OXYGEN-18 DYNAMICS IN PRECIPITATION AND STREAMFLOW IN A SEMI-ARID AGRICULTURAL WATERSHED, EASTERN WASHINGTON

By

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To the Faculty of Washington State University:

The members of the Committee appointed to examine the thesis of BRYAN GEORGE MORAVEC find it satisfactory and recommend that it be accepted.

Chair

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OXYGEN-18 DYNAMICS IN PRECIPITATION AND STREAMFLOW IN A SEMI-ARID AGRICULTURAL WATERSHED, EASTERN WASHINGTON

Abstract

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Understanding flow pathways and mechanisms that generate streamflow is important to understanding agrochemical contamination in surface waters in agricultural watersheds. This study tested the conceptual hydrologic framework developed in previous research in the semi-arid agricultural Missouri Flat Creek watershed, near Pullman Washington, using stable isotope hydrology. Two environmental tracers, $\delta^{18}O$ and electrical conductivity (EC), were monitored in tile drainage (draining 12 ha) and stream water (draining 660 – 5700 ha) from 2000 to 2008. Tile drainage and streamflow generated in the watershed was found to have a baseline $\delta^{18}O$ of ~–14.7‰ year round, which only changed during episodic events. Winter precipitation accounted for 67% of total annual precipitation and was found to be the primary contribution to streamflow and tile drainage, while summer precipitation did not contribute appreciably. "Old" and "new" water partitioning in streamflow was not identifiable using $\delta^{18}O$, but seasonal shifts of nitrate-corrected EC suggest that shallow soil pathways did contribute significantly to streamflow generation during winter (mean EC 200 μS/cm), while deep soil pathways primarily generated summer streamflow (mean EC 250 μS/cm). Using summer isotopic and EC excursions of stream waters from tile drainage, evaporation fractions were estimated to be from 0.2 to 0.4, with the highest evaporation occurring from August to October. Rapid shallow soil water lateral flow during saturated conditions was the most important pathway for nitrate loss to stream waters in the watershed. Seasonal watershed dynamics and streamflow generation in the MFC watershed may represent these processes at larger watershed scales in the Palouse River basin.

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1. INTRODUCTION

1.1. INTRODUCTION

Stable isotopes of water (^{2}H and ^{18}O) have been useful tools in wastershed studies over the past 40 years (e.g. Zimmermann, 1967; Gat and Levy, 1978; Gat and Gonfiantini, 1981; Barnes and Allison, 1983, 1984, 1988; Gibson et al., 1993, 1998, 2000, 2002, 2005; Gat, 1996; Kendall & McDonnell, 1998; Gibson, 2001, 2002). They have helped hydrologists gain insight into the hydrologic dynamics of watersheds, evapotranspiraton, water sources, and inputs of precipitation to water budgets. By combining stable isotope hydrology with water geochemistry, a better understanding of the hydrologic processes that shape intra-watershed dynamics can be achieved.

Understanding the isotope hydrology of managed agricultural environments and ecosystems could contribute to: (1) optimizing productivity while minimizing environmental impacts, (2) development of fate and transport models to understand surface and ground water contamination as a result of agricultural practices, and (3) the implementation of environmentally-sound artificial tile drainage systems.

Artificially drained catchments via tile drains can produce significant agrochemical pollution to surface waterways in many areas of the US (Kladivko et al., 1991; Randall et al., 1997; Cambardella et al., 1999). As a result of this export of pollutants, it is vital to understand the surface and subsurface pathways that these chemicals travel.

1.2. BACKGROUND

Numerous studies have investigated intra-watershed dynamics during events using isotopic and geochemical compositions observed at different reaches of small watersheds. Most of this research has been conducted in a relatively few climatic conditions, including humid and temperate forested catchments (Hooper and Shoemaker, 1986; Hooper et al., 1990; Genereux et al., 2002, 2004, and 2006; Peters and Radcliffe, 1998; Gburek and Folmer, 1999; Gibson et al. 2000; Endreny, 2002; Shanley et al., 2002), alpine or northern latitude catchments (Laudon and Slaymaker, 1997; Carey and Quinton, 2005; Gibson et al. 1993), and coastal semi-arid catchments in Australia (Barnes and Allison, 1983, 1984, and 1988; Walker and Brunel, 1990; Marimuthu et al., 2005), or they have been aimed at identifying spring source and precipitation contribution to groundwater in arid climates (Winograd et al. 1997).

Stable isotopes have been applied to storm hydrograph separation (e.g. Sklash et al., 1976; Sklash and Farvolden, 1979), and can identify "old" and "new" water (pre-event and event waters, Genereux and Hooper, 1998) contributions to streamflow during events. On the other hand, electrical conductivity (EC) can identify hydrologic pathways, based on local geology and mineral-water interaction time, where higher EC implies long and deep subsurface pathways and lower EC implies short and shallow subsurface pathways (Freeze and Cherry, 1979). Hooper and Shoemaker (1986) at the Hubbard Brook Experimental Forest in New Hampshire and Shanley et al. (2002) at the Sleepers River Research Watershed in Vermont both used geochemical and stable isotope data to create hydrograph separations to identify "old" and "new" water contributions to stream flow during storm events and spring snowmelt. Both studies observed deuterium (δD)

and $\delta^{18}O$ values that were enriched during the winter and depleted in April as snow pack (isotopically depleted relative to rain) melted and increased discharge from the watersheds. They also found that baseflow actually contributes a substantial amount of water to streamflow generation even during storm events. Genereux et al. (2002, 2004, 2006) identified sources of groundwater to surface water using both geochemical and stable isotope data in a small lowland watershed in Costa Rica. Isotopic variation in precipitation was not large (mean of –3.4‰, standard deviation of 2.04), but was slightly seasonal. They also found that isotopic data are sometimes unreliable and geochemical data are needed to perform water budget calculations. Additionally, Hooper et al. (1990) used stream water chemistries to produce hydrograph separations in the Panola watershed in Georgia.

Unfortunately, research on small-scale watershed dynamics in semi-arid agricultural catchments is largely absent from the literature. The Palouse region in Eastern Washington offers a unique opportunity to investigate catchment-to-basin hydrologic dynamics in a non-irrigated semi-arid agricultural watershed. Washington State University's Cook Agronomy Farm (CAF) located within the Missouri Flat Creek (MFC) Watershed is a no-till experimental farm operated by the U.S. Department of Agriculture (USDA) and has been used extensively for agronomic and hydrologic study since 1999 (Figures 1, 2).

1.3. PREVIOUS RESEARCH IN THE PALOUSE, THE CAF, AND MFC

The Palouse region is typical of many water-stressed parts of the world in that groundwater exploitation is greater than recharge to the regional aquifer. Concern for the long-term sustainability of the Grande Ronde aquifer has lead to a number of recent studies regarding regional aquifer recharge (Lum et al. 1990; Larson et al., 2000; O'Geen et al., 2005; Douglas et al., 2007) that have only briefly characterized surface hydrology. Although this work has established that the aquifer, the source for municipal and university drinking water in the Palouse, is essentially isolated from surface recharge, they have also shown that this water source is currently mined and endangered. This fact leads to the need to evaluate surface and shallow groundwater (Wanapum aquifer) as possible future water resources. As a result, understanding surface flow pathways and water quality is essential.

Hydrologic monitoring has been done on the MFC watershed from October 2000 to February 2008. Seasonal discharges from 12 ha to 5700 ha scales are similar in their temporal patterns (Simmons, 2003; Wannamaker, 2005; Suzuki 2005; Goodwin, 2006; and Keller et al., 2008). Precipitation inputs in winter drive high flow regimes in both small scale and large-scale reaches of the watershed. Overland flow is an important form of transport of water as shown by two pesticides used as tracers in hydrograph separations by Simmons (2003). Summer discharge is low and represents a drying out or evaporation driven regime.

Comparisons of discharge from TD-12 (tile drained field approximately 12 ha in size) and MFC-660 (a composite of tile and non-tile drained fields draining approximately 660 ha) (Figure 1) as observed by Suzuki (2005) and reported by Keller et al (2008) suggest that TD-12 discharge is typical of streamflow generated both by tile drainage and by soil water seepage to ditches tributary to the MFC.

Wannamaker (2005) and Keller et al. (2008) observed that about 150 mm of fall precipitation is required to saturate the upper 1m of soil in lower-slope positions. When saturation is attained, water and residual nitrate are mobilized throughout the profile and large drainage discharges with high nitrate concentrations occur. As shallow soil water reaches the drain, high drainage nitrate concentrations are associated with lower EC. Goodwin (2006) used $\delta^{18}O$ from precipitation, soil water (collected in tension and zero-tension lysimeters) and tile drainage to model soil-water mean residence time (MRT) following Maloszewski and Zuber (1982, 1996, 1998) and McGuire et al. (2002). This model traced $\delta^{18}O$ variation in precipitation, through the soil profile and into discharge at catchment outlets. She estimated that catchment MRT for waters, including tile drainage, were 4-7 months, and that most discharges were from precipitation earlier that same water year.

The goal of this research was to investigate the behavior of oxygen isotopes in precipitation, soil water, and stream water over a period of 7 years to identify the sources and mechanisms of streamflow generation and trace the seasonal isotopic evolution of stream waters in this watershed. The primary objectives were to (1) perform long-term monitoring at multiple soil water and surface water sampling stations within the MFC watershed; (2) characterize seasonal watershed response to precipitation inputs using stable isotope geochemistry and EC of surface and soil waters; (3) characterize the isotopic evolution of $\delta^{18}O$ in surface waters from catchment-to-basin watershed scales ranging from monthly to annual time scales; (4) estimate evaporative flux from stream waters in summer using both stable isotope and EC mass balances; and (5) test the conceptual hydrologic frameworks presented by previous researchers for the MFC watershed.

2. METHODS

2.1. SITE DESCRIPTION

Research was performed at the MFC watershed, located north of Pullman, Washington, in the semi-arid area of the Palouse in eastern Washington and northern Idaho (Figure 1). Annual precipitation in the area ranges between 31-58 cm/yr (Donaldson et al. 1980), with the majority of precipitation occurring in winter. Mean annual high and low temperatures ranged from 27ºC in the summer and –7ºC in the winter (Geyer et al., 1992). Agricultural activities dominate the region and crops consist mostly of wheat, lentils, and garbanzo beans, which are rotated. The area's topography is characterized by rolling hills (up to 50m of local relief) of deflation loess deposits overlying Columbia River Basalt (CRB) flows (McDonald and Busacca, 1992; Keller et al., 2008). Soils in the region are silt loam Mollisols, which have been mapped as part of the Palouse-Thatuna Association soil series (USDA, 1978). Lateral flow components make important contributions to streamflow, particularly during periods of high precipitation after soil wetting has occurred (Keller et al., 2008). As is common in areas of poor drainage, low-lying areas are artificially drained with tile drains (perforated PVC pipe that is buried horizontally in the ground), which act as linear sinks for soil water during periods of high precipitation, short-circuiting soil drainage pathways to streams.

2.2. SAMPLING LOCATIONS

Sampling was performed in the MFC watershed (Figure 1) at six locations consisting of five nested sub-watersheds, and was conducted at least bimonthly, and more frequently during periods of high precipitation. Location ES-6 on the CAF was an ephemeral rill draining approximately 6 ha and flowed episodically during winter after precipitation events or periods of snowmelt. Location ES-106 on the CAF was an ephemeral stream draining approximately 106 ha; TD-12 was a tile drain draining approximately 12 ha of CAF throughout the year and was only dry in August; MFC-660 was a ditch draining 660 ha consisting of tile and non-tile drained fields in the MFC watershed across the road from TD-12, and flowed throughout the year; MFC-4700 was an ephemeral stream draining approximately 4700ha of the MFC watershed; MFC-5700 was an ephemeral stream at the southwestern boundary of the MFC and drained approximately 5700 ha of the MFC watershed. Surface water levels at MFC-660 and MFC-4700 were measured every hour with a Global Logger® pressure transducer and gauged to calculate discharge. Discharge at TD-12 was periodically measured with a bucket and stopwatch.

2.3. SAMPLE COLLECTION AND LAB PREPARATION

Field collection methods for waters were designed to be consistent with U.S. Geological Survey (USGS) sampling methods (Shelton, 1994). All samples were collected in 250 mL Nalgene® bottles that were first acid washed and then rinsed with ultrapure distilled water (Nanopure); with 500 mL Nalgene® bottles used to collect additional water at TD-12 and at MFC-660. Grab samples were tested for field pH and temperature using an Oakton® pH meter (300 Series) (Samples collected from 5/10/06 to present only), and then placed in a cooler for transport back to the lab. Field method blanks consisted of 250mL of ultrapure distilled water poured from a 1000mL Nalgene® bottle.

Water levels in nested piezometers near the tile drain and further up the watershed at the ES-6 sampling station were measured with an electronic measuring tape. Grab samples were taken from the piezometers (Appendix M) during periods that soil water was close enough to the surface to measure (piezometers near ES-06 were typically dry after May 1st until November; piezometer samples were only taken from 5/10/2006 to present). Tension and zero-tension lysimeters 10 m north of the tile drain were sampled regularly until a large flooding event pulled the tubing from the lysimeter cups (after which piezometers were used to sample soil waters at greater depths).

Upon arriving in the lab, samples were measured for turbidity using a Hach® 2100P portable turbidimeter (Appendix A). Three turbidity standards (0-10, 0-100, and 0-1000 NTU) were placed in the turbidimeter to ensure proper meter response. Samples were then placed in glass vials, capped, shaken, and wiped clean with a velvet cloth, then placed one by on into the turbidimeter and recorded for NTU.

Samples were also measured for EC and temperature using a temperature compensated electrical conductivity probe (model 115, Orion/ThermoFisher Scientific) (Appendix A). In uncontaminated water samples, EC is a good proxy for ionic load, mineral – water interaction time, and flow pathway (Freeze and Cheery, 1979). The probe was calibrated with ultrapure water having an EC of <1 μS/cm and an EC standard solution of 1413 μS/cm at 25°C. The probe was rinsed twice with ultrapure water between each measurement to avoid contamination. Because nitrate and its counterion affect EC measurements (Keller et al., 2008), Simmons (2003) and Wannamaker (2005) outlined a two-step calibration method for the EC meter to attain nitrate corrected EC (henceforth referred to as EC) (Appendix L).

Samples were then vacuum filtered thorough Whatmann 0.45 μm cellulose nitrate membrane filters, poured into two acid washed 20 mL scintillation bottles (for nitrate concentration and $\delta^{18}O$ of waters), two 60 mL Nalgene® bottles (for cation and anion analysis), one 125 mL Nalgene® bottles (as an archived sample), and 500 mL Nalgene® bottles (for future $\delta^{15}N$ and $\delta^{18}O$ of nitrate analysis). The 20 mL scintillation bottles for $\delta^{18}O$ analysis were placed in a tray upside down to minimize evaporation in a dark cabinet, and kept at room temperature. The other 20 mL sample bottles were placed in a freezer later to be analyzed for nitrate concentration by the Washington State University USDA – Agricultural Research Service (WSU USDA-ARS) laboratory by continuous flow analysis (Model RFA300, Alpkem / OI Analytical). One 60 mL bottle was treated with 75 μL nitric acid to $pH<2$ and placed in a refrigerator to be later analyzed for anions. The other 60 mL bottle was placed in the freezer without acid treatment to be later analyzed for major cations. The 125 mL and 500 mL bottles were placed in the freezer to be used for $\delta^{15}N$ and $\delta^{18}O$ of nitrate analysis (Appendix I, J, and K).

Precipitation samples were collected in a 1000 mL Nalgene® bottle draining a tipping-bucket precipitation collector at TD-12. Metrological data was collected at ES-6 up to January 2006. As a result of vandalism to the rain collector at ES-6, meteoric data after January 2006 was used from the Smokey Air Data (SAD) website published by the Washington State University (WSU) College of Engineering as part of their environmental measurements course (http://smokey.ce.wsu.edu/airdata/Met_Data/). SAD meteoric data was collected hourly and for this study precipitation amounts, temperature, and humidity were reported as daily averages (Appendix F). The SAD sampling location was in Pullman on the WSU campus. SAD precipitation data were compared to precipitation data collected on the CAF prior to vandalism. The two data sets were found to have similar precipitation frequencies and amounts on both daily and monthly timescales.

2.4. ANALYSIS OF $\delta^{18}O$ OF WATERS

$\delta^{18}O$ isotopic analysis of waters was conducted on a Delta S continuous-flow gas chromatograph mass spectrometer (Gas Bench) located in the GeoAnalytical Lab (GAL) in the School of Earth and Environmental Sciences (SEES) at WSU. Stored samples were analyzed in groups of 150 – 200 samples to minimize analysis cost, and as a result, some samples remained in storage for up to 12 months. Possible enrichment due to evaporation of stored samples may have occurred for some samples from 2001-2004 (Goodwin, 2006).

Before sample analysis, each scintillation vial was vigorously shaken to ensure that any water vapor in the headspace of the bottle is reconstituted back into the aqueous phase to reduce isotopic discrimination. For each sample, 500 μL of water was pipetted into a borosilicate vial then tightly fitted with a septa. Samples were then placed in a temperature-controlled tray set at 32^0 C. The Gas Bench is fully automated and method sequence is controlled through the Isotope Data (ISODAT) computer program. CO_2 gas with a known oxygen isotopic composition at 5000 ppm (or 0.5 %) CO_2 in an inert helium carrier gas was then injected automatically into each vial via a dual syringe attached to a motorized arm and left over night to equilibrate the ^{18}O isotopic composition of the headspace CO_2 to the water in the vial. The isotopic composition of the water overwhelms the isotopic composition of the CO_2 gas; after eight hours of equilibration, headspace CO_2 is equal to the isotopic composition of the water. After equilibration, headspace CO_2 in then drawn out of the vial to the mass spectrometer via a helium carrier gas and sent through MS which has 3 Faraday detectors measuring 44, 45, and 46 atomic masses. For Gas Bench oxygen isotope analysis performed at the GAL in SEES at WSU, analytical uncertainty is ±0.28 ‰ and method uncertainty, considering storage issues prior to 2004, is ±0.58 ‰ (Goodwin, 2006).

Raw isotopic data retrieved from the Gas Bench were converted to Excel spreadsheets by ISODAT, and corrected according to known isotopic standards, Vienna Standard Mean Ocean Water (VSMOW) (Coplen, 1995), Standard Light Antarctic Precipitation (SLAP) (Coplen, 1995), Greenland Ice Sheet Project (GISP) (Farquhar et al. 1997), and 3 internal standards: WAWA 1, WAWA 2, and DIWA (Goodwin, 2006), which isotopically encapsulate (high to low) typical $\delta^{18}O$ values for Palouse waters. Raw $\delta^{18}O$ values were temperature corrected by subtracting 38.78 as per Bottinga and Craig (1969) and Bottinga and Javoy (1973) to accommodate equilibrium CO_2-water oxygen fractionation at 32°C. Standard correction consists of plotting known isotope values verses observed isotope values, calculating the slope, and applying the slope to observed water sample $\delta^{18}O$ values to get the actual $\delta^{18}O$ value. The known $\delta^{18}O$ values for the standards are as follows: VSMOW ($\delta^{18}O$ = 0.0 ‰), GISP ($\delta^{18}O$ = -24.78 ‰), SLAP ($\delta^{18}O$

= -55.5 ‰), WAWA 1 ($\delta^{18}O$ = -16.478 ‰), WAWA 2 ($\delta^{18}O$ = -16.671 ‰), and DIWA ($\delta^{18}O$ = -18.874 ‰).

Isotopic measurements for precipitation were both monthly and seasonally volume weighted (Appendix D).

3. RESULTS

3.1. PRECIPITATION AND STREAMFLOW GENERATION IN THE MISSOURI FLAT CREEK WATERSHED

Precipitation amounts were monitored from October 2000 to December 2007 and followed typical seasonal trends for the Palouse as reported by Simmons (2003), Suzuki (2005) Wannamaker (2005), Goodwin (2006) and Keller et al. (2008) (Table 1a and Figure 3). Precipitation in the region originates from westerly storm fronts that move into eastern Washington from the Pacific, British Columbia, or periodically from California. Over the study interval, an average of 67% of annual precipitation fell between October and April. Winter precipitation took the form of snow during the coldest parts of the wet season between November and February where mean monthly temperatures were below 0ºC (Appendix F). Typically, snow pack was occasional during winter as warm weather usually melted snow between events. Late winter precipitation was usually in the form of rain and was regional in nature. Summer precipitation was usually in the form of short, isolated thunderstorms that rarely produced significant overland flow.

Discharges at both TD-12 and MFC-660 were large in the winter; beginning typically in Jan-Feb after soils were saturated by fall rains (Keller et al., 2008) (Figure 3). Summer discharges at all sites in the watershed dropped dramatically as soil water content decreased after the onset of spring crop growth. Discharge at TD-12, MFC-660, or MFC-4700 during some years was nonexistent towards the end of summer.

Alfalfa (*Medicago sativa*) was planted in the spring of 2006 and consisted of a 20 m strip abutting the drainage ditch and running north along Whelan Road from the TD-12 outlet. Alfalfa is a deep-rooted perennial that is often used as a hydrologic barrier of subsurface drainage to edge of field ditches. TD-12 discharge for the water year 2006-2007 was consistent with previous years and was not apparently affected by the alfalfa.

Stream water discharge at both MFC-4700 and MFC-5700 was monitored from 2000-2008, but hydrograph data were unreliable for MFC-5700 after August 2005 and not included here. Peak winter discharge fluxes [mm^3/mm^2 * day] observed at MFC-660, MFC-4700, and MFC-5700 were similar in relative magnitude and contemporaneous to TD-12 peak discharge flux. Summer discharges at MFC-4700 (Figure 3) consistently decreased as summer progressed until harvest in August. During some years, MFC-5700 and MFC-4700 tended to dry out by the end of July as localized riparian ecology developed around the streams and water uptake by plants was the greatest. Evapotranspiration loss of soil waters (Keller et al., 2008) compounded the decrease in baseflow contribution to surface water as crops matured in early summer.

Runoff ratios (surface water flux/precipitation flux) were calculated from small scales within the MFC watershed up to the Palouse River gauging station at Hooper, WA (~647,500 ha) (Table 1a, 1b). Years with low runoff ratios corresponded to years with below normal precipitation. Runoff ratios for the MFC ranged between 0.1 and 0.4 with an average of 0.2. For this study, discharge measured at MFC-660 was probably the most accurate within the MFC because TD-12 discharge was gauged manually when sampling rather than hourly, and MFC-4700 stream morphology changed during the study. A data logger malfunction occurred from July to September 2007 at MFC-660, but flow was minimal at this time and this malfunction did not cause significant error in runoff ratio calculations for that year. Runoff ratios were calculated for USGS historical data (Williams and Pearson, 1985) at the MFC outlet, South Fork of the Palouse River at Pullman, and Palouse River at Hooper. Runoff ratios at these scales within the greater watershed averaged 0.2 and were similar to runoff ratios calculated at TD-12, MFC-660 and MFC-4700 for most years of this study.

3.2. STABLE ISOTOPES OF MISSOURI FLAT CREEK WATERS

Monthly volume weighted $\delta^{18}O$ values for CAF precipitation (Appendix D) were depleted with respect to VSMOW and exhibited seasonal variability (Table 2, Figure 4, and Appendix D). The observed $\delta^{18}O$ depletion of precipitation can be attributed to both latitude effect and continental effect (Craig 1961; Gat 1996). In general, monthly volume-weighted winter precipitation samples (Figure 4) showed more depleted $\delta^{18}O$ values than summer precipitation. Varying winter depletion of precipitation $\delta^{18}O$ can be attributed to a combination of temperature effect and source area effects (in this case, latitude effect with storm front origin of BC versus California). In the Palouse, monthly volume-weighted winter precipitation $\delta^{18}O$ values ranged from –18 ‰ to –12 ‰, while summer months had $\delta^{18}O$ values ranging from –11 ‰ to –4 ‰.

Observed TD-12 and MFC-660 $\delta^{18}O$ discharge values (Figure 5) were consistent from season to season and year-to-year, averaging –14.7 ‰. Mean values for $\delta^{18}O$ at TD-12 and MFC-660 were the same as reported mean $\delta^{18}O$ for loess ground waters on the Palouse (Larson et al., 2000). Three sharp depletion events occurred March 2002, January 2004, and December 2007 where TD-12 $\delta^{18}O$ values were –16.1 ‰, -16.4 ‰, and –15.8 ‰, respectively. MFC-660 waters were even more depleted at these times and closely matched $\delta^{18}O$ values from ES-6. These events coincided with very low EC. One abnormal enrichment peak event occurred in March 2003 with a TD-12 $\delta^{18}O$ value of –13.0 ‰, which coincided with highly enriched winter precipitation and overland flow at ES-6.

MFC-4700 and MFC-5700 $\delta^{18}O$ values responded rhythmically and consistently from summer to winter (Figure 6). Summer $\delta^{18}O$ values exhibited enrichment that consistently peaked at ~–11 ‰ and ~-11.9 ‰ in July and August for MFC-4700 and MFC-5700, respectively. Four extreme enrichment events at MFC-4700, which were not seen in MFC-5700, occurred in June 2001, April, 2003, August 2005, and July 2007, with $\delta^{18}O$ reaching –6.6 ‰, -5.1 ‰, -4.8 ‰, and –8.2 ‰, respectively. Winter $\delta^{18}O$ values consistently dipped to –14.5 ‰ in January for most years. Two extreme depletion events occurred in January/February 2002 and January 2004, with $\delta^{18}O$ reaching –17.4 ‰ and –18.6 ‰, respectively for MFC-4700 and –16.9 ‰ and –17.8 ‰ for MFC-5700. These depletion events coincided with depletion events observed at ES-6, TD-12, and MFC-660, as well as highly depleted precipitation at that time.

Soil water $\delta^{18}O$ dynamics are shown in Figure 7a-e. Shallow lysimeters had a more rapid, high-amplitude isotopic response to precipitation inputs than deeper lysimeters, and TD-12 $\delta^{18}O$ during some peak flows reflected a shallow soil water input to tile drainage. However, this shallow water signal appeared to be short-lived where sampling frequency was sufficient to test this (e.g. Dec 03 – Jan 04, Figures 7c and 7e).

3.3. ELECTRICAL CONDUCTIVITY OF MISSOURI FLAT CREEK WATERS

EC was measured to be near 0 μS/cm for most precipitation samples (Appendix A). However, occasional samples did have detectable EC that may represent contamination of rain droplets in summer as a result of through fall to the rain collector (precipitation that fell on leaves, collected dust and then fell into the rain collector), or settling of dust particles during late summer harvest that accumulated in the rain collector and interacted with slightly acidic rainwater in the sampling container.

TD-12 discharge EC showed definite seasonality with an average nitrate corrected EC of 240 μS/cm in summer and an average of 205 μS/cm during the winter (Figure 5). Keller et al. (2008) hypothesized that lower TD-12 EC in the winter was the result of mobilized shallow pore water mixing with deeper profile waters, while higher EC in the summer was dominantly deeper soil water. Dramatic dips of very low EC were observed in January 2002 and January 2004, and are consistent with the highest discharges observed during this study.

Surface waters at MFC-4700 and MFC-5700 show greater seasonal EC variability than TD-12 and MFC-660, with average summer EC of 375μS/cm and 480μS/cm for MFC-4700 and MFC-5700, respectively. Average winter EC was 200μS/cm for both MFC-4700 and MFC-5700 (Table 2 and Figure 6). MFC-5700 waters exhibited EC values that were slightly higher than EC for MFC-4700 for the same sample date.

4. DISCUSSION

4.1. PRECIPITATION $\delta^{18}O$ INPUT TO SOIL WATER AND RESULTING $\delta^{18}O$ COMPOSITION OF STREAMFLOW

An arresting aspect of our data is the consistency of $\delta^{18}O$ in discharge from TD-12 and MFC-660 over the study period (Figure 5, 7a-e). With highly seasonal $\delta^{18}O$ values for precipitation inputs to soil, it might be expected that TD-12 discharge would follow seasonal trends if simple piston flow were the primary mechanism of soil water transport from surface to tile drain. This is not the case, as average TD-12 discharge is isotopically indistinguishable from winter precipitation (Figures 8a, b). Thus winter precipitation seems to control the soil water isotopic signature, while summer precipitation has little if any influence. Our TD-12 discharge is isotopically very similar to the shallowest groundwater values found by Larson et al (2000), who reported average $\delta^{18}O$ was -14.5 ‰ for groundwater in loess on the Palouse.

TD-12 $\delta^{18}O$ stability throughout the year is due to summer precipitation that does not reach drain depth, and $\delta^{18}O$ variability of winter precipitation lost due to mixing. Soil water content from shallow to middle depths reached minimum values during summer (Figure 3) and lysimeters were unable to collect pore waters at these times (Figure 7a-d and Appendix M). It can be concluded that the isotopic content of summer precipitation was "filtered out" as any summer precipitation that infiltrated the soil was taken up by plants and transpired. Conversely, winter precipitation that infiltrated into the soil mixed with deeper pore water and any variability in precipitation $\delta^{18}O$ was lost, except during events (Figure 7b, c). This mixing of winter precipitation reduced TD-12 $\delta^{18}O$

seasonality, and as a result “old” and “new” water contributions to tile drainage were indistinguishable.

Seasonal variability of TD-12 EC indicates different MRT among isotopically indistinguishable waters. Observed lower EC in winter TD-12 discharge (Table 2) can be understood as a combination of shallow and deep-water inputs. This is contrary to results found by Shanley et al. (2002) who found that during peak meltwater discharge, lower EC occurred with the most depleted $\delta^{18}O$ at their agricultural site. One of the hypotheses proposed by Shanley et al. (2002) to explain this behavior was that tile drainage lowered the water table and therefore limited the storage of “old” water, which consequently decreased the “old” water contribution while passing more seasonal precipitation variability more directly to stream water. By contrast at TD-12, $\delta^{18}O$ seasonal variability is all but absent due to the filtering and mixing effects of a relatively deep, high water-storage drainage pathway.

In discharge from MFC-660 and TD-12, there were a few isolated cases where high flow was associated with lower EC and depleted $\delta^{18}O$ similar to the results found at the agricultural site in the Sleeper River study (Shanley et al., 2002). In January 2004, the isotopic composition of the TD-12 discharge (–16.4 ‰) was close to the monthly volume-weighted $\delta^{18}O$ for precipitation in January 2004 (-17.2 ‰) (Figure 7e). Additionally, the relatively stable soil water content (SWC) at depth (85cm) was also affected by this period of high flow (Figure 7e). However, these occurrences are probably attributable to preferential flow pathways and were not typical or recurring events for the MFC watershed over this 7-year study period. The event that occurred in

January 2004 had a short-term impact on the hydrologic dynamics of soil waters, but it did not have lasting effects on water chemistry for the following year.

In addition to preferential flow that occurred at TD-12, MFC-660 $\delta^{18}O$ matched closely to $\delta^{18}O$ for ES-6 during high flow events, and these events coincided with depleted and enriched monthly volume-weighted winter precipitation $\delta^{18}O$ at those times. The close relationship of ES-6 and MFC-660 during events suggests that Horton overland flow or saturation overland flow occurs during events in non-tile drained fields, as hypothesized by Simmons (2003).

4.2. ROLE OF EVAPORATION IN ISOTOPE-GEOCHEMICAL EVOLUTION OF STREAM WATER

Winter $\delta^{18}O$ values for surface waters at all catchment scales were consistent from year to year, with mean winter $\delta^{18}O$ closely matching the isotopic signature of mean TD-12 discharge (Figures 5 and 6, Table 2). Superimposed upon this steady signal are the signatures (e.g. ES-6) of occasional events, observed at MFC-660 and propagated down the watershed; and the rhythmic summer-season enrichment excursions observed at MFC-4700 and MFC-5700 (Figure 6). These observations are consistent with a conceptual framework in which soil water seepage via tile drains or directly to ditches, originating as winter precipitation and occasionally augmented by overland-flow events, is the dominant source of streamflow generation in the MFC watershed; and some other process or source modifies the fundamental $\delta^{18}O$ signature during low flow at large catchment scales. Simmons (2003), observing high EC at MFC-4700 during the summer, envisioned groundwater from shallow basalts as a primary component of down stream surface waters during low flow. If this were the case, the $\delta^{18}O$ of this shallow basalt component would have to be from –12 ‰ to –11 ‰ or heavier according to observed summer $\delta^{18}O$ values at MFC-4700 (Figure 9). However, this hypothesis in not consistent with Larson et al (2000) because the $\delta^{18}O$ they found in basalt groundwater was more negative (-15.2 ‰ SD 0.3 in the shallow aquifer and –16.7 ‰ SD 0.6 in the deeper aquifer) than $\delta^{18}O$ observed at MFC-4700 at any time from 2000-2008 (except during occasional winter events) especially during summer (Figure 6).

Figure 9 shows how $\delta^{18}O$ and EC of MFC-4700 and MFC-5700 were rhythmically and synoptically enriched compared to discharge from TD-12. I hypothesize that this was due to evaporation from the stream water surface. The extent of evaporation may be estimated by two independent evaporation indices, $E/I_{\delta^{18}O}$ and E/I_{EC}, and checked against potential evapotranspiration (PET) as estimated by the Thornthwaite equation (Thornthwaite, 1948) (Appendix B). $E/I_{\delta^{18}O}$ is the fraction of evaporation to input water (Gibson et al. 1993), represented in this case by TD-12 discharge, estimated using observed differences between $\delta^{18}O$ of TD-12 discharge and $\delta^{18}O$ of surface waters (Appendix E). This calculation takes into account phase-change oxygen isotope fractionation, which is both humidity and temperature dependent. E/I_{EC} is the fraction of evaporation to input water estimated using the difference in observed EC from TD-12 discharge and surface waters.

Estimates for $E/I_{\delta^{18}O}$ for MFC-5700 show significant evaporative loss from August to October after harvest, with $E/I_{^{18}O}$ ranging between 0.25 and 0.35 from 2001-2007 (Table 3). Calculated $E/I_{^{18}O}$ for MFC-4700 from August to October, included extremely enriched outlying $\delta^{18}O$ that produced $E/I_{^{18}O}$ values greater than 1 (not tabulated). As a result, summer (April – October) $\delta^{18}O$ values for MFC-4700 were averaged to estimate $E/I_{^{18}O}$; MFC-4700 $E/I_{^{18}O}$ values ranged from 0.14 – 0.45. For the same time periods, E/I_{EC} for both MFC-4700 and MFC-5700 ranged between 0.3 - 0.4 and were comparable to estimated $E/I_{^{18}O}$ (Table 3).

This analysis supports the hypothesis that $\delta^{18}O$ enrichment observed at both MFC-4700 and MFC-5700 is due to evaporative enrichment of surface water in summer, and does not reflect differing proportions of "old" and "new" water. Shanley et al. (2002) inferred that observed isotopic enrichment of surface waters at Sleeper River at the beginning of summer was due to enriched summer precipitation contributing to streamflow. This cannot be the case in the MFC watershed, as baseline $\delta^{18}O$ for streamflow contributions are stable at winter-precipitation values throughout the year where they are monitored at TD-12 and MFC-660; i.e. summer precipitation is "filtered out" and does not mix with shallow groundwater as discussed above. Evaporation is the primary driver in isotopic variability observed in MFC-4700 and MFC-5700, especially in summer.

4.3. IMPLICATIONS FOR STREAMFLOW GENERATION IN THE PALOUSE RIVER WATERSHED AND SHALLOW GROUNDWATER RECHARGE IN EASTERN WASHINGTON

The isotopic composition at the Palouse River Watershed USGS gauging station at Hooper from 2000-2001 showed strongly seasonal fluctuations with enriched $\delta^{18}O$ values in the summer (~-11 ‰) and depleted $\delta^{18}O$ during the winter (~-14.5 ‰) (Figure

10). This seasonal variation for the Hooper gauging station, located 96 km west of the MFC (Figure 1) and representing more than 100 times the area of our largest catchment, conforms closely to observed isotopic seasonality at MFC-4700 and MFC-5700. In addition, the runoff ratios calculated at several different scales within the watershed were similar (Table 1a, b). This indicates that the MFC watershed may be typical for agricultural watersheds in the Palouse region, and suggests that the mechanisms of streamflow generation and the surface hydrologic dynamics observed in the MFC may be typical of other similar catchments and watersheds in the Palouse.

Larson et al. (2000) suggested that shallow basalt ground water was recharged by recent precipitation (within the past 10-100 years). They reported that shallow groundwater in the Wanapum aquifer had mean $\delta^{18}O$ composition of -15.2 ‰, which was statistically indistinguishable from groundwater in loess with a mean $\delta^{18}O$ composition of –14.7‰. These values are close to those of mean winter precipitation (Figure 8b) and mean streamflow (Figure 5). Taken together, these results indicate that winter precipitation is the source of both surface and groundwater resources in this region.

There appears to be a slight overall enrichment trend in $\delta^{18}O$ for TD-12 and MFC-660 discharge from 2000-2007 (Figure 5), which cannot be attributed to errors. Average $\delta^{18}O$ for water year 2000-2001 was –15.1 ‰ and 2006-2007 was –14.2 ‰. Although slight, this decadal trend towards less negative $\delta^{18}O$ values may be a result of increased average temperatures locally for the Palouse. Using the global precipitation isotope-temperature relationship from Dansgaard (1964) a rough estimation of temperature increase that could account for the slight enrichment of TD-12 $\delta^{18}O$ is 1.3° C ±0.5° C. Alternatively, a gradual increase in baseline $\delta^{18}O$ at TD-12 may be due to decadal climatic changes in North America due to a series of recurring El Niño/Southern Oscillation (ENSO) events over the past decade (Jacobs et al., 1994). However, ENSO events are short lived (persistence of 6-18 months) and have primary effects on climate in the southwestern United States and the tropics (Andrade and Sellers, 1988), with only a secondary effect in the northwestern US. The more likely cause for the gradual enrichment of $\delta^{18}O$ in MFC soil waters (Appendix N) may be the Pacific Decadal Oscillation (PDO), which has been shown to have primary and sustained effects (cycles of 20 years) on the climate of the northwestern US and Canada (Kitzberger et al., 2007). For the past decade, the PDO has exhibited a warming phase that has been marked by warmer coastal waters off of Washington and British Columbia, a colder Pacific Ocean north of 20°N (http://jisao.washington.edu/pdo/), a higher incidence of forest fires (Kitzberger et al., 2007), and climatic changes in the western US (Benson et al., 2003). This warm coastal water and increased springtime temperatures may affect the isotopic dynamics of late winter precipitation with less rainout and lower depletion of residual vapor masses that precipitate over the Palouse.

Keller et al. (2008) put forth a conceptual framework that stated that streamflow generation was primarily from discharge of soil water, and increased discharge in winter was due predominantly to rapid lateral flow of shallower soil water after soil water content (SWC) was sufficiently high. This was supported by observed seasonal variability of EC in TD-12 and MFC-660, interpreted to indicate long (and deep) flowpaths during summer, on which were superposed by shorter (and shallower) flowpaths in winter. A stable $\delta^{18}O$ baseline of –14.7 ‰ for TD-12 and MFC-660 discharge is not inconsistent with this conceptual framework, but rather highlights the fact that isotopically "new" and "old" waters in discharge were not distinguishable in this dataset except during occasional events. Goodwin (2006) estimated that that TD-12 discharge was mostly water precipitated earlier in the same water year, and MRT was 4-7 months. The major uncertainty in application of a lumped parameter flow model to discharge data collected at TD-12 was that little of the required seasonal changes in TD-12 $\delta^{18}O$ due to input precipitation isotopic variability were observed (Goodwin, 2006). Nevertheless, TD-12 EC data suggests that the whole soil profile contributed to TD-12 discharge over the course of a stream water outflow season, and Goodwin (2006) MRT estimates were reasonable.

Agrochemical export to surface waters in the MFC watershed was highly seasonal (Simmons, 2003; Wannamaker, 2005; Keller et al., 2008) and dependent on the timing of stream water generation within the watershed. Keller et al. (2008) observed high nitrate concentrations of 25-30 mg/L N-NO_3^- in TD-12 and MFC-660 discharge occurring during high flow (winter), and low nitrate concentrations of 4 mg/L N-NO_3^- during low flow (summer). Seasonality in nitrate concentrations, which is dependent on biological activity in soils, did not affect $\delta^{18}O$ values in discharge waters at TD-12 or MFC-660 (Figure 7a). Peak nitrate concentration in TD-12 discharge occurred shortly before and during the lowest measured EC, indicating that there was a short and shallow flowpath component to TD-12 discharge. This offers support to Kellers et al. (2008) conceptual model that residual soil nitrate was mobilized by increased tile drainage as a result of winter precipitation and increased lateral flow due to shallow pore water saturation. In addition, Simmons (2003) observed increased pesticide flux to stream waters during winter events and zero flux during low flow in summer. The winter export flux of pesticides was hypothesized by Simmons (2003) to be a result event-driven overland flow. Except during events, discharge at TD-12 during low flow is “old” winter precipitation from deeper soil profiles and zero fluxes of pesticides would be expected, as natural attenuation would eliminate traces of pesticide at depth.

In contrast with the results of most previous isotope-hydrologic watershed studies, we found that seasonal isotopic changes were observed only at larger catchment scales, due to in-stream evaporation effects during the summer. Summer precipitation did not affect the isotopic composition of stream water as it did in watersheds at Hubbard Brook (Hooper and Shoemaker, 1986), Sleeper River (Shanley et al., 2002), Panola (Hooper et al., 1990), or La Selva Biological Station in Costa Rica (Genereux et al., 2002, 2004, 2006). Hooper and Shoemaker (1986) observed strong depletion events in stream waters as a result of spring snowmelt at Hubbard Brook. This type of strong depletion in early spring was not observed at the MFC. Genereux et al. (2002, 2004, and 2006) observed two distinctive sources of groundwater in stream waters in Costa Rica. By contrast, it seems clear that soil water, and shallow groundwater drained by drain tiles in the summer, were the principal sources of streamflow generation in the MFC watershed, and that evaporation (summer) and occasional events (winter) were the principal sources of isotopic variation in stream water. Event-based monitoring could resolve the contributions of shallow and deep pore waters during these events (e.g. Simmons, 2003). However, the stability of the TD-12 and MFC-660 isotopic records is an important aspect of this watershed, and the superposed effect of evaporation on EC and $\delta^{18}O$ in surface waters increases the complexity of defining end-members in hydrograph separations.

5. CONCLUSIONS

Isotopic data collected in tile drainage throughout the course of this study showed that winter precipitation was the primary source of shallow groundwater recharge in the MFC watershed. $\delta^{18}O$ values for groundwater collected in the shallow basalt aquifer (Wanapum, $\delta^{18}O$: -15.2 ‰) (Larson et al., 2000) were statistically indistinguishable from our TD-12 $\delta^{18}O$ data (-14.7 ‰), suggesting that recharge to the shallow aquifer was from recent winter precipitation. As a result, contamination of the shallow basalt aquifer is likely to occur as agrochemicals have been shown to mobilize during high flow in winter (Simmons, 2003; Wannamaker, 2005).

The isotopic seasonality of stream waters in the MFC watershed from 2000 to 2008 was due to stream water evaporation of streamflow generated with the isotopic signature of winter precipitation, and does not represent a separate basalt groundwater source in this watershed. Identification of seasonally-variable "new' and "old" water contributions to TD-12 and MFC-660 discharges was not possible using $\delta^{18}O$ end-member mixing models, because soil water seepage and tile drainage to ditches throughout the year was generated by infiltration and mixing of winter precipitation. Seasonal trends of EC from both TD-12 and MFC-660 suggest that short, shallow subsurface pathways contributed to winter stream water generation and long, deep subsurface pathways dominated summer stream waters. Events that rapidly changed water chemistry and isotopes were occasionally important to stream water dynamics in the MFC watershed.

Isotope geochemistry for the MFC appears to be characteristic of the larger Palouse River watershed. A slight long-term enrichment trend in our tile drain data, and the enrichment of seasonally volume-weighted precipitation $\delta^{18}O$ over the past decade, suggest that decadal scale, climatic changes, such as PDO, have impacted the hydrology of the region.

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Table 1a: Seasonal Precipitation $\delta^{18}O$ and Runoff Ratios at Different Scales in the Missouri Flat Creek Watershed

Season/year (October-March: Winter) (April-September: Summer)	Total Seasonal Precipitation (mm)	Seasonal Volume weighted d18O (‰)	Yearly Precipitation totals (mm)	Annual Discharge Fux TD-12 (mm/yr)	Annual Discharge Flux MFC-660 (mm/yr)	Annual Discharge Flux MFC-4700 (mm/yr)	Annual Runoff Ratio (TD-12/PPT)	Annual Runoff Ratio (MFC-660/PPT)	Annual Runoff Ratio (MFC-4700/PPT)
Winter 2000-2001	195.15	No Data	336.12	78.07	69.27	32.16	0.23	0.21	0.10
Summer 2001	140.97	-12.44							
Winter 2001-2002	344.18	-15.55	455.56	428.96$	94.70	148.75	0.94$	0.21	0.33
Summer 2002	111.38	-13.77							
Winter 2002-2003	372.13	-12.97	468.9	106.29	68.29	185.85	0.23	0.15	0.40
Summer 2003	96.77	-11.21							
Winter 2003-2004	267.46	-15.84	441.71	211.85	123.17	202.63	0.48	0.28	0.46
Summer 2004	174.25	-10.2							
Winter 2004-2005	185.93	-12.96	333.88	56.97	46.36	72.93	0.17	0.14	0.22
Summer 2005	147.95	-12.67							
Winter 2005-2006	259.56	-14.53	432.74	138.39	99.70	487.81#	0.32	0.23	1.13#
Summer 2006	173.18	-12.62							
Winter 2006-2007	311.83	-13.67	420.7	102.36	67.94*	118.15	0.24	0.16*	0.28
Summer 2007	108.87	-12.67							
Winter 2007-2008	152.02	-13.66							
		Average precipitation	412.80						

Winter and summer seasonal weighted precipitation values from 2000-2007. Winter precipitation contributes to most of the precipitation through out the year in the Palouse region. For Winter 2007-2008, precipitation data is only current to Dec 10, 2007 and does not include any precipitation data for 2008 months. Annual discharge flux is the total annual discharge/area. Annual runoff ratio is the Annual discharge flux/precipitation flux.

Notes:

$ Discharge at TD-12 is 2-4 times average discharge from this site is unreliable for 2001-2002

* Stream gauge data for 2006-2007 were not complete, July-September were not measured.

Flux for MFC-4700 during 2005-2006 is not correct, discharge during this water year is overestimated due to change in stream morphology.

Table 1b: Historical Stream Gauging Data and Runoff Ratios, Palouse River Watershed

Gauging Station (USGS ID)	**Drainage Area (ha)**	**Period of Historical Data**	**Average Watershed Precipitation (mm)**	**Average Discharge (m3/day)**	**Average Discharge Flux (mm/yr)**	**Average Runoff Ratio**
Missouri Flat Creek at Pullman (13348500)	7019	1934 - 1979	533.40	20716	107.73	0.202
SF Palouse River at Pullman (13348000)	34188	1935 - 1980	558.80	96309	102.82	0.184
Palouse River at Hooper (13351000)	647497	1898 - 1979	457.20	1513193	85.30	0.187

Historical gauging data collected by the USGS at various stations within the Palouse River Watershed (Williams and Person, 1985). Average Watershed Precipitation and Average Discharge are the annual mean over the collection period for each site. Runoff ratio is the Average Discharge Flux/Average Watershed Precipitation.

Table 2: Seasonal $\delta^{18}O$ and EC for Precipitation and at Increasing Watershed Scale

Sample Site	Average Winter d18O	SD	Average Summer d18O	SD	Average d18O for Site	SD	Average Winter EC (uS/cm)	SD	Average Summer EC (uS/cm)	SD
ES-6	-15.35	1.88	-13.34	1.20	-14.82	1.94	130.08	123.64	222.59	56.22
ES-106	-15.07	1.75	-13.13	1.53	-14.40	1.91	134.82	109.63	249.39	42.22
TD-12	-14.79	0.69	-14.59	1.22	-14.72	0.93	205.09	81.18	239.75	26.16
MFC-660	-14.55	1.78	-14.30	0.74	-14.41	1.43	199.31	95.89	257.16	38.92
MFC-4700	-14.45	3.12	-12.56	2.19	-13.63	2.90	216.70	92.53	317.80	54.78
MFC-5700	-13.86	1.43	-14.39	1.40	-13.18	1.16	248.91	116.20	661.67	82.15
PPT @ A (Seasonally Weighted)	-14.26	3.14	-11.97	3.01	-13.31	3.27	6.86	9.75	74.03	90.27

Table 2: Seasonal weighted d18O for precipitation and sampling sites from 2000 to 2007. Winter months are from October 1 to March 31 and summer months are from April 1 to September 31.

Table 3: Estimation of Evaporation Flux at MFC-4700 and MFC-5700

Site	Water Year (MFC-4700), Summer Period (MFC-5700)	Total Annual Precipitation (mm)	Summer d18O TD-12	Summer d18O surface water	Average Summer Humidity	dvO	d*O	E/I d18O	Evaporation d18O (mm)	Average Summer EC TD-12	Average Summer EC Surface Water	E/I EC
MFC-4700	2000-2001	336.12	-15.12	-12.82	0.40	-23.20	-0.11	0.27	91.54	226.48	309.56	0.27
	2001-2002	455.56	-15.16	-13.90	0.40	-24.29	-0.07	0.14	62.19	244.66	294.43	0.17
	2002-2003	468.90	-14.53	-11.21	0.40	-21.60	-0.17	0.45	211.76	246.04	311.86	0.21
	2003-2004	441.71	-14.56	-12.87	0.40	-23.25	-0.11	0.20	87.92	239.72	308.38	0.22
	2004-2005	333.88	-14.47	-11.68	0.40	-22.06	-0.16	0.36	121.29	240.14	325.38	0.26
	2005-2006	432.74	-14.70	-12.92	0.40	-23.30	-0.11	0.21	90.44	259.99	333.16	0.22
	2006-2007	420.70	-14.22	-12.28	0.40	-22.67	-0.13	0.24	100.63	226.64	347.78	0.35
MFC-5700	7/11-10/24/01	336.12	-14.64	-12.42	0.38	-22.81	-0.16	0.29	97.54	267.85	405.43	0.34
	9/20-11/20/02	455.56	-14.81	-12.72	0.38	-23.11	-0.15	0.27	121.33	261.26	396.60	0.34
	8/1-9/27/03	468.90	-14.56	-11.82	0.38	-22.21	-0.19	0.38	177.09	269.42	428.24	0.37
	8/20-10/1/04	441.71	-14.22	-11.97	0.38	-22.36	-0.18	0.31	135.04	263.26	409.78	0.36
	8/19-10/7/05	333.88	-14.70	-11.88	0.38	-22.27	-0.18	0.39	129.02	259.62	432.21	0.40
	8/10-10/6/06	432.74	-14.75	-12.19	0.38	-22.58	-0.17	0.34	147.67	263.36	498.96	0.47
	6/19-10/19/07	420.70	-14.39	-12.35	0.38	-22.73	-0.17	0.27	113.49	248.89	435.01	0.43

Estimation of Evaporation flux versus Input Flux. Both d18O stable isotopes are used as well as electrical conductivity (EC) of waters.

Notes:

1) **E/I d18O** for 2001, 2007: Data for Aug-Oct not present because MFC-5700 was dry.

2) Maximum evaporation occurs during August - October, after harvest.

3) **Summer d18O** for MFC-5700 was from the dates listed in the table, when soils were driest, evaporation was large, and d18O show most enrichment over a 3 month period.

4) **Summer d18O** for MFC-4700 averaged from April - Oct, and extreme enriched outliers were not included.

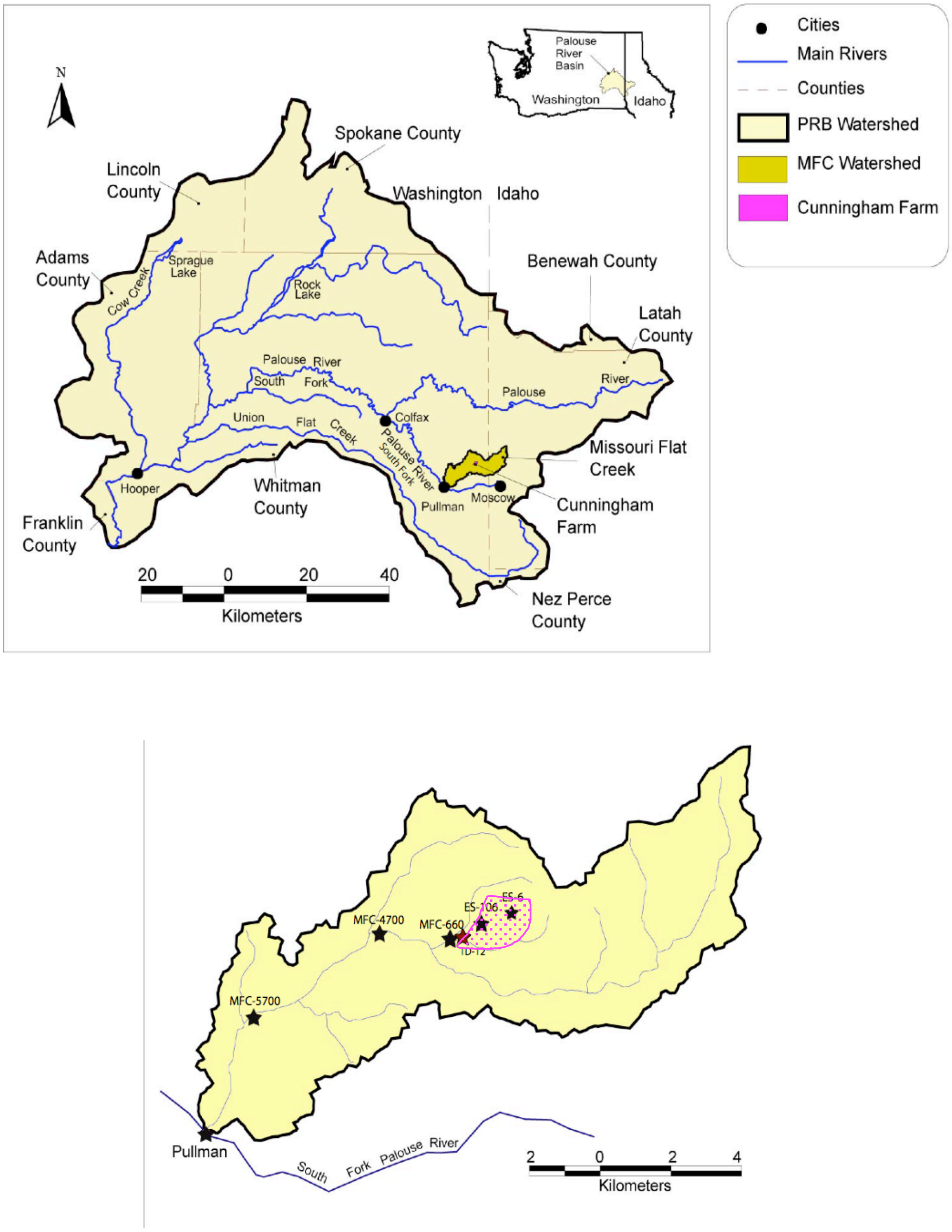
5) d18O of vapor (**dvO**) is calculated as per Horita and Wesolowski (1994) estimation of 10^3lnA(L-V), where T=8.38C.

6) **d*O** and **E/I d18O** are calculated as per Gibson et al. (1993).

7) Humidity is estimated at 0.4 for the Palouse.

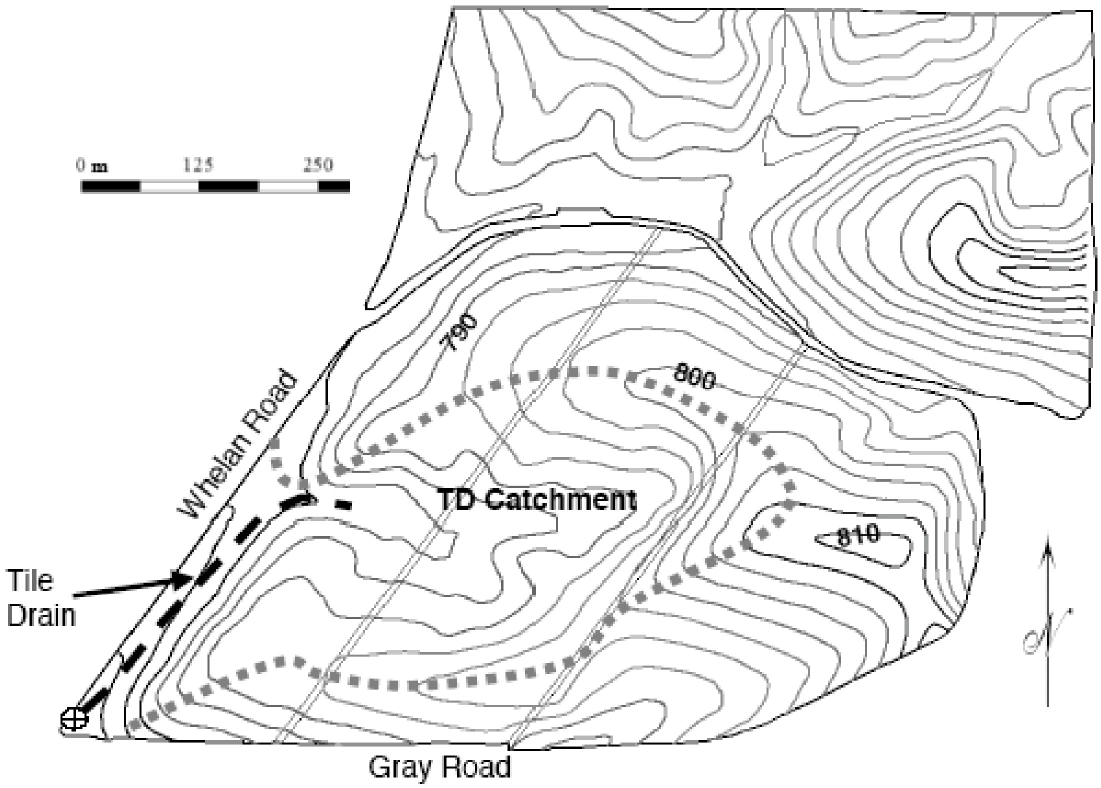
8) **E/I EC** is calculated using a 2 end mixing model of Input EC (**Average Summer EC TD-12**) and Reactor EC (**Average Summer EC Surface Water**)

Figure 1: Map of Sampling Locations in the Missouri Flat Creek Watershed and the Palouse River Watershed



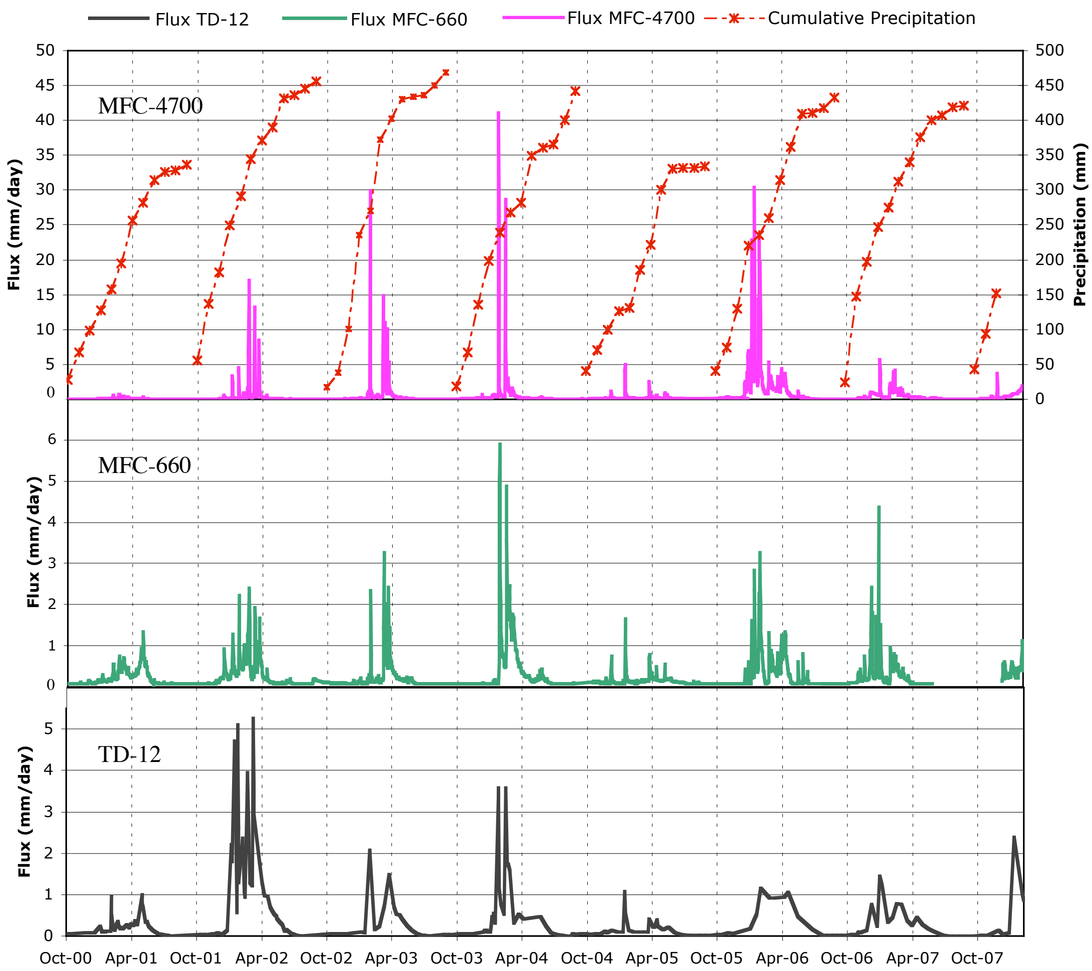
Missouri Flat Creek (MFC) (6000 ha) drains to the South Fork of the Palouse River and is tributary to the Palouse River (647,500 ha). All sampling sites in the MFC are identified with stars with corresponding area of drainage in ha. Tile Drain is TD-12; ES is Ephemeral Stream (Modified from Goodwin, 2006).

Figure 2: Map of Estimated Location of Tile Drain and Cook Agronomy Farm



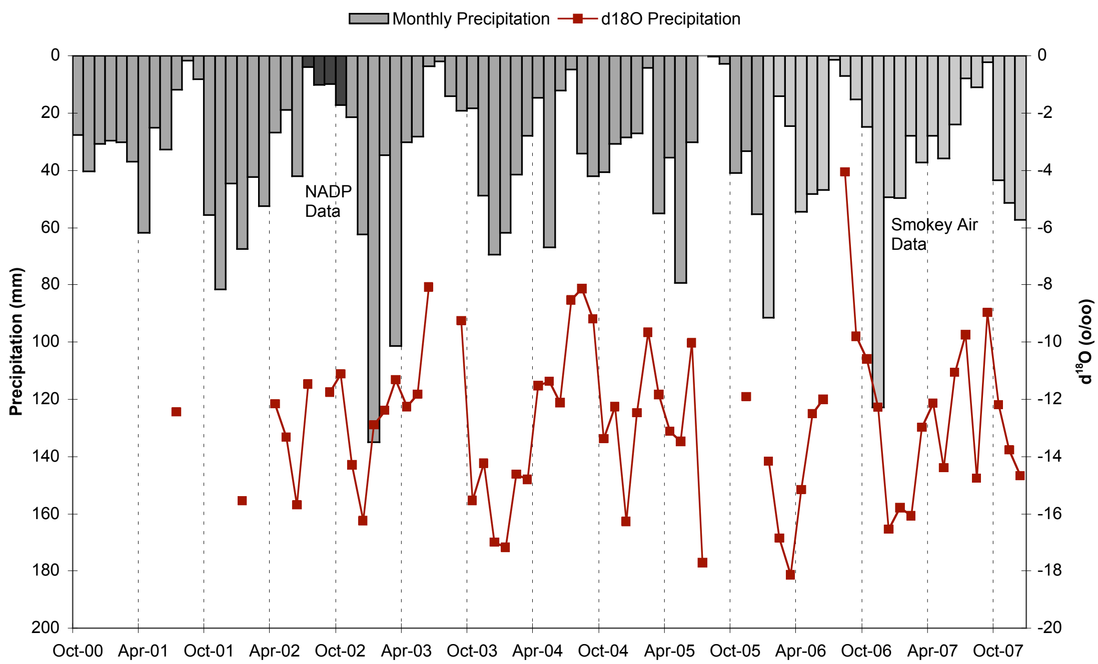
The solid line encompassing all contours outlines the boundary of the Cook Agronomy Farm (CAF). The approximate location of the tile drain is shown by the dark dashed line. The lighter dashed line outlines the boundary of the tile drainage area (12 ha); double parallel lines illustrate the boundaries of crop rotation areas (From Keller et al., 2008).

Figure 3: Hydrographs of TD-12, MFC-660, MFC-4700 and Cumulative Precipitation



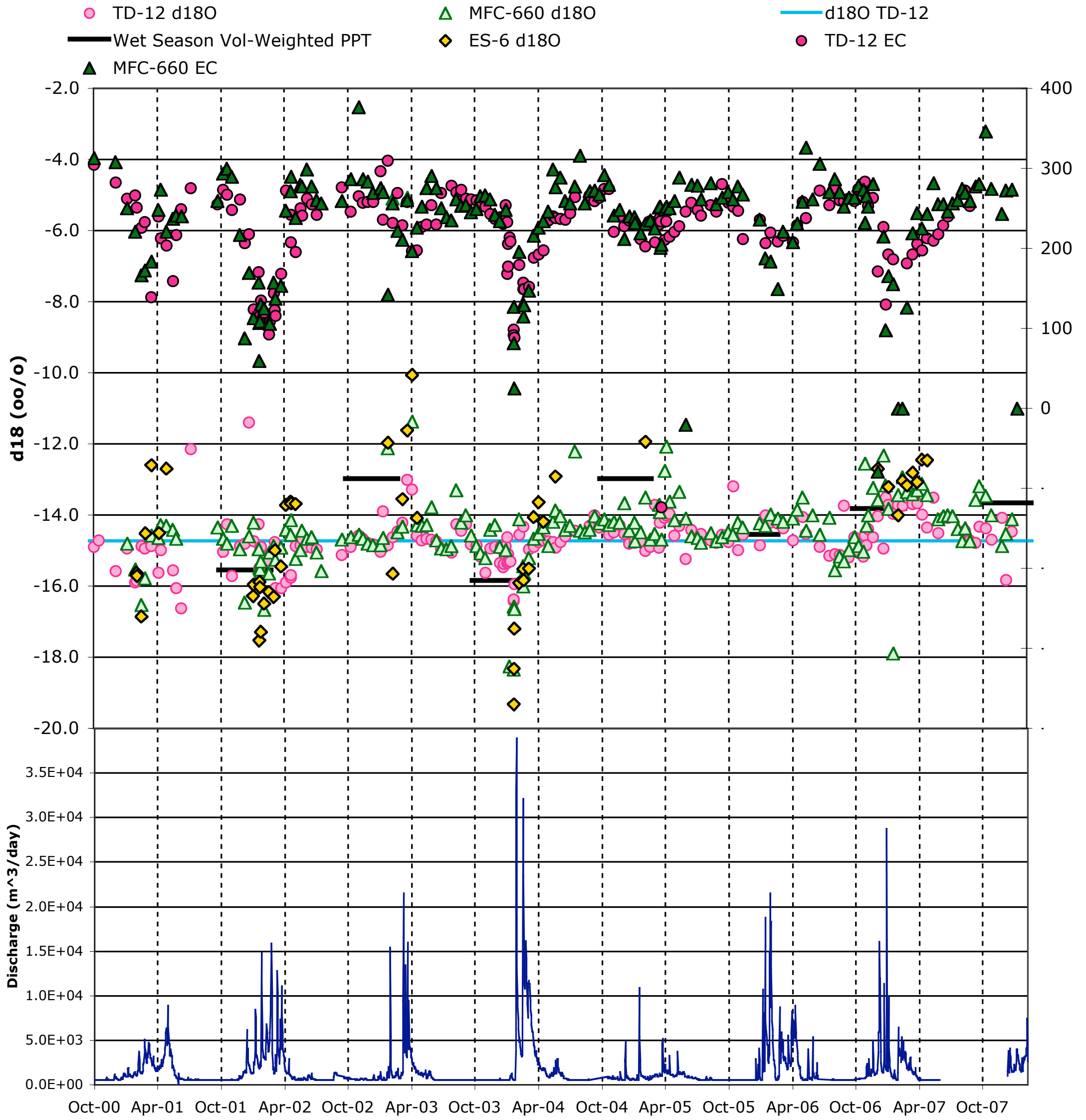
Hydrographs of discharge fluxes at 3 scales in MFC (TD-12, MFC-660, and MFC-4700) in mm/day. Relative hydrologic response to precipitation inputs is similar at these different scales. Cumulative precipitation is initially higher (steeper slope) soon after October 1 and plateaus in summer.

