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Basic American Foods Land Application Site (Moses Lake)

Groundwater Review

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For more information contact:

Publications Coordinator
Environmental Assessment Program
P.O. Box 47600, Olympia, WA 98504-7600
Phone: (360) 407-6764

Washington State Department of Ecology - www.ecy.wa.gov/

- Headquarters, Olympia (360) 407-6000
- Northwest Regional Office, Bellevue (425) 649-7000
- Southwest Regional Office, Olympia (360) 407-6300
- Central Regional Office, Yakima (509) 575-2490
- Eastern Regional Office, Spokane (509) 329-3400

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Basic American Foods Land Application Site (Moses Lake)

Groundwater Review

by
Melanie Redding
Licensed Geologist, Licensed Hydrogeologist

Eastern Operations Section
Environmental Assessment Program
Washington State Department of Ecology
Olympia, Washington 98504-7710

Waterbody Number: WA-41-9280GW

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Abstract

Basic American Foods (BAF) is a potato processing facility near the city of Moses Lake, Washington. The facility uses a land treatment system to manage their process wastewater, and this wastewater is land applied year-round to approximately 2300 acres.

Washington State requires that all wastewater be treated with AKART (all known, available, and reasonable methods of prevention, control, and treatment) prior to being discharged to the environment. AKART for industrial land treatment systems in Washington typically includes winter storage and the agronomic application of wastewater during the growing season. This is the industry standard unless a facility can present site-specific conditions and a wastewater management strategy that demonstrates an alternate treatment system will be equally protective of the environment.

The objective of this assessment is to provide an independent evaluation of all relevant reports, site-specific data, and literature in order to provide a technically defensible AKART determination regarding winter storage of BAF wastewater. This review also considers compliance with Washington State Groundwater Quality Standards and the antidegradation policy. This report does not evaluate the groundwater modeling (MODFLOW) conducted by BAF or Washington State University, nor does it attempt to resolve the controversy surrounding these two efforts.

Based on this review, it was concluded that BAF is the predominant source of groundwater nitrate contamination beneath its wastewater sprayfield site. The low cation exchange capacity of sandy soils, and the year-round application of nitrogen-rich wastewater, provide a situation which promotes nitrate leaching into groundwater. Groundwater pumping from the BAF irrigation well network on a seasonal basis, and the placement of the irrigation wells, are not sufficient to ensure containment of the nitrate contaminant plume.

It was determined that the innovative treatment that BAF has been using is not protective of groundwater quality. This report recommends that BAF's treatment technology should be amended to limit their application of process wastewater to agronomic rates during the growing season. During the non-growing season, BAF cannot land apply their wastewater. There are alternatives to year-round application, which include winter storage, discharging to a publicly owned treatment works, or discharging to a surface waterbody.

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Introduction

Basic American Foods (BAF) is a potato processing facility located approximately three miles south of the city of Moses Lake in Grant County, Washington (Figure 1). BAF uses a land treatment system to manage their process wastewater by land applying year-round. Groundwater contamination is present beneath the land application site.

The Washington State Department of Ecology (Ecology) guidance on minimum treatment technology (AKART[1]) for land treatment of industrial wastewaters state that a lined lagoon is necessary to contain process wastewater generated over the winter when crops are dormant and agronomic application of wastewater is not a viable treatment option. AKART allows for site-specific considerations to modify the minimum level of treatment, if the proposed treatment is at least as protective of water quality and the environment. (Ecology, 2004)

Ecology's Water Quality Program, Eastern Regional Office, has requested an objective independent review of submitted documents to determine if BAF is in compliance with the Groundwater Quality Standards and if the treatment system meets the AKART requirement. This assessment includes providing (1) a technically defensible recommendation on the necessity of winter storage of wastewater, and (2) a determination of whether winter storage of wastewater provides greater protection to groundwater than year-round land application at the BAF sprayfield site.

Issue

BAF acknowledges that past practices have contaminated groundwater quality. These practices include hydraulically overloading their sprayfield from 1966 to 1993, which resulted in excessive soil nitrogen levels. Additionally, the leveling of the sand dunes in 1994 to create an agricultural-based land treatment system caused nitrogen mineralization and resulted in nitrate leaching to groundwater. These past BAF practices have resulted in a groundwater contamination plume that extends the length of the sprayfield site. (Uhlman and Coffan, 2001) BAF claims that the continued year-round application of wastewater on their current sprayfield site is providing greater groundwater protection than winter storage of wastewater would allow (Burgard, 2003).

There is continuing debate about the necessity for winter storage of process wastewater at the BAF sprayfield site. There are contradictory reports and modeling efforts by various parties attempting to clarify this issue. Uhlman and Coffan (2001) state that, despite the past impacts to groundwater quality, BAF is meeting the Groundwater Quality Standards. An independent review of BAF's modeling and water quality permit documents was conducted by Washington State University (WSU). Based on this review, WSU concluded that "*Overall groundwater quality has been adversely impacted by the BAF sprayfields.*" (Qui et al., 2005)

[1] AKART = All known, available, and reasonable methods of prevention, control, and treatment.

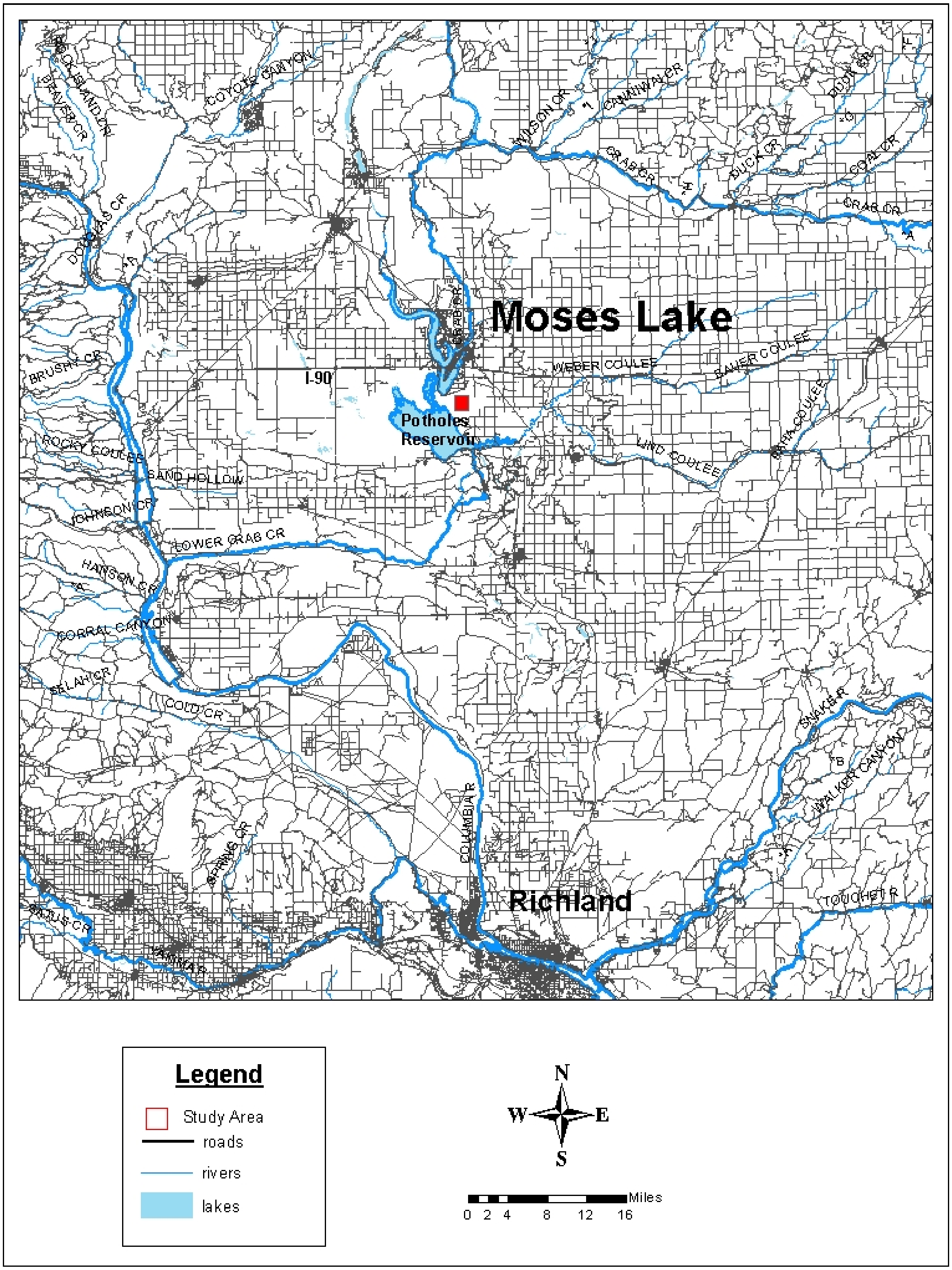

Figure 1. Location of the Basic American Foods (BAF) sprayfield near the city of Moses Lake, WA.

This Ecology review does not attempt to settle the modeling controversy between BAF and WSU. Both modeling efforts appear to do a thorough job of addressing current hydrogeologic[2] conditions and assessing impacts to groundwater quality. There were numerous discrepancies between the two reports, which make them difficult to compare. Considerable effort and resources have already been applied towards this issue. Rather than duplicating efforts and further complicating the controversy, this report focuses on other aspects of quantifying wastewater treatment and assessing impacts to the environment.

Background

BAF is a potato processing facility which uses a land treatment system to manage their process wastewater. During the period studied for this review (2001-2009), BAF land applied approximately 1.42 million gallons per day of wastewater year-round onto 22 fields comprising 2,301 acres. This sprayfield is partly owned by BAF and partly owned by private farmers. In 2006, Ecology's Water Quality Program, Eastern Regional Office, issued BAF a State Waste Discharge Permit #5213 for discharging industrial wastewater to the environment.

Ecology has not yet approved the engineering report submitted by BAF, pending determination of whether the land treatment system meets the AKART standard.

BAF is also within the federal Columbia Basin Irrigation Project area, which is an integrated system of distribution canals that transport Columbia River water, as well as groundwater, to approximately 500,000 acres in the area. Potholes Reservoir, to the west of the BAF sprayfield, is part of the irrigation system and functions as an irrigation return reservoir.

In 1966, BAF initiated a land treatment system by using land application to manage their food processing wastewater on 206 acres in an area underlain by natural sand dunes. This original sprayfield site is part of the current sprayfield, which has been continually used by BAF. The area of land used for land treatment was increased from the years 1992 to 1998. Table 1 describes the chronological history of BAF and the major environmental changes. Currently, process wastewater is land applied via center pivot irrigation. Supplemental water is pumped from 17 irrigation wells on-site. BAF operates continuously for 11 months out of the year. (Venner, 2001)

BAF processes approximately 400 million lbs of raw potatoes a year and produces approximately 70 million lbs of dehydrated potato granules. This process includes washing, steam peeling, cooking, blending, dehydration, and packaging. (Ecology, 2006; Venner, 2001) The wastewater, also known as *process water*, contains varying concentrations of potato solids, starches, sugars, nutrients, and minerals.

BAF acknowledges that past wastewater application practices have contaminated groundwater beneath the sprayfield site, which has resulted in a plume of elevated nitrate concentrations that extends across the area of the irrigation fields (Uhlman and Coffan, 2001). Currently wastewater nitrogen loading to the site during the growing season is less than the agronomic requirements of

[2] Hydrogeologic = the distribution, characterization, and movement of groundwater in the soil and rocks below the earth's surface.

the crops (Venner, 2001). Process wastewater has been applied year-round since BAF began their land treatment system in 1966.

Agricultural activities have different goals for irrigation and fertilizer use than a land treatment system which is land applying process wastewater. The primary goal of agricultural production is to maximize crop yields. The primary goal for a land treatment system is waste management, not maximizing crop yields. (Ecology, 2006) Applying fertilizer during the non-growing season is not a common agricultural practice.

Table 1. Chronological history of BAF and environmental changes.

Year	Environmental Modifications
1966	BAF food processing facility operated by land applying wastewater on 206 acres until saturation occurred and then allowing the soil to rest to promote nitrification/ denitrification. Hydraulic loading was approximately 5 ft/acre/yr.
1966 - 1992	Recommended chemical oxygen demanding substances (COD) loading at the site was 137-274 lbs/acre/day. (Average COD load = 125 lbs/acre/day, with instantaneous loads from 4,000 to 6,000 lbs/acre/day).
1984	Moses Lake Dunes Wastewater Treatment Plant opened as a new facility. It was designed to treat 2.5 mgd wastewater with a rapid infiltration system on 18.7 acres. (State Waste Discharge Permit (SWDP) #8012).
1986	Monitoring wells installed at the BAF sprayfield site up and down gradient. Total dissolved solids = 200 mg/L; nitrate increased from 1 to 20 mg/L in groundwater.
1988	Ecology recommended that BAF upgrade the system so a crop could be grown to improve nitrogen utilization.
1989	BAF installed a freshwater well and 2 five-acre test plots.
1990	Test plot was set up to provide data to develop a nutrient management plan. Determined site has 600 lbs of total Kjeldahl nitrogen (TKN) removal potential/acre/year.
1991	BAF leveled and planted its first new 130-acre center pivot field.
	BAF previously processed vegetables, but now only potatoes. Discharge = 750,000 gpd.
1992 - 1994	Three additional center pivot fields were added. Sprayfield expanded to 455 acres to reduce nutrient and hydraulic loading. Land application changed to center pivot irrigation.
1993 - 1994	Old BAF sprayfield leveled.
1993	Test plots from 1990 study were determined to be atypical of land application site. When it became apparent that crop utilization would be less than that indicated by the test plots, BAF began searching for additional land area.
1994 - 1998	BAF partnered with Isaac/Cox Farms using these fields as part of the BAF treatment system, with low to moderate application rates.
1996 - 1998	BAF converted fields from reed canary grass to alfalfa to enhance nitrogen uptake.
	Sprayfield expansion of 1850 acres was achieved by negotiating a long-term lease with adjacent landowner Isaac/Cox to discharge wastewater to his land.
1997	Alfalfa nitrogen removal rates were higher than wastewater application rates.
2002- 2003	Wastewater discharge was reduced by 35%.
2006	Ecology issued new State Waste Discharge Permit.
2010	BAF reduced their process wastewater to 258.7 million gallons per year.

(Venner, 2001; 5/8/08 meeting with BAF; Ecology, 2006; Uhlman and Coffan, 2001).

Nitrogen Literature Review

Washington State University (WSU) (Hermanson et al., 2000) conducted a literature review on nitrogen dynamics in the soil. The purpose of this review was to assist Ecology in determining the fate and transport of wastewater nitrogen in the subsurface for land treatment systems. The following is a list of some of the relevant general principles identified in this review:

- The estimation of the agronomic rate for a crop must factor in all sources of nitrogen available during the growing season.
- All nitrogen applied to the soil, that is not volatilized, will eventually convert to nitrate.
- Soil nitrogen that moves below the root zone will eventually leach to groundwater as nitrate.
- Denitrification may reduce nitrate loading to groundwater under some conditions, though it is of little importance in well-drained soils.
- Nitrogen applied at agronomic rates will minimize the buildup of soil organic nitrogen.
- Wastes applied substantially before or after maximum crop demand may result in nitrate leaching.
- Organic wastes applied during the non-growing season will partially or totally convert to nitrate before the next growing season.
- Nitrates leached beyond the root depths of the crop to be grown during the following season will be susceptible for transport to groundwater.
- Steps should be taken to minimize movement of nitrogen below the root zone during the growing and non-growing season.
- Applying organic wastes during the non-growing season has an inherent risk in terms of leaching nitrogen to the groundwater.
- The use of storage facilities to minimize waste applications during the non-growing season is a safe alternative.

The WSU literature review (Hermanson et al., 2000) does not completely rule out the application of wastewater outside of the growing season. However, it is apparent that there are enough uncertainties associated with nitrogen dynamics in the subsurface that it is concluded that applying wastewater to crops and soil systems during the non-growing season is not reliably protective of groundwater (Ecology, 2004).

Groundwater Quality Standards

The goal of Washington State Groundwater Quality Standards (Chapter 173-200 WAC) is to maintain a high quality of groundwater and to protect existing and future beneficial uses through the reduction or elimination of contaminants discharged to the subsurface. This goal is achieved through three mechanisms: AKART, the antidegradation policy, and the numeric and narrative criteria. These standards affect all activities which have a potential to impact groundwater quality. (Kimsey, 1996)

A discharge cannot cause groundwater degradation, even if the discharge mobilizes or exacerbates existing contaminants.

Antidegradation Policy

The antidegradation policy is designed to ensure the protection of the state's groundwaters and the natural environment. The antidegradation policy and AKART form the primary mechanisms for protecting groundwater quality. Antidegradation protects background water quality and prevents degradation of the state's waters beyond the criteria. Criteria are the numeric values and narrative standards that represent contaminant concentrations which are not to be exceeded in groundwater. Regardless of the quality of the receiving water, AKART must be applied to all wastes. Degradation of water quality which would either harm a beneficial use or violate the Groundwater Quality Standards is allowed only in extreme circumstances. AKART must always be applied to the wastewater, and the goal is to maintain existing high quality water and improve degraded groundwater whenever possible.

Antidegradation applies when background water quality contaminant concentrations are less than criteria defined in the Groundwater Quality Standards. If discharges will result in exceedance of the criteria, facilities must apply additional treatment before Ecology can permit the discharge. In order to meet the antidegradation policy, the facility must prepare an AKART engineering analysis (which is reviewed and approved by Ecology) that demonstrates that discharges to groundwater will not result in increasing background contaminant concentrations. (Kimsey, 1996)

Point of Compliance

The point of compliance is the location where the facility must be in compliance with the Groundwater Quality Standards. The point of compliance should be located in groundwater as near and directly downgradient from the pollutant source as technically, hydrogeologically, and geographically feasible. The Groundwater Quality Standards protect all water in the saturated zone; therefore, the facility must be in compliance with established limits everywhere under the property and in water originating from all wells located on site. (Kimsey, 1996)

Enforcement Limits

Enforcement limits are the site-specific permit limits which are established to achieve compliance with the Groundwater Quality Standards. The limits are defined on a case-by-case basis, and compliance with these limits is met at the point of compliance. Enforcement limits are established sufficiently below the criteria to provide an adequate margin of safety to ensure pollution does not extend beyond the property boundary.

The Implementation Guidance for the Groundwater Quality Standards discusses enforcement limits. Background water quality is a statistical calculation of contaminant concentrations without the impacts of the proposed activity. Ecology defines background water quality for most contaminants as the 95% upper tolerance limit. This means that Ecology is 95% confident that 95% of future measurements will be less than the upper tolerance limit. (Kimsey, 1996)

Definition of Agronomic Rate

Agronomic rate for land treatment systems is defined as the rate at which a viable crop can be maintained and there is minimal leaching of chemicals downwards below the root zone. Crops should be managed for maximum nutrient uptake when crops are used for wastewater treatment. (Kimsey, 1996)

AKART

AKART[3] must be applied to wastes prior to entry into groundwater. AKART should reduce the contaminant load sufficiently to assure that the criteria will not be exceeded. If AKART does not reduce the contaminant load sufficiently to prevent degradation of a beneficial use or cause an exceedance of a criterion, than additional treatment may be required. The discharge cannot cause an impairment of a beneficial use. (Kimsey, 1996)

AKART encompasses the design, operation, and maintenance for land treatment systems that include (1) the application of wastewater and its nutrients at rates, times, and durations that do not exceed the crop's agronomic rates, and (2) the storage of wastewater in properly lined lagoons that is produced in excess of the crop's requirement or outside of the growing season. (Ecology, 2004) An AKART analysis includes a pollution prevention component.

Ecology Guidance on Land Treatment Systems

Ecology has extensive experience with land treatment systems and their effects on groundwater quality. Ecology concludes that the current AKART definition addresses the many uncertainties and potential negative consequences to groundwater quality associated with excessive nitrogen that is land applied during the non-growing season. Ecology will consider site-specific demonstrations of innovative approaches to achieving treatment that are determined to be equivalent in effectiveness for protecting groundwater quality as the current AKART approach. (Ecology, 2004)

The primary goal of land treatment systems is to maximize contaminant uptake by the crop and minimize contaminant leaching below the root zone to protect the beneficial uses of the groundwater. Maximizing crop yield is not equivalent to maximizing crop uptake. Maximizing crop yield is not the goal of a land treatment system. Land treatment systems that have been approved and permitted by Ecology (AKART) require that water and nutrients must not be applied in excess of the agronomic rate of the site's cover crop. (Ecology, 2004)

For facilities that operate year-round, a critical element in meeting AKART is the management of their wastewater that is produced during the winter non-growing season. At those times when a crop is not actively growing, or the growth rate is very slow at low air and soil temperatures and not able to use nutrients supplied in the wastewater, continued application will most likely exceed the agronomic rate and AKART will not be achieved. A management strategy that has been approved by Ecology (AKART) and implemented by most year-round dischargers that use

[3] All known, available, and reasonable methods of prevention, control, and treatment.

land treatment is the storage of wastewater in lined impoundments during the non-growing season.

Ecology's guidance concluded the following about AKART for land treatment systems:

- Nitrogen applied to land in the form of ammonia or organic nitrogen will convert to nitrate during the non-growing season, and will leach out of the soils and migrate to the groundwater.
- Applying wastewater to the land during the non-growing season does not reliably protect the groundwater, and therefore does not meet the AKART requirement.
- Ecology will consider site-specific demonstrations of innovative plans to manage wastewater during the non-growing season. Approval of these plans will depend on their achieving nitrogen treatment equivalent in effectiveness for protecting the groundwater as the current approved AKART. (Ecology, 2004)

Previously Ecology has also considered other options for managing excess wastewater (Ecology, 2004). These include:

- Storage in a properly constructed lined lagoon.
- Discharge to a surface waterbody in accordance with Chapter 173-201A WAC and Chapter 173-220 WAC.
- Discharge to a publicly owned treatment works (POTW) in accordance with Chapter 173-216 WAC.

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Geology

BAF is located on the central Washington Columbia plateau which was formed by basalt flows erupting through fissures during the Miocene Epoch. The Columbia Plateau was created during one of the largest basalt flows in the world, creating an igneous province of approximately 63,000 square miles with a thickness of 6,000 feet. As the lava emerged at the earth's surface, the earth's crust gradually subsided creating the plateau. (Drost et al., 1990)

The Missoula Floods were cataclysmic events which swept through eastern Washington at the end of the last ice age. These floods occurred when there were sudden ruptures of the ice dam which impounded Glacial Lake Missoula. During the end of the last ice age, a finger of the Cordilleran ice sheet moved south forming an ice dam. The dam created the massive lake over 2,000 feet deep, containing more than 500 cubic miles of water near the current city of Missoula, Montana. When the ice dam broke releasing the water, coulees were cut into the underlying bedrock. Over time the ice dam and lake were recreated as the Cordilleran ice sheet continued moving south. This sequence which caused vast flooding reoccurred numerous times over 2,500 years. (Bretz et al., 1956)

The channeled scablands that extend throughout the Columbia Plateau are a unique erosional feature created by the Missoula Floods scouring the Columbia River plateau during the Pleistocene Epoch. The channeled scablands have a non-traditional rectangular shape for an erosional feature caused by water. Rivers typically form a 'V' shape, while glaciers carve a 'U' shape. Arial photographs reveal the eroded channels have a braided appearance, and there are vast potholes and ripple marks, which are magnitudes larger than those normally present in rivers. These unique erosional features have been determined to be the result of the Missoula Floods. (Bretz et al., 1956)

This unique geologic history has created complex hydrogeologic characteristics. As the erosion of the basalts occurred during the flood events, it left interflow zones between the basalt ridges which created significantly different hydrogeologic properties.

Hydrogeology

The BAF sprayfield site is located in an area with complex hydrogeologic features. There are aeolian deposits which developed into sand dunes. Some of these dunes were partially leveled by BAF to accommodate efficient crop production.

There are three main hydrogeologic units which affect groundwater flow near the BAF site (Whiteman et al., 1994).

1. **Glacio Fluvial dune sands and gravels**. This unit is also known as the Columbia Plateau Overburden. This is the primary surficial aquifer and is comprised of unconsolidated Pleistocene-age flood deposits.
2. **Ringold Formation**. This formation is discontinuous across the site. It is comprised of loess and volcanic ash. This unit acts as an aquitard, and the thickness ranges from 0 to 40 feet.

3. **Wanapum Basalt**. Fractures in the Wanapum Basalt promote water production in this aquifer.

Whiteman et al. (1994) calculate the median horizontal hydraulic conductivity for the Columbia Plateau overburden aquifer at 240 feet/day. Pitz (2003) estimates hydraulic conductivity values for the glacio-fluvial aquifer at 2,800 – 28,000 feet/day with average seepage velocities of 1100 feet/day. Regional groundwater flow direction is south/southwest, towards Potholes Reservoir (Figure 1). The land elevation at the BAF sprayfield is approximately 1,300 feet above mean sea level, and the Potholes Reservoir elevation is approximately 1,040 feet above mean sea level.

Depth-to-groundwater is generally between 15 to 40 feet below land surface. The depth of water is affected by seasonal groundwater irrigation pumping, crop irrigation, Columbia River water use, leakage from the expansive irrigation canal distribution system, the water level in Potholes Reservoir, and precipitation.

