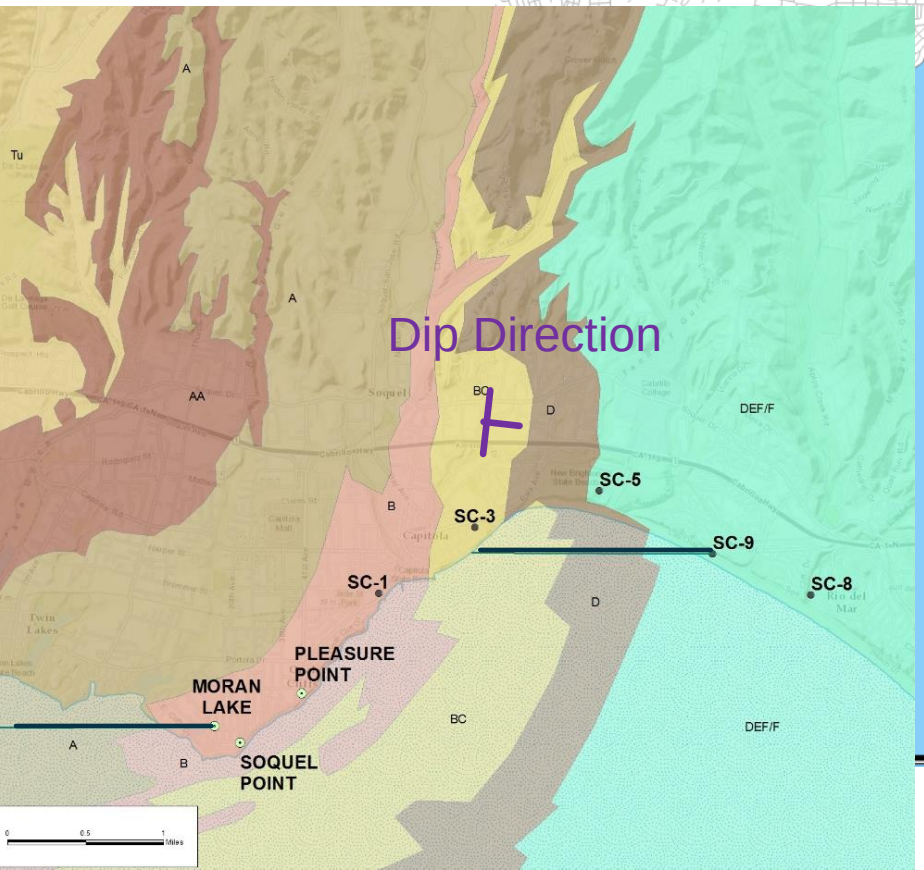
Seaside Basin

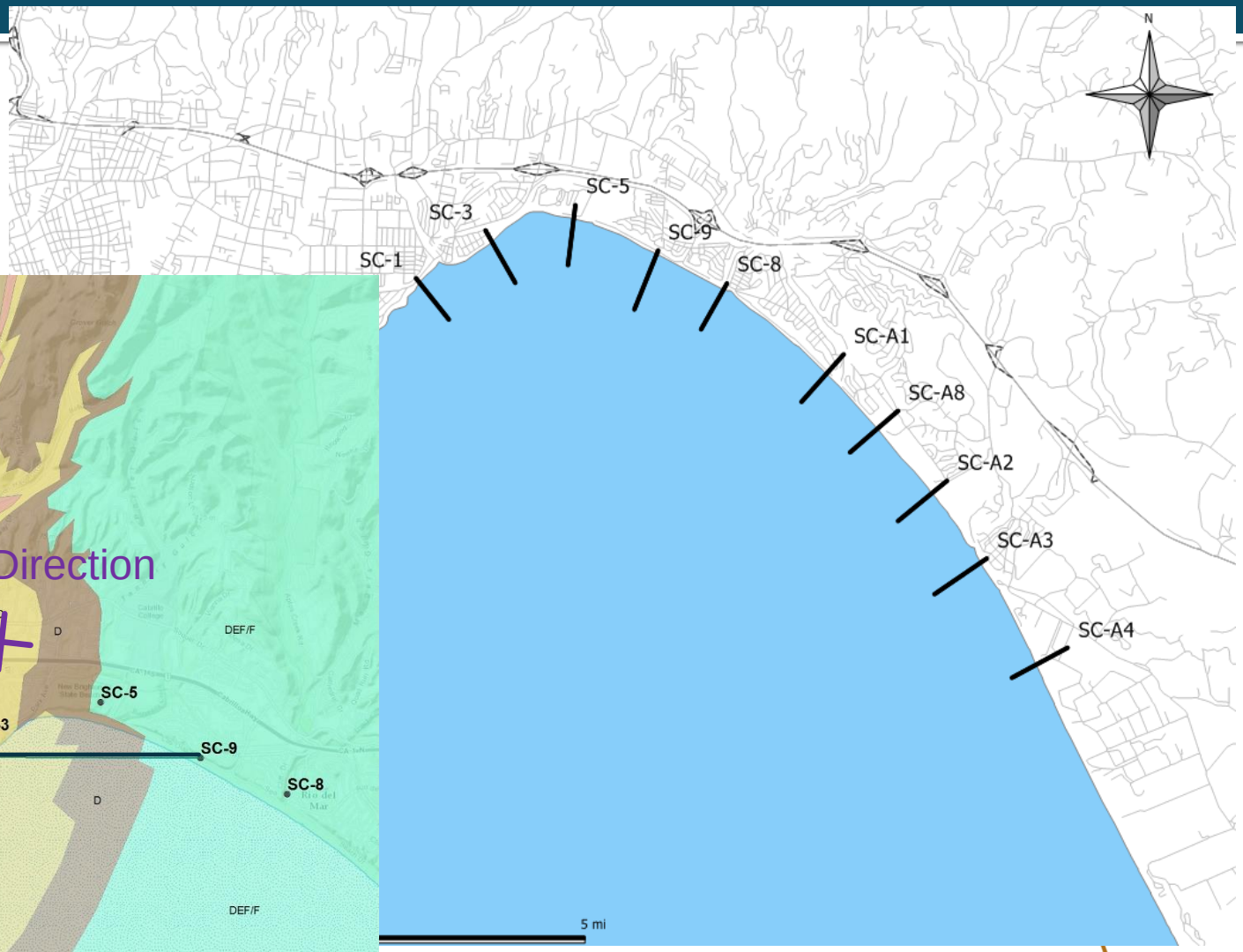




Cross-Sectional Models

Santa Cruz Mid-County Basin





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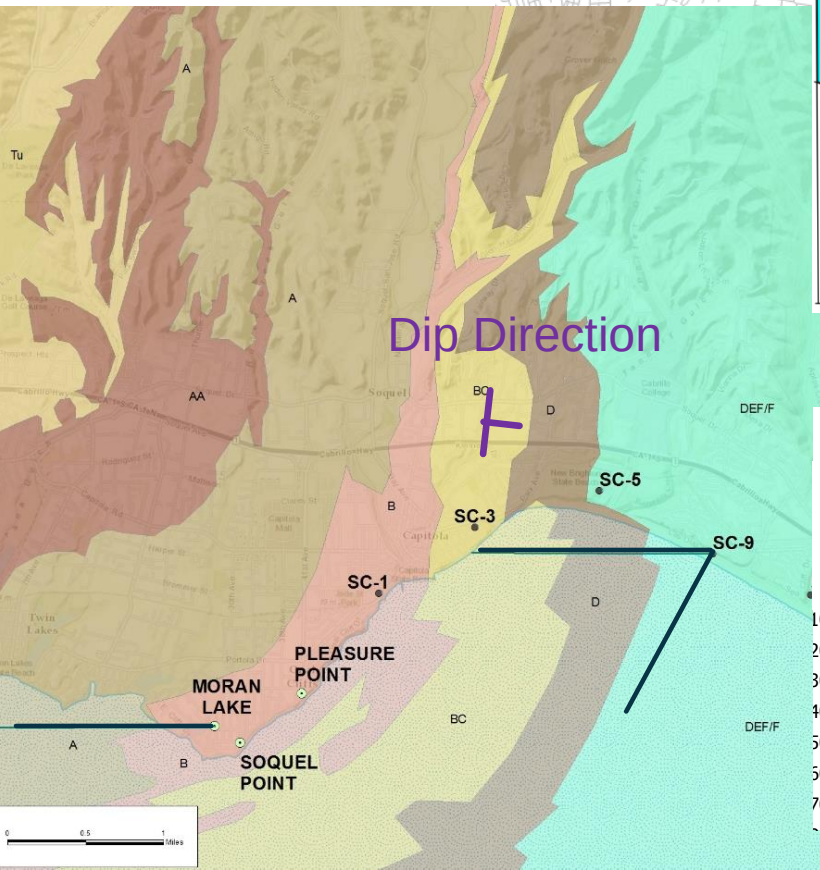
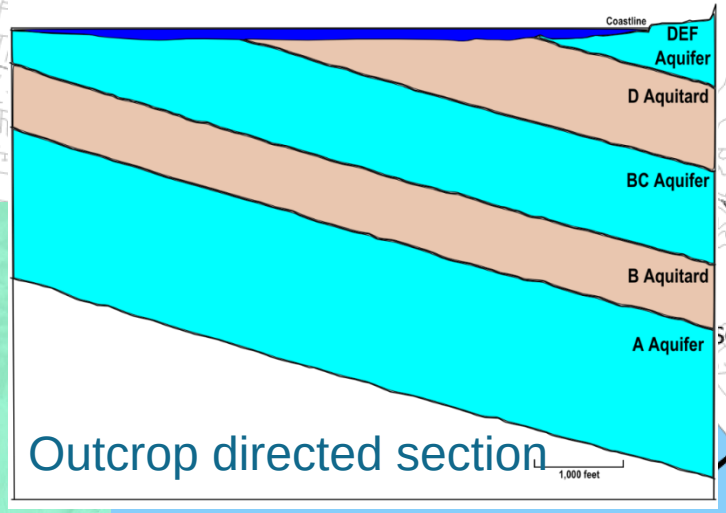
Cross-Sectional Models

