MAGEEP Education Network

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Water System Adaptation to Hydrological Changes

Module 2

Stormwater Management and Sewer Performance under Intense Storms: Case Study from Lawrence, Massachusetts, U.S.A.

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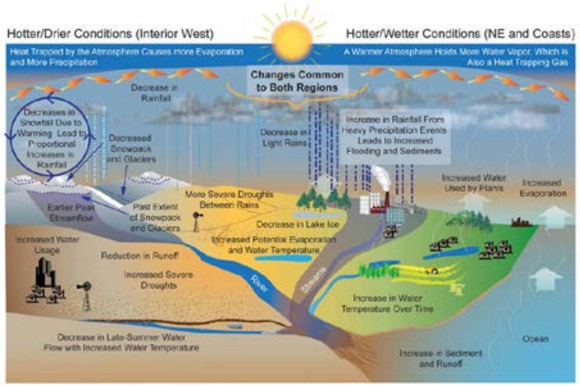


Course Roadmap

Project and case studies

Case Studies to illustrate specific water system stressors and adaptation considerations

Research and data needs

(Modules 1-6)

Region-specific applications

Adaptation Principles: Definition and application to different scenarios

Assignment 1

(Module 7)

Hands-on exercises

Policy considerations: Examples of current policy frameworks. Opportunities and challenges for systematizing climate adaptation.

Research and data needs for decision support

Assignment 2

(Module 8)

Decision-support

Methods, models, and tools relevant to individual and combined effects from water system stressors

Research and data needs

Assignment 3

(Modules 9-14)

Course outcomes

Knowledge about water system stressors

Adaptation principles

Governance

Strengths and limitations of models

Research directions

Module 2 Learning Objectives:

- Understand linkages between water systems, multiple stressors, and water adaptation to hydrological changes
- Define water system resilience under multiple stressors varying in intensity, duration, and frequency

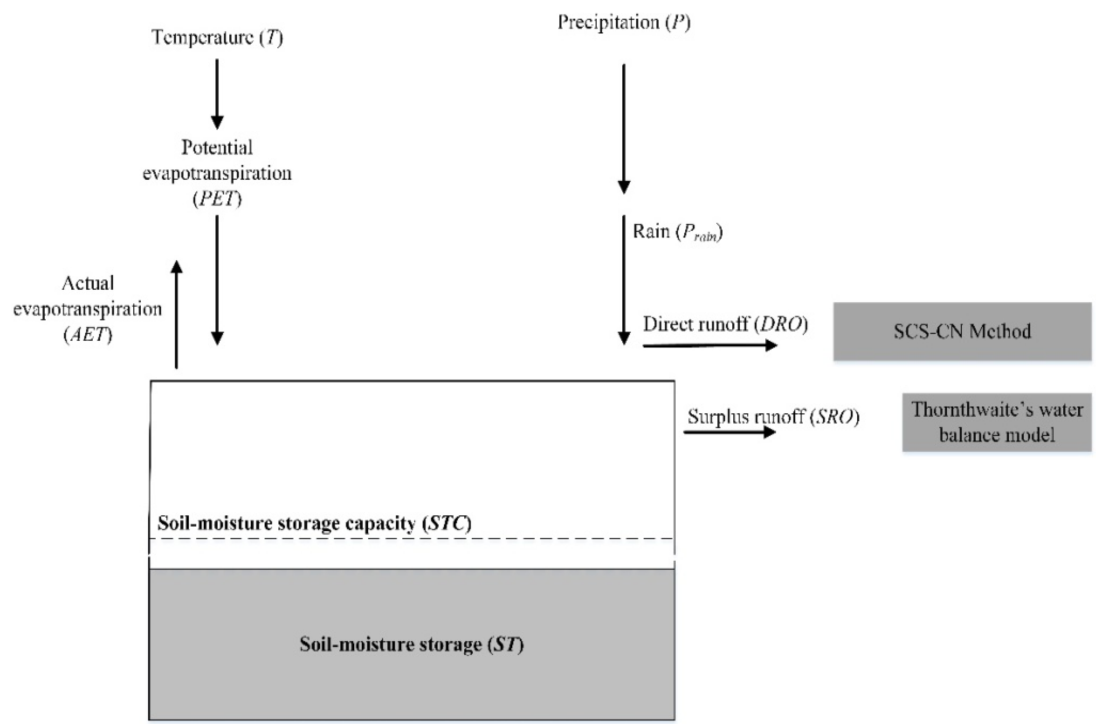
Key Topics: Module 2

- Case Study context
- Locational attributes
- Multiple stressors
- Adaptation opportunities
- Policy/governance considerations
- Data and information needs
- Availability of appropriate models
- Research questions

