Real Time Control in Urban Stormwater Management

IEEE Smart Cities Shanghai

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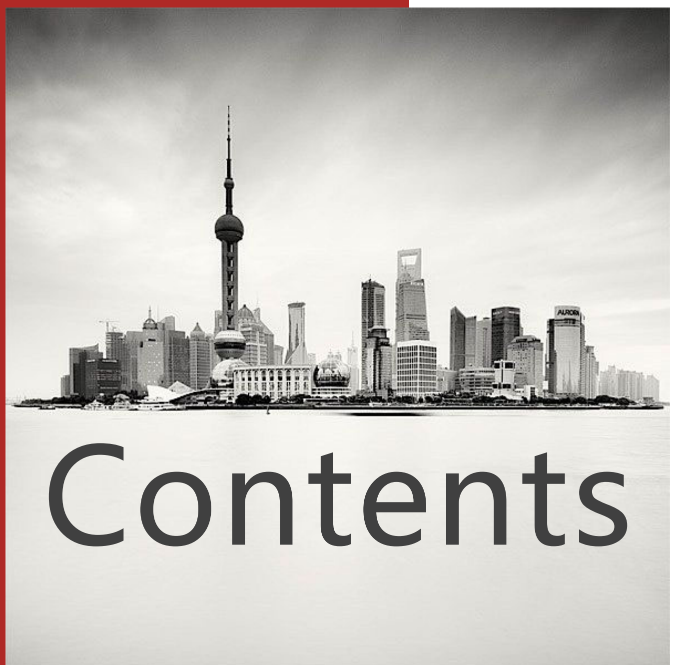


Contents

The Problem of Urban Flooding

Jinan, July 2005

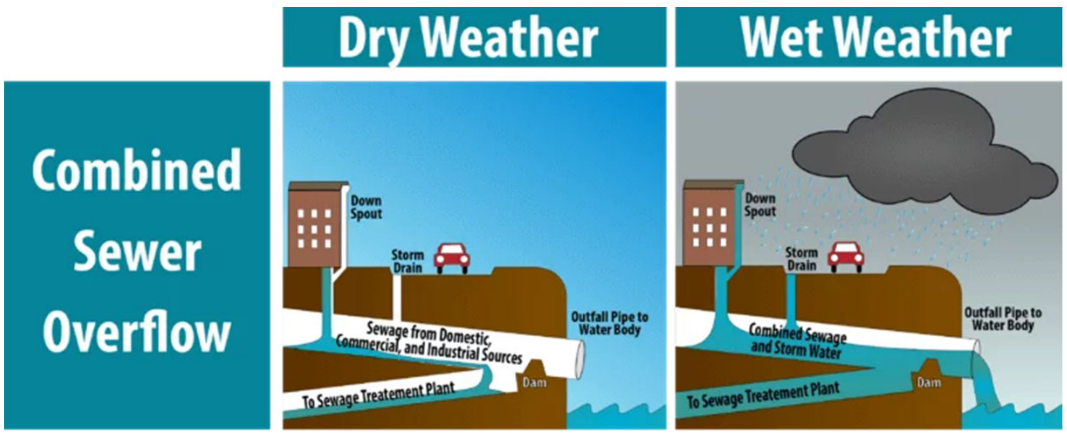
Chicago, June 2021

A Serious Problem

- Tangible Impacts: annual loses range in $7 billion to $9 billion,
  greatest loss in 2015 caused $55 billion (US EPA);
- Impacted People: 83% of surveyed residents experienced urban flooding nationwide,
  unproportionally high percentage of low-income community flooded;
- Intangible Impacts: spread of disease; impacted public service; loss of life;
  landslides; degradation of the ecological system;
- Increasing Frequency: extreme weather events;
  development within floodplain could double by 2050 relative to 2001.

References: Farming the challenge of urban flooding in the United States; trends affecting Urban Flooding; The growing threat of urban flooding

The Formation of Urban Flooding



- Rapid increase of impermeable surface;
- More frequent extreme events;
- Rigid volume capacity of sewage pipes;
- Combined with municipal wastewater;
- The risk of sea water intrusion..

