



# *Water System Adaptation To Hydrological Changes*

## Module 5

### Water Quality and Infrastructure Response to Rapid Urbanization: Adaptation Case Study in China

Y. Jeffrey Yang, Ph. D.

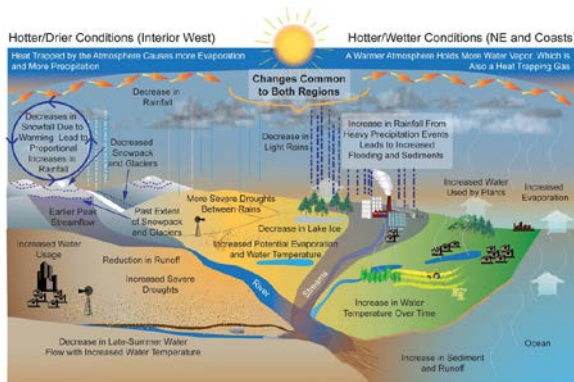
U.S. Environmental Protection Agency

Audrey Levine, Ph.D.

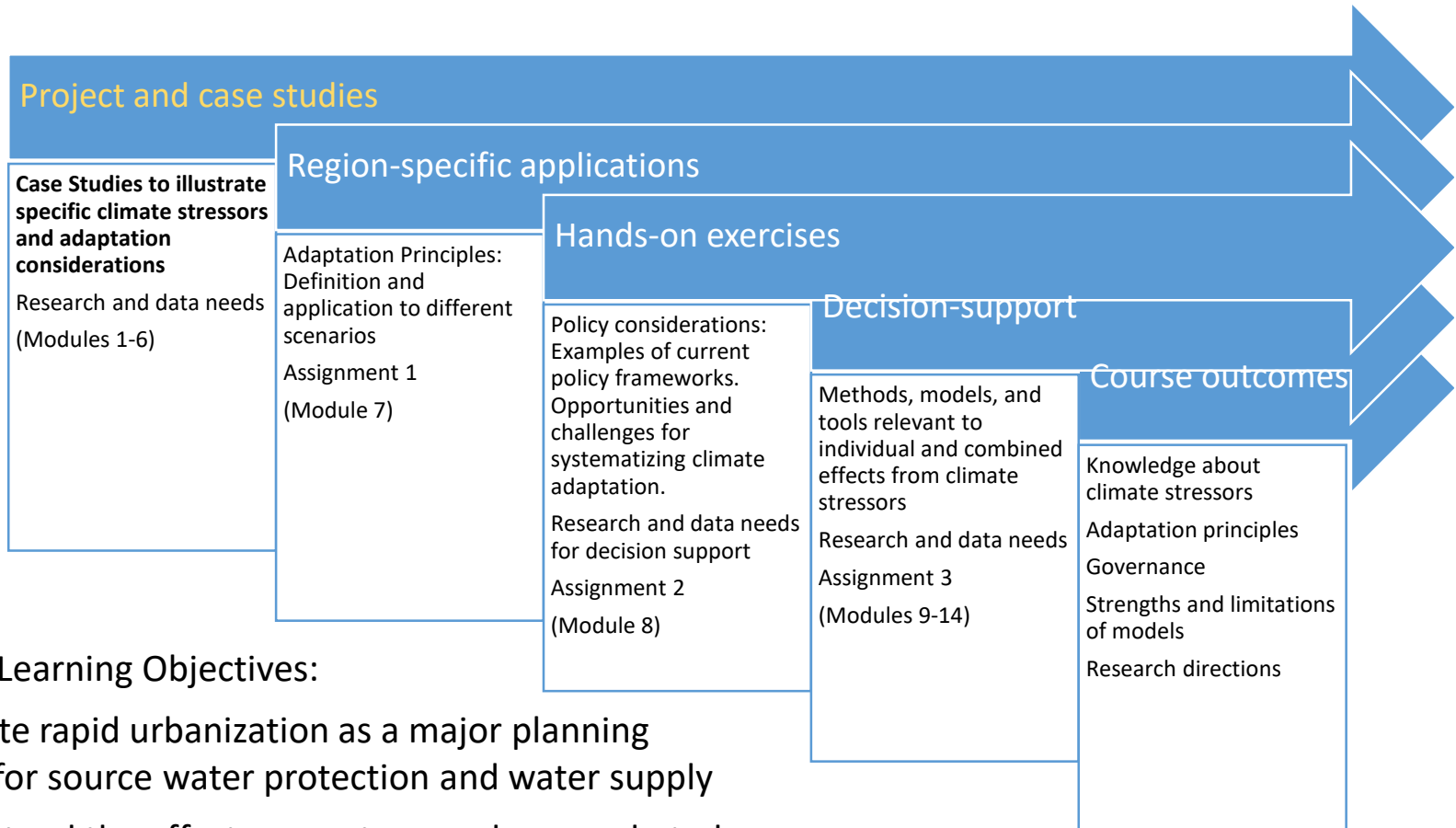
University of California, Santa Cruz

James A. Goodrich, Ph.D.

U.S. Environmental Protection Agency



# Course Roadmap



## Module 5 Learning Objectives:

- Illustrate rapid urbanization as a major planning factor for source water protection and water supply
- Understand the effects on water supply exacerbated by climate-related hydrological changes