Regional surface water flows follow the regional trend of the basalt flows along the north-south ridges and fractures formed in the Wanapum Basalt. The surficial flow is southwesterly towards Moses Lake and Potholes Reservoir.

Soils

According to the National Resource Conservation Service (USDA, 2009), there are three predominant types of soils at the BAF sprayfield:

- **Quincy Sand:** This soil type forms the dunes which are comprised of aeolian sands. It is somewhat excessively drained, has a low available water capacity, and is comprised of sand from 0 to 60 inches deep.
- **Burbank Loamy Fine Sand:** This soil type forms the outwash terraces which are comprised of aeolian sands over gravelly glacial outwash. It is excessively drained, has a very low available water capacity, and is comprised of loamy fine sand, gravelly loamy fine sand, and extremely gravelly sand.
- **Quincy Loamy Fine Sand:** This soil type forms the dunes and terraces which are comprised of aeolian sands. It is somewhat excessively drained, has a moderate available water capacity, and is comprised of loamy fine sand and fine sand.

BAF's Proposal of Year-Round Application of Wastewater as AKART

BAF states that *"The potential to leach nitrate to groundwater under year-round land application is equal to or less than the potential nitrate leaching under land application with storage"* (Burgard, 2003). Their rationale for this conclusion is based on the following line of reasoning:

- Based on a site-specific risk analysis, the results indicate that an equal amount of nitrate will be leached from year-round land application compared to use of a storage pond in winter because of the need to leach salts to control soil salinity. *"Since the leaching requirements for year-round land application and land application with winter storage are equal, there is no advantage to constructing a winter storage pond. Additional irrigation will be needed to leach salts with or without a pond. It therefore makes sense to continue year-round land application."* (Burgard, 2003)
- Winter application of process wastewater is specifically used to help leach salts out of the soil column to maintain the vitality of the soils. This is justified since chloride is not a primary component of the TDS content in the wastewater. Additional application of water is needed in the non-growing season to meet the salt leaching requirement; therefore, winter storage is not necessary. This action does result in salts migrating to groundwater.
- TDS is not a problematic contaminant for BAF since the predominant ions present in the wastewater are calcium, magnesium, and carbonate. Chloride and sulfate, which have drinking water maximum contaminant levels, are not problematic and are not expected to become so. (Uhlman and Coffan, 2001)
- There is minimal organic nitrogen mineralization and nitrification occurring in the subsurface due to low soil temperatures in the winter. This phenomenon prevents nitrogen leaching to groundwater.
- The form of nitrogen produced by BAF is organic nitrogen and ammonia; both forms are immobile in soils.
- The irrigation wells at the sprayfield site effectively capture and recycle groundwater potentially affected by BAF activities.
- BAF concluded from detailed modeling (Burgard, 2003) that it is best management practices to keep the soil nitrate to a minimum at the end of the growing season.
- There are other sources of contaminants in the area which are impacting groundwater quality:
    - Past BAF practices.
    - City of Moses Lake Dunes Wastewater Treatment Plant (WWTP).
    - Upgradient sources.

Sources of Groundwater Contamination

Groundwater modeling conducted by BAF shows a plume of high nitrate groundwater that extends the length of the sprayfield site. The location of the BAF sprayfield is directly downgradient of the Moses Lake Dunes WWTP (Figure 2). The WWTP discharges treated and disinfected wastewater into a series of rapid infiltration ponds. BAF estimates the significant sources of groundwater contamination include releases to groundwater due to past practices in the old BAF field, the Moses Lake WWTP effluent plume, the release of naturally occurring salts due to the disturbance of arid climate soils, and the agricultural use of commercially available fertilizers. (Uhlman and Coffan, 2001)

BAF states that the leveling of the old sprayfields in 1994 was the most significant contributor to contaminants impacting groundwater, but they claim that the elevated nitrate plume is contained by the pumping of their on-site irrigation wells. There are 17 large capacity irrigation wells operating seasonally, extracting 2,110 million gallons annually. BAF calculated that 74.8 million gallons of contaminated groundwater escapes the site (year 1998). However, they conclude that they are effectively capturing and recycling contaminated BAF groundwater. (Uhlman and Coffan, 2001)

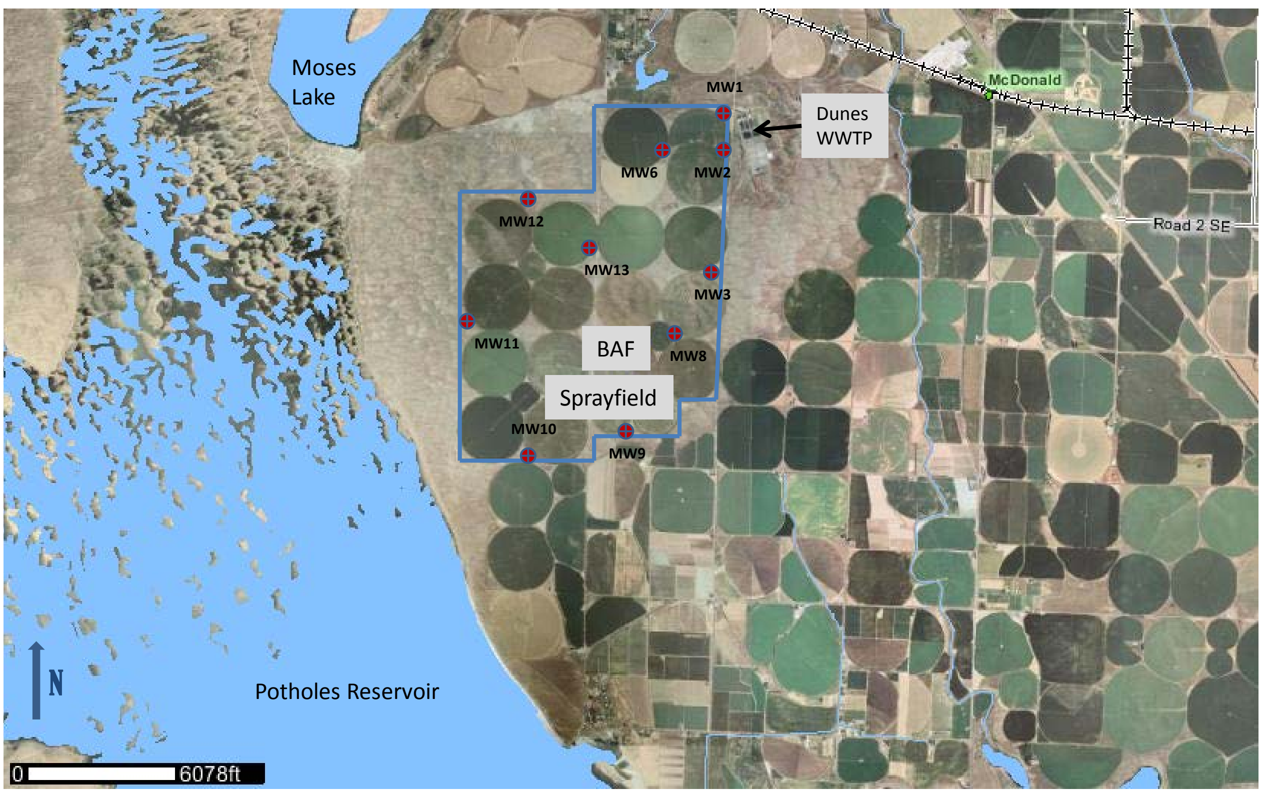

Figure 2. Location of BAF groundwater monitoring wells.

Crop Management

Storing total Kjeldahl nitrogen (TKN) in the soils during the winter months will result in improvements to groundwater quality since less commercial fertilizer will be needed. Fertilizer has a high potential to leach to groundwater.

The BAF engineering report (Venner, 2001) and BAF annual sprayfield reports (Nelson, 2009) state:

- Water and nitrogen loadings to the site during the growing season are less than the crop requirements.
- Perennial crops (alfalfa and grass) require year-round application of water.
- There is little change in nitrate during the non-growing season due to low soil temperatures, which allows for soil mineral management and soil storage of organic nitrogen (Venner, 2001).
- Detailed modeling and statistical analysis concluded that the potential of nitrate loss to groundwater in year-round application of wastewater is equal to the use of winter storage when leaching for salinity management is practiced in the fall, compared to the leaching for salinity control in late winter. The conclusion is that year-round land application can be managed so that the risk of nitrate loss is not greater than when winter storage is used. (Burgard, 2003)
- During the winter, crops are dormant or growth is very slow, but root growth and the associated nitrogen uptake continue (Burgard, 2003).
- At sites with low winter precipitation, such as BAF, there is not enough water percolated into the soils to control soil salinity (Burgard, 2003).

BAF Proposed Permit Compliance Measures

The following recommendations are permit conditions proposed by BAF to demonstrate compliance with Water Quality Standards (Burgard, 2003):

- Percolate loss will be permitted only in winter.
- Three-year average end-of-crop soil profile will be stable or declining.
- Cover crops will be used to maximize nitrogen uptake.

Groundwater Quality

BAF model simulations (MODFLOW) indicate that impacted groundwater is effectively captured and recycled by BAF's existing irrigation wells. Approximately 2,110 million gallons of contaminated groundwater is extracted by these irrigation wells, and 74.8 million gallons of contaminated groundwater leave the site uncaptured by these irrigation wells. (Uhlman and Coffan, 2001)

Uhlman and Coffan state that the model presented in BAF's hydrogeologic study (2001) demonstrates that year-round application of process wastewater meets the intent of the Groundwater Quality Standards (Chapter 173-200 WAC), and that contaminants in groundwater are decreasing.

AKART

BAF concludes that their wastewater management is equivalent to AKART and provides environmental protection greater to or equal than agronomic application of process wastewater and winter storage of process wastewater (Burgard, 2003). Venner (2001) states in the Engineering Report that the storage of process water nitrogen in the soils during the non-growing season meets the definition of AKART.

Evaluation

The objective of this assessment is to provide an independent evaluation of all relevant reports, site-specific data, and literature in order to provide a technically defensible AKART determination regarding winter storage of BAF wastewater. This review considers the environmental data from January 2001 to December 2009 to ensure consistency and to evaluate positive improvements made to facility operations. This review also considers compliance with Washington State Groundwater Quality Standards and the antidegradation policy.

This report does not evaluate the groundwater modeling (MODFLOW) conducted by BAF or Washington State University, nor does it attempt to resolve the controversy surrounding these two efforts.

Water Quality Parameters

Groundwater quality data are presented in a tabular format in Appendices E and F and are graphically displayed in Appendix C. Statistical analysis of nitrate and TDS data were evaluated using the Mann-Kendall test for trends. Sanitas Statistical Software (version 9.2) was used to generate Figures D.1 – D.28 in Appendix D. Table D.1 summarizes the trend analysis and indicates where statistically significant trends in the data were identified. Additionally, water quality trends and statistics are summarized in Tables 2 and 3.

Nitrate

Groundwater quality in the BAF sprayfield area is contaminated with elevated nitrate concentrations above the groundwater criterion of 10 mg/L.

Upgradient Groundwater Quality

Groundwater quality data from 2001 through 2009 were compared from BAF and the Dunes WWTP monitor wells (Table 2). These data indicate that upgradient groundwater from both facilities is generally of good quality, with mean nitrate concentrations below the Groundwater Quality Standard of 10 mg/L.

Both wells MW-1 BAF and MW-1 Dunes have average nitrate concentrations below 3 mg/L, which is indicative of groundwater unimpacted by anthropogenic sources (Hem, 1989). MW-12 BAF, which is also upgradient, but downgradient of other agricultural activities, has a higher average nitrate concentration of approximately 7 mg/L. However, the nitrate concentrations in this well have been relatively stable since 2001.

MW-2 at BAF is upgradient of the BAF sprayfield and downgradient of the Dunes WWTP. The location of this well is very close to MW-5 at the Dunes WWTP, which is illustrated by the similarity of concentrations for nitrate and TDS (Tables 2 and 3).

Table 2. Statistical summary comparison of nitrate data (mg/L) from BAF and the Dunes WWTP.

Location	BAF					Dunes WWTP				
	Well	Mean	Max	Min	Trend	Well	Mean	Max	Min	Trend
Wastewater (TKN)	--	54	108	0.5	↓	--	11.7	29.8	0.4	↓
Upgradient	MW-1	2.0	4.4	0.9	--	MW-1	0.28	9.1	0.06	↓
	MW-2	9.2	23.1	0.4	↓					
	MW-12	6.9	8.5	1.1	--					
Downgradient	MW-3	4.3	14.9	0.7	↓	MW-5	8.3	26.4	0.07	↓
	MW-6	43.3	99.2	3.9	--					
	MW-8	19.2	38.2	14.9	--					
	MW-9	29	51	14.9	↑					
	MW-10	52	99.3	20.5	--					
	MW-11	21.7	55	11.7	--					
	MW-13	48.7	67.7	28	↓					

-- No significant trend.

Downgradient Water Quality

Data from monitoring wells in the area indicate that groundwater quality is contaminated with nitrates, TDS, and other associated parameters. Based on the hydrogeologic model and the water quality data, it appears that both BAF and the Dunes WWTP have contributed to this existing contamination.

A statistically significant increasing nitrate trend was identified for BAF’s MW-9, which is a downgradient well.

Downgradient water quality results indicate that BAF consistently exceeds (does not meet) the criterion for mean nitrate concentrations in all six of their downgradient wells: MW-6, MW-8, MW-9, MW-10, MW-11, and MW-13. MW-10 is the most downgradient well at the BAF sprayfield (Figure 2), and nitrate concentrations have remained elevated during the comparative period of 2001-2009. The average concentration is 52 mg/L with a range between 20 and 99 mg/L. Figure 3 illustrates the distribution of nitrate concentrations in the area.

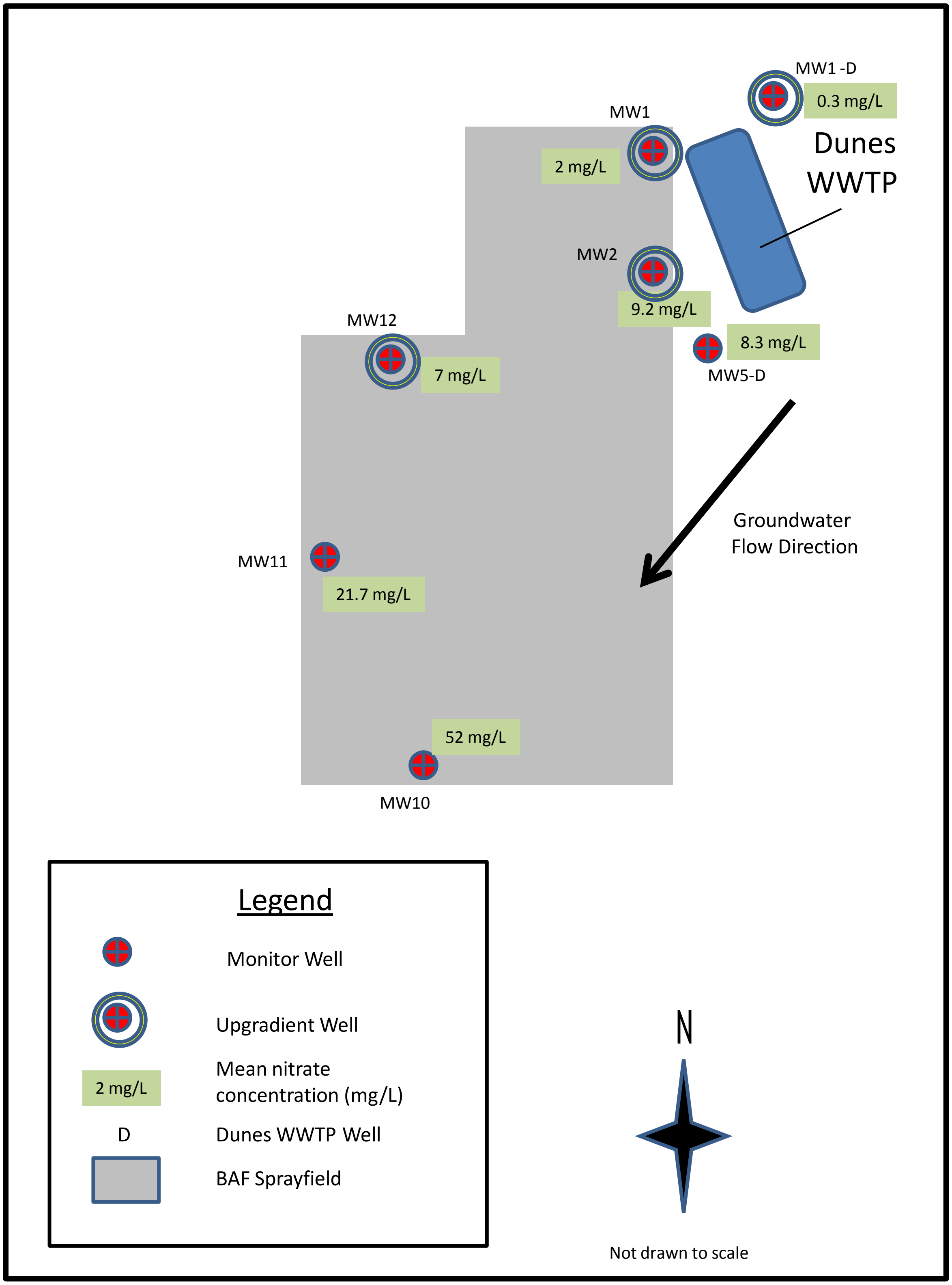

Figure 3. Mean nitrate concentrations (2001-2009) for BAF and Dunes WWTP monitoring wells.

Total Dissolved Solids (TDS)

TDS are comprised of volatile and fixed solids. The difference between TDS and fixed dissolved solids (FDS) is that the volatile solids portion is removed in FDS. The volatile portion is the organic portion, which includes sugars and starches. The FDS portion is the inorganic portion, which are comprised primarily of the salt constituents.

The State Waste Discharge Permit for BAF requires the wastewater to be monitored for FDS due to the high concentration of starch in the process wastewater.

TDS has a Groundwater Quality Standard of 500 mg/L and is elevated in the uppermost aquifer. Based on data from the Dunes WWTP from 2001 through 2009, it appears that their discharge is causing a significant impact to groundwater quality. The average upgradient TDS concentration in MW-1 Dunes is 156 mg/L, and the average downgradient concentration in MW-5 is 614 mg/L (Table 3).

Table 3. Summary statistical comparison of dissolved solids data (mg/L) from BAF and the Dunes WWTP.

<table>
<tr><th rowspan="2">Location:</th><th colspan="5">BAF (FDS)</th><th colspan="5">Dunes WWTP (TDS)</th></tr>
<tr><th></th><th>Mean</th><th>Max</th><th>Min</th><th>Trend</th><th></th><th>Mean</th><th>Max</th><th>Min</th><th>Trend</th></tr>
<tr><td>Wastewater</td><td></td><td>626</td><td>908</td><td>291</td><td>↓</td><td></td><td>576</td><td>680</td><td>293</td><td>↓</td></tr>
<tr><th rowspan="2">Location:</th><th colspan="5">BAF (TDS)</th><th colspan="5">Dunes WWTP (TDS)</th></tr>
<tr><th>Well</th><th>Mean</th><th>Max</th><th>Min</th><th>Trend</th><th>Well</th><th>Mean</th><th>Max</th><th>Min</th><th>Trend</th></tr>
<tr><td rowspan="3">Upgradient</td><td>MW-1</td><td>204</td><td>265</td><td>171</td><td>--</td><td rowspan="3">MW-1</td><td rowspan="3">156</td><td rowspan="3">216</td><td rowspan="3">122</td><td rowspan="3">--</td></tr>
<tr><td>MW-2</td><td>628</td><td>1389</td><td>422</td><td>↓</td></tr>
<tr><td>MW-12</td><td>416</td><td>480</td><td>371</td><td>--</td></tr>
<tr><td rowspan="7">Downgradient</td><td>MW-3</td><td>544</td><td>595</td><td>506</td><td>↓</td><td rowspan="7">MW-5</td><td rowspan="7">614</td><td rowspan="7">740</td><td rowspan="7">543</td><td rowspan="7">--</td></tr>
<tr><td>MW-6</td><td>1296</td><td>1663</td><td>481</td><td>--</td></tr>
<tr><td>MW-8</td><td>465</td><td>588</td><td>400</td><td>↑</td></tr>
<tr><td>MW-9</td><td>402</td><td>697</td><td>239</td><td>↑</td></tr>
<tr><td>MW-10</td><td>756</td><td>1112</td><td>339</td><td>↑</td></tr>
<tr><td>MW-11</td><td>557</td><td>971</td><td>472</td><td>--</td></tr>
<tr><td>MW-13</td><td>891</td><td>1148</td><td>739</td><td>↑</td></tr>
</table>

-- No significant trend.

The impacts to groundwater quality from the Dunes WWTP are reflected in BAF's MW-2 TDS concentrations, where the average TDS concentration is 628 mg/L. BAF's MW-1, which is upgradient of both BAF and the Dunes WWTP, is similar to the Dunes upgradient well. BAF's MW-1 TDS concentration is 204 mg/L (Figure 4).

Statistically significant increasing TDS trends were identified for BAF's MW-8, MW-9, MW-10, and MW-13, which are all downgradient wells.

MW-10, which is a downgradient well at BAF, has an average TDS concentration of 756 mg/L. This well shows a measurable increase of TDS in groundwater of an additional 130 mg/L across BAF's sprayfield site.

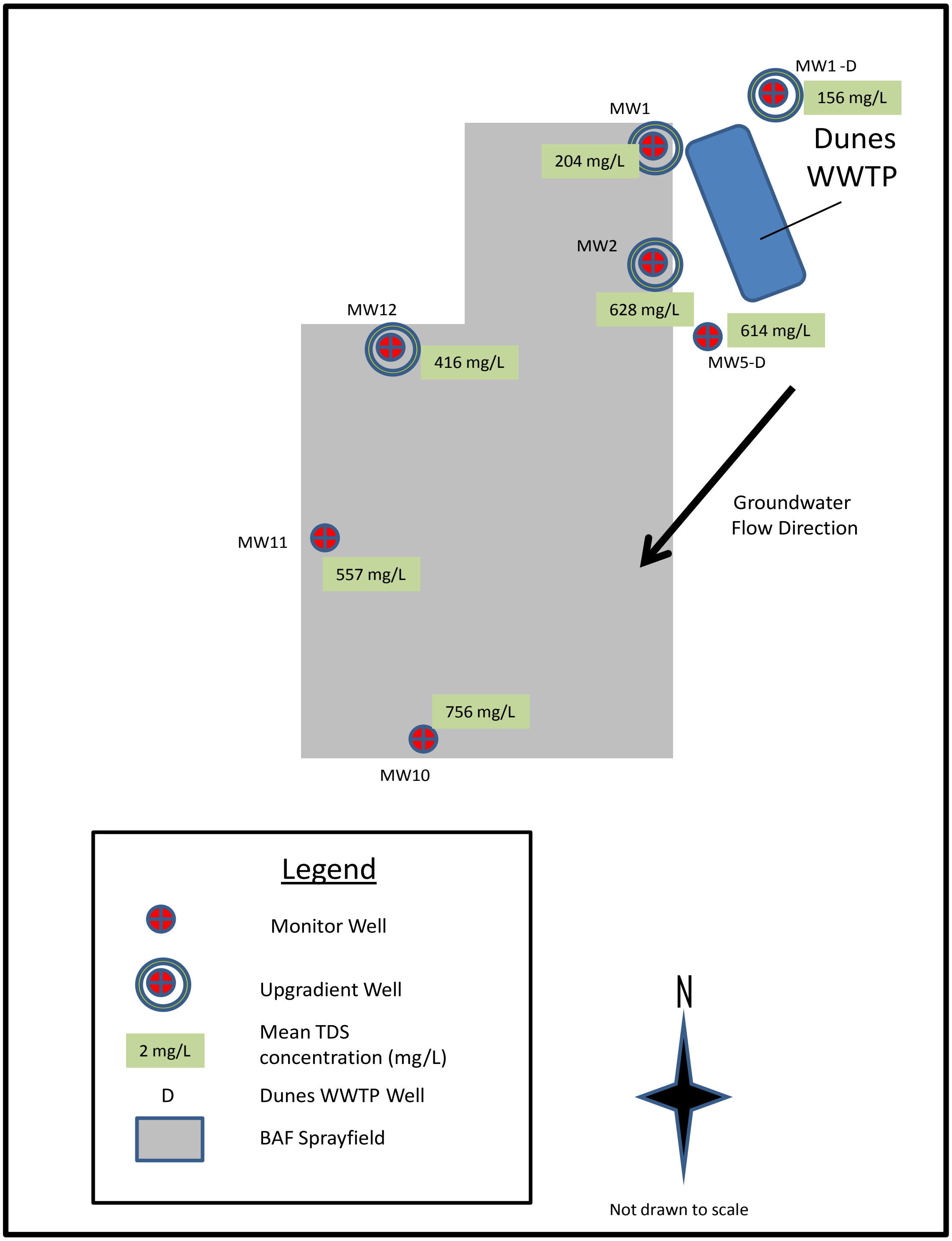

Figure 4. Mean total dissolved solids (TDS) concentrations (2001-2009) for BAF and Dunes WWTP monitoring wells.

