RECLAMATION

Managing Water in the West

SECURE Water Act Section 9503(c)—Reclamation Climate Change and Water 2016

Chapter 9: Truckee River Basin

U.S. Department of the Interior
Bureau of Reclamation

March 2016

Mission Statements

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

SECURE Water Act Section 9503(c) Report to Congress

Chapter 9: Truckee River Basin

Prepared for

United States Congress

Prepared by

U.S. Department of the Interior
Bureau of Reclamation

U.S. Department of the Interior
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Policy and Administration
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Acronyms and Abbreviations

CMIP	Coupled Model Intercomparison Project
OCAP	Operating Criteria and Procedures
Reclamation	Bureau of Reclamation
TCID	Truckee-Carson Irrigation District
TMWA	Truckee Meadows Water Authority
TRIT	Truckee River Basin Recovery Implementation Team
TROA	Truckee River Operating Agreement
USACE	U.S. Army Corps of Engineers
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
WCRP	World Climate Research Program

About this Chapter

This summary chapter is part of the 2016 SECURE Water Act Report to Congress prepared by the Bureau of Reclamation (Reclamation) in accordance with Section 9503 of the SECURE Water Act. The 2016 SECURE Water Act Report follows and builds on the first SECURE Water Act Report, submitted to Congress in 2011[1], which characterized the impacts of warmer temperatures, changes to precipitation and snowpack, and changes to the timing and quantity of streamflow runoff across the West.

This chapter provides a basin-specific summary for the Truckee River Basin. This chapter is organized as follows:

- **Section 1**: Description of the river basin setting,
- **Section 2**: Overview of the implications for various water and environmental resources,
- **Section 3**: Potential adaptation strategies considered to address basin water supply and demand imbalances, and
- **Section 4**: Coordination activities within the basin to build climate resilience.

Truckee River Basin Setting

States: California and Nevada

Major U.S. Cities: South Lake Tahoe, Reno, Sparks

River Length: 119 miles

River Basin Area: 3,000 square miles

Major River Uses: Municipal (400,000 people), Agricultural (55,000 acres of land), Hydropower (4 megawatts), Recreation, Flood Control, Navigation, and Fish and Wildlife

Notable Reclamation Facilities: Lake Tahoe Dam, Boca Dam, Stampede Dam, and Marble Bluff Dam

This chapter provides updated information from Reclamation studies completed or initiated in the basin over the past five years. The key study referenced in this chapter is the Truckee River Basin Study, conducted through a partnership of the Bureau of Reclamation, Placer County Water Resources Agency, Tahoe Regional Planning Agency, Truckee Meadows Water Authority, and the Truckee River Flood Management Authority to identify strategies to address current and future water demands in the basin. Additional information relevant to the Truckee River Basin, including the latest climate and hydrology projections for the basin, is included in Chapter 2: Hydrology and Climate Assessment.

[1] The first SECURE Water Act Report, submitted to Congress in 2011 is available on the Reclamation website: www.usbr.gov/climate/secure/docs/2011secure/2011SECUREreport.pdf.

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1 Basin Setting

From its origins in the high Sierra Nevada Mountains at elevations over 10,000 feet, the Truckee River is a vital source of water for more than 400,000 people in both California and Nevada. The Upper Truckee River originates in California with headwaters in the mountains near Carson Pass at Highway 88 where it flows northerly until it reaches Lake Tahoe (Figure 9–1). The mainstem of the Truckee River originates at the outlet of Lake Tahoe, and runs northeast to its terminus at Pyramid Lake, located approximately 50 miles (119 river miles) away in the desert of northwestern Nevada.

The Truckee River Basin includes the Lake Tahoe, Martis Valley, and Truckee Meadows sub-basins. The Truckee River Basin encompasses an area of approximately 3,060 square miles (1,958,400 acres) in the States of California and Nevada. Of the basin's total area, approximately 760 square miles (486,400 acres), or almost 25 percent of the basin is located within the State of California, where most of the precipitation occurs and where Truckee's reservoirs are located. The remaining 2,300 square miles (1,472,000 acres), or 75 percent of the basin, is located within the State of Nevada, where the most demand exists for Truckee water. This geographic imbalance between the basin's water supplies and water demands has led to disputes surrounding the rights to, and the uses of water resources within the Truckee River Basin.

The Truckee River Basin experiences wide fluctuations in annual runoff volumes ranging from high water year averages of about 2 million acre-feet to about 115,000 acre-feet in low water years. In an average water year, total runoff volume is about 580,000 acre-feet. Most water storage capacity in the Truckee River Basin is in Federal reservoirs, including Lake Tahoe, which is the largest, Prosser Creek, Stampede, Boca, and Martis Creek. Two non-Federal managed reservoirs at Donner and Independence Lakes are natural lakes where small dams have been constructed to increase storage capacity. All of these reservoirs are entirely in California except for Lake Tahoe, which is partly in California and partly in Nevada. Lake Tahoe has an average annual usable storage capacity of 557,100 acre-feet, while the other four Federal reservoirs combined store approximately 237,300 acre-feet in an average year (Table 9–1). The collective operation of these reservoirs provides the vast majority of water for the Truckee River, and they have a combined total capacity of about 1 million acre-feet.