Mass Balance of Stormwater Flow in Urban Settings

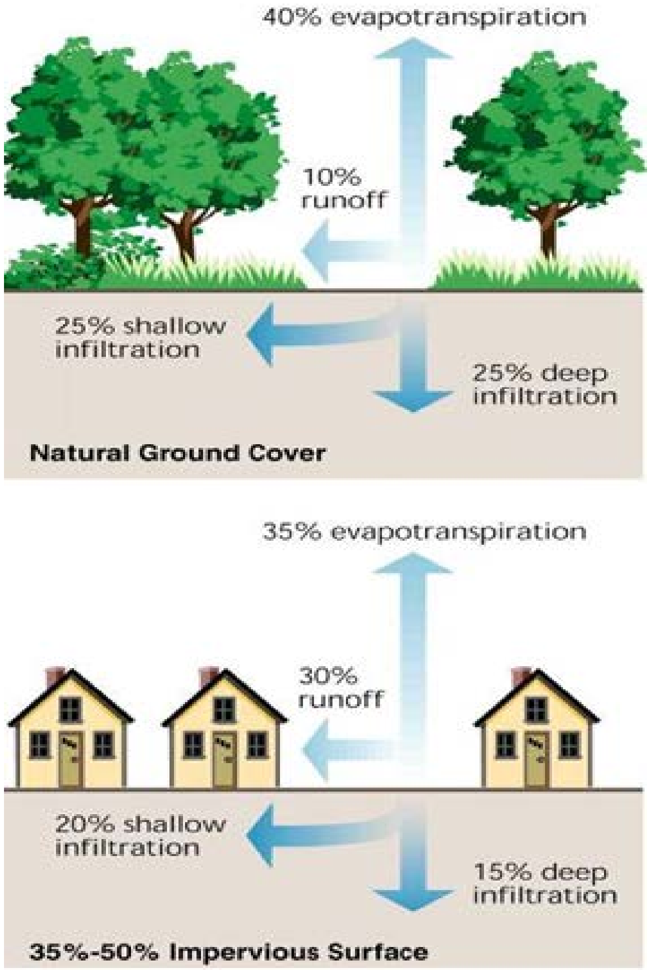
- Main concepts
  - Runoff in urban catchments varies with location, time, land-use, and infrastructure
  - Direct cumulative runoff (*DRO*) depends on precipitation (*P*), initial abstraction (or rain absorption before runoff takes place) (*Ia*), and curve number (*CN*)
  - Antecedent weather affects soil saturation and assimilative capacity

- Adaptation questions
  - How can we ensure that adequate storage capacity is available for intense storms
  - Where are the most vulnerable components of the system?
  - What options are available to build resilience?
  - Can surplus storm water be collected and reused?



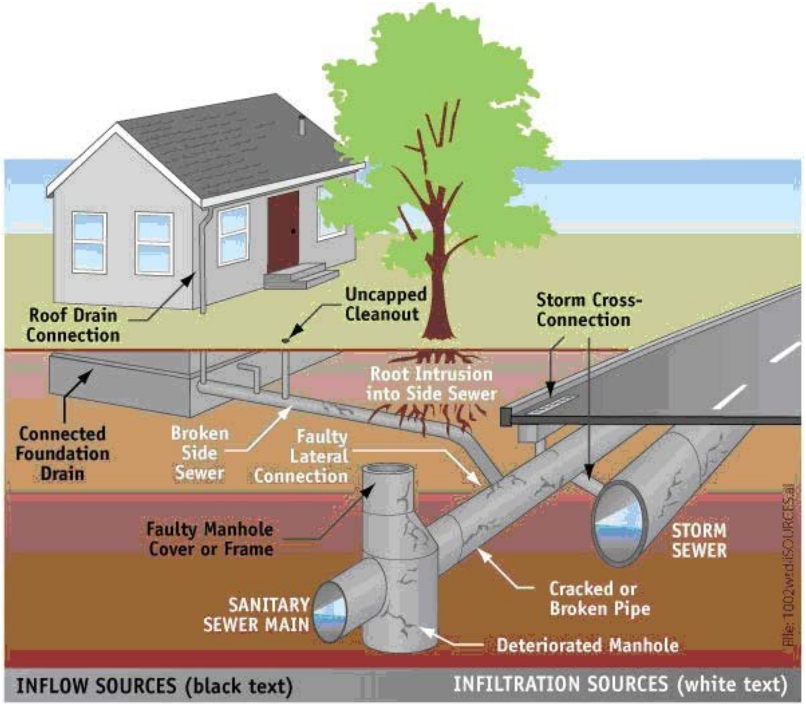
Data Requirements for modeling Stormwater Flow in Urban Settings

