Appendix A
Flow-Stage Relationships for the Truckee Canal

Newlands Project Planning Study
Special Report

Prepared by

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Abbreviations and Acronyms

cfs	cubic feet per second
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
RR3	Risk Rating 3
Study	Newlands Project Planning Study
TCID	Truckee-Carson Irrigation District
TROA	Truckee River Operating Agreement

Appendix A – Flow-Stage Relationships for the Truckee Canal

The following document explains the flow-stage terminology that has been adopted for describing operating restrictions on the Truckee Canal and used in the Newlands Project Planning Study (Study) Special Report. This document also evaluates the ability of the Truckee Canal to make deliveries to the Truckee Division at various flow stages.

Since 2008, restrictions have been placed on the Truckee Canal to address public health and safety concerns by limiting the volume of water in the urbanized portion of the canal (i.e., the Fernley Reach, as shown in Figure A-1). Throughout several studies and reports, these restrictions are often expressed in terms of a flow rate (e.g., 350 cubic feet per second (cfs)). These restrictions, however, are actually based on the depth and surface elevation of the water in the canal (stage) at a specified flow rate and location in the canal during conditions when the checks in the canal are not used (unchecked flow rate). Nonetheless, the use of "cfs" has become familiar shorthand for describing the canal's capacity restrictions.

