

# Dashboard for Irrigation Efficiency Management (DIEM)

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**Abstract.** *In areas with limited irrigation capacity and irregular seasonal rainfall, methods to efficiently distribute available irrigations are challenging due to the inability to control soil profile water levels at times of critical crop water needs, the environmental effects on irrigation distributions, and changes in irrigation capacity within a growing season. The Dashboard for Irrigation Efficiency Management (DIEM) was developed to help make irrigation decisions in the short-season, semi-arid environment of the Texas High Plains where irrigation capacities from the Ogallala Aquifer are rapidly decreasing and cotton is the predominant row crop. DIEM is a web-based software solution for forecasting optimized field-specific irrigation schedules based on water availability. This is accomplished by configuring basic historic, near real-time, and future agronomic information including weather, soil and crop characteristics, and irrigation parameters into an interactive data visualization for portraying key aspects supporting irrigation decisions. The public beta-version of DIEM is available at <https://diem.tamu.edu>.*

**Keywords.** Irrigation, Cotton, Evapotranspiration, Texas High Plains, Irrigation Scheduling, Dashboard

## Introduction

Evapotranspiration (ET) based methods have traditionally been used to efficiently schedule irrigation applications. With ample irrigation capacity, irrigation scheduling can be rather straightforward, i.e., determine crop ET ( $ET_c$ ) since the last irrigation, subtract effective precipitation, and apply this net amount at regular intervals or at set soil moisture thresholds. With the availability of cellular automation and regional weather networks, growers have immediate access to daily estimates of irrigation requirements for specific crops at specific locations (TAWC, 2017; Texas A&M AgriLife Extension, 2017; Kansas State Research and Extension, 2017; CSU Extension, 2017; University of Missouri Extension Service, 2017; Vellidis, et al., 2014). In areas with limited irrigation capacity and irregular seasonal rainfall, methods to efficiently distribute available irrigation applications can be more challenging due to

reduced control of soil water levels related to crop water needs, environmental effects on irrigation distribution, and the changes in irrigation capacity within a growing season.

The continuing decline in well capacities within the Ogallala Region of the central US has resulted in available irrigation being truly supplemental to seasonal rainfall on much of the available cropland. For example, peak cotton production is hampered on approximately two million acres in the Texas High Plains (THP) by falling irrigation capacities, irregular rain events, and irrigation volume limits. Ongoing field experiments conducted at Texas A&M AgriLife Research Center, Halfway, have focused on irrigation productivity within specific cotton growth periods using center pivot (LEPA) irrigation (Bordovsky, et al., 2015). One of the most notable findings has been that early season irrigation applications intended to increase water available in the root zone for later seasonal use was only marginally effective in increasing final cotton yields. For example, at the 0.25 inch/d irrigation capacity, over the 4-year test period, the traditional "try filling the root zone early" treatment used 14.1 inches of irrigation per year to produce 1255 lb. lint/acre compared to the "just keep the plant going during the first period" treatment which resulted in 1246 lb. lint/acre with 11.3 inches/year, a 20% reduction in irrigation water use. Similar results were seen at lower irrigation capacities. The results were attributed to the typically harsh early season environmental conditions, contributing primarily to high evaporation losses, and not having sufficient irrigation capacity in the latter periods to support "large" plants resulting from irrigation in excess of plant needs during the vegetative period. Preseason rainfall evaporation losses from large weighing lysimeters at the nearby USDA-ARS Conservation and Production Research Laboratory in Bushland, TX support this conclusion (Marek, et al., 2015).

The Dashboard for Irrigation Efficiency Management (DIEM) was developed to capture these and other research results in a single integrated, web-based software solution for forecasting field-specific irrigation schedules that will help THP cotton growers optimize rainfall and irrigation productivity in a short-season, limited irrigation environment. This was accomplished by configuring basic historic, near real-time, and future agronomic information including weather, soil and crop characteristics, and irrigation parameters into an interactive data visualization for portraying key aspects supporting irrigation decisions. The remainder of this paper describes elements of the DIEM irrigation scheduling tool.

