CSU 2015-2016 Subsurface Water Storage Initiative

Final Report

to

Colorado State University Water Center

By

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Introduction

In July of 2015, the Colorado State University (CSU) Water Center awarded Drs. Sale, Ronayne, Bailey, and Sanford a $15k grant to advance a CSU subsurface water storage (SWS) initiative. The central tenants of the project were to:

- Build relationships with Colorado water purveyors that will set a foundation for a well-funded SWS program at CSU.
- Through student research, develop knowledge, tools, and people that can advance SWS in Colorado and around the world.

The following document results from funded activities.

Results

Activities 1 and 2 - Meeting with Interest Parties and Proposals

Parties interested in SWS were contacted, meetings were held, funding opportunities were identified, and five proposals were submitted. Meetings involved both faculty and students. All five proposal were funded, including Town of Castle Rock $25k, South Metro Water Supply Authority (SMWSA) $50k, City of Fort Collins $50k, $ Colorado Water Conservation Board 50k, and CSU Water Center $20k. Details regarding newly funded projects are presented in the following text. All of the noted projects hold the promise of long-term funding.

1) Town of Castle Rock ($25k)

- Scope:
  - Demonstrate CSU's Theis Well Field Superposition model as a:
    - Diagnostic tools for well fields
    - Means of predicting the long-term performance of aquifer storage and recovery (ASR) wells, based on the Town's ongoing ASR test well program.
  - Evaluate sustainable yields from the Denver Basin Aquifers in the vicinity of Castle Rock, CO.
- Primary contacts:
  - Heather Justus/City Engineer
  - Mark Marlowe/Utilities Director for the Town of Castle Rock

2) South Metro Water Supply Authority ($50k)

- Scope:
  - Demonstrate novel tools for characterizing the hydrogeology of potential ASR well fields.
  - Validate CSU's Theis Well Field Superposition for prediction of the performance of ASR wells based on 15 years of ASR water level and pumping records from Centennial Water and Sanitation's well field.
  - Validate CSU's ASR cost model based on pumping and cost data from Centennial Water and Sanitation's well field.
- Primary Contacts:
  - Eric Heycox/SMWSA Executive Director
  - John Kaufman/South Metro Board Member and General Manager of Centennial Water and Sanitation District
  - Mark McCluskey/CDM Smith Project Engineer

3) City of Fort Collins ($50k)

- Scope (A joint project with Hemenway Groundwater Engineering):
  - Develop conceptual designs for ASR well fields in the vicinity of Fort Collins
  - Explore critical feasibility issues including water rights, domain/control of water, water quality, and costs.
  - Develop a preliminary plan for an ASR test well program in the Fountain Formation
- Primary Contacts:
  - Donnie Dustin/City of Fort Collins Water Resources Engineer
  - Adam Jokerst/ City of Fort Collins Water Resources Engineer
  - Wade Troxell/City of Fort Collins Mayor

4) Colorado Water Institute - Fountain Formation Study ($50k)

- Scope:
  - Resolving the feasibility of ASR in the Fountain Formation based on:
    - Published hydrogeologic reports
    - Data from the Colorado State Engineers AquaMaps database
    - Inspections of geologic outcrops
    - Collection and analysis of water samples
    - Meetings with local drilling and pump contractors

        - Meeting with staff in the state engineers office
        - Hydraulic and cost modeling

- Primary Contact:
    - Reagan Waskom/Director of the Colorado Water Institute Colorado State University Water Center

5) CSU Subsurface Water Storage Symposium (20k)

- Scope:
    - Organize and hold a subsurface water storage symposium at CSU in November 2016.
    - Coordinate a key note speaker (David Pyne) and presentation by other interested parties in Colorado.
- Primary Contacts:
    - Reagan Waskom/Director of the Colorado Water Institute Colorado State University Water Center
    - David Pyne/ASR Systems LLC
    - Courtney Hemenawy/HGE

In addition, conversations were initiated with the North Poudre Irrigation Company and the Loveland-Fort Collins Water District. Furthermore, steps needed to develop National Science Foundation Subsurface water storage center at CSU were explored. It is hoped that these initiates will also lead to additional funding for SWS research at CSU.

