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Research article

Application of natural resource valuation concepts for development of sustainable remediation plans for groundwater

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ABSTRACT

This paper explores the application of natural resource assessment and valuation procedures as a tool for developing groundwater remediation strategies that achieve the objectives for health and environmental protection, in balance with considerations of economic viability and conservation of natural resources. The natural resource assessment process, as applied under U.S. and international guidelines, entails characterization of groundwater contamination in terms of the pre-existing beneficial services of the impacted resource, the loss of these services caused by the contamination, and the measures and associated costs necessary to restore or replace the lost services. Under many regulatory programs, groundwater remediation objectives assume that the impacted groundwater may be used as a primary source of drinking water in the future, even if not presently in use. In combination with a regulatory preference for removal or treatment technologies, this assumed exposure, while protective of human health, can drive the remedy selection process toward remedies that may not be protective of the groundwater resource itself or of the other natural resources (energy, materials, chemicals, etc.) that may be consumed in the remediation effort. To achieve the same health and environmental protection goals under a sustainable remediation framework, natural resource assessment methods can be applied to restore the lost services and preserve the intact services of the groundwater so as to protect both current and future users of that resource. In this paper, we provide practical guidelines for use of natural resource assessment procedures in the remedy selection process and present a case study demonstrating the use of these protocols for development of sustainable remediation strategies.

1. Introduction

Sustainable remediation, as defined in current guidelines, entails coordination of the resource consumption of the remediation effort with the benefits achieved in terms of the economic viability, conservation of natural resources and biodiversity, and the enhancement of the quality of life in surrounding communities (ASTM, 2013; Ellis and Hadley, 2009; SURF, 2016). A key consideration in selection of a sustainable remedy at a given site is the loss of natural resource service caused by the contamination (AFCEE, 2009) and the ability of the remediation program to restore this service at a cost that is commensurate with the lost value. Environmental economists and regulatory authorities in the US (Desvousges, 2010; Dunford, 2004; Dunford and Locke, 2015) and abroad (Deloitte, 2013; UKEA, 2007) have reviewed methodologies for estimation of the economic value of groundwater and consideration of the lost value caused by contamination. Other authors have evaluated the evolving legal and regulatory policies related to assessment of groundwater resource damages and restoration of beneficial use (Dunn, 2008; Israel, 2015; Reed, 2014; Tolan, 2008).

However, under regulatory and technical guidelines for groundwater remediation, these resource assessment and valuation concepts have not commonly been integrated in the remedy selection process. In the US, under both the CERCLA and RCRA programs, the principal remedy selection factors (hereinafter referred to as "conventional remedy section criteria") are long-term effectiveness and permanence; reduction of the toxicity, mobility, or volume of waste; short-term effectiveness; implementability; and cost, wherein cost is considered as a secondary criterion to compare "disproportionate costs" among remedy options (USEPA,

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1992, 1997, 2014, 2015). These regulatory programs incorporate a preference for treatment options (USEPA, 1992), which can drive the remedy toward chemical or physical modification of the impacted natural resource (e.g., groundwater), rather than containment or natural attenuation of the contaminants. In addition, many regulatory provisions specify that the remedy be completed in a "reasonable" timeframe (40 CFR §300.430(a)(1)(iii)(F)), without providing specific guidance on what constitutes "reasonable."

Parties seeking to encourage sustainable remediation have noted a deficiency in the remedy selection process with regard to the protection and efficient use of the groundwater resource:

> "*Current water quality standards require that treated groundwater quality be suitable for the intended reuse application. Although these regulations protect groundwater quality, they do not emphasize the beneficial reuse of the water that all too often is lost as a result of remediation activities*." (SURF, 2013, p. 5).

> *When developing remedial action objectives and groundwater cleanup goals, the function and services provided by groundwater should be considered. Depending on the importance of groundwater in a particular area, regional factors such as geography, climate, local industry, and population drive the valuation of groundwater*." (SURF, 2013, p. 13).

Other authors have noted the importance consideration of net environmental benefit in remedy selection (Raymond et al., 2009) and have reviewed methodologies for evaluating the positive and negative effects of the remedy on natural resource services (Fiorenza et al., 2009).

Remedial alternatives that, based on conventional remedy selection criteria (i.e., long-term effectiveness; reduction of the toxicity, mobility, or volume, etc.), are expected to provide equal protection to human health may nevertheless entail very different net effects on the services provided by the groundwater resource. Failure to consider the natural resource implications poses concern with regard to damage to the groundwater resource undergoing remediation, as well as investment, in terms of capital and resource consumption, that is disproportionate to the value of the impacted groundwater.

