Understanding the potential of phosphorus transport to water resources via leaching

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ABSTRACT

Phosphorus (P) accumulation on agricultural lands has built up soil P levels that often exceed crop needs. For many years, the research focus had been on P transport associated with sediment and P dissolved in surface runoff water. Recently P leaching into subsoil, and its possible loss with subsurface drainage, has emerged as a new topic. This study seeks to better understand what happens to P when it, and the water transporting it, reaches the water table. The objective of this study was to determine the rate of P removal from water flowing laterally through P-deficient subsoil as the water traveled to tile drains.

Water was ponded in two trenches dug parallel and adjacent to an existing two-section tile line. This ponding of water was intended to establish saturated, steady state conditions in the subsoil surrounding the trenches and to create lateral flow to the tile line. Then a solution containing P and bromide (Br) was ponded in the trenches. The Br was used as a tracer to determine when and how much of the solution soaking into the subsoil reached the tile line. Water samples were collected from monitoring wells located between the trenches and the tile line and from tile line outlets; these samples were analyzed for Br and molybdate-reactive P to determine their concentrations and their rates of movement. After ponding was ceased and the trenches were allowed to drain dry, subsoil samples were collected from the wall of each trench closest to the tile line and analyzed for available P to determine the extent of P binding or adsorption. Based on the Br concentrations detected in water samples from the monitoring wells and tile line outlets, it was evident that the majority of the water flowing with tile drainage was coming from the solution in the trenches. Data indicated that the added P was not moving nearly as fast or as far as the added Br. Most of

the added P was being removed from the laterally flowing water by some means, presumably by precipitation and/or adsorption in the P-deficient subsoil.

CHAPTER 1. INTRODUCTION

The United States has made tremendous advances in the past 25 years to clean up the aquatic environment by controlling pollution from industries and sewage treatment plants. However, we have not done enough to control pollution from diffuse, or nonpoint, sources. Today, nonpoint source pollution (NPS) is our Nation's largest overall source of water quality problems. NPS pollution is the primary reason why approximately 40% of our surveyed rivers, lakes, and estuaries are not clean enough to meet basic uses such as swimming and fishing (EPA, 2000). In its *National Water Quality Inventory: 1998 Report to Congress*, the U.S. Environmental Protection Agency (EPA) implicated agriculture as the leading source of water quality impairments to surveyed rivers, streams, lakes, ponds, and reservoirs, and the fifth largest source of impairments to surveyed estuaries (EPA, 1998).

Agricultural activities that cause NPS pollution include concentrated animal feeding operations (CAFOs), grazing, tillage, pesticide spraying, irrigation, fertilizing, planting, and harvesting. The major agricultural NPS pollutants resulting from these activities are sediment, nutrients, pathogens, pesticides, and salts (EPA, 2000a). Agricultural activities also can damage animal habitats and stream channels. However, agricultural impacts on surface water and groundwater quality can be minimized by properly managing activities that can cause NPS pollution.

Nitrogen (N) and phosphorus (P) are the two major nutrients originating from agricultural lands that degrade water quality. All plants require nutrients for growth. In aquatic environments, nutrient availability usually limits plant growth. N and P generally are present at background or natural levels below 0.3 and 0.01 mg/L, respectively (EPA, 2000a).

When P is introduced into a body of fresh water at higher rates, aquatic plant productivity may increase dramatically. This process, referred to as eutrophication, may adversely affect the suitability of a given body of freshwater for beneficial uses.

P accumulation on many agricultural lands, resulting from excessive fertilizer and/or manure applications, has built up soil P levels that often exceed the needs of crops. Today, there are serious concerns that agricultural runoff (surface and subsurface) and erosion from high P-test soils may be major contributing factors to surface water eutrophication. Agricultural runoff is termed here to include all water that drains from an area (a field or a watershed) including surface runoff and subsurface flow, by both natural means and through tile drain systems. P loss in agricultural runoff is not much of an economic concern to farmers because the loss usually amounts to only 1-2% of the P applied (USDA, 1999). But, P loss can lead to significant off-site economic impacts, which may occur in some cases several miles from the P sources. By the time these water quality impacts are discovered, remedial strategies may be – and usually are – difficult and expensive to implement. Furthermore, these impacts cross regional and political boundaries, and, because of past P loading, water quality improvements are apt to take a long time to occur.

Because of these concerns about water quality impacts, there has been increased interest in improving the management of agricultural P from animal manure and commercial fertilizers. For many years, the focus had been on P transport associated with sediment and P dissolved in surface water runoff. Recently, however, P leaching into subsoil, and its possible loss with subsurface drainage, has emerged as a topic of new concern and interest. Some studies have indicated that surface water leached to subsurface water may get returned to surface water sources – rivers, lakes, and reservoirs – via manmade, artificial subsurface tile lines or by more natural and gradual means, i.e. through subsurface water base flow.

Mostly, these studies, discussed in the literature review in Chapter 2, have determined the degree of water leaching vertically and draining directly to a tile line in a field setting or percolating through vertical soil columns in a laboratory setting. Measured P concentrations in solution at the outflow end of these settings often were substantially higher than measured P concentrations typically found in field subsurface drainage water. Not usually considered, when using these studies to assess the degree of P leaching, is the potential of P-deficient subsoil to attenuate the movement and transport of P. After leached water percolates through the subsoil to an existing subsurface water table, the mixed water has to move laterally through the water table and its subsoil before the water reaches a drain line and eventually emerges again in a surface water resource. This lateral water movement could take a long time to traverse the distance to a subsurface drain line. Therefore, more information in the short term is needed regarding the degree of this potential P attenuation in subsoil. Moreover, more information is needed as to whether the capacity for this attenuation over the long term is diminished to a point where management plans for P must consider P leaching more thoroughly. Effective P management plans must be based on this additional scientific information for all soil types.

Accordingly, the overall objective of the research grant funding this study was to determine the rate of P removal from water flowing laterally through P-deficient subsoil as the water traveled to tile drains.

CHAPTER 2. LITERATURE REVIEW

Phosphorus Concerns in the Environment

Impacts and Implications of Eutrophication

Eutrophication is a natural process whereby a lake or other body of water evolves from a low productivity/low nutrient concentration state to a high productivity/high nutrient concentration state. This process is greatly accelerated by nutrient enrichment from human activities. Results of eutrophication in a water body can include algal blooms, low dissolved oxygen content, and changes in the composition of aquatic life. P loss from agricultural lands to water bodies is becoming more important in understanding the forces that drive the process of eutrophication.

Increased aquatic plant productivity results in the addition of more organic matter to the aquatic system. This added organic matter eventually dies and decays. Microbial organisms such as bacteria decomposing this organic matter deplete the oxygen supply in the water and produce unpleasant tastes and odors. Depleted oxygen levels, especially in colder bottom waters where decaying organic matter tends to accumulate, can reduce the quality of fish habitat and encourage the propagation of fish that are adapted to less oxygen or to warmer surface waters. Anaerobic conditions can also cause the release of additional nutrients from bottom sediments. Highly enriched waters will stimulate algae production, consequently increasing turbidity levels and color. Excess plant growth may also interfere with recreational activities such as swimming and boating. Furthermore, the increased turbidity results in less sunlight penetration and availability to submerged aquatic vegetation.

Since this vegetation provides habitat for small or juvenile fish, its loss can have severe consequences for the food web.

Extent of Eutrophication – Globally, Nationally, and Locally

Eutrophication, caused by P enrichment, is not a new environmental problem. It first came to the fore in North America in the 1960s, most notably in the Great Lakes region of the USA and Canada. In the following decade, a host of other lakes, suffering from varying degrees of P enrichment, were identified as eutrophic throughout Western Europe and elsewhere around the world. Within the British Isles, the continuing relevance of P enrichment was highlighted by the detection of toxin-producing algal blooms in many reservoirs during a hot summer of 1989 and the realization that previously large and pristine Irish lakes had experienced significant P enrichment during the 1980s (Tunney et al., 1997).

Iowa's agricultural landscape has changed drastically from 125 years ago when less than 3% of the land was used for agricultural production. Most of Iowa's land was converted to agricultural use after the installation of an extensive network of subsurface drains, open ditches, and straightened streams between 1910 and the 1930s. Although this increased agricultural production, modification of the local and regional hydrology contributed to increased occurrences of peak flows from agricultural lands. This resulted in the direct transfer of NPS pollutants to the Missouri and Mississippi rivers. Addressing NPS pollution, therefore, has become Iowa's number one water quality priority (ISWRRI, 2000).

NPS pollution is now recognized as an important environmental and social issue in Iowa and the Midwest. Excessive use of nutrients in agricultural watersheds can have serious and deleterious impacts on the quality of surface and groundwater resources. Several states, including Iowa, are in the process of developing nutrient criteria and creating laws to reduce nitrate-nitrogen (NO_3-N) and P runoff and leaching to surface and ground waters from mineral fertilizers and manure applications.

Sources of Phosphorus Leading to Eutrophication

P occurs naturally in soil, mainly in mineral forms; however, it can also be found in organic matter. P can be found in the soil in dissolved, colloidal, or particulate forms. Although the P content of most soils in their natural condition is low (0.01 to 0.20% by weight), soil test results show that the P content of most cropped soils in the Northeast U.S. has climbed to the high or very high range with respect to soil fertility (Sims, 1992). Applying manure or commercial P fertilizer increases the level of available P in the soil to promote plant growth, but many soils now contain higher P levels than plants need (Sharpley et al., 1994). Manure is normally applied at rates to meet crop N needs, such as in corn, yet the ratio of N to P in most manure results in over-application of P (Sharpley et al., 1996).

Agricultural Production and Soil Phosphorus Surpluses

A major source of agricultural income in several of our Nation's States comes from CAFOs. Animal manure resulting from these operations can be a valuable resource for improving soil structure and for increasing vegetative cover. These improvements can reduce surface runoff and the potential for soil erosion. However, the rapid growth and intensification of crop and animal production has created, in many areas, regional and local imbalances in P inputs and outputs. On average, only about 30% of the fertilizer and feed P input to farming systems is output in crop and animal production. When averaged over the total useable agricultural land area in the United States, a surplus of about 33 kg of P/ha exists annually (National Research Council, 1993).

Before World War II, farming communities tended to be self-sufficient because enough animal feed was produced locally and recycled to meet animal requirements, and animal manure was returned to the land. After World War II, fertilizer use in crop production increased and fragmented farming systems, creating specialized crop and animal operations that coexisted efficiently in different regions within and among countries. Since commercial fertilizer production and distribution became less expensive than using manure, farming operations did not have to depend on manure as a crop nutrient source. Hence, they could separate grain and animal production spatially (USDA, 1999). By 1995, major animal producers imported more than 80% of their grain for feed (Lanyon and Thompson, 1996). Furthermore, less than a third of the grain produced on a farm is fed to the animals on the farm where it is grown (USDA, 1989).

At the farm scale, the potential for a P surplus can increase when farming systems change from cropping to intensive, concentrated animal production due to P inputs dominated by feed rather than fertilizer. For example, only 27% of the P in purchased feed for a 74,000-laying-hen operation on a 12.14-ha farm in Pennsylvania could be accounted for in annual P output. Annual P input in feed on this farm was 1541kg/ha/yr, and its annual P output was 409 kg/ha/yr. The P output included 375.4 kg/ha/yr in eggs, 22.4 kg/ha/yr sold in crops (corn and alfalfa), and 11.2 kg/ha/yr in manure exported from the farm (Lanyon and Thompson, 1996; Bacon et al., 1990). This nutrient budget clearly indicates that the largest input of P to the farm was in animal feed. Similarly, Sims (1997) estimated annual surpluses of about 90 to 123 kg P/ha/yr for a typical poultry grain farm in Delaware. This type of situation is consistent with other concentrated animal production industries, including dairy and hog producers.

Phosphorus Movement in the Landscape

Phosphorus Movement Factors

P movement can be separated into transport, source, and management factors. Transport factors include the mechanism by which P moves within the landscape; these are rainfall, irrigation, erosion, surface runoff, and subsurface drainage factors. Factors influencing the source and amount of P available to be transported are soil P content and the form and amount of P applied. Lastly, P management factors include the method of P application, timing, tillage, and land placement as influenced by the management of application equipment (USDA, 1994).

Phosphorus Transport

When rainfall, snowmelt, or irrigation water runs over land or through the ground, it picks up P and deposits it into rivers, lakes, and coastal waters or introduces the P into groundwater. Imagine the path taken by a single raindrop from the time the raindrop hits the ground to when it reaches a river, groundwater, or the ocean. Any P the raindrop picks up on its journey can become part of the eutrophication problem.

P is transported in dissolved (DP) and particulate (PP) forms. Most P is often PP or sediment-attached. However, both forms can contribute to eutrophication. PP includes P sorbed by soil particles and in organic matter eroded during runoff events and usually constitutes the major portion of P transported from cultivated land – about 75 to 90% (USDA, 1994). Grassland or forestland runoff normally carries little sediment; therefore, DP generally dominates the P loss from these lands. While DP essentially is immediately available for biological uptake, PP can provide a long-term source of P for aquatic life. The bioavailability of PP can vary from 10 to 90% of the total P, depending on the nature of the eroding soil (USDA, 1994). Together, DP and bioavailable PP constitute bioavailable P (BAP), or P available for assimilation by aquatic life (EPA, 2000). BAP and DP, together, account for the P that promotes eutrophication of surface waters.

The transport of DP starts with desorption, dissolution, and extraction of P from the soil, plant, and organic material. These processes take place when rain and runoff water interact with the thin layer of surface soil (e.g., the top 2 to 10 mm). Some water infiltrates into the soil and percolates through the soil profile where sorption of P can result in a low DP concentration in subsurface and return flow. A high DP concentration can be expected in water percolating through organic, coarse-textured, oxygen-depleted (reduced), and water logged soils.

Soil pH can also affect the movement and availability of P to crops. In soils with calcium (Ca) at high pH values, with iron (Fe) and aluminum (Al) at low pH values, and with high clay content, availability of P to crops is reduced. Liming may increase P availability in soils by stimulating mineralization of organic P or may decrease it by forming insoluble calcium phosphates at pH values greater than 6.5 (Sharpley and Rekolainen, 1997).

During the transport of P from the edge of a field to a receiving water body, DP and PP fractions continuously change as a result of in-stream processes. These processes include uptake of DP by aquatic life, transformations between PP and DP caused by changes in stream equilibrium conditions, deposition of suspended PP, and re-suspension of streambed or stream-bank PP. The direction and extent of these P transformations during transport depend on the time of year, the relative amounts of P entering from different sources, and, in particular, the rate of flow (Sharpley and Rekolainen, 1997). The interaction between PP and runoff DP is very dynamic and the transport mechanism is very complex. Therefore, it is quite difficult to predict the transformation and ultimate fate of P as it moves through the landscape.

Surface Pathways of Phosphorus Loss

Surface runoff has, in terms of nutrient transfer, a clear link from agricultural lands to receiving waters. Therefore, it follows that the extent of P export by this pathway has been well documented for a range of different land uses in several geographic areas (Heathwaite et al., 1990; Foy and Withers, 1995; Schuman et al., 1973; Timmons et al., 1973; Rompkens and Nelson, 1974; Barisas et al., 1978; and Baker and Laflen, 1982). Both PP and DP fractions may be transported in surface runoff, although the former usually predominates. Transport of eroded material in surface runoff is particle-size selective and highly effective at transporting P adsorbed onto organic-rich clay and silt-sized soil fractions. Storage or transformation of P during transit may occur and depends largely on physical factors, such as the different land uses over which surface runoff may pass and the infiltration capacity of the soil surface. Chemical (e.g. adsorption/desorption) and biological (e.g. plant uptake) factors may come into play, but they may be more important for subsurface P transport (Heathwaite, 1997).

Subsurface Transport of Phosphorus

Losses of P from soil to drainage water were previously considered to be of very little significance, other than in a few specialized cases such as in poorly drained soils high in organic matter (Sharpley et al., 1994). Therefore, the process of P transport in subsurface runoff has not received as much attention as P transport via surface runoff. Some reports in the scientific literature, though, have illustrated that P in subsurface runoff might well reach concentrations that have clear environmental implications (Ryden et al., 1973). Also, increased concerns about this problem have been raised more recently in regions with a history of long-term applications of organic manures (Breeuwsma et al. 1995; Lookman et al., 1995).

It is assumed that most subsurface transport of P is in the soluble fraction, where typical concentrations of soluble P percolating through soil are about 0.1 mg/L of soluble molybdate-reactive P (MRP) even where soil P concentrations are high (Withers, 1994). Similar research suggests that other P fractions such as insoluble ones may also be transported in this manner (Dils and Heathwaite, 1996). Soil characteristics and P transformations along flow pathways become relatively more important in characterizing P loss below the ground surface. Sharpley and Syers (1979) and Sharpley et al. (1992) found that these P transformations include re-adsorption of DP by soil particles.

Soil structure will influence P fractionation through its indirect control of the length of contact time between percolating water, soil water, and soil particles. Therefore, soil fissures (or macropores) will enable rapid bypass of water flow through the soil and decrease the contact time between water and soil. These macropores constitute a large pore system created in soil by such things as wormholes and plant roots. Collectively, these macropores contribute to subsurface flow phenomena referred to as "preferential flows" – flow paths and patterns that follow preexisting features in the soil profile – although flow paths created by roots and worms are usually more vertical than horizontal. Dils and Heathwaite (1996) have presented evidence to suggest that water moving through these preferential flow paths may show elevated P concentrations.

Subsurface preferential flow probably transports P in a similar form to that recorded in surface flow, but it does not require the high rainfall intensities and durations characteristic of infiltration-excess or saturation-excess overland flow conditions. Thus P may be transported by preferential flow for relatively small rainfall events. Similar arguments exist for artificial tile drains, which act essentially as large, and more or less permanent, horizontal macropores in the soil (Heathwaite, 1997).

Phosphorus Loss in Leaching Studies

As mentioned before, the issue of the degree of importance of P transport with leaching water is not as well documented or understood as that of P transport in surface runoff. But some studies have been done in attempts to determine the degree and the relevance of subsurface drainage to P transport. Many researchers, having made direct measurements of P losses via leaching, have expressed concerns for these losses to surface waters – with preferential flow paths potentially identified as a major factor in the leaching process.

In one study, Sawhney (1977) measured movement of P through vertical saturated columns of either a fine sandy loam soil or a silt loam soil. In the fine sandy loam, P breakthrough occurred after about 50 pore volumes; in the silt loam, P emerged after about 100 pore volumes. For each soil type, the amount of P adsorbed to the soil before breakthrough was about equal to the soil's previously determined sorption capacity. The sorption capacity of each soil was determined from an isotherm over an ample reaction time.

In a study of P leaching in drainage water from the Broadbalk soil experiment at Rothamsted, Thomas et al. (1997) found that P was being leached in drainage water despite the large adsorption potential of the subsoil. They concluded that one possible explanation for the P loss to the drainage water was that the water was flowing down "large, possibly permanent, cracks in the soil (preferential flow), thus reducing the effective sorption capacity of the Broadbalk subsoil."

Howse et al. (1997) measured concentrations of MRP and total P (TP) in subsurface drainage water from clay soils from 20 hydrologically isolated 0.2-ha plots. They also measured MRP and TP in combined surface runoff and in interflow in the cultivated topsoil. The MRP and TP measurements were collected from 1990-1995. They found MRP concentrations in most drainage water and surface runoff plus interflow samples were greater than the minimum (20 ug P/L) thought to cause eutrophication. However, restricting the drain flow so water was held for longer periods in contact with the soil decreased soluble P losses by 29-52%.

Stamm et al. (1997) measured MRP in subsurface drainage from two catchment area sites in Switzerland that accommodated intensive hog production. At one site for one rainfall event, P dynamics were characterized by simultaneous increases and decreases in MRP with discharge rate. During base flow at that site, MRP ranged between 50-150 ug P/L, whereas maximum MRP concentrations reached values of 600-1500 ug P/L during peak flows. Extreme values up to 4800 ug P/L were measured during rainfall events shortly after manure application. MRP fluxes equated to losses that varied between a few grams up to 500 g/ha. At the other site, total MRP losses ranged between 600-1900 g/ha. At the first site, losses of MRP ranged between 1100-1600 g/ha for a 6-month period from April to October 1994. They stated that even the lower estimates were above the accepted value of 400 g/ha/yr for critical losses. Also, they conducted experiments using a dye tracer that showed evidence of preferential flow paths in the drainage areas. They concluded this transport mechanism explained the increased P concentrations in subsurface drains during storms.

Stamm et al. (1998) measured MRP in a study of P leaching from drained wetland soils receiving manure. During peak flows from two soils derived from glacial till, they measured MRP concentrations up to 5000 ug P/L. MRP concentration in pure matrix flow was estimated to be ~50 ug/L. They found evidence of preferential flow paths in the soils from results of dye tracer experiments. Preferential flow was implicated again as an "efficient mechanism of P export into tile drains."

In another study measuring P losses in tile drainage water from 27 soils, Beauchemin et al. (1998) stated that P leaching from most mineral soils is not really considered as an environmental issue of any consequence. But they did state their concern for soils that had large amounts of P stored in them as well as decreased capacities for adsorption in soil surface horizons. MRP concentrations in their tile drain samples were usually less than 25 ug/L, yet the P concentrations were often greater than 50 ug/L if PP was included.

These six studies are only a small representation of the types of studies investigating P leaching in various soils. They demonstrate that dissolved reactive P levels in subsurface drainage may be rather low (less than 50 ug/L) during periods of sustained low flows. But, at times of high flows (possibly with surface water ponding), P movement from surface water to the water table can occur rapidly. This phenomenon has been demonstrated both in vertical column studies and in measurements taken in field studies of vertical water and P movement through subsoil. In this context, the operative word here is "vertical." In each of the studies cited, the water and P movement was vertical. An extensive review of the scientific literature revealed no research reports studying horizontal or lateral P transport or movement through subsoil.

Therefore, one of the issues this research project seeks to address – at least partially – is what happens to P when it, and the water transporting the P, reaches the water table. Once in the water table, P must pass laterally through subsoil before returning back to surface water or into an artificial subsurface tile drain. The general goal of this project was not only to provide new information about lateral P transport and movement in subsoil but also to assess the impact on the potential for P losses via leaching. To reiterate, the objective of this project as stated at the end of Chapter 1 was to determine the rate of P removal from water flowing laterally through P-deficient subsoil as the water traveled to tile drains.

CHAPTER 3. MATERIALS AND METHODS

Project Summary

In the summer of 2002, two trenches (one per replication) were excavated parallel to and 3 m from an existing subsurface tile drain line that had been sectioned into two parts with two outlets. Six monitoring wells (MW; three per replication) were installed midpoint between the trenches and the tile line (Fig. 3.1 through 3.3). During the study water only, a solution of P (~10 mg P/L as KH_2PO_4) and Br anion (~100 mg Br/L as KBr), and, finally, a solution of P only were sequentially added to and ponded in both trenches.

Periodically, the wells were monitored for the depth to the water table and for the concentration of P and Br in the well water. Also the two tile line outfalls were monitored for their flow rates and for the concentrations of P and Br in tile drainage water. The Br anion was used as a tracer to determine when and how much of the water soaking into the trench reached the tile drain. Finally, after ponding was ceased and each trench drained completely, subsoil samples were taken from each trench wall face nearest the wells at points below the ponded water level. The subsoil samples were analyzed for pH and for available P using both the Bray-1 and the Olsen available P tests.

