CI-WATER

A Utah-Wyoming Cyberinfrastructure Water Modeling Collaboration

Climate and Urban Water Management Modeling

Steven Burian, Courtney Strong, Erfan Goharian, Adam Kochanski

THE UNIVERSITY OF UTAH

Motivation

- Lacking access to climate projections appropriate for regional and urban water resources research in SLC, Utah-Wyoming, and nationally
- Inability to simulate the integrated urban water system of SLC to study climate, population growth, and other impacts on system sustainability
- Opportunities to advance integration of system and process models to study urban water systems
- Missing broad metrics to evaluate urban water system vulnerability, sustainability, and resiliency to climate variability

Motivation

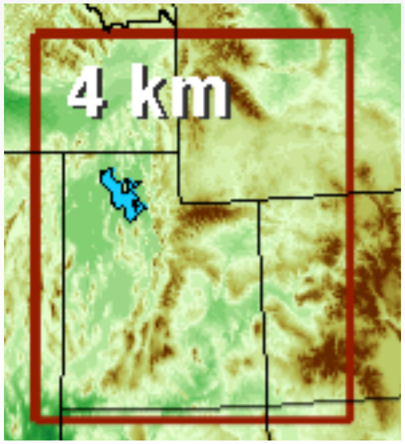
- Lacking access to climate projections appropriate for regional and urban water resources research in SLC, Utah-Wyoming, and nationally
- Inability to simulate the integrated urban water system of SLC to study climate, population growth, and other impacts on system sustainability
- Opportunities to advance integration of system and process models to study urban water systems
- Missing broad metrics to evaluate urban water system vulnerability, sustainability, and resiliency to climate variability

Climate modeling

Completed development of our CI-WATER climate modeling framework (Strong et al. 2014):

- Weather Research and Forecasting (WRF) model with a 4-km inner domain nested within larger 12-km and 36-km domains
- Incorporated an urban irrigation model
- Incorporated model of Great Salt Lake
- Completed suite of sensitivity analyses

Inner domain with 4-km resolution

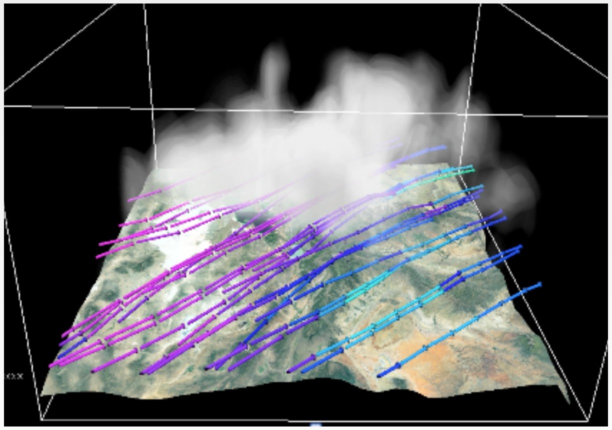


Strong C, Kochanski AK, and Crosman ET (2014), A slab model of the Great Salt Lake for regional climate simulation, *Journal of Advances in Modeling Earth Systems*, **6,** 602–615.

Climate modeling

- Completed historical reference period 1985-2004 using boundary conditions from the Climate Forecast System Reanalysis (CFSR)
- Determined that the Community Climate System Model (CCSM) provides the most reliable boundary conditions for simulation of Great Basin precipitation (Smith et al., 2014)
- Completed decade centered on 2090 using output form CCSM as boundary conditions

visualization of clouds and wind



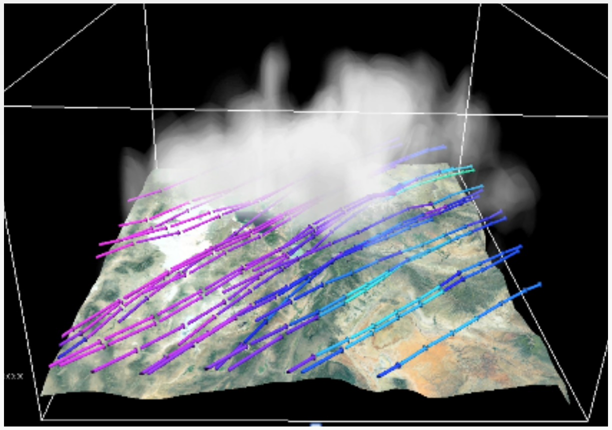
Smith K, Strong C, Wang S (2014) Connectivity between historical Great Basin precipitation and interannual to multidecadal Pacific Ocean variability: A CMIP5 model comparison, *Journal of Climate*, conditionally accepted.

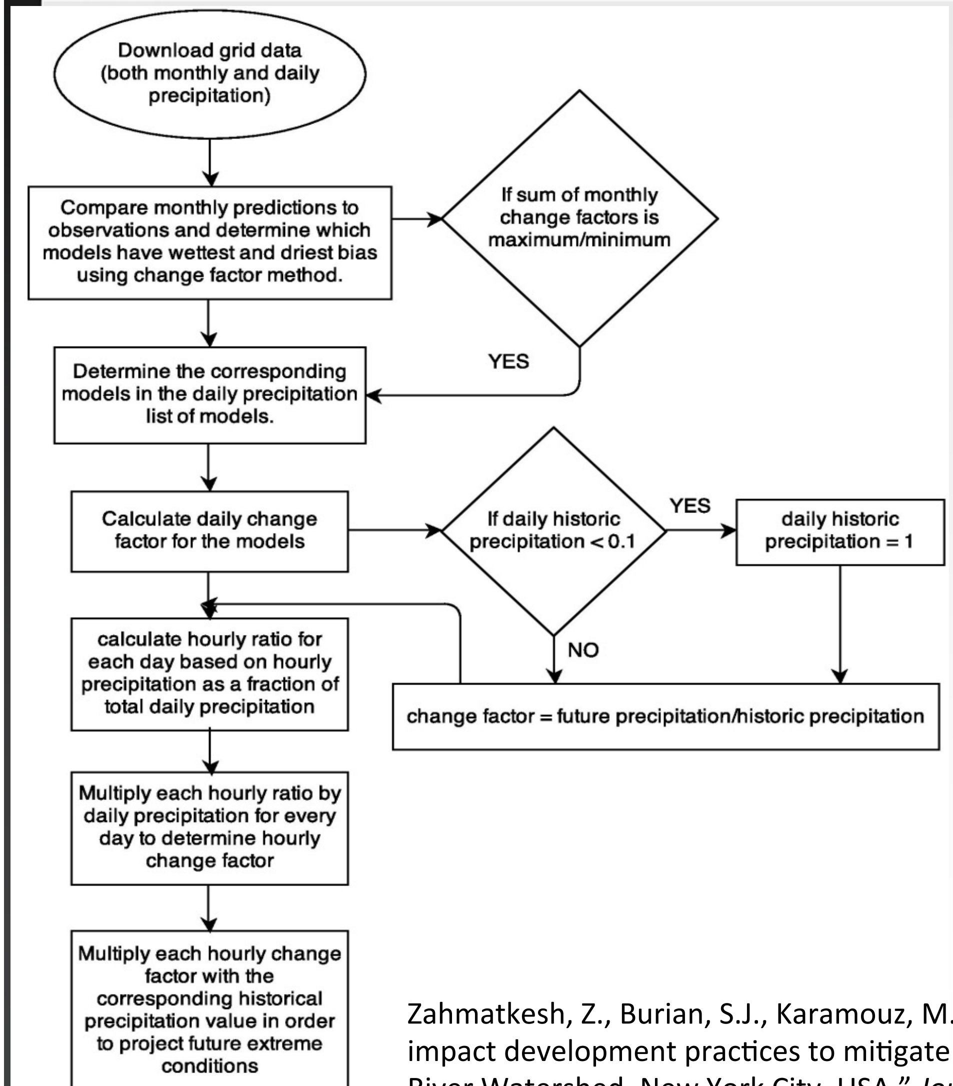
Climate modeling

To be completed this year:

- Future decades centered on 2030 and 2060 using output from CCSM as boundary conditions (utilizes existing allocation on Yellowstone)
- Decomposition of future snowpack change into effects related to temperature, humidity, and storm track shifts (will require additional allocation on Yellowstone)

visualization of clouds and wind





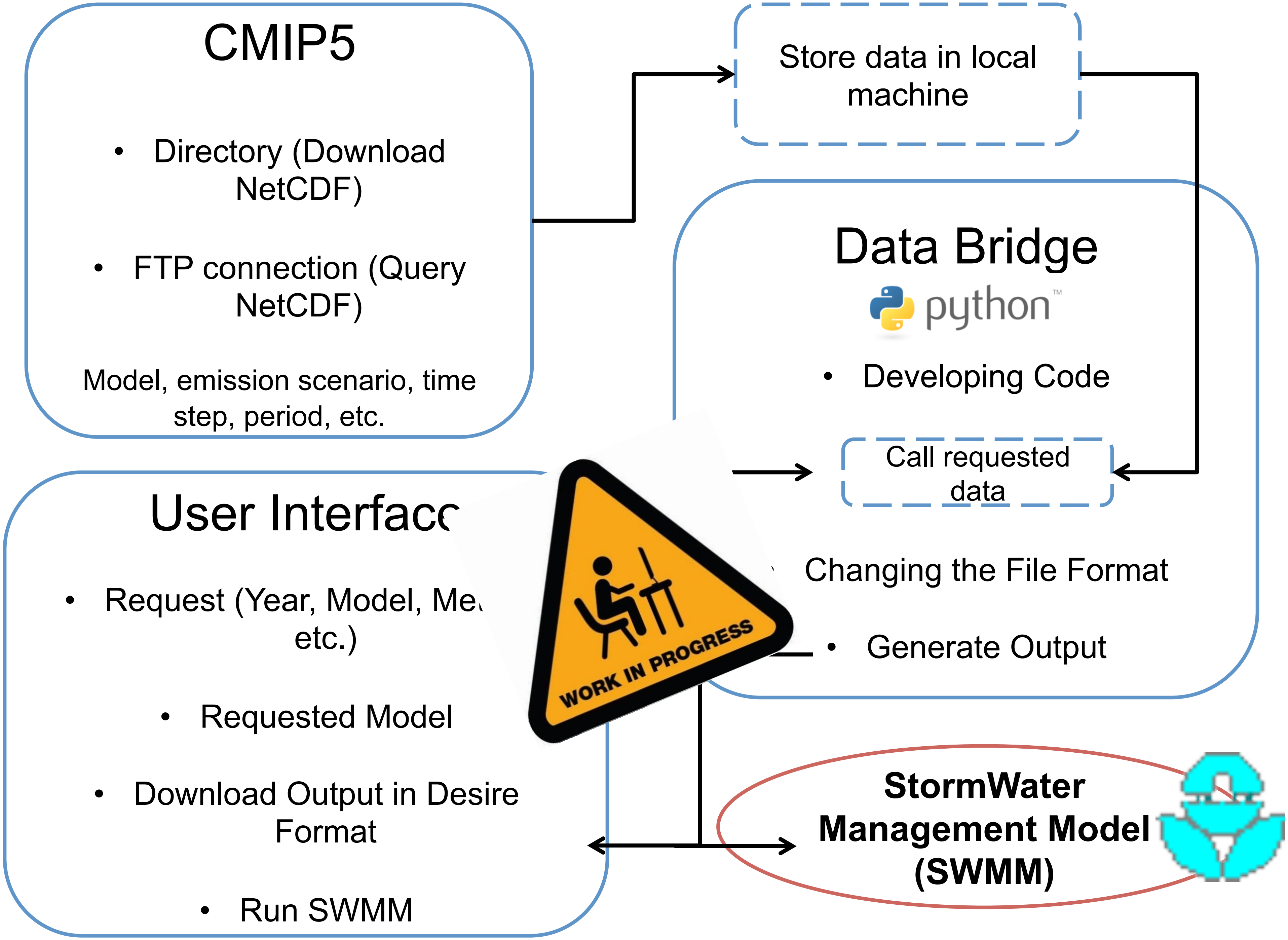
Climate Data Access

- **Using CMIP5 projections**
- **Code identifies GCM with wettest and driest bias (BCSD 5)**

