RECLAMATION

Managing Water in the West

Special Technical Embankment Examination

Truckee Main Canal, Newlands Project, Nevada

U.S. Department of the Interior
Bureau of Reclamation
Mid-Pacific Region

January 2008

U.S. Department of the Interior
Mission Statement

The mission of the Department of the Interior is
to protect and provide access to our Nation's natural and cultural heritage
and honor our trust responsibilities to Tribes
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Mission of the
Bureau of Reclamation

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

TRUCKEE MAIN CANAL
TRUCKEE-CARSON IRRIGATION DISTRICT
NEWLANDS PROJECT, NEVADA
MID-PACIFIC REGION

MANAGEMENT SUMMARY

This report covers the special technical examination of the embankments along the Truckee Main Canal performed on **January 15-17, 2008**. The exam is being conducted because of the Truckee Canal breach that occurred January 5, 2008. This exam is to determine the existing condition of the canal and if, or under what conditions, the canal can be returned to service.

A thorough review of the canal embankments, while the Canal was dewatered, has led to the recommendation that the canal flow should be restricted and closely monitored until priority of canal repairs can be assigned and needed urgent repairs are implemented. The Regional Director shall approve, in writing, the restricted flow and any subsequent changes in flow must be approved in writing by the Regional Director.

The Truckee Carson Irrigation District is responsible for operating and maintaining the Newlands Project's conveyance, distribution, and drainage system serving agricultural lands in Lyon, Story and Churchill counties in Nevada. This technical exam generated several recommendations for consideration by the Regional Director to determine if, or under what conditions, the canal can be returned to service. This exam had a specialized purpose and is not fully consistent with the Review of Operation and Maintenance procedures for inspection exams. The findings and recommendations of this exam will not be recorded in the Dam Safety Information System (DSIS) system, although they may be used as guidance in future Review of Operations and Maintenance Exams.

Areas discovered and determined to be of special concern to the examination team are noted in the body of the report. As this exam covered the entire length of the Canal, Appendix A is a table of the observations made along the 30.8 miles of the Truckee Main Canal from Derby Dam to Lahontan Reservoir, with specific information about the type of issues encountered.

RECOMMENDATIONS

CATEGORY 1 TYPE RECOMMENDATIONS:

1-A The canal flow shall be restricted and closely monitored until priority of canal repairs can be assigned and needed urgent repairs are implemented. The flow restriction shall be approved in writing by the Regional Director and any changes in canal flow must subsequently be approved in writing by the Regional Director.

CATEGORY 2 TYPE RECOMMENDATIONS:

2-A Install mileage markers along the sides of the canal for easy identification of location during monitoring and inspection.

2-B Develop and implement a written Emergency Action Plan (EAP), for ensuring timely and correct responses and procedures, 24 hours 7 days a week for canal emergencies. Plan should include procedures for:

- Detecting and responding to various emergency scenarios such as flooding, canal leaks and sudden breaks, illegal dumping of barrels, trash, hazardous chemical spills, etc.

- Specific written procedures to effectively provide public warnings and notifications to emergency response agencies and media, District and LBAO management and maintenance personnel, to isolate and/or drain canal.

- Repair affected/damaged canal sections and structures according to design standards; and to obtain materials, equipment, specifications and procedures for conducting emergency repairs.

2-C Establish a prioritization system and develop a written Standard Operating Procedure (SOP), by stationing or milepost, for needed canal maintenance and repair based on the potential for and consequences of an embankment failure. Include both the left and right banks of the canal. Items to consider could include (but are not limited to):

- Population at risk of injury or death by a canal embankment failure

- Significance of damage caused by an embankment failure (including damage to homes, businesses, highways, railroads, utility failures, etc.)

- Height of embankment (elevation of top of canal freeboard above elevation of natural ground at toe of outer canal banks)

- Adequacy of the canal prism (shape of canal as seen in cross section) to prevent failure – including embankment width and freeboard

- Known problems which could cause a failure (such as, significant seepage)

2-D Repair the concrete lining damage at Stations 279+00, 291+00, 294+00, 300+00, 315+00, 320+00, 327+00, 346+25, 359+00, 519+50, and seal the cracks in the liner between Station 270+25 and 403+00.

2-E Set up a system at the Dog Kennel Seep to monitor for embankment movement progression and the stability of the area should be evaluated by a Geotechnical Engineer.

2-F Establish a program for the periodic removal and control of trees and other detrimental (bushy) vegetation.

2-G Remove from the interior of the canal prism, all soil debris, concrete debris and other debris with the potential to reduce the flow carrying capacity of the canal.

2-H Determine if the property owner at 75+50 to 80+50 is encroaching on the Federal Project land. If the property owner is encroaching on Federal Land, follow up with recommendation 3-A. At a minimum the drums containing potentially hazardous material must be removed from the influence of the canal.

2-I Perform needed maintenance and conduct a reassessment of the stability of the entire 1,600 foot long section of the south bank of Highway 95 West toward the TC-1 Head.

2-J Perform basic geologic mapping of the canal to obtain a basis of understanding about the native soils used in construction and where they are located along the canal and why some areas may be more susceptible to failures than others.

2-K Develop and implement a rodent control program.

2-L In accordance with the priorities established by 2-C, locate all holes (rodent/erosion) that protrude further than 2 feet into the embankment, as determined be the Area Office and fill all holes with suitable and properly compacted backfill material. Excavation may be necessary in areas where soil has sloughed or collapsed surrounding the void. Depending on the severity of rodent activity and soil type, an assessment should be made as to the viability of lining the interior channel prism.

2-M Investigate the cause and extent of saturated sections of canal embankments and implement corrective actions as required.