Site Characteristics

After a preliminary trial run in the autumn of 2001 (see Appendix A for these data), this field study was conducted from late June through early September 2002 at Iowa State University's Agronomy and Agricultural Engineering Research Center (AAERC) located about 13 km west of Ames in Boone County, Iowa. An existing 10-cm clay tile line drains the plot area. The tile spacing is 36.6 m and the average depth of this tile line is about 0.9 to

1.1 m below the ground surface. The site slopes about 4% downward from northeast to southwest. The field was planted to corn during this study, but the corn was cut down on the study site and cut back about 3 m on all sides adjacent to it. AAERC records dating back to April 1996 revealed that the only soil amendment applied since then (not including herbicides) was N in the spring of 2002 at a rate of 168 to 179 kg/ha. On 30 April 1996, lime at 14,570 kg/ha was applied to all of this area. This particular area is known as a cultivate/no cultivate plot (continuous corn). Based on previous studies, Br concentrations in soil water at the AAERC are usually less than 0.1 mg Br/L, and MRP concentrations in tile drainage water in this area usually range from 0.10 to 0.50 mg P/L.

The soil at this site, typical of soil found in central and north-central Iowa, generally is classified as a Clarion loam and is derived from calcareous, loamy, glacial till. The subsoil, sampled from 60 to 120 cm below ground level in the fall of 2001, had an average available P of 0.9 and 1.2 mg/kg as Bray-1 and Olsen P, respectively. From earlier soil surveys (USDA, 2002), specific chemical and physical property data are available for given depth ranges. In the 0 to 45 cm depth range, these properties were: soil pH, 5.6 to 7.3; organic matter, 3.0 to 4.0%; calcium carbonate, 0%; clay, 18 to 24%; and USDA texture, loam. In the 45 to 100 cm depth range, these properties were: soil pH, 5.6 to 7.8; organic matter, 0.5 to 1.0%; calcium carbonate, 0 to 15%; clay, 24 to 30%; and USDA texture, loam to clay loam. In the 100 to 150 cm depth range, these properties were: soil pH, 7.4 to 8.4; organic matter, 0 to 0.5%; calcium carbonate, 5 to 30%; clay, 12 to 22%; and USDA texture, loam to sandy loam.

Layout and Preparation of Site

After the site was selected, it was divided into two separate and distinct plots. At approximately 15 m from the main drain sump, a hole was excavated to expose the 10-cm tile line (Fig. 3.1). This line was cut so a 5-cm PVC pipe could be inserted into it leading to the main drain sump. Therefore, the 10-cm line drained replication 1 (rep 1) and the 5-cm line drained replication 2 (rep 2). The cut end of the 10-cm line draining rep 1 was sealed to exclude any drainage from rep 2. Fig. 3.2 shows an overhead view of the main drain sump, located at the west end of the site, configured to accommodate the individual drain sumps for each replication.

The plot area was laid out to the measurements indicated in Fig. 3.1 with the existing 10-cm tile line located with a tile line probe and flagged. The two trenches and six monitoring wells were marked and flagged as well with respect to the tile line. Each 6 m long trench was dug 3 m away from and parallel to the existing 10-cm drain line as shown in Fig. 3.1. The trenches were excavated to a depth of 107 cm using a trenching machine that made an 18 cm wide cut. Then flexible, perforated drainage tubing (10-cm I.D. and 6-mm wall thickness – including corrugations) was placed lengthwise in the bottom of each trench, with about 60 cm of tubing protruding above ground at each end of the trench. This tubing was used to ensure a uniform flow of ponded water from the trench bottom in case of a cave-in of the trench walls.

A stilling well and float switch assembly were positioned in each trench as shown in Fig. 3.1. Each stilling well was a 1.2 m long, 30 cm diameter piece of PVC pipe installed between the trench walls so it would not move. Each float switch was of the type used to provide livestock with drinking water. Each switch was secured to a piece of 2.5-cm flat metal stock welded to a 1.8-m length of 1.26 cm diameter rebar. The rebar, with the attached float switch, was installed in the stilling well and driven into the soil at the bottom of the trench. The rebar could be moved up or down as necessary to adjust the level of the float switch.

MW1, MW2, and MW3 were installed midpoint between the trench for rep 1 and the tile line (Fig. 3.3) for measuring the depth of the water table and for taking water samples from the saturated zone (likewise for MW4, MW5, and MW6 in rep 2). Each monitoring well hole was made by removing two vertical soil cores from the ground (the first one from 0 to 1.2 m and the second one from 1.2 to 2.4 m directly below the first). The soil sampling equipment was manufactured by the Newton Company. A 3-m length of 1.26 cm diameter PVC pipe (with slits cut about every 15 cm on alternate sides of the pipe for groundwater to seep in) was pushed down into each 2.4-m hole until it hit bottom. Each well had about 60 cm of pipe protruding above the ground. Fig.3.3 shows a cross-sectional end view of rep 1 as if one were looking towards the east. Rep 2 to the east is a mirror image of rep 1.

A 3785-L water tank was placed about 6 m from the east end of the plot. This tank was used to supply water or the chemical solutions by gravity to each trench. A 5-cm hose from the tank outlet ran on the ground above the tile line to the point adjacent to the stilling well on rep 2. Here a Y-connection was used to split the flow from the 3785-L tank into two supply lines - each supply line being a length of standard garden hose feeding a float switch.

A staff gauge was used to monitor the ponded water level in each trench at about 60 cm below the ground surface. Each gauge was made from a 1.5-m length of 2.5 cm diameter PVC pipe attached to a 0.6 m square wooden board. For rep 1, the board was placed flat on the ground over the trench directly in line with MW2. The board was partially buried with soil to keep it stationary. The pipe was attached with rope vertically to the side of the board with the bottom of the pipe resting on top of the 10-cm flexible tubing in the trench bottom. Two marks were made on the pipe with a permanent marker. The first mark was made on the pipe adjacent to the bottom of the board; the second mark was made at 60 cm below the first mark. The level of ponded water or chemical solutions was to be maintained at the lower mark. A similar staff gauge was installed for rep 2 in line with MW5.

Saturation of the Subsoil

On 28 June 2002, addition of water from the 3785-L tank to each trench commenced. Four to five times daily this tank had to be refilled. This was done by pumping water from an 1893-L tank (situated on a flatbed trailer) to the larger tank. This trailer was used to haul water from a source about 0.4 km away. The water source was subsurface drainage collected in a large sump for a wetland study.

Initially, water from the larger tank was added directly to each trench through the garden hose disconnected from the float switch. Once the ponded water in each trench reached the lower mark on the gauge, the garden hose was attached to the float switch. This constant ponding of water was done in an attempt to establish saturated, steady state conditions in terms of the hydraulic gradient (from the ponded water level in the trench to the bottom of the tile line). Water-only ponding continued until 9 July 2002.

Water Table Depth Measurements

The depth of the water table at each monitoring well was measured periodically by slowly inserting one end of a 1.0 cm diameter, 2.4 m long piece of flexible plastic tubing down into each well while simultaneously blowing on the other end until air coming out of the inserted end contacted the water table. As soon as the sound of air bubbling into the water was heard, insertion of the tubing was stopped; the total distance the tubing extended into the well was then measured and recorded. The length of well pipe protruding above the ground was subtracted from the first measurement, with the difference being the depth of the water table. The time of this measurement was recorded.

Tile Drain Flow Rate Measurements

The flow rate at each tile line outlet was also measured periodically by collecting tile line outflow in a bucket for a specific number of minutes. The volume collected was measured using a graduated cylinder. The flow rate, in mL/min, was calculated as the volume collected divided by the time. The time of this measurement was recorded.

Preparation of Phosphorus-Bromide Solution

Potassium phosphate, monobasic (KH_2PO_4: formula weight 136.09) was purchased from Fisher Scientific Company (Stock #P285); the P/ KH_2PO_4 ratio is 0.2276. The solution was made in 1514-L batches with 10 mg P/L requiring 66.53 g KH_2PO_4 per batch. Potassium bromide (KBr: formula weight 119.01) was also purchased from Fisher Scientific Company (Stock #P205); the Br/KBr ratio is 0.6714. For 1514 L of 100 mg Br/L, 225.52 g of KBr were required. For ease of preparation, pre-weighed amounts of KH_2PO_4 (66.53 g) and KBr (225.52 g) were dissolved in de-ionized water and made up volumetrically to 1 L. This concentrated solution was transferred to a plastic bottle and stored until ready for use.

Addition of Phosphorus-Bromide Solution to Trenches

On 9 July 2002, 12 days after ponding of water only, addition of P-Br solution to each trench commenced. The larger tank was allowed to drain completely, and then it was filled with 3785 L of the 100 mg Br/L and 10 mg P/L solution. Working on one trench at a time, this solution was added manually to each trench through the 5-cm hose while simultaneously pumping the existing ponded water from the trench. This step was intended to minimize mixing of the ponded water with the P-Br solution and to maintain the hydraulic head and saturated conditions in the subsoil surrounding the trench. When the ponded water level in a trench rose to the lower mark on the staff gauge, the garden hose was reconnected to the 5-cm hose to restore automatic flow control of the incoming P-Br solution.

Additions of the P-Br solution to the larger tank were made from the portable tank. Whenever the portable tank was emptied, another batch of P-Br solution was made by pouring a 1-L bottle of concentrated P-Br solution into the portable tank and pumping water into it to the 1514-L mark.

Addition of the P-Br solution and the P-only solution continued until 26 July and 2 August 2002, respectively. The supply of Br was exhausted first and its addition was stopped earlier than the P.

Water Sample Collection

All water samples were collected in Nalgene Brand 125-mL, wide-mouth, HDPE bottles. Whenever the P-Br solution in the portable tank was pumped to the larger tank, a grab sample of the solution was collected at the pump discharge. Whenever a flow rate measurement was made at each tile line outfall, a grab sample of the outflow was collected. After each set of periodic water table depth measurements was recorded for MW1 through MW6, a grab sample from each well was collected using a Nalgene MityVac II hand-operated vacuum pump connected by tubing to a two-holed rubber stopper fitting the sample bottle mouth. Shortly after collection, the samples were taken to the Water Quality Laboratory at Iowa State University and stored at 4°C until they were analyzed.

Water Sample Analysis

Determination of P and Br in solution was done colorimetrically on the unfiltered water samples. A Perkin-Elmer Lambda 3B UV/VIS spectrophotometer (880 nm, 5.0-cm light path length) was the instrument used to analyze for P. P was determined as soluble MRP using the molybdate ascorbic acid method of Murphy and Riley (1962). An MRP calibration curve was prepared using nine standards: 0; 0.005; 0.010; 0.025; 0.050; 0.100; 0.200; 0.500; and 0.750 mg P/L. A Lachat QuikChem 8000, incorporating flow-injection technology, was the instrument used to analyze for Br (APHA, 1998). A Br calibration curve was prepared using seven standards: 0; 1.0; 2.5; 5.0; 15.0; 30.0; and 60.0 mg Br/L.

Subsoil Sample Collection

Subsoil samples were collected on 10 September 2002 (about five weeks after the ponded solution in each trench was allowed to drain dry). These samples were collected from each trench wall face nearest to the monitoring wells. Six 25-cm long horizontal subsoil cores (three per replication) were taken from the trench wall in line with each monitoring well at a point below the ponded water/solution level. The 25-cm long cores were cut into five, 5 cm long sections (0-5 cm to 20-25 cm). Each of these sections was put into a soil sample bag and taken to the Soil Test Laboratory at Iowa State University.

Subsoil Sample Analysis

Determination of P in the subsoil samples was assessed using both the Bray-1 and Olsen available P soil tests (NCR, 1998). The Olsen test was used because of the calcareous nature of the subsoil. These samples were also analyzed for soil pH.

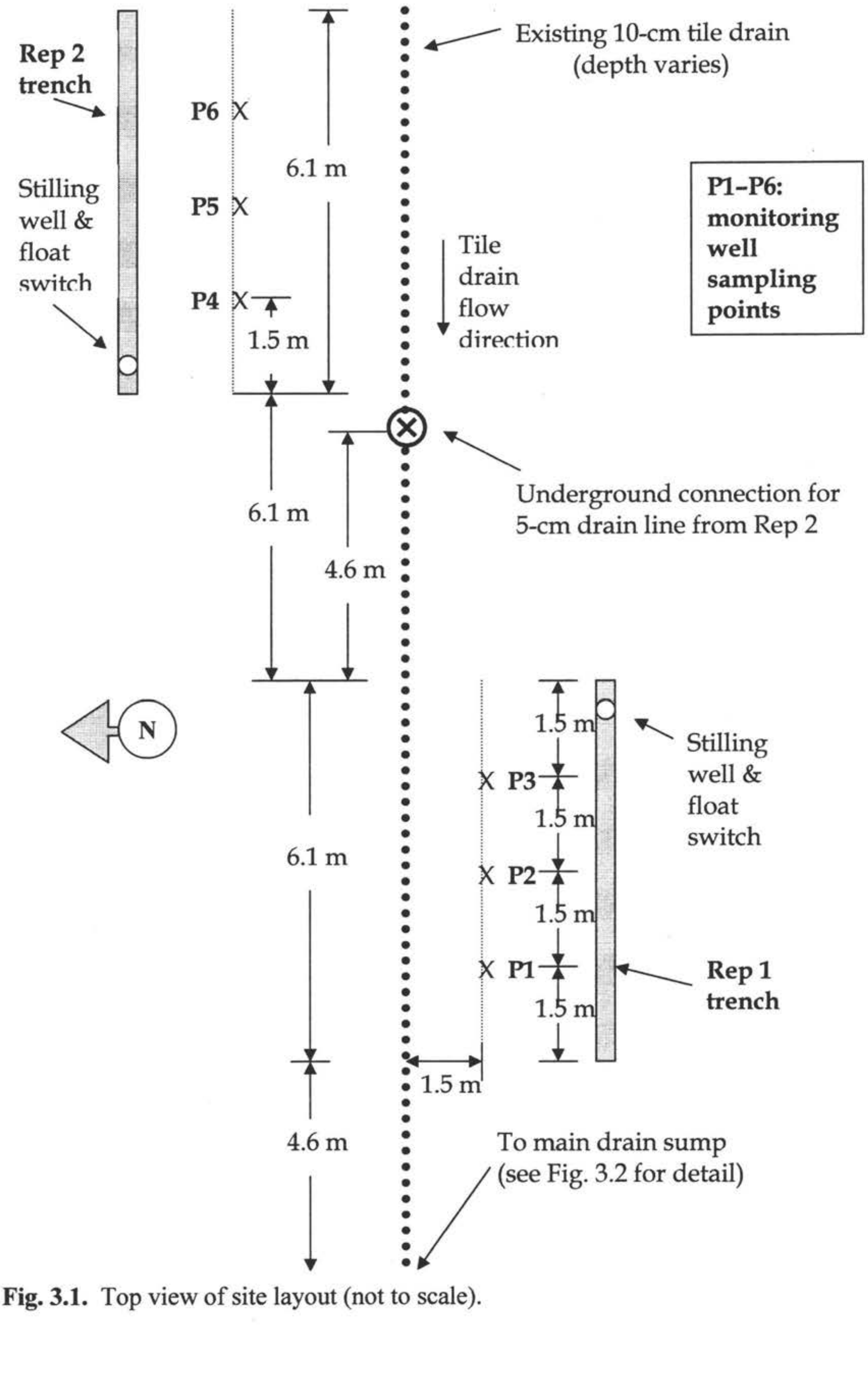

Fig. 3.1. Top view of site layout (not to scale).

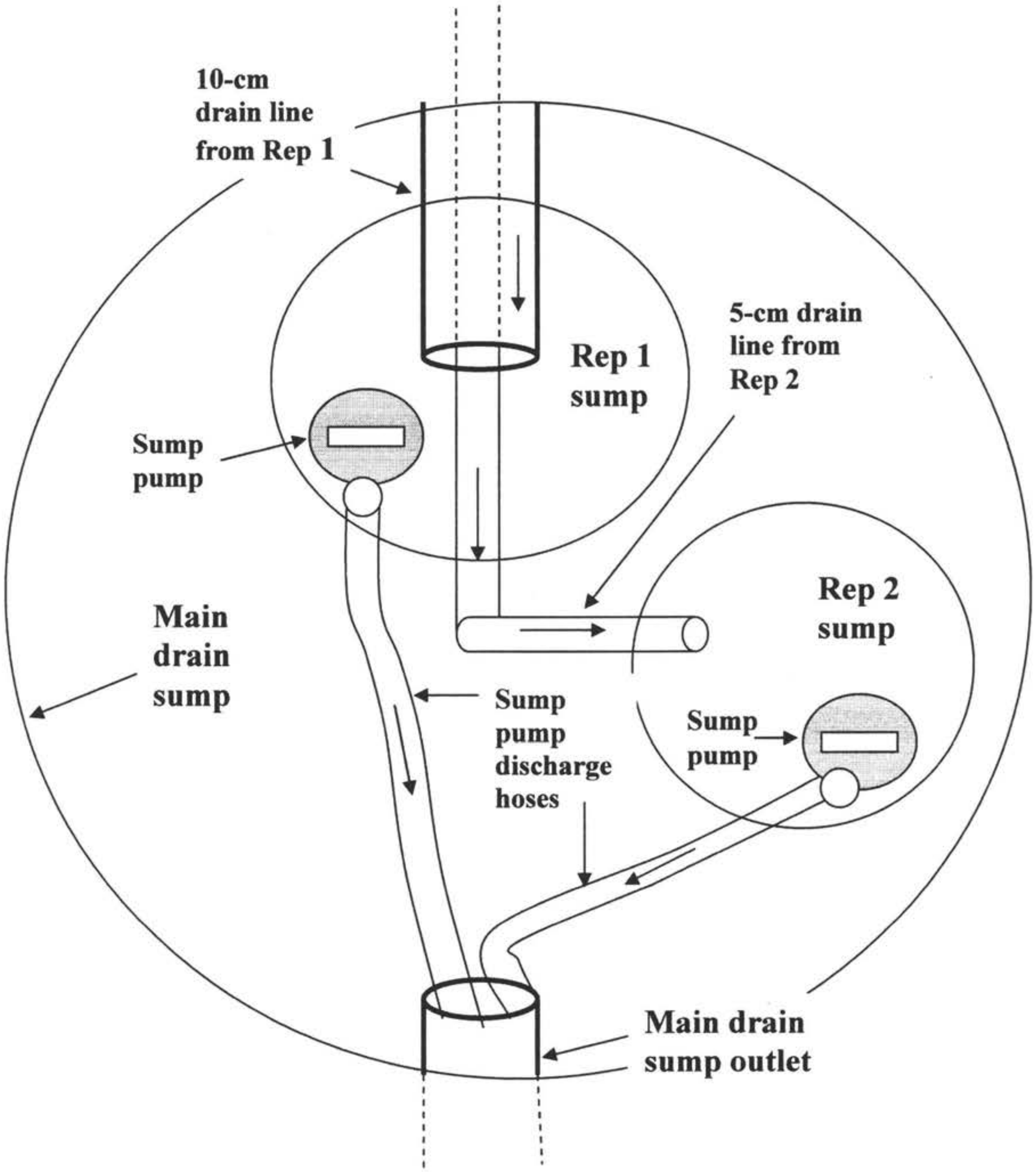

Fig. 3.2. Top view of main drain sump.

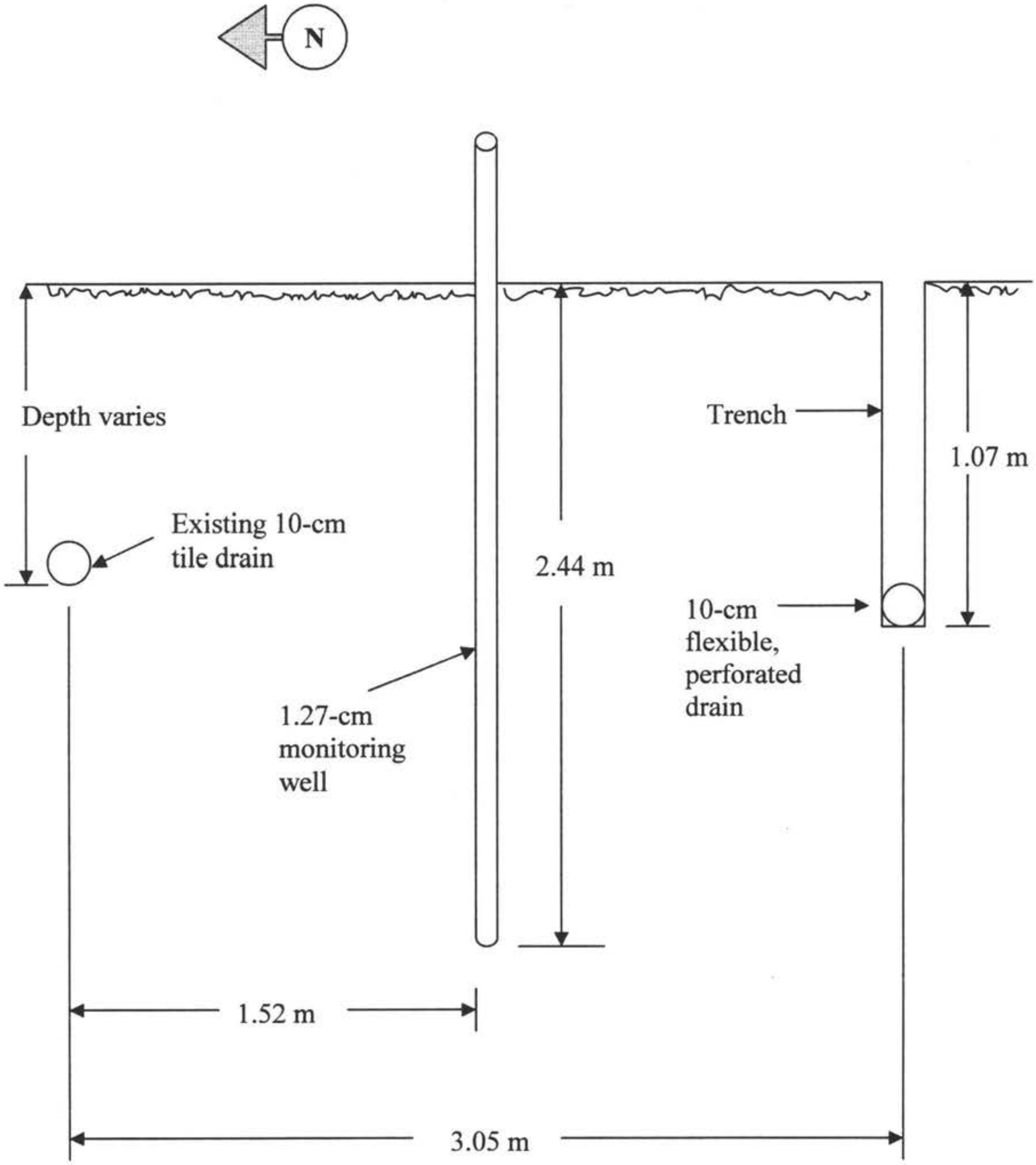

Fig. 3.3. End view of rep 1 (not to scale).

CHAPTER 4. RESULTS AND DISCUSSION

Relative Elevations of Study Components

An elevation profile of the study components is presented in Fig. 4.1. All elevations on this graph are relative to a point at the bottom of the tile line (0 cm) – arbitrarily selected at a point about 4.5 m upslope from the main drain sump. The slope of the tile line was calculated to be about 2.6% (sloping downward from northeast to southwest), and the slope of the ground surface directly above the tile line was calculated to be about 4%. Fig. 4.1 also shows the slope of the two trench bottoms with respect to the tile line and the ground surface slope. Ponded water levels and MW equilibrium water levels were calculated as average values for each parameter under steady state conditions, i.e., when there was no influence on these levels due to a recent rainfall event.

