The Importance of Capture in the Sustainable Management of Groundwater Storage

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Outline

- Compare surface vs. groundwater storage
- Capture-based measures for sustainable yield
  - Sustainable Capture Fractions
  - Capture Efficiency
- Adaptive management of stream/aquifer systems
  - Restoration characteristics after prolonged overdraft
- Conclusions

Relative Merits of Groundwater vs. Surface Water Storage (adapted from Harvey)

Surface Reservoirs	Subsurface Reservoirs
Disadvantages	**Advantages**
Few new sites available (USA)	Many large capacity sites available
Need large areas of land	Need very small areas of land
High evaporative losses	Practically no evaporative loss
May fail catastrophically	Practically no danger of failure
Easily polluted	Usually high biological purity, although pollution can occur
Water must be conveyed	Internal conveyance (no need for canals)

Management of Groundwater vs. Surface Water Storage

Surface Reservoirs	Subsurface Reservoirs
Advantages	**Disadvantages**
Well defined boundaries	Boundaries often unknown
High rates of flow possible	Limited rates of extraction/injection
Only 1 measurement needed	Need many measurements in space
Responds as a level pool	Response depends on location and can be nonlinear
Response time is relatively fast	Response time is relatively slow
Well defined conveyance system	Internal conveyance

Motivational Quotes

- "Surface water is commonly connected to ground water, but the interactions are *difficult to observe and measure* and commonly have been ignored…" -Winter et al., 1998
- "All water discharged by wells is balanced by a loss somewhere." – Theis, 1941
  - Storage, induced recharge, reduced discharge (capture)