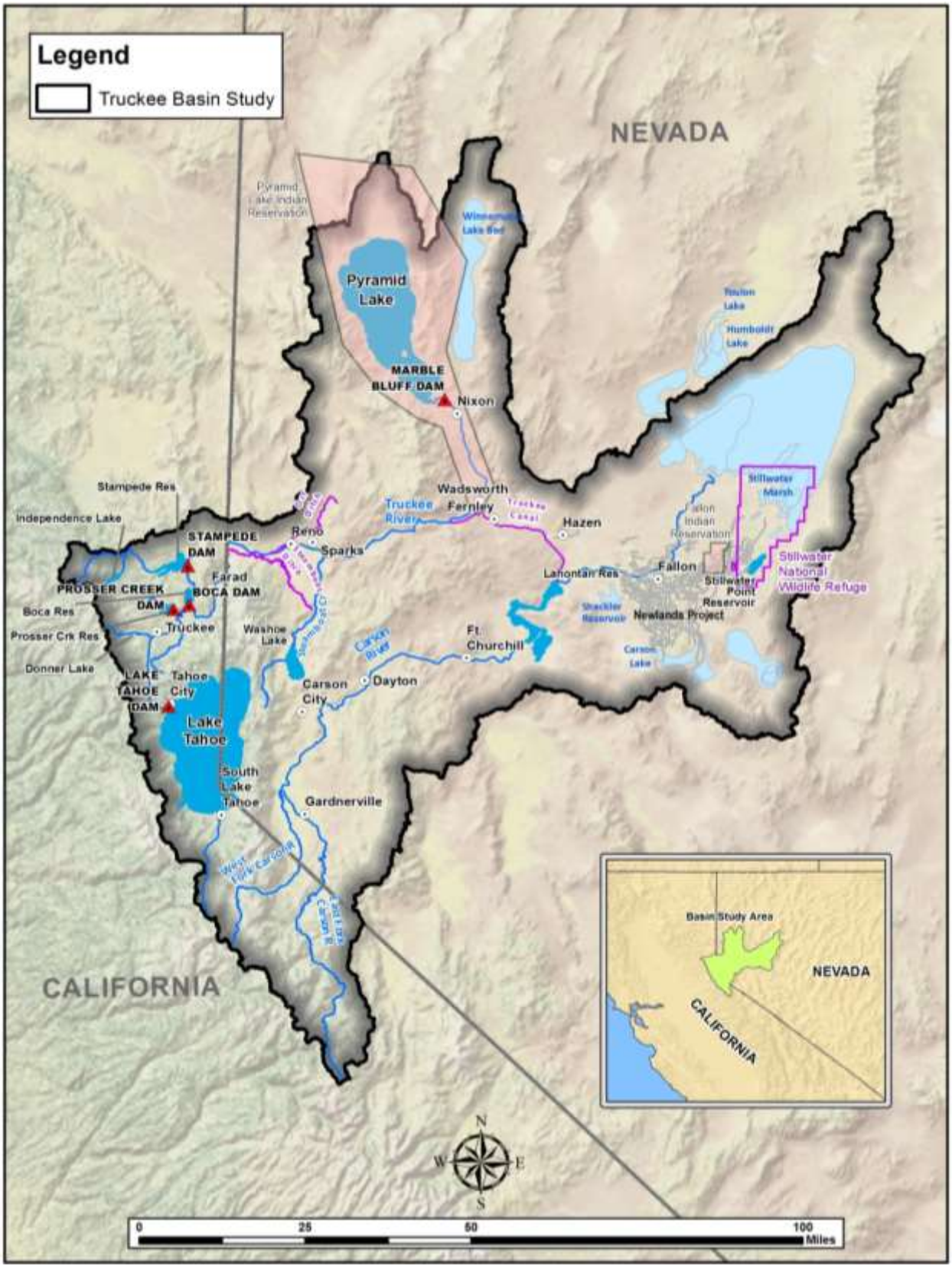

Figure 9–1. Truckee River Basin and the adjacent Carson River Basin.

Table 9–1. Truckee River Basin Storage Locations

Water Body	Elevation (feet)	Designed Maximum Storage Capacity (acre-feet)
California		
Lake Tahoe	6,229	744,600
Donner	5,936	9,500
Martis Creek Lake	5,838	20,000
Prosser Creek Reservoir	5,741	29,800
Independence Lake	6,949	17,500
Stampede Reservoir	5,949	226,500
Boca Reservoir	5,754	41,100
Lahontan Reservoir	4,164	313,000
Nevada		
Pyramid Lake	3,795	NA

Year-to-year variations in precipitation cause wide swings in river flows, leading to potential imbalances. For example, in very wet years, major floods have occurred along the lower Truckee, usually resulting in widespread property damage in the Reno-Sparks metropolitan area. The 1997 New Year's Day Flood, the flood of record, resulted in over $450 million (U.S. Army Corps of Engineers [USACE] 2013) in damages in six Nevada counties. Climate-related changes are predicted, which include increases in storm intensity and duration. These conditions make it harder to predict the potential frequency, duration, intensity and extent of floods along the Truckee River. Currently, the Truckee Meadows Water Authority (i.e., the Reno-Sparks metropolitan area) is working with USACE to design and build a flood management project to reduce damages from a potential 117-year flood. This project is estimated to cost approximately $1.6 billion dollars, and will be designed with climatic variations in mind.