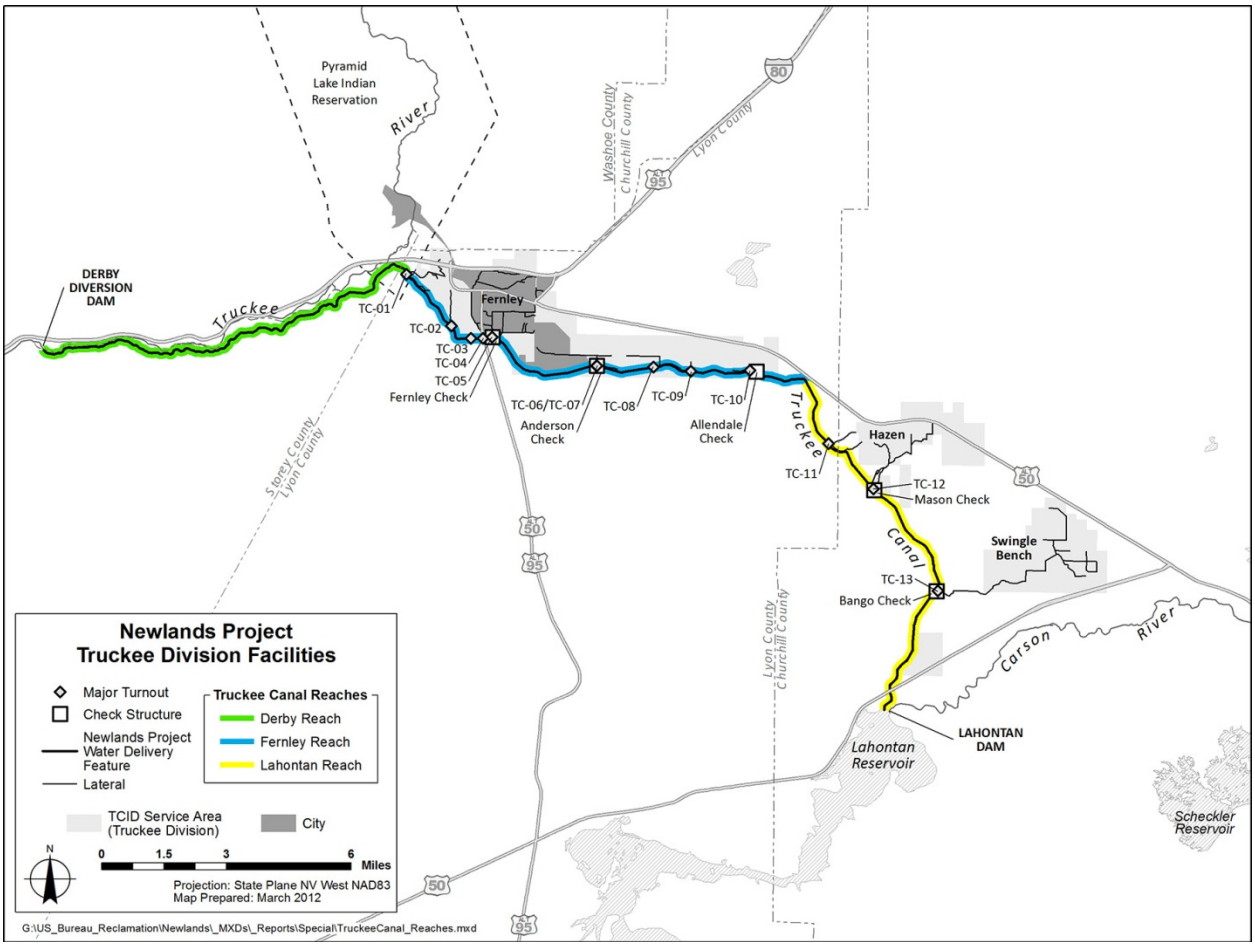


Figure A-1. Truckee Canal with Turnout and Check Structure Locations

Using flow rates as a surrogate for depth-based limitations on the Truckee Canal presents challenges. A direct relationship typically exists between stage and flow in unchecked canals, where a given stage indicates a specific flow rate. This relationship, however, only remains constant if conditions within the canal remain the same. During the past couple of years, the presence of the aquatic weed milfoil (*Myriophyllum* spp.) in the Truckee Canal has increased its "roughness." This means, the stage-flow relationship in the canal has changed from its previous condition, and stages in the canal indicate lower flow rates than previously observed. If the limitations on the canal were based on flow, then the canal would be permitted to carry higher elevations to allow for the same flow rates. However, this is not the case; stages in the canal must remain at or below those associated with the specified flow levels, for the previous condition of the Truckee Canal (with less milfoil). Additionally, the use of a flow rate to designate elevation can become confusing when explaining the use of checks, which back water up in the canal. For instance, a flow of 50 cfs through the canal can be backed up so that the canal has elevations similar to an unchecked flow of 350 cfs. Explaining this operation can become burdensome for audiences not already familiar with canal operations.

To ensure both accuracy and clarity, this report uses the term "flow stage" in conjunction with a cfs flow rate to describe canal capacity restrictions. The use of flow-stage terminology clarifies that the restrictions are elevation-based, but allows continued use of the cfs designations that are more familiar to some. The following sections of this document explain the origins and basis for the flow stages referenced by the Study, and assumptions about how the Truckee Canal would function as a result of these flow stages.

Flow-Stage Relationships for the Truckee Canal

Relationships between flow and stage for the Truckee Canal are based on hydraulic modeling that was conducted by the U.S. Department of the Interior, Bureau of Reclamation (Reclamation) shortly after the 2008 breach of the Truckee Canal (Reclamation, Jeff Rieker, personal communication, 2011). To develop these relationships, Reclamation simulated steady-state flow through the entire length of the Truckee Canal ending at Lahontan Reservoir, without loss, diversion, or interference from control structures (i.e., all checks are simulated as being open, turnouts are simulated as being closed). The relationships among flow, stage, and elevation at various structures and locations in the canal are shown in Table A-1 and Figure A-2. Reclamation applied an understanding of these same relationships to develop the current operational restrictions on the Truckee Canal. These restrictions have been broadly applied for both the Truckee Canal Risk Assessments (Reclamation 2011a, b, c, d) and Corrective Action Study (Reclamation 2011e).

Table A-1. Relationship Among Depth, Elevation, and Flow Rates in the Truckee Canal

Reach	Structure	Water Surface Elevation (feet)	Equivalent Unchecked Flow Rate in the Truckee Canal (cfs)
Derby	Derby Dam[1]	4,199	*0*
		4,201	*150*
		4,203	*250*
		4,203	*350*
		4,205	*600*
		4,208	*700*
	Diversion TC-1	4,186	*0*
		4,191	*150*
		4,192	*250*
		4,192	*350*
		4,194	*600*
		4,195	*700*

