IRRIGATION TRAINING & RESEARCH CENTER

Flathead Indian Irrigation Project

Jocko Canal Unit Modernization

U.S. Bureau of Indian Affairs
Branch of Irrigation & Power

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JOCKO CANAL UNIT MODERNIZATION

The Jocko Canal Unit is an isolated service area in the southern portion of the Flathead Irrigation Project that supplies irrigation water to approximately 15,000 irrigated acres.

The operational challenges experienced by FIIP staff are largely systematic and inherent to the existing infrastructure. The following characteristics currently impede management and operations in the Jocko Canal Unit:

1. The lack of:
    a. Good flow measurement at key points in the system
    b. Well-designed, practical water level and flow rate control structures
2. Long main canals (e.g., S Feeder Canal, K Canal) characterized by significant lag time and the accumulation of flow discrepencies
3. Limited staff and budget to operate the many miles of small lateral canals
4. A large area of small fields south of the Jocko River, with specific issues:
    a. A lack of canal access, inhibiting adequate control and maintanenance
    b. Gravelly soils and excessive canal seepage
5. Numerous remote diversion points, such as the S Canal Diversion, that:
    a. Require field visits to monitor or to make gate adjustments
    b. Require extensive travel time to visit

Modernization Plan

This modernization plan addresses the challenges listed above through basin level and site-specific improvements, including:

- Constructing buffer reservoirs along the K and J Canals to capture canal flow rate surpluses for future redistribution when needed to make up for downstream canal deficits
- Dividing long canals (K, J, E, and S Feeder Canals) into two or more units to decrease operational complexity and provide for:
    - A “restart” of the canal flow rate back to the target flow rate
    - The capacity to direct canal flow rate discrepancies (surpluses and deficits), via interties and specific control strategies at bifurcations, to the two new buffer reservoirs along the K and J Canals for partial or complete correction
- Replacing miles of small canals and laterals with pipelines (e.g., R and K Canals) to simplify operations, improve service to farmers, and decrease operational losses (seepage and spill) for systems overlying gravel soils that have been difficult to control and access.
- Improving and properly configuring stream and river structures to maintain minimum instream flow rates while automatically maximizing diversions up to, but not over safe canal capacities.

Many of the proposed improvements illustrated in Figure 1 are also expected to benefit the Tribe by improving in-stream flow rates and downstream water quality.

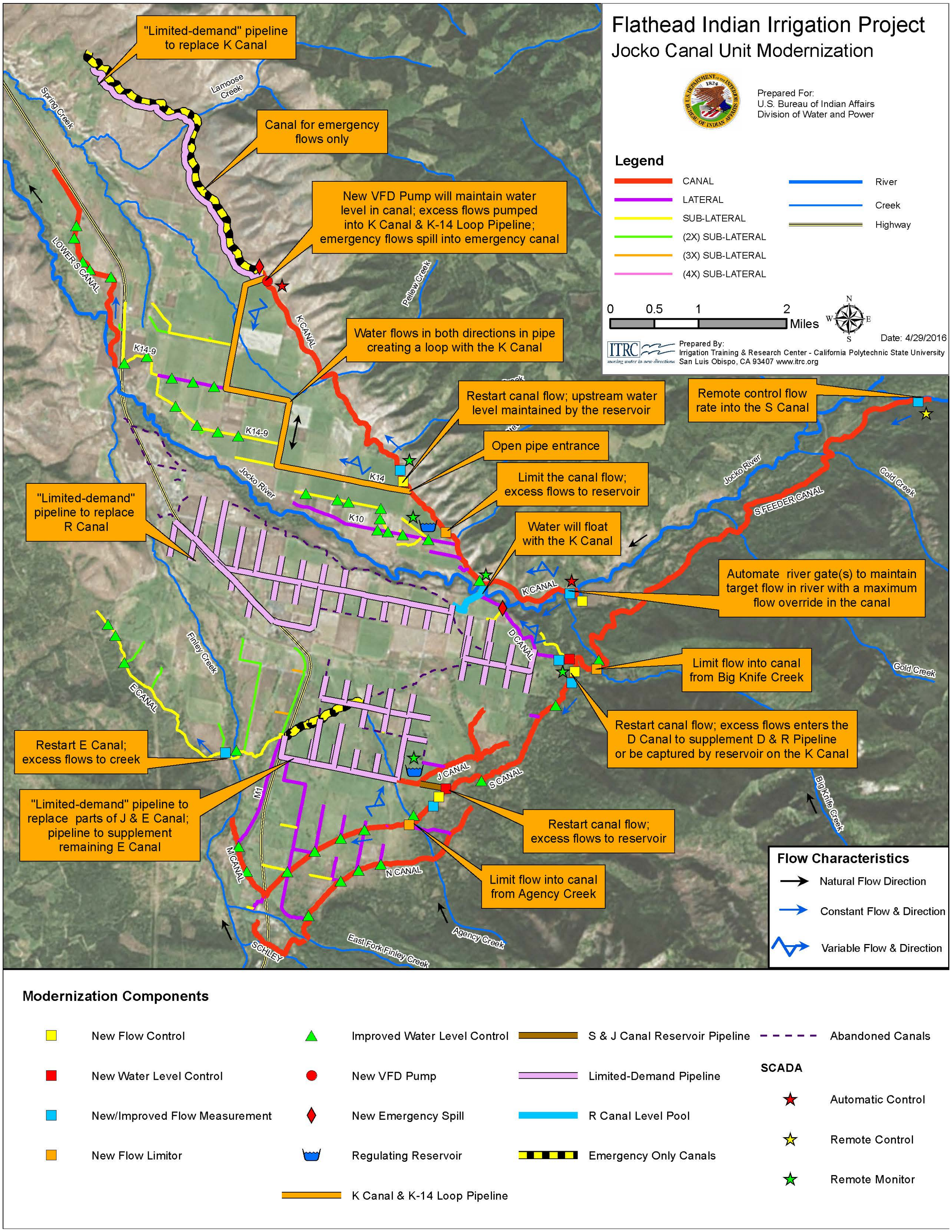

Figure 1. Proposed major improvements for the Jocko Canal Unit

The major proposed Jocko Canal Unit improvements are divided into four categories:

1. K Canal. The K Canal will be equipped with key structures to automatically absorb flow changes to/from the Jocko River, the R Canal, and the area traditionally served by the K Canal. Changes include:
    a. Switching the control strategy at the K Canal heading to provide automatic flow control of the Jocko River to direct the remaining Jocko River flows into K Canal.
    b. Installing a new limited-demand pipeline to replace the existing E and R Canals as well as provide an intertie to the D and S Canals. The intertie will direct excess S Canal flows into K Canal.
    c. Installing a new 80 acre-foot buffer reservoir to capture and reuse surplus flows. The buffer reservoir will supplement downstream demands as deficits occur.
    d. The very downstream end of the K Canal will be pipelined, to eliminate high occasional seepage losses that occur over a large distance to supply just a small acreage. This will also eliminate the maintenance requirements for that section of canal.
2. K14 Canal. The K14 Canal will incorporate a specially designed loop pipeline to provide very flexible service at the heads of sub-lateral canals.
    a. Installing a new K14 Loop Pipeline to provide pressurized water on demand to various K Canal laterals as well as provide a conduit for directing surpluses and supplementing water in both upstream and downstream directions.
    b. Installing a VFD-equipped pump and float valve at the northern end of the K14 pipeline. The float valve is intended to supplement downstream deficits and the pump will return downstream surpluses further upstream for reuse.
3. R Canal. The majority of the R Canal will be pipelined. A special feature will be that the inlet of the new pipeline system will have the same water surface as in the K Canal at zero flow. This will enable the R Canal to operate with a very high flexibility (called "limited rate demand"), because the R Canal will indirectly be tied into the new K Canal Reservoir.
4. S and J Canals. The S Canal will be modified to operate in shorter, more manageable sections. Key features will include:
    a. Remote monitoring and remote manual control of the S Feeder Canal diversion.
    b. Constructing a new flow control structure along K Canal at the D Canal heading to:
        i. Re-regulate S Canal flows
        ii. Direct surpluses to D Canal for use downhill in the present R Canal area
    c. Constructing a new S and J Canal buffer reservoir along J Canal to capture surplus flows for future reuse.
    d. Installing a new flow control structure along K Canal just downstream of the new S and J Canal Reservoir to re-regulate S Canal flows and direct surpluses to the new S and J Canal Reservoir.
    e. Abandoning the majority of the E Canal and repurpose the upstream sections for drainage.
    f. Installing a new limited-demand pipeline to replace various E and J Canal channels as well as the remainder of the E Canal.
    g. Creating a new level pool along E Canal just downstream of Highway 93 that is supplied by the new S and J Canal Reservoir and provides the target flow rate with little lag time.

K Canal Unit – Modernization Overview

An overview of the modernization components for the K Canal area is provided in Figure 2.

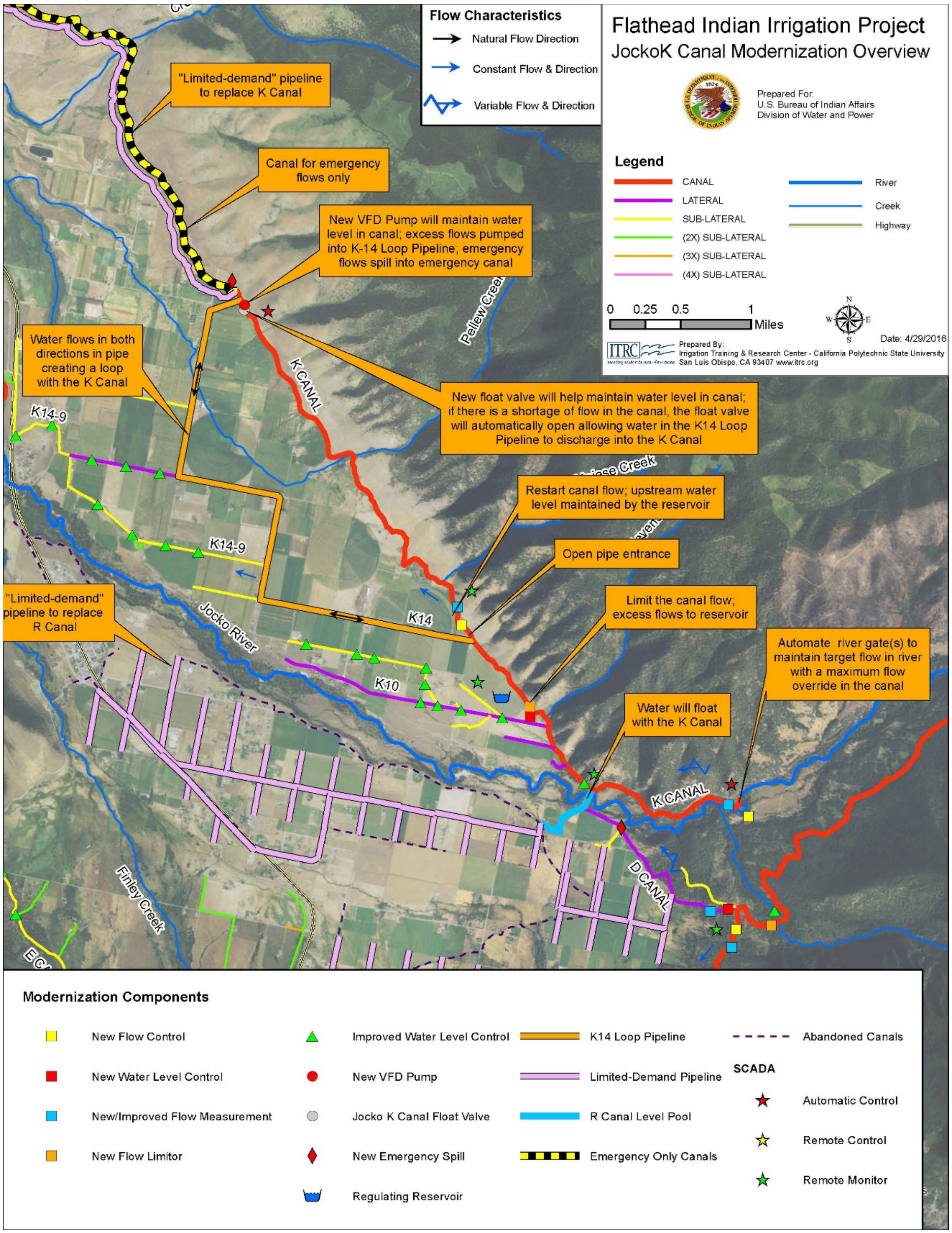

Figure 2. K Canal area modernization components

The modifications proposed at these various sites are intended to work cohesively as a larger operational unit as shown in Figure 3.

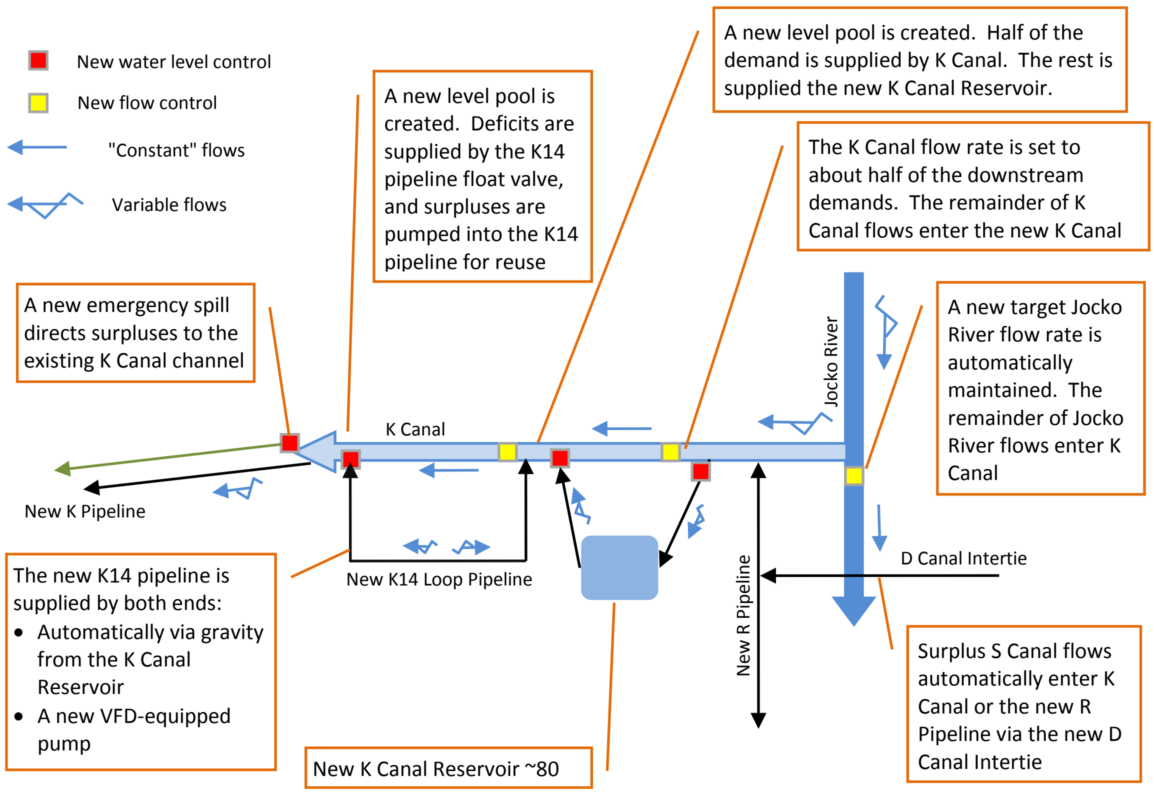

Figure 3. Schematic K Canal Reservoir system improvements

The major changes to the operation of K Canal after the modernization changes are:

- The target water depth in the reservoir is about half full.
- If the reservoir begins to fill, at least one of the following actions should be completed:
  - The Jocko River flow rate target at the K Canal heading should be increased to divert <u>less</u> water into K Canal. FIIP will have the capacity to make this adjustment remotely via SCADA or locally.
  - Decrease the S Feeder Canal diversion flow rate if significant inflows are measured from D Canal to K Canal. FIIP will have the capacity to make this adjustment remotely via SCADA or locally.
  - The options above all involve some lag time. If the scenario calls for less reaction time:
    - Turn off the VFD pump at the beginning of the K Canal pipeline.
    - Increase the flow rate down K Canal by adjusting the two new flow control structures.
- If the reservoir begins to empty, most of the available actions above would be reversed:
  - The Jocko River flow rate target at the K Canal heading should be decreased to divert <u>more</u> water into K Canal. FIIP will have the capacity to make this adjustment remotely via SCADA or locally.
  - Increase the S Feeder Canal diversion flow rate if capacity is still available in the D Canal Intertie pipeline to K Canal. FIIP will have the capability to make this adjustment remotely via SCADA or locally.

K Canal Diversion

The existing infrastructure at the K Canal diversion is listed below and illustrated in Figure 4:

- A structure in the Jocko River to raise the upstream water level (see Figure 5), composed of:
  - Two sluice gates, one of which feeds a simple fish ladder
  - Seven flashboard bays
- A large, new overflow fish screen (see Figure 6). Debris, fish and water that is not screened is returned to the river.
- Water passing through the fish screen flows downstream to a pair of open-geared sluice gates.
- The two sluice gates are adjusted to set the K Canal flow rate.

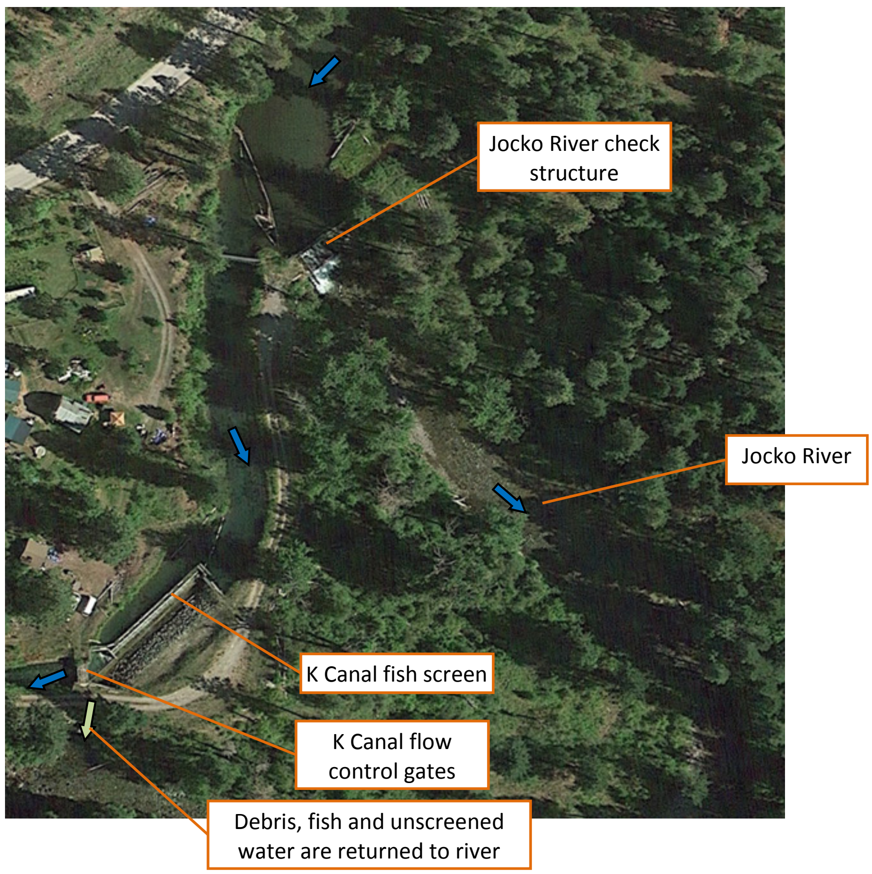

Figure 4. Overview of existing infrastructure at K Canal heading

Figure 5. Jocko River check structure at K canal, looking upstream

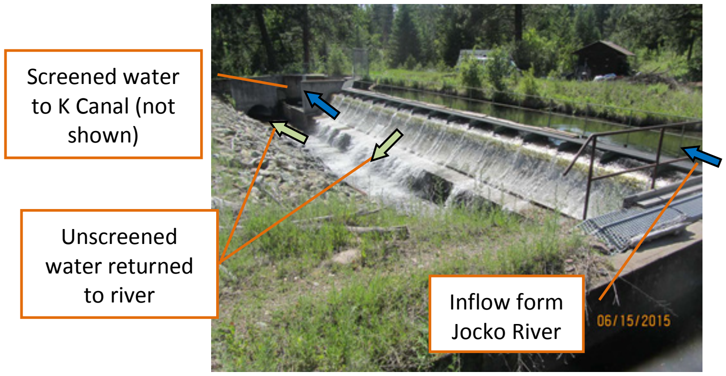

Figure 6. K Canal heading fish screen looking downstream

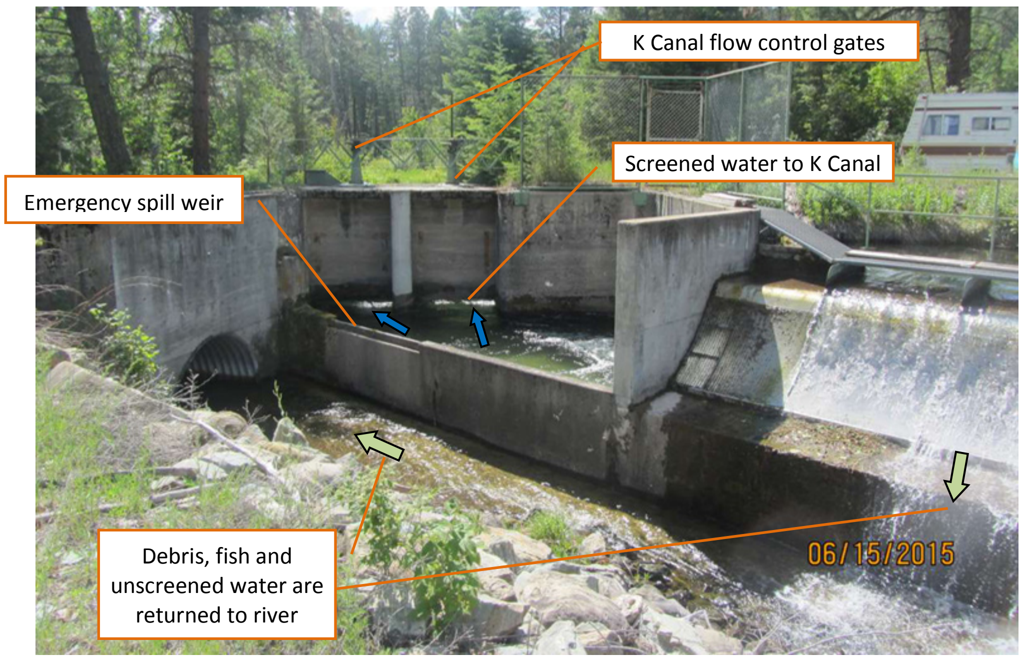

Figure 7. K Canal heading flow control gates looking downstream

While no fundamental flaws were identified regarding the existing structure configurations, the focus of the improvements at the K Canal heading is to amplify the anticipated benefits of modernization components at other sites.

