Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Estimating Global Groundwater Resources

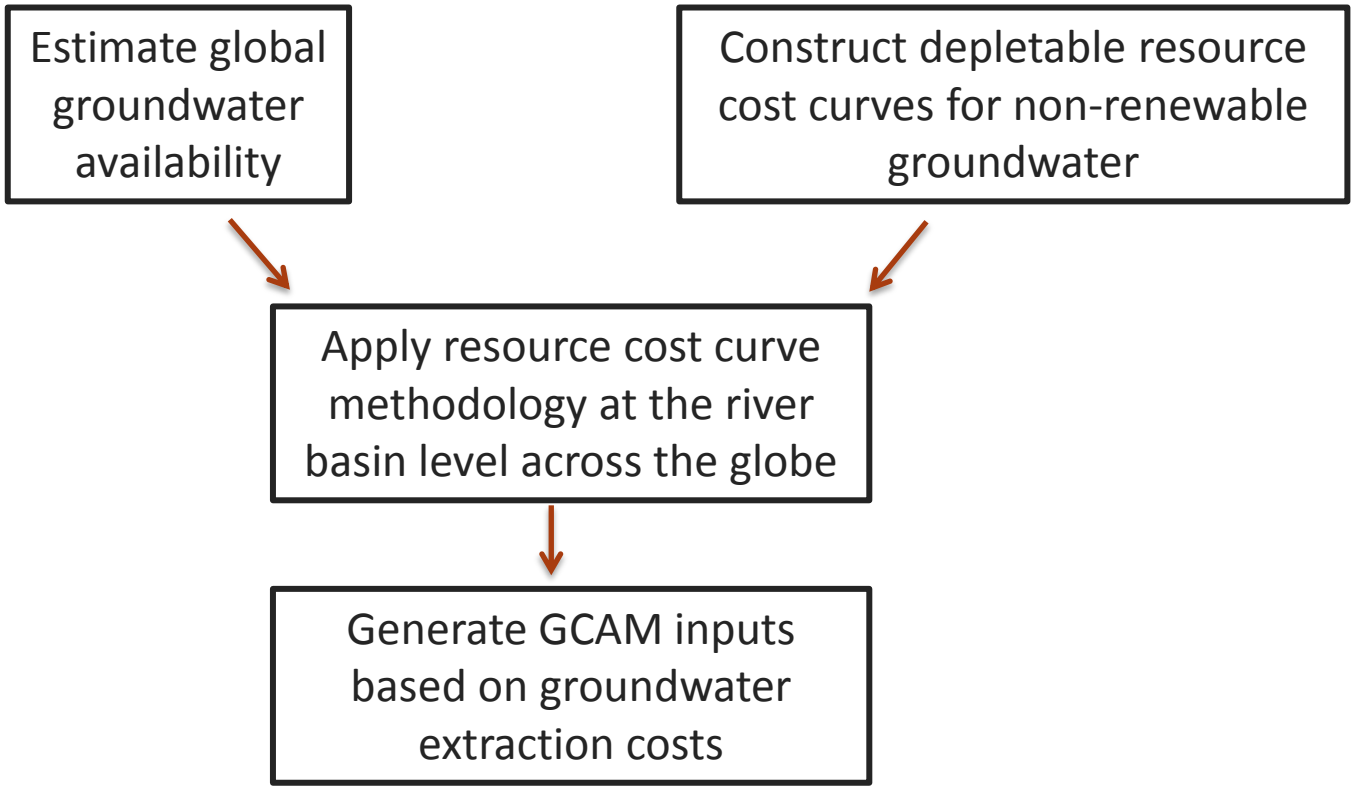
Catherine Yonkofski[1], DJ Watson[1], Mohamad Hejazi[1,2]

