Review of Draft UNFC Supplemental Specifications for Groundwater Resources by Michelle Walvoord, Ph.D., Research Hydrologist, United States Geological Survey, Earth Systems Processes Division

I have reviewed the draft document United Nations Framework Classification For Resources (UNFC) – Supplemental Groundwater Specifications prepared by the Groundwater Resources Working Group of the Expert Group on Resource Management. The document describes a groundwater specification classification system to aid management and decision making associated with groundwater-resource projects using a consistent framework for evaluation. Resource projects are classified based on three criteria: (1) environmental, social, and economic viability, (2) technical feasibility and maturity, and (3) confidence in the expected outcomes. Overall, I found the material described at a level that is appropriate for the intended audience of resource managers and groundwater professionals involved with operating projects to estimate groundwater quantity and quality. I identified some areas for improvement with respect to technical correctness, consistency, and clarity, as detailed below. With minimal experience in water management or policy, I abstained from weighing in on the usefulness of this classification scheme and will offer this review from the technical perspective of a groundwater scientist.

Introduction, Groundwater Overview: This section could use some clarification as to what is meant by "shallow" and "deep" groundwater. To some "deep" may imply > 10^1 to 10^2 meters deep; to others "deep" may imply > 10^3 to 10^4 m deep. Without some distinction, I would question the blanket statement that deep groundwater "has high mineral and salt content and requires treatment".

Also, with respect to the statement that "Deep groundwater…participates in the rock cycle…" I would note that shallow groundwater is also influenced by weathering processes, though typically on shorter timescales.

In addition to mineral content, nutrients, metals, and pathogens in groundwater are also key concerns for groundwater use. Consider adding these relevant concerns.

Consider adding some descriptive text regarding unconfined aquifers and confined aquifers that may be useful to follow up in the context of classifying environmental viability within the E-Axis score and associated descriptions on page 27. Using terminology like unconfined and confined aquifers may have may more relevance and extensibility than shallow and deep.

Introduction, Socially Necessary Groundwater Projects: The rationale for the inclusion of a new sub-category of "socially necessary" groundwater projects is well described in this section.

Terms and Definitions, Groundwater Sources and Products: A groundwater source is defined in great detail in the section. I would suggest making a clarifying statement on whether frozen groundwater would be considered a source: for example, porewater ice, ice lenses, or ice wedges in permafrost. As written, this subsurface water source is not clearly included, nor is it excluded by the bulleted list in this section. I would recommend including subsurface ground ice as a groundwater source due to the rapid changes in permafrost expected for the foreseeable future.

Environmental, Social, and Economic Viability – The E-Axis Score: The four classes described at the bottom of page 10 to the top of page 11 and Table 1 for the E-Axis include definitions that consider only

groundwater quantity, not quality, with respect to sustainability. The authors do make some notes regarding water quality toward the middle of page 11. These elements could be expanded for improved clarity as to how the chemical quality of groundwater should be considered in this classification axis. Some effort is made in E-Axis- Environmental-Social Economic Viability: Schedule E.A. and E-Axis-Environmental-Social Economic Viability: Schedule E.B. to provide some clarity along these lines.

Technical feasibility and Maturity– The F-Axis Score: The classification scheme associated with the F-axis score is quite straightforward and well explained. One suggestion is to follow the line of chemical quality acceptability/treatability mentioned in F1 into the Additional Groundwater Context text in F2-F4 in Table 4.

Degree of Confidence in Groundwater Deliverability – The G-Axis Score: The classification scheme associated with the G-axis score is well explained using both statistical and plain language. I would suggest adding high confidence and low confidence in the definition column of Table 5 for the low case and high case, respectively, to promote clarity.