Activity 3 – Student Research

Graduate student Cat Cannan (M.S. in Hydrogeology) was supported by this project during the spring 2016 semester. Cat is investigating the hydrogeologic framework in the South Metro area and performing numerical flow modeling to evaluate the impact of geologic heterogeneity on ASR system performance. This work provides insight into the fate of stored water in a realistic aquifer setting.

Describing the Hydrogeologic Framework

To characterize the heterogeneity in the region and create representative geologic cross-sections, geophysical well logs in the vicinity of Highlands Ranch were evaluated to identify the position of sandstone and siltstone-shale interbeds. Geophysical and visual logs for 10 wells were downloaded from the Colorado Division of Water Resources well log database (https://data.colorado.gov/Water/DWR-Well-Geophysical-Log/cfyk-gwjj). Gamma ray, shallow resistivity, and deep resistivity data for each well were converted into digital datasets at 0.15-meter intervals using NeuraLog digitizing software (Neuralog Inc., Stafford, TX). Threshold values corresponding to resistivity and gamma ray lines were chosen such that resistivity values above the threshold indicated sandstone while gamma counts above the threshold indicated siltstone-shale. To account for the varying strengths and weaknesses of each geophysical method, a combination of all three parameters was used to make a lithology call for each depth interval.

Geologic cross-sections were generated using RockWare (RockWare Inc., Golden, CO) by importing the location and lithologic calls for each of the 10 wells and allowing the program to interpret lithology between boreholes. Northwest-southeast and southwest-northeast cross-sections were chosen so that each section was based on a minimum of 5 wells, the sections were perpendicular to one another, and the sections were oriented along or perpendicular to the major axis of the Wildcat Mountain alluvial fan, an important depositional structure characterized by abundant coarse-grained material. The cross-sections are shown in Figure 1.

Flow Modeling

The geologic cross-sections (Figure 1) are used as input for pattern-based geostatistical simulation to create multiple realizations of the aquifer structure in the South Metro region of the Denver Basin. For each realization, numerical flow modeling is being performed to investigate the influence of heterogeneity (i.e., inclusion of sandstone and siltstone, sand body geometry and connectivity) on ASR system performance. Our current modeling considers a single well with 90 days of injection, a 30-day storage period, followed by 90 days of groundwater extraction. Injection/extraction rates are based on data from Arapahoe aquifer wells operated by Centennial Water & Sanitation District. We are using three metrics to evaluate ASR performance: (i) furthest extent of head change (i.e., area of hydraulic impact bounded by zero drawdown), (ii) particle travel distance (the min, max, average distance traveled for a suite of injected particles), and (iii) recovery efficiency (the percentage of injected water molecules that are recovered during the extraction phase). Particle tracking is being performed to evaluate metrics (ii) and (iii). Multiple realizations allow for the generation of statistically significant results.

Preliminary results, based on comparison to a homogeneous aquifer model, indicate that performance metric (i) has minimal sensitivity to the imposed geologic structure. Metric (ii) is highly sensitive. Interconnected high-K sand bodies allow for rapid migration of some particles (water molecules) away from the injection site. This highlights the important difference between head-change propagation and particle transport behavior. Metric (iii) is moderately sensitive to the heterogeneity. Recovery efficiencies are generally lower (compared to a homogeneous model) when heterogeneity is included.

