RGDSS Memorandum

To: Mike Sullivan, P.E. Colorado Division of Water Resources
Andy Moore, P.E. Colorado Water Conservation Board
From: HRS Water Consultants, Inc.
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Subject: Hydrogeologic Review of Saguache Creek upstream of Town of Saguache, Saguache County CO
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INTRODUCTION

This memorandum summarizes the results of a review of the hydrogeology of the Saguache Creek valley in the area upstream / upgradient (west) of the town of Saguache as far as the Saguache Creek streamgage (see Figure 1). This work was done as part of HRS' participation in the peer review process to identify and implement improvements to the RGDSS. The study area for this hydrogeologic review included the reach of Saguache Creek generally upstream of Saguache, although the more detailed part of the review was done between the Saguache Creek streamgage and the town of Saguache (called "upper Saguache Creek" for the purposes of this memorandum).

Interim modeling results showed that where Layers 1 and 2 only are represented in upper Saguache Creek, the model has had difficulty in replicating the water levels and streamflow observed in the upper Saguache Creek valley. HRS was asked to review the available hydrogeologic data and find out whether it would be more accurate also to represent Layer 3 and Layer 4 in this area, which were not represented in the model for upper Saguache Creek. Based on recommendations from this review (most of which was done in 2011, although documentation was not completed until 2012) the model now represents Layer 3 in upper Saguache Creek in addition to Layer 1 and Layer 2. Layer 4 and Layer 5, appropriately in our opinion, are not now represented in the model in upper Saguache Creek.

We have relied on published and unpublished geologic and hydrologic data, including work done during previous phases of RGDSS, previous project work by HRS personnel, and on our

observations made during visits and field work in the upper Saguache Creek region over many years.

APPROACH

This review has been based on evaluation of available documents on the geology and hydrogeology of the upper Saguache Creek valley, including geologic maps of the area. HRS also reviewed existing well logs and well tests in the study area. No additional aquifer testing or test drilling were done as part of this review.

Upper Saguache Creek Valley: Previous Geologic Mapping and Investigations

The geology of the upper Saguache Creek valley area has been documented in published and unpublished maps and studies since at least 1971. The study area of this review is included in a geologic map and article done as part of a 1971 geologic guidebook to the San Luis Valley region[1] (Brun and others, 1971). A preliminary geologic map encompassing the study area[2] (Tweto et al, 1976) also shows the formations and general stratigraphy of the upper Saguache Creek valley. These publications provide information on the bedrock formations that underlie the Saguache Creek valley between the streamgage and the town of Saguache.

Thesis work that relates to ground water in the study area includes Huntley[3] (1976) and Frisbee[4] (2010). The Huntley study encompassed the entirety of the northern San Luis Valley, and included specific discussion of the hydrogeologic characteristics of the bedrock formations that exist in the study area. The Frisbee study was primarily a geochemical study of the hyporheic zone (zone of surface water / ground water mixing) in the Saguache Creek watershed.

[1] Bruns, D.L., R. Epis, R. Weimer, T. Steven, 1971, Stratigraphic relations between Bonanza Center and adjacent parts of the San Juan Volcanic Field, South-Central Colorado. In James, H.L., Editor, Guidebook of the San Luis Basin, Colorado. New Mexico Geological Society Guidebook.
[2] Tweto, Ogden, Steven, T.A., Hail, W.J., Jr., and Moench, R.H., 1976, Preliminary geologic map of the Montrose 1 X 2 quadrangle, southwestern Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF-761
[3] Huntley, D., 1976, Ground water recharge to the aquifers of the northern San Luis Valley: a remote sensing investigation. Colorado School of Mines, Golden, CO, Ph.D. thesis T-1864, 247 pages, plus plates and appendices.
[4] Frisbee, M., 2010, Streamflow Generation Processes and Residence Times in a Large, Mountainous Watershed in the Southern Rocky Mountains of Colorado, USA. New Mexico Tech, Ph.D. Thesis, Socorro, NM. 229 pages.

Other ground-water related studies have been done that encompass the study area. These include a San Luis Valley-wide study of the deep aquifers in the San Luis Valley done by HRS in 1987[5] and a U.S. Geological Survey (1986) study by Hearne and Dewey[6].

Formations in the Upper Saguache Creek Study Area

The formations in the upper Saguache Creek study area consist of the alluvium of Saguache Creek and its tributaries, consisting of Holocene and earlier Quaternary stream deposits, alluvial fans, and remnant terraces (Bruns et al, 1971, and Tweto et al, 1976). Together, the saturated portion of these deposits comprise Layer 1 in the RGDSS model in the study area.

