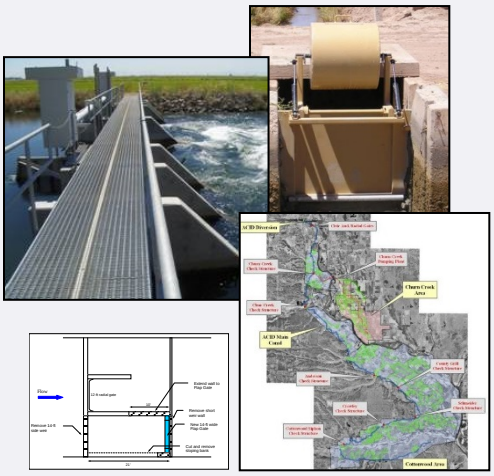

RAPID APPRAISAL PROCESS

Pixley ID

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October 2017

Sponsored by

California Dept. of Water Resources, Agriculture Unit

Sabrina Cook and Fethi Benjemaa

ITRC

moving water in new directions

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Executive Summary – Focus on Groundwater

Technical assistance was provided to Pixley ID (PIXID) to make improvements to their overall operation because groundwater supplies are used both by the district and local disadvantaged communities (DACs). Funding for this was provided by the California Dept. of Water Resources, Agriculture Unit.

PIXID contributes to groundwater recharge, which benefits the water supplies for DACs. By more effectively managing available water supplies through various modernization projects, PIXID will have the potential to increase groundwater recharge and decrease pumping by the agricultural users. In turn, this will provide more groundwater availability for the DACs. This report focuses on modernization opportunities for water conservation and improved water management.

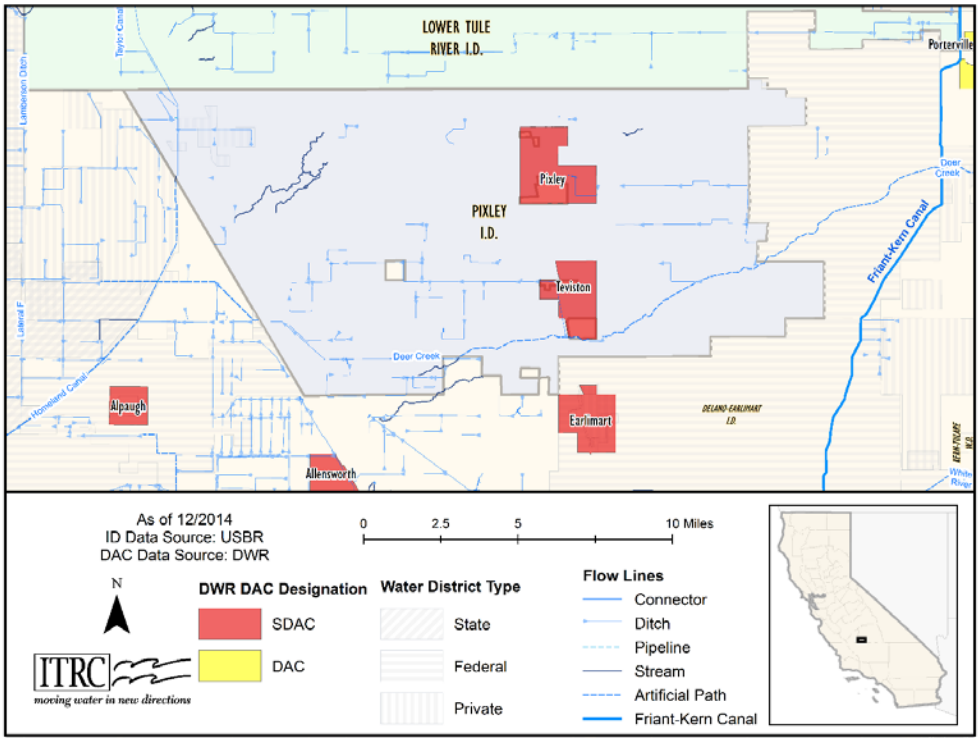


Figure 1. DACs in PIXID and the surrounding area

The ITRC Rapid Appraisal Process (RAP) makes a relatively quick assessment of a district's overall movement of water. A RAP typically provides recommendations for modernization of hardware and operations procedures that will accomplish the following:

1. Reduce spills from the irrigation district. At first glance this is not a problem with PIXID because almost all spills are recovered in recharge basins.
2. Improve water delivery service to farmers. PIXID already has reasonable surface water delivery service, which is made relatively simple because of three factors:
    a. Water level control can be somewhat imprecise in the canals, because farmers generally use pumps to extract water from the canals.

   b. The district has a relatively short total length of canals, which are easily accessed by operators.
   c. Any "spill" simply flows into recharge reservoirs located throughout the irrigation district.
3. Any investments in improved water delivery service must be tempered by two huge facts:
   a. Surface water is typically only delivered June, July, and August. Farmers must rely on well water for the other months.
   b. The last year the district received surface water was 2012.

   In other words, the issue is groundwater management first, second, and third, and surface water deliveries fourth.
4. Reduce energy consumption. This can sometimes be accomplished by extending the period of time surface water deliveries are available so that farmers do not need to pump as much groundwater.
5. Improve the ease of operations.

This RAP report primarily contains a variety of recommendations for improving the ease of operations and improving water delivery service. However, the major issue is sustainable groundwater for both PIXID and the town of Pixley, which is the primary DAC in the district.

The following figures show the elevations of groundwater surface, produced by two different entities and for different dates. Elevations are shown rather than depths to groundwater because the elevation contours show the direction of groundwater movement.

- Figure 2 was supplied by California DWR for the spring of 2011 – before the serious droughts. It is clear that there was a cone of depression to the east of Pixley.
- Figure 3 shows more overdraft by the spring of 2014 – with two major cones of depression in PIXID – the same one to the east of Pixley, and an additional one just to the west of Pixley. The numbers do not provide excellent agreement, but that is likely due to the quality of data and the methods used to interpolate the data. It is clear, however, that there is serious overdraft to both the east and west of Pixley.

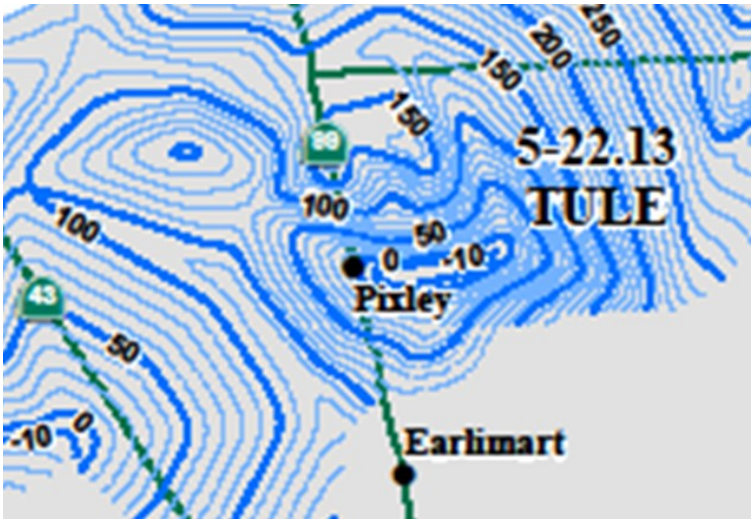


Figure 2. Spring 2011. Groundwater elevation contours from California DWR

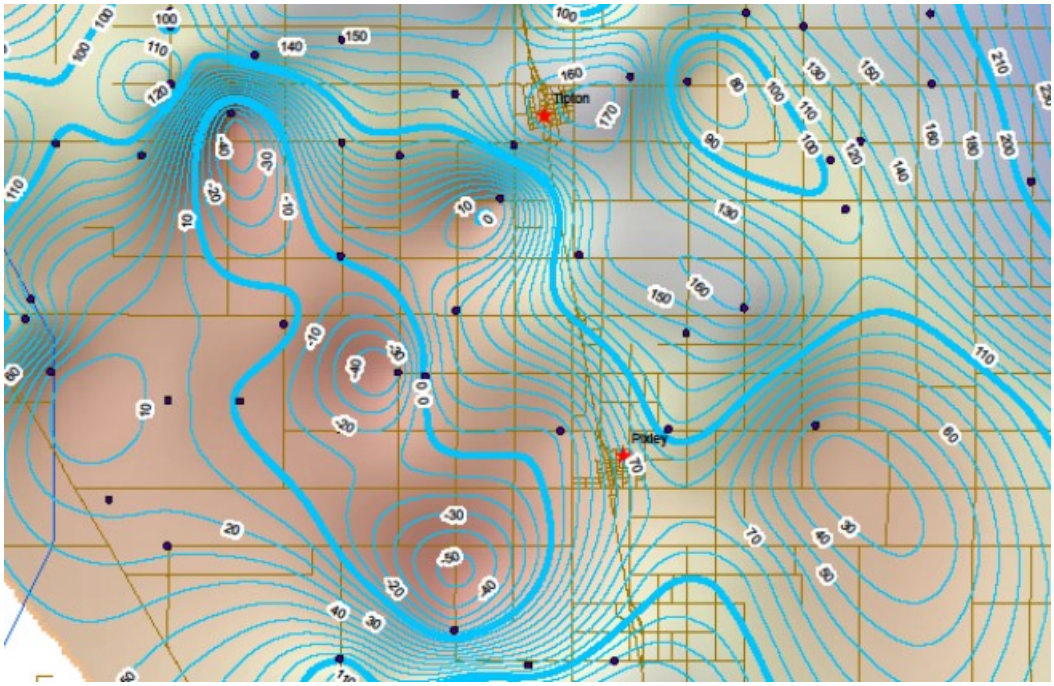


Figure 3. Spring 2014. Groundwater elevation contours supplied by Pixley ID

Figure 4 provides an overview of the district canals and recharge basins ("pits").

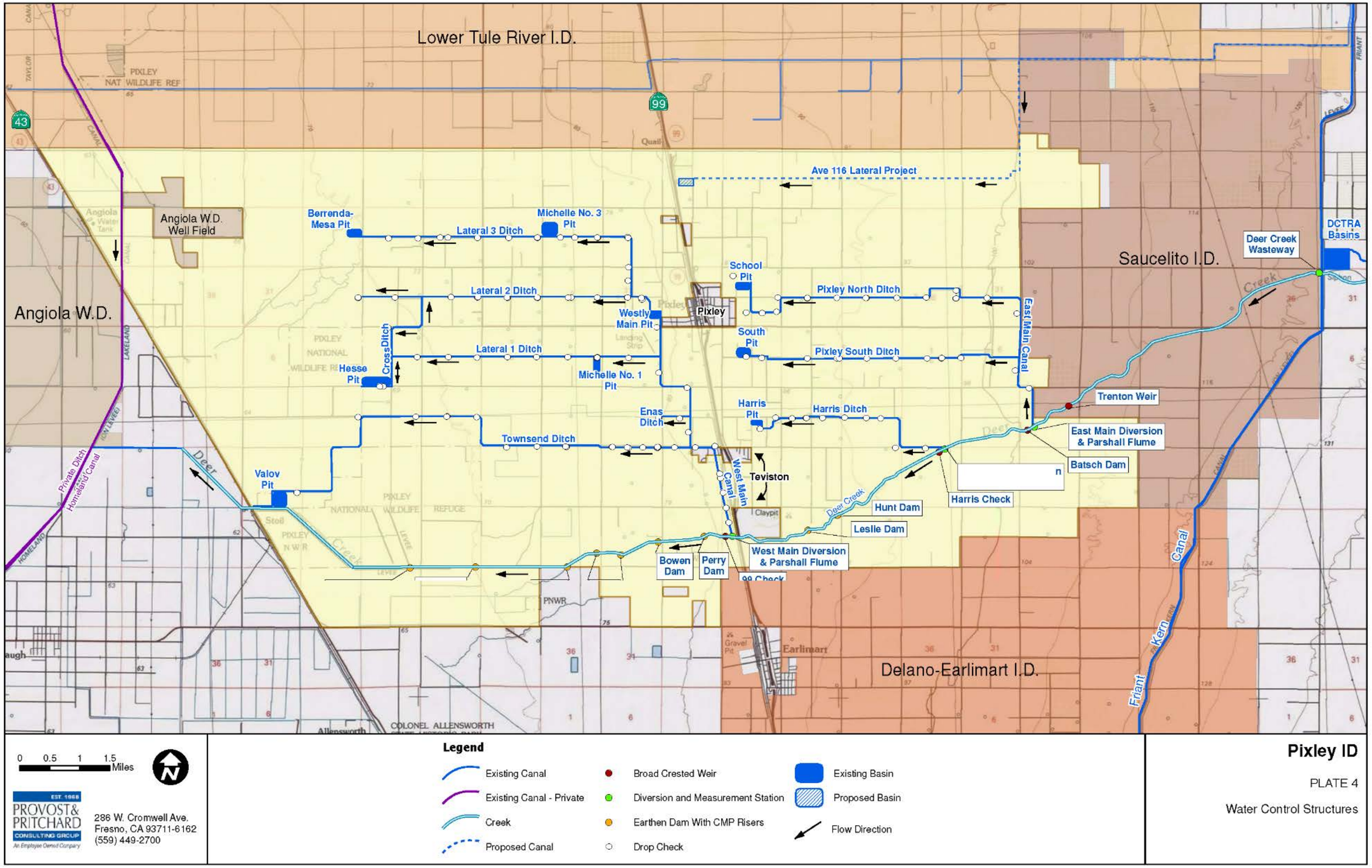


Figure 4. PIXID facilities from the 2010 AWMP. The Ave. 116 lateral and terminal reservoir has since been installed. The Valov Pit is private, and is not used.