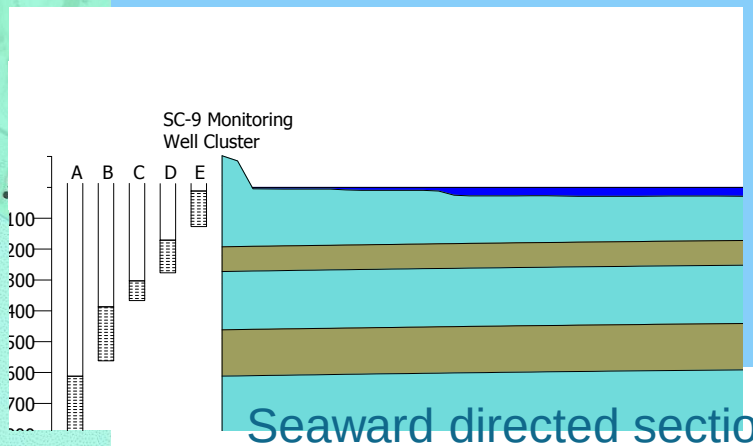
Santa Cruz Mid-County Basin



Dip Direction



Outcrop directed section



Seaward directed section

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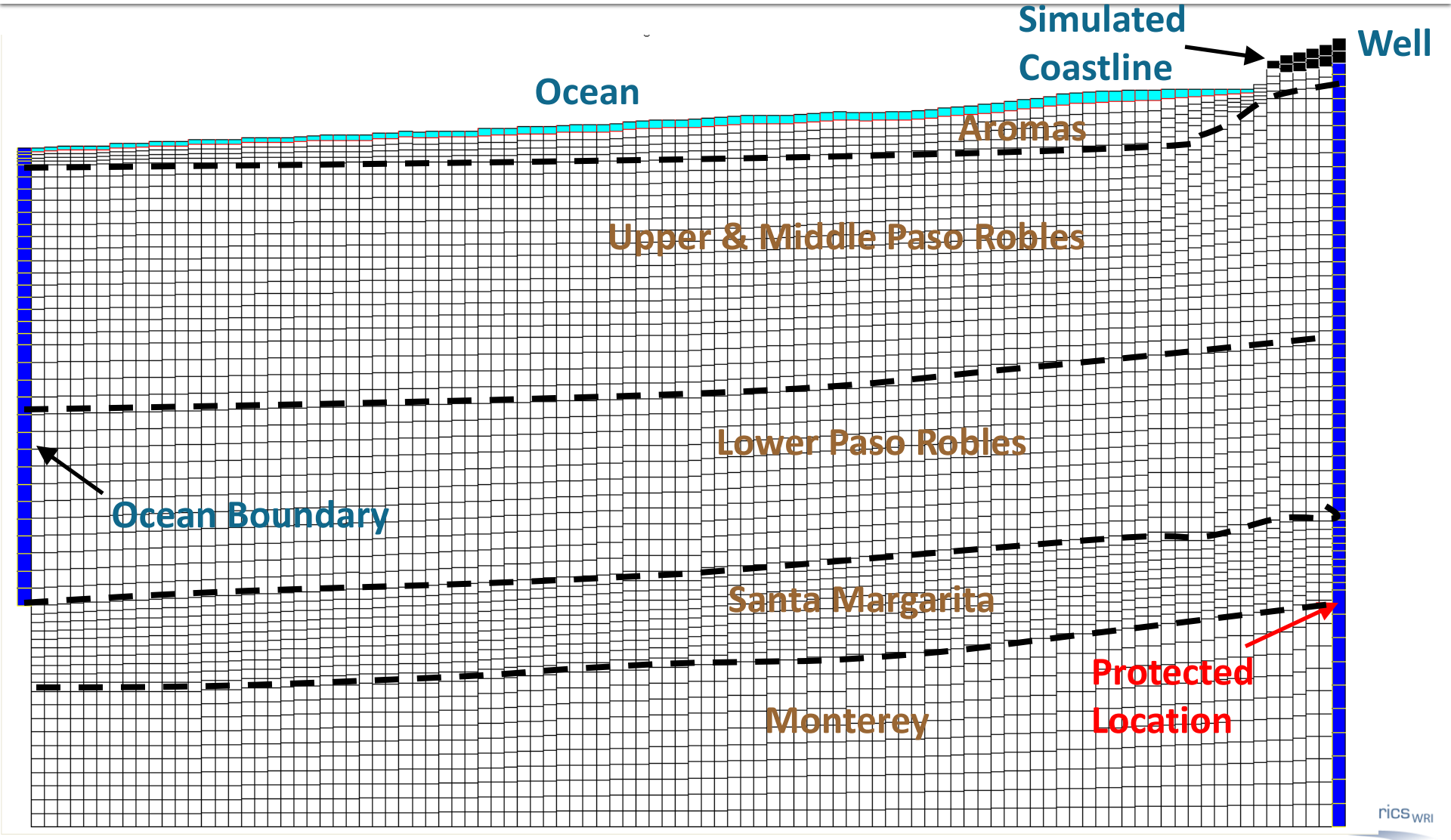
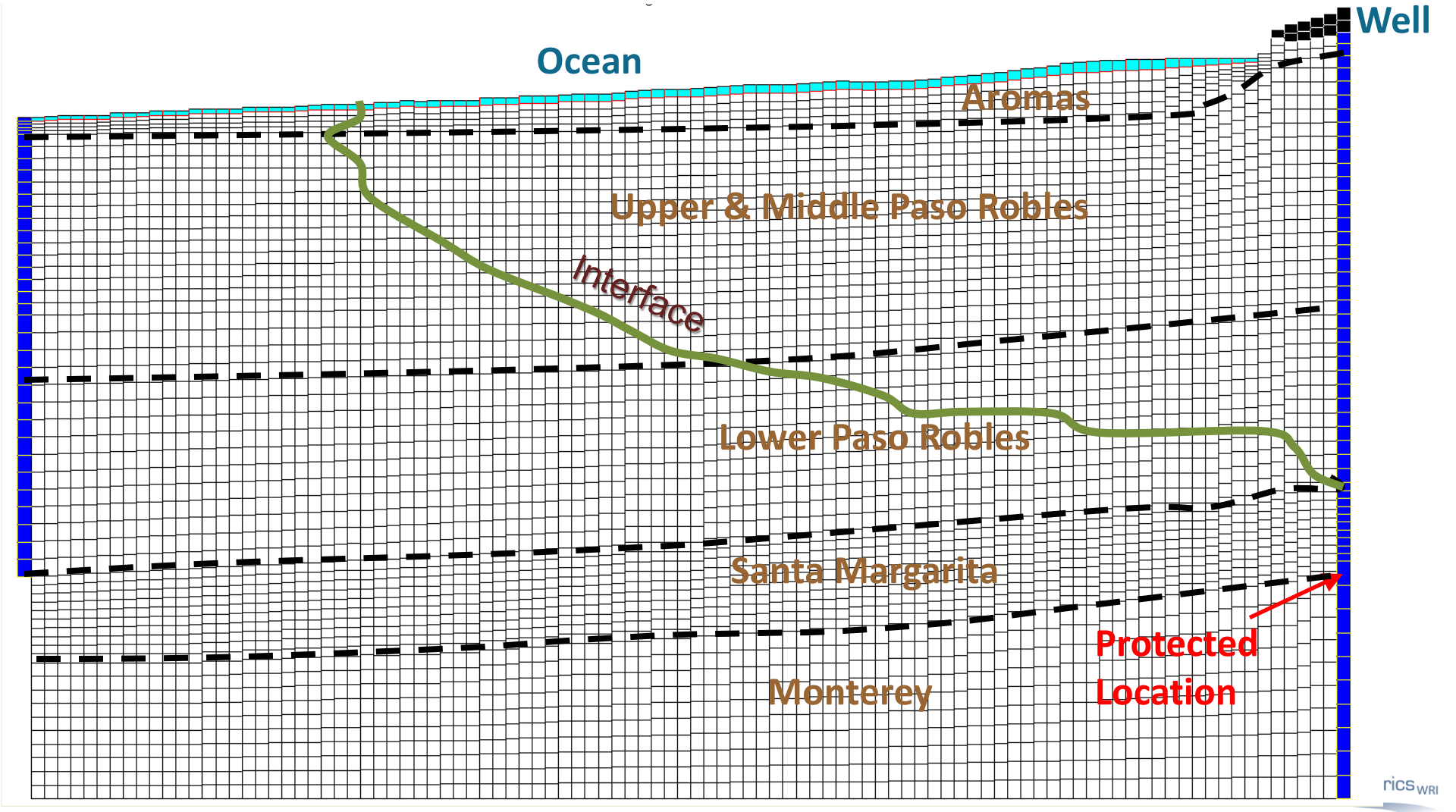
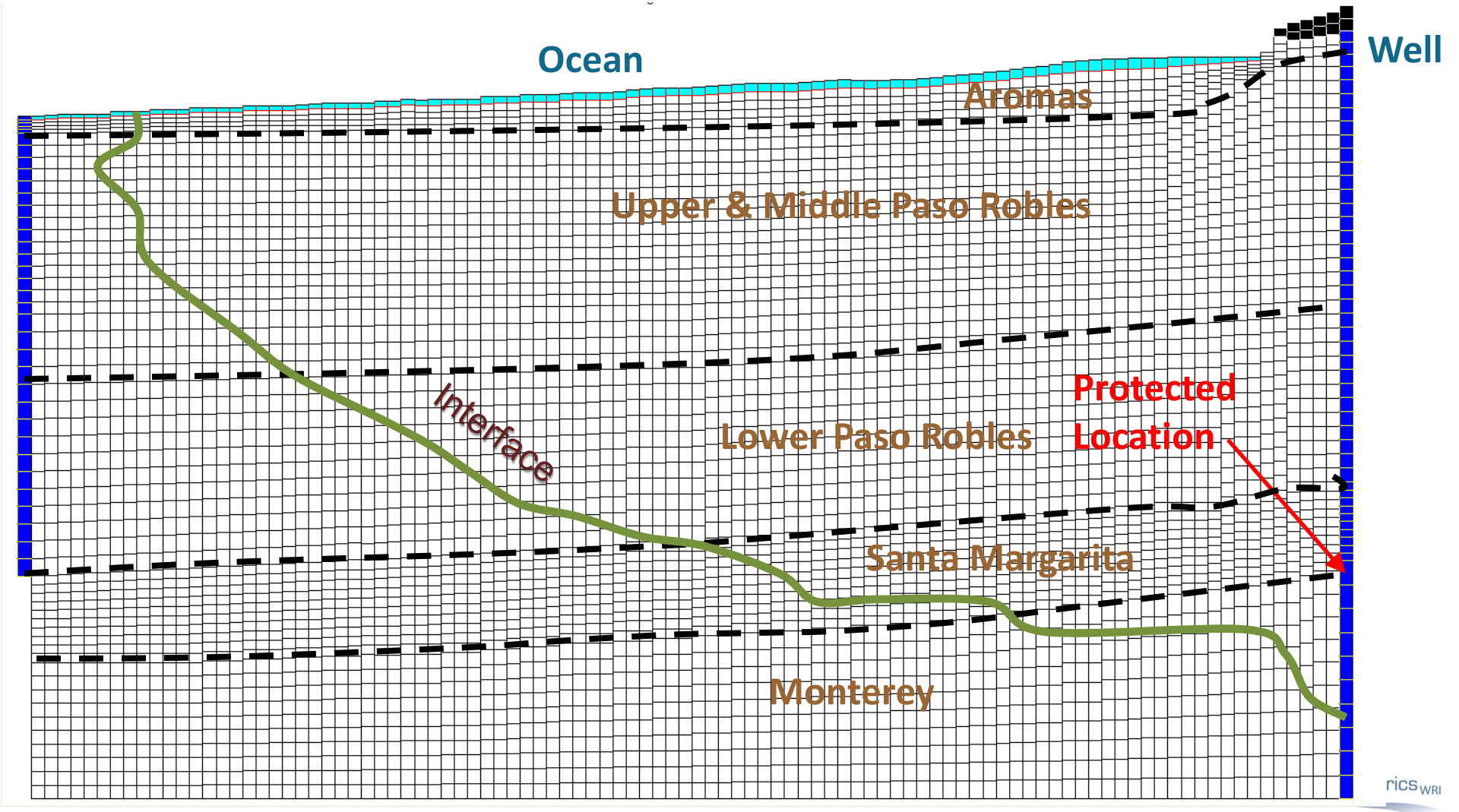
SEAWAT 2000 Grid