There exists a geologic sequence of bedrock layers that comprise a relatively complete stratigraphic record of volcanic rock deposition in the study area. The bedrock formations are particularly well represented in Houghland Hill, located just south of the Saguache Creek streamgage (Bruns et al, 1971) (see Figure 1). However, with the exception of the deepest group of formations, Saguache Creek has eroded through the entire sequence of bedrock layers.

In the study area, the bedrock formations that underlie the Layer 1 alluvial deposits, and that are judged to comprise model Layers 2 and 3 (in the absence of more exact stratigraphy), are various volcanic and volcaniclastic rocks that can be mapped individually in some areas (Bruns et al, 1971) but which are generally considered to be part of the Conejos Formation and related formations. ("Volcaniclastic" means rocks derived from erosion and sedimentation of rocks of volcanic origin). The bedrock that is mapped below the alluvium in this area is described as:

> "Pre-ash flow andesitic lavas and breccias (Oligocene) -- vent-facies lavas and breccias an numerous widely scattered volcano sources surrounded by coalescing aprons of volcaniclastic debris. Includes extensive bodies of San Juan, Lakes Fork, Conejos, and West Elk formations as well as many local units."[7]

[5] HRS Water Consultants, Inc., with Robert Moran, 1987, San Luis Valley confined aquifer study phase one final report. Consultant's report prepared for Colorado Water Resources and Power Development Authority.
[6] Hearne, G., and J. Dewey, 1988, Hydrologic analysis of the Rio Grande Basin North of Embudo, New Mexico, Colorado and New Mexico. U.S. Geological Survey Water-Resources Investigations Report 86-4113. 244p.
[7] Tweto et al, map description for "Tpl".

Although no wells are known to penetrate to crystalline basement rock in the upper Saguache Creek valley, the available geologic mapping does show the presence of outcrops of Precambrian – age "Interlayered felsic and hornblendic gneisses" just north of the Saguache Creek floodplain in contact with Conejos formation volcanic rocks approximately halfway between the streamgage and Saguache.[8] From this, we hypothesize that Layer 4 and Layer 5 are not present in this study area.

Hydrogeologic Characteristics in the Study Area

In order to try to estimate appropriate characteristics for the aquifer layers present, HRS has reviewed the available drillers logs for wells within the study area of the upper Saguache Creek valley from the gaging station in Section 14, T45N, R6E downstream to near the Town of Saguache. There are not many wells within this area, and fewer for which driller's logs exist. The following is a brief description of the pertinent wells, listed from upstream to downstream:

- Permit No. 153117-A, Sec. 25, T45N,R6E: solid rock at 48 ft.
- Permit No. 47101-FR, Sec. 5, T44N,R7E: rocks and clay, clay, sandstone, brown, green, red, gray and black rock starting at 58 ft.
- Permit No. 20649-4, Sec. 4, T44N,R7E: sandy clay, yellow clay, brown shale, rock and hard rock starting at 70 ft.
- Permit No. 20619-3, Sec. 2, T44N,R7E: white and brown clay with sandstone and sandstone to rock starting at 89 ft.
- Permit No. 196300-A, Sec. 8, T44N,R7E: sandstone, clay, red and gray malpie starting at 2 ft.
- Permit No. 58966-A, Sec. 11, T44N,R7E: lava rock starting at 100 ft.
- Permit No. 27332, Sec. 11, T44N,R7E: volcanic rock starting at 8 ft.
- Permit No. 20618-1, Sec. 12, T44N,R7E: rock, porous rock and gravel starting at 182 ft.

Most of the driller's logs describe the Layer 1 alluvial materials as gravel, sand and gravel, or gravel with boulders, below which a clay near the base of the alluvium appears to be present in a

[8] Tweto et al, map description for "Xfh".

majority of the logs reviewed. Only one well (20618-1 F) was described as high capacity (390 gpm from a depth of 80 feet), although from the descriptions the Layer 1 alluvium even in low-production wells the alluvium appears relatively conductive to ground water flow.

