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CHALLENGES TO WATER SECURITY HETAO IRRIGATION DISTRICT, YELLOW RIVER, INNER MONGOLIA

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The Speed of Disasters

- Rapid events (typhoons, tsunamis, floods, earthquakes *etc*)

But

- Slowly evolving (droughts, famine, climate change, water quality)

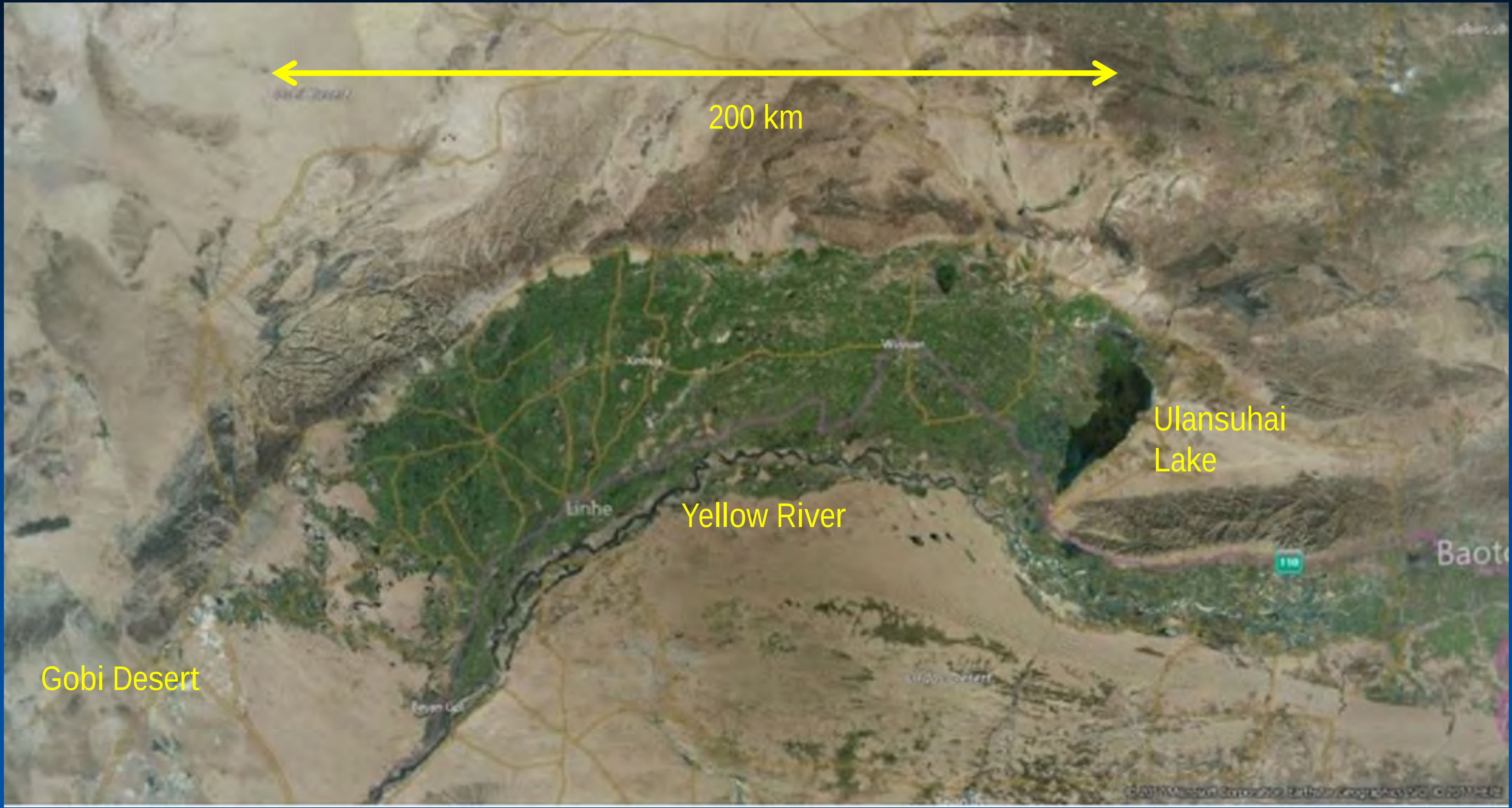
- Can have long-lasting impacts on water-security & communities

Outline

1. Hetao Irrigation District, Inner Mongolia
2. External & Internal Challenges
3. Irrigation Water Losses
4. Salinity Accumulation
5. Restoring the Salt Balance

United Nations Educational, Scientific and Cultural Organization · International Hydrological Programme