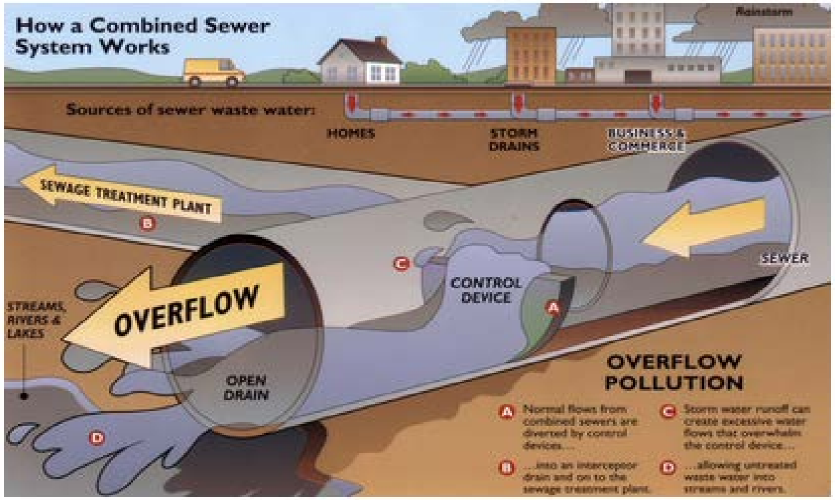
- Data requirements
  - Intensity, duration and frequency (IFD) of precipitation (design storm)
  - Proportion of pervious surfaces; catchment properties
  - Assimilative/storage capacity
  - Temperature profile
- Modeling questions to answer
  - What is the maximum capacity of current storm water collection system?
  - How is the maximum capacity compared to the flow under current and future precipitation?
  - How can land cover and land use in the catchment be modified using green infrastructure to change the runoff?



Sewer Overflow Scenarios

- Sewer overflows occur when runoff exceeds flow diversion set point due to infiltration, inflow, or capacity exceedance:
  - Sanitary sewer overflows (SSO)
  - Combined sewer overflows (CSO)
  - Stormwater collection systems
- The consequences of overflows include flooding, water quality contamination, erosion, and nuisance conditions.



