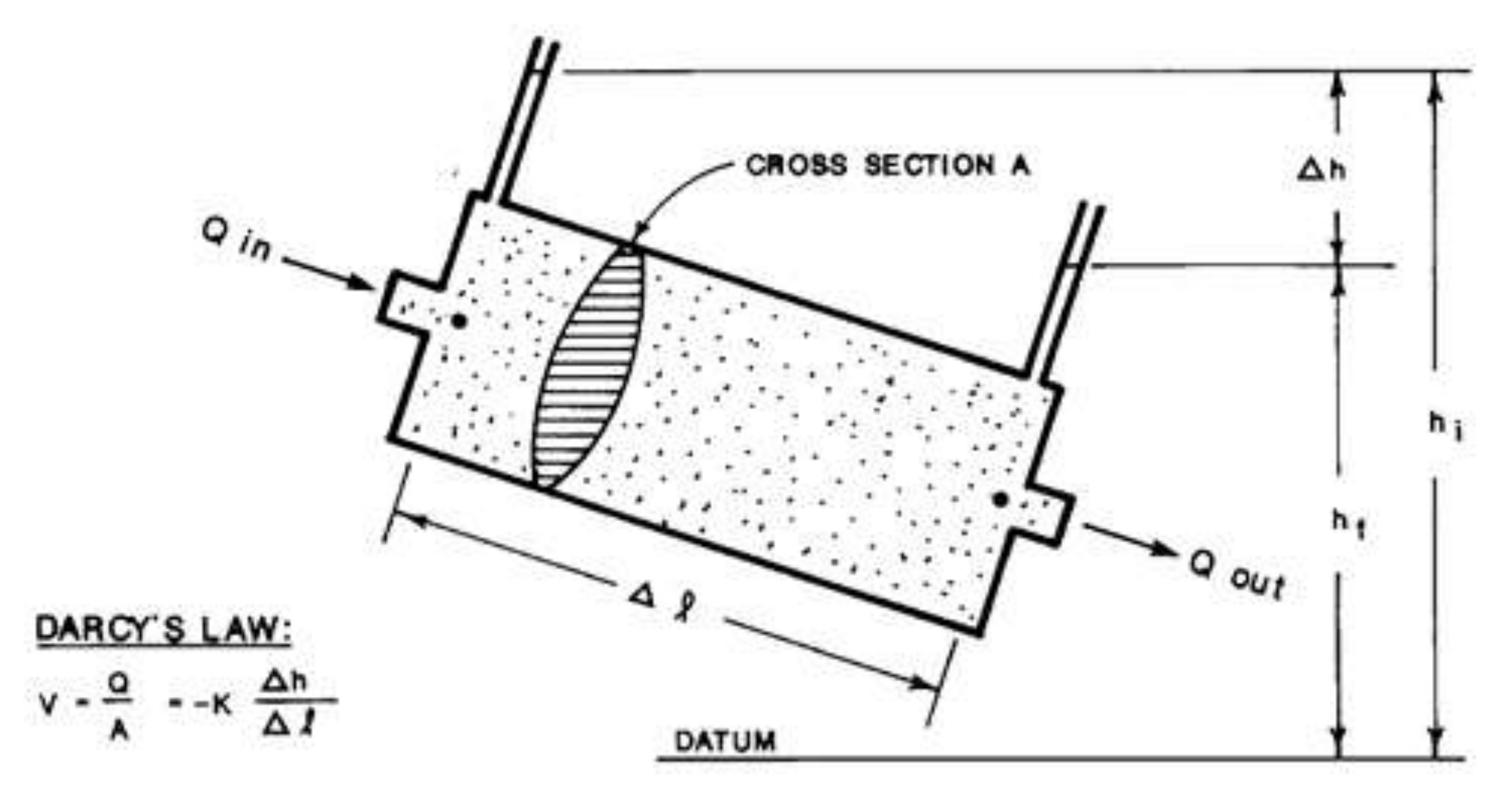
Our Eastern Shore Groundwater
Part I
Where is the groundwater and how much is there?

Britt McMillan, Malcolm Pirnie, Inc.

A Review of Groundwater Flow



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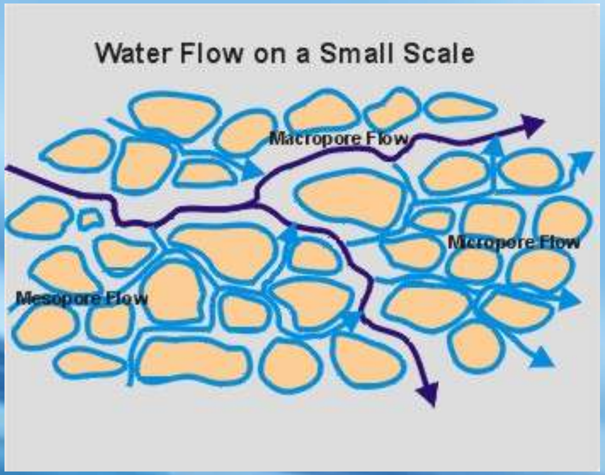
Groundwater is Not like an Underground River!

- **Groundwater flows through porous soils and sediment that includes gravels, sands, silts, and clay.**



Soil/Sediment Type Determines if it can be used as a source of water

An Aquifer is a Source for Groundwater and is:

Any coarse grained material (sand, gravel) that can supply sufficient water for a beneficial use

A Confining Unit Impedes Movement of Groundwater and is:

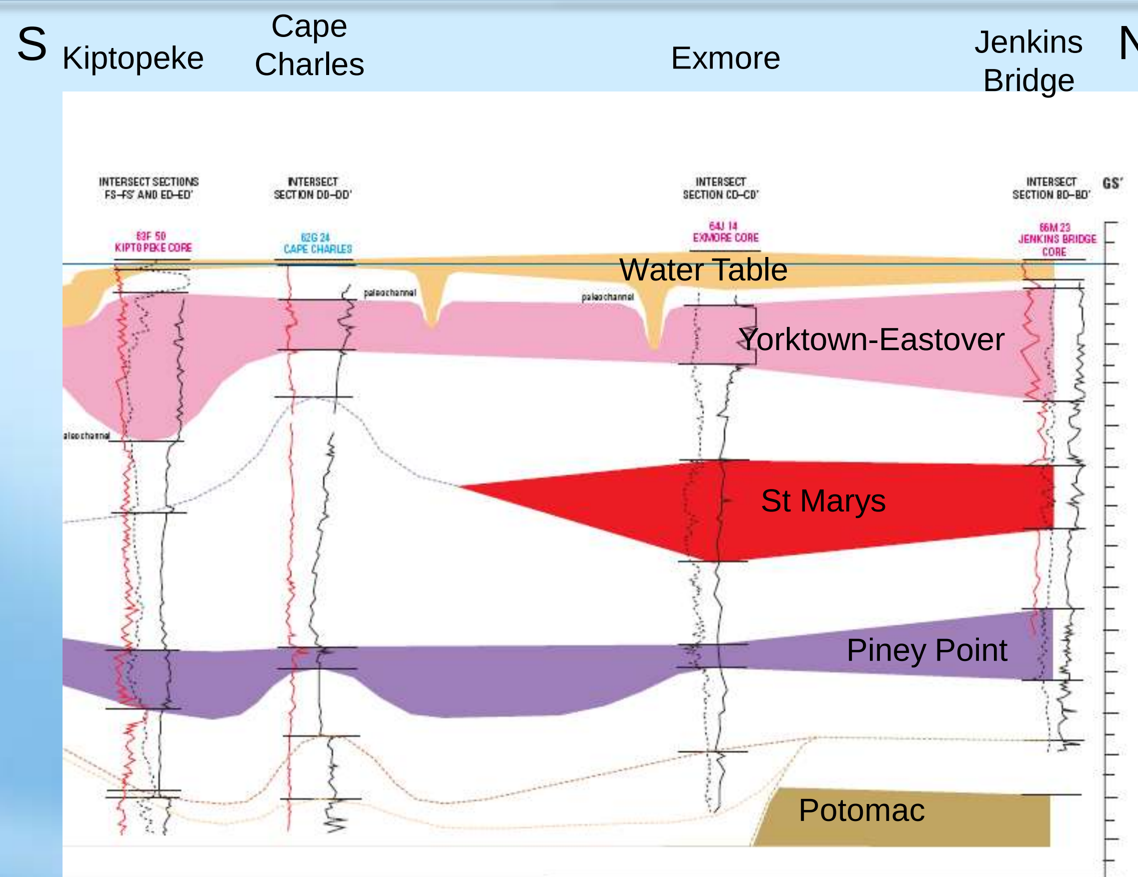
Any fine grained material (silt, clay) that can significantly restrict vertical movement of groundwater such that the resulting groundwater is under pressure.

Aquifers are defined by where they appear relative to a confining layer

- **Water Table**
  - Water is not "under pressure"
  - Well yield is lower than comparable confined aquifers
  - Replenished (recharged) directly by precipitation
  - More vulnerable to contamination from surface activities
- **Confined aquifer**
  - Water is under pressure, confined by an overlying layer(s) of silt and clay
  - Replenished from vertical flow through the confining unit (recharge is much lower than a water table aquifer)
  - More vulnerable to saltwater intrusion

All Groundwater Aquifers on the Eastern Shore

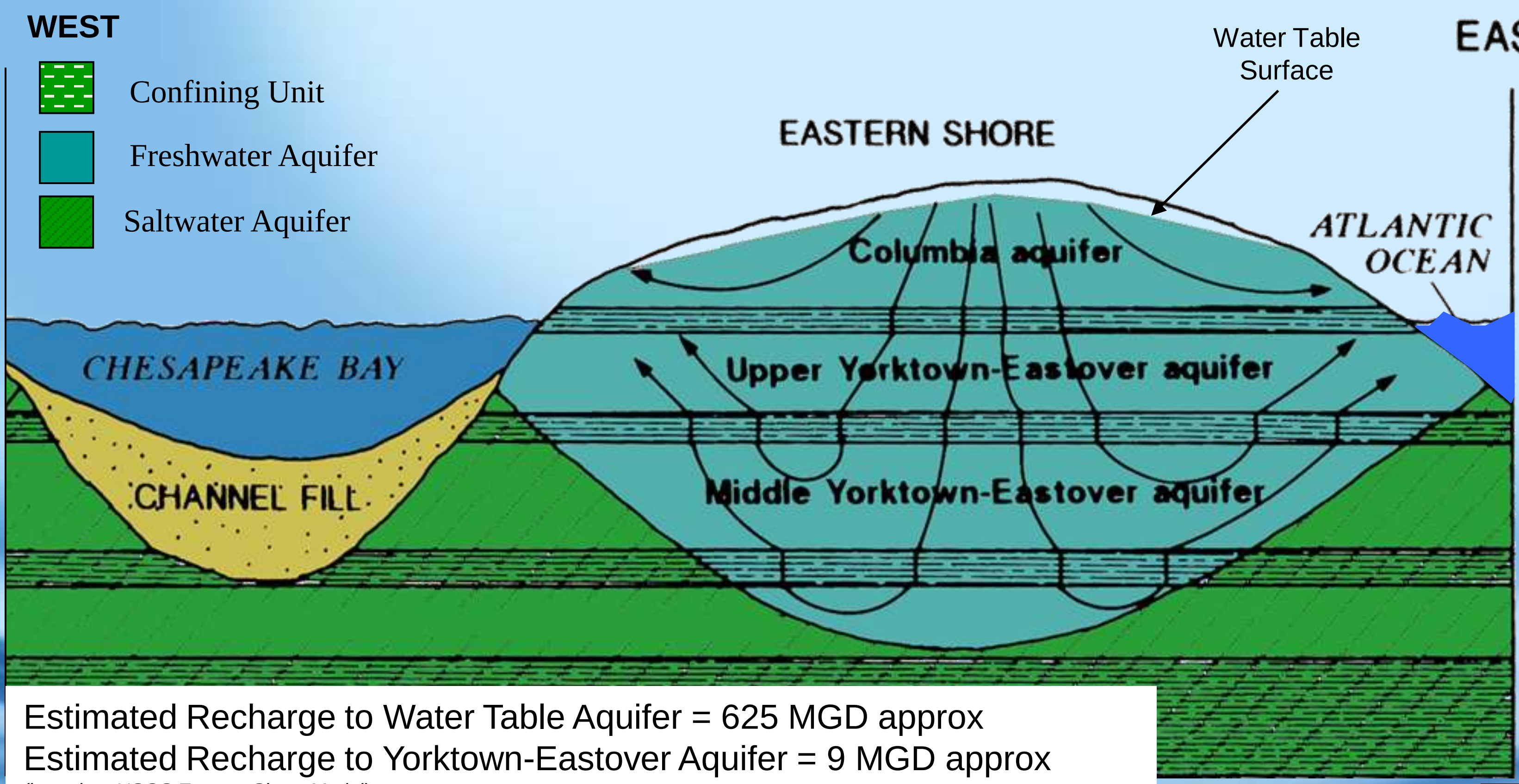
- **Fresh Groundwater is restricted to the Columbia (Water Table) aquifer and significant portions of the Yorktown-Eastover aquifer**
- **Brackish groundwater is found in portions of the Yorktown-Eastover, all of the St. Marys Aquifer, Piney Point, and Potomac aquifers**
- **The Columbia, Yorktown-Eastover, and Piney Point aquifers are found throughout the Eastern Shore**
- **St. Marys and Potomac Aquifers are absent in the southern portion of the Shore**



Source: McFarland and Bruce, 2006

Water Table and Fresh Water Confined Aquifers on the Eastern Shore

Fresh ground water is restricted to depths less than 350 feet



Estimated Recharge to Water Table Aquifer = 625 MGD approx
Estimated Recharge to Yorktown-Eastover Aquifer = 9 MGD approx
(based on USGS Eastern Shore Model)

The Factor Most Important in Controlling Rate of Groundwater Flow is Hydraulic Conductivity

Hydraulic Conductivity for Silty Clay to Coarse Sand Varies by 1,000,000 ft/day (1 million ft/day)

Fine Grain Size — Coarse Grain Size

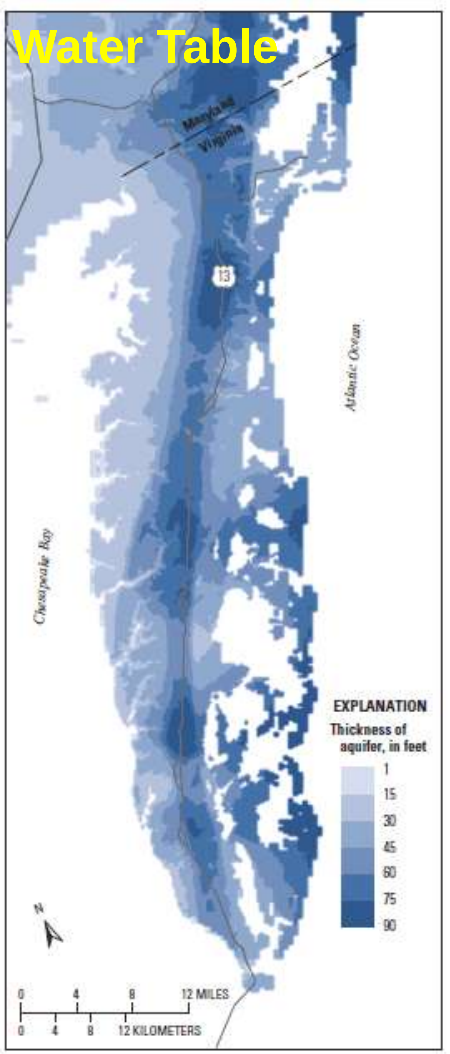
Clay	<<	Silt	<	Silty Sand	<<	Fine Sand	<	Coarse Sand	<<	Gravel
0.0000001 to 0.001 ft/day		0.001 to 1 ft/day		0.01 to 10 ft/day		1 to 10 ft/day		10 to 100 ft/day		100 to 10,000 ft/day