PIXID has about 45 miles of unlined canals, plus the unlined Deer Creek. All of these serve as recharge facilities in addition to the various pits seen in Figure 4. The pits are in locations that clearly recharge groundwater for PIXID farmers.

Groundwater levels in PIXID, Lower Tule River ID, Saucelito ID, Delano Earlimart ID, and other neighboring districts are all inter-connected. There are only two solutions to the problem of declining groundwater levels on a regional basis:

1. **Reduce consumption of water** (also known as "ET" or Evapotranspiration). At the moment, there is no regulation that grants each acre a "water consumption" allowance. Eventually, this type of regulation must be implemented – as opposed to giving gross pumping permits of "xx" acre-feet/year.
2. **Increase the surface water supply**. This need is obviously well understood by everyone in the area, but perhaps some new possibilities could be considered, especially in light of the apparent increase in rainfall in the Sierras with an associated decrease in snowpack. Climate change could have major implications on timing/amounts of local surface water supplies. Friant Dam and Success Dam work reasonably well with snowpack melting, but have grossly insufficient storage if snowmelt changes to rainfall runoff.

It is understood that PIXID can only purchase surplus surface water from the Friant system. That will limit its options. Nevertheless, it is recommended that PIXID join with other districts along the Friant-Kern Canal to discuss new operation rules for the dams. PIXID specifically might change its focus in two ways:

a. The primary goal would be groundwater recharge, with surface water deliveries to farms having a secondary importance.
b. The district would attempt to keep its canals and ponds full all winter long (for seepage and groundwater storage) if water is available. The district would take as much of its annual expected allotment during the winter as possible. Specifically, it is suggested that PIXID begin to consider itself a winter recipient of water when possible, as opposed to focusing on obtaining water during the summer.

Obviously, it would be good to also receive surface water deliveries in the summer. However, this is a suggestion to change the dam operation to focus more on winter flows for groundwater recharge – for those districts that could benefit from a change. This is opposed to the current practice of attempting to fill up the dams in the winter and then begin deliveries in the spring. The dam operation would shift, as much as possible, to being a diversion dam for winter flows that are distributed to districts for groundwater recharge, with more storage being available for spring flood flows.

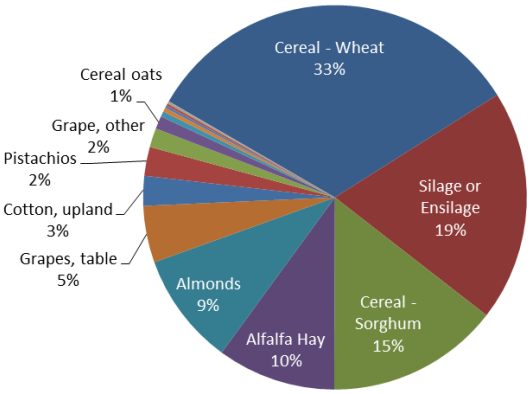
Overview of the District

Pixley ID operates on a scheduled delivery system, with water orders being placed at least 24 hours in advance. The district has 45 miles of unlined canals, and 15 miles of conveyance channel (Deer Creek). PIXID has nine groundwater recharge pits. The Agricultural Water Management Plan of 2010 lists the following flow measurement devices and locations on canals:

Pixley ID	
Name/Location	Type
Deer Creek Wasteway from FKC	Broad Crested Weir
East Main Canal	Parshall Flume
Harris Ditch	Parshall Flume
West Main Canal	Parshall Flume

The main crops in the district as of 2014 were:

- Wheat (approximately 33% of the total acres)
- Silage or Ensilage (approx. 19%)
- Sorghum (approx. 15%)
- Alfalfa Hay (approx. 10%)
- Almonds (approx. 9%)



The major irrigation methods are seen in the table below.

Pixley ID		
Method	Acres	%
Furrow	25,474	48
Border Strip	16,000	30
Low Volume	11,321	21
Sprinkler	478	1

The most recent physical addition to the district is the Avenue 116 Canal, which was completed in March of 2015. It has a capacity of 130 CFS. Most of the district water is delivered from the Friant Kern Canal through Deer Creek, with a turnout capacity of approximately 300 CFS.

Overview of the Existing System

Typical Structures

Farms rely on conjunctive use – a combination of well water and canal water. This water is usually moved within and between fields through an underground network of private pipelines. District turnouts are typically equipped with farmer-supplied pumps (see Figure 5) that lift water into a standpipe that supplies a pipeline network.

Figure 5. Typical conjunctive use system in PIXID. A well pump (on the left) is discharging into a standpipe. A low lift pump (right side) will lift canal water into the same standpipe.

Check structures along the canal laterals are very basic, with flashboard designs as seen in Figure 6 through Figure 8.

Figure 6. Typical check structure and turnout on the North Canal. Typical flow rate is 15-20 CFS.

Figure 7. Lateral 3 check structure, looking from downstream side

Figure 8. Old vertical culvert-check

Flow measurement at canal turnouts is rudimentary. In some locations there is no evidence of a flow measurement device; other locations have metergates.

Overall Operation

Figure 9 provides an overview of the current system and key operation facts and control features.