The improvements proposed for the K Canal heading are shown in Figure 8 and listed below:

1. Remove the existing Jocko River sluice gates and two bays of flashboards. Install four new sluice gates fitted with electric actuators and adjust the flashboards to function as emergency spill weirs.
2. Install a new flow measurement structure approximately 400 feet downstream of the existing fish screen.
3. Adjust the existing K Canal flow control gates to manually limit the K Canal flow rate to a safe maximum.
4. Construct a short concrete or rubble "bump" to maintain submerged flow conditions on the downstream side of the new Jocko River sluice gates, for simpler flow measurement computations.

5. Establish a SCADA site to provide:
   - Jocko River flow measurement
   - Automatic flow control for the Jocko River to maintain a relatively constant target flow rate by adjusting the new sluice gate positions
   - Automatic override of the Jocko River flow control and alarm if the K Canal flow rate exceeds a safe, preset set point. The Jocko River gates would then transition to automatic K Canal flow control.
   - Supplemental monitoring information (e.g., battery voltages, gate positions, etc.)

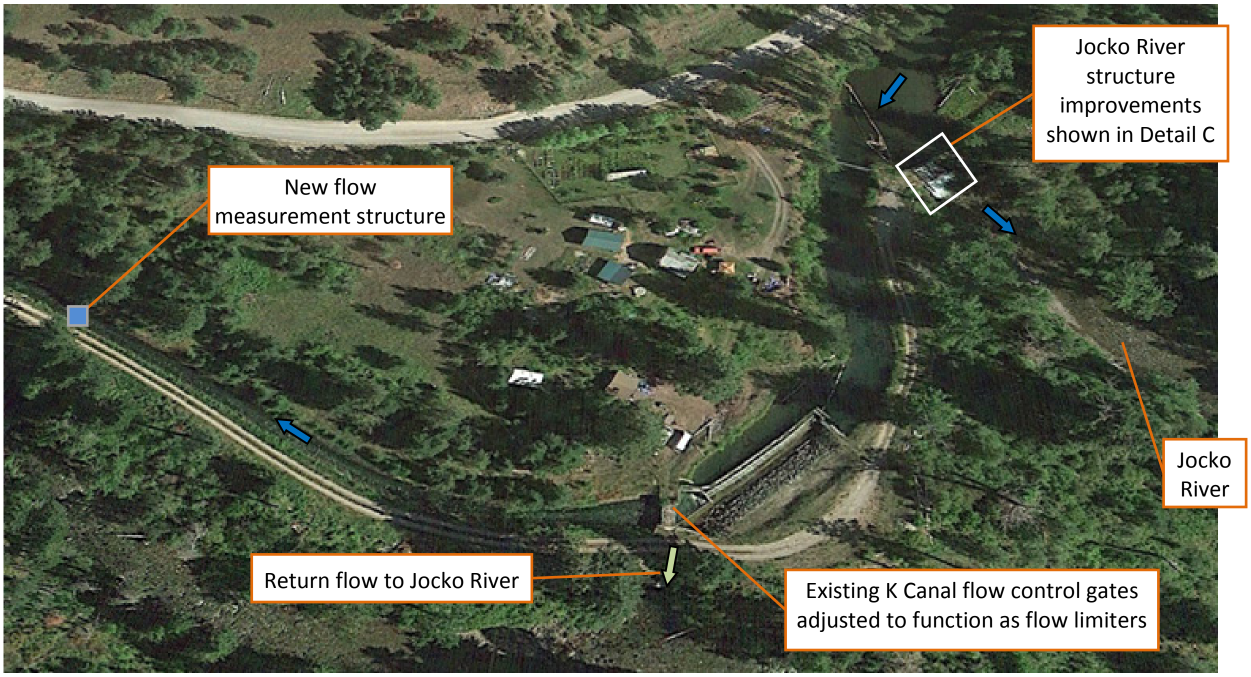

Figure 8. K Canal improvements at Jocko River, plan view

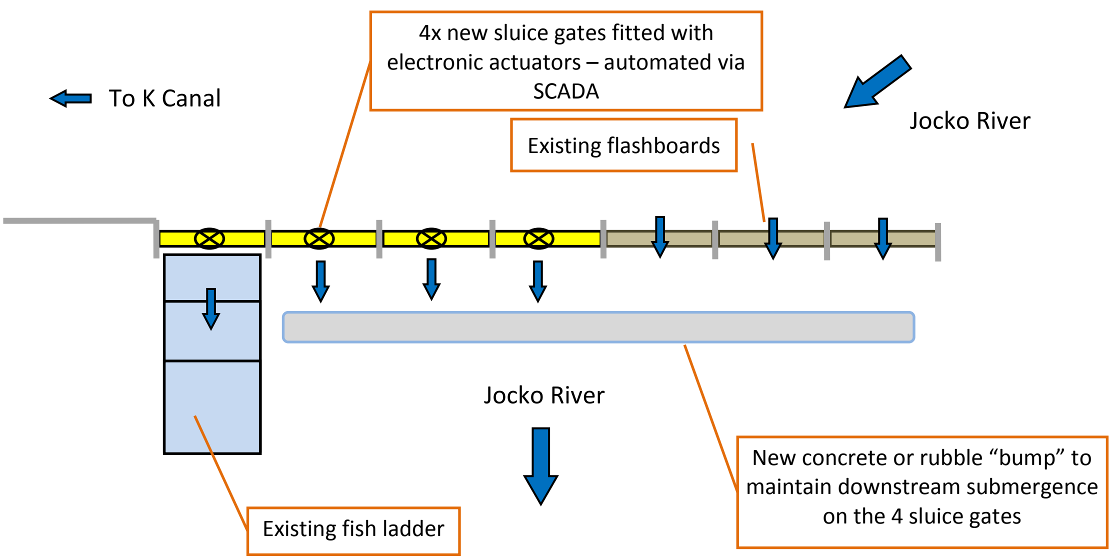

Figure 9. Detail C – K Canal improvements at Jocko River, plan view (not to scale)

The anticipated benefits of the proposed improvements are:

- Maximizing Jocko River diversions while simultaneously maintaining minimum environmental flows
- Automatic Jocko River flow control override to keep K Canal flows within safe limits
- Decreased labor and site visit frequency with automation and remote monitoring

K Canal Heading Operations Strategy

The control strategy for the K Canal heading with the proposed improvements is described below:

- The new sluice gates will be configured to automatically maintain a relatively constant target Jocko River flow rate. The target Jocko River flow rate set point will be adjustable remotely via SCADA or with a local user interface.
- Jocko River flow rate measurements will be programmed into the automatic control code using the sum of:
    - Submerged flow gate discharge equations
    - Flashboard weir flow equations
- The remainder of the Jocko River inflow is automatically directed into K Canal.
- The position of the two existing K Canal sluice gates just downstream of the existing fish screen will be initially set and left to limit the flow rate into the K Canal to its maximum capacity.
- If the Jocko River inflow rate continues to increase, causing the K Canal flow rate to near its maximum capacity, two things will happen:
    - Some of the Jocko River inflows will be automatically bypassed at the fish screen and return to the river. Similarly, water will begin to spill over the Jocko River flashboards.
    - The logic will automatically switch to override mode. The override control mode will monitor the K Canal flow rate at the new flow measurement structure downstream of the fish screen and adjust the new Jocko River sluice gates to automatically maintain a safe K Canal flow rate.

R, D and E Canal Improvements

K Canal supplies numerous smaller, but relatively long canals as shown in **Figure 10**.

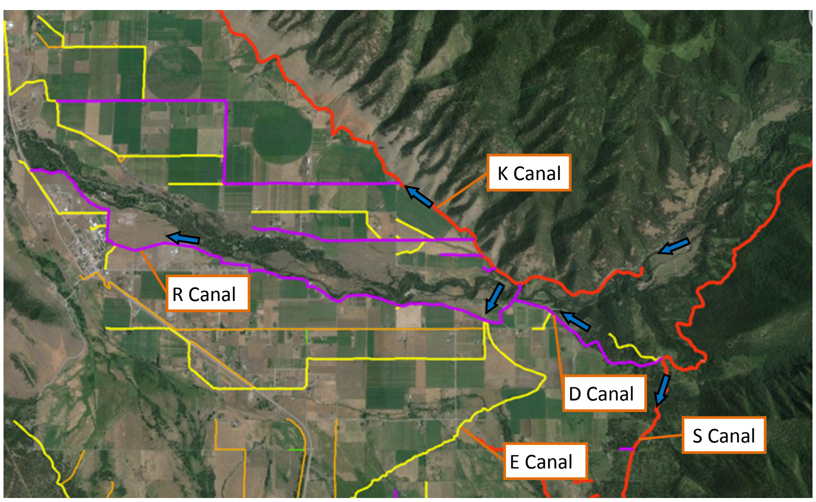

Figure 10. Existing R, D and E Canal alignments

Figure 11. Existing R Canal headgate and siphon entrance looking downstream

Figure 11 shows the existing R Canal headgate and siphon entrance. The existing infrastructure presents FIIP staff with the following operational challenges:

- The area is serviced by relatively long canals, leading to amplified lag time and flow rate uncertainties.
- Flow rate uncertainties are distributed among the canals, making operations difficult.
- Miles of small canals and laterals are difficult to access, control and maintain.
- Most of the canals lack good flow measurement and water level control.
- Additional water must be diverted to account for notable open channel seepage with local gravelly soils.

It is proposed to abandon the E and R Canals and laterals entirely. These open channels will be replaced by installing new limited-demand pipelines. There will be two new pipelines to replace E and R Canals and laterals:

1. R Pipeline – originates from the K Canal and replaces the majority of the acreage serviced by the R Canal.
    - A new long-crested weir (LCW) will be installed just downstream of the pipeline entrance in K Canal to better maintain the upstream water level for the R Pipeline.
    - An automatic trash screen will be installed in the level pool just upstream of the R Pipeline entrance.
    - The existing R Canal overshot head gate will be removed and the concrete box modified to function as an open pipeline entrance with improved air venting.
    - A new bi-directional flow meter will be installed to measure flow rates and flow direction between K Canal and R Pipeline.
    - A level pool will be created downstream of the R Canal siphon and upstream of the new limited-demand R pipeline:
        - The canal banks along the level pool will be raised so that the top of bank at the R pipeline entrance is at the same elevation as the top of the bank in the K Canal.
        - One foot minimum of freeboard is required in the level pool.
        - Bidirectional flow will occur in the level pool.
        - The existing flume that is located downstream of the siphon in the R Canal cannot be used for flow measurement because critical flow will no longer exist at that location due to the creation of the level pool.

2. D Pipeline – originates from the D Canal and replaces a small portion of acreage serviced by the E Canal.
    - A new long-crested weir (LCW) will be installed just downstream of the pipeline entrance in D Canal to better maintain the upstream water level for the D Pipeline.
    - A new automatic trash screen will be installed at the new D Canal Pipeline entrance.
    - A new flow meter will be installed to measure flow rates into D Pipeline.

Additionally, a SCADA site will be established to monitor:

- Inflows to R Pipeline from the K Canal
- Water level of the level pool
- Inflows to D Pipeline from the D Canal
- Supplemental monitoring information (e.g., battery voltages, etc.)

The modernization components listed above are shown in Figure 12 and Figure 13.

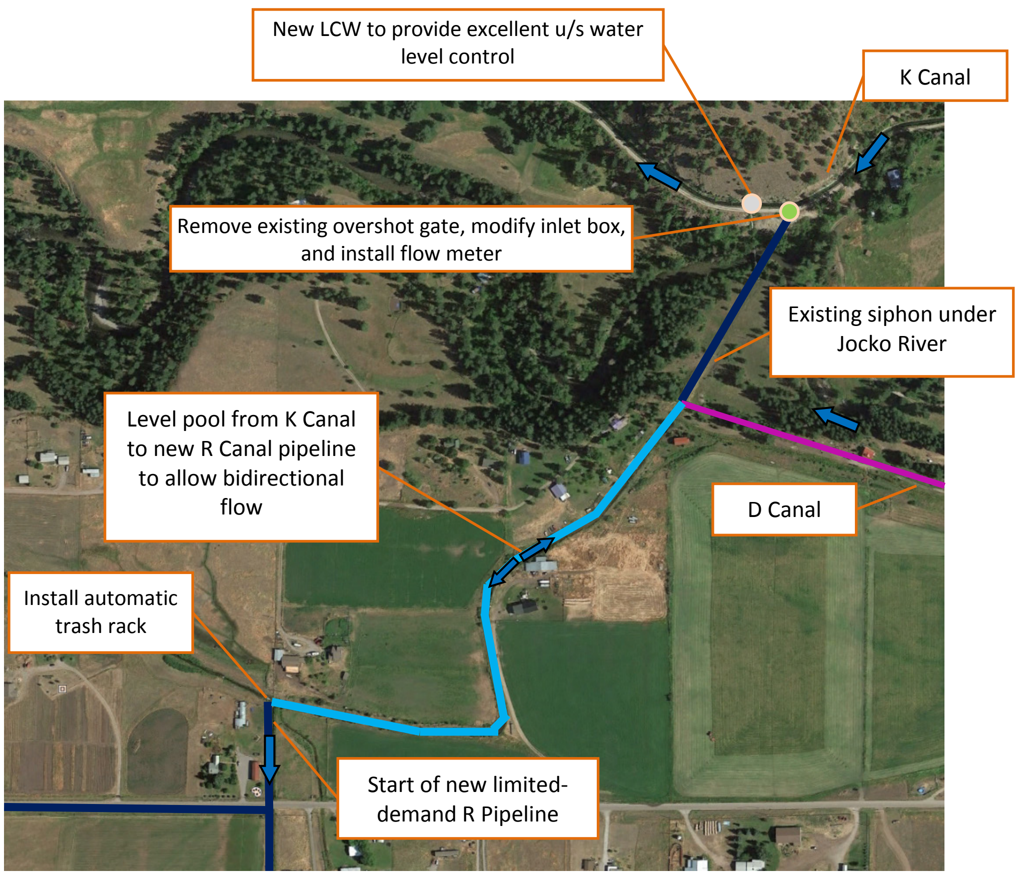

Figure 12. Modifications at the head of new limited-demand R Pipeline

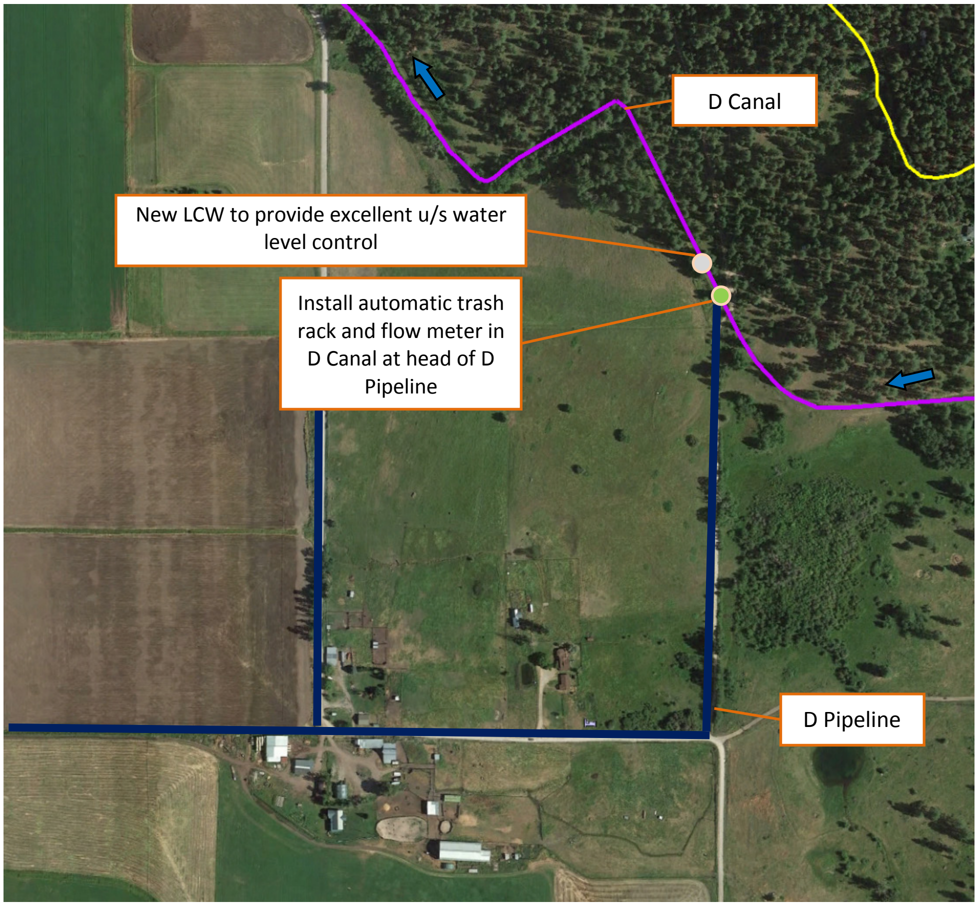

Figure 13. Modifications at the head of new limited-demand D Pipeline

R Canal Pipeline Control Strategy

The control strategy of the new limited-demand pipeline is generally automatic, except for periodic visits to clean trash from the sites' structures.

K Canal Reservoir

K Canal is relatively long, with no online storage. Furthermore, K Canal supplies a relatively large service area as shown in Figure 14.