Drought is also a problem. With a total storage capacity of less than two times the average inflow volumes, the ability of the Truckee reservoir system to provide adequate storage over a protracted drought is problematic. Recent studies indicate that potential climate changes in the Truckee watershed are projected to result in droughts of greater severity and duration. Paleo-records indicate that Lake Tahoe has regularly experienced extremely low water periods, suggesting that similar decades-long droughts may recur in the future. When droughts occur, the resulting low river water levels also adversely affect agriculture, fresh-water-migrating fish, resident fish, and domestic water supplies.

1.1 Truckee River Basin Study Overview

The Truckee River Basin provides a compelling demonstration of how changes in demands and/or a region's climate will influence both natural and human water uses. Packed into this relatively small basin are every form of water use and every type of water user that exist in the Western United States, including tribal lands and trusts; irrigated agriculture; municipalities and industry; mining and geothermal energy exploration; Federal water projects; hydropower generation; lake, stream, and reservoir recreation; and restoration efforts for diminished wetlands and endangered aquatic species. Correspondingly, the diversity of water uses within its borders has made the basin home to every type of water resources conflict.

Despite this natural conflict, communities in the basin have actively managed and adapted to water scarcity for as long as the arid region has been inhabited. Management activities include a number of massive water resource facilities, built through both Federal and local investment over the past century-and-a-half. In parallel with the construction of these facilities, regulations to govern their use have been promulgated in response to demands and provide the flexibility to deal with highly variable weather patterns. As in many basins in the West, water management practices in the Truckee River Basin, including diversion regulations, have been developed through a century of infrastructure improvements followed by decades of litigation. However, unlike in most basins, the closed hydrologic condition of this basin creates a zero-sum game for water. In the Truckee River each drop from its headwaters at Lake Tahoe to its terminus at Pyramid Lake is claimed and serves important human uses and ecological functions. As a result, even small changes in future conditions (e.g., increases in demand or changes in climate) are perceptible and potentially contentious.

The Truckee River Basin Study was conducted by Reclamation in partnership with four non-Federal cost-share partners: Placer County Water Agency, Tahoe Regional Planning Agency, Truckee Meadows Water Authority (TMWA), and Truckee River Flood Management Authority. Each of these partners represents a unique geopolitical position in the Truckee River Basin with diverse interests ranging from preserving Lake Tahoe's environmental conditions to increasing flood protection in the lower Truckee River Basin. The Basin Study was designed to analyze existing and future basin-wide water supplies and demands, identify potential risks of climate change to supplies and demands, and to identify potential adaptive measures to mitigate identified impacts on future supplies and demands.

2 Analysis of Impacts to Water Resources

The Truckee River Basin is located in the Great Basin, a hydrographic region that includes most of Nevada, half of Utah, and portions of California, Idaho, Oregon, and Wyoming. The Great Basin includes more than 180,000 square miles of contiguous, endorheic (also called "terminal") basins, having no river or ocean outlet. The Truckee Basin's climate is typical of areas within the Great Basin where snow accumulation and melt cycles have dominated the hydrologic processes.

- **Temperatures** vary widely in the region and are generally cooler in high elevation areas in the Sierra Nevada and Truckee River Basin, whereas the lower elevation areas (Carson Sink, Pyramid Lake) are generally warmer (Figure 9–2). The climate in the lower Truckee River Basin in Nevada is semiarid to arid, and summers have clear, warm days and cool nights.

