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August 8, 2023

Mr. Denis Payre, President and CEO
Nature & People First Arizona PHS, LLC
405 Waltham Street, Suite 145
Lexington, MA 02421

RE: Technical Memorandum – Evaluation of Pumping from the C Aquifer Beneath the Proposed Pumped Hydro Storage Project, Navajo County, Arizona

Dear Mr. Payre:

Matrix New World Engineering (Matrix) has conducted a cursory review of published hydrogeologic information for the regional C aquifer beneath the proposed Pumped Hydro Storage (PHS) project in Navajo County, Arizona. This technical memorandum evaluates the C aquifer as potential supply to the PHS project considering comments received from the Tribe on the proposed use of wells in the N aquifer. References and sources include reports by United States Geological Survey (USGS), Arizona Department of Water Resources (ADWR), U.S. Bureau of Reclamation, and others.

Aquifer Characteristics

Below the Navajo Sandstone (e.g., N aquifer) at the project are the primary mudstone and shale beds of the Moenkopi Formation from approximately 2,000 to 2,750 feet below land surface (bls). The Moenkopi Formation acts as confining layer to groundwater in the primary sandstone unit of the C aquifer that is the Coconino Sandstone (beneath the Kayenta Mine Complex) or the De Chelly Sandstone (east of the project towards the Defiance Uplift). The sandstone is approximately 610 to 730 feet thick and lies above primary shale beds of the Supai Formation (or Organ Rock Formation). From results of drilling at the Kayenta Mine Complex (Stetson, 1966), the C aquifer is described as a light reddish brown, fine-grained, poorly cemented sandstone with thin beds of soft white clay.

Groundwater movement in the C aquifer is generally north from the Mogollon Rim towards the Little Colorado River (LCR). However, groundwater also flows north and west into Black Mesa Basin from the Defiance Uplift near Gallup, New Mexico. Static level elevation of C aquifer beneath the PHS project is approximately 5,100 feet above mean sea level (amsl), i.e. 970 feet bls. Based on review of readily available published data and inputs to regional groundwater flow models, estimated aquifer parameters of the C aquifer beneath the PHS project are summarized in the following chart.

Chart 1 – Estimated aquifer characteristics of the C aquifer beneath the project

Static Water Level (feet bls)	Depth to Top (feet)	Thickness (feet)	Transmissivity (gallons per day per foot)	Porosity (%)	Hydraulic Conductivity (feet/day)	Pump Capacity (gallons per minute)
970	2,750	700	70 – 1,500	11	0.02 – 0.5	100 – 350

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Recharge

The C aquifer covers an area greater than 27,000 square miles (Jones and Robinson, 2019) that includes more than 1,000 wells and springs sites in the surface drainage of the LCR Basin. The average annual amount of natural recharge to the C aquifer from rain and snow is estimated at 290,000 acre-feet that is roughly equal to the estimated discharge of 319,000 acre-feet per year (AFY) to springs in LCR and the Verde Valley (USBR, 2006). Areas with the greatest potential of direct recharge to the C aquifer are located along the Mogollon Rim (e.g., Springerville, Arizona to Flagstaff) and at the Defiance Uplift. The amount of groundwater storage in the C aquifer is estimated at approximately 400 million acre-feet (Hart et al. 2002)

Existing Withdrawals

Groundwater pumping from the C aquifer of approximately 140,000 AFY (Hart et al., 2002) is concentrated off the Navajo reservation along the Interstate-40 corridor between St. Johns and Winslow, Arizona where depth to water in the C aquifer is generally less than 1,000 feet bls (ADWR, 2009). Primary pumping from the C aquifer is for industrial uses (e.g., three power plants) followed by municipal demands for Flagstaff, Winslow, and Holbrook.

Total groundwater withdrawals on the Navajo reservation from all aquifers (i.e., T, D, N, and C) to meet demand of both residential and commercial users is approximately 15,300 AFY (ADWR, 2009), excluding pumping at the Kayenta Mine Complex. Twin Arrows Casino and communities of Cameron, Ganado, Leupp, and Chinle rely on the C aquifer (CRBTTP, 2018), that when combined, are estimated to use approximately 1,200 AFY. As such, pumping by the Navajo Nation from the C aquifer is estimated to account for less than 1% of the total pumping from C aquifer.

Production Wells

Production rates reported for wells in the C aquifer range from less than 15 gallons per minute (gpm) to over 1,000 gpm. The capacity of a well is a function of secondary porosity from fractures or cavities, well design (e.g., diameter), and penetrated aquifer thickness. Using the aquifer parameters for the C aquifer shown in **Chart 1**, the proposed PHS project demand of 3,000 AFY for 2-years (i.e., 1,860 gallons per minute) will likely require installation of *at least* six (6) wells, and potentially as many as twenty (20) wells. For groundwater to be withdrawn exclusively from the C aquifer, it is proposed to construct each project well with a telescoped configuration like that shown on **Figure 1**. The estimated cost and schedule for drilling, construction, and pumping from a well installed in the C aquifer beneath the project is summarized in the following chart.