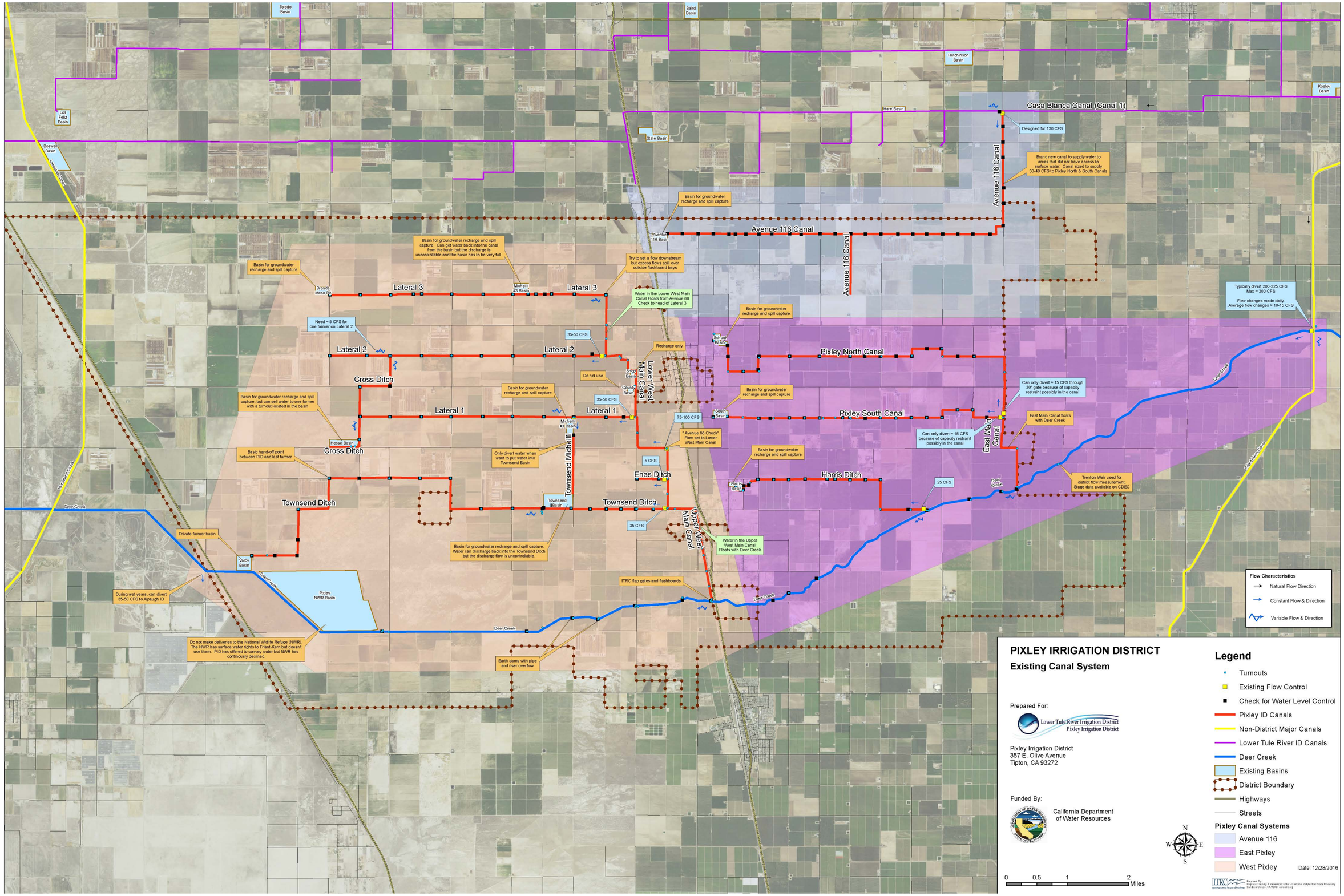


Figure 9. Overview of current system

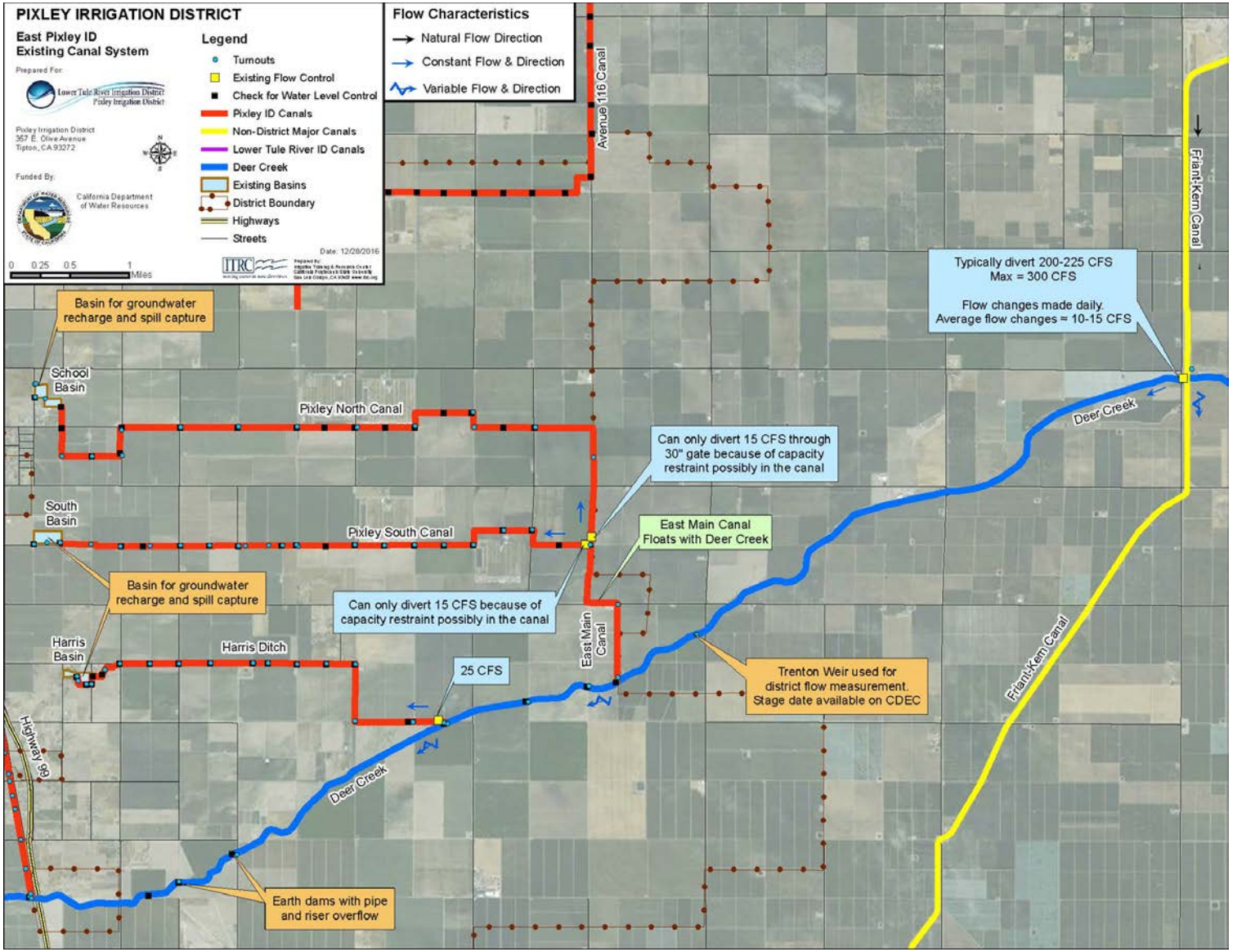


Figure 10. Existing operation – east side of Pixley ID

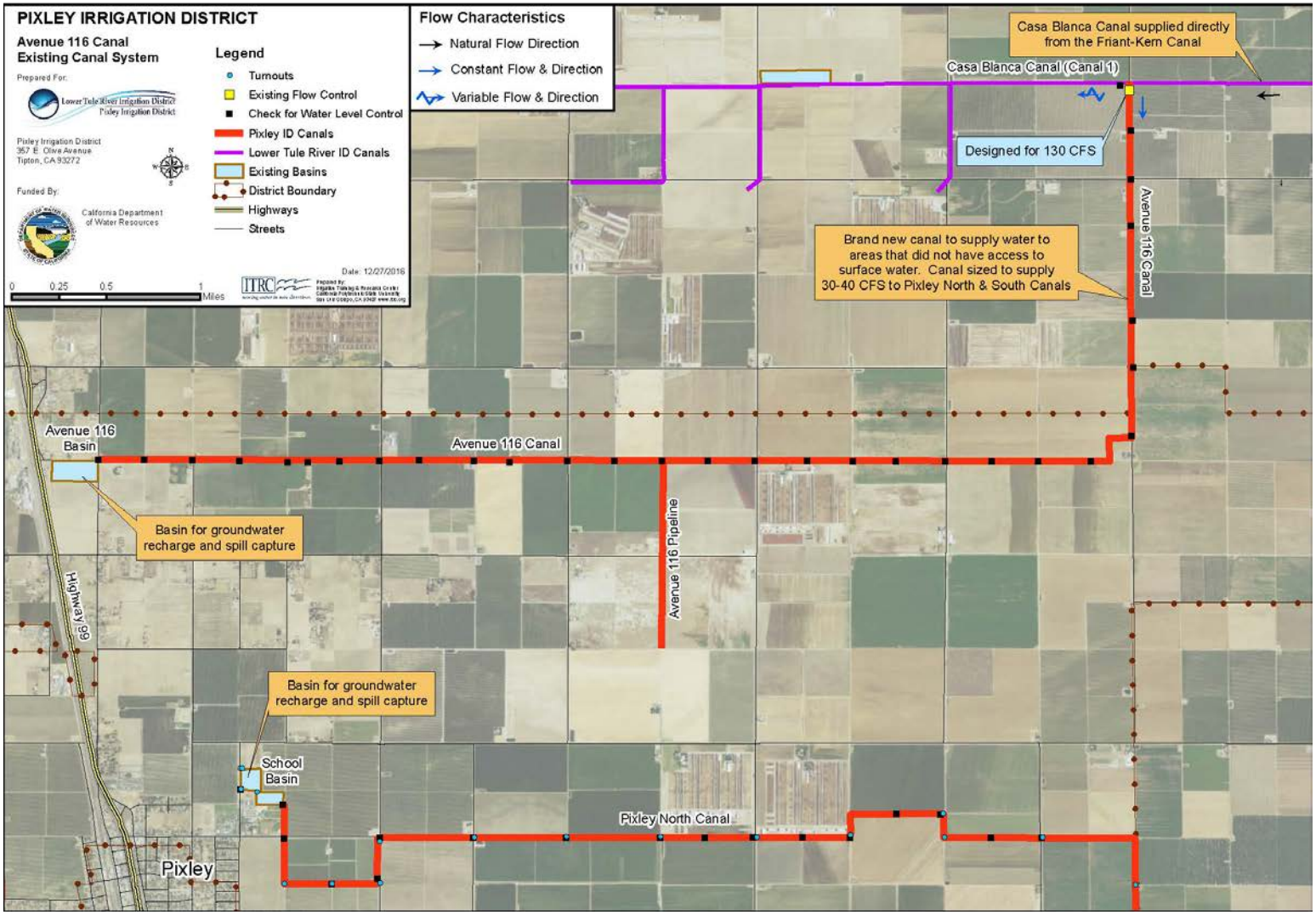


Figure 11. Existing operation – Avenue 116 Canal System

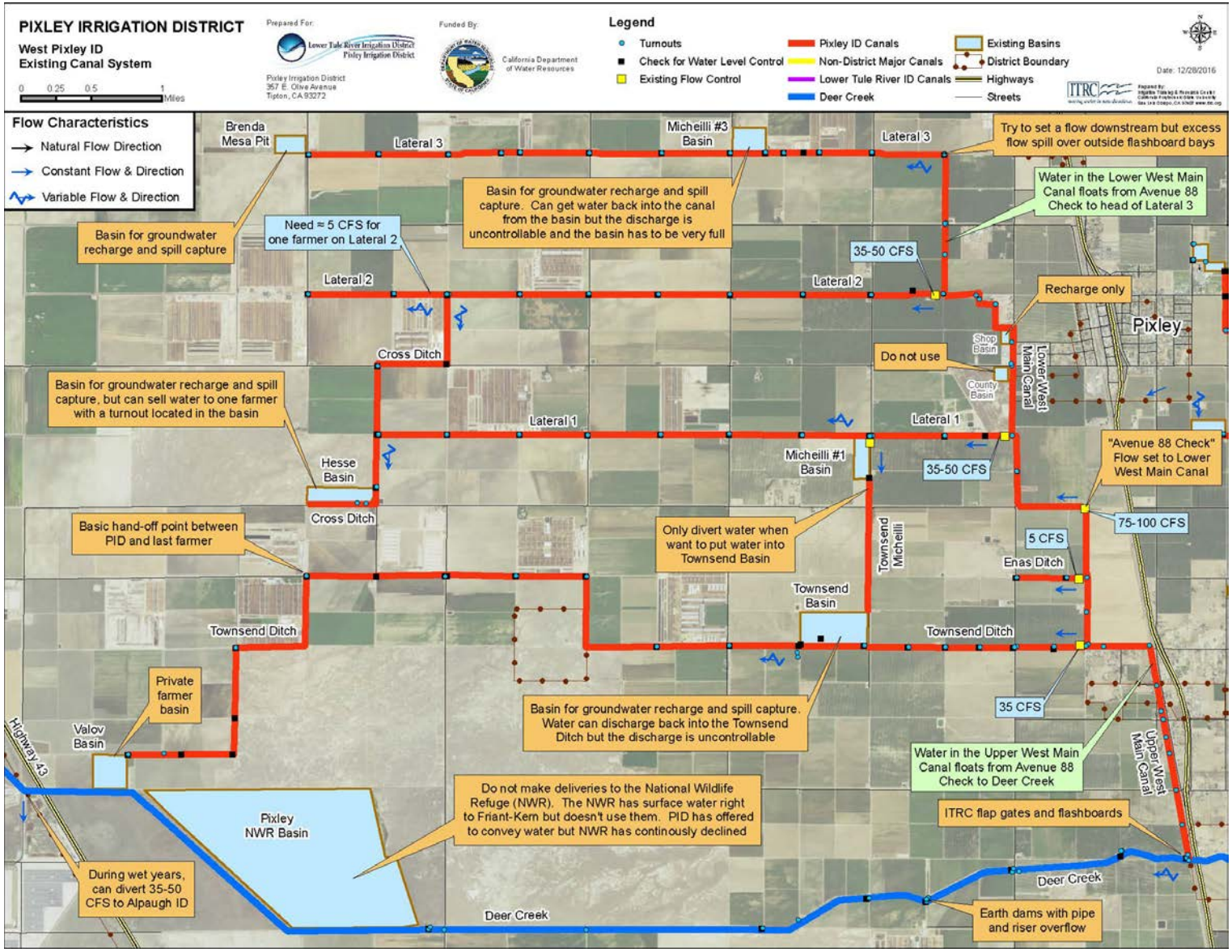


Figure 12. Existing operation – west side of Pixley ID

Overall Modernization Recommendations

Water Level Control

There are numerous flashboard structures throughout the district. The structures are small, and the flow rates in the laterals are typically fairly small (less than 30 CFS). Precise water level control is not essential where low lift pumps are used to pump into standpipes – a 0.5' change in water level will have a relatively small impact on the pump flow rate.

Therefore, any focus on improved water level control should be made where a turnout supplies a field (or another canal) with gravity flow. In those cases, a slight change in the supply water level will have a relatively large impact on the turnout flow rate.

For these small canals and structures, no serious engineering design is needed. It is recommended that PIXID staff visit Chowchilla ID to examine the relatively small but longer flashboard weirs that have been built in front of similar check structures with similar flow rates. An example is shown in Figure 13. Simplistically, by making the overflow length four times as great, there will be only 25% as much water level fluctuation in the canal. The upstream-facing design is recommended. It is important to pour a thick enough floor so that the floor does not float at low flow rates.

Figure 13. Retrofitted long-crested weir at Chowchilla ID

Controlling Flow Rates on the Western Ends of Canals

Modifications near the ends of Laterals 1-3, and the Townsend Ditch (at the intersection with the Cross Ditch) are recommended to more easily control flows via improved diversions into the Hesse and Micheilli #3 basins.