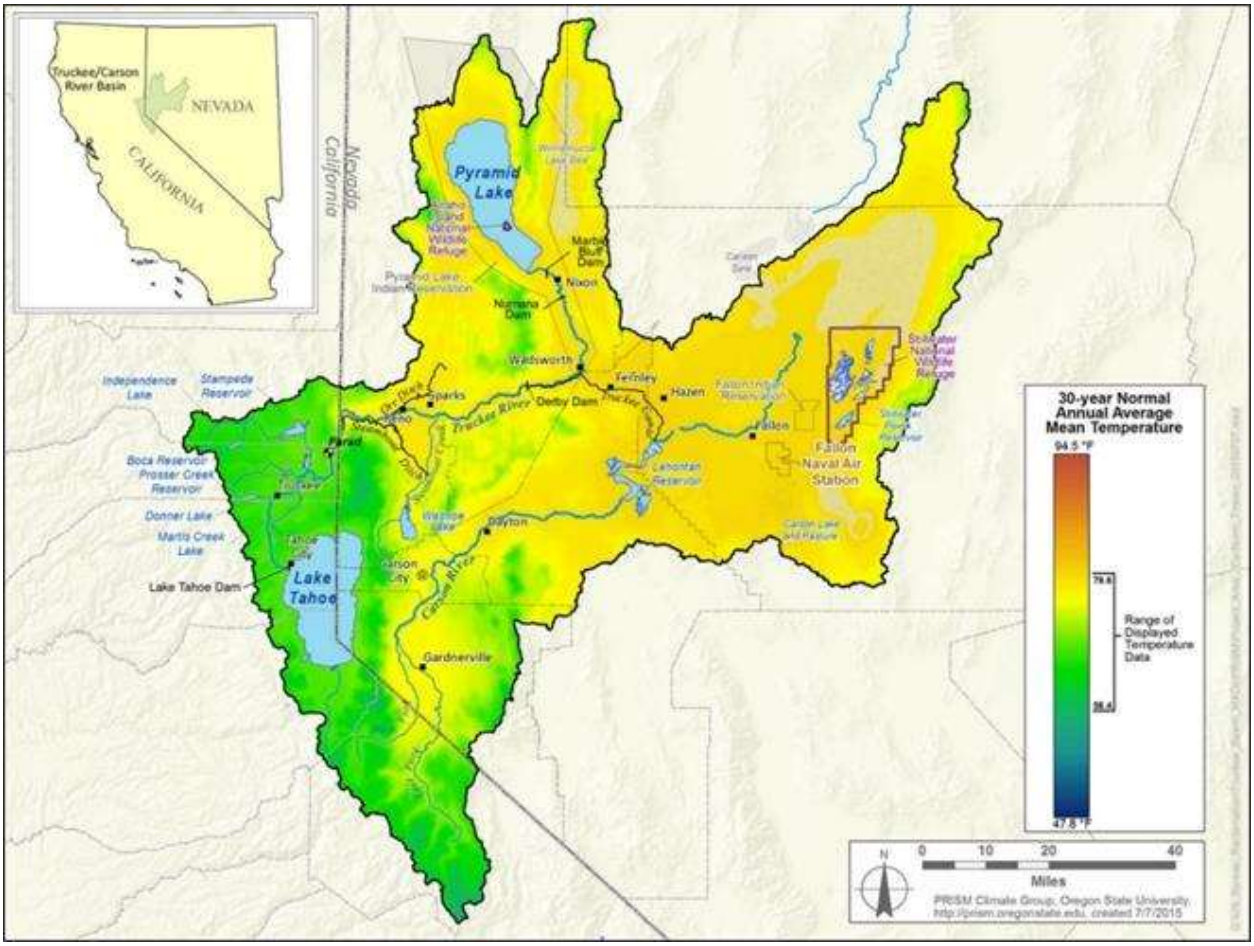

Figure 9–2. Average annual temperature in Truckee River Basin (1981 to 2010). Source: Truckee River Basin Study (2016).

- **Precipitation** also varies widely in the region. Areas in the mountains surrounding Lake Tahoe receive well over 70 inches of precipitation per year, whereas areas in Nevada receive less than 10 inches on average. The lower regions around the Carson River are especially dry, receiving on average less than 5 inches of precipitation each year. Average precipitation for 1981 to 2010 for is shown in Figure 9–3.

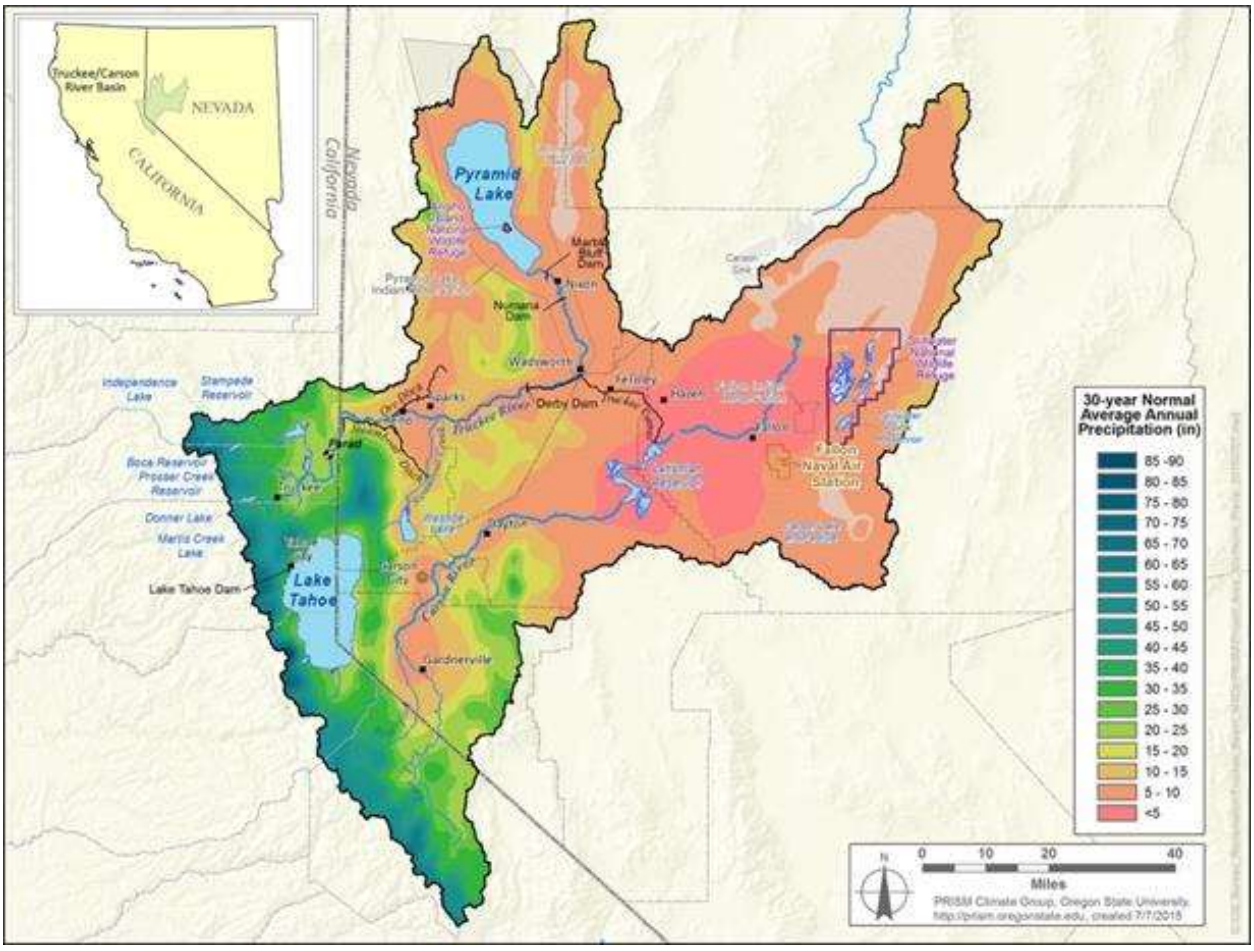

Figure 9–3. Average annual precipitation in Truckee River Basin (1981 to 2010). Source: Truckee River Basin Study (2016).