Hydrology

Ponded water levels in the trenches relative to the average depth of the tile line are shown as a function of time in Fig. 4.2. Although the design of this study called for equal hydraulic gradients from each trench to the tile line, the water level in the trench for rep 2 was slightly higher than for rep 1. As presented in Table 4.1, water-only addition to each trench began on 28 June, or day –11. The reason for this negative timeline (of –11 days) is that water-only ponding was done for 11 days before P-Br solution ponding commenced on 9 July, defined as day 0. P-Br solution ponding in each trench continued for 18 days until 27 July; on that date P-Br solution was replaced with P-only solution. P-only solution ponding lasted for seven more days until 2 August. The total duration of all ponding phases was 36 days, and the total volume of liquid added was 257,900 L (Table 4.1).

The influence of rainfall events on trench ponded water levels is also shown in Fig. 4.2, the biggest of which was a 7.86-cm rainfall event on day 1. This rainfall had a significant impact on the ponded water level in each trench as evidenced by the spike upwards in the levels on day 1. Table 4.1 shows total rainfall during each ponding phase.

The slight drop in both ponded water levels on 22 July (day 13) was due to an equipment problem: a flat tire on the flatbed tank trailer that occurred late at night on 21 July. The tire was repaired early the next morning, and, with the supply of solution resumed, the ponded water level in each trench returned to normal within 2 h.

Figs. 4.3 and 4.4 show the position of the water table in each well for reps 1 and 2, respectively, relative to the average depth of the tile line for each replication. The depth of the water table for a given well in a given replication was almost identical to the depth of the other two wells. Rep 2 showed more variability between wells than rep 1 especially during the ponding phase of the study. When all ponding was ended on 2 August (day 24), the water table in each well fell rapidly to the pre-ponded levels that existed on day –11. The sharp spikes upward in water table levels were attributed to the significant rainfall events on days 1, 26, and 27. The spikes upward around day 45 were due to the cumulative rainfall amounts from day 34 to day 44. During periods of little or no rainfall after ponding had ended, all water table measurements showed steadily decreasing trends towards pre-ponded levels; some of these water table measurements were less than the pre-ponded levels.

Daily tile line outflow per replication and cumulative flow volume with time are illustrated, respectively, in Figs. 4.5 and 4.6. During the ponding phase, outflow from rep 2 was about 1.5 to 2 times higher than outflow from rep 1. This was especially evident after the significant rainfall events during ponding. Possibly this greater outflow was due to a larger hydraulic gradient from the ponded water level in the trench for rep 2 to the tile line.

Conversely, after ponding had ceased on day 24 and after significant rains on days 26 and 27, outflow from rep 2 was less than from rep 1. After these two days, the elevation and hydraulic gradient differences between replications became smaller, thus the smaller outflow from rep 2. As might be expected based on the data presented in Fig. 4.5, cumulative flow volume from rep 2 was greater than from rep 1 (Fig. 4.6). Based on observed daily float movements in the stilling wells, more inflow was added to rep 2 than rep 1. The empirical data support these experimental observations.

Bromide Transport

Br analyses were done on 83 P-Br solution grab samples collected from the outlet of the portable refill tank. The average Br concentration in these samples was 98 mg Br/L with values ranging from 91 to 105 mg/L. Although each liter of concentrated P-Br solution was prepared gravimetrically in the water quality laboratory (to make 1,514 L of solution with 100 mg Br and 10 mg P per L), filling the portable tank with water exactly to the 1,514-L mark in the field proved to be difficult. Because of the uneven ground surface, the 1,514-L mark likely was undershot or overshot by a few liters almost every time the portable tank was refilled.

Br concentrations in the well samples taken from reps 1 and 2 as a function of time are shown in Figs. 4.7 and 4.8, respectively. Br was not detected in any of the wells from day –5 (the day of initial well sampling) to day 0. Br in solution was added to the trenches starting shortly before noon on day 0. Within 10 h after it was added to the trenches, Br was detected in samples of water flowing by every well. With the continued addition of P-Br solution, increasing Br concentrations were detected in subsequent well-water samples. By day 10, a Br concentration of at least 78 mg/L was detected in every well except for MW3; this well had a maximum Br concentration of 67 mg/L.

Although slight differences in Br flow patterns existed, general trends up and down for Br were similar not only among wells but also between replications. As evidenced by the increasing Br concentrations in well-water samples, a large portion of the water flowing by the wells had to be coming from the P-Br solution ponded in the trenches. Between days 10 and 18, the Br concentration in any given well-water sample (with the exception of MW3) was at least 83 mg/L. It was particularly difficult to obtain a water sample from MW3 during the study; on several occasions when sampling MW3, the hand-operated vacuum pump had to be pumped for a few minutes to get sufficient water for analysis into the sample bottle.

In general, the flow of Br through each of the six wells exhibited a similar pattern: a sharp increase shortly after P-Br solution addition to the trenches on day 0; somewhat of a plateau at sustained inflow rates; a sharp decrease after Br addition had ceased; and a period of about 30 days in which residual Br concentrations ranged from ~10 to ~20 mg/L.

Similar patterns existed over time for Br concentrations found in samples of tile line outflow (Figs. 4.9 and 4.10). From day –7 to day 0 during water-only ponding, Br was not detected in samples of tile line outflow, but it was detected in subsequent samples within a few hours of adding the P-Br solution to the trenches. By the time Br addition ended on day 18, its maximum concentration in reps 1 and 2 was 83 and 97 mg/L, respectively. Based on the Br concentrations found in the well-water and tile line outflow samples, it was evident that the majority of the water leaving the study plot as tile line outflow was coming from the P-Br solution in the trenches. Residual Br concentrations after ponding ended were about

20 mg/L in tile line outflow samples collected around day 60 of the study. It is reasonable to assume that most, if not all, of the Br added to the trenches eventually would get transported off site. Some of the Br in solution could be expected to diffuse into and be trapped with some immobile water in dead-end pores in the subsoil. This mobile-immobile water phenomenon associated with some types of subsoil could explain why average Br concentrations of ~20 mg/L were consistently detected some 30 days after Br addition was terminated.

Phosphorus Transport

Seven grab samples of the subsurface drainage water in the sump for the wetland study were analyzed for MRP to determine background P levels in the source water. These samples were collected one per day from 2 to 8 July. The average MRP concentration of these samples was 0.006 mg/L; the range of values was from not detected to 0.019 mg/L.

One hundred and eleven grab samples of the P-Br solution collected from the outlet of the portable refill tank were also analyzed for MRP. The average MRP concentration in these samples was 8.7 mg/L with values ranging from 6.4 to 14.0 mg/L. The 8.7 mg P/L in the inflowing P-Br solution was less than the intended 10 mg P/L for the same reason that the Br concentration in the P-Br solution was 98 mg Br/L instead of the intended 100 mg Br/L.

MRP concentrations in well-water samples collected from reps 1 and 2 as a function of time are shown in Figs. 4.11 and 4.12, respectively. MRP was detected in well-water samples during the water-only input phase from day –11 to day 0. During this phase, MRP values ranged from 0.014 to 0.034 mg/L. MRP concentrations in samples of tile line outflow as a function of time are shown in Figs. 4.13 and 4.14 for reps 1 and 2, respectively. The

MRP data illustrated in Figs. 4.11 through 4.14 do not show a large and rapid response to the high P concentration in the inflow solution. This is in contrast to the Br data.

MRP concentrations in every well except for MW4 exhibited an upward trend over time during the 24 days of P addition. MW1 and MW3 samples showed slight upward trends, whereas MW2, MW5, and MW6 samples showed sharper upward trends. The highest MRP concentration detected in any well-water sample was 1.2 mg/L on day 25 from MW6.

Data presented in Fig. 4.14 illustrate that MRP concentrations in tile line outflow for rep 2 as a function of time show virtually no effect of the high P concentration in the trench inflow water. In fact, for rep 2 the highest MRP concentration was 0.035 mg/L on day 13. Data presented in Fig. 4.13 for rep 1 do show a slight increase, but the highest MRP concentration still was only 0.13 mg/L on day 24. Although the Br data clearly indicate that Br in solution added to each trench was reaching the monitoring wells and tile drains in compelling amounts, the P data illustrate that P in solution was not moving as quickly to those same sampling locations. Hence, P was being removed from the inflowing water by some means, e.g., by adsorption or precipitation.

Flow Volume, Bromide, and Phosphorus Inputs and Outputs

Table 4.2 shows the calculated flow volume, Br, and P inputs and outputs for the study. Cumulative flow volume from each tile line as a function of time is shown graphically in Fig. 4.6. Tile flow volumes for reps 1 and 2 were 206,500 L and 265,600 L, respectively. These totals include water-only, P-Br solution, P-only solution, rainfall, and any other subsurface base flow. The total mass of Br added was 13.10 kg. Of that amount, 4.07 kg were lost in rep 1 and 6.00 kg were lost in rep 2. Therefore, 77% of the Br applied to the trenches was lost via the tile lines during the time they were monitored. Fig. 4.15 shows these cumulative Br losses by replication. The total mass of P added was 1.65 kg. As Fig. 4.16 and Table 4.2 show, total cumulative P lost via the tile lines was 6.23×10^{-3} kg (4.92×10^{-3} kg in rep 1 and 1.31×10^{-3} kg in rep 2). This was equal to 0.38% of the P applied to the trenches.

Soil Test Available Phosphorus

Results from the soil test laboratory for Olsen available P by replication are shown in Figs. 4.17 and 4.18, respectively. As previously mentioned, each of the six, 25-cm long horizontal subsoil cores was cut into five equal sections and analyzed for Olsen P. The five points on each of the three trend lines in Figs. 4.17 and 4.18 represent the average horizontal distance into the trench wall face for each 5 cm long section. Overall, Olsen available P decreased with increasing distance into the subsoil from the trench walls, except for MW2 and MW6 samples. These data support the MRP in solution data in that the majority of the added P was not moving with the water in the water table but was being retained elsewhere.

Results of the Bray-1 available P soil test can be found in Appendix B, but they will not be discussed except to state that the Bray-1 test results gave little useful information because of the calcareous nature of the subsoil.

Soil test pH values are presented in Figs. 4.19 and 4.20 for reps 1 and 2, respectively. These data show that the pH range was very narrow for each 5 cm long soil section. Mention is made regarding soil test pH only because soil pH can affect the movement and availability of P to crops. The availability of P to crops is reduced in a soil having a high pH and containing calcium.

Table 4.1. Summary of water-only, P-Br solution, and P-only solution inputs.

Input	Start date	Start day #	End date	End day #	Volume added (liters)	Rainfall, cm
Water-only	28-Jun	-11	9-Jul	0	73,900	4.18
P-Br solution	9-Jul	0	27-Jul	18	133,600	9.08
P-only solution	27-Jul	18	2-Aug	24	50,400	0.13
Total					257,900[a]	13.39

[a] Excludes rainfall and subsurface base flow.

Table 4.2. Inputs and outputs of flow volume, Br, and P.

		Volume (liters)	Mass Br (kg)	Mass P (kg)
Inputs (water and solutions)		257,900[a]	13.10	1.65
Outputs				
	Rep 1	206,500	4.07	4.92×10^{-3}
	Rep 2	265,600	6.00	1.31×10^{-3}
	Total	472,100[b]	10.07	6.23×10^{-3}
% of applied		NA	77%	0.38%

[a] Excludes rainfall and subsurface base flow.

[b] Includes inputs, rainfall, and subsurface base flow.

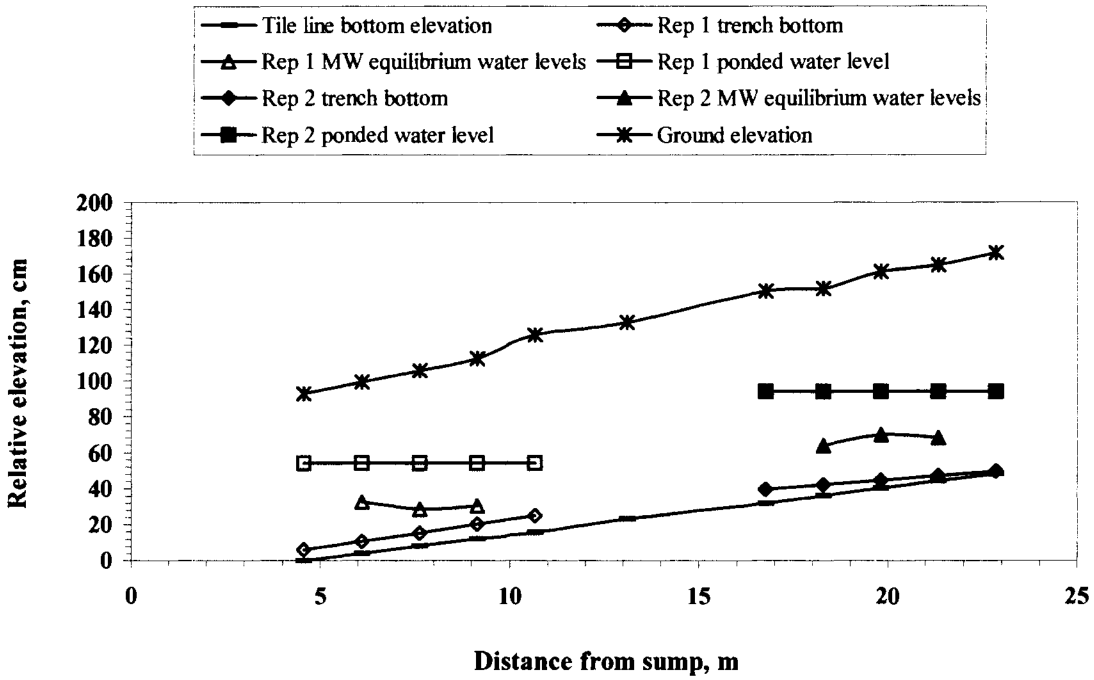

Fig. 4.1. Elevation profile of study components.

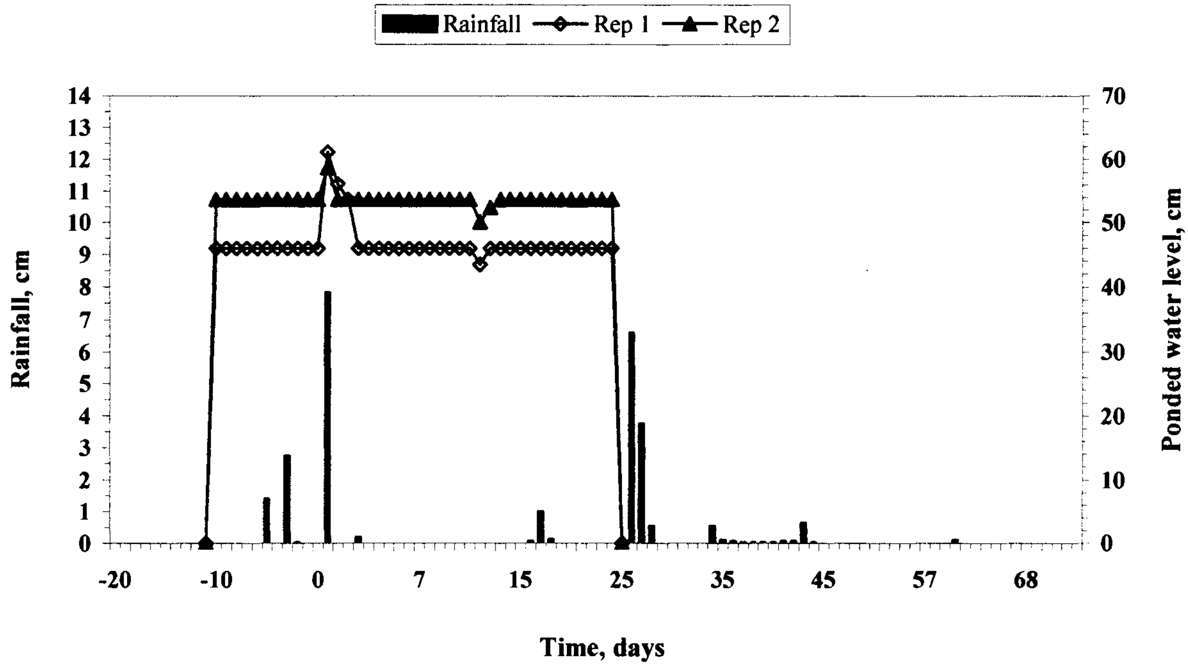

Fig. 4.2. Total rainfall and its influence on ponded water levels in the trenches relative to the average depth of the tile line.

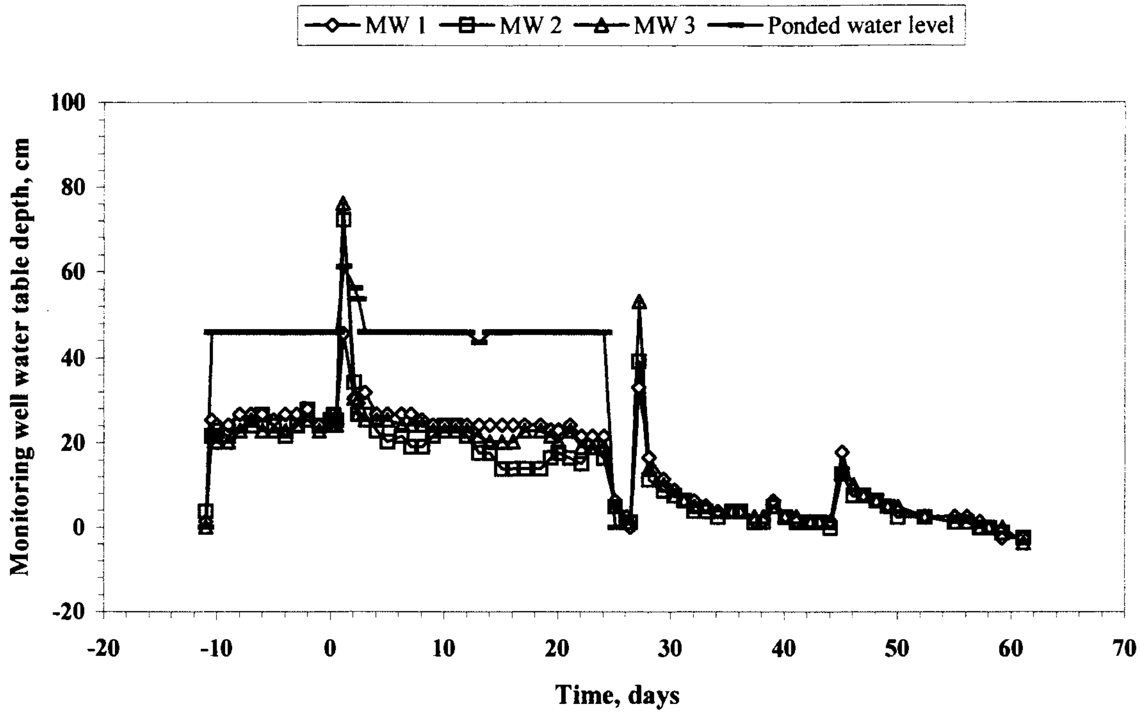

Fig. 4.3. Rep 1 monitoring well water table depth relative to the average depth of the tile line.

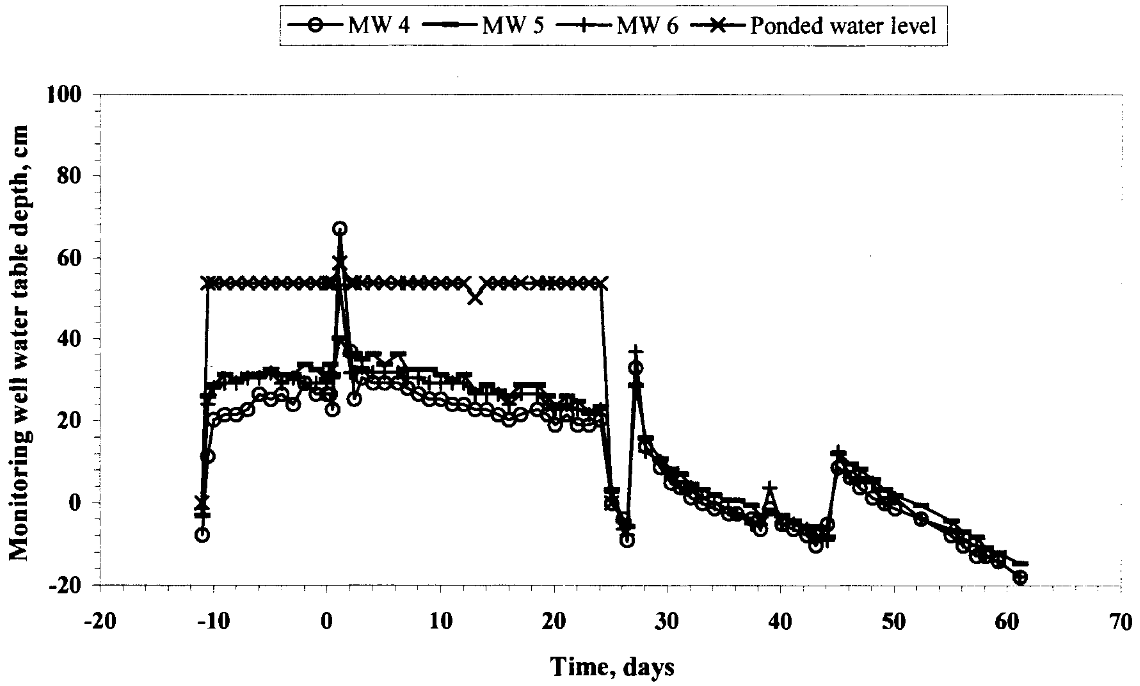

Fig. 4.4. Rep 2 monitoring well water table depth relative to the average depth of the tile line.

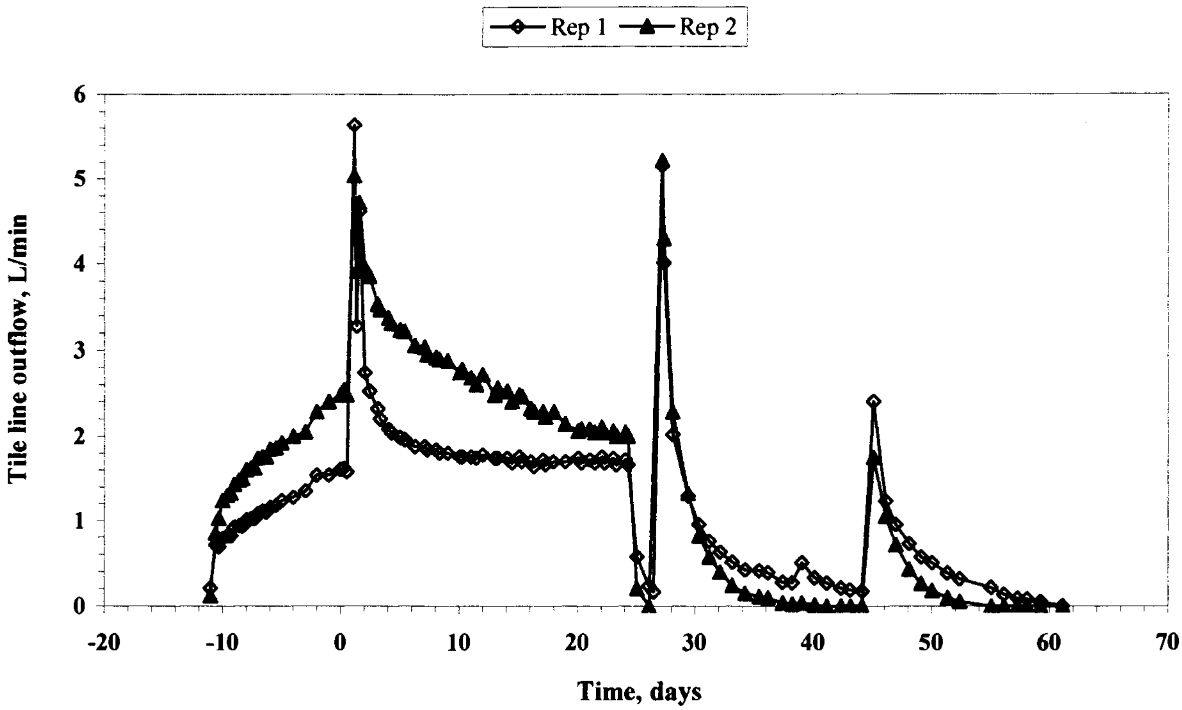

Fig. 4.5. Tile line outflow.