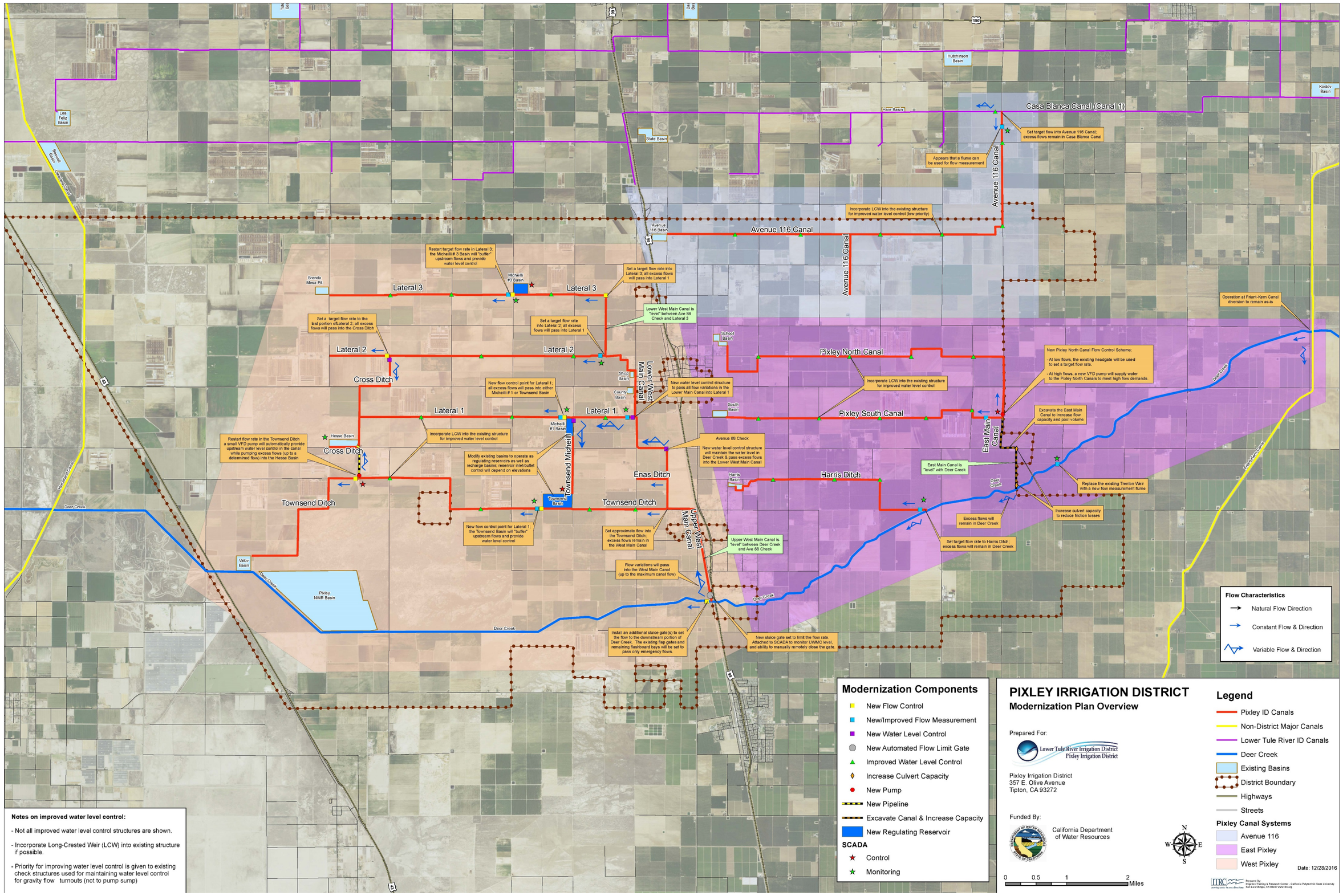


Figure 14. Overall modernization changes

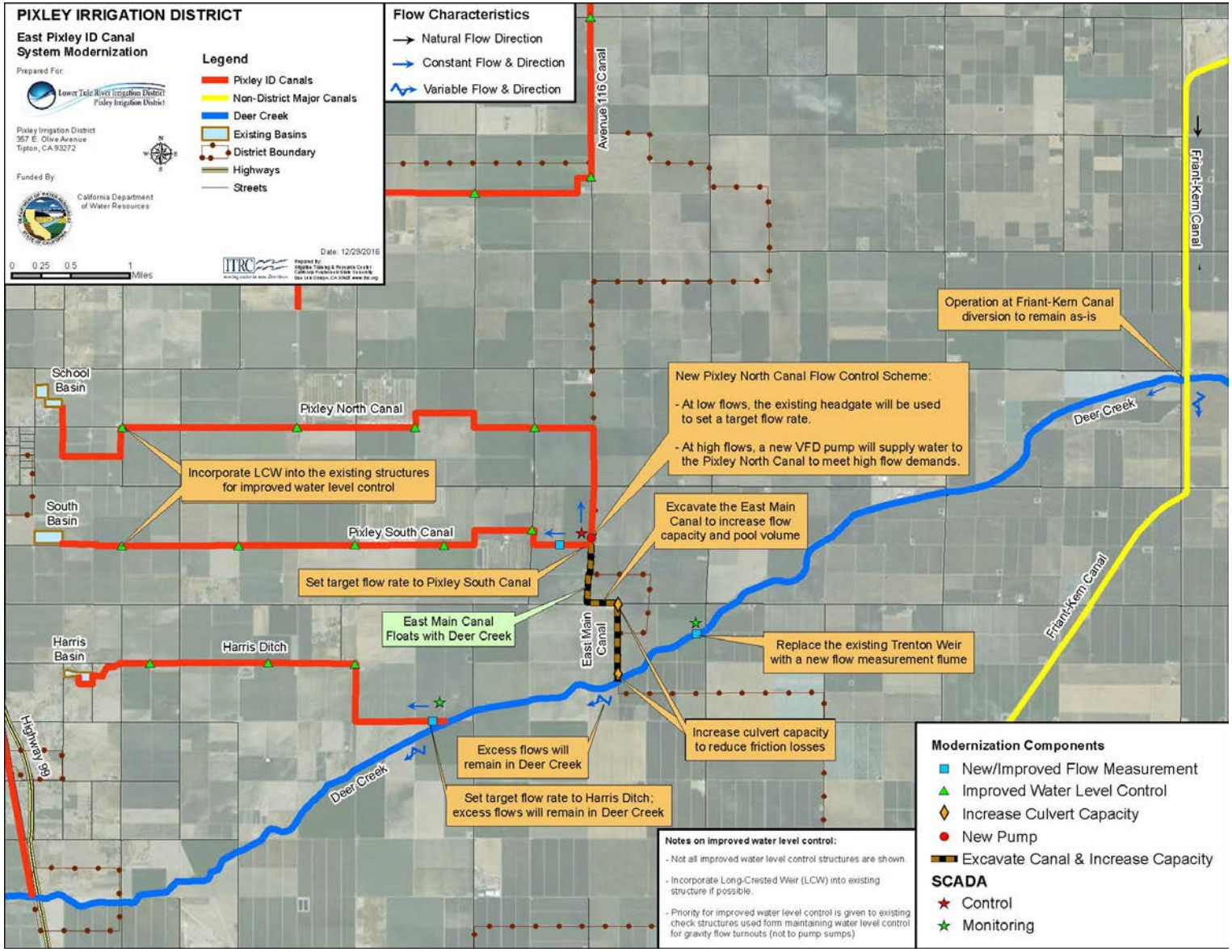


Figure 15. Modernization changes – east side of Pixley ID

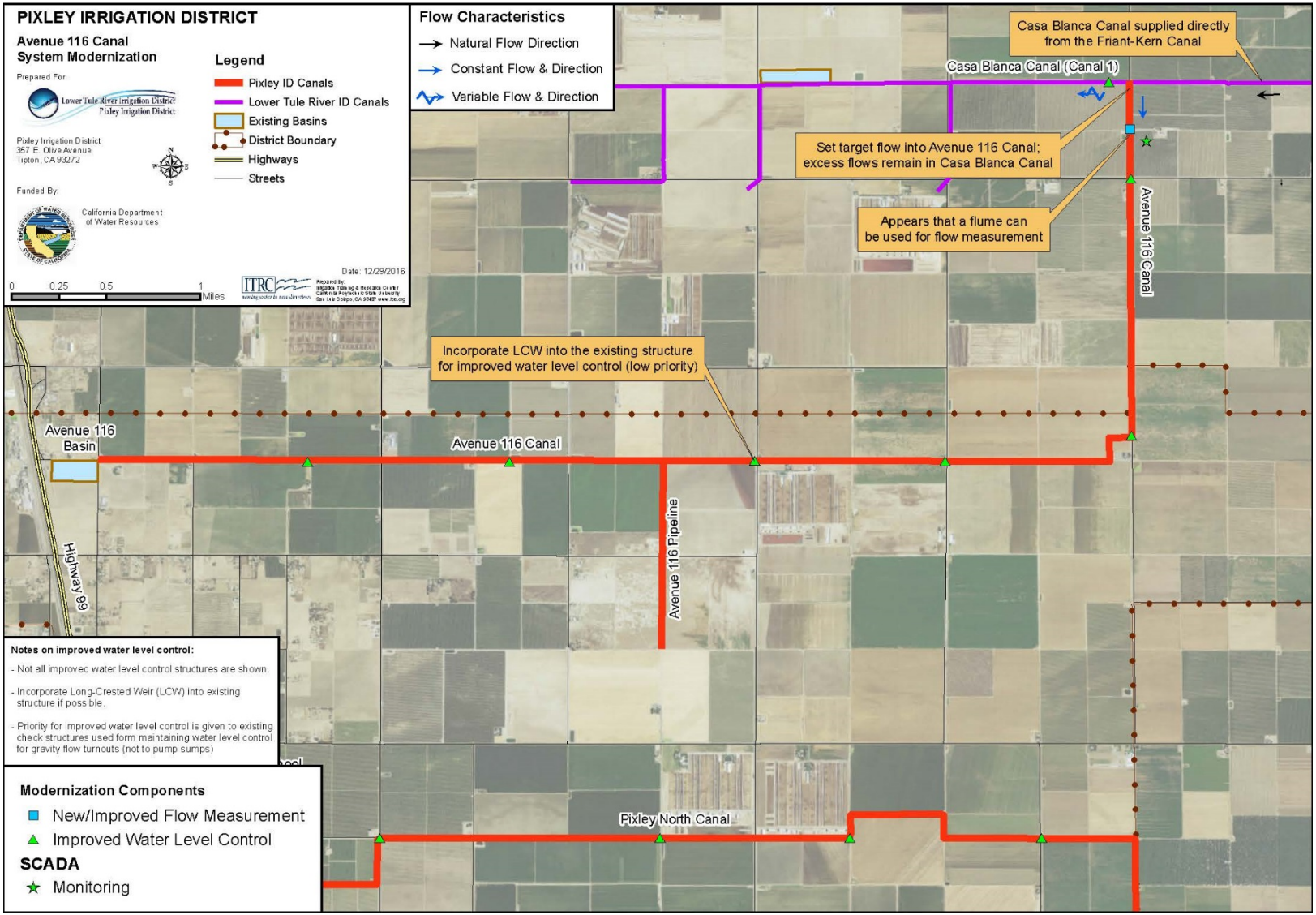


Figure 16. Modernization changes – Avenue 116 Canal System

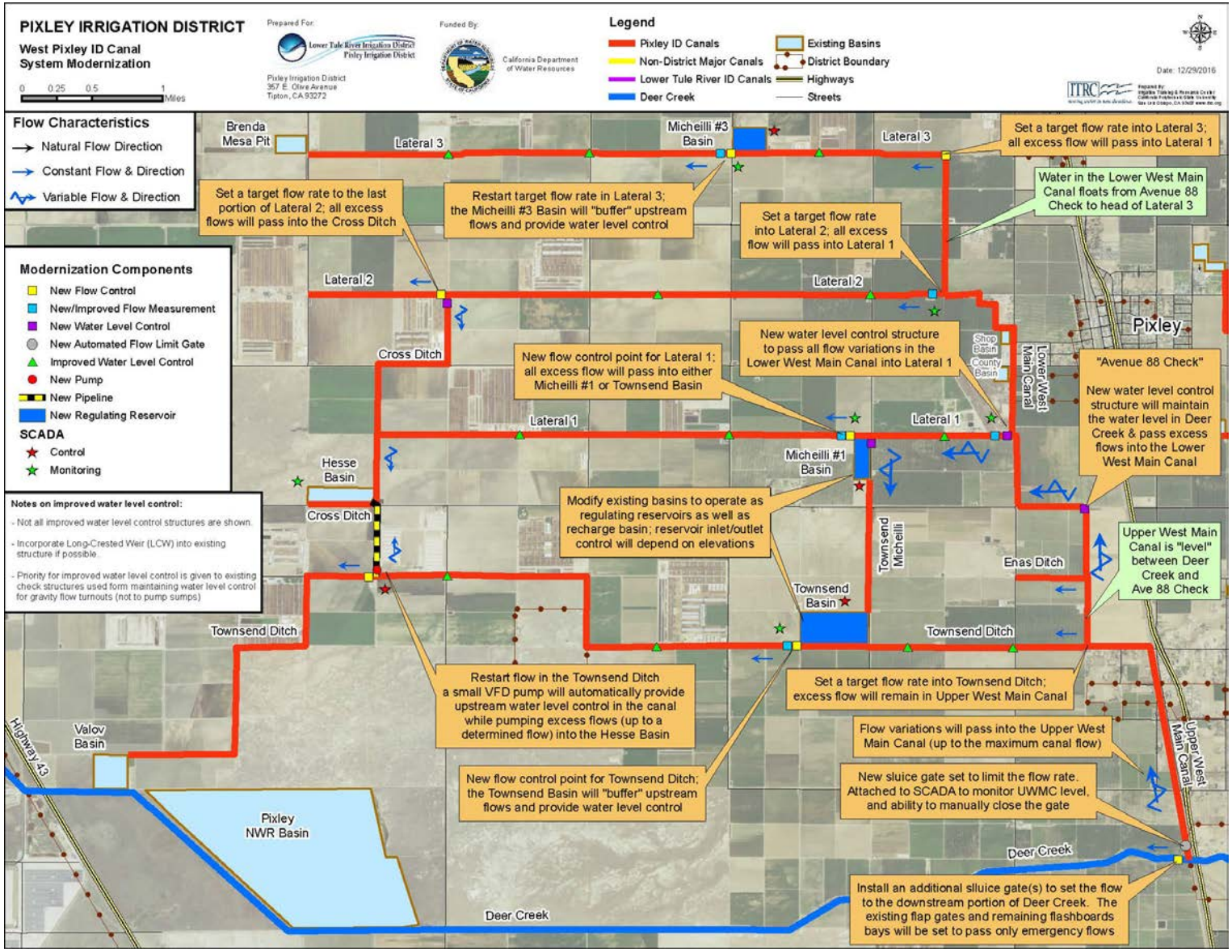


Figure 17. Modernization changes – west side of Pixley ID

Recommendations for Specific Sites

Details are provided in the next sections for some of the specific sites. In general, the details are provided sequentially to match how the water flows downstream from the Friant Kern Canal.

Head of 116 Canal

The Avenue 116 Canal is new and has not yet been operated to any great extent. Figure 18 shows the current configuration.

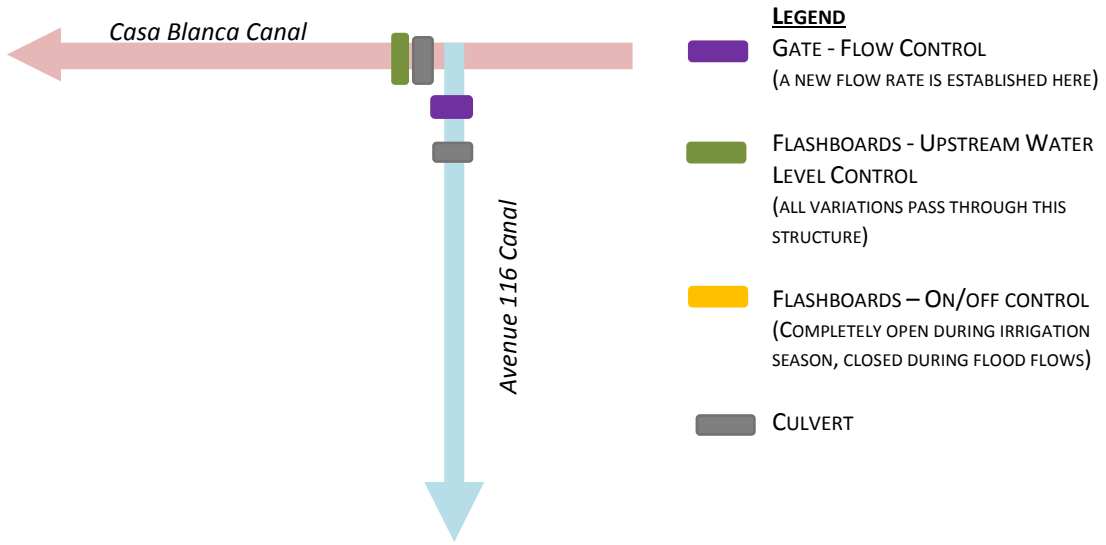


Figure 18. Current operation at Casa Blanca Canal and Avenue 116 Canal

Currently,

1. A concrete diversion box on the Casa Blanca Canal (Figure 19) diverts flow to the head of the Avenue 116 Canal through a 6' Waterman flow control gate.
2. There are three flashboard bays in the Casa Blanca Canal directly downstream of the two culvert pipes (Figure 20).
    a. Each flashboard bay is approximately 65" wide.
    b. There are two farmer turnouts directly upstream of the Casa Blanca check structure.