Or

- **Any individual model upon user request**
- **Disaggregates wettest & driest scenarios to hourly (BCCA 5)**
- **Applicable for entire U.S.**

Zahmatkesh, Z., Burian, S.J., Karamouz, M., Tavakol-Davani, H., and Goharian, E. (2014). “Potential of low impact development practices to mitigate climate change effects on urban stormwater runoff in the Bronx River Watershed, New York City, USA.” *Journal of Irrigation and Drainage Engineering*, DOI: 10.1061/(ASCE)IR.1943-4774.0000770.


CMIP5
Directory (Download NetCDF)
FTP connection (Query NetCDF)
Model, emission scenario, time step, period, etc.
Store data in local machine
Data Bridge
python
Developing Code
Call requested data
Changing the File Format
Generate Output
User Interfac
Request (Year, Model, Me
etc.)
Requested Model
Download Output in Desire Format
Run SWMM
WORK IN PROGRESS
StormWater Management Model (SWMM)

Motivation

- Lacking access to climate projections appropriate for regional and urban water resources research in SLC, Utah-Wyoming, and nationally
- Inability to simulate the integrated urban water system of SLC to study climate, population growth, and other impacts on system sustainability
- Opportunities to advance integration of system and process models to study urban water systems
- Missing broad metrics to evaluate urban water system vulnerability, sustainability, and resiliency to climate variability

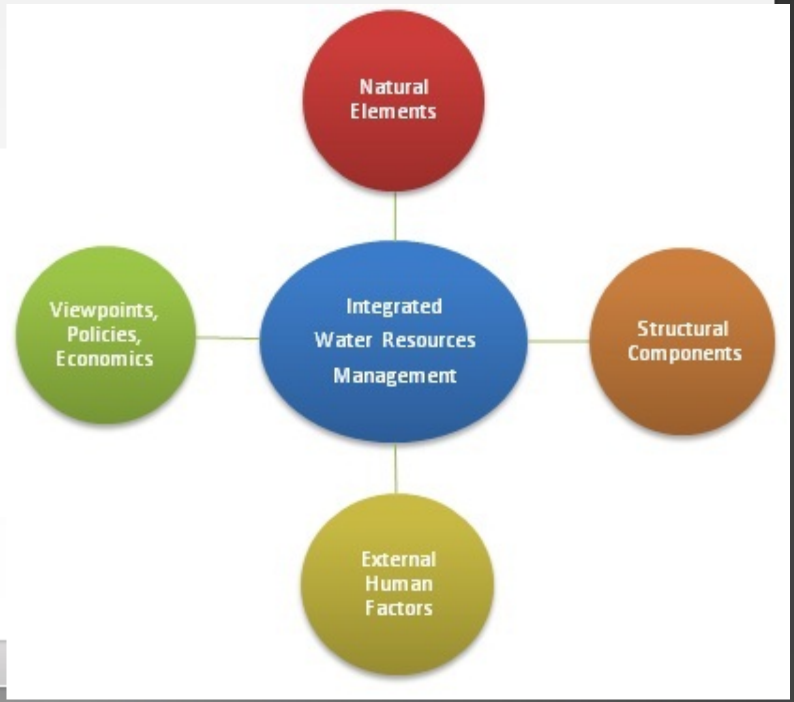
Simulate the integrated urban water system

- **Goal:** Develop capacity to simulate the integrated urban water system of SLC to study climate, population growth, and other impacts on system sustainability

Processing Modelling

+

System Modeling



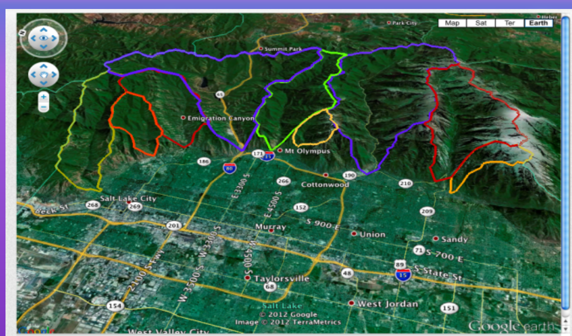
Supported Tools and Models

Tools	Models
Watershed Delineation (TauDEM)	ADHydro integrated distributed hydrologic model
Data Access	UEB Snowmelt
Model element and mesh generation	GSSHA gridded surface subsurface hydrologic models
Rescaling data in space/time	***Integrated Water Resource Management (GoldSim)***
Results visualization	

Use future climate modeling and downscaling to inform probabilistic scenario development

Natural system hydrologic and hydraulic modeling

streamflow forecasts

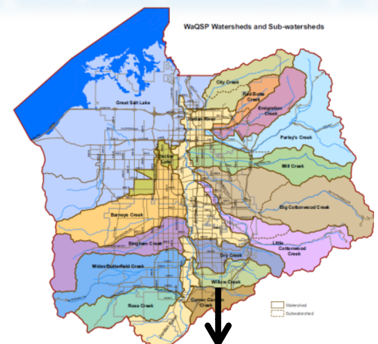


http://www.hiddenwaters.org/

climate change flows

Urban watershed and green infrastructure modeling

Hydrologic Models



Water quality modeling

Operations model

Planning model

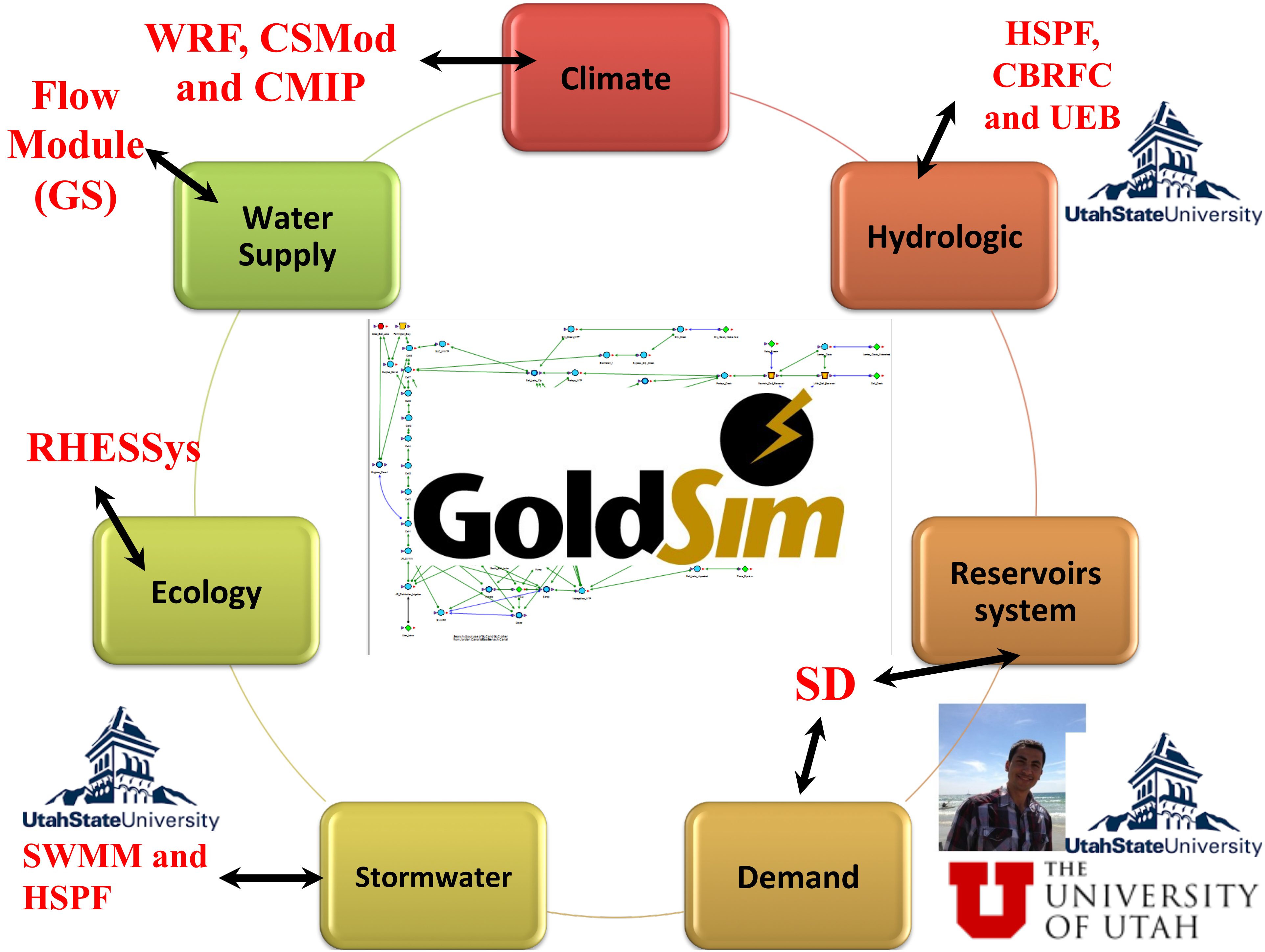
Water System Models

Demand scenarios

Outcomes

Expanded information for:

- climate-water science
- water operations
- long-term planning
- infrastructure upgrades