- Show innovative adaptation measures available to address the challenges in multiple dimensions

# Rapid Urbanization and Environmental Pressure in China



## *Compounding Effects of Rapid Urbanization and Climate-related Hydrological Changes*

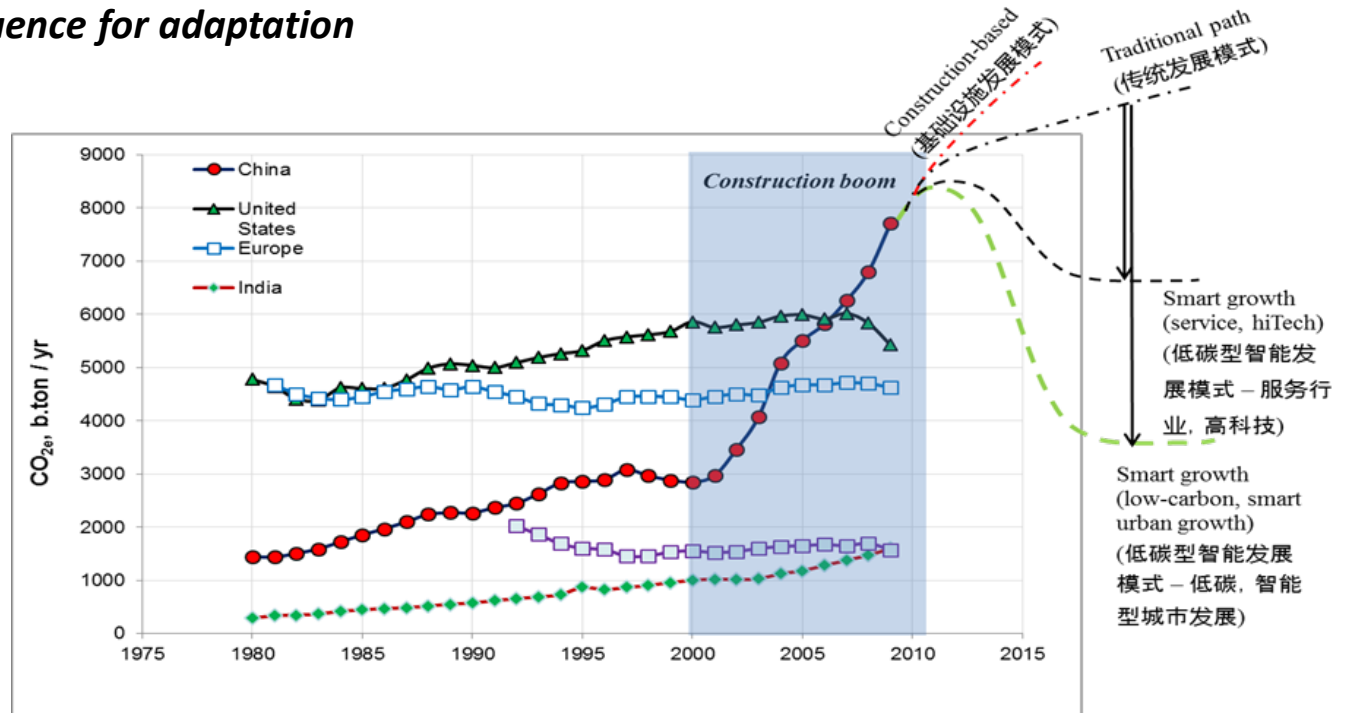
- Land use change compounding climate impacts on watershed hydrology (Module 4)
- In China, rapid urbanization and land use change toward impervious surface with widespread pollution
- Water stress from urbanization as the dominant factor affecting water infrastructure adaptation
- Often unconventional and innovative adaptation measures taken for effectiveness