1. PNNL
2. JGCRI

Objective

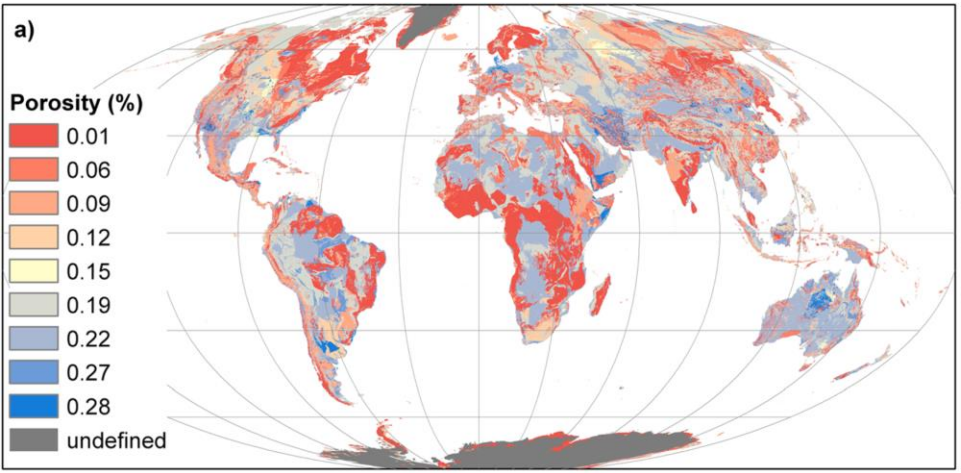
- Incorporate non-renewable groundwater extraction cost-curves into GCAM
- Under what circumstances could deep, potable groundwater serve as a feasible alternative resource for drinking water or agriculture?

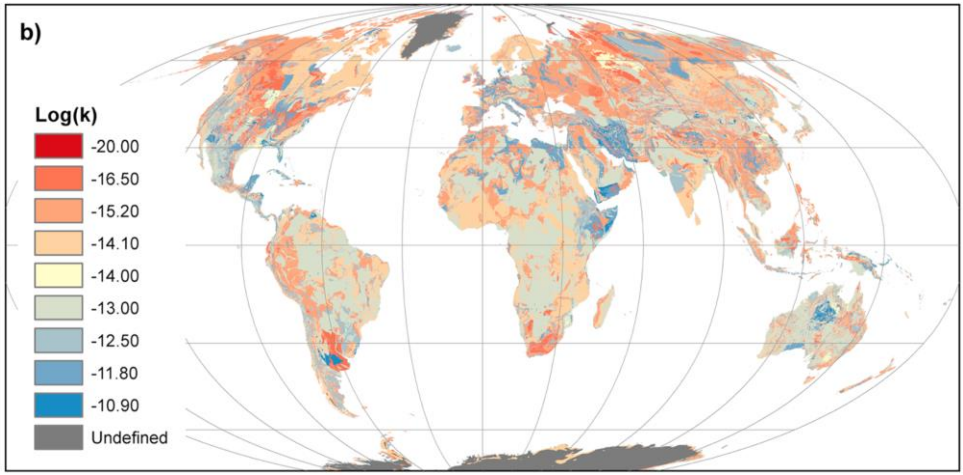
Overview


Estimate global groundwater availability
Construct depletable resource cost curves for non-renewable groundwater
Apply resource cost curve methodology at the river basin level across the globe
Generate GCAM inputs based on groundwater extraction costs

