Prepared in cooperation with U.S. Army Corps of Engineers; U.S. Pacific Command; United Nations Educational, Scientific and Cultural Organization (UNESCO) and International Center for Integrated Water Resources Management under the auspices of UNESCO; Government of Mongolia Ministry of Environment, Green Development, and Tourism; and Freshwater Institute, Mongolia

Building Groundwater Modeling Capacity in Mongolia

Introduction

Ulaanbaatar, the capital city of Mongolia (fig. 1), is dependent on groundwater for its municipal and industrial water supply. The population of Mongolia is about 3 million people, with about one-half the population residing in or near Ulaanbaatar (World Population Review, 2016). Groundwater is drawn from a network of shallow wells in an alluvial aquifer along the Tuul River. Evidence indicates that current water use may not be sustainable from existing water sources, especially when factoring the projected water demand from a rapidly growing urban population (Ministry of Environment and Green Development, 2013). In response, the Government of Mongolia Ministry of Environment, Green Development, and Tourism (MEGDT) and the Freshwater Institute, Mongolia, requested technical assistance on groundwater modeling through the U.S. Army Corps of Engineers (USACE) to the U.S. Geological Survey (USGS). Scientists from the USGS and USACE provided two workshops in 2015 to Mongolian hydrology experts on basic principles of groundwater modeling using the USGS groundwater modeling program MODFLOW-2005 (Harbaugh, 2005). The purpose of the workshops was to bring together representatives from the Government of Mongolia, local universities, technical experts, and other key stakeholders to build in-country capacity on hydrogeology and groundwater modeling.

A preliminary steady-state groundwater-flow model was developed as part of the workshops to demonstrate groundwater modeling techniques to simulate groundwater conditions in alluvial deposits along the Tuul River in the vicinity of Ulaanbaatar. ModelMuse (Winston, 2009) was used as the graphical user interface for MODFLOW for training purposes during the workshops. Basic and advanced groundwater modeling concepts included in the workshops were groundwater principles; estimating hydraulic properties; developing model grids, data sets, and MODFLOW input files; and viewing and evaluating MODFLOW output files. A key to success was developing in-country technical capacity and partnerships with the Mongolian University of Science and Technology; Freshwater Institute, Mongolia, a non-profit organization; United Nations Educational, Scientific and Cultural Organization (UNESCO); the Government of Mongolia; and the USACE.

Figure 1. Moderate resolution imaging spectroradiometer (MODIS) image of Mongolia (image acquired by National Aeronautics and Space Administration and processed by U.S. Geologic Survey [USGS] Earth Resources Observation and Science [EROS] Data Center).

The Tuul River upstream from Ulaanbaatar provides significant recharge to the alluvial aquifer (Tsujimura and others, 2013). Photograph by Kyle Davis, U.S. Geological Survey.

Problem and Purpose

Current water use and the projected water demand from a rapidly growing urban population may not be sustainable from existing groundwater sources (fig. 2). In addition, a better understanding and optimization of adaptation actions are needed to address challenges such as melting permafrost, which is posed by climate change in Mongolia (Sharkhuu, 2003; Government of Mongolia Ministry of Environment and Green Development, 2013).

The purpose of the workshops was to bring together representatives from the Government of Mongolia, local universities, technical experts, and other key stakeholders to build in-country capacity on groundwater modeling and monitoring through training workshops. The objectives of the training workshops were to provide understanding of groundwater principles, aquifer characterization, and data acquisition needed to design, construct, and use groundwater models with case study application for the Tuul River Basin in Mongolia. An additional purpose was to meet and discuss with decision makers in Mongolia for consideration of future water-related planning activities.