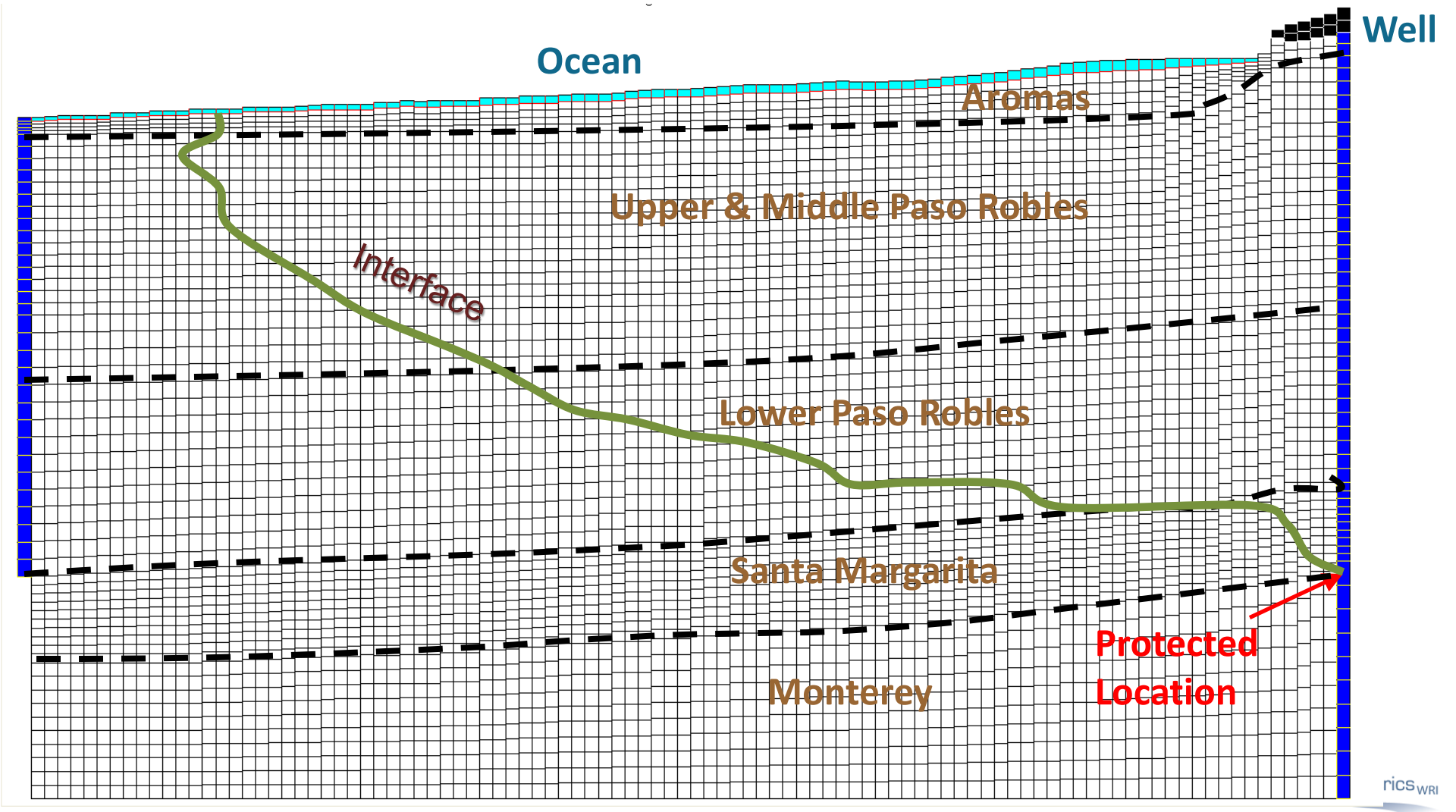
Not Protective – Too Low



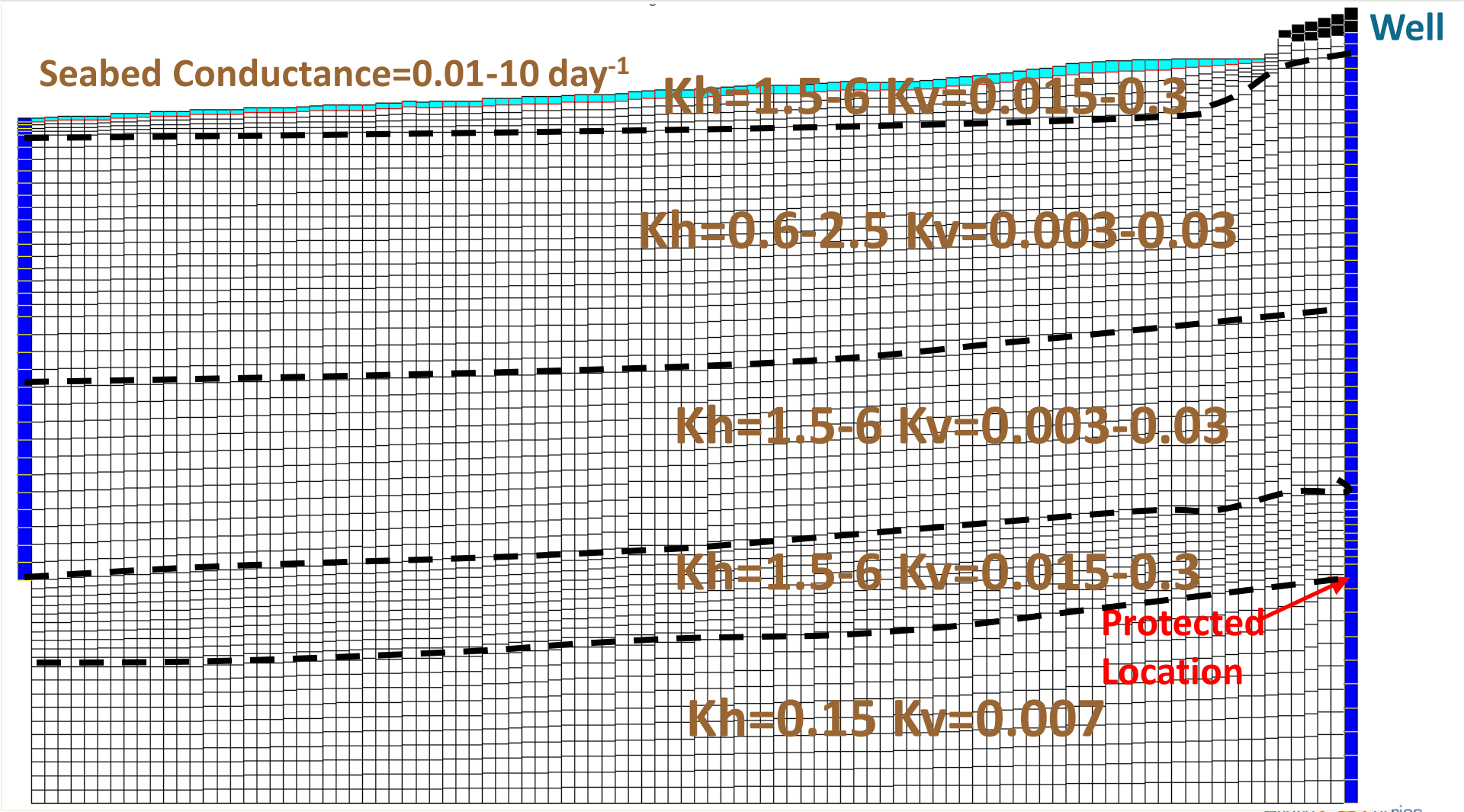
Too Protective – Too High



Protective Interface – Minimum Groundwater Elevation to Protect Location



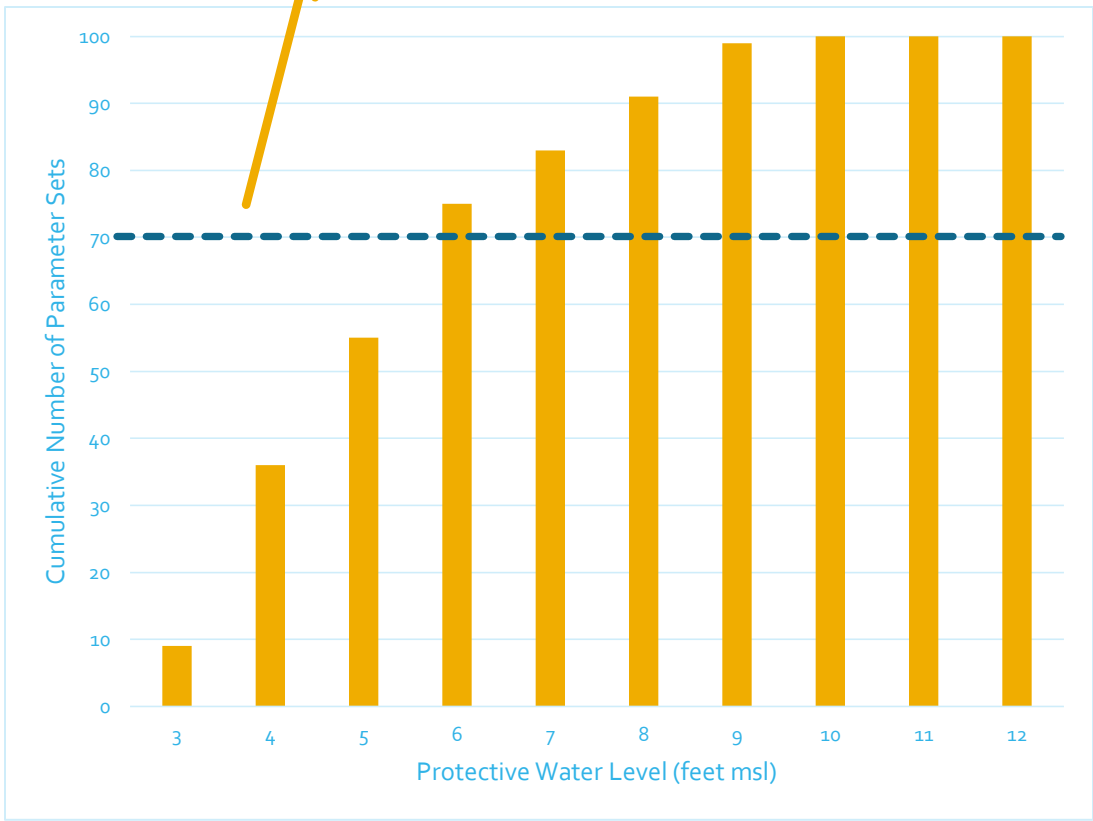
Parameter Uncertainty



Hydraulic conductivity (K) in meters per day

Monte Carlo Analysis

