Hydrology of Irrigated River Basins and Impacts of Irrigation Efficiency

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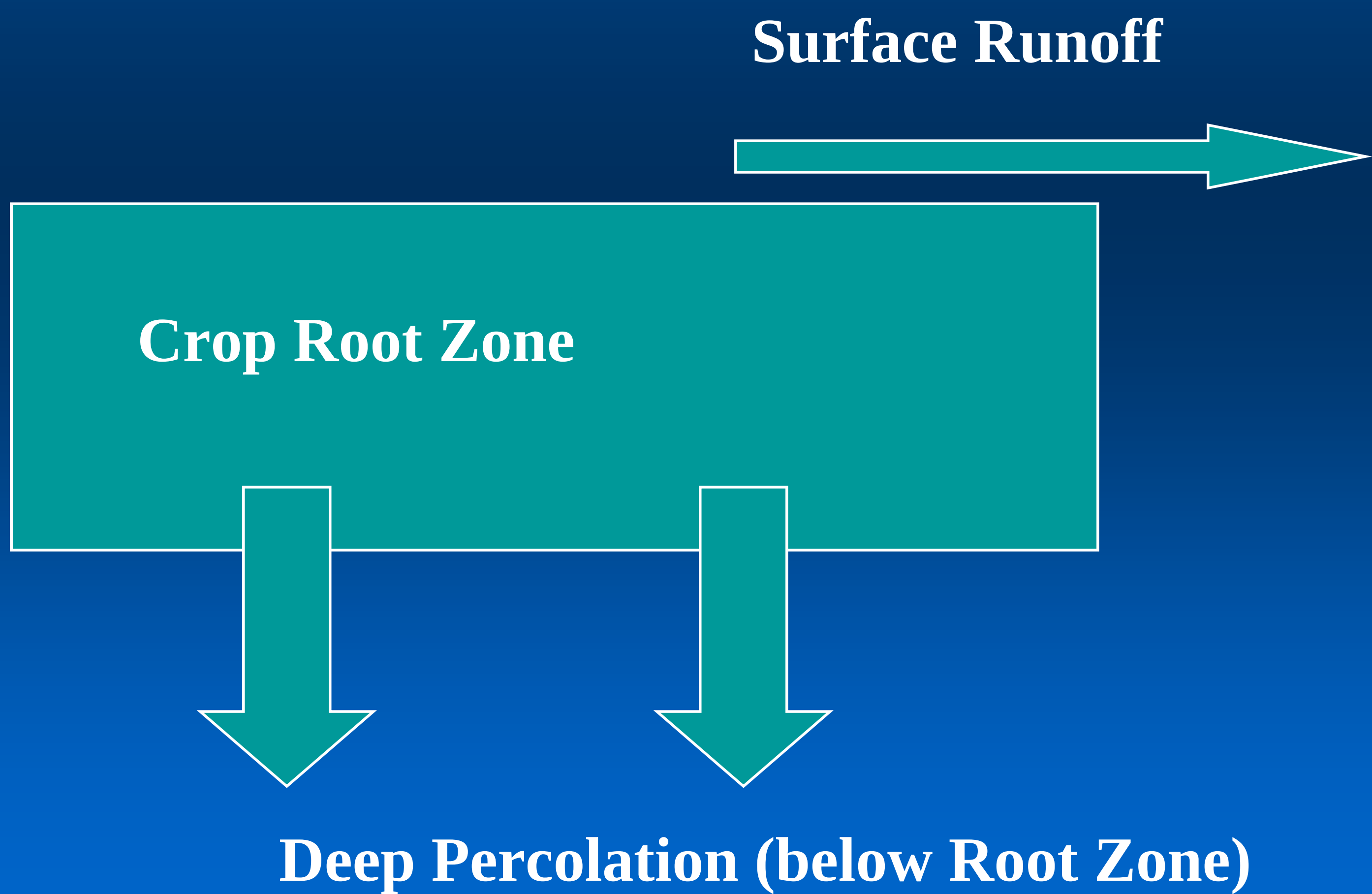
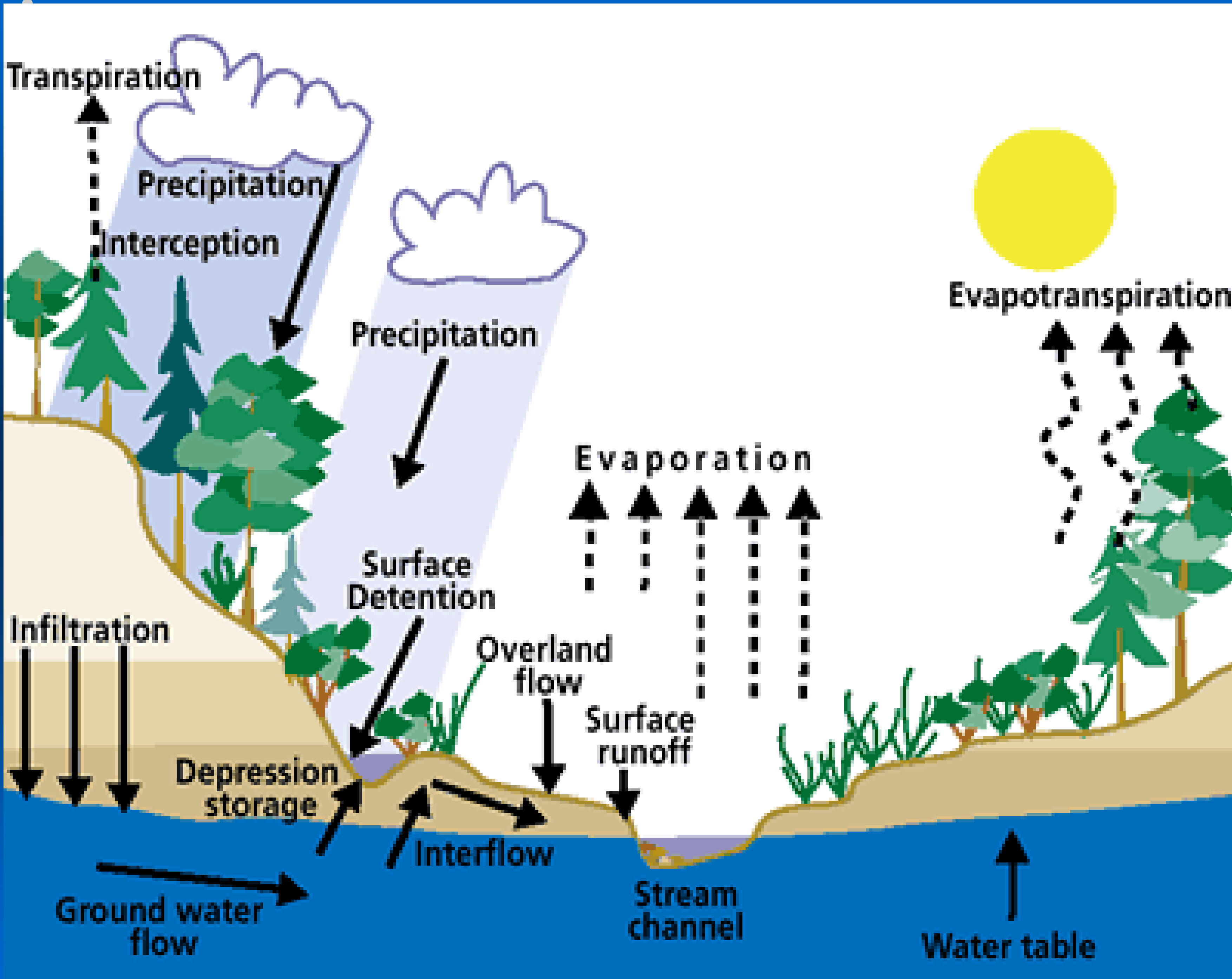
Irrigation "Losses"

- Are they really Lost????

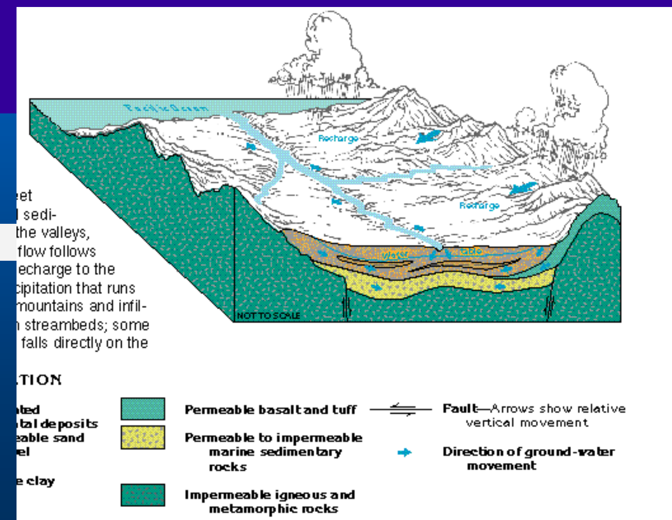


Hydrologic Cycle



slide courtesy MNR, Ontario, Canada

Irrigation Hydrology



Basic Hydrologic Truths:

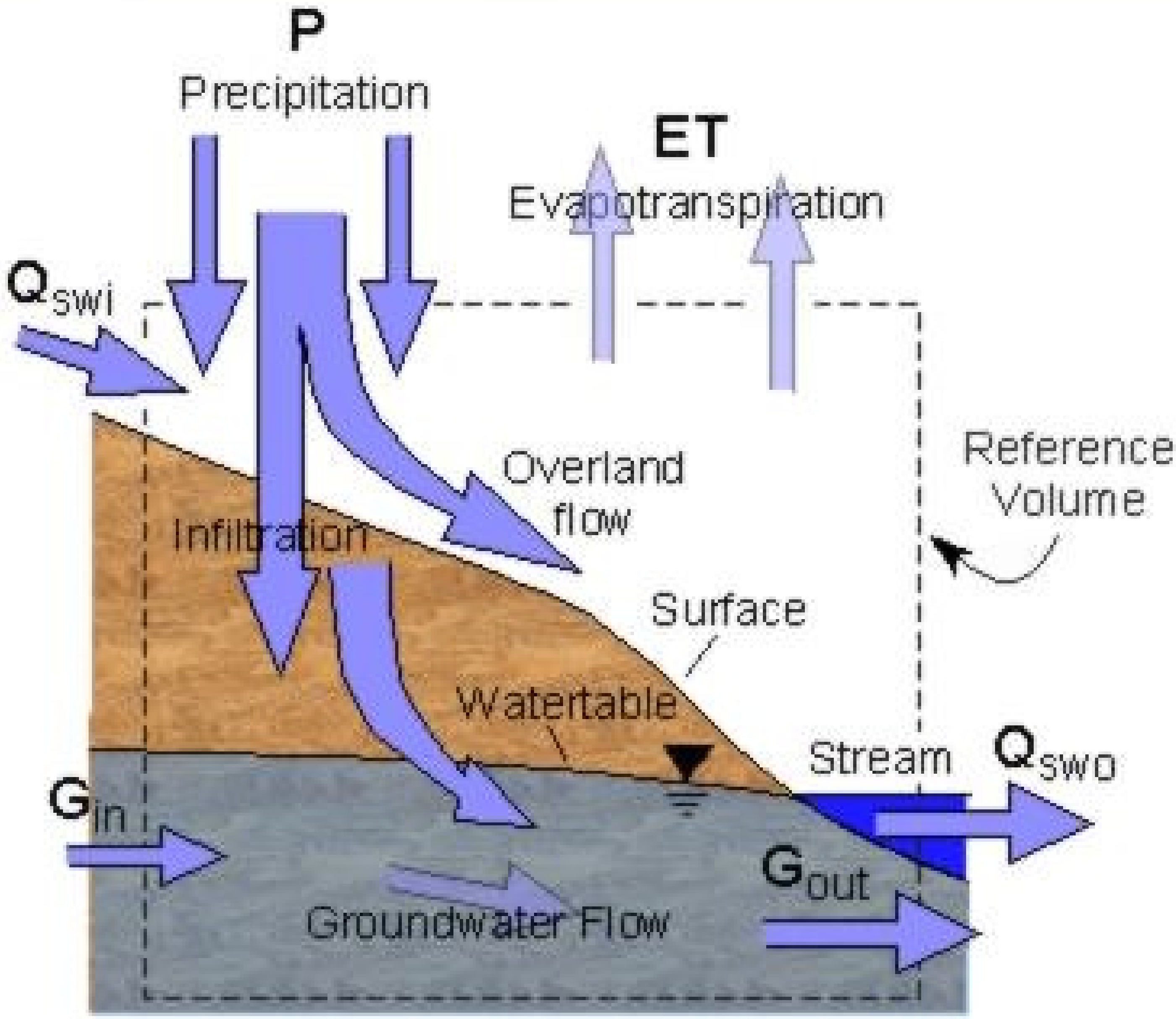
- 99% of the earth is underlain by groundwater

  (Freeze and Cherry, 1979)

- Deep percolation "losses" are not "lost" to the hydrologic system

- 1. “Losses” seep downward vertically to groundwater.

