PILOT RECHARGE MODELS OF THE EDWARDS AQUIFER, TEXAS

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ABSTRACT: The Edwards Aquifer, a karst limestone formation, is the primary source of water supply for the City of San Antonio, Texas and many surrounding communities. Historically, two methods have been applied to calculate recharge to the Edwards Aquifer using a monthly water balance equation. The Edwards Aquifer Authority (EAA), in cooperation of HDR Engineering, Inc. has developed a new method for calculating recharge on a daily timestep using Hydrologic Simulation Program – FORTRAN (HSPF) Release 11, documented by the U.S. Geological Survey.

Pilot recharge models of the Nueces and Blanco River Basins effectively simulate hydrologic and hydraulic processes of rainfall, interception, evaporation, infiltration, evapo-transpiration, streamflow, and deep percolation using HSPF modules in order to quantify aquifer recharge. Simulated streamflows for a 40-year historical period are highly correlated with measured streamflows at proximate gage locations used to verify model calibration. Resulting estimates of aquifer recharge represent a significant improvement over previous estimates and will be used in the ongoing development, calibration, and application of a new groundwater simulation model of the Edwards Aquifer.

KEY TERMS: recharge estimation, HSPF, Edwards Aquifer, Texas

INTRODUCTION

The Edwards Aquifer, a karst limestone formation, is the primary source of water supply for the City of San Antonio and the source of Comal Spring and San Marcos Spring, the two largest in Texas. In order to resolve decades of continuous debate involving municipal and agricultural interests dependent upon the Edwards Aquifer for water supply as well as concerns regarding threats to endangered species and surface water rights holders below the major springs, the Texas Legislature created the Edwards Aquifer Authority (EAA) to serve both regulatory and research functions. Clearly, aquifer recharge is a matter of significant importance from both the regulatory and research perspectives. Hence, the EAA has initiated the development of new hydrologic models for the calculation of recharge.

Traditionally, recharge estimates have been calculated by the United States Geological Survey (USGS) using methods dating back to the late 1970s and published annually. Alternative estimates of historical Edwards Aquifer recharge for the 1984-1996 period were developed by HDR Engineering, Inc. (HDR) in the course of studies sponsored by the Edwards Underground Water District, Nueces River Authority, and as part of the Trans-Texas Water Program. These recharge estimates differ significantly from one another in both geographical and temporal distribution. The greatest volumetric differences in recharge estimates are most evident in the Nueces and the Blanco Recharge Basins (Figure 1), hence their selection for pilot recharge model development. The hydrologic process in each basin is simulated using HSPF to determine recharge to the Edwards Aquifer. The recharge results of this modeling effort are presented and compared with the previous calculation methods.

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MODELING APPROACH

The EAA in cooperation with HDR has developed a new method for calculating recharge on a daily timestep using Hydrologic Simulation Program – FORTRAN (HSPF) Release 11, documented by the U.S. Geological Survey. HSPF is based upon the Stanford Watershed Model developed in the late 1950s, with significant enhancements and refinements occurring over the last four decades. Pilot recharge models of the Nueces and Blanco River Basins effectively simulate hydrologic and hydraulic processes of rainfall, interception, evaporation, infiltration, evapo-transpiration, streamflow, and deep in order to quantify aquifer recharge. Processes simulated using HSPF in the pilot recharge models are listed in Table 1 and illustrated in Figure 2.

Table 1. Hydrologic & Hydraulic Processes / HSPF

<table>
<thead>
<tr>
<th>Hydrologic Process</th>
<th>Reference # on Figure 2</th>
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<tbody>
<tr>
<td>Precipitation on Pervious Land Segment</td>
<td>1b</td>
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<tr>
<td>Evaporation from Interception Storage</td>
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<td>Runoff from Pervious Land Segment</td>
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<td>Evaporation from Detention Storage</td>
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<tr>
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<td>Infiltration</td>
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<tr>
<td>Evapo-Transpiration from Upper Root Zone</td>
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<tr>
<td>Percolation (from Upper Zone to Lower Zone)</td>
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<tr>
<td>Evapo-Transpiration from Lower Root Zone</td>
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<td>Interflow</td>
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<td>Active Groundwater Inflow</td>
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<td>Baseflow</td>
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<td>Channel Losses</td>
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<td>Recharge to Inactive Groundwater (Deep Percolation)</td>
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</table>
Figure 2. Hydrologic Processes / HSPF

MODEL CALIBRATION

Effectiveness of the pilot recharge models of the Nueces and Blanco Recharge Basins in simulating the natural hydrologic and hydraulic processes was measured by comparison with and calibration to gaged historical streamflows at locations immediately downstream of the Edwards Aquifer outcrop. Because of the daily, rather than hourly, time-step used in the pilot recharge models, calibration of the rainfall/runoff simulation process was measured by the following (listed in order of importance):

- Annual streamflow volumes;
- Recession limbs of storm hydrographs; and
- Storm hydrograph peaks.