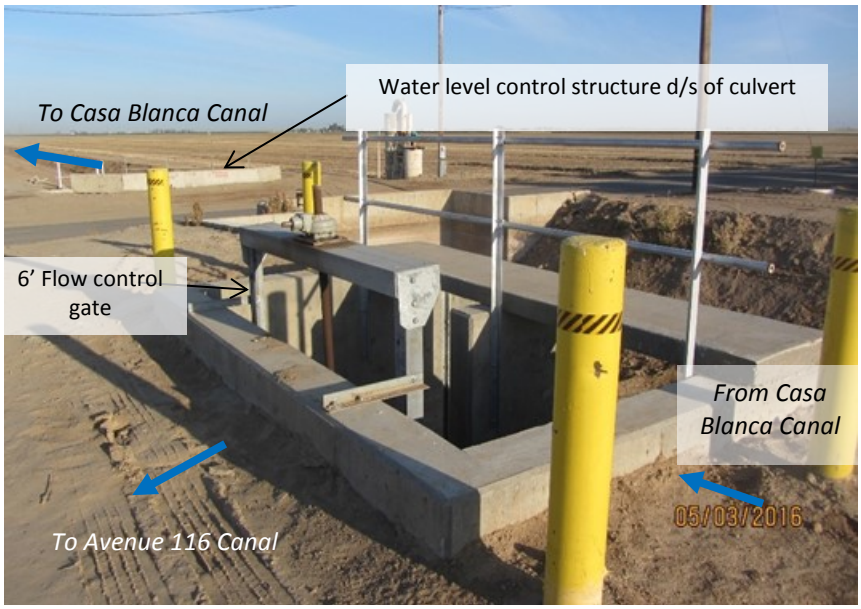


Figure 19. Existing diversion structure to Avenue 116 Canal from Casa Blanca Canal

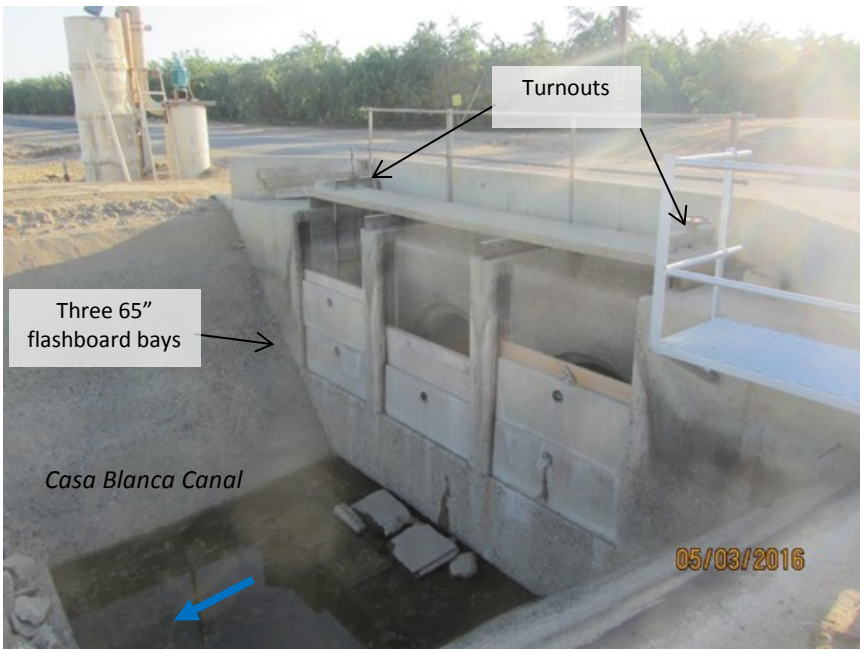


Figure 20. Check structure in the Casa Blanca Canal, just downstream of Avenue 116 Canal entrance

Figure 21. View of the Avenue 116 Canal, looking downstream from its entrance

The recommendations for improvement at this location are:

1. Install a flume in the Avenue 116 Canal so that the flow rate into it can be measured. Before doing this, the water levels need to be surveyed at high flow rate and at low flow rate to verify that it is possible. Also, it is likely that the energy dissipation jump in the floor on the downstream side of the 116 entrance structure will need to be jackhammered out and smoothed out, to reduce the head loss there.
2. Install a downstream-facing long-crested weir in the center bay of the Casa Blanca Canal check structure. This will help stabilize the flow rate into the Avenue 116 Canal very quickly at any time a flow change is made, and will also help to maintain a constant flow rate into the Avenue 116 Canal after that flow rate change is made. A new flume in the Avenue 116 Canal will reduce the water level drop across the flow control structure at the head of the Avenue 116 Canal, making it more sensitive to changes in water level (over time) in the Casa Blanca Canal. The long-crested weir will minimize those Casa Blanca Canal water level fluctuations, and keep a constant flow going into the Avenue 116 Canal.

Trenton Weir on Deer Creek

Trenton Weir is located approximately 450 ft downstream of Road 176 in Deer Creek. The operation is as follows:

1. The structure is a trapezoidal concrete weir that is approximately 10.5 feet wide and spans the entire width of Deer Creek.
2. The weir also functions as a one lane road.
3. The downstream concrete wall of the weir is approximately 1.5 feet lower than the upstream wall of the weir.
4. The Army Corp of Engineers has a gauging station that collects data of flows in Deer Creek.
    a. Flows are recorded weekly and supplied on the California Data Exchange Center (CDEC) website.
    b. District staff reviews flows on a weekly basis and will make adjustments at the heads of the East Main and West Main Canal accordingly.

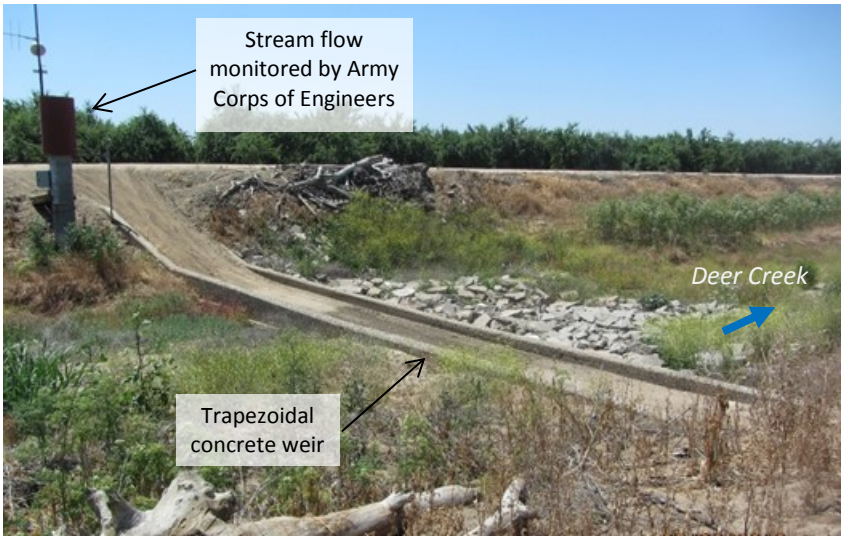


Figure 22. Existing Trenton Weir in Deer Creek used for flow measurement

This is by no means a standard measurement structure, and it is likely sensitive to the downstream channel conditions. However, this is likely not a high priority site unless it is used to determine water rights. It appears that its most important use is to estimate flood flow rates. It is too large to accurately estimate smaller flow rates of 200 CFS.

Unless this is an important site, it is recommended that PIXID focus on improving the flow rate measurement into the downstream canals, rather than modifying this structure.

Upper East Main Canal and Deer Creek

The current operation of the Upper East Main Canal is depicted in Figure 23.

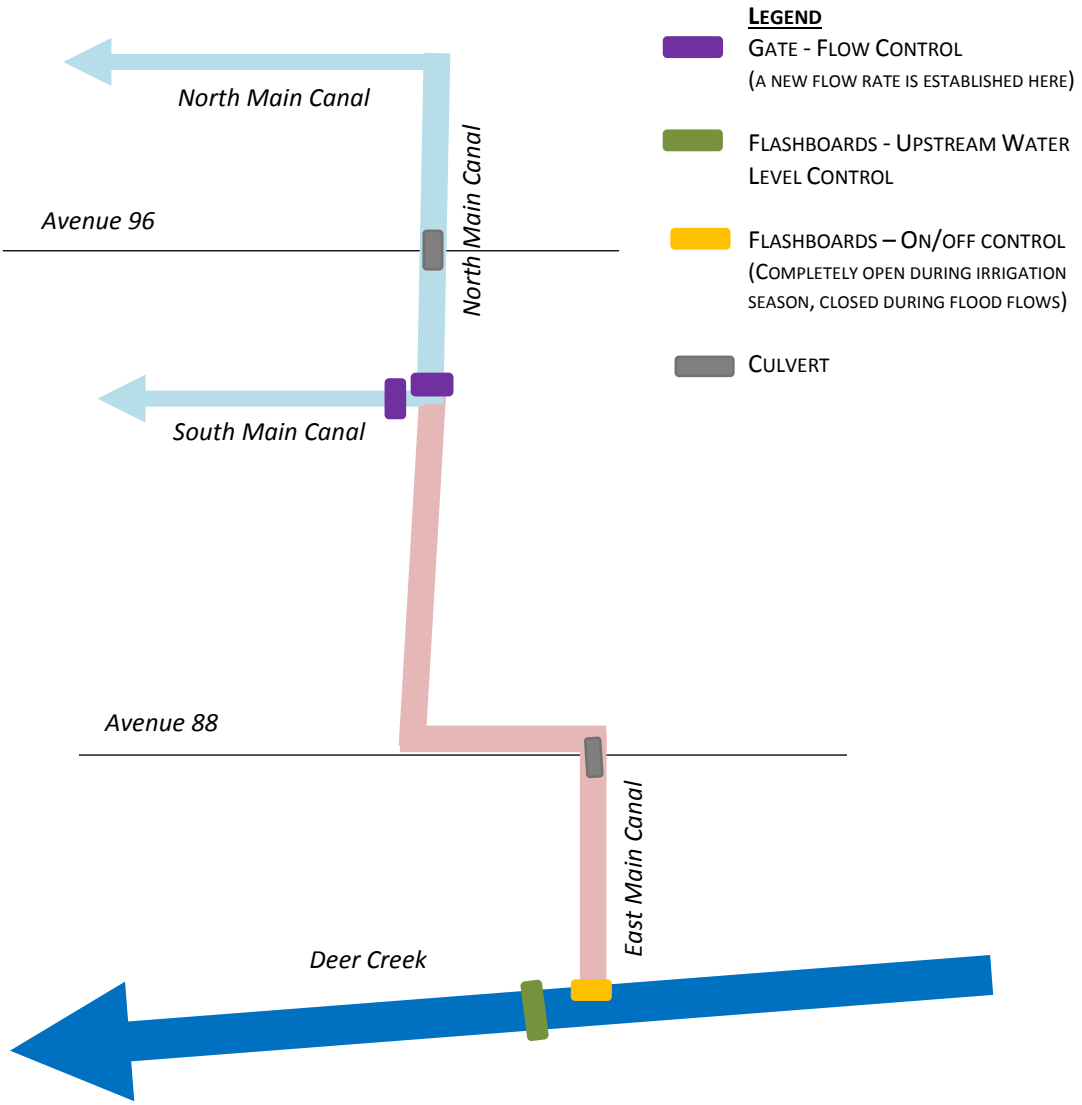


Figure 23. Current of the head of the East Main Canal

Currently,

1. A diversion dam in Deer Creek (Figure 24) provides upstream water level control for the East Main Canal. Flow variations pass over the diversion dam and continue down Deer Creek to service the West Main Canal. The structure is composed of twelve flashboard bays that are each approximately 64" wide.
2. A flashboard structure at the head of the East Main Canal (Figure 25) is used for on/off control of the canal. During the irrigation season, the boards are removed so that the first section of the East Main Canal has the same water level as does Deer Creek. Boards are only installed in the structure to prevent winter flood flows in Deer Creek from entering the canal.

3. Average flow diverted to the East Main canal is approximately 30 CFS.
    a. Flows are diverted through a 30” ARMCO gate to the North Main Canal:
        i. average of 15 CFS
        ii. maximum of 20-25 CFS
    b. Flows are diverted through a 36” ARMCO gate to the South Canal:
        i. average of 15 CFS
4. It has been difficult for district staff to divert necessary flows into the East Main Canal. Land subsidence is suspected as the cause.
5. A preliminary survey conducted by the ITRC of the East Main Canal starting at Deer Creek and terminating at the head of the North Canal shows that there is only about **0.18 ft** of head loss from the High Water Level (HWL) in Deer Creek and the HWL at the head of the North Canal. The elevations of the canal bank, going north until the North Canal turns west, are almost all the same. Basically, there is very little slope to enable large flows to move along the East Main Canal.
6. There are roads on both sides of the canal, which will make it difficult to widen the canal.

Figure 24. Diversion dam on Deer Creek at the head of the East Main Canal

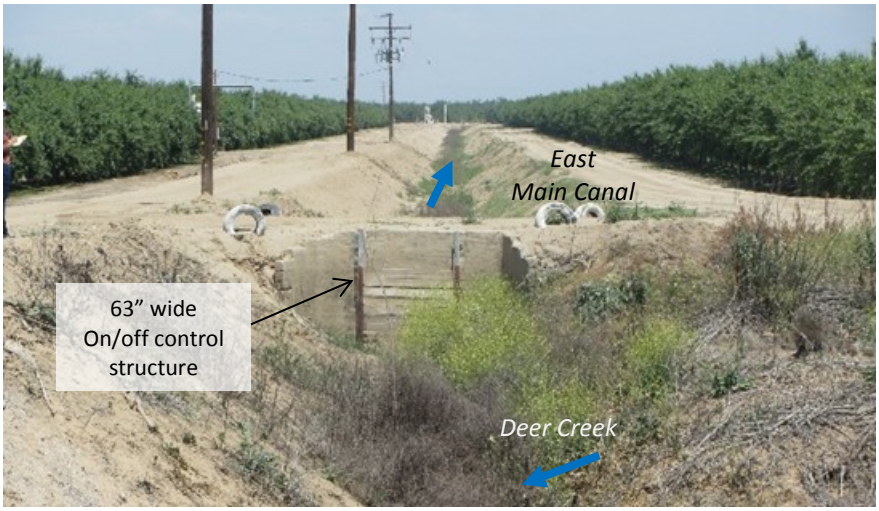


Figure 25. Existing structure at the head of the East Main Canal used for on/off control. During the irrigation season, the boards are removed.

The following modifications can be considered for the East Main Canal:

1. The design of the Avenue 116 Canal evidently assumed that some of its flow could eventually continue south to the Pixley North Canal. However, there is a rise in elevation going straight south from the initial southerly leg of the Avenue 116 Canal, and connecting to the East Main Canal. This would make it difficult to flow via gravity along that route.
2. It may be possible to install the flashboards in Deer Creek several inches higher.
3. The road crossing Avenue 88 creates a flow restriction, as seen in Figure 26. It is understood that there had been no flow for several years, and it can be expected that after that time, the 53" ID culvert would be partially plugged. However, the following items can be noted:
    a. If the culvert is kept clean, there will be about 0.25 feet of head loss across the whole structure. There is little that can be done in this case to reduce that loss.
    b. A key goal is to keep this and other restricting culverts clean. Shotcreting the channel for about 40' upstream of the culvert entrance can be considered to help keep it clean.

