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BREAKING THE TECHNOLOGY BARRIERS IMPOSED BY CAST-IN-PLACE CONCRETE PIPE IN IRRIGATION DISTRICTS - CASE STUDY OF SOUTH SAN JOAQUIN IRRIGATION DISTRICT-

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ABSTRACT

South San Joaquin Irrigation District (SSJID) in Manteca, California, is beginning an ambitious modernization program to increase its water delivery flexibility. The district has over 200 miles of 30-60 inch cast-in-place (CIP) concrete pipeline that currently allow for little flexibility. SSJID will install four reinforced concrete interceptor pipelines and regulating reservoirs to redistribute water among the CIP pipelines and provide improved flexibility. The district's goal is to improve efficiency and encourage farmers with pressurized irrigation systems to shift from well water to surface water.

INTRODUCTION

South San Joaquin Irrigation District (SSJID) consists of 71,000 acres of which 59,650 acres are irrigated. It is located in Central California near the town of Manteca. The primary crops are almonds (56%), corn/oats (10%), and grapes (7%). The farm irrigation methods are border strip and furrow irrigation (56%), drip (3%), microsprayer (6%), undertree sprinkler (32%) and miscellaneous (3%). Its water distribution system consists of a main canal that brings water into the service area, plus 3 smaller distribution canals. Although the canals do provide some direct delivery turnouts to farmers, the vast majority of deliveries are made from large diameter (762 mm – 1220 mm) monolithic, cast-in-place (CIP) concrete pipe. All flows are gravity; pumps are not used. The pipeline sizes and their lengths are shown in Table 1.

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Table 1. CIP Pipeline Diameters and Lengths in SSJID.

Pipe Diameter		Lengths	
inches	mm.	feet	meters
30	762	51,363	15,655
36	914	595,024	181,363
42	1067	21,050	6,416
48	1219	446,808	136,187
60	1524	8,124	2,476

CIP pipe is common in irrigation districts on the east side of the San Joaquin Valley, where approximately 2.3 million meters are in place (Burt and Wegener, 1994). The pipe is usually 40+ years old, and as a result suffers from a high incidence of cracking – hence the local joke that it is "cracked in place" pipeline. In SSJID, applying more than 1.5m of pressure on the pipe generally results in excessive leakage.

SSJID irrigation district is one of the few districts remaining in California that supplies water on a rotational schedule. Historically, farmers surface irrigated with large flow rates of .6 - .7 m^3s^{-1} (20 – 25 CFS). The CIP system was designed to deliver 1-2 “heads” of this size simultaneously through any one pipeline. Deliveries are often made to individual border strips directly from large alfalfa valves placed on top of the district pipelines. There are very few of the standard “turnouts” common in most irrigation districts; that is, there is not a single delivery point and flow meter for each 10-30 ha field. Instead, a one or two “head” flow rate enters at the head of each pipeline, and one or two farmers receive water simultaneously. The only flow rate measurements are estimates at the heads of the pipelines. Farmers are charged a per-acre fee rather than a volumetric fee for water.

The present pipeline system is very inflexible, and has bottlenecks in the lower ends of the district. Some of the pipelines are 10 miles (16 km) long (Figure 1). With the long pipelines it is difficult to quickly switch supplies from an area of temporary excess to one of deficit. As a result, spills occur on some pipelines while other areas of the district lack sufficient water. Because of the inflexibility, the system is incapable of providing surface water to the increasing number of growers who are switching to sprinkler or drip/micro irrigation. Those growers rely on groundwater instead of surface water – resulting in extractions from the aquifer while simultaneously reducing groundwater recharge.