WRF, CSMod and CMIP
Climate
HSPF, CBRFC and UEB
Flow Module (GS)
Water Supply
Hydrologic
UtahStateUniversity
GoldSim
RHESSys
Ecology
Reservoirs system
SD
UtahStateUniversity
SWMM and HSPF
Stormwater
Demand
UtahStateUniversity
THE UNIVERSITY OF UTAH

Case Study

- 60% from the four of the seven canyons above the City:

City Creek,

Parleys Creek,

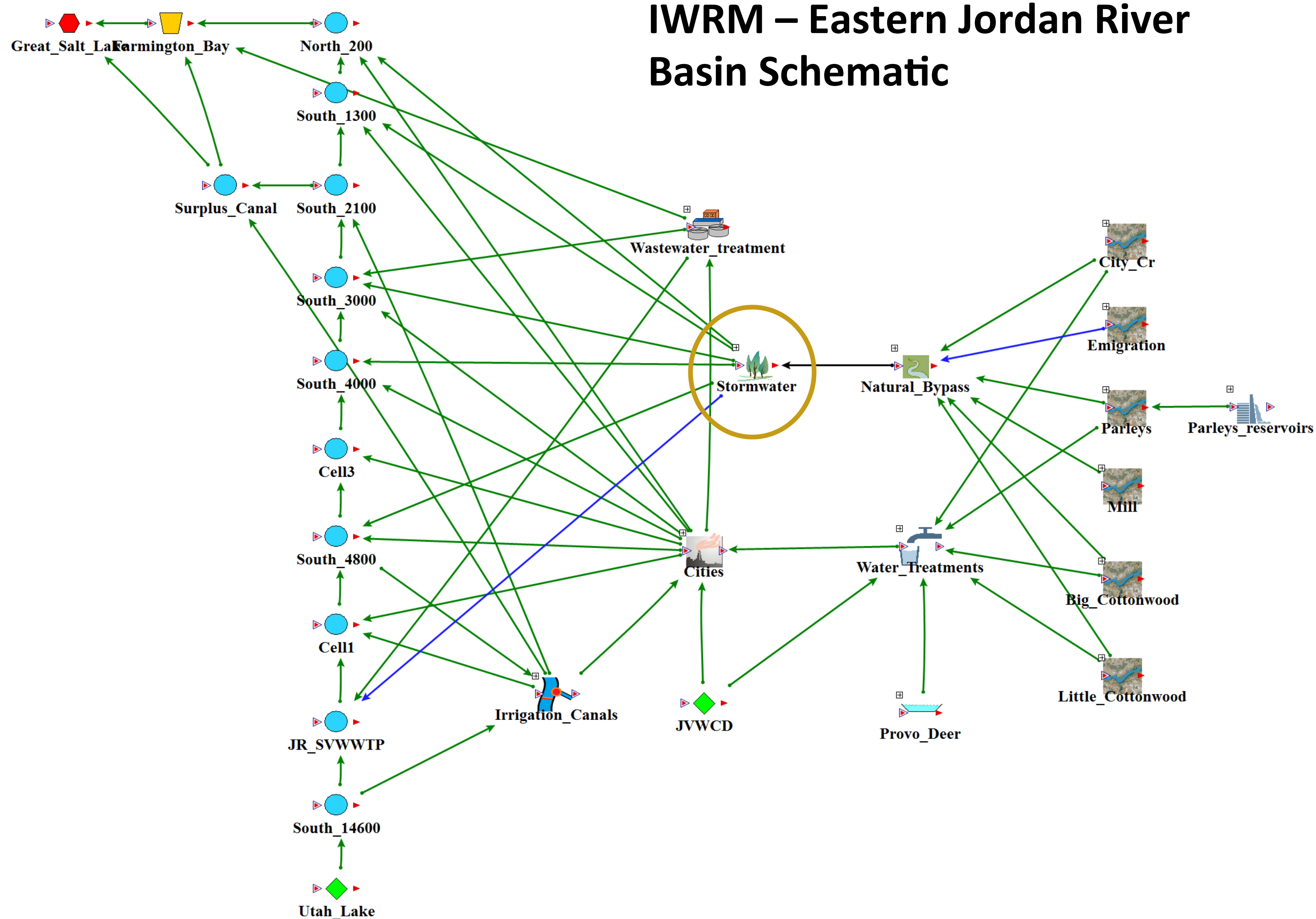
Big Cottonwood and Little Cottonwood

- 20% Deer Creek and Provo System
- Rest from wells, springs and groundwater

Targeted Users/Partners

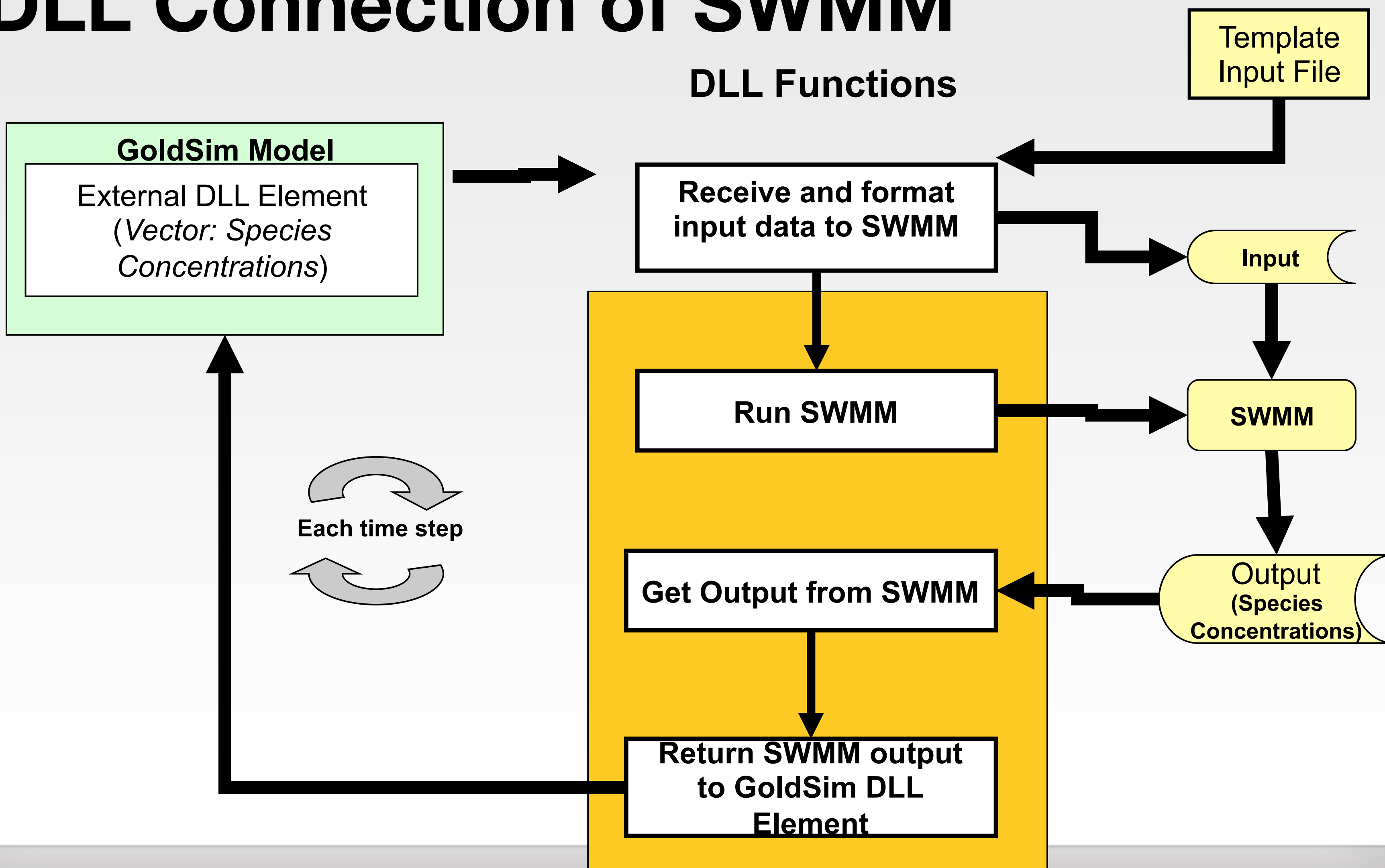
- **Researchers** need a modeling framework to analyze future climate, population growth, water management, etc. impacts on water system performance
- **Water managers** need a tool to evaluate performance of reservoir and water systems under different infrastructure and management choices
- **Society** desires ways to better comprehend the performance of their water systems and how climate, infrastructure choices, and other factors influence the performance

