IID/MWD WATER CONSERVATION PROGRAM – IMPROVED IRRIGATION WATER MANAGEMENT THROUGH SYSTEM AUTOMATION

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ABSTRACT

Imperial Irrigation District (IID) services 450,000 acres in Imperial Valley, California, USA. The sole source of supply is the Colorado River. Imperial Dam diverts water from the Colorado River into the All American Canal (AAC) and subsequently into three main canals. Each main canal is approximately 40 miles in length and can divert 1,200 to 2,200 cfs. Lateral canals are then serviced by the main canals. There are 240 laterals that vary in length from 1 to 10 miles and from 40 to 160 cfs in capacity. Farm deliveries are made through laterals via 5,500 individual user gates. Each has a 20 cfs minimum capacity. On average each delivery services 80 acre parcels. Based on operational considerations, the geographic distribution of control sites, the high inertia of the system and the harsh desert environment a distributed control design was implemented. Commercially available industrial control components were integrated into a SCADA system in a non-traditional manner. Three subsystems were developed; field site automation, communication network, water control center. The level of automation implemented at field sites allows more flexible main canal operation. This allowed the various projects developed under the IID/MWD Water Conservation Agreement to be optimally managed and have water savings verified.

DESCRIPTION OF IMPERIAL IRRIGATION DISTRICT

General

The Imperial Irrigation District (IID) is a special district formed under California's Water Code. A five-

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member board is elected using the general election process. The board develops policy that guides long term and day to day activities of the IID.

IID provides agricultural irrigation water and drainage services within an identified area of the Imperial Valley referred to as the Imperial Unit. Only areas within the Imperial Unit can be serviced with Colorado River water.

Electric power services are also provided by the IID. Power generation, transmission and distribution are supplied to a service area that includes all of Imperial County and parts of Riverside County.

Colorado River Watershed

IID is located in southeastern California within the Colorado River Watershed. The Colorado River originates in the Rocky Mountains being fed by melting snow from these mountains. It is the third longest river in America, winding 1,700 miles through deep canyons of seven southwest States toward the Gulf of California in Mexico. Its drainage basin covers approximately 245,000 square miles, one-twelfth the area of the contiguous United States. Although the River has many tributaries in the upper basin, there are few in the lower basin. It is the sole source of water for the IID.

Imperial Dam

Serving as a diversion structure, Imperial Dam facilities include the All American Canal Headworks for diversion and desilting works to eliminate the sediment problem from Colorado River water. It is located on the California-Arizona border.

Various facilities are located at Imperial Dam:

- All American Canal Heading and desilting works
- California Waste Way
- Gila Gravity Main Canal Headworks

All American Canal

At the California end of the Imperial Dam is located the intake for the All-American Canal (AAC). Four 75-ft. (22.9 m) roller-dam-type gates supply separate channels. Each of the first three channels leads to a pair of desilting basins, and the fourth leads through a bypass directly to the AAC. The water from each of the first three channels enters a gradually contracting influent channel feeding a pair of desilting basins. Clarified water is distributed uniformly by openings in the side walls of the basins into the AAC. Along the AAC flows are diverted through a series of drops, where hydropower has been developed. It then serves the main canals of the IID system along the south side of the service area.

The AAC is the link between the Colorado River and the Imperial Valley. It is 80 miles (49.7 km) in length and varies in width from 230-ft. (70.1 m) at the headworks to a width of 100-ft. (30.48 m) at its point of termination. The water surface elevation of the lake above Imperial Dam, the point of beginning, is 180.00 feet above mean sea level (msl). At the end of the AAC, the water surface elevation is 5.8 feet (1.8 m) below msl. Flow capacity is 15,500 cfs at the heading.

Structures along the All-American Canal include:

- AAC Headworks
- Desilting Basins
- Station 48+50 Check
- Station 60+00 Flow Metering Station
- Station 1035+00 Level Metering Station
- Pilot Knob Check and Spillway
- Drop No.1 Check
- Drops No. 2, 3, 4 and 5
- East Highline Check and T.O.
- Allison Check
- Alamo River Check and Spillway
- Central Main Check T.O.
- New River Check and Spillway
- Wistaria Check
- Woodvine Check
- West Side Main Heading

Irrigation System

IID operates an open-channel-gravity system exclusively. There are three main canals, three supply canals and over 450 laterals and sub-lateral canals.

Main Canals: East Highline Canal is 45 (28 km) miles in length, 120 ft. (36.58 m) wide at the heading with a gradual decreasing width to 15 ft. (4.57 m) near the end. It has a capacity of 2600-cfs (73.63 m^3/s) at the head and can carry approximately 120 cfs (3.40 m^3/s) near the end. The diversions from this canal consist of 72 lateral canals, two supply canal systems and numerous direct farm deliveries. The water surface elevation of the pond upstream of the headworks gates is 42.50 ft. (12.95 m) above sea level and at the end the elevation is 57 ft. below see level.