Compliance with the Groundwater Quality Standards

Washington State Groundwater Quality Standards (Chapter 173-200 WAC) specify that wastewater discharges must be protective of groundwater quality and that all discharges must meet AKART.

Parameters of concern for BAF include nitrogen, phosphorus, and TDS. The groundwater criterion for nitrate is 10 mg/L, and the groundwater criterion for TDS is 500 mg/L.

Antidegradation

The goal of the antidegradation policy is to preserve background water quality and prevent degradation of the state's waters beyond the criteria. Criteria are the numeric values and narrative standards that represent contaminant concentrations which are not to be exceeded in groundwater.

There are only a few specific instances which allow a discharge to harm a beneficial use or violate the Groundwater Quality Standards. These instances are described under WAC 173-200-050(3)(b). BAF does not meet any of these listed conditions.

BAF is not protecting background water quality as directed by the antidegradation policy. Upgradient water quality in monitor wells MW-1, MW-2 and MW-12 is significantly lower than downgradient water quality in monitor wells MW-6, MW-10, MW-11 and MW-13. The criterion for nitrate of 10 mg/L is exceeded in groundwater, and the criterion for TDS of 500 mg/L is also exceeded in groundwater.

Point of Compliance

Elevated concentrations of nitrate and TDS in BAF's downgradient monitor wells illustrate non-compliance with the Groundwater Quality Standards. The standards specifically protect all waters in the saturated zone. The point of compliance is located in groundwater as near and directly downgradient from the pollutant source as possible (WAC 173-200-060(1)). The point of compliance is not necessarily located at the property boundary.

WSU Review of BAF

Washington State University (WSU) conducted an independent review of BAFs data in order to assess the validity of their modeling efforts and determine the appropriateness of year-round land application. This report (Qui et al., 2005) concluded the following:

- *"Many of the conclusions of the BAF Hydrogeologic Report (Uhlman and Coffan, 2001) are regarded as inappropriate.*
- *Overall the groundwater quality has been adversely impacted by the BAF sprayfields. The long term impact is due to 1) salt leaching in winter, 2) nitrate leaching in spring, and 3) potential ammonia leaching is substantial.*

- *Although complex interactions of numerous factors, including agricultural activities, the old BAF field reconstruction and WWTP operation, may all contribute to degrading groundwater quality, our analysis clearly indicates the adverse impact of the current BAF practice on groundwater quality including the evident trend of increasing concentration of nitrate and TDS in the groundwater monitoring wells. Therefore, it is difficult to evaluate the BAF land treatment system as AKART.*
- *It is not certain that the land treatment system is appropriate for the existing and future beneficial uses of the groundwater in terms of nitrate concentration according to the state's water quality standards (Chapter 173-200 WAC)."*

Containment of the Contaminant Plume

MODFLOW modeling by BAF shows a plume of high nitrate groundwater that extends the length of the sprayfield site. BAF states that the contaminated groundwater plume is contained by the BAF irrigation wells. The proposed theory is that these wells (Figure 5) pump a sufficient volume of groundwater every year to effectively contain the contaminant plume.

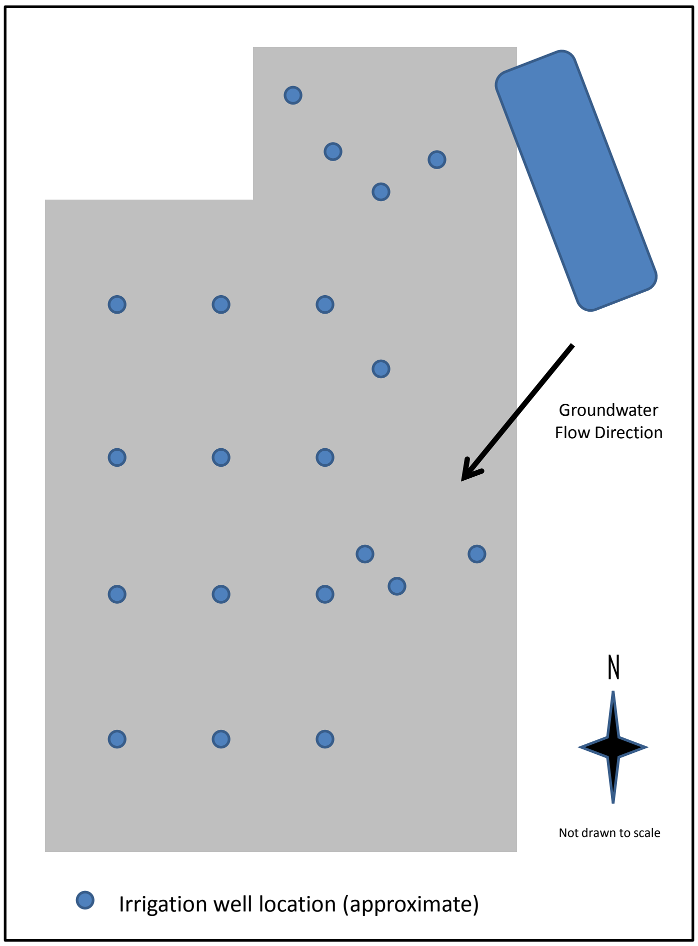

Figure 5. Location of irrigation wells in the BAF sprayfield.

EPA Containment Guidance

The U.S. Environmental Protection Agency (EPA) has established protocol and numerous guidance documents that describe the essential components of an effective groundwater containment system (Ross, 1990). These components include:

1. A three-dimensional model design of the capture zone.
2. A capture zone system designed to completely contain and treat contaminated groundwater.
3. Extraction wells.
4. Groundwater monitoring to determine effectiveness.
5. Evaluation of the containment system.

Performance of the groundwater containment system must be evaluated to determine its effectiveness and assess the limitations of the system. The modeled capture zone must be compared with the actual capture zone achieved. Both the horizontal and the vertical capture of the contaminant plume must be ensured. There are many options listed in the EPA guidance documents to assist in maximizing a system's capture zone effectiveness. For example; a facility can determine if augmenting extraction wells is necessary, or the facility can apply aggressive source removal technology to contain and treat the contaminated groundwater. (EPA, 2002)

EPA's guidance cautions that increased contaminant concentrations in downgradient wells may indicate inadequate capture by the extraction system, or these concentrations may indicate the presence of continuing contamination to the aquifer. Additionally, this guidance also notes that in order for a containment system to be effective, the source of pollution must be taken away. (EPA, 2001)

A three-dimensional model is necessary to evaluate the groundwater captured by the extraction wells. The capture zone is equivalent to the zone of hydraulic containment. A capture zone analysis is an essential element. One of the many considerations is accounting for the system's down time when wells are not pumping and accounting for where groundwater flows during this time.

Burden (2008) identifies a systematic approach to evaluate capture zones:

1. Review site data, develop a conceptual model, and define remedy objectives.
2. Define site-specific capture zones.
3. Interpret water level data.
4. Perform flow rates and capture zone calculations.
5. Evaluate concentration trends.
6. Interpret actual capture zones and compare to target capture zones.

BAF's Adherence to the EPA Containment Guidance

BAF has completed portions of the containment protocol:

- Groundwater quality has been characterized.
- A groundwater flow model has been developed which takes into account water level data and capture zones.

The containment system design does not completely follow all the elements in the recommended EPA guidance (EPA, 2001). The irrigation wells were not originally intended to be extraction wells to contain or capture contaminated groundwater. The location, design, and construction of these wells were intended to provide an even distribution of irrigation water to each of the fields. These wells are not strategically located to provide containment of the groundwater contaminant plume.

The well construction details are summarized in Appendix B for the BAF monitoring wells, the irrigation wells at the BAF sprayfield, and the Dunes WWTP monitoring wells. The irrigation wells are deeper, with an average depth of 190 feet below land surface, and are completed in the lower fractured basalt aquifer. The monitoring wells are shallower, with an average depth of 60 feet below land surface, and are predominantly completed in the uppermost sand aquifer. It is inaccurate to claim that extraction wells, completed significantly deeper in a different aquifer, would sufficiently contain a contaminant plume in the surficial aquifer. For extraction wells to properly contain a contaminant plume, the wells must be completed in the same aquifer as the contamination.

BAF states that "*The conceptual hydrogeologic model for the sprayfield site comprises an overburden aquifer in hydraulic communication with a fractured basalt regional water supply aquifer.*" (Uhlman and Coffan, 2001). Even in areas where hydraulic communication between the units is occurring, the most efficient means of capturing contaminated groundwater is to target the zone where contamination is the greatest. In this situation with nitrate and TDS, the targeted zone should be near the top of the water table.

The upper sand aquifer is separated from the lower fractured basalt aquifer by the Ringold Formation which is a discontinuous fine-grained restrictive unit (aquitard). Based on the cross-sections presented in Uhlman and Coffan (2001), the aquitard is present in the southern half of the sprayfield site and extends from the Dunes WWTP in the northeast corner to the southwest corner of the BAF sprayfield site. While there may be some hydraulic communication in areas where this formation is present, the finer grained stratigraphic matrix restricts vertical hydraulic flow.

The BAF irrigation wells are pumped only when irrigation water is required for growing crops. The wells are used 214 days of the year (Uhlman and Coffan, 2001). The pumps are turned off the other 151 days. According to the EPA containment guidance described above, a containment system must account for days when extraction wells are not operating. Management of the "containment system" is not addressed in the facilities operations for the 41% of the time when the irrigation wells are not operating.

The irrigation wells are only used to provide irrigation water when needed; it is inappropriate and misleading to disguise these wells as containment wells. According to the definition in the EPA containment guidance (EPA, 2001), these irrigation wells are not containment wells.

Groundwater monitoring at BAF indicates that nitrate concentrations are increasing across the site (Figure 3). The assessment and evaluation component of the EPA guidance stresses that if groundwater quality is not improving, then definitive management steps need to be taken to address the problem. These steps include:

- Eliminating the source of pollution, and/or
- Providing contaminant treatment.

These two elements are not included in BAF's management of process wastewater. The source of pollution continues through year-round land application, and there is no contingency plan to provide additional wastewater treatment to assure compliance with the Groundwater Quality Standards.

The BAF extraction wells are not adequately containing the contaminant plume in the uppermost sand aquifer. Groundwater is contaminated beneath the sprayfield site. This conclusion is based on the depth of the extraction (irrigation) wells in the lower basalt aquifer as well as the presence of a discontinuous aquitard, the placement of the wells, and the extensive time when the wells are not pumping. Overall, the proposed theory that the irrigation wells at the BAF sprayfield are containing the contaminated groundwater plume beneath the sprayfield site is one which has not been thoroughly demonstrated. BAF has not provided adequate assurance that containment is occurring with a high level of confidence.

Sources of Groundwater Contamination

BAF identified other sources of contaminants which are contributing to groundwater contamination. These include (1) past BAF practices, (2) City of Moses Lake Dunes WWTP, and (3) upgradient agricultural activities. These three sources were evaluated along with BAF's current practices to determine which are significant sources of groundwater contamination.

City of Moses Lake, Dunes Wastewater Treatment Plant (WWTP)

The City of Moses Lake, Dunes WWTP is located directly upgradient of the BAF land application site (Figure 6). The WWTP was located at its present site in 1984 and was designed to treat 2.5 mgd, with a discharge to a series of rapid infiltration basins covering approximately 19 acres. The City of Moses Lake upgraded the Dunes WWTP in 2005 with an extended aeration activated sludge Biolac® treatment system with ultra-violet disinfection discharging to rapid infiltration basins. This system was designed to reduce total nitrogen concentrations to less than 10 mg/L and nitrates to less than 6 mg/L. These improvements were evident in the dunes effluent in October 2005, and nine months later in the Dunes downgradient well MW-5 in July 2006 (Figures 7 and 9).

Ecology re-issued the facility a State Waste Discharge Permit ST-8012 on June 25, 2007, with an expiration date of June 30, 2012.

The maximum nitrate concentration in the Dunes downgradient monitoring well MW-5 was 26.4 mg/L in February 2004. The mean nitrate concentration in MW-5 from January 2001 to December 2009 was 8.3 mg/L. These figures do not support the theory that the Dunes WWTP is solely responsible for contaminating the groundwater which flows under BAF's sprayfield, since the maximum nitrate concentration in the Dunes downgradient monitoring well has always been lower than the downgradient monitoring wells at BAF.

Additionally, the Dunes WWTP provided nitrogen removal treatment which is evident in the Dunes downgradient monitoring well MW-5. Prior to May 2006, the mean nitrate concentration in the Dunes MW-5 was 12.3 mg/L. After the Biolac® treatment system was installed in May 2006, the average nitrate concentration decreased to 1.4 mg/L.

The Dunes WWTP has contributed to existing groundwater contamination. These impacts were predominantly mitigated with plant upgrades. Currently the impacts to groundwater quality are measurable but allowable under the antidegradation policy as it is defined in the Groundwater Quality Standards (Chapter 173-200 WAC).

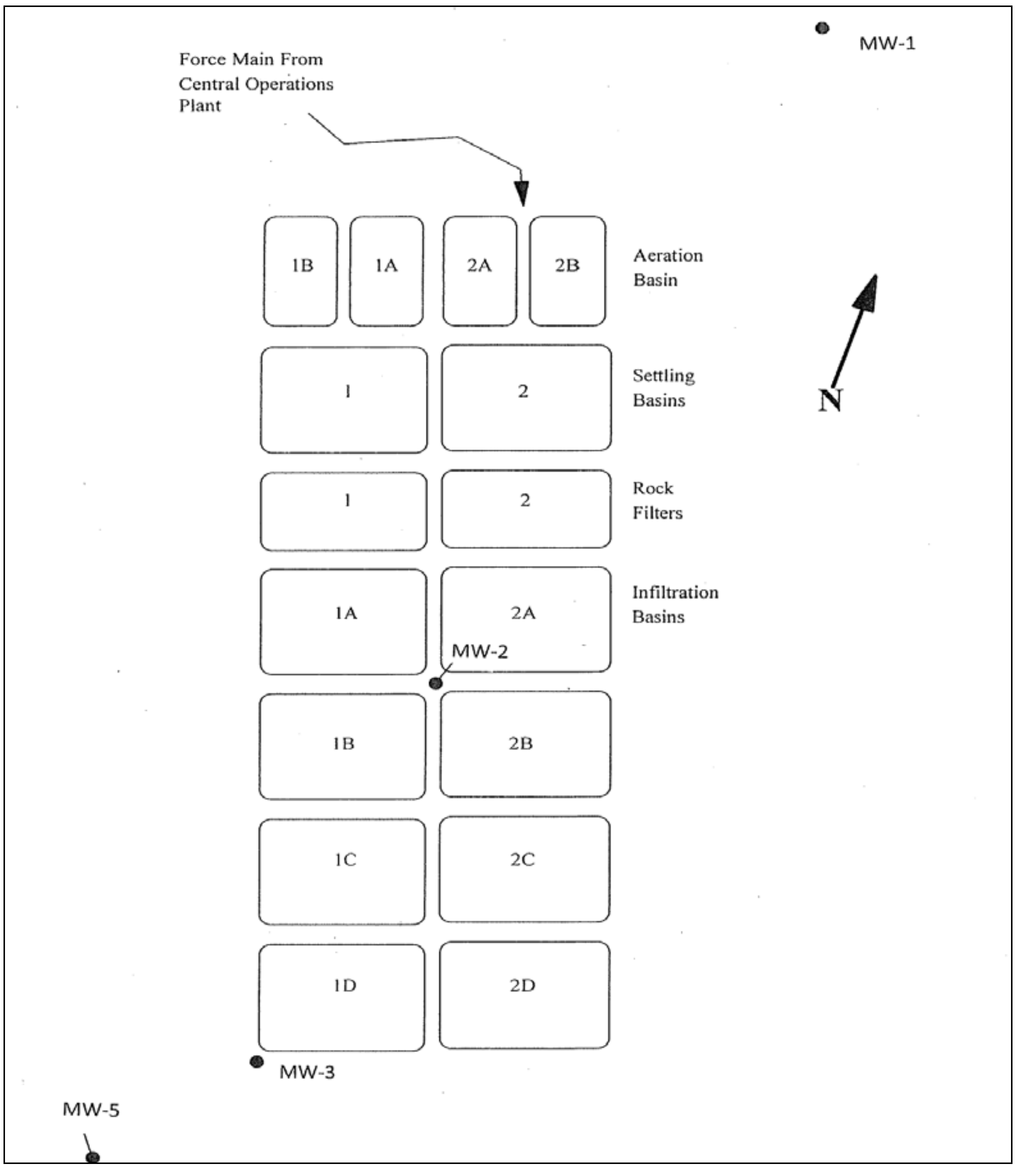

Figure 6. Location of Dunes WWTP monitoring wells (Sinclair, 1999).

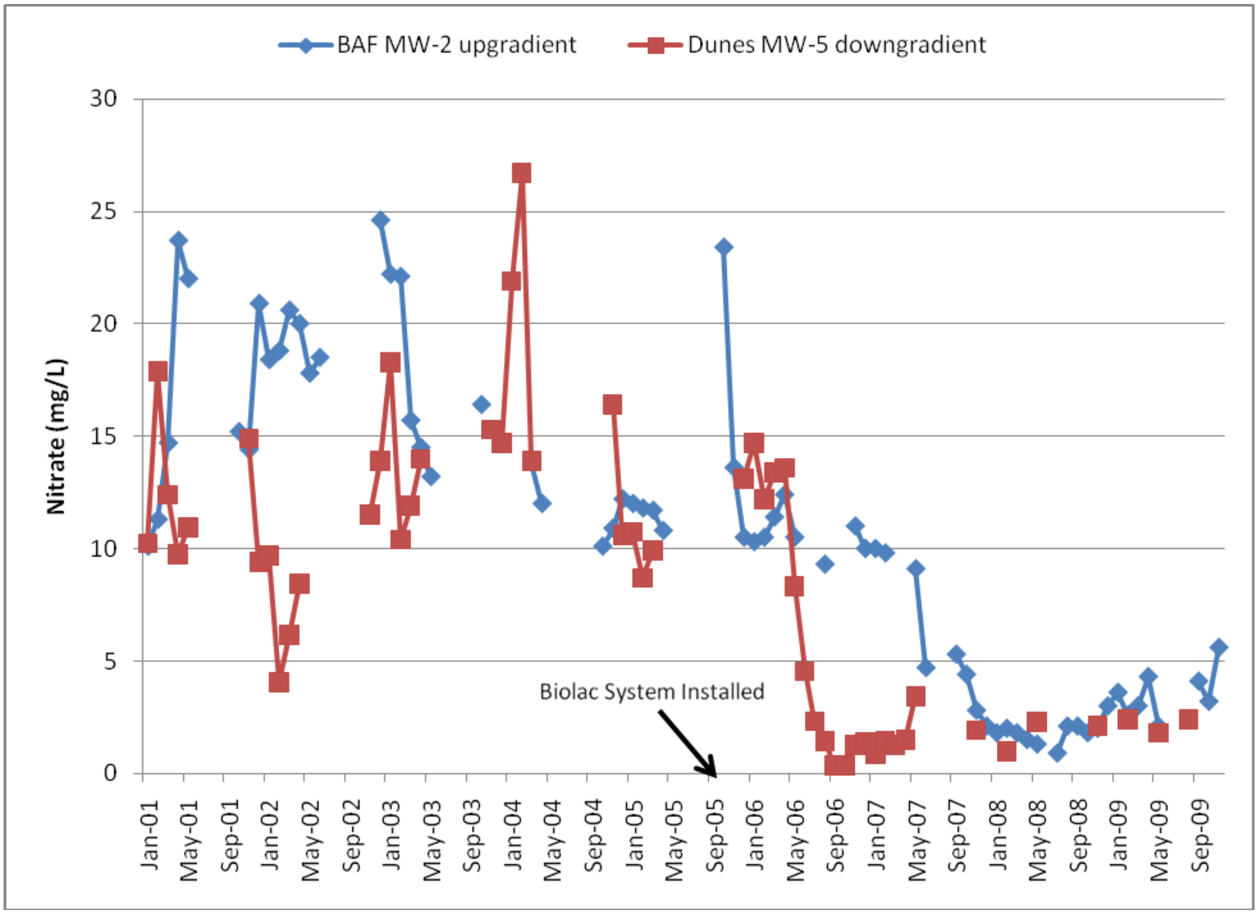

Figure 7. Dunes WWTP downgradient well (MW-5) and BAF upgradient well (MW-2) nitrate concentrations.

Figure 7 illustrates groundwater nitrate trends at the Dunes MW-5 downgradient well and BAF's MW-2 upgradient monitoring well, which are closely located. The declining nitrate concentrations in these graphs coincide with the installation of a Biolac® treatment system (which provides nitrogen removal) at the Dunes WWTP. Additionally, Figure 9 illustrates the wastewater quality improvements in the Dunes WWTP effluent.

The Dunes WWTP effluent has an average maximum TDS concentration of 576 mg/L, with a range of 293 – 680 mg/L. The State Waste Discharge Permit effluent limit for TDS is 1000 mg/L. This limit was established through an overriding public interest determination conducted under WAC 173-200-050(3)(b)(vi). BAF has an average FDS concentration of 626 mg/L, with a range of 291 – 908 mg/L (Figure 8).

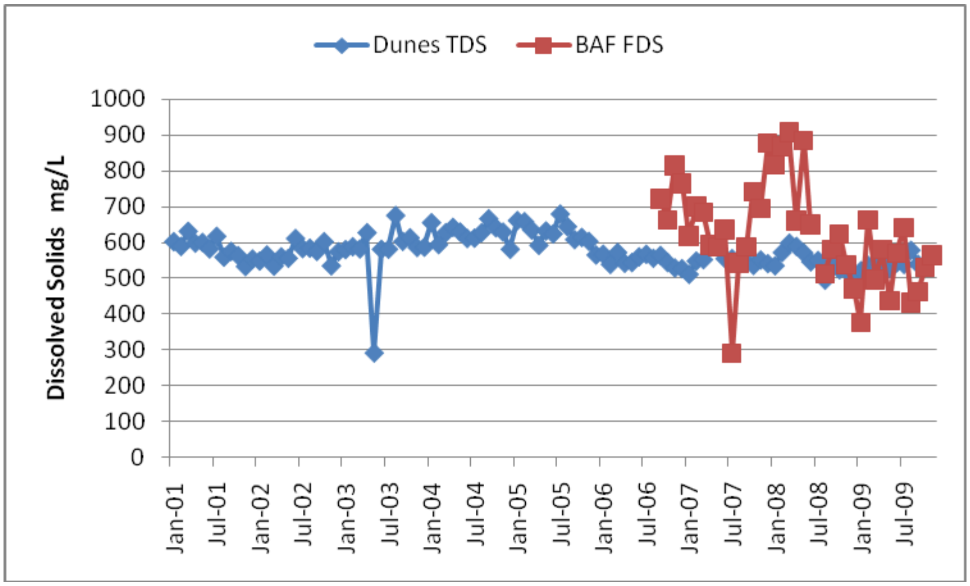

Figure 8. BAF effluent fixed dissolved solids (FDS) concentrations and Dunes WWTP total dissolved solids (TDS) concentrations.

Upgradient Sources

Irrigated agriculture is the predominant land use in this area. While it is difficult to discern whether groundwater has been impacted by agriculture or another source, the Groundwater Quality Standards attempt to account for this occurrence by establishing enforcement limits which protect background water quality. This provision is included in the standards to prevent one facility from being responsible for another facility's (or activity's) impacts to the environment (Kimsey, 1996). This protection is realized through the establishment of a background water quality well, which indicates the quality of groundwater entering a property at the upgradient boundary.

At BAF there are two monitoring wells (MW-1 and MW-12) which are identified as upgradient wells (Uhlman and Coffan, 2001). The MW-1 average nitrate concentration was 2.0 mg/L from 2001 through 2009. Nitrate concentrations below 3 mg/L are generally regarded as unimpacted by anthropogenic sources (Hem, 1989).

Monitoring well MW-12 is downgradient of agricultural activities. The average nitrate concentration in MW-12 was 6.9 mg/L and the average TDS concentration was 416 mg/L. These higher background concentrations may reflect upgradient agricultural uses which have contributed to groundwater degradation, and could be the basis for establishing background water quality at BAF.

MW-2 is also an upgradient BAF monitoring well; it is located directly downgradient of the Dunes WWTP. This well could be used to establish background water quality which has been impacted by the WWTP.

Past BAF Practices: Hydraulically Overloading the Fields and Leveling the Sand Dunes

Past BAF practices are defined as the process wastewater management activities which occurred from 1966 until approximately 1991. During these years, BAF operated the original sprayfield area according to an Ecology accepted and permitted design. The sprayfield was managed by (1) saturating the soils with excessive hydraulic loads of process wastewater, (2) overloading the soils with chemical oxygen demanding substances (COD) to create anaerobic conditions which would denitrify the nitrogen in the wastewater, (3) allowing the soils to rest, and (4) creating aerobic soil conditions which would then nitrify the nitrogen in the soils. These practices were conducted on the original 206 acres, which are located in the northeast corner of the sprayfield. (Uhlman and Coffan, 2001)

From 1991 to 1998, BAF transitioned to a land treatment system with an expanded sprayfield and improved application methods. During the sprayfield expansion, the soils were disturbed as the sand dunes were leveled, and the wastewater distribution system was converted to an aerobic center pivot irrigation system.