Chart 2 – Estimated well drilling, construction, and pumping costs for C aquifer

Total Depth (feet)	Casing Diameters (in)	Well Construction Cost	Pump, Pipe, & Controls Cost	Total Cost Per Well	Schedule to Complete Each Well
3,600	24, 16, 8	$2,860,000	$655,000	$3,515,000	4 – 6 months

Test Well

A test well is proposed to be installed at the PHS project as part of a feasibility study. The purpose of the test well is to measure depth, thickness, aquifer parameters, and water quality of the C aquifer. The test borehole should be a total depth of approximately 4,000 feet bls to penetrate the full thickness of the Coconino Sandstone and into the middle unit of the Supai Formation. Lithologic and geophysical logging performed during borehole drilling can be used to design a small diameter test well. The test well can be completed with several depth specific grout-plugs and casing perforations and installed with a small diameter pump and packers for purposes of low flow testing and sampling. The estimated cost to drill a test well and to install a pump set to 3,000 feet bls that is capable to withdrawal 15 gpm is approximately $750,000 to $1.2MM. If the results of the test well are favorable it may be possible to convert it into a production well that pumps 100 gpm or more.

Water Quality

The concentration of total dissolved solids (TDS) is a broad measure of water salinity that has been studied extensively in the C aquifer. National Primary Drinking Water Regulations do not set a Maximum Contaminant Level (MCL) for TDS. However, the EPA does set a Secondary Guideline (non-enforceable) of 500 mg/L, and Health Advisory if water is above 2,000 mg/L. Water with TDS ranging from 3,000 – 10,000 mg/L is considered brackish; seawater has TDS that is typically about 35,000 mg/L. Approximately 50% of tap water in Arizona has TDS concentrations that fall between 500 to 1,000 mg/L.

USBR (2006) reports that water quality of the C aquifer generally has higher concentration of TDS at greater distance from areas of natural recharge (e.g., Mogollon Rim and Defiance Uplift) and at increasing depth. Wells that penetrate the upper and middle members of the Supai Formation that include evaporite deposits will have much higher TDS concentration. Groundwater from the C aquifer is found to have TDS concentration over 3,000 mg/L in areas south of the Navajo reservation along the Interstate-40 corridor. Conversely, TDS concentration at wells installed in the C aquifer approximately 35 miles east-southeast of the PHS project near Many Farms, Arizona have reported TDS concentration that is less than 500 mg/L. TDS concentration of a sample collected from the C aquifer beneath the Kayenta Mine Complex was 740 mg/L. Based on the nearest data points, the quality of groundwater in the C aquifer beneath the PHS project can be reasonably assumed to be less than 1,000 mg/L.

A widely used and proven technology to reduce TDS concentration (desalination) is reverse osmosis (RO). RO uses a semi-permeable membrane to separate the salts from the water. Depending on total hardness and sulfate concentrations, RO combined with softening and blending is capable to treat brackish water to levels below 500 mg/L. Approximately 25% of RO feedwater is discharged as waste that must be treated, contained, or otherwise disposed in accordance with applicable laws (e.g., landfill). Treatment costs range widely depending on influent concentration and scale of operation. A single industrial RO system to produce approximately 300 gpm is estimated to cost $2MM to $4MM.

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Permitting

A Water Well Drilling Application/Permit must be filed with the Navajo Department of Water Resources (DWR) Technical , Construction and Operations Branch (TCOB) for each well on the project. Water Use Permit Application(s) must be filed for the source of water used during drilling the well, and within 30-days of completion of the well. Use of water at the well(s) must be metered and reported to NDWR on an annual basis and paid for at the applicable water use rate fee. The filing fee for these permits is $25, respectively.

Navajo Nation Code Title 4, Chapter 13, otherwise cited as Navajo Nation Clean Water Act (NNCWA), provides the definitions and policy of the Navajo Nation Council to protect the residents of Navajo Nation from point and non-point sources pollutants into surface waters. Implementation and enforcement of NNCWA is by the Navajo Nation EPA. The Director is ultimately responsible to establish water quality standards for the PHS project and to adopt criteria for monitoring or other assessment methods consistent with the NNCWA. Even if there is no applicable limitation or standard for the activity in question, the Director must certify that the application for discharge is compliant with federal water pollution control requirements. A meeting with NNEPA is recommended to initiate discussion of discharge permits for the PHS project.

Please contact the undersigned at (928) 771-0610 with any questions.

Respectfully,

Matrix New World Engineering

REGISTERED GEOLOGIST
CERTIFICATE NO. 46233
DYLAN J. EASTHOUSE
Date Signed 8-8-23
ARIZONA, U.S.A.
Expires: 6/30/25

Dylan J. Easthouse, RG
Senior Project Hydrogeologist

Attachments: Figure 1 – Conceptual Design, C aquifer Well

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References

Arizona Department of Water Resources (ADWR), 1994, Arizona water resources assessment, V. II, Hydrologic summary: Arizona Department of Water Resources, Hydrology Division, 236 p.

Arizona Department of Water Resources (ADWR), 2009, Arizona Water Atlas, Volume 2 Eastern Plateau Planning Area, December 2009.

