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Abstract

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KEYWORDS: groundwater, restoration, natural resource damage assessment, water conservation, source control, recharge

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IDENTIFYING, SCALING, AND EVALUATING GROUNDWATER RESTORATION PROJECTS AS COMPENSATION FOR GROUNDWATER INJURIES

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ABSTRACT

Restoration of natural resources is the ultimate goal of natural resource damage assessment (NRDA). According to the U.S. Department of Interior regulations for NRDA (43 CFR Part 11), Trustees of natural resources develop alternatives that will "restore, rehabilitate, replace, and/or acquire the equivalent of the injured resources." Identification, scaling, and evaluation of groundwater restoration projects has proven challenging. This paper describes potential categories of groundwater restoration projects, including: 1) Generating clean water, 2) Conserving water, 3) Storing water for times of scarcity, and 4) Accessing new sources of water that were previously inaccessible or unusable. Examples of specific types of projects within these broad categories are provided, together with discussion of the particular challenges associated with scaling and evaluating these projects.

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1. INTRODUCTION

Restoration of injured natural resources is the ultimate goal of the natural resource damage assessment (NRDA) provisions within the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Trustees of natural resources, including state and federal agencies and Native American tribes, need to determine the amount of restoration required to compensate the public for injuries to natural resources caused by releases of hazardous substances. To accomplish this goal, Trustees must quantify the injury, identify potential restoration projects, and then use a scaling technique to determine how much restoration is required to balance past and future injuries. Even when economic approaches are used to value damages, in the post-award phase of a case Trustees must still identify and implement restoration projects with the recovered damages.

According to the U.S. Department of Interior regulations for NRDA (43 CFR Part 11), restoration alternatives need to "restore, rehabilitate, replace, and/or acquire the equivalent of the injured resources." For biological resources, identification and scaling of restoration alternatives can be relatively straight-forward. Revegetation of off-site degraded riparian habitat, for

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example, may compensate for riparian habitat injured by heavy metals from mine tailings. Scaling this type of project can be done on a resource-to-resource basis, using techniques such as habitat equivalency analysis. Injured habitat can be quantified as acres injured over time and restored habitat can be quantified as acres benefited over time, using a discount rate to convert losses and gains to a common year (see Unsworth and Bishop, 1994; Chapman et al., 1998; Allen et al., 2005).

When groundwater resources are involved, however, identification and scaling of restoration alternatives has presented challenges for Trustees.. For example, groundwater restoration projects may not adequately compensate the public for injuries when they restore different kinds of services than those that were lost. For example, restoration projects that only provide drinking water services (such as a project that improves a water treatment plant) only capture a partial component of the total value of groundwater. In addition, Trustees may be unaware that restoration alternatives exist that can compensate for groundwater injuries on a resource-to-resource basis, even when the groundwater is not currently in use as a drinking water supply.

This paper will present distinct categories of groundwater restoration projects and discuss the specific issues associated with identifying, scaling, and evaluating groundwater restoration projects in these categories. The project categories included are: 1) Generating clean water, 2) Conserving water, 3) Storing water for times of scarcity, and 4) Accessing new sources of water that were previously inaccessible or unusable. Within each category, examples of specific projects will be given, with a discussion of factors that should be taken into account when evaluating each type of project.

In deciding upon appropriate restoration projects, Trustees should generally consider the following factors: proximity of the project to the injury; similarity of the injured and restored aquifers, where applicable; long-term maintenance and monitoring requirements; technical feasibility of the project and associated success/failure rates; the likelihood the project would have occurred in the absence of NRD funding; the potential for any collateral environmental harm; public acceptance; and cost-effectiveness. In addition to these general factors, individual projects also require consideration of factors specifically relevant to those projects.

2. CATEGORIES OF POTENTIAL GROUNDWATER RESTORATION PROJECTS

2.1 Generating clean water

To compensate for injuries to groundwater, Trustees can undertake restoration projects that generate clean water. These types of projects provide the public with the equivalent of the injured resource by providing new sources of clean water as compensation for the injured groundwater. Typically these projects either convert groundwater from a contaminated to a clean state, or prevent groundwater from becoming contaminated in the first place. These projects can be scaled on a resource-to-resource basis and may provide a match to groundwater injury, especially if the restoration project benefits the same aquifer that was injured. Examples of projects that can generate clean water include cleanup of orphan plumes, protection of recharge zones, and source control.