## **DIEM Development**

DIEM originated from spreadsheets using the daily soil water balance method (Allen, et al., 1998) to schedule cotton irrigation for experiments at Texas A&M AgriLife Research at Halfway. These spreadsheets evolved over time resulting from changes in deficit irrigation treatments and experiments. Accommodations were made in scheduling methods to include the way irrigation applications were limited (fraction of full  $ET_c$ , irrigation capacity, irrigation volume limits, or by combinations of these) and by the method of irrigation delivery (low elevation spray application, LESA; low energy precision application, LEPA; or subsurface drip irrigation, SDI). Differences in soil surface evaporation among delivery methods, particularly early in the growing season, and reductions in crop transpiration rates as root zone water depletion occurred with low capacity wells were considered. This scheduling method was used in a 4-year field experiment having 27 replicated irrigation regimes composed of combinations of irrigation capacities and growing season irrigation periods (Bordovsky, et al., 2015). Among other outcomes, this experiment resulted in relationships among season-long soil profile (root zone) water contents and cotton yields that could be used to systematically adjust irrigations so that yield or water productivity are optimized within the water constraints of a specific field.

DIEM is a visual web-based tool that provides a season-long “prescription” for irrigation applications within specific fields. DIEM uses a customizable information dashboard that leverages a highly robust technology called the Information Dashboard Framework (IDF). IDF was developed by researchers at the Texas A&M Engineering Experiment Station’s Texas Center for Applied Technology (TCAT) and has been used in the development of AgConnect® for the Institute for Infectious Animal Diseases (IIAD), a Department of Homeland Security Science and Technology Center of Excellence. This technology framework which also incorporates visual analytic tools, was used to create an integrated irrigation information dashboard. The public beta-version of DIEM is available at <https://diem.tamu.edu> .

Within DIEM, once a field and scenario are identified, a soil water chart is updated showing effective rain, irrigation applications, target soil water content, transpiration limiting soil water content, and estimated soil water content over a user defined growing season. Each time DIEM is accessed during a current growing season, projected weather data (from historical weather records) are replaced by updated, near term data from specified weather stations and future irrigation applications reconfigured to optimize the crop yield score. Rainfall, irrigation, and soil water editors allow user override / in-season corrections. At any time, users can change field specific parameters and immediately observe their effects on soil water distribution, yield, and water productivity scores.

## The Dashboard

When DIEM is opened, the dashboard will appear and load the previously active scenario. A scenario is a collection of factors that define an irrigated field through model inputs and ultimately leads to an irrigation schedule. Scenarios are grouped by the field from which they get their soil and geographic parameters. From this screen, the user can view the current outputs of an activated scenario; edit

