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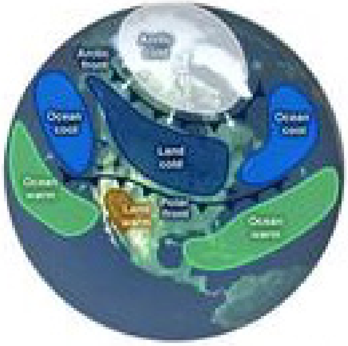

Water System ... tion To Hydrological Changes

Module 14: Life Cycle Analysis (LCA) and Prioritization Tools in Water System Adaptation

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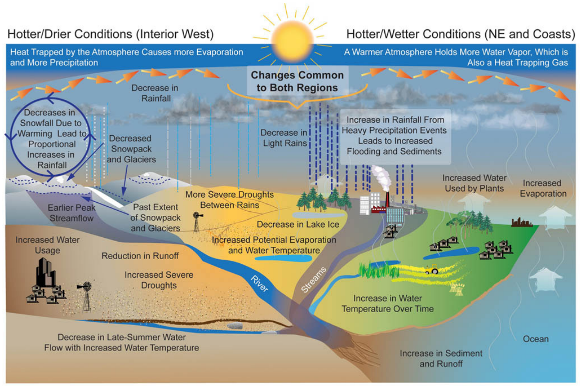


Course Roadmap

Project and case studies

Case Studies to illustrate specific climate 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 climate stressors

Research and data needs

Assignment 3

(Modules 9-14)

Course outcomes

Knowledge about climate stressors

Adaptation principles

Governance

Strengths and limitations of models

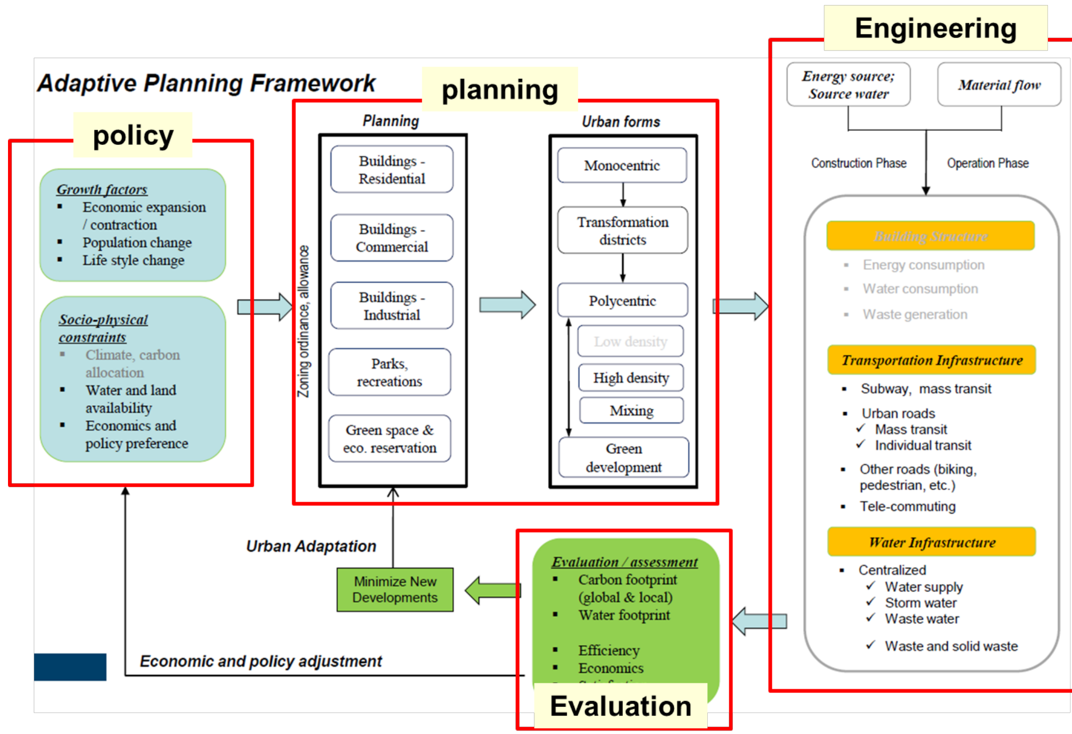
Research directions

Module 14 Learning Objectives:

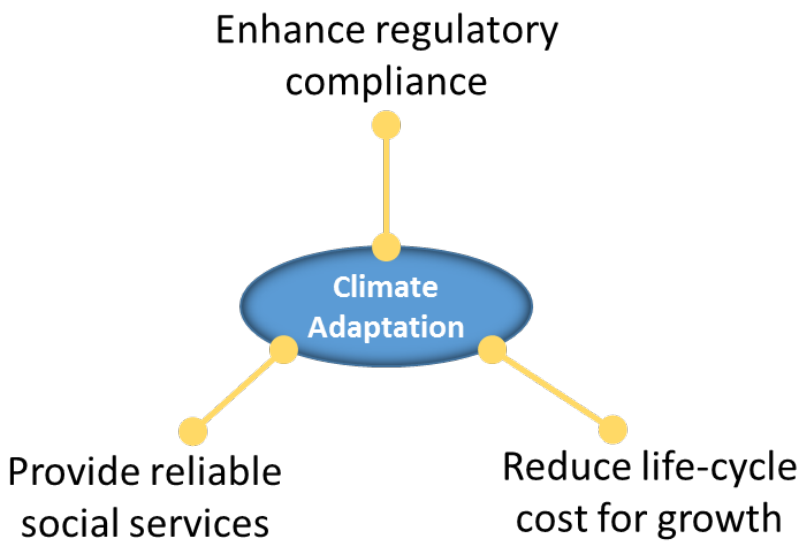
- Compare adaptation options for action
- Learn ways to quantify environmental benefits using carbon and water footprints in a life cycle analysis
- Review an example of water infrastructure master planning in adaptaton

Key Topics: Module 14

- Multiple adaptation options exist for a given management objective
- How to compare and select options using carbon and water index
- Economics or adaptation cost is the other important parameter
- Life-cycle benefit analysis (LCA) method for adaptation option among competing objectives
- Example of LCA in water infrastructure master planning in Manatee County, Florida, USA



Criteria and Methods in Adaptation Option Selection



Triple bottom line

Adaptation Objectives

- Ensure adequate and uninterrupted water supply to customers
- Comply with drinking water quality standards (e.g., Cl_f, THM, HAA, etc.)
- Increase operational efficiency (e.g., reducing energy, economics)

LCA in Option Selection

- Cost and cash flow
- Capacity and capacity reserve
- Environmental index (e.g., carbon footprint)

LCA for Water System Adaptation

Reasons to use LCA

- Multiple adaptation options often exist
- Water infrastructure has large footprint and difficult to change after construction, making it necessary to select the best or optimal adaptation options
- LCA allows one to evaluate adaptation benefits systematically
- Compare options on the same basis among independent and competing criteria such as cost, environmental indices, and carbon emission or avoidance

Sustainability opportunity

- Adaptation as an infrastructure improvement opportunity for better resilience and sustainability
- Sustainability examined in time span of future climate (>30 years)

LCA for Water System Adaptation

Water infrastructure service stages

- Design, engineering and construction phase
- Operation phase
- Decommission phase

