Saltwater Intrusion in Two Population Centers of the United States

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University Honors in Marine Science

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Coastal Populations

- ~70% World Population
- Increasing
- Require reliable freshwater source

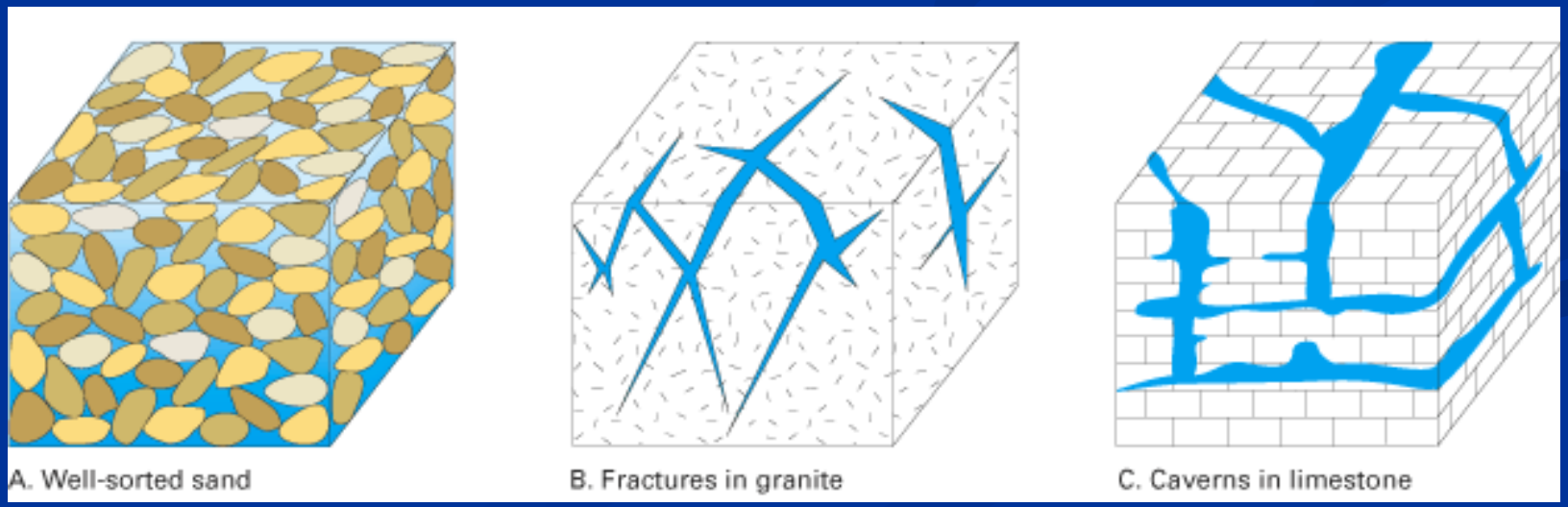
http://www.southbeachrealestateblog.com/wp-content/uploads/2007/05/051207-0129-newestaddit1.jpg

Groundwater

- Important to coastal populations, economies, ecosystems
- 1995: supplied ¼ total freshwater
- Primary or sole drinking water source for many communities
- Use increasing
- Vulnerable to overuse/contamination

Aquifers: A groundwater crash course

- Groundwater—in geologic formations
  - Pores
  - Fractures
  - Solution cavities
- Hydraulic conductivity: permeability of material
- General flow
  - High water to low
  - Inland to coast



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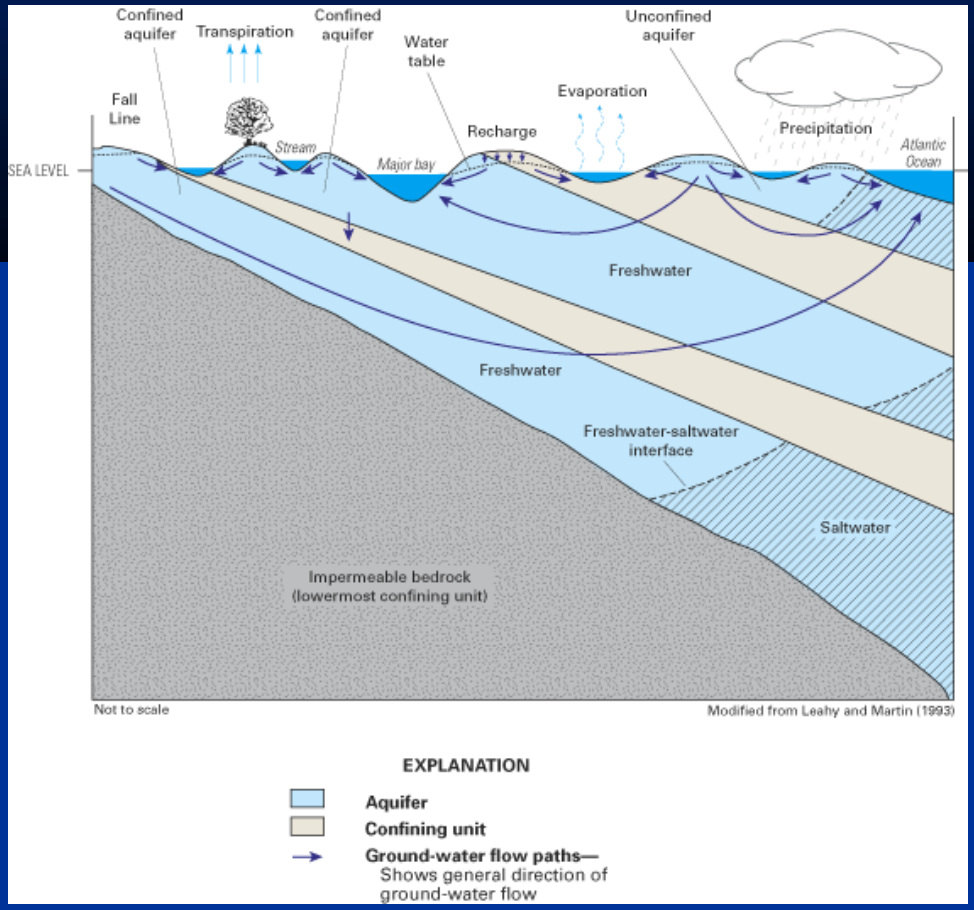
Artesian vs. Water-table Aquifers