- 2. Groundwater moves laterally and discharges to a surface water source.



Local Hydrologic Cycle in a Watershed

Definition of ***Conservation***:

'Conserve' means to reduce 'consumption' of water and to increase water 'supply.'

Is this always true?????

Does it always occur???

Evaluate:

We need to ask:

"What is the *impact* of Irrigation Water Conservation (or increasing efficiency) *inside* and *outside* of the Irrigation Project or inside and outside of the City?"

Fundamental Precepts

The law of Conservation of Mass

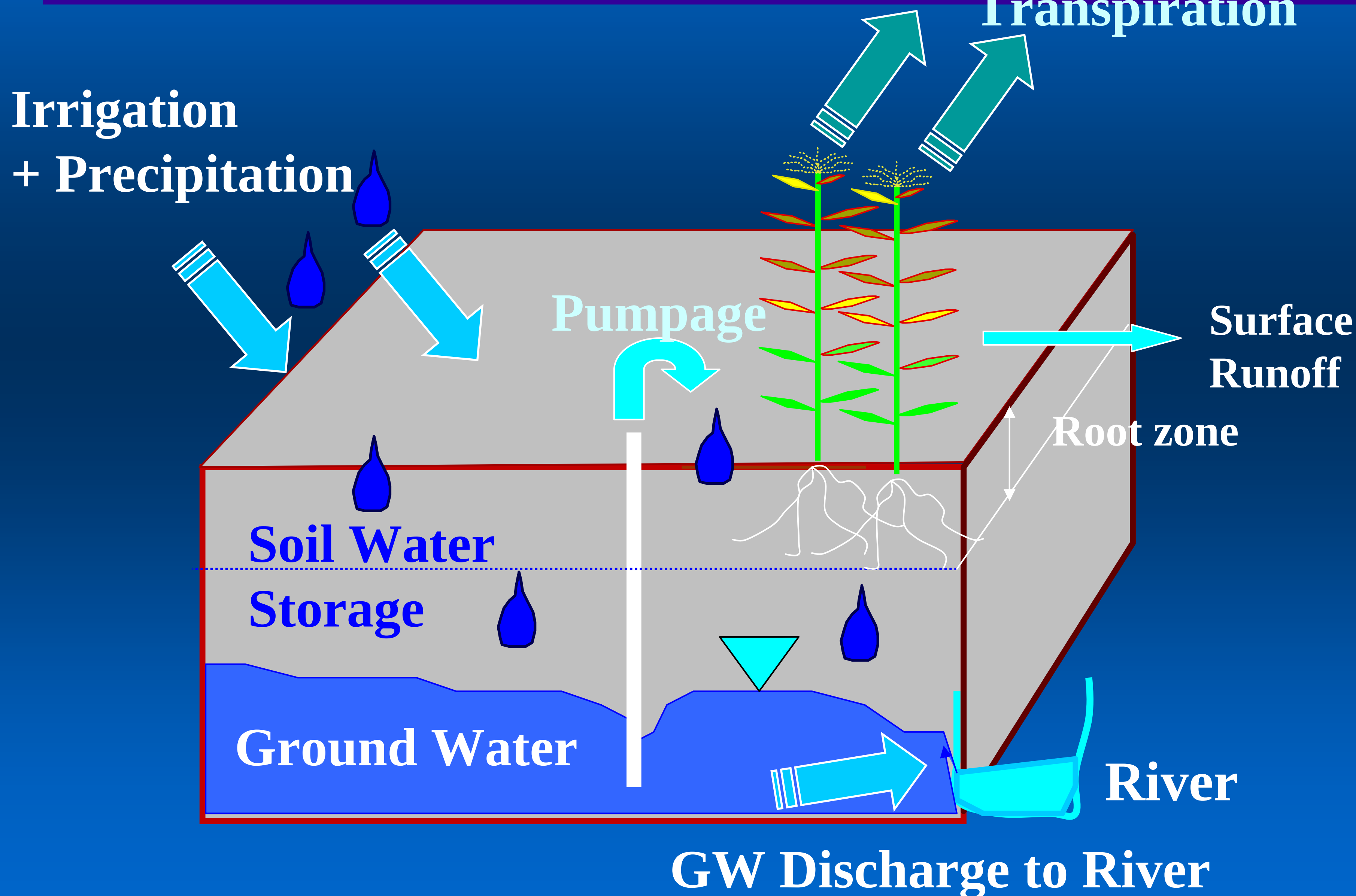
Matter can not be created nor destroyed

All liquid water *(not evaporated)* can not be created nor destroyed.

Thus all nonevaporated components must be "somewhere" and must reappear "somewhere."

Irrigation Hydrology:

"Follow the Water"



Water “Reappears” -- back to River

Ground-water discharge

Surface Water Return (contains sediments)

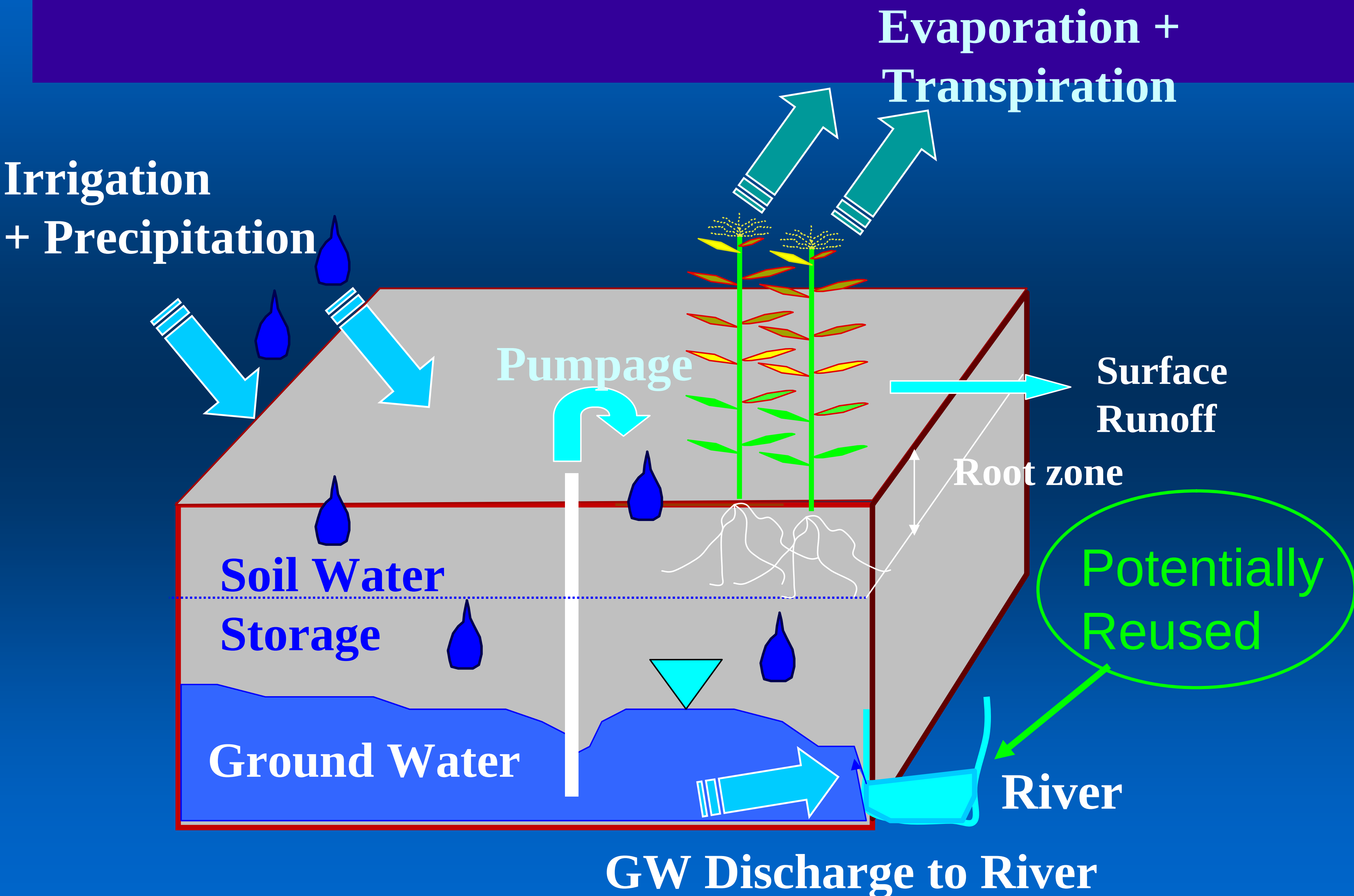
Drain discharge

Where do those "losses" go?

"They definitely go to China!"

"They definitely go to the USA!"