2-N Update the current monitoring program to include the newly identified seepage monitoring locations, areas with high concentrations of willows at the outer toe and the locations of all previous breaches. Seepage monitoring should include visual inspection for turbidity of the water, any rapid change in the size of a wet area, flow quantity or location of seepage. New seep locations are highlighted in Appendix A.

2-O In accordance with the priorities established by 2-C, remove all deep rooted trees including all dead trees and stumps from the canal prism, on the canal embankment and from within 15 feet of the outside toe of the canal embankment, including the root ball and reconstruct any remaining voids with properly compacted backfill, under the direction of a qualified engineer.

2-P Perform a crest profile survey to determine where settlement has occurred and whether or not adequate freeboard and adequate crest width are still available to prevent overtopping. Priority should be giving to those areas where populations at risk are present.

2-Q Obtain a copy of the local Property and Structures (P&S or structures list) maps spanning the length of the canal and ensure that the locations of all turnouts, takeouts, pipes, check structures, bridges, etc. are denoted on the maps. All abandoned and unauthorized structures should be removed from the canal.

2-R Prepare inundation mapping to determine the locations of populations at risk in the event of a canal failure. Maps should be developed using the worst case scenario involving the maximum designed capacity of the canal and uncontrolled release through a breach. Include the inundation mapping in the EAP developed with 2-B.

2-S Repair concrete lining damage at approximate Station 1630+10 and erosion of supporting foundation material for the concrete canal lining located at approximate station 1631+10, both upstream of Lahontan Check.

2-T In accordance with the priorities established by 2-C, re-establish the canal prism including suitable side slopes, crest width and freeboard height, including those areas where the canal prism has significantly changed due to bank oversteepening, erosion, or dredging operations.

CATEGORY 3 TYPE RECOMMENDATIONS:

3-A Develop and enforce a program to contact property owners placing any item including trash, personal landscaping, unauthorized fences, retaining walls, and canal take outs on property within BOR right of way and remove the items.

3-B Regrade both the operating roadway (generally left side) and the maintenance roadway (generally right side) to assure adequate travel for O&M equipment and activities, and to provide for proper drainage, such that the erosion of the canal banks are prevented.

3-C Ensure canal cleaning equipment operators are instructed as to the need for an inside canal sideslope and to be cautious not to oversteepen the slopes.

3-D Update all records to show that as-built cross sections for this canal do not exist. Design drawings are no where near the current condition of the canal.

3-E Efforts should be made to compile any available background information and make available during time of inspection, including:
- Surveys (anything depicting the current channel prism or profile)
- Soil Testing/Soil Type
- Operational Records (date, flow quantity, amount of available freeboard, etc.)
- P&S Maps showing the locations of all public utility, turnouts, takeouts, check structures, etc.
- As-built construction records for previous breach repairs and any embankment modifications (e.g. widening the crest adjacent to new developments in the community).

DEFINITION OF RECOMMENDATION CATEGORIES

Category 1 - Recommendations involving the correction of severe deficiencies where immediate and responsive action is required to ensure structural safety and operational integrity of a facility.

Category 2 - Recommendations covering a wide range of important matters where action is needed to prevent or reduce further damage or preclude possible operational failure of the facility.

Category 3 - Recommendations resulting in less important matters, but believed to be sound and beneficial suggestions to improve or enhance the operation and maintenance of the facility.

GENERAL INFORMATION:

The Newlands Project was one of the first Reclamation projects, providing a portion of the water from the Truckee and Carson Rivers in Nevada, for irrigating the lower Carson Valley in and around the city of Fallon. The drainage basin covers nearly 3,400 square miles with a combined average runoff of about 850,000 acre-feet.

Water is diverted from the Truckee River at Derby Diversion Dam into the Truckee Main Canal for irrigating the Truckee Division, and for conveyance to Lahontan Dam and Reservoir on the Carson River for storage. All water stored in the reservoir is for irrigation, and is released back into the Carson River either through Lahontan Dam or through Lahontan Powerplant, and then diverted into the "T" and "V" Canals at the Carson Diversion Dam (3 miles downstream) for irrigation of the Carson Division.

The District is responsible for operating and maintaining the large conveyance, distribution, and drainage system serving agricultural lands in Lyon, Churchill and Story counties in Nevada. The system consists of:

- Four diversion dams including Derby on the Truckee River, and Carson, Coleman and Sagouspe on the Carson River.
- Approximately 200 miles of canal including the 31 mile long Truckee Main and the A, D, E, G, L, R, S, T and V lines.
- 315 miles of open laterals.
- 370 miles of open drains.
- Four regulating reservoirs – Sheckler, Harmon, S-Line, and Old River.
- One hydroelectric powerplant at the 26-ft drop on the V-line canal
- Associated canal appurtenances – bridges, wasteways, check structures, turnouts, etc.

The District has been the O&M contractor for the delivery system for most of the years it has been in operation. The facilities were constructed between 1903 and 1915 and were transferred to the District contractually for O&M on December 18, 1926. In 1973, Reclamation provided notice to the District for termination of the 1926 contract. In 1983 the District Court allowed the Secretary of the Interior to terminate the 1926 contract, placing O&M responsibility with Reclamation. On February 14, 1984, Reclamation entered into a temporary O&M agreement transferring O&M responsibility back to the District.

On November 25, 1996 the current O&M contract was ratified between Reclamation and the District. The contract requires the District to accumulate an annual emergency fund with annual deposits or investments of not less than $20,000, until a minimum amount of $300,000 has accumulated, as further described in the contract. The District's current annual O&M budget is approximately $3.1 million.