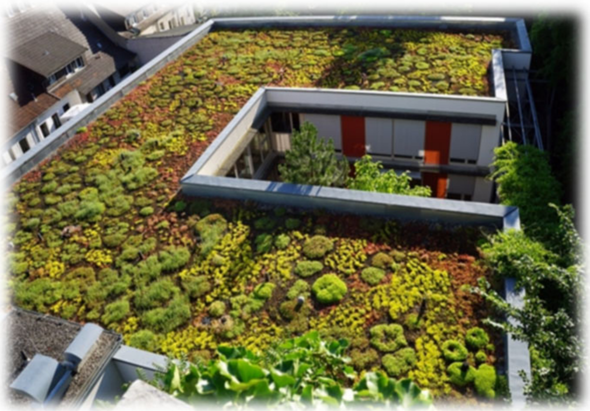
Reference: [sanitary vs combined sewer systems]

Green vs Grey Cities

Reference: [‘Sponge City’ in Jinhua, Zhejiang, China]

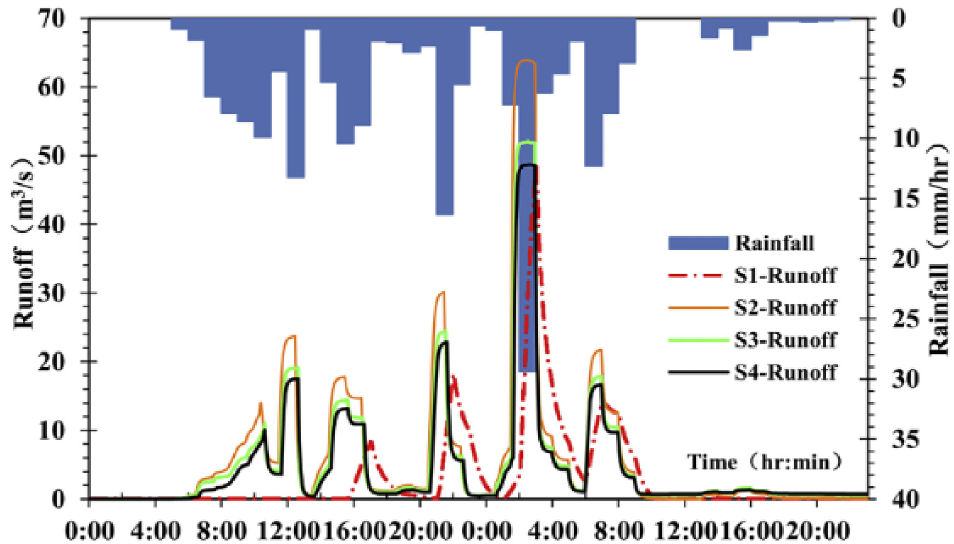
Turning Grey Surfaces Green

Sponge City, Green Infrastructure, Best Management Practices

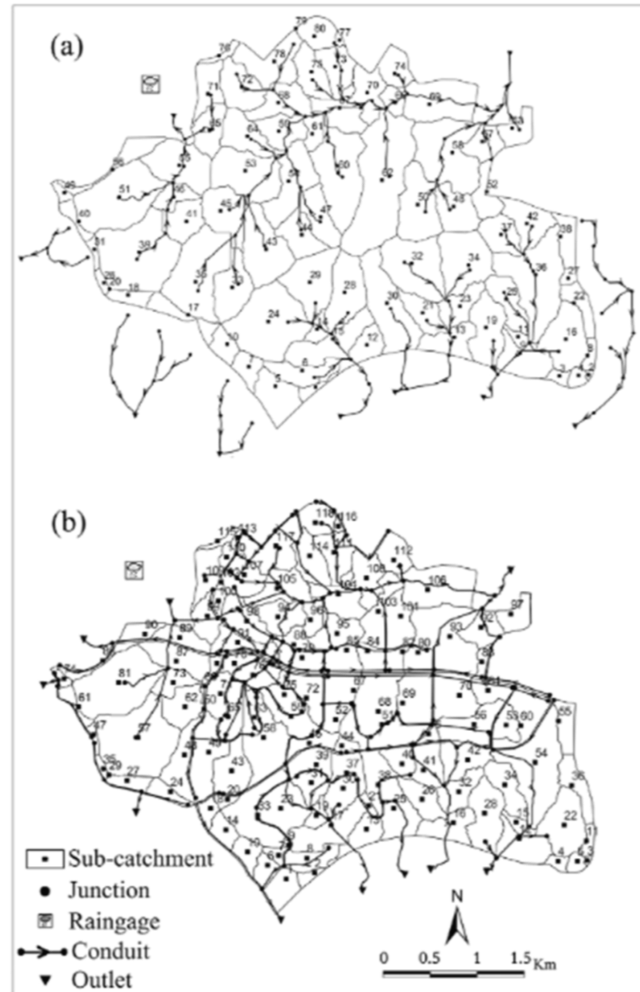


Reference: [The Stormwater BMPs]