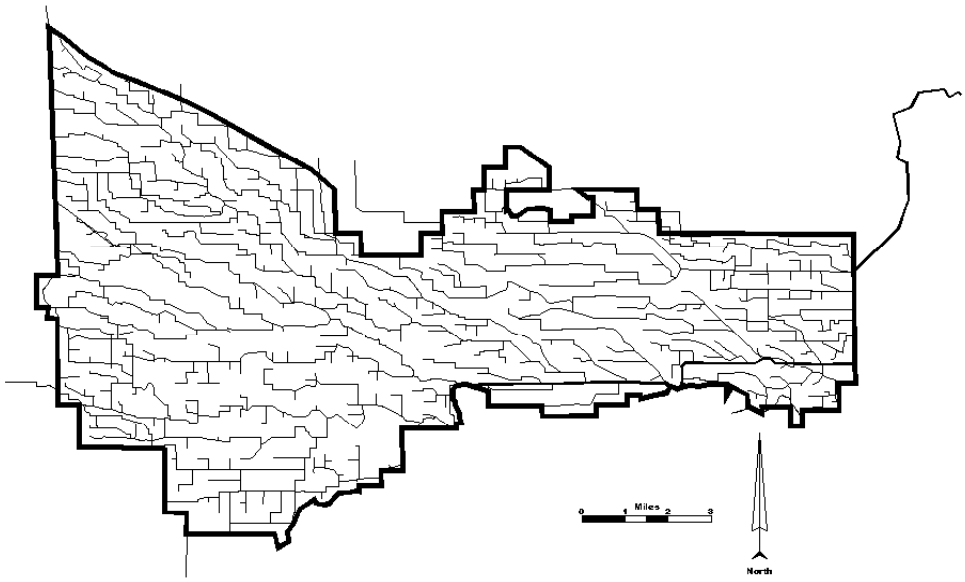

Fig. 1. Present Water Distribution System in SSJID.

SSJID has an existing Supervisory Control and Data Acquisition (SCADA) system on its canal system. The Main Canal (shown as a darker line in Figure 1, originating on the NE side of the district), which uses automatic overshot hinge gates, has Remote Terminal Units (RTUs) at each gate. The gates are automated for upstream control. ITRC provided the control algorithm and tuning constants for those gates at an earlier date.

MODERNIZATION OF SSJID

Background of the Present Modernization

SSJID's management and Board of Directors have recognized the need for improved flexibility and reliability in water deliveries. In 1997, the senior author was asked to do a Rapid Assessment of the district and brainstorm ideas for improvement. There were numerous small improvements that could be made, but the Rapid Assessment identified two strategic recommendations:

1. Eliminate several capacity bottlenecks in the distribution system.
2. Install two interceptor pipelines that would cross perpendicular to many of the existing CIP pipelines. These new interceptors would both receive and supply water from existing CIP pipelines. One of the interceptors would be sized to supply water to a new grid of pressurized lateral pipelines which would facilitate water delivery to drip/micro irrigation systems.

At the end of 1999, SSJID again contacted Cal Poly ITRC and expressed a desire to obtain a preliminary design that incorporated the 1997 recommendations. In

July 2000, ITRC provided an initial framework for the System Improvements for Distribution Efficiency (SIDE) project, with a rough cost estimate of $13.8 million. Further discussions resulted in the addition of several sub-projects. In late 2000, the California Energy Commission (CEC) funded Cal Poly ITRC to provide technical assistance to districts that wished to explore options for modernizing their CIP pipeline systems. In February 2001, SSJID, with ITRC participation, interviewed consulting engineering companies that could provide the final design drawings and project management; Provost and Pritchard Engineering Group of Fresno was selected. SSJID is using Northern Digital, Inc. of Bakersfield as the SCADA integrator.

The project will be installed in phases. One area (the "Northwest Pipeline") was chosen for the first phase because it incorporates almost all of the engineering features that are contained in the other larger sub-projects. Construction of some pipelines and a reservoir for the Northwest pipeline began in Fall 2001, and completion of this sub-project is expected in July 2002. A description of the project and some aspects of its implementation follows.

Modernization Strategy

The modernization strategy recognized the following points:

1. It is infeasible to replace all of the CIP pipelines. Replacement costs are approximately $100/ft ($328/m).
2. The field layouts for surface irrigation require the high flow rates that are currently being provided. Therefore, any design options must guarantee the same high flow rate deliveries.
3. Members of the Board of Directors are elected from geographical regions within the district, so it is politically important to improve service to all areas of the district.
4. The farmers at the downstream end of the system (the west side) generally farm annual crops. They believe that their primary constraint is the lack of flexibility (and water) because of bottlenecks upstream.
5. Farmers in the eastern side of the district, who primarily grow almonds and apples, are shifting away from surface irrigation and are installing drip/micro and sprinkler systems that use well water. They would use surface water if it could be supplied with more flexibility and better filtration.
6. Most of the CIP pipelines are operated partially full or at very low pressures to minimize seepage losses. This means that they are operated as upstream controlled canals. Many hours are required before a change in flow rate moves from the inlet end of a pipe to the downstream end.

