INTERAGENCY COOPERATION IN AN INTERNATIONAL PROGRAM: USACE-HEC HYDROLOGIC MODELING FOR THE TIGRIS AND EUPHRATES IN SUPPORT OF USAID-RECONSTRUCTION PROGRAM IN IRAQ

Darryl W. Davis, P.E., D.WRE, darryl.w.davis@usace.army.mil, Fauwaz U. Hanbali, Fauwaz.u.hanbali@usace.army.mil, Matthew M. McPherson, P.E., matthew.m.mcpherson@usace.army.mil, US Army Corps of Engineers Hydrologic Engineering Center, 609 Second Street, Davis, California

Abstract The U.S. Corps of Engineers Hydrologic Engineering Center (USACE-HEC) teamed up with the U.S. Agency for International Development (USAID) to develop a hydrologic model for the Tigris and Euphrates basins. This effort was made possible via a contractual partnership between HEC and Development Alternatives, Inc. (DAI), the USAID prime contractor for the Iraq Marshlands Restoration Program (IMRP). The IMRP is a multifaceted program focusing on environmental and socio-economic aspects with respect to possible re-flooding of the desiccated Mesopotamian marshes, as well as supporting agro-economic development and health care for the marsh population. As a team member of the IMRP, HEC was specifically responsible for providing support to the Iraq Ministry of Water Resources (MoWR) in studying the water control management system and assessing the competing water demands in the entire basin to provide alternatives for possible marshland ecosystem restoration. HEC and the MoWR jointly developed a reservoir simulation model, using the HEC-ResSim software, for the heavily regulated Tigris and Euphrates river system. This paper gives an account of the U.S. interagency cooperation that transpired in providing technical consultation and support to the Iraq MoWR to enhance its water management mission.

INTRODUCTION

Avid concern and significant resources have been dedicated by the international community to champion the cause of reviving the marshes (The Iraq Foundation 2003), (Italian Ministry for the Environment 2004), (UNEP 2003) and support both the MoWR and the newly established Ministry of Environment in their water management and environmental missions. On the ground investigations and programs, $4 million worth of funded tasks, were initiated in 2003 by the U.S. Agency for International Development (USAID) through its agent Development Alternatives, Inc. (DAI). USAID has developed an action plan which "supports the restoration of the ecosystem through improved management and strategic re-flooding and provides social and economic assistance to the local population" (USAID 2004). One key challenge in the overall scheme is evaluating the available water resources in the entire basin and flow circulation characteristics in the marshes to determine the feasibility and extent of re-flooding these ancient wetlands. To that end, the USAID action plan includes a task for hydrologic and hydraulic modeling to produce scenario-based analyses that may quantify excess Tigris and Euphrates flows and their timing for potential and sustainable restoration of the marshes. It is this item for which USAID/DAI requested technical assistance from HEC for streamflow gage data compilation and adjustment, and water management system modeling.

THE SETTING AND WATER MANAGEMENT INFRASTRUCTURE

More than seventy percent of surface water available to Iraq originates outside its borders. For a geographic point of reference, as shown in Figure 1, the southeastern region of Turkey is the source for both the Tigris and Euphrates; Syria and Iraq are the downstream nations sharing the Euphrates with Turkey; and Iraq is essentially the sole downstream riparian to the Tigris, where the upper reaches of the main stem lie in Turkey and the headwaters of its major tributaries fall from Iran's Zagros Mountains. The mean annual discharge for the Euphrates is on the order of thirty two billion cubic meters (bcm), which is near 1,000 cubic meters per second (cms), ninety five percent of which is generated in Turkey while the remaining five percent comes from the tributaries in Syria. For the Tigris, the average annual discharge is close to fifty bcm (1,400 cms), which is roughly figured as around 20 bcm (650 cms) from the main stem, and almost 30 bcm (900 cms) from the tributaries (Soffer 1999).

