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MAIN CANAL DECISION SUPPORT SYSTEM FOR SCHEDULING FLOW CHANGES ON MAIN CANALS IMPERIAL IRRIGATION DISTRICT EFFICIENCY CONSERVATION PROGRAM

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ABSTRACT

In 2003 the Imperial Irrigation District (IID, or District), a 450,000-acre water district in Southern California, was one party to a package of decisions and agreements known collectively as the Quantification Settlement Agreement and Related Agreements (QSA). Under one aspect of the QSA, IID agreed to a long-term transfer of water conserved within the IID to the San Diego County Water Authority (SDCWA) and the Coachella Valley Water District (CVWD). IID must conserve and transfer 303,000 acre-feet of water each year, nearly 10% of the District's total annual water use, by 2026. In 2007, IID completed the Efficiency Conservation Definite Plan (ECDP) outlining strategies for delivery system and on-farm water savings. Although court review of some aspects of the QSA continues, the parties have agreed to continue to abide by the agreement. This paper describes the Main Canal Decision Support System (MCDSS) developed by IID to support main canal flow change scheduling decisions. The IID distribution system consists of three main canals, 11 regulating and interceptor reservoirs, more than 200 laterals, and over 5,500 deliveries to users. The MCDSS was developed within IID's Water Information System (WIS) to assist IID Water Control in operating this large, multifaceted water distribution system with maximum efficiency while providing delivery flexibility, responsiveness, and reliability to IID water users. The MCDSS supports IID's main canal water delivery scheduling and daily water accounting processes; and automates IID's long standing paper processes in a manner that eases the transition for main canal operators. The MCDSS is an integrated collection of decision support tools designed to provide support to Water Control Center (WCC) main canal operations. Meeting these objectives required developing a system of complex computer applications integrated within the MCDSS framework. The MCDSS development process and modules will be described in this paper.

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BACKGROUND

The Imperial Irrigation District (IID) was established 100 years ago and delivers Colorado River water for irrigation to approximately 450,000 acres in Southern California (Figure 1). The IID distribution system consists of three main canals, 11 regulating and interceptor reservoirs, more than 200 laterals, and over 5,500 deliveries to users. The water delivered to growers supports the production of a significant portion of the winter vegetables consumed in the United States. Other significant crops include alfalfa and other hay crops supporting dairy and livestock industries. Imperial County in California ranks as one of the top counties in the United States in terms of gross agricultural production and sales primarily due to the Colorado River water supplied to growers by the IID.

Figure 1. Imperial Irrigation District Location.

In October 2003, the IID entered into the Quantification Settlement Agreement (QSA) and Related Agreements. As part of these agreements, the IID agreed to a long-term transfer of water to the San Diego County Water Authority and the Coachella Valley Water District. To enable IID to meet its water transfer obligations pursuant to the agreements, IID and its farmers must conserve 303,000 acre-feet of water per year by 2026.

In 2005, IID begin developing the Efficiency Conservation Definite Plan (ECDP) to identify a mix of on-farm actions, delivery system improvements and incentive packages that would conserve the water required. The ECDP was completed in early 2007 and provides the technical foundation for IID's Efficiency Conservation Program (ECP).

The ECP, initiated in 2008, implemented seepage interception systems, developed the on-farm efficiency conservation program and developed an integrated data management system to track and forecast the volumes of water conserved. Testing and refinement of the delivery system and farm delivery measurement improvements led to the System Conservation Plan (SCP) featuring reduction, recapture and re-use of spillage from IID laterals.

In 2010, IID completed Phase 1 of the Main Canal Decision Support System (MCDSS). The MCDSS supports IID's main canal water delivery scheduling and daily water accounting processes. Of key importance was the need to automate IID's long standing paper processes in a manner that eases the paper to computer transition for the main canal operators.

MCDSS OVERVIEW

The Main Canal Decision Support System (MCDSS) is an integrated collection of decision support tools designed to provide support to IID's Water Control Center (WCC) main canal operations. WCC decisions are of two types: flow scheduling and system operation (to achieve the scheduled flows). Scheduling decisions involve planning horizons ranging from a half-day to a year, while operation decisions are executed in real time, or within hours. The principal scheduling decisions involve: 1) determining the master water order for the District from the Colorado River (annual forecast, weekly forecast four days in advance, and daily finalization of tomorrow's order); 2) allocation of tomorrow's water to the IID Divisions by main canal sales area, and; 3) scheduling daily main canal (reservoirs, main canal headings, checks, etc.) and lateral heading flow changes. Most operation decisions are the result of unscheduled changes and operational error (lack of precision in gate settings and measurement error) during the day, requiring changes at main canal control points (reservoirs, main canal headings, checks, etc.) and lateral headings.

Version 1.0 of the MCDSS focuses on automation of the Daily Water Record (DWR) and scheduling of main canals, also referred to as the Main Canal Breakdown (MCB). The main objective for this version of the MCDSS is to provide main canal dispatchers (operators) with the information to support main canal scheduling decisions. In addition, supplying this information and performing required calculations through the MCDSS reduced errors and the time spent preparing the information to support scheduling decisions. The MCDSS provides more timely and accurate information for operational decisions, ultimately supporting IID's water conservation goals. To ensure the success of the automation process, two important additional goals were to ease the transition from paper to computer and to enhance dispatcher confidence in the new tools. These two goals were accomplished by designing the application interface in close cooperation with the dispatchers with a look similar to paper forms to which they were accustomed. Table

1 lists WCC scheduling and operations decisions, respectively, supported by Version 1.0 of the MCDSS.

