Hydrogeological Site Features
Turkey Point Units 6 & 7

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The information provided in the following presentation is of a preliminary nature and is considered DRAFT

Presentation Overview

- **Data Sources**
- **Regional Hydrostratigraphic Units**
- **Floridan Aquifer System**
  - Upper Floridan aquifer
  - Middle confining unit
  - Lower Floridan aquifer (Boulder zone)
- **Boulder Zone**
  - Hydraulic and geochemical properties
  - Deep well injection
- **Regional Groundwater Flow**
- **Fate and Transport of Injectate**

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Data Sources

Bush, P. and Johnston, R., *Groundwater Hydraulics, Regional Flow and Groundwater Development of the Floridan Aquifer System in Florida and in parts of Georgia, South Carolina and Alabama,* Professional Paper 1403-C, U.S. Geological Survey, 1988.

Maliva, R.G., and Walker, C.W., Hydrogeology of Deep-Well Disposal of Liquid Wastes in Southwestern Florida, USA, *Hydrogeology Journal*, 6: 538-548, 1998.

Maliva, R.G., Guo, W., and Missimer, T., Vertical Migration of Municipal Wastes in Deep Injection Well Systems, South Florida, USA, *Hydrogeology Journal*, 7: 1387-1396, 2007.

Meyer, F., *Hydrogeology, Ground-water Movement, and Subsurface Storage in the Florida Aquifer System in Southern Florida, Regional Aquifer-System Analysis-Floridan Aquifer System*, Professional Paper 1403-G, U.S. Geological Survey, 1989.

Miller, J.A., *Hydrologic Framework of the Floridan Aquifer System in Florida and in Parts of Georgia, Alabama, and South Carolina*, Professional Paper 1403-B, U.S. Geological Survey, 1986.

Miller, J.A., *Ground Water Atlas of the United States, Alabama, Florida, Georgia, and South Carolina*, Hydrologic Atlas 730-G, U.S. Geological Survey, 1990.

Reese, R., *Hydrogeology and the Distribution and Origin of Salinity in the Floridan Aquifer System, Southeastern Florida*, Water-Resources Investigations Report 94-4010, U.S. Geological Survey, 1994.

Reese, R., and Richardson, E., *Synthesis of the Hydrogeologic Framework of the Floridan Aquifer System and Delineation of a Major Avon Park Permeable Zone in Central and Southern Florida*, Scientific Investigations Report 2007-5207, U.S. Geological Survey, 2008.

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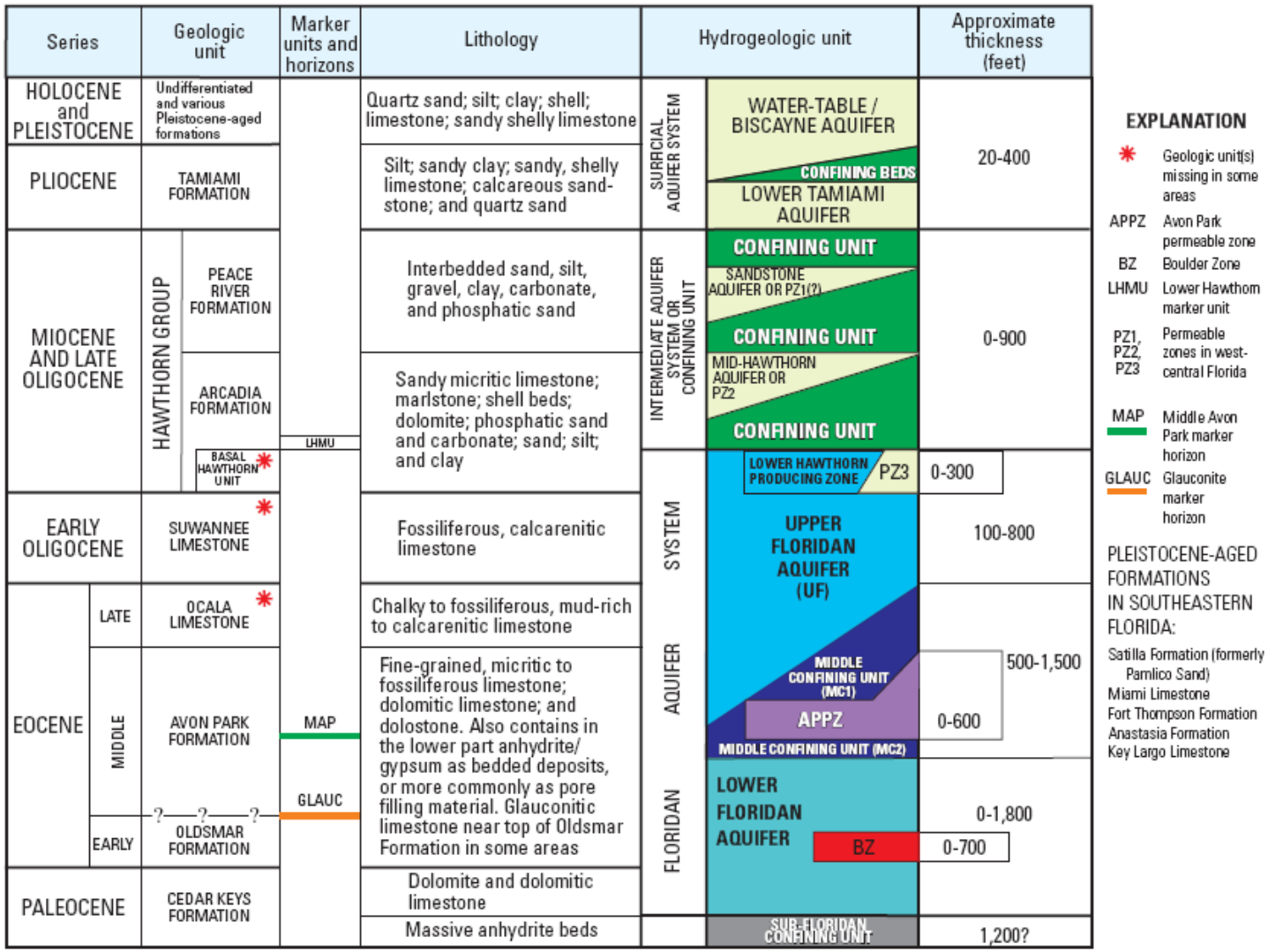
Regional Hydrostratigraphic Units

