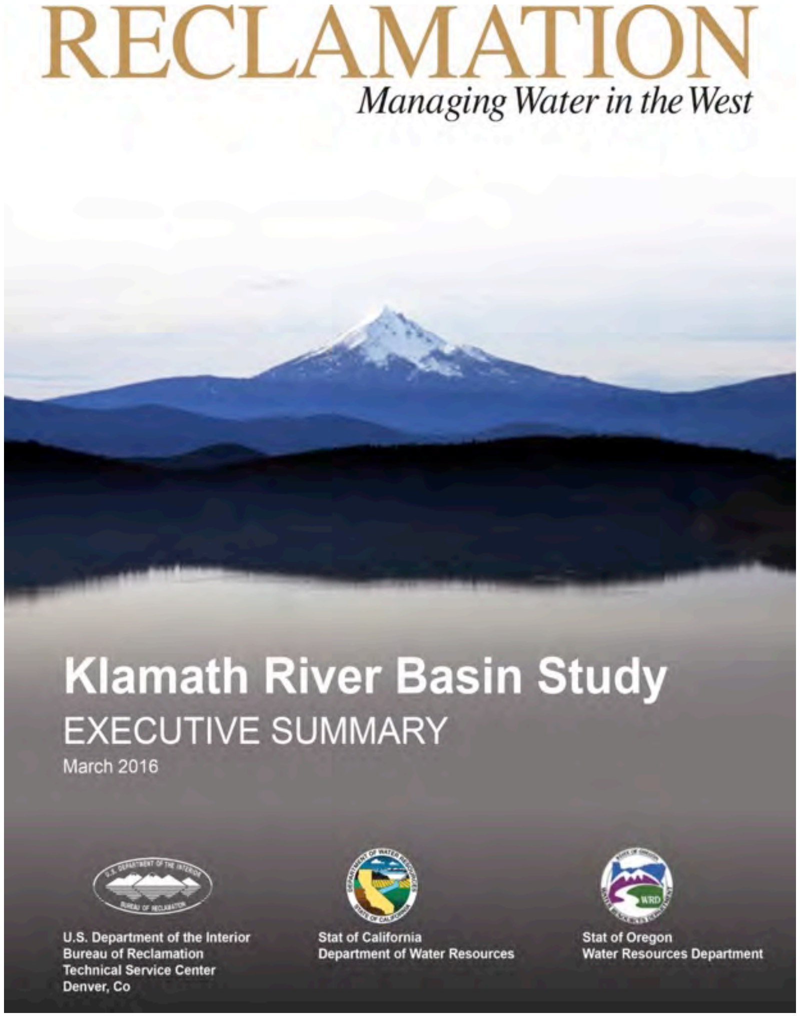
An upside-down river

Klamath River Basin Study

Peter Coombe
DWR Senior Environmental Scientist (Specialist)

Overview

- Study area background
- Issues in the Basin
- Purpose and objectives
- Approach
- Findings



RECLAMATION
Managing Water in the West

Klamath River Basin Study
EXECUTIVE SUMMARY
March 2016

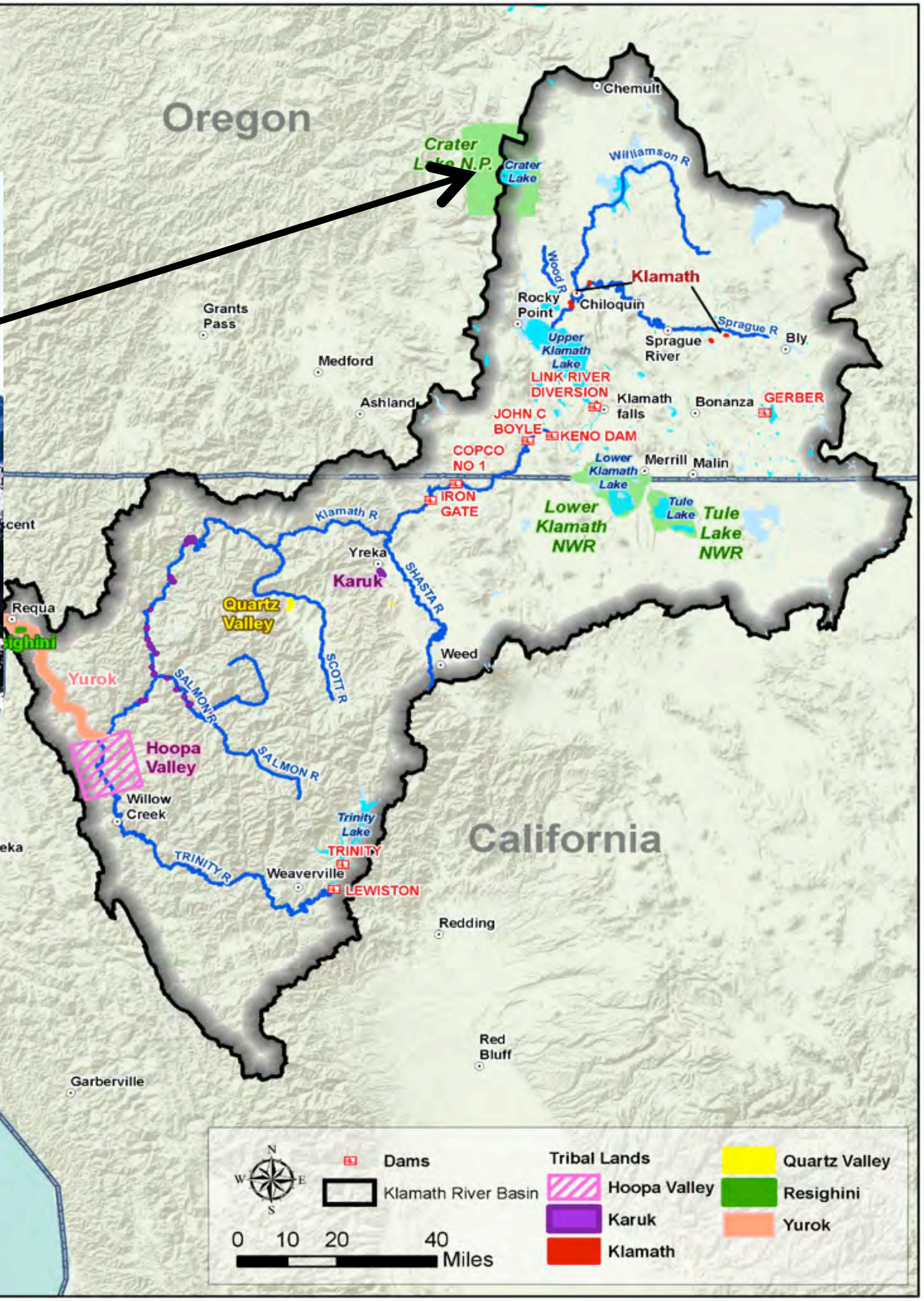
U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Co

Stat of California
Department of Water Resources

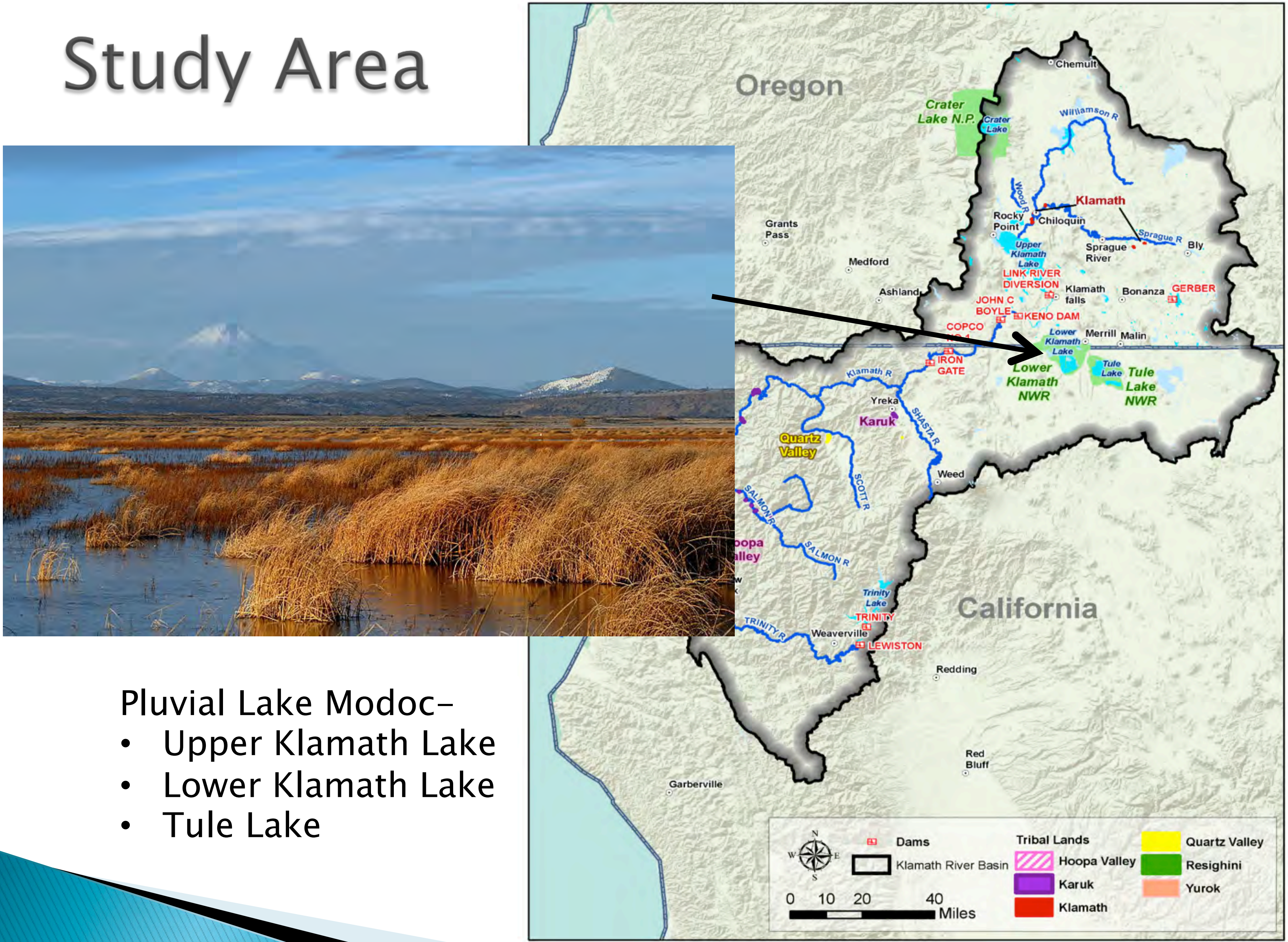
Stat of Oregon
Water Resources Department