Hetao Irrigation District Cool Semi-Arid, Arid

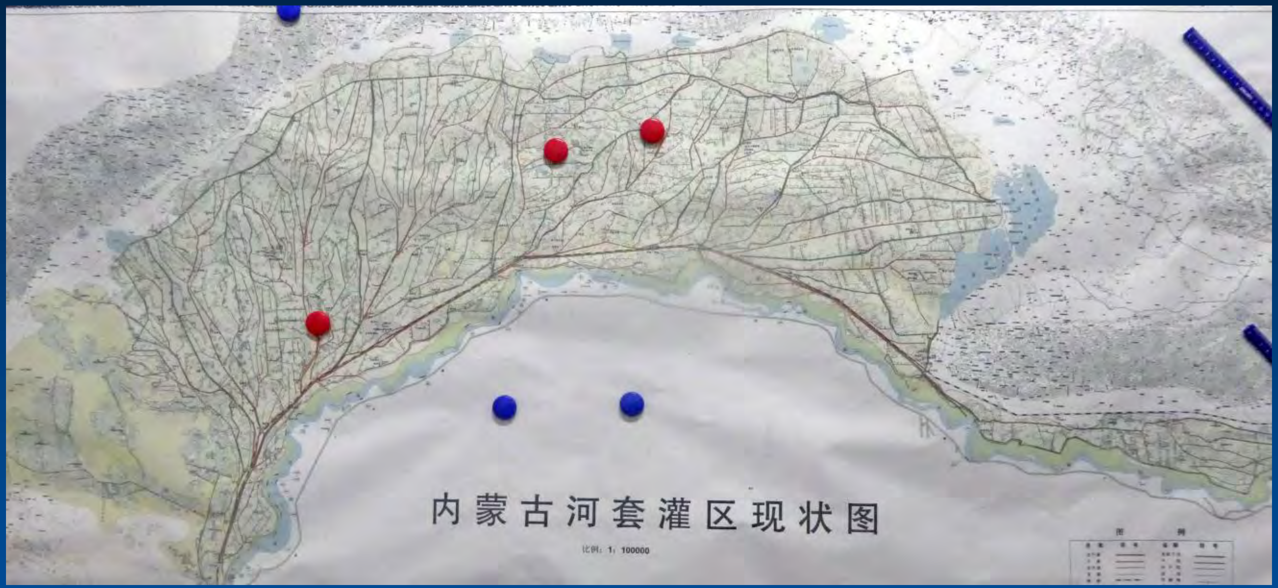


Google Earth

Yellow River Challenges to Water Security

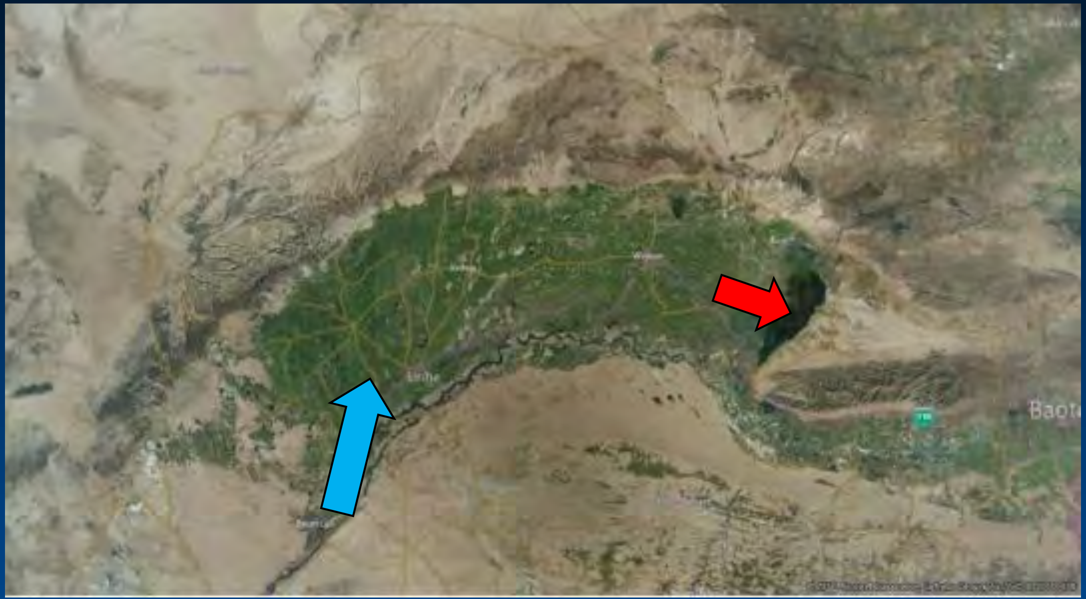
- 140 Million dependent on Yellow River
- Increasing downstream demand for water
    - Expanding Industries
    - Growing Cities
- Upstream Irrigators have high water use
- Mandated 15% Reduction in Irrigation Supply for Hetao Basin – 4.0 km^3/y
- To be phased in

Challenges to Water Security Hetao Basin



1. 15% Reduction in Irrigation Supply
2. Leaky Canals – 59% Losses
3. Shallow Groundwater
4. Yellow River Sediment Load
5. Limited Incentives
6. Limited economies of scale

Irrigation Characteristics



Total Area : 10,677 km^2

Irrigated Area: 5,744 km^2

Water source: Yellow River

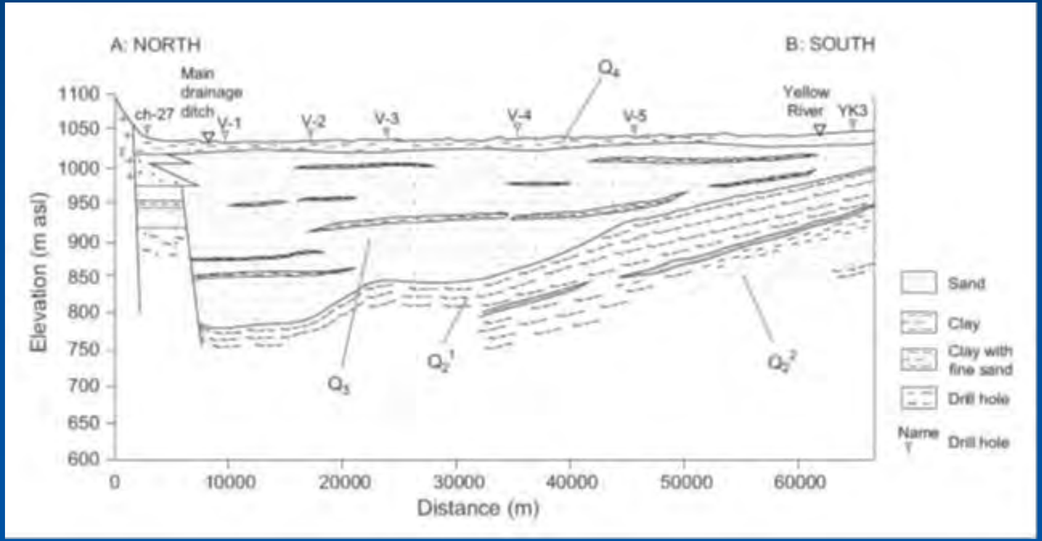
Irrigation Off-take: 4.7 km^3/y

Drainage Return: 0.41 km^3/y

Irrigation Efficiency: 41%

Supply Period: April to October

Groundwater Characteristics

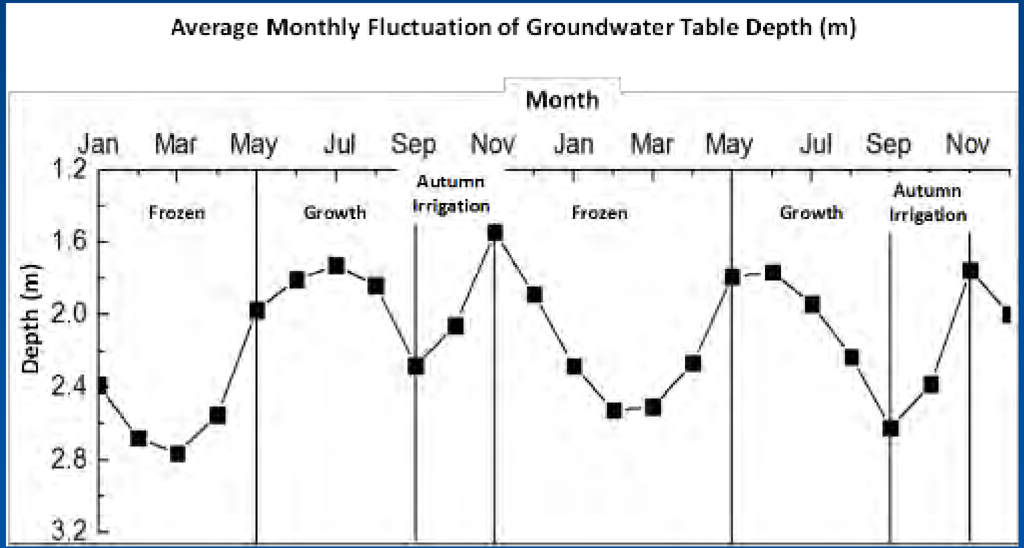


Xu et al. (2010)