# China: A Living Example of Rapid Changes and Environmental Pressure



*Rapid growth and urbanization come with environmental consequence for adaptation*



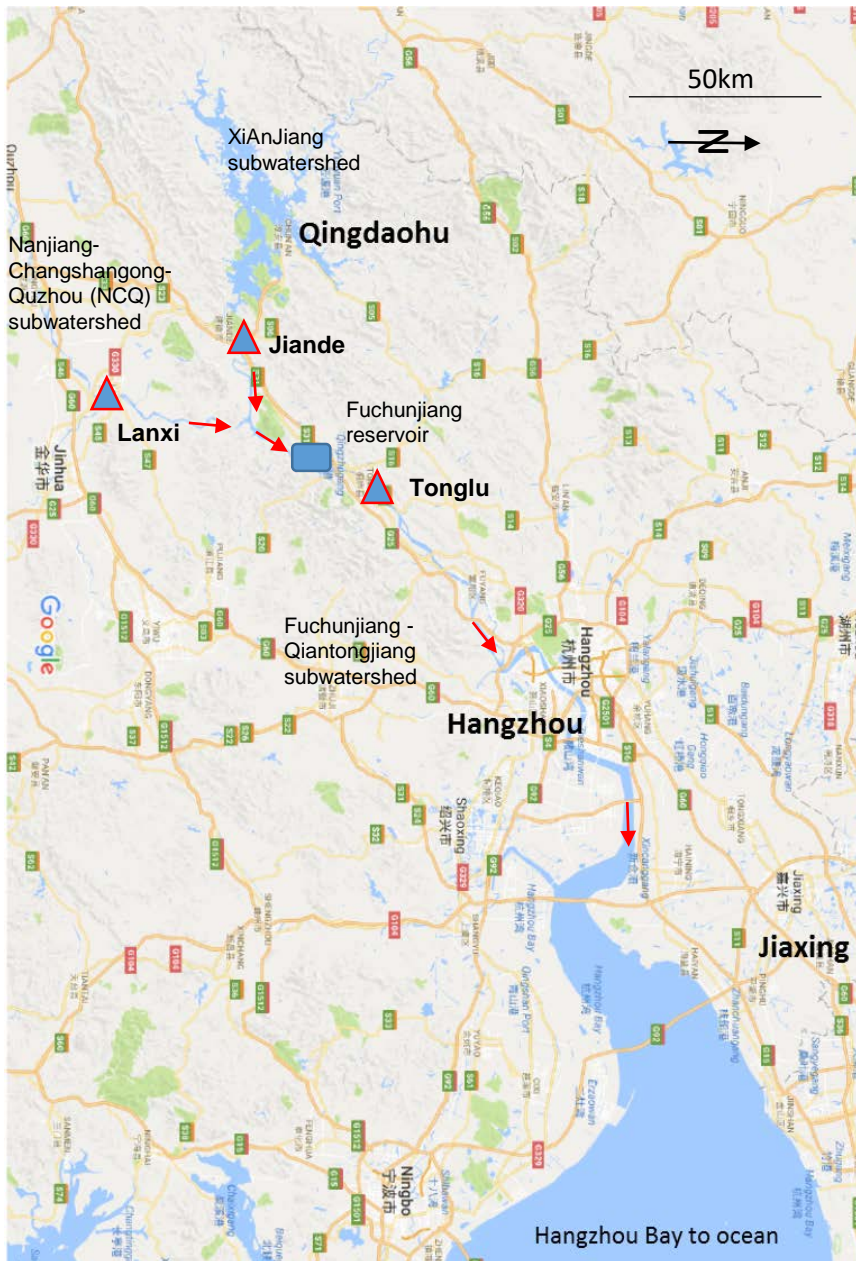
- Total carbon emission from China increased rapidly to  $>8,000 \times 10^9$  ton/yr, largely due to construction and urbanization in the 2000s
- Urbanization took place in unprecedented rate all over the country
- Industrial production and urbanization led to increased runoff and water pollution
- Climate-related hydrological changes exacerbate the environmental impacts