Figure 4: Monthly Precipitation Amounts and Monthly Volume-Weighted $\delta^{18}O$



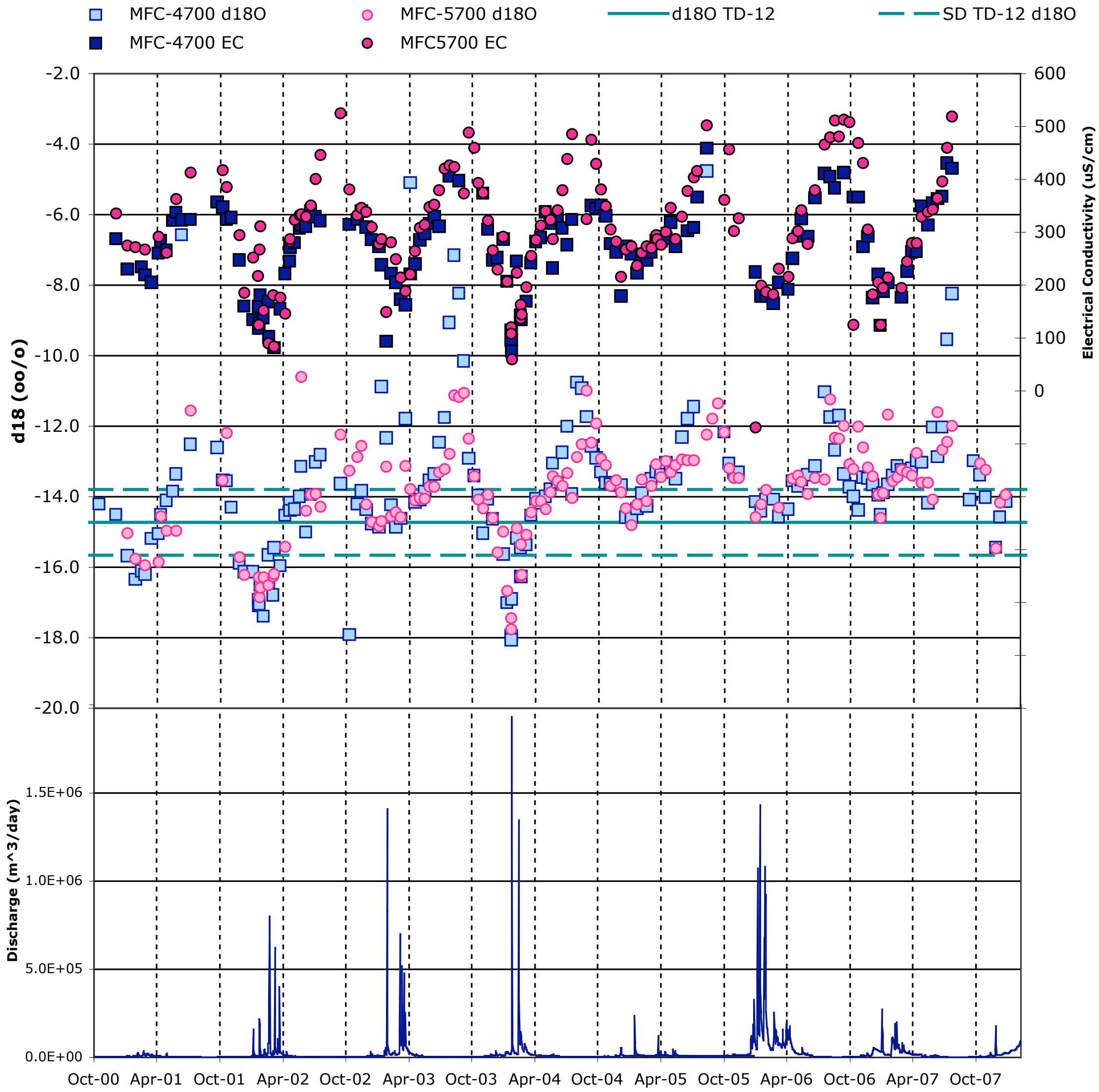
Precipitation was monitored on the CAF from 2000-2006. Precipitation amounts from July to October 2002 are from the National Atmospheric Deposition Program (NADP) and precipitation amounts from January 2006 to the end of the study are from the WSU College of Engineering Smokey Air Data (SAD) collection program. Precipitation $\delta^{18}O$ is monthly volume weighted (Appendix D). Generally, $\delta^{18}O$ is highly variable, but monthly volume weighted precipitation $\delta^{18}O$ tends to be depleted in winter months and enriched during summer.

Figure 5: Seasonal Stability of δ18O and Seasonal Variability of EC in TD-12 and MFC-660 Discharge



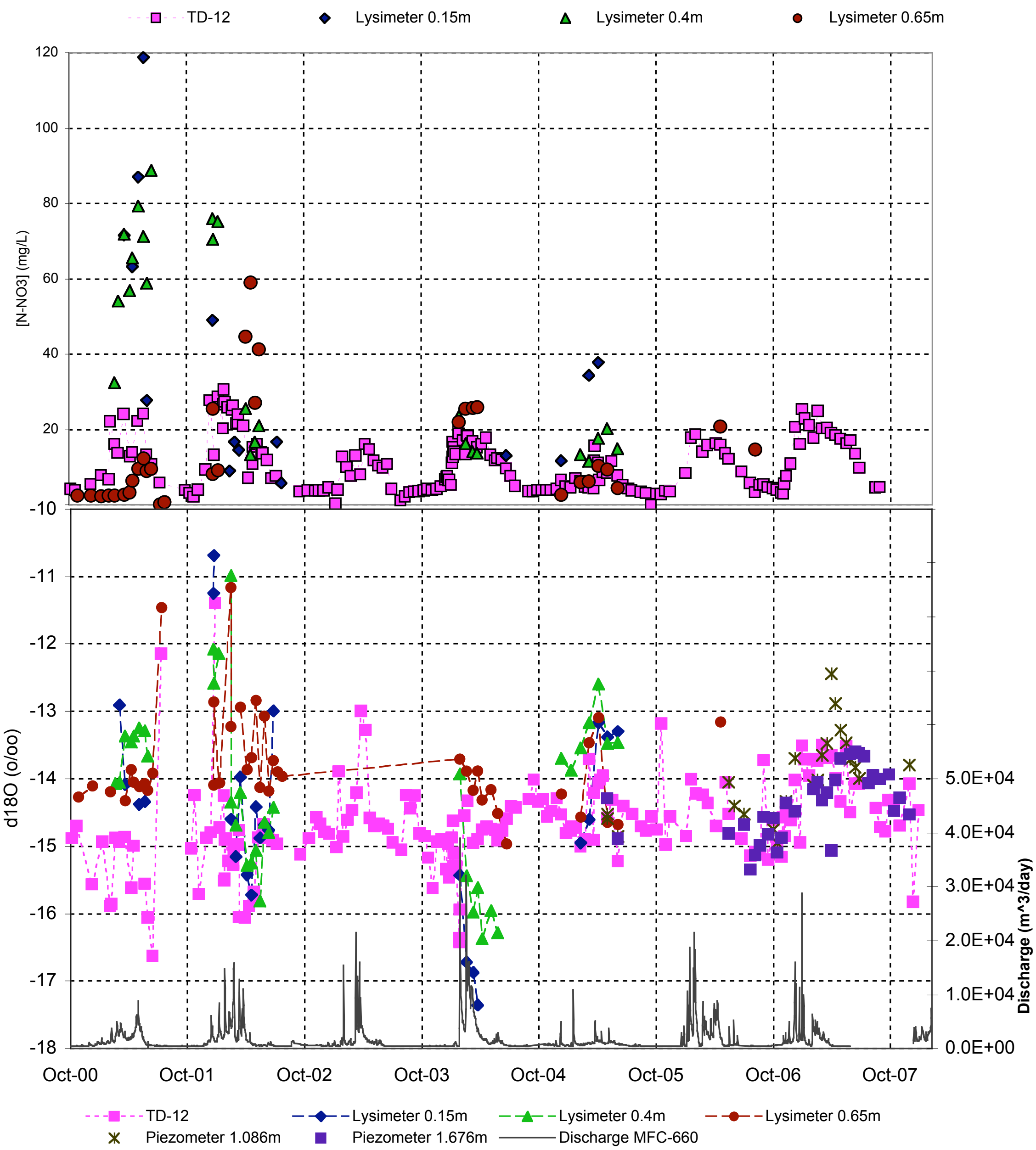
Soil water seepage and tile drainage to ditches from MFC-660 and TD-12 show dampened response from precipitation inputs with respect to $\delta^{18}O$. TD-12 and MFC-660 EC were much more seasonal with values of 250 μS/cm in summer (representing long deep subsurface flowpaths) and 200 μS/cm in winter (representing a composite of short shallow flowpaths superposed onto long deep flowpaths). Discharge is for MFC-660 (m^3/day). Average $\delta^{18}O$ of the TD-12 at –14.7‰ (Light blue line, SD=0.92). Sharp depletion and enrichment events for MFC-660 are response to high precipitation events as reflected by ES-6 $\delta^{18}O$ overland flow and seasonal volume-weighted precipitation $\delta^{18}O$. However, TD-12 $\delta^{18}O$ is not affected as severely as MFC-660 by these events.

Figure 6: Seasonal Variability of $\delta^{18}O$ and EC in MFC-4700 and MFC-5700 Discharge



MFC-4700 and MFC-5700 streamflow show seasonal sinusoidal trends in both $\delta^{18}O$ and EC. Discharge is for MFC-4700. Enriched $\delta^{18}O$ and EC are concurrent with increased evaporation, higher temperatures, and low flow. Decreased EC and depleted $\delta^{18}O$ are contemporaneous with decreased evaporation in winter and coincide with $\delta^{18}O$ values for MFC-660 and TD-12 of ~–14.7‰ (Light blue band, SD=0.92).

Figure 7a: N-NO_3^- Concentration and $\delta^{18}O$ in Lysimeters and TD-12 from 2000-2008



TD-12 [N-NO_3^-] and $\delta^{18}O$ with lysimeter [N-NO_3^-] and $\delta^{18}O$ at depths of 0.15m, 0.4m, and 0.65m. [N-NO_3^-] in lysimeters and TD-12 discharge increased in winter months, while $\delta^{18}O$ remained stable except during events.

Figure 7b: $\delta^{18}O$ in Lysimeters and TD-12 from 2001-2002

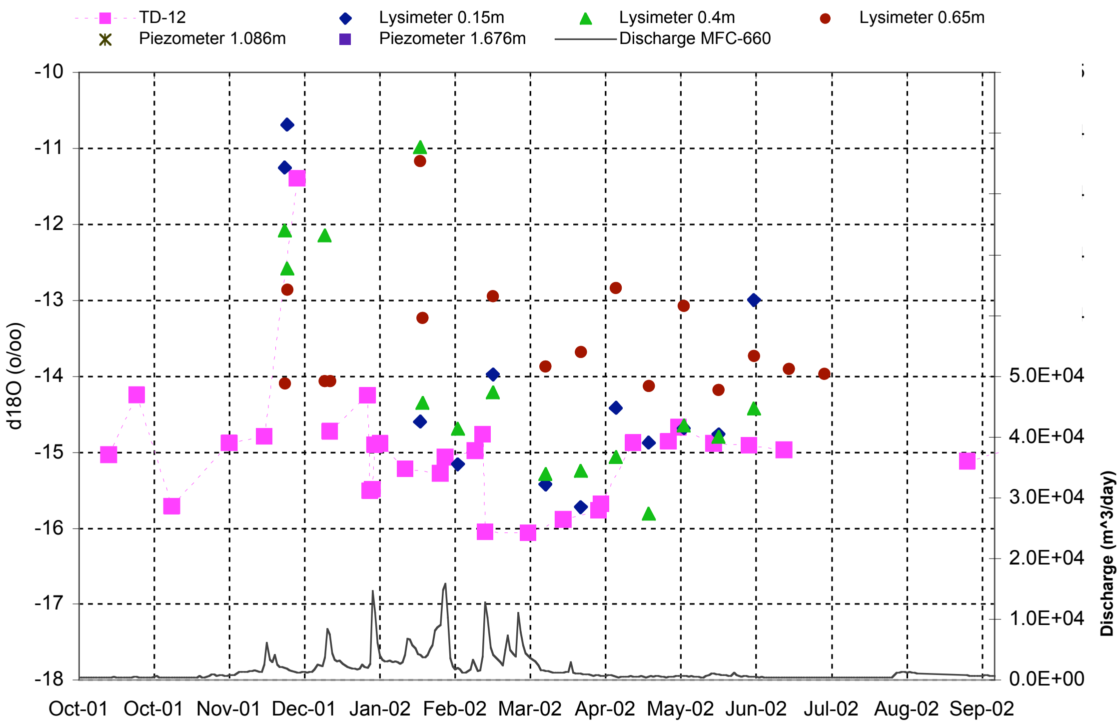


Figure 7c: δ[18]O in Lysimeters and TD-12 from 2003-2005

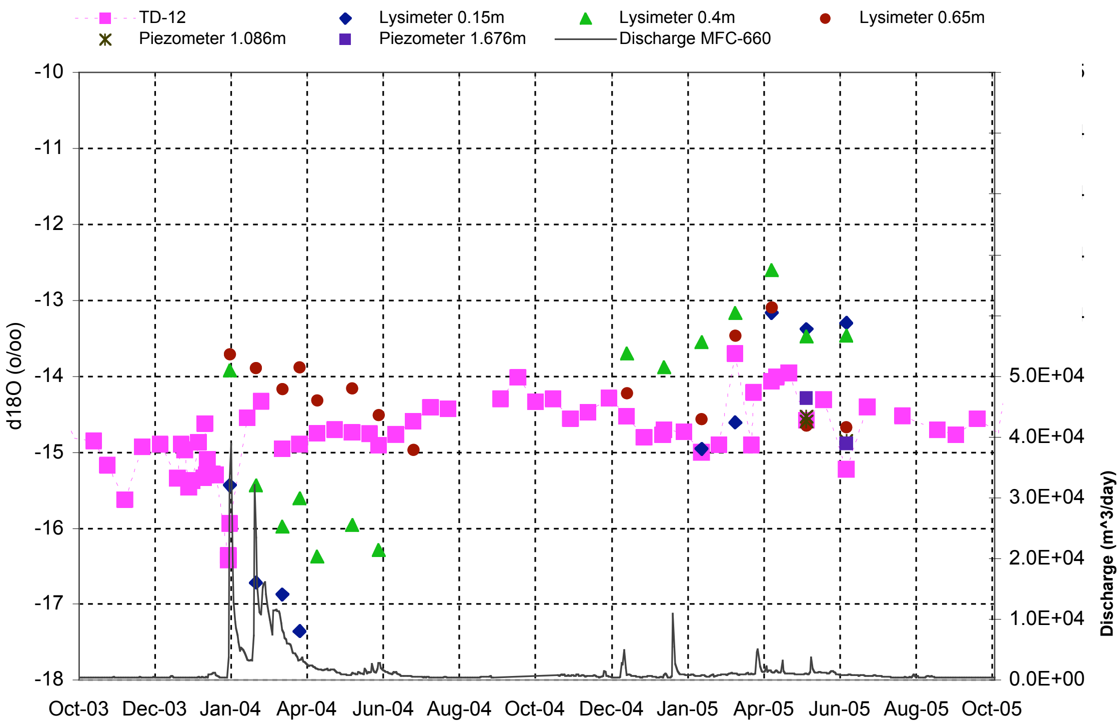
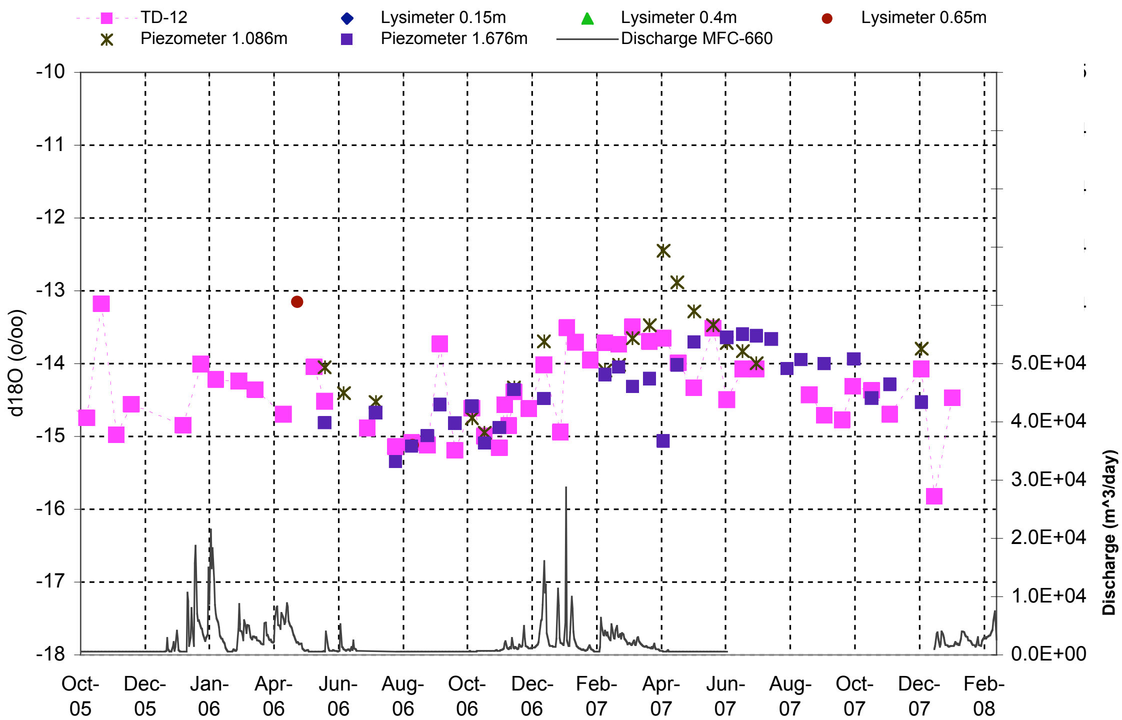
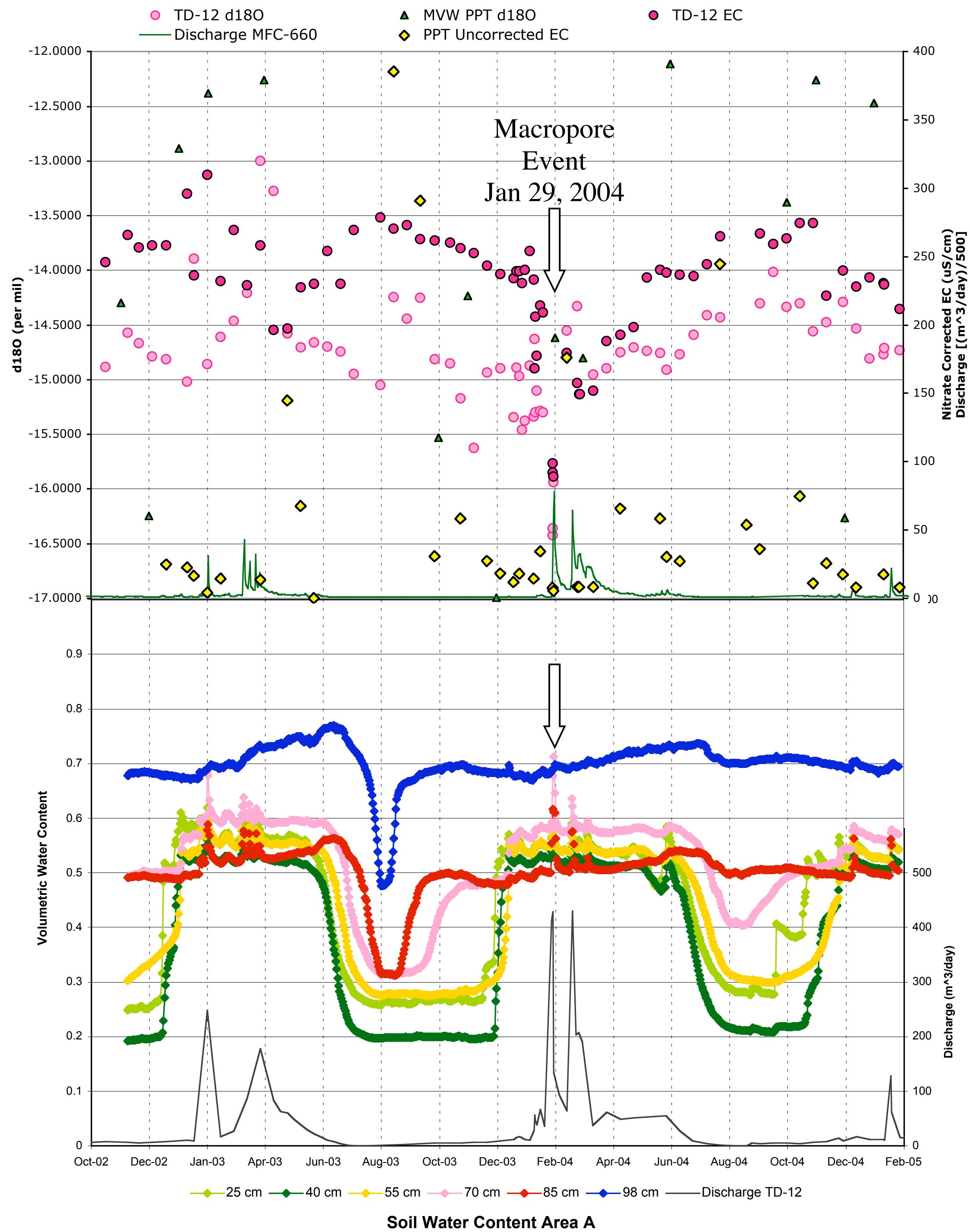


Figure 7d: δ18O in Lysimeters, Piezometers, and TD-12 from 2005-2008



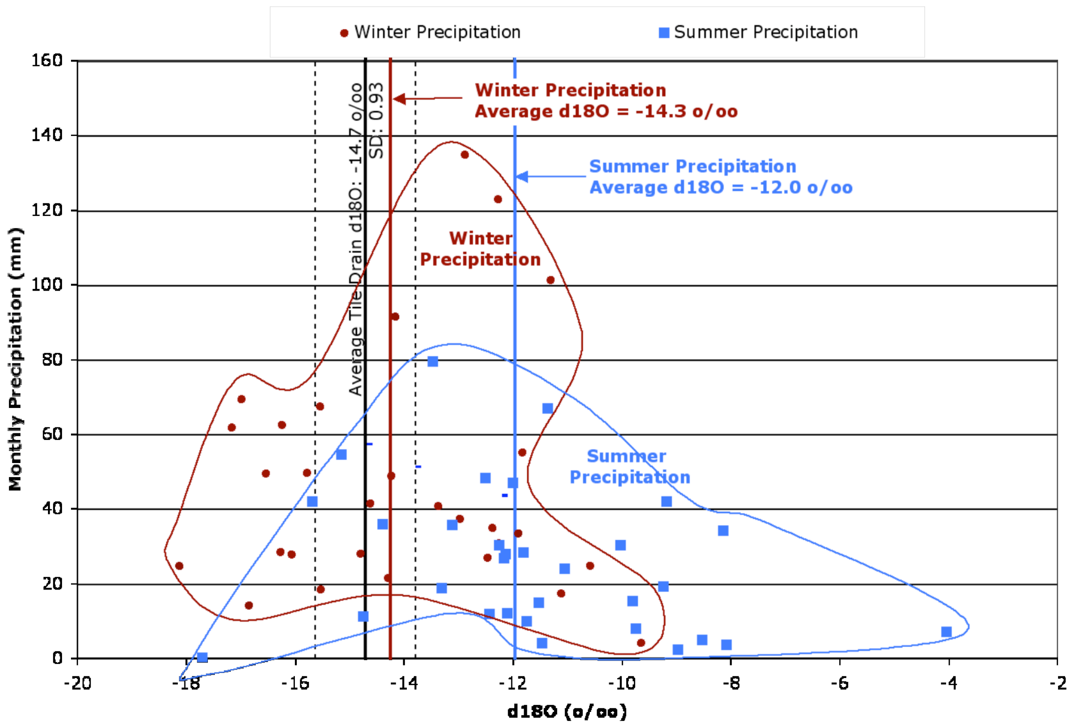
Lysimeter and piezometer δ18O collected 10m north of TD-12 outlet (Figures 7b, c, d). Lysimeter δ18O values are averaged for nested lysimeters at depths of 0.15m, 0.4m, and 0.65m. As a result of flooding and damage to lysimeter nest, adjacent piezometers were sampled from June 2006 to January 2008 (d) (Appendix M), though no shallow soil water data is represented after August 2005. TD-12 δ18O is dependent on δ18O in shallow lysmeters during high flow. During low flow, TD-12 δ18O closely tracks δ18O for deeper lysimeters (b, c). TD-12 δ18O closely tracks piezometer δ18O (d).

Figure 7e: Preferential Flow Event in January 29, 2004



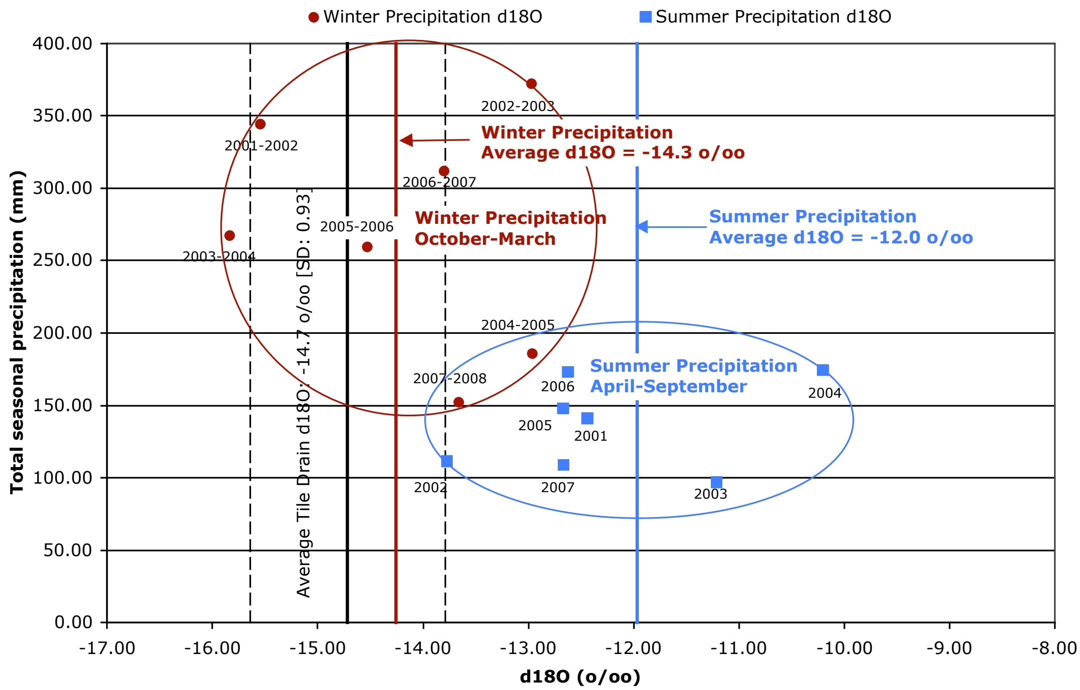
High discharges at both MFC-660, TD-12 corresponds to high soil water content (SWC) at shallow to middle depths, including 85cm. Isotopic composition of TD-12 discharge is very depleted (-16.4‰) and close to precipitation $\delta^{18}O$ at this time (-17‰). EC is also very low (~100µS/cm) and is consistent with water undertaking short and shallow flow pathways with reduced deep soil water input (compared to TD-12 discharge the rest of the year).

Figure 8a: Summer Versus Winter Monthly Volume-Weighted $\delta^{18}O$ of Precipitation and Resulting Average TD-12 $\delta^{18}O$



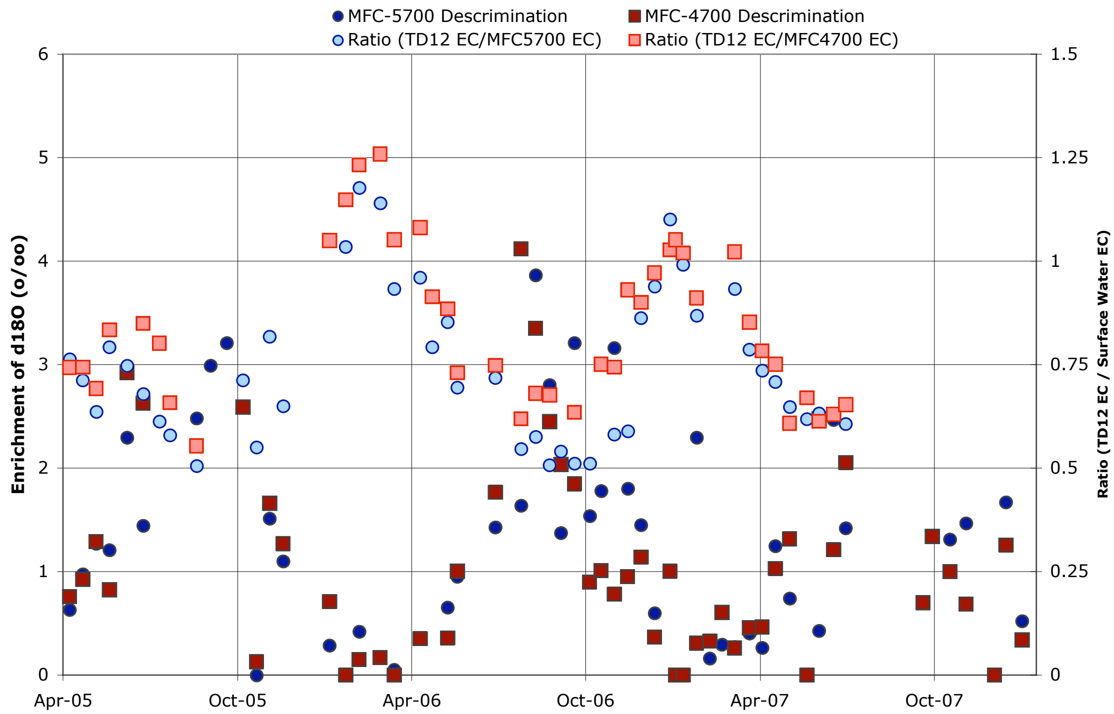
Monthly volume weighted precipitation $\delta^{18}O$ and contribution to the isotopic signature of tile drainage. Variation in precipitation $\delta^{18}O$ during summer months is nearly indistinguishable from winter precipitation; TD-12 $\delta^{18}O$ cannot be partitioned based on monthly volume weighted precipitation $\delta^{18}O$.

Figure 8b: Summer Versus Winter Seasonally Volume-Weighted $\delta^{18}O$ of Precipitation and Resulting Average TD-12 $\delta^{18}O$



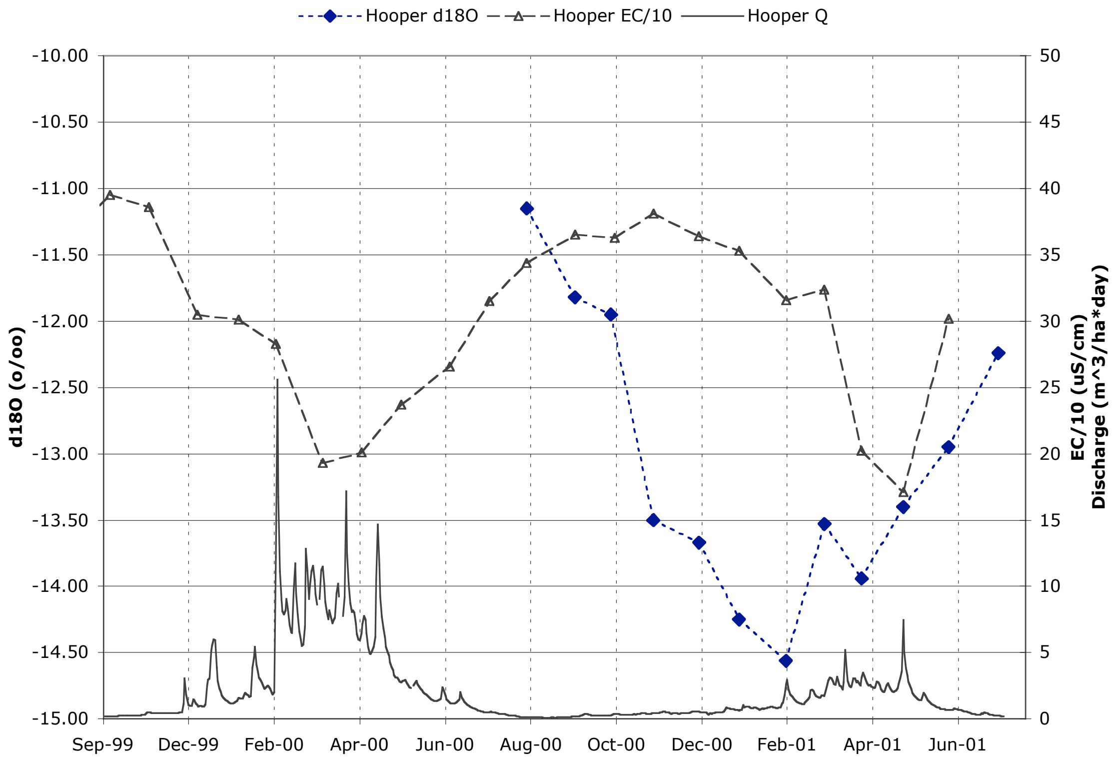
Seasonally weighted precipitation $\delta^{18}O$ (summer: April – September; winter: October - March) showed more seasonality with regards to precipitation $\delta^{18}O$ (summer being enriched, winter being depleted). Winter precipitation was the main contributor to TD-12 $\delta^{18}O$ as average winter precipitation $\delta^{18}O$ was within one standard deviation of average TD-12 $\delta^{18}O$. Summer precipitation $\delta^{18}O$ contribution to TD-12 was minimal.

Figure 9: δ^{18}O Discrimination Due to Evaporation at MFC-4700 and MFC-5700



Enrichment of stream waters due to isotopic discrimination during evaporation (called evaporative flux, δE, by Craig and Gordon, 1967) was calculated by:
$-1(\delta^{18}O_{TD-12}-\delta^{18}O_{Surface\ Water})$
Ratio of $EC_{TD-12}/EC_{Surface\ Water}$ estimates the volume independent evaporation from TD-12 drainage to ditches up to the sampling points at MFC-4700 and MFC-5700. When observed isotopic discrimination is minimal (in winter) the ratio of $EC_{TD-12}/EC_{Surface\ Water}$ is near 1, which suggests that TD-12, MFC-4700, and MFC-5700 waters are the same. Conversely, when isotopic discrimination is the greatest (in summer), the ratio of $EC_{TD-12}/EC_{Surface\ Water}$ is near 0.5, suggesting that the increase in observed $EC_{Surface\ Water}$ is due to evaporation; not a shallow basalt aquifer source.

Figure 10: δ18O, EC and Hydrograph for Palouse River Gauging Station at Hooper, WA



$\delta^{18}O$ and EC (USGS data) dynamics observed in waters collected at the Palouse River gauging station at Hooper, WA were similar to $\delta^{18}O$ and EC dynamics observed at both MFC-4700 and MFC-5700 in the MFC watershed. For the Palouse River watershed, "new" and "old" winter precipitation mixed at depth and was discharged to stream waters via soil water seepage and tile drainage (as indicated by a minimum $\delta^{18}O$ value of –14.5‰), decreased EC in winter indicates a short shallow subsurface pathway contribution to streamflow generation superposed onto year round stream water outflow. Similar to summertime $\delta^{18}O$ and EC stream-water evolution in the MFC watershed, enrichment of $\delta^{18}O$ and increased EC during the summer suggests that evaporation is the primary driver for seasonal $\delta^{18}O$ and EC variability in the Palouse River. The observed similarities between MFC and Palouse River dynamics also suggest that the MFC watershed is a typical catchment in the Palouse River watershed.

APPENDIX A Water Chemistry Data for Missouri Flat Creek Watershed 2000-2008

All water chemistry data is located in abbreviated form and in its entirety on accompanying DVD. Samples include: Field Blanks, precipitation, tile drain samples, and surface water samples. Sample designations in data entry spreadsheet correspond according to the following list:

ES-6	Rill @ C
ES-106	Trib @ B
TD-12	Tile @ A
MFC-660	Gray Rd.
MFC-4700	McGreevy Rd.
MFC-5700	Kitzmiller Rd (Kitz)
Rain A	Rain @ A
Rain C	Rain @ C
FB (Field Blank)	FB Plastic

All water chemistry data from 10/2000 to 6/2005 were reported previously by Wannamaker (2005).

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
Field Blank	10/6/00	-	-	-	-	-	-	-
Field Blank	10/19/00	-	-	-	-	-	-	-
Field Blank	12/7/00	-	-	-	-	-	-	-
Field Blank	1/9/01	-	-	-	-	-	-	-
Field Blank	2/3/01	-	-	-	-	-	-	-
Field Blank	2/6/01	-	-	-	-	-	-	-
Field Blank	2/19/01	-	-	-	-	-	-	-
Field Blank	3/3/01	-	-	-	-	-	-	-
Field Blank	3/20/01	-	-	-	-	-	-	-
Field Blank	4/9/01	-	-	-	-	-	-	-
Field Blank	4/16/01	-	-	-	-	-	-	-
Field Blank	5/2/01	-	-	-	-	-	-	-
Field Blank	5/21/01	-	-	-	-	-	-	-
Field Blank	5/30/01	-	-	-	-	-	-	-
Field Blank	6/14/01	-	-	-	-	-	-	-
Field Blank	7/11/01	-	-	-	-	-	-	-
Field Blank	9/27/01	-	-	-	-	-	-	-
Field Blank	10/13/01	-	-	-	-	-	-	-
Field Blank	10/24/01	-	-	-	-	-	-	-
Field Blank	11/7/01	-	-	-	-	-	-	-
Field Blank	11/30/01	-	-	-	-	-	-	-
Field Blank	12/14/01	-	-	-	-	-	-	-
Field Blank	12/27/01	-	-	-	-	-	-	-
Field Blank	1/7/02	-	-	-	-	-	-	-
Field Blank	1/9/02	-	-	-	-	-	-	-
Field Blank	1/24/02	-	-	-	-	-	-	-
Field Blank	1/25/02	-	-	-	-	-	-	-
Field Blank	1/26/02	-	-	-	-	-	-	-
Field Blank	1/27/02	-	-	-	-	-	-	-
Field Blank	1/29/02	-	-	-	-	-	-	-
Field Blank	2/8/02	-	-	-	-	-	-	-
Field Blank	2/22/02	-	-	-	-	-	-	-
Field Blank	2/24/02	-	-	-	-	-	-	-
Field Blank	3/8/02	-	-	-	-	-	-	-
Field Blank	3/11/02	-	-	-	-	-	-	-
Field Blank	3/12/02	-	-	-	-	-	-	-

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
Field Blank	3/29/02	-	-	-	-	-	-	-
Field Blank	4/12/02	-	-	-	-	-	-	-
Field Blank	4/26/02	-	-	-	-	-	-	-
Field Blank	4/27/02	-	-	-	-	-	-	-
Field Blank	5/10/02	-	-	-	-	-	-	-
Field Blank	5/24/02	-	-	-	-	-	-	-
Field Blank	5/28/02	-	-	-	-	-	-	-
Field Blank	6/11/02	-	-	-	-	-	-	-
Field Blank	6/25/02	-	-	-	-	-	-	-
Field Blank	7/9/02	-	-	-	-	-	-	-
Field Blank	7/23/02	-	-	-	-	-	-	-
Field Blank	9/20/02	-	-	-	-	-	-	-
Field Blank	10/16/02	-	-	-	-	-	-	-
Field Blank	11/8/02	-	-	-	-	-	-	-
Field Blank	11/20/02	-	-	-	-	-	-	-
Field Blank	12/4/02	-	-	-	-	-	-	-
Field Blank	12/19/02	-	0.40	-	-	-	-	0.28
Field Blank	1/10/03	-	0.04	-	-	-	-	-
Field Blank	1/17/03	-	0.27	-	-	-	-	0.59
Field Blank	1/31/03	-	0.33	-	-	-	-	0.50
Field Blank	2/14/03	-	0.40	-	-	-	-	0.22
Field Blank	2/28/03	-	0.36	-	-	-	-	0.16
Field Blank	3/14/03	-	0.28	-	-	-	-	1.86
Field Blank	3/28/03	-	0.70	-	-	-	-	0.36
Field Blank	4/11/03	-	0.82	-	-	-	-	0.15
Field Blank	4/25/03	-	0.16	-	-	-	-	0.23
Field Blank	5/9/03	-	0.26	-	-	-	-	0.27
Field Blank	5/23/03	-	0.13	-	-	-	-	0.12
Field Blank	6/6/03	-	0.38	-	-	-	-	0.13
Field Blank	6/20/03	-	0.26	-	-	-	-	0.24
Field Blank	7/4/03	-	0.15	-	-	-	-	0.29
Field Blank	7/18/03	-	0.24	-	-	-	-	0.22
Field Blank	8/1/03	-	0.30	-	-	-	-	0.13
Field Blank	8/15/03	-	0.28	-	-	-	-	0.23
Field Blank	8/29/03	-	0.22	-	-	-	-	0.20
Field Blank	9/12/03	-	0.35	-	-	-	-	0.22

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
Field Blank	9/27/03	-	0.37	-	-	-	-	0.39
Field Blank	10/13/03	-	0.79	-	-	-	-	0.50
Field Blank	10/24/03	-	0.40	-	-	-	-	0.14
Field Blank	11/7/03	-	0.85	-	-	-	-	0.33
Field Blank	11/21/03	-	0.20	-	-	-	-	0.32
Field Blank	12/5/03	-	0.40	-	-	-	-	0.21
Field Blank	12/19/03	-	0.26	-	-	-	-	0.26
Field Blank	12/22/03	-	0.26	-	-	-	-	0.27
Field Blank	12/25/03	-	0.20	-	-	-	-	0.69
Field Blank	12/28/03	-	0.20	-	-	-	-	0.23
Field Blank	12/31/03	-	0.33	-	-	-	-	0.26
Field Blank	1/5/04	-	0.60	-	-	-	-	0.32
Field Blank	1/9/04	-	0.46	-	-	-	-	0.26
Field Blank	1/10/04	-	0.40	-	-	-	-	0.34
Field Blank	1/11/04	-	0.46	-	-	-	-	1.21
Field Blank	1/12/04	-	0.46	-	-	-	-	0.31
Field Blank	1/16/04	-	0.33	-	-	-	-	0.63
Field Blank	1/19/04	-	0.40	-	-	-	-	0.27
Field Blank	1/29/04	-	0.40	-	-	-	-	0.27
Field Blank	1/29/04	-	0.53	-	-	-	-	0.30
Field Blank	1/30/04	-	0.73	-	-	-	-	0.27
Field Blank	2/13/04	-	0.26	-	-	-	-	0.29
Field Blank	2/19/04	-	-	-	-	-	-	-
Field Blank	2/24/04	-	0.31	-	-	-	-	0.26
Field Blank	2/26/04	-	0.14	-	-	-	-	-
Field Blank	2/27/04	-	0.54	-	-	-	-	0.21
Field Blank	3/11/04	-	-	-	-	-	-	-
Field Blank	3/12/04	-	0.28	-	-	-	-	0.40
Field Blank	3/26/04	-	0.20	-	-	-	-	0.00
Field Blank	4/9/04	-	0.52	-	-	-	-	0.38
Field Blank	4/23/04	-	0.39	-	-	-	-	0.32
Field Blank	5/7/04	-	0.47	-	-	-	-	0.26
Field Blank	5/21/04	-	0.30	-	-	-	-	0.65
Field Blank	5/28/04	-	1.48	-	-	-	-	0.39
Field Blank	6/11/04	-	0.33	-	-	-	-	0.43
Field Blank	6/25/04	-	0.45	-	-	-	-	0.24

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
Field Blank	7/9/04	-	0.51	-	-	-	-	0.54
Field Blank	7/23/04	-	0.34	-	-	-	-	0.39
Field Blank	8/6/04	-	0.70	-	-	-	-	0.71
Field Blank	8/20/04	-	0.43	-	-	-	-	0.51
Field Blank	9/3/04	-	0.95	-	-	-	-	0.31
Field Blank	9/17/04	0.02	0.54	0.01	0.53	-	-	0.76
Field Blank	10/1/04	0.01	0.45	-0.07	0.52	-	-	0.36
Field Blank	10/15/04	-	0.79	-	-	-	-	0.24
Field Blank	10/29/04	-	0.38	-	-	-	-	0.71
Field Blank	11/12/04	0.02	0.44	0.01	0.43	-	-	0.61
Field Blank	11/29/04	0.02	0.61	0.01	0.60	-	-	0.33
Field Blank	12/13/04	0.05	0.33	0.24	0.08	-	-	0.37
Field Blank	12/27/04	0.02	0.38	0.01	0.38	-	-	0.37
Field Blank	1/11/05	-	0.27	-	-	-	-	0.18
Field Blank	1/12/05	-	0.27	-	-	-	-	0.35
Field Blank	1/28/05	-	0.35	-	-	-	-	0.30
Field Blank	2/11/05	-	0.80	-	-	-	-	0.70
Field Blank	2/25/05	-	0.10	-	-	-	-	0.28
Field Blank	3/10/05	-	0.47	-	-	-	-	0.60
Field Blank	3/23/05	0.01	0.30	-0.07	0.37	-	-	0.46
Field Blank	3/25/05	-	0.30	-	-	-	-	0.35
Field Blank	3/27/05	-	0.38	-	-	-	-	0.50
Field Blank	3/29/05	-	0.24	-	-	-	-	0.51
Field Blank	4/8/05	-	0.27	-	-	-	-	0.48
Field Blank	4/12/05	0.00	0.27	-0.14	0.41	-	-	0.73
Field Blank	4/22/05	0.03	0.30	0.08	0.22	-	-	0.39
Field Blank	5/6/05	-	0.38	-	-	-	-	0.34
Field Blank	5/20/05	-	0.47	-	-	-	-	0.36
Field Blank	6/7/05	-	0.49	-	-	-	-	0.29
Field Blank	6/24/05	-	0.86	-	-	-	-	0.56
Field Blank	7/11/05	0.15	0.79	1.01	-0.22	-	-	1.26
Field Blank	7/22/05	-	1.33	-	-	-	-	0.44
Field Blank	8/19/05	-	0.53	-	-	-	-	1.03
Field Blank	9/3/05	-	1.00	-	-	-	-	0.63
Field Blank	9/20/05	-	0.51	-	-	-	-	0.25
Field Blank	10/7/05	-	2.34	-	-	-	-	0.56

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
Field Blank	10/21/05	-	0.47	-	-	-	-	0.60
Field Blank	11/4/05	-	0.46	-	-	-	-	0.77
Field Blank	11/18/05	-	0.53	-	-	-	-	0.50
Field Blank	1/6/06	-	0.55	-	-	-	-	0.35
Field Blank	1/23/06	-	-	-	-	-	-	-
Field Blank	2/6/06	-	0.20	-	-	-	-	-
Field Blank	2/28/06	-	0.63	-	-	-	-	0.81
Field Blank	3/15/06	-	0.27	-	-	-	-	0.53
Field Blank	4/11/06	-	1.67	-	-	-	-	0.46
Field Blank	4/24/06	-	0.74	-	-	-	-	1.62
Field Blank	5/10/06	0.01	1.84	-0.10	1.94	5.73	-	0.85
Field Blank	5/20/06	0.01	0.86	-0.06	0.93	5.83	-	0.55
Field Blank	6/7/06	0.05	0.98	0.22	0.76	5.84	-	8.00
Field Blank	6/29/06	0.16	0.47	1.12	-0.65	5.81	-	0.24
Field Blank	7/7/06	-	-	-0.15	-	-	-	-
Field Blank	7/26/06	-	1.05	-	-	5.75	-	0.49
Field Blank	8/10/06	0.01	0.71	-0.10	0.80	5.58	-	0.60
Field Blank	8/25/06	0.05	0.62	0.26	0.36	6.37	-	0.29
Field Blank	9/6/06	-	0.58	-	-	5.50	-	0.26
Field Blank	9/20/06	-	0.74	-	-	7.80	-	0.31
Field Blank	10/6/06	-	0.86	-	-	7.24	-	0.82
Field Blank	10/18/06	0.03	1.72	0.09	1.64	7.57	-	0.86
Field Blank	11/1/06	0.04	1.67	0.16	1.51	8.50	-	0.34
Field Blank	11/6/06	0.03	1.78	0.09	1.70	8.92	-	0.80
Field Blank	11/10/06	0.04	2.73	0.16	2.56	8.51	-	0.54
Field Blank	11/15/06	0.03	10.86	0.09	10.78	8.02	-	0.58
Field Blank	11/29/06	0.02	0.55	0.01	0.54	7.30	-	0.53
Field Blank	12/13/06	0.03	0.80	0.09	0.71	9.15	-	0.42
Field Blank	12/29/06	0.08	0.94	0.48	0.46	7.94	-	0.14
Field Blank	1/4/07	0.07	2.20	0.40	1.80	9.47	-	0.31
Field Blank	1/12/07	0.08	2.40	0.48	1.92	7.12	-	0.14
Field Blank	1/26/07	0.09	2.71	0.56	2.15	8.90	-	0.55
Field Blank	2/9/07	0.05	0.85	0.24	0.60	8.36	-	0.50
Field Blank	2/22/07	0.02	-	0.01	-	7.78	-	0.00
Field Blank	3/7/07	0.03	0.84	0.09	0.75	8.69	-	0.61
Field Blank	3/23/07	0.02	0.81	0.01	0.80	9.40	-	0.57

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
Field Blank	4/5/07	0.05	0.58	0.24	0.33	7.74	-	0.53
Field Blank	4/19/07	0.05	0.97	0.24	0.73	8.15	-	0.52
Field Blank	5/4/07	0.02	1.56	0.01	1.56	7.75	-	0.51
Field Blank	5/22/07	0.02	6.13	0.01	6.12	9.39	-	0.54
Field Blank	6/4/07	0.02	0.75	0.01	0.74	8.60	-	0.20
Field Blank	6/19/07	0.06	0.98	0.32	0.66	9.22	-	21.00
Field Blank	7/2/07	-	0.59	-	-	-	-	17.10
Field Blank	7/16/07	0.04	1.03	0.16	0.87	9.10	-	21.00
Field Blank	7/31/07	0.04	0.55	0.16	0.38	8.95	-	20.60
Field Blank	8/13/07	0.06	0.31	0.32	-0.02	8.62	-	23.30
Field Blank	8/21/07	0.07	0.43	0.40	0.02	-	-	0.00
Field Blank	9/4/07	0.07	0.74	0.40	0.33	7.99	-	19.30
Field Blank	9/21/07	-	0.83	-	-	6.77	-	17.20
Field Blank	10/1/07	-	1.08	-	-	8.50	-	18.80
Field Blank	10/19/07	-	0.44	-	-	7.99	-	0.26
Field Blank	11/5/07	-	0.52	-	-	7.81	-	0.30
Field Blank	12/5/07	-	0.90	-	-	8.64	-	0.28
Field Blank	12/17/07	-	1.54	-	-	-	-	0.38
Field Blank	1/3/08	-	0.87	-	-	8.43	-	0.50
Field Blank	1/18/08	-	-	-	-	-	-	0.00

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
ES-6	10/5/00	-	-	-	-	-	-	-
ES-6	10/19/00	-	-	-	-	-	-	-
ES-6	12/8/00	-	-	-	-	-	-	-
ES-6	1/9/01	-	-	-	-	-	-	-
ES-6	2/5/01	2.94	414.09	23.15	390.93	-	-	68.90
ES-6	2/6/01	41.88	446.49	331.86	114.63	-	-	25.00
ES-6	2/19/01	43.93	427.80	348.11	79.69	-	-	49.80
ES-6	3/3/01	33.80	394.15	267.80	126.35	-	-	178.00
ES-6	3/20/01	32.70	394.15	259.08	135.07	-	-	18.20
ES-6	4/12/01	30.87	431.53	244.57	186.96	-	-	10.50
ES-6	4/16/01	-	-	-	-	-	-	-
ES-6	5/2/01	38.14	382.94	302.21	80.73	-	-	8.19
ES-6	5/21/01	-	-	-	-	-	-	-
ES-6	5/30/01	-	-	-	-	-	-	-
ES-6	6/14/01	-	-	-	-	-	-	-
ES-6	7/11/01	-	-	-	-	-	-	-
ES-6	9/27/01	-	-	-	-	-	-	-
ES-6	10/13/01	-	-	-	-	-	-	-
ES-6	10/24/01	-	-	-	-	-	-	-
ES-6	11/7/01	-	-	-	-	-	-	-
ES-6	11/30/01	-	-	-	-	-	-	-
ES-6	12/14/01	-	-	-	-	-	-	-
ES-6	12/27/01	-	-	-	-	-	-	-
ES-6	1/7/02	5.71	102.95	45.11	57.83	-	-	28.90
ES-6	1/9/02	10.13	162.27	80.15	82.12	-	6.10	0.07
ES-6	1/24/02	7.25	168.50	57.32	111.18	-	0.60	6.76
ES-6	1/25/02	5.36	79.32	42.34	36.98	-	5.20	123.00
ES-6	1/26/02	5.34	106.95	42.18	64.77	-	3.50	19.30
ES-6	1/27/02	6.34	129.13	50.11	79.02	-	2.00	11.50
ES-6	1/29/02	8.85	180.84	70.01	110.83	-	-0.40	7.06
ES-6	2/8/02	7.30	136.11	57.72	78.39	-	0.30	10.90
ES-6	2/22/02	7.20	132.74	56.93	75.82	-	6.00	15.30
ES-6	2/24/02	-	-	-	-	-	-	-
ES-6	3/8/02	7.72	177.85	61.05	116.80	-	0.20	13.70
ES-6	3/11/02	6.28	125.52	49.63	75.88	-	8.60	45.60

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
ES-6	3/12/02	-	-	-	-	-	-	-
ES-6	3/29/02	3.29	153.92	25.93	127.99	-	11.10	7.96
ES-6	4/12/02	1.01	204.51	7.85	196.66	-	11.30	21.20
ES-6	4/26/02	0.19	222.21	1.35	220.85	-	11.00	6.92
ES-6	4/27/02	0.23	216.47	1.67	214.80	-	12.60	27.50
ES-6	5/10/02	0.74	273.29	5.71	267.58	-	9.50	10.80
ES-6	5/24/02	-	-	-	-	-	-	-
ES-6	5/28/02	-	-	-	-	-	-	-
ES-6	6/11/02	-	-	-	-	-	-	-
ES-6	6/25/02	-	-	-	-	-	-	-
ES-6	7/9/02	-	-	-	-	-	-	-
ES-6	7/23/02	-	-	-	-	-	-	-
ES-6	9/20/02	-	-	-	-	-	-	-
ES-6	10/16/02	-	-	-	-	-	-	-
ES-6	11/8/02	-	-	-	-	-	-	-
ES-6	11/20/02	-	-	-	-	-	-	-
ES-6	12/4/02	-	-	-	-	-	-	-
ES-6	12/19/02	-	-	-	-	-	-	-
ES-6	1/10/03	-	-	-	-	-	-	-
ES-6	1/17/03	-	-	-	-	-	-	-
ES-6	1/31/03	7.96	247.13	62.95	184.17	-	-	211.00
ES-6	2/14/03	6.85	439.01	54.14	384.86	-	3.20	12.60
ES-6	2/28/03	-	-	-	-	-	-	-
ES-6	3/14/03	22.84	376.71	180.89	195.82	-	-	56.40
ES-6	3/28/03	10.37	432.78	82.02	350.76	-	9.00	8.80
ES-6	4/11/03	17.22	391.66	136.39	255.27	-	-	11.80
ES-6	4/25/03	13.27	316.90	105.01	211.89	-	6.00	21.50
ES-6	5/9/03	-	-	-	-	-	-	-
ES-6	5/23/03	-	-	-	-	-	-	-
ES-6	6/6/03	-	-	-	-	-	-	-
ES-6	6/20/03	-	-	-	-	-	-	-
ES-6	7/4/03	-	-	-	-	-	-	-
ES-6	7/18/03	-	-	-	-	-	-	-
ES-6	8/1/03	-	-	-	-	-	-	-
ES-6	8/15/03	-	-	-	-	-	-	-

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
ES-6	8/29/03	-	-	-	-	-	-	-
ES-6	9/12/03	-	-	-	-	-	-	-
ES-6	9/27/03	-	-	-	-	-	-	-
ES-6	10/13/03	-	-	-	-	-	-	-
ES-6	10/24/03	-	-	-	-	-	-	-
ES-6	11/7/03	-	-	-	-	-	-	-
ES-6	11/21/03	-	-	-	-	-	-	-
ES-6	12/5/03	-	-	-	-	-	-	-
ES-6	12/19/03	-	-	-	-	-	-	-
ES-6	12/22/03	-	-	-	-	-	-	-
ES-6	12/25/03	-	-	-	-	-	-	-
ES-6	12/28/03	-	-	-	-	-	-	-
ES-6	12/31/03	-	-	-	-	-	-	-
ES-6	1/5/04	-	-	-	-	-	-	-
ES-6	1/9/04	-	-	-	-	-	-	-
ES-6	1/10/04	-	-	-	-	-	-	-
ES-6	1/11/04	-	-	-	-	-	-	-
ES-6	1/12/04	-	-	-	-	-	-	-
ES-6	1/16/04	-	-	-	-	-	-	-
ES-6	1/19/04	-	-	-	-	-	-	-
ES-6	1/29/04	-	140.25	-	-	-	0.30	75.10
ES-6	1/29/04	-	147.78	-	-	-	0.30	101.00
ES-6	1/30/04	12.60	162.00	99.74	62.26	-	2.70	112.00
ES-6	2/13/04	11.35	-	-	-	-	-	-
ES-6	2/19/04	-	-	-	-	-	6.00	-
ES-6	2/24/04	13.05	190.43	103.30	87.13	-	4.50	226.00
ES-6	2/26/04	12.63	184.33	99.97	84.35	-	7.10	39.10
ES-6	2/27/04	-	183.08	-	-	-	7.20	36.60
ES-6	3/11/04	-	-	-	-	-	-	-
ES-6	3/12/04	4.98	144.70	39.33	105.38	-	10.90	33.90
ES-6	3/26/04	2.22	228.44	17.45	210.99	-	9.30	26.10
ES-6	4/9/04	2.03	274.54	15.94	258.60	-	9.60	44.10
ES-6	4/23/04	-	295.72	-	-	-	12.00	58.60
ES-6	5/7/04	-	-	-	-	-	-	-
ES-6	5/21/04	-	-	-	-	-	-	-

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
ES-6	5/28/04	0.49	314.41	3.73	310.68	-	13.00	105.00
ES-6	6/11/04	-	-	-	-	-	-	-
ES-6	6/25/04	-	-	-	-	-	-	-
ES-6	7/9/04	-	-	-	-	-	-	-
ES-6	7/23/04	-	-	-	-	-	-	-
ES-6	8/6/04	-	-	-	-	-	-	-
ES-6	8/20/04	-	-	-	-	-	-	-
ES-6	9/3/04	-	-	-	-	-	-	-
ES-6	9/17/04	-	-	-	-	-	-	-
ES-6	10/1/04	-	-	-	-	-	-	-
ES-6	10/15/04	-	-	-	-	-	-	-
ES-6	10/29/04	-	-	-	-	-	-	-
ES-6	11/12/04	-	-	-	-	-	-	-
ES-6	11/29/04	-	-	-	-	-	-	-
ES-6	12/13/04	-	-	-	-	-	-	-
ES-6	12/27/04	-	-	-	-	-	-	-
ES-6	1/11/05	-	-	-	-	-	-	-
ES-6	1/12/05	-	-	-	-	-	-	-
ES-6	1/28/05	-	-	-	-	-	-	-
ES-6	2/11/05	-	-	-	-	-	-	-
ES-6	2/25/05	-	-	-	-	-	-	-
ES-6	3/10/05	-	-	-	-	-	-	-
ES-6	3/23/05	-	-	-	-	-	-	-
ES-6	3/25/05	-	-	-	-	-	-	-
ES-6	3/27/05	31.68	347.22	250.99	96.23	-	-	118.00
ES-6	3/29/05	-	-	-	-	-	-	-
ES-6	4/8/05	-	-	-	-	-	-	-
ES-6	4/12/05	-	-	-	-	-	-	-
ES-6	4/22/05	-	-	-	-	-	-	-
ES-6	5/6/05	-	-	-	-	-	-	-
ES-6	5/20/05	-	-	-	-	-	-	-
ES-6	6/7/05	-	-	-	-	-	-	-
ES-6	6/24/05	-	-	-	-	-	-	-
ES-6	7/11/05	-	-	-	-	-	-	-
ES-6	7/22/05	-	-	-	-	-	-	-

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
ES-6	8/19/05	-	-	-	-	-	-	-
ES-6	9/3/05	-	-	-	-	-	-	-
ES-6	9/20/05	-	-	-	-	-	-	-
ES-6	10/7/05	-	-	-	-	-	-	-
ES-6	10/21/05	-	-	-	-	-	-	-
ES-6	11/4/05	-	-	-	-	-	-	-
ES-6	11/18/05	-	-	-	-	-	-	-
ES-6	1/6/06	-	-	-	-	-	-	-
ES-6	1/23/06	-	-	-	-	-	-	-
ES-6	2/6/06	-	-	-	-	-	-	-
ES-6	2/28/06	-	-	-	-	-	-	-
ES-6	3/15/06	-	-	-	-	-	-	-
ES-6	4/11/06	-	-	-	-	-	-	-
ES-6	4/24/06	-	-	-	-	-	-	-
ES-6	5/10/06	-	-	-	-	-	-	-
ES-6	5/20/06	-	-	-	-	-	-	-
ES-6	6/7/06	-	-	-	-	-	-	-
ES-6	6/29/06	-	-	-	-	-	-	-
ES-6	7/7/06	-	-	-	-	-	-	-
ES-6	7/26/06	-	-	-	-	-	-	-
ES-6	8/10/06	-	-	-	-	-	-	-
ES-6	8/25/06	-	-	-	-	-	-	-
ES-6	9/6/06	-	-	-	-	-	-	-
ES-6	9/20/06	-	-	-	-	-	-	-
ES-6	10/6/06	-	-	-	-	-	-	-
ES-6	10/18/06	-	-	-	-	-	-	-
ES-6	11/1/06	-	-	-	-	-	-	-
ES-6	11/6/06	-	-	-	-	-	-	-
ES-6	11/10/06	-	-	-	-	-	-	-
ES-6	11/15/06	-	-	-	-	-	-	-
ES-6	11/29/06	-	-	-	-	-	-	-
ES-6	12/13/06	23.64	262.08	187.26	74.82	-	9.60	217.00
ES-6	12/29/06	-	-	-	-	-	-	-
ES-6	1/4/07	-	-	-	-	-	-	-
ES-6	1/12/07	40.80	434.03	323.29	110.73	-	1.20	12.90

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
ES-6	1/26/07	47.04	684.47	372.76	311.71	-	1.40	38.40
ES-6	2/9/07	36.50	-	289.21	-	-	4.00	-
ES-6	2/22/07	-	-	-	-	-	5.00	-
ES-6	3/7/07	30.84	385.43	244.33	141.10	-	9.40	53.20
ES-6	3/23/07	20.48	480.13	162.20	317.92	-	10.80	16.40
ES-6	4/5/07	19.60	380.45	155.23	225.22	-	14.60	40.70
ES-6	4/19/07	-	366.74	-	-	-	8.70	21.80
ES-6	5/4/07	11.85	335.59	93.79	241.80	-	10.10	18.50
ES-6	5/22/07	-	-	-	-	-	-	-
ES-6	6/4/07	-	-	-	-	-	-	-
ES-6	6/19/07	-	-	-	-	-	-	-
ES-6	7/2/07	-	-	-	-	-	-	-
ES-6	7/16/07	-	-	-	-	-	-	-
ES-6	7/31/07	-	-	-	-	-	-	-
ES-6	8/13/07	-	-	-	-	-	-	-
ES-6	8/21/07	-	-	-	-	-	-	-
ES-6	9/4/07	-	-	-	-	-	-	-
ES-6	9/21/07	-	-	-	-	-	-	-
ES-6	10/1/07	-	-	-	-	-	-	-
ES-6	10/19/07	-	-	-	-	-	-	-
ES-6	11/5/07	-	-	-	-	-	-	-
ES-6	12/5/07	-	-	-	-	-	-	-
ES-6	12/17/07	-	-	-	-	-	-	-
ES-6	1/3/08	-	-	-	-	-	-	-
ES-6	1/18/08	-	-	-	-	-	-	-

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
ES-106	10/5/00	-	-	-	-	-	-	-
ES-106	10/19/00	-	-	-	-	-	-	-
ES-106	12/8/00	-	-	-	-	-	-	-
ES-106	1/9/01	-	-	-	-	-	-	-
ES-106	2/3/01	17.07	311.92	135.17	176.75	-	-	19.00
ES-106	2/6/01	-	-	-	-	-	-	-
ES-106	2/19/01	13.80	255.85	109.25	146.60	-	-	89.40
ES-106	3/2/01	11.43	188.44	90.46	97.98	-	-	362.00
ES-106	3/20/01	12.14	372.97	96.09	276.88	-	-	85.70
ES-106	4/9/01	14.25	375.46	112.82	262.65	-	-	40.10
ES-106	4/16/01	-	-	-	-	-	-	-
ES-106	5/2/01	26.79	402.88	212.23	190.65	-	-	12.80
ES-106	5/17/01	14.30	445.24	113.21	332.03	-	-	25.50
ES-106	5/30/01	-	-	-	-	-	-	-
ES-106	6/14/01	-	-	-	-	-	-	-
ES-106	7/11/01	-	-	-	-	-	-	-
ES-106	9/27/01	-	-	-	-	-	-	-
ES-106	10/13/01	-	-	-	-	-	-	-
ES-106	10/24/01	-	-	-	-	-	-	-
ES-106	11/7/01	-	-	-	-	-	-	-
ES-106	11/30/01	-	-	-	-	-	-	-
ES-106	12/14/01	-	-	-	-	-	-	-
ES-106	12/27/01	-	-	-	-	-	-	-
ES-106	1/7/02	-	-	-	-	-	-	-
ES-106	1/9/02	4.35	144.58	34.33	110.25	-	7.90	39.50
ES-106	1/24/02	4.42	172.99	34.89	138.10	-	2.90	18.10
ES-106	1/25/02	3.67	77.82	28.94	48.88	-	0.40	129.00
ES-106	1/26/02	6.01	124.39	47.49	76.90	-	-1.40	72.20
ES-106	1/27/02	8.12	156.67	64.22	92.45	-	3.30	54.70
ES-106	1/29/02	8.04	199.53	63.59	135.94	-	-1.30	19.80
ES-106	2/8/02	-	-	-	-	-	-	-
ES-106	2/22/02	9.21	156.79	72.86	83.93	-	9.00	452.00
ES-106	2/24/02	7.84	158.04	62.00	96.04	-	-	53.00
ES-106	3/8/02	12.44	209.87	98.47	111.40	-	-0.20	48.90
ES-106	3/11/02	5.82	127.14	45.99	81.15	-	3.80	649.00

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
ES-106	3/12/02	7.12	170.62	56.29	114.33	-	7.10	87.70
ES-106	3/29/02	-	187.19	-0.15	-	-	10.20	25.60
ES-106	4/12/02	2.34	220.71	18.40	202.31	-	10.50	28.30
ES-106	4/26/02	1.34	262.08	10.47	251.61	-	9.30	13.80
ES-106	4/27/02	0.63	233.42	4.84	228.58	-	12.10	32.20
ES-106	5/10/02	1.76	282.01	13.80	268.21	-	8.60	5.53
ES-106	5/24/02	0.27	274.54	1.99	272.55	-	24.80	18.70
ES-106	5/28/02	0.13	294.47	0.88	293.59	-	22.60	52.90
ES-106	6/11/02	0.05	272.05	0.24	271.80	-	28.30	24.50
ES-106	6/25/02	-	-	-	-	-	-	-
ES-106	7/9/02	-	-	-	-	-	-	-
ES-106	7/23/02	-	-	-	-	-	-	-
ES-106	9/20/02	-	-	-	-	-	-	-
ES-106	10/16/02	-	-	-	-	-	-	-
ES-106	11/8/02	-	-	-	-	-	-	-
ES-106	11/20/02	-	-	-	-	-	-	-
ES-106	12/4/02	-	-	-	-	-	-	-
ES-106	12/19/02	-	-	-	-	-	-	-
ES-106	1/10/03	-	-	-	-	-	-	-
ES-106	1/17/03	-	-	-	-	-	-	-
ES-106	1/31/03	8.31	233.42	65.70	167.72	-	-	541.00
ES-106	2/14/03	12.94	339.33	102.46	236.87	-	2.80	27.50
ES-106	2/28/03	11.45	358.02	90.65	267.37	-	3.30	5.84
ES-106	3/14/03	17.93	339.33	141.96	197.37	-	-	166.00
ES-106	3/28/03	21.65	321.89	171.51	150.37	-	10.30	13.40
ES-106	4/11/03	15.54	330.61	123.05	207.56	-	-	11.00
ES-106	4/25/03	10.01	328.12	79.16	248.95	-	6.10	22.80
ES-106	5/9/03	15.88	326.87	125.74	201.13	-	16.70	13.40
ES-106	5/23/03	11.05	320.64	87.49	233.15	-	21.30	34.10
ES-106	6/6/03	-	-	-	-	-	20.40	-
ES-106	6/20/03	-	-	-	-	-	-	-
ES-106	7/4/03	-	-	-	-	-	-	-
ES-106	7/18/03	-	-	-	-	-	-	-
ES-106	8/1/03	-	-	-	-	-	-	-
ES-106	8/15/03	-	-	-	-	-	-	-