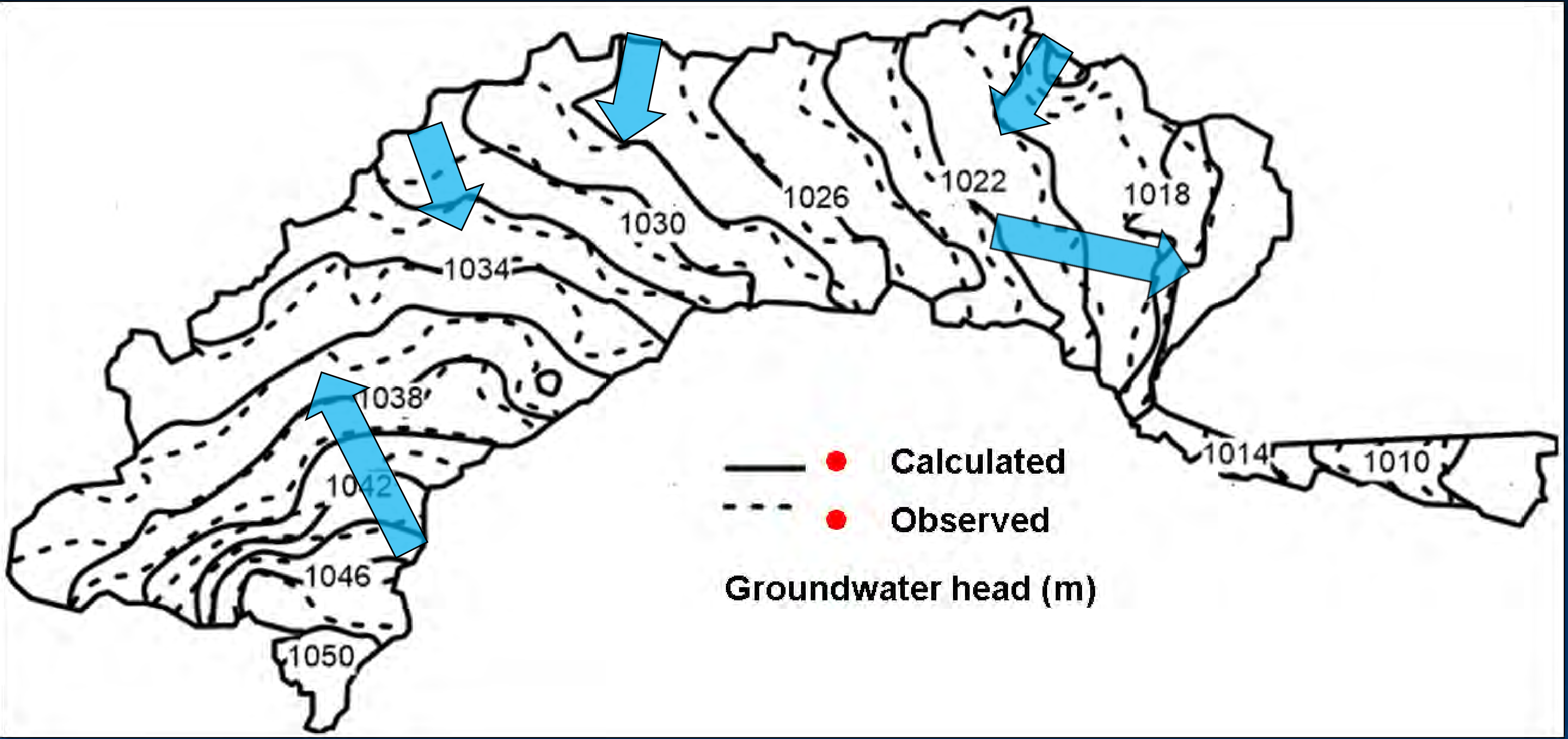
Groundwater Units

1. Surface aquitard: ~ 20 m depth
2. Unconfined Aquifer 1: 20 to 240 m deep
3. Confined Aquifer 2: < Aquifer 1

Water Table Depth: 1.2 to 3 m

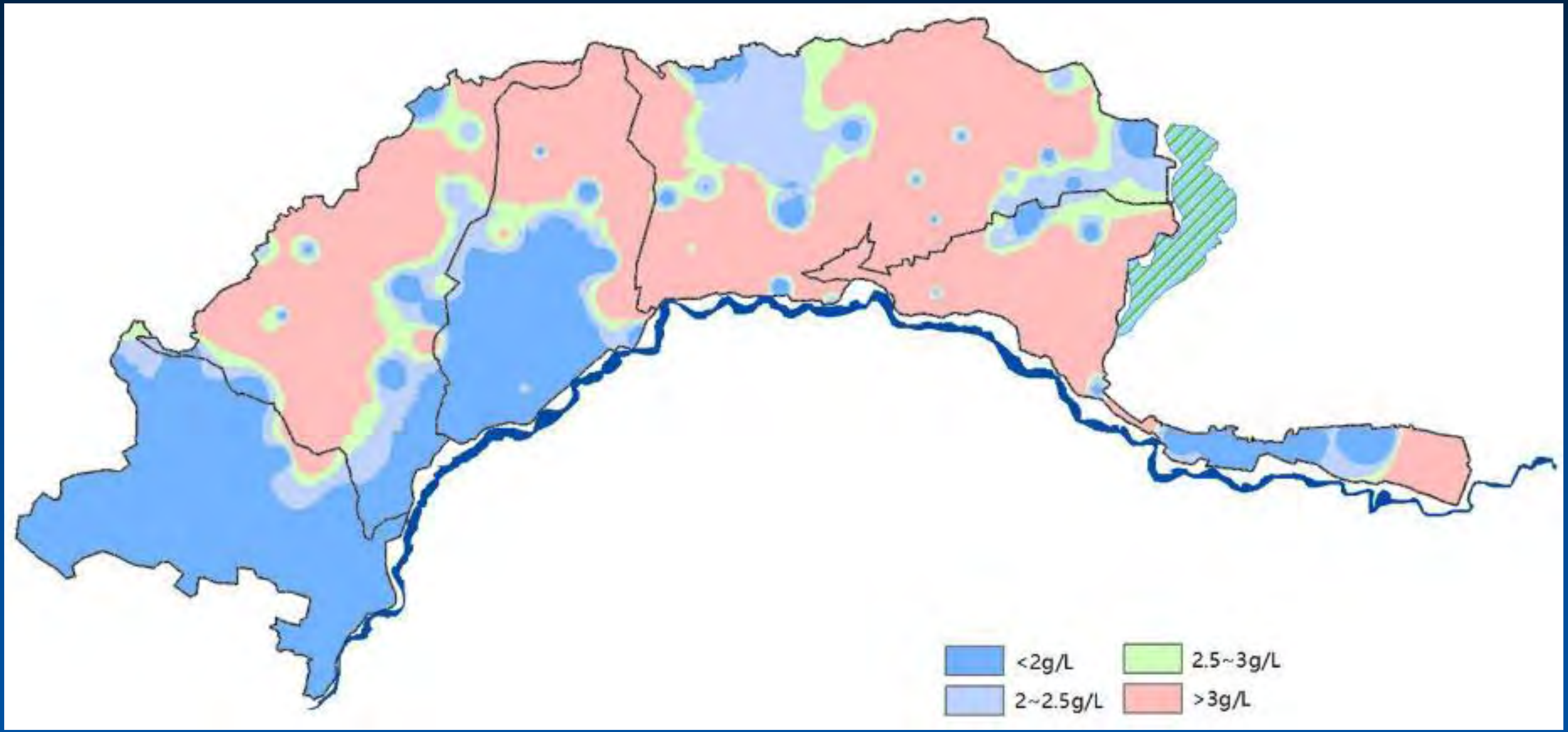


Seepage, Recharge and Hydraulic Head