Irrigation Hydrology



There are *Valid* Reasons to *Conserve Water* by Increasing "Efficiency" of Water Application

- Reduce costs for treating water
  (smaller diversions)
- Reduce costs for pumping water
- Reduce costs for added distribution capacity in an area of growth
- Reduce leaching of fertilizers and chemicals and degradation of ground-water

There are *Valid* Reasons to *Conserve Water* by Increasing "Efficiency" of Water Application

- Sustain flows in streams threatened by low flows
  (for fish enhancement, etc.)
  (where "nonevaporated" diverted water bypasses the segment)
- Where "nonevaporated" components of diverted water enter a saline system (ocean, saline lake, or brackish groundwater)
- Where "nonevaporated" water pumped from deep aquifer percolates to a shallow unconfined aquifer
  (if undesireable)

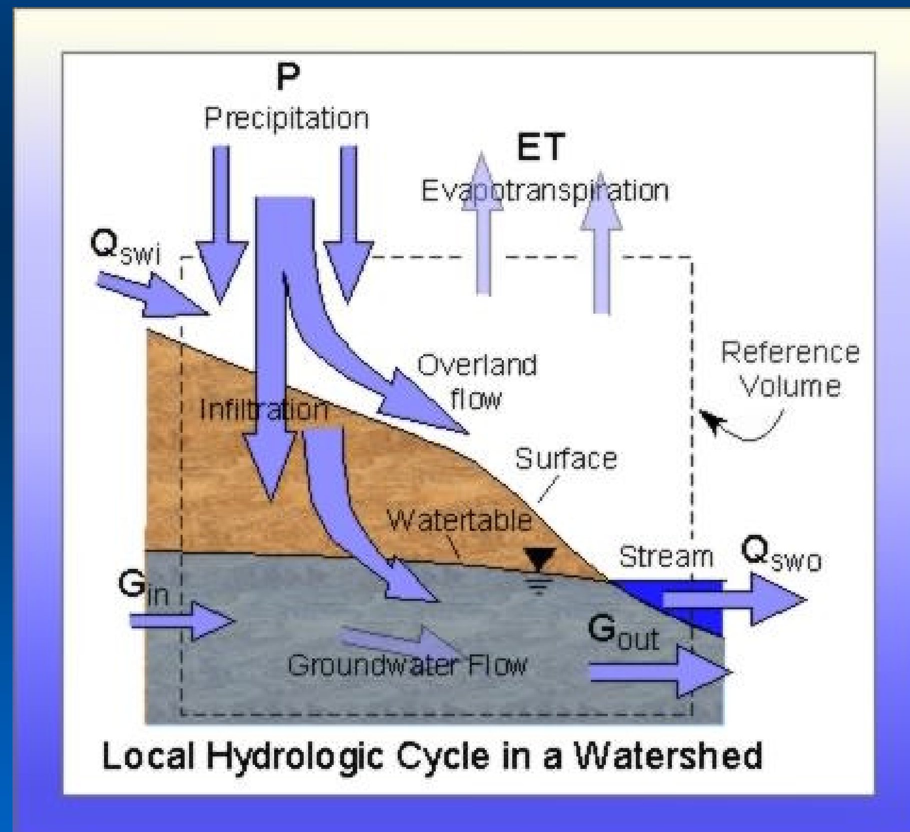
Appropriate Reasons to *Conserve Water* by Increasing "Efficiency" of Water Application:

In Agriculture:

- Reduce waterlogging and improve salinity control
- Enhance equity among users
- Maximize the total fraction of water delivered to crops to increase crop yields *(but this can reduce water available to other users)*
- Reduce soil erosion

Irrigation Hydrology

Only <u>one</u> of the *previous* eleven reasons really *"saves"* water in regard to the total fresh water supply



Therefore, we must be careful in how we use the "saved" label

Realization:

The only *substantial* ways to "save" water via "conservation" are to:

1. Reduce flows to saline systems (ocean, etc)

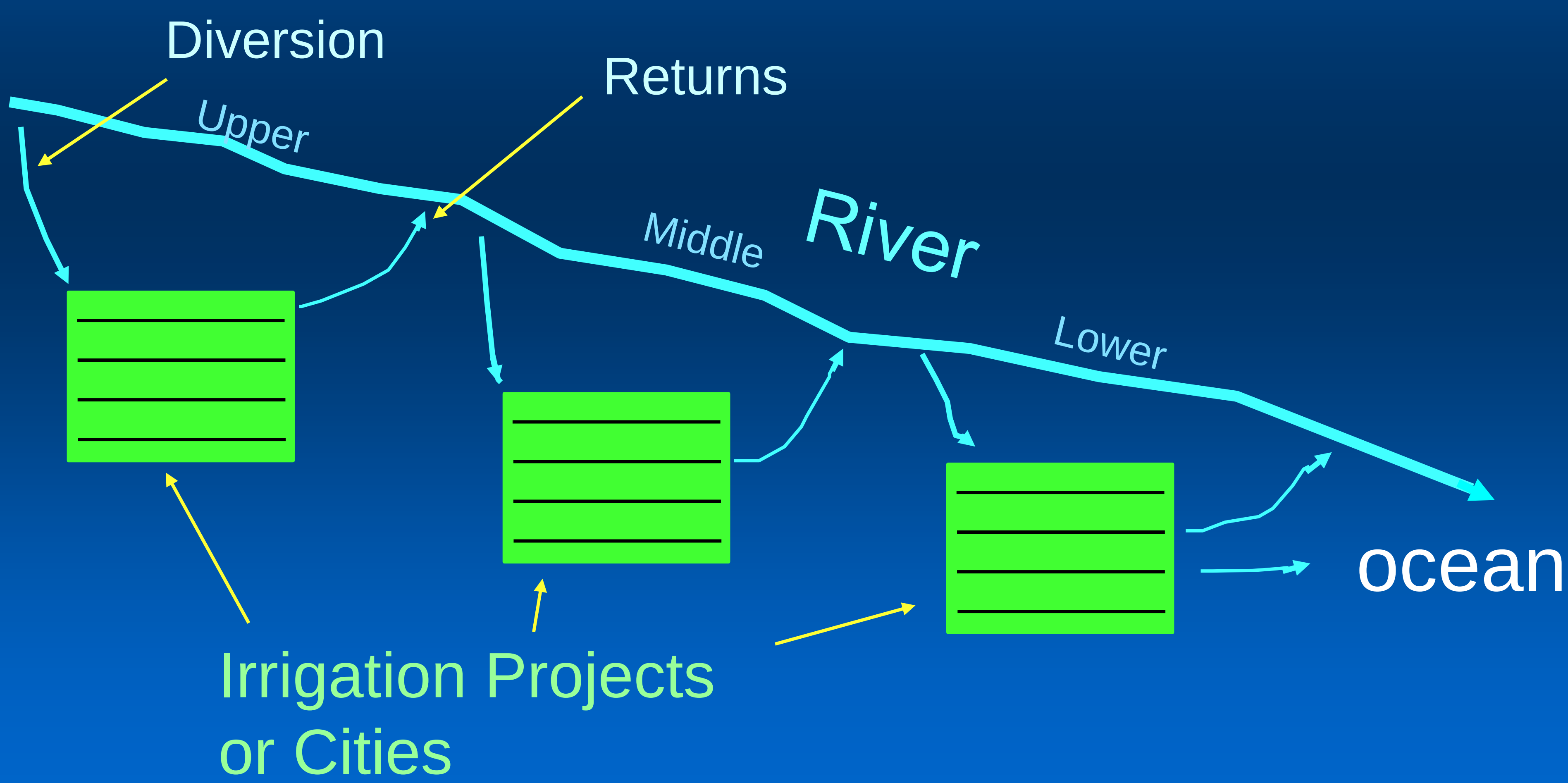
2. Reduce evaporation (or ET) of water

Location can mean everything...

Impacts of Conservation change with:

- **Location in a River basin:**
  - Upper Basin
  - Mid Basin
  - Lower Basin

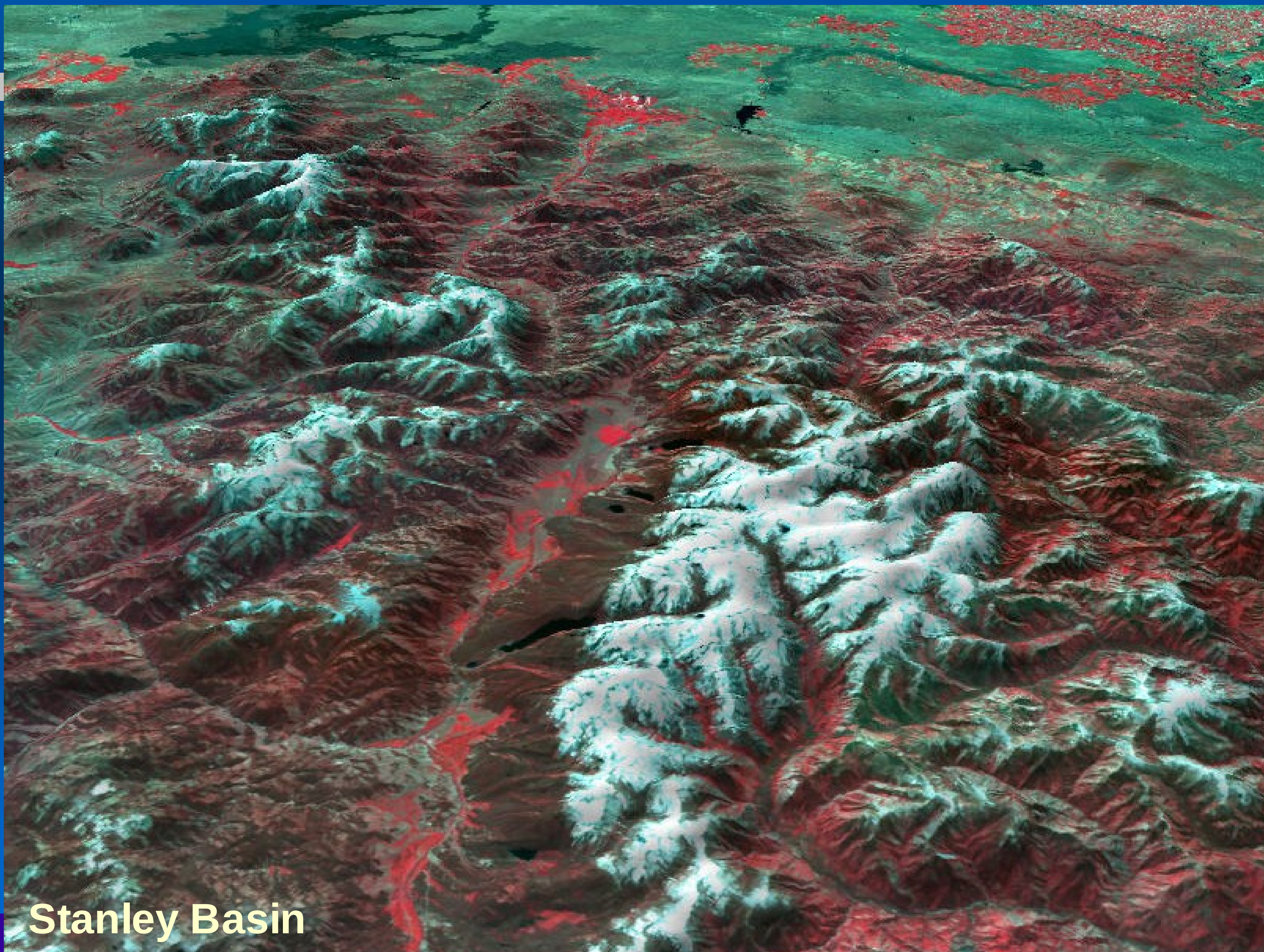
Return and Reuse of Diversions



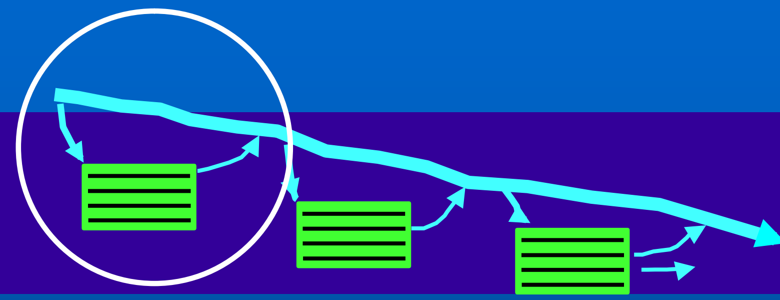
“Upper Basins”