- **Extreme events:** The Truckee River Basin has historically been characterized by floods and periods of drought. There is high variability in flow throughout the historical record. Consecutive years of low precipitation in the Lake Tahoe Basin and Truckee River upstream from Farad produce dry conditions and meteorological drought cycles for the entire Truckee River Basin.

The Truckee River Basin Study modelled climate change impacts not only geographically, but also over time. Projections of future conditions for the Truckee River Basin's climate include a range of potential changes in both the

volume of annual precipitation and the seasonal temperature conditions. Increases or decreases in average annual precipitation would directly influence the availability of water supplies by changing the amount of water running off into the basin's lakes, reservoirs, and rivers, as well as the amount of water recharging groundwater basins. Key findings related to projected changes in water supply due to climate change are presented below.

- **A wide range of uncertainty exists for Truckee River Basin water supplies.** At Pyramid Lake, the scenarios diverge to span a difference in lake surface elevation of more than 200 feet by the end of the century. The outer bounds are defined by the divergence between wetter and drier climate scenarios.
- **Increases in temperature will reduce water supplies**. While changes in precipitation remain highly uncertain, there is a consensus among climate models that the regional climate will warm. Warming temperatures will increase evaporation at the region's lakes and reservoirs, most notably at Tahoe and Pyramid lakes because of their vast surface area.
- **In comparison to the uncertainty in future supplies, the uncertainty in water demands is less significant**. Projected differences in demand affect end-of-century Pyramid Lake elevations by approximately 6 feet, temperatures by 28 feet, and precipitation by 161 feet.
- **Maintaining the historical balance between supply and demand may not be possible if the climate changes significantly, even with exceptional changes in human behavior.** In comparison to the future demand conditions, scenarios in which demand is held constant at 2012 levels produce approximately 16-foot higher elevations at Pyramid Lake for all future supply conditions. By inference, this is the maximum potential supply that would be generated if water demands were prevented from increasing over the coming century.

The Basin Study also assessed changes in demand for a range of current and potential future water diversions and in-river water uses in the Truckee River Basin. The basin's water rights are highly regulated, and its water uses have been carefully planned for by local communities, tribes, the States of California and Nevada, and the Federal Government. Key findings related to projected changes in demand due to climate change are summarized below.

- The added complexity of a changing climate also increases needs of ecosystems and crops.
- Changes in ambient temperatures and seasonality shifts in streamflow will alter the timing of breeding patterns of aquatic species.
- Climate changes are expected to affect water demand for native vegetation that supports migratory birds using Lahontan Valley wetlands and other lakes, as well as riparian and meadow areas along the Truckee and Carson rivers at resting points on the Pacific Flyway.

- Increased water demands will occur due to earlier plant growth and greater water needs for each acre of managed wetland. Bird migration patterns are expected to be affected by global climate changes across the entire migratory flyway, and shifts in arrival at Lahontan Valley wetlands would not match available food supplies.
- Changes in climate are also projected to increase overall crop demand. Future changes in climate (including maximum and minimum temperature, solar radiation, wind speed, humidity, and precipitation) will influence agricultural water use by changing crop water demands and irrigation requirements to meet these needs.
- Higher year-round temperatures can increase evapotranspiration rates that, unless offset by increased local precipitation, would require additional irrigation.
- Higher temperatures are also expected to prolong the growing season, which changes the seasonal demand for water for crops that mature earlier in time and, in turn, increases the volume and duration of irrigation water deliveries needed for every farm. Decreases in local precipitation would increase irrigation requirements to meet crop water demand.

Projected future conditions in the Truckee River Basin are expected to vary widely. Generally, the largest vulnerabilities in the Truckee River Basin stem from uncertainties in future supplies (i.e., future rates of precipitation and temperatures).

The Truckee River Basin has a diverse set of water users and interests, including municipal, agricultural, and environmental. Each water user has different goals and visions for how economic conditions, land uses, and other factors could change in the future and affect – or be affected by – water supply reliability. Additionally, the manner in which each type of water use occurs varies based on geography, diversion facilities and other infrastructure, and whether the source is surface water or groundwater. As with other assessments completed for the Basin Study, the risk and reliability assessment relies on the use of water user communities to describe concerns and conditions in a way that captures the variation throughout the basin.

The Basin Study used a set of performance indicators which were developed with input and guidance from water users and formed the basis for assessing reliability for each water user community. The SECURE Water Act water resources themes represent the range of reliability concerns for Basin communities, and provide important context for understanding the connections between water resources and water uses. Table 9–2 provides a general summary of some of the effects of climate change on future reliability in the basin for resources of concern to water users, organized under each of the SECURE Water Act themes.