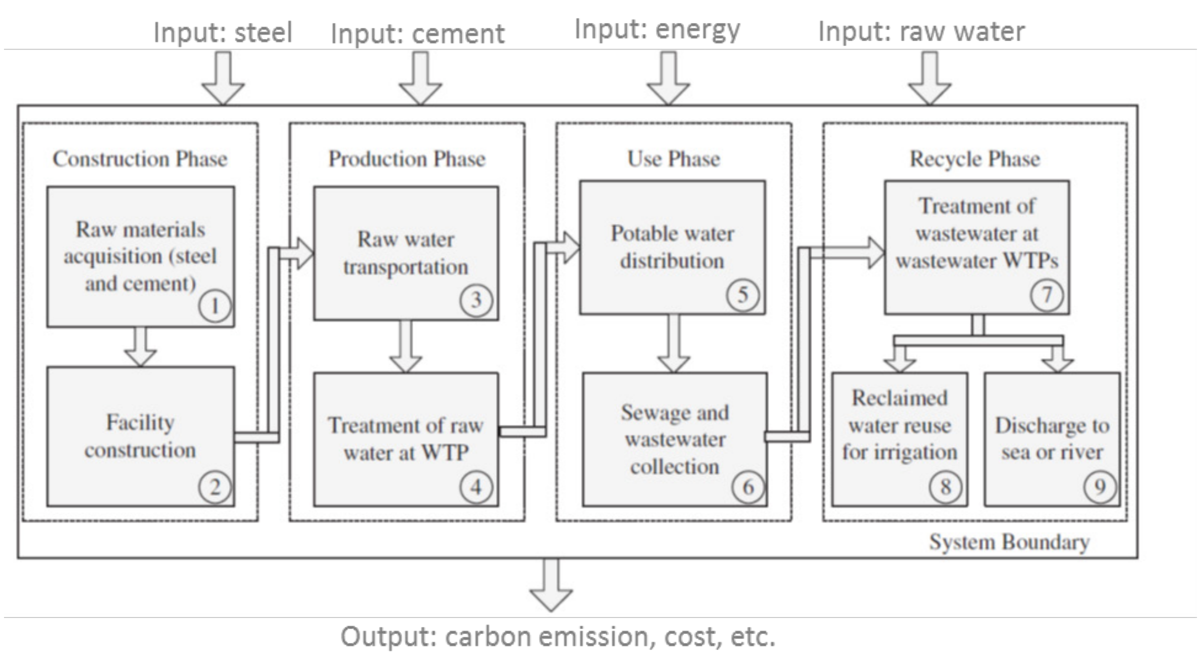
Carbon and cash flow in each service stage

- Materials and energy used, and waste disposal from each activity
- Options in system construction
- Policy and incentives in operation scenarios

Optimization model and programs

- Multi-objective mixed integer programming using compromise programming model (Zeleny, 1973)
- Pareto optimal solution analysis

System LCA diagram for the water system expansion in Manatee County, U.S.A.



Courtesy of Chang et al. (2012)