Study Area

Mount Mazama – Caldera filled partially with water



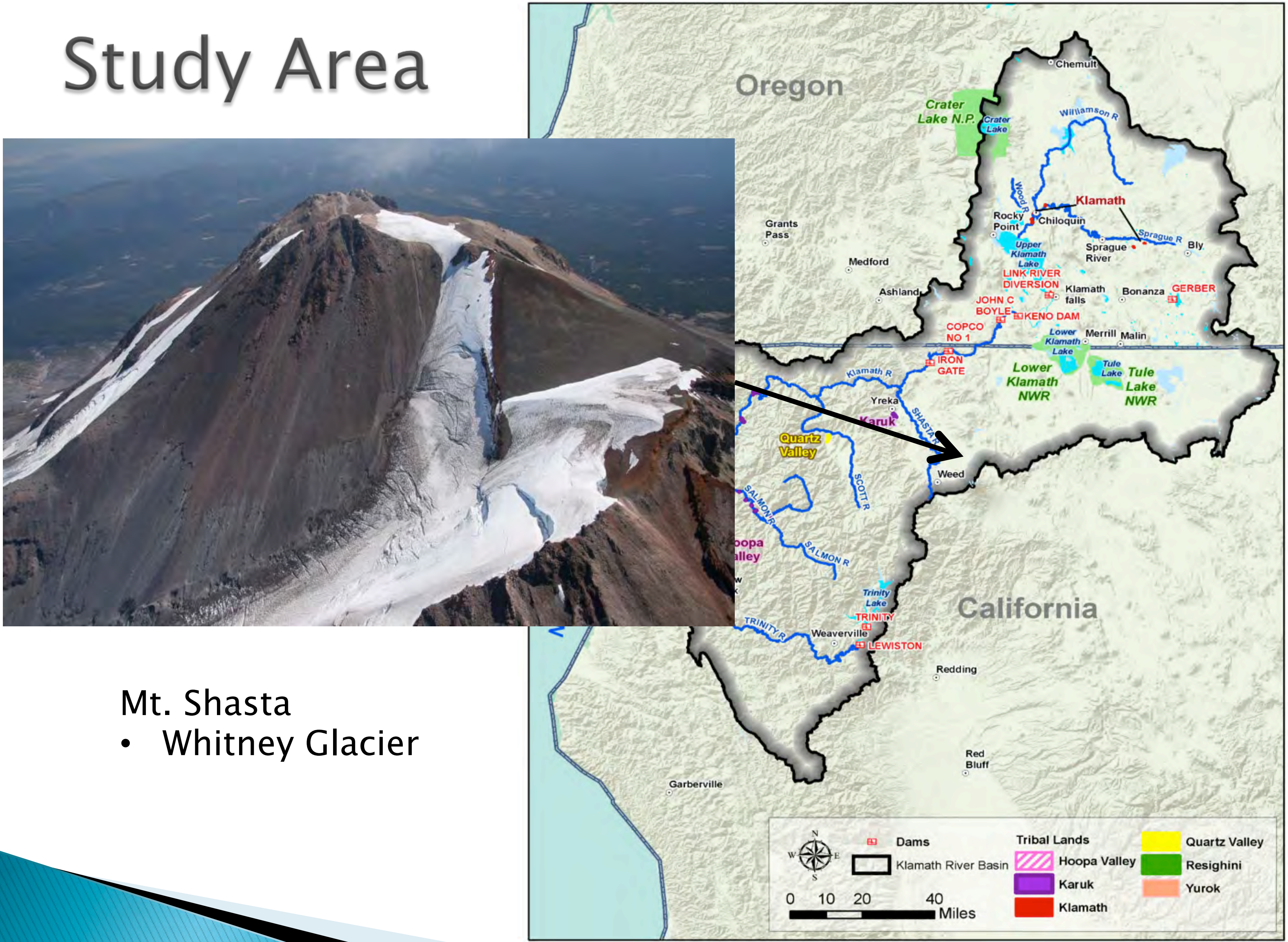
Study Area



Pluvial Lake Modoc–

- Upper Klamath Lake
- Lower Klamath Lake
- Tule Lake

Study Area



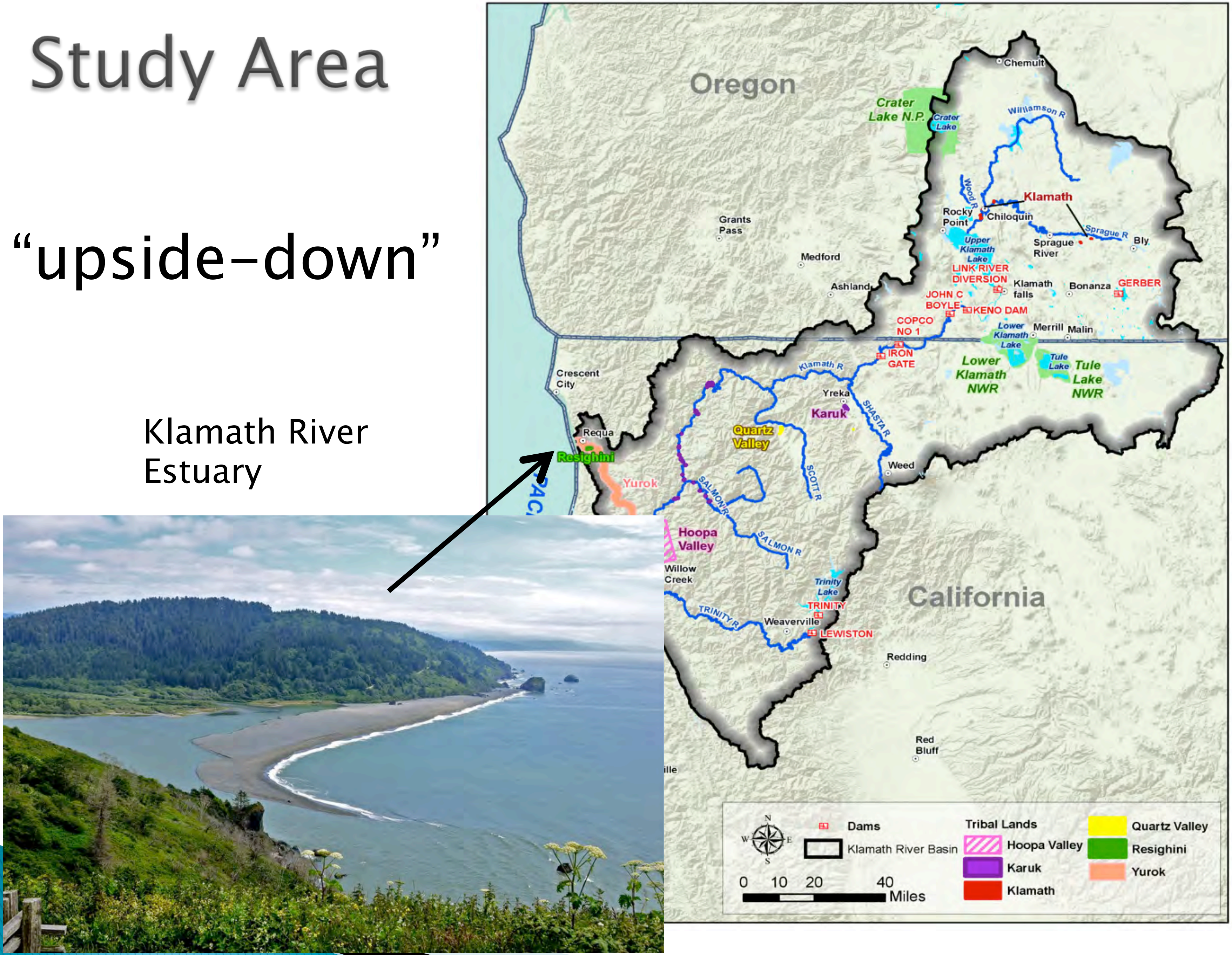
Mt. Shasta

- Whitney Glacier

Study Area

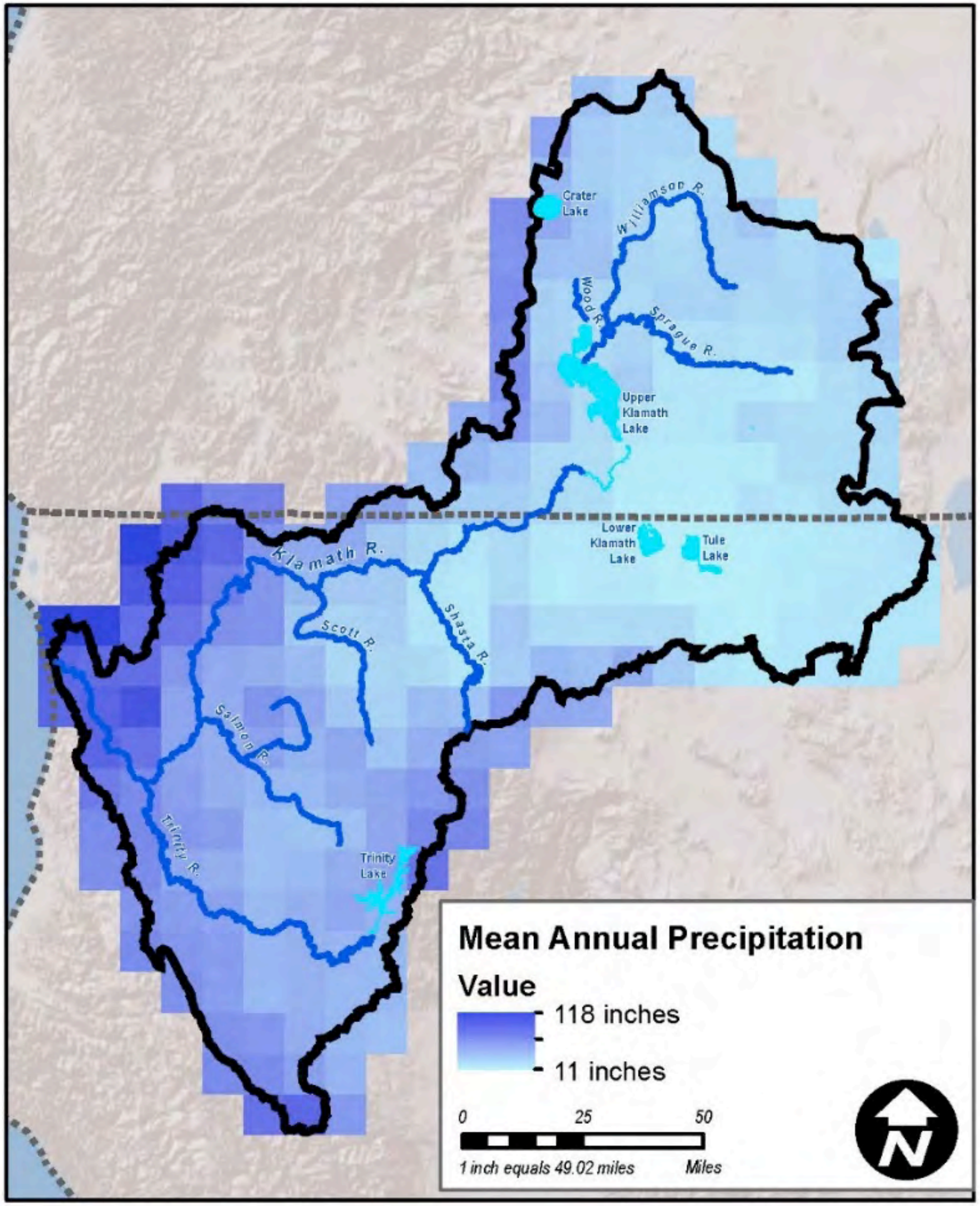
“upside–down”

Klamath River
Estuary



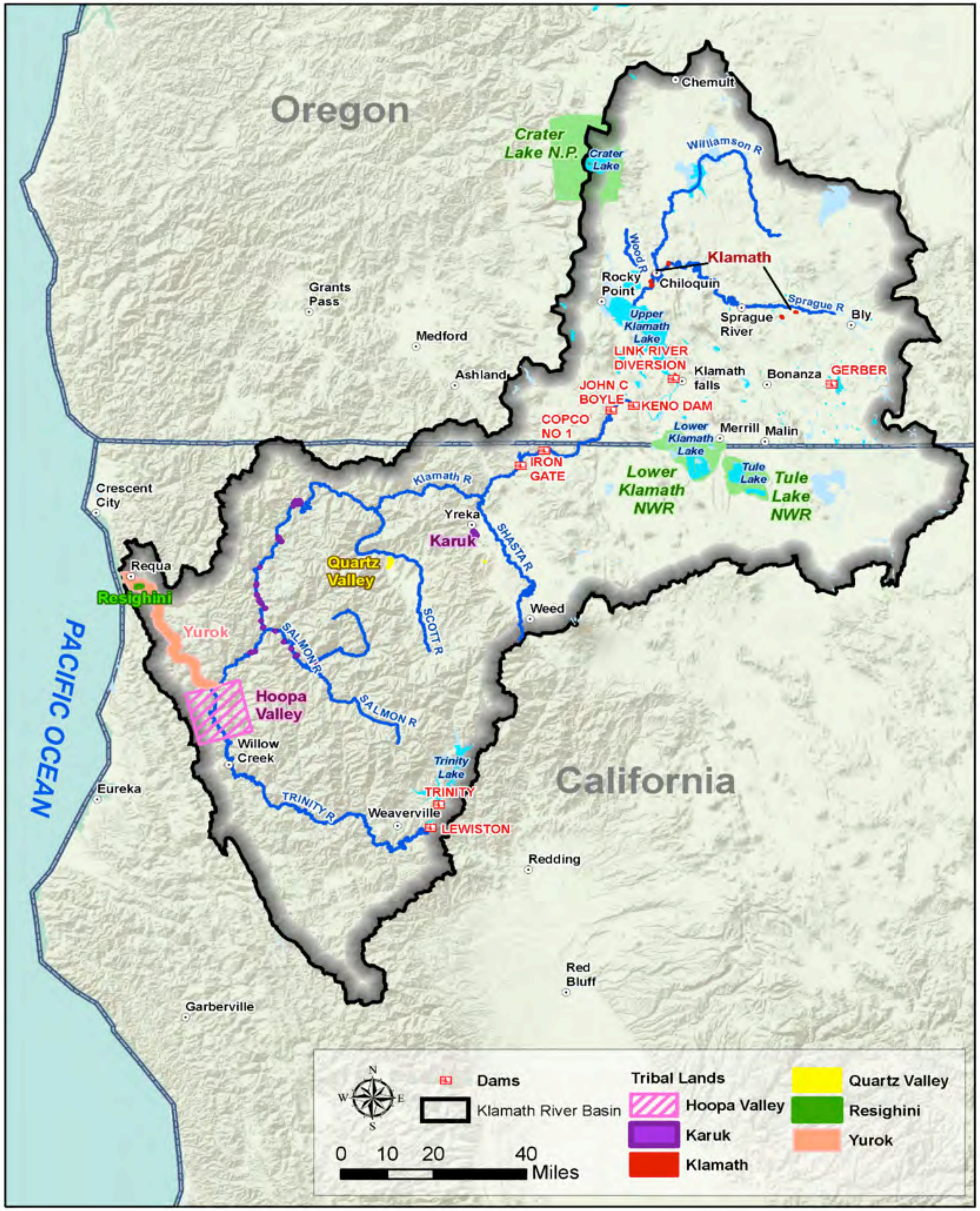
Study Area

“upside-down”



