Marsh Restoration Module -- Geoff Klise

SAND2008-1233C

1. Description of the data (monthly from 1965-1990, then annually after that . . .) with citations.

The Marsh Module takes most of its monthly flow input data from the surface water model. Salinity data is taken from a variety of sources and is used as an initial value for the start of the simulation. Volume – Surface Area – Water Stage Level and management target curves are all taken from the New Eden report. References are listed below.

1.1 For the Hawizah Marsh, the inputs are as follows:

- Sanaf Pond flow
  - See Surface Water Module
- Karkheh River flow
  - The Karkheh River inputs reside in the Transboundary Module and consist of monthly measured data from 1954-1999. Years 1950-1953 and 2000 are partially complete. The model uses average flows from the measured years to fill in incomplete months. Data obtained from *Azadegan Environmental Baseline Studies: Report 1. The Natural Environment [azadegan-eia-study[1].pdf] Page 51, Table 5.8.*
- Tigris River flow
  - See Surface Water Module
- **SALINITY**:
  - Initial value of 1,600 ppm taken from page 76 of the above *Azedegan Environmental Baseline Studies* report.
  - For salt flux into marsh, see initial values as defined in the Surface Water Module.
- The "Volume – Elevation" and "Area – Elevation" curves on page 23 [*Volume II (Current and Future Water Resources Requirements in the Marshlands Area) - Book 5 (Modeling) of the New Eden Master Plan*] were used to help calculate evapotranspiration and define target marsh levels based on different restoration scenarios.
- A "Target Curve" is used to determine when the marshes should be full and when they should be emptied for optimal conditions. It is applied to all marshes and is copied from page 41 of [*Volume II (Current and Future Water Resources Requirements in the Marshlands Area) - Book 6 (Marshlands Management Plan) of the New Eden Master Plan*]. The curve is normalized to an average depth/elevation for each marsh.
- For outflows from the marsh, graph curves were taken from page 31 of [*Volume II (Current and Future Water Resources Requirements in the Marshlands Area) - Book 5 (Modeling) of the New Eden Master Plan*]. These curves look at different outflow possibilities that can help the marsh reach the target curve as described above.

1.2 For the Central Marsh:

- Tigris River flow
  - See Surface Water Module
- **SALINITY**:
  - Initial value of 896 ppm taken from the "Tech-Amman 1-4_MOWR_Water Quality of Marshlands_Mr_A_Qadir1(2).pdf" presentation. (can't find link)
  - For salt flux into marsh, see initial values as defined in the Surface Water Module.
- The "Volume – Elevation" and "Area – Elevation" curves on page 22 [*Volume II (Current and Future Water Resources Requirements in the Marshlands Area) - Book 5 (Modeling) of the New Eden Master Plan*] were used to help calculate evapotranspiration and define target marsh levels based on different restoration scenarios.

- A "Target Curve" is used to determine when the marshes should be full and when they should be emptied for optimal conditions. It is applied to all marshes and is copied from page 41 of [*Volume II (Current and Future Water Resources Requirements in the Marshlands Area) - Book 6 (Marshlands Management Plan) of the New Eden Master Plan*]. The curve is normalized to an average depth/elevation for each marsh.
- For outflows from the marsh, graph curves were taken from page 31 of [*Volume II (Current and Future Water Resources Requirements in the Marshlands Area) - Book 5 (Modeling) of the New Eden Master Plan*]. These curves look at different outflow possibilities that can help the marsh reach the target curve as described above.

1.3 For the <u>Abu Zaragh Marsh</u>:

- Tigris River flow
  - See Surface Water Module
- Euphrates River flow
  - See Surface Water Module
- **SALINITY**:
  - Initial value of 768 ppm taken from the "Tech-Amman 1-4_MOWR_Water Quality of Marshlands_Mr_A_Qadir1(2).pdf" presentation for November 2003. (can't find link)
  - For salt flux into marsh, see initial values as defined in the Surface Water Module.
- The "Volume – Elevation" and "Area – Elevation" curves on page 25 [*Volume II (Current and Future Water Resources Requirements in the Marshlands Area) - Book 5 (Modeling) of the New Eden Master Plan*] were used to help calculate evapotranspiration and define target marsh levels based on different restoration scenarios.
- A "Target Curve" is used to determine when the marshes should be full and when they should be emptied for optimal conditions. It is applied to all marshes and is copied from page 41 of [*Volume II (Current and Future Water Resources Requirements in the Marshlands Area) - Book 6 (Marshlands Management Plan) of the New Eden Master Plan*]. The curve is normalized to an average depth/elevation for each marsh.
- For outflows from the marsh, graph curves were taken from page 31 of [*Volume II (Current and Future Water Resources Requirements in the Marshlands Area) - Book 5 (Modeling) of the New Eden Master Plan*]. These curves look at different outflow possibilities that can help the marsh reach the target curve as described above.