Table 9–2. Projected Impacts by SECURE Water Act Themes in the Truckee River Basin

Source: Reclamation 2016 (Truckee)

Theme	Potential Impacts in the Truckee River Basin
Water Delivery and Allocation	Anticipated increases to evapotranspiration have a pronounced impact on water supplies from Lake Tahoe due to its large surface area, which puts one-third of typical Truckee River flows at risk. Warming temperatures also shift the timing of runoff, complicating the operation of reservoirs.
Hydropower	TMWA generates hydropower at several locations along the Truckee River; however this generation is not regionally significant and risks to its future availability correspond with the potential for reduced flow in the river. For the Newlands Project, which diverts Truckee River water, hydropower generation revenue provides 40 percent of the operating budget of Truckee-Carson Irrigation District (TCID), and reductions in future supplies at Lahontan Reservoir may present a risk to hydropower generation.
Recreation	Recreation resources could experience negative effects stemming from the shifts in the peak runoff, which could affect lake levels during peak recreation periods, flows for spot fisheries, and flows in-river for rafting and kayaking. Snow-dependent winter sports may also be diminished in value over time. See also the effects for "Fish and Wildlife Habitat."
Fish and Wildlife Habitat	Habitat requirements for sport fisheries would be challenged by difficulties in operating reservoirs for meeting primary benefits of the reservoirs (water deliveries, riverine fisheries) in a reliable manner. Also, riparian communities would be impacted by changes in timing and volume of runoff. See also the effects for "Endangered, Threatened or Candidate Species."
Endangered, Threatened or Candidate Species	Effects on cui-ui and Lahontan cutthroat trout are difficult to assess with certainty. The volumes of water available for fishery flows could be diminished, and sustaining them from February through August will be more difficult because of changes in the natural hydrology, especially under warmer/hotter or drier conditions. A significant uncertainty also exists in how the fisheries might adapt to changes in the natural flows. Scenarios with higher evaporative losses prevent migratory passage between Pyramid Lake and the Truckee River, which would prevent passage for both cui-ui and Lahontan cutthroat trout to current breeding areas. Also, Lahontan cutthroat trout in Independence Lake would be affected during spawning if spring lake levels flows into upper Independence Creek are not adequate.
Water Quality	Meeting water quality standards in the lower Truckee River is expected to be more difficult for TMWA to maintain as natural flows in the late summer recede. Clarity in Lake Tahoe is difficult to address under these general conditions, because lake clarity is the related to sedimentation and turbidity resulting from human activity and natural sources. The Basin Study did not include a predictive model that describes how climate change may change those influencing factors.
Flow and Water-dependent Ecological Resiliency	Water supplies for the Stillwater National Wildlife Refuge may be at risk, particularly for scenarios where spills from Lahontan Reservoir on the Carson River are lower. See also "Endangered, Threatened or Candidate Species."
Flood Control Management	Flood frequency relationships will change, with peak flows being higher in magnitude and frequency due to diminished snow accumulation and a greater potential for larger atmospheric rivers hitting the Sierra Nevada.

3 Potential Adaptation Strategies to Address Vulnerabilities

Water supply conditions for the coming century will affect Truckee River Basin water user communities in diverse ways. This Basin Study measured the risks and vulnerabilities of individual water user communities relative to a set of baseline conditions for the basin, and identified a set of strategies or actions that can be considered in an attempt to address future supply-demand imbalances.

The Basin Study team obtained input from stakeholders to identify individual actions, or "options," for responding to climate change. The options presented in this report were identified or suggested for investigation by Basin water users and other stakeholders, including municipalities, irrigators, Tribes, resource agencies, local and regional planning agencies, and environmental or conservation groups (Table 9–3).

3.1 Process for Evaluating Options

This Basin Study's process for evaluating options included an initial, high-level assessment for all options suggested by Basin water users, followed by a more detailed analysis using Basin Study tools for a select number of options based on the prioritization below.

Options were prioritized and selected for further evaluation based on:

- **Completeness**: In order to be evaluated, options must have a measurable or specified effect on Basin supplies, demands, or operations.
- **Applicability to Basin-Wide Vulnerabilities**: The options selected for further evaluation are those anticipated either to address water supply vulnerabilities for the entire Basin, or to help restore a balance between supplies and demands, and among users and uses.
- **Use of Basin Study Tools**: The use of an equivalent process to evaluate the different effects of options allows for more thorough comparisons. Where possible, options were tested using the Truckee River Operating Agreement (TROA)-light Planning Model.

The options evaluated in detail through the Basin Study process, along with key findings on performance and implementation considerations, are shown in Table 9–4.

Table 9–3. Options Identified by Water Users

Source: Reclamation 2016 (Truckee)

Adaptation Strategy	Grouping	Option
Institutional Changes	Basin-wide Planning	Define regional priorities and goals for water use
		Eliminate prior appropriation
	Surface Water Reservoir Management	Allow Truckee-Carson Irrigation District (TCID) carryover storage in Truckee River reservoirs
		Change balance of credit storage available to users at Truckee River reservoirs
		Remove storage limits at Truckee River reservoirs
		Modify flood control curves to adapt to climate
		Modify Operating Criteria and Procedures (OCAP) criteria at Lahontan Dam to improve success of refill
	Surface Water Rights Management	Allow management of water between Pyramid Lake fisheries and Lahontan Valley wetlands
		Create open water markets
		Consolidate agricultural water rights
Supply Augmentation	Alternative Sources	Interbasin transfer of groundwater
	Conveyance Facility Improvements	Augment Truckee Canal capacity
	Groundwater Storage	Enhanced groundwater recharge
	Modifications to the Hydrologic Cycle	Forestry-based watershed management
		Weather modification
		Wetland, meadow, and stream corridor restoration
	Surface Storage	Additional Carson River storage
		Increase Truckee River reservoir storage
Demand Management	Agricultural Use	Convert to low water-use crops
		Reduce conveyance losses
		Transfer agricultural water rights to municipal and industrial uses
		Water rights retirement
		Water use efficiency improvements
	Environmental Flows	Revise flow targets to correspond with peak flows under climate change
	Municipal & Industrial Use	Increase outreach and education on conservation
		Mandate efficiency improvements
		Outdoor use efficiency improvements
	Water Quality	Water quality improvements for the lower Truckee River