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
ES-106	8/29/03	-	-	-	-	-	-	-
ES-106	9/12/03	-	-	-	-	-	-	-
ES-106	9/27/03	-	-	-	-	-	-	-
ES-106	10/13/03	-	-	-	-	-	-	-
ES-106	10/24/03	-	-	-	-	-	-	-
ES-106	11/7/03	-	-	-	-	-	-	-
ES-106	11/21/03	-	-	-	-	-	-	-
ES-106	12/5/03	-	-	-	-	-	-	-
ES-106	12/19/03	14.47	330.92	114.56	216.36	-	2.10	11.00
ES-106	12/22/03	8.68	242.27	68.66	173.62	-	3.40	98.90
ES-106	12/25/03	7.52	233.08	59.46	173.61	-	2.60	149.00
ES-106	12/28/03	-	-	-	-	-	0.07	-
ES-106	12/31/03	-	-	-	-	-	-	-
ES-106	1/5/04	-	-	-	-	-	-	-
ES-106	1/9/04	-	-	-	-	-	-	-
ES-106	1/10/04	-	-	-	-	-	-	-
ES-106	1/11/04	-	282.41	-	-	-	0.30	16.40
ES-106	1/12/04	5.46	150.29	43.13	107.16	-	0.10	132.00
ES-106	1/16/04	6.42	175.38	50.74	124.63	-	-	109.00
ES-106	1/19/04	-	207.15	-	-	-	0.20	51.10
ES-106	1/29/04	7.04	111.32	55.66	55.66	-	0.40	267.00
ES-106	1/29/04	8.43	131.56	66.68	64.88	-	0.30	286.00
ES-106	1/30/04	18.74	216.35	148.41	67.94	-	0.50	461.00
ES-106	2/13/04	33.39	428.76	264.55	164.21	-	0.30	10.10
ES-106	2/19/04	-	-	-	-	-	-	-
ES-106	2/24/04	15.04	230.93	119.08	111.85	-	3.80	1202.00
ES-106	2/26/04	19.60	270.80	155.23	115.57	-	4.50	117.00
ES-106	2/27/04	18.35	269.55	145.32	124.23	-	5.30	45.70
ES-106	3/11/04	-	-	-	-	-	-	-
ES-106	3/12/04	15.37	268.31	121.69	146.61	-	7.90	24.50
ES-106	3/26/04	11.64	284.51	92.12	192.38	-	6.80	22.00
ES-106	4/9/04	21.70	386.68	171.88	214.80	-	9.40	13.20
ES-106	4/23/04	15.70	346.81	124.31	222.49	-	12.00	24.00
ES-106	5/7/04	18.66	396.65	147.78	248.87	-	24.20	51.10
ES-106	5/21/04	6.34	358.02	50.11	307.91	-	16.40	32.80

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
ES-106	5/28/04	6.44	374.22	50.90	323.32	-	12.70	125.00
ES-106	6/11/04	9.12	391.66	72.15	319.51	-	17.60	51.20
ES-106	6/25/04	-	-	-	-	-	-	-
ES-106	7/9/04	-	-	-	-	-	-	-
ES-106	7/23/04	-	-	-	-	-	-	-
ES-106	8/6/04	-	-	-	-	-	-	-
ES-106	8/20/04	-	-	-	-	-	-	-
ES-106	9/3/04	-	-	-	-	-	-	-
ES-106	9/17/04	-	-	-	-	-	-	-
ES-106	10/1/04	-	-	-	-	-	-	-
ES-106	10/15/04	-	-	-	-	-	-	-
ES-106	10/29/04	-	-	-	-	-	-	-
ES-106	11/12/04	-	-	-	-	-	-	-
ES-106	11/29/04	-	-	-	-	-	-	-
ES-106	12/13/04	30.16	512.15	238.94	273.20	-	3.10	19.40
ES-106	12/27/04	-	-	-	-	-	-	-
ES-106	1/11/05	-	-	-	-	-	-	-
ES-106	1/12/05	-	-	-	-	-	-	-
ES-106	1/28/05	29.52	404.88	233.87	171.01	-	3.80	20.90
ES-106	2/11/05	-	-	-	-	-	-	-
ES-106	2/25/05	-	-	-	-	-	-	-
ES-106	3/10/05	-	-	-	-	-	-	-
ES-106	3/23/05	8.88	428.64	70.24	358.39	-	7.40	17.60
ES-106	3/25/05	-	-	-	-	-	-	-
ES-106	3/27/05	20.36	423.40	161.25	262.14	-	7.10	345.00
ES-106	3/29/05	18.08	379.72	143.18	236.54	-	-	114.00
ES-106	4/8/05	15.80	366.09	125.10	240.99	-	-	29.40
ES-106	4/12/05	11.50	336.39	91.02	245.38	-	-	43.70
ES-106	4/22/05	-	-	-	0.00	-	-	-
ES-106	5/6/05	-	-	-	0.00	-	-	-
ES-106	5/20/05	16.80	434.23	133.03	301.20	-	13.80	47.60
ES-106	6/7/05	-	-	-	-	-	-	-
ES-106	6/24/05	-	-	-	-	-	-	-
ES-106	7/11/05	-	-	-	-	-	-	-
ES-106	7/22/05	-	-	-	-	-	-	-

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
ES-106	8/19/05	-	-	-	-	-	-	-
ES-106	9/3/05	-	-	-	-	-	-	-
ES-106	9/20/05	-	-	-	-	-	-	-
ES-106	10/7/05	-	-	-	-	-	-	-
ES-106	10/21/05	-	-	-	-	-	-	-
ES-106	11/4/05	-	-	-	-	-	-	-
ES-106	11/18/05	-	-	-	-	-	-	-
ES-106	1/6/06	-	-	-	-	-	-	-
ES-106	1/23/06	-	-	-	-	-	-	-
ES-106	2/6/06	-	-	-	-	-	-	-
ES-106	2/28/06	-	-	-	-	-	-	-
ES-106	3/15/06	-	-	-	-	-	-	-
ES-106	4/11/06	-	-	-	-	-	-	-
ES-106	4/24/06	-	-	-	-	-	-	-
ES-106	5/10/06	-	-	-	-	-	-	-
ES-106	5/20/06	-	-	-	-	-	-	-
ES-106	6/7/06	-	-	-	-	-	-	-
ES-106	6/29/06	-	-	-	-	-	-	-
ES-106	7/7/06	-	-	-	-	-	-	-
ES-106	7/26/06	-	-	-	-	-	-	-
ES-106	8/10/06	-	-	-	-	-	-	-
ES-106	8/25/06	-	-	-	-	-	-	-
ES-106	9/6/06	-	-	-	-	-	-	-
ES-106	9/20/06	-	-	-	-	-	-	-
ES-106	10/6/06	-	-	-	-	-	-	-
ES-106	10/18/06	-	-	-	-	-	-	-
ES-106	11/1/06	-	-	-	-	-	-	-
ES-106	11/6/06	-	-	-	-	-	-	-
ES-106	11/10/06	-	-	-	-	-	-	-
ES-106	11/15/06	-	-	-	-	-	-	-
ES-106	11/29/06	-	-	-	-	-	-	-
ES-106	12/13/06	17.64	280.77	139.69	141.08	-	9.30	165.00
ES-106	12/29/06	-	-	-	-	-	-	-
ES-106	1/4/07	-	-	-	-	-	-	-
ES-106	1/12/07	38.04	434.03	301.41	132.61	-	0.40	16.00

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
ES-106	1/26/07	38.94	-	-	-	-	1.00	19.60
ES-106	2/9/07	30.26	-	-	-	-	4.30	-
ES-106	2/22/07	33.81	-	-	-	-	5.00	-
ES-106	3/7/07	-	-	-	-	-	-	-
ES-106	3/23/07	24.08	410.35	190.74	219.61	-	10.60	15.40
ES-106	4/5/07	24.82	421.57	196.61	224.95	-	15.50	16.70
ES-106	4/19/07	28.16	409.11	223.09	186.02	-	10.80	7.17
ES-106	5/4/07	25.92	434.03	205.33	228.69	-	13.80	8.86
ES-106	5/22/07	19.54	359.27	154.75	204.51	-	20.70	31.70
ES-106	6/4/07	-	-	-	-	-	-	-
ES-106	6/19/07	-	-	-	-	-	-	-
ES-106	7/2/07	-	-	-	-	-	-	-
ES-106	7/16/07	-	-	-	-	-	-	-
ES-106	7/31/07	-	-	-	-	-	-	-
ES-106	8/13/07	-	-	-	-	-	-	-
ES-106	8/21/07	-	-	-	-	-	-	-
ES-106	9/4/07	-	-	-	-	-	-	-
ES-106	9/21/07	-	-	-	-	-	-	-
ES-106	10/1/07	-	-	-	-	-	-	-
ES-106	10/19/07	-	-	-	-	-	-	-
ES-106	11/5/07	-	-	-	-	-	-	-
ES-106	12/5/07	-	300.70	-	-	-	5.00	20.60
ES-106	12/17/07	-	-	-	-	-	-	-
ES-106	1/3/08	-	303.20	-	-	-	3.10	11.40
ES-106	1/18/08	-	-	-	-	-	-	-

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
TD-12	10/6/00	4.25	338.08	33.54	304.54	-	-	-
TD-12	10/19/00	3.96	-	-	-	-	-	-
TD-12	12/7/00	5.50	325.62	43.45	282.17	-	-	0.92
TD-12	1/9/01	7.90	324.38	62.48	261.90	-	-	0.73
TD-12	2/2/01	6.84	320.64	54.07	266.57	-	-	0.66
TD-12	2/6/01	22.17	426.55	175.60	250.95	-	-	2.78
TD-12	2/19/01	16.15	354.28	127.88	226.40	-	-	3.06
TD-12	3/2/01	13.75	341.82	108.85	232.97	-	-	1.73
TD-12	3/20/01	24.17	330.61	191.46	139.15	-	-	1.75
TD-12	4/9/01	12.90	341.82	102.11	239.71	-	-	0.73
TD-12	4/16/01	13.97	323.13	110.60	212.53	-	-	0.84
TD-12	5/2/01	22.25	380.45	176.24	204.21	-	-	0.91
TD-12	5/21/01	24.19	350.54	191.62	158.93	-	-	0.71
TD-12	5/30/01	13.30	321.89	105.28	216.60	-	-	0.73
TD-12	6/14/01	10.78	334.35	85.31	249.04	-	11.50	0.79
TD-12	7/11/01	5.91	321.89	46.70	275.19	-	11.50	1.19
TD-12	9/27/01	3.97	287.00	31.32	255.68	-	-	-
TD-12	10/13/01	3.18	298.21	25.06	273.15	-	12.40	-
TD-12	10/24/01	2.18	284.51	17.13	267.38	-	11.20	-
TD-12	11/7/01	4.07	280.77	32.11	248.65	-	10.50	0.8
TD-12	11/30/01	9.40	335.59	74.37	261.22	-	8.30	0.72
TD-12	12/14/01	27.77	426.55	220.00	206.55	-	6.80	2.51
TD-12	12/27/01	13.28	323.13	105.13	218.00	-	6.10	0.71
TD-12	1/7/02	-	-	-	-	-	-	-
TD-12	1/9/02	28.78	351.79	228.00	123.79	-	8.50	1.39
TD-12	1/24/02	20.32	331.85	160.94	170.92	-	5.10	1.3
TD-12	1/25/02	26.73	326.87	211.75	115.12	-	4.80	12
TD-12	1/26/02	30.64	351.79	242.75	109.04	-	1.70	4.42
TD-12	1/27/02	-	350.54	-	-	-	2.50	3.27
TD-12	1/29/02	27.41	351.79	217.14	134.65	-	-0.90	0.89
TD-12	2/8/02	25.91	325.62	205.25	120.37	-	3.20	4.1
TD-12	2/22/02	25.21	291.98	199.70	92.28	-	8.20	7.59
TD-12	2/24/02	26.45	318.15	209.53	108.61	-	-	4.96
TD-12	3/8/02	21.62	315.66	171.24	144.41	-	2.60	1.01
TD-12	3/11/02	21.78	295.72	172.51	123.21	-	3.40	20.6
TD-12	3/12/02	24.08	306.93	190.74	116.19	-	4.80	4.91
TD-12	3/29/02	20.94	334.35	165.85	168.49	-	4.80	0.75
TD-12	4/12/02	7.17	329.36	56.69	272.67	-	10.50	4.75
TD-12	4/26/02	15.36	329.36	121.62	207.75	-	7.80	0.62
TD-12	4/27/02	10.85	328.12	85.86	242.25	-	7.00	0.95

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
TD-12	5/10/02	16.14	323.13	127.80	195.33	-	7.20	0.97
TD-12	5/24/02	13.87	360.51	109.80	250.71	-	10.30	0.84
TD-12	5/28/02	13.68	349.30	108.30	241.00	-	10.30	1.09
TD-12	6/11/02	11.96	356.77	94.66	262.11	-	14.60	1.12
TD-12	6/25/02	7.11	311.92	56.21	255.70	-	13.60	1.05
TD-12	7/9/02	7.67	303.20	60.65	242.54	-	14.10	0.73
TD-12	7/23/02	-	-	-	-	-	-	-
TD-12	9/20/02	3.55	304.44	27.95	276.49	-	15.60	0.67
TD-12	10/16/02	3.79	275.78	29.92	245.86	-	17.40	4.74
TD-12	11/8/02	3.79	295.72	29.90	265.82	-	13.40	1.01
TD-12	11/20/02	3.82	287.00	30.11	256.88	-	10.30	0.61
TD-12	12/4/02	3.82	288.24	30.10	258.14	-	8.80	6.65
TD-12	12/19/02	4.58	294.47	36.17	258.31	-	6.90	1.29
TD-12	1/10/03	0.26	298.21	1.93	296.28	-	6.00	1.36
TD-12	1/17/03	4.05	268.31	31.95	236.36	-	5.90	1.42
TD-12	1/31/03	12.84	411.60	101.61	309.99	-	-	15.4
TD-12	2/14/03	10.08	311.92	79.76	232.16	-	5.10	0.59
TD-12	2/28/03	7.70	330.61	60.90	269.71	-	4.80	1.05
TD-12	3/14/03	13.14	333.10	104.01	229.09	-	-	1.44
TD-12	3/28/03	8.07	321.89	63.83	258.06	-	5.30	1.98
TD-12	4/11/03	16.16	324.38	127.98	196.39	-	-	1.01
TD-12	4/25/03	14.78	314.41	116.98	197.43	-	7.70	2.24
TD-12	5/9/03	11.79	320.64	93.28	227.36	-	7.90	0.71
TD-12	5/23/03	10.49	313.16	83.01	230.16	-	7.80	1.39
TD-12	6/6/03	9.82	331.85	77.69	254.17	-	9.10	0.92
TD-12	6/20/03	10.79	315.66	85.40	230.26	-	10.30	1.07
TD-12	7/4/03	4.25	303.20	33.58	269.62	-	10.70	2.25
TD-12	7/18/03	-	-	-	-	-	-	-
TD-12	8/1/03	1.19	288.24	9.27	278.97	-	14.80	1.18
TD-12	8/15/03	2.26	288.24	17.74	270.51	-	15.10	0.9
TD-12	8/29/03	3.31	299.46	26.11	273.35	-	14.70	0.99
TD-12	9/12/03	3.56	290.74	28.06	262.67	-	13.40	0.95
TD-12	9/27/03	3.69	290.74	29.12	261.62	-	12.00	0.95
TD-12	10/13/03	3.86	290.74	30.47	260.27	-	12.50	1
TD-12	10/24/03	4.19	289.49	33.09	256.40	-	11.10	5.72
TD-12	11/7/03	3.90	283.26	30.79	252.47	-	9.30	0.68
TD-12	11/21/03	4.20	276.56	33.15	243.41	-	8.50	1.31
TD-12	12/5/03	4.89	275.72	38.63	237.10	-	7.60	1.11
TD-12	12/19/03	6.82	288.27	53.91	234.35	-	7.10	0.89
TD-12	12/22/03	7.35	297.47	58.12	239.35	-	7.00	1.02

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
TD-12	12/25/03	7.58	299.14	59.94	239.20	-	6.80	1.41
TD-12	12/28/03	6.65	283.25	52.57	230.68	-	6.70	0.86
TD-12	12/31/03	6.60	292.45	52.17	240.28	-	6.70	0.76
TD-12	1/5/04	5.28	295.79	41.71	254.09	-	6.20	0.78
TD-12	1/9/04	11.16	321.72	88.32	233.40	-	6.20	2.5
TD-12	1/10/04	16.76	300.81	132.71	168.10	-	6.00	4.23
TD-12	1/11/04	12.71	306.67	100.61	206.06	-	6.00	2.45
TD-12	1/12/04	15.34	299.14	121.46	177.68	-	-	1.71
TD-12	1/16/04	14.21	326.74	112.50	214.24	-	5.80	1.56
TD-12	1/19/04	13.49	315.86	106.79	209.07	-	5.80	1.25
TD-12	1/29/04	20.03	257.33	158.64	98.69	-	3.70	21.1
TD-12	1/29/04	19.82	248.96	156.97	91.99	-	-	13.4
TD-12	1/30/04	18.92	238.93	149.84	89.09	-	3.60	11.2
TD-12	2/13/04	17.19	315.86	136.12	179.74	-	5.00	1.06
TD-12	2/19/04	13.49	-	-	-	-	3.60	-
TD-12	2/24/04	18.55	304.44	146.90	157.54	-	4.50	1.17
TD-12	2/26/04	18.29	294.47	144.84	149.63	-	-	2.41
TD-12	2/27/04	18.29	294.47	144.84	149.63	-	-	2.39
TD-12	3/11/04	-	-	-	-	-	-	-
TD-12	3/12/04	16.90	285.75	133.82	151.93	-	4.80	1.44
TD-12	3/26/04	15.29	309.43	121.06	188.36	-	6.00	0.88
TD-12	4/9/04	16.16	320.64	127.96	192.68	-	6.20	1.05
TD-12	4/23/04	17.82	339.33	141.12	198.21	-	7.40	1.14
TD-12	5/7/04	13.34	340.58	105.60	234.97	-	7.50	0.99
TD-12	5/21/04	11.87	334.35	93.95	240.40	-	8.60	0.9
TD-12	5/28/04	12.42	336.84	98.31	238.53	-	10.10	3.15
TD-12	6/11/04	12.01	331.85	95.06	236.79	-	10.20	1.06
TD-12	6/25/04	9.61	311.92	76.03	235.89	-	9.70	1.53
TD-12	7/9/04	7.72	305.69	61.05	244.64	-	11.40	1.51
TD-12	7/23/04	5.03	304.44	39.72	264.72	-	13.10	2.04
TD-12	8/6/04	-	-	-	-	-	-	-
TD-12	8/20/04	-	-	-	-	-	-	-
TD-12	9/3/04	3.66	295.72	28.86	266.86	-	13.10	1.88
TD-12	9/17/04	3.67	288.24	28.94	259.30	-	12.10	1.07
TD-12	10/1/04	3.91	294.47	30.84	263.63	-	11.60	1.08
TD-12	10/15/04	3.93	305.69	31.00	274.68	-	11.20	1.14
TD-12	10/29/04	3.95	305.69	31.16	274.53	-	10.30	1.13
TD-12	11/12/04	3.90	252.18	30.77	221.42	-	9.20	1.22
TD-12	11/29/04	4.19	272.80	33.06	239.74	-	8.10	1.07
TD-12	12/13/04	6.58	280.14	52.01	228.13	-	7.20	2.11

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
TD-12	12/27/04	4.89	273.50	38.61	234.88	-	6.30	1.07
TD-12	1/11/05	4.72	267.91	37.27	230.64	-	5.60	0.87
TD-12	1/12/05	4.66	266.51	36.79	229.72	-	5.30	1.39
TD-12	1/28/05	7.12	267.91	56.29	211.62	-	5.20	1.11
TD-12	2/11/05	6.30	252.53	49.79	202.74	-	5.60	0.91
TD-12	2/25/05	4.71	271.75	37.19	234.56	-	5.60	0.73
TD-12	3/10/05	4.58	243.80	36.16	207.64	-	5.60	0.85
TD-12	3/23/05	4.95	268.96	39.09	229.87	-	5.60	1.39
TD-12	3/25/05	4.37	272.45	34.49	237.96	-	6.00	0.76
TD-12	3/27/05	11.68	326.96	92.44	234.52	-	5.90	21
TD-12	3/29/05	15.64	-	123.84	-123.84	-	-	-
TD-12	4/8/05	11.10	299.01	87.84	211.16	-	-	1.73
TD-12	4/12/05	6.56	285.73	51.85	233.88	-	-	1.21
TD-12	4/22/05	8.76	283.98	69.29	214.69	-	-	1.59
TD-12	5/6/05	8.46	287.47	66.92	220.56	-	7.90	0.94
TD-12	5/20/05	11.62	319.62	91.97	227.65	-	9.50	1
TD-12	6/7/05	7.82	308.44	61.84	246.60	-	10.00	0.98
TD-12	6/24/05	5.22	298.21	41.23	256.98	-	-	1.16
TD-12	7/11/05	4.32	282.01	34.09	247.92	-	12.10	3.35
TD-12	7/22/05	3.89	272.05	30.69	241.36	-	13.90	0.74
TD-12	8/19/05	3.41	280.77	26.88	253.89	-	14.60	1.39
TD-12	9/3/05	3.12	270.80	24.58	246.22	-	14.10	1.05
TD-12	9/20/05	0.02	280.77	-0.01	280.78	-	13.50	1.11
TD-12	10/7/05	2.94	280.77	23.15	257.61	-	12.50	0.93
TD-12	10/21/05	2.88	274.54	22.68	251.86	-	11.80	1.38
TD-12	11/4/05	3.78	277.03	29.81	247.22	-	-	4.4
TD-12	11/18/05	3.50	239.65	27.59	212.05	-	9.40	1.38
TD-12	1/6/06	8.46	303.20	66.92	236.28	-	6.70	1.67
TD-12	1/23/06	17.88	348.05	141.59	206.46	-	6.00	1.58
TD-12	2/6/06	18.68	367.99	147.94	220.05	-	-	1.7
TD-12	2/28/06	14.10	320.64	111.63	209.01	-	4.60	5.07
TD-12	3/15/06	15.86	341.82	125.58	216.24	-	4.90	0.94
TD-12	4/11/06	16.34	336.84	129.38	207.45	-	6.60	2.74
TD-12	4/24/06	15.96	355.53	126.37	229.15	-	7.60	1.26
TD-12	5/10/06	13.70	366.74	108.46	258.29	6.73	12.00	0.99
TD-12	5/20/06	12.20	334.35	96.56	237.78	6.63	13.10	1.15
TD-12	6/7/06	-	-	-	-	-	-	0
TD-12	6/29/06	8.91	343.07	70.48	272.58	6.54	14.60	6.72
TD-12	7/7/06	-	-	-	-	-	-	-
TD-12	7/26/06	5.85	300.70	46.22	254.48	6.86	19.50	1.37

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
TD-12	8/10/06	3.33	301.95	26.25	275.70	7.21	18.40	1.51
TD-12	8/25/06	5.32	301.95	42.02	259.93	7.16	18.20	1.63
TD-12	9/6/06	5.39	301.95	42.58	259.37	6.88	21.40	1.04
TD-12	9/20/06	4.73	299.46	37.35	262.11	7.28	14.50	1.42
TD-12	10/6/06	4.41	294.47	34.81	259.66	7.24	16.70	1.62
TD-12	10/18/06	4.05	306.93	31.95	274.98	7.13	12.30	1.46
TD-12	11/1/06	3.26	298.21	25.69	272.52	7.18	8.40	2.09
TD-12	11/6/06	3.07	308.18	24.19	283.99	6.82	12.20	6.37
TD-12	11/10/06	5.64	309.43	44.56	264.87	6.78	8.90	1.53
TD-12	11/15/06	7.70	314.41	60.89	253.52	6.58	9.30	1.55
TD-12	11/29/06	10.90	349.30	86.26	263.04	6.91	1.50	0.79
TD-12	12/13/06	20.73	335.59	164.19	171.40	6.44	10.10	4.81
TD-12	12/29/06	16.12	354.28	127.64	226.64	6.48	5.20	0.98
TD-12	1/4/07	25.45	331.85	201.61	130.25	6.54	9.10	4.61
TD-12	1/12/07	22.93	374.22	181.63	192.59	6.63	3.40	1.74
TD-12	1/26/07	21.21	354.28	167.99	186.29	6.60	4.20	1.19
TD-12	2/9/07	17.83	na	141.20	-	6.59	5.30	0
TD-12	2/22/07	24.88	na	197.09	-	7.03	5.50	0
TD-12	3/7/07	20.28	341.82	160.62	181.20	6.70	9.30	0.43
TD-12	3/23/07	20.39	354.28	161.49	192.79	6.74	8.90	0.77
TD-12	4/5/07	19.10	356.77	151.26	205.51	7.00	12.90	0.7
TD-12	4/19/07	18.49	344.31	146.43	197.88	7.79	7.20	0.84
TD-12	5/4/07	17.52	351.79	138.74	213.05	7.16	10.80	0.51
TD-12	5/22/07	16.31	339.33	129.15	210.18	7.01	15.10	0.78
TD-12	6/4/07	17.11	353.04	135.49	217.55	6.82	16.80	0.62
TD-12	6/19/07	13.63	336.84	107.90	228.94	6.83	16.00	19.3
TD-12	7/2/07	9.81	318.15	77.62	240.53	-	-	16.9
TD-12	7/16/07	-	-	-	-	-	-	-
TD-12	7/31/07	-	-	-	-	-	-	-
TD-12	8/13/07	-	-	-	-	-	-	-
TD-12	8/21/07	4.62	309.43	36.47	272.95	-	-	18.3
TD-12	9/4/07	4.76	290.74	37.58	253.15	6.96	17.70	19.8
TD-12	9/21/07	-	301.95	-	-	7.13	18.60	17.3
TD-12	10/1/07	-	288.24	-	-	7.36	9.50	18.1
TD-12	10/19/07	-	296.97	-	-	7.08	10.90	1.24
TD-12	11/5/07	-	294.47	-	-	7.05	12.30	0.76
TD-12	12/5/07	-	339.33	-	-	6.71	5.90	1.23
TD-12	12/17/07	-	295.72	-	-	-	-	0.59
TD-12	1/3/08	-	316.90	-	-	6.72	4.10	1.21
TD-12	1/18/08	-	-	-	-	-	-	-

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Tubidity (NTU)
MFC-660	10/6/00	3.40	339.33	26.80	312.53	-	-	-
MFC-660	10/19/00	3.06	-	-	-	-	-	-
MFC-660	12/7/00	4.33	341.82	34.17	307.65	-	-	24.50
MFC-660	1/9/01	9.19	323.13	72.70	250.43	-	-	34.30
MFC-660	2/2/01	6.66	273.29	52.65	220.65	-	-	36.80
MFC-660	2/6/01	-	-	-	-	-	-	-
MFC-660	2/19/01	11.29	255.85	89.35	166.50	-	-	87.30
MFC-660	3/2/01	18.98	323.13	150.31	172.82	-	-	708.00
MFC-660	3/20/01	29.93	420.32	237.12	183.20	-	-	55.00
MFC-660	4/9/01	17.13	384.19	135.65	248.54	-	-	26.90
MFC-660	4/16/01	15.60	396.65	123.52	273.13	-	-	37.50
MFC-660	5/2/01	15.91	346.68	125.98	220.70	-	-	24.80
MFC-660	5/21/01	10.74	321.89	84.99	236.89	-	-	8.95
MFC-660	5/30/01	10.79	326.87	85.39	241.48	-	-	4.47
MFC-660	6/15/01	8.44	306.93	66.76	240.18	-	12.00	3.43
MFC-660	7/11/01	-	-	-	-	-	12.00	-
MFC-660	9/27/01	4.61	295.72	36.39	259.33	-	-	-
MFC-660	10/13/01	1.42	304.44	11.10	293.34	-	10.50	-
MFC-660	10/24/01	0.97	306.93	7.54	299.40	-	9.60	-
MFC-660	11/7/01	3.15	314.41	24.82	289.59	-	7.00	11.10
MFC-660	11/30/01	17.61	356.77	139.45	217.32	-	3.70	-
MFC-660	12/14/01	30.40	328.12	240.85	87.27	-	1.50	141.00
MFC-660	12/27/01	27.15	384.19	215.08	169.10	-	2.10	4.65
MFC-660	1/7/02	-	-	-	-	-	-	-
MFC-660	1/9/02	25.14	311.92	199.15	112.77	-	3.60	62.50
MFC-660	1/24/02	21.41	326.87	169.58	157.29	-	1.50	14.60
MFC-660	1/25/02	40.47	380.45	320.68	59.77	-	1.60	70.00
MFC-660	1/26/02	24.27	299.46	192.25	107.21	-	-0.10	138.00
MFC-660	1/27/02	22.54	287.00	178.54	108.46	-	3.30	123.00
MFC-660	1/29/02	27.06	344.31	214.37	129.94	-	-2.10	27.80
MFC-660	2/8/02	11.05	212.74	87.45	125.29	-	0.30	138.00
MFC-660	2/22/02	12.32	204.76	97.52	107.25	-	8.20	410.00
MFC-660	2/24/02	16.88	239.65	133.67	105.98	-	-	170.00
MFC-660	3/8/02	14.12	269.55	111.79	157.77	-	-2.60	119.00
MFC-660	3/11/02	-	-	-	-	-	3.70	-
MFC-660	3/12/02	9.69	213.36	76.67	136.69	-	5.50	239.00
MFC-660	3/29/02	17.35	290.74	137.39	153.34	-	8.80	18.60
MFC-660	4/12/02	7.81	309.43	61.76	247.66	-	9.40	24.00
MFC-660	4/26/02	6.51	323.13	51.46	271.67	-	7.30	23.00

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Tubidity (NTU)
MFC-660	4/27/02	3.09	314.41	24.34	290.07	-	10.60	135.00
MFC-660	5/10/02	11.48	329.36	90.86	238.50	-	7.40	39.50
MFC-660	5/24/02	8.83	349.30	69.85	279.45	-	16.70	13.60
MFC-660	5/28/02	6.92	331.85	54.71	277.15	-	-	18.40
MFC-660	6/11/02	6.19	348.05	48.92	299.13	-	18.10	5.42
MFC-660	6/25/02	5.97	324.38	47.18	277.20	-	17.10	7.57
MFC-660	7/9/02	5.58	304.44	44.08	260.36	-	16.50	4.06
MFC-660	7/23/02	3.93	287.00	31.00	255.99	-	20.60	5.47
MFC-660	9/20/02	4.57	295.72	36.11	259.61	-	16.10	0.00
MFC-660	10/16/02	3.83	316.90	30.21	286.69	-	16.60	5.40
MFC-660	11/8/02	3.00	400.38	23.60	376.78	-	11.00	8.76
MFC-660	11/20/02	3.40	313.16	26.81	286.35	-	9.50	4.12
MFC-660	12/4/02	3.57	311.92	28.15	283.76	-	8.30	44.60
MFC-660	12/19/02	3.78	299.46	29.82	269.63	-	3.00	5.44
MFC-660	1/10/03	4.17	308.18	32.88	275.30	-	2.30	7.89
MFC-660	1/17/03	4.58	306.93	36.14	270.79	-	4.50	12.40
MFC-660	1/31/03	9.20	215.35	72.81	142.54	-	-	805.00
MFC-660	2/14/03	9.99	335.59	79.03	256.56	-	3.90	44.20
MFC-660	2/28/03	10.22	303.20	80.83	222.36	-	0.60	11.70
MFC-660	3/14/03	10.25	291.98	81.07	210.91	-	-	143.00
MFC-660	3/28/03	7.29	318.15	57.67	260.48	-	8.40	47.80
MFC-660	4/11/03	16.96	330.61	134.28	196.33	-	-	10.90
MFC-660	4/25/03	13.81	335.59	109.34	226.25	-	7.10	13.80
MFC-660	5/9/03	11.30	341.82	89.41	252.41	-	13.10	11.50
MFC-660	5/23/03	9.21	348.05	72.86	275.20	-	13.90	10.80
MFC-660	6/6/03	8.21	355.53	64.94	290.59	-	13.80	4.54
MFC-660	6/20/03	7.15	331.85	56.56	275.29	-	12.00	4.16
MFC-660	7/4/03	4.02	282.01	31.68	250.33	-	15.00	4.68
MFC-660	7/18/03	1.24	248.37	9.65	238.72	-	15.80	15.40
MFC-660	8/1/03	3.85	265.82	30.36	235.46	-	15.80	21.00
MFC-660	8/15/03	3.54	289.49	27.90	261.59	-	16.40	59.40
MFC-660	8/29/03	3.71	282.01	29.23	252.78	-	15.20	2.56
MFC-660	9/12/03	3.70	283.26	29.18	254.08	-	12.20	2.92
MFC-660	9/27/03	4.01	277.03	31.63	245.40	-	11.90	2.95
MFC-660	10/13/03	3.39	275.78	26.69	249.09	-	10.80	50.00
MFC-660	10/24/03	3.66	294.47	28.87	265.61	-	7.40	3.18
MFC-660	11/7/03	3.69	295.72	29.07	266.65	-	4.00	7.18
MFC-660	11/21/03	2.58	281.58	20.29	261.29	-	2.50	13.30
MFC-660	12/5/03	4.06	274.05	32.05	242.00	-	3.60	50.30

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Tubidity (NTU)
MFC-660	12/19/03	7.81	295.79	61.76	234.03	-	3.30	19.80
MFC-660	12/22/03	-	-	-	-	-	-	-
MFC-660	12/25/03	-	-	-	-	-	-	-
MFC-660	12/28/03	-	-	-	-	-	-	-
MFC-660	12/31/03	-	-	-	-	-	-	-
MFC-660	1/5/04	4.57	284.09	36.08	248.01	-	1.00	42.30
MFC-660	1/9/04	-	-	-	-	-	-	-
MFC-660	1/10/04	-	-	-	-	-	-	-
MFC-660	1/11/04	-	-	-	-	-	-	-
MFC-660	1/12/04	-	-	-	-	-	-	-
MFC-660	1/16/04	-	260.67	-0.15	-	-	0.60	76.60
MFC-660	1/19/04	-	-	-	-	-	-	-
MFC-660	1/29/04	10.09	161.16	79.84	81.32	-	1.00	401.00
MFC-660	1/29/04	16.38	256.49	129.70	126.79	-	-	197.00
MFC-660	1/30/04	22.92	206.32	181.55	24.77	-	1.00	380.00
MFC-660	2/13/04	33.93	464.72	268.83	195.88	-	0.60	36.40
MFC-660	2/19/04	-	-	-	-	-	-	-
MFC-660	2/24/04	18.07	274.54	143.10	131.44	-	4.20	110.00
MFC-660	2/26/04	18.49	260.83	146.43	114.40	-	4.00	65.10
MFC-660	2/27/04	18.50	275.78	146.51	129.27	-	4.30	52.10
MFC-660	3/11/04	-	-	-	-	-	-	-
MFC-660	3/12/04	17.91	289.49	141.83	147.66	-	5.80	52.40
MFC-660	3/26/04	14.35	329.36	113.61	215.75	-	6.20	26.50
MFC-660	4/9/04	20.19	385.43	159.91	225.53	-	7.40	6.33
MFC-660	4/23/04	17.33	371.73	137.23	234.49	-	9.20	15.60
MFC-660	5/7/04	10.33	328.12	81.74	246.38	-	12.70	7.76
MFC-660	5/21/04	6.66	351.79	52.65	299.14	-	13.10	9.43
MFC-660	5/28/04	8.56	344.31	67.71	276.61	-	11.90	177.00
MFC-660	6/11/04	7.70	349.30	60.89	288.41	-	10.50	9.31
MFC-660	6/25/04	7.44	318.15	58.83	259.32	-	12.20	4.53
MFC-660	7/9/04	5.43	299.46	42.89	256.56	-	11.40	7.41
MFC-660	7/23/04	3.54	305.69	27.91	277.78	-	13.30	75.10
MFC-660	8/6/04	3.11	340.58	24.50	316.07	-	13.50	307.00
MFC-660	8/20/04	3.55	284.51	27.99	256.51	-	15.20	72.30
MFC-660	9/3/04	3.42	298.21	26.96	271.25	-	11.90	78.50
MFC-660	9/17/04	3.72	301.95	29.34	272.61	-	11.90	5.81
MFC-660	10/1/04	3.89	298.21	30.69	267.53	-	10.80	15.30
MFC-660	10/15/04	3.20	316.90	25.22	291.69	-	10.10	28.20
MFC-660	10/29/04	3.03	303.20	23.87	279.33	-	7.60	11.70

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Tubidity (NTU)
MFC-660	11/12/04	2.81	263.02	22.12	240.89	-	6.70	16.60
MFC-660	11/29/04	3.33	274.90	26.25	248.65	-	3.00	9.27
MFC-660	12/13/04	7.24	268.96	57.24	211.71	-	4.10	20.10
MFC-660	12/27/04	4.04	272.10	31.88	240.23	-	2.90	13.40
MFC-660	1/11/05	3.85	269.31	30.37	238.94	-	1.60	7.37
MFC-660	1/12/05	3.61	260.57	28.47	232.10	-	2.60	25.20
MFC-660	1/28/05	6.80	272.80	53.76	219.04	-	4.80	28.50
MFC-660	2/11/05	4.46	266.51	35.20	231.31	-	2.50	8.27
MFC-660	2/25/05	4.30	268.96	33.94	235.02	-	2.40	5.88
MFC-660	3/10/05	3.66	254.28	28.86	225.42	-	5.20	7.69
MFC-660	3/23/05	2.55	271.40	20.06	251.34	-	5.50	18.80
MFC-660	3/25/05	3.33	278.04	26.25	251.79	-	4.60	28.50
MFC-660	3/27/05	11.08	288.52	87.69	200.84	-	6.10	451.00
MFC-660	3/29/05	12.24	301.45	96.88	204.57	-	-	236.00
MFC-660	4/8/05	6.85	303.90	54.15	249.75	-	-	30.20
MFC-660	4/12/05	5.56	296.21	43.93	252.29	-	-	30.50
MFC-660	4/22/05	7.02	305.64	55.50	250.15	-	-	11.10
MFC-660	5/6/05	5.34	301.10	42.18	258.92	-	9.70	5.44
MFC-660	5/20/05	7.11	345.13	56.21	288.91	-	10.90	19.20
MFC-660	6/7/05	5.08	19.65	40.12	-20.47	-	12.50	6.81
MFC-660	6/24/05	3.43	306.93	27.04	279.89	-	-	197.00
MFC-660	7/11/05	2.07	294.47	16.26	278.22	-	16.10	18.30
MFC-660	7/22/05	2.15	278.28	16.89	261.38	-	15.50	36.40
MFC-660	8/19/05	1.28	291.98	9.99	281.99	-	13.60	6.41
MFC-660	9/3/05	2.35	273.29	18.48	254.81	-	16.10	5.27
MFC-660	9/20/05	2.78	285.75	21.89	263.86	-	10.60	3.80
MFC-660	10/7/05	2.73	291.98	21.49	270.49	-	11.10	5.31
MFC-660	10/21/05	2.99	284.51	23.55	260.95	-	11.30	6.42
MFC-660	11/4/05	2.21	294.47	17.37	277.11	-	7.00	37.20
MFC-660	11/18/05	2.66	288.24	20.94	267.31	-	6.60	12.20
MFC-660	1/6/06	6.50	287.00	51.38	235.62	-	5.60	24.50
MFC-660	1/23/06	12.70	288.24	100.53	187.71	-	4.10	41.60
MFC-660	2/6/06	13.42	289.49	106.24	183.25	-	4.10	17.00
MFC-660	2/28/06	8.67	217.59	68.58	149.01	-	4.90	210.00
MFC-660	3/15/06	12.10	316.90	95.77	221.13	-	4.60	39.00
MFC-660	4/11/06	9.85	285.75	77.93	207.82	-	9.10	38.10
MFC-660	4/24/06	11.18	319.39	88.48	230.91	-	9.50	15.50
MFC-660	5/10/06	12.60	358.02	99.74	258.28	7.33	13.20	18.60
MFC-660	5/20/06	7.94	389.17	62.79	326.38	7.36	17.20	102.00

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Tubidity (NTU)
MFC-660	6/7/06	9.48	336.84	75.00	261.84	7.06	19.90	54.80
MFC-660	6/29/06	6.09	354.28	48.13	306.15	7.00	15.90	12.80
MFC-660	7/7/06	-	-	-0.15	-	-	-	0.00
MFC-660	7/26/06	5.37	313.16	42.42	270.74	7.20	19.30	12.10
MFC-660	8/10/06	3.99	318.15	31.48	286.67	7.60	20.40	13.20
MFC-660	8/25/06	4.10	303.20	32.35	270.84	7.50	17.50	9.69
MFC-660	9/6/06	4.62	288.24	36.47	251.77	7.27	24.40	8.15
MFC-660	9/20/06	3.80	293.23	29.97	263.25	6.75	14.50	18.40
MFC-660	10/6/06	4.07	295.72	32.11	263.61	7.41	14.10	9.90
MFC-660	10/18/06	3.57	306.93	28.15	278.78	7.33	11.60	15.10
MFC-660	11/1/06	2.80	295.72	22.04	273.67	7.28	7.70	6.19
MFC-660	11/6/06	3.36	258.34	26.48	231.85	6.94	13.50	1000.00
MFC-660	11/10/06	5.28	306.93	41.71	265.23	6.65	8.90	15.20
MFC-660	11/15/06	6.74	305.69	53.28	252.41	6.84	7.30	12.60
MFC-660	11/29/06	7.92	343.07	62.63	280.43	6.96	-0.70	24.50
MFC-660	12/13/06	43.33	264.57	343.35	-78.78	6.70	10.20	393.00
MFC-660	12/29/06	23.37	400.38	185.12	215.27	6.57	3.50	13.70
MFC-660	1/4/07	31.09	344.31	246.32	98.00	6.65	8.30	114.00
MFC-660	1/12/07	30.45	406.61	241.24	165.37	6.58	0.70	20.80
MFC-660	1/26/07	27.61	374.22	218.73	155.49	6.63	3.00	24.10
MFC-660	2/9/07	26.69	-	211.44	-	6.63	3.80	0.00
MFC-660	2/22/07	29.00	-	229.75	-	7.09	5.20	0.00
MFC-660	3/7/07	31.50	375.46	249.57	125.90	6.84	10.40	64.70
MFC-660	3/23/07	22.92	400.38	181.55	218.83	6.98	9.10	15.90
MFC-660	4/5/07	20.50	406.61	162.36	244.25	7.00	15.20	26.30
MFC-660	4/19/07	19.04	375.46	150.79	224.67	7.75	8.70	14.40
MFC-660	5/4/07	15.63	366.74	123.76	242.99	7.19	11.50	15.80
MFC-660	5/22/07	10.74	366.74	84.99	281.75	7.56	16.50	22.30
MFC-660	6/4/07	6.24	304.44	49.32	255.13	7.18	23.10	22.70
MFC-660	6/19/07	5.80	300.70	45.83	254.88	6.92	17.70	19.60
MFC-660	7/2/07	3.95	277.03	31.16	245.87	-	-	17.70
MFC-660	7/16/07	2.22	273.29	17.45	255.84	7.16	20.00	21.20
MFC-660	7/31/07	2.75	282.01	21.65	260.36	6.95	20.70	21.10
MFC-660	8/13/07	3.37	300.70	26.56	274.14	6.71	19.80	21.50
MFC-660	8/21/07	3.59	298.21	28.31	269.90	-	-	18.00
MFC-660	9/4/07	3.54	287.00	27.91	259.09	7.18	18.40	19.50
MFC-660	9/21/07	-	277.03	-0.15	277.18	7.06	19.70	17.30
MFC-660	10/1/07	-	280.77	-0.15	280.92	7.57	9.90	18.70
MFC-660	10/19/07	-	345.56	-0.15	345.71	7.29	10.50	173.00

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Tubidity (NTU)
MFC-660	11/5/07	-	274.54	-0.15	274.69	7.30	11.90	15.00
MFC-660	12/5/07	-	243.39	-0.15	243.54	6.78	4.80	54.70
MFC-660	12/17/07	-	272.05	-0.15	272.20	-	-	16.50
MFC-660	1/3/08	-	273.29	-0.15	273.44	6.77	3.30	12.90
MFC-660	1/18/08	-	-	-0.15	-	-	-	0.00

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
MFC-4700	10/5/00	-	-	-	-	-	-	-
MFC-4700	10/19/00	0.00	-	-	-	-	-	-
MFC-4700	12/7/00	2.62	308.18	20.62	287.56	-	-	1.17
MFC-4700	1/9/01	9.71	306.93	76.82	230.11	-	-	34.6
MFC-4700	2/2/01	-	-	-	-	-	-	-
MFC-4700	2/6/01	-	-	-	-	-	-	-
MFC-4700	2/19/01	7.03	290.74	55.58	235.16	-	-	14
MFC-4700	3/2/01	13.22	324.38	104.65	219.73	-	-	39.1
MFC-4700	3/20/01	10.31	287.00	81.58	205.42	-	-	77.2
MFC-4700	4/9/01	5.21	301.95	41.15	260.80	-	-	11.3
MFC-4700	4/16/01	3.83	314.41	30.21	284.20	-	-	6.67
MFC-4700	5/2/01	4.76	303.20	37.58	265.61	-	-	55.3
MFC-4700	5/21/01	0.68	328.12	5.24	322.88	-	-	6.71
MFC-4700	5/30/01	0.50	341.82	3.81	338.01	-	-	4.77
MFC-4700	6/15/01	0.12	324.38	0.80	323.58	-	23.00	3.41
MFC-4700	7/11/01	0.08	324.38	0.48	323.90	-	23.00	4.24
MFC-4700	9/27/01	0.08	358.02	0.48	357.54	-	-	-
MFC-4700	10/13/01	0.07	348.05	0.40	347.65	-	11.20	-
MFC-4700	10/24/01	0.06	325.62	0.32	325.30	-	7.20	-
MFC-4700	11/7/01	-	328.12	-0.15	328.27	-	9.50	10.8
MFC-4700	11/30/01	2.62	268.31	20.62	247.69	-	1.70	4.67
MFC-4700	12/14/01	16.39	290.74	129.78	160.95	-	-	40.9
MFC-4700	12/27/01	-	-	-	-	-	-	-
MFC-4700	1/7/02	-	-	-	-	-	-	-
MFC-4700	1/9/02	16.67	267.06	132.00	135.06	-	4.00	56
MFC-4700	1/24/02	-	-	-	-	-	-	-
MFC-4700	1/25/02	5.60	204.14	44.24	159.90	-	3.60	394
MFC-4700	1/26/02	12.77	219.71	101.08	118.63	-	-1.20	115
MFC-4700	1/27/02	15.64	252.11	123.84	128.27	-	3.80	70.3
MFC-4700	1/29/02	15.47	303.20	122.49	180.71	-	0.30	27.6
MFC-4700	2/8/02	12.43	237.16	98.39	138.77	-	1.70	56.8
MFC-4700	2/22/02	0.44	172.12	3.34	168.78	-	8.80	412
MFC-4700	2/24/02	10.91	189.19	86.34	102.85	-	-	170
MFC-4700	3/8/02	-	264.57	-	-	-	-0.50	79.5
MFC-4700	3/11/02	6.67	134.86	52.72	82.14	-	3.30	2085.33333
MFC-4700	3/12/02	-	-	-	-	-	-	-
MFC-4700	3/29/02	9.36	229.68	74.05	155.63	-	9.00	33.5
MFC-4700	4/12/02	5.91	268.31	46.70	221.61	-	11.70	15.2
MFC-4700	4/26/02	6.09	293.23	48.13	245.10	-	12.10	4.62

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
MFC-4700	4/27/02	4.20	304.44	33.14	271.30	-	10.30	8.41
MFC-4700	5/10/02	2.90	303.20	22.84	280.36	-	10.60	3.21
MFC-4700	5/24/02	1.25	318.15	9.76	308.39	-	18.60	9.94
MFC-4700	5/28/02	0.80	320.64	6.19	314.45	-	-	54.3
MFC-4700	6/11/02	0.44	314.41	3.34	311.07	-	21.20	19.3
MFC-4700	6/25/02	0.29	343.07	2.15	340.92	-	16.40	12.3
MFC-4700	7/9/02	0.03	329.36	0.09	329.28	-	29.40	24.3
MFC-4700	7/23/02	0.02	321.89	0.01	321.88	-	29.20	8.43
MFC-4700	9/20/02	-	364.25	-	-	-	15.70	14.2
MFC-4700	10/16/02	0.20	316.90	1.43	315.47	-	11.40	5.4
MFC-4700	11/8/02	0.64	329.36	4.90	324.46	-	3.30	8.83
MFC-4700	11/20/02	0.25	341.82	1.80	340.03	-	11.90	13.6
MFC-4700	12/4/02	0.86	316.90	6.70	310.20	-	2.10	4.62
MFC-4700	12/19/02	1.08	294.47	8.41	286.06	-	0.80	28.3
MFC-4700	1/10/03	3.60	301.95	28.39	273.55	-	0.70	238
MFC-4700	1/17/03	3.59	267.06	28.31	238.75	-	2.30	136
MFC-4700	1/31/03	6.35	143.96	50.19	93.77	-	-	4000
MFC-4700	2/14/03	7.83	284.51	61.94	222.56	-	2.90	29.9
MFC-4700	2/28/03	8.10	269.55	64.05	205.50	-	1.30	75.3
MFC-4700	3/14/03	7.08	229.68	55.96	173.72	-	-	79.2
MFC-4700	3/28/03	10.34	244.63	81.81	162.82	-	6.00	48
MFC-4700	4/11/03	8.45	288.24	66.86	221.38	-	-	7.19
MFC-4700	4/25/03	5.65	284.51	44.63	239.88	-	8.60	13.9
MFC-4700	5/9/03	3.05	309.43	24.00	285.42	-	14.80	15
MFC-4700	5/23/03	1.06	305.69	8.27	297.41	-	2.19	6.77
MFC-4700	6/6/03	0.51	320.64	3.90	316.74	-	20.10	6.19
MFC-4700	6/20/03	0.44	333.10	3.32	329.78	-	15.50	5.37
MFC-4700	7/4/03	0.08	311.92	0.50	311.42	-	20.00	10.8
MFC-4700	7/18/03	-	354.28	-	-	-	21.70	11.7
MFC-4700	8/1/03	0.00	406.61	-0.13	406.75	-	20.00	1.36
MFC-4700	8/15/03	-	437.76	-	-	-	16.70	205
MFC-4700	8/29/03	0.01	397.89	-0.10	397.99	-	15.20	7.24
MFC-4700	9/12/03	-	390.42	-	-	-	14.50	23.2
MFC-4700	9/27/03	-	382.94	-	-	-	13.10	2.04
MFC-4700	10/13/03	-	338.08	-	-	-	8.00	8.9
MFC-4700	10/24/03	-	366.74	-	-	-	5.70	1.6
MFC-4700	11/7/03	0.76	380.45	5.84	374.60	-	3.00	556
MFC-4700	11/21/03	0.45	309.17	3.41	305.77	-	2.60	5.42
MFC-4700	12/5/03	1.83	262.34	14.35	248.00	-	4.50	14.4

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
MFC-4700	12/19/03	4.94	291.61	39.01	252.60	-	2.70	72.9
MFC-4700	12/22/03	-	-	-	-	-	-	-
MFC-4700	12/25/03	-	-	-	-	-	-	-
MFC-4700	12/28/03	-	-	-	-	-	-	-
MFC-4700	12/31/03	-	-	-	-	-	-	-
MFC-4700	1/5/04	2.63	307.50	20.70	286.80	-	0.50	17.8
MFC-4700	1/9/04	-	-	-	-	-	-	-
MFC-4700	1/10/04	-	-	-	-	-	-	-
MFC-4700	1/11/04	-	-	-	-	-	-	-
MFC-4700	1/12/04	-	-	-	-	-	-	-
MFC-4700	1/16/04	9.37	281.58	74.13	207.45	-	1.60	37.2
MFC-4700	1/19/04	-	-	-	-	-	-	-
MFC-4700	1/29/04	12.77	216.35	101.08	115.27	-	0.10	1000
MFC-4700	1/29/04	10.76	180.39	85.15	95.24	-	-	1554
MFC-4700	1/30/04	14.35	189.59	113.61	75.98	-	0.70	791
MFC-4700	2/13/04	12.25	342.62	96.96	245.66	-	0.70	17.1
MFC-4700	2/19/04	-	-	-	-	-	-	-
MFC-4700	2/24/04	15.69	267.06	124.23	142.83	-	3.80	43.6
MFC-4700	2/26/04	15.79	259.59	125.02	134.56	-	4.30	47.8
MFC-4700	2/27/04	15.80	259.59	125.10	134.48	-	4.40	37.3
MFC-4700	3/11/04	-	-	-	-	-	-	-
MFC-4700	3/12/04	13.84	279.52	109.57	169.96	-	5.50	17.8
MFC-4700	3/26/04	9.71	319.39	76.82	242.57	-	6.70	5.63
MFC-4700	4/9/04	5.93	329.36	46.86	282.50	-	7.90	5.57
MFC-4700	4/23/04	2.94	313.16	23.15	290.01	-	9.70	2.9
MFC-4700	5/7/04	0.86	345.56	6.67	338.89	-	12.90	4.84
MFC-4700	5/21/04	0.25	318.15	1.83	316.32	-	15.90	3.79
MFC-4700	5/28/04	1.25	242.14	9.76	232.38	-	12.90	644
MFC-4700	6/11/04	0.51	330.61	3.89	326.72	-	13.40	3.63
MFC-4700	6/25/04	0.20	309.43	1.43	307.99	-	23.80	10.3
MFC-4700	7/9/04	0.04	277.03	0.16	276.86	-	16.60	13.8
MFC-4700	7/23/04	0.01	324.38	-0.07	324.45	-	18.60	98.8
MFC-4700	8/6/04	-	349.30	-	-	-	17.10	102
MFC-4700	8/20/04	-	384.19	-	-	-	20.80	60
MFC-4700	9/3/04	-	405.37	-	-	-	12.20	11.8
MFC-4700	9/17/04	0.02	350.54	0.01	350.54	-	14.10	22.3
MFC-4700	10/1/04	0.02	345.56	0.01	345.55	-	12.60	7.81
MFC-4700	10/15/04	0.03	351.79	0.09	351.70	-	9.40	3.12
MFC-4700	10/29/04	0.14	331.85	0.96	330.90	-	5.80	3.97

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
MFC-4700	11/12/04	0.23	280.49	1.67	278.82	-	5.60	2.22
MFC-4700	11/29/04	1.76	276.64	13.80	262.84	-	0.80	6.47
MFC-4700	12/13/04	16.96	313.68	134.30	179.38	-	3.80	11.5
MFC-4700	12/27/04	4.42	309.14	34.89	274.25	-	0.60	3.57
MFC-4700	1/11/05	-	-	-	-	-	-	-
MFC-4700	1/12/05	2.67	280.14	21.01	259.12	-	0.50	22.7
MFC-4700	1/28/05	7.04	279.09	55.66	223.43	-	3.80	9.03
MFC-4700	2/11/05	4.13	288.87	32.59	256.28	-	0.80	2.79
MFC-4700	2/25/05	1.99	263.72	15.62	248.09	-	0.80	13.4
MFC-4700	3/10/05	0.35	264.41	2.62	261.79	-	7.30	2.93
MFC-4700	3/23/05	-	-	-	-	-	-	-
MFC-4700	3/25/05	0.39	287.82	2.94	284.89	-	4.50	22.9
MFC-4700	3/27/05	0.53	283.63	4.05	279.58	-	6.80	11.2
MFC-4700	3/29/05	-	-	-	-	-	-	-
MFC-4700	4/8/05	1.73	297.96	13.56	284.39	-	-	8.8
MFC-4700	4/12/05	-	-	-	-	-	-	-
MFC-4700	4/22/05	0.80	294.81	6.16	288.65	-	-	8.55
MFC-4700	5/6/05	0.11	319.62	0.74	318.89	-	11.60	13.3
MFC-4700	5/20/05	0.10	273.85	0.64	273.21	-	12.70	12.7
MFC-4700	6/7/05	-	296.56	-	-	-	14.30	7.42
MFC-4700	6/24/05	0.06	303.20	0.36	302.84	-	21.60	286
MFC-4700	7/11/05	0.03	309.43	0.12	309.31	-	20.10	7.75
MFC-4700	7/22/05	0.33	369.23	2.46	366.77	-	17.20	6.1
MFC-4700	8/19/05	0.01	458.95	-0.07	459.01	-	16.80	111
MFC-4700	9/3/05	-	-	-	-	-	-	-
MFC-4700	9/20/05	-	-	-	-	-	-	-
MFC-4700	10/7/05	-	429.04	-	-	-	10.70	4.38
MFC-4700	10/21/05	-	350.54	-	-	-	9.30	1.66
MFC-4700	11/4/05	-	314.41	-	-	-	4.80	2.75
MFC-4700	11/18/05	-	293.23	-	-	-	2.20	1.72
MFC-4700	1/6/06	8.12	289.49	64.22	225.27	-	4.80	54.7
MFC-4700	1/23/06	11.80	273.29	93.39	179.90	-	3.40	59.2
MFC-4700	2/6/06	10.70	263.32	84.67	178.65	-	3.20	42.5
MFC-4700	2/28/06	8.03	229.68	63.51	166.17	-	5.10	244
MFC-4700	3/15/06	8.71	274.54	68.90	205.64	-	5.80	42.4
MFC-4700	4/11/06	6.49	243.39	51.30	192.09	-	9.30	71.3
MFC-4700	4/24/06	6.78	304.44	53.60	250.84	-	12.50	10.1
MFC-4700	5/10/06	3.62	320.64	28.55	292.09	8.93	17.10	5.64
MFC-4700	5/20/06	0.49	329.36	3.74	325.62	8.68	20.90	6.06

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
MFC-4700	6/7/06	2.00	308.18	15.70	292.48	7.47	19.90	50.6
MFC-4700	6/29/06	0.42	367.99	3.19	364.80	7.40	21.50	45.2
MFC-4700	7/7/06	-	-	-0.15	-	-	-	-
MFC-4700	7/26/06	0.08	411.60	0.51	411.09	7.22	20.80	18.3
MFC-4700	8/10/06	0.02	405.37	0.04	405.33	7.13	22.10	81.6
MFC-4700	8/25/06	0.00	384.19	-0.13	384.31	7.27	17.40	21.5
MFC-4700	9/6/06	-	394.15	-	-	7.14	21.00	5.31
MFC-4700	9/20/06	0.00	412.84	-0.13	412.97	7.51	13.50	51.8
MFC-4700	10/6/06	-	364.25	-	-	7.32	10.80	121
MFC-4700	10/18/06	0.05	366.74	0.24	366.50	7.51	10.20	3.1
MFC-4700	11/1/06	0.07	366.74	0.40	366.34	7.27	2.50	11.6
MFC-4700	11/6/06	-	-	-	-	-	-	0
MFC-4700	11/10/06	-	-	-	-	-	-	0
MFC-4700	11/15/06	1.06	280.77	8.25	272.52	7.27	4.90	123
MFC-4700	11/29/06	2.34	310.67	18.40	292.27	6.85	1.50	9.28
MFC-4700	12/13/06	8.77	245.88	69.37	176.51	6.84	4.90	94
MFC-4700	12/29/06	8.21	285.75	64.93	220.82	6.82	5.00	45.2
MFC-4700	1/4/07	10.88	209.99	86.10	123.89	6.63	8.90	224
MFC-4700	1/12/07	17.10	324.38	135.41	188.97	6.62	1.60	42.7
MFC-4700	1/26/07	12.13	300.70	96.01	204.69	6.71	4.00	17.2
MFC-4700	2/9/07	13.70	-	108.46	-	6.56	3.10	0
MFC-4700	2/22/07	14.78	-	117.02	-	7.00	4.00	0
MFC-4700	3/7/07	12.29	274.54	97.28	177.26	7.02	10.30	28.2
MFC-4700	3/23/07	10.65	310.67	84.28	226.39	7.14	9.10	16.5
MFC-4700	4/5/07	7.01	318.15	55.42	262.73	7.87	12.50	3.26
MFC-4700	4/19/07	4.05	295.72	31.95	263.76	8.59	8.20	4.87
MFC-4700	5/4/07	1.64	363.00	12.85	350.15	7.14	10.10	3.76
MFC-4700	5/22/07	0.70	319.39	5.40	314.00	7.45	15.20	5.52
MFC-4700	6/4/07	0.08	355.53	0.48	355.05	7.14	20.40	5.77
MFC-4700	6/19/07	0.38	366.74	2.86	363.88	7.14	14.60	19.7
MFC-4700	7/2/07	0.14	369.23	0.96	368.28	-	-	16.9
MFC-4700	7/16/07	0.07	431.53	0.40	431.13	7.19	19.60	21.3
MFC-4700	7/31/07	0.09	421.57	0.56	421.00	8.20	17.10	20.3
MFC-4700	8/13/07	-	-	-	-	-	-	0
MFC-4700	8/21/07	-	-	-	-	-	-	0
MFC-4700	9/4/07	-	-	-	-	-	-	0
MFC-4700	9/21/07	-	354.28	-	-	6.53	20.10	16.8
MFC-4700	10/1/07	-	387.92	-	-	6.75	11.00	18.8
MFC-4700	10/19/07	-	359.27	-	-	6.99	9.00	2.55

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
MFC-4700	11/5/07	-	306.93	-	-	7.12	4.20	1.18
MFC-4700	12/5/07	-	234.67	-	-	6.98	3.90	94.4
MFC-4700	12/17/07	-	284.51	-	-	-	-	4.14
MFC-4700	1/3/08	-	303.20	-	-	6.78	2.80	92.6
MFC-4700	1/18/08	-	-	-	-	-	-	0

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
MFC-5700	10/5/00							
MFC-5700	10/19/00							
MFC-5700	12/7/00	2.96	359.27	23.31	335.95			3.72
MFC-5700	1/9/01	9.54	350.54	75.48	275.07			13.2
MFC-5700	2/2/01	5.58	316.90	44.08	272.82			124
MFC-5700	2/6/01							
MFC-5700	2/20/01							
MFC-5700	3/2/01	5.61	311.92	44.32	267.60			59.9
MFC-5700	3/21/01							
MFC-5700	4/9/01	4.85	330.61	38.30	292.31			7.77
MFC-5700	4/16/01							
MFC-5700	5/2/01	4.99	300.70	39.41	261.30			106
MFC-5700	5/21/01							
MFC-5700	5/30/01	1.32	374.22	10.31	363.90			2.91
MFC-5700	6/15/01							
MFC-5700	7/11/01	1.13	421.57	8.81	412.76			4.46
MFC-5700	9/27/01							
MFC-5700	10/13/01	5.49	461.44	43.37	418.07		8.10	
MFC-5700	10/24/01	0.80	391.66	6.19	385.47		7.60	
MFC-5700	11/7/01							
MFC-5700	11/30/01	2.63	315.66	20.70	294.96		1.10	22.4
MFC-5700	12/14/01	18.35	331.85	145.32	186.53		5.60	41.4
MFC-5700	12/27/01							
MFC-5700	1/7/02							
MFC-5700	1/9/02		252.11	-0.15	252.26		2.90	59.9
MFC-5700	1/24/02	11.59	309.43	91.73	217.70		1.00	18.2
MFC-5700	1/25/02	11.49					0.70	
MFC-5700	1/26/02	13.67	233.42	108.22	125.20		-1.40	104
MFC-5700	1/27/02		267.06	-0.15	267.21		0.80	64.3
MFC-5700	1/29/02		311.92	-0.15	312.07		-0.70	27.5
MFC-5700	2/8/02	12.06	248.37	95.45	152.92		1.80	67.2
MFC-5700	2/22/02	11.02	177.72	87.21	90.51		3.20	334
MFC-5700	2/24/02							
MFC-5700	3/8/02	13.24	285.75	104.81	180.94		-2.00	56.1
MFC-5700	3/11/02	9.10	156.29	71.99	84.30		4.20	1437
MFC-5700	3/12/02							
MFC-5700	3/29/02	11.54	268.31	91.33	176.97		8.10	30.3
MFC-5700	4/12/02	19.39	300.70	153.56	147.14		11.10	9.91
MFC-5700	4/26/02	4.68	319.39	36.95	282.44		11.70	4.86

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
MFC-5700	4/27/02	4.70	324.38	37.11	287.27		10.40	5.12
MFC-5700	5/10/02	3.55	351.79	27.99	323.80		9.00	4.28
MFC-5700	5/24/02	2.47	351.79	19.43	332.36		13.30	3.32
MFC-5700	5/28/02	1.64	346.81	12.85	333.96			5.87
MFC-5700	6/11/02	1.24	339.33	9.68	329.65		14.30	2.48
MFC-5700	6/25/02	1.42	361.76	11.10	350.65		17.40	3.41
MFC-5700	7/9/02	1.67	414.09	13.09	401.00		16.50	4.71
MFC-5700	7/23/02	0.78	452.72	6.03	446.68		20.20	1.59
MFC-5700	9/20/02	0.03	526.23	0.11	526.12		12.60	10.3
MFC-5700	10/16/02	1.37	391.66	10.68	380.98		7.10	2.56
MFC-5700	11/8/02	1.63	345.56	12.78	332.78		2.30	1.99
MFC-5700	11/20/02	1.16	355.53	9.02	346.51		14.90	2
MFC-5700	12/4/02	0.34	341.82	2.55	339.27		2.90	2.35
MFC-5700	12/19/02	1.46	321.89	11.43	310.46		1.10	9.84
MFC-5700	1/10/03	5.01	318.15	39.57	278.58		1.20	19.8
MFC-5700	1/17/03	3.88	318.15	30.63	287.52		2.00	10.2
MFC-5700	1/31/03	5.99	197.29	47.36	149.92			2319
MFC-5700	2/14/03	5.73	326.87	45.28	281.59		4.30	20.7
MFC-5700	2/28/03	5.99	296.97	47.36	249.61		0.30	17.8
MFC-5700	3/14/03	7.06	270.80	55.78	215.01			0.24
MFC-5700	3/28/03	9.78	265.82	77.41	188.41		5.60	44
MFC-5700	4/11/03	8.47	288.24	66.96	221.28			15.2
MFC-5700	4/25/03	5.96	311.92	47.11	264.81		8.30	7.84
MFC-5700	5/9/03	4.11	340.58	32.40	308.17		12.50	6.53
MFC-5700	5/23/03	2.09	331.85	16.41	315.45		13.40	3.32
MFC-5700	6/6/03	1.24	358.02	9.64	348.38		15.20	2.04
MFC-5700	6/20/03	1.50	364.25	11.78	352.47		14.10	2.71
MFC-5700	7/4/03	1.46	391.66	11.43	380.23		16.00	3.42
MFC-5700	7/18/03	0.47	424.06	3.56	420.50		17.70	2.89
MFC-5700	8/1/03	0.05	426.55	0.26	426.29		19.00	13.1
MFC-5700	8/15/03	0.00	424.06	-0.12	424.18		16.40	3.49
MFC-5700	8/29/03	na	457.70				15.00	6.1
MFC-5700	9/12/03	2.92	396.65	23.01	373.63		13.50	11.6
MFC-5700	9/27/03	0.65	493.83	5.00	488.84		14.90	11.7
MFC-5700	10/13/03	0.71	465.18	5.48	459.69		7.90	2.38
MFC-5700	10/24/03	0.79	400.38	6.08	394.30		8.50	3.68
MFC-5700	11/7/03	1.54	386.68	12.04	374.64		2.10	4.91
MFC-5700	11/21/03	1.12	330.92	8.73	322.19		3.20	3.98
MFC-5700	12/5/03	2.56	285.76	20.18	265.58			6.25