## Case Study in Qiantangjiang River Basin

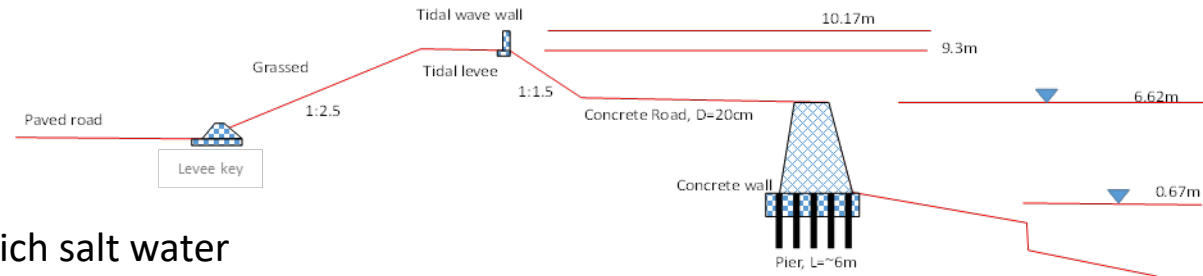
- Tidal-related **salt water intrusion along the river**
- **Source water pollution** from nutrients and algae blooms for the Jiaxing drinking water plant

# Case Study in Qiantangjiang River Basin



- **Case study objective:** Water supply for Hangzhou and water treatment in Jiaxing water plant
- **Climate drivers:** Salt water intrusion along QTJ River, and source water pollution for Jiaxing plant
- Three distinct watersheds:
  - ❖ XiAnJiang subwatershed: pristine, natural and protected watershed
  - ❖ NCQ subwatershed: urbanization LULC, large river flow contribution
  - ❖ Fuchunjiang – Qiantangjiang subwatershed: heavily urbanized with industrial, tidal and sea-level rise effects
- QTJ river is known for its **astronomical tide** leading to **salt water intrusion**. Sea level rise increases the impacts
- **Source water pollution** from nutrients and algae blooms for the Jiaxing drinking water plant

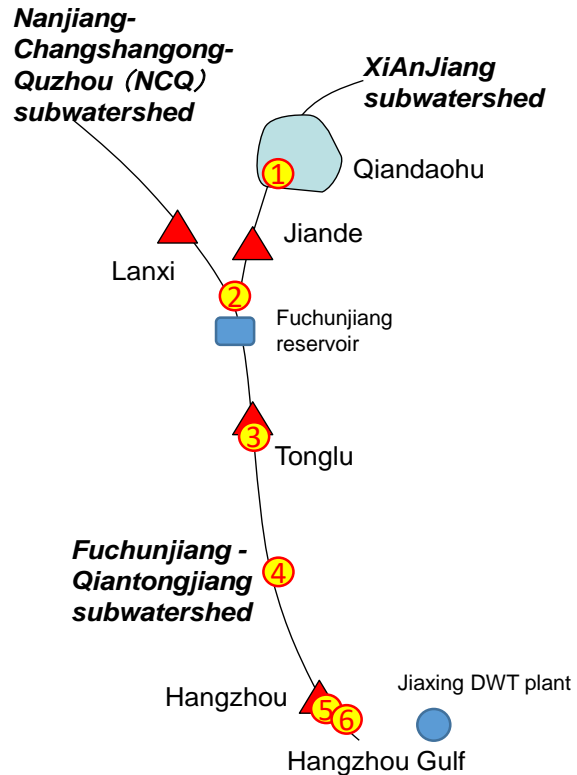
# Qiantangjiang River Tide and Salt Water Intrusion