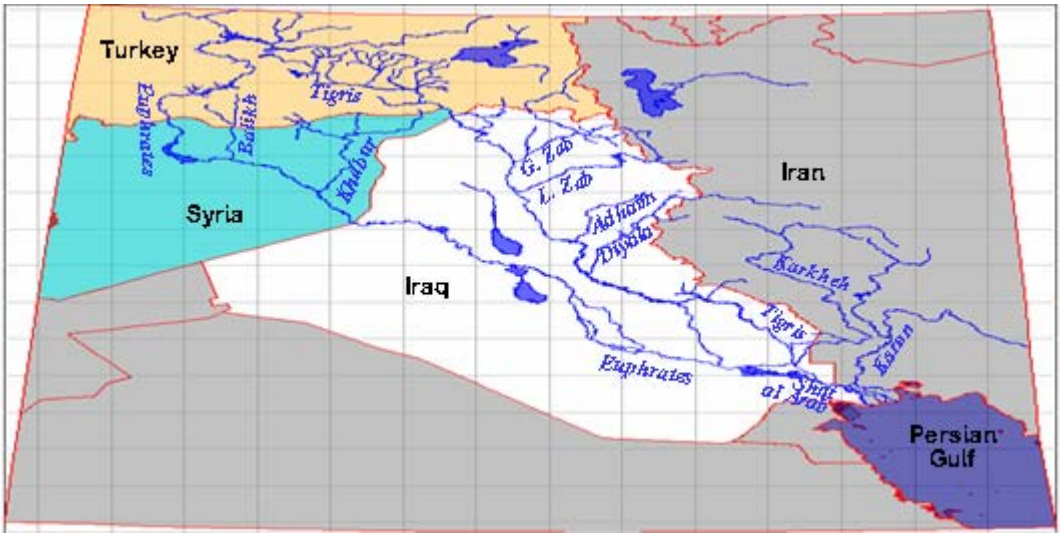

Figure 1 Tigris and Euphrates Rivers

The formerly extensive body of wetlands, known as the Mesopotamian Marshes, lies in the lower part of the basin, where the Tigris and Euphrates meet. The Marshes are divided into three sections: Hawizah Marshes on the eastern bank of the Tigris near Qal'at Saleh, Central Marshes between the final reaches of the Tigris and Euphrates, and Hammar Marshes on the downstream most western bank of the Euphrates.

The Tigris and Euphrates are associated with ancient civilization where irrigation schemes had been developed circa the Fifth Millennium BC, but plans and construction of grand scale water resources development projects began in the early part of the Twentieth Century (Soffer 1999). Iraq completed its first modern low-head diversion structures, Hindiyah Barrage on the Euphrates and Kut Barrage on the Tigris, in 1914 and 1939, respectively, to supply irrigation canals in the lower basin. Then, flood control studies in the 1950's prompted the construction of large dams and storage reservoirs in Iraq, particularly, the Samarra-Tharthar off-stream storage scheme in 1954 for flood

control on the Tigris, Dokan Dam in 1961 and Derbendi Khan Dam in 1962 on the Lesser Zab and Diyala, respectively. Hemrin Dam was completed in 1980 on the Diyala. By 1985, Iraq added its head dams, Mosul on the Tigris and Haditha on the Euphrates, to impound and control the river flows as they enter the country. The current level of water resources development in Iraq is high with irrigated areas constituting over three million hectares (ha). Ninety percent of water consumed is for irrigation.

Early Twentieth Century plans for development were formulated by the upstream nations, but significant development only began in the mid 1970's with the construction of Syria's Tabqa dam in the Middle Euphrates, and Turkey's Keban Dam in the Upper Euphrates. With a storage capacity near 12 bcm, the Tabqa reservoir accounts for most of the storage capacity along the Euphrates for Syria. The extent of Syria's irrigation development projects along the Euphrates is still considerably below the ultimate target level of 345,000 ha (Kolars 1991). In progress since 1976 Turkey's Southeastern Anatolyia Project (GAP), promises a total of twenty two dams in the upper basins of the Tigris and Euphrates for generating hydropower and developing 1,700,000 hectares (ha) of agricultural land (Kibaroğlu 2002). To date, only a few minor GAP project dams are operational in the upper catchments of the Tigris. The most significant of the planned GAP dams have already been constructed on the Euphrates, particularly the keystone project Ataturk Dam that holds 49 bcm in storage capacity.