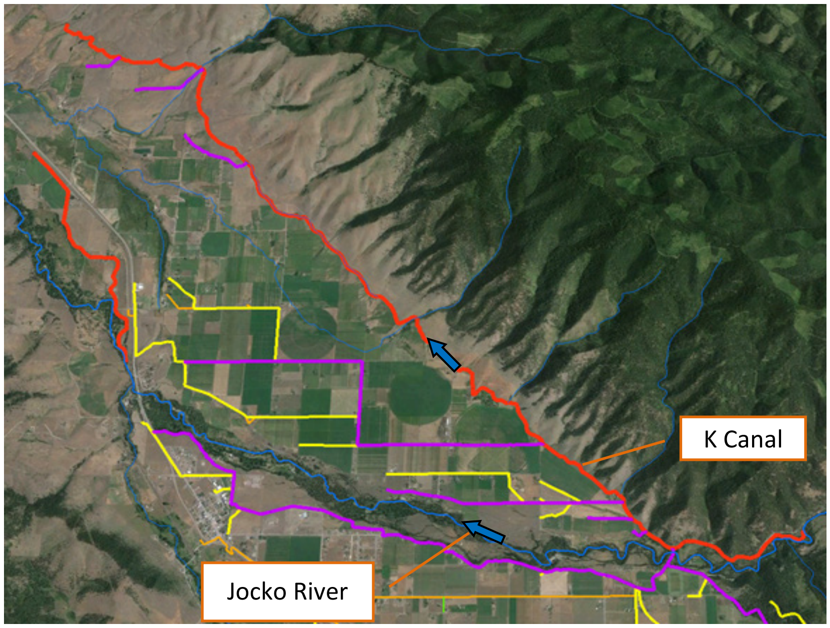

Figure 14. Existing K Canal alignment and laterals

The proposed modifications are listed below and shown in Figure 15:

- A new buffer reservoir will be constructed just downstream of Lateral K10. The preliminary storage volume is 80 acre-feet.
- A new flow control structure will be installed in K Canal about 1000 feet downstream of Lateral K10.
  - The flow control gate will be set to pass approximately 75% of the downstream canal flow.
  - The remaining flow will spill over a new long-crested weir (LCW) constructed just upstream of the new flow control structure and flow directly into the reservoir via a pipe.
- A second new flow control structure will be installed in K Canal, just downstream of Lateral K14. This will be the official flow restart point of the K Canal.
- A flow measurement flume will be installed downstream of the restart point and fitted with remote monitoring via SCADA.
- A short section of the K Canal upstream of the restart point will operate as a level pool.
- The level pool will be maintained by a float valve installed at the end of the reservoir discharge pipeline in order to maintain a constant target water level. The float valve will automatically regulate the discharge flow from the reservoir into the canal.
- The new K14 Loop Pipeline will divert water automatically from the level pool to supply the existing sub-laterals to the west. Water will freely move in and out of the pipeline with the reservoir automatically handling the flow rate changes.

The new K Canal Reservoir is shown in its preliminary location in Figure 15. Figure 16 shows the reservoir components.

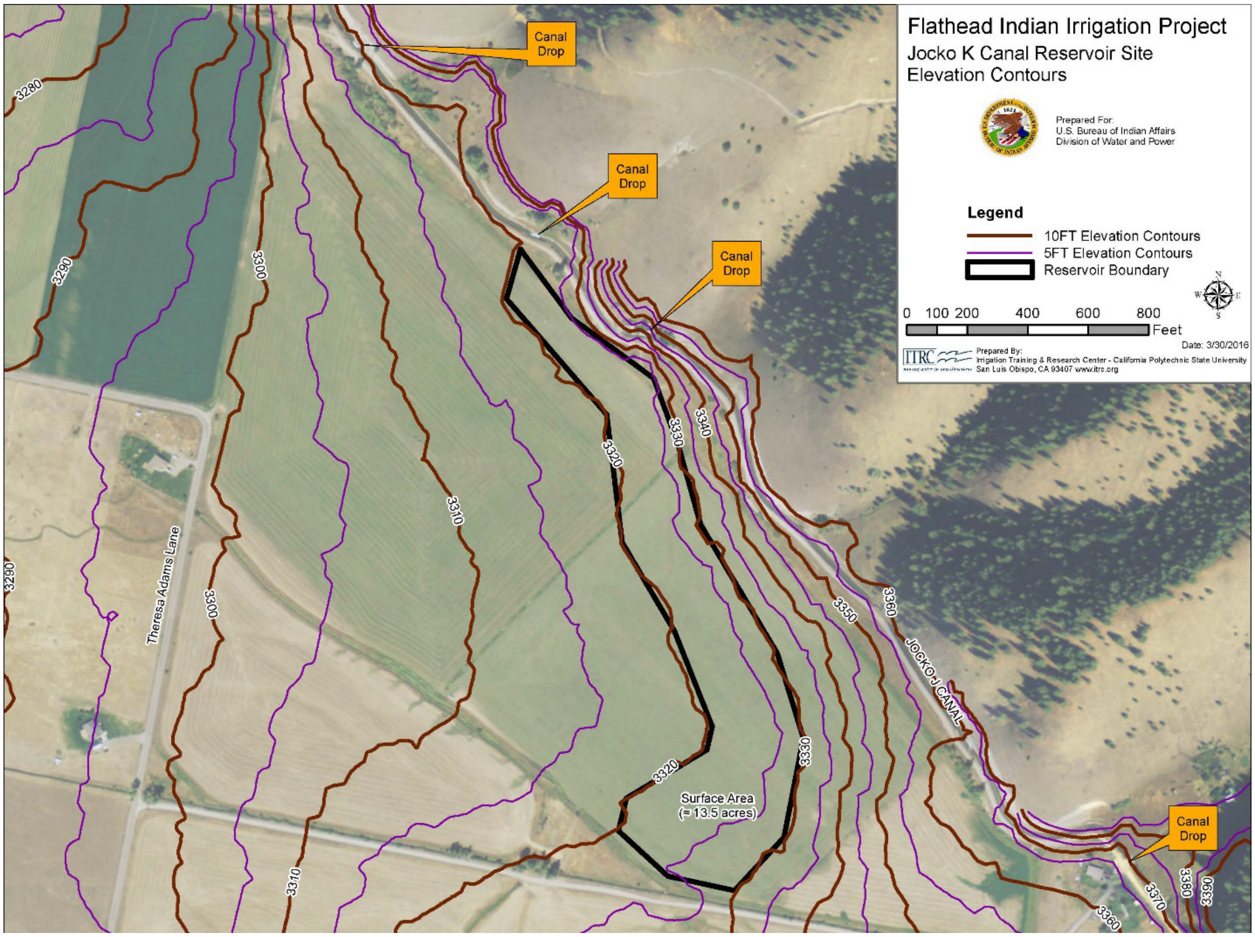

Figure 15. Preliminary K Canal Reservoir location and boundaries with elevation contours, plan view

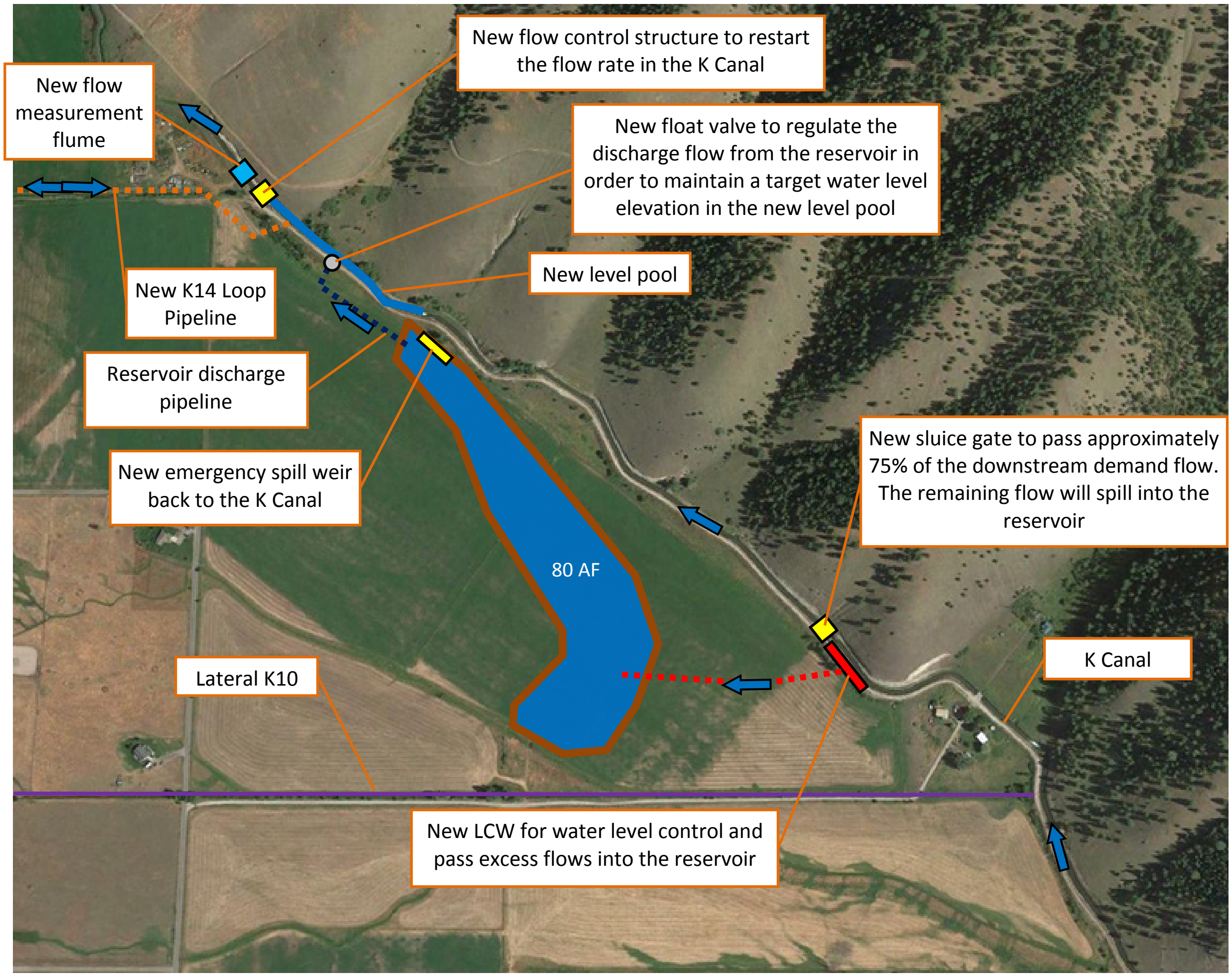

Figure 16. K Canal regulating reservoir operational components and strategies

The operations and control structures are illustrated in Figure 17 with the respective control devices.

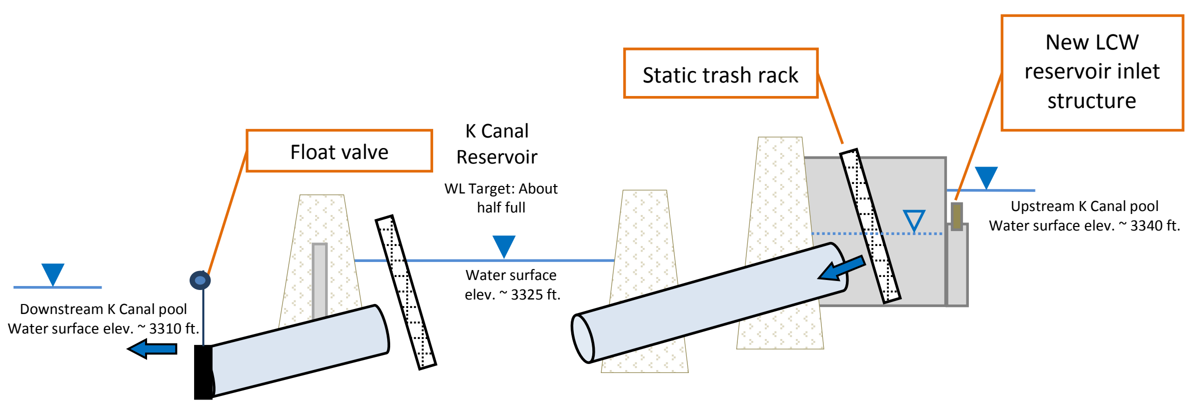

Figure 17. Conceptual S and J Reservoir control structures and operational description, elevation view (not to scale)

K14 Loop Pipeline and K Canal Pipeline

Figure 18 shows the proposed K14 Loop and K Canal Pipelines.

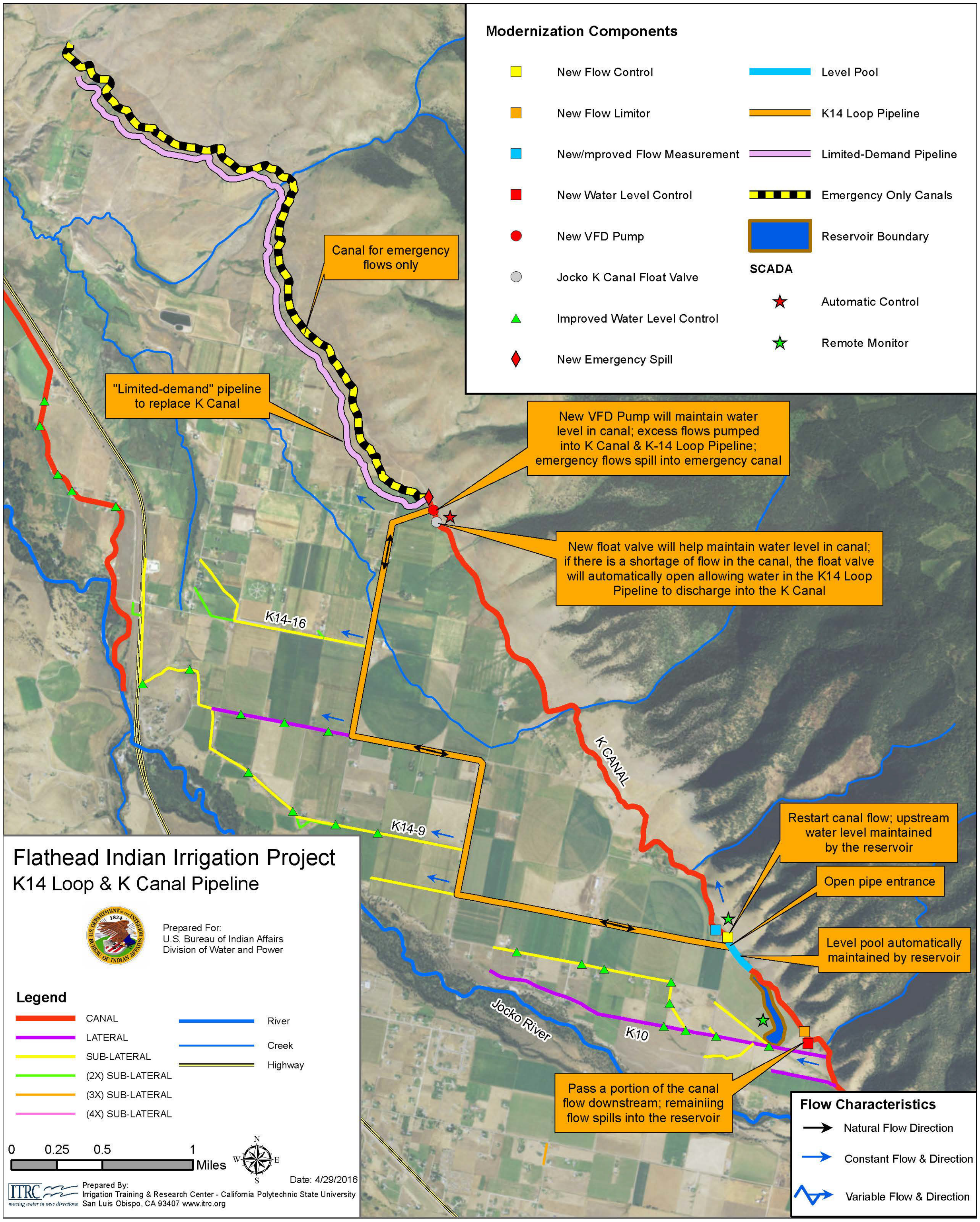

Figure 18. Proposed K14 Loop Pipeline and K Canal Pipeline

The modernization components and control will be as follows:

- The flow rate in the K Canal will be restarted at the new regulating reservoir.
- The last 3.5 miles of the K Canal will be replaced with a new limited-demand pipeline to service a small number of fields.
- A new K14 Loop Pipeline will be constructed to allow water to move back and forth from the new regulating reservoir and the end of the K Canal (just upstream of the new limited-demand pipeline).
    - Multiple existing sub-laterals will be serviced directly from the loop pipeline. The diverted flows to the sub-laterals will have the ability to be changed at any time.
    - A small level pool will be created at the northern end of the new K14 pipeline. The small level pool will directly supply the new K Canal limited-demand pipeline. The control of the new level pool will be as follows:
        - All excess flows in the level pool will be automatically pumped into a large standpipe attached to the K14 Pipeline. The pump will be equipped with a VFD and programmed for automatic water level control.
        - A float valve attached to the K14 Pipeline will automatically supplement flow to the level pool if there was a shortage of flow in the K Canal.
        - An emergency flap gate will be installed in the level pool to automatically spill emergency flows if the excess flows in the canal exceed the pump capacity.
    - Any excess flows that enter the K14 Pipeline will automatically flow back to the south and discharge directly into the level pool at the regulating reservoir. The reservoir will then automatically adjust its discharge flow rate into the level pool.
- The last portion of the K Canal will remain open in order to pass any emergency flows that may occur.

Not enough time was permitted to perform a hydraulic analysis of the K14 Loop Pipeline, K Canal Pipeline, and the K Canal Pump. Further investigation is need to determine if this a cost effective modernization option.

S Canal Unit – Modernization Overview

Modernization components in the S Canal Unit are shown in Figure 19 and will be operated as a distinct subsystem within the Jocko Area.

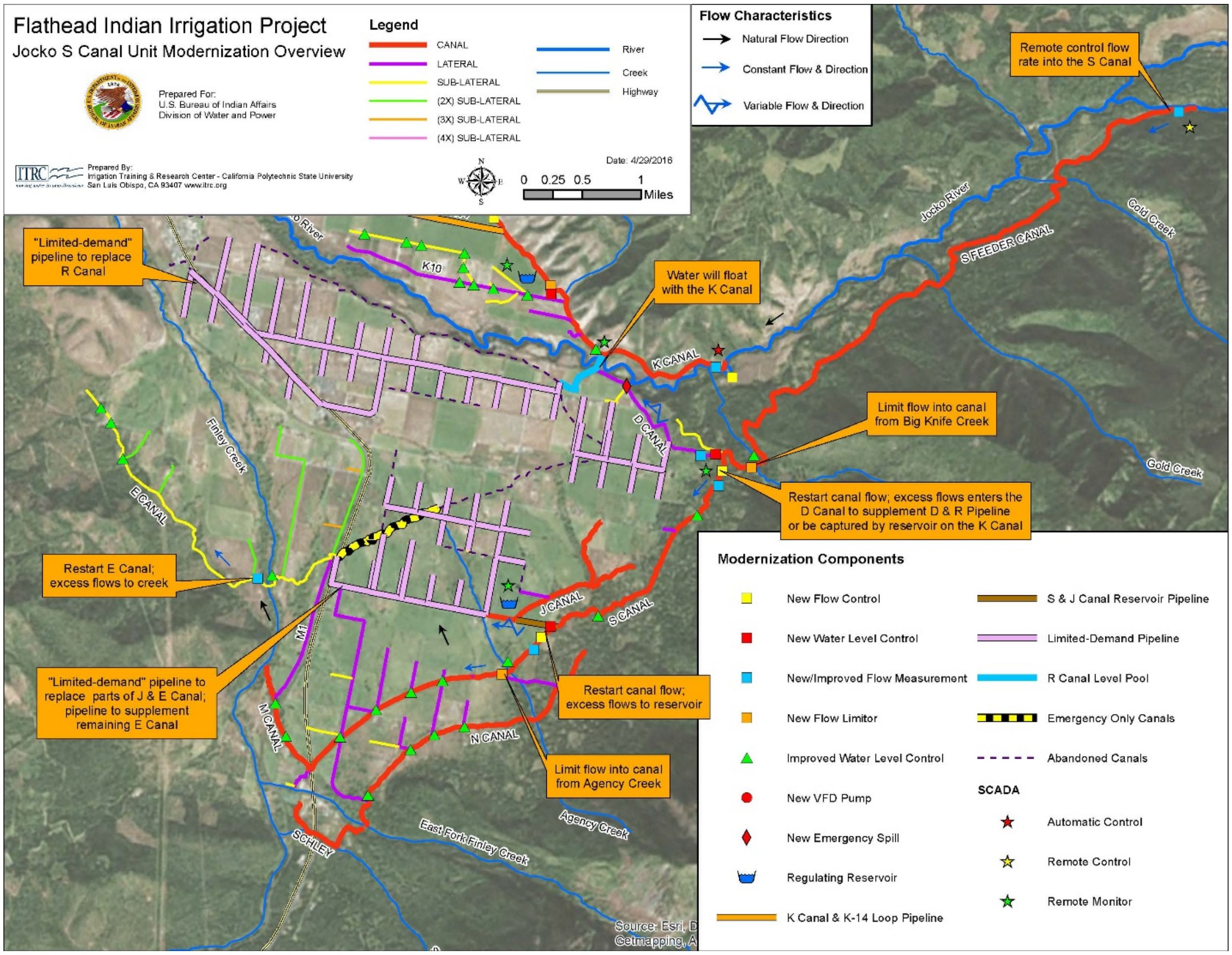

Figure 19. Jocko S Canal Unit modernization component overview

S Feeder Canal Diversion

Figure 20 and Figure 21 show the existing control components at the S Feeder Canal diversion on the Jocko River.