Beneath the Layer 1 alluvium, the logs describe various rock types, varying from sandstone to lava rock, to "malpie" (i.e. hard volcanic rock generally dark red, brown, or black in color) to "porous rock"; sometimes described as interbedded with shale or clay, as shown above. Pumping rates in the few wells completed into the Conejos bedrock range from low (less than 10 gpm) to moderate (30 to 200 gpm), indicating a hydraulic conductivity that is highly variable (probably due in part to secondary permeability from fracturing) but which generally is in the medium range for most rocks and sediments in the San Juan foothills and the valleys tributary to the San Luis Valley.

According to Huntley (1976) a well owned by the Town of Saguache was perforated in a 524-foot interval consisting of " ..lava flows, laharic breccia and water-laid tuff, all of the Conejos Formation." [9] A 24-hour specific capacity test on this well yielded a transmissivity (T) value of "11,800 to 14,000 gpd/ft, giving a range of average hydraulic conductivity for the section of 1.3 x 1^{-3} – 1.6 10^{-3} cm/sec."[10] Huntley's estimates of hydraulic conductivity (K) for the Conejos Formation in the Saguache well convert to 3.7 to 4.5 ft/day. These are probably representative of a relatively unfractured Conejos section and therefore, based on our judgment from the many fractured zones of Conejos materials we have observed in the study area, we would consider this to be in the low range of K. From various tests conducted for the RGDSS, HRS has noted K values in the range of 100 to 200 ft/day in fractured volcanic rocks.

It is probably more representative, in this study area to consider T rather than K because the depth to the bottom of the Conejos volcanic and volcaniclastic rocks, and therefore the formation thickness of water-yielding material, is not known from driller's logs. It is not known, for example, whether the Conejos was fully penetrated in the Saguache town well, or whether the T would have been higher, still in the Conejos Formation, had the well been drilled deeper.

[9] Huntley, pp. 53-54.
[10] Ibid.

Based on the Huntley estimates of T (11,800 to 14,000 gpd/ft, equal to ~1,600 to ~1,900 ft^2/day) and an estimated range of T in the Conejos from the 1987 CWRPDA deep-aquifer study (10,000 to 25,000 gpd/ft, equal to ~1,340 to ~3,300 ft^2 / day)[11], we believe this would be a reasonable estimate of the low range of total T for Layer 2 and Layer 3 combined, in the area between Saguache and the Saguache stream gage. There are no deep water wells to define the bottom of the formation, and no pumping tests in the Conejos Formation in the study area other than the Town of Saguache specific capacity test cited by Huntley. Based on our observations of fracturing in volcanic rocks in that area, and from observations of higher hydraulic conductivity and transmissivity in fractured volcanic rocks in the San Luis Valley, we believe a more representative T probably is higher than the Huntley test estimate, most likely in the range of 50,000 ft^2/day to 100,000 ft^2/day as a total T between Layer 2 and Layer 3.

Conclusions

1. This review has shown that it would be appropriate to represent Layer 2 and Layer 3 in the upper Saguache Creek valley (between Saguache and the Saguache Creek streamgage)..
2. The available evidence shows that a lower end of T values for the combination of Layer 2 and Layer 3 in the study area is approximately 1,000 to 3,000 ft^2/day with a thickness range of 100 to 400 feet total for the two layers together at the low end of T, and in the range of 50,000 to 100,000 ft^2/day at the higher end of reasonable T values. These values are considered appropriate based on the available information, but these can be reviewed and revised as additional information becomes available.
3. From the available geologic mapping, Precambrian basement rock (gneissic rock of very low hydraulic conductivity) exists in the study area underlying the Conejos Formation. This leads to the conclusion that aquifer Layer 4 and Layer 5 are not present in this study area, and therefore it would not be appropriate to represent layers 4 and 5 in the model in this study area.

[11] HRS Water Consultants, Inc., with Robert Moran, 1987, San Luis Valley confined aquifer study phase one final report. Consultant's report prepared for Colorado Water Resources and Power Development Authority.
[11] Hearne, G., and J. Dewey, 1988, Hydrologic analysis of the Rio Grande Basin North of Embudo, New Mexico, Figure

Recommendations

From this review, we recommend that it is appropriate to refine the RGDSS model as follows:

a. Extend Layer 2 and Layer 3 upstream as far as the Saguache Creek streamgage.
b. Characterize the layers according to conclusion no. 2 above, unless better information becomes available.
c. HRS does not recommend representing Layers 4 and 5 in the model in this study area.

Comments and Concerns

None.

Figure 1: Study area of upper Saguache Creek valley: between the town of Saguache and the Saguache Creek stream gage.