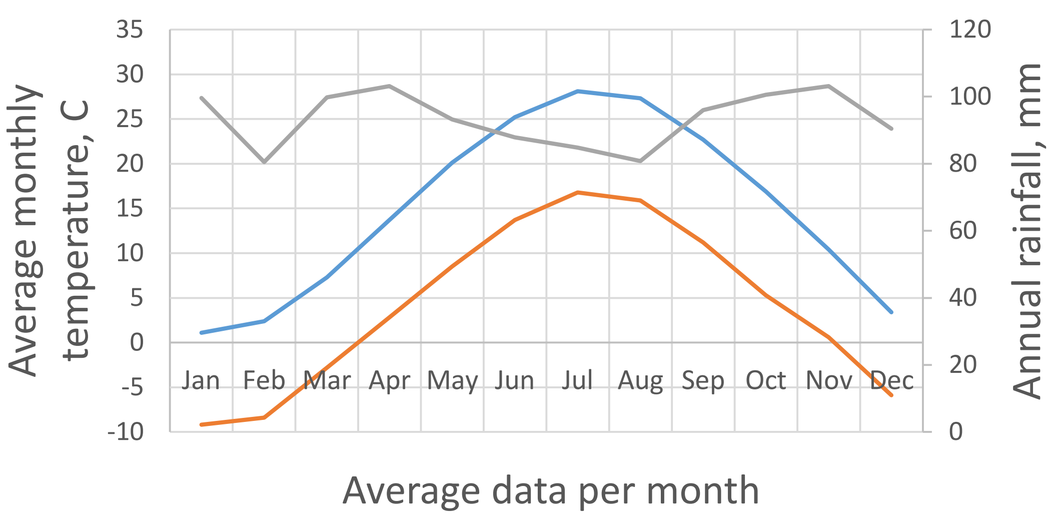


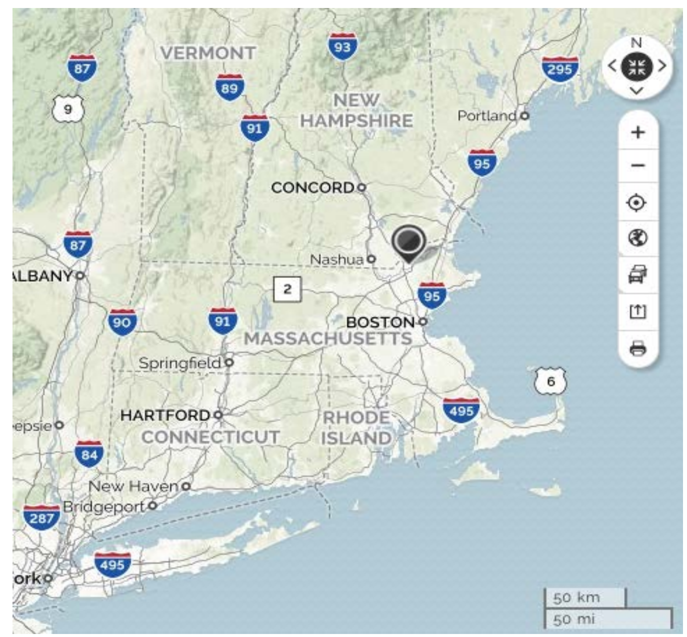
Case Study I: Context

- Historically, cities developed along waterways
  - Ready access to freshwater supply
  - Ready access to receiving waters for discharges of (treated) wastewater and storm water
  - Navigation routes
- Typical infrastructure design principles
  - 30-50 year design life
  - Hydrological analysis for historical flow and precipitation patterns
  - Attention mostly on land-use projections and extent of pervious/impervious surfaces
  - Water withdrawal and patterns based on historical precedents
- Stressors
  - Storm and drought frequency, intensity, and duration
