HRC TECHNICAL BULLETIN #2.5.2

Plume Cut-Off Treatment Example

A biologically active barrier treatment zone can be constructed by applying HRC in rows of injection points. This is often referred to as a "permeable reactive barrier". This design approach is recommended for sites where the entire plume cannot be injected with HRC for reasons of cost or accessibility. Construction of an HRC barrier provides a means to intercept and cut-off the down gradient migration of the contaminant plume in a very cost effective manner.

The design process for this treatment strategy is described below for a hypothetical site. After the example, a description of the various spreadsheet input parameters is provided for reference.

Step 1: Gather Relevant Site Assessment Information

As with the grid design example, the relevant site assessment data should be collected. For the purposes of this example, we have assumed the same site conditions as listed in the previous grid example. However, in this case the plume is much larger, on the order of 300 feet wide by 600 feet long.

It should be noted that for barrier designs the groundwater velocity is an important piece of information since it controls the contaminant loading on the barrier, as well as the length of time that a barrier must be maintained. For instance, if the groundwater velocity is 10 feet per year, it will take many years for an entire plume to migrate through the barrier zone unless multiple barriers are used, or if an additional grid-based HRC application is applied up gradient of the barrier.

Step 2: Evaluate Site Data and Specify HRC Grid Design and Cost

As in the grid example above, the presence of daughter products of the biodegradation of PCE and the geochemical parameter values indicates that HRC could be used to create a biologically active barrier zone to passively intercept the contaminant migration. After evaluating site-specific remediation strategies and regulatory criteria, the resulting conceptual model of the contaminant plume is constructed by the remediation designer:

• Length and vertical thickness of barrier needed to intercept the contaminant plume: 300 feet wide by 15 feet deep

• Contaminant loading on barrier: 5 mg/L PCE, 0.5 mg/L TCE, 0.5 mg/L, cis-1,2-DCE at a velocity of 60 feet/year

The quantity of HRC needed to fuel the reductive dechlorination of this contaminant load is estimated by using the HRC Barrier Design worksheet and specifying the following design variables:

• <u>Site information:</u> Plume dimensions, aquifer transport parameters, and contaminant and CEA concentrations are entered into the worksheet.

• <u>Demand factors:</u> A microbial demand factor of 3x is used, and an additional demand factor of 2x is chosen since, in this case, the majority of the contaminant load comes from flow into the barrier as opposed to potential sorbed or residual phase in a source area.

- Number of HRC delivery points and HRC dosing: An individual HRC barrier consists of a series of delivery point rows. Each row is typically spaced 10 feet-on-center and is constructed in a staggered orientation relative to other rows to minimize the overall barrier delivery point spacing perpendicular to groundwater flow. Two or more rows are constructed to provide a sufficient supply of HRC for the contaminant and CEA loading for a specified length of time. For a one-year life span, an HRC dose rate of 6 pounds per vertical foot is calculated for two rows of 30 points each (i.e., ten-foot spacing for each row and an overall spacing of 5 feet-on-center perpendicular to flow). This results in a total of 60 injection points and 5,400 lbs of HRC.

- Cost estimate: The HRC material cost is $6/lb for a total of $32,400. Costs for shipping and applicable taxes vary from site to site and should be requested from Regenesis' Technical Support Staff. HRC installation costs can be estimated using a daily rate for the injection subcontractor and an estimate of the production rate for the site. For this example, the installation cost for 60 injection points to a depth of 25 feet is $9,000 resulting in a total installation and HRC material cost of approximately $42,500.

To summarize, the following issues should be considered during the HRC barrier design and cost estimation process:

- Injection point spacing typically ranges from 5 to 15 feet-on-center, and its specification depends on groundwater velocity, soil permeability, and required HRC injection amounts.

- The HRC injection rate for each point typically ranges from 4 to 10 lb/ft, and its specification depends on the contaminant and competing electron acceptor loading rate, competing microbial demand, and soil type.

- For long barriers and/or large ranges of contaminant concentrations, the HRC vertical dose rate should be adjusted as appropriate (i.e., the barrier length plume can be divided into high, medium, and low contaminant concentration areas, each with a specific HRC dose rate).

Input and Output Parameters for HRC Design Software

1) General Information on Software Use

User input parameters are shown in blue, whereas cells containing the results of calculations are shown in black. Red warnings or guiding comments may be generated in response to the spreadsheet calculations. Dialog boxes and point and click buttons are available to assist with data entry and to navigate the software.

2) Basic Site Characteristics

Basic site characteristic parameters are needed to specify the physical site characteristics. The width and depth of the contaminant plume refer to the planned treatment area, which can vary depending on remedial goals and cleanup strategy.

Thickness of the Contaminated Saturated Zone specifies the vertical thickness across which HRC will be delivered. The vertical thickness is dictated by the estimated thickness of the contaminant plume. For instance, if a site has a contaminant plume spanning the saturated zone above an aquitard, then the

design should treat the aquifer down to the aquitard. If the contaminant plume is limited to a localized depth interval or lithologic layer, then HRC injection can be limited to the contaminated depth interval.

The HRC material cost is proportional to the thickness specification. Therefore, it is important to determine the vertical contaminant distribution as accurately as possible. If only moderate concentrations of contaminant are present, and no vertical profile of the plume has been done, Regenesis suggests that the user assume a thickness of approximately 20 feet. Porosity refers to the total porosity of the aquifer soil matrix. Using the above input parameters, the software will calculate the treatment zone pore volume.