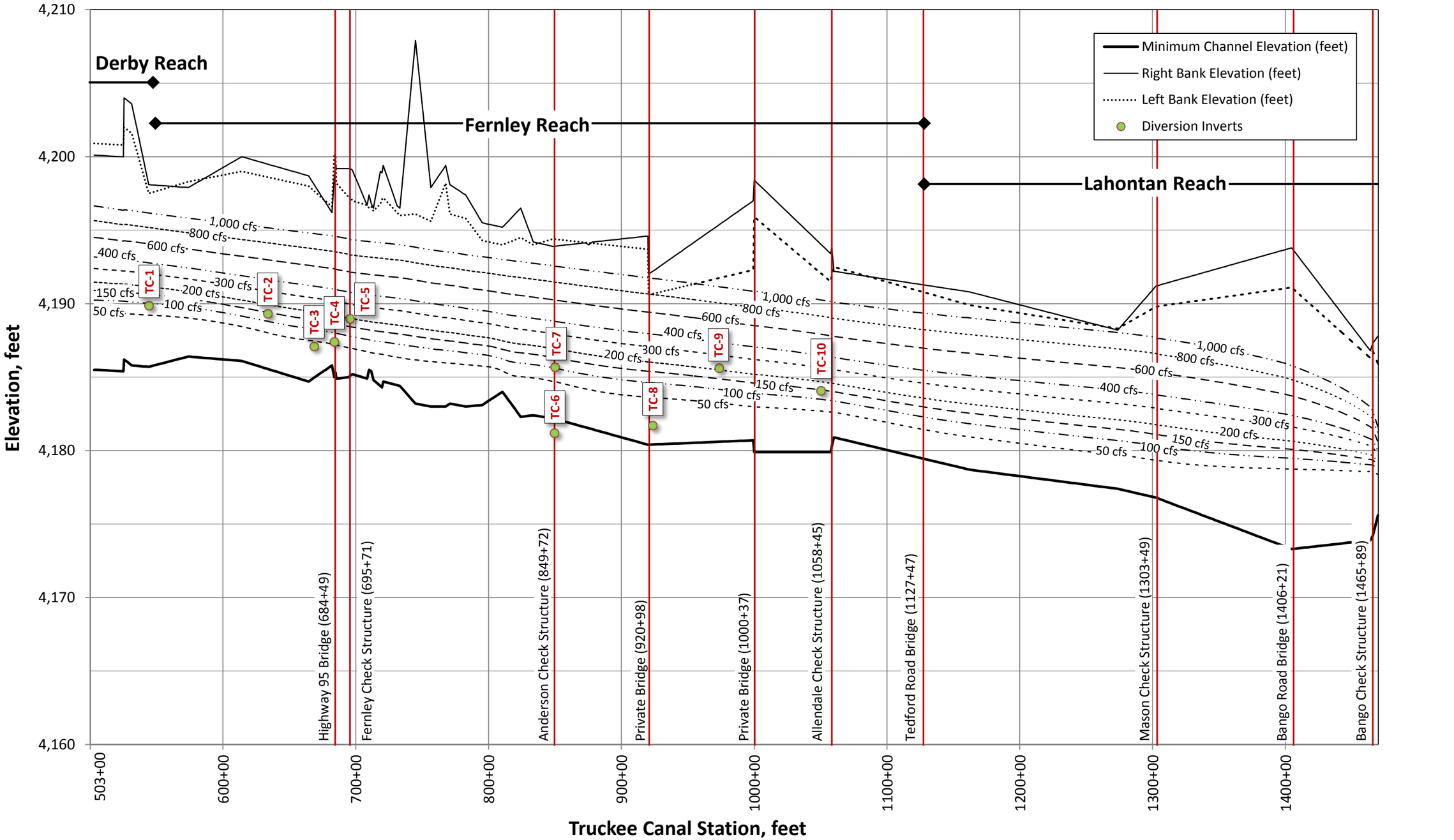
Table A-1. Relationship Among Depth, Elevation, and Flow Rates in the Truckee Canal (contd.)

Reach	Structure	Water Surface Elevation (feet)	Equivalent Unchecked Flow Rate in the Truckee Canal (cfs)
Fernley	Fernley Check Structure	4,185	*0*
		4,188	*150*
		4,189	*250*
		4,190	*350*
		4,192	*600*
		4,193	*700*
	Anderson Check Structure	4,182	*0*
		4,186	*150*
		4,187	*250*
		4,188	*350*
		4,190	*600*
		4,191	*700*
	Allendale Check Structure	4,180	*0*
		4,184	*150*
		4,185	*250*
		4,186	*350*
		4,188	*600*
		4,188	*700*
Lahontan	Bango Check Structure	4,175	*0*
		4,179	*150*
		4,180	*250*
		4,180	*350*
		4,181	*600*
		4,182	*700*

Notes:

[1] The original Truckee Canal Steady-State Flow HEC-RAS model does not begin until Station 503+00 (downstream from Derby Dam). Values at Derby Dam were computed using the Truckee Risk Assessment HEC-RAS model. For all other locations, the original Truckee Canal Steady Flow HEC-RAS model was used.