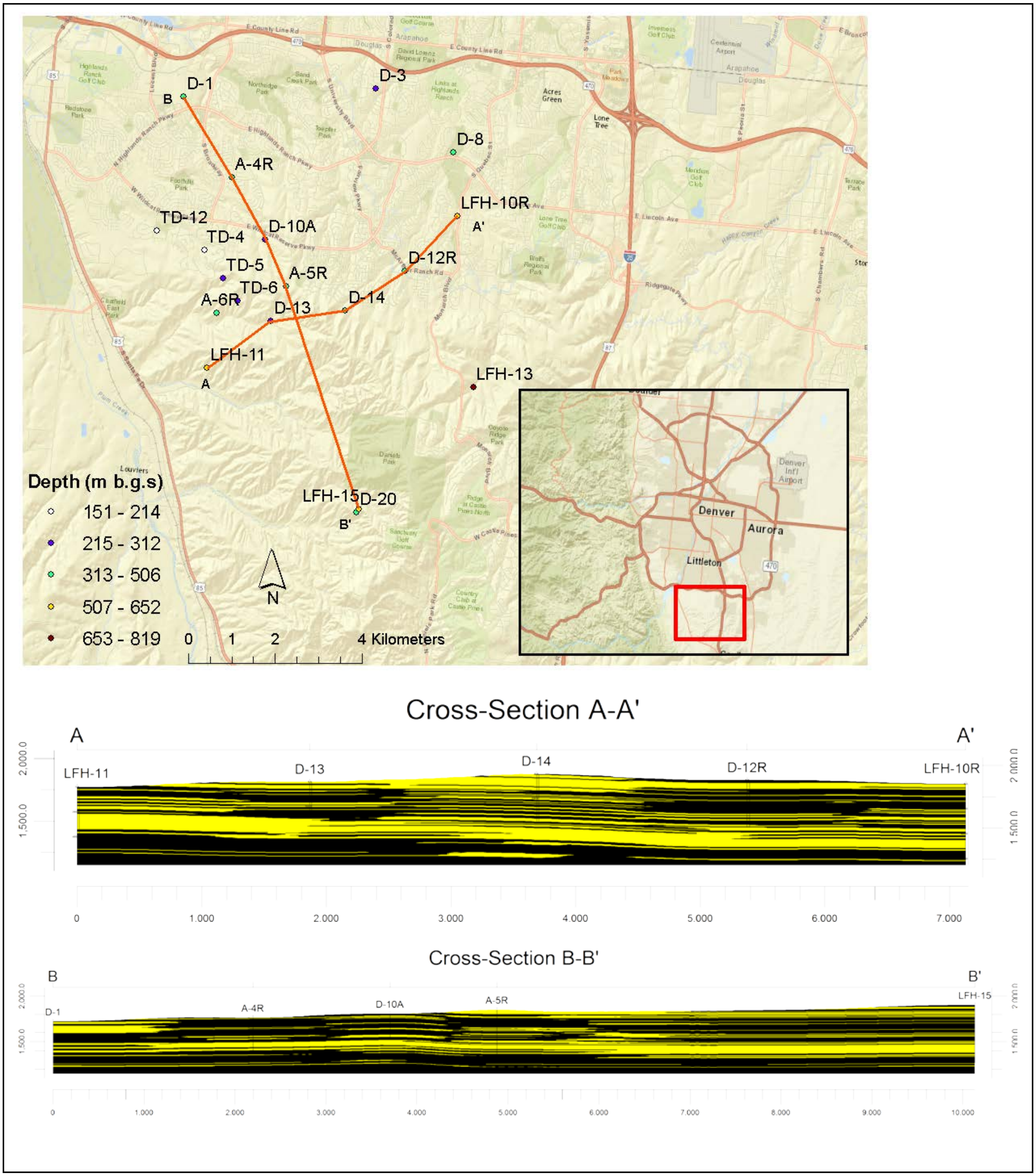

Figure 1. Base map and geologic cross sections in the vicinity of Highlands Ranch, Colorado. On cross-sections, sandstone is represented by yellow, and siltstone-shale is black. The horizontal scale is marked in kilometers; vertical scale is in meters.