IWRM – Eastern Jordan River Basin Schematic

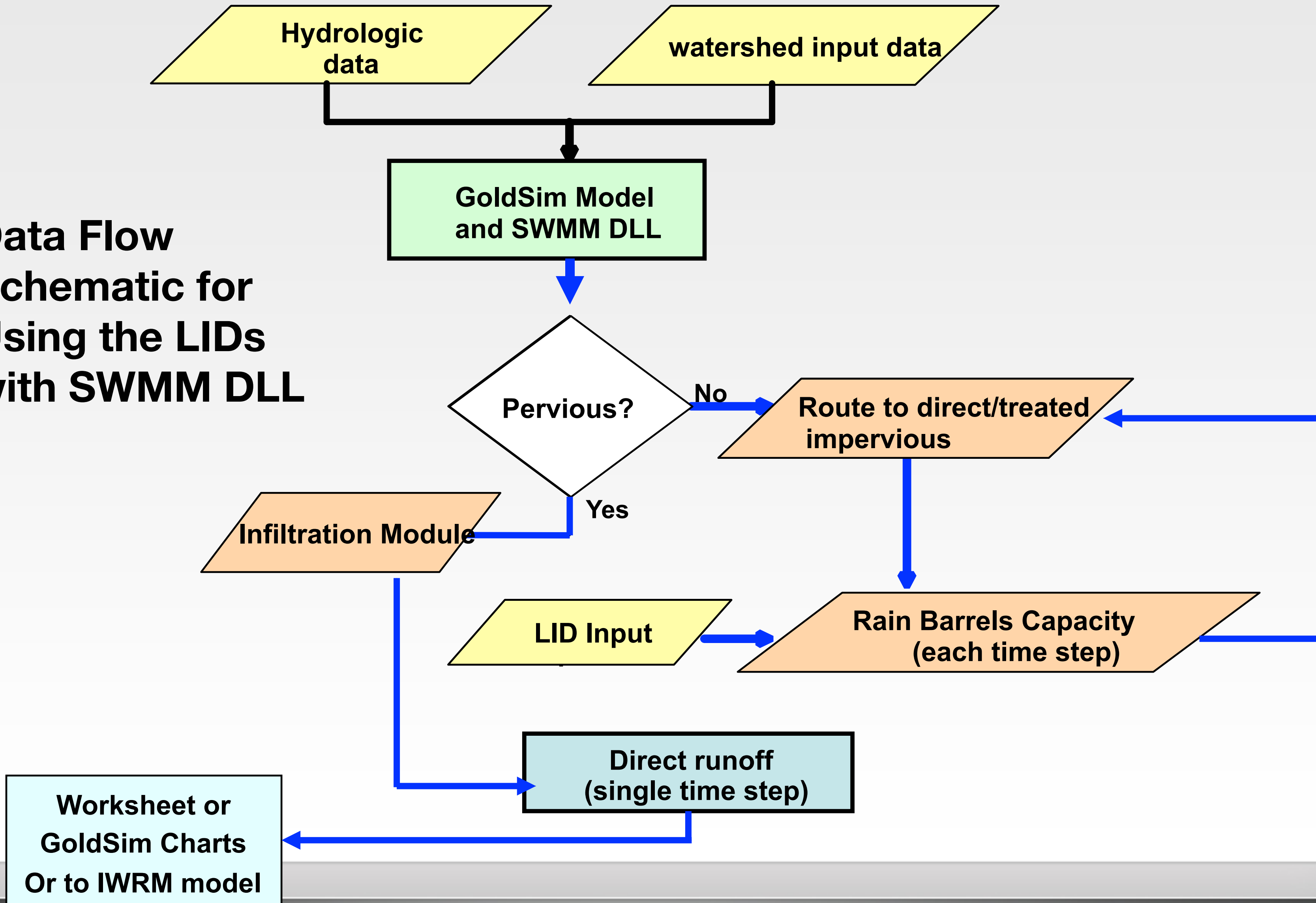


A Utah-Wyoming Cyberinfrastructure Water Modeling Collaboration

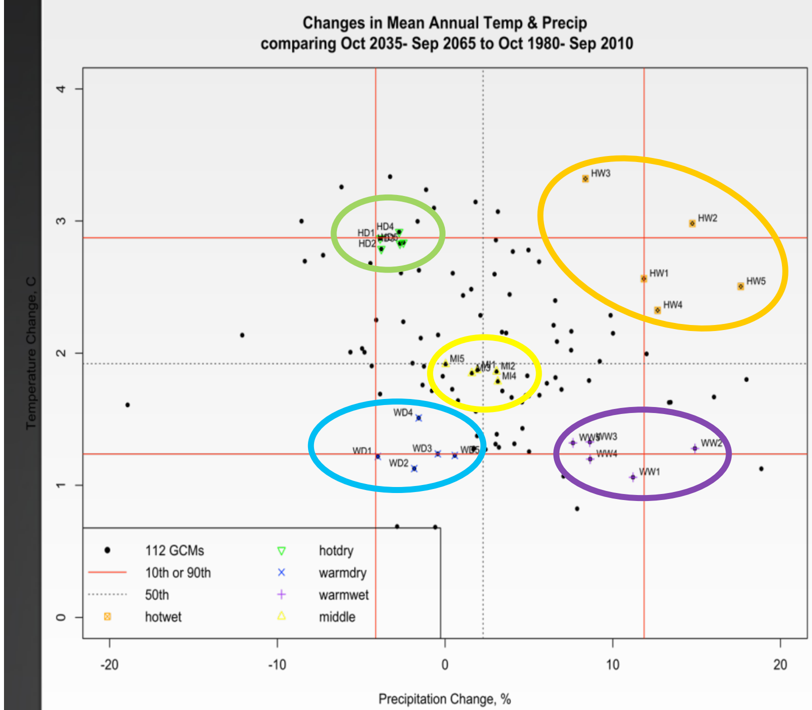
DLL Connection of SWMM

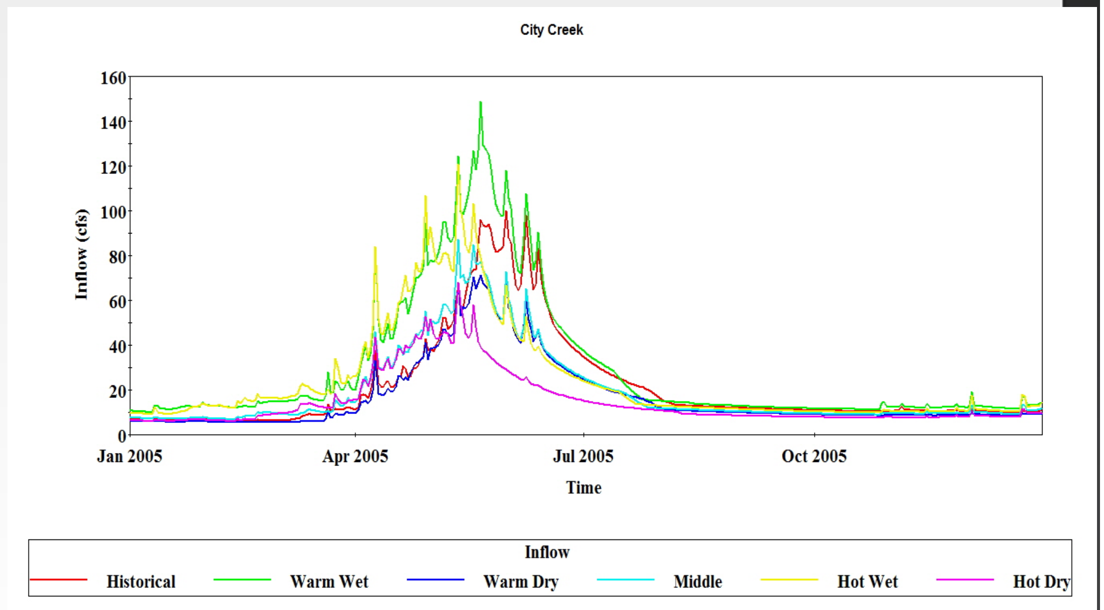


Data Flow Schematic for Using the LIDs with SWMM DLL



Climate Change Evaluation





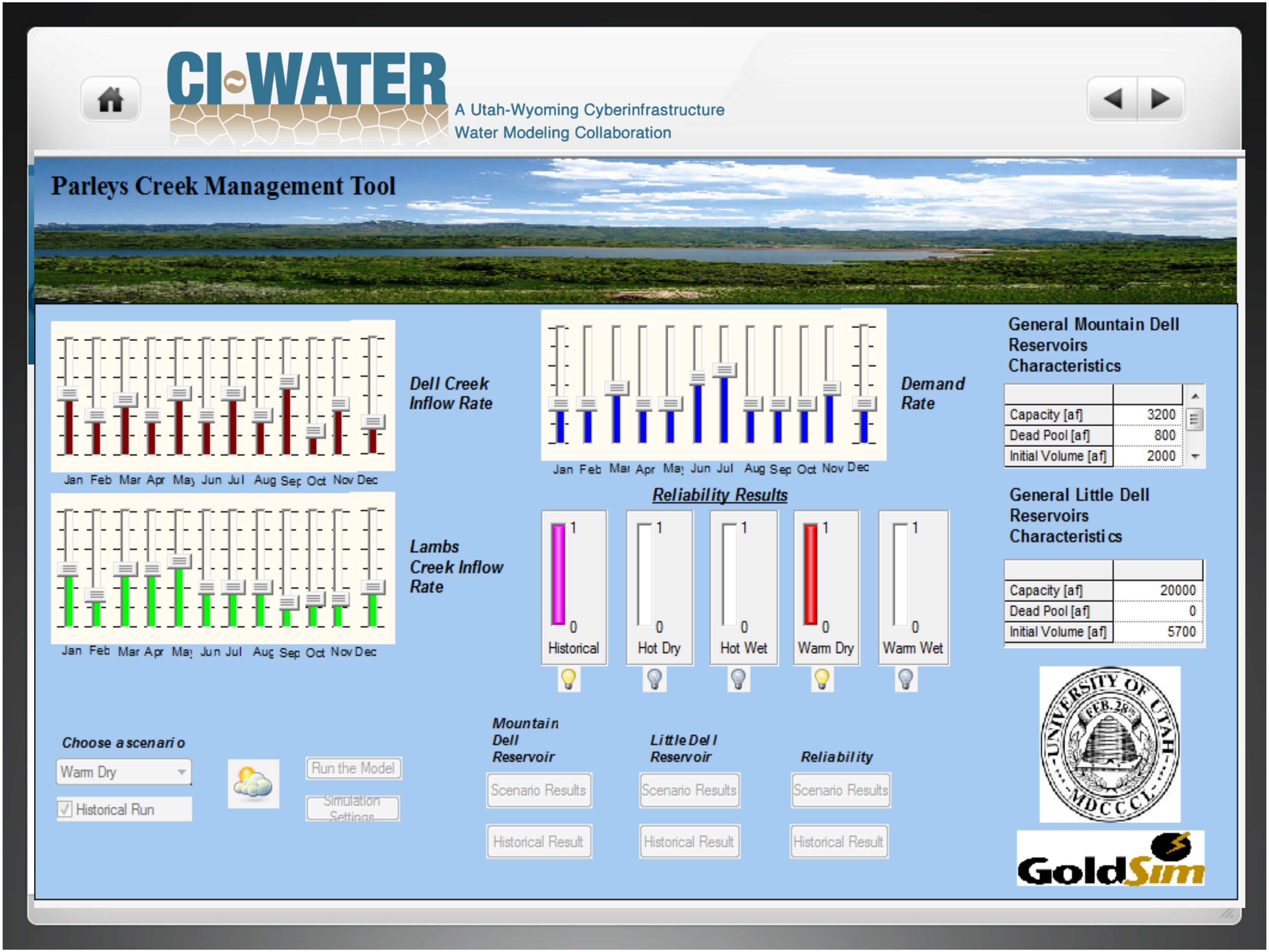
Bardsley, T., Wood, A., Hobbins, M., Kirkham, T., Briefer, L., Niermeyer, J., and Burian, S. (2013). "Planning for an uncertain future: Climate change sensitivity assessment towards adaptation planning for public water supply." *Earth Interactions*, 23 (Paper 23).