Study Area

- 6 national wildlife refuges
- 1 national park
- 2 national monuments
- 2 federal irrigation projects
- 5 national forests
- Managed by 5 federal agencies, 6 federally recognized Tribes
- 2 states, and numerous local and private organizations
- 6 dams while still retaining large sections of wild and scenic designations



Issues in the Basin

Management Challenges

- Interstate watershed
- Irrigation diversions
- Endangered species recovery
- Hydropower production
- Water rights adjudication
- Tribal treaty rights
- Arid headwaters in upper basin
- Recreational uses
- Compliance with water quality criteria
- Multiple interrelated and coordinated agreements and projects

Issues in the Basin

Agreements:

- 1957- The Klamath River Basin Compact
- 2000- FERC relicensing process was initiated for PacifiCorp's Klamath River project
- 2010-The Klamath Basin Restoration Agreement (KBRA)
- 2010-Klamath Hydroelectric Settlement Agreement (KHSA)
- 2014- Upper Klamath Basin Comprehensive Agreement (UKBA)
- 2016- KHSA agreement-in-principle

Issues in the Basin

Current Issues:

- 2002- Klamath River fish kill

Low flow of 800 CFS in September 1908 (before irrigation began)

September of the 2001 irrigation shut-off, an average of 688 CFS

During the 2002 fish kill, flows of 475 cubic feet per second

Purpose and objectives

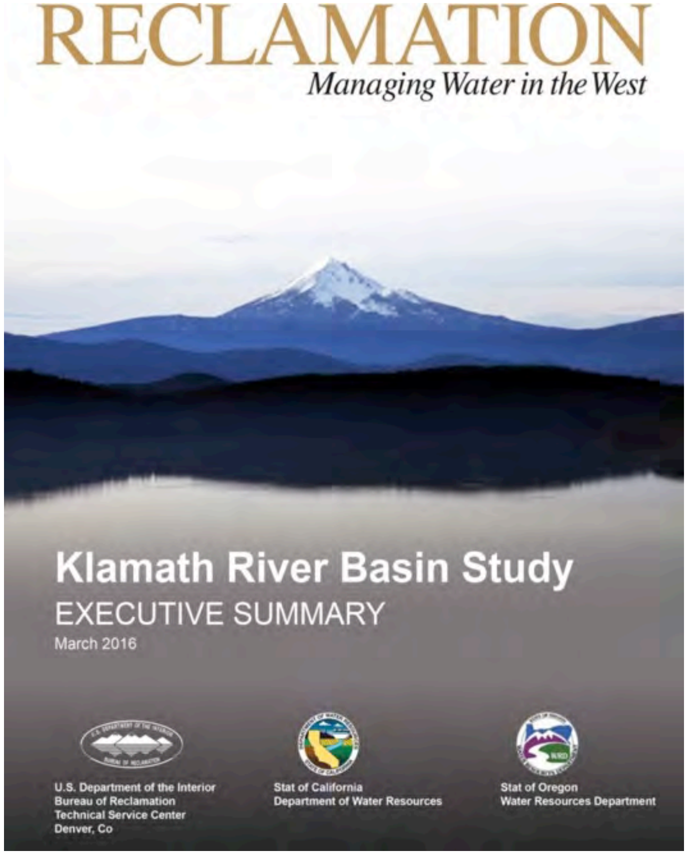
Klamath River Basin Study :

- Evaluate current and projected future water supply and demand using applied climate change science

- Identify and evaluate potential adaptation strategies which may reduce any identified imbalances

- The Federal SECURE Water Act of 2009

  Authorizes Federal water and science agencies to work with State and local water managers to pursue and protect sustainable water supplies and plan for future climate change.



RECLAMATION
Managing Water in the West

Klamath River Basin Study
EXECUTIVE SUMMARY
March 2016

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Co

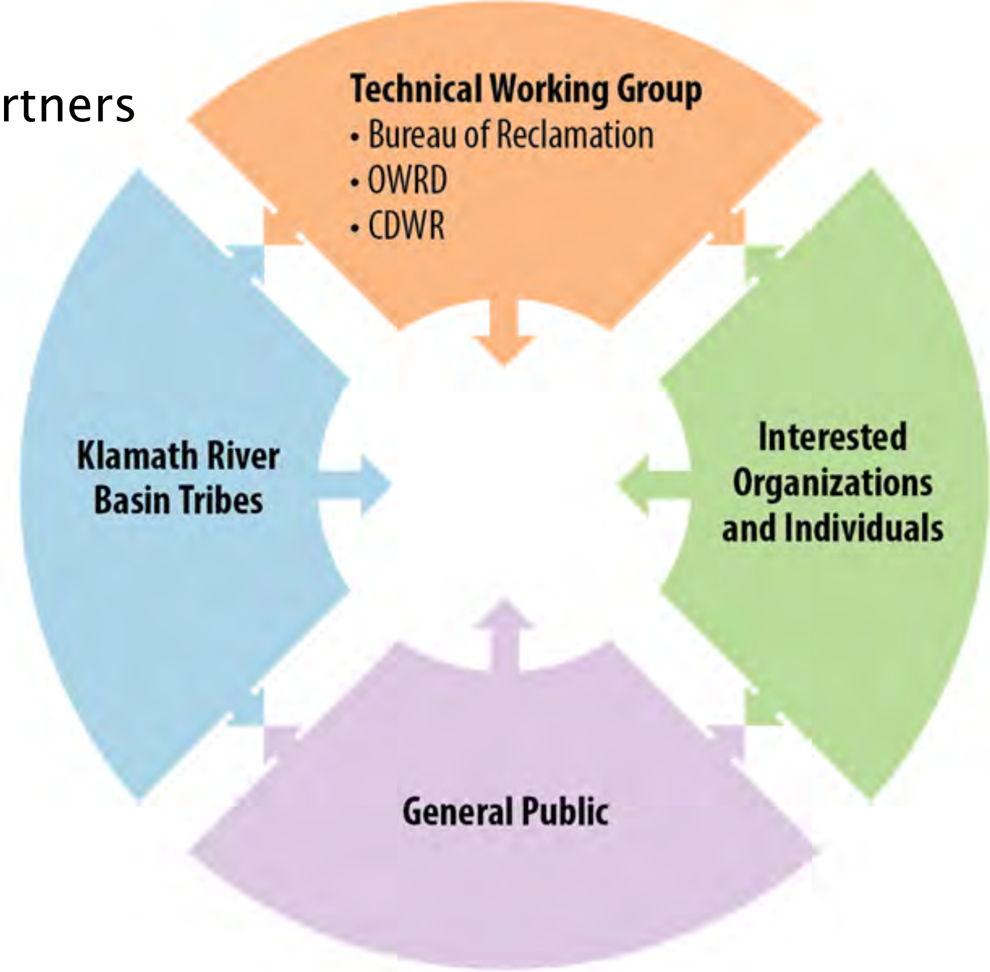
Stat of California
Department of Water Resources

Stat of Oregon
Water Resources Department

Approach

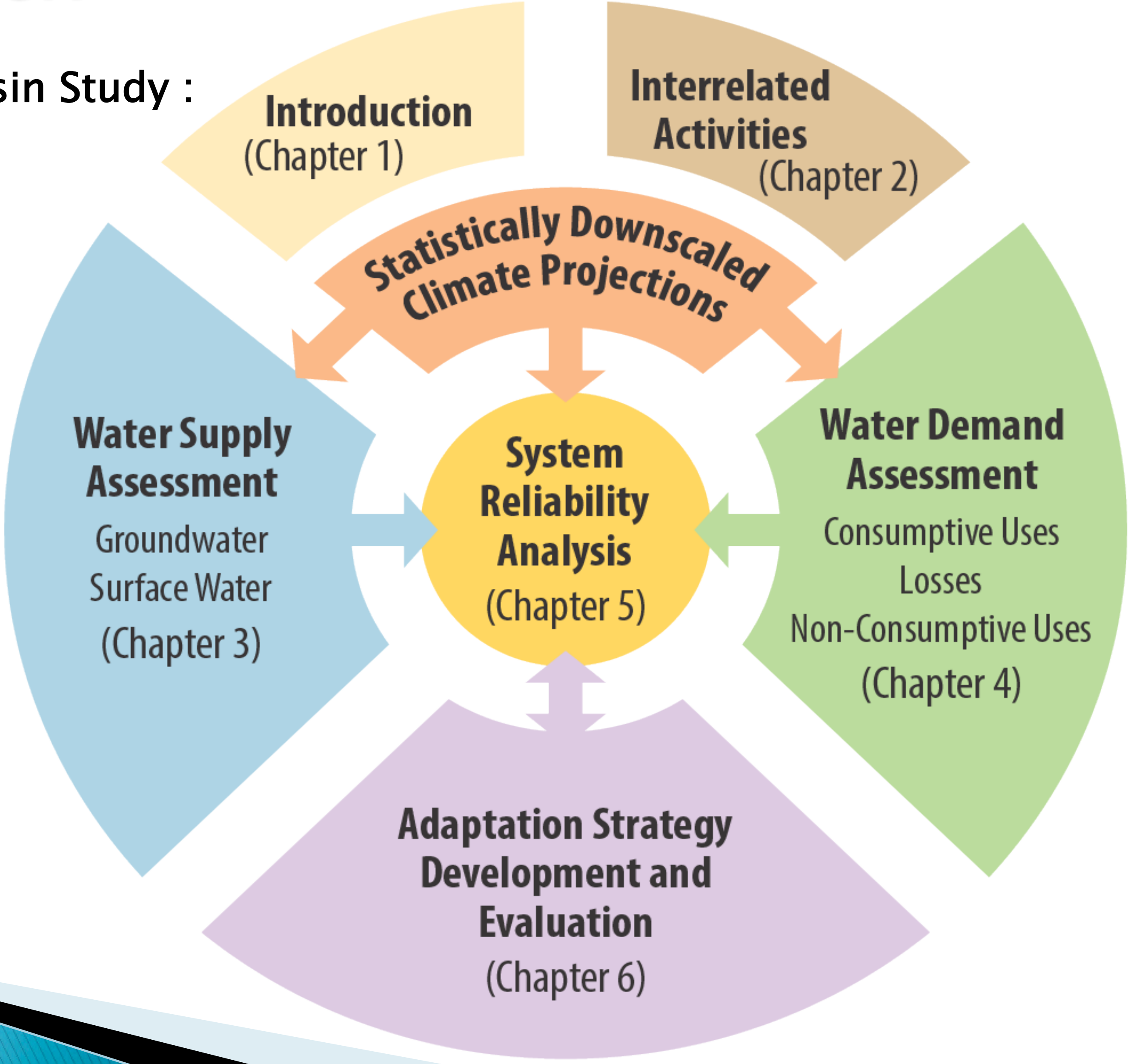
Klamath River Basin Study :

- Technical Working Group
  - Bureau of Reclamation
  - Non-federal cost share partners