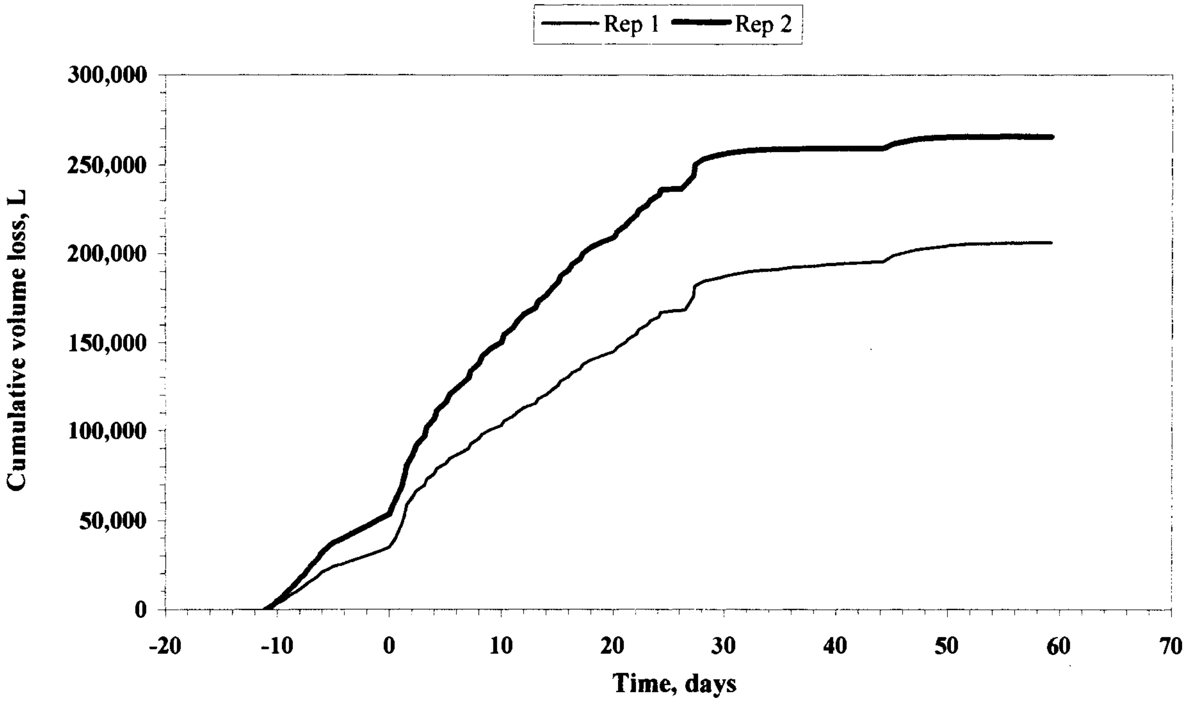

Fig. 4.6. Cumulative volume loss with tile flow.

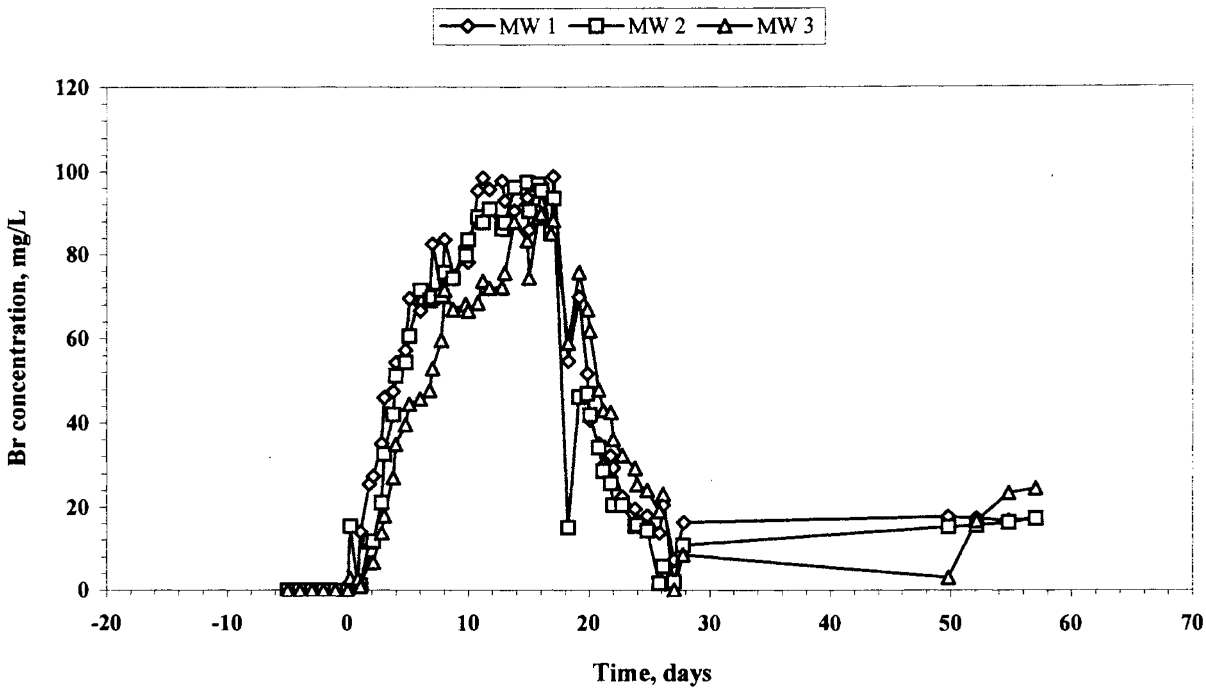

Fig. 4.7. Rep 1 monitoring well Br concentrations.

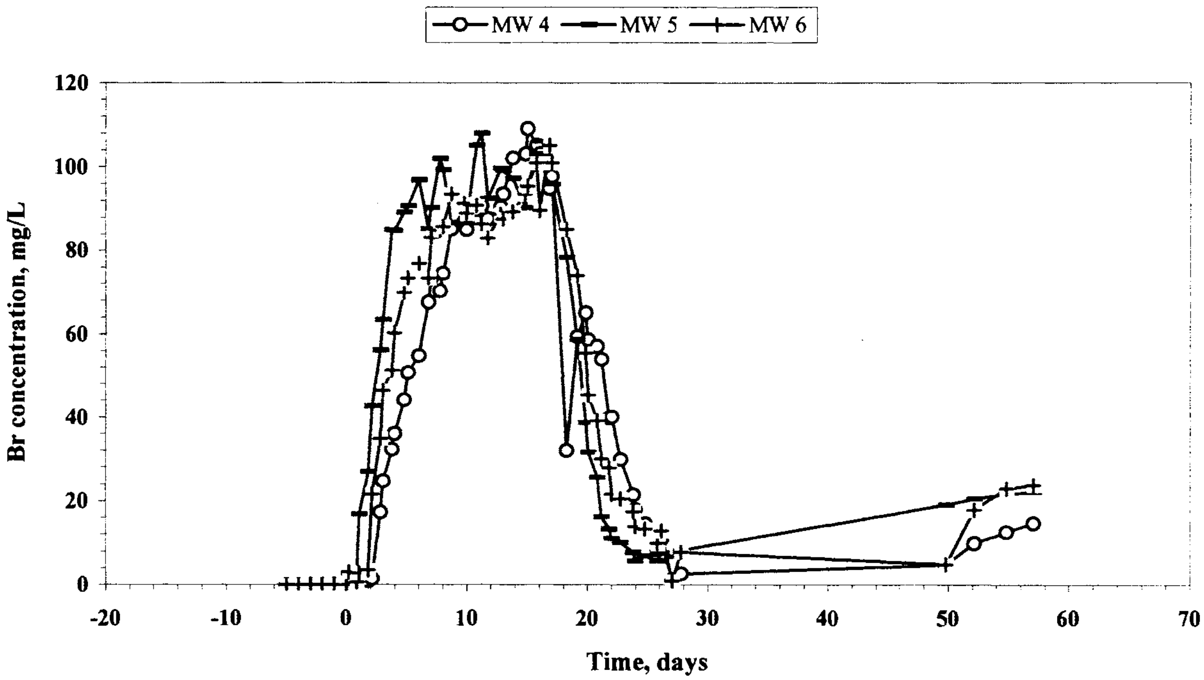

Fig. 4.8. Rep 2 monitoring well Br concentrations.

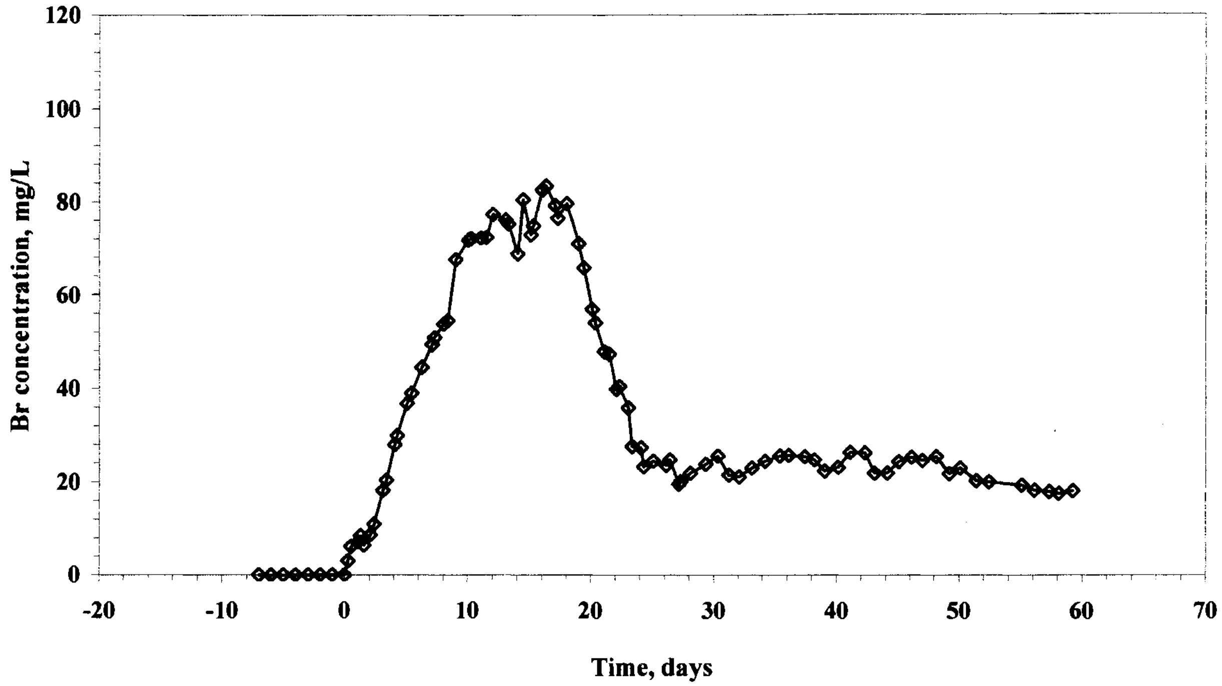

Fig. 4.9. Rep 1 tile line Br concentrations.

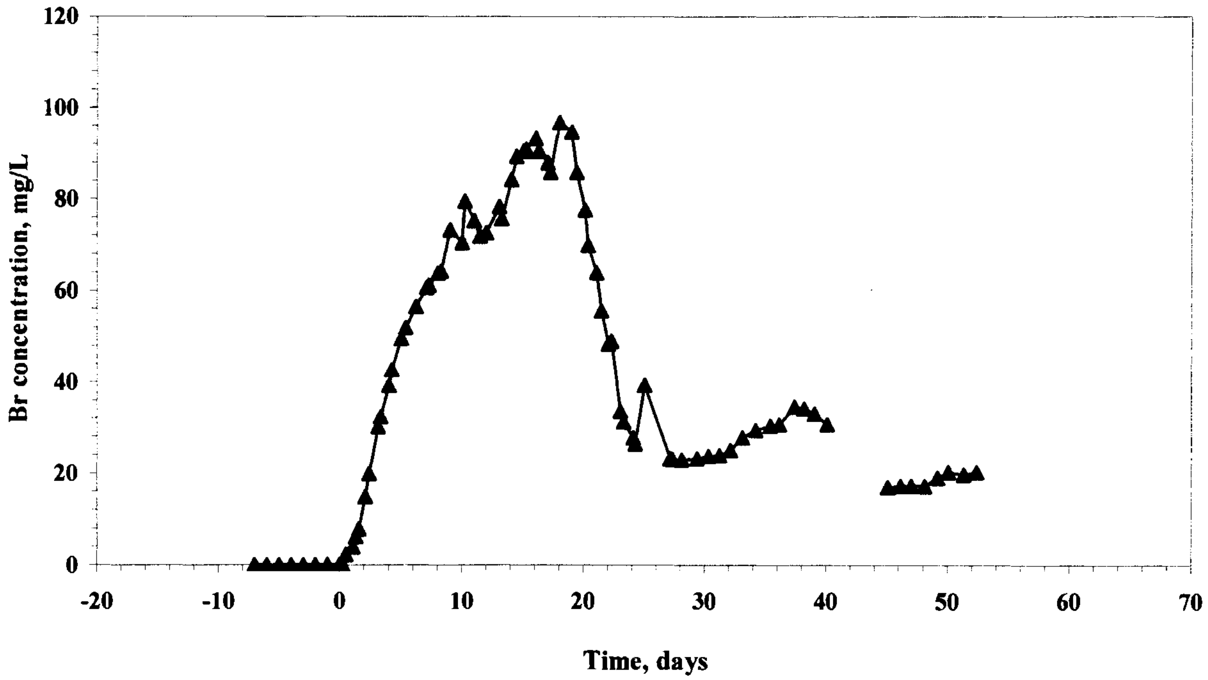

Fig. 4.10. Rep 2 tile line Br concentrations.

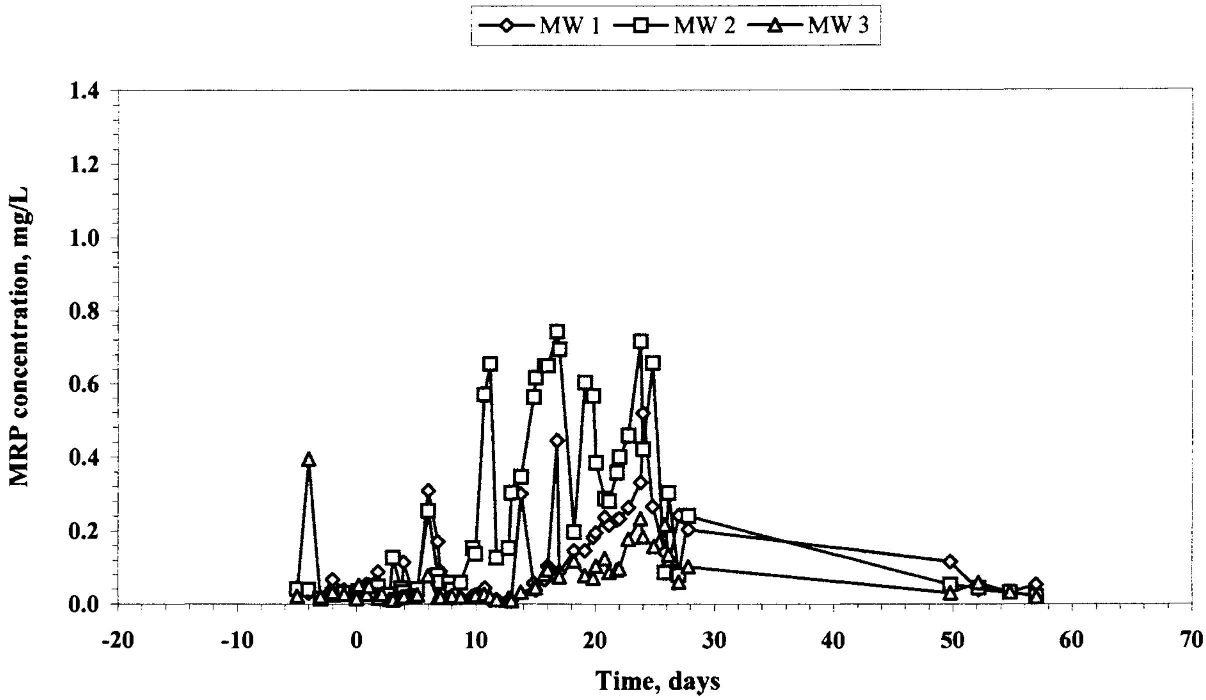

Fig. 4.11. Rep 1 monitoring well MRP concentrations.

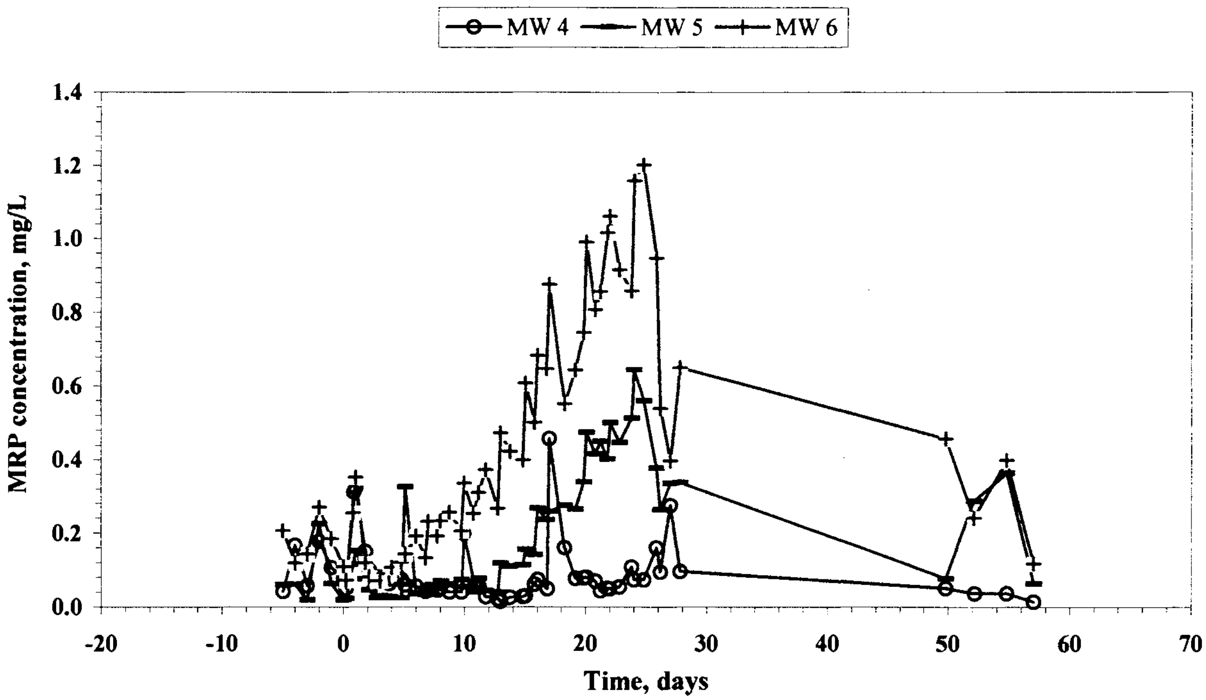

Fig. 4.12. Rep 2 monitoring well MRP concentrations.

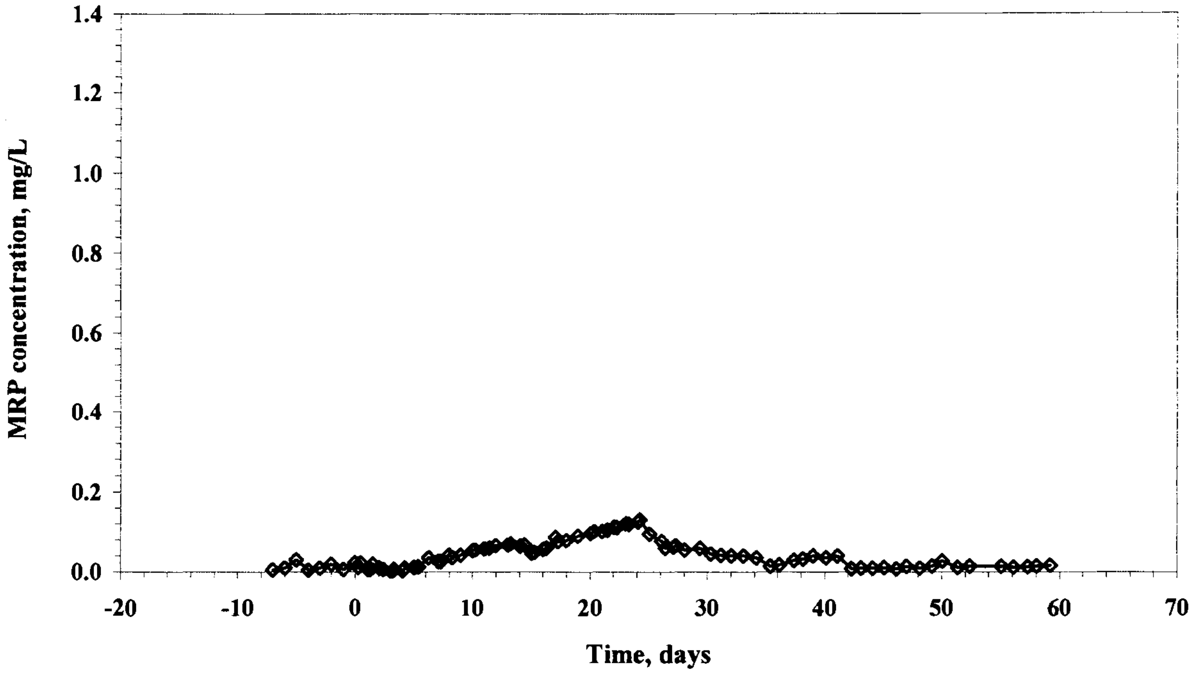

Fig. 4.13. Rep 1 tile line MRP concentrations.