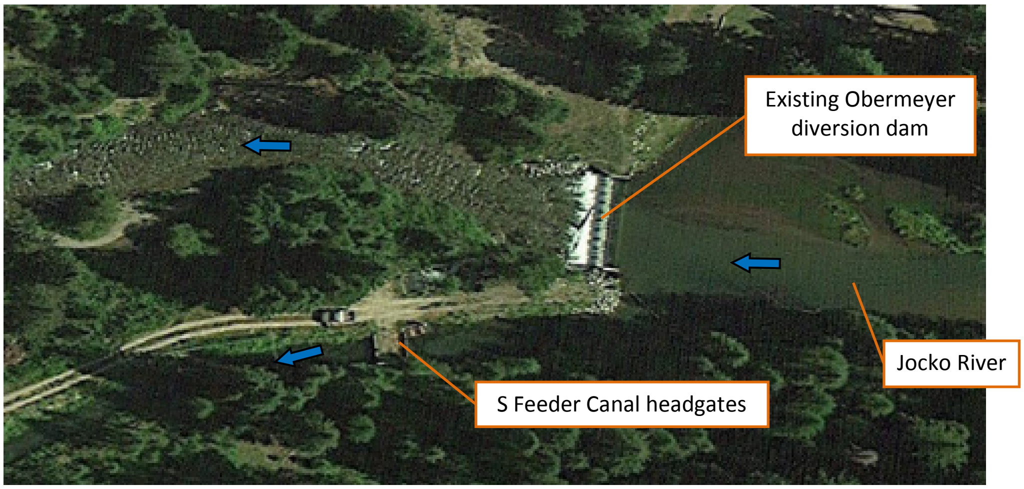

Figure 20. Aerial view of key existing control components at the S Feeder Canal diversion on the Jocko River

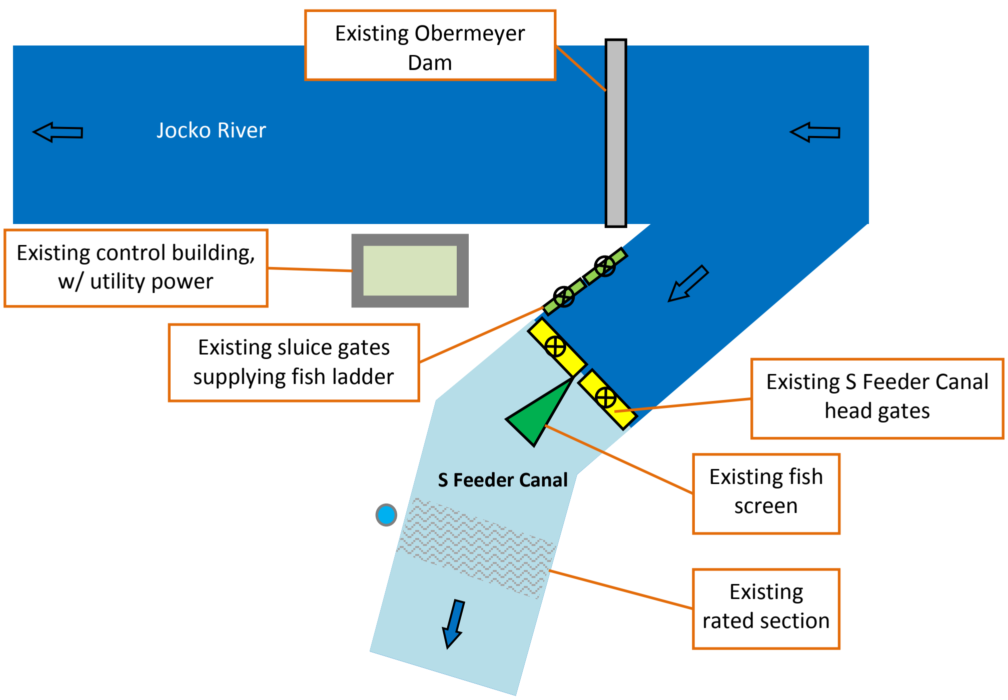

Figure 21. Existing S Feeder Canal diversion conceptual overview (not to scale)

The S Feeder Canal diverts water from the Jocko River. At this location the Jocko River is supplied by controlled releases from the Lower Jocko Reservoir and other streams. An inflatable Obermeyer dam, shown in Figure 22, raises the river water level just upstream of the S Feeder Canal Diversion.

Figure 22. Obermeyer dam in Jocko River just downstream of the S Feeder Canal diversion channel

The flow rate into the S Feeder Canal is manually controlled by adjusting the opening of two relatively new sluice gates, shown in Figure 23.

Figure 23. S Feeder Canal head gates on the right

Two additional sluice gates fitted with newer self-cleaning screens, located upstream of the S Feeder Canal, are shown in red in Figure 23. They are used to supply water to a fish ladder downstream of the Obermeyer gate.

Figure 24. S Feeder head gates (to the left) and the bypass gates fitted with screens

Site-Specific Challenges

The existing S Feeder Canal and infrastructure can be characterized by the following issues:

- It is unreasonable to expect FIIP ISOs to frequently visit the site to monitor river flow rates and make well-timed gate adjustments, due to the remote location. As such:
    - Opportunities to react to surges in river flow rate are missed; in some cases more water could have been diverted.
    - In other cases, too much water is diverted.
- Problems can only be identified during a site visit.
- FIIP staff report that the air compressor supplying the Obermeyer dam runs excessively.
- The existing gauging station requires periodic verification and adjustments to the discharge equation due to sedimentation and/or scouring. There is likely also significant delay between flow rate changes and a representative (stable) reading at the gauging station.

The site improvement recommendations are listed below and illustrated in Figure 25:

1. Abandon the existing rated section and install an improved flow measurement structure approximately 100 feet downstream to minimize the effects of upstream curves in the canal.
2. Establish a SCADA site, with the following other key points:
    a. The SCADA system would enable FIIP operators to remotely monitor key site parameters and remotely adjust both S Feeder Canal head gate positions.
    b. Satellite communication will likely be used to send monitoring data back to the office on an hourly basis; however, remote control commands would be executed immediately.
    c. Redundant sensors would measure:
        i. S Feeder Canal gate positions
        ii. Downstream water level for flow measurement
    d. Other monitoring information would also be sent such as battery voltages, and perhaps some basic information about the Obermeyer dam status (e.g., air pressure).
3. Diagnose and repair the Obermeyer dam control system and fix any compressed air leaks.

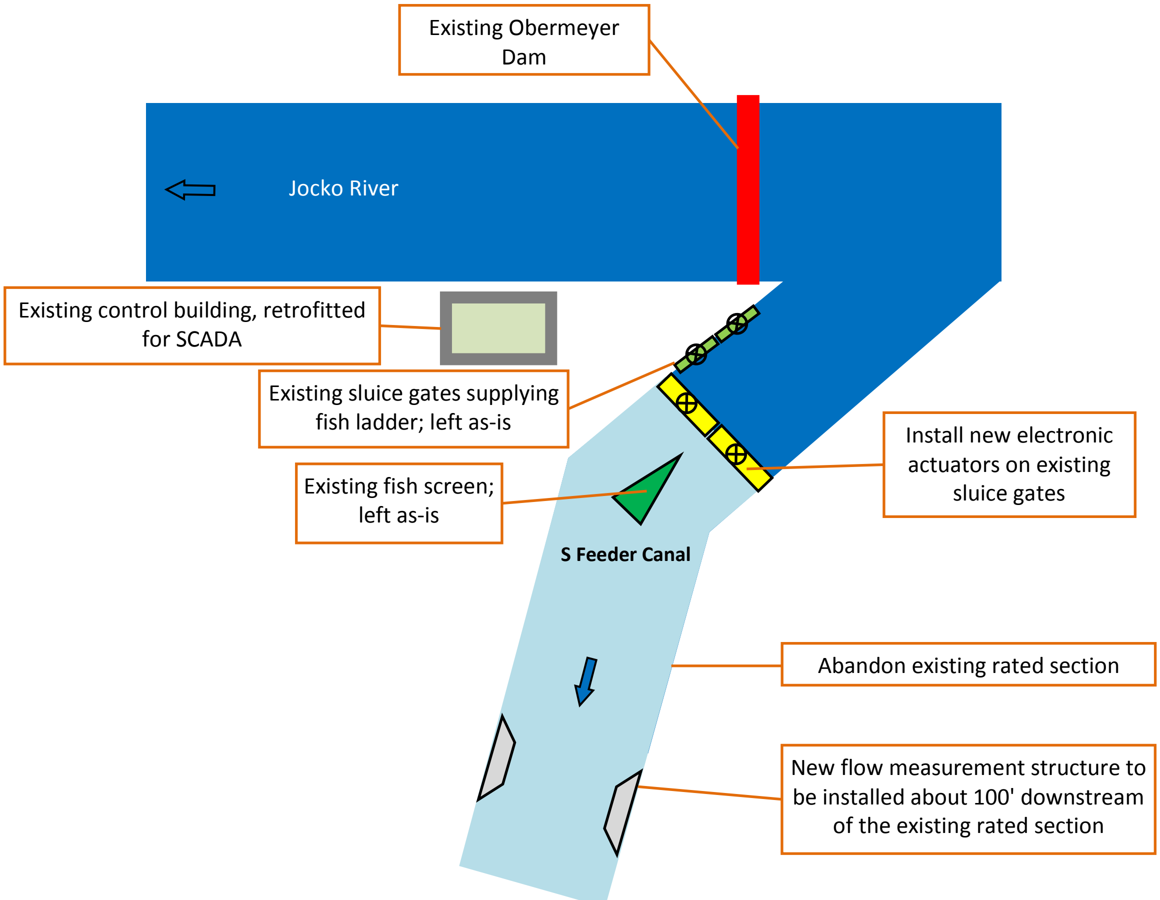

Figure 25. Proposed S Feeder Canal diversion improvements

The recommended improvements address the S Feeder Canal diversion site-specific challenges by:

- Minimizing delays in decision making and execution by providing remote monitoring and remote manual control capabilities
- Improving flow measurement accuracy and stabilization time, and eliminate continual adjustments to the flow measurement calculation

Control and Operational Strategies

The control and operations strategy with the proposed improvements is explained below:

- After an initial manual (remote, via SCADA or local) adjustment of the S Feeder Canal Diversion head gates, user-defined high and low diversion flow rate alarms would automatically notify FIIP staff of unexpected diversion flow rate changes. If properly configured, these alarms would indicate that a manual (remote, via SCADA or local) adjustment of the gate positions is necessary to bring the diversion flow rate back within a reasonable range of the target.
- The site would be visited once a week or more frequently to verify sensor readings and other critical systems.

S Feeder Canal at Big Knife Creek

At this site, water in Big Knife Creek flows directly into the S Feeder Canal. An overview of the existing control is shown in Figure 26. The basic configuration is fine, with the sluice gate controlling flow into the S Feeder Canal and flashboards to spill into the Big Knife Creek. The problem is that the spill is too small.

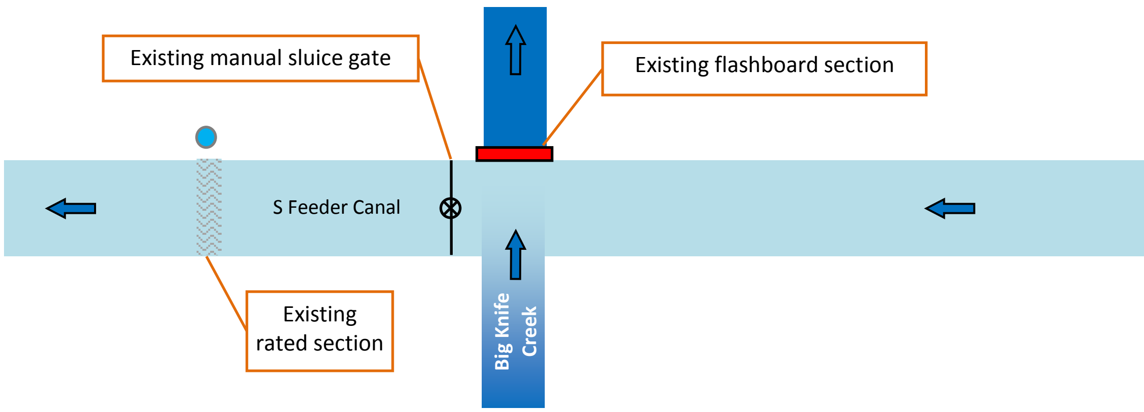

Figure 26. Existing conditions at S Feeder Canal at Big Knife Creek

Figure 27 shows the inflow of Big Knife Creek into the S Feeder Canal.

Figure 27. Confluence of Big Knife Creek and S Feeder Canal

Figure 28 shows the existing control immediately downstream of the confluence:

- An existing sluice gate restarts the flow rate to the downstream portion of the S Feeder Canal. The maximum capacity of the downstream portion of the canal is approx. 50 CFS.
- All excess flows pass over a flashboard structure back to Big Knife Creek.

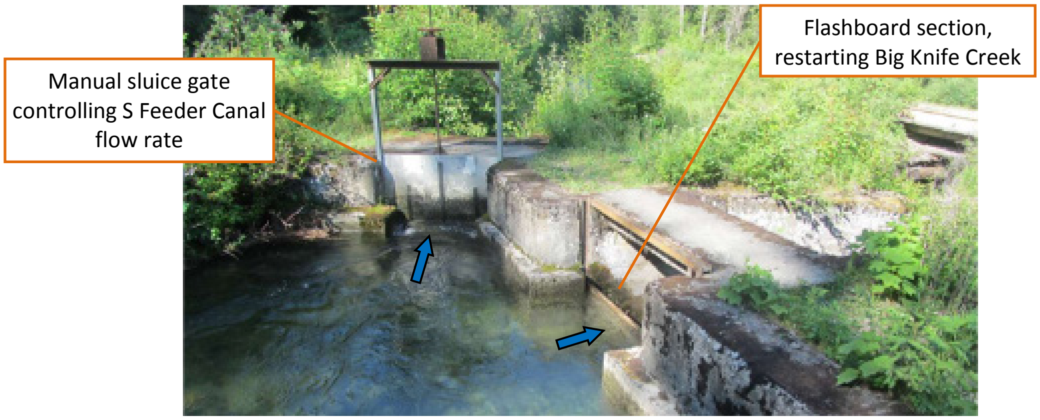

Figure 28. Existing control structures located at the confluence of Big Knife Creek and S Feeder Canal

Site-Specific Challenges

During snow melt and rain events in the early part of the irrigation season, up to 50 CFS can discharge from Big Knife Creek directly into the S Feeder Canal. The existing infrastructure is capable of easily handling the sudden flow increase which then affects the flow rate to the downstream portion of the S Feeder Canal.

During most of the irrigation season, it is in the interest of FIIP to:

- Maximize the use of inflows from Big Knife Creek to be used for irrigation.
- Maintain a constant instream flow rate to the downstream portion of Big Knife Creek.
- Automatically handle all storm flows without having a negative effect on safety or on the flow rate diverted to the downstream portion of the S Feeder Canal.

Recommended Control Improvements

Figure 29 shows the new control components and operational scheme for the S Feeder Canal at Big Knife Creek.

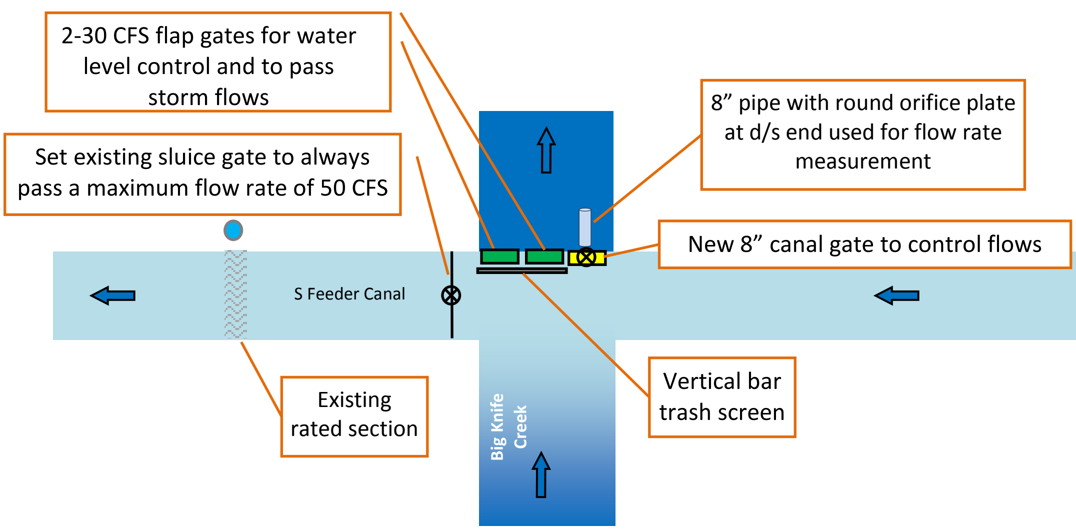

Figure 29. Conceptual overview of improvements for the S Feeder Canal at Big Knife Creek (not to scale)

The new control components and operational scheme include the following:

- The existing sluice gate in the S Feeder Canal will be set to always pass a maximum canal flow of 50 CFS to the downstream canal.
- A new concrete structure (see Figure 30) will house two new 30 CFS flap gates that will:
  - Maintain a fairly constant upstream water level in the canal if the flow from Big Knife Creek gets too high, maintaining a maximum flow of 50 CFS though the existing sluice gate to the downstream portion of the S Feeder Canal.
  - Automatically pass all canal or storm flows that exceed 50 CFS back to Big Knife Creek.

An 8" canal gate will continually discharge environmental flows into Big Knife Creek. It will have a 10' length of 8" pipe extending from the structure, with an orifice plate on the end of it. By measuring the water depth just upstream of the orifice plate, the flow rate will be known. This is similar to what is recommended for the Camas River diversion structure.

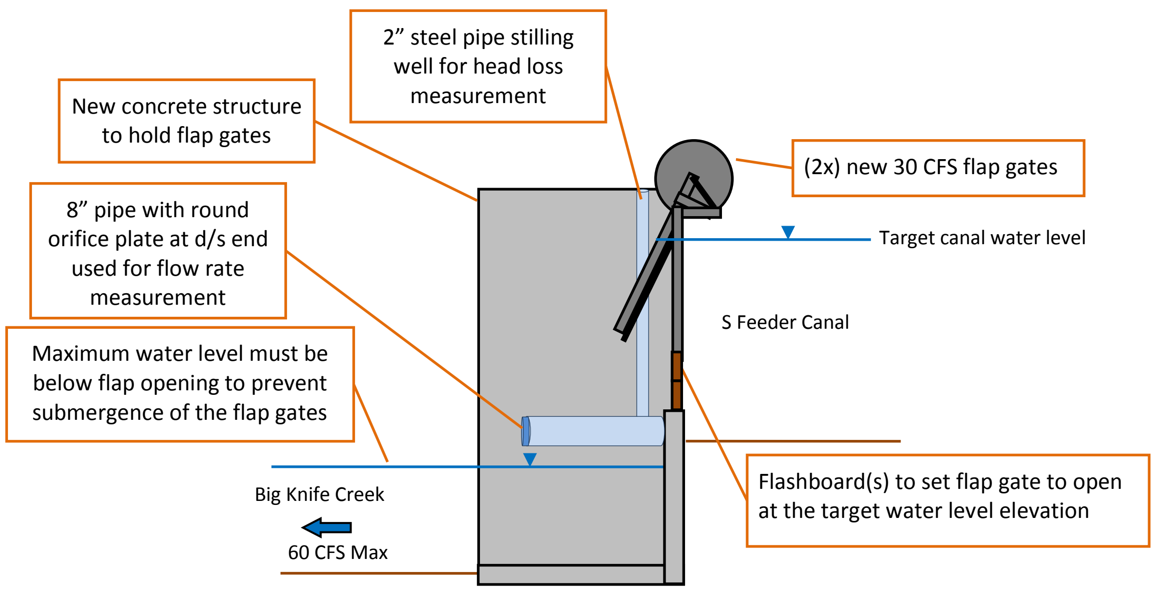

Figure 30. Conceptual side view of new flap gate spill structure (not to scale)

D Canal Heading along S Feeder Canal

The D Canal heading is located approximately 2,200 feet downstream of the confluence of Big Knife Creek and S Feeder Canal. A plan view of the D Canal heading is shown below.