Effects of Green Infrastructures

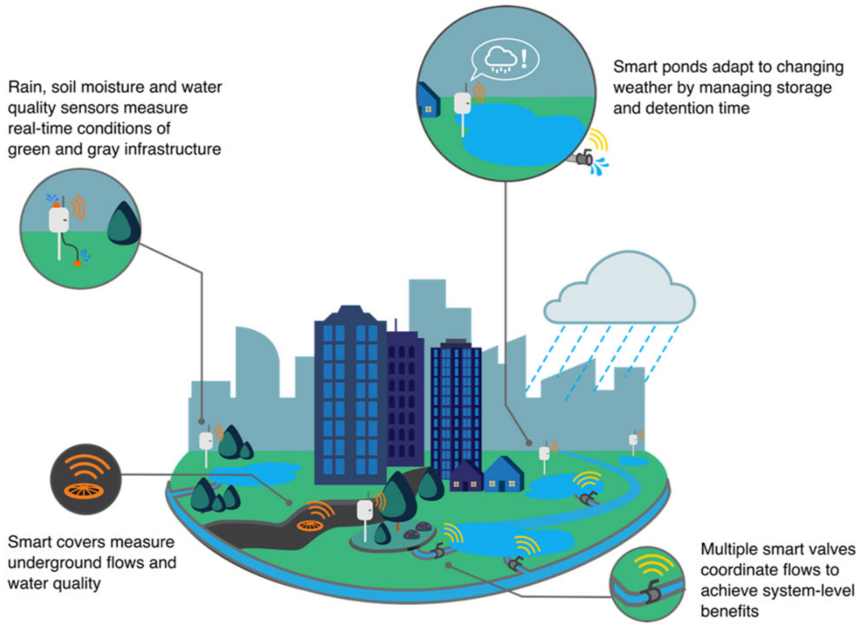


- With grey development, 33% increase of impervious surface yield to 92% increase of runoff;
- A 17% decrease of grey surface by implementing GIs results in 17% and 19% reduction of runoff volume and peak;
- A careful design of routing result in another 11% runoff reduction.



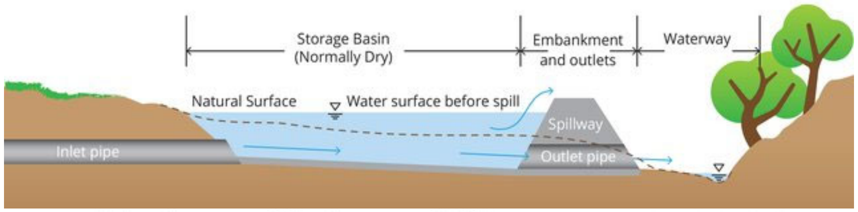
Reference: [Fanhua Kong, et., al.]

