CITY OF MOAB UTAH

TO: Moab Water Conservation and Drought Management Board

FROM: Dr. Kenneth Kolm and Paul van der Heijde
Hydrologic Systems Analysis, LLC

SUBJECT: Response to June 13, 2018 Comments Regarding "Hydrologic and Hydrogeologic Assessment of the Surface Water and Groundwater Resources Affecting the Moab City Springs and Wells, Moab, Utah: Phase 1 Hydrologic and Environmental Systems Analysis and Conceptual Models (HESA) by comment number.

DATE: May 25, 2019

The following is a response to comments and questions by number as referenced in June 13, 2018 memorandum:

General comment: The USGS Report is still in draft phase and is not officially published or released, therefore, all of their findings and data are still subject to change and should not be assumed to be correct or officially released. HSA/HHI, at the request of and through the auspices of the City of Moab Engineers office, have TWICE (Version 2 and Version 3) submitted extensive comments regarding the accuracy and interpretation of the USGS draft report, and have received no response from the USGS. Therefore, this Board should not assume that their report is accurate or official until it is released. Many of the comments submitted by HSA/HHI raise many of the questions regarding the interpretation of their data, and many of these suspected interpretations are what the Board has chosen to stand behind in questioning the Kolm and van der Heijde report. Therefore, many of the responses in this memorandum will contain comments that Kolm and van der Heijde have submitted to the USGS, and the Board will need to refer back to the USGS Draft Version 3 to fully understand the comments. It should be noted that all of the USGS data, although not officially released in the Draft document, fit the Kolm and van der Heijde conceptual model, including the isotope data. Pending approval from the City Engineering Department, the Kolm and van der Heijde comments regarding the DRAFT USGS Report (Version 3) should be released to the Board for further understanding of the system.

Comment on Question 1:

Page 11, 37, 38, 52: The report emphasizes no groundwater connectivity between the Glen Canyon Group (GCG) (older, lower elevations) and Tertiary Intrusives (younger, higher elevations). This finding is in direct contradiction to the draft report of the United States Geologic Survey (USGS) that stated, based on isotopes, the water in the Glen Canyon Group (GCG) actually precipitated in the higher elevations above 9,000 feet.

This finding is not in direct contradiction to the isotope data. We have determined that close to half (45%) of recharge to the Glen Canyon Mill Creek aquifer is from losing reaches of Mill Creek, which has the high elevation isotope signature derived from the discharge of high altitude groundwater subsystems 1a, 2a, and 2b into the surface water of the GSMC system (subsystem 3) as stated in the Phase 1 report. The USGS states that there is no connection isotopically to the Grandstaff system (Phase 1, subsystem 4), which we agree with. Check out Figures 9, 10, 11, and 12 in the USGS Draft 3 Report. Then check out their description starting on page 54 of Draft #3.

Here are the comments we provided *in black Italics* and on the recent draft in blue to the USGS statements in red on that part of USGS Draft #3:

P54, 55 and 56 Version 2;

.... for Site C .....the calculated CMB net-infiltration rate is about 14 mm/yr (*about 0.55 inch/year)*.

For matrix flow at that elevation and site, this net-infiltration number is quite possible. The infiltration at the ephemeral wash site, which is probably a fracture zone, is higher and faster, hence the Tritium has already passed through as stated in the report: The tritium profile at Site C (diffuse infiltration) shows a peak of 7.5 TU at a depth of 90 ft (fig. 7). In contrast, the tritium profile at Site B (ephemeral wash) shows concentrations of less than 1 TU at all depths (fig. 7).

.... for Site C … the *(Tritium)* net-infiltration rate is 35 mm/yr *(about 1.4 inches per year)*

This is close to the 10 – 12% of precipitation average that most modelers use in these environments. So by two methods, 0.55 – 1.4 inches per year recharge for a region that experiences 300 -350 mm/yr (12 – 14 in/yr) at 10% is 1.2 to 1.4 in/yr recharge rate. These rates were back calculated using water balance approaches and used in mathematical MODFLOW models (for example, Kolm, K.E. and S.M. Smith. 2012. Chapter 5. Modeling Paleohydrological System Structure and Function. In Emergence and Collapse of Early Villages: Models of Central Mesa Verde Archaeology. Edited by T.A. Kohler and M.D. Varien, University of California Press; Los Angeles, CA., pp. 73-83). The isotope methods don't include line recharge by losing tributaries (when flowing) and streams.

P56 Version 2; Statement still holds; looks like the section has been rewritten.

Because of low tritium throughout the entire profile at Site B (ephemeral wash), a 1963 tritium peak could not be detected and a TDTP net-infiltration rate was not calculated for this site.