- Return Flow is usually:
  - recaptured by other surface water diverters downstream

Hydrology of reuse in Upper Basins



“Upper Basins”

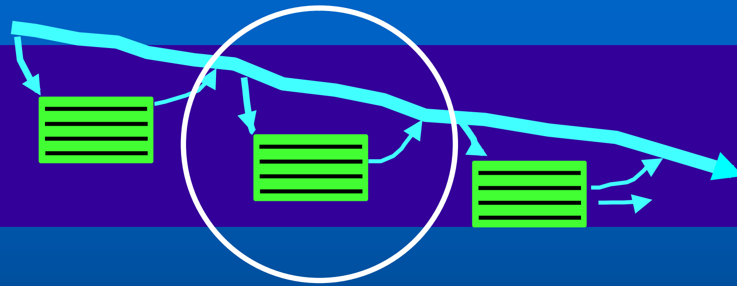


- Return flows come back to the resource with high quality *(there are usually no salt sinks)*
- Gradients are steep and subsurface returns are relatively quick
- Low efficiencies may be relatively inconsequential
- Conservation practices in upper basins may not create new water to the (mid and lower) basin

“Upper Basins”

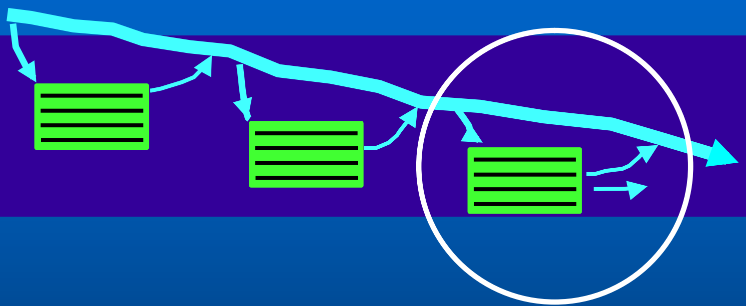
- Benefits of low "efficiencies” in upper basins:
  - large diversions during snow melt can reduce downstream flooding
  - return flows can augment low stream flows in late summer due to the time delay for the returns
  - Creation of wetlands

“Mid Basins”



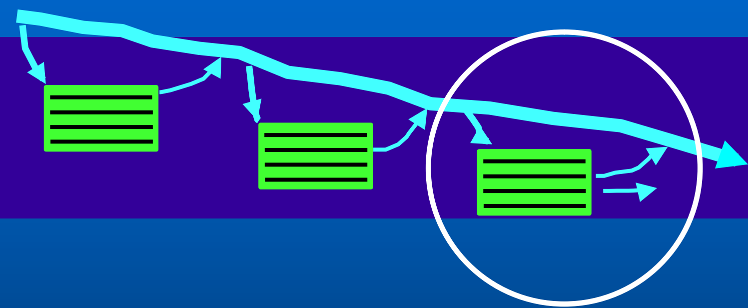
- land is less steep than in ‘high basins’
    - longer subsurface flow paths
    - larger time lags for return flows
- often there can be problems with ***minimum stream flows*** and ***water quality***

"Lower Basins"



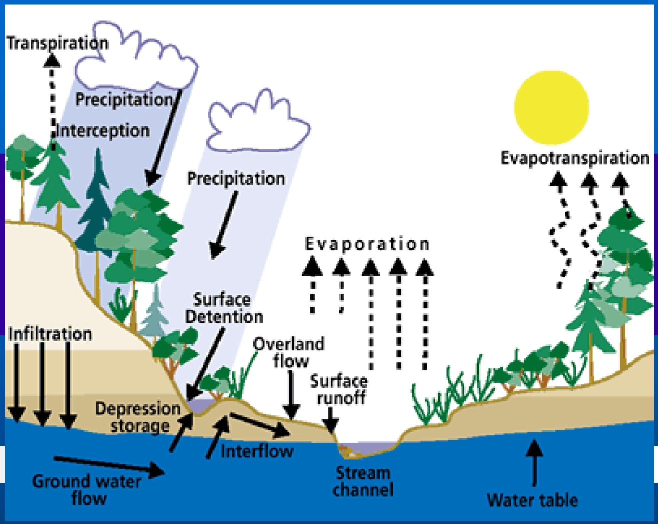
- Defined as where returns readily enter a saline sink before recapture
- Include
  - ***<u>coastal cities</u> (cities by the ocean)***
  - ***<u>coastal irrigation projects</u>***
  - diversions upgradient of salt sinks

“Lower Basins”



- Quality is naturally low
- Upstream ET, not efficiency, exacerbates water quality and quantity problems
- Here, local, low efficiencies *<u>do</u>* hurt
- <u>Return flows are often nonrecoverable</u>

The Real Losses

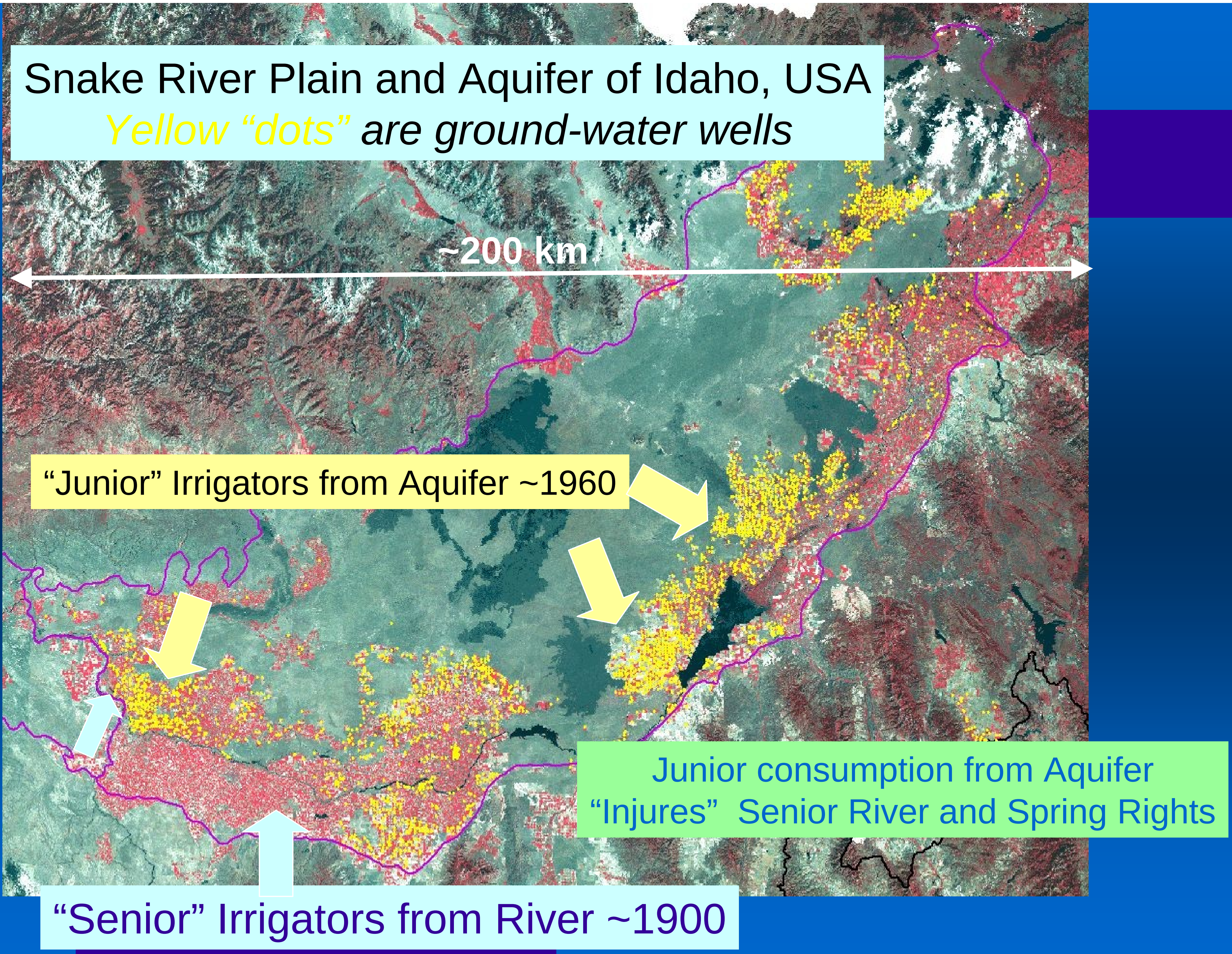


- The real "Losses" of irrigation water are
  - Evapotranspiration
  - Deep losses to the <u>Ocean</u> or Brackish Systems
  - Surface flows to the <u>Ocean</u> or Brackish Systems

➔ Usually, All other "losses" are <u>reuseable</u>

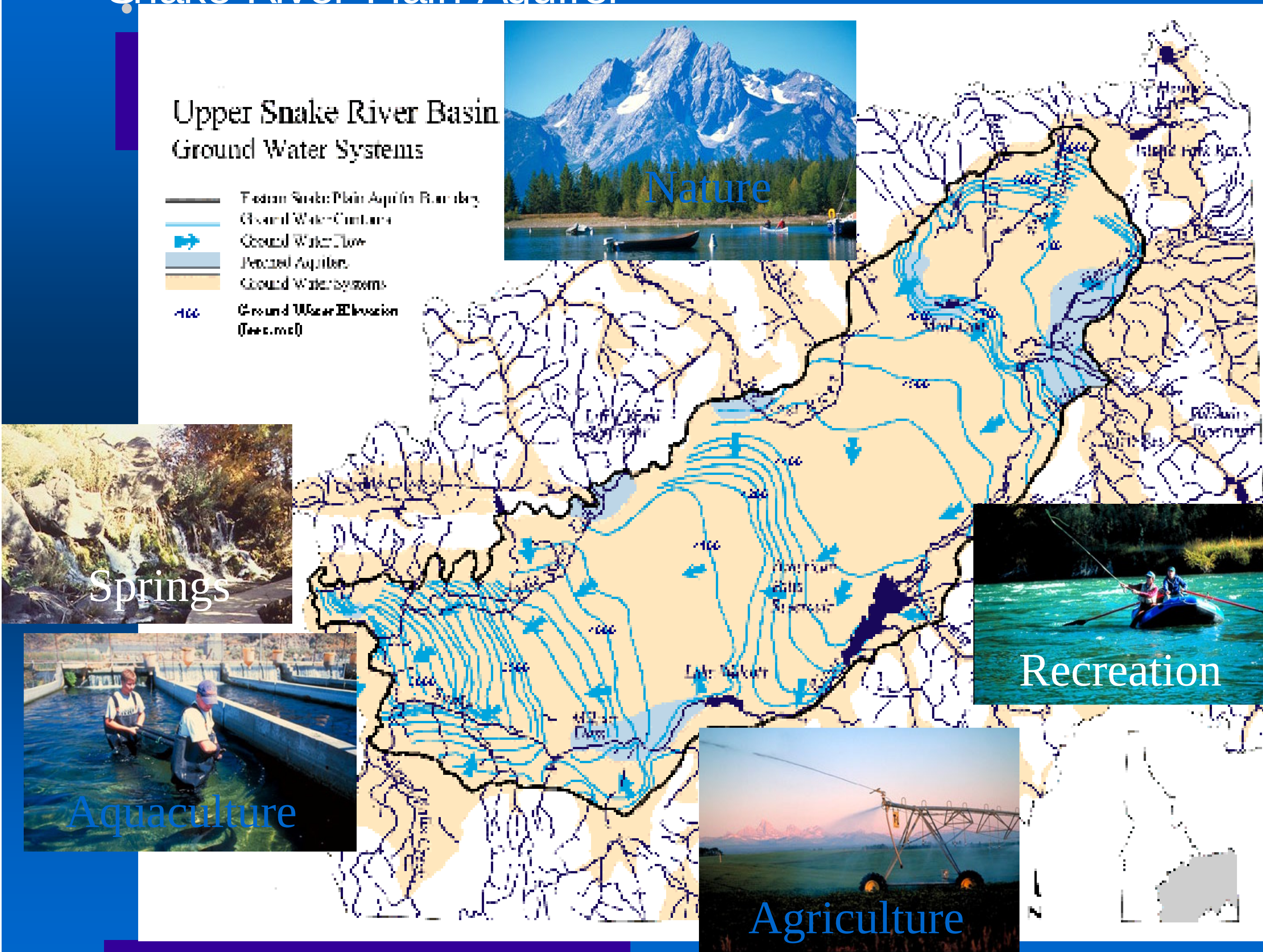
(unless flowing through saline marine deposits)