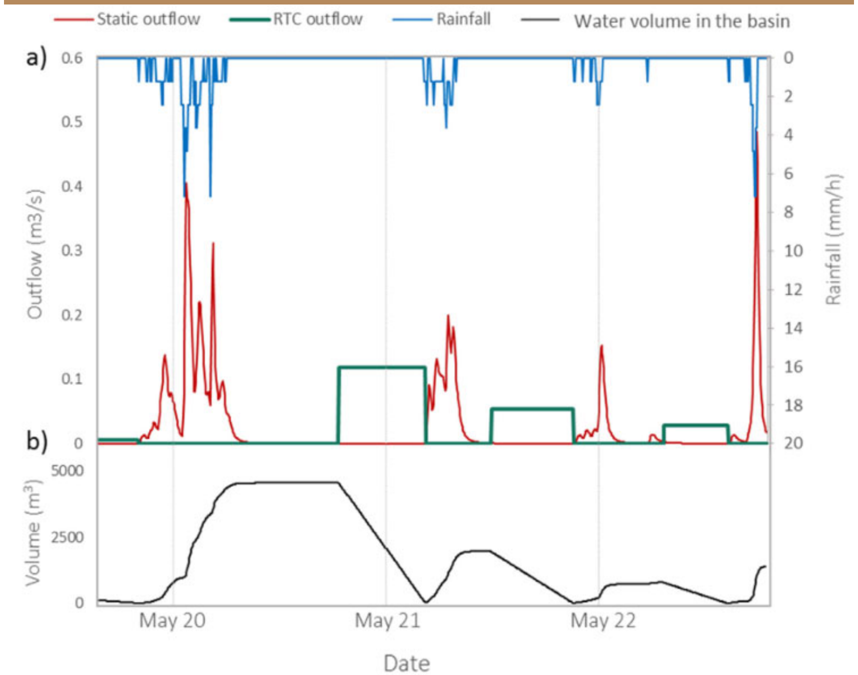
Make It Smart with Real Time Control



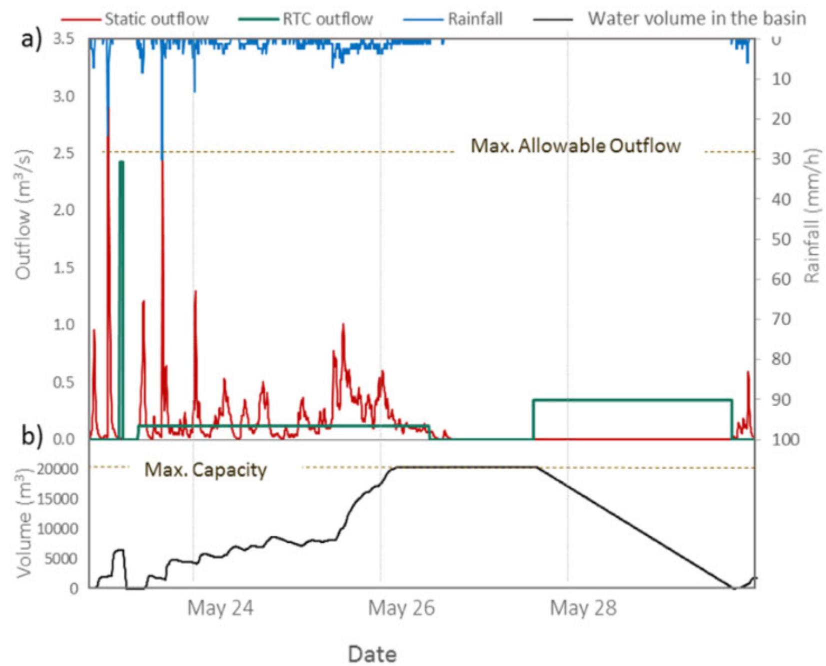
- Integration of Weather Forecasts;
- Balancing between Hydrological and Water Quality Perspectives

The Hydrological Perspectives





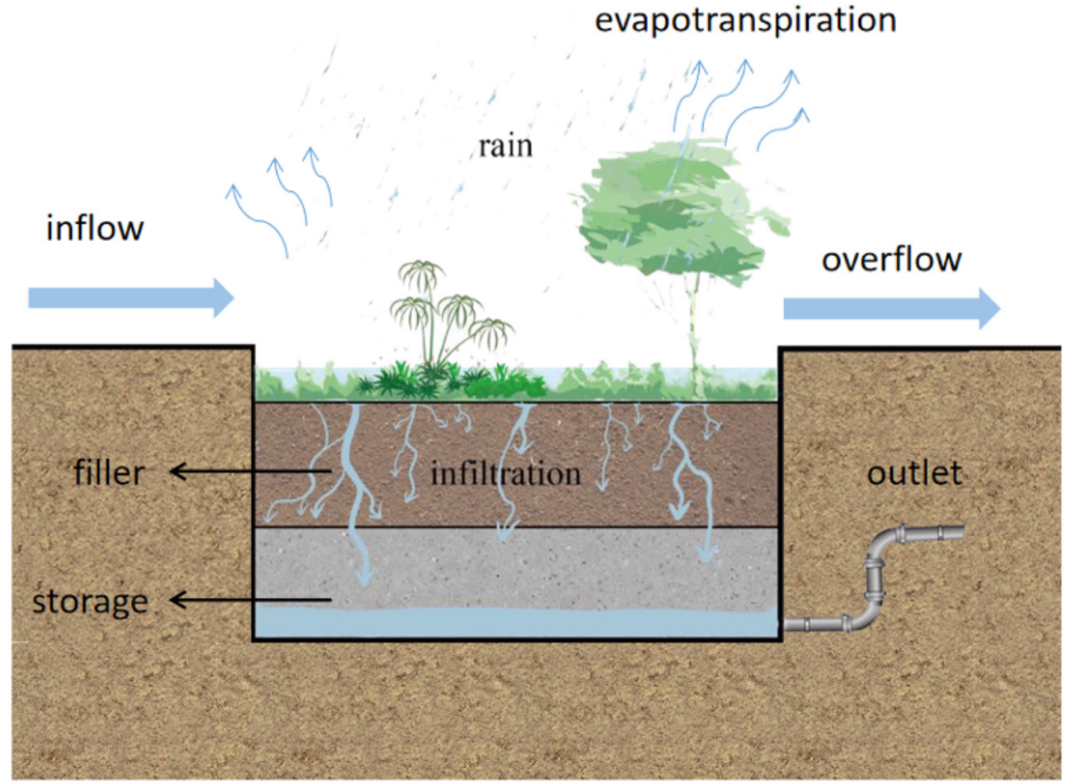
- ➢ Control of outlet pipe valves according to predictions on weather conditions, water supply requirements, and downstream hydrology.