2.1.1 Cleanup of orphan plumes

Cleanup of orphan groundwater plumes (i.e., plumes for which there is no viable party responsible for cleanup) can be easily explained to the public and the courts as "like for like" restoration that provides the equivalent of the injured groundwater resource. To identify this type of project, Trustees may contact local and state hazardous waste bureaus to determine if there is existing information about orphan plumes in the vicinity of the injured groundwater resource. State and federal abandoned mine land programs may have information about groundwater plumes associated with abandoned mines. State drinking water programs may have information about areas where groundwater wells have failed to meet drinking water standards because of orphan groundwater plumes. Orphan plumes targeted for cleanup do not necessarily need to be contaminated with CERCLA-designated hazardous substances. For example, a plume of high nitrate concentrations may render groundwater unfit for drinking water or agricultural uses. Cleanup of this type of plume may provide groundwater services to the public.

The techniques used for cleanup of an orphan plume will depend on the size and characteristics of the plume. Some plumes are best treated with "pump and treat" systems that pump out the contaminated water, treat it using biological or chemical treatment systems, and then either reinject the water downstream of the plume or discharge the water to a surface water body or sewage treatment plant (Suthersan, 1996). In situ restoration options also are possible. For example, nitrate plumes can be treated by injecting substances that enhance microbial conversion of nitrate into harmless gases (a process termed denitrification) (Interstate Technology and Regulatory Council, 2002).

Scaling orphan plume cleanup projects requires information about the amount and expected duration of groundwater contamination as well as information about aquifer properties. If the groundwater injury has been calculated as an injury to a yield of groundwater over time (e.g., in units of acre-feet per year) then ideally the scaling will be based on equivalent information about the yield of water that would benefit from the restoration project. If the groundwater injury has been calculated as an injury to a volume of water, then it is important to have information about the volume of water that would benefit from the restoration project over its lifetime. It is also important to know the expected rate of natural recovery of the orphan plume, if any. The benefit of an orphan plume cleanup project should be quantified as the incremental benefit that occurs from the restoration project above any recovery that is expected to occur naturally or expected to occur through other likely funding mechanisms.

Trustees can take into account a variety of factors when evaluating different potential orphan plume restoration projects. In addition to the general factors listed in Section 1, specific factors to consider could include the expected rate of natural recovery and whether the treatment method has a proven track record or is considered experimental. Finally, the Trustees may want to consider the degree of harm on the injury side and the comparable degree of benefit on the restoration side. For example, an orphan plume cleanup project that converts water suitable only for agricultural uses to a condition suitable for drinking water would be a good match for an injury that converted high quality drinking water to that suitable only for agricultural uses.

2.1.2 Protection of recharge zones

Protection of areas that are critical for allowing groundwater recharge can help prevent future losses of groundwater resources. For example, development of infrastructure that covers groundwater recharge areas with impermeable surfaces, may decrease the quantity of groundwater recharge. Purchasing land or securing conservation easements for critical recharge zones may provide the public with a continued supply of groundwater into the future (Ernst, 2004). In situations where surface water recharges an aquifer, preventing contamination of that surface water may protect groundwater quality. Through avoiding likely future harm to groundwater, this type of restoration project may provide the equivalent of the injured groundwater resource.

To identify this type of project, Trustees can contact the local drinking water utility or the relevant state or local departments of environmental protection. EPA requires that drinking water utilities develop source water protection plans. These plans include an assessment and mapping of the areas that supply groundwater to a drinking water well or a spring (e.g., Pennsylvania DEP, 2002). However, available federal funding is not sufficient to achieve all the source water protection goals that are laid out in these plans (Edwards et al., 2006). In addition to examining areas linked to drinking water supplies, Trustees can look to identify key groundwater recharge zones that are not necessarily linked to drinking water supplies, but may be important sources of recharge for an alluvial or regional aquifer or have an important connection to surface water resources such as a wetland. Identifying key locations that are vulnerable to development can help Trustees prioritize protection programs.