The strategy for modernization treated the pipeline distribution system as if it was similar to a canal system. Several perpendicular interceptor pipelines, each with a

regulating reservoir, were designed. Each interceptor pipeline will provide the following functions:

New Supply: First, they establish a "new supply" for the existing CIP pipelines. At its intersection with the CIP pipe, the interceptor pipeline will be able to add water from a regulating reservoir or from other pipelines that have an excess supply. This water will be available to downstream users regardless of the amount of water used by irrigators upstream of the interceptor pipeline. This not only improves the service to downstream users by introducing an additional supply of water into the existing pipelines; it also improves the service to upstream users because they can now use water that would otherwise have been reserved to supply growers further down the line.

Flexibility: Second, the interceptor pipeline can recover excess water in the existing pipelines and move it to other crossing pipelines that are short of water. If there are no shortages in other pipelines, it can move the water to the buffer reservoir where it will be stored until needed. However, this "minimization of waste" is actually a minor element when one considers the requirements for the future. The primary advantage of this project is that upstream CIP operators and users will no longer need to follow precise schedules in duration and flow rate; discrepancies will simply move downstream and be absorbed by the interceptor pipeline. System operators will be able to err "on the high side" of the amount of water sent down a pipeline without fear of losing the excess water to spillage, resulting in improved water delivery service for all the users along the pipeline.

Distribution System for Pressurized Irrigation: Finally, some of the interceptor pipelines will form the supply backbone of new distribution systems for irrigators that use sprinkler or drip irrigation. With the installation of new laterals, adjacent farmland will have a supply of water under moderate pressure that can be boosted to the appropriate irrigation pressure using private on-farm booster pumps.

Design Features

Interceptor Pipelines: The project includes 4 interceptor pipelines. The interceptor pipelines are constructed of reinforced concrete pipe. Sizes range from 60" – 36" (1524 mm – 914 mm). The pipelines will be continually pressurized by pumps at interceptor boxes and at the regulating reservoirs. The pipelines were initially sized using an economic pipe size method to obtain the lowest annual cost of power and fixed costs. However, the economic pipe sizes were small enough that, depending upon the magnitude and location of flows, considerable pressure fluctuations could occur in the pipeline. In order to select pumps and valves (described below) that could be automated easily, it was desirable to have less variation in pipeline pressures. Therefore, several pipe sizes were increased to lower the friction.

Interceptor Boxes: At each point where the interceptor crosses a key CIP pipeline, an interceptor box will be installed in the existing CIP pipeline. An interceptor box will have two functions:

1. It will serve as the beginning of the downstream CIP pipeline segment. The flow rate will be controlled and measured at this point.
2. It will serve as the end of the upstream CIP pipeline segment. Any excess flow from the upstream segment will be recaptured.

To accomplish these functions, there must be mechanisms to:

1. Supply the interceptor boxes with any additional flow that is needed downstream.
2. Remove excess flow that enters the boxes from the upstream segments.

The interceptor pipeline will serve both purposes, of supplying water and accepting excess flow. Figures 2-4 show the basic design of the interceptor boxes.