- **Astronomical tide** in which salt water moves upstream passing the City of Hangzhou
- **Fuchunjiang reservoir** in the middle of the river has the dam preventing further salt water intrusion, but receives industrial pollution upstream
- **Erosion and inland flooding** in lower river stretch (Hangzhou and vicinities) are major concerns for water infrastructure protection
- **Climate-related sea level rise and storm surge** worsen the condition



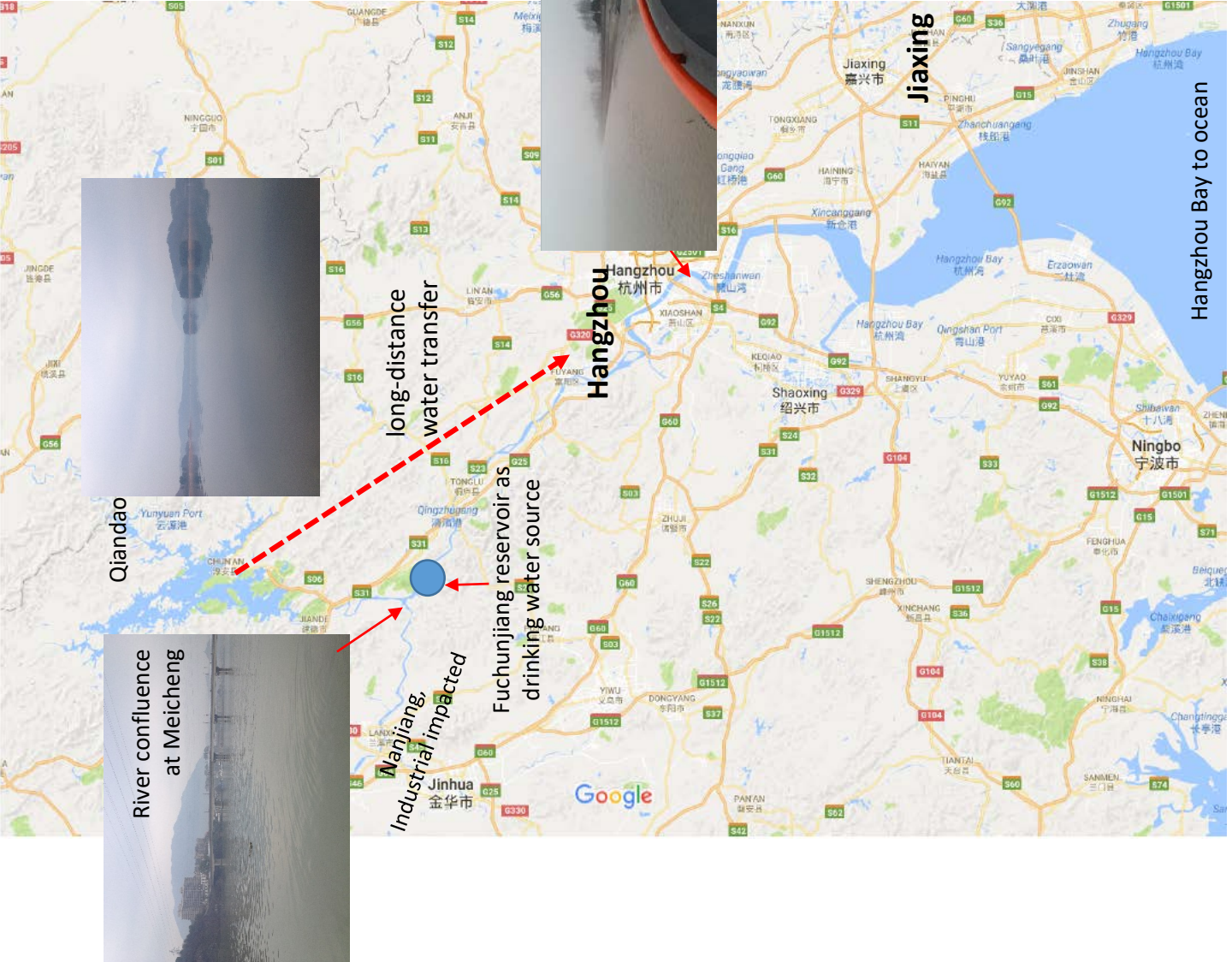
# Upper Qiantangjiang River with Anthropogenic Pollutions