Scaling recharge protection projects requires information about the rate of recharge in an area, the size of the area expected to be protected, the timing of the likely development threat, and the net recharge loss due to development. The benefit of a recharge protection project begins when development is expected to occur and can be calculated using the probability of development in a given year; thus, an expected 50% risk of development could equate to a 50% benefit for the project (Chapman and Julius, 2005). Use of a discount rate helps convert expected future benefits to past, present, and future losses.

Important specific factors to consider when evaluating a recharge protection project include the rate of recharge, the degree of development threat, and the net efficacy of the project in preserving recharge. The risk of development can be evaluated by looking at development trends in the area and consulting permits, build-out plans and other long-range planning documents for an area.

2.1.3 Source control projects

Source control projects are projects that protect groundwater resources from current or potential future sources of contamination. These projects can include wellhead protection programs that are specifically focused on mitigating threats to drinking water wells. These projects are similar to aquifer protection programs in that they primarily mitigate future risk to groundwater. The focus here is on preventing threats to the quality of groundwater, while the focus with recharge zone protection projects is protecting the future quantity of groundwater.

To identify this type of project, Trustees can contact the local drinking water utility or the relevant state or local departments of environmental protection to determine if they have any inventories of potential sources of contamination in a watershed that were identified as part of a source water protection plan or wellhead protection program. Trustees also can talk to agencies that are responsible for underground storage tanks, abandoned oil and gas wells, abandoned mines, and other potential sources that can pose threats to groundwater. Programs that reduce contaminated urban runoff and prevent contaminated water from infiltrating into groundwater aquifers also fit into this category.

Abandoned oil wells may provide an example of a source control restoration project in some locations. Abandoned wells can pose a threat to groundwater because they serve as conduits that can allow highly salty groundwater ("brine"), often contaminated with heavy metals and other contaminants, to seep into nearby freshwater aquifers (Rail and Rail, 2000). These wells often have no viable responsible parties, and state programs may have insufficient funding to plug these wells quickly (Texas Land & Mineral Owners Association, 2004). An NRD restoration project that seals abandoned oil wells may avoid future harm to groundwater and thus could provide the equivalent of the injured groundwater resource.

Scaling source control projects can be difficult because only limited information is usually available about potential threats. Ideally, scaling would require information about the amount of groundwater that would likely be contaminated in the absence of the source control, the timing of the expected harm, and the degree of potential harm posed by the contamination. This could be estimated by quantifying the likely size of a plume originating at the source of contamination. The duration of benefits should take into account when the contamination source would likely have been addressed through some mechanism other than NRD funding and the probability of success or failure of the project. For example, an NRD project that seals a well that would likely have been sealed by a State program within the next 10 years can be considered as providing benefits only for those 10 years.

Evaluating source control projects requires obtaining the best possible understanding of the likelihood and degree of potential harm posed by the contamination source. Trustees should then use their judgment to determine whether a source control project with a low degree of likelihood but a high degree of potential harm should have a higher priority for NRD funding than another such project with a higher likelihood of occurrence but a lower degree of potential harm.

2.2 Water conservation

Another category of projects that can compensate for injuries to groundwater involve water conservation. Water conservation projects can either specifically target reducing losses of water to the atmosphere from soil evaporation or plant transpiration (collectively termed "evapotranspiration") or they can reduce water waste in general. Projects that reduce evapotranspiration losses include conversion of turf from non-native to drought-tolerant species, increased irrigation efficiency, increased industrial cooling tower efficiency, and removal of exotic species from riparian areas. Projects that reduce water waste include projects that are focused on household conservation, leaky or poorly managed irrigation systems, and leaky, man-made ponds. In this second category of projects, the water that is conserved would not have been lost to evapotranspiration, but instead would likely have been returned to the system either through run-off, a sewage treatment plant, or by seeping into shallow groundwater.