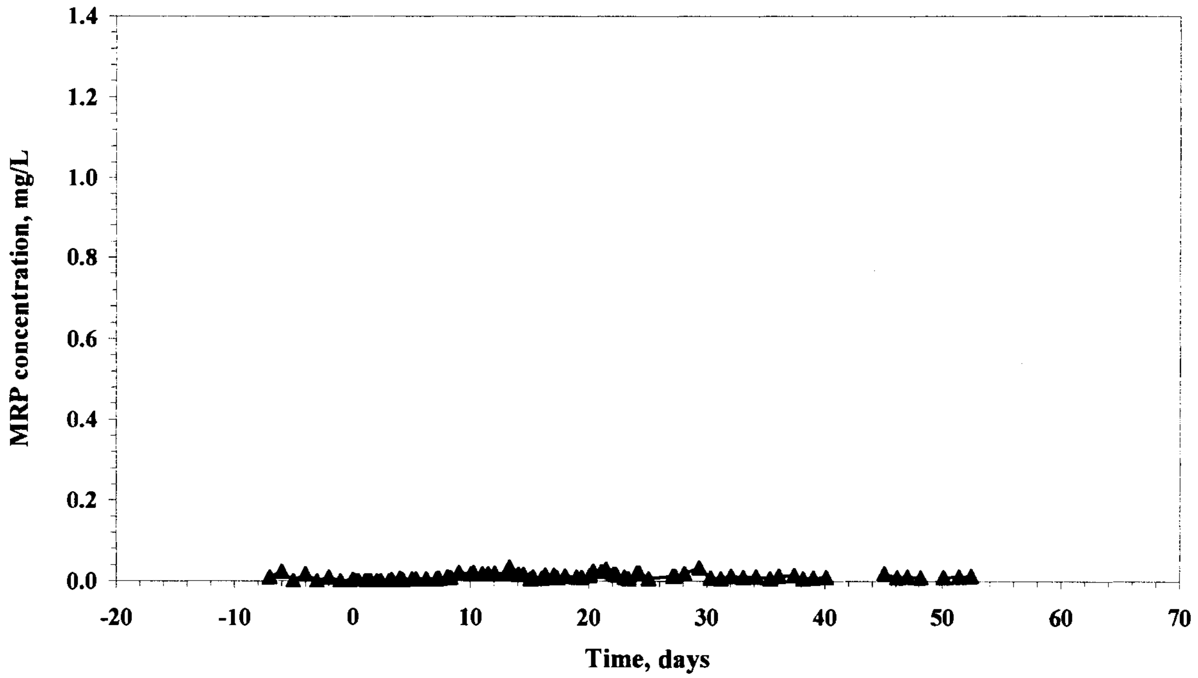

Fig. 4.14. Rep 2 tile line MRP concentrations.

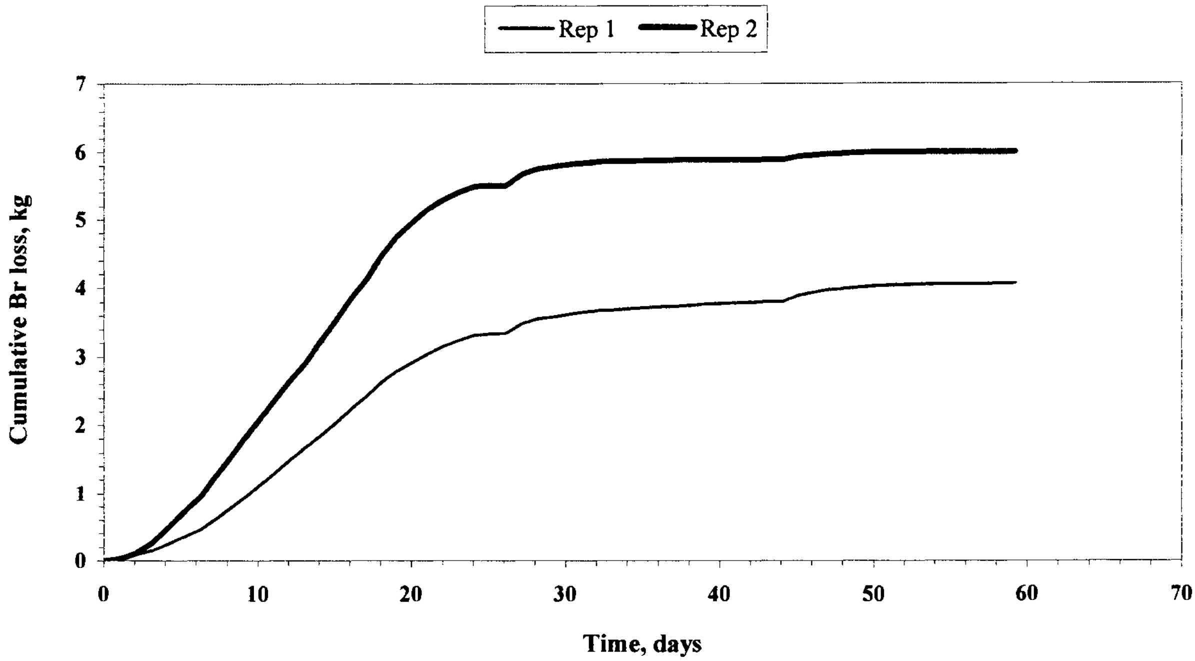

Fig. 4.15. Cumulative Br loss with tile flow.

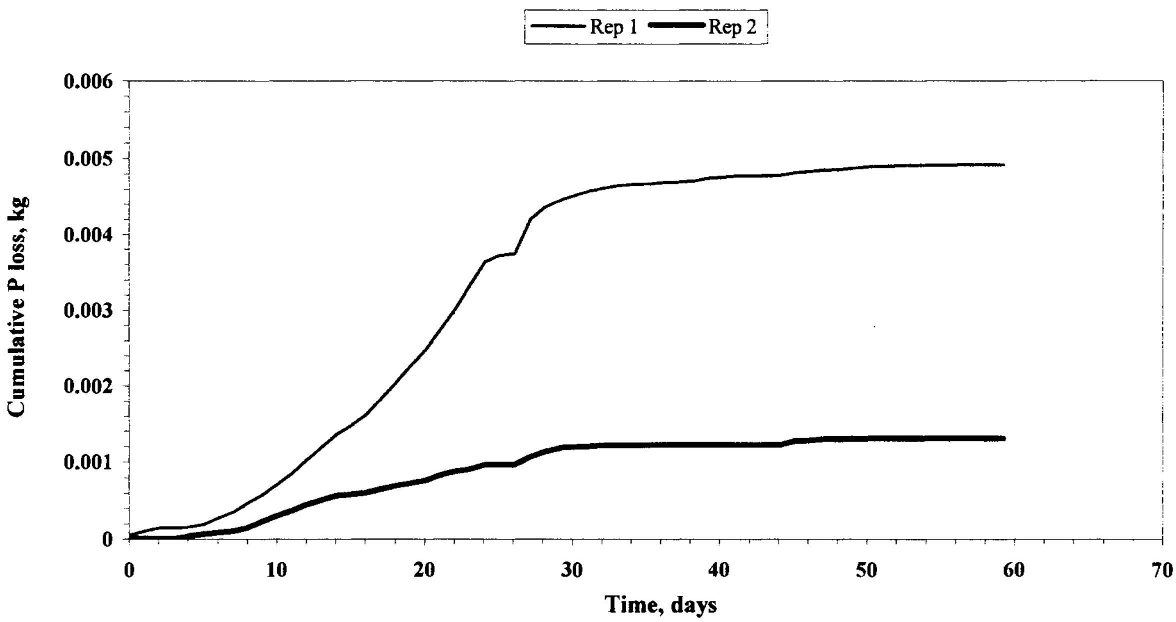

Fig. 4.16. Cumulative P loss with tile flow.

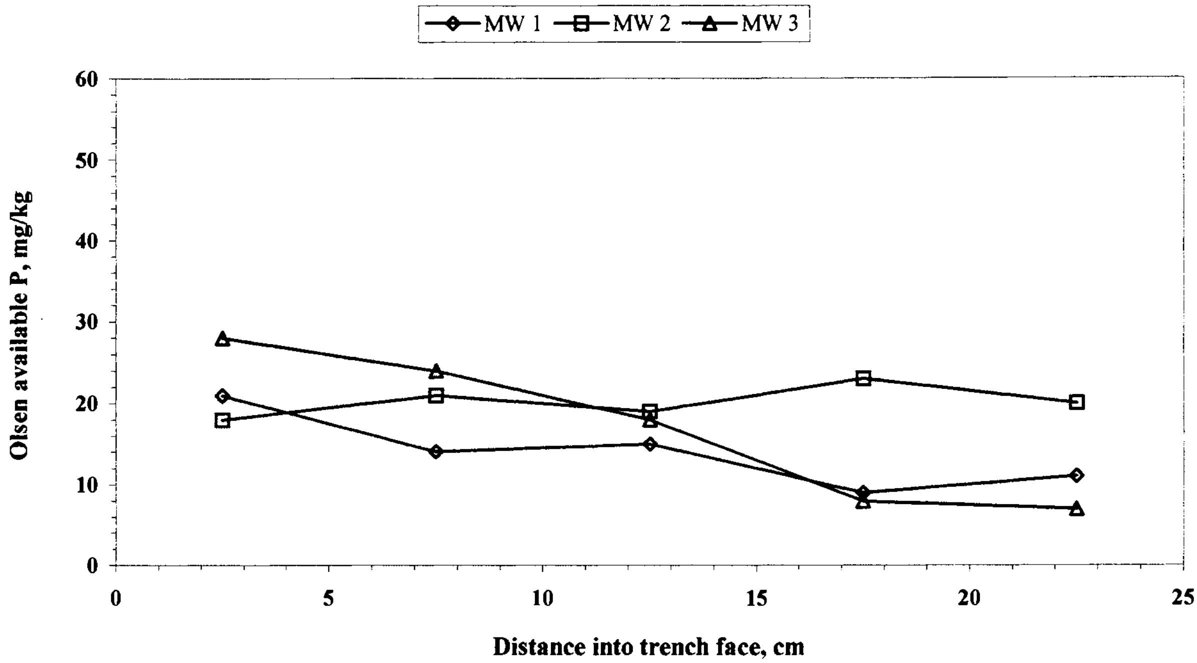

Fig. 4.17. Rep 1 Olsen available P in horizontal subsoil samples from trench wall.

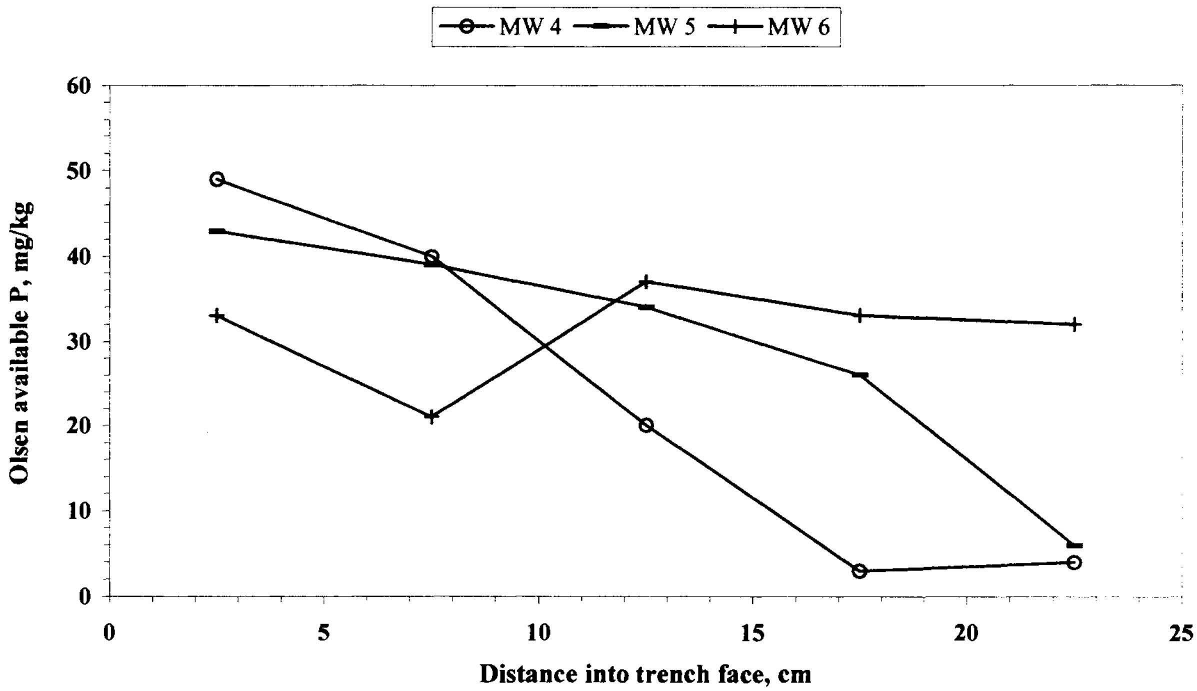

Fig. 4.18. Rep 2 Olsen available P in horizontal subsoil samples from trench wall.

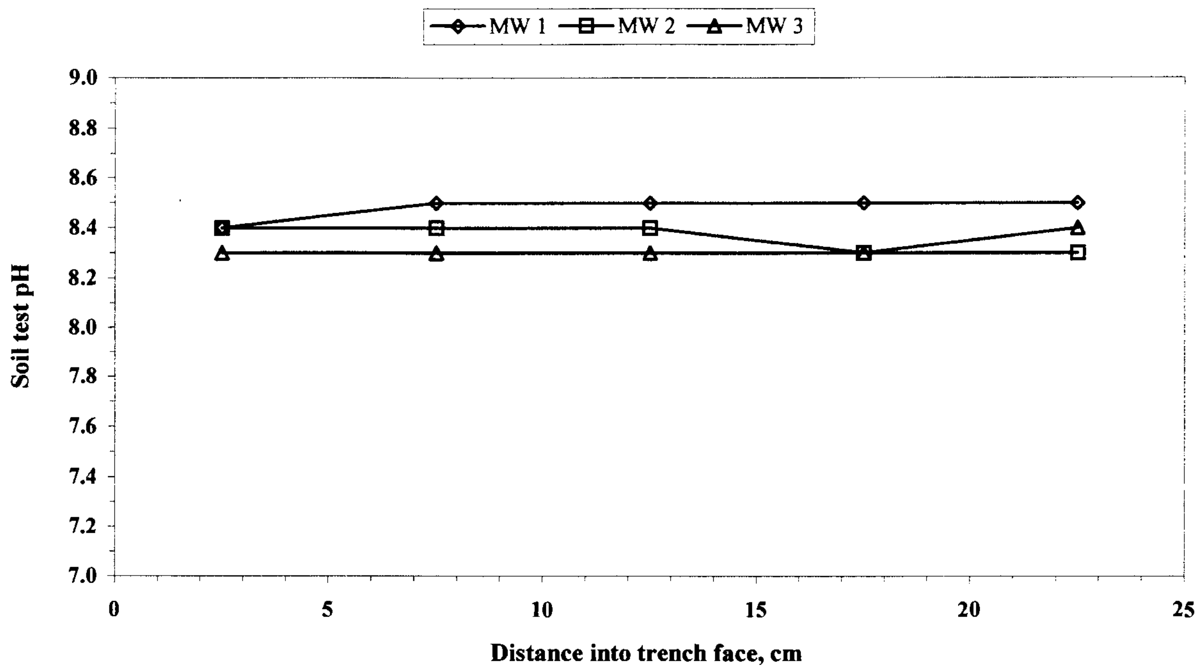

Fig. 4.19. Rep 1 soil test pH in horizontal subsoil samples from trench wall.

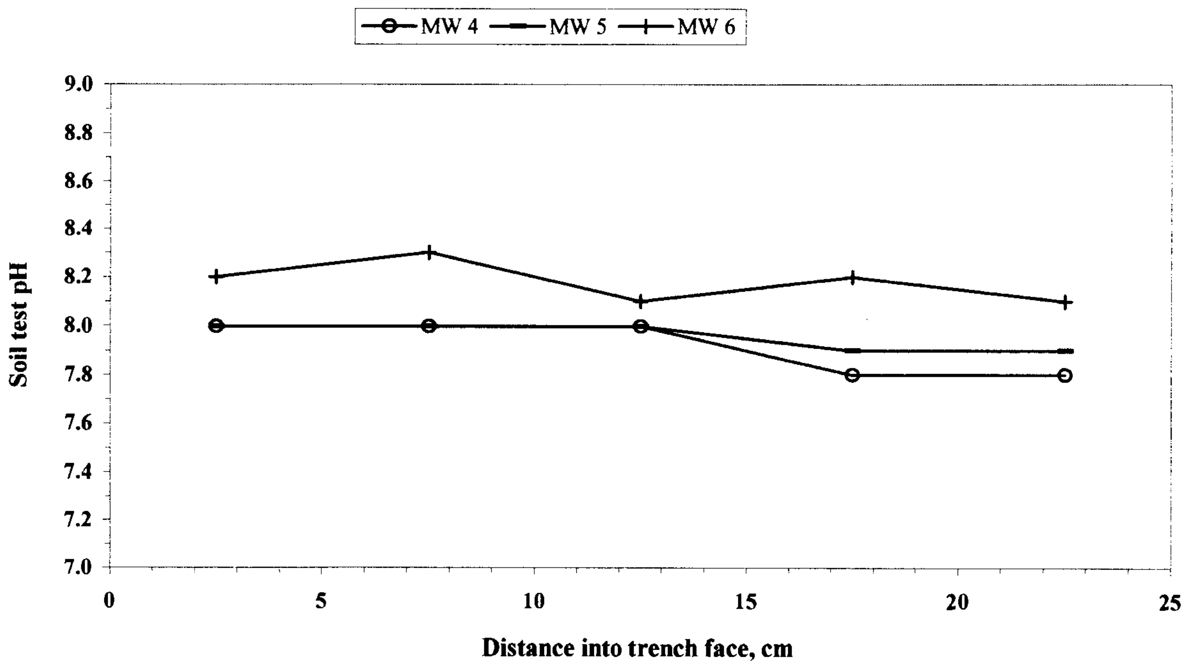

Fig. 4.20. Rep 2 soil test pH in horizontal subsoil samples from trench wall.

CHAPTER 5. SUMMARY AND CONCLUSIONS

There are concerns among some environmental professionals that agricultural drainage (surface runoff and subsurface flow) and erosion from high P-test soils may play a major role in contributing to surface water eutrophication. Economically, P loss in agricultural runoff may lead to significant off-site water quality impacts. Because of the concerns about these impacts, there has been a move towards improving agricultural P management from animal manures and commercial fertilizers. In the past, the primary focus associated with these issues had been on P transported with sediment and P dissolved in surface water runoff. However, there is recent interest regarding P leaching into subsoil and moving with subsurface drainage water. Therefore, the general goals of this study were to provide some new information about lateral P transport and movement with water and also to assess the impact on the potential for P losses via leaching. The specific objective of this study was to determine the rate of P removal from water flowing laterally through P-deficient subsoil as the water traveled to a tile line.

Water was ponded in two trenches dug parallel and adjacent to an existing tile line that was sectioned into two parts with two outlets. This ponding of water was intended to establish saturated, steady state conditions in the subsoil surrounding the trenches and to create lateral flow to the tile line. Then a solution containing average concentrations of 8.7 mg P/L and 98 mg Br/L was ponded in the trenches. The Br was used as a tracer to determine when and how much of the solution soaking into the subsoil reached the tile drain. Water samples were collected from monitoring wells - located midpoint between the trenches and the tile line - and from tile line outlets; these samples were analyzed for Br and MRP to determine their rates of movement. After ponding was ceased and the trenches were allowed to drain dry, subsoil samples were collected from the wall of each trench closest to the tile line and analyzed for available P to determine the extent of P binding or adsorption.

Based on the Br concentrations detected in water samples from the monitoring wells and tile line outlets over time, it was evident that the majority of the water flowing from the drains was coming from the solution in the trenches. Before Br addition to each trench ended, the maximum Br concentration was 83 mg/L in one tile line outlet and 97 mg/L in the other.

Those same water samples analyzed for MRP did not show a similar large and rapid response to the high P concentration in the inflowing solution as was evident for the Br. The maximum MRP concentration found in a sample from one tile line outlet was 0.035 mg P/L; whereas, the maximum MRP concentration found in a sample from the second tile line was 0.130 mg P/L. It was in this second set of tile line samples that a slight increase was noticed in MRP concentrations, but this increase was minimal with respect to the 8.7 mg P/L concentration in the trench inflow.

Data from this study indicated that the P in solution was not moving nearly as fast or as far as the Br. Virtually all of the added P was being removed from the laterally flowing water by some means, presumably by precipitation and/or adsorption in the P-deficient subsoil.

Following are some recommendations to improve the methods used during this study. A way possibly could have been devised to exclude rainfall from the study site. Perhaps a tenting arrangement large enough to cover this size plot could have been erected to keep rainfall off the site. Also some type of permanent berm should have been constructed on all sides of the plot to exclude surface runoff from making its way into the trenches; this measure was attempted using soil excavated from the trenches, but the berms were washed away by rain. Water tanks with larger capacities should have been used, if feasible. It took a time-consuming and labor-intensive effort to keep both tanks full of either water or solution. The portable tank had to refilled four to five times daily; at least half of the time spent on this project was devoted to keeping the larger tank replenished with water or solution from the portable tank. A flow-metering device could have been used to accurately monitor the flow of water pumped into the portable tank. Using such a device would have ensured greater accuracy of the P and Br concentrations in the inflowing solution. Finally, the physical measurements and water sampling should have commenced on the same date. This was not done at the beginning of this project, and it made data compilation and analysis more difficult than necessary.

In future research, depending on the availability of funding and personnel, perhaps the overall duration of a study such as this could be increased. This may help to further determine any potential short- or long-term impacts on water quality from the continuous addition of a high concentration of P in solution to subsurface drainage water. Furthermore, studies similar to this one could be conducted on other soil types found in Iowa and elsewhere. After sufficient data were accumulated and analyzed for these various soil types, then possibly a computer model could be used to aid in predicting and assessing any potential impacts on water quality from P leaching to subsurface water. Scientists, policy-makers, and legislators who are charged with the onerous, and increasingly important, responsibility of making informed decisions regarding water quality issues could then use these assessments accordingly.