This special exam reports the full list of deficiencies observed along the Truckee Main Canal in Appendix A. The items reported in the body of this document are locations that stood out to the team as having a high probability of significant damage to the canal. Due to the exorbitant amount of rodent holes, brush, trees and other contributing factors including lack of design criteria and inability to observe many sections of the embankment due to vegetation and debris, the list is not necessarily all inclusive. However, the examination teams did walk the 30 + miles of the canal in order to develop this list.

DATE OF THIS EXAMINATION

January 15-17, 2008

DATE OF LAST EXAMINATION

March 9, 2007 – Interim Review of Operation and Maintenance Report

EXAMINATION PARTICIPANTS

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DETAILS OF EXAMINATION

The exam was done January 15-17, 2008, under mostly clear skies. The temperature was in the low to mid 30's on each of the exam days. Trace precipitation was recorded during each of the three days leading up to the exam. The canal was dewatered to repair the breach in the city of Fernley.

FACILITIES EXAMINED

The special embankment examination of the Truckee Main Canal started at Station 0+00 (Derby Diversion Dam) and ended at Station 1638+00 (Lahontan Reservoir). Three independent teams worked on the inspection of the canal. The Derby team inspected the area from Station 0+00 to 543+10; the Fernley team inspected from Station 543+10 to 1126+40; and the Lahontan team inspected from 1126+40 to1638+00. Stationing was chosen to specify the locations along the canal as the canal is currently without mile markers or location identification. Recommendation **2-A** suggests mileage markers be placed along the canal for easy identification of location during normal monitoring and inspection.

Due to the breach in the Fernley reach of the Truckee Main Canal, recommendation **2-B** suggests an EAP be developed and written to ensure a 24 hour 7 day a week, timely and correct response and procedure plan is available. The plan should include detecting and responding to various emergency scenarios, written procedures to effectively provide public warnings and notifications to emergency response agencies and obtain materials, equipment, specifications and procedures for conducting emergency repairs.

The inspection found many deficiencies and did not have enough information to assign a priority to them. **2-C** recommends a priority system and written SOP for needed canal maintenance and repair be established. The priority system needs to take into consideration the consequences for embankment failure including population at risk and what damage may occur. The priority system should also take into consideration height of the embankment, adequacy of the canal prism and any known problems. Until priorities of the canal repairs are assigned and urgent repairs are implemented, recommendation **1-A** suggests a restriction on canal flow. The restricted flow shall be approved in writing by the Regional Director and any subsequent changes in canal flow be approved in writing by the Regional Director.

DERBY REACH

Areas Examined

The Derby reach started at station 0+00 (Derby Diversion Dam) and extended to 543+10 where the Fernley reach began. The entire examination was done from the left side of the canal and from the canal prism. The right side of the canal throughout the Derby reach was an extreme cut section and had no access to the right side. The tunnels were not inspected during this exam.

Concrete Canal Lining

The canal is concrete lined in some areas but much of the canal is unlined. The overall condition of the concrete canal lining is fair. There are locations where the canal liner has buckled and cracking is apparent. An area where the repair has been deferred is at 334+25 (**Photo D101**). At this location a major liner failure occurred and the section has been in disrepair for 10 + years. The damage occurs over 100 feet in length with voids behind the liner up to 8-inches. The original 1970's liner is about 3-inches thick and shows many signs of damage. The District's plan to repair this area is to replace the section with rip-rap. The failure has occurred because of a sideflow situation, it is believed using rip rap will prevent future failures. Recommendation **2-D** calls for repair of the concrete lining damage at Stations 279+00, 291+00, 294+00, 300+00, 315+00, 320+00, 327+00, 346+25, 359+00, 519+50 and sealing the cracks in the liner between

Station 270+25 and 403+00. The concrete liner between Station 270+25 and 403+00 is observed as being approximately 3 inches thick.

Canal Embankment

The canal embankments are considered to be in fair to poor condition. Several locations were observed as having signs of scarping, tree root damage, erosion damage, animal burrows, and rodent activity. Much of the Derby reach had crest widths of greater than 30'. The crest width was cautiously factored into the level of concern for an area with erosion, rodents, or other possible embankment failures. However, when sediment from the canal is removed, the spoil is often placed on the outer bank or on the crest at the top of the inner canal. The spoil then becomes part of the embankment but is not an engineered material.

Erosion

Erosion was a problem in several locations along the canal. The erosion occurred generally in locations where there was a low spot in the O&M road. At Stations 346+25 and 420+50 (**Photo D102**), the erosion cut deeply into the left outer bank. The crest width at 346+25 is 25'. Although a failure in this location may not lead to the immediate and obvious loss of property and life, the O&M road is in danger of being washed away.

At station 46+50 an eddy current in a bend of the Truckee River is eroding the left outer bank and undercutting the outside toe (**Photo D103**). The District intends to repair the undercut by placing 700 - 1000 cubic feet of material. The District has applied for and received the permits to work in the Truckee River.

Rodents

A large amount of the canal in the Derby reach of the inspection has concrete lining and rockier soils. Rodent holes were generally more prevalent in locations where vegetation was present. This was the case for the 3 mile section from station 0+00 (Derby Diversion Dam) to station 155+00. At station 84+00 there is a rodent hole 25-ft long near the high water mark on canal left where the crest width if 35 feet. This location is near where a resident lives along the canal and should be investigated further.

A change in the soil type started at station 525+00 and continued to station 543+10 where the Fernley teams' exam began. The soil consisted of more fines and was softer. There were several rodent holes throughout this section. At 530+25, a 10-inch diameter rodent hole measuring 15 feet deep into the embankment was located. The hole occurs near the high-water mark, and about 4 feet down from crest. The crest is approximately 100 feet wide at this location.

