Naval Facilities Engineering Systems Command
EXWC Engineering & Expeditionary Warfare Center

FRTR 2021: Impacts of a Saltwater Intrusion Barrier at Naval Weapons Station Seal Beach, CA.

Sophia Lee, PG
NAVFAC EXWC

Sea Level Rise: A Clear and Present Concern

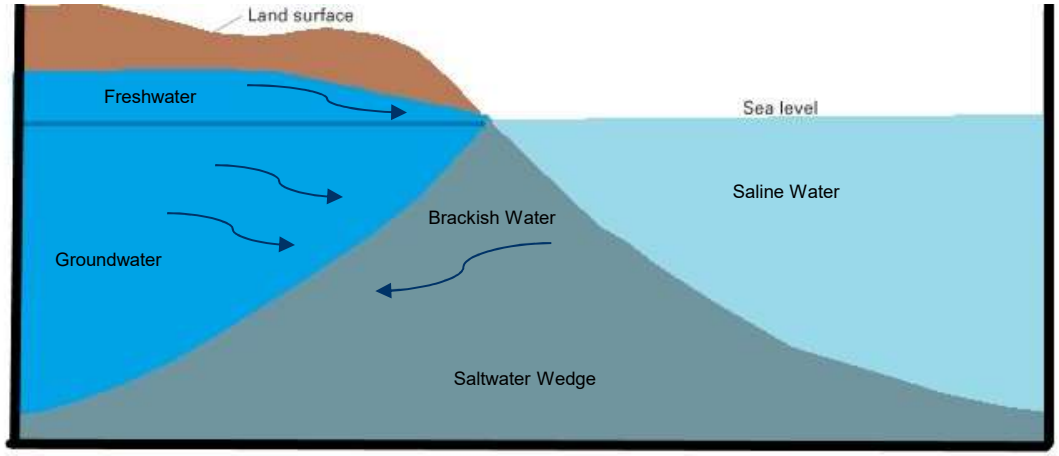
- **The 2014 *Department of Defense Climate Change Adaptation Roadmap* named "rising sea levels and associated storm surge," as one of four primary climate change related phenomena likely to impact DoD installations**

- **2019 report by the Government Accountability Office (GAO) found that DoD installations have not consistently assessed these risks, exposing facilities to "greater than anticipated" damage from climate change phenomena like sea level rise**

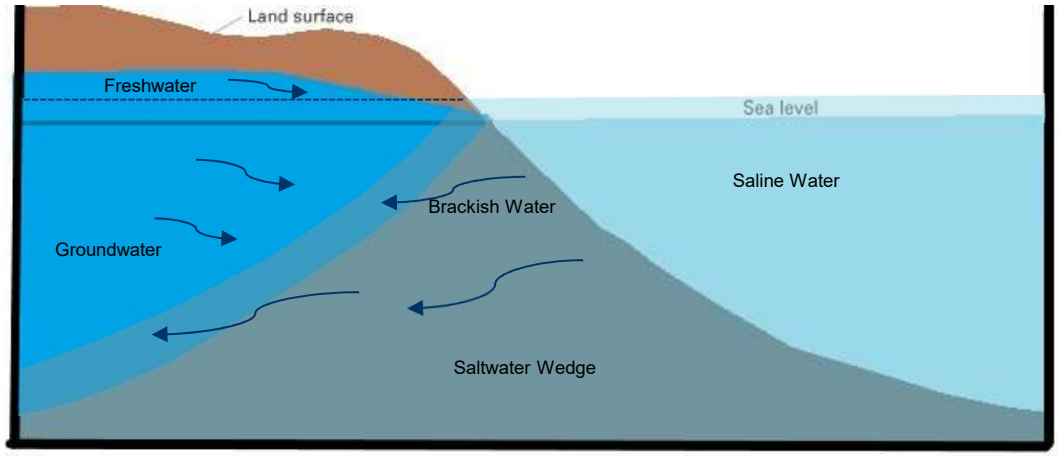
Sea level rise impacts can include not only surface water related events (such as storm surge), but also groundwater flow