In all, current storage capacities in the Tigris and Euphrates River Basins are near 110 bcm in Iraq, 14 bcm in Syria, and 90 bcm in Turkey. Effectively, the basins are now heavily regulated with cumulative storage capacity in Turkey, Syria, and Iraq amounting to two and a half times more than the combined mean annual flows of the Tigris and Euphrates. Further development is ongoing, independently by each riparian, to achieve national plans for economic growth and social progress. Projected demand claimed by the three countries will exceed the available water resources. There are many challenging issues concerning the management of the Tigris and Euphrates River Basins as a whole and continuing debate on the expected water shortages based on overwhelming demands by the three riparian countries sharing these resources (Dellapenna 1997).

DATA AND MODEL DEVELOPMENT

As part of the USAID-supported reconstruction effort in Iraq, the U.S. Army Corps of Engineers Hydrologic Engineering Center (HEC), in association with DAI, undertook the task of constructing a reservoir simulation model for the Tigris and Euphrates river basins. Essential data on the water management system in Iraq, including river flow records, characteristics and functions of flow regulation projects, and water withdrawal requirements were accumulated. In addition, HEC worked in collaboration with Iraqi engineers from the MoWR, hosted at Davis, California. A preliminary reservoir model was completed incorporating major storage structures, diversion projects, and operational criteria as dictated by the MoWR regulation plan for its water management system. The model continues to be refined to serve as a planning-aid tool for performing water budget analyses, and model derivatives are being formed into a decision-support tool for real-time operation.

Streamflow data are a critical element of developing a credible Tigris-Euphrates Water Management System Model (WMSM). In years past, a reliable system of streamflow gages was in place in Iraq, located where the Tigris and Euphrates enter Iraq, and at key locations along their main stems and on tributaries. Many of these gages continue to be operational although the measuring equipment and ratings of the sites have not been updated in more than a decade. None-the-less, a long-term gaged flow record for most key gage locations was assembled and validated to the extent possible, and coded into electronic files. Sources included published records through about the 1970s, and paper records retrieved from regional sites since. Because substantial project development occurred at various times in the record that are reflected in flow diversions and depletions, the long-term gaged record was then adjusted to a base flow state of circa 1930, further adjusted to flow states representing project development in place throughout the basin circa 2004 and flow states representing a projected basin development condition circa 2030. Estimates of diversions and depletions for the upper basin states is taken from publicly available records, and determined by indirect means.

The stream flow records were electronically archived into the HEC-Data Storage System Visual Utility Engine (HEC-DSSVue). HEC-DSSVue is a Graphical User Interface (GUI) database system that allows efficient storage and retrieval of sequential data, such as times series records and other types of data used in water resources management (HEC 2003). The program, one of HEC's Next Generation (NexGen) software packages, offers convenient editing, copying, and visual display of data via tables and plots, in addition to having various mathematical, basic hydrologic and statistical functions. A HEC-DSSVue database file was produced containing daily and monthly discharge records, dating back to 1930, for select gaging stations in Iraq. The adjusted streamflow records, configured to conform to the WMSM model structure, are also stored in HEC-DSSVue records.

Additional data assembled as input to the reservoir model consisted of a detailed inventory of existing dams and barrages, reservoir storage and dam outlet capacities, storage zone definition, and installed hydroelectric capacities. More importantly, general operation and demand criteria were defined and confirmed during several discussions with the visiting Iraqi engineers.

The software used to create the reservoir simulation model for the Tigris and Euphrates system is HEC-ResSim (HEC 2003b), another HEC-developed NexGen product initially released to the public in September 2003. HEC-ResSim is a deterministic model that simulates the behavior of multi-reservoir water resources systems based on user-specified rules for reservoir operation, in addition to methods for flow allocation and conveyance in the river network. The program fits the need by the MoWR to use advanced analysis tools and support its decision-making duties, which encompass both planning and regulatory aspects of water control management. The Tigris-Euphrates WMSM model contains a configuration of the physical layout of all projects and control points that have a bearing on the formulation of the MoWR regulation plan. Digitized stream alignments and project elements are laid over a GIS-based background map of the region, making a geo-referenced schematic of the watershed. Routing reaches, which link upstream

junctions to downstream junctions, complete the network connectivity of the Iraq water control system model. The resulting reservoir system network is shown in Figure 2.