Table 1. WCC Scheduling Decisions Supported by MCDSS v1.0

Decision	**Cause for Decision**	**DSS Development Phase**
Schedule changes at lateral headings	Changes in water orders from previous day	Phase I
Schedule main canal flow changes (reservoirs, main canal headings, checks, etc.)	Changes in water orders from previous day	Phase I
Schedule changes in response to 12-hour order changes	Changes in water orders due to 12-hour order changes	Phase I

Daily Water Record (DWR)

The DWR forms the basis for the daily scheduling and operation of IID's main canal system. All lateral heading and direct delivery orders and deliveries are entered on the DWR and main canal operations planned accordingly. Automation of the DWR and the associated main canal breakdowns is the core of the MCDSS.

In its paper form, the DWR, also called the "desk sheet," was a large format, hand-entered, daily water ledger of flows for IID's main canal system. The DWR within the MCDSS preserves the same functionality and basic structure of the paper version. The DWR screen displays rows for each lateral heading and main canal direct delivery. Lateral headings and main canal direct deliveries (main canal deliveries) are grouped into delivery areas corresponding to MCB points. For each lateral heading and main canal direct delivery there is an entry for the ordered water for the day (24-hour deliveries) and the A.M. and P.M. deliveries (12-hour morning and afternoon deliveries, respectively). In addition, all actual delivery rate changes and the time they occurred are recorded and averaged to determine the mean daily delivery rate.

The water order and flow data stored on the DWR serve as a database for the IID water distribution system and are used for two main functions. First, water flow data are used in various reports to document where water is used within IID. Second, the water order totals at these main canal system control and delivery points are utilized to schedule flow changes throughout the distribution system to ensure that all water order requests are fulfilled. This function is completed by transferring these totals to the MCB, which, prior to the MCDSS, was a manual process involving a second set of paper forms.

Prior to the MCDSS, three DWR sheets (TOMORROW, TODAY, and YESTERDAY) were used to develop the schedule of daily flow changes. Lateral heading orders for the following day, plus required operational water, were aggregated by IID's Water Order Entry (WOE) system by summing the orders on each lateral scheduled to run tomorrow plus required operational water. These lateral heading orders were then hand-entered into the Ordered column of the TOMORROW DWR sheet. Morning and afternoon flows and deliveries reported by IID field staff and SCADA were written on the TODAY DWR sheet in the A.M. and P.M. columns. The differences between today's flows and tomorrow's orders together with today's computed losses and reservoir trends, formed the basis for the MCB, used to schedule main canal flow changes. Final accounting calculations were completed in the YESTERDAY DWR sheet, once morning flows reported by IID field staff were written on the TODAY DWR sheet and deliveries were complete and entered into the WOE system. Selected data from the DWR were then used for various reports and to develop the Master Water Order.

Main Canal Breakdown (MCB)

The MCB divides the main canal into operational reaches, starting at the downstream end, and working upstream. In this manner, scheduled changes for downstream reaches are incorporated into the planned changes for upstream reaches. The water order totals and current flows at various main canal system control and delivery points from TOMORROW and TODAY DWR sheets were utilized to schedule flow changes throughout the distribution system. These totals were transferred to various MCB paper sheets that, together with information on reservoir storage and return to system flows, provided the dispatcher with all the information required to schedule flow changes at the various main canal control points. MCB sheets were linked by writing the summations of flows at the head of downstream breakdowns in the next upstream MCB.

Reports

Both the DWR and MCB include task critical reports that could be executed directly from these applications. Additional reports identified through a series of workshops with Water Department staff are included with the MCDSS and can be executed from the MCDSS.

AUTOMATION OF THE DWR AND MCB

Increasing amounts of the information that was hand-entered on the DWR sheets is digital data from IID's WOE, SCADA, and the Water Information System (WIS) computer systems. Because the DWR is at the center of WCC operations, development of the MCDSS had to begin there. Manually entering information not already in digital form into a computer system provided the basis for computer-calculation of sums by MCB reach, thereby reducing errors and saving time. This provides the dispatchers with more time to concentrate on making the correct operational decisions. Automation of the DWR and MCB also provides a foundation supporting scheduling and operations closer to real-time.

The primary data sources for the automated DWR are the same as for the manual DWR: (1) the WOE system for all customer orders and deliveries and (2) either SCADA or manual entry of field measurements for all main canal control points (reservoirs, main canal headings, checks, etc.), lateral headings, and direct deliveries. In the automated DWR, all data for the DWR flow directly to the WIS where queries aggregate data by control point and lateral heading and store results in keyed and time stamped tables (Figure 2). Once the dispatchers gain confidence and experience in the new computer environment, their suggestions will be incorporated in the next version of the MCDSS further enhancing their productivity.