The Central Main Canal (CM) is 26 miles (41.8 km) in length, 85 ft. (25.5 m) wide at the heading and 45 ft. (13.7 km) wide at the end. It has a capacity of 1,300 cfs (36.8 m^3/s) at the head and can carry approximately 500 cfs (14.2 m^3/s) at the end. The diversions from this canal consist of 14 lateral canals and numerous direct farm deliveries. The water surface elevation of the pond above the head gates is 13.50-ft. (4.1 m) above sea level and at the end the elevation is 97.7-ft. (29.8 m) below sea level.

Westside Main Canal is 45.5 miles (72 km) long to the Trifolium Extension Canal Heading. This canal is 90-ft. (27 m) wide at the heading with a gradual decreasing width to 25 ft. at the end. It has a capacity of 1,300 cfs (36.8 m^3/s) at the head and approximately 200 cfs (5.66 m^3/s). The water surface elevation of the pond upstream of the head gates is 994.20-ft. (287.8 m); the pond elevation at the Trifolium Extension Canal is 836.4 ft. (254.9 m).

The three supply canals are the:

- Rositas Supply Canal
- Briar Supply Canal
- Vail Supply Canal

These are sub-main canals supplying a limited number of laterals for hydraulic purposes.

Reservoirs: At the present time there are six main-canal reservoirs in operation:

- Sperber
- Fudge
- Sheldon
- Singh
- Carter
- Galleano

The primary use for main canal reservoirs is for flow management. Long-term storage capacity is not available because of the flow capacity of the adjacent main canal system. Typically reservoirs have a maximum capacity of 300 acre-feet.

There are also three interceptor reservoirs serving intercepted laterals systems:

- Bevins on the Plum-Oasis Interceptor system
- Young on the Mulberry-D Interceptor system
- Russel on the Mulberry-D Interceptor system
- Wiley on the Trifolium Interceptor system

Drainage System

IID operates an extensive agricultural drainage system. It is made up of open channel lateral drains, main drains and a collector basin.

Drains: There are more than 1,450 miles(2,300 km) of drains in the IID that drain into the New River, Alamo River and Salton Sea. Drains collect tailwater and leach water from farm fields. Drains are generally parallel to irrigation canals and laterals. Where the drains cannot be constructed deep enough to receive farm discharge sumps and pumps are operated and maintained by the IID.

Rivers: Two rivers are used as drainage collection channels. New River and Alamo River were formed originally when the Colorado River breached its banks near Yuma, Arizona, and flowed naturally into the Salton Sea. The river channels are now used as drains for agricultural and municipal discharges.

Salton Sea: Salton Sea lies in the depression known historically as Lake Cauhilla. It was filled early this century when the Colorado River breached its banks twice. Subsequently, its main source of water has been agricultural and municipal runoff from Imperial Valley, Coachella Valley and the Mexicali Valley in Mexico.

SYSTEM OPERATION

Hydraulics of the Irrigation System

IID operates a network of open channel gravity canals and minimal pumping in the system. No ground water is used due to its saline content.

Upstream Supply Based: Water is scheduled in advance from the Colorado River. No changes can be made without a three day notice. All deliveries to IID are coordinated by the USBR and strictly adhered to.

Flexible Deliveries: Within the IID the water users can order water for either 24-hour or 12-hour periods. With a three-hour notice these deliveries can be increased, decreased or cancelled.

Upstream Level Control: The canal ponds are maintained as close to steady state in upstream level control using check structures. Lateral headings located upstream of checks can then be set manually at the required flow.

Downstream Flow Control: All lateral headings are in downstream flow control. Aggregate delivery orders within each lateral plus operational flow requirements are maintained through the required period.

Annual Water Order: The annual volume of water required for operation is provided to USBR in October for delivery the following year. An estimate is prepared using all information which is available at the time; crop patterns, federal crop programs, etc. Data is usually very scarce, as crop patterns have not been formulated for the year. The best source for crop information is the County Agricultural Commissioner's Office. Various activities can affect water use; for example government subsidy programs which can cause a significant change in water use for the year.

Weekly Master Schedule of Orders: In addition to the Annual Water Order, weekly requirements are supplied to USBR. Every Wednesday an order for the following week, defined as Monday through Sunday, is supplied by Water Control to the River Division. USBR accumulates the order from all water users of the lower Colorado River and prepares a Master Schedule of Flows. The amount of water scheduled on the Master Schedule of flows is the quantity of water the IID is entitled to unless it is revised by the Watermaster at least 72 hours in advance. It is a common occurrence for the Watermaster to ask for and receive extra water above the Master Schedule of flows allotment. Normally excess flows are not scheduled as it could be counted against the IID's allotment in years when the water supply is low.

Daily Operation: Water orders originate with the water users and are accumulated by the three operating divisions. The divisions stop accepting water delivery orders at 12:00 noon daily. A summary of these orders is called in to the Water Control Section by each division, stating the amount lined up to run and amount to be carried over. Carry-overs are caused by water orders exceeding the capacity of the system or the available water. Water Control personnel then must allot available amounts to each division making sure that the percentage of carry-overs is balanced throughout the divisions. By 1:00 p.m. River Division is notified by Water Control to place a firm order for the following day and to make any change in the Master Schedule for the fourth day following. As soon as this order is confirmed by USBR, the Water Control Office allots all available water back to the three divisions in amounts keeping carry-overs balanced.

SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA)

The objective of the System automation Program is to improve water management utilizing modern control technology. Through the use of automation the maximum benefits of the water conservation program were achieved. The SCADA system discussion that follows includes Field Sites, Communications network and a new Water Control Center, maintenance and benefits.

Field Sites

The water conservation program impacted on all aspects of the district from the All American Canal, to the Lateral Canals and on-farm projects. The SCADA system integrates all of these different needs into one system. The IID system includes three types of field sites: remote-monitoring sites, small canal sites and major sites.

Remote Monitoring Sites: These installations provide level/flow information via radio telemetry. The monitoring sites are solar powered and consist of a level sensor, a remote terminal unit (RTU) and a radio. The units were designed to be easily relocated, as warranted by the verification program. The number on units in service varies depending on the needs of the verification program and may be up to forty units.

The RTU is programmed to provide analog signal averaging; daily minimum and maximum with time stamp and storage of readings at a selected time interval. In addition to multiple level sensors the system battery voltage is also monitored. The controller retains several days of readings and in the event of a loss of communications the data can be retrieved locally from the RTU.

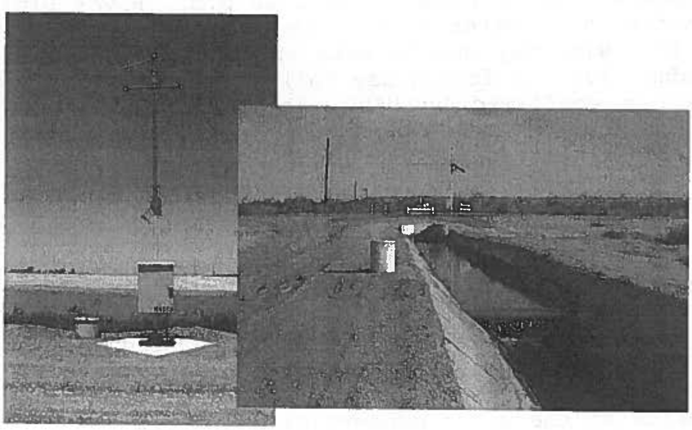


Fig. 1 Remote Monitoring Site

Small Canal Sites: These sites consist of solar powered single gate structures and a level sensor, a programmable logic control (PLC) and a motorized gate. These sites are designed to provide stand-alone automatic control and provide either a constant upstream water level or a downstream flow.

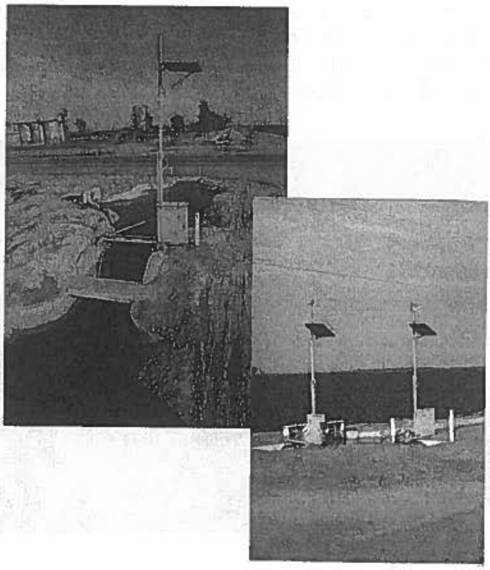


Fig. 2 Small Canal Sites providing automatic level control and flow control.

In addition to providing constant upstream level control, the Lateral Interceptor "interface gates" monitor the water level in the Lateral Interceptor canal and automatically switch to flow control when the Lateral Interceptor canal reach it's maximum capacity. In this event, the adjacent spillway gate which is programmed to maintain a higher level set point, takes over upstream level control.

There are a total of one hundred and ten of these sites. Some of sites include radio telemetry for data collection as part of the verification program.

Major Sites: These sites are also designed to operate as a stand-alone automatic sites, but to further enhance the control of the main canal system, radio telemetry provides real time monitoring of the system and provides the ability to remotely change set points. The installation consists of a level sensor, often one upstream and one downstream, a PLC and several motorized gates or pumps or a combination of both. The sites provide automatic upstream level control or downstream flow control and may also automatically switch between level and flow control.

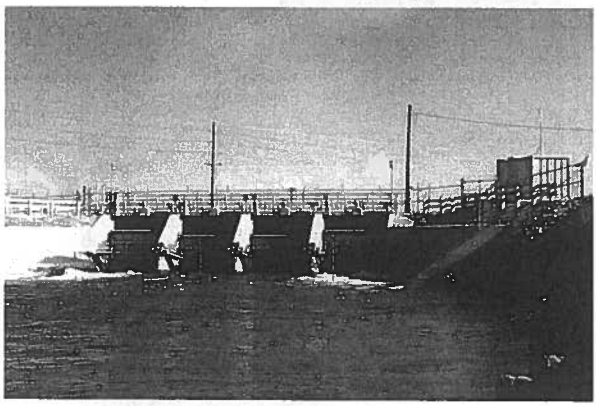


Fig. 3 Main Canal Check Structure

Some sites consist of a combination of gate control structures and pumping plants that provide different functions depending on whether there is a shortage or access flow in the system. The flow control sites include the provision to set a flow setpoint with a time for the new setpoint to take effect.

