REAL TIME WATER DELIVERY MANAGEMENT AND PLANNING IN IRRIGATION AND DRAINAGE NETWORKS

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ABSTRACT

This paper focuses on delivery and demand management in irrigation and drainage networks as the largest water resource consumer. A model is developed for water demand management in irrigation networks. The model is capable of predicting actual water requirements in every field blocks and produces water delivery schedule for all network elements. In this model, planning water delivery schedule in irrigation network is accomplished by considering three important factors including crops irrigation calendars, water distribution method, and canals hydraulic conditions and performance. The model incorporates CANAL ROTATION & SEMI DEMAND method for water distribution in canals. Due to sizable quantity and spatial and temporal variations of required data and the necessity for updating the results in real time operation, all the required data are classified, stored and managed in a database system. The developed model is also capable of planning water delivery in canals upon sound simplifications of irrigation planning regarding proper water distribution criteria. In dry periods, the developed model compares actual required water with available water resources and modifies quantity and/or delivery time considering amount of available water. The model is incorporated in planning water delivery management system for RMC lot (4500 ha) in Irrigation and drainage Scheme (Aji-Chai) located in Tabriz plain, East Azerbaijan, Northwest of Iran.

INTRODUCTION

Nowadays, in most of developing countries the need for more productions together with scarcity of available water resources jeopardizes sustainable development in agricultural sector making it be facing with several numerous challenges. Due to lack of an accurate and proper management system in this sector, optimum usage of limited available water resources isn't achievable. The recent drought and decrease of rainfall and also over consumption have resulted in reduce available water resources. Irrigation and drainage systems are the greatest water consumer in the basins. Therefore, incorporation of optimum water use methods in these systems is essential. This would be achieved through revising the water resources allocations and incorporation of accurate delivery and demand management. In this paper, planning water delivery schedule in irrigation networks is investigated through considering three important factors: Crops irrigation calendar, water distribution method, and hydraulic conditions and performance of distribution canal. Results of these investigations have resulted in development of scheme-wise water delivery schedule model. The model determines the required amount and time of water delivery

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to each farm plot for each irrigation turn. The model also compares scheme water requirement with available water resources and specifies the time & amount of water shortages during a cropping year. A case study has been conducted in Aji-Chai irrigation and drainage scheme located in Tabriz plain, in northwest of Iran to produce the water delivery schedule is RMC lot measuring 4500 ha.

METHODOLOGY

Water Delivery Management in Irrigation Networks

Water delivery management is conducted in irrigation schemes to supply farming plots water requirements based on proper water distribution criteria and methods to achieve a balance between deliveries and demands in the whole scheme. The main objective of in-scheme delivery management is timely distribution of adequate water to meet crop water requirements are more closer the gap between available water and actual requirements. Recognition of water resources and their potential yields as well as understanding the consumptions and demands are of high importance in irrigation scheduling & water distribution in irrigation networks. The irrigation management requires data on soils, climate, irrigation and drainage, canals layout, crops, land tenures, land uses and etc. Outputs of management activities include wide varieties of issues regarding water delivery & distribution existing drainage management, repair and maintenance requirement & planning and etc.

The data of each irrigation and drainage network must be carefully collected, packed and entered the system since they constitute the basis of all required calculations. The data are categorized in four classes as follows:

a) Irrigation Network Layout and Specifications: All specifications and properties of different parts of a network including available water resources, main canal, secondary & tertiary canals, intake gates, area downstream of each intake and etc.
b) Cropping Pattern Water Requirement: including reference crop ET, Gross and net irrigation requirements.
c) Irrigation Planning: in most of irrigation networks, the areas under cultivation of different crops and amount of available water resources are managed carefully. Also, climatically condition and market needs role over the areas under cultivation. Therefore, the planning would be different in different years.
d) Water distribution schedule: operation of a water distribution network varies considerably due to changes in management factors, climatic conditions, water quantity and quality, conveyance and distribution structures and distribution methods. There are several different methods for water distribution scheduling, which are selected & applied based on available water resources and demands volume and time. In current study, Semi Demand & Canal Rotational method is selected as the proper water delivery & distribution scheduling method regarding the domination conditions in the case study area. In this method, the demands are announced by farmers to network manager. The network manager, then, announces the time, discharge and volume of deliveries to farms after modifying the demands based on actual water resources and network capacity. In this system, rotation is incorporated in both tertiary & secondary canals. Rotation method

varies along irrigation seasons and region by regain. Rotation duration is based on calculations and experimental knowledge of each region. The delivery discharges must match the intakes gates capacity. One of the advantages of this method is its applicability and practicability during high demands or during droughts periods. In cases where actual available water resources are less then actual water requirements, following policies would be incorporated:

- Cultivation of low demand and early mature crops
- Local return flow reuse
- Reduction of irrigation requirements through deficient irrigation and exclusion of crops with high water consumption
- Irrigation efficiency improvement through farmers training and undertake proper irrigation management.
- Balancing water shortage in network by adapting water allocation from each water resource. In other words, incorporation uses of surface & groundwater resources.

MODEL STRUCTURE

Irrigation Network Water Delivery Management Model consists of three different interrelated parts including database data entry & storage, water delivery scheduling and demand modification.

Database Data Entry & Storage

All required information and parameters are entered into the database in the form of fixed and variable parameters. The parameters include three groups of information:

- Data on available water resources including surface & groundwater resources in different months. Dialogue from of these data is shown in figure 1.

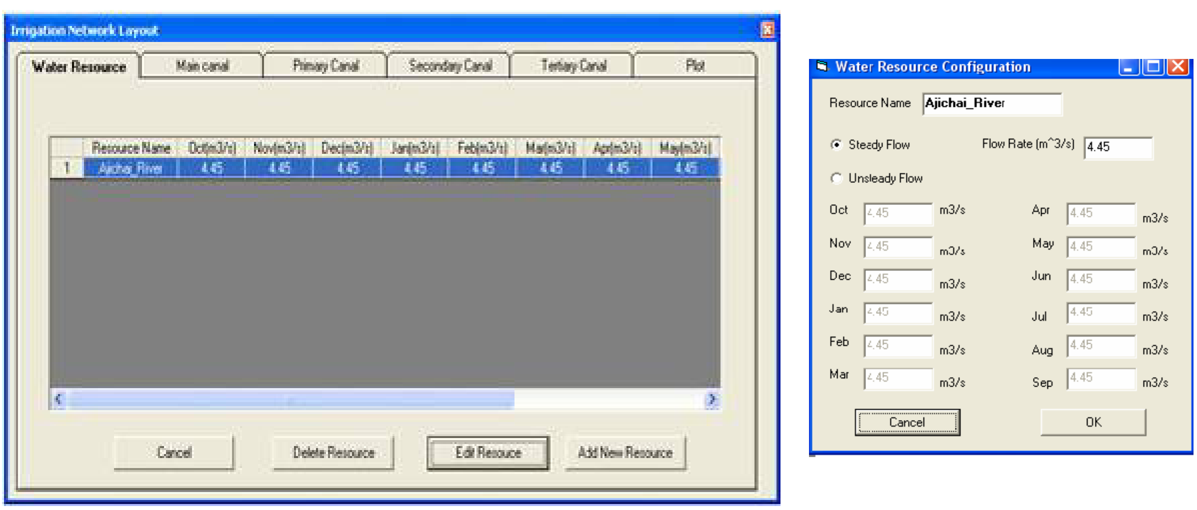


Figure1. Dialogue from of Water Resource Data

- Data on network layout, hydraulic characteristics of network parts, defined from upstream towards downstream as fixed parameters. Dialogue from of these data for tertiary canals definition with theirs hydraulic characteristics is shown in figure 2.

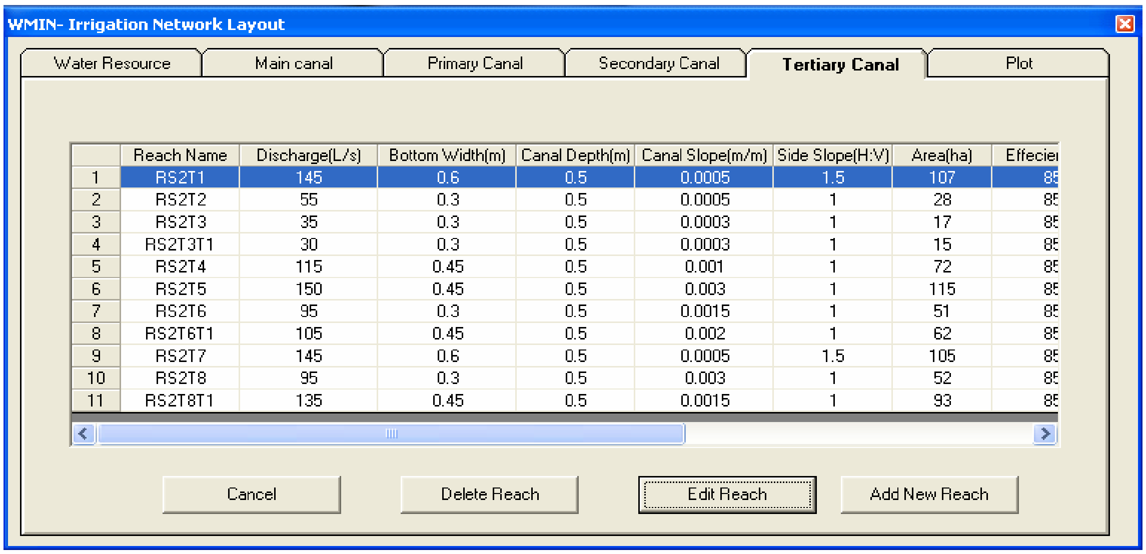


Figure2. Tertiary Canals Definition with Their Hydraulic Characteristics

- Data on cropping pattern and scheme water requirements. These data include cropping pattern, farming lots (area and crops cultivated in each lot), gross water requirements of all crops in cropping pattern, efficiencies, irrigation calendar and irrigation turns. Dialogue from of these data is shown in figure 3.

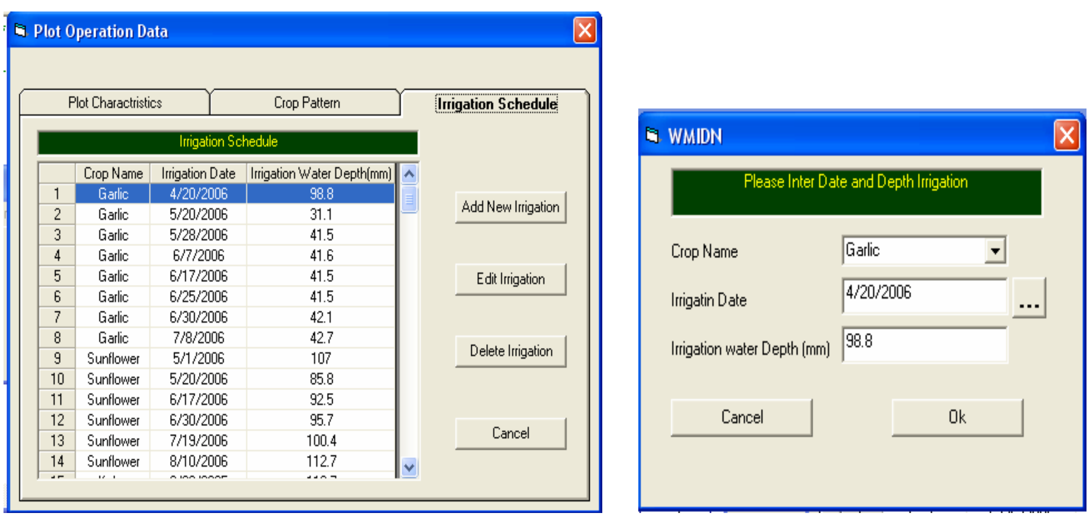


Figure 3. Irrigation Calendar of Crops in Cropping Pattern

In case of a highly variable cropping pattern, making use of irrigation schedule is either impossible or very difficult. In months with maximum requirement, often from June to august, all intakes must be operation on more than %70 of all days; this is impossible due to limitation in canals and structures design and water resources constraints. To resolve the problem same modifications and simplifications should be made on irrigation calendar. FAO has presented some levels of simplifications. To incorporate the methods one must consider actual cropping pattern to specify to what extent the designed cropping pattern is adhered to. In current study, irrigation calendar modification has been performed based on crop type, cropping calendar, crop susceptibility to water shortage in different development stages, yield reduction coefficient and etc.

Water Delivery Scheduling

Upon entry of all required data the model performs the calculations to determine irrigation intervals, the gate opening schedule and other needed parameters. To do so, the required volume of water at each farming plot is calculated based on and time and depth of irrigation for each crop cropping pattern. Considering hydraulic properties of intake all discharges passing through intake gates are calculated and, hence after, the gates opening time and delivered volume of water is determined. Number of gates that can be functioning at a same time may be determined based on tertiary canals hydraulic properties and water rotation program among the gates. The number of opened gates should be such that their total discharge does not exceed the canal discharge and the constraints on minimum velocity and Froude number are observed and fulfilled. Henceforth, the minimum and maximum number of tertiary intakes that can be functioning in each irrigation turn is specified. In this regard, to have a better management on water distribution among canals, their intakes are operated from downstream to upstream. These calculations are preformed in entire network for a cropping season and all irrigation turns resulting in determination of required water to be supplied and delivered to the scheme.

Water Demand Modification

To make the available water resource sufficient modification of water demands is considered. The model modifies the water demand based on available water resources. During pick demands or drought periods water demands do not correspond to available water resources. In such cases the model informs user on amount of deficiency and the difference between available and required water. Therefore the user can reduce the water demands to available water resources by incorporating different methodologies such as deficit irrigation, reduction of area under cultivation of high demand crops and etc.

Model Outputs

Main model outputs include irrigation parameters for farming plots separately farming units consumed water daring specified periods, gates opening and closing times, canal discharges and different water resources withdrawals. The model can also produce data required for crisis management such as delivery and demand management in low flow seasons or cropping pattern control. The model produces all required data in table formats.

Flowchart of calculation procedure is shown in Figure 4.

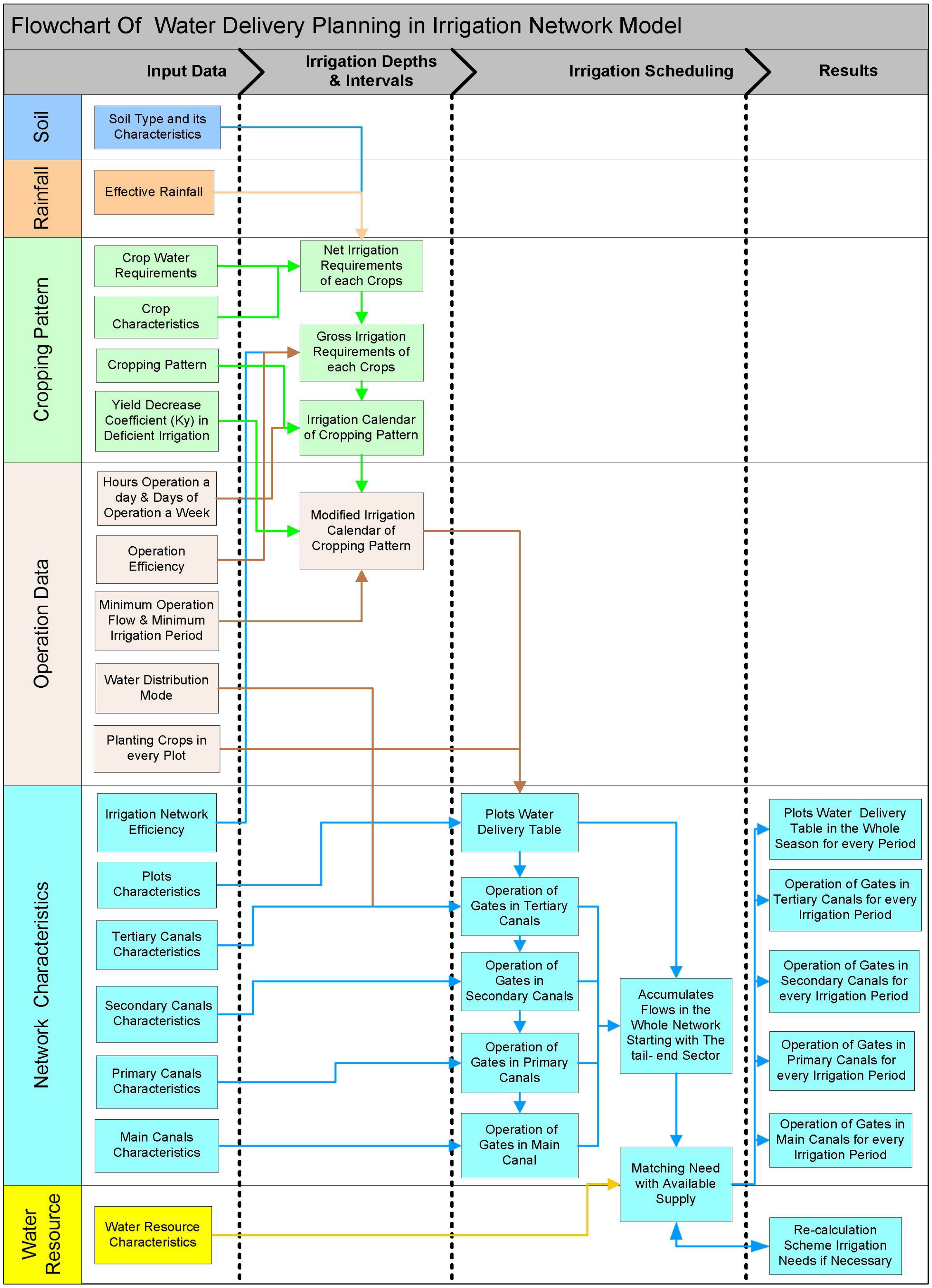


Figure 4. Flowchart of Water Delivery Planning for Irrigation Scheme

CASE STUDY

A part of Tabriz Plain Irrigation Scheme is used to test the model capabilities. The scheme is located on left bank of SENIKH CHAI with a gross area of 25000 ha subdivided into LMC, AMC and RMC lots. In current study, the model is applied on RMC lot measuring 5000 ha gross. The plan of studied irrigation network is shown in figure (5).

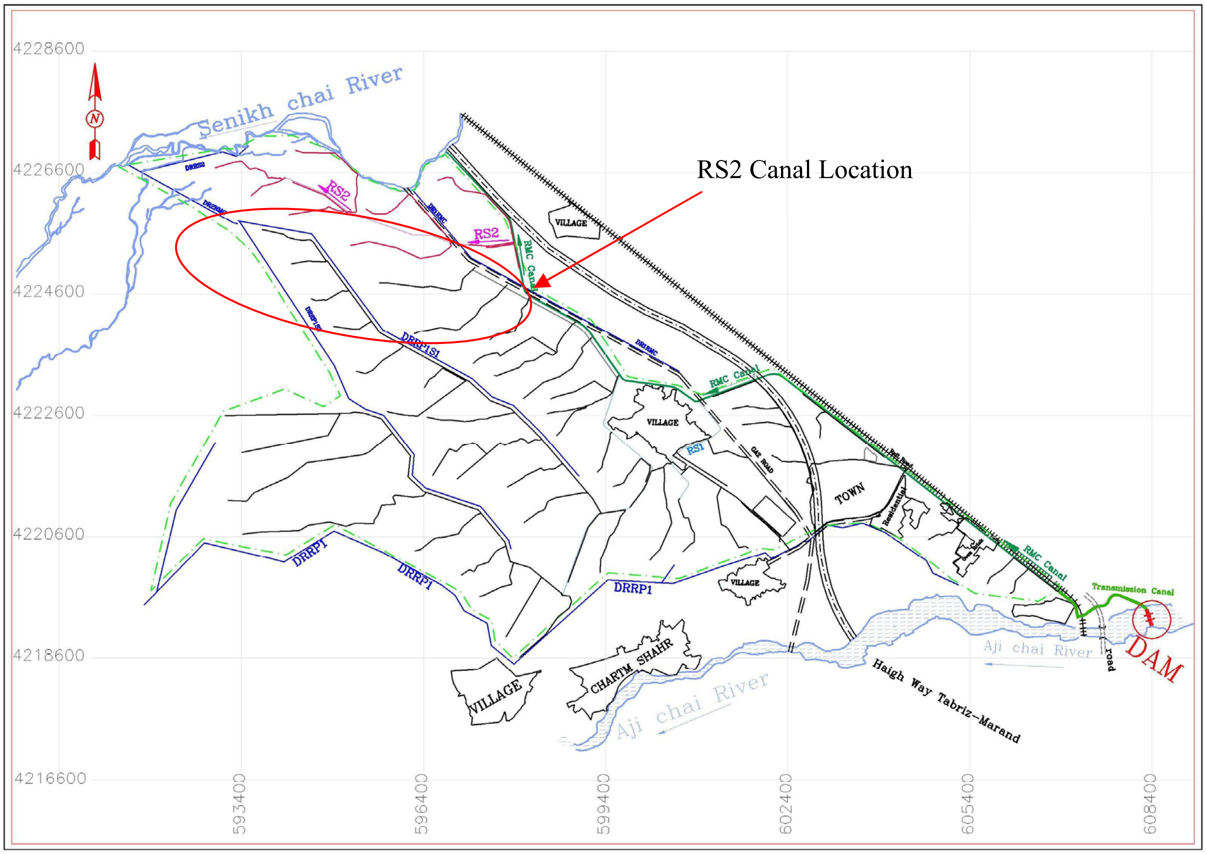


Figure 5. Plan of RMC Lot of Tabriz Plain Irrigation Network.

All of physical and hydraulic characteristics of irrigation network components such as cropping pattern, irrigation calendar, area of crops in each farming lot and the characteristics of all canals are stored in a data bank. The model always has access to the data bank. The model retrieves the data from the data bank and stores the results of all calculations in related tables in the data bank.

Adjustment Tabriz Plain Irrigation Calendar

Because of diversity in crops included in cropping pattern (17 crops) in Tabriz plain irrigation scheme and irregular irrigation dates during the cropping season, especially in high demanding months, using this irrigation calendar in this irrigation scheme is not possible. As an assumption considering cropping pattern in each farm and using this irrigation calendar will result in 18 days of operating canals and intake gates in July. On the other hand, respecting tertiary canals capacity and the allowable flow velocity in the farm canal, in some days of peak demanding months, the gate of intake must be kept open more than 24 hours. This will result in overlapping of irrigating turns and periods. During irrigation period with low water requirement the problem of flow velocity Re-reduction and sedimentation in canals arises. Therefore, the irrigation calendar has been modified and adjusted based on crops susceptibility to water deficit during its different growth stages (referenced to FAO publication no.33). To do so, the objective was to achieve minimum yield reduction due to changes in irrigation dates considering the most susceptible crop growth stage (table1). In this process, the constraints observed included canal hydraulic specifications, minimum and maximum allowable gates discharges and a maximum 24 hours opening time for each gate during each irrigation turn. The irrigation calendars for June and July, before and after modifications and adjustments, are presented in table 2 and 3, respectively.

Table 1. Yield Reduction Coefficients in Tabriz Plain Cropping Pattern at Difference Growth Stages

NO.	CROP_NAME	Initial	Development	Mid	Late	Total
1	Garlic	0.4	1.1	0.8	0.4	1.05
2	Sunflower	0.4	0.6	0.8	0.8	0.95
3	Kolza	0.2	0.8	1	0.3	0.85
4	Cumin	0.2	0.8	1	0.3	0.85
5	Onion	0.45	0.6	0.8	0.3	1.1
6	Orchards	0.4	0.6	0.8	0.8	0.8
7	Grape	0.2	0.7	0.85	0.4	0.85
8	Cow-Pea	0.2	0.7	0.85	0.4	0.85
9	Wheat	0.2	0.6	0.5	0.4	0.6
10	Pea	0.2	0.7	0.85	0.4	0.85
11	Alfalfa	1	1	1	1	1
12	Potato	0.45	0.8	0.8	0.3	1.1
13	Barley	0.2	0.6	0.5	0.4	1
14	Safflower	0.3	0.55	0.6	0.2	0.8
15	Sorghum	0.2	0.55	0.45	0.2	0.9
16	Sugerbeet	0.5	0.8	1.2	1	1
17	Vegetables	0.8	0.4	1.2	1	1

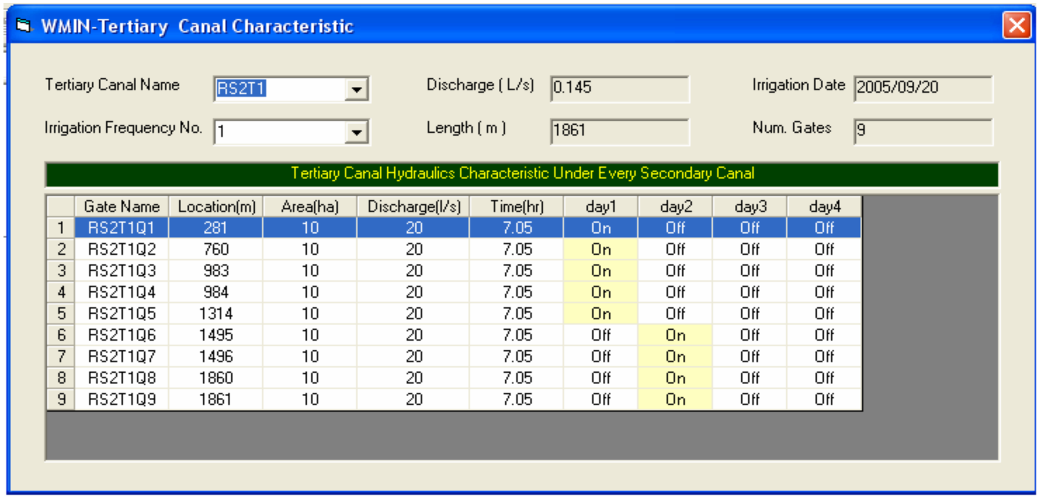
Table 2. Cropping Pattern Irrigation Calendar Base on Calculated Water Requirement in Peak Months (mm) (Before Adjustment)

No	Crop Name	June																	July																	
		1	2	5	7	8	9	10	13	16	17	20	21	22	25	26	29	30	1	3	8	10	11	13	15	16	17	19	20	22	23	24	27	28	30	31
1	Garlic				42						42					42				42			43													
2	Sunflower									93								96											100							
3	Kolza											67																								
4	Cumin											56																								
5	Onion					37					37				37				37		38				40					41				35		
6	Orchards	80															82															85				
7	Grape	65																	80																	82
8	Cow-Pea	28																31			39					44					42				45	
9	Wheat		72											83																						
10	Pea			58									60						61				59													
11	Alfalfa				71													84									85									
12	Potato						32						38					44			42					44						45				
13	Barley							91																												
14	Safflower								91																											
15	Sorghum																125											123								
16	Sugerbeet									66								81						85									89			
17	Vegetables										29							37			45	40						45					45			

Table 3. Adjustment Irrigation Calendar of Tabriz Plain in Peak Months (mm)

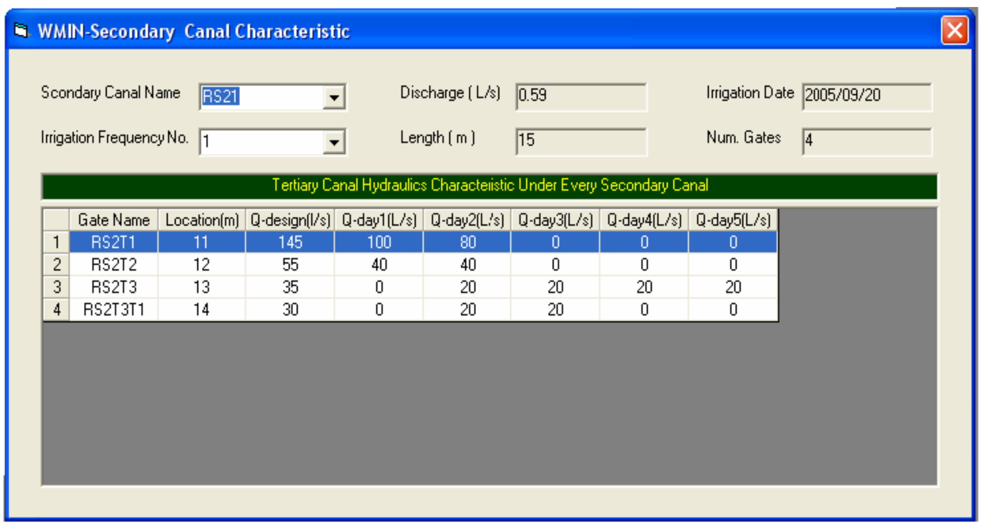
No	Crop Name	June								July						
		1	5	9	13	17	21	25	30	7	12	16	20	23	27	31
1	Garlic		42			42		42	42		43					
2	Sunflower					93			96				100			
3	Kolza						67									
4	Cumin						56									
5	Onion	36		37		37		37	37	38		40		41	35	
6	Orchards	80							82					85		
7	Grape	65							80							82
8	Cow-Pea	28							31	39		44		42		45
9	Wheat	72					83									
10	Pea		58				60		61		59					
11	Alfalfa		71						84			85				
12	Potato			32			38		44	42		44		45		45
13	Barley			91												
14	Safflower				91											
15	Sorghum							125					123			
16	Sugerbeet					66			81		85				89	
17	Vegetables					29			37	40			45		45	

The samples of irrigation schedule in RS2 canal located in Tabriz Plain RMC lot are shown in figures 6and 7.



	Gate Name	Location(m)	Area(ha)	Discharge(l/s)	Time(hr)	day1	day2	day3	day4
1	RS2T1Q1	281	10	20	7.05	On	Off	Off	Off
2	RS2T1Q2	760	10	20	7.05	On	Off	Off	Off
3	RS2T1Q3	983	10	20	7.05	On	Off	Off	Off
4	RS2T1Q4	984	10	20	7.05	On	Off	Off	Off
5	RS2T1Q5	1314	10	20	7.05	On	Off	Off	Off
6	RS2T1Q6	1495	10	20	7.05	Off	On	Off	Off
7	RS2T1Q7	1496	10	20	7.05	Off	On	Off	Off
8	RS2T1Q8	1860	10	20	7.05	Off	On	Off	Off
9	RS2T1Q9	1861	10	20	7.05	Off	On	Off	Off

Figure 6. The Gate Opening Schedule Table in RS2T1 Tertiary Canal in the First Irrigation Turn



	Gate Name	Location(m)	Q-design(l/s)	Q-day1(L/s)	Q-day2(L/s)	Q-day3(L/s)	Q-day4(L/s)	Q-day5(L/s)
1	RS2T1	11	145	100	80	0	0	0
2	RS2T2	12	55	40	40	0	0	0
3	RS2T3	13	35	0	20	20	20	20
4	RS2T3T1	14	30	0	20	20	0	0

Figure 7. Water Delivery Table to Tertiary Canals of RS21 Canal in the First Irrigation Turn

CONCLUSIONS

Real time management of irrigation and drainage scheme are not possible except using computer models. As shown, the developed model is capable to provide the irrigation calendar based on cropping pattern, characteristics of irrigation network and accessible water resources. In other words, the water distribution program for the next year upon selling of water to farmers in the beginning of the cropping year, respecting to type and area under cultivation of crops, and considering the accessible water resources will be setup. This program contains the duration, discharge and volume of deliverable water to each farming lot.

Water delivery program to tertiary canals including discharge, time, hydraulic properties, and intake gates opening-closing order based on their capacity is developed based on program of water delivery to farming lots. Water delivery programs for all upstream canals including secondary, primary and main canals are developed as well. Therefore the scheme water requirement is determined for each irrigation turn. Upon comparing the requirement and allocated water, deficit or surplus of resources is determined. In case of water deficit, the scheme manager can modify the demand-delivery relationship by taking appropriate measures. These measures include adjustment of cropping pattern and reducing area under cultivation of high demand crops, incorporating deficit irrigation, reduction of total area under cultivation, and incorporation of water reuse techniques.

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