MODELING WATER ALLOCATION BETWEEN WETLAND AND IRRIGATED AGRICULTURE: CASE STUDY OF THE JARRAHI BASIN, IRAN

S.SIMA
Department of civil engineering, Sharif University of Technology, Iran, Tehran, Azadi Ave; ph (+98 (21) 66164185); email:sima@mehr.sharif.edu

M.TAJRISHY
Department of civil engineering Sharif University of Technology, P.O. Box 11365-9313; Iran, Tehran, Azadi; ph (+98 (21)6 6164182); email:tajrishy@sharif.edu

The Shadegan Wetland is a Ramsar-listed wetland in the south-west of Iran at the head of the Persian Gulf. It is the largest wetland of Iran covering about 400,000 hectares. It supports a very diverse flora and fauna and is the most important site in the world for Marbled Teal. The water regime is threatened by upstream abstraction of water for irrigation and the saline discharge from sugar cane industries and irrigation schemes. This results in an overall reduction in wetland water quantity and quality, leading to a change in plant community composition. In this paper different scenarios were evaluated to fulfill determined water requirements. In order to quantify wetland functions, the wetland health index, which consists of water quantity and quality, was defined. Results showed in the current state, wetland inflow is much less than minimum determined environmental water requirements (level 1) that lead to the 100% failure in the wetland. According to the results, although returning to the predevelopment condition is not possible, causing some changes in the reservoir operation and diverting sugar cane discharge makes it possible to meet wetland requirements up to level 2 (minimum requirements of vegetation).

INTRODUCTION

Wetlands functions, values and attributes can only be maintained if the ecological processes of wetlands are allowed to continue functioning. A key requirement for wetland conservation and wise use is to insure that adequate water of right quality is allocated to wetlands at the right time. Environmental water allocation for wetlands associated with river systems has frequently been incorporated into the flow allocation process for the river system [2]**.** According to the Ramsar Convention handbook, national policy to support the allocation of water, especially to protect and maintain wetland ecosystems, is relatively new in most countries where it has been implemented [5].

In this paper we look at the ability of a basin to fulfill determined water requirements of a wetland and the effect of this requirement on irrigated agricultures.

STUDY AREA

The study Area includes the Jarrahi Basin in southwest of Iran. It covers 24310 Km^2. This part of Iran is characterized by a Mediterranean climate consisting of hot and dry summers and mild and rainy winters. Jarrahi River, the main river in the basin, consists of Maroon & Allah Rivers. The river network consists of two large reservoirs (Maroon and Jarreh) mainly used for irrigation (see Figure 1).Water extraction by Jarreh Dam for its down stream plains results in a significant reduction in the quantity and quality of water reaching Jarrahi River. On the other hand there are also some irrigation schemes along Jarrahi River which are dependent on the Maroon dam releases. Table 1 summarizes the main characteristics of Maroon dam. Shadegan Marshes are located on the lower Jarrahi River, at the head of the Persian Gulf. It is the largest wetland of Iran covering about 4000 Km^2. The marshes are a Ramsar site wetland and are of considerable importance for water birds specially Marbled Teal. The wetland freshwater has been supplied by the Jarrahi River (90%) and Karun River (10%). Main threats to the habitats and ecological communities of wetlands in the basin include inadequate flooding regimes and increasing salinity as a result of irrigation return flows. A schematic overview of the river, irrigation plains and wetland were shown in Figure2.

Table 1. Characteristics of the Maroon Dam

Reservoir volume(MCM)	1200
Annual supply(MCM)	1556
Normal operation level (m)	505
Minimum operation level (m)	440
Regulated volume(MCM)	723
Dead storage(MCM)	121

ENVIRONMENTAL WATER REQUIREMENTS OF SHADEGAN MARSHES

In the determination of a suitable water regime for Shadegan Marshes, a holistic methodology was applied. An outline of the step-by-step frame work used to determine environmental water allocations to this area is given below.