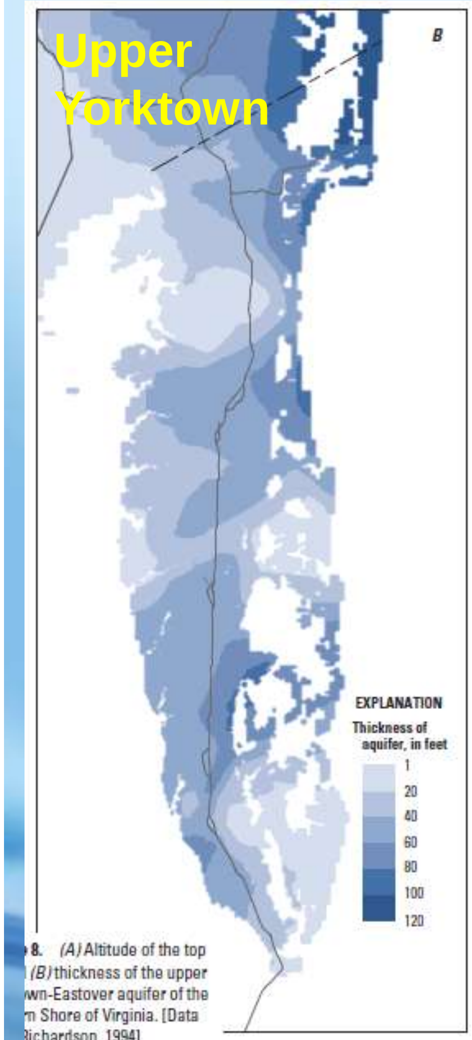
Confining Unit | **Aquifer**

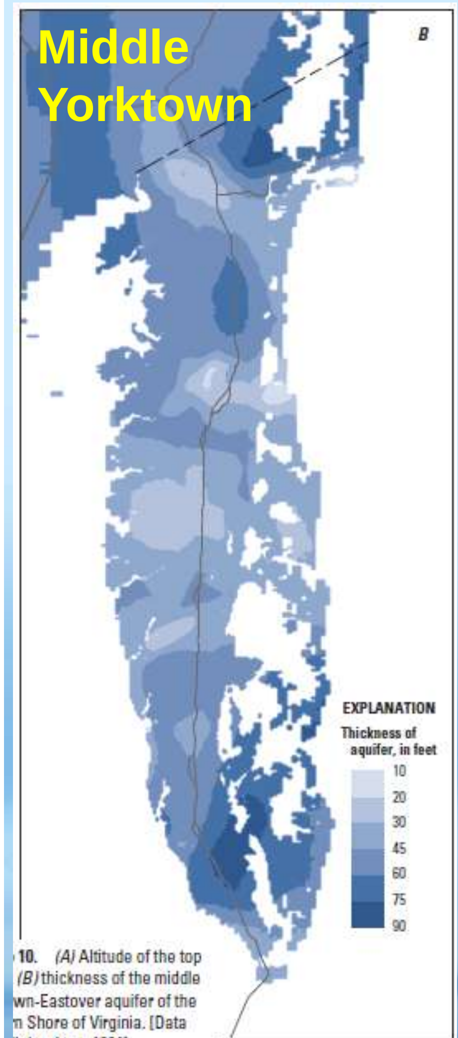
The Second Most Important Factor is Aquifer Thickness

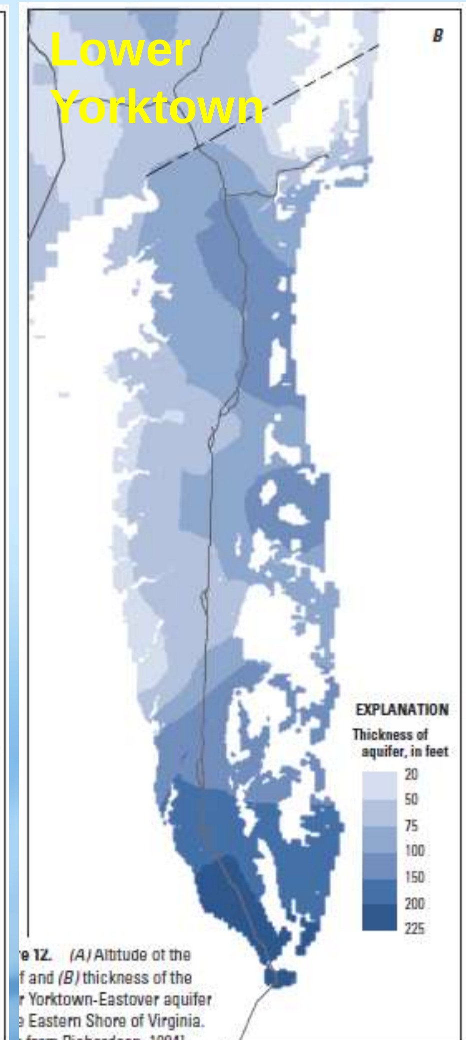
- The amount of water that can flow through and aquifer increases linearly with increase in thickness (doubling the thickness doubles the potential flow)
- Hydraulic conductivity times the aquifer thickness is called Transmissivity, and is the primary term describing groundwater flow

The Water Table aquifer is thin compared to the Yorktown aquifer

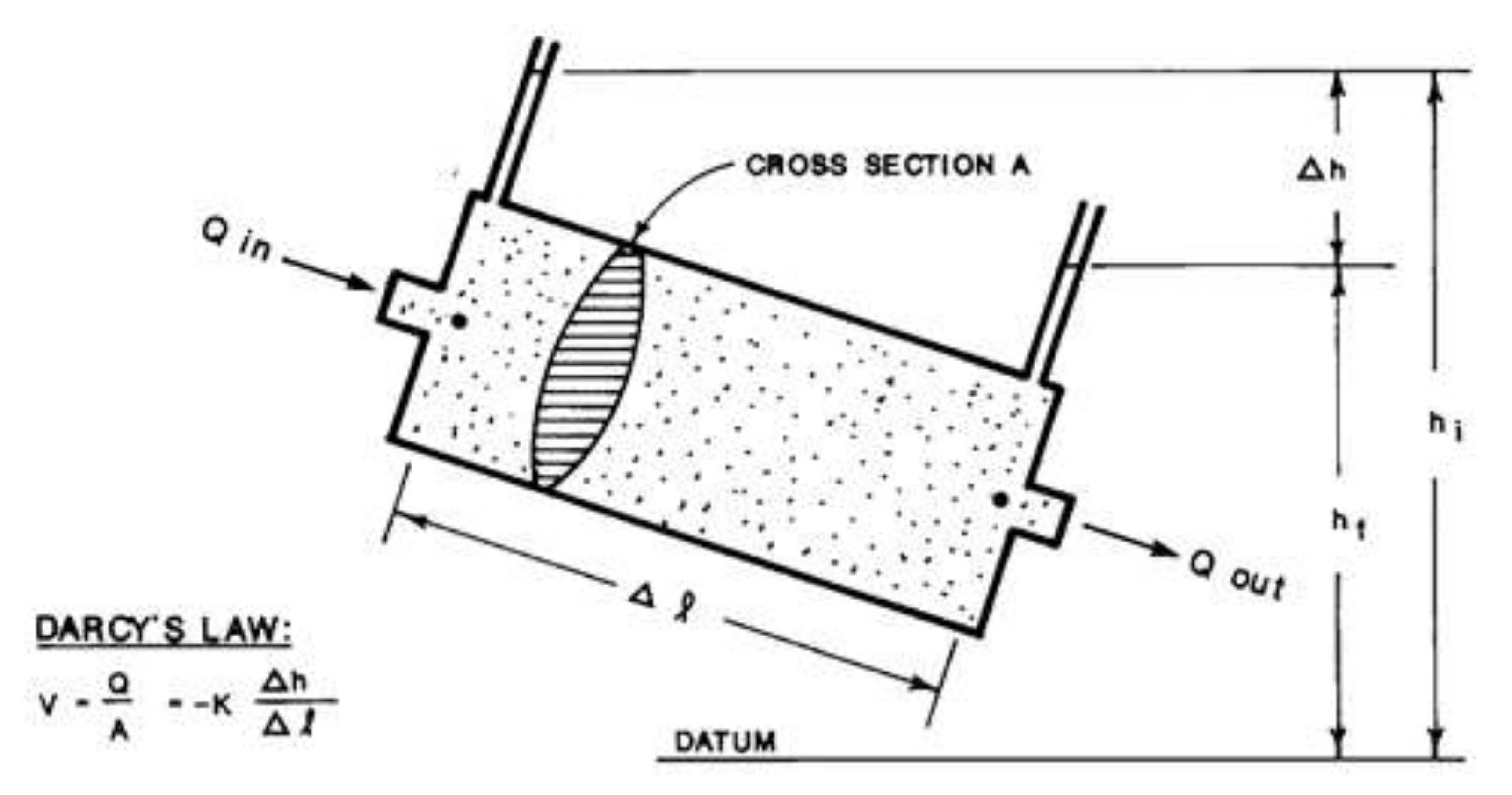






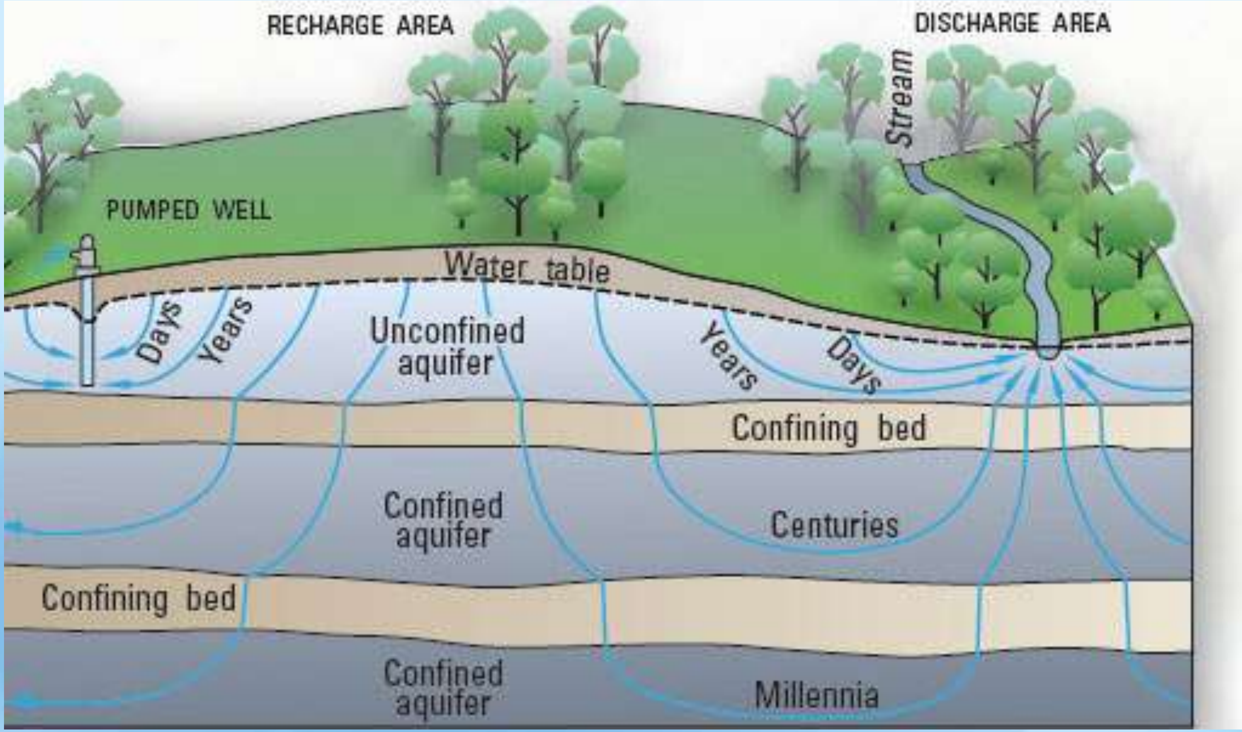


Transmissivity determines how fast groundwater CAN flow but a gradient is needed to make if flow.



Hydraulic Gradient Under Non-Pumping Conditions

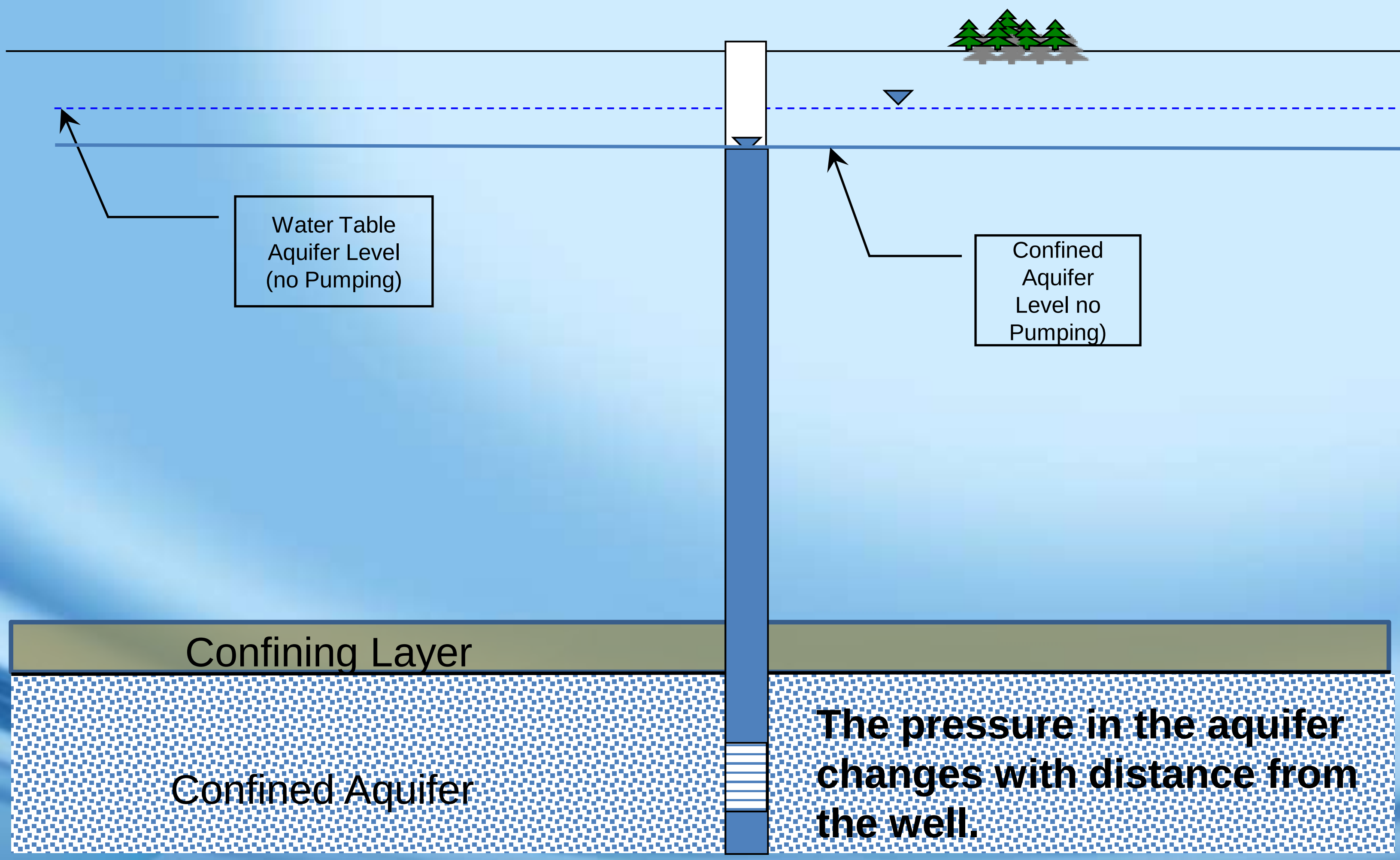
- **Horizontal flow typically toward a surface water body. Gradient is often low and the actual flow rate is low**
- **Vertical flow typically downward and very low**