An example of such resource impacts is a groundwater pumping and treatment system that removes contaminants from the aquifer by flushing the impacted zone with clean water drawn from the surrounding area. In the course of this process, this remediation system may extract and contaminate a groundwater volume that is orders of magnitude greater than the volume that would have been affected in the absence of remediation. Similarly, under the commonly used regulatory definition of "potentially usable" groundwater (i.e., groundwater with a Total Dissolved Solid content < 10,000 ppm from a well capable of producing more than 500 L per day; 40 CFR §144.3), a relatively low-value groundwater unit (unused, low-yield and/or brackish) and a relatively high-value groundwater unit (in use, high-yield, and fresh) may warrant equivalent remediation efforts - even though the high-quality unit supports a significant user population and the low-value unit supports no users and at best could be considered an optional, back-up supply.

Subject to applicable environmental regulations, both groundwater units may require remediation, as needed to protect human health and the environment; however, the timeframe and level of resources applied to the low-value vs. the high-value groundwater unit would reasonably be expected to be quite different. Conventional remedy selection criteria do not provide guidance with regard to distinction between high-value and low-value groundwater or to consideration of either resource value or consumption in development of the remedial strategy.

A number of regulatory authorities in the US and abroad have adopted "non-groundwater use" provisions that allow affected groundwater to remain in place in excess of drinking water standards within aquifers that are not current sources of drinking water, subject to certain technical specifications and institutional controls. Examples include the Municipal Settings Designation in Texas (Texas Health and Safety Code Chapter 361 Subchapter W), the Model Groundwater Ordinance in Illinois (35 Ill. Adm. Code 742.1015), the Groundwater Use Restriction in Colorado (CDPHE, 2015), and the Groundwater Classification Exception Area in New Jersey (N.J.A.C. 7:9C-1.6). Similar provisions are provided in Catchment Abstraction Management Strategies in the United Kingdom (UKEA, 2013), in Environmental Protection Orders in Alberta, Canada (Alberta Environmental Protection and Enhancement Act Provision 156), and in Groundwater Quality Restricted Use Zones in Victoria, Australia (EPA, 2014).

For sites meeting these non-use provisions, remediation is not required for groundwater resources that would be characterized as low value, based upon their location and the presence of alternative, higher-quality water supplies. However, for sites that do not qualify for these exclusions or are located in jurisdictions where such provisions are not available, concerns remain regarding the net effect of the remedy on the services provided by the groundwater and other natural resources.

Guidelines for assessment of groundwater resource value and damage are addressed in various US and international guidelines (43 CFR Part 11; EU Directive 2004/35/CE; Deloitte, 2013; Desvousges, 2010; Dunford, 2004; Dunford and Locke, 2015; UKEA, 2007). Under these systems, the impacted groundwater resource is evaluated with regard to its baseline services to humans and the environment, the loss of service caused by the contamination, and the measures needed to restore and/or compensate for the lost service without degrading the other services that are still provided by the groundwater. Consequently, as a supplement to conventional remedy selection criteria, natural resource assessment protocols may serve as a systematic process for incorporating sustainability objectives into remedy selection and design.

In this paper, we apply groundwater resource assessment and valuation methods, as defined in US and international guidelines, as a tool for evaluating the relative sustainability of alternative remedies in terms of net resource benefits and the consistency of the timing and resource consumption of the remedy with the demand for the impaired groundwater. We present a step-wise process for applying resource assessment concepts to the remedy selection process and provide case study examples for development of remediation strategies that are protective of a groundwater resource and the users of that resource, while meeting the objectives of sustainability.

2. Technical background on natural resource assessment protocols for groundwater

In the U.S., the concept of liability for damage to natural resources was first codified under the Trans-Alaska Pipeline Authorization Act (TAPAA) of 1973 and the Deepwater Port Act (DPA) of 1974, which required owners or operators of pipelines or marine vessels to compensate the public official serving as trustee of the damaged natural resource (Lee and Bridgen, 2014). These provisions and the concept of "natural resource damage" were expanded under the federal Clean Water Act, Comprehensive Environmental Response, Compensation and Liability Act, and the Oil Pollution Act. Regulations for implementing NRDA have been promulgated by the U.S. Department of Interior (DOI) in 43 CFR Part

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