Figure 26. Avenue 88 culvert of the East Main Canal

4. The major recommendation is to install a VFD-equipped pump to supply the North Canal, located at the bifurcation of the North and South Canals. There must be two considerations:
    a. This is a very low lift pump, and it must be carefully selected to provide a range of flows between 5 and 20 CFS without having vibration problems. Most pumps of this type are unstable under VFD operation. Figure 27 shows example system/pump curves for a Cascade 20AP pump that is suitable for VFD operation. At 20 CFS, this would require about 30 HP into the motor.

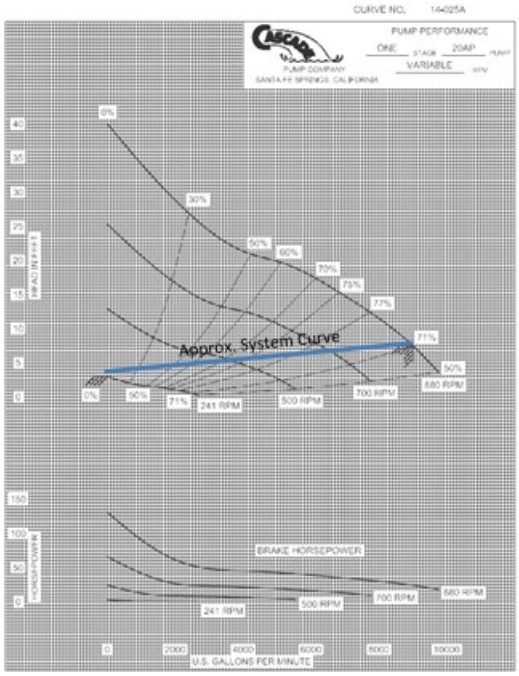


Figure 27. Cascade pump system curves

b. ITRC is developing new specifications for VFD controls, on behalf of PG&E. But those are not yet ready. Key attributes that should be required include:
   i. 50 deg. C temperature rating.
   ii. Panel must be shielded from the sun.
   iii. Overall efficiency must be greater than 96%.
   iv. Cooling must be guaranteed to maintain a temperature below 45 deg. Celsius in the panel. No outside air can be drawn into the panel.
   v. Harmonics generated by the VFD shall be addressed as follows:
      1. Line side harmonics shall be limited to no greater than allowed by IEEE 519 at the Point of Connection to the Utility.
      2. Load side harmonics shall be limited so as not to cause damage to the electric motor or conductors.
   vi. The VFD Controller and associated equipment shall be designed and installed properly, based on the latest editions of the National Electric Code (NFPA 70), the California Electric Code (CEC) and any local codes. The owner shall provide proof that the Authority Having Jurisdiction (AHJ) over the installation, such as a County Building Department that issues permits and conducts inspections of work done, has approved the completed work.
   vii. The VFD and associated equipment shall be of sufficient current or horsepower rating to meet the motor nameplate Full Load Amps (FLA) as well as any adjustment for ambient temperature above the rated maximum ambient temperature of the VFD.
   viii. The VFD and associated equipment shall have a short-circuit current (Isc) rating greater than the maximum potential Isc the equipment could be exposed to.

ix. The VFD shall be marked with the manufacturer's name or identification, the voltage, current or horsepower rating, the short circuit current rating, and other necessary data to properly indicate the applications for which it is suitable for. For VFD's that are an integral part of equipment approved as a unit, the above markings shall be permitted on the equipment nameplate.

x. The VFD and all associated equipment shall be enclosed in an enclosure rated for the environment where the enclosure will be located.

xi. A Single-Line drawing of the electrical circuits and equipment associated with the VFD shall be developed showing the following equipment and be available for anyone to review who needs to work on or around the circuits or equipment:

    1. Point of connection (POC) to the utility or separately derived power source
    2. Short-circuit current at the POC
    3. Conductor length and size
    4. Disconnects
    5. Protective devices (including the manufacturer, model, rating and Isc rating)
    6. VFD (including the manufacturer, model, rating and Isc rating)
    7. Motor (including HP, RPM and FLA at the design voltage)

xii. A two year warrantee shall be provided for all equipment and labor associated with the installation of the VFD starting from the date of commissioning and handover of the project to the owner.

Upper West Main Canal

The current operation of the Upper West Main Canal is depicted in Figure 28.

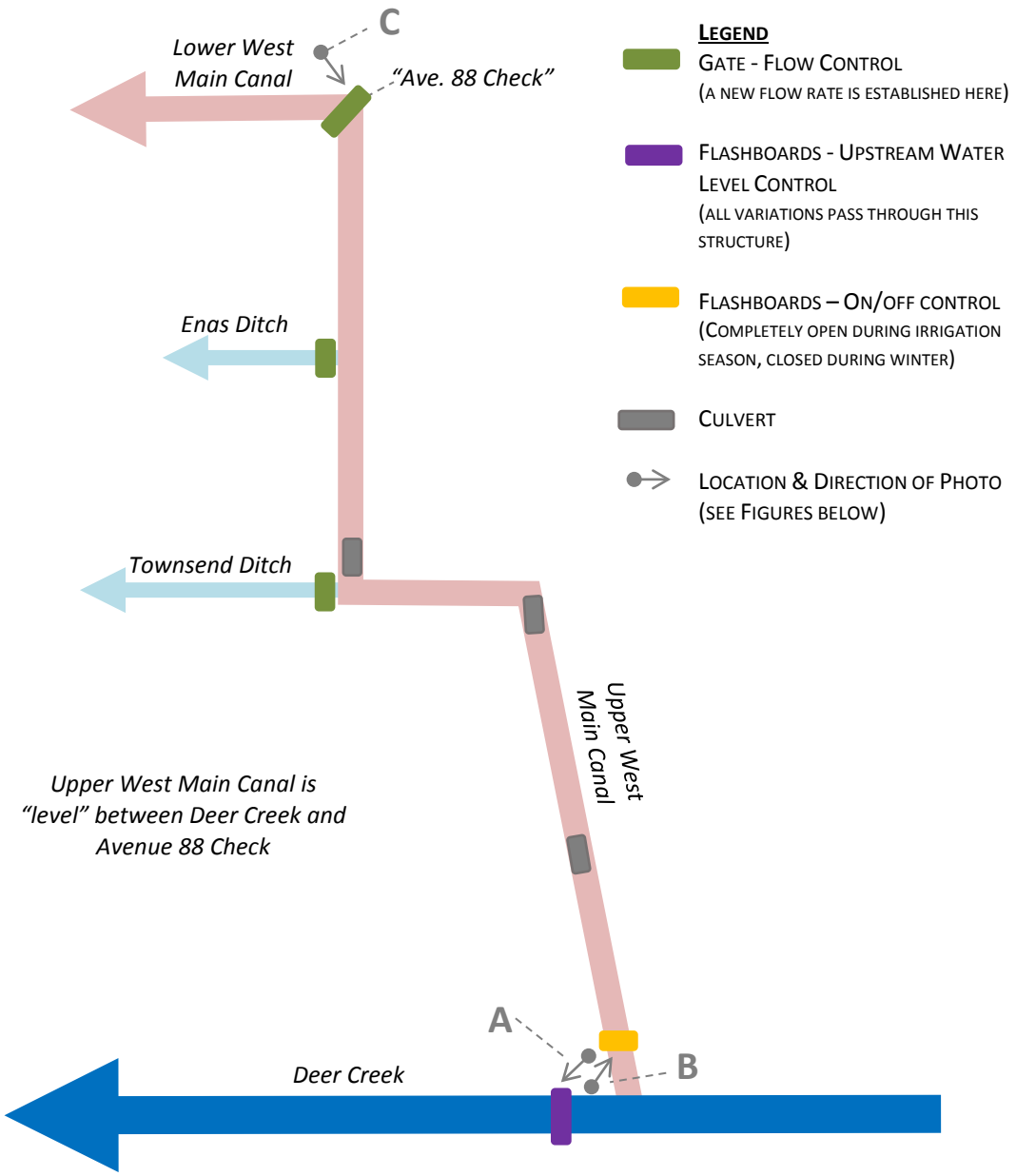


Figure 28. Current operation at Deer Creek and Upper West Main Canal

Presently,

1. A diversion dam in Deer Creek provides upstream water level control for the Upper West Main Canal. Flow variations pass over the diversion dam and continue down Deer Creek to service a few individual turnouts. The structure is composed of the following:
    a. A single sluice gate used to set a flow downstream to Deer Creek.
    b. Three identical ITRC flap gates to maintain a fairly constant upstream water level.

   c. Multiple flashboard bays to pass excess flows that exceed the capacity of the three flap gates.
2. A flashboard structure at the head of the Upper West Main Canal is used to for on/off control of the canal. During the irrigation season, the structure is completely open. Boards are only installed in the structure to prevent winter flood flows in Deer Creek from entering the canal.
3. The water level in the Upper West Main Canal all the way to the "Avenue 88 Check" floats with the water level in Deer Creek.
4. A 48" Waterman gate is used to set a target flow rate of approximately 35-40 CFS into the Townsend Ditch.
5. Approximately 5 CFS is diverted into the Enas Ditch.
6. A target flow rate of approximately 100 CFS is set through two identical sluice gates installed in the "Avenue 88 Check".

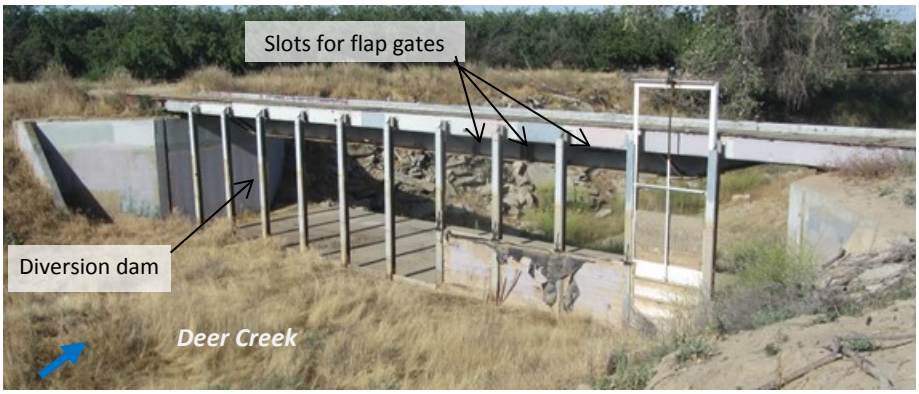


Figure 29. View "A" from Figure 28. Existing diversion dam on Deer Creek at the head of the Upper West Main Canal. The original flap gates were removed at the time of the photo

Figure 30. View "B" from Figure 28. Existing structure at the head of the Upper West Main Canal used for on/off control. During the irrigation season, the structure is wide open.

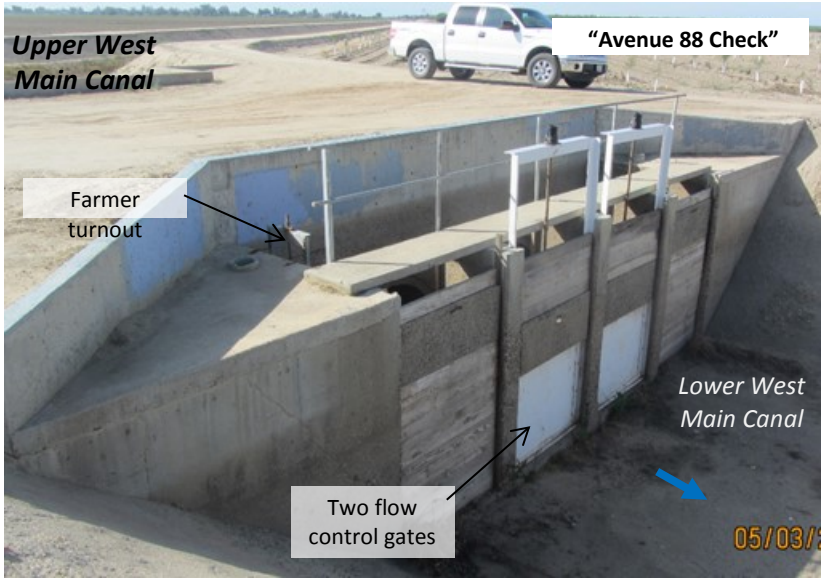


Figure 31. View "C" from Figure 28. Avenue 88 Check; Flow control gates at the entrance to the Lower West Main Canal

Figure 32 shows the modernization recommendations for the Upper West Main Canal.