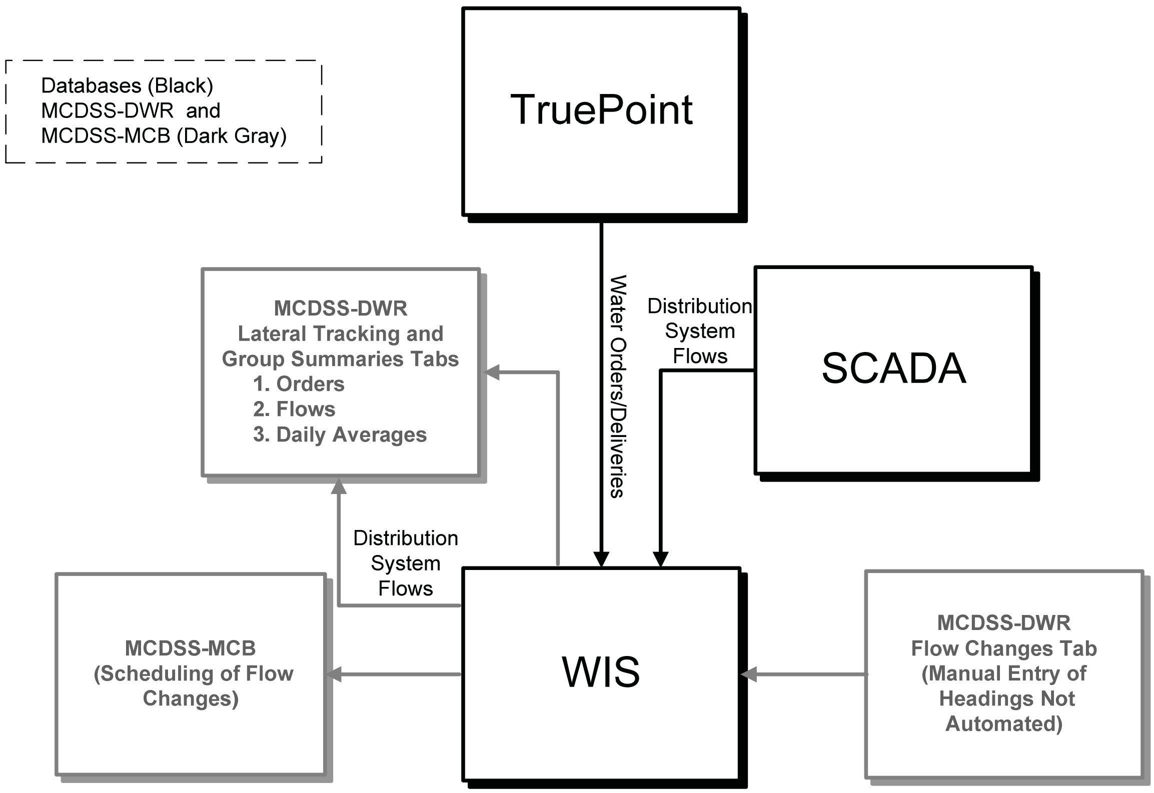

Figure 2. Schematic of Data Flow in the MCDSS

MCDSS-DWR Development

As the core of the MCDSS, the DWR Human Machine Interface (HMI) was developed first as four tabs. The *Flow Change* tab (Figure 3) is used for manual entry of all orders and flows not yet available through the SCADA system. The *Lateral Tracking* tab (Figures 4a, 4b and 4c) serves as the HMI for viewing the selected DWR sheet. The *Group Summaries* tab (Figure 5) was developed to display the various DWR totals. These totals are sums of more than one flow measurement location serving various accounting functions. Certain parameter settings in the MCDSS – DWR can be changed by the user, via the *Maintenance* tab. The MCDSS – DWR was tested and validated for two months prior to the initiating testing of the MCB prototype spreadsheet described in the following section.