The major sites are powered by utility power but the PLC and all sensors operate on 24 Volts DC which is supplied by a battery back up system. Many of the sites also include a standby generator. The system was designed so that the PLC can control the standby generator and provides monitoring of generator status including fuel level. The PLC is programmed to automatic test the backup systems once a week and the PLC control also provides the ability to remotely control the generator to conserve fuel and extend operation in a power outage.

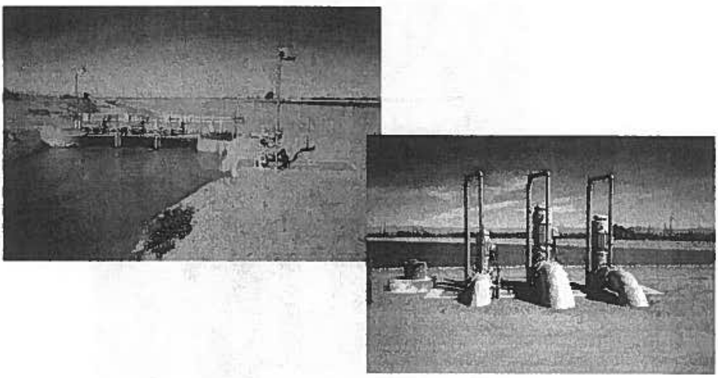


Fig. 4 Interceptor Reservoir with pumps

Construction: The remote monitoring units were pre-assembled and the only site work required was the installation of a level sensor stilling well. The small canal installations were also pre-assembled and required minimal site work. In addition to installing a level sensor stilling well the existing gate was removed so that the new gate could be installed in the same guides of the concrete structure. The main canal sites included existing electrically operated gates which were previously operated remotely by a tone telemetry system.

These sites were upgraded with new gate hoists and new electrical wiring. To minimize the disruption of service during the transition of a site from the old control equipment to the new equipment a pre-fabricated control building was used in the design. Working with the manufacture of sea-going cargo containers, the specially constructed units were designed to require very little maintenance and also to be bullet resistant. The units were delivered to the IID's yard where the control equipment was installed and tested.

At the site a concrete pad is constructed and conduits installed. The control unit was then delivered to the site and the field wiring is completed.

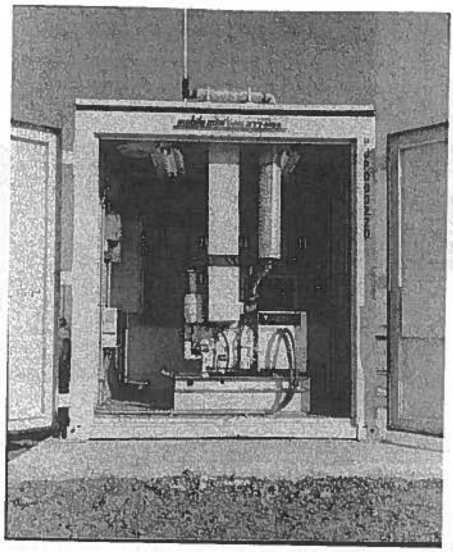


Fig. 5 Standby Generator

To better prepare district staff to maintain the system it was decided that IID staff should be involved in the actual construction of the new control system. To facilitate this approach the design drawings were prepared to "shop drawing" details. The staff was also involved in the site checkout and commissioning.

Hardware: The equipment used at the field sites is industrial grade and of very high quality. For example the PLCs have a Mean Time Between Failure (MTBF) of almost 1 million hours. Over 40,000 units of this brand of PLC are produced annually and they are in use and supported in over 130 countries around the world. They were first used in 1968 in the automobile manufacturing and are now used by power utilities, in water treatment plants and all types of manufacturing processes.

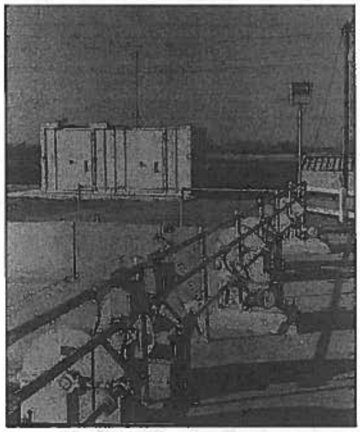


Fig. 6 Prefabricated control building

Several PLC manufactures were evaluated and this specific brand of PLC was chosen because of its robust communications protocol and its highly desirable feature of being able to make program changes remotely and without stopping the program.

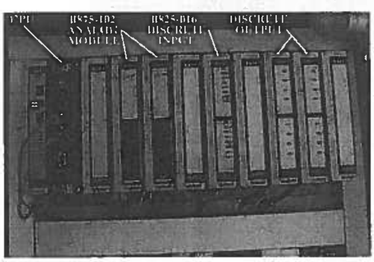


Fig. 7 Programmable Logic Controller (PLC)

The RTU used for remote monitoring applications was a single board controller. It supported the same communications protocol as the PLCs but provided additional data storage capability over the PLC, as well as being lower in cost and using less power.