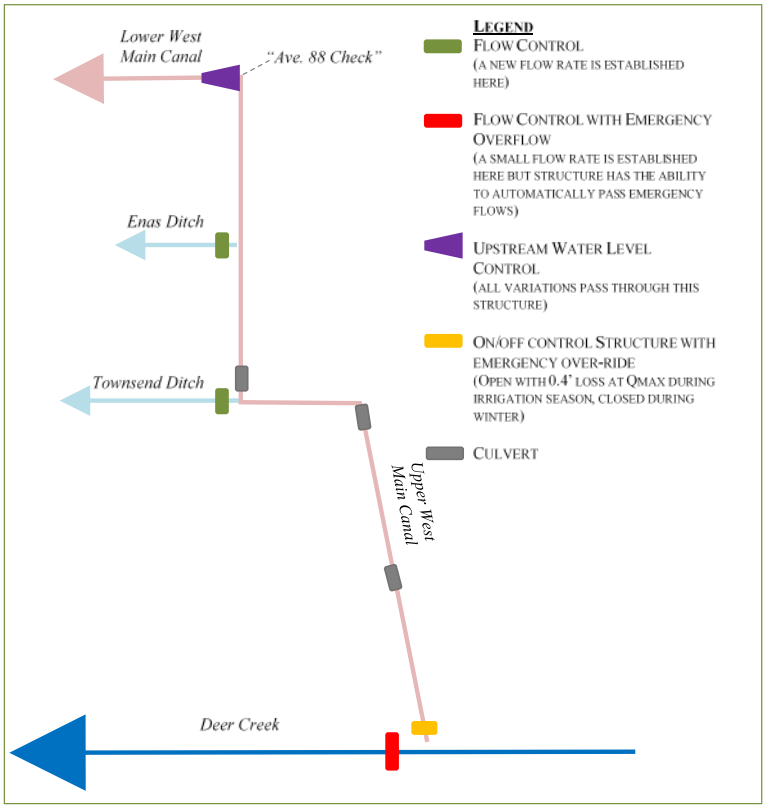


Figure 32. New operation of the Deer Creek and the Upper West Main Canal

1. The Deer Creek diversion dam will continue to operate as-is during the irrigation season. The only water that will continue to flow downstream will be regulated through the existing sluice gate.
2. The entrance to the Upper West Main Canal will have a new motorized sluice gate installed and will be connected to SCADA. Key aspects to this will be:
    a. The sluice gate will be positioned to have about 0.4' of head loss at the expected *maximum* flow rate.
    b. If a higher flow rate comes down Deer Creek, the water level upstream of the new sluice gate will rise. If the flow into the Upper Main Canal increases by 40%, the water level upstream of the sluice gate will rise by about 0.5'. This will be sufficient to send an alarm over the SCADA system.
    c. The sluice gate can be remotely (manually) operated from the office in case the flow is too high.
    d. SCADA will provide information on the water levels upstream and downstream of the new sluice gate, as well as the sluice gate opening.

Figure 33. Proposed modifications at Upper West Main Canal and Deer Creek

3. Variable flows in Deer Creek will move into the Upper West Main Canal. The water level in the Upper West Main Canal will remain relatively constant with a new long-crested weir located at the transition between the Upper West Main Canal, and the Lower West Main Canal, at Avenue 88. Flow rates into the Townsend Ditch and the Enas Ditch will remain almost constant, once they are adjusted. All flow variations will pass over the long-crested weir, and will eventually be captured in the either the Micheilli # 1 Basin or the Townsend

Basin (described below). The variable flow will then be re-regulated when needed to improve flexibility for farmers in the west.

4. If the upstream water level in Deer Creek were to rise above the target water level elevation, the excess flow would automatically spill through the three flap gates installed in the diversion dam. If the water continued to rise, the excess flows will then spill over the flashboards.

Figure 34 shows the proposed modifications to the Avenue 88 Check. A 100 ft long (minimum effective length) downstream facing long-crested weir (LCW) without a walkway top will be constructed to maintain the upstream water level in the Upper West Main Canal and Deer Creek.

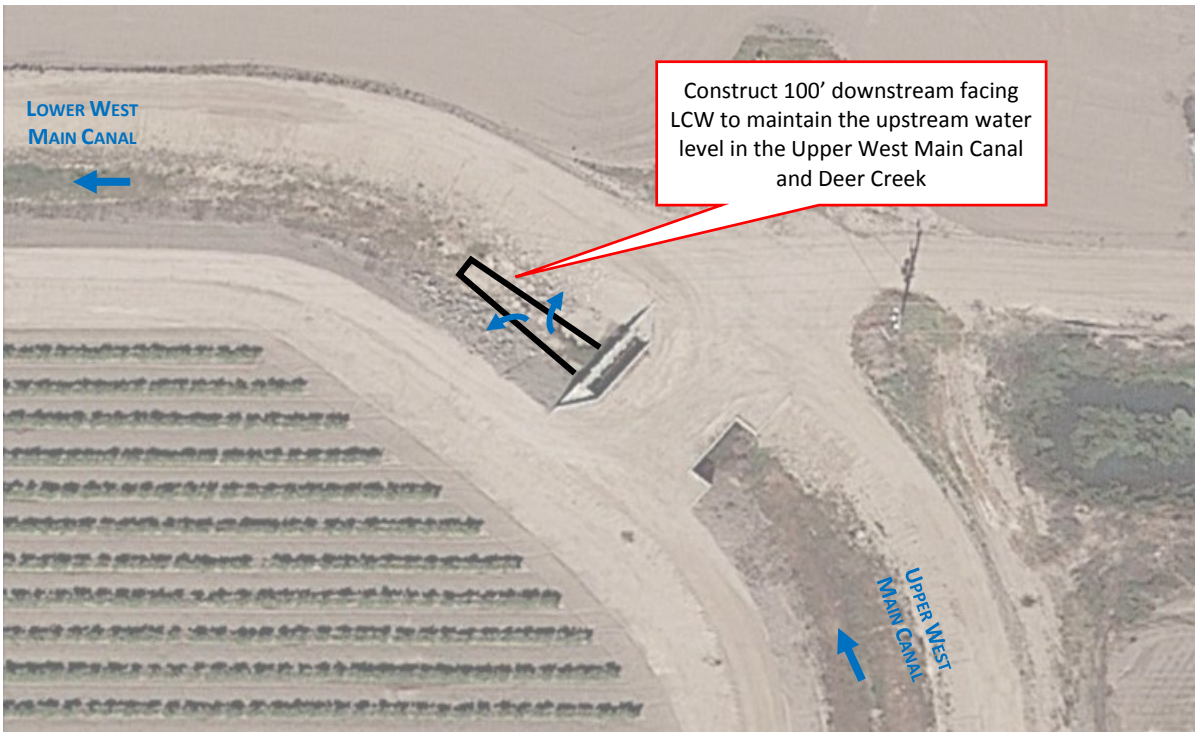


Figure 34. Modifications to the Avenue 88 Check

Design notes for the LCW include:

1. The LCW will be constructed in the middle two bays. The two existing sluice gates will be removed. The two outside flashboard bays will remain as-is.
2. One of the existing sluice gates will be installed at the very tail end of the LCW for passing part of the canal flow as well as continuous flushing for sediment. A walkway from the side of the canal must be constructed to access that gate. No walkway would cover the LCW.
3. A 6" flashboard will be used for the crest so that the target water level elevation can be adjusted after construction if needed.

Lower West Main Canal

The current operations of the Lower West Main Canal is depicted in Figure 35.

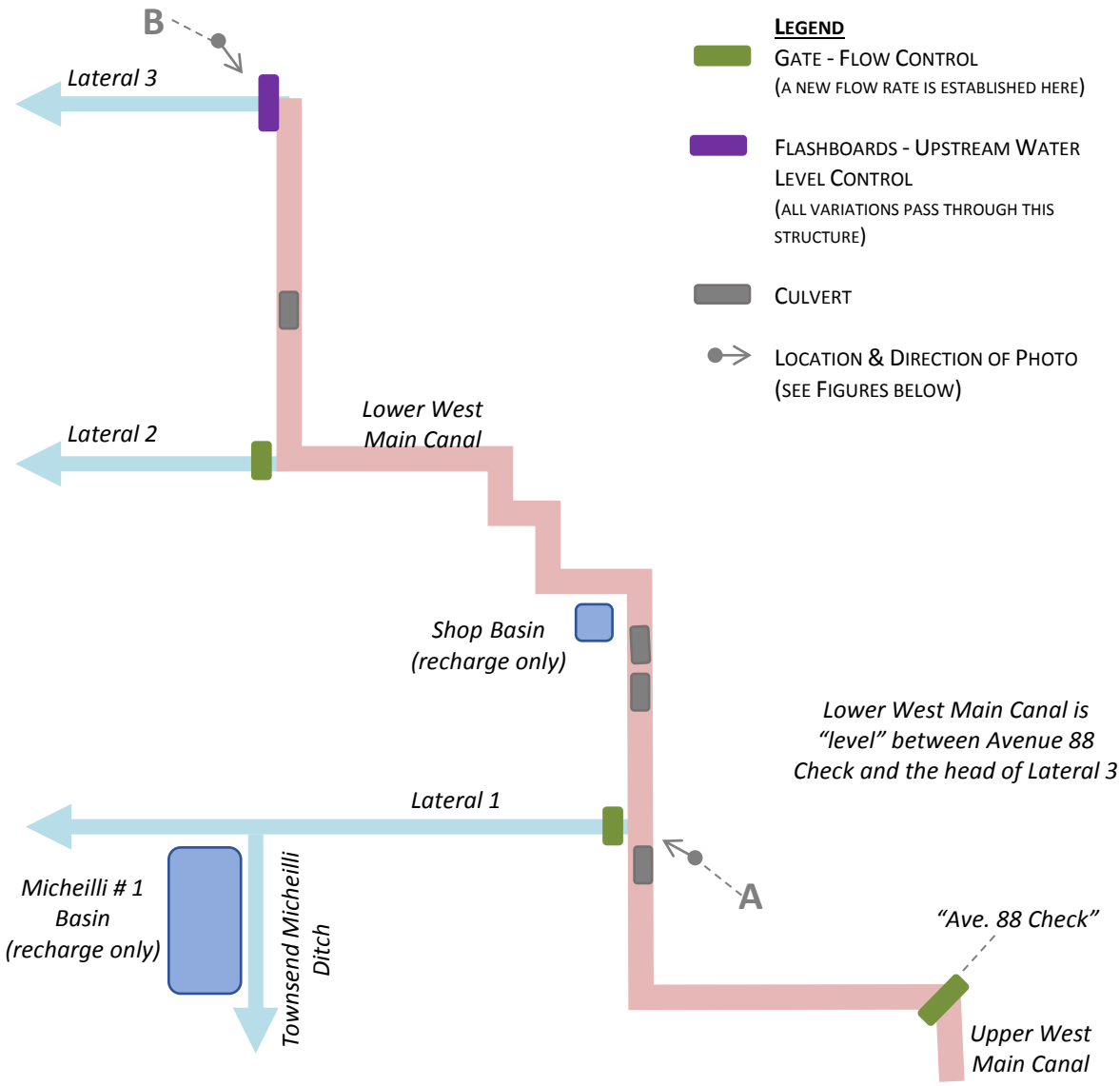


Figure 35. Current operation of the Lower West Main Canal

Presently,

1. A target flow rate of approximately 100 CFS is diverted at the Avenue 88 Check into the Lower West Main Canal from the Upper West Main Canal.
2. Approximately 35-50 CFS is diverted into both Lateral 1 and Lateral 2 through manually operated 48" Waterman gates.
3. At the head of Lateral 3, a circular gate and flashboard combination structure regulates the water level in the Lower West Main Canal. The 48" Waterman is used to pass majority of the flow with the flow variations passing over the two outside flashboard bases into Lateral 3.

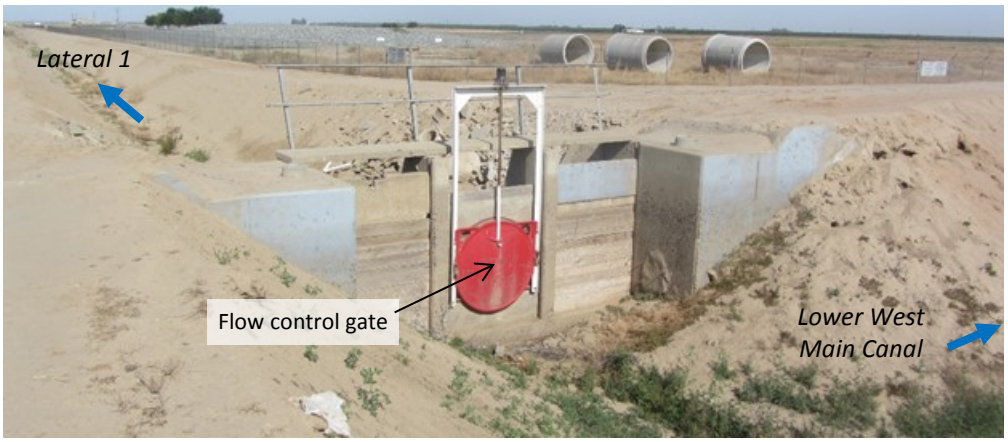


Figure 36. Existing Lateral 1 flow control headgate on the Lower West Main Canal

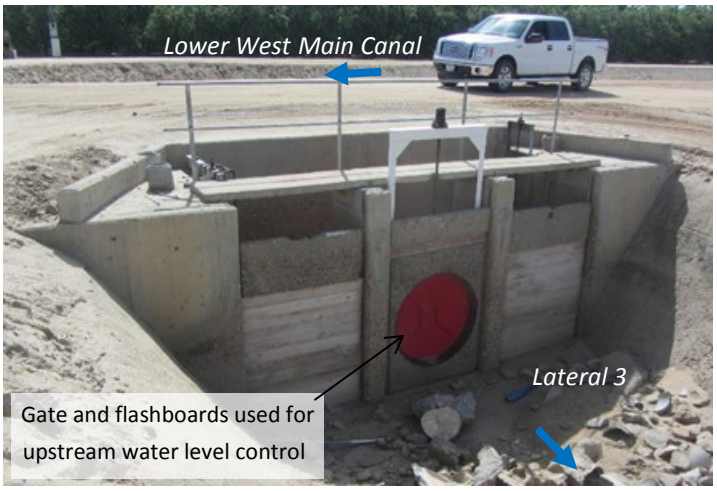


Figure 37. Existing check structure at start of Lateral 3 that provides upstream water level control in the Lower West Main Canal

Proposed Modifications

The functions of the existing structures at the head of Lateral 1 and Lateral 3 will be switched. Figure 38 shows the proposed new operations of the Lower West Main Canal. The new operations include:

1. The existing Lateral 1 head structure will be modified to include an 80' long-crested weir that will provide water level control in the Lower West Main Canal while simultaneously passing all flow variations into Lateral 1. The variations will flow west towards the Micheilli # 1 Basin where the variations will be captured and re-regulated.
2. The existing structure at the head of Lateral 3 will only provide flow control to set a target flow rate in to Lateral 3.
3. SCADA will be used to remotely monitor water levels in the reservoirs. If a reservoir becomes too full, excess flows can be diverted to another reservoir.