Seeps

The known seep locations referred to as Dog Kennel Seep and Pine Tree Seep were unable to be closely inspected for this exam. A dog at Pine Tree Seep did not appear friendly. Although dogs at Dog Kennel Seep were friendly, work was taking place at the residence. The Gay Seep was inspected and found to be dry. At station 162+00, Dog Kennel Seep, an approximate 100-ft section of the operating road above the seep has a low spot with several transverse cracks across the 11-ft wide asphalt cement pavement (**Photo D104**). A 30 ft± long segment near station 162+00 has longitudinal cracking, with the left canal, left crest portion showing differential settlement of the pavement. Inspection of the top of the canal liner behind this reach revealed a

40-ft long area where the embankment has pulled away and the void was filled with rock (**Photo D105**). The distance from the liner to the edge of the road is 30-ft. This area is directly above a private residence, it is recommended (**2-E)** that a monitoring system is put into place to monitor for movement progression and the stability of the area be evaluated by a Geotechnical Engineer.

Vegetation

The vegetation for most of the Derby section was limited to small willows and sagebrush. Recommendation **2-F** suggests establishing a program for the periodic removal and control of trees and other detrimental vegetation. It is important that the vegetation be controlled. It hinders the ability to inspect the embankments and contributes to embankment instability. The bushy vegetation and failure to remove the brush from the site provides a habitat for rodents. Station 431+50 is an example of the thicker brush found in the Derby section. It consisted mostly of four to seven feet tall sagebrush and is pervasive along both the inner and outer banks of canal left and right.

Flow Obstructions

At two specific locations, sideflow conditions are causing canal obstructions. The cut section side of the canal at Station 173+00 and 179+50 has soil debris deposited into the canal from a hillside drainage sideflow (**Photo D106**), diverting canal flow against the inner canal left bank. Recommendation **2-G** calls for the removal of all concrete debris and other debris from the interior channel prism with the potential to reduce the flow carrying capacity of the channel.

Encroachments

The property owner at 75+50 has a PVC pipe and pump for pumping from canal left inner bank. The shoulder of the O&M road is used as a storage area by the property owner. The amount of debris stored at this location is extreme (**Photo D107**). Potential hazardous materials are stored within a distance to the canal that could cause contamination of a public water supply. Recommendation **2-H** is to determine if the property owner at 75+50 is encroaching on the Federal Project land. If the property owner is encroaching on Federal Land, follow up with recommendation **3-A**. At a minimum the drums containing potentially hazardous material must be removed from the influence of the canal. Recommendation **3-A** suggests the development and enforcement a program to contact property owners placing any item including trash, personal landscaping, unauthorized fences, retaining walls, and canal take outs on property within BOR right of way and remove the items.

FERNLEY REACH

Areas Examined

The Fernley reach was primarily examined from the left (North) side of the canal, except for a section of the right (South) bank which was walked from Highway 95 West about 1600 feet. Due to heavy vegetation recommendation **2-I** suggests needed maintenance be performed and a reassessment of the section be conducted. The right side of the canal throughout the rest of the Fernley reach was a cut section with the natural land topography higher than the canal banks. Virtually no public land use appeared to be occurring along the right bank with the exception of those areas as noted in the table in Appendix A. Access to the right side of the canal through this

reach is limited. Terms such as many or numerous are used where there is such a high volume of occurrence that it would not be advantageous to list every observance. In these instances, the table provided in Appendix A should be referenced for detailed lists of each item.

Canal Embankment

The canal embankments are considered to be in fair to poor condition. The site orientation used while walking the embankments included Derby Dam (upstream), Lahontan Dam (downstream), and canal bank right (South) and canal bank left (North). Several locations were observed as having signs of scarping, sloughing, collapsed soils, soil saturation, tree root damage, erosion damage, animal burrows, and rodent activity. A reassessment will be needed of the stability of the entire 1,600 foot long section of the right bank from Highway 95 West toward the TC-1 turnout. This area was virtually inaccessible due to vegetation and exhibited numerous structural problems.

Erosion & Canal Lining

The canal is unlined through the entire length of the Fernley reach for the exception of few areas where cobbles are naturally occurring in the native soil type or that appear to have been dumped along the interior of the canal prism. Rough attempts to visually classify the native soils used to construct the embankments were made; however, no formal soil classification was performed. It is recommended (**2-J**) that geologic mapping of the canal be performed to obtain a basic understanding about the native soils used in construction of the canal, where they are located along the canal and why some areas may be more susceptible to failures. A preliminary best guess at the type of soil used is as follows:

Stations	Soils/Bedrock
Sta.540+00 - 574+00:	(CL)s (Lean Clay), SC (Clayey Sand w/ Gravel), SM (Silty Sand)
Sta.574+00 - 576+00:	Siltstone and Sandstone
Sta.576+00 - 610+00:	(SP)g (Poorly graded sands with gravel), GM (Silty gravel)
Sta.610+00 - 650+00:	Siltstone and Sandstone
Sta.650+00 - 710+00:	SP,SM,some GP (Poorly graded gravel) (Inside of canal is armored with gravel & cobbles)
Sta. 710+00 - 1100+50:	SP,SM,(GP)s,(GM)s
Sta. 1100+50 - 1120+70:	(GP)s, GM

Areas of the canal, particularly in sections where the canal is comprised of coarse-grained soil with gravels and cobbles, appears to be lined with cobbles and small boulders which are likely contributing to the prevention of significant scour and erosion below the water surface. Far less vegetation, rodent activity and other visible indication of deficiencies exist through these areas. Other areas comprised of more fine-grained soil, silty, sand, or clay soils are unlined and laden with rodent holes. Significant scour, erosion and oversteepening are concentrated through these areas as well. Significant loss of bank width combined with rodent holes can lead to failure of the embankment. An assessment should be made as to the best course of action for preventing potential piping or stability failure through these sections. Viable options may include some form of lining through these areas (concrete, aggregate, grouted aggregate, fabric, etc.), an aggressive rodent (**2-K**) and vegetation removal program (**2-F**), construction of a concrete cutoff wall through the bank, or some other means of preventing scour, erosion, sloughing, seepage, siltation and to deter rodent activity and vegetation growth. A bedding layer underlainment

should also be included in the design modification of the canal lining if this option is deemed most viable.