2.2.1 Turf conversion and increased irrigation efficiency

Turf conversion involves replacing water-intensive exotic turf grasses (e.g., Kentucky bluegrass) with water-efficient and drought-resistant species (usually native grasses such as buffalo grass). Irrigation efficiency projects involve replacing inefficient irrigation systems with methods that use less water, such as converting irrigation systems from a fixed schedule to a schedule based on weather conditions and plant needs ("evapotranspiration controllers"). These types of project are particularly appropriate in arid and semi-arid environments where substantial amounts of water are used to irrigate turf and landscaping in parks, sports fields, residences, and other locations. To identify this type of project on publicly owned land, Trustees can contact municipalities that often manage acres of turf in public parks and other areas. In addition, water utilities may have programs in place to promote turf conversion and irrigation efficiency for private residences and businesses. These types of projects provide the equivalent of the injured resource by saving groundwater that would otherwise be lost to evaporation or excessive transpiration.

Conversion of exotic turf grasses to water-efficient species and implementation of projects to improve irrigation efficiency have been carried out successfully in many locations. In Colorado, conversion of turf grasses to native grasses can save approximately 2 acre-feet of water per acre each year (Koski, 2006), with estimated costs for installing buffalo grass of $430 per acre (see http://www.bamertseed.com/buffalo-brochure.html). The amount of savings from turf conversion and increased irrigation efficiency would depend on typical irrigation practices and climate. These types of projects can provide cost-effective benefits and are flexible in terms of the scale at which they are carried out. For turf conversion, public preference for softer, exotic turf-grasses can limit the use of native grasses to areas not used for picnicking or active recreation.

Scaling a turf conversion or irrigation efficiency project requires information about the irrigation practices currently used, the species currently in place, the water-efficient species designated for replacement, the time-frame over which the projects would take place, and success/failure rates. Published literature exists that can be used to estimate the difference in water use between the exotic and native grasses. Estimates of savings from irrigation efficiency also can be made depending on the nature of the irrigation improvement.

Specific factors to consider when evaluating potential projects could include: location of the project on public or private lands; the water source currently used for irrigation; the potential for water savings; and public preference. A turf conversion or irrigation efficiency site that directly uses groundwater for irrigation provides a direct link to the injury. However, projects that save water at sites irrigated with surface water may also conserve groundwater if they reduce the need for groundwater pumping in another location.

2.2.2 Increased industrial cooling tower efficiency

Substantial water savings can be achieved by increasing the efficiency of industrial cooling towers. These projects can involve implementation of best management practices (U.S. Department of Energy, 2008), minor upgrades (such as installing water meters to detect leaks), or replacement of old towers with more efficient equipment. These types of projects may provide the equivalent of the injured resource by saving water that would otherwise be lost through evaporation.

Scaling a cooling tower efficiency program requires information about the expected water savings from the particular type of equipment to be replaced and the expected lifespan of the equipment. In addition, the Trustees should know if and when the equipment conversion would likely have occurred without NRD funding.

Specific factors to consider when evaluating potential projects could include: ownership of the project by public or private entities; the water source currently used for the cooling tower; and the potential for water savings. An efficiency site that uses groundwater provides a direct link to the injury. However, as discussed previously, in some instances surface water savings at one site can reduce groundwater pumping in another location.

2.2.3 Removal of invasive species from riparian areas

In certain situations, removal of invasive species from riparian areas can reduce evapotranspiration and result in water savings because they can use more water than native species for a given area. Extensive control programs for species such as salt cedar (*Tamarisk spp*) and Russian Olive (*Elaeagnus angustifolia*) have been undertaken in the hope of decreasing alluvial groundwater use by these plants and increasing surface water flow as a result. In many situations, however, the water savings have been less than expected. Recent studies of tamarisk along the Colorado River have demonstrated that exotic control programs can provide water savings only in specific situations (Nagler et al., 2008). Trustees can contact river or watershed management organizations or invasive species control programs to identify locations that have been impacted by invasive species. To provide long-term benefits, removal of invasive species needs to be followed with replanting of natives, if natural regeneration does not occur easily. Projects also require long-term monitoring and maintenance to prevent regrowth of the invasive species (Tamarisk Coalition, 2008). These types of projects provide the equivalent of the injured resource by saving alluvial groundwater that would otherwise be lost to evapotranspiration by undesirable invasive species.

Scaling an invasive species removal program requires information about the density of the invasion, the water use of the expected replacement species, the time period until exotics may grow back, and the area over which the control effort would take place. In addition, the Trustees should know if and when the invasive species control would have occurred without NRD funding.

