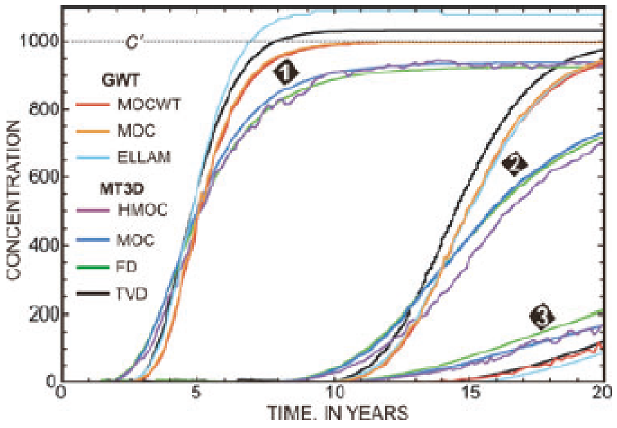
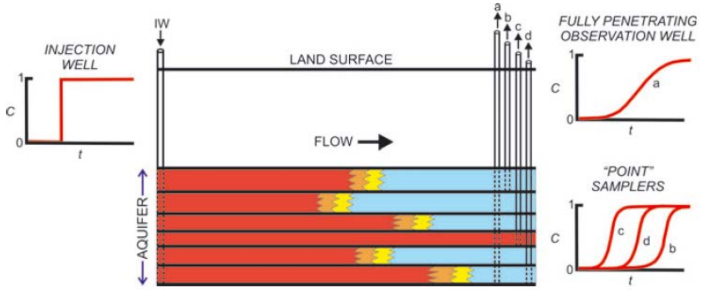
Contaminant Transport

Today's agenda

- Groundwater remediation
- Coastal hydrogeology

“...the secret to successful solute-transport modeling may simply be to lower expectations.”





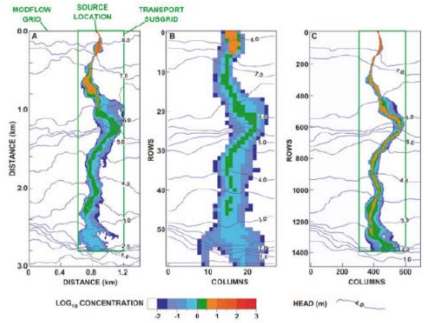
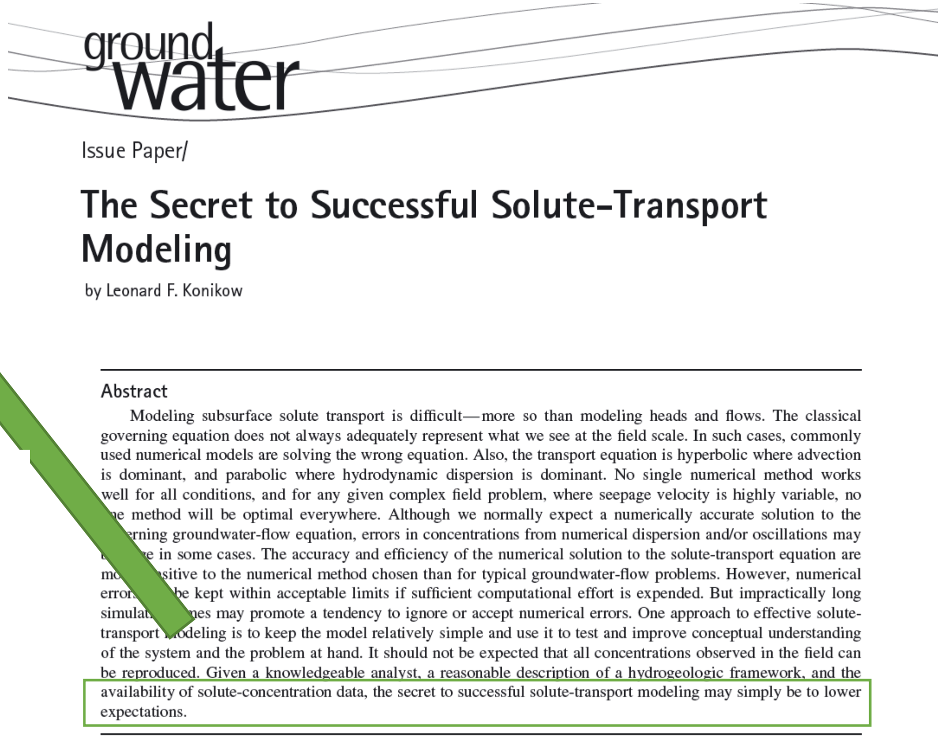


Figure 8. Effect of scale of discretization and resolution of heterogeneity on calculated heads and concentrations for case of hypothetical contaminant release from a leaky borehole in a regional aquifer: (A) grid spacing = 2 m; (B) grid spacing = 50 m; and (C) T defined on 50-m spacing from B, but numerical solution obtained using grid spacing = 2 m.


ground water

Issue Paper/

The Secret to Successful Solute-Transport Modeling

by Leonard F. Konikow

Abstract

Modeling subsurface solute transport is difficult—more so than modeling heads and flows. The classical governing equation does not always adequately represent what we see at the field scale. In such cases, commonly used numerical models are solving the wrong equation. Also, the transport equation is hyperbolic where advection is dominant, and parabolic where hydrodynamic dispersion is dominant. No single numerical method works well for all conditions, and for any given complex field problem, where seepage velocity is highly variable, no ...e method will be optimal everywhere. Although we normally expect a numerically accurate solution to the ...erning groundwater-flow equation, errors in concentrations from numerical dispersion and/or oscillations may ...e in some cases. The accuracy and efficiency of the numerical solutions to the solute-transport equation are mo... ...sitive to the numerical method chosen than for typical groundwater-flow problems. However, numerical error... ...be kept within acceptable limits if sufficient computational effort is expended. But impractically long simulat... ...nes may promote a tendency to ignore or accept numerical errors. One approach to effective solute-transport ...odeling is to keep the model relatively simple and use it to test and improve conceptual understanding of the system and the problem at hand. It should not be expected that all concentrations observed in the field can be reproduced. Given a knowledgeable analyst, a reasonable description of a hydrogeologic framework, and the availability of solute-concentration data, the secret to successful solute-transport modeling may simply be to lower expectations.

Groundwater remediation

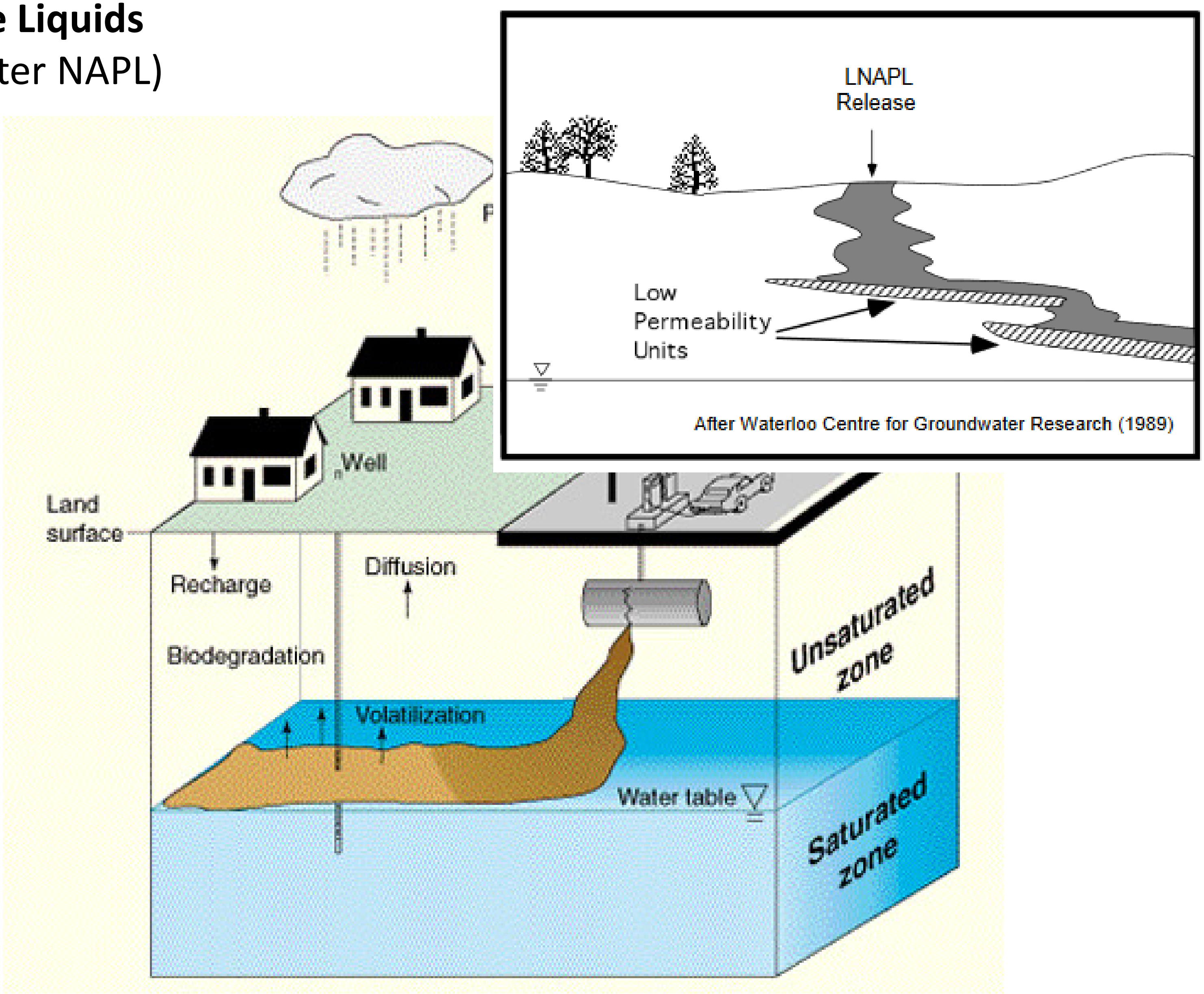
Immiscible compounds serve as a source of dissolved groundwater contamination.

NAPLs: Non-Aqueous Phase Liquids

LNAPL (lighter-than-water NAPL)

LNAPL (denser-than-water NAPL)

- Examples: gasoline (BTEX), diesel fuel
- Plume forms on surface of water table
- Migrates down water table gradient
- Must be skimmed



http://toxics.usgs.gov/

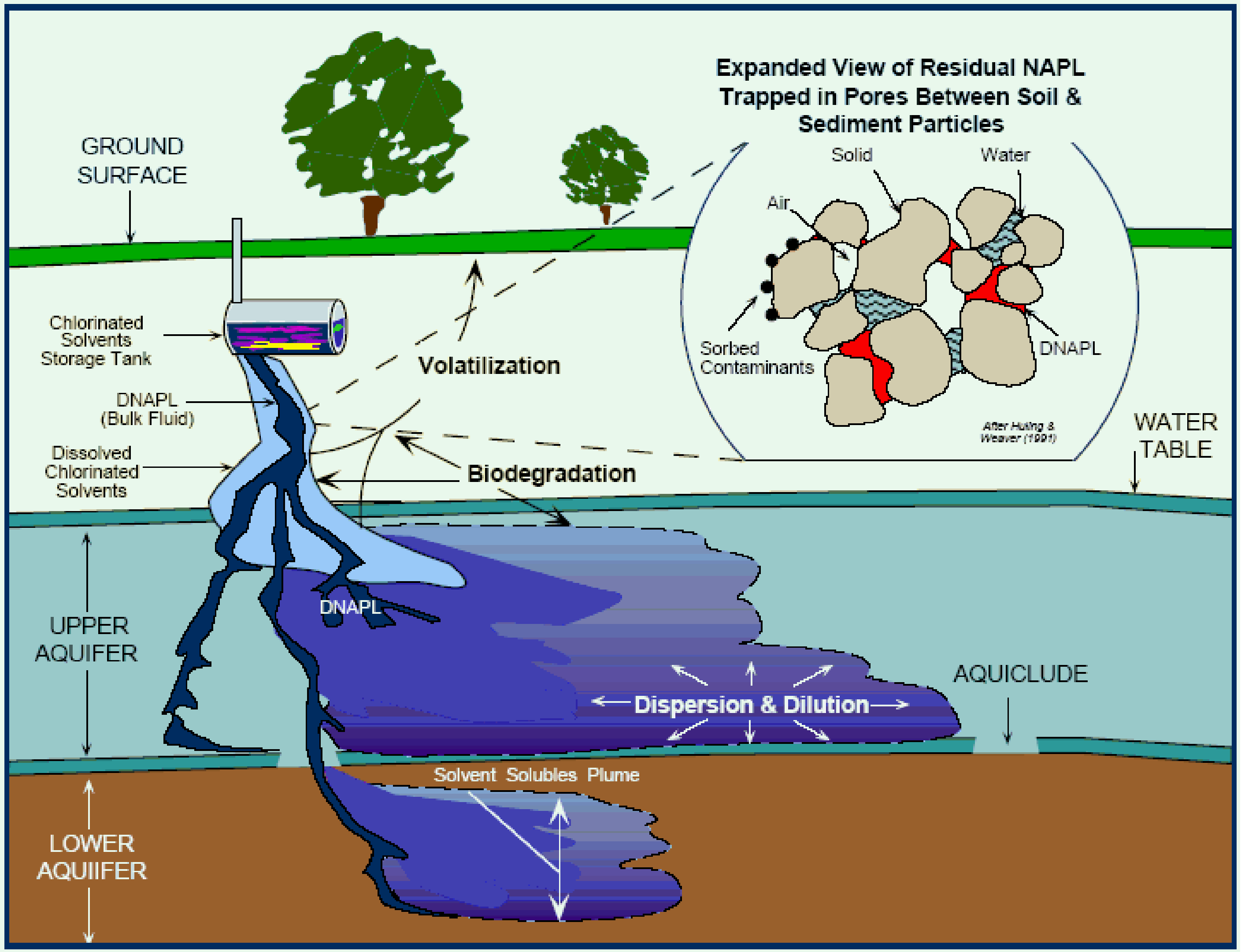
Immiscible compounds serve as a source of dissolved groundwater contamination.

NAPLs: Non-Aqueous Phase Liquids

DNAPL (denser-than-water NAPL)

DNAPL (denser-than-water NAPL)

- Examples: chlorinated hydrocarbons (TCE, TCA, Carbon Tetrachloride)
- Can sink to bottom of aquifer to form pool
- Can migrate down dip on aquifer bottom (**against hydraulic gradient**)
- Recovery difficult to impossible

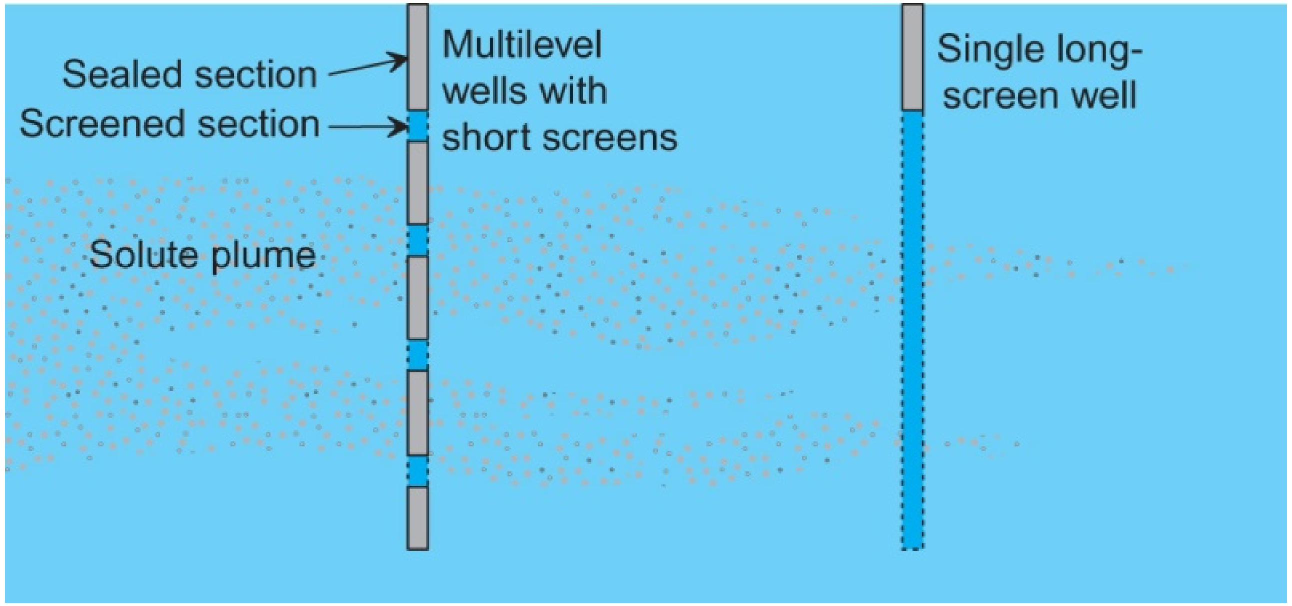


http://oceanworld.tamu.edu/resources/environment-book/groundwaterremediation.html

Groundwater remediation

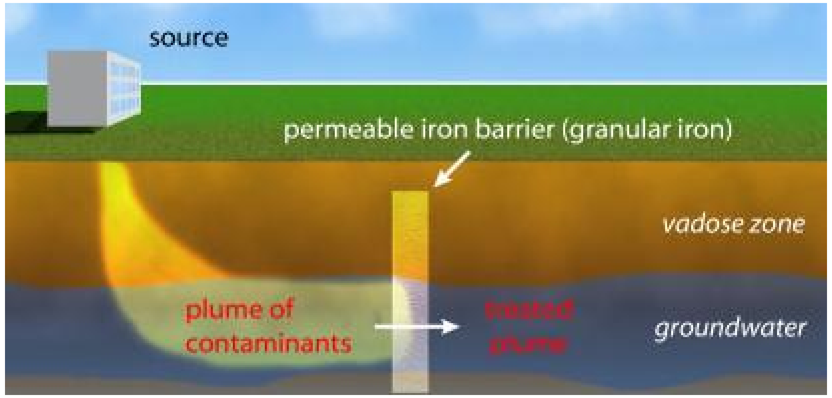
First, identify the location and extent of the plume

So how do we ‘know’ the extent of a pollutant plume?



Remediation strategies

Remediation strategies



- Physical
  - Pump and treat
    - On/offsite
  - Air Sparging
- Biological (Bioremediation)
- Chemical
  - Reactive Barriers
  - Oxidation
  - Ion exchange
  - Carbon absorption

Groundwater remediation

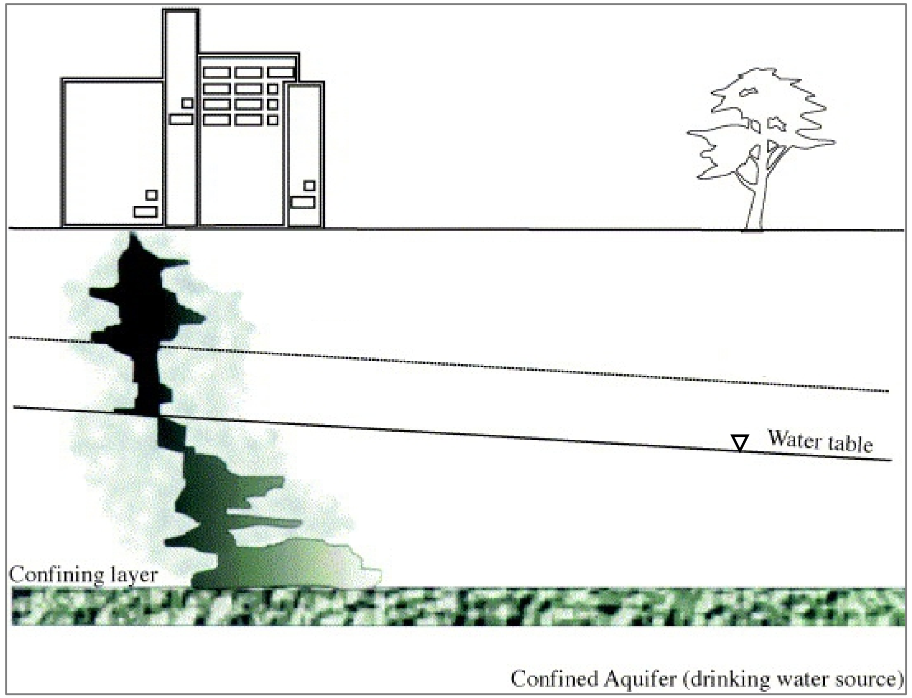
Pump and treat

Cleaning up after pollutant spills is expensive and time consuming.

Likely that the system will never return to pristine conditions

Pump and treat. But when the well is turned off…

Example of a high density pollutant



Modified from: Valkenburg and Annable (2002)
Journal of Contaminant Hydrology

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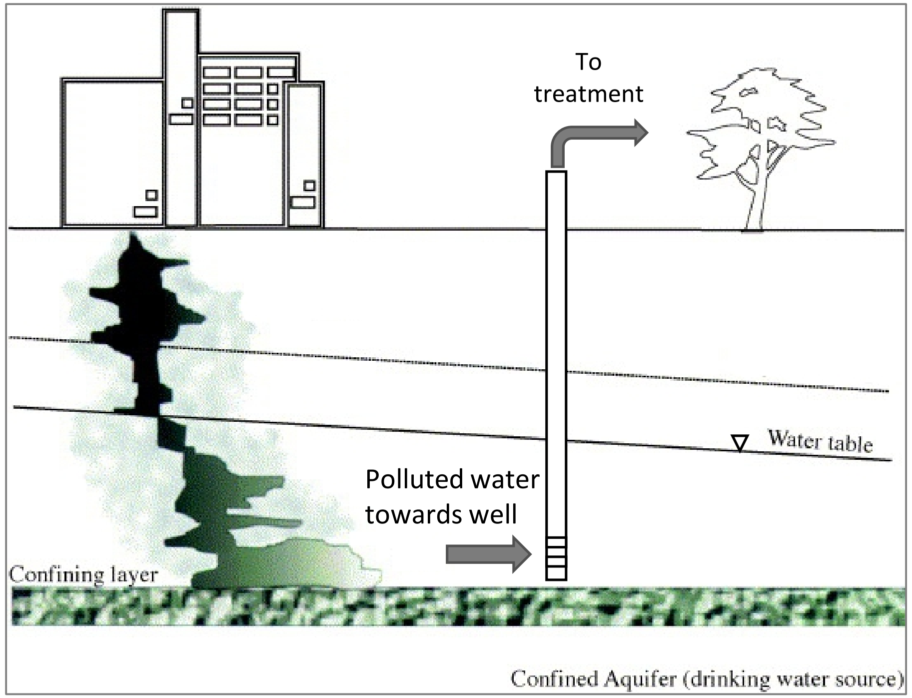

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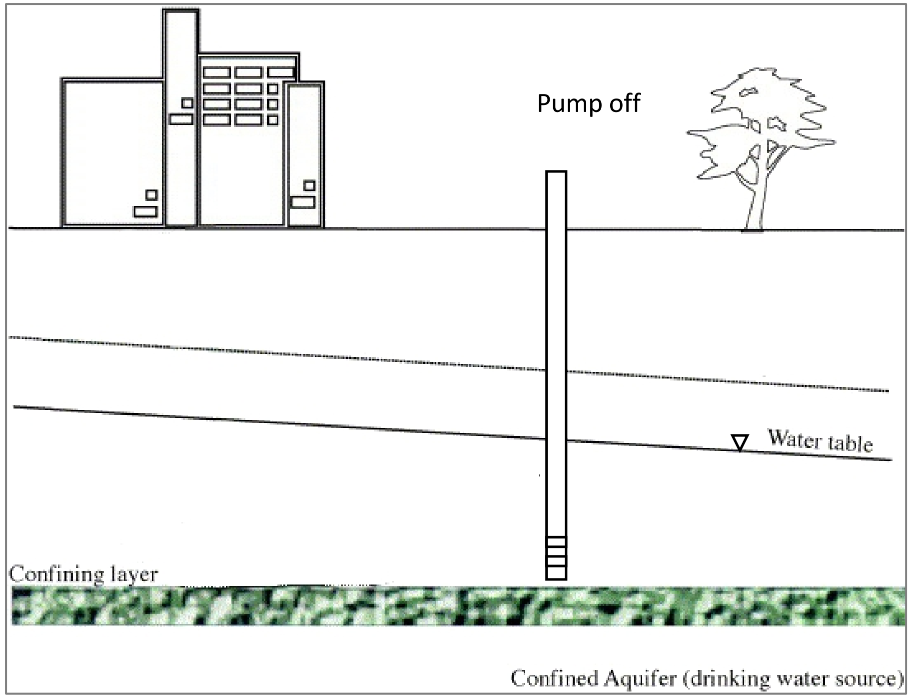

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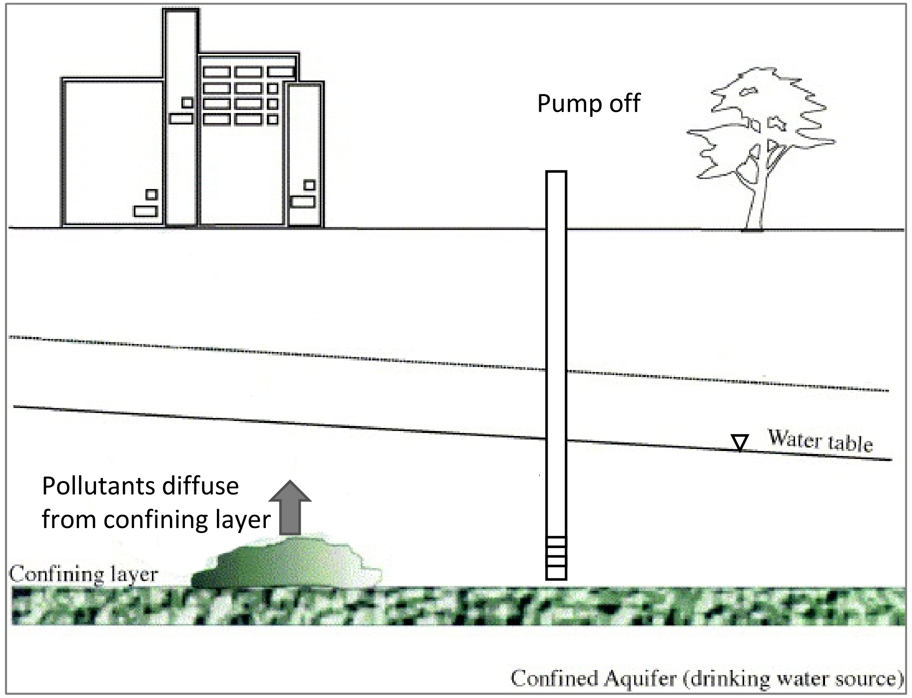


Modified from: Valkenburg and Annable (2002)
Journal of Contaminant Hydrology

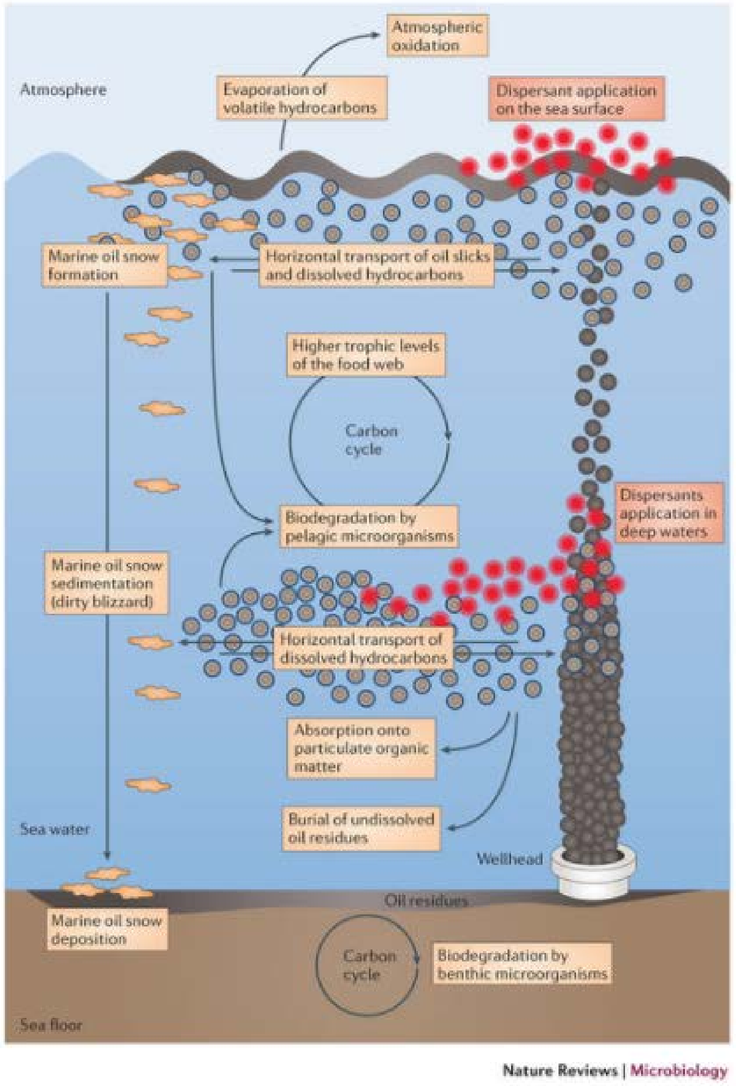
Groundwater remediation

Bioremediation

The good news is that some organic pollutants (like polychlorinated biphenyls, PCBs) strongly adsorb to porous media (limiting their transport)

Organic contaminants become food for microbes. Fuel spills would be much worse without microbial degradation.

Figure 2: Hydrocarbon degradation following the Deepwater Horizon oil spill.

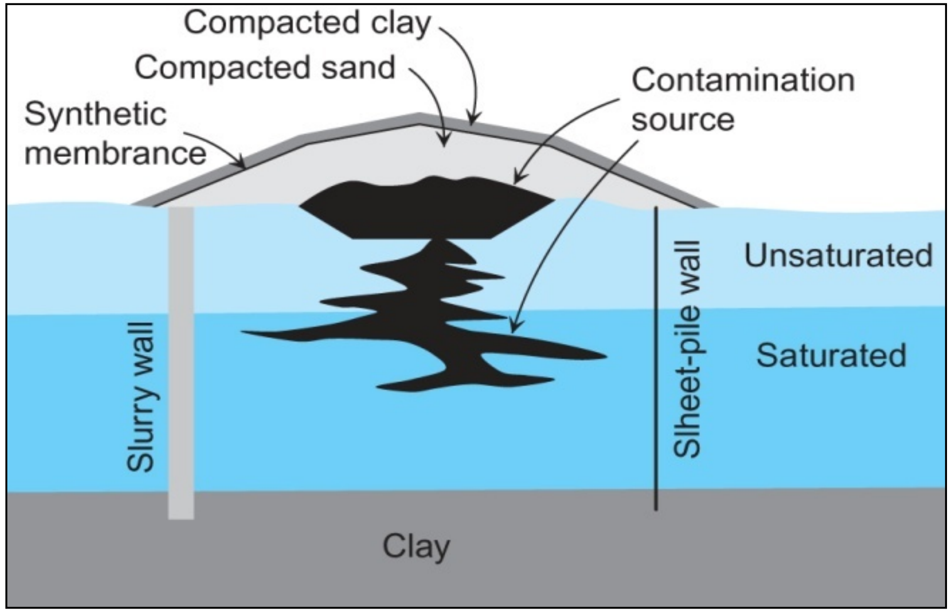


Groundwater remediation

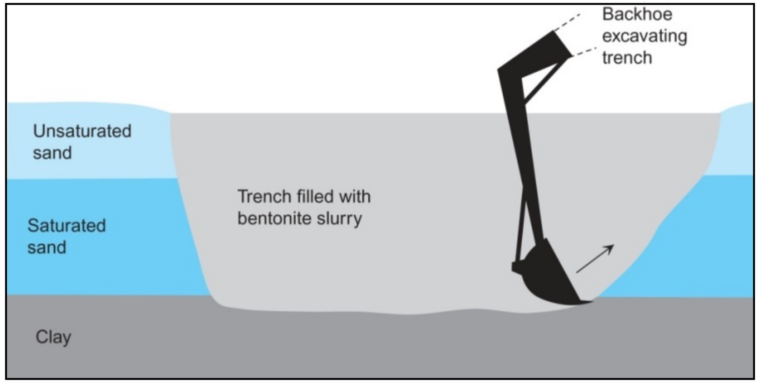
Isolation

An alternative approach to remediation is isolation.

e.g. Use of low hydraulic conductivity barriers to restrict movement.



Side on view
(walls just thicker than the backhoe 'bucket')



https://www.youtube.com/watch?time_continue=218&v=-jyg5PYOcEA

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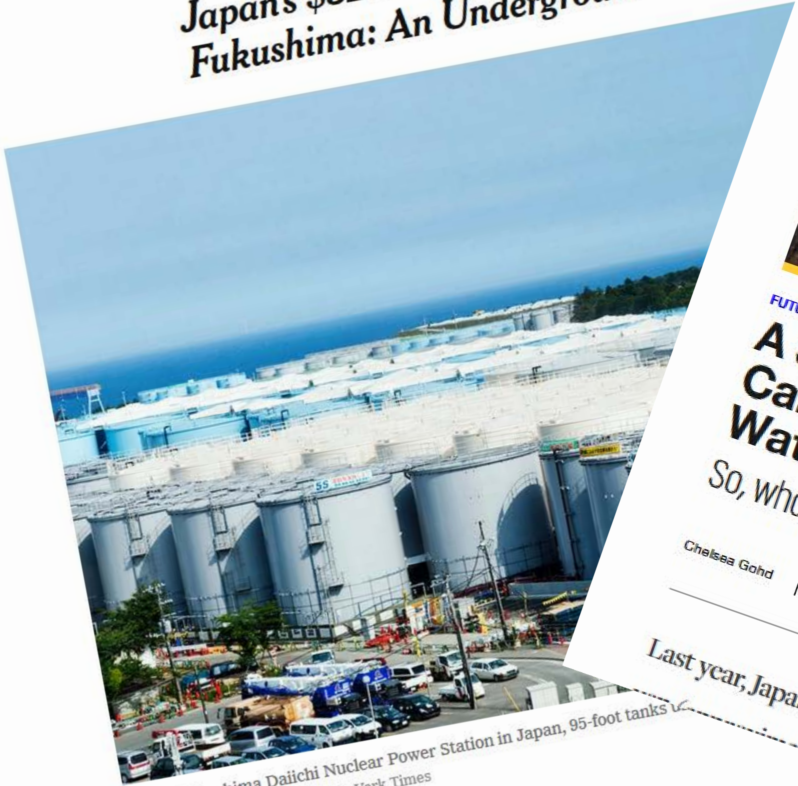
The New York Times

SCIENCE

Japan's $320 Million Gamble at Fukushima: An Underground Ice Wall



At the Fukushima Daiichi Nuclear Power Station in Japan, 95-foot tanks ... abound. Ko Sasaki for The New York Times

By Martin Fackler

Aug. 29, 2016

FUKUSHIMA DAIICHI NUCLEAR POWER STATION — The part above ground doesn't look like much, a few silver pipes running in a

FUTURE SOCIETY

A $320 Million Ice Wall Still Can't Contain Radioactive Water Near Fukushima

So, what can we do?

Chelsea Gohd | March 8th 2018

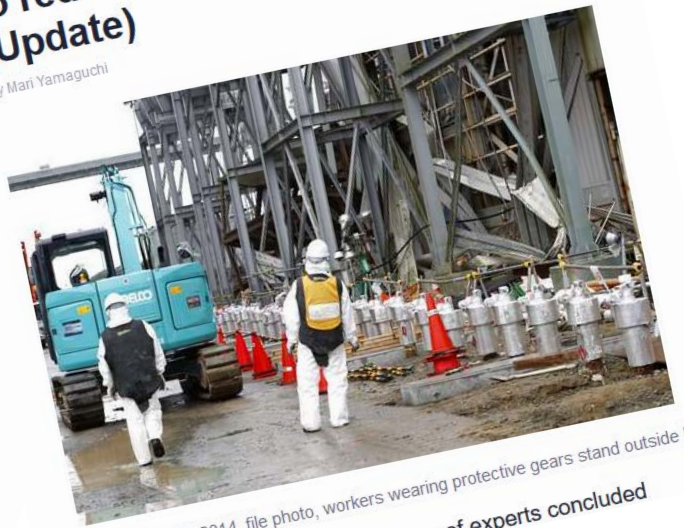
Last year, Japan's central government completed a 35 billion

Home / Technology / Energy & Green Tech

MARCH 7, 2018

Experts: Fukushima must do more to reduce radioactive water (Update)

by Mari Yamaguchi



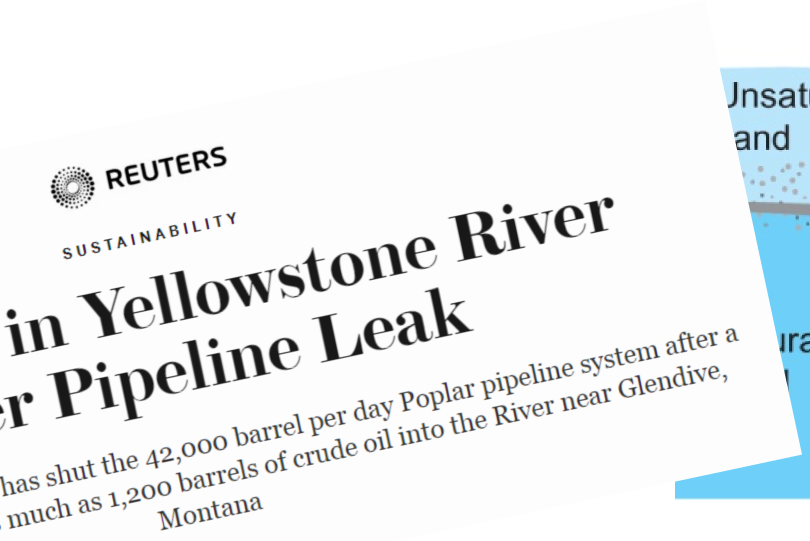
In this Nov. 12, 2014, file photo, workers wearing protective gears stand outside F...

A government-commissioned group of experts concluded

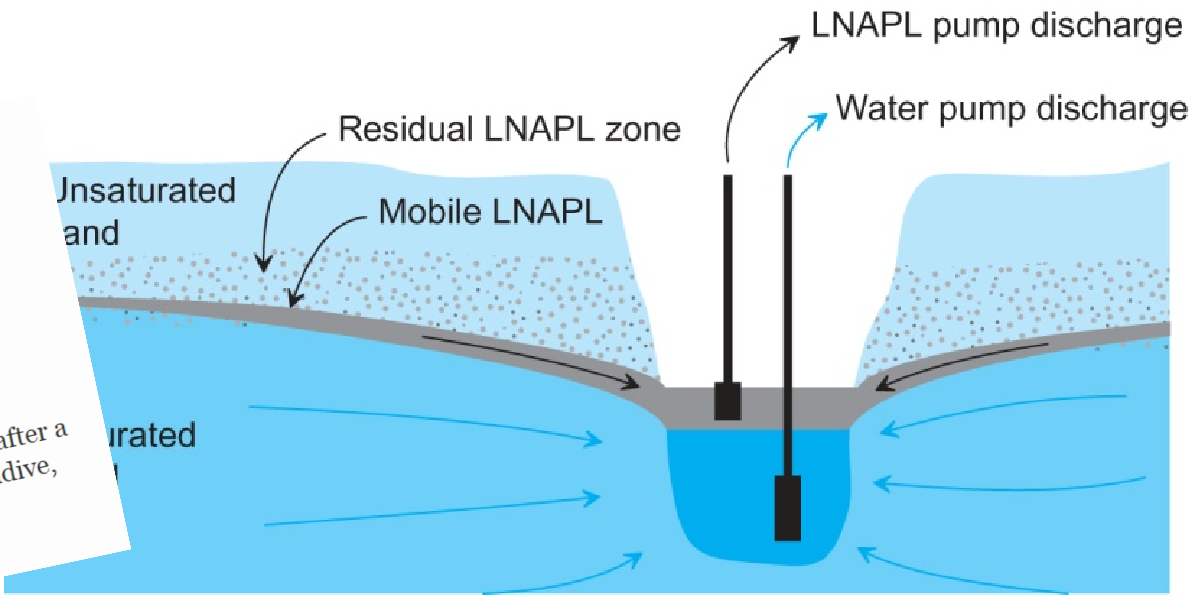
Removing LNAPLs

Requires two pumps. One for water, one for LNAPL.

In some cases the LNAPL can be reused, although it is typically t
polluted, and must be treated and disposed of.



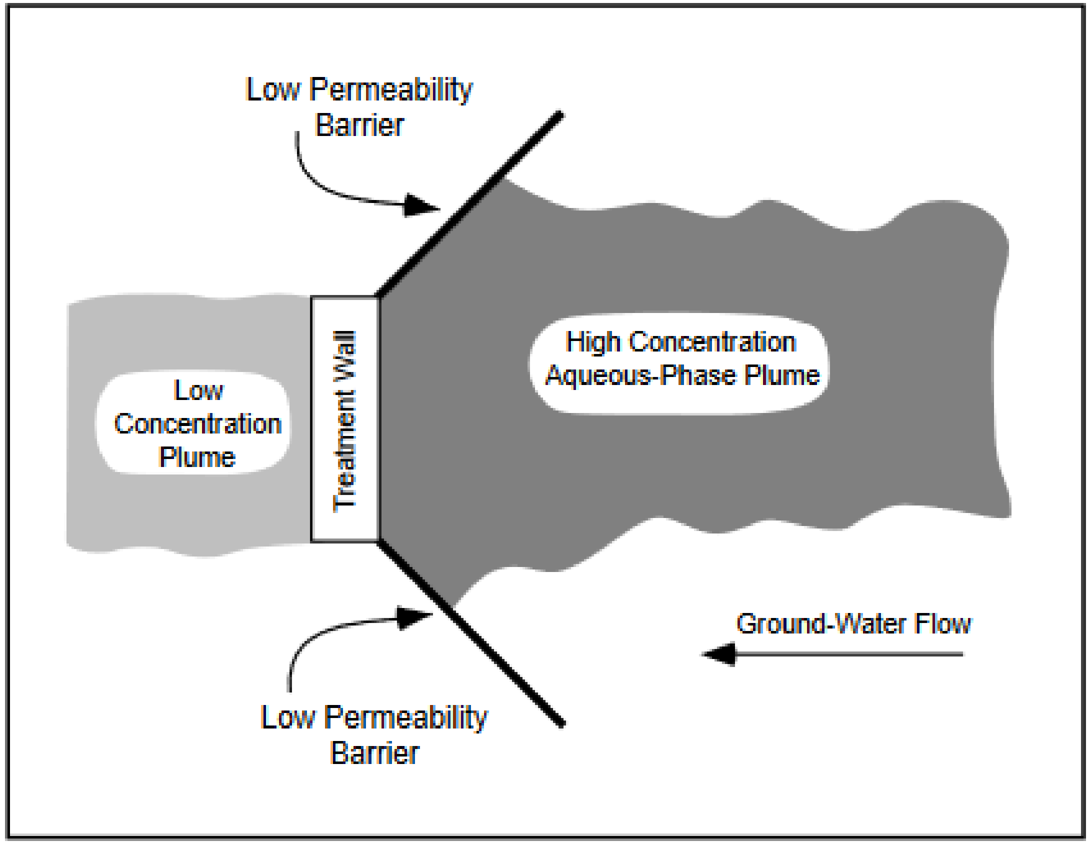
REUTERS
SUSTAINABILITY
in Yellowstone River
r Pipeline Leak
has shut the 42,000 barrel per day Poplar pipeline system after a
much as 1,200 barrels of crude oil into the River near Glendive,
Montana



Ice Hampers Clea
Yellowstone's Rar
The effort offers cautionary tales for the proposed
By Christina Nunez, National Geographic
PUBLISHED FEBRUARY 1, 2015

Groundwater remediation

Combined methods



https://www.epa.gov/sites/production/files/2015-06/documents/lnapl.pdf

Removing DNAPLs

There is no easy method of removing DNAPLs. Many methods have been attempted:

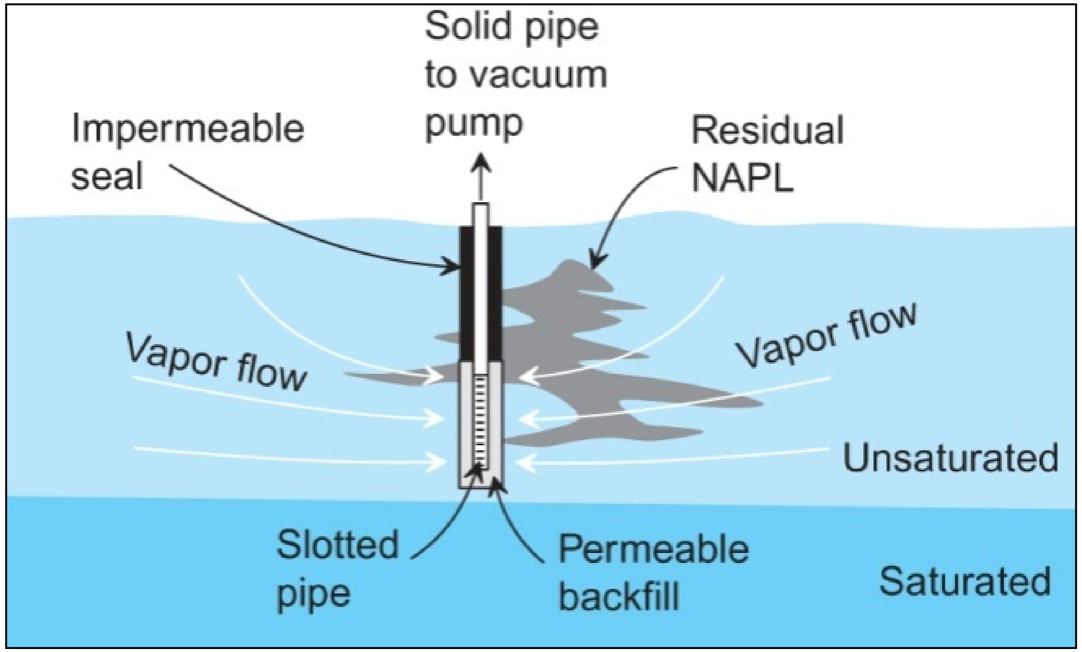
- Steam injection
- Surfactants
  (like in your dishwashing liquid)
- Excavation
- Isolation

Groundwater remediation

Air sparging (unsaturated zone)

Pollution occurs in liquid and gas phases.

Use soil vapor extraction (SVE) techniques.



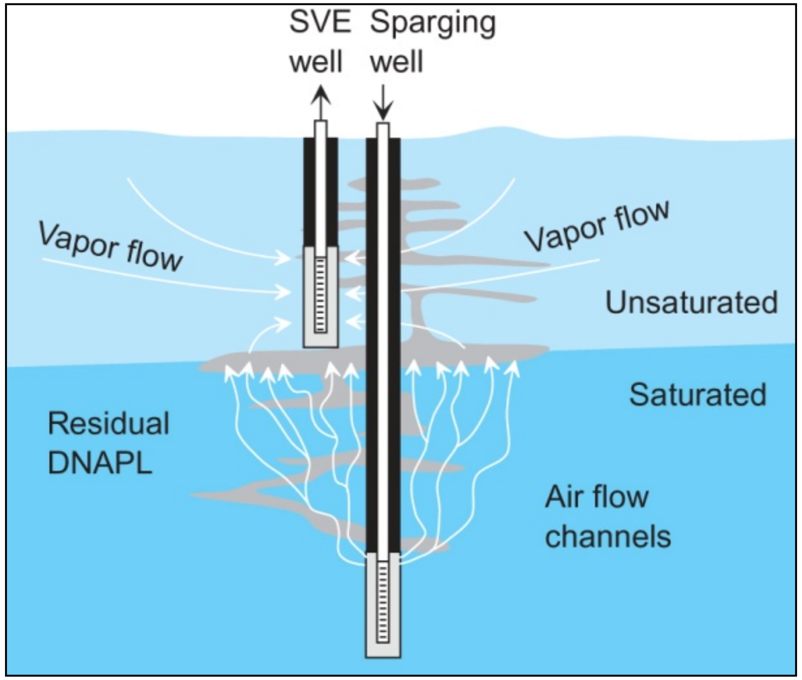
Groundwater remediation

Air sparging (unsaturated zone)

Pollution occurs in liquid and gas phases.

Use soil vapor extraction (SVE) techniques.

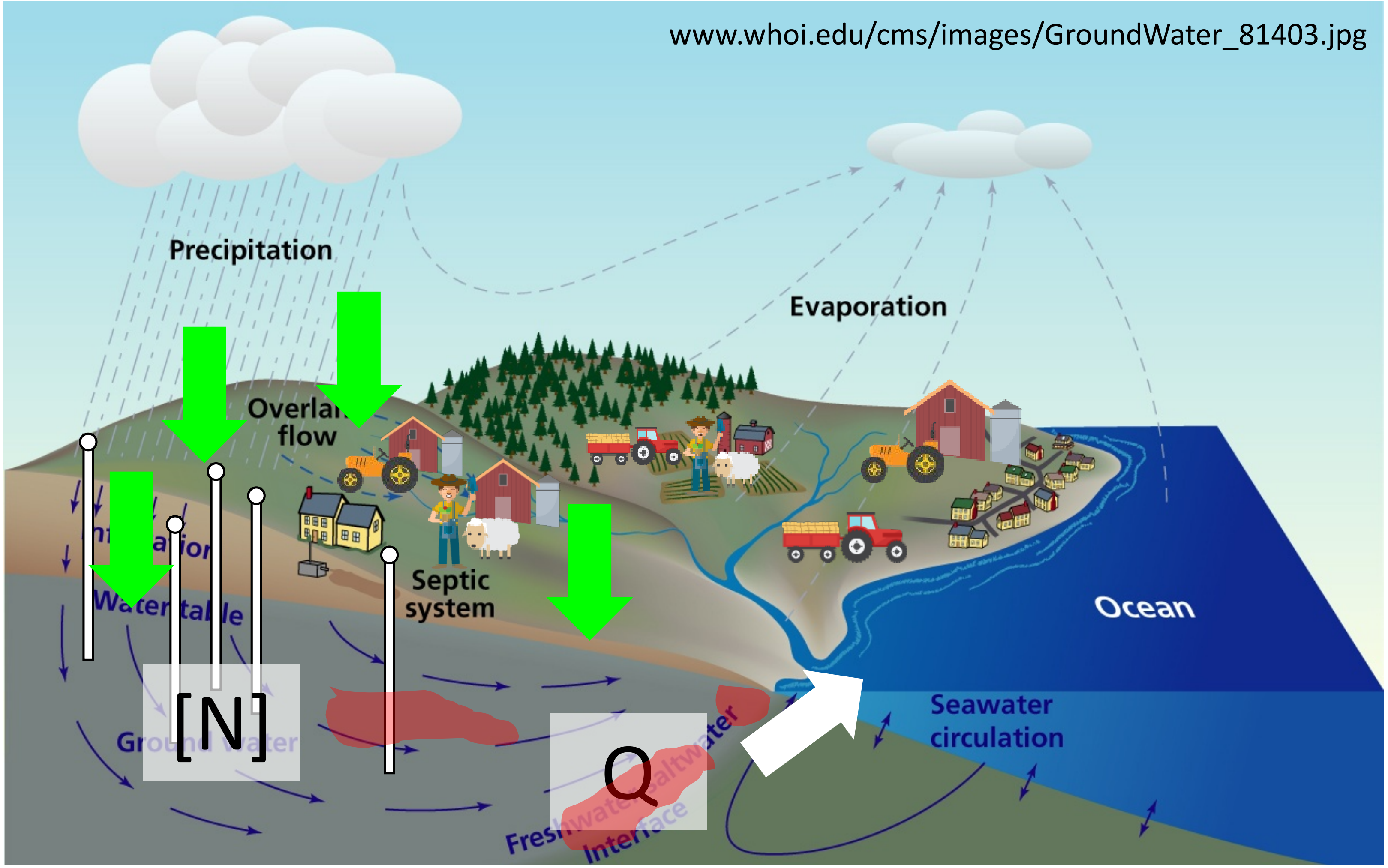
Unfortunately air from saturated zone follows preferential flow pathways, rather than air randomly bubbling through the aquifer.



Variable Density Groundwater Flow
and
Coastal Hydrogeology

Deltares - https://publicwiki.deltares.nl/display/FRESHSALT/Download

Simple density-driven flow in porous media



[N] x Q ≠ N Flux to Surface Water

The Ecological Significance of the Submarine Discharge of Groundwater

R. E. Johannes

CSIRO Division of Fisheries and Oceanography, P. O. B

The Effect of Submarine Groundwater Discharge on the Ocean

Nutrient inputs to the coastal ocean through submarine groundwater discharge: controls and potential impact

f South Carolina, Columbia,

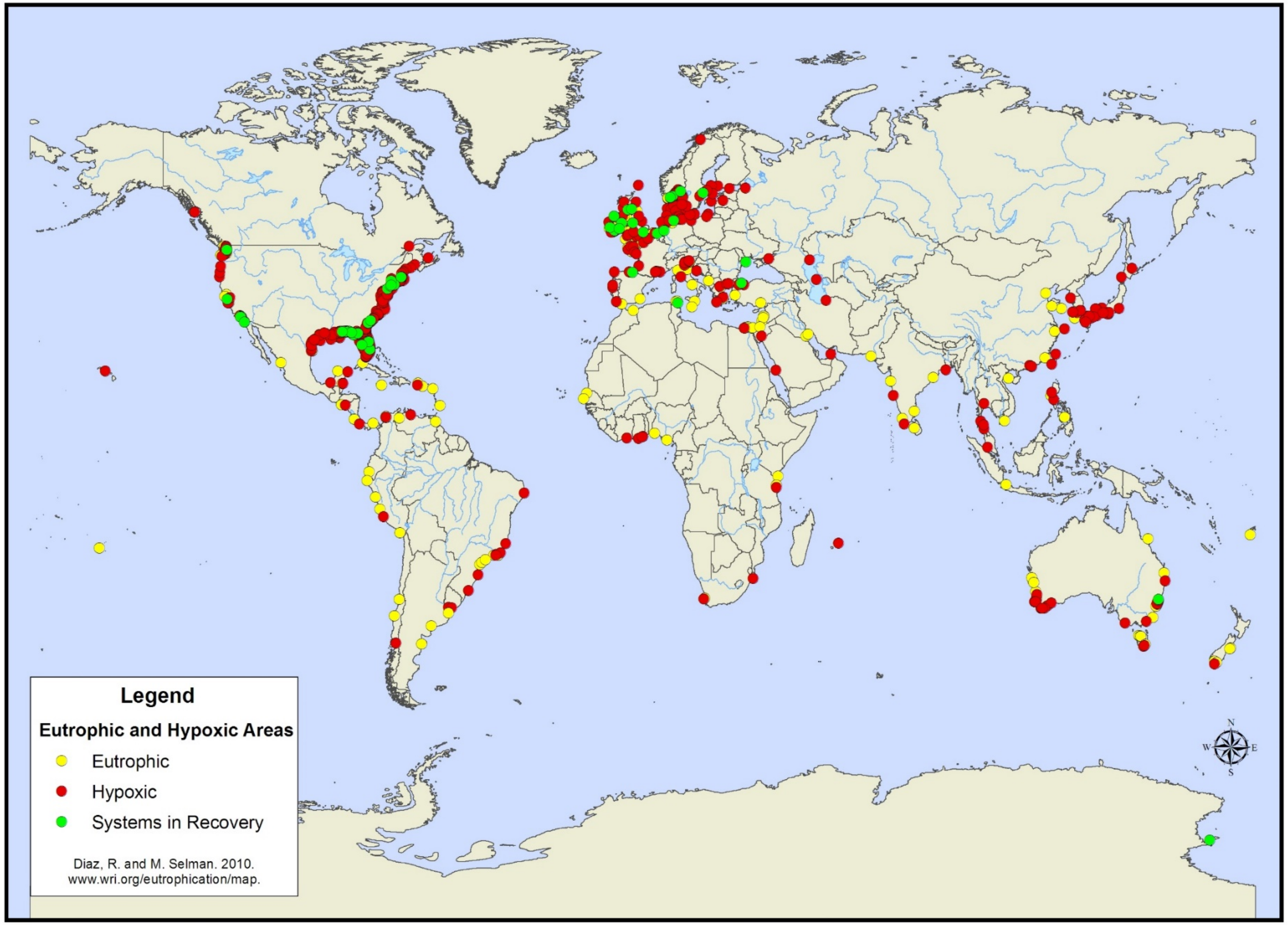
Caroline P. Slomp*, Philippe Van Cappellen

doi:10.1088/1748-9326/8/3/034035

Global land–ocean linkage: direct inputs of nitrogen to coastal waters via submarine groundwater discharge

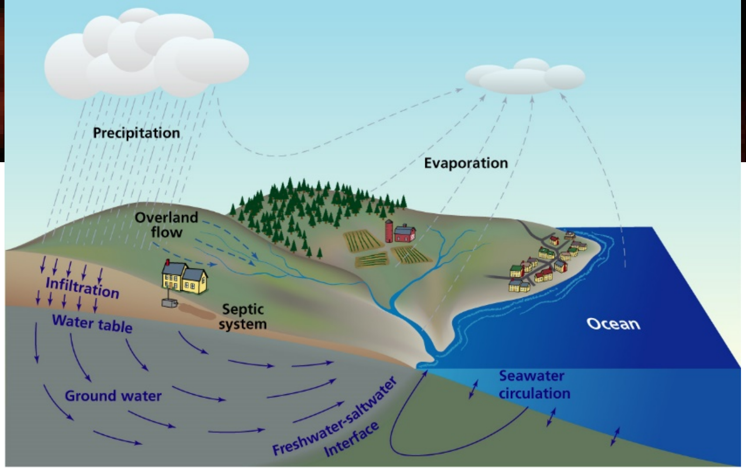
A H W Beusen[1,2], C P Slomp[1] and A F Bouwman[1,2]

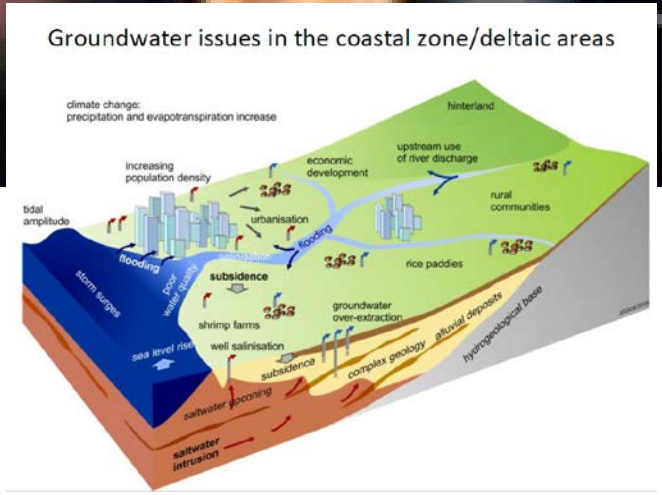
World Hypoxic and Eutrophic Coastal Areas



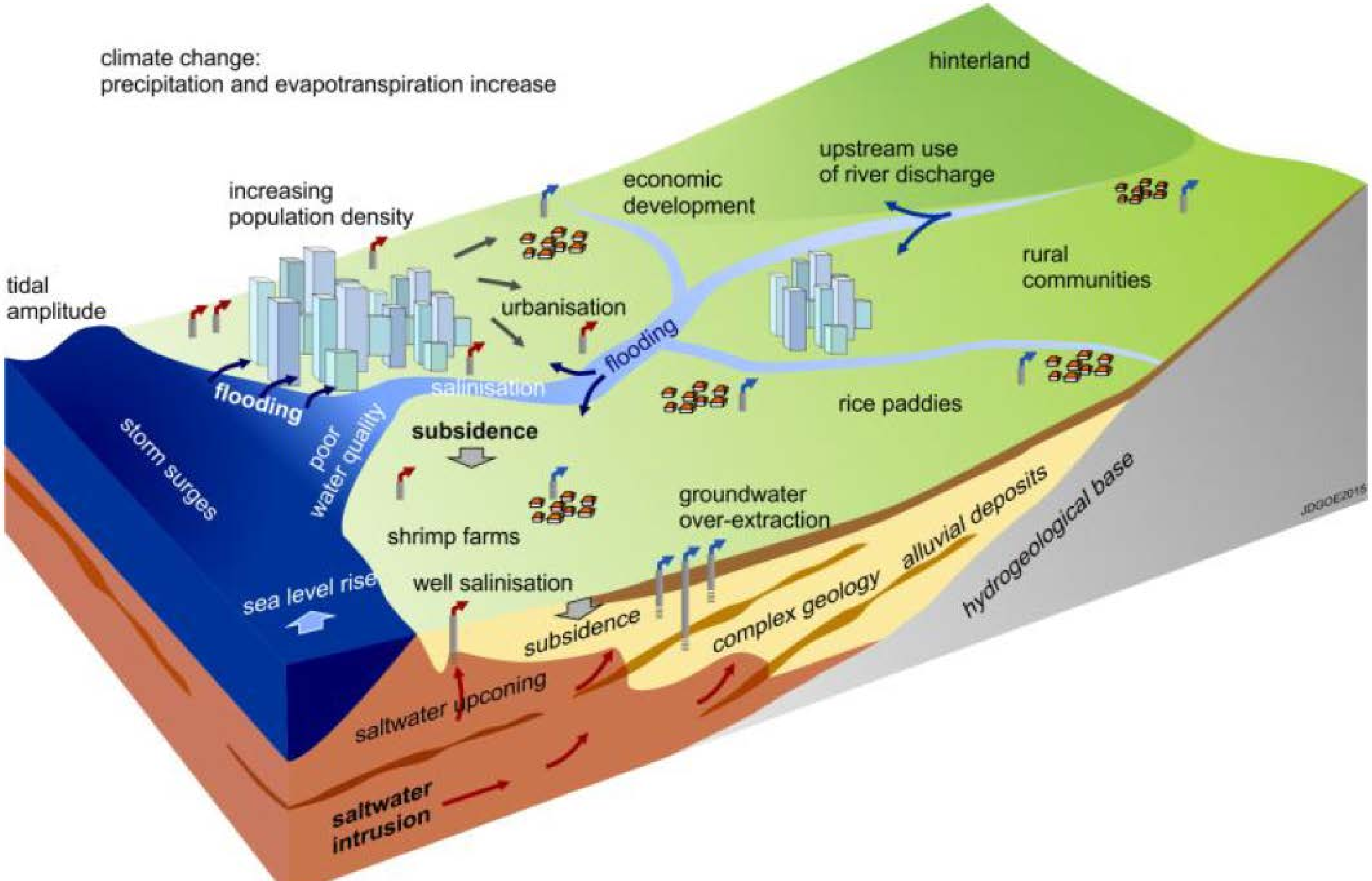

Notice
An algae bloom has made
Avoid direct contact with
visible surface scum.
Economic
SAFETY NOTICE
NO SWIMMING
Recreational
PEOPLE AND ANIMALS SHOULD AVOID SWIMMING
AND WADING UNTIL FURTHER NOTICE
Human health
EXPOSURE TO ALGAL TOXINS MAY CAUSE ILLNESS
Call your doctor or veterinarian if you or your animals
have sudden or unexplained sickness or signs of poisoning.
Ecological
Commercial


PANDORA
BATTLE
EAST COAST
VS.
WEST COAST


Precipitation
Evaporation
Overland flow
Infiltration
Water table
Septic system
Ocean
Ground water
Seawater circulation
Freshwater-saltwater interface

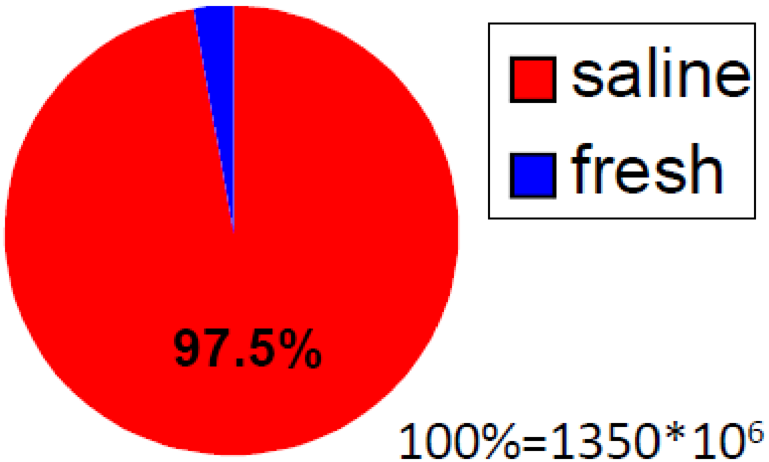

Groundwater issues in the coastal zone/deltaic areas
climate change:
precipitation and evapotranspiration increase
hinterland
upstream use
of river discharge
economic
development
increasing
population density
tidal
amplitude
urbanisation
flooding
rural
communities
rice paddies
flooding
poor
water quality
storm surges
subsidence
shrimp farms
groundwater
over-extraction
alluvial deposits
hydrogeological base
well salinisation
sea level rise
subsidence
complex geology
saltwater upconing
saltwater
intrusion

Groundwater issues in the coastal zone/deltaic areas



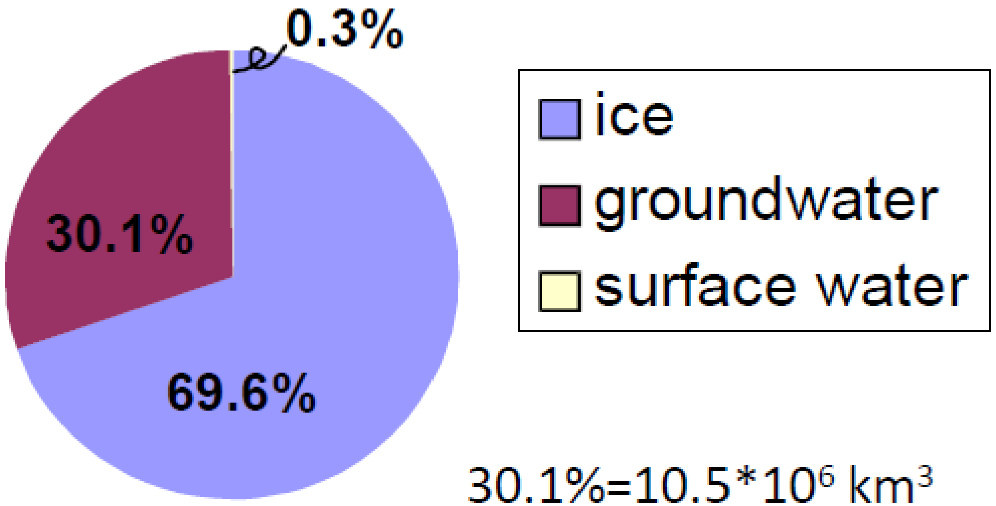
Water on Earth

Total water on Earth



100%=1350*10^6 km^3

Total fresh water on Earth



30.1%=10.5*10^6 km^3

Demand for groundwater (now 30%) increases due to:

- increase world population & economical growth
- loss of surface water due to contamination
- great resource: available in large quantities
- still unpolluted (relative to surface water)

Cheng, 1998

Circulation cell and dispersion! - Cooper

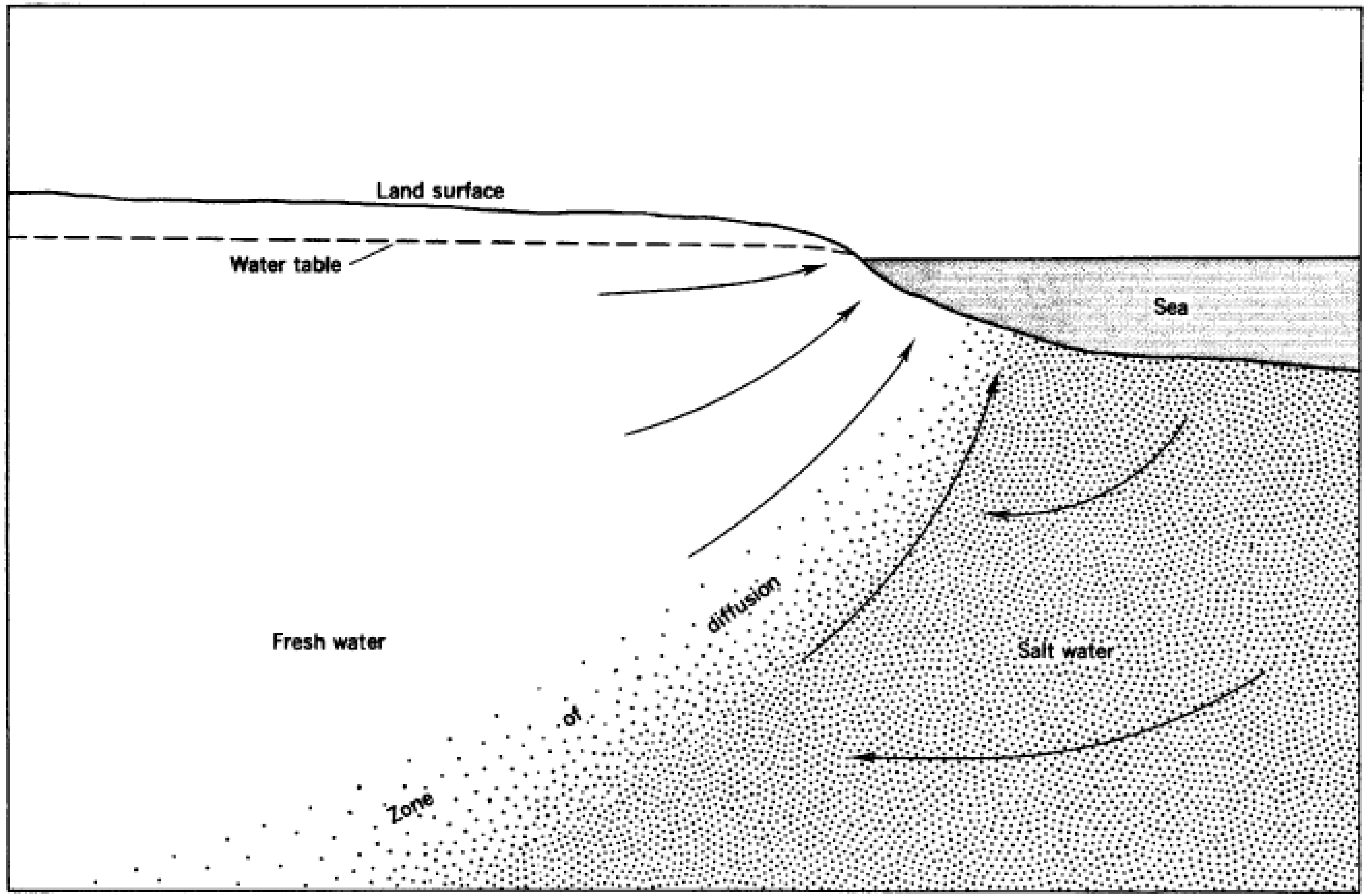
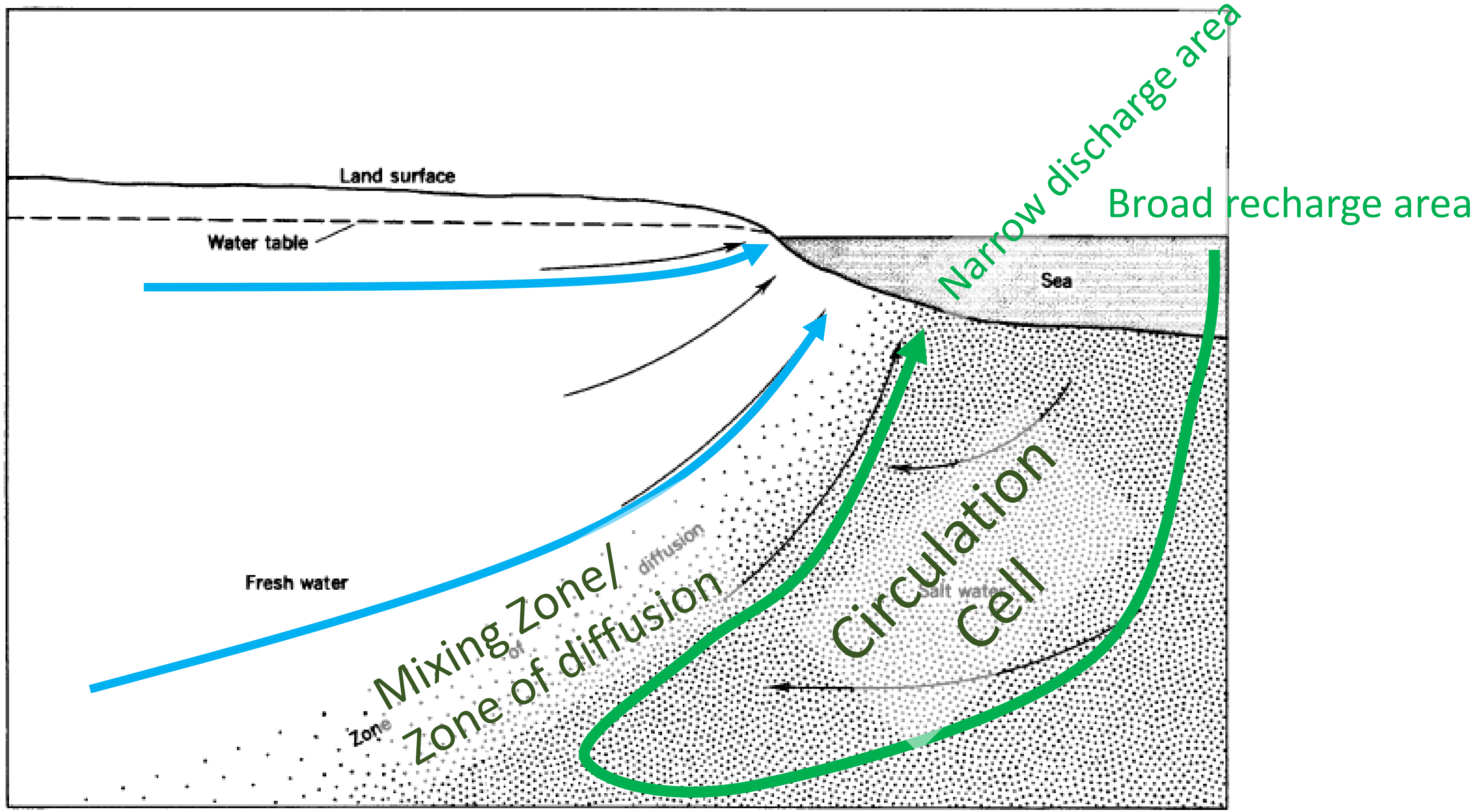


FIGURE 2.—Circulation of salt water from the sea to the zone of diffusion and back to the sea.

Circulation cell and dispersion! - Cooper



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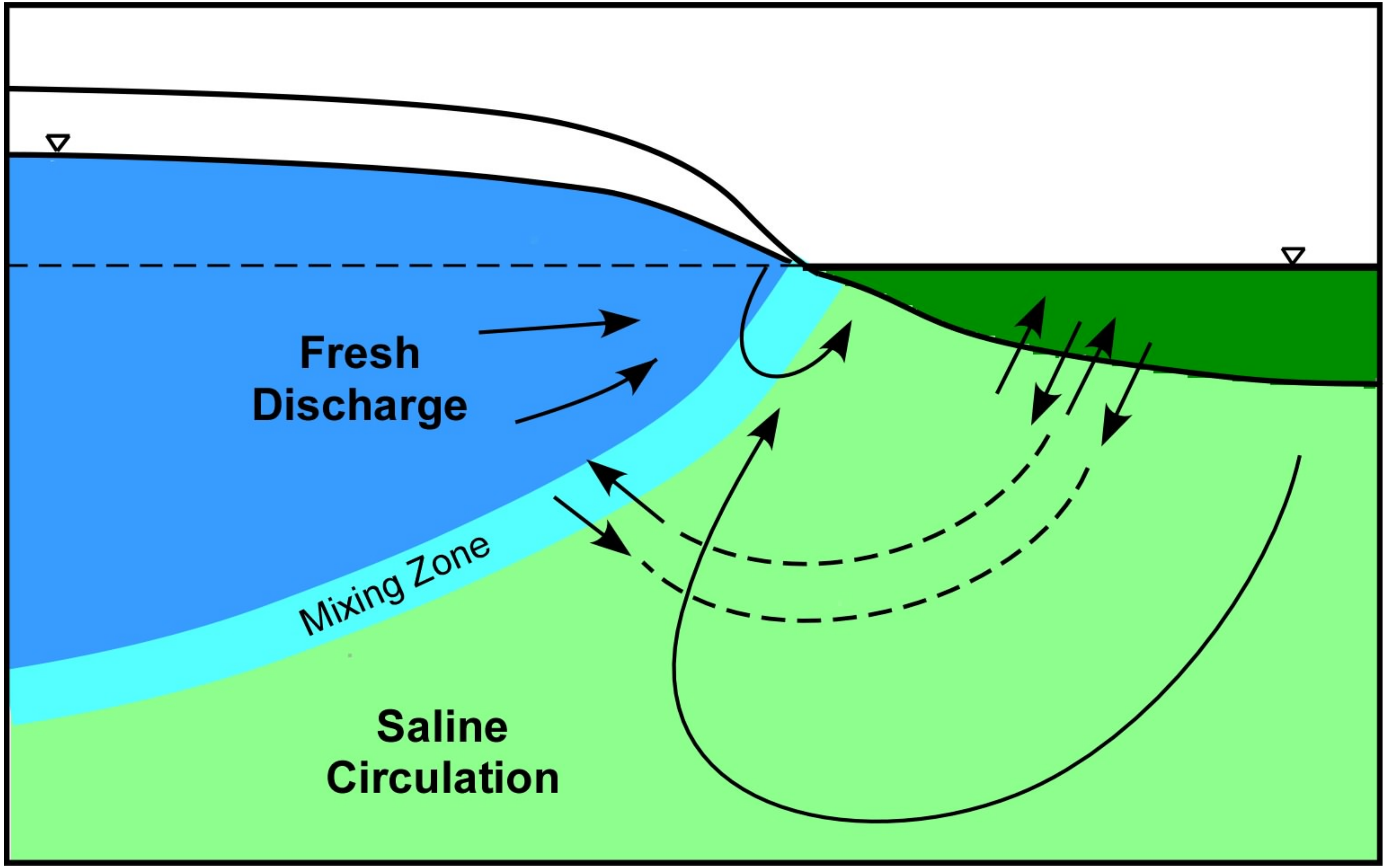
Driving Mechanisms of SGD



Freshwater lens beneath an island