Estimate Global Groundwater Availability

Groundwater Volume = Saturated Thickness x Aquifer Areal Extent x Porosity



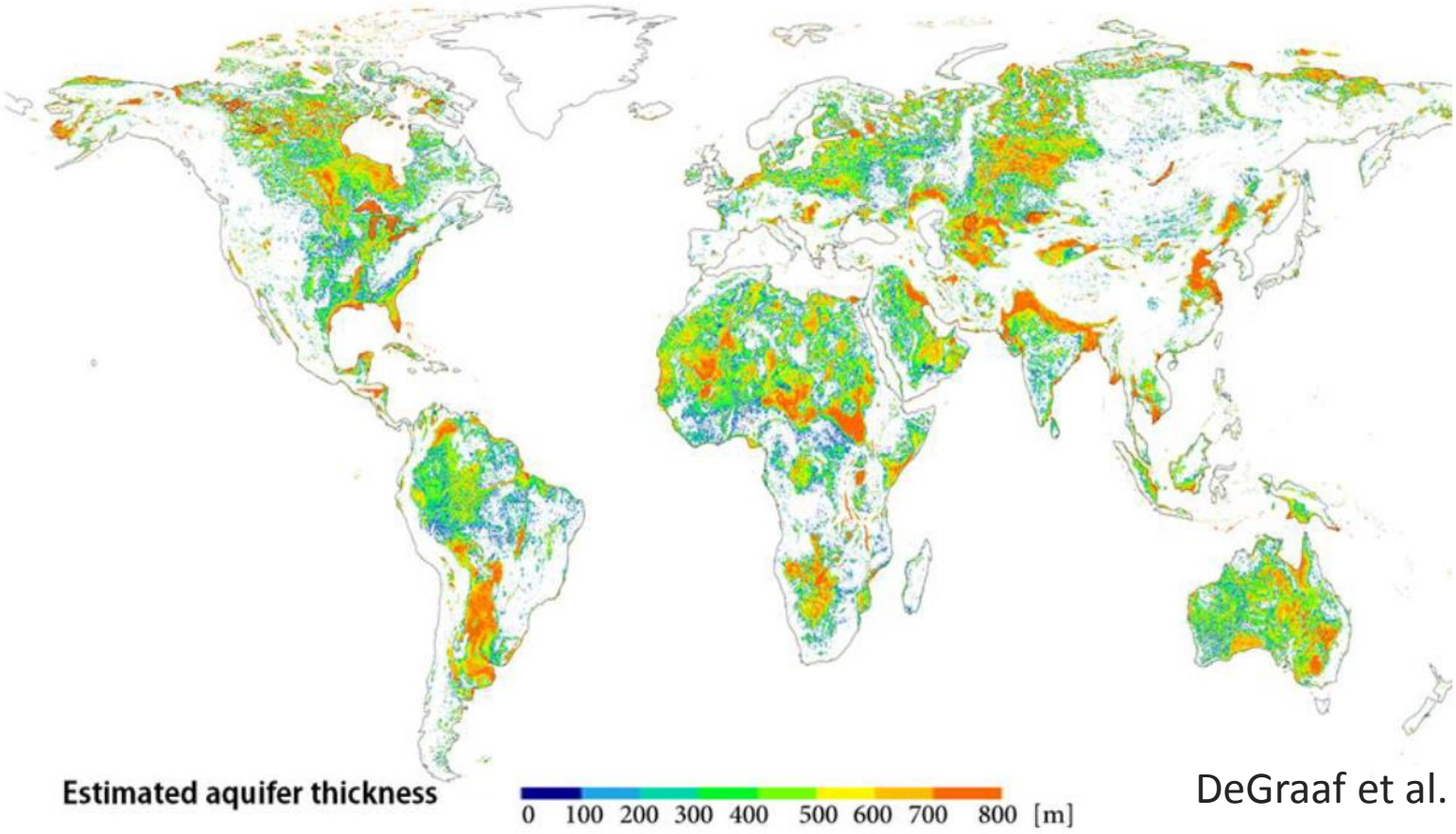


GLobal HYdrogeology MaPS (GLHYMPS)

Gleeson et al. (2014)