All sensors and transmitters used produced an industry standard 4-20 mA which is much less effected by electrical noise than a voltage signal. The analog inputs are protected by surge protection devices which provide additional protection to the PLC input modules. If the sensors are considerable distance away from the control building then surge protection devices are installed at the field devices as well.

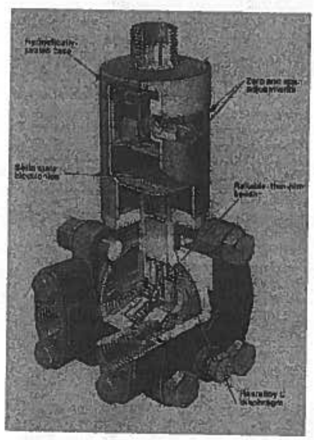


Fig. 8 Differential Pressure Transmitter

The level sensor used water levels greater than 1200mm (4ft) was a differential pressure transmitter. These units have an accuracy of 0.1% as compared to the more common accuracy of 0.25% for such devices.

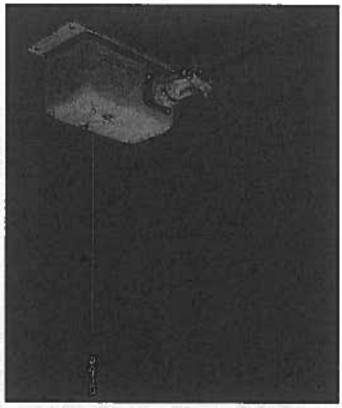


Fig. 9 Level sensor (shown without float)

For water level spans of less than 1200mm (4ft) a low cost level sensor was used. It consisted of a potentiometer driven by a float connected to a cable which is under tension by a torsion spring. Both sensors provide an adjustable span, which further enhances the level measurement accuracy.

New gate hoists were installed at most of the major sites. The new hoists include over torque protection, limit switches and gate position transmitters. A special gate transmitter enclosure was designed for the project which was required because of the limited working space between the gate hoists in these multi-gate installations.

Accurate flow measurement was an important consideration not only for the operation of the system but as well for accurate data collection for the verification program. To obtain flow measurement in the All American Canal a design was developed for an acoustical velocity meter that could be installed with the canal flowing.

The design involved installing power poles in the canal and using them to mount the transducers. Divers accomplished the final alignment of the transducers. A simpler installation was also used in a concrete canal where there was no head available for a weir or other head measurement device.

Fig. 10 Open Channel Acoustical Flow Meter

Acoustic flow meters were used to obtain pumping plant flows on the Lateral Interceptor projects. This meter allowed monitoring of the pumped flow but also provided reverse gravity flow, which was possible in some applications.

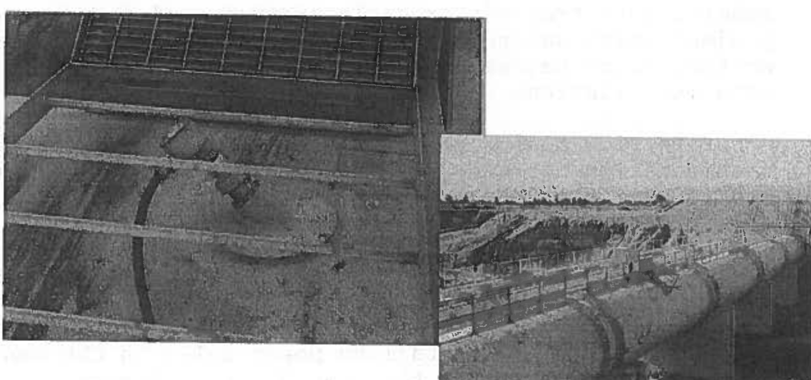


Fig. 11 Acoustical Pipe Flow Meter

This type of unit was also used to obtain flow measurement through a pair of seventeen and one half-foot diameter siphons. The manufacturer modified their electronics to handle the longer signal paths.

Software: A large portion of the PLC software provides for "safety and order" which is critical for the large control sites, including major points on the All American Canal. This was also important for the smaller sites since they operate automatically without remote monitoring and use less expensive components.

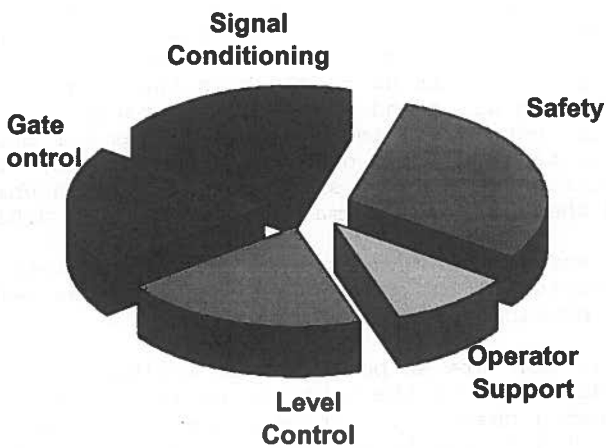


Fig. 12 Software Components

The software functions in a cascade fashion. The lowest level provides communications support. The next level functions to condition and verify all analog inputs.