Possible Users

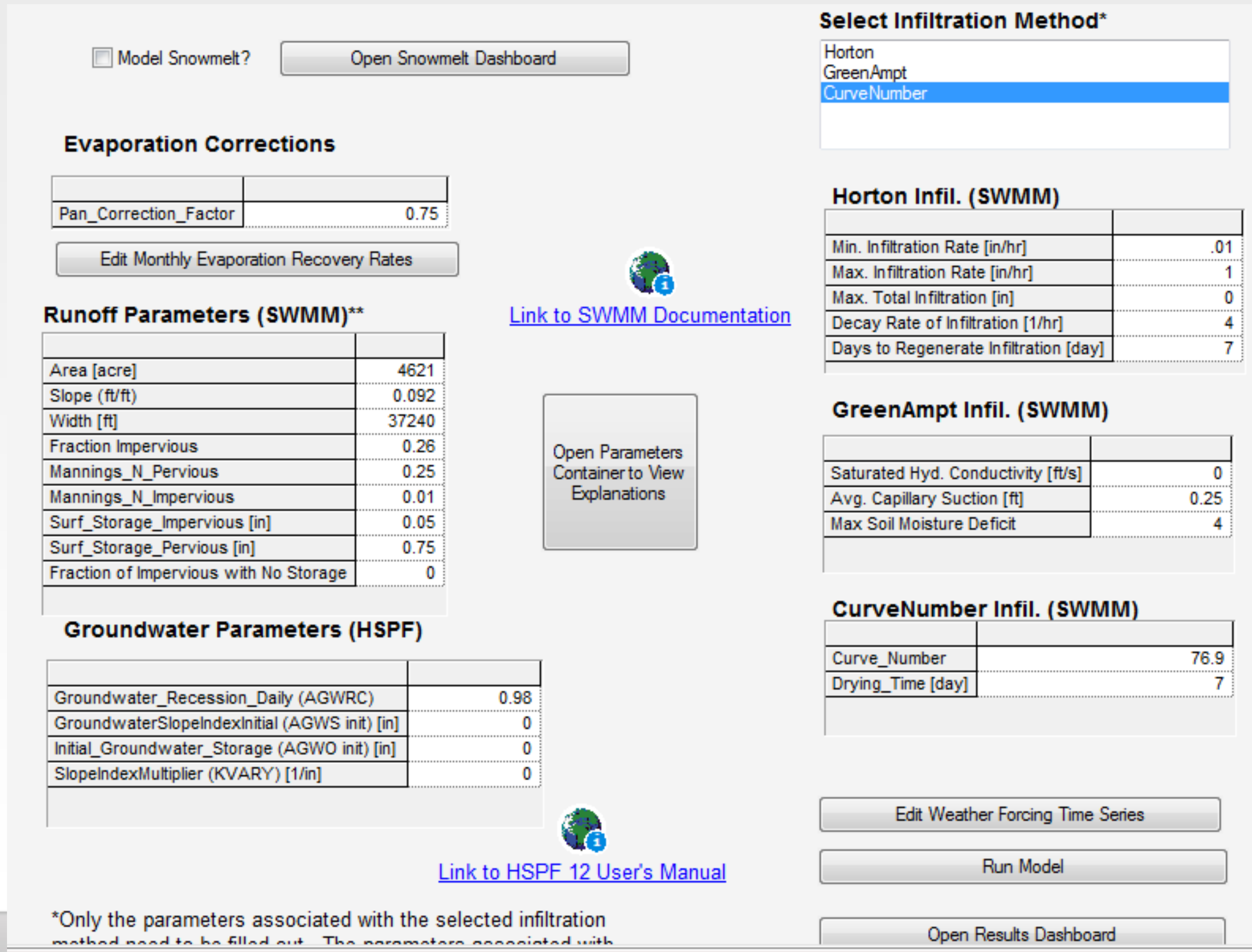
- **Researchers** need a modeling framework to analyze future climate, population growth, water management, etc. impacts on water system performance.

- **Water managers** need a tool to evaluate performance of reservoir and water systems under different infrastructure and management choices.

- **Society** desires ways to better comprehend the performance of their water systems and how climate, infrastructure choices, and other factors influence the performance


CI-WATER
A Utah-Wyoming Cyberinfrastructure
Water Modeling Collaboration
Parleys Creek Management Tool
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Dell Creek Inflow Rate
Lambs Creek Inflow Rate
Demand Rate
Reliability Results
Historical
Hot Dry
Hot Wet
Warm Dry
Warm Wet
General Mountain Dell Reservoirs Characteristics
Capacity [af] 3200
Dead Pool [af] 800
Initial Volume [af] 2000
General Little Dell Reservoirs Characteristics
Capacity [af] 20000
Dead Pool [af] 0
Initial Volume [af] 5700
Choose a scenario
Warm Dry
Historical Run
Run the Model
Simulation Settings
Mountain Dell Reservoir
Little Dell Reservoir
Reliability
Scenario Results
Historical Result
UNIVERSITY OF UTAH
FEB. 28
MDCCCL
GoldSim

SWMM Runoff Model (GoldSim)



CI~WATER

A Utah-Wyoming Cyberinfrastructure
Water Modeling Collaboration

RWH Dashboard

Jordan River Subbasin

Rainbarrel Numbers

200 Gal	2,500 Gal
15000	0

Percentage of roofs from Imperv area: 50

LCC Subbasin

Rainbarrel Numbers

200 Gal	2,500 Gal
13000	0

Percentage of roofs from Imperv area: 50

LRB Subbasin

Rainbarrel Numbers

200 Gal	2,500 Gal
4000	0

Percentage of roofs from Imperv area: 50

RWH 1 | Run | + | -

Outdoor Supply SLC

Bypass

Total RWH used for outdoor demand (Gal)

LEM Subbasin

Rainbarrel Numbers

200 Gal	2,500 Gal
6000	0

Percentage of roofs from Imperv area: 50

LPC Subbasin

Rainbarrel Numbers

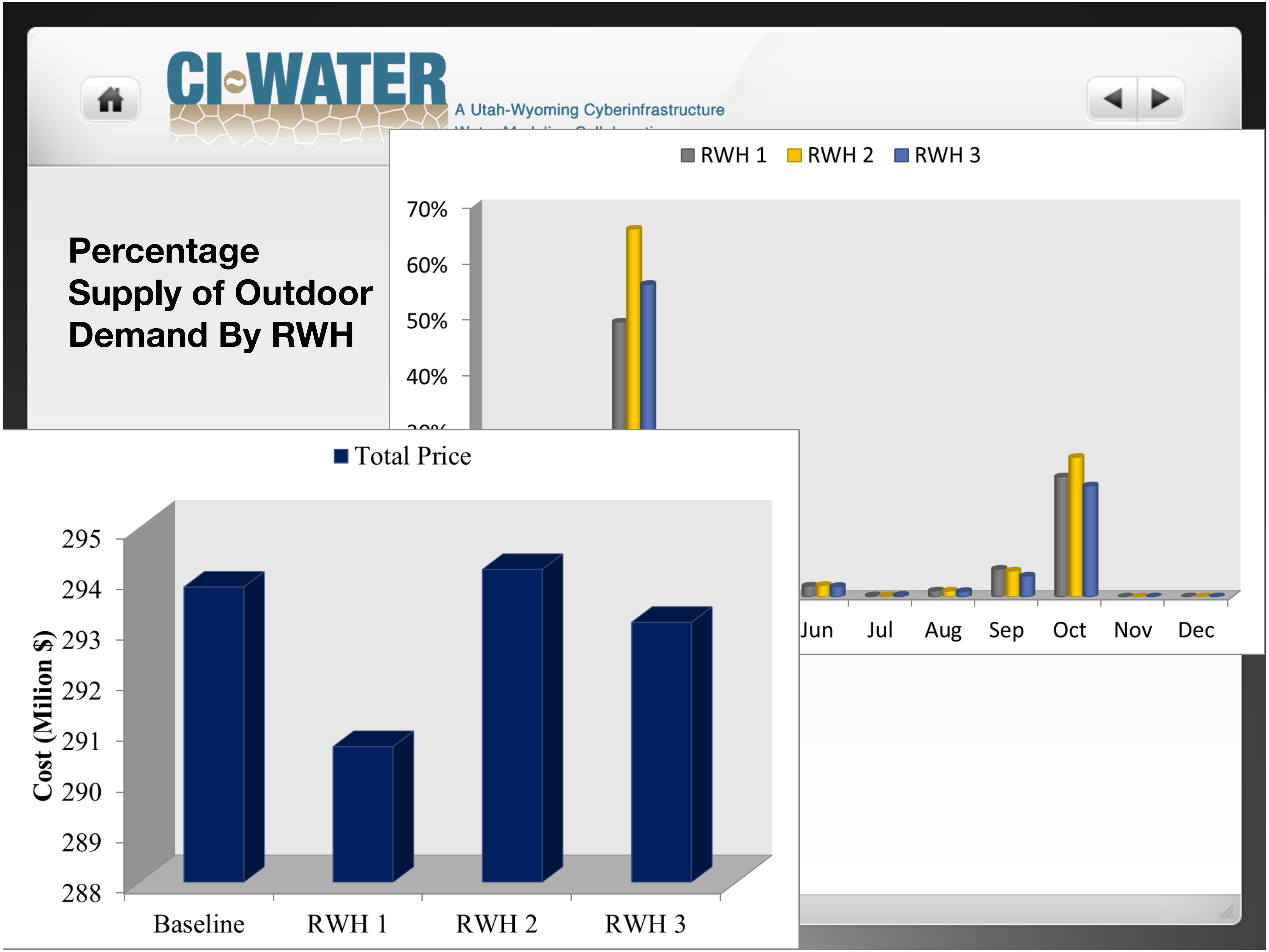
200 Gal	2,500 Gal
8000	0

Percentage of roofs from Imperv area: 50

2 containers with the maximum size of 100 gallons each on-site
Price: ~ $200 each one

Underground storage and the law permits up to 2,500 gallons in one container.
Price: ~ $2500-$3000

About 80,000 buildings, parks and properties serviced by the Public Utilities. I'd say use 75,000 to exclude industrial users and multiple users per building.