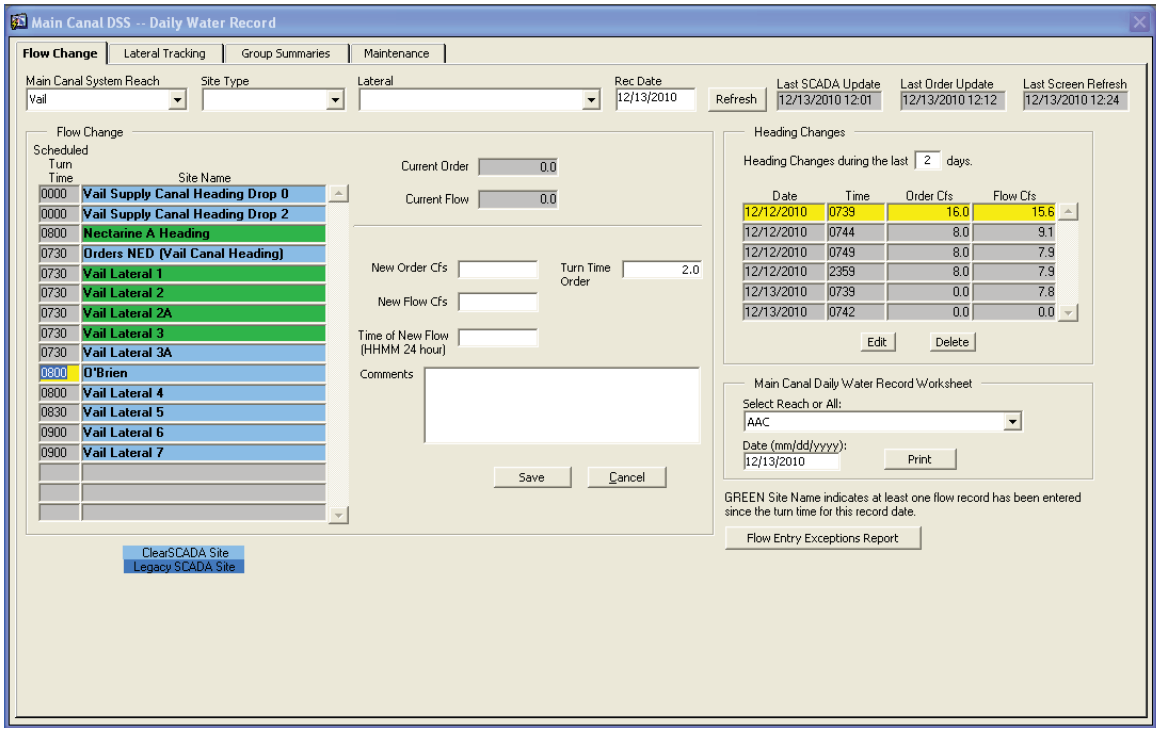

Figure 3. MCDSS-DWR Flow Change tab

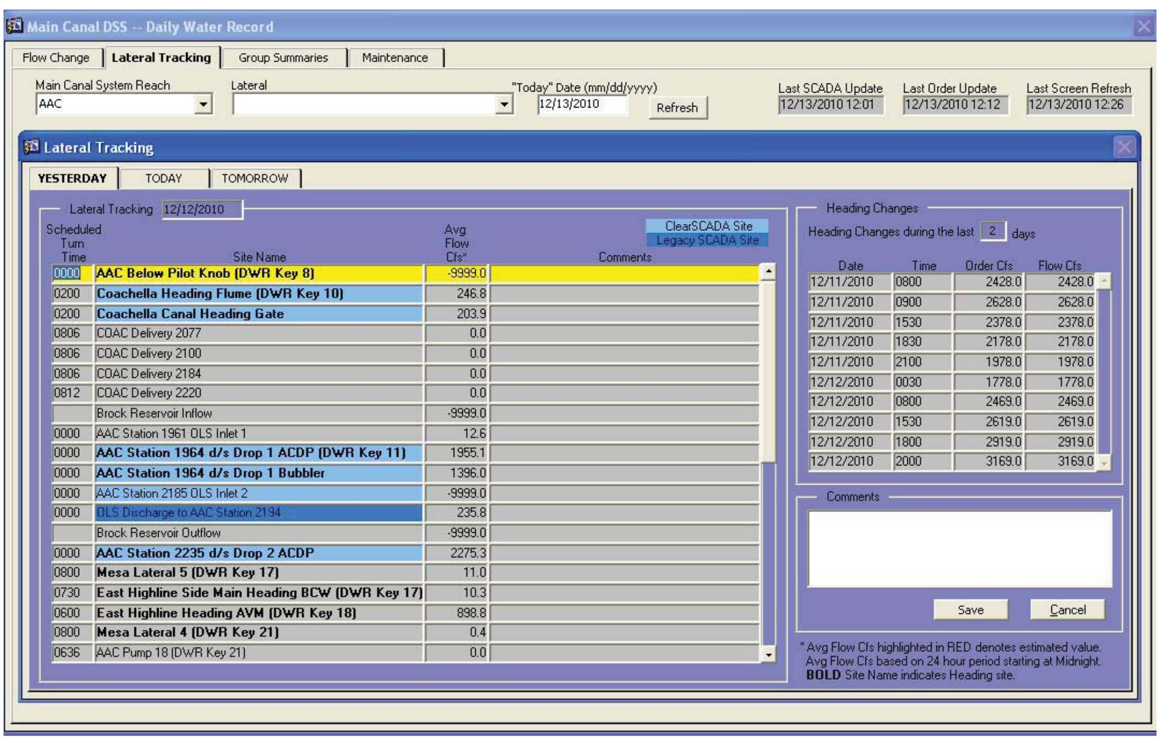

Figure 4a. MCDSS-DWR Lateral Tracking - Yesterday's Data

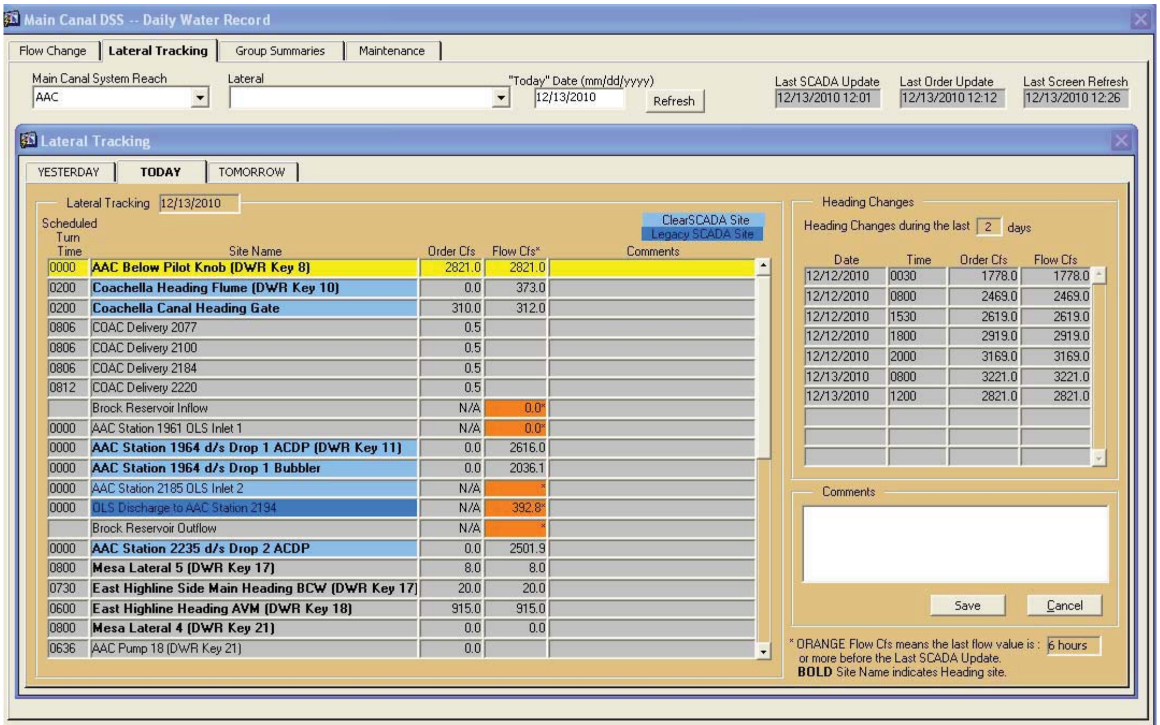

Figure 4b. MCDSS-DWR Lateral Tracking - Today's Data

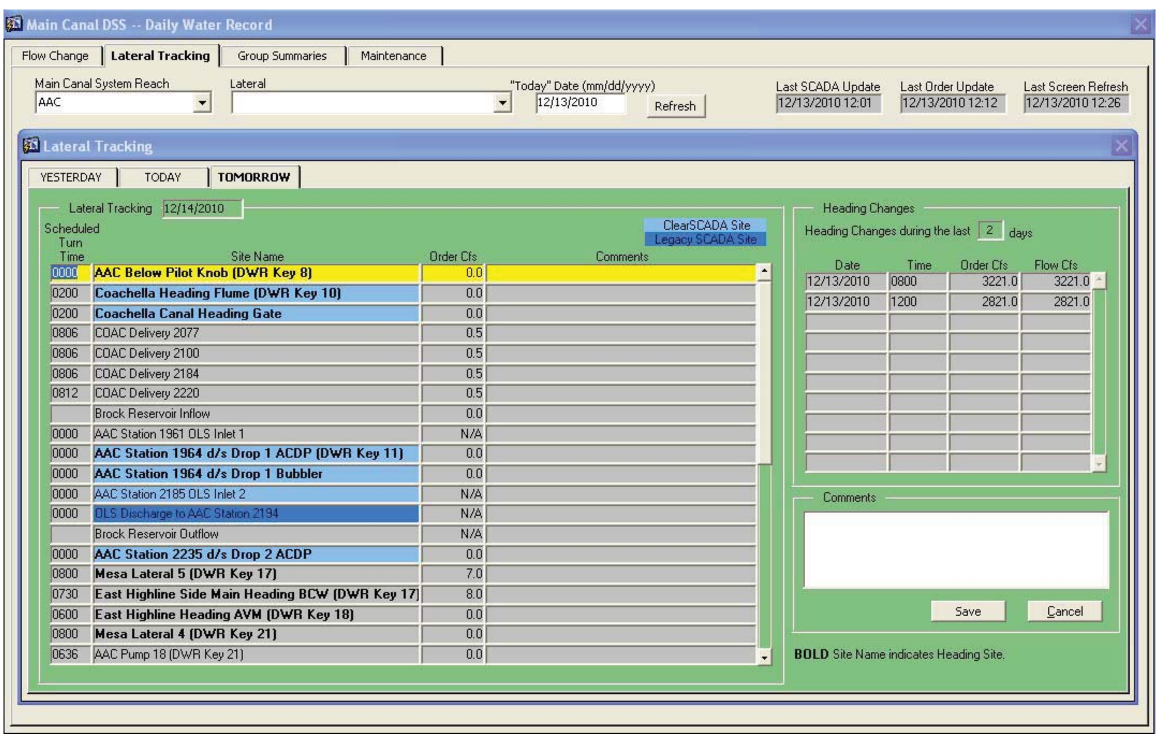

Figure 4c. MCDSS-DWR Lateral Tracking - Tomorrow's Data

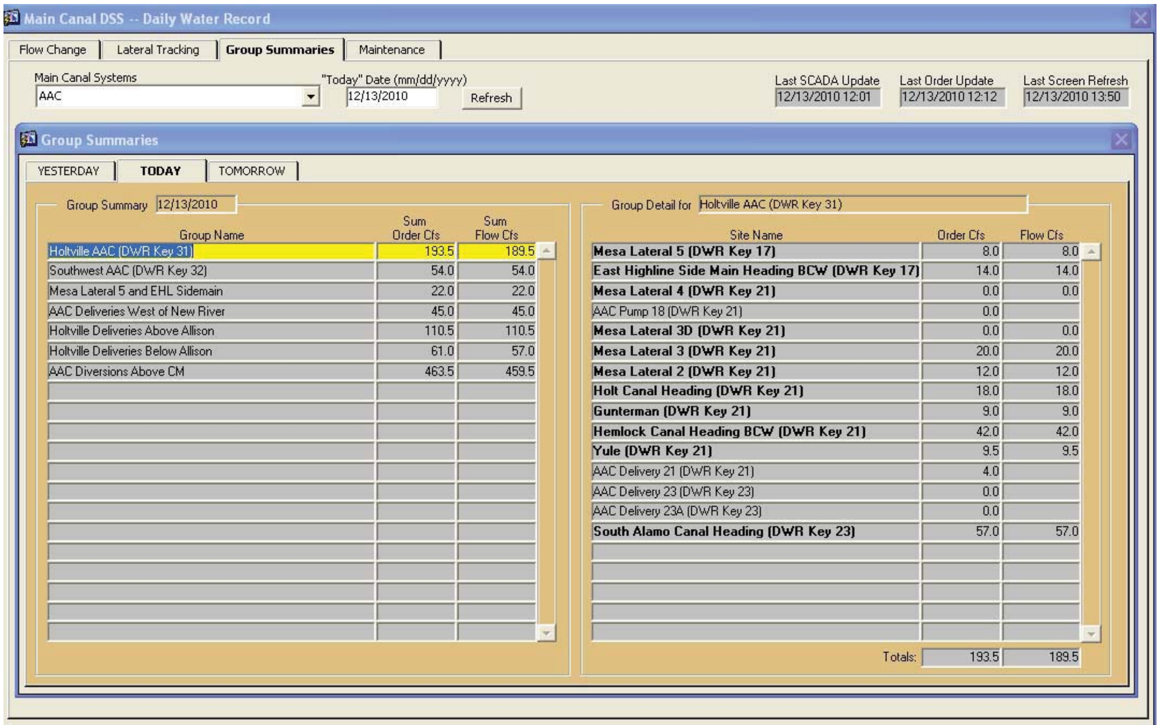

Figure 5. MCDSS-DWR Group Summaries - Today's Data

MCDSS-MCB Development

Automation of the MCB was prototyped in an Excel spreadsheet and then ported to the WIS after functionality testing was completed. The spreadsheet had all the functions needed to complete the Main Canal Breakdown and was linked to the WIS through an MSAccess database. This linkage imported to the