APPENDIX A. FALL 2001 TRIAL RUN DATA

Trial Run - Flow into trench

Date	Actual clock time	Estimated volume, gal
11/8/2001	1110	0
11/8/2001	1546	209
11/9/2001	810	411
11/10/2001	1127	580
11/11/2001	1042	45
11/12/2001	905	405
11/12/2001	1300	100
11/12/2001	2020	100
11/13/2001	850	450
11/13/2001	1108	124
11/13/2001	2115	350
11/14/2001	849	380
11/14/2001	1630	270
11/14/2001	1915	100
11/15/2001	905	400
11/15/2001	1105	50
11/15/2001	1730	250
11/16/2001	825	450
11/16/2001	930	50
11/16/2001	1545	200
11/16/2001	1710	50
11/17/2001	945	550
11/17/2001	1425	0

Trial Run - Tile line outflow

Date	Actual clock time	Outflow, mL/min
11/8/2001	1333	0
11/13/2001	1200	0
11/13/2001	1347	25.36
11/14/2001	940	158
11/15/2001	1002	220
11/15/2001	1219	231.5
11/15/2001	1632	233.5
11/16/2001	859	272.5
11/16/2001	1630	291
11/17/2001	1008	349
11/17/2001	1444	227
11/17/2001	1626	176.5
11/17/2001	1734	131
11/17/2001	2151	73

Trial Run - Trench ponded water level

Date	Actual clock time	Trench water table height above tile line, inches
11/8/2001	1110	0
11/8/2001	1333	6
11/8/2001	1435	6
11/9/2001	810	6
11/10/2001	1127	6
11/11/2001	1125	6
11/12/2001	1225	6
11/12/2001	2053	18
11/13/2001	1108	18
11/13/2001	2008	18
11/14/2001	849	18
11/17/2001	1110	18
11/17/2001	1425	11
11/18/2001	906	6

Trial Run - [Ortho-P] & [Br] in inflow

Date/Time	Sample I.D.	[Ortho-P], mg/L	[Br], mg/L
11/8/2001 16:36	Leo P/Br-1	1.432	103.292
11/13/2001 14:15	Leo P/Br-3	1.419	100.133
11/14/2001 17:29	Leo P/Br-4	1.395	103.273
11/16/2001 9:12	Leo P/Br-5	0.416	16.919
11/17/2001 10:20	Leo P/Br-6	0.173	2.448

Trial Run - East MW [ortho-P] & [Br]				
		Actual		
Sample		clock	[Ortho-P],	[Br],
I.D.	Date	time	mg/L	mg/L
	11/8/2001	1333	-----	-----
LEO East-1	11/8/2001	1620	0.02	0.637
LEO East-2	11/9/2001	905	0.008	0.618
LEO East-3	11/9/2001	1615	0.01	0.707
LEO East-4	11/10/2001	1249	0.005	0.744
LEO East-5	11/17/2001	1044	0.01	12.702
LEO East-6	11/17/2001	1705	0.005	10.145
LEO East-7	11/18/2001	927	0.005	8.505

Trial Run - Middle MW [ortho-P] & [Br]				
		Actual		
Sample		clock	[Ortho-P],	[Br],
I.D.	Date	time	mg/L	mg/L
	11/8/2001	1333	-----	-----
LEO Mid-1	11/8/2001	1622	0.04	6.639
LEO Mid-2	11/9/2001	911	0.019	6.765
LEO Mid-3	11/9/2001	1620	0.014	6.565
LEO Mid-4	11/10/2001	1254	0.009	7.919
LEO Mid-5	11/17/2001	1049	0.02	12.936
LEO Mid-6	11/17/2001	1708	0.015	17.731
LEO Mid-7	11/18/2001	931	0.01	23.624

Trial Run - West MW [ortho-P] & [Br]				
		Actual		
Sample		clock	[Ortho-P],	[Br],
I.D.	Date	time	mg/L	mg/L
	11/8/2001	1333	-----	-----
LEO West-1	11/8/2001	1624	0.007	4.394
LEO West-2	11/9/2001	929	0.004	7.538
LEO West-3	11/9/2001	1625	0.005	9.149
LEO West-4	11/10/2001	1258	0.004	10.255
LEO West-5	11/17/2001	1053	0.005	16.677
LEO West-6	11/17/2001	1712	0.005	30.248
LEO West-7	11/18/2001	935	0.005	32.781

Trial Run - [Ortho-P] & [Br] in tile flow				
	Actual			
	clock	Sample	[Ortho-P],	[Br],
Date	time	I.D.	mg/L	mg/L
11/8/2001	1333	N/A	-----	-----
11/13/2001	1223	LEO-001	0.031	15.623
11/13/2001	1237	LEO-002	0.017	17.076
11/13/2001	1253	LEO-003	0.023	17.239
11/13/2001	1301	LEO-004	0.024	17.467
11/13/2001	1312	LEO-005	0.022	17.483
11/13/2001	1325	LEO-006	0.026	17.413
11/13/2001	1353	LEO-007	0.009	16.287
11/13/2001	1402	LEO-008	0.012	16.189
11/13/2001	1412	LEO-009	0.027	15.878
11/13/2001	1422	LEO-010	0.016	15.747
11/13/2001	1500	LEO-011	0.02	15.847
11/13/2001	1533	LEO-012	0.014	15.511
11/13/2001	1559	LEO-013	0.012	15.259
11/13/2001	1631	LEO-014	0.015	14.791
11/13/2001	2022	LEO-015	0.005	16.318
11/13/2001	2042	LEO-016	0.007	16.353
11/13/2001	2102	LEO-017	0.008	16.105
11/13/2001	2121	LEO-018	0.013	15.802
11/13/2001	2141	LEO-019	0.025	16.126
11/14/2001	917	LEO-020	0.024	18.838
11/14/2001	929	LEO-021	0.015	19.001
11/14/2001	1805	LEO-022	0.032	23.26
11/14/2001	1823	LEO-023	0.034	22.596
11/14/2001	1844	LEO-024	0.031	22.796
11/14/2001	1900	LEO-025	0.016	22.88
11/15/2001	1009	LEO-026	0.037	25.195
11/15/2001	1111	LEO-027	0.018	25.767
11/15/2001	1208	LEO-028	0.027	26.157
11/15/2001	1308	LEO-029	0.024	26.451
11/15/2001	1423	LEO-030	0.033	26.444
11/15/2001	1526	LEO-031	0.014	26.399
11/15/2001	1619	LEO-032	0.025	26.211
11/15/2001	1717	LEO-033	0.011	26.125
11/16/2001	830	LEO-034	0.005	27.286
11/16/2001	905	LEO-035	0.014	26.948
11/16/2001	925	LEO-036	0.016	27.195
11/16/2001	1615	LEO-037	0.009	27.486
11/16/2001	1635	LEO-038	0.016	27.558
11/16/2001	1700	LEO-039	0.005	27.601
11/17/2001	948	LEO-040	0.004	26.774
11/17/2001	1015	LEO-041	0.008	26.916
11/17/2001	1057	LEO-042	0.003	27.181
11/17/2001	1430	LEO-043	0.004	27.999
11/17/2001	1505	LEO-044	0.004	28.06
11/17/2001	1607	LEO-045	0.006	28.247
11/17/2001	1720	LEO-046	0.008	28.439
11/17/2001	2137	LEO-047	0.003	30.864
11/18/2001	950	LEO-048	0.004	31.737

Trial Run - East MW water table height relative to tile line			
		Water table	Distance
	Actual	depth below	above/below
	clock	soil surface,	tile line,
Date	time	inches	inches
11/8/2001	930	<96	-57
11/8/2001	1510	41.5	-2.5
11/8/2001	1618	51.5	-12.5
11/9/2001	847	42	-3
11/9/2001	1600	47	-8
11/10/2001	1238	47	-8
11/11/2001	1045	55	-16
11/11/2001	2157	48	-9
11/12/2001	1240	47	-8
11/13/2001	1146	34.5	4.5
11/13/2001	1604	33.5	5.5
11/13/2001	2030	33	6
11/14/2001	902	31.5	7.5
11/14/2001	1714	31.5	7.5
11/15/2001	936	31.5	7.5
11/15/2001	1229	31.5	7.5
11/15/2001	1642	30.5	8.5
11/16/2001	842	30.5	8.5
11/16/2001	1643	30	9
11/17/2001	1002	30	9
11/17/2001	1448	33	6
11/17/2001	1650	33.5	5.5
11/17/2001	2202	37	2
11/18/2001	917	40.5	-1.5

Trial Run - Mid MW water table height relative to tile line			
		Water table	Distance
	Actual	depth below	above/below
	clock	soil surface,	tile line,
Date	time	inches	inches
11/8/2001	1000	<96	-57
11/8/2001	1512	52.5	-13.5
11/8/2001	1617	47	-8
11/9/2001	852	46	-7
11/9/2001	1603	51	-12
11/10/2001	1242	44	-5
11/11/2001	1048	50	-11
11/11/2001	2159	44.5	-5.5
11/12/2001	1242	44	-5
11/13/2001	1148	33	6
11/13/2001	1606	32	7
11/13/2001	2033	31.5	7.5
11/14/2001	904	31	8
11/14/2001	1716	30.5	8.5
11/15/2001	939	30	9
11/15/2001	1231	30.5	8.5
11/15/2001	1645	30	9
11/16/2001	844	30.5	8.5
11/16/2001	1645	30	9
11/17/2001	1004	30	9
11/17/2001	1450	32	7
11/17/2001	1653	33	6
11/17/2001	2205	36	3
11/18/2001	920	40	-1

Trial Run - West MW water table height relative to tile line			
		Water table	Distance
	Actual	depth below	above/below
	clock	soil surface,	tile line,
Date	time	inches	inches
11/8/2001	1030	<96	-57
11/8/2001	1514	43.5	-4.5
11/8/2001	1616	42.5	-3.5
11/9/2001	856	47.5	-8.5
11/9/2001	1605	41.5	-2.5
11/10/2001	1244	44	-5
11/11/2001	1051	50	-11
11/11/2001	2202	45.5	-6.5
11/12/2001	1244	43	-4
11/13/2001	1150	32.5	6.5
11/13/2001	1608	30.5	8.5
11/13/2001	2036	30.5	8.5
11/14/2001	906	29.5	9.5
11/14/2001	1719	29	10
11/15/2001	942	29	10
11/15/2001	1233	28.5	10.5
11/15/2001	1650	27.5	11.5
11/16/2001	846	28	11
11/16/2001	1647	27.5	11.5
11/17/2001	1006	27.5	11.5
11/17/2001	1452	31.5	7.5
11/17/2001	1655	32	7
11/17/2001	2208	35.5	3.5
11/18/2001	922	38.5	0.5

Trial run (11/01)- Leopold field 5 soil test results of 3/19/02											
TUBE	DEPTH	STL	Bray-1	Olsen	pH	TUBE	DEPTH	STL	Bray-1	Olsen	pH
1	24-30"	54977	2.3	1.8	7.30	15	24-30"	55032	1.5	1.6	7.70
1	30-36"	54978	2.0	0.9	8.00	15	30-36"	55033	1.6	1.2	8.05
1	36-42"	54979	0.0	0.6	8.25	15	36-42"	55034	0.1	0.5	8.15
1	42-48"	54980	0.0	1.3	8.25	15	42-48"	55035	0.0	0.7	8.30
2	24-30"	54981	0.6	0.5	7.50	16	24-30"	55036	1.2	0.7	7.95
2	30-36"	54982	0.5	1.4	7.75	16	30-36"	55037	1.8	1.4	8.05
2	36-42"	54983	2.0	1.7	7.95	16	36-42"	55038	0.0	1.1	8.15
2	42-48"	54984	0.3	0.4	8.25	16	42-48"	55039	0.4	0.6	8.30
3	24-30"	54985	0.8	0.4	7.35	17	24-30"	55040	0.8	1.2	7.60
3	30-36"	54986	2.1	1.5	7.55	17	30-36"	55041	1.5	1.8	7.85
3	36-42"	54987	1.7	1.2	8.05	17	36-42"	55042	0.3	1.2	8.20
3	42-48"	54988	0.0	0.5	8.25	17	42-48"	55043	0.5	1.1	8.20
4	24-30"	54989	1.7	1.8	7.40	18	24-30"	55044	1.1	0.8	7.65
4	30-36"	54990	1.1	1.1	8.15	18	30-36"	55045	2.7	1.8	7.75
4	36-42"	54991	0.0	0.4	8.30	18	36-42"	55046	2.3	2.8	not enough
4	42-48"	54992	0.0	0.4	8.30	19	24-30"	55047	1.3	1.3	7.55
5	24-30"	54993	1.9	1.6	7.75	19	30-36"	55048	0.7	1.0	8.20
5	30-36"	54994	1.4	1.1	8.05	19	36-42"	55049	0.0	1.3	8.20
5	36-42"	54995	0.4	0.5	8.20	19	42-48"	55050	0.0	2.8	8.35
5	42-48"	54996	0.0	0.7	8.15	20	24-30"	55051	0.7	1.2	7.65
6	24-30"	54997	2.1	1.8	7.65	20	30-36"	55052	1.7	0.7	7.75
6	30-36"	54998	1.6	0.9	8.00	20	36-42"	55053	1.2	1.5	8.10
6	36-42"	54999	1.3	2.5	7.90	20	42-48"	55054	0.0	0.4	8.30
6	42-48"	55000	0.0	1.2	not enough	21	24-30"	55055	0.8	0.3	7.90
7	24-30"	55001	0.7	0.7	7.45	21	30-36"	55056	1.8	0.8	7.95
7	30-36"	55002	2.1	1.4	7.85	21	36-42"	55057	2.0	3.0	7.80
7	36-42"	55003	0.1	0.6	8.25	21	42-48"	55058	2.9	3.6	7.75
7	42-48"	55004	0.1	0.6	not enough	22	24-30"	55059	2.0	1.3	7.65
8	24-30"	55005	2.1	1.7	7.65	22	30-36"	55060	1.0	0.7	8.20
8	30-36"	55006	0.0	2.1	8.00	22	36-42"	55061	0.1	0.7	8.30
8	36-42"	55007	0.1	0.8	8.25	22	42-48"	55062	0.0	0.3	8.35
9	24-30"	55008	1.3	1.3	7.75	LeoWest	24-30"	55063	1.5	1.2	7.50
9	30-36"	55009	1.5	1.3	8.15	LeoWest	30-36"	55064	1.7	0.9	8.05
9	36-42"	55010	1.1	1.7	8.05	LeoWest	36-42"	55065	0.1	0.1	8.35
9	42-48"	55011	1.1	1.9	8.05	LeoWest	42-48"	55066	0.1	1.6	8.40
10	24-30"	55012	1.0	1.3	7.45	LeoWest	48-54"	55067	0.1	0.7	8.30
10	30-36"	55013	1.3	0.8	7.85	LeoWest	54-60"	55068	0.1	0.3	8.40
10	36-42"	55014	1.1	1.8	8.05	LeoWest	60-66"	55069	0.1	2.0	8.35
10	42-48"	55015	0.8	2.1	8.15	LeoWest	66-72"	55070	0.0	1.0	8.35
11	24-30"	55016	1.0	1.0	7.55	LeoWest	72-78"	55071	0.1	0.7	8.25
11	30-36"	55017	1.4	1.5	8.00	LeoWest	78-84"	55072	0.1	0.9	8.30
11	36-42"	55018	1.7	2.4	7.95	LeoWest	84-90"	55073	0.0	0.8	8.50
11	42-48"	55019	0.4	1.8	8.35	LeoEast	24-30"	55074	2.2	1.8	7.85
12	24-30"	55020	2.0	2.0	7.60	LeoEast	30-36"	55075	1.0	1.8	8.10
12	30-36"	55021	2.4	1.6	7.80	LeoEast	36-42"	55076	0.4	0.3	8.25
12	36-42"	55022	2.9	3.8	8.00	LeoEast	42-48"	55077	0.1	0.8	8.35
12	42-48"	55023	0.1	0.6	8.30	LeoEast	48-54"	55078	0.6	0.4	8.35
13	24-30"	55024	0.3	1.5	7.60	LeoEast	54-60"	55079	0.0	0.6	8.40
13	30-36"	55025	0.6	1.5	7.55	LeoEast	60-66"	55080	0.0	1.6	8.40
13	36-42"	55026	1.5	1.5	7.95	LeoEast	66-72"	55081	0.1	0.6	8.40
13	42-48"	55027	0.8	0.7	8.25	LeoEast	72-78"	55082	0.1	0.7	8.40
14	24-30"	55028	0.6	2.0	7.55	LeoEast	78-84"	55083	0.1	0.7	8.40
14	30-36"	55029	2.3	1.6	7.80	LeoEast	84-90"	55084	0.1	1.0	not enough
14	36-42"	55030	0.0	0.5	8.15	LeoMid	24-30"	55085	0.8	0.6	7.55
14	42-48"	55031	0.7	1.2	8.25	LeoMid	30-36"	55086	1.4	1.1	7.75
						LeoMid	36-42"	55087	1.4	1.5	8.05
						LeoMid	42-48"	55088	0.4	0.3	8.35

APPENDIX B. SUMMER 2002 REP 1 AND REP 2 DATA

Daily/total water, P-Br sol'n, and/or P-only added				
	Water	P-Br	P-only	Cum.
	only,	solution,	solution,	volume,
Date	gal	gal	gal	gal
28-Jun	1325			1325
29-Jun	1375			2700
30-Jun	1468			4168
1-Jul	1605			5773
2-Jul	1650			7423
3-Jul	1750			9173
4-Jul	1730			10903
5-Jul	1940			12843
6-Jul	1710			14553
7-Jul	1950			16503
8-Jul	1975			18478
9-Jul	1050	1400		20928
10-Jul		1175		22103
11-Jul		1325		23428
12-Jul		1840		25268
13-Jul		1935		27203
14-Jul		1975		29178
15-Jul		2225		31403
16-Jul		2025		33428
17-Jul		2150		35578
18-Jul		2150		37728
19-Jul		2000		39728
20-Jul		2150		41878
21-Jul		2000		43878
22-Jul		2200		46078
23-Jul		1950		48028
24-Jul		2055		50083
25-Jul		1975		52058
26-Jul		1990		54048
27-Jul		775	1125	55948
28-Jul			1950	57898
29-Jul			2145	60043
30-Jul			1980	62023
31-Jul			2145	64168
1-Aug			2225	66393
2-Aug			1750	68143

[Br] (500 gal tank)				[Ortho-P] (500 gal tank)					
	[Br]		[Br]		[Ortho-P]		[Ortho-P]		[Ortho-P]
Date	mg/L	Date	mg/L	Date	mg/L	Date	mg/L	Date	mg/L
9-Jul	93	19-Jul	99	9-Jul	10.6	19-Jul	7.9	28-Jul	10.7
9-Jul	96	19-Jul	95	9-Jul	8.9	19-Jul	7.4	28-Jul	12.1
10-Jul	95	19-Jul	96	10-Jul	7.6	19-Jul	7.2	28-Jul	12.9
10-Jul	95	19-Jul	101	10-Jul	8.3	19-Jul	7.8	28-Jul	12.0
10-Jul	95	19-Jul	94	10-Jul	8.1	19-Jul	8.6	29-Jul	14.0
11-Jul	102	20-Jul	99	11-Jul	7.5	20-Jul	8.4	29-Jul	10.4
11-Jul	102	20-Jul	98	11-Jul	7.1	20-Jul	8.0	29-Jul	9.9
11-Jul	94	20-Jul	101	11-Jul	8.2	20-Jul	7.6	29-Jul	9.4
12-Jul	96	20-Jul	95	12-Jul	11.0	20-Jul	8.7	29-Jul	8.8
12-Jul	95	20-Jul	96	12-Jul	9.3	20-Jul	9.1	29-Jul	9.9
12-Jul	96	21-Jul	98	12-Jul	8.5	21-Jul	8.6	30-Jul	9.3
12-Jul	101	21-Jul	95	12-Jul	7.1	21-Jul	9.1	30-Jul	9.7
12-Jul	94	21-Jul	94	12-Jul	7.8	21-Jul	8.5	30-Jul	9.2
13-Jul	98	21-Jul	100	13-Jul	7.7	21-Jul	9.1	30-Jul	7.8
13-Jul	95	21-Jul	102	13-Jul	8.6	21-Jul	10.9	30-Jul	9.6
13-Jul	96	22-Jul	101	13-Jul	8.0	22-Jul	8.8	31-Jul	8.9
13-Jul	105	22-Jul	101	13-Jul	7.5	22-Jul	9.6	31-Jul	9.8
13-Jul	98	22-Jul	91	13-Jul	8.4	22-Jul	8.5	31-Jul	9.8
14-Jul	95	22-Jul	92	14-Jul	8.0	22-Jul	9.3	31-Jul	9.0
14-Jul	95	22-Jul	93	14-Jul	8.0	22-Jul	8.0	31-Jul	8.8
14-Jul	97	23-Jul	104	14-Jul	7.0	23-Jul	8.7	1-Aug	9.8
14-Jul	102	23-Jul	94	14-Jul	11.8	23-Jul	8.2	1-Aug	9.2
14-Jul	99	23-Jul	95	14-Jul	9.1	23-Jul	8.3	1-Aug	8.7
15-Jul	95	23-Jul	97	15-Jul	10.3	23-Jul	8.8		
15-Jul	102	23-Jul	94	15-Jul	9.5	23-Jul	7.6	**Avg =**	8.7
15-Jul	96	24-Jul	101	15-Jul	9.2	24-Jul	8.5	for 111 1-L additions	
15-Jul	99	24-Jul	102	15-Jul	8.5	24-Jul	7.2		
15-Jul	97	24-Jul	95	15-Jul	7.7	24-Jul	8.0		
16-Jul	99	24-Jul	103	16-Jul	9.2	24-Jul	7.7		
16-Jul	98	24-Jul	92	16-Jul	7.3	24-Jul	8.2		
16-Jul	95	25-Jul	101	16-Jul	6.4	25-Jul	8.9		
16-Jul	101	25-Jul	103	16-Jul	7.1	25-Jul	8.5		
16-Jul	100	25-Jul	95	16-Jul	7.8	25-Jul	9.1		
17-Jul	98	25-Jul	96	17-Jul	6.6	25-Jul	7.7		
17-Jul	94	25-Jul	96	17-Jul	7.4	25-Jul	8.6		
17-Jul	102	26-Jul	98	17-Jul	7.5	26-Jul	9.3		
17-Jul	96	26-Jul	99	17-Jul	6.8	26-Jul	7.7		
17-Jul	96	26-Jul	98	17-Jul	6.1	26-Jul	9.8		
18-Jul	103	26-Jul	104	18-Jul	7.1	26-Jul	9.8		
18-Jul	96			18-Jul	6.8	27-Jul	9.8		
18-Jul	97	**Avg =**	98	18-Jul	9.0	27-Jul	10.7		
18-Jul	98	for 83 1-L additions		18-Jul	7.8	27-Jul	7.0		
18-Jul	98			18-Jul	8.3	27-Jul	11.2		
18-Jul	96			18-Jul	7.7	27-Jul	10.8		

Ponded water level in trenches above tile line vs. time & daily rainfall data						
Date	Rep2 ponding, inches	Rep1 ponding, inches	Rep2 ponding, cm	Rep1 ponding, cm	Daily rainfall, inches	Daily rainfall, cm
6/28/2002 10:00	0	0	0	0		
6/29/2002 8:00	18	18	53.65	46.02		
6/30/2002 8:50	18	18	53.65	46.02		
7/1/2002 9:25	18	18	53.65	46.02		
7/2/2002 8:50	18	18	53.65	46.02		
7/3/2002 9:37	18	18	53.65	46.02		
7/4/2002 10:17	18	18	53.65	46.02	0.55	1.40
7/5/2002 21:30	18	18	53.65	46.02		
7/6/2002 8:00	18	18	53.65	46.02	1.081	2.75
7/7/2002 8:00	18	18	53.65	46.02	0.01	0.03
7/8/2002 8:30	18	18	53.65	46.02		
7/9/2002 11:40	18	18	53.65	46.02		
7/10/2002 9:45	20	24	58.73	61.26	3.093	7.86
7/10/2002 12:15	18	22	53.65	56.18		
7/10/2002 20:45	18	21	53.65	53.64		
7/11/2002 9:46	18	18	53.65	46.02	0.07	0.18
7/11/2002 17:00	18	18	53.65	46.02		
7/12/2002 8:05	18	18	53.65	46.02		
7/13/2002 8:00	18	18	53.65	46.02		
7/14/2002 8:30	18	18	53.65	46.02		
7/15/2002 7:45	18	18	53.65	46.02		
7/16/2002 9:00	18	18	53.65	46.02		
7/17/2002 8:00	18	18	53.65	46.02		
7/18/2002 8:00	18	18	53.65	46.02		
7/19/2002 8:45	18	18	53.65	46.02		
7/20/2002 8:45	18	18	53.65	46.02		
7/21/2002 8:00	18	18	53.65	46.02		
7/22/2002 9:10	17	17	50.11	43.48		
7/22/2002 9:40	17.5	18	52.38	46.02		
7/22/2002 14:40	18	18	53.65	46.02		
7/23/2002 8:30	18	18	53.65	46.02		
7/24/2002 8:30	18	18	53.65	46.02		
7/25/2002 15:35	18	18	53.65	46.02	0.02	0.05
7/26/2002 8:30	18	18	53.65	46.02	0.39	0.99
7/27/2002 7:15	18	18	53.65	46.02	0.05	0.13
7/28/2002 7:20	18	18	53.65	46.02		
7/29/2002 9:00	18	18	53.65	46.02		
7/30/2002 9:45	18	18	53.65	46.02		
7/31/2002 9:20	18	18	53.65	46.02		
8/1/2002 9:10	18	18	53.65	46.02		
8/2/2002 11:10	18	18	53.65	46.02		
8/3/2002 9:45	0	0	0	0		
8/4/2002 10:56					2.592	6.58
8/5/2002 12:04					1.481	3.76
8/6/2002 10:31					0.21	0.53
8/7/2002 16:59						
8/8/2002 16:17						
8/9/2002 13:04						
8/10/2002 10:10						
8/11/2002 10:48						
8/12/2002 12:44					0.21	0.53
8/13/2002 17:38					0.04	0.10
8/14/2002 11:39					0.02	0.05
8/15/2002 17:59					0.01	0.03
8/16/2002 12:48					0.01	0.03
8/17/2002 9:19					0.01	0.03
8/18/2002 10:47					0.01	0.03
8/19/2002 11:03					0.02	0.05
8/20/2002 16:10					0.02	0.05
8/21/2002 11:02					0.251	0.64
8/22/2002 10:49					0.01	0.03
8/23/2002 10:02						
8/24/2002 11:24						
8/25/2002 8:20						
8/26/2002 11:38						
8/27/2002 12:14						
8/28/2002 9:57						
8/29/2002 16:51						
8/30/2002 18:05						
9/2/2002 9:56						
9/3/2002 11:05						
9/4/2002 14:58						
9/5/2002 10:18						
9/6/2002 13:27						
9/8/2002 10:30					0.04	0.10