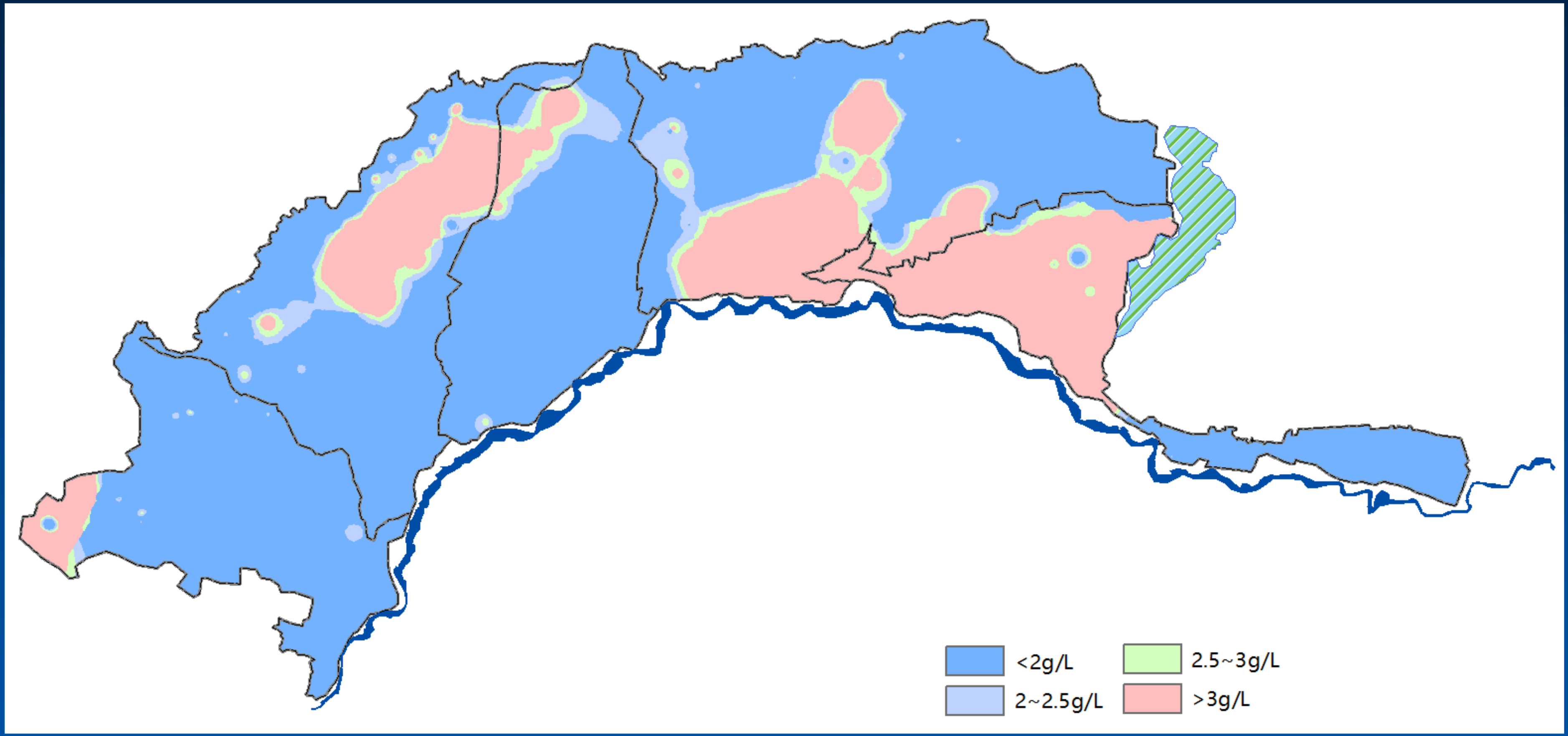


Hydraulic gradient ≈ 1/8000 Darcy Velocity ≈ 0.64 mm/d

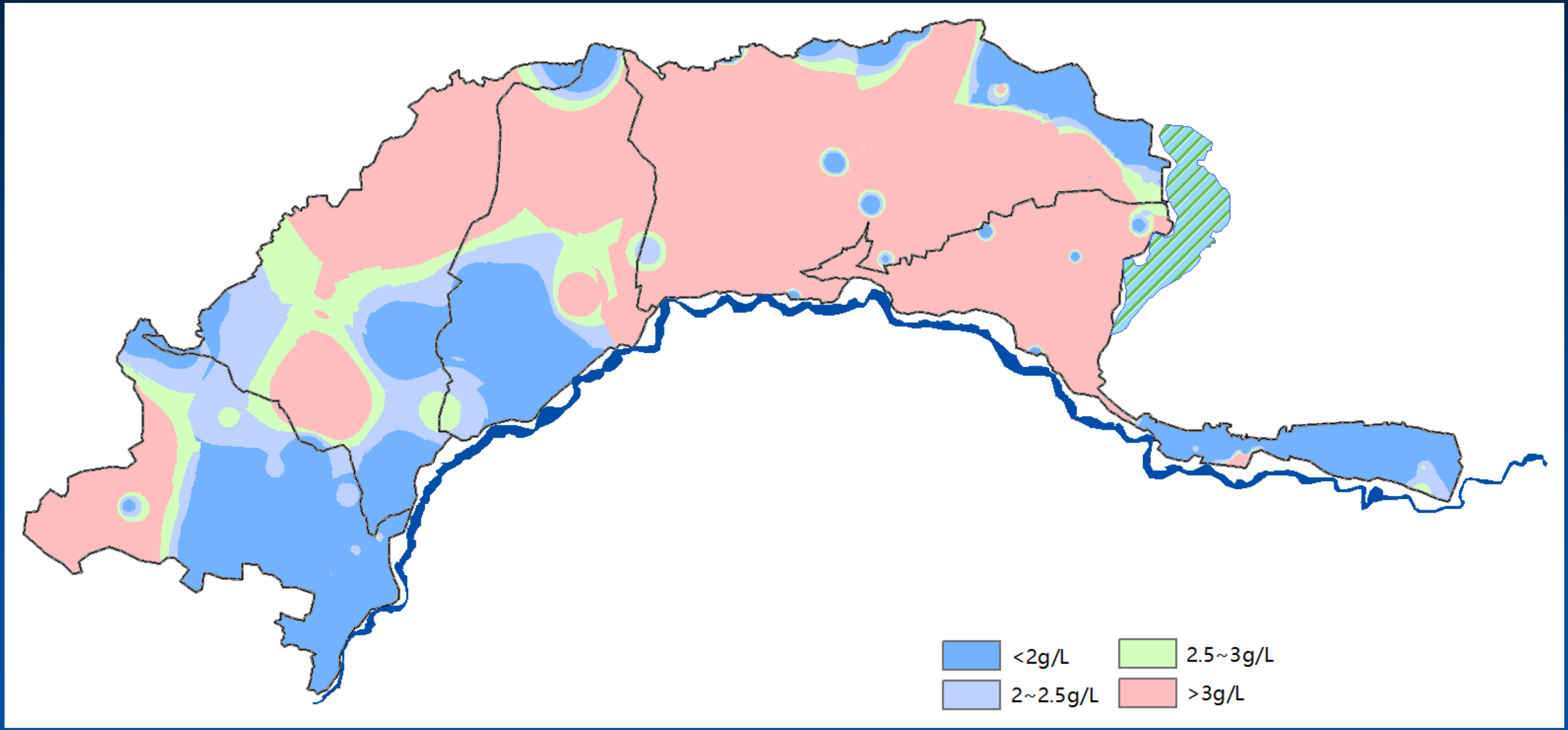
Groundwater Salinity Top Aquitard



Groundwater Salinity Unconfined Aquifer 1



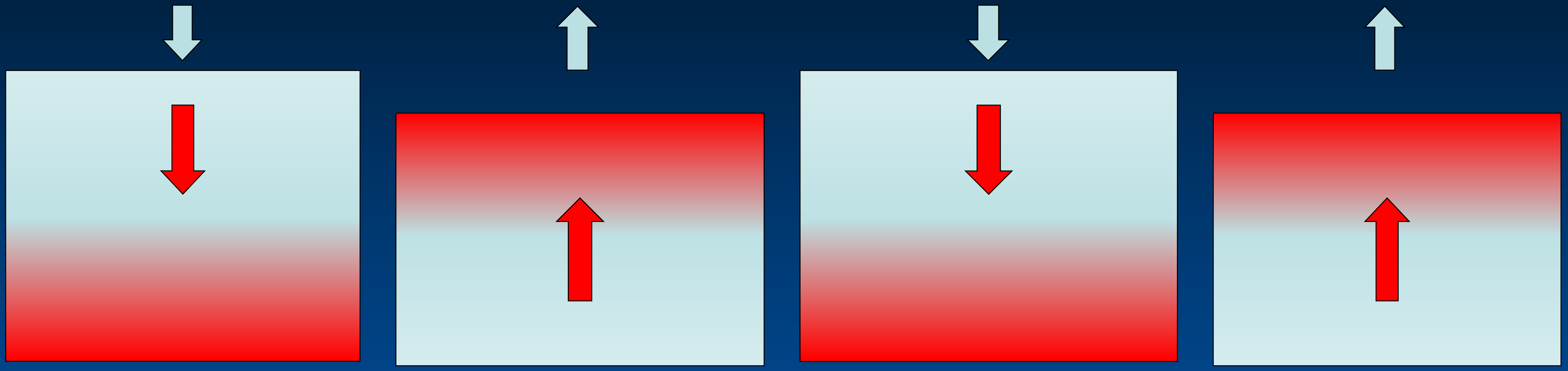
Groundwater Salinity Confined ? Aquifer 2



