5.3.3 Surface Water Resources

5.3.3.1 Affected Environment

Utah's surface waters are prone to extremes of floods and droughts. Five major floods have occurred in recent history, the most recent in 2010. In addition, seven multi-year statewide droughts have been recorded, the most recent from 2008 through 2012 (WRCC 2015). The following summaries of streamflows and reservoir storage reflect this variability.

5.3.3.1.1 Water Regulation.

The Utah Division of Water Rights regulates water allocation and distribution. Utah abides by the prior appropriation system. The State Engineer administers Utah's water law. Surface and groundwater in most of the area of potential effect are considered fully appropriated, meaning that there is no additional water available to be claimed for beneficial use.

5.3.3.1.2 Streams.

Table 5-18 summarizes the period of record for daily streamflows dating back to 1941 or if more recently, to the start of records. All streamflow data and stream gage photographs were obtained from the USGS NWIS database (USGS 2014) unless otherwise noted. Conditions of streams potentially affected by the LPP Project without recent daily flow records are described based on available information such as drainage area.

Table 5-18
Streamflow Periods of Record for Streams in the Area of Potential Effect

Gage Number	Location	Period of Record (Water Years)	Drainage Area (square miles)	Mean Flow (cfs)
09403600	Kanab Creek near Kanab, Utah	1979 – 2014	194	11.4
09406000	Virgin River at Virgin, Utah	1941 – 1972, 1979 – 2014	956	196.9
09413500	Virgin River near St. George, Utah	1951 – 1957, 1992 – 2014	4,123	186
09415000	Virgin River at Littlefield, Arizona	1941 – 2014	5,090	239.8
09413000	Santa Clara at St. George, Utah	1951 – 1956, 1985 – 2014	541	16.2
09380000	Colorado River at Lees Ferry, Arizona	1941 – 2014	111,800	14,740
09381800	Paria River near Kanab	2002 – 2014	647	20.7

Source: 2014 water data reports, Mean Flow calculated for period of record summarized in report with exception of Colorado River which is calculated for water years 1965 – 2014 (after Glen Canyon Dam construction).

5.3.3.1.2.1 Colorado River.

The Colorado River is an important resource for the southwest United States. It drains an area of over 244,000 square miles and passes through seven states and Mexico. Many reservoirs have been constructed in the Colorado River system to regulate the water for various uses. More than 24 million people from Salt Lake City, to Phoenix, to Denver, to San Diego rely on the river for water supply (UDWRe 2002). The river is also used for agricultural irrigation, recreation, and power generation. Figure 5-17 depicts the Colorado River Basin.

Source: UDWRe (2002)

Figure 5-17
Colorado River Basin

The rules pertaining to division of the flow of the Colorado River are referred to as the Law of the River. The Law of the River is comprised of compacts (e.g., Colorado River Compact), court decisions and decrees, and regulatory guidelines. The Colorado River Compact (Compact) is one of many documents constituting the Law of the River. It divides the river basin into the Upper Basin (comprised of Colorado, New Mexico, Utah and Wyoming) and the Lower Basin (comprised of Nevada, Arizona and California). The Lees Ferry Compact Point divides the system into the Upper Basin and Lower Basin. In general, each basin is allocated 7.5 million acre feet (MAF) per year. The Upper Basin states cannot deplete the flow of the river below 7.5 MAF during any period of ten consecutive years. The Law of the River allocates the State of Utah 23 percent of the Upper Basin apportionment (Reclamation 2007), which equates to 1.725 MAF of the 7.5 MAF Upper Basin allocation.

The Colorado River below Lake Powell is part of the study area because it is located downstream of the LPP intake. At this point, the Colorado River flows through a narrow part of Glen Canyon. Flows are greatly modified from natural streamflows because of the impoundment of Lake Powell behind Glen Canyon Dam, which began filling in 1963, and many other storage facilities located on the Colorado River and its tributaries upstream of Lake Powell. The Lees Ferry gage is located on the Colorado River 15.5 miles downstream of Glen Canyon Dam. Flows at Lees Ferry are primarily the result of releases made from the dam. Releases are made by Reclamation based on complicated guidelines developed to fulfill multiple purposes that are consistent with the Law of the River as briefly described below.

Releases from Glen Canyon Dam are scheduled on an annual, monthly, and hourly basis. Annual release volumes are made according to the Long Range Operating Criteria (LROC) of Colorado River Reservoirs, which includes a minimum objective release of 8.23 MAF, storage equalization between Lake Powell and Lake Mead under prescribed conditions, and the avoidance of spills. Annual releases greater than the minimum can be made for a variety of reasons based on operation requirements (Reclamation 2007).

Each spring, the Secretary of the Interior declares the Colorado River water supply availability for the Lower Basin States in terms of Normal, Surplus, or Shortage. This declaration affects the operation of Lake Powell for the following year. Operating guidelines for the Normal and Surplus conditions have long been established. Interim Guidelines for Shortage conditions were established in 2007. The Interim Guidelines will be in effect for operating decisions through 2026. These guidelines direct the Annual Operating Plan, which determines the water supply available to the Lower Basin water users and annual releases from Lake Powell. The four operational tiers for Lake Powell and Lake Mead and releases from Lake Powell are as follows (Reclamation 2008):

- Equalization Tier – greater than 9.5 MAF
- Upper Level Balancing Tier – between 7.48 and 9.5 MAF
- Mid-Elevation Tier – 7.48 MAF
- Lower Elevation Balancing Tier - between 7.48 and 9.5 MAF

Shorter-term Glen Canyon Dam release constraints are currently based on the 1996 Glen Canyon ROD, which was developed consistent with the Grand Canyon Protection Act of 1992 (Reclamation 2007). These constraints are summarized in Table 5-19.

Table 5-19
Glen Canyon Dam Release Constraints

Parameter	Release (cfs)	Conditions
Maximum Flow [1]	25,000	
Minimum Flow	5,000	Nighttime
	8,000	7 am to 7 pm
Ascending Ramp Rate	4,000	Per hour
Descending	1,500	Per hour
Daily fluctuations [2]	5,000 to 8,000	

Notes:
[1] Non-emergency, non-extreme hydrological conditions
[2] Daily fluctuation limit is 5,000 cfs for months with release volumes less than 0.6 maf; 6,000 cfs for monthly release volumes of 0.6 maf to 0.8 maf; and 8,000 cfs for monthly volumes over 0.8 maf.
Source: Reclamation (2007)

Figure 5-18 summarizes daily streamflow for the Colorado River at Lees Ferry gage. This gage is located upstream of the Lee Ferry Compact Point with a tributary, Paria River, entering the Colorado River in between (Figure 5-19). The hydrograph of the Colorado River changed drastically after Lake Powell began to fill. Glen Canyon Dam operation has reduced peak flows, increased minimum flows, and increased the diurnal range in discharge because of hydropower operations. Figure 5-20 shows the daily mean and daily range of flows over the calendar year since 1970.

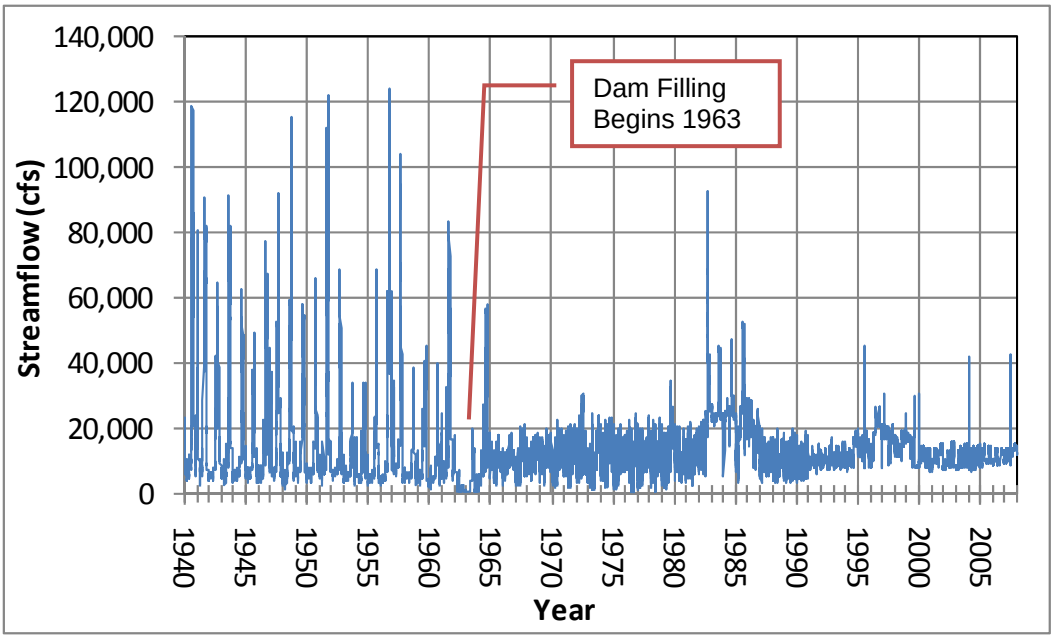
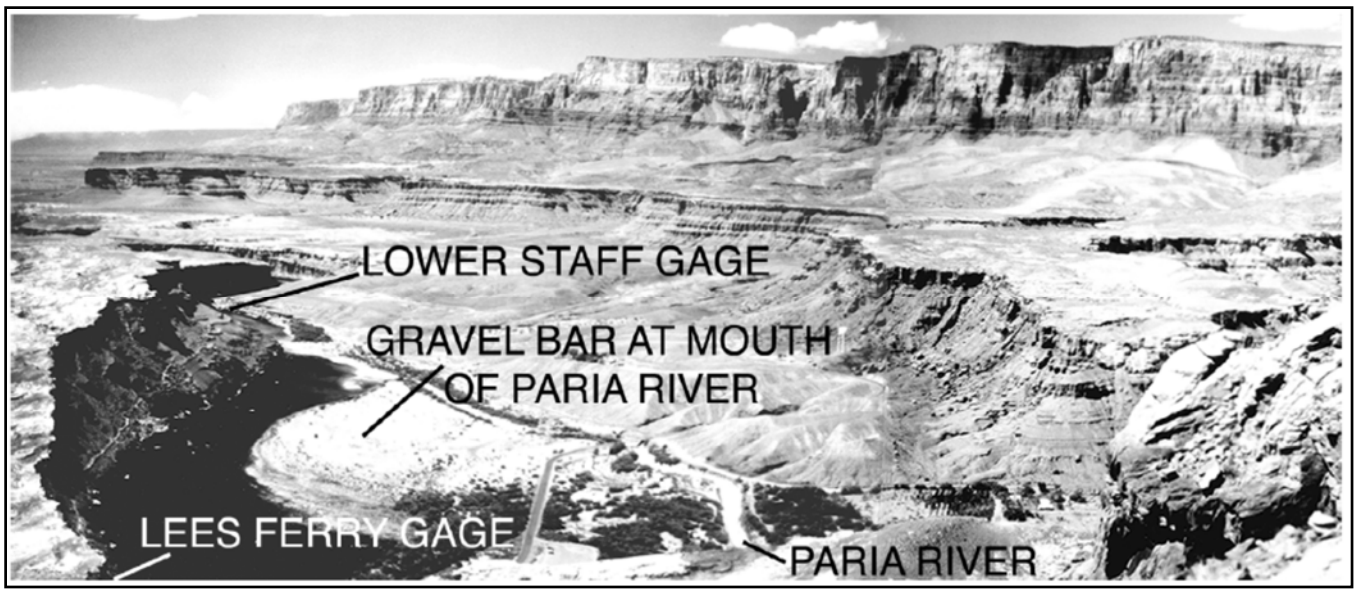


Figure 5-18
Colorado River at Lees Ferry Daily Flows



Source: Topping et al (2003)

Figure 5-19
Colorado River at Lees Ferry Facing Downstream (1995), Flow of 9,500 cfs

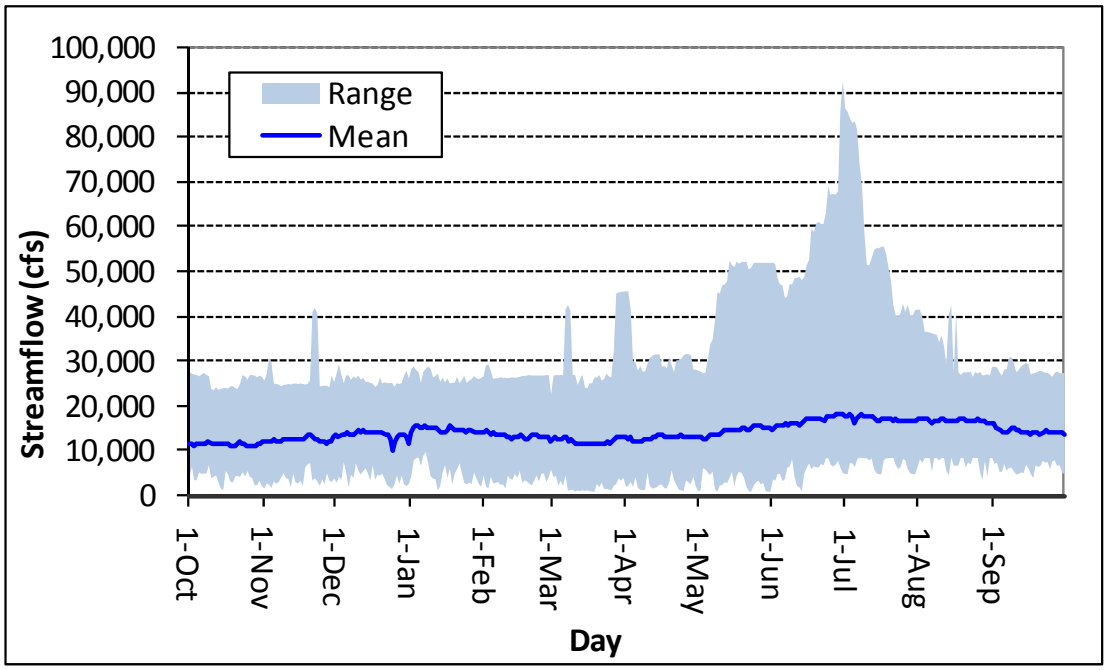


Figure 5-20
Colorado River at Lees Ferry Daily Mean and Range of Flow (1970-2008)

Figure 5-21 summarizes annual mean water year flows. Since 1968, the annual mean has equaled or exceeded 11,000 cfs. Figure 5-22 depicts the flow exceedance curve, limited to 1970 to 2008 to capture flows after the filling of Lake Powell. The curve shows a median flow of the Colorado River at Lees Ferry of about 13,000 cfs for this period.

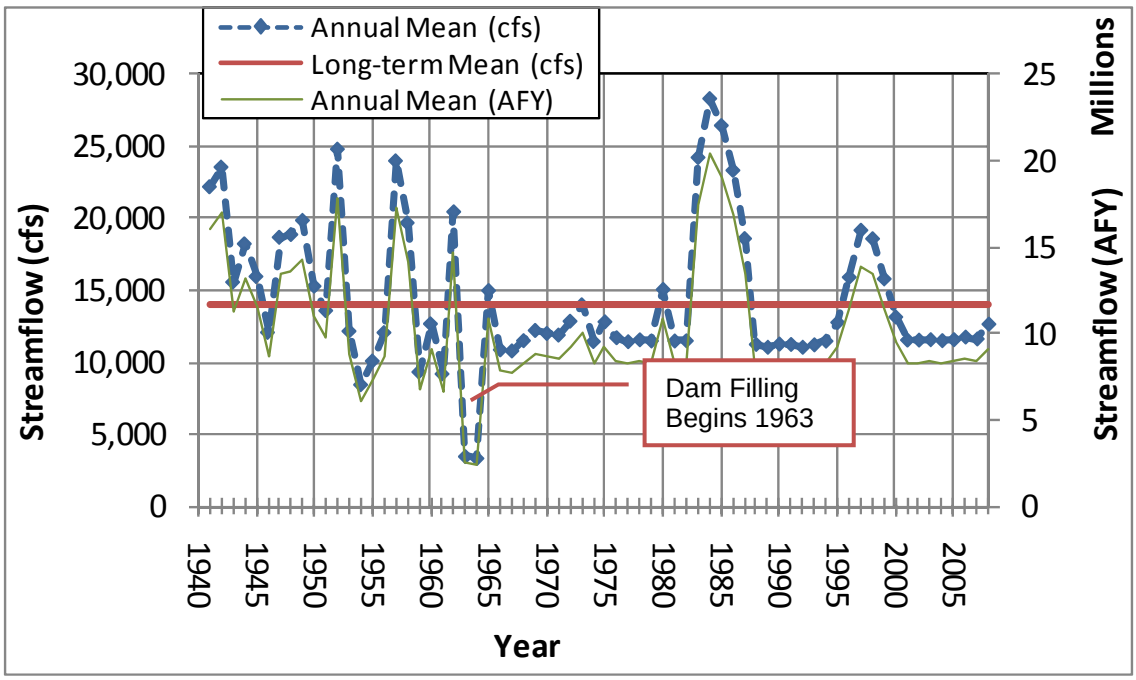


Figure 5-21
Colorado River at Lees Ferry Annual Mean Flows

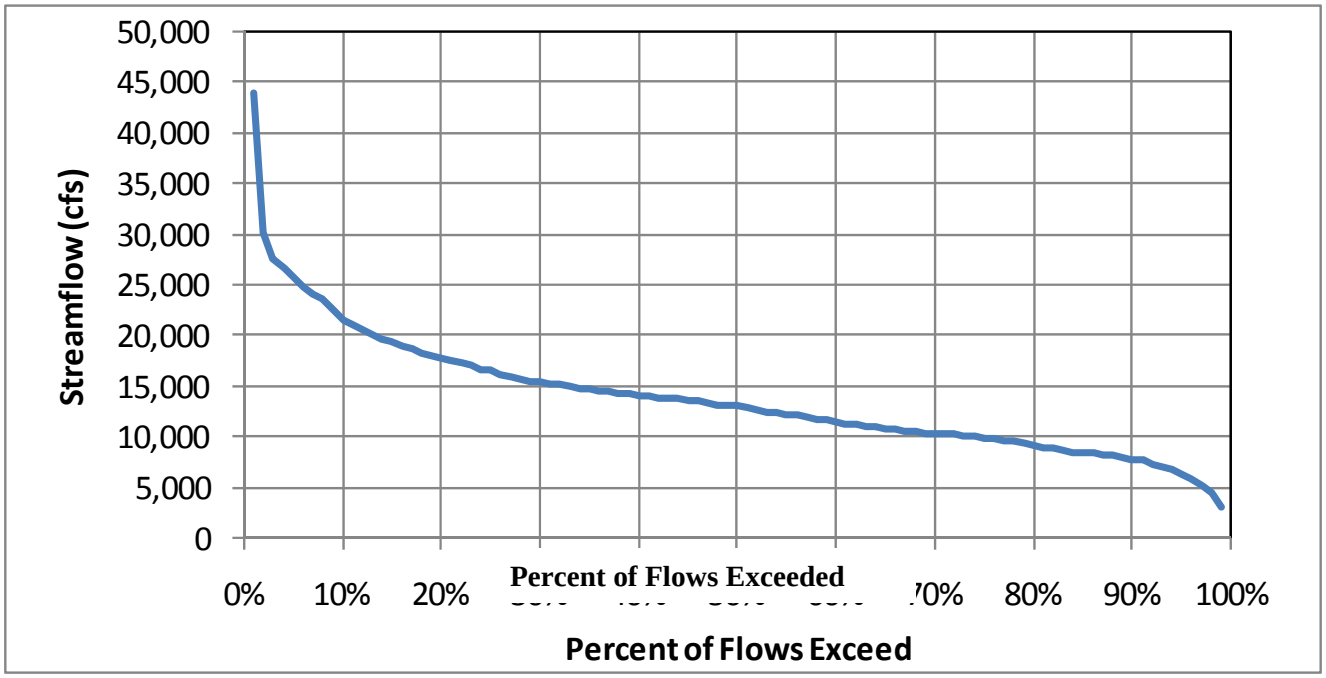


Figure 5-22
Colorado River at Lees Ferry Flow Exceedance (1970 – 2008)

Flows in the Colorado River at Lees Ferry can vary considerably from year to year. Figure 5-23 and Figure 5-24 depict historical flows for a year with the minimum flow, 2004, and a year with higher flows, 1998. Depending on the month, surplus years can result in sustained flows more than 10,000 cfs higher than flows occurring under Shortage or Normal conditions. Figure 5-25 depicts the stage-discharge rating curve for the Colorado River at Lees Ferry gage.

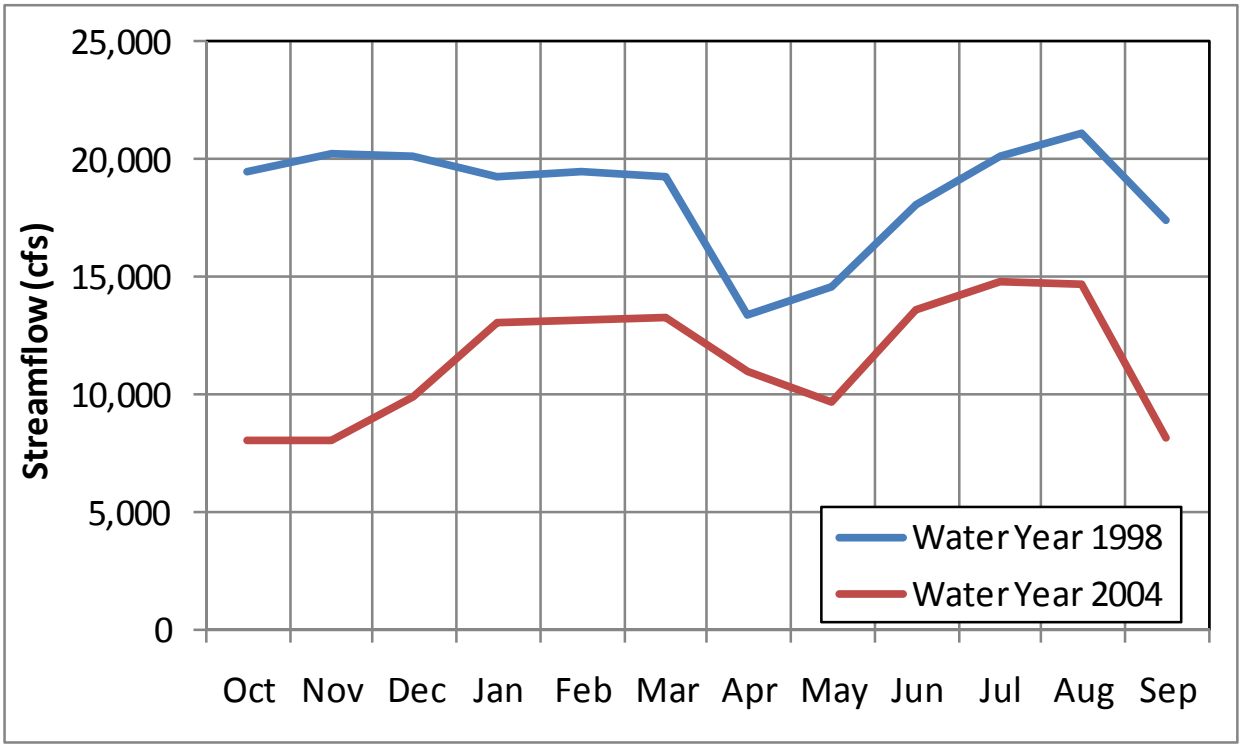


Figure 5-23
Colorado River at Lees Ferry Monthly Mean Flows (Wet and Dry Year)

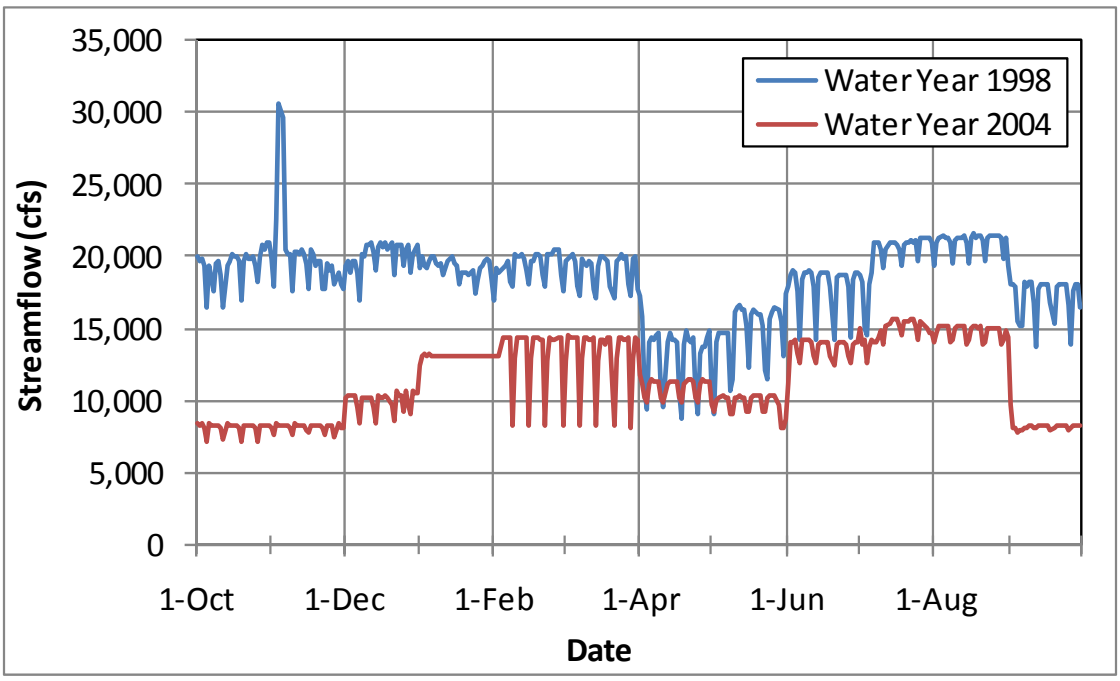


Figure 5-24
Colorado River at Lees Ferry Daily Flows (Wet and Dry Year)

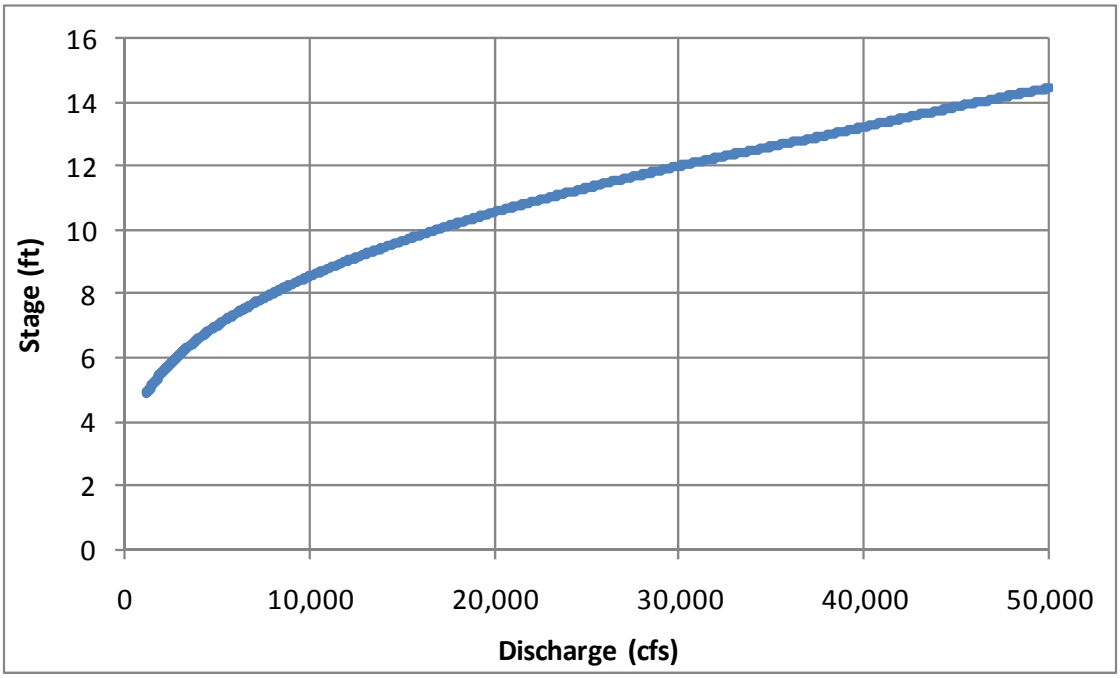
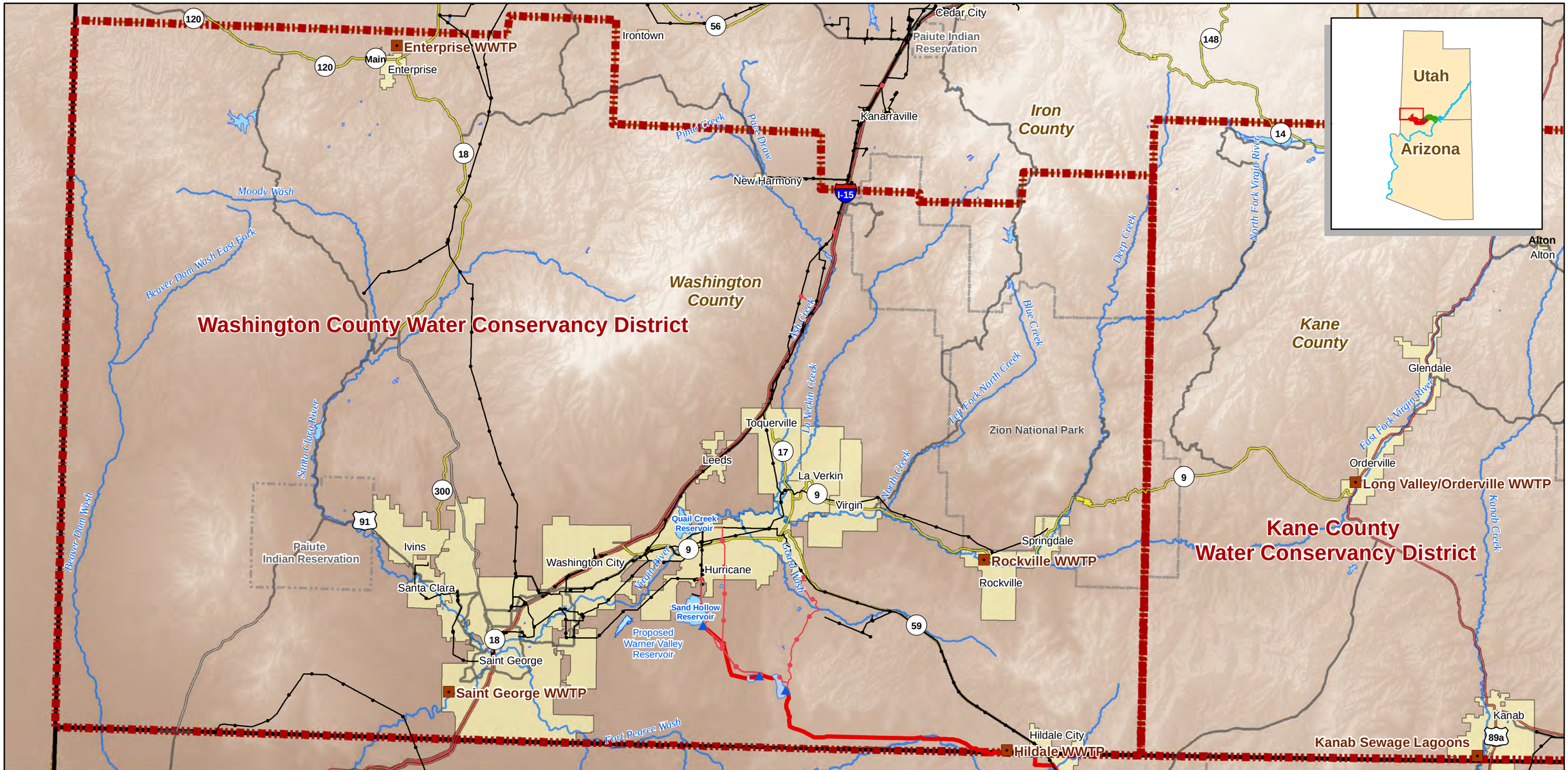


Figure 5-25
Colorado River at Lees Ferry – Stage Discharge Rating Curve
Note: Rating curves are subject to change over time

5.3.3.1.2.2 Virgin River Drainages.

The Virgin River lies within the lower Colorado River basin. The Virgin River basin is bound by mountains with elevations reaching over 10,000 feet with the Bull Valley and Beaver Dam mountains to the west, the Harmony Mountains to the north, the Glendale Bench and Block Mesas to the east. The lowest elevation is about 2,500 feet where the Virgin River crosses the state line into Arizona. Most Virgin River streamflow originates as snow with runoff resulting in high flows from March through May. The greatest water-producing area is the headwaters of the North Fork of the Virgin River (UDWRe 1993).