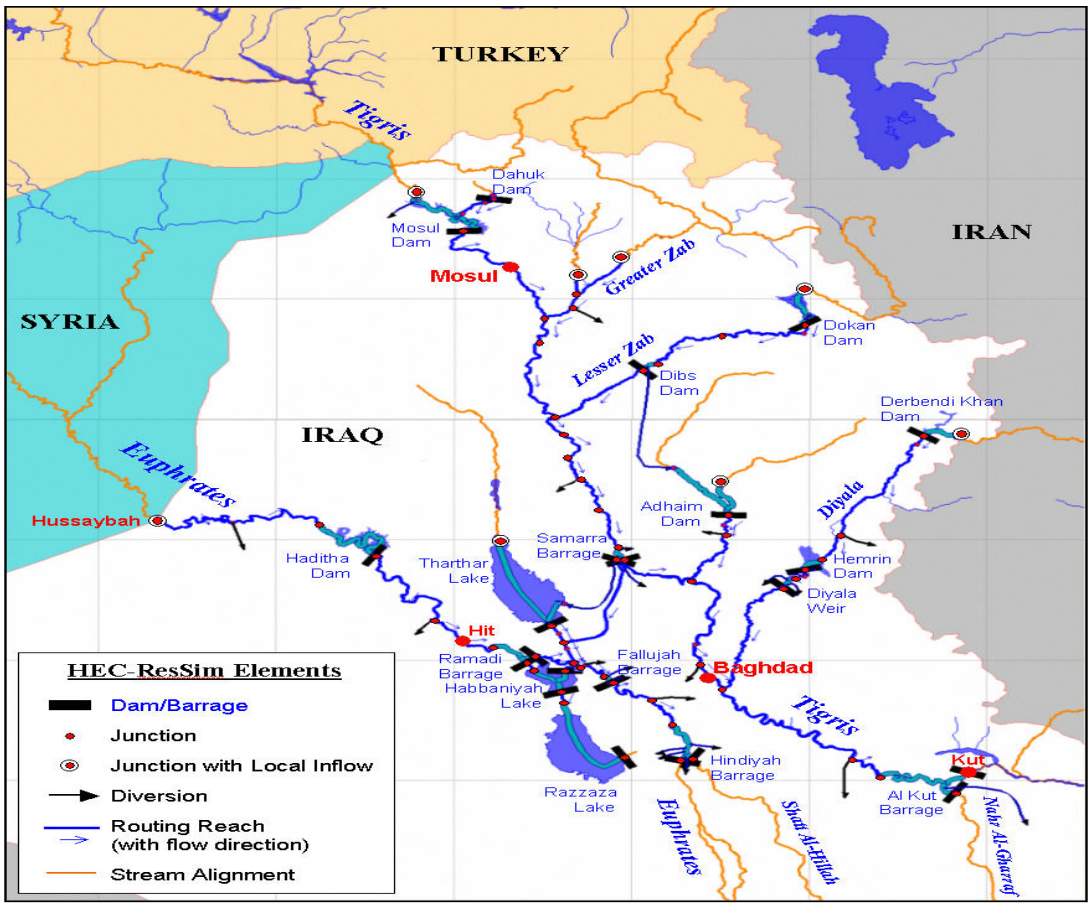

Figure 2 HEC-ResSim Reservoir Network for the Tigris and Euphrates.