spreadsheet all data manually entered through the automated MCDSS-DWR and transferred to the WIS from the WOE and SCADA systems. To enhance dispatcher confidence in the MCB and ease the transition to the new system, the groupings in each MCB area remained the same as in the paper system. The only difference from the paper sheets was the introduction of the 12-hour main canal breakdown analysis[5]. This additional breakdown provides information that enhances the scheduling of afternoon changes resulting from 12-hour deliveries. This was made possible with the MCDSS automation of the DWR. The order type in the WOE system provides the information to separate AM and PM orders.

Following one month of functionality testing of the spreadsheet, the validated functionality was developed on the WIS. The Main Canal Breakdown (MCB) consists of two tabs: the *ORDERS*

[5] 12-hour deliveries were introduced to IID as a component of the Metropolitan Water District transfer agreement. Generally the total volume of daytime (AM) 12-hour deliveries exceeds the nighttime (PM) 12-hour deliveries. Water is ordered to meet the AM requirement and the excess water in the PM is stored in-line and in reservoirs. Before the MCDSS, the change in deliveries and canal flow between AM and PM was seen as change in system gain or loss. The MCDSS automation will allow explicit AM and PM scheduling.

tab and the *MCB* tab. The *ORDERS* tab (Figure 6) provides an entry screen for entering orders not available in IID's WOE software. Under the *MCB* tab, the main canal system is divided into