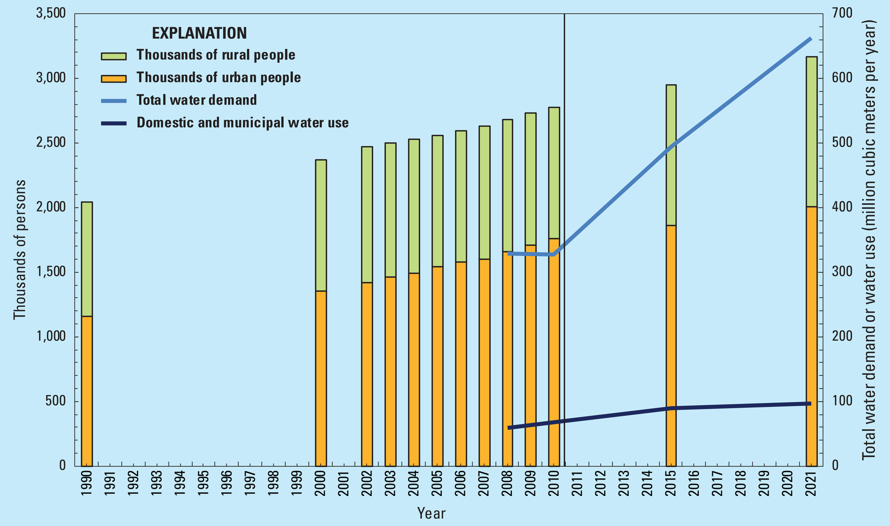

Figure 2. Population in 2008–10 and projected population growth to 2021 for Mongolia, total water demand (includes domestic, municipal, agricultural, industrial, and energy water use) in 2008–10 and projected total water demand to 2021, and domestic and municipal water use in 2008–10 and projected domestic and municipal water use to 2021. (Data source is Government of Mongolia Ministry of Environment and Green Development, 2013.)

Alluvial deposits along the Tuul River are the source of water supply to the capital city of Ulaanbaatar. Photograph by Michelle Haynes, U.S. Army Corps of Engineers.

Method Development

A preliminary steady-state groundwater-flow model was developed as part of the workshops to demonstrate groundwater modeling techniques to simulate groundwater conditions in alluvial deposits along the Tuul River in the vicinity of Ulaanbaatar. The preliminary model grid area was about 8,200 square kilometers (fig. 3*A*) and consisted of 2 layers, 226 rows, and 260 columns with uniform 500-meter grid spacing. A 500-meter grid spacing was assumed to be an appropriate discretization of the model to represent the heterogeneity of the Tuul River alluvial aquifer properties for the groundwater flow model, given the intended objectives of the workshop training. The upper model layer (active layer 1, fig. 3*B*) represented the extent of the alluvial aquifer and was digitized from surficial geology maps provided by the Freshwater Institute, Mongolia. The lower model layer (active layer 2, fig. 3*C*) represented the underlying bedrock, which includes, in part, areas that can be characterized by permafrost. The lower model layer for the model was assigned a uniform thickness because of limited subsurface data in the study area. Groundwater withdrawals were assigned to well fields (fig. 3*D*) based on production data provided by the Freshwater Institute, Mongolia. Recharge was initially estimated as a percentage of precipitation for the Tuul River Basin and adjusted manually as necessary to demonstrate model calibration techniques. ModelMuse (Winston, 2009) was used as the graphical user interface for MODFLOW for training purposes during the workshops. Groundwater modeling concepts were taught as part of the workshop and included basic groundwater principles, estimating hydraulic properties, developing MODFLOW input files, and evaluating MODFLOW output files.

Following the workshops, the Freshwater Institute, Mongolia took charge of the model. The model can be modified and updated by Mongolian scientists as more data become available. Ultimately the model could be used to assist managers in developing a sustainable water supply for current use and changing climate scenarios. Alternative water-management methods such as artificial recharge, injection wells, and high-flow diversions are under consideration. Model development was discussed with key government officials in September 2015.