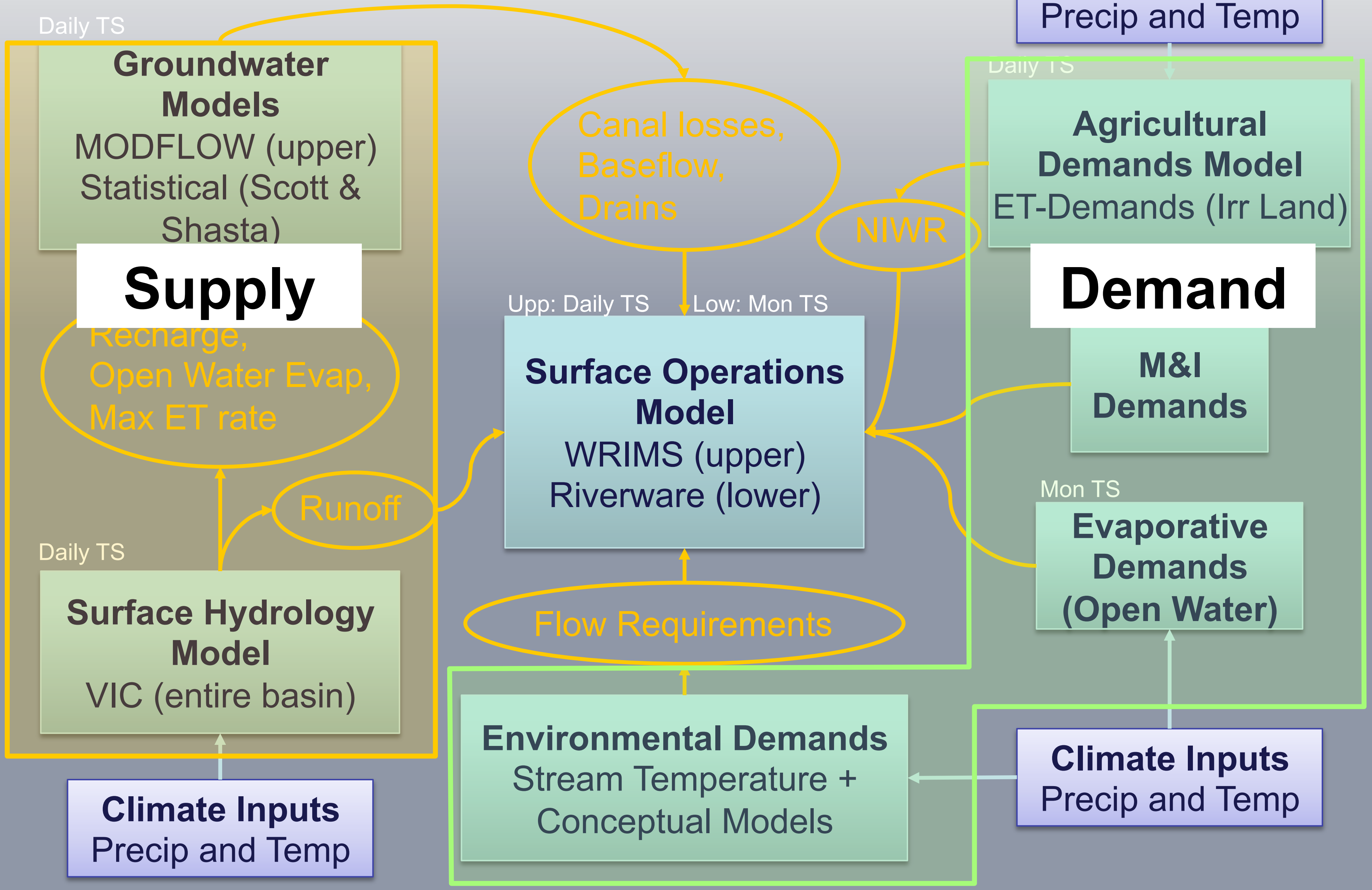


Approach

Klamath River Basin Study :



Modeled Systems Diagram



Daily TS

Groundwater Models
MODFLOW (upper)
Statistical (Scott & Shasta)

Supply

Recharge,
Open Water Evap,
Max ET rate

Runoff

Daily TS

Surface Hydrology Model
VIC (entire basin)

Climate Inputs
Precip and Temp

Canal losses,
Baseflow,
Drains

NIWR

Upp: Daily TS

Low: Mon TS

Surface Operations Model
WRIMS (upper)
Riverware (lower)

Flow Requirements

Environmental Demands
Stream Temperature +
Conceptual Models

Climate Inputs
Precip and Temp

Daily TS

Agricultural Demands Model
ET-Demands (Irr Land)

Demand

M&I Demands

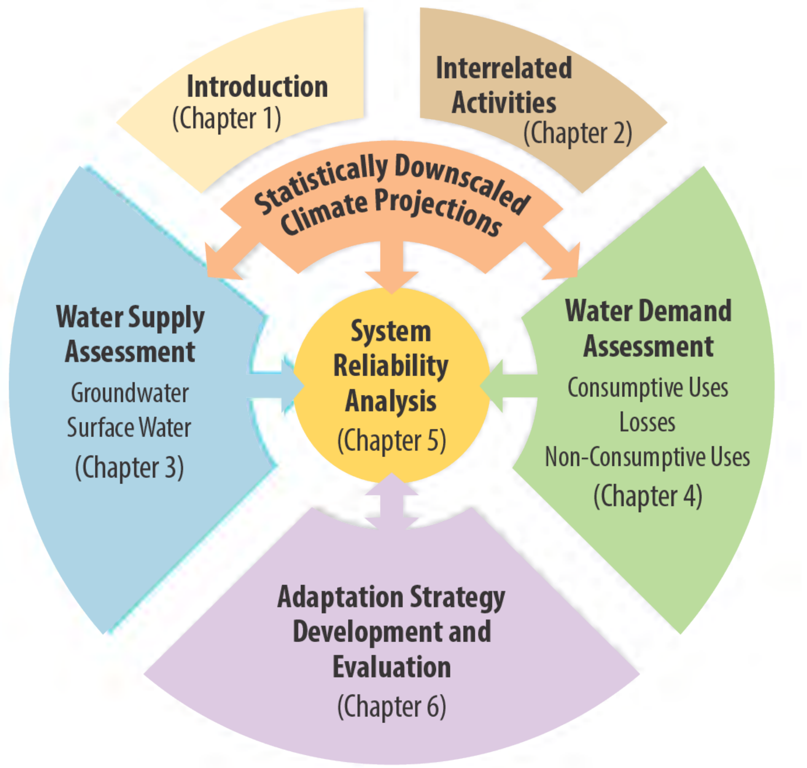
Mon TS

Evaporative Demands (Open Water)

Climate Inputs
Precip and Temp

Water Supply Assessment

- Future Scenario Development
- Historical Water Supply
- Projected Future Water Supply
  - Surface Water
  - Groundwater



Introduction
(Chapter 1)

Interrelated Activities
(Chapter 2)

Statistically Downscaled Climate Projections

Water Supply Assessment
Groundwater
Surface Water
(Chapter 3)

System Reliability Analysis
(Chapter 5)

Water Demand Assessment
Consumptive Uses
Losses
Non-Consumptive Uses
(Chapter 4)

Adaptation Strategy Development and Evaluation
(Chapter 6)

Water Supply Assessment

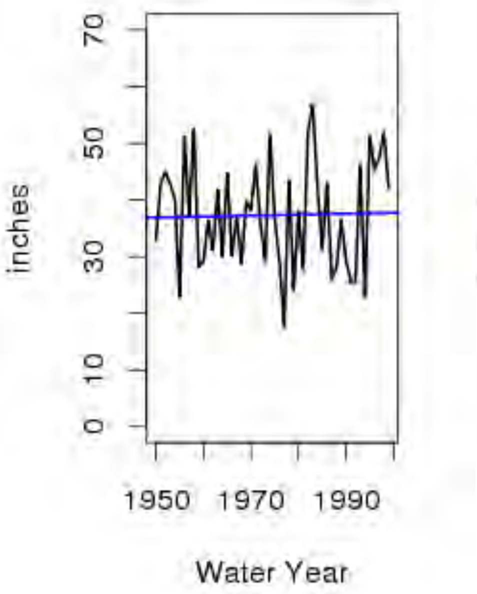
- Future Scenario Development
  - Scenario planning approach
    - Consistent with other basin studies
    - Both CMIP3- and CMIP5-based projections
    - GCM projections to derive a smaller number of climate change scenarios
    - Scenarios were generated using a period change approach for two future time horizons
    - 2030s (2020-2049)
    - 2070s (2060-2089)

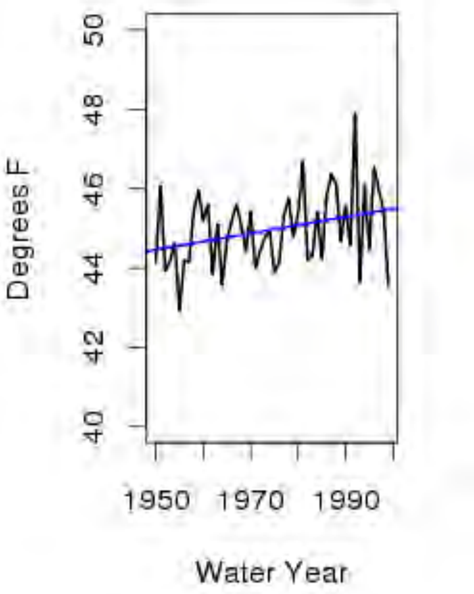
Water Supply Assessment

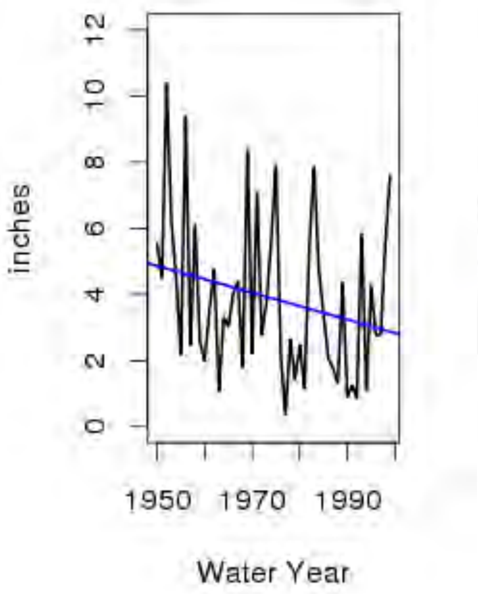
- Future Scenario Development
  - All climate projections over the Klamath River Basin suggest a warmer future
  - However with a range of drier to wetter conditions, compared to history
    - warm–wet (WW)
    - warm–dry (WD)
    - hot–wet (HW)
    - hot–dry (HD)
    - central tendency (CT)
  - Total of 10 HDe climate scenarios for each of two future time horizons 2030s and 2070s

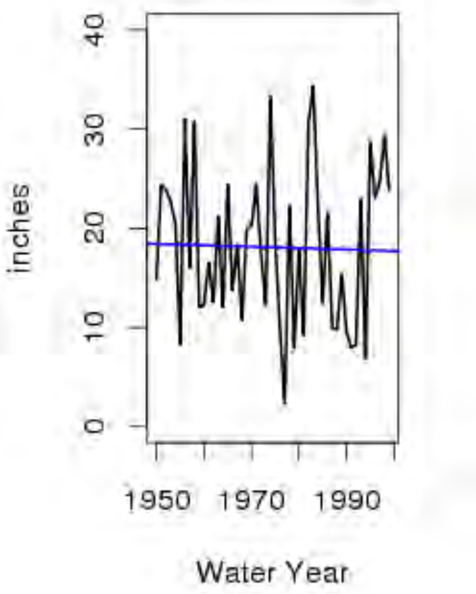
Water Supply Assessment

Basin Wide Historical- Mean change over 1950–1999 period (water years)


Mean Ann. Prcp
+0.8in (+2%)


Mean Ann. Tavg
+1.0°F


Mean April 1 SWE
-2.0in (-41%)


Mean Ann. Runoff
-0.7in (-4%)

Of historical Prcp, Tavg, SWE, RO, ET, Soil Moisture, only statistically significant trends at 95th percentile level are:

- Tavg (all regions), ET (North Coast Climate Division)

Water Supply Assessment

- Projected Future Water Supply

CMIP3 and CMIP5 water balance projections are largely consistent.

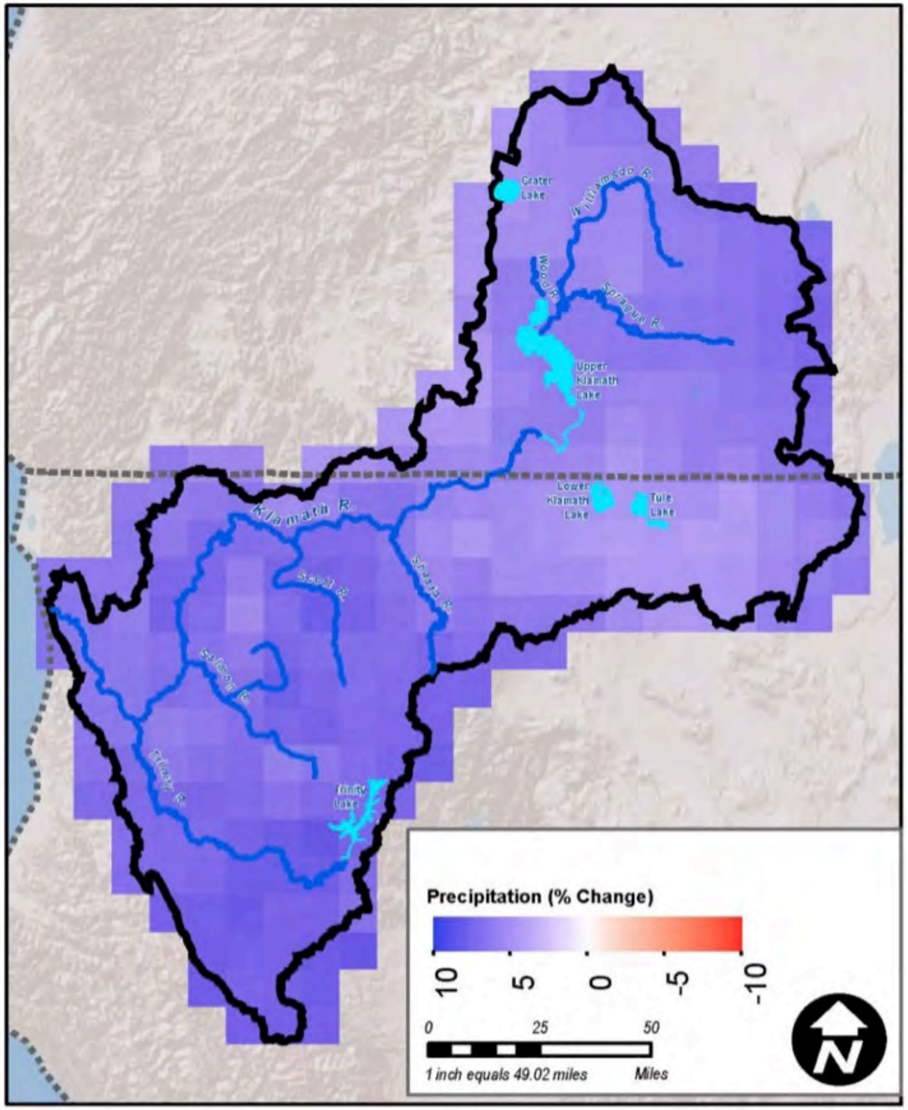
2030s	
Prcp, CMIP3	+2.4 %
Prcp, CMIP5	+4.1 %
Tavg, CMIP3	+2.2 degF
Tavg, CMIP5	+2.7 degF
2070s	
Prcp, CMIP3	+5.2 %
Prcp, CMIP5	+6.1 %
Tavg, CMIP3	+4.2 degF
Tavg, CMIP5	+4.5 degF