In some areas, groundwater contamination can continue for years after a discharge ceases, due to residual soil nitrogen levels. When the sand dunes were leveled in 1993, the residual organic nitrogen was mineralized and migrated to groundwater. Maximum soil TKN was measured at 2,630 mg/kg in 1988. (Uhlman and Coffan, 2001)

BAF made positive environmental steps over the last 20 years by discontinuing the practice of hydraulically overloading the sprayfield. BAF maintains that nitrogen losses from the soil into groundwater continue from the past practices of excessive hydraulic loading of wastewater.

The hydrogeologic study (Uhlman and Coffan, 2001) states that elevated groundwater concentrations would continue to occur during the transitional period when the excessive nitrogen soil concentrations would leach over time. However, after two decades of continued improved wastewater management practices, nitrogen concentrations in groundwater continue to remain elevated, exceeding (not meeting) the Groundwater Quality Standards.

Current BAF Practices

BAF process wastewater TKN concentrations have improved, as indicated by the linear trendline on Figure 9. This illustration shows a decline in TKN values from approximately 62 mg/L in January 2001, to approximately 46 mg/L in December 2009. Additionally, the Mann-Kendall test for trends also indicates a statistically significant decreasing trend, (Appendix D, Figure D.1).

While there has been an improvement in the BAF TKN effluent concentrations, these values are still higher than the mean Dunes WWTP effluent concentration, which is 11.7 mg/L (Table 4). Prior to the Dunes WWTP upgrade in October 2005, the mean TKN value in the effluent was 19 mg/L, which is significantly lower than the nitrate concentrations in BAF's downgradient monitoring wells.

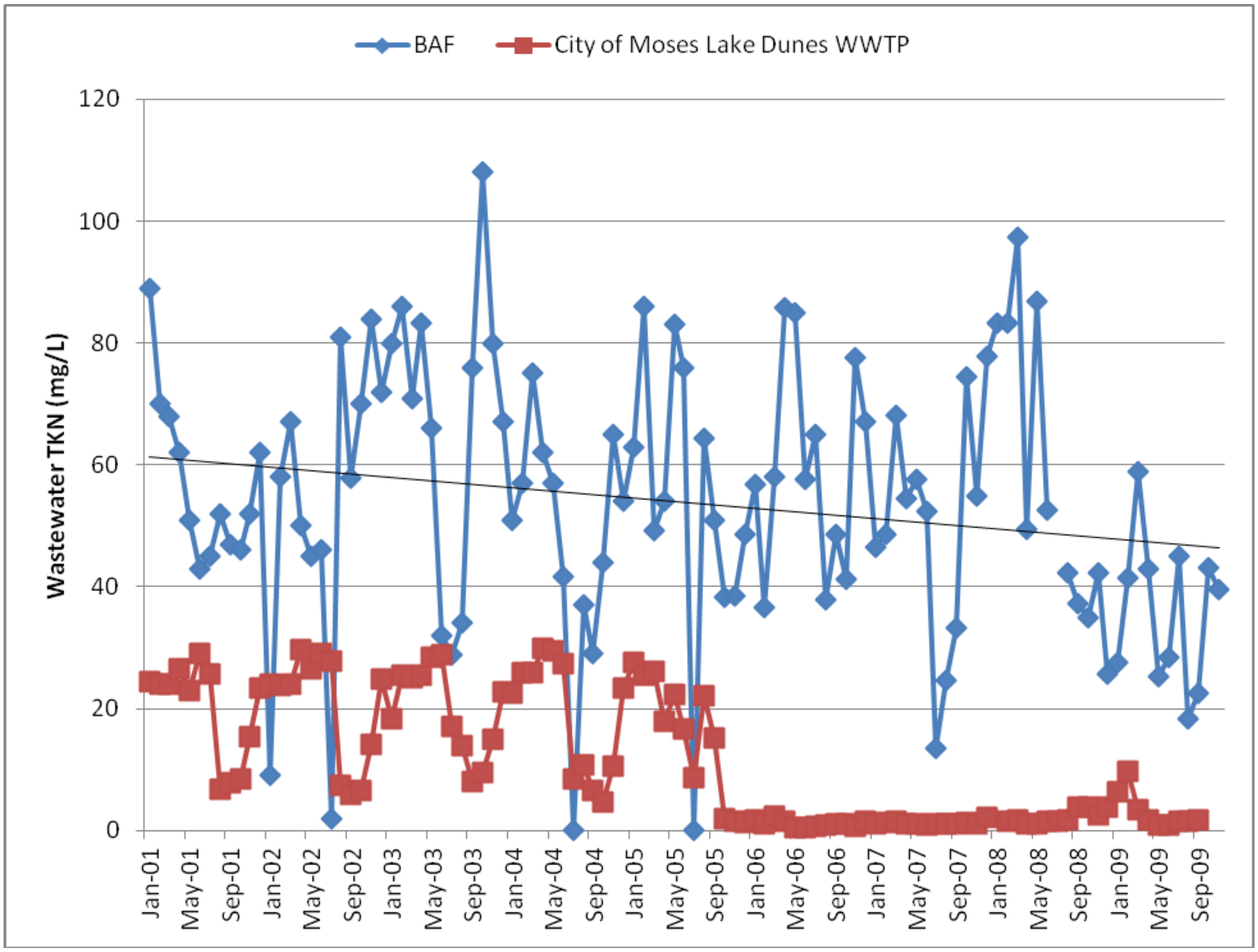

Figure 9. BAF and Dunes WWTP wastewater total Kjeldahl nitrogen (TKN) concentrations.

Table 4. Summary statistical comparison of total Kjeldahl nitrogen (TKN) data (mg/L) from BAF and the Dunes WWTP, January 2001 through December 2009.

Facility	Mean	Maximum Value	Minimum Value	Trend
BAF (2001-09)	54	108	0.1	↓
Dunes WWTP (2001-09)	11.7	29.8	0.4	↓
Dunes Pre-plant upgrade 2001-05	19.05	29.8	1.4	ND
Dunes Post-plant upgrade 2005-09	1.79	9.7	0.4	ND

ND: Not determined.

Comparing discharge data from the Dunes WWTP as it enters the environment to BAF process wastewater data as it enters the environment provides an opportunity to compare relative impacts to the environment. BAF utilizes a land treatment system which also provides the opportunity for crop uptake and contaminant attenuation.

BAF has historically generated more nitrogen in their wastewater than the Dunes WWTP (Figure 9 and Table 4). Groundwater quality beneath the BAF sprayfield also has contained higher concentrations of nitrate than the areas underlying the Dunes WWTP or the upgradient agricultural areas. Downgradient monitoring wells at the BAF site contain nitrate concentrations which exceed the groundwater quality criterion of 10 mg/L. The average nitrate concentration in MW-10 is 51 mg/L; this is the most downgradient BAF monitoring well.

Soil Retention of Contaminants

There are a number of factors affecting the retention of contaminants in soils. These include chemical properties of the soils, cation exchange capacity of the soils, climatic conditions, and quality of the wastewater.

Phosphorus

Phosphorus is an essential nutrient for plant growth. Excessive amounts of phosphorus can promote algae growth and cause eutrophication of waterbodies (Hem, 1989). Phosphorus has traditionally been assumed to be immobile in the subsurface and therefore not a contaminant of concern for groundwater. However, case studies indicate that phosphorus can be carried long distances in the subsurface. Walter (1995) found elevated phosphorus concentrations (> 0.05 mg/L) in groundwater over 3000 feet downgradient in a sand and gravel aquifer. Hem (1989) determined that orthophosphate is the dominant phosphorus species in groundwater. Elevated orthophosphate in groundwater may be due to exhaustion of the attenuation capacity of the soils, desorption, or dissolution.

Zanini (1998) determined that phosphorus concentrations in groundwater were highest in coarse grained calcareous sediments. pH buffering of calcium carbonate prevents acidic conditions and promotes phosphate sorption. Redox conditions also affect adsorption. Under oxidizing conditions, iron and manganese provide sorption sites for phosphorus. Reducing conditions release iron and manganese and reduce the number of sorption sites available. Change in the soil redox conditions can be caused by the application of organic-rich wastewater.

Phosphorus concentrations in BAF effluent averaged 15 mg/L with a range of 6 to 67 mg/L. Phosphorus concentrations in the Dunes WWTP effluent were typically around 3 mg/L with a range of less than 1 to 10 mg/L. Phosphorus was detected in groundwater in the monitoring wells at the Dunes WWTP (2001 data) at approximately 0.1 to 0.2 mg/L. Tables F-3 and F-4 in Appendix F contain the water quality data for the Dunes WWTP.

Cation Exchange Capacity (CEC)

The higher the CEC value, the more positively charged nutrients and salts can be stored in the soil profile. The CEC value for sand is very low, typically ranging from 3 to 5 milliequivalents (meq)/100g. The capacity of a soil to adsorb and desorb cations depends on the total number of negatively charged sites available. (Hem, 1989) Some ions sorb to soils more readily than others. BAF's process wastewater contains organic matter, which aids in developing soil adsorption sites.

Qui et al. (2005) conducted a site evaluation for the BAF facility and reviewed the regulatory documents and data generated by BAF. They noted that the sand content of the soil is high with an average of 85% (range 70% to 90%), and low in organic matter (range 0.2% to 0.6%). This results in low CEC with an average of 6.6 meq/100g and ranging from 4.8 to 9.7 meq/100g. Qui et al. (2005) concluded that the low CEC soil is readily saturated by NH_4^+ and other easily adsorbed ions.

They noted that the elevated potassium load in the process wastewater competes with NH_4^+ for sorption sites. The average soil potassium concentrations in the top foot of the soil have not changed substantially since 1994 and remain approximately 600 mg/kg. The potassium levels at the 2.5 foot depth have been steadily increasing. Qui et al. (2005) interpret these soil characteristics as an indication that the CEC above the 2.5 depth probably has been exceeded. They conclude that if the CEC is exceeded, there is a high probability that NH_4^+ will leach to groundwater when the facility is applying process wastewater during the winter months for salt leaching.

Nitrification

Nitrification is temperature dependent. In the winter when temperatures are low, nitrification is thought to be insignificant. Theoretically, the organic nitrogen that is land applied during the non-growing season should be retained in the soils and available in the spring as the temperature increases. However, as the springtime temperatures rise, nitrification of soil nitrogen occurs rapidly, when crop growth is low and the ability to uptake nitrogen is also low. This creates a risk that nitrate will leach and migrate to groundwater. Qui et al. (2005) concluded that year-round application of process wastewater is probably fine for winter, but not justifiable for late spring.

Sodium Adsorption Ratio (SAR)

SAR is a measure of the suitability of water for use in agricultural irrigation, as determined by the concentrations of solids dissolved in the water. Although SAR is only one factor in determining the suitability of water for irrigation, in general, the higher the sodium adsorption ratio, the less suitable the water is for irrigation. Irrigation water with a high sodium adsorption ratio may require soil amendments to prevent long-term damage to the soil.

The formula for calculating the sodium adsorption ratio is:

$$SAR = [Na^+] / \{([Ca^{2+}] + [Mg^{2+}]) / 2\}^{1/2}$$

where sodium, calcium, and magnesium are in meq/liter (Hem, 1989).

Using the mean wastewater concentrations from BAF's wastewater from January 2001 through December 2009, the resulting SAR is 0.48. Technical guidance (Hem, 1989) indicates that there is not excessive sodium in the wastewater, which might have impacted soil structure or plant growth.

Salt Leaching

The need to leach accumulated salts from the soils is the main reason that BAF is employing year-round application of wastewater. There is an increased risk of nitrate being leached to groundwater when additional process water is used to promote leaching of salts.

BAF's process wastewater contains an average of 823 mg/L of TDS, while fresh irrigation water in the area contains an average of 556 mg/L of TDS. Use of process wastewater for salt leaching is counterproductive to the goal of improving the soil condition, since the additional load of salt from the wastewater will increase the salt content in the soil, which in turn increases the leaching requirement. (Qui et al., 2005) Best management practices (BMPs) for salt leaching recommend using freshwater or precipitation. This avoids introducing additional salts and other contaminants which are also present in the wastewater. Precipitation typically contains 15 mg/L of TDS. (Hem, 1989)

Soil salinity is a recognized issue which needs to be addressed to maintain the health of the soils; however, soil management measures must be consistent with the Groundwater Quality Standards (Chapter 173-200 WAC). The need to leach salts from the soil is not an acceptable reason to contaminate groundwater.

Groundwater Velocity

The average hydraulic conductivity of the surficial glacio-fluvial aquifer is 240 ft/day (Whiteman, 1994). Pitz (2003) cites a hydraulic conductivity range in the Moses Lake area as 2800 to 28,000 ft/day, with an average seepage velocity of 1100 ft/day. Based on the size of the sprayfield and the average groundwater hydraulic conductivity, the hydraulic gradient, and the mobility of nitrate and chloride in groundwater, it is concluded that the contamination from past practices should have migrated off-site within six years of BAF facility improvements. This has not occurred. Given the extensive period of time that BAF has had to make improvements to their facility and operations, there should be documented improvements to groundwater quality. Since groundwater remains contaminated with no significant improvements in groundwater quality trends (Appendix D, Tables 2 and 3), additional action must be taken to improve groundwater quality.

Qui et al. (2005) estimated in a Technical Review of BAF's land treatment system that it would take three years for chloride and nitrate ions to migrate from the Dunes WWTP downgradient and off-site of the BAF sprayfield. Uhlman and Coffan (2001) estimated in the BAF Hydrogeologic Study that it would take 36 years for contaminated groundwater to migrate off-site.

In some areas, groundwater contamination can continue for years after a discharge ceases, due to elevated soil nitrogen levels. However, when the Dunes WWTP made improvements to their system in 2005, dramatic improvements to groundwater quality were recorded in downgradient monitor wells within nine months.

Unfortunately, nitrate concentrations remain elevated at BAF downgradient monitoring wells, with MW-10 showing a stable trend over the comparative period, 2001 to 2009 (Appendix D, Figure D.8).

Conclusions

AKART[4] for land treatment of industrial wastewaters is typically defined, in part, as agronomic application during the growing season and discharge to a lined lagoon to contain process wastewater generated over the winter when crops are dormant. Previously Ecology has also considered other options for managing excess wastewater including discharge to a surface waterbody and discharge to a publicly owned treatment works (POTW). Ecology will also consider site specific demonstrations of innovative approaches to achieving treatment that are determined to be equivalent in effectiveness for protecting groundwater quality as the current AKART approach. (Ecology, 2004)

The current AKART definition was developed to address the many uncertainties and potential negative consequences to groundwater quality associated with excessive nitrogen which is land applied during the non-growing season. Ecology develops guidance to assist in making efficient, consistent, and technically sound decisions. This guidance, in conjunction with environmental monitoring, is the basis for determining compliance with water quality laws and regulations.

The innovative treatment technology that the BAF facility, near the city of Moses Lake, has been employing was evaluated. Ecology has determined that the current land treatment system is not protective of groundwater quality, and therefore the determination is that it is not equivalent to AKART. Consequently BAF must modify their treatment technology. AKART for BAF must include (1) agronomic application of process wastewater during the growing season and (2) a lined lagoon for winter storage of process wastewater, an approved discharge to surface waters, or an approved discharge to a POTW.

Sources of Groundwater Contamination

Based on the analyses of nitrogen loading and management practices of contaminant sources in the area, it is determined that BAF is the predominant source of nitrate load to the subsurface. All other nitrate sources, including the Dunes WWTP and other upgradient agricultural activities, have impacts that are below the 10 mg/L groundwater standard. BAF continues to discharge process wastewater with a mean total Kjeldahl nitrogen (TKN) value of 54 mg/L. The continued elevated nitrogen concentrations in the BAF downgradient monitoring wells are a result of their own process wastewater management. The continued elevated nitrogen concentrations beneath the sprayfield site likely represent historical accumulations resulting from mineralization of soil nitrogen. This accumulated soil nitrogen is the result of historic overloading from previous BAF management. BAF continues to land apply year-round, providing loading to the land when crops are dormant and cannot utilize the existing soil nitrogen.

Past BAF practices ended approximately 20 years ago. Based on the stratigraphic and hydrogeologic characteristics of the aquifer, the groundwater contamination plume from past practices should have already migrated off-site as cleaner process water has infiltrated into the subsurface and better quality upgradient groundwater migrates under the site. The continued

[4] All known, available, and reasonable methods of prevention, control, and treatment.

elevated nitrate concentrations in the downgradient monitoring wells indicate that groundwater contamination is still occurring.

Groundwater in the area has been impacted by total dissolved solids contamination from multiple sources including agriculture, the Dunes WWTP, and BAF.

Soil Retention of Contaminants

The year-round land application of process wastewater is not an effective or reliable wastewater management tool at this site. The cation exchange capacity of aeolian deposits is low. Phosphorus and potassium concentrations in the wastewater are significant, creating a situation where other easily adsorbed ions occupy the limited cation exchange sites. Other contaminants in the wastewater, such as the nitrogen species, can remain mobile and migrate through the subsurface towards groundwater. Therefore, it is not advisable to (1) store nitrogen in the soils during the winter months when crops are dormant and (2) assume the nitrogen will remain available to crops during the growing season.

Containment of the Contaminant Plume

The EPA groundwater containment protocol for cleanup sites entails design, assessment, and evaluation of groundwater quality and the containment system. Containment of a groundwater contamination plume is not assured through the centrally located BAF irrigation wells, which pump only 59% of the year. The well construction, positioning of wells, and timing of the pumping of wells do not meet the requirements to adequately assure containment of the contaminant plume. Completion of BAF irrigation wells in the lower basalt aquifer is not conducive to containment of contaminants in the upper surficial aquifer.

The groundwater contamination caused by BAF's wastewater discharge is not adequately contained by BAF's irrigation wells.

Salt Leaching

BAF's statement that salt leaching necessitates year-round land application of process wastewater (Burgard, 2003) is not a technically valid reason to contaminate groundwater. Additionally, this is not considered a typical or accepted practice for land treatment systems in Washington State. Additional nitrogen is migrating to groundwater when BAF uses process wastewater, which contains elevated salts to control soil salinity by leaching salt from the root zone. If it is determined that salt leaching is necessary, then it should be conducted consistent with established best management practices (BMPs) using precipitation or fresh irrigation water.

Groundwater Contamination

Groundwater is contaminated beneath the BAF sprayfield site. The Washington State Groundwater Quality Standard for nitrate is 10 mg/L. This regulation (Chapter 173-200 WAC) contains an antidegradation policy, which ensures the protection of the state's groundwaters and the natural environment. Antidegradation protects background water quality and prevents degradation of the state's waters beyond criteria. Groundwater quality has been documented to be consistently degraded at the BAF sprayfield. This is illustrated in Figure 10.

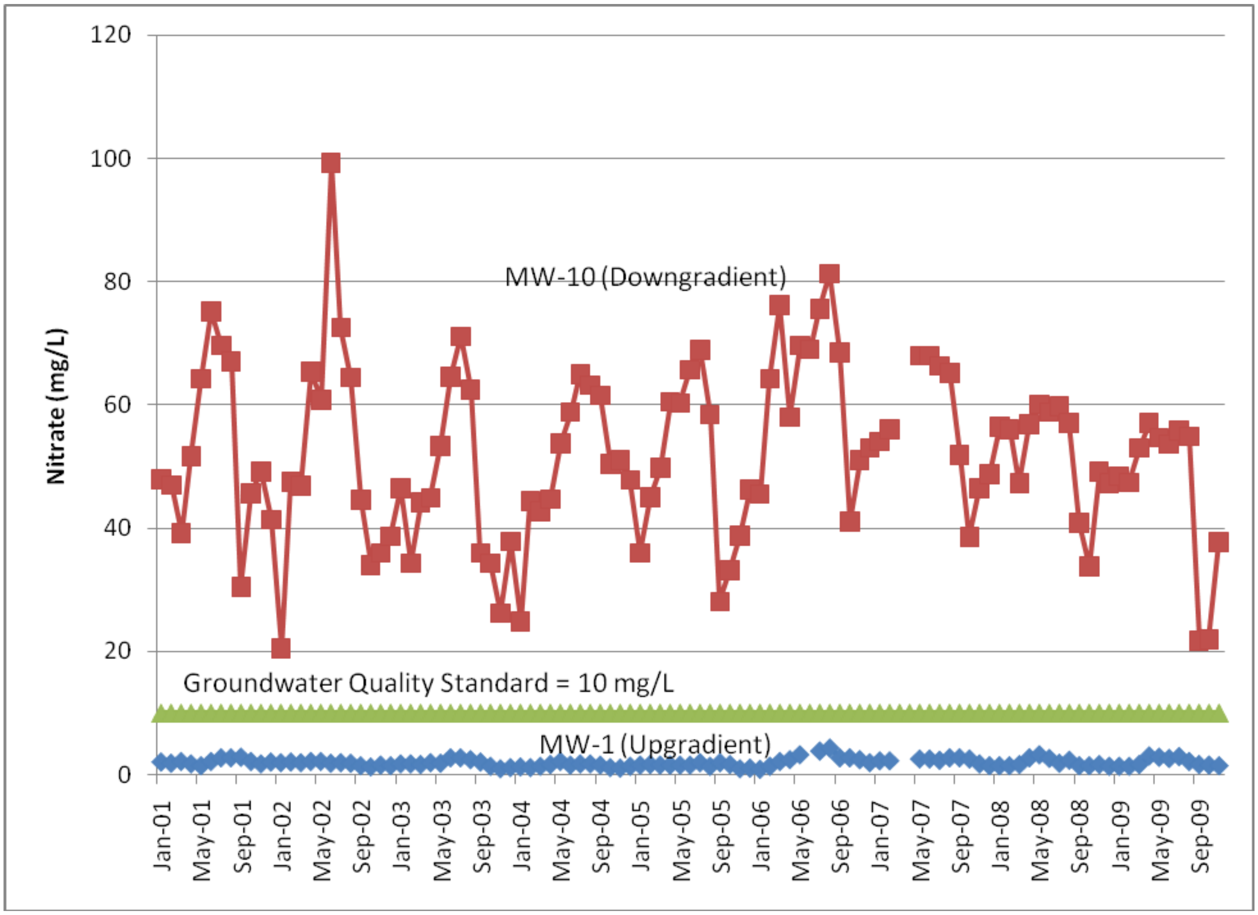

Figure 10. Nitrate concentrations in BAF's upgradient (MW-1) and downgradient (MW-10) wells in comparison to the Washington State Groundwater Quality Standard.

BAF has made significant improvements over the last 20 years by increasing their acreage, reducing the volume of their wastewater discharge, and enhancing their crop rotation. However, year-round land application of process wastewater has occurred at this site continuously since BAF began operations in 1966. If these improvements were adequate to achieve compliance with the Groundwater Quality Standards, then theoretically these should have translated into improvements to groundwater quality. Figures 11 and 12 illustrate that there have not been dramatic improvements in groundwater quality tied to BAF improvements in process wastewater management.

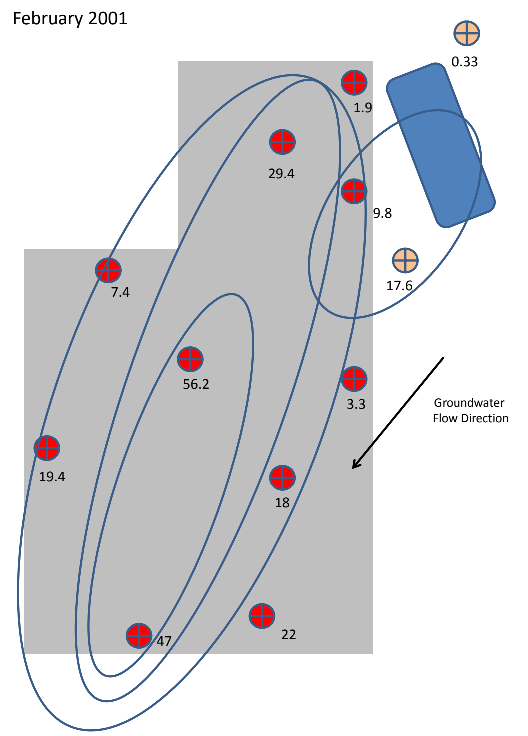

Figure 11. February 2001 groundwater nitrate concentrations (mg/L).

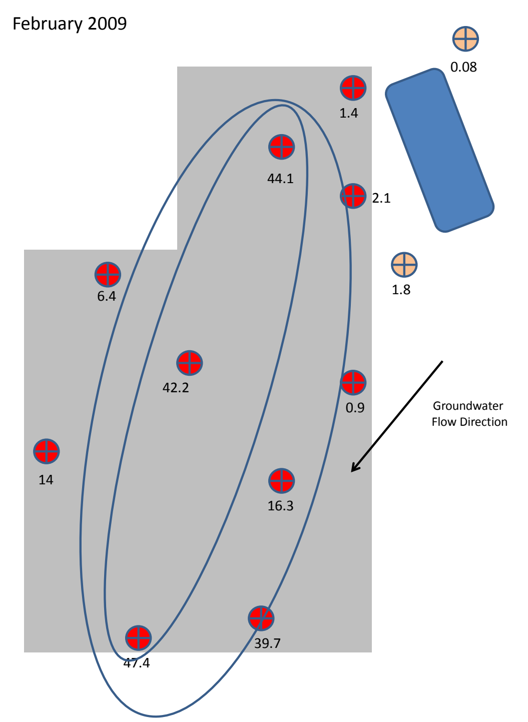

Figure 12. February 2009 groundwater nitrate concentrations (mg/L).