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
MFC-5700	12/19/03	13.28	335.10	105.13	229.97		2.60	17.2
MFC-5700	12/22/03							
MFC-5700	12/25/03							
MFC-5700	12/28/03							
MFC-5700	12/31/03							
MFC-5700	1/5/04	9.01	362.69	71.28	291.42		0.40	6.66
MFC-5700	1/9/04							
MFC-5700	1/10/04							
MFC-5700	1/11/04							
MFC-5700	1/12/04							
MFC-5700	1/16/04	12.23	303.32	96.80	206.52		1.90	26.5
MFC-5700	1/19/04							
MFC-5700	1/29/04	11.52	211.33	91.17	120.16		1.90	618
MFC-5700	1/29/04	11.18	197.12	88.48	108.64			1118
MFC-5700	1/30/04	16.88	194.61	133.67	60.94		1.30	707
MFC-5700	2/13/04	15.69	348.48	124.23	224.25		1.30	9.62
MFC-5700	2/19/04							
MFC-5700	2/24/04	15.55	287.00	123.12	163.88		3.90	39.9
MFC-5700	2/26/04	15.56	260.83	123.20	137.63		3.70	56.6
MFC-5700	2/27/04	15.32	265.82	121.30	144.52		4.20	41
MFC-5700	3/11/04							
MFC-5700	3/12/04	12.85	298.21	101.72	196.49		6.30	16.8
MFC-5700	3/26/04	9.62	331.85	76.11	255.74		7.10	5.42
MFC-5700	4/9/04	6.97	341.82	55.10	286.72		8.70	2.39
MFC-5700	4/23/04	5.11	353.04	40.36	312.68		9.60	3.03
MFC-5700	5/7/04	2.37	359.27	18.64	340.63		12.00	4.06
MFC-5700	5/21/04	1.67	336.84	13.09	323.75		14.00	5.36
MFC-5700	5/28/04	1.34	298.21	10.47	287.74		12.90	196
MFC-5700	6/11/04	1.52	354.28	11.90	342.38		11.40	4.05
MFC-5700	6/25/04	1.36	390.42	10.63	379.79		15.50	4.04
MFC-5700	7/9/04	1.33	448.98	10.39	438.59		13.00	38.4
MFC-5700	7/23/04	0.67	491.34	5.16	486.18		16.10	19.4
MFC-5700	8/6/04		536.20				15.10	17.1
MFC-5700	8/20/04		561.12				17.20	5.42
MFC-5700	9/3/04	1.01	333.10	7.85	325.24		13.00	47.2
MFC-5700	9/17/04	2.57	495.08	20.22	474.86		12.60	15.7
MFC-5700	10/1/04	1.41	440.26	11.03	429.23		9.20	1.45
MFC-5700	10/15/04	2.21	399.14	17.37	381.77		7.60	1.83
MFC-5700	10/29/04	1.93	365.50	15.15	350.35		5.10	8.49

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
MFC-5700	11/12/04	1.07	314.38	8.33	306.05		4.90	2.19
MFC-5700	11/29/04	1.32	292.72	10.31	282.40		1.50	9.93
MFC-5700	12/13/04	9.84	294.46	77.86	216.61		3.70	22.7
MFC-5700	12/27/04	5.07	308.09	40.04	268.05		1.00	4.51
MFC-5700	1/11/05							
MFC-5700	1/12/05	2.94	297.61	23.15	274.45		0.60	43.9
MFC-5700	1/28/05	7.12	293.07	56.29	236.77		3.40	7.94
MFC-5700	2/11/05	4.14	294.46	32.67	261.80		0.50	4.58
MFC-5700	2/25/05	2.65	294.81	20.86	273.96		0.70	4.07
MFC-5700	3/10/05	1.28	281.54	9.99	271.54		5.70	2.88
MFC-5700	3/23/05							
MFC-5700	3/25/05	0.84	301.10	6.51	294.60		4.60	2.02
MFC-5700	3/27/05	3.31	314.03	26.09	287.94		5.80	34.3
MFC-5700	3/29/05	na						
MFC-5700	4/8/05	3.04	300.75	23.95	276.81			14.9
MFC-5700	4/12/05	na						
MFC-5700	4/22/05	2.18	318.92	17.13	301.79			6.28
MFC-5700	5/6/05	1.52	358.75	11.90	346.86		11.30	6.04
MFC-5700	5/20/05	1.23	297.26	9.60	287.66		12.60	23.7
MFC-5700	6/7/05	1.90	345.13	14.91	330.22		10.70	2.21
MFC-5700	6/24/05	1.19	387.92	9.28	378.64		15.30	153
MFC-5700	7/11/05	1.19	414.09	9.28	404.81		16.50	3.67
MFC-5700	7/22/05	0.41	419.07	3.07	416.01		16.40	2.2
MFC-5700	8/19/05	0.01	502.56	-0.04	502.59		12.70	4.52
MFC-5700	9/3/05	na	491.34				12.20	5.34
MFC-5700	9/20/05	na	508.79				8.20	6.18
MFC-5700	10/7/05	2.21	379.20	17.37	361.83		8.40	5.06
MFC-5700	10/21/05	0.99	465.18	7.68	457.49		11.80	2.44
MFC-5700	11/4/05	4.63	339.33	36.55	302.78		5.70	27.3
MFC-5700	11/18/05	1.60	339.33	12.53	326.80		3.10	1.93
MFC-5700	1/6/06	8.70		68.82	-68.82		3.90	22.5
MFC-5700	1/23/06	11.20	288.24	88.64	199.61		3.50	56.2
MFC-5700	2/6/06	10.90	273.29	86.26	187.03		6.10	40.3
MFC-5700	2/28/06	8.07	247.13	63.82	183.30		4.90	273
MFC-5700	3/15/06	8.54	299.46	67.55	231.91		3.80	26.8
MFC-5700	4/11/06	5.81	262.08	45.91	216.17		8.40	95.2
MFC-5700	4/24/06	6.91	344.31	54.63	289.69		11.00	7.22
MFC-5700	5/10/06	4.91	341.82	38.77	303.05	8.52	16.40	4.98
MFC-5700	5/20/06	2.48	361.76	19.51	342.25	7.79	20.00	17.6

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
MFC-5700	6/7/06	2.29	295.72	18.00	277.72	7.47	19.00	209
MFC-5700	6/29/06	1.21	389.17	9.44	379.73	7.59	19.40	6.03
MFC-5700	7/7/06			-0.15				
MFC-5700	7/26/06	0.56	470.16	4.30	465.86	7.38	20.10	5.65
MFC-5700	8/10/06	0.20	481.37	1.41	479.96	8.06	21.50	5.74
MFC-5700	8/25/06	0.37	515.02	2.77	512.24	7.51	15.50	9.18
MFC-5700	9/6/06	0.07	481.37	0.41	480.96	7.61	19.90	3.21
MFC-5700	9/20/06	0.54	517.51	4.13	513.38	7.36	13.50	6.94
MFC-5700	10/6/06	2.60	528.72	20.46	508.26	7.68	12.00	5.25
MFC-5700	10/18/06	2.56	146.20	20.14	126.06	7.22	12.30	4.44
MFC-5700	11/1/06	2.99	492.59	23.55	469.04	7.18	5.20	1.94
MFC-5700	11/6/06	na						0
MFC-5700	11/10/06	na						0
MFC-5700	11/15/06	2.76	452.72	21.73	430.99	7.15	7.00	6.37
MFC-5700	11/29/06	9.51	380.45	75.24	305.21	6.30	5.30	13.2
MFC-5700	12/13/06	10.53	265.82	83.33	182.49	6.62	5.70	538
MFC-5700	12/29/06	10.85	291.98	85.86	206.12	7.68	4.60	65.1
MFC-5700	1/4/07	12.57	224.70	99.50	125.20	6.52	9.60	292
MFC-5700	1/12/07	17.35	331.85	137.39	194.46	7.72	4.40	40.1
MFC-5700	1/26/07	13.23	319.39	104.73	214.66	6.32	6.60	15.1
MFC-5700	2/9/07	14.08	na	111.47		5.93	12.00	
MFC-5700	2/22/07	14.19	na	112.34		4.48	4.60	
MFC-5700	3/7/07	12.01	289.49	95.06	194.43	6.67	12.20	21.8
MFC-5700	3/23/07	10.35	326.87	81.90	244.97	7.04	8.60	6.17
MFC-5700	4/5/07	7.29	336.84	57.64	279.20	7.65	10.70	4.05
MFC-5700	4/19/07	4.46	314.41	35.20	279.20	7.03	8.50	4.23
MFC-5700	5/4/07	2.71	350.54	21.33	329.21	7.59	10.10	3.96
MFC-5700	5/22/07	1.54	351.79	12.06	339.73	7.43	13.70	26
MFC-5700	6/4/07	0.98	351.79	7.62	344.17	7.26	19.90	2.07
MFC-5700	6/19/07	1.26	374.22	9.84	364.38	7.05	14.30	19.8
MFC-5700	7/2/07	1.14	405.37	8.89	396.48			17.3
MFC-5700	7/16/07	0.36	462.68	2.70	459.98	6.81	17.70	20.9
MFC-5700	7/31/07	0.12	520.00	0.80	519.20	6.73	15.10	20.4
MFC-5700	8/13/07	na						0
MFC-5700	8/21/07	na						0
MFC-5700	9/4/07	na						0
MFC-5700	9/21/07	na						0
MFC-5700	10/1/07	na						0
MFC-5700	10/19/07	na	422.81			7.03	9.10	2.52

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbidity (NTU)
MFC-5700	11/5/07	na	406.61			7.24	4.50	1.68
MFC-5700	12/5/07	na	209.6204			6.87	5.2	69.5
MFC-5700	12/17/07	na	338.083					3.48
MFC-5700	1/3/08	na	338.083			6.45	6.2	5.47
MFC-5700	1/18/08	na						

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbitiy (NTU)
Rain @ A	10/5/00	-	-	-	-	-	-	-
Rain @ A	10/19/00	-	-	-	-	-	-	-
Rain @ A	12/8/00	-	-	-	-	-	-	-
Rain @ A	1/9/01	-	-	-	-	-	-	-
Rain @ A	2/5/01	-	-	-	-	-	-	-
Rain @ A	2/6/01	-	-	-	-	-	-	-
Rain @ A	2/19/01	-	-	-	-	-	-	-
Rain @ A	3/3/01	-	-	-	-	-	-	-
Rain @ A	3/20/01	-	-	-	-	-	-	-
Rain @ A	4/12/01	-	-	-	-	-	-	-
Rain @ A	4/16/01	-	-	-	-	-	-	-
Rain @ A	5/2/01	-	-	-	-	-	-	-
Rain @ A	5/21/01	-	-	-	-	-	-	-
Rain @ A	5/30/01	-	-	-	-	-	-	-
Rain @ A	6/14/01	-	-	-	-	-	-	-
Rain @ A	7/26/01	-	-	-	-	-	-	-
Rain @ A	9/27/01	-	-	-	-	-	-	-
Rain @ A	10/13/01	-	-	-	-	-	-	-
Rain @ A	10/24/01	-	-	-	-	-	-	-
Rain @ A	11/7/01	-	-	-	-	-	-	-
Rain @ A	11/30/01	-	-	-	-	-	-	-
Rain @ A	12/14/01	-	-	-	-	-	-	-
Rain @ A	12/27/01	-	-	-	-	-	-	-
Rain @ A	1/7/02	-	-	-	-	-	-	-
Rain @ A	1/10/02	-	-	-	-	-	-	-
Rain @ A	1/24/02	-	-	-	-	-	-	-
Rain @ A	1/25/02	-	-	-	-	-	-	-
Rain @ A	1/26/02	-	-	-	-	-	-	-
Rain @ A	1/27/02	-	-	-	-	-	-	-
Rain @ A	1/29/02	-	-	-	-	-	-	-
Rain @ A	2/8/02	-	-	-	-	-	-	-
Rain @ A	2/22/02	-	-	-	-	-	-	-
Rain @ A	2/24/02	-	-	-	-	-	-	-
Rain @ A	3/8/02	-	-	-	-	-	-	-
Rain @ A	3/11/02	-	-	-	-	-	-	-
Rain @ A	3/12/02	-	-	-	-	-	-	-
Rain @ A	3/29/02	-	-	-	-	-	-	-
Rain @ A	4/12/02	-	-	-	-	-	-	-
Rain @ A	4/26/02	-	-	-	-	-	-	-

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbitiy (NTU)
Rain @ A	4/27/02	-	-	-	-	-	-	-
Rain @ A	5/10/02	-	-	-	-	-	-	-
Rain @ A	5/24/02	-	-	-	-	-	-	-
Rain @ A	5/28/02	-	-	-	-	-	-	-
Rain @ A	6/11/02	-	-	-	-	-	-	-
Rain @ A	6/25/02	-	-	-	-	-	-	-
Rain @ A	7/9/02	-	-	-	-	-	-	-
Rain @ A	7/23/02	-	-	-	-	-	-	-
Rain @ A	9/20/02	-	-	-	-	-	-	-
Rain @ A	10/16/02	-	-	-	-	-	-	-
Rain @ A	11/8/02	-	-	-	-	-	-	-
Rain @ A	11/20/02	-	-	-	-	-	-	-
Rain @ A	12/4/02	-	-	-	-	-	-	-
Rain @ A	12/19/02	-	24.78	-	-	-	-	-
Rain @ A	1/10/03	-	22.59	-	-	-	-	-
Rain @ A	1/17/03	-	16.42	-	-	-	-	-
Rain @ A	1/31/03	-	4.21	-	-	-	-	-
Rain @ A	2/14/03	-	14.36	-	-	-	-	-
Rain @ A	2/28/03	-	-	-	-	-	-	-
Rain @ A	3/14/03	-	-	-	-	-	-	-
Rain @ A	3/28/03	-	13.62	-	-	-	-	-
Rain @ A	4/11/03	-	-	-	-	-	-	-
Rain @ A	4/25/03	-	144.70	-	-	-	-	-
Rain @ A	5/9/03	-	67.45	-	-	-	-	-
Rain @ A	5/23/03	-	0.13	-	-	-	-	-
Rain @ A	6/6/03	-	-	-	-	-	-	-
Rain @ A	6/20/03	-	-	-	-	-	-	-
Rain @ A	7/4/03	-	-	-	-	-	-	-
Rain @ A	7/18/03	-	-	-	-	-	-	-
Rain @ A	8/1/03	-	-	-	-	-	-	-
Rain @ A	8/15/03	-	385.43	-	-	-	-	-
Rain @ A	8/29/03	-	-	-	-	-	-	-
Rain @ A	9/12/03	-	290.74	-	-	-	-	-
Rain @ A	9/27/03	-	30.77	-	-	-	-	-
Rain @ A	10/13/03	-	-	-	-	-	-	-
Rain @ A	10/24/03	-	58.18	-	-	-	-	-
Rain @ A	11/16/03	-	-	-	-	-	-	-
Rain @ A	11/21/03	-	27.29	-	-	-	-	-
Rain @ A	12/5/03	-	18.06	-	-	-	-	-

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbitiy (NTU)
Rain @ A	12/19/03	-	11.70	-	-	-	-	-
Rain @ A	12/22/03	-	-	-	-	-	-	-
Rain @ A	12/25/03	-	17.93	-	-	-	-	-
Rain @ A	12/28/03	-	-	-	-	-	-	-
Rain @ A	12/31/03	-	-	-	-	-	-	-
Rain @ A	1/5/04	-	-	-	-	-	-	-
Rain @ A	1/9/04	-	14.38	-	-	-	-	-
Rain @ A	1/10/04	-	-	-	-	-	-	-
Rain @ A	1/11/04	-	-	-	-	-	-	-
Rain @ A	1/12/04	-	-	-	-	-	-	-
Rain @ A	1/16/04	-	34.25	-	-	-	-	-
Rain @ A	1/19/04	-	-	-	-	-	-	-
Rain @ A	1/29/04	-	7.76	-	-	-	-	-
Rain @ A	1/30/04	-	5.48	-	-	-	-	-
Rain @ A	2/13/04	-	176.21	-	-	-	-	-
Rain @ A	2/19/04	-	-	-	-	-	-	-
Rain @ A	2/24/04	-	8.37	-	-	-	-	-
Rain @ A	2/26/04	-	8.11	-	-	-	-	-
Rain @ A	2/27/04	-	-	-	-	-	-	-
Rain @ A	3/11/04	-	-	-	-	-	-	-
Rain @ A	3/12/04	-	8.29	-	-	-	-	-
Rain @ A	3/26/04	-	-	-	-	-	-	-
Rain @ A	4/9/04	-	65.76	-	-	-	-	-
Rain @ A	4/23/04	-	400.38	-	-	-	-	-
Rain @ A	5/7/04	-	-	-	-	-	-	-
Rain @ A	5/21/04	-	58.38	-	-	-	-	-
Rain @ A	5/28/04	-	30.17	-	-	-	-	-
Rain @ A	6/11/04	-	26.98	-	-	-	-	-
Rain @ A	6/25/04	-	-	-	-	-	-	-
Rain @ A	7/9/04	-	-	-	-	-	-	-
Rain @ A	7/23/04	-	244.63	-	-	-	-	-
Rain @ A	8/6/04	-	-	-	-	-	-	-
Rain @ A	8/20/04	-	53.60	-	-	-	-	-
Rain @ A	9/3/04	-	35.95	-	-	-	-	-
Rain @ A	9/17/04	-	-	-	-	-	-	-
Rain @ A	10/1/04	-	-	-	-	-	-	-
Rain @ A	10/15/04	-	74.73	-	-	-	-	-
Rain @ A	10/29/04	-	10.88	-	-	-	-	-
Rain @ A	11/12/04	-	25.43	-	-	-	-	-

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbitiy (NTU)
Rain @ A	11/29/04	-	17.35	-	-	-	-	-
Rain @ A	12/13/04	-	7.87	-	-	-	-	-
Rain @ A	12/27/04	-	-	-	-	-	-	-
Rain @ A	1/11/05	-	17.27	-	-	-	-	-
Rain @ A	1/12/05	-	-	-	-	-	-	-
Rain @ A	1/28/05	-	8.01	-	-	-	-	-
Rain @ A	2/11/05	-	-	-	-	-	-	-
Rain @ A	2/25/05	-	-	-	-	-	-	-
Rain @ A	3/10/05	-	-	-	-	-	-	-
Rain @ A	3/23/05	-	-	-	-	-	-	-
Rain @ A	3/25/05	-	23.45	-	-	-	-	-
Rain @ A	3/27/05	-	7.46	-	-	-	-	21.40
Rain @ A	3/29/05	-	-	-	-	-	-	-
Rain @ A	4/8/05	-	8.15	-	-	-	-	-
Rain @ A	4/12/05	-	33.46	-	-	-	-	-
Rain @ A	4/22/05	-	13.33	-	-	-	-	-
Rain @ A	5/6/05	-	-	-	-	-	-	-
Rain @ A	5/20/05	-	9.72	-	-	-	-	-
Rain @ A	6/7/05	-	4.91	-	-	-	-	-
Rain @ A	6/24/05	-	17.47	-	-	-	-	-
Rain @ A	7/11/05	-	50.41	-	-	-	-	-
Rain @ A	7/22/05	-	-	-	-	-	-	-
Rain @ A	8/19/05	-	252.11	-	-	-	-	-
Rain @ A	9/3/05	-	-	-	-	-	-	-
Rain @ A	9/20/05	2.89	304.44	22.76	281.68	-	-	-
Rain @ A	10/7/05	-	253.36	-	-	-	-	-
Rain @ A	10/21/05	-	44.62	-	-	-	-	-
Rain @ A	11/4/05	-	20.60	-	-	-	-	-
Rain @ A	11/18/05	-	13.19	-	-	-	-	-
Rain @ A	1/6/06	-	12.79	-	-	-	-	-
Rain @ A	1/23/06	-	0.07	-	-	-	-	-
Rain @ A	2/6/06	-	9.19	-	-	-	-	48.10
Rain @ A	2/28/06	-	13.65	-	-	-	-	-
Rain @ A	3/15/06	-	11.93	-	-	-	-	-
Rain @ A	4/11/06	-	9.82	-	-	-	-	-
Rain @ A	4/24/06	-	-	-	-	-	-	-
Rain @ A	5/10/06	-	-	-	-	-	-	-
Rain @ A	5/20/06	0.26	11.47	1.94	9.53	6.36	-	9.32
Rain @ A	6/7/06	-	-	-	-	-	-	-

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbitiy (NTU)
Rain @ A	6/29/06	-	-	-	-	-	-	-
Rain @ A	7/7/06	0.45	14.05	3.44	10.61	-	-	-
Rain @ A	7/26/06	-	-	-	-	-	-	-
Rain @ A	8/10/06	-	-	-	-	-	-	-
Rain @ A	8/25/06	5.67	239.65	44.80	194.85	-	-	-
Rain @ A	9/6/06	-	-	-	-	-	-	-
Rain @ A	9/22/06	1.45	52.10	11.34	40.76	-	-	-
Rain @ A	10/6/06	-	-	-	-	-	-	-
Rain @ A	10/18/06	1.13	38.74	8.81	29.94	7.69	-	-
Rain @ A	11/1/06	0.60	17.05	4.60	12.44	7.72	-	-
Rain @ A	11/6/06	0.26	10.83	1.91	8.92	7.56	-	-
Rain @ A	11/10/06	0.19	7.60	1.35	6.25	7.62	-	-
Rain @ A	11/15/06	0.24	9.39	1.75	7.64	7.80	-	-
Rain @ A	11/29/06	0.29	8.96	2.15	6.81	-	-	-
Rain @ A	12/13/06	0.51	10.22	3.89	6.33	7.72	-	-
Rain @ A	12/29/06	0.32	11.32	2.38	8.94	-	-	-
Rain @ A	1/4/07	0.14	4.73	0.96	3.78	7.79	-	-
Rain @ A	1/12/07	0.50	-	3.81	-	-	-	-
Rain @ A	1/26/07	-	-	-	-	-	-	-
Rain @ A	2/9/07	1.48	-	11.58	-	-	-	-
Rain @ A	2/22/07	0.36	-	2.70	-	-	-	-
Rain @ A	3/7/07	0.45	-	3.42	-	-	-	-
Rain @ A	3/23/07	0.49	10.35	3.73	6.61	7.51	-	-
Rain @ A	4/5/07	0.50	12.74	3.81	8.93	-	-	-
Rain @ A	4/19/07	-	-	-	-	-	-	-
Rain @ A	5/4/07	1.42	32.16	11.10	21.06	-	-	-
Rain @ A	5/22/07	0.89	24.48	6.90	17.58	7.50	-	-
Rain @ A	6/4/07	1.16	34.95	9.04	25.91	7.42	-	-
Rain @ A	6/19/07	0.51	18.01	3.89	14.12	7.29	-	19.90
Rain @ A	7/2/07	-	345.56	-	-	-	-	20.00
Rain @ A	7/16/07	-	-	-	-	-	-	-
Rain @ A	7/31/07	5.07	233.42	40.04	193.38	9.98	-	22.40
Rain @ A	8/13/07	-	-	-	-	-	-	-
Rain @ A	8/21/07	1.52	97.86	11.90	85.97	-	-	18.80
Rain @ A	9/4/07	1.38	68.85	10.79	58.06	7.25	-	21.00
Rain @ A	9/21/07	-	250.86	-	-	6.98	-	19.50
Rain @ A	10/1/07	-	143.71	-	-	6.98	-	19.20
Rain @ A	10/19/07	-	26.08	-	-	7.35	-	-
Rain @ A	11/5/07	-	-	-	-	-	-	-

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbitiy (NTU)
Rain @ A	12/5/07	-	22.09	-	-	-	-	-
Rain @ A	12/17/07	-	-	-	-	-	-	-
Rain @ A	1/3/08	-	6.55	-	-	-	-	14.30
Rain @ A	1/18/08	-	-	-	-	-	-	-

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbitiy (NTU)
Rain @ C	10/5/00	-	-	-	-	-	-	-
Rain @ C	10/19/00	-	-	-	-	-	-	-
Rain @ C	12/8/00	-	-	-	-	-	-	-
Rain @ C	1/9/01	-	-	-	-	-	-	-
Rain @ C	2/5/01	-	-	-	-	-	-	-
Rain @ C	2/6/01	-	-	-	-	-	-	-
Rain @ C	2/19/01	-	-	-	-	-	-	-
Rain @ C	3/3/01	-	-	-	-	-	-	-
Rain @ C	3/20/01	-	-	-	-	-	-	-
Rain @ C	4/12/01	-	-	-	-	-	-	-
Rain @ C	4/16/01	-	-	-	-	-	-	-
Rain @ C	5/2/01	-	-	-	-	-	-	-
Rain @ C	5/21/01	-	-	-	-	-	-	-
Rain @ C	5/30/01	-	-	-	-	-	-	-
Rain @ C	6/14/01	-	-	-	-	-	-	-
Rain @ C	7/11/01	-	-	-	-	-	-	-
Rain @ C	9/27/01	-	-	-	-	-	-	-
Rain @ C	10/13/01	-	-	-	-	-	-	-
Rain @ C	10/24/01	-	-	-	-	-	-	-
Rain @ C	11/7/01	-	-	-	-	-	-	-
Rain @ C	11/30/01	-	-	-	-	-	-	-
Rain @ C	12/14/01	-	-	-	-	-	-	-
Rain @ C	12/27/01	-	-	-	-	-	-	-
Rain @ C	1/7/02	-	-	-	-	-	-	-
Rain @ C	1/9/02	-	-	-	-	-	-	-
Rain @ C	1/24/02	-	-	-	-	-	-	-
Rain @ C	1/25/02	-	-	-	-	-	-	-
Rain @ C	1/26/02	-	-	-	-	-	-	-
Rain @ C	1/27/02	-	-	-	-	-	-	-
Rain @ C	1/29/02	-	-	-	-	-	-	-
Rain @ C	2/8/02	-	-	-	-	-	-	-
Rain @ C	2/22/02	-	-	-	-	-	-	-
Rain @ C	2/24/02	-	-	-	-	-	-	-
Rain @ C	3/8/02	-	-	-	-	-	-	-
Rain @ C	3/11/02	-	-	-	-	-	-	-
Rain @ C	3/12/02	-	-	-	-	-	-	-
Rain @ C	3/29/02	-	-	-	-	-	-	-
Rain @ C	4/12/02	-	-	-	-	-	-	-
Rain @ C	4/26/02	-	-	-	-	-	-	-

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbitiy (NTU)
Rain @ C	4/27/02	-	-	-	-	-	-	-
Rain @ C	5/10/02	-	-	-	-	-	-	-
Rain @ C	5/24/02	-	-	-	-	-	-	-
Rain @ C	5/28/02	-	-	-	-	-	-	-
Rain @ C	6/11/02	-	-	-	-	-	-	-
Rain @ C	6/25/02	-	-	-	-	-	-	-
Rain @ C	7/9/02	-	-	-	-	-	-	-
Rain @ C	7/23/02	-	-	-	-	-	-	-
Rain @ C	9/20/02	-	-	-	-	-	-	-
Rain @ C	10/16/02	-	-	-	-	-	-	-
Rain @ C	11/8/02	-	-	-	-	-	-	-
Rain @ C	11/20/02	-	-	-	-	-	-	-
Rain @ C	12/4/02	-	-	-	-	-	-	-
Rain @ C	12/19/02	-	-	-	-	-	-	-
Rain @ C	1/10/03	-	-	-	-	-	-	-
Rain @ C	1/17/03	-	-	-	-	-	-	-
Rain @ C	1/31/03	-	-	-	-	-	-	-
Rain @ C	2/14/03	-	-	-	-	-	-	-
Rain @ C	2/28/03	-	-	-	-	-	-	-
Rain @ C	3/14/03	-	-	-	-	-	-	-
Rain @ C	3/28/03	-	-	-	-	-	-	-
Rain @ C	4/11/03	-	-	-	-	-	-	-
Rain @ C	4/25/03	-	-	-	-	-	-	-
Rain @ C	5/9/03	-	-	-	-	-	-	-
Rain @ C	5/23/03	-	-	-	-	-	-	-
Rain @ C	6/6/03	-	-	-	-	-	-	-
Rain @ C	6/20/03	-	-	-	-	-	-	-
Rain @ C	7/4/03	-	-	-	-	-	-	-
Rain @ C	7/18/03	-	-	-	-	-	-	-
Rain @ C	8/1/03	-	-	-	-	-	-	-
Rain @ C	8/15/03	-	-	-	-	-	-	-
Rain @ C	8/29/03	-	-	-	-	-	-	-
Rain @ C	9/12/03	-	-	-	-	-	-	-
Rain @ C	9/27/03	-	-	-	-	-	-	-
Rain @ C	10/13/03	-	-	-	-	-	-	-
Rain @ C	10/24/03	-	-	-	-	-	-	-
Rain @ C	11/7/03	-	-	-	-	-	-	-
Rain @ C	11/21/03	-	-	-	-	-	-	-
Rain @ C	12/5/03	-	-	-	-	-	-	-

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbitiy (NTU)
Rain @ C	12/19/03	-	-	-	-	-	-	-
Rain @ C	12/22/03	-	-	-	-	-	-	-
Rain @ C	12/25/03	-	-	-	-	-	-	-
Rain @ C	12/28/03	-	-	-	-	-	-	-
Rain @ C	12/31/03	-	-	-	-	-	-	-
Rain @ C	1/5/04	-	-	-	-	-	-	-
Rain @ C	1/9/04	-	-	-	-	-	-	-
Rain @ C	1/10/04	-	-	-	-	-	-	-
Rain @ C	1/11/04	-	-	-	-	-	-	-
Rain @ C	1/12/04	-	-	-	-	-	-	-
Rain @ C	1/16/04	-	-	-	-	-	-	-
Rain @ C	1/19/04	-	-	-	-	-	-	-
Rain @ C	1/29/04	-	-	-	-	-	-	-
Rain @ C	1/29/04	-	-	-	-	-	-	-
Rain @ C	1/30/04	-	-	-	-	-	-	-
Rain @ C	2/13/04	-	-	-	-	-	-	-
Rain @ C	2/19/04	-	-	-	-	-	-	-
Rain @ C	2/24/04	-	-	-	-	-	-	-
Rain @ C	2/26/04	-	-	-	-	-	-	-
Rain @ C	2/27/04	-	-	-	-	-	-	-
Rain @ C	3/11/04	-	-	-	-	-	-	-
Rain @ C	3/12/04	-	-	-	-	-	-	-
Rain @ C	3/26/04	-	-	-	-	-	-	-
Rain @ C	4/9/04	-	-	-	-	-	-	-
Rain @ C	4/23/04	-	-	-	-	-	-	-
Rain @ C	5/7/04	-	-	-	-	-	-	-
Rain @ C	5/21/04	-	-	-	-	-	-	-
Rain @ C	5/28/04	-	-	-	-	-	-	-
Rain @ C	6/11/04	-	-	-	-	-	-	-
Rain @ C	6/25/04	-	-	-	-	-	-	-
Rain @ C	7/9/04	-	-	-	-	-	-	-
Rain @ C	7/23/04	-	-	-	-	-	-	-
Rain @ C	8/6/04	-	-	-	-	-	-	-
Rain @ C	8/20/04	-	-	-	-	-	-	-
Rain @ C	9/3/04	-	-	-	-	-	-	-
Rain @ C	9/17/04	-	-	-	-	-	-	-
Rain @ C	10/1/04	-	-	-	-	-	-	-
Rain @ C	10/15/04	-	-	-	-	-	-	-
Rain @ C	10/29/04	-	-	-	-	-	-	-

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbitiy (NTU)
Rain @ C	11/12/04	-	3.82	-	-	-	-	-
Rain @ C	11/29/04	-	9.55	-	-	-	-	-
Rain @ C	12/13/04	-	3.60	-	-	-	-	-
Rain @ C	12/27/04	-	-	-	-	-	-	-
Rain @ C	1/11/05	-	9.30	-	-	-	-	-
Rain @ C	1/12/05	-	-	-	0.00	-	-	-
Rain @ C	1/28/05	-	4.18	-	4.18	-	-	-
Rain @ C	2/11/05	-	-	-	0.00	-	-	-
Rain @ C	2/25/05	-	-	-	0.00	-	-	-
Rain @ C	3/10/05	-	-	-	0.00	-	-	-
Rain @ C	3/23/05	-	-	-	0.00	-	-	-
Rain @ C	3/25/05	-	6.36	-	6.36	-	-	-
Rain @ C	3/27/05	-	1.75	-	1.75	-	-	-
Rain @ C	3/29/05	-	-	-	0.00	-	-	-
Rain @ C	4/8/05	-	2.59	-	2.59	-	-	-
Rain @ C	4/12/05	-	-	-	0.00	-	-	-
Rain @ C	4/22/05	-	-	-	0.00	-	-	-
Rain @ C	5/6/05	-	-	-	0.00	-	-	-
Rain @ C	5/20/05	-	2.73	-	2.73	-	-	-
Rain @ C	6/7/05	-	5.19	-	5.19	-	-	-
Rain @ C	6/24/05	-	10.98	-	10.98	-	-	-
Rain @ C	7/11/05	-	4.18	-	4.18	-	-	-
Rain @ C	7/22/05	-	-	-	-	-	-	-
Rain @ C	8/19/05	-	-	-	-	-	-	-
Rain @ C	9/3/05	-	-	-	-	-	-	-
Rain @ C	9/20/05	-	-	-	-	-	-	-
Rain @ C	10/7/05	-	12.28	-	12.28	-	-	-
Rain @ C	10/21/05	-	41.83	-	41.83	-	-	-
Rain @ C	11/4/05	-	15.21	-	15.21	-	-	-
Rain @ C	11/18/05	-	4.46	-	4.46	-	-	-
Rain @ C	1/6/06	-	2.67	-	2.67	-	-	-
Rain @ C	1/23/06	-	-	-	-	-	-	-
Rain @ C	2/6/06	-	-	-	-	-	-	-
Rain @ C	2/28/06	-	-	-	-	-	-	-
Rain @ C	3/15/06	-	-	-	-	-	-	-
Rain @ C	4/11/06	-	-	-	-	-	-	-
Rain @ C	4/24/06	-	-	-	-	-	-	-
Rain @ C	5/10/06	-	-	-	-	-	-	-
Rain @ C	5/20/06	-	-	-	-	-	-	-

Sample location	Sample Date	N-NO3- (mg/L)	Meter Corrected EC (uS/cm)	EC Correction	Corrected EC (uS/cm)	Field pH	Field Temp (C)	Turbitiy (NTU)
Rain @ C	6/7/06	-	-	-	-	-	-	-
Rain @ C	6/29/06	-	-	-	-	-	-	-
Rain @ C	7/7/06	-	-	-	-	-	-	-
Rain @ C	7/26/06	-	-	-	-	-	-	-
Rain @ C	8/10/06	-	-	-	-	-	-	-
Rain @ C	8/25/06	-	-	-	-	-	-	-
Rain @ C	9/6/06	-	-	-	-	-	-	-
Rain @ C	9/20/06	-	-	-	-	-	-	-
Rain @ C	10/6/06	-	-	-	-	-	-	-
Rain @ C	10/18/06	-	-	-	-	-	-	-

APPENDIX B Potential Evaporation as an Upper Constraint on Total Evaporation

Potential evapotranspiration (PET) is an estimate for the upper constraint for ET that may occur in a watershed. The Thornthwaite (1948) method of PET estimation utilizes average monthly temperatures, latitude of the site, length of daylight, but does not consider humidity, different plant types, wind, or precipitation amounts. PET for the MFC watershed was estimated using the Thornthwaite equation (Thornthwaite, 1948):

$$PET_{Thornwaite} = 1.6\left(\frac{10T_{average}}{I}\right)^{a} \quad (1)$$

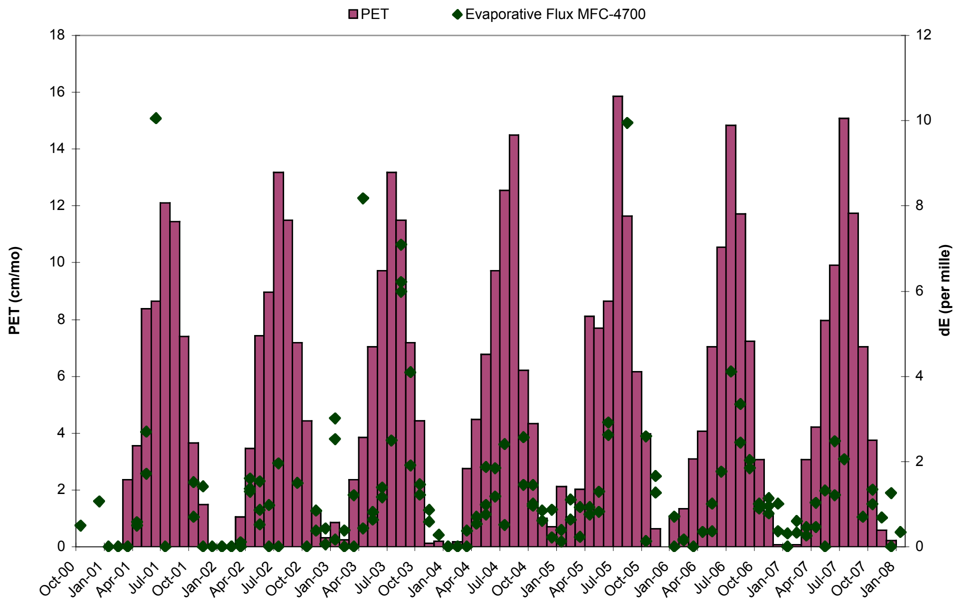
$$a = \left(6.75\times10^{-7}\right)I^{3} - \left(7.71\times10^{-5}\right)I^{2} + \left(1.792\times10^{-2}\right)I + 0.49239 \quad (2)$$

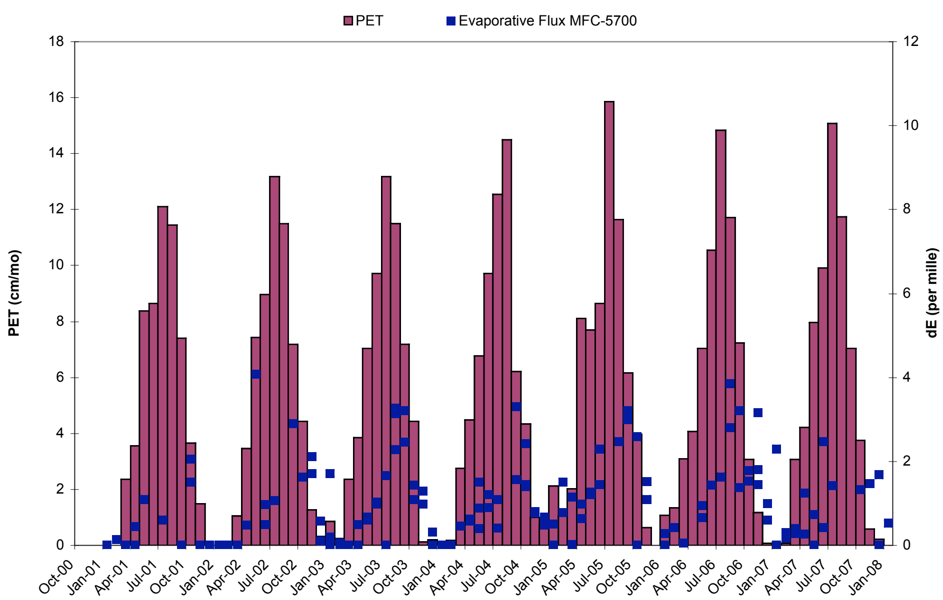
$$I = \sum_{i=month}^{n}\left(\frac{T_{average}}{5}\right)^{1.514} \quad (3)$$

Where $PET_{Thornwaite}$ is the potential evapotranspiration for a given month in cm/month, I is the annual Temperature Index, $T_{average}$ is the average temperature in ºC for a given month, a is a empirical constant based the temperature index for a given year. The $PET_{Thornwaite}$ calculates potential evapotranspiration for a 12 hour day and 30 day month, therefore $PET_{Thornwaite}$ is corrected for the latitude of the site, in the case of Pullman latitude is ~48º N, the average length of daylight for that month, and the number of days in the month.

Potential evapotranspiration (PET) according to the Thornthwaite equation qualitatively determines the periods of highest $\delta^{18}O$ fractionation due to ET that occurs at both MFC-4700 and MFC-5700 (Figures 10a, 10b). There is a departure from winter baseline $\delta^{18}O$ (TD-12), which appears to be driven by surface water evaporation when ET is the highest. A time lag for the most enriched surface waters is 1-2 months after the highest calculated $PET_{Thornewaite}$ (usually in July) and is probably due to disturbance (i.e. August harvest) that increases the amount of surface water exposure to ET. On the other hand, during periods of high humidity (early summer), fractionation due to evaporation is less and may lead to the observed delay of $\delta^{18}O$ enrichment in surface waters (late summer when humidity is low).

Figures APP B 1, APP B 2





Calculated $PET_{Thornewaite}$ and observed fractionation of surface waters at MFC-4700 (Figure APP B 1 and MFC-5700 (Figure APP B 2). Highest $PET_{Thornewaite}$ occurs in July. Highest isotope fractionation occurs during August and September.

Appendix B

Date	Max Tc	Min Tc	Avg Tc	Monthly index I	Temperature Index, I	a	Uncorrected PET (cm/mo)	Lat/ daylight correction	Days/ month Correction	Corrected PET (cm/mo)	Monthly PPT (mm)	Cumulative PPT (mm)
Oct-00											27.7	27.7
Nov-00											40.2	67.9
Dec-00	2.79	-25.08	-3.19	0.00							30.73	98.63
Jan-01	6.65	-13.93	-1.37	0.00	30.33	0.98	0.00	0.77	1.03	0.00	29.46	128.09
Feb-01	6.49	-11.91	-1.21	0.00			0.00	0.80	0.93	0.00	30.23	158.32
Mar-01	18.46	-5.12	4.27	0.79			2.24	1.02	1.03	2.36	36.83	195.15
Apr-01	23.80	-5.32	5.99	1.31			3.13	1.14	1.00	3.56	61.72	256.87
May-01	31.35	-3.17	12.09	3.81			6.24	1.30	1.03	8.38	25.15	282.02
Jun-01	28.71	0.32	12.71	4.11			6.55	1.32	1.00	8.65	32.77	314.79
Jul-01	33.37	3.57	17.18	6.48			8.81	1.33	1.03	12.11	11.68	326.47
Aug-01	36.34	0.94	17.70	6.78			9.07	1.22	1.03	11.44	1.52	327.99
Sep-01	35.93	-4.49	13.83	4.67			7.12	1.04	1.00	7.40	8.13	336.12
Oct-01	28.30	-3.93	7.30	1.78			3.80	0.93	1.03	3.65	55.63	55.63
Nov-01	16.17	-8.52	3.62	0.61			1.91	0.78	1.00	1.49	81.54	137.17
Dec-01	5.06	-10.82	-1.34	0.00			0.00	0.73	1.03	0.00	44.7	181.87
Jan-02	9.43	-14.60	-0.87	0.00	36.16	1.07	0.00	0.77	1.03	0.00	67.31	249.18
Feb-02	10.02	-10.62	-0.15	0.00	Average Temp I for entire data series used to estimate Temp I for 2002, due to data logger malfunction.		0.00	0.80	0.93	0.00	42.42	291.6
Mar-02	16.66	-10.10	2.31	0.31			0.99	1.02	1.03	1.04	52.58	344.18
Apr-02	18.11	-5.94	6.57	1.51			3.03	1.14	1.00	3.46	26.67	370.85
May-02	36.19	-3.43	11.50	3.53			5.53	1.30	1.03	7.43	18.8	389.65
Jun-02	32.79	-1.28	13.93	4.72			6.79	1.32	1.00	8.96	41.91	431.56
Jul-02	No Data						0.00	1.33	1.03		3.9	435.46
Aug-02							0.00	1.22	1.03		10.2	445.66
Sep-02							0.00	1.04	1.00		9.9	455.56
Oct-02							0.00	0.93	1.03		17.3	17.3
Nov-02	13.92	-7.06	3.68	0.63			1.63	0.78	1.00	1.27	21.336	38.636
Dec-02	11.18	-5.99	1.03	0.09			0.42	0.73	1.03	0.31	62.484	101.12
Jan-03	12.18	-4.62	2.20	0.29	32.53	1.02	1.07	0.77	1.03	0.85	134.866	235.986
Feb-03	8.57	-11.11	0.66	0.05			0.32	0.80	0.93	0.24	34.798	270.784
Mar-03	19.41	-11.38	4.51	0.85			2.23	1.02	1.03	2.35	101.346	372.13
Apr-03	19.52	-3.43	6.76	1.58			3.37	1.14	1.00	3.84	30.226	402.356
May-03	30.70	-3.86	10.45	3.05			5.24	1.30	1.03	7.04	28.194	430.55
Jun-03	31.47	0.39	14.60	5.06			7.36	1.32	1.00	9.72	3.556	434.106
Jul-03	35.98	1.05	18.92	7.50			9.59	1.33	1.03	13.18	1.778	435.884
Aug-03	34.63	1.84	18.02	6.97			9.12	1.22	1.03	11.50	13.97	449.854
Sep-03	34.21	-2.03	13.72	4.61			6.92	1.04	1.00	7.19	19.05	468.904

Appendix B

Date	Max Tc	Min Tc	Avg Tc	Monthly index I	Temperature Index, I	a	Uncorrected PET (cm/mo)	Lat/ daylight correction	Days/ month Correction	Corrected PET (cm/mo)	Monthly PPT (mm)	Cumulative PPT (mm)
Oct-03	28.37	-12.61	9.21	2.52			4.61	0.93	1.03	4.43	18.288	18.288
Nov-03	12.95	-18.01	0.30	0.01			0.14	0.78	1.00	0.11	48.768	67.056
Dec-03	6.64	-14.22	0.51	0.03			0.24	0.73	1.03	0.18	69.342	136.398
Jan-04	8.57	-31.10	-1.39	0.00	36.27	1.07	0.00	0.77	1.03	0.00	61.722	198.12
Feb-04	10.67	-9.86	0.54	0.03			0.21	0.80	0.93	0.16	41.402	239.522
Mar-04	22.99	-4.48	5.69	1.22			2.60	1.02	1.03	2.74	27.94	267.462
Apr-04	23.72	-4.12	8.37	2.18			3.93	1.14	1.00	4.47	14.732	282.194
May-04	23.66	-1.81	10.56	3.10			5.04	1.30	1.03	6.77	66.802	348.996
Jun-04	37.01	-0.13	15.03	5.29			7.36	1.32	1.00	9.71	11.938	360.934
Jul-04	35.26	0.82	18.39	7.18			9.13	1.33	1.03	12.55	4.826	365.76
Aug-04	45.20	3.05	22.79	9.94			11.50	1.22	1.03	14.50	34.04	399.8
Sep-04	27.55	-0.19	12.36	3.94			5.96	1.04	1.00	6.20	41.91	441.71
Oct-04	24.68	-1.23	9.52	2.65			4.51	0.93	1.03	4.33	40.64	40.64
Nov-04	25.82	-7.83	2.95	0.45			1.28	0.78	1.00	1.00	30.734	71.374
Dec-04	13.80	-9.30	2.18	0.28			0.93	0.73	1.03	0.70	28.448	99.822
Jan-05	19.14	-6.00	6.56	1.51	42.63	1.17	2.65	0.77	1.03	2.11	26.924	126.746
Feb-05	19.93	-6.80	3.78	0.65			1.39	0.80	0.93	1.04	4.064	130.81
Mar-05	18.62	-9.73	4.99	1.00			1.92	1.02	1.03	2.03	55.118	185.928
Apr-05	27.40	-0.60	15.28	5.42			7.11	1.14	1.00	8.11	35.56	221.488
May-05	30.10	0.80	12.70	4.10			5.73	1.30	1.03	7.69	79.42	300.908
Jun-05	32.10	2.00	14.26	4.89			6.56	1.32	1.00	8.66	30.2	331.108
Jul-05	35.20	5.62	23.12	10.16			11.54	1.33	1.03	15.86	0.005	331.113
Aug-05	35.58	3.81	19.11	7.62			9.24	1.22	1.03	11.65	0.13	331.24
Sep-05	27.42	-1.55	13.08	4.29			5.93	1.04	1.00	6.17	2.63	333.87
Oct-05	23.50	-0.19	9.57	2.67			4.12	0.93	1.03	3.96	40.78	40.78
Nov-05	14.90	-5.90	2.34	0.32			0.80	0.78	1.00	0.62	33.4	74.18
Dec-05	10.52	-18.47	-1.30	0.00			0.00	0.73	1.03	0.00	55.33	129.51
Jan-06	10.56	-1.39	3.29	0.53	38.32	1.10	1.35	0.77	1.03	1.08	91.39	220.9
Feb-06	9.20	-0.63	4.24	0.78			1.79	0.80	0.93	1.34	14.06	234.96
Mar-06	13.67	-0.10	6.65	1.54			2.94	1.02	1.03	3.10	24.6	259.56
Apr-06	23.39	-1.45	7.93	2.01			3.57	1.14	1.00	4.07	54.53	314.09
May-06	27.35	-2.52	11.22	3.40			5.24	1.30	1.03	7.04	48.13	362.22
Jun-06	32.74	3.53	16.45	6.07			7.99	1.32	1.00	10.55	46.86	409.08
Jul-06	37.01	4.91	21.61	9.17			10.80	1.33	1.03	14.84	1.44	410.52
Aug-06	35.23	2.38	18.86	7.47			9.29	1.22	1.03	11.72	7.08	417.6
Sep-06	33.57	-1.40	14.49	5.01			6.95	1.04	1.00	7.22	15.14	432.74

Appendix B

Date	Max Tc	Min Tc	Avg Tc	Monthly index I	Temperature Index, I	a	Uncorrected PET (cm/mo)	Lat/ daylight correction	Days/ month Correction	Corrected PET (cm/mo)	Monthly PPT (mm)	Cumulative PPT (mm)
Oct-06	21.09	-9.89	7.18	1.73			3.20	0.93	1.03	3.07	24.78	24.78
Nov-06	17.61	-14.07	3.57	0.60			1.48	0.78	1.00	1.15	122.9	147.68
Dec-06	10.10	-8.74	0.31	0.01			0.10	0.73	1.03	0.07	49.46	197.14
Jan-07	9.08	-9.97	-1.28	0.00	36.87	1.08	0.00	0.77	1.03	0.00	49.6	246.74
Feb-07	13.49	-6.50	0.25	0.01			0.09	0.80	0.93	0.06	27.81	274.55
Mar-07	18.18	-5.38	6.38	1.45			2.90	1.02	1.03	3.05	37.28	311.83
Apr-07	20.68	-1.31	7.99	2.03			3.70	1.14	1.00	4.21	27.91	339.74
May-07	27.43	-0.72	12.39	3.95			5.94	1.30	1.03	7.98	35.8	375.54
Jun-07	31.80	4.05	15.40	5.49			7.51	1.32	1.00	9.92	23.97	399.51
Jul-07	36.47	5.58	21.86	9.33			10.98	1.33	1.03	15.09	7.95	407.46
Aug-07	35.33	2.99	18.78	7.42			9.32	1.22	1.03	11.74	11.03	418.49
Sep-07	29.64	-0.40	13.96	4.73			6.76	1.04	1.00	7.03	2.21	420.7
Oct-07	26.44	-6.34	8.39	2.19			3.90	0.93	1.03	3.75	43.47	43.47
Nov-07	14.58	-8.78	1.80	0.21			0.74	0.78	1.00	0.58	51.24	94.71
Dec-07	12.17	-7.61	0.74	0.06			0.28	0.73	1.03	0.21	57.31	152.02
		Average	8.38									

APPENDIX C $\delta^{18}O$ Data for Sampling Sites

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	Field Blank	10/6/00	-	-13.91
*	Field Blank	10/19/00	-	-13.90
*	Field Blank	12/7/00	-	-16.10
*	Field Blank	1/9/01	-	-17.28
*	Field Blank	2/3/01	-	-16.96
*	Field Blank	2/6/01	-	-
*	Field Blank	2/19/01	-	-17.56
*	Field Blank	3/3/01	-	-17.10
*	Field Blank	3/20/01	-	-17.27
*	Field Blank	4/9/01	-	-17.49
*	Field Blank	4/16/01	-	-17.38
*	Field Blank	5/2/01	-	-17.55
*	Field Blank	5/21/01	-	-17.53
*	Field Blank	5/30/01	-	-17.55
*	Field Blank	6/14/01	-	-17.53
*	Field Blank	7/11/01	-	-15.26
*	Field Blank	9/27/01	-	-
*	Field Blank	10/13/01	-	-
*	Field Blank	10/24/01	-	-
*	Field Blank	11/7/01	-	-
*	Field Blank	11/30/01	-	-16.60
*	Field Blank	12/14/01	-	-17.06
*	Field Blank	12/27/01	-	-
*	Field Blank	1/7/02	-	-
*	Field Blank	1/9/02	-	-14.50
*	Field Blank	1/24/02	-	-14.87
*	Field Blank	1/25/02	-	-17.08
*	Field Blank	1/26/02	-	-17.09
*	Field Blank	1/27/02	-	-17.42
*	Field Blank	1/29/02	-	-16.92
*	Field Blank	2/8/02	-	-17.18
*	Field Blank	2/22/02	-	-17.22
*	Field Blank	2/24/02	-	-
*	Field Blank	3/8/02	-	-15.14
*	Field Blank	3/11/02	-	-15.24
*	Field Blank	3/12/02	-	-17.78
*	Field Blank	3/29/02	-	-17.47
*	Field Blank	4/12/02	-	-17.57
*	Field Blank	4/26/02	-	-16.54
*	Field Blank	4/27/02	-	-16.73
*	Field Blank	5/10/02	-	-17.40

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	Field Blank	5/24/02	-	-16.55
*	Field Blank	5/28/02	-	-15.94
*	Field Blank	6/11/02	-	-16.96
*	Field Blank	6/25/02	-	-18.76
*	Field Blank	7/9/02	-	-
*	Field Blank	7/23/02	-	-17.32
*	Field Blank	9/20/02	-	-
*	Field Blank	10/16/02	-	-16.44
*	Field Blank	11/8/02	-	-16.83
*	Field Blank	11/20/02	-	-14.84
*	Field Blank	12/4/02	-	-16.75
*	Field Blank	12/19/02	-	-17.32
*	Field Blank	1/10/03	-	-17.25
*	Field Blank	1/17/03	-	-13.38
*	Field Blank	1/31/03	-	-11.86
*	Field Blank	2/14/03	-	-12.38
*	Field Blank	2/28/03	-	-17.03
*	Field Blank	3/14/03	-	-16.96
*	Field Blank	3/28/03	-	-16.20
*	Field Blank	4/11/03	-	-13.94
*	Field Blank	4/25/03	-	-16.97
*	Field Blank	5/9/03	-	-17.18
*	Field Blank	5/23/03	-	-17.26
*	Field Blank	6/6/03	-	-17.43
*	Field Blank	6/20/03	-	-17.17
*	Field Blank	7/4/03	-	-17.29
*	Field Blank	7/18/03	-	-17.19
*	Field Blank	8/1/03	-	-17.26
*	Field Blank	8/15/03	-	-16.20
*	Field Blank	8/29/03	-	-16.61
*	Field Blank	9/12/03	-	-16.62
*	Field Blank	9/27/03	-	-16.63
*	Field Blank	10/13/03	-	-16.70
*	Field Blank	10/24/03	-	-17.60
*	Field Blank	11/7/03	-	-17.60
*	Field Blank	11/21/03	-	-17.15
*	Field Blank	12/5/03	-	-17.10
*	Field Blank	12/19/03	-	-
*	Field Blank	12/22/03	-	-17.08
*	Field Blank	12/25/03	-	-17.37
*	Field Blank	12/28/03	-	-17.65
*	Field Blank	12/31/03	-	-17.12

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	Field Blank	1/5/04	-	-17.19
*	Field Blank	1/9/04	-	-17.09
*	Field Blank	1/10/04	-	-17.06
*	Field Blank	1/11/04	-	-17.72
*	Field Blank	1/12/04	-	-17.24
*	Field Blank	1/16/04	-	-17.68
*	Field Blank	1/19/04	-	-17.56
*	Field Blank	1/29/04	-	-17.72
*	Field Blank	1/29/04	-	-16.96
*	Field Blank	1/30/04	-	-16.72
*	Field Blank	2/13/04	-	-17.56
*	Field Blank	2/19/04	-	-
*	Field Blank	2/24/04	-	-16.67
*	Field Blank	2/26/04	-	-17.40
*	Field Blank	2/27/04	-	-16.86
*	Field Blank	3/11/04	-	-
*	Field Blank	3/12/04	-	-16.77
*	Field Blank	3/26/04	-	-16.99
*	Field Blank	4/9/04	-	-16.82
*	Field Blank	4/23/04	-	-16.91
*	Field Blank	5/7/04	-	-
*	Field Blank	5/21/04	-	-
*	Field Blank	5/28/04	-	-
*	Field Blank	6/11/04	-	-
*	Field Blank	6/25/04	-	-
*	Field Blank	7/9/04	-	-
*	Field Blank	7/23/04	-	-
*	Field Blank	8/6/04	-	-
*	Field Blank	8/20/04	-	-
*	Field Blank	9/3/04	-	-
*	Field Blank	9/17/04	-	-
*	Field Blank	10/1/04	-	-
*	Field Blank	10/15/04	-	-
*	Field Blank	10/29/04	-	-
*	Field Blank	11/12/04	-	-
*	Field Blank	11/29/04	-	-
*	Field Blank	12/13/04	-	-
*	Field Blank	12/27/04	-	-
*	Field Blank	1/11/05	-	-
*	Field Blank	1/12/05	-	-
*	Field Blank	1/28/05	-	-
*	Field Blank	2/11/05	-	-

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	Field Blank	2/25/05	-	-
*	Field Blank	3/10/05	-	-
*	Field Blank	3/23/05	-	-
*	Field Blank	3/25/05	-	-
*	Field Blank	3/27/05	-	-
*	Field Blank	3/29/05	-	-
*	Field Blank	4/8/05	-	-
*	Field Blank	4/12/05	-	-
*	Field Blank	4/22/05	-	-
	Field Blank	5/6/05	5/16/06	-16.78
	Field Blank	5/20/05	5/16/06	-17.04
	Field Blank	6/7/05	5/16/06	-16.92
	Field Blank	6/24/05	5/16/06	-16.86
	Field Blank	7/11/05	5/18/06	-17.07
	Field Blank	7/22/05	5/18/06	-16.82
	Field Blank	8/19/05	5/18/06	-16.73
	Field Blank	9/3/05	5/18/06	-16.73
	Field Blank	9/20/05	5/18/06	-16.85
	Field Blank	10/7/05	5/18/06	-16.98
	Field Blank	10/21/05	5/18/06	-16.79
	Field Blank	11/4/05	5/18/06	-16.79
	Field Blank	11/18/05	5/18/06	-16.72
	Field Blank	1/6/06	5/18/06	-16.85
	Field Blank	1/23/06	-	-
	Field Blank	2/6/06	5/22/06	-12.47
	Field Blank	2/28/06	5/22/06	-16.68
	Field Blank	3/15/06	5/22/06	-16.77
	Field Blank	4/11/06	5/22/06	-16.72
	Field Blank	4/24/06	5/22/06	-16.72
	Field Blank	5/10/06	5/22/06	-16.85
	Field Blank	5/20/06	11/8/06	-16.94
	Field Blank	6/7/06	11/8/06	-18.07
	Field Blank	6/29/06	11/8/06	-18.97
	Field Blank	7/7/06	-	-
	Field Blank	7/26/06	11/8/06	-17.27
	Field Blank	8/10/06	2/9/07	-17.21
	Field Blank	8/25/06	2/9/07	-17.65
	Field Blank	9/6/06	2/9/07	-17.50
	Field Blank	9/20/06	2/9/07	-16.87
	Field Blank	10/6/06	2/9/07	-18.17
	Field Blank	10/18/06	2/9/07	-17.11
	Field Blank	11/1/06	2/9/07	-17.21

Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
Field Blank	11/6/06	2/9/07	-17.11
Field Blank	11/10/06	2/9/07	-16.50
Field Blank	11/15/06	2/9/07	-17.21
Field Blank	11/29/06	2/13/07	-16.49
Field Blank	12/13/06	2/13/07	-16.94
Field Blank	12/29/06	2/13/07	-16.50
Field Blank	1/4/07	2/13/07	-16.75
Field Blank	1/12/07	2/13/07	-16.20
Field Blank	1/26/07	2/13/07	-16.79
Field Blank	2/9/07	2/13/07	-16.75
Field Blank	2/22/07	1/10/08	-16.80
Field Blank	3/7/07	1/10/08	-16.43
Field Blank	3/23/07	1/10/08	-16.76
Field Blank	4/5/07	1/10/08	-17.06
Field Blank	4/19/07	1/15/08	-16.41
Field Blank	5/4/07	1/15/08	-16.54
Field Blank	5/22/07	1/15/08	-16.46
Field Blank	6/4/07	1/15/08	-16.45
Field Blank	6/19/07	1/15/08	-17.85
Field Blank	7/2/07	1/15/08	-16.38
Field Blank	7/16/07	1/15/08	-16.40
Field Blank	7/31/07	1/15/08	-16.46
Field Blank	8/13/07	1/17/08	-16.65
Field Blank	8/21/07	1/17/08	-16.74
Field Blank	9/4/07	1/17/08	-16.57
Field Blank	9/21/07	1/17/08	-16.62
Field Blank	10/1/07	-	-
Field Blank	10/19/07	1/17/08	-16.64
Field Blank	11/5/07	1/17/08	-16.62
Field Blank	12/5/07	1/17/08	-16.93
Field Blank	12/17/07	1/17/08	-16.64
Field Blank	1/3/08	1/17/08	-16.75
Field Blank	1/18/08	-	-

* Denotes samples that were analyzed by Angela Goodwin (2006).