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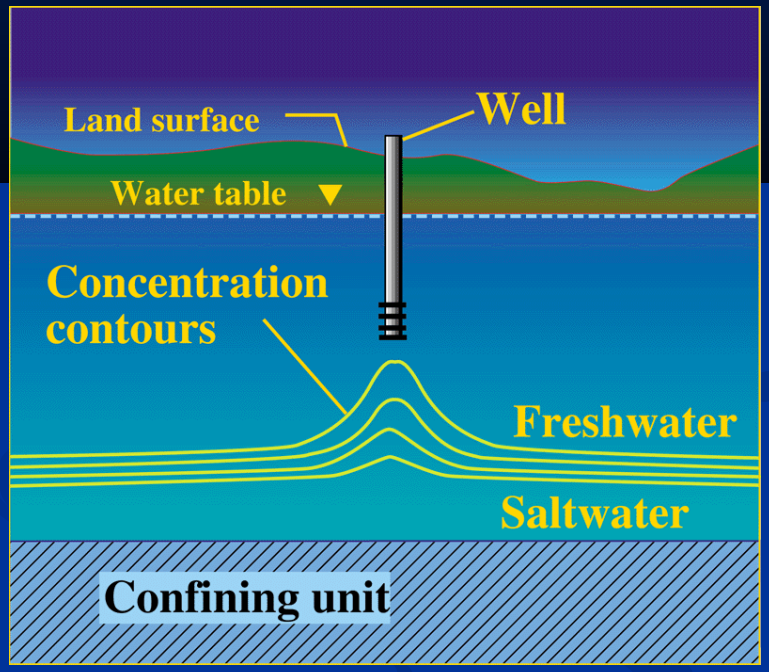
- Artesian/confined
  - Water completely fills pore spaces
  - Overlain by confining unit
- Water Table/unconfined
  - Water partially fills pore spaces
  - Water table free to rise and decline
- Unconfined may overlay one or more confined

What is Saltwater Intrusion?

- Movement of saline water into freshwater aquifers
- Driven by lowering of aquifer freshwater levels
- 3 primary mechanisms
  - Subsurface seawater movement (lateral large scale intrusion)
  - Seepage from tidal canals and streams
  - Connate upward movement from lower formations (well withdrawals)
- Regional long term changes more important than seasonal



http://water.usgs.gov/ogw/gwrp/saltwater/fig4.html

Factors controlling the extent of intrusion

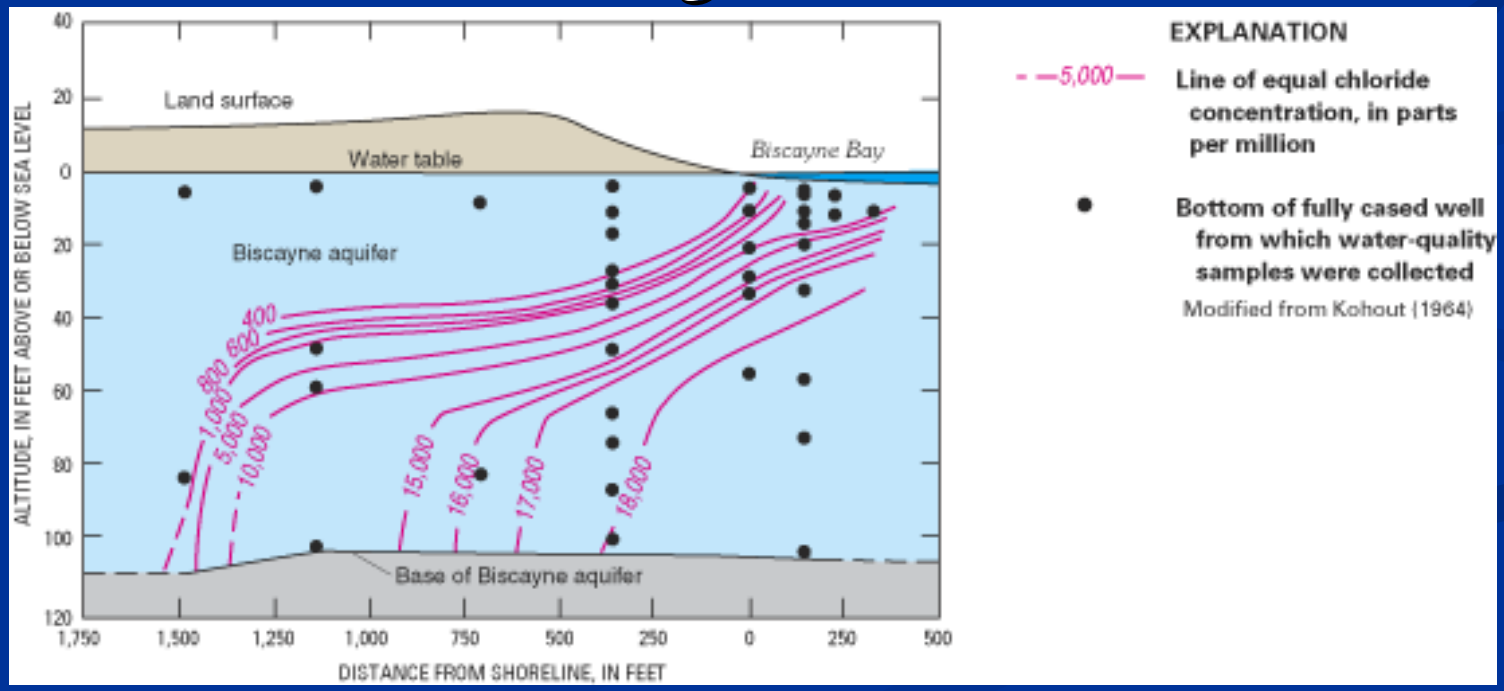
- Rate of withdrawal vs. freshwater recharge
- Distance of stress from saltwater source
- Geologic structure
- Presence of confining units