This is precisely the most important finding of the infiltration study! The infiltration rate is extremely rapid. The 1963 tritium peak is long gone! On Site A and D, the VERTICAL infiltration is inhibited. The HORIZONTAL movement is for recharge water to move laterally to the nearest fracture zone.

P 62 Version 2; Version 3 Section is rewritten.

..... samples sourced from precipitation falling at higher altitudes and (or) during the winter should be isotopically lighter (more negative values) and plot lower and farther to the left along the global and arid-zone meteoric water lines, whereas samples sourced from precipitation falling at lower altitudes and (or) during the summer should be isotopically heavier (less negative values) and plot higher and farther to the right (fig. 9).

This fits a conceptual model that has the GCGA being recharged by infiltration of surface water (Mill, Rill, North Fork Mill Creeks) into the upper reaches of the GCGA groundwater system. This Mill Creek water would have a signature of high altitude water as this surface runoff enters the groundwater system.

Sites 15 and 14 would fit this signature. High altitude is probably 7,000 feet for recharge water for upper Navajo and Entrada rocks in the areas just below the Morrison Fm. on South and Wilson Mesas. Instead of speculation, precipitation and appropriate surface water samples should be tested at each of these elevations to see what is really falling and flowing.

P63 Version 2; Statement holds.

….. a groundwater divide likely exists, possibly along or south of the watershed upstream from Morning Glory Arch Spring., South of this divide, the GCG rocks are hydraulically connected to the primary GCGA which receives its recharge from high in the La Sal Mountains, while north of this divide, the GCG rocks are likely recharged from a lower-altitude source.

Indeed, recent analysis by reviewers showed that the Grandstaff surface water/groundwater system and the Mill Creek/North Fork/Rill Creek GCGA system are two separate hydrologic systems. Note that this latter system is not recharged high in the La Sal Mountain, but lower in the Mill Creek watershed where the GCGA system is in direct hydraulic contact with the creeks carrying high elevation mountain water.

P 64 Version 2; Statements hold.

It is also apparent that none of the stable-isotope ratios of streamflow samples intersect the region of observed GCGA waters at any point during the year, providing strong evidence that GCGA groundwater originates as recharge from distinctly higher altitudes in the watershed than even the groundwater that provides baseflow to these streams.

This statement is absolutely incorrect. The overlap of Mill Creek ratios and the GCGA range during baseflow periods of January, February, and March, as shown on Figures 9 (Plus Signs) and 10 (blue dots), is indisputable. The data presented shows a direct connection between Mill Creek data at Sheley Tunnel and Glen Canyon Group aquifer data. The statement should read "It is also apparent that several of the stable-isotope ratios of streamflow samples intersect the region of observed GCGA waters during January, February, and March, providing strong evidence that GCGA groundwater originates from distinctly higher altitudes in the watershed before recharging the GCGA at lower altitudes where Mill Creek is observed to be a losing stream (Blanchard, 1990).

P66 Version 2; Statement holds.

This spring emanates from a topographically isolated high-altitude outcrop of Glen Canyon Group bedrock above the altitude of the road, constraining its recharge location to within about 2 miles and below 7,500 ft.

This interpretation is absolutely correct as are the interpretations of samples #14, #16.

Continued Comments on Question 1:

Figure 18 of your report shows a fault-fracture zone extending from the high elevation mountains to the Johnsons Up-on-Top/ Kayenta Heights area. High elevation springs shown in Figure 24 appear to occur along the upper elevations while losing reaches from Figure 8b appear to occur along the lower elevations. Page 32 describes the fault fracture zone as "open" and the last paragraph notes that fractured Ti "focusing groundwater towards drainages in the Older Alluvial fans/ slope deposits (Qas)" and further discusses vertical movement of groundwater in the fault and fracture zones. Figure 15 shows several Qas regions along the upper reaches of the hydrostructures in Figure 18, while Figure 16 shows some of the same areas to be Morrison.

- What is happening between these Unconsolidated and Bedrock units?

As explained in the text, the groundwater in subsystems 1a, 1b, 2a,and 2b ultimately discharge, with their high altitude isotopic water, into the springs and surface water systems that then flow down, either during events or as perennial streams, into subsystem 3 or subsystem 5 to recharge the groundwater of these subsystems.

- How does one determine the extent that the Morrison is confining versus a "fractured and matrix Salt Wash member of the Morrison Fm" as noted on page 24?

The fractured and matrix Salt Wash member of the Morrison Fm is local, and mostly discontinuous units of the Dakota Burro Canyon units, beneath the 1a, 1b, 2a, and 2b subsystems. Interactions there (recharge and discharge) occur locally in the upper reaches of the landscape around the La Sal Mtns. Their high altitude ground water will discharge into the upper Mill Creek and Pack Creek systems.