A complex hydrologic setting with multiple factors over source water quality:

- **Fuchunjiang reservoir** in the middle of the river provides source water to regions' water plants
- **XiAnJiang** subwatershed is a protected area with pristine **Qiandaohu** lake
- **NCQ subwatershed** hosts industrial activities, leading polluted water to the reservoir
- **Tidal-related salt water intrusion** in lower river stretch below the dam is major concern
- **Nutrient pollution, erosion and inland flooding** are also concerns for the low river stretch

Sampling at locations along the river confirmed the above observations



This map illustrates the Hangzhou Bay region, highlighting the long-distance water transfer project from the Fuchunjiang reservoir to Hangzhou. The reservoir is marked as a drinking water source, while the Nannjiang area is noted as being impacted by industry. The map also shows the river confluence at Meicheng and the location of Qindao. Two inset photographs show the river confluence at Meicheng and the Fuchunjiang reservoir.

Map of Hangzhou Bay area showing water transfer project. The map highlights the Fuchunjiang reservoir as a drinking water source for Hangzhou. A red dashed arrow indicates a long-distance water transfer from the reservoir to Hangzhou. A red solid arrow points to the confluence of the Nannjiang river, labeled "Industrial impacted". Two inset photos show the river confluence at Meicheng and the Qiantang River. The map includes labels for cities like Hangzhou, Ningbo, Shaoxing, and Jiaxing, and bodies of water like Hangzhou Bay and the Qiantang River.

- 
- Map of Hangzhou Bay area showing water transfer project. The map highlights the Fuchunjiang reservoir as a drinking water source for Hangzhou. A red dashed arrow indicates a long-distance water transfer from the reservoir to Hangzhou. A red solid arrow points to the confluence of the Nannjiang river, labeled "Industrial impacted". Two inset photos show the river confluence at Meicheng and the Qiantang River. The map includes labels for cities like Hangzhou, Ningbo, Shaoxing, and Jiaxing, and bodies of water like Hangzhou Bay and the Qiantang River.



## Case Study in Qiantangjiang River Basin

- Tidal-related **salt water intrusion along the river**
- **Source water pollution** from nutrients and algae blooms for the Jiaying drinking water plant

# Water Supply Adaptation in Rapid Urbanization



**Source water pollution** in the lower QTJ River stretch:

- High nutrient contents in surface water
- Untreated discharge to watersheds a daunting challenge
- Rapid urbanization and hydrologic changes compromising source water protection
- Agricultural runoffs

The streams, ponds, and small lakes all serve as **the main source water** for drinking water plants