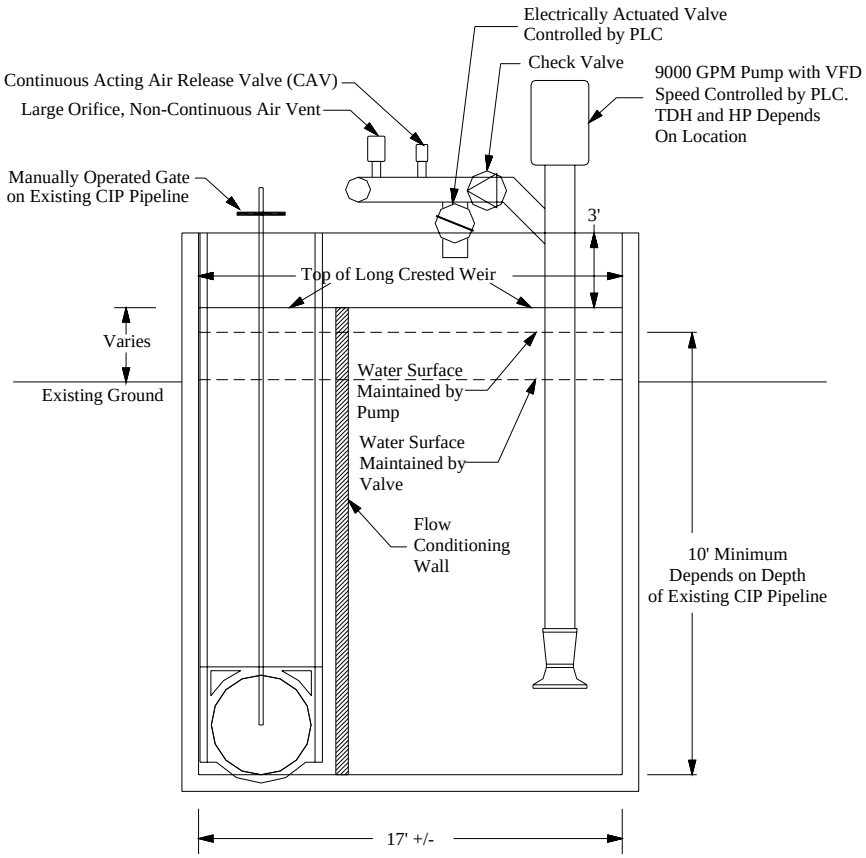

Fig. 2. Front View of an Interceptor Box (Not to Scale).

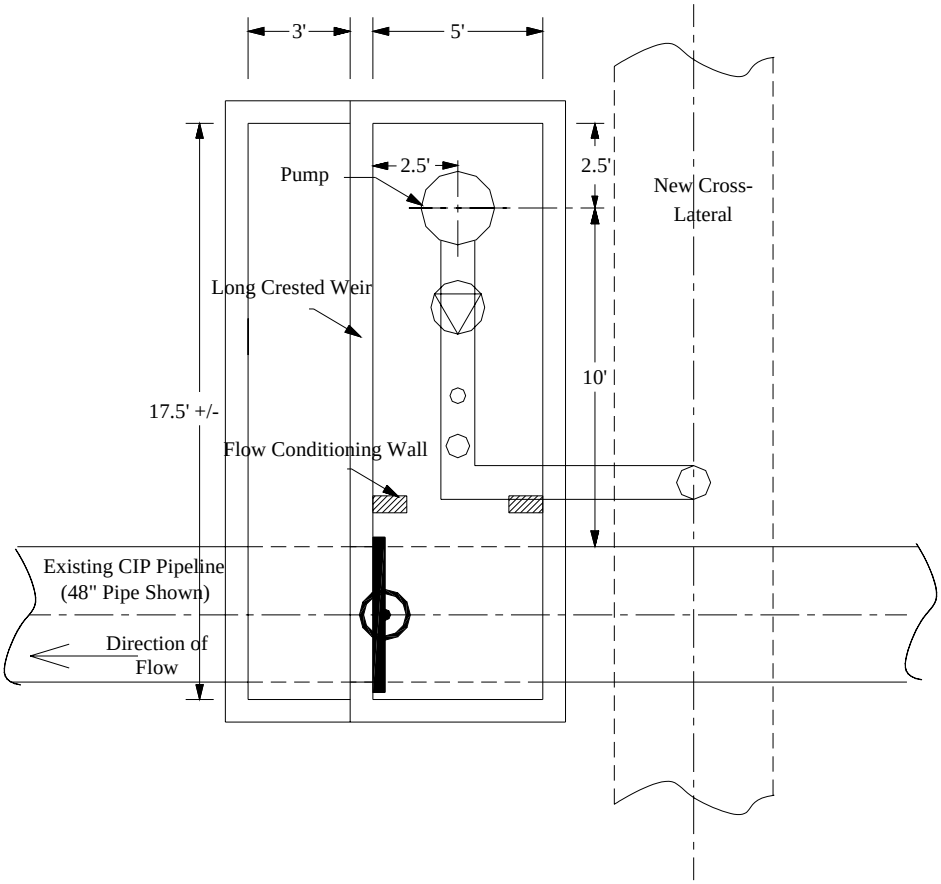

Fig. 3. Plan View of an Interceptor Box (Not to Scale).