References: Shadab Shishegar,et., al. An integrated optimization and rule-based approach for predictive real time control of urban stormwater management systems.

The Water Quality Benefits
and Why Bioretention Systems are of Special Interest

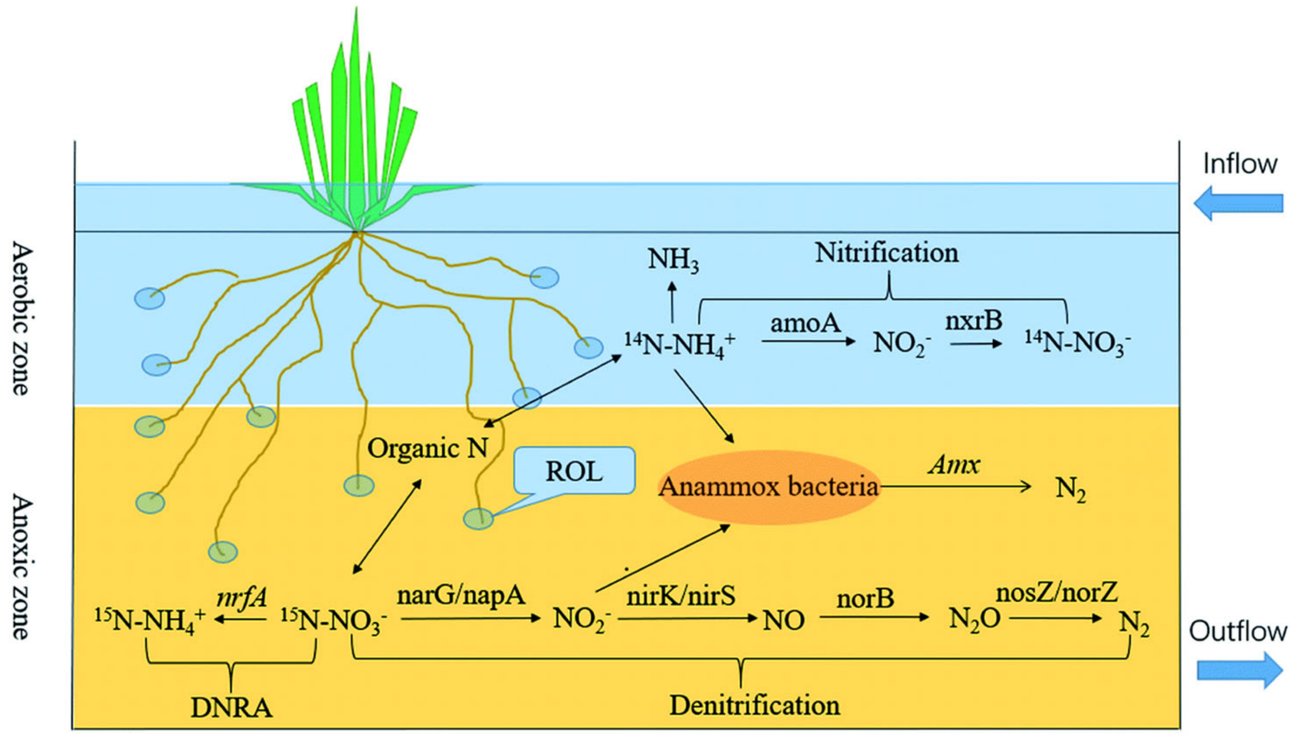
- Sediment Control;
- Capture of Total Suspended Solids;
- Pathogen Removal;
- Reduction of Nutrients, including Total Phosphorous, *Total Nitrogen, Ammonium, and Nitrate*;
- Degradation of oil and grease, and other organic chemicals;
- Adsorption of heavy metals…



References: [Guohao Li, et., al. Design influence and evaluation model of bioretention in rainwater treatment: a review]