Since the level sensor is the primary device it is constantly monitored for abnormal readings; too low, too high or too fast a change. If the level sensor is determined to be unreliable the sensor is failed and automatic operation is halted.

The next level is the gate control logic. The gate position sensor is monitored to detect drifting when the gate is not being moved, when the gate is moving; the rate of change in the gate position is monitored for too slow or too fast a change in readings. If the gate position is determined to be unreliable then the gate is failed and in a single gate site automatic operation is halted. In multiple gate sites, automatic control would continue with the remaining available gates. The logic also looks at the Hand/Off/Auto switch and if a gate is not in Auto then the gate cannot be moved by the PLC and gate control is failed, and again automatic operation is halted.

The gate control logic includes a routine to always position a gate from a lower position to a higher position. If a gate is being lowered it is driven past setpoint then raised to the desired setpoint. This ensures there is no backlash in the hoist gear reduction units and provides repeatable gate positioning. The logic also provides for multiple re-tries to obtain the desired gate position. The gate position setpoint is shown in engineering units (feet) and the gates are normally positioned to 0.01 feet.

The software includes soft limits that limit the operation of the gate hoists and provides redundancy to the physical limit switches.

Sites that are AC powered also include power monitoring to determine if the power is ok which can include checking phases of a three-phase service and/or checking to see if AC power is available. If the AC power is determined to not be ok or is unavailable, then gate control is failed and automatic operation is halted.

For multiple gate structures, the gate control logic includes a staging sequence, which allows for opening the gates in a sequence that best suits the canal and structure hydraulics. This logic also handles failed gates in the staging logic.

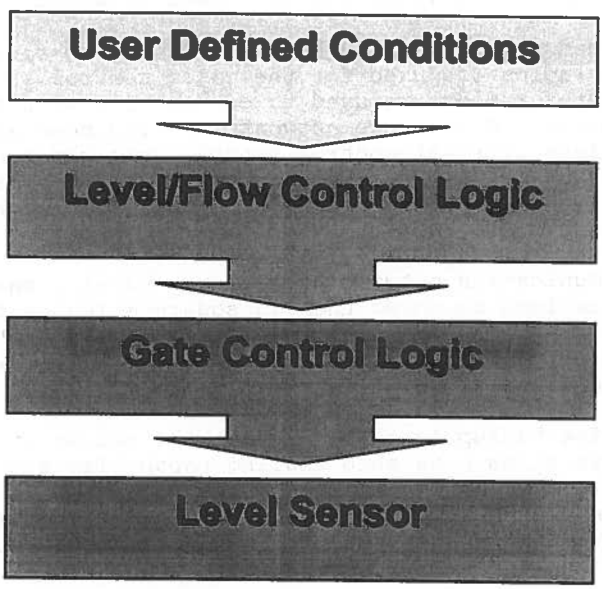
The pump control logic also includes staging sequences for adding and removing pumps similar to the gate stager. The pump control also incorporates logic to control the sequencing of the pumps to provide equal running time. Several of the pumping plants include

Variable Frequency Drives (VFD) which provide more exact control and reduce energy costs.

The final level of logic is level/flow control. Both of these modes of control use Proportional Integral and Derivative (PID) control logic. IID Lateral canals are on slopes greater than 0.002 ,which results in the flow in the concrete canals to be nearing critical velocity. This combined with farm deliveries of 0.6cms (20 cfs), results in dramatic flow changes in these small canals.

The proportional part of the logic adjusts the gate set point proportional to the deviation in level or flow. Integral logic works to bring the level or flow back to setpoint within a time period. Derivative logic looks at how fast the deviation is changing and adds to the other two terms to speed up the return to set point.

For sites requiring maximum accuracy control is tuned to maintain the water level within +/- 3mm (0.01 feet) and flows are maintained to the equivalent flow for +/- 3mm (0.01 feet) of level or +/- 3mm (0.01 feet) of gate opening, which ever flow is larger. Less critical sites may be tuned to maintain the water level to +/- 10mm to reduce the amount of wear on equipment.



As mentioned earlier, flow control sites often include the provision to set an "automatic flow up date" with a time for the new setpoint to take effect. The level setpoint is not often changed at sites that are maintaining a constant upstream level setpoint, however the software includes logic to control the rate at which a new level setpoint is achieved. This was specifically designed to reduce bank instability due to de-watering an unlined canal to rapidly.

Communications

To meet the IID's different SCADA requirements, three radio systems are incorporated and function as one system. The three radio systems provide different levels of service in terms of reliability and speed. Each of the radio systems include several master radios which are connected by a microwave system and a combination of high-speed digital and low-speed analog modem links to Water Control.

The RTUs, which are used to collect historical information, are polled using lower frequency (450 MHz); lower cost radios and lower speed modems (1,200 baud). At present, two master radios handle the current data traffic on the low speed network.

High-speed network (9,600 baud) using higher frequency 960 MHz radios are used for the major control sites. Four master radios are used to communicate with the major sites. A midrange network has also been added to handle less critical control sites. This radio highway uses low cost 450 MHz, 9600 baud radio modems. In total nearly two hundred field units are polled through the communications network.