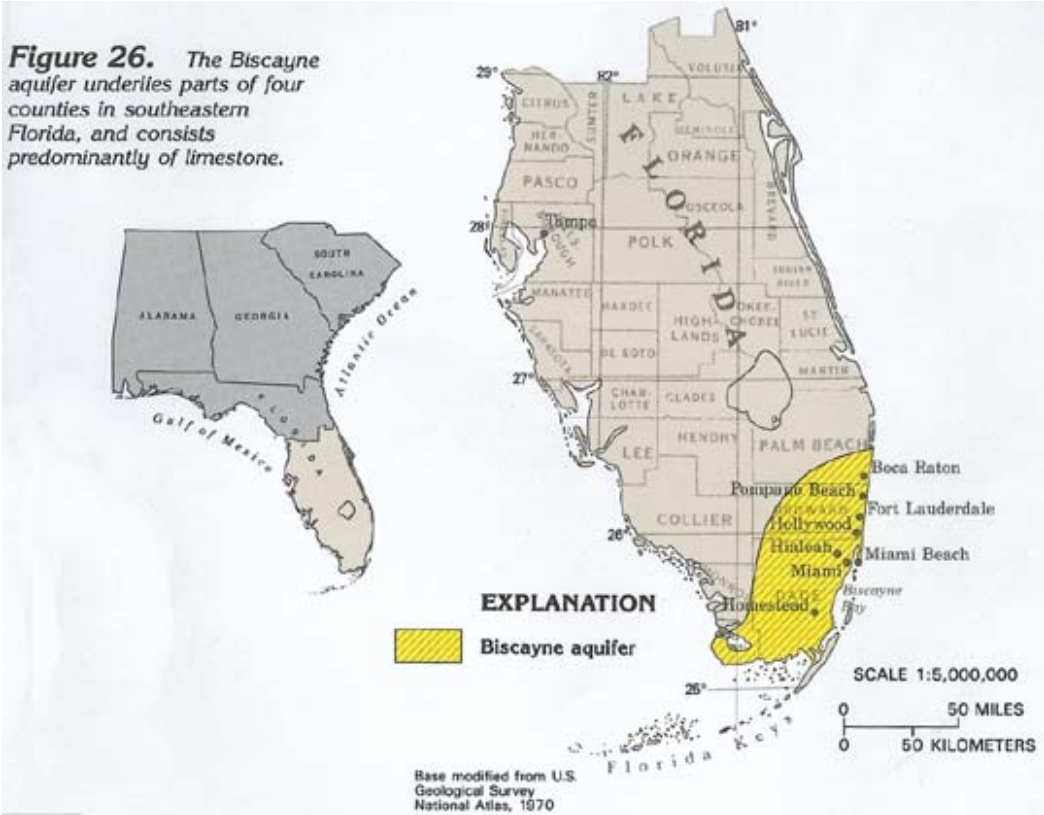


Source: Reese and Richardson (2008)

Regional Hydrostratigraphic Units

Surficial Aquifer System

- "The permeable hydrogeologic unit contiguous with the land surface that is comprised principally of unconsolidated to poorly indurated, siliciclastic deposits."
- Includes Biscayne aquifer
- 20-400 ft thick



Source: Miller (1990)

Regional Hydrostratigraphic Units

Intermediate Aquifer System / Confining Unit

- **"All rocks that lie between and collectively retard the exchange of water between the overlying surficial aquifer system and the underlying Floridan aquifer system"**
- **Interlayered aquifer/aquitard system comprised of Hawthorn Group sediments**
- **Up to 900 ft thick**
- **Brackish water quality**

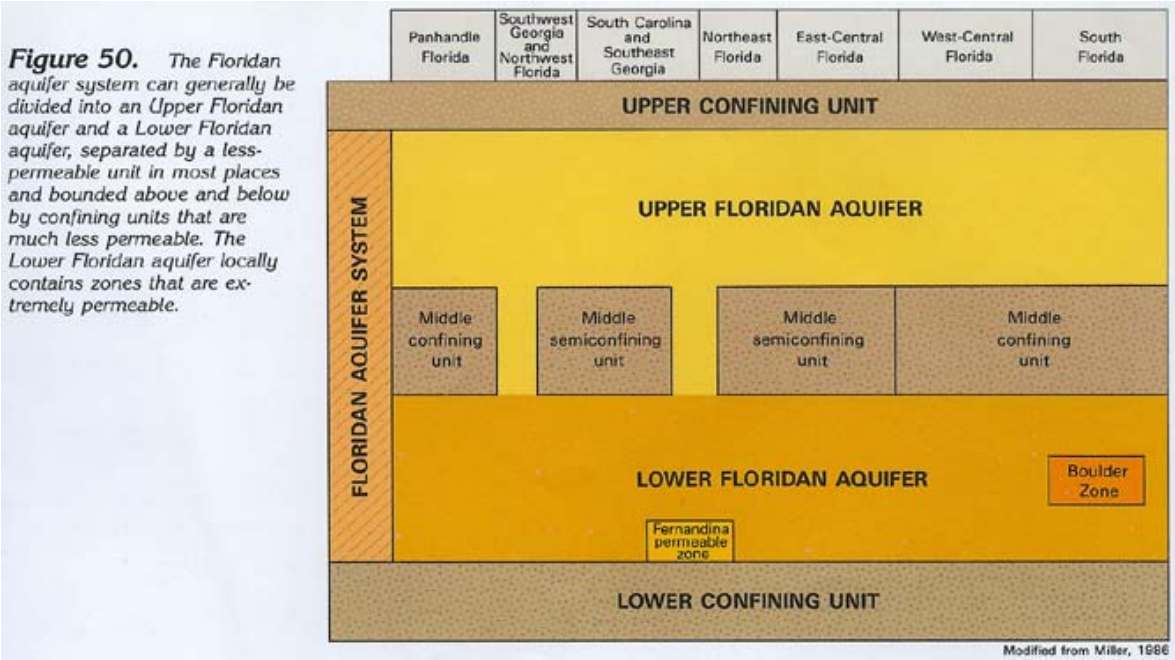


Figure 50. *The Floridan aquifer system can generally be divided into an Upper Floridan aquifer and a Lower Floridan aquifer, separated by a less-permeable unit in most places and bounded above and below by confining units that are much less permeable. The Lower Floridan aquifer locally contains zones that are extremely permeable.*

Source: Miller (1990)

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Regional Hydrostratigraphic Units

Floridan Aquifer System

- "Vertically continuous sequence of interbedded carbonate rocks of Tertiary age that are hydraulically interconnected by varying degrees and with permeabilities several orders of magnitude greater than the hydrogeologic systems above and below."
- Comprised of shallow-water limestone and dolomite beds
- 2300 to 2400 ft thick in southern Florida
- Brackish to marine water quality