Estimate Global Groundwater Availability

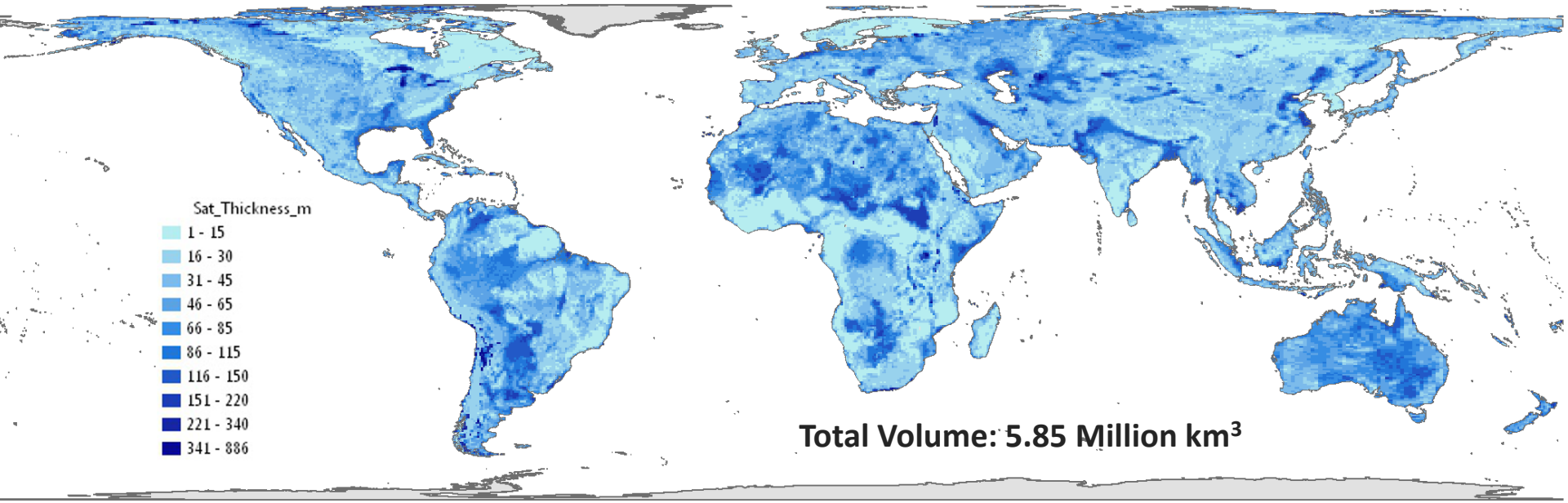
Groundwater Volume = Saturated Thickness x Aquifer Areal Extent x Porosity



DeGraaf et al. (2015)

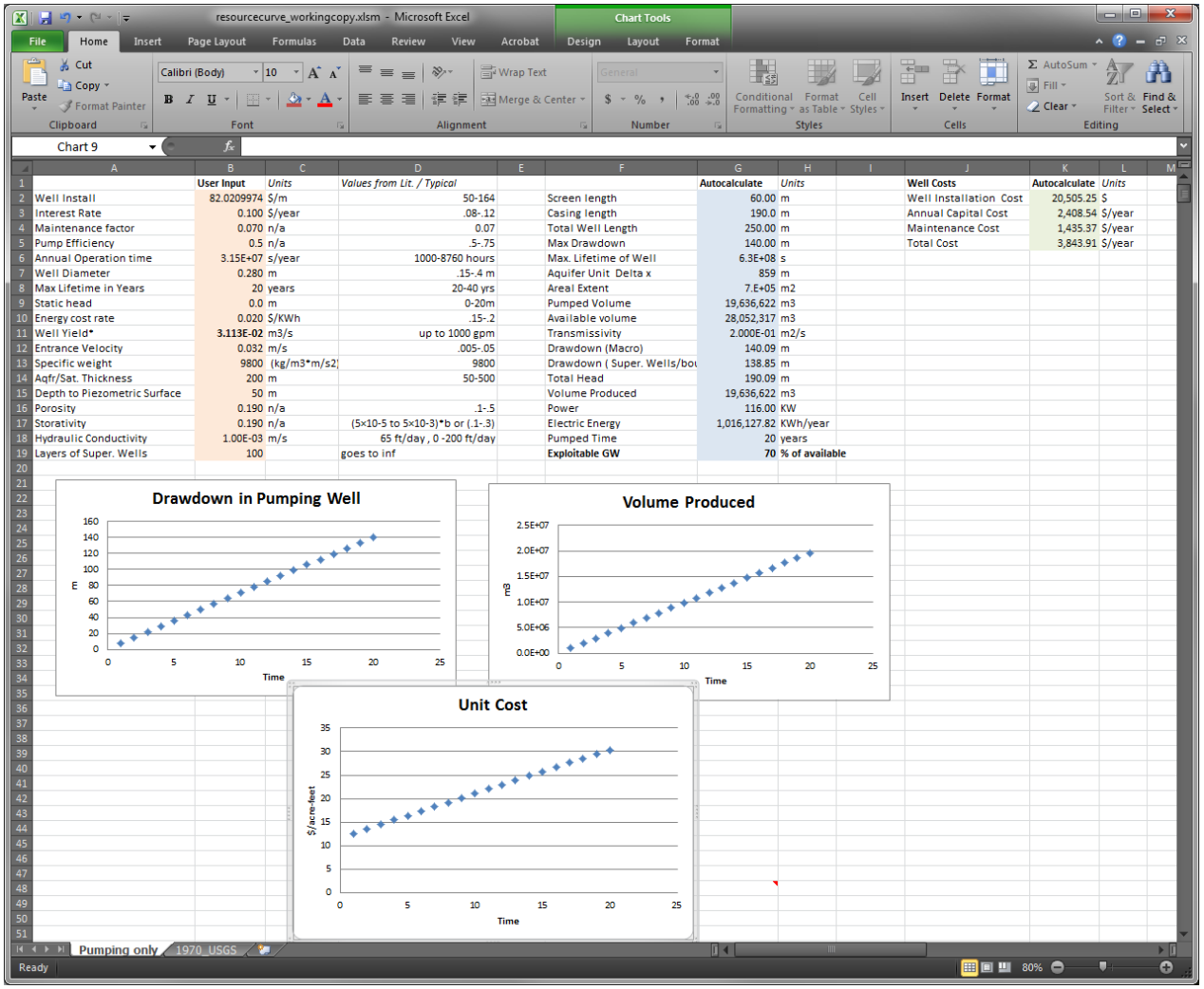
Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Results: Available Groundwater Volume