  - Temperature variability
  - Changing patterns of water use
  - Flooding risk and water quality impairment
- Is adaptation feasible or practicable?

Case Study I:
Infrastructure Resilience under Climate Variability

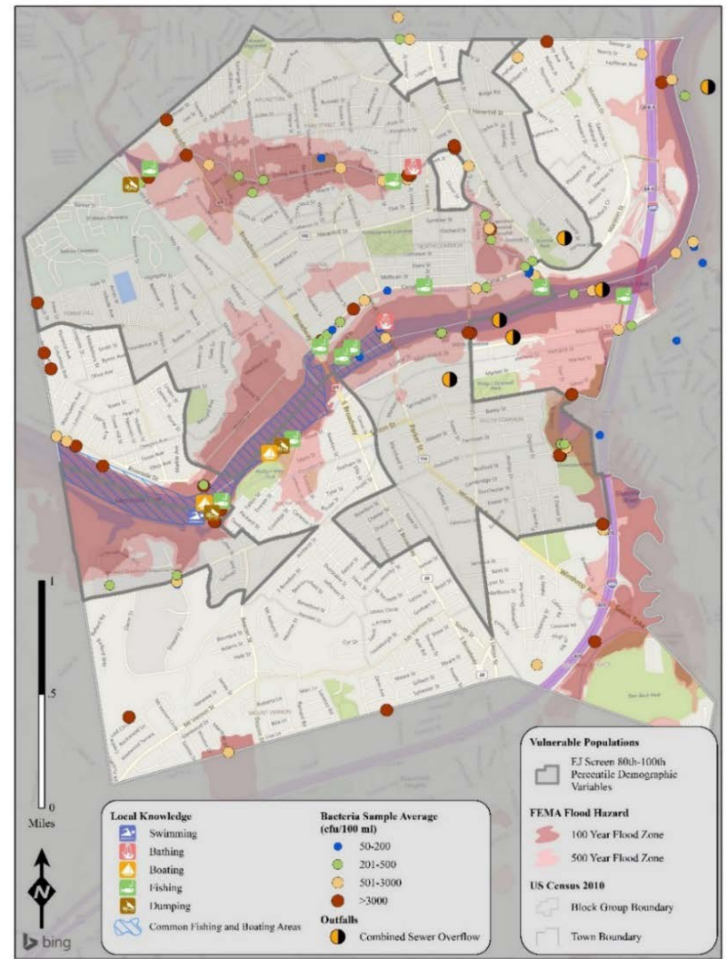
- [Lawrence, Massachusetts, USA]
    - Northeastern US
    - Population: 77,000
    - Settled in 1655; incorporated in 1853
    - 19.2 km^2 (7.4 $miles^2$)
- Economy
    - Textile manufacturing in 19^{th} and 20^{th} centuries
    - Currently manufacturing of electronic equipment, textiles, footwear, paper products
- Seasonal temperature and rainfall trends