The communication network uses radio and microwave communications to cover the 700 square miles of the district. It has been found that a microwave dish may shifted off alignment as a result of an earthquake and communications could be lost.

To provide backup in such an event the modems at the microwave sites have auto dialing capability and use special high priority emergency phone lines. The equipment has been configured so that if the microwave link is lost the backup system will automatically connect and restore communications.

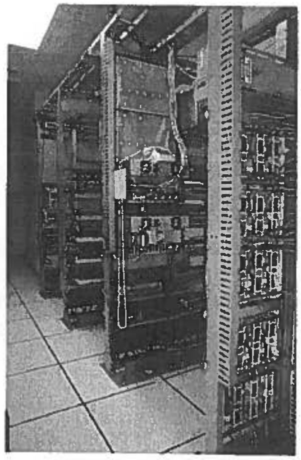


Fig. 13 Communication Rack

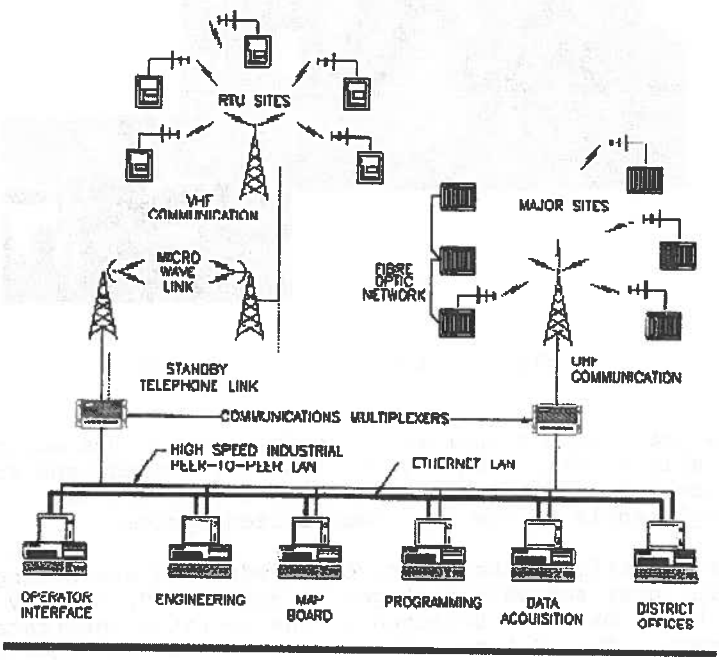


Fig. 14 Communication Network

New Water Control Center

The 10,000 square foot Water Control Center is designed around a large control room which has several operator stations and three 67" rear projection screens. The IID's main canal system is displayed graphically on the rear projection screens with key information such as flow rates, reservoir storage, gate positions and water levels displayed in real time. This approach provides software-configurable mapboards and better accommodates future expansion.

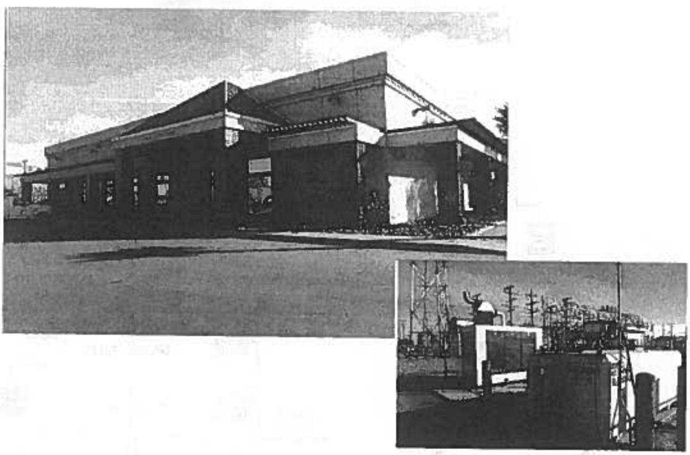


Fig. 15 Water Control Center

A low cost graphic operator interface system was setup initially to help identify the District's needs and to provide the staff with a gradual move from the old control panels to the new computerized system.

After identifying the District's needs, and evaluating several host software packages in early 1990, Factory Link by US Data was selected as the operator interface software. The US Data software was offered for several operating systems; DOS, Windows, OS2 and Unix with an easy upgrade path. For the IID application, OS2 was chosen mainly as a more reliable operating platform than Windows while not being as expensive as Unix.

IID staff were trained on the configuration of the operator screens at the new Water Control center and as sites were commissioned in the field they added them to the operator screens.

Fig. 16 Computer Generated Map Board

The new Control Center is also backed up by standby generator, which is also controlled by a PLC with the same functionality as the field sites. The control center is designed to be an emergency operation center in a disaster.

Maintenance Program

The district's maintenance program has been developed using a maintenance scheduling computer program. The software allows for tracking all tasks and costs and scheduling of maintenance. This has helped refine the interval between maintenance schedules and has shown areas where preventative maintenance could be replaced by predictive maintenance.

Documentation for maintenance has been developed using a web browser. It provides complete documentation in one package and includes site description, site drawings, calibration information and even site photos.

The maintenance manual is written to a CD so that it is available to the maintenance staff in the field.