Key:
cfs = cubic feet per second
TC = Truckee Canal takeout



Source: (Reclamation 2012)

Figure A-2. Profile of the Truckee Canal, Including Flow-Stage Relationships for 50 cfs Through 1,000 cfs, Locations of Prominent Infrastructure, and Minimum Stages for Diversion Structures

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Commonly Referenced Flow-Stage Relationships

With the exception of canal decommissioning, flow-stage relationships form the basis for Study alternatives. This approach is described in Chapters 2 and 4 of the Study Special Report. In particular, four flow stages are commonly referenced to describe: how a given planning study alternative has approached meeting the required level of safety for urbanized portions of the Truckee Canal; and the resulting allowable water surface elevations within the Truckee Canal. These four commonly referenced flow stages are: 600, 350, 250, and 150 cfs.

Tables A-2 through A-5 present the maximum allowable water surface elevations and depths at key control structures within the Truckee Canal for each flow stage. These limitations assure that canal operations pose acceptable levels of risk, contingent on the implementation of one of the methods that were identified by Reclamation to address Risk Rating 3 (RR3) in the Corrective Action Study (Reclamation 2011e). Reducing this level of risk addresses problems judged to have the highest likelihood of causing the canal embankment to fail, or which would present the greatest hazard to life and property should failure occur. Addressing problems at RR1 is a part of reducing risk at all risk levels. These tables only display the flow stage limitations, and do not infer that the Truckee Canal will achieve the limitations during operation.

Table A-5 presents the maximum water surface elevations at various locations in the canal that meet Reclamation safety standards without performing additional corrective actions. The equivalent unchecked flow rate varies throughout the canal, based upon differences in structural problems and other risk factors along the canal. As described in Chapter 3, corrective actions are necessary for allowing flow levels to exceed the 150 cfs flow stage in the Fernley Reach, as presented in Table A-2.

Table A-2. Restrictions for the Truckee Canal After Achieving Safety Objective (RR3) for 600 cfs, as Provided by the Corrective Action Study

Reach	Structure	Maximum Allowable Water Surface Elevation (feet)	Equivalent Unchecked Flow Rate in the Truckee Canal (cfs)
Derby	Derby Dam	4,208	*700*
	Diversion TC-1	4,194	*600*
Fernley	Fernley Check Structure	4,192	*600*
	Anderson Check Structure	4,190	*600*
	Allendale Check Structure	4,188	*600*
Lahontan	Bango Check Structure	4,181	*600*

Source: Reclamation 2011e
Key:
cfs = cubic foot per second
RR3 = Risk Rating 3
TC = Truckee Canal takeout

Table A-3. Restrictions for the Truckee Canal After Achieving Safety Objective (RR3) for 350 cfs, as Provided by the Corrective Action Study

Reach	Structure	Maximum Allowable Water Surface Elevation (feet)	Equivalent Unchecked Flow Rate in the Truckee Canal (cfs)
Derby	Derby Dam	4,208	*700*
	Diversion TC-1	4,192	*350*
Fernley	Fernley Check Structure	4,190	*350*
	Anderson Check Structure	4,188	*350*
	Allendale Check Structure	4,186	*350*
Lahontan	Bango Check Structure	4,180	*350*

Source: Reclamation 2011e
Key:
cfs = cubic foot per second
RR3 = Risk and Reliability Rating 3
TC = Truckee Canal takeout

Table A-4. Restrictions for the Truckee Canal After Achieving Safety Objective (RR3) for 250 cfs, as Provided by the Corrective Action Study

Reach	Structure	Maximum Allowable Water Surface Elevation (feet)	Equivalent Unchecked Flow Rate in the Truckee Canal (cfs)
Derby	Derby Dam	4,208	*700*
	Diversion TC-1	4,192	*250*
Fernley	Fernley Check Structure	4,189	*250*
	Anderson Check Structure	4,187	*250*
	Allendale Check Structure	4,185	*250*
Lahontan	Bango Check Structure	4,180	*350*