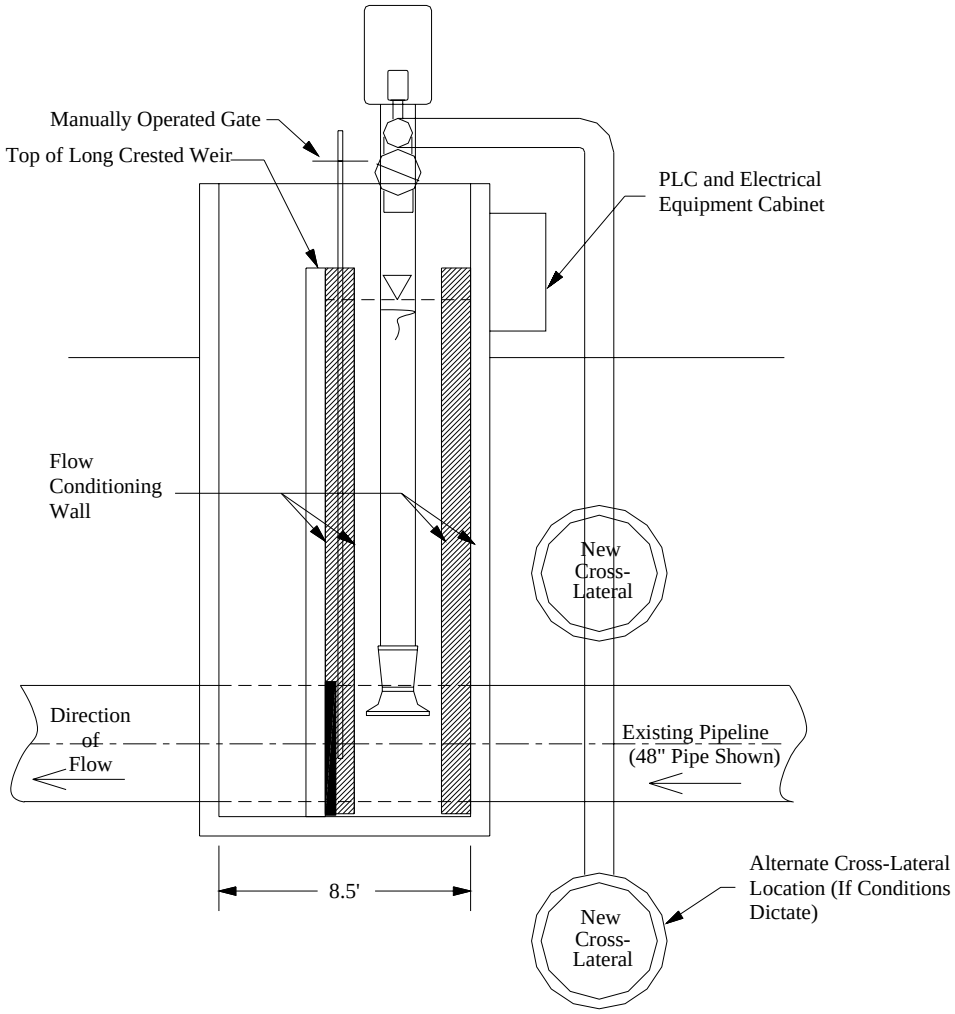

Fig. 4. End View of an Interceptor Box (Not to Scale).

Figures 2-4 illustrate the following physical features:

1. One or two pumps with variable frequency drive motors will be installed in each box. The pump will prevent the water level in the box, upstream of the weir, from rising too high when excess water enters from the upstream segment of the CIP pipeline. The pump will automatically place any excess flow that enters the box into the interceptor pipeline ("new cross-lateral"). The pump responds to the water level in the box.
2. A valve will automatically supply water from the new interceptor pipeline into the box if the water level drops in the box upstream of the weir. The valve responds to the water level in the box.