Table 9–4. Summary of Option Performance and Evaluations

Source: Truckee River Basin Study (2016)

Option	Ability of Options to Mitigate for Undesirable Future Conditions		Implementation Considerations
	Basin-wide Vulnerabilities	Water User Shortages	
Adapt Flood Management Operations	Mitigates for some seasonality shifts by capturing precipitation that would have been held in snowpack in the historical climate. Availability of storage space is much smaller than snowpack, and thus cannot completely mitigate for climate changes.	Small shifts in the timing of managed flows occur related to capture of additional water. Option does not fully restore the historical operating regime or the supply-demand balance under the Reference scenario. Reduces shortages for M&I and agriculture by 3 to 9 percent. Increases years with adequate spawning flows at Pyramid Lake by up to 15 percent. Reduces adult passage flows by up to 13 percent in drier scenarios. Shifts benefits among lifecycle stages for Pyramid Lake fisheries, challenging passage but improving spawning conditions.	Could affect flood management in the basin and would require balancing water supply benefits with flood risks. Entities required for implementation would likely include the USACE and the Truckee River Flood Management Authority for developing acceptable flood management strategies, and the Pyramid Lake Paiute Tribe for fisheries and water rights-related concerns.
Adapt OCAP Storage Targets	Mitigates for seasonality shifts by adjusting Newlands Project OCAP operations and end-of-month storage targets at Lahontan Dam. Does not mitigate for Basin-wide changes.	Helps Lahontan Reservoir refill at the end of the century when climate changes have the most pronounced effect on hydrology, but violates central tenets of OCAP by over-diverting Truckee River water in the earlier portions of the century when climate has subtle changes in hydrology.	Implementation would require detailed study and careful evaluation in close coordination with the Pyramid Lake Paiute Tribe and TCID to ensure the intended balance in water supplies is not disrupted.
Consolidate Agricultural Rights	Responds to increased crop water demands by reducing acreages of cultivation. Allows for an earlier beginning of the irrigation season, but does not otherwise mitigate Basin-wide changes.	Reduces frequency of shortages in the Newlands Project by up to 28 percent without significantly affecting any other water users in the basin.	Implementation would likely require major changes to water rights law and would need to be closely coordinated with parties to the *Orr Ditch* and *Alpine* decrees, TCID, and the Nevada State Engineer.
Truckee Canal Rehabilitation	Addresses seasonality shifts and reductions in precipitation by restoring Truckee Canal diversion and conveyance capacity.	Reduces the frequency of annual crop demand shortages for the Newlands Project by 4 to 12 percent. Increases spills to Lahontan Valley wetlands by 6 percent and reduces long-term shortages to wetlands by up to 3 years. Increases TCID hydropower generation by 4 to 14 percent.	Implementation is currently underway for a similar action. Reclamation is undertaking a NEPA process to document potential environmental effects, such as impacts to fisheries impacts at Pyramid Lake or groundwater for Fernley. Likely coordination among the Pyramid Lake Paiute Tribe, TCID, and the City of Fernley.

Option	Ability of Options to Mitigate for Undesirable Future Conditions		Implementation Considerations
	Basin-wide Vulnerabilities	Water User Shortages	
Additional Truckee River Basin Storage	Mitigates for some seasonality shifts and reductions in precipitation and snowpack by capturing and storing additional supply that would otherwise be spilled.	This option, tested in a conceptual manner, shows some ability for a new storage facility to reduce future shortfalls for all water users in the basin. Full mitigation for losses associated with climate change would require facilities that more than double the current available storage in the basin.	Implementation would require study by a project proponent to determine specific details of future storage, including potential locations and storage capacities. Other entities required for implementation would likely include the Pyramid Lake Paiute Tribe for fisheries and water rights-related concerns, and possibly USACE and the Truckee River Flood Management Authority for consideration of flood management operations.
Forest Management	Reduces evapotranspiration from forest cover. Could be an important contribution to water supplies originating in the upper Basin, but performance is uncertain.	Water supplies could be improved for all water users, but there may be limitations of this option during dry years and when supplies are most needed.	Implementation likely requires coordination with U.S. Forest Service (USFS), other public or private landowners, and the Tahoe Regional Planning Agency. Option requires vegetation maintenance across large areas of forested land, and likely requires periodic clearing of vegetation to maintain the water supply benefit. More rigorous study is needed to understand the full potential of this option to improve water supplies, particularly in dry conditions.
Raise Lahontan Dam	Increases storage of Carson River supplies for the Newlands Project, effectively increasing availability of supplies Basin-wide.	Reduces diversions from the Truckee River in wetter conditions only. Does not change reliability for the Newlands Project. Increases flow to Pyramid Lake by up to 5 percent, but reduce supply to Lahontan Valley wetlands by up to 9 percent.	Implementation would likely require study to determine effects on fisheries and water-dependent ecosystems at Pyramid Lake and Lahontan Valley wetlands. Entities required for implementation would include TCID and U.S. Fish and Wildlife Service (USFWS).
Adapt Fish Flow Regimes	Mitigates for seasonality shifts by changing the timing of flow regimes in the Truckee River. Does not otherwise mitigate Basin-wide changes.	Increases adult passage flows by 1 to 10 percent and spawning flows by 10 to 71 percent. Does not change duration of years with poor spawning flows.	Implementation would likely require involvement of the range of agencies that previously developed the six-flow regime for the Truckee River (TRIT 2003).