1.4 For the <u>Hammar Marsh</u>:

- Euphrates River flow
  - See Surface Water Module
- Abu Zaragh Marsh flow
  - Model allows water to flow directly from Abu Zaragh into Hammar (no intermediate step of water flowing into Euphrates River).
- **SALINITY**:
  - Initial value of 1240 ppm taken from Chapter 5 of the USAID Report, Table 5.1 p.153 (representing June 2003).
  - For salt flux into marsh, see initial values as defined in the Surface Water Module.
- The "Volume – Elevation" and "Area – Elevation" curves on page 24 [*Volume II (Current and Future Water Resources Requirements in the Marshlands Area) - Book 5 (Modeling) of the New Eden Master Plan*] were used to help calculate evapotranspiration and define target marsh levels based on different restoration scenarios.

- A “Target Curve” is used to determine when the marshes should be full and when they should be emptied for optimal conditions. It is applied to all marshes and is copied from page 41 of [*Volume II (Current and Future Water Resources Requirements in the Marshlands Area) - Book 6 (Marshlands Management Plan) of the New Eden Master Plan*]. The curve is normalized to an average depth/elevation for each marsh.
- For outflows from the marsh, graph curves were taken from page 31 of [*Volume II (Current and Future Water Resources Requirements in the Marshlands Area) - Book 5 (Modeling) of the New Eden Master Plan*]. These curves look at different outflow possibilities that can help the marsh reach the target curve as described above.

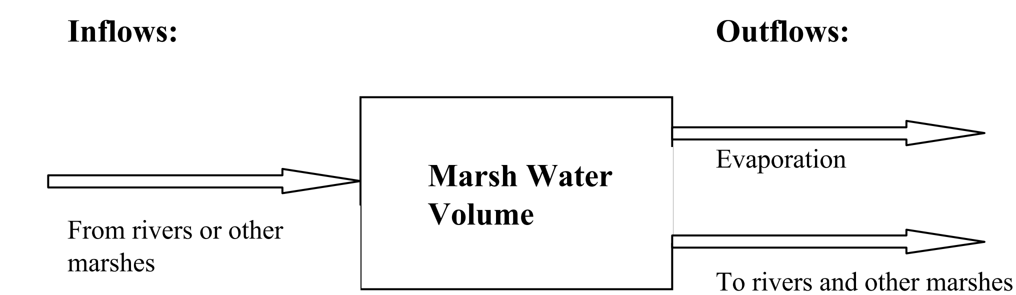
1.5 For ALL MARSHES:

- Evaporation as applied to all marshes is obtained from the New Eden Master Plan Volume II Book 5 Water Planning Models, Page 30, Table 1 - Evaporation Patterns

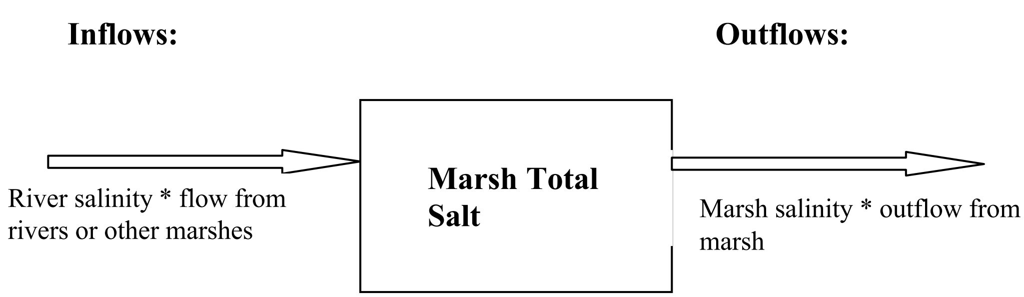
2. Simplified model structure (use a diagram if you want -- and/or say what it does in English or math)

Model Structure:

The model works as shown below. Each marsh is defined as a volume of water at the end of a time step that has inflows added to it and outflows subtracted from it. The added curves as described above help translate one measurement into another. For example, it allows for the Marsh Water Volume to be translated into a surface area to determine evaporation, into an elevation for determining optimal stage level as defined by the target curve and to determine an outflow flow rate based on a hypothetical outflow structure. The model is also set up to allow for flooding when the total surface area is greater than the maximum marsh pool (as defined by 75% of the 1973-1976 surface areas).



The same can be said for salinity. The same diagram is applied as above, but in this case, the total salt mass at the end of the time step is calculated. Salinity is obtained by Marsh Total Salt mass divided by Marsh Water Volume.