Water System Constraints

- Population and industry are adjacent to Merrimack River
  - ❖ Drinking water supply for Lawrence and nearby communities along the river
  - ❖ Water treatment facility on river bank
- Combined stormwater and wastewater collection system
  - ❖ Outdated and under-designed infrastructure with inadequate capacity
  - ❖ Changing patterns of high-intensity storms and precipitation events
    - ❖ 10-yr Return Interval (RI) : increased from 4.94 to 6.5 inches
    - ❖ 25-yr-RI: increased from 6.08 to 8.4 inches
  - ❖ Collection systems (combined sewers and sanitary sewers) prone to overflows
- Water quality concerns
  - ❖ Pathogens and chemicals in river
  - ❖ Waste and refuse accumulating in river



Courtesy of Zartarian (2016)

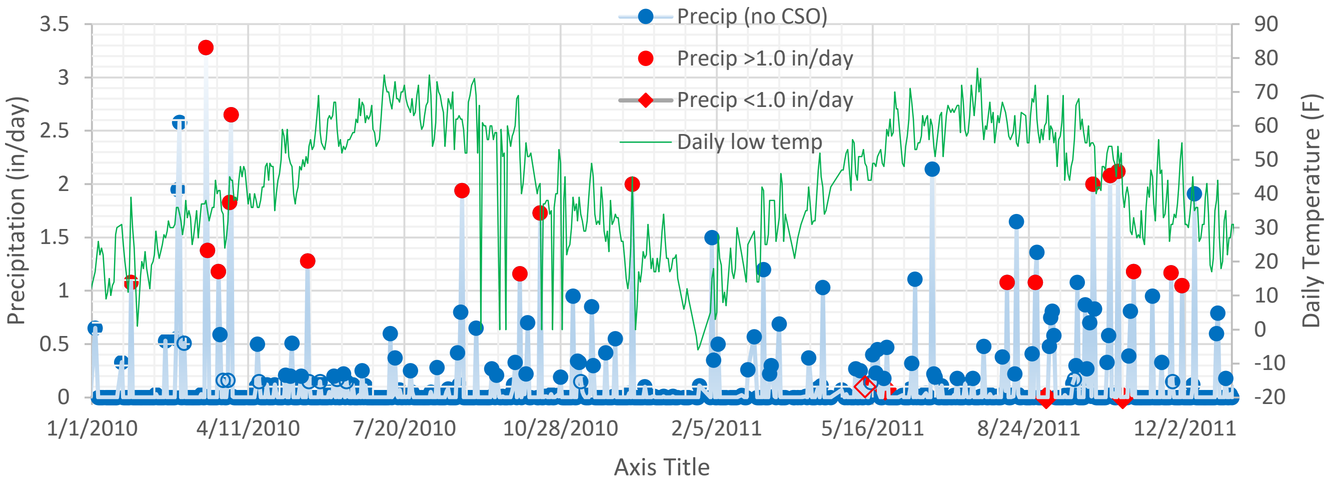
Stressors

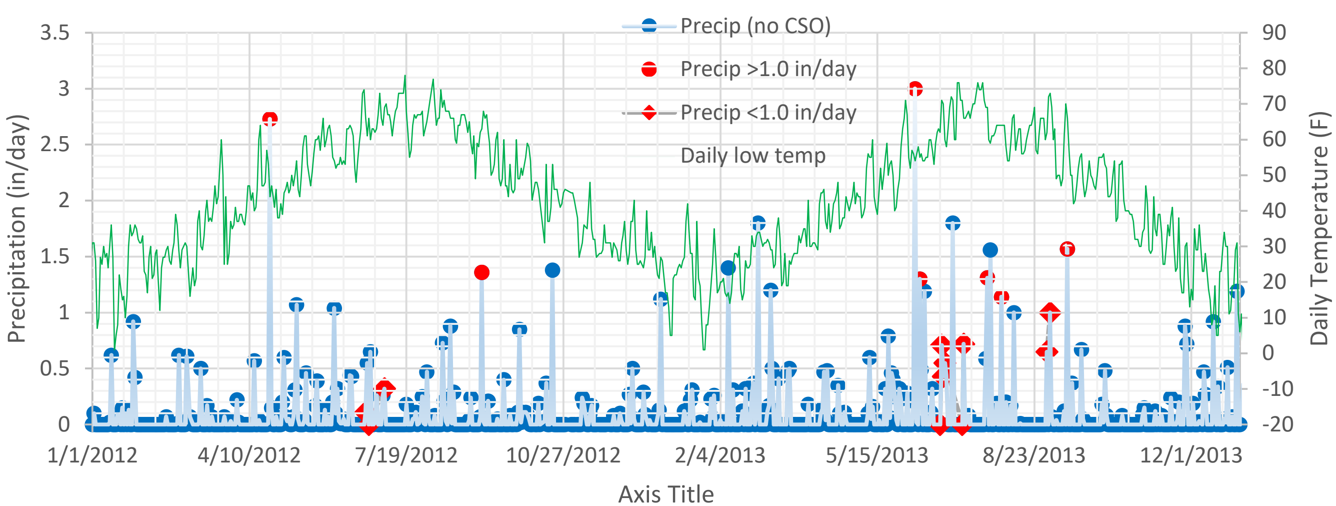
- Extreme storm events
  - Urban flooding and Inundation of water infrastructure: flooding risk
  - Public health concerns: pathogens, nutrients, chemical contaminants
  - Impaired or interrupted river function for navigation and recreation
  - Environmental justice
- Combined Sewer Overflows (CSOs)
  - Precipitation > 1 in/day (or 2.5 cm/day). See slide #12
  - Typically between March and December (non winter conditions)
  - Correlated to water quality impairment in the River (microorganisms, nutrients)

Key Adaptation Questions

Question	Data inputs	Modeling concepts
Are there detectable changes in precipitation patterns that should be considered in designing and adapting water infrastructure systems?	Hydrologic data	Precipitation return interval
To what extent are changes in the frequency, intensity, and duration of storm events responsible for sewer overflows?	Infrastructure condition	Stormwater runoff volume, peak flow, and time of concentrations
Are there predictable water quality changes that are correlated to storm events?	Literature review, historic data	Statistical analysis
Can the HACCP framework be used to define feasible critical control points?	CSO health risk, surface water quality standards	Control threshold on CSO occurrence