Specific factors to consider when evaluating potential projects could include: ownership of the adjacent land by public or private entities; long-term management plans for the project site; presence of the invasive species in nearby locations; and the potential for water savings. This type of project provides a water benefit on an annual basis (measured as acre-feet per year) and provides a closer link to injuries to alluvial groundwater that have been calculated on the basis of flux.

2.2.4 Household water conservation

Household water conservation is an example of a conservation project that reduces water waste but doesn't focus specifically on evapotranspiration losses. These projects promote water efficiency through programs that result in upgrades to water fixtures such as toilets, faucets, showerheads, and washing machines. Water savings of 5,000 - 27,000 gallons per household per year have been measured for programs that replace old toilets with low-flow models and inefficient washing machines with efficient models (Little, 2005; Vickers, 2001; A&N Technical Services, 2000). These types of projects can be administered as replacement programs, where a crew will come to a participating household and replace the water fixture, or as incentive programs, where a municipality or water utility will provide a rebate to customers who undertake the improvement themselves.

Scaling the benefits from these projects poses several issues that Trustees should address. One challenge is what is known as the "free rider problem". A certain percentage of individuals who receive rebate payments may have undertaken the improvement even without the rebate (Whitcomb, 2002; A&N Technical Services, 2003). Since the actual water savings associated with a project should be calculated as the total water savings minus the estimate of savings that would have occurred without the incentive, the net gain in such instances could be minimal. Another challenge is that in many instances household water use (excluding irrigation) is returned to a waterway through a sewer system and water treatment plant. Thus, household water conservation programs reduce the use of treated water provided by a water utility but may not increase the total amount of water available in a watershed.

In essence, household conservation projects prevent the degradation of high-quality water to lower-quality water released after sewage treatment. These types of projects provide a link to injuries where groundwater has been degraded below potable standards but may still be usable for some industrial or agricultural purposes.

2.2.5 Fixing leaky irrigation systems and lining lakes or ponds to prevent seepage

Projects that fix leaky irrigation systems can target turf irrigation in public parks, agricultural irrigation, or other locations where there are large-scale irrigation systems with substantial leaks. These projects also can include lining man-made lakes or ponds (such as ornamental duck ponds in city parks) with impermeable liners to prevent seepage of lake water into the ground.

Similar to household conservation projects, fixing leaky irrigation systems or ponds can pose a challenge to Trustees because leaked water generally enters alluvial groundwater. Thus, while there can be water savings for the individual water user, the water system as an integrated whole may not benefit from this type of project. In some locations, irrigation efficiency improvements may not be permitted under water law, because downstream users have vested rights in the "return flow" of the irrigation

Trustees might want to take into account the characteristics of the aquifer or water source used for the irrigation water and the characteristics of the aquifer where the leaked water would enter. For example, leaked high-quality irrigation water may infiltrate a shallow alluvial aquifer with poor water quality. Thus, a project to fix leaky irrigation prevents the degradation of high-quality water to lower-quality water.

Scaling the benefits from these types of projects involves quantifying the amount of water that currently leaks and estimating the improvements that would come from different types of projects. These types of projects provide benefits that are more easily scaled on a flux basis (acre-feet of savings per year).

2.3 Storing water for times of scarcity

Storage of water for times of scarcity in above-ground or below-ground reservoirs could be considered as an NRD groundwater restoration project. In the projects discussed so far, the quality or quantity of clean groundwater would be increased, either directly or through reducing future threats to groundwater. In contrast, a water storage project does not increase the quantity of water, but rather increases the benefits provided by the water by making that water available during times of scarcity. In some situations, increasing storage of surface water also can save groundwater that would otherwise be pumped during a time of scarcity.

The techniques used for storing water will depend on the climate and geography of a given area. For example, in locations where there is abundant water in the springtime after snowmelt, high spring flows are captured and then released in the summer or fall. Locations that are subject to periodic drought may store water during high water years and then release it during drought years. Water can be stored behind dams, in off-channel aboveground storage reservoirs, and in belowground reservoirs that may require pumping to store or remove the water. Trustees should be aware of the potential negative environmental consequences associated with some types of water storage (e.g., construction of dams) and should make sure that their projects would result in a net environmental benefit that is acceptable to the public.