3. A wall with a long crested weir separates the upstream and downstream CIP pipeline segments. The design allows flows to pass through the box in case the pump malfunctions.
4. The flow rate into the downstream segment of the CIP pipeline will be controlled with a sluice gate built into the long crested weir wall. Initially, the flow rate will be manually controlled. Ultimately, the gate may be motorized and automated. The water level upstream of the sluice gate will be maintained sufficiently high and constant to provide a fairly constant, manually controlled flow into the downstream pipe segment.
5. A flow measurement device (not shown) will be installed on the CIP pipeline, downstream of the box. This will have both a visual and analog output. The meter will allow the operator to set the flow rate properly, and will eventually allow automatic flow rate control.
6. Remote monitoring (not shown). Each box will be remotely monitored through SSJID's SCADA system. From the control center, it will be possible to change any of the automatic pump or valve control parameters, or to bypass automatic features and remotely manually operate the pumps or valves.
7. A rotating trash screen belt (not shown) was designed to filter water before it enters the pump(s). This is needed to remove debris that enters the pipe between the source and the interceptor pipeline.

Regulating Reservoirs: Each of the 4 interceptor pipelines must have a reservoir to supply water to the interceptor pipelines when there is a deficit, or receive water from the pipelines when there is an excess. Excess and deficit flow rates will automatically shift within the interceptor pipeline between interceptor boxes that have excess and deficit flows. Three of the interceptor pipelines require new reservoir construction; the fourth will use the Main Canal as a reservoir. The Main Canal has a regulating reservoir built into it, downstream of the point where the new interceptor will connect to the Main Canal.

The regulating reservoirs will include pumps to supply water to the interceptor pipelines. The pumps at the regulating reservoir will be programmed to respond to the pressure in the interceptor pipelines. If the pressure drops to a pre-set level, the pumps will inject additional water into the interceptor pipeline. Likewise, the valves will open and discharge water into the reservoirs if the pressure in the interceptor pipeline rises too high.

Supply to the Regulating Reservoirs: In two locations, additional CIP pipeline inter-ties will be installed upstream of the interceptor pipelines to ensure that additional water can be quickly brought into the regulating reservoirs when needed. One of the regulating reservoirs is adjacent to a canal (the "R" canal). This canal's cross regulators (check structures) between the Main Canal and the regulating reservoir will be modified with long crested weirs and ITRC Flap Gates. These modifications will allow SSJID to easily vary flows down the R

canal to the regulating reservoir without needing frequent check structure adjustments. The changes can be made by simply changing the flow rate at the head of the R canal.

The water level in each regulating reservoir will be remotely monitored. The regulating reservoirs will have sufficient capacity to receive or supply a discrepancy in flow rate for about 5 hours. This is enough time for the SSJID operators to make adjustments to flows at the heads of pipelines or canals and to have those flows reach the regulating reservoirs before the reservoir dries up or overflows.

Example Interceptor

The Southwest Pipeline, shown in Figure 5, is an example interceptor. It is about 3.2 miles long, and is generally aligned in a north-south direction. It will intercept 5 CIP pipelines that notoriously have discrepancies between supply and demand. The TBB pipeline (on the north end of the interceptor) typically has excess capacity, while the southern pipelines often suffer deficits. The new reservoir will have a live storage capacity of about 41 Acre-feet.