70% threshold for defining protective elevation informed by stakeholder input



Protective at 6+ Feet

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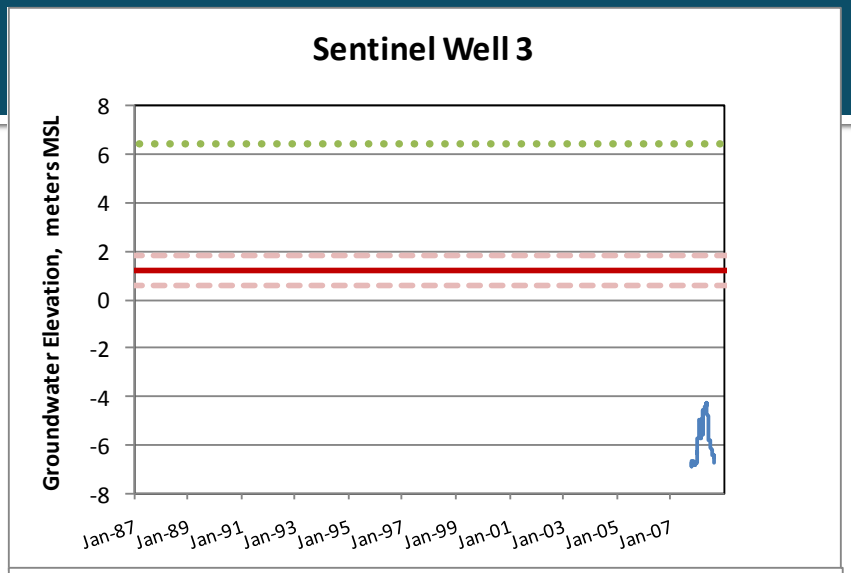
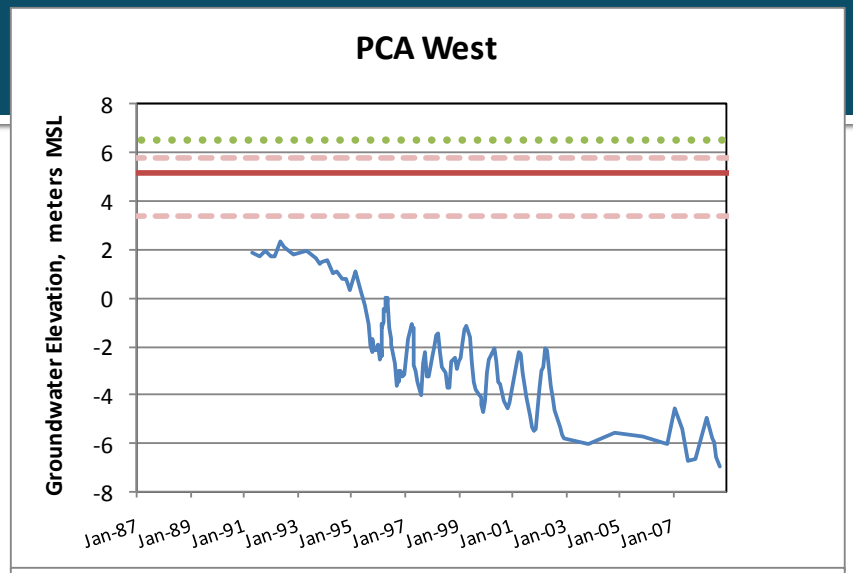
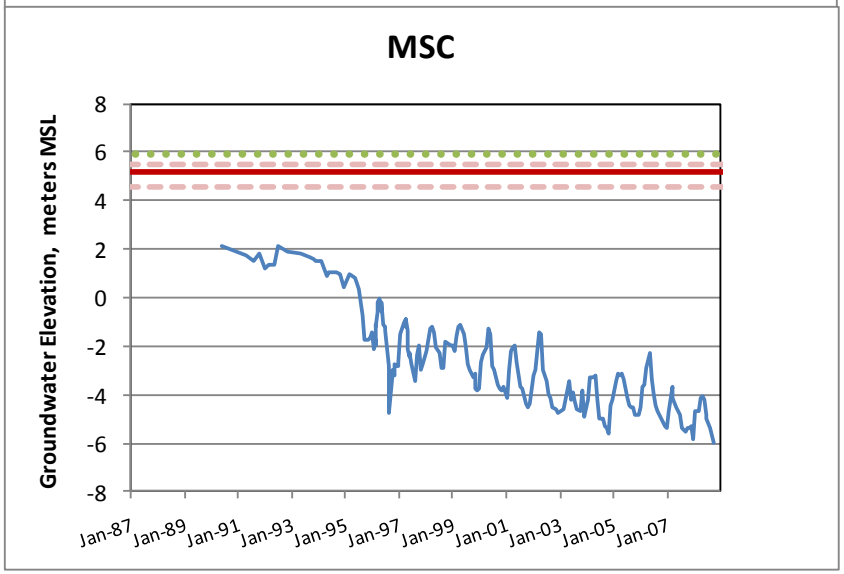
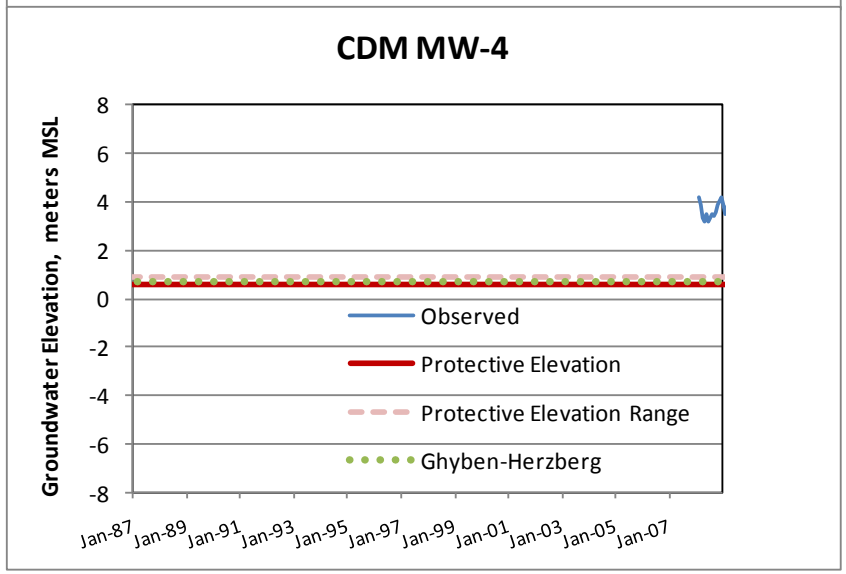
Protective Groundwater Elevations – Seaside Basin









