Sustainability of Groundwater Resources: Basic Principles and Use of Models

By

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Emery & Garrett Groundwater, Inc.

Waterville, ME

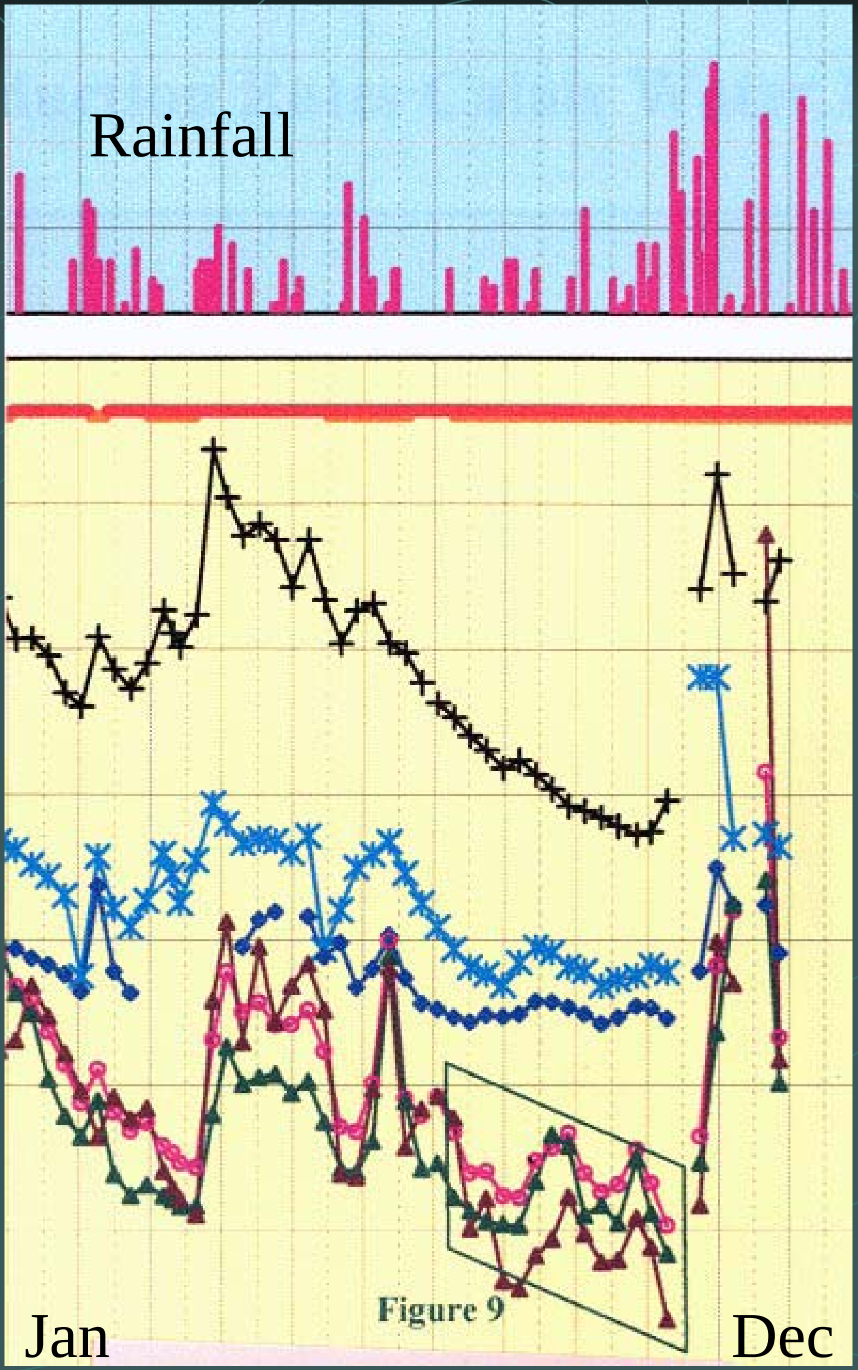
Definitions of Sustainability: 1

- Maximum yield of a well that can be sustained under drought conditions (180 days without recharge).

180+ Days of No Significant Recharge

Background Well

Pumping Wells



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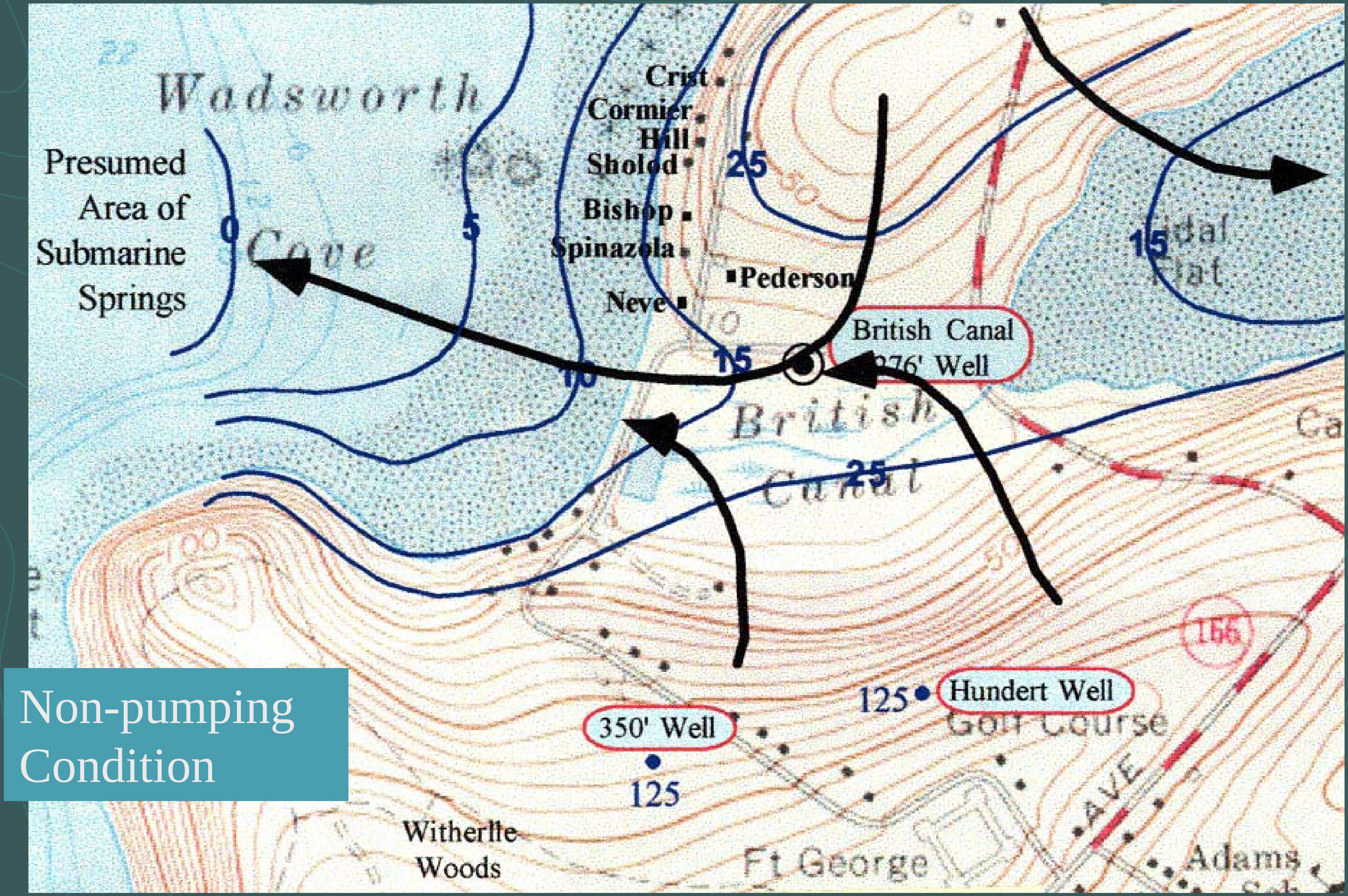
Definitions of Sustainability: 2

- Maximum yield of a well that can be sustained under drought conditions (180 days without recharge).
- Maximum yield that can be sustained without drawing in contamination.

Avoiding Salt Water Intrusion: 1



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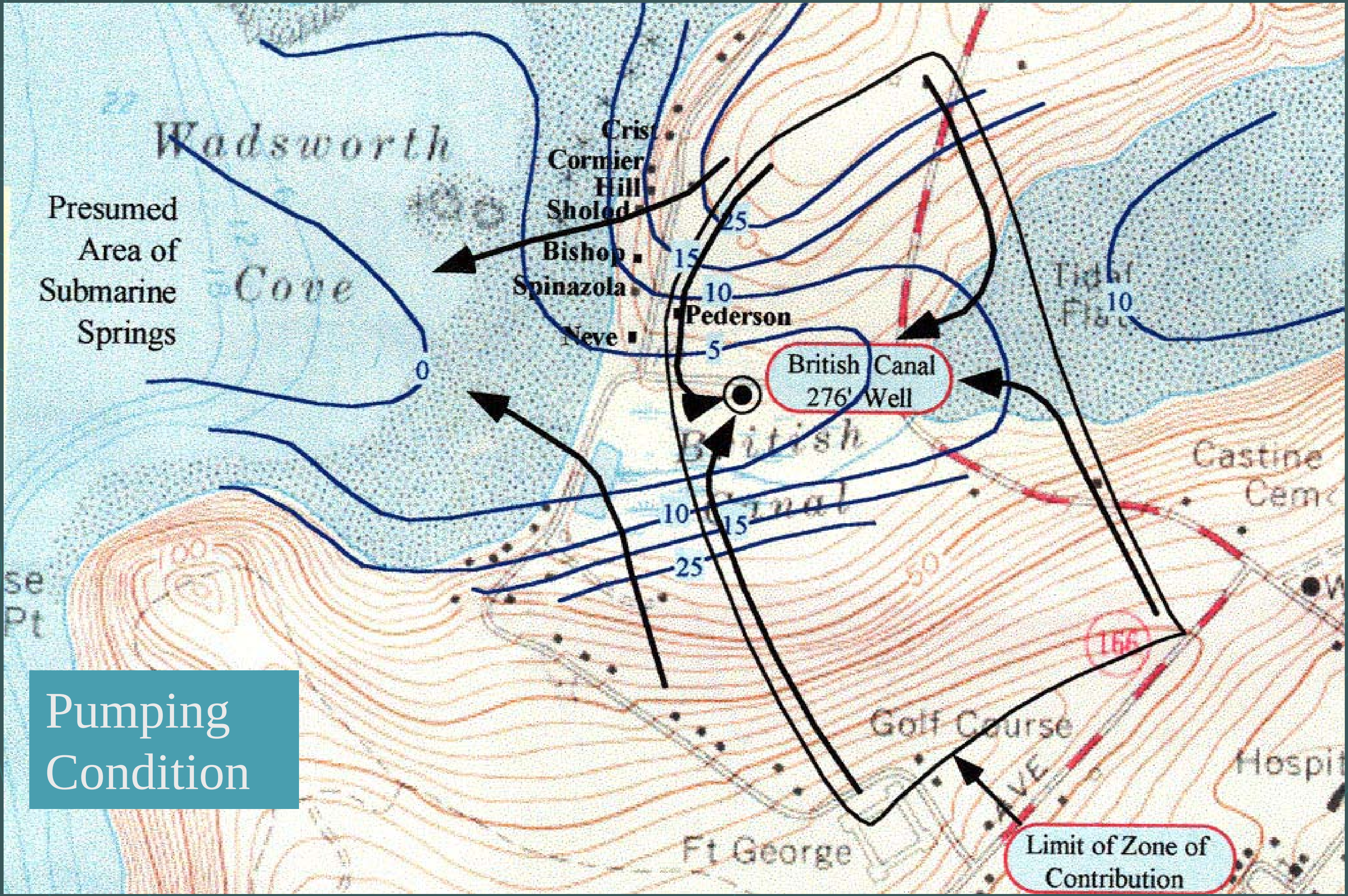
Avoiding Salt Water Intrusion: 2



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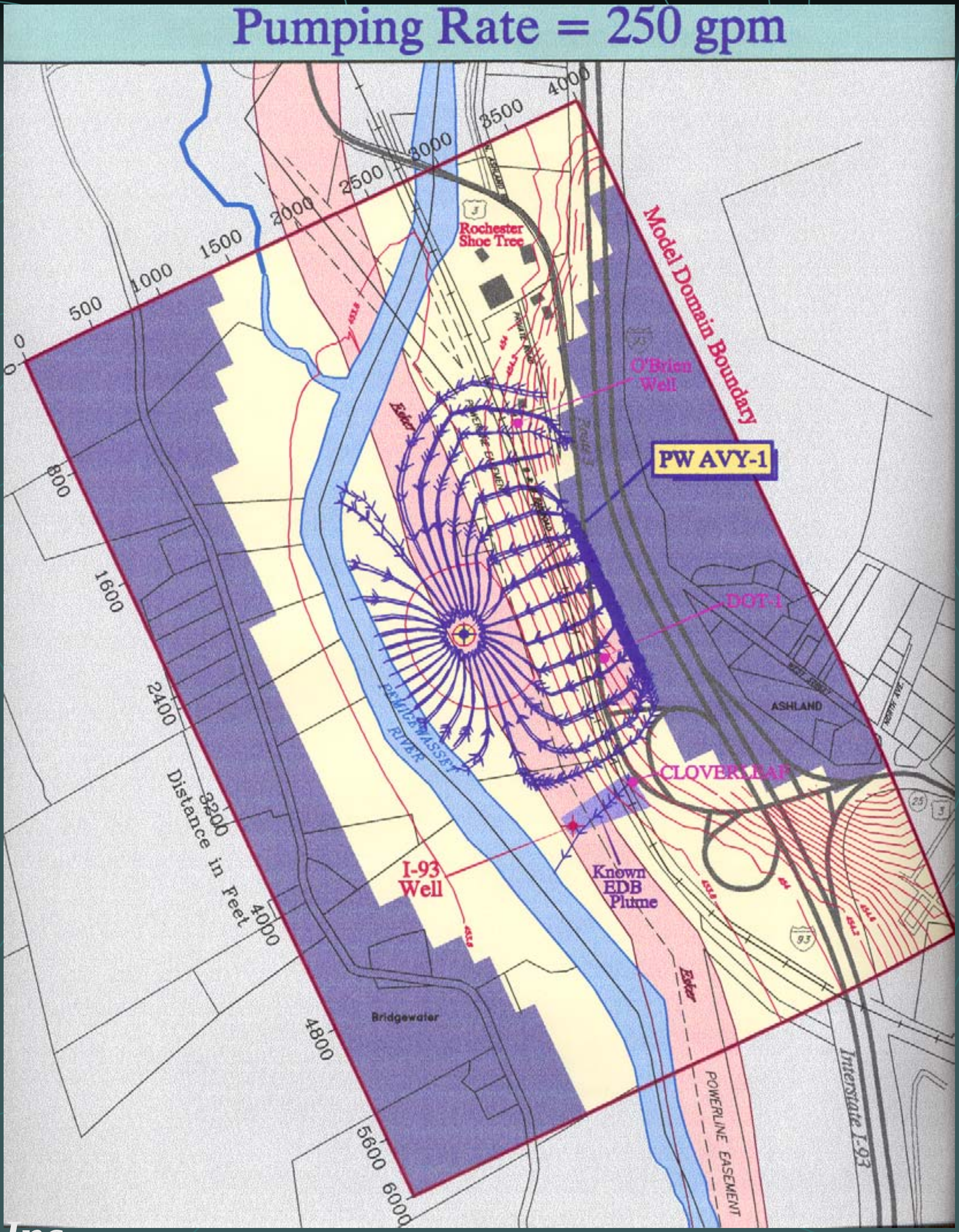
Avoidance of a known plume of contamination



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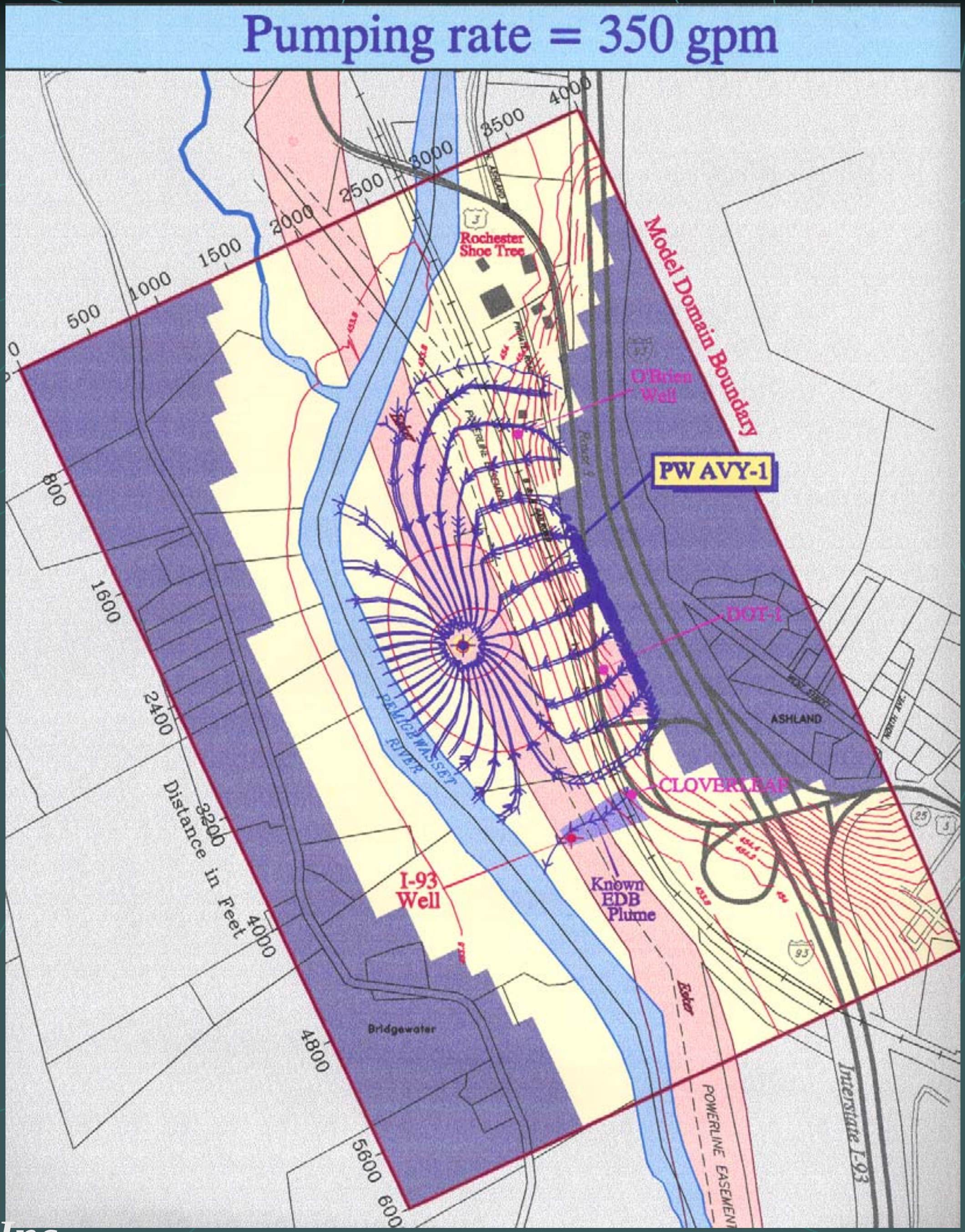

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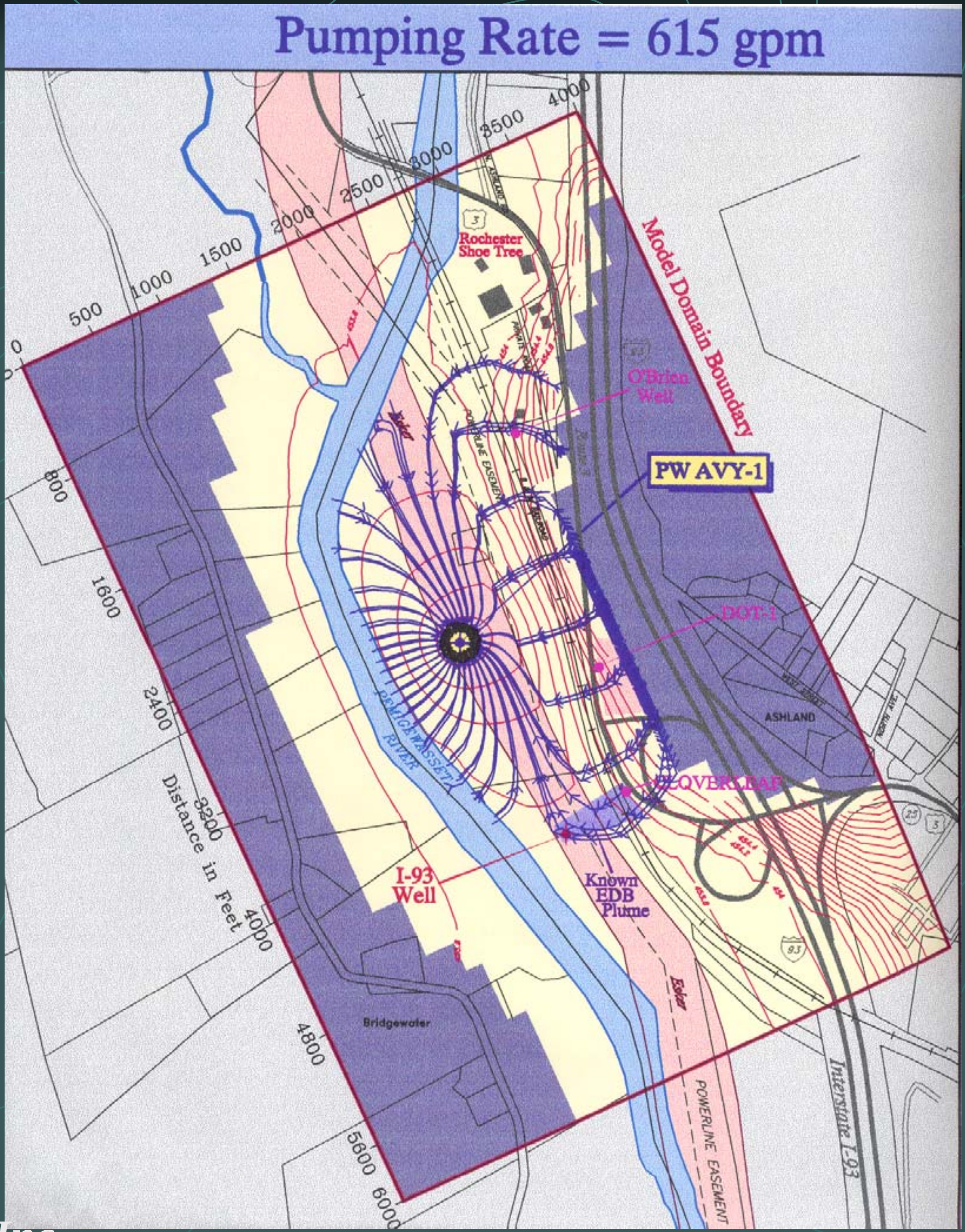
Avoidance of a known plume of contamination



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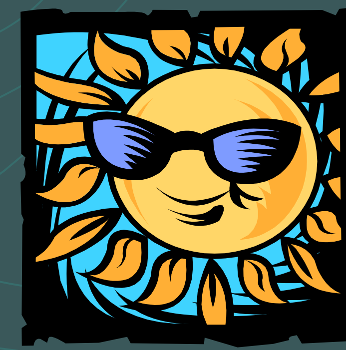
Definitions of Sustainability: 3

- Maximum yield of a well that can be sustained under drought conditions (180 days without recharge).
- Maximum yield that can be sustained without drawing in contamination.
- Maximum yield that can be sustained without reducing surface water flow below some limit.

Stream Flow in Summer represents Baseflow (from groundwater discharge)

Water Budget: Income Side



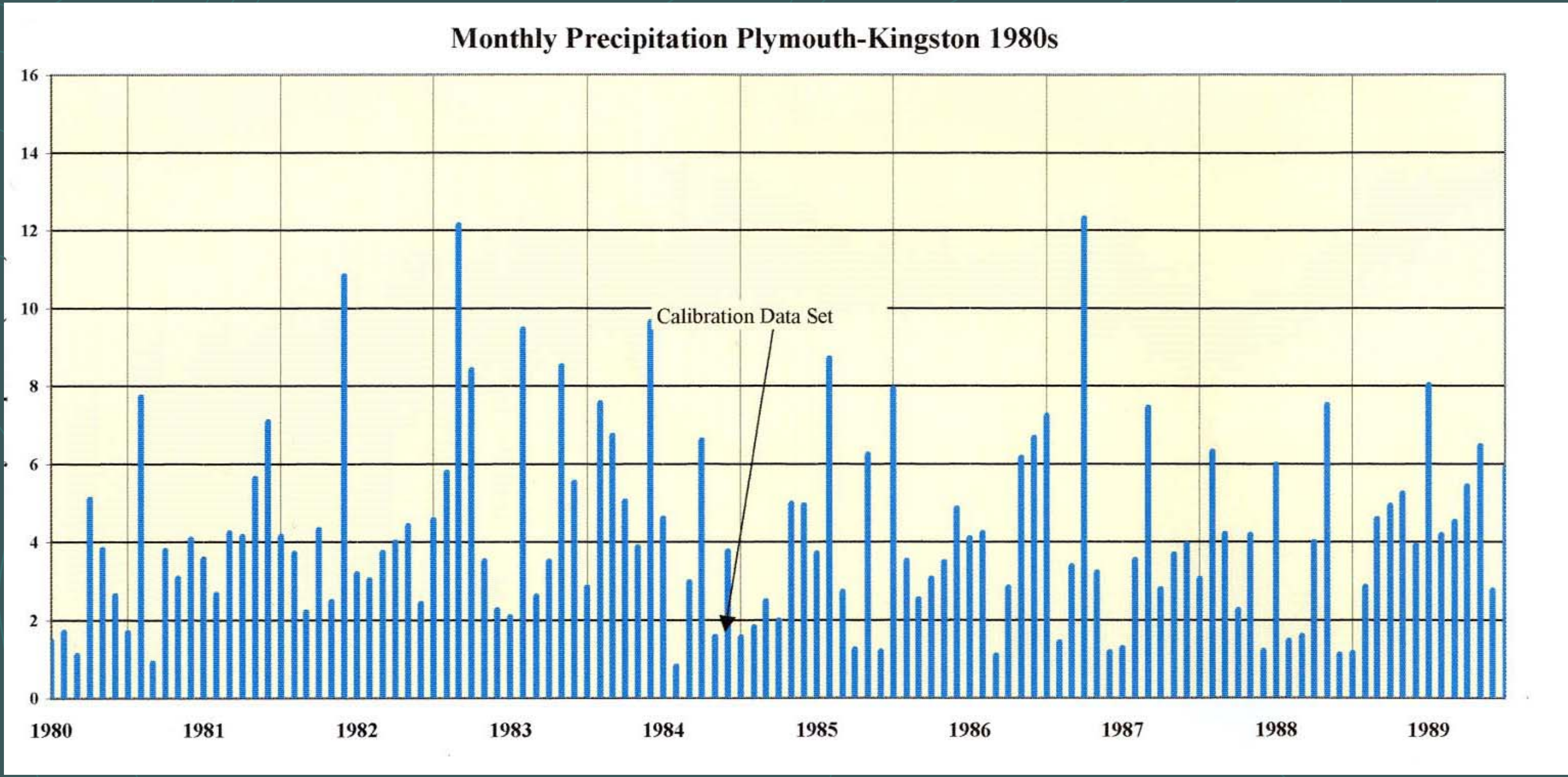
Groundwater Recharge is…

- Precipitation (rain & snow)

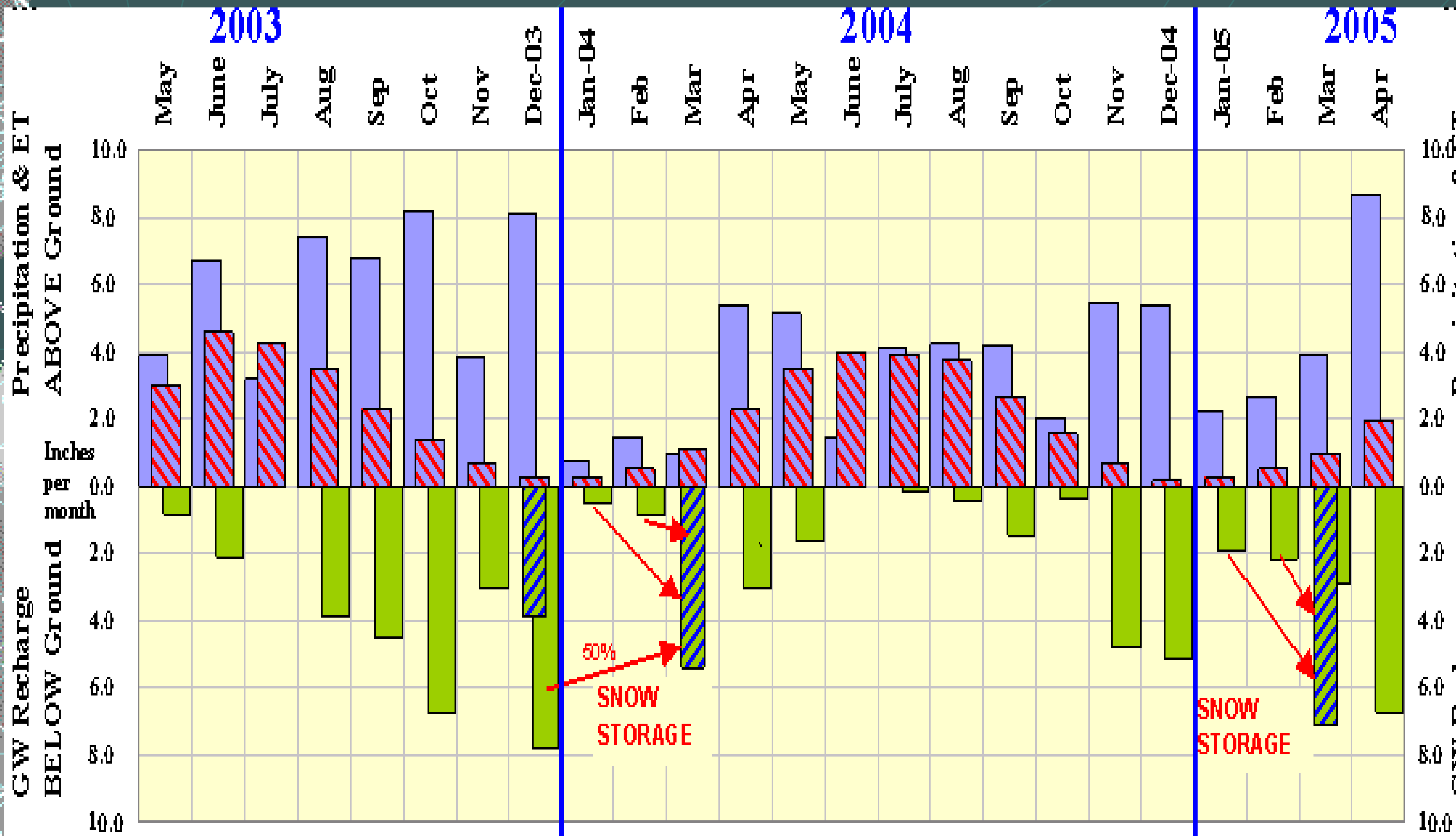
  minus

  - Evaporation
  - Transpiration
  - Runoff

Monthly Precipitation, 1980s



Precipitation, ET, and Recharge



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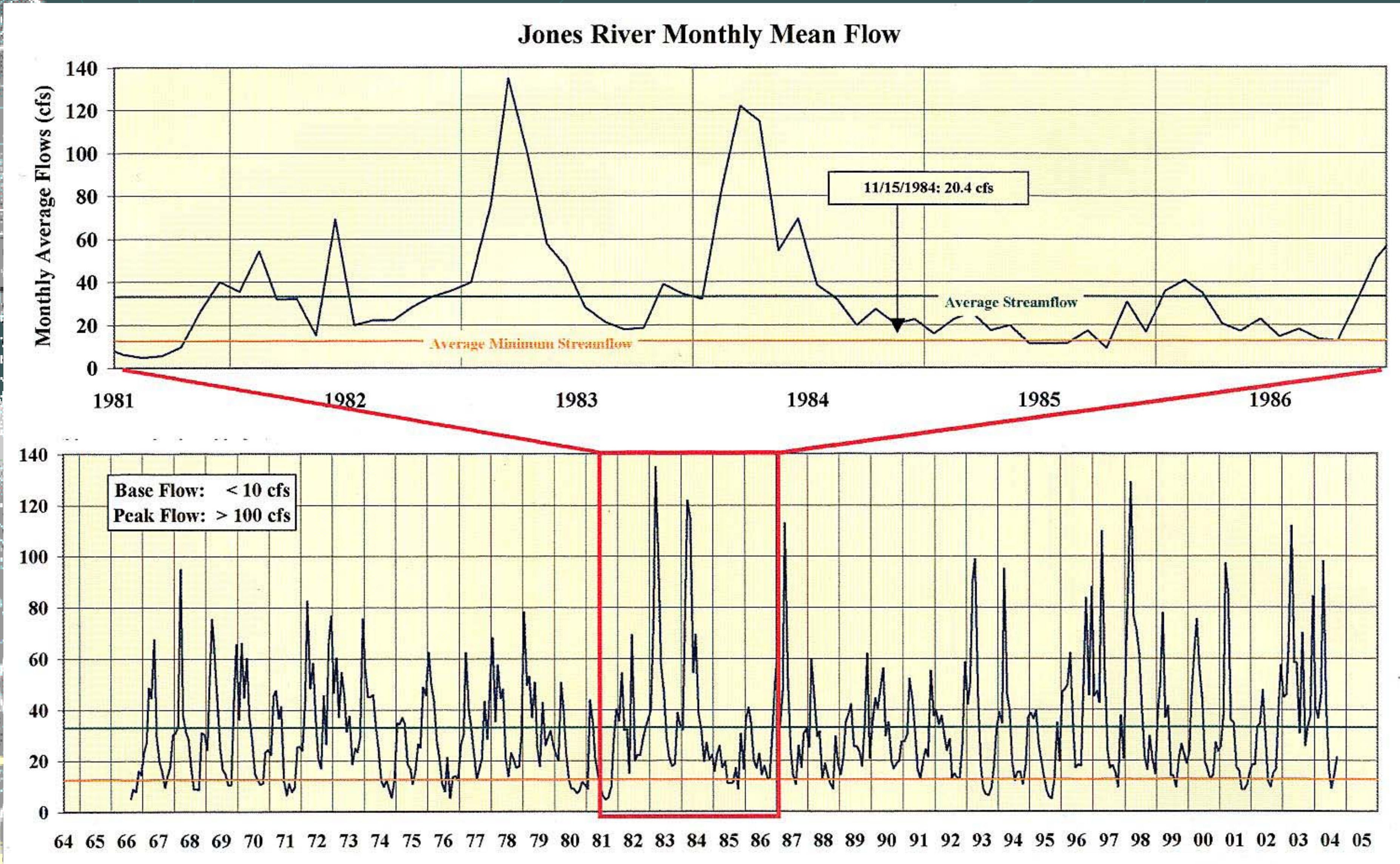
Water Budget: Expense Side

Groundwater can flow out through:

- Visible Springs and Seeps
- Invisible seepage to Rivers, Lakes and Ocean
- Withdrawal from Wells

Well House and Spring

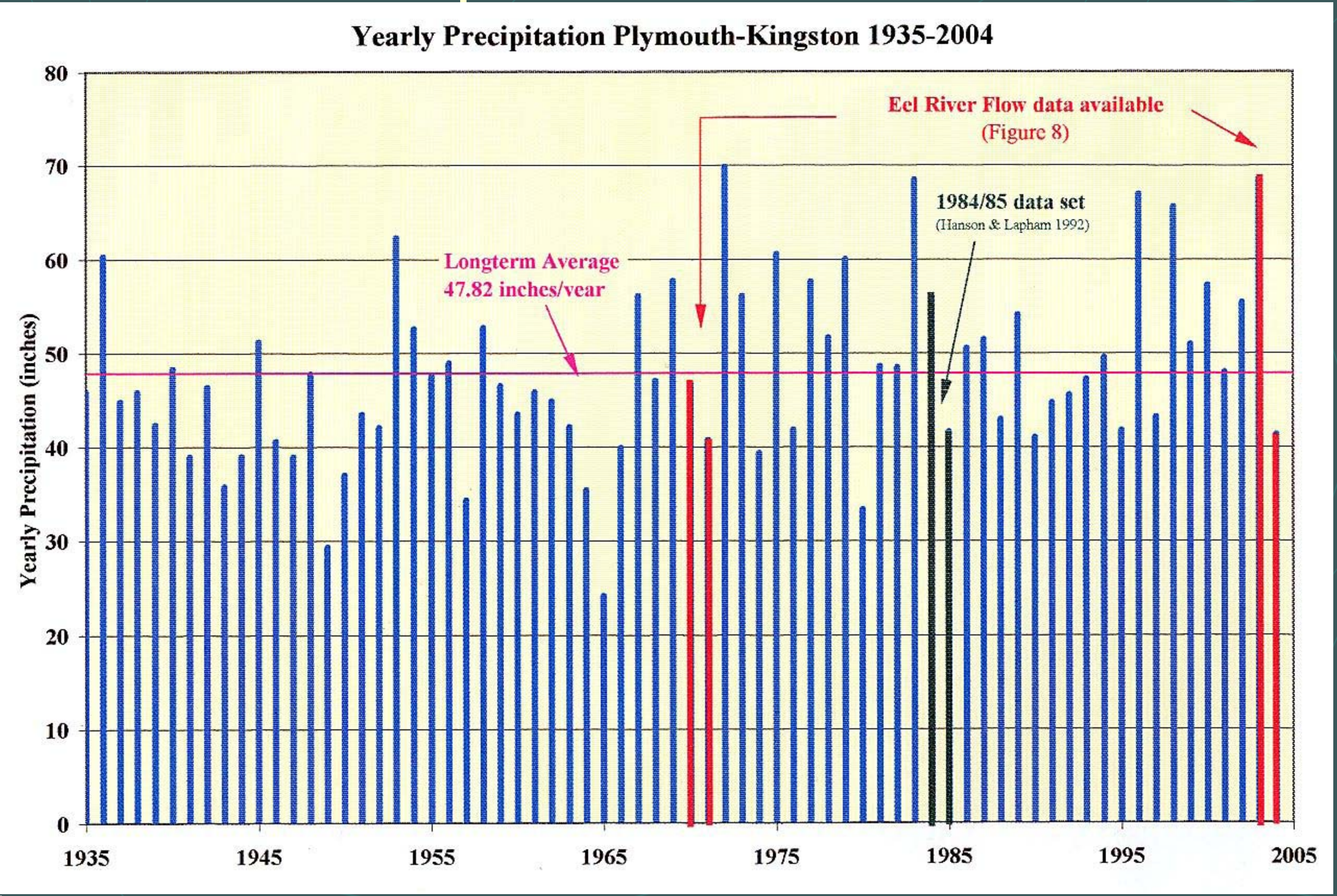
Streamflow Hydrographs



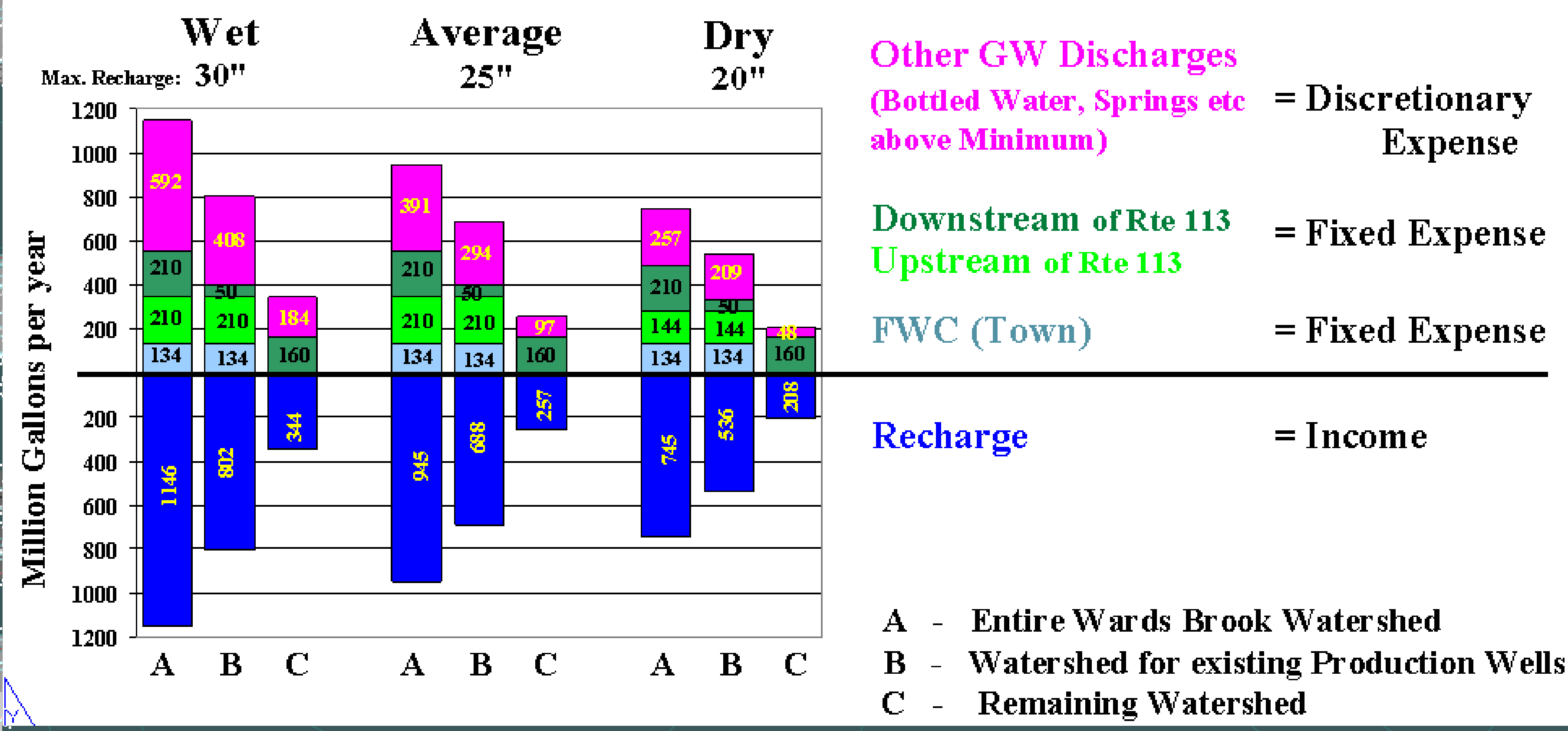
Average vs. Drought

- Expect the Average
- Plan for the Drought
- Wet years are a bonus
- How do we deal with Extreme Droughts?

Annual Precipitation



Annual Groundwater Budget



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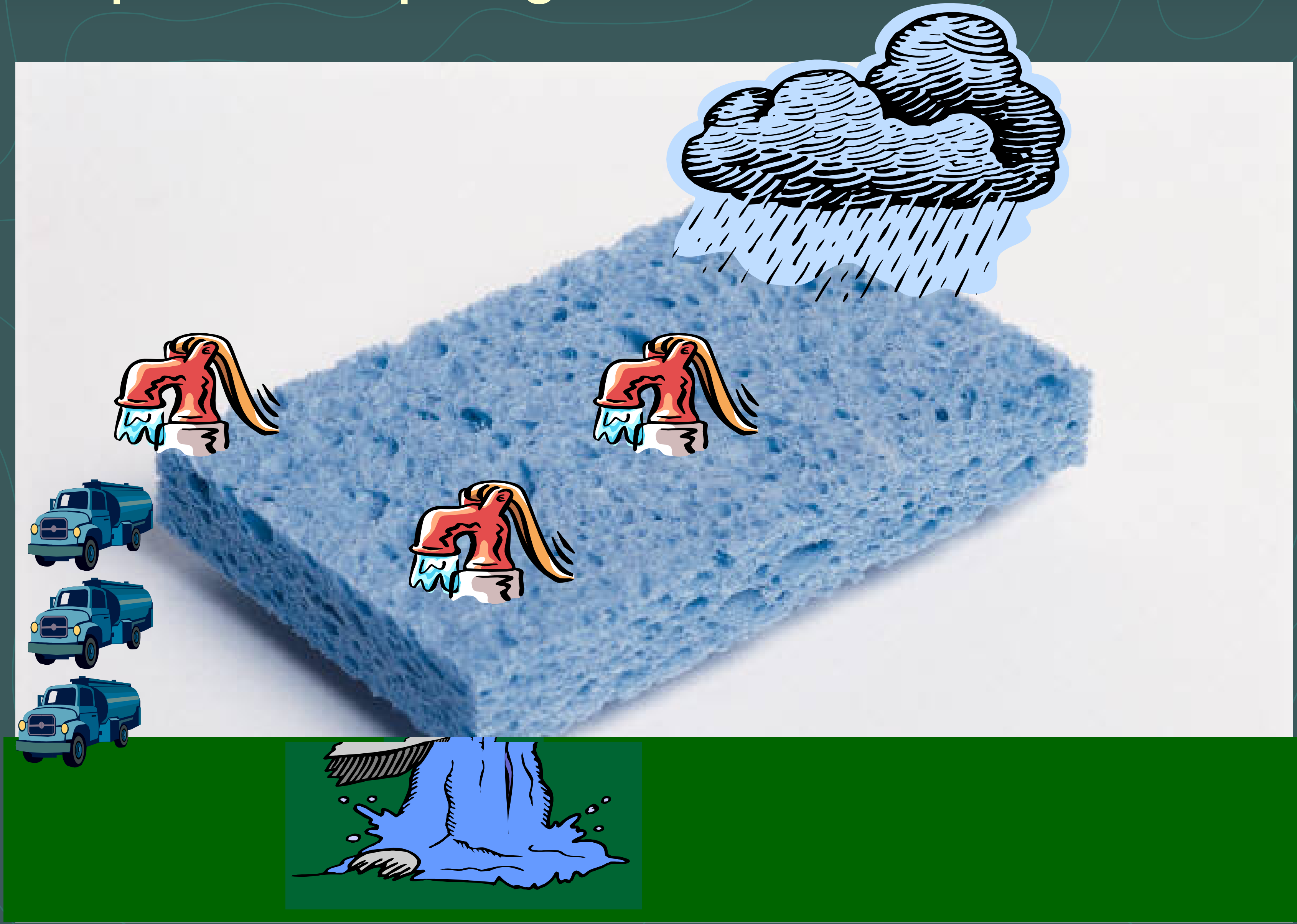
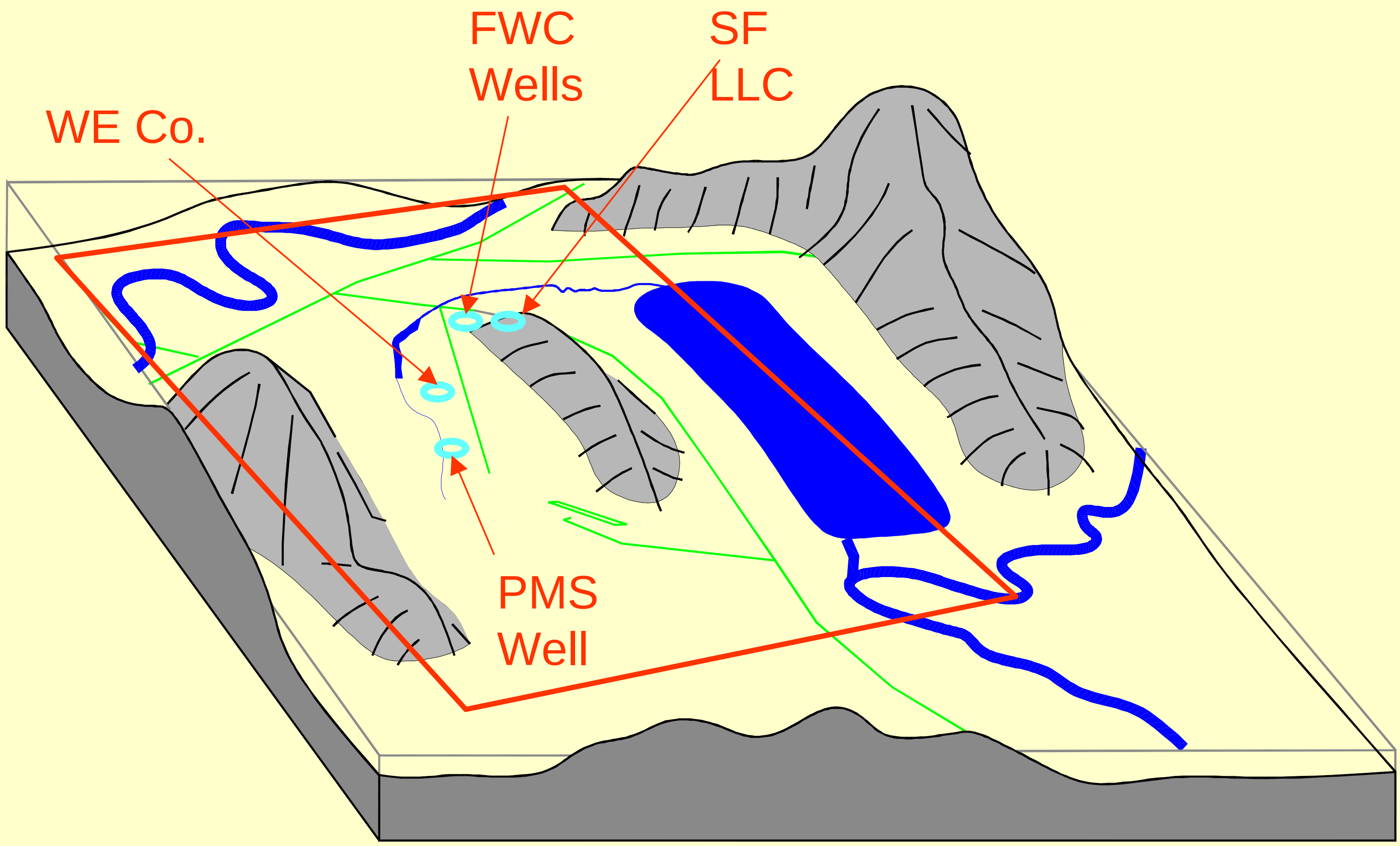
Simplified “Sponge” Model



Mathematical Models:
Their Limits
Their Uses

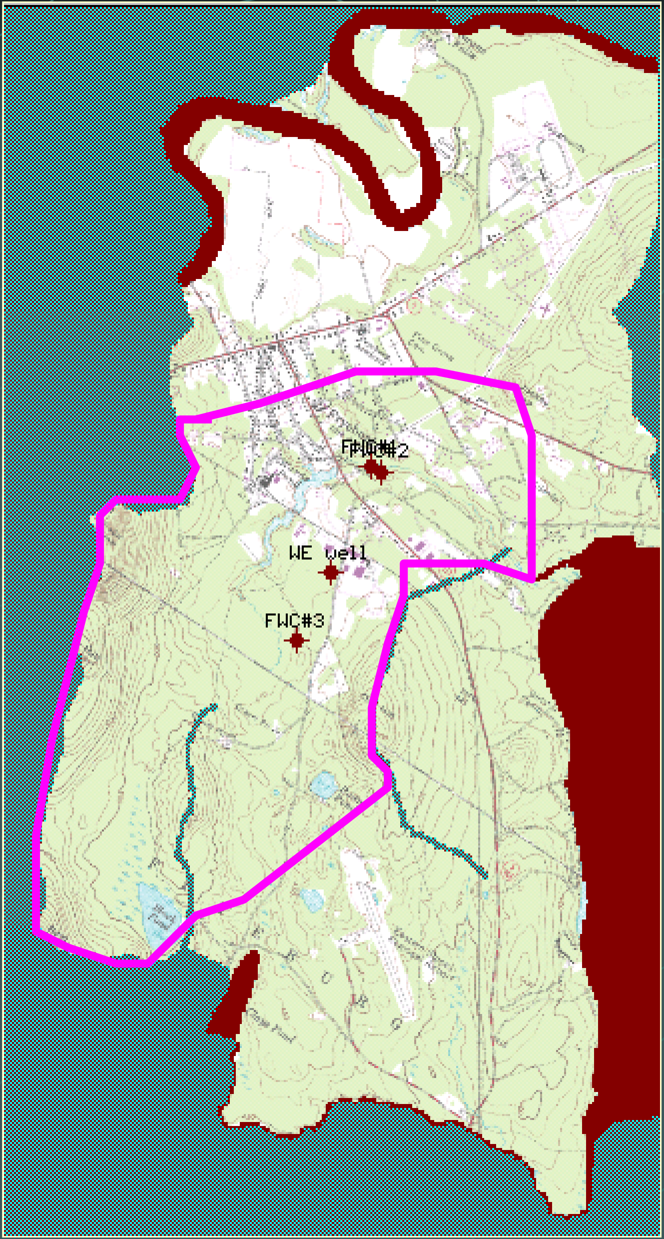
- Mathematical Constructs
- Limited by the data
- Useful aid to thinking
- Offering opportunities for What If questions
- Defensible Delineations for Wellhead Protection

3D-View Study Area & Model



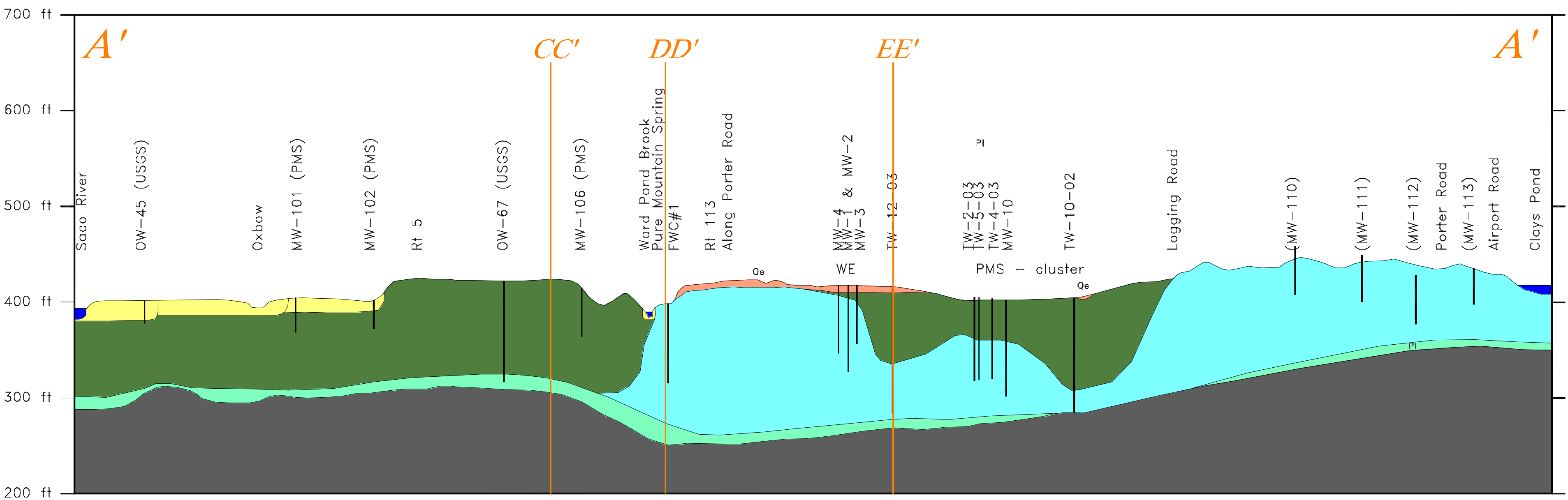
Active Model Domain & Boundary Conditions

- Constant Head
- Drain
- Stream
- Hillside recharge
- Pumping



The Third Dimension

Geological Cross-section, north-south



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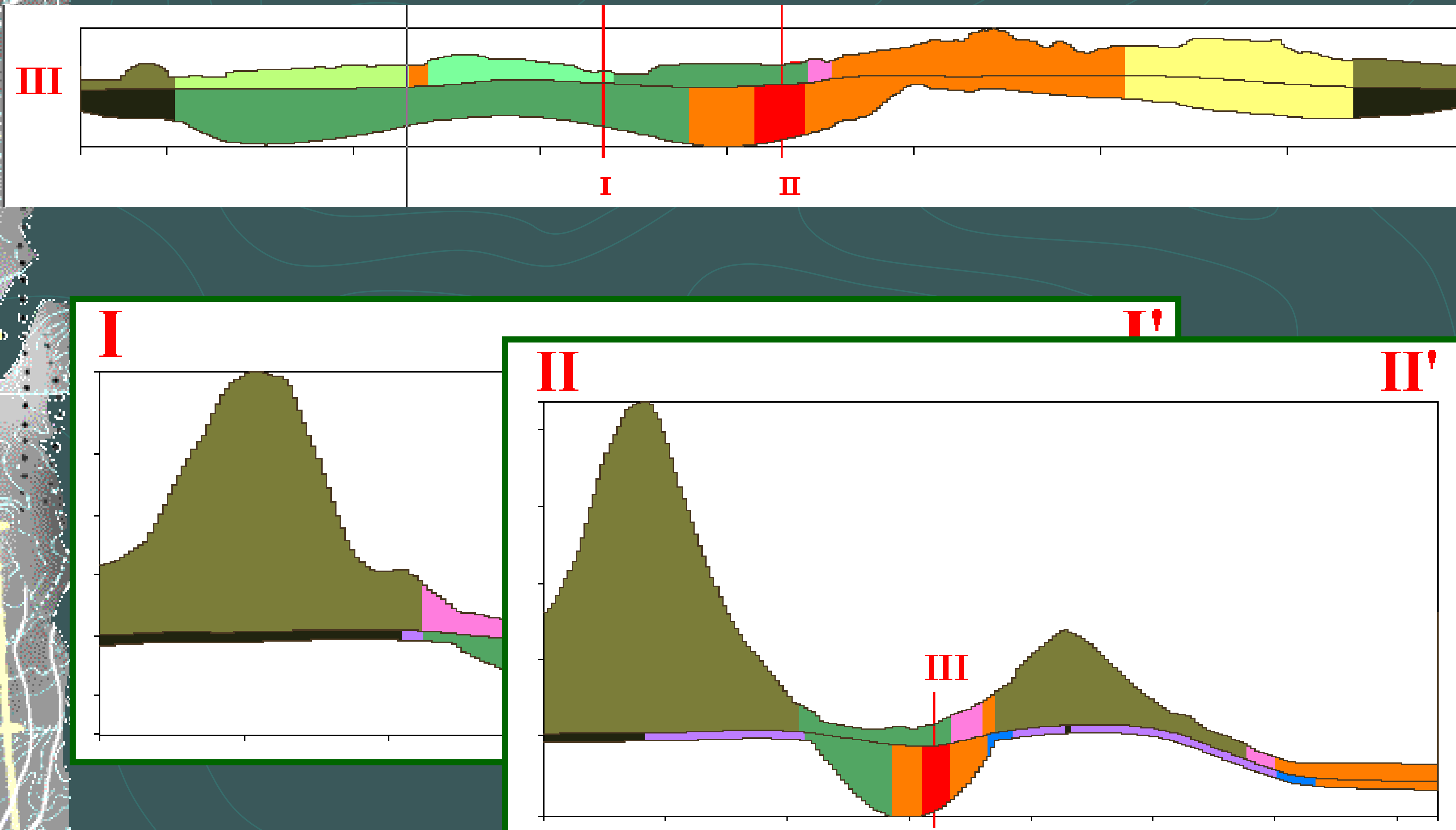
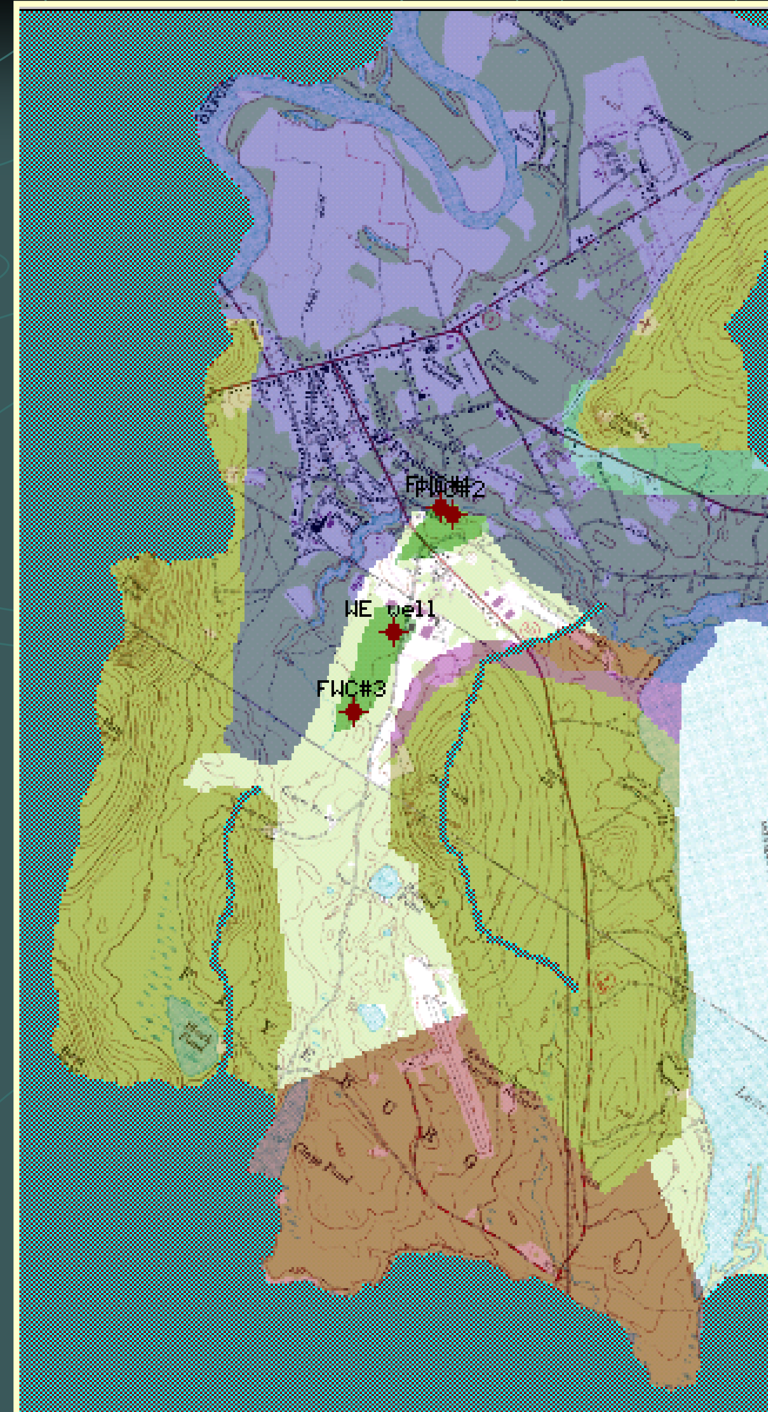
Modeled Third Dimension



Hydraulic Conductivity Layer 2

Zone		Kx [ft/d]
1		150
2		7
3		300
4		30
5		70
6		15
7		30



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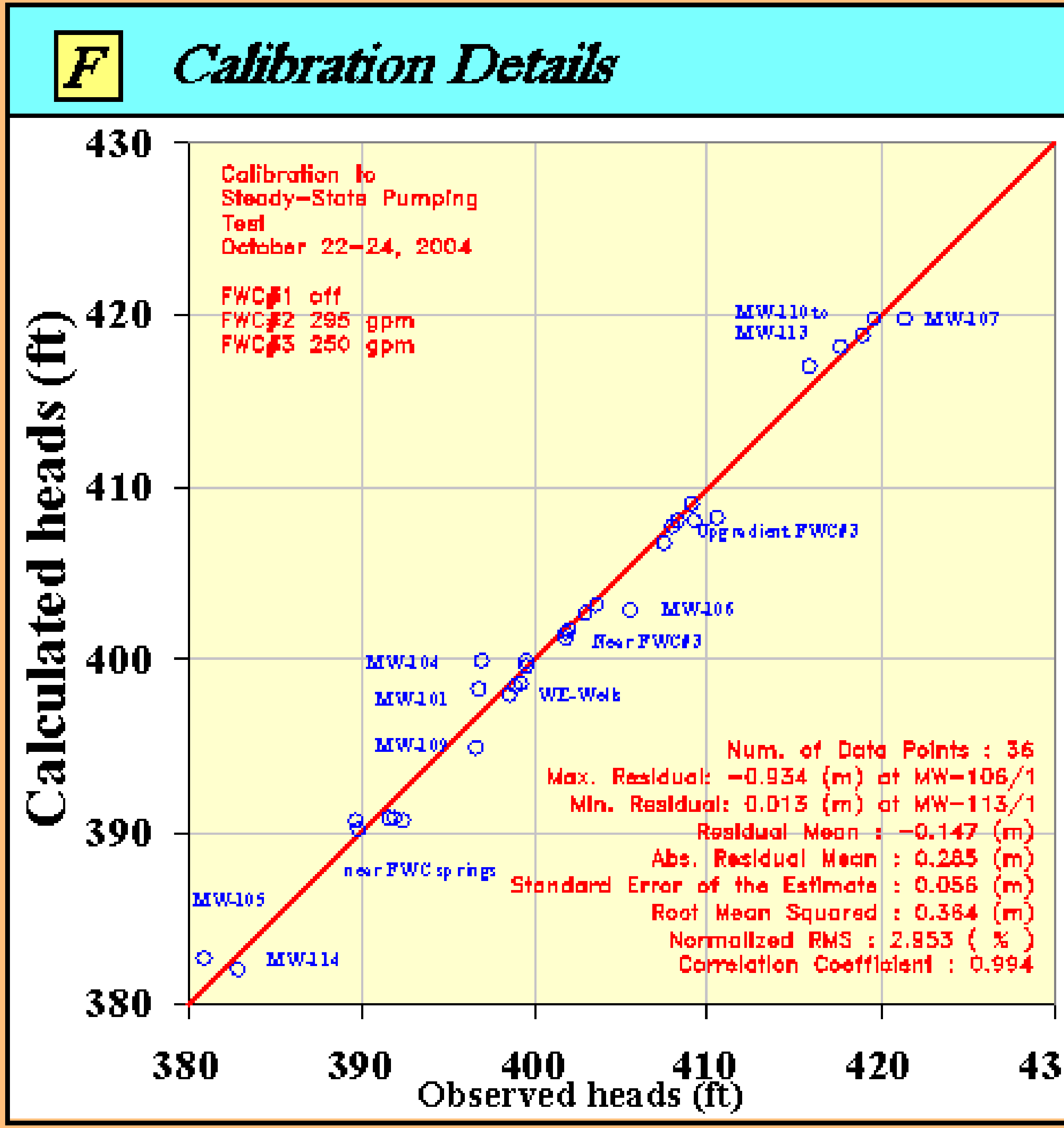
Steady State Model Calibration



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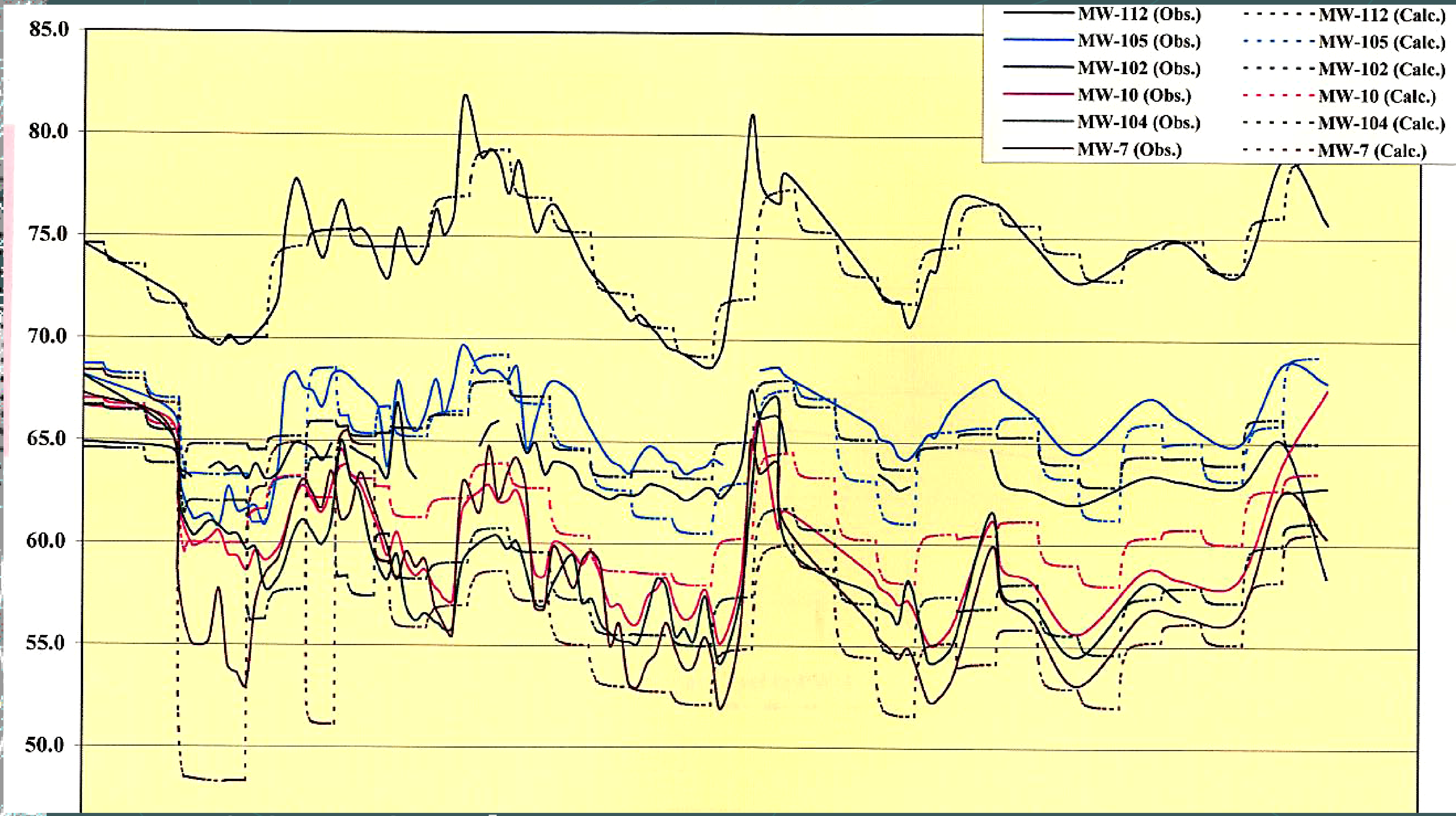
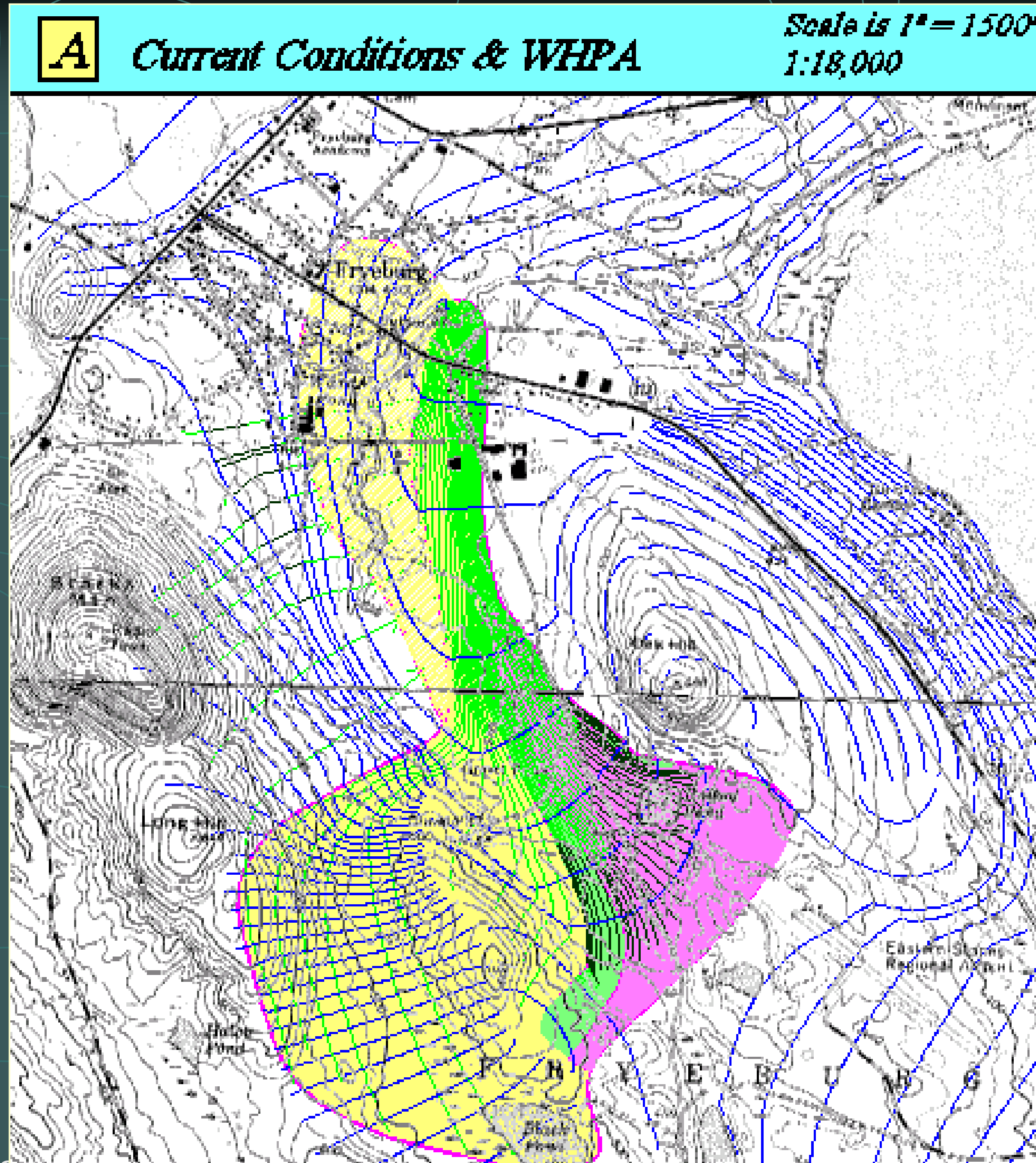
Validation using Transient Conditions

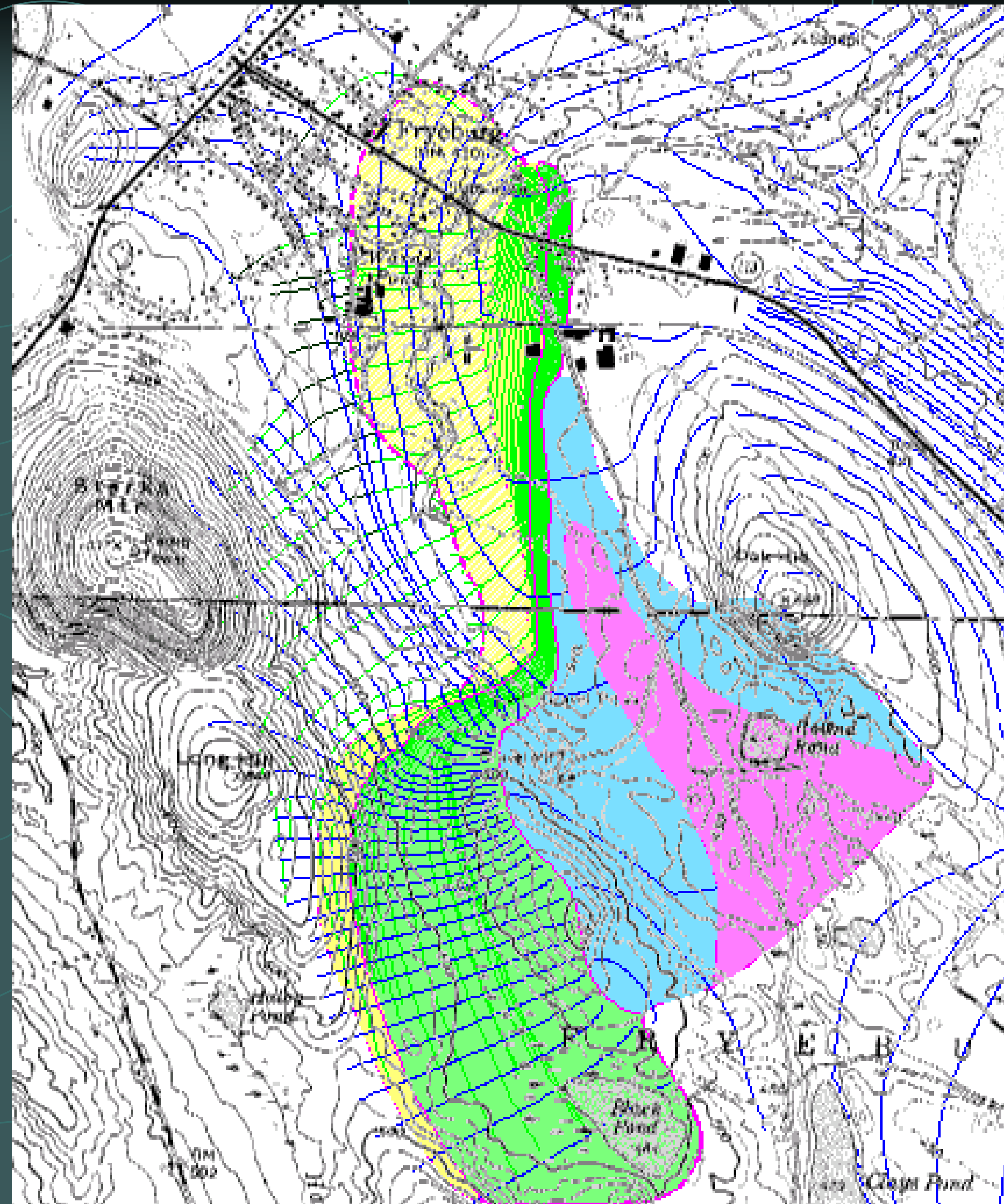


Wellhead Protection for Current Pumping

FWC#1 300k
FWC#2 67k
FWC #3 300k



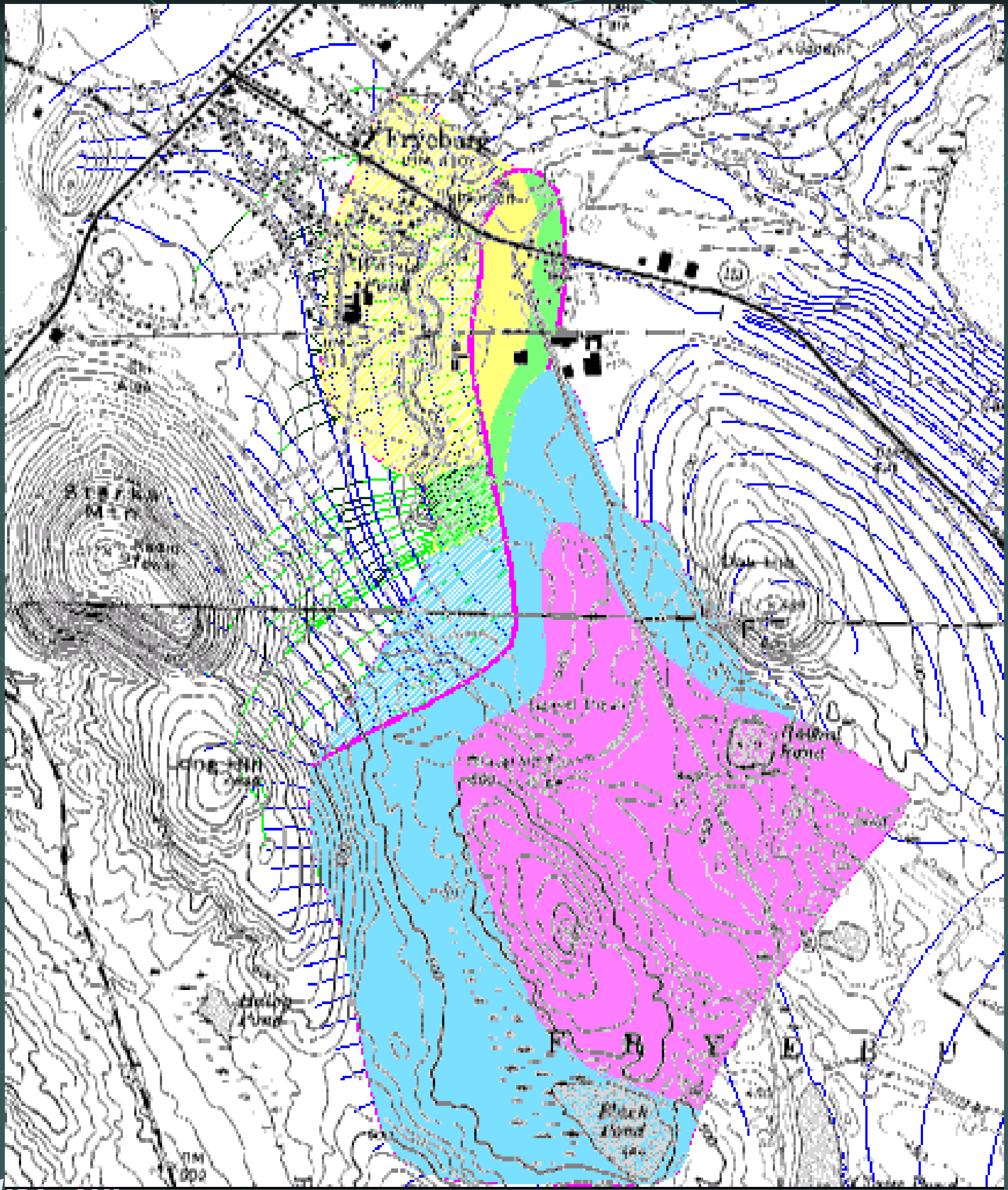
Wellhead Protection for Future Pumping



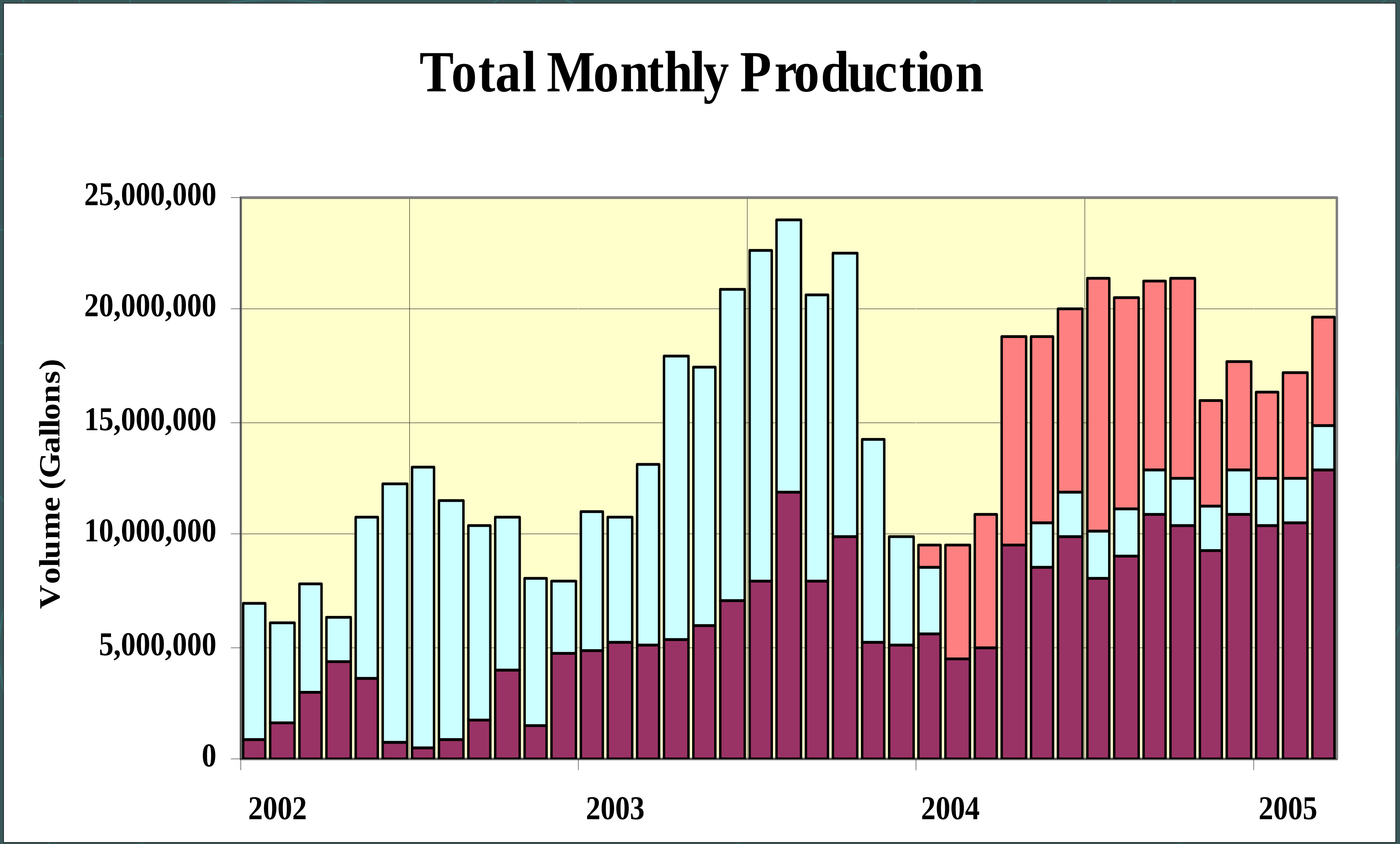
FWC#1 300k
FWC#2 67k
FWC #3 300k
WE well 300k

Wellhead Protection for Maximum Pumping

FWC#1 300k
FWC#2 67k
FWC #3 600k
WE well 450k



Pumping from the Aquifer



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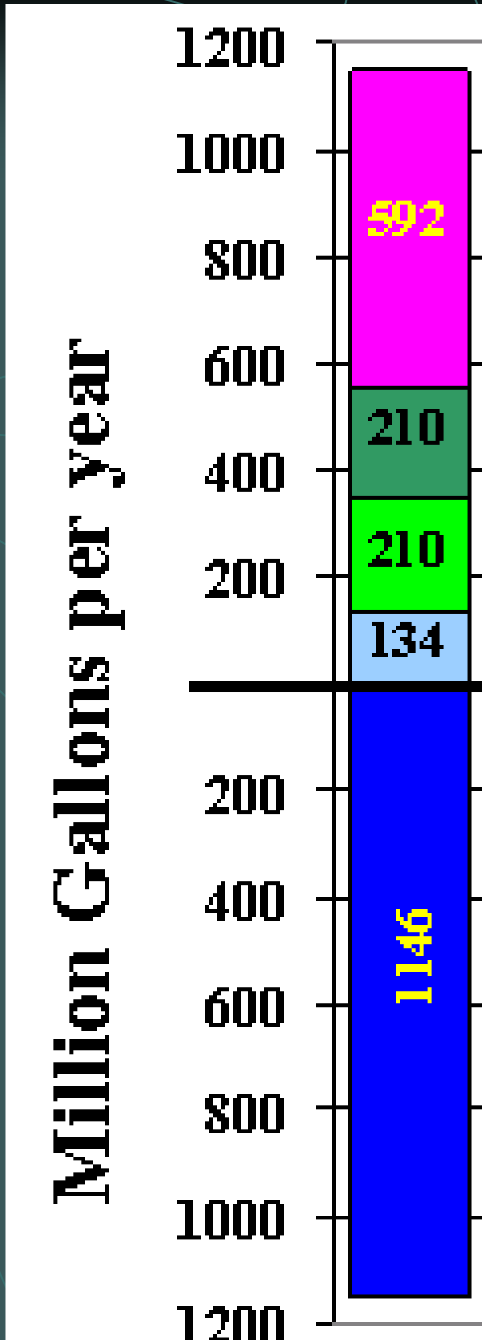
Assessing Sustainable Yield



Bottled Water or Brook Flow >minimum = Discretionary Expense

Minimum Flow in Wards Brook = Fixed Expense

Fryeburg WC for Town = Fixed Expense

Groundwater Recharge = Income

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The Definition of Sustainability requires:

- A thorough understanding of natural limits
  - Water Budget for the Local Aquifer
  - The potential of the well
  - Streamflow
  - Constraints on Other Local Resources
- Some man-made Decision-making
  - Regulations, Ordinances, Guidelines

Influence of Groundwater Flow on Surface Water Quality

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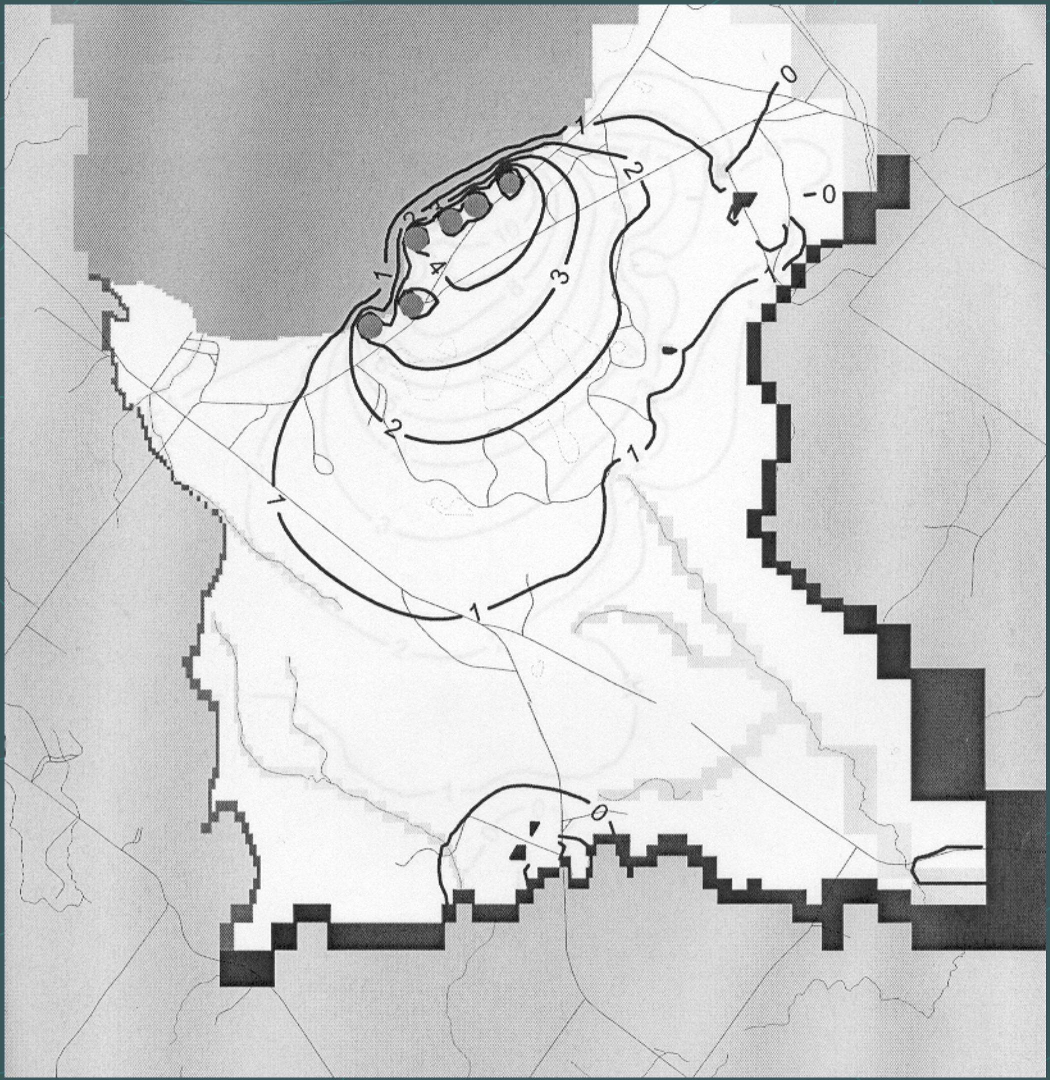
Pumping from an aquifer adjacent to Sebago Lake:
7 million gallons per day



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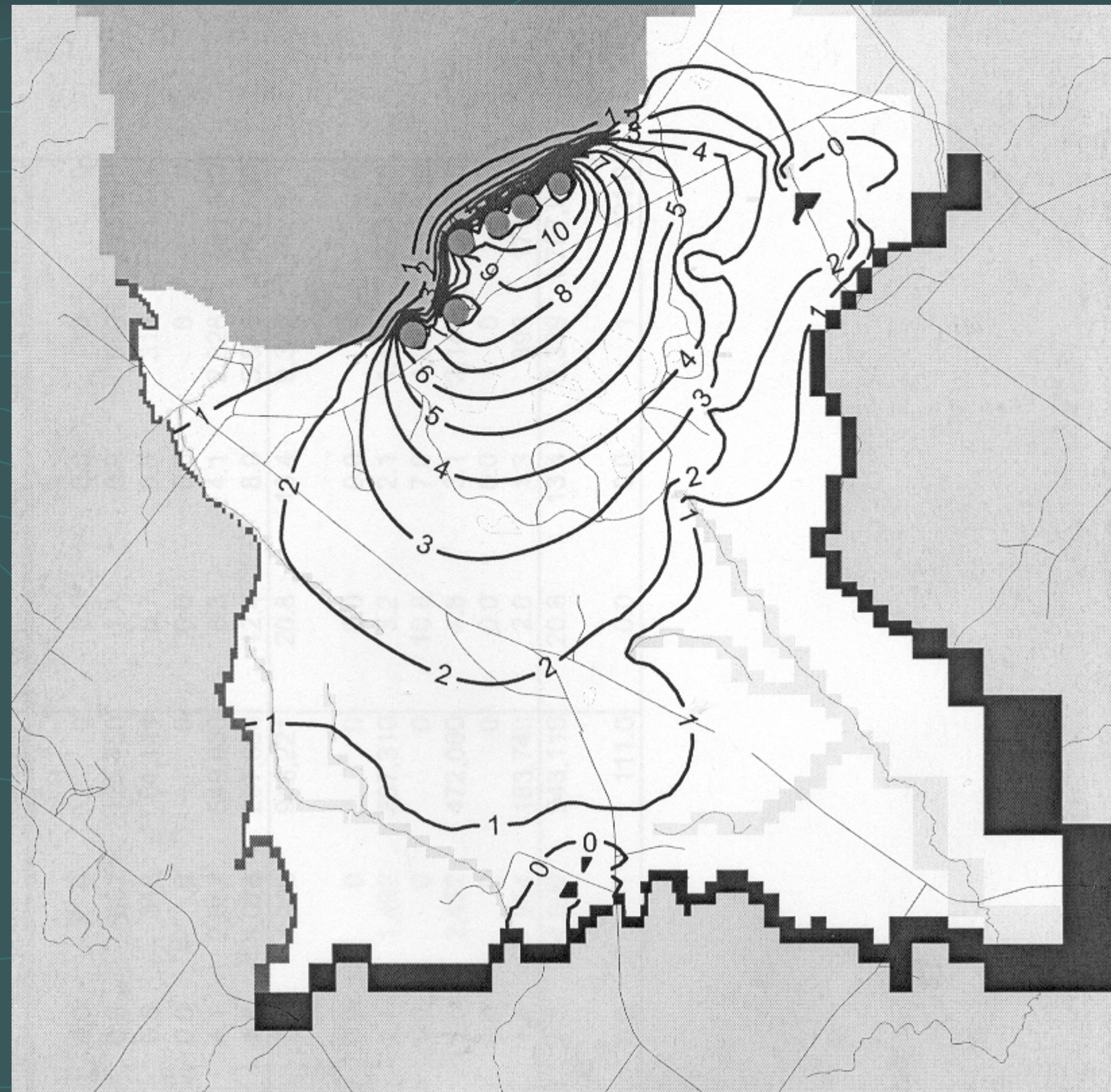
Pumping from an aquifer adjacent to Sebago Lake: 15 million gallons per day



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