The HEC-ResSim program simulates reservoir operation to meet seasonal target storage (Rule Curve) and reservoir release criteria as prescribed for the various operating zones, most importantly the flood and conservation zones (Figure 3). In the Tigris and Euphrates model, operating for hydropower generation is desirable, but the primary objectives of the multipurpose reservoir operation are water conservation to satisfy irrigation demand and flood mitigation. Special constraints to limit maximum allowable releases and provide for minimum downstream flows influence the reservoir operation, specifically how desired reservoir storage levels are achieved and downstream requirements are met. In addition, coordinated operation and storage balancing of two or more reservoirs can be established, as in the case of the tandem pair of Derbendi Khan and Hemrin reservoirs along the Diyala River.

Data and model analysis for the Tigris and Euphrates system in Iraq continues as a collaborative effort between HEC and MoWR. Standardized hydrologic data sets of adjusted observed stream flows are being generated to account for upstream flow

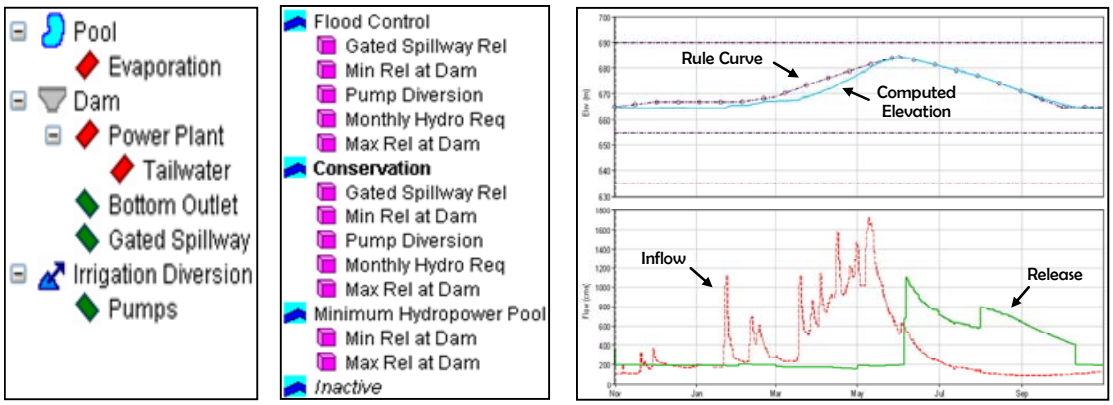

Figure 3a **Figure 3b** **Figure 3c**

Figure 3. HEC-ResSim (a) Dam and Reservoir Physical Characteristic; (b) Operating Zones and Rules; (c) Reservoir Simulation Plot.

regulation and depletion, and return flow effects on the surface water that comes into Iraq. The standard, adjusted stream flow records are being used in period-of-record reservoir model simulation of current and future levels of basin development. MoWR staff is gaining experience with the HEC-ResSim model, and base alternatives considering primary operating objectives and marsh restoration scenarios are being formulated for simulation and incorporation in water budget and allocation studies. Preliminary system model results thus far indicate that in the near future, water shortages will become evident, perhaps exacerbated by successive years of low streamflow. The substantial storage in Iraq will greatly assist in carrying through seasonal and moderate dry periods, but major shortages with attendant critical need to re-assess existing water allocation loom on the horizon. Over the next twenty years, the flow of the Euphrates entering Iraq from Syria could be less than half the historic average and the flow of the Tigris from Turkey could be reduced by as much as one-forth. Additionally, continued development in Iran is expected to diminish inflows to the Mesopotamian marshes by perhaps more than half. The models and data compiled in these studies will be key tools in assessing and resolving critical water management issues.

SUMMARY AND CONCLUSIONS

The Tigris-Euphrates HEC-ResSim model and associated flow data sets are intended for use by the MoWR and its agents in current operations analysis and for future studies of plans for sustainable marsh restoration as well as other comprehensive water management planning on a national scale. Significant issues of water allocation among Iraq and the upper basin states of Syria and Turkey are looming and Iraq will make important choices of water allocation within its boarders in the near future. While the models and data developed and described herein are considered to be excellent tools for application in these critical studies, it should be noted, however, that more thorough analyses and collaboration with the MoWR are required to improve the data sets as better information becomes available on upper basin development, updated gage ratings, and field validation of flows takes place.

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