In the Virgin River watershed in Utah, most of the public water supply is provided through the WCWCD. Figure 5-26 depicts the WCWCD service area along with the cities and surface water features. Figure 5-27 is a schematic of the Virgin River basin in Utah. The figure is valid through 1990 and there have been some changes in river operation in that time including the construction of Sand Hollow Reservoir, although the major 1890 priority irrigation diversions have been unchanged. Therefore, the volumes shown in the figure, particularly downstream of the diversion to the reservoirs, do not necessarily represent current conditions. However, it provides a general idea of the magnitude of streamflow in the Virgin River system.



FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWRe **Figure 5-26** MWH

Washington County Water Conservancy District

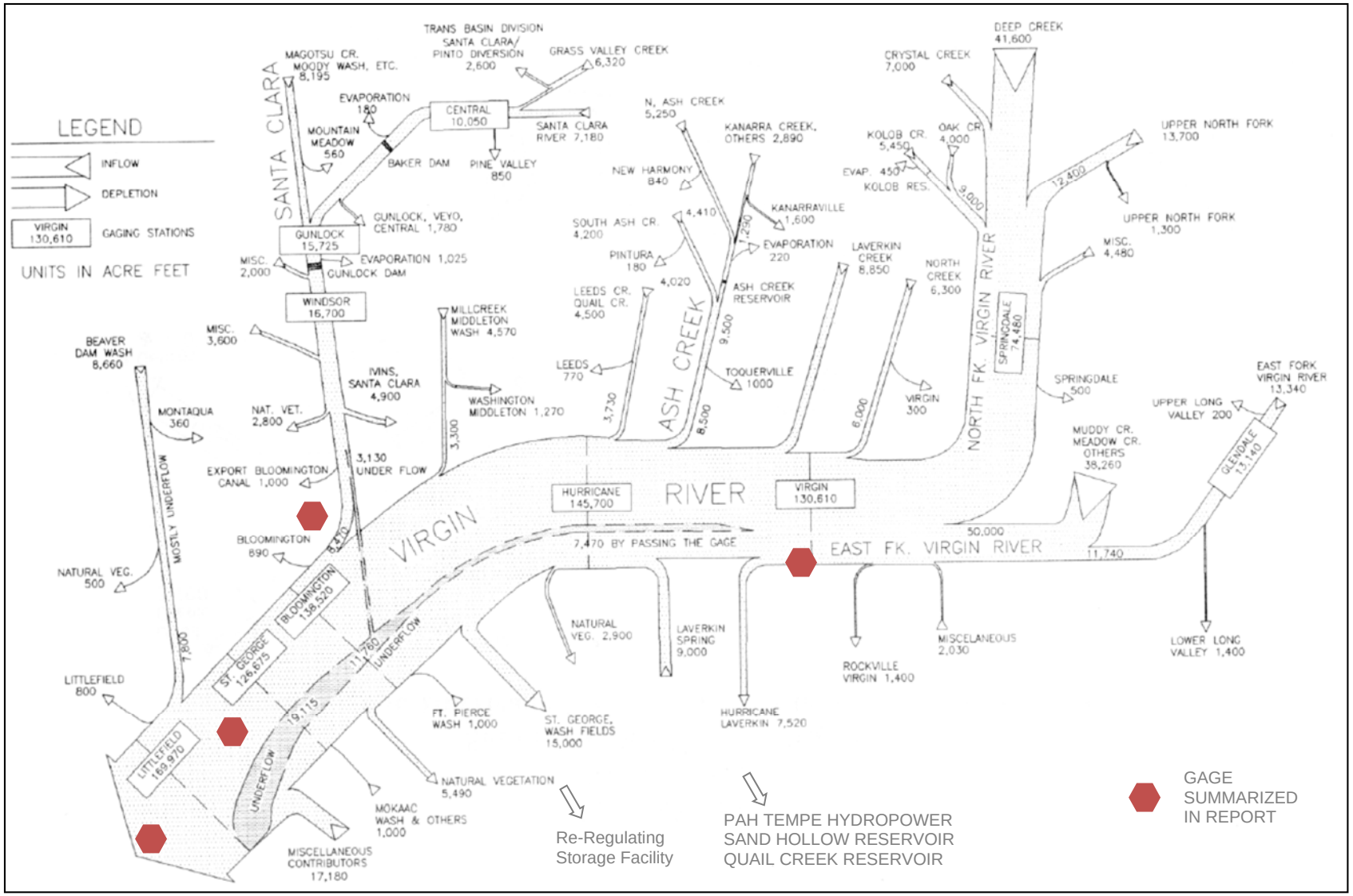


Figure 5-27
Virgin River System in Utah – Streamflow and Depletion Chart (1941-1990)
Source: Modified From UDWRe (1993), flow numbers do not represent current conditions

Historical streamflows are summarized at the following locations in the Virgin River Basin:

- Virgin River at Virgin, Utah
- Virgin River at St. George, Utah
- Virgin River at Littlefield, Arizona
- Santa Clara River at St. George

Figure 5-28 demonstrates the Virgin River is typically a gaining stream from Virgin, Utah to Littlefield, Arizona in fall and early winter months. From January through August, flows decrease through St. George and increase again downstream of the state line. Historical canal company diversions dry-dammed the Virgin River immediately downstream of the current Quail Creek Diversion and at the Washington Fields Diversion.

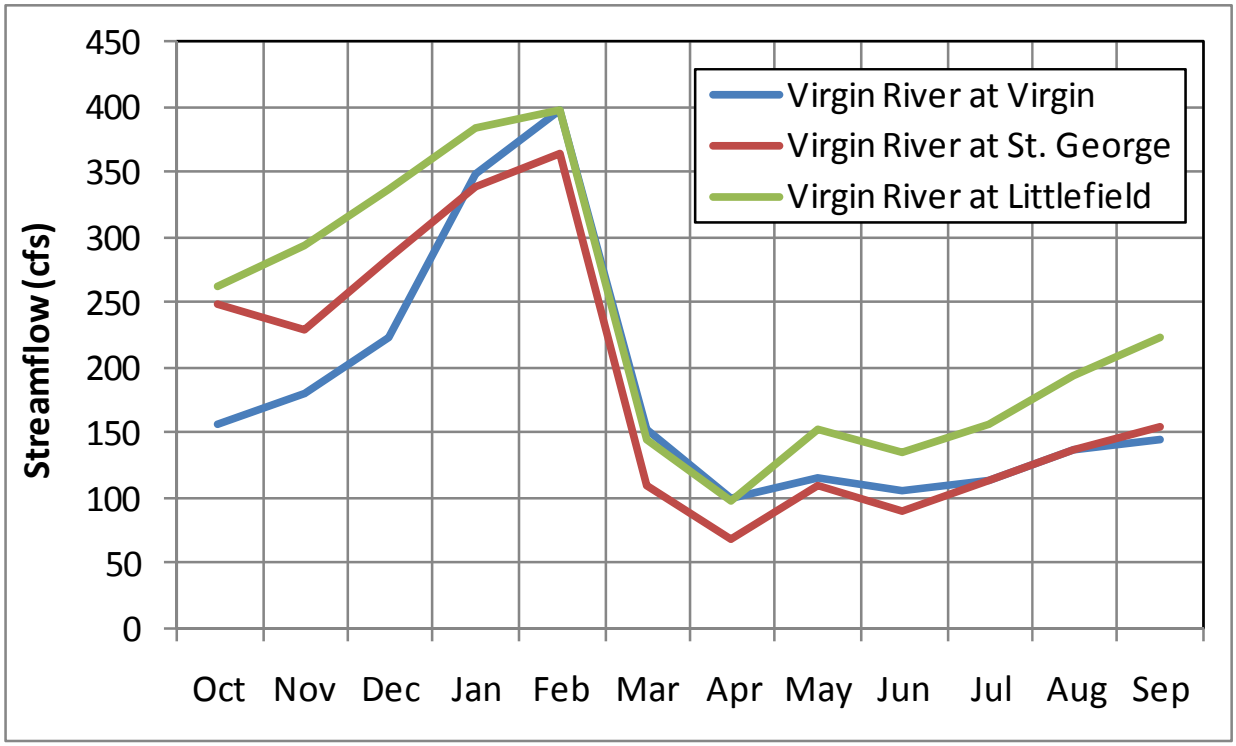


Figure 5-28
Monthly Streamflows in the Virgin River from Virgin, Utah to Littlefield, Arizona

WCWCD operates its system in accordance with the priority water rights of the three major historical diversions on the Virgin River, so that the lesser of 86 cfs or the natural flow in the river reaches the Washington Fields Diversion (UDWRe 1993).

Virgin River at Virgin, Utah

This gage location is upstream of any major diversions and upstream of areas that would receive LPP water. Therefore, it is upstream from the potential effects of return flows under the Proposed Action. Figure 5-29 depicts the historical daily flows for the Virgin River. Figure 5-30 shows the daily mean and daily range of flows over the calendar year based on the period of record. Figure 5-31 shows the flow exceedance curve for the gage. The 90

percent exceedance value is 68 cfs (i.e. 90 percent of flows exceed 68 cfs), while the 10 percent exceedance value is 320 cfs. The median flow, which corresponds to the 50 percent exceedance level, is 122 cfs.

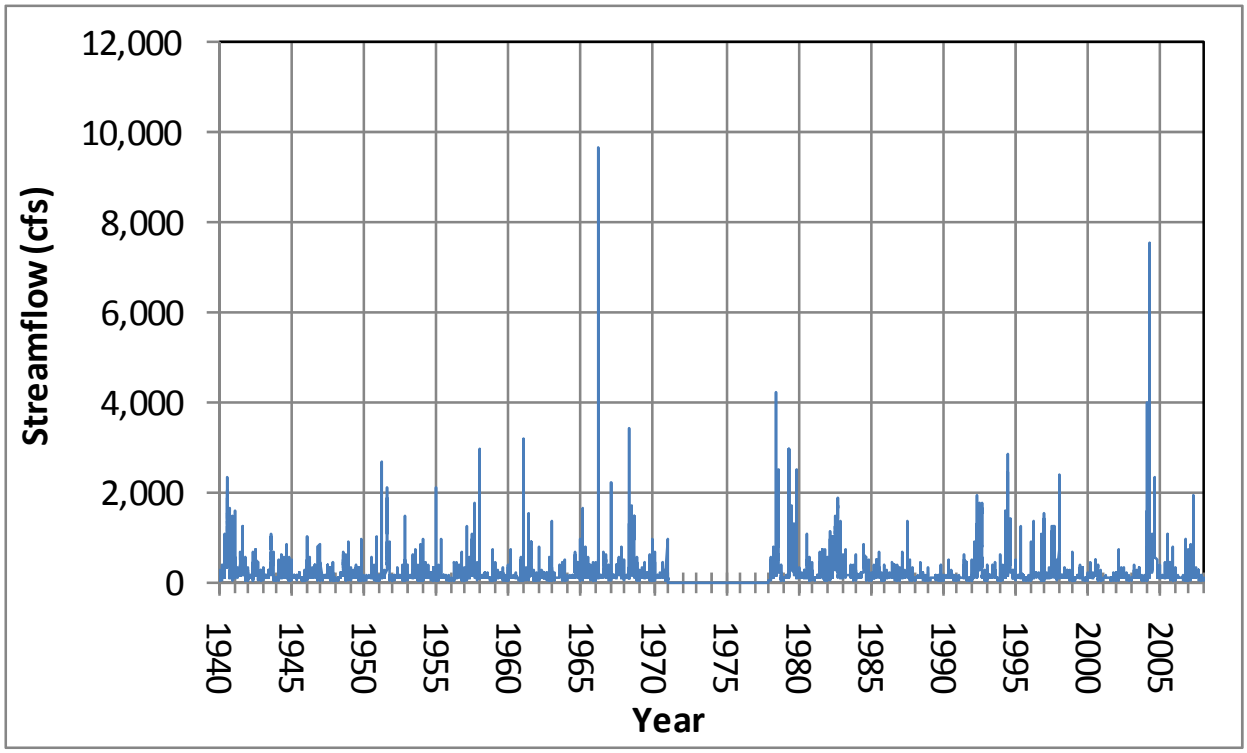


Figure 5-29
Virgin River at Virgin, Daily Flows

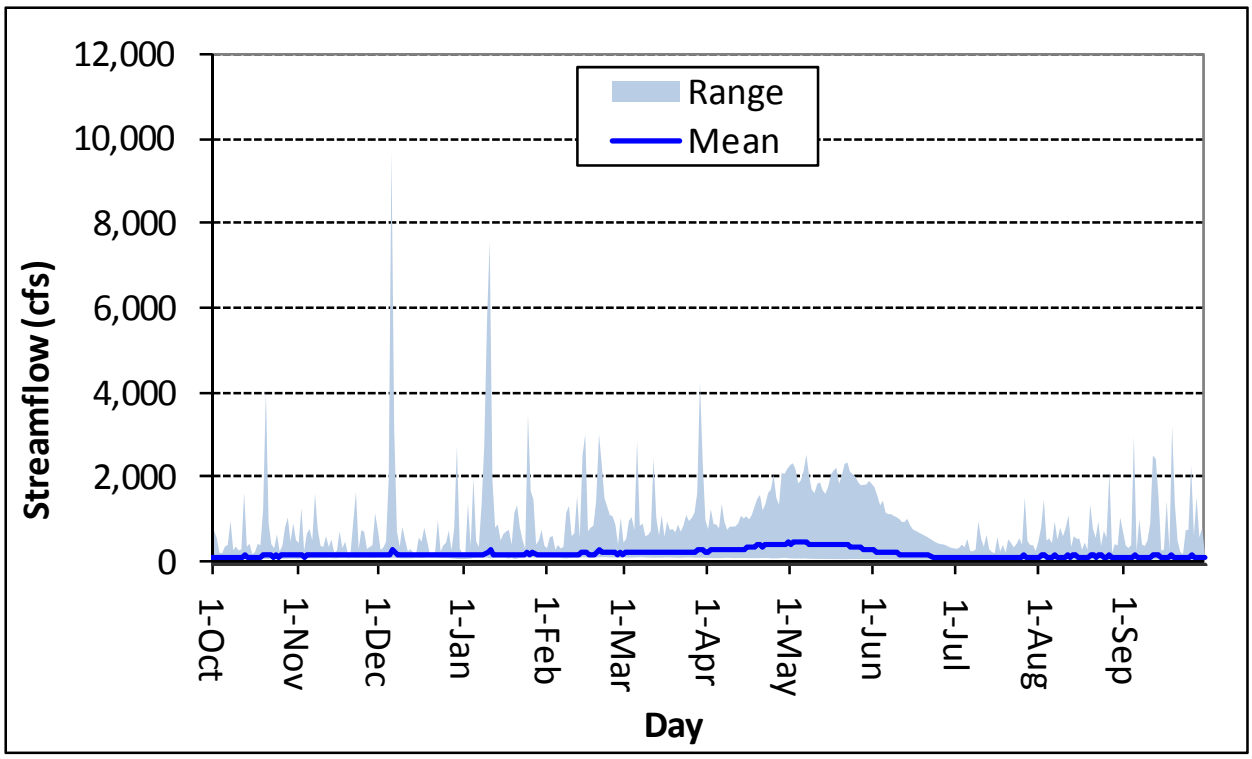


Figure 5-30
Virgin River at Virgin, Daily Mean and Range of Flow

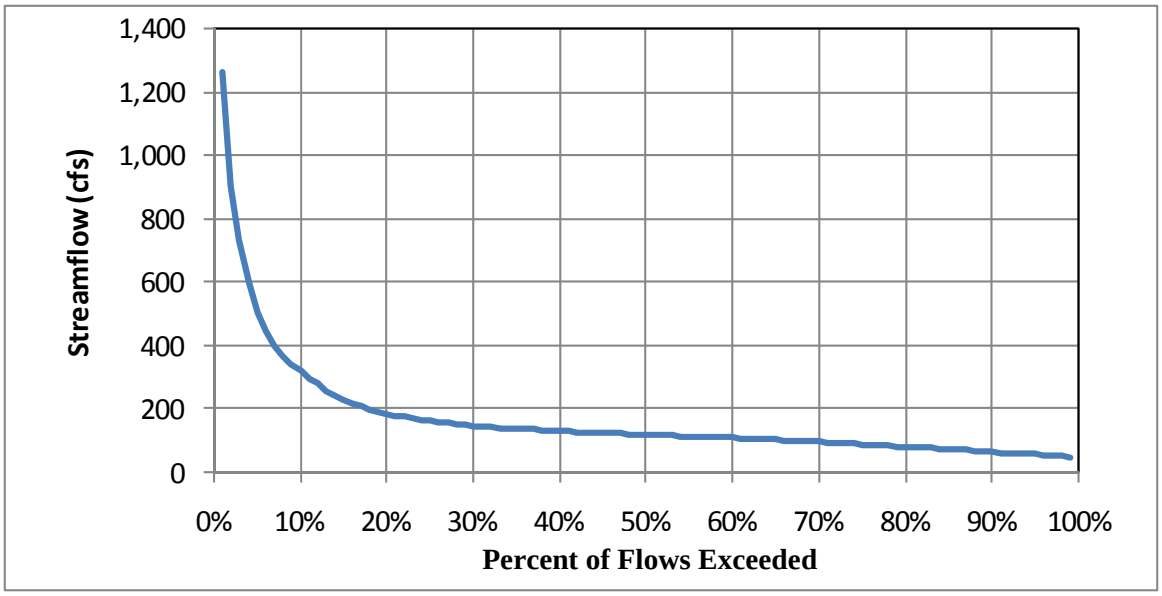


Figure 5-31
Virgin River at Virgin, Daily Flow Exceedance

Figure 5-32 shows monthly mean flows for the Virgin River at Virgin gage. The flows show a distinct seasonal pattern with peak flows in May. Figure 5-33 shows the variation in streamflow from year to year. Monthly mean and annual mean flows do not show the variation that can occur in the Virgin River on a daily basis. Large fluctuations in Virgin River daily and weekly flows reflect the large percentage of the drainage basin comprised of impervious area (exposed bedrock) and relatively short time of concentration during precipitation runoff events. The long term mean annual streamflow is 182 cfs. Annual streamflow is usually greater than 100 cfs and in high flow years can exceed 300 to 400 cfs. Figure 5-34 shows the stage discharge rating curve for the Virgin River at Virgin.

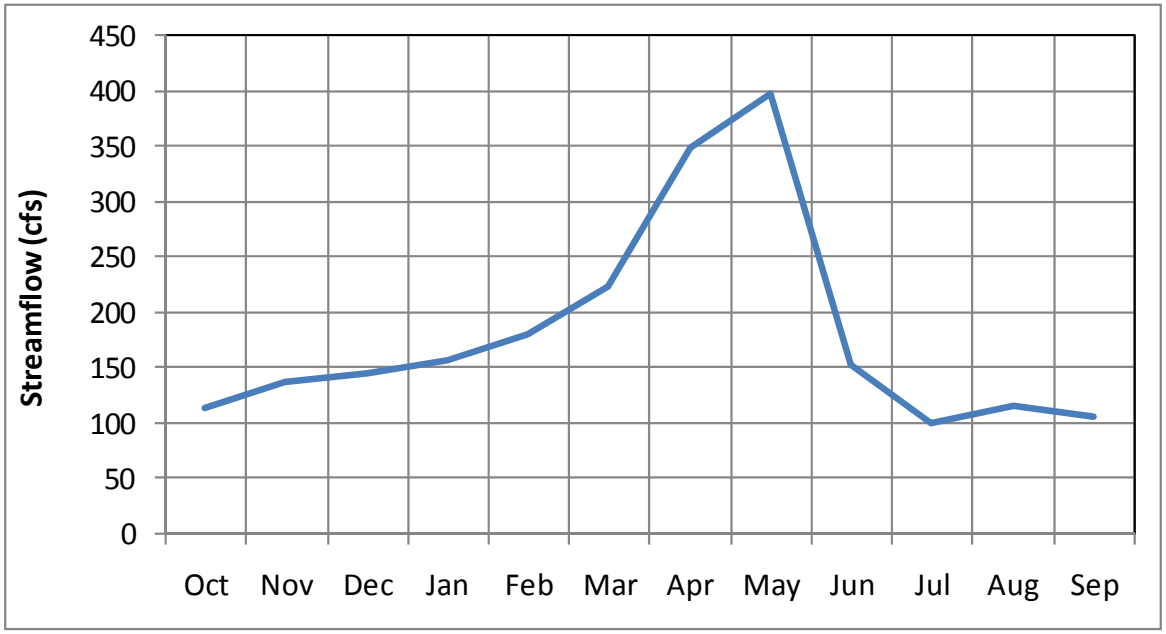


Figure 5-32
Virgin River at Virgin, Monthly Mean Flows

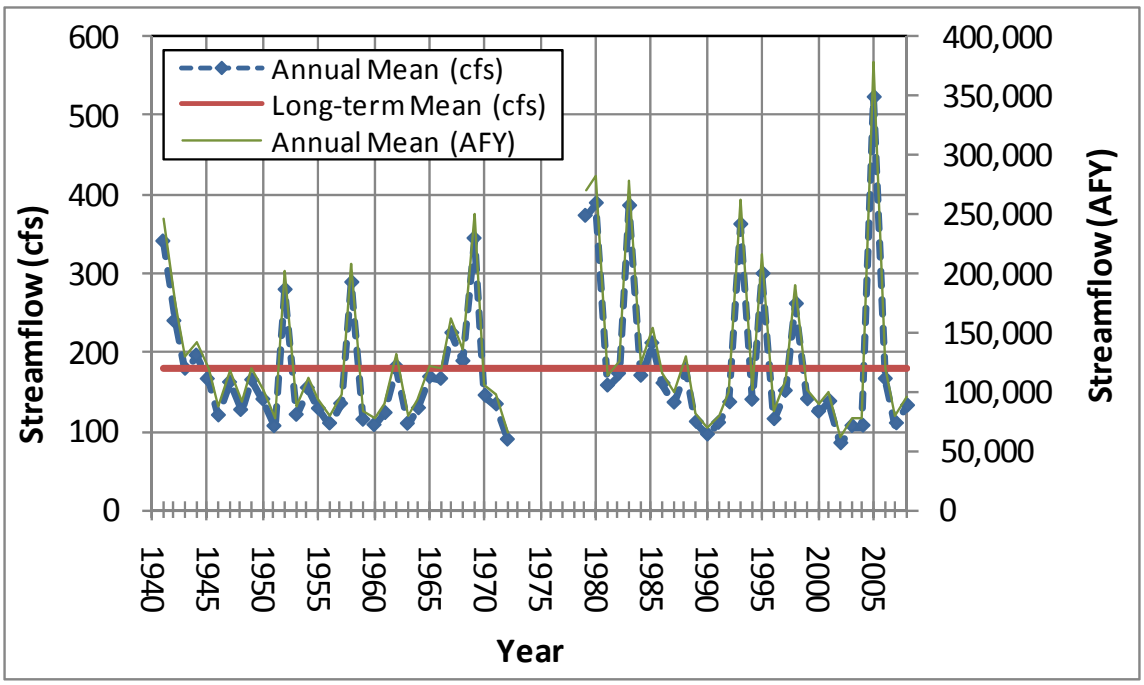


Figure 5-33
Virgin River at Virgin, Annual Mean Flows

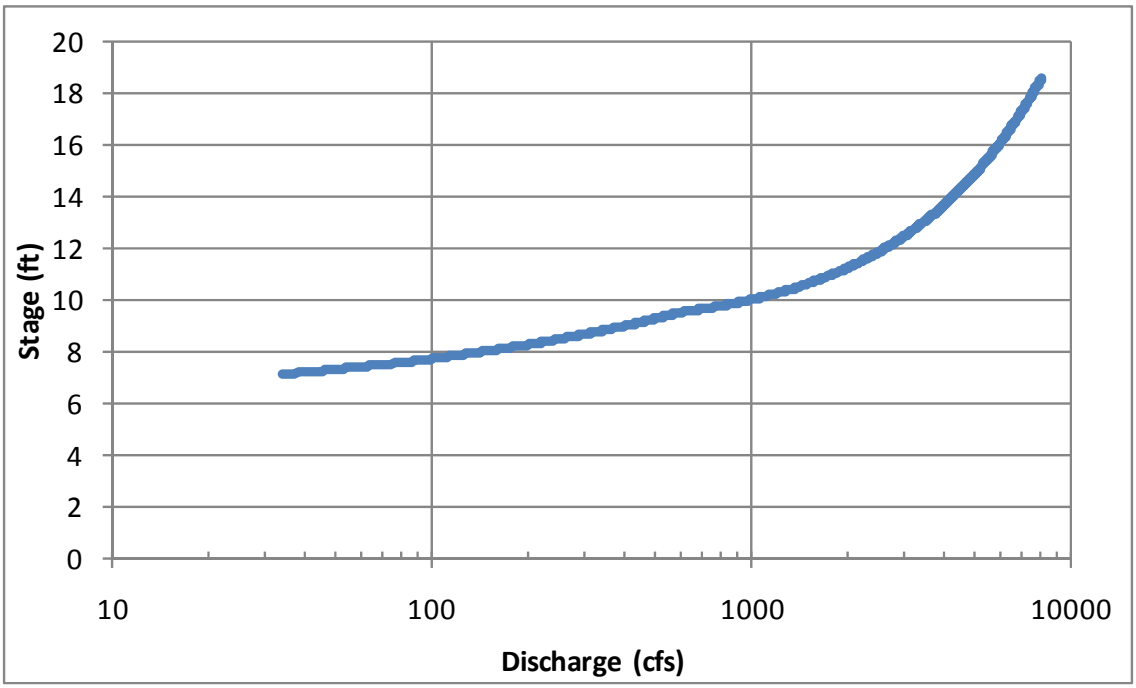


Figure 5-34
Virgin River at Virgin – Stage Discharge Rating Curve
Note: Rating curves are subject to change over time

Virgin River Near St. George, Utah

The St. George gage is located downstream of St. George where the Virgin River enters a canyon section. Figure 5-35 is a USGS photograph of the gage location. There are several major inflows and diversions from the Virgin River between the Virgin and St. George gages including:

- Diversion to Quail Creek Reservoir, Hurricane and LaVerkin
- Diversion to St. George, Washington Fields
- Inflow from Santa Clara River, Ash Creek, LaVerkin Creek, LaVerkin Spring
- Return flows from St. George wastewater treatment facility

Figure 5-35
Virgin River Near St. George Gage Location

As shown in the daily streamflow chart in Figure 5-36, the period of record for this gage is relatively short. Figure 5-37 shows the daily mean and daily range of flows over the calendar year based on the period of record. Figure 5-38 shows the flow exceedance curve for the Virgin River for the period of 1992 through 2008. The 90 percent exceedance value is 26 cfs, while the 10 percent exceedance value is 460 cfs. The median flow is 110 cfs.

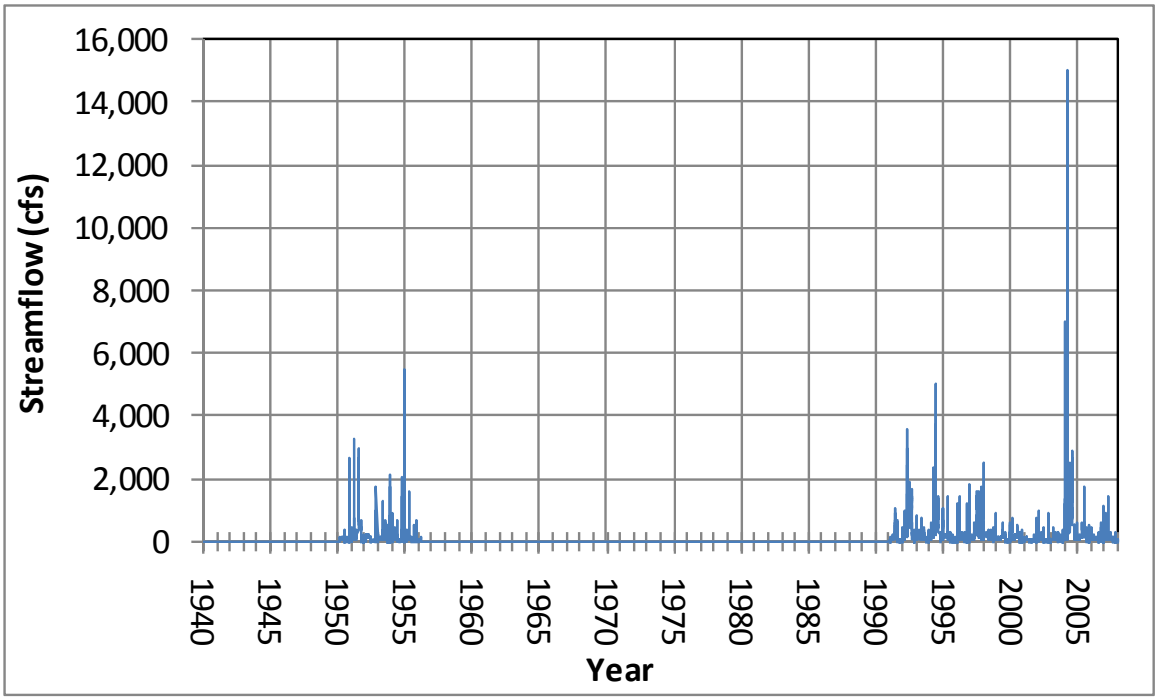


Figure 5-36
Virgin River near St. George, Daily Flows

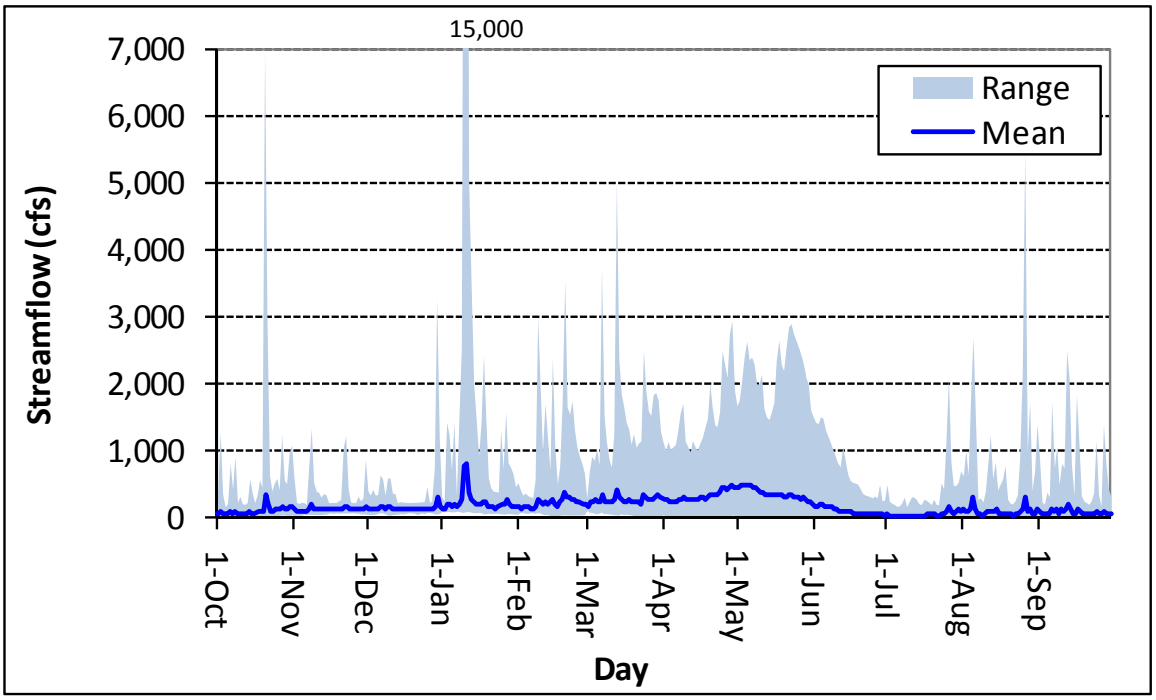


Figure 5-37
Virgin River Near St. George, Daily Mean and Range of Flow

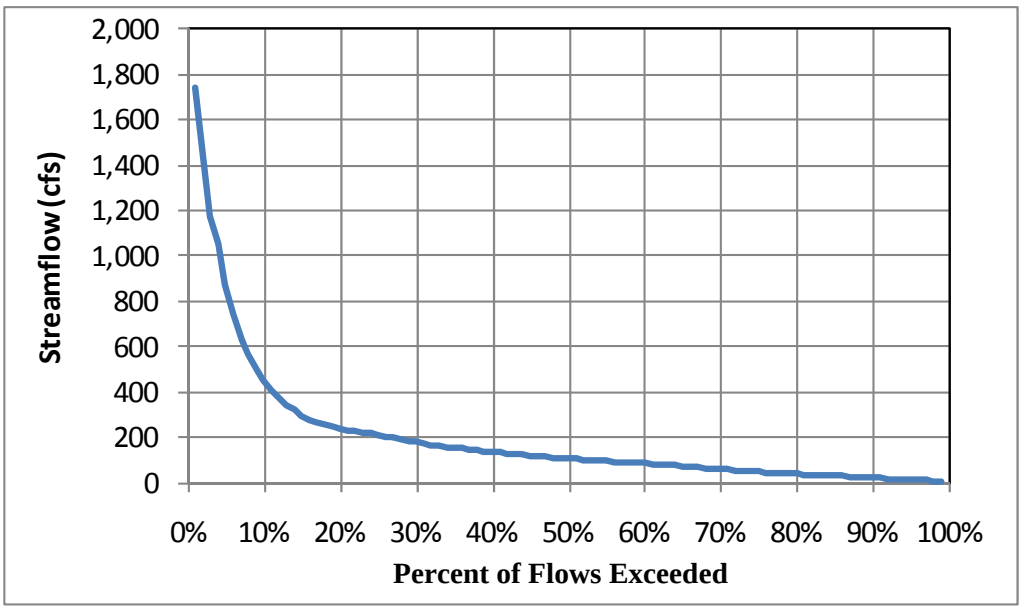


Figure 5-38
Virgin River near St. George Flow Exceedance (1992 – 2006)

Figure 5-39 depicts monthly mean flows for the Virgin River at St. George, Utah gage for the period of 1992 through 2006. Compared to the upstream location, peak seasonal flows occur in late spring with low flows in summer. Figure 5-40 shows the historical annual mean flows in the Virgin River. The long term annual mean was not calculated due to the short period of record. Figure 5-41 depicts the stage-discharge curve for the gage.