Scaling a storage project can be challenging for Trustees. The stored water can be valued monetarily by considering the cost that would be required to provide water during the time of scarcity, in the absence of the storage project. Resource equivalency also could be made directly on a volume basis (acre-foot of stored water compared to acre-foot of injured water), especially where the injury was primarily to the "option" value for groundwater. For example, an injury that occurred to groundwater that was not being used as a drinking water source but had value because of its potential use in the future could be appropriately offset with a project that provides the option of additional water resources during times of scarcity.

Trustees can take into account a variety of factors when evaluating potential water storage projects. Specific factors to consider could include: the potential for any collateral environmental harm and the expected water loss from evaporation for above-ground reservoirs. The Trustees also should closely examine the feasibility of any proposed water storage projects. Below-ground storage projects may have significant technical issues, depending on the hydrogeology of the site. Water rights administration also can pose significant complications in the West. Finally, the Trustees should consider whether the project is only benefiting one specific segment of the public. For example, a project that stores water to benefit agriculture but harms in-stream resources would not provide the best compensation for injured groundwater that migrates to surface water and injures the same in-stream resources.

2.4 Accessing new sources of water that were previously inaccessible or unusable.

To provide the equivalent of the injured resource, Trustees can identify projects that access new sources of water that were previously inaccessible or unusable. These projects could include techniques to extract water from aquifers with low flux rates (e.g., "hydrofracturing"; Ettling, 2005) and methods to treat water at a drinking water plant that allows use of aquifers that would otherwise not be potable. For example, advanced membrane filtration can create potable water from aquifers that are high in nitrates, total dissolved solids, salt, or other constituents (e.g., Sutherland, 2001). Water treatment projects only restore the drinking-water services of groundwater which is only a portion of the total value of groundwater. Scaling can be based on the flux of water (acre-feet per year) made available by these projects.

These projects require careful review and attention by Trustees to determine whether they are acceptable to the public as NRD groundwater restoration projects. For example, extraction of water from aquifers with low flux rates can result in water mining from aquifers that may take thousands of years to recharge. Advanced membrane filtration can be very energy-intensive and result in membrane residuals or concentrates that are difficult to dispose. These types of projects often seem to privilege current generations over future generations and may not be sustainable over the long-term.

3. ANALYSIS

The brief survey of potential groundwater restoration options given above shows some of the range of possibilities that exist for compensating for groundwater injuries. Identifying the most appropriate type of groundwater compensation project for a particular injury begins with developing a thorough understanding of the injury. What aquifers have been injured? What are the characteristics of these aquifers, including volume, flux rate, water quality, nexus to surface water, current uses, and potential future uses? What is the time-frame of injury? Is the injury expected to recover naturally, is a treatment program underway, or is the injury expected to persist in perpetuity? Does the groundwater injury result in part from the imposition of institutional controls over groundwater use? Are the Trustees choosing to quantify injury as a static volume of injured groundwater, as an annual flux of injured groundwater, or both?

Based on the answers to these questions, Trustees can identify specific projects that provide an appropriate match to the scale and type of groundwater injury. The nexus between injury and restoration may depend both on the availability of different groundwater restoration projects and whether the restoration project is being identified in anticipation of litigation, as part of a cooperative assessment, or during the post-award phase of a case.

4. CONCLUSION

Identifying appropriate groundwater restoration projects can take substantial effort and outreach by the Trustees; these efforts should be started early in the assessment process. After projects are identified, developing the information that is necessary for evaluation and scaling also can be challenging and time-consuming.

For evaluating different potential projects, Trustees may want to take into account a number of factors. As discussed previously, these factors include: proximity of the project to the injury; ownership of the project site by public or private entities; long-term maintenance and monitoring requirements; technical feasibility of the project and explicit quantification of success/failure rates; the likelihood the project would have occurred in the absence of NRD funding; the potential for any collateral environmental harm; public acceptance; and cost-effectiveness. This information is not always available and Trustees must use their best judgment to make decisions in the absence of complete information.

Trustees that develop NRD groundwater restoration projects based on a clear understanding of the injury, a diligent investigation of a wide-range of potential projects, and a careful vetting of individual projects versus evaluation criteria stand a better chance of achieving an outcome that can “make the public whole” for groundwater injuries.

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