1. Identification of wetland main habitats for Biota
2. Characterize the wetland hydrological regime
3. Monitoring vegetation cover changes
4. Identifying relationships between biota and water regime:
    - relationship between vegetation and water regime
    - relationship between the abundance of Marbled Teal and water regime
5. Wetland water quality simulation
6. Determining the desired water regime to fulfill management objectives
7. Setting a performance indicator

Using remote sensing (RS) data the water regime requirements of vegetation were first examined with an objective of maintaining the existing distributions. With regards to the mentioned analysis the three levels of supply for Environmental Water Requirements (EWR) of Shadegan Marshes were determined as follows:

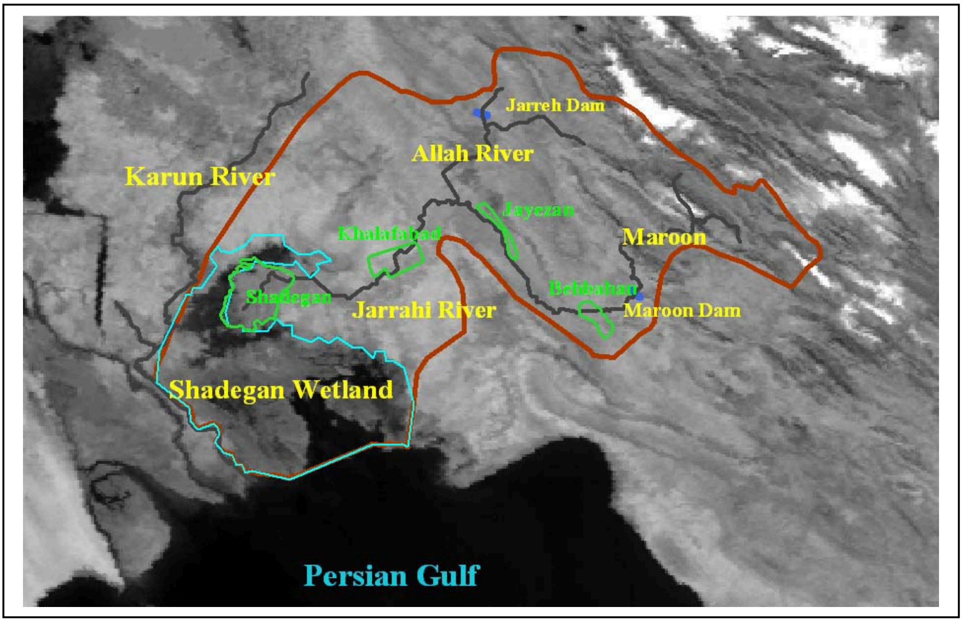

Figure 1. Study Area

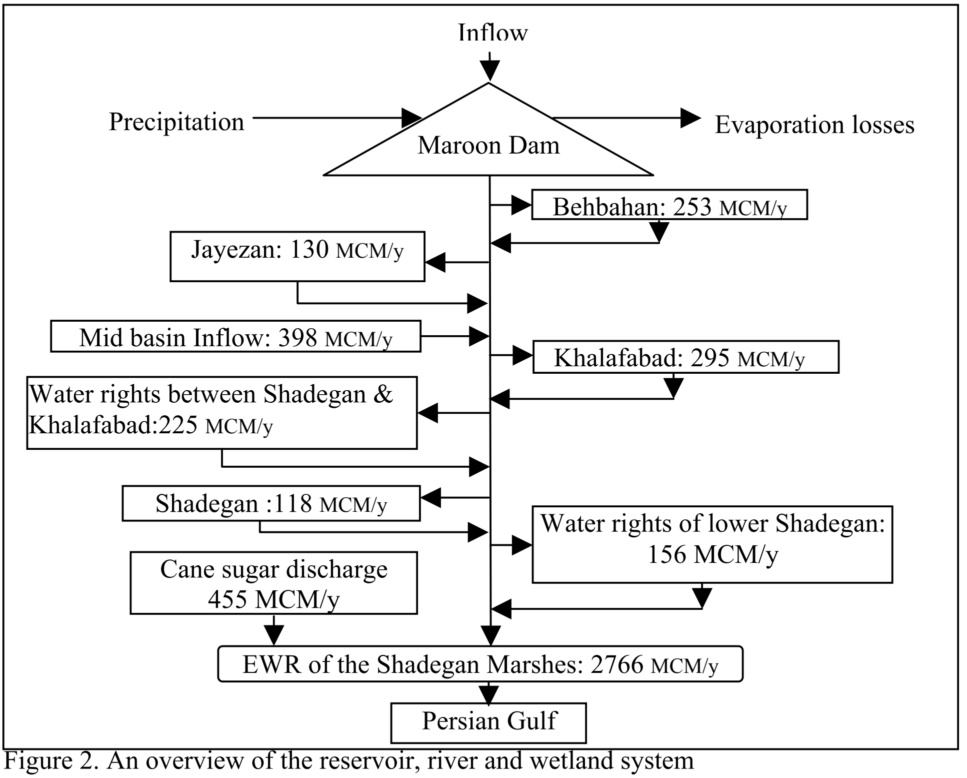

Figure 2. An overview of the reservoir, river and wetland system

Level 1: Minimum requirements of hydrological regime
Level 2: Minimum requirements of vegetation cover
Level 3: Minimum requirements of vegetation, Marbled Teal and suitable inundation
Table 2 gives the water surface and volume of the wetland in each level of the supply.

Table 2. Environmental Water Requirements (EWR) of Shadegan Marshes

EWR Supply Level	Pr	Parameter	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Mean Annual Volume (MCM)
Level 1	90	Water Volume	14	48	84	144	229	233	275	227	144	82	32	0	1513
		Water Surface	75	307	393	534	687	692	753	658	601	187	211	131	
Level 2	80	Water Volume	30	66	127	198	273	286	317	268	186	103	47	16	1917
		Water Surface	159	340	466	615	748	764	810	721	655	290	244	167	
Level 3	60	Water Volume	69	112	212	306	360	392	401	350	269	155	83	57	2766
		Water Surface	329	419	611	777	870	909	926	845	763	498	324	256	