2.1 Detailed Discussion of Model Inputs Controlled by User:

For each marsh, the user has the option of setting many input variables that will impact the volume and salinity of the marsh. The first option is for the user to set the initial volume and initial salinity of the marsh. Each input is set so that for each model run, the variable does not change unless the user changes it. This can be changed by "restoring permanent variables" to their default value in the player mode.

2.2 Initializing Values -

- The user can slide the initial marsh volume of up to 75% of the 1973-1976 extent. This is chosen as the highest possible value because based on current land use practices and water availability, 100% restoration may not be feasible.
- The initial salinity for each marsh is set at a measured/published value. The user can increase or decrease the initially salinity value.

2.3 Marsh Target –

- This is an important slider that gives the user the ability to determine at what percentage of the 1973-1976 conditions the marsh should be restored to. The default value is 100% (75% of the 1973-1976 conditions). This value will move the target curve so that either more or less water is requested from upstream to match the target curve. This does not control all flows, instead if water is requested, any extra on top of what is will already enter the marsh is available to the marsh. The target curve does not impact outflows, although choosing different outflows will help the marsh meet the desired target curve. The user has that control in the "Marsh Discharge" portion of the user interface.

2.4 Limited Time Frame –

- The simulation time may be too long to see any trends or details over a shorter or more specific time period. The slider bar allows the user to use a different start year, starting in 1973 and moving up to 2004, to visualize the results. The only two results that are currently visible in the limited time frame are **marsh surface area/target marsh surface area** and **marsh salinity**.

2.5 Marsh Discharge –

- Each marsh has the ability to not discharge any water, or use one of the hypothetical outflow structures as outlined on page 31 of *Volume II (Current and Future Water Resources Requirements in the Marshlands Area) - Book 5 (Modeling) of the New Eden Master Plan*. The default on all marshes is "No outflow". The outflow is controlled by the maximum flow in the outlet structure so no extra water is released beyond the capacity of the structure. Flood flows do occur in the model and are not controlled by the discharge choices.

2.6 How the Model Works:

After the user chooses the initializing, target, discharge and limited time frame values, the model goes through the following steps to calculate marsh volume, stage, surface area and salinity for each time step:

2.7 Flow Portion -

1. The Marsh Target percentage is applied to the 75% area under 1973-1976 conditions constant, which goes into an area – to – depth graph function, resulting in a maximum water depth for the marsh under the chosen percentage. If the chosen value is 100%, then that represents the full recovery (75% of 1973-1976 surface area) conditions. If a lesser percentage is used, then the maximum water depth decreases.
2. This value is used as the upper bound on the "Target Curve" as described in the New Eden report and the target curve is normalized to that upper bound because each marsh has a different capacity. The end of the month depth is calculated (beginning of next month) from that curve to be used in determining if the marsh needs more water and is translated into a target volume for that month.
3. The marsh demand calculates how much water is in the marsh as compared to the target volume. If it is short, then the demand asks for water up-stream. If water is available, it will be made available to the inflows into the marsh on top of what would have made it to the marsh if there was no upstream call. If not, no extra water is delivered.
4. Evaporation is handled by applying the evaporation rate to the surface area of the marsh. The surface area is calculated using one of the curves that translates volume into surface area.
5. The outflow scenarios are user controlled and can be "0" with the assumption that no water leaves the marsh with the exception of evaporation and flooding. The other options are for hypothetical engineered outflow structures as discussed in the New Eden report that can control

outflow up to a certain discharge rate. Because these are on a curve, a lower stage will result in a lower discharge, higher stage in a higher discharge. These structures currently don't allow flow above the choice to occur, but in reality, floods will happen and emergency spillways or water over a levee will push more water out of the marsh. This is dealt with by allowing water to flood the marsh when the actual surface area would be greater than the maximum marsh pool surface area at the end of the timestep. The Abu Zaragh marsh has a smaller outflow capacity than the three other marshes. This is based on the New Eden report recommendations.

2.8 Salinity Portion –

1. The initial marsh salinity is set in the model based on a published value. It is set on a slider bar if the user wants to change the value. The salt load coming into the marsh is calculated as a flux by multiplying the inflow rate by the salinity.
2. The total salt in the marsh is calculated on a monthly basis and is converted to salinity by total marsh divided by marsh volume. This value is needed to calculate the salt flux out of the marsh.
3. The salt flux out of the marsh is calculated by multiplying the outflow rate by the salinity. Flood events are also added to the outflows.