So, why is this a problem?

- Saltwater unfit for human consumption, other anthropogenic uses
- Reduces groundwater storage
- Abandonment of supply wells
- Coastal ecosystems sensitive to salinity changes
  - Red tides, fish kills, loss of seagrass habitat, destruction of coral reef

Management and Prevention

- Engineering techniques
- Regulatory (legislative) approaches
- Scientific monitoring/assessment



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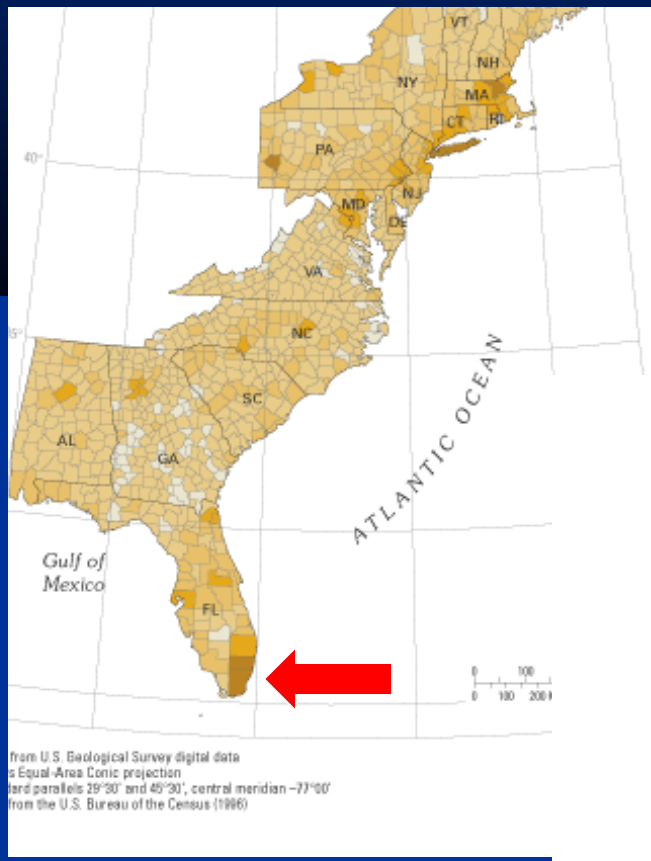
Two Case Studies

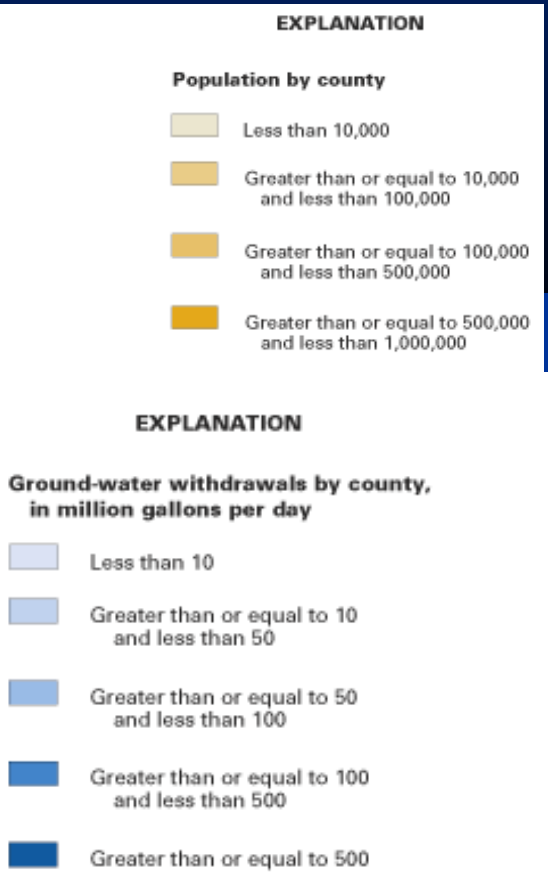
- Miami-Dade County, Florida
- Los Angeles County, California

