

THE ANTHROHYDROLOGIC CONCEPTUAL MODEL FOR GROUNDWATER REMEDY DESIGN UNDER CLIMATE CHANGE

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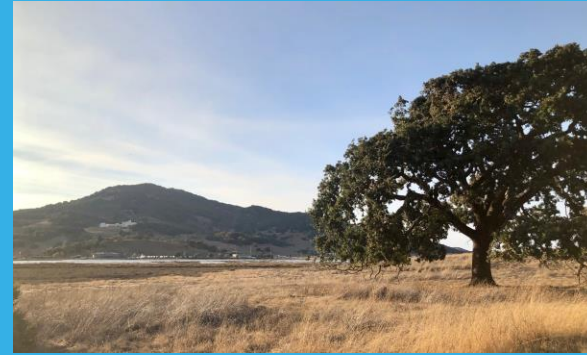
March 29-30, 2022

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Warner, et al., 2022. Integrating Anthrohydrology into the
Groundwater Remedy Design Process. Environmental
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*Pacific Ocean
from Bodega Head,
Sonoma County, Calif USA
All photos by S. D. Warner*

HONOURING CARETAKERS OF THE LAND



We acknowledge the Traditional Custodians of the land in which we reside and pay our respect to Elders past, present and emerging.

We extend this acknowledgement to the Awabakal people of the land in which the Uni Newcastle Callaghan campus resides and which we work.

We extend this acknowledgement to the Miwok people of the land in coastal Northern California in which the presenter resides and works.

Organization for Today's Discussion

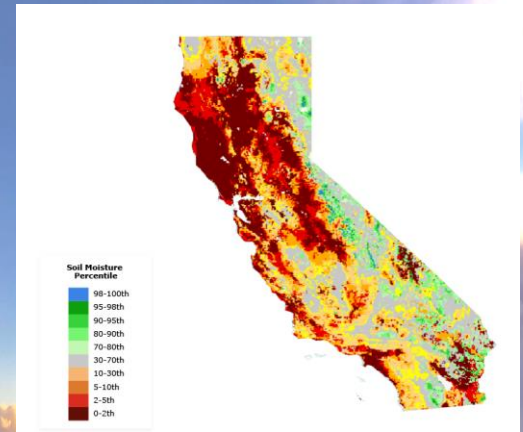
❖ Why this Topic / What is Different

- ❖ Adequacy of Integration:
 - Hydrologic Cycle
 - Conceptual Hydrologic Model
 - Anthropogenic Influence

❖ Climatic/Hydrologic Stress and Remedy Design

❖ Closing

Background photograph: Marin County, California USA after record precipitation March 2019



Above: Soil Moisture Map, California, 3/16/2022 <https://cwww.water.ca.gov/>

Below: Air quality degradation Northern California Wildfires, September 2020

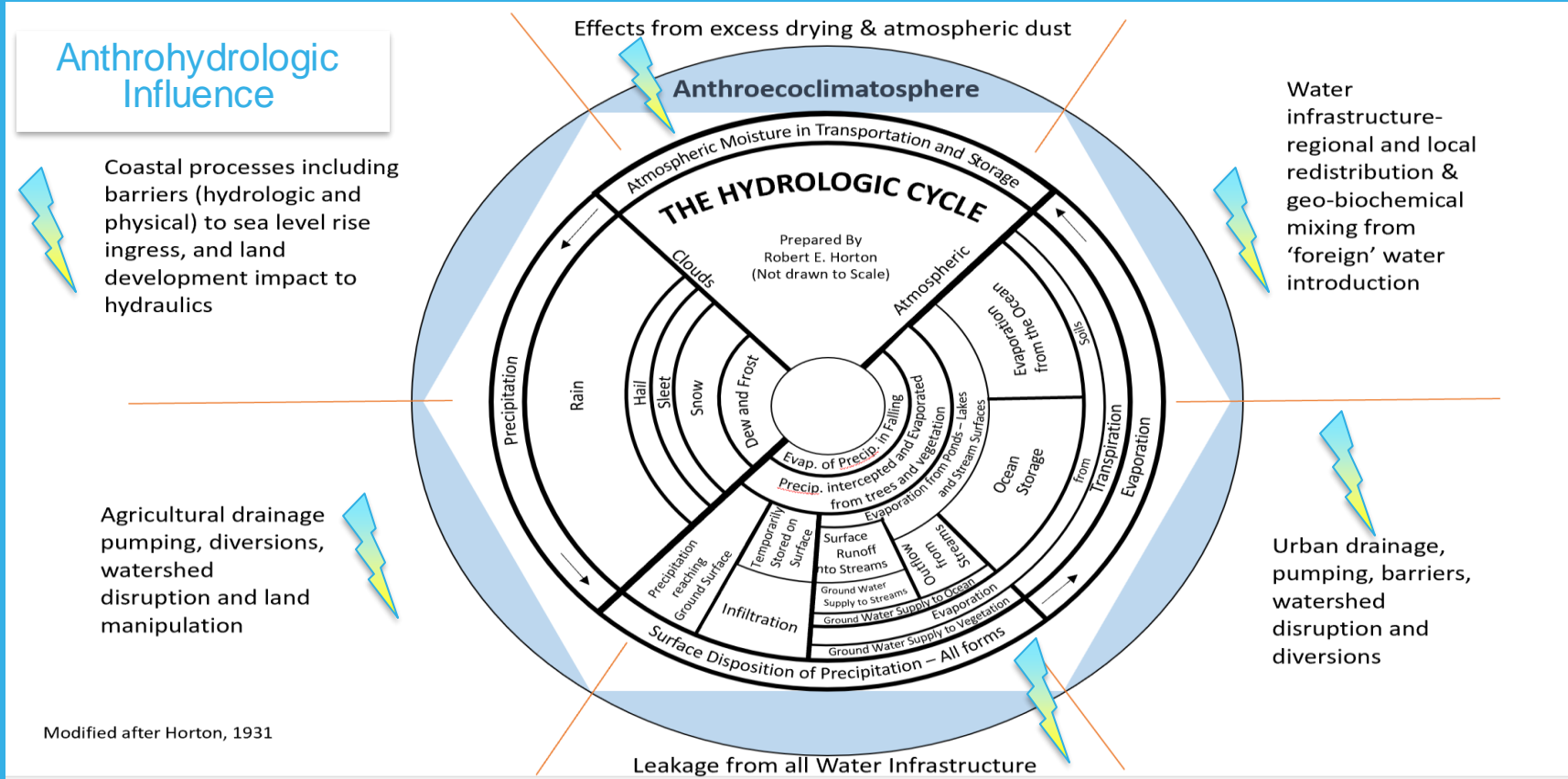
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THE HYDROLOGIC CYCLE



THE HYDROLOGIC CYCLE – Anthropogenic Contribution

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Horton, R. E., 1931a. The field, scope, and status of the science of hydrology. *Transactions, American Geophysical Union*, 12(1). <https://doi.org/10.1029/TR012i001p00189-2>

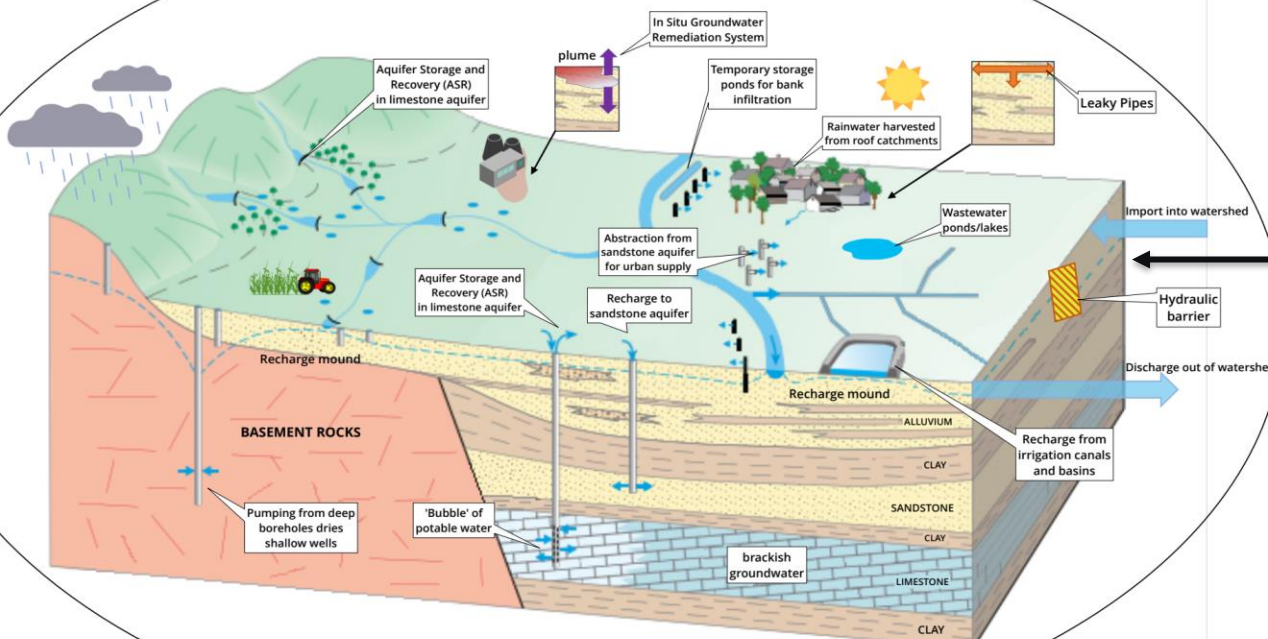
CONCEPTUAL HYDROLOGIC MODEL (CHM) CHM + Anthropogenic Influence

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Integrating Anthrohydrology into the Groundwater Remedy
Design Process. *Environmental Technology & Innovation*

Climatic Stress increase with time →

Vulnerability Envelope

$$\Sigma \text{ Hydrologic Cycle} = f(H^0 + \Delta H^A)$$



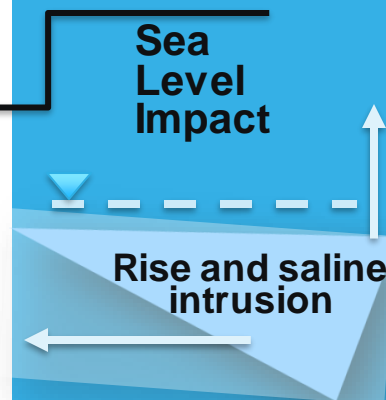
Remedial Design as a function of system stress over time

Modified after IAH (2019) Climate Change
Adaptation and Groundwater
(https://iaah.org/wp-content/uploads/2019/07/IAH_Climate-ChangeAdaptationGdwtr.pdf)

$$H^0 = \text{Natural Hydrologic cycle} \quad | \quad H^A = \text{Anthropogenic influence on } \Delta H^0$$

Sea
Level
Impact

Rise and saline
intrusion



THREAT OF CLIMATIC FACTORS TO CONTAMINANT SITES NATURAL AND ANTHROPOGENIC

USGAO (2019) Superfund Vulnerability <https://www.gao.gov/assets/710/702306.pdf>

ENGLISH 中文 (CHINESE) ESPAÑOL

The New York Times

Tuesday, February 6, 2018 | Today's Paper | Video | 77°F | Shanghai -3.35% ↓

Floods Are Getting Worse, and 2,500 Chemical Sites Lie in the Water's Path

By HIROKO TABUCHI, NADJA POPOVICH, BLACKI MIGLIOZZI and ANDREW W. LEHREN FEB. 6, 2018

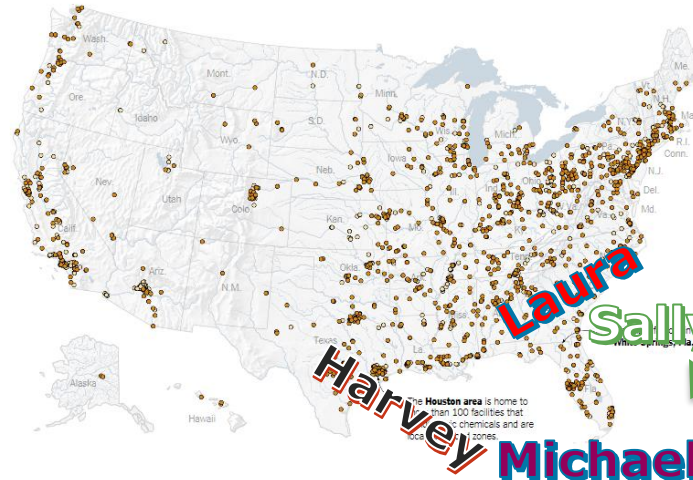
Anchored in flood-prone areas in every American state are more than 2,500 sites that handle toxic chemicals, a New York Times analysis of federal floodplain and industrial data shows. About 1,400 are located in areas at highest risk of flooding.

As flood danger grows — the consequence of a warming climate — the risk is that there will be more toxic spills like the one that struck Baytown, Tex., where Hurricane Harvey swamped a chemicals plant, releasing lye. Or like the ones at a Florida fertilizer plant that leaked phosphoric acid and an Ohio refinery that released benzene.

Source: NYT, February 6, 2018

More Than 2,500 Sites That Handle Toxic Chemicals
Are Located in Flood-Prone Areas Across the Country.

● Site in area at high risk of flooding ○ Site in area at moderate risk of flooding



Sandy

Florence

Laura

Sally

Harvey

Michael

15 Sept
2020



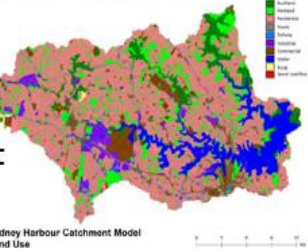
SEA LEVEL INUNDATION/GROUNDWATER INTERACTION CALIFORNIA AND AUSTRALIA



Fort Denison, Sydney Harbour

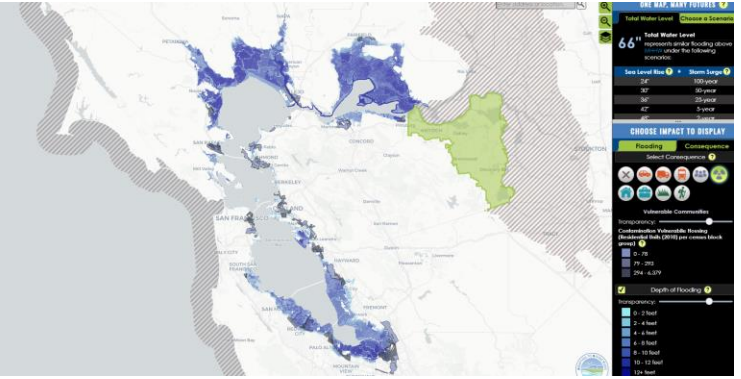
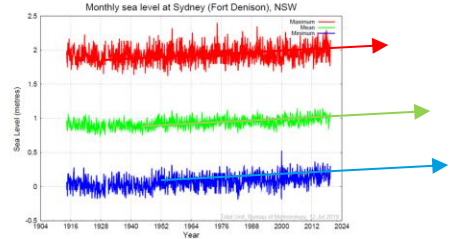
Figure 4: Land use in the Sydney Harbour catchment¹⁸

Sydney Harbour Catchment

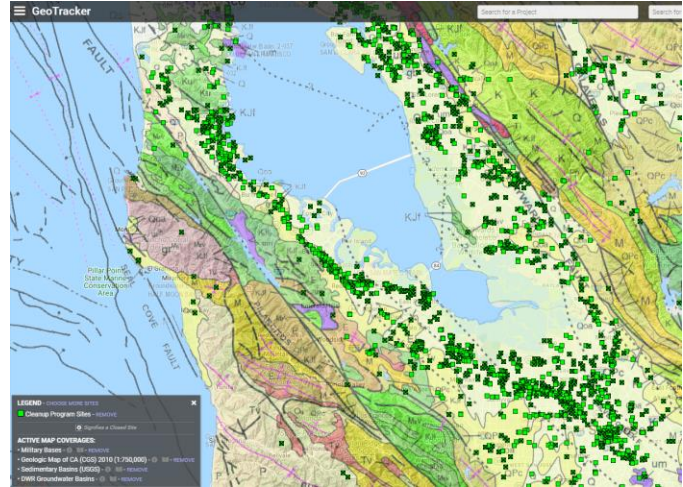


Sydney Harbour Catchment Model Land Use

Montoya, 2015. Briefing Paper No. 03/2015 for the NSW Parliamentary Research Service



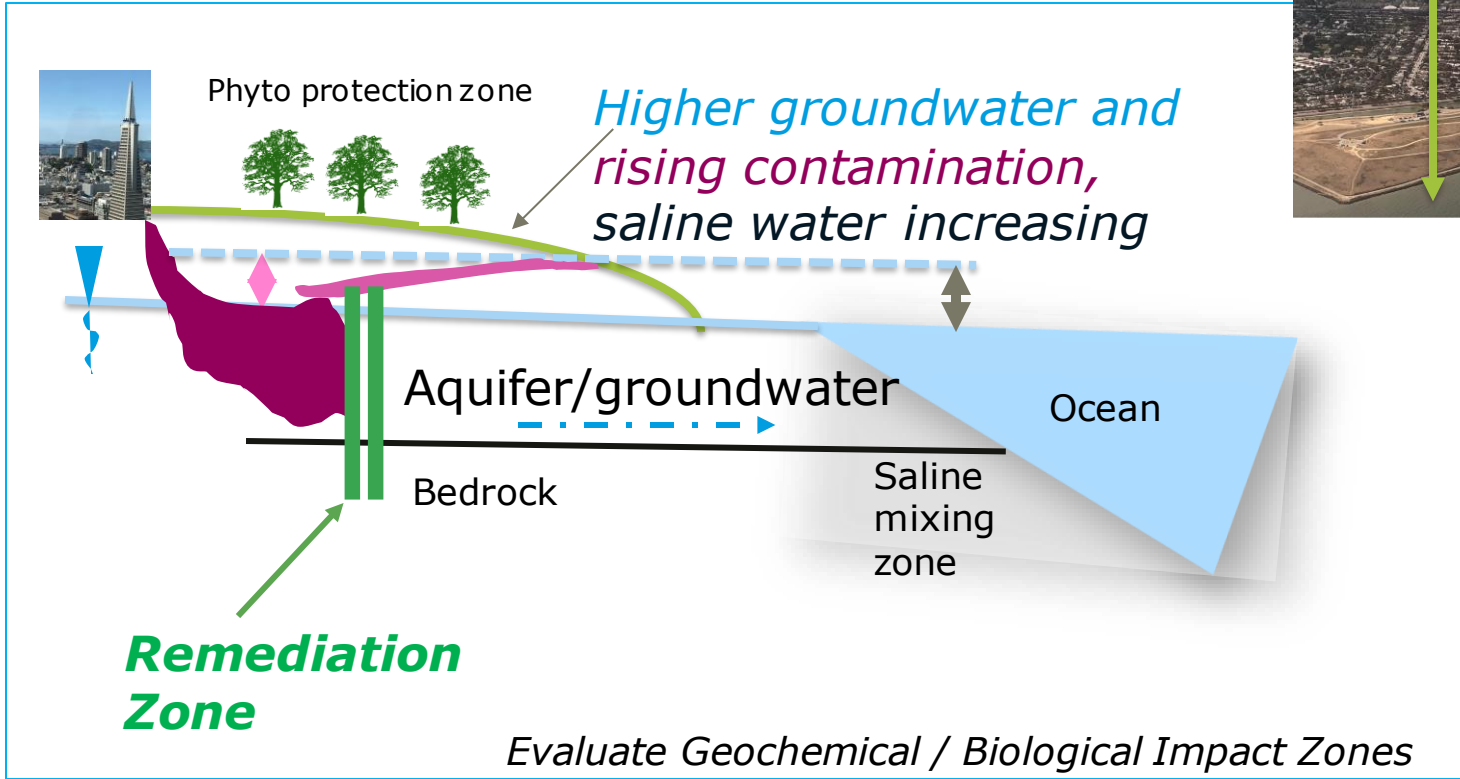
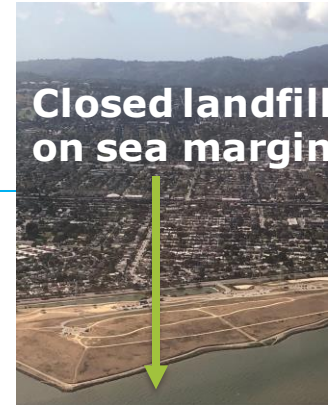
<https://www.adaptingtorisingtides.org/>



<https://geotracker.waterboards.ca.gov>

San Francisco Bay, USA
"Approximately 3000 clean-up sites may potentially be affected by sea level rise and groundwater rise."

REMEDIATION CHALLENGE WITH RISING SEAS/GROUNDWATER



CLIMATE-INDUCED POTENTIAL CHANGES CRITICAL TO REMEDIATION DESIGN PERFORMANCE

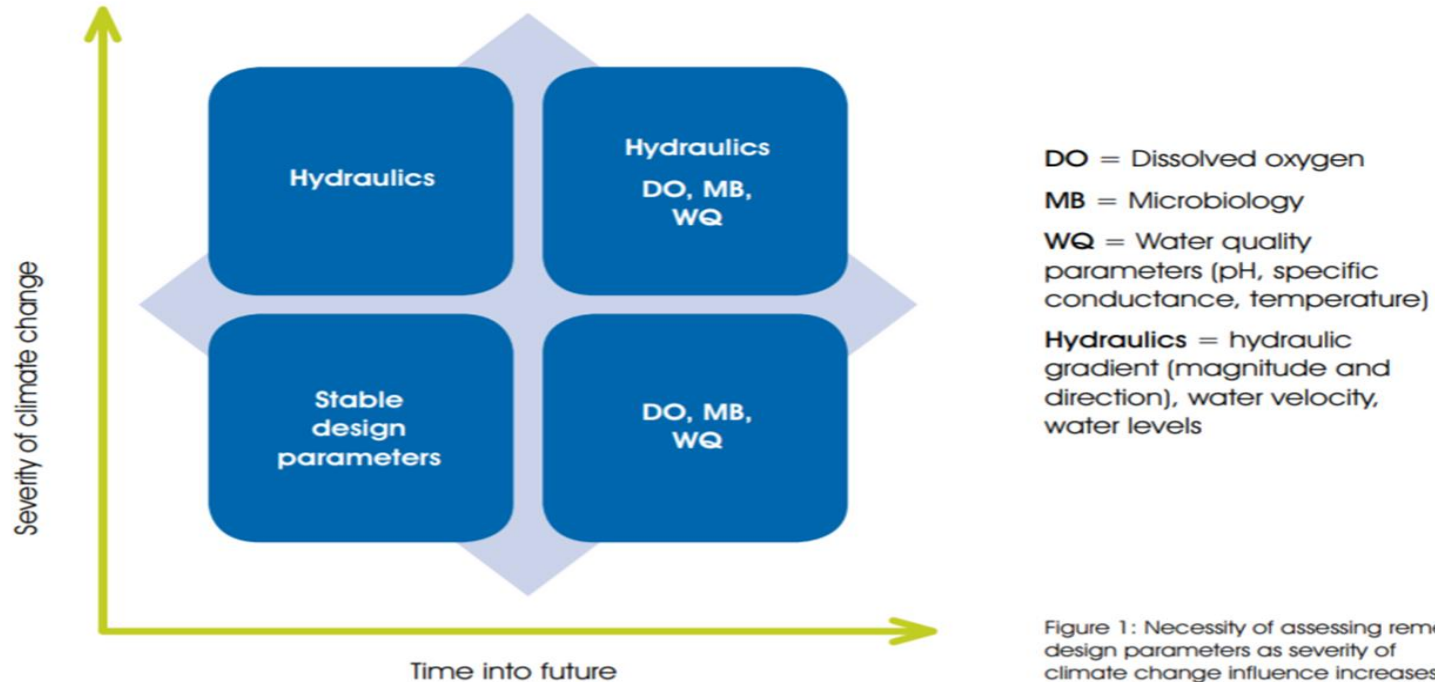


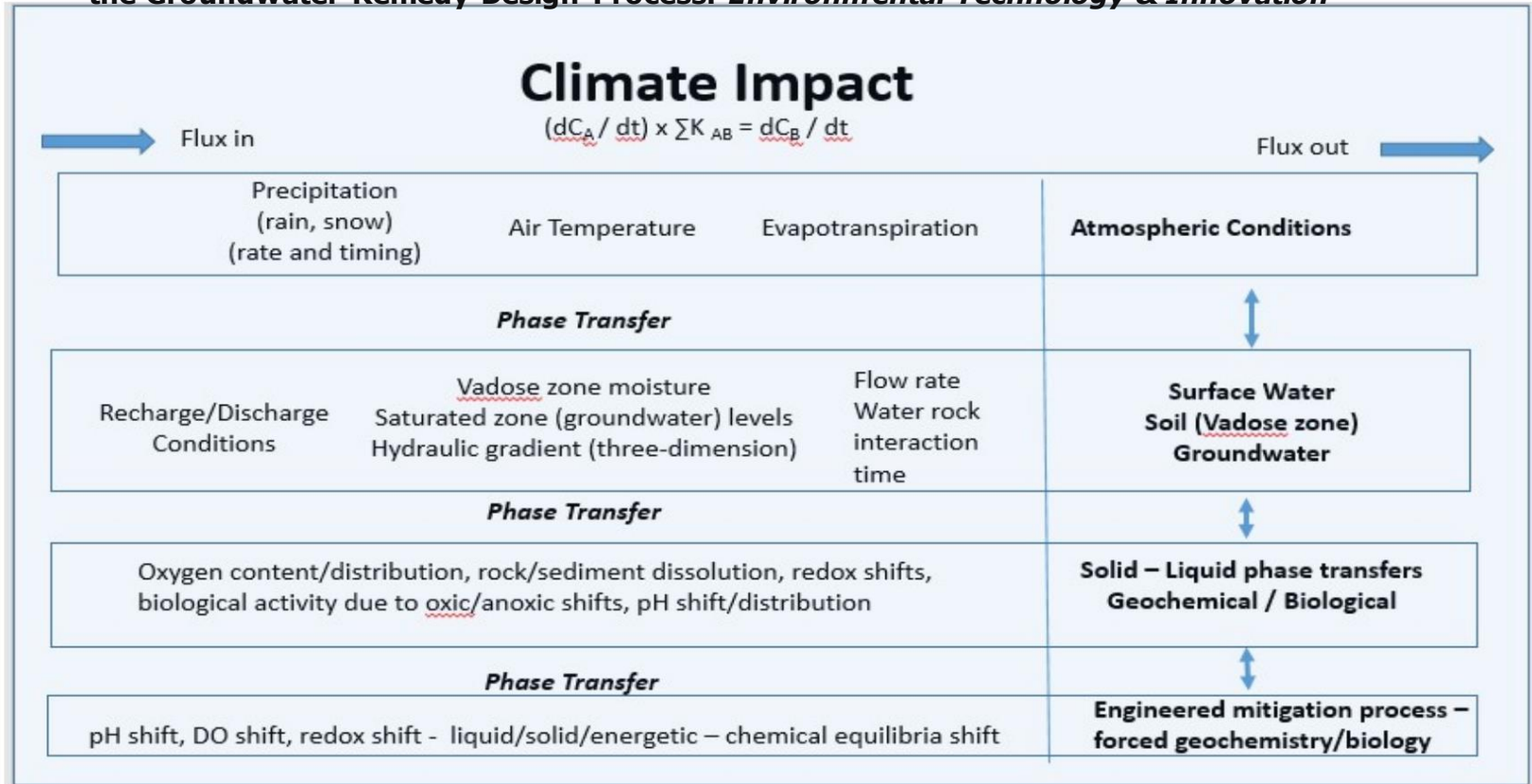
Figure 1: Necessity of assessing remedy design parameters as severity of climate change influence increases.

Warner (2014). *Remediation Australasia* No. 16

<https://www.crccare.com/files/dmfile/RemediationAustralasia161.pdf>

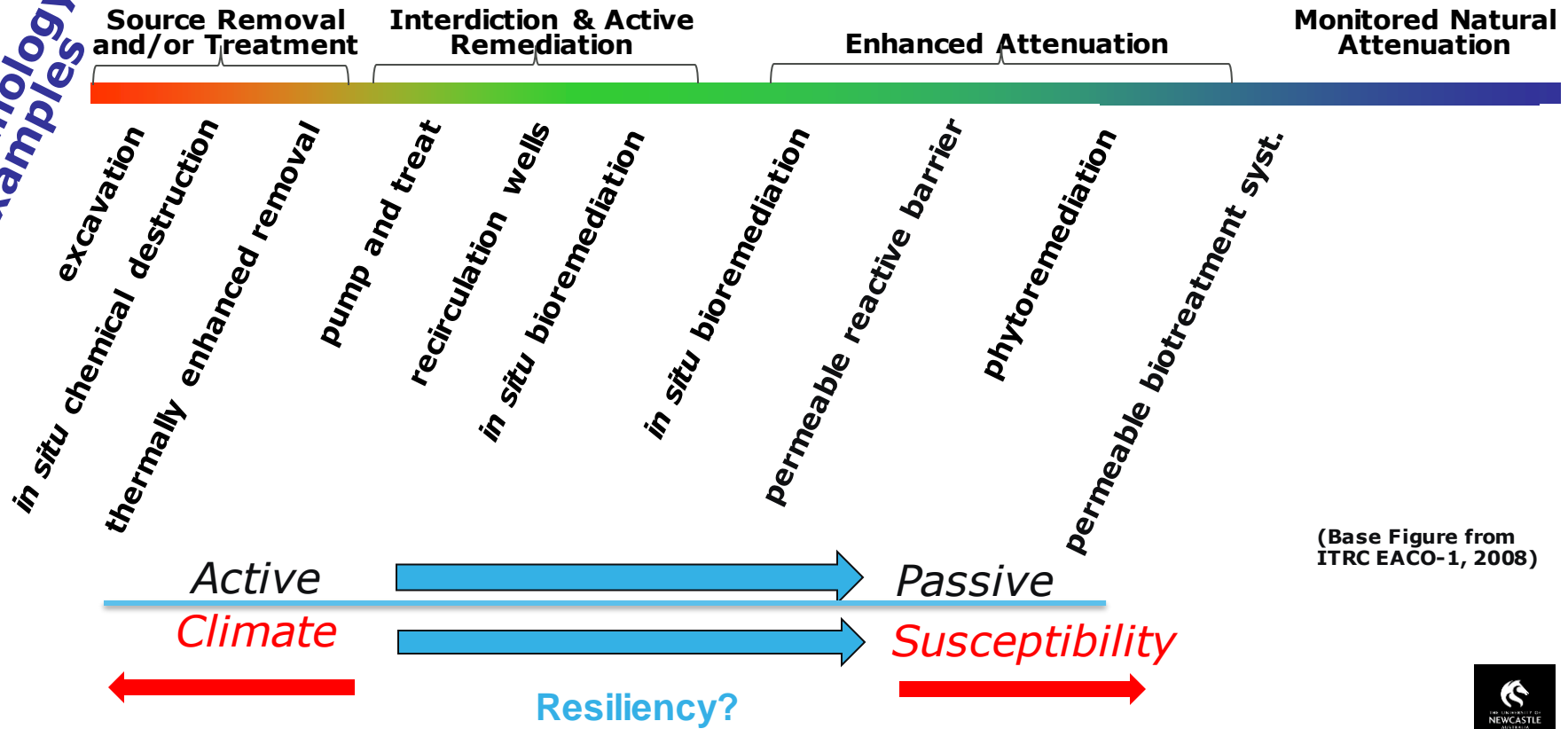
ANTHROPOGENIC HYDROLOGIC MODEL "ANTHYM"

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SUSCEPTIBILITY OF REMEDIATION MEASURES TO CLIMATE AND ANTHROPOGENIC INFLUENCE

Technology Examples



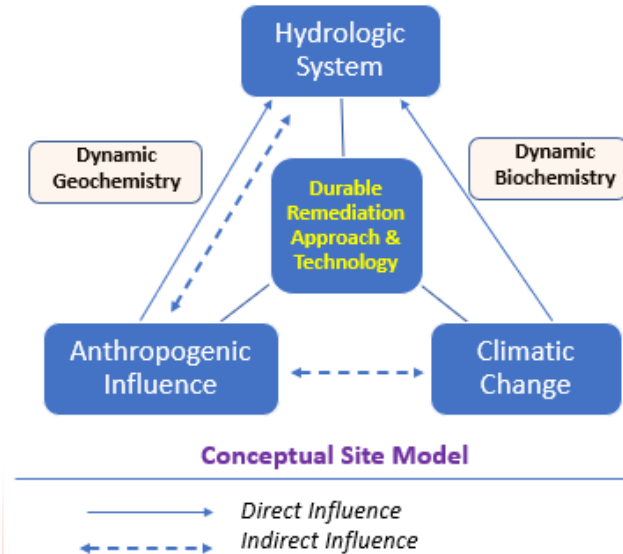
(Base Figure from ITRC EACO-1, 2008)



MODIFY THE CONCEPTUAL SITE MODEL (CSM) FOR CONTAMINATED LAND SITES USING FUTURE SCENARIOS

Framework for Sustainable and Durable Remediation Approach

Contaminant Occurrence and Distribution



Potential Vulnerabilities for Remedial Measures

- Sea level rise/**higher hydraulic** head near shore
- Land use changes to **hydrologic gradient** and drainage
- **Mobilization** of contaminant mass
- **Erosion** of protective barriers
- **Saline/geochemistry changes to remedial** methods including: *Bioremediation, abiotic, phytoremediation*
- Performance metrics – **longevity, uniformity, capture**

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CLOSING

- Evaluate anthropogenic influence – present and future – within the CHM.
- Lack of considering anthropogenic influence may result in deficiencies in:
 - ✓ Site characterization
 - ✓ Risk management approach for contaminated land
- Model or predictive scenarios would consider:
 - ✓ future hydrologic impacts
 - ✓ potential geochemical and biological changes
 - ✓ remedy vulnerabilities due to future changes
- The Anthropogenic Hydrologic Model (*ANTHYM*) is a process for evaluating, projecting, and testing evolving conditions.

THANK YOU

For additional information, please contact

SCOTT WARNER (415-328-0955)

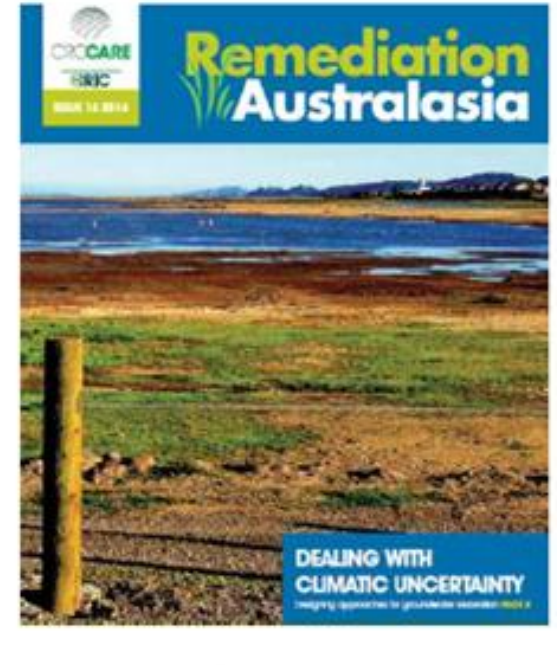
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<https://www.crccare.com/files/dmfile/RemediationAustralasia161.pdf>



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