Hydraulic Gradient Under Confined Pumping Conditions

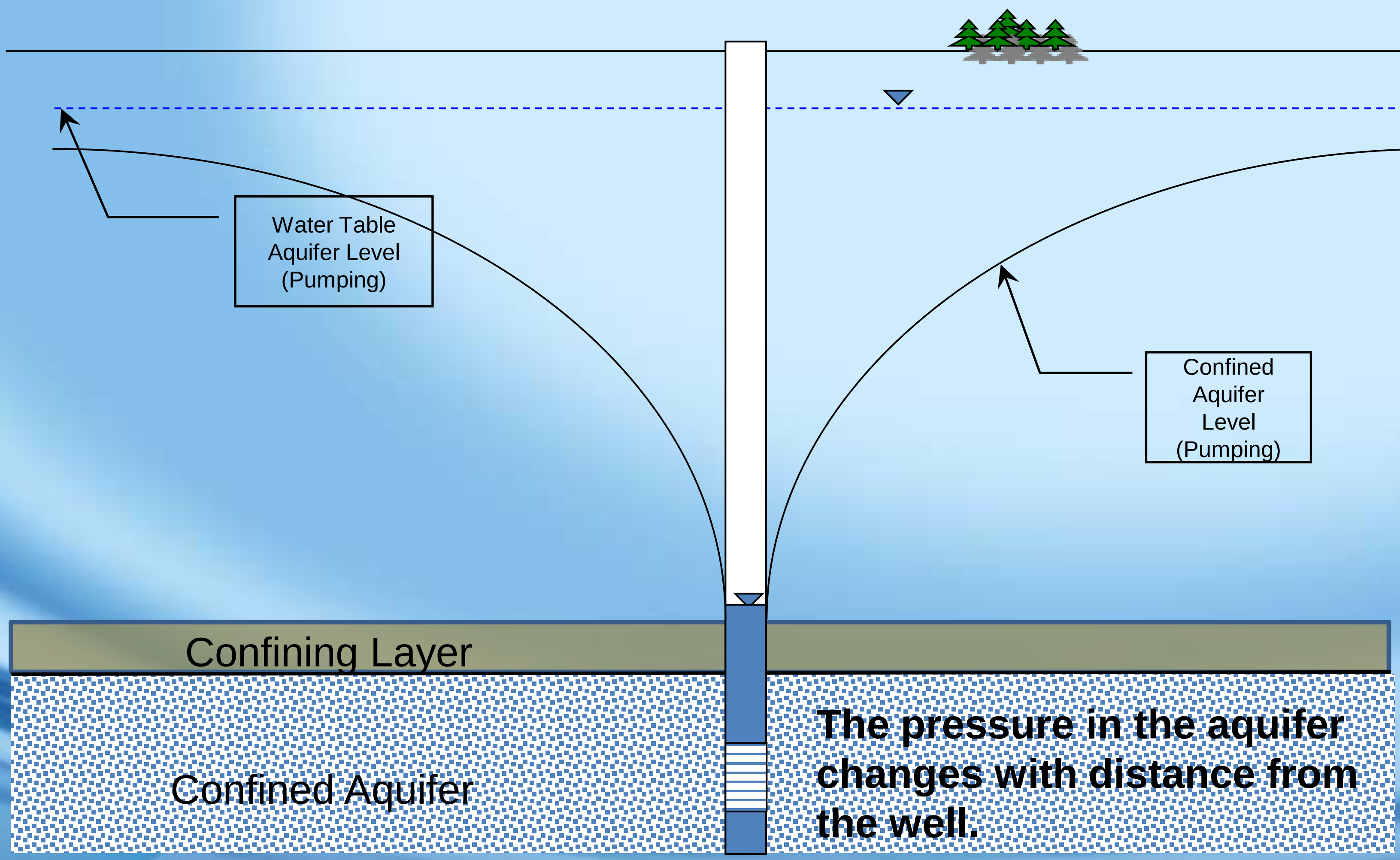
- **Horizontal flow may be re-oriented toward well. Gradient (flow rate) is often significantly increased**
- **Vertical flow remains downward but rate often significantly increased**

Groundwater Levels under no Pumping



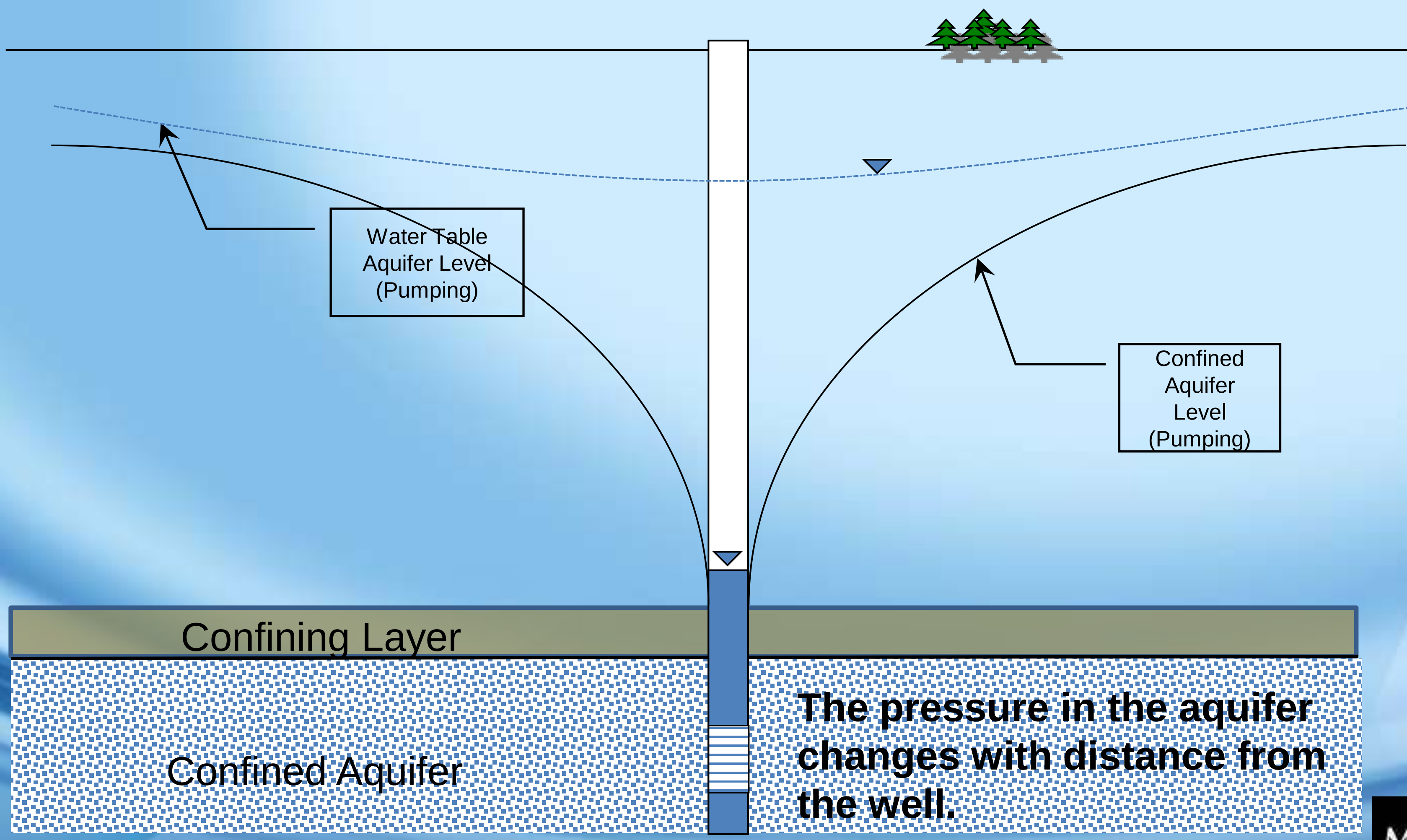
The pressure in the aquifer changes with distance from the well.

Pumping from a confined aquifer with little leakance through the confining layer



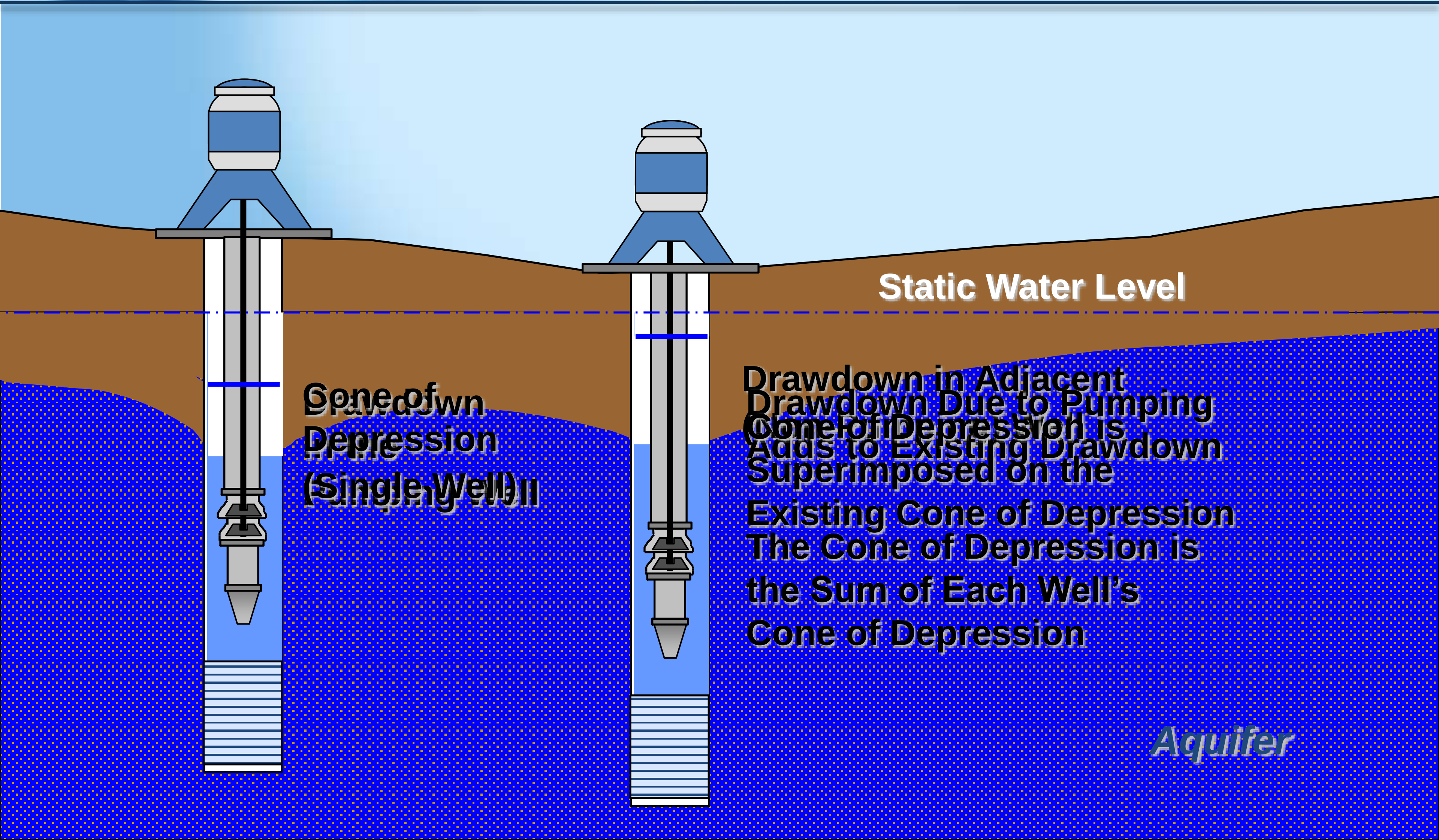
The pressure in the aquifer changes with distance from the well.

Pumping from a confined aquifer with significant leakance through the confining layer

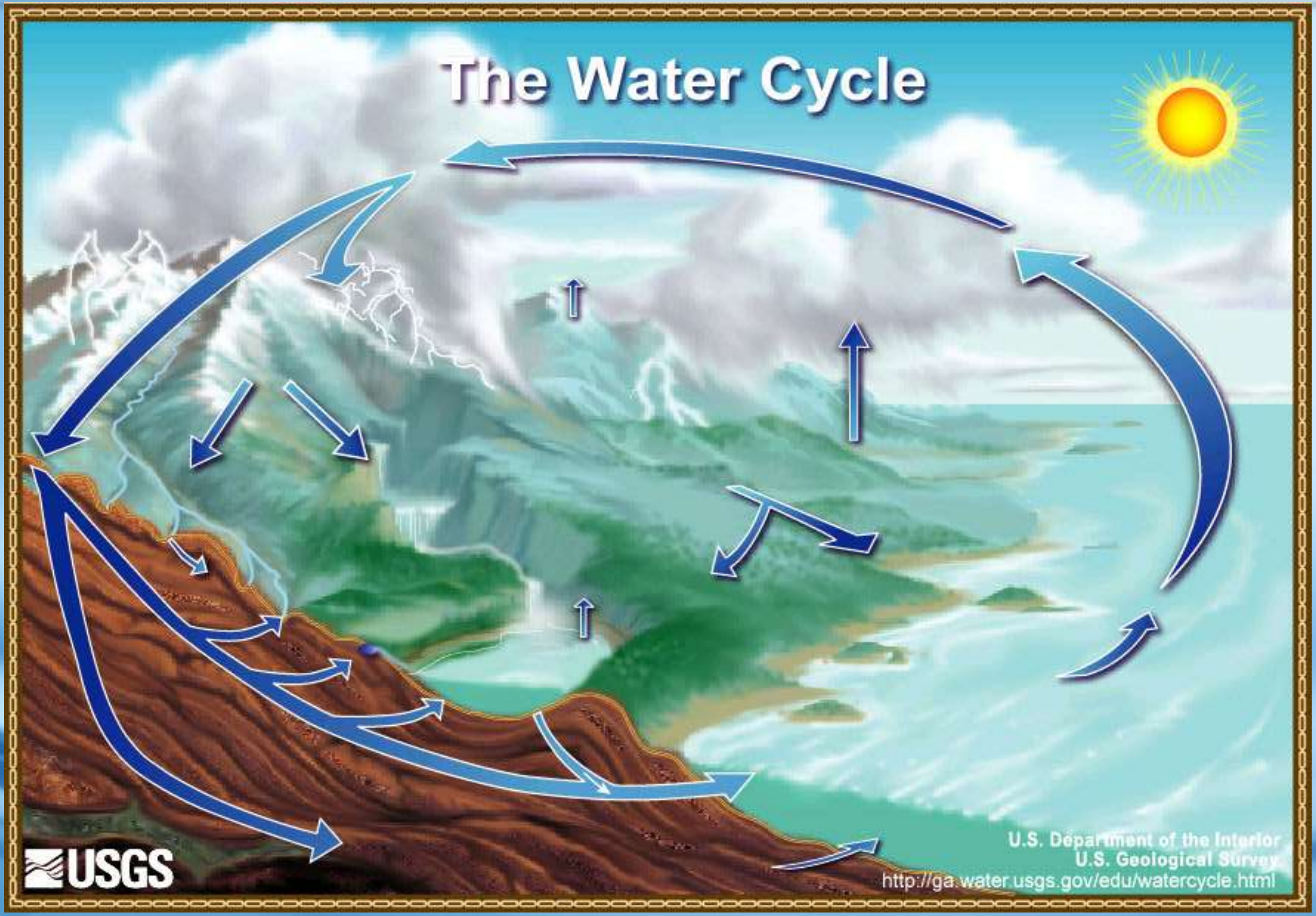


The pressure in the aquifer changes with distance from the well.

Multiple Wells Additively Increase Water Level Declines

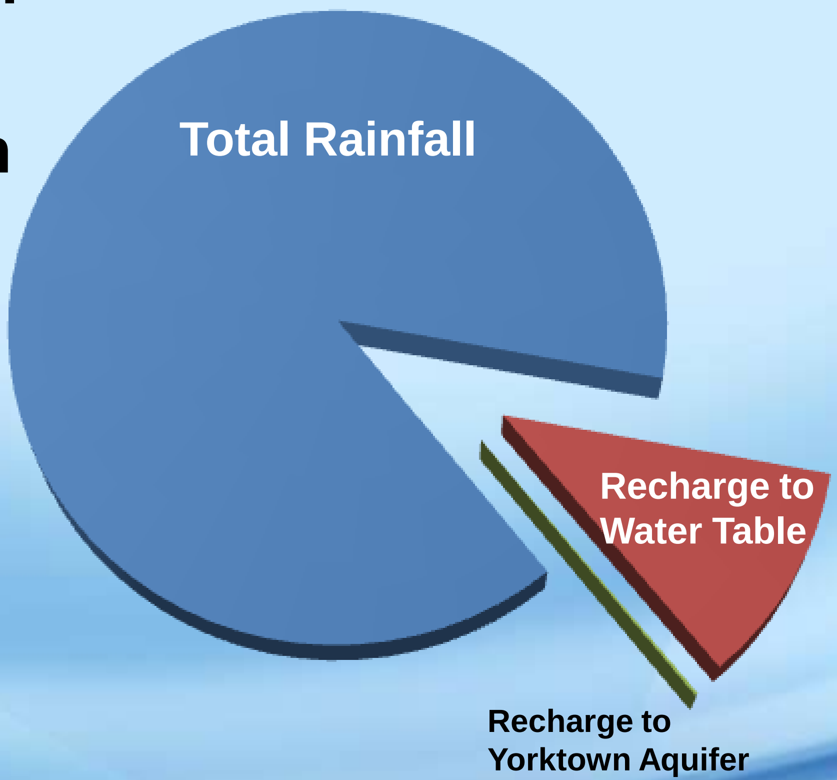


Water Balance on the Eastern Shore



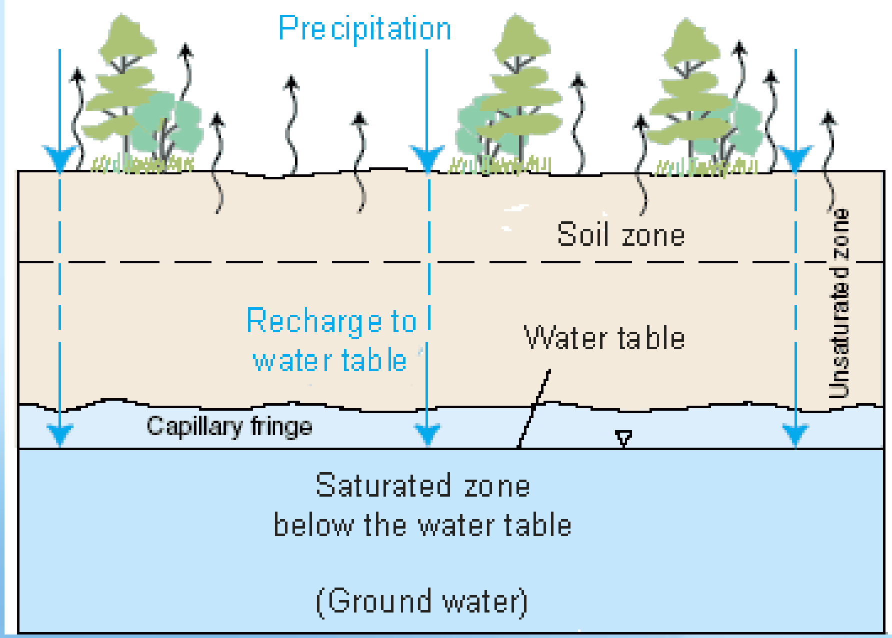
How Much Water Recharges the Aquifers?