All of the information in this report indicates that BAF practices have contaminated groundwater in the past and continue to contaminate groundwater. This investigation did not substantiate BAF's claim that: *"Year-round application of wastewater provides greater or the equivalent degree of ground water protection"* (Burgard, 2003), and therefore should be considered AKART for their facility.

This investigation concludes that the innovative treatment which BAF has been using is not protective of groundwater. The fact that groundwater remains contaminated after numerous mitigative approaches and many years leads Ecology to conclude that it is imperative for BAF to take more protective measures to mitigate groundwater contamination. This can be achieved by only land applying process wastewater during the growing season. BAF needs to mitigate groundwater contamination through additional wastewater management measures. AKART for BAF near Moses Lake, Washington, limits their land application of process wastewater at agronomic rates only during the growing season. During the non-growing season, BAF cannot land apply their wastewater. Instead they have the options of using winter storage, discharging to a publicly owned treatment works, or discharging to a surface waterbody.

Permit Compliance Measures

BAF's recommended performance standards (Burgard, 2003) for assessing environmental impacts of their process wastewater are not protective of groundwater and are not adequate indicators of compliance with Washington State laws and regulations. Permit compliance measures should be adequate to evaluate impacts to the environment and determine compliance with the Groundwater Quality Standards.

Compliance with the Groundwater Quality Standards (Chapter 173-200 WAC)

BAF is not meeting the intent of antidegradation policy, they are not meeting the criterion at the point of compliance, and they are not using the Ecology recommended AKART for land treatment systems. If the treatment technology is not protective of groundwater, then additional treatment must be used to achieve compliance with Groundwater Quality Standards.

Recommendations

Continued nitrate contamination of groundwater at the BAF site needs to be addressed. Past and current improvements to BAF's facility operations have not resulted in successful remediation of groundwater quality. Proven precautionary measures which will protect groundwater quality are needed for this site.

Winter Storage

Groundwater degradation should be mitigated with the use of winter storage for BAF process wastewater. Winter storage (or the options of discharging to a publicly owned treatment works or discharging to a surface waterbody) is the safest choice for protecting groundwater quality at this location. Reports reviewed for this investigation and associated data indicate that contaminants in BAF's process wastewater are mobile and are impacting groundwater quality. Conservative steps, which are protective, need to be taken to mitigate continued degradation.

Because of past practices where BAF contaminated groundwater, BAF should be required to err on the side of caution to prevent additional contamination by using proven wastewater management measures. Agronomic application of wastewater should be based on crop needs. Winter storage of wastewater should be used during the non-growing season to avoid disposal of wastewater which will contaminate groundwater.

BAF has made significant improvements to their facility over the years, and they should continue to make improvements which will protect groundwater quality, and allow them to demonstrate compliance with Chapter 173-200 WAC.

Previously, Ecology also considered other options available for managing excess wastewater. (Ecology, 2004). These include:

- Storage in a properly constructed lined lagoon.
- Discharge to a surface waterbody in accordance with Chapter 173-201A WAC and Chapter 173-220 WAC.
- Discharge to a publicly owned treatment works (POTW) in accordance with Chapter 173-216 WAC.

Agronomic Application

Agronomic application includes applying the amount of nutrients that a crop needs to remain viable, but it also includes applying the nutrients at the proper time. Crops cannot uptake significant nutrients when they are dormant. Using average annual application rates are not protective.

Agronomic application considers hydraulic loading, salt loading, and nutrient (e.g., nitrate) loading. These three parameters must be assessed, and land application should be based on the design-limiting parameter.

Salt Leaching

Salt leaching should be conducted with freshwater or precipitation to minimize the re-introduction of salts to the soils. Ideally the freshwater used should contain minimal salts.

Soil salinity issues should be managed by using freshwater, rather than BAF process wastewater, since process wastewater contains significantly higher concentrations of salts (total dissolved solids) than precipitation or irrigation water. Additionally, using water low in total dissolved solids for leaching will reduce the soil salinity content and reduce the soil leaching requirement.

Soil Properties

The soil characteristics at the BAF site should be considered, along with the composition of the BAF wastewater. A low cation exchange capacity soil, such as a sand dune, does not have the ability to attenuate the complex suite of ions discharged at this site on a year-round basis.

Permit Compliance Measures

Using BAF's proposed approach for assessing environmental impacts of their process wastewater is not protective of groundwater. Instead, the following recommendations are made for the BAF facility:

- Groundwater quality must be monitored, and enforcement limits established, based on background water quality.
- Nitrogen loading must not be higher than the estimated treatment capacity of the site.
- The facility must achieve a stable or declining trend for the end-of-the-year soil nitrate profile for a progressive three-year period for each sprayfield.
- The facility must not exceed agronomic rates. (Application of wastewater during the non-growing season constitutes non-agronomic application.)
- The facility must be operated so that it will not cause a violation of the Washington State Groundwater Quality Standards.

Nitrate Contamination of Groundwater

In areas with documented groundwater contamination, the most protective and reliable measures should be put in place to prevent further degradation and mitigate existing nitrate contamination. Winter storage of wastewater and agronomic application of wastewater should be considered AKART in all areas of Washington State where there is documented groundwater contamination or areas susceptible to contamination.

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Appendices

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Appendix A. Glossary, Acronyms, and Abbreviations

Glossary

Adsorption: The adhesion of a substance to the surface of soil.

Aeolian deposits: Sediments that are deposited by wind (i.e., sand dunes).

Anthropogenic: Human-caused.

Antidegradation: Policy designed to ensure the protection of the state's groundwaters and the natural environment. Antidegradation protects background water quality and prevents degradation beyond the criteria. The antidegradation policy and AKART form the primary mechanisms for protecting groundwater quality.

Aquifer: A saturated permeable geologic unit that can transmit significant quantities of water under ordinary hydraulic gradients.

Aquitard: The less-permeable beds in a stratigraphic sequence. Aquitards often restrict vertical hydraulic movement.

Attenuation: A gradual diminishing in the strength of something.

Capture zone: The area surrounding a well that will supply groundwater to that well when pumped at a specified rate for a specified period of time.

Cation: A positively charged ion.

Conductivity: A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

Depth-to groundwater: A measure of depth to the water (i.e., water level) in a well.

Desorb: A process where a substance is removed from the surface of soil.

Discharge: The rate of streamflow at a given instant in terms of volume per unit of time, typically cubic feet per second.

Downgradient: The direction of flow, as defined by the hydraulic gradient.

Enforcement limits: Values assigned to a contaminant for the purpose of regulation under WAC 173-200-020(11). These limits assure that a criterion will not be exceeded and that background water quality will be protected.

Eutrophication: An increase in productivity resulting from nutrient loads from human conditions such as fertilizer runoff and leaky septic systems.

Groundwater: Water in the subsurface that saturates the rocks and sediment in which it occurs. The upper surface of groundwater saturation is commonly termed the water table.

Hydraulic gradient: The difference in hydraulic head between two measuring points, divided by the distance between the two points.

Hydraulic loading: Flows to a treatment process, such as a land application sprayfield.

Hydrogeologic: The distribution, characterization, and movement of groundwater in the soil and rocks below the earth's surface.

Leaching: The process of removing substances from the soil by percolating liquid. The downward movement of the water dissolves salts and nutrients and moves them through the soil.

Nitrate: The most common form of nitrogen found in groundwater.

Non-degradation: Non-degradation prohibits any increase in contaminant concentrations in groundwater. Non-degradation applies only in specific situations.

Nonpoint source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities, including but not limited to atmospheric deposition, surface water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the National Pollutant Discharge Elimination System (NPDES) program. Generally, any unconfined and diffuse source of contamination. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

Parameter: Water quality constituent being measured (analyte). A physical, chemical, or biological property whose values determine environmental characteristics or behavior.

Plume: Describes the three-dimensional concentration of particles in the water column (example, a cloud of sediment).

Point of compliance: The location where the groundwater quality enforcement limit shall not be exceeded. [WAC 173-200-020(21)]

Point source: Sources of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites that clear more than 5 acres of land.

Pollution: Contamination or other alteration of the physical, chemical, or biological properties of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or are likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Process wastewater: In this study, process wastewater is BAF wastewater containing varying concentrations of potato solids, starches, sugars, nutrients, and minerals.

Redox: Any chemical reaction which involves oxidation and reduction.

Sorption: The process in which one substance takes up (absorption) or holds another (adsorption).

Sprayfield: Land where wastewater is applied.

Subsurface: Beneath the land surface.

Upgradient: In hydrology, an *upgradient* location is one that exhibits a larger hydraulic head in comparison to a *downgradient* location. Water flows from areas of high hydraulic head to areas of low hydraulic head. Hydraulic head is the total pressure exerted by a water mass at any given point. Total hydraulic head is the sum of elevation head, pressure head, and velocity head.

Acronyms and Abbreviations

AKART	All known, available, and reasonable methods of prevention, control, and treatment.
BAF	Basic American Foods near Moses Lake, Washington
BMP	Best management practices
CEC	Cation Exchange Capacity
DMR	Discharge Monitoring Report
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
FDS	Fixed dissolved solids
GIS	Geographic Information System software
POTW	Publicly owned treatment works
RPD	Relative percent difference
SAR	Sodium Adsorption Ratio
TDS	Total dissolved solids
TKN	Total Kjeldahl nitrogen
USGS	U.S. Geological Survey
WAC	Washington Administrative Code
WRIA	Water Resource Inventory Area
WSU	Washington State University
WWTP	Wastewater treatment plant

Chemicals

Ca	Calcium
Cl	Chloride
HCO_3	Bicarbonate

K	Potassium
Mg	Magnesium
N	Nitrogen
Na	Sodium
NH_4^+	Ammonium
NO_3	Nitrate
NO_2+NO_3	Nitrate plus nitrate
P	Phosphorus
SO_4	Sulfate

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
d	day
ft	feet
g	gram, a unit of mass
gpd	gallons per day
kg	kilograms, a unit of mass equal to 1,000 grams
lbs	pounds
m	meter
meq	milliequivalents
mg	milligrams
mgd	million gallons per day
mg/L	milligrams per liter
s.u.	standard units
umhos/cm	micromhos per centimeter

Appendix B. Well Construction Summary

Table B-1. Construction Summary for BAF Wells and Dunes WWTP Wells.

Well ID	Well Type	Depth (feet)	Static Water Level (feet)	Elevation (feet)	Unit
Basic American Foods (BAF)					
MW-1	Monitoring	35	24	1155	sand
MW-2	Monitoring	52	38	1160	sand
MW-3	Monitoring	55	44	1154	sand
MW-6	Monitoring	41	27	1146	fractured basalt
MW-8	Monitoring	80	69	1143	sand
MW-9	Monitoring	75	63	1117	sand
MW-10	Monitoring	75	59	1100	sand
MW-11	Monitoring	75	62	1116	sand
MW-12	Monitoring	47	39	1125	fractured basalt
MW-13	Monitoring	44	33	1113	fractured basalt
14	Irrigation	160	40	1160	fractured basalt
43	Irrigation	286	65	1150	fractured basalt
40	Irrigation	130		1147	fractured basalt
30	Irrigation	272	69	1140	fractured basalt
29	Irrigation	80		1140	fractured basalt
32	Irrigation	172	67	1140	fractured basalt
24	Irrigation	118	38	1140	fractured basalt
37	Irrigation	259	82	1140	fractured basalt
35	Irrigation	170	60	1120	fractured basalt
33	Irrigation	137	32	1100	fractured basalt
34	Irrigation	162		1100	fractured basalt
77	Irrigation	145	52	1100	fractured basalt
36	Irrigation	149	67	1140	fractured basalt
38	Irrigation	275	69	1140	fractured basalt
15	Irrigation	190	22	1120	fractured basalt
45	Irrigation	265	70	1140	fractured basalt
44	Irrigation	275	67	1140	fractured basalt
Dunes Wastewater Treatment Plant (WWTP)					
MW-1	Monitoring	38.5	28	1156	sand
MW-2	Monitoring	29	26	1152	sand
MW-3	Monitoring	33	30	1153	sand
MW-4	Monitoring	34		1157	sand
MW-5	Monitoring	46	42	1157	sand

Appendix C. Chemical Concentration Time Series Graphs for BAF Monitoring Wells

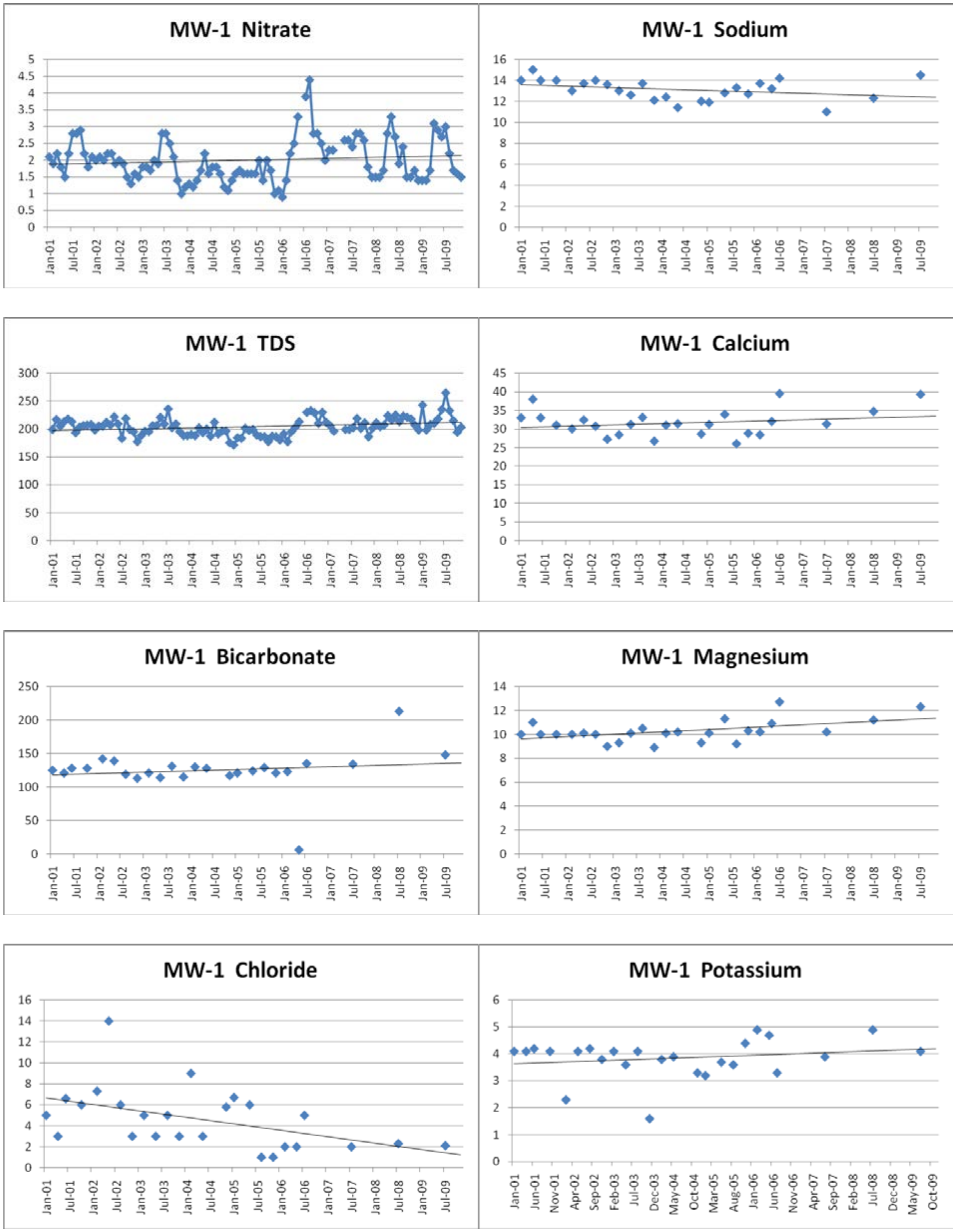

Figure C-1. MW-1 Chemical Concentration Time-Series Graphs.

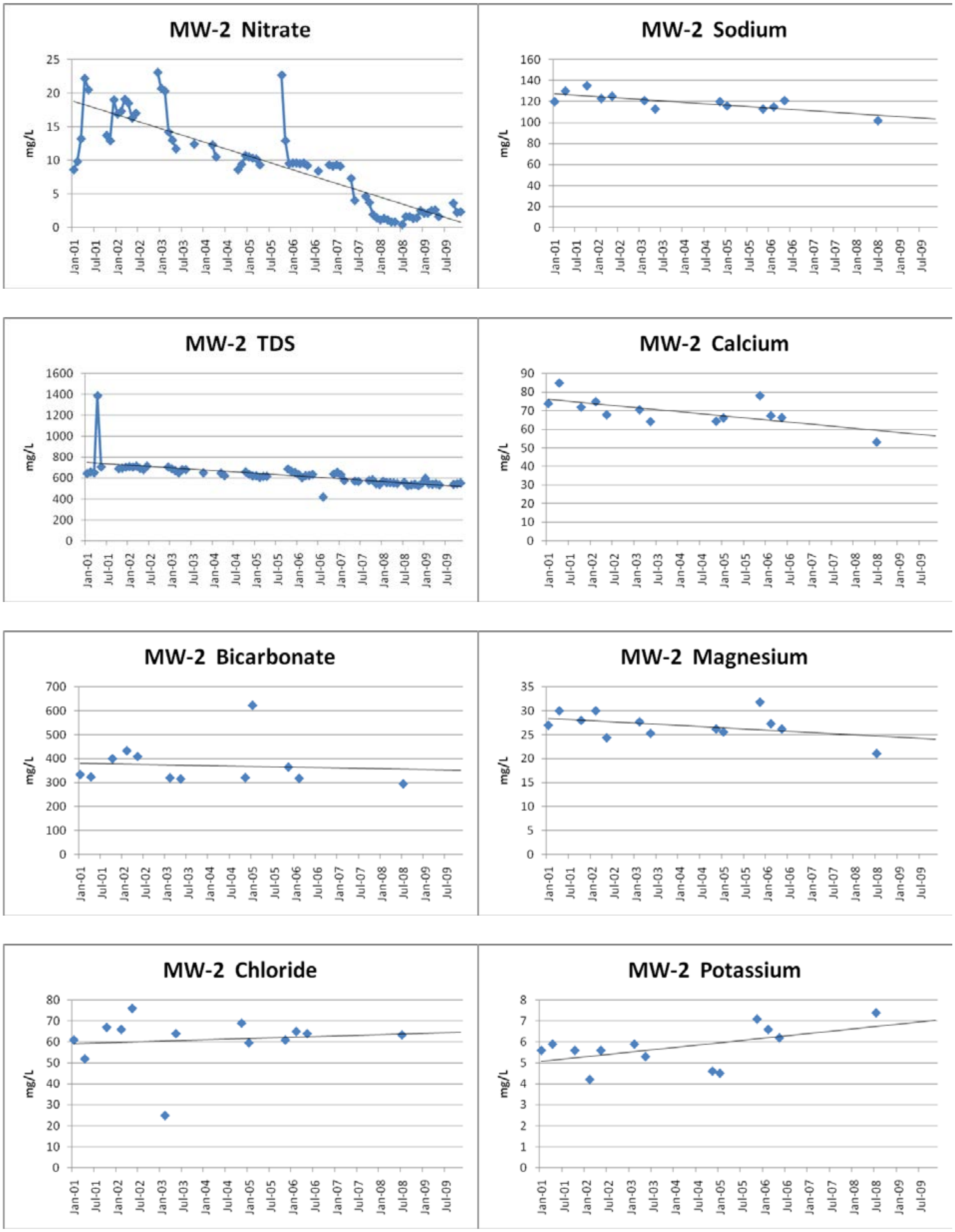

Figure C-2. MW-2 Chemical Concentration Time-Series Graphs.

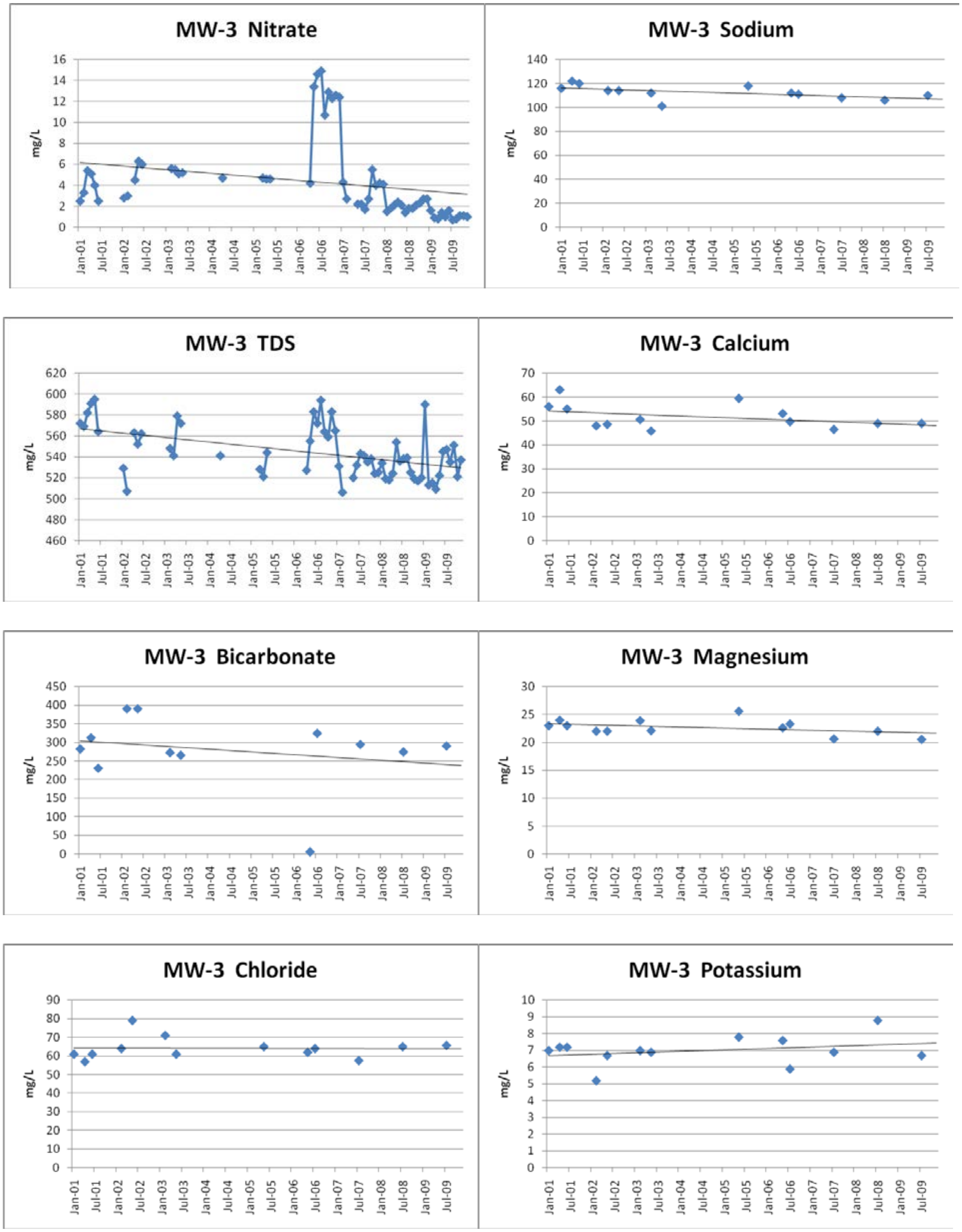

Figure C-3. MW-3 Chemical Concentration Time-Series Graphs.