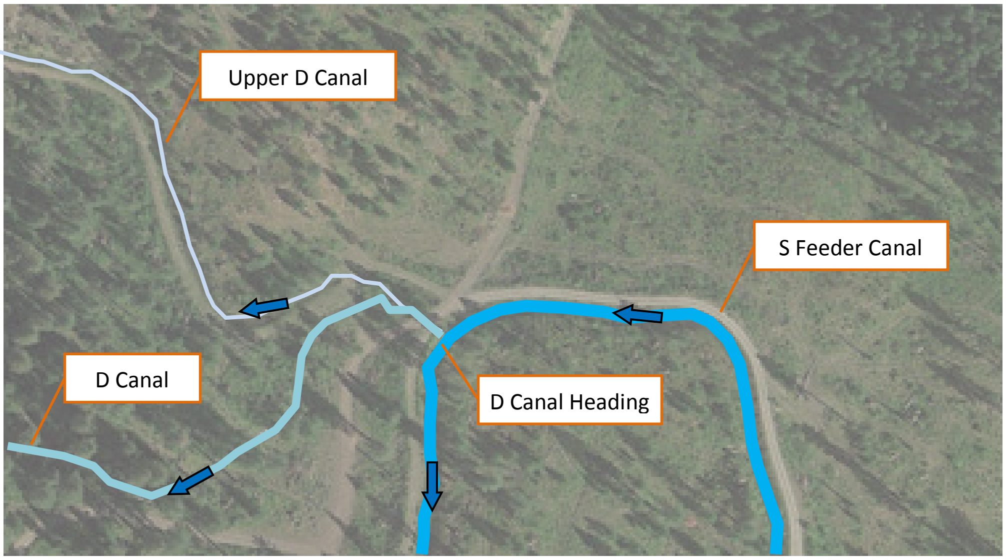

Figure 31. D Canal heading along S Feeder Canal – plan view

The D Canal heading is shown in Figure 32.

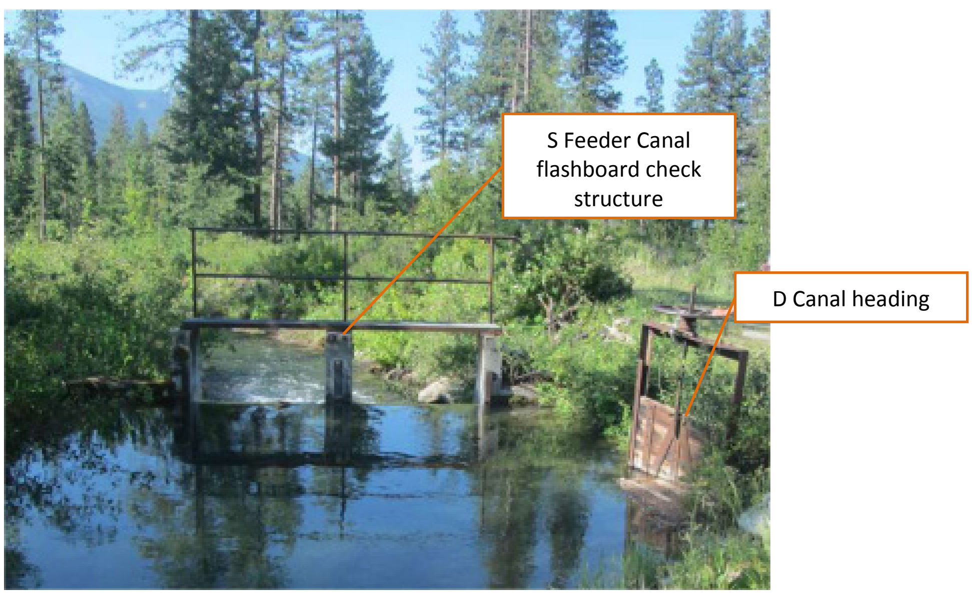

Figure 32. D Canal heading looking downstream at S Feeder Canal – D Canal diverts to the right

A plan view schematic is provided in Figure 33 to outline the existing structures and their functions.

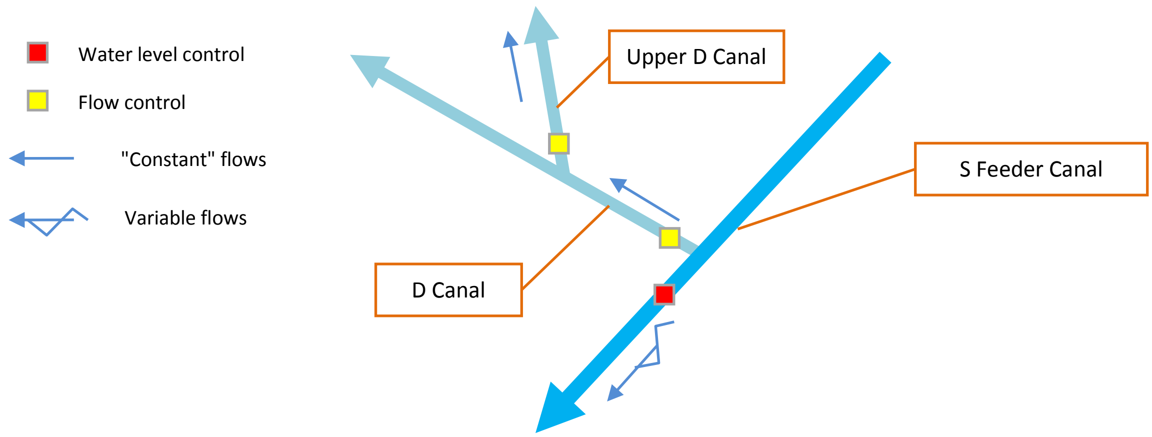

Figure 33. Plan view schematic of the existing D Canal and Upper D Canal headings

The existing structures at the D Canal heading are described below:

- Two 5-foot long flashboard bays provide manual upstream water level control in the S Feeder Canal. With this arrangement flow rate variations continue down S Feeder Canal.
- A single slide gate provides manual flow rate control into D Canal.

Again, the basic configuration is good, but in this case, the total 10’ flashboard length is too small. The primary change for this site will be to incorporate a long-crested weir into the existing flashboard structure. The sluice gate leading to the D Canal could be calibrated for flow measurement, or a new weir/flume installed in the D Canal, downstream of the inlet.

Recommended Improvements

Recommended improvements are summarized in the sketch in Figure 34.

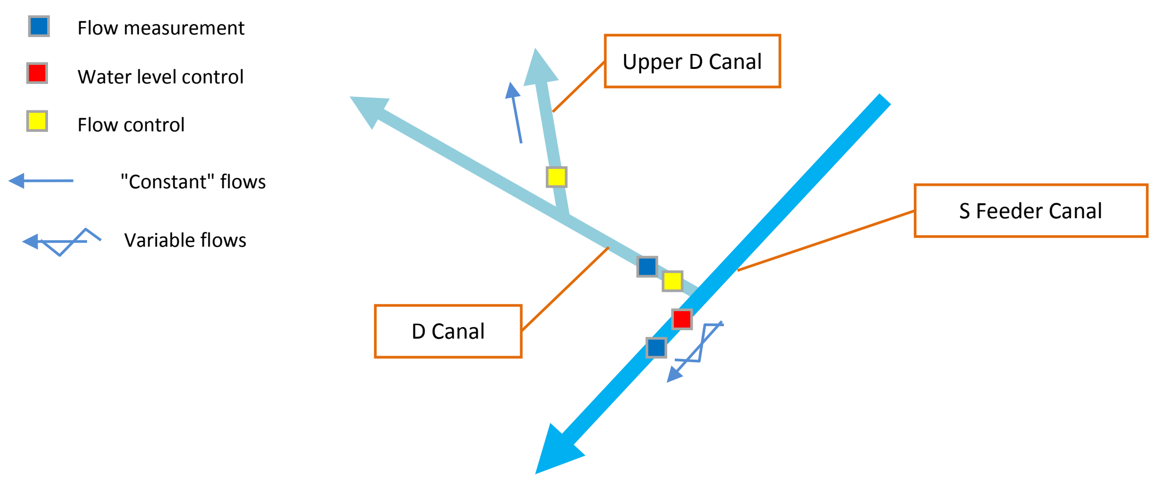

Figure 34. Plan view schematic of recommended improvements at the D Canal heading

Additional design details are provided below and illustrated in Figure 35 and Figure 36:

- S Feeder Canal improvements:
    - One of the flashboard bays will be left as-is. At very low flows, most of the flashboards will be in place. At very high flows, several flashboards will be removed. The objective will be to install enough flashboards to maintain about 4" of water depth over the long-crested weir.
    - The second flashboard bay will be converted to a 30' long-crested weir. Although the crest will be a board, it is not expected that the height of this board will be changed after the initial installation. Install a new flow measurement structure approximately 300 feet downstream of the existing flashboard structure. The details of this flow measurement structure are not defined because of a lack of elevation data.
- Proposed D Canal heading improvements are illustrated in Figure 35.

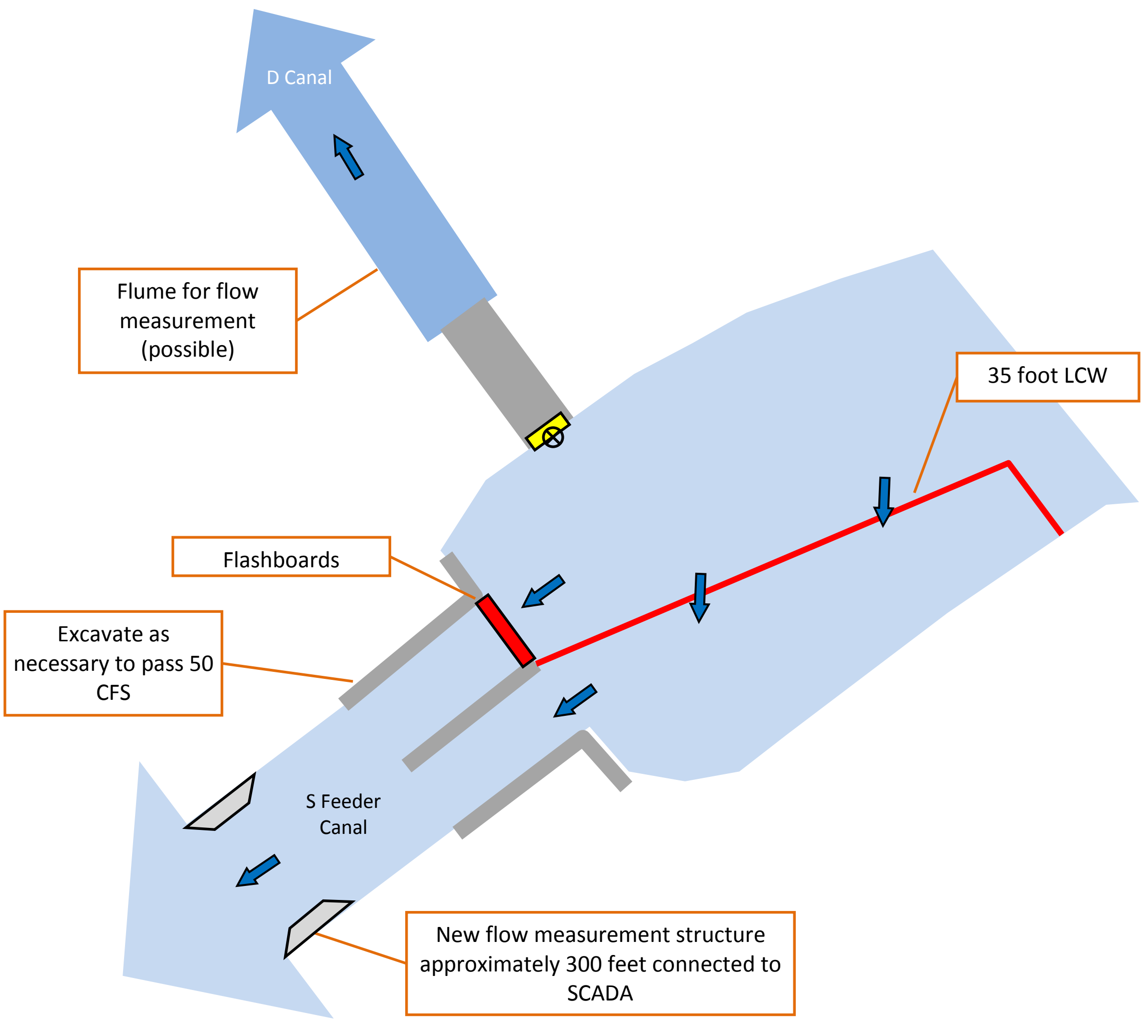

Figure 35. Conceptual design details for the D Canal heading - plan view, not to scale

Figure 36. Additional perspective of conceptual D Canal heading improvements

S Feeder Canal at Agency Creek

At this site water in Agency Creek is diverted into the S Feeder Canal. An overview of the site is provided in Figure 37.

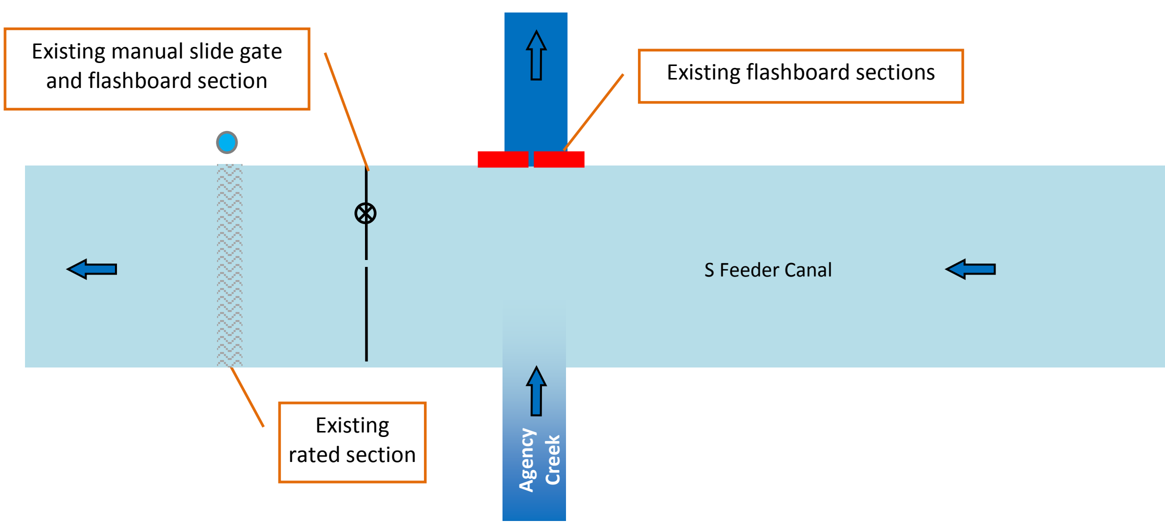

Figure 37. Conceptual depiction of existing infrastructure at S Feeder Canal and Agency Creek, plan view

Agency Creek converges with the S Feeder Canal channel, as shown in Figure 38.

Figure 38. Confluence of Agency Creek and S Feeder Canal

The two flashboard bays that discharge back into Agency Creek are approximately 5 feet wide and are shown in Figure 39.

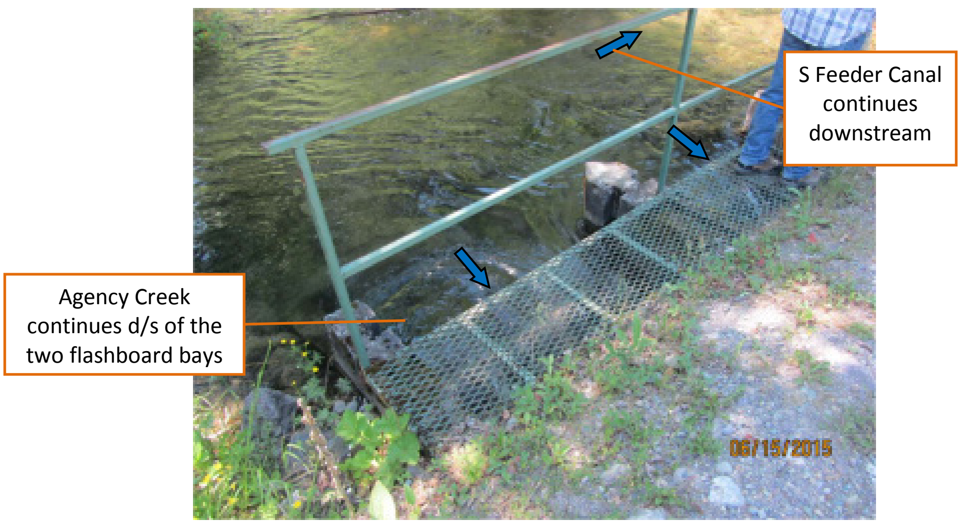

Figure 39. Agency Creek flashboard bays

Just downstream of the flashboard bays, still within the S Feeder Canal channel, is an existing check structure as shown in Figure 40. The check structure is composed of two ~4.3 foot wide bays. Flashboards are installed in one bay, while the other is a slide gate.

Figure 40. Existing S Feeder Canal check structure just downstream of its confluence with Agency Creek

Site-Specific Challenges

During most of the irrigation season, it is in the interest of FIIP to maximize creek diversions, while maintaining some creek flow for environmental purposes. However, during snow melt and rain events the existing infrastructure is unable to automatically control the unexpected, excess inflows to the S Feeder Canal. The configuration of the existing site infrastructure is not particularly suited to:

- Maximize creek diversions within a safe S Feeder Canal capacity and automatically discharge excess S Feeder Canal flows to the creek.
- Maintain a temporarily static 8 CFS minimum flow rate in Agency Creek downstream of Upper J Canal (which might also contribute to Agency Creek flows). Additionally, the Agency Creek flow rate requirements will soon transition to variable monthly requirements between 3 and 15 CFS.

Recommended Improvements

An overview of the recommended site improvements are listed below and illustrated in Figure 41:

- Replace the existing flashboards and install two flap gates to automatically maintain a target upstream water level. Excess flow rates will be automatically discharged downstream to Agency Creek. The total design flow rate of both flap gates should be about 60 CFS.
- Replace the existing check structure (see Figure 40) with two new 4-foot wide manual sluice gates and add guard rails to the walkway.
- Adjust the new S Feeder Canal sluice gate positions to limit their discharge flow rate to less than 55 CFS.
- Install a small metergate in parallel with the flap gates to measure and manually control the environmental return flows to Agency Creek.
- Install a floating trash boom to deflect trash and debris away from the flap gates. Floating trash can get stuck in the flap gate opening, which could stop the gate from fully shutting.

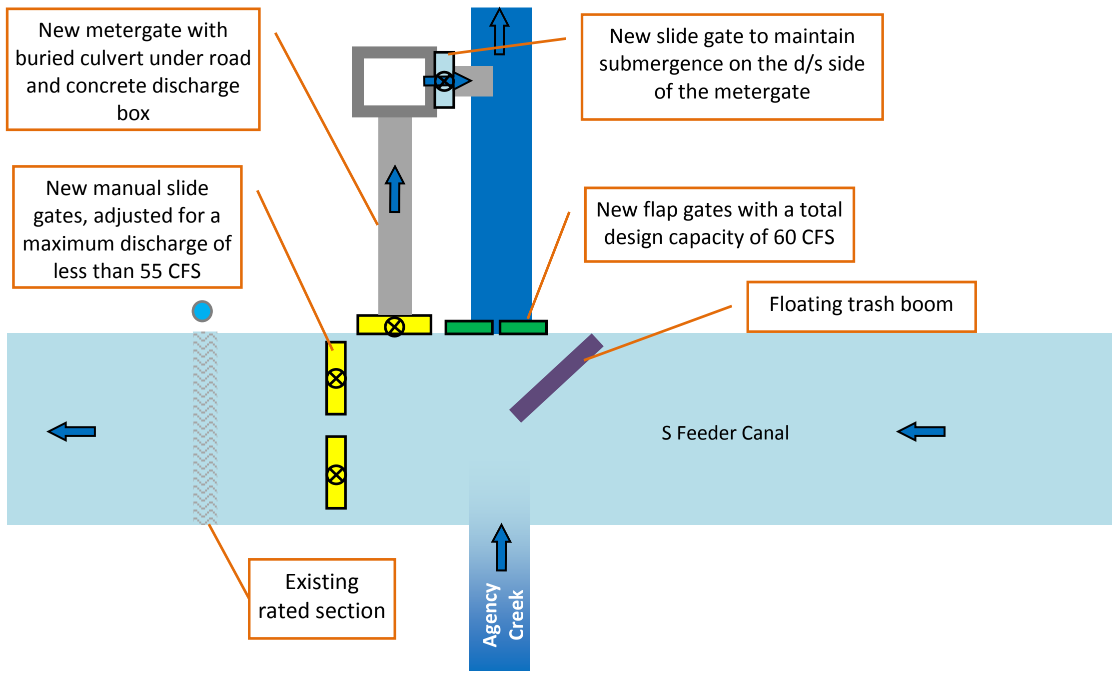

Figure 41. Conceptual overview of improvements for the S Feeder Canal at Agency Creek, plan view

Additional design details for the proposed combination structure are:

- A pair of identical flap gates would be installed in the existing flashboard slots. Each flap gate would be designed to pass 30 CFS for a total capacity of 30 CFS.
- The target upstream water level elevation of the flap gates should be set to provide at least 0.5 feet of freeboard.
- The metergate is a specially configured canal gate that is rated to provide a means of flow measurement using standard discharge tables. The metergate and related devices would be configured as follows:
  - A round canal gate mounted to a pre-fabricated headwall with the correct dimensions and accessories. Metergate details are provided in another section of this report.
  - The canal gate discharges into a buried corrugated pipe underneath the canal access road.
  - The corrugated pipe discharges into a pre-fabricated concrete box fitted with a slide gate to maintain the submergence on the downstream side of metergate.