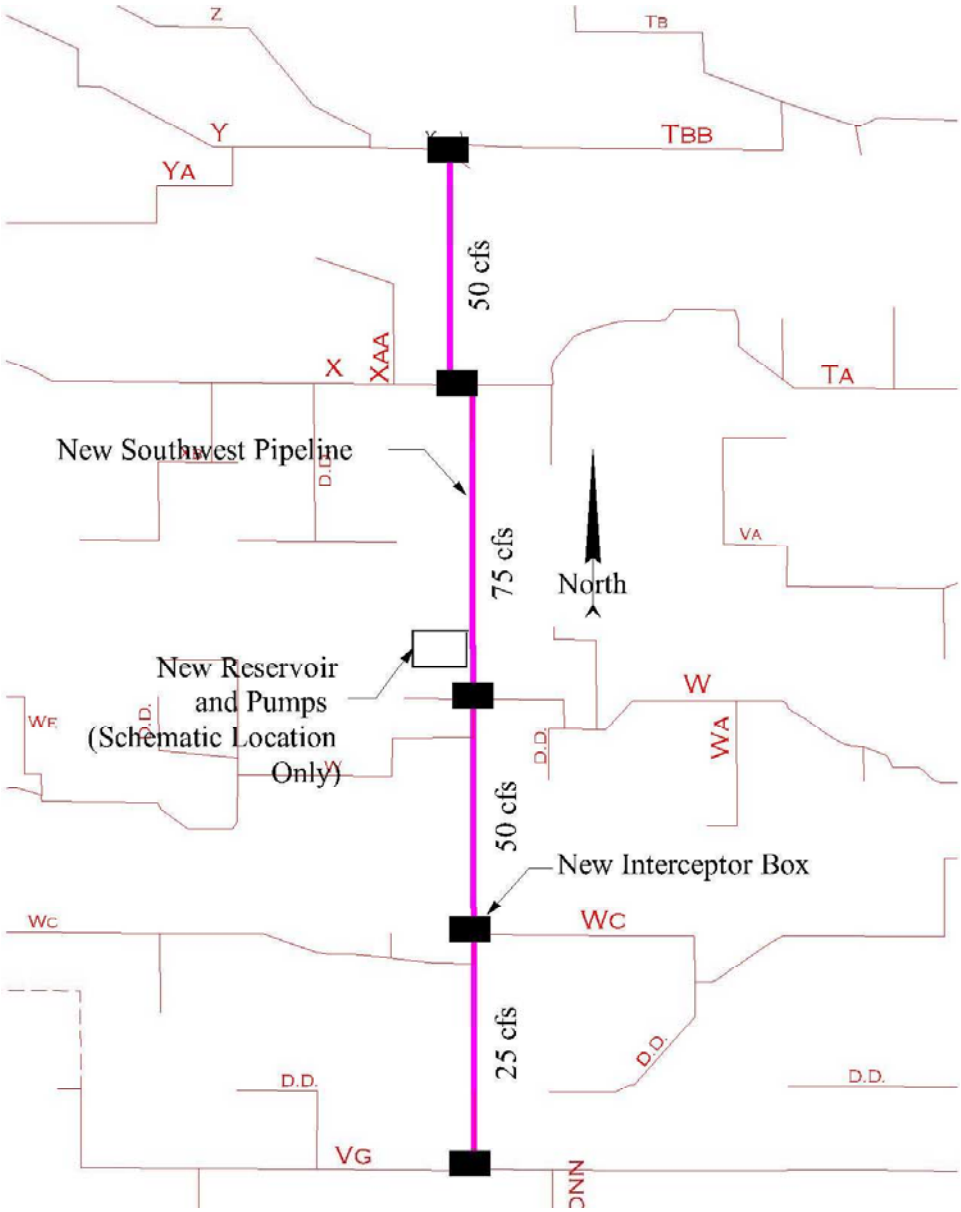

Fig. 5. Southwest Pipeline.

Implementation

Phase 1: Construction began on the Northwest Pipeline (Figure 6) in Fall 2001, and this first phase is expected to be operational by September 2002. Full operational status requires that the check structures in the R canal be modified. Those structures will be upgraded for improved upstream control in Fall 2002.