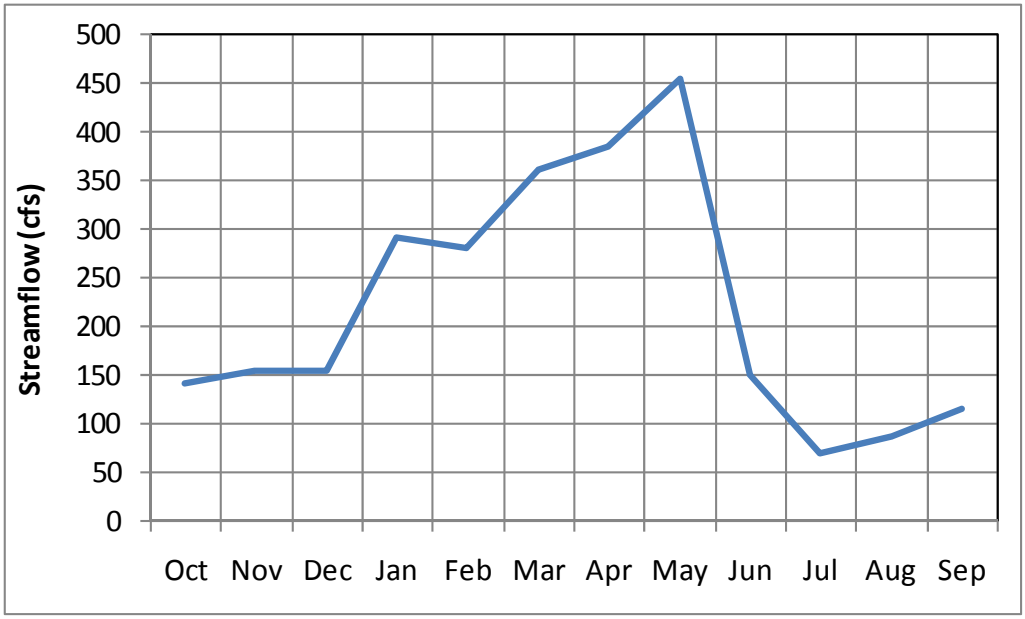


Figure 5-39
Virgin River near St. George Monthly Mean Flows (1992 – 2006)

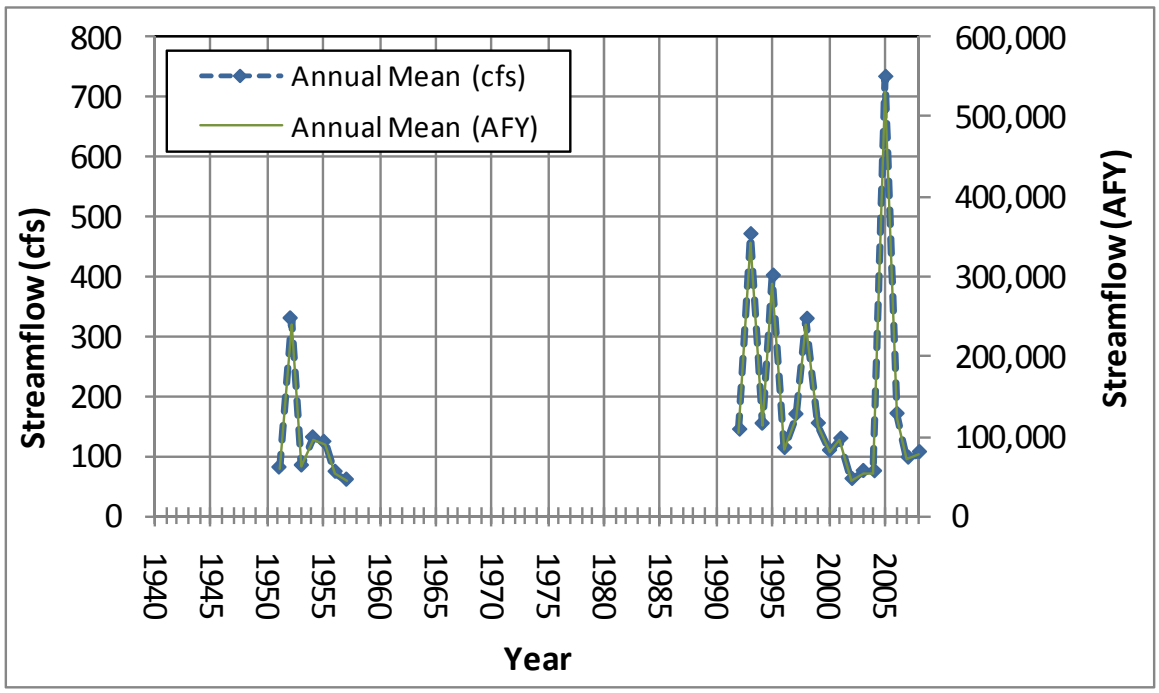


Figure 5-40
Virgin River near St. George Annual Mean Flows

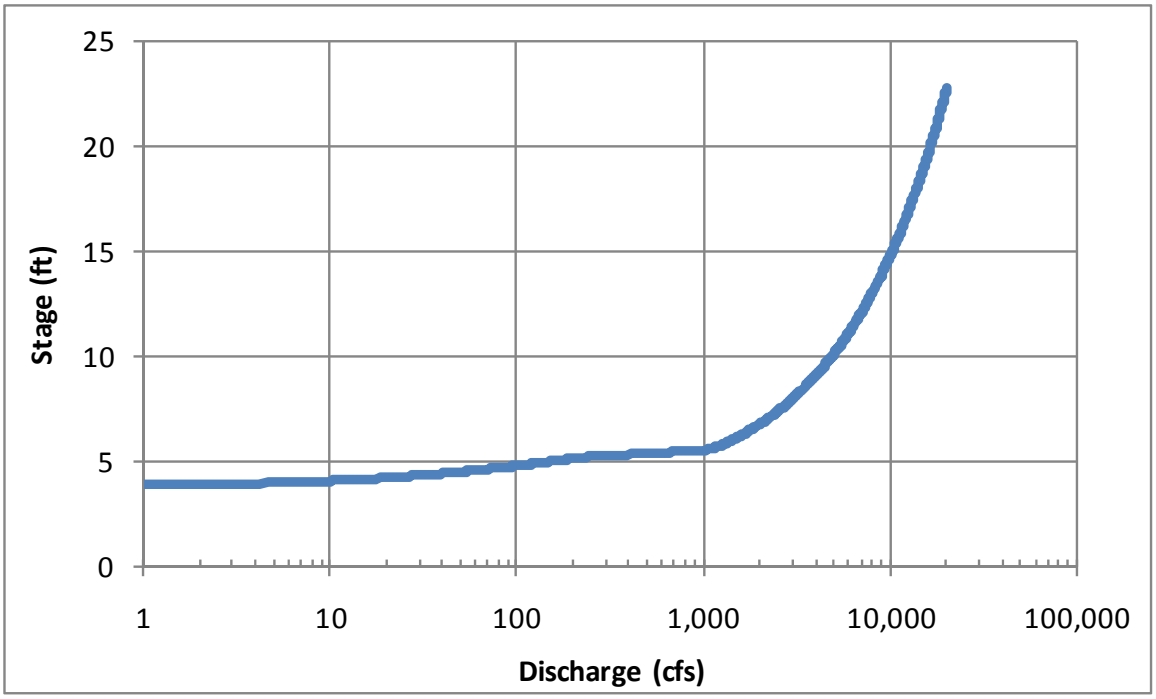


Figure 5-41
Virgin River Near St. George – Stage Discharge Rating Curve
Note: Rating curves are subject to change over time

Virgin River at Littlefield, Arizona

The Virgin River at Littlefield, Arizona gage is located a few miles downstream of the state line. Figure 5-42 depicts historical daily flows. Figure 5-43 shows the daily mean and daily range of flows over the calendar year based on the period of record. Figure 5-44 shows the flow exceedance curve. The 90 percent exceedance value is 62 cfs, while the 10 percent exceedance value is 401 cfs. The median flow is 145 cfs.

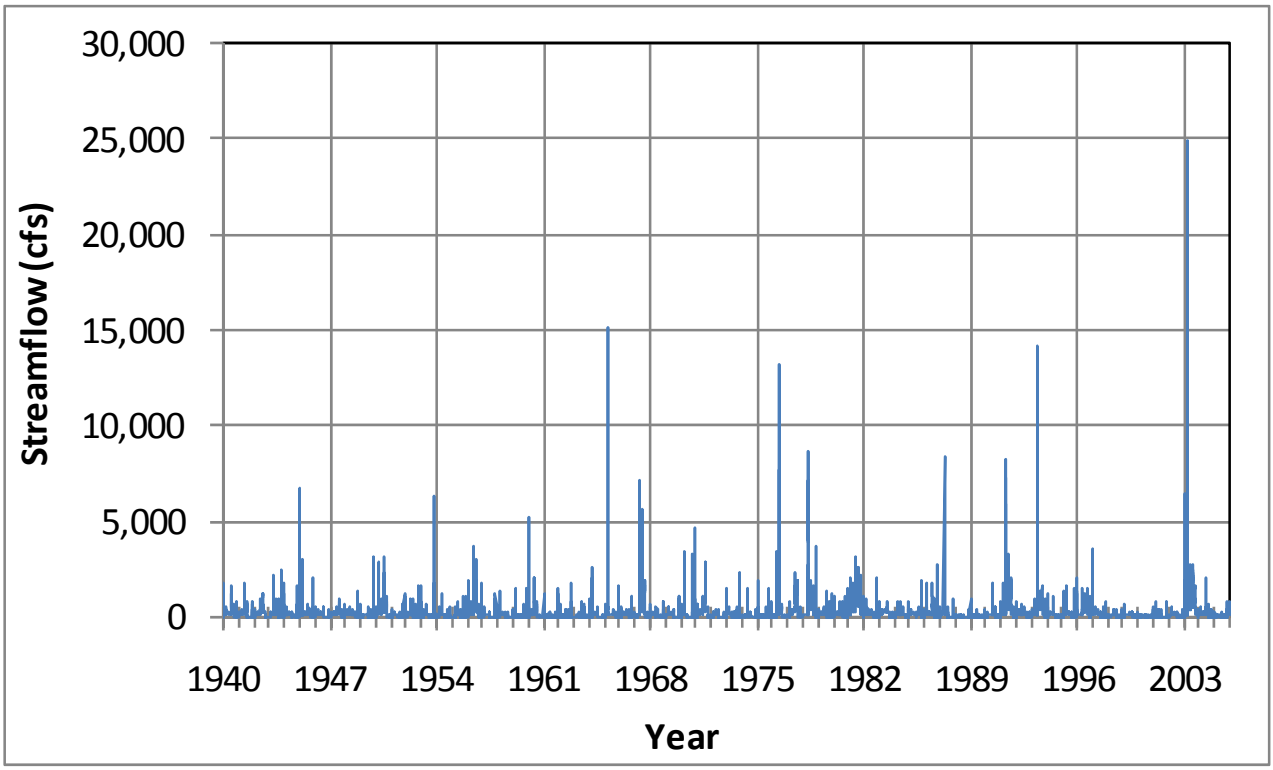


Figure 5-42
Virgin River at Littlefield, Daily Flows

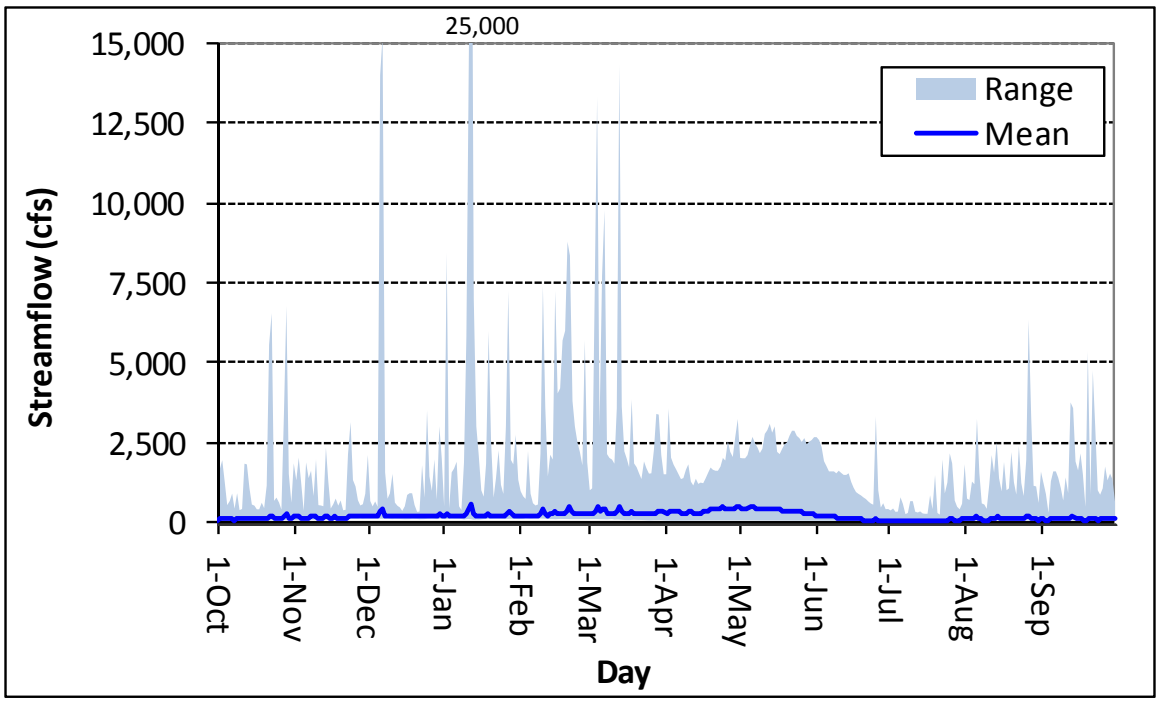


Figure 5-43
Virgin River at Littlefield, Daily Mean and Range of Flow

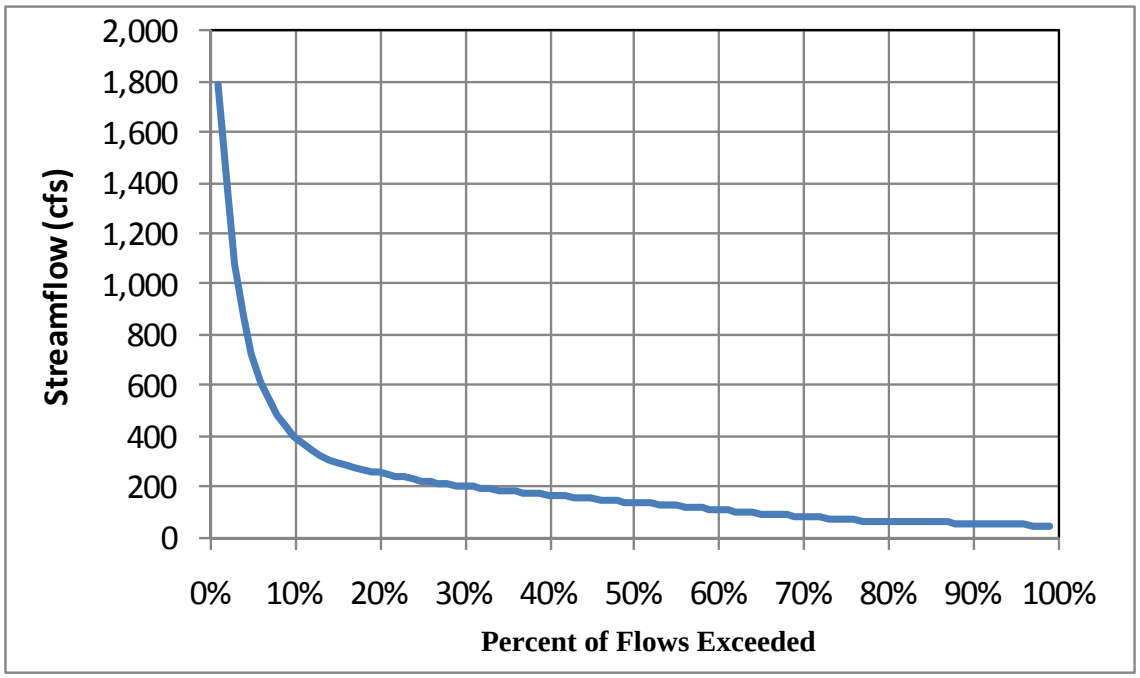


Figure 5-44
Virgin River at Littlefield, Flow Exceedance

Figure 5-45 shows monthly average flows for the Virgin River at Littlefield. Similar to the upstream locations, peak flows occur in late summer with low flows in the fall. Figure 5-46 depicts the historical annual mean flows. The long term mean is 235 cfs. Figure 5-47 depicts the stage-discharge curve for the gage.

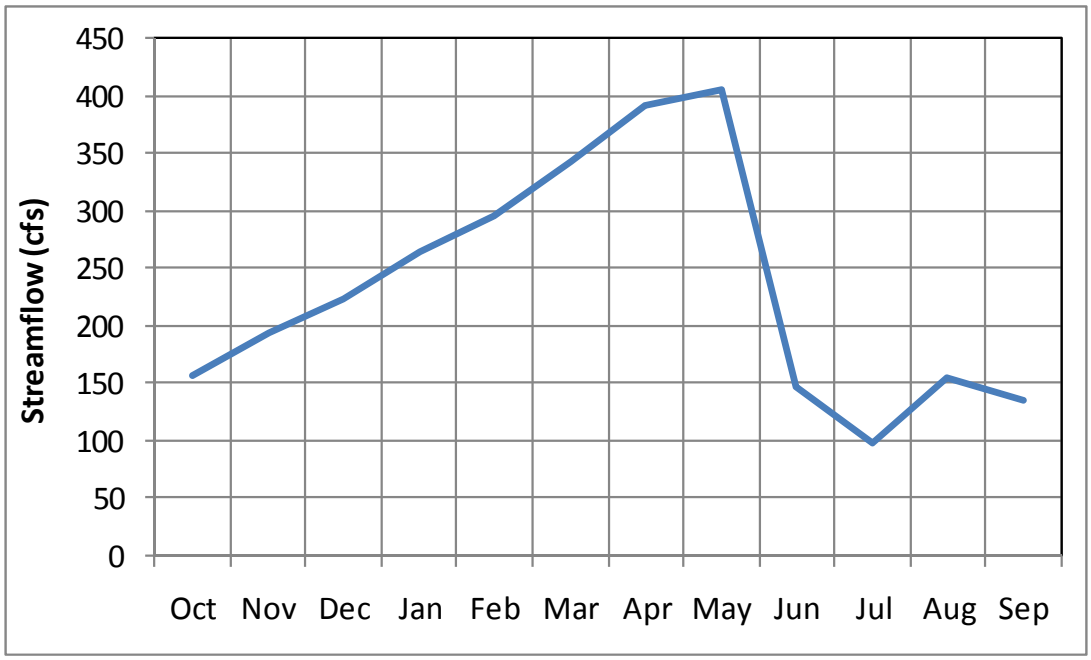


Figure 5-45
Virgin River at Littlefield, Monthly Mean Flows

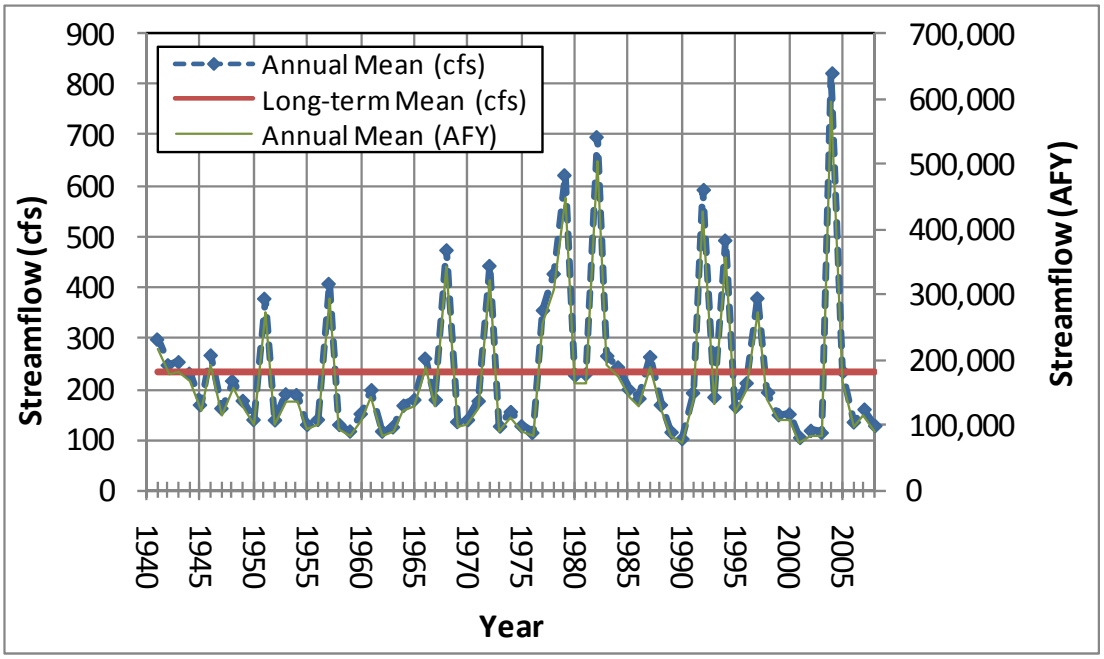


Figure 5-46
Virgin River at Littlefield, Annual Mean Flows

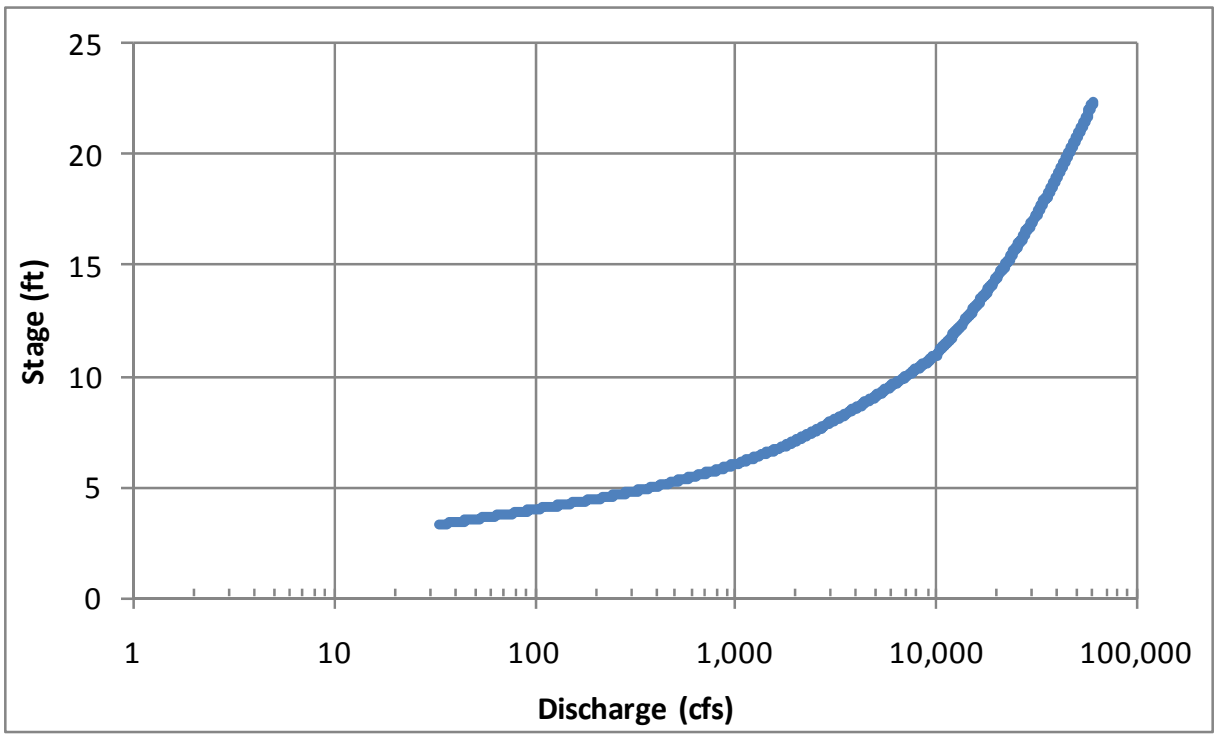


Figure 5-47
Virgin River at Littlefield – Stage Discharge Rating Curve
Note: Rating curves are subject to change over time

Santa Clara River at St. George

The Santa Clara River originates in the Pine Valley Mountain Wilderness north of St. George. This perennial stream flows though several communities including Ivins and Santa Clara before its confluence with the Virgin River at the southern end of St. George. The Santa Clara River at St. George gage is located about a mile upstream of the confluence with the Virgin River. The flow of the Santa Clara River is regulated by upstream reservoir and irrigation diversions. Figure 5-48 shows the daily historical flows in the Santa Clara River. There is a gap in the streamflow record between 1956 and 1985. Figure 5-49 shows the daily mean and daily range of flows over the calendar year based on the period of record. Figure 5-50 shows the flow exceedance curve. The 90 percent exceedance value is 1 cfs, while the 10 percent exceedance value is 27 cfs. The median flow is 4 cfs.

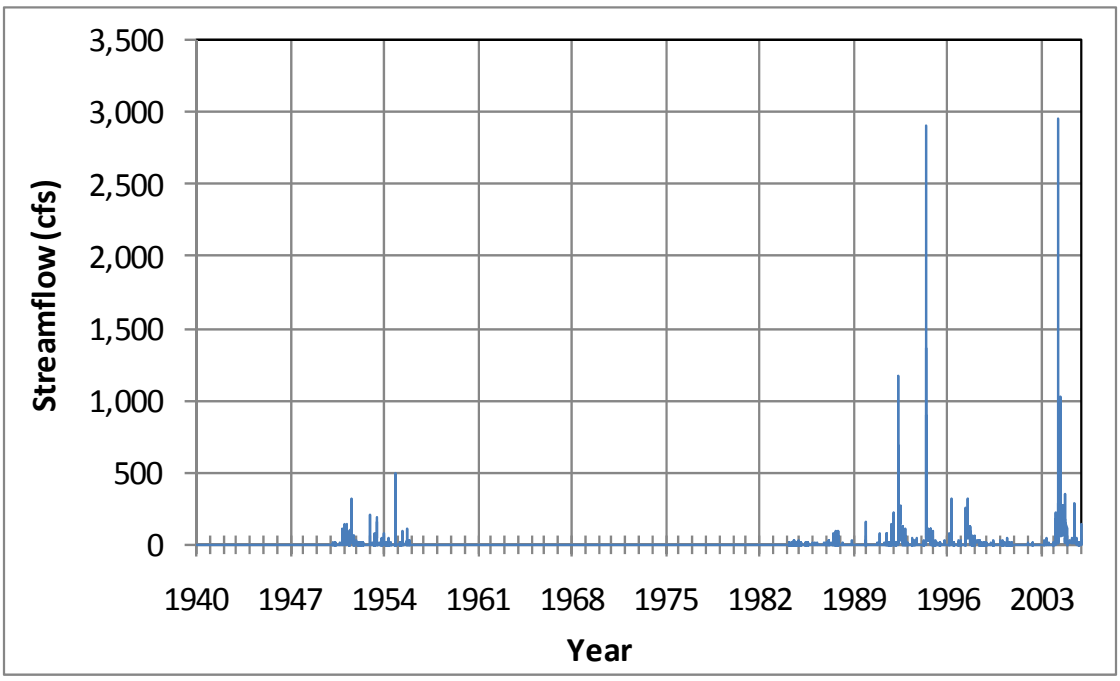


Figure 5-48
Santa Clara River at St. George Daily Flows

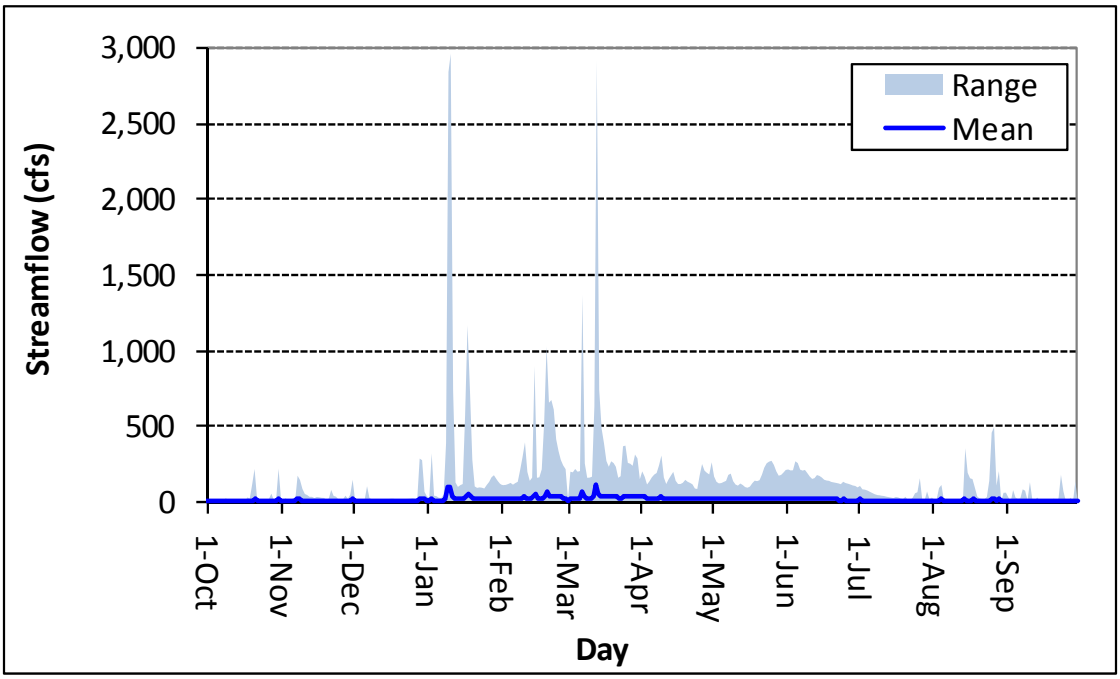


Figure 5-49
Santa Clara River at St. George Daily Mean and Range of Flow

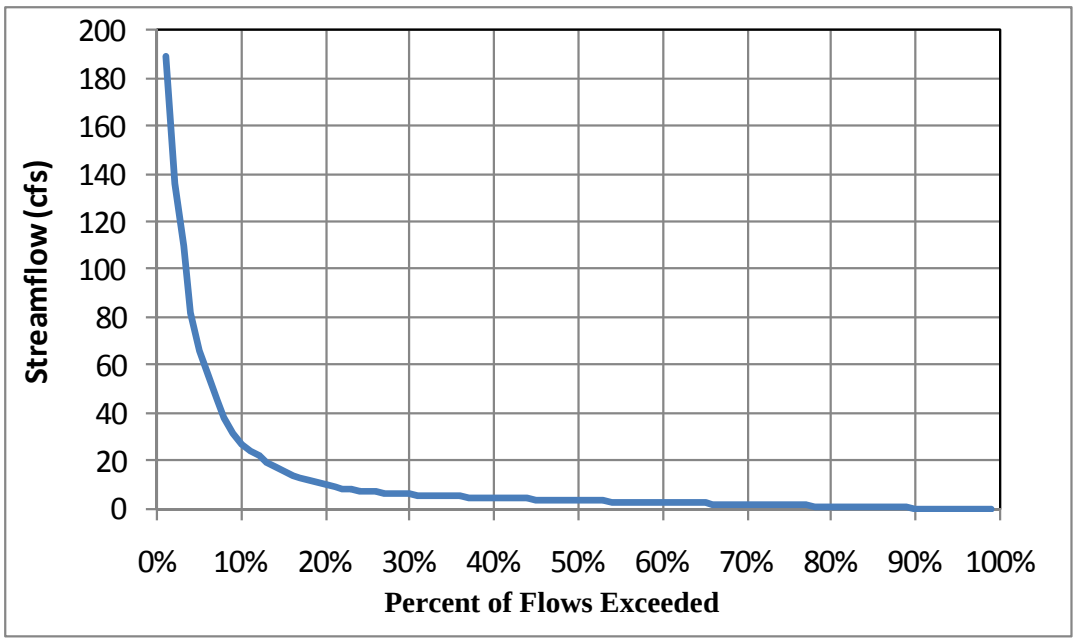


Figure 5-50
Santa Clara River at St. George Flow Exceedance

Figure 5-51 shows monthly mean flows for the Santa Clara River. Peak flows occur in spring with low flows occurring in late summer into fall. Figure 5-52 shows the historical annual mean streamflow; the long-term mean is not depicted due to the relatively short period of record. Figure 5-53 depicts the stage-discharge curve for the gage.