Examples

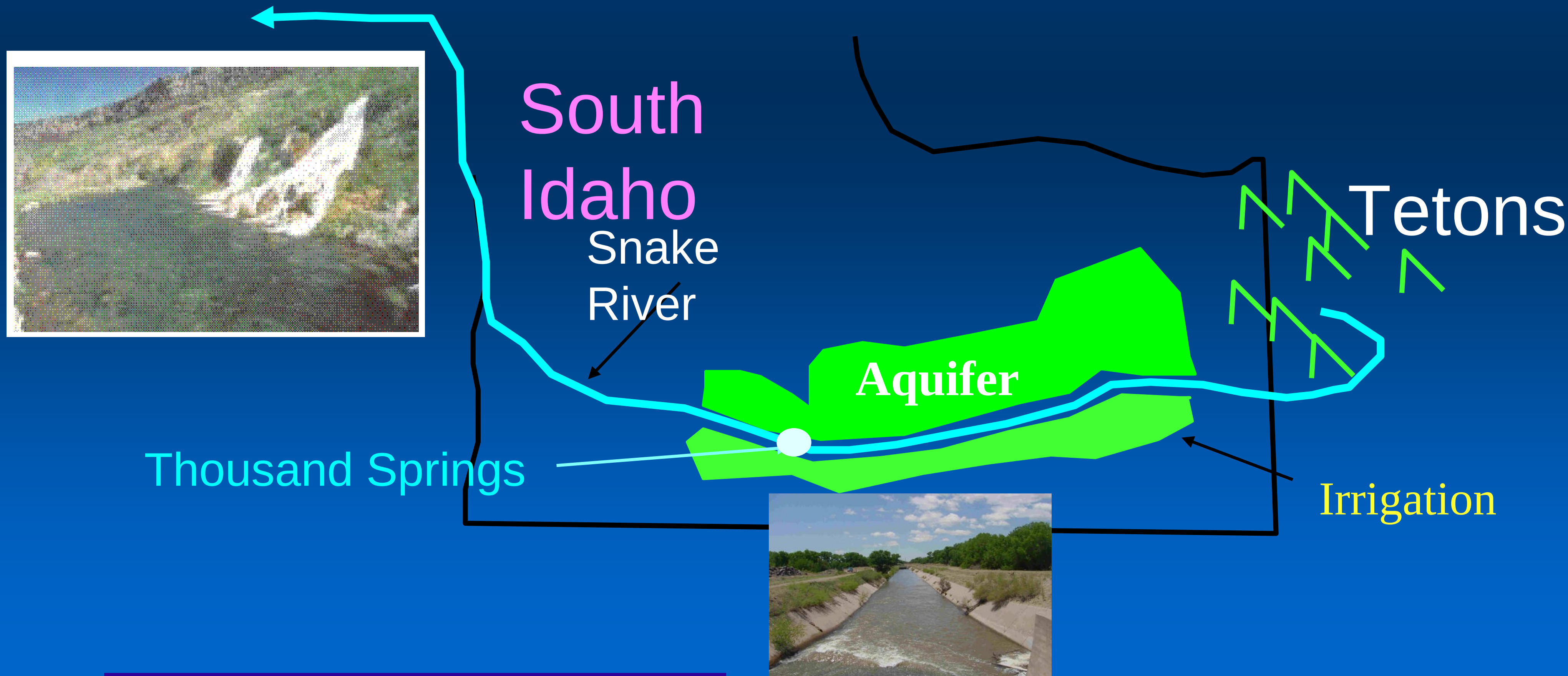


Snake River Plain and Aquifer of Idaho, USA
Yellow "dots" are ground-water wells
~200 km
"Junior" Irrigators from Aquifer ~1960
Junior consumption from Aquifer
"Injures" Senior River and Spring Rights
"Senior" Irrigators from River ~1900

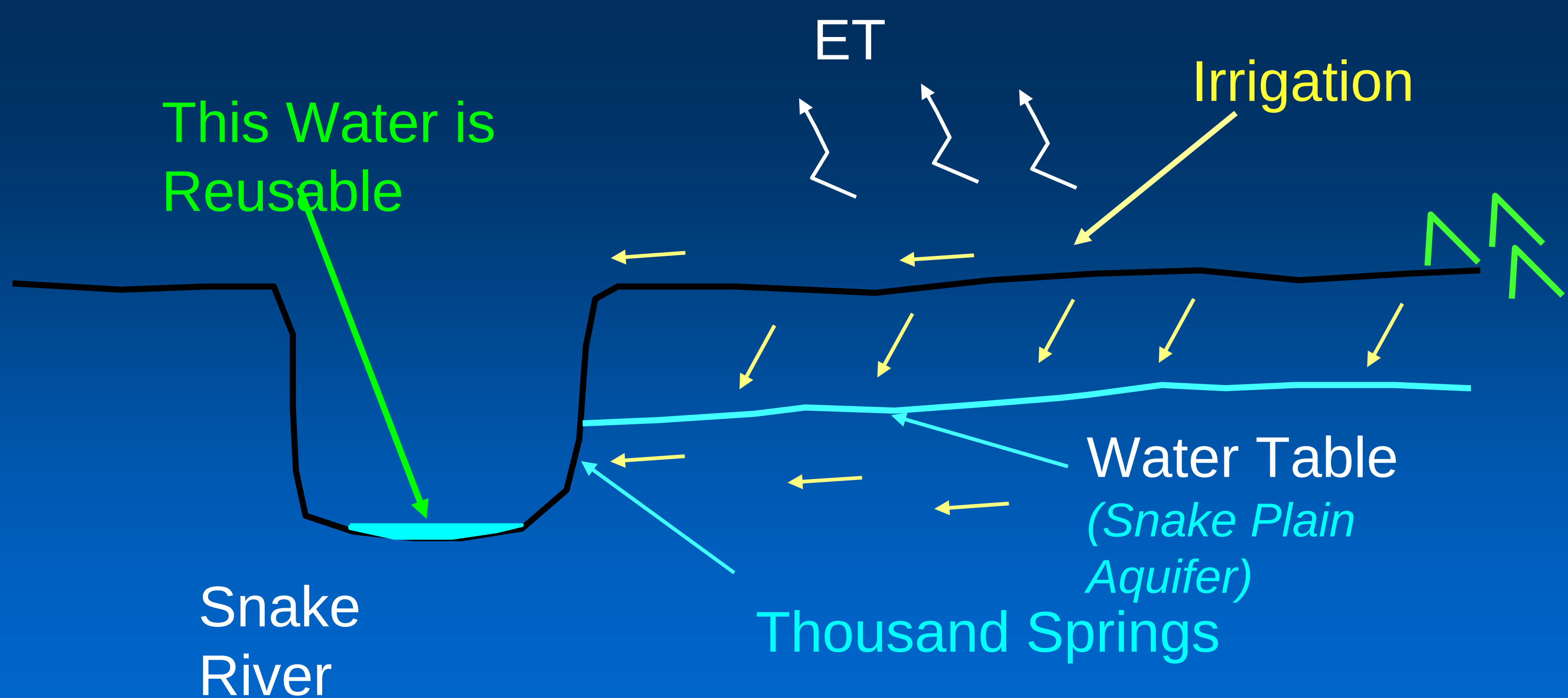
Snake River Plain Aquifer



Example:
Upper/Middle Snake River



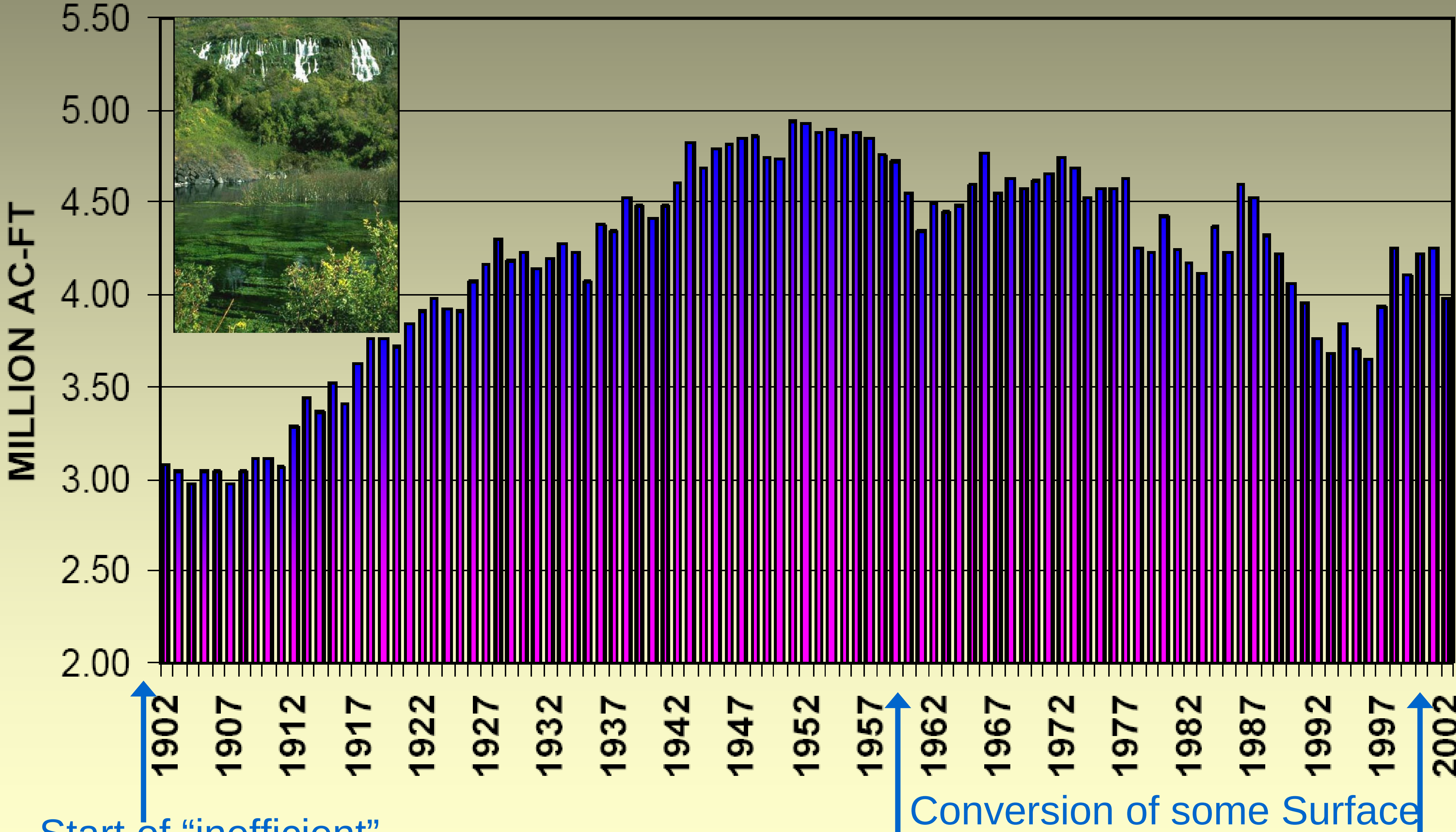
Example: Upper/Middle Snake River



1 million acre-feet = 1,200,000,000 m^3

AVERAGE ANNUAL SPRING DISCHARGE TO SNAKE RIVER BETWEEN MILNER AND KING HILL

1902-2002 (Thousand Springs area)