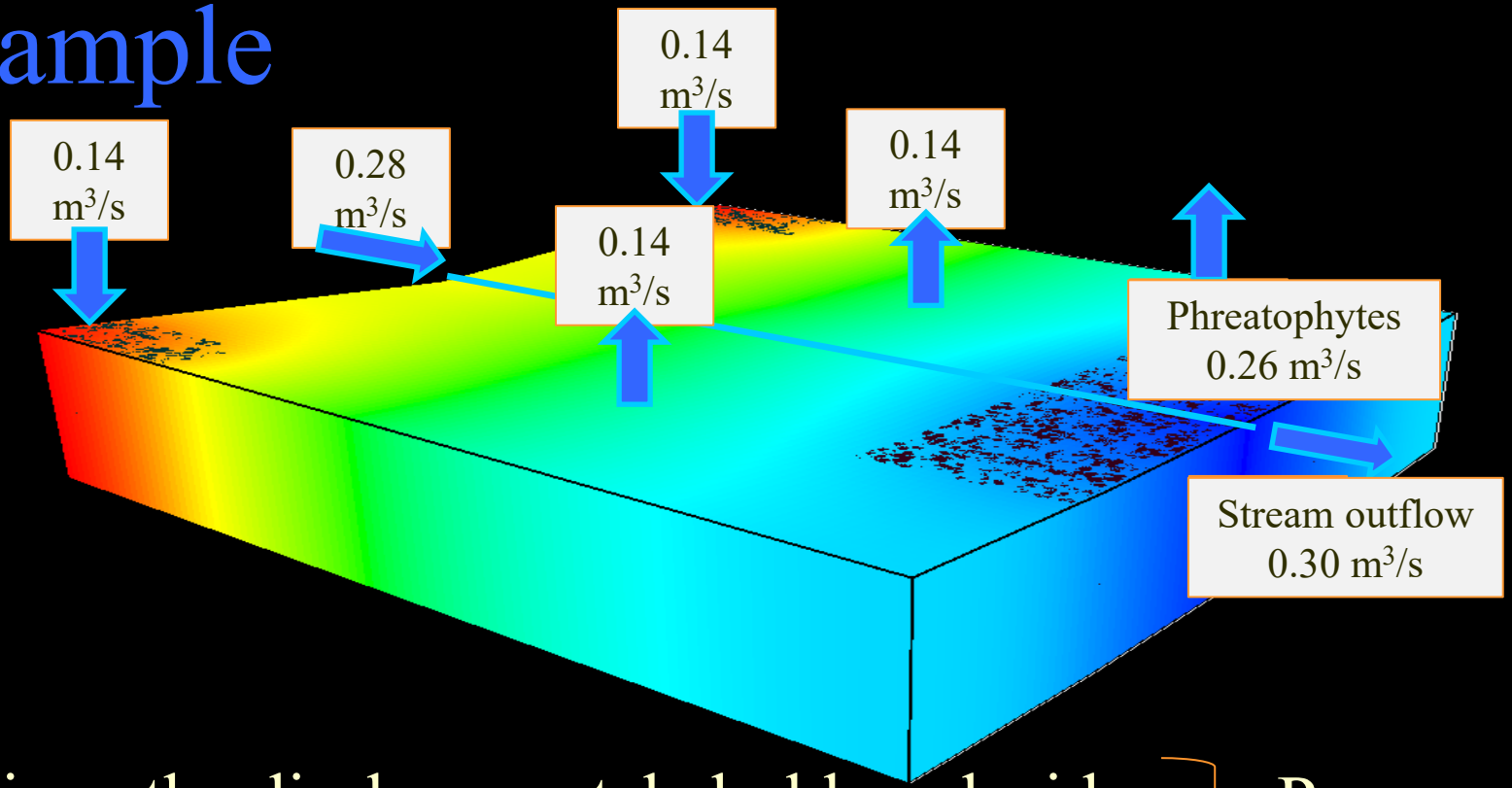
Sustainable Capture Concepts

- Apply concepts of capture to each discharge flow path
- SCF = Sustainable Capture Fraction
  - Stakeholder driven process
    - Fraction of flow path that can be “sustainably” captured?
    - Ranges between 0 and 1

Sustainable Capture Concepts

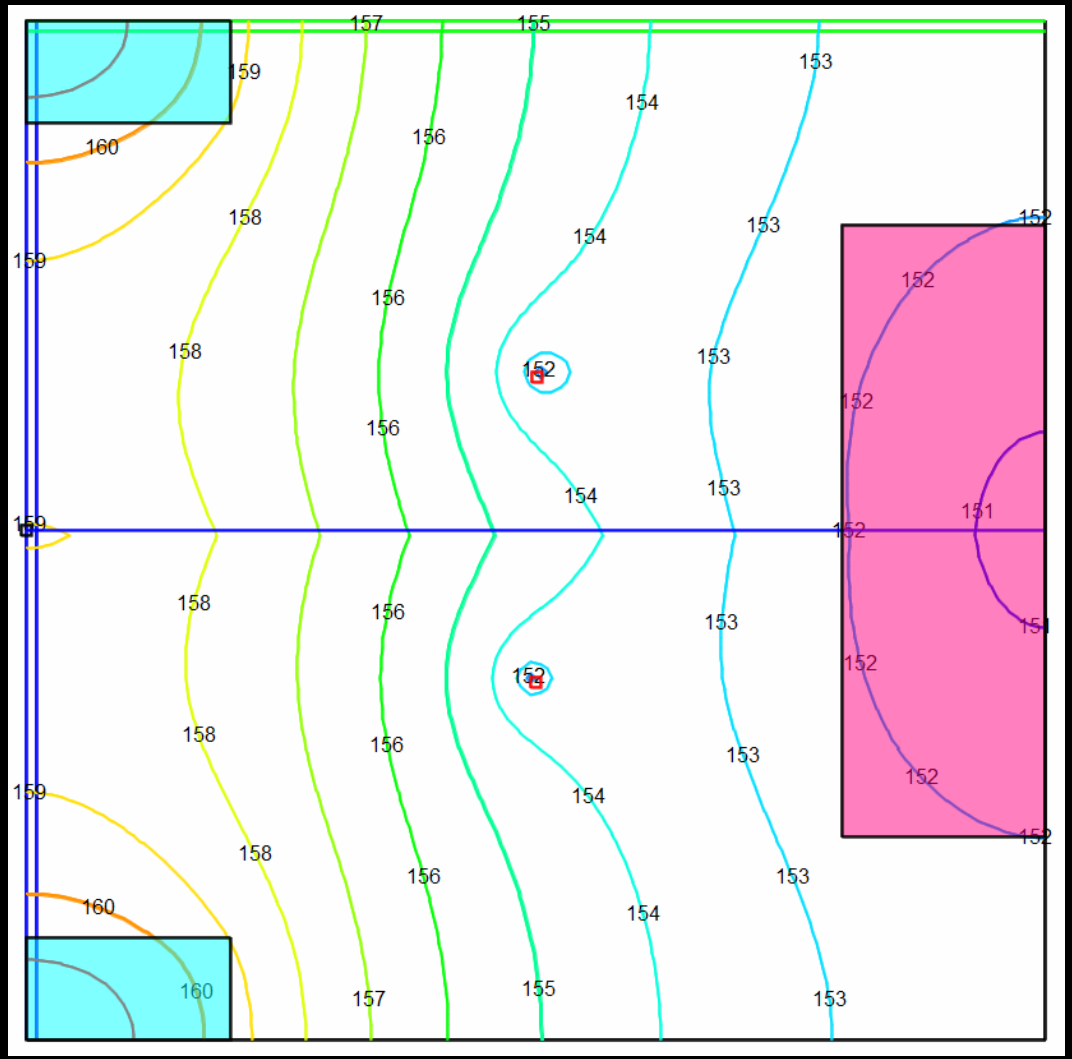
- SCT = Sustainable Capture Threshold
  - Could be related to SGMA thresholds based on flows
- SCT = Σ (SCF*discharge)= rate of sustainable extraction
  - Like a Sustainable Yield, but based on capture
- CE = Capture Efficiency
- CE = Ratio of the actual discharge captured over the SCT
- CE can be a for a discharge flow path or the overall CE
- 100% indicates that the capture threshold has been reached