- **All water comes from precipitation falling directly on the Shore**
- **About 88% of the precipitation never infiltrates to the groundwater**



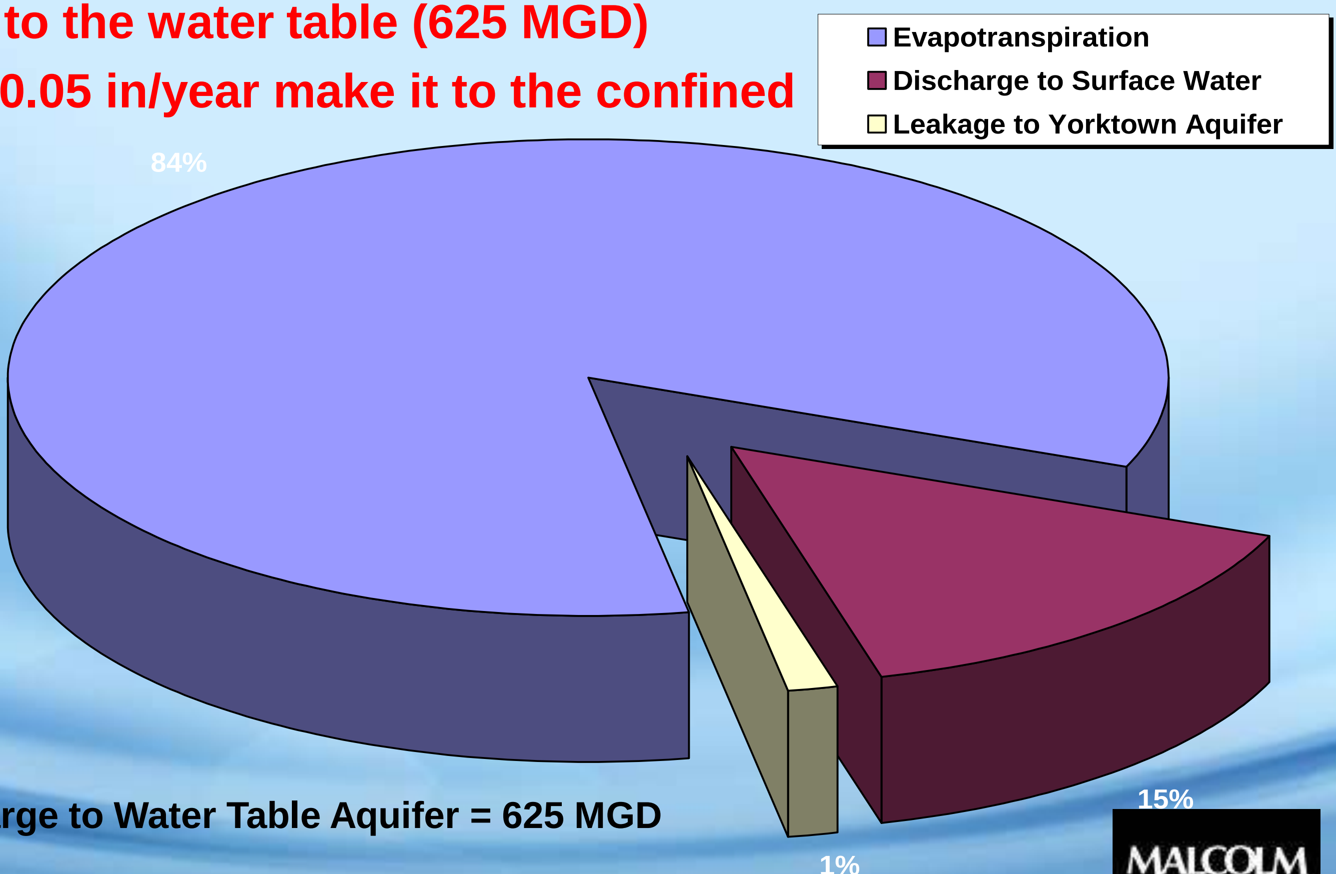
How Much Water Recharges the Aquifers?

- **Most of the rainfall never infiltrates to the groundwater and is lost through:**
  - Evaporation
  - Interception (on plants and trees)
  - Direct runoff
  - Evapotranspiration



Of the water infiltrating to the water table, only a small amount reaches the Yortkown aquifer

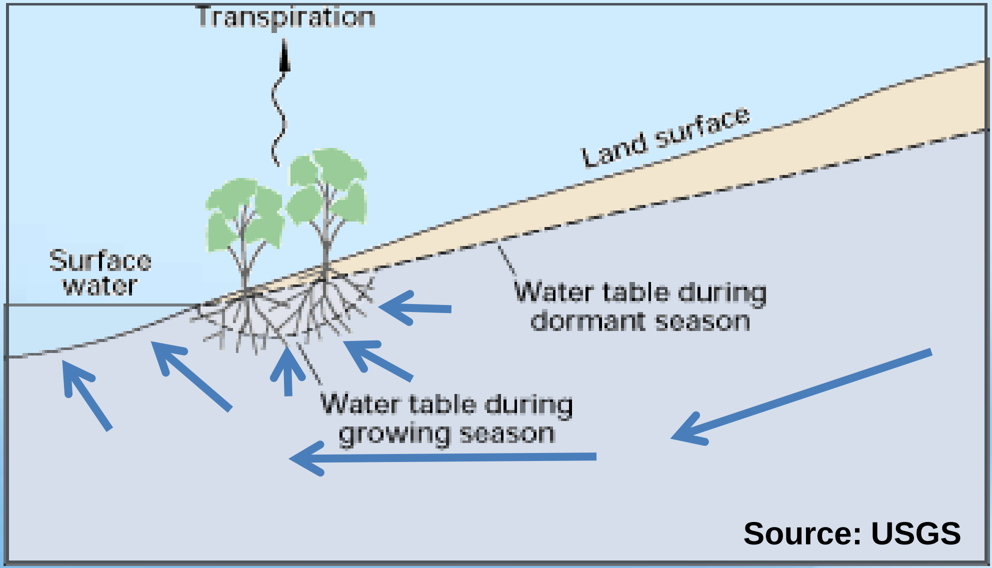
- **Limited Recharge:**
  - Of the 44-inches of annual precipitation only 5 to 6 inches infiltrate to the water table (625 MGD)
  - And only about 0.05 in/year make it to the confined aquifer (9 MGD)



Total Estimated Recharge to Water Table Aquifer = 625 MGD

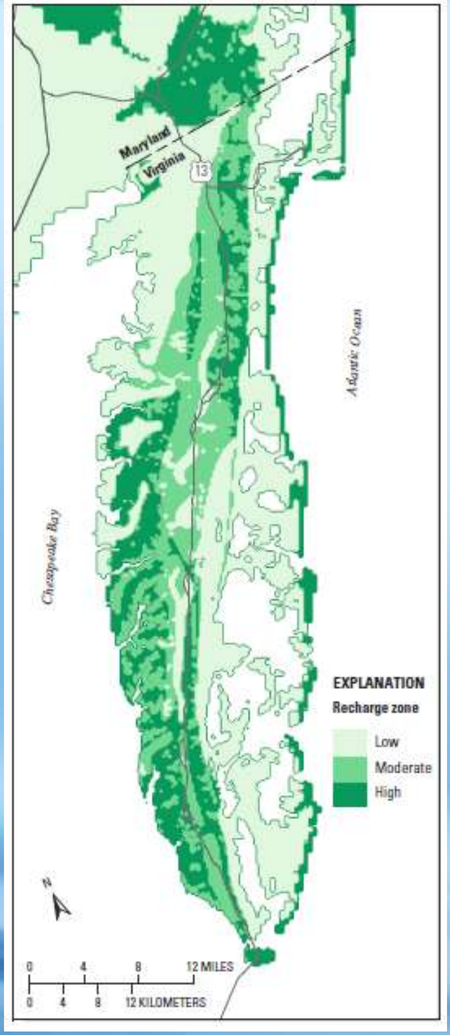
Water Balance for the Water Table Aquifer

- **99% of the water leaves through:**
  - **Evapotranspiration (84%) or**
  - **Flow into surface waters (15%)**

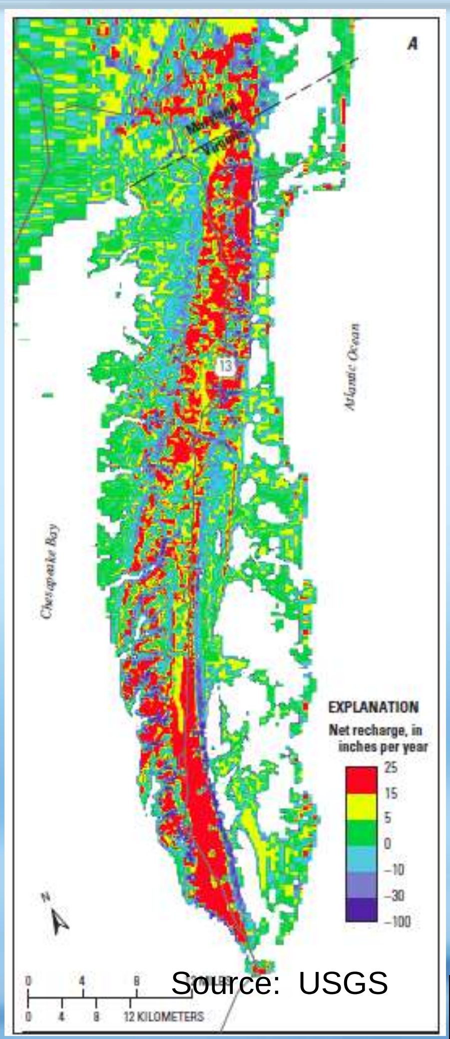


Recharge to the water table is a function of soil type, slope, and location

Potential Recharge areas (based on soil type and slope)



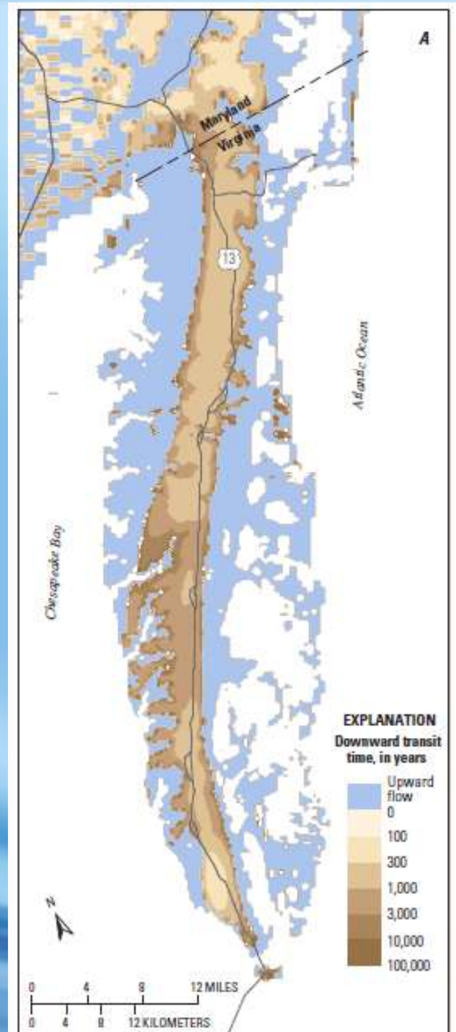
Estimated Recharge Rates



Source: USGS

Recharge to the Yorktown depends more on where pumping from the aquifer is occurring

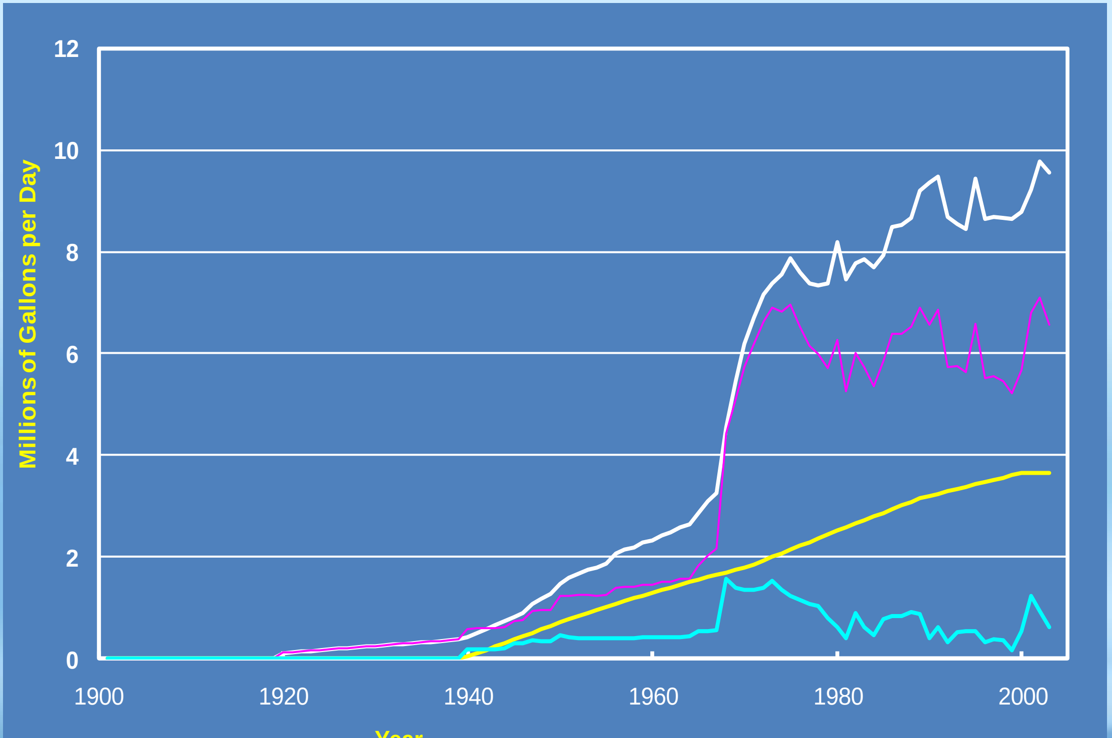
Estimated in 1900 (pre-pumping)



Estimated in 2003 (Effects of pumping)

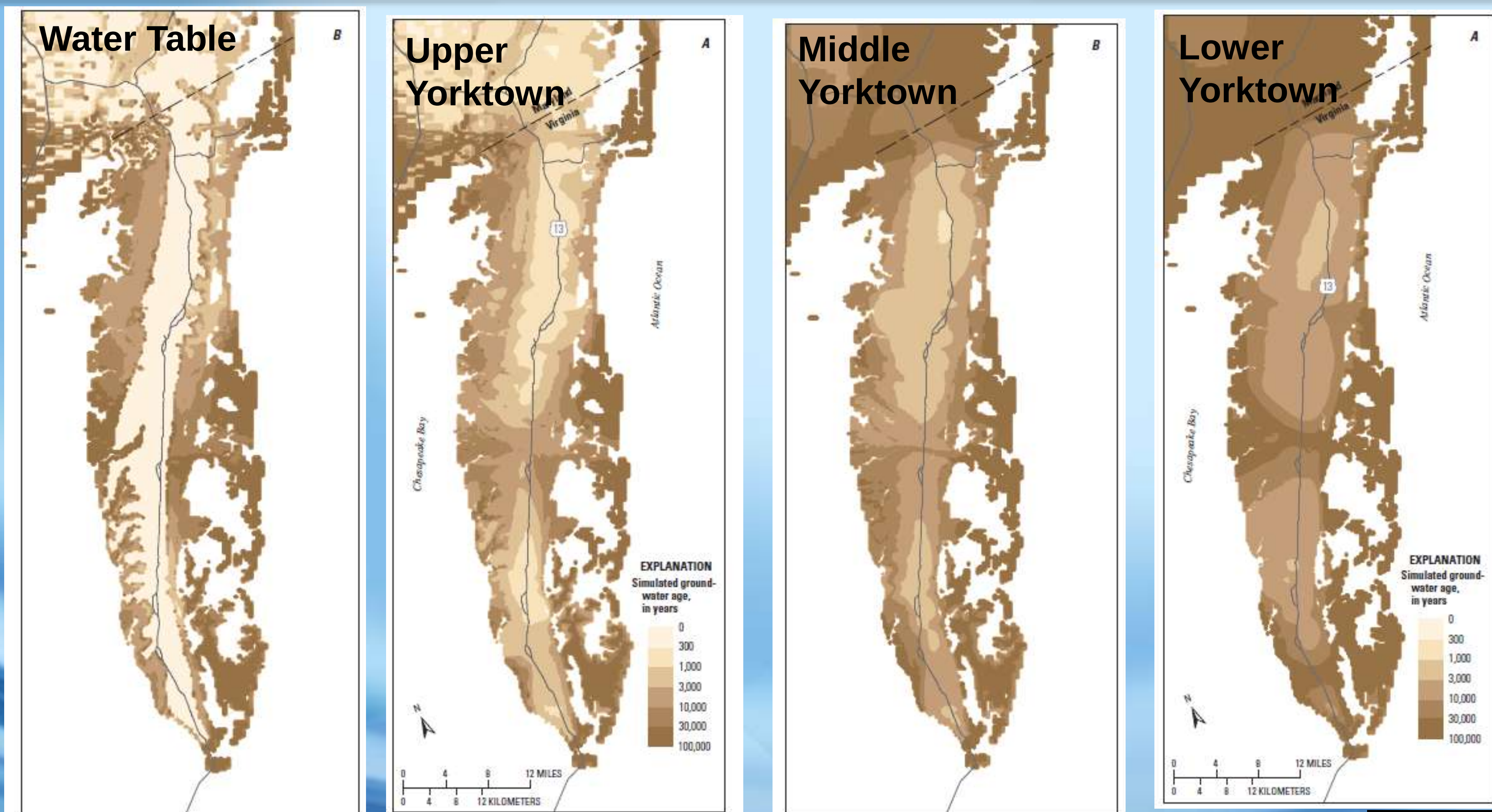
Recharge rate to the Yorktown has increased over time due to pumping