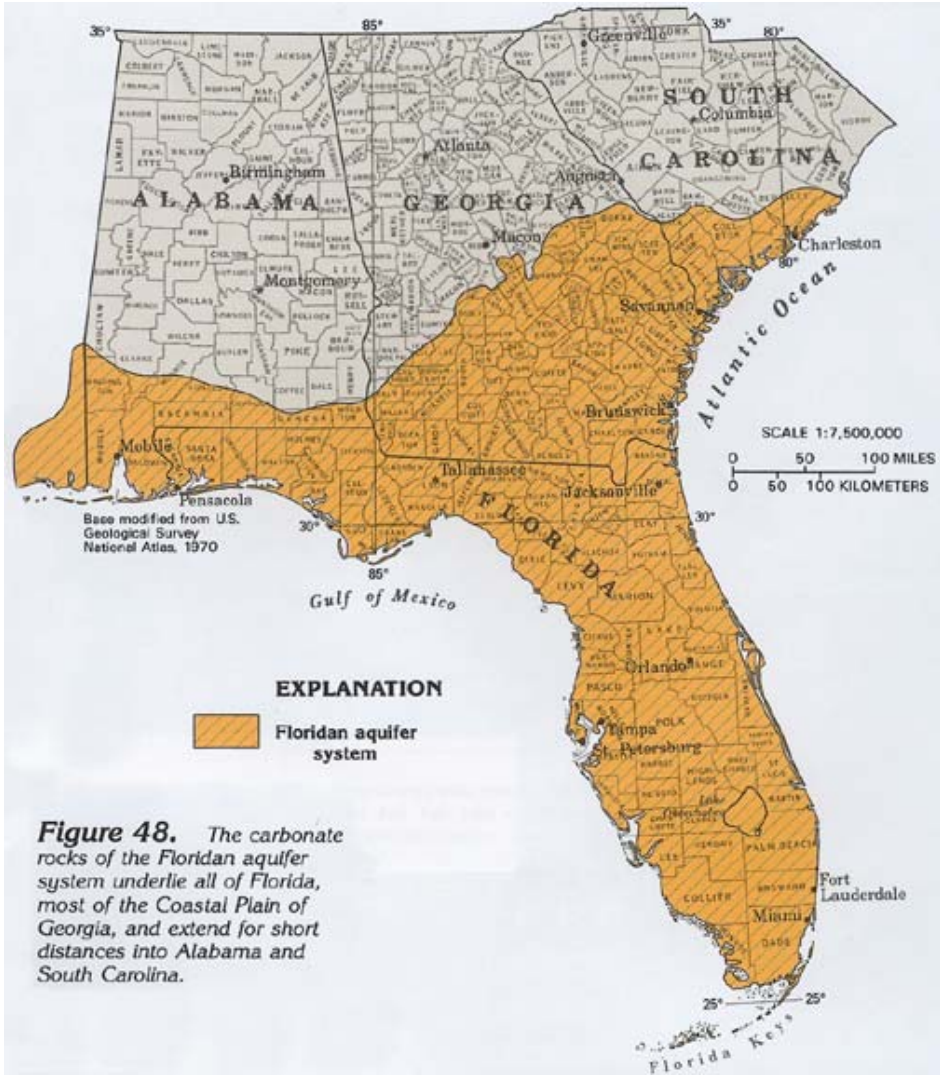
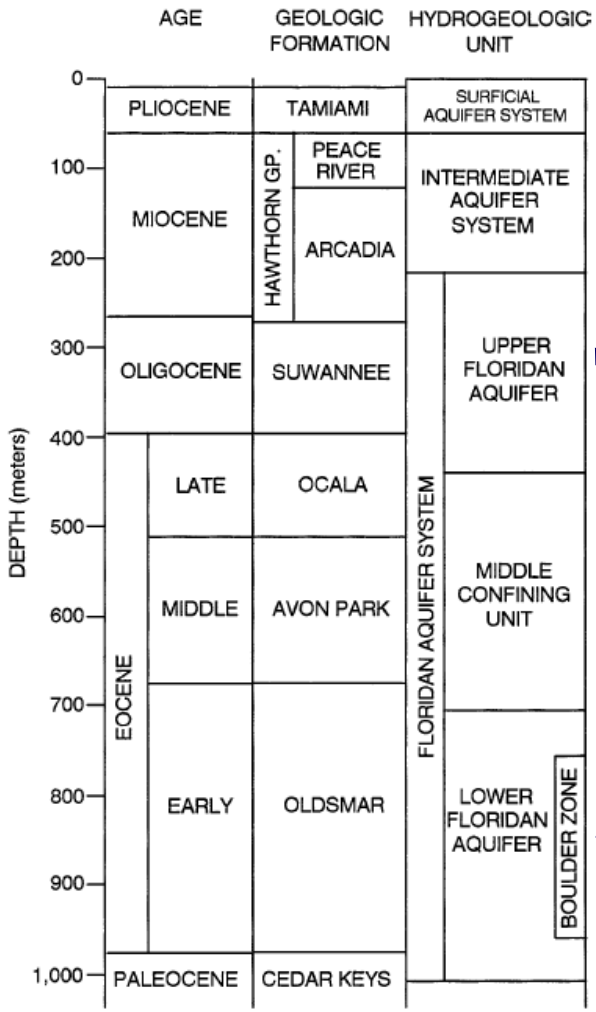


Figure 48. *The carbonate rocks of the Floridan aquifer system underlie all of Florida, most of the Coastal Plain of Georgia, and extend for short distances into Alabama and South Carolina.*

Source: Miller (1990)

Floridan Aquifer System



Upper Floridan Aquifer

- Porous limestones / dolomites
- 100 to 400 ft in thickness
- Transmissivities of 10,000 to 60,000 ft^2/d
- Brackish water quality

Middle Confining Unit

- Interbedded, low permeability dolomites and limestones
- About 900 ft thick in SE Dade County
- Vertical hydraulic conductivities of 10^{-7} to 10^{1} ft/d (10^{-10} to 10^{-2} cm/s)

Lower Floridan Aquifer

- Permeable dolostones separated by less permeable limestones
- Up to 2000 ft in thickness
- Lower dolostone termed “Boulder Zone” and highly transmissive
- Marine water quality

Source: Maliva and Walker (1998)

Boulder Zone

Geology

- Intervals of cavernous and fractured dolomites in the Early Eocene Oldsmar Formation
- Occurs at a depth of about 2900 ft near site