Example



- Given the discharge, stakeholders decide:
  - SCF_{SW} = 0.50 (0.15 m^3/s of stream outflow)
  - SCF_{GW} = 0.50 (0.13 m^3/s phreatophytes)

Proposed GW pumping = 0.28 m^3/s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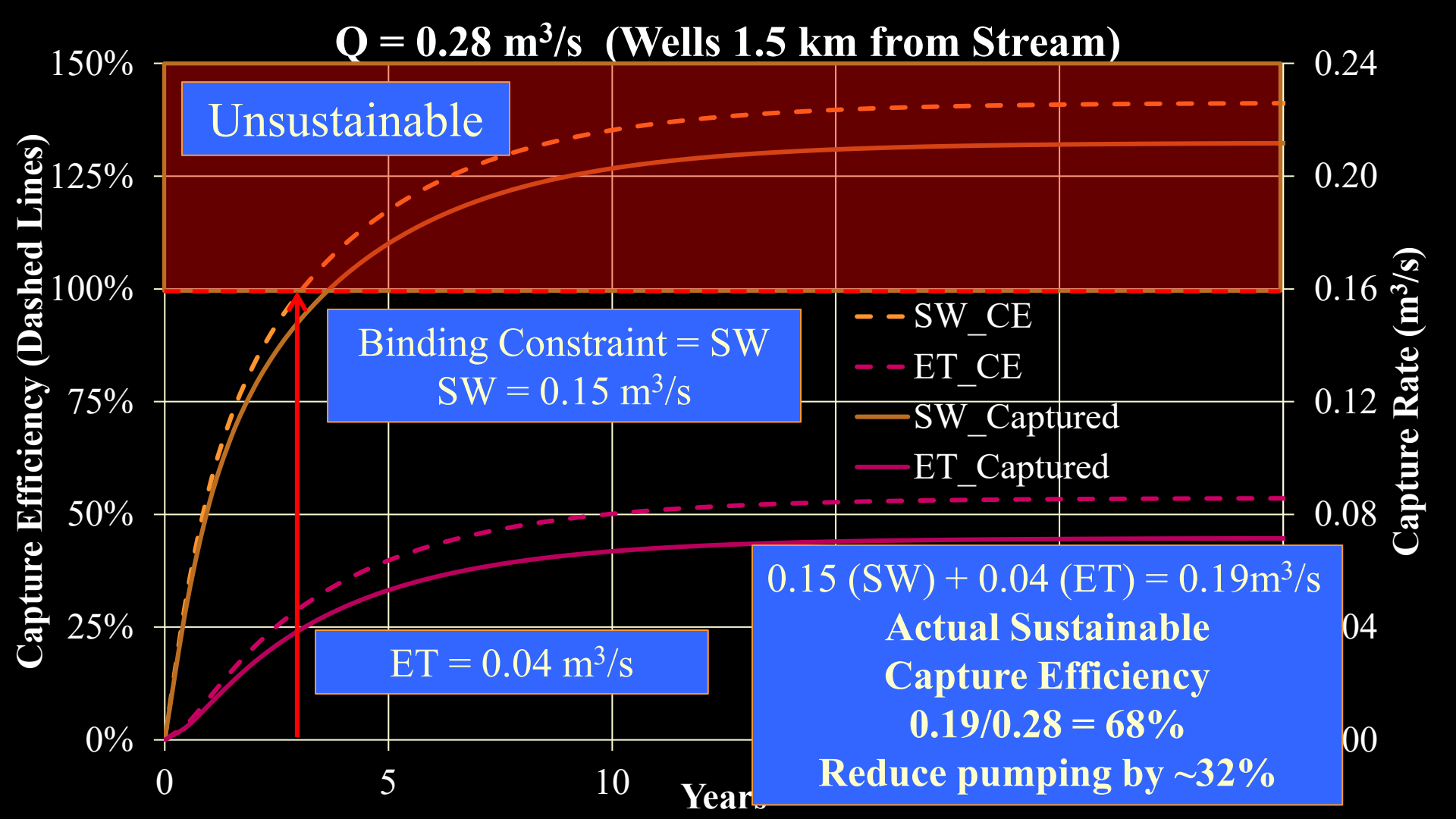
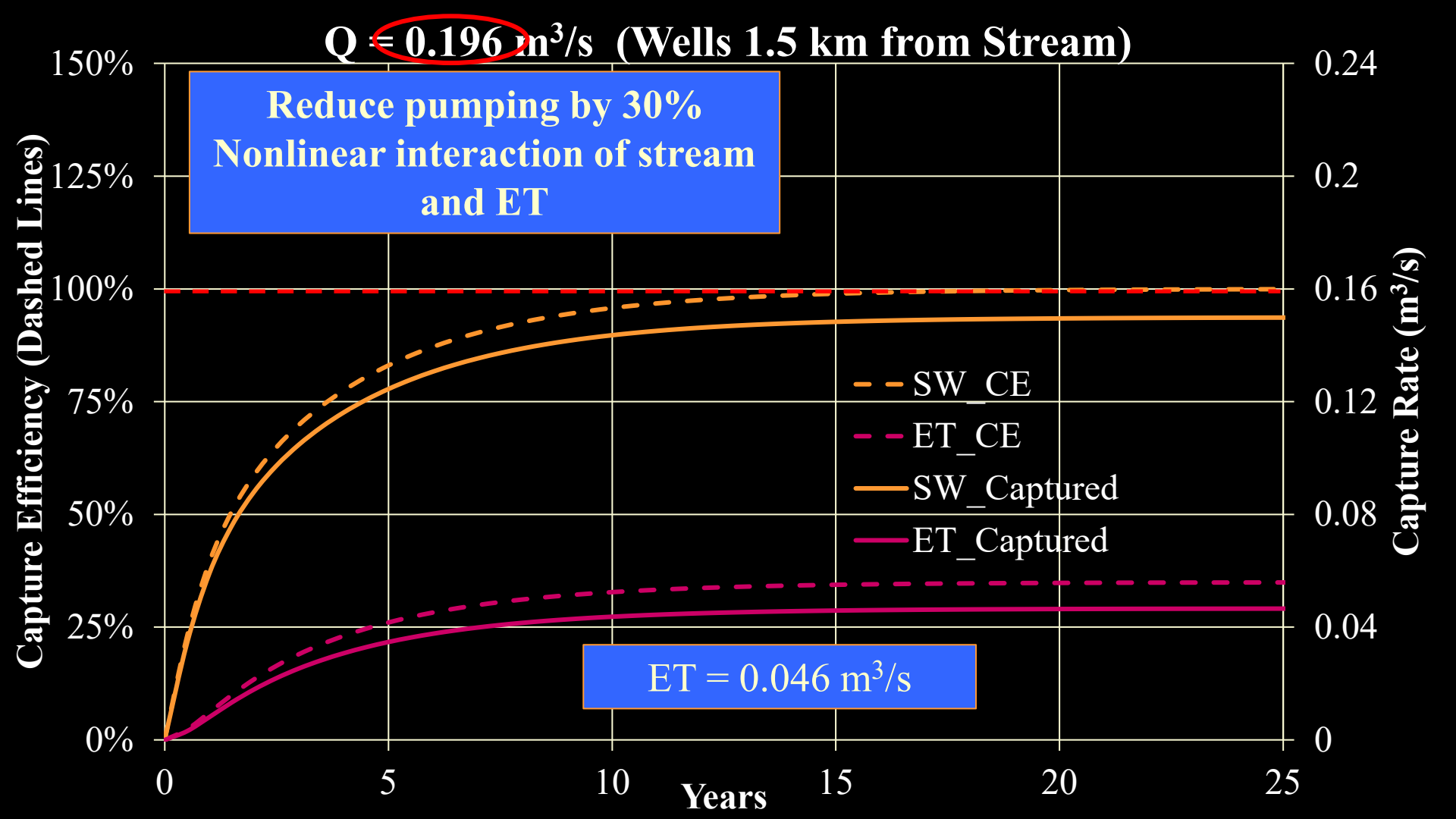
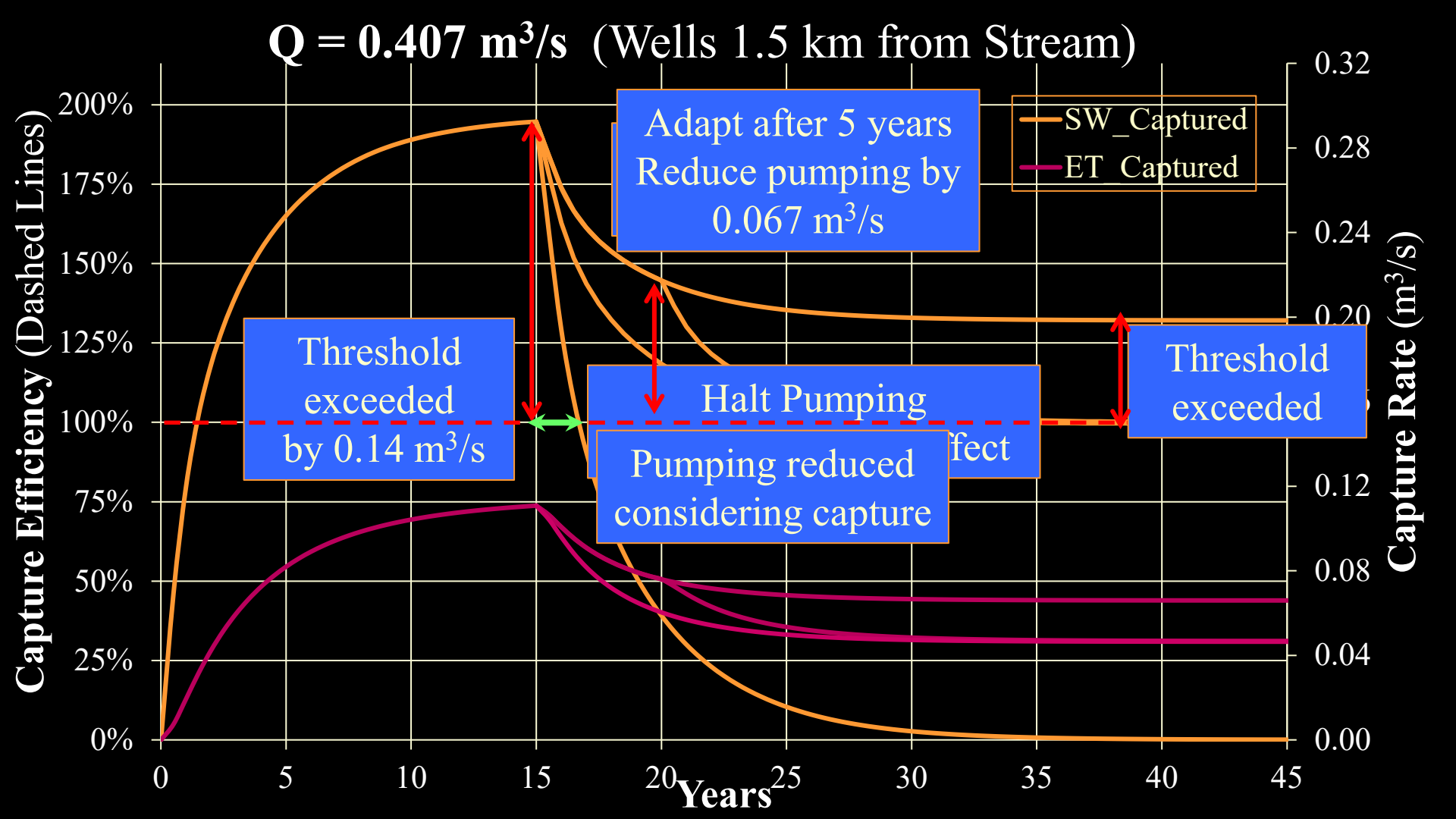

