The Anthrohydrologic Conceptual Model for Groundwater Remedy Design under Climate Change

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Background/Objectives. The environmental and economic health of most global communities is linked to the security of fresh-water resources and the implementation of reliable and protective groundwater restoration and water resource protection measures. Since the early 1980s, the groundwater remediation design practice has implemented clean-up remedies that by and large have not considered climate-induced acute or chronic changes to the hydrologic character of sites for which clean-up remedies are designed. With the continued progress of climatic shifts, the stress on existing groundwater and surface water protection measures, and the ability to design new protection and cleanup approaches will continue to increase dramatically. Climate-induced changes in hydrologic conditions is not the only threat because of accompanied changes to the geochemical and biological character of groundwater systems which directly impact the performance and longevity of in situ groundwater remedies. These continuing chronic changes that can be reflected in an updated “anthrohydrologic conceptual model” or (ANTHYM) can be applied to any of the numerous landfill, industrial, and accidental chemical release sites within the shoreline area; thawing permafrost in arctic regions that may now allow once stable chemical releases to enter the hydrologic system; and extreme flooding events can create long-lasting impacts that rapidly move contaminants outside protective systems. This research is a continuing effort to assess the application of conventional and innovative remedial measures with respect to their likely performance in a climate-new environment. The consideration of technology “coping” and adaptation is part of developing a clean-up and protection framework for groundwater remediation that will effectively meet current and anticipated future conditions with a level of acceptable performance. The objectives of this presentation include summarizing the background problem, identifying potential solutions, and discussing the approach to developing the framework using geochemical and hydrogeological data for active clean-up sites.

Approach/Activities. Since the late 1980s, attempts to reduce the use of resource-intensive groundwater remediation methods, including groundwater extraction with above ground treatment (aka "pump and treat") have resulted in an evolution of in situ treatment approaches that have grown from a few applications of bioremediation in the early 1990s, permeable reactive barriers (PRBs) in the mid-1990s, and enhanced methods using in situ oxidation, reduction, phytoremediation, thermal and other innovations over the ensuing 30 years. Although some of these remedies do represent "sustainable", the design approaches for these methods seldom, if at all, involved a quantitative assessment of future environmental conditions (under the assumption that the remedies in place would be necessary for quite some time under typical slow advective mass flux conditions). This work evaluates both site conditions and remedies for their ability to adapt to longer-term changes in hydrology, geochemistry, and biology and to develop a framework for which a resilient design can be deployed. The concept starts with the ANTHYM approach where longer-term projections and potential changes to the geochemical, biochemical, and hydrological conditions are evaluated. Like the “rating” or scoring that new sustainability tools consider, the goal here is to understand longer-term outcomes that will negatively affect remedy viability and longevity. Consideration of changes in pH, dissolved

oxygen content, mineralization due to these affects as well as changes to the biological system from aerobic to anaerobic (and reversed) are design considerations in addition to physical hydrologic projections for nearly every in situ remedy applied with the exception of short-term physical or extreme-thermal approaches. Understanding these effects leads to rating adaptability and then what engineering or design changes may be applied to increase resilience.

Results/Lessons Learned. The process involves a two-step approach: (1) determination of the potential impact that change will affect a potential remedy, and (2) the selection of remedy and application of design that would result in a high "resiliency factor" or "RF" showing that a remedy design can withstand the anticipated changes in site conditions. We have reviewed cases from the past that did not consider these changes and have compared them with considerations for the design of current projects. The developing process suggests that consideration of the ANTHYM in concert with remedial design alternatives will be a valuable part of the RI/FS process and provide decision makers and designers more confidence in the selection of remedial technologies.