Transmissivity

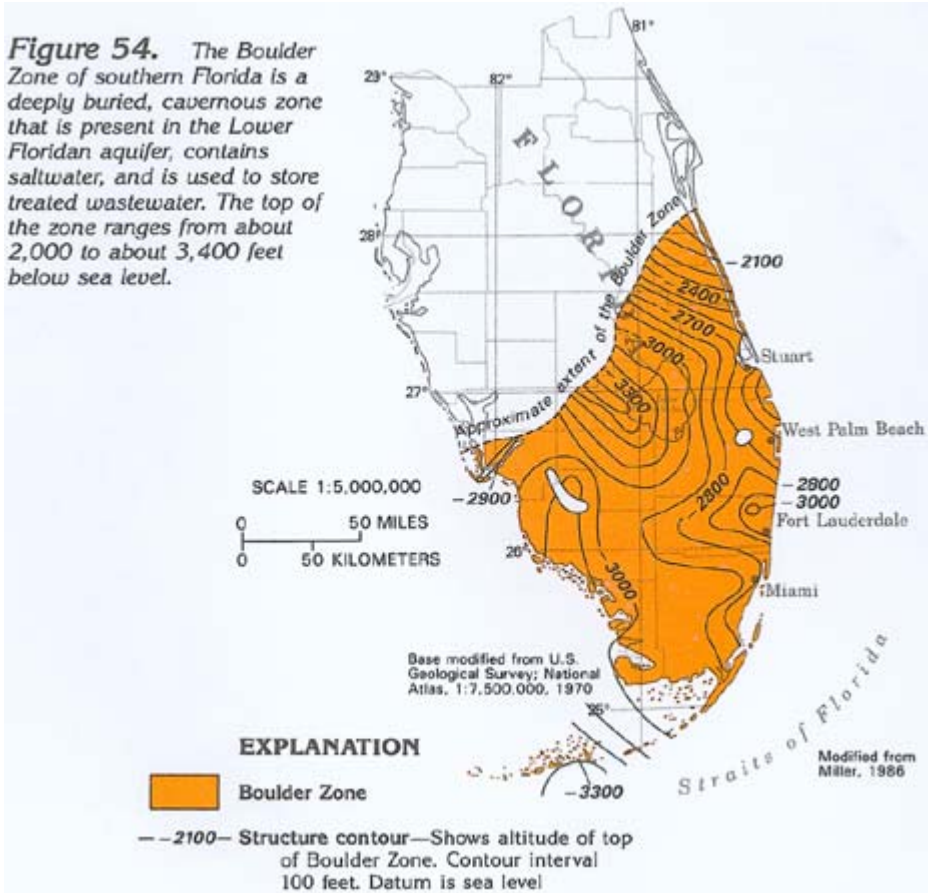
- 3,200,000 to 24,600,000 ft^2/d

Water Quality

- Geochemically similar to modern seawater (35,000 mg/L TDS)
- Anomalous water temperature (nominally 50°F near coast)

Use

- Wastewater disposal by deep well injection
- Oil field brines, municipal and industrial wastewater



Source: Miller (1990)

Regional Groundwater Flow

- **"Variations in water quality, hydraulic head, and water temperature within the carbonate rocks that make up the Floridan aquifer system in southern Florida suggest that the flow system is complex." (Meyer, 1989)**
- **Regional flow in Boulder Zone difficult to assess due to:**
  - Limited number of hydraulic head observations
  - Very high transmissivities $\Rightarrow$ very low hydraulic gradients
  - Transitory effects of tides (ocean and atmospheric)
- **USGS (Meyer, 1989) determined regional flow patterns from**
  - Temperature data
  - Water quality data
  - Groundwater age dating
  - Hydraulic head data

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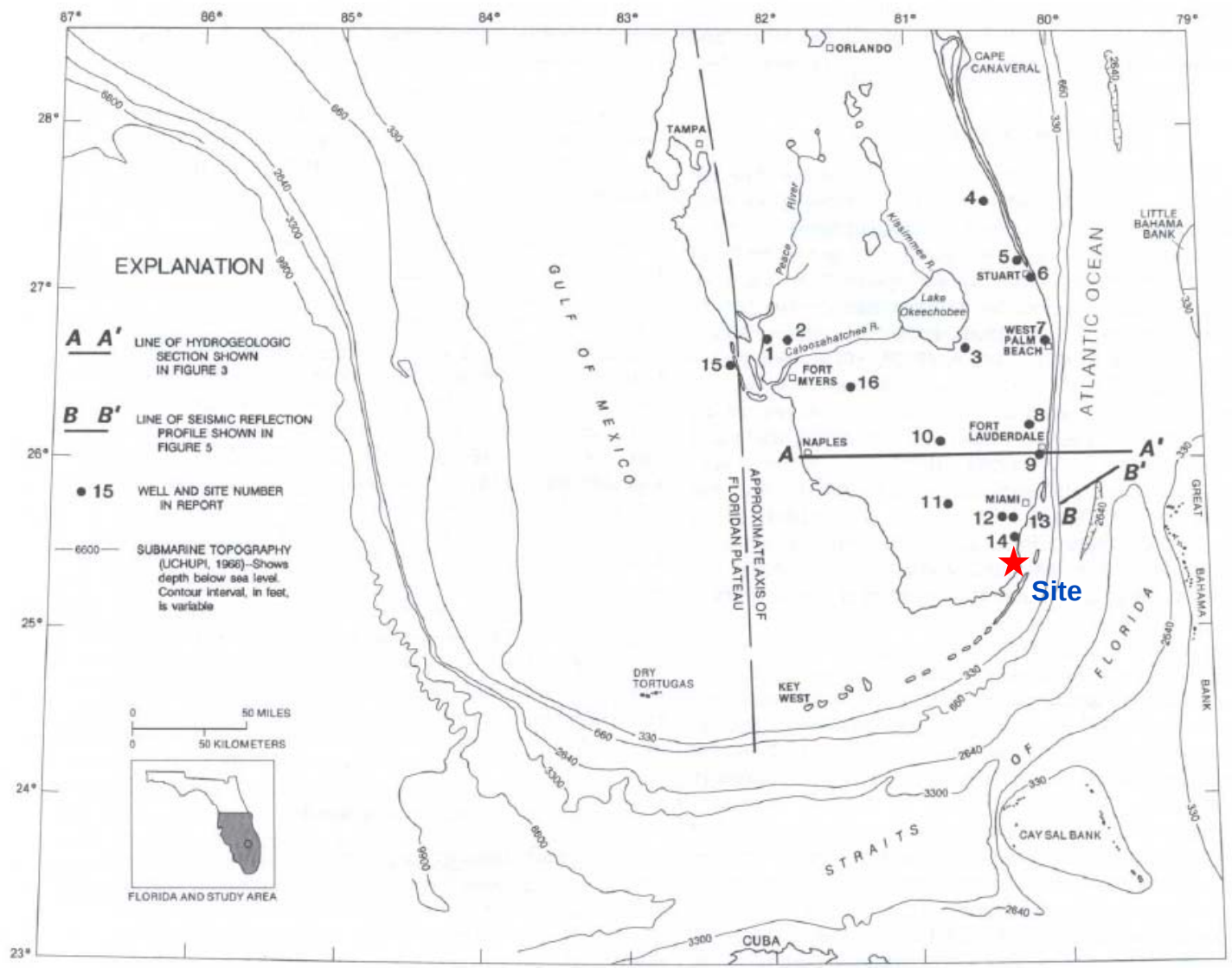
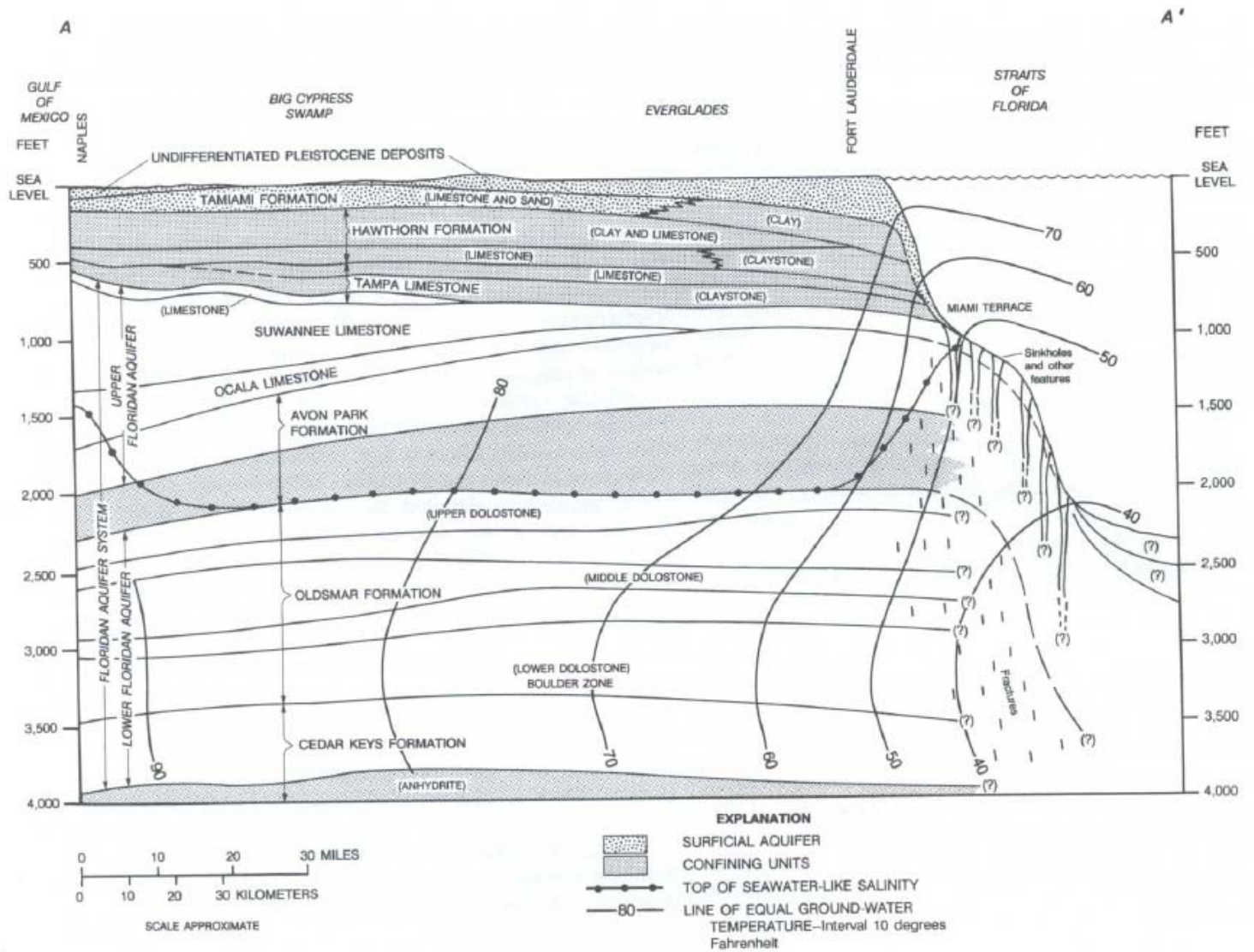
South Floridan Plateau