http://www.onebillionbulbs.com/img/us-map.gif

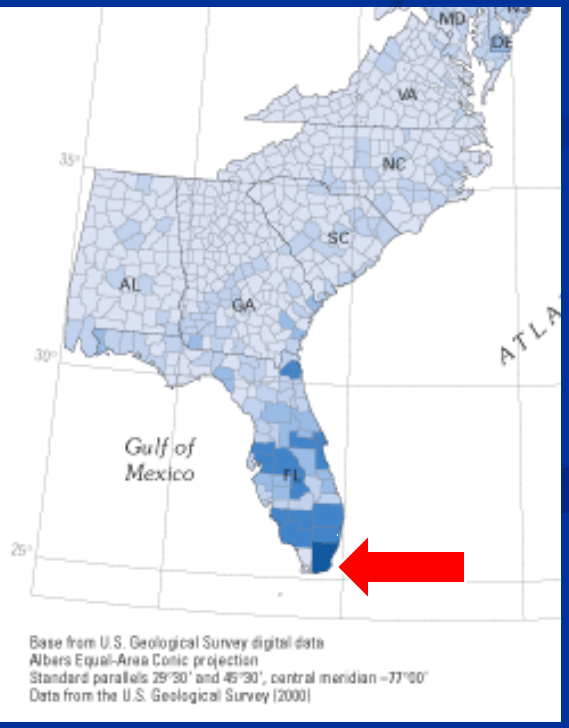
Miami-Dade County, Florida



Population



Groundwater Withdrawals



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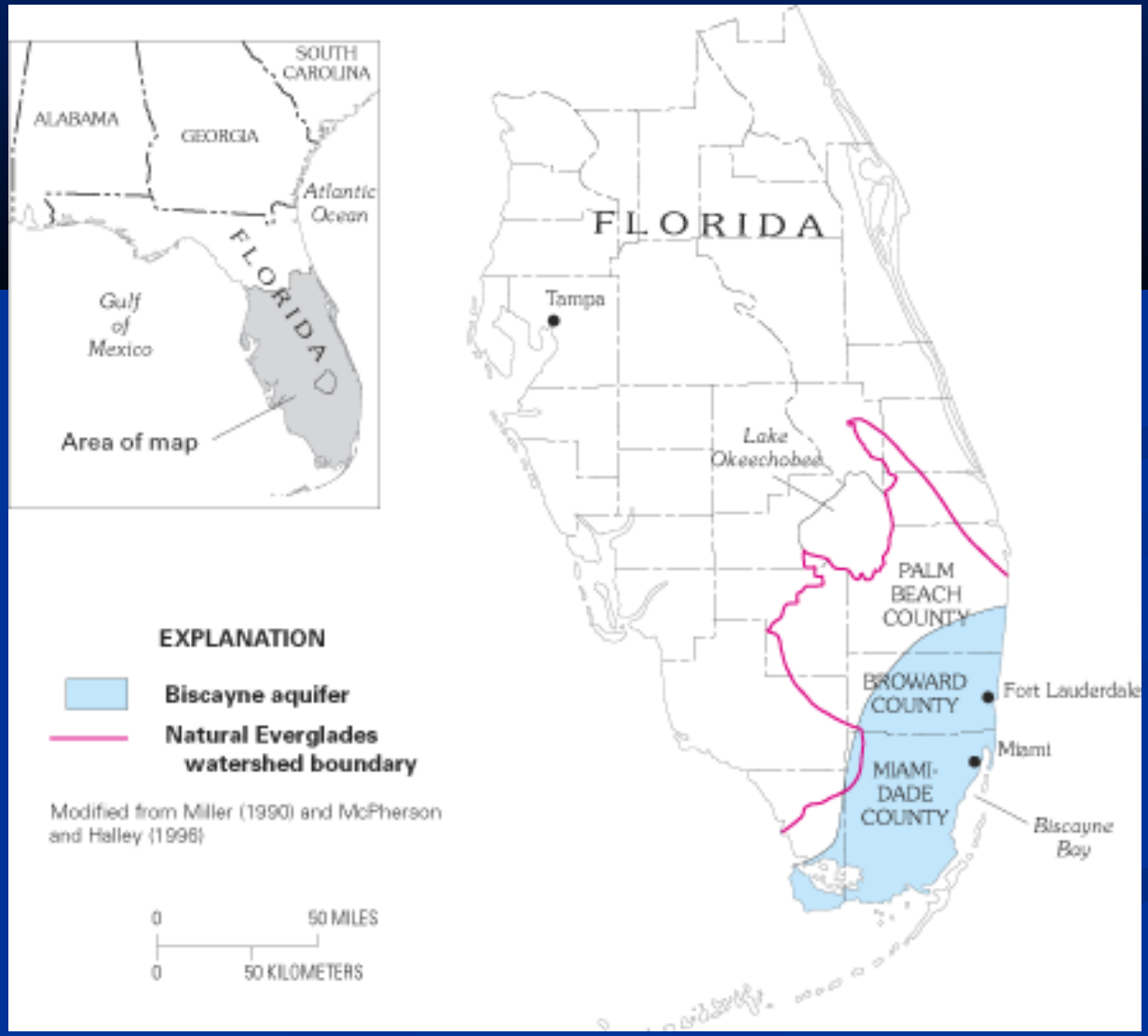
The Biscayne Aquifer