Water Supply Assessment

- Projected Future Water Supply

Precipitation projections:
Indicate wetter winters and slightly drier summers

Assessment did not include changes in extreme precipitation events



Projected increases in 2070 precipitation levels

Water Supply Assessment

- Projected Future Water Supply

Surface water projections:

April 1 SWE:
−40% (2030s)
−62% (2070s)

Spring (April – September) runoff:
−25% (2030s)
−40% (2070s)

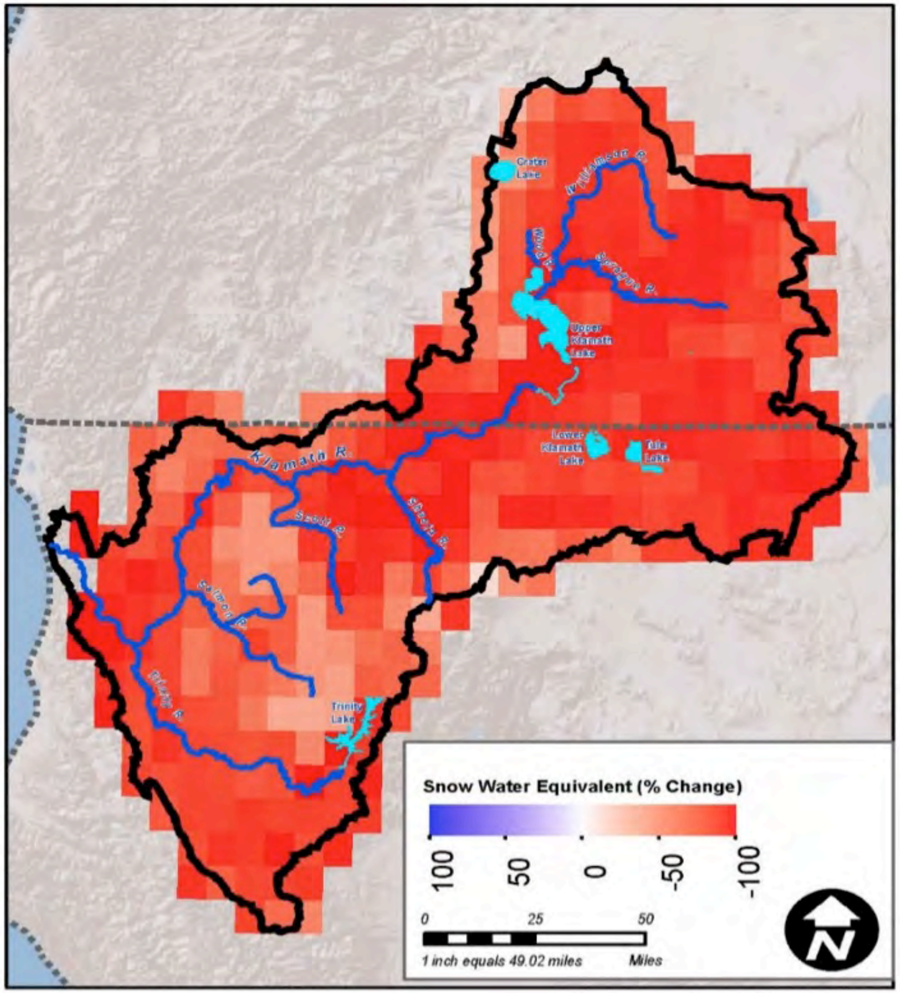


Figure ES-8. Projected Change in Snowpack (Apr 1SWE)
Comparison of percent change in mean April 1 SWE (Apr1SWE, top row) for the central tendency HDe scenarios based on CMIP5.

Water Supply Assessment

- Projected Future Water Supply

Surface water projections:

Both CMIP3- and CMIP5-based projections indicate a decrease in spring and summer streamflow for the 2030s and a greater decrease by the 2070s.

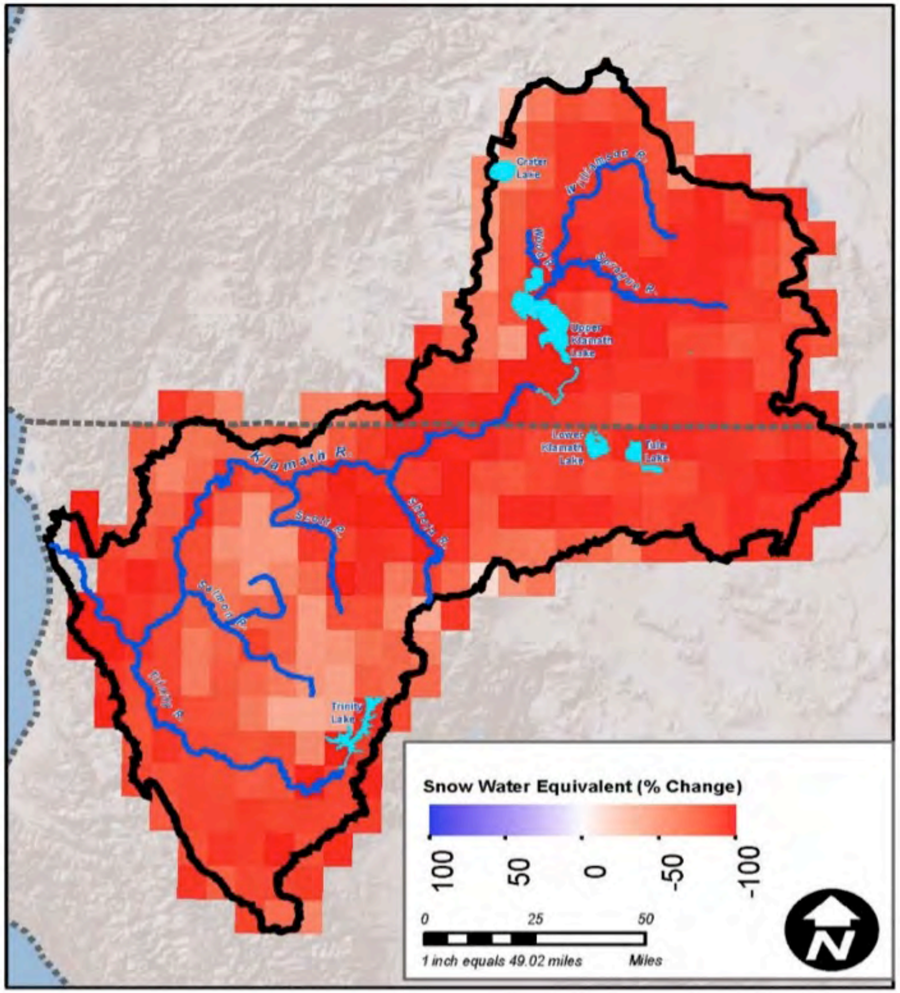
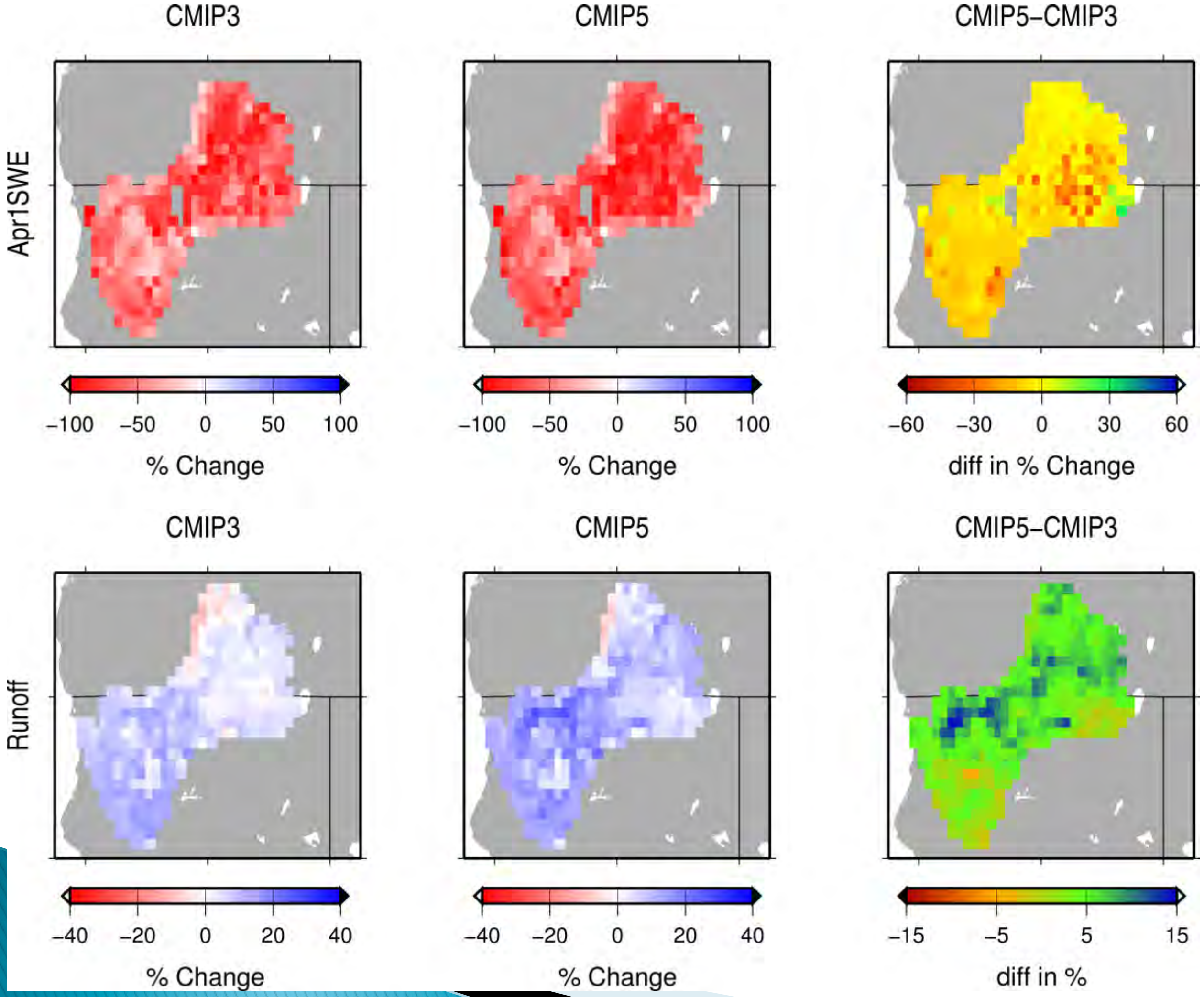


Figure ES-8. Projected Change in Snowpack (Apr 1SWE)

Comparison of percent change in mean April 1 SWE (Apr1SWE, top row) for the central tendency HDe scenarios based on CMIP5.