Simulated streamflows for a 40-year historical period are highly correlated with measured stream flows as shown in Figures 3 and 4. Linear recession analysis was performed on the correlation and in both basins the slopes of the recession are approximately 1.0 (1.0006 in the Nueces River Basin and 1.0247 in the Blanco River Basin), indicating that the long-term average annual streamflow was replicated in the simulations. Similarly, the y-intercepts, while not zero, were determined not to be statistically significantly different from zero. Additionally, recession limbs of streamflow hydrographs in the Nueces and Blanco Rivers are well replicated, as shown in Figures 5 and 6. The years 1981 in the Nueces River Basin and 1957 in the Blanco River Basin were shown, because these years represent typical (mean annual volume with large storm events and long dry periods between) streamflow in the respective basins.
Figure 3. Nueces River @ Uvalde – Streamflow Comparison

Figure 4. Blanco River @ Kyle – Streamflow Comparison

Figure 5. Nueces River @ Uvalde – Streamflow Comparison (1981)

Figure 6. Blanco River @ Kyle – Streamflow Comparison (1957)
RECHARGE ESTIMATES

The purpose of this modeling effort is to develop recharge estimates for the Nueces and Blanco Recharge Basins. With the calibration of simulated streamflow to historical streamflow, recharge was estimated by determining the component of sub-surface flow lost to deep percolation. Important contributors to this estimation were the associated land coverage, soils coverage, evapo-transpiration parameters, and recession coefficients.

Figure 7 illustrates the comparison of the long-term annual average (Nueces: 1950 – 1996; and Blanco 1956 – 1996) recharge estimates between the USGS Method, HDR Method, and the HSPF Simulations for the Nueces and Blanco Recharge Basins. Simulations in HSPF (HSPF Method) indicate that recharge in the Nueces Recharge Basin has a long-term annual average of 114,651 acft/yr, which is slightly less than the USGS Recharge estimate (119,524 acft/yr) and notably greater than that of the HDR Method (88,608 acft/yr). The HSPF Method simulates that recharge in the Blanco Recharge Basin has a long-term annual average of 71,638 acft/yr, compared to 72,261 acft/yr using the HDR Method and 49,254 acft/yr using the USGS Method.

![Figure 7. Comparison of Average Annual Recharge Estimates](image)

CONCLUSIONS

The pilot recharge models are consistent with EAA objectives of obtaining more accurate recharge estimates for input to a new aquifer model, and retain the strengths and overcome the weaknesses of the methods presently in use. Several perceived strengths and weaknesses of the previous methods are as follows:

**Strengths**
- Straightforward recharge computation procedure for most watersheds;
- Limited data requirements (streamflow, precipitation, and curve number); and
- Direct use of measured streamflow at long-term USGS gaging stations.
Weaknesses

- No provisions for geographic distribution of recharge within a recharge basin (e.g. separation of mainstem and tributary recharge, consideration of measured loss rates in stream segments traversing the outcrop);
- Dependence upon assumption that portions of a watershed atop the outcrop will respond to measured precipitation similarly to a partner watershed ("lumped parameter" modeling);
- Recharge not readily computed or reported on a daily timestep;
- Data from the EAA precipitation network not used;
- Limited capability to account for changes in watershed characteristics over time (e.g. land development, dam construction, brush proliferation); and
- Appropriate accounting for discharge from the Edwards-Trinity (Plateau) and Trinity Aquifers that contributes to recharge of the Edwards Aquifer.

Resulting estimates of aquifer recharge from the Pilot Recharge Models of the Nueces and Blanco Recharge Basins represent a significant improvement over previous estimates and will be used in the ongoing development, calibration, and application of a new groundwater simulation model of the Edwards Aquifer. It is with these improved recharge estimates that the EAA hopes will yield a better, more accurate MODFLOW groundwater model for use in planning and regulation of the Edwards Aquifer System.

REFERENCES