Soil & Groundwater Salinity

Managing Soil & Groundwater Salinity is a Major Challenge in parts of the Basin

How do Farmers Manage Salinity (since Qin Dynasty)?



Spring - flush accumulated salt

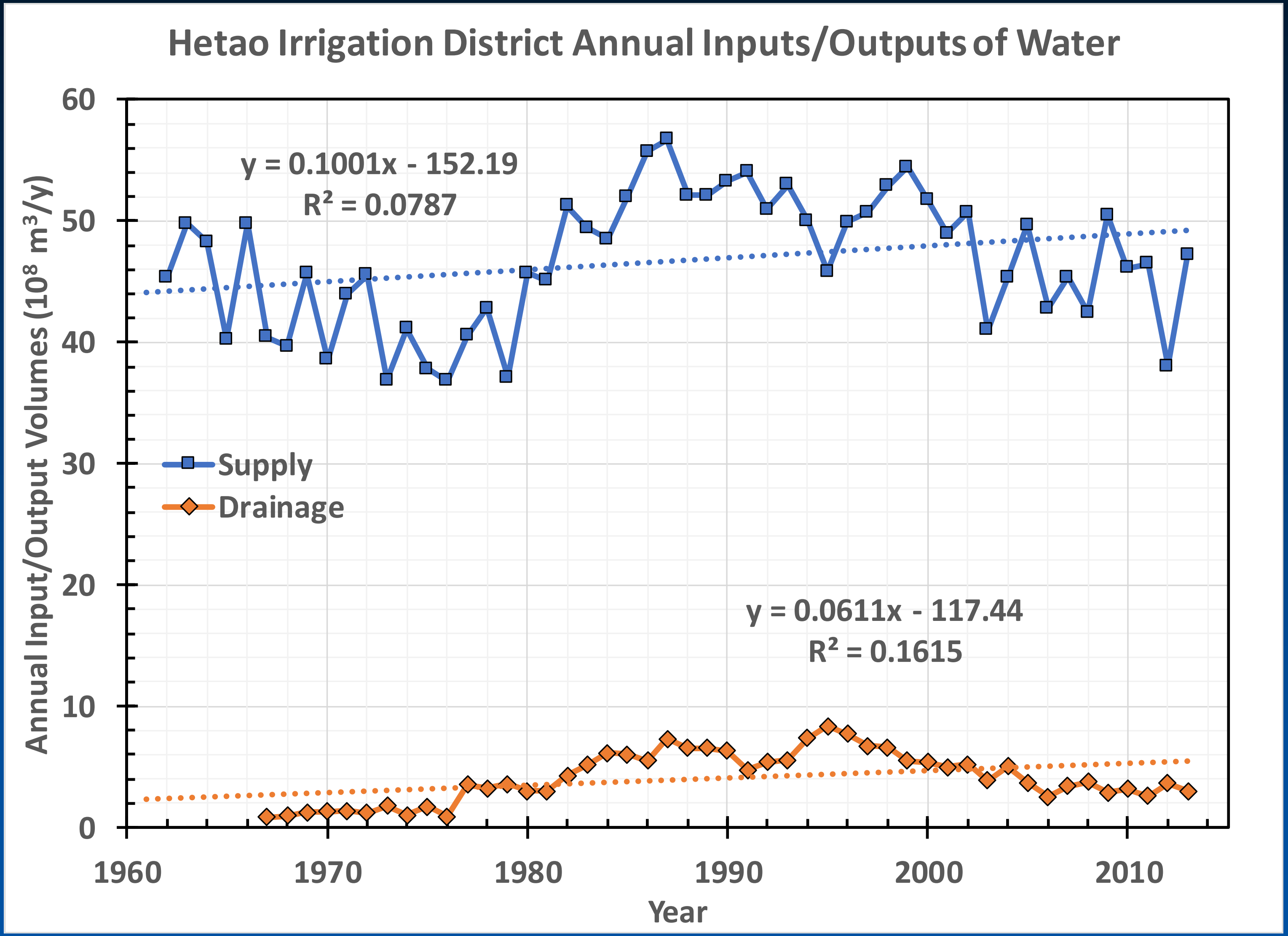
Growing season salt accumulates

Autumn - flush accumulated salt

Winter - salt accumulates

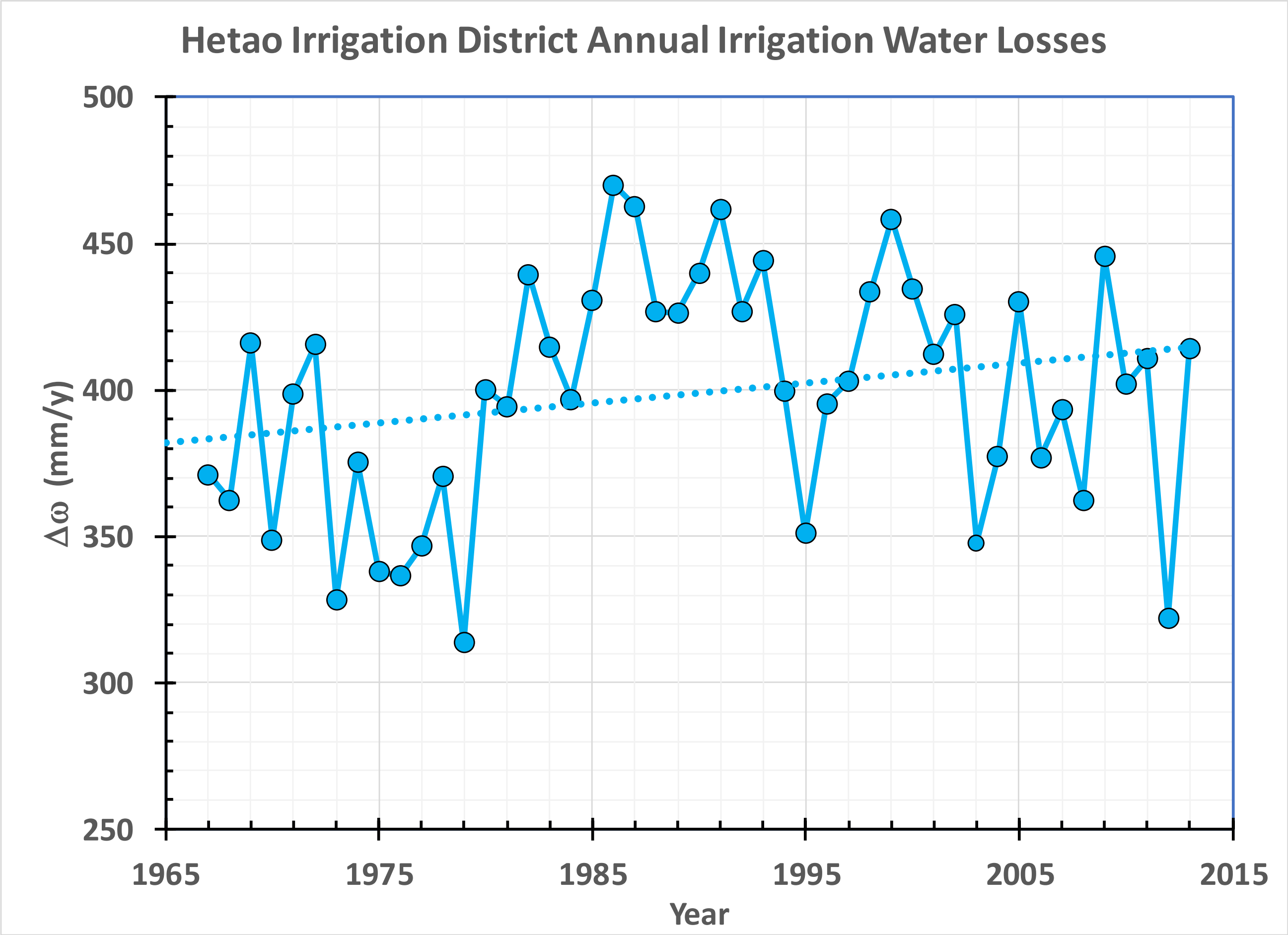
Annual Salt Flushing in Spring and Autumn uses 1.3 km^3 Yellow River Water