Previous Estimates	*Million km³*
Nace (1969)	1-7
Nace (1971)	4-60
Garmonov (1974)	23.4 (3.6 active)
L'Vovich (1974)	60 (4 active)
NRC (1986)	15.3
Gleeson et al. (2016)	22.6 (0.35 young)

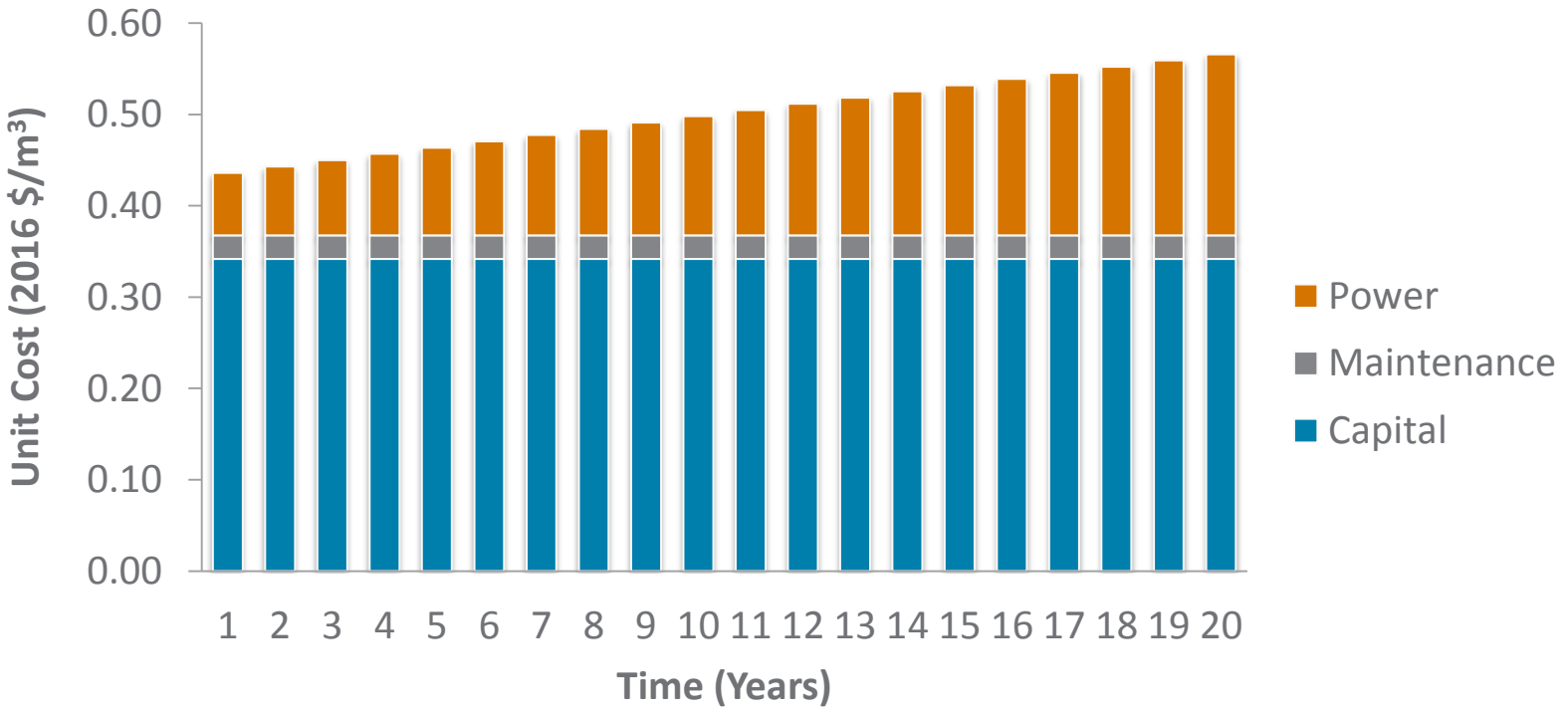
Groundwater Production Cost Curves



We've generated a framework that defines a cost function for production from a single well based on an analytical GW flow solution.

Current costs reflect the cost of electricity to produce water and well drilling/installation.