Water Supply Assessment

Central Tendency HDe Projections (2030s shown)



- Despite projected increases in Prcp (2030s & 2070s), April 1 SWE is still projected to decline, primarily due to projected increases in mean annual temperature (exception: Mt Shasta)
- Mean annual runoff is projected to increase in the Lower Klamath Basin, while changes in the Upper Klamath Basin vary between CMIP3 and CMIP5 both in magnitude and direction

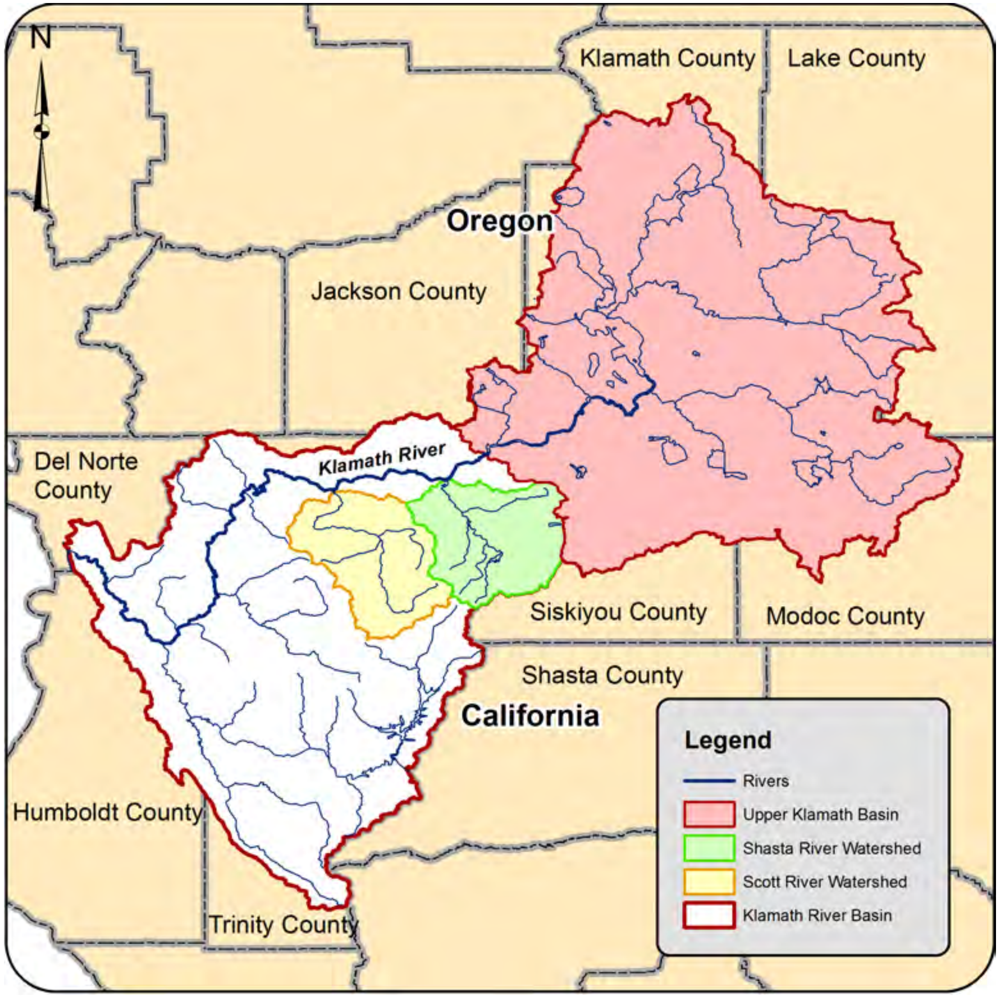
Water Supply Assessment

- Projected Future Water Supply

Groundwater projections:

Upper Klamath Basin:
+1.8 to 7.8 feet (2030s)
+4.4 to 8.2 feet (2070s)

Groundwater Models
MODFLOW (upper)
Statistical (Scott & Shasta)



Water Supply Assessment

- Projected Future Water Supply

Groundwater projections:

Scott Valley (CT):
+15 feet (2030s)
+23 feet (2070s)

Shasta Valley (CT):
+24 feet (2030s)
+25 feet (2070s)

Groundwater Models
MODFLOW (upper)
Statistical (Scott & Shasta)

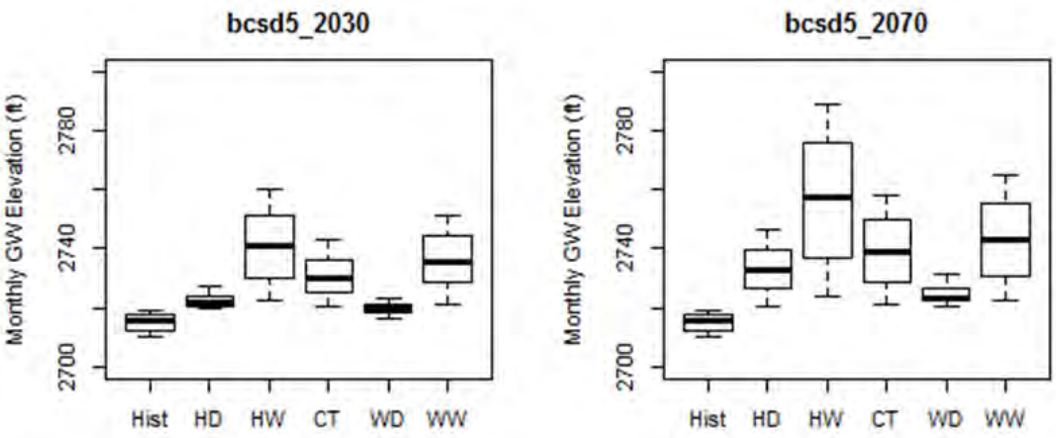
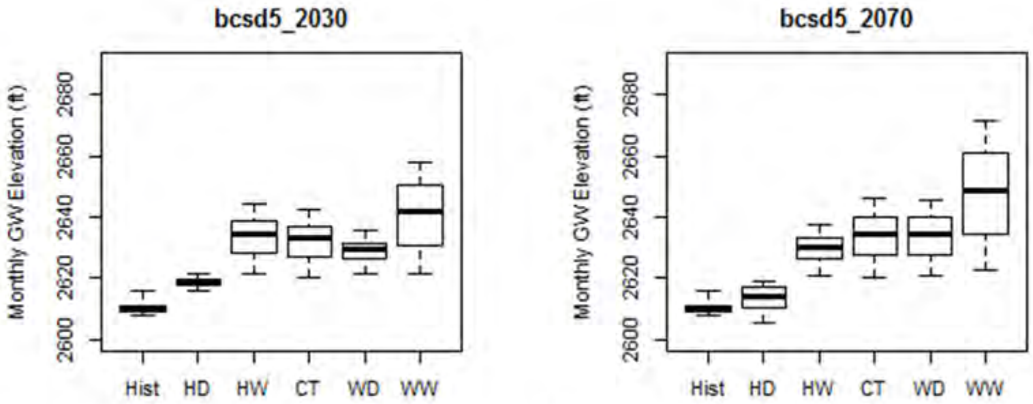


Figure 3-41. Summary of projected groundwater elevation for Scott Valley

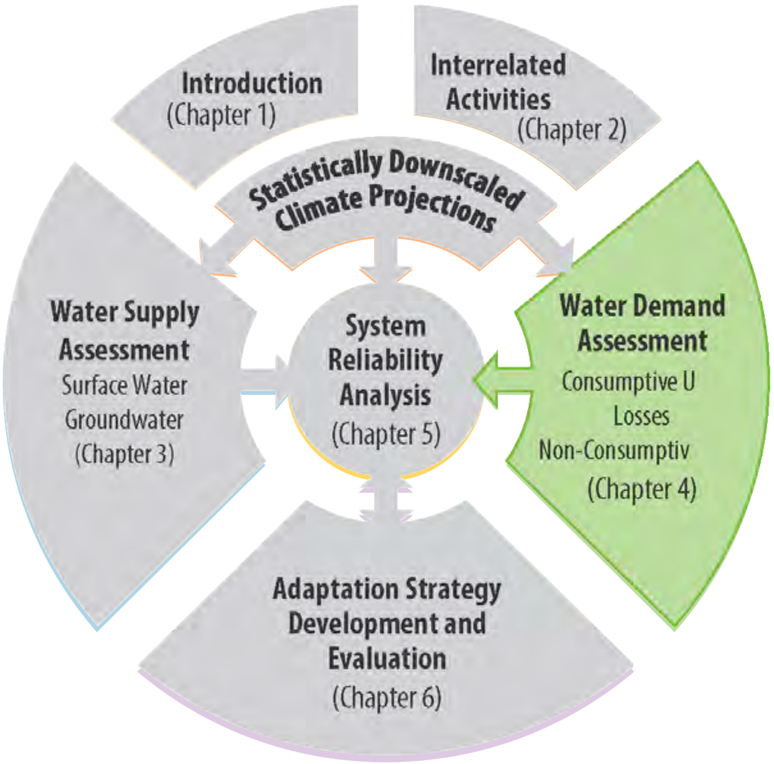


a) b)

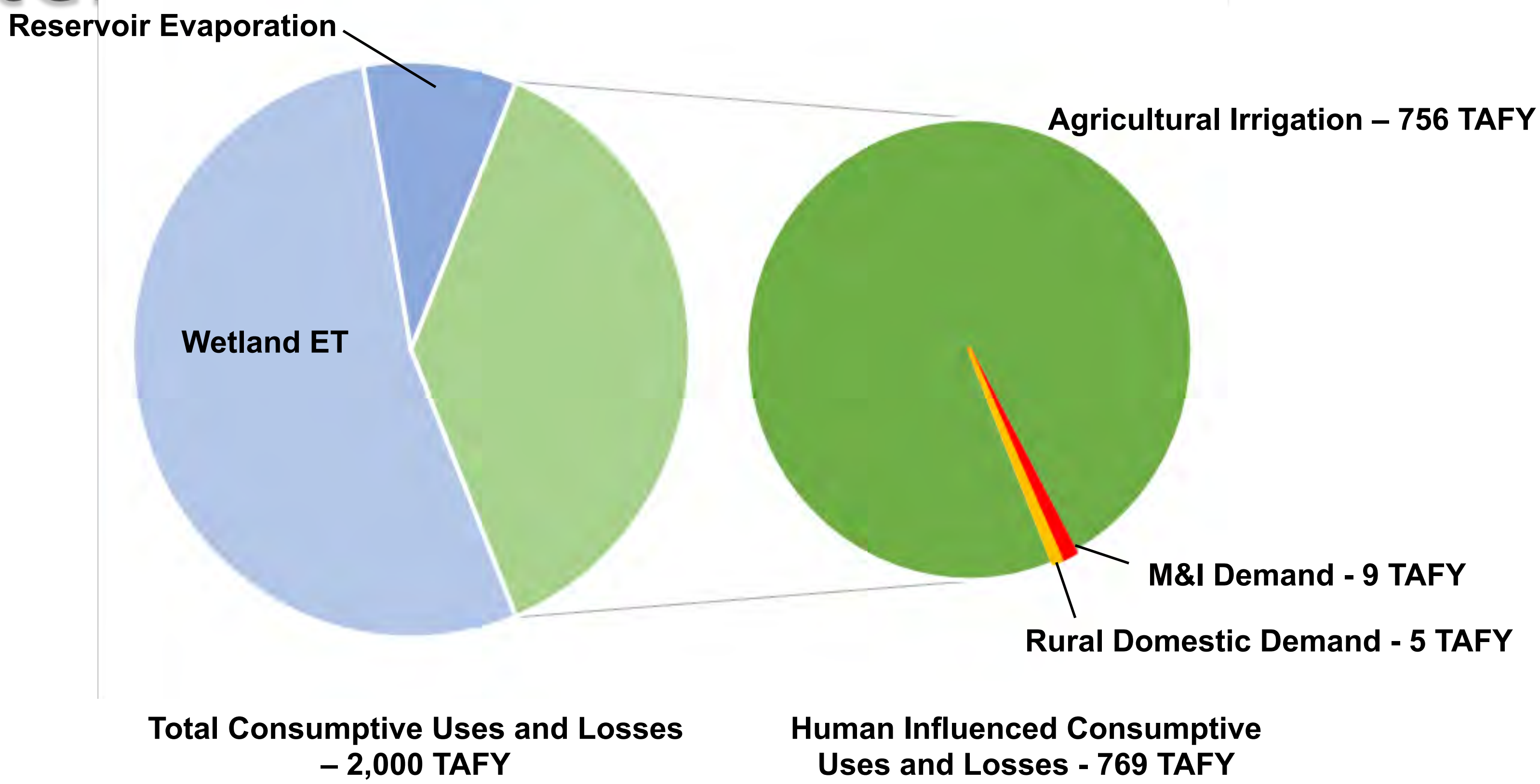
Figure 3-42. Summary of projected groundwater elevation for Shasta Valley