Q = 0.28 m³/s (Wells 1.5 km from Stream)
Unsustainable
Binding Constraint = SW
SW = 0.15 m³/s
ET = 0.04 m³/s
SW_CE
ET_CE
SW_Captured
ET_Captured
0.15 (SW) + 0.04 (ET) = 0.19m³/s
Actual Sustainable
Capture Efficiency
0.19/0.28 = 68%
Reduce pumping by ~32%
Capture Efficiency (Dashed Lines)
Capture Rate (m³/s)
150%
125%
100%
75%
50%
25%
0%
0.24
0.20
0.16
0.12
0.08
04
00
0
5
10
Years


Q = 0.196 m3/s (Wells 1.5 km from Stream)
Reduce pumping by 30%
Nonlinear interaction of stream and ET
SW_CE
ET_CE
SW_Captured
ET_Captured
ET = 0.046 m3/s
Capture Efficiency (Dashed Lines)
Capture Rate (m3/s)
Years
150%
125%
100%
75%
50%
25%
0%
0.24
0.2
0.16
0.12
0.08
0.04
0
0
5
10
15
20
25

Management After Overdraft

- Same example, but 15 years of over pumping
- How should pumping be changed for sustainability?
  - Adaptive management based on:
    - Water budget overdraft
    - Capture


Q = 0.407 m³/s (Wells 1.5 km from Stream)
Capture Efficiency (Dashed Lines)
Capture Rate (m³/s)
Years
SW_Captured
ET_Captured
Adapt after 5 years
Reduce pumping by
0.067 m³/s
Threshold
exceeded
by 0.14 m³/s
Halt Pumping
Pumping reduced
considering capture
Threshold
exceeded
200%
175%
150%
125%
100%
75%
50%
25%
0%
0.32
0.28
0.24
0.20
0.12
0.08
0.04
0.00
0
5
10
15
20
25
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Conclusions

Storage, Capture, and Sustainable Yield

- Changes in groundwater storage alters capture
  - Managing groundwater storage should:
    - Consider effects on capture on groundwater discharges
    - Adaptive management and continued monitoring is important
- Sustainable yield in stream/aquifer systems
  - Management based only on overdraft can be problematic
  - Capture Efficiency can help determine pumping rates