Sea Level Rise Impacts

Current Conditions



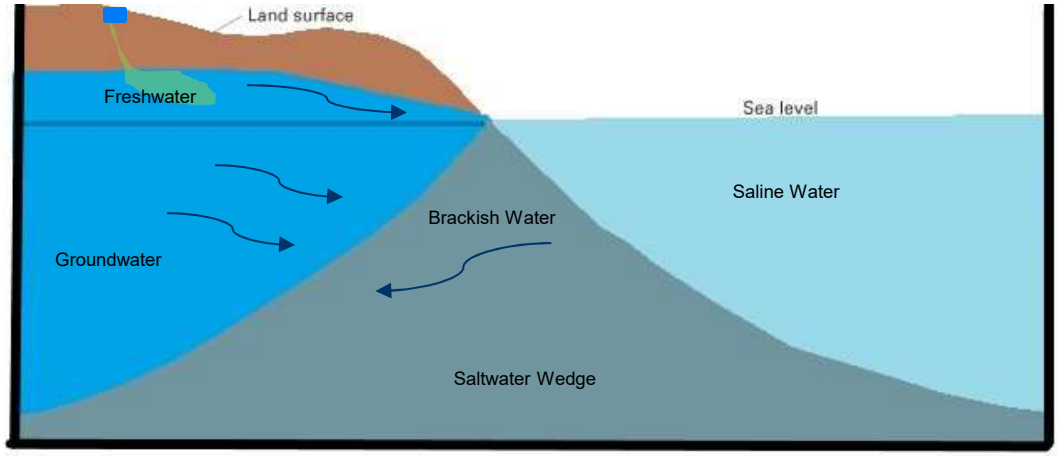
Sea Level Rise Conditions



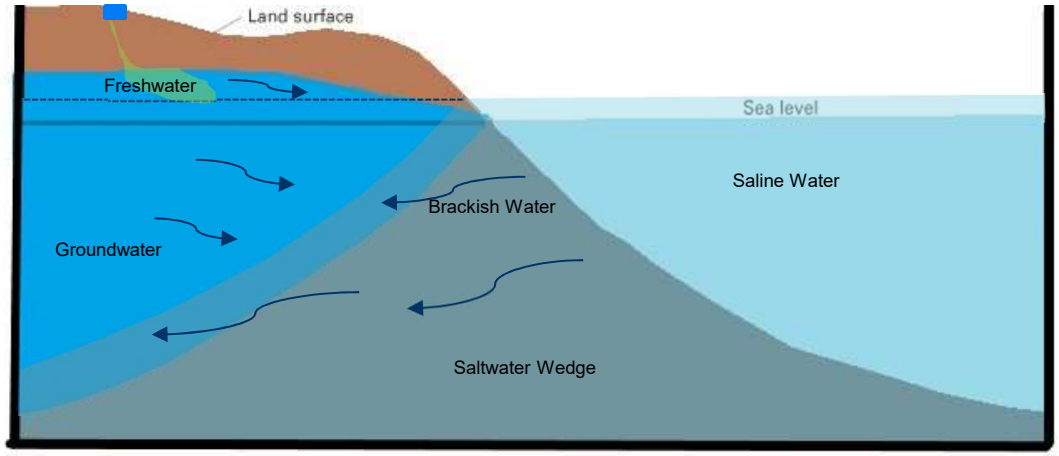
- Sea level rise impacts groundwater through multiple means:
  - Increases in brackish surface water infiltration from increases in storm surge
  - Inundation of shallow (and sometimes deeper) aquifers from encroaching saltwater wedge effects
- Bureau of Reclamation (USBR, 2013)) estimated regional mean sea level along the Southern California coast to rise by 1.5 to 12 inches by 2030, 5 to 24 inches by 2050, and 16 to 66 inches by 2100.

Shallow Groundwater and Sea Level

Current Conditions



Sea Level Rise Conditions



Potential for restoration impacts could include:

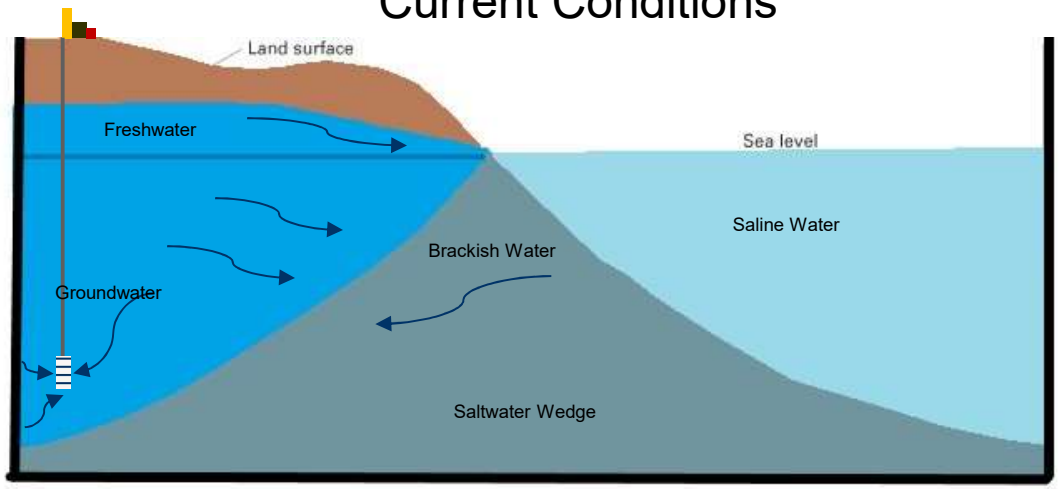
- Remedy ineffectiveness due to changing gradients
- Geochemical changes resulting in remedy failure
- Changes in constituent flow paths due to changes in subsurface density geometry

Impacts would likely be highly dependent on distance from the coast and therefore site specific

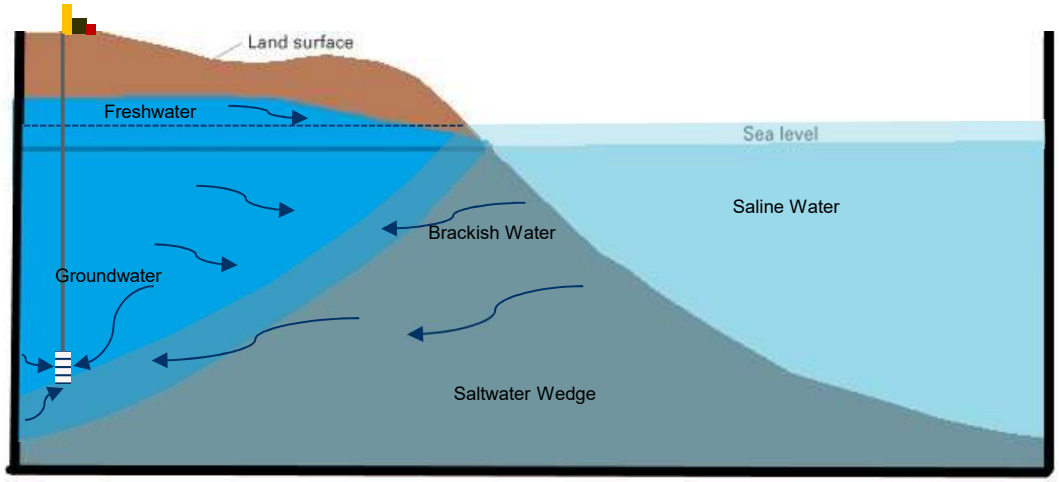
Generally, long term tidal influences on gradients are not considered a major concern for many remediation projects

Shallow Groundwater, Sea Level and Humans

Current Conditions



Sea Level Rise Conditions

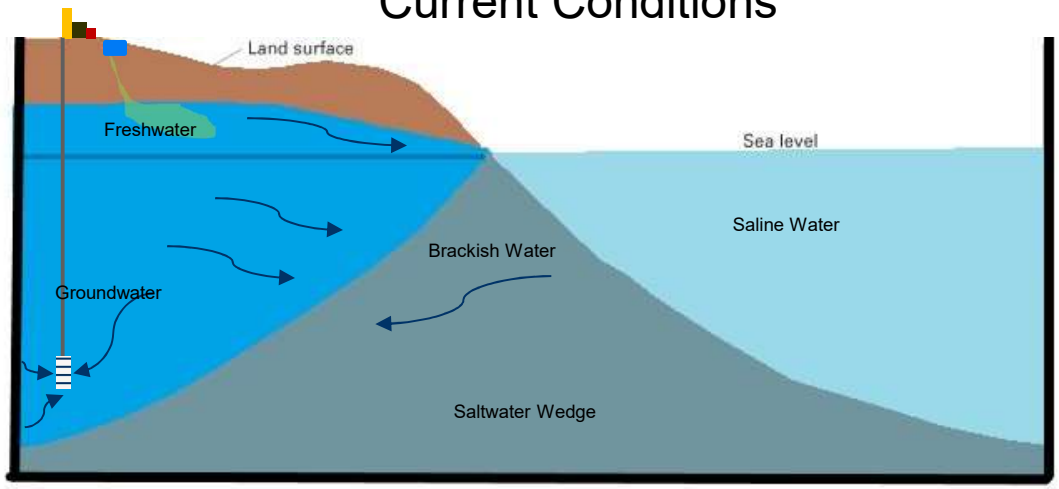


Typically, most military installations near the coast include infrastructure, or are near population centers