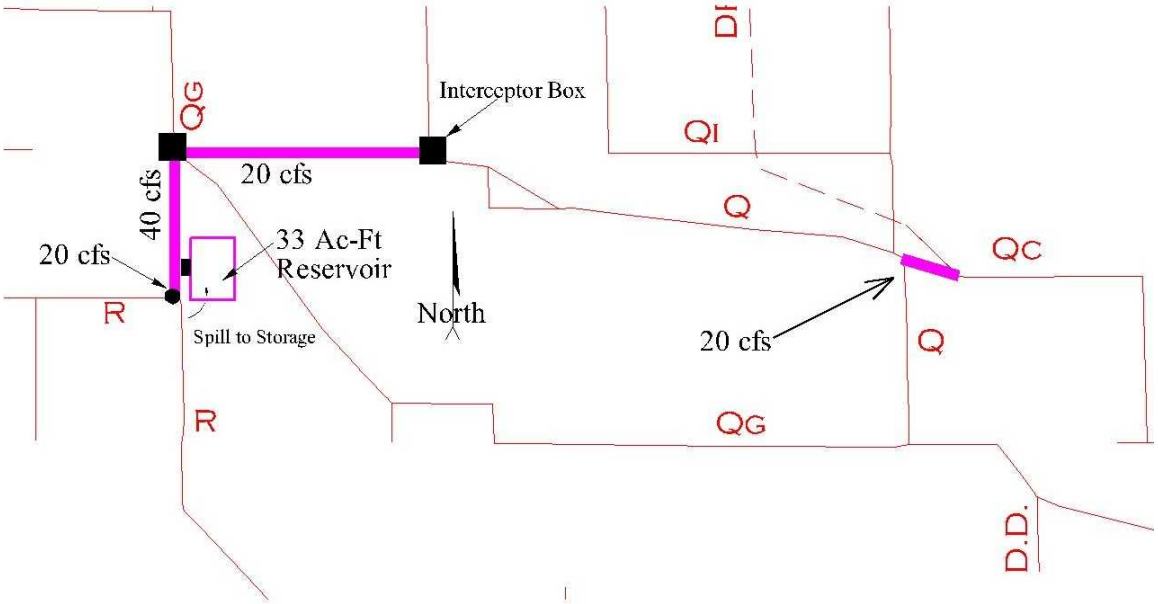

Fig. 6. Northwest Pipeline – Initial Layout.

Interesting aspects of the Northwest Pipeline implementation have been:

1. The operational concepts depicted in Figure 6 remain the unchanged (interception of the Q, Q_C, and Q_G pipelines and the R canal).
2. The actual locations of the new pipelines and the reservoir have been shifted because of the district's desire to purchase rights-of-way and land from willing landowners.
3. Obtaining rights-of-way that simultaneously satisfy land owner desires and the hydraulic requirements of the interceptor systems has required considerable effort in surveying, landowner discussions, land value assessment, identification of legal ownership records, etc.
4. The active involvement of SSJID operators has been considered to be a key ingredient for the eventual success of the project. The operators are involved in all meetings that involve the engineers and SSJID management. Because of the active solicitation by SSJID management of input from the operators, the operators have brainstormed among themselves and have come up with tough questions and excellent recommendations for modifications and improvement. Among other things, operators have identified several inter-ties between pipelines (similar to the Q – Q_C connection shown above) that they feel will enable them to maximize the benefit of the changes.
5. The proposed operation of the systems will involve considerably more flexibility than the operators are accustomed to. Their initial thinking focused on supplying extra water to some areas in times of shortage. The concept of also using reservoirs to <u>receive</u> temporary <u>excess</u> water as part of a flexible operation has been more difficult to understand.
6. While some districts would do much of the construction with in-house employees, SSJID has decided to contract out all of the work. This, of

course, requires very detailed engineering drawings for all aspects of the civil and electrical works.

Using Surface Water for Drip/Micro: It will be a challenge to convince many growers to use surface water rather than well water for drip/micro and sprinkler systems – even if the water is delivered with a high degree of flexibility. This is because the depth to groundwater is still relatively shallow (less than 30 meters) in most areas, and because the surface water requires much more elaborate filtration than well water. Based on discussions with farmers, the following points are noted:

1. Pressurized laterals can be installed on each of the interceptors to provide water to farmers with a minimum of 5' (1.5 m) of pressure.
2. The district has decided that it will install outlets on the interceptors at potential PVC lateral locations. However, it will only install the laterals when farmers join together and form improvement districts to pay for individual laterals.
3. Rather than install the moving trash screens at each interceptor box, SSJID is now considering the installation of the trash screens at the heads of the CIP pipelines – where they receive water from the canals. This will provide coarsely filtered water to all farmers, not just those taking water from the interceptors. Currently, some dairy farmers use the CIP pipes as drains – thereby introducing straw and manure into the pipelines. That practice will be prohibited in the future.
4. The shift to surface water will be stimulated in some areas of the district by the decreasing groundwater quality. In some areas, the groundwater is high in salts and nitrates – both detrimental to tree fruit growth.

REFERENCES

Burt, C.M. and J. Wegener. 1994. Monolithic Concrete Irrigation Pipe. ASAE Paper 94-2061. Presented in Kansas City, Missouri.