- Page 42 describes the Pack Creek lower alluvium subsystem as containing fractured and faulted Entrada sandstone and Glen Canyon Group and hydrostructures, and as being "directly connected from the top of the La Sal Mountains".

By surface water. The recharge to these units under Spanish Valley is via Pack Creek water infiltrating through the gravels to the Glen Canyon rocks below. See Figure 31 for flow paths.

- What evidence is there that the GCG in this subsystem is not connected to the GCG Mill Creek subsystem?

Water quality in the wells is the main direct line of evidence. Take away Ken's Lake, and the GCG is Sulfate water. There are no major springs or seeps in the Spanish Valley to indicate connection, and there are no structural features indicating a major connection. The question is easily posed as what evidence is there that the two GCG subsystems are connected?

- What is the relative portion of matrix flow versus fracture flow in the Glen Canyon group bedrock (page 46)? Where is the matrix flow occurring?

These are good questions that are answered in the Phase 2 report. Most of the fractured vrs. matric flow areas are isolated based on geomorphology and structural geology with the aid of aerial views and field work.

- How does each flow type interact with the Valley fill aquifer?

In Spanish Valley, the valley fill aquifer interacts with all types of aquifer materials that are observed beneath it, but the gravels do not connect with the Kayenta Fault and Fracture Zones from the Golf Course area downvalley. The gravels do partially overlay the upper valley east side extension of the Kayenta Fault and Fracture Zone above the Golf Course area.

- What is the evidence supporting the claim of "*absolutely* no water with a La Sal Mountain source" in the Grandstaff system and the absence of a La Sal Mountain source in the GCG?

Besides the entire HESA results, USGS isotopes isolate Grandstaff water as unique. This is stated as a major conclusion in the USGS report, however, the report is not officially released. However, we agree with their assessment.

Comments on Question 2: Page 13: There isn't any discussion on Mill Creek from the confluence with Pack Creek to the Colorado River. We thought it was a gaining stream.

The report didn't address details on the Pack Creek Valley Alluvium beyond the general flow direction. Mill Creek is a losing stream downstream from the Powerhouse. However, beyond the confluence with Pack Creek, Mill Creek is probably a gaining stream. We are proposing to complete this as Phase 4 for the City of Moab.

Comments on Question 3: Page 14: Loss of water to evaporation at Faux Falls may be considerable. Somewhere in this section it should be identified and discussed as part of the water budget.

Phase 1 was an analysis of the overall area to determine how the surface water and ground water subsystems work and did not focus on water budgets, which are part of Phase 2. On a general note, once the water gets removed by the Sheley diversion, the surface water becomes part of the Pack Creek Valley Alluvium subsystem, and indeed would experience high ET along the Faux Falls Channel, and maybe infiltration and recharge into the Glen Canyon Hydrogeologic Group, and substantial ET and infiltration into the groundwater system will occur at Ken's Lake. This is proposed for Phase 4, and yes should be in the PCVA subsystem water budget.

Comments on Question 4: Page 17: The document identifies lake storage as a net loss of water to the Pack Creek system. Please explain your reference to lakes on the Pack Creek system.

There are several small lakes at the end of the Pack Creek diversion ditch near the San Juan and Grand County lines. When filled, these lakes will experience ET.

Comments on Question 5: Page 42: The document notes that all of the subsystems have some form of interconnectedness with the other subsystems, mostly by tributary or truck stream flow. What do you mean by truck?

Misspelling, should be trunk as in trunk stream or main channel.

Comments on Question 6: Page 45: The document discusses several northeast-southwest trending fracture zones that are important to the Moab City Springs and Wells. There is also one other fracture zone that would warrant discussion, which is essentially along the Sand Flats road and could affect the Skakel Springs. There is concern about development in that area.

The Kayenta Fault and Fracture Zone is a zone and includes the syncline and fault that borders the top of the western edge of sand flats. If the concern is the Lionsback Development, the authors agree that for Phase 3, protection of the Skakel Spring will probably extend to include part of that area as the surface water and ground water may affect the water quality of Skakel Spring.

Comments of Question 7: Page 56: The document discusses the lower Spanish Valley and influences to Pack Creek. We would appreciate understanding this system better. There are numerous springs on the southwest side of Pack Creek that have fairly high Total Dissolved Solids (TDS). Is the TDS being leached out of the alluvium or is the groundwater in the Paradox formation adding high TDS water to the valley fill system?

Phase 1 determined the 5 subsystems of the study area. With the focus on the City's identified Wells and Springs, the details became the Glen Canyon Mill Creek subsystem, and the other 4 subsystems were kept to general conditions. The authors have not detailed the west side of Spanish Valley as to its hydrogeologic fracture zone yet, but have proposed this analysis for Phase 4. We would agree that the high TDS of the hydrogeologic feature could be due to several processes: 1) the Pack Creek recharge water provides significant TDS by flowing over predominantly Morrison Fm water upstream; 2) recharge from runoff of the Rim provides significant TDS by flowing over Moenkope and Chinle Fm units; and 3) there could be interaction between the Cutler and Paradox units with the groundwater near the spring discharge areas. We would "flush" this out (poor pun) in Phase 4.