Irrigation Input & Drainage Output



Increasing trends in time due to developments in the irrigation Basin

Estimated Annual Specific Irrigation Losses

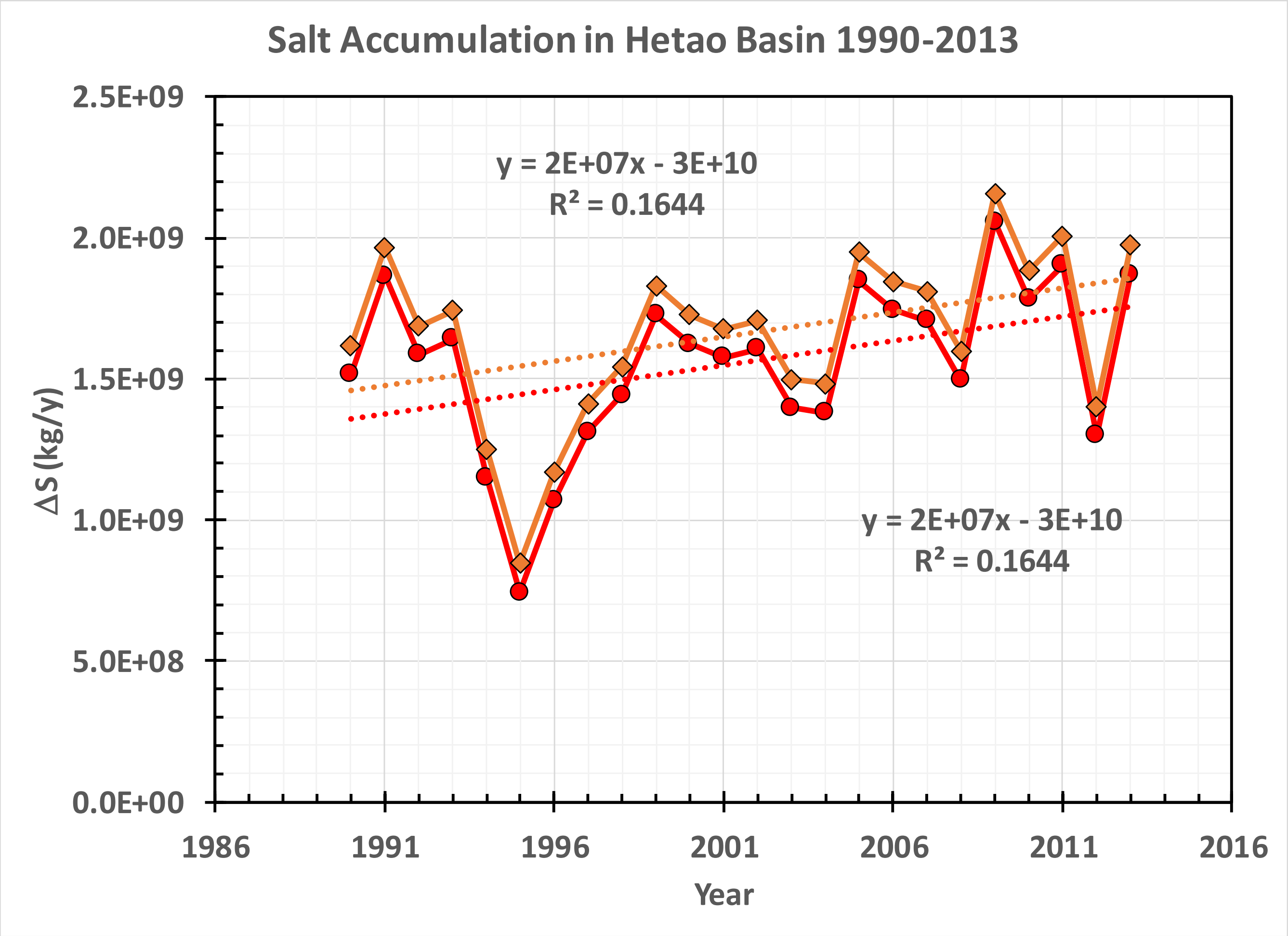


- Mean specific irrigation water losses 1967-2013 = 420 ± 42 mm/y
- No significant trend with time
- Assumes closed Basin

But if this water is evaporated from the Basin what happens to the salt imported in the irrigation supply (plus salt in seepage & rainfall)?

$C_I = 0.5$ kg/L

Annual Accumulation of Salt in Hetao Basin



Estimated salt storage based on estimated drainage salinity of 2 kg/m^3 to Lake Ulansu