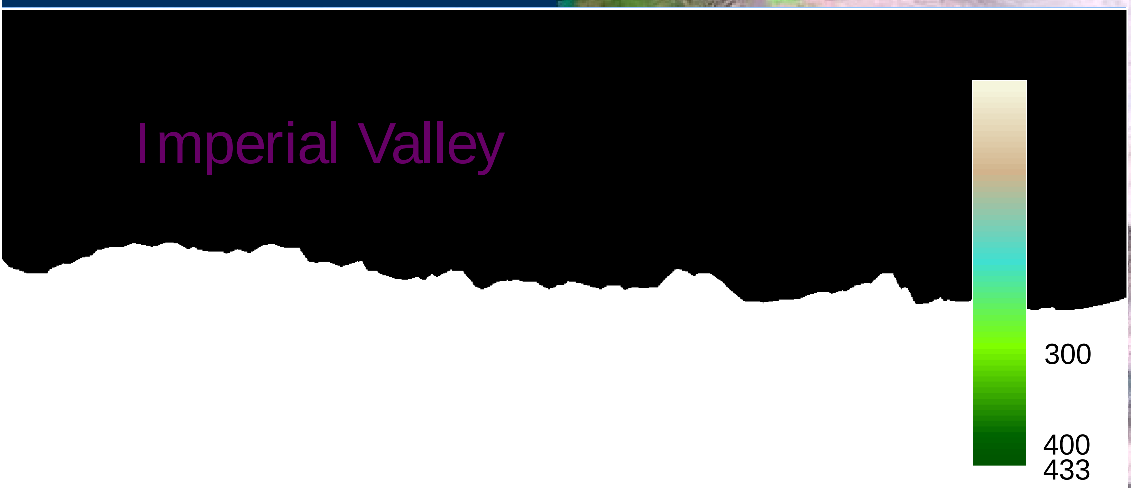
Start of "inefficient" Irrigation Development

Conversion of some Surface Irrigation to Sprinkler + More GW Pumping

Snake River Basin

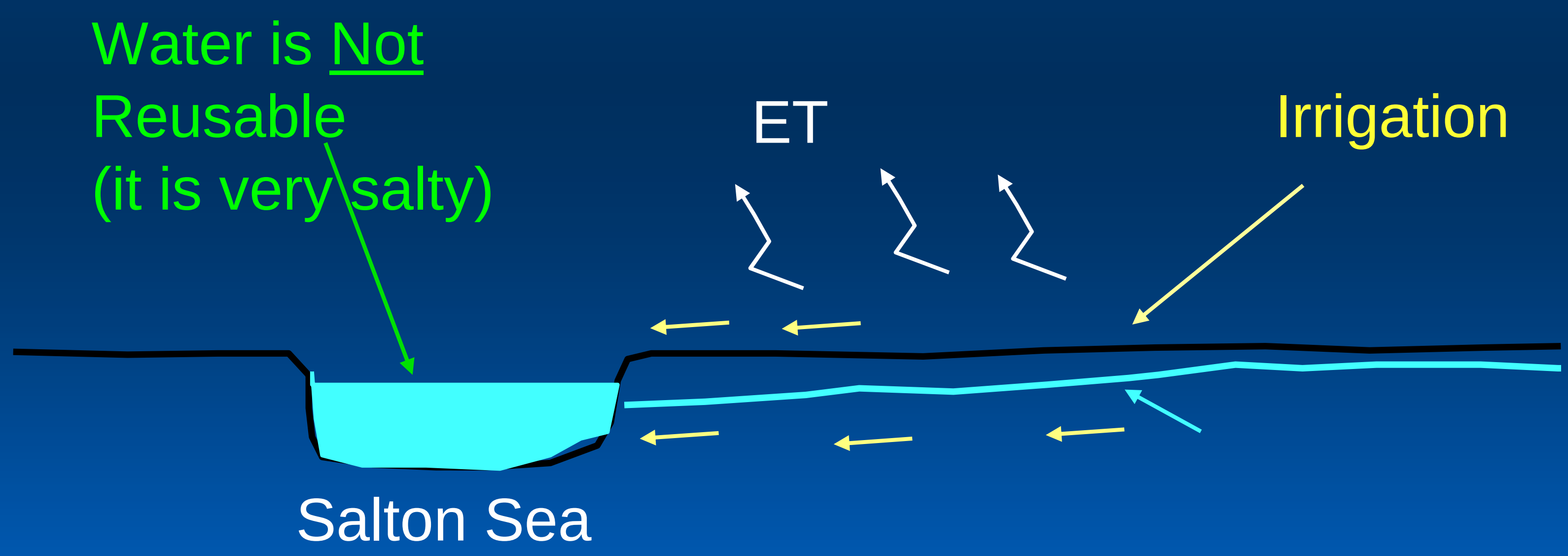
- Inefficient irrigation has <u>increased</u> groundwater levels and thus spring flow
- Recharge from Irrigation has <u>increased</u> late summer stream flow
- <u>Reduced</u> irrigation 'losses' have <u>increased</u> declines in spring flows *(plus GW pumping)*
- Declines in spring flows have injured a large spring-fed trout aquiculture and "senior" river water diverters (irrigators), both groups now in litigation.

Example: Salton Sea Area, California



ET during January – March, 2003

Example:
Salton Sea Area



Therefore, Increases in Efficiency are very good

Reasons for Action:

- *IF* water use is near a saline system (ocean, brackish sink, etc)

  and nonevaporated components are impaired or lost via quality change, then:

  – a conservation program will have a ***good hydrologic impact*** and water is “saved”

Use of *Fractions*
(instead of 'efficiency')

for better description and communication in:

Hydrology
and
Conservation Programs

(use 'fraction terms' instead of 'efficiency' terms)

Evaporated Fraction

$$EF = \frac{Q_{ET}}{Q_{Div}}$$

Q_{ET} = Quantity Evaporated *(changed to vapor)*

Q_{Div} = Quantity Diverted *(initial diversion)*

(to replace 'irrigation efficiency' term)

Consumed Fraction

$$CF = \frac{Q_{ET} + Q_{NR}}{Q_{Div}}$$

(to ocean)

Q_{NR} = Quantity not reusable *(besides ET)*

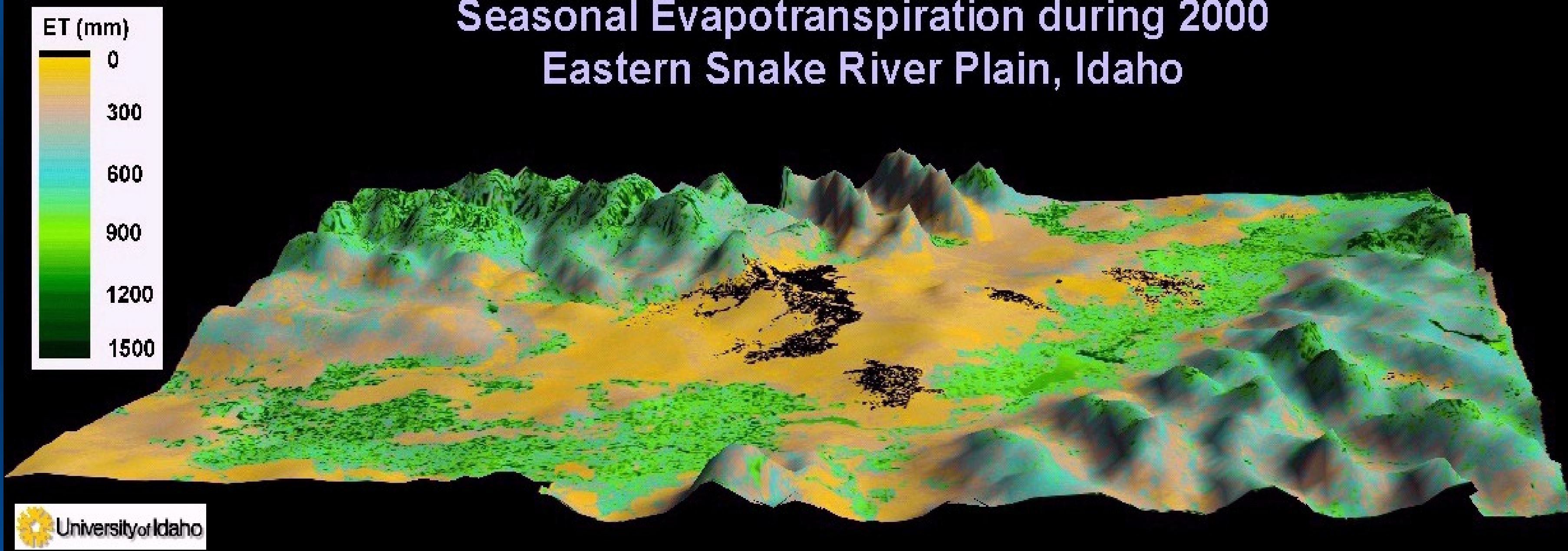
(to replace 'irrigation efficiency' term)

Reusable Fraction

$$RF = \frac{Q_{Div} - Q_{ET} - Q_{NR}}{Q_{Div}}$$

$$(RF = 1 - CF)$$

Examples Snake River:



Evapotranspiration from METRIC/Landsat
 -- mm per year

Examples

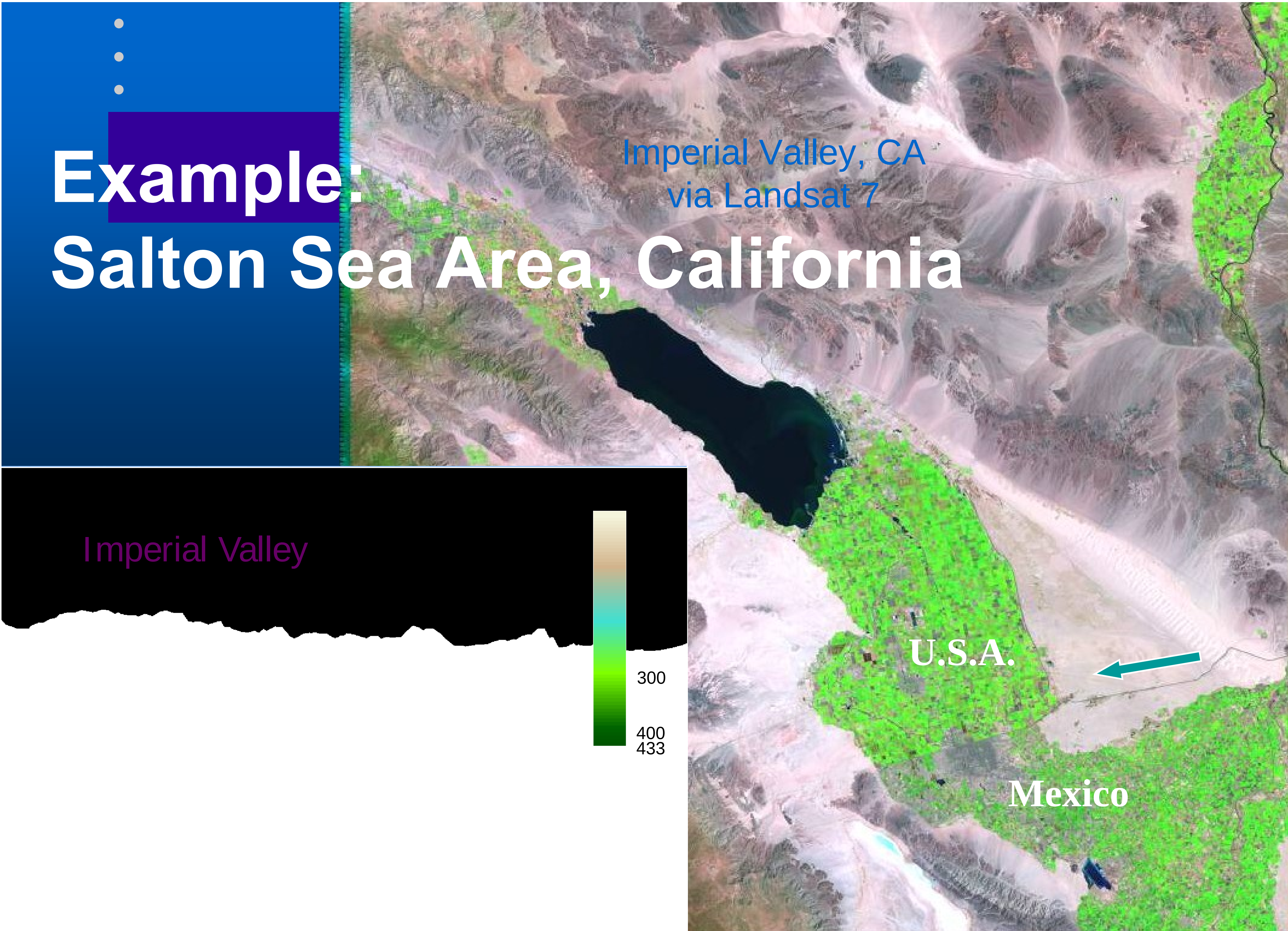
Snake River:

EF ~ 0.40 *(Irrigation Efficiencies are Low)*

NRF ~ 0.0 and RF ~ 0.60

Therefore: CF ~ 0.40 *(60 % returns for reuse downstream)*

Example:
Salton Sea Area, California



ET during January – March, 2003

Examples

Salton Sea Area:

EF ~ 0.65 *(Irrigation Efficiencies are High)*

NRF ~ 0.35 and RF ~ 0.00

Therefore: CF ~ 1.00 *(NO reuse downstream)*

Basic Conservation Questions:

- How much of the water abstraction gets consumed or moves beyond local control?
  - (What is the “Consumed Fraction”?)
  - *Is Evapotranspiration being Reduced?*
- Who benefits from “wasted” water when it reappears and is recovered?
- Are current “downstream” users better off by any higher efficiencies created in systems upgradient by a water conservation program?
  - Are the downstream users benefited quality wise?

Summary

- 'Low' irrigation efficiency is not 'bad'
  - If: 'losses' come back to the river
  - If: 'losses' come back to the groundwater
  - If: Other people can use the 'losses'
- Money can be saved by not investing in 'Conservation' programs where water is recycled.

Thank You

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- Extra Slides Follow:

Question:

What are the Impacts
of Irrigation Water Conservation?

1. *to reduce consumption of liquid, fresh water?   or ---*

2. *to reduce diversions, but not to reduce consumption??*

Question:

What is the *Explicit Goal*
of Irrigation Water Conservation?

To *Increase Net Effective* Water Supplies
to Others *Outside the 'System'*?

To *Increase Net Effective* Water Supplies
to Users *Within the 'System'*?

Question:

Will the conservation effort reduce the depletion of the ‘*total*’ liquid water resource *(thus “saving water”),*

or is it merely reducing diversions?

We must be “hydrologically correct”

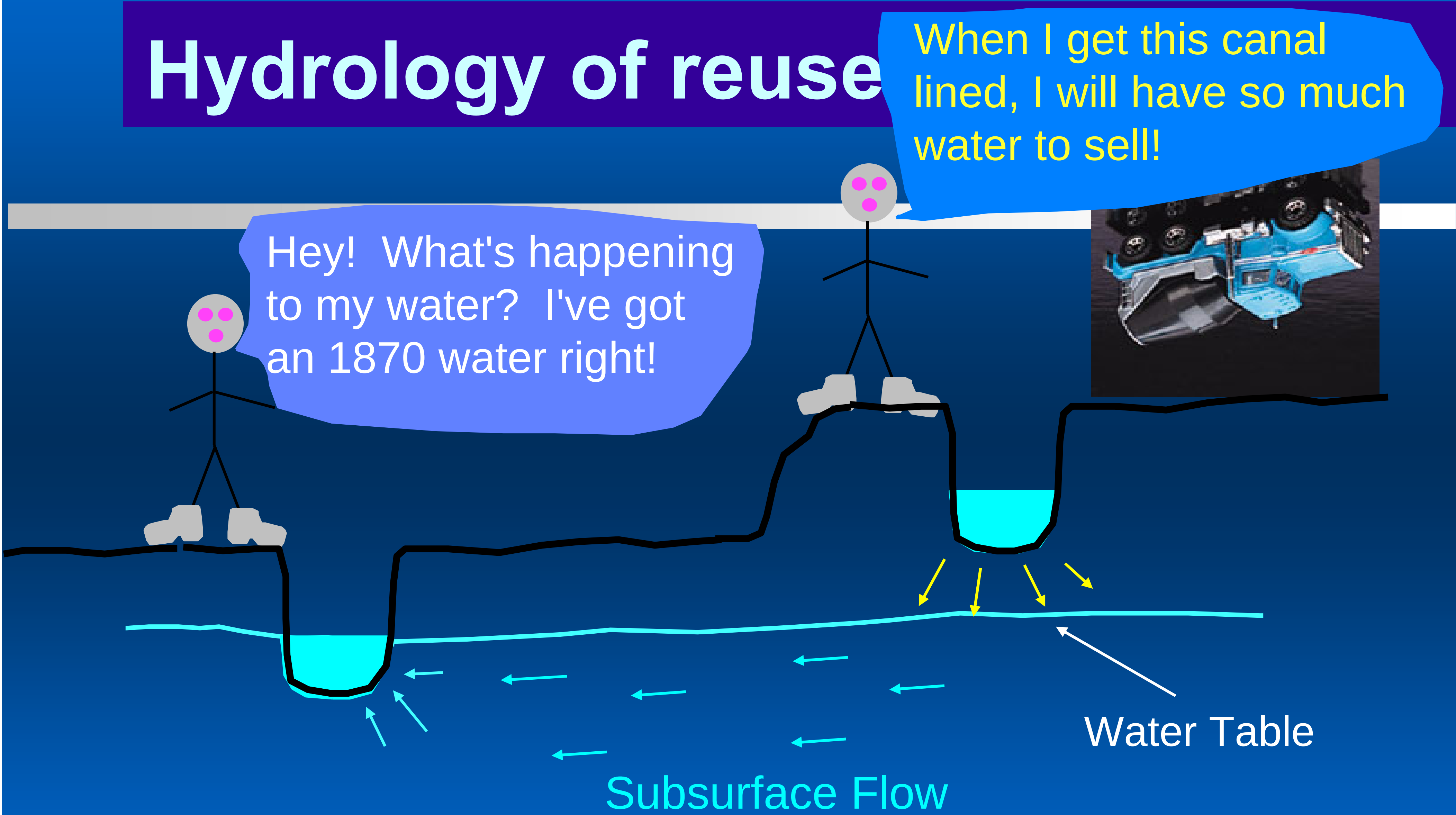
<u>**Ineffective**</u> Approaches to Conserve Water by Increasing "Efficiency" of Water Application

- Attempt to 'Create' *"new"* water *<u>downstream</u>* ***<u>IF</u>*** return flows <u>already reenter</u> the water resource at an appropriate time and place *(via groundwater or stream)*

- Attempt to 'Enhance' streamflows at significant distances downstream when return flows <u>already reenter</u> the water resource at an appropriate time and place

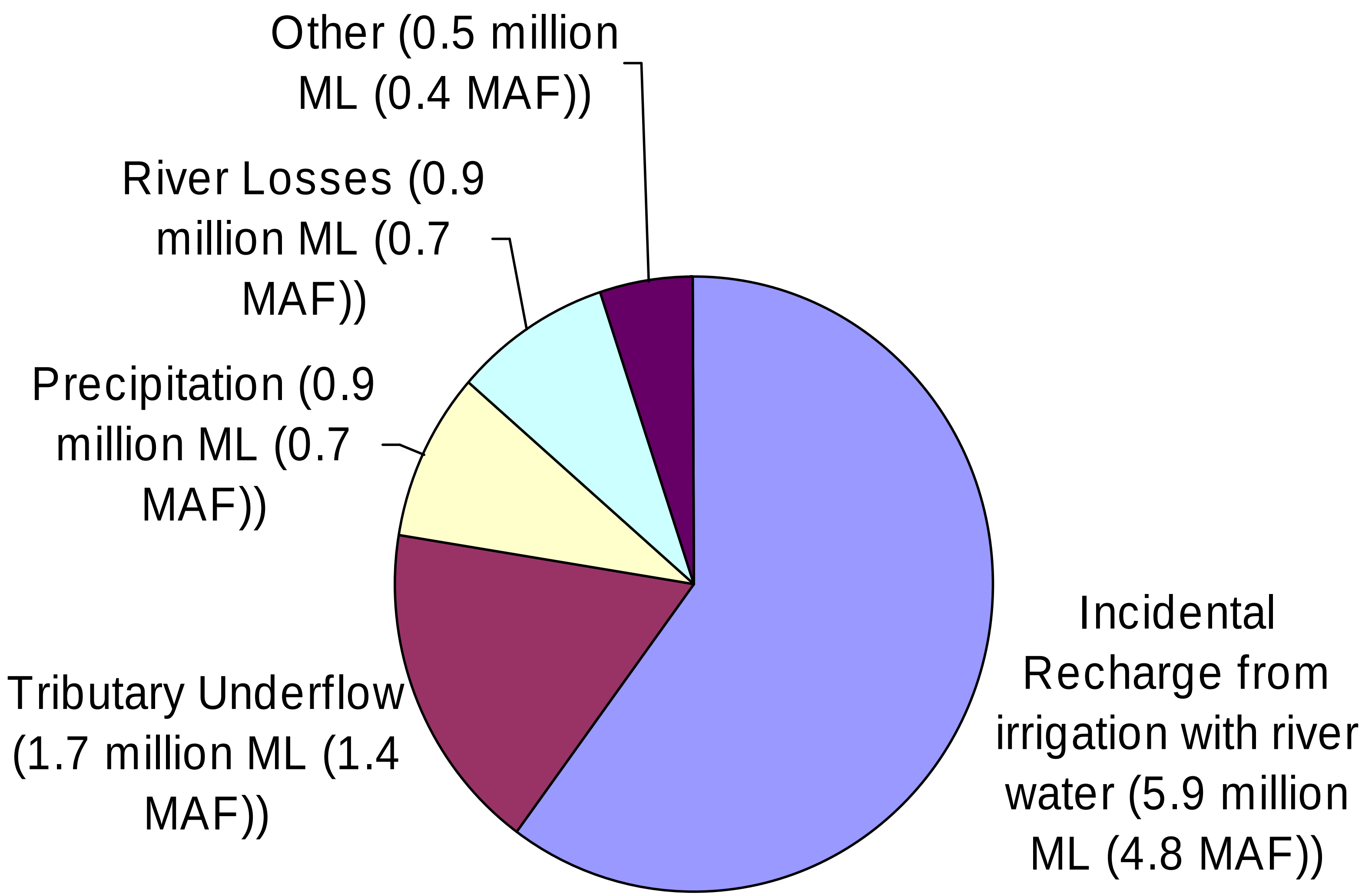
- Attempt to 'Extend' the life of an unconfined aquifer when return flows (from nonevaporated diversions) <u>already reenter</u> the aquifer with acceptable quality