Lawrence Case Study: Precipitation and CSOs





Symbols: ● ◆ - CSO events

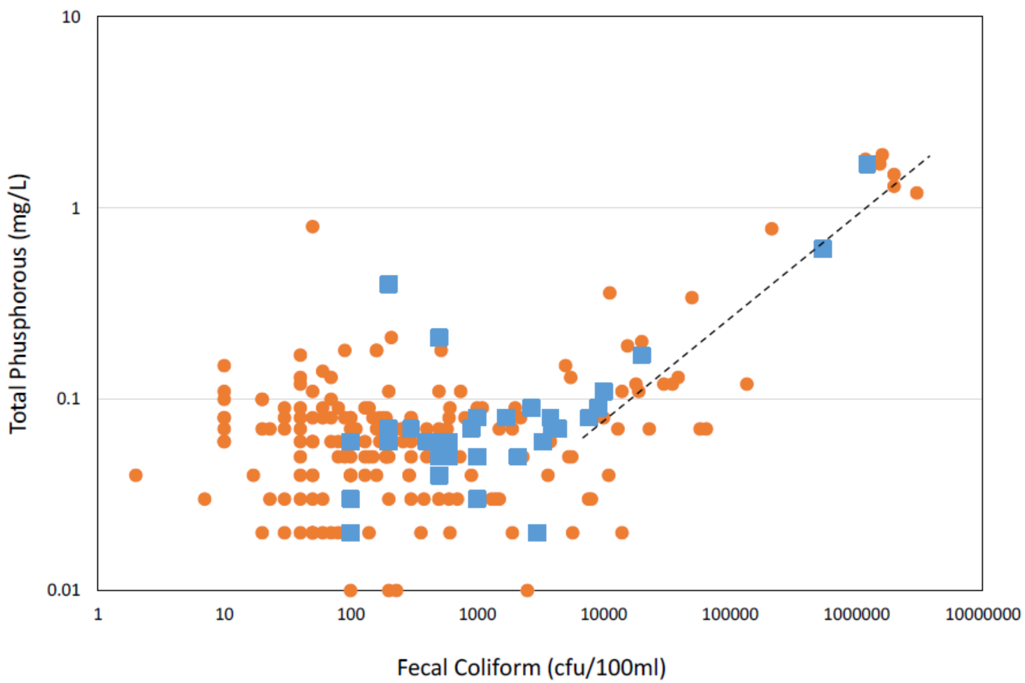
Monitoring Data & Observations

- Seasonal patterns 2010-2013
  - CSO events occurred when intense precipitation >1 inch/day
- Significant increase in frequency of high-intensity storms after 1990s

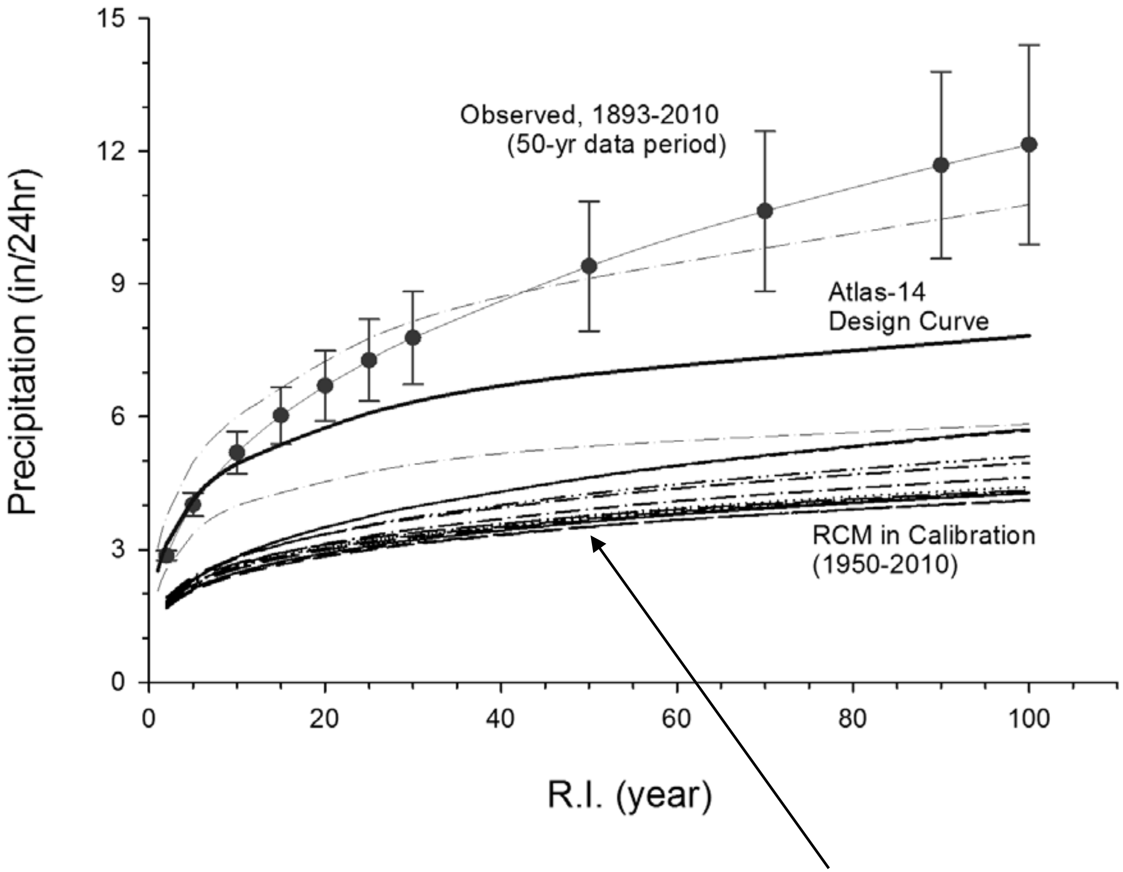
Lawrence Case Study: CSO events and Water Quality