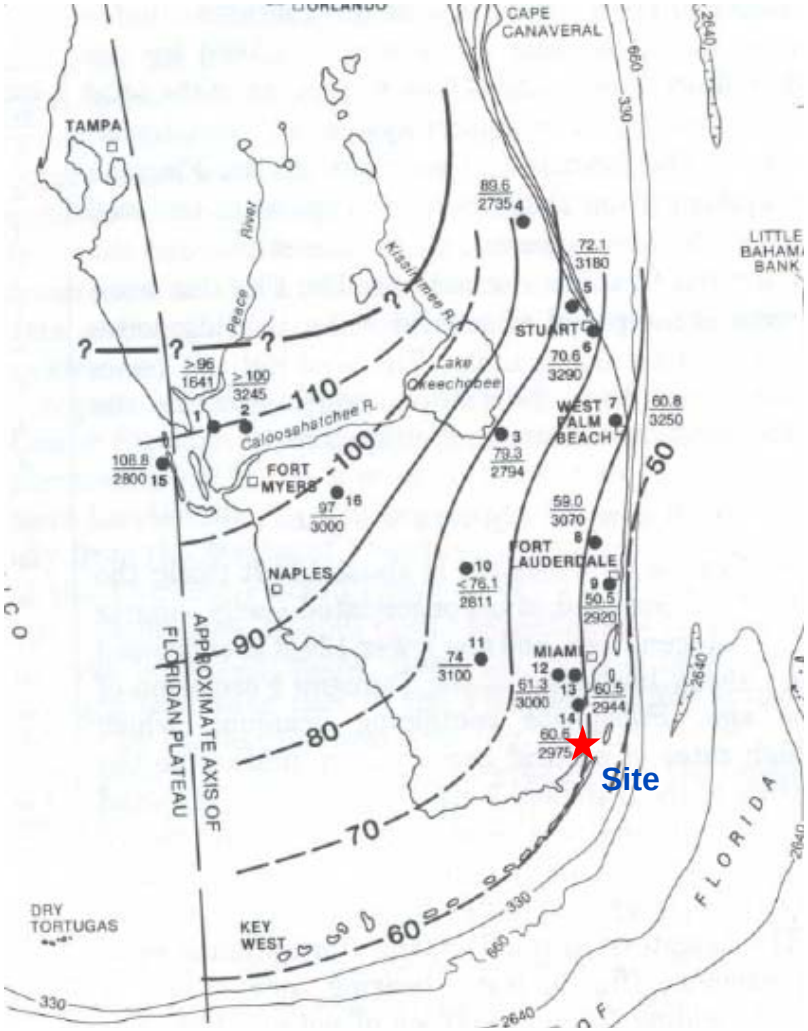
Source: Meyer (1989)