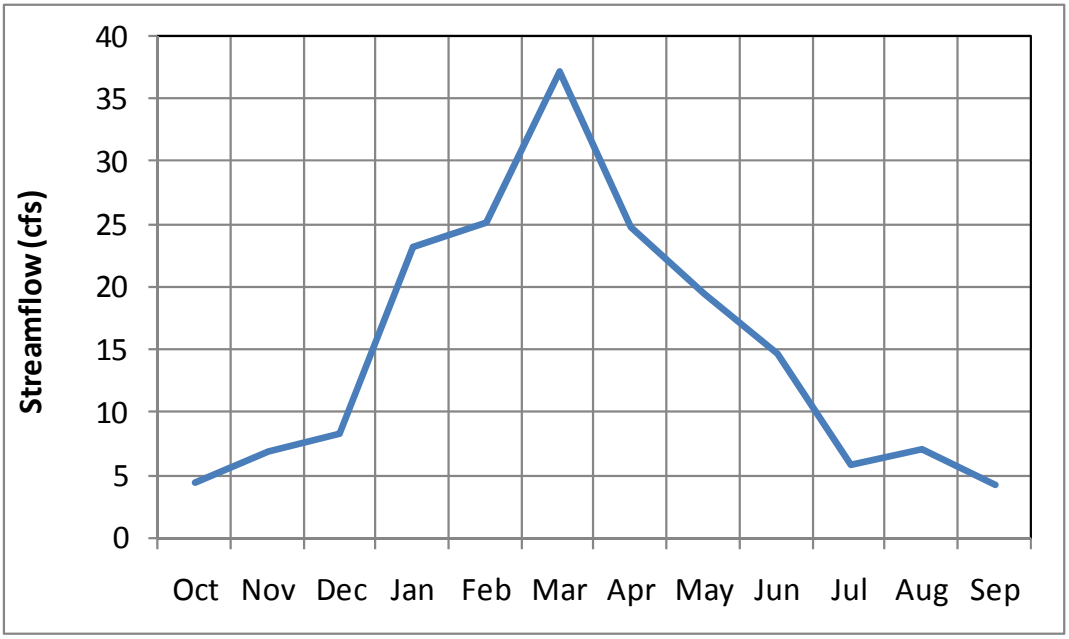


Figure 5-51
Santa Clara River at St. George Monthly Mean Flows

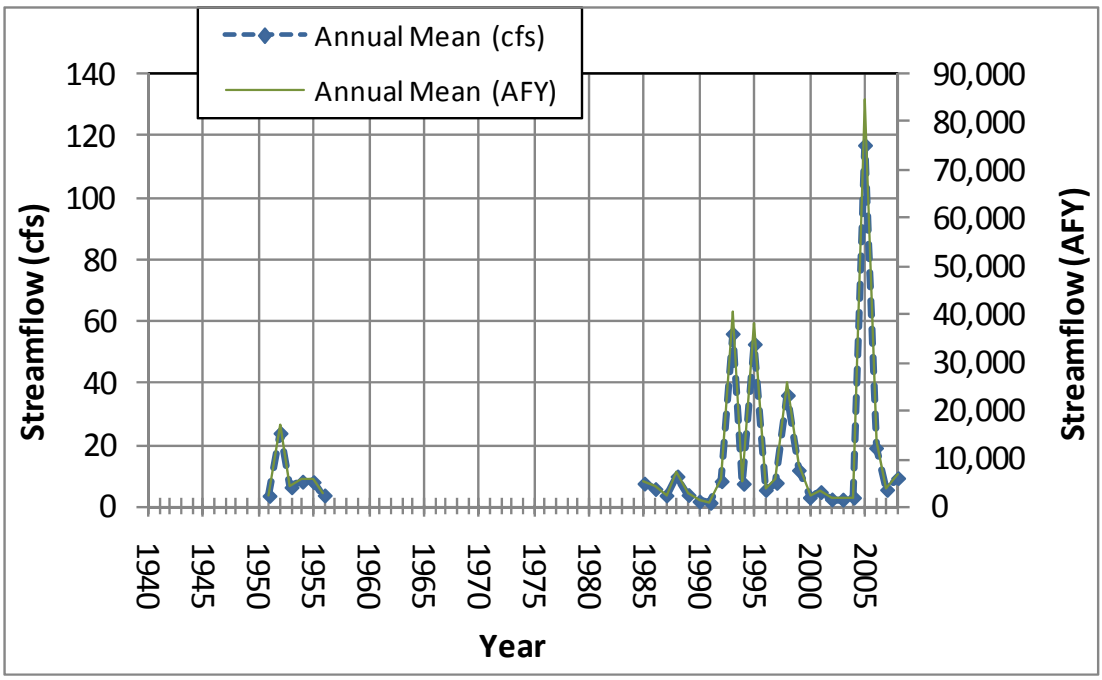


Figure 5-52
Santa Clara River at St. George Annual Mean Flows

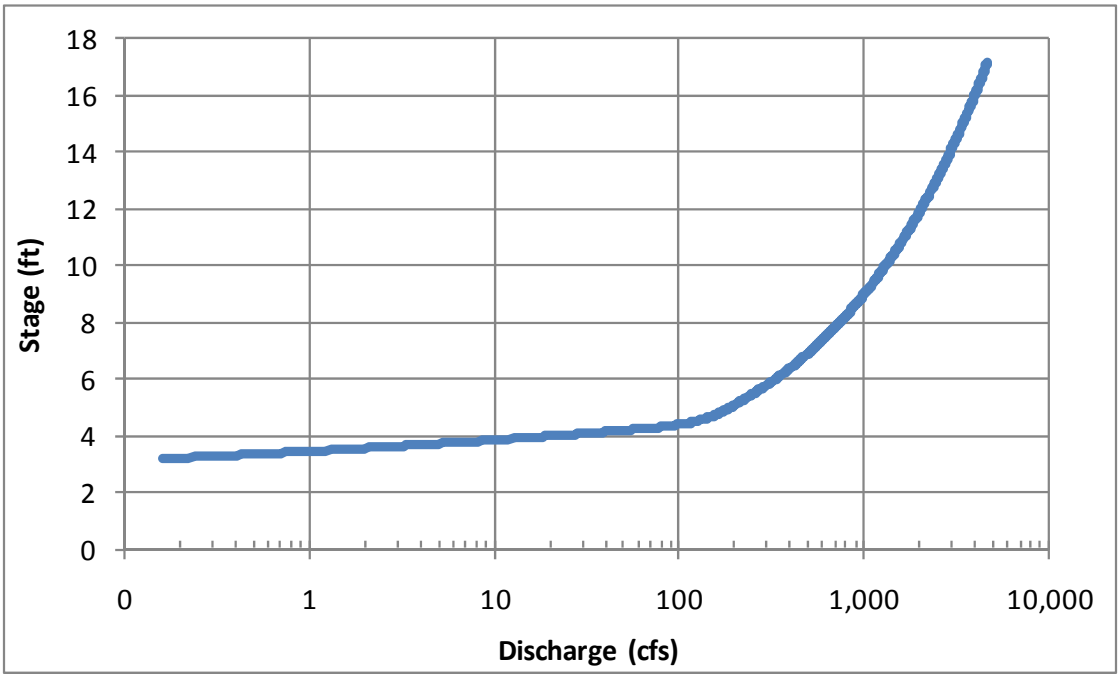


Figure 5-53
Santa Clara River at St. George – Stage Discharge Rating Curve
Note: Rating curves are subject to change over time

5.3.3.1.2.3 Other Potentially Affected Streams

Gould Wash and Fort Pierce Wash could both be affected by non-sewered return flows. Neither stream has an active stream gage within the area of potential effect.

5.3.3.1.2.4 Kane, Mohave and Coconino County Drainages.

Figure 5-54 shows the KCWCD service area and project facilities within the area. The additional water supply used by KCWCD could potentially generate return flows to Kanab Creek in Utah and in Arizona. In addition, the pipeline would cross several washes in Kane, Mohave, and Coconino counties with the crossing locations dependent on which LPP alignment is selected. With the exception of Kanab Creek and the Paria River, all of the crossings would be of ephemeral streams. Short Creek in Colorado City, Arizona would not receive any potential future return flows from LPP water.

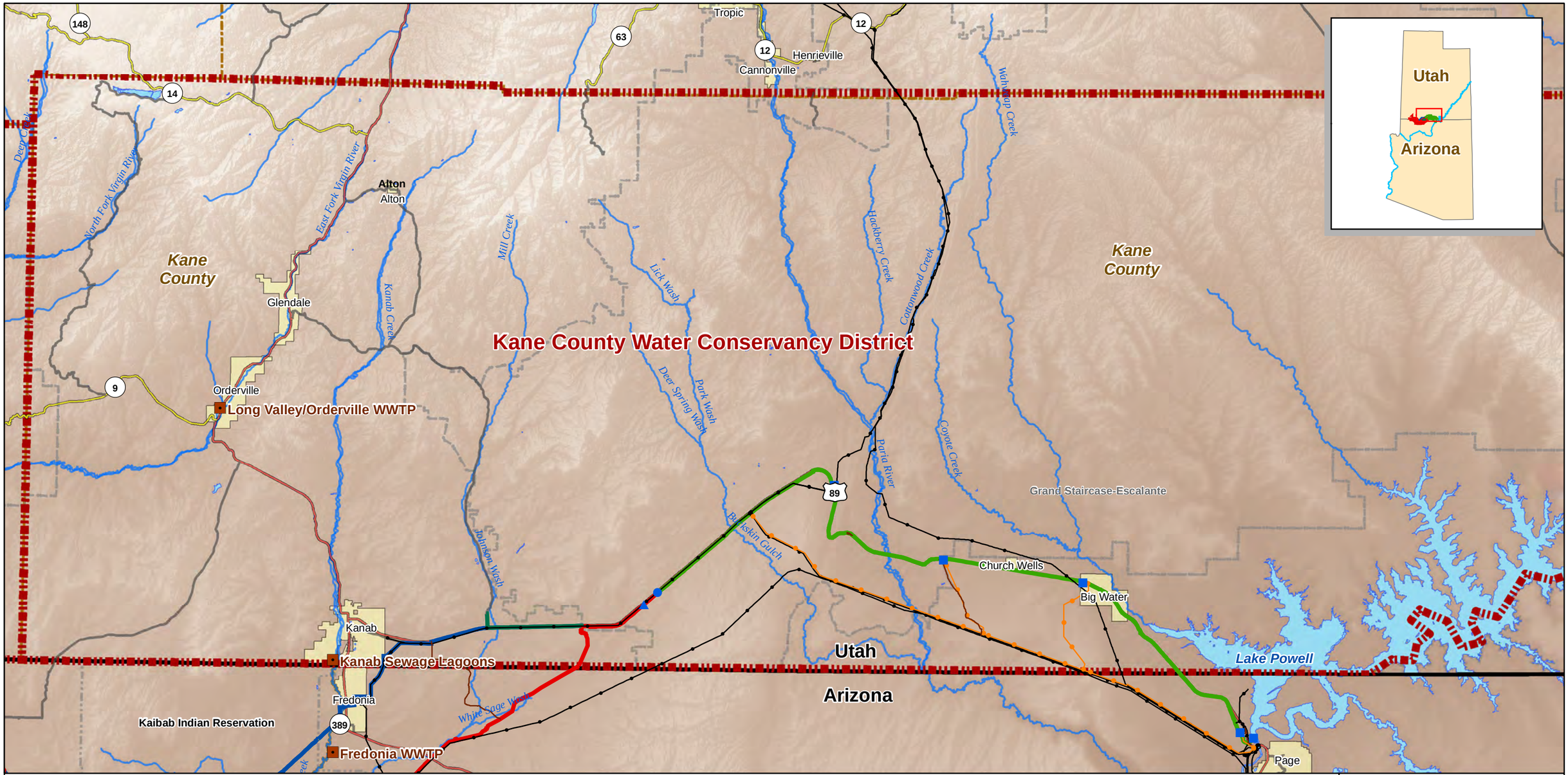
Kanab Creek

In southwest Utah, Kanab Creek drains a narrow valley from north to south with peak elevations of 9,000 feet in the Dixie National Forest. Most of the watershed upstream of Kanab is undeveloped. The Kanab Creek near Kanab gage is located 3.5 miles north of Kanab at an elevation of 5,060 feet. Downstream of the gage, Kanab Creek is generally completely diverted at Kanab City.

Figure 5-55 shows the historical daily flows in Kanab Creek upstream of the Kanab diversion. Figure 5-56 shows the daily mean and daily range of flows over the calendar year based on the period of record. Figure 5-57 depicts the flow exceedance curve. The 90 percent exceedance value is 5 cfs, while the 10 percent exceedance value is 19 cfs. The median flow is 9 cfs.

Figure 5-58 shows the mean monthly flows for Kanab Creek. Peak flows occur in spring and low flows in summer. Figure 5-59 shows historical annual mean streamflows. The long-term mean annual streamflow is 12 cfs. Figure 5-60 depicts the stage-discharge curve for the gage.

The Paria River originates near Bryce Canyon National Park and drains to the south through Grand Staircase-Escalante National Monument. The Paria River is a tributary to the Colorado River between Glen Canyon Dam and Lees Ferry in Arizona.



Project Pump Station
Project Regulating Tank
Project Hydro Station
Wastewater Treatment Plants
Existing Transmission Line
Water Conveyance System
Hydro System - South Alternative
Hydro System, Existing Highway Alternative
KCWCD System
Access Roads
Project Transmission Line
Interstate
US Highway
ST Highway
Hwy
Major Road
Water Conservancy Districts
State Boundaries
Hurricane Cliffs Forebay/Afterbay
Lakes/Reservoirs
Major Rivers & Streams
National Park/Monument
Tribal Lands
County Boundaries
Cities

FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472

N

0 2.5 5 10 15 Miles

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWRe Figure 5-54 MWH

Kane County Water Conservancy District

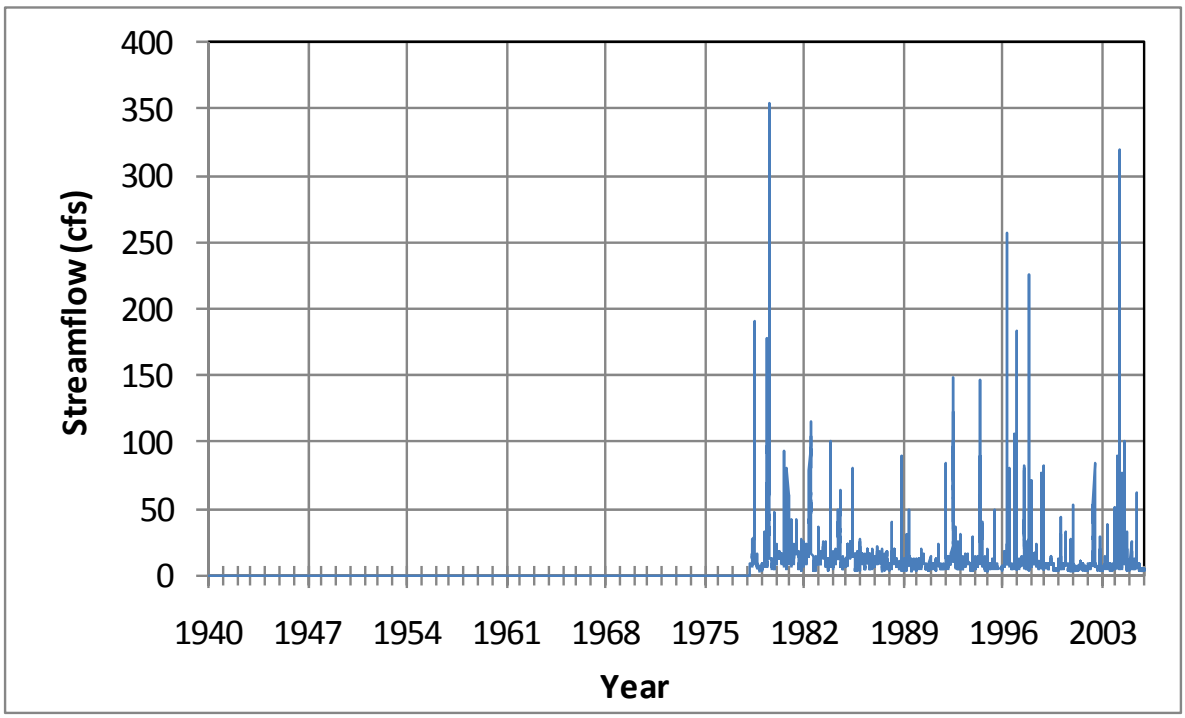


Figure 5-55
Kanab Creek near Kanab, Daily Flows

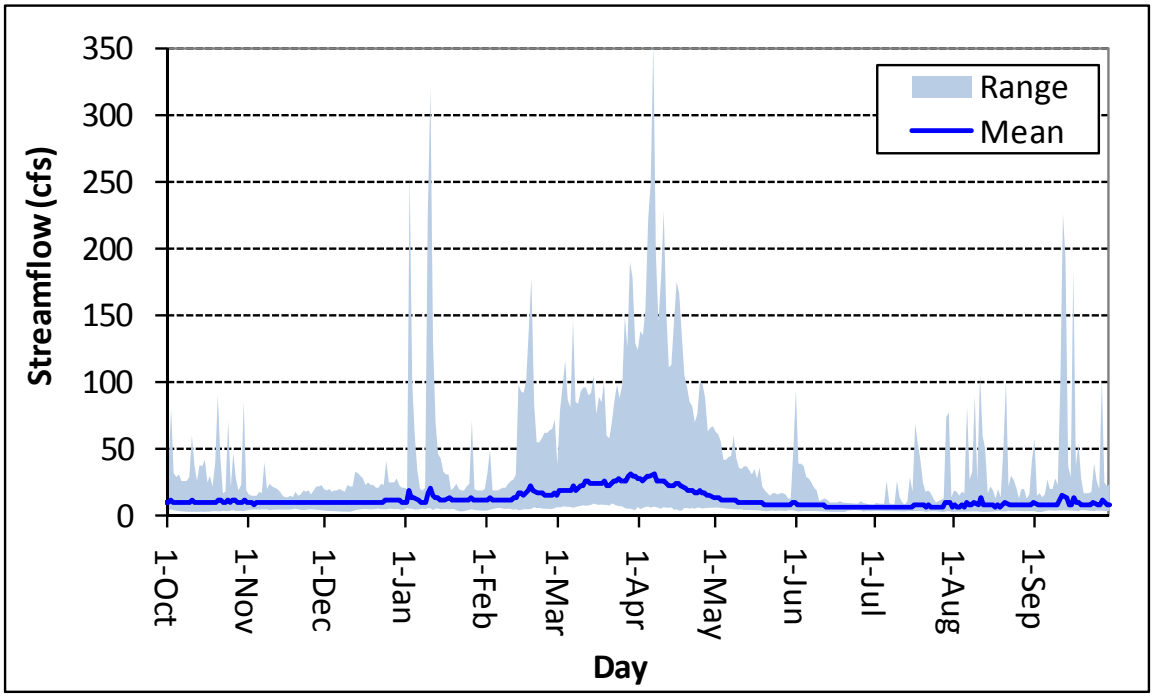


Figure 5-56
Kanab Creek near Kanab, Daily Mean and Range of Flow

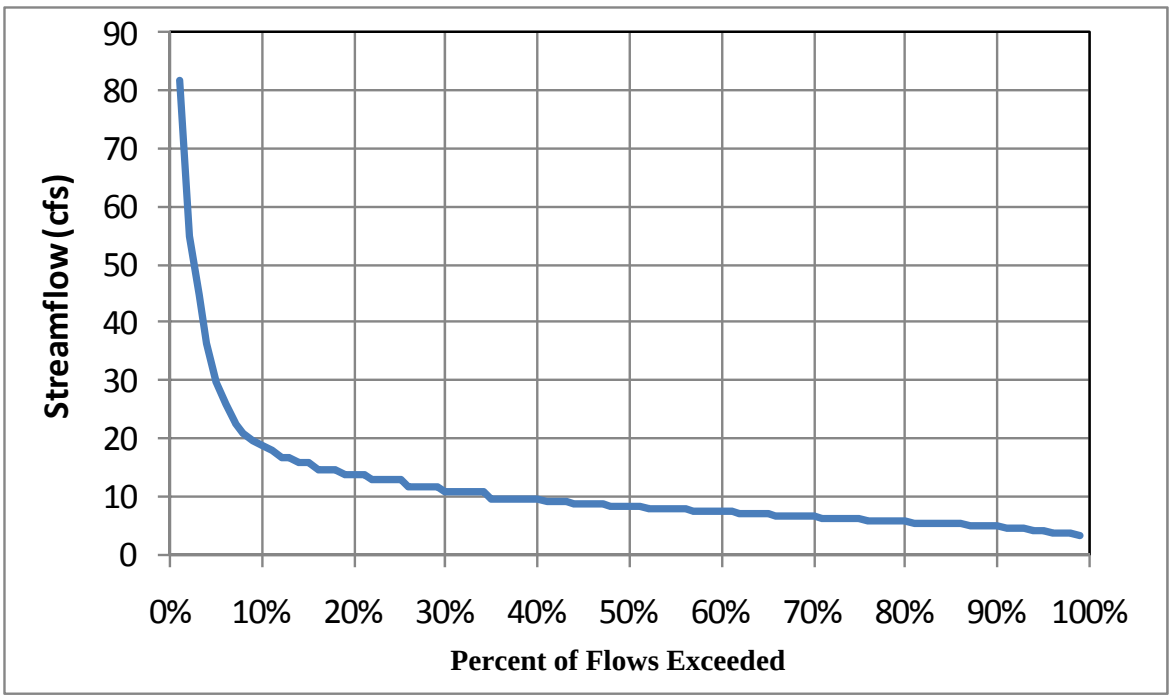


Figure 5-57
Kanab Creek near Kanab, Flow Exceedance

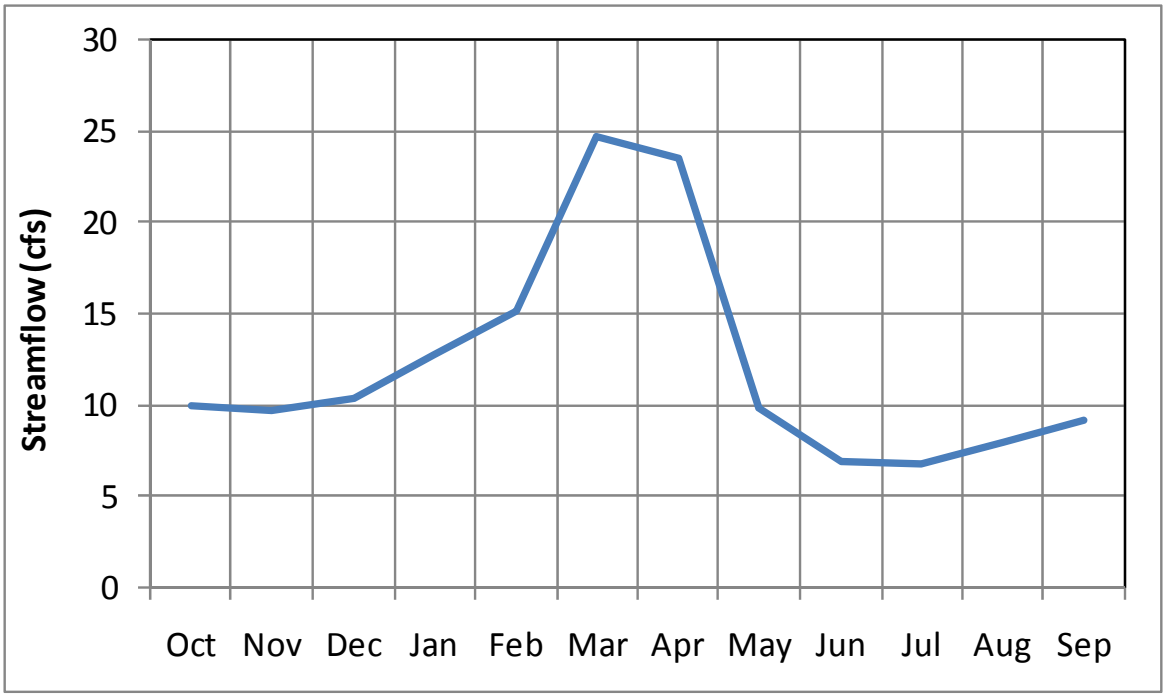


Figure 5-58
Kanab Creek near Kanab, Monthly Mean Flows

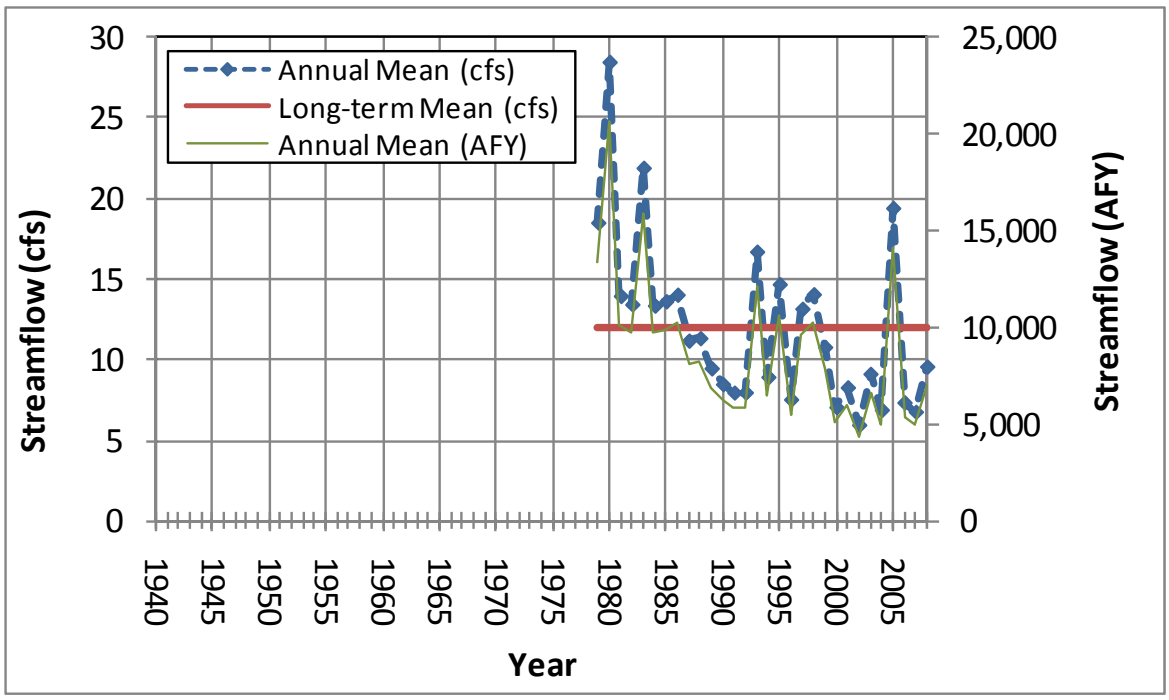


Figure 5-59
Kanab Creek near Kanab Annual Mean Flows

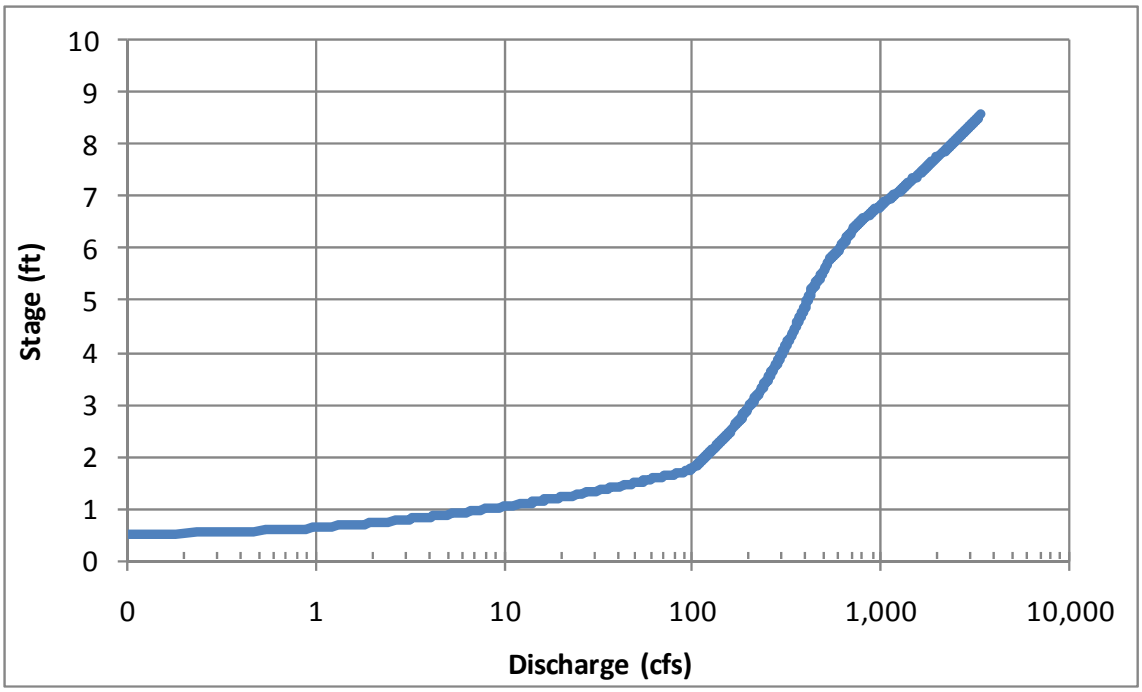


Figure 5-60
Kanab Creek near Kanab – Stage Discharge Rating Curve
Note: Rating curves are subject to change over time

Paria River

The LPP would cross the Paria River at Highway 89 in Utah, the same location as a relatively new stream gage site. At this point, the drainage area is 647 square miles. The USGS streamflow gage named "Paria River near Kanab" has a short period of record and the gage records are considered poor. Therefore, only a limited set of streamflow charts are presented. Figure 5-61 shows daily flows for the Paria River near Kanab period of record. Although flows are mostly less than 40 cfs, there are sporadic and short-term peak flow events. Figure 5-62 shows the daily mean and daily range of flows over the calendar year based on the six-year period of record. During this period, peak flows occurred from August through January. Figure 5-63 depicts the flow exceedance curve. The 90 percent exceedance value is 0 cfs, while the 10 percent exceedance value is 38 cfs. The median flow is 7 cfs. Figure 5-64 depicts the stage-discharge curve for the gage. Annual means for the period of record range from 10.9 cfs in 2003 to 42.1 cfs in 2005.