Water Demand Assessment

- Consumptive
- Non-consumptive uses
- Projected Future Water Demand



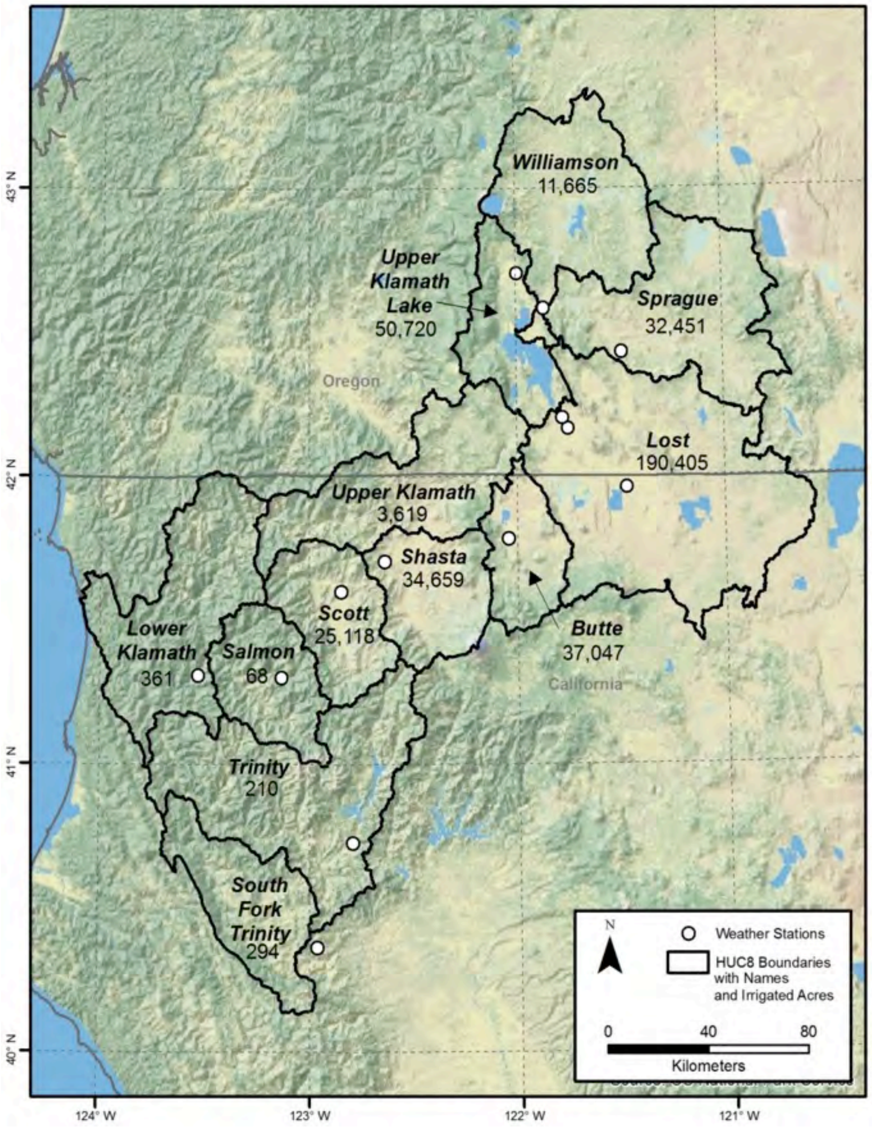
Water Demand Assessment



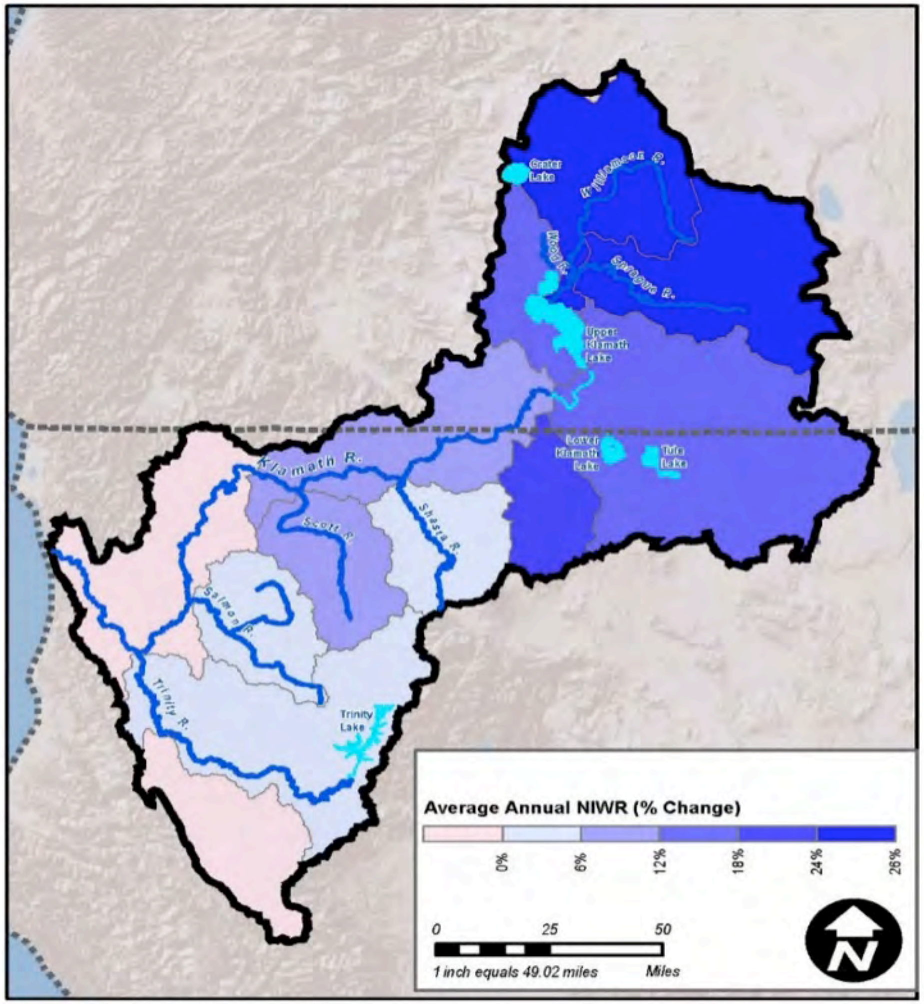
Total consumptive water demand for human uses in the basin is about 800 thousand acre-feet/year (TAFY) and about 98% of the total human influenced demand is for agricultural irrigation.

NIWR Estimates

- Historical gridded climate data set (Maurer et al. 2002) bias corrected to local weather stations
- ET Demands calibrated to local growing patterns
  - Green-up
  - Harvest
  - Senescence
  - Freeze

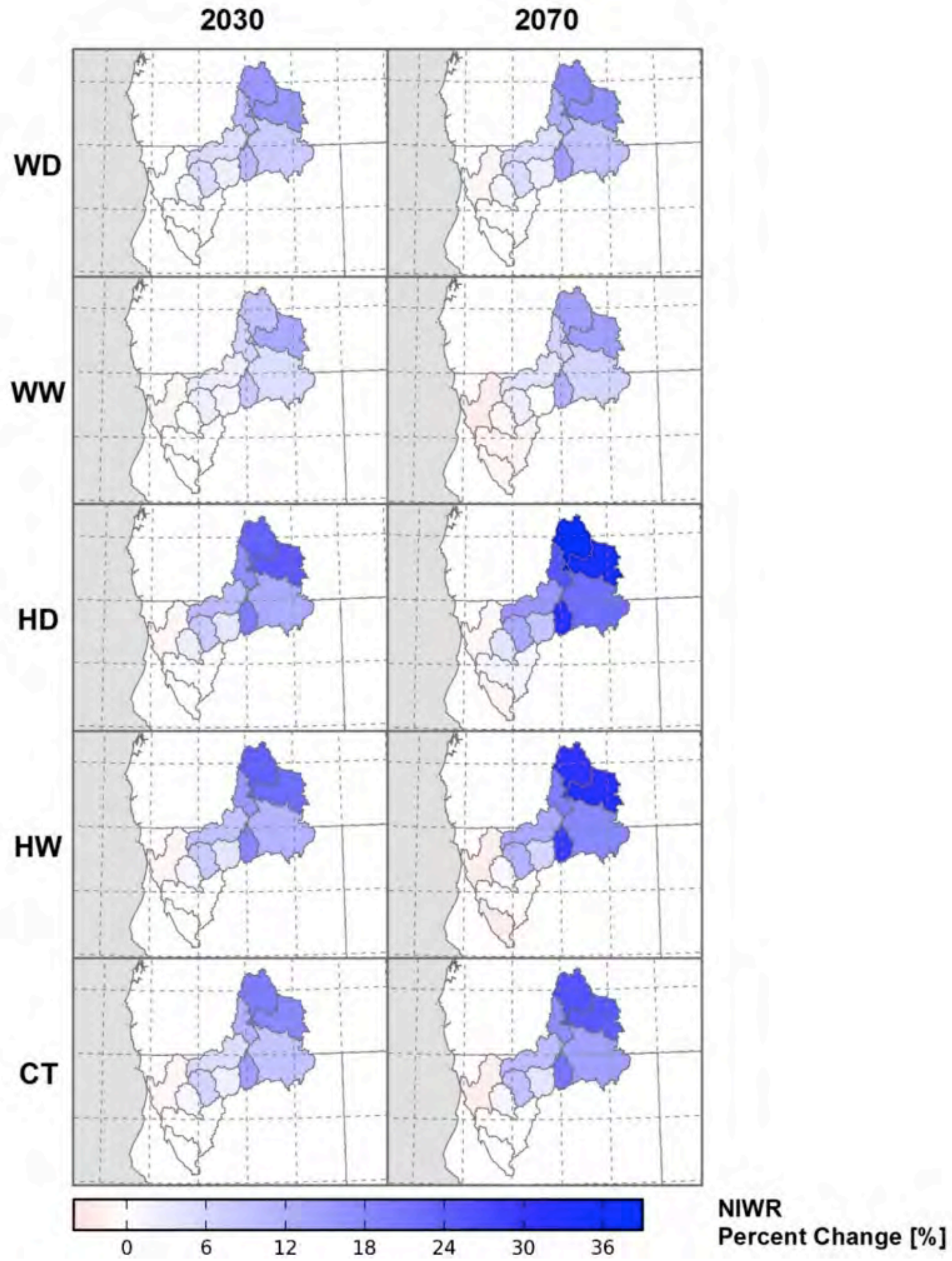


Water Demand Assessment



Central tendency scenario for the 2070s

Change in Future NIWR From Historical Baseline (CMIP5)



Projected Change Basin Wide:

2030s: +10%
2070s: +14%

CRLE Results – Net Evaporation *

Complementary Relationship Lake Evaporation (CRLE) Model

Reservoir	Historical (AFY)	Central Tendency CMIP5 2030s (AF | %)		Central Tendency CMIP5 2070s (AFY | %)	
Upper Klamath Lake	125,977	126,320	0.27%	132,732	5.36%
Clear Lake	57,300	58,916	2.82%	60,946	6.36%
Gerber Reservoir	4,862	4,899	0.76%	5,120	5.31%
Tule Lake	17,484	17,975	2.81%	18,544	6.06%
JC Boyle Reservoir	371	375	1.02%	391	5.51%
Copco Reservoir	1,626	1,641	0.95%	1,707	5.00%
Iron Gate Reservoir	2,089	2,135	2.18%	2,204	5.46%
Trinity Lake	-28,412	-29,478	3.75%	-30,975	9.02%

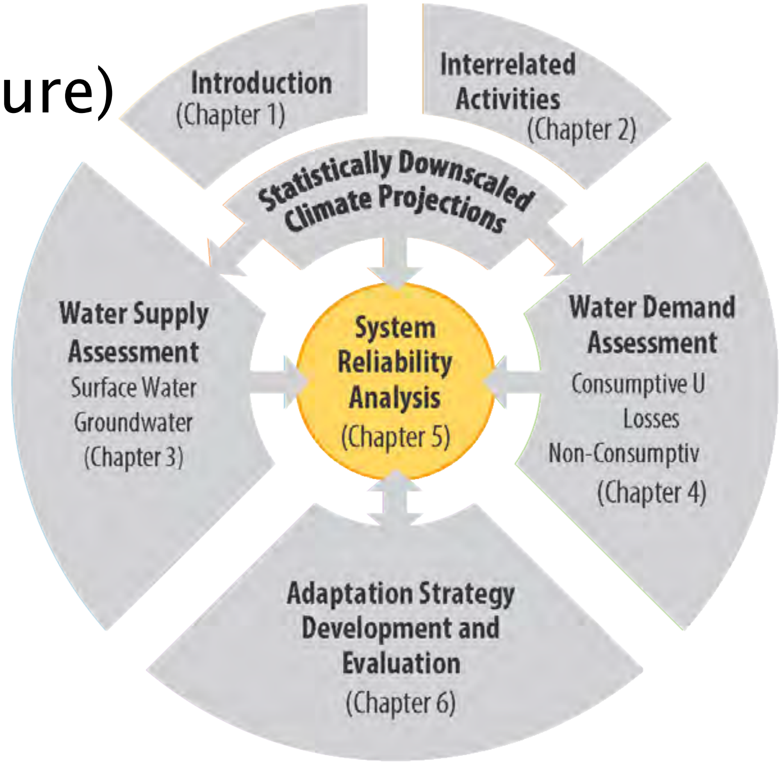
*** Net evaporation = Evaporation - Precipitation**

Future M&I and Rural Domestic Demand Estimates

Future Period and Scenario	M&I (% Change)	Rural Domestic (% Change)
2030 Base Demand	8%	9%
2030 Central CMIP3	11%	12%
2030 Central CMIP5	11%	13%
2070 Base Demand	17%	20%
2070 Central CMIP3	22%	27%
2070 Central CMIP5	22%	28%