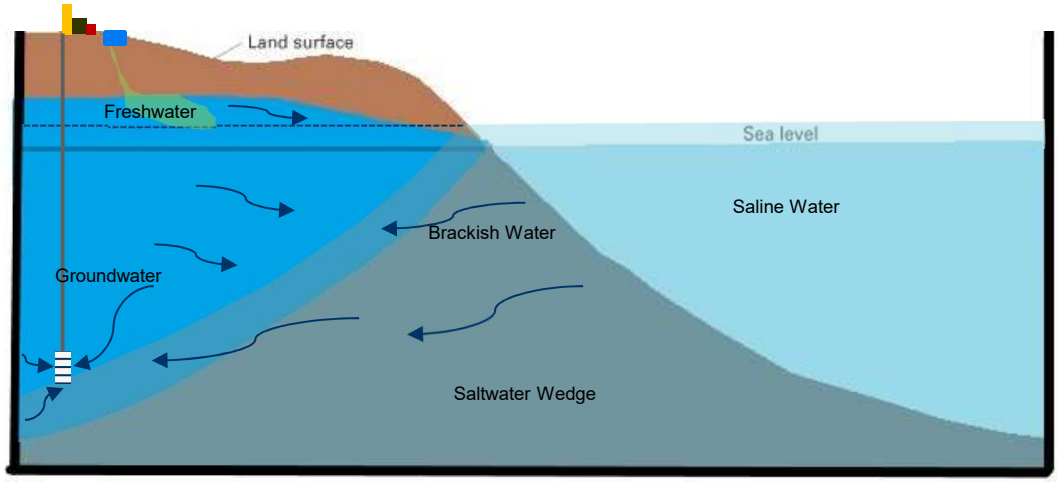
With the presence of human activity, come additional considerations and impacts on sea level rise

Shallow Groundwater and Sea Level in Developed Areas with Contaminated sites

Current Conditions



Sea Level Rise Conditions

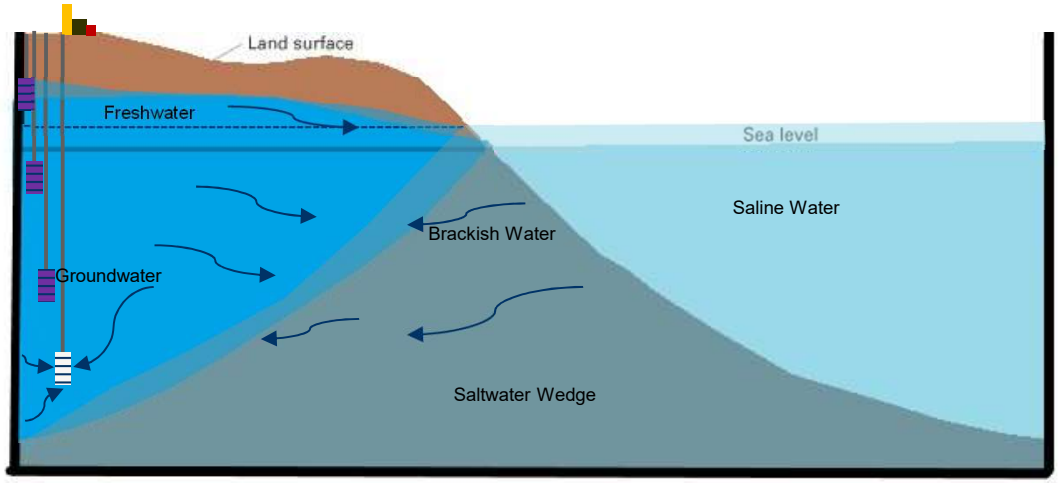


Impacts of anthropogenic activities are taken into consideration during remedial design, and even with the impacts of sea level rise would likely not result in remedy failure if properly accounted for

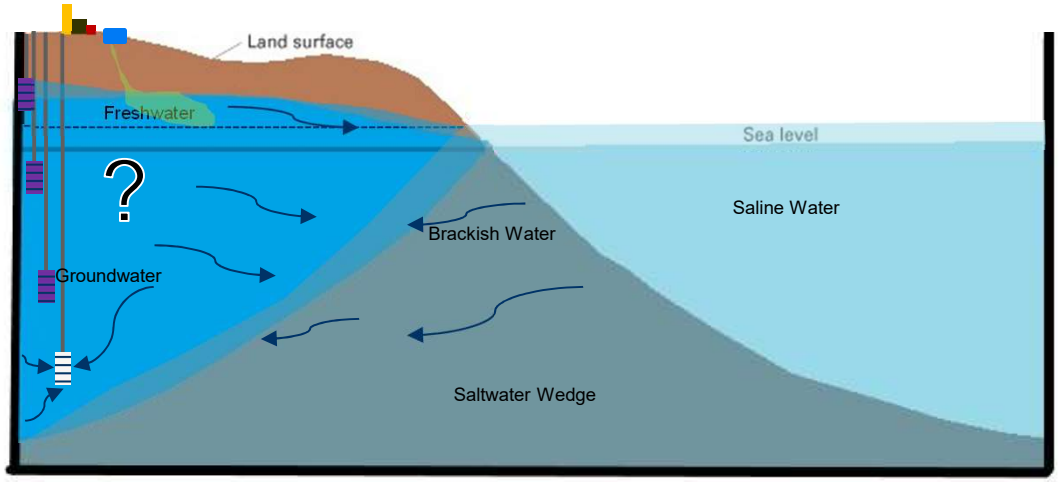
Ultimately, in this case, a remedy would need to be assessed with any changes in operation taken into account, however this would be done during the five-year review process

The Human Element

Sea Level Rise Corrective Actions



Sea Level Rise Conditions



Changes in regional conditions have different impacts depending on the location, but the likelihood of local populations not attempting to counteract negative impacts is small. Counteractive measures can include (but are not limited to):