According to these data, increasing supply from level 1 to 3 (a hydrological regime with the probability of exceedance equal from 90 to 60 percent respectively), it is possible to meet both hydrological and ecological values. Thus the best hydrological regime that can meet minimum requirements of vegetation cover, Marbled Teal and suitable inundation was set at the probability exceedance of 60% (2766 MCM/year) [6].

WETLAND HEALTH INDEX (WHI)

In order to monitor both the water quantity and quality of the wetland and set the amount of diversion from the desired condition, a non dimensional index called Wetland Health Index was defined. Equations 1 to 3 show its formulation.

$$WHI = (1 - \frac{V_{sh}}{V_d}) \times (1 - \frac{C_r}{C_d}) \tag{1}$$

$$C_r = \frac{1}{2}\left((C - C_d) + \left|C - C_d\right|\right) \tag{2}$$

$$V_{sh} = \frac{1}{2}\left((V_d - V) + \left|V_d - V\right|\right) \tag{3}$$

Where,
C, C_r are the wetland monthly and residual salt concentration in mg/L, respectively.
V, V_{sh} are the wetland monthly water volume and shortage in MCM,
V_d, C_d are the desired volume and salt concentration of wetland in MCM and mg/L.

As mentioned before, desired water volume of the wetland was determined using RS data and the wetland surface-volume relationship. As the study region of the wetland is a freshwater ecosystem, it seems logical to take the salt concentration as a quality criterion and define its optimum concentration with regards to ecological values. There are different thresholds cited in literature, but most of them suggest a threshold level of 1500 mg/L for the fresh water biota. For many non-halophobic biota, lethal and sub lethal effects would be manifest at increasing this level [1,4]. With regards to monthly fluctuation in salt concentrations of the wetland, its desired monthly TDS concentrations were set as given in Table 6.The upper limit of the index is 1, which indicates extremely desired conditions. If the index is positive and lower than 1, this is a situation where water shortage dominated. When salinity concentration exceeds critical values (double the desired concentration) it shows a negative value.