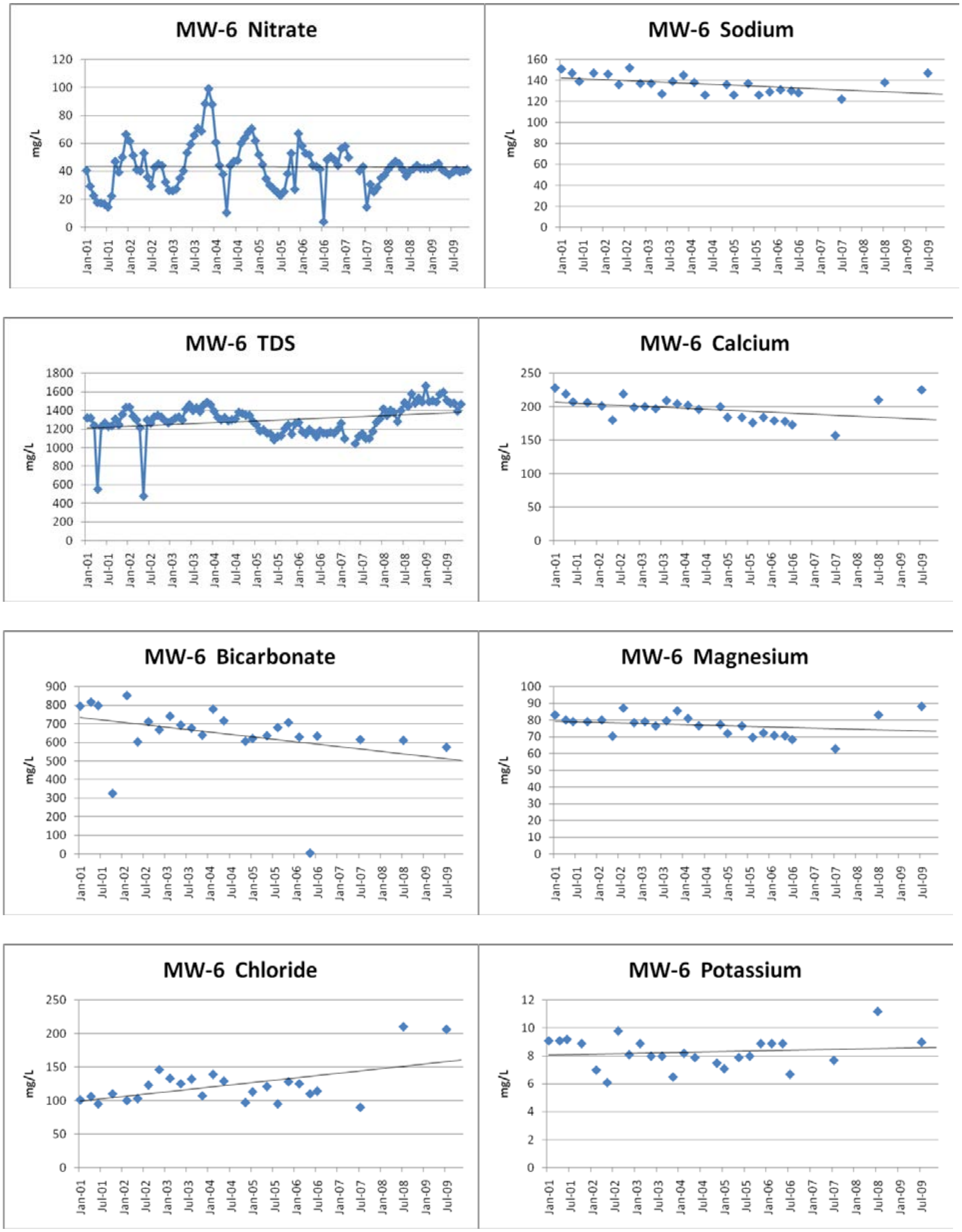

Figure C-4. MW-6 Chemical Concentration Time-Series Graphs.

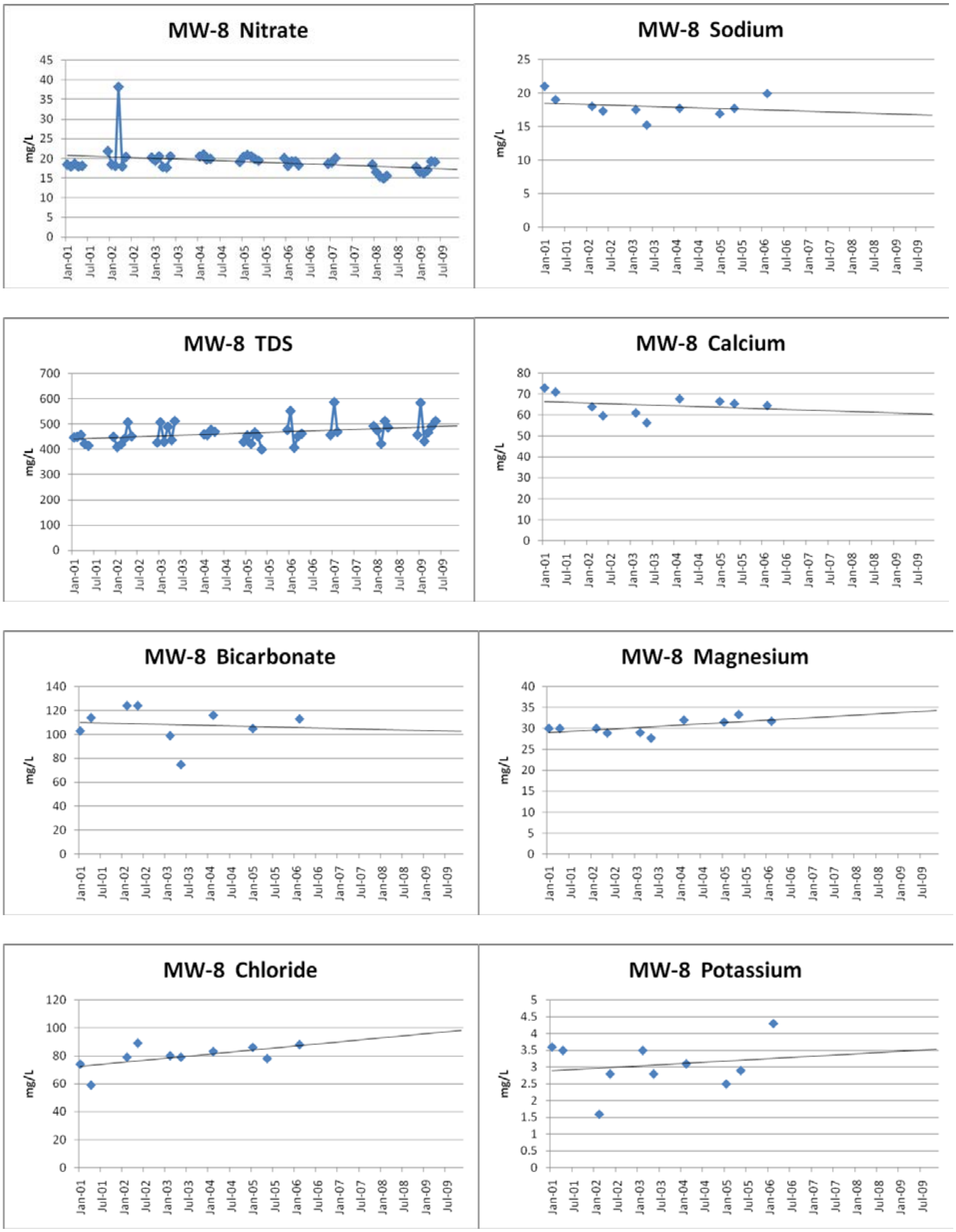

Figure C-5. MW-8 Chemical Concentration Time-Series Graphs.

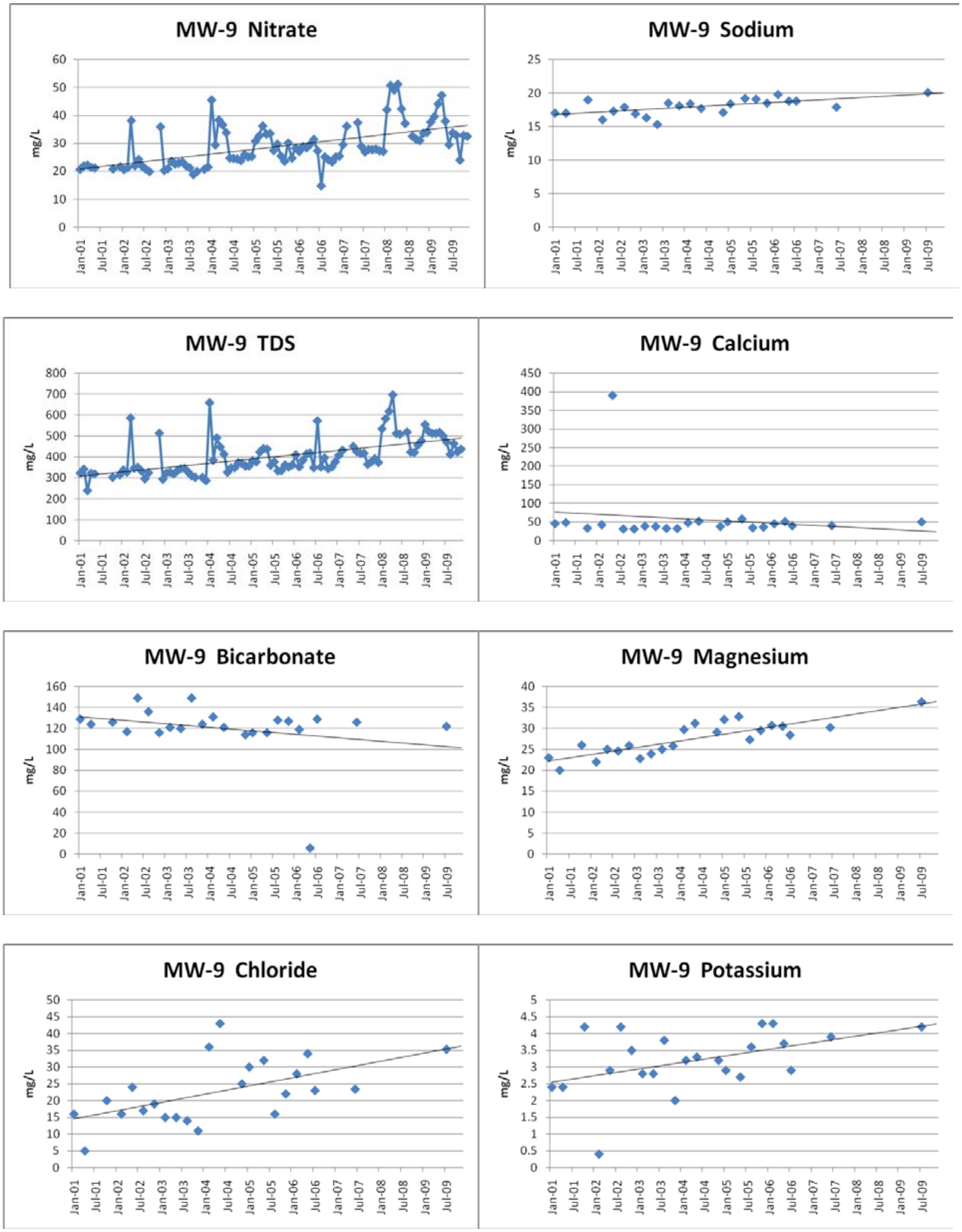

Figure C-6. MW-9 Chemical Concentration Time-Series Graphs.

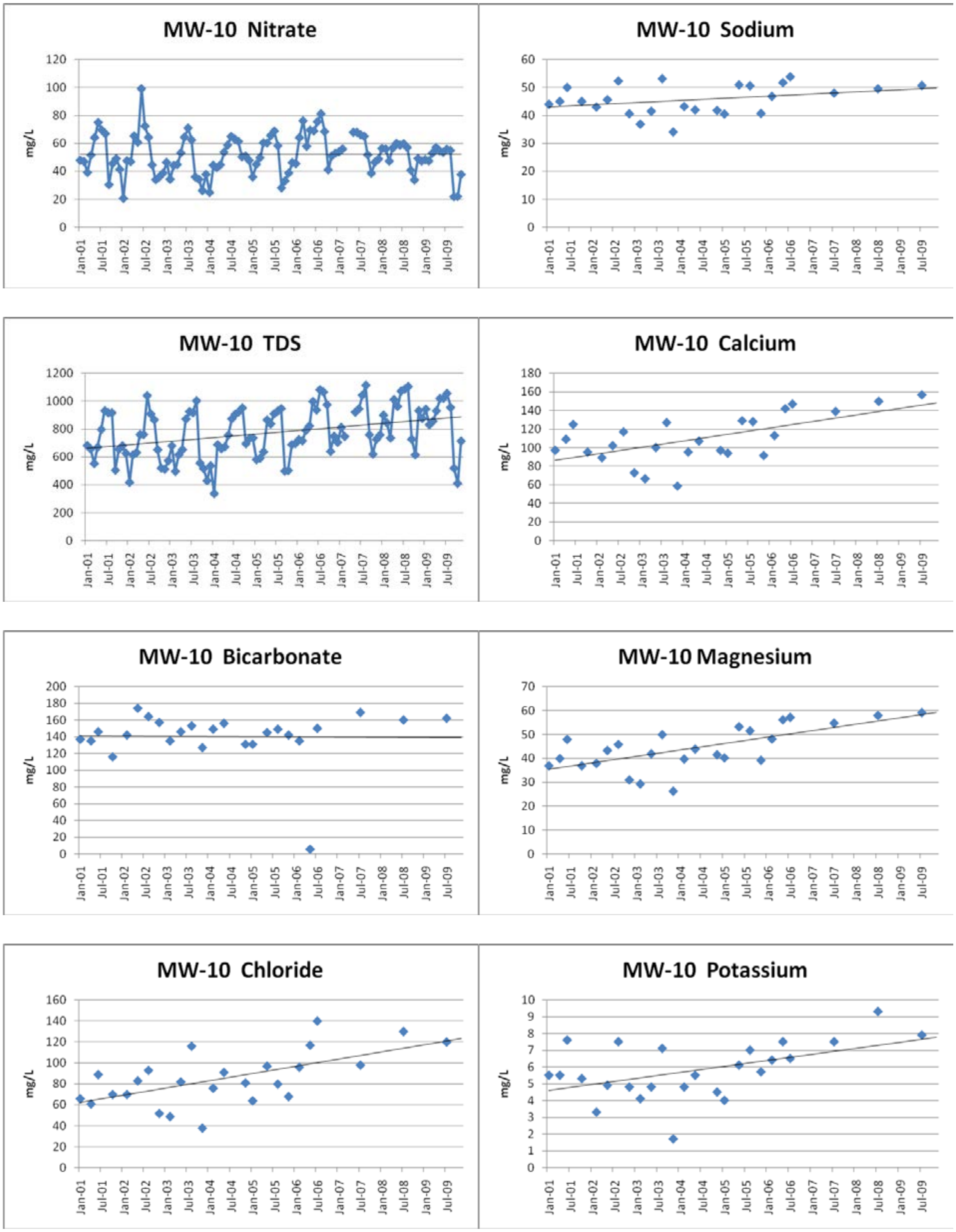

Figure C-7. MW-10 Chemical Concentration Time-Series Graphs.

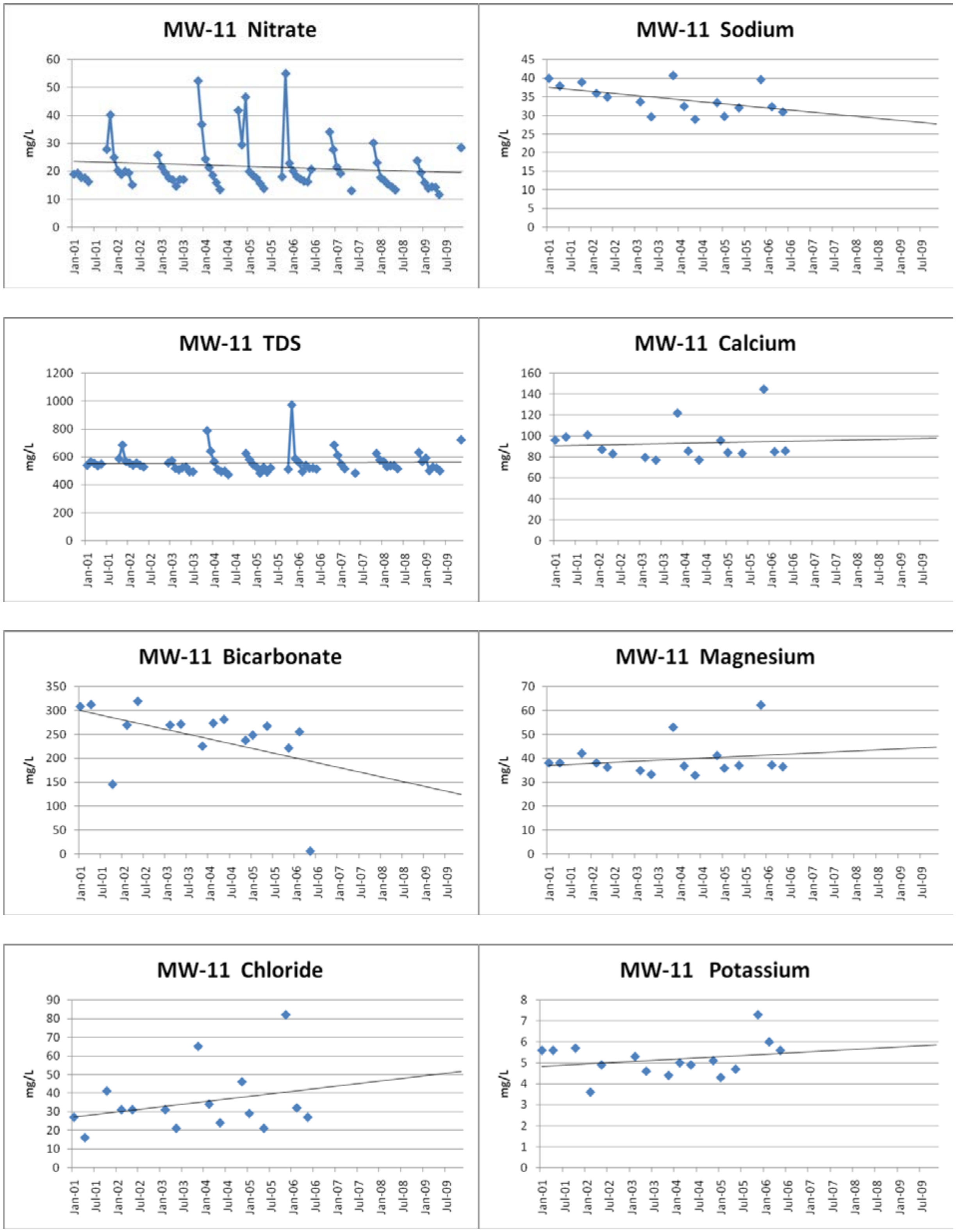

Figure C-8. MW-11 Chemical Concentration Time-Series Graphs.

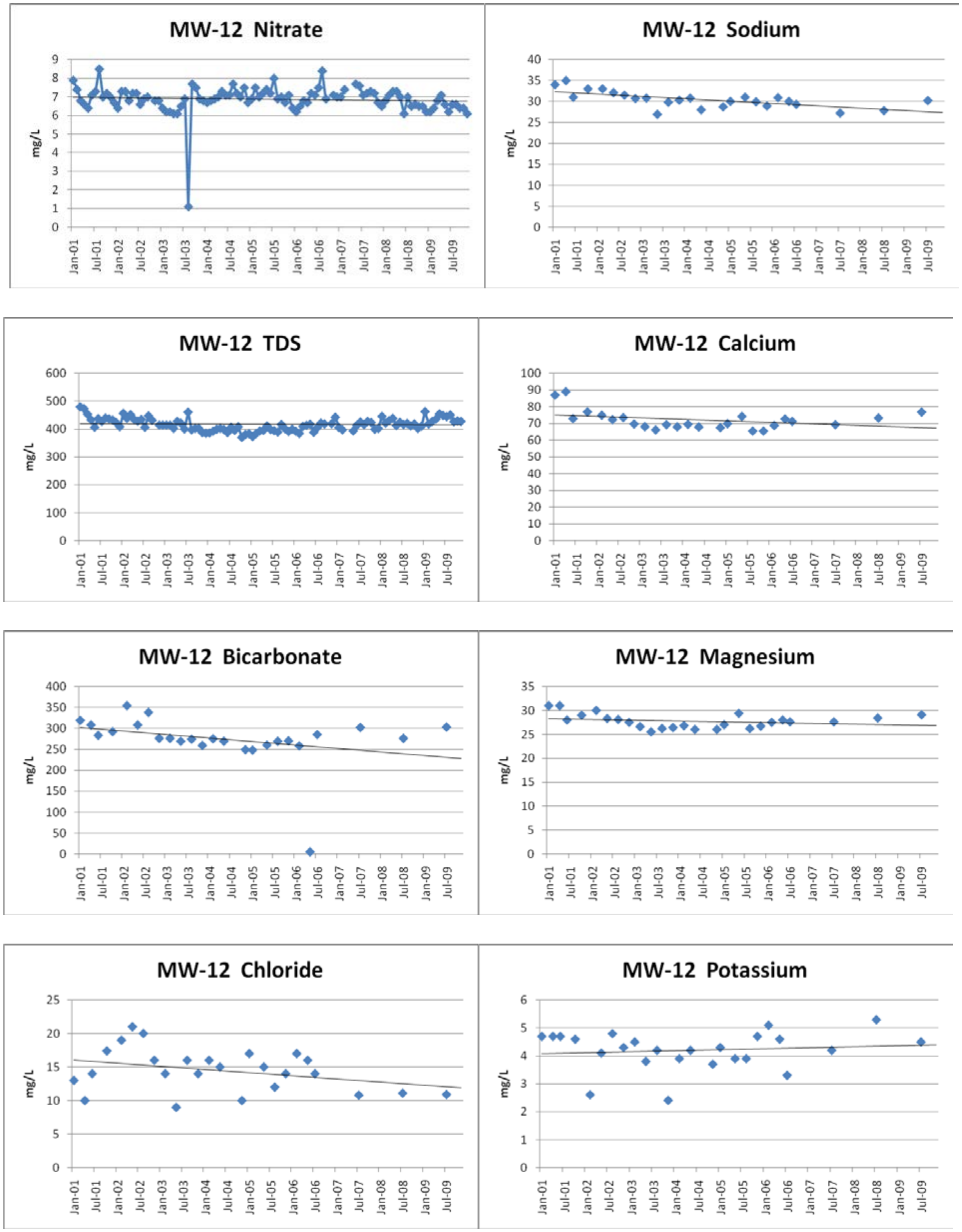

Figure C-9. MW-12 Chemical Concentration Time-Series Graphs.

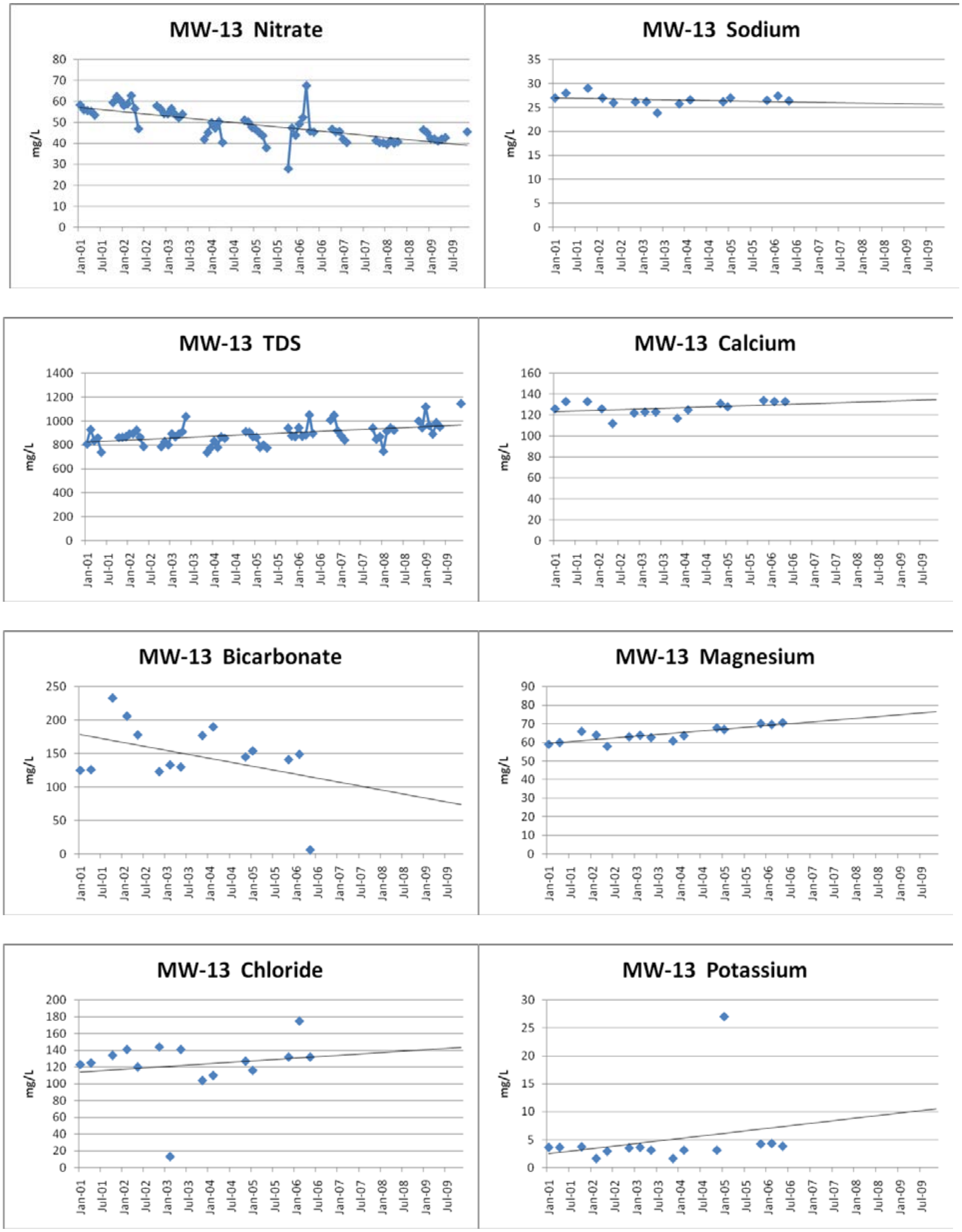

Figure C-10. MW-13 Chemical Concentration Time-Series Graphs.