Comments of Question 8: Page 57: The document discusses groundwater return flow to lower Mill Creek from irrigation and other sources. We are assuming you are speaking about Mill Creek after it enters the Spanish Valley near Powerhouse Lane. Please elaborate on your interpretation of lower Mill Creek's location.

Yes, this would be part of Phase 4, but the initial water quality observations show that the groundwater system below the Pack Creek confluence is affected by Skakel and Ranch House Springs contributions, and by the deep brine near Mathewson wetlands and the Colorado River.

Comments on Question 9: Page 64: The document states "There is no significant direct groundwater connection between the Glen Canyon Group Mill Creek (GCMC) subsystem and surrounding subsystems through shallow or deep hydrogeologic units." It seems some of the material in this report may not substantiate this statement. Are we sure the groundwater in the GCG under the valley fill system is completely separated from the Mill Creek GCG groundwater?

Phase 4 should provide more defining evidence on this question. The Chapman aquifer test and the San Juan County aquifer analysis confirm the presence of the extension of the Kayenta high K fault and fracture zone on the north east side of the Spanish Valley. Neither of the aquifer tests were conducted long enough to prove connectivity to anything whether Mill Creek or Ken's Lake. Both aquifer tests found the fracture zone almost immediately and were shut off as successful. Until there were wells, there was no smoking gun….no major springs, no seeps, and really, no defining hydrogeologic structure to carry the ground water through basically Johnson's Up On Top (a hydrogeologic dam if you will). An analysis of the pre 1980 data may help clarify this in Phase 4 meaning what was the water quality like then in the wells as there was no Ken's Lake or springs, and very little recharge from JUOT as the glacial gravels overlie relatively poorly fractured Entrada in the southern part – a veritable parking lot surface if you will with not a lot of water gushing anywhere on the sides or bottom.

Comments on Question 10: The narrative on gaining and losing reaches does not seem to accurately reflect the data presented in Figure 8 a – c (based on Blanchard 1990)

- Page 12 - What happens to the water from the losing reach above Sheley diversion (MC 7 at 0.8 Cubic Feet Per Second (cfs) or 579 Acre Feet (AF)?

We have two fracture zone/French drains accepting recharge from Mill Creek. The first is the linear stretch coming from the La Sal Mtns to the Sheley diversion. This reach of the "upper" Mill Creek drain is deep and porous, and begins to fill with ground water here, hence the losing reaches.

- There are losing reaches immediately below Sheley diversion (MC 9 at 0.55 cfs or 398 AF) and near upper Johnsons Up-on-Top (MC 11 at 0.9 cfs or 65 AF). How much do these losing reaches contribute to the Gaining reaches at MC 12 + MC 13 compared to the gains from the additional recharge catchment areas above these points (assuming a recharge of 1-2 inches of annual precipitation (per page 7)?

This is the second and main reach of the Mill Creek French Drain, and the depth of the drain is from 200- 500 ft or more (based on well data), the width of the drain is up to several hundred feet, and the length of the drain is the Mill Creek drainage. We have a lot of French Drain to fill. For quantitative amounts, see calculations in Phase 2 under storage. The drain is so deep, it precludes flow across the first cross valley fracture referred to as the Sheley diversion or Faux Falls fracture zone. However, the Drain is full by Spring Creek or the second cross valley fracture system, so water has a pathway to the City Wells and Springs. This is the second major losing stretch of Mill Creek.

Comments on question 11: Page 13 – There are three data points on losing reaches (MC 17 – MC 19) immediately upstream of the confluence with North Fork. Do these losing reaches function similarly to the Moab City Springs fracture zone described on page 32? Please explain.

This is the third reach of the Mill Creek French Drain, although we don't have wells here to calibrate depth. We are filling up the French drain here again, and the cross valley fracture zone is the North Fork through Powerhouse section, and Mill Creek exits through here to the main Spanish Valley with its surface water and ground water.

- The last full paragraph on page 47 only discusses the two losing reaches that most directly align with the City springs and wells and needs elaboration to describe where water from these other losing reaches goes. Can you share a table of the gaining/ losing reaches compared to contributing watershed area and known spring discharges?

Blanchard has this data in table form of his report although he isn't looking to correlate these values with recharge area. Existing studies and data have not identified sufficient data to delineate capture zones for the city's springs and wells. Blanchard also may have had Cottonwoods and Willows providing ET and sucking surface water levels down during his measurement dates.