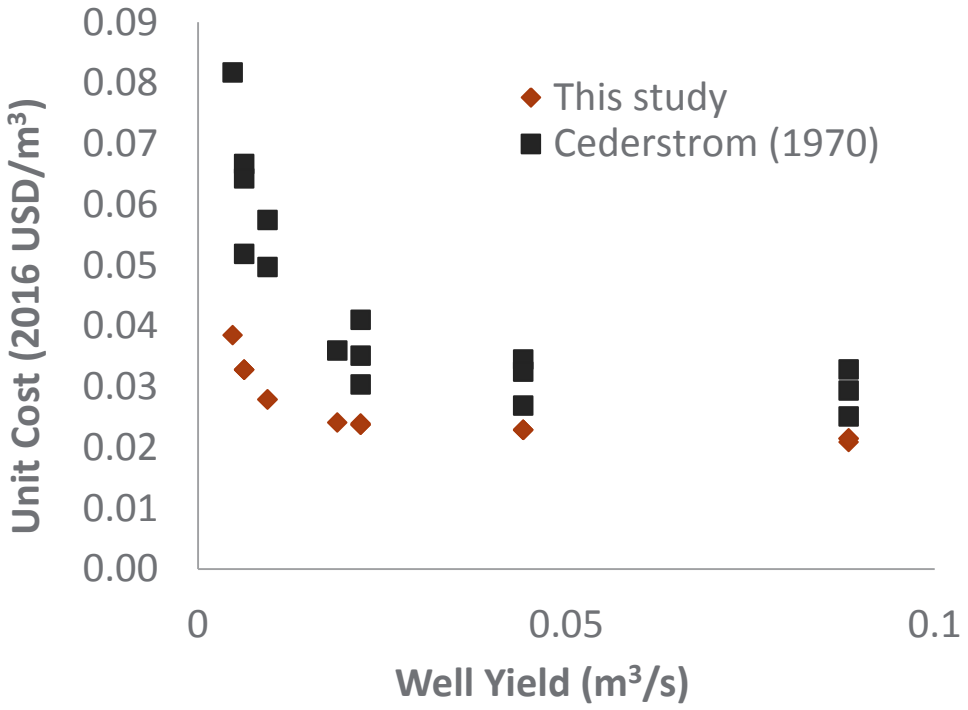
Unit Cost Breakdown



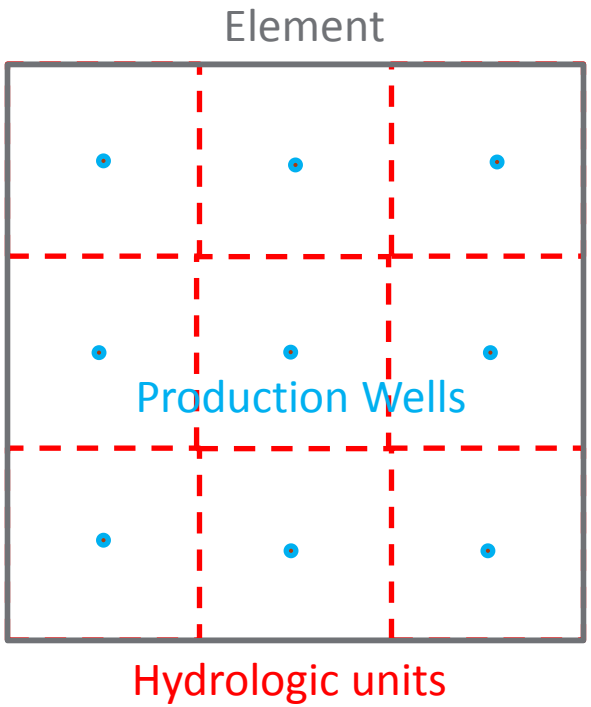
Unit Cost Comparison

USGS study evaluated groundwater unit prices for the North Atlantic Region (Cederstrom, 1970)

- Included capital costs, maintenance costs, and power costs.
- Evaluated production costs in variable geologic materials: coastal plain, consolidated rocks, and glacial deposits.