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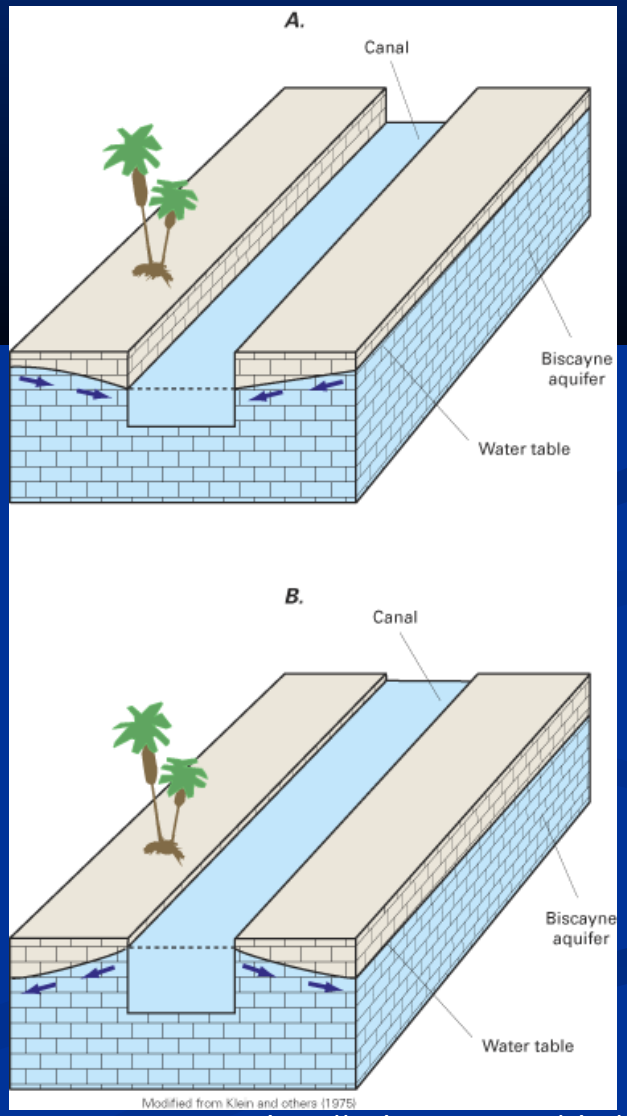
Lowering of Water Level in Biscayne Aquifer

- coastal urbanization
- municipal well fields
- construction of drainage canals

Salt Water Intrusion Timeline

- 1904: interface at or near coast
- 1930's: construction of drainage canals, pumping at coastal well fields=lowering of water level
- 1946: installation of control structures



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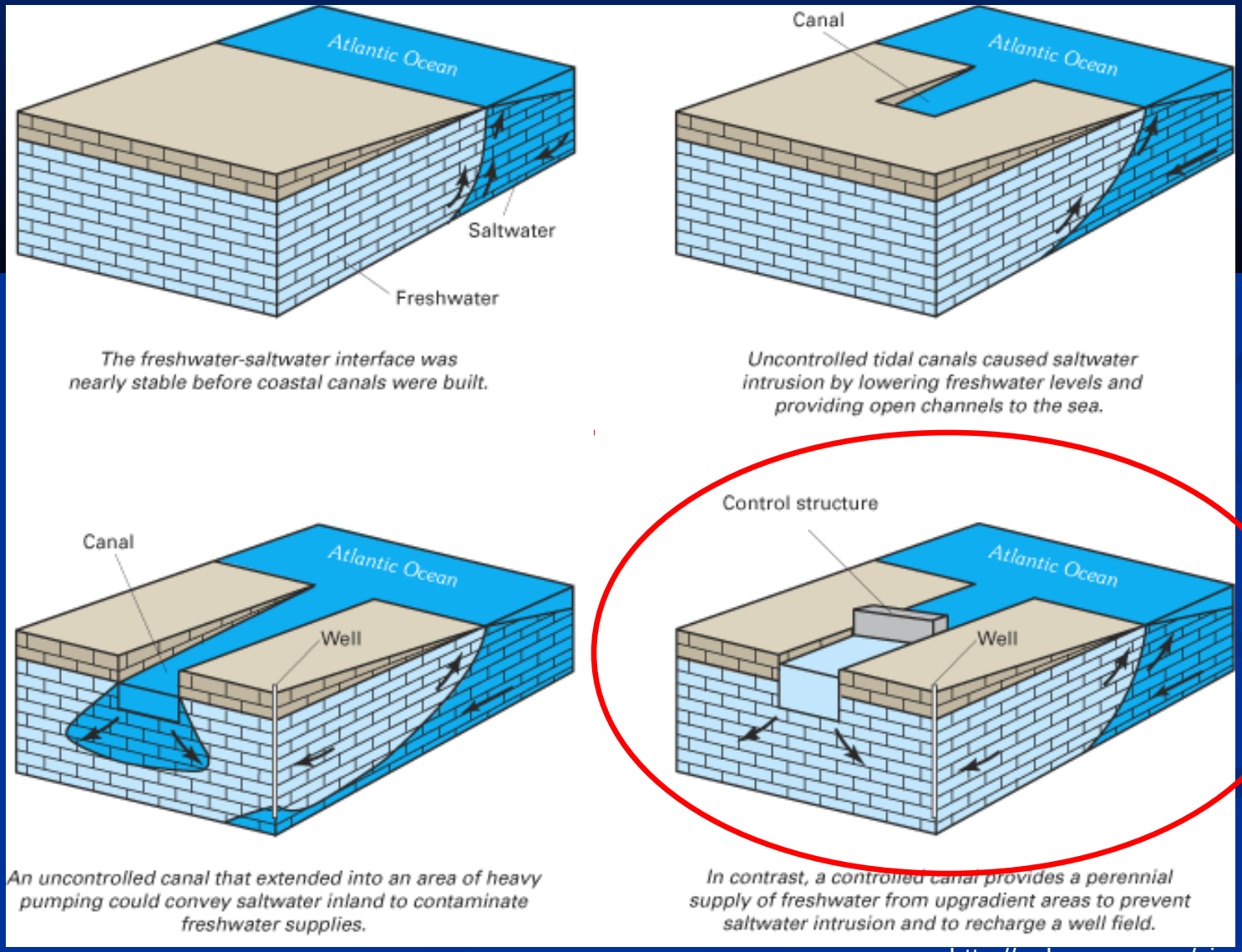
Canals before and after 1946