LCA for Water System Adaptation

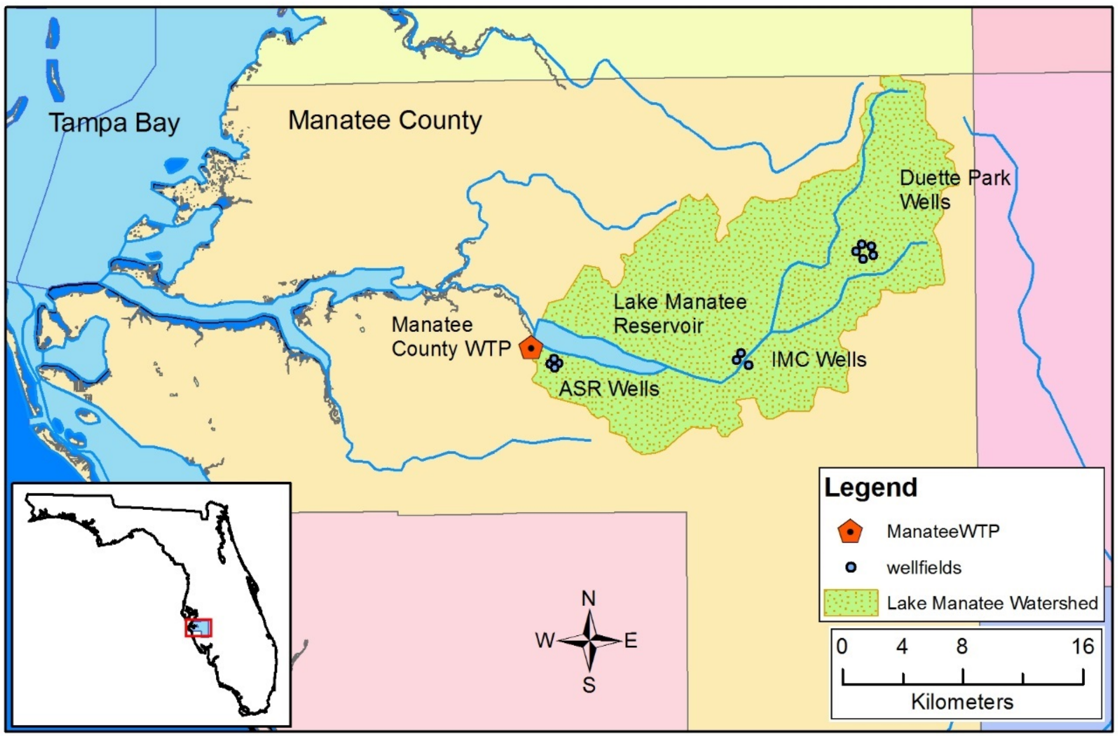
Major components of LCA analysis

- Define the physical boundary
- Clarify management objectives in developing evaluation criteria
- Engineering evaluation of all adaptation options
- For technically feasible options, analyze LCA attributes of the adaptation including cost, environmental indices, etc.

Models and methods for each of components (See subsequent examples)

Manatee Water System Master Planning:
A LCA Example

Adaptation in Water System Master Planning



Courtesy of Chang et al. (2012)

Background

- Manatee Country plans to expand its water supply system to meet the increasing water demand
- 20 options of expansion possible using groundwater, surface water, water use permit trading, regional water transfer, and water exploration from swamp and desalination
- Manatee River and groundwater aquifer are main sources, but depleting due to drought and increasing demand
- Precipitation change has made the water availability a pressing issue

Adaptation in Water System Master Planning

Examples of 20 expansion options in master planning

#	Name of Alternative	Brief Description
Ground Water Options		
1	MARS-I	This option is to supply new groundwater by developing a new wellfield in central Duette Park area near the existing ECWF-1.
2	MARS-II	This option is to supply new groundwater by developing a new wellfield in Erle Road Tank site.
3	MARS-III	These options are to supply new groundwater by developing a new wellfield. The location of the new wellfield has not yet been decided.

Courtesy of Chang et al. (2012)

Adaptation in Water System Master Planning

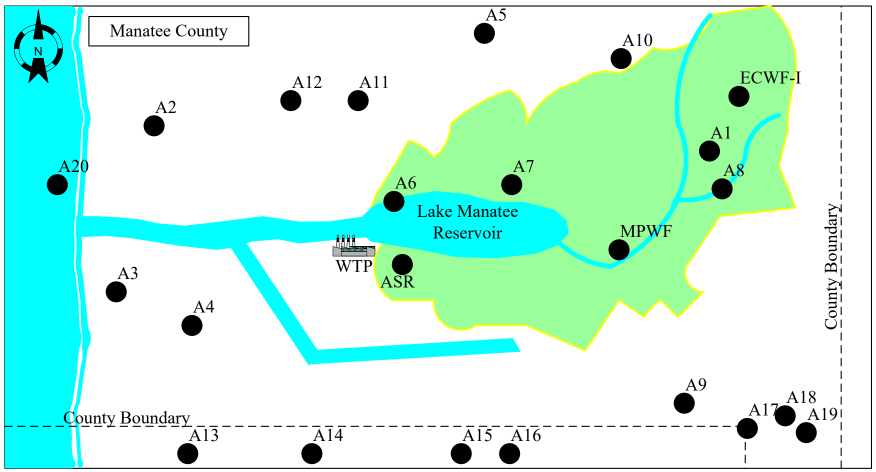


Illustration of relative locations for 20 water expansion options

Courtesy of Chang et al. (2012)