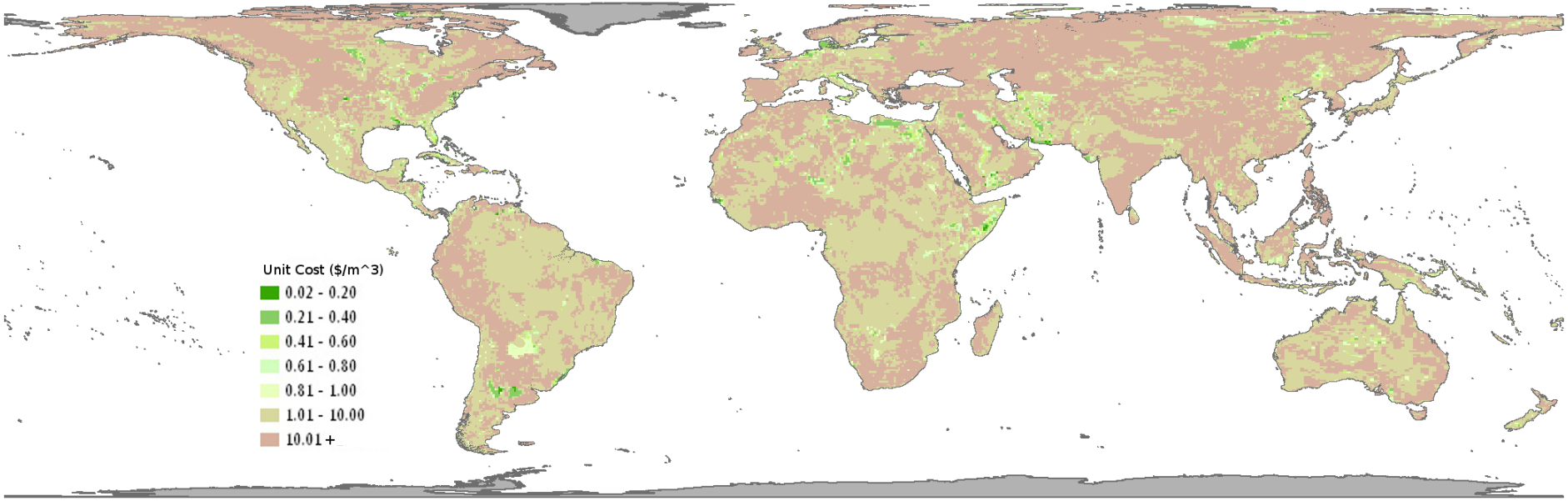


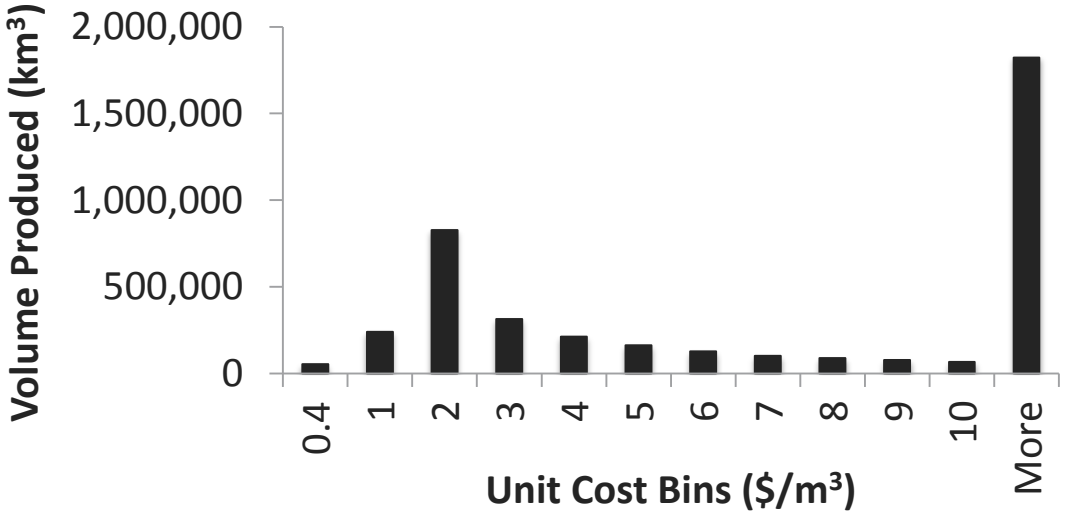
Global Application of Groundwater Production Cost Curves



- Optimize well spacing based on maximum production.
- Hydrologic units are assumed to be identical.
- The solution scheme calculates production and unit costs ($/m^3 water) for one hydrologic unit.
- We apply the solution to the entire aquifer of interest.
  - The unit cost is the same
  - Total volume produced is sum of all production

Results: Global Unit Costs of Groundwater Production





Conclusions and Next Steps

- Global aquifer properties from previous studies were combined to estimate the volume of groundwater available within range of reported global values.
  - Specific regional studies may replace broad global property assumptions.

- A framework was created defining a cost function based on an analytical GW flow solution.
  - Unit costs reflect the cost of electricity and well drilling/installation.
  - Results were compared to groundwater unit cost estimates from other methods.
  - Initial results calculated groundwater unit costs based on a relatively dense network of production wells over a fixed amount of time. Next steps will reduce number of wells and prolong the duration of production.
  - Other capital costs (the pump, water treatment, and transport) may be added.

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Questions?

Catherine Yonkofski, Ph.D.
Subsurface Scientist
Energy and Environment Directorate
Hydrology Group

Pacific Northwest National Laboratory
Battelle Seattle Research Center