- Microbial indicators (fecal coliform) and phosphorus levels in river water correlate to CSO events
- Networked stations along the river for water quality monitoring
- Pilot-testing of early warning system
    - Project water quality in next hours
    - Alerts and trigger points

Actual monitoring data at two CSO outfalls (circle and square symbols) at Merrimack River in Lawrence, MA



Analysis of Precipitation Patterns



R.I. – Return interval (yr)

All RCMs significantly under-predict design storm across the board

Observation

- High-intensity precipitation has changed since 1990s, and potentially into future

Future Prediction

- Regional climate models under-estimate the design storms for calibration period
- Post-processing of RCM data is necessary for projections and in design storm revision

Building Resilience for Intense Storms: Data and Modeling Considerations

- Data requirements for water treatment plants
  - Water quality trends in river
  - Water treatment system operation and performance
  - Infrastructure integrity (plant, pumps and controls, and distribution)
  - Water use patterns
  - Energy demand
- Model availability
  - Flood risk assessment (EPA CREAT)
  - Water quality (EPA WTP-ccam)
  - Source water variation to climate Stressors

Turbidity, TP, TOC, Precipitation, T …

Guiding Principles of Water System Adaptation

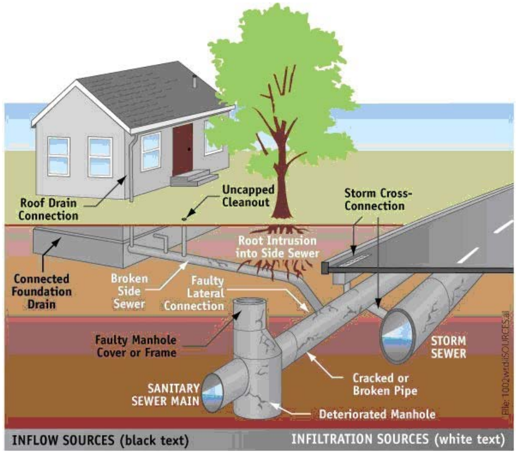
- Analyze the source, intensity, duration, and frequency of hydrologic disruptions at local, regional, and watershed scales
- Establish short-, medium-, and long-term goals, benchmarks, and milestones
- Evaluate and triage integrity, resilience, and security of water systems
- Define vulnerability to hydrologic threats and identify points-of-control
- Review literature and available decision-support tools
- Determine data and information needs and sources
- Develop actionable short-, medium-, and long-term adaptation plan

Lawrence Case Study: Adaptation options

Issue	Adaptation Option	Mechanism	Feasibility
Reduce potential for sewer overflows	• Decrease loading on wastewater collection systems • Increase stormwater management capacity	• Green infrastructure • Pipeline rehabilitation • Design modification to CSO division mechanisms • Additional storage facility	Good to fair
Public health protection	Safeguard drinking water system	• Treatment and upgrades • Real-time source water monitoring and treatment optimization • Flooding prevention measures • Communication for community support	Fair

Summary

- Aged CSO systems vulnerable to short- and medium-term increases in flow due to intense storm events
  - Runoff from watershed
  - Infrastructure limitations
  - Flooding
- Adaptation approaches also need to take a holistic analysis of watershed hydrology, land-use trends, and Infrastructure condition
- CSO mitigation and early warning systems critical to water supplies and health risk management



Turbidity, TP, TOC, Precipitation, T ...

Research questions

- What kinds of data are needed to develop actionable adaptation options for drinking water systems relying on rivers and streams
- Can sewer overflows be prevented? How?
- Can weather predictions and historical precedents serve as basis for early-warning of CSO occurrence?
- How to develop a water quality monitoring plan to reduce CSO-related risk in water treatment and supply?

Looking ahead to the next module.....

- Case study: Consequences of prolonged drought on urban water system resilience
- Scoping of project topics