Source: Reclamation 2011e
Key:
cfs = cubic foot per second
RR3 = Risk and Reliability Rating 3
TC = Truckee Canal takeout

Table A-5. Restrictions for the Truckee Canal Under the Likely Future Without-Action Condition (Approximately 150 cfs)

Reach	Structure	Maximum Allowable Water Surface Elevation (feet)	Equivalent Unchecked Flow Rate in the Truckee Canal (cfs)
Derby	Derby Dam	4,208	*700*
	Diversion TC-1	4,191	*150*
Fernley	Fernley Check Structure	4,188	*150*
	Anderson Check Structure	4,186	*150*
	Allendale Check Structure	4,184	*150*
Lahontan	Bango Check Structure	4,180	*350*

Key:
cfs = cubic foot per second
TC = Truckee Canal takeout

Truckee Canal Performance at a Range of Flow Stages

An important consequence of restricting water surface elevations in the Truckee Canal is that it has the potential to limit the amount of water that can be delivered to Lahontan Reservoir for use by the Carson Division, or to laterals along the Truckee Canal for use by the Truckee Division.

The ability to deliver water to Lahontan Reservoir depends on a combination of factors, including the available supply for diversion at Derby Dam, the required diversion rate for making Truckee Division deliveries, rates of loss within the Truckee Canal and its laterals, and the storage in Lahontan Reservoir relative to storage targets identified in the 1997 Operating Criteria and Procedures for the Newlands Project. These factors are determined by the particular blend of corrective actions and water supply measures combined in a given alternative. Therefore, assessments of the volume of water that may be conveyed through the Truckee Canal to Lahontan Reservoir will be evaluated in simulations with the Pre-Truckee River Operating Agreement (TROA) Planning Model (see Appendix B1).

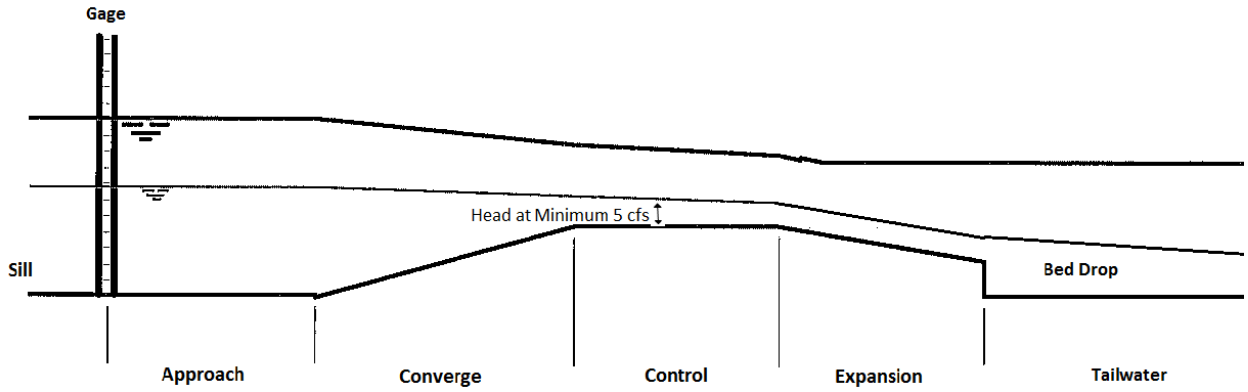
The ability to deliver water to water rights holders in the Truckee Division depends upon the water surface elevations at each takeout, and whether check structures in the canal can be operated in a manner that raises water surface elevations (head) to levels above those takeouts without also violating the depth restrictions at other locations in the canal. Table A-6 compares surface water elevations within the Fernley Reach for the common flow-stage conditions to the minimum head elevation needed to operate each takeout. For any specific takeout to function, the head in the Truckee Canal must be above what is referred to as the "minimum head elevation." Minimum head elevations are specified in the design drawings for each takeout and can be calculated as the top of the control elevation plus the head required for the ramp flume to convey 5 cfs (see Figure A-3). These thresholds have been provided by Truckee-Carson Irrigation District (TCID) (Winder, 2012), and reflect elevations that will exist following a conduit repair construction project that TCID initiated in February 2012.