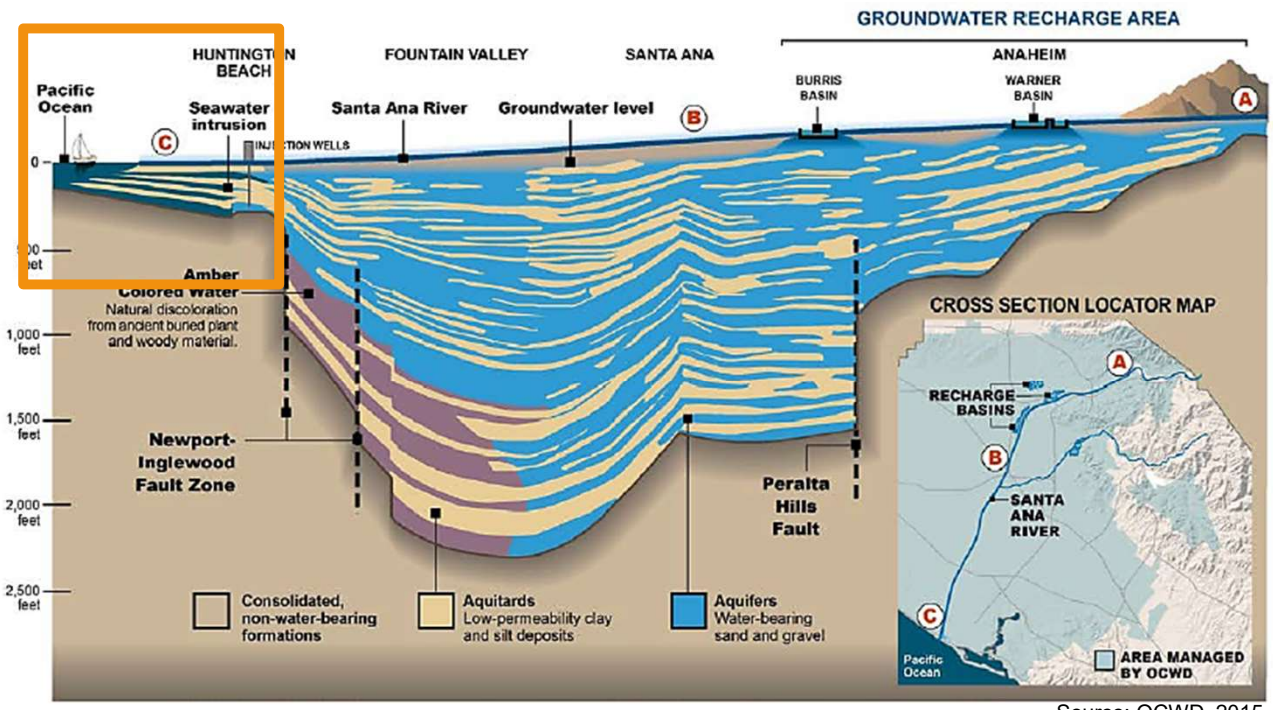
- Reductions in regional pumping
- Surface water control mechanisms (rip rap, sea walls, etc.)
- Infiltration barriers
- Relocation of production centers to accommodate/minimize saltwater intrusion at depth

What are the impacts of such activities on plume migration?

CASE STUDY: NAVAL WEAPONS STATION SEAL BEACH IR SITE 70

Orange County Hydrogeology

- Down gradient portion of the Santa Ana River Watershed
- Unconfined conditions at depth with semi-confined conditions in the shallow zones
- Newport-Inglewood Fault acts as the primary (if leaky) coastal barrier to seawater intrusion
  - when inland groundwater levels are below sea level intrusion can occur in vital areas



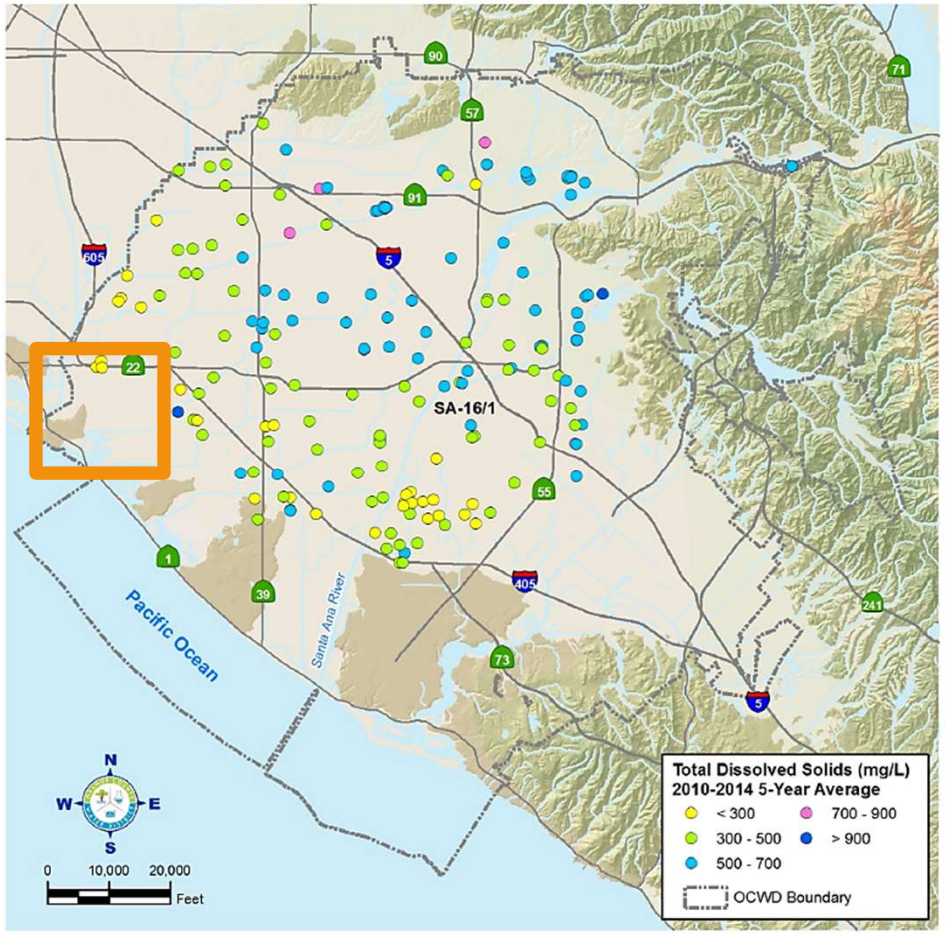
Source: OCWD, 2015

Figure 3-2: Geologic Cross-Section, Orange County Groundwater Basin

Approximate location of installation

Regional Salinity

Source: OCWD, 2015



Source: OCWD, 2015

Figure 7-7: Sunset Gap Monitoring and Production Wells with Chloride Concentration Contour