Table 3. Wetland desired concentration of salinity (mg/L)

Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept
3500	3500	3500	1500	1500	1500	1500	1500	1500	3500	3500	3500

SYSTEM SIMULATION

To study the effects of water diversions on the Shadegan Marshes, a model based on water and salt balances was developed. The river and wetland system was simulated in flowing states: pre and post development. In the former, the quantity and quality of the wetland inflow data were gathered from hydrological stations while, in the latter, these data were calculated through the basin simulation from the reservoir to the wetland entity. The Shadegan Marshes were assumed to be a well-mixed reservoir despite the fact that, salt will accumulate more in some locations than in others depending on water depth. Although a homogeneous distribution of water and salt inflow is a simplification of reality, this will not change the water requirement to any significant extent.

System simulation in predevelopment state

Predevelopment simulation addresses wetland water quantity and quality in the 15 years before dam construction and irrigation schemes. The main objective of this simulation is to find the amount of failure that the wetland has experienced in the past. Given the quantity and quality of wetland inflow and evaporation data from local hydrological stations, and remotely sensed monthly water surface data with mass balance equation, wetland monthly salinity concentrations were calculated for each month of the study years. Results showed that in 27% of the months wetland is in desired conditions, whereas 38% of the time critical conditions (WHI<0) occur. In the July of 2001 saline discharge from sugar cane industries entered the wetland and since then this continues. This leads to the negative values of WHI during 2001-2002 that increase the number of failure from 50 to 65 months (Table4).

Table 4. Results of the system simulation in predevelopment state

	Without considering sugar cane	After sugar cane discharge
Failure number (month)	50	65
Failure percent	33	38

System simulation after implementing development schemes

To simulate a system after implementing the development schemes by developing a reservoir simulation model, reservoir monthly release during the study years were calculated. We assumed the return flow from main plains equal to 30% of the irrigation water and its salinity concentration 2 times that [3].Then, considering water and salt budget along the river, the quality and quantity of wetland inflow were calculated; and its monthly water volume and salinity concentration were determined. Then WHI was calculated for each month of the study years to compare the failure with the pre-disturbance value. In this section six different scenarios were evaluated in which the first three relate to the reservoir operation and the last three are relevant to the wetland condition. These scenarios are discussed in detail in the following sections.

SCENARIO RESULTS

Scenario 1: Giving priority to the irrigation demands without considering EWR of the wetland (current state)

The results of the reservoir operation in the current state are summarized in Table 8. In this model the flood control volume is allowed to operate so to have a 13000 ha increase in the irrigated area. In addition return flows from irrigation plains have been assumed to be 15% of irrigation water. As shown in the same table, in the current state wetland will receive just 830 MCM annually that is much less than the determined environmental water requirement. Without any doubt, if reservoir operation continues in this way wetland health will encounter 100% failure.

Scenario 2: Giving equal priorities to the irrigation demands and the wetland

In this scenario based upon the capacity sharing principal, the wetland is considered as an individual user like irrigation plains. Thus any failure to supply irrigation demands will damage the wetland water requirement supply. It is impossible to supply this, as it doubles downstream demands.

Scenario 3: Giving first priority to the irrigation demands and second to the wetland

In this scenario the first priority is given to the irrigation demands as the main purpose of dam construction. Then some changes in the reservoir operation are applied to improve wetland conditions. These changes are as follows: not operate the flood control volume and consider irrigated water to the real values. The first one leads to a decrease in downstream flood damage as well as an increase in wetland inflow. These modifications enable the reservoir to supply 20 percent of wetland monthly water shortage from January to April in addition to the irrigation demands. Despite the increasing wetland inflow, as sugar cane discharge continues, there is no improvement in the WHI. But if this scenario is assessed with the scenario of the diverting sugar cane discharge simultaneously, significant (15%) decline in the failure can be seen (Table 5).

Scenario 4: Diverting sugar cane discharge through a channel to the Persian Gulf
As mentioned previously, a combination of this scenario with the third scenario has the most considerable effect on the wetland conditions, so to reduce failure up to 15%.