4 Coordination Activities

Truckee River water users and stakeholders have long understood that growing demands, coupled with the potential for reduced supplies due to climate change, may put water users and resources relying on the river at risk of prolonged water shortages in the future. The Basin Study is built on earlier work and is the next significant step in developing a comprehensive knowledge base and suite of tools and options that could address the risks posed by water supply-demand imbalances in the Truckee River Basin.

The Truckee River Basin Study indicates that water conservation, reuse, and augmentation projects could improve the reliability and sustainability of the Truckee River system to help meet current and future water needs. Addressing future imbalances in the Truckee River Basin will require diligent planning and collaboration that applies a wide variety of ideas at local, state, and Basin-wide levels. Central to this collaboration are partnerships and the recognition that pursuing further study must cultivate and build upon the broad, inclusive stakeholder process that was initiated by the Truckee River Basin Study.

4.1 Incorporation of Future Risks into Existing Water User Plans

While Reclamation's Basin Study Program provides standardized scientific information on how climate change affects water resources across the Western U.S., the processes for incorporating climate change into political and decision making forums varies widely by region and community. Effectively incorporating future risks identified by the Basin Study into existing water resources planning processes could be supported by locally or regionally driven efforts to expand upon the information generated through the Basin Study, such as:

- **Regional Planning Forums**: Plans and responses to climate change will have implications which would benefit from a common Basin-wide understanding of risks, transparency in the vision held by individual communities for the future, and/or a collective commitment to take action. A regional planning process with participants representing a broad coalition of interests could be helpful in achieving these by providing a common processes for the interpretation of future risks, options for responding to risks, tradeoffs among communities for future actions, and a mechanism for cost-sharing on future studies. Considerable investments have been made to develop a regional understanding about the implications of water use in the basin, particularly surrounding and through TROA negotiations and implementation. The efforts to support TROA implementation could serve as a useful model for a regional planning process.

- **Improvement of Indicators by Water Users**: An effort by water users and Basin communities to refine the performance indicators developed during the Basin Study could improve the degree to which the Basin Study's assessments can be used for future planning. The indicators developed for this Basin Study report on the quality of future conditions in a relative manner. For example, the frequency of water supply shortages experienced by a particular water user can be counted for each scenario, and scenarios with lower or fewer shortages will receive higher ratings among corresponding indicators. However, the Basin Study indicators do not provide objective value judgments; it may be possible that even the "worst" scenario can be accommodated by a given water user. Identifying whether conditions are either good or bad can depend on multiple considerations. From a technical standpoint, the effect of future conditions depends on the water requirements of each community, the capabilities of their existing infrastructure, and the characteristics of various available water supplies for managing their needs. Political and administrative considerations also provide important context for interpreting future conditions.

4.2 Development of Modeling Tools and Information

The Basin Study relied upon projected future conditions that were assembled before, and absent the context of, the key vulnerabilities that emerged from the Basin Study's risk and reliability assessment. As the first of its kind in the basin, the Basin Study presents an opportunity to inspect sources of uncertainty in supplies and demands and determine whether uncertainty in the analysis could be reduced or corrected with additional investments in modeling and analysis.

The following assessments and model development tasks were identified through input from technical stakeholders, or by the Basin Study team through the process of conducting analysis of vulnerabilities and adaptation options.

- **Refinement of ecosystem needs and vulnerabilities**: An understanding of the relationship between changes in the climate, changes in the needs of aquatic, wetland, and riparian ecosystems and migratory waterfowl and shorebirds that result from changes in the climate and the ability to accommodate these needs with existing supplies would benefit from further analysis and model development.
- **Incorporation of paleohydrology and updated climate information**: Inspection of the next phase of climate projections[2] would provide an updated understanding for whether uncertainties in the future climate have been converging or changing.

[2] Climate projections from the World Climate Research Programme's (WCRP) Coupled Model Intercomparison Project (CMIP) Phase 5.

- **Inclusion of the Carson River Basin**: Development of supply, demand, and infrastructure and operational conditions in the Carson Basin upstream of Lahontan Reservoir would benefit water users in this neighboring basin, including Reclamation's Newlands Project.
- **Coupled groundwater/surface water model development**: The communities in the basin who rely on groundwater as a primary source of water supply would benefit from an improved understanding of how climate change may alter natural processes for groundwater recharge and storage.
- **Economics model for the Truckee River Basin**: For communities that rely heavily upon recreational uses of water, such as snow-dependent or lake recreation, the application of a regional socioeconomics model may provide further clarification about the implications of climate change on the goals of each community.
- **TROA implementation refinements**: Several aspects of the TROA-light Planning Model require further discussion and refinement before they may be implemented in the model, including the California Guidelines for recreation, and the use of credit storage for water quality on the lower Truckee River.

5 References

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