Approximate location of installation

Sunset Gap Intrusion

- Basin monitoring for potential seawater intrusion in the vicinity of the Sunset Gap began in the 1950s.
- Through county scientific investigation it was determined that seawater intrusion through the gap would likely be prevented through the installation of additional injection wells

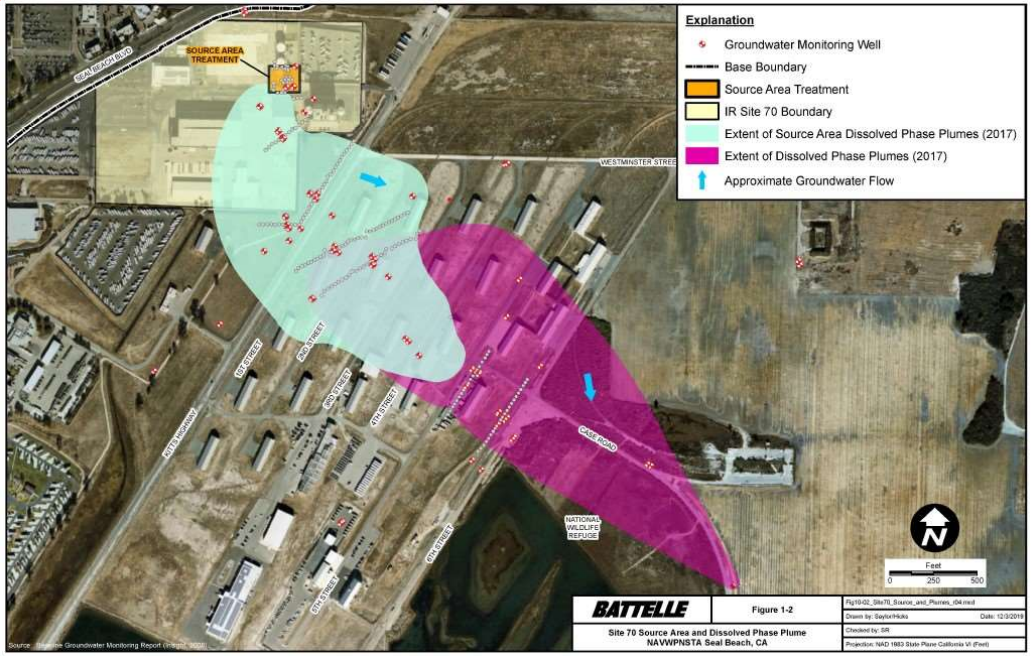
Source: OCWD, 2017

Figure 2-2: Fault Zones

Approximate location of installation

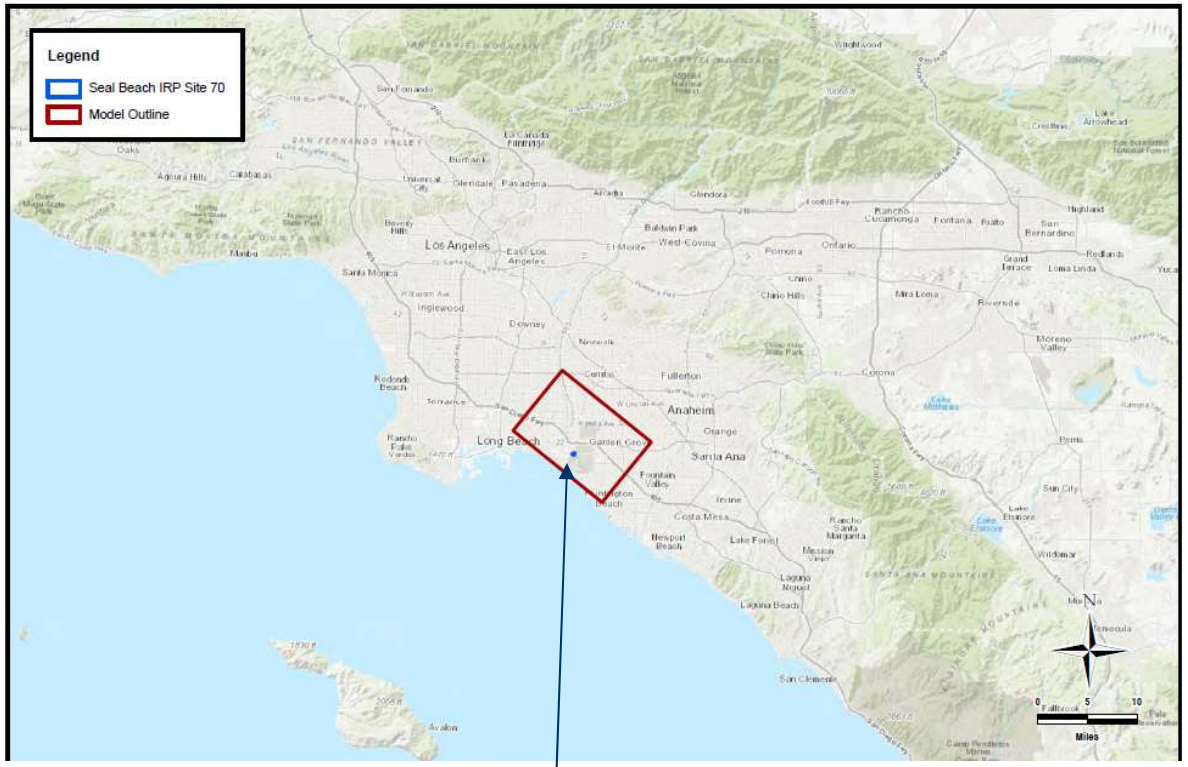
IR Site 70 Background

- DNAPL plume ~10 to 50 ft bgs over an area of 23,000 ft2
- 4,000 ft-long dissolved phase plume extending to a depth of ~160 ft bgs
- Complex shallow site geology with many discrete subzones, but five principal units
- Installation of permeable reactive barriers (PRBs) was completed between 2008 and 2010
- Emulsified vegetable oil (EVO) and KB-1 culture introduced to stimulate in-situ bioremediation
- Additional EVO injected in 2013