Generalized Hydrogeologic Section

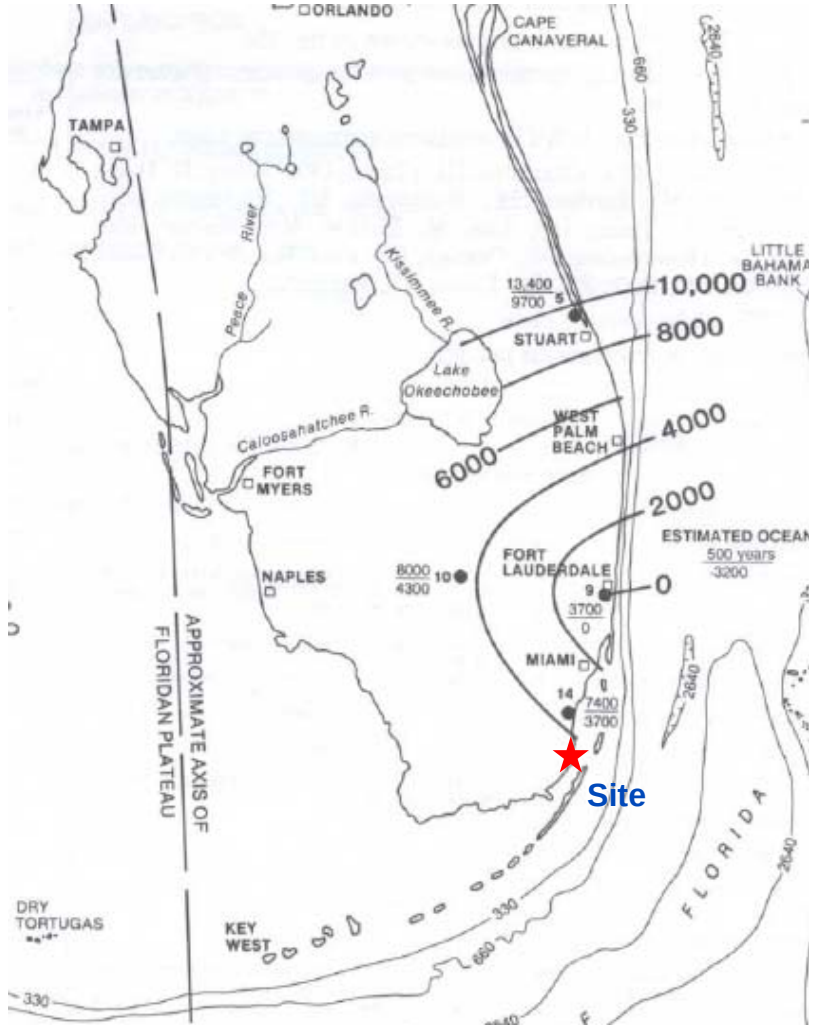


Source: Meyer (1989)

Groundwater Temperature (°F)

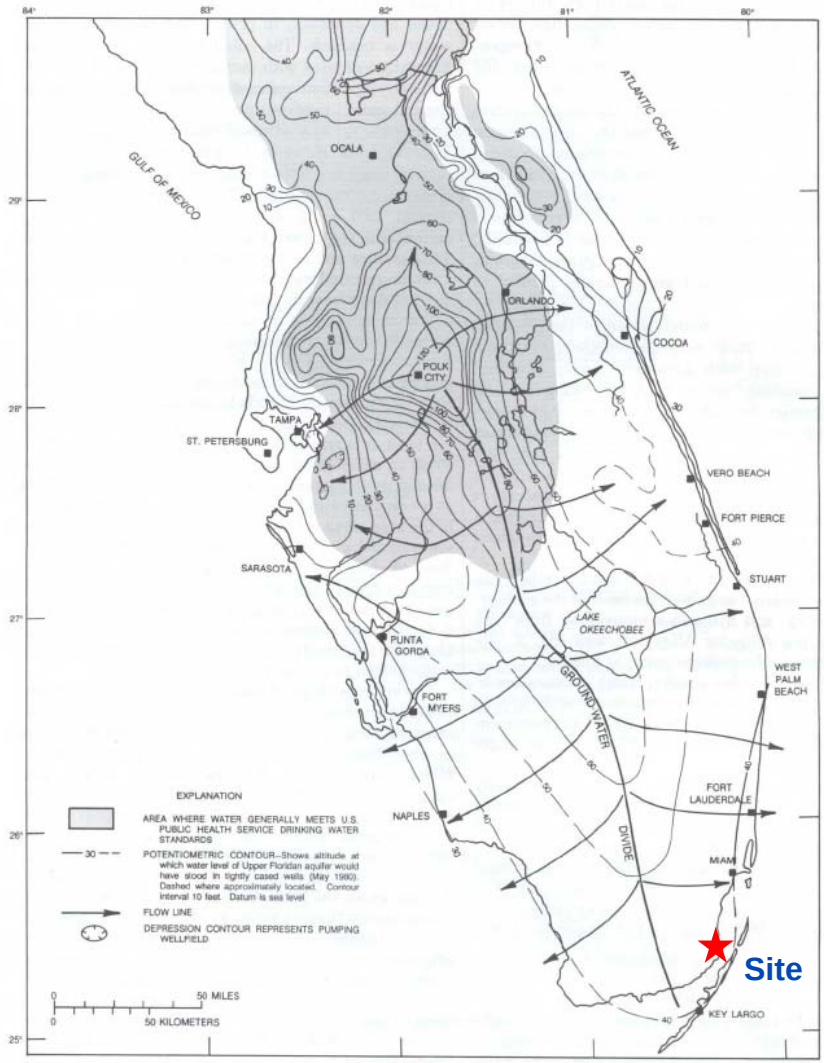


Relative Age (y) in Boulder Zone



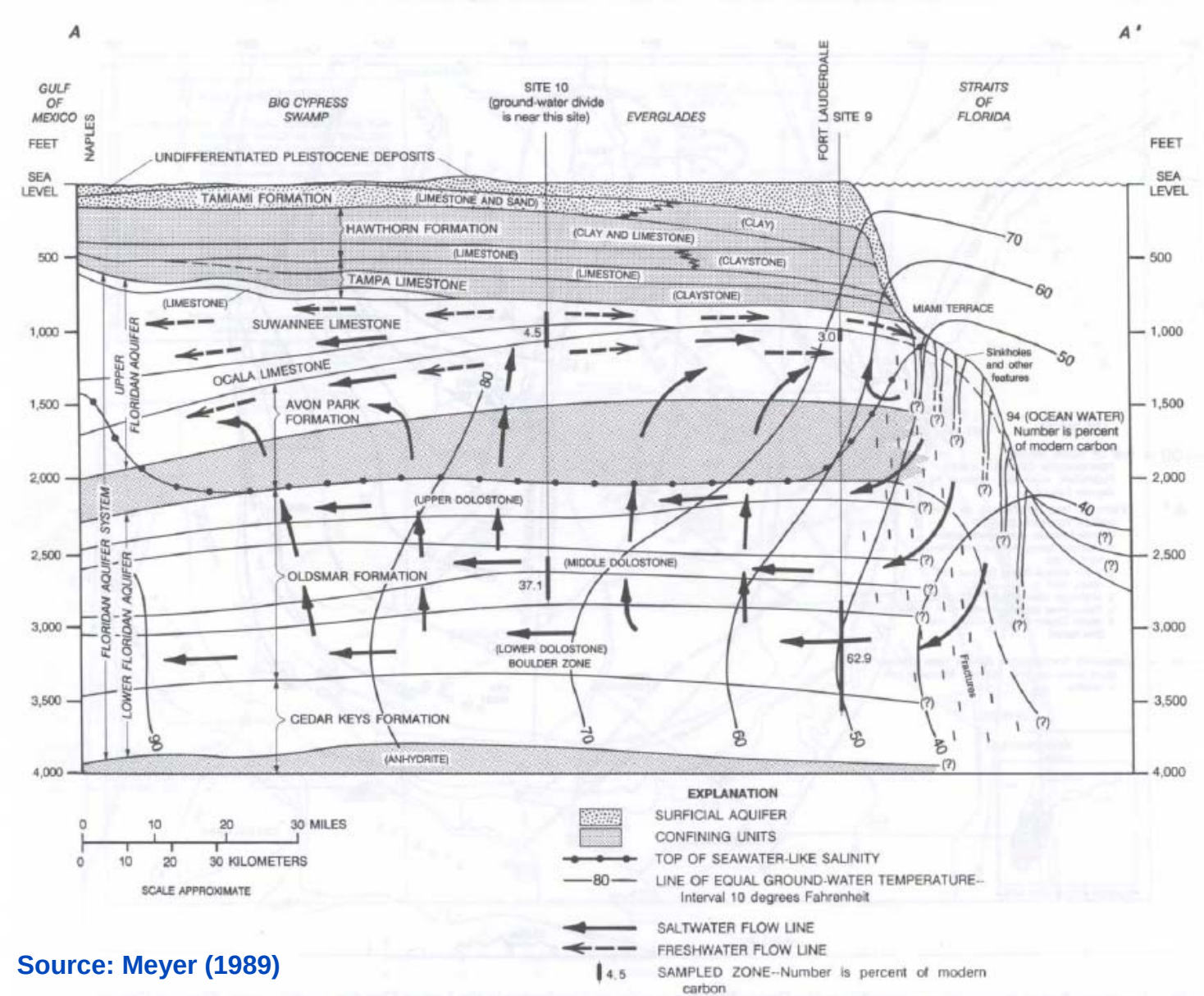
Source: Meyer (1989)