Erosion is a problem in several locations along the slopes of the canal along the shoulders of the crest. At station 692+65 the erosion cuts deeply into the left inner bank where the total bank crest width is 21 feet. A failure in this location could potentially lead to property loss as homes exist on the other side of the canal and the O&M road would also be in jeopardy. Deep erosion rills and channels are cut into the inside and outer banks of the canal which should be repaired **(2-L)**. Deep erosion channels can migrate through the canal and lead to overtopping failure at that location. A good grass cover or rock slope protection is most desirable for protecting the slopes from surface runoff erosion. Many areas, primarily along the stretch of canal from Highway 95 west to the TC-1 turnout, of the crest shoulders are collapsed into voids below the crest significantly reducing the crest width. This is primarily due to surface runoff percolating into either rodent holes or cavities surrounding root systems of trees and bushes.

The crest and side slopes appear saturated in localized areas along the length of the canal from Highway 95 west to the TC-1 turnout. This condition may be an indication of one or more possible issues: surface runoff is unable to properly drain from the crest and it ponds and saturates the material, the soil type is such that it retains high concentrations of water for longer lengths of time than soils immediately adjacent to those areas, or perhaps the entire embankment section is saturated indicating a more serious structural concern. The areas of concern falling within this category are flagged and noted on the spreadsheet as such. At flag #18 is an area where the crest exhibits a well defined dip in the alignment, is saturated, erosion is occurring on the inside bank, and willows line the inner and outer slopes. Another area from station 589+00 to station 590+56 exhibit saturated soils. Station 590+56 is the location of the old Carol Way breach area. These areas should be investigated as to the cause and severity of saturation and any issue resolved prior to placing significant loading on the embankment **(2-M)**. The crests should be graded to allow for proper drainage **(3-B)**, either crowned (slightly, not rounded) such that equal flows are transmitted to both the inner and outer slopes, or better should be graded to slope toward the inside of the channel which should be lined with coarse material to prevent erosion. Vegetation should be removed and erosion should be repaired.

Much of the inner canal embankment along the Fernley Reach is oversteepened. Some areas through the town of Fernley exhibit little or no inside slope for the entire height of the embankment. Vertical side channel banks comprised of this type of soil possess a far greater potential for sloughing and significant erosion which can deposit soil into the channel reducing the flow carrying capacity and can also lead to weakening of the embankment. Sloughing and erosion is evident along the length of the canal. Some of the oversteepening is due to sloughing; however, the most significant areas appear to be the result of cleaning operations, where the operator has cut into the bank trying to remove sediment buildup from the invert of the canal. Dredge operators should be advised to ensure at least a 1.5:1 side slope is left along the inside of the channel in order to prevent destabilization **(3-C)**.

Rodents

Several rodent holes from station 667+00 to 683+00 are coupled with heavy vegetation, particularly willows, on the crest and slopes of the right embankment. One hole measured from the inside face of the right embankment is at least 25 feet deep (total length of tape), 8 ft below crest, and 4 ft below the high water mark. At this location, the crest width is about 10 ft wide but is not level. Both inner and outer shoulders of the crest are highly rounded. Another rodent hole

at station 611+83 measured about 16 vertical feet into the outer shoulder of the embankment. A rodent hole at station 670+72 measured 12 vertical feet into the inside bank of the embankment, about 6 feet down from the crest below the high water mark. Another measured 12 vertical feet into the inside bank about 10 feet below the crest at station 788+00. These rodent holes were the deepest and most severe however many others protrude the core of the canal embankment and should be backfilled **(2-L)**. A rodent eradication program should be instituted and more notably, the vegetation creating an ideal habitat for the rodents should be removed.

Seepage

The known seepage locations within the Fernley Reach are referred to as the Ricci Lane Seep, and the Dave Stix Seep, which reference the land owner's property at these locations. Newly identified and existing areas should be closely monitored, especially during times when the canal contains flows above 350cfs. Three new seepage areas were identified during this examination which should be added to the District's existing monitoring program **(2-N)**. All three areas are directly above private residences and should be monitored for change in seepage conditions (e.g. turbidity of flows, amount of flow, size of wet areas, etc.) and movement among the slopes. The stability of the areas should be evaluated by a Geotechnical Engineer. The first area is located at station 562+46 where the homeowner reports flowing water from the canal, which fills the irrigation ditch adjacent to the property. Lush green vegetation could be seen at the toe of the embankment in this area. The other two areas are located downstream (East) of the breach area adjacent to a new subdivision. The crest of the left (North) canal bank was widened by the development contractor to about 35 feet wide. No construction details for the berms were available for review during this examination, but reportedly exist. Documentation of all construction records should be maintained and available for inspection of the facility (**3-D**). The soil type of the outer berm appears significantly less dense (soft, saturated soil) than the original canal embankment in this area. Willows line the outer bank toe and flowing seepage has been reported near station 740+10. Another visible seep is reported at the toe of the outer left bank about 2000 feet further downstream (station 756+60) in the same subdivision.