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	ES-6	10/5/00	-	-
*	ES-6	10/19/00	-	-
*	ES-6	12/8/00	-	
*	ES-6	1/9/01	-	-
*	ES-6	2/5/01	-	-15.63
*	ES-6	2/6/01	-	-15.71
*	ES-6	2/19/01	-	-16.85
*	ES-6	3/3/01	8/6/03	-14.51
*	ES-6	3/20/01	-	-12.59
*	ES-6	4/12/01	-	-14.50
*	ES-6	4/16/01	-	-
*	ES-6	5/2/01	-	-12.69
*	ES-6	5/21/01	-	-
*	ES-6	5/30/01	-	-
*	ES-6	6/14/01	-	-
*	ES-6	7/11/01	-	-
*	ES-6	9/27/01	-	-
*	ES-6	10/13/01	-	-
*	ES-6	10/24/01	-	-
*	ES-6	11/7/01	-	-
*	ES-6	11/30/01	-	-
*	ES-6	12/14/01	-	-
*	ES-6	12/27/01	-	-
*	ES-6	1/7/02	-	-16.27
*	ES-6	1/9/02	-	-15.96
*	ES-6	1/24/02	-	-
*	ES-6	1/25/02	8/6/03	-17.53
*	ES-6	1/26/02	-	-15.88
*	ES-6	1/27/02	-	-16.02
*	ES-6	1/29/02	-	-17.29
*	ES-6	2/8/02	-	-16.49
*	ES-6	2/22/02	-	-16.15
*	ES-6	2/24/02	-	-
*	ES-6	3/8/02	-	-16.30
*	ES-6	3/11/02	-	-14.99
*	ES-6	3/12/02	-	-
*	ES-6	3/29/02	-	-15.45
*	ES-6	4/12/02	-	-13.72
*	ES-6	4/26/02	-	-13.62
*	ES-6	4/27/02	-	-13.67
*	ES-6	5/10/02	-	-13.68
*	ES-6	5/24/02	-	-

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	ES-6	5/28/02	-	-
*	ES-6	6/11/02	-	-
*	ES-6	6/25/02	-	-
*	ES-6	7/9/02	-	-
*	ES-6	7/23/02	-	-
*	ES-6	9/20/02	-	-
*	ES-6	10/16/02	-	-
*	ES-6	11/8/02	-	-
*	ES-6	11/20/02	-	-
*	ES-6	12/4/02	-	-
*	ES-6	12/19/02	-	-
*	ES-6	1/10/03	-	-
*	ES-6	1/17/03	-	-
*	ES-6	1/31/03	3/11/03	-11.96
*	ES-6	2/14/03	3/11/03	-15.65
*	ES-6	2/28/03	-	-
*	ES-6	3/14/03	3/11/03	-13.55
*	ES-6	3/28/03	3/12/03	-11.62
*	ES-6	4/11/03	3/12/03	-10.06
*	ES-6	4/25/03	3/12/03	-14.08
*	ES-6	5/9/03	-	-
*	ES-6	5/23/03	-	-
*	ES-6	6/6/03	-	-
*	ES-6	6/20/03	-	-
*	ES-6	7/4/03	-	-
*	ES-6	7/18/03	-	-
*	ES-6	8/1/03	-	-
*	ES-6	8/15/03	-	-
*	ES-6	8/29/03	-	-
*	ES-6	9/12/03	-	-
*	ES-6	9/27/03	-	-
*	ES-6	10/13/03	-	-
*	ES-6	10/24/03	-	-
*	ES-6	11/7/03	-	-
*	ES-6	11/21/03	-	-
*	ES-6	12/5/03	-	-
*	ES-6	12/19/03	-	-
*	ES-6	12/22/03	-	-
*	ES-6	12/25/03	-	-
*	ES-6	12/28/03	-	-
*	ES-6	12/31/03	-	-
*	ES-6	1/5/04	-	-

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	ES-6	1/9/04	-	-
*	ES-6	1/10/04	-	-
*	ES-6	1/11/04	-	-
*	ES-6	1/12/04	-	-
*	ES-6	1/16/04	-	-
*	ES-6	1/19/04	-	-
*	ES-6	1/29/04	2/15/04	-19.32
*	ES-6	1/29/04	2/15/04	-18.31
*	ES-6	1/30/04	7/26/04	-17.20
*	ES-6	2/13/04	7/29/04	-15.91
*	ES-6	2/19/04	-	-
*	ES-6	2/24/04	7/28/04	-15.51
*	ES-6	2/26/04	7/29/04	-15.82
*	ES-6	2/27/04	-	-
*	ES-6	3/11/04	-	-
*	ES-6	3/12/04	7/29/04	-15.50
*	ES-6	3/26/04	7/26/04	-14.06
*	ES-6	4/9/04	7/30/04	-13.64
*	ES-6	4/23/04	7/30/04	-14.18
*	ES-6	5/7/04	-	-
*	ES-6	5/21/04	-	-
*	ES-6	5/28/04	8/2/04	-12.91
*	ES-6	6/11/04	-	-
*	ES-6	6/25/04	-	-
*	ES-6	7/9/04	-	-
*	ES-6	7/23/04	-	-
*	ES-6	8/6/04	-	-
*	ES-6	8/20/04	-	-
*	ES-6	9/3/04	-	-
*	ES-6	9/17/04	-	-
*	ES-6	10/1/04	-	-
*	ES-6	10/15/04	-	-
*	ES-6	10/29/04	-	-
*	ES-6	11/12/04	-	-
*	ES-6	11/29/04	-	-
*	ES-6	12/13/04	-	-
*	ES-6	12/27/04	-	-
*	ES-6	1/11/05	-	-
*	ES-6	1/12/05	-	-
*	ES-6	1/28/05	-	-
*	ES-6	2/11/05	4/26/05	-11.93
	ES-6	2/25/05	-	-

Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
ES-6	3/10/05	-	-
ES-6	3/23/05	-	-
ES-6	3/25/05	-	-
ES-6	3/27/05	-	-
ES-6	3/29/05	-	-
ES-6	4/8/05	-	-
ES-6	4/12/05	-	-
ES-6	4/22/05	-	-
ES-6	5/6/05	-	-
ES-6	5/20/05	-	-
ES-6	6/7/05	-	-
ES-6	6/24/05	-	-
ES-6	7/11/05	-	-
ES-6	7/22/05	-	-
ES-6	8/19/05	-	-
ES-6	9/3/05	-	-
ES-6	9/20/05	-	-
ES-6	10/7/05	-	-
ES-6	10/21/05	-	-
ES-6	11/4/05	-	-
ES-6	11/18/05	-	-
ES-6	1/6/06	-	-
ES-6	1/23/06	-	-
ES-6	2/6/06	-	-
ES-6	2/28/06	-	-
ES-6	3/15/06	-	-
ES-6	4/11/06	-	-
ES-6	4/24/06	-	-
ES-6	5/10/06	-	-
ES-6	5/20/06	-	-
ES-6	6/7/06	-	-
ES-6	6/29/06	-	-
ES-6	7/7/06	-	-
ES-6	7/26/06	-	-
ES-6	8/10/06	-	-
ES-6	8/25/06	-	-
ES-6	9/6/06	-	-
ES-6	9/20/06	-	-
ES-6	10/6/06	-	-
ES-6	10/18/06	-	-
ES-6	11/1/06	-	-
ES-6	11/6/06	-	-

Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
ES-6	11/10/06	-	-
ES-6	11/15/06	-	-
ES-6	11/29/06	-	-
ES-6	12/13/06	2/13/07	-12.70
ES-6	12/29/06	-	-
ES-6	1/4/07	-	-
ES-6	1/12/07	2/13/07	-13.21
ES-6	1/26/07	-	-
ES-6	2/9/07	1/10/08	-14.00
ES-6	2/22/07	1/10/08	-13.03
ES-6	3/7/07	1/10/08	-13.16
ES-6	3/23/07	1/10/08	-12.81
ES-6	4/5/07	1/10/08	-13.07
ES-6	4/19/07	1/15/08	-12.45
ES-6	5/4/07	1/15/08	-12.45
ES-6	5/22/07	-	-
ES-6	6/4/07	-	-
ES-6	6/19/07	-	-
ES-6	7/2/07	-	-
ES-6	7/16/07	-	-
ES-6	7/31/07	-	-
ES-6	8/13/07	-	-
ES-6	8/21/07	-	-
ES-6	9/4/07	-	-
ES-6	9/21/07	-	-
ES-6	10/1/07	-	-
ES-6	10/19/07	-	-
ES-6	11/5/07	-	-
ES-6	12/5/07	-	-
ES-6	12/17/07	-	-
ES-6	1/3/08	-	-
ES-6	1/18/08	-	-

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	ES-106	10/5/00	-	-
*	ES-106	10/19/00	-	-
*	ES-106	12/8/00	-	-
*	ES-106	1/9/01	-	-15.33
*	ES-106	2/3/01	-	-
*	ES-106	2/6/01	-	-
*	ES-106	2/19/01	-	-16.92
*	ES-106	3/2/01	-	-15.62
*	ES-106	3/20/01	-	-13.01
*	ES-106	4/9/01	-	-13.06
*	ES-106	4/16/01	-	-
*	ES-106	5/2/01	-	-13.16
*	ES-106	5/17/01	-	-12.16
*	ES-106	5/30/01	-	-
*	ES-106	6/14/01	-	-
*	ES-106	7/11/01	-	-
*	ES-106	9/27/01	-	-
*	ES-106	10/13/01	-	-
*	ES-106	10/24/01	-	-
*	ES-106	11/7/01	-	-
*	ES-106	11/30/01	-	-
*	ES-106	12/14/01	-	-
*	ES-106	12/27/01	-	-
*	ES-106	1/7/02	-	-
*	ES-106	1/9/02	-	-
*	ES-106	1/24/02	-	-14.53
*	ES-106	1/25/02	-	-16.06
*	ES-106	1/26/02	-	-16.05
*	ES-106	1/27/02	-	-15.81
*	ES-106	1/29/02	-	-15.52
*	ES-106	2/8/02	-	-
*	ES-106	2/22/02	8/6/03	-15.44
*	ES-106	2/24/02	-	-
*	ES-106	3/8/02	-	-14.97
*	ES-106	3/11/02	-	-14.93
*	ES-106	3/12/02	-	-14.45
*	ES-106	3/29/02	-	-14.66
*	ES-106	4/12/02	-	-14.14
*	ES-106	4/26/02	-	-14.03
*	ES-106	4/27/02	-	-14.03
*	ES-106	5/10/02	-	-14.04
*	ES-106	5/24/02	-	-13.34

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	ES-106	5/28/02	8/6/03	-7.30
*	ES-106	6/11/02	-	-12.92
*	ES-106	6/25/02	-	-
*	ES-106	7/9/02	-	-
*	ES-106	7/23/02	-	-
*	ES-106	9/20/02	-	-
*	ES-106	10/16/02	-	-
*	ES-106	11/8/02	-	-
*	ES-106	11/20/02	-	-
*	ES-106	12/4/02	-	-
*	ES-106	12/19/02	2/13/04	-14.49
*	ES-106	1/10/03	-	-
*	ES-106	1/17/03	-	-
*	ES-106	1/31/03	3/11/03	-12.83
*	ES-106	2/14/03	3/11/03	-14.83
*	ES-106	2/28/03	3/11/03	-14.63
*	ES-106	3/14/03	3/11/03	-14.28
*	ES-106	3/28/03	3/12/03	-11.87
*	ES-106	4/11/03	3/12/03	-13.07
*	ES-106	4/25/03	3/12/03	-13.91
*	ES-106	5/9/03	3/12/03	-14.21
*	ES-106	5/23/03	8/13/03	-14.19
*	ES-106	6/6/03	-	-
*	ES-106	6/20/03	-	-
*	ES-106	7/4/03	-	-
*	ES-106	7/18/03	-	-
*	ES-106	8/1/03	-	-
*	ES-106	8/15/03	-	-
*	ES-106	8/29/03	-	-
*	ES-106	9/12/03	-	-
*	ES-106	9/27/03	-	-
*	ES-106	10/13/03	-	-
*	ES-106	10/24/03	-	-
*	ES-106	11/7/03	-	-
*	ES-106	11/21/03	-	-
*	ES-106	12/5/03	-	-
*	ES-106	12/19/03	-	-
*	ES-106	12/22/03	2/13/04	-15.01
*	ES-106	12/25/03	2/13/04	-15.68
*	ES-106	12/28/03	-	-
*	ES-106	12/31/03	-	-
*	ES-106	1/5/04	-	-

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	ES-106	1/9/04	-	-
*	ES-106	1/10/04	-	-
*	ES-106	1/11/04	2/14/04	-18.61
*	ES-106	1/12/04	2/14/04	-18.84
*	ES-106	1/16/04	2/14/04	-17.34
*	ES-106	1/19/04	2/15/04	-16.77
*	ES-106	1/29/04	2/15/04	-18.91
*	ES-106	1/29/04	2/15/04	-18.30
*	ES-106	1/30/04	7/26/04	-16.70
*	ES-106	2/13/04	7/26/04	-15.01
*	ES-106	2/19/04	-	-
*	ES-106	2/24/04	7/28/04	-15.87
*	ES-106	2/26/04	7/29/04	-15.52
*	ES-106	2/27/04	7/29/04	-15.57
*	ES-106	3/11/04	-	-
*	ES-106	3/12/04	7/29/04	-15.27
*	ES-106	3/26/04	7/30/04	-14.44
*	ES-106	4/9/04	7/30/04	-14.36
*	ES-106	4/23/04	7/30/04	-14.68
*	ES-106	5/7/04	8/2/04	-13.33
*	ES-106	5/21/04	8/2/04	-13.33
*	ES-106	5/28/04	8/2/04	-13.28
*	ES-106	6/11/04	8/2/04	-13.14
*	ES-106	6/25/04	-	-
*	ES-106	7/9/04	-	-
*	ES-106	7/23/04	-	-
*	ES-106	8/6/04	-	-
*	ES-106	8/20/04	-	-
*	ES-106	9/3/04	-	-
*	ES-106	9/17/04	-	-
*	ES-106	10/1/04	-	-
*	ES-106	10/15/04	-	-
*	ES-106	10/29/04	-	-
*	ES-106	11/12/04	-	-
*	ES-106	11/29/04	-	-
*	ES-106	12/13/04	4/21/05	-12.61
*	ES-106	12/27/04	-	-
*	ES-106	1/11/05	-	-
*	ES-106	1/12/05	-	-
*	ES-106	1/28/05	4/25/05	-13.33
*	ES-106	2/11/05	4/26/05	-12.00
*	ES-106	2/25/05	-	-

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	ES-106	3/10/05	-	-
*	ES-106	3/23/05	4/26/05	-12.75
*	ES-106	3/25/05	-	-
*	ES-106	3/27/05	-	-
*	ES-106	3/29/05	4/26/05	-13.80
*	ES-106	4/8/05	4/28/05	-12.10
*	ES-106	4/12/05	4/28/05	-10.94
	ES-106	4/22/05	-	-
	ES-106	5/6/05	-	-
	ES-106	5/20/05	5/16/06	-13.21
	ES-106	6/7/05	-	-
	ES-106	6/24/05	-	-
	ES-106	7/11/05	-	-
	ES-106	7/22/05	-	-
	ES-106	8/19/05	-	-
	ES-106	9/3/05	-	-
	ES-106	9/20/05	-	-
	ES-106	10/7/05	-	-
	ES-106	10/21/05	-	-
	ES-106	11/4/05	-	-
	ES-106	11/18/05	-	-
	ES-106	1/6/06	-	-
	ES-106	1/23/06	-	-
	ES-106	2/6/06	-	-
	ES-106	2/28/06	-	-
	ES-106	3/15/06	-	-
	ES-106	4/11/06	-	-
	ES-106	4/24/06	-	-
	ES-106	5/10/06	-	-
	ES-106	5/20/06	-	-
	ES-106	6/7/06	-	-
	ES-106	6/29/06	-	-
	ES-106	7/7/06	-	-
	ES-106	7/26/06	-	-
	ES-106	8/10/06	-	-
	ES-106	8/25/06	-	-
	ES-106	9/6/06	-	-
	ES-106	9/20/06	-	-
	ES-106	10/6/06	-	-
	ES-106	10/18/06	-	-
	ES-106	11/1/06	-	-
	ES-106	11/6/06	-	-

Sample location	Sample Date	δ^{18}O Analysis Date	δ^{18}O Value (‰)
ES-106	11/10/06	-	-
ES-106	11/15/06	-	-
ES-106	11/29/06	-	-
ES-106	12/13/06	-	-12.96
ES-106	12/29/06	-	-
ES-106	1/4/07	-	-
ES-106	1/12/07	-	-13.38
ES-106	1/26/07	-	-
ES-106	2/9/07	1/10/08	-14.13
ES-106	2/22/07	1/10/08	-13.26
ES-106	3/7/07	-	-
ES-106	3/23/07	1/10/08	-12.88
ES-106	4/5/07	1/10/08	-13.22
ES-106	4/19/07	1/10/08	-13.12
ES-106	5/4/07	1/15/08	-12.75
ES-106	5/22/07	1/15/08	-12.80
ES-106	6/4/07	-	-
ES-106	6/19/07	-	-
ES-106	7/2/07	-	-
ES-106	7/16/07	-	-
ES-106	7/31/07	-	-
ES-106	8/13/07	-	-
ES-106	8/21/07	-	-
ES-106	9/4/07	-	-
ES-106	9/21/07	-	-
ES-106	10/1/07	-	-
ES-106	10/19/07	-	-
ES-106	11/5/07	-	-
ES-106	12/5/07	1/17/08	-14.75
ES-106	12/17/07	-	-
ES-106	1/3/08	1/17/08	-14.12
ES-106	1/18/08	-	-

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	TD-12	10/6/00	-	-14.88
*	TD-12	10/19/00	-	-14.70
*	TD-12	12/7/00	-	-15.57
*	TD-12	1/9/01	-	-14.93
*	TD-12	2/2/01	-	-15.89
*	TD-12	2/6/01	-	-15.86
*	TD-12	2/19/01	-	-14.88
*	TD-12	3/2/01	-	-14.93
*	TD-12	3/20/01	-	-14.86
*	TD-12	4/9/01	-	-15.62
*	TD-12	4/16/01	-	-14.99
*	TD-12	5/2/01	-	-
*	TD-12	5/21/01	-	-15.55
*	TD-12	5/30/01	-	-16.06
*	TD-12	6/14/01	-	-16.62
*	TD-12	7/11/01	-	-12.15
*	TD-12	9/27/01	-	-
*	TD-12	10/13/01	-	-15.03
*	TD-12	10/24/01	2/10/04	-14.25
*	TD-12	11/7/01	-	-15.71
*	TD-12	11/30/01	-	-14.88
*	TD-12	12/14/01	-	-14.79
*	TD-12	12/27/01	-	-11.40
*	TD-12	1/7/02	-	-
*	TD-12	1/9/02	-	-14.72
*	TD-12	1/24/02	-	-14.25
*	TD-12	1/25/02	-	-15.51
*	TD-12	1/26/02	-	-15.49
*	TD-12	1/27/02	-	-14.90
*	TD-12	1/29/02	-	-14.89
*	TD-12	2/8/02	-	-15.22
*	TD-12	2/22/02	-	-15.28
*	TD-12	2/24/02	-	-15.07
*	TD-12	3/8/02	-	-14.98
*	TD-12	3/11/02	-	-14.76
*	TD-12	3/12/02	-	-16.05
*	TD-12	3/29/02	-	-16.06
*	TD-12	4/12/02	-	-15.88
*	TD-12	4/26/02	-	-15.77
*	TD-12	4/27/02	-	-15.68
*	TD-12	5/10/02	-	-14.87
*	TD-12	5/24/02	-	-14.86

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	TD-12	5/28/02	-	-14.67
*	TD-12	6/11/02	-	-14.88
*	TD-12	6/25/02	-	-14.91
*	TD-12	7/9/02	-	-14.97
*	TD-12	7/23/02	12/4/03	-14.61
*	TD-12	9/20/02	8/6/03	-15.12
*	TD-12	10/16/02	8/7/03	-14.88
*	TD-12	11/8/02	8/7/03	-14.57
*	TD-12	11/20/02	8/7/03	-14.67
*	TD-12	12/4/02	8/7/03	-14.79
*	TD-12	12/19/02	8/7/03	-14.81
*	TD-12	1/10/03	8/7/03	-15.02
*	TD-12	1/17/03	8/11/03	-13.89
*	TD-12	1/31/03	8/11/03	-14.86
*	TD-12	2/14/03	8/11/03	-14.61
*	TD-12	2/28/03	8/11/03	-14.46
*	TD-12	3/14/03	8/11/03	-14.21
*	TD-12	3/28/03	8/12/03	-13.00
*	TD-12	4/11/03	8/12/03	-13.27
*	TD-12	4/25/03	8/12/03	-14.58
*	TD-12	5/9/03	8/12/03	-14.70
*	TD-12	5/23/03	8/13/03	-14.66
*	TD-12	6/6/03	8/13/03	-14.70
*	TD-12	6/20/03	8/14/03	-14.74
*	TD-12	7/4/03	8/14/03	-14.94
*	TD-12	7/18/03	-	-
*	TD-12	8/1/03	8/14/03	-15.05
*	TD-12	8/15/03	2/11/04	-14.25
*	TD-12	8/29/03	2/11/04	-14.44
*	TD-12	9/12/03	2/11/04	-14.25
*	TD-12	9/27/03	2/11/04	-14.81
*	TD-12	10/13/03	2/11/04	-14.85
*	TD-12	10/24/03	2/12/04	-15.17
*	TD-12	11/7/03	2/12/04	-15.62
*	TD-12	11/21/03	2/12/04	-14.93
*	TD-12	12/5/03	2/12/04	-14.89
*	TD-12	12/19/03	2/13/04	-15.34
*	TD-12	12/22/03	2/13/04	-14.89
*	TD-12	12/25/03	2/13/04	-14.97
*	TD-12	12/28/03	2/13/04	-15.46
*	TD-12	12/31/03	2/13/04	-15.37
*	TD-12	1/5/04	2/14/04	-14.87

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	TD-12	1/9/04	2/13/04	-15.34
*	TD-12	1/10/04	2/14/04	-14.63
*	TD-12	1/11/04	2/14/04	-15.30
*	TD-12	1/12/04	2/14/04	-15.10
*	TD-12	1/16/04	2/14/04	-15.29
*	TD-12	1/19/04	2/15/04	-15.30
*	TD-12	1/29/04	2/15/04	-16.42
*	TD-12	1/29/04	2/15/04	-16.36
*	TD-12	1/30/04	2/15/04	-15.94
*	TD-12	2/13/04	7/26/04	-14.55
*	TD-12	2/19/04	-	-
*	TD-12	2/24/04	7/28/04	-14.33
*	TD-12	2/26/04	-	-
*	TD-12	2/27/04	-	-
*	TD-12	3/11/04	-	-
*	TD-12	3/12/04	7/29/04	-14.95
*	TD-12	3/26/04	7/30/04	-14.90
*	TD-12	4/9/04	-	-14.75
*	TD-12	4/23/04	8/2/04	-14.71
*	TD-12	5/7/04	8/2/04	-14.74
*	TD-12	5/21/04	8/2/04	-14.76
*	TD-12	5/28/04	8/2/04	-14.91
*	TD-12	6/11/04	8/2/04	-14.77
*	TD-12	6/25/04	8/2/04	-14.59
*	TD-12	7/9/04	8/3/04	-14.41
*	TD-12	7/23/04	8/3/04	-14.43
*	TD-12	8/6/04	-	-
*	TD-12	8/20/04	-	-
*	TD-12	9/3/04	4/20/05	-14.30
*	TD-12	9/17/04	4/20/05	-14.01
*	TD-12	10/1/04	4/20/05	-14.34
*	TD-12	10/15/04	4/20/05	-14.30
*	TD-12	10/29/04	4/20/05	-14.56
*	TD-12	11/12/04	4/21/05	-14.48
*	TD-12	11/29/04	4/21/05	-14.29
*	TD-12	12/13/04	4/21/05	-14.53
*	TD-12	12/27/04	4/24/05	-14.81
*	TD-12	1/11/05	4/25/05	-14.77
*	TD-12	1/12/05	4/25/05	-14.71
*	TD-12	1/28/05	4/25/05	-14.73
*	TD-12	2/11/05	4/25/05	-15.00
*	TD-12	2/25/05	4/25/05	-14.90

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	TD-12	3/10/05	4/26/05	-13.70
*	TD-12	3/23/05	4/26/05	-14.91
*	TD-12	3/25/05	4/26/05	-14.21
*	TD-12	3/27/05	-	-
*	TD-12	3/29/05	-	-
*	TD-12	4/8/05	4/28/05	-14.07
*	TD-12	4/12/05	4/28/05	-14.01
*	TD-12	4/22/05	4/28/05	-13.96
	TD-12	5/6/05	5/16/06	-14.58
	TD-12	5/20/05	5/16/06	-14.31
	TD-12	6/7/05	5/16/06	-15.22
	TD-12	6/24/05	5/16/06	-14.41
	TD-12	7/11/05	5/18/06	-14.75
	TD-12	7/22/05	5/18/06	-14.52
	TD-12	8/19/05	5/18/06	-14.71
	TD-12	9/3/05	5/18/06	-14.77
	TD-12	9/20/05	5/18/06	-14.56
	TD-12	10/7/05	5/18/06	-14.75
	TD-12	10/21/05	5/18/06	-13.18
	TD-12	11/4/05	5/18/06	-14.98
	TD-12	11/18/05	5/18/06	-14.56
	TD-12	1/6/06	5/18/06	-14.85
	TD-12	1/23/06	5/22/06	-14.01
	TD-12	2/6/06	5/22/06	-14.22
	TD-12	2/28/06	5/22/06	-14.24
	TD-12	3/15/06	5/22/06	-14.36
	TD-12	4/11/06	5/22/06	-14.70
	TD-12	4/24/06	5/22/06	-13.85
	TD-12	5/10/06	5/22/06	-14.05
	TD-12	5/20/06	11/8/06	-14.52
	TD-12	6/7/06	-	-
	TD-12	6/29/06	11/8/06	-14.89
	TD-12	7/7/06	-	-
	TD-12	7/26/06	11/8/06	-15.14
	TD-12	8/10/06	2/9/07	-15.09
	TD-12	8/25/06	2/9/07	-15.12
	TD-12	9/6/06	2/9/07	-13.73
	TD-12	9/20/06	2/9/07	-15.20
	TD-12	10/6/06	2/9/07	-14.62
	TD-12	10/18/06	2/9/07	-15.00
	TD-12	11/1/06	2/9/07	-15.16
	TD-12	11/6/06	2/9/07	-14.57

Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
TD-12	11/10/06	2/9/07	-14.85
TD-12	11/15/06	2/13/07	-14.39
TD-12	11/29/06	2/13/07	-14.62
TD-12	12/13/06	2/13/07	-14.02
TD-12	12/29/06	2/13/07	-14.95
TD-12	1/4/07	2/13/07	-13.51
TD-12	1/12/07	2/13/07	-13.71
TD-12	1/26/07	2/13/07	-13.95
TD-12	2/9/07	1/10/08	-13.71
TD-12	2/22/07	1/10/08	-13.73
TD-12	3/7/07	1/10/08	-13.50
TD-12	3/23/07	1/10/08	-13.70
TD-12	4/5/07	1/10/08	-13.65
TD-12	4/19/07	1/10/08	-13.99
TD-12	5/4/07	1/15/08	-14.34
TD-12	5/22/07	1/15/08	-13.52
TD-12	6/4/07	1/15/08	-14.50
TD-12	6/19/07	1/15/08	-14.07
TD-12	7/2/07	1/15/08	-14.07
TD-12	7/16/07	-	-
TD-12	7/31/07	-	-
TD-12	8/13/07	-	-
TD-12	8/21/07	1/17/08	-14.43
TD-12	9/4/07	1/17/08	-14.72
TD-12	9/21/07	1/17/08	-14.78
TD-12	10/1/07	1/17/08	-14.32
TD-12	10/19/07	1/17/08	-14.37
TD-12	11/5/07	1/17/08	-14.70
TD-12	12/5/07	1/17/08	-14.08
TD-12	12/17/07	1/17/08	-15.83
TD-12	1/3/08	1/17/08	-14.47
TD-12	1/18/08	-	-

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	MFC-660	10/6/00	-	-
*	MFC-660	10/19/00	-	-
*	MFC-660	12/7/00	-	-
*	MFC-660	1/9/01	-	-14.79
*	MFC-660	2/2/01	-	-15.53
*	MFC-660	2/6/01	-	-
*	MFC-660	2/19/01	-	-16.52
*	MFC-660	3/2/01	-	-15.78
*	MFC-660	3/20/01	-	-14.57
*	MFC-660	4/9/01	-	-14.65
*	MFC-660	4/16/01	-	-14.27
*	MFC-660	5/2/01	-	-14.30
*	MFC-660	5/21/01	8/6/03	-14.41
*	MFC-660	5/30/01	-	-14.67
*	MFC-660	6/15/01	-	-
*	MFC-660	7/11/01	-	-
*	MFC-660	9/27/01	-	-14.34
*	MFC-660	10/13/01	-	-14.66
*	MFC-660	10/24/01	-	-14.81
*	MFC-660	11/7/01	-	-14.31
*	MFC-660	11/30/01	-	-14.95
*	MFC-660	12/14/01	-	-16.46
*	MFC-660	12/27/01	-	-14.59
*	MFC-660	1/7/02	-	-
*	MFC-660	1/9/02	2/11/04	-14.20
*	MFC-660	1/24/02	-	-14.97
*	MFC-660	1/25/02	-	-15.47
*	MFC-660	1/26/02	-	-15.66
*	MFC-660	1/27/02	-	-15.53
*	MFC-660	1/29/02	-	-15.30
*	MFC-660	2/8/02	-	-16.66
*	MFC-660	2/22/02	-	-15.63
*	MFC-660	2/24/02	-	-15.06
*	MFC-660	3/8/02	-	-14.87
*	MFC-660	3/11/02	-	-
*	MFC-660	3/12/02	-	-15.26
*	MFC-660	3/29/02	-	-14.92
*	MFC-660	4/12/02	-	-14.42
*	MFC-660	4/26/02	-	-14.55
*	MFC-660	4/27/02	-	-14.13
*	MFC-660	5/10/02	-	-15.24
*	MFC-660	5/24/02	-	-14.98

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	MFC-660	5/28/02	-	-14.43
*	MFC-660	6/11/02	-	-14.67
*	MFC-660	6/25/02	-	-14.63
*	MFC-660	7/9/02	-	-15.05
*	MFC-660	7/23/02	-	-15.56
*	MFC-660	9/20/02	8/7/03	-14.68
*	MFC-660	10/16/02	8/7/03	-14.63
*	MFC-660	11/8/02	8/7/03	-14.55
*	MFC-660	11/20/02	8/7/03	-14.68
*	MFC-660	12/4/02	8/7/03	-14.79
*	MFC-660	12/19/02	8/7/03	-14.86
*	MFC-660	1/10/03	8/7/03	-14.86
*	MFC-660	1/17/03	8/11/03	-14.65
*	MFC-660	1/31/03	8/11/03	-12.12
*	MFC-660	2/14/03	8/11/03	-5.10
*	MFC-660	2/28/03	8/11/03	-14.49
*	MFC-660	3/14/03	8/11/03	-14.32
*	MFC-660	3/28/03	8/12/03	-5.08
*	MFC-660	4/11/03	8/12/03	-11.37
*	MFC-660	4/25/03	8/12/03	-14.27
*	MFC-660	5/9/03	8/12/03	-14.29
*	MFC-660	5/23/03	8/13/03	-14.27
*	MFC-660	6/6/03	8/13/03	-13.77
*	MFC-660	6/20/03	8/14/03	-14.72
*	MFC-660	7/4/03	8/14/03	-14.93
*	MFC-660	7/18/03	8/14/03	-14.97
*	MFC-660	8/1/03	8/14/03	-14.87
*	MFC-660	8/15/03	2/11/04	-13.30
*	MFC-660	8/29/03	2/11/04	-14.21
*	MFC-660	9/12/03	2/11/04	-14.00
*	MFC-660	9/27/03	2/11/04	-14.57
*	MFC-660	10/13/03	2/11/04	-14.87
*	MFC-660	10/24/03	2/12/04	-15.07
*	MFC-660	11/7/03	2/12/04	-15.20
*	MFC-660	11/21/03	2/12/04	-14.40
*	MFC-660	12/5/03	2/12/04	-14.27
*	MFC-660	12/19/03	2/13/04	-14.90
*	MFC-660	12/22/03	-	-
*	MFC-660	12/25/03	-	-
*	MFC-660	12/28/03	-	-
*	MFC-660	12/31/03	-	-
*	MFC-660	1/5/04	2/14/04	-14.99

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	MFC-660	1/9/04	-	-
*	MFC-660	1/10/04	-	-
*	MFC-660	1/11/04	-	-
*	MFC-660	1/12/04	-	-
*	MFC-660	1/16/04	2/15/04	-18.26
*	MFC-660	1/19/04	-	-
*	MFC-660	1/29/04	2/15/04	-18.34
*	MFC-660	1/29/04	2/15/04	-16.57
*	MFC-660	1/30/04	7/26/04	-16.63
*	MFC-660	2/13/04	7/27/04	-14.12
*	MFC-660	2/19/04	-	-
*	MFC-660	2/24/04	7/28/04	-15.44
*	MFC-660	2/26/04	7/29/04	-16.01
*	MFC-660	2/27/04	7/29/04	-15.65
*	MFC-660	3/11/04	-	-
*	MFC-660	3/12/04	7/29/04	-15.21
*	MFC-660	3/26/04	7/30/04	-14.67
*	MFC-660	4/9/04	7/30/04	-14.53
*	MFC-660	4/23/04	8/2/04	-14.35
*	MFC-660	5/7/04	8/2/04	-14.86
*	MFC-660	5/21/04	8/2/04	-14.19
*	MFC-660	5/28/04	8/2/04	-13.86
*	MFC-660	6/11/04	8/2/04	-14.03
*	MFC-660	6/25/04	8/2/04	-14.42
*	MFC-660	7/9/04	8/3/04	-14.30
*	MFC-660	7/23/04	8/3/04	-12.20
*	MFC-660	8/6/04	4/20/05	-14.43
*	MFC-660	8/20/04	4/20/05	-14.48
*	MFC-660	9/3/04	4/20/05	-14.42
*	MFC-660	9/17/04	4/20/05	-14.03
*	MFC-660	10/1/04	4/20/05	-14.24
*	MFC-660	10/15/04	4/20/05	-14.12
*	MFC-660	10/29/04	4/20/05	-14.29
*	MFC-660	11/12/04	4/21/05	-14.18
*	MFC-660	11/29/04	4/21/05	-14.21
*	MFC-660	12/13/04	4/22/05	-13.67
*	MFC-660	12/27/04	4/24/05	-14.43
*	MFC-660	1/11/05	4/25/05	-14.22
*	MFC-660	1/12/05	4/25/05	-14.73
*	MFC-660	1/28/05	4/25/05	-14.48
*	MFC-660	2/11/05	4/25/05	-13.50
*	MFC-660	2/25/05	4/25/05	-14.68

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	MFC-660	3/10/05	4/26/05	-14.53
*	MFC-660	3/23/05	4/26/05	-13.71
*	MFC-660	3/25/05	4/26/05	-13.91
*	MFC-660	3/27/05	-	-
*	MFC-660	3/29/05	4/26/05	-14.69
*	MFC-660	4/8/05	4/28/05	-12.76
*	MFC-660	4/12/05	4/28/05	-12.06
*	MFC-660	4/22/05	4/28/05	-13.62
	MFC-660	5/6/05	5/16/06	-14.15
	MFC-660	5/20/05	5/16/06	-13.35
	MFC-660	6/7/05	5/16/06	-14.10
	MFC-660	6/24/05	5/16/06	-14.60
	MFC-660	7/11/05	5/18/06	-14.65
	MFC-660	7/22/05	5/18/06	-14.78
	MFC-660	8/19/05	5/18/06	-14.50
	MFC-660	9/3/05	5/18/06	-14.73
	MFC-660	9/20/05	5/18/06	-14.62
	MFC-660	10/7/05	5/18/06	-14.48
	MFC-660	10/21/05	5/18/06	-14.55
	MFC-660	11/4/05	5/18/06	-14.22
	MFC-660	11/18/05	5/18/06	-14.35
	MFC-660	1/6/06	5/18/06	-14.24
	MFC-660	1/23/06	5/22/06	-14.31
	MFC-660	2/6/06	5/22/06	-13.99
	MFC-660	2/28/06	5/22/06	-14.10
	MFC-660	3/15/06	5/22/06	-14.18
	MFC-660	4/11/06	5/22/06	-14.10
	MFC-660	4/24/06	5/22/06	-13.85
	MFC-660	5/10/06	5/22/06	-13.50
	MFC-660	5/20/06	11/8/06	-14.44
	MFC-660	6/7/06	11/8/06	-14.00
	MFC-660	6/29/06	11/8/06	-14.54
	MFC-660	7/7/06	-	-
	MFC-660	7/26/06	11/8/06	-14.08
	MFC-660	8/10/06	2/9/07	-15.55
	MFC-660	8/25/06	2/9/07	-15.17
	MFC-660	9/6/06	2/9/07	-15.30
	MFC-660	9/20/06	2/9/07	-14.98
	MFC-660	10/6/06	2/9/07	-14.61
	MFC-660	10/18/06	2/9/07	-14.87
	MFC-660	11/1/06	2/9/07	-15.03
	MFC-660	11/6/06	2/9/07	-12.55

Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
MFC-660	11/10/06	2/9/07	-14.31
MFC-660	11/15/06	2/13/07	-14.01
MFC-660	11/29/06	2/13/07	-13.23
MFC-660	12/13/06	2/13/07	-13.57
MFC-660	12/29/06	2/13/07	-12.32
MFC-660	1/4/07	2/13/07	-13.17
MFC-660	1/12/07	2/13/07	-13.83
MFC-660	1/26/07	2/13/07	-17.90
MFC-660	2/9/07	1/10/08	-13.44
MFC-660	2/22/07	1/10/08	-12.93
MFC-660	3/7/07	1/10/08	-13.35
MFC-660	3/23/07	1/10/08	-13.41
MFC-660	4/5/07	1/10/08	-13.31
MFC-660	4/19/07	1/15/08	-13.13
MFC-660	5/4/07	1/15/08	-13.45
MFC-660	5/22/07	1/15/08	-14.81
MFC-660	6/4/07	1/15/08	-14.12
MFC-660	6/19/07	1/15/08	-14.03
MFC-660	7/2/07	1/15/08	-14.01
MFC-660	7/16/07	1/15/08	-14.03
MFC-660	7/31/07	1/17/08	-14.38
MFC-660	8/13/07	1/17/08	-14.72
MFC-660	8/21/07	1/17/08	-14.38
MFC-660	9/4/07	1/17/08	-14.73
MFC-660	9/21/07	1/17/08	-13.56
MFC-660	10/1/07	1/17/08	-13.18
MFC-660	10/19/07	1/17/08	-13.45
MFC-660	11/5/07	1/17/08	-14.00
MFC-660	12/5/07	1/17/08	-14.87
MFC-660	12/17/07	1/17/08	-14.53
MFC-660	1/3/08	1/17/08	-14.11
MFC-660	1/18/08	-	-

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	MFC-4700	10/5/00	-	-
*	MFC-4700	10/19/00	-	-14.21
*	MFC-4700	12/7/00	-	-14.50
*	MFC-4700	1/9/01	-	-15.67
*	MFC-4700	2/2/01	-	-16.34
*	MFC-4700	2/6/01	-	-
*	MFC-4700	2/19/01	-	-16.10
*	MFC-4700	3/2/01	-	-16.20
*	MFC-4700	3/20/01	-	-15.19
*	MFC-4700	4/9/01	-	-15.04
*	MFC-4700	4/16/01	-	-14.50
*	MFC-4700	5/2/01	-	-14.10
*	MFC-4700	5/21/01	-	-13.84
*	MFC-4700	5/30/01	-	-13.36
*	MFC-4700	6/15/01	-	-6.56
*	MFC-4700	7/11/01	-	-12.51
*	MFC-4700	9/27/01	-	-12.61
*	MFC-4700	10/13/01	-	-13.52
*	MFC-4700	10/24/01	-	-13.55
*	MFC-4700	11/7/01	-	-14.30
*	MFC-4700	11/30/01	-	-15.88
*	MFC-4700	12/14/01	-	-16.13
*	MFC-4700	12/27/01	-	-
*	MFC-4700	1/7/02	-	-
*	MFC-4700	1/9/02	-	-16.12
*	MFC-4700	1/24/02	-	-
*	MFC-4700	1/25/02	-	-16.92
*	MFC-4700	1/26/02	-	-17.09
*	MFC-4700	1/27/02	-	-17.03
*	MFC-4700	1/29/02	-	-16.48
*	MFC-4700	2/8/02	-	-17.38
*	MFC-4700	2/22/02	-	-15.64
*	MFC-4700	2/24/02	-	-16.47
*	MFC-4700	3/8/02	-	-16.78
*	MFC-4700	3/11/02	-	-15.44
*	MFC-4700	3/12/02	-	-
*	MFC-4700	3/29/02	-	-15.96
*	MFC-4700	4/12/02	-	-14.52
*	MFC-4700	4/26/02	-	-14.17
*	MFC-4700	4/27/02	-	-14.39
*	MFC-4700	5/10/02	-	-14.35
*	MFC-4700	5/24/02	-	-13.99

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	MFC-4700	5/28/02	-	-13.13
*	MFC-4700	6/11/02	-	-15.00
*	MFC-4700	6/25/02	-	-13.94
*	MFC-4700	7/9/02	-	-13.01
*	MFC-4700	7/23/02	-	-12.81
*	MFC-4700	9/20/02	8/7/03	-13.62
*	MFC-4700	10/16/02	8/7/03	-17.91
*	MFC-4700	11/8/02	8/7/03	-14.20
*	MFC-4700	11/20/02	8/7/03	-13.82
*	MFC-4700	12/4/02	8/7/03	-14.36
*	MFC-4700	12/19/02	8/7/03	-14.76
*	MFC-4700	1/10/03	8/7/03	-14.85
*	MFC-4700	1/17/03	8/11/03	-10.88
*	MFC-4700	1/31/03	8/11/03	-12.33
*	MFC-4700	2/14/03	8/11/03	-14.23
*	MFC-4700	2/28/03	8/11/03	-14.86
*	MFC-4700	3/14/03	8/12/03	-14.61
*	MFC-4700	3/28/03	8/12/03	-11.78
*	MFC-4700	4/11/03	8/12/03	-5.09
*	MFC-4700	4/25/03	8/12/03	-14.15
*	MFC-4700	5/9/03	8/12/03	-14.07
*	MFC-4700	5/23/03	8/13/03	-13.85
*	MFC-4700	6/6/03	8/13/03	-13.54
*	MFC-4700	6/20/03	8/14/03	-13.35
*	MFC-4700	7/4/03	8/14/03	-12.45
*	MFC-4700	7/18/03	8/14/03	-11.75
*	MFC-4700	8/1/03	8/14/03	-9.06
*	MFC-4700	8/15/03	2/11/04	-7.15
*	MFC-4700	8/29/03	2/11/04	-8.22
*	MFC-4700	9/12/03	2/11/04	-10.15
*	MFC-4700	9/27/03	2/11/04	-12.90
*	MFC-4700	10/13/03	2/12/04	-13.39
*	MFC-4700	10/24/03	2/12/04	-13.95
*	MFC-4700	11/7/03	2/12/04	-15.04
*	MFC-4700	11/21/03	2/12/04	-14.07
*	MFC-4700	12/5/03	2/12/04	-14.62
*	MFC-4700	12/19/03	-	-
*	MFC-4700	12/22/03	-	-
*	MFC-4700	12/25/03	-	-
*	MFC-4700	12/28/03	-	-
*	MFC-4700	12/31/03	-	-
*	MFC-4700	1/5/04	2/13/04	-15.63

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	MFC-4700	1/9/04	-	-
*	MFC-4700	1/10/04	-	-
*	MFC-4700	1/11/04	-	-
*	MFC-4700	1/12/04	-	-
*	MFC-4700	1/16/04	2/14/04	-17.00
*	MFC-4700	1/19/04	-	-
*	MFC-4700	1/29/04	2/29/04	-17.94
*	MFC-4700	1/29/04	2/29/04	-18.06
*	MFC-4700	1/30/04	7/26/04	-16.90
*	MFC-4700	2/13/04	7/27/04	-15.17
*	MFC-4700	2/19/04	-	-
*	MFC-4700	2/24/04	7/29/04	-15.45
*	MFC-4700	2/26/04	7/29/04	-16.27
*	MFC-4700	2/27/04	7/29/04	-16.28
*	MFC-4700	3/11/04	-	-
*	MFC-4700	3/12/04	7/29/04	-15.36
*	MFC-4700	3/26/04	7/30/04	-14.52
*	MFC-4700	4/9/04	7/30/04	-14.05
*	MFC-4700	4/23/04	8/2/04	-14.17
*	MFC-4700	5/7/04	8/2/04	-13.99
*	MFC-4700	5/21/04	8/2/04	-13.77
*	MFC-4700	5/28/04	8/2/04	-13.04
*	MFC-4700	6/11/04	8/2/04	-13.59
*	MFC-4700	6/25/04	8/2/04	-12.74
*	MFC-4700	7/9/04	8/3/04	-12.00
*	MFC-4700	7/23/04	8/3/04	-13.92
*	MFC-4700	8/6/04	4/20/05	-10.75
*	MFC-4700	8/20/04	4/20/05	-10.92
*	MFC-4700	9/3/04	4/20/05	-11.73
*	MFC-4700	9/17/04	4/20/05	-12.56
*	MFC-4700	10/1/04	4/20/05	-12.89
*	MFC-4700	10/15/04	4/20/05	-13.29
*	MFC-4700	10/29/04	4/20/05	-13.60
*	MFC-4700	11/12/04	4/21/05	-13.63
*	MFC-4700	11/29/04	4/21/05	-13.68
*	MFC-4700	12/13/04	4/22/05	-13.66
*	MFC-4700	12/27/04	4/24/05	-14.58
*	MFC-4700	1/11/05	-	-
*	MFC-4700	1/12/05	4/25/05	-14.59
*	MFC-4700	1/28/05	4/25/05	-14.34
*	MFC-4700	2/11/05	4/25/05	-13.90
*	MFC-4700	2/25/05	4/26/05	-14.26

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	MFC-4700	3/10/05	4/26/05	-13.48
*	MFC-4700	3/23/05	-	-
*	MFC-4700	3/25/05	4/26/05	-13.29
*	MFC-4700	3/27/05	-	-
*	MFC-4700	3/29/05	-	-
*	MFC-4700	4/8/05	4/28/05	-13.31
*	MFC-4700	4/12/05	-	-
*	MFC-4700	4/22/05	4/28/05	-13.03
	MFC-4700	5/6/05	5/16/06	-13.29
	MFC-4700	5/20/05	5/16/06	-13.49
	MFC-4700	6/7/05	5/16/06	-12.30
	MFC-4700	6/24/05	5/18/06	-11.78
	MFC-4700	7/11/05	5/18/06	-11.44
	MFC-4700	7/22/05	5/18/06	-9.90
	MFC-4700	8/19/05	5/18/06	-4.76
	MFC-4700	9/3/05	-	-
	MFC-4700	9/20/05	-	-
	MFC-4700	10/7/05	5/18/06	-12.16
	MFC-4700	10/21/05	5/18/06	-13.05
	MFC-4700	11/4/05	5/18/06	-13.32
	MFC-4700	11/18/05	5/18/06	-13.29
	MFC-4700	1/6/06	5/22/06	-14.14
	MFC-4700	1/23/06	5/22/06	-14.40
	MFC-4700	2/6/06	5/22/06	-14.07
	MFC-4700	2/28/06	5/22/06	-14.07
	MFC-4700	3/15/06	5/22/06	-14.56
	MFC-4700	4/11/06	5/22/06	-14.35
	MFC-4700	4/24/06	5/22/06	-13.54
	MFC-4700	5/10/06	5/22/06	-13.69
	MFC-4700	5/20/06	11/8/06	-13.51
	MFC-4700	6/7/06	11/8/06	-13.37
	MFC-4700	6/29/06	11/8/06	-13.12
	MFC-4700	7/7/06	-	-
	MFC-4700	7/26/06	11/8/06	-11.03
	MFC-4700	8/10/06	2/9/07	-11.74
	MFC-4700	8/25/06	2/9/07	-12.68
	MFC-4700	9/6/06	2/9/07	-11.69
	MFC-4700	9/20/06	2/9/07	-13.35
	MFC-4700	10/6/06	2/9/07	-13.72
	MFC-4700	10/18/06	2/9/07	-13.99
	MFC-4700	11/1/06	2/9/07	-14.38
	MFC-4700	11/6/06	-	-

Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
MFC-4700	11/10/06	-	-
MFC-4700	11/15/06	2/13/07	-13.44
MFC-4700	11/29/06	2/13/07	-13.48
MFC-4700	12/13/06	2/13/07	-13.66
MFC-4700	12/29/06	2/13/07	-13.94
MFC-4700	1/4/07	2/13/07	-14.52
MFC-4700	1/12/07	2/13/07	-13.89
MFC-4700	1/26/07	2/13/07	-13.64
MFC-4700	2/9/07	2/13/07	-13.39
MFC-4700	2/22/07	1/10/08	-13.13
MFC-4700	3/7/07	1/10/08	-13.23
MFC-4700	3/23/07	1/10/08	-13.24
MFC-4700	4/5/07	1/10/08	-13.19
MFC-4700	4/19/07	1/15/08	-12.96
MFC-4700	5/4/07	1/15/08	-13.02
MFC-4700	5/22/07	1/15/08	-14.17
MFC-4700	6/4/07	1/15/08	-12.02
MFC-4700	6/19/07	1/15/08	-12.86
MFC-4700	7/2/07	1/15/08	-12.02
MFC-4700	7/16/07	-	-9.54
MFC-4700	7/31/07	1/17/08	-8.24
MFC-4700	8/13/07	-	-
MFC-4700	8/21/07	-	-
MFC-4700	9/4/07	-	-
MFC-4700	9/21/07	1/17/08	-14.08
MFC-4700	10/1/07	1/17/08	-12.98
MFC-4700	10/19/07	1/17/08	-13.37
MFC-4700	11/5/07	1/17/08	-14.01
MFC-4700	12/5/07	1/17/08	-15.43
MFC-4700	12/17/07	1/17/08	-14.57
MFC-4700	1/3/08	1/17/08	-14.13
MFC-4700	1/18/08	-	-

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	MFC-5700	10/5/00	-	-
*	MFC-5700	10/19/00	-	-
*	MFC-5700	12/7/00	-	-
*	MFC-5700	1/9/01	-	-15.03
*	MFC-5700	2/2/01	-	-15.75
*	MFC-5700	2/6/01	-	-
*	MFC-5700	2/20/01	-	-
*	MFC-5700	3/2/01	-	-15.94
*	MFC-5700	3/21/01	-	-
*	MFC-5700	4/9/01	-	-15.85
*	MFC-5700	4/16/01	-	-14.54
*	MFC-5700	5/2/01	-	-14.96
*	MFC-5700	5/21/01	-	-
*	MFC-5700	5/30/01	-	-14.96
*	MFC-5700	6/15/01	-	-
*	MFC-5700	7/11/01	-	-11.54
*	MFC-5700	9/27/01	-	-
*	MFC-5700	10/13/01	-	-13.54
*	MFC-5700	10/24/01	-	-12.19
*	MFC-5700	11/7/01	-	-
*	MFC-5700	11/30/01	-	-15.70
*	MFC-5700	12/14/01	-	-16.20
*	MFC-5700	12/27/01	-	-
*	MFC-5700	1/7/02	-	-
*	MFC-5700	1/9/02	-	-
*	MFC-5700	1/24/02	-	-
*	MFC-5700	1/25/02	-	-16.27
*	MFC-5700	1/26/02	-	-16.80
*	MFC-5700	1/27/02	-	-16.85
*	MFC-5700	1/29/02	-	-16.57
*	MFC-5700	2/8/02	-	-16.28
*	MFC-5700	2/22/02	-	-16.51
*	MFC-5700	2/24/02	-	-
*	MFC-5700	3/8/02	-	-16.25
*	MFC-5700	3/11/02	-	-16.18
*	MFC-5700	3/12/02	-	-
*	MFC-5700	3/29/02	-	-
*	MFC-5700	4/12/02	-	-15.40
*	MFC-5700	4/26/02	-	-
*	MFC-5700	4/27/02	-	-
*	MFC-5700	5/10/02	-	-
*	MFC-5700	5/24/02	-	-

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	MFC-5700	5/28/02	-	-10.59
*	MFC-5700	6/11/02	-	-14.38
*	MFC-5700	6/25/02	-	-13.94
*	MFC-5700	7/9/02	-	-13.91
*	MFC-5700	7/23/02	-	-14.27
*	MFC-5700	9/20/02	8/7/03	-12.23
*	MFC-5700	10/16/02	8/7/03	-13.25
*	MFC-5700	11/8/02	8/7/03	-12.87
*	MFC-5700	11/20/02	8/7/03	-12.55
*	MFC-5700	12/4/02	8/7/03	-14.22
*	MFC-5700	12/19/02	8/7/03	-14.71
*	MFC-5700	1/10/03	8/7/03	-14.83
*	MFC-5700	1/17/03	8/11/03	-14.68
*	MFC-5700	1/31/03	8/11/03	-13.15
*	MFC-5700	2/14/03	8/11/03	-14.56
*	MFC-5700	2/28/03	8/11/03	-14.45
*	MFC-5700	3/14/03	8/12/03	-14.57
*	MFC-5700	3/28/03	8/12/03	-13.12
*	MFC-5700	4/11/03	8/12/03	-13.77
*	MFC-5700	4/25/03	8/12/03	-14.09
*	MFC-5700	5/9/03	8/13/03	-14.04
*	MFC-5700	5/23/03	8/13/03	-14.05
*	MFC-5700	6/6/03	8/13/03	-13.71
*	MFC-5700	6/20/03	8/14/03	-13.72
*	MFC-5700	7/4/03	8/14/03	-13.29
*	MFC-5700	7/18/03	8/14/03	-13.22
*	MFC-5700	8/1/03	8/14/03	-12.77
*	MFC-5700	8/15/03	2/11/04	-11.11
*	MFC-5700	8/29/03	2/11/04	-11.16
*	MFC-5700	9/12/03	2/11/04	-11.04
*	MFC-5700	9/27/03	2/11/04	-12.36
*	MFC-5700	10/13/03	2/12/04	-13.42
*	MFC-5700	10/24/03	2/12/04	-14.08
*	MFC-5700	11/7/03	2/12/04	-14.34
*	MFC-5700	11/21/03	2/12/04	-13.95
*	MFC-5700	12/5/03	2/12/04	-14.59
*	MFC-5700	12/19/03	2/13/04	-15.57
*	MFC-5700	12/22/03	-	-
*	MFC-5700	12/25/03	-	-
*	MFC-5700	12/28/03	-	-
*	MFC-5700	12/31/03	-	-
*	MFC-5700	1/5/04	2/14/04	-14.98

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	MFC-5700	1/9/04	-	-
*	MFC-5700	1/10/04	-	-
*	MFC-5700	1/11/04	-	-
*	MFC-5700	1/12/04	-	-
*	MFC-5700	1/16/04	2/15/04	-16.67
*	MFC-5700	1/19/04	-	-
*	MFC-5700	1/29/04	2/15/04	-17.75
*	MFC-5700	1/29/04	2/15/04	-17.45
*	MFC-5700	1/30/04	-	-
*	MFC-5700	2/13/04	7/27/04	-14.88
*	MFC-5700	2/19/04	-	-
*	MFC-5700	2/24/04	7/29/04	-15.34
*	MFC-5700	2/26/04	7/29/04	-16.25
*	MFC-5700	2/27/04	7/29/04	-16.20
*	MFC-5700	3/11/04	-	-
*	MFC-5700	3/12/04	7/29/04	-15.06
*	MFC-5700	3/26/04	7/30/04	-14.45
*	MFC-5700	4/9/04	7/30/04	-14.13
*	MFC-5700	4/23/04	8/2/04	-14.12
*	MFC-5700	5/7/04	8/2/04	-14.34
*	MFC-5700	5/21/04	8/2/04	-13.87
*	MFC-5700	5/28/04	8/2/04	-13.41
*	MFC-5700	6/11/04	8/2/04	-13.55
*	MFC-5700	6/25/04	8/2/04	-13.70
*	MFC-5700	7/9/04	8/3/04	-13.32
*	MFC-5700	7/23/04	8/3/04	-14.02
*	MFC-5700	8/6/04	4/20/05	-12.87
*	MFC-5700	8/20/04	4/20/05	-12.51
*	MFC-5700	9/3/04	4/20/05	-10.99
*	MFC-5700	9/17/04	4/20/05	-12.46
*	MFC-5700	10/1/04	4/20/05	-11.91
*	MFC-5700	10/15/04	4/20/05	-12.90
*	MFC-5700	10/29/04	4/20/05	-13.11
*	MFC-5700	11/12/04	4/21/05	-13.68
*	MFC-5700	11/29/04	4/21/05	-13.52
*	MFC-5700	12/13/04	4/23/05	-13.87
*	MFC-5700	12/27/04	4/24/05	-14.32
*	MFC-5700	1/11/05	-	-
*	MFC-5700	1/12/05	4/25/05	-14.79
*	MFC-5700	1/28/05	4/25/05	-14.22
*	MFC-5700	2/11/05	4/25/05	-13.50
*	MFC-5700	2/25/05	4/26/05	-14.12

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	MFC-5700	3/10/05	4/26/05	-13.68
*	MFC-5700	3/23/05	-	-
*	MFC-5700	3/25/05	4/26/05	-13.07
*	MFC-5700	3/27/05	-	-
*	MFC-5700	3/29/05	-	-
*	MFC-5700	4/8/05	4/28/05	-13.44
*	MFC-5700	4/12/05	-	-
*	MFC-5700	4/22/05	4/28/05	-12.98
	MFC-5700	5/6/05	5/16/06	-13.31
	MFC-5700	5/20/05	5/16/06	-13.11
	MFC-5700	6/7/05	5/16/06	-12.93
	MFC-5700	6/24/05	5/18/06	-12.96
	MFC-5700	7/11/05	5/18/06	-13.49
	MFC-5700	7/22/05	5/18/06	-13.42
	MFC-5700	8/19/05	5/18/06	-12.23
	MFC-5700	9/3/05	5/18/06	-11.78
	MFC-5700	9/20/05	5/18/06	-11.35
	MFC-5700	10/7/05	5/18/06	-12.16
	MFC-5700	10/21/05	5/18/06	-13.18
	MFC-5700	11/4/05	5/18/06	-13.47
	MFC-5700	11/18/05	5/18/06	-13.46
	MFC-5700	1/6/06	5/18/06	-14.57
	MFC-5700	1/23/06	5/22/06	-14.22
	MFC-5700	2/6/06	5/22/06	-13.80
	MFC-5700	2/28/06	5/22/06	-13.77
	MFC-5700	3/15/06	5/22/06	-14.31
	MFC-5700	4/11/06	5/22/06	-13.62
	MFC-5700	4/24/06	5/22/06	-13.48
	MFC-5700	5/10/06	5/22/06	-13.40
	MFC-5700	5/20/06	11/8/06	-13.57
	MFC-5700	6/7/06	11/8/06	-13.92
	MFC-5700	6/29/06	11/8/06	-13.46
	MFC-5700	7/7/06	-	-
	MFC-5700	7/26/06	11/8/06	-13.50
	MFC-5700	8/10/06	2/9/07	-11.23
	MFC-5700	8/25/06	2/9/07	-12.32
	MFC-5700	9/6/06	2/9/07	-12.35
	MFC-5700	9/20/06	2/9/07	-11.99
	MFC-5700	10/6/06	2/9/07	-13.08
	MFC-5700	10/18/06	2/9/07	-13.22
	MFC-5700	11/1/06	2/9/07	-12.00
	MFC-5700	11/6/06	-	-

Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
MFC-5700	11/10/06	-	-
MFC-5700	11/15/06	2/13/07	-12.59
MFC-5700	11/29/06	2/13/07	-13.17
MFC-5700	12/13/06	2/13/07	-13.42
MFC-5700	12/29/06	2/13/07	-13.94
MFC-5700	1/4/07	2/13/07	-14.59
MFC-5700	1/12/07	2/13/07	-13.89
MFC-5700	1/26/07	2/13/07	-11.66
MFC-5700	2/9/07	2/13/07	-13.55
MFC-5700	2/22/07	1/10/08	-13.44
MFC-5700	3/7/07	1/10/08	-13.22
MFC-5700	3/23/07	1/10/08	-13.29
MFC-5700	4/5/07	1/10/08	-13.39
MFC-5700	4/19/07	-	-12.75
MFC-5700	5/4/07	1/15/08	-13.59
MFC-5700	5/22/07	1/15/08	-13.61
MFC-5700	6/4/07	1/15/08	-14.07
MFC-5700	6/19/07	1/15/08	-11.61
MFC-5700	7/2/07	1/15/08	-12.65
MFC-5700	7/16/07	1/15/08	-12.43
MFC-5700	7/31/07	1/15/08	-11.98
MFC-5700	8/13/07	-	-
MFC-5700	8/21/07	-	-
MFC-5700	9/4/07	-	-
MFC-5700	9/21/07	-	-
MFC-5700	10/1/07	-	-
MFC-5700	10/19/07	1/17/08	-13.06
MFC-5700	11/5/07	1/17/08	-13.23
MFC-5700	12/5/07	1/17/08	-15.46
MFC-5700	12/17/07	1/17/08	-14.16
MFC-5700	1/3/08	1/17/08	-13.94
MFC-5700	1/18/08	-	-

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	Rain @ A	10/5/00	-	-
*	Rain @ A	10/19/00	-	-
*	Rain @ A	12/8/00	-	-
*	Rain @ A	1/9/01	-	-
*	Rain @ A	2/5/01	-	-
*	Rain @ A	2/6/01	-	-
*	Rain @ A	2/19/01	-	-
*	Rain @ A	3/3/01	-	-
*	Rain @ A	3/20/01	-	-
*	Rain @ A	4/12/01	-	-
*	Rain @ A	4/16/01	-	-
*	Rain @ A	5/2/01	-	-
*	Rain @ A	5/21/01	-	-
*	Rain @ A	5/30/01	-	-
*	Rain @ A	6/14/01	-	-
*	Rain @ A	7/26/01	-	-12.44
*	Rain @ A	9/27/01	-	-
*	Rain @ A	10/13/01	-	-
*	Rain @ A	10/24/01	-	-
*	Rain @ A	11/7/01	-	-
*	Rain @ A	11/30/01	-	-
*	Rain @ A	12/14/01	-	-
*	Rain @ A	12/27/01	-	-
*	Rain @ A	1/7/02	-	-
*	Rain @ A	1/10/02	-	-13.21
*	Rain @ A	1/24/02	-	-16.80
*	Rain @ A	1/25/02	-	-16.62
*	Rain @ A	1/26/02	-	-
*	Rain @ A	1/27/02	-	-
*	Rain @ A	1/29/02	-	-
*	Rain @ A	2/8/02	-	-
*	Rain @ A	2/22/02	-	-
*	Rain @ A	2/24/02	-	-
*	Rain @ A	3/8/02	-	-
*	Rain @ A	3/11/02	-	-
*	Rain @ A	3/12/02	-	-
*	Rain @ A	3/29/02	-	-
*	Rain @ A	4/12/02	-	-
*	Rain @ A	4/26/02	-	-12.72
*	Rain @ A	4/27/02	-	-
*	Rain @ A	5/10/02	-	-
*	Rain @ A	5/24/02	-	-12.77

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	Rain @ A	5/28/02	-	-11.23
*	Rain @ A	6/11/02	-	-17.08
*	Rain @ A	6/25/02	-	-15.76
*	Rain @ A	7/9/02	-	-12.04
*	Rain @ A	7/23/02	-	-
*	Rain @ A	9/20/02	-	-12.32
*	Rain @ A	10/16/02	-	-7.09
*	Rain @ A	11/8/02	-	-13.26
*	Rain @ A	11/20/02	-	-
*	Rain @ A	12/4/02	-	-
*	Rain @ A	12/19/02	-	-16.16
*	Rain @ A	1/10/03	-	-17.70
*	Rain @ A	1/17/03	-	-14.18
*	Rain @ A	1/31/03	-	-12.37
*	Rain @ A	2/14/03	-	-15.29
*	Rain @ A	2/28/03	-	-
*	Rain @ A	3/14/03	-	-
*	Rain @ A	3/28/03	-	-11.86
*	Rain @ A	4/11/03	-	-8.03
*	Rain @ A	4/25/03	-	-14.36
*	Rain @ A	5/9/03	-	-14.03
*	Rain @ A	5/23/03	-	-15.82
*	Rain @ A	6/6/03	-	-7.50
*	Rain @ A	6/20/03	-	-
*	Rain @ A	7/4/03	-	-
*	Rain @ A	7/18/03	-	-
*	Rain @ A	8/1/03	-	-
*	Rain @ A	8/15/03	-	-
*	Rain @ A	8/29/03	-	-
*	Rain @ A	9/12/03	-	-9.61
*	Rain @ A	9/27/03	-	-7.77
*	Rain @ A	10/13/03	-	-16.10
*	Rain @ A	10/24/03	-	-
*	Rain @ A	11/16/03	-	-14.27
*	Rain @ A	11/21/03	-	-12.54
*	Rain @ A	12/5/03	-	-16.62
*	Rain @ A	12/19/03	-	-18.80
*	Rain @ A	12/22/03	-	-
*	Rain @ A	12/25/03	-	-15.65
*	Rain @ A	12/28/03	-	-
*	Rain @ A	12/31/03	-	-
*	Rain @ A	1/5/04	-	-

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	Rain @ A	1/9/04	-	-17.62
*	Rain @ A	1/10/04	-	-
*	Rain @ A	1/11/04	-	-
*	Rain @ A	1/12/04	-	-
*	Rain @ A	1/16/04	-	-14.80
*	Rain @ A	1/19/04	-	-
*	Rain @ A	1/29/04	-	-18.49
*	Rain @ A	1/30/04	-	-
*	Rain @ A	2/13/04	-	-13.30
*	Rain @ A	2/19/04	-	-14.60
*	Rain @ A	2/24/04	-	-
*	Rain @ A	2/26/04	-	-15.00
*	Rain @ A	2/27/04	-	-16.81
*	Rain @ A	3/11/04	-	-
*	Rain @ A	3/12/04	-	-
*	Rain @ A	3/26/04	-	-16.56
*	Rain @ A	4/9/04	-	-
*	Rain @ A	4/23/04	-	-13.41
*	Rain @ A	5/7/04	-	-12.11
*	Rain @ A	5/21/04	-	-8.88
*	Rain @ A	5/28/04	-	-12.90
*	Rain @ A	6/11/04	-	-10.49
*	Rain @ A	6/25/04	-	-12.41
*	Rain @ A	7/9/04	-	-
*	Rain @ A	7/23/04	-	-
*	Rain @ A	8/6/04	-	-11.36
*	Rain @ A	8/20/04	-	-
*	Rain @ A	9/3/04	-	-13.59
*	Rain @ A	9/17/04	-	-6.77
*	Rain @ A	10/1/04	-	-
*	Rain @ A	10/15/04	-	-
*	Rain @ A	10/29/04	-	-9.20
*	Rain @ A	11/12/04	-	-15.08
*	Rain @ A	11/29/04	-	-8.22
*	Rain @ A	12/13/04	-	-14.26
*	Rain @ A	12/27/04	-	-16.33
*	Rain @ A	1/11/05	-	-
*	Rain @ A	1/12/05	-	-21.38
*	Rain @ A	1/28/05	-	-
*	Rain @ A	2/11/05	-	-11.24
*	Rain @ A	2/25/05	-	-8.15
*	Rain @ A	3/10/05	-	-

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	Rain @ A	3/23/05	-	-
*	Rain @ A	3/25/05	-	-
*	Rain @ A	3/27/05	-	-12.17
*	Rain @ A	3/29/05	-	-11.72
*	Rain @ A	4/8/05	-	-
*	Rain @ A	4/12/05	-	-15.80
*	Rain @ A	4/22/05	-	-8.76
	Rain @ A	5/6/05	5/16/06	-13.53
	Rain @ A	5/20/05	5/16/06	-12.19
	Rain @ A	6/7/05	-	-14.78
	Rain @ A	6/24/05	-	-8.85
	Rain @ A	7/11/05	5/18/06	-17.16
	Rain @ A	7/22/05	-	-17.71
	Rain @ A	8/19/05	-	-
	Rain @ A	9/3/05	-	-
	Rain @ A	9/20/05	-	-
	Rain @ A	10/7/05	-	-
	Rain @ A	10/21/05	-	-
	Rain @ A	11/4/05	5/18/06	-10.91
	Rain @ A	11/18/05	5/18/06	-14.36
	Rain @ A	1/6/06	5/18/06	-16.44
	Rain @ A	1/23/06	5/22/06	-17.93
	Rain @ A	2/6/06	5/22/06	-13.99
	Rain @ A	2/28/06	5/22/06	-16.90
	Rain @ A	3/15/06	5/22/06	-14.45
	Rain @ A	4/11/06	5/22/06	-18.13
	Rain @ A	4/24/06	11/8/06	-15.16
	Rain @ A	5/10/06	-	-
	Rain @ A	5/20/06	11/8/06	-12.50
	Rain @ A	6/7/06	11/8/06	-14.18
	Rain @ A	6/29/06	-	-
	Rain @ A	7/7/06	-	-
	Rain @ A	7/26/06	-	-12.00
	Rain @ A	8/10/06	-	-
	Rain @ A	8/25/06	2/9/07	-4.05
	Rain @ A	9/6/06	-	
	Rain @ A	9/22/06	2/9/07	-9.80
	Rain @ A	10/6/06	11/8/06	-
	Rain @ A	10/18/06	2/9/07	-11.39
	Rain @ A	11/1/06	2/9/07	-9.66
	Rain @ A	11/6/06	2/9/07	-9.43
	Rain @ A	11/10/06	2/9/07	-11.46

Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
Rain @ A	11/15/06	2/13/07	-17.80
Rain @ A	11/29/06	2/13/07	-11.88
Rain @ A	12/13/06	2/13/07	-15.99
Rain @ A	12/29/06	2/13/07	-17.05
Rain @ A	1/4/07	2/13/07	-16.69
Rain @ A	1/12/07	2/13/07	-10.30
Rain @ A	1/26/07	-	-
Rain @ A	2/9/07	1/10/08	-15.42
Rain @ A	2/22/07	1/10/08	-15.19
Rain @ A	3/7/07	1/10/08	-16.17
Rain @ A	3/23/07	1/10/08	-16.34
Rain @ A	4/5/07	1/15/08	-10.93
Rain @ A	4/19/07	-	-12.13
Rain @ A	5/4/07	1/15/08	-11.24
Rain @ A	5/22/07	1/15/08	-15.27
Rain @ A	6/4/07	1/15/08	-10.34
Rain @ A	6/19/07	1/15/08	-11.22
Rain @ A	7/2/07	1/15/08	-10.91
Rain @ A	7/16/07	-	-
Rain @ A	7/31/07	1/17/08	-9.74
Rain @ A	8/13/07	-	-
Rain @ A	8/21/07	1/17/08	-14.76
Rain @ A	9/4/07	1/17/08	-8.95
Rain @ A	9/21/07	1/17/08	-9.12
Rain @ A	10/1/07	1/17/08	-13.73
Rain @ A	10/19/07	1/17/08	-12.19
Rain @ A	11/5/07	-	-
Rain @ A	12/5/07	1/17/08	-13.78
Rain @ A	12/17/07	-	-
Rain @ A	1/3/08	1/17/08	-14.68
Rain @ A	1/18/08	-	

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	Rain @ C	10/5/00	-	-
*	Rain @ C	10/19/00	-	-
*	Rain @ C	12/8/00	-	-
*	Rain @ C	1/9/01	-	-
*	Rain @ C	2/5/01	-	-
*	Rain @ C	2/6/01	-	-
*	Rain @ C	2/19/01	-	-
*	Rain @ C	3/3/01	-	-
*	Rain @ C	3/20/01	-	-
*	Rain @ C	4/12/01	-	-
*	Rain @ C	4/16/01	-	-
*	Rain @ C	5/2/01	-	-
*	Rain @ C	5/21/01	-	-
*	Rain @ C	5/30/01	-	-
*	Rain @ C	6/14/01	-	-
*	Rain @ C	7/11/01	-	-
*	Rain @ C	9/27/01	-	-
*	Rain @ C	10/13/01	-	-
*	Rain @ C	10/24/01	-	-
*	Rain @ C	11/7/01	-	-
*	Rain @ C	11/30/01	-	-
*	Rain @ C	12/14/01	-	-
*	Rain @ C	12/27/01	-	-
*	Rain @ C	1/7/02	-	-
*	Rain @ C	1/9/02	-	-
*	Rain @ C	1/24/02	-	-
*	Rain @ C	1/25/02	-	-
*	Rain @ C	1/26/02	-	-
*	Rain @ C	1/27/02	-	-
*	Rain @ C	1/29/02	-	-
*	Rain @ C	2/8/02	-	-
*	Rain @ C	2/22/02	-	-
*	Rain @ C	2/24/02	-	-
*	Rain @ C	3/8/02	-	-
*	Rain @ C	3/11/02	-	-
*	Rain @ C	3/12/02	-	-
*	Rain @ C	3/29/02	-	-
*	Rain @ C	4/12/02	-	-
*	Rain @ C	4/26/02	-	-
*	Rain @ C	4/27/02	-	-
*	Rain @ C	5/10/02	-	-
*	Rain @ C	5/24/02	-	-

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	Rain @ C	5/28/02	-	-
*	Rain @ C	6/11/02	-	-
*	Rain @ C	6/25/02	-	-
*	Rain @ C	7/9/02	-	-
*	Rain @ C	7/23/02	-	-
*	Rain @ C	9/20/02	-	-
*	Rain @ C	10/16/02	-	-
*	Rain @ C	11/8/02	-	-
*	Rain @ C	11/20/02	-	-
*	Rain @ C	12/4/02	-	-
*	Rain @ C	12/19/02	-	-
*	Rain @ C	1/10/03	-	-
*	Rain @ C	1/17/03	-	-
*	Rain @ C	1/31/03	-	-
*	Rain @ C	2/14/03	-	-
*	Rain @ C	2/28/03	-	-
*	Rain @ C	3/14/03	-	-
*	Rain @ C	3/28/03	-	-
*	Rain @ C	4/11/03	-	-
*	Rain @ C	4/25/03	-	-
*	Rain @ C	5/9/03	-	-
*	Rain @ C	5/23/03	-	-
*	Rain @ C	6/6/03	-	-
*	Rain @ C	6/20/03	-	-
*	Rain @ C	7/4/03	-	-
*	Rain @ C	7/18/03	-	-
*	Rain @ C	8/1/03	-	-
*	Rain @ C	8/15/03	-	-
*	Rain @ C	8/29/03	-	-
*	Rain @ C	9/12/03	-	-
*	Rain @ C	9/27/03	-	-
*	Rain @ C	10/13/03	-	-
*	Rain @ C	10/24/03	-	-
*	Rain @ C	11/7/03	-	-
*	Rain @ C	11/21/03	-	-
*	Rain @ C	12/5/03	-	-
*	Rain @ C	12/19/03	-	-
*	Rain @ C	12/22/03	-	-
*	Rain @ C	12/25/03	-	-
*	Rain @ C	12/28/03	-	-
*	Rain @ C	12/31/03	-	-
*	Rain @ C	1/5/04	-	-

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	Rain @ C	1/9/04	-	-
*	Rain @ C	1/10/04	-	-
*	Rain @ C	1/11/04	-	-
*	Rain @ C	1/12/04	-	-
*	Rain @ C	1/16/04	-	-
*	Rain @ C	1/19/04	-	-
*	Rain @ C	1/29/04	-	-
*	Rain @ C	1/29/04	-	-
*	Rain @ C	1/30/04	-	-
*	Rain @ C	2/13/04	-	-
*	Rain @ C	2/19/04	-	-
*	Rain @ C	2/24/04	-	-
*	Rain @ C	2/26/04	-	-
*	Rain @ C	2/27/04	-	-
*	Rain @ C	3/11/04	-	-
*	Rain @ C	3/12/04	-	-
*	Rain @ C	3/26/04	-	-
*	Rain @ C	4/9/04	-	-
*	Rain @ C	4/23/04	-	-
*	Rain @ C	5/7/04	-	-
*	Rain @ C	5/21/04	-	-
*	Rain @ C	5/28/04	-	-
*	Rain @ C	6/11/04	-	-
*	Rain @ C	6/25/04	-	-
*	Rain @ C	7/9/04	-	-
*	Rain @ C	7/23/04	-	-
*	Rain @ C	8/6/04	-	-
*	Rain @ C	8/20/04	-	-
*	Rain @ C	9/3/04	-	-
*	Rain @ C	9/17/04	-	-
*	Rain @ C	10/1/04	-	-
*	Rain @ C	10/15/04	-	-
*	Rain @ C	10/29/04	-	-
*	Rain @ C	11/12/04	-	-10.38
*	Rain @ C	11/29/04	-	-11.36
*	Rain @ C	12/13/04	-	-16.42
*	Rain @ C	12/27/04	-	-
*	Rain @ C	1/11/05	-	-19.74
*	Rain @ C	1/12/05	-	-
*	Rain @ C	1/28/05	-	-9.56
*	Rain @ C	2/11/05	-	-8.34
*	Rain @ C	2/25/05	-	-8.35

	Sample location	Sample Date	$\delta^{18}O$ Analysis Date	$\delta^{18}O$ Value (‰)
*	Rain @ C	3/10/05	-	-
*	Rain @ C	3/23/05	-	-
*	Rain @ C	3/25/05	-	-11.41
*	Rain @ C	3/27/05	-	-12.40
*	Rain @ C	3/29/05	-	-
*	Rain @ C	4/8/05	-	-17.26
*	Rain @ C	4/12/05	-	-
*	Rain @ C	4/22/05	-	-
	Rain @ C	5/6/05	5/16/06	-7.90
	Rain @ C	5/20/05	5/16/06	-15.04
	Rain @ C	6/7/05	5/16/06	-8.72
	Rain @ C	6/24/05	5/16/06	-10.95
	Rain @ C	7/11/05	5/18/06	-12.84
	Rain @ C	7/22/05	-	-
	Rain @ C	8/19/05	5/18/06	-9.50
	Rain @ C	9/3/05	-	-
	Rain @ C	9/20/05	-	-
	Rain @ C	10/7/05	5/18/06	-10.57
	Rain @ C	10/21/05	-	-
	Rain @ C	11/4/05	5/18/06	-12.32
	Rain @ C	11/18/05	5/18/06	-13.87
	Rain @ C	1/6/06	5/18/06	-17.27
	Rain @ C	1/23/06	-	-
	Rain @ C	2/6/06	-	-
	Rain @ C	2/28/06	-	-
	Rain @ C	3/15/06	-	-
	Rain @ C	4/11/06	-	-
	Rain @ C	4/24/06	-	-
	Rain @ C	5/10/06	-	-
	Rain @ C	5/20/06	-	-
	Rain @ C	6/7/06	-	-
	Rain @ C	6/29/06	-	-
	Rain @ C	7/7/06	-	-
	Rain @ C	7/26/06	-	-
	Rain @ C	8/10/06	-	-
	Rain @ C	8/25/06	-	-
	Rain @ C	9/6/06	-	-
	Rain @ C	9/20/06	-	-
	Rain @ C	10/6/06	-	-
	Rain @ C	10/18/06	-	-

APPENDIX D Equations for Monthly Volume-Weighted $\delta^{18}O$ for Precipitation

Precipitation $\delta^{18}O$ was volume weighted to resolve isotopic inputs from short and small events from longer and more statistically significant precipitation events values for $\delta^{18}O$ from precipitation were volume weighted for precipitation volume on a monthly basis using equation 1 from Goodwin (2006):

$$\delta^{18}O_{sample} = \frac{\sum_{i=sample}^{month} \delta^{18}O_i P_i}{\sum_{i=sample}^{month} P_i} \tag{1}$$

Precipitation volume weighted $\delta^{18}O$-H_2O were also volume weighted seasonally using equations 2 and 3:

$$\delta^{18}O_{w\,\mathrm{int}\,erseason} = \frac{\sum_{i=monthlyweighted}^{w\,\mathrm{int}\,ermonths} \delta^{18}O_i P_i}{\sum_{i=monthlyweighted}^{w\,\mathrm{int}\,ermonths} P_i} \tag{2}$$

And

$$\delta^{18}O_{summerseason} = \frac{\sum_{i=monthlyweighted}^{summermonths} \delta^{18}O_i P_i}{\sum_{i=monthlyweighted}^{summermonths} P_i} \tag{3}$$

Where P_i is the precipitation amount in mm, $\delta^{18}O_i$ is the isotopic composition of precipitation for the stated precipitation amount P_i.