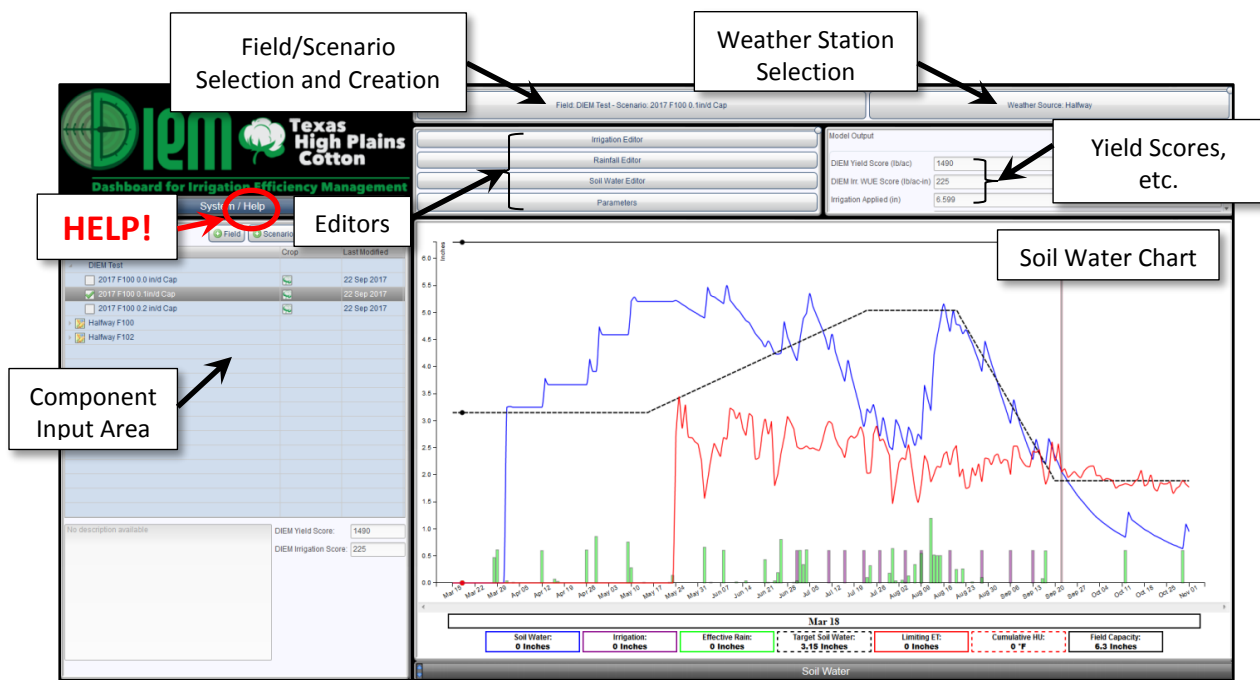


Figure 1. DIEM dashboard containing access to fields and scenarios, weather station selection, parameter editing, as well as dynamic outputs that include year-long profile water estimates and yield scores.

individual parameters of a field or the active scenario; create new scenarios for an existing field; or create new fields and associated scenarios. The soil water chart displays a season-long estimate of soil profile water status and a combination of actual and recommended irrigation applications for the active scenario. Other outputs include irrigation quantity and crop yield scores.

## Field and Scenario

At the top of the DIEM dashboard, the name of the currently active field and scenario are displayed. This panel will open the Field and Scenario Manager (Figure 2) allowing the activation of previously defined scenarios and the creation, editing, or deletion of scenarios and fields. An unlimited number of fields and scenarios can be described for single DIEM accounts; however, users may have difficulties managing large numbers (i.e., hundreds) of scenarios and dashboard response times may be reduced with increased scenario numbers. In newly created scenarios, initial dashboard outputs in the Model Output and Soil Water chart result from default parameters and weather station values that must be modified to describe the new field and scenario.

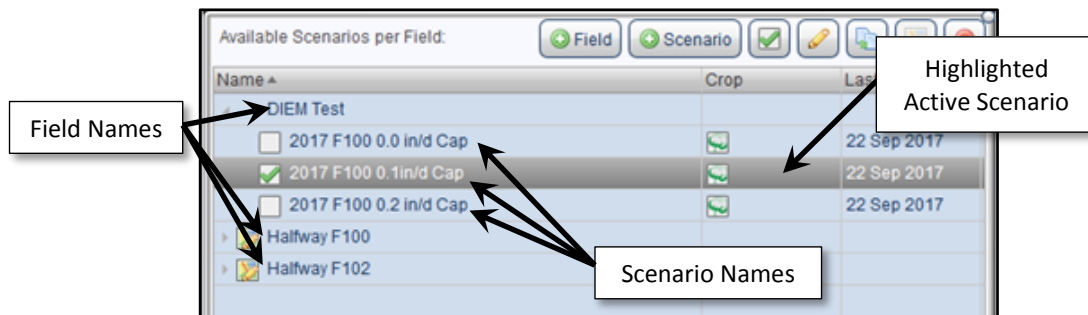


Figure 2. Field and Scenario Manager component displayed in the DIEM dashboard.

## Weather Station

The name of the primary weather station used for the current scenario is displayed at the top right of the DIEM dashboard (Figure 1). This panel opens the Weather Station Manager (Figure 3) where weather data sources are selected. Custom weather sources may also be managed by uploading data sets for use in scenarios. At least two weather data sets are required for DIEM to correctly function in an ongoing growing season. DIEM accesses the current year's weather data up to the current date from the first (upper most listed) weather data set; daily records from the second or subsequent weather data sets are employed only if information is not available from the first weather station. Therefore, for a current year, the first data set would typically be the current year data from the closest weather station. The second station could be a "backup" current year station located nearby providing daily measurements if data availability becomes an issue from the first station. The second or third (and subsequent) weather station data sets would be historic season-long data, such as a file of "average" data from the closest weather station with this data used to project the weather (and indirectly the soil water content) for the remainder of the growing season. As an alternative to "average" data, the user may choose from years characterized as being "wet" or "dry" or weather data from a specific year in the past to initialize the projected weather scenario. To analyze a previous year's water use and compare the actual crop yield to the DIEM's estimated yield score, the weather data set from the previous year at the appropriate location would be positioned as the first data set.