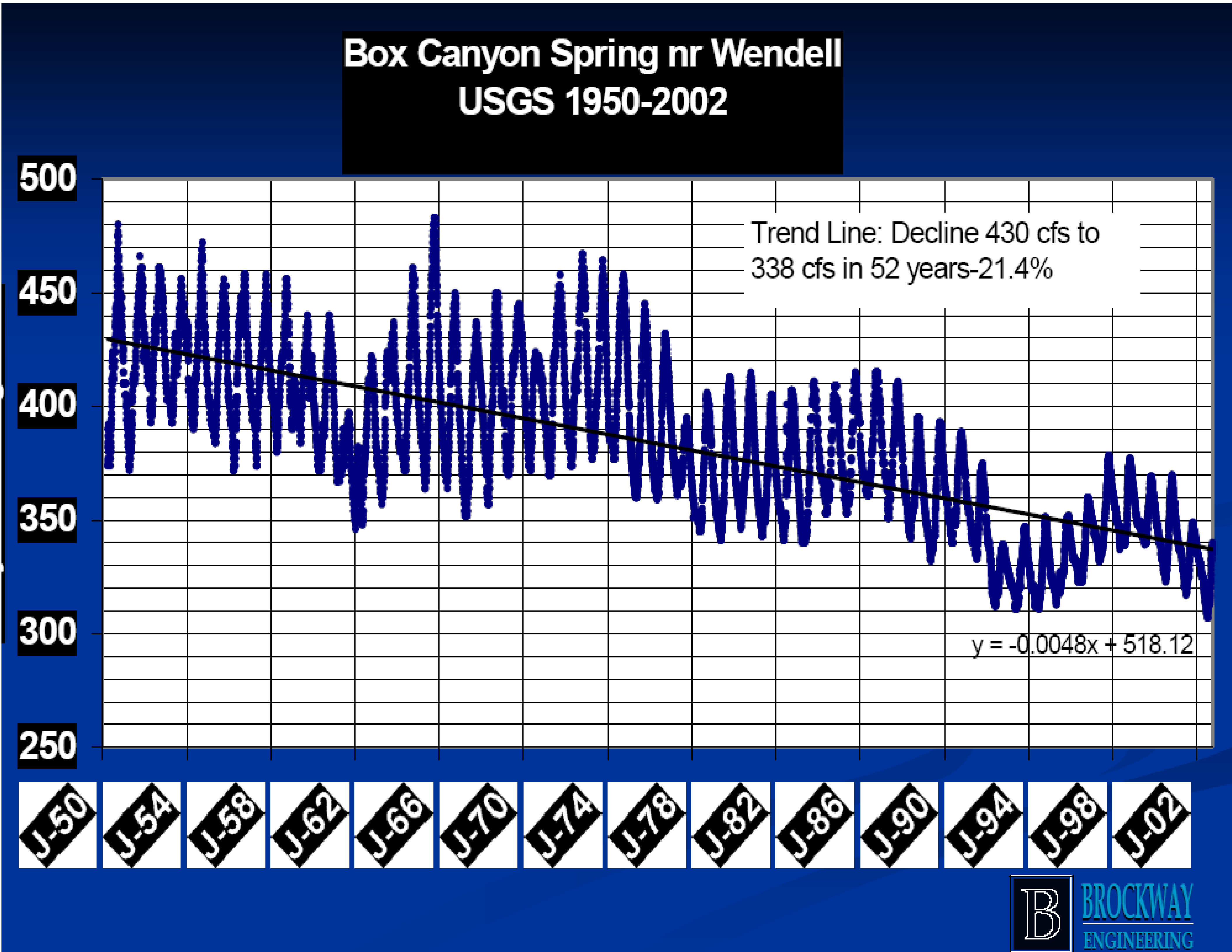
Hydrology of reuse



What are the economics of higher "efficiency"?

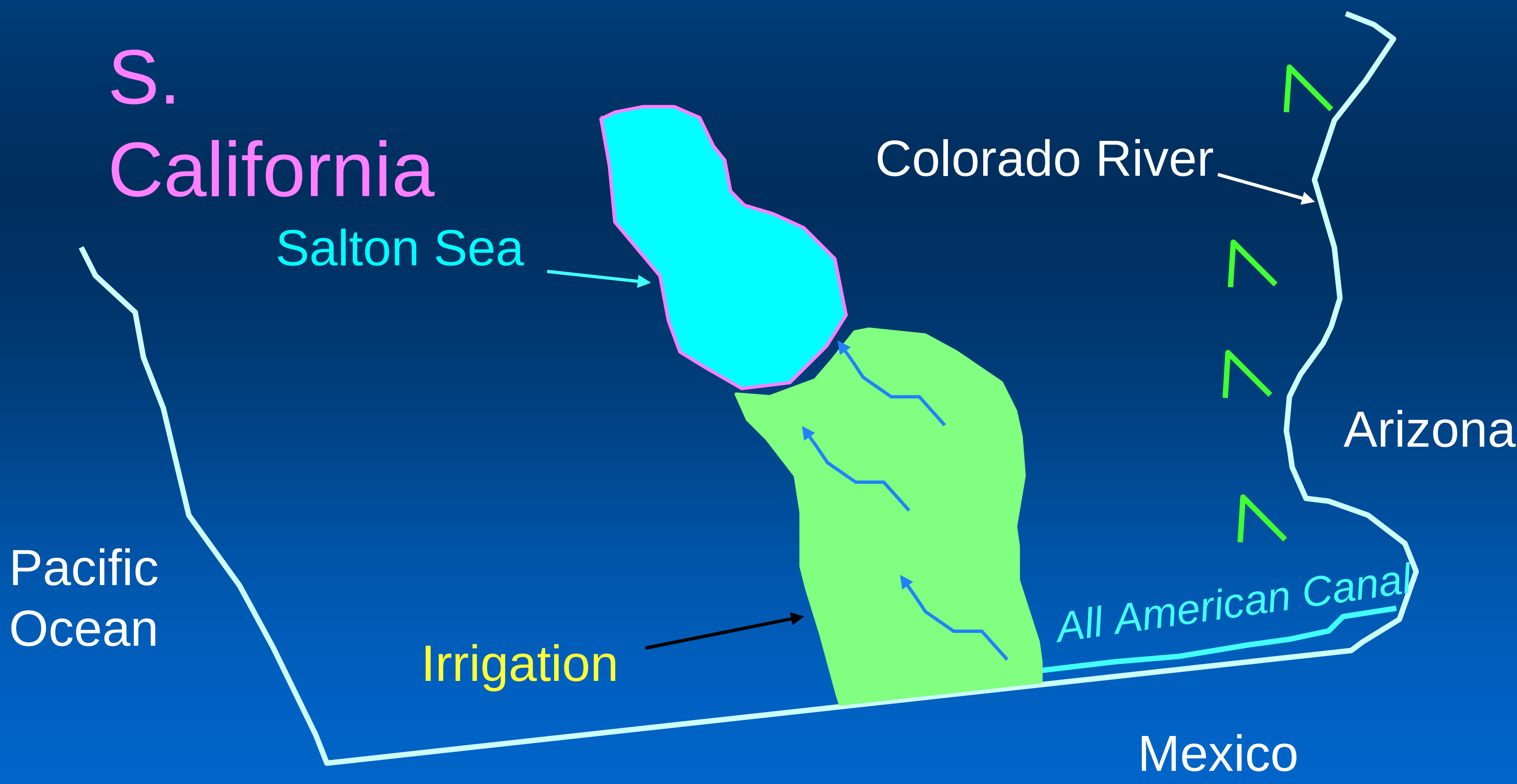
Breakdown of annual recharge to the Eastern Snake aquifer





Box Canyon Spring nr Wendell
USGS 1950-2002
500
450
400
350
300
250
Trend Line: Decline 430 cfs to 338 cfs in 52 years-21.4%
y = -0.0048x + 518.12
J-50
J-54
J-58
J-62
J-66
J-70
J-74
J-78
J-82
J-86
J-90
J-94
J-98
J-02
BROCKWAY ENGINEERING

Example:
Salton Sea Area



Hydrologic Questions to Ask

(to see if water is "saved"):

- Where does the delivered water come from? (i.e., is it from a stream, ground-water, or a lake?)
  - Where is the location of the abstraction?
- At what time of the year are the abstractions made?
  - (i.e., what does the abstraction "hydrograph" look like?)
- Where does the *nonevaporated* component of any applied water go?
- *At what times*? (i.e., what is the hydrograph of flows of nonevaporated components)

Hydrologic Questions to Ask:

- Where does the *nonevaporated* water *reappear* as part of a ground-water or surface water system?
  - At what times?
  - In what quantities?
  - With what quality?

- What happens in the mean time?
  (between the abstraction and the return to the resource)

- What are the consequences of this time lag or spatial lag? (i.e., is there local stream dewatering?
  Are there junior appropriators?

Reasons for Action:

- *IF* there are *local* instream flow needs not being met:
  - Reduce diversions with conservation
  - However, the conservation program will not create new water for other users outside of the specific system or enterprise
  - In fact, the conservation program may be an "ET sustenance" program at the expense of downstream users and may:
    - Increase total evaporation of water
    - and reduce downstream flows

Reasons for Action:

- If there are system capacity constraints

  or

- If there is large invested treatment (culinary) or energy costs, then

  – a conservation program should be considered for

    - local economic reasons

      but

    - Will probably not result in savings to the water resource

NonReusable Fraction

$$NRF = \frac{Q_{NR}}{Q_{Div}}$$

Q_{NR} = Quantity not reusable *(besides ET)*

During Droughts:

Irrigation Water Conservation Programs <u>may</u>:

- Leave *<u>less!!!</u>* water in the River downstream b*ecause:*
    - -- ET within entity is *Sustained*
    - -- Maximum diversion may still be taken
    - -- Less Return Flow

      (Leaks are Plugged)