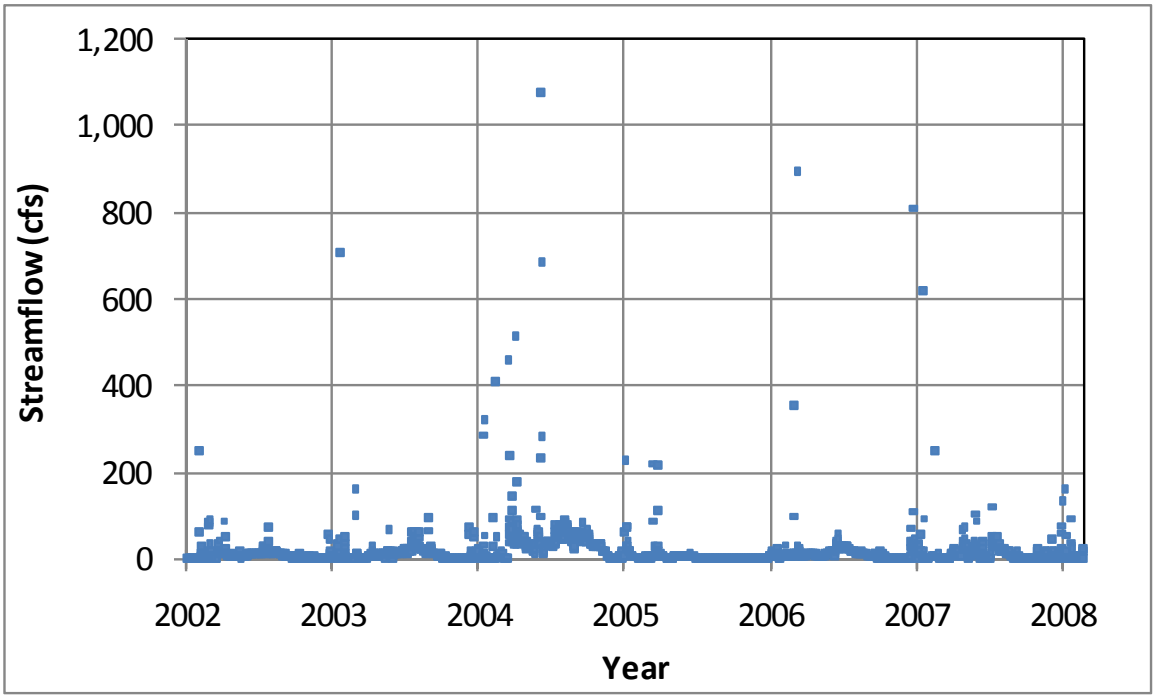


Figure 5-61
Paria River near Kanab, Daily Flows

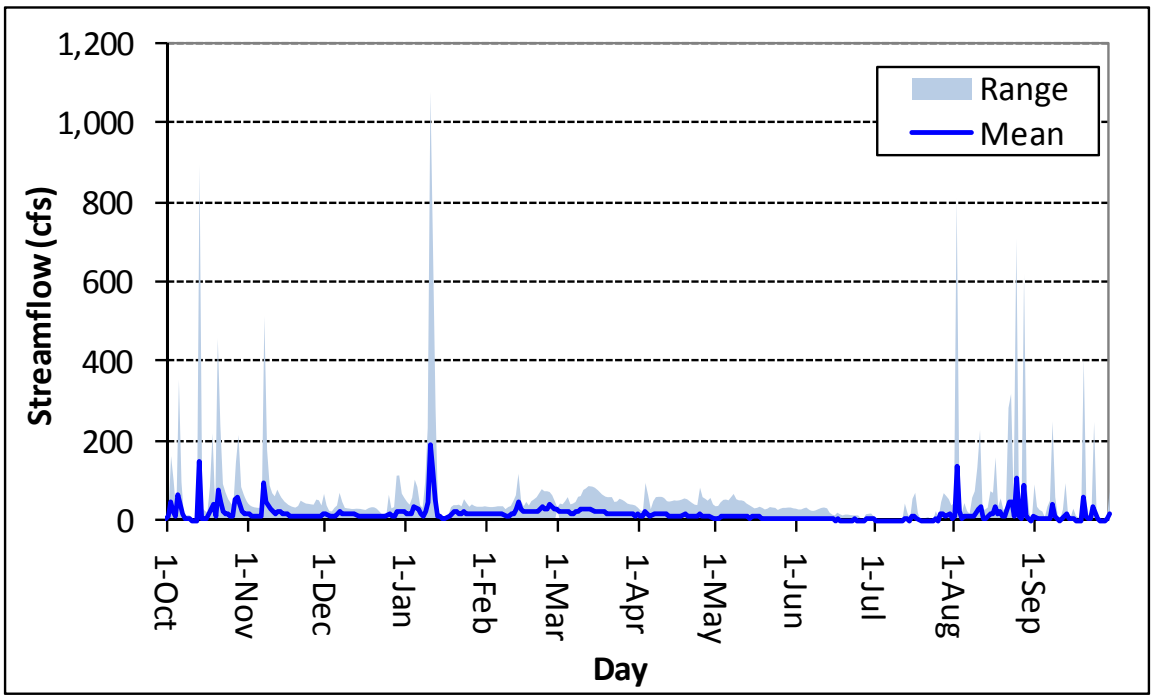


Figure 5-62
Paria River near Kanab, Daily Mean and Range of Flow

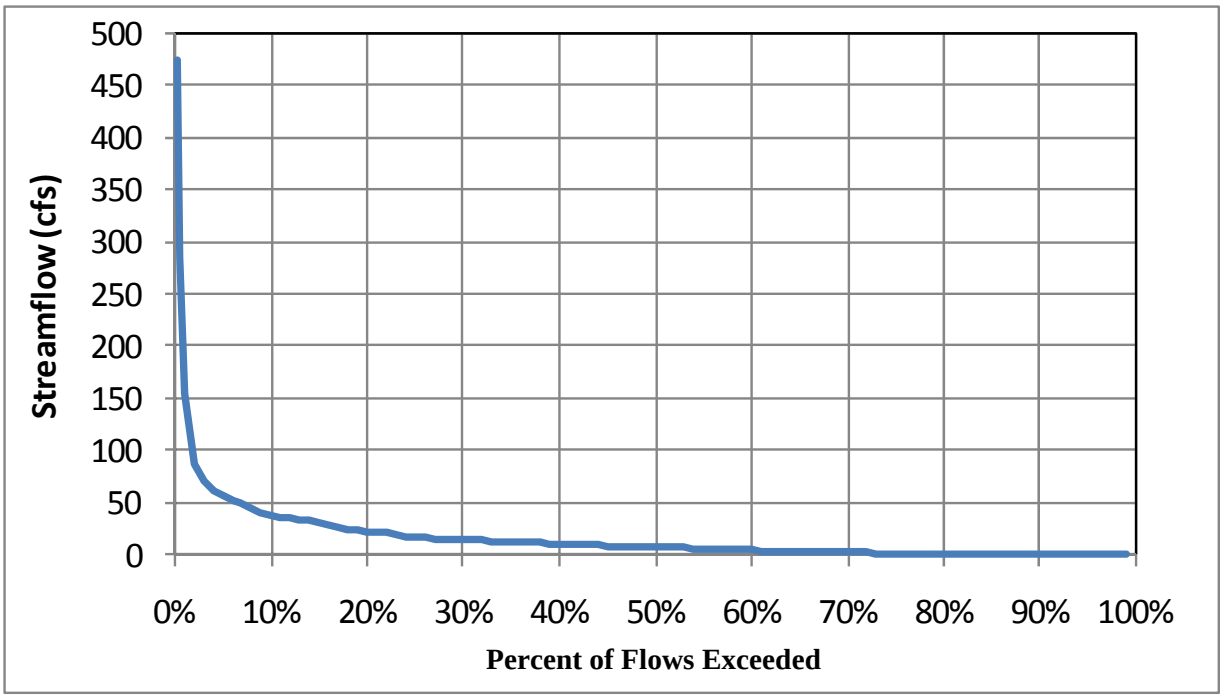


Figure 5-63
Paria River near Kanab Flow Exceedance

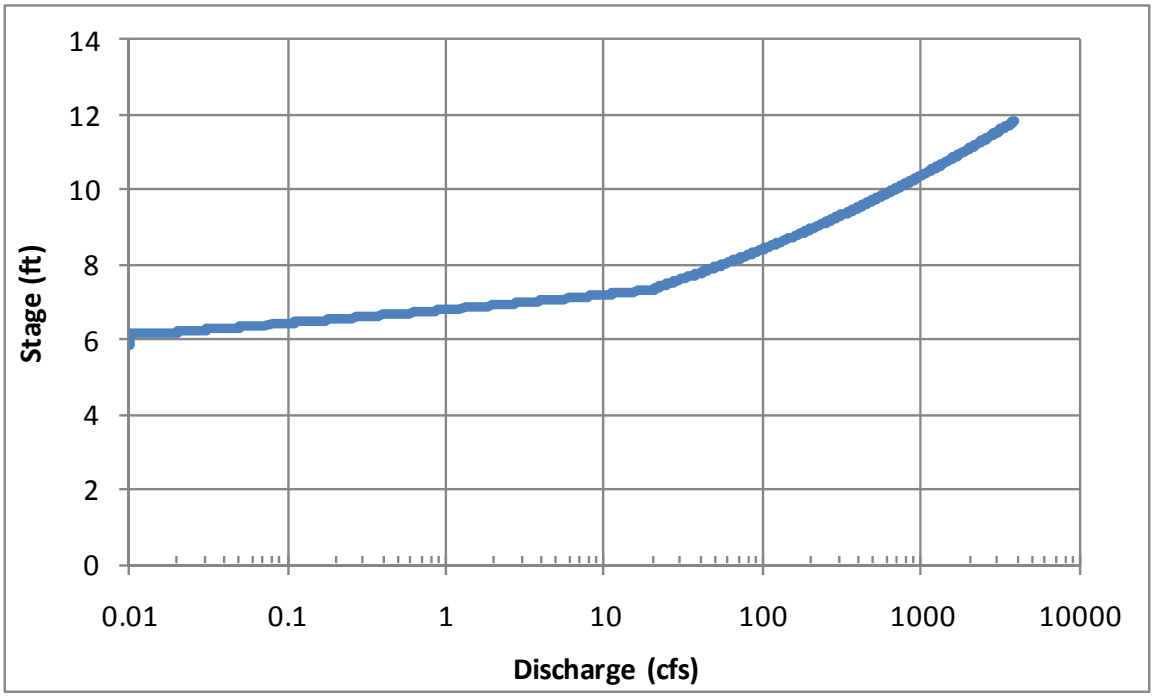


Figure 5-64
Paria River near Kanab – Stage Discharge Rating Curve
Note: Rating curves are subject to change over time

5.2.3.11.10 Return Flows.

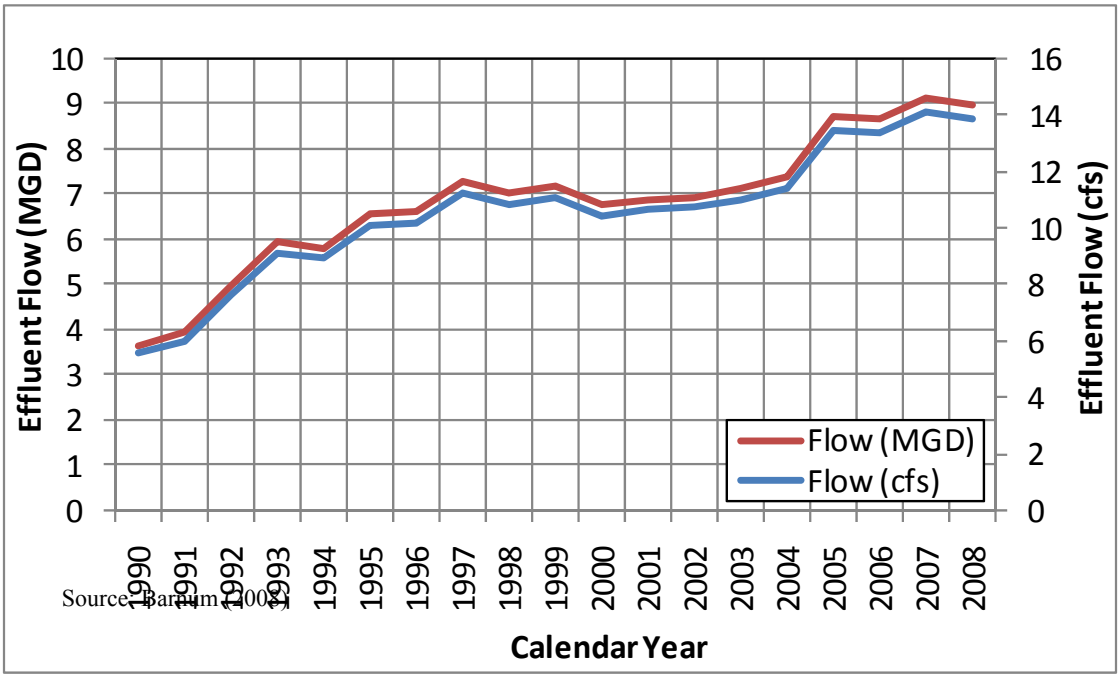
The St. George wastewater treatment plant (WWTP) serves the communities of St. George, Ivins, Santa Clara, and Washington. According to the 2005 M&I Water Supply and Use Report for the Kanab Creek/Virgin River Basin, for the communities served by the St. George WWTP, 43 percent of M&I water use was indoor water use and 57 percent was outdoor water use. A total of 13,890 acre-feet returned to the wastewater treatment facility at St. George, 95 percent of the total indoor use. Most of the wastewater treatment plant flow, 98 percent, was considered sewered return flow and the effluent returned to the Virgin River. Of the 19,100 acre-feet of outdoor water use, UDWRe assumed that 33 percent, returned to the Virgin River as non-sewered return flow (UDWRe 2009). Table 5-20 summarizes water use and return flow estimates for 2005 for communities involved in the LPP.

The St. George WWTP discharges to the Virgin River southwest of St. George (Figure 5-24). Figure 5-65 depicts historical flows through the wastewater treatment plant, which represent historical sewered return flows. Sewered return flows have increased at a steady rate since 1990. In 2008, wastewater effluent flows totaled 9 MGD, or about 14 cfs. In 2006 St. George completed a wastewater reuse plant that takes water from the WWTP and treats it for use as secondary water. The plant is designed for 10 mgd capacity. The wastewater reuse plant only has one current large customer, a golf course, but the Shivwits Band of the Paiute Tribe of Utah is entitled to 2,000 AF per year pursuant to the Shivwits Band of the Paiute Indian Tribe of Utah Water Rights Settlement Agreement (2003). The city has approved plans to store reuse water in a new 2,500 acre-foot reservoir and expand the system in the future. This expansion would reduce future sewered return flows to the Virgin River.

Table 5-20
20010 Water Use and Return Flow Summary for Major LPP Water Users (ac-ft)

Water Supplier	Total Water Use	Outdoor Water Use	Non-Sewered Return Flow	Indoor Water Use	Wastewater Treatment Inflow	Sewered Return Flow
Ivins	1,521.3	914.2	457.1	607.1	523.5	513
Santa Clara Municipal	1,579.2	980	490	599.2	548	537
St. George City	30,140.6	16,725	8,362	13,416	11,710	11,258
Washington Municipal	6,590.7	4,188	2093.9	2,403	2,097	2,055
Total St. George WWTP					**14,878**	**14,363**
Toquerville	489.5	385.4	192.7	104.1	96.1	94.2
Hurricane	5,181.3	3,440	1720	1,741	1,559	1,528
LaVerkin	775.0	446.1	223.1	328.9	306.2	300.1
Total Ash Creek WWTP					**1,961**	**1,922**
Kanab	1,440.6	871.2	435.6	569.4	533.9	263.2

Source: UDWRe 2014



Source: Barnum (2008)

Figure 5-65
St. George Wastewater Plant Historical Effluent Flows

Wastewater for the towns of Toquerville, Hurricane, and LaVerkin, Utah is treated at the Ash Creek Special Service District wastewater treatment lagoons. For the communities served by the Ash Creek lagoons 39 percent of M&I water use was indoor water use and 61 percent was outdoor water use. A total of 1,898 acre-feet returned to the Ash Creek lagoons, 97 percent of the total indoor use. Water from the lagoons is land applied and does not

have a surface return flow to the Virgin River. However, after accounting for evaporation, UDWRe considered that 87 percent of the water delivered to the lagoons returned to the Virgin River. Of the 3,030 acre-feet of outdoor water use, UDWRe assumed that 33 percent eventually returned to surface waters as non-sewered return flow (UDWRe 2009).

The City of Kanab uses a lagoon system for wastewater treatment. Water use data for 2005 showed that 38 percent of M&I water use was indoor water use and 62 percent was outdoor water use. A total of 583 acre-feet returned to the wastewater lagoons, 97 percent of the total indoor use. After accounting for evaporation, UDWRe considered that 53 percent of the water delivered to the lagoons returned to Kanab Creek. Of the 981 acre-feet of outdoor water use, UDWRe assumed that 33 percent eventually returned to surface waters as non-sewered return flow (UDWRe 2009).

5.3.3.1.4 Reservoirs.

The following sections describes storage information for potentially affected reservoirs and lakes in the area of potential effect.

5.3.3.1.4.1 Lake Powell.

Lake Powell is the reservoir impounded by Glen Canyon Dam. As previously described in Section 5.1.4, Lake Powell primarily provides water storage for use in meeting the delivery requirements to the Lower Colorado River consistent with the Law of the River. Releases are also timed for hydropower production. Lake Powell is an important regional resource for water-based recreation. Reclamation retains authority and discretion for the operation of Glen Canyon Dam and Lake Powell (Reclamation 2007).

The operating range of Lake Powell is between elevations 3,490 and 3,700 feet mean sea level. The elevation capacity curve for Lake Powell is shown in Figure 5-66. Pipeline intakes for LPP are proposed at three invert elevations: 3575, 3475, and 3375 feet above sea level.

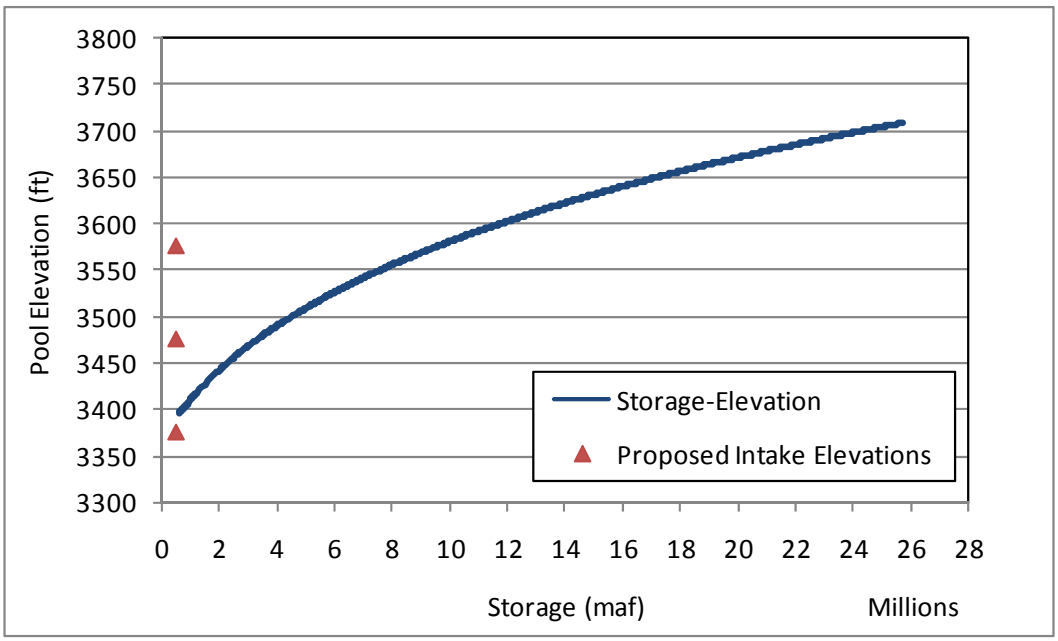
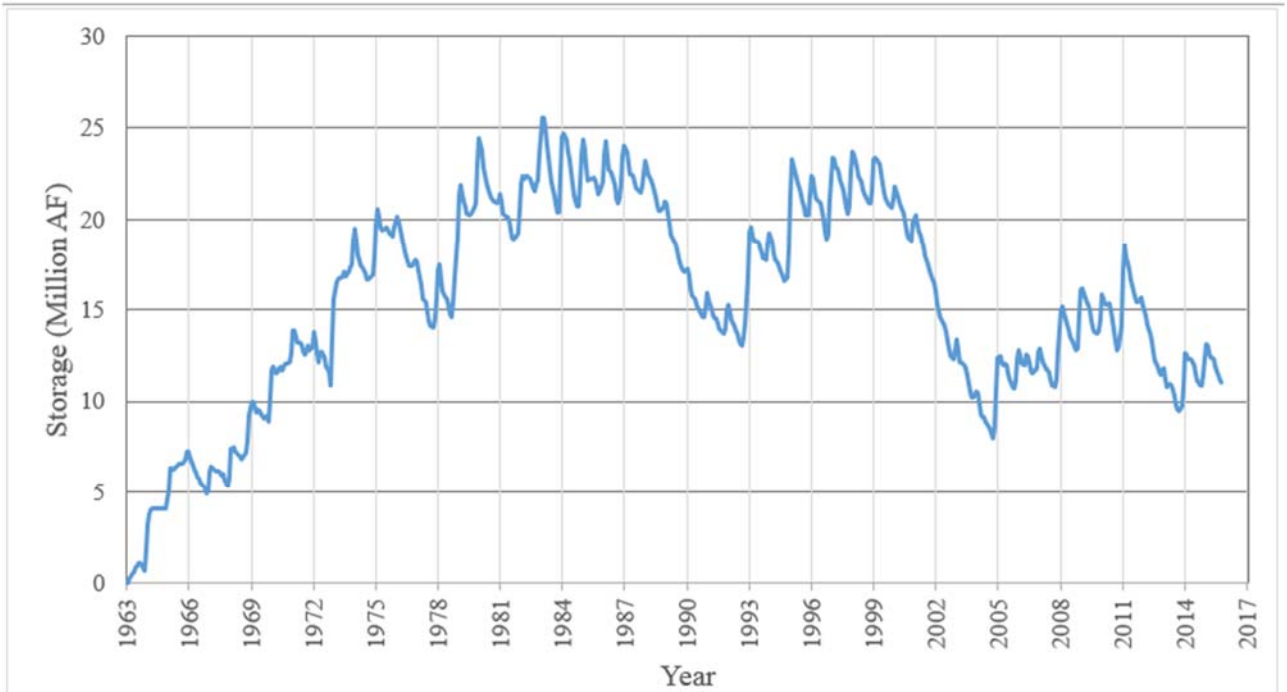


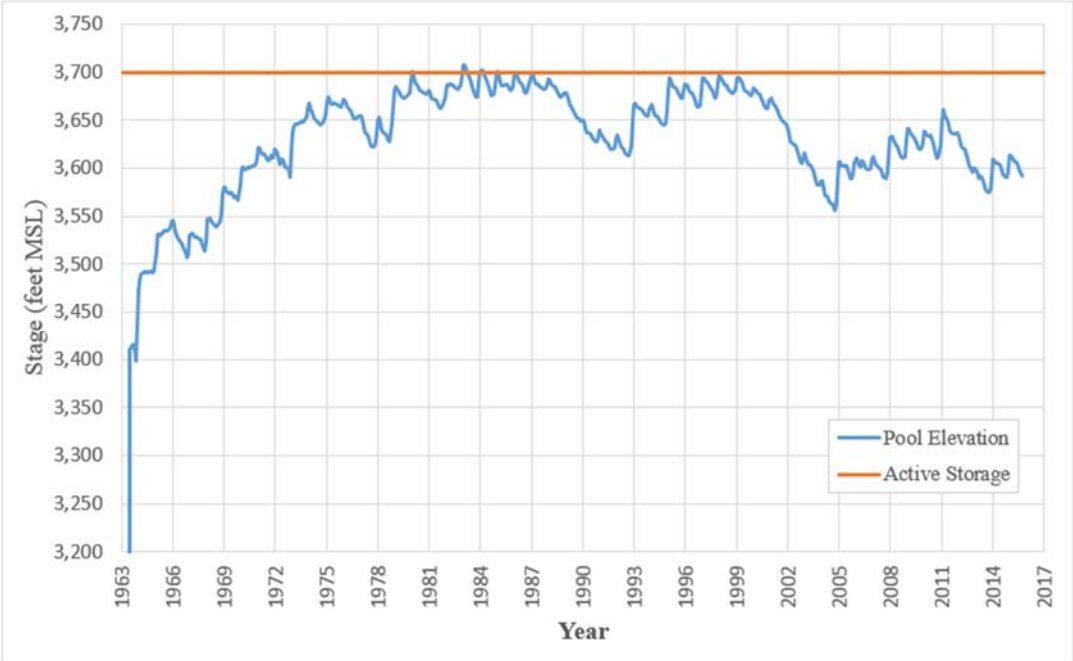
Figure 5-66
Lake Powell Elevation Capacity Curve

Historical storage data for Lake Powell is plotted in Figure 5-67, however, because of changes in the operational plans, historical data is not necessarily comparable to future conditions. The reservoir began filling in 1963. The fluctuations in elevations are primarily the result of highly variable hydrologic inflows into the Upper Colorado River Basin (Reclamation 2007). The substantial drawdown from 1999 through 2004 during the extended drought in the Upper Colorado River Basin is apparent. Figure 5-68 shows historical pool elevation, or stage, in Lake Powell. Emergency spills were made from the dam in 1983. Figure 5-69 depicts historical releases made from the dam.



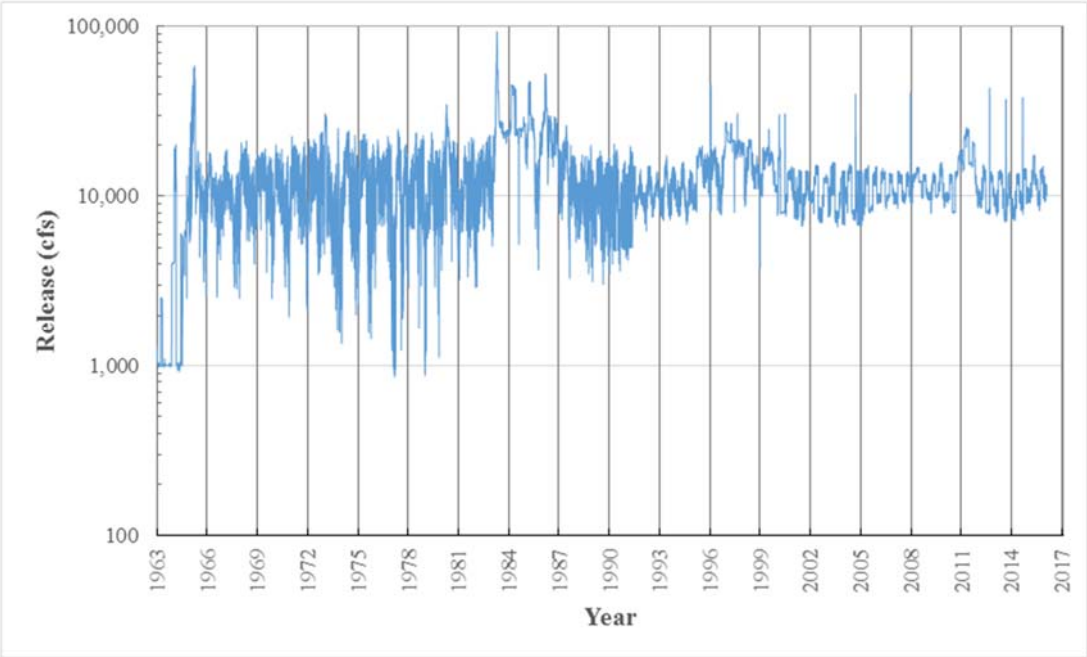
Source: Reclamation (2016)

Figure 5-67
Lake Powell Historical Storage



Source: Reclamation (2016)

Figure 5-68
Lake Powell Historical Stage



Source: Reclamation (2016)

Figure 5-69
Lake Powell Historical Daily Releases

5.3.3.1.4.2 Quail Creek Reservoir.

Located approximately 15 miles northeast of St. George, Quail Creek Reservoir is formed by two dams on Quail Creek, a minor tributary to the Virgin River. The reservoir was constructed by WCWCD and was completed in April 1985. Quail Creek Reservoir is owned and operated by WCWCD to meet regional culinary M&I water demands. Water for storage in Quail Creek Reservoir originates in the Virgin River. It is diverted at the Quail Creek Diversion Dam, and is delivered to the reservoir in a pipeline. The diversion also supplies the towns of LaVerkin and Hurricane, the Hurricane Hydropower plant, Sand Hollow Reservoir, and Quail Creek Reservoir. Seepage from Quail Creek Reservoir returns to the Virgin River though Quail Creek.

Based on modeling performed by UDWRe, the combined average annual yield of Quail Creek and Sand Hollow reservoirs is 24,922 ac-ft per year (UDWRe 2009). WCWCD operates a water treatment plant adjacent to the reservoir for culinary distribution to WCWCD customers.

The reservoir has a storage capacity of 40,000 acre-feet and has a surface area of 620 acres. It has a minimum pool of 5,525 acre-feet. The area-elevation-capacity curve is included as Figure 5-70. Historical storage is plotted in Figure 5-71.