2.9 Output Graphs –

1. The first column shows inflow to the marshes on a monthly basis.
2. The second column shows outflows from the marshes on a monthly basis. This is the sum of outflows, which includes controlled discharge as defined by the user and flood flows to the same river.
3. The third column has four graphs to show the different relationships the marsh has to the target curve. The first is volume, the second is stage, the third is surface area and the fourth is for surface area over a user-defined limited time period.
   - The flows are shown by the blue line, the targets based on the target curve are shown with the green line. One can see that if water is available, the marsh gets the water it needs up to, and sometimes beyond the target. Outflows do not typically follow the falling limb of the target curve, and are lagged. This could either be to a model issue, or the inability of the marsh to drain fast enough in order to meet the target curves. The New Eden report also shows the same thing. By increasing the discharge capacity at the controlled outflows, the falling limb moves left towards the target, but doesn't always reach it.
   - The last graph on the bottom shows the limited time frame as defined by the user. The start year can be picked past 1973 and the graph will start once the simulation reaches the start year.
4. The fourth column has two graphs that show marsh salinity over the simulation time period.
   - The first shows salinity over the entire simulation time period. The second shows the limited time frame as defined by the user. The start year is connected to the start year for the surface area/target curve comparison.

3. Major assumptions

For the FLOW portion of the marsh module:

Marsh Volume:

3.1 General

Marsh total depths are an average over the entire area of the marsh.

Most inflows to the marshes are aggregated and do not represent the exact inflow and outflows to each marsh. This is done for simplicity and to match the surface water module portion of the model.

Overbank flooding is goes into the same river as the outputs from the marsh. Right now, flooding doesn't automatically move from one marsh to the other. E.g., if the Hammar floods and the Central does not, water could move from Hammar to Central. The model doesn't currently allow for that. A better understanding of marsh dynamics, namely stage/discharge relationships in the rivers will help. It is understood that there are emergency culverts and pipes that can pass this floodwater, but nothing is known about capacity because they are not gauged.

The outflow control structures only allow water to flow up to the desired discharge. In reality, these could become flooded and water could flow over the structures. This is not explicitly dealt with in the model, other than the way the marsh deals with flooding for the entire marsh.

The outflows as shown in the marsh are hypothetical and based on the New Eden recommendations. There are outflows from each marsh, but they are not well understood.

3.2 Specific Marshes

Hawizah marsh has a feature that reduces inflows from the Karkheh River in 2005 because that is when an Iranian levee was supposed to be finished, potentially reducing inflows from that source.

Hawizah marsh is treated as one marsh for simplicity and inflows from the Tigris River are aggregated into one inflow.

Any outflow of Hawizah to the Tigris (via Al Kassara) only occurs when the marsh stage is above 2 meters. Al Kassara has two channels that meet as one before it reaches the Tigris River. For the model, it is lumped into one channel. Any outflow to Shat Al-Arab (via As Suwayb) only occurs when the marsh starge is above 3 meters.

Central Marsh is treated as one marsh and outflows are lumped into outflows that leave Abu Zaragh marsh.

Outflow of Central marsh to the Euphrates only occurs when the marsh stage is above 1 meter. Based on an e-mail from fadhil, the outflow depends on the stage of the Euphrates.

Outflow of Abu Zaragh marsh to the Euphrates only occurs when the marsh stage is above 1 meter.

Abu Zaragh is lumped together into one marsh and it is understood that a levee in the middle of the marsh divides it into two.

Hammar marsh is lumped together into one marsh. Based on e-mails from fadhil, it works as two marshes with no outflows from the western portion and tidal influx influencing volume and salinity in the southeastern portion. We treat it as one marsh with outflows entering Shat-Al Basrah.

3.3 For the SALINITY portion of the marsh module:

The maximum solubility used in the marsh is 250,000 ppm and the model is set up so that the salinity does not go beyond this value. This is added because when marsh volumes decrease, the salinity can increase dramatically since the model does not allow for salt to precipitate out. The model ends up concentrating the salt, resulting in very high salinity values.

In addition, a function is added to prevent the model from dividing by zero and the salinity from going to infinity.

4. Data and information gaps

Outflow conditions are not known. It would be great if there was some gauge data, or at least anecdotal reports of how the marshes empty during the flood months.

Stage-discharge relationships for the Tigris and Euphrates would be helpful because it may be a more realistic way of redistributing water for Central, Abu Zaragh and Hammar marshes.

5. Interface issues (should we put slider bars on these 60 items, or just on 10 . . .?),

The interface is complete, however the graphs may need to be larger, or some graphs deleted that may not be necessary. Right now there are many graphs to look at and we should see which ones the users want to see. Tables may also be necessary, or summary statistics for model runs or specific time periods.

6. Other issues

Time delay in request vs. actual. Is that real or a bug/mistake in the model. Need to look at that issue in more detail after the meeting.

Need to do some more research on the New Eden report and see how they describe elevation above msl and stage. Sometimes it appears they mix the two when they should be separate.

7. Next steps

Incorporate GIS maps into the model? Wait and see if the Iraqis have more information that could be useful in the model, or change things to show what they want to see or not see in the model.