Control and Operational Strategies

The control and operations at the site are described below:

1. After installation the following initial, one-time adjustments are needed:
   a. Adjust the two manual sluice gates to limit the S Feeder Canal flow rate to less than 55 CFS.
   b. Fine-tune the flap gate position. By setting the flap gate inside flashboard slots, and setting the flap gate on top of boards, the final flap gate elevation can be easily adjusted. The final flap gate elevation will be determined in a future contract.
   c. Fine-tune the flap gate counterweight mass to slightly adjust its target upstream water level elevation.
2. Once the initial adjustments are made, the control at the site is mostly automatic; however, the site should be visited regularly to clear trash or to adjust the metergate flow rate to meet environmental flow targets in Agency Creek.

S and J Canal Reservoir

A new buffer reservoir and other improvements are proposed in the Jocko Canal Unit in the J Canal area. The existing infrastructure is shown in Figure 42.

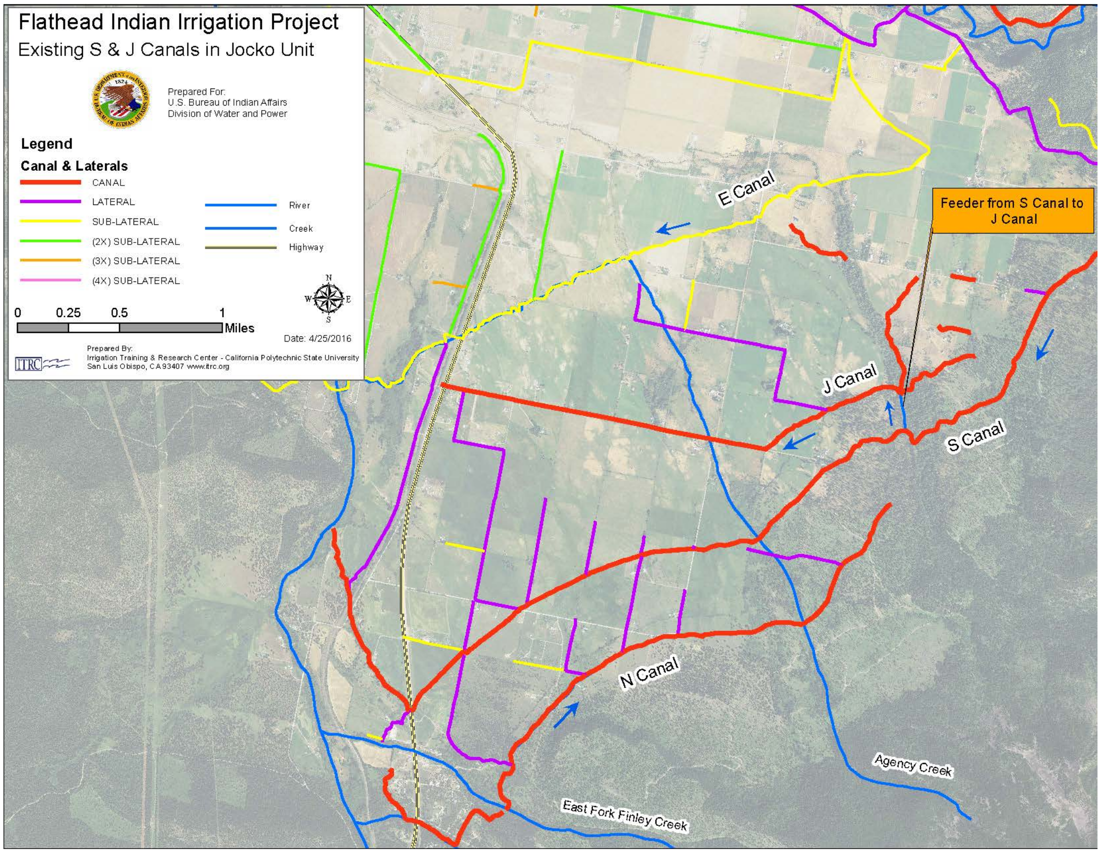

Figure 42. S and J Canal area existing infrastructure

With the existing infrastructure FIIP staff are presented with the following operational challenges:

- The areas serviced by the tail end of relatively long canals with numerous creek inflows experience amplified lag time and flow rate uncertainties.
- The flow rate uncertainties are distributed among the canals, making operations difficult.
- Miles of small canals and laterals are difficult to access, control and maintain.
- Most of the canals lack good flow measurement and water level control.

The proposed J Canal Reservoir includes changes to multiple Jocko Canal Unit canals and structures. The approximate reservoir location is shown in Figure 43. An overview of the reservoir operational components is shown in Figure 44.

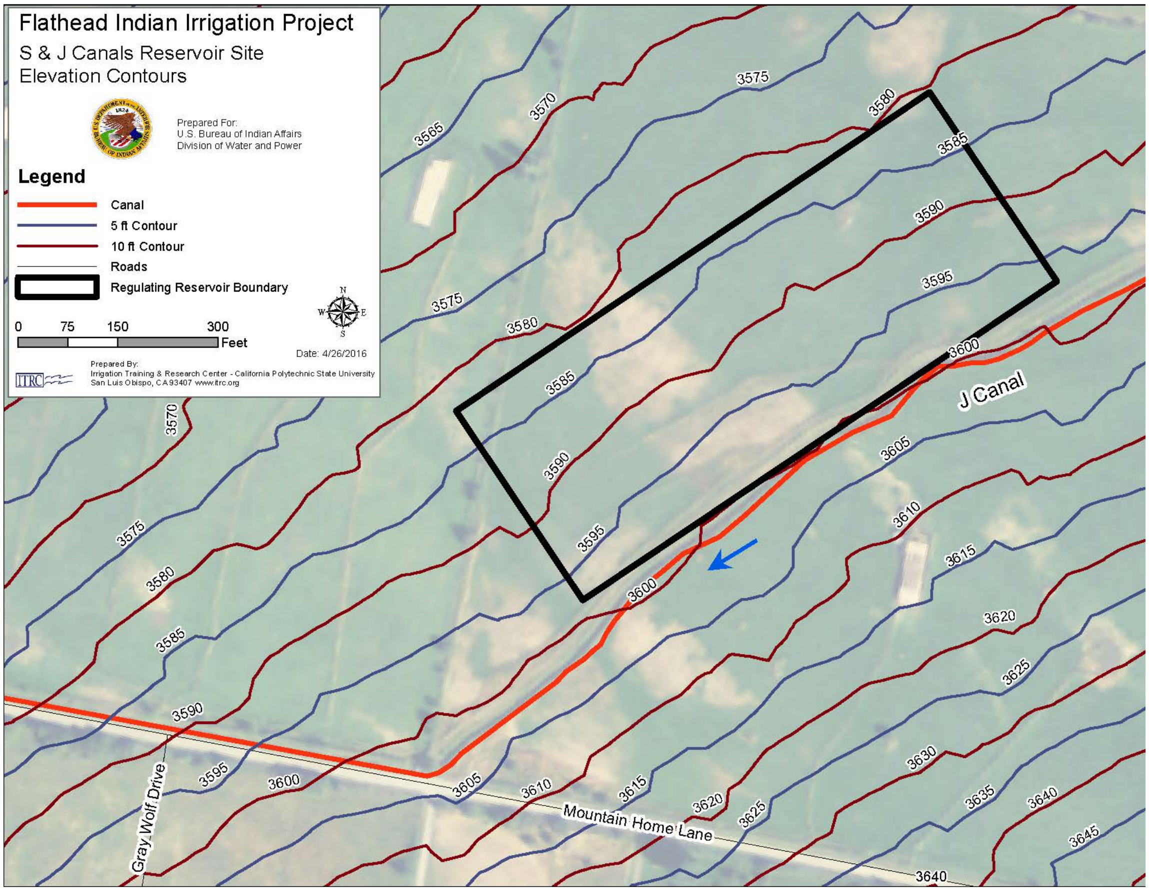

Figure 43. S and J Canal approximate regulating reservoir location with contours

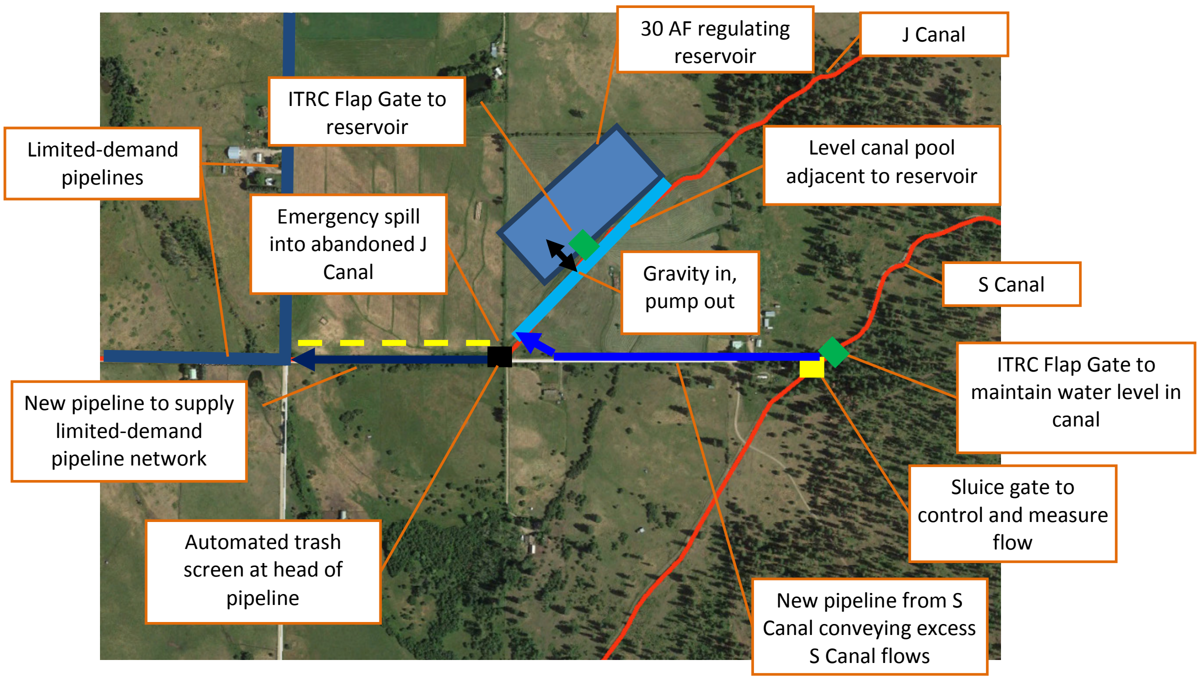

Figure 44. S and J Canal regulating reservoir operational components and strategies

The key S Canal modifications are illustrated in Figure 45:

- A new bifurcation point will be installed.
- The flow into the remainder of the S Canal will be re-regulated at this point.
- Any excess flows will go into a new pipeline that will discharge into the new J Canal level pool.
- Water level control on the side of the S Canal with a 30 CFS flap gate (Figure 45)
- An emergency high flow bypass around the S Canal flow control gate (Figure 46).
- The pipeline will be 30" Polyethylene Drain pipe.

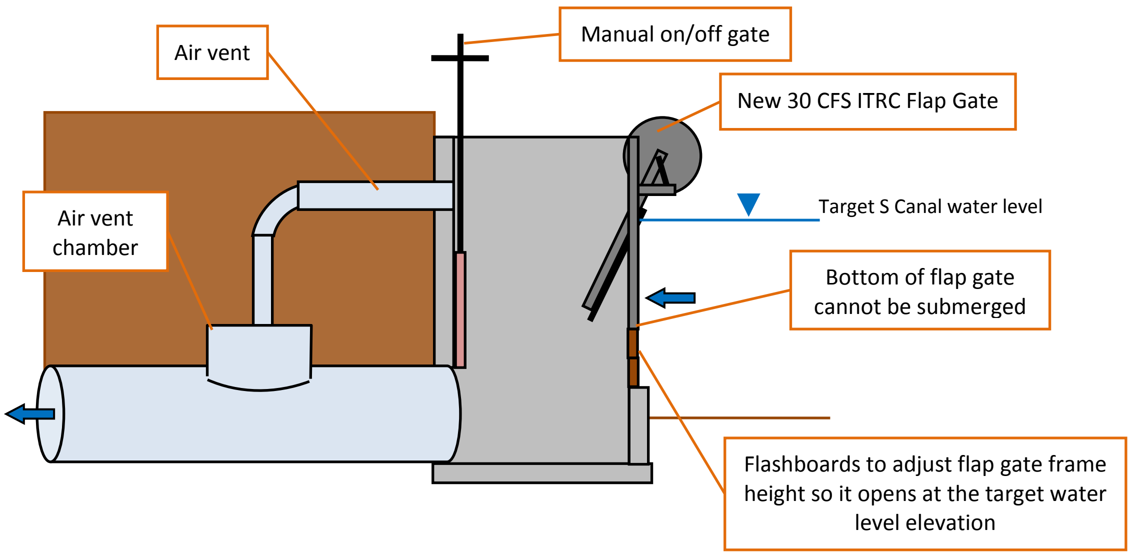

Figure 45. Conceptual design of the new flap gate structure and pipeline inlet, elevation view (not to scale)

The key J Canal modifications include:

- At the point where the J Canal turns straight westward, a new pipeline will be installed parallel to, or below grade of, the existing J Canal.
- The entrance to the new pipeline will be equipped with an automatic trash screen.
- The new pipeline will supply a new pipeline network downstream of this point.
- An emergency overflow (spill) will be installed adjacent to the trash screen, and will discharge into the existing, in-the-future-abandoned J Canal, to be directed into a creek about 0.3 miles to the west.
- A new regulating reservoir will be installed just downhill of a level canal pool in the J Canal.
    - Flow into the regulating reservoir will be gravity in. It will likely pass through an ITRC Flap Gate, sized for 30 CFS.
    - Flow from the regulating reservoir will be pumped, to supplement canal flows when needed:
        - Approximate TDH = 25'
        - Flow rate = 20 CFS
        - Approximate input HP to motor = 78 HP
        - Pump discharge pipe = 24"
        - VFD control with inverter duty motor
    - The reservoir will have about 30 AF storage capacity.
    - A SCADA site will be established to monitor reservoir cell water levels and other important information.

Flow Control Structure

The new S Feeder Canal flow control structure will be located about 100 feet upstream of Gray Wolf Drive. Key flow control structure design details are illustrated in Figure 46. The flow control structure will provide:

- Manual control of the re-regulated S Feeder Canal flow rate
- Flow measurement using a gate discharge equation

Using the sluice gate as the flow measurement device requires:

- Special consideration of the inlet conditions
- Standardized downstream conditions – the downstream side should always flow submerged
- At least 0.5 feet of head drop across the gate. The banks may need to be raised for an unknown distance upstream.

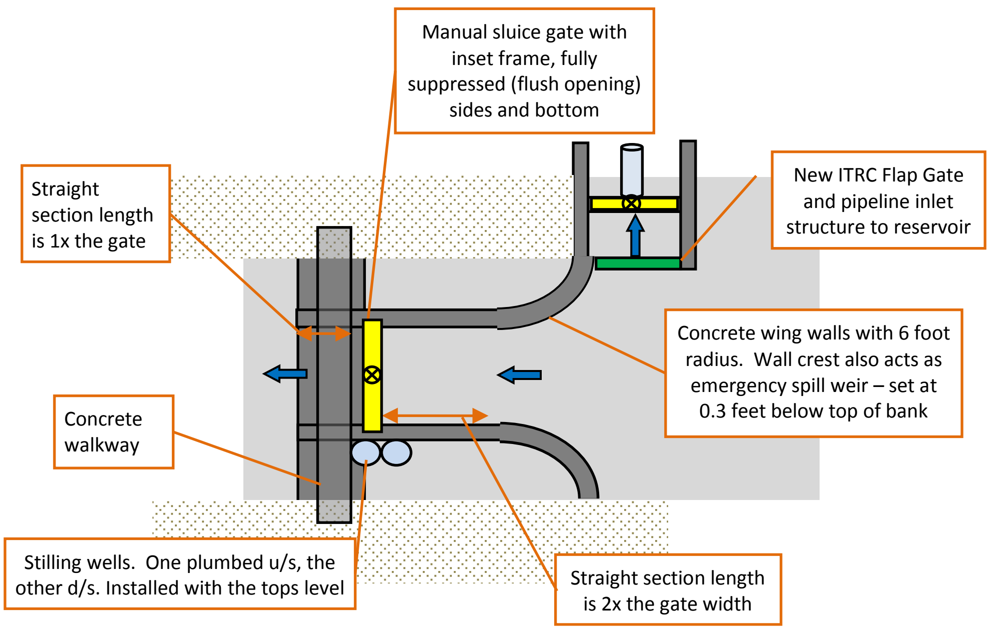

Figure 46. S Canal flow control structure design details, plan view (not to scale)

Flow Control Structure Operation

The flow control structure will be adjusted as needed to meet downstream flow demands. The instantaneous gate discharge flow rate will be determined with a gate discharge table. The gate discharge table will be developed in a future contract once the gate size is selected, using the following equation:

$$Q = 0.61\left[1 + 0.15\left(\frac{GW + 2z}{2GW + 2z}\right)\right] GW * z * \sqrt{2gh}$$

Where, Q = flow rate (CFS)
GW = gate width (feet)
z = gate opening (feet).
g = acceleration of gravity = 32.2 ft./sec^2
h = head differential across the gate (ft.)

The procedure for using the gate discharge table is described below:

1. Make three discrete measurements:
    a. Upstream water depth
    b. Downstream water depth
    c. Gate opening
2. Calculate the difference between the upstream and downstream water levels.
3. Use the gate discharge table using the gate opening and computed head differential.

Reservoir Operation

The day-to-day operation of the proposed S and J Reservoir is largely automatic:

1. Water automatically enters the reservoir from two pipelines that convey:
    a. The remainder of the J Canal flow rate
    b. Excess flows from S Canal
2. Although water enters the reservoir at the Upper Cell, all reservoir inflows are automatically directed to the lowest possible cell through two Waterman Type B gates, operating under downstream control. In other words, the reservoir fills "from the bottom up".
3. FIIP staff will periodically monitor the water level of the Middle Cell remotely via SCADA.
4. S and J Canal diversions will be adjusted by FIIP staff to maintain an ideal set of reservoir cell water levels as follows:
    a. Lower Cell, full
    b. Middle Cell, about halfway full
    c. Upper Cell, just enough water to reach the Upper Cell outlet to the Middle Cell
5. If the Middle Cell becomes full, the diversion flow rates of the S and/or J Canals would be decreased.
6. Similarly, if the Middle Cell becomes empty, the diversion flow rates of the S and/or J Canals would be increased.

The control strategies for the new S and J Reservoir are illustrated in Figure 47 with the proposed control structures.