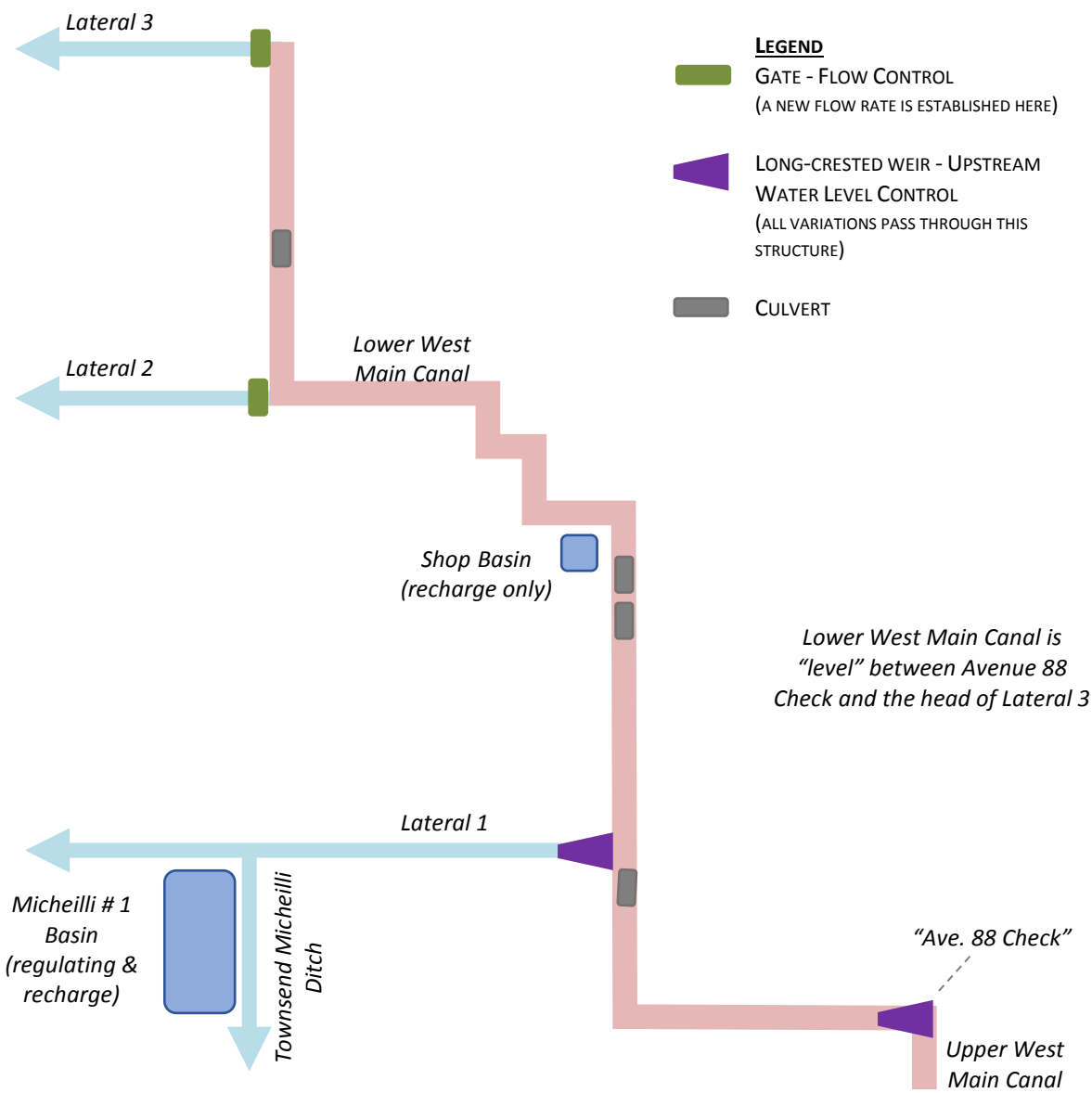


Figure 38. Future conceptual operation of the Lower West Main Canal

Modifications at the Micheilli #1 and Townsend Basins

It appeared that the operation of both of these basins might be modified to:

1. improve flexibility of regular irrigation season operation
2. improve recharge capabilities in this critical region of PIXID
3. improve the ease of moving variable flows from Deer Creek into the recharge basins during the irrigation season.

Earlier in this report, a plan was described for automatically moving the variable flows from the Deer Creek into Lateral 1. The strategy for improvement will require new hardware at both basins, as well as a new way of controlling water levels and flows. The basic strategy is seen in Figure 39.

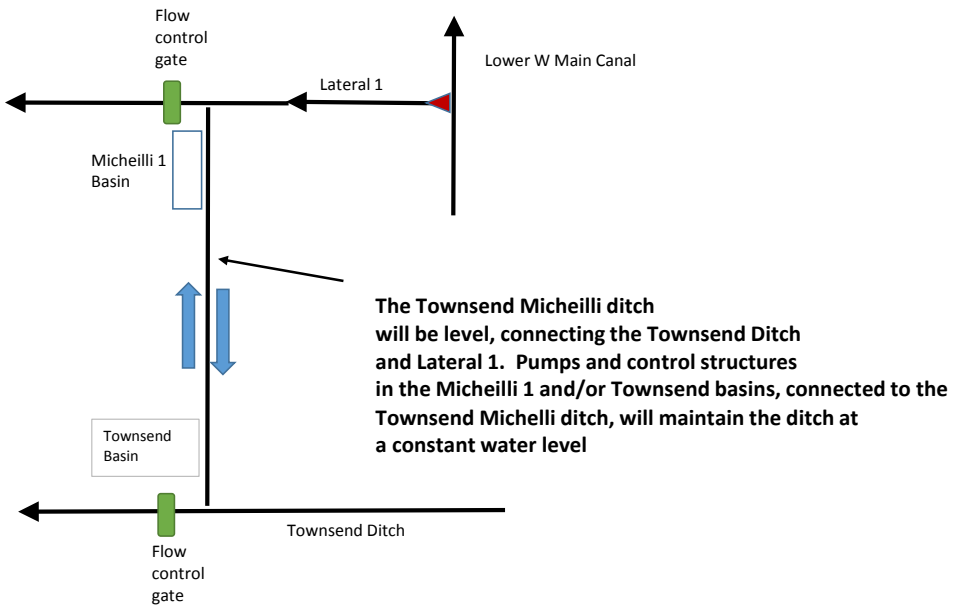


Figure 39. Proposed changes for the Townsend and Micheilli Basins

Cross Ditch and Hesse Basin

Modifications are recommended for consideration at both the north and south ends of the Cross Ditch. With these modifications, the Hesse Basin will receive excess flows from the Townsend Ditch, Lateral 1, and Lateral 2. The proposed changes are shown in Figure 40.

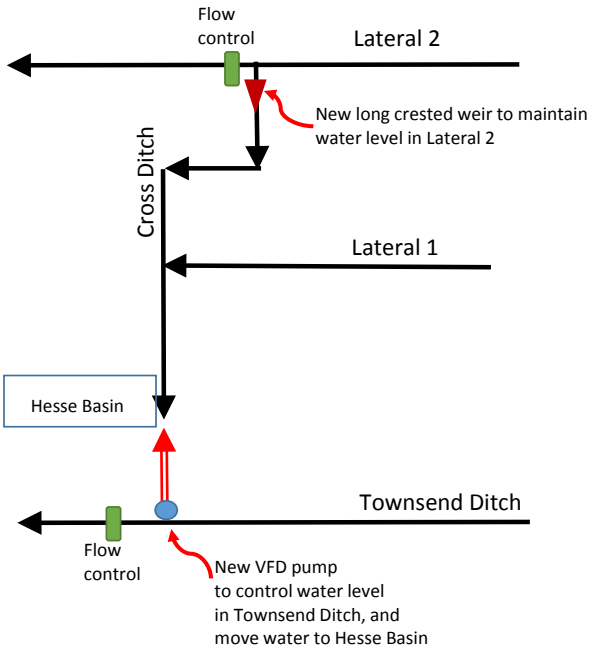


Figure 40. Proposed new controls on the Cross Ditch ends

Current Recharge versus Potential Additional Recharge with Recommendations

Over the past 15 years (2003-2017), on average, approximately 26% of the flow into the district percolates to (recharges) the groundwater through the canals. An additional 13% and 2% percolates through the basins and creek, respectively, on average, resulting in a total recharge rate of 41% of the inflow. A simplified analysis based on weather data and an estimate of the open water surface area in the district was used to estimate evaporation from the canals and basins, and showed it to be minor in comparison to deliveries and recharge. These values are summarized in Figure 41 below. Figure 42 shows that the total recharge as a percent of the inflow fluctuates between about 35% in drier years and almost 50% in wetter years (note that water years in the graph are March to March).

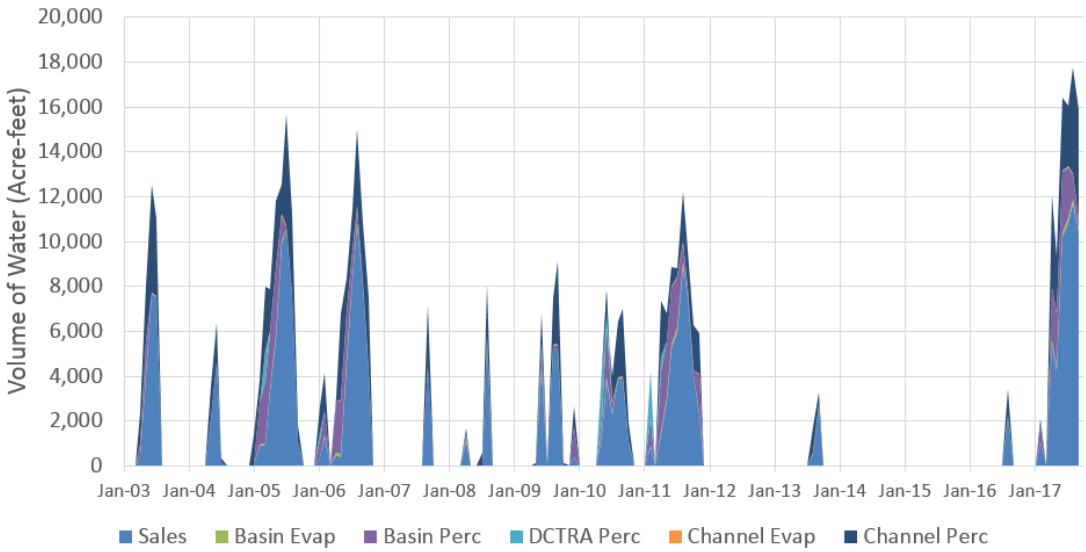


Figure 41. Distribution of flows in PIXID, monthly from 2003 to 2017

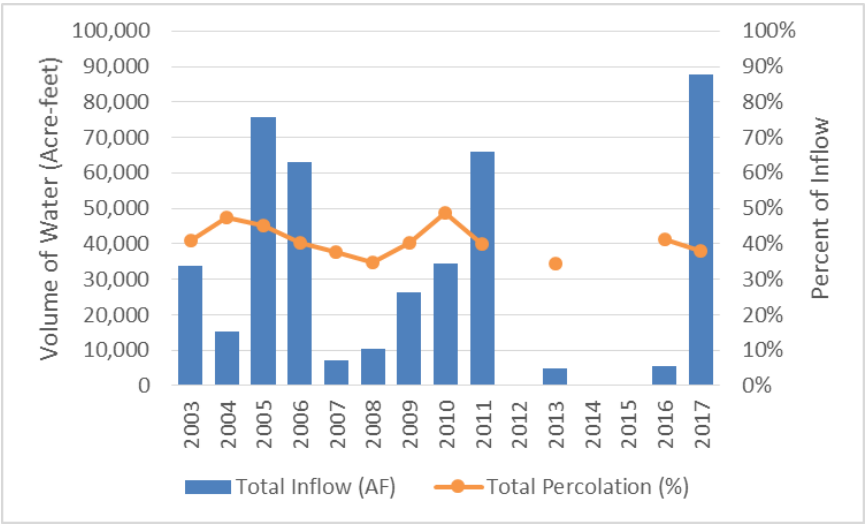


Figure 42. Inflows into PIXID compared to total percolation (recharge) as a percent of inflows, annually from 2003 to 2017

An analysis of the canal system during full capacity showed an average percolation rate of approximately 30 ft^3 (224 gallons) per ft (length) of filled canal per day. This is an average value, as canal widths and depths vary throughout the system. However, it does show that a significant amount of water can percolate the canal system if it can readily and efficiently be moved through the canal system to available canals and basins for percolation.

The recommendations in this report will primarily affect the groundwater recharge in two ways:

1) The current recharge facilities are at the ends of each system (the three systems are shown in Figure 9). A significant portion of these basins are along the western (downstream) edge of the district, and those facilities' recharge likely primarily benefits users outside of the district boundaries (to the west of the district). The recommendations in this report will provide the district with better control throughout the district, allowing the district to recharge groundwater at basins within (rather than at the end of) the eastern system. This will make the recharged water primarily available to (agricultural and residential) users within the district. This is a difficult benefit to quantify.
2) The improved control will also allow the district to move any available excess flows (winter or otherwise) efficiently through the district for recharge. Given the comparatively low evaporation rates (especially in the winter months), nearly all of this water should percolate and recharge the groundwater basin. As a general estimate, a 10% increase in inflow solely directed toward recharge would result in about a 16% increase in groundwater recharge. Likewise, a 20 percent increase in inflow solely directed toward recharge would result in about a 39% increase in groundwater recharge.