Date	Precipitation Monthly Sum (mm)	Precipitation cumulative sum (mm)	Precipitation Monthly Volume Weighted d18O	Precipitation Monthly Average EC	Average d18O TD-12	Average d18O MFC-4700
Oct-00	27.70	27.70			-14.79	-14.21
Nov-00	40.20	67.90				
Dec-00	30.73	98.63			-15.57	-14.50
Jan-01	29.46	128.09			-14.93	-15.67
Feb-01	30.23	158.32			-15.54	-16.22
Mar-01	36.83	195.15			-14.90	-15.69
Apr-01	61.72	256.87			-15.30	-14.77
May-01	25.15	282.02			-15.80	-13.77
Jun-01	32.77	314.79			-16.62	-6.56
Jul-01	11.68	326.47	-12.44		-12.15	-12.51
Aug-01	1.52	327.99				
Sep-01	8.13	336.12				-12.61
Oct-01	55.63	55.63			-14.64	-13.54
Nov-01	81.54	137.17			-15.29	-15.09
Dec-01	44.70	181.87			-13.09	-16.13
Jan-02	67.31	249.18	-15.55		-14.96	-16.73
Feb-02	42.42	291.60			-15.19	-16.50
Mar-02	52.58	344.18			-15.46	-16.06
Apr-02	26.67	370.85	-12.17		-15.77	-14.36
May-02	18.80	389.65	-13.31		-14.80	-13.83
Jun-02	41.91	431.56	-15.69		-14.90	-14.47
Jul-02	3.90	435.46	-11.47		-14.97	-12.91
Aug-02	10.20	445.66				
Sep-02	9.90	455.56	-11.75		-15.12	-13.62
Oct-02	17.30	17.30	-11.12		-14.88	-17.91
Nov-02	21.34	38.64	-14.30		-14.62	-14.01
Dec-02	62.48	101.12	-16.25		-14.80	-14.56
Jan-03	134.87	235.99	-12.89		-14.59	-12.69
Feb-03	34.80	270.78	-12.38		-14.54	-14.55
Mar-03	101.35	372.13	-11.31		-13.60	-13.20
Apr-03	30.23	402.36	-12.26		-13.93	-9.62
May-03	28.19	430.55	-11.82		-14.68	-13.96
Jun-03	3.56	434.11	-8.08		-14.72	-13.44
Jul-03	1.78	435.88			-14.94	-12.10
Aug-03	13.97	449.85			-14.58	-8.15
Sep-03	19.05	468.90	-9.24		-14.53	-11.53
Oct-03	18.29	18.29	-15.53		-15.01	-13.67
Nov-03	48.77	67.06	-14.24		-15.28	-14.55
Dec-03	69.34	136.40	-17.00		-15.16	-14.62

Date	Precipitation Monthly Sum (mm)	Precipitation cumulative sum (mm)	Precipitation Monthly Volume Weighted d18O	Precipitation Monthly Average EC	Average d18O TD-12	Average d18O MFC-4700
Jan-04	61.72	198.12	-17.17		-15.45	-17.10
Feb-04	41.40	239.52	-14.62		-14.44	-15.79
Mar-04	27.94	267.46	-14.80		-14.92	-14.94
Apr-04	14.73	282.19	-11.53		-14.73	-14.11
May-04	66.80	349.00	-11.37		-14.80	-13.60
Jun-04	11.94	360.93	-12.12		-14.68	-13.17
Jul-04	4.83	365.76	-8.53		-14.42	-12.96
Aug-04	34.04	399.80	-8.14			-10.84
Sep-04	41.91	441.71	-9.19		-14.16	-12.14
Oct-04	40.64	40.64	-13.38		-14.40	-13.26
Nov-04	30.73	71.37	-12.26		-14.38	-13.65
Dec-04	28.45	99.82	-16.27		-14.67	-14.12
Jan-05	26.92	126.75	-12.47		-14.74	-14.46
Feb-05	4.06	130.81	-9.66		-14.95	-14.08
Mar-05	55.12	185.93	-11.83		-14.27	-13.38
Apr-05	35.56	221.49	-13.12		-14.01	-13.17
May-05	79.42	300.91	-13.47		-14.45	-13.39
Jun-05	30.20	331.11	-10.03		-14.81	-12.04
Jul-05	0.01	331.11	-17.71		-14.52	-11.44
Aug-05	0.13	331.24			-14.71	-4.76
Sep-05	2.63	333.87			-14.56	
Oct-05	40.78	40.78			-13.97	-12.61
Nov-05	33.40	74.18	-11.91		-14.77	-13.31
Dec-05	55.33	129.51				
Jan-06	91.39	220.90	-14.16		-14.43	-14.27
Feb-06	14.06	234.96	-16.85		-14.23	-14.07
Mar-06	24.60	259.56	-18.13		-14.36	-14.56
Apr-06	54.53	314.09	-15.16	9.53	-14.70	-13.95
May-06	48.13	362.22	-12.50		-14.28	-13.60
Jun-06	46.86	409.08	-12.00	10.61	-14.89	-13.25
Jul-06	1.44	410.52		194.85	-15.14	-11.03
Aug-06	7.08	417.60	-4.05	40.76	-15.10	-12.21
Sep-06	15.14	432.74	-9.80	29.94	-14.46	-12.52
Oct-06	24.78	24.78	-10.60	8.41	-14.81	-13.86
Nov-06	122.90	147.68	-12.28	7.63	-14.72	-13.76
Dec-06	49.46	197.14	-16.54	3.78	-14.48	-13.80
Jan-07	49.60	246.74	-15.79		-13.72	-14.02
Feb-07	27.81	274.55	-16.07	6.61	-13.72	-13.26

Date	Precipitation Monthly Sum (mm)	Precipitation cumulative sum (mm)	Precipitation Monthly Volume Weighted d18O	Precipitation Monthly Average EC	Average d18O TD-12	Average d18O MFC-4700
Mar-07	37.28	311.83	-12.99	8.93	-13.60	-13.24
Apr-07	27.91	339.74	-12.13	19.32	-13.82	-13.08
May-07	35.80	375.54	-14.39	20.02	-13.60	-13.24
Jun-07	23.97	399.51	-11.06	193.38	-14.29	-12.44
Jul-07	7.95	407.46	-9.74	85.97		-8.89
Aug-07	11.03	418.49	-14.76	58.06	-14.43	
Sep-07	2.21	420.70	-8.97		-14.75	-14.08
Oct-07	43.47	43.47	-12.19		-14.34	-13.17
Nov-07	51.24	94.71	-13.78		-14.70	-14.01
Dec-07	57.31	152.02	-14.68		-14.95	-15.00

Season/year (oct-mar=wint) (apr-sep=sum)	Seasonal Precipitation Sum (mm)	Seasonal weighted d18O (PPT)	Average d18O TD-12	Average d18O MFC-4700	Average d18O MFC-5700
Winter 00-01	195.15		-15.17	-15.57	-15.46
Summer 01	140.97	-12.44	-15.16	-14.37	-12.82
Winter 01-02	344.18	-15.55	-14.91	-15.78	-15.92
Summer 02	111.38	-13.77	-15.16	-13.53	-13.90
Winter 02-03	372.13	-12.97	-14.48	-13.91	-14.05
Summer 03	96.77	-11.21	-14.53	-12.95	-11.21
Winter 03-04	267.46	-15.84	-15.20	-15.31	-15.60
Summer 04	174.25	-10.20	-14.58	-13.33	-12.86
Winter 04-05	185.93	-12.96	-14.55	-13.59	-13.78
Summer 05	147.95	-12.67	-14.47	-12.70	-11.68
Winter 05-06	259.56	-14.53	-14.35	-13.65	-13.67
Summer 06	173.18	-12.62	-14.71	-12.92	-12.92
Winter 06-07	311.83	-13.80	-14.25	-13.22	-13.69
Summer 07	108.87	-12.67	-14.21	-12.90	-12.21
Winter 07-08	152.02	-13.66	-14.63	-13.97	-14.08

APPENDIX E: Summary of Isotopic Discrimination due to Environmental Conditions and Derivation of the Equations for Estimation of Surface Water Evaporation Based on $\delta^{18}O$ Isotopes and Electrical Conductivity

Oxygen stable isotopes are measured as a ratio of the heavier isotope (^{18}O) to the lighter more common isotope (^{16}O) and is denoted as:

$$R = \frac{N^{18}O}{N^{16}O} \tag{1}$$

Where *N* is the number of isotopes from a particular substrate. Stable isotope compositions are reported in δ form, which is the isotopic ratio of the R_{Sample} to $R_{Standard}$. This is defined as:

$$\delta(‰) = \frac{R_{Sample}}{R_{Standard}} \times 1000 \tag{2}$$

Samples with δ(‰) values less than 0‰ are considered depleted in the heavier isotope compared to the standard (or more negative), where δ(‰) values greater than 0‰ are considered enriched in the heavier isotope compared to the standard (or more positive). The standard for $\delta^{18}O$ is defined by the International Atomic Energy Agency (IAEA) as Vienna Standard Meteoric Ocean Water (VSMOW) in which $\delta^{18}O$ = 0‰.

Stable isotopes in water have been used as conservative tracers for years to characterize hydrologic processes from meteorology to surface and ground water dynamics. Craig (1961) was the first researcher to characterize the Mean Water Line (MWL). The MWL utilizes $\delta^{2}H$ and $\delta^{18}O$ in which all meteoric waters fit. This line has a slope of ~8. Any divergence from the MWL indicates fractionation processes that have helped numerous researchers to identify hydrologic processes (such as evaporation) around the globe.

Craig and Gordon (1965) utilized both $\delta^{2}H$ and $\delta^{18}O$ to estimate evaporation from freestanding water bodies at steady state plotting these stable isotopes on the MWL and calculating the divergence from a slope of 8. (Their observed slope was ~6 indicating fractionation due to evaporation). The Craig-Gordon Model as reported by Craig and Gordon (1965) and latter summarized Gat (1996) has lead to modeling efforts of the fractionation of δ^2H due to evaporation of pore water in saturated soils (Zimmermann, 1967), and unsaturated soils (Barnes and Allison, 1983, 1984, and 1988). The Zimmermann (1967) analysis defined the term evaporative front, in which diffusion of shallow, heavy water balanced the evaporative convection of deep, lighter water upwards. DePaolo et al. (2004) modeled the propagation of an evaporative front in the thick vadose zone at Hanford, WA. For isotopic fractionation in surface waters, Gibson, et al (1993) modeled the effects of evaporation on the isotopic signatures of surface waters at non-steady state for 2 catchments in Canada. They were able to estimate the evaporative flux that had occurred within the year using a simple mass balance from isotopic data.

In general, isotopic fractionation is due to several mechanisms that will lead to enrichment of residual waters in both $\delta^{18}O$ and δ^2H (Craig and Gordon, 1965, Gibson et al., 1993, Clark and Fritz, 1997, Kendall and Caldwell, 1998). In the simplest terms, water vapor will be isotopically more negative or depleted in both δ^2H and $\delta^{18}O$ compared to liquid water because of the thermodynamic ease of the lighter ^1H and ^{16}O isotopes to escape to water vapor phase compared to the heavier ^2H and ^{18}O. Along the same lines, ice will be isotopically heavier or more positive than the liquid water from which it came. The Craig-Gordon model identifies a surface – vapor interface in which fractionation is driven by turbulent flow above a layer of vapor that is in equilibrium with surface water. This diffusive vapor layer induces isotopic fractionation where vapor will be depleted and residual waters will be enriched.

As clouds move towards continental interiors, heavier isotopes will rainout and a continental effect causes isotopic depletion of precipitation further from the coast. In contrast, in transit evaporation of raindrops, which occurs primarily during the summer, causes isotopic enrichment of precipitation compared to clouds from which it came. Snowfall does not exhibit this rainout enrichment and will be very similar to the isotopic composition of clouds from which they precipitated. As a result of these fractionation processes, Craig (1961) showed that seasonal trends of heavy isotopes would indicate summer precipitation and lighter would point to winter precipitation.

CRAIG-GORDON MODEL OF EVAPORATIVE FLUX AND MODIFICATION BY GIBSON ET AL (1993)

The Craig-Gordon model (Craig and Gordon, 1965) as modified by Gibson et al. (1993) was used to estimate the evaporative flux as calculated by the observed isotopic fractionation of surface waters at MFC-4700 and MFC-5700 during the hot dry summer in the Palouse. There are three assumptions that are made in order to utilize the Craig-Gordon model as summarized by Gat (1996):

(1) Equilibrium conditions exist at the air/water interface such that relative humidity is 100%, $h = 1$, and $R_{Vapor} = \alpha^{*} R_{Liquid}$. Where R is the ratio of the isotopic composition of the water vapor or liquid and α^{*} is the fractionation factor.

(2) A constant vertical flux, there is no convergence of divergence in the air column.

(3) There is no isotopic fractionation during fully turbulent transport.

The Craig-Gordon model of the evaporative flux, δ_E, in delta form is defined as:

$$\delta_E = \frac{\alpha^* \delta_L - h\delta_a - \varepsilon^* - \Delta\varepsilon}{(1-h) + \Delta\varepsilon/10^3} \approx \frac{\delta_L - h\delta_a - \varepsilon^* - \Delta\varepsilon}{(1-h)} \tag{3}$$

Where

$$\varepsilon^* = (1-\alpha^*) \cdot 10^3 \tag{4}$$

$$\Delta\varepsilon = (1-h) \cdot \theta \cdot n \cdot C_D \cdot 10^3 \tag{5}$$

And

$$C_D = 28.515‰$$
$$\theta = 1$$
$$n = 0.5$$

And h is the relative humidity, 1 = 100% and 0 = 0%, δ_a is the isotopic composition of water vapor in air, δ_L is the isotopic composition of the liquid, θ is the weighting factor which is 1 for small surface water evaporation that does not induce an increase relative humidity, n is an empirical term that is 0.5 for an open water body under natural conditions. See Gat (1996) for an in depth description and derivation of the Craig-Gordon model.

A model developed by Gibson et al. (1993), modifies the Craig-Gordon model of evaporation from a steady-state surface body (Craig and Gordon, 1965, Gat, 1996) in order to estimate the evaporation-to-input fraction (*E/I*), or the percentage of evaporation based on isotopic data of input water and evaporated surface water, for two lakes in northern Canada. This isotopic mass balance approach utilizes the equilibrium fractionation factor for liquid water-to-water vapor ($\Delta_{L\text{-}V}$) established by Horita and Wesolowski (1994):

$$10^3 \ln\alpha_{L-V} \approx \Delta_{L-V} = \delta^{18}O_L - \delta^{18}O_V \tag{1}$$

$$\Delta_{L-V} \approx -7.685 + 6.7123\left(\frac{10^3}{T}\right) - 1.6664\left(\frac{10^6}{T^2}\right) + 0.35041\left(\frac{10^9}{T^3}\right) \tag{2}$$

$$\delta^{18}O_V = \delta^{18}O_L - \Delta_{L-V} \tag{3}$$

Where $\delta^{18}O_V$ is the estimated isotopic composition of water vapor, $\delta^{18}O_L$ is the isotopic composition of the evaporated liquid, and T is the average temperature in Kelvin for the entire study period (8.38ºC = 281.53ºK) for the MFC watershed.

Gibson et al. (1993) used the approximate value for $\delta^{18}O_V$ (Equation 3) and measured $\delta^{18}O_L$ to estimate the limiting isotopic enrichment (δ^*) for two Canadian lakes, where δ^* is defined as:

$$\delta^* = \frac{h\delta^{18}O_V + \Delta_{L-V}}{h - \Delta_{L-V}} \tag{4}$$

And

$$E/I_{^{18}O} = \frac{1-h}{h} \cdot \frac{\delta^{18}O_L - \delta^{18}O_P}{\delta^* - \delta^{18}O_L} \tag{5}$$

Where h is relative humidity, 0.0-1.0, δ^* is the limiting isotopic enrichment according to local hydrometeorological conditions as defined by the Local Evaporation Line (LEL), $E/I_{^{18}O}$ is the evaporation-to-input fraction, and $\delta^{18}O_P$ is the isotopic composition of the source water (precipitation $\delta^{18}O$ for Gibson et al, 1993; TD-12 $\delta^{18}O$ for MFC inputs during summer). Isotopic fractionation due to evaporation is dependent on the relative humidity and will decrease as relative humidity increases until isotopic equilibrium is met at 100% humidity (Craig, 1961). As a result of this humidity dependence, the limiting isotopic enrichment, δ^*, will greatly depend on humidity and $\delta^{18}O_V$, and not so much on

$\Delta_{L\text{-}V}$, which does not vary considerably among monitored temperature ranges for the Palouse (Horita and Wesolowski, 1994 and Figure APP E-1). Moreover, $E/I_{^{18}O}$ will equally critically depend on accurate estimate of relative humidity, *h,* during periods of evaporation (Figure APP E-2). An average relative humidity of 0.384 was estimated based on humidity data collected in Pullman by the WSU College of Engineering from 2005-2007 (Appendix F) as well as estimates of relative humidity from other vadose zone evaporation studies in the region (DePaolo et al., 2004). For summer $\delta^{18}O$ values that are less negative than the estimated δ^*, the $E/I_{^{18}O}$ fraction is greater than 1; for this reason, MFC-4700 $\delta^{18}O$ values were averaged over the entire summer because there were $\delta^{18}O$ values measured to be higher than the δ^* between August – October.

To check the estimated $E/I_{^{18}O}$ for a given year, a simple mass balance using the EC evaporation to input fraction (E/I_{EC}) was calculated using the following equation.

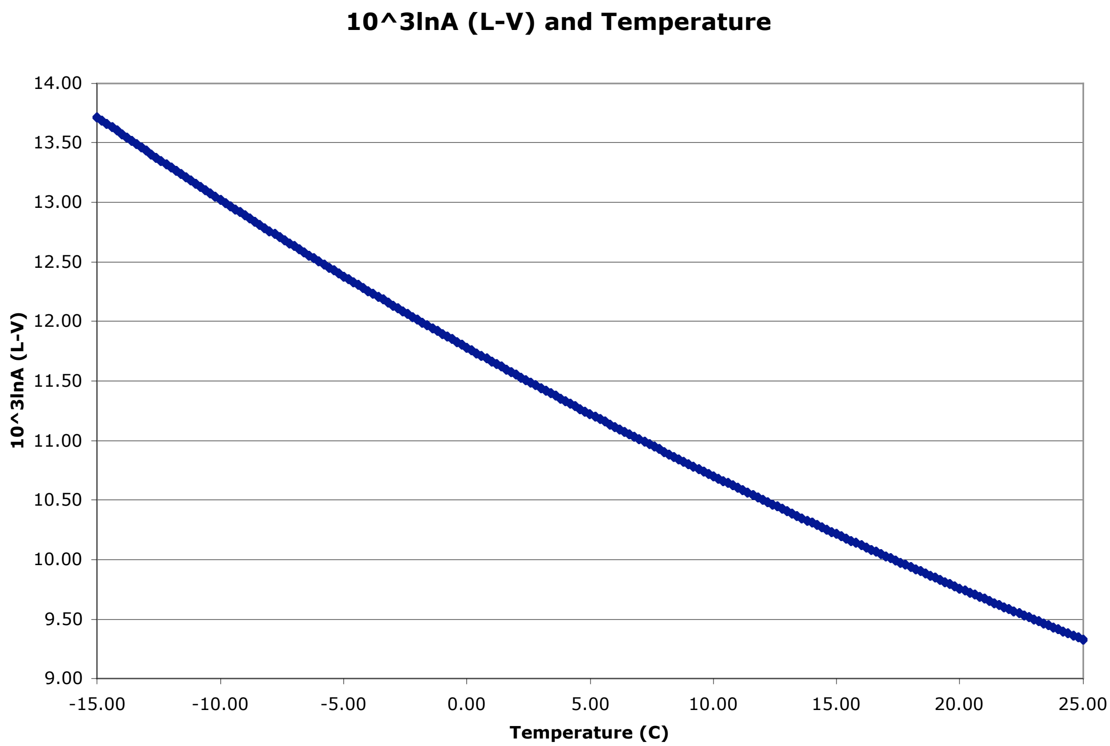
$$E/I_{EC} = \frac{(EC_{SurfaceWater} - EC_{TD-12})}{EC_{SurfaceWater}} \qquad (11)$$

Where $EC_{SurfaceWater}$ is the average nitrate corrected EC over the entire summer (MFC-4700) or the average nitrate corrected EC from August-October (MFC-5700). This relationship is a function of the simple steady state chemical relationship:

$$V_{unevaporated} \times C_{unevaporated} = V_{evaporated} \times C_{evaporated} \qquad (12)$$

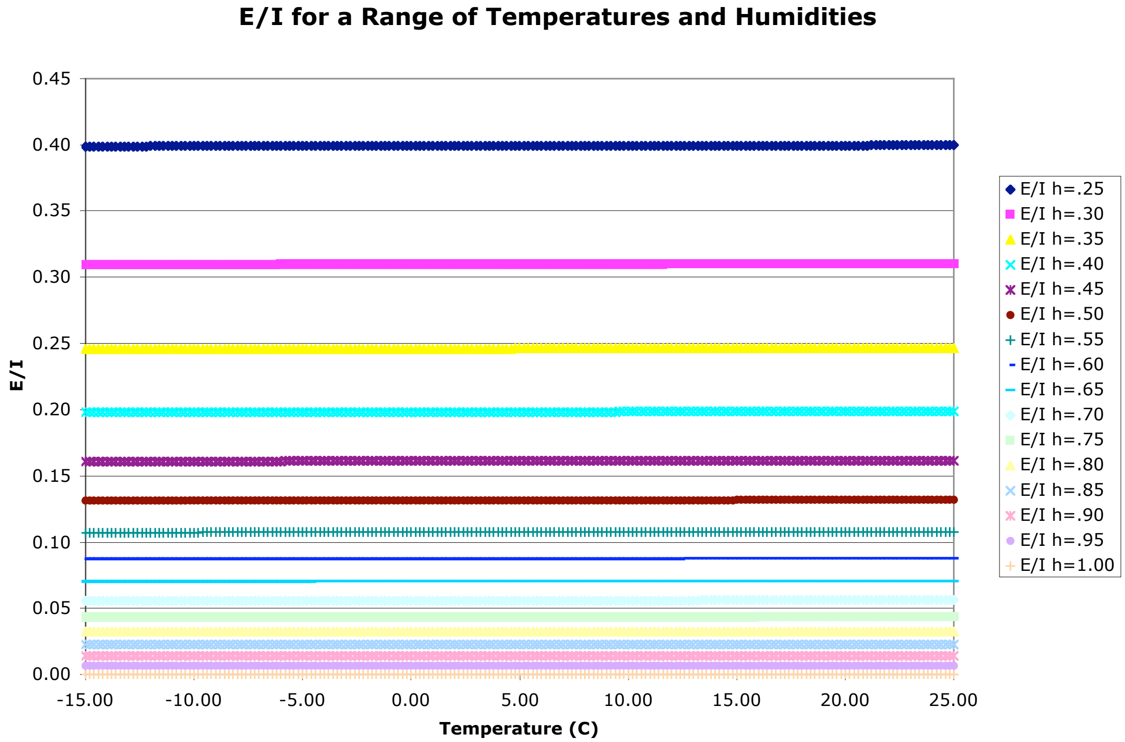
Where C is the concentration and V is the volume (assumed to be 1 for lack of accurate volume data available for this watershed). Although $E/I_{^{18}O}$ seems to vary more than estimated E/I_{EC} over the same time periods, they do agree and the estimation of evaporation flux based on $\delta^{18}O$ fractionation is valid.

Figure APP E 1



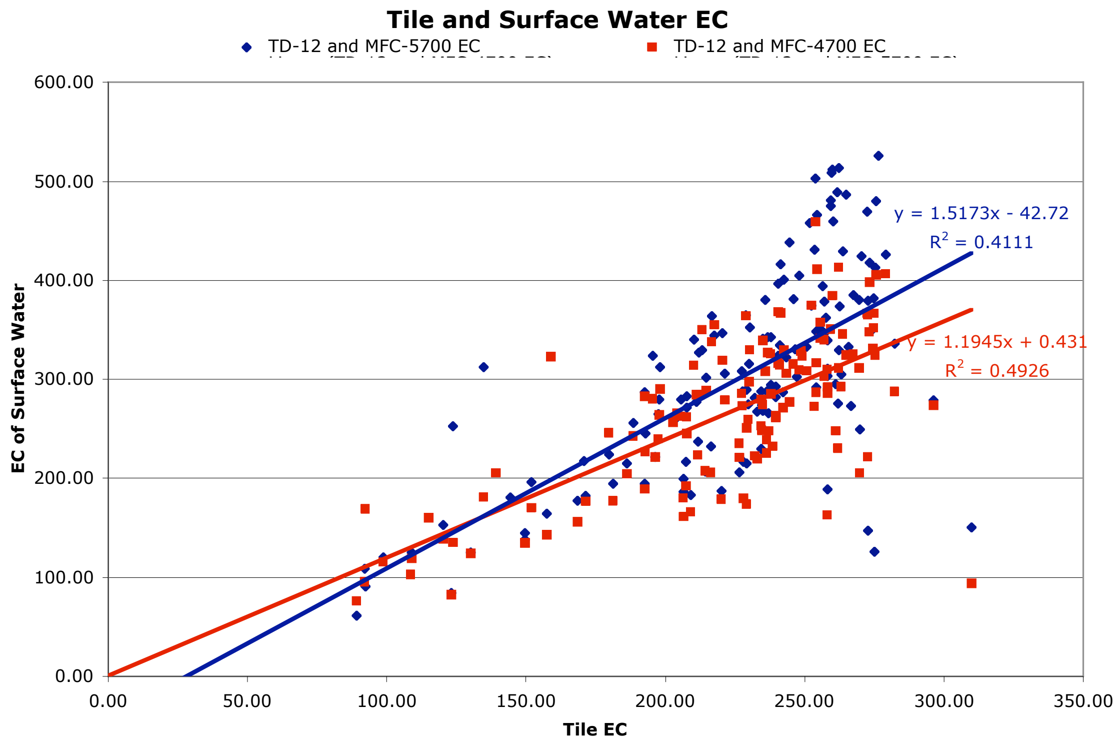
Fractionation due to temperature change is negligible in ranges seen in the Palouse. 10^3lnA (L-V) was calculated for a series of temperature ranges using equation 1 and 2.

Figure APP E 2



E/I fraction is humidity dependent and will vary as much as 9% with a change in humidity from 0.25 – 0.30. As relative humidity increases, isotopic equilibrium is reached and fractionation due to evaporation is negligible.

Figure APP E 3



Relationship between TD-12 EC and surface water EC. Low surface water EC was usually associated with low TD-12 EC and vice versa. There are occasionally high TD-12 EC not associated with high surface water EC, which could be associated with increased saturation overland flow or shallow soil water seepage down the watershed.

References for Appendix E

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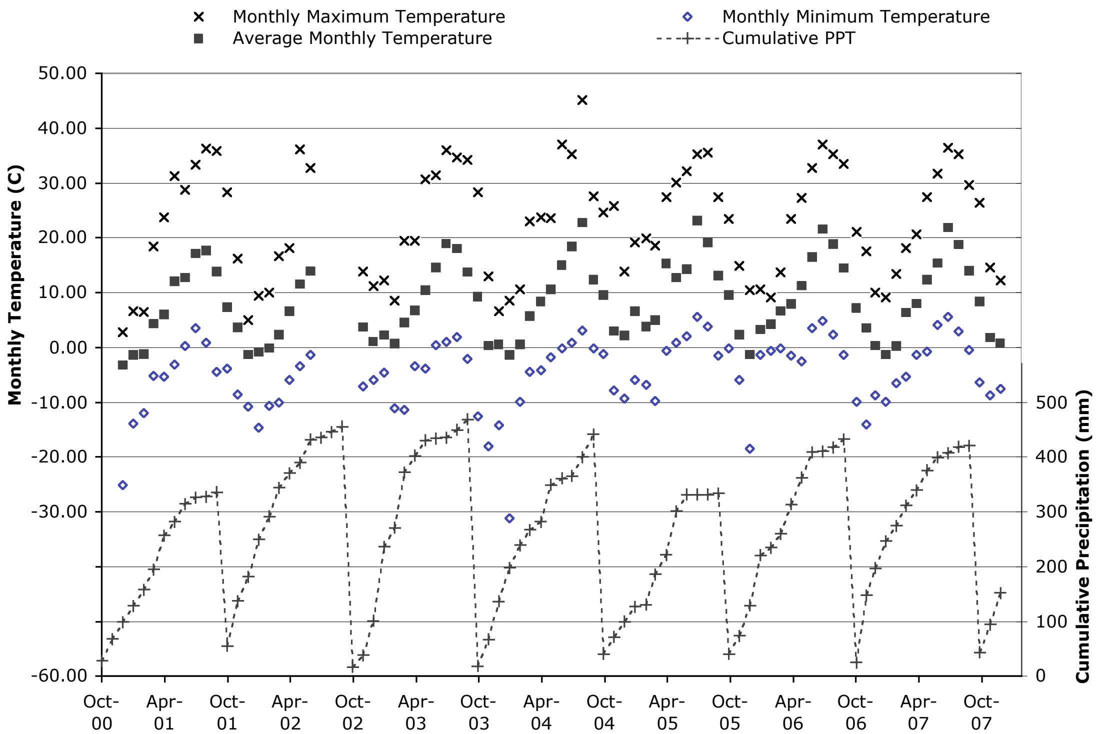
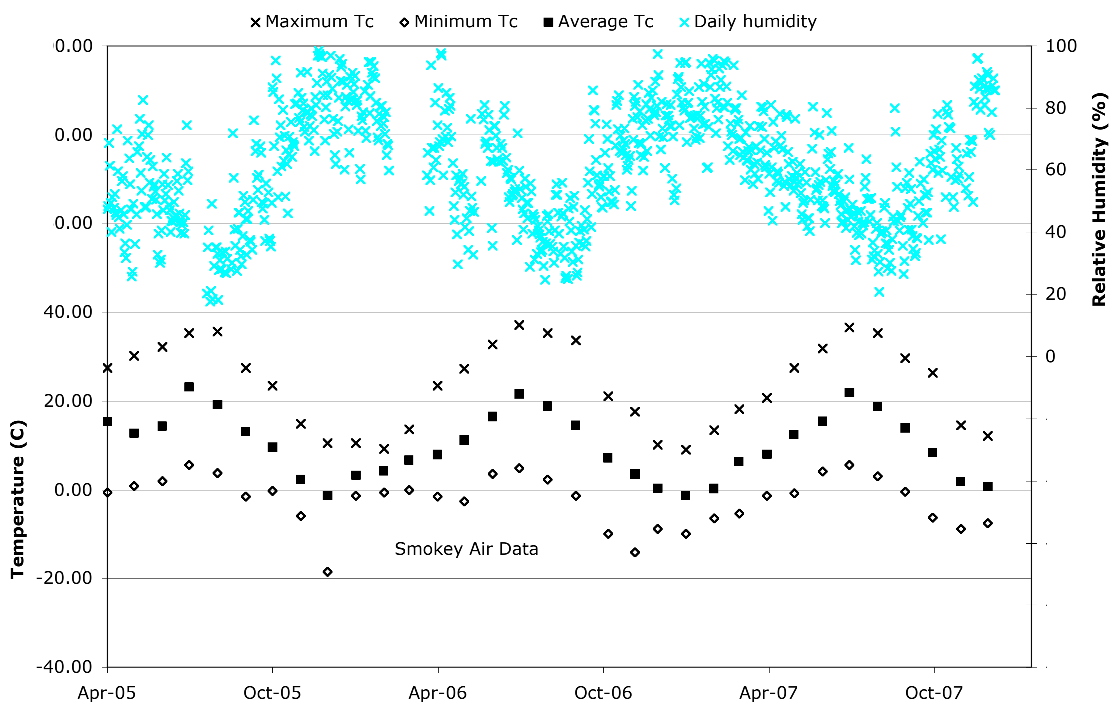
APPENDIX F: Temperature and Humidity data from 2000-2007

Figure APP F 1



Monthly temperature for the minimum, maximum and average for MFC watershed. Data after January, 2006 is from SAD website maintained by the College of Engineering at Washington State University.

Figure APP F 2



Smokey Air data (SAD) from the WSU College of Engineering for years April 2005 to January 2008 (humidity data is daily average and tabulated below). Relative humidity shows seasonality with high humidity associated with cold wet winters and low humidity during the hot dry summer.

Date	Maximum T (C^{o})	Minimum T (C^{o})	Average T (C^{o})
Dec-00	2.79	-25.08	-3.19
Jan-01	6.65	-13.93	-1.37
Feb-01	6.49	-11.91	-1.21
Mar-01	18.46	-5.12	4.27
Apr-01	23.80	-5.32	5.99
May-01	31.35	-3.17	12.09
Jun-01	28.71	0.32	12.71
Jul-01	33.37	3.57	17.18
Aug-01	36.34	0.94	17.70
Sep-01	35.93	-4.49	13.83
Oct-01	28.30	-3.93	7.30
Nov-01	16.17	-8.52	3.62
Dec-01	5.06	-10.82	-1.34
Jan-02	9.43	-14.60	-0.87
Feb-02	10.02	-10.62	-0.15
Mar-02	16.66	-10.10	2.31
Apr-02	18.11	-5.94	6.57
May-02	36.19	-3.43	11.50
Jun-02	32.79	-1.28	13.93
Jul-02			
Aug-02		No Data	
Sep-02			
Oct-02			
Nov-02	13.92	-7.06	3.68
Dec-02	11.18	-5.99	1.03
Jan-03	12.18	-4.62	2.20
Feb-03	8.57	-11.11	0.66
Mar-03	19.41	-11.38	4.51
Apr-03	19.52	-3.43	6.76
May-03	30.70	-3.86	10.45
Jun-03	31.47	0.39	14.60
Jul-03	35.98	1.05	18.92
Aug-03	34.63	1.84	18.02
Sep-03	34.21	-2.03	13.72
Oct-03	28.37	-12.61	9.21
Nov-03	12.95	-18.01	0.30
Dec-03	6.64	-14.22	0.51
Jan-04	8.57	-31.10	-1.39
Feb-04	10.67	-9.86	0.54
Mar-04	22.99	-4.48	5.69
Apr-04	23.72	-4.12	8.37
May-04	23.66	-1.81	10.56
Jun-04	37.01	-0.13	15.03
Jul-04	35.26	0.82	18.39

	Date	Maximum T (C^o)	Minimum T (C^o)	Average T (C^o)
	Aug-04	45.20	3.05	22.79
	Sep-04	27.55	-0.19	12.36
	Oct-04	24.68	-1.23	9.52
	Nov-04	25.82	-7.83	2.95
	Dec-04	13.80	-9.30	2.18
	Jan-05	19.14	-6.00	6.56
	Feb-05	19.93	-6.80	3.78
	Mar-05	18.62	-9.73	4.99
	Apr-05	27.40	-0.60	15.28
	May-05	30.10	0.80	12.70
	Jun-05	32.10	2.00	14.26
	Jul-05	35.20	5.62	23.12
	Aug-05	35.58	3.81	19.11
	Sep-05	27.42	-1.55	13.08
	Oct-05	23.50	-0.19	9.57
	Nov-05	14.90	-5.90	2.34
	Dec-05	10.52	-18.47	-1.30
*	Jan-06	10.56	-1.39	3.29
*	Feb-06	9.20	-0.63	4.24
*	Mar-06	13.67	-0.10	6.65
*	Apr-06	23.39	-1.45	7.93
*	May-06	27.35	-2.52	11.22
*	Jun-06	32.74	3.53	16.45
*	Jul-06	37.01	4.91	21.61
*	Aug-06	35.23	2.38	18.86
*	Sep-06	33.57	-1.40	14.49
*	Oct-06	21.09	-9.89	7.18
*	Nov-06	17.61	-14.07	3.57
*	Dec-06	10.10	-8.74	0.31
*	Jan-07	9.08	-9.97	-1.28
*	Feb-07	13.49	-6.50	0.25
*	Mar-07	18.18	-5.38	6.38
*	Apr-07	20.68	-1.31	7.99
*	May-07	27.43	-0.72	12.39
*	Jun-07	31.80	4.05	15.40
*	Jul-07	36.47	5.58	21.86
*	Aug-07	35.33	2.99	18.78
*	Sep-07	29.64	-0.40	13.96
*	Oct-07	26.44	-6.34	8.39
*	Nov-07	14.58	-8.78	1.80
*	Dec-07	12.17	-7.61	0.74

* Denotes data from Smokey Air Data set from the WSU College of Engineering

Date	Average Daily Humidity (%)
4/1/05	47.40
4/2/05	48.49
4/3/05	68.62
4/4/05	61.36
4/5/05	49.36
4/6/05	40.17
4/7/05	51.23
4/8/05	47.94
4/9/05	52.30
4/10/05	46.38
4/11/05	45.43
4/12/05	73.13
4/13/05	59.60
4/14/05	44.83
4/15/05	41.19
4/16/05	47.21
4/17/05	56.47
4/18/05	58.00
4/19/05	45.70
4/20/05	33.49
4/21/05	36.38
4/22/05	31.79
4/23/05	42.38
4/24/05	69.45
4/25/05	63.68
4/26/05	55.38
4/27/05	47.34
4/28/05	25.66
4/29/05	27.26
4/30/05	49.11
5/2/05	36.19
5/3/05	45.87
5/4/05	65.83
5/6/05	67.55
5/7/05	76.55
5/8/05	59.04
5/9/05	53.43
5/10/05	71.60
5/11/05	82.62
5/12/05	48.21
5/13/05	47.79
5/14/05	48.21
5/15/05	64.21
5/16/05	71.28

Date	Average Daily Humidity (%)
5/17/05	74.55
5/18/05	55.94
5/19/05	63.28
5/20/05	50.64
5/21/05	61.11
5/22/05	54.77
5/23/05	55.49
5/24/05	53.19
5/25/05	50.53
5/26/05	45.68
5/27/05	32.83
5/28/05	39.53
5/29/05	30.17
5/30/05	31.26
5/31/05	40.55
6/1/05	55.32
6/2/05	46.98
6/3/05	58.74
6/4/05	50.26
6/5/05	52.19
6/6/05	63.94
6/7/05	55.21
6/8/05	48.74
6/9/05	47.11
6/10/05	40.19
6/11/05	43.81
6/12/05	43.43
6/13/05	44.72
6/14/05	49.62
6/15/05	43.62
6/16/05	45.60
6/17/05	56.60
6/18/05	58.87
6/19/05	53.23
6/20/05	46.17
6/21/05	43.21
6/22/05	39.70
6/23/05	42.47
6/24/05	43.28
6/25/05	39.53
6/26/05	45.66
6/27/05	62.32
6/28/05	74.34
6/29/05	56.83

Date	Average Daily Humidity (%)	Date	Average Daily Humidity (%)
6/30/05	59.70	9/9/05	50.52
7/20/05	20.27	9/10/05	76.11
7/21/05	35.02	9/12/05	66.09
7/22/05	40.70	9/13/05	68.41
7/24/05	17.61	9/14/05	57.53
7/25/05	21.03	9/15/05	53.72
7/26/05	49.18	9/16/05	58.65
7/27/05	18.48	9/17/05	67.78
7/28/05	29.18	9/18/05	65.68
7/30/05	35.20	9/19/05	49.81
7/31/05	35.18	9/20/05	47.66
8/1/05	33.04	9/21/05	49.15
8/2/05	18.27	9/22/05	43.86
8/3/05	27.75	9/23/05	37.29
8/4/05	31.00	9/24/05	55.82
8/5/05	28.21	9/26/05	52.95
8/6/05	33.63	9/27/05	37.95
8/9/05	27.10	9/28/05	37.11
8/10/05	33.88	9/29/05	35.43
8/11/05	26.88	9/30/05	49.38
8/12/05	31.40	10/1/05	86.59
8/16/05	27.98	10/2/05	85.14
8/17/05	30.24	10/3/05	67.74
8/18/05	71.92	10/4/05	95.16
8/19/05	57.51	10/5/05	89.62
8/20/05	40.89	10/6/05	59.54
8/21/05	35.64	10/7/05	51.38
8/22/05	27.58	10/8/05	82.65
8/23/05	41.18	10/9/05	70.63
8/24/05	46.39	10/10/05	74.47
8/25/05	46.40	10/11/05	61.25
8/26/05	34.37	10/12/05	79.33
8/27/05	32.37	10/13/05	62.95
8/28/05	29.77	10/14/05	70.98
8/29/05	38.79	10/15/05	51.42
8/30/05	51.88	10/16/05	66.29
8/31/05	49.68	10/17/05	61.86
9/1/05	44.19	10/18/05	46.04
9/2/05	32.77	10/19/05	65.12
9/3/05	44.23	10/20/05	70.78
9/4/05	46.90	10/21/05	75.57
9/6/05	37.49	10/22/05	64.26
9/7/05	36.92	10/23/05	69.03
9/8/05	34.44	10/24/05	68.30

Date	Average Daily Humidity (%)
10/25/05	67.70
10/26/05	81.20
10/28/05	81.49
10/29/05	84.92
10/30/05	76.66
10/31/05	75.37
11/1/05	91.41
11/2/05	83.35
11/3/05	79.19
11/4/05	81.53
11/5/05	73.93
11/6/05	72.30
11/7/05	78.65
11/8/05	91.66
11/9/05	78.50
11/10/05	69.47
11/11/05	74.24
11/12/05	77.82
11/13/05	79.83
11/14/05	77.36
11/15/05	72.91
11/16/05	66.00
11/17/05	83.55
11/18/05	80.86
11/19/05	88.00
11/20/05	96.72
11/21/05	98.26
11/22/05	97.46
11/23/05	96.83
11/24/05	96.18
11/25/05	91.08
11/26/05	83.97
11/27/05	76.21
11/28/05	69.47
11/29/05	80.09
11/30/05	88.47
12/1/05	84.09
12/2/05	90.60
12/4/05	96.69
12/5/05	89.69
12/6/05	86.19
12/7/05	76.50
12/8/05	71.62
12/9/05	64.81

Date	Average Daily Humidity (%)
12/10/05	61.96
12/11/05	72.36
12/12/05	75.63
12/13/05	83.18
12/14/05	95.82
12/15/05	88.87
12/16/05	93.25
12/17/05	94.20
12/18/05	88.42
12/19/05	60.01
12/20/05	80.37
12/21/05	83.58
12/22/05	87.31
12/23/05	82.13
12/24/05	73.19
12/25/05	65.66
12/26/05	89.99
12/27/05	82.48
12/28/05	91.33
12/29/05	85.21
12/30/05	87.65
12/31/05	90.40
1/1/06	82.35
1/2/06	81.00
1/3/06	82.46
1/4/06	72.51
1/5/06	60.35
1/6/06	56.87
1/7/06	77.42
1/8/06	75.97
1/9/06	78.48
1/11/06	85.46
1/12/06	72.60
1/13/06	70.38
1/14/06	87.32
1/15/06	94.81
1/16/06	78.44
1/17/06	83.69
1/18/06	94.60
1/19/06	91.36
1/20/06	90.12
1/21/06	93.49
1/22/06	89.43
1/23/06	81.69

Date	Average Daily Humidity (%)	Date	Average Daily Humidity (%)
1/24/06	75.83	4/20/06	44.07
1/25/06	70.65	4/21/06	52.90
1/26/06	69.44	4/22/06	58.28
1/27/06	78.12	4/23/06	39.20
1/28/06	80.39	4/24/06	29.76
1/29/06	74.19	4/25/06	56.44
1/30/06	80.70	4/26/06	57.50
1/31/06	74.96	4/27/06	55.52
2/1/06	76.96	4/28/06	55.73
2/2/06	71.62	4/29/06	58.94
2/3/06	78.70	4/30/06	52.06
2/4/06	64.76	5/1/06	54.54
2/5/06	68.49	5/2/06	41.71
2/6/06	67.88	5/4/06	44.49
2/7/06	59.85	5/5/06	34.46
3/21/06	58.39	5/6/06	40.27
3/22/06	65.52	5/7/06	46.79
3/23/06	46.77	5/8/06	76.45
3/24/06	56.61	5/9/06	51.59
3/25/06	93.56	5/10/06	47.78
3/26/06	67.26	5/11/06	32.78
3/28/06	60.78	5/12/06	46.71
3/29/06	67.20	5/20/06	56.60
3/30/06	81.68	5/21/06	78.20
3/31/06	63.19	5/22/06	76.21
4/1/06	74.49	5/23/06	80.98
4/2/06	86.50	5/24/06	68.42
4/3/06	67.70	5/25/06	69.23
4/4/06	68.96	5/26/06	68.89
4/5/06	97.60	5/27/06	67.09
4/6/06	96.74	5/28/06	77.76
4/7/06	70.00	5/29/06	72.75
4/8/06	58.27	5/30/06	63.09
4/9/06	79.21	5/31/06	41.51
4/10/06	70.85	6/1/06	35.56
4/11/06	84.82	6/2/06	62.73
4/12/06	73.55	6/3/06	74.23
4/13/06	69.07	6/4/06	74.06
4/14/06	79.74	6/5/06	71.05
4/15/06	83.26	6/6/06	67.07
4/16/06	80.56	6/7/06	63.61
4/17/06	70.76	6/8/06	62.81
4/18/06	62.20	6/9/06	62.72
4/19/06	48.34	6/10/06	68.53

Date	Average Daily Humidity (%)
6/12/06	67.06
6/13/06	63.07
6/14/06	77.71
6/15/06	80.56
6/16/06	64.11
6/17/06	59.10
6/18/06	60.00
6/19/06	51.20
6/20/06	49.70
6/21/06	57.39
6/22/06	56.96
6/23/06	51.76
6/24/06	52.23
6/25/06	53.02
6/26/06	53.74
6/27/06	53.03
6/28/06	37.55
6/29/06	71.82
7/1/06	59.88
7/2/06	53.99
7/3/06	51.00
7/4/06	47.41
7/5/06	40.82
7/6/06	46.02
7/7/06	57.26
7/8/06	54.74
7/9/06	49.33
7/10/06	44.44
7/11/06	49.53
7/12/06	29.00
7/13/06	55.59
7/14/06	52.99
7/15/06	39.47
7/16/06	45.76
7/17/06	44.89
7/18/06	31.16
7/19/06	44.03
7/20/06	33.13
7/21/06	41.81
7/22/06	40.68
7/23/06	39.21
7/24/06	38.27
7/25/06	33.55
7/26/06	34.23

Date	Average Daily Humidity (%)
7/27/06	36.86
7/28/06	29.10
7/29/06	24.83
7/30/06	36.45
7/31/06	45.20
8/1/06	43.52
8/2/06	45.86
8/3/06	40.46
8/4/06	36.22
8/6/06	35.27
8/7/06	33.93
8/8/06	30.16
8/9/06	40.52
8/10/06	52.02
8/11/06	55.38
8/12/06	52.05
8/13/06	46.24
8/14/06	39.68
8/15/06	33.15
8/16/06	44.91
8/17/06	56.06
8/18/06	46.10
8/19/06	35.42
8/20/06	31.70
8/21/06	25.30
8/22/06	26.08
8/23/06	25.07
8/24/06	47.67
8/25/06	43.52
8/26/06	51.02
8/27/06	40.51
8/28/06	33.79
8/29/06	30.48
8/30/06	48.09
8/31/06	51.75
9/1/06	35.68
9/2/06	26.01
9/3/06	27.09
9/4/06	31.24
9/5/06	36.57
9/6/06	40.23
9/8/06	42.15
9/9/06	36.14
9/10/06	40.73

Date	Average Daily Humidity (%)	Date	Average Daily Humidity (%)
9/11/06	47.02	10/25/06	73.48
9/12/06	35.36	10/26/06	68.48
9/13/06	37.27	10/27/06	64.89
9/14/06	44.36	10/28/06	60.01
9/15/06	56.02	10/29/06	61.38
9/16/06	69.95	10/30/06	63.25
9/17/06	59.67	10/31/06	64.55
9/18/06	41.57	11/1/06	48.46
9/19/06	52.36	11/2/06	53.40
9/20/06	85.58	11/3/06	76.41
9/21/06	79.39	11/4/06	69.87
9/22/06	79.18	11/5/06	83.62
9/23/06	74.82	11/6/06	80.73
9/24/06	63.31	11/7/06	81.97
9/25/06	58.34	11/8/06	77.03
9/26/06	55.28	11/9/06	87.35
9/27/06	54.61	11/10/06	68.80
9/28/06	55.66	11/11/06	78.89
9/29/06	51.31	11/12/06	64.87
9/30/06	48.11	11/13/06	68.40
10/1/06	48.01	11/14/06	74.46
10/2/06	58.04	11/15/06	59.85
10/3/06	58.03	11/16/06	64.29
10/4/06	65.68	11/17/06	76.04
10/5/06	74.72	11/18/06	81.15
10/6/06	69.88	11/19/06	66.17
10/7/06	60.76	11/20/06	76.40
10/8/06	53.09	11/21/06	84.96
10/9/06	58.05	11/22/06	79.58
10/10/06	49.58	11/23/06	71.10
10/11/06	49.98	11/24/06	83.29
10/12/06	49.74	11/25/06	85.63
10/13/06	48.82	11/26/06	78.41
10/14/06	53.56	11/27/06	77.55
10/15/06	67.87	11/28/06	88.40
10/16/06	80.92	11/29/06	78.59
10/17/06	82.35	11/30/06	80.56
10/18/06	73.06	12/1/06	97.33
10/19/06	84.16	12/2/06	90.46
10/20/06	66.11	12/3/06	70.70
10/21/06	70.94	12/4/06	66.51
10/22/06	65.47	12/5/06	82.09
10/23/06	66.80	12/6/06	73.31
10/24/06	69.36	12/7/06	70.41

Date	Average Daily Humidity (%)	Date	Average Daily Humidity (%)
12/9/06	60.54	1/23/07	75.07
12/10/06	77.48	1/24/07	60.64
12/11/06	81.27	1/25/07	60.94
12/12/06	77.51	1/26/07	73.82
12/13/06	76.20	1/27/07	94.57
12/14/06	74.10	1/28/07	86.63
12/15/06	81.00	1/29/07	90.56
12/16/06	74.09	1/30/07	92.40
12/17/06	57.36	1/31/07	95.86
12/18/06	70.90	2/1/07	95.15
12/19/06	52.04	2/2/07	82.89
12/20/06	50.30	2/3/07	71.80
12/21/06	54.16	2/4/07	79.90
12/22/06	84.31	2/5/07	81.63
12/23/06	89.29	2/6/07	76.34
12/24/06	90.01	2/7/07	92.74
12/25/06	74.39	2/8/07	86.74
12/26/06	94.37	2/9/07	88.97
12/27/06	86.58	2/10/07	93.81
12/28/06	81.63	2/11/07	80.32
12/29/06	80.07	2/12/07	94.99
12/30/06	79.07	2/13/07	80.04
12/31/06	94.57	2/14/07	94.50
1/1/07	94.82	2/15/07	86.92
1/2/07	68.91	2/16/07	81.77
1/3/07	81.33	2/17/07	67.58
1/4/07	81.66	2/18/07	63.36
1/5/07	85.24	2/19/07	74.84
1/6/07	76.68	2/20/07	72.46
1/7/07	76.92	2/21/07	71.41
1/8/07	77.42	2/22/07	65.99
1/10/07	73.51	2/23/07	93.77
1/11/07	77.58	2/24/07	79.77
1/12/07	69.74	2/25/07	79.39
1/13/07	70.85	2/26/07	79.78
1/14/07	77.81	2/27/07	75.02
1/15/07	86.55	2/28/07	76.21
1/16/07	70.18	3/1/07	70.00
1/17/07	77.50	3/2/07	64.71
1/18/07	94.11	3/3/07	70.36
1/19/07	81.85	3/4/07	84.06
1/20/07	74.58	3/5/07	65.87
1/21/07	87.60	3/6/07	64.00
1/22/07	80.52	3/7/07	56.84

Date	Average Daily Humidity (%)	Date	Average Daily Humidity (%)
3/8/07	72.03	4/21/07	48.27
3/9/07	63.20	4/22/07	77.70
3/10/07	62.99	4/23/07	77.04
3/11/07	66.08	4/24/07	65.75
3/12/07	67.30	4/25/07	61.96
3/13/07	74.18	4/26/07	56.95
3/14/07	60.20	4/27/07	55.30
3/15/07	66.27	4/28/07	57.92
3/16/07	55.50	4/29/07	62.65
3/17/07	61.81	4/30/07	53.43
3/18/07	58.79	5/1/07	56.11
3/19/07	67.32	5/2/07	76.49
3/20/07	67.57	5/3/07	57.61
3/21/07	62.58	5/4/07	59.11
3/22/07	57.21	5/5/07	55.37
3/23/07	74.26	5/6/07	56.19
3/24/07	66.39	5/7/07	61.85
3/25/07	80.34	5/8/07	52.51
3/26/07	74.04	5/9/07	45.68
3/27/07	80.12	5/10/07	43.91
3/28/07	78.95	5/11/07	49.49
3/29/07	70.05	5/12/07	50.21
3/30/07	61.76	5/13/07	59.37
3/31/07	60.84	5/14/07	56.06
4/1/07	65.63	5/15/07	41.78
4/2/07	46.97	5/16/07	44.49
4/3/07	58.75	5/17/07	44.50
4/4/07	52.80	5/18/07	40.22
4/5/07	80.99	5/19/07	50.48
4/6/07	60.80	5/21/07	66.76
4/7/07	43.71	5/22/07	80.36
4/8/07	75.35	5/23/07	72.01
4/9/07	67.06	5/24/07	59.34
4/10/07	69.20	5/25/07	53.57
4/11/07	56.43	5/26/07	54.12
4/12/07	59.71	5/27/07	50.21
4/13/07	58.91	5/28/07	55.19
4/14/07	55.98	5/29/07	71.28
4/15/07	78.00	5/30/07	56.12
4/16/07	68.01	5/31/07	48.37
4/17/07	71.07	6/1/07	50.23
4/18/07	66.54	6/2/07	48.21
4/19/07	55.00	6/3/07	47.72
4/20/07	56.13	6/4/07	42.94

Date	Average Daily Humidity (%)	Date	Average Daily Humidity (%)
6/5/07	56.64	7/19/07	57.57
6/6/07	78.43	7/20/07	63.39
6/7/07	63.48	7/21/07	50.72
6/8/07	65.34	7/22/07	50.77
6/9/07	60.39	7/23/07	43.43
6/10/07	65.71	7/24/07	45.60
6/11/07	72.55	7/25/07	50.93
6/12/07	54.81	7/26/07	31.31
6/13/07	53.43	7/27/07	36.78
6/14/07	56.52	7/28/07	32.21
6/15/07	52.85	7/29/07	34.16
6/16/07	55.43	7/30/07	41.13
6/17/07	58.63	7/31/07	42.91
6/18/07	58.72	8/1/07	33.07
6/19/07	52.20	8/2/07	27.40
6/20/07	49.84	8/3/07	20.90
6/21/07	48.71	8/4/07	30.44
6/22/07	45.89	8/5/07	39.49
6/23/07	43.01	8/6/07	40.34
6/24/07	43.49	8/7/07	40.09
6/25/07	49.89	8/8/07	47.77
6/26/07	51.35	8/9/07	49.54
6/27/07	41.35	8/10/07	36.35
6/28/07	46.99	8/11/07	40.51
6/29/07	44.02	8/12/07	28.41
6/30/07	67.13	8/13/07	36.23
7/1/07	56.99	8/14/07	34.44
7/2/07	47.46	8/15/07	30.14
7/3/07	44.89	8/16/07	27.61
7/4/07	48.88	8/17/07	37.74
7/5/07	46.19	8/18/07	44.98
7/6/07	41.94	8/19/07	43.58
7/7/07	34.26	8/20/07	79.95
7/8/07	31.02	8/21/07	72.28
7/9/07	39.72	8/22/07	60.79
7/10/07	46.68	8/23/07	54.68
7/11/07	43.42	8/24/07	43.79
7/12/07	38.99	8/25/07	40.61
7/13/07	46.73	8/26/07	44.79
7/14/07	39.68	8/27/07	45.61
7/15/07	42.82	8/29/07	35.61
7/16/07	42.27	8/30/07	26.56
7/17/07	43.19	8/31/07	30.72
7/18/07	54.63	9/1/07	54.24

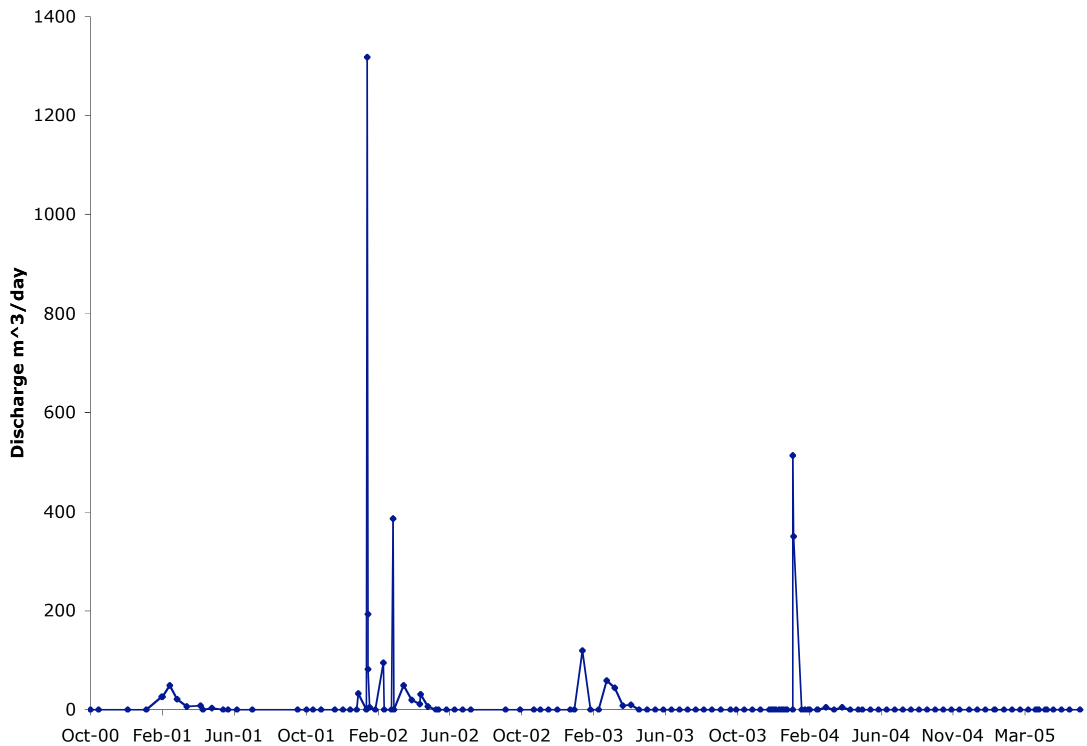
Date	Average Daily Humidity (%)
9/2/07	55.95
9/3/07	47.79
9/4/07	40.75
9/5/07	59.08
9/6/07	49.09
9/7/07	53.83
9/8/07	40.94
9/9/07	38.84
9/10/07	34.52
9/11/07	32.20
9/12/07	33.32
9/13/07	38.19
9/14/07	38.10
9/15/07	45.29
9/16/07	50.05
9/17/07	62.76
9/18/07	55.63
9/20/07	43.01
9/21/07	57.06
9/22/07	51.97
9/23/07	46.36
9/24/07	51.74
9/25/07	46.21
9/26/07	52.96
9/27/07	37.37
9/28/07	65.30
9/29/07	62.21
10/1/07	60.10
10/2/07	71.32
10/3/07	66.05
10/4/07	63.62
10/5/07	73.12
10/6/07	77.99
10/7/07	59.01
10/8/07	66.55
10/9/07	64.40
10/10/07	37.81
10/11/07	69.38
10/12/07	59.80
10/15/07	51.36
10/16/07	78.80
10/17/07	80.85
10/18/07	77.85
10/19/07	73.85

Date	Average Daily Humidity (%)
10/20/07	73.64
10/21/07	73.31
10/22/07	57.81
10/23/07	51.35
10/24/07	48.27
10/26/07	56.76
10/27/07	67.25
10/28/07	63.62
10/29/07	57.17
10/30/07	61.10
10/31/07	58.57
11/7/07	54.17
11/8/07	65.28
11/9/07	51.70
11/10/07	57.89
11/11/07	69.80
11/12/07	65.87
11/13/07	69.77
11/14/07	69.25
11/15/07	49.65
11/16/07	81.92
11/17/07	87.04
11/18/07	80.78
11/19/07	95.76
11/20/07	95.94
11/21/07	88.91
11/22/07	86.18
11/23/07	79.34
11/24/07	88.15
11/25/07	89.62
11/26/07	87.01
11/27/07	80.87
11/28/07	83.44
11/29/07	86.12
11/30/07	91.53
12/1/07	90.61
12/2/07	72.14
12/3/07	86.23
12/4/07	71.42
12/5/07	78.54
12/6/07	87.12
12/7/07	89.52
12/8/07	85.74
12/9/07	85.64

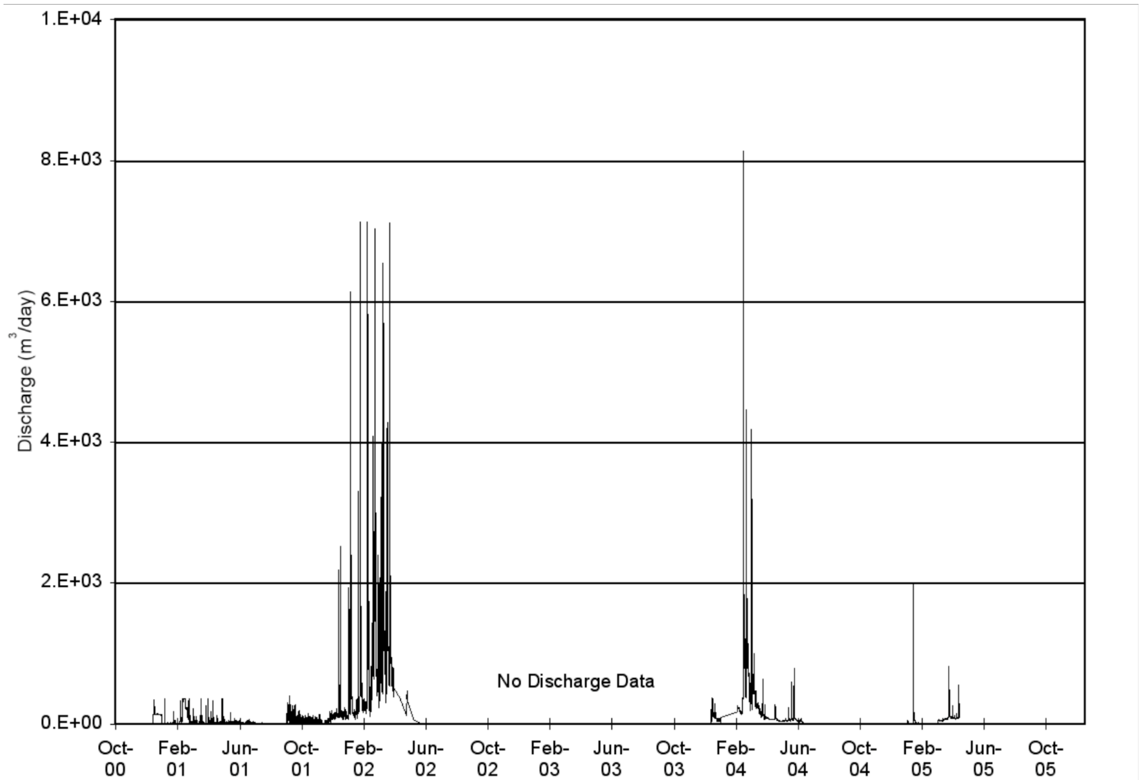
APPENDIX G: Discharge Data (on Accompanying DVD) and Hydrographs for Sampling Stations in MFC Watershed

All tabulated discharge data is located on accompanying DVD. Discharge data includes ES-6, ES-106, TD-12, MFC-660, MFC-4700, and MFC-5700.

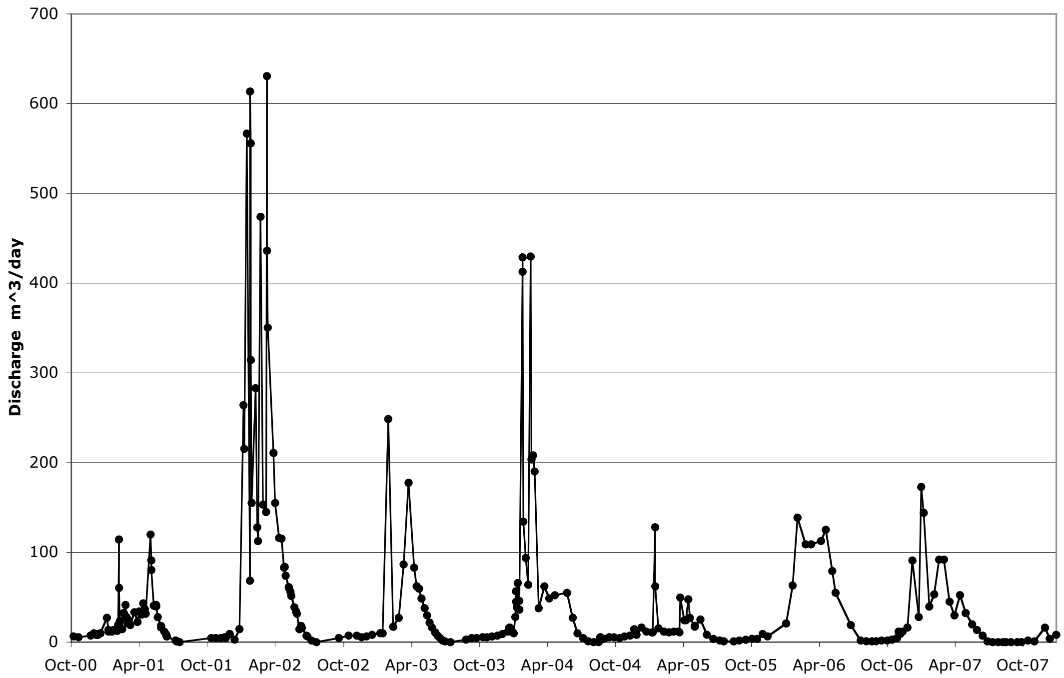
Hydrograph for ES-6



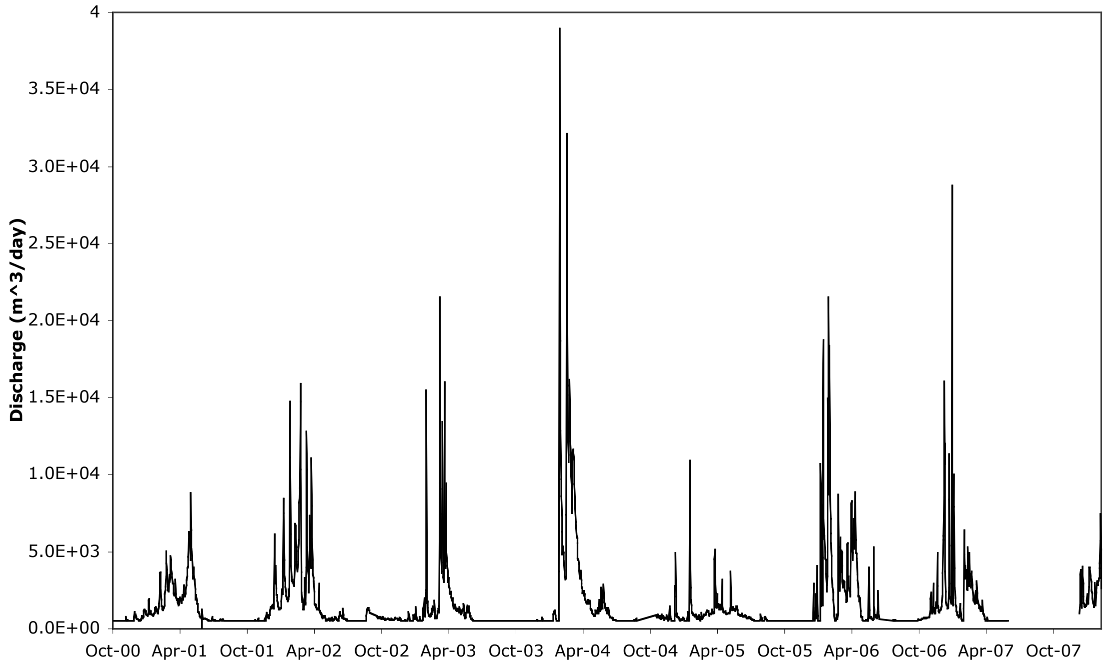
Hydrograph for ES-106



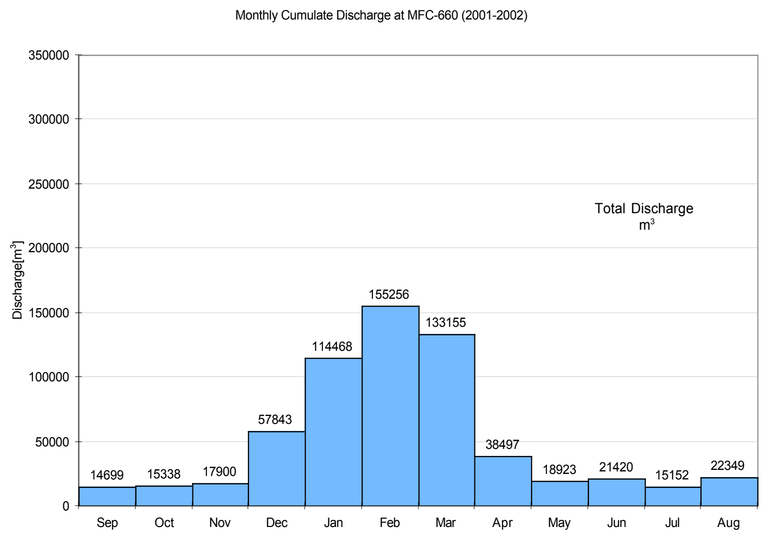
Hydrograph for TD-12

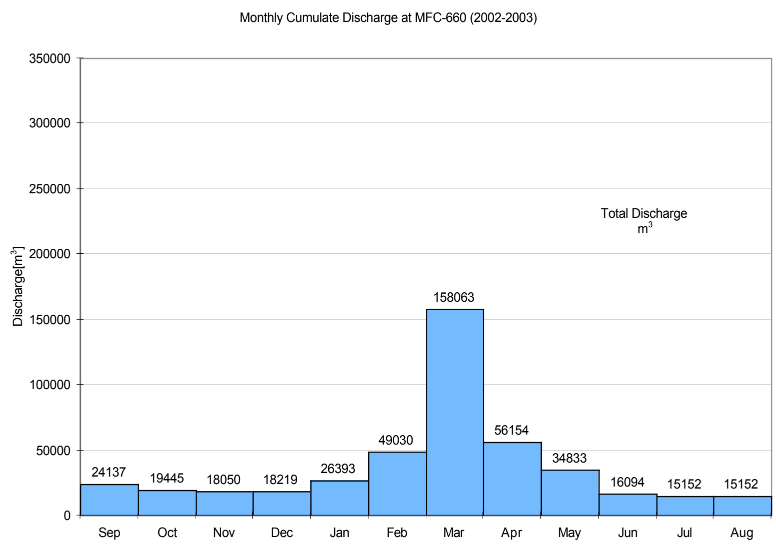


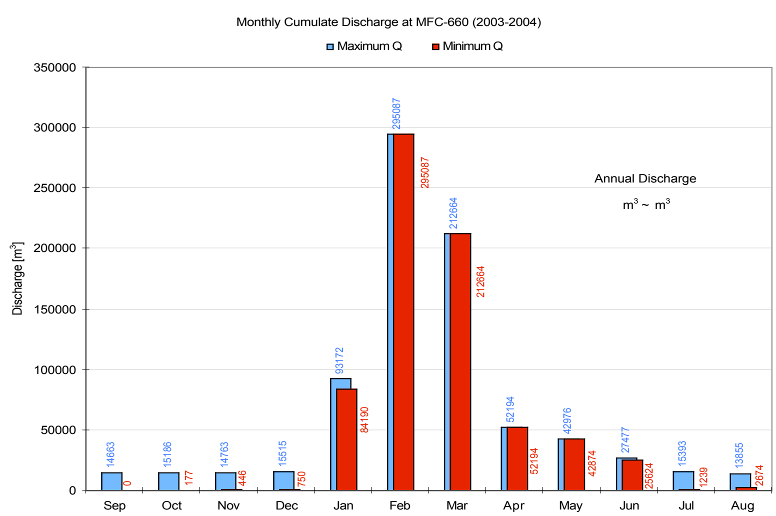
Hydrograph for MFC-660



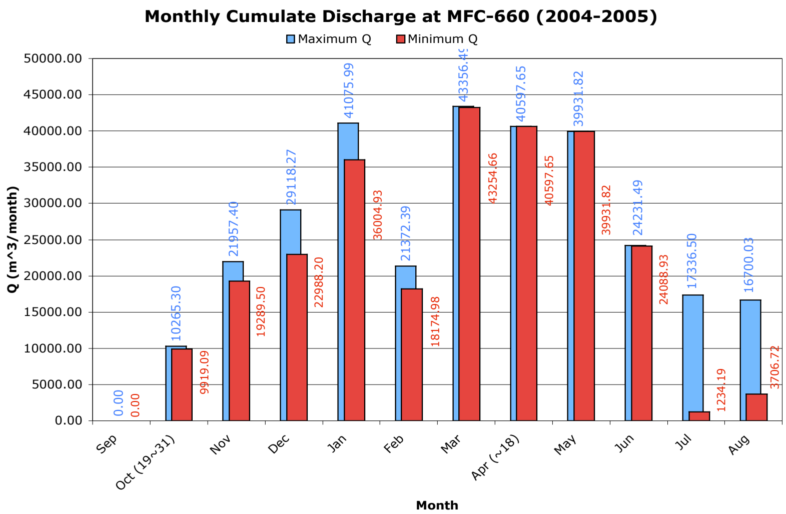
Monthly Cumulative Discharge MFC-660 (2001-2004)

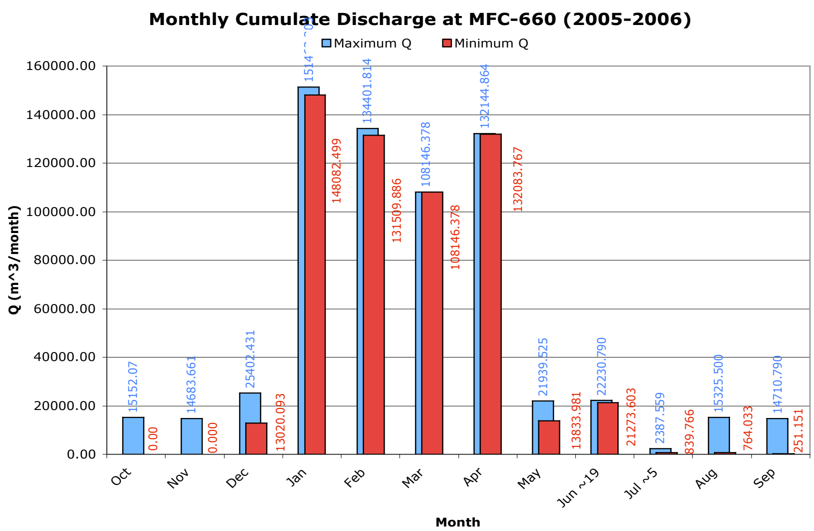


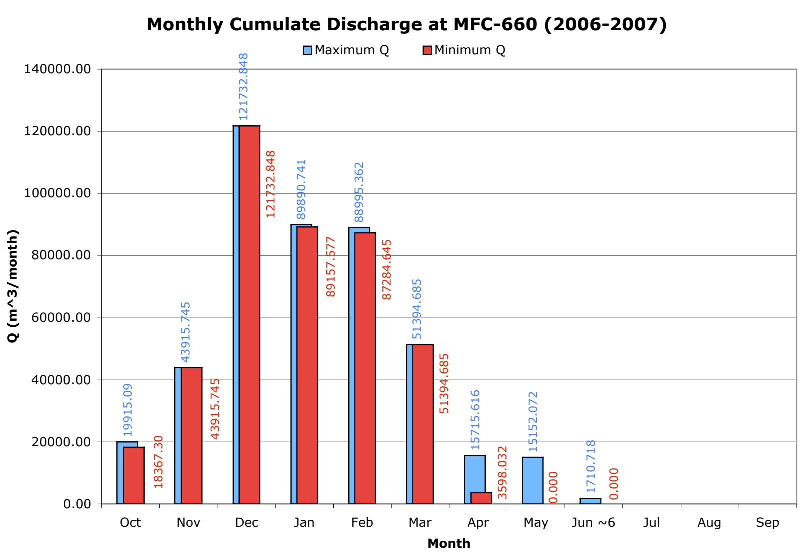




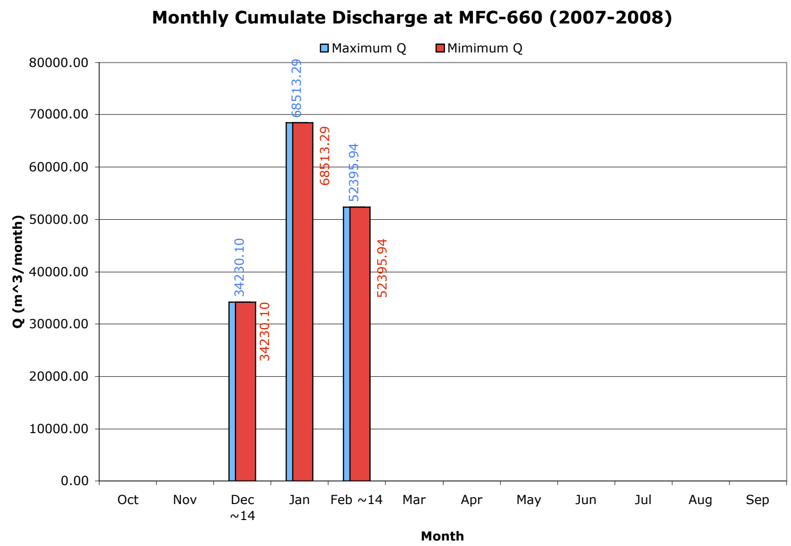
Monthly Cumulative Discharge MFC-660 (2004-2007)



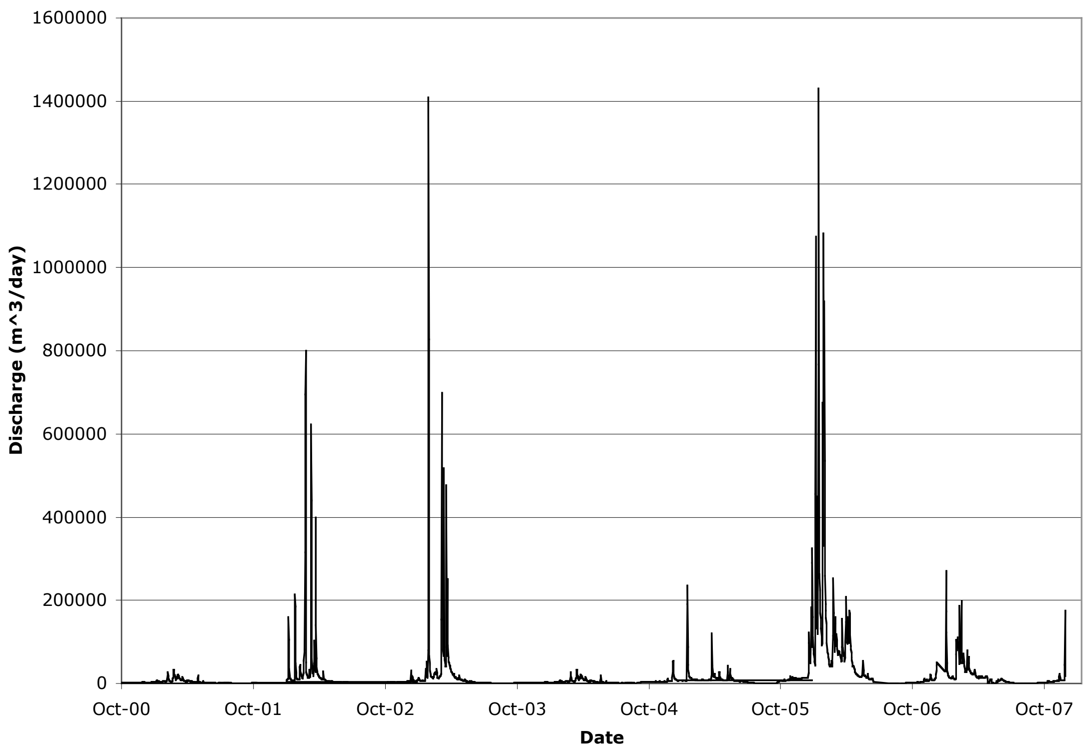




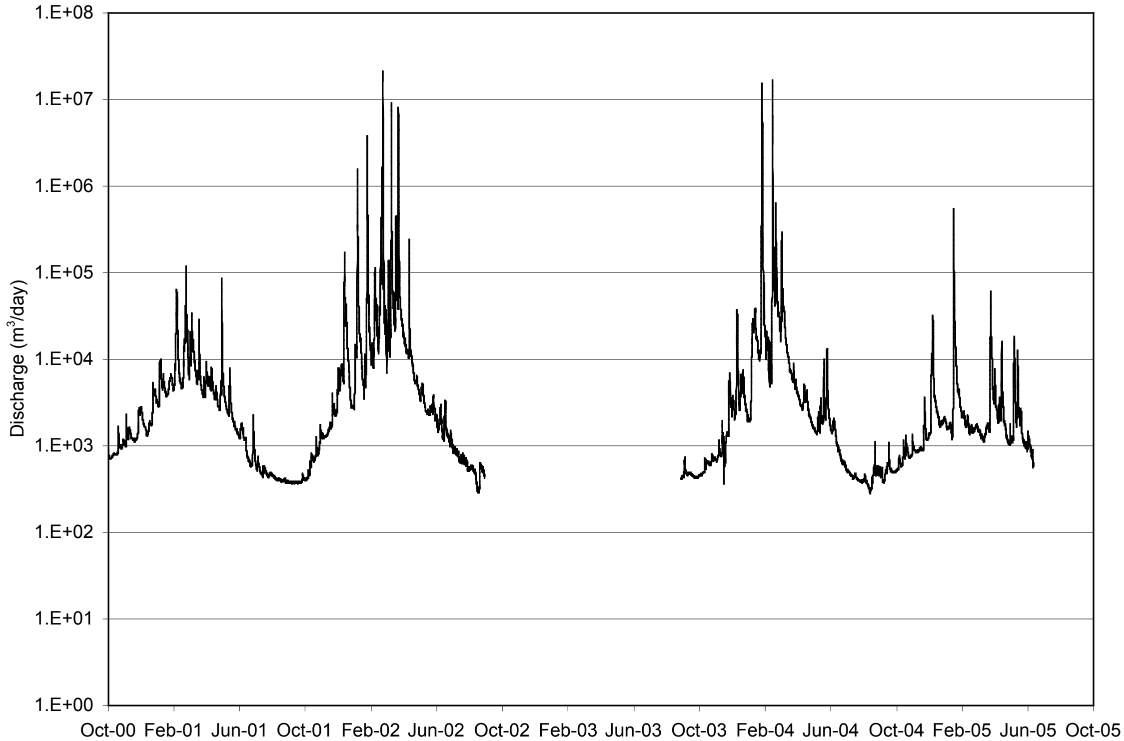
Monthly Cumulative Discharge MFC-660 (2007-2008)



Hydrograph for MFC-4700

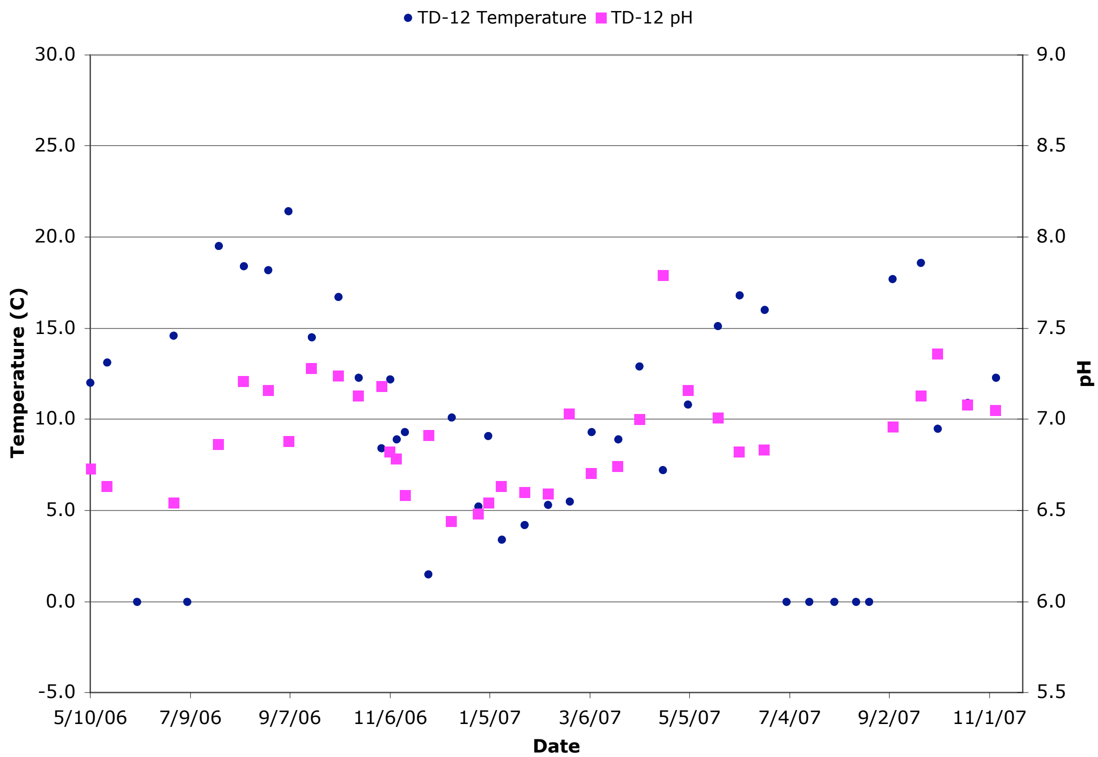


Hydrograph for MFC-5700

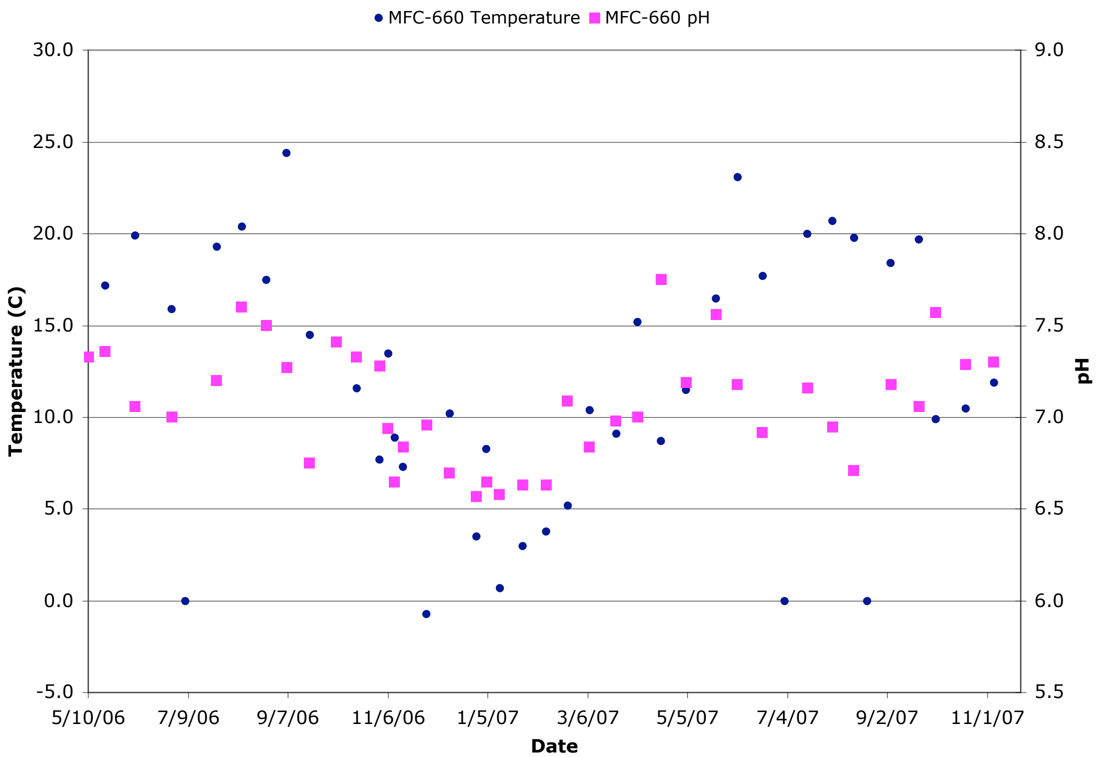


APPENDIX H Seasonal Trends for Field pH and Temperature

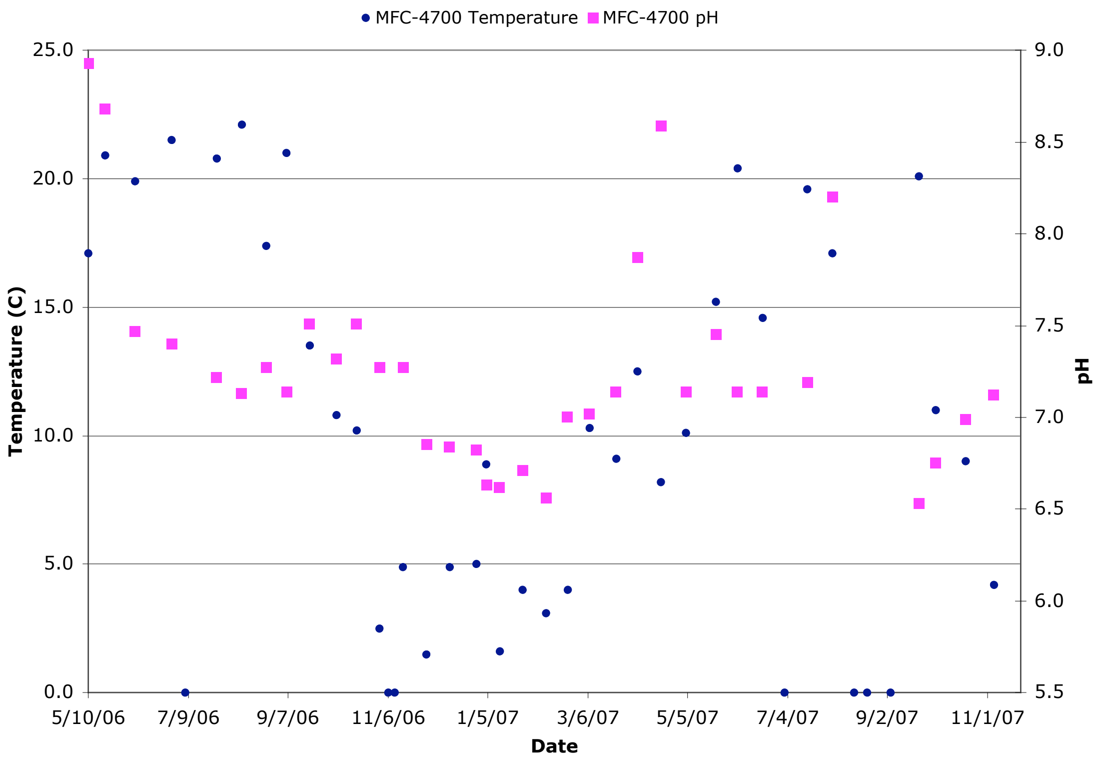
Temperature and pH Trend for TD-12 (2006-2008)



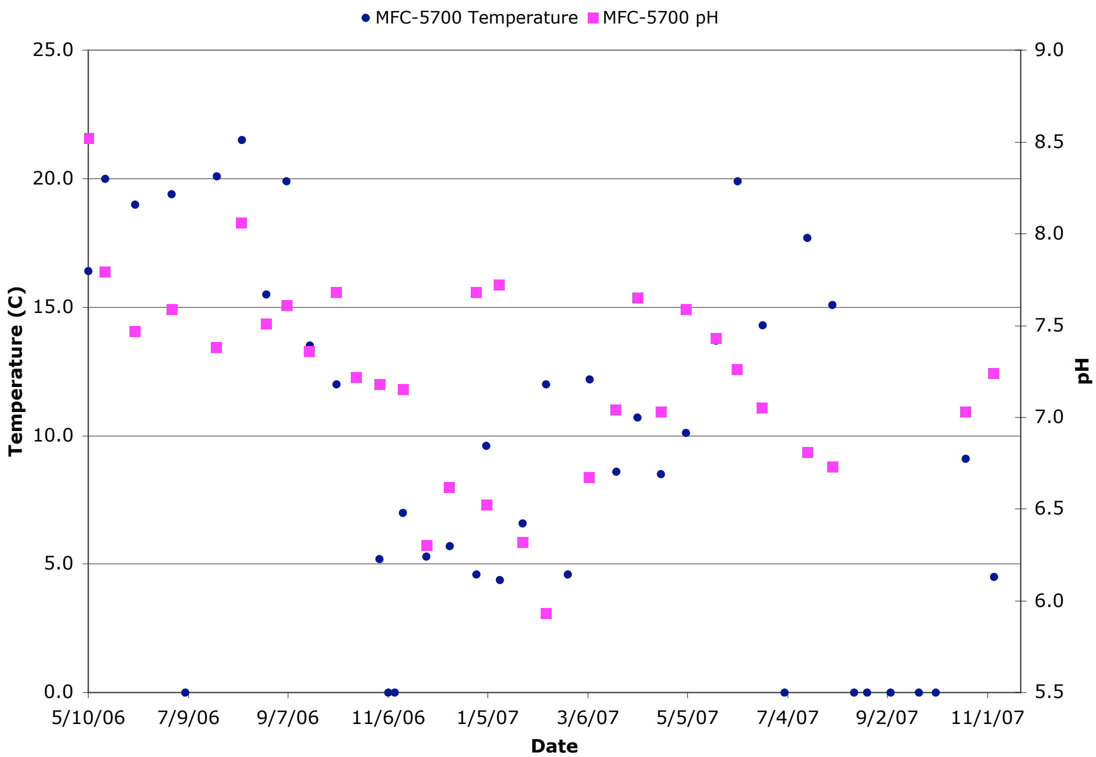
Temperature and pH Trend for MFC-660 (2006-2008)



Temperature and pH Trend for MFC-4700 (2006-2008)



Temperature and pH Trend for MFC-5700 (2006-2008)



APPENDIX I Method Development for Nitrate Extraction with Anion and Cation Resins and Isotopic Analysis

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1 INTRODUCTION

1.1 Nitrate as an Environmental Pollutant

Nitrate pollution as a result of over utilization of N fertilizers has recently become of great interest because of its ill effects on public health and the environment, and because it is a waste of fossil fuel and agricultural resources (Hatfield, 1999). Over utilization of N fertilizers in the US over the past several decades has increased nutrient pollution of waterways, lakes, rivers and ground water (Pierzynski et al, 1994). In many parts of the world, N saturation across various types of ecosystems as a result of artificial N fixation (including, but not limited to N fertilization, combustion of fossil fuels, and cultivation of N fixing leguminous crops) has resulted in decreased biodiversity and species richness (Vitousek et al., 1997). By increasing available N in ecosystems evolved to flourish in N poor environments, a few N demanding plant species are able to out compete and dominate the ecosystem thereby decreasing biodiversity and ecosystem stability (Lawes and Gilbert, 1880, Brenchley and Warington, 1958, Thurston, 1969, Silvertown, 1980, Tillman and Downing, 1994).

Nitrogen is an easily dissolvable nutrient in the oxidized form (as nitrate, NO_3^-) and can have a positive effect on the terrestrial and aquatic ecosystems in low amounts, especially when N is the limiting nutrient in areas such as forest ecosystems, heathlands, etc (Muchovej and Rechcigl, 1994). In natural settings, N is fixed, and thereby limited, by certain microbial and fungal species that can break the triple di-nitrogen bond of atmospheric N_2 and reduce it to a usable form as ammonia, amines, and amino acids. Inorganic N, in the form of NO_3^- and NH_4^+ as well as organic N in the form of amines and amino acids, are absorbed by plants and transformed in a series of processes to form proteins and nucleic acids. These transformed N sources are then consumed by higher biota or recycled to the soil and future plants in the form of dead plant material (Vitousek et al, 2002).

Conversely, in sizeable amounts, a surplus of N is created and is converted to various oxidized and reduced forms of N some of which escapes the ecosystem to the atmosphere as NO and NO_x gases (even in natural settings this gaseous emission of NO and NO_x occurs as part of the N cycle, but as N is often a limiting nutrient in natural ecosystems this emission is probably insignificant) or to surface and groundwater as nitrate. Nitrous oxide and reactive N released as gases during biologically induced oxidative and reductive transformations of N are significant green house gases and contribute a few percentages to overall global warming (Albritton et al., 1995, Galloway and Cowling, 2002). Nitrous oxide in the atmosphere increases ozone concentration in the troposphere and decreases protective ozone in the stratosphere by reacting with excited O atoms catalyzing ozone destruction (Cowling et al., 2002, Crutzen and Ehhart, 1977).

Nitrate has been determined to be a major source of non-point source agricultural pollution due to its high mobility in water relative to other forms of N (Moody, 1990, Howarth et al, 1996). High concentrations of nitrate ingested in the body, >10 mg/L N-NO_3^-, is converted to nitrite in the stomach and is absorbed in the bloodstream, which in turn causes hemoglobin to convert to methomoglobin. Methmoglobin is ineffective in transporting oxygen in blood and causes a condition called Methemoglobinemia and can be fatal to infants and young children (a condition called Blue Baby Disease) (Lee, 1970).

Examining the relationship of nitrate derived from over-fertilization in industrial agricultural areas with the area's hydrology is tantamount in understanding the overall foundation of N pollution in various spheres in which we live.

1.2 Utilizing N and O Stable Isotopes to Pinpoint Nitrate Pollution Sources

Historically, one of the most common research tools utilized in investigating nitrate pollution sources has been to use the stable isotope ratio of $^{15}N/^{14}N$ as denoted by the $\delta^{15}N$ (in per mille or ‰) relative to a known isotopic standard, usually atmospheric N. The delta ratio for N is defined as:

$$\delta N^{15}(‰) = \left(\frac{R_{Sample}}{R_{S\tan dard}}\right) \times 1000 \qquad (1)$$

Where R_{Sample} is the $^{15}N/^{14}N$ ratio for the sample nitrate; and $R_{Standard}$ is the $^{15}N/^{14}N$ ratio for a standard nitrate salt of known $\delta^{15}N(‰)$ relative to atmospheric $\delta^{15}N(‰)$, which is equal to 0‰.

Kendall and McDonnell (1998) state that the using $\delta^{15}N(‰)$ has the advantage of unidirectional kinetic fractionation effects that involve metabolic N transformations. In other words, the $\delta^{15}N(‰)$ of residual NO_3^- will be "more positive", or exhibit isotopic enrichment, as a result of biological "activity." For example, animals and microbes are slightly enriched in N relative to their diets. This is thought to be from the excretion of isotopically lighter N in urine (Wolterink et al, 1979), therefore causing any N derived product (such as manure) from the animal or microbe to reflect this enrichment of the heavier ^{15}N isotope, in this case microbially fixed NO_3^-.

For many years, it was accepted to evaluate different sources for NO_3^- only using $\delta^{15}N$. Unfortunately, only looking at $\delta^{15}N$ in nitrate caused ambiguous conclusions, because the ratio has an overlap that crosses many different source types and only varies a few ‰ (Amberger and Schmidt, 1987, Bedard-Haughn et al, 2003, Kendall and Aravena, 2000).

As a result of the limited usefulness of $\delta^{15}N$, the incorporation of the $\delta^{18}O$ as part of a dual isotope analysis became the norm for nitrate source analyses (Kendall and Aravena, 2000). It is widely accepted that during the formation of nitrate through the process of bacterial nitrification, dissolved O derived from the atmosphere only occupies 1/3 of the total O of the nitrate molecule, whereas the remaining 2/3 is derived from a local water source, presumably the pore water in which the bacteria reside (Amberger and Schmidt, 1987, Kendall and Aravena, 2000). Therefore, using $\delta^{18}O$ to isolate the source of the nitrate, when the isotopic composition of the surrounding water is known, may allow for very precise estimates of when N was nitrified and with what waters this occurred.

The major problem associated with $\delta^{18}O$in nitrate analysis has been the lack of effective isolation of the O portion of nitrate. Attempts at O isolation have left somewhat complicated and hazardous laboratory procedures that are yet to be fully effective at obtaining a relatively pure sample for $\delta^{18}O$ analysis (Amberger and Schmidt, 1987, Silva et al. 2000). One of the major contributors of O contamination to the $\delta^{18}O$ of nitrate has been presumably from polar and non-polar organic compounds and other O-bearing compounds, such as sulfate and phosphate, found in natural and agricultural soils (Michalski, Per. Comm, 2006, Haberhauer and Blochberger, 1999). This ubiquitous O problem has lead to the fabrication and culmination of a creative and seemingly effective nitrate purification technique developed by several researchers (e.g. Révész et al. 1997; Haberhauer and Blochberger, 1999; Silva et al. 2000; Stickrod and Marshall, 2000; Casciotti et al. 2002; Révész and Bohkle, 2002; Böhkle et al. 2003; Fukada et al. 2003; Michalski et al. 2004)

It is possible to use $\delta^{18}O$ of NO_3^- to identify the waters in which nitrification occurs because $\delta^{18}O$ of NO_3^- is completely reset when nitrate is reduced to ammonium or is incorporated into biomass and subsequently nitrified (Kendall and McDonnell, 1998 and Chang et al., 2004). In the poorly drained soils of the Palouse, nitrification and ammonification occur cyclically, throughout the year. Determination of $\delta^{18}O$ in NO_3^- of collected water samples from the MFC watershed may suggest when and with what waters nitrification occurred. Keller et al. (2008) observed high nitrate concentration spikes occurring after 150 mm of cumulative precipitation had fallen over the MFC watershed in fall and early winter, with highest nitrate concentrations from January to March. Keller et al. (2008) hypothesized that high nitrate spikes in tile drainage in early winter was due to mobilization of residual nitrate near tile drainpipe perforations. Later spikes were due to rapid mobilization of shallow soil water after saturated conditions were met above the tile drain (Keller et al. 2008).

2 Methods

2.1 Site Description

Please refer to section 2.1 in Moravec (2008).

2.2 Sampling Locations

Please refer to section 2.2 in Moravec (2008).

2.3 Sample Collection and Lab Preparation

Please refer to section 2.3 in Moravec (2008).

2.4 Analysis of $\delta^{18}O$ of Waters

Please refer to Section 2.4 in Moravec (2008).

2.5 Nitrate Extraction and $\delta^{18}O$ and $\delta^{15}N$ Analysis

Nitrate extractions for $\delta^{18}O$ and $\delta^{15}N$ analysis were conducted in the Vadose Zone Hydrology Lab (VZHL) located in the School of Earth and Environmental Sciences (SEES) at Washington State University (WSU). Anion and cation resins were employed to extract nitrate from samples following well-established resin extraction methodology (Silva et al., 2000; Stickrod and Marshall, 2000; Fukada et al., 2003; and Michalski et al. 2004), with slight modifications. All nitrate $\delta^{18}O$ and $\delta^{15}N$ analyses were conducted in the Stable Isotope Core Laboratory (SICL) located in the School of Biological Sciences (SBS) at WSU. Analysis for $\delta^{18}O$ was conducted on a Finnigan Delta Plus High Temperature Pyrolysis Elemental Analyzer – Isotope Ratio Mass Spectrometer (TC/EA - IRMS), and analysis for $\delta^{15}N$ was conducted on a Finnigan Delta Plus Elemental Analyzer – Isotope Ratio Mass Spectrometer (EA - IRMS). Analytical precision for the TC/EA-IRMS is 1‰ for O and the EA-IRMS is 0.5‰ for N.

Concentrations of nitrate (as $N\text{-}NO_3^-$) in MFC waters ranged from 4mg/L in summer up to 40mg/L during mid winter nitrate spikes. As a result, an average [$N\text{-}NO_3^-$] of 10-15 mg/L was assumed for most field samples; all standards during method development had [$N\text{-}NO_3^-$] between 5 and 25mg/L. Generally, 200 mL of water was used to extract nitrate; it was found that any volume less than this would not produce enough nitrate salt required to be analyzed in the (TC/EA - IRMS). Waters with high $N\text{-}NO_3^-$ concentrations (>25mg/L) could use less water volume, if necessary. Agricultural soils in the Palouse generally have high concentrations of soil organic carbon (SOC); an issue that was encountered during initial trials runs of $\delta^{18}O$ analysis was organic contaminants "clogging" the gas chromatograph (GC) requiring an extra purification step during extraction (Mickalski 2004; Michalski, Pers. Comm., 2006).

Nitrate extraction using ion exchange resins followed the following procedure:

Ion exchange columns were built using 20mL Bio-Rad chromatography columns. Several columns were employed during extraction so that several waters could be extracted at the same time. Anion and cation resins arrive in the lab dry and must be rinsed, defined, and exercised in order for the resins to be used for nitrate extraction (N.B. definition and exercising the resins may not be necessary if the resins are in the Cl^- form straight from Sigma-Aldrich, but it may be a good idea to follow this procedure if the resin is to be converted to Br^- form, or if definition of the resin is not know). First place resins in large beaker and fill with nanopure, stir the slurry with a stir rod (don't use a magnetic stir bar) for several minutes, allow the resins to settle for up to 45 minutes, decant floating resin and water from beaker and repeat several more times until resins are about the same size and water is clear. Install filter disk in 20mL chromatography columns (if not already installed) and pour slurry into the column until about 5mL resin is in the column. Place another filter disk in the column, making sure that it is not installed at an angle, and press it down into the column with a stir rod. All the water should be expelled from the column during this process and any remaining water should be forced out with a positive pressure bulb – stopper assembly. Be sure not to smash the resin with the filter disk, as this greatly reduces the conductivity of the resin and will increase extraction time. The next step exercises the resin as Cl^- form. Add 3mL aliquots of 3N HCl to the column allowing the acid to drip through the resin (positive pressure with the stopper – bulb assembly may be necessary to get it started); as the acid reaches the level of the resin, induce positive pressure and blow the resin dry. Add several aliquots of HCl in a similar manner. Next, rinse the resin with several aliquots of nanopure, drying the resin each time with the stopper – bulb assembly; check the pH of the eluent with a pH electrode. When the eluent has pH>6, the resin is defined and exercised and ready to use; if the resin is to be stored, saturate the resin with nanopure and place the column in the refrigerator upright, with the cap tightly closed. The method to rinse, define and exercise the cation resin is the same, it will be in the H^+ form; HCl can be used as the acid.

Poly (polyvinylpolypyrodone) (PVPP) (which is a Solid Phase Extraction (SPE) resin) was recommended by Greg Michalski to sorb organic carbon from natural waters as high SOC will cause fractionation of $\delta^{18}O$ in nitrate and should be removed prior to nitrate extraction. PVPP particles are much smaller than the ion exchange resins; so removing smallest particles is vital to reducing extraction time. Scoop several mL of PVPP into a beaker and add nanopure, stir the slurry with a stir rod for several minutes and let it settle for several minutes (up to 45 minutes), decant floating particles and water, repeat several times until water is relatively clear. Add the slurry to the chromatography columns so that no more than 2mL of PVPP is in the column. 1mL of silica gel is then added to onto the PVPP and the filter disk is pressed into place. PVPP and silica gel do not need to be defined nor exercised. To clean the PVPP between runs, small amounts of methanol was added to the resin and rinsed with several aliquots of nanopure. An alternative to PVPP in chromatography columns was to use a small scoop of PVPP (~1mL) added directly to the water sample, stirred, let to sit for at least 8 hours, then vacuum filtered with 0.45 μm cellulose nitrate membrane.

Proper rinsing of Ag_2O is critical to reducing contamination of nitrate in the $AgNO_3$ salts resulting from extraction. The first step to rinsing Ag_2O is to pore all the Ag_2O into a large ehrlimyer flask and fill the flask with nanopure water. Place a magnetic stirbar in the flask and stir at medium speed for several hours. Turn off the stirrer and allow particles to settle, decant the liquid into a hazardous waste container (as the liquid will contain dissolved Ag) and repeat several more times. Decanted liquid should have an [N-NO_3^-] of less than 0.5mg/L as verified by a Hach spectrophotometer. Place the slurry into a Pyrex glass bread pan that has been acid washed and dried in a muffle furnace, then place the slurry/bread pan into a drying oven set at 50-60ºC until the Ag_2O is completely dry. Scrape the clean Ag_2O into brown glass bottles and leave in the dark until use.

The standard operating procedure (SOP) from the USGS recommends that water volumes should be adequate to precipitate 100-200 mmoles of nitrate. Nitrate concentration was measured using a Hach spectrophotometer to measure nitrate concentration in the water sample before extraction and the eluent after extraction; this was to ensure that most of the nitrate is captured and not overloading the exchange capacity of the resin. The anion and cation resins have an exchange capacity of 1.2 meq/mL; so 4 - 5 mL of resin should have an exchange capacity of 4.8 - 6.0 meq.

The first step to extraction is to measure 200 mL of water, estimate the [N-NO_3^-], place water in funnel over the PVPP column and use a vacuum flask and peristaltic pump to draw water through the PVPP and silica gel. This step may take upwards to 1 hours depending on how tightly packed the PVPP and silica gel are, or how "dirty" the water is with DOC. Silica gel and PVPP resins capture non-polar and slightly polar organic compounds. Next, add 2 mL of 1 M Ba_2Cl solution to the water to precipitate sulfates and possible phosphates; leave the solution overnight in the refrigerator to allow precipitates to settle, and then filtered through Whatman 0.45μm nitrate cellulose membrane filters.

Waters are then run through the cation resin; drip rate through the column is regulated by a stopcock and is set at about 1 drip per second. This step captures surplus Ba^+ ions and possibly protonates polar organic acids. As the water reaches the level of the cation resin, expel the remaining water with the stopper – bulb assembly. The water is then run through the anion resin. The drip rate is much slower than the cation resin due to the lower conductivity of the anion resin; samples are loaded onto the anion resin and left overnight to pass through the resin. All columns are tightly fitted with a funnel so that all the water can be left to run through the resin. As nitrate is exchanged onto the resins, the resin will visible darken near the top as water is run through. Using a Hach spectrophotometer as a check, eluent water will show a value less than 0.5 mg/L N-NO_3^- showing that nearly all nitrates is captured in the resin (Nanopure water will show about the same nitrate concentration on the Hach). Running 200mL through the PVPP – silica gel, cation, and anion resins will take at least 2 hours, but may take longer, especially if a larger volume is needed because of low nitrate concentrations. Running multiple samples on several resin columns at the same time is ideal.

The following steps must be done immediately. The anion resin is eluted with 21 mL of 3 M HCl, which is sent through in 3 mL aliquots and then blown out with a positive pressure stopper – bulb assembly; Silva et al. (2000) has shown quantitatively that 3 mL increments seem to elute nitrate ions more effectively than in one 21 mL burst. The eluant will have a volume of about 20 mL and will have a distinctly nitric acid smell. This eluant is dripped into a 60mL plastic centrifuge vial, then placed into a cool water bath, and ~6 g of Ag_2O is added to the eluant in 1 g increments to neutralize the solution to about pH 5 - 6. Neutralization follows the following equation:

$$HCl_{(Aq)} + HNO_{3(Aq)} + Ag_2O_{(S)} \leftrightarrow AgNO_{3(Aq)} + H_2O_{(l)} + AgCl_{(S)}$$

It is important to note that increasing the amount of HCl will require more Ag_2O to neutralize the solution, but hasn't been shown in the literature whether or not increasing the HCl volume increases the likelihood that nitrate will be exchanged off the resin more completely. It was suggested by Greg Michalski to use HBr as an alternative to HCl during elution because Br^- has a stronger affinity for the resin than Cl^- (hence using less acid to elute) and neutralization could be achieved with significantly less Ag_2O (This requires that the anion resin be redefined and exercised in the Br^- form, which was not attempted as of the time of this writing). Complete neutralization of the solution is absolutely critical to reduce isotopic fractionation, so using excess Ag_2O is preferable to not enough. After each addition of Ag_2O, the centrifuge vial is capped and shaken with a vortexer, which effectively crushes up the Ag_2O clumps. The vials are returned to the cool water bath for several minutes after each spin on the vortexer to dissipate the heat of reaction. The Ag_2O will turn a pinkish color indicating AgCl formation after each addition. As each Ag_2O increment is added, the solution will eventually turn a milky color and then become clear, the pink powder will turn a dark grey, pH is verified with pH paper.

The neutralized solution is vacuum filtered through a .22μm GS filter and transferred to a clean, acid rinsed 60 mL centrifuge vial. The AgCl residue is rinsed with excess nanopure to get all complexed $AgNO_3$. The final volume is usually around 40 – 60 mL. This solution is placed in a low temperature oven (set at 50^0C) and allowed to evaporate. After 2 –3 days of drying, a precipitate will form and appear dark grey, and under 10X microfication a light-colored crystalline $AgNO_3$ precipitate will be apparent. The vials are weighed, capped, and placed in the dark to limit photodegradation until isotope analysis can be performed. Centrifuge vials may degas during oven drying, and as a result, glass may be preferable to plastic for this step. $AgNO_3$ yields will be about 20 mg (depending on original nitrate concentration), which is sufficient for both δ^{18}O and δ^{15}N analysis and duplicates.

Isotopic analysis

Sample preparation for isotopic analysis was performed in the SICL in the SBS at WSU. Stored samples that were analyzed for δ^{15}N were weighed a day before EA-IRMS analysis and placed into silver sample boats; tin sample boats will react with the $AgNO_3$, therefore silver boats must be used. Approximately 1 mg of $AgNO_3$ salt and about 2mg of sucrose was added to each sample boats following suggested methodology from Silva

(2000). Initial pilot studies for $\delta^{15}N$ analysis did not use sucrose. The cups were crimped and folded and made into tight balls. Samples for $\delta^{18}O$ were analyzed by a TC/EA – IRMS where samples were weighed a day before analysis and placed beside the machine to equilibrate with ambient O. Sample weights were 1mg of $AgNO_3$ and about 2 mg of spectroscopic quality graphite and placed into silver analysis boats, then crimped and folded. Initial pilot studies for $\delta^{18}O$ analysis did not use graphite as a C source and $\delta^{18}O$ values were not consistent between duplicates (up to 7 ‰ difference). Minimum detection limit for nitrate for the TC/EA is 50μg, and efforts were made to concentrate $AgNO_3$ salts that were substantially greater than this.

2.6 Method Development and Problems Associated with Resin Nitrate Extraction

Several problems were encountered through the process of nitrate extraction and method development. Several trial runs of standard KNO_3 (a KNO_3 standard salt located in the SEES GAL chemical storage was used as the standard nitrate salt in that standards are extremely expensive; this salt was labeled to be from 1976, isotopic homogeneity of the salt was assumed but not verified) solutions at varying concentrations, natural waters from the sampling sites with spiked additions of KNO_3, and nanopure blank samples were used to weed out possible sources of contamination and isotopic fractionation.

The first problem that was encountered was the possible O contamination from dissolved organic matter (DOM) as a result of the provenance of collected waters from agricultural soils. In addition, high DOM is recognized to permanently clog ion exchange resins and lead to possible fractionation of isotopes. To remove DOM from the water, silica gel and PVPP were used as a preliminary filter. Silica gel will sorb non polar organic to its matrix and PVPP will sorb slightly polar organics and phenolics (Michalski, Pers. Comm.). Silva (2000) used the cation exchange resin before the anion exchange resin to remove organics from waters, but Silva (2000) stated this as only useful for low concentrations of DOM, and it seems that the PVPP – silica gel step is effective for waters collected in the Palouse. In order to determine if isotopic fractionation occurred as a result of the PVPP - silica gel step, standard KNO_3 solution splits were measured with a volumetric flask with one split passed through the silica gel – PVPP column, while the other split was not. Each split was then extracted via cation and anion resins following the above stated methodology. Analytical data from this experiment was not completed as of the writing of this document.

Several other possible sources of contamination and fractionation were hypothesized to occur during the cation – anion extraction method. Each of these possible sources were isolated and independently assessed to identify the severity of fractionation and/or contamination.

1) DOM contamination on O bearing compounds.
    a. DOM as a contaminate will clog resins.
    b. DOM has O and will contaminate $\delta^{18}O$ data.
2) Nitrate contamination from Ag_2O.
    a. During formation of Ag_2O, nitrate forms and can contribute to skewed results.
    b. Silva (2000) suggests using DI to rinsed Ag_2O for nitrate.
    c. Initial nitrate was at about 17 mg/L.
    d. Washed Ag_2O to about 1mg/L – can't rinse anymore than this.
    e. Nitrate in nanopure is possible and may limit Ag_2O rinse.
3) Nitrate contamination from nanopure.
    a. Possible contamination from nanopure
    b. Average nitrate concentration of nanopure is about 0.05mg/L by continuous flow autoanalysis.
4) Possible heterogeneity of KNO_3 standard
    a. Using KNO_3 standard from geo analytical lab may not have consistent isotope values

b. Use KNO_3 in aqueous solution and allowed to equilibrate for a few days before using – should eliminate heterogeneity of solution

5) Matrix effects from natural samples
   a. Use natural waters from site to see if matrix effect exists
   b. Spike sample with known concentrations of KNO3 and run through the extraction
   c. Assess yield of nitrate for unspiked and spiked samples
6) Nitrate contamination from glassware
   a. Glassware used during extraction may have residual nitrate from either nitric acid bath or from previous samples
   b. Bake glassware at 500°C for 2 hours to volatize inorganics
7) Nitrate contamination from nitrate membrane filters
   a. Residual nitrate may contaminate waters via filtration
   b. Run blank through nitrate membrane and one with out see if there's a nitrate component to nitrate membrane blank
8) Incomplete elution of nitrate from anion resin
   a. Incomplete elution will cause isotopic enrichment due to lighter isotopes being exchanged for Cl^- ions during acid elution first
   b. Run a split sample that uses 20mL of HCl and one that uses 30 and 40 mL HCl.
   c. If samples are different, incomplete elution may pose problem
9) Incomplete neutralization of acid eluant
   a. Will cause fractionation (enrichment) due to NO_3^- volatilization during evaporation (either freeze drying or oven baking process).
   b. Can solve by using excess Ag_2O for every neutralization.
10) Possible nitrate contamination from resins
   a. Resins have some nitrate in them, may cause a skewed δ value.
   b. Stickrod and Marshall (2000) assessed to see if resins caused any change in $\delta^{15}N$ value – was negligible.
   c. No indication if this is the case for O
11) ^{18}O contamination from ambient water vapor.
   a. $AgNO_3$ is very soluble and may absorb some water from ambient air.
   b. This would force $\delta^{18}O$ values towards more atmospheric $\delta^{18}O$ ~8‰
   c. Test dry samples in desiccator with water sample of known $\delta^{18}O$ composition (e.g. VSMOW) to see if this is a problem
12) Possible ^{18}O contamination from glassware
   a. SiO_2 from degassing of glass may contribute to skewed delta O
   b. Use plastic for evaporation step
13) Plastic contamination of ^{18}O.
   a. Possible contamination from plastic ware
   b. Probably not a problem because of plastic composition – mostly C and H
14) IRMS problem
   a. Addition of sucrose to samples run for $\delta^{15}N$ in EA-IRMS may increase consistency in data. Not sure what quantity to use.
   b. Addition of C source in graphite form may increase consistency of $\delta^{18}O$ analysis in TC/EA-IRMS. Again, not sure what quantity to use.

2.7 Comparison of $\delta^{18}O$ of Water and Nitrate: Theory

The primary objective of the analysis of $\delta^{15}N$ and $\delta^{18}O$ of nitrate was to compare the $\delta^{18}O$ values of water and nitrate to assess the timing in which N was oxidized in the soil out at the CAF. Kendall and McDonnell (1998) state that the three O's of nitrate come from two sources during nitrification: one from atmospheric O_2 ($\delta^{18}O$ =~8‰) and two from soil or ground water (for the CAF and MFC, $\delta^{18}O$ =-14.7‰ with slight variability during events). Due to nitrate's strong electrostatic valency,

$$\frac{Valency}{Coodination\#} = \frac{5}{3} = 1.6667 \text{ for nitrate,}$$

it was hypothesized that the exchange of O atoms from nitrate to the aqueous solution would be minimal and the isotopic signature of the $\delta^{18}O$ of nitrate would reflect the $\delta^{18}O$ of the water in which it nitrified. The $\delta^{18}O$ of the nitrate will not be exactly that of water, it will shift in a positive direction and seasonal trends in the $\delta^{18}O$ of nitrate should match $\delta^{18}O$ seen in H_2O. The addition of very depleted $\delta^{18}O$ to water during events (i.e. January 2004) may be visible in $\delta^{18}O$ record of nitrate and lead to the approximate nitrification age of that nitrate molecule or position in the soil profile. As of this writing, stalled method development had prevented the testing of this hypothesis. However, $\delta^{15}N$ and $\delta^{18}O$ of nitrate values from near Hanford, WA analyzed by Isotech Laboratories, Inc., Champaign IL for Kyle B. Brown, Jennifer McIntosh, Laura Rademacher (University of the Pacific), and Kathleen Lohse at the University of Arizona (*Pers. Comm*) showed $\delta^{18}O$ values near our expected ranges (-5‰ to –10‰), which provides some hope that the strategy of $\delta^{18}O$ comparison of nitrate and waters is practical.

RESULTS

Outline of Research Results

1.) Precipitation and Water Discharge Results $\delta^{18}O$
   a. Precipitation $\delta^{18}O$ shows a general trend of being isotopically lighter during winter months and heavier during summer months
      i. Average $\delta^{18}O$ is –13‰
   b. Tile Drain $\delta^{18}O$ exhibits an average $\delta^{18}O$ of –14.5‰ and much less seasonal variation.
   c. Gray Road $\delta^{18}O$ exhibits an average $\delta^{18}O$ of –14.5‰, but substantially more seasonal variation.
      i. Some water years exhibit heavier $\delta^{18}O$ during summer months, while lighter $\delta^{18}O$ are during winter months
      ii. Presumably due to inputs of precipitation and base-flow (or soil water) mixing.

2.) Nitrate concentrations and seasonal variability.
   a. Nitrate concentrations increase during periods of high soil wetting and subsequent discharge from pores.
   b. Nitrate concentrations decrease with lower soil moisture and may be due to plant uptake of nitrate or nitrate sequestration within micropore water during months of lower precipitation.

3.) Fractionation of $\delta^{18}O$ and $\delta^{15}N$ of Nitrate during nitrate extraction
   a. Note** This fractionation hasn't been established, but due to the complexity of the extraction process, it is assumed that there is a certain amount of fractionation that occurs. I am going to conduct an extraction of nitrate-laden water of known isotopic composition and for both O and N and nitrate concentration and run it against the same nitrate salt. This may provide some info about a possible fractionation coefficient.

4.) $\delta^{18}O$ and $\delta^{15}N$ of Nitrate
   a. Initial conditions of Nitrate isotopic composition from soil cores taken after fall application of N fertilizer.
      i. Soil cores were pulled at depths of 15cm, 15-30cm and 30-45cm below surface in the catchment above the tile drain. (12 samples)
      ii. Nitrates were planned to be extracted from soils using DDI water, but were not as of the time of this writing.
   b. As of the time of this writing, $\delta^{18}O$ analysis has shown that nitrate from TD-12 water have an $\delta^{18}O$ of 0.0‰. (1-2 samples)
   c. Previous $\delta^{15}N$ analysis has shown an average $\delta^{15}N$ of +2.5‰ ±0.5‰ for Gray Road waters, and an average $\delta^{15}N$ of –2.0‰ ±2.0‰ for tile drain waters. (Total of 6 samples)

APPENDIX J List of References for Nitrate Extraction Methodology

Reference list for stable isotope work on nitrates.

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APPENDIX K Experimental Data for Nitrate Extraction Methodology

All data reported in this appendix is experimental, collected as part of method development of anion and cation resin extraction of nitrate from 2006-2008. All extractions were performed by Bryan Moravec in the Vadose Hydrology Lab in the School of Earth and Environmental Sciences at Washington State University.

Copied from Watershed Notebook
By: Bryan Moravec
3/24/07
Running SPE Experiment, Free HPLC samples from Sigma-Aldrich
Tile @ A nitrate concentration = 13.5 mg/L
Nitrate conc measured on Hach DR/2010 spectrophotometer
with nanopure as blanks

Standard KNO_3 at 20 mg/L is 5.7 NO_3-N when measured
on Hach Spec.

Running SPE	Volume H2O (mL)	Volume SPE (mL)	[NO3-N] after SPE	[NO3-N] after An/Ct Resins
SPE Normal Phase DSC-DIOL	200	6	19.7	4
SPE Reversed Phase DSC-PH	200	3	16.3	2.5
DPA-6S	200	6	18.5	2.8
DSC-18	200	3	-	0.6
None	200	0	-	0.5

Note
I'm not entirely sure why the [NO3-N] are different here, I think that the concentration of the standard solution was 20 mg/L as reflected by the [NO3-] after SPE column.

Copied from Watershed Notebook
By: Bryan Moravec
4/13/07
Running SPE Experiment, Free HPLC samples from Sigma-Aldrich
Part 2

Extraction Method A

Use of SPE resins: DSC-Si, DSC-18 before use of cation/anion resins

Step	
1	Add 6mL of 0.1M $BaCl_2$ to solution, let sit overnight, filter through 0.45um nitrate filter.
2	Vacuum flask with fitted column on custom made stopper, peristaltic pump draws water through DSC-Si
3	Vacuum flask with fitted column on custom made stopper, peristaltic pump draws water through DSC-18
4	Gravity drip water through cation resin
5	Gravity drip through anion resin
6	Elute resin with 5 3mL shots of 3N HCl (total acid 15mL)
7	Neutralize elutant with 6.5 g Ag_2O
8	Filter AgCl
9	Split into 2 samples: 1 for freeze drier, 1 for oven dry

Extraction Method B

Use of SPE resins: DSC-Si, DSC-18 before use of cation/anion resins (following Silva et al. 2000)

Step	
1	Vacuum flask with fitted column on custom made stopper, peristaltic pump draws water through DSC-Si
2	Vacuum flask with fitted column on custom made stopper, peristaltic pump draws water through DSC-18
3	Gravity drip through anion resin
4	Elute resin with 5 3mL shots of 3N HCl (total acid 15mL)
5	Neutralize elutant with 6.5 g Ag_2O
6	Split into 2 samples : 1 for d15N and 1 for d18O
7	Sample for d15N: evaporate, add 2mL water then evaporate
8	for d18O sample: Add 2mL of 1M $BaCl_2$, leave overnight
9	Filter through 0.45um nitrate filter
10	Run through cation resin, blow dry, rinse with 5mL nanopure
11	Neutralize elutant with 1 g Ag_2O
12	Filter through 0.45um nitrate filter
13	Evaporate water, Add 2mL water, evaporate again

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By: Bryan Moravec
8/27/07
Experiment to see if 60mL samples will work for nitrate extraction

Using KNO_3 standard solution from GAL chemical storage, made on 8/8/2007

Sample	[NO3-N] (mg/L)	Volume (mL)	d18O (per mil)
1	8.8	60	5.9
2	17.3	60	2.94

Steps	
1	Vacuum filter sample through PVPP/silica gel column
2	Add 2mL 1M $BaCl_2$, leave overnight
3	Run through 0.45 um nitrate filter
4	Run through cation resin
5	Run through anion resin
6	Elute with 5 3mL shots of 3N HCl (total 15mL)
7	Neutralize with 6.5 g of Ag_2O
8	Filter through 0.45 um nitrate filter
9	Dry in oven in glass beaker.

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By: Bryan Moravec
9/14/07

Standard preparation for KNO_3 standard yield experiment

Used weight % of N to calculate mass of KNO_3 to add to 1000mL of nanopure in a volumeteric flask.

To calculate mass of KNO_3 to add, use following formula:

Element	AW
Ag	107.8682
K	39.0982
N	14.00674
O	15.9994

Total weight of KNO_3 = 101.103 g/mol
N% = 14.00674/101.103 = 13.85 %

So to get 10mg/L NO_3-N
(10mg/L NO_3-N) (1.0 L H_2O) (1/0.1385) = 72.2mg KNO_3

Therefore:

Want [NO3-N] mg/L	Add KNO3 mg
5	36.1
10	72.2
15	108.3
20	144.4
25	180.5

KNO3 salt d18O (per mil) Run Date: 10/30/07
3.12
2.86
4.07
4.6

To make 1M $BaCl_2$ solution, 104.123 mg of $BaCl_2$ salt is added to 1L nanopure.
For analysis, actual $BaCl_2$ added to 1000mL of nanopure, was 106.5mg

Three 1L standard KNO_3 solutions were made for standard yield experiment
Initial volumes were 1000mL +/- 0.3mL using volumetric flask
15 mL were removed for nitrate concentration on Hach spec
20 mL was removed for d18O analysis of nanopure waters

Sample #	Desired [NO3-N] mg/L	Actual KNO3 added (mg)	Volume	d18O (duplicate) (per mil)	Note
1	10	72.3	1000	15.19	
2	15	108.5	1000	9.54	
3	20	144.4	1000	-	Spilled (not used)
4	20	144.2	1000	7.84	
5a	10	72.3	1000	14.81 (14.88)	Split into 5a, 5b
5b				8.66 (9.06)	
BM 11/5	10	74.2	1000	-	Split into 7 samples (a,b,c,d,e,f,g)

Samples for BM 11/5 were designed to evaluate fractionation during each extraction step. Each step had 2 splits.

Sample	Extraction steps
BM 11/5 a,b	PVPP, Si gel, Cation resin, Anion resin with BaCl2
BM 11/5 c,d	Cation resin, Anion resin only, with BaCl2
BM 11/5 e,f	Anion resin only with BaCl2
BM 11/5 g	PVPP, Si gel, Cation resin, Anion resin only

Copied from Watershed Notebook
By: Bryan Moravec
10/4/07

Matrix Effect Experiment (Gray Road and Tile @ A)

Goal: To use real water sample from field, split into 2 equal (volumtric) samples, add known amount of KNO3 standard (1977) to one sample, the other without. Run both samples through exactly same extraction process and drying process. Weight samples, sample with spike should have known weight plus sample nitrate. Unspiked will act as baseline. If weights of dryed samples do not follow this expectation, then methodology is flawed and matrix effect is present.

Methodology: Use 1L of real sample from field (1L gray road, 1L of tile @ A) split into 4 250mL samples (using volumetric flask) spike as listed below:

Assume [NO3-N] in field sample is 5mg/L

	No Spike	1.5 spike	2.0 spike	2.5 spike
[NO3-N]	5 mg/L	10 mg/L	15 mg/L	20 mg/L

field sample	Sample volume (mL)	[NO3-N] spike increase (mg/L)	Final [NO3-N] estimated (mg/L)	Add KNO3 (mg)	Actual added KNO3 (mg)	Actual [N-NO3] mg/L	Expected AgNO3 (mg) from KNO3 spike only	Expected AgNO3 (mg) from KNO3 and NO3	Actual AgNO3 (mg)	d18O
Gray Rd 1	250	0	5	0	0	2.7	0.00	8.19	11.8	-0.45
Gray Rd 2	250	5	10	9.025	10.8		15.16	23.35	19.6	5.86
Gray Rd 3	250	10	15	18.05	21.7		30.33	38.51	32.8	6.21
Gray Rd 4	250	15	20	27.075	30.5		45.49	53.68	49.2	7.45
Tile @ A 1	250	0	5	0	0	3.7	0.00	11.20	11.2	-0.5
Tile @ A 2	250	5	10	9.025	9.7		15.16	26.36	19.2	3.54
Tile @ A 3	250	10	15	18.05	20.3		30.33	41.53	28.7	4.08
Tile @ A 4	250	15	20	27.075	29.2		45.49	56.69	49.5	6.26

Figure APP K 1

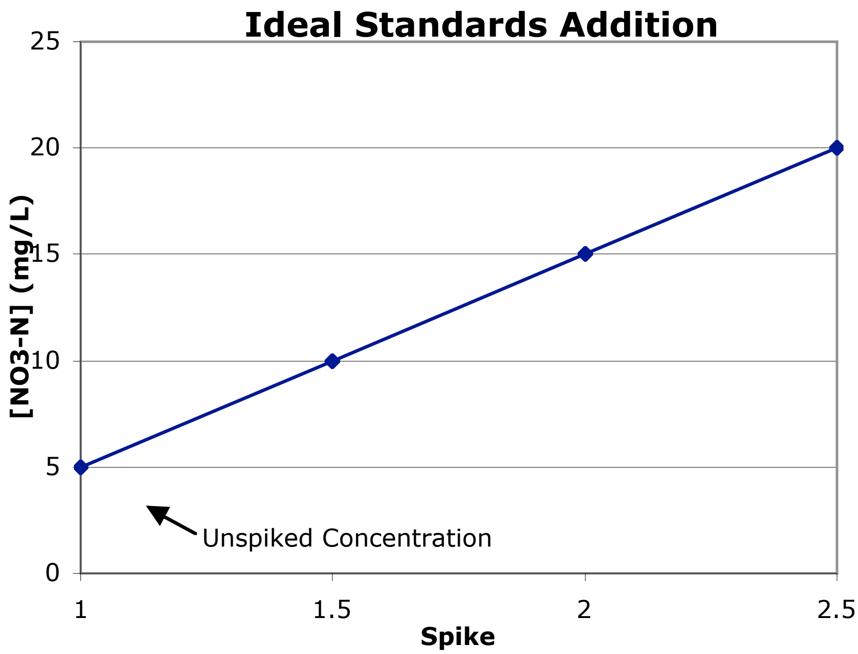
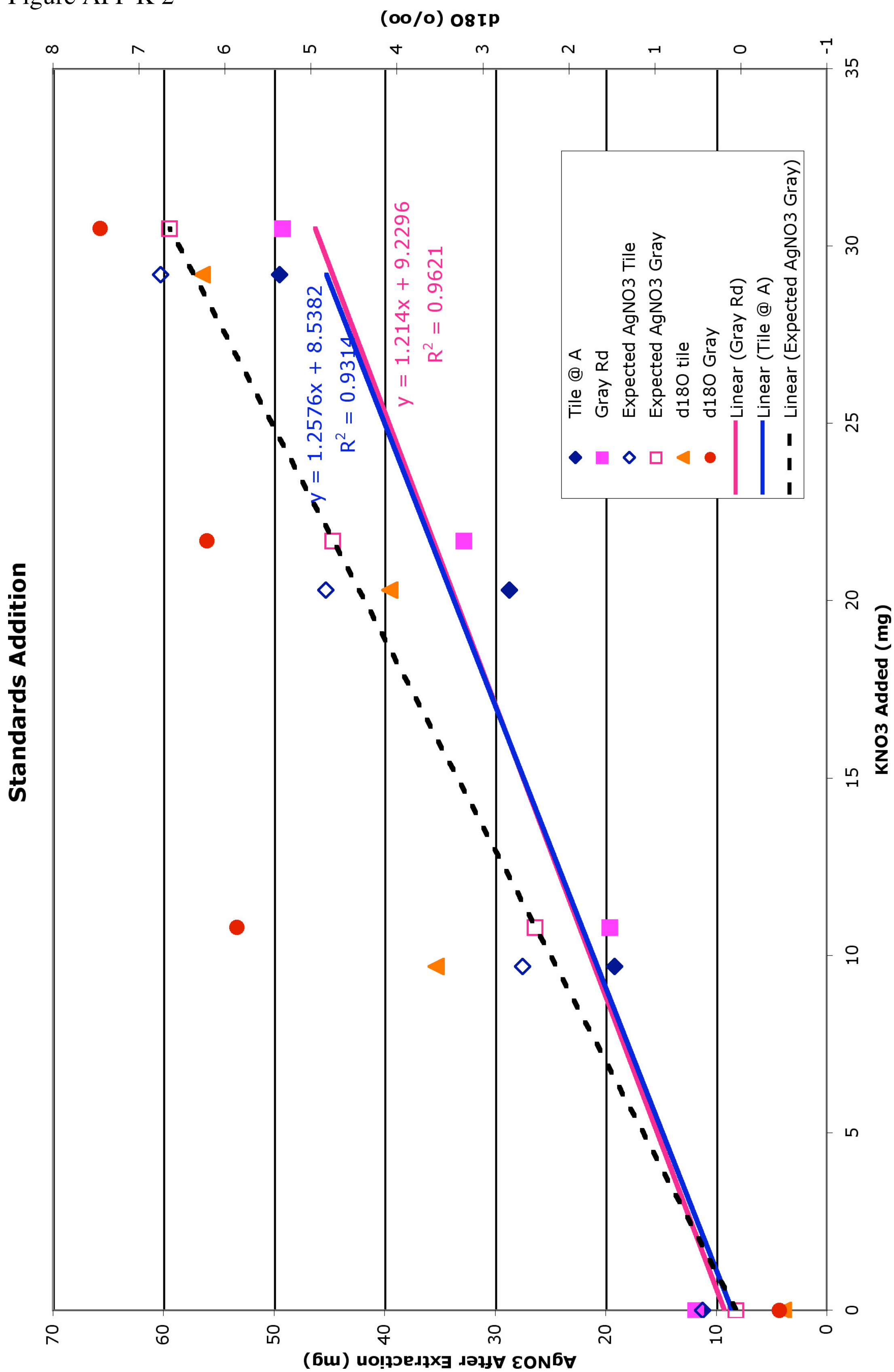


Figure APP K 2



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By: Bryan Moravec
No Date, but was between 11/7/2007 and 1/7/2008

Extraction Blanks

Goal: To determine if contamination occurs with Ag_2O or another source such as glassware etc.

Methods: 3 splits of 500 mL nanopure water (B1, B2, B3) were divided into blanks, each 500mL were split into 250mL a and b splits. B4 was 30mL of 3N HCl passed through resins, B5 was 6 mg rinsed in 30mL of nanopure.

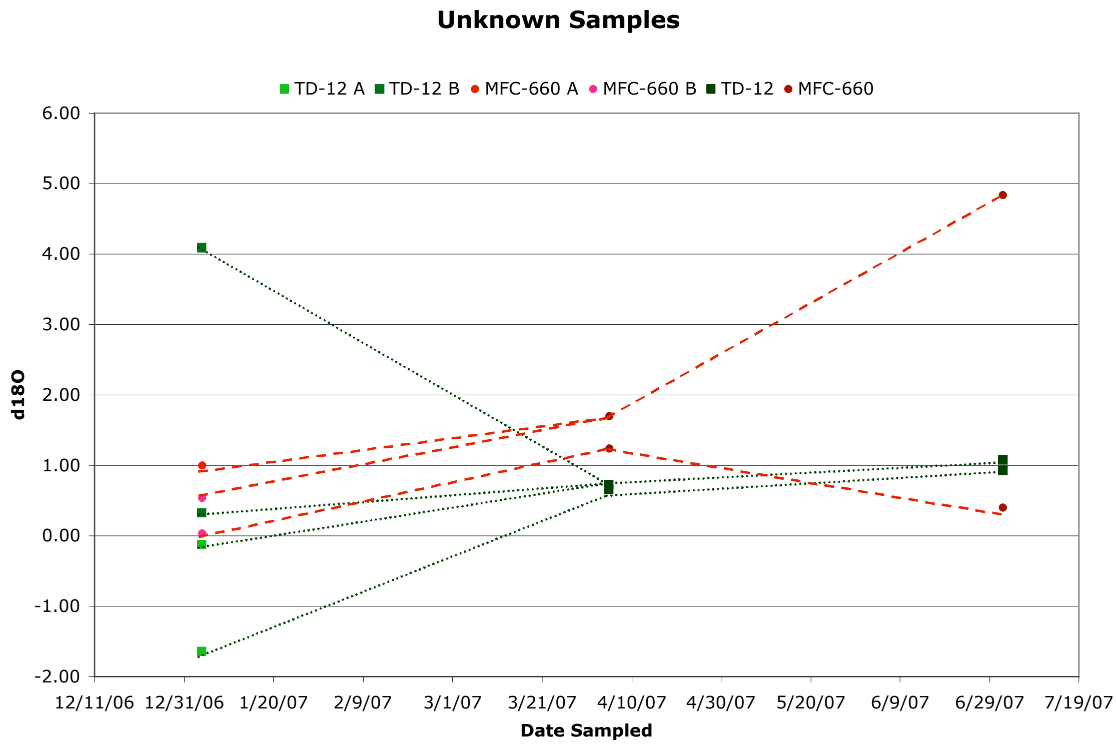
Sample	Purpose (To test if…)	Method
B1	NO_3 filter is contaminant	500 mL nanopure ran through nitrate filter then split into 250mL splits, a and b, run through cation/anion resins, eluted, neutralize, oven dry. All glassware is baked at 500 C
B2	nanopure NO_3 is contaminant	500 mL nanopure not run through nitrate filter then split into 250mL splits, a and b, run through cation / anion resins, eluted, neutralize, oven dry. All glassware is baked at 500 C
B3	glassware is contaminant	500 mL nanopure not ran through nitrate filter then split into 250mL splits, a and b, run through cation/anion resins, eluted, neutralize, oven dry. Regular non-baked glass ware used.
B4	HCl elution produces NO_3 from resins	30mL 3 N HCl passed through anion resin, split into 25mL splits, a and b
B5	Ag_2O NO_3 is contaminant	Use 6g of Ag_2O, rinse in 30mL of nanopure, filter with 0.22 um non-nitrate filter, split into a and b, oven dry.

	Sample ID	Sample Description	1000x $\delta^{18}O_{VSMOW}$	O%	Sample ID 2
	kno3 stdA	KNO3 standard A GAL	11.46	45.07	KNO3 Std A
	kno3 stdA	KNO3 standard A GAL	11.91	44.75	KNO3 Std A
	kno3 stdA	KNO3 standard A GAL	11.68	44.53	KNO3 Std A
	kno3 stdB	KNO3 standard B GAL	11.85	44.79	KNO3 Std B
	kno3 stdB	KNO3 standard B GAL	12.04	44.47	KNO3 Std B
	kno3 stdB	KNO3 standard B GAL	11.43	44.4	KNO3 Std B
$	T 1-4-07A	TD-12 1/4/07 A	-0.12	24.7	TD-12 A
$	T 1-4-07A	TD-12 1/4/07 A	-1.64	24	TD-12 A
$	T 1-4-07B	TD-12 1/4/07 B	0.33	24.66	TD-12 B
$	T 1-4-07B	TD-12 1/4/07 B	4.09	24.44	TD-12 B
$	T 4-5-07	TD-12 4/5/07	0.66	23.65	TD-12
$	T 4-5-07	TD-12 4/5/07	0.73	24.83	TD-12
$	T 7-2-07	TD-12 7/2/07	1.08	23.71	TD-12
$	T 7-2-07	TD-12 7/2/07	0.93	23.93	TD-12
$	G 1-4-07A	MFC-660 1/4/07 A	0.10	24.43	MFC-660 A
$	G 1-4-07A	MFC-660 1/4/07 A	-0.96	24.97	MFC-660 A
$	G 1-4-07B	MFC-660 1/4/07 B	0.54	24.42	MFC-660 B
$	G 1-4-07B	MFC-660 1/4/07 B	0.04	24.85	MFC-660 B
$	G 4-5-07	MFC-660 4/5/07	1.24	23.56	MFC-660
$	G 4-5-07	MFC-660 4/5/07	1.70	24.68	MFC-660
$	G 7-2-07	MFC-660 7/2/07	4.84	20.65	MFC-660
$	G 7-2-07	MFC-660 7/2/07	0.40	23.7	MFC-660
	T 0_0	TD-12 0 mg KNO3 added	-16.75	23.45	Tile @ A 1
	T9_7	TD-12 9.7 mg KNO3 Added	6.89	23.43	Tile @ A 2
	T20_3	TD-12 20.3 mg KNO3 Added	-0.06	25.74	Tile @ A 3
	T29_2	TD-12 29.2 mg KNO3 Added	9.10	25.08	Tile @ A 4
	G0_0	MFC-660 0 mg KNO3 added	3.96	21.83	Gray Rd 1
	G10_8	MFC-660 10.8 mg KNO3 added	7.06	22.2	Gray Rd 2
	G21_7	MFC-660 21.7 mg KNO3 added	9.26	24.44	Gray Rd 3
	1	10mg KNO3 added to Nanopure	18.71	26.33	
	1	10mg KNO3 added to Nanopure	18.84	26.51	
	2	15mg KNO3 added to Nanopure	11.99	26.5	
	2	15mg KNO3 added to Nanopure	11.88	26.25	
	4	20mg KNO3 added to Nanopure	11.66	26.35	
	4	20mg KNO3 added to Nanopure	11.83	26.54	
	5a	10mg KNO3 added to Nanopure	18.18	26.45	
	5a	10mg KNO3 added to Nanopure	18.10	26.53	
	5b	10mg KNO3 added to Nanopure	12.34	26.61	
	5b	10mg KNO3 added to Nanopure	12.01	26.39	
	T NO3	TD-12 NO3 Filter	1.80	18.05	
	T Mil	TD-12 Millipore Filter			
	G NO3	MFC-660 NO3 Filter	2.71	20.8	
	G Mil	MFC-660 Millipore Filter	5.72	18.12	

Sample ID	Sample Description	1000x $\delta^{18}O_{VSMOW}$	O%	Sample ID 2
11_5a	PVPP, Si, Cation, Anion, BaCl2	14.18	21.96	BM 11/5a
11_5b	PVPP, Si, Cation, Anion, BaCl2	10.99	22.25	BM 11/5b
11_5c	Cation, Anion, BaCl2	11.40	21.52	BM 11/5c
11_5d	Cation, Anion, BaCl2	13.04	23.77	BM 11/5d
11_5e	Anion resin only with BaCl2	12.04	27.36	BM 11/5e
G 4-5-07				

Samples analyzed for this data set were run on 4/15/08 using the TC/EA-IRMS in the Stable Isotope Core Lab in the School of Biological Sciences at WSU. $AgNO_3$ samples were measured at 0.8mg with 0.5mg of nicklized C added as a C source for the TC/EA. KNO_3 samples were measured at 0.5mg with 0.5 mg nicklized C added. Samples were left to equilibrate for a couple of days and then run together on 4/15/08. Some samples were locked up in the sample chute, and may have $\delta^{18}O$ values that are incorrect. GAL is the GeoAnalytical Lab in School of Earth and Environmental Sciences at WSU. TD-12 is equivalent to Tile @ A, MFC-660 is Gray Rd.

Figure APP K 3



Unknown samples that were analyzed for $\delta^{18}O$ in nitrate. Samples were collected from MFC-660 and TD-12 sampling sites then kept frozen until extraction and analysis. Unknown samples are the samples listed in the above table and indicated by $.

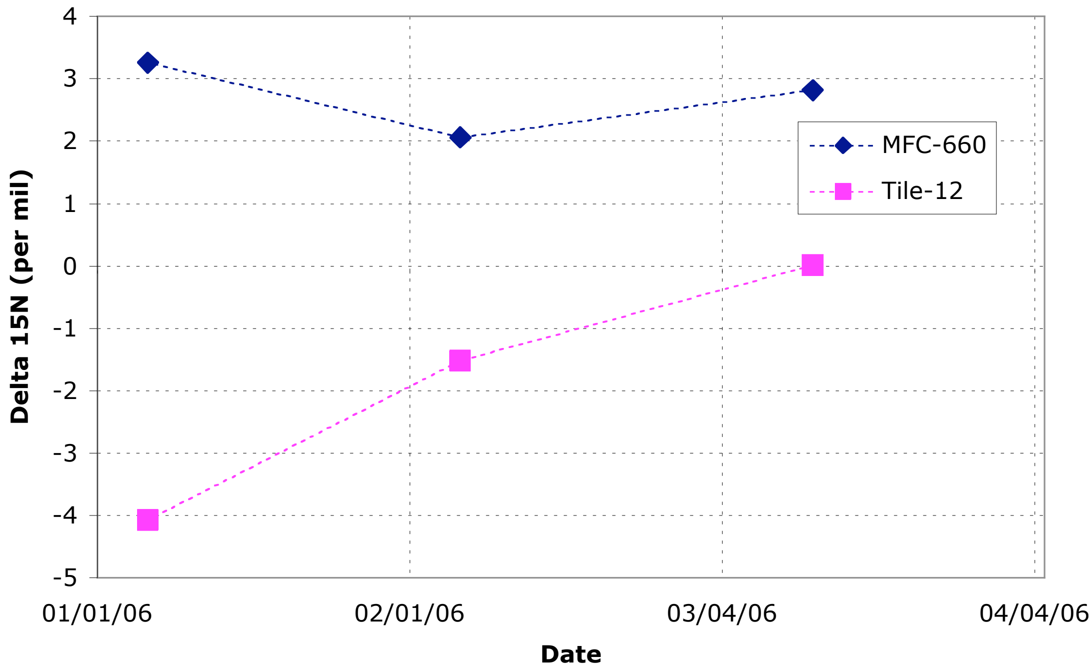
Sample location	Sample ID	Sample Date	Analysis Date	Amount (mg)	Area under N peak	Mass Fraction N x 100	Hourly Drift Corr	Final $\delta^{15}N$ ‰
?	BM34	12/04/06	12/4/06	1.1495	78.987	12.21	-0.19	**-4.65**
MFC-660	BM002	11/15/06	12/4/06	0.155	2.145	2.46	-0.31	**-4.47**
MFC-660	BM006	10/18/06	12/4/06	0.5018	4.539	1.61	-0.37	**-0.96**
TD-12	BM009	08/25/06	12/4/06	0.333	2.287	1.22	-0.43	**-6.5**
TD-12	BM013	06/29/06	12/4/06	0.1632	3.643	3.97	-0.56	**0.98**
MFC-660	BM014	06/29/06	12/4/06	0.6914	2.155	0.55	-0.74	**-2.97**
TD-12	BM018	03/13/06	12/4/06	0.5414	23.399	7.68	-0.81	**0.01**
MFC-660	BM019	03/13/06	12/4/06	1.0515	40.072	6.77	-0.87	**2.82**
TD-12	BM020	02/06/06	12/4/06	0.7419	32.427	7.77	-0.93	**-1.52**
MFC-660	BM021	02/06/06	12/4/06	0.658	26.932	7.27	-0.99	**2.06**
TD-12	BM022	01/06/06	12/4/06	0.5811	23.97	7.33	-1.06	**-4.07**
MFC-660	BM023	01/06/06	12/4/06	0.8358	22.148	4.71	-1.12	**3.26**
10mg/L Std	BM030	11/24/06	12/4/06	0.4143	3.924	1.68	-1.18	**-0.05**
20 mg/L Std	BM031	11/24/06	12/4/06	0.9341	2.093	0.4	-1.24	**-5.93**
?	BM032	12/04/06	12/4/06	0.4173	33.188	14.13	-1.3	**-6.85**
?	BM033	12/04/06	12/4/06	0.992	79.61	14.26	-1.37	**-6.55**

[yellow box] = Sample had malfunction with freeze drier, Area under peak is less than 20 mV/s. Other samples should have reliable delta 15N.

Sample analysis performed in SICL EA-IRMS on 12/4/2006. The same is for the following table. Isotope analysis was done for $\delta^{15}N$ in nitrate. Nitrate extraction was done as per Stickrod and Marshall (2000). No sugar was added to sample boats.

SICL LabID	Sample Date	Sample Location	Sample ID	Run Date	Amount (mg)	Area	Mass Fraction N x 100	**Final $\delta^{15}N$ ‰**	Ignore Analysis
N-1105	1/6/06	TD-12	BM022	12/1/06	0.3935	12.99	5.3	**1.83**	TRUE
N-1105	1/6/06	TD-12	BM022	12/4/06	0.5811	23.97	7.33	**-4.07**	FALSE
N-1106	1/6/06	MFC-660	BM023	12/1/06	1.111	29.556	4.27	**5.32**	FALSE
N-1106	1/6/06	MFC-660	BM023	12/4/06	0.8358	22.148	4.71	**3.26**	FALSE
N-1103	2/6/06	TD-12	BM020	12/1/06	0.3666	11.218	4.91	**-0.86**	FALSE
N-1103	2/6/06	TD-12	BM020	12/4/06	0.7419	32.427	7.77	**-1.52**	FALSE
N-1104	2/6/06	MFC-660	BM021	12/1/06	0.9915	36.75	5.95	**2.6**	FALSE
N-1104	2/6/06	MFC-660	BM021	12/4/06	0.658	26.932	7.27	**2.06**	FALSE
N-1101	3/13/06	TD-12	BM018	12/1/06	0.8427	35.273	6.71	**0.45**	FALSE
N-1101	3/13/06	TD-12	BM018	12/4/06	0.5414	23.399	7.68	**0.01**	FALSE
N-1102	3/13/06	MFC-660	BM019	12/1/06	0.6943	25.286	5.84	**3.26**	FALSE
N-1102	3/13/06	MFC-660	BM019	12/4/06	1.0515	40.072	6.77	**2.82**	FALSE
N-1098	5/10/06	TD-12	BM016	12/1/06	0.54	3.691	1.1	**6.83**	FALSE
N-1099	5/10/06	MFC-660	BM017	12/1/06	0.634	4.614	1.17	**8.65**	FALSE
N-1096	6/29/06	TD-12	BM013	12/1/06	1.3	23.838	2.94	**6.49**	FALSE
N-1096	6/29/06	TD-12	BM013	12/4/06	0.1632	3.643	3.97	**0.98**	FALSE
N-1088	6/29/06	MFC-660	BM014	12/1/06	0.344	1.175	0.55	**5.85**	FALSE
N-1088	6/29/06	MFC-660	BM014	12/4/06	0.6914	2.155	0.55	**-2.97**	FALSE
N-1097	8/25/06	TD-12	BM009	12/1/06	1.6	11.731	1.18	**9.97**	FALSE
N-1097	8/25/06	TD-12	BM009	12/4/06	0.333	2.287	1.22	**-6.5**	FALSE
N-1092	8/25/06	MFC-660	BM010	12/1/06	2.03	2.523	0.2	**5.92**	FALSE
N-1100	10/18/06	TD-12	BM005	12/1/06	1.401	5.291	0.61	**5.3**	FALSE
N-1094	10/18/06	MFC-660	BM006	12/1/06	1.15	1.27	0.18	**0.76**	FALSE
N-1094	10/18/06	MFC-660	BM006	12/4/06	0.5018	4.539	1.61	**-0.96**	FALSE
N-1089	11/15/06	TD-12	BM001	12/1/06	0.943	2.175	0.37	**512.92**	TRUE
N-1095	11/15/06	MFC-660	BM002	12/1/06	0.98	2.379	0.39	**2.23**	FALSE
N-1095	11/15/06	MFC-660	BM002	12/4/06	0.155	2.145	2.46	**-4.47**	FALSE
N-1090	-	10 mg/L Std	BM030	12/1/06	0.51	4.583	1.44	**5.44**	FALSE
N-1090	-	10 mg/L Std	BM030	12/4/06	0.4143	3.924	1.68	**-0.05**	FALSE
N-1091	-	20 mg/L Std	BM031	12/1/06	1.23	2.85	0.37	**5.76**	FALSE
N-1091	-	20 mg/L Std	BM031	12/4/06	0.9341	2.093	0.4	**-5.93**	FALSE
N-1087	-	?	BM032	12/4/06	0.4173	33.188	14.13	**-6.85**	FALSE
N-1093	-	?	BM033	12/4/06	0.992	79.61	14.26	**-6.55**	FALSE
N-1087	?	?	BM032	12/1/06	0.912	75.679	13.31	**-4.84**	FALSE
N-1093	?	?	BM033	12/1/06	1.58	131.981	13.4	**-4.88**	TRUE
N-1107	?	?	BM34	12/1/06	3.528	299.351	13.61	**-4.36**	FALSE
N-1107	?	?	BM34	12/4/06	1.1495	78.987	12.21	**-4.65**	FALSE

Figure APP K 4



$\delta^{15}N$ for nitrate in samples from MFC-660 and TD-12. Sample volumes were small (~100mL) and extraction may not have yielded adequate nitrate to produce enough $AgNO_3$ for reliable isotopic analysis.

APPENDIX L Electrical Conductivity Correction Data

This Appendix is from Appendix I of Simmons (2003) and Appendix B of Wannamaker (2005)

Simmons, A. (2003). Dissolved pesticide mass discharge in a semi-arid dryland agricultural watershed at the field and basin scale. Thesis. Washington State University, Pullman, WA.

Wannamaker, C. (2005). Edge of field nitrate occurrence and loss in a semi-arid dryland agricultural setting. Thesis. Washington State University, Pullman, WA.

It was necessary to apply two correction factors to raw electrical conductivity measurements. The first correction adjusts for differences in true and observed EC due to the EC meter. The second correction accounts for the effect of nitrate (NO_3^- as N) on the electrical conductivity of the field sample.

METER CALIBRATION

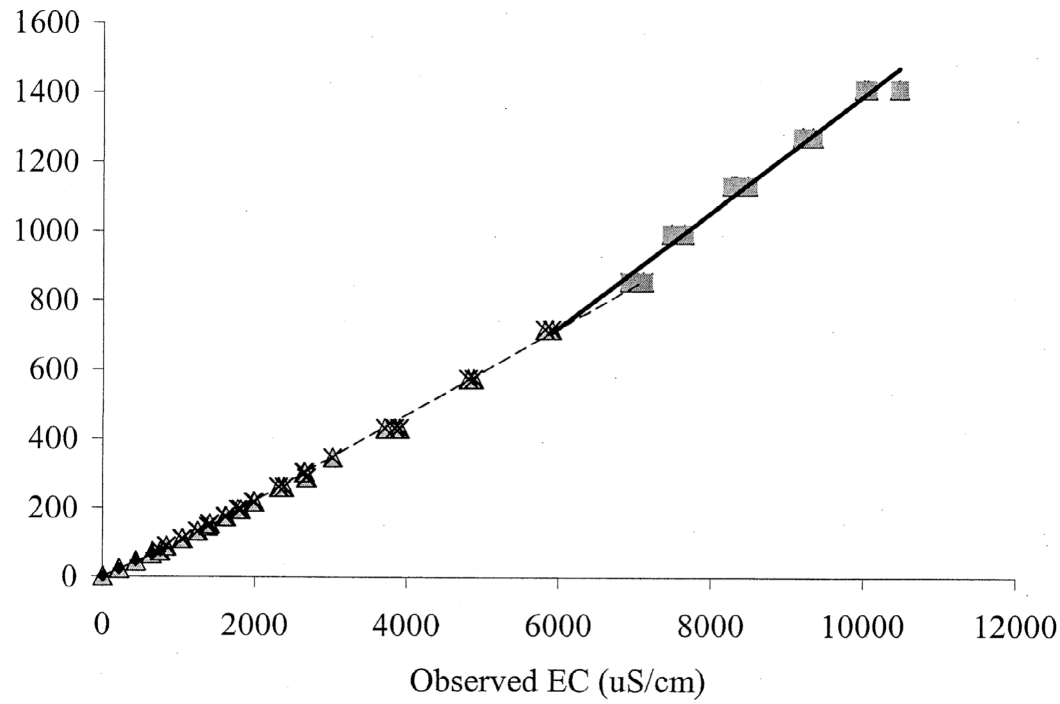
To calibrate the EC meter a series of dilutions were completed on a solution of potassium chloride (KCl) in water. The data for the experiment is on the following 3 pages.

This table gives the values used to correct the meter calibration using Equation 1 below. The segment used on raw EC concentration is μS/cm is based on the X cross point values that it fits between. For example, is if the raw EC of a sample is 952 μS/cm then the low segment is used. The EC meter cell constant must be set to 1.000 for the meter correction to work properly.

For Meter Correction				
	m	b	Cross points	
			x	y
Low	0.0997	-0.5408		
Medium	0.1246	-26.995	1062.4177	105.3822
High	0.1679	-284.41	5944.9192	713.7419
			11000	

$$EC_M = mEC_{Raw} + b \quad (1)$$

where EC_M and EC_{Raw} is the meter corrected EC and raw EC (uncorrected), m and b are the slope and intercept, respectively from the following table.



This figure shows the low, medium, and high segments to adjust for the differences associated with the EC meter. From Wannamaker (2005).

KCl Concentration (N)	Conductivity (uS/cm)	Regressed True Conductivity (uS/cm)	Percent Difference	Observed d EC (uS/sm)	slope	intercept
KCl Concentration to true EC						
0.0005	73.9	76.94	0.0411		147800	
0.001	147	147.4205	0.0029		146200	0.8
0.005	717.8	711.2642	-0.0091		142700	4.3
0.01	1413	1416.0695	0.0022		139040	22.6

y = 140961x + 6.4595
R2 = 0.9999

140961 6.4595

Volume 0.003N KCl (ml)	Observations: KCl Concentration (N)	Conductivity (uS/cm)	Regressed True Conductivity (uS/cm)	Percent Difference	Observed d EC (uS/sm)	Cal Curve	% Difference
0	0		0		13.8	0.83506	
0	0		0		10.9	0.54593	
0.5	0.00015		22.17		221	21.4929	-3.1%
0.5	0.00015		22.17		230	22.3902	1.0%
1	0.0003		44.34		443	43.6263	-1.6%
1	0.0003		44.34		447	44.0251	-0.7%
1.5	0.00045		66.51		655	64.7627	-2.6%
1.5	0.00045		66.51		652	64.4636	-3.1%
	0.0005		73.9		769	76.1285	3.0%
	0.0005		73.9		765	75.7297	2.5%
2	0.0006		88.52		850	84.2042	-4.9%
2	0.0006		88.52		845	83.7057	-5.4%
2.5	0.00075		110.45		1059	105.042	-4.9%
2.5	0.00075		110.45		1047	103.845	-6.0%
3	0.0009		132.38		1248	128.506	-2.9%
3	0.0009		132.38		1255	129.378	-2.3%
	0.001		147		1388	145.95	-0.7%
	0.001		147		1389	146.074	-0.6%
3.5	0.00105		154.135		1409	148.566	-3.6%
3.5	0.00105		154.135		1411	148.816	-3.5%
4	0.0012		175.54		1611	173.736	-1.0%
4	0.0012		175.54		1626	175.605	0.0%
4.5	0.00135		196.945		1783	195.167	-0.9%
4.5	0.00135		196.945		1820	199.777	1.4%
5	0.0015		218.35		1983	220.087	0.8%

The nitrate correction is necessary to apply to meter corrected EC concentrations because it was noted that samples with high nitrate concentrations had very high EC concentrations. Therefore, the following experiment was completed. Solutions of both calcium nitrate ($CaNO_3$) and sodium nitrate ($NaNO_3$) in water were used. The data from the sodium nitrate solution is used to correct for nitrate in water samples. It was found that there was a linear relationship between nitrate concentration and EC. There are two linear segments, low and high, that fit the data (shown on the following page).

The data in the following table gives the two linear segments.

For nitrate correction			
	m	b	Cross points
			x
Low	7.9276	-0.1524	
High	7.2547	17.932	26.8753158

The crosspoint is the nitrate (as $N\text{-}NO_3^-$) concentration in mg/L that is between the two line segments. However, for corrections in this study, a crosspoint of 40 mg/L was used because there is little difference between 26 mg/L and 40 mg/L nitrate and most water samples had nitrate concentrations of less than 40 mg/L.

$$EC_{CF} = mC_{N-NO_3^-} + b \qquad (2)$$

where EC_{CF} is the correction factor and $C_{N-NO_3^-}$ is the nitrate concentration of the water sample in mg/L. EC correction for nitrate is determined using the following equation:

$$EC_N = EC_C - EC_{CF} \qquad (3)$$

Where EC_N is the EC concentration corrected for nitrate.

Calibration Curve for NO3 effect on EC
Prepared by: Thomas P. Van Biersel
Prepared on: 7/12/2001
Data Analysis revised by rmak, 5/17/02 (EC meter calibration included)
Data From Thomas

Concentration (mg/L)	Conc (mg/L as N)	n	Mean observed EC/10	Std Dev Observed EC	True EC (uS/cm)	Std Dev observed EC
nanopure	0	19	0.6	0.1	0.1	0
1	0.16	3	1.4	0	0.9	0
2	0.33	3	2.2	0	1.6	0
5	0.82	3	8.4	0.1	7.8	0.1
10	1.65	3	13.3	0.1	12.7	0.1
20	3.29	3	27.1	0.3	26.4	0.3
50	8.24	3	65.1	1.7	64.4	1.6
100	16.47	3	124.5	1.6	128	1.6
150	24.71	3	181.6	1.7	199.3	1.8
200	32.94	3	230	6.2	259.6	7
1000	164.71	3	891.7	9.5	1212.7	12.9
750	123.53	3	720	15.6	924.5	20.1
500	82.35	3	499.7	26.5	595.6	31.6
250	41.18	3	281.3	3.2	323.5	3.7
hach standard 10	10	3	97.1	0.6	96.3	0.6
84 uS/cm		3	80.2	1.3	79.4	1.3

Data from JLS during 5/02

Concetration (mg/L as N)	Observed EC/10	True EC (uS/cm)	Concetration (mg/L as N)	Observed EC/10	True EC (uS/cm)
NaNO3 Solution			CaNO3 Solution		
0.4	5.81	5.3	0.4	6.07	5.5
1	11.4	10.8	1	13.9	13.3
2	18.2	17.6	2	20.2	19.6
4	34.9	34.3	4	38.9	38.2
8	68.9	68.2	8	70.3	69.5
12	95.2	94.4	12	99.7	98.9
16	127.9	132.4	16	139.8	147.2
20	156.4	167	20	156.3	167.8
24	184.8	203.3	24	184.8	203.3
28	207	230.9	28	206	229.7
32	228	257.1	32	236	267.1
36	251	285.8	36	259	295.7
40	273	313.2	40	285	328.1
52.94	16284.1	278.035	0.4		
72.94	30911.6	383.07	0.4		
92.94	50187.1	488.106	0.4		
112.94	74100.7	593.141	0.4		
132.94	102682	298.176	0.4		
152.94	135902	803.212	0.4		
172.94	173769	908.247	0.4		
192.94	216285	1013.28	0.4		
212.94	263448	1118.32	0.4		

APPENDIX M Piezometer and Lysimeter $\delta^{18}O$ and Nitrate Concentration Data

Lysimeter data in Appendix M are composite from nested tension and zero-tension lysimeters 20m north of TD-12 and are divided into three types: shallow (0.15 m), middle (0.4 m), and deep (0.65 m).

Piezometers were nested 20m north of TD-12 at depths of 1.086 m (Piezo AA) and 1.676 m (Piezo AB). Piezometers were only regularly sampled after 5/10/2006.

Complete lysimeter and piezometer data can be accessed on the accompanying DVD under folder name “lysimeters”.

Date	Piezometer ID	$\delta^{18}O$ (‰)
5/6/05	Piezo AA	-14.53
6/7/2005	Piezo AA	-14.85
5/20/06	Piezo AA	-14.05
6/7/06	Piezo AA	-14.40
7/7/06	Piezo AA	-14.53
10/6/2006	Piezo AA	-14.75
10/18/2006	Piezo AA	-14.95
11/1/2006	Piezo AA	-18.58
11/15/06	Piezo AA	-14.33
12/13/06	Piezo AA	-13.69
2/9/07	Piezo AA	-14.10
2/22/07	Piezo AA	-14.02
3/7/07	Piezo AA	-13.65
3/23/07	Piezo AA	-13.47
4/5/07	Piezo AA	-12.44
4/18/07	Piezo AA	-12.88
5/4/07	Piezo AA	-13.28
5/22/07	Piezo AA	-13.47
6/4/07	Piezo AA	-13.71
6/19/07	Piezo AA	-13.83
7/2/07	Piezo AA	-13.99
12/5/07	Piezo AA	-13.80

Date	Piezometer ID	$\delta^{18}O$ (‰)
6/7/2005	Piezo AB	-14.89
5/6/2005	Piezo AB	-14.29
5/20/06	Piezo AB	-14.81
7/7/06	Piezo AB	-14.68
7/26/06	Piezo AB	-15.35
8/10/2006	Piezo AB	-15.14
8/25/2006	Piezo AB	-14.99
9/6/2006	Piezo AB	-14.56
9/20/2006	Piezo AB	-14.82
10/6/2006	Piezo AB	-14.59
10/18/2006	Piezo AB	-15.09
11/1/2006	Piezo AB	-14.88
11/15/06	Piezo AB	-14.36
12/13/06	Piezo AB	-14.48
2/9/07	Piezo AB	-14.15
2/22/07	Piezo AB	-14.05
3/7/07	Piezo AB	-14.31
3/23/07	Piezo AB	-14.21
4/5/07	Piezo AB	-15.06
4/18/07	Piezo AB	-14.02
5/4/07	Piezo AB	-13.70
6/4/07	Piezo AB	-13.64
6/19/07	Piezo AB	-13.60
7/2/07	Piezo AB	-13.62
7/16/07	Piezo AB	-13.67
7/31/07	Piezo AB	-14.07
8/13/07	Piezo AB	-13.95
9/4/07	Piezo AB	-14.00
10/2/07	Piezo AB	-13.94
10/19/07	Piezo AB	-14.47
11/5/07	Piezo AB	-14.29
12/5/07	Piezo AB	-14.53

Sample Date	Shallow $\delta^{18}O$ (‰)	Shallow [N-NO_3^-] (mg/L)	Middle $\delta^{18}O$ (‰)	Middle [N-NO_3^-] (mg/L)	Deep $\delta^{18}O$ (‰)	Deep [N-NO_3^-] (mg/L)
10/27/00	-	-	-	-	-14.27	2.46
12/8/00	-	-	-	-	-14.11	2.43
1/9/01	-	-	-	-	-	2.37
2/2/01	-	-	-	-	-14.19	2.46
2/6/01	-	-	-	-	-	-
2/19/01	-	-	-14.07	32.56	-	2.42
3/3/01	-12.91	163.67	-14.05	54.12	-	-
3/21/01	-14.09	71.67	-13.37	71.82	-14.32	2.77
4/8/01	-	-	-13.45	56.97	-13.86	3.36
4/16/01	-	63.29	-13.37	65.48	-14.05	6.37
5/4/01	-14.37	87.08	-13.25	79.33	-14.11	9.68
5/21/01	-14.34	118.86	-13.29	71.29	-14.07	12.31
5/31/01	-	27.80	-13.67	58.82	-14.17	9.05
6/14/01	-	-	-	88.89	-13.91	9.52
7/12/01	-	-	-	-	-11.46	0.20
7/26/01	-	-	-	-	-	0.76
12/22/01	-11.25	49.07	-12.08	76.09	-14.09	8.24
12/23/01	-10.69	-	-12.58	70.40	-12.86	25.52
1/7/02	-	-	-12.15	75.21	-14.07	9.17
1/9/02	-	-	-	-	-14.06	-
2/14/02	-14.60	9.04	-10.99	-	-11.16	-
2/15/02	-	-	-14.35	-	-13.23	-
3/1/02	-15.16	16.74	-14.69	-	-	-
3/15/02	-13.97	14.62	-14.21	-	-12.94	-
4/5/02	-15.42	-	-15.28	25.66	-13.87	44.72
4/19/02	-15.72	-	-15.25	13.33	-13.68	59.00
5/3/02	-14.42	-	-15.06	16.70	-12.83	27.06
5/16/02	-14.88	-	-15.81	20.99	-14.13	41.31
5/30/02	-14.68	-	-14.65	-	-13.07	-
6/13/02	-14.76	-	-14.79	-	-14.18	-
6/27/02	-12.99	-	-14.42	-	-13.73	-
7/9/02	-	-	-	-	-	-
7/11/02	-	16.78	-	-	-13.90	-
7/25/02	-	5.79	-	-	-13.97	-
1/30/04	-15.43	-	-13.93	23.51	-13.71	21.95
2/20/04	-16.72	-	-15.43	16.36	-13.89	25.51
3/12/04	-16.87	-	-15.98	14.14	-14.17	25.86
3/26/04	-17.35	-	-15.61	13.70	-13.88	26.03
4/9/04	-	-	-16.37	-	-14.31	-
5/7/04	-	-	-15.95	-	-14.16	-
5/28/04	-	-	-16.28	-	-14.51	-
6/25/04	-	13.08	-	-	-14.97	-

Sample Date	Shallow $\delta^{18}O$ (‰)	Shallow $[N\text{-}NO_3^-]$ (mg/L)	Middle $\delta^{18}O$ (‰)	Middle $[N\text{-}NO_3^-]$ (mg/L)	Deep $\delta^{18}O$ (‰)	Deep $[N\text{-}NO_3^-]$ (mg/L)
7/23/04	-	-	-	-	-	-
12/13/04	-	11.76	-13.70	-	-14.22	2.63
1/12/05	-	-	-13.88	-	-	-
2/11/05	-14.95	-	-13.55	13.40	-14.57	6.08
3/10/05	-14.60	34.40	-13.17	11.64	-13.46	6.26
4/8/05	-13.16	37.80	-12.60	17.60	-13.09	10.32
5/6/05	-13.38	-	-13.47	20.25	-14.65	9.49
6/7/05	-13.30	-	-13.46	14.84	-14.67	4.50
2/6/06	-	-	-	-	-	-
4/24/06	-	-	-	-	-13.15	20.80
6/29/06	-	-	-	-	-	-
8/11/06	-	-	-	-	-15.11	14.64

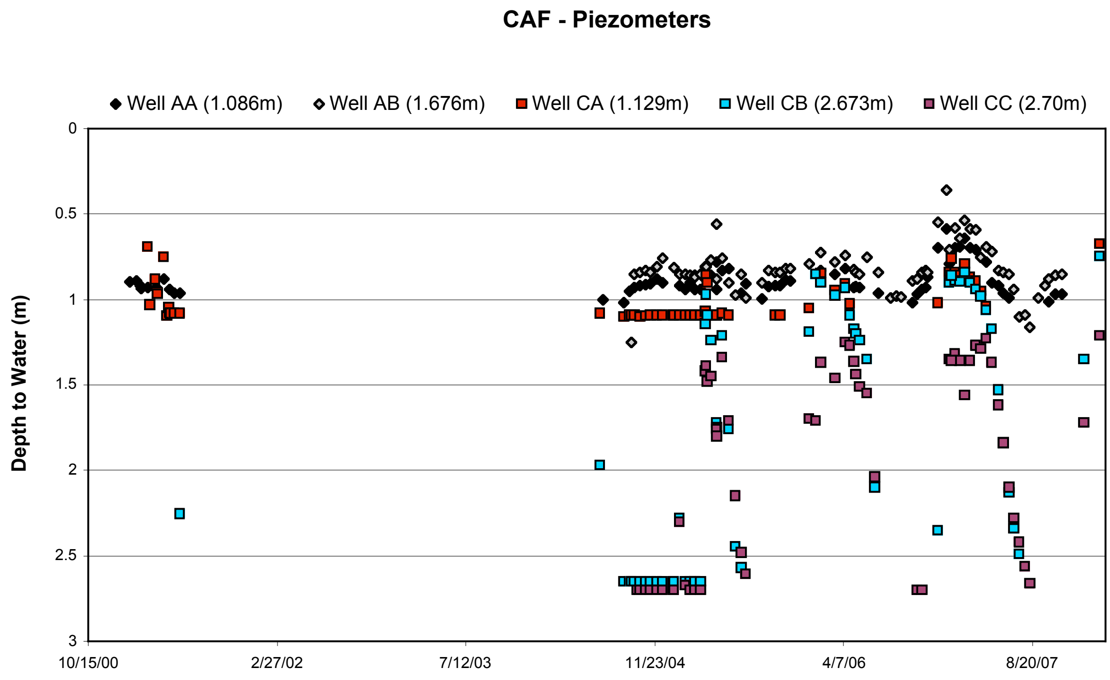
Total depth	Well AA 1.086 (m)	Well AB 1.676 (m)	Well CA 1.129 (m)	Well CB 2.673 (m)	Well CC 2.70 (m)
Date					
1/11/01					
2/2/01	0.895				
2/19/01	0.893				
3/2/01	0.918				
3/3/01	0.935				
3/20/01	0.93		0.69		
3/27/01			1.03		
4/9/01	0.935		0.88		
4/16/01	0.934		0.968		
5/2/01	0.882		0.751		
5/11/01			1.095		
5/16/01			1.047		
5/17/01	0.938		1.078		
5/21/01			1.08	2.673	
5/30/01	0.963		1.08	2.673	
6/14/01	0.962		1.08	2.253	
7/1/04			1.08	1.97	
7/9/04	1				
9/3/04	1.02		1.1	2.65	
9/17/04	0.95		1.09	2.65	
9/22/04			1.09	2.65	
9/23/04		1.25			
10/1/04	0.93	0.85	1.09	2.65	
10/8/04					2.7
10/15/04	0.92	0.84	1.1	2.65	2.7
10/29/04	0.915	0.83	1.093	2.65	2.7
11/12/04	0.91	0.84	1.09	2.65	2.7
11/29/04	0.88	0.81	1.09	2.65	2.7
12/13/04	0.9	0.76	1.09	2.65	2.7
1/11/05			1.09	2.65	2.7
1/12/05		0.815	1.09	2.65	2.7
1/28/05	0.92	0.85	1.09	2.28	2.3
2/11/05	0.94	0.85	1.09	2.65	2.67
2/25/05	0.9	0.86	1.09	2.65	2.7
3/9/05	0.94	0.86	1.09	2.65	2.7
3/10/05	0.94	0.87	1.09	2.65	2.7
3/25/05	0.94	0.85	1.09	2.65	2.7
4/7/05	0.88	0.81	1.07	1.14	1.42
4/8/05	0.88	0.81	0.86	0.97	1.39
4/12/05			0.9	1.09	1.48
4/22/05	0.86	0.77	1.09	1.24	1.45
5/5/05	0.78	0.56	1.09	1.72	1.76

Total depth	Well AA 1.086 (m)	Well AB 1.676 (m)	Well CA 1.129 (m)	Well CB 2.673 (m)	Well CC 2.70 (m)
Date					
5/6/05	0.94	0.88	1.09	1.75	1.8
5/20/05	0.83	0.76	1.08	1.21	1.34
6/7/05	0.82	0.9	1.09	1.76	1.71
6/24/05		0.975		2.445	2.15
7/11/05	0.96	0.85		2.57	2.48
7/22/05	0.91	0.99			2.605
9/2/05	0.995	0.9			
9/20/05	0.925	0.83			
10/7/05	0.92	0.84	1.09		
10/21/05	0.92	0.84	1.09		
11/4/05	0.885	0.82			
11/18/05	0.89	0.82			
12/20/05					
1/6/06		0.79	1.05	1.19	1.7
1/23/06				0.85	1.71
2/6/06	0.83	0.725	0.845	0.9	1.37
2/28/06					
3/15/06	0.85	0.78	0.945	0.975	1.46
4/11/06	0.82	0.74	0.91	0.93	1.25
4/24/06			1.025	1.09	1.27
5/5/06	0.93	0.825		1.17	1.365
5/10/06	0.925	0.84		1.2	1.44
5/20/06	0.93	0.85		1.24	1.51
6/7/06		0.75		1.35	1.55
6/29/06				2.1	2.04
7/7/06	0.96	0.84			
7/26/06					
8/10/06		0.99			
8/25/06		0.98			
9/6/06		0.985			
9/20/06					
10/6/06	1.02	0.89			
10/18/06	0.97	0.88			2.7
11/1/06	0.94	0.84			2.7
11/10/06	0.93	0.83			
11/15/06	0.87	0.84			
11/29/06					
12/13/06	0.7	0.55	1.02	2.35	
12/29/06					
1/4/07	0.585	0.36			
1/12/07	0.79	0.71	0.84	0.9	1.35
1/26/07	0.7	0.58	0.84	0.89	1.32

Total depth	Well AA 1.086 (m)	Well AB 1.676 (m)	Well CA 1.129 (m)	Well CB 2.673 (m)	Well CC 2.70 (m)
Date					
2/9/07	0.69	0.64	0.86	0.895	1.36
2/22/07	0.64	0.54	0.79	0.84	1.56
3/7/07	0.7	0.585	0.87	0.9	1.36
3/23/07	0.71	0.595	0.89	0.94	1.27
4/5/07	0.97	0.75	0.95	0.98	1.29
4/19/07	0.78	0.69	1.04	1.06	1.23
5/4/07	0.9	0.72		1.17	1.37
5/22/07	0.92	0.83		1.53	1.62
6/4/07	0.96	0.84		1.84	1.84
6/19/07	0.99	0.85		2.13	2.1
7/2/07		0.94		2.34	2.28
7/16/07		1.1		2.49	2.42
7/31/07		1.09			2.56
8/13/07		1.16			2.66
8/21/07					
9/4/07		0.99			
9/21/07		0.92			
10/1/07	1.01	0.88			
10/19/07	0.97	0.86			
11/5/07	0.97	0.85			
12/5/07					
12/17/07					
1/3/08				1.35	1.72
1/18/07			0.76	0.86	1.36
2/8/07					
2/14/08			0.675	0.745	1.21

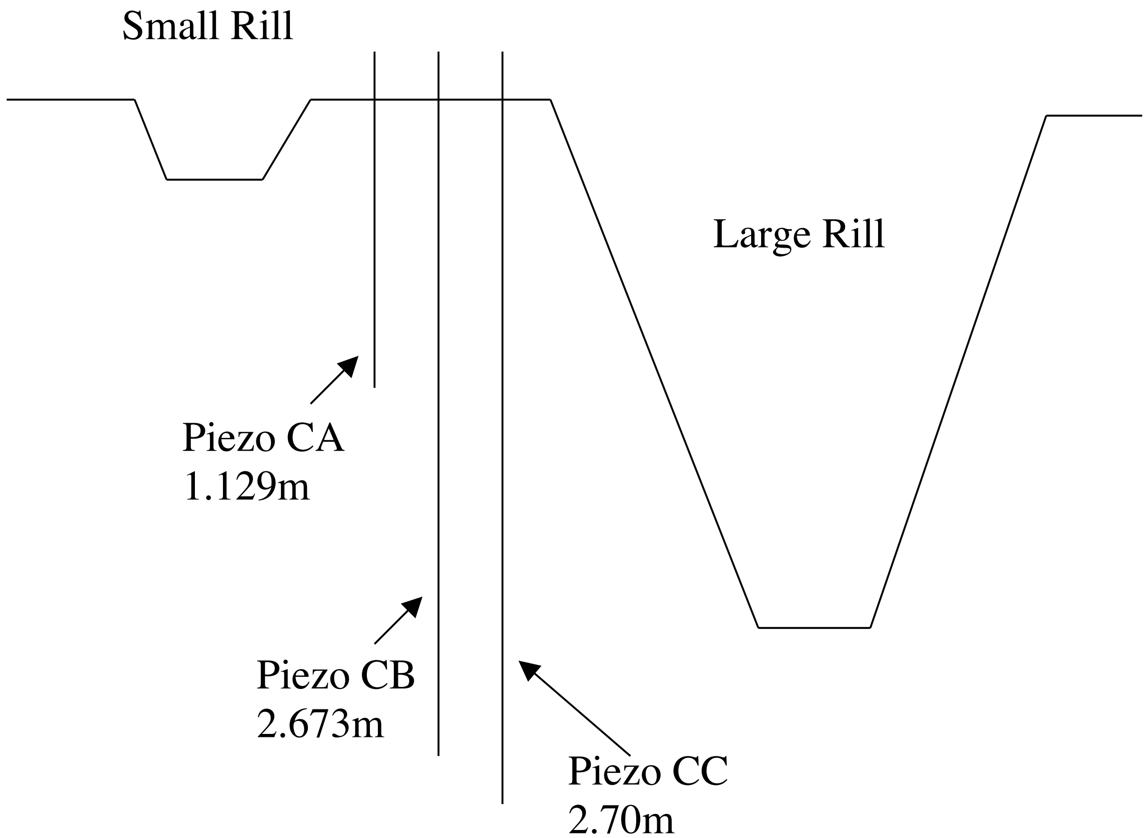
All measurements are depth to water (DTW) using an electrical measuring tape.

Figure APP M 1



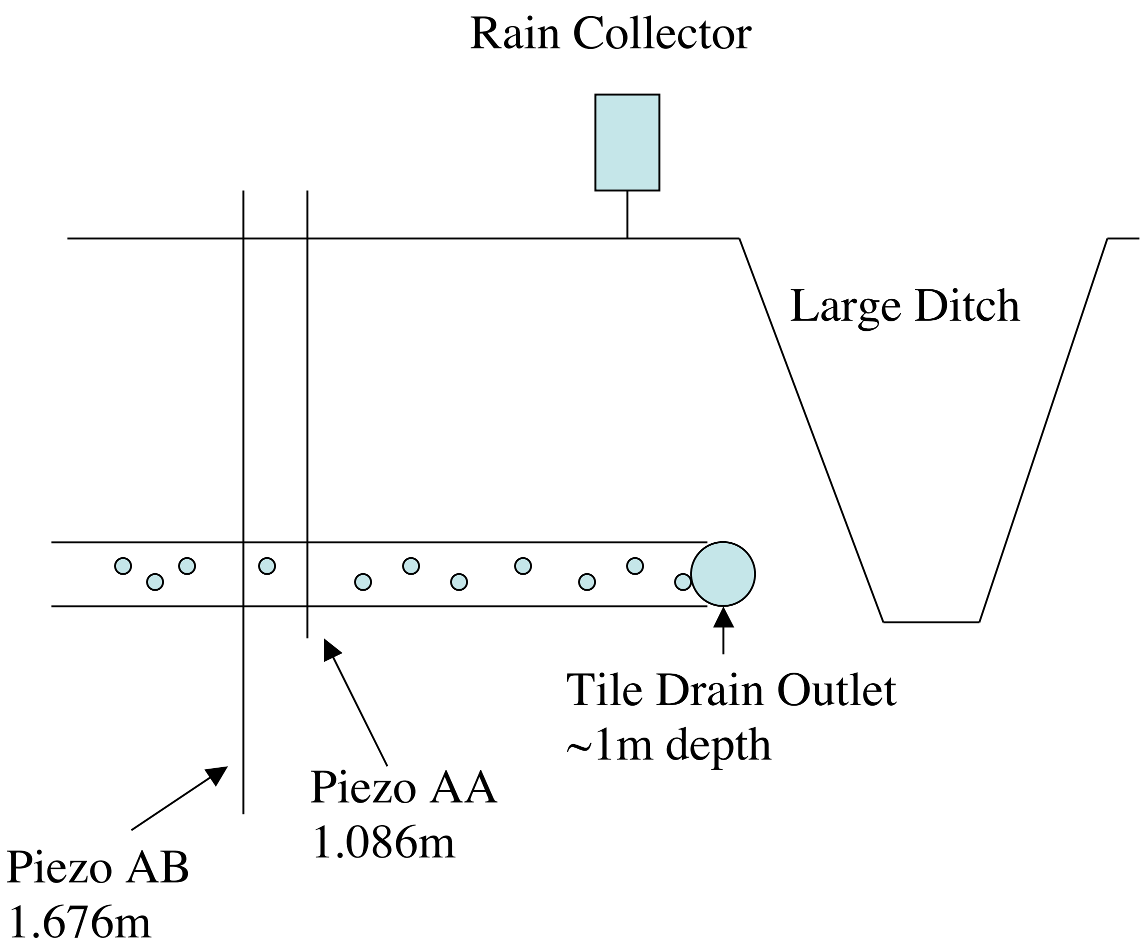
Depth to water for all Piezometers located on CAF.

Figure APP M 2



Schematic of nested piezometer locations and depths (not to scale) at Area C near MFC-6 sampling site on the CAF. Piezometers are not labeled in the field. Schematic is looking north.

Figure APP M 3



Schematic of nested piezometer locations and depths (not to scale) at Area A at TD-12 sampling site on the CAF. Piezometers are located approximately 10m north of the tile drain outlet. Schematic is looking east. Piezometers are not labeled in the field.

APPENDIX N Pacific Decadal Oscillation Effects on TD-12 and Precipitation $\delta^{18}O$

Pacific Decadal Oscillation data is from http://jisao.washington.edu/pdo/PDO.latest. Sea Surface Temperature (SST) is the divergence from the average SST, which is set at 0.

Date	Difference From Average Sea Surface Temp (^oC)	MFC Monthly Precipitation $\delta^{18}O$	Monthly TD-12 $\delta^{18}O$	Monthly MFC-4700 $\delta^{18}O$
Jan-00	-2.00			
Feb-00	-0.83			
Mar-00	0.29			
Apr-00	0.35			
May-00	-0.05			
Jun-00	-0.44			
Jul-00	-0.66			
Aug-00	-1.19			
Sep-00	-1.24			
Oct-00	-1.30		-14.79	-14.21
Nov-00	-0.53			
Dec-00	0.52		-15.57	-14.50
Jan-01	0.60		-14.93	-15.67
Feb-01	0.29		-15.54	-16.22
Mar-01	0.45		-14.90	-15.69
Apr-01	-0.31		-15.30	-14.77
May-01	-0.30		-15.80	-13.77
Jun-01	-0.47		-16.62	-6.56
Jul-01	-1.31	-12.44	-12.15	-12.51
Aug-01	-0.77			
Sep-01	-1.37			-12.61
Oct-01	-1.37		-14.64	-13.54
Nov-01	-1.26		-15.29	-15.09
Dec-01	-0.93		-13.09	-16.13
Jan-02	0.27	-15.55	-14.96	-16.73
Feb-02	0.64		-15.19	-16.50
Mar-02	0.43		-15.46	-16.06
Apr-02	-0.32	-12.17	-15.77	-14.36
May-02	-0.63	-13.31	-14.80	-13.83
Jun-02	-0.35	-15.69	-14.90	-14.47
Jul-02	-0.31	-11.47	-14.97	-12.91
Aug-02	0.60			
Sep-02	0.43	-11.75	-15.12	-13.62
Oct-02	0.42	-11.12	-14.88	-17.91
Nov-02	1.51	-14.30	-14.62	-14.01
Dec-02	2.10	-16.25	-14.80	-14.56
Jan-03	2.09	-12.89	-14.59	-12.69
Feb-03	1.75	-12.38	-14.54	-14.55
Mar-03	1.51	-11.31	-13.60	-13.20
Apr-03	1.18	-12.26	-13.93	-9.62

Date	Difference From Average Sea Surface Temp (°C)	MFC Monthly Precipitation $\delta^{18}O$	Monthly TD-12 $\delta^{18}O$	Monthly MFC-4700 $\delta^{18}O$
May-03	0.89	-11.82	-14.68	-13.96
Jun-03	0.68	-8.08	-14.72	-13.44
Jul-03	0.96		-14.94	-12.10
Aug-03	0.88		-14.58	-8.15
Sep-03	0.01	-9.24	-14.53	-11.53
Oct-03	0.83	-15.53	-15.01	-13.67
Nov-03	0.52	-14.24	-15.28	-14.55
Dec-03	0.33	-17.00	-15.16	-14.62
Jan-04	0.43	-17.17	-15.45	-17.10
Feb-04	0.48	-14.62	-14.44	-15.79
Mar-04	0.61	-14.80	-14.92	-14.94
Apr-04	0.57	-11.53	-14.73	-14.11
May-04	0.88	-11.37	-14.80	-13.60
Jun-04	0.04	-12.12	-14.68	-13.17
Jul-04	0.44	-8.53	-14.42	-12.96
Aug-04	0.85	-8.14		-10.84
Sep-04	0.75	-9.19	-14.16	-12.14
Oct-04	-0.11	-13.38	-14.40	-13.26
Nov-04	-0.63	-12.26	-14.38	-13.65
Dec-04	-0.17	-16.27	-14.67	-14.12
Jan-05	0.44	-12.47	-14.74	-14.46
Feb-05	0.81	-9.66	-14.95	-14.08
Mar-05	1.36	-11.83	-14.27	-13.38
Apr-05	1.03	-13.12	-14.01	-13.17
May-05	1.86	-13.47	-14.45	-13.39
Jun-05	1.17	-10.03	-14.81	-12.04
Jul-05	0.66	-17.71	-14.52	-11.44
Aug-05	0.25		-14.71	-4.76
Sep-05	-0.46		-14.56	
Oct-05	-1.32		-13.97	-12.61
Nov-05	-1.50	-11.91	-14.77	-13.31
Dec-05	0.20			
Jan-06	1.03	-14.16	-14.43	-14.27
Feb-06	0.66	-16.85	-14.23	-14.07
Mar-06	0.05	-18.13	-14.36	-14.56
Apr-06	0.40	-15.16	-14.70	-13.95
May-06	0.48	-12.50	-14.28	-13.60
Jun-06	1.04	-12.00	-14.89	-13.25
Jul-06	0.35		-15.14	-11.03
Aug-06	-0.65	-4.05	-15.10	-12.21

Date	Difference From Average Sea Surface Temp (^{o}C)	MFC Monthly Precipitation $\delta^{18}O$	Monthly TD-12 $\delta^{18}O$	Monthly MFC-4700 $\delta^{18}O$
Sep-06	-0.94	-9.80	-14.46	-12.52
Oct-06	-0.05	-10.60	-14.81	-13.86
Nov-06	-0.22	-12.28	-14.72	-13.76
Dec-06	0.14	-16.54	-14.48	-13.80
Jan-07	0.01	-15.79	-13.72	-14.02
Feb-07	0.04	-16.07	-13.72	-13.26
Mar-07	-0.36	-12.99	-13.60	-13.24
Apr-07	0.16	-12.13	-13.82	-13.08
May-07	-0.10	-14.39	-13.60	-13.24
Jun-07	0.09	-11.06	-14.29	-12.44
Jul-07	0.78	-9.74		-8.89
Aug-07	0.50	-14.76	-14.43	
Sep-07	-0.36	-8.97	-14.75	-14.08
Oct-07	-1.45	-12.19	-14.34	-13.17
Nov-07	-1.08	-13.78	-14.70	-14.01
Dec-07	-0.58	-14.68	-14.95	-15.00
Jan-08	-1.00		-14.47	-14.13
Feb-08	-0.77			
Mar-08	-0.71			

Figure APP N 1

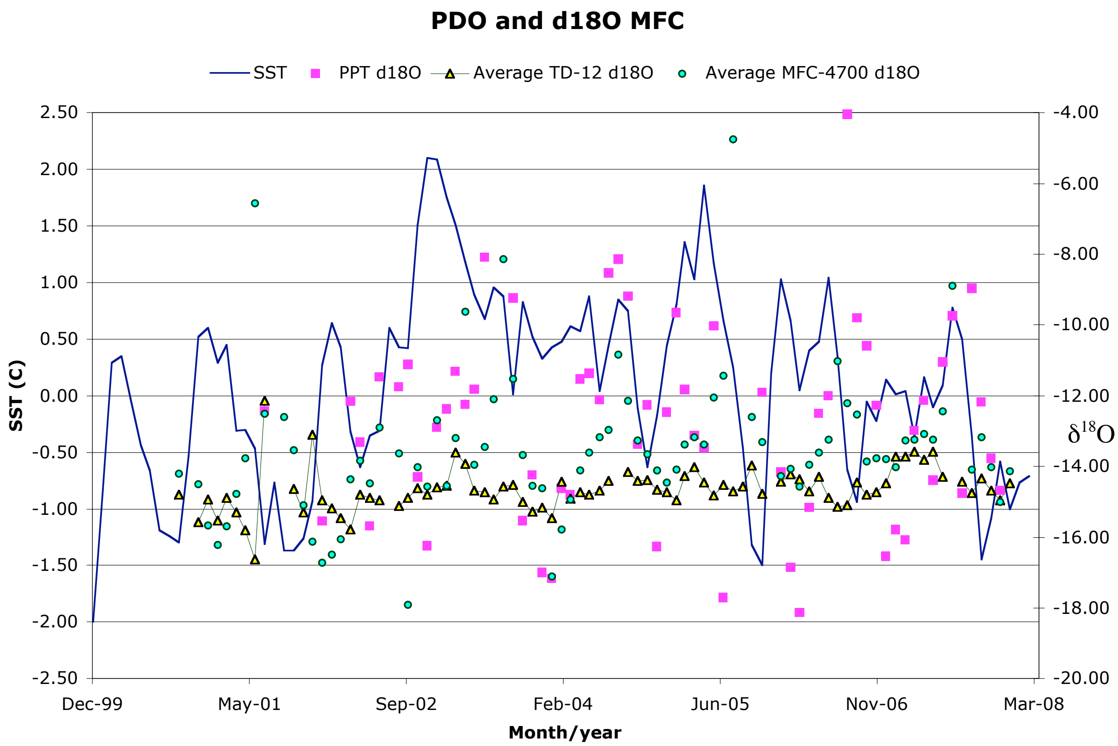


Figure APP N 2

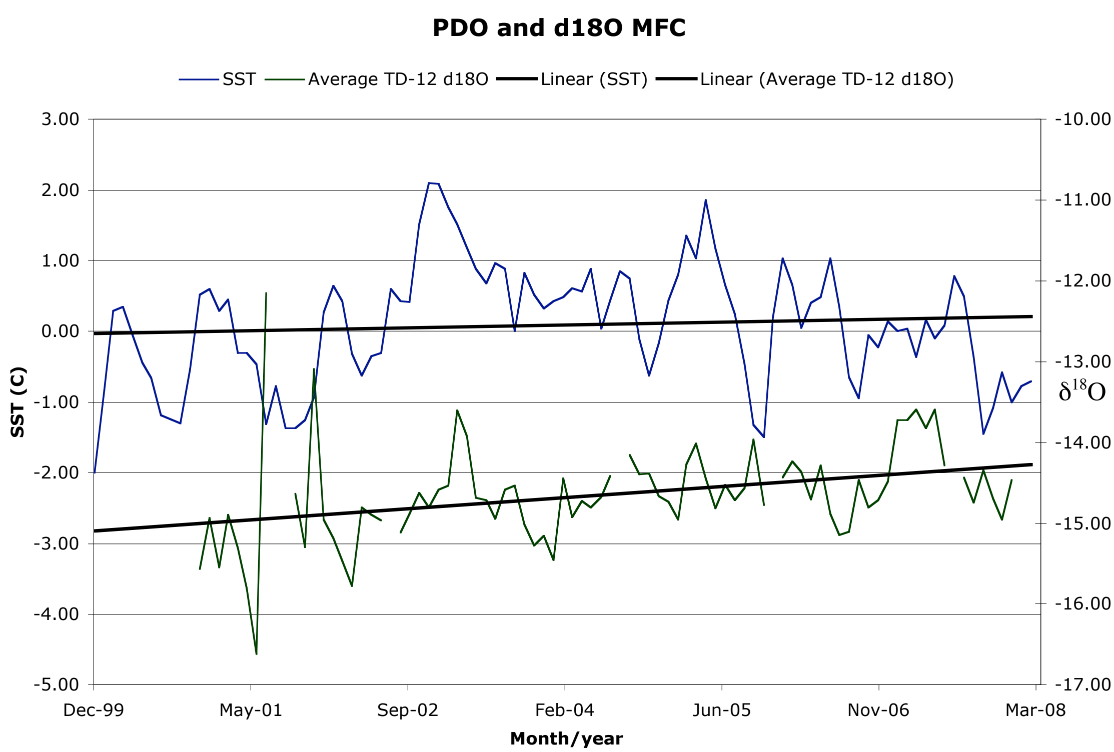


Figure APP N 3

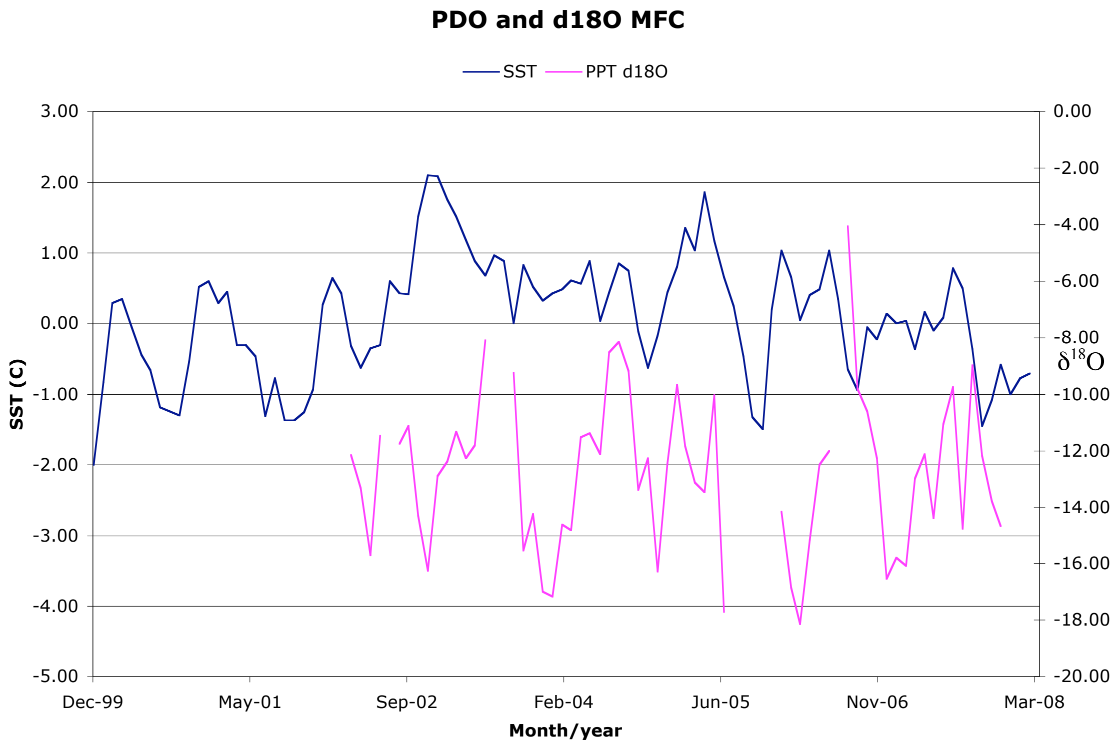


Figure APP N 4