Potentiometric Surface Upper Floridan Aquifer



Source: Meyer (1989)

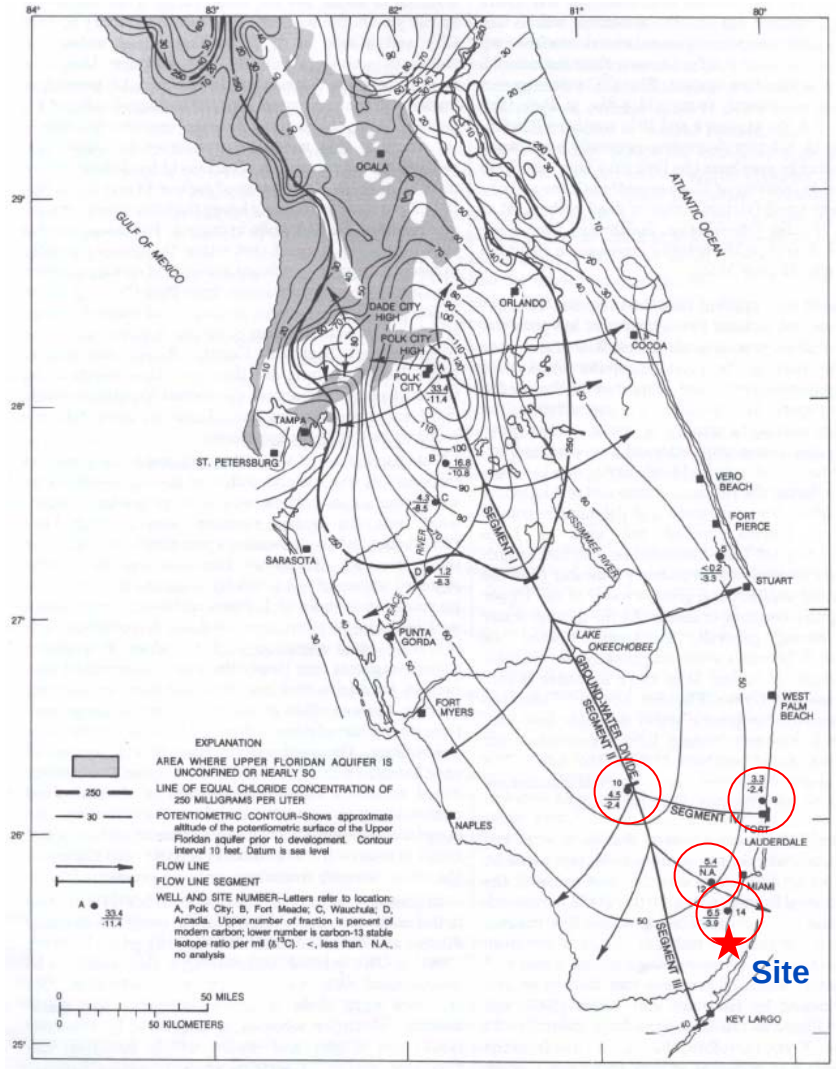
Regional Groundwater Circulation



Source: Meyer (1989)

Time Scales for Groundwater Circulation

- **Measureable C-14 activity in Upper Floridan aquifer suggests source younger than 40,000 years**
- **Transit times from aquifer recharge areas >> 40,000 years**
- **C-14 attributed to upwelling from Lower Floridan aquifer**
- **Percent Modern Carbon (PMC) in Upper Floridan aquifer**
  - 3.3% ≤ PMC ≤ 6.5%
- **Apparent age (before 1950)**
  - Age = -8033 ln (PMC×10^{-2})
  - 22,000 y ≤ Age ≤ 27,000 y



Source: Meyer (1989)

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Injectate Characteristics

- **Injection Rates**
  - Cooling tower blowdown
    - -- 12,500 gpm for reclaimed water source (COC = 4)
    - -- 58,000 gpm for marine water source (COC = 1.5)
  - Normal plant releases
    - -- 3 gpm
- **Physical Characteristics**
  - Reclaimed water source
    - Salinity = 4 x 1,000 mg/l = ~4,000 mg/L TDS
    - Temperature = 92°F = 33.2°C
    - Density = 997.607 kg/m^3
  - Marine water source
    - Salinity = 1.5 x 35,000 mg/l = ~52,500 mg/l TDS
    - Temperature = 92°F = 33.2°C
    - Density = 1033.721 kg/m^3

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Injectate Characteristics

- **Ambient Boulder Zone Water**
  - Salinity = 35,000 mg/l TDS
  - Temperature = 60°F = 15.6°C
  - Density = 1025.866 kg/m^3
- **Density Differences**
  - Reclaimed water source
    - -- Injectate (997.607 kg/m^3) < groundwater (1025.866 kg/m^3)
    - -- Positively buoyant
  - Marine water source
    - -- Injectate (1033.721 kg/m^3) > groundwater (1025.866 kg/m^3)
    - -- Negatively buoyant