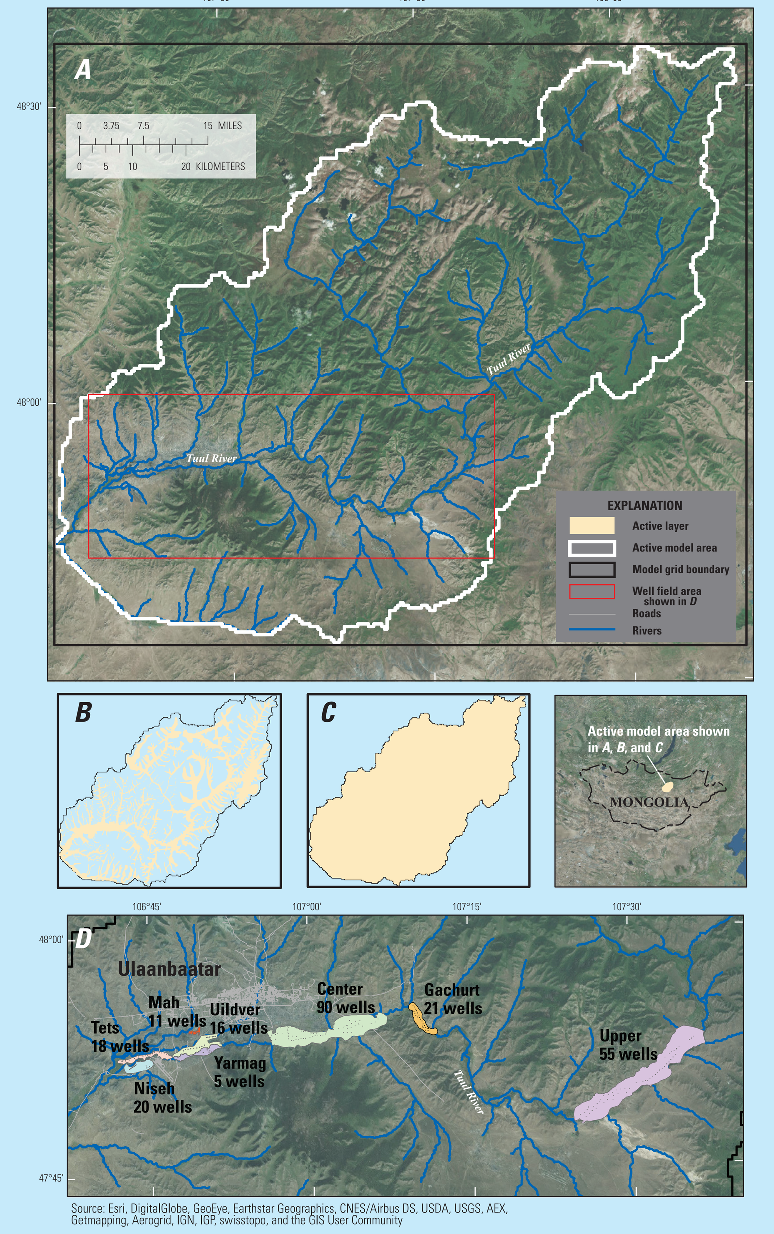

Figure 3. Images showing *A*, Preliminary model grid area and stream network; *B*, active layer 1 (representing alluvial aquifer); *C*, active layer 2 (representing bedrock); and *D*, well fields for Ulaanbaatar, Mongolia.

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Collaboration

Collage of photographs showing collaboration during workshops and meetings. Photographs by U.S. Army Corps of Engineers and U.S. Geological Survey.

- About 40 Mongolian scientists, professors, students, and government officials were trained in groundwater principles and MODFLOW, the USGS groundwater modeling software.
- Hands-on exercises using ModelMuse and class participation was a main focus to help engage the students and allow for more interactive learning.
- Meeting with small groups during breaks and at meals allowed for one-on-one learning and provided additional opportunities to discuss and answer detailed questions.

Participants for the March 2015 workshop. Photograph courtesy of U.S. Army Corps of Engineers.

Participants for the September 2015 workshop. Photograph courtesy of U.S. Geological Survey.

Conclusions

- In-country support for training, development of working relations with local contacts, and engaged participants are critical for success.
- Mongolian officials have expressed a need for more groundwater knowledge and technical ability; they know and understand the value of their limited resource.
- Future needs include more groundwater training for local hydrologists working in the Tuul River Basin and Gobi region, technical assistance for measuring water levels in wells and monitoring borehole temperatures for permafrost implications, subsurface mapping with microgravity techniques, and Gravity Recovery and Climate Experiment (GRACE) monitoring for the Gobi region.
- Groundwater monitoring and modeling with advanced technology training are crucial to capacity building and improving knowledge to address upcoming water security challenges in Mongolia.

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