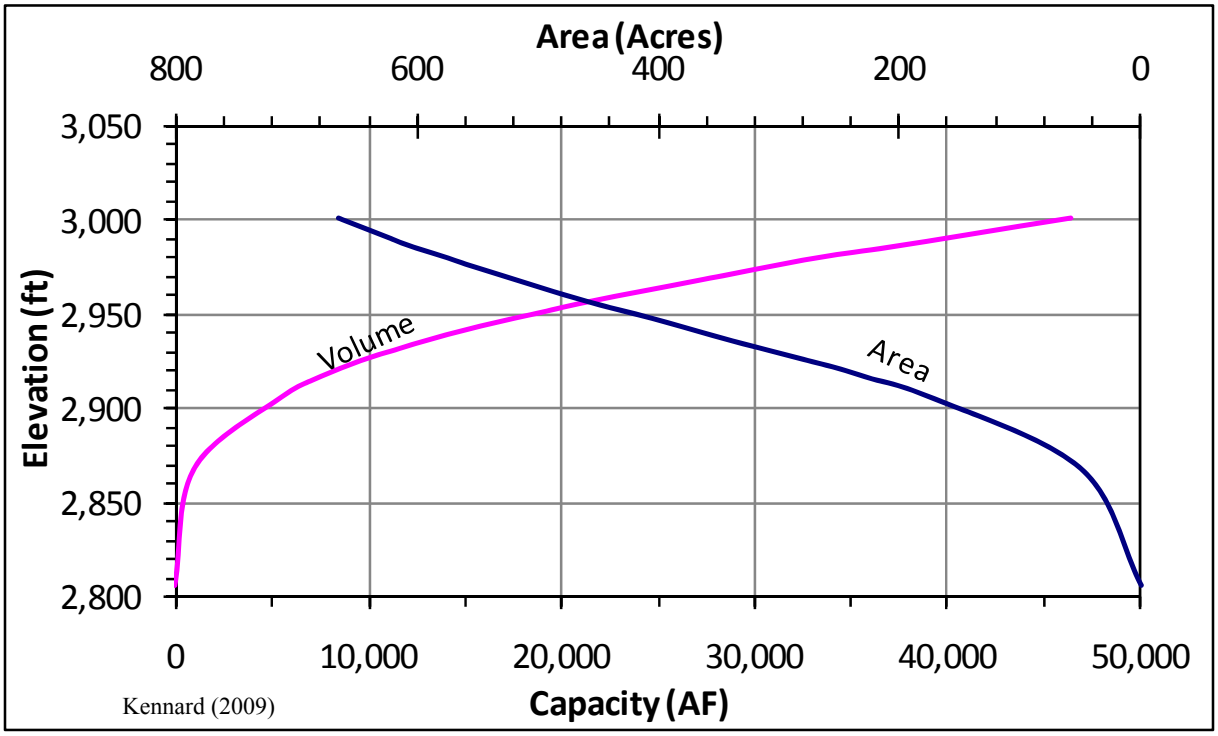


Figure 5-70
Area-Elevation-Capacity for Quail Creek Reservoir

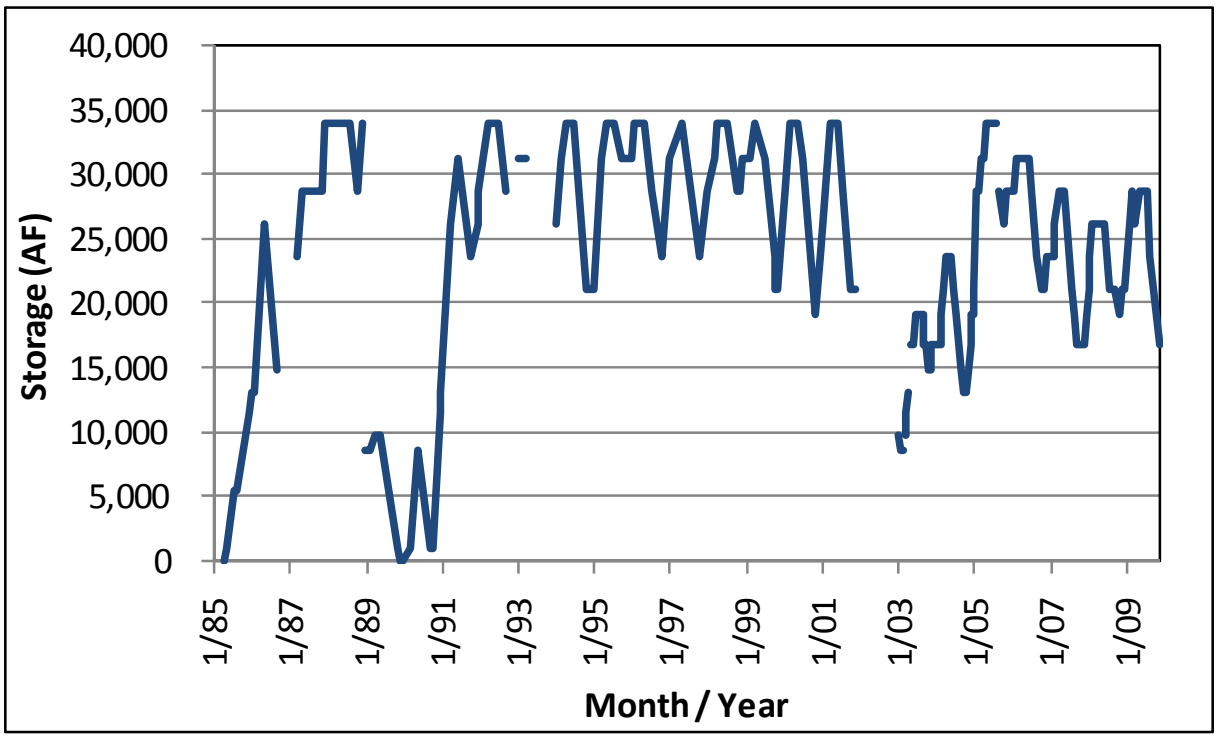


Figure 5-71
Quail Creek Reservoir Historical Storage
Source: Utah Division of Water Rights (2009) and Silva (2009)

5.3.3.1.4.3 Sand Hollow Reservoir.

Sand Hollow Reservoir is a 50,000 ac-ft storage facility located about 5 miles southwest of Hurricane. The reservoir was constructed by WCWCD in 2002 and is used for culinary supply for WCWCD customers. Water to fill Sand Hollow Reservoir is conveyed from the Virgin River in the same pipeline serving Quail Creek Reservoir. The reservoir has an active pool of about 30,000 acre-feet and a drought pool of 20,000 acre-feet that would provide water supplies in an extreme drought. Sand Hollow Reservoir also serves as a groundwater recharge facility for the Navajo Sandstone Aquifer. Figure 5-72 shows the area-elevation capacity curve for Sand Hollow Reservoir. Figure 5-73 shows historical reservoir storage in Sand Hollow Reservoir.

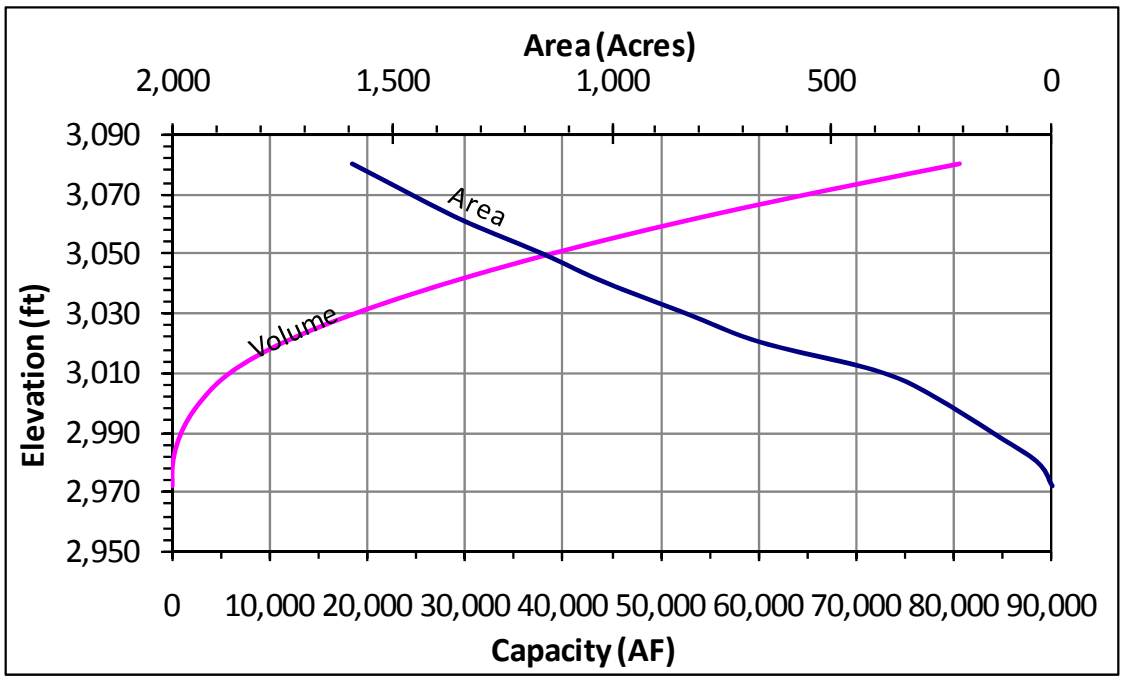


Figure 5-72
Area-Elevation-Capacity for Sand Hollow Reservoir
Data Source: Kennard (2009)

Figure 5-73
Historical Storage - Sand Hollow Reservoir
Data Source: Heilweil and Susong (2007)

5.3.3.1.5 Peak Flows.

In the Kanab and Virgin River basins, streams are prone to flash flooding from regional storm runoff or large snow runoff events from warm weather or rain on the snowpack. The unique rock formations in the study area convert nearly all precipitation to runoff. The sparse vegetation adds to the high flash flood potential of the region. The larger streams have potential for flooding caused by general storms originating in the Pacific Ocean (FEMA 2009).

Flood events can cause extreme erosion and sedimentation (UDWRe 1993, UDWRe 1995). The 2005 flood in Washington County resulted in peak flows of 21,000 cfs at the Virgin River at Bloomington gage, close to the 100-year peak flow, and 6,200 cfs at the Santa Clara River at St. George gage, less than the 50-year peak flow. This flood resulted in an estimated $200 million in damage and a federal disaster declaration (FEMA 2009). The December 2010 flood in Washington County resulted in peak flows of 10,000 cfs at the Virgin River at Virgin gage, and 8,000 cfs at the Virgin River at St. George gage. The winter storm brought intense warm rain over mountain snow pack with high moisture content, producing stream flow conditions approximately a 50-year flood event. This flood caused widespread damage to WCWCD infrastructure and facilities, endangered fish recovery structures, municipal infrastructure, and private property.

Table 5-21 summarizes estimated peak flows for various return intervals for streams in the study area. The peak flow data comes from the following various sources:

- Santa Clara River, Fort Pierce Wash, and Virgin Rivers – 2009 Flood Insurance Study for Washington County
- Kanab Creek – Estimates using USGS regression equations because there is no recent Flood Insurance Study

Table 5-21 Summary of Estimated Peak Flows				
Flooding Source and Location	**Drainage Area (Sq. Miles)**	**Peak Flow (cfs)**		
		10-Year	**50-Year**	**100-Year**
Santa Clara River				
From USGS gage near Santa Clara to Santa Clara City limit	424	NA	NA	8,200
From Santa Clara City limits to confluence with Sand Hollow Wash	446	2,450	6,000	8,200
From confluence with Sand Hollow Wash to Dixie Drive Bridge	538	3,650	9,150	12,500
From Dixie Drive Bridge to Virgin River	540	3,750	9,500	13,000
Fort Pearce Wash				
From Utah State line to confluence with Virgin River	1,680	NA	NA	22,000
Virgin River				
From USGS gage near Hurricane to Washington City limits	1540	NA	NA	23,500
From Washington City limit to confluence with Fort Pearce Wash	1,640	12,000	19,500	23,500
From confluence with Fort Pearce Wash to St. George City limit	3,840	12,000	19,500	27,500
From St. George City west limit to Utah/Arizona state line	4,000	NA	NA	27,500
Kanab Creek				
Near Kanab	194	2,390	3,870	4,570
Source: Santa Clara and Virgin - FEMA (2009), Kanab – USGS (2010) NA = not available				

5.3.3.1.6 Geomorphic Conditions.

5.3.3.1.6.1 Colorado River.

Construction of Glen Canyon Dam modified the channel characteristics of the Colorado River downstream of Lake Powell. This is caused by sediment being trapped upstream of the dam and releases of clear water with the potential to erode the channel downstream of the dam.

A study of the 25 km downstream of the dam through Glen Canyon found that high releases that occurred in the 1960s and 1980s scoured substantial amounts of sediment from the channel bottom. The average size of bed material remaining in the channel is now 20 mm compared to 0.2 mm in 1956. Without peak flows, little change occurred to the channel bed between 1990 and 2004 (Grams et al 2004). The channel is now considered "armored" because the large size of channel material is resistant to movement from typical flows.

Several resources in Glen Canyon downstream of the dam and further downstream in the Grand Canyon are sensitive to geomorphology including:

- Archaeological sites
- Recreational uses such as sport fishing and associated day and overnight use on sand bars and alluvial terraces
- Spawning habitat for trout (gravel/cobble bed)
- Camping beaches

The Glen Canyon Adaptive Management Program allows scientists to test if high flows from the dam will:

- Remove or reduce predation of nonnative fish on endangered native fish
- Rejuvenate backwater habitats for native fish, especially the endangered humpback chub (*Gila cypha*)
- Re-deposit sand at higher elevations
- Preserve and restore camping beaches
- Reduce near-shore vegetation

High flow experiments from Glen Canyon Dam have been performed a few times since 1996. The most recent high flow release from Glen Canyon Dam was made in November 2014 when adequate sediment in side-channels of the Grand Canyon was thought to be available for mobilization (Reclamation, 2014a). The experimental high flow events have not resulted in changes to the annual total amount of water released from Glen Canyon Dam.

5.3.3.1.6.2 Remaining Streams in the Area of Potential Effect.

The Virgin River and Santa Clara River have both been the subject of geomorphic studies. The conclusions of the studies indicate that channel and bank changes for these streams generally result from peak flow events. UDWRe's basin plans for the Kanab Creek, Virgin River, and Cedar/Beaver basins confirmed that much of the region is prone to flash flooding and associated erosion of stream banks and channels (UDWRe 1993, UDWRe 1995). FEMA's recent Flood Insurance Study for Washington County (2009) further supported the conclusion that local streams are erosion prone:

> *Streams are generally comprised of highly mobile sands, which can result in significant erosion and deposition during flood events. This situation is compounded by fast growing vegetation within the channels and floodplains in the project area, which restrict conveyance capacity and provide a potential source of debris during flood events.*

None of the studies reviewed described the effects, if any, of baseflow on channel stability. The Virgin River and Santa Clara River are discussed in further detail below.

Virgin River Stability

The hazard of bank erosion and lateral channel movement on the Virgin River is extreme. For the last 1,000 years, peak flow events have caused numerous shifts in the active channel location (Fuller 2007). Erosion and channel migration is generally attributed to high flow events, although even moderate flooding can cause stability problems on the Virgin River near St. George (Fuller 2005). Prior to a major flood event in 2005, dense vegetation including tamarisk on both sides of the Virgin River low flow channel created a narrow corridor. The flood event of 2005 scoured away much of the vegetation and once again established a wider channel with steep unvegetated banks. As of 2007, the wider channel had not developed vegetation to stabilize the banks. In addition, wide point bars along much of the Virgin River indicated ongoing rapid lateral channel movement. With the vegetation lost since the 2005 flood, the Virgin River is now susceptible to greater channel and bank change during peak flow events (Fuller 2007).

Structures were added to portions of the Virgin River through St. George after the 2005 flood event to reduce the likelihood of erosion and channel migration in future floods. However, those structures implemented by the NRCS were only designed for the peak discharge of 2005, substantially less than the 100-year flow. According to Fuller (2007), these structures would be susceptible to overtopping and other types of failures for flows exceeding the 2005 flood but less than the 100-year flood event.

A damaging flood occurred during the week of December 20, 2010. At that time the mountain snowpack was very high as was the moisture content of the snow. Heavy precipitation occurred in this time period and it occurred as a very warm rain which, by itself, would create a large flood. The warm rain contributed to snow melt and the rain and snow melt together produced stream flow conditions approximating a 50-year flood event. Following the earlier 2005 flood which resulted in almost 30 homes suffering severe damage making them a total loss or literally washing the homes away by unprecedented downward and lateral bank erosion, the Natural Resource Conservation Service funded and installed river restoration and stream bank protection projects. In the absence of this protection and stream function improvements to bridges, other public facilities and infrastructure, utilities, and personal property, the damage would have been significantly greater. In addition to the stream protection measures, the district initiated professional studies and reports to provide stream restoration recommendations for public and private properties. Erosion hazard mapping effort was also accomplished by the district and incorporated into municipal code. This municipal code limits activities not only in the regulatory floodplain, but in the broader river corridor which has experienced historical lateral bank erosion and stream movement of its meanders. This was one of the most effective tools to not limit the size of the flooding, but the flood damage.

Santa Clara River Stability

The Santa Clara River remained relatively stable from 1938 to 1984 even though several peak flow events occurred during that period. Since 1984, channel instability tended to occur in areas where humans disturbed the floodplain, channel, and vegetation. Fuller (2007) concluded that stream velocities are such that the Santa Clara River through Santa Clara and St. George will erode if not protected. Historically, vegetation provided adequate protection and areas where vegetation has been disturbed are subject to lateral erosion and degradation during high flow events. The 2005 flood that occurred on the Santa Clara River was equivalent to about a 25-year flood and it resulted in serious channel movement and flood damage. Floods of greater magnitude are likely on the Santa Clara River and could potentially result in additional channel change.

5.3.3.2 Environmental Effects

5.3.3.2.1 Significance Criteria.

Significance criteria were not developed for surface water resources because the changes estimated in this analysis were used to evaluate the significance of the effects that flow and water level changes would have on other affected resources. These resources include surface water quality, wetlands and riparian resources, aquatic resources, special status aquatic resources, and special status wildlife species.

The following significance criterion is identified regarding peak flows and geomorphology:

- Effects on peak flows and/or geomorphology that could result in property effects such as damage to bridges or other structures would be a significant effect

5.3.3.2.2 Streams and Return Flows.

5.3.3.2.2.1 Colorado River.

The LPP Project effects on the Colorado River are based on the results of Colorado River System Simulation (CRSS) modeling performed by Reclamation. This section summarizes the simulated releases from Glen Canyon Dam. The CRSS model was run by Reclamation (2015) using more than 100 inflow hydrology datasets each for DNF and Climate Change (CC) scenarios resulting in more than 100 sets of model results for both inflow hydrology approaches. These time series results, or traces, are summarized by ranking the results at each time step and determining the 10th, 50th, and 90th percentiles at each time step. These percentiles were selected to represent the high, low, and middle range of depletion scenarios and are presented to summarize the LPP depletion scenario results based on their probability of occurring. However, it is important to keep in mind that each percentile summary does not represent any one continuous trace, but rather a statistic that summarizes the results of all of the traces. Therefore, percentile results presented as a time series do not represent reservoir operations as they would occur sequentially under any particular inflow scenario. Figure 5-74 is an example from a previous Reclamation report of how selected traces and percentile statistics compare for simulated storage in Lake Mead. This example figure demonstrates how individual model traces may or may not correspond to one of the selected percentile values.

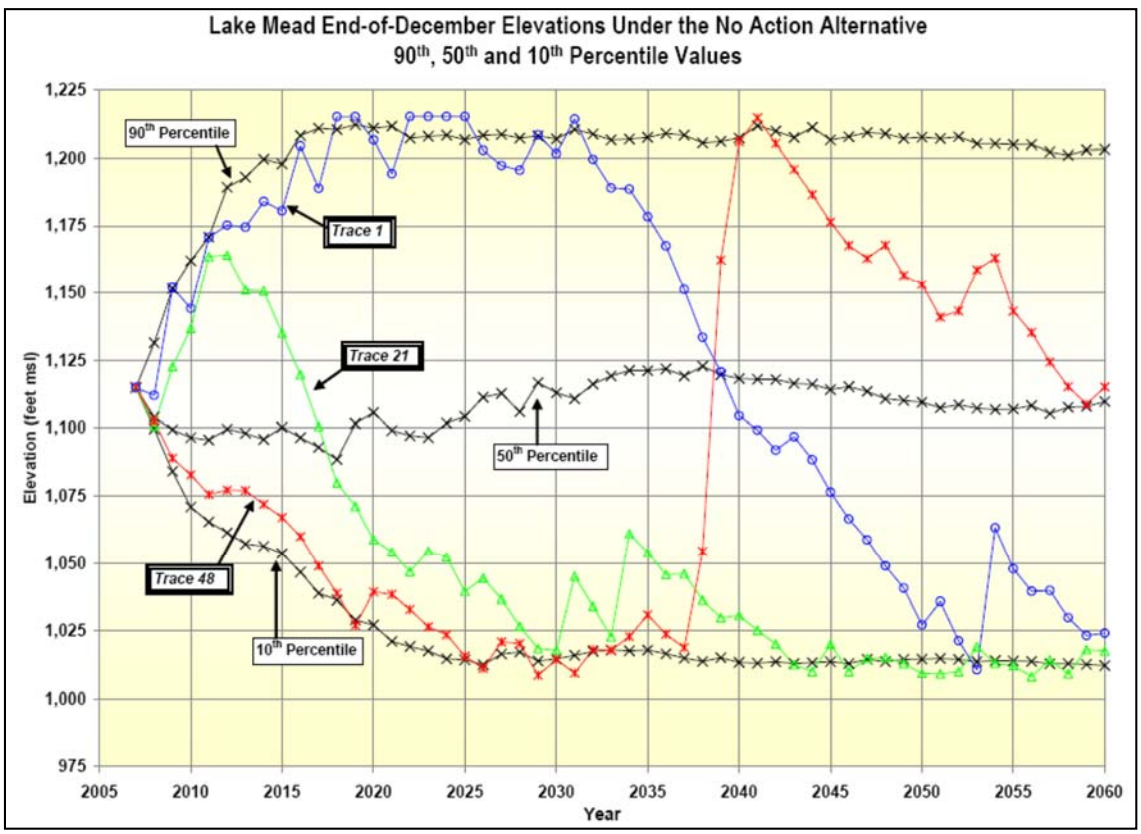


Figure 5-74
Example of Trace Results vs. Percentile Results

Source: Reclamation (2007)

Two future depletion scenarios were modeled: (1) no Lake Powell Pipeline depletions (No Action) and (2) Lake Powell Pipeline depletions up to 86,249 ac-ft per year (Proposed Action). For both scenarios, it was assumed that Upper Basin depletions without state legislation, or a tribal resolution or Federal Indian water settlement, or a Federal finding of no significant effect (FONSI) or record of decision (ROD), remained constant at the 2015 depletion levels currently in CRSS. The depletions assumed reasonably foreseeable include Central Utah Project, Animas-La Plata, Dolores Project, Navajo-Gallup, Ute Indian Compact, and Navajo Indian Irrigation Project. For each depletion scenario (No Action and Proposed Action), two future inflow hydrology scenarios were modeled. The DNF inflow scenario uses data from the observed stream flow record (1906-2010). The CC inflow scenario uses hydrologic data derived from climate change driven stream flow projections (Reclamation 2013) to represent a range of possible future inflows under the assumption of climate change in the Colorado River Basin.

Two alternatives were simulated in the CRSS analysis. The Proposed Action assumes all Upper Basin depletions are held constant at 2015 levels *except* reasonably foreseeable depletions, and adds the LPP depletion from Lake Powell at 86,249 ac-ft per year resulting in over 100 sets of model results for each inflow hydrology scenario (DNF and CC). Similarly, the same inflow hydrology datasets (DNF and CC) were run with the Upper Basin depletions held constant at 2015 levels *except* reasonably foreseeable depletions and no LPP depletion from Lake Powell, which represents the No Action alternative.

Reclamation's CRSS modeling of effects assumes that Utah's total annual depletions would remain the same for the Proposed Action and No Action scenarios and would match those in the Final EIS of the Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (2007 Shortage EIS). The spatial distribution of depletions for the State of Utah was modified for the Proposed Action scenarios to make the 86,249 acre-foot withdrawals directly from Lake Powell rather than upstream of Lake Powell.

Figure 5-75 illustrates the differences between the DNF inflow simulations for the 86,249 acre-foot Proposed Action (pipeline) depletion and No Action. Glen Canyon Dam releases for the 10th, 50th and 90th percentiles are plotted for 2015 through 2060. DNF was the primary inflow dataset used for the 2007 Shortage EIS and therefore the results of this analysis are more comparable to those performed for that EIS. The year 2027 is when reservoir operations in the simulation revert to the 2007 Shortage EIS No Action Alternative. For the 10th and 50th percentiles, there would be no difference in releases between the Proposed Action and No Action under the DNF inflow scenario. There would be minimal differences in releases between the Proposed Action and No Action alternatives at the 90th percentile under the DNF inflow scenario.

Figure 5-76 illustrates the differences between the CC inflow simulations for the 86,249 acre-foot Proposed Action (pipeline) depletion and No Action. Glen Canyon Dam releases for the 10th, 50th and 90th percentiles are plotted for 2015 through 2060. For the 50th percentile, there would be no distinguishable difference in releases between the Proposed Action and No Action under the CC inflow scenario. There would be minimal differences in releases between the Proposed Action and No Action alternatives at the 10th and 90th percentiles under the CC inflow scenario.

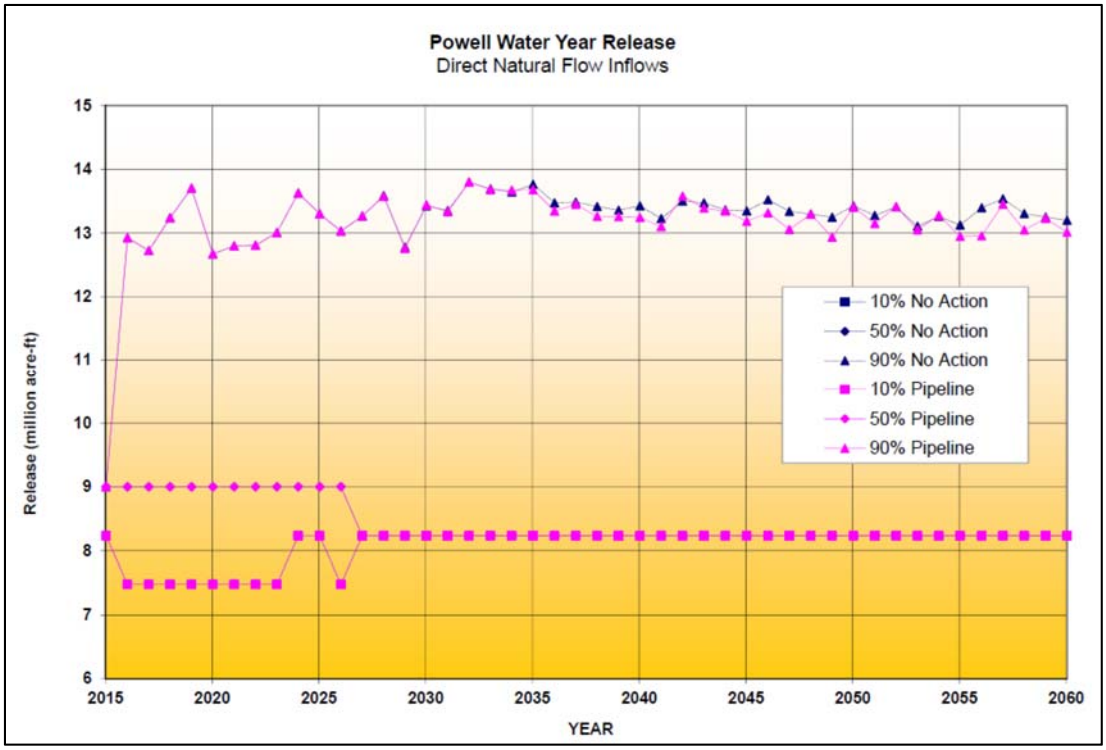


Figure 5-75
Glen Canyon Dam Releases with Proposed Action and No Action Depletions (DNF)

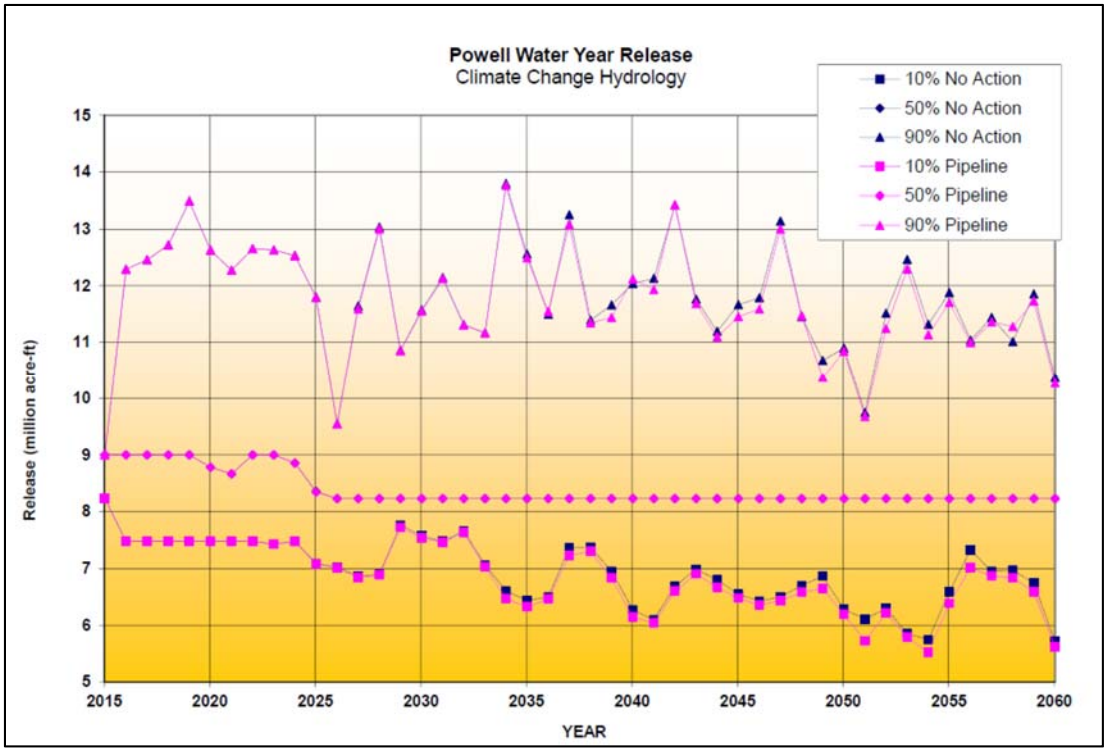


Figure 5-76
Glen Canyon Dam Releases with Proposed Action and No Action Depletions (CC)

Table 5-22 summarizes the differences in annual Glen Canyon Dam releases at the 10th, 50th, and 90th percentiles for the DNF and CC inflow hydrology scenarios under the Proposed Action and No Action. Most of the differences summarized round to 0 percent when compared with the large volume of water released to the Colorado River from Glen Canyon Dam. The DNF inflow hydrology for No Action would release an average of 69,202 ac-ft per year more than the Proposed Action at the 90th percentile, a 0.5 percent change. The CC inflow hydrology would have minimal differences between the Proposed Action and No Action. The CC inflow hydrology for No Action would release an average of 80,846 ac-ft per year more than the Proposed Action at the 10th percentile, a -1.2 percent change. The CC inflow hydrology for No Action would release an average of 61,593 ac-ft per year more than the Proposed Action at the 90th percentile, a -0.5 percent change. The CC inflow hydrology would yield slightly higher average differences at the 10th percentile compared to the DNF inflow hydrology.

Table 5-22
Summary of Glen Canyon Dam Annual Release Differences (Proposed Action and No Action)

	Ac-ft per year			Percent Difference		
Percentile	**10th**	**50th**	**90th**	**10th**	**50th**	**90th**
DNF Average Difference	0	0	-69,202	0%	0%	-0.5%
DNF Maximum Difference	0	0	-442,674	0%	0%	-3.3%
CC Average Difference	-80,846	-383	-61,593	-1.2%	0%	-0.5%
CC Maximum Difference	-382,075	-13,427	-311,526	-6.3%	-1.6%	-2.9%

Difference = Proposed Action – No Action; Percent Difference = Difference/No Action

Figure 5-77 illustrates the Glen Canyon Dam release flow duration curve differences between the DNF inflow simulations for the 86,249 ac-ft Proposed Action (pipeline) depletion and No Action for the period 2027 through 2060. DNF was the primary inflow dataset used for the 2007 Shortage EIS and therefore the results of this analysis are more comparable to those performed for that EIS. The year 2027 is when reservoir operations in the simulation revert to the 2007 Shortage EIS No Action Alternative. There would be minimal differences in Glen Canyon Dam release flow duration curves between the Proposed Action and No Action under the DNF inflow scenario. The No Action flows between 1 and 42 percent exceedance would be slightly higher than the Proposed Action flows.

Figure 5-78 illustrates the Glen Canyon Dam release flow duration curve differences between the CC inflow simulations for the 86,249 ac-ft Proposed Action (pipeline) depletion and No Action for the period 2027 through 2060. Glen Canyon Dam releases for the 10th, 50th and 90th percentiles are plotted for 2015 through 2060. There would be minimal differences in Glen Canyon Dam release flow duration curves between the Proposed Action and No Action under the CC inflow scenario. The Proposed Action and No Action flow duration curves are nearly identical for Glen Canyon Dam releases under the CC inflow scenario.