- **Current Yorktown-Eastover Aquifer use exceeds recharge by approximately 1 MGD**
  - **Recharge will increase as use increases – but will NOT keep pace with pumping**

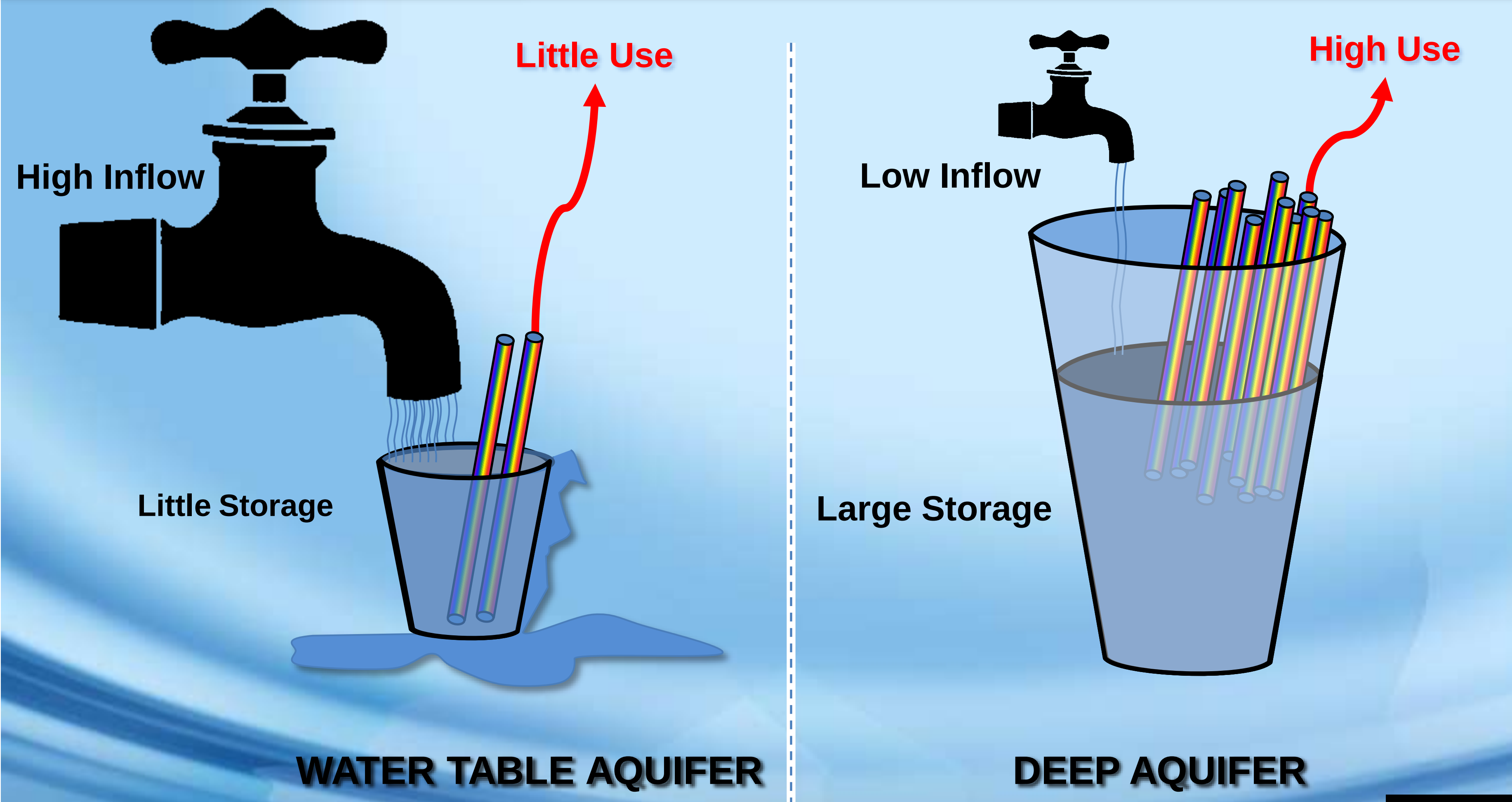


Source: USGS Eastern Shore Model

Estimated Water Ages Reflect Recharge Rates

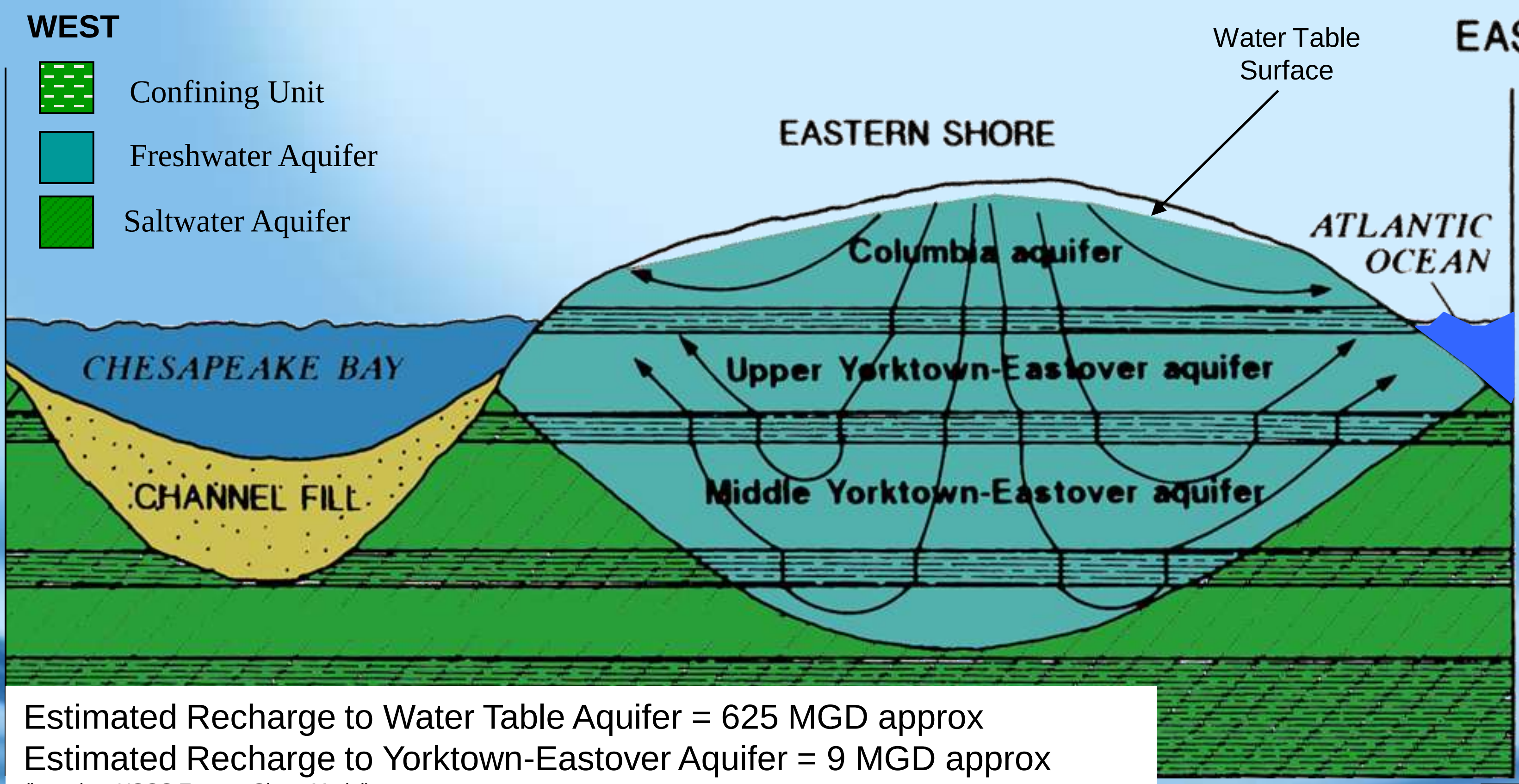


Water Table / Yorktown Dilemma



Ultimately the Balance of Recharge to Use Dictates Stability of the Fresh Water Lens

Fresh ground water is restricted to depths less than 350 feet



Estimated Recharge to Water Table Aquifer = 625 MGD approx
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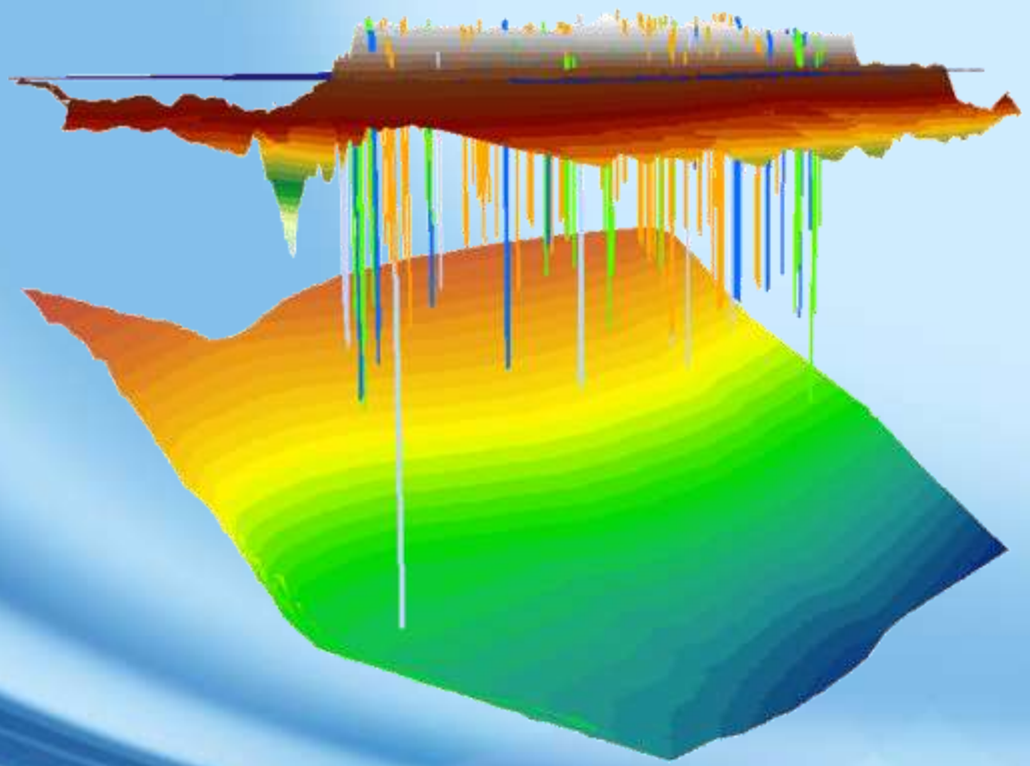
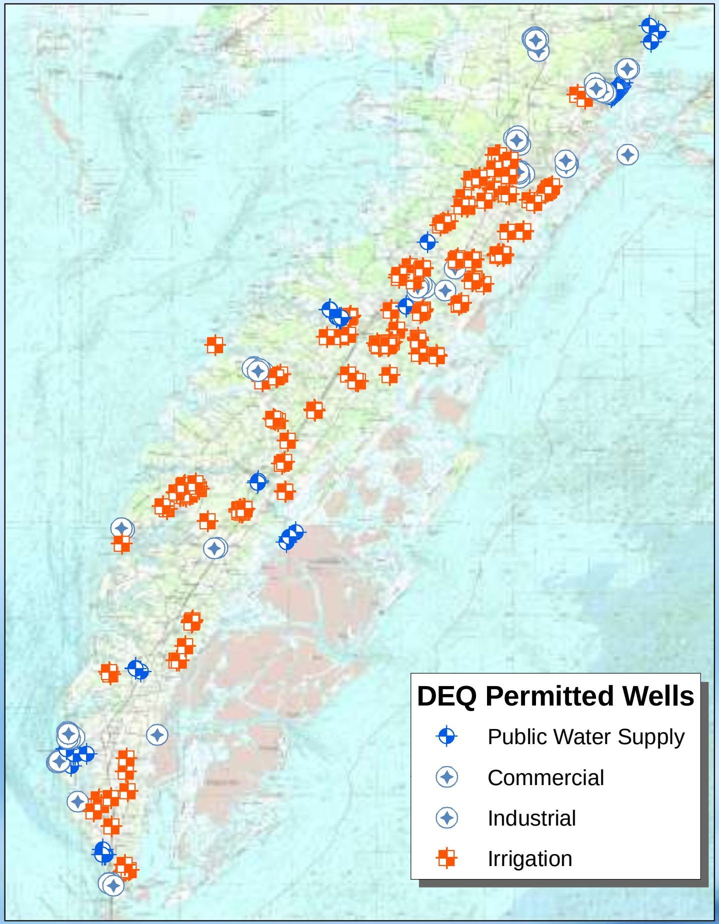
Groundwater Use on the Eastern Shore