Table A-6. Comparison of Elevations for Takeouts and Water Surfaces in the Truckee Canal for Four Flow Stages

Takeout[1]			Depth of Water (feet) Above Minimum Head Elevation of Takeout, at Maximum Water Surface Elevation for Given Flow Stage			
Name	Top of Control (feet)	Minimum Head Elevation (feet)[2]	600 cfs flow stage	350 cfs flow stage	250 cfs flow stage	150 cfs flow stage
TC-01	4189.5	4189.9	4.2	2.6	1.8	0.8
TC-02	4188.8	4189.3	3.7	1.9	1.1	0.1
TC-03[3]	4187.1	4187.1	5.5	3.7	2.8	1.8
TC-04	4186.8	4187.4	5.0	3.2	2.3	1.3
TC-05	4188.5	4189.0	3.2	1.4	0.5	-0.5
TC-06[4]	4180.7	4181.2	9.0	7.2	6.3	5.1
TC-07[4]	4185.2	4185.7	4.6	2.7	1.8	0.7
TC-08	4181.3	4181.7	7.7	5.8	4.9	3.7
TC-09	4185.1	4185.6	3.2	1.3	0.4	-0.7
TC-10	4183.6	4184.1	3.9	2.0	1.1	0.1

Notes:
[1] Engineering information on take outs based on TCID design specifications, dated November 8, 2011
[2] Minimum head elevation = top of control + head at the minimum 5 cfs flow rate.
[3] Turnout design specifications for TC-03 were not available for this study. Assumed the top of control elevation was the bottom of the pipe and that there were no minimum head requirements.
[4] TC-06 and TC-07 are being combined into one turnout.

Key:
cfs = cubic feet per second
TC = Truckee Canal takeout



Source: Reclamation 2012; Winder, 2012

Figure A-3. Typical Takeout Profile on the Truckee Canal

Table A-6 only evaluates the Fernley Reach because survey data were not available for invert locations in the Derby and Lahontan reaches, and because the flow-stage restrictions are not expected to limit deliveries outside of the Fernley Reach (TCID, Walt Winder, personal communication, 2012). Locations of each takeout were identified in the hydraulic model of the Truckee Canal.

When flows in the Truckee Canal are at or below the 150 cfs flow stage, the head at two takeouts (TC-05 and TC-09) is below the control structures, meaning that delivery of water would not be possible without the use of pumps. Additionally, the heads at several other locations (TC-01, TC-02, TC-07, and TC-10) are within a foot of the minimum head elevations for the takeouts, which may result in some reduction in service. Heads are also within a foot of the minimum for the 250 cfs flow stage, which may reduce service at a few of the same locations (TC-02, TC-05, TC-09, and TC-10). The affected takeouts, which are limited to those within the Fernley Reach, provide a significant portion of the water delivered to the entire Truckee Division, as shown in Table A-7.

Table A-7. Truckee Canal Diversions and Direct Takeout Diversions and Fernley Pipeline

Diversions	2001 – 2010 Average Annual Diversion (TAF)	Percent of Total Diversions
TC-01	392	3%
TC-02	314	2%
TC-03	283	2%
TC-04	994	7%
TC-05	816	6%
TC-06	1,057	8%
TC-07	849	6%
TC-08	2,143	15%
TC-09	533	4%
TC-10	725	5%
TC-11	1,266	9%
TC-12	1,106	8%
TC-13	2,317	17%
Truckee Canal Direct Takeouts	791	6%
Fernley Pipeline	487	3%
Total Truckee Division Diversions	**14,042**	**100%**

Source: Reclamation records of diversions from the Truckee Canal, as recorded at the Reclamation Fallon Field Office

Key:
TAF = thousand acre-feet
TC = Truckee Canal takeout

For conditions where safety concerns restrict the Truckee Canal to flow stages below 250 cfs, pumps may need to be installed at takeouts where the water surface does not support gravity-fed diversions. Water supplies, however, would be sufficient for meeting the water supply needs of the Truckee Division under these conditions. For the purposes of the Study, it is assumed that TCID would accommodate the installation and operation of any pumps necessary for supplying takeouts under the authority of their operations and maintenance contract with Reclamation.

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