Water table depth relative to tile line						Water table depth relative to tile line					
MW1	MW1	MW2	MW2	MW3	MW3	MW4	MW4	MW5	MW5	MW6	MW6
Date/time	MW W.T. depth, inches	Date/time	MW W.T. depth, inches	Date/time	MW W.T. depth, inches	Date/time	MW W.T. depth, inches	Date/time	MW W.T. depth, inches	Date/time	MW W.T. depth, inches
6/28/2002 9:25	36	6/28/2002 9:27	39	6/28/2002 9:29	43	6/28/2002 9:31	46.5	6/28/2002 9:33	46.5	6/28/2002 9:35	47
6/28/2002 16:11	26.5	6/28/2002 16:13	32	6/28/2002 16:15	34	6/28/2002 16:17	39	6/28/2002 16:19	35	6/28/2002 16:21	37
6/29/2002 8:30	27	6/29/2002 8:32	31.5	6/29/2002 8:34	35	6/29/2002 8:36	35.5	6/29/2002 8:38	34	6/29/2002 8:40	35.5
6/30/2002 10:07	27	6/30/2002 10:09	32	6/30/2002 10:11	35	6/30/2002 10:13	35	6/30/2002 10:15	33	6/30/2002 10:17	35
7/1/2002 9:11	26	7/1/2002 9:13	31	7/1/2002 9:14	34	7/1/2002 9:16	35	7/1/2002 9:17	33.5	7/1/2002 9:18	35
7/2/2002 9:08	26	7/2/2002 9:09	31	7/2/2002 9:11	33	7/2/2002 9:12	34.5	7/2/2002 9:14	33	7/2/2002 9:15	34.5
7/3/2002 9:42	26	7/3/2002 9:43	30	7/3/2002 9:45	34	7/3/2002 9:46	33	7/3/2002 9:47	33	7/3/2002 9:49	34.5
7/4/2002 10:30	26.5	7/4/2002 10:32	31	7/4/2002 10:33	34	7/4/2002 10:36	33.5	7/4/2002 10:38	32.5	7/4/2002 10:39	34
7/5/2002 9:00	26	7/5/2002 9:02	32	7/5/2002 9:04	34	7/5/2002 9:32	33	7/5/2002 9:36	33	7/5/2002 9:37	35
7/6/2002 8:15	26	7/6/2002 8:16	31	7/6/2002 8:18	33.5	7/6/2002 8:19	34	7/6/2002 8:20	33	7/6/2002 8:21	34.5
7/7/2002 8:33	25.5	7/7/2002 8:36	29.5	7/7/2002 8:38	33	7/7/2002 8:39	32	7/7/2002 8:41	32	7/7/2002 8:43	35
7/8/2002 8:55	27	7/8/2002 8:56	31	7/8/2002 8:57	34	7/8/2002 8:59	33	7/8/2002 9:00	32.5	7/8/2002 9:02	35
7/9/2002 8:28	26.5	7/9/2002 8:30	30.5	7/9/2002 8:35	33.5	7/9/2002 8:45	33	7/9/2002 8:46	33.5	7/9/2002 8:48	35
7/9/2002 15:10	26	7/9/2002 15:11	30	7/9/2002 15:13	33.5	7/9/2002 15:16	33	7/9/2002 15:18	32	7/9/2002 15:19	34
7/9/2002 20:41	26.5	7/9/2002 20:42	30.5	7/9/2002 20:43	33.5	7/9/2002 20:45	34.5	7/9/2002 20:47	33	7/9/2002 20:48	34.5
7/10/2002 11:00	18.5	7/10/2002 11:03	12	7/10/2002 11:05	13	7/10/2002 11:07	17	7/10/2002 11:10	29.5	7/10/2002 11:12	25.5
7/11/2002 10:08	24.5	7/11/2002 10:10	27	7/11/2002 10:12	31	7/11/2002 10:14	29	7/11/2002 10:16	31	7/11/2002 10:19	34
7/11/2002 18:08	25	7/11/2002 18:10	30	7/11/2002 18:11	32.5	7/11/2002 18:14	33.5	7/11/2002 18:16	31	7/11/2002 18:17	34
7/12/2002 10:12	24	7/12/2002 10:13	30	7/12/2002 10:15	33	7/12/2002 10:17	31.5	7/12/2002 10:18	31.5	7/12/2002 10:20	33.5
7/13/2002 9:24	26	7/13/2002 9:26	31.5	7/13/2002 9:27	33	7/13/2002 9:29	32	7/13/2002 9:30	31	7/13/2002 9:31	34
7/14/2002 9:27	26	7/14/2002 9:28	32.5	7/14/2002 9:29	33	7/14/2002 9:30	32	7/14/2002 9:31	32	7/14/2002 9:33	34
7/15/2002 14:33	26	7/15/2002 14:35	32	7/15/2002 14:36	33.5	7/15/2002 14:38	32	7/15/2002 14:39	31	7/15/2002 14:41	34
7/16/2002 10:30	26	7/16/2002 10:31	33	7/16/2002 10:33	33.5	7/16/2002 10:34	32.5	7/16/2002 10:36	32.5	7/16/2002 10:37	34.5
7/17/2002 9:28	26.5	7/17/2002 9:29	33	7/17/2002 9:30	33.5	7/17/2002 9:32	33	7/17/2002 9:33	32.5	7/17/2002 9:35	34.5
7/18/2002 8:30	27	7/18/2002 8:31	32	7/18/2002 8:32	34	7/18/2002 8:34	33.5	7/18/2002 8:35	32.5	7/18/2002 8:36	35
7/19/2002 9:06	27	7/19/2002 9:08	31	7/19/2002 9:09	34	7/19/2002 9:11	33.5	7/19/2002 9:13	33	7/19/2002 9:14	35
7/20/2002 9:02	27	7/20/2002 9:03	31	7/20/2002 9:04	34	7/20/2002 9:07	34	7/20/2002 9:08	33.5	7/20/2002 9:09	35
7/21/2002 8:45	27	7/21/2002 8:46	32	7/21/2002 8:47	34	7/21/2002 8:49	34	7/21/2002 8:50	33	7/21/2002 8:52	35
7/22/2002 9:47	27	7/22/2002 9:48	33.5	7/22/2002 9:49	34.5	7/22/2002 9:51	34.5	7/22/2002 9:52	34.5	7/22/2002 9:54	36
7/23/2002 9:33	27	7/23/2002 9:34	33.5	7/23/2002 9:36	35	7/23/2002 9:38	34.5	7/23/2002 9:40	34	7/23/2002 9:41	36
7/24/2002 10:55	27	7/24/2002 10:57	35	7/24/2002 10:58	35	7/24/2002 11:00	35	7/24/2002 11:01	34.5	7/24/2002 11:02	36
7/25/2002 9:29	27	7/25/2002 9:31	35	7/25/2002 9:33	35	7/25/2002 9:35	35.5	7/25/2002 9:37	35	7/25/2002 9:38	37
7/26/2002 10:09	27	7/26/2002 10:11	35	7/26/2002 10:13	34	7/26/2002 10:16	35	7/26/2002 10:18	34	7/26/2002 10:20	36
7/27/2002 20:50	27	7/27/2002 20:52	35	7/27/2002 20:54	34	7/27/2002 20:56	34.5	7/27/2002 20:58	34	7/27/2002 21:00	36
7/28/2002 17:35	27.5	7/28/2002 17:37	34	7/28/2002 17:39	34.5	7/28/2002 17:42	35	7/28/2002 17:44	35	7/28/2002 17:46	37
7/29/2002 10:32	27.5	7/29/2002 10:34	33.5	7/29/2002 10:35	35	7/29/2002 10:37	36	7/29/2002 10:38	36	7/29/2002 10:40	37.5
7/30/2002 10:40	27	7/30/2002 10:42	34	7/30/2002 10:44	34	7/30/2002 10:47	35	7/30/2002 10:49	35	7/30/2002 10:51	37
7/31/2002 10:21	28	7/31/2002 10:22	34.5	7/31/2002 10:23	35.5	7/31/2002 10:25	36	7/31/2002 10:27	35.5	7/31/2002 10:28	37.5
8/1/2002 9:30	28	8/1/2002 9:32	33	8/1/2002 9:34	35.5	8/1/2002 9:36	36	8/1/2002 9:38	36.5	8/1/2002 9:39	38
8/2/2002 10:46	28	8/2/2002 10:48	34	8/2/2002 10:50	35.5	8/2/2002 10:53	35.5	8/2/2002 10:55	36	8/2/2002 10:57	37.5
8/3/2002 10:10	34	8/3/2002 10:11	38.5	8/3/2002 10:13	41	8/3/2002 10:16	43.5	8/3/2002 10:17	44	8/3/2002 10:19	45.5
8/4/2002 11:00	35.5	8/4/2002 11:04	40	8/4/2002 11:07	42.5	8/4/2002 11:10	45	8/4/2002 11:11	47	8/4/2002 11:13	49
8/4/2002 19:02	36.5	8/4/2002 19:05	40	8/4/2002 19:07	42.5	8/4/2002 19:09	47	8/4/2002 19:11	47.5	8/4/2002 19:12	49.5
8/5/2002 12:15	23.5	8/5/2002 12:18	25	8/5/2002 12:20	22	8/5/2002 12:23	30.5	8/5/2002 12:25	34	8/5/2002 12:26	32
8/6/2002 10:40	30	8/6/2002 10:42	36	8/6/2002 10:43	37.5	8/6/2002 10:46	38	8/6/2002 10:47	39	8/6/2002 10:49	41.5
8/7/2002 17:06	32	8/7/2002 17:07	37	8/7/2002 17:09	39	8/7/2002 17:11	40	8/7/2002 17:13	41	8/7/2002 17:14	42.5
8/8/2002 16:31	33	8/8/2002 16:33	37.5	8/8/2002 16:34	40	8/8/2002 16:37	41.5	8/8/2002 16:39	42	8/8/2002 16:40	44
8/9/2002 13:10	34	8/9/2002 13:12	38	8/9/2002 13:13	40.5	8/9/2002 13:15	42	8/9/2002 13:17	42.5	8/9/2002 13:18	45
8/10/2002 10:19	34	8/10/2002 10:20	39	8/10/2002 10:21	41	8/10/2002 10:24	43	8/10/2002 10:25	43.5	8/10/2002 10:26	45
8/11/2002 10:51	34.5	8/11/2002 10:53	39	8/11/2002 10:54	41	8/11/2002 10:57	43.5	8/11/2002 10:58	44	8/11/2002 10:59	46
8/12/2002 12:48	35	8/12/2002 12:50	39.5	8/12/2002 12:51	41.5	8/12/2002 12:53	44	8/12/2002 12:55	44.5	8/12/2002 12:56	46.5
8/13/2002 17:42	35	8/13/2002 17:44	39	8/13/2002 17:45	41.5	8/13/2002 17:48	44.5	8/13/2002 17:49	45	8/13/2002 17:51	47
8/14/2002 11:43	35	8/14/2002 11:45	39	8/14/2002 11:46	41.5	8/14/2002 11:48	44.5	8/14/2002 11:50	45	8/14/2002 11:51	47.5
8/15/2002 18:02	36	8/15/2002 18:03	40	8/15/2002 18:05	42	8/15/2002 18:08	45	8/15/2002 18:09	45.5	8/15/2002 18:10	48.5
8/16/2002 12:56	36	8/16/2002 12:58	40	8/16/2002 12:59	42	8/16/2002 13:01	46	8/16/2002 13:03	46.5	8/16/2002 13:04	48.5
8/17/2002 9:30	34	8/17/2002 9:32	38.5	8/17/2002 9:33	40.5	8/17/2002 9:38	44	8/17/2002 9:40	46	8/17/2002 9:41	45
8/18/2002 11:00	35.5	8/18/2002 11:01	39.5	8/18/2002 11:02	42	8/18/2002 11:04	45.5	8/18/2002 11:06	46.5	8/18/2002 11:07	48.5
8/19/2002 11:08	36	8/19/2002 11:09	40	8/19/2002 11:11	42	8/19/2002 11:13	46	8/19/2002 11:14	47	8/19/2002 11:16	48.5
8/20/2002 16:15	36	8/20/2002 16:16	40	8/20/2002 16:18	42.5	8/20/2002 16:20	46.5	8/20/2002 16:21	47.5	8/20/2002 16:23	49
8/21/2002 11:07	36	8/21/2002 11:08	40	8/21/2002 11:09	42.5	8/21/2002 11:12	47.5	8/21/2002 11:14	47.5	8/21/2002 11:15	49.5
8/22/2002 10:56	36	8/22/2002 10:58	40.5	8/22/2002 11:00	42.5	8/22/2002 11:02	45.5	8/22/2002 11:04	48.5	8/22/2002 11:06	50
8/23/2002 10:29	29.5	8/23/2002 10:30	35.5	8/23/2002 10:32	37.5	8/23/2002 10:35	40	8/23/2002 10:37	40.5	8/23/2002 10:38	41.5
8/24/2002 11:32	33	8/24/2002 11:34	37.5	8/24/2002 11:35	39	8/24/2002 11:38	41	8/24/2002 11:39	41.5	8/24/2002 11:40	44
8/25/2002 8:25	33.5	8/25/2002 8:27	37.5	8/25/2002 8:29	40	8/25/2002 8:32	42	8/25/2002 8:34	42	8/25/2002 8:36	44
8/26/2002 11:44	34	8/26/2002 11:45	38	8/26/2002 11:46	40.5	8/26/2002 11:49	43	8/26/2002 11:50	43	8/26/2002 11:51	44.5
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Rep1 daily & cumulative tile flow			Rep1 daily & cumulative tile flow			Rep2 daily & cumulative tile flow			Rep2 daily & cumulative tile flow		
Date/time	Daily, mL/min	Cum., L	Date/time	Daily, mL/min	Cum., L	Date/time	Daily, mL/min	Cum., L	Date/time	Daily, mL/min	Cum., L
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7/23/2002 19:33	1680	122961.6	9/6/2002 13:27	56	206519	7/23/2002 19:32	2400	180193	9/8/2002 10:30	0	265616.6
7/24/2002 9:56	1760	125496	9/8/2002 10:30	0	206519	7/24/2002 9:55	2480	183764.2			
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Bromide concentration in MW						Bromide concentration in MW					
MW1	MW1	MW2	MW2	MW3	MW3	MW4	MW4	MW5	MW5	MW6	MW6
Date/time	[Br], mg/L	Date/time	[Br], mg/L	Date/time	[Br], mg/L	Date/time	[Br], mg/L	Date/time	[Br], mg/L	Date/time	[Br], mg/L
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7/11/2002 10:27	25.5	7/11/2002 10:30	11.6	7/11/2002 10:33	6.6	7/11/2002 10:36	0.83	7/11/2002 10:39	26.8	7/11/2002 10:41	3.48
7/11/2002 18:47	27.3	7/11/2002 18:49	11.7	7/11/2002 18:52	6.7	7/11/2002 18:56	1.44	7/11/2002 18:59	42.6	7/11/2002 19:01	21.5
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8/1/2002 9:44	22.5	8/1/2002 9:46	20.4	8/1/2002 9:48	32.2	8/1/2002 9:52	29.7	8/1/2002 9:54	10.1	8/1/2002 9:56	20.5
8/2/2002 10:51	19.5	8/2/2002 10:53	15.4	8/2/2002 10:55	29.1	8/2/2002 10:58	21.3	8/2/2002 11:00	7.8	8/2/2002 11:02	17.4
8/2/2002 15:13	16.7	8/2/2002 15:15	15.8	8/2/2002 15:17	25.3	8/2/2002 15:20	17.9	8/2/2002 15:22	5.67	8/2/2002 15:24	13.9
8/3/2002 10:24	17.9	8/3/2002 10:26	14.4	8/3/2002 10:28	23.9	8/3/2002 10:31	14.5	8/3/2002 10:33	6.91	8/3/2002 10:35	13.3
8/4/2002 11:18	13.8	8/4/2002 11:20	1.61	8/4/2002 11:23	18.9	8/4/2002 11:26	8.21	8/4/2002 11:28	5.59	8/4/2002 11:31	9.91
8/4/2002 19:17	20.4	8/4/2002 19:20	5.85	8/4/2002 19:22	23.1	8/4/2002 19:25	10.8	8/4/2002 19:27	7.65	8/4/2002 19:29	12.8
8/5/2002 16:03	7.38	8/5/2002 16:05	2.15	8/5/2002 16:08	0.17	8/5/2002 16:11	1.26	8/5/2002 16:13	6.77	8/5/2002 16:15	0.96
8/6/2002 10:53	16.3	8/6/2002 10:56	10.9	8/6/2002 10:58	8.54	8/6/2002 11:01	2.53	8/6/2002 11:04	8.23	8/6/2002 11:06	7.84
8/28/2002 10:24	17.7	8/28/2002 10:26	15.3	8/28/2002 10:28	3.01	8/28/2002 10:31	4.69	8/28/2002 10:33	19.1	8/28/2002 10:35	4.84
8/30/2002 18:27	17.2	8/30/2002 18:29	15.5	8/30/2002 18:31	16.6	8/30/2002 18:33	9.93	8/30/2002 18:35	20.5	8/30/2002 18:38	17.8
9/2/2002 10:12	16.8	9/2/2002 10:14	16.3	9/2/2002 10:16	23.4	9/2/2002 10:20	12.5	9/2/2002 10:22	21.6	9/2/2002 10:24	22.8
9/4/2002 15:17	17.2	9/4/2002 15:19	17.2	9/4/2002 15:20	24.5	9/4/2002 15:23	14.6	9/4/2002 15:25	22	9/4/2002 15:28	23.7

Bromide tile drain data for Rep 1				Bromide tile drain data for Rep 2			
Rep 1	Rep 1	Rep 1	Rep 1	Rep 2	Rep 2	Rep 2	Rep 2
	[Br],		[Br],		[Br],		[Br],
Date/time	mg/L	Date/time	mg/L	Date/time	mg/L	Date/time	mg/L
7/2/2002 10:00	0	7/29/2002 10:24	56.9	7/2/2002 9:56	0	7/29/2002 10:23	77.6
7/3/2002 9:37	0	7/29/2002 16:43	54	7/3/2002 9:35	0	7/29/2002 16:42	70
7/4/2002 10:17	0	7/30/2002 9:51	47.9	7/4/2002 10:14	0	7/30/2002 9:49	64
7/5/2002 8:16	0	7/30/2002 19:29	47.3	7/5/2002 8:14	0	7/30/2002 19:28	55.6
7/6/2002 8:32	0	7/31/2002 10:14	39.9	7/6/2002 8:30	0	7/31/2002 10:12	48.4
7/7/2002 8:23	0	7/31/2002 15:36	40.4	7/7/2002 8:19	0	7/31/2002 15:35	48.9
7/8/2002 8:48	0	8/1/2002 9:23	35.9	7/8/2002 8:45	0	8/1/2002 9:21	33.6
7/9/2002 8:19	0	8/1/2002 16:28	27.6	7/9/2002 8:16	0	8/1/2002 16:26	31.2
7/9/2002 14:37	3.02	8/2/2002 10:44	27.4	7/9/2002 14:33	0	8/2/2002 10:42	27.7
7/9/2002 20:28	6.22	8/2/2002 15:06	23.2	7/9/2002 20:25	2.19	8/2/2002 15:04	26.3
7/10/2002 10:43	7.1	8/3/2002 10:04	24.4	7/10/2002 10:37	3.85	8/3/2002 9:58	39.3
7/10/2002 15:52	8.59	8/4/2002 10:56	23.5	7/10/2002 15:47	6.08	8/5/2002 12:02	23.1
7/10/2002 21:00	6.43	8/4/2002 18:56	24.7	7/10/2002 21:02	7.75	8/5/2002 15:51	23
7/11/2002 9:54	8.67	8/5/2002 12:04	19.5	7/11/2002 9:50	14.8	8/6/2002 10:29	22.9
7/11/2002 17:50	11	8/5/2002 15:53	20.1	7/11/2002 17:47	19.8	8/7/2002 16:56	23.2
7/12/2002 11:32	18.1	8/6/2002 10:31	21.8	7/12/2002 11:29	30.1	8/8/2002 16:15	23.7
7/12/2002 16:38	20.4	8/7/2002 16:59	23.8	7/12/2002 16:35	32.4	8/9/2002 13:02	23.9
7/13/2002 9:15	28.1	8/8/2002 16:17	25.5	7/13/2002 9:11	39.1	8/10/2002 10:07	25
7/13/2002 14:20	29.9	8/9/2002 13:04	21.4	7/13/2002 14:16	42.6	8/11/2002 10:44	27.7
7/14/2002 9:19	36.9	8/10/2002 10:10	21	7/14/2002 9:16	49.5	8/12/2002 12:40	29.4
7/14/2002 17:30	39	8/11/2002 10:48	23	7/14/2002 17:27	51.9	8/13/2002 17:33	30.4
7/15/2002 14:25	44.6	8/12/2002 12:44	24.5	7/15/2002 14:22	56.5	8/14/2002 11:35	30.6
7/16/2002 10:24	49.4	8/13/2002 17:38	25.5	7/16/2002 10:22	60.6	8/15/2002 17:52	34.5
7/16/2002 15:31	50.8	8/14/2002 11:39	25.7	7/16/2002 15:28	61.2	8/16/2002 12:50	34.1
7/17/2002 9:03	53.7	8/15/2002 17:59	25.4	7/17/2002 9:00	63.9	8/17/2002 9:27	33
7/17/2002 15:24	54.5	8/16/2002 12:48	24.7	7/17/2002 15:22	64.2	8/18/2002 10:49	30.7
7/18/2002 8:25	67.6	8/17/2002 9:19	22.2	7/18/2002 8:23	73.3	8/19/2002 11:00	
7/19/2002 8:59	71.9	8/18/2002 10:47	23.1	7/19/2002 8:57	70.5	8/20/2002 16:10	
7/19/2002 14:20	72.1	8/19/2002 11:03	26.4	7/19/2002 14:18	79.6	8/21/2002 11:02	
7/20/2002 8:55	72.3	8/20/2002 16:10	26.3	7/20/2002 8:53	75.2	8/22/2002 10:49	
7/20/2002 19:45	72.4	8/21/2002 11:02	21.8	7/20/2002 19:42	71.9	8/23/2002 10:00	16.9
7/21/2002 8:38	77.4	8/22/2002 10:49	21.9	7/21/2002 8:37	72.6	8/24/2002 11:22	17.1
7/22/2002 9:38	76.1	8/23/2002 10:02	24.3	7/22/2002 9:36	78.3	8/25/2002 8:18	17.1
7/22/2002 14:50	75.3	8/24/2002 11:24	25.3	7/22/2002 14:48	75.7	8/26/2002 11:36	17.2
7/23/2002 9:27	68.8	8/25/2002 8:20	24.6	7/23/2002 9:25	84.3	8/27/2002 12:12	18.9
7/23/2002 19:33	80.5	8/26/2002 11:38	25.4	7/23/2002 19:32	89.3	8/28/2002 9:53	20.2
7/24/2002 9:56	73	8/27/2002 12:14	21.7	7/24/2002 9:55	90.5	8/29/2002 16:54	19.7
7/24/2002 15:22	74.9	8/28/2002 9:57	22.9	7/24/2002 15:20	90.9	8/30/2002 18:08	20.2
7/25/2002 9:22	82.6	8/29/2002 16:51	20.2	7/25/2002 9:20	93.3	9/2/2002 9:53	
7/25/2002 15:48	83.4	8/30/2002 18:05	19.9	7/25/2002 15:46	90.4	9/3/2002 11:00	
7/26/2002 10:03	79.3	9/2/2002 9:56	19.3	7/26/2002 10:02	88	9/4/2002 14:55	
7/26/2002 15:16	76.6	9/3/2002 11:05	18.2	7/26/2002 15:15	85.9	9/5/2002 10:13	
7/27/2002 8:00	79.7	9/4/2002 14:58	17.9	7/27/2002 7:58	96.7		
7/28/2002 8:04	71	9/5/2002 10:18	17.5	7/28/2002 8:03	94.6		
7/28/2002 18:22	65.8	9/6/2002 13:27	18	7/28/2002 18:20	85.9		