Next, information regarding aquifer transport properties are requested. The hydraulic gradient and conductivity are used to calculate the groundwater seepage velocity, which can be used to select delivery point spacing and evaluate flow dynamics within the grid.

3) Dissolved-phase Groundwater Concentrations

Under this category of input parameters, representative contaminant concentrations are specified for the area where HRC will be delivered. Specifically, dissolved-phase concentrations that are determined by groundwater well sampling and analysis are entered here. While it is important to consider the most recent data available, the input values should represent the concentration that the user judges to be indicative of actual subsurface conditions over the course of an entire hydrogeologic cycle.

Regenesis has included input spaces for the most commonly encountered chlorinated solvents; however, HRC will stimulate the degradation of a myriad of pollutants. If the contaminant the user is concerned with is not listed for input, please contact Regenesis directly. We will be glad to assist in determining the amount of HRC required to treat other less common contaminants.

4) Sorbed Phase Contaminant Mass

For HRC grid designs, there is usually a multiple of the total dissolved contaminant mass that is bound to the saturated soil zone matrix. This is called hydrophobically sorbed contamination and can be visualized as a thin layer of contaminant that is retained by clean aquifer materials when they come into contact with a dissolved contaminant flow. The mass of contaminant sorbed to the aquifer matrix is a function of the bulk density of the aquifer matrix, the fraction of organic carbon in the matrix (f_{OC}), and the contaminant-partitioning coefficient (K_{OC}). An estimate of the mass of sorbed contamination is calculated in this section by entering the factors mentioned above. Input values for the soil, the bulk density, and the fraction of organic carbon (f_{OC}) can be measured or estimated based on soil type. The K_{OC} value can be obtained for each contaminant from any number of published references.

5) Competing Electron Acceptor Concentrations

The concentrations of competing electron acceptors (CEAs) such as dissolved oxygen, nitrate, ferric iron, and sulfate have an effect on the amount of HRC required for enhancing in-situ bioremediation. Hydrogen from the HRC is used to reduce these CEAs to create redox conditions that are conducive to reductive dechlorination processes. As a result, the CEA demand for hydrogen (and consequently HRC) must be considered in the specification of the amount of HRC required for a project.

Groundwater data indicating the actual site values for these parameters are important in determining an accurate final design for HRC application. However, in the absence of these data, reasonable estimates of these values can be made to generate a preliminary design and cost estimate.

6) Microbial Demand Factor

In addition to contaminant and CEA demand for HRC, subsurface microbes will use some of the lactic acid as a source of energy or structural carbon. Therefore, in designing an HRC application, these competing microbial processes must be taken into account. Regenesis' experience indicates that a value of 3 suffices under most conditions. However, if site-specific laboratory microcosm data are available, the designer can input the appropriate value directly.

7) Additional Demand Factor

Additional Demand Factor is used to account for uncertainty about the potential sinks for electron donor. This factor can be thought of as a contingency or safety factor, which is used to account for the many uncertainties inherent in a subsurface investigation and in-situ remediation project. Potential sources of additional HRC demand include higher than expected contaminant mass (in the form of residual phase DNAPL and/or high concentration hot spots), microbial demand in excess of the estimated 3x, and uncertainty about the quantity of HRC required for the reduction of iron and manganese. The simple measurement of the concentrations of these competing electron acceptors in groundwater samples does not give an accurate representation of the iron and manganese reduction demand since these species may be present either as colloids or attached to the soil matrix. Regenesis recommends an additional demand factor of 2 to 3 for a first application at a site.

8) Life Span for One Application (for barrier designs)

For HRC barrier designs, the life span for one application should be input in this field. This value is used with the groundwater seepage velocity to estimate the flow of contaminant mass into the barrier during this period of time.

9) HRC Delivery Point Spacing and HRC Dosing Rate

For grid designs, the recommended spacing for HRC delivery points ranges from 5 feet-on-center to 15 feet-on-center. Spacing is a function of soil type, groundwater velocity, and necessary HRC dosing. Generally, the lower the hydraulic conductivity of the soil matrix, the closer the spacing. For sites with silts and clay, delivery point spacing should be 5 to 8 feet-on-center, while a site with sands and gravels may have a spacing up to 15 feet-on-center. The Delivery Point Spacing section of the Grid Design worksheet allows the designer to calculate the required number of points and HRC dose rate for a given plume size and spacing.

For barrier designs, a series of staggered HRC injection point rows are typically constructed. The effective spacing of delivery points perpendicular to the groundwater flow should be no more than 10 feet-on-center. The Delivery Point Spacing section of the Barrier Design worksheet allows the designer to estimate the required number of points and HRC dose rate for a given barrier length and contaminant flow rate.

10) Proposed HRC Grid Specifications

In this section of the worksheet, the designer may adjust the total number of injection points and the HRC dosing rate or leave it as calculated. The software will then calculate the cost of HRC material

and estimate the cost of shipping and taxes for the given scope of the project (i.e., number of points, treatment thickness, and HRC dosing rate).

11) HRC Installation Cost Estimate and Total Project Cost

Although Regenesis does not perform installation services, our experience on many applications has given us an understanding of the costs associated with installing the HRC. This section offers the designer an opportunity to estimate how much the HRC grid or barrier application will cost. The suggested input parameters required are based on Regenesis' experience. The result of this section is an estimated subcontractor installation cost. This estimate should be adjusted based on local contractor costs. The Total Project Cost provided represents the sum of the HRC Installation Cost Estimate and the HRC Material Costs. It does not include the costs associated with groundwater monitoring, reporting, or consulting oversight.