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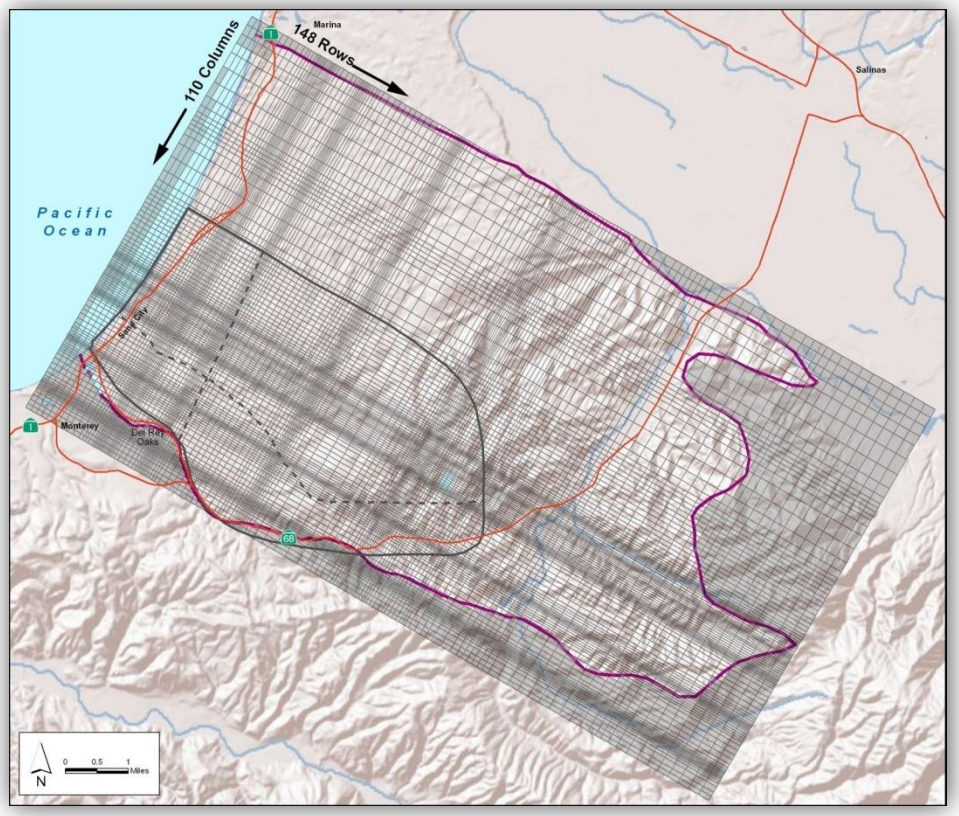
Seaside Basinwide Groundwater Flow Model

- Calibrated to 1987-2008 groundwater level data
- Used to evaluate 5 management alternatives
  - Baseline case
  - 1) In-lieu recharge
  - 2) In-lieu recharge and injection
  - 3) Shallow/deep groundwater injection
  - 4) Coastal injection barrier
  - 5) Redistribution of pumping away from coastal area
- Predictive Period 2009-2031



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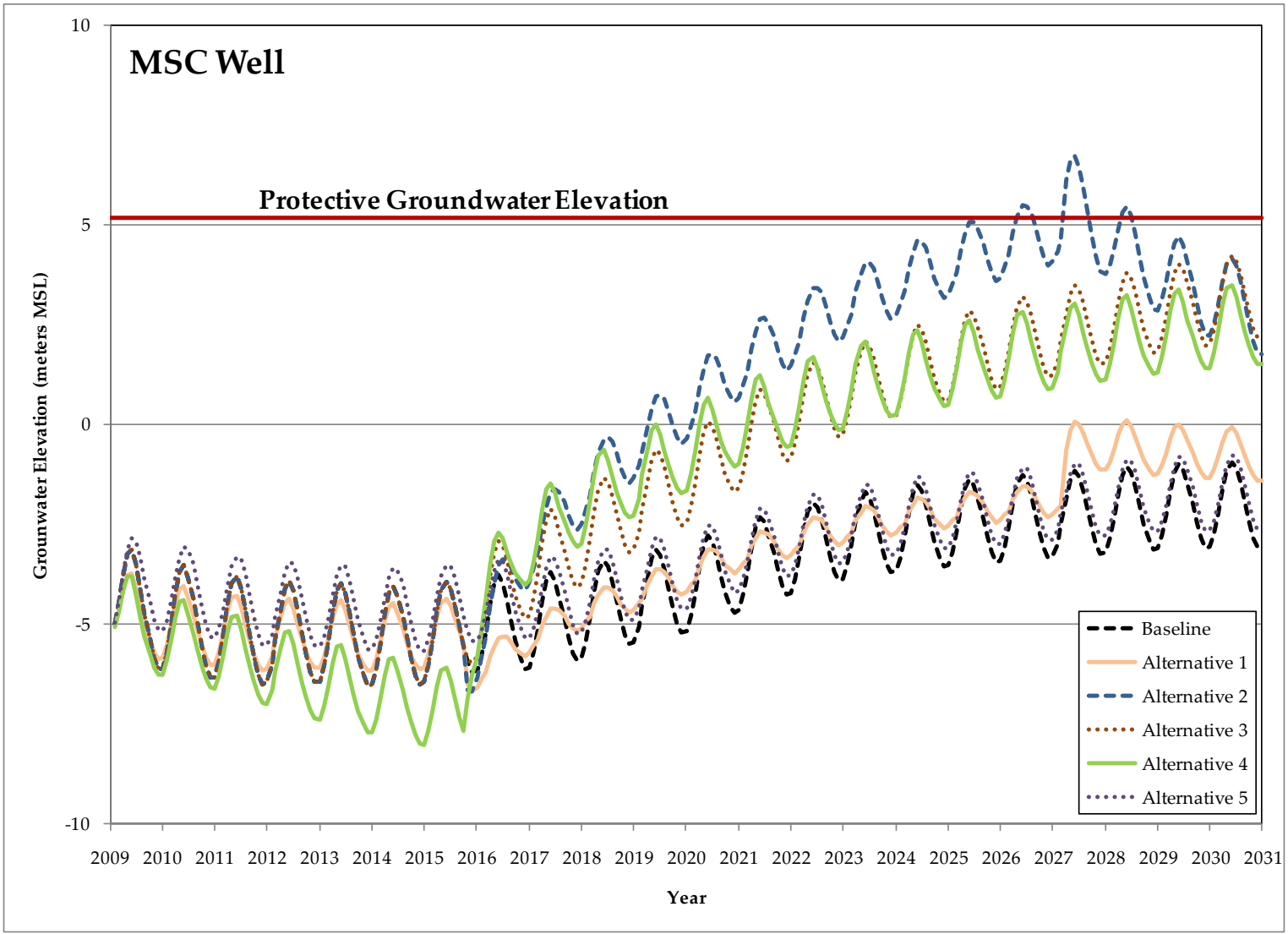
Evaluate vs. Protective Elevation



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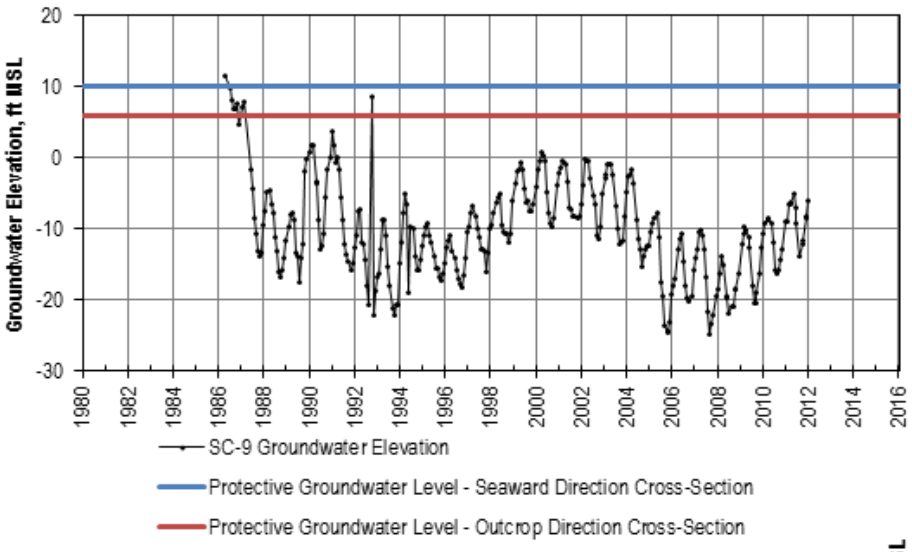
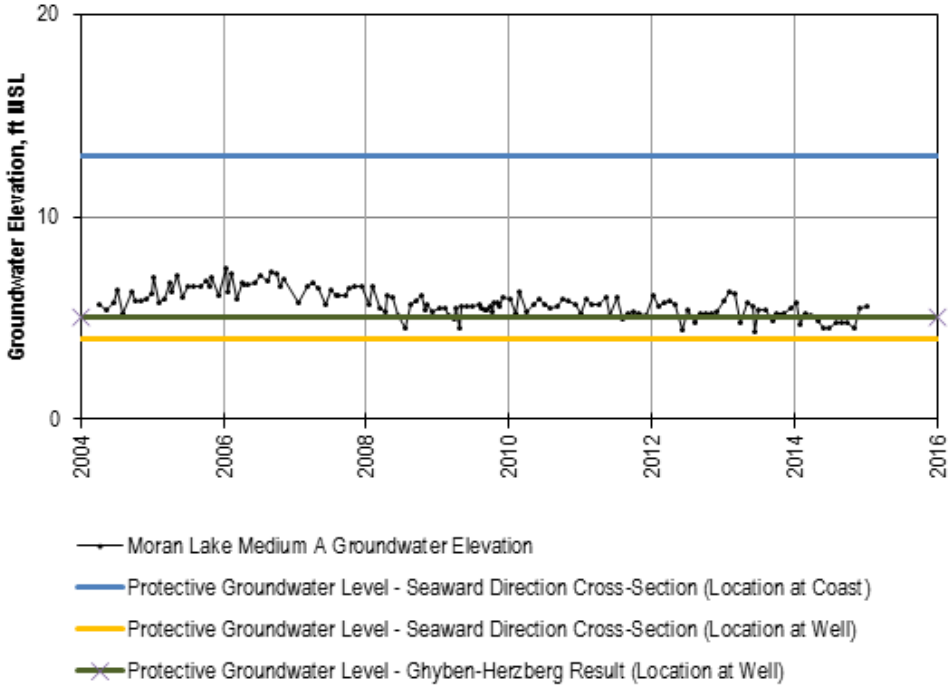
Protective Groundwater Elevations: Santa Cruz Mid-County Basin