Objectives

- A feasibility analysis to lay out major components and their implementation for each master planning option
- LCA of each option to calculate present-day total cost and life-cycle carbon emission
- Pareto optimization to compare and select the optimal planning option at compromised cost and carbon emission
- Fine tune analysis to configure the best construction sequences for the selected option
- System operation to base on 20-year period in comparison

Adaptation in Water System Master Planning

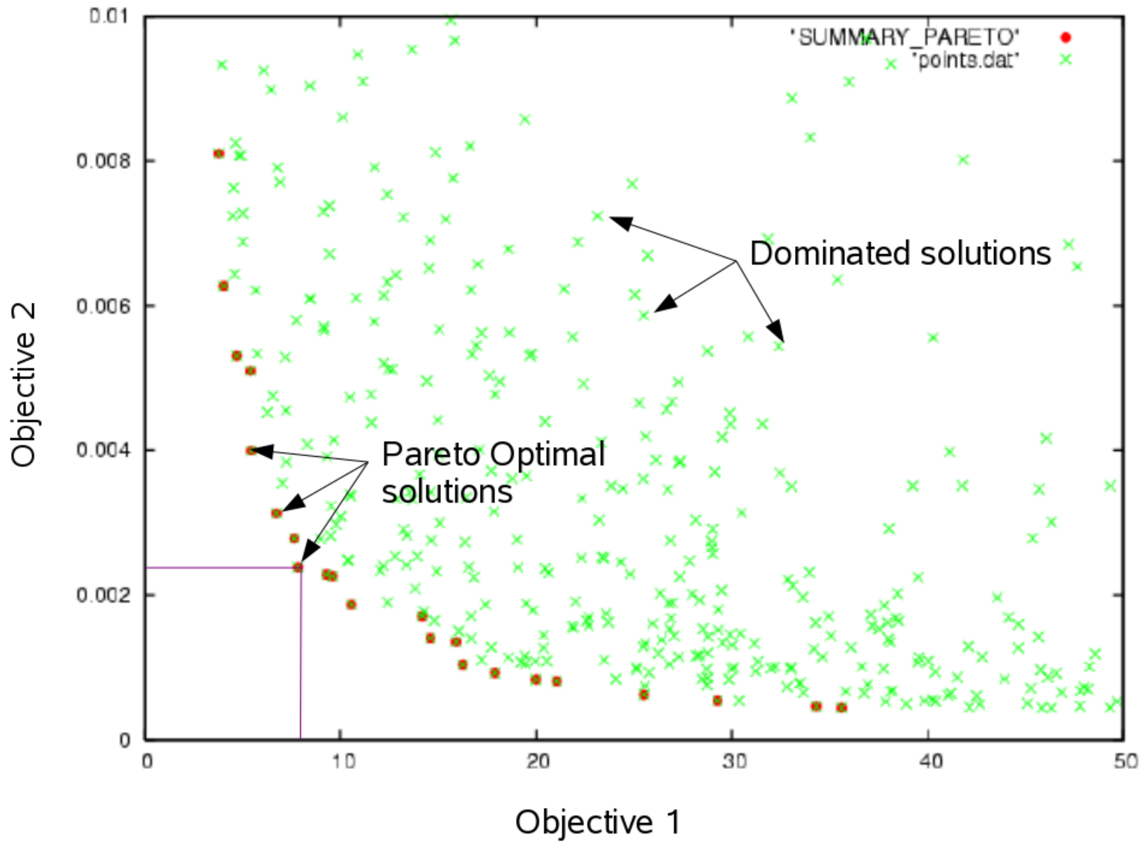
Calculated life-cycle carbon emission from the 20 expansion options (similar calculation for the cost in present-day value)