Many other areas were identified along the entire length of the Fernley reach where large concentrations of willows exist at the toe of the outer left bank. Willows typically thrive in soils with high water content and may be indicative of seepage through the embankment. Numerous areas are denoted (by highlighting in light turquoise) on the table in Appendix A. The willows in these areas should be cut and assessment made as to whether they are fed by potential seepage water or from surface runoff, drainage or irrigation ditches or some other means. All potential seepage areas should be noted on a map and monitored for seepage during times of flows above 350cfs in the canal. The locations of any visible indications of seepage should be added to the permanent seepage monitoring program.

The large cottonwood and other types of trees along the toe of the outer banks, may also be an indication of seepage through the embankment or foundation and should be removed. See discussion on vegetation removal.

Vegetation

Vegetation consists of single trees and groves of large cottonwood, elm, fir and other large trees on both the inside and outside banks and at the toe areas of both the left and right sides of the canal throughout the length. Willows are prominent on the outer bank, at the outer bank toe, and along the high water line on the inside bank. The locations of single trees and groves of trees are

noted on the excel spreadsheet included in Appendix A. The trees growing on the inside and outside banks of the canal prism may provide a seepage pathway through the embankment along the root systems and should all be removed, including the root balls **(2-O)**. Large trees can blow over during high winds and erode the embankment and potentially initiate a breach. Compacted backfill should be replaced within the remaining voids and all reconstruction should be accomplished under the direction of a qualified engineer. The large root systems and dead trees on any of the faces of the canal prism should be addressed by removal, including removal of the root ball and voids refilled w/ suitable compacted backfill **(2-O)**. Decaying root systems leave potential seepage pathways through the embankment. Special attention should be paid to those trees emerging from banks where the cross section has narrowed beyond design specification, as the entire embankment may have to be removed and replaced. Live trees should be removed from with 15 feet of the outer footprint of the canal banks.

From station 667+00 to 683+00, heavy vegetation, particularly willows, on the crest and slopes of the right embankment appear to be holding the embankment in place. The rounded crest varies from 4 ft to 12 ft wide. The minimum freeboard through this location is unknown; however, as indicated by a rim of vegetation, freeboard may be as shallow as 2 ft from the crest. Recommendation **2-O** suggests all vegetation be removed and any remaining voids in the soil should be engineered and filled with appropriate compacted materials. This 1,600 foot long area of concern includes large trees located on both the inner and outer banks of the canal.

Bushy vegetation (like rabbit and sage brush) is detrimental to embankment slopes as the root systems create seepage pathways into the slope, it provides an ideal habitat for burrowing rodents, but most importantly it obstructs good visual inspection of the slopes. Numerous areas of the banks of the embankments were not able to be visually inspected due to vegetation. There are many areas with high concentrations of rodent holes surrounding root systems from brush where the adjacent soils have sloughed or collapsed into the voids. A rigorous program for removal of bushy vegetation and other detrimental vegetation should be established and maintained at the canal **(2-F)**.

*Notes for recommendation **2-F**. Reclamation's "Guidelines for Removal of Trees and Other Vegetative Growth from Earth Dams, Dikes, and Conveyance Features" can be referred to in regard to the reasons for control and removal and recommended clearance zones from structures. The guidelines are included in Reclamation's Water Operations and Maintenance Bulletin No. 150, December 1989, which can be viewed at http://www.usbr.gov/pmts/infrastructure/inspection/waterbulletin/

Flow Obstructions & Overtopping

Low areas along the crest of the banks may pose the potential for overtopping in those areas. No channel cross sections are available, so the actual flow carrying capacity of the canal is unknown. The canal is reportedly designed for 1,000cfs; however, other reports indicate 1,500cfs. Without good as-built drawings, crest profiles and operational documentation including specific flow parameters and the amount of freeboard available at varying water levels, the true potential for overtopping is unknown. Recommendation **2-P** suggests a crest profile survey be performed to determine where settlement has occurred and whether or not adequate freeboard and adequate crest width are available to prevent overtopping. Recommendation **3-E** suggests efforts be made to compile any available background information and make it available during future inspections.

Sediment runoff and sloughing and slides from the embankment can decrease the flow carrying capacity of the channel. The district is doing a fair job of cleaning out areas where sediments accumulate and water ponds higher than the normal water surface. The inlet area to the check structure at station 849+00 should be cleaned.

Excessive runoff from the right bank and sideflow through breaches and drain pipes in the right bank could contribute to overtopping of the canal if not closely monitored. Two ponds are formed on the outside of the right bank at stations 658+00 and 895+10 which saturate the embankment material and may then become unstable and slough into the channel.

Other flow obstructions like concrete debris, trash and a floating dock (station 920+50) should be removed to ensure the full flow carrying capacity of the channel is maintained **(2-G)**.

Appurtenant Features

No map was available showing the locations of approved turnouts, takeouts, bridges, check structures, water lines and/or other utility lines through the canal. Many private residences had various forms of takeouts, pipes, siphons, hoses, etc., some of which may not have been permitted. A map denoting the locations of all approved structures should be prepared so that unauthorized or abandoned equipment may be easily located and removed. A property and structures (P&S) map reportedly exists which should be updated to reflect all current features entering the canal right of way **(2-Q)**. No gate tests of any of the check structures or turnouts were performed; therefore, the operating condition of the gates was not assessed. A general overview of the concrete structures was made and all appeared in satisfactory condition.