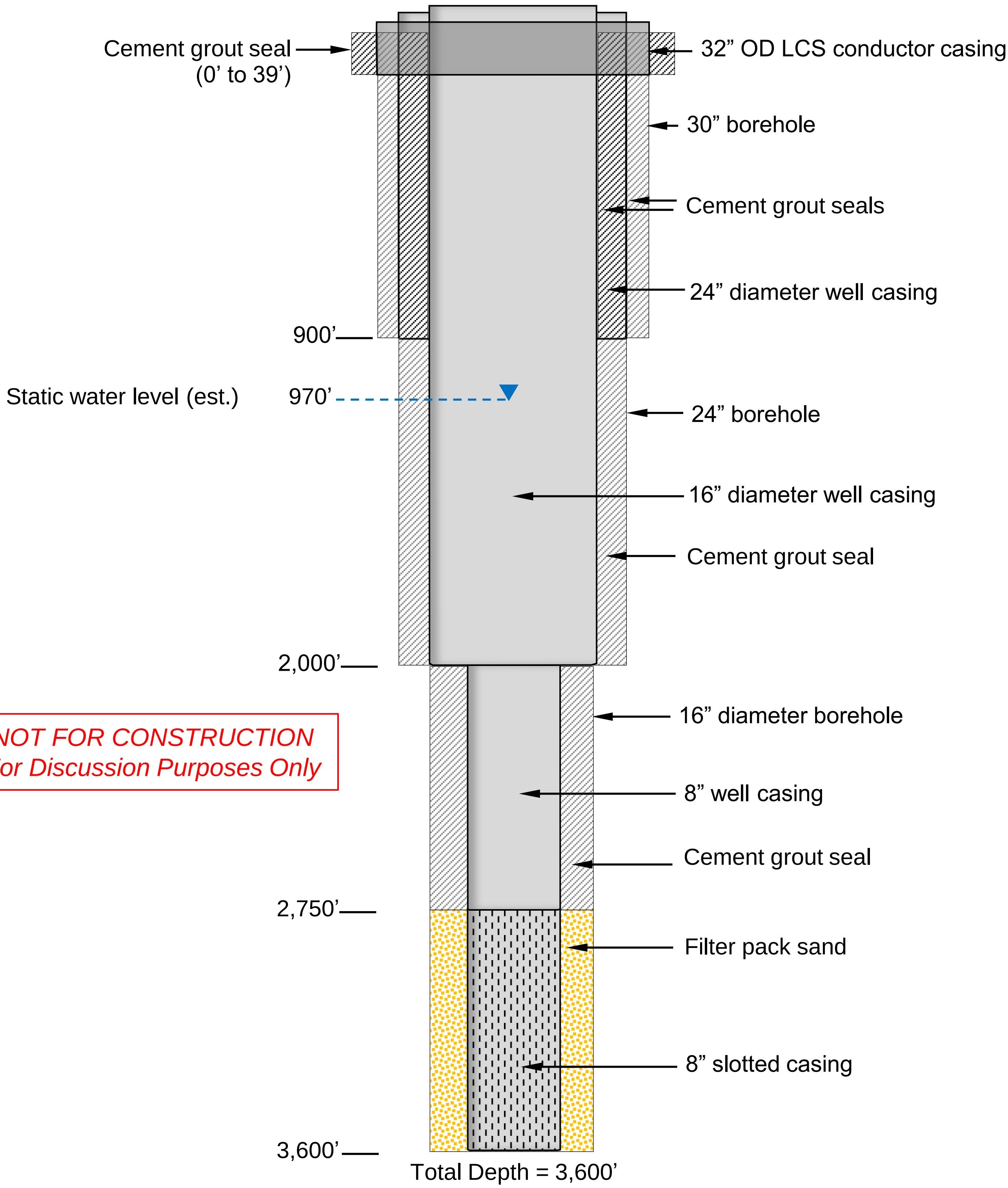
Colorado River Basin Ten Tribes Partnership (CRBTTP), 2018, Tribal Water Study, Chapter 5.5-8. Navajo Nation, December 2018

Hart, RJ, J.J. Ward, D.J. Bills and M.E. Flynn, 2002, Generalized hydrology and ground water budget for the C aquifer, Little Colorado River basin and parts of the Verde and Salt River basins, Arizona and New Mexico: USGS Water Resources Investigations Report 02-4026.

Jones, C.J.R., and Robinson, M.J., 2021, Groundwater and surface-water data from the C-aquifer monitoring program, Northeastern Arizona, 2012–2019: U.S. Geological Survey Open-File Report 2021–1051, 34 p.

Navajo Nation Department of Water Resources (NNDWR), 2011, Draft Water Resource Development Strategy for the Navajo Nation, July 2011. 127 p.

United States Department of the Interior Bureau of Reclamation (USBR), 2006, North Central Arizona Water Supply Study – Report of Findings, October 2006. 341 p.



NOT FOR CONSTRUCTION
For Discussion Purposes Only

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CONCEPTUAL DESIGN
C AQUIFER WELL

PHS Project, Navajo County, Arizona

FIGURE NUMBER:
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