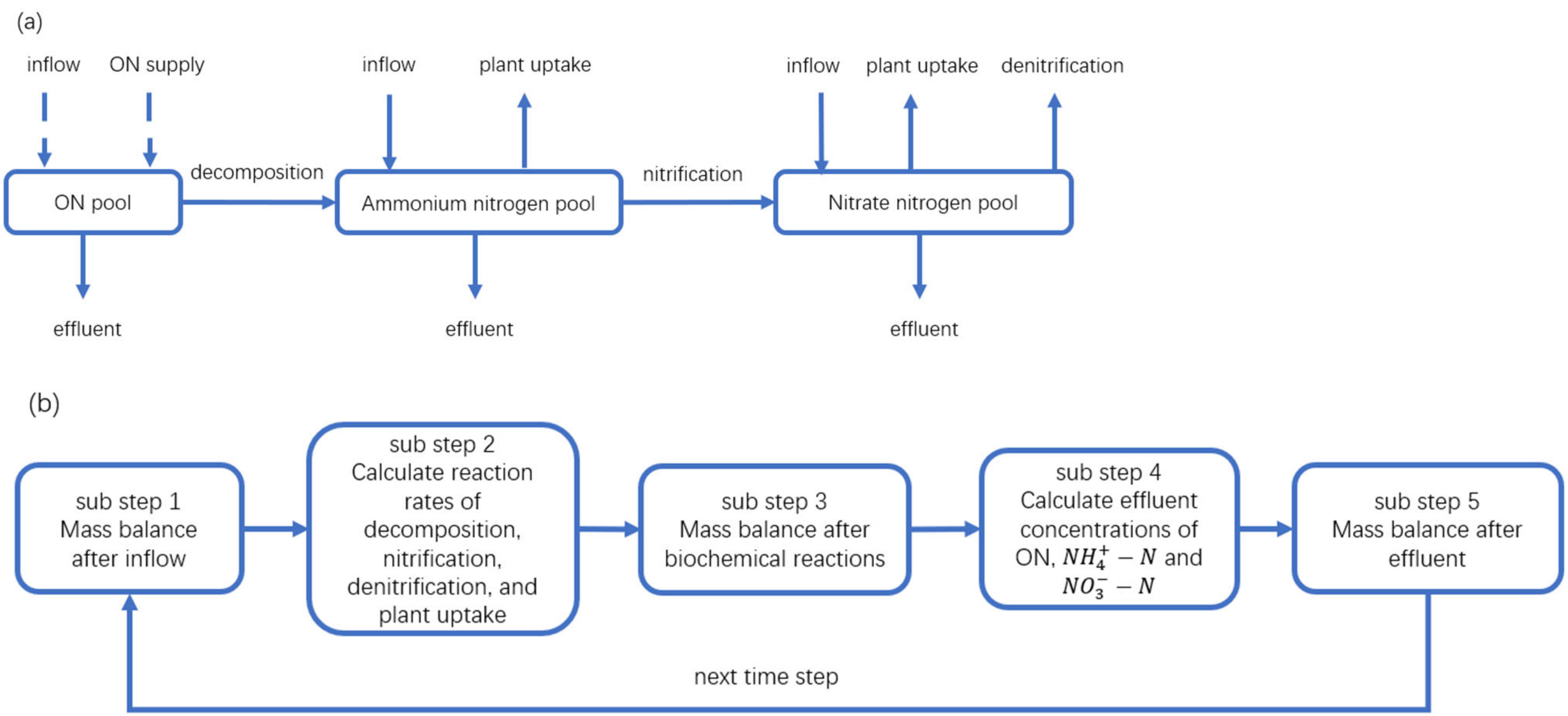
Handling Nutrients Removal
Where the Current Sensors and Models are Limited