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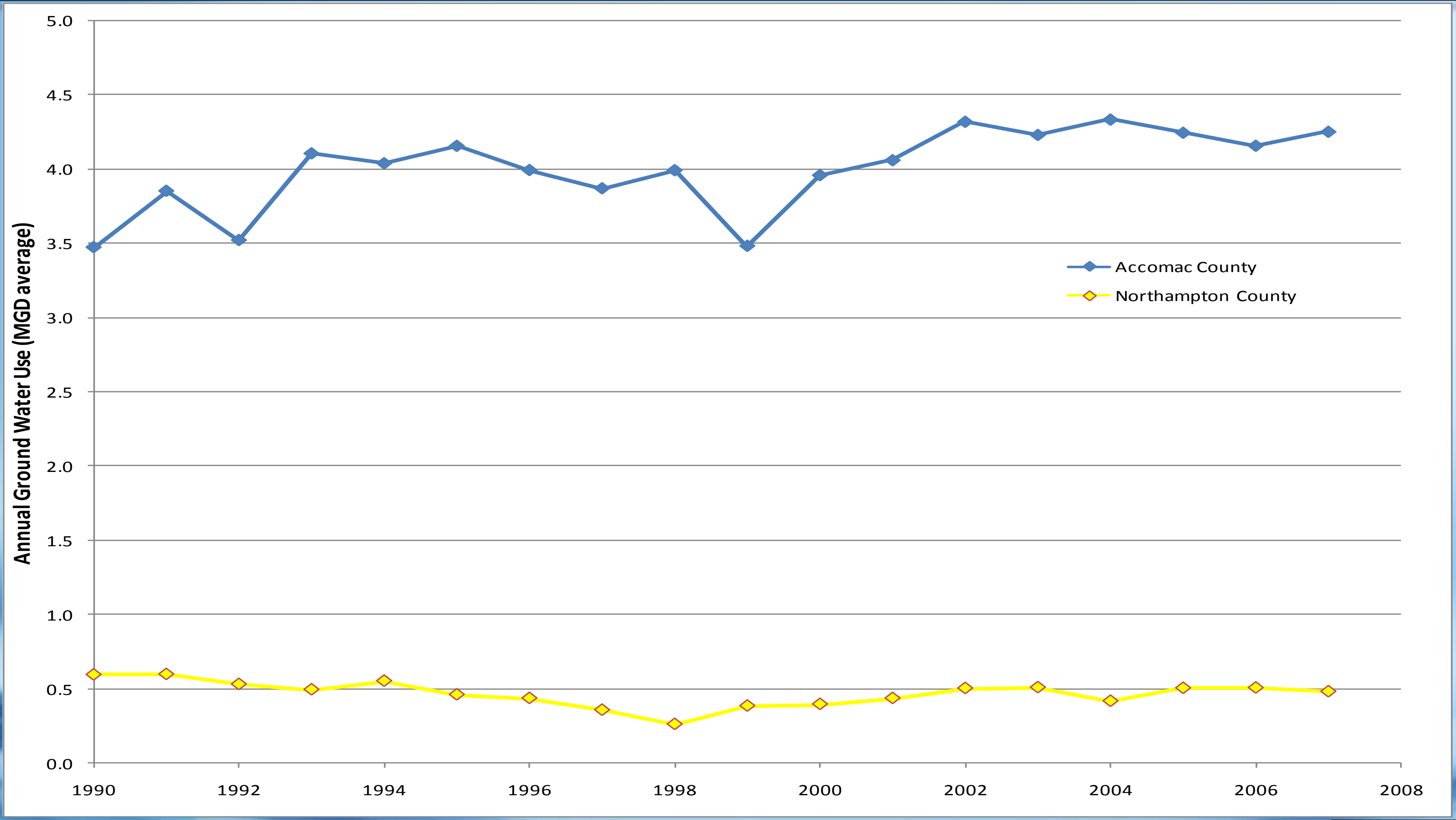
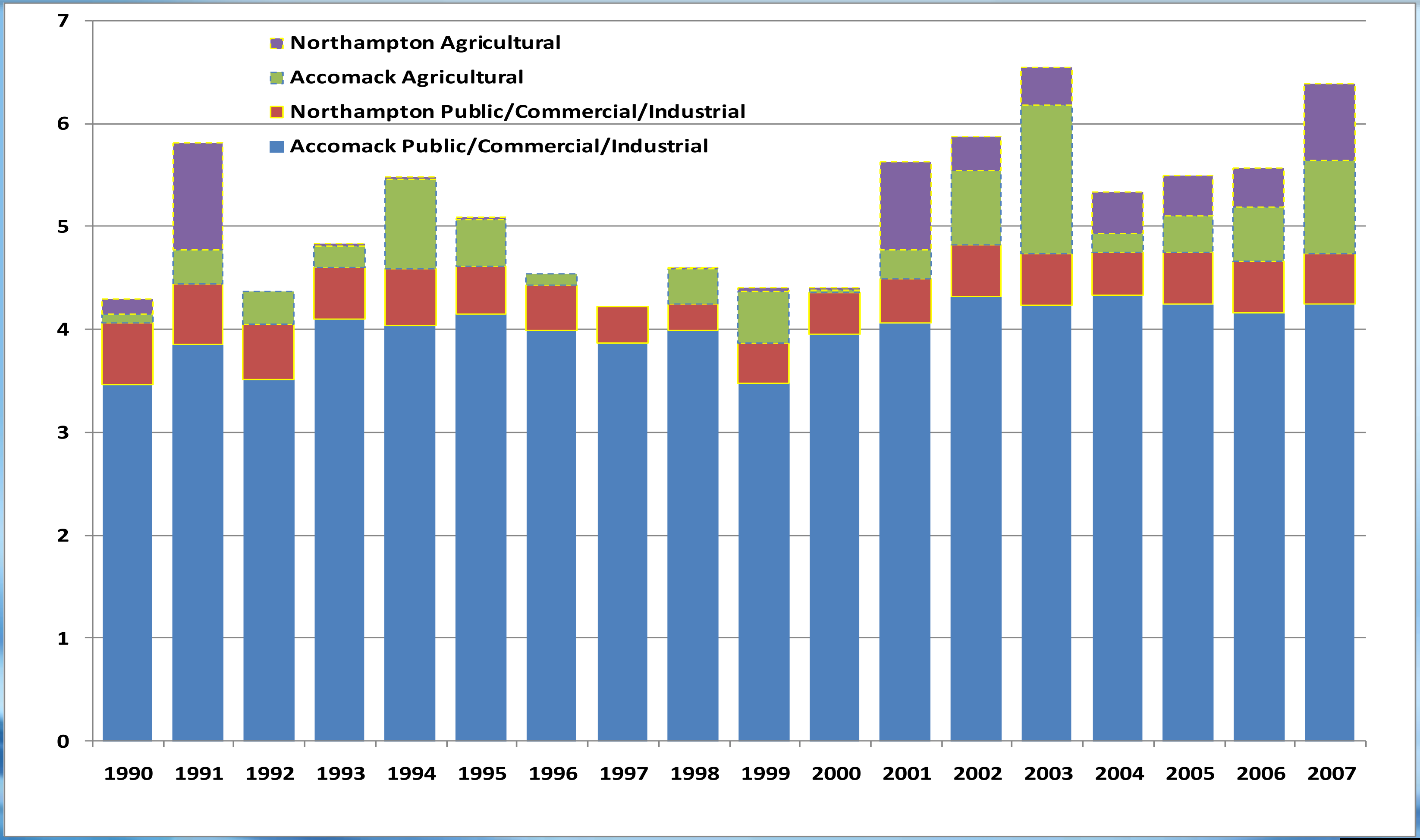
Ground Water Use and Ground Water Level Measurements

- **Ground Water Use for permitted wells (wells pumping greater than 300,000 gallons-per-month) are submitted to VDEQ**
- **Ground Water Levels are routinely measured in Observation Wells by the USGS**

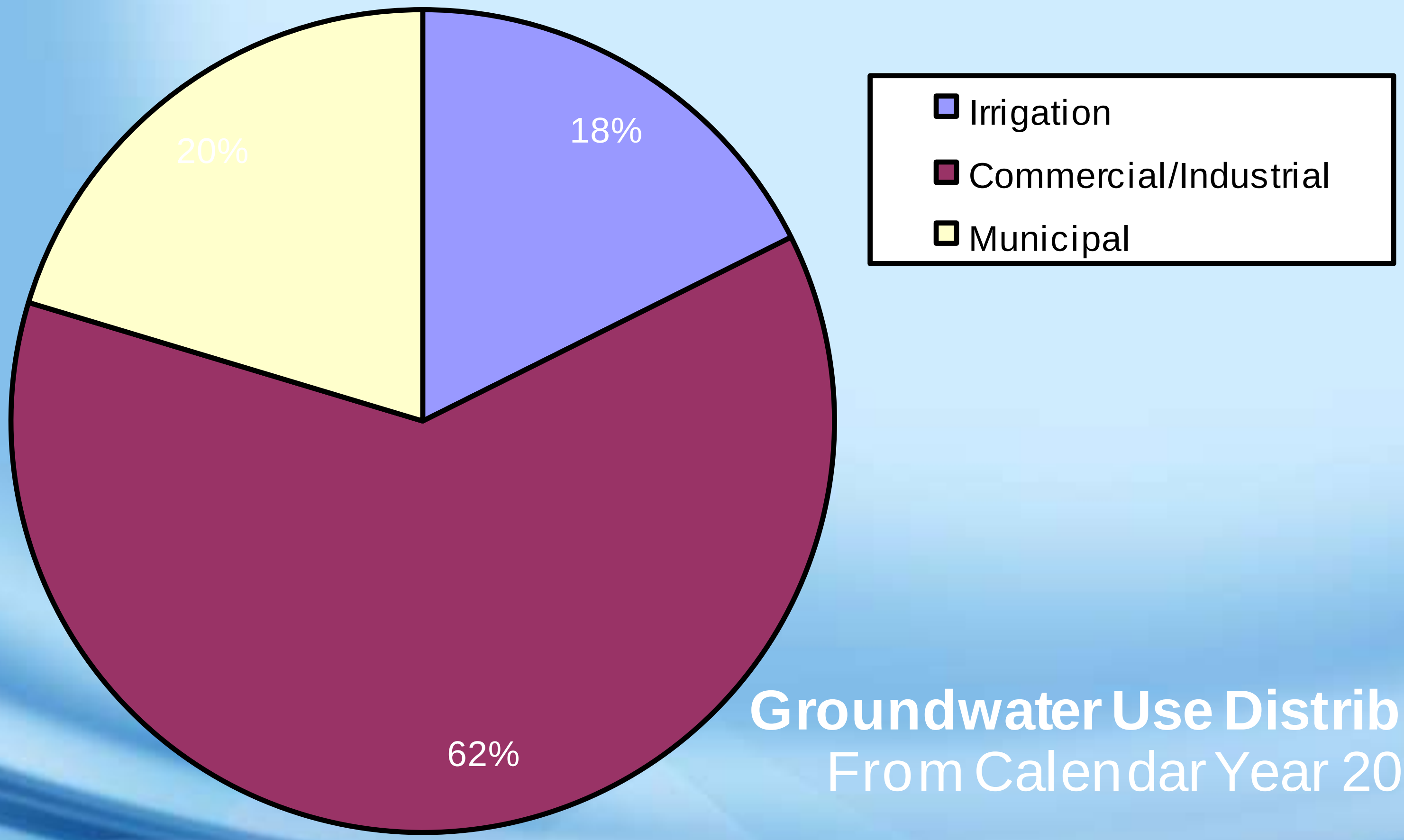
Non-Agricultural Ground Water Use Trends



All Permitted Ground Water Use



Types of Groundwater Use

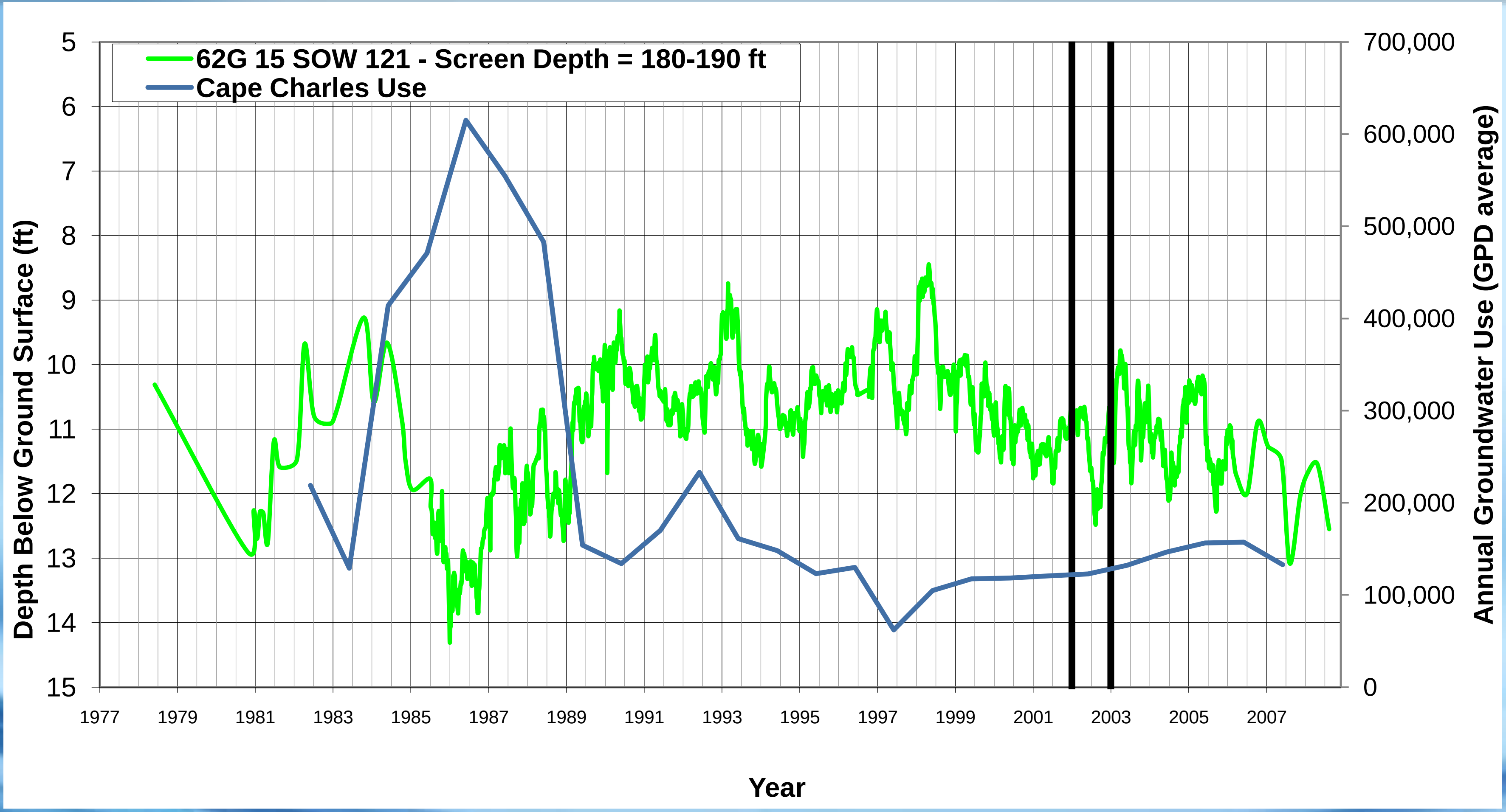


Groundwater Use Distribution
From Calendar Year 2002

Why Measure Ground Water Levels?

- **Ground water use:**
  - **Lowers ground water levels, reducing available water to other ground water users**
  - **Reduces the size of the freshwater lens**
- **Impact of ground water use can be evaluated:**
  - **Indirectly using models**
  - **Measured directly from pumping wells and observation wells**