Alternative Number		CO_2 equivalent emissions in constructional phase Process ① + ② (g)	CO_2 equivalent emissions in operational phase. Process ③+④+⑤+⑥+⑦+⑧+⑨ $(g\cdot m^{-3})$
Groundwater	1	1.31×10^{10}	2346
	2	1.90×10^{10}	2681
	3	1.39×10^{10}	2480
	4	2.75×10^{10}	2865
Surface water	5	2.27×10^{10}	2714
	6	1.88×10^{10}	1156
	7	5.54×10^{10}	1985
	8	1.16×10^{11}	3745
	9	6.85×10^{10}	3125
Water use permit transfer	10	Negligible*	1156
	11	Negligible*	1156
	12	Negligible*	1156
Regional water	13	1.83×10^{11}	5890
	14	2.22×10^{11}	6853
	15	1.30×10^{11}	3351
	16	1.30×10^{11}	3351
	17	8.31×10^{10}	2706
Others	18	7.17×10^{10}	2706
	19	7.76×10^{10}	2706
	20	4.31×10^{10}	3278

Source: Qi et al. (2010)

* water permit transfer is simply an administrative action with almost no obvious carbon footprint relative to other options.

LCA and Optimal Option Selection

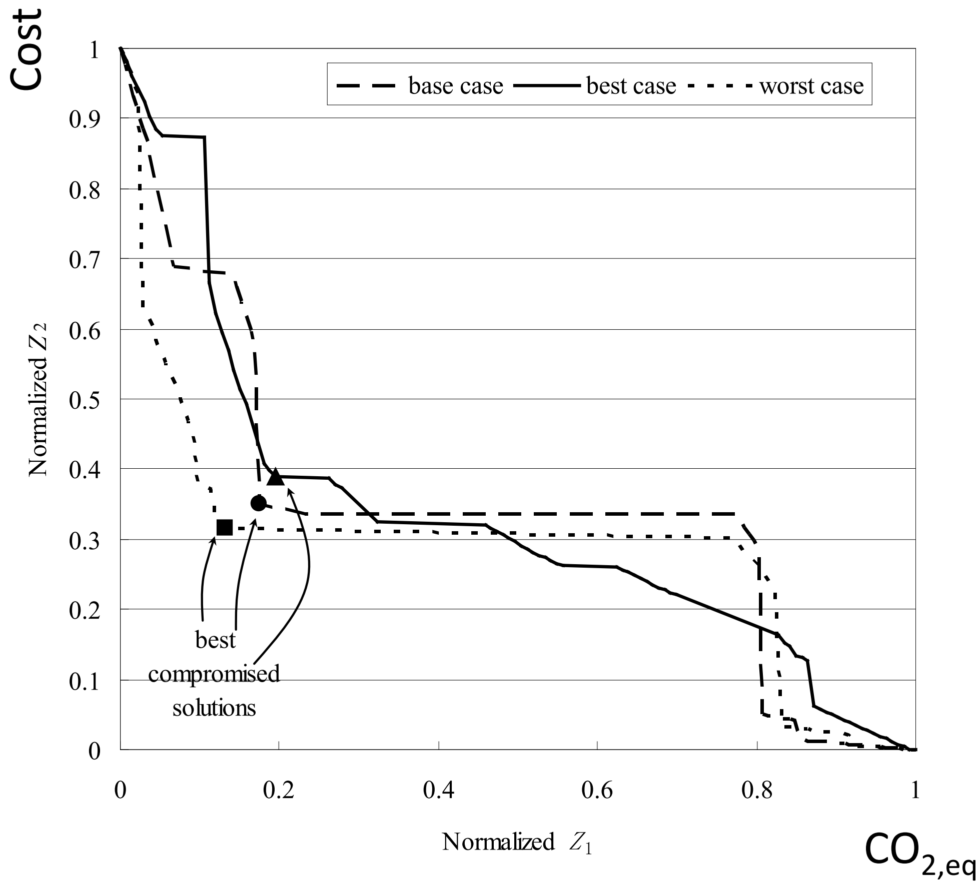


- Multi-objective programming is a method to compare multiple independent variables in multi-dimensions
- In the Manatee case study, the independent variables are cost and carbon emission.
- Assuming each option is engineeringly feasible, Pareto optimization is used to identify the best option

Pareto optimality is a state of competitive allocation of resources for a compromise or optimization

Courtesy of Chang et al. (2012)

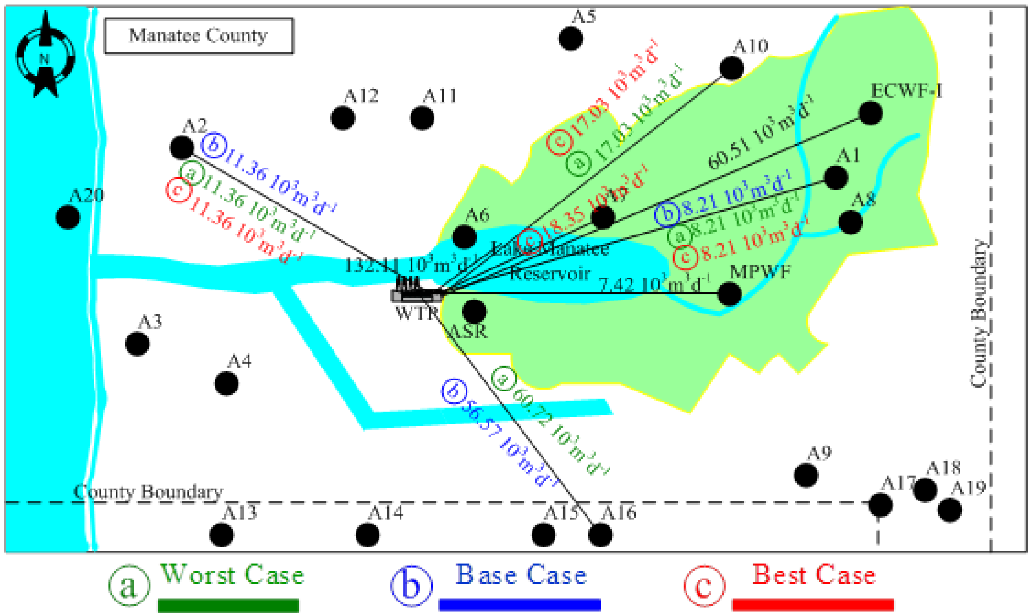
Water Adaptation and Model Applications at Urban Scales



- Potential combinations of water expansion options are plotted in the Pareto chart
- The best compromise solutions are found
- The best solutions are composed of actions in the period 1 (2011-2015), period 2 (2016-2020), period 3 (2021-2025), and period 4 (2026-2030)

Courtesy of Chang et al. (2012)

Water Adaptation and Model Applications at Urban Scales



Optimal expansion options in time period 3: Year 2021~2025

- Potential combinations of water expansion options are plotted in the Pareto chart
- The best compromise solutions are found
- The best solutions are composed of actions in the period 1 (2011-2015), period 2 (2016-2020), period 3 (2021-2025), and period 4 (2026-2030)

Courtesy of Chang et al. (2012)

Summary

- Adaptation planning follows rigorous apple-to-apple comparison of competing adaptation options
- Each option has a set of attributes in meeting the management objectives. One can evaluate the option performance through LCA of criteria such as:
  - Adaptation cost
  - Environmental or social benefits
  - Climate mitigation co-benefits (e.g., CO_2 emission avoidance)
- Multi-objective mixed integral programming, Pareto front analysis, and other competitive LCA comparison techniques are essential in the adaptation option analysis
- Proper definition of physical boundary critical to the LCA evaluation among adaptation options

Research Questions

- Are LCA methods used in screening water system adaptation options in your country? Please provide an example and reference
- How are the LCA time frame and physical boundaries defined in climate adaptation analysis? Use an infrastructure expansion for illustration
- List major phases of an infrastructure service life for LCA calculation

Looking ahead to the next module.....

- Next module: Course Summary and Presentations
- Scoping of project topics