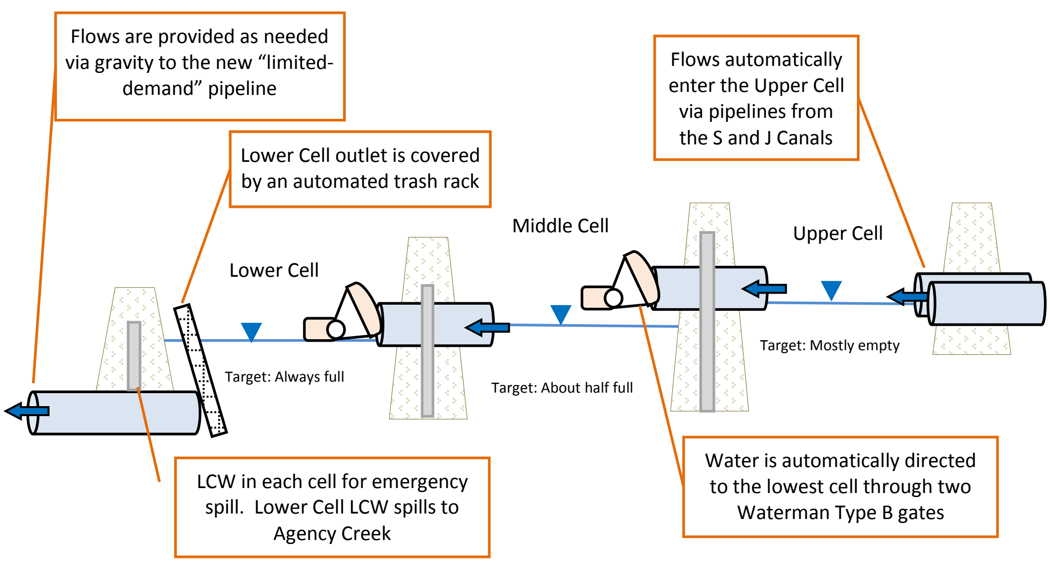

Figure 47. Conceptual S and J Reservoir control structures and operational description, elevation view (not to scale)

E Canal Modifications

E Canal is currently supplied by R Canal and Finley Creek as well as numerous additional, but minor, drainage and creek inflows. The existing downstream E Canal alignment is shown in Figure 48.

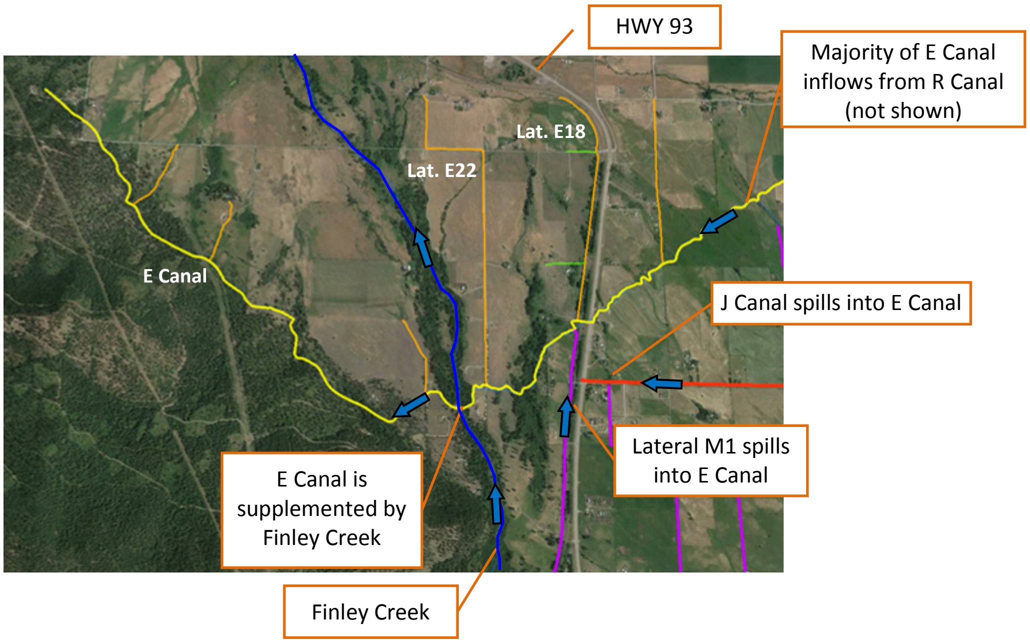

Figure 48. Existing canal alignments including spill and drainage inflows for the downstream portion of E Canal

The following major operational challenges are inherent to the existing E Canal infrastructure:

1. E Canal is relatively long and difficult to access for operations and maintenance.
2. Excessive canal lag time amplifies flow rate uncertainties caused by fluctuating spill inflows and unscheduled deliveries.
3. The majority of the existing structures are poorly configured for their intended purpose, or overly complex. Either the structures require frequent attention and manipulation to provide good service, or the structures simply never work as well as intended, regardless of the amount of ISO labor input. As a result:
   a. The canals are maintained at high flow rates whenever possible to minimize the potential for downstream shortages and complaints.
   b. Operational adjustments, in general, are infrequent.
   c. Pool water levels and turnout flow rates are inconsistent.

These challenges are addressed by the modifications proposed along E Canal at Finley Creek and Highway 93. These locations and ancillary improvements (discussed previously) are identified in Figure 49.

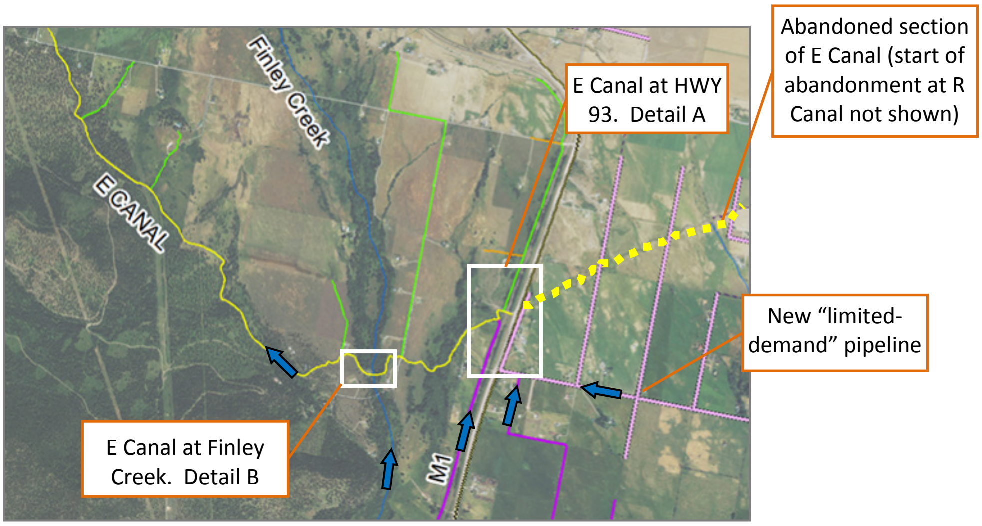

Figure 49. E Canal improvement locations and supporting modifications

The modifications proposed for E Canal at Highway 93 are listed below and shown in Figure 50:

1. E Canal will be abandoned from the heading at R Canal to just downstream of Highway 93. E Canal irrigation water deliveries will be supplied by new limited-demand pipelines; however, the E Canal channel will remain to convey irrigation runoff and general drainage.
2. A new flow control structure will be installed just downstream of the confluence of Lateral M1 and E Canal. The new flow control structure will be fitted with emergency spill side weirs, and flow measurement with a gate discharge equation.
3. A new level pool will be created upstream of the new flow control structure.
4. A new turnout and pipeline will cross Highway 93 and discharge into the new level pool. The pipeline will be fitted with:
    a. A float valve to automatically maintain a relatively constant water depth in the new level pool
    b. A flow meter upstream of the float valve for flow measurement and volumetric accounting
    c. A manual on/off valve at the upstream end for maintenance

The new turnout pipeline and associated valves will be sized to supply all downstream E Canal demands.

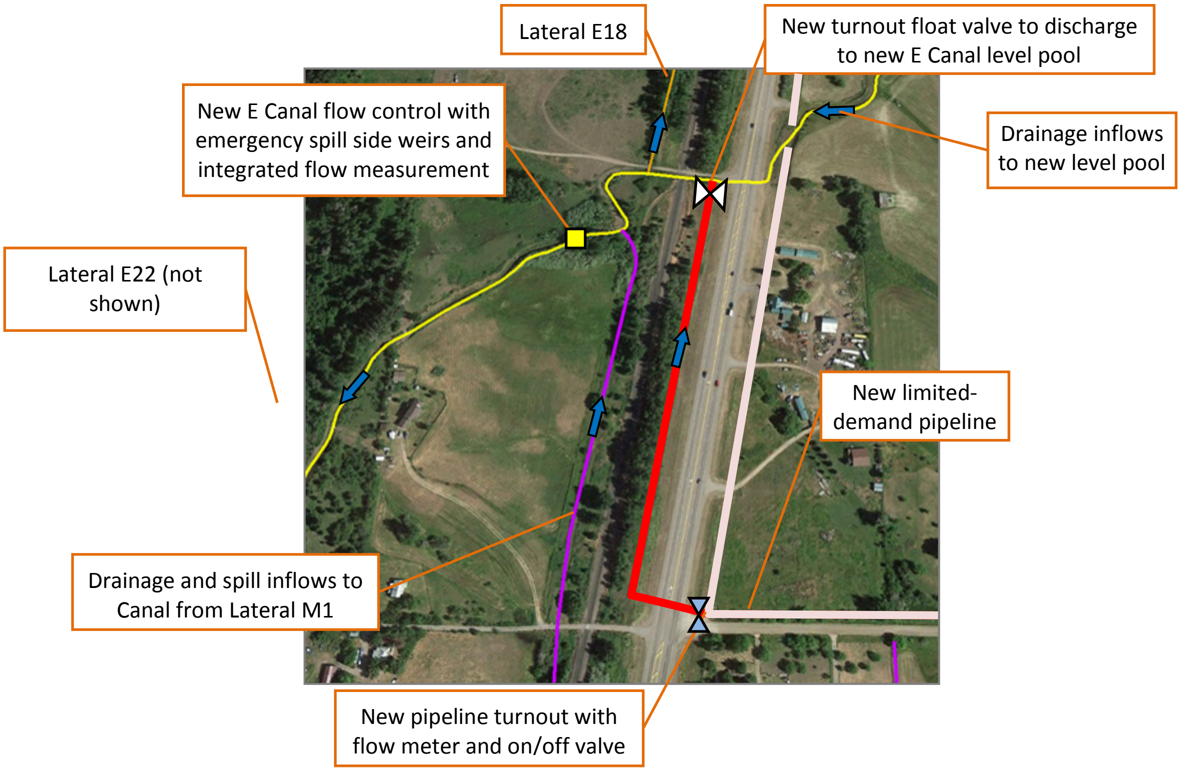

Figure 50. E Canal modifications at Highway 93 – Detail A, plan view

The anticipated benefits of these improvements at E Canal and Highway 93 are:

- Further utilization of stored water captured in the new S and J Reservoir
- Re-regulated flow rate to the downstream portion of the E Canal
- Utilization of all incoming drainage and spill flows with automatic supplementation from the limited-demand pipeline together fully supplying:
  - The new re-regulated flow rate
  - Lateral E18 demand

In addition, the following modifications are proposed at E Canal at Finley Creek:

- A new manual flow control structure will be installed just downstream of the existing fish screen.
- A new flow measurement structure will be installed approximately 200 feet downstream of the new flow control structure.
- A new level pool will be created just upstream of the new flow control structure.
- A new long-crested weir (LCW) will provide excellent water level control for the new level pool. Flow over the new LCW will return to Finley Creek via a new, short pipeline.
- The water level in Finley Creek will be raised just downstream of the existing Finley Creek diversion gate by constructing a new rubble dam.

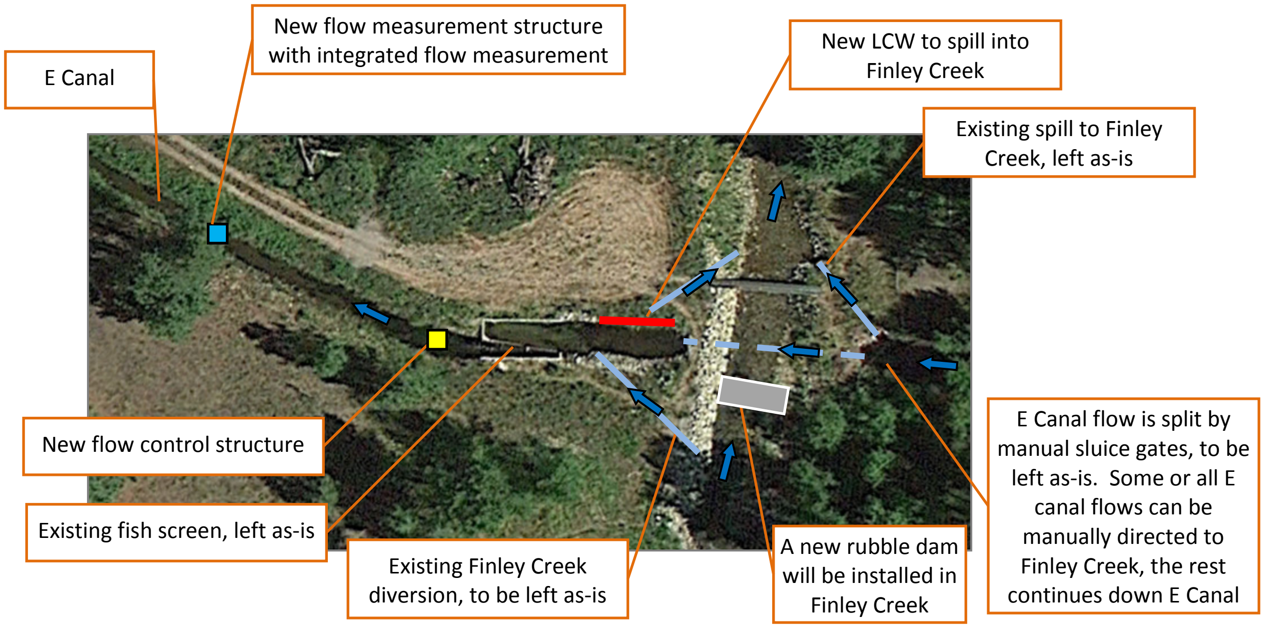

Figure 51. E Canal modifications at Finley Creek – Detail B, plan view

The anticipated benefits of these improvements at E Canal and Finley Creek are:

- Consistent manual flow rate re-regulation to meet E Canal demand downstream of Finley Creek
- Increased water depth at the fish screen to improve fish screening operations by decreasing screen inlet water velocities
- Providing flexibility to FIIP staff to select the water supply to meet downstream E Canal demand. The downstream E Canal demand can be met with water from the new S and J Reservoir or Finley Creek. More details are provided in the following section.

An overview control schematic is provided in Figure 52, to illustrate how the E Canal improvements at Highway 93 and Finley Creek will complement each other.

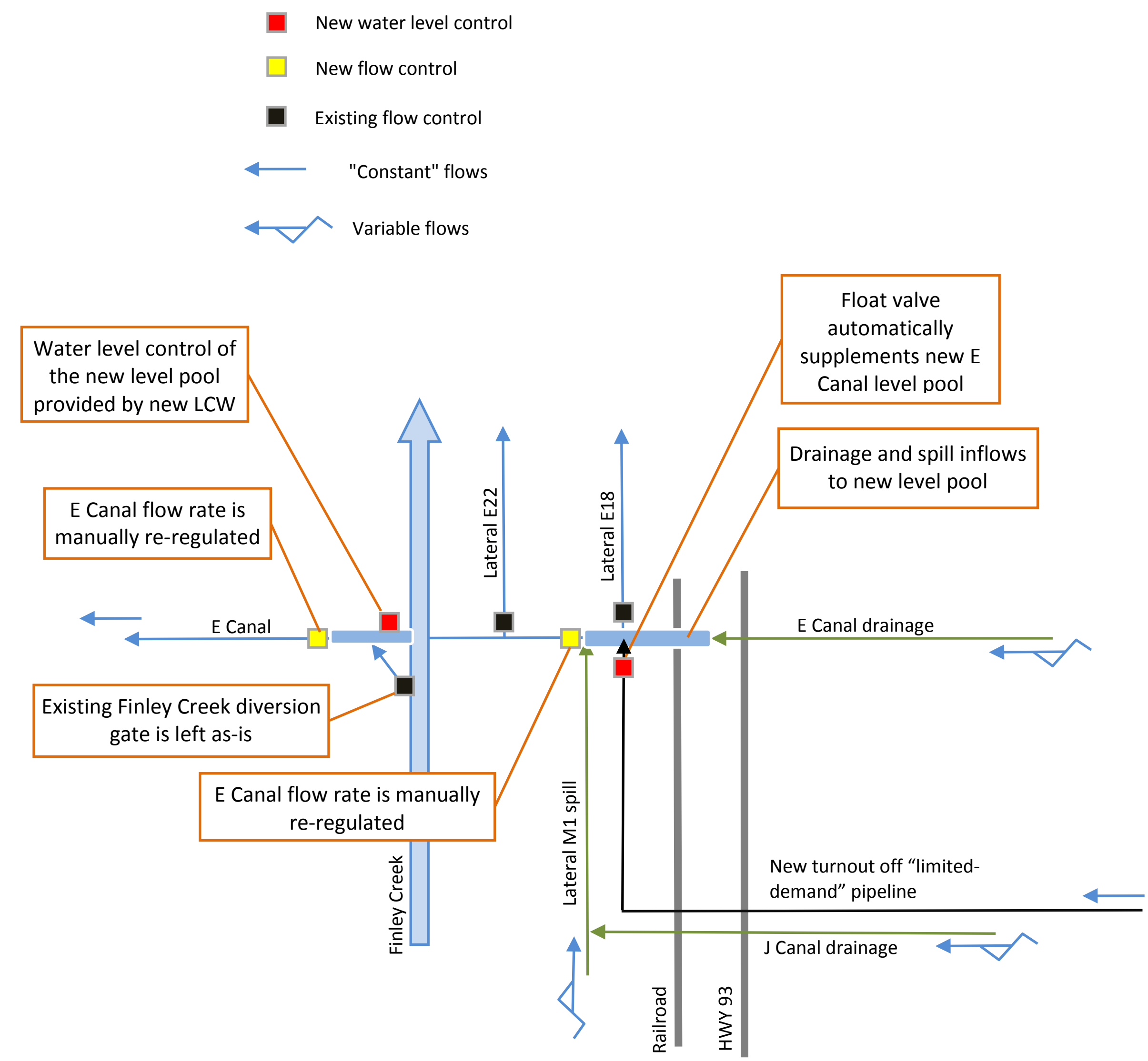

Figure 52. Overview of E Canal improvements, plan view

E Canal Operational Changes

FIIP staff will have the ability to switch between three available operational modes, in which the supply for E Canal demands downstream of Finley Creek are met by one of the following options:

- Finley Creek
- S and J Reservoir via the new turnout pipeline, assuming there is sufficient supply
- Some proportion of each

For each scenario, the operation of the new or improved structures would be as described below.

Scenario 1: The majority of E Canal will be supplied by water from Finley Creek

1. Adjust the new flow control structure just downstream of Highway 93 to meet Lateral E22 demand. This flow rate will be supplied by the combination of any upstream drainage inflows, and the remainder will be automatically provided by the new turnout float valve.
2. Adjust the existing Finley Creek diversion gate to meet all downstream E Canal demands, plus about 2 CFS.
3. Adjust the new flow control gate just downstream of Finley Creek to meet all downstream E Canal demand.
4. All excess flows in E Canal just downstream of Finley Creek will be automatically spilled and returned to Finley Creek by the new LCW.

Scenario 2: E Canal will be supplied by water from the new S and J Reservoir

1. Adjust the new flow control structure just downstream of Highway 93 to meet all downstream E Canal demand plus about 2 CFS. This flow rate will be supplied by the combination of any upstream drainage inflows, and the remainder will be automatically provided by the new turnout float valve.
2. Fully close the Finley Creek diversion gate.
3. Adjust the new flow control gate just downstream of Finley Creek to meet all downstream E Canal demand.
4. All excess flows in E Canal just downstream of Finley Creek will be automatically spilled and returned to Finley Creek by the new LCW.

Scenario 3: E Canal will be supplied by both Finley Creek and the new S and J Reservoir

1. Adjust the new flow control structure just downstream of Highway 93 to meet Lateral E22 demand, plus the target portion of downstream E Canal demand. This flow rate will supplied by the combination of any upstream drainage inflows, and the remainder will be automatically provided by the new turnout float valve.
2. Adjust the existing Finley Creek diversion gate to meet the remainder of all downstream E Canal demands, plus about 2 CFS.
3. Adjust the new flow control gate just downstream of Finley Creek to meet all downstream E Canal demand.
4. All excess flows in E Canal just downstream of Finley Creek will be automatically spilled and returned to Finley Creek by the new LCW.