CI~WATER
A Utah-Wyoming Cyberinfrastructure
Percentage Supply of Outdoor Demand By RWH
RWH 1 RWH 2 RWH 3
70%
60%
50%
40%
Jun Jul Aug Sep Oct Nov Dec
Total Price
Cost (Milion $)
295
294
293
292
291
290
289
288
Baseline RWH 1 RWH 2 RWH 3

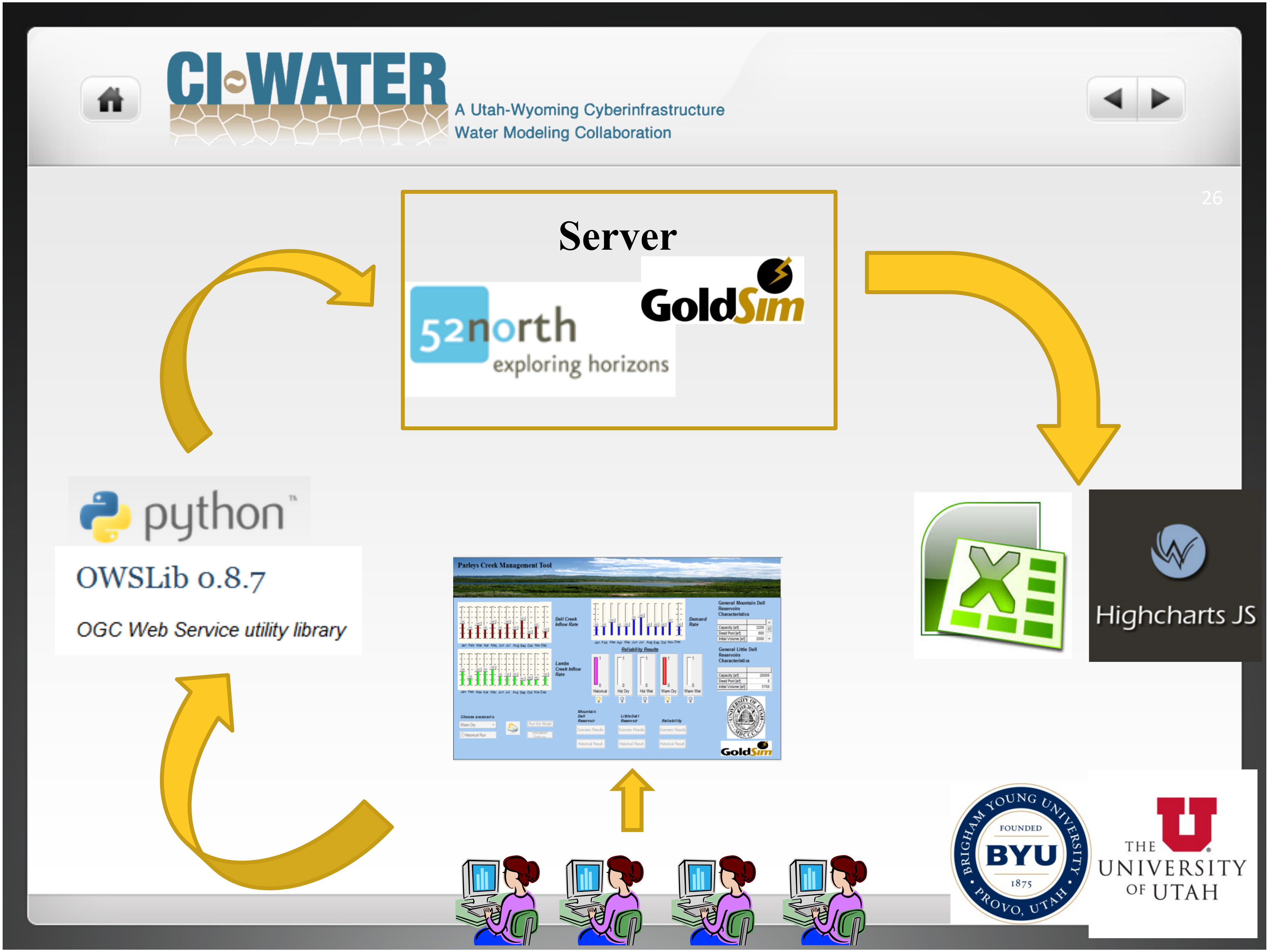
CI~WATER
A Utah-Wyoming Cyberinfrastructure
Water Modeling Collaboration

Possible Users

- **Researchers** need a modeling framework to analyze future climate, population growth, water management, etc. impacts on water system performance.

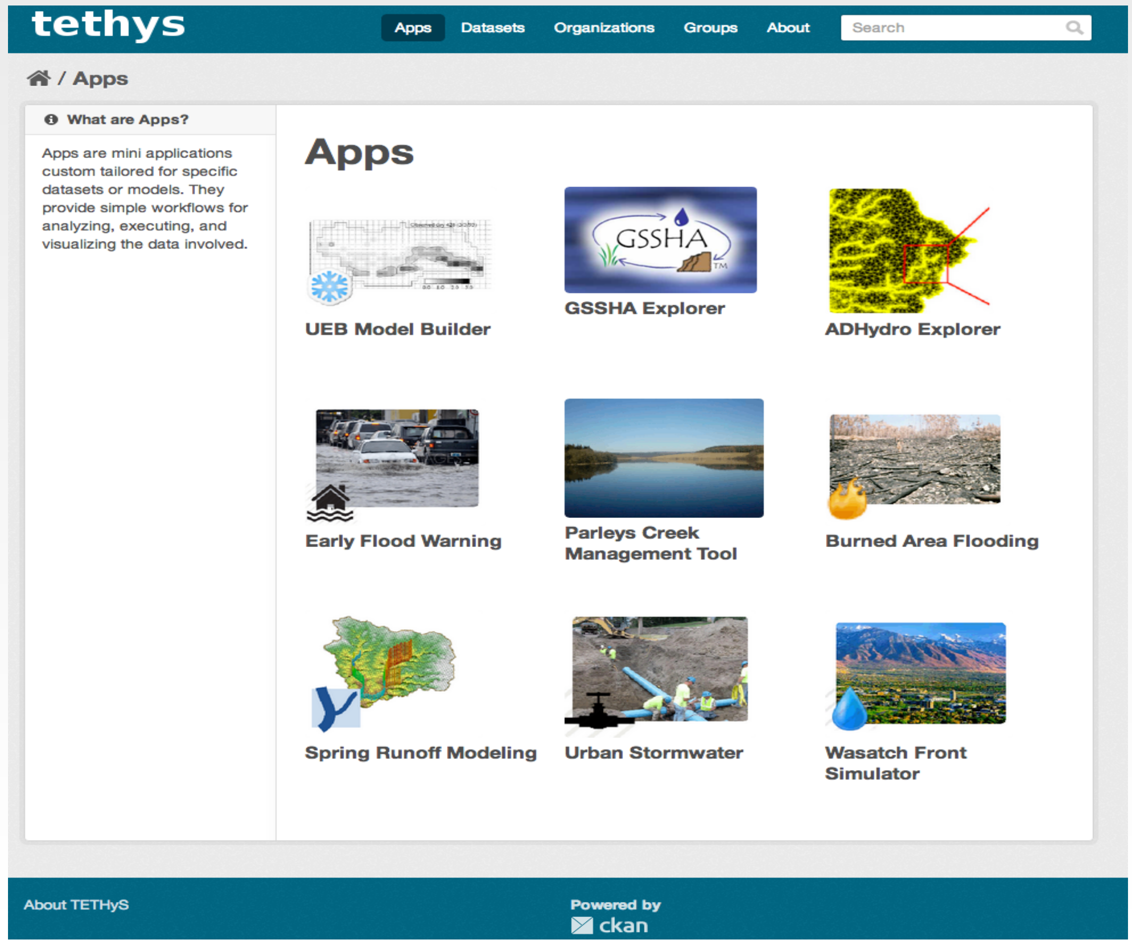
- **Water managers** need a tool to evaluate performance of reservoir and water systems under different infrastructure and management choices.

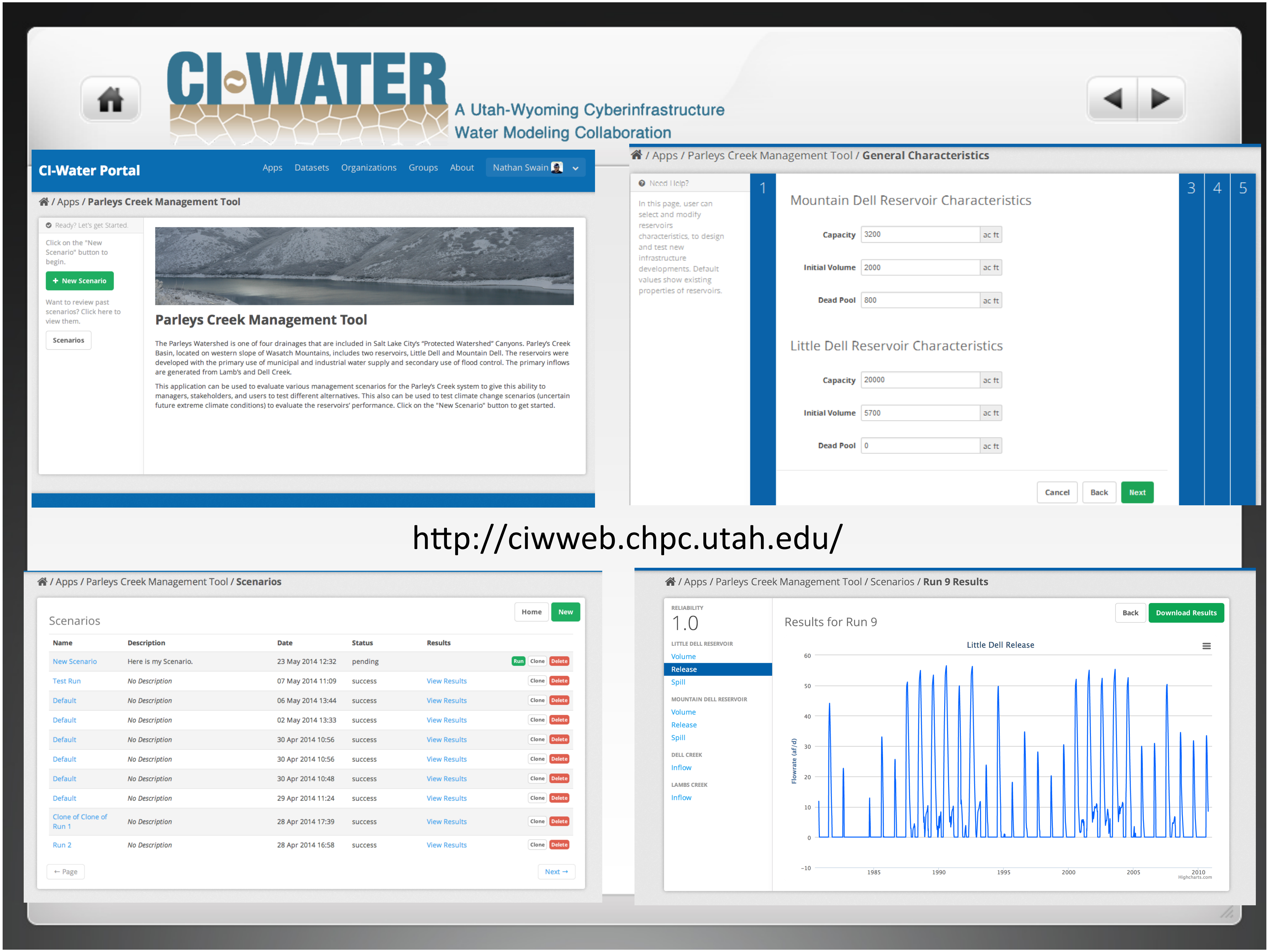
- **Society** desires ways to better comprehend the performance of their water systems and how climate, infrastructure choices, and other factors influence the performance