1100 Dexter Ave. N. Suite 367
Seattle, WA 98109
Phone: (206) 528-3450

catherine.yonkofski@pnnl.gov

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

References

Cederstrom, D.J., 1970. The Cost of Ground Water. North Atlantic Regional Water Resources Study Coordinating Committee.

De Graaf, I.E.M., Sutanudjaja, E.H., Van Beek, L.P.H. and Bierkens, M.F.P., 2015. A high-resolution global-scale groundwater model. Hydrology and Earth System Sciences, 19(2), pp.823-837.

Garmonov, I. V., Konoplyantsev, A. A., Lushnikova, N. P., 1974. The World Water Balance and Water Resources of the Earth (ed K.I. Korzun). Hydrometeoizdat. 48-50.

Gleeson, T., Moosdorf, N., Hartmann, J. and Beek, L.P.H., 2014. A glimpse beneath earth's surface: GLobal HYdrogeology MaPS (GLHYMPS) of permeability and porosity. Geophysical Research Letters, 41(11), pp.3891-3898.

Gleeson, T., Befus, K.M., Jasechko, S., Luijendijk, E. and Cardenas, M.B., 2016. The global volume and distribution of modern groundwater. Nature Geoscience, 9(2), pp.161-167.

L'vovich, M.I., 1979. World water resources and their future. American Geophysical Union.

Nace, R. L., 1969. Water, Earth, and Man: A Synthesis of Hydrology, Geomorphology, and Socio-Economic Geography (ed. Chorley, R. J.).

Nace, R.L., 1971. Scientific framework of the world water balance. Paris, United Nations Educational, Scientific and Cultural Organization, Technical Papers in Hydrology, (7).

National Research Council (NRC), 1986. Global change in the geosphere-biosphere: initial priorities for an IGBP. National Academy Press. Ch. 6, 72-82.