Appendix D. Statistical Analysis of Nitrate and TDS Trends

Table D.1 Statistical Trends Summary

Well ID	Confidence Level	Slope (mg/L per year)	Mann-Kendall	Critical Value	Trend	% Confidence Level
Basic American Foods (BAF)						
Nitrate						
Wastewater (TKN)	0.01	-2.069	-2.495	-2.33	decreasing	98%
MW-1	0.01	0	0.259	2.33	no significant	98%
MW-2	0.01	-2.091	-8.033	-2.33	decreasing	98%
MW-3	0.01	-0.5694	-5.791	-2.33	decreasing	98%
MW-6	0.01	-0.1325	-0.288	-2.33	no significant	98%
MW-8	0.01	-0.257	-2.312	-2.33	no significant	98%
MW-9	0.01	1.549	6.682	2.33	increasing	98%
MW-10	0.01	0.246	0.3987	2.33	no significant	98%
MW-11	0.01	-0.4796	-2.055	-2.33	no significant	98%
MW-12	0.01	-0.03426	-1.932	-2.33	no significant	98%
MW-13	0.01	-2.192	-6.585	-2.33	decreasing	98%
Total Dissolved Solids (TDS)						
Wastewater	0.01	-68.04	-253	186	decreasing	98%
MW-1	0.01	1.161	1.992	2.33	no significant	98%
MW-2	0.01	-21.04	-8.355	-2.33	decreasing	98%
MW-3	0.01	-4.869	-3.959	-2.33	decreasing	98%
MW-6	0.01	11.98	1.8	2.33	no significant	98%
MW-8	0.01	5.481	2.861	2.33	increasing	98%
MW-9	0.01	19.56	7.465	2.33	increasing	98%
MW-10	0.01	27.59	4.148	2.33	increasing	98%
MW-11	0.01	-1.484	-0.5664	-2.33	no significant	98%
MW-12	0.01	0	0.08552	2.33	no significant	98%
MW-13	0.01	14.62	4.107	2.33	increasing	98%
Dunes Wastewater Treatment Plant (WWTP)						
Nitrate						
Wastewater (TKN)	0.01	-2.623	-6.978	-2.33	decreasing	98%
MW-1	0.01	-0.0141	-4.054	-2.33	decreasing	98%
MW-5	0.01	-1.546	-4.254	-2.33	decreasing	98%
Total Dissolved Solids (TDS)						
Wastewater	0.01	-6.899	-4.566	-2.33	decreasing	98%
MW-1	0.01	1.284	1.648	2.33	no significant	98%
MW-5	0.01	-3.09	-1.405	-2.33	no significant	98%

BAF Nitrate Trends

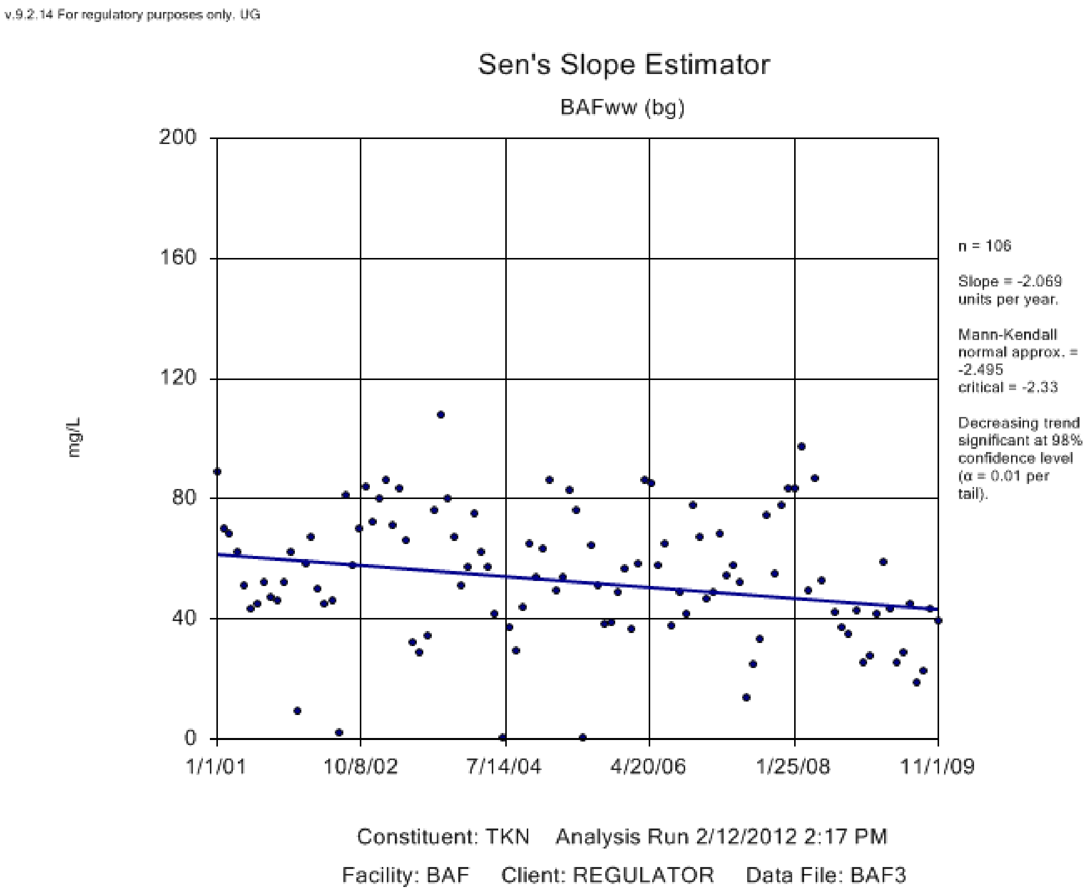

Figure D.1 Trend for BAF Wastewater using Total Kjeldahl Nitrogen (TKN) Values.

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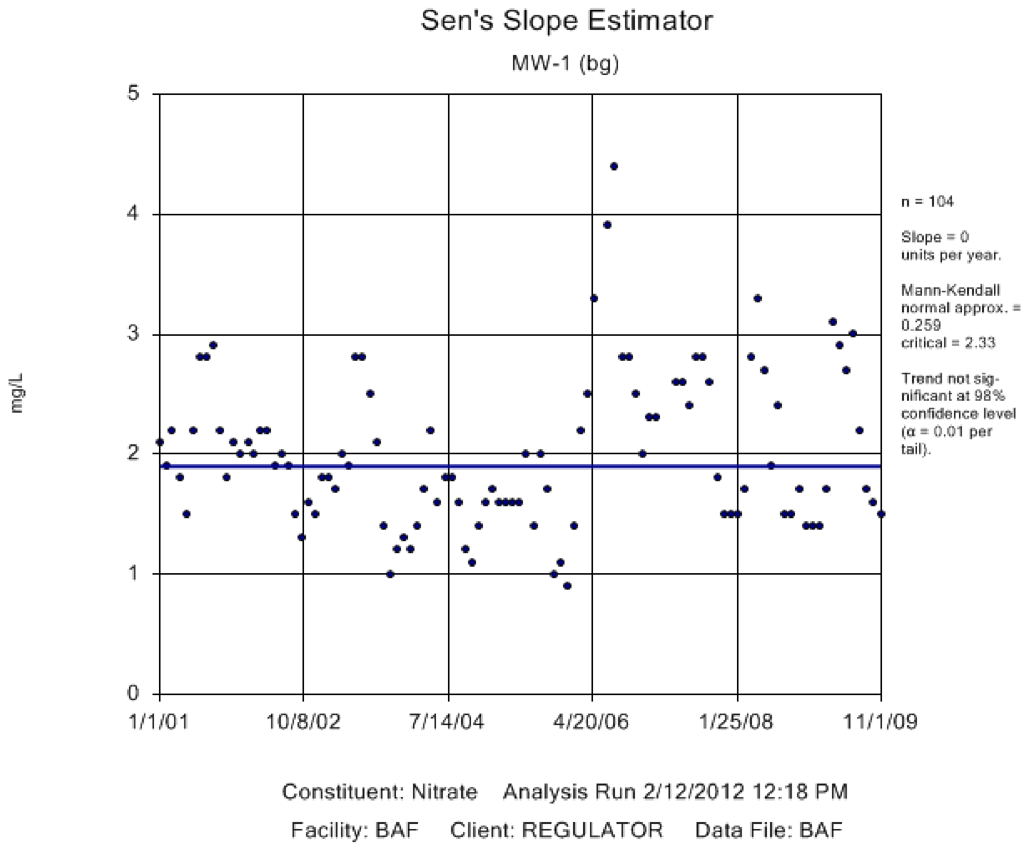

Figure D.2 Trend for BAF MW-1 using Nitrate Values.

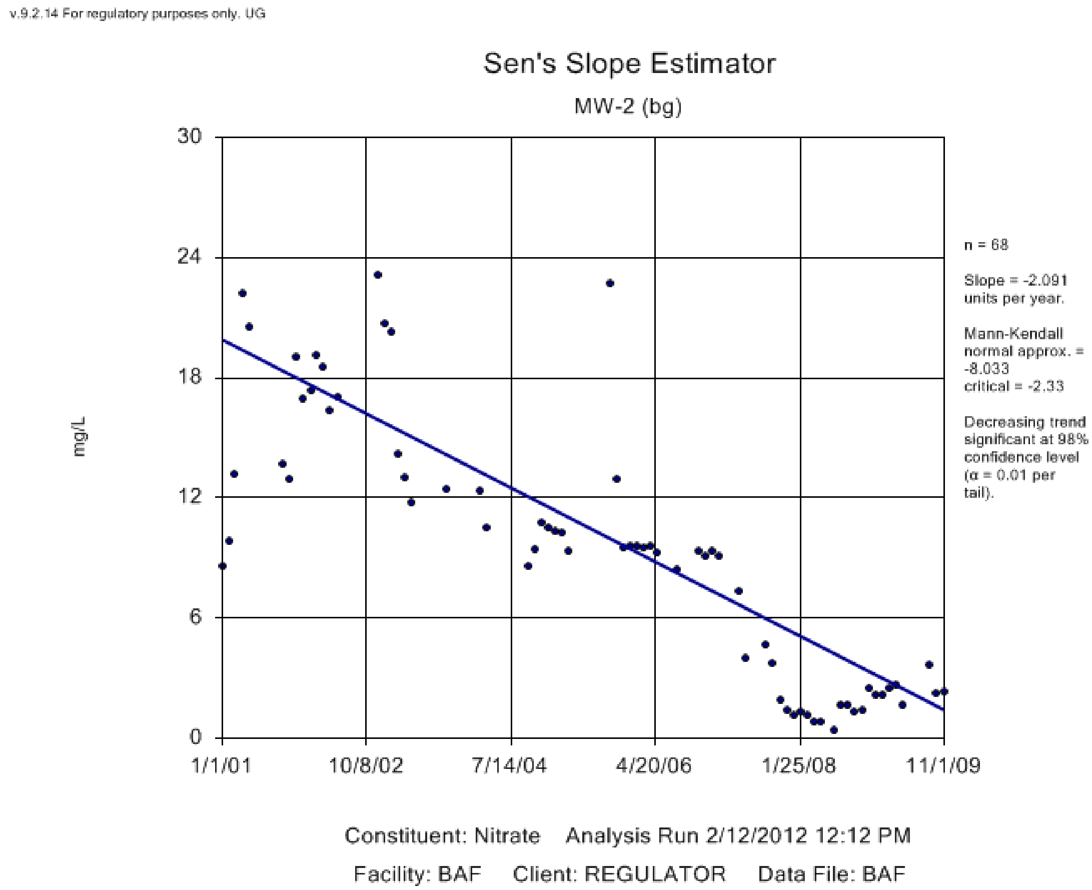

Figure D.3 Trend for BAF MW-2 using Nitrate Values.

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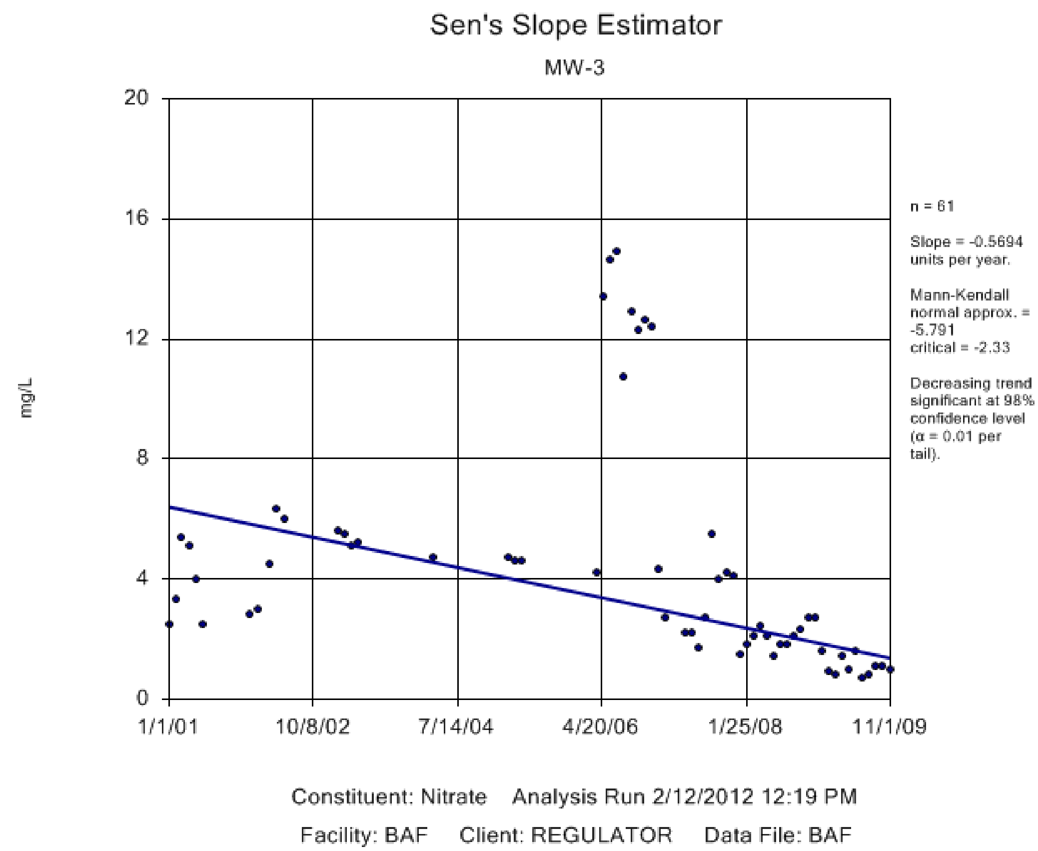

Figure D.4 Trend for BAF MW-3 using Nitrate Values.

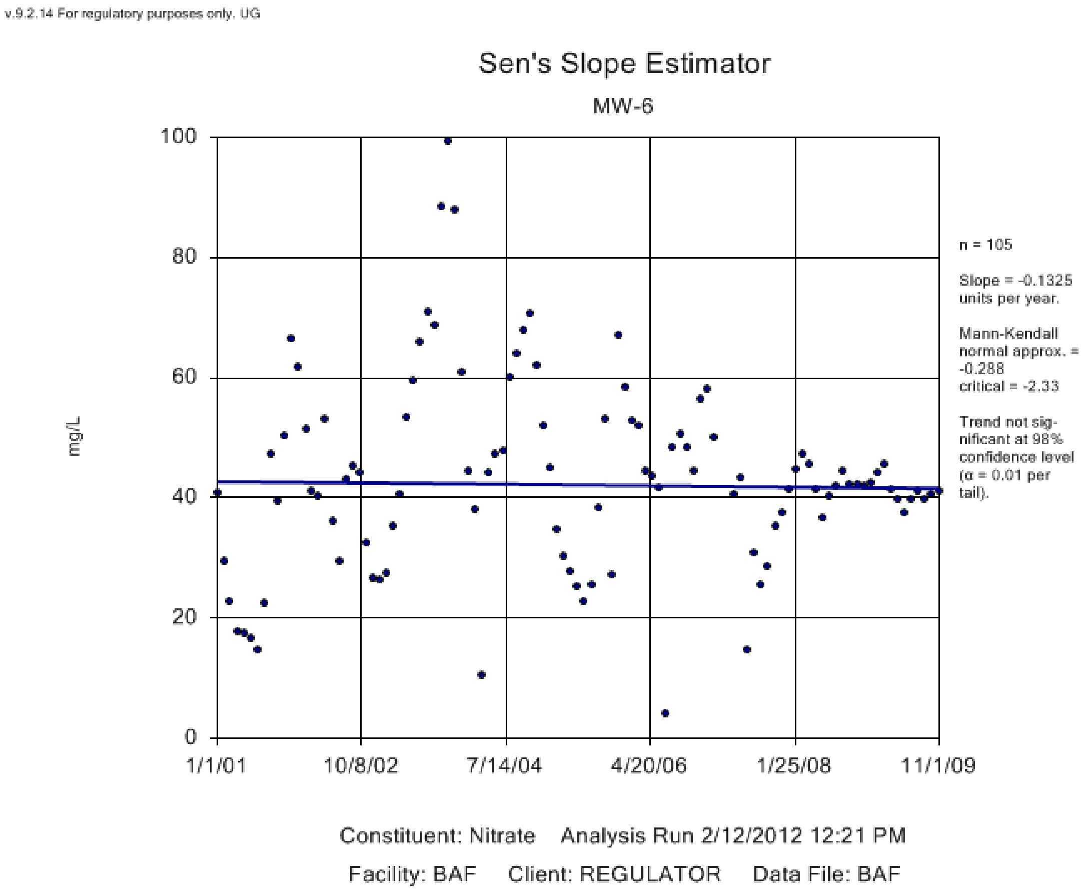

Figure D.5 Trend for BAF MW-6 using Nitrate Values.

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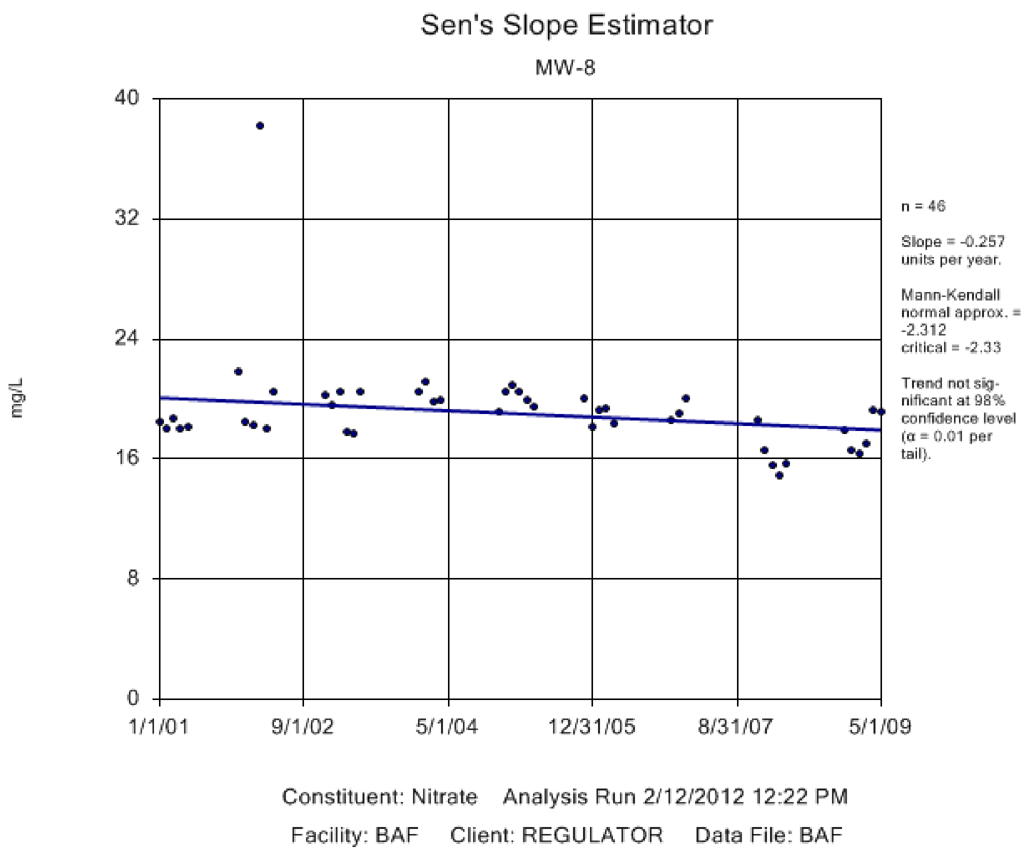

Figure D.6 Trend for BAF MW-8 using Nitrate Values.

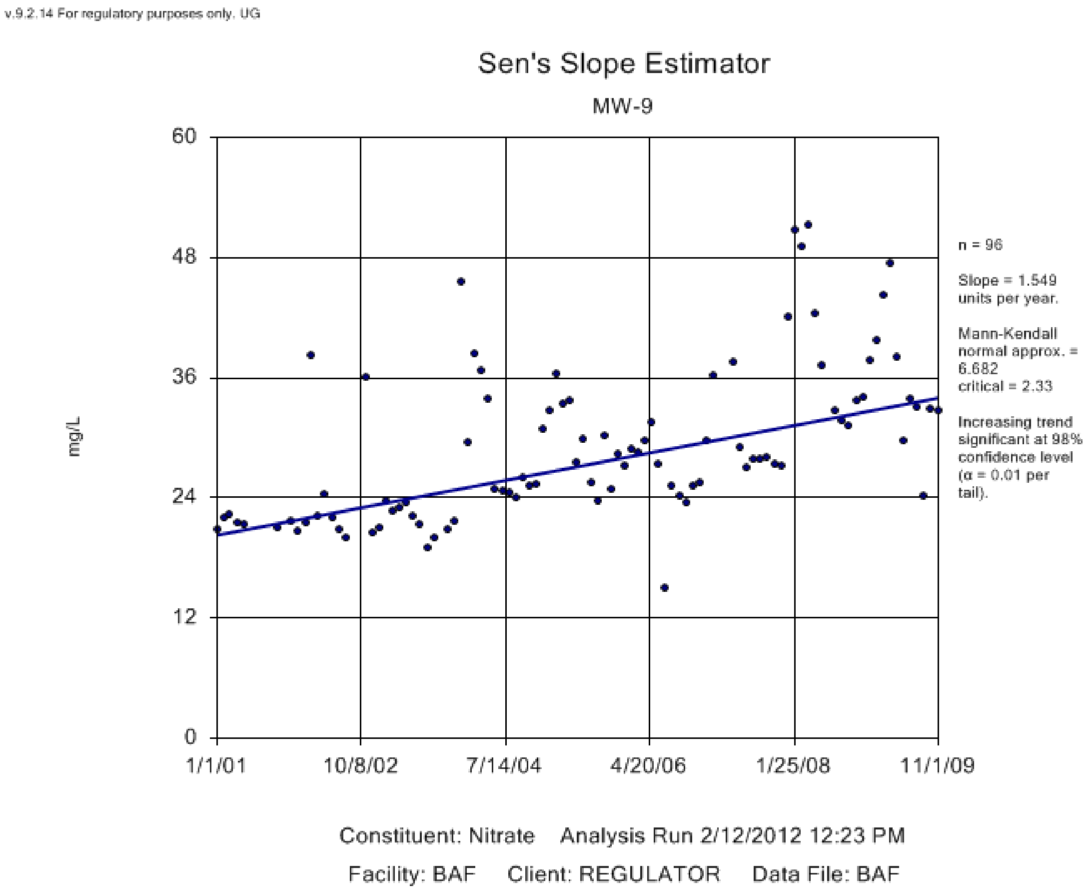

Figure D.7 Trend for BAF MW-9 using Nitrate Values.

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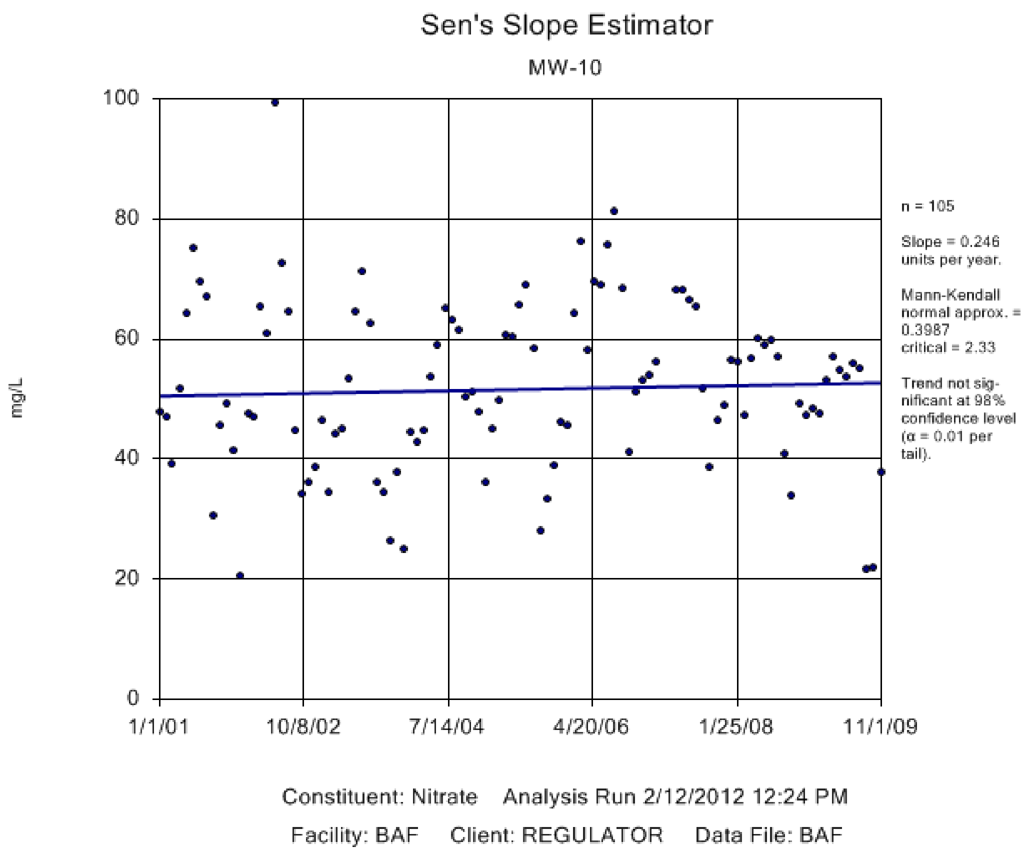

Figure D.8 Trend for BAF MW-10 using Nitrate Values.