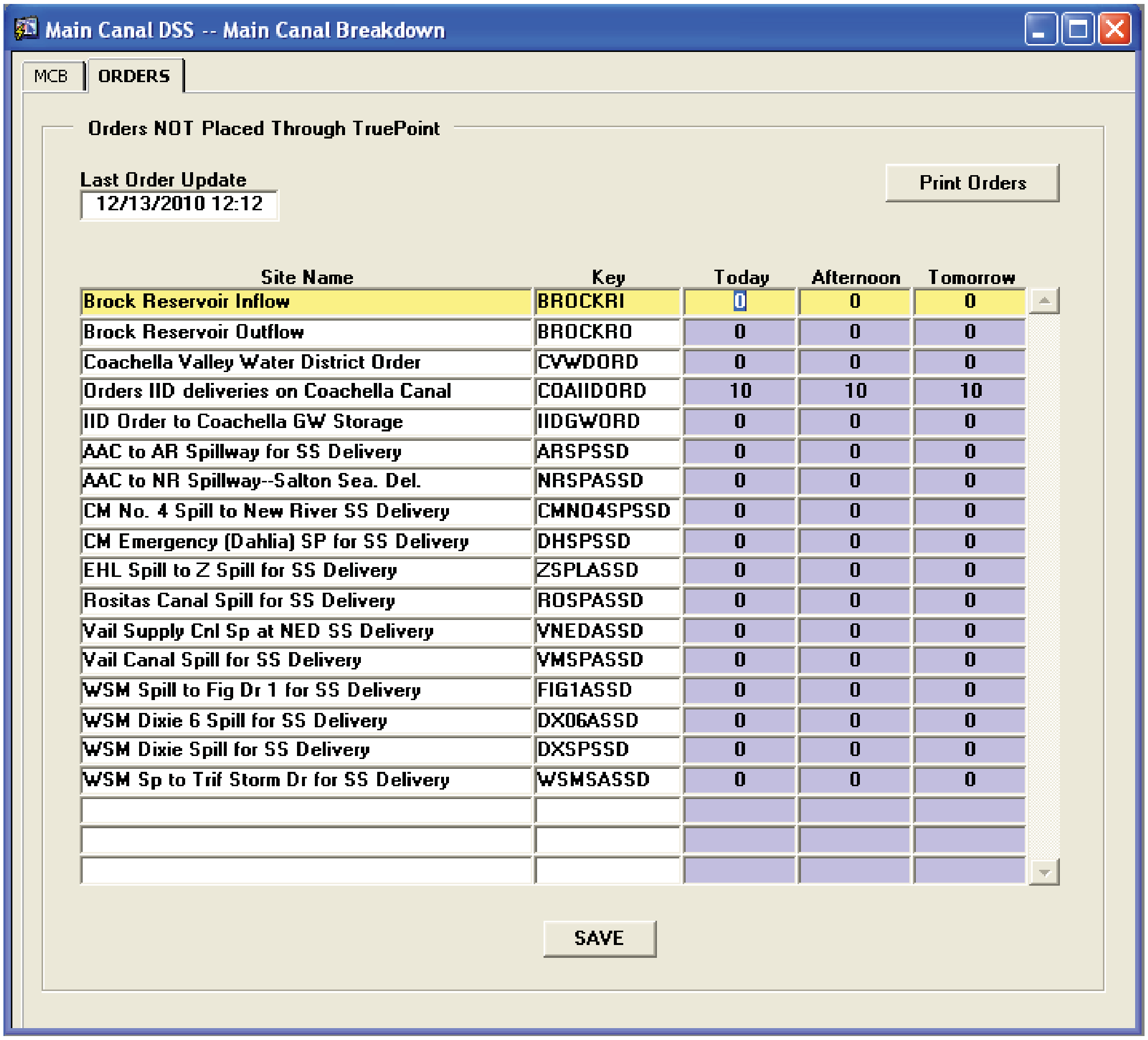

Figure 6. MCDSS-MCB Orders Tab

17 reaches (Table 2). Each reach begins at a control point where flow changes are scheduled. The screen is organized the same for each main canal control point, but different data is retrieved and displayed depending on the selected MCB reach. Many, but not all, of these control points have some storage available. Each reach below the control points is further broken down into groups of lateral and main canal outflows. A single flow change at the reach control point will supply water to the groups of laterals and main canal outflows below that control point at the correct time to serve customers. The Dispatcher can select each control point and corresponding reach breakdowns to schedule flow changes in response to order changes for the afternoon and tomorrow.

Table 2. IID Main Canal Breakdown by Reach in the MCB

No.	Reach Name	No.	Reach Name
1	Westside Main Below No. 8 Heading MCB	10	East Highline Below Nectarine MCB
2	Westside Main All MCB	11	East Highline All MCB
3	Central Main Below No. 4 MCB	12	Briar Old MCB
4	Central Main Below Dahlia MCB	13	Briar All MCB
5	Central Main All MCB	14	All American Canal Below Central Check MCB
6	Vail below NED MCB	15	All American Canal Below Drop 2 to Central Check MCB
7	Vail Supply Canal MCB	16	Coachella Canal MCB
8	Redwood Canal MCB	17	All American Canal from Pilot Knob to Drop 2 MCB
9	Rositas MCB		

The *MCB* tab (Figure 7) consists of six sections. Dispatchers can enter data into cells with a light blue background. Reductions in flow are displayed in red font and enclosed in brackets. The *Reach* section allows the Dispatcher to select the MCB reach and provides information about the timing of the available data. The *Canal Reach* section "breaks down" the reach into groups of orders. The *Schedule Changes* section is where the Dispatcher enters the flow change amounts and the scheduled time to make the flow change. The *Reservoirs* section provides information on storage volumes and storage volume trends in the reservoirs which can contribute supply to the reach. The *Flows* section provides information about the flow passing selected checks today and the expected flow passing those checks tomorrow. The *RTS* section provides information on flows that are returned to the system in the selected reach. These flows may be from a reservoir in the reach or from the end of a canal that flows into the reach.