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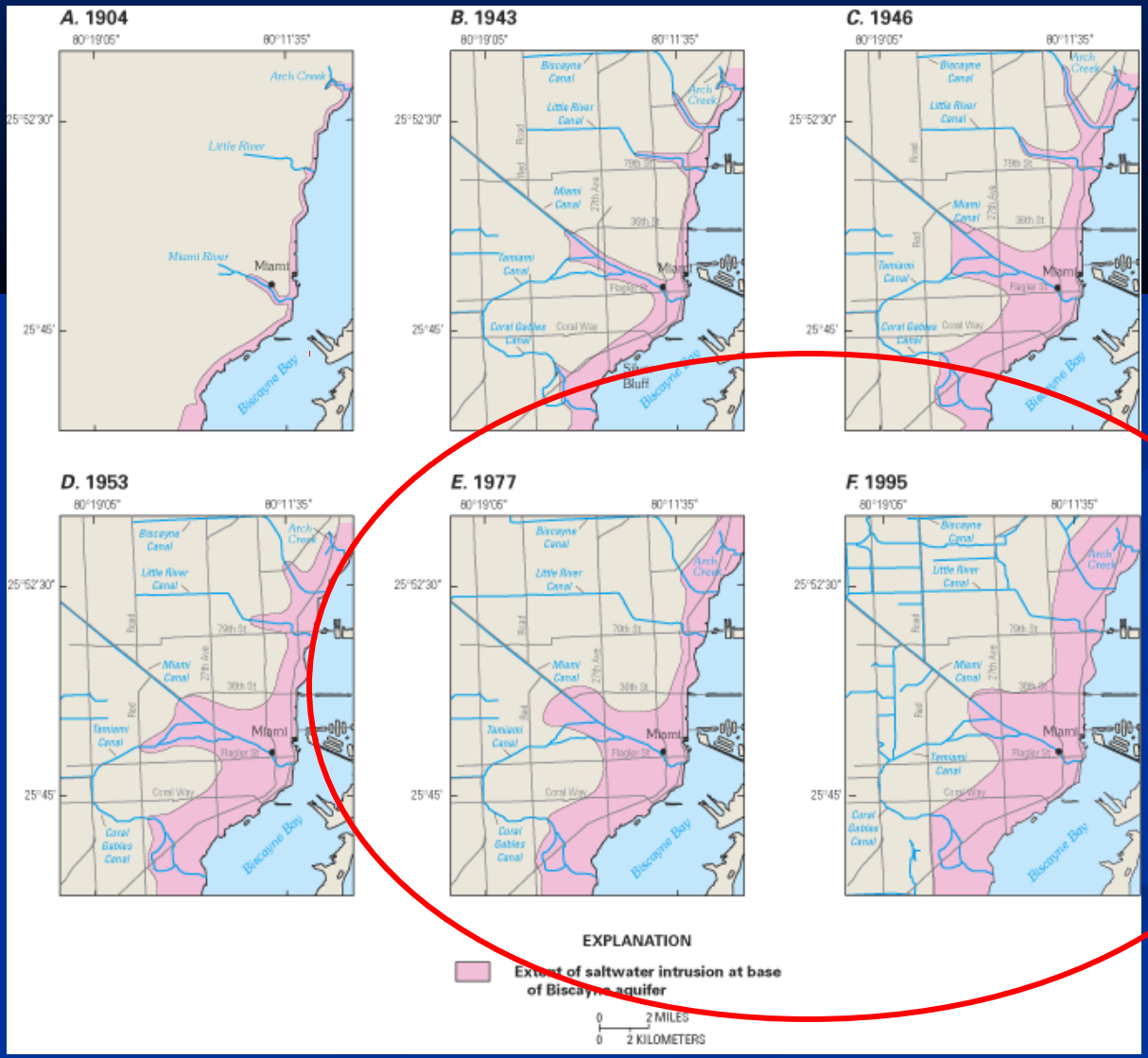
Progression of intrusion



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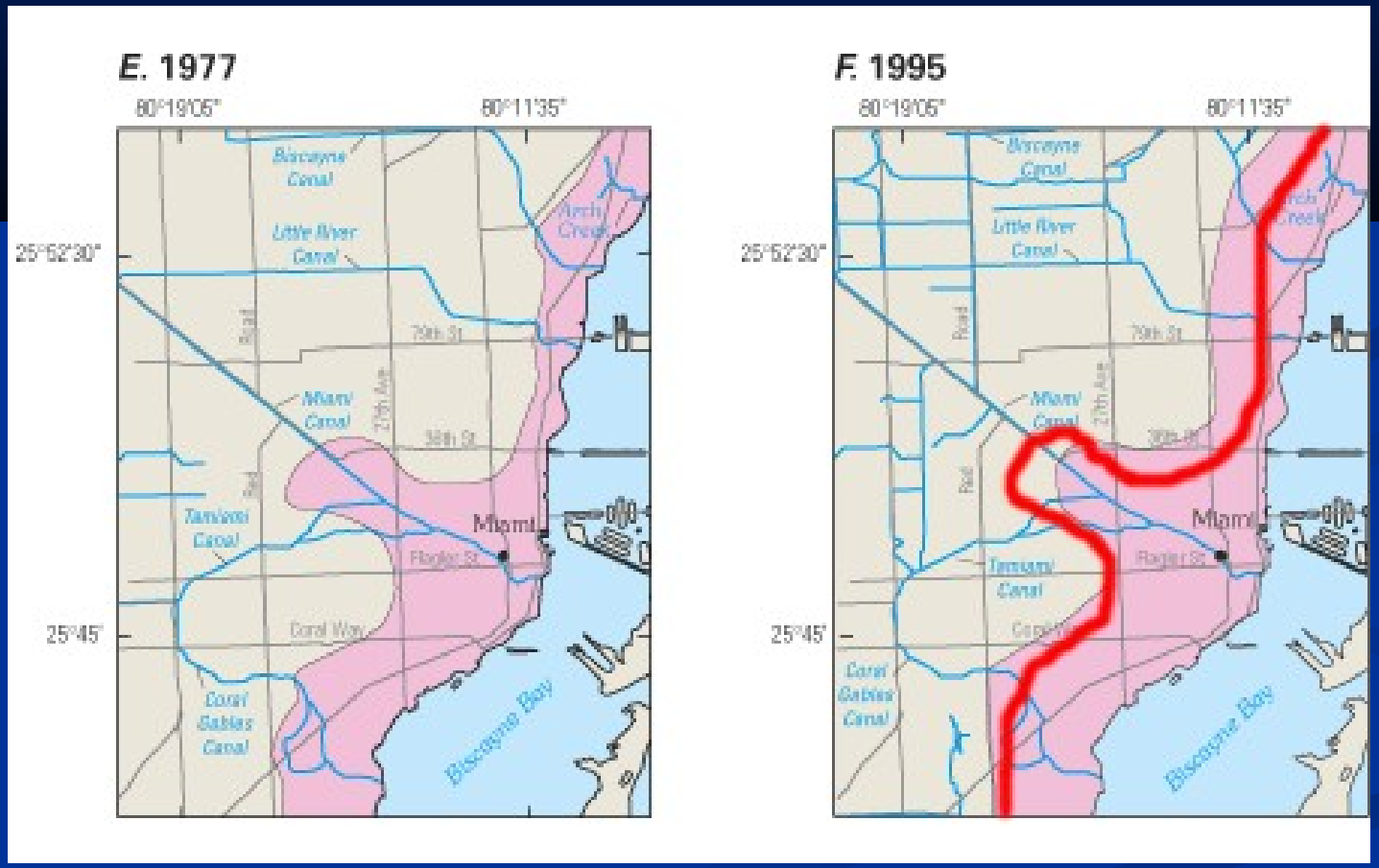
1977-1995 progression and retreat