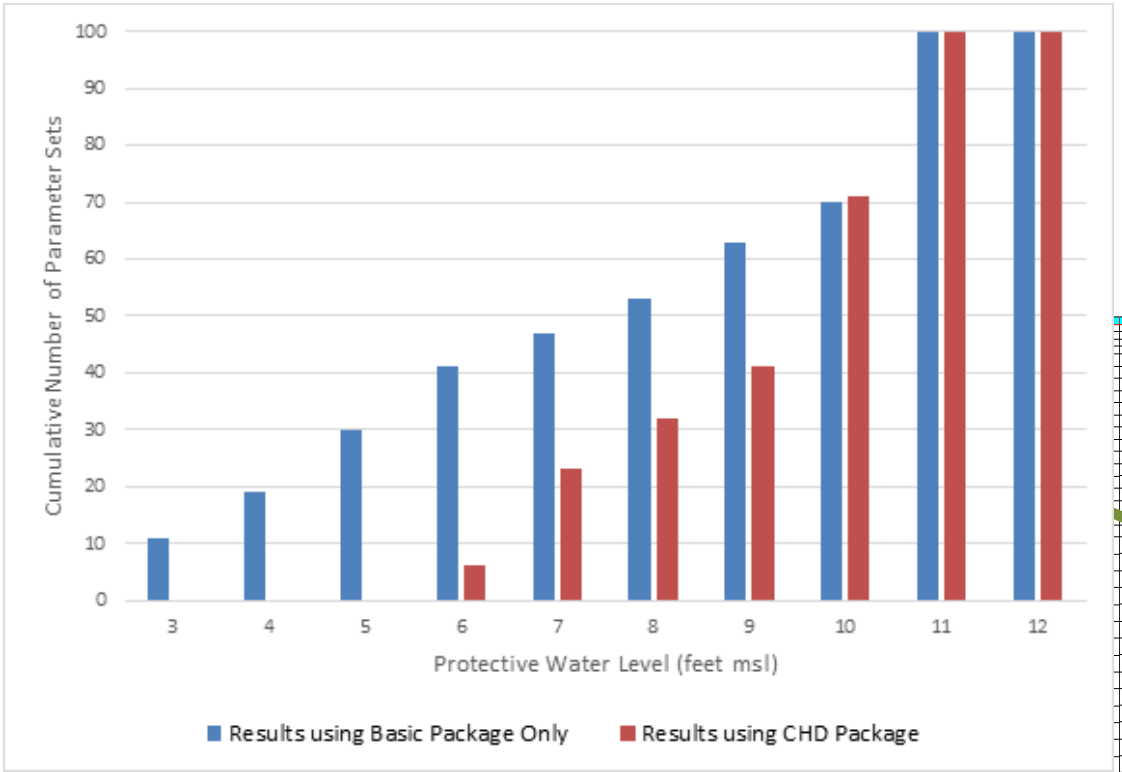
Sensitivity to orientation of cross-section