The MCDSS - MCB was tested for one month, and following correction of all errors noted, IID staff began using the MCDSS on November 1, 2010. The last date for the paper DWR and MCB forms was October 31, 2010. The prototype spreadsheet was modified to serve as an emergency MCB backup with manual data entry.

WIS Code and Structures Required

Six scripts, 15 procedures and 10 functions assemble data from 17 tables in the MCDSS. All code and required data is stored in the WIS Oracle database at IID. The computer code comprising the applications is stored in the WIS Oracle database.

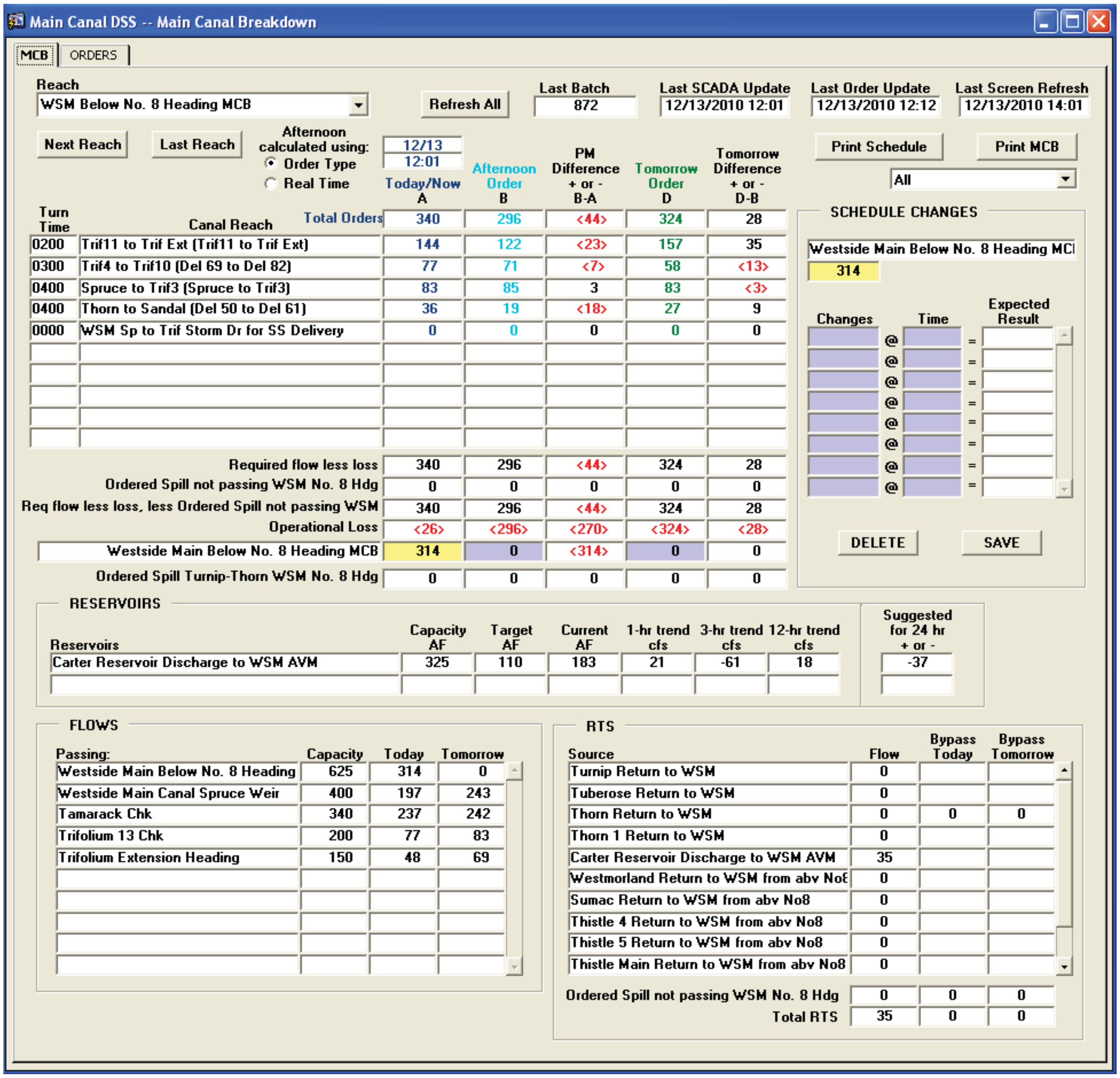

Figure 7. MCDSS-MCB MCB Tab

CONCLUSION

IID has been using the MCDSS since November 1, 2010. The MCDSS has achieved the two main objectives of providing better and more timely information on which to base operational decisions. The MCDSS development process eased the transition from paper to computer and enhanced staff confidence in the new tools by designing the application interface in close cooperation with the dispatchers and remaining consistent with the paper forms that they were accustomed to. The MCDSS provides IID with a framework to build upon. As staff continues to use the system, their suggestions for improvements and enhancements will be included in the next phase and additional decision support tools beyond presenting information will be incorporated.