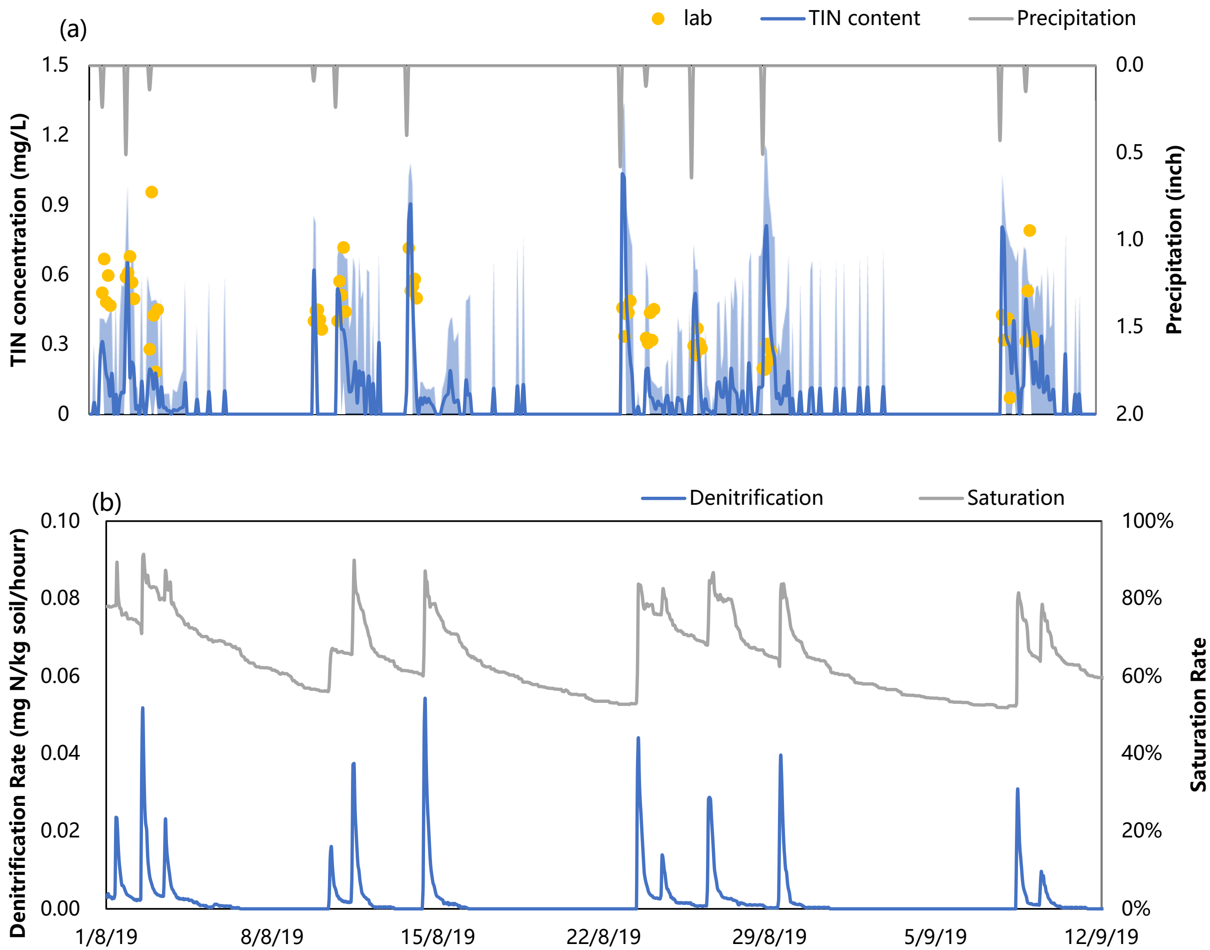
- ➢ Multiple nitrogen-related biochemical processes;
- ➢ Significant impacts of environmental factors;
- ➢ Lack of long-term monitoring data;
- ➢ Previous overlook of contaminant removal



References: [Tao Chen, et., al. Plant rhizosphere, soil microenvironment, and functional genes in the nitrogen removal process of bioretention]