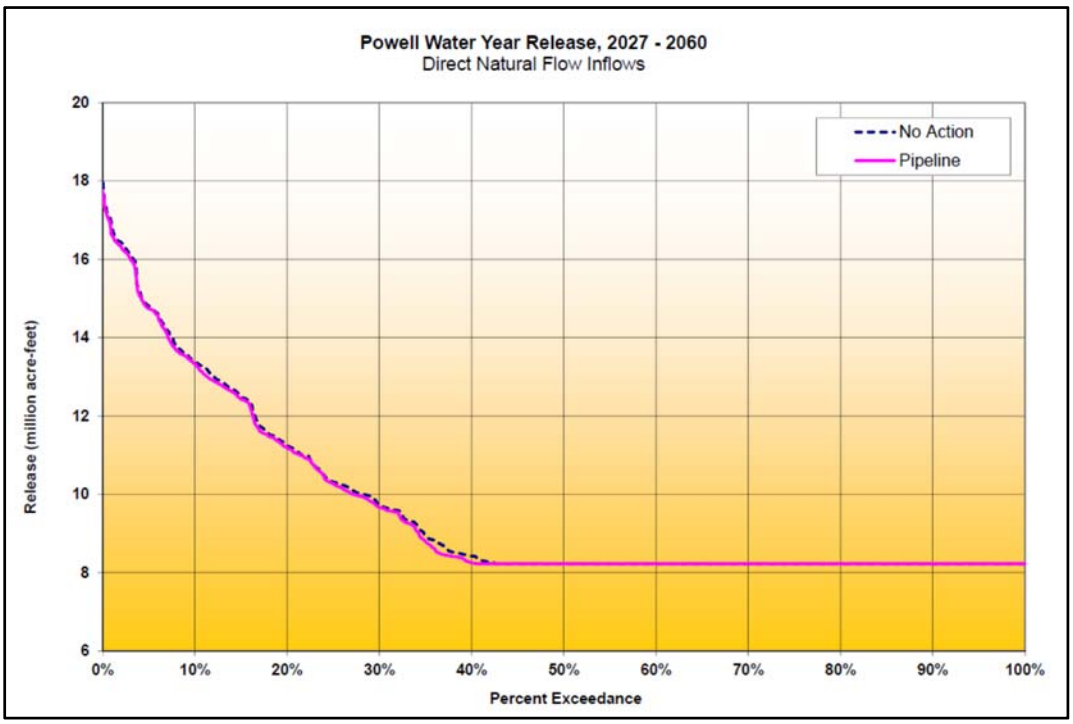


Figure 5-77
Glen Canyon Dam Release Flow Duration Curves for Proposed Action and No Action (DNF)

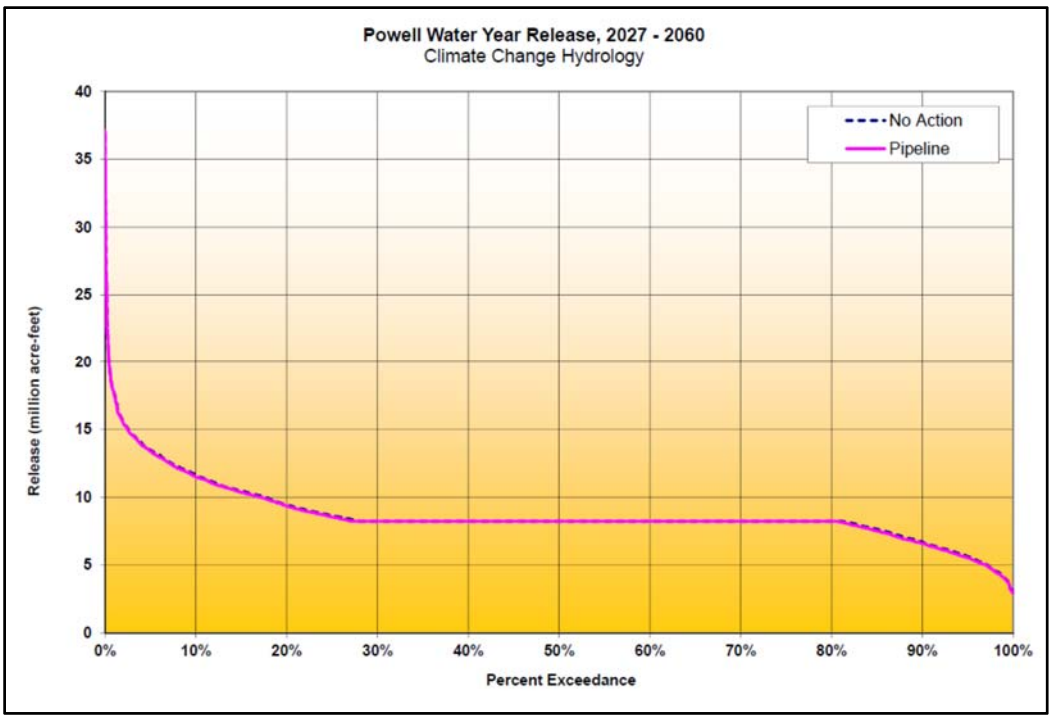


Figure 5-78
Glen Canyon Dam Release Flow Duration Curves for Proposed Action and No Action (CC)

5.3.3.2.2.2 Virgin River Drainages.

The Virgin River Daily Simulation Model (UDWRe 2015) was used to evaluate hydrologic effects for two scenarios. Two simulations were performed with the model. Scenario 1 simulated the Base Case with full utilization of Virgin River water rights, without any additional storage or Lake Powell Pipeline deliveries. Scenario 2 represents the Proposed Action future conditions with the expanded secondary system utilizing 3,000 acre feet of re-regulating storage and 69,000 acre feet of annual Lake Powell Pipeline deliveries. Future deliveries of 13,249 acre-feet would be made to the Apple Valley area of Washington County directly from the LPP Project, which are not included in the Virgin River Daily Simulation Model. The model simulates the maximum yield in the St. George area with a specified maximum shortage in the worst year (10 percent in the Lake Powell Pipeline project simulations), while providing priority water rights in accordance with their terms to the canal companies for Hurricane, LaVerkin and Washington Fields.

The model includes five service areas. In the simulations, water deliveries to the Hurricane, LaVerkin and Washington Fields service areas were unchanged between scenarios. Thus, return flows from these three service areas did not change between the simulations. Deliveries to service areas 4 and 5, representing the greater St. George area M&I demand and the Washington Fields secondary use system were different between the scenarios. Deliveries to these service areas are calculated by optimizing the resources in the model until an allowed maximum shortage value of 10 percent is reached. Table 5-23 shows the deliveries that would be made to each service area under future conditions without and with the LPP Project.

Table 5-23 VRDSM Simulated Water Deliveries to the St. George Area (acre-feet)		
Service Area	**Future Without LPP (Base Case)**	**Future With the LPP (Proposed Action)**
1-LaVerkin	2,628	2,628
2-Hurricane	13,484	13,484
3-Washington Fields	62,160	62,012
4-St George Area M&I	24,842	93,030
5-Washington Fields Secondary	13,991	57,677
Total	**117,105**	**228,831**

Note:
*Difference in water delivered to Service Area 5 – Washington Fields Secondary between Scenario 1 and Scenario 2 represents reuse water from the St. George Regional Water Reclamation Facility

The USGS Annual Water Data Report provides qualitative descriptions about the accuracy of the USGS stream gage measurements. Three USGS gages are used to measure stream flow in the Virgin River in the St. George area: USGS 09408150 (Virgin River below Quail Creek), USGS 09413200 (Virgin River below Santa Clara River), and USGS 09413500 (Virgin River at the Utah-Arizona State Line). The USGS 09408150 gage accuracy is rated "good" with 10 percent accuracy for average measured stream flow and is rated "poor" for daily stream flows with greater than 16 percent accuracy. The USGS 09413200 and USGS 09413500 gage accuracies are described as "fair" which means that measurements are within 16 percent of the actual flows (USGS, 2015). Differences between the future without the LPP Project (Base Case) and future with the LPP Project (Proposed Action) in simulated stream flow along the Virgin River in the lower St. George area would be small, and within the degree of accuracy of the USGS stream gages in this reach of the Virgin River. Therefore, the differences between Virgin River flows under the future without the LPP Project (Base Case) and future with the LPP Project (Proposed Action) would not be measurable. Table 5-24 shows the VRDSM flow results incorporating the 50th percentile climate change projections for the future without the LPP Project (Base Case) and for the future with the LPP Project (Proposed Action) compared with USGS gage accuracies.

Table 5-24
Lake Powell Pipeline
Virgin River Daily Simulation Model Flow Results
Comparison Between Climate Change 50th Percentile Existing Facilities and LPP Climate Change 50th Percentile
With USGS Gage Accuracy

USGS Gage No.	Gage Accu.	VRDSM Node	Scenario and Description	Water Year Months (cfs)											
				Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
09408150	10%	QX21	1. Future w/CC 50+Ex. F.	96	95	116	112	132	235	296	253	103	92	97	103
			2. LPP w/CC 50+3000SS	95	95	116	113	131	221	279	242	100	91	97	101
			Flow Difference	1	0	0	1	1	14	17	11	3	1	0	2
			Gage Accuracy (flow)	10	10	12	11	13	22	28	24	10	9	10	10
09413200	16%	QX26	1. Future w/CC 50+Ex. F.	11	9	30	26	46	149	210	167	17	6	11	17
			2. LPP w/CC 50+3000SS	11	9	30	27	45	135	193	156	15	5	11	17
			Flow Difference	0	0	0	1	1	14	17	11	2	1	0	0
			Gage Accuracy (flow)	2	1	5	4	7	22	31	25	2	1	2	3
09413200	16%	QX27	1. Future w/CC 50+Ex. F.	40	46	75	78	100	199	253	201	46	31	36	43
			2. LPP w/CC 50+3000SS	44	50	79	83	103	189	240	196	49	36	40	48
			Flow Difference	4	4	4	5	3	10	13	5	3	5	4	5
			Gage Accuracy (flow)	6	7	12	12	16	30	38	31	7	5	6	7
09413200	16%	QX28	1. Future w/CC 50+Ex. F.	58	68	110	118	149	259	291	231	68	47	52	60
			2. LPP w/CC 50+3000SS	64	75	115	124	154	250	280	227	73	54	58	66
			Flow Difference	6	7	5	6	5	9	11	4	5	7	6	6
			Gage Accuracy (flow)	9	11	18	19	24	40	45	36	11	8	8	10
09413500	16%	QX29	1. Future w/CC 50+Ex. F.	61	76	117	123	154	262	291	231	68	47	52	61
			2. LPP w/CC 50+3000SS	64	75	120	138	168	257	280	227	73	54	59	66
			Flow Difference	3	1	3	15	14	5	11	4	5	7	7	5
			Gage Accuracy (flow)	10	12	19	20	25	41	45	36	11	8	8	10

Key: Flow difference exceeds USGS gage accuracy

Flow difference is less than or equal to USGS gage accuracy

Figure 5-79 shows simulated mean monthly flows and Figure 5-80 shows the simulated flow duration curves in the Virgin River below Quail Creek for the future without the LPP Project (Base Case) and future with the LPP Project (Proposed Action). This location is downstream of return flows from Hurricane and LaVerkin, which do not change between simulations. It is also downstream of Quail Creek seepage and spill outflow to the Virgin River. This location is upstream of the Washington Fields Diversion, where the 86 cfs flow is measured. The mean monthly flows in the Virgin River below Quail Creek would be slightly lower during the high flow spring runoff months (March through May) for the future with the LPP Project compared to the future without the LPP Project. These differences in mean monthly flows would be within the accuracy of the USGS gage on the Virgin River below Quail Creek. The simulated flow duration curves are nearly identical and indicate unmeasurable differences in return flows between the future without the LPP Project (Base Case) and future with the LPP Project (Proposed Action).

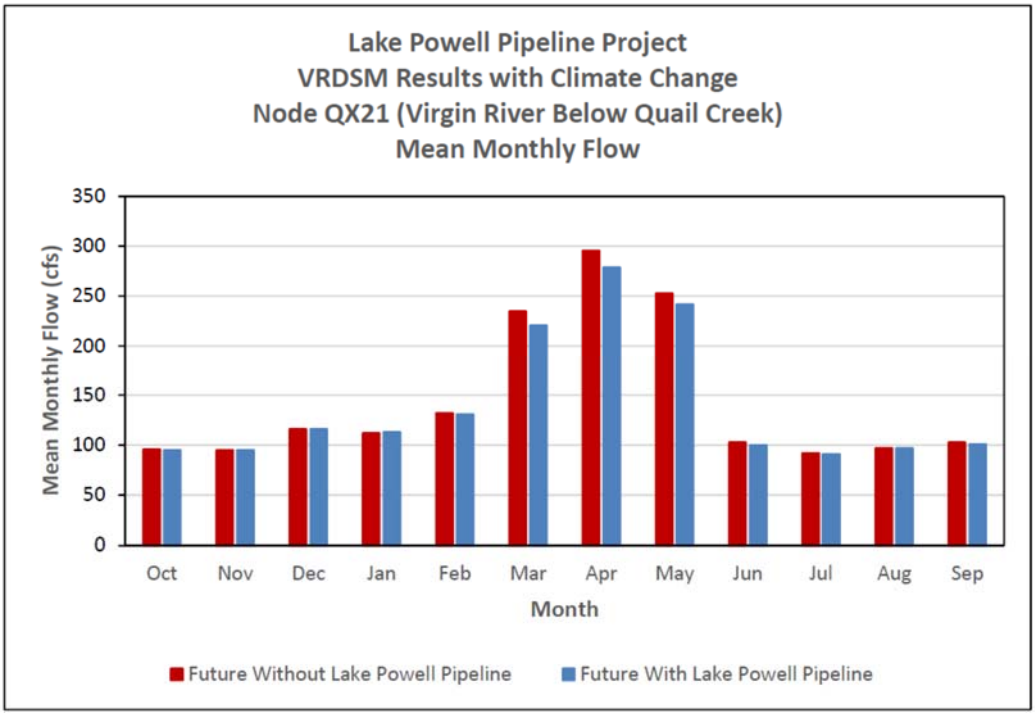


Figure 5-79
Virgin River Below Quail Creek – Simulated Mean Monthly Flows

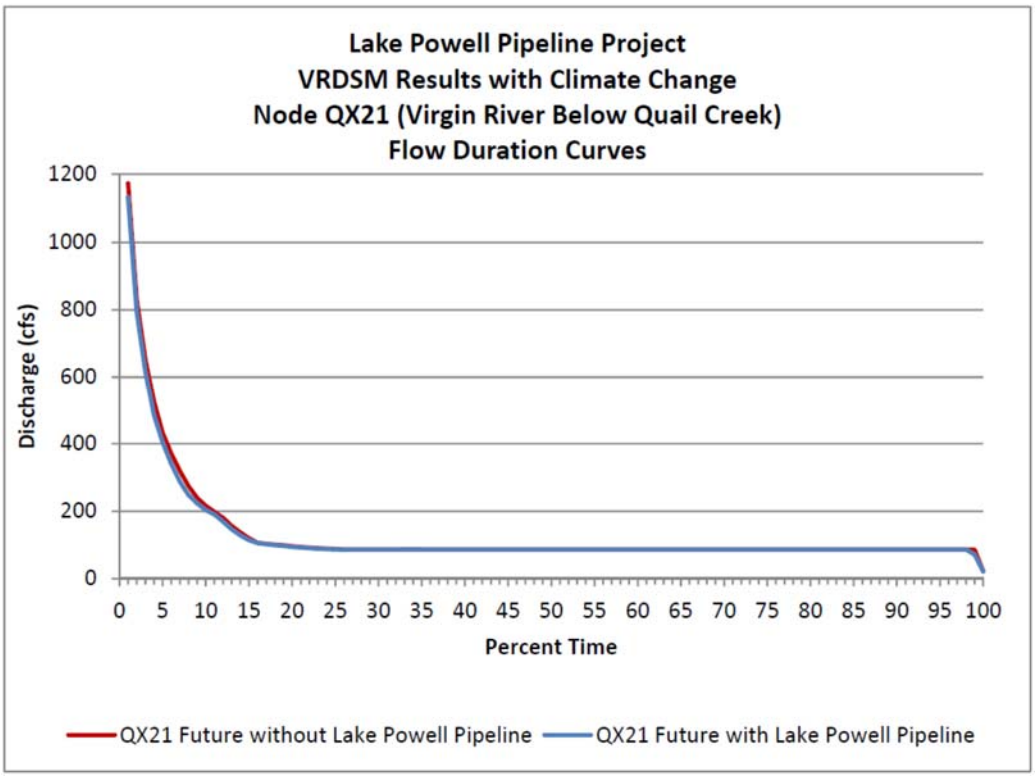


Figure 5-80
Virgin River Below Quail Creek – Simulated Flow Duration Curves

Figure 5-81 shows simulated mean monthly flows and Figure 5-82 shows the simulated flow duration curves in the Virgin River below Washington Fields Diversion for the future without the LPP Project (Base Case) and future with the LPP Project (Proposed Action). Both simulations resulted in low flows during the summer and fall months in this reach as storage is used and refilled in response to secondary water demand throughout the summer. The mean monthly flows in the Virgin River below Washington Fields Diversion would be slightly lower during the high flow spring runoff months (March through May) for the future with the LPP Project compared to the future without the LPP Project. These differences in mean monthly flows would be within the accuracy of the closest downstream USGS gage on the Virgin River below Washington Fields Diversion. The simulated flow duration curves are nearly identical and indicate unmeasurable differences in return flows between the future without the LPP Project (Base Case) and future with the LPP Project (Proposed Action).

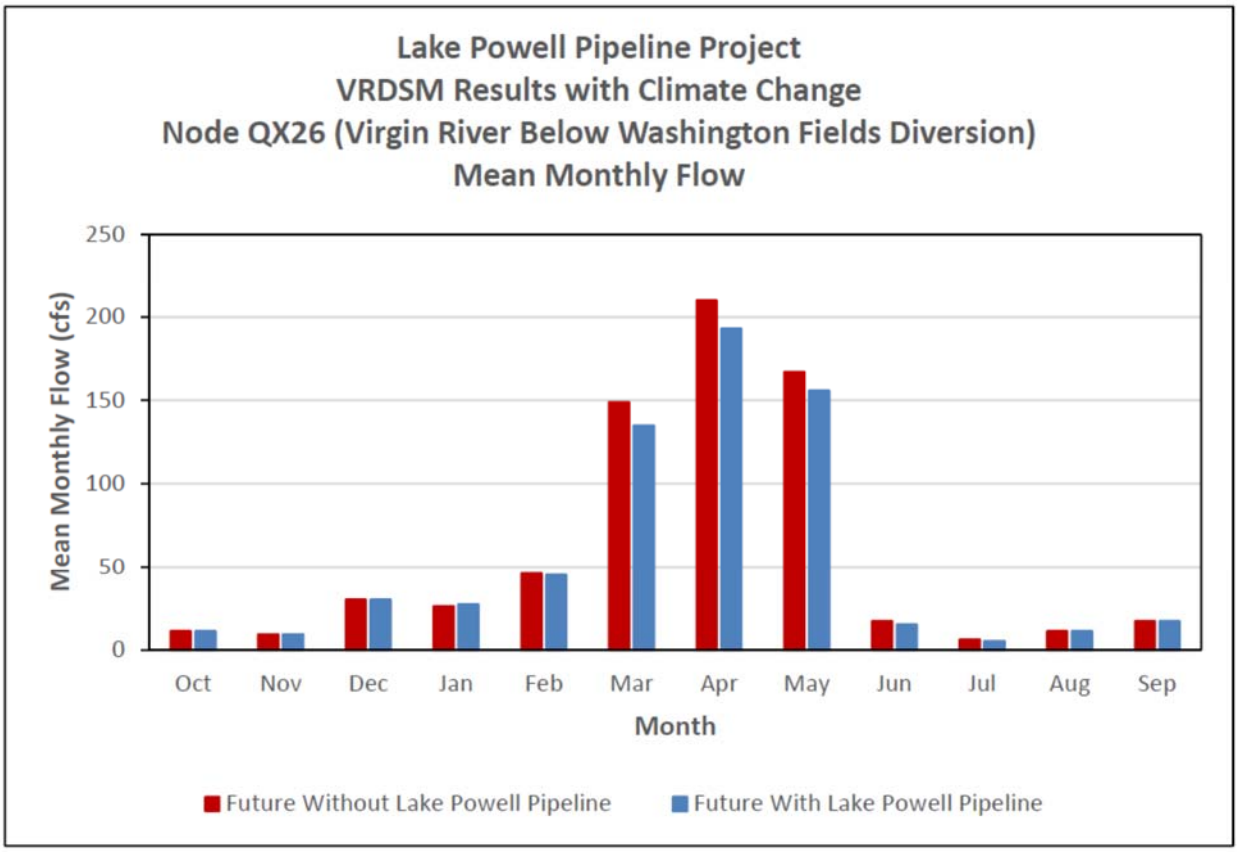


Figure 5-81
Virgin River Below Washington Fields Diversion – Simulated Mean Monthly Flows

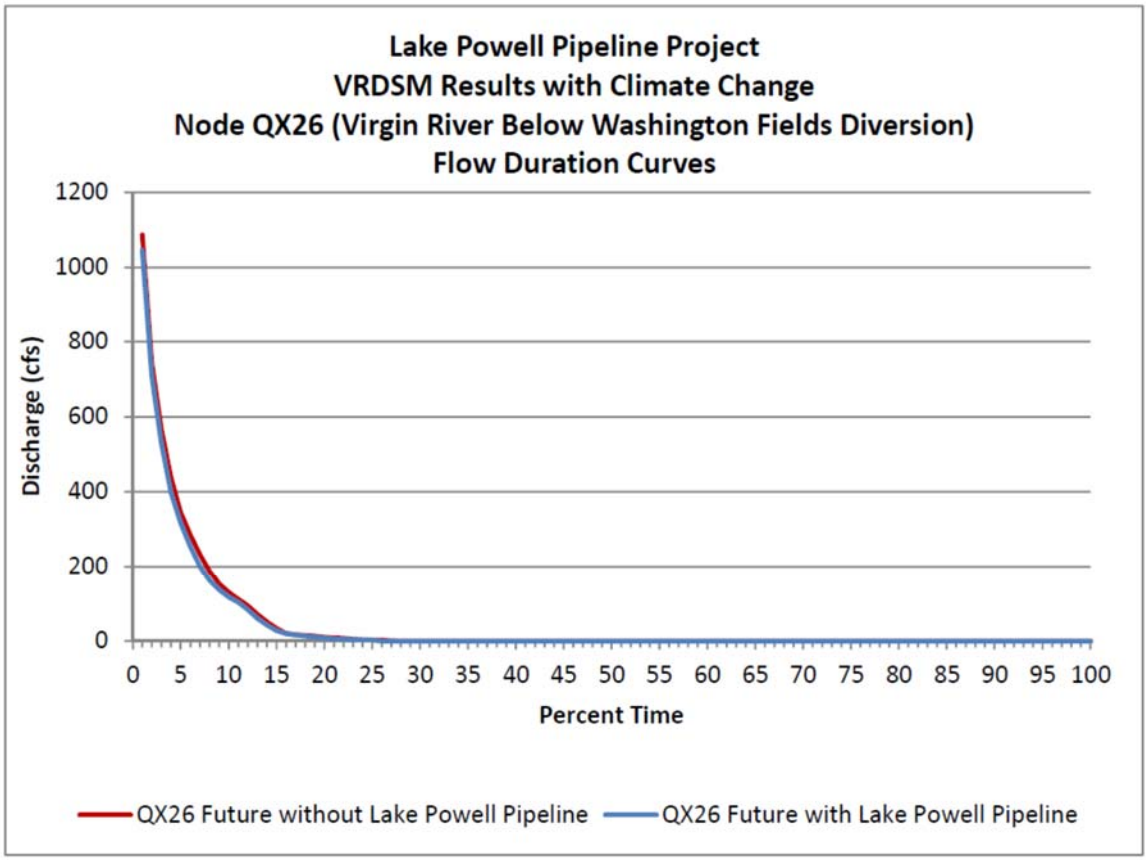


Figure 5-82
Virgin River Below Washington Fields Diversion – Simulated Flow Duration Curves

Figure 5-83 shows simulated mean monthly flows and Figure 5-84 shows the simulated flow duration curves in the Virgin River below the Bloomington Bridge for the future without the LPP Project (Base Case) and future with the LPP Project (Proposed Action). A portion of the Washington Fields M&I and secondary return flows would occur in this Virgin River reach. The mean monthly flows in the Virgin River below the Bloomington Bridge would be slightly lower during the high flow spring runoff months (March through May) and slightly higher for the other months under the future with the LPP Project compared to the future without the LPP Project. These differences in mean monthly flows would be within the accuracy of the closest downstream USGS gage on the Virgin River below the Bloomington Bridge. The simulated flow duration curves are nearly identical and indicate unmeasurable differences in return flows between the future without the LPP Project (Base Case) and future with the LPP Project (Proposed Action).

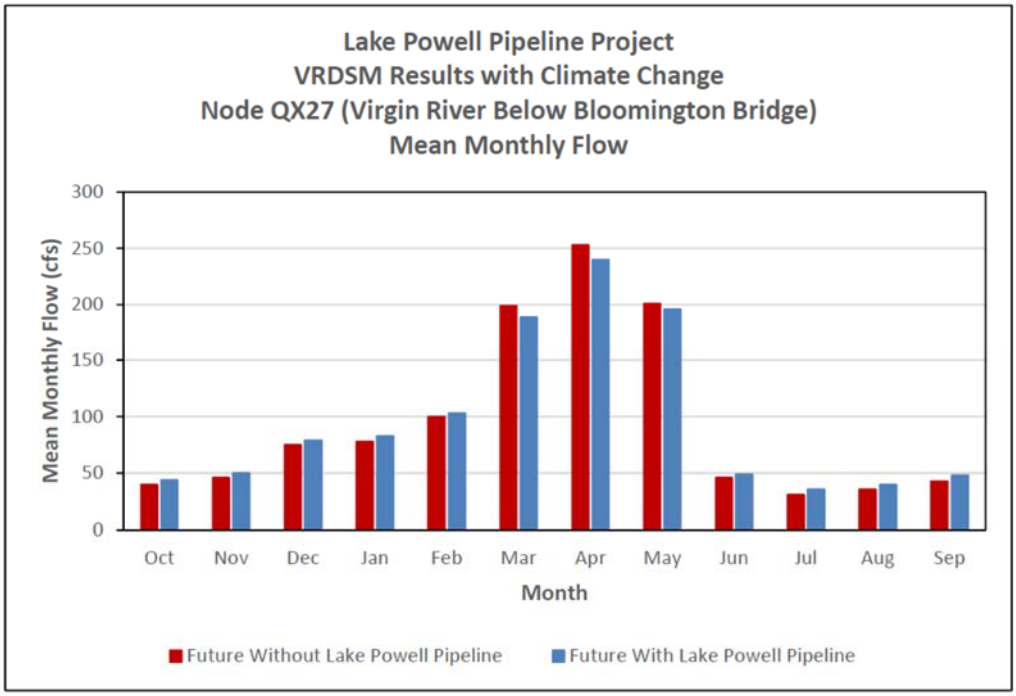


Figure 5-83
Virgin River Below Bloomington Bridge – Simulated Mean Monthly Flows

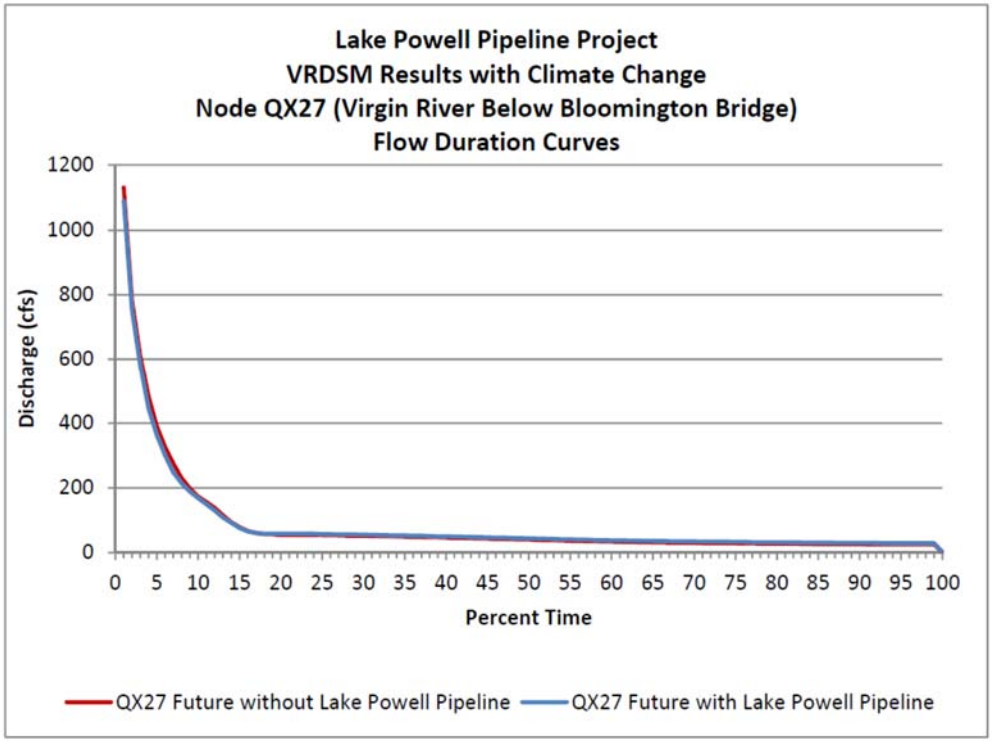


Figure 5-84
Virgin River Below Bloomington Bridge – Simulated Flow Duration Curves

Figure 5-85 shows simulated mean monthly flows and Figure 5-86 shows the simulated flow duration curves in the Virgin River below the Santa Clara River for the future without the LPP Project (Base Case) and future with the LPP Project (Proposed Action). The remainder of the Washington Fields M&I and secondary return flows would occur in this Virgin River reach. The mean monthly flows in the Virgin River below the Santa Clara River would be slightly lower during the high flow spring runoff months (March through May) and slightly higher for the other months under the future with the LPP Project compared to the future without the LPP Project. These differences in mean monthly flows would be within the accuracy of the USGS gage on the Virgin River below the Santa Clara River. The simulated flow duration curves are nearly identical and indicate unmeasurable differences in return flows between the future without the LPP Project (Base Case) and future with the LPP Project (Proposed Action).

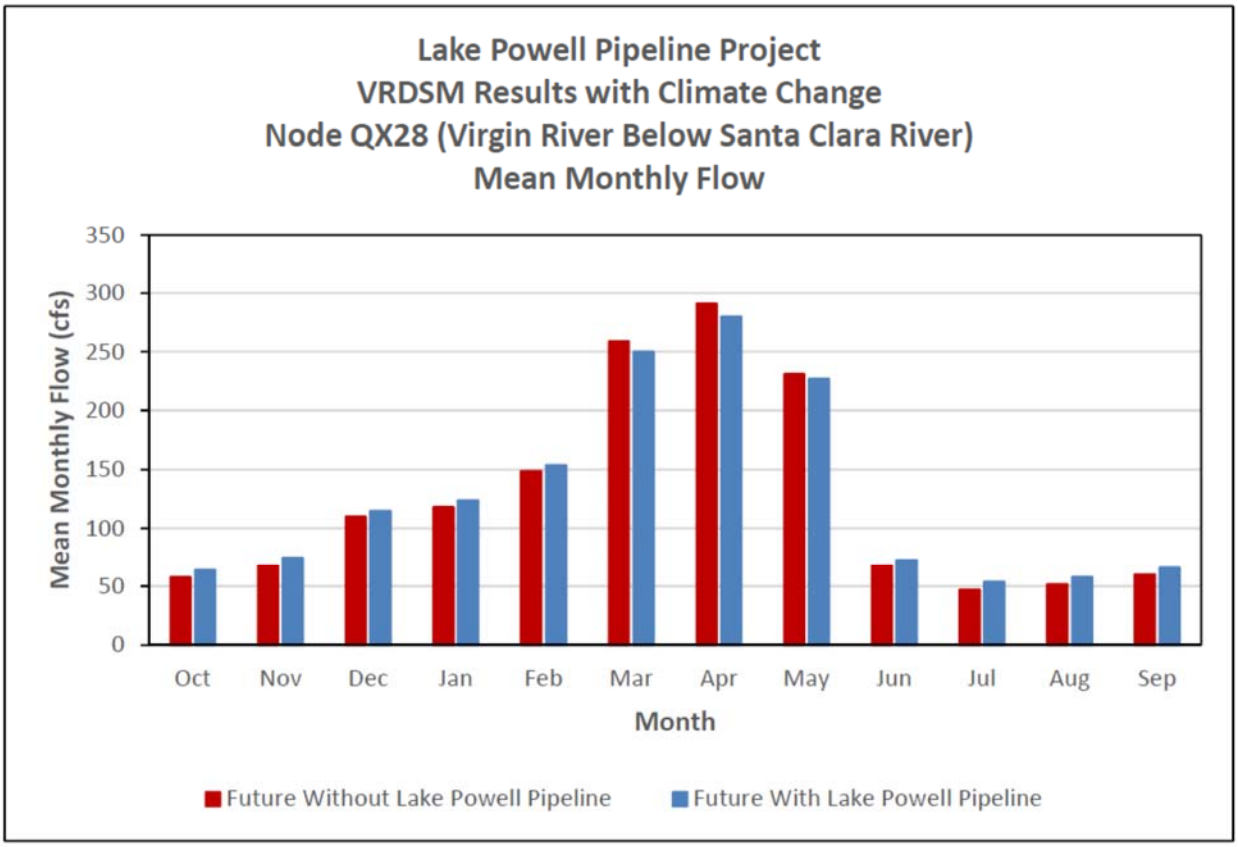


Figure 5-85
Virgin River Below Santa Clara River – Simulated Mean Monthly Flows

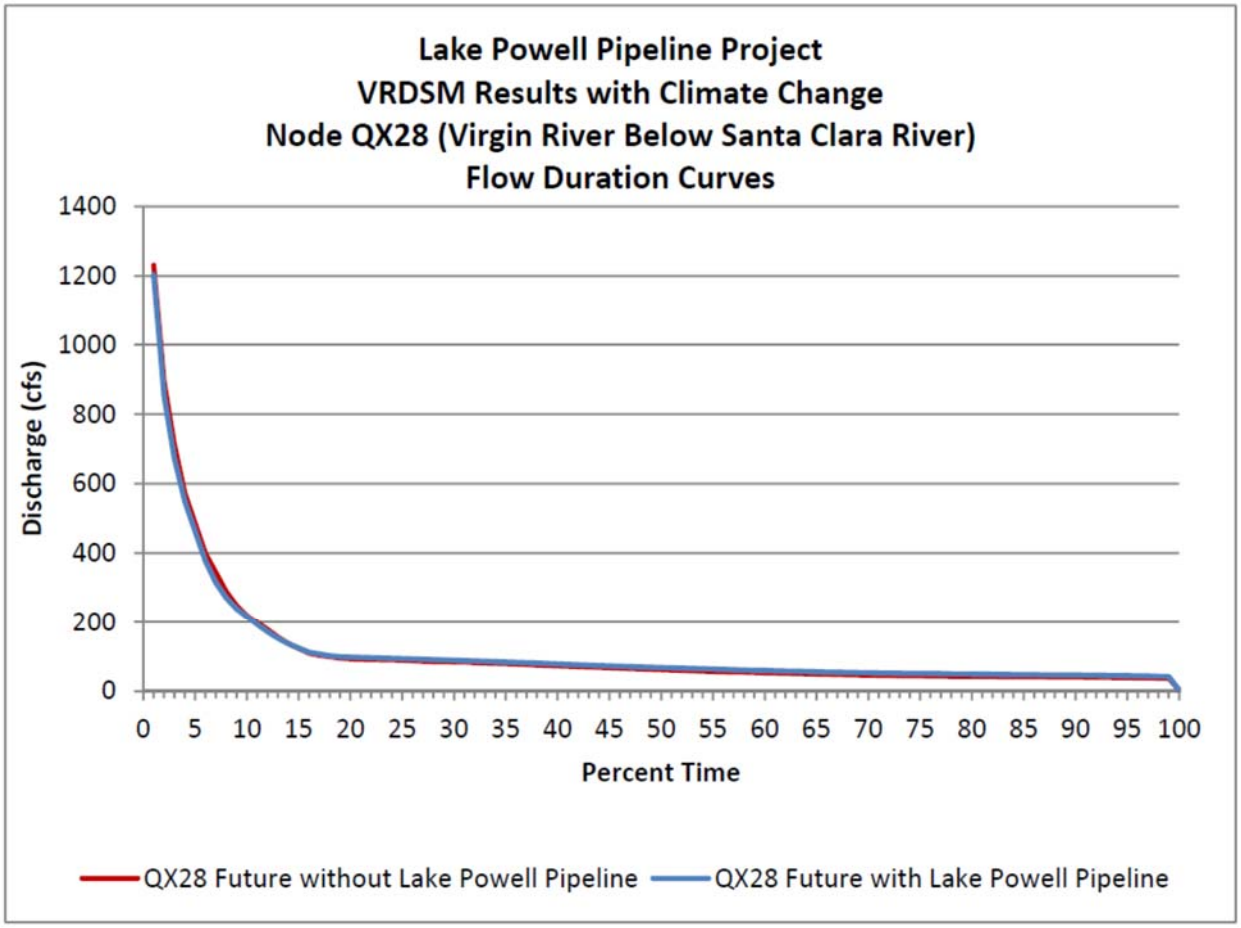


Figure 5-86
Virgin River Below Santa Clara River – Simulated Flow Duration Curves

Figure 5-87 shows simulated mean monthly flows and Figure 5-88 shows the simulated flow duration curves in the Virgin River at the Utah-Arizona state line for the future without the LPP Project (Base Case) and future with the LPP Project (Proposed Action). Remaining St. George M&I return flows would occur in this Virgin River reach. The mean monthly flows in the Virgin River at the Utah –Arizona state line would be slightly lower during the high flow spring runoff months (March through May) and slightly higher for the other months under the future with the LPP Project compared to the future without the LPP Project. These differences in mean monthly flows would be within the accuracy of the USGS gage on the Virgin River at the Utah –Arizona state line. The simulated flow duration curves are nearly identical and indicate unmeasurable differences in return flows between the future without the LPP Project (Base Case) and future with the LPP Project (Proposed Action).

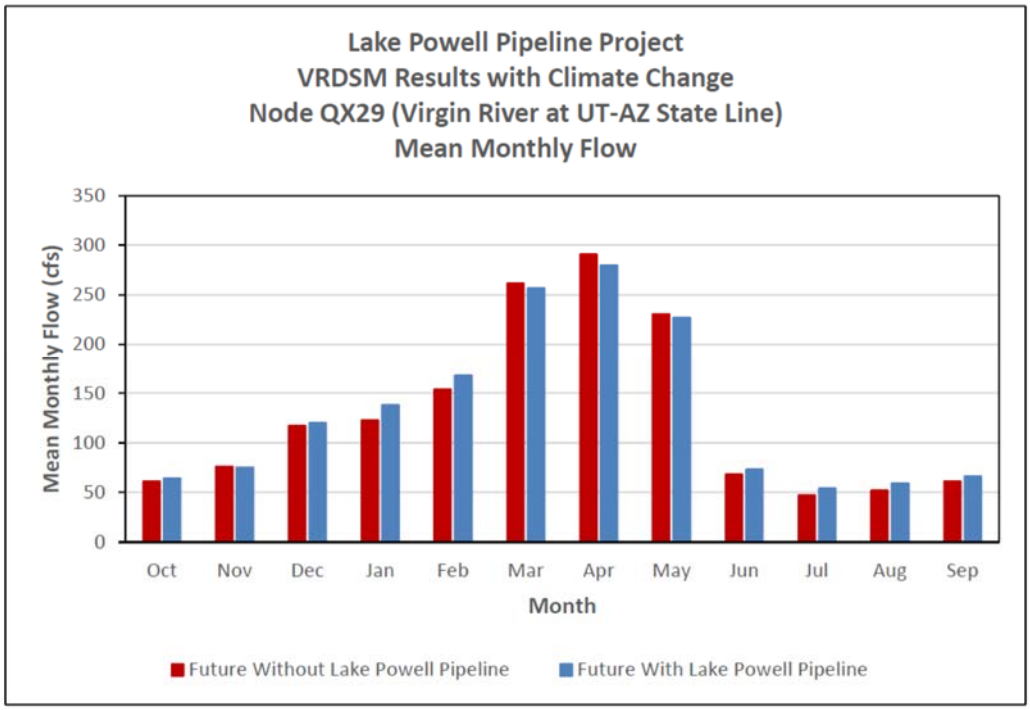


Figure 5-87
Virgin River at the Utah-Arizona State Line – Simulated Mean Monthly Flows

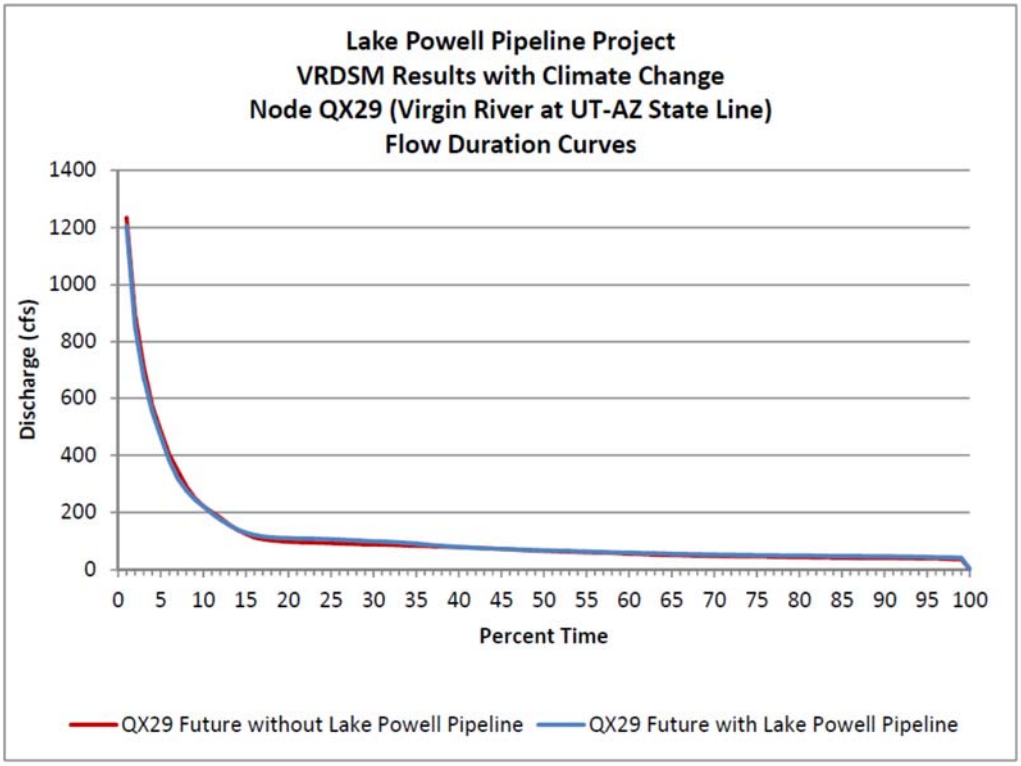


Figure 5-88
Virgin River at the Utah-Arizona State Line – Simulated Flow Duration Curves

5.3.3.2.2.3 Kane, Mohave and Coconino County Drainages.

In the Lake Powell Pipeline Development Act, the Utah legislature allocated KCWCD LPP Project water. KCWCD would receive up to 4,000 ac-ft per year of LPP Project water, with the first LPP depletions beginning in 2035. KCWCD is expected to be using over 3,300 ac-ft per year by 2060 in the Johnson Canyon and Kanab areas. Should the actual water demand exceed the projected demand, KCWCD could receive additional LPP water up to 4,000 ac-ft per year. Based on the 2005 wastewater effluent return flow from the Kanab area, the 2060 wastewater effluent return flow could increase to 574 ac-ft per year. In 2060, the Kanab area wastewater effluent would likely be land-applied for pasture grass or other indirect use. The Kane County duty of water for agricultural land is 5 ac-ft of water per year, and the total pasture area of approximately 115 acres could be irrigated with wastewater effluent in 2060. Therefore, no wastewater effluent is expected to return as measurable surface flow to Kanab Creek or other Kanab area drainages.

Figure 5-89 shows Kanab Creek downstream of Kanab, at the proposed location of the Existing Highway Alternative crossing. Based on field observations, the creek is frequently dry at this location and the channel is filled with vegetation. The same seasonal flow variation is expected to continue with use of LPP water in the Kanab area from 2035 through 2060.

Figure 5-89
Kanab Creek in Fredonia Near Arizona Route 389 Looking Downstream

The LPP Hydro System penstock would cross several intermittent and ephemeral streams in Kane, Mohave and Coconino counties. Numerous field visits of the Proposed Action Kanab Creek crossing, Existing Highway alternative alignment Kanab Creek crossing, and Short Creek crossing in Colorado City demonstrated that these sites are frequently dry. At intermittent streams, open cuts for penstock construction could be scheduled for the most likely dry season to avoid affecting active stream flows or ephemeral aquatic habitat. The penstock would be

encased in reinforced concrete and buried under each stream channel when construction is completed such that the streams or stream flow would not be affected by LPP operation.

The LPP Water Conveyance System pipeline would cross under the Paria River on the upstream side of the Highway 89 Bridge. There is typically a small amount of flow in the Paria River at the proposed crossing location. Figure 5-90 shows the highway bridge across the Paria River and the USGS stream gage. The Proposed Action and other LPP alternatives would include an open cut across this reach for pipeline construction. The open cut would likely require construction in one-half of the stream channel at a time using temporary coffer dams to direct active flow and potential storm runoff flows to another part of the wide channel cross section. Stream flows would not be measurably affected; however, the redirection of flow to a portion of the wide channel cross section could result in short-term effects including different flow velocities and potential bank and bed material erosion. Refer to section 5.3.3.3 for mitigation measures related to erosion.

Figure 5-90
Paria River Crossing by Highway 89 and USGS Gage

Source: USGS (2009)

5.3.3.2.3 Reservoirs.

5.3.3.2.3.1 Lake Powell.

The effects on Lake Powell water levels are based on the results of CRSS modeling completed by Reclamation (2015). The CRSS model was run by Reclamation using more than 100 inflow hydrology datasets each for DNF and CC scenarios resulting in more than 100 sets of model results for both inflow hydrology approaches. These time series results, or traces, are summarized by ranking the results at each time step and determining the 10th, 50th, and 90th percentiles at each time step. These percentiles are presented to summarize the LPP depletion scenario results based on their probability of occurring. However, it is important to keep in mind that each percentile summary does not represent any one continuous trace, but rather a statistic that summarizes the results of all of the traces. Therefore, percentile results presented as a time series do not represent reservoir operations as they would occur sequentially under any particular inflow scenario.

Two future depletion scenarios were modeled: (1) no Lake Powell Pipeline depletions (No Action) and (2) Lake Powell Pipeline depletions up to 86,249 ac-ft per year (Proposed Action). For both scenarios, it was assumed that Upper Basin depletions without state legislation, or a tribal resolution or Federal Indian water settlement, or a Federal FONSI or ROD, remained constant at the 2015 depletion levels currently in CRSS. The depletions assumed reasonably foreseeable include Central Utah Project, Animas-La Plata, Dolores Project, Navajo-Gallup, Ute Indian Compact, and Navajo Indian Irrigation Project. For each depletion scenario (No Action and Proposed Action), two future inflow hydrology scenarios were modeled. The DNF inflow scenario uses data from the observed stream flow record (1906-2010). The CC inflow scenario uses hydrologic data derived from climate change driven stream flow projections (Reclamation 2013) to represent a range of possible future inflows under the assumption of climate change in the Colorado River Basin.

Two alternatives were simulated in the CRSS analysis. The Proposed Action assumes all Upper Basin depletions are held constant at 2015 levels *except* reasonably foreseeable depletions, and adds the LPP depletion from Lake Powell at 86,249 ac-ft per year resulting in over 100 sets of model results for each inflow hydrology scenario (DNF and CC). Similarly, the same inflow hydrology datasets (DNF and CC) were run with the Upper Basin depletions held constant at 2015 levels *except* reasonably foreseeable depletions and no LPP depletion from Lake Powell, which represents the No Action alternative.

Reclamation's CRSS modeling of effects assumes that Utah's total annual depletions would remain the same for the Proposed Action and No Action scenarios and would match those in the Final EIS of the Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (2007 Shortage EIS). The spatial distribution of depletions for the State of Utah was modified for the Proposed Action scenarios to make the 86,249 acre-foot withdrawals directly from Lake Powell rather than upstream of Lake Powell.

Figure 5-91 illustrates the Lake Powell elevation differences between the DNF inflow simulations for the 86,249 acre-foot Proposed Action (pipeline) depletion and No Action in December of each year. Lake Powell levels for the 10th, 50th and 90th percentiles are plotted for 2015 through 2060. DNF was the primary inflow dataset used for the 2007 Shortage EIS and therefore the results of this analysis are more comparable to those performed for that EIS. The year 2027 is when reservoir operations in the simulation revert to the 2007 Shortage EIS No Action Alternative. For the 90th, 50th, and 10th percentiles, there would be minimal average differences in Lake Powell levels between the Proposed Action and No Action under the DNF inflow scenario.

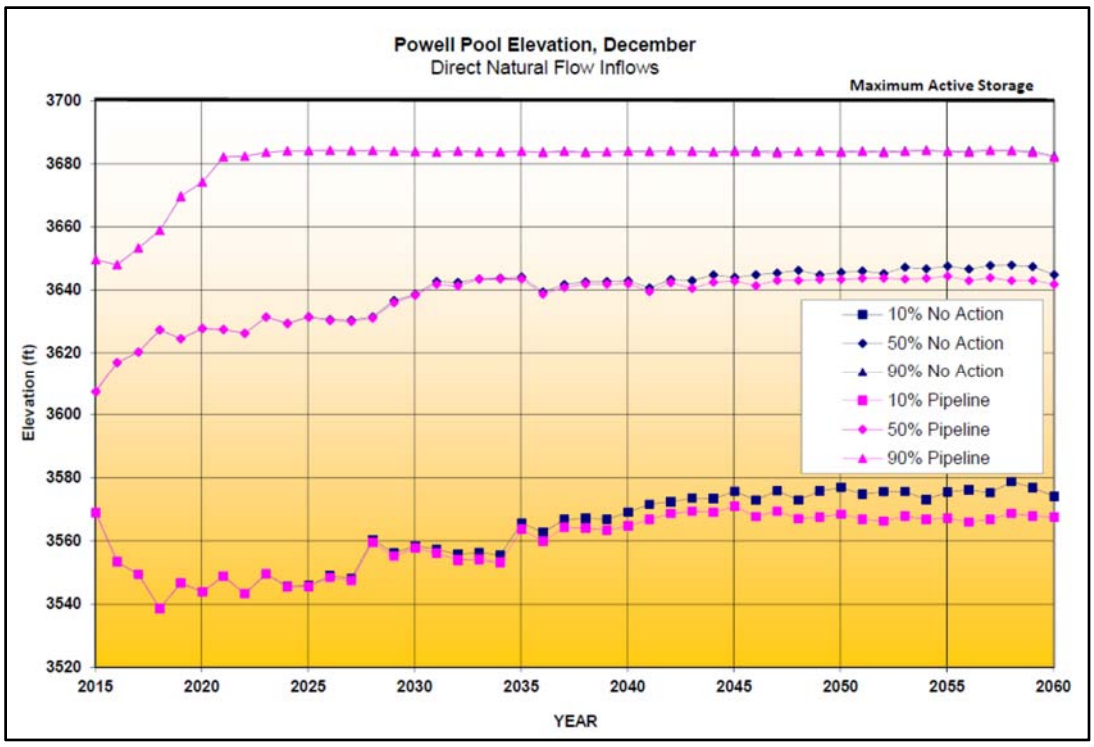


Figure 5-91
Lake Powell Pool Elevation with Proposed Action and No Action Depletions (DNF)

Figure 5-92 illustrates the Lake Powell elevation differences between the CC inflow simulations for the 86,249 acre-foot Proposed Action (pipeline) depletion and No Action. Lake Powell levels for the 10th, 50th and 90th percentiles are plotted for 2015 through 2060. For the 90th, 50th, and 10th percentiles, there would be minimal average differences in Lake Powell levels between the Proposed Action and No Action under the CC inflow scenario.

Table 5-25 summarizes the differences in annual Lake Powell elevations at the 10th, 50th, and 90th percentiles for the DNF and CC inflow hydrology scenarios under the Proposed Action and No Action. Most of the differences summarized round to 0 percent elevation change between the Proposed Action and No Action under the DNF and CC inflow hydrology. The DNF inflow hydrology for No Action would have an average 3.7-foot higher annual elevation difference than the Proposed Action at the 10th percentile, a -0.1 percent difference. The CC inflow hydrology for No Action would have an average 2-foot higher annual elevation difference than the Proposed Action at the 50th percentile, a -0.1 percent difference. The CC inflow hydrology would have slightly lower average annual elevation difference at the 10th percentile compared to the DNF inflow hydrology. The DNF inflow hydrology would have slightly lower average annual elevation difference at the 50th percentile compared to the CC inflow hydrology. The elevation differences in Lake Powell would be on an annual basis (over a one-year period) and not absolute or instantaneous.

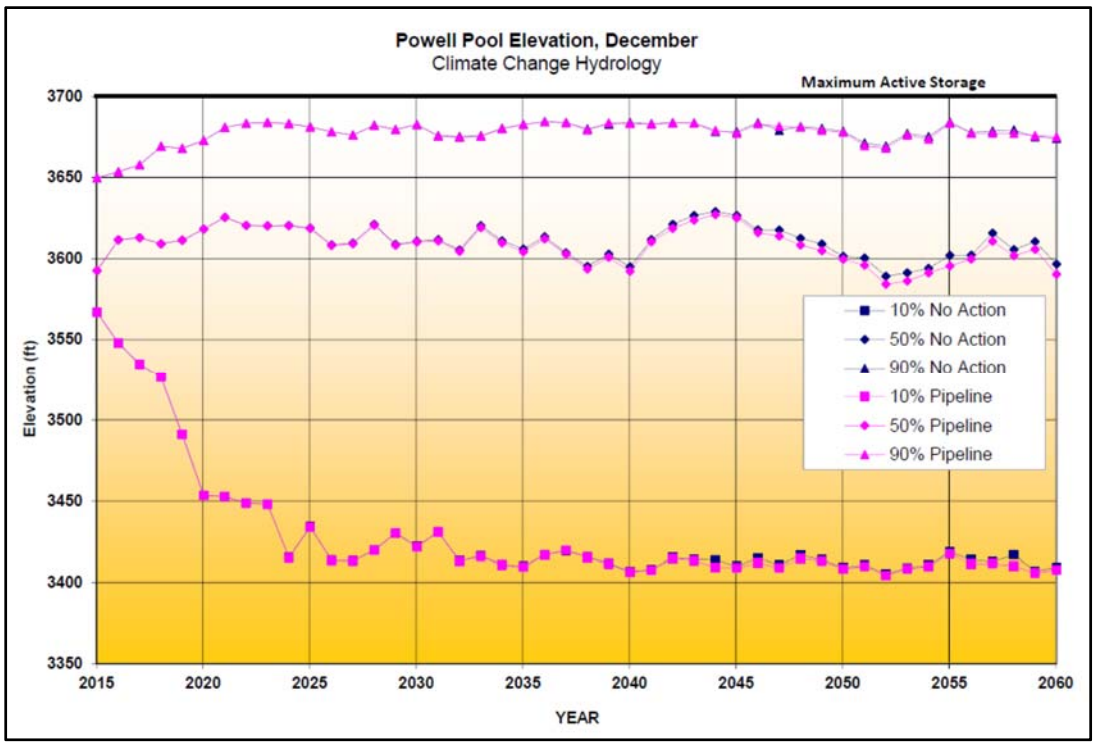


Figure 5-92
Lake Powell Pool Elevation with Proposed Action and No Action Depletions (CC)

Table 5-25
Summary of Lake Powell Annual Elevation Differences (Proposed Action and No Action)

	Elevation Difference (feet)			Percent Difference		
Percentile	**10th**	**50th**	**90th**	**10th**	**50th**	**90th**
DNF Average Difference	-3.7	-1.4	-0.2	-0.1%	0%	0%
DNF Maximum Difference	-10.3	-4.9	-0.5	-0.3%	-0.1%	0%
CC Average Difference	-0.9	-2.0	-0.3	0%	-0.1%	0%
CC Maximum Difference	-7.0	-6.6	2.5	-0.2%	-0.2%	0.1%
Elevation Difference = Proposed Action – No Action; Percent Difference = Difference/No Action						

5.3.3.2.3.2 Quail Creek Reservoir.

The LPP alternatives would have an indirect long-term positive effect on Quail Creek Reservoir operation. Discharge of LPP water into Sand Hollow Reservoir would increase the WCWCD water supply and indirectly increase the duration and annual quantity of Virgin River water that could be stored in Quail Creek Reservoir.

5.3.3.2.3.3 Sand Hollow Reservoir.

The LPP alternatives would have a direct long-term positive effect on Sand Hollow Reservoir operation. Discharge of LPP water into Sand Hollow Reservoir would increase the WCWCD water supply, increase the

duration and annual quantity of water stored in the reservoir, increase the potential for additional groundwater recharge from Sand Hollow Reservoir into the Navajo sandstone aquifer, and provide more flexibility in WCWCD operations to maximize efficiency of water storage.

5.3.3.2.3.4 Future Warner Valley Reservoir.

The No Lake Powell Water Alternative would include adding a future Warner Valley Reservoir as a key component to provide off-stream storage for Virgin River water diverted at the Washington Fields Diversion and for reuse water generated by the St. George Regional Water Reclamation Facility. The long-term effects of this reservoir on surface water resources would include increasing raw water storage by 69,030 ac-ft per year to meet local water needs, increasing the quantity of surface water evaporated (4,717 ac-ft per year) from the future reservoir, and diversion of water from the Virgin River at the Washington Fields Diversion.

5.3.3.2.4 Peak Flows.

The effects on peak flows would be minimal because the Proposed Action would not include construction of any on-channel reservoirs. In cases of particularly erosive stream beds or channels, the pipeline or penstock would be protected by a reinforced concrete encasement, and if necessary a constructed grade control structure would be buried beneath the channel bed on the downstream side of the pipe or penstock. If a grade control structure were to be uncovered during a peak flow event, it could potentially affect local peak flows. These effects would be short-term and limited to the local area around pipeline or penstock crossing.

The Hurricane Cliffs Hydropower forebay and afterbay reservoirs could slightly reduce peak flows by storing storm runoff in the drainage area tributary to Fort Pearce Wash. However, the tributary areas of the forebay and afterbay reservoirs would be relatively small and the associated runoff volume would be relatively small. Therefore, the effect of these Proposed Action reservoirs would be an unmeasurable decrease in flood peaks and volumes downstream in Fort Pearce Wash. The LPP alternatives would have no significant effects on peak flows.

The No Lake Powell Water Alternative would have no measurable effects on peak flows in the St. George metropolitan area. Water from peak flood flows would not be diverted into a future Warner Valley Reservoir because the accompanying sediment and debris would damage the pumps and reduce water storage volume in the reservoir. The Warner Valley Reservoir tributary drainage basin would be relatively small and the associated runoff volume would be relatively small. Therefore, the Warner Valley Reservoir could have an unmeasurable decrease in flood peaks and volumes in the Virgin River. The No Lake Powell Water Alternative would have no significant effects on peak flows.

5.3.3.2.5 Geomorphology.

Streams in the area of potential effect are highly susceptible to bed and bank erosion from peak flow events. The LPP alternatives would have no measurable effects on peak flow rates in the area of potential effect, and therefore, would not result in changes to stream channel movement or sediment transport during peak events. Reinforced concrete encasements of the pipeline or penstock or adjacent buried grade control structures that temporarily become uncovered during peak flow events could have minor short-term local effects on channel geomorphology. The sediment bed-load in potentially affected streams would be re-deposited in and around uncovered pipeline or penstock encasements or grade control structures during the falling limb of the peak flow hydrograph. The LPP alternatives would have no significant effects on stream geomorphology.

There could be short-term localized minimal effects on geomorphology during LPP alternative construction at stream crossings where water is actively flowing. Temporary coffer dams used as diversion structures during construction in stream channels would minimize local short-term geomorphologic changes. The LPP alternatives would have no significant effects on geomorphology at stream crossings by the pipeline or penstock.

The LPP alternatives would have no measurable effect on flows in the Colorado River downstream from Glen Canyon Dam and therefore no measurable change in the sediment transport or channel forming flows. In addition, because there would be minor effects on Lake Powell elevations and associated storage, there would not be any effect on the ability to conduct high flow experimental releases from Lake Powell. The high flow experimental releases have been shown to affect geomorphology in the Colorado River downstream of Glen Canyon Dam and in the Grand Canyon.

The No Lake Powell Water Alternative could have minor effects on geomorphology in the Virgin River. Higher runoff flows diverted and pumped from the Washington Fields Diversion into the future Warner Valley Reservoir would not be available to transport deposited sediments in the channel reach downstream from the Washington Fields Diversion. These potential minor effects on geomorphology in the Virgin River would be localized and would not be significant.

5.3.3.3 Protection, Mitigation and Enhancement Measures

5.3.3.3.1 Pipeline and Penstock Stream Crossings.

Construction procedures at flowing, dry and ephemeral stream crossings, where applicable, would include planning for excavation during the most likely dry period during the year, installing temporary coffer dams at stream crossings, diverting streams and potential runoff flows through side channels to avoid excavation in active flow channels, minimizing the length of time open cuts are made through drainage channels, utilizing silt fence and straw bales to control potential erosion and sedimentation, and restoring channel bed and bank materials to pre-construction conditions. These measures would protect streams and channels from short-term effects during construction. There would be no adverse effects from implementing these short-term protection and mitigation measures. Stream alteration permits would be acquired before any undertaking any work requiring such permits.

Long-term protection and mitigation measures at stream crossings would include encasing the pipeline and penstock in reinforced concrete through the stream crossing area, installing structural grade controls downstream from encased pipelines and penstocks to prevent head-cutting and control local grades where a stream crosses a buried pipeline or penstock, and armoring the stream bed above a buried, concrete-encased pipeline or penstock with rock riprap to prevent erosion of pipeline bedding and soil from around encasements. There would be minimal long-term adverse localized effects on natural geomorphologic processes from implementing protection and mitigation measures at locations where the pipeline or penstock crosses streams and drainage channels.

5.3.3.4 Cumulative Effects

5.3.3.4.1 Proposed Action.

The Proposed Action would have minimal short-term effects on surface water resources during construction. Therefore, there would be no measurable cumulative effects of the LPP alternatives on surface water resources when combined with other past, present, and reasonably foreseeable future actions. The unmeasurable short-term cumulative effects would not be significant.

The Proposed Action could have minimal long-term cumulative effects on surface water resources in Lake Powell and Glen Canyon Dam releases when combined with the following past, present, and reasonably foreseeable future actions during operations:

- Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead EIS and ROD
- Operation of Glen Canyon Dam EIS and ROD
- Interim Surplus Criteria EIS and ROD

- Bureau of Reclamation and National Park Service LTEMP EIS

These interrelated actions determine the elevation, storage, release, operational timing, and volume of water in Lake Powell and release rates, release volumes, and operational timing of Glen Canyon Dam releases to the Colorado River. The Proposed Action would have minimal effects on elevations, storage, release, operational timing and volume of water in Lake Powell, and when combined with these interrelated actions, there would be long-term minimal cumulative effects on surface water resources. Similarly, the Proposed Action would have minimal effects on Glen Canyon Dam release rates, release volumes, and operational timing of releases and when combined with these interrelated actions, there would be long-term minimal cumulative effects on surface water resources. These long-term cumulative effects would not be physically measurable in Lake Powell and Glen Canyon Dam releases; however, they would result from depletions up to 86,249 ac-ft per year from Lake Powell and would have minimal cumulative effects on Bureau of Reclamation operations and other actions implemented by the U.S. Department of the Interior. These cumulative effects in surface water resources would not be significant.

5.3.3.4.2 Existing Highway Alternative.

The cumulative effects of the Existing Highway Alternative would be the same as described for the Proposed Action in Section 5.3.3.4.1.

5.3.3.4.3 Southeast Corner Alternative.

The cumulative effects of the Southeast Corner Alternative would be the same as described for the Proposed Action in Section 5.3.3.4.1.

5.3.3.4.4 No Lake Powell Water Alternative.

The No Lake Powell Water Alternative would have a long-term cumulative effect on surface water resources when combined with the operation of the St. George Wastewater Reuse Project. All of the available reclaimed wastewater effluent from the St. George Regional Wastewater Reclamation Facility would be conveyed to a future Warner Valley Reservoir for mixing with Virgin River water pumped from the Washington Fields Diversion, comprising the raw water supply for RO treatment processes. No reclaimed water would be available for reuse in city parks, golf courses and cemeteries. This cumulative effect on surface water resources could be moderate and could be a significant cumulative effect, due to cessation of irrigating city parks, golf courses and cemeteries with reuse water.

5.3.3.5 Unavoidable Adverse Effects

5.3.3.5.1 Proposed Action.

The Proposed Action would have minor short-term unavoidable adverse effects on surface water resources, including temporary diversions at actively flowing stream crossings. The Proposed Action would have minor long-term unavoidable adverse effects on surface water resources, including Lake Powell levels and associated volumes, Glen Canyon Dam releases to the Colorado River, Virgin River flows through the St. George metropolitan area, and minor cumulative effects in combination with Bureau of Reclamation operating decisions on Lake Powell elevations and Glen Canyon Dam releases.

5.3.3.5.2 Existing Highway Alternative.

The unavoidable adverse effects of the Existing Highway Alternative would be the same as described for the Proposed Action in Section 5.3.3.5.1.

5.3.3.5.4 Southeast Corner Alternative.

The unavoidable adverse effects of the Southeast Corner Alternative would be the same as described for the Proposed Action in Section 5.3.3.5.1.

5.3.3.5.4 No Lake Powell Water Alternative.

The No Lake Powell Water Alternative would have no short-term unavoidable adverse effects on surface water resources. The No Lake Powell Water Alternative could have moderate long-term unavoidable adverse effects and significant unavoidable adverse cumulative effects on surface water resources in the St. George metropolitan area associated with repurposing St. George Water Reuse Project water for RO treatment after mixing with diverted Virgin River water and storage in a future Warner Valley Reservoir. All available surface water resources, including reuse water, would be collected and conveyed to the enlarged Warner Valley Reservoir for use as inflow to the RO treatment plant. Repurposing the reuse water as part of the supply for the reverse osmosis treatment would have unavoidable adverse effects on parks, golf courses, cemeteries and other areas that currently use reuse water for irrigation.

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