ENVIRONMENTAL RESTORATION

Groundwater to Surface Water Interface: Overview and Management (Part 1)

Introduction

The discharge of impacted groundwater to surface water has been identified as a key risk driver at several Department of the Navy (DON) Environmental Restoration (ER) sites. This fact sheet describes the physical, chemical, and biological attenuation processes that occur at the groundwater to surface water interface (GW-SWI). These attenuation processes should be incorporated into the evaluation of exposure pathways at GW-SWI sites and considered in adaptive site monitoring and management strategies.

Background

Management of water resources traditionally has focused on either surface water or groundwater. However, nearly all surface water features (streams, lakes, reservoirs, wetlands, and estuaries) interact with groundwater affecting the quality of both resources. Based on recent studies, a significant number of cleanup sites are likely to be influenced by groundwater to surface water interactions:

- About 75% of the Resource Conservation and Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) sites are located within 0.8 km of a surface water body (Lorah and Olsen, 1999).
- A National Research Council (NRC) study reports that 43% of the 67 Navy installations on the National Priorities List (NPL) are located in coastal areas of California, Florida, Virginia, and Washington (NRC, 2003).
- A Naval Facilities Engineering Systems Command (NAVFAC) optimization study evaluated 32 sites and concluded that 78% of the sites (25 out of 32 sites) have groundwater plumes discharging to surface water (NAVFAC, 2017).

Understanding Transformation Processes at the GW-SWI

The subsurface interface between groundwater and surface water is referred to as the hyporheic zone as shown in Figure 1 (United States Geological Survey [USGS], 1998). The size and geometry of hyporheic zones below surface water bodies vary greatly. The hyporheic zone can be a dynamic area of mixing between groundwater and surface water. As a result, the physical, chemical, and biological characteristics may differ markedly from adjacent groundwater and surface water. The hyporheic zone is generally distinguished by demonstrating characteristics of both groundwater and surface water, with different gradients to each (Banks et al., 2019).

The types of interfaces include: 1) a freshwater interface such as found below streams, lakes, and freshwater wetlands, and 2) a freshwater/saltwater interface found in marine and estuarine coastal regions where groundwater plumes often discharge directly into oceans, estuaries, and other marine regions. The flow of water into and out of the hyporheic zone varies over space and time. It is dependent on many factors including subsurface soil and sediment conditions and the elevation of the water table in the vicinity of the surface water body (USGS, 1998).

A typical coastal setting can also include tidal flushing as seawater mixes with groundwater at high tide. The tidal pumping is more critical at sites with coarser, more permeable sediments. Contaminants can significantly attenuate as a result of this mixing process that occurs over repeated tidal cycles. Flushing of clean water from the tidal cycles assists with the attenuation (USGS, 1998).

