CHAPTER 1. INTRODUCTION

This research is concerned with measuring the hydraulic conductivity of soil-bentonite cutoff walls and addressing the issue of variability in hydraulic conductivity and its effect on contaminant transport through subsurface barriers. A large portion of the research was done at the new pilot-scale Subsurface Barrier Test Facility (SBTF) that was constructed for this purpose.

1.1 Background and Introduction

Soil-bentonite cutoff walls are constructed using the slurry-trenching technique. A vertical trench is excavated in the ground with a slurry (usually a bentonite-water slurry) in the trench to support the excavation. A base soil (either the excavated material from the trench or material from off-site) is mixed with bentonite in the form of bentonite-water slurry, and perhaps in dry form also, to create a low-permeability backfill mixture called soil-bentonite. This low-permeability backfill is placed in the trench and displaces the lighter support slurry to form the cutoff wall. Soil-bentonite cutoff walls are frequently used for the containment of contaminants in the subsurface (Evans, 1993 and Rumer and Ryan, 1995). Good overviews of soil-bentonite cutoff wall technology are in Schneider (1994) and D'Appolonia (1980).

Despite the widespread use of soil-bentonite cutoff walls, Evans et al. (1995) stated that "there is a serious lack of information on the actual in situ behavior of constructed vertical barrier walls at contaminated sites," which indicates the need for the type of research in this dissertation. The hydraulic conductivity of a cutoff wall is a key factor in its effectiveness as a barrier. Methods of measuring the hydraulic conductivity of cutoff walls have been developed, but there is still uncertainty in their ability to represent actual barrier performance and in the interpretation of the test results in some cases. For example, what effect does the close proximity of the trench walls have in the results of a slug test performed inside the cutoff wall itself? The majority of this dissertation involves investigation of the following methods of measuring the hydraulic conductivity of cutoff walls:

- Laboratory tests on remolded and undisturbed samples of the soil-bentonite.
- Constant and variable head (slug) tests performed inside the cutoff wall itself with a piezometer.
- Piezocone soundings.

This part of the research was done at the SBTF, where three pilot-scale soil-bentonite cutoff walls were installed and tested. The facility enables measurement of the average hydraulic conductivity of the entire pilot-scale cutoff wall, which is a valuable measurement to compare with the other measurements, and therefore draw conclusions regarding their effectiveness.

While the influence of hydraulic conductivity on contaminant transport has been discussed in the literature, the influence of variability in hydraulic conductivity on contaminant transport has not. Evans (1993) said that low hydraulic conductivity is needed for a groundwater barrier, and consideration of hydrodynamic dispersion is needed for contaminant transport studies. It is a hypothesis of this dissertation that variability in hydraulic conductivity should also be considered in contaminant transport studies.

A common remediation scheme is to construct a circumferential cutoff wall around a contaminated area, and then induce an inward hydraulic gradient by extracting groundwater from inside the enclosure. The inward hydraulic gradient insures that the contaminant will not escape the enclosure due to advection, and also counteracts the escaping tendency of the contaminant due to diffusion. The selected magnitude of the inward hydraulic gradient is determined by two factors: 1) a high gradient is desired to more effectively counteract the outward diffusive flux of contaminant and 2) a low gradient is desired to reduce the costs associated with pumping and treating the contaminated groundwater extraced from the enclosure. These factors must be considered when selecting the magnitude of the gradient. To counteract the diffusive flux, a certain inward seepage velocity is required. In order to calculate what hydraulic gradient is needed to cause this seepage velocity, the hydraulic conductivity of the cutoff wall is required. One way to evaluate the average hydraulic conductivity of the cutoff wall is by pumping out groundwater from within the enclosure, and back-calculating the conductivity from the pumping rate, the induced hydraulic gradient across the wall, and the area of the wall through which flow occurs (i.e., applying Darcy's law). This average hydraulic conductivity is used to set the hydraulic gradient across the wall. If variability in the hydraulic conductivity of the cutoff wall is considered, is the magnitude of the inward hydraulic gradient—based on calculations with only the average hydraulic conductivity—still as effective at reducing the outward diffusive flux? It will be shown in Chapter 7 that variability in hydraulic conductivity has the effect of reducing the effectiveness of the inward hydraulic gradient.

Because there is still much to be learned about subsurface barrier technologies, such as the effectiveness of hydraulic conductivity measurement techniques and the influence of variability in hydraulic conductivity on contaminant transport, a pilot-scale facility was envisioned where issues such as these could be studied. Constructing and testing subsurface barriers at a pilot-scale enables effects found at the field-scale to be studied (such as the properties of barriers constructed using equipment that is similar to field-scale equipment) in a controlled testing environment.

1.2 Research Objectives

The three main objectives of this research are:

1. Build a facility for constructing and testing pilot-scale vertical subsurface barriers. The facility should be able to accommodate the construction of various types of vertical barriers, such as slurry-excavated cutoff walls, grout curtains, vibrating beam cutoff walls, deep soil-mixed walls, and composite walls. In addition, establish a procedure for constructing soil-bentonite cutoff walls in the facility.

2. Evaluate the effectiveness of various methods of measuring barrier hydraulic conductivity, and discuss the key issues involved in performing the tests and interpreting the results. The methods of measuring hydraulic conductivity should include laboratory and in situ methods. Compare the results of the methods to the average hydraulic conductivity of the barrier measured in the facility.

3. Investigate the influence of variability in hydraulic conductivity on contaminant transport through barriers. Analyze this influence quantitatively. Summarize information on hydraulic conductivity variability from case histories.

1.3 Organization of Dissertation

This dissertation is divided into the following chapters:

Chapter 2. Literature Review. A review of relevant literature is presented, including 1) current methods of measuring the hydraulic conductivity of cutoff walls, 2) use of a circumferential cutoff wall and inward hydraulic gradient for contaminant containment, and 3) variability in hydraulic conductivity.

Chapter 3. The Subsurface Barrier Test Facility. The Subsurface Barrier Test Facility (SBTF) at Virginia Tech is described. The concept of the facility is discussed. General pilot-scale cutoff wall construction at the facility is outlined.

Chapter 4. Construction of Pilot-Scale Soil-Bentonite Cutoff Walls. This chapter describes the details of the construction of the three pilot-scale soil-bentonite cutoff walls at the facility that were tested in this research. The construction techniques, equipment, and materials are described.

Chapter 5. Measuring the Hydraulic Conductivity of the Pilot-Scale Cutoff Walls. Application of the methods of measuring hydraulic conductivity to the pilot-scale cutoff walls is described, including descriptions of procedures, equipment, and interpretation of test data. The method used to evaluate the average hydraulic conductivity of an entire pilot-scale cutoff wall is described.

Chapter 6. Results of Hydraulic Conductivity Tests. The results of the hydraulic conductivity measurements from the various methods are presented for each pilot-scale cutoff wall. The results from the methods are compared to one another, and conclusions are drawn regarding the effectiveness of the methods and appropriate test interpretation techniques.

Chapter 7. The Effect of Variability in Hydraulic Conductivity on Contaminant Transport through Soil-Bentonite Cutoff Walls. The effect of variability in hydraulic conductivity on contaminant transport through cutoff walls is investigated. An experiment showing the influence of variability is described. A statistical analysis is performed on hydraulic conductivity data from four case histories to identify the distribution and statistical parameters that appropriately describe the hydraulic conductivity data. Finally, the theoretical effect of variability on the flux through a cutoff wall is investigated using the advection-diffusion equation.

Chapter 8. Summary and Conclusions. The research and conclusions in this dissertation are summarized and recommendations are made for future work.