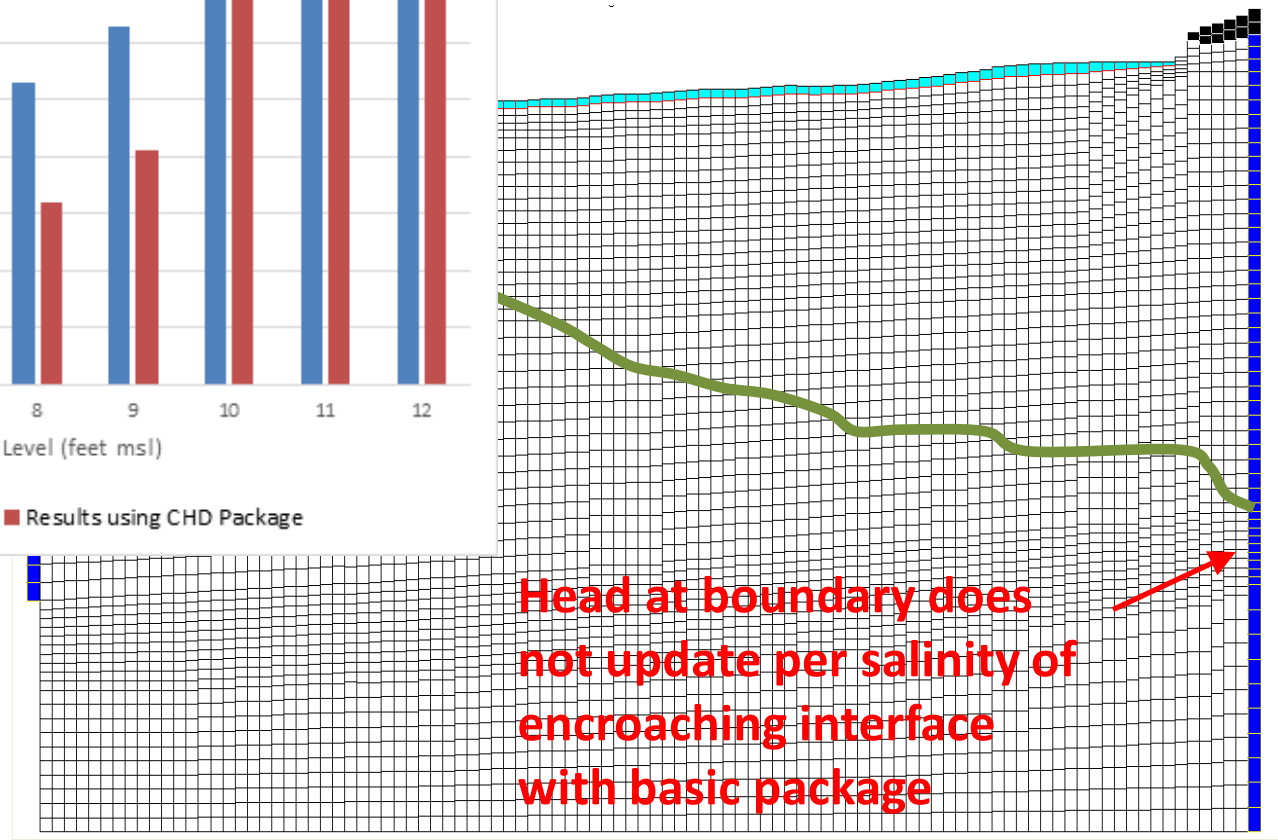
Variation from Ghyben-Herzberg Result

Sensitivity to observation point



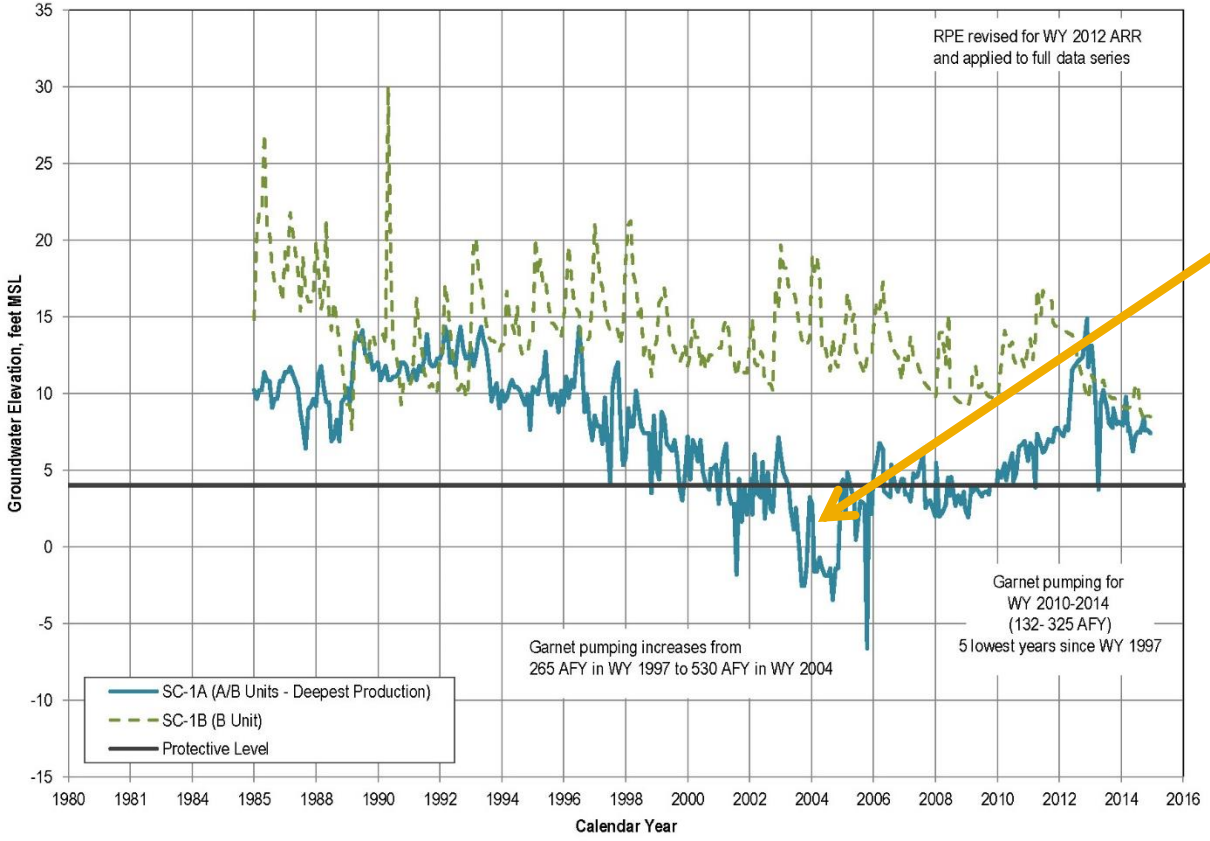
Sensitivity to Boundary Conditions





Santa Cruz Mid-County Basin Management

- Cross-sectional model results have informed changes to pumping configuration



Pumping shifted inland from coastal wells, groundwater levels recover to above protective level

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Santa Cruz Mid-County Basin Management

- Protective Groundwater Elevations used as monitoring criteria for Purisima Formation
- Protective Groundwater Elevations will be used to evaluate results of forthcoming groundwater-surface water model

Conclusions

- Method is an improvement over direct calculations
- Establishes flexible, locally-specific measureable objectives
- Specifically accounts for uncertainty
- Can be used for adaptive management and planning

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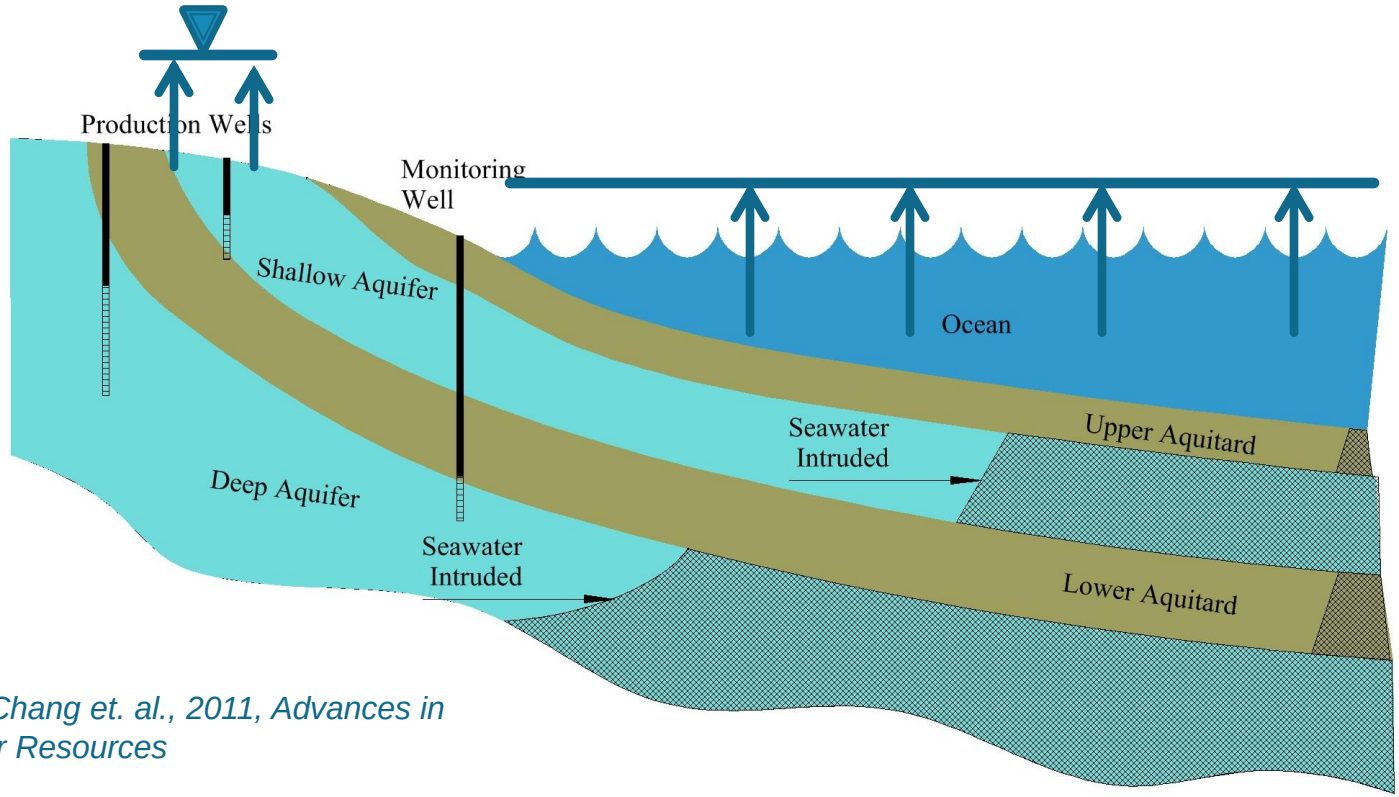
Sea Level Rise and Intrusion

- Sea level rise may propagate inland through confined aquifers – potentially low risk to protective groundwater elevations
  - If discharge from freshwater aquifer remains constant, long-term impact of intrusion may be mitigated



See Chang et. al., 2011, Advances in Water Resources

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Acknowledgements and Contact

- Seaside Basin Watermaster
- Watermaster Technical Advisory Committee
- Soquel Creek Water District
- City of Santa Cruz
- Santa Cruz Mid-County Groundwater Agency

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