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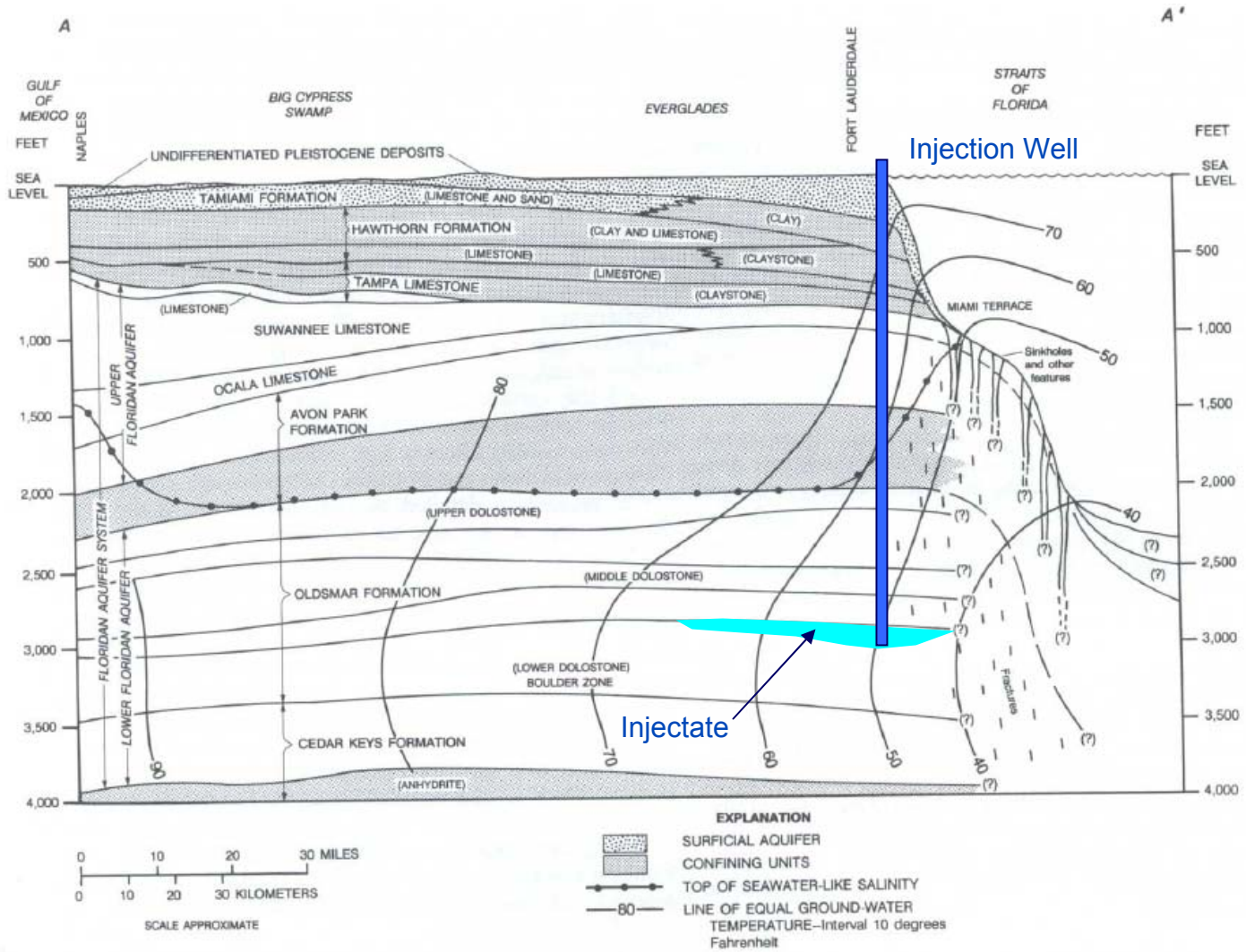
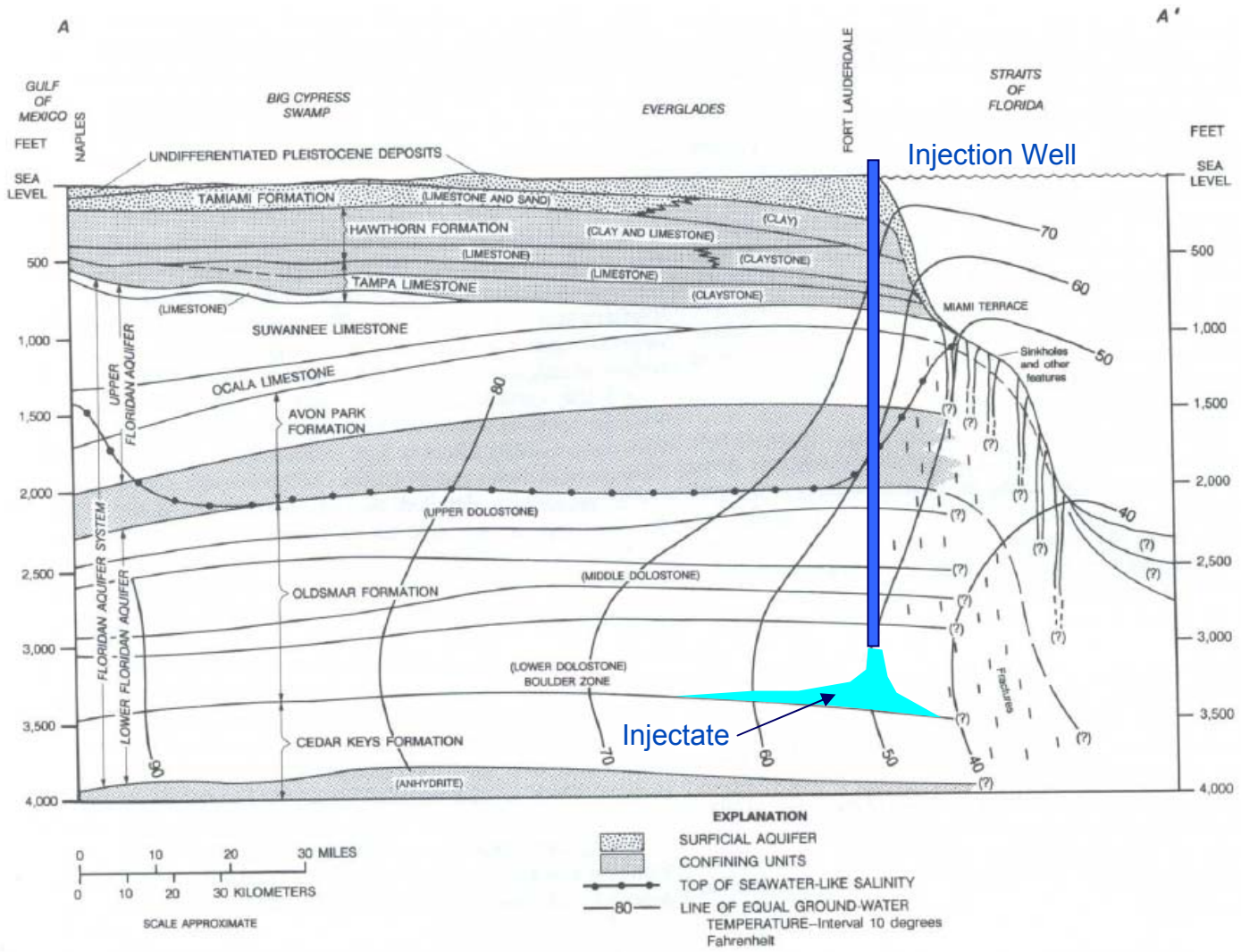
Injectate Transport – Reclaimed Water Source



Injectate Transport – Marine Water Source



Postulated Injectate Fate and Transport

- **Initial spreading of injectate "bubble" governed by buoyancy-driven flow and geologic structure**
- **Dissolution of injectate into ambient groundwater with subsequent advective transport along ambient groundwater pathways and attenuation due to:**
  - Hydrodynamic dispersion
  - Retardation
  - Radioactive decay
- **Plausible groundwater pathways could:**
  - Be confined to the saline, Lower Floridan aquifer
    - -- No potential exposure
  - Include upwelling to the brackish, Upper Floridan aquifer
    - -- Travel times > 10,000 y

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