Mean Salt Accumulation

$= (1.6\pm0.3)\times10^9$ kg/y

Specific Salt Storage

= 1,510 kg/ha/y

Trend + $(0.17\pm0.08)\times10^9$ kg/y/y

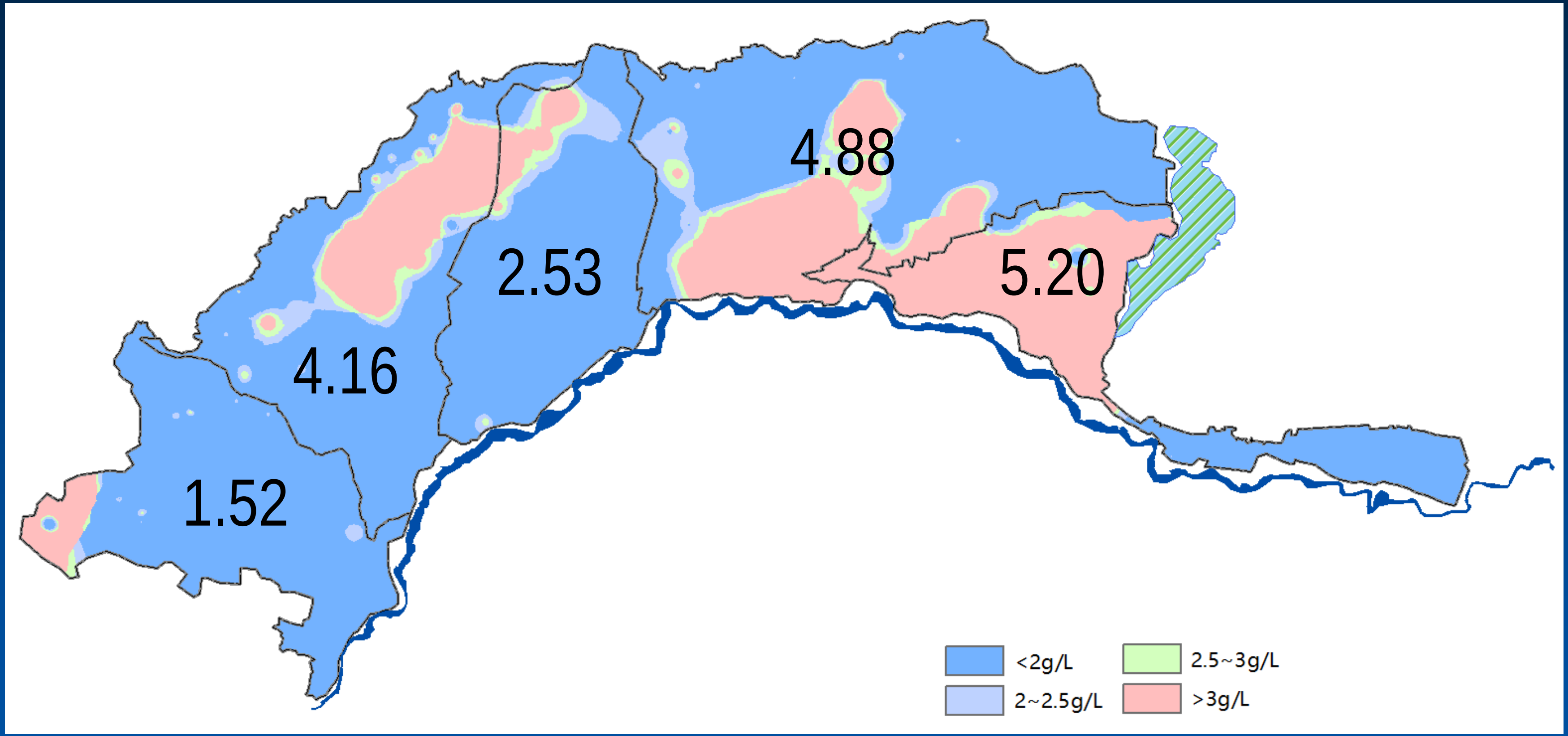
$p > 0.95$

Predictions of this Analysis

1. Salinity of the shallow, unconfined groundwater is increasing
2. Should be a gradient in salinity in Aquifer 1 with highest salinity at base
3. To re-establish equilibrium need to increase saline drainage.

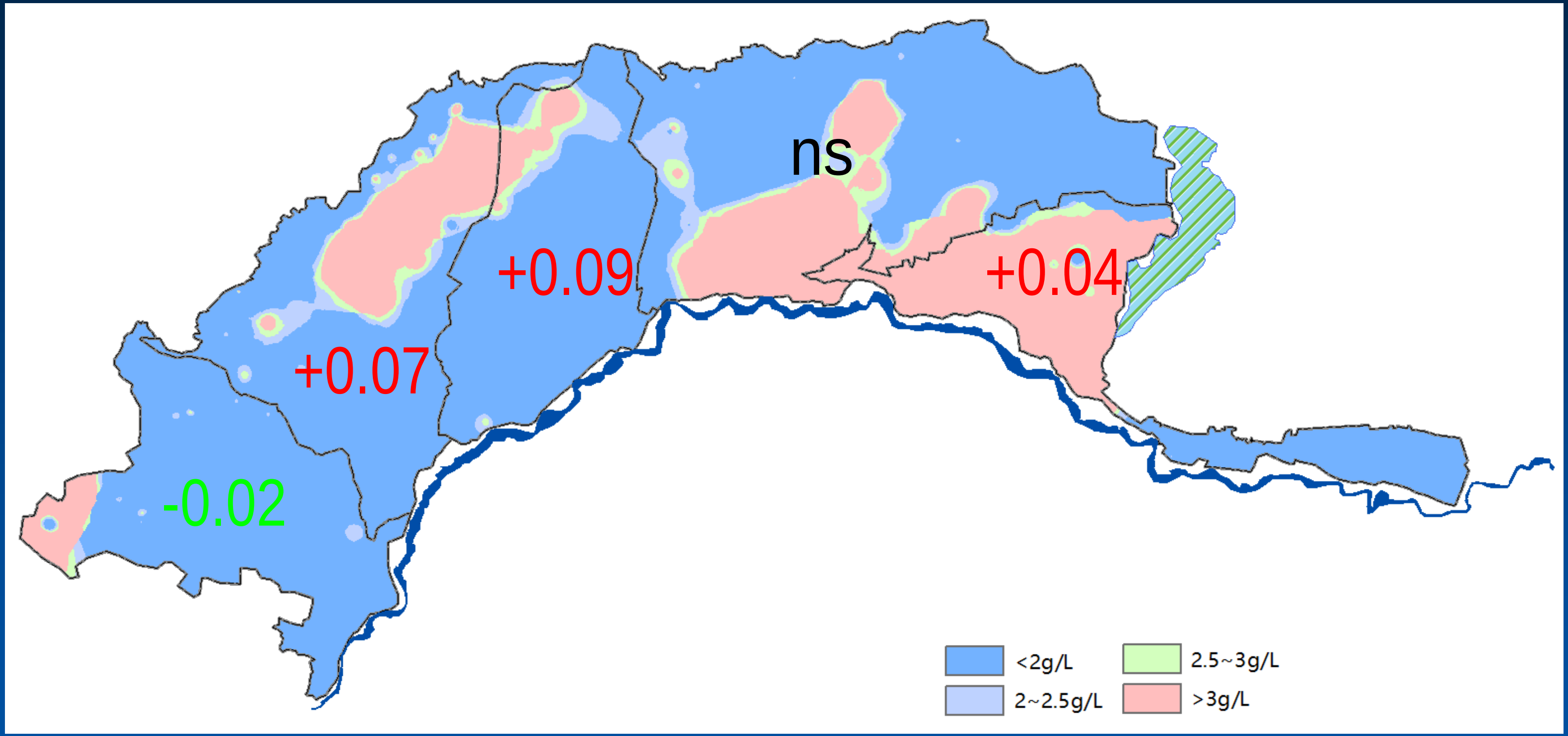
Is the Salinity of Aquifer 1 Increasing?

Mean Salinity 1980-2013, kg/m^3



Is the Salinity of Aquifer 1 Increasing?