Novel Nitrogen Modules





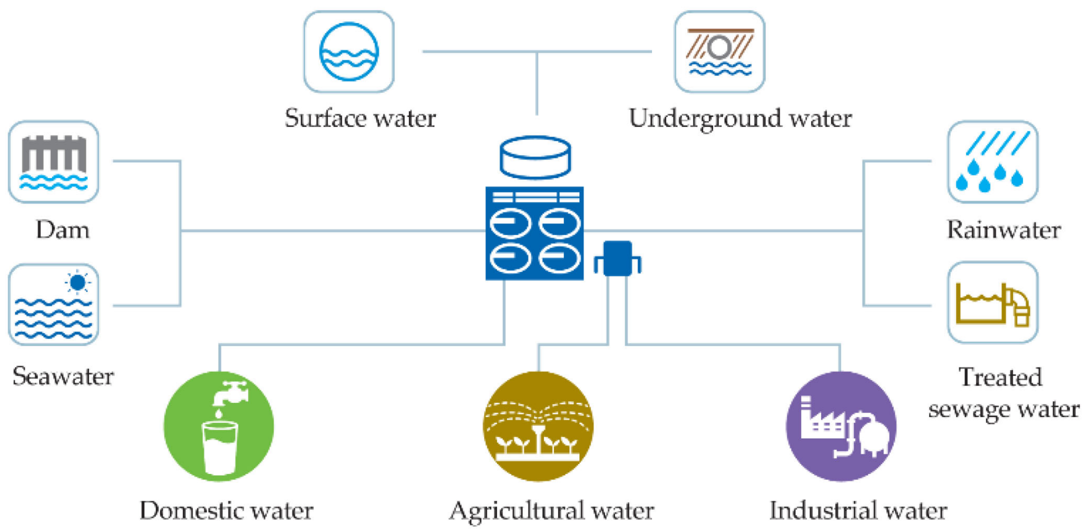
Novel Nitrogen Modules

- Calibrated with tested nitrogen concentrations;
- 20% higher prediction accuracy on nitrogen removal rates and effluent concentrations;
- Offers time series of biochemical reaction rates and nitrogen contents;
- Assists the design of RTC;
- Assists the research on interactions among nitrogen transformation processes and the influence of environmental factors.

Testing RTC Strategies for the Future

- Under future weather conditions projected for year 2100;
- RTC1: retain water for certain time period, discharge according to weather forecasts (discharge water until field capacity at 24 hours prior to the next event; keep bioretention 80% saturated until next discharge);
- RTC2: RTC1 +maintain saturation rate during events (discharge water 24 hours prior to the next event, retain 80% saturation rate during events until 24 hours after each event);
- RTC3: RTC2 + consider impact of temperature (discharge water 24 hours prior to the next event, retain 80% saturation rate during events, for 24 hours when daily average temperature >30 ℃, and 48 hours when daily average <30℃);
- Test with uncertainties from weather forecasts: longer, heavier, earlier events compared to forecast

Make It Smarter: The Perspectives



- Connecting the entire urban water system

Q & A

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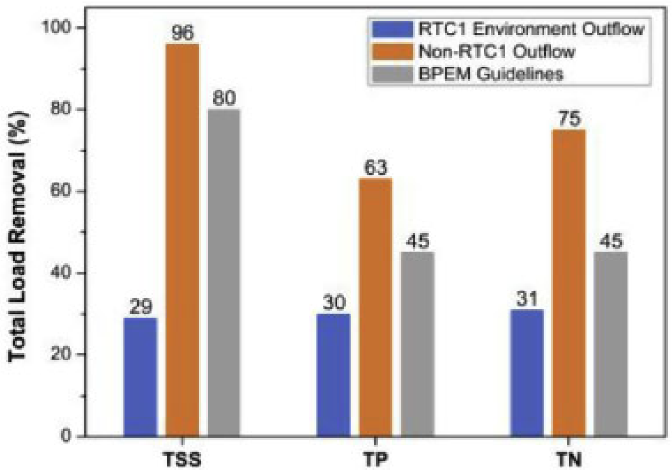
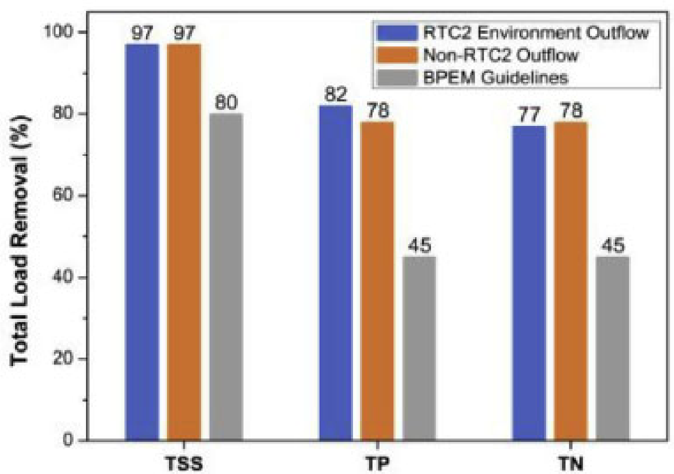


Round 1: RTC Strategy 1 (Harvesting)



Round 2: RTC Strategy 2 (Harvesting-Environment)

Volume Reduction vs Contaminant Reduction

The Conflicting Requirements from Hydrologic and Water Quality Perspectives

- Primary goal: prevent overflow vs harvest water;
- Real Time Control Strategies categorized:
  - ✓ Water detained for certain time period;
  - ✓ Maintaining water levels in bioretention;
  - ✓ Depending on weather forecast;
  - ✓ Depending on contaminant levels…

Reference: Pengfei Shen, et., al. Real time control of biofilters delivers stormwater suitable for harvesting and reuse