Scenario 5: Continues discharge from sugar cane industries and diversion of irrigated water from the river
Irrigated water being taken in to account as a water resource to supply irrigation demands, its diversion from the river will increase the failure in down stream demand supply. However, sugar cane discharge is so saline that diversion of the irrigated water won't cause any improvement in WHI values. As a result, the positive effect of the irrigated water in demand supply is more important than its negative effect on the wetland water quality.

Scenario 6: Supplying part of the wetland EWR through the Karun River
In the past Karun River has supplied 10 percent of the wetland annual inflow (210 MCM). In this scenario, the effect of supplying part of the wetland requirements, up to 500 MCM/y from Karun River, was investigated. Due to the positive effect of flushing flows on the wetland quality, the more increasing the supply doesn't necessarily mean a better condition for the wetland. According to the results, if 40% of wetland water requirements can be supplied by Karun during four months of the year, from January to April, it will be possible to meet wetland EWR up to level 2. In addition, failure in the wetland health will reduce to 78%.

Table 5. Results of the assessment different scenarios

Parameter	Scenarios				
	1	3	3,4	5	3,4,6
Number of failure(months)	73	59	59	86	59
Average annual shortage(MCM)	57	39	39	61	39
Maximum yearly failure (%)	59.1	45	45.1	50	45
Minimum yearly failure (%)	0.6	0.14	0.14	3.5	0.14
Mean annual spill volume(MCM)	665	789	789	814	789
Mean annual regulated volume(MCM)	114	720	720	774	720
Mean annual wetland inflow from the river(MCM)	830	1268	1268	1142	1268
Mean annual wetland shortage (MCM)	1847	1283	1594	1663	1010
Failure to meet the wetland health (%)	100	99.4	85.8	85.8	78

CONCLUSIONS

In our previous study we determined the requirements to maintain wetland desired water quantity and quality [6]. Using a holistic approach, three levels of supply were assigned for wetland environmental water requirements where the best hydrological regime was set at a probability of exceedance equal to 60%. In this paper, the river and wetland system were simulated both in pre and post development states. According to the results, in the past, wetland had experienced about 30 percent failure, while in future under current states it will encounter 100 percent failure. This necessitates implementing some modifications in the system operation. To do this, six scenarios were evaluated. Results of the scenario assessment showed that there is no possibility to increase dam release for the wetland environmental requirements, as irrigation demands are high. However, by giving priority to irrigation demands and causing some changes, it is possible to meet wetland water requirements up to level 2 and reduce the total number of failure in wetland health. These modifications are written according to their effects on wetland health:

- Diverting sugar cane discharge from wetland through a channel and releasing it directly to the Persian Gulf.
- Not operating from reservoir flood control capacity
- Supplying 40% of wetland water demand in four months of the year (from January to April) through the Karun River that is equal to 584 MCM/y.

All of these promoting actions can just reduce the failure to 78% of the months during the study years. However, returning the wetland to its predevelopment condition is impossible. Therefore it is suggested to conserve some parts of the wetland with the aid of regulators according to the ecological priorities.

REFERENCES

[1] Anzecc. and Armcanz. (2000). "Australian and New Zealand Guidelines for Fresh and Marine Water Quality", Australian and New Zealand Environment Conservation Council

[2] Davis, JA, Froend, R.H. (2001). "Environmental Water Requirements to Maintain Wetlands of National and International Importance", Environmental Flows Initiative, Technical Report Number 1, Commonwealth of Australia, Canberra.

[3] Droogers, P., Salemi, H.R., and Mamanpoush, A.R. (2001). "Exploring basin-scale salinity problems using a simplified water accounting model: The example of Zayandeh Rud Basin, Iran", Irrigation and drainage.Vol.50, No.40,, PP.335-348.

[4] Nadine, A., Marshall, A.B., Paul C. E. and Bailey, A. (2004),"Impacts of secondary Stalinization on freshwater ecosystems", Marine and Freshwater Research, No.55, PP.509-523.

[5] Ramsar Convention, (2004), Handbook4,"Riverbasin management: Integrating wetland conservation and wise use in to river basin management ".

[6] Sima., S., Tajrishy, M. (2006),"Water allocation for wetland Environmental Water Requirements". World Environment and Water Resources Congress, ASCE.