CI~WATER
A Utah-Wyoming Cyberinfrastructure
Water Modeling Collaboration
26
Server
52north
exploring horizons
GoldSim
python
OWSLib 0.8.7
OGC Web Service utility library
Parleys Creek Management Tool
Highcharts JS
BRIGHAM YOUNG UNIVERSITY
FOUNDED
BYU
1875
PROVO, UTAH
THE UNIVERSITY OF UTAH

The Engineering Toolbox for Hydrologic Simulation (TETHyS)

- Open source
- Python Powered
- Data Management and CKAN
- Geospatial Datasets
- Cloud Computing Resources
- Post Processing
- Visualization




CI-WATER
A Utah-Wyoming Cyberinfrastructure
Water Modeling Collaboration
CI-Water Portal
Apps
Datasets
Organizations
Groups
About
Nathan Swain
/ Apps / Parleys Creek Management Tool
Ready? Let's get Started.
Click on the "New Scenario" button to begin.
New Scenario
Want to review past scenarios? Click here to view them.
Scenarios
Parleys Creek Management Tool
The Parleys Watershed is one of four drainages that are included in Salt Lake City's "Protected Watershed" Canyons. Parley's Creek Basin, located on western slope of Wasatch Mountains, includes two reservoirs, Little Dell and Mountain Dell. The reservoirs were developed with the primary use of municipal and industrial water supply and secondary use of flood control. The primary inflows are generated from Lamb's and Dell Creek.
This application can be used to evaluate various management scenarios for the Parley's Creek system to give this ability to managers, stakeholders, and users to test different alternatives. This also can be used to test climate change scenarios (uncertain future extreme climate conditions) to evaluate the reservoirs' performance. Click on the "New Scenario" button to get started.
/ Apps / Parleys Creek Management Tool / General Characteristics
Need Help?
In this page, user can select and modify reservoirs characteristics, to design and test new infrastructure developments. Default values show existing properties of reservoirs.
1
3
4
5
Mountain Dell Reservoir Characteristics
Capacity 3200 ac ft
Initial Volume 2000 ac ft
Dead Pool 800 ac ft
Little Dell Reservoir Characteristics
Capacity 20000 ac ft
Initial Volume 5700 ac ft
Dead Pool 0 ac ft
Cancel
Back
Next
http://ciwweb.chpc.utah.edu/
/ Apps / Parleys Creek Management Tool / Scenarios
Home
New
Scenarios
Name | Description | Date | Status | Results
New Scenario | Here is my Scenario. | 23 May 2014 12:32 | pending | Run Clone Delete
Test Run | No Description | 07 May 2014 11:09 | success | View Results Clone Delete
Default | No Description | 06 May 2014 13:44 | success | View Results Clone Delete
Default | No Description | 02 May 2014 13:33 | success | View Results Clone Delete
Default | No Description | 30 Apr 2014 10:56 | success | View Results Clone Delete
Default | No Description | 30 Apr 2014 10:56 | success | View Results Clone Delete
Default | No Description | 30 Apr 2014 10:48 | success | View Results Clone Delete
Default | No Description | 29 Apr 2014 11:24 | success | View Results Clone Delete
Clone of Clone of Run 1 | No Description | 28 Apr 2014 17:39 | success | View Results Clone Delete
Run 2 | No Description | 28 Apr 2014 16:58 | success | View Results Clone Delete
← Page
Next →
/ Apps / Parleys Creek Management Tool / Scenarios / Run 9 Results
RELIABILITY
1.0
LITTLE DELL RESERVOIR
Volume
Release
Spill
MOUNTAIN DELL RESERVOIR
Volume
Release
Spill
DELL CREEK
Inflow
LAMBS CREEK
Inflow
Back
Download Results
Results for Run 9
Little Dell Release
Flowrate (af/d)
1985
1990
1995
2000
2005
2010

Motivation

- Lacking access to climate projections appropriate for regional and urban water resources research in SLC, Utah-Wyoming, and nationally
- Inability to simulate the integrated urban water system of SLC to study climate, population growth, and other impacts on system sustainability
- Opportunities to advance integration of system and process models to study urban water systems
- Missing broad metrics to evaluate urban water system vulnerability, sustainability, and resiliency to climate variability

Climate Change Vulnerability assessment

- $Vulnerability = RVI_{CC} \times W_{rv} + PI \times W_{p} + S \times W_{s} + PS \times W_{ps} + WSACI \times W_{w} + SACI \times W_{s}$

- Pair-wise comparison among the variables and Analytic Hierarchy Process (**AHP**) to calculate related weights

- **Jenks Optimization method** is a data classification method designed to determine the best arrangement of values into different classes.

Water system performance index

Determining Dependence between Simulation Inputs

Using copula function

Estimating the Copula dependent

Selecting best copula function

Developing Water System Performance Index

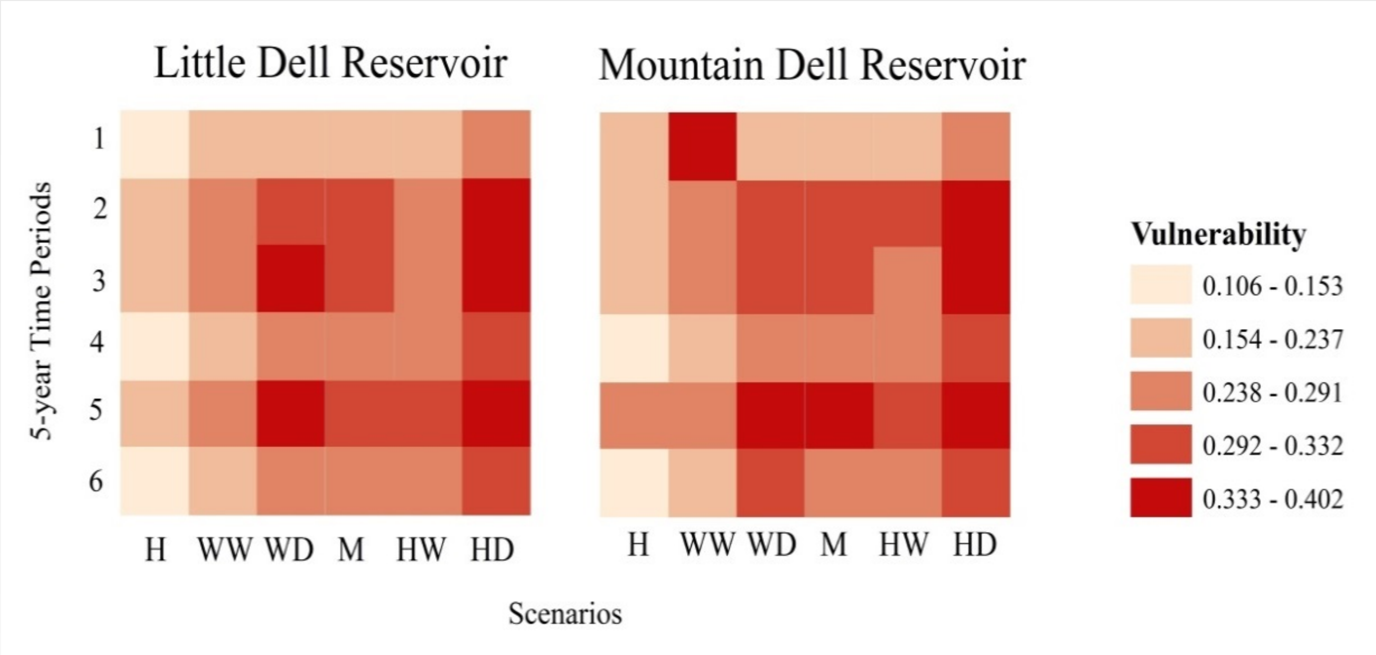
Editor - C:\University of Utah\My Papers & Presentations\Journals\8. Joint Probability\Copula Codes\My Codes 10.10.14\JP 10.13.m

File Edit Text Go Cell Tools Debug Desktop Window Help

This file uses Cell Mode. For information, see the rapid code iteration video, the publishing video, or help.

```
%%%%%%%%%%%%%%%%%%%%% Determining of WSPI Index by using joint distributions of Reliability and Vulnerability %%%%%%%%%%%%%%%%%%%%%
%%%%% "Parameters Estimation Copulas included 'Clyton', 'Ali-Mikhail-Haq','Farlie-Gumbel-Morgenstern',
%%%%% 'Frank', 'Galambos', 'Gumbel-Hougaard', 'Plackett', 'Genest-Ghoudi', 'JOE', 'Gumbel-Barnett' %%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% By "Erfan Goharian" %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% University of Utah %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% Version 1.00 10/13/2014 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

clc;
clear all;
close all;

% Loading Data

P=xlsread('Metrics 2.xlsx','F:G');

rel=P(:,1);
vul=P(:,2);

% plot rel and vul
figure(1)
plot(rel,vul, 'ro')
xlabel('Reliability')
ylabel('Vulnerability')
print('-dpng', 'x_y.png')

% draw the scatter plot of data with histograms
figure (2)
scatterhist(rel,vul,'Direction','out')

% Parameter Estimation for Generalized Pareto Distribution
```

#	Reliability	Vulnerability	WSPI
1	0.0083	0.9883	0.9997
2	0.7250	0.6301	0.1771
3	0.1833	0.8801	0.9862
4	0.7833	0.4365	0.0034
5	1.000	0.0000	0.0000