Ortho-P concentration in MW						Ortho-P concentration in MW					
MW1	MW1	MW2	MW2	MW3	MW3	MW4	MW4	MW5	MW5	MW6	MW6
	[Ortho-P],		[Ortho-P],		[Ortho-P],		[Ortho-P],		[Ortho-P],		[Ortho-P],
Date/time	mg/L	Date/time	mg/L	Date/time	mg/L	Date/time	mg/L	Date/time	mg/L	Date/time	mg/L
7/4/2002 10:46	0.044	7/4/2002 10:52	0.041	7/4/2002 10:57	0.021	7/4/2002 11:01	0.042	7/4/2002 11:04	0.059	7/4/2002 11:08	0.207
7/5/2002 9:08	0.03	7/5/2002 9:11	0.038	7/5/2002 9:13	0.394	7/5/2002 9:17	0.166	7/5/2002 9:20	0.061	7/5/2002 9:22	0.118
7/6/2002 8:41	0.018	7/6/2002 8:44	0.014	7/6/2002 8:46	0.02	7/6/2002 8:50	0.057	7/6/2002 8:53	0.019	7/6/2002 8:56	0.142
7/7/2002 8:48	0.066	7/7/2002 8:52	0.025	7/7/2002 8:55	0.032	7/7/2002 9:00	0.177	7/7/2002 9:03	0.225	7/7/2002 9:06	0.271
7/8/2002 9:08	0.039	7/8/2002 9:11	0.03	7/8/2002 9:14	0.027	7/8/2002 9:18	0.105	7/8/2002 9:20	0.062	7/8/2002 9:23	0.184
7/9/2002 15:25	0.027	7/9/2002 15:29	0.024	7/9/2002 15:32	0.014	7/9/2002 15:35	0.077	7/9/2002 15:41	0.019	7/9/2002 15:45	0.108
7/9/2002 20:54	0.027	7/9/2002 20:59	0.035	7/9/2002 21:02	0.051	7/9/2002 21:09	0.051	7/9/2002 21:13	0.023	7/9/2002 21:15	0.071
7/10/2002 11:24	0.052	7/10/2002 11:28	0.037	7/10/2002 11:33	0.026	7/10/2002 11:40	0.312	7/10/2002 11:43	0.115	7/10/2002 11:46	0.255
7/10/2002 16:34	0.051	7/10/2002 16:37	0.027	7/10/2002 16:40	0.048	7/10/2002 16:43	0.323	7/10/2002 16:45	0.15	7/10/2002 16:47	0.351
7/11/2002 10:27	0.088	7/11/2002 10:30	0.048	7/11/2002 10:33	0.015	7/11/2002 10:36	0.149	7/11/2002 10:39	0.074	7/11/2002 10:41	0.117
7/11/2002 18:47	0.017	7/11/2002 18:49	0.023	7/11/2002 18:52	0.026	7/11/2002 18:56	0.099	7/11/2002 18:59	0.045	7/11/2002 19:01	0.08
7/12/2002 10:26	0.02	7/12/2002 10:29	0.025	7/12/2002 10:32	0.012	7/12/2002 10:35	0.072	7/12/2002 10:38	0.024	7/12/2002 10:40	0.069
7/12/2002 16:16	0.018	7/12/2002 16:20	0.126	7/12/2002 16:22	0.011	7/12/2002 16:25	0.08	7/12/2002 16:28	0.029	7/12/2002 16:30	0.07
7/13/2002 9:39	0.014	7/13/2002 9:42	0.042	7/13/2002 9:45	0.017	7/13/2002 9:48	0.063	7/13/2002 9:50	0.027	7/13/2002 9:52	0.089
7/13/2002 14:29	0.114	7/13/2002 14:31	0.032	7/13/2002 14:34	0.02	7/13/2002 14:37	0.074	7/13/2002 14:40	0.025	7/13/2002 14:42	0.105
7/14/2002 9:39	0.024	7/14/2002 9:42	0.019	7/14/2002 9:44	0.023	7/14/2002 9:48	0.073	7/14/2002 9:51	0.025	7/14/2002 9:53	0.119
7/14/2002 17:38	0.025	7/14/2002 17:40	0.041	7/14/2002 17:43	0.024	7/14/2002 17:46	0.059	7/14/2002 17:49	0.326	7/14/2002 17:51	0.142
7/15/2002 14:48	0.309	7/15/2002 14:51	0.254	7/15/2002 14:53	0.077	7/15/2002 14:57	0.056	7/15/2002 14:59	0.035	7/15/2002 15:02	0.191
7/16/2002 10:42	0.17	7/16/2002 10:45	0.079	7/16/2002 10:47	0.018	7/16/2002 10:50	0.042	7/16/2002 10:52	0.033	7/16/2002 10:55	0.131
7/16/2002 15:40	0.09	7/16/2002 15:42	0.059	7/16/2002 15:44	0.017	7/16/2002 15:48	0.046	7/16/2002 15:50	0.053	7/16/2002 15:52	0.23
7/17/2002 9:39	0.02	7/17/2002 9:41	0.058	7/17/2002 9:44	0.018	7/17/2002 9:46	0.045	7/17/2002 9:49	0.049	7/17/2002 9:51	0.19
7/17/2002 15:32	0.025	7/17/2002 15:35	0.038	7/17/2002 15:38	0.021	7/17/2002 15:41	0.052	7/17/2002 15:44	0.07	7/17/2002 15:46	0.233
7/18/2002 8:40	0.018	7/18/2002 8:41	0.057	7/18/2002 8:43	0.02	7/18/2002 8:46	0.039	7/18/2002 8:48	0.061	7/18/2002 8:50	0.257
7/19/2002 9:18	0.021	7/19/2002 9:19	0.152	7/19/2002 9:21	0.019	7/19/2002 9:24	0.04	7/19/2002 9:25	0.072	7/19/2002 9:27	0.205
7/19/2002 14:28	0.025	7/19/2002 14:30	0.136	7/19/2002 14:33	0.023	7/19/2002 14:35	0.197	7/19/2002 14:38	0.053	7/19/2002 14:40	0.336
7/20/2002 9:14	0.044	7/20/2002 9:16	0.57	7/20/2002 9:18	0.027	7/20/2002 9:21	0.056	7/20/2002 9:23	0.04	7/20/2002 9:25	0.253
7/20/2002 20:00	0.01	7/20/2002 20:02	0.654	7/20/2002 20:05	0.02	7/20/2002 20:08	0.054	7/20/2002 20:11	0.077	7/20/2002 20:13	0.311
7/21/2002 8:56	0.013	7/21/2002 8:58	0.126	7/21/2002 9:00	0.012	7/21/2002 9:13	0.028	7/21/2002 9:16	0.044	7/21/2002 9:18	0.372
7/22/2002 10:00	0.01	7/22/2002 10:02	0.153	7/22/2002 10:04	0.015	7/22/2002 10:07	0.022	7/22/2002 10:09	0.039	7/22/2002 10:11	0.267
7/22/2002 14:58	0.008	7/22/2002 15:00	0.303	7/22/2002 15:02	0.009	7/22/2002 15:05	0.015	7/22/2002 15:12	0.118	7/22/2002 15:14	0.473
7/23/2002 9:48	0.3	7/23/2002 9:50	0.346	7/23/2002 9:52	0.032	7/23/2002 9:55	0.026	7/23/2002 9:57	0.109	7/23/2002 9:59	0.422
7/24/2002 11:06	0.056	7/24/2002 11:09	0.563	7/24/2002 11:12	0.042	7/24/2002 11:15	0.027	7/24/2002 11:18	0.112	7/24/2002 11:20	0.399
7/24/2002 15:30	0.037	7/24/2002 15:32	0.615	7/24/2002 15:34	0.043	7/24/2002 15:38	0.03	7/24/2002 15:40	0.154	7/24/2002 15:43	0.607
7/25/2002 9:42	0.064	7/25/2002 9:45	0.648	7/25/2002 9:47	0.081	7/25/2002 9:50	0.06	7/25/2002 9:52	0.141	7/25/2002 9:54	0.501
7/25/2002 15:55	0.104	7/25/2002 15:58	0.648	7/25/2002 16:00	0.092	7/25/2002 16:03	0.072	7/25/2002 16:05	0.267	7/25/2002 16:09	0.682
7/26/2002 10:25	0.443	7/26/2002 10:24	0.743	7/26/2002 10:26	0.082	7/26/2002 10:29	0.048	7/26/2002 10:31	0.236	7/26/2002 10:33	0.647
7/26/2002 15:24	0.085	7/26/2002 15:26	0.693	7/26/2002 15:28	0.073	7/26/2002 15:32	0.457	7/26/2002 15:34	0.258	7/26/2002 15:36	0.875
7/27/2002 20:54	0.146	7/27/2002 20:56	0.197	7/27/2002 20:58	0.117	7/27/2002 21:01	0.16	7/27/2002 21:03	0.276	7/27/2002 21:05	0.551
7/28/2002 18:30	0.145	7/28/2002 18:32	0.602	7/28/2002 18:34	0.077	7/28/2002 18:37	0.076	7/28/2002 18:39	0.265	7/28/2002 18:49	0.643
7/29/2002 10:54	0.183	7/29/2002 10:57	0.566	7/29/2002 10:59	0.07	7/29/2002 11:02	0.078	7/29/2002 11:04	0.34	7/29/2002 11:06	0.745
7/29/2002 16:02	0.195	7/29/2002 16:03	0.384	7/29/2002 16:25	0.103	7/29/2002 16:28	0.079	7/29/2002 16:30	0.474	7/29/2002 16:32	0.989
7/30/2002 9:58	0.236	7/30/2002 10:00	0.288	7/30/2002 10:02	0.125	7/30/2002 10:06	0.069	7/30/2002 10:08	0.415	7/30/2002 10:10	0.807
7/30/2002 19:37	0.216	7/30/2002 19:41	0.28	7/30/2002 19:43	0.086	7/30/2002 19:47	0.044	7/30/2002 19:49	0.451	7/30/2002 19:51	0.856
7/31/2002 10:32	0.229	7/31/2002 10:34	0.358	7/31/2002 10:36	0.092	7/31/2002 10:39	0.05	7/31/2002 10:41	0.402	7/31/2002 10:43	1.015
7/31/2002 15:43	0.233	7/31/2002 15:46	0.4	7/31/2002 15:48	0.097	7/31/2002 15:50	0.048	7/31/2002 15:52	0.5	7/31/2002 15:54	1.061
8/1/2002 9:44	0.263	8/1/2002 9:46	0.457	8/1/2002 9:48	0.177	8/1/2002 9:52	0.054	8/1/2002 9:54	0.447	8/1/2002 9:56	0.915
8/2/2002 10:51	0.332	8/2/2002 10:53	0.716	8/2/2002 10:55	0.233	8/2/2002 10:58	0.108	8/2/2002 11:00	0.513	8/2/2002 11:02	0.858
8/2/2002 15:13	0.519	8/2/2002 15:15	0.42	8/2/2002 15:17	0.184	8/2/2002 15:20	0.072	8/2/2002 15:22	0.644	8/2/2002 15:24	1.16
8/3/2002 10:24	0.267	8/3/2002 10:26	0.657	8/3/2002 10:28	0.157	8/3/2002 10:31	0.072	8/3/2002 10:33	0.559	8/3/2002 10:35	1.203
8/4/2002 11:18	0.142	8/4/2002 11:20	0.086	8/4/2002 11:23	0.218	8/4/2002 11:26	0.159	8/4/2002 11:28	0.377	8/4/2002 11:31	0.946
8/4/2002 19:17	0.105	8/4/2002 19:20	0.304	8/4/2002 19:22	0.135	8/4/2002 19:25	0.093	8/4/2002 19:27	0.263	8/4/2002 19:29	0.539
8/5/2002 16:03	0.242	8/5/2002 16:05	0.078	8/5/2002 16:08	0.059	8/5/2002 16:11	0.275	8/5/2002 16:13	0.337	8/5/2002 16:15	0.397
8/6/2002 10:53	0.203	8/6/2002 10:56	0.24	8/6/2002 10:58	0.102	8/6/2002 11:01	0.096	8/6/2002 11:04	0.338	8/6/2002 11:06	0.649
8/28/2002 10:24	0.115	8/28/2002 10:26	0.052	8/28/2002 10:28	0.03	8/28/2002 10:31	0.051	8/28/2002 10:33	0.076	8/28/2002 10:35	0.457
8/30/2002 18:27	0.039	8/30/2002 18:29	0.044	8/30/2002 18:31	0.058	8/30/2002 18:33	0.037	8/30/2002 18:35	0.287	8/30/2002 18:38	0.24
9/2/2002 10:12	0.031	9/2/2002 10:14	0.032	9/2/2002 10:16	0.032	9/2/2002 10:20	0.037	9/2/2002 10:22	0.364	9/2/2002 10:24	0.398
9/4/2002 15:17	0.052	9/4/2002 15:19	0.021	9/4/2002 15:20	0.019	9/4/2002 15:23	0.013	9/4/2002 15:25	0.062	9/4/2002 15:28	0.116

Ortho-P tile drain data for Rep 1				Ortho-P tile drain data for Rep 2			
Rep 1	Rep 1	Rep 1	Rep 1	Rep 2	Rep 2	Rep 2	Rep 2
	[Ortho-P],		[Ortho-P],		[Ortho-P],		[Ortho-P],
Date/time	mg/L	Date/time	mg/L	Date/time	mg/L	Date/time	mg/L
7/2/2002 10:00	0.005	7/29/2002 10:24	0.097	7/2/2002 9:56	0.01	7/29/2002 10:23	0.014
7/3/2002 9:37	0.009	7/29/2002 16:43	0.102	7/3/2002 9:35	0.023	7/29/2002 16:42	0.026
7/4/2002 10:17	0.031	7/30/2002 9:51	0.102	7/4/2002 10:14	0	7/30/2002 9:49	0.023
7/5/2002 8:16	0.005	7/30/2002 19:29	0.105	7/5/2002 8:14	0.018	7/30/2002 19:28	0.03
7/6/2002 8:32	0.009	7/31/2002 10:14	0.112	7/6/2002 8:30	0	7/31/2002 10:12	0.017
7/7/2002 8:23	0.019	7/31/2002 15:36	0.111	7/7/2002 8:19	0.01	7/31/2002 15:35	0.016
7/8/2002 8:48	0.006	8/1/2002 9:23	0.121	7/8/2002 8:45	0	8/1/2002 9:21	0.009
7/9/2002 8:19	0.023	8/1/2002 16:28	0.119	7/9/2002 8:16	0.003	8/1/2002 16:26	0.006
7/9/2002 14:37	0.012	8/2/2002 10:44	0.125	7/9/2002 14:33	0	8/2/2002 10:42	0.02
7/9/2002 20:28	0.022	8/2/2002 15:06	0.13	7/9/2002 20:25	0	8/2/2002 15:04	0.021
7/10/2002 10:43	0.007	8/3/2002 10:04	0.095	7/10/2002 10:37	0	8/3/2002 9:58	0.006
7/10/2002 15:52	0.006	8/4/2002 10:56	0.077	7/10/2002 15:47	0	8/5/2002 12:02	0.013
7/10/2002 21:00	0.02	8/4/2002 18:56	0.06	7/10/2002 21:02	0	8/5/2002 15:51	0.012
7/11/2002 9:54	0.01	8/5/2002 12:04	0.062	7/11/2002 9:50	0	8/6/2002 10:29	0.019
7/11/2002 17:50	0.007	8/5/2002 15:53	0.066	7/11/2002 17:47	0	8/7/2002 16:56	0.033
7/12/2002 11:32	0	8/6/2002 10:31	0.054	7/12/2002 11:29	0	8/8/2002 16:15	0.008
7/12/2002 16:38	0.007	8/7/2002 16:59	0.059	7/12/2002 16:35	0.003	8/9/2002 13:02	0.007
7/13/2002 9:15	0.003	8/8/2002 16:17	0.045	7/13/2002 9:11	0.007	8/10/2002 10:07	0.012
7/13/2002 14:20	0.009	8/9/2002 13:04	0.042	7/13/2002 14:16	0.003	8/11/2002 10:44	0.01
7/14/2002 9:19	0.012	8/10/2002 10:10	0.041	7/14/2002 9:16	0.005	8/12/2002 12:40	0.011
7/14/2002 17:30	0.013	8/11/2002 10:48	0.041	7/14/2002 17:27	0.004	8/13/2002 17:33	0.007
7/15/2002 14:25	0.036	8/12/2002 12:44	0.036	7/15/2002 14:22	0.005	8/14/2002 11:35	0.012
7/16/2002 10:24	0.025	8/13/2002 17:38	0.015	7/16/2002 10:22	0.005	8/15/2002 17:52	0.014
7/16/2002 15:31	0.025	8/14/2002 11:39	0.018	7/16/2002 15:28	0.006	8/16/2002 12:50	0.007
7/17/2002 9:03	0.042	8/15/2002 17:59	0.029	7/17/2002 9:00	0.009	8/17/2002 9:27	0.008
7/17/2002 15:24	0.035	8/16/2002 12:48	0.032	7/17/2002 15:22	0.008	8/18/2002 10:49	0.01
7/18/2002 8:25	0.042	8/17/2002 9:19	0.041	7/18/2002 8:23	0.021	8/19/2002 11:00	
7/19/2002 8:59	0.053	8/18/2002 10:47	0.036	7/19/2002 8:57	0.018	8/20/2002 16:10	
7/19/2002 14:20	0.054	8/19/2002 11:03	0.04	7/19/2002 14:18	0.021	8/21/2002 11:02	
7/20/2002 8:55	0.058	8/20/2002 16:10	0.008	7/20/2002 8:53	0.017	8/22/2002 10:49	
7/20/2002 19:45	0.059	8/21/2002 11:02	0.009	7/20/2002 19:42	0.017	8/23/2002 10:00	0.019
7/21/2002 8:38	0.066	8/22/2002 10:49	0.009	7/21/2002 8:37	0.019	8/24/2002 11:22	0.009
7/22/2002 9:38	0.068	8/23/2002 10:02	0.011	7/22/2002 9:36	0.017	8/25/2002 8:18	0.011
7/22/2002 14:50	0.071	8/24/2002 11:24	0.008	7/22/2002 14:48	0.035	8/26/2002 11:36	0.01
7/23/2002 9:27	0.064	8/25/2002 8:20	0.014	7/23/2002 9:25	0.016	8/27/2002 12:12	
7/23/2002 19:33	0.067	8/26/2002 11:38	0.009	7/23/2002 19:32	0.016	8/28/2002 9:53	0.009
7/24/2002 9:56	0.046	8/27/2002 12:14	0.015	7/24/2002 9:55	0.005	8/29/2002 16:54	0.011
7/24/2002 15:22	0.048	8/28/2002 9:57	0.028	7/24/2002 15:20	0.009	8/30/2002 18:08	0.013
7/25/2002 9:22	0.057	8/29/2002 16:51	0.012	7/25/2002 9:20	0.006	9/2/2002 9:53	
7/25/2002 15:48	0.06	8/30/2002 18:05	0.014	7/25/2002 15:46	0.014	9/3/2002 11:00	
7/26/2002 10:03	0.087	9/2/2002 9:56	0.014	7/26/2002 10:02	0.014	9/4/2002 14:55	
7/26/2002 15:16	0.075	9/3/2002 11:05	0.012	7/26/2002 15:15	0.008	9/5/2002 10:13	
7/27/2002 8:00	0.079	9/4/2002 14:58	0.013	7/27/2002 7:58	0.013		
7/28/2002 8:04	0.09	9/5/2002 10:18	0.015	7/28/2002 8:03	0.01		
7/28/2002 18:22	0.107	9/6/2002 13:27	0.016	7/28/2002 18:20	0.01		

Elevation profile Rep 1 & Rep 2 (English units)						
Position on plot	Distance from sump, ft	Tile line bottom elevation, ft	Trench bottom elevation, ft	MW water level at equilibrium, ft	Trench ponded water level, ft	Ground elevation, ft
Flag 1	15	0	0.2		1.77	3.04
MW1	20	0.1325	0.355	1.07	1.77	3.2558
MW2	25	0.265	0.51	0.94	1.77	3.4716
MW3	30	0.3975	0.665	1.00	1.77	3.6874
Flag 2	35	0.52	0.82		1.77	4.13
Flag 3	43	0.77				4.36
Flag 4	55	1.05	1.3		3.08	4.94
MW4	60	1.1925	1.385	2.09	3.08	4.9822
MW5	65	1.325	1.47	2.29	3.08	5.29
MW6	70	1.4575	1.555	2.24	3.08	5.4138
Flag 6	75	1.59	1.64		3.08	5.63

Soil test lab results Rep 1 & Rep 2						
MW#	Horizontal depth, in	Horizontal depth, cm	Olsen P, mg/kg	Soil test pH	Avg. horiz. depth, cm	Bray-1 P, mg/kg
1	0-2	0-5	21	8.4	2.5	1
1	2-4	5-10	14	8.5	7.5	0
1	4-6	10-15	15	8.5	12.5	0
1	6-8	15-20	9	8.5	17.5	0
1	8-10	20-25	11	8.5	22.5	0
2	0-2	0-5	18	8.4		0
2	2-4	5-10	21	8.4		0
2	4-6	10-15	19	8.4		0
2	6-8	15-20	23	8.3		0
2	8-10	20-25	20	8.3		0
3	0-2	0-5	28	8.3		4
3	2-4	5-10	24	8.3		2
3	4-6	10-15	18	8.3		25
3	6-8	15-20	8	8.3		4
3	8-10	20-25	7	8.4		8
4	0-2	0-5	49	8.0		60
4	2-4	5-10	40	8.0		48
4	4-6	10-15	20	8.0		23
4	6-8	15-20	3	7.8		2
4	8-10	20-25	4	7.8		2
5	0-2	0-5	43	8.0		53
5	2-4	5-10	39	8.0		48
5	4-6	10-15	34	8.0		42
5	6-8	15-20	26	7.9		30
5	8-10	20-25	6	7.9		7
6	0-2	0-5	33	8.2		6
6	2-4	5-10	21	8.3		14
6	4-6	10-15	37	8.1		43
6	6-8	15-20	33	8.2		35
6	8-10	20-25	32	8.1		40

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