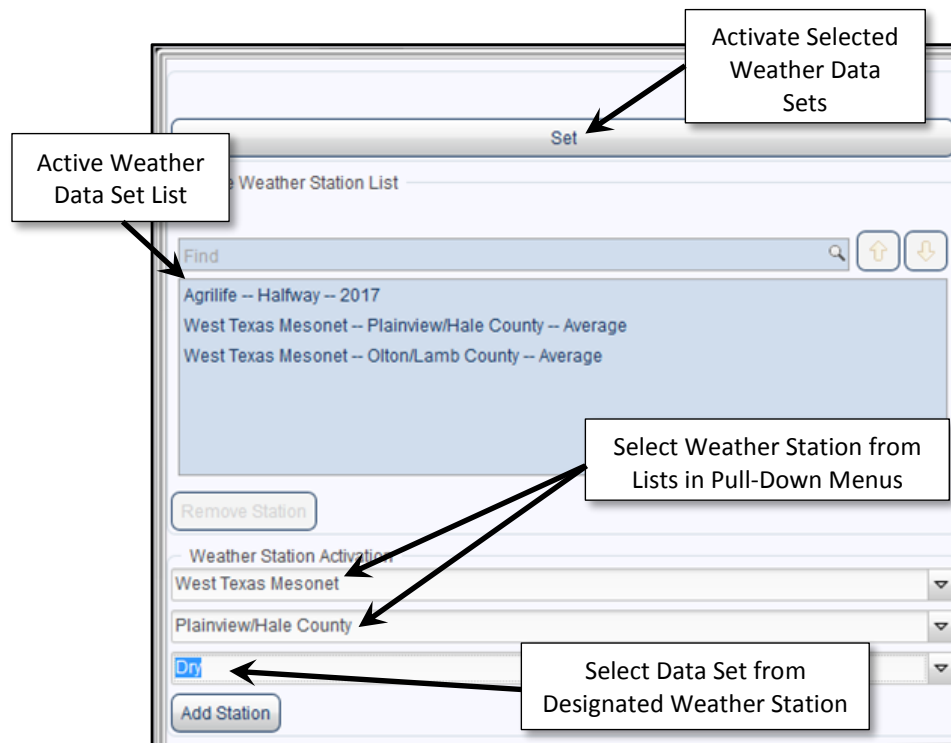


Figure 3. Weather Station Manager component displayed in the DIEM dashboard.

## Field and Crop Parameters

Specific field and basic crop information for an activated scenario can be modified by accessing the Parameters screen (Figure 4). This screen is divided into four sections entitled Model Control Dates, Soil Profile, Planting, and Irrigation Inputs. Each group of parameters initially contains default or dated values that must be replaced with relevant data. Parameter values are generally entered during initial scenario development or at the beginning of a growing season; however, certain irrigation values might be changed as the season progresses. All parameters can be changed prior to planting to investigate various “what-if” scenarios or can be modified, along with the appropriate weather data set, so that DIEM simulates previous crop years. Graphic and numerical outputs are revised following date changes or with updated numerical inputs followed by “Model Execution.” Irrigation schedules are printed by activating the “Export Report” button.

**Model Control Dates.** To provide boundary conditions for model execution, DIEM requires *Model Start* and *End* dates. This period can cover 365 days starting on January 1, however computational speed increases and uncorrected soil water estimates will be more precise by simulating the spring and summer crop growth period (rather than the full year). The *Model Focus* value is a date, between the model start and end dates, that sets a graphic marker in the Soil Water output chart; for user convenience, its default value is the current calendar date.

**Soil Profile.** The *Root Zone Depth* sets the depth of the soil profile as it relates to plant water availability for the crop considered in the active scenario. *Water Holding Capacity* is the plant available water holding capacity of the soil profile with default values based on soil texture. *Initial Soil Water and Date* provide an estimate of early season soil profile water content and is used to initiate soil water balance calculations. Initial estimates might be a best guess using the soil feel and appearance method (USDA-

NRCS, 1996) or measurements using soil moisture sensors or gravimetric methods. After model initialization, corrections to DIEM soil water can be made in the *Soil Water Editor* (discussed below).

**Planting.** Currently, cotton is the only *Crop* available for irrigation scheduling within DIEM. Irrigation scheduling for grain sorghum will be added soon with other crops added as appropriate crop functions are developed from local field evaluation and other relevant documented sources. *Planting* and *Emergence Dates* are used in the plant development functions that directly impact soil water calculations.

The image shows a screenshot of the DIEM Model parameter editor interface. The interface is organized into several sections, each with a title and a list of parameters. Callouts with arrows point to specific sections:

- Model Control Dates:** Includes Model Start (03/15), Model End (11/01(231 days)), Model Today (09/22), and Model Focus (09/22).
- Soil Profile:** Includes Root Zone Depth (ft) (3.5), Water Holding Capacity of Soil (in. H2O/ft. of soil) (1.8), Initial Soil Water Estimate Date (04/01), and Initial Soil Water in Soil Profile (in) (3.25).
- Planting:** Includes Crop (Cotton), Planting Date (05/15), and Emergence Date (05/24).
- Irrigation Inputs:** Includes Total Annual Irrigation Limit (in) (15.0), Irrigated Area (acres) (125.0), Available Flow Rate to Area (gpm) (238.0), Max Irrig delivery Rate (gpm/acre) (1.904), Max Irrigation Capacity (in/day) (0.1), Irrigation Per Application (in) (0.6), Desired Available Profile Water at Planting (in) (empty), Last Practical Day of Irrig. (09/20), Irrigation Type (LEPA), and Irrigation Iterative Computation (checked).
- Economic Inputs:** Includes Price Per Unit - High (\$/lb) and Price Per Unit - Low (\$/lb) (both empty).

At the bottom of the interface, there are two buttons: "Execute Model" and "Export Report". Callouts point to these buttons with the text "Execute Model for Updated Output" and "Print Irrigation Schedule" respectively.

Figure 4. Field and Crop Parameter editor component displayed in the DIEM dashboard.

Irrigation Inputs. The *Total Annual Irrigation Limit* is an irrigation volume restriction that can be set due to policy or user imposed limits. *Irrigated Area* and *Available Flow Rate* determine maximum irrigation delivery rate or irrigation capacity. Following confirmation of actual irrigation applications (*Irrigation Editor*, Figure 5), the *Available Flow Rate* can be adjusted during the growing season in response to seasonal flow rate reductions such as water table declines or flow rate additions as when irrigation capacity is added from a new water well. *Irrigation Depth per Application* is based on irrigation system type, applicator characteristics, and user experience. For center pivot irrigation, this value is generally the maximum irrigation depth that does not cause irrigation runoff issues; for SDI, soil texture and irrigation system management may affect this value. This parameter can be adjusted during the growing season. The *Desired Available Profile Water at Planting* value might be entered when simulating early season conditions where pre-plant irrigation is required to elevate soil profile water to reasonable levels for crop establishment. The *Last Practical Day of Irrigation* sets the calendar date for last DIEM simulated irrigation regardless of developmental state of the crop. This date not only ends scheduled irrigations, but can also affect unconfirmed irrigation distributions, the rate of target soil water decline in the profile at the end of the crop season, and total irrigation volume. The *Irrigation System Type* directly impacts soil surface evaporation during and immediately following an irrigation event, and therefore affects daily changes in estimated soil water content and ultimately simulated crop productivity. DIEM currently considers the soil surface to be wetted at 0, 40, and 100 percent when irrigations are with SDI, LEPA and spray systems, respectively. The *Irrigation Iterative Computation* option allows alternative irrigation distributions to be automatically considered, which may result in higher yield score and slightly increases computation time.

## **Irrigation, Rainfall and Soil Water Editors**

Irrigation Editor. Growing season irrigation applications are scheduled to achieve high yield and water productivity based on imposed water constraints. Irrigation amounts on specific days are displayed in calendar format in the irrigation editor screen (Figure 5). When actual irrigations differ from DIEM recommendations, corrections on appropriate dates can be entered and confirmed. As the growing season progresses, confirmation of actual irrigations up to the current date allows DIEM to reconfigure future irrigations for the remaining growing season, based on current data.

Rainfall Editor. Rainfall amounts from the selected weather station data sets are automatically downloaded and displayed in the rainfall editor. If necessary, this editor allows the correction of rainfall data with more accurate field measurements up to the current date. When simulating the current year, each time a scenario is activated, the rainfall editor is updated.

Soil Water Editor. The daily estimated available soil profile water content within the designated model period is displayed in the soil water editor. Daily values can be changed on any date to better reflect the actual soil water content in the field being simulated with values obtained through field observations or measurements.

## **Technical Help**

Directions to the DIEM User Guide and e-mail help desk are accessed through the “System / Help” button (Figure 1).

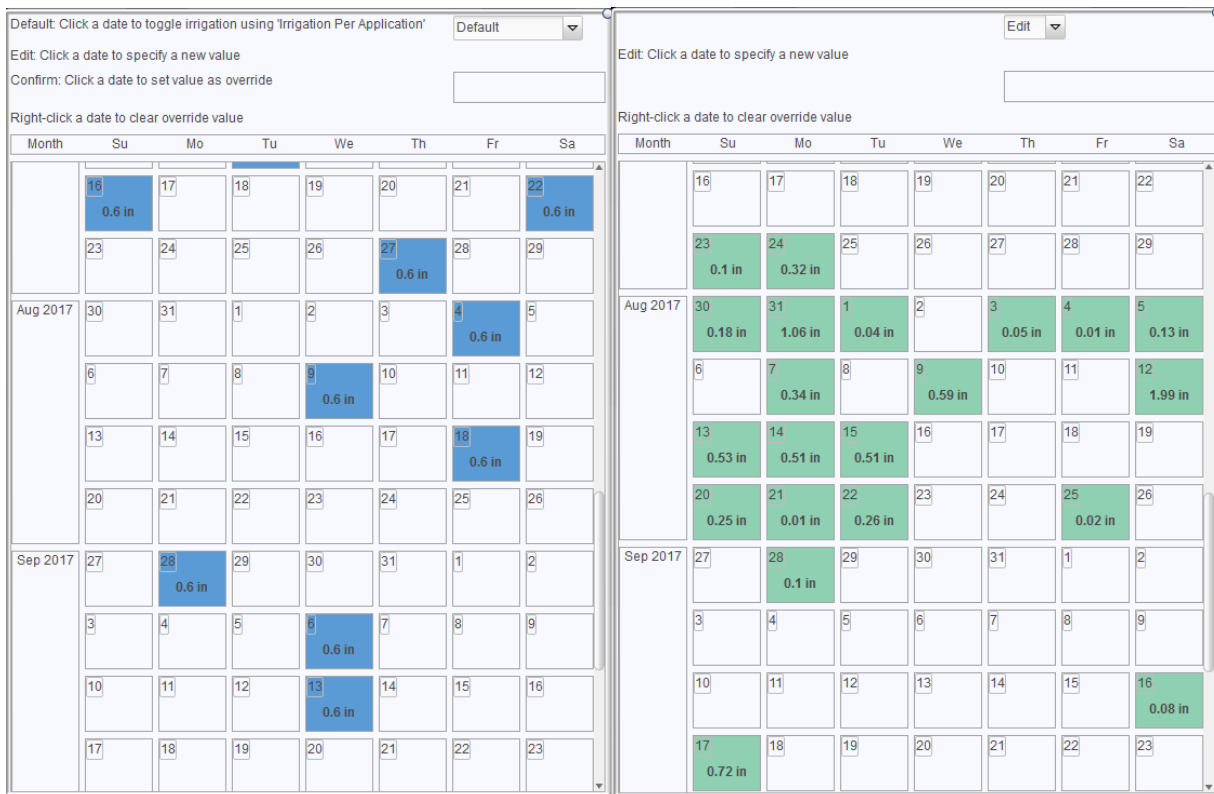


Figure 5. Irrigation (left) and Rainfall (right) Editors component displayed in the DIEM dashboard.

## Outputs

Among other outputs, the main DIEM dashboard provides an integrated soil water chart, a numeric score block, and an option to print a one-page irrigation summary. The soil water chart (Figure 6) displays daily data over the date range specified in the model start and end dates (x-axis). The y-axis ranges from zero to the maximum plant available soil water in the root zone for the active scenario. The *Target Soil Water* is a dynamic, crop-specific, soil profile (root zone) water content above which irrigations are not recommended. This target is a function of the crop emergence date, heat unit accumulation, soil water holding capacity, and local empirical data. For cotton, a planned decline of soil water after peak bloom reduces the possibility of late-season excess vegetative growth, promotes maturity of existing cotton bolls, and allows plants to consume remaining stored soil water (Bordovsky and Lyle, 1996). Daily *Estimated Soil Water* is determined from weather station or field rainfall measurements, irrigation quantities, and crop ET ( $ET_c$ ).  $ET_c$  is derived from weather station data and experimentally derived dual crop coefficients. As estimated soil water declines below crop stress levels, transpiration is reduced. This stress level is determined daily and is shown in the soil water chart, *Limiting Transpiration*. The adjusted  $ET_c$  ( $ET_{cadj}$ ) is determined by multiplying  $ET_c$  by a dimensionless transpiration reduction factor ( $K_s$ ) that is a function of a crop depletion factor ( $p$ ) according to Allen, et al. (1998). *Irrigation* and effective *Rainfall* are also charted. Any change in a parameter value, an amount in any of the three editors, or weather station input results in a revised soil water chart. *Yield* and *Water Use Efficiency Scores* for the active scenario are updated. Yield scores are derived from functions that relate to the availability of soil water through the growing season and to crop water stress, and the irrigation productivity score is the result of dividing the yield score by the estimated seasonal irrigation.



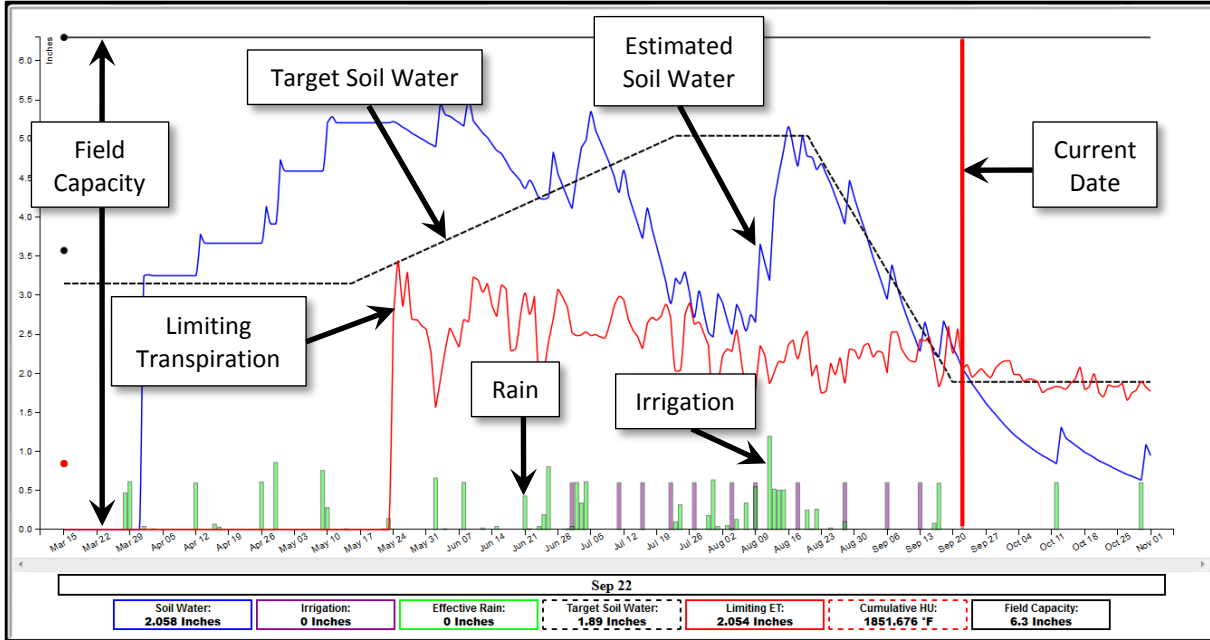


Figure 6. DIEM Soil Water Chart showing estimates of past and future soil water relationships and recommended irrigations based on water availability, irrigation system type, soil characteristics, and crop water needs.

At any point during a growing season, a printed irrigation schedule (Figure 7) can be obtained by executing the “Export Report” button in the Parameters panel (Figure 4). The report provides basic information concerning the field and scenario as well as weekly rainfall, crop ET and irrigation amounts up to the current week and recommendations or estimates thereafter.

## Conclusions

The Dashboard for Irrigation Efficiency Management (DIEM) was developed to support irrigation decisions in the short season, semi-arid environment of the Texas High Plains where the irrigation capacity of the Ogallala Aquifer is rapidly decreasing and cotton is the predominant row crop. DIEM is a web-based software solution for forecasting optimized field-specific irrigation schedules base on water availability. This is accomplished using minimal inputs by configuring basic historic, near real-time, and future agronomic information including weather, soil and crop characteristics, and irrigation parameters into an interactive data visualization for portraying key aspects supporting irrigation decisions. Upcoming plans include accommodating other crops or crop types, adding complementary soil and/or plant based data streams to the DIEM output, and the deployment of a mobile friendly DIEM application.

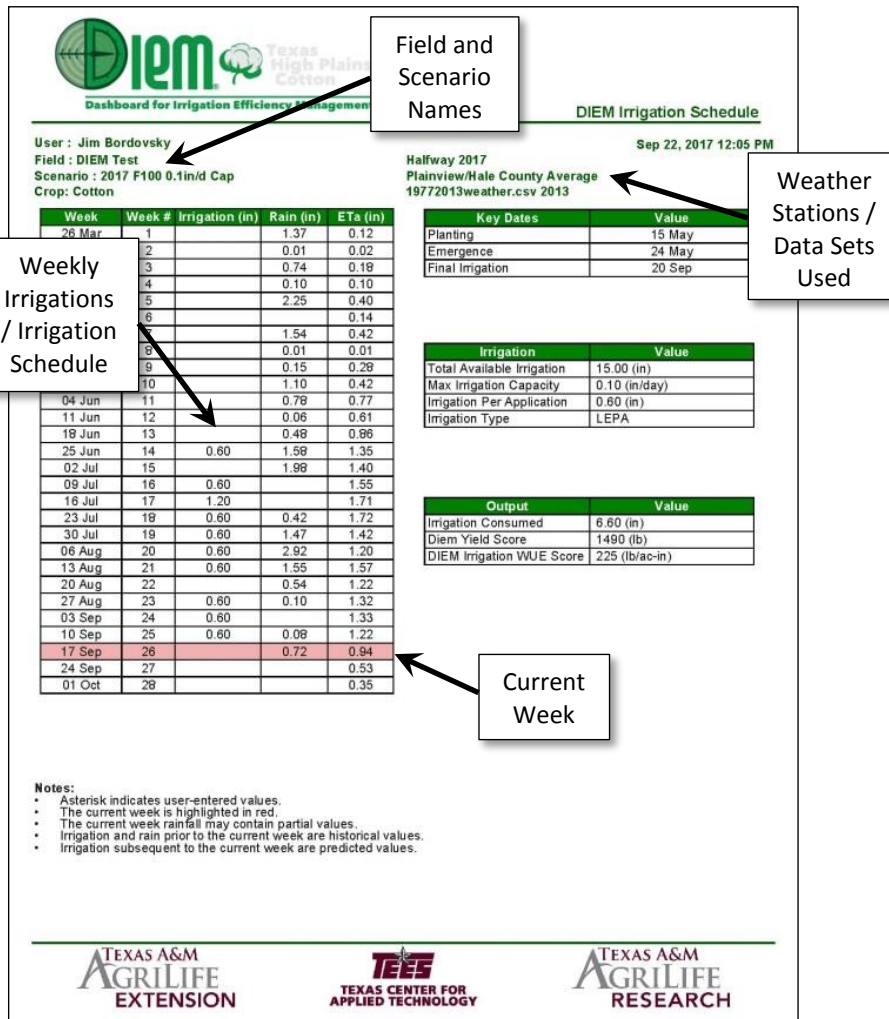


Figure 7. Exported DIEM report providing historic, recommended, or predicted values based on the most recent available data.

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