Rate of Change of Salinity 1980-2013, $kg/m^3/y$



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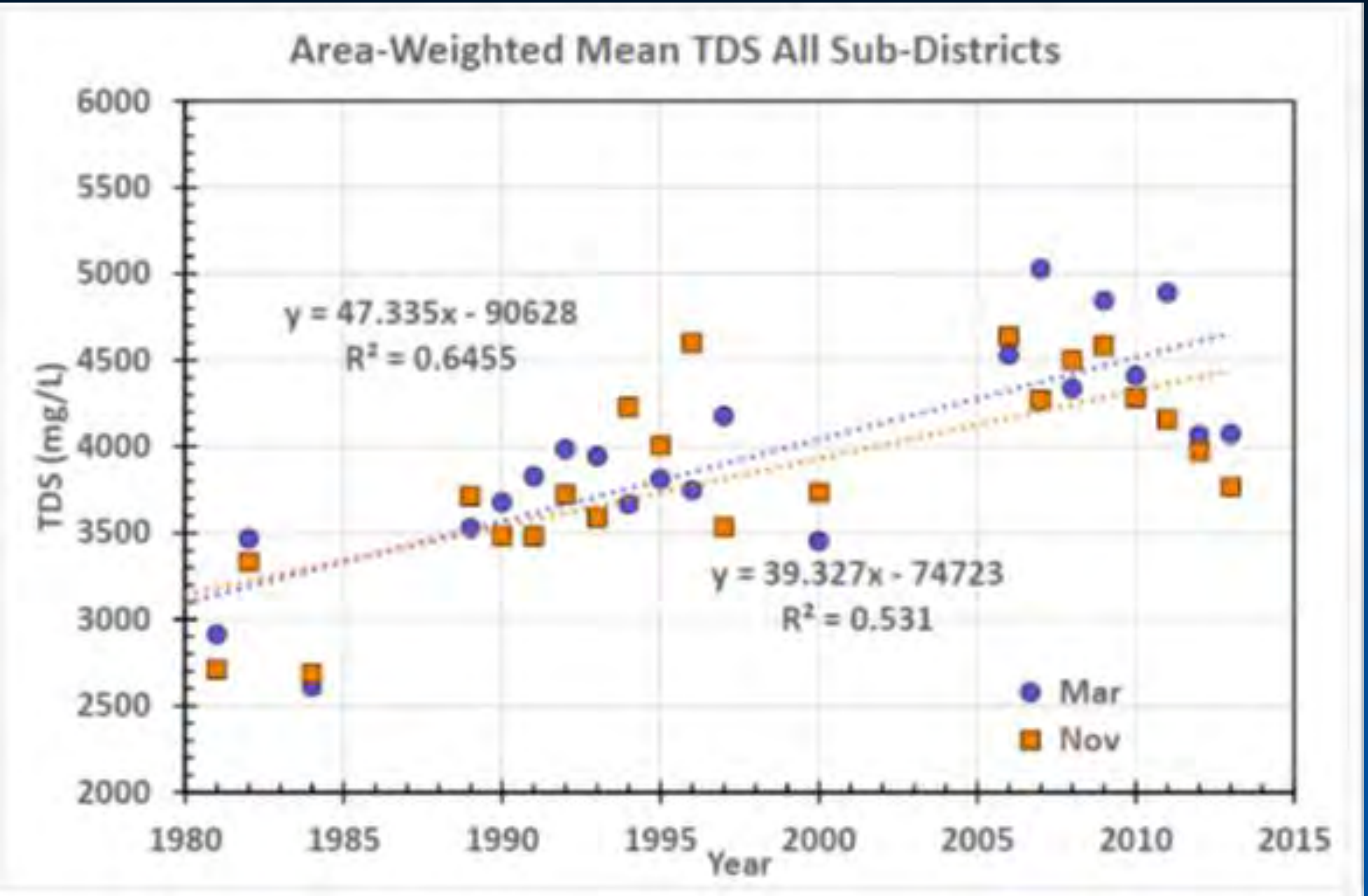


Rate of Increase

+0.043 kg/m^3/y

Very significant

P > 0.995

Regression and non-parametric

Is there a Limit to Groundwater Salinity Increase?

If no changes then :

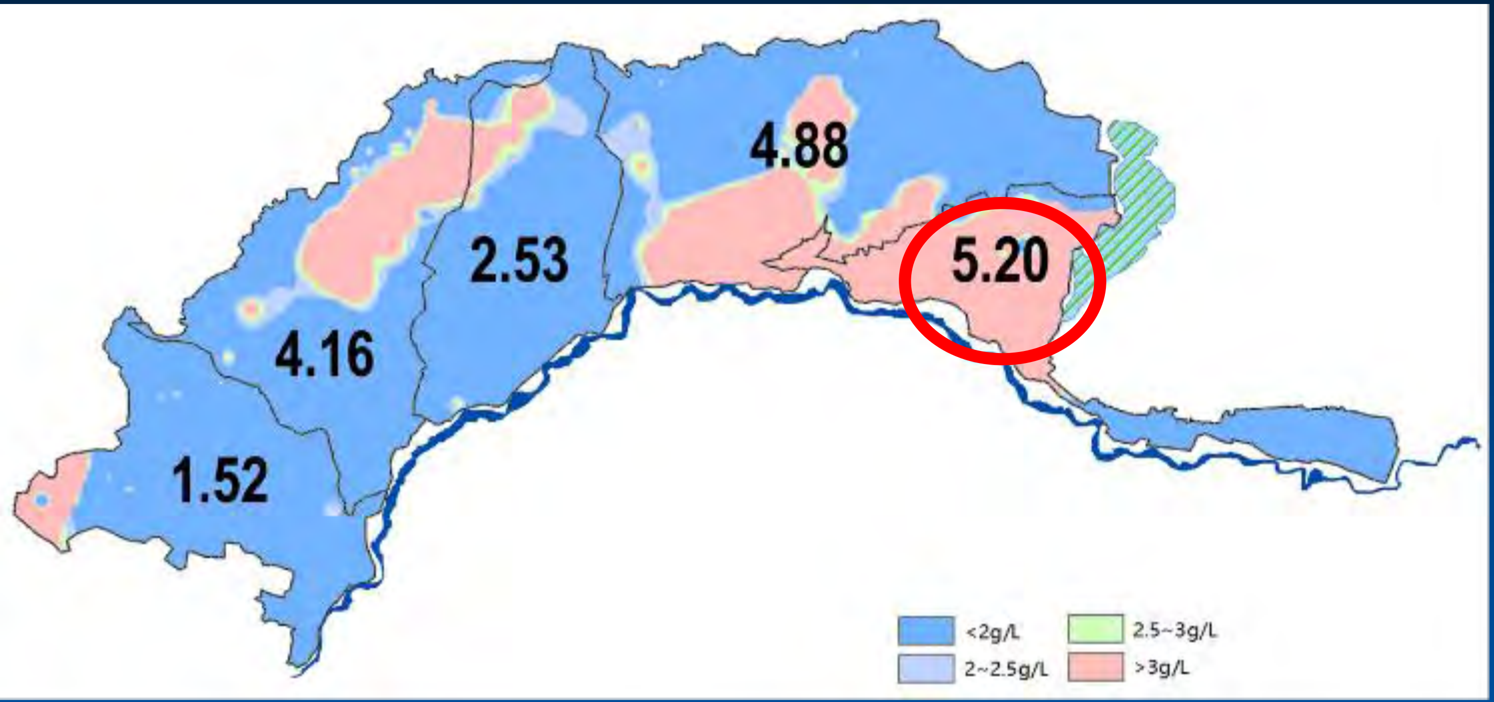
- in 50 years mean salinity of GW = 6.0 kg/m^3
- in 100 years mean salinity of GW = 8.2 kg/m^3

Field Crops impacts on seedlings > 2 kg/m^3

Mature crops productivity declines > 5 kg/m^3

Would increase Water Demand from Yellow River for salt flushing

Where would you pump saline groundwater from?



- If density-driven convection hypothesis is correct
- From base of saline > 5 kg/m^3 areas in Aquifer 1
- Drainage Rate should be increased by 0.23 km^3/y or 56% at groundwater salinity 5.5 kg/m^3 to maintain salt balance

Conclusions

The water security of the Hetao Basin for food supply is challenged by:

- 15% mandated reduction in irrigation supply
- Increasing salinity in unconfined groundwater
- Limited incentives (but changes are coming)
- Situation can be improved by a 50 to 100% increase in saline water drainage rate (expensive – use solar pumping?)

Many research questions involving integrated approaches