Ground Water Use and Ground Water Level Trends



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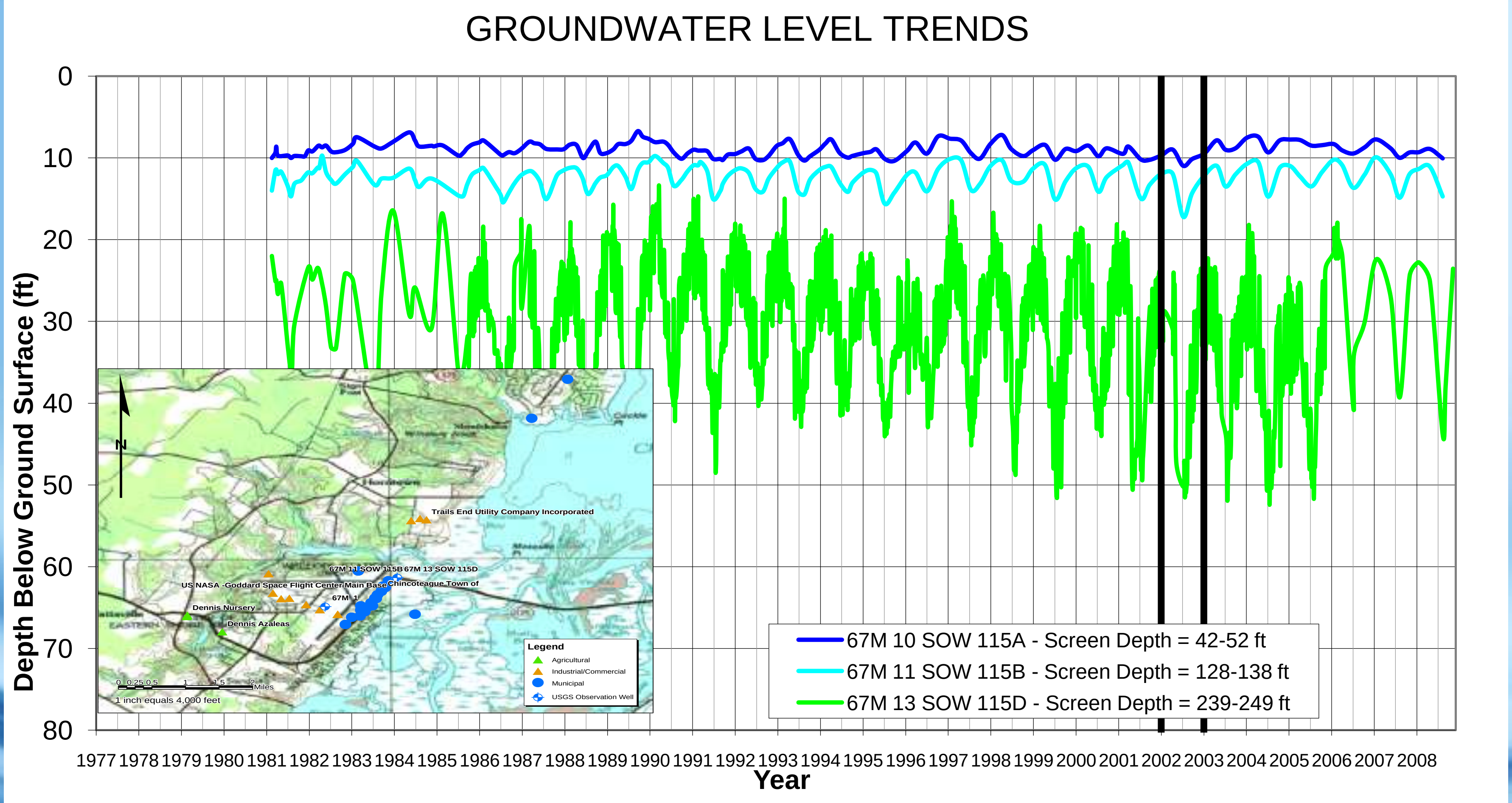
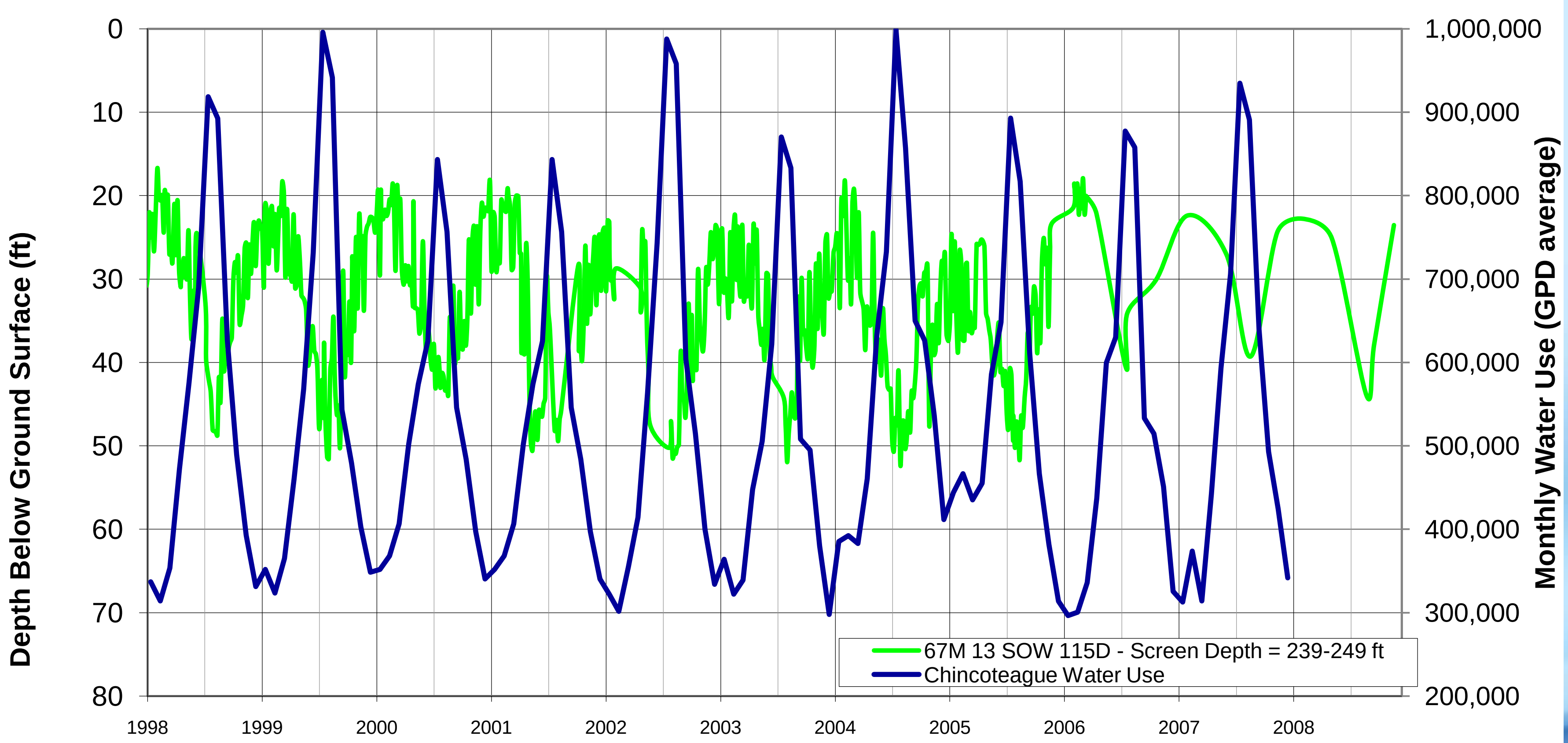
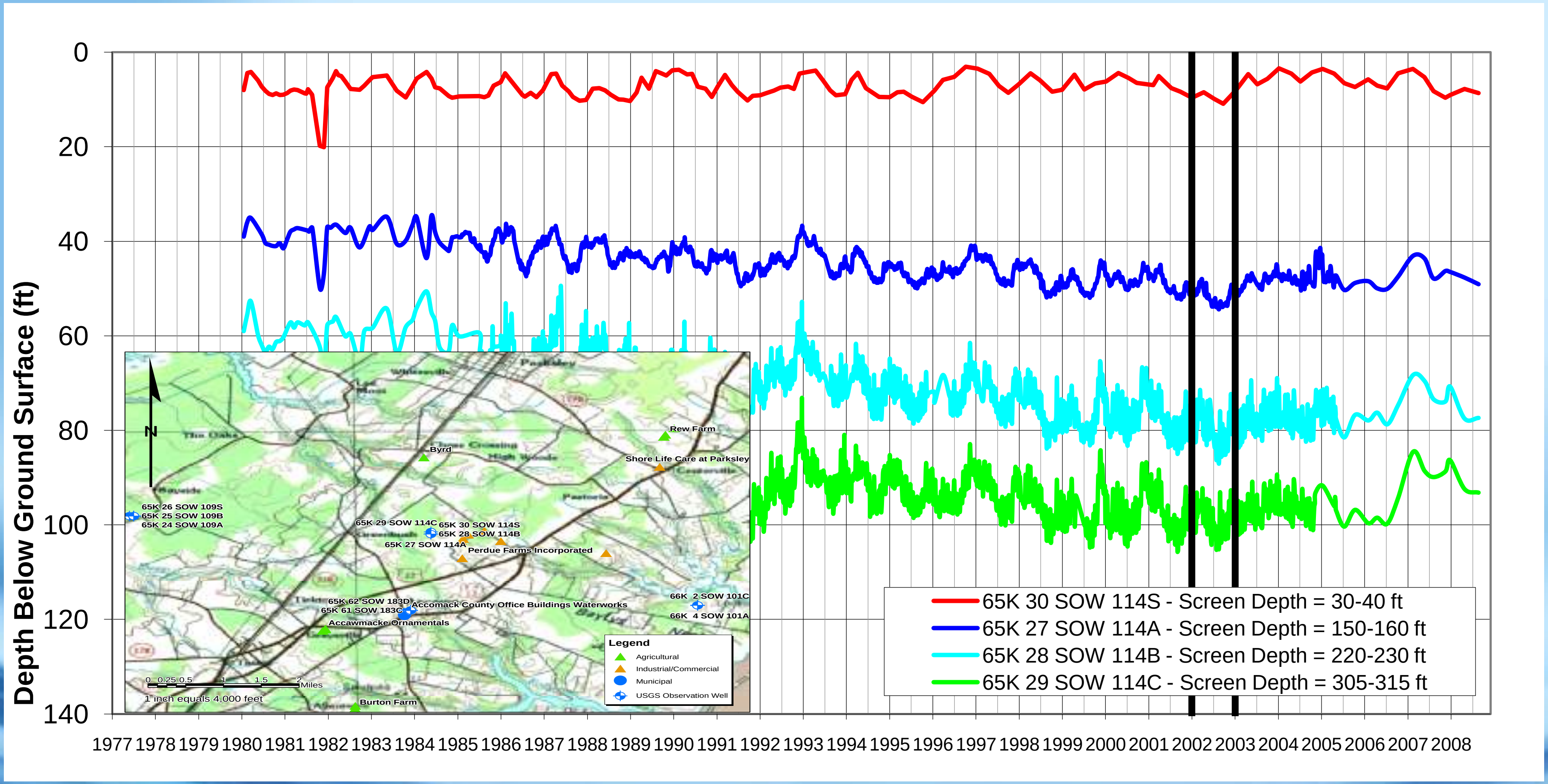
Long Term Drawdown and Episodic Withdrawals



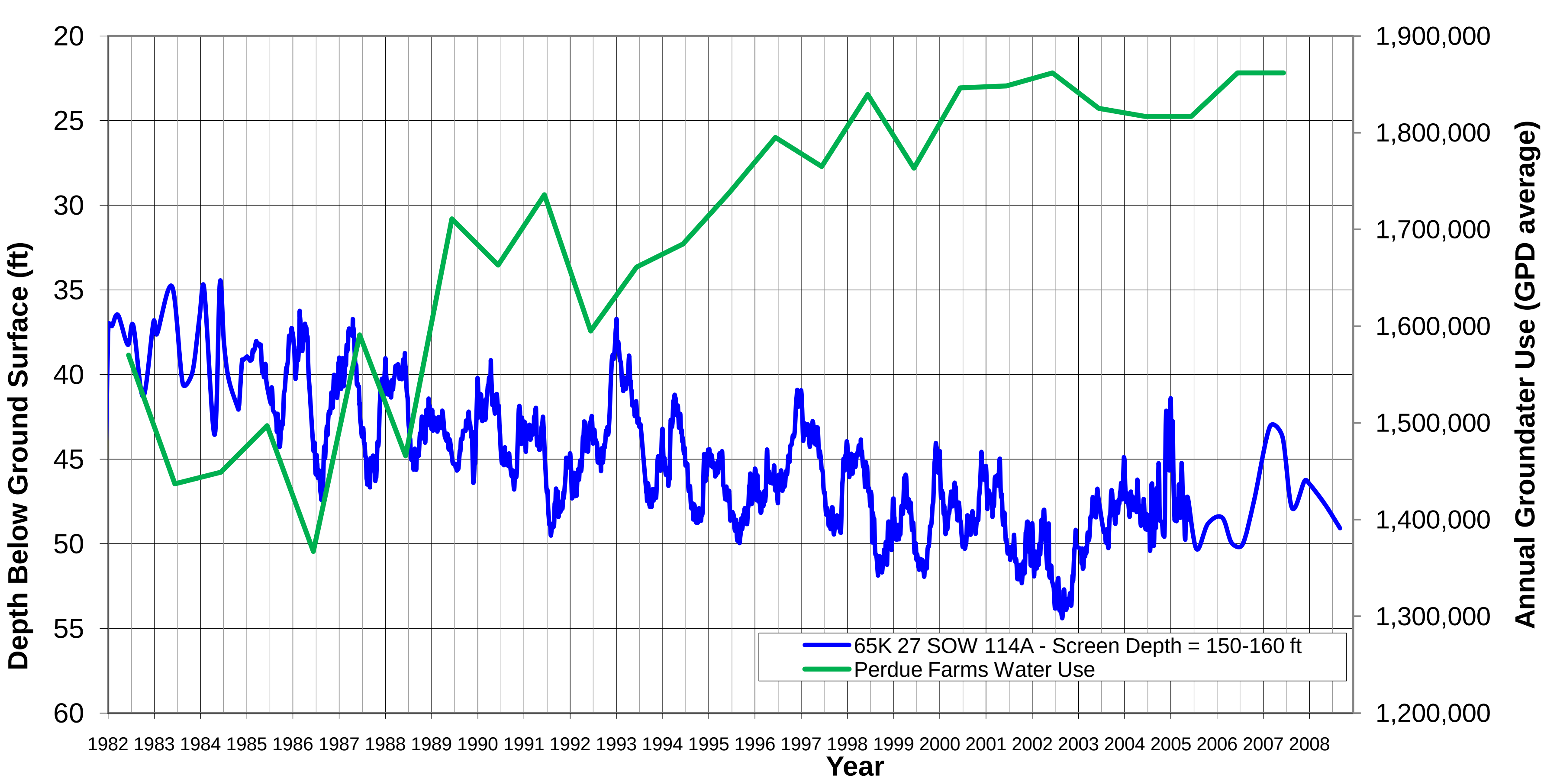
Water Level Change and Monthly Use



Ground Water Levels Near Perdue Foods



Water Level Change and Annual Use Near Perdue Farms



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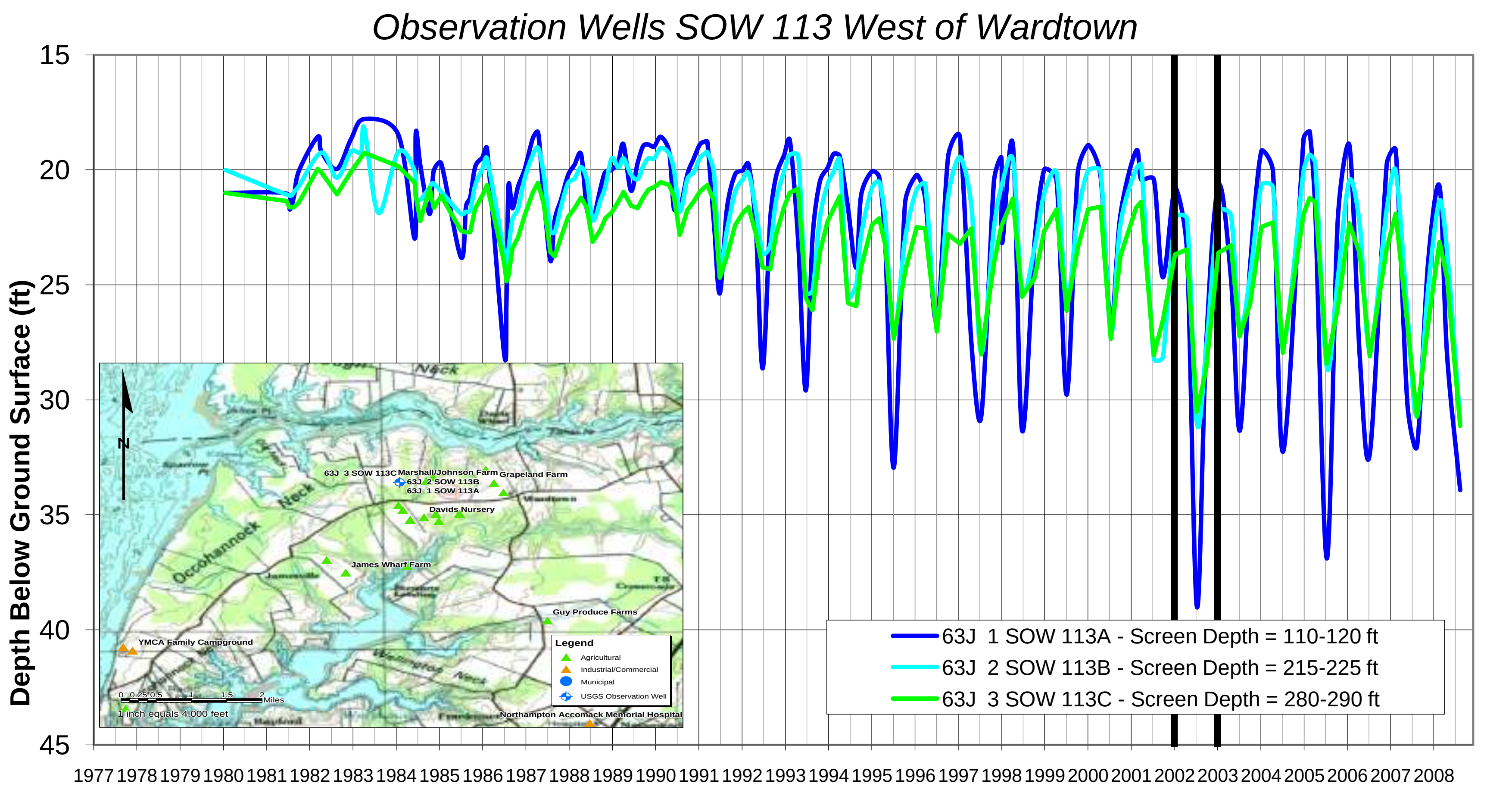
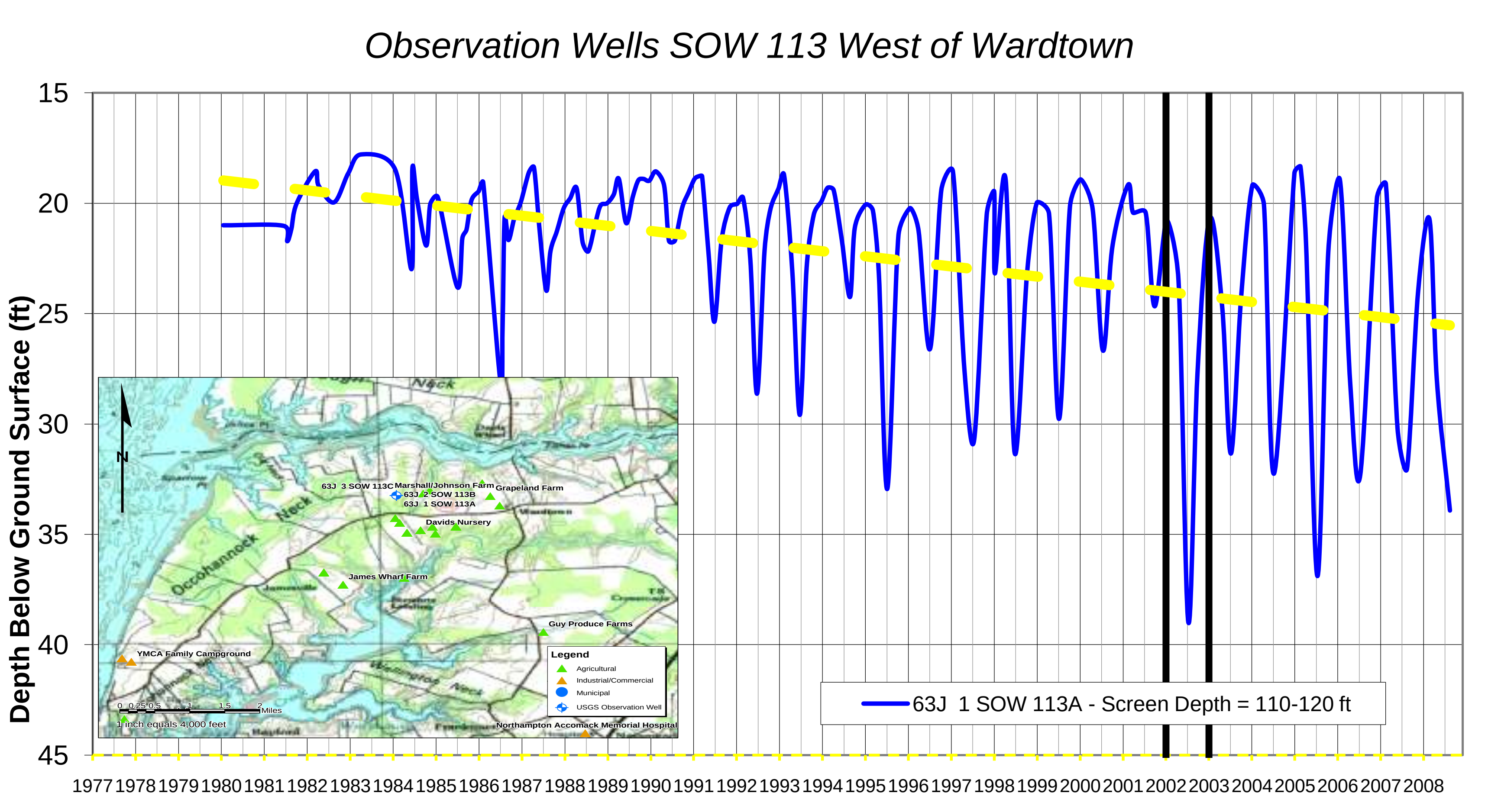
Effect of Irrigation Use