Canal and Lateral Water Level Control Improvements

Improvements to many of the existing water level control structures throughout the Jocko Canal Unit are proposed, as shown in Figure 53.

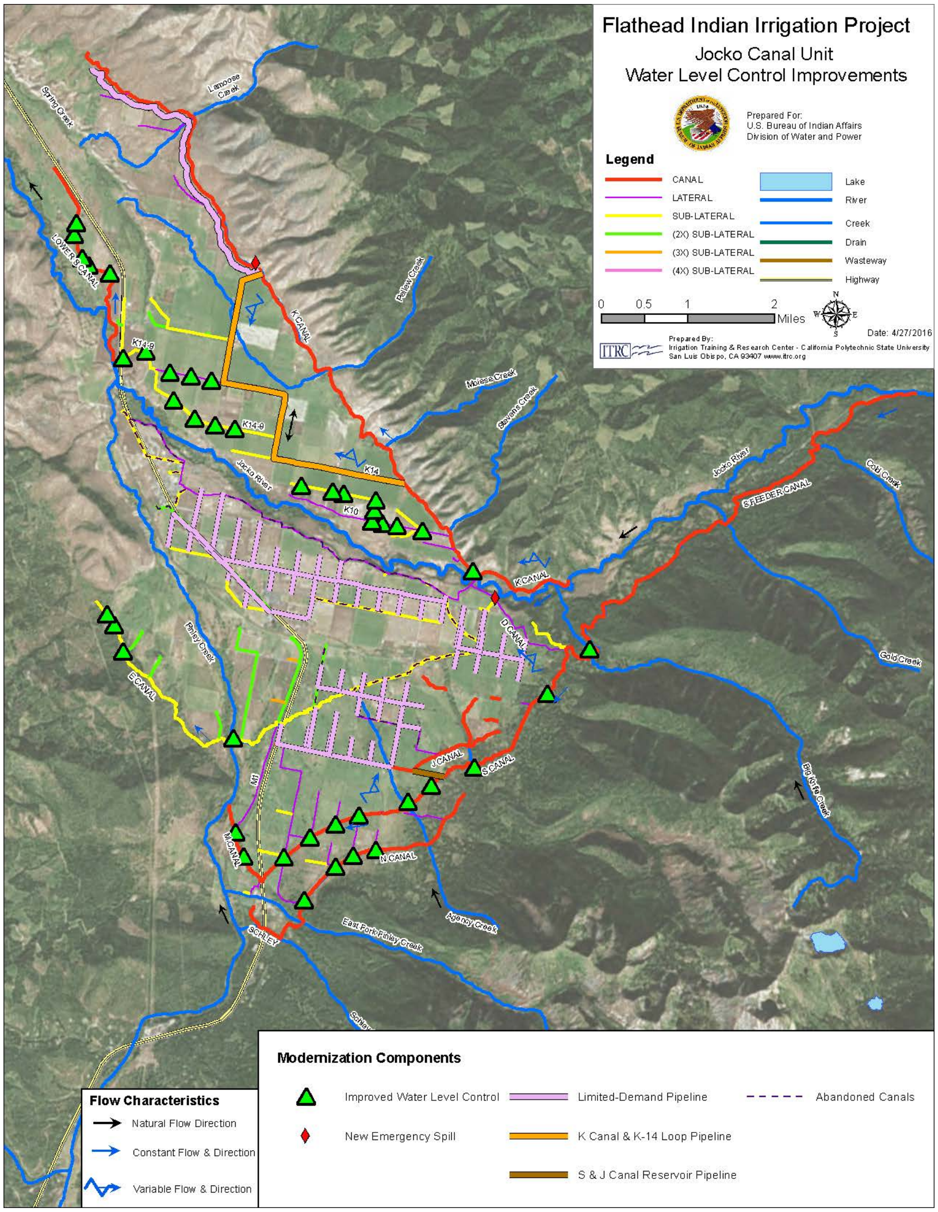

Figure 53. Jocko Canal Unit water level control improvement locations

The improvements at each site will entail modifying or replacing the existing flashboards or concrete weirs with long-crested weirs (LCWs). It is anticipated that an appropriately sized LCW will outperform the existing water level structures by maintaining a more consistent upstream water level, which in turn:

- Minimizes fluctuations in turnout deliveries
- Decreases lag time
- Decreases labor input, compared to constantly adjusting flashboards

Limited-Demand Pipelines

The Jocko Area – Existing Conditions

Limited-demand pipelines will completely replace R Canal and portions of E and J Canals. Existing canals and irrigated acreage are shown in Figure 54. Most of the existing laterals are difficult to operate due to high seepage and lack of water level control and flow measurement structures.

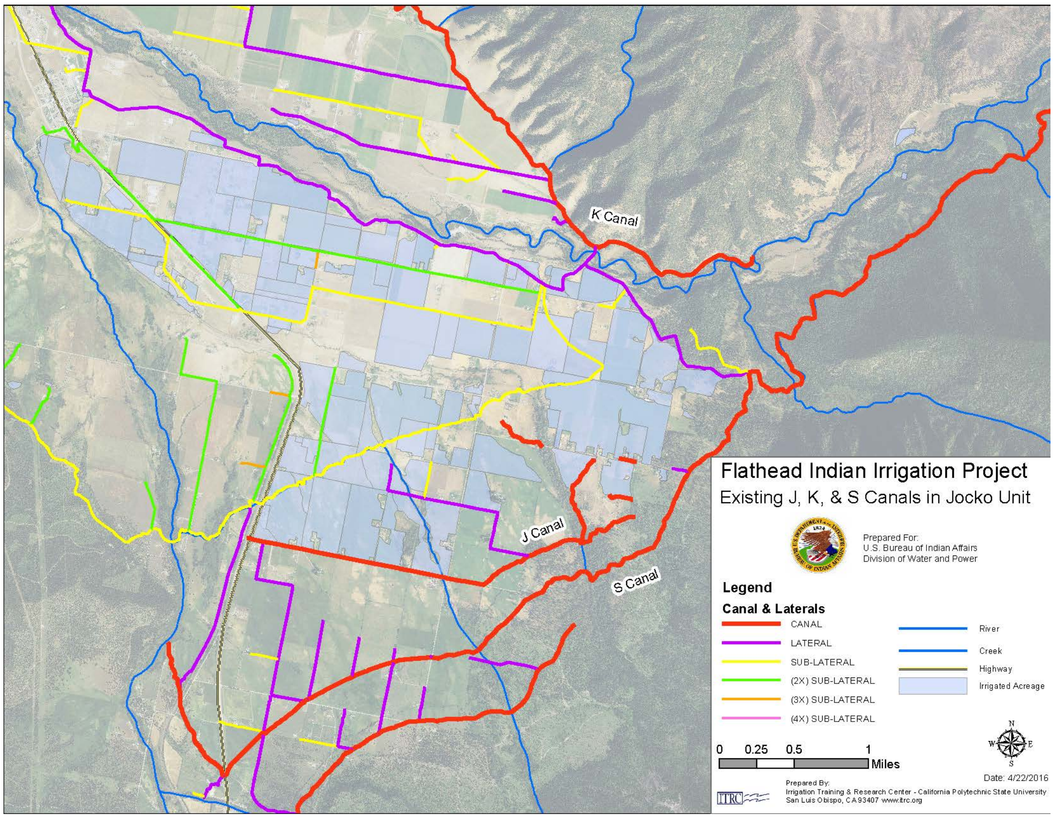

Figure 54. Existing J, K, and S Canals and acreage served

The Appeal of Pipelines

Various objectives for the tribe and USBIA include reasonably accurate volumetric accounting and billing of water deliveries to individual fields. To achieve this, it will be necessary to provide:

1. A good flow meter for each field, with the ability to also account for volumetric deliveries.
2. Ease of access by the USBIA operators. This means the meters must be next to a road. The road could be a county road or a well-maintained and easily accessed canal road – with no private gates or fences blocking the way.
3. A valve that can be shut off or locked at the flow meter location.

With pipelined laterals, these requirements can be met.

Pipelined laterals have the following advantages:

- They can go up and down hills and swales, which means they can be positioned along roads. This provides the easy turnout access that is needed for good operation and accountability.
- Pipelines also provide some of the pressure required for sprinkler irrigation. This will reduce power bills for farmers if they modify their pumps properly and use VFD controllers on electric pumps.
- Pipelines have very few maintenance requirements, compared to open ditches and canals.
- The irrigation water can be filtered to a reasonable degree at the heads of the piped laterals. This centralized filtration, plus the lack of many miles of un-serviced ditches with weeds, will provide much cleaner water to individual fields. This will minimize the need for individual field filters for sprinkler systems.

The primary disadvantage of pipelines is the cost of initial installation.

Assumptions and Pipeline Design

The pipeline design considered a variety of factors:

- The flow rate requirement is very different from the volumetric allocation. For efficient irrigation with most irrigation systems, the flow rate that is needed is dependent upon the irrigation system design. For example, a wheel line (side roll) sprinkler design will have a design flow rate requirement. The turnout must meet that flow rate requirement.
- The volumetric limitation can be enforced if USBIA operators have easy access to accurate flow meters with totalizers. In other words, a high flow rate can be allowed, but not 24/7.
- The design flow rate for individual 40 acre turnouts was 8 GPM/acre. A check of various sprinkler designs in the area indicated that this was adequate.
- The lateral pipes themselves have been sized using demand theory, which is similar to the logic used to size phone system capacities. The key design criteria for the large lateral pipe sizing is that 95% of the time, the pipes will be able to meet farmer demand. The demand is assumed to be that on the average, the turnouts of 320 GPM will individually be operating only 60% of the time during the middle of the summer.
- Major pipelines are located adjacent to roads, where possible, for ease of access for flow and volume measurement by FIIP staff.
- All turnout flow meters and emergency on/off valves are located adjacent to roads. The normal operating valves and final discharge flanges are located at the high point of each 40 acre area.

Other considerations for the conceptual design include:

- The maximum velocity in the large pipelines is limited to 5.5 feet/second. There should be no water hammer damage at these velocities, because the total flow rate cannot be stopped simultaneously.
- Maximum pipeline pressures (which occur under static conditions in this case) must be less than 75% of the pressure rating of the pipes.
- A minimum pressure rating of 80 psi is required for all pipes 12" and above. Smaller pipes (6" – 10") are rated at a minimum of 100 psi. These minimum pressures are selected based on the properties needed for external soil loading and installation requirements.

Field Turnout Design

In the *Modernization Plan* for the Jocko area, the high point of every 40 acres would be supplied by an individual meter and shutoff valve that is located along a road.

The key ingredients for turnouts are:

- The materials and design must be robust so parts do not easily break.
- The flow meter must provide readings of both instantaneous flow rate, plus totalized volume.
- The flow meter must be positioned so that there is a good straight section of pipe upstream of it (for good accuracy), and the pipe must always flow full.
- A buried emergency on/off valve is included.
- A typical on/off/regulation valve (manual) is needed for normal operation.
- Air vents will provide air release for the supply pipelines.
- The unit should be of fairly low profile, and easy to monitor and service.
- The responsibility of the USBIA will end just downstream of the operating valve. A flange will be provided for the farmer to make any connection desired.
- Each turnout (supplying 40 acres) is sized for a flow rate of 320 GPM.
- If the 40 acre field is not adjacent to a road, the operating on/off valve and discharge flange will be located at the high point of the serviced field.

Because the water should be relatively free of vegetation and sand, it will be possible to select from a variety of types/brands of flow meters. Propeller meters should work well; magnetic meters are also popular. The prices are similar. Full bore magnetic meters do not require as much straight pipe before and after, but their batteries need to be replaced every 1-2 years. Propeller meters usually need to be removed and calibrated every 5-6 years. If propeller meters are selected, the design must account for the ease of removal of the moving parts for calibration.

K Canal Pipeline Layouts

In the K Canal area, two new limited-demand pipelines will replace R Canal and portions of E Canal (Figure 55):

1. The R Pipeline will replace the entire R Canal and will serve approximately 2,230 acres. The R Pipeline has a portion that will go under Highway 93 in the same location that the existing R Canal passes under Highway 93.
2. The D Pipeline will serve approx. 480 acres and replace portions of the existing E Canal.

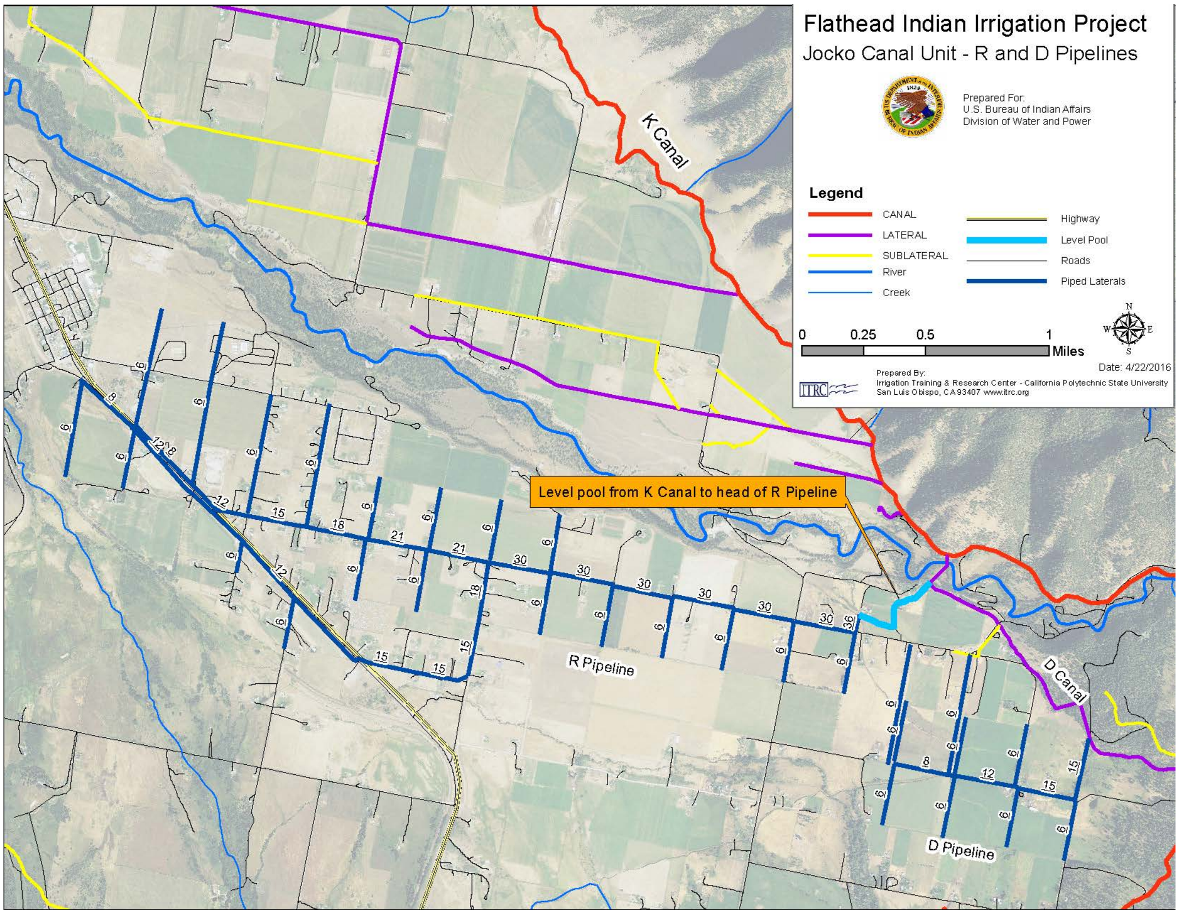

Figure 55. Overview of limited-demand pipelines to replace R Canal and portions of E Canal

S Canal Pipeline Layouts

A limited-demand pipeline will be installed to service the turnouts on the portions of E and J Canals and laterals; however, the existing channels will be kept for drainage and emergencies. This new pipeline, "E Pipeline", will serve approximately 1,040 acres. Additionally, E Pipeline will supplement flows to the remaining portions of E Canal when possible and necessary. More specifically, the portion of the E Pipeline that connects to the E Canal is sized for an assumed flow rate of 10 CFS.

The preliminary pipe alignments for the new E Canal are shown in Figure 56.

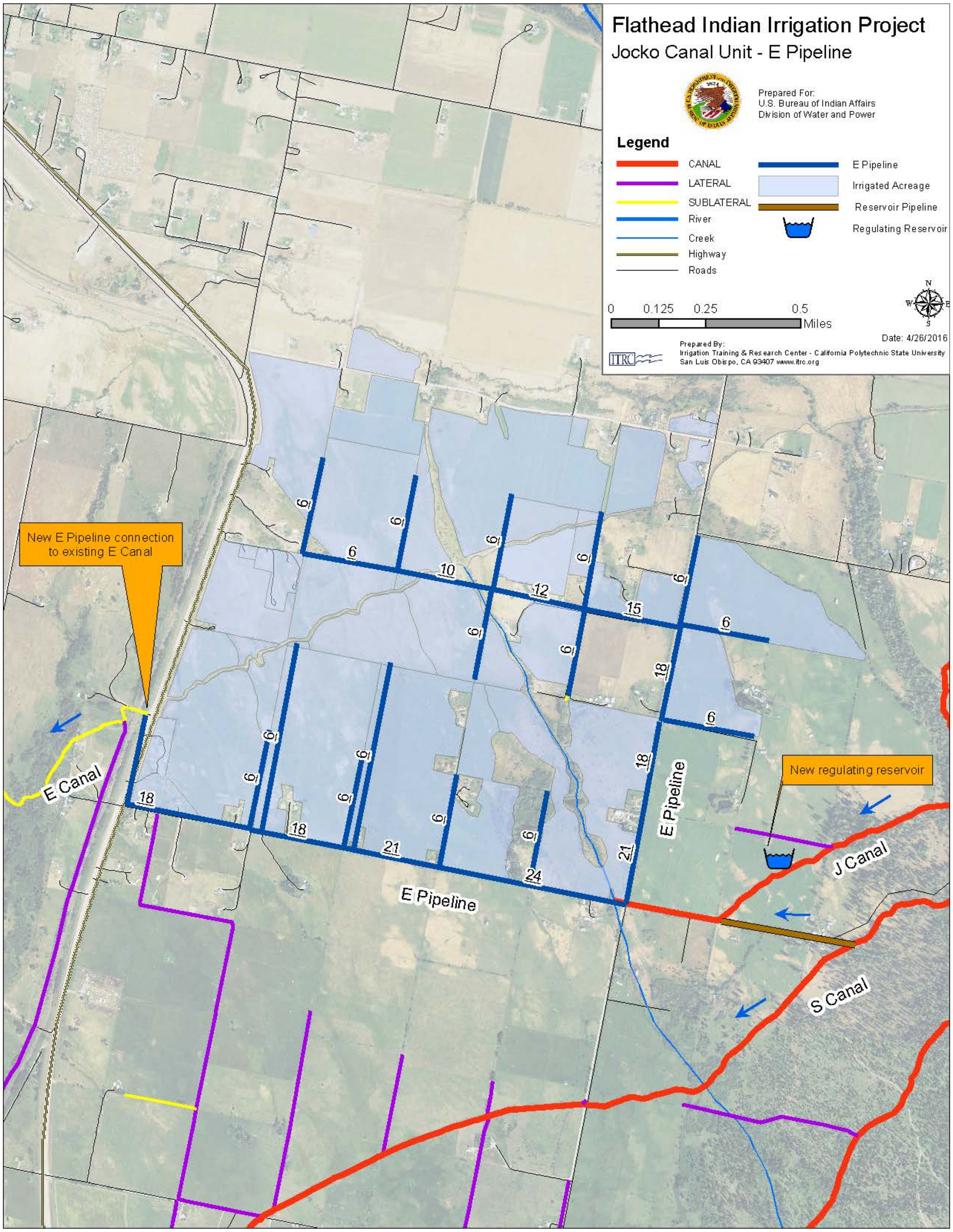

Figure 56. Overview of limited-demand pipelines to replace portions of E Canal

Cost Summary

Table 1 summarizes the service area and construction cost of each proposed limited-demand pipeline.

Table 1. Cost summary for the three limited-demand pipelines in the Jocko Canal Unit

Canal	Service Area (Acres)	Cost
K Canal Unit		
R Pipeline – Serves R Canal area	2,230	$4,127,800
D Pipeline – Serves portions of E Canal area	480	$709,400
S Canal Unit		
E Pipeline – Serves portions of E Canal area	1,040	$2,434,200