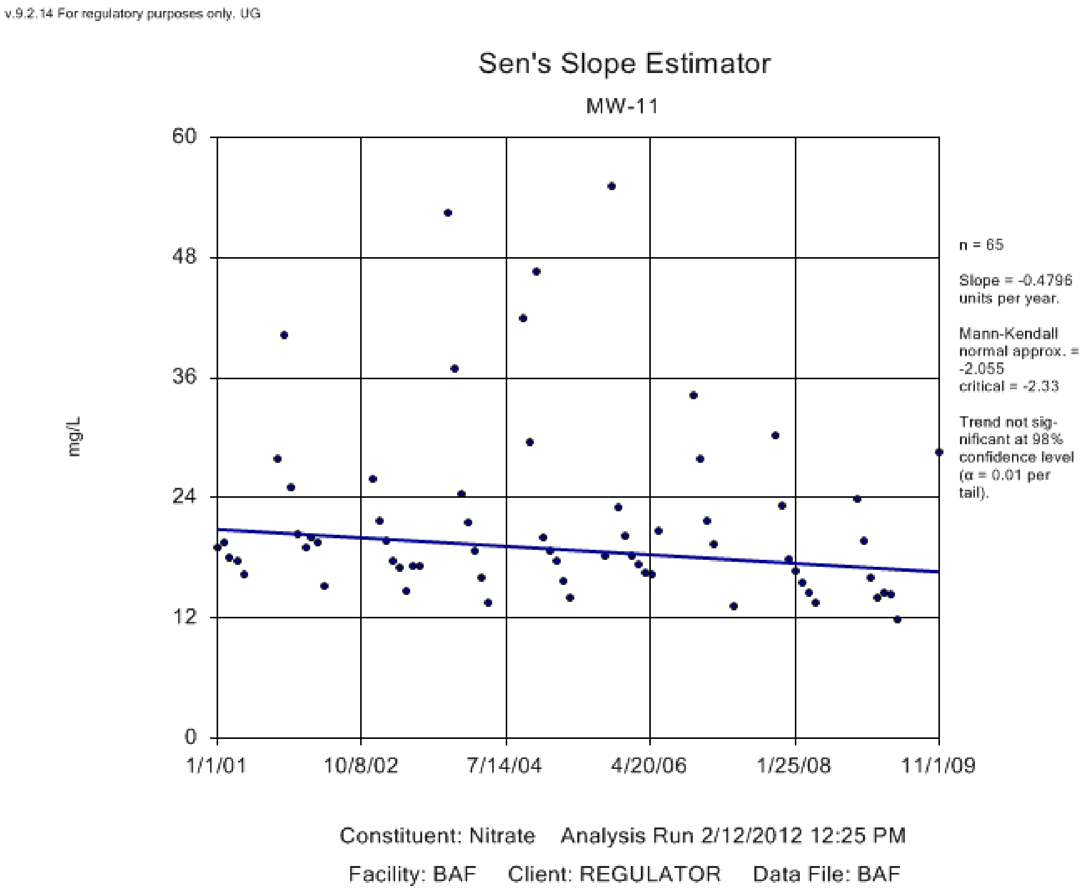

Figure D.9 Trend for BAF MW-11 using Nitrate Values.

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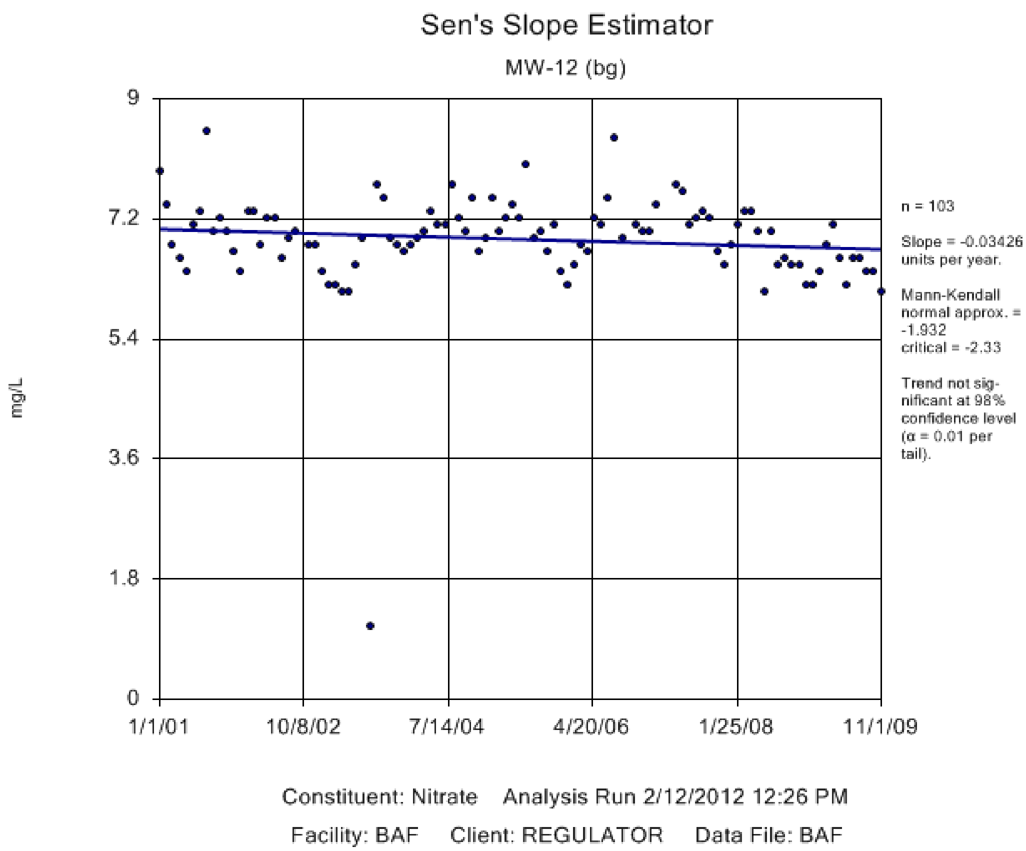

Figure D.10 Trend for BAF MW-12 using Nitrate Values.

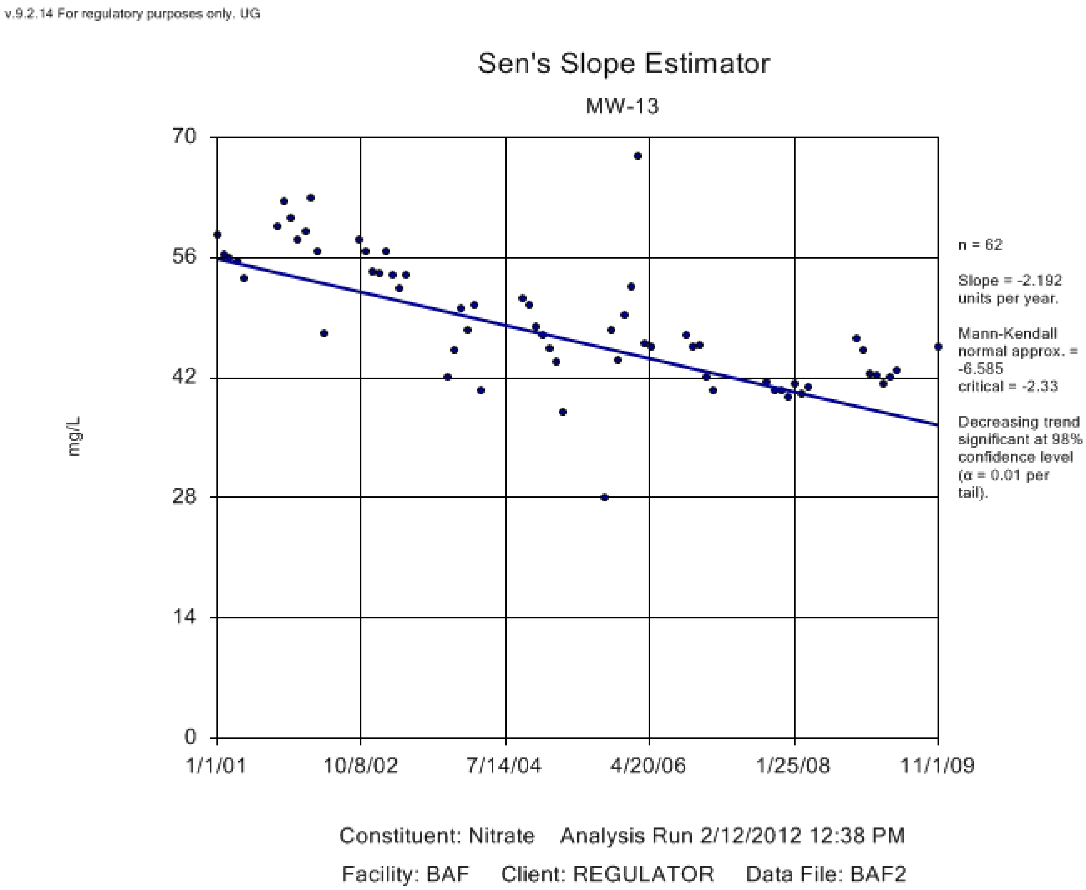

Figure D.11 Trend for BAF MW-13 using Nitrate Values.

BAF Total Dissolved Solids (TDS) Trends

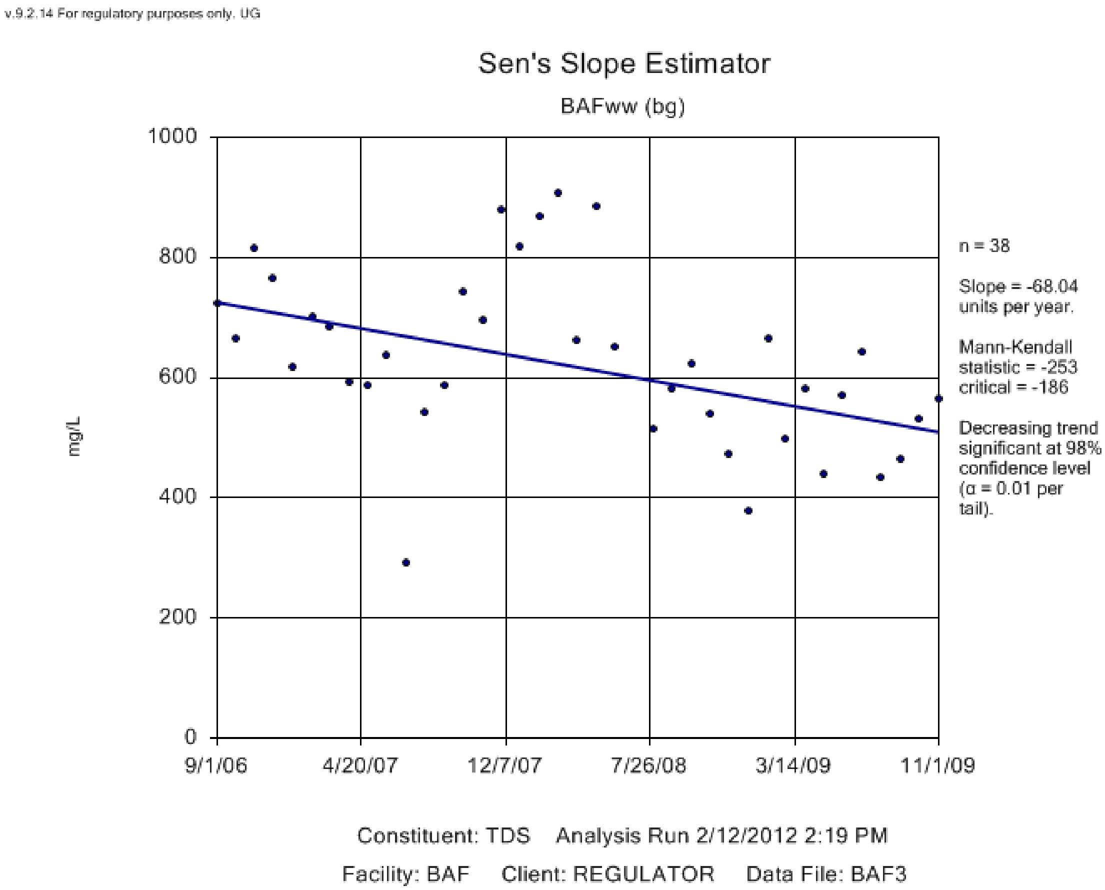

Figure D.12 Trend for BAF Wastewater using FDS Values.

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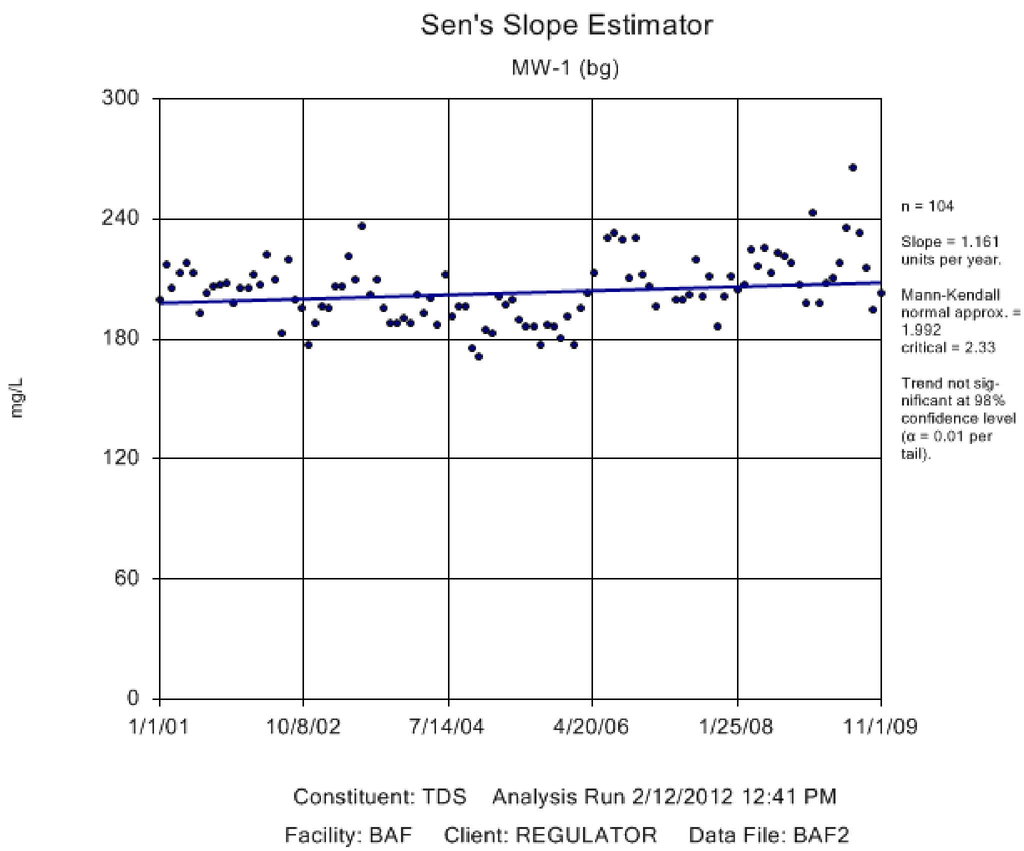

Figure D.13 Trend for BAF MW-1 using TDS Values.

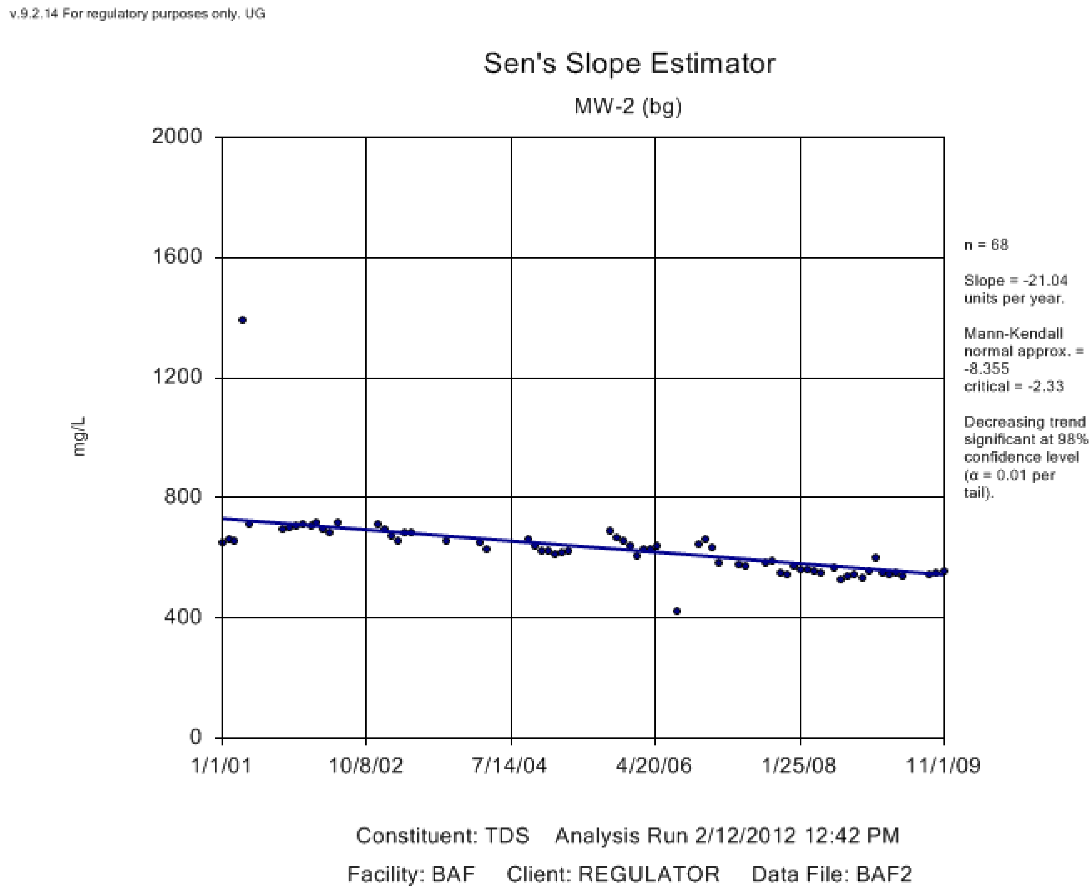

Figure D.14 Trend for BAF MW-2 using TDS Values.

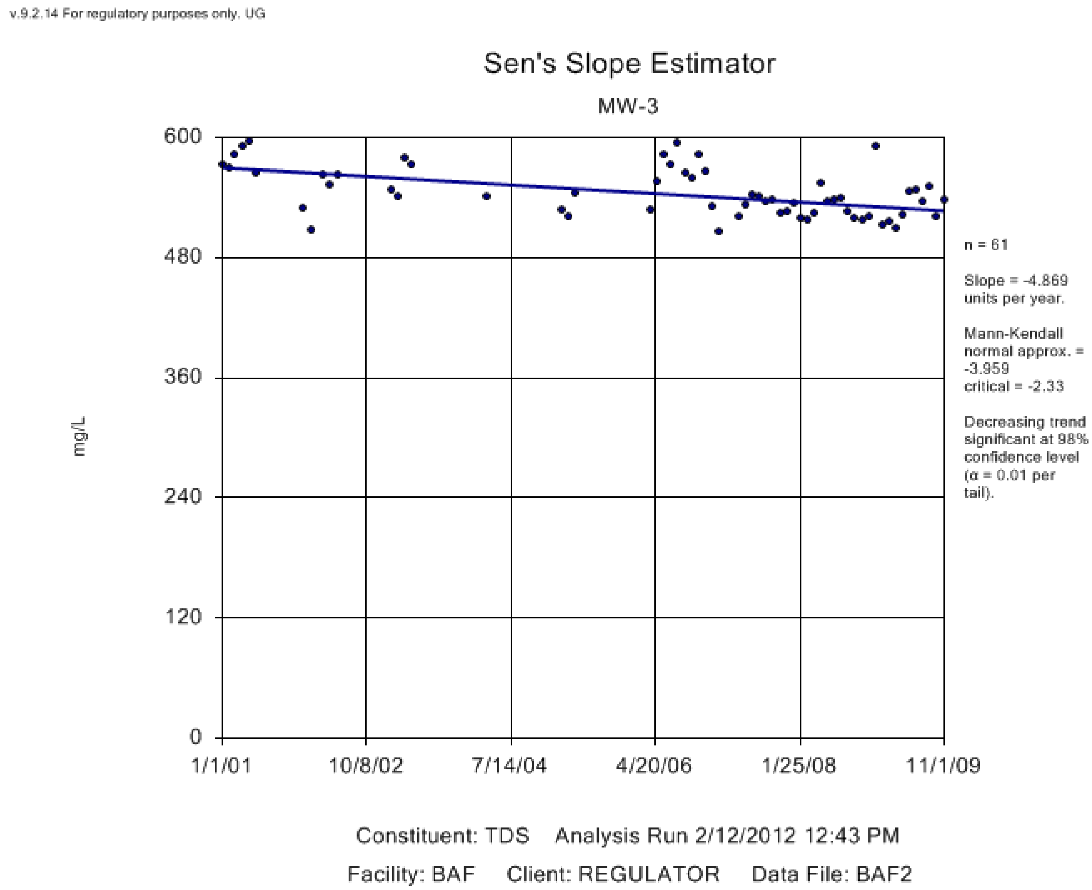

Figure D.15 Trend for BAF MW-3 using TDS Values.

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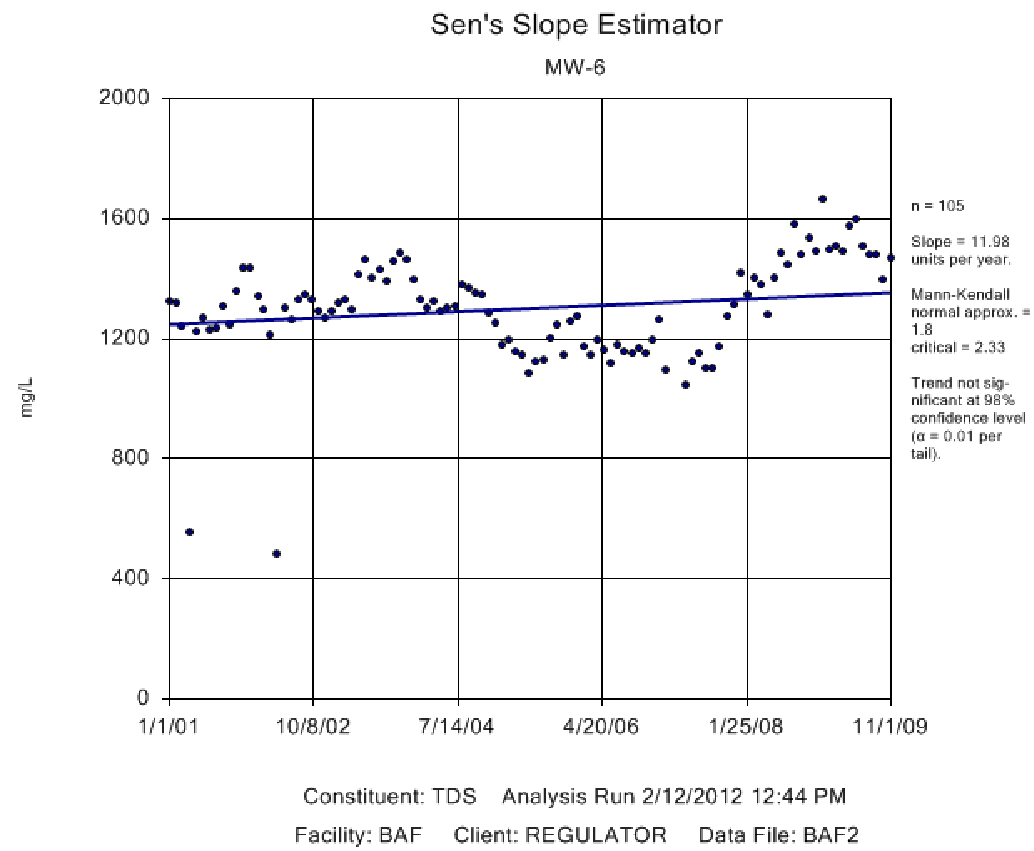

Figure D.16 Trend for BAF MW-6 using TDS Values.