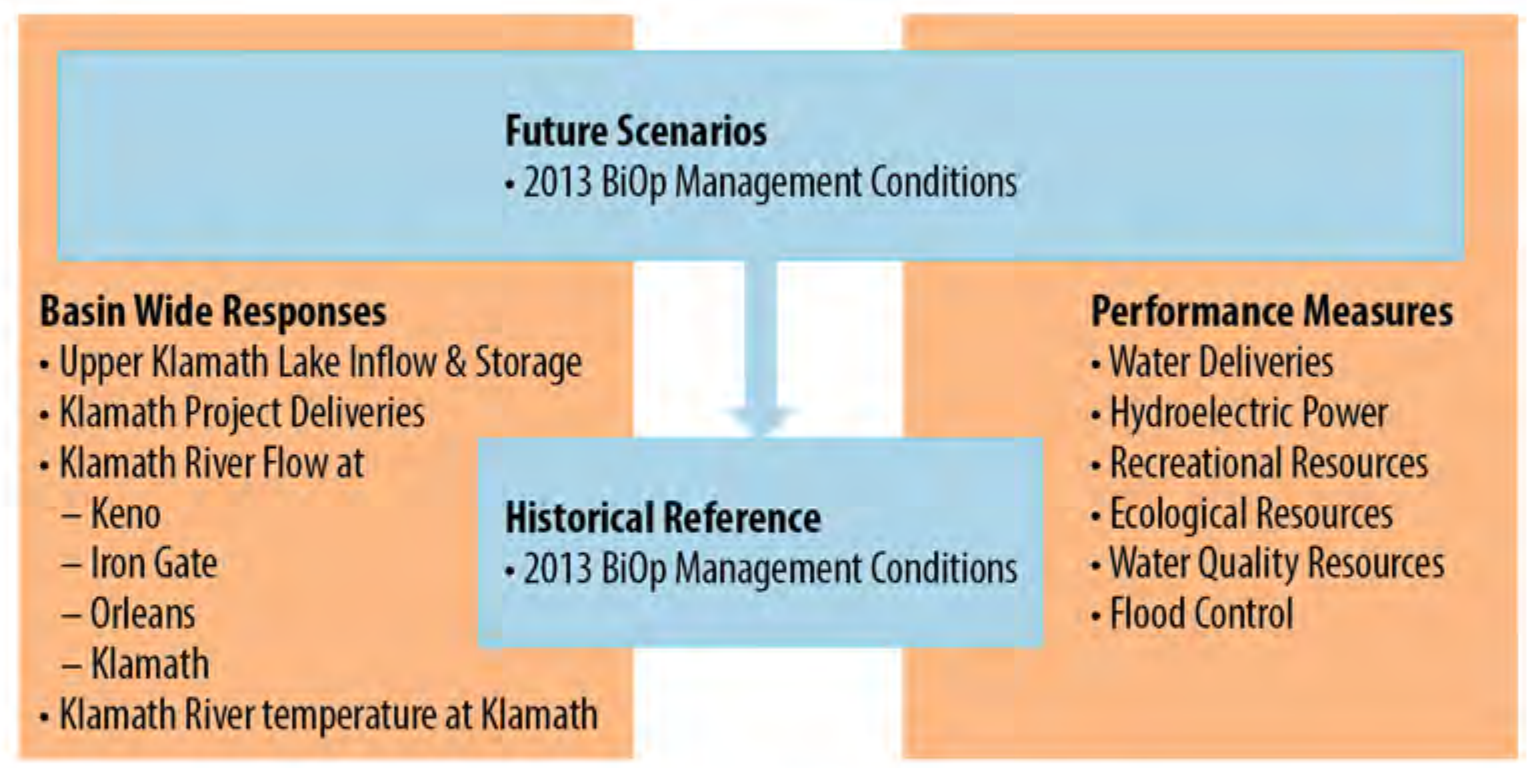
System Reliability Analysis

- Selected performance measures
  - Water Delivery
  - Hydroelectric Power Resources
  - Recreational Resources (fishing and boating)
  - Ecological Resources
  - Water Quality (water temperature)
  - Flood Control



System Reliability Analysis

Simulations (with historical and future hydrology conditions) were performed using existing operational constraints under the 2013 BiOp for Klamath Project operations, which dictates operations throughout the Upper Klamath Basin.



Future Scenarios
- 2013 BiOp Management Conditions

Basin Wide Responses
- Upper Klamath Lake Inflow & Storage
- Klamath Project Deliveries
- Klamath River Flow at
  - Keno
  - Iron Gate
  - Orleans
  - Klamath
- Klamath River temperature at Klamath

Historical Reference
- 2013 BiOp Management Conditions

Performance Measures
- Water Deliveries
- Hydroelectric Power
- Recreational Resources
- Ecological Resources
- Water Quality Resources
- Flood Control

Figure ES-12. System Reliability Assessment Approach

System Reliability Analysis

- Results of the system risk and reliability analysis support the common understanding that the Klamath River basin has historically experienced difficulties in meeting the range of water needs.

- For example, according to model simulations, average annual deliveries to Klamath Project irrigators were about 93% of full delivery volume (assumed to be 390,000 acre-feet) over water years 1970-1999.

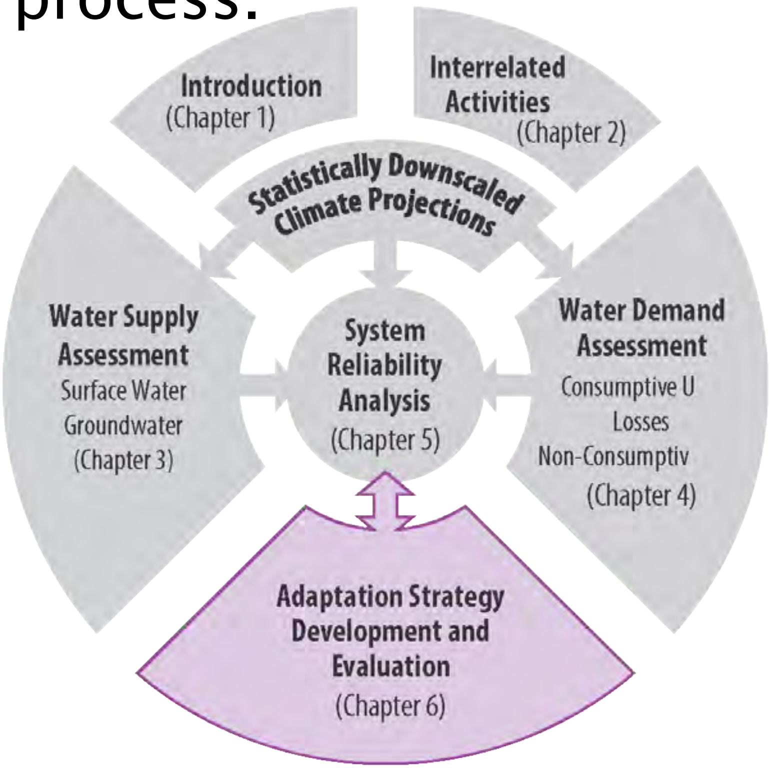
System Reliability Analysis

- Projected increases in precipitation and flow volumes at many locations in the basin as a result of climate change alone may reduce water supply gaps in some ways.

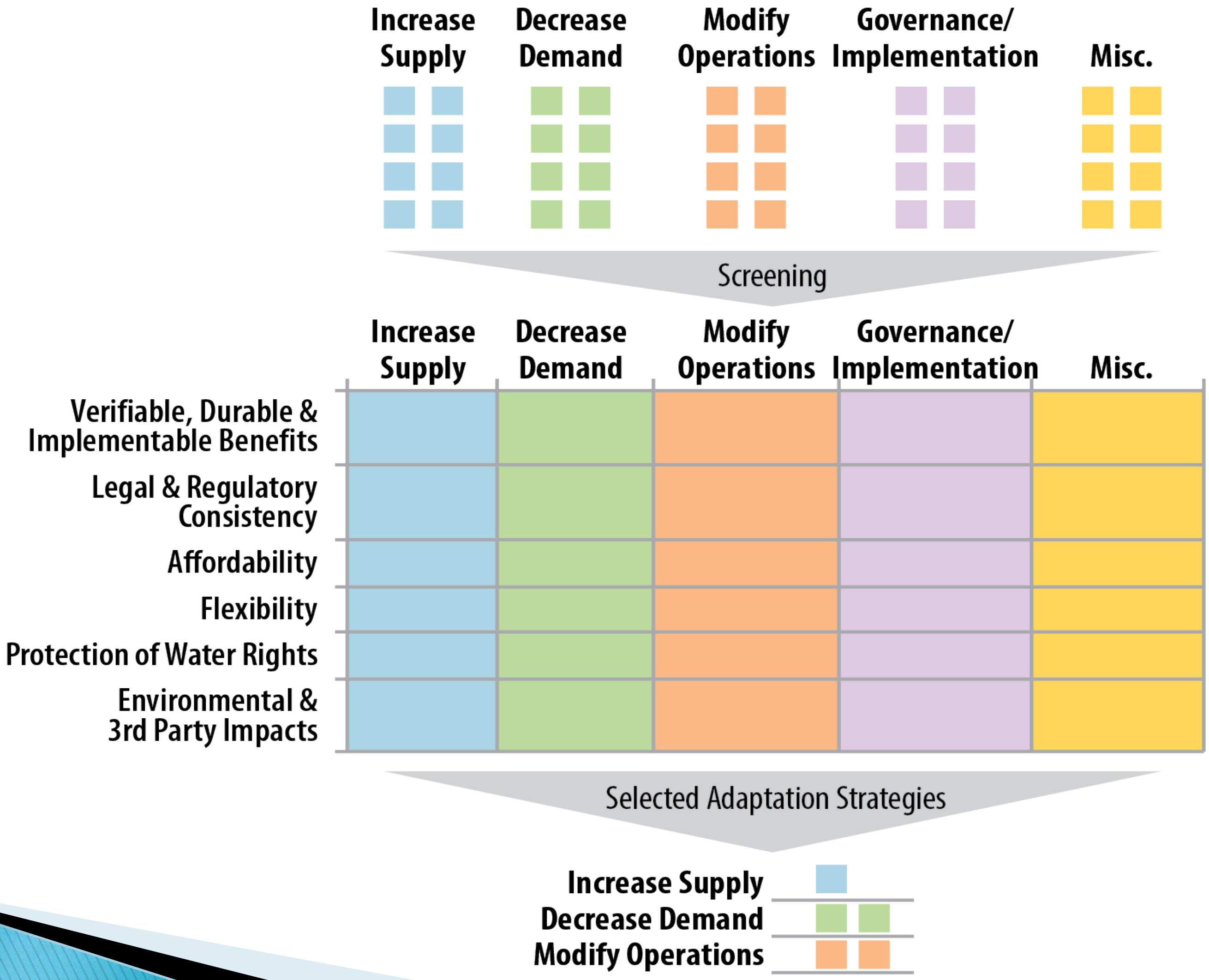
- However, there are projected to be greater challenges for ecological resources such as fish and wildlife, as well as irrigators in the Upper Klamath Basin.

Adaptation Strategies

- A literature review effort identified over 180 unique adaptation strategies and stakeholders provided another 5 strategies. These were carried forward for evaluation in the screening process.



Screening process



Increase Supply

Decrease Demand

Modify Operations

Governance/ Implementation

Misc.

Screening

Verifiable, Durable & Implementable Benefits

Legal & Regulatory Consistency

Affordability

Flexibility

Protection of Water Rights

Environmental & 3rd Party Impacts

Selected Adaptation Strategies

Increase Supply

Decrease Demand

Modify Operations

Adaptation Strategies

- **Increase Supply**

Additional Surface Water Storage Capacity:

- Defined as the incremental “excess water” remaining after releases are made to the Klamath Project and to meet environmental needs (including instream flow needs in the Klamath River and water stored in Upper Klamath Lake to maintain elevations).

- Under this strategy, surface water that could be stored for future use; however, it is acknowledged that under the current (2013) Biological Opinion , this quantity is categorized as environmental water.

Adaptation Strategies

- **Decrease Demand**

Agricultural Water Conservation: Reductions in agricultural water demand might be obtained through canal lining and pump operation optimization; crop idling, irrigated land retirement and rain-fed agriculture; shifting agricultural production to more drought tolerant crops; and, converting irrigation systems to more efficient technologies along with the use of cover crops to improve soil productivity.

Adaptation Strategies

- **Decrease Demand**

Additional Supply to Upper Klamath Lake. This adaptation strategy concept captures the additional 30,000 acre-feet of water provided for Upper Klamath Lake in the KHSA, KBRA and (UKBA) Upper Klamath Basin Comprehensive Agreement as generated by land retirement actions in the Upper Klamath Basin.

This strategy also assumes that operating rules are not modified to compensate for the additional Upper Klamath Lake inflow.

Key Findings

- Klamath River water users and stakeholders have long have long called for a comprehensive and integrated approach to water management to balance the needs of all water users.
- The Basin Study builds on earlier work and is the next significant step in developing a comprehensive knowledge base about climate change and suite of tools and options that could address the risks posed by Klamath River Basin water supply-demand imbalances.

An upside-down River

Photo: P. Coombe 2004