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December 2020

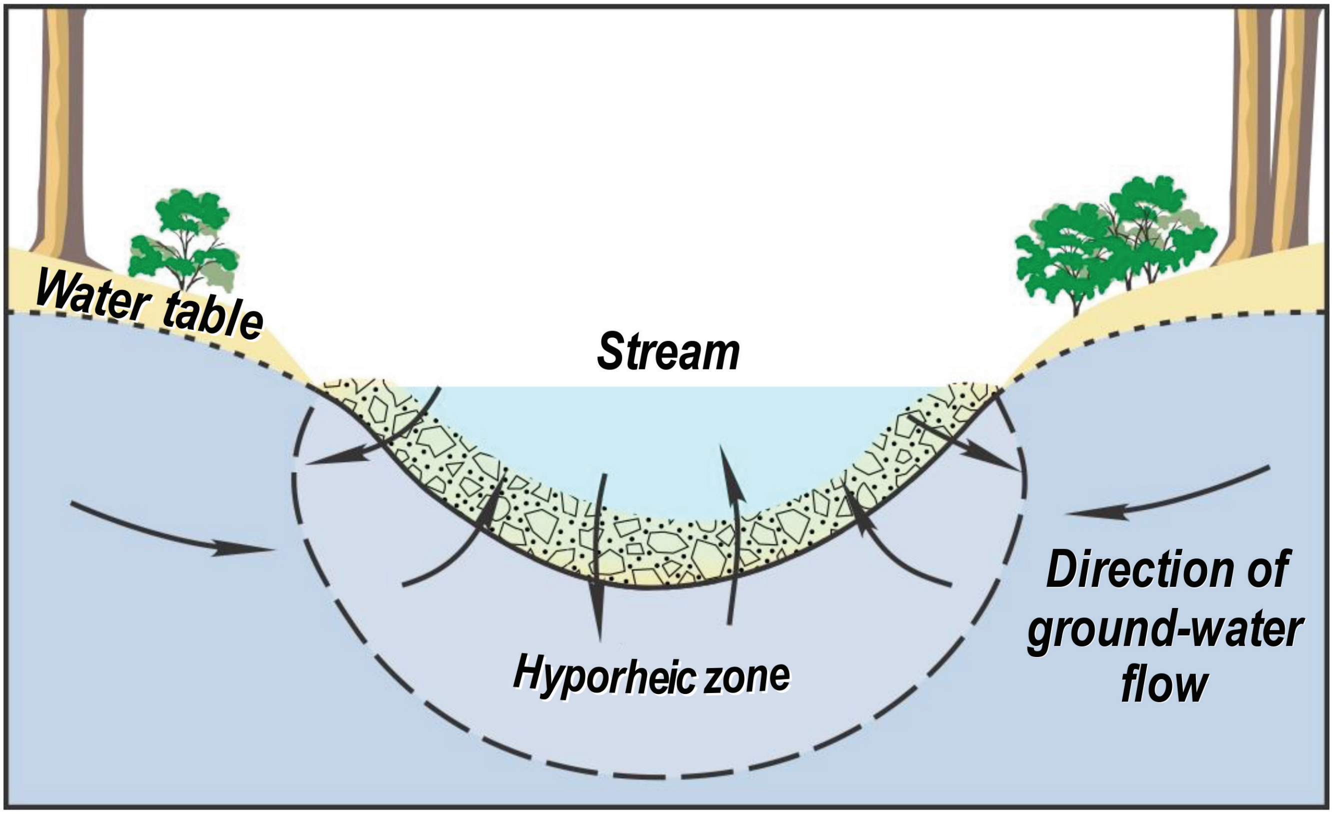

Figure 1. Hyporheic Zone (*Source: U.S. Geological Survey [USGS], 1998)*

Understanding Transformation Processes at the GW-SWI (Continued)

Several attenuation processes occur at the GW-SWI including hydrodynamic mixing (dilution), redox reactions, biodegradation, sorption, and mineral precipitation/dissolution. As summarized in Table 1, the various attenuation mechanisms can be grouped into physical, chemical, and biological transformation processes (NAVFAC, 2015).

Several of these processes may combine to contribute to attenuation across the GW-SWI. For example, the hydrogeology of the GW-SWI transition zone strongly influences the spatial and temporal distribution of both aerobic and anaerobic microbial processes. It also influences the concentration of nutrients, trace metals, and contaminants in surface and groundwater. In coastal wetlands, organic-rich sediments provide for anaerobic geochemical conditions that lead to increased biodegradation of compounds such as chlorinated solvents over relatively short distances. Thus, monitored natural attenuation (MNA) may serve as an effective remedial option for discharges of chlorinated solvent plumes into wetlands.

Evaluating Exposure Pathways at the GW-SWI

Surface water is generally viewed as the exposure pathway completion endpoint. Based on past practices, shoreline wells were sometimes used for the surface water quality point of compliance. However, these wells are designed to monitor groundwater and do not account for the enhanced attenuation processes occurring at the transition zone or at the GW-SWI. There is an opportunity for significant attenuation between the shoreline wells and the surface water body receptor. Therefore, the point of compliance should be established as close as possible to the relevant point of exposure for risk assessment purposes.

It is important to identify the location of groundwater discharge zones and to quantify natural attenuation processes at the GW-SWI in the conceptual site model (CSM). This helps to more accurately evaluate exposure pathways for both human health

Table 1. Transformation Processes Occurring at the GW-SWI

Physical Transformation	Physical processes include dilution, mineral precipitation, diffusion, and advection. Dilution occurs through hydrodynamic mixing of water with different concentration gradients. Mineral precipitation reactions result in minerals being formed (precipitated) from ions that are dissolved in water. Diffusion consists of mass transfer of contaminant into or out of a matrix due to a concentration gradient. Advection involves the movement of contaminants as carried by the flowing groundwater and discharging to surface water.
Chemical Transformation	Chemical processes include sorption, oxidation-reduction reactions, and abiotic transformation. Contaminants can be sorbed to the solid materials in an aquifer or streambed. Redox reactions take place when electrons are exchanged among solutes. Oxidation (loss of electrons) of certain elements is accompanied by the reduction (gain of electrons) of other elements. Abiotic transformation involves a chemical reaction between naturally-occurring minerals and the contaminant that leads to degradation.
Biological Transformation	Biological processes include biogeochemical transformation, biodegradation, and other microbial processes. Biogeochemical transformation can occur over small scales and can be influenced by the presence of organic-rich sediments. Biodegradation is the decomposition of organic chemicals by microorganisms using enzymes. Several biotically-mediated processes can be ongoing at a site based on site-specific conditions.

and ecological risk assessments. The CSM should evaluate both human health risk (e.g., from potable water and/or fish consumption) and ecological risk (e.g., ecological impacts to benthic organisms and/or fish) as applicable for completed exposure pathways at the site. For these evaluations, the point of compliance should be driven by the human health or ecological risk assessment endpoint.

Developing Adaptive Site Monitoring and Management Strategies

An adaptive site monitoring and management strategy is used to manage the uncertainty inherent to complex sites. The primary objective with an adaptive strategy is to control the exposure pathways from groundwater discharges to surface water to remain protective of human health and the environment. For GW-SWI sites, adaptive site management strategies include the use of alternative points of compliance, interim remediation goals, and alternative endpoints.

Alternative points of compliance such as GW-SWI points can be developed and built into the overall site strategy to meet the remedial action objectives (RAOs). Groundwater cleanup levels can be updated to meet alternate concentration limits (ACLs) (CERCLA Section 121 provides authority for establishing ACLs). ACLs are appropriate for sites under three specific conditions: (a) groundwater discharges to surface water; (b) no significant increase of surface water concentrations or accumulation; and (c) no human exposure prior to the point of groundwater entry into surface water.

Conclusions

Groundwater discharge to surface water is an important exposure pathway for evaluation as it commonly drives risk. Wetland and coastal settings are typically encountered at Navy sites and provide unique environments and conditions that affect attenuation. The attenuation observed at the GW-SWI should be incorporated into the overall site management strategy. The information can also be used to inform adaptive site monitoring and management strategies and to develop alternative points of compliance, interim remediation goals, and alternative endpoints.

References

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