*High nutrients at Jiaxing*



*Algae blooms in Wuxi*



*Discharge of untreated water*



# Water Supply Adaptation in Rapid Urbanization



- **Climate and land use factors**
  - High temperature enhancing algae blooms in nutrient-rich water bodies
  - High-intensity precipitation and urbanization with impervious surface leading to increasing runoff and other hydrological changes
  - All increase nutrient flux into water bodies
- **Adaptation considerations**
  - Source water protection in long-term planning
  - Smart urban development to reduce combined impacts of climate and land use changes
  - Use of innovative engineering solutions such as wetland system to increase treatment plant resilience

# Wetland Treatment System in Jiaxing Water Treatment Plant



Source water

Wetland  
inflow

Wetlands

Ponds

## *Innovative Adaptation in Treatment Engineering*

- Surface water in streams of high levels of nutrients, TOC and other man-made pollutants
- Adaptation using constructed wetlands for water pretreatment and also for scenic values as a local park
- Total nitrogen and phosphorus reduced by a half before water reaching to the water treatment plant
- The plant using a sequence of aeration, coagulation, ozonation, GAC filtration, flocculation, and sand filtration, produces stable water production for the communities

Diversion weir

Water plant

# QTJ River Watershed Case Study: Adaptation Opportunities



| Issue  | Adaptation Option   | Mechanism  | Feasibility   |
|--|---|--|---|
| Salt water intrusion and inland urban flooding   | <ol style="list-style-type: none"> <li>1. Manage salt-lock dams and reservoirs for projected SLR</li> <li>2. Monitor and manage streams in lower river stretch</li> <li>3. Enhance storm water management systems</li> </ol>  | <ol style="list-style-type: none"> <li>1. Optimize salt-diversion dam and reservoir operations</li> <li>2. Prevent stream pollution for source water quality</li> <li>3. Systematically upgrade stormwater systems</li> <li>4. Use of green infrastructures</li> </ol>                     | <ol style="list-style-type: none"> <li>1. Good</li> <li>2. Good</li> <li>3. Fair</li> <li>4. Very good</li> </ol>               |
| Long-term high-quality water supply for Hangzhou   | <ol style="list-style-type: none"> <li>1. Water transfer from Qiantaohu Lake</li> <li>2. Use existing Fuchunjiang reservoir</li> </ol>  | <ol style="list-style-type: none"> <li>1. Build new canal from the lake to treatment plants;</li> <li>2. Shorter transfer distance, but greater watershed protection in Nanjiang subwatershed</li> </ol>   | <ol style="list-style-type: none"> <li>1. Very good</li> <li>2. Good</li> </ol>   |
| Operational resilience during the interim period to against source water quality deterioration | <ol style="list-style-type: none"> <li>1. Enhance water pre-treatment through the wetland system</li> <li>2. Increase treatment capacity for multiple pollutants</li> <li>3. Improve water disinfection efficiency and reduce disinfection by-products formation</li> </ol> | <ol style="list-style-type: none"> <li>1. Develop systematic monitoring datasets for optimal system operation</li> <li>2. Unit process optimization (e.g., using WTP-ccam)</li> <li>3. Remove TOC and its reactivity in source water</li> <li>4. Different disinfection methods</li> </ol> | <ol style="list-style-type: none"> <li>1. Very good</li> <li>2. Very good</li> <li>3. Possible</li> <li>4. Very good</li> </ol> |



# Summary

- Rapid urbanization as the dominant stressor on water supply, and climate impacts are also important factors
- Rapid urbanization and economic activities leading to high levels of nutrients in surface water – the source water for water supply
- Climate and Qiantangjiang River tide inducing salt water intrusion along the river
- A series of data needs for analysis of potential adaptation opportunities
- Research questions



# Research Questions



- How does the impervious surface in urban development affect precipitation runoff and nutrient influx into streams? (Hint, review Module #2 and preview of module #12)
- What are major approaches to promote urbanization while protecting surface water quality?
- Describe the functions of green infrastructure and wetland systems for surface water management in urban development
- List known locations with significant salt water intrusion problem along the coastal rivers/streams in your country

# Looking ahead to the next module.....

- Case study: Systems approach to adapt water systems in multiple threats from storm surge and sea level rise
- Scoping of project topics