Encroachments

From TC-1 Head east to Highway 95, private residences abut the left and right embankments. The canal easement is reportedly 100 feet from the centerline of the canal; however, many property owners appear to be encroaching within the right of way. Access roads and stairways are built from yards up the outer bank of the canal to the crest. Fences and retaining walls are constructed at the toe and in some cases on the outer bank of the canal. Landscaping including irrigation systems, tree, and shrub plantings has been installed on the bank of the canal. In those instances where encroachment is an issue, the homeowner should be notified and steps should be taken to rectify the issue.

Due to the increase in residential populations along the canal, recommendation **2-R** suggests inundation maps should be prepared and included in the EAP. The maps should be developed using the worst case scenario involving the maximum designed capacity of the canal and uncontrolled release through a breach.

LAHONTAN REACH

Concrete Canal Lining

The Lahontan reach canal prism is generally unlined. However, at the downstream end of the section, from approximately the abandoned original penstock turnout for the Old Lahontan Powerplant (approximate station 1623+00) to the Lahontan Check (approximate station 1633+00), there is full height concrete lining on the left inside bank and partial height concrete

lining on the right inside bank. The concrete lining appears to be in generally satisfactory condition (Photo LL-30); however, a small section of lining failure has occurred at the base of the inner right bank at approximate station 1630+10 (flag LR-15) (Photo LL-31). The collapsed panel should be replaced to prevent erosion of the underlying bank materials. Additionally, erosion of concrete liner foundation material is occurring downstream at approximate station 1631+10 (flag LR-16). Repair at both locations is recommended **(2-S)**.

Canal Embankment

The Lahontan team examined their reach of canal (sta. 1126+40 to sta. 1638+00) by walking concurrently both its left and right sides, from upstream to downstream. Four individuals examined the left side and three individuals examined the right side. Generally the left side of the Lahontan reach has higher embankment heights than the right side, and can be generally characterized as the fill (or embankment) side of the canal; whereas, the right side of the canal can be generally characterized as the cut side of the canal. No significant residential or commercial developments or structures exist along the reach from Tedford Bridge downstream to Lahontan Dam. The left (North) side of the canal has some turnouts (both active and abandoned) and reported seep areas; however, no turnouts and/or prior reported seep areas are noted along the right (South) side. The left side has the main O&M road along the top of its embankment. The right side has a secondary maintenance road along its top.

Erosion / Rodents

The left or north bank of the Truckee Canal, proceeding from Tedford Bridge downstream to Lahontan Dam is in poor to satisfactory condition. Significant rill/runoff erosion (**Photos LL-2, LL-4, LL-5, LL-8, LL-9, LL-12, and LL-13**) with undercutting and oversteepening of the inner bank was observed down the majority of the 10 mile stretch of the canal to Lahontan Dam. This is primarily due to the non-cohesive nature of the soils of the canal embankment and lack of canal slope protection. Adding to the deteriorated nature of the canal slopes was extensive rodent holes (**Photos LL-1, LL-3, LL-5, LL-7, LL-8, and LL-10**) and several areas of willows and cotton wood trees (**Photos LL-6, LL-11, LL-14, and LL-15**) on both the inner and outer banks of the canal. The primary areas of immediate rodent and/or erosional concern on the left bank of the canal occurred at:

1) Station 1128+30 (flag LL-3) – Rodent hole – 5 feet down from crest, 3 foot diameter by 3 foot deep (**Photo LL-1**),
2) Station 1143+20 (flag LL-8) – Sloughing scarp on inner crest of bank, approximately 1.5 feet deep by 11.75 feet long, cutting into approximately a third of the bank (**Photo LL-4**),
3) Station 1199+70 (flag LL-13) – Rodent hole – 6 feet below crest and waterline, 2.5 to 3 foot diameter by 6 feet deep (**Photo LL-8**),
4) Station 1259+00 (flag LL-16) – Rodent hole – 1 foot below crest, 2 feet diameter by 2 feet deep (**Photo LL-10**), and
5) Station 1611+00 (flag 26) – Runoff/rill erosion on the inner bank – 10 feet long by 2 feet wide by 3 feet deep, with large voids forming, typically 3 feet diameter by 4 to 5 feet deep (**Photo LL-13**).

The sloughing scarp located at station 1143+20 (**Photo LL-4**) is of the most immediate concern and should be repaired as soon as possible. The scarp appears to have cut into approximately one third of the embankment. If the scarp were to fail, the bank could narrow enough to be a location for a potential breach to occur. The rodent holes (protruding deeper than 2 feet into the

bank) and erosional areas should be filled and compacted to prevent further deterioration and piping of materials which could lead to potential failure of the canal bank **(2-L)**.

On the right side of the canal there are extensive areas where the upper section of the inner bank is oversteepened. There are also numerous locations where surface runoff from the maintenance road along the top of the embankment has caused erosion of the inner bank, resulting in narrowing of the embankment width. There are several larger erosion "scarp" areas at the top of the inner bank. Some of these scarps are associated with tree growth on the inner bank. Recommendations **2-T** and **2-L** call for repair of the eroded areas. Recommendation **3-B** calls for regrading of the maintenance road to help prevent erosion of the inner bank due to roadway surface runoff. Cattle activity along the right side was also noted and is contributing to the inner bank erosion, but the impact currently appears minor. Regrading of the roadway per recommendation **3-B** should help to prevent continued erosional damage on the inner slope due to cattle activity.

On the right side of the canal there are two locations where very deep rodent holes were discovered at the inner bank. These are at approximate station 1137+30 (flag LR-1), measuring approximately 20 feet into the bank, and at approximate station 1140+30 (flag LR-2), measuring approximately 23 feet into the bank. There are numerous other random locations along the inner bank where rodent activity is occurring. In some cases depth of the holes into the bank varied from 1 foot to 8 feet deep. Recommendation **2-L** calls for repair of rodent holes and recommendation **2-K** calls for a rodent control program.