Long Term Decline from Irrigation Use



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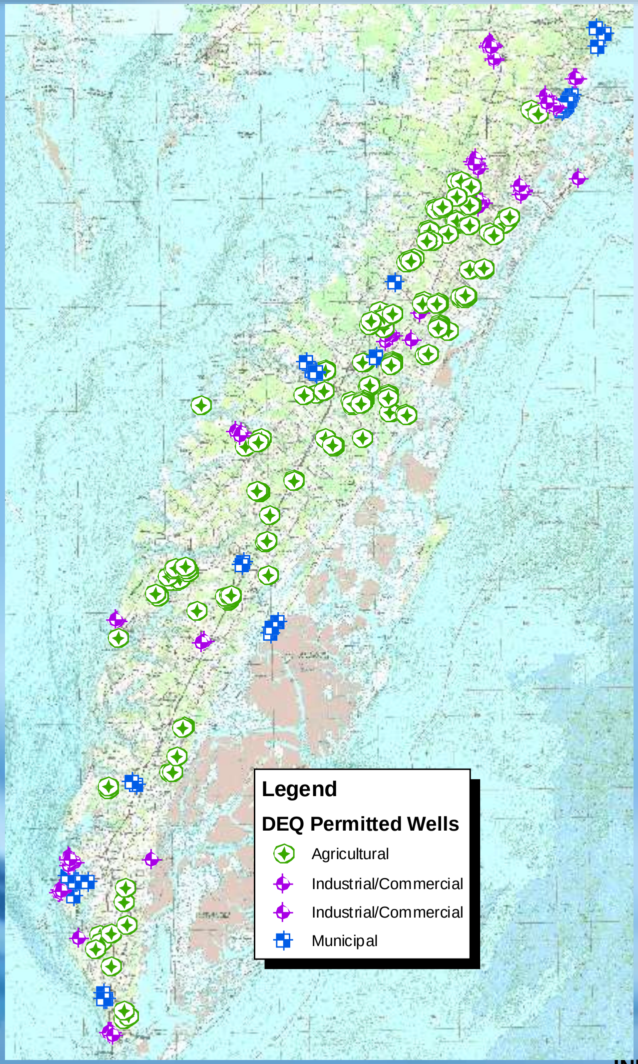
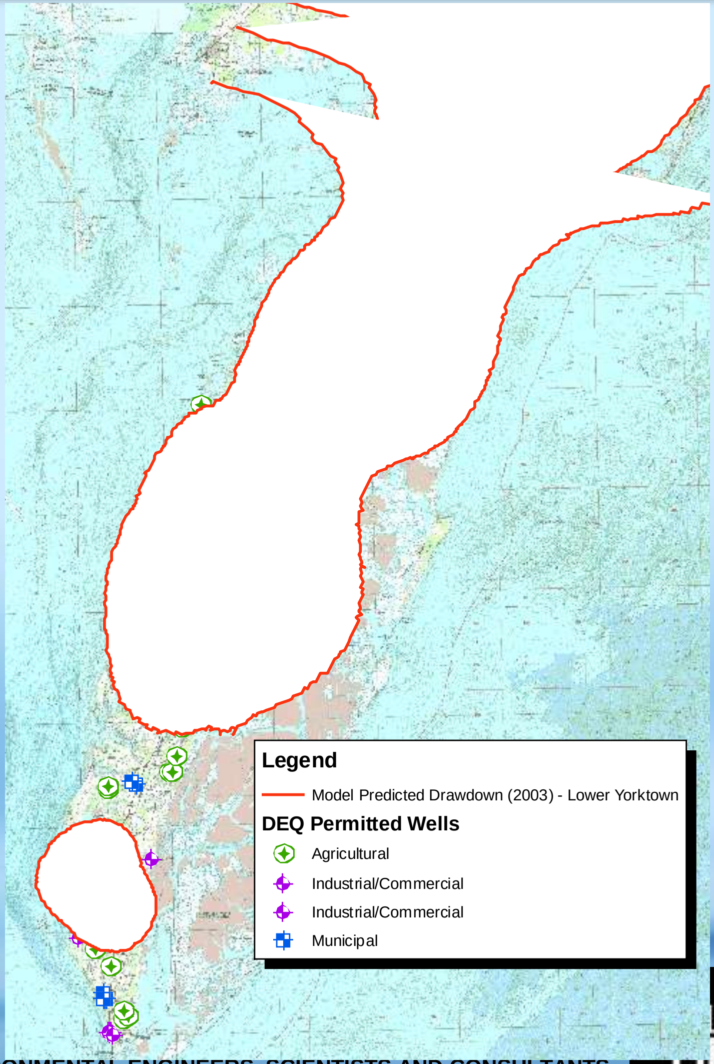
Amount of water level decline in the Lower Yorktown Aquifer





Local and Regional Water Supply Planning

- **Regulations: 9 VAC 25-780**
- **Purpose:**
  - **Ensure that adequate and safe drinking water is available to all citizens of the commonwealth**
  - **Encourage, promote, and protect all other beneficial uses**
  - **Encourage, promote, and develop incentives for alternative water sources, included but not limited to desalinization**

Components of a Water Supply Plan

- **Existing Water Sources** *(Description of water systems)*
- **Existing Water Use** *(Description of current and historical use)*
- **Existing Water Resource Conditions** *(Groundwater Resource, Natural Resoruces)*
- **Projected Water Demand** *(Future water use)*
- **Water Demand Management** *(Water Conservation and Management)*
- **Drought Response and Contingency Plan**
- **Statement of Need and Alternatives** *(Use / Resource Constraints; alternate sources / technologies)*

Existing Water Sources

- **Requirement:**
  - **Basic information on community water system** *(number of wells, well construction, permitted withdrawal amounts)*
  - **Information on self supplied users of more than 300,000 gallons per month. Information varies depending on use.**
  - **Information on any Source Water Assessment Plans / wellhead protection program.**
- **Data sources:**
  - **VDEQ Groundwater Withdrawal Permit Applications**
  - **VDEQ Groundwater Withdrawal Permit Program database**
  - **VDH Engineering Datasheets**

Existing Water Use

- **Requirement:**
  - **Basic information on community water systems** *(population & connections, actual use, type of use)*
  - **Groundwater and surface water use for self supplied users of more than 300,000 gallons per month.**
- **Data sources:**
  - **VDEQ Groundwater Withdrawal Permit Applications**
  - **VDEQ Groundwater Permit Program database**
  - **VDEQ Groundwater Withdrawal Permit Program database**
  - **VDH Engineering water use records**

Existing Resource Conditions

- **Requirement:**
  - **Comprehensive description of the resources on the Shore, including wetlands, endangered or threatened species, archaeological sites**
- **Data sources:**
  - **County Comprehensive Plans**
  - **USGS Groundwater Reports**
  - **Eastern Shore Groundwater Supply Protection and Management Plan**

Projected Water Demands

- **Requirement:**
  - **Estimate water demand for a minimum 30 and maximum 50 year period**
- **Data sources:**
  - **VDEQ Groundwater Withdrawal Permit Applications**
  - **VDEQ Groundwater Permit Program database**
  - **VDEQ Groundwater Withdrawal Permit Program database**
  - **VDH Engineering water use records**
  - **County Comprehensive Plan**

Water Demand Management

- **Requirement:**
  - **Describe water conservation and management measures. Most required by DEQ groundwater withdrawal permits:**
    - **BOCA low flow devices**
    - **Xeriscape landscaping**
    - **Efficient irrigation**
    - **Leak detection and repair**
  - **Data Sources:**
    - **County Ordinances**
    - **Groundwater Withdrawal Permits**

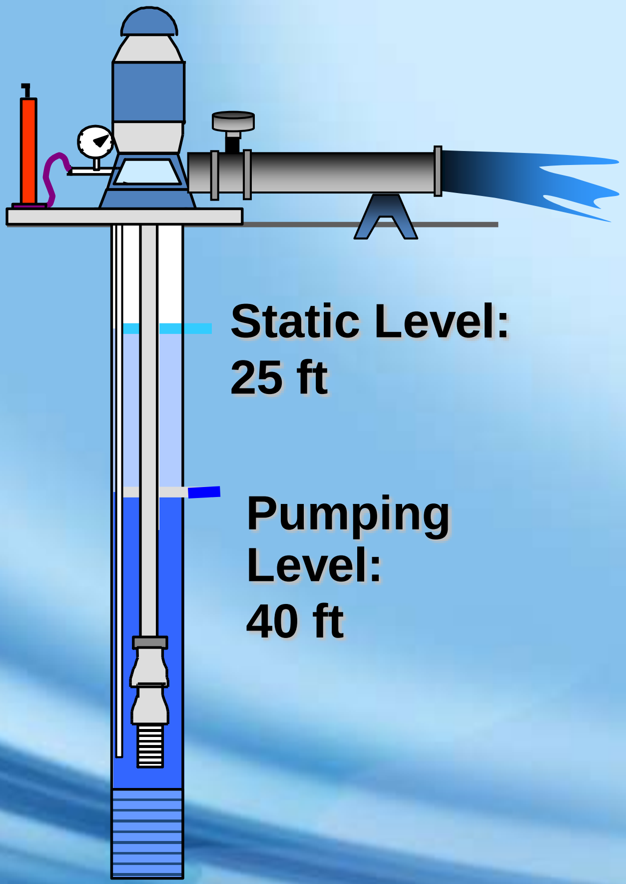
Drought Response and Contingency Plan

- **Requirements:**
  - Applies to all surface water and groundwater withdrawals with a combined withdrawal averaging greater than 300,000 gallons per month.
  - Differs from the Groundwater Withdrawal Permit – which applies to all groundwater withdrawals that equal to or exceeds 300,000 gallons per month (as opposed to average).
- **Data Sources:**
  - County/Town Ordinances
  - Virginia Drought Assessment and Response Plan

Statement of Need and Alternatives

- **Requirements:**
  - Describe Potential Water Savings
  - Alternate Sources of Water
  - Potential Impacts to Resources
- **Data Sources:**
  - County Comprehensive Plans
  - USGS Groundwater Reports
  - Eastern Shore Groundwater Supply Protection and Management Plan

Types of Well Performance Tests – Specific Capacity

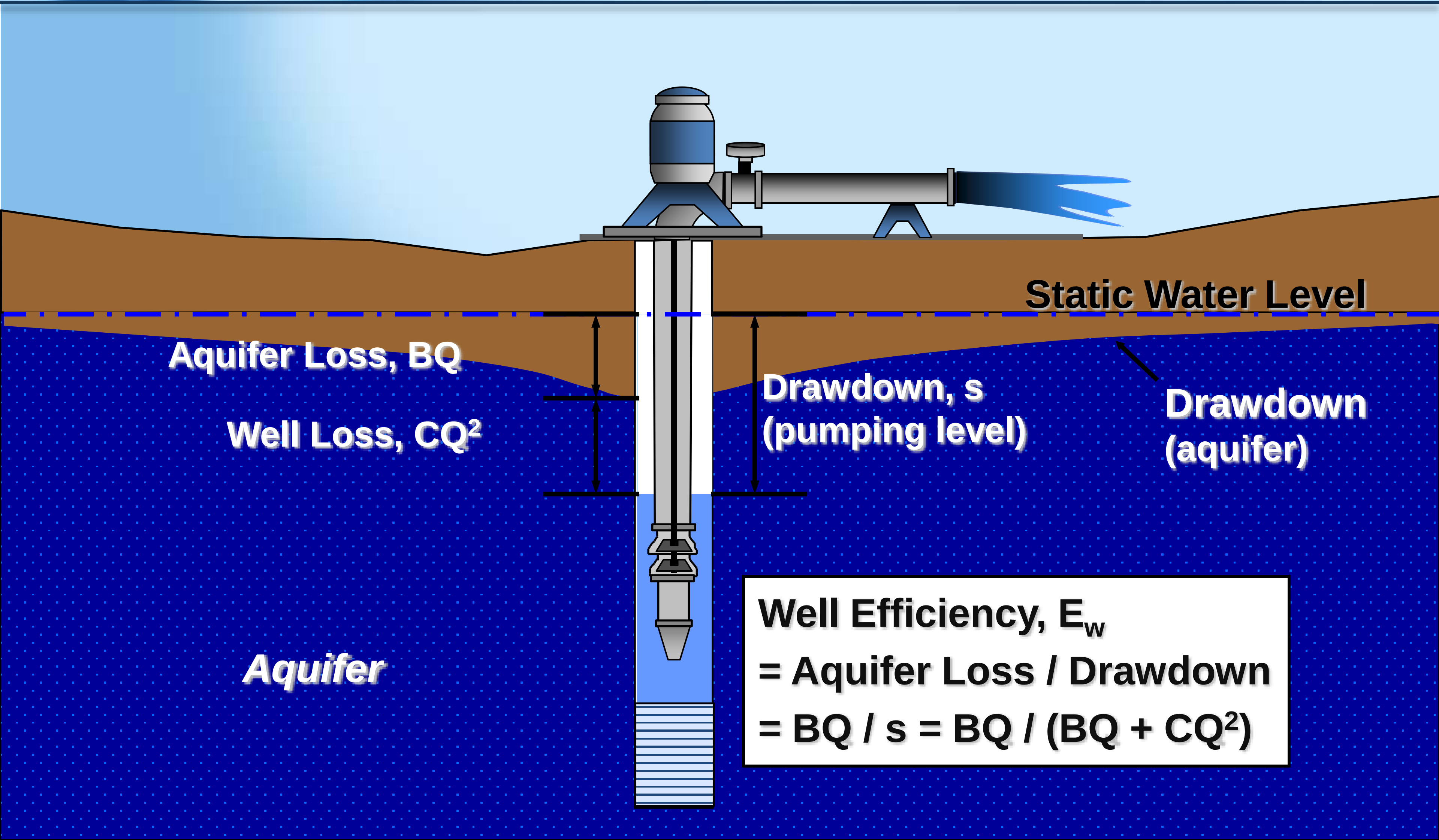


Drawdown, s =
Pumping level (40') –
Static Level (25')
= 15 feet

Pumping Rate, Q = 450 gpm

Specific Capacity, S_c = Q/s =
450 gpm / 15 feet = 30 gpm / ft

Well Efficiency
Key Indicator of Well Performance



Well Efficiency, E_w
= Aquifer Loss / Drawdown
= $BQ / s = BQ / (BQ + CQ^2)$