OPERATIONAL BENEFITS

Equipment Independence

Site operation is fully automated. This provides the system operator with the ability to concentrate on system wide water management. Automatic system override is available to the operator all times at various levels.

Level Control: The operator can select to have a level setpoint maintained and be assured of continuous monitoring and control by the PLC. Level setpoints can alternatively be raised or lowered to a target setpoint at a selected rate.

Flow Control: Continuous flow monitoring and control is maintained by the PLC. The operator can preset updates that match the dispatching schedule and the actual arrival of water.

Reservoir Operation: Site operation is fully automated. This provides the system operator with the ability to concentrate with system on water management. Automatic system override is available to the operator all times at various levels. Normally reservoirs maintain level at adjacent upstream ponds. The software allows the reservoir to be placed offline and have an adjacent structure resume upstream level control.

Field Operators: Local site operation can be conducted by field personnel, at various levels of control. In fully automatic mode field staff can change setpoints and monitor operation using a man-machine-interface (MMI)device. Local-supervisory control is also available through the MMI. In this mode the field operator takes responsibility of the site through various cascaded fallback modes.

System Management

With the various levels of automatic to supervisory control provided by the software operations staff is able to concentrate efforts on managing the system instead of operating equipment. This has allowed to fine tuned their own skills at another level of operation.

Reliability: Site operation was made more reliable due to various factors. The use of industrial grade ruggedized equipment reduces the failure rate. This allows more up time for operation and less down time maintenance and repair.

Fall back features were then incorporated into the system so that if a piece of equipment fails a strategy is in place that allows the control system, a remote operator or a local operator continue with the process.

Accuracy: Increasing the accuracy of the measurement devices and the operating equipment increases the ability to achieve target setpoints with minimal operating variations.

This allows the operator to reduce the operating fraction from the total amount of water being requested from the source upstream. Each point in the system thus reduces the operating fraction of water required. In a large system such as the IID this can be a considerable amount of water, but it has not been quantified.

Uniform Operation: Variations in system operation can be caused the person scheduled to work, and the flow season of the year. This can result in more or less fluctuations in the levels and flows.

Invariably staff developed skills to varying degrees based on individual skill and interest in the operation. Previously the IID operated 22 remotely controlled sites and 38 field operated sites. Each was manned 24 hours a day with rotating shift staff. The individual abilities of each operator were reflected in the amount of fluctuation that developed at each site and the overall flow balance in the system.

The SCADA system reduces the need to operate individual sites and equipment at each site. Sites are controlled independent of the operator with consistent system-wide criteria and operating parameters providing uniform operation.

Timeliness: Prior to the development of the SCADA system on the main canals, the upstream level at each site was checked and modified once an hour at remotely controlled sites, or as soon as a hydrographer could return, at field operated sites.

With the new system level control sites benefit from the continuous operation of the level control logic operated at each site. Fluctuations are managed by the system as they arrive at the site.

At flow control sites flow changes were managed by the hydrographer based on his standard schedule. Flow fluctuations were checked and adjusted when the hydrographer had time during his work period.

The new system allows for multiple flows and their appropriate diversion time to be entered remotely. At the scheduled time the flow change is made and continuously maintained with feed back from a measurement system.

Flexibility: At key sites dual functionality is provided by the software; level or flow control. Some locations allow the fluctuation of the level and serve as inline reservoir. These sites are normally operated in flow control with high and low level overrides that convert the site to level control if the system edges towards either extreme.

This dual mode is also provided at sites with multiple structures. Each structure can be the primary level control point depending on equipment availability, seasonal operational requirements or emergency operations.

WATER CONSERVATION PROGRAM IMPACTS

Integration Of Projects

Flexible service to the water user was one of the main goals of the water conservation program. Various projects were implemented to achieve this. This created main canal fluctuations because of the size and number of change orders made by the water users. The new SCADA system was able to provide the system operators with the ability to manage the system.

12-hour deliveries were devised to match on-farm irrigation needs. Normally water deliveries are made in 24-hour periods. The 12-hour program allowed the water user to irrigate more accurately by allowing a finish order to be placed on the system. At the end of the 12-hour period the water is returned to the system for use elsewhere.

Interceptor systems permit a water user operating within the area to have the water order to his farm cutoff by IID personnel when the irrigation has been finished. This can occur any time of the day and creates large numbers of returned orders.

Pump-back systems capture water that is reaching the lower end of an irrigated field and re-circulate it to the upper part for reuse. At the point in time that water is re-circulated the order is reduced by the same amount. The reduced portion of the order is returned to the system and can occur at various times of the day.

All returned flows are returned to the main canal system and managed via the SCADA System by providing accurate measurement and timely control.

Program Verification

One of the main aspects of the IID/MWD agreement was the Verification Program. In order to quantify the amount of water being conserved by the various projects an extensive monitoring program was developed. Without the ability to identify "wet" water, the Water Conservation Program would not have been accepted by the parties involved.

The Verification Program required installation of flow measurement sites, continuous monitoring and data storage. The SCADA system provides for data retrieval and storage for the quality control system that is used to verify water conservation projects. It also allowed the integration of small monitoring sites with the numerous large control sites within one operating environment.