Vegetation

The observed areas of immediate vegetative concern on the left bank of the canal section are as follows:

1) Station 1157+10 (flag LL-11) – Large cottonwood trees growing on the outer left bank (**Photo LL-6**), and
2) Station 1612+40 (flag LL-27) – Large cotton wood trees growing on the inner left bank (**Photo LL-14**).

The large cotton wood trees growing on the inner left bank are of the most immediate concern (Sta. 1612+40) (**Photo LL-14**) and should be removed as soon as possible. The deep root systems for these trees can provide seepage paths which could lead to potential piping failure of the canal bank. All trees growing on the inner and outer banks of the canal should be removed, stumps and root systems should be grubbed, and the bank should be reconstructed with properly compacted materials under the direction of a qualified engineer **(2-O)** (**Photos LL-6, LL-14, and LL-15**). In addition, willow growth can be an indication of seepage and operators should continue to remove and maintain the brush to allow for proper observation of the canal banks **(2-M)** (**Photo LL-11**).

On the right side of the canal, stands of small trees (willows) are growing at various locations along the inner bank. Additionally, there are a few larger trees with trunk diameters of approximate 12 inches growing on the inner bank and a few large trees with truck diameters greater than 12 inches growing within 15 feet of the outer bank toe. These trees should also be removed, the stumps and root systems grubbed out, and the bank reconstructed in accordance with recommendation **2-O.**

Seeps

Four known seepage areas were pointed out by operators and observed along the left side of the Lahontan reach. All four areas were dry during this examination, with no indications of piped materials or boils. Operators indicated they monitor these areas for any significant changes in moisture, flows, piped materials, etc. Monitoring of these areas should be continued and any areas of heavy willow and/or vegetative growth (indicative of seepage) should also be included in the seepage monitoring program. No new seepage areas, other than areas of heavy willow growth (**Photo LL-11**), were observed during this examination. It should be noted that the canal was dewatered during this examination.

No known seep areas are reported to occur along the right side of the canal and no seepage areas were observed on the right side during this examination.

Flow Obstructions

No flow obstructions were observed in the Lahontan reach of the Truckee Canal during this examination. However, there were no provisions (such as underchutes, overchutes, or drain inlets) constructed along the right or uphill side of the canal to pass natural surface drainage from the right (south - uphill) side to the left (north - downhill) side of the canal. Generally, there are no significant impacts to the right side of the canal due to the lack of these drainage provisions. Surface water drainage appears adequately handled by some small amount of ponding to the right of the canal, natural infiltration into the ground, and evaporation of ponded areas.

Appurtenant Features

There were approximately 14 appurtenant features observed along the Lahontan reach. All of these features were given a cursory inspection for structural condition and any apparent erosion at or around the structures that could indicate potential failure of the structures and/or points of concern for piping or erosion of bank materials. Turnouts and diversion gates along the Lahontan Dam reach consisted of TC-11 (**Photo LL-16**), Mason Dam turnout (**Photo LL-17**), TC-12 (**Photo LL-18**), TC-13 (**Photo LL-19**), TC-14 (**Photo LL-20**), TC-15 (**Photo LL-21**), and Rock Ditch turnout (**Photo LL-22**). The metal work and concrete of all of these structures tends to be in fair to satisfactory condition with evidence of minor deterioration of the concrete and some rusting of the metal work. None of the gates were operated during this examination; however, TC-14 and TC-15 are abandoned structures. TC-15 has been grouted in from the downhill or outer side of the bank. The other structures encounter along the Lahontan reach consisted of the Mason Check Structure and Foot Bridge (**Photo LL-23**), Bango Road Bridge (**Photo LL-24**), Bango Check Structure (**Photo LL-25**), Bango Bridge (**Photo LL-26**), Cipoletti/V-notch Weir at Hazen (**Photo 27**), Railroad Bridge (**Photo 28**), and Highway 50 Bridge (**Photo 29**). All of these structures appeared to be in satisfactory condition with no evidence of serious deterioration, structural instability, or erosion around the abutments that could potentially cause failure of the structure, resulting in a breach or blockage of the canal channel.

Encroachments

No encroachments were observed during this examination, in or along the left or right banks of the Lahontan reach of the Truckee Canal.

Other deficiencies

A known minor sink area is located on the left outer bank of the concrete lined canal wall which discharges into Lahontan Reservoir (**Photo LL-32**). The area measures approximately 15 feet in diameter and 1 to 1.5 feet deep. Operators should continue to monitor this area for changing conditions, which could indicate a need for investigation and repair.
No other deficiencies were observed during this examination, in or along the left or right banks of the Lahontan reach of the Truckee Canal.

CONCLUSIONS

The special technical exam of the Truckee Canal did not find any locations where an obvious and immediate failure would occur if flow was allowed through the canal. However, the quantity of issues pertaining to vegetation, rodents erosion and seepage has created many areas where the potential for failure is high if the canal is returned to full service before a prioritized list of repairs is made and implemented. Recommendation **2-C** suggests a priority system for needed canal maintenance and repair be established. Until priorities of canal repairs are assigned and urgent repairs are implemented, recommendation **1-A** calls for the canal flows to be restricted. The restricted flow shall be approved in writing by the Regional Director and any subsequent changes in canal flow be approved in writing by the Regional Director

Recommendation **2-B** suggests an EAP be developed and written to ensure a 24 hour 7 day a week, timely and correct response and procedure plan is available. Due to the encroachment of urban populations along the canal it is crucial the facilities be maintained in a manner consistent with Reclamation Standards.