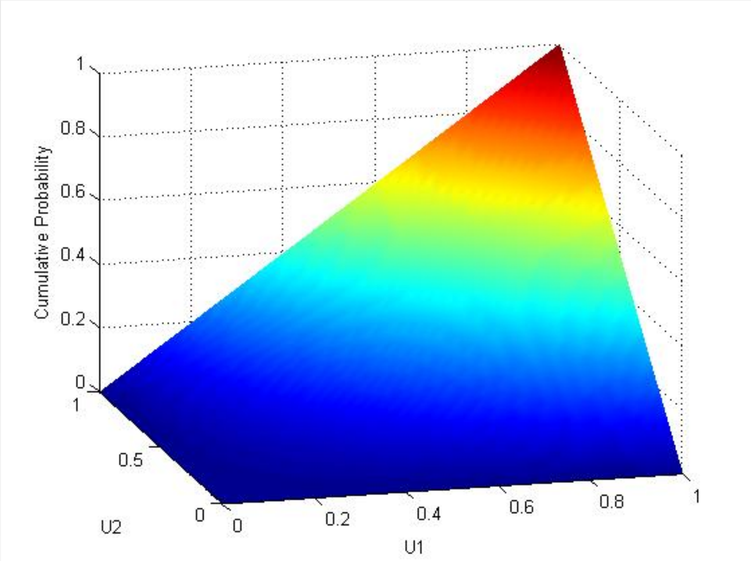


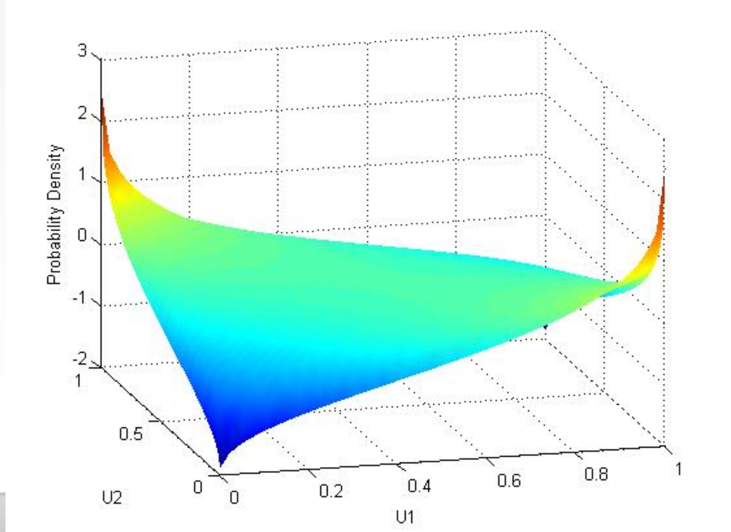
Goharian, E., Burian, S.J., Bardsley, T., and Strong, C. "A new metric integrating flooding and water shortage to evaluate vulnerability of water systems subject to climate change." *Journal of Water Resources Planning and Management*

Water System Performance Index

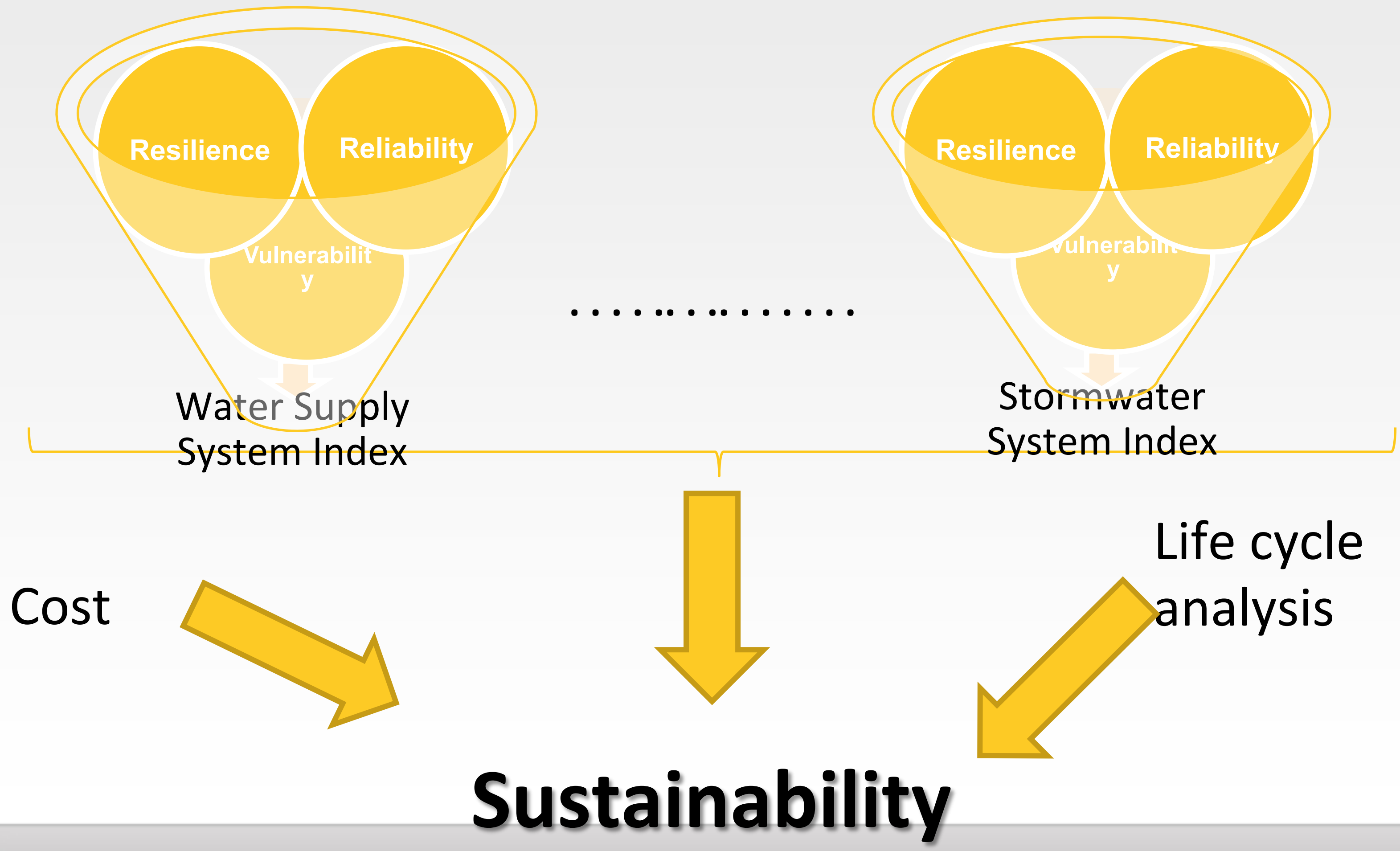
$$WSPI = P(R > r, V \leq v)$$

#	Reliability	Vulnerability	WSPI
1	0.0083	0.9883	0.9997
2	0.7250	0.6301	0.1771
3	0.1833	0.8801	0.9862
4	0.7833	0.4365	0.0034
5	1.000	0.0000	0.0000





Sustainability decision analysis (SDA)



CI~WATER

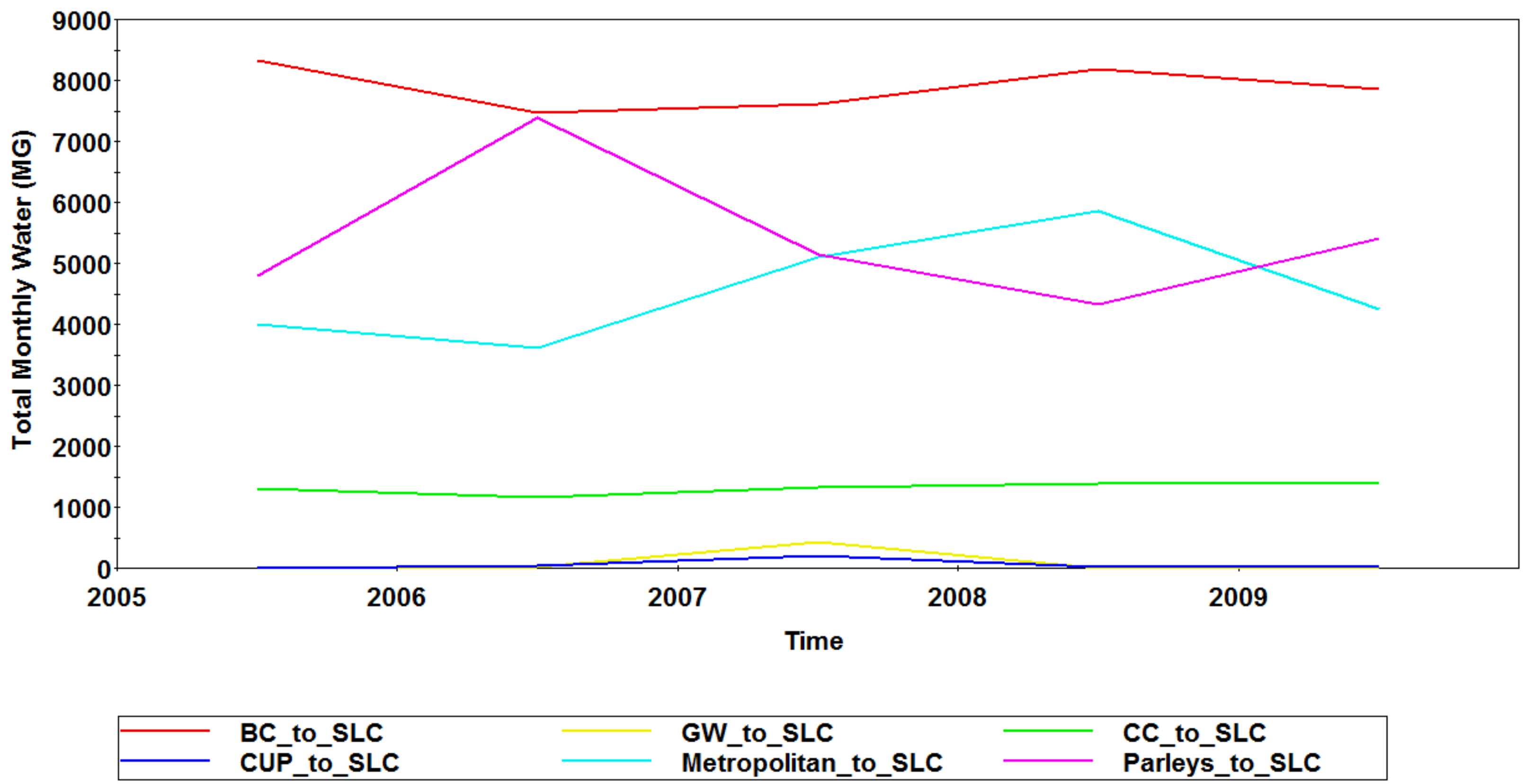
A Utah-Wyoming Cyberinfrastructure Water Modeling Collaboration

Next steps

- WRF Simulations, CSMod Development, Climate Data Access for Urban Water Modeling, Post processor for sustainability and resiliency evaluation, Web-Based Model
- Papers:
    - Macro water budget (Strong et al.)
    - Use of copula functions to produce integrated urban water system vulnerability metrics (Goharian et al.)
    - Climate impacts on integrated water resources system sustainability (Goharian et al.)
    - Demonstration of WamDam for urban water management (USU + UU collaboration)
    - LID controls for urban water system resiliency (Hansen et al.)
    - Web-based simulation (BYU + UU collaboration)

CI-WATER
A Utah-Wyoming Cyberinfrastructure
Water Modeling Collaboration

Water Supply to Salt Lake City



Monte-Carlo Simulation