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Los Angeles County

- High population density
- High freshwater demand
- Prior to development, aquifer under artesian pressure
- ~500 extraction wells

Groundwater Timeline

- 1905: Artesian area significantly decreased
- 1950's
  - extractions double natural (safe) yield
  - water level dropping approx 3m/yr
  - Coastal wells contaminated with salt water

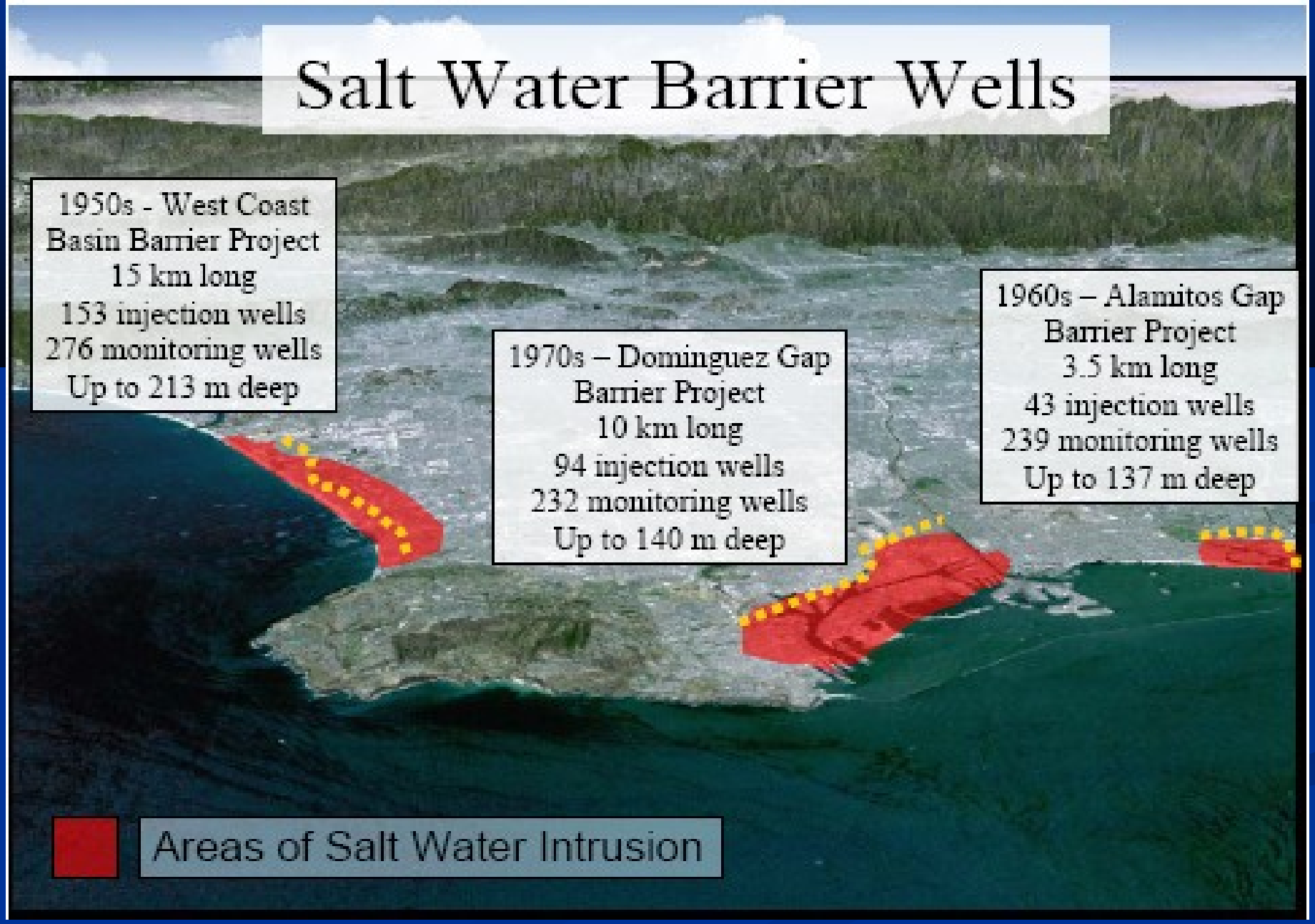
Intrusion Control

- 1950's
  - LA Flood Control Dept:
    - tested and installed injection wells
    - Successful
  - Replenishment District created
    - Attempt to eliminate overdraft
    - Artificial recharge
- Early 1960's
  - Total allowable extractions capped at 310x10^6 m3/yr

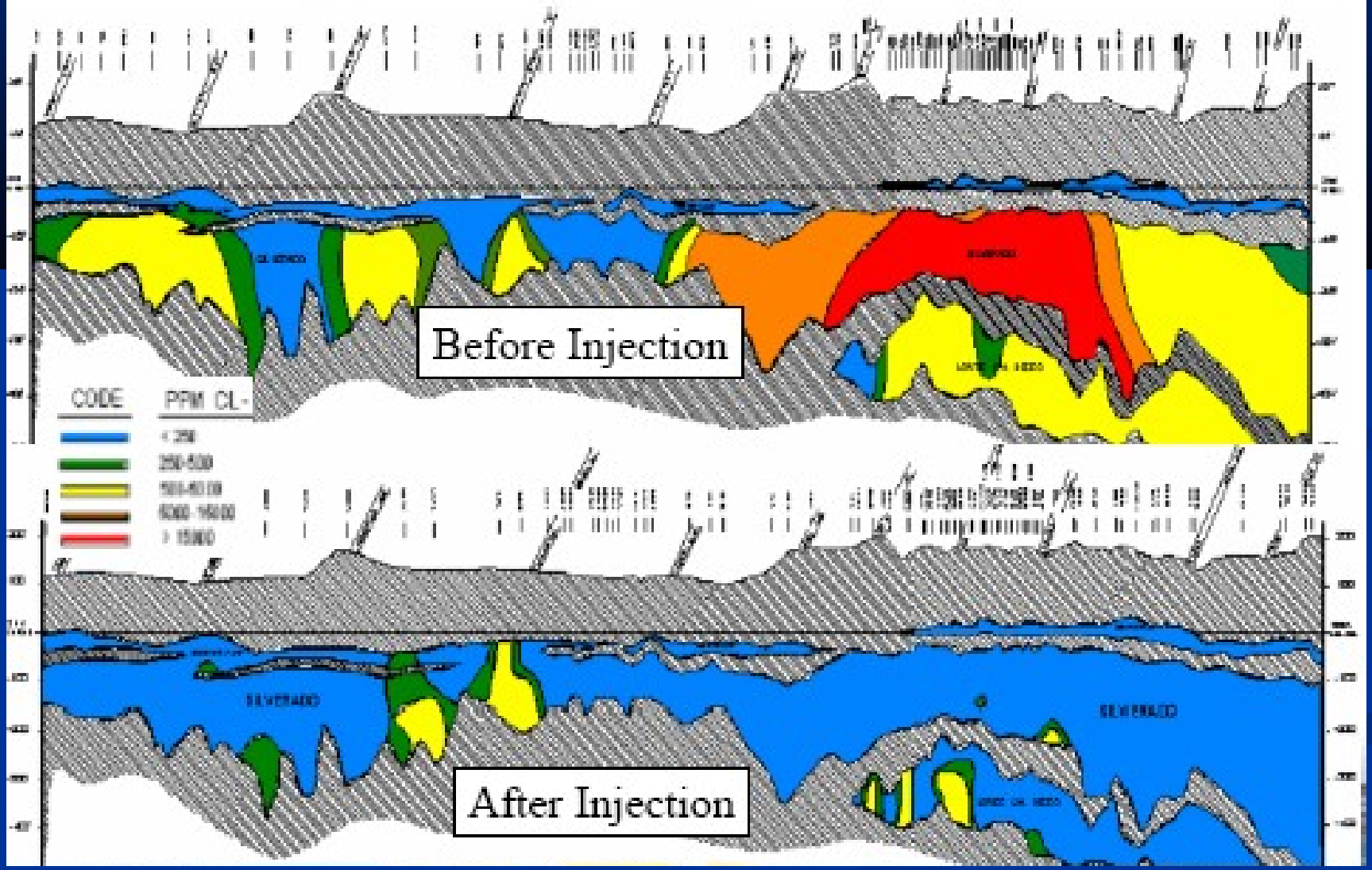
Barrier Wells

- Build up pressure in confined aquifers
- Injected water replenishes aquifers
- Recharge requires high quality water: imported through aqueducts
- Expensive

Salt Water Barrier Wells



Effectiveness of Barrier



Sources of Injected Water

- 1950's-present: treated drinking water
- Beginning in mid 1990's: advance treated reclaimed waste water

Alternatives to injection wells

- underground dams
- gas injection instead of water (nitrogen)
- modeling optimization to manage pumping patterns to minimize intrusion
- variations to vertical injection wells

Looking to the future…

- Management must be tailored to specific situation
- Populations continue to grow
- Rising sea level

Resources

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- Sonenshein, Roy S. “Delineation of Saltwater Intrusion in the Biscayne Aquifer, Eastern Dade County, Florida, 1995.” USGS. Water-Resources Investigations Report 96-4285. 1995. < http://fl.water.usgs.gov/Miami/online_reports/wri964285/>

Questions?