Groundwater Modeling of Sunset Gap

- As the Installation was located in the area of the Sunset Gap, concern was raised about the potential impact of the planned injection system on shallow groundwater plumes



Site 70

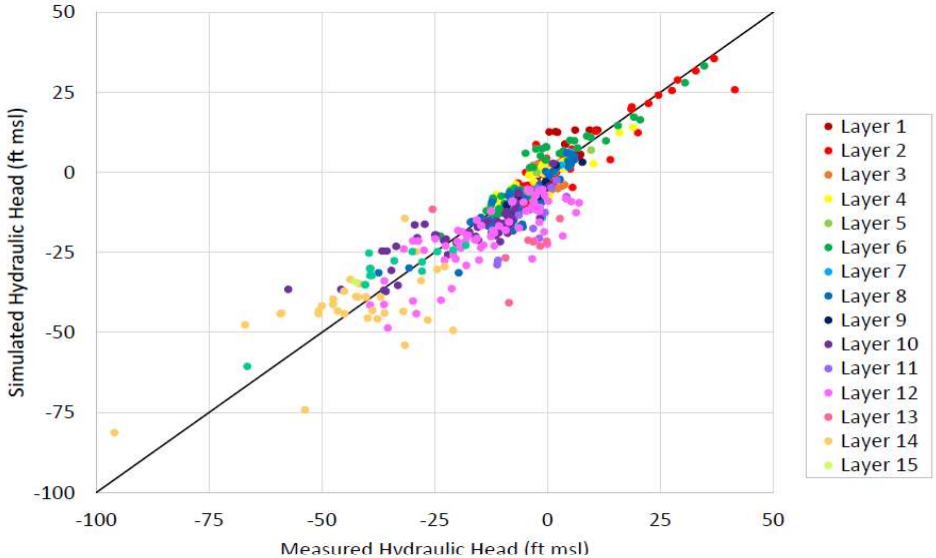
Local Geology and Modeled Zones

- Approximate plume depth

Age	Series	Formation Name	Aquifer Names					Model Layers	
			IRP Site 70 Model	Approximate Depth at Site (ft bgs)	OCWD Designations	Alamitos Barrier	OCWD Aquifer System	OCWD Sunset Gap	IRP Site 70
Recent	Holocene	Recent	Upper Fines	0-60	Perched/Other		Shallow	(not represented)	1
Quaternary			First Sand	60-105	Recent, Talbert, Bolsa	Recent		1	2
								2 (aquitard)	3
			Shell Horizon Unit	105-135	Upper Alpha	C Zone		3	4
								4 (aquitard)	5
			Second Sand Unit	135-170	Lower Alpha	B Zone		5	6
	Upper Pleistocene	Lakewood	Deep Clay Unit	170-190				6 (aquitard)	7
			Deep Sand Unit	>190	Beta	A Zone (upper)	Principal	7	8
								8	9
					Lambda	A Zone (lower)		9	10
								10 (aquitard)	11
	Lower Pleistocene	San Pedro			Omicron	I Zone (upper)		11	12
					Upper Rho	I Zone (lower)			
								12 (aquitard)	13
					Lower Rho	Main		13	14
					Main	Main			
								14 (aquitard)	15
					Lower Main	Sunnyside	Deep	15	16

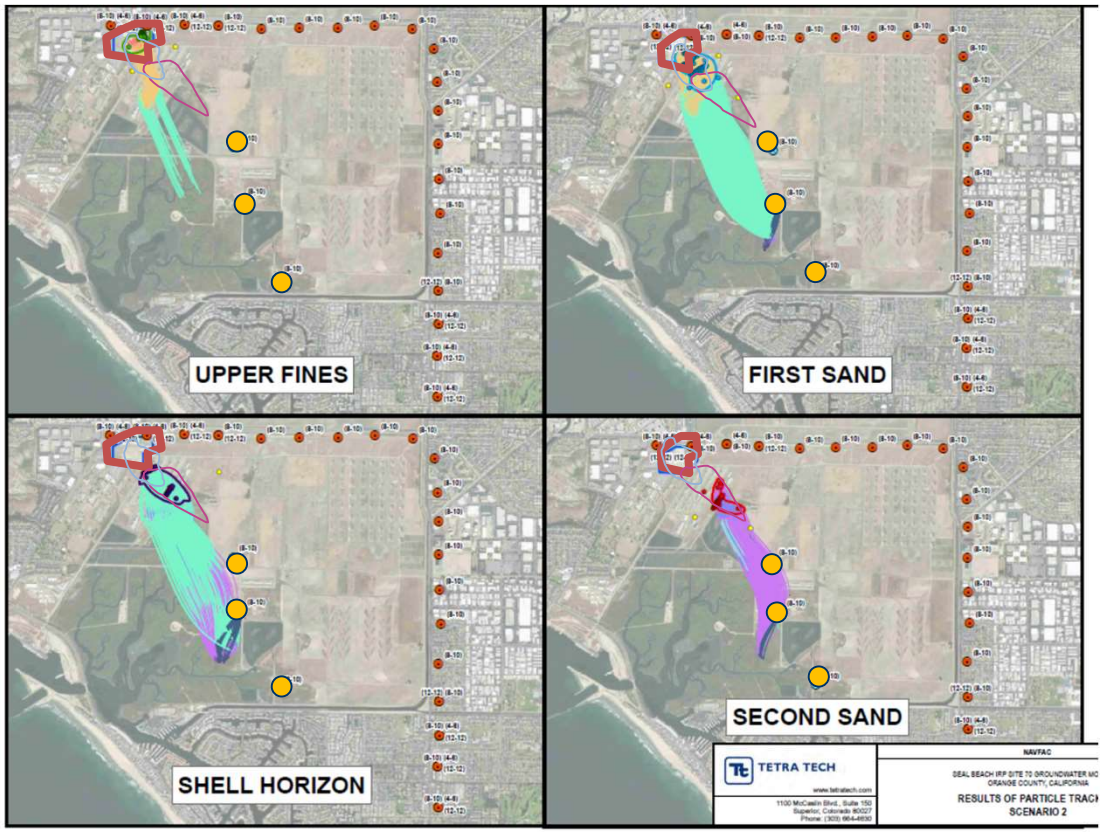
Steady State Model Calibration

- Modified Sunset Gap model provided by OCWD
- Converted to Steady State
- Added additional surficial aquifer units
- Re-Calibrated
- Simulated potential extent of plume deviation (if any) using particle tracking



Metric	Steady-State Value	Units
Residual Mean	1.74	feet
Minimum Residual	-20.88	feet
Maximum Residual	32.20	feet
Range of Observations	137.44	feet
Standard Deviation	6.49	feet
Absolute Residual Mean	4.60	feet
Scaled Statistics		
Mean/Range	0.013	
Absolute Mean/Range	0.034	
Standard Deviation/Range	0.047	
Number of Observations	545	

Model Findings



In general, particle tracking suggested that the large injection system at depth could contribute to a change in direction of flow from the current plume footprint

Further work with regional stakeholders is anticipated to alleviate deviation of plume footprint

Conclusions and Remarks

- Sea level rise is a DoD priority for installation resiliency and warfighter protection
- Groundwater can be impacted both directly and secondarily by sea level rise
- Anthropogenic considerations change as sea level mitigation activities are designed and implemented
- Any major changes to flow directions should be assessed regarding their impact to potential site remedy impacts
- In the case of this case study, more investigations are warranted after initial assessments showed potential for remedy impacts
- The best path forward towards addressing these impacts is proactive, rather than after the installation of a mitigation strategy

Naval Facilities Engineering Systems Command

EXWC Engineering & Expeditionary Warfare Center

THANK YOU

Sophia Lee

NAVFAC EXWC

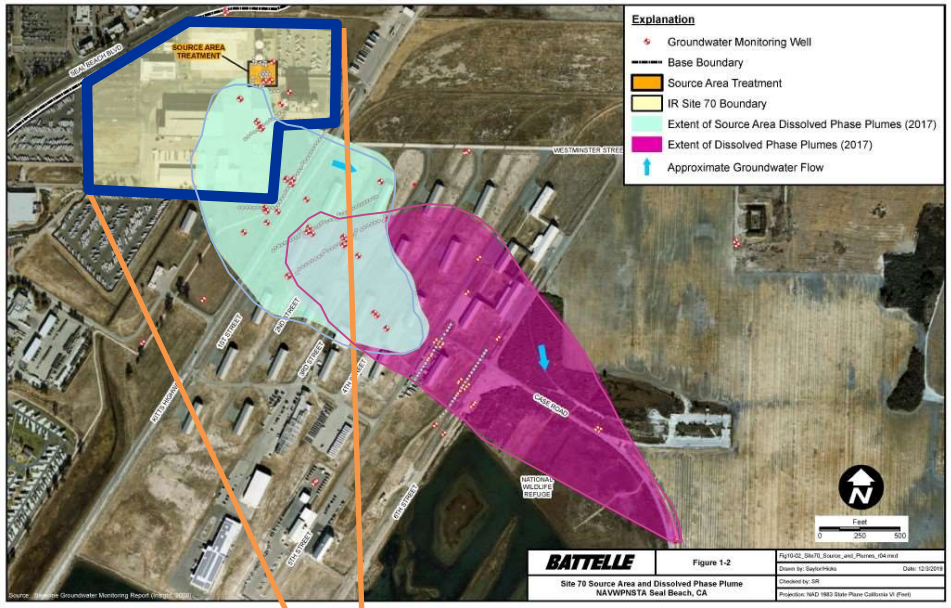
Sophia.a.lee6.civ@us.navy.mil

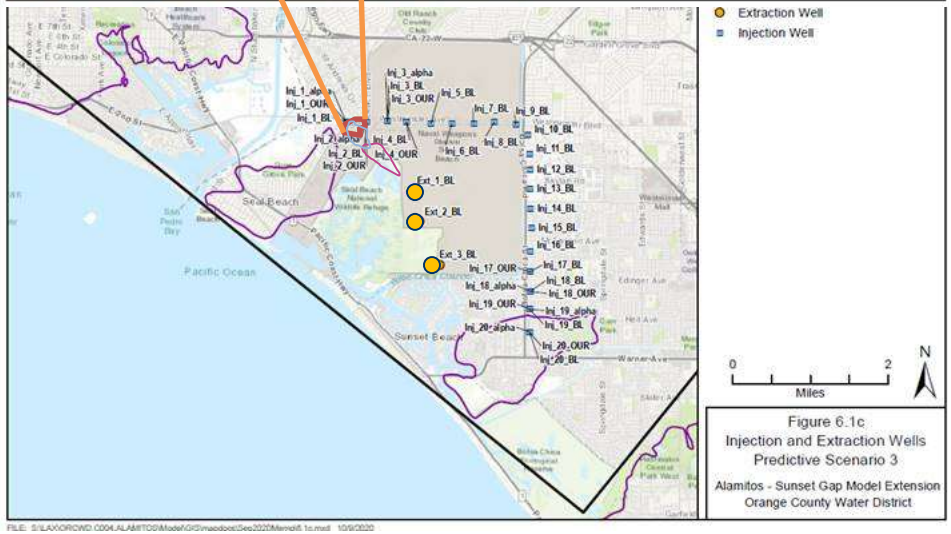
References

- United States. Department of Defense. *Department of Defense 2014 Climate Change Adaptation Roadmap*. Office of the Deputy Under Secretary of Defense for Installations and Environment, 2014.
- Maurer, Diana. *Climate Resilience: DOD Needs to Assess Risk and Provide Guidance on Use of Climate Projections in Installation Master Plans and Facilities Designs*. GOVERNMENT ACCOUNTABILITY OFFICE WASHINGTON DC, 2019.
- Woodside, Greg and Westropp, Marsha. *Orange County Water District Groundwater Management Plan 2015 Update.* Orange County Water District, 2015.
- Orange County Water District. *Basin 8-1 Alternative.* Orange County Water District, 2017.
- U.S Bureau of Reclamation. *Climate Change Analysis for the Santa Ana River Watershed, Santa Ana Watershed Basin Study, California Lower Colorado Region*. U.S. Bureau of Reclamation, Water and Environmental Resources Division (86-68200) Water Resources Planning and Operations Support Group (86-68210) Technical Services Center, Denver Colorado Technical Memorandum No. 86-68210-2013-02. 2013.

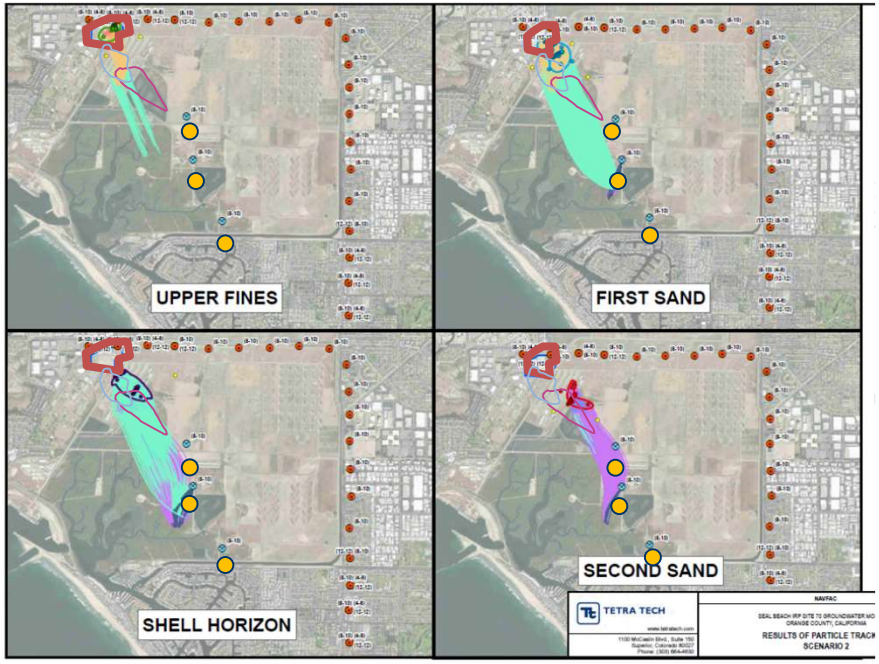
BACKUP SLIDES

Seal Beach IRP Site 70 GW Modeling





- IRP Site70 is located on NWSTA Seal beach in Seal Beach, CA
- Dissolved Phase Plume: Two Biobarriers in the First Sand, two in the Shell Horizon, and one in the Second Sand
- Local Water District is installing sea water intrusion barriers to counteract sea level rise and local pumping conditions
- Modeling of proposed plan (TO 27) shown to potentially directly impact TCE plumes at depth



Regional Watershed

Source: OCWD, 2017

Figure 5-4: Santa Ana River Watershed

Impacts of Climate Change

- The U.S. Bureau of Reclamation conducted a study in collaboration with SAWPA of the potential impacts to water resources due to climate change in the Santa Ana River Watershed.
- (USBR, 2013)Likely impacts of changing climatic conditions in the Santa Ana River Watershed include a decrease of surface water supplies, increase in temperatures, more severe flood events, and increase dependency on groundwater supplies.

Source: OCWD, 2015

- Regional mean sea level along the Southern California coast is projected to rise by 1.5 to 12 inches by 2030, 5 to 24 inches by 2050, and 16 to 66 inches by 2100. Regional sea level rise may be higher or lower than global mean sea level rise due to regional changes in atmospheric and ocean circulation patterns.
- Sea level rise is likely to increase the coastal area vulnerable to flooding during storm events. OCWD conducted a study to evaluate the potential effects of projected sea level rise on coastal Orange County groundwater conditions

Source: OCWD, 2015

Precipitation

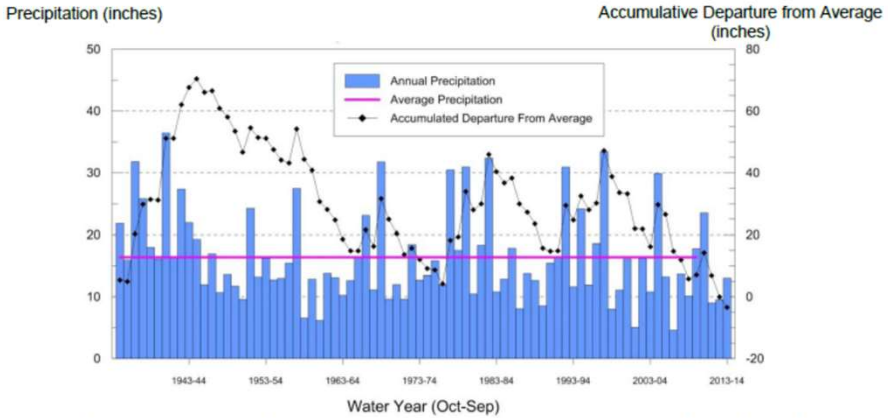


Figure 5-7: Precipitation at San Bernardino, Water Year (Oct.-Sept.) 1934-35 to 2013-14

Source: OCWD, 2015

Groundwater Withdrawals

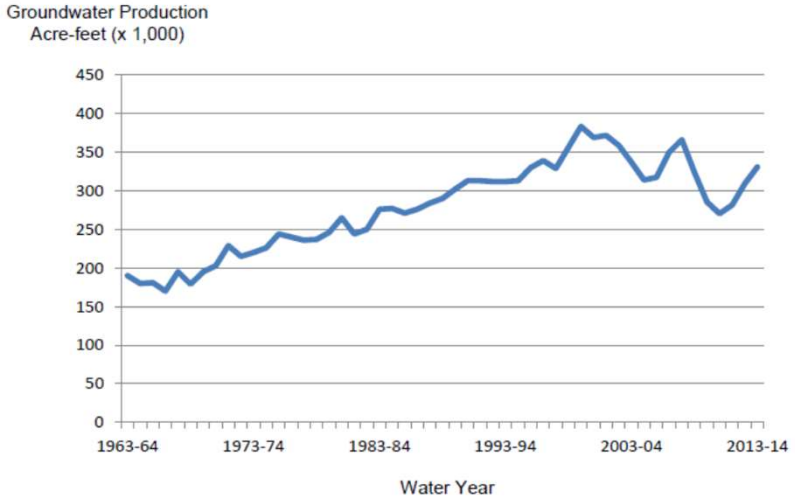


Figure ES-9: Groundwater Production, Water Year 1963-64 to 2013-14

Source: OCWD, 2015

Sunset Gap

Figure 7-7: Sunset Gap Monitoring and Production Wells with Chloride Concentration Contour

Source: OCWD, 2015

- Two locations were selected for analysis near the Talbert and Alamitos seawater intrusion injection barriers. The study model used data from well logs, aquifer pump tests, groundwater elevation measurements, hand-drawn contour maps, geologic cross sections, water budget spreadsheets and other data stored in OCWD's Water Resources Management System database.
- In the case of the Alamitos Barrier, seawater intrusion throughout the gap would likely be prevented once current plans to construct additional injection wells are implemented.
- A future southern extension of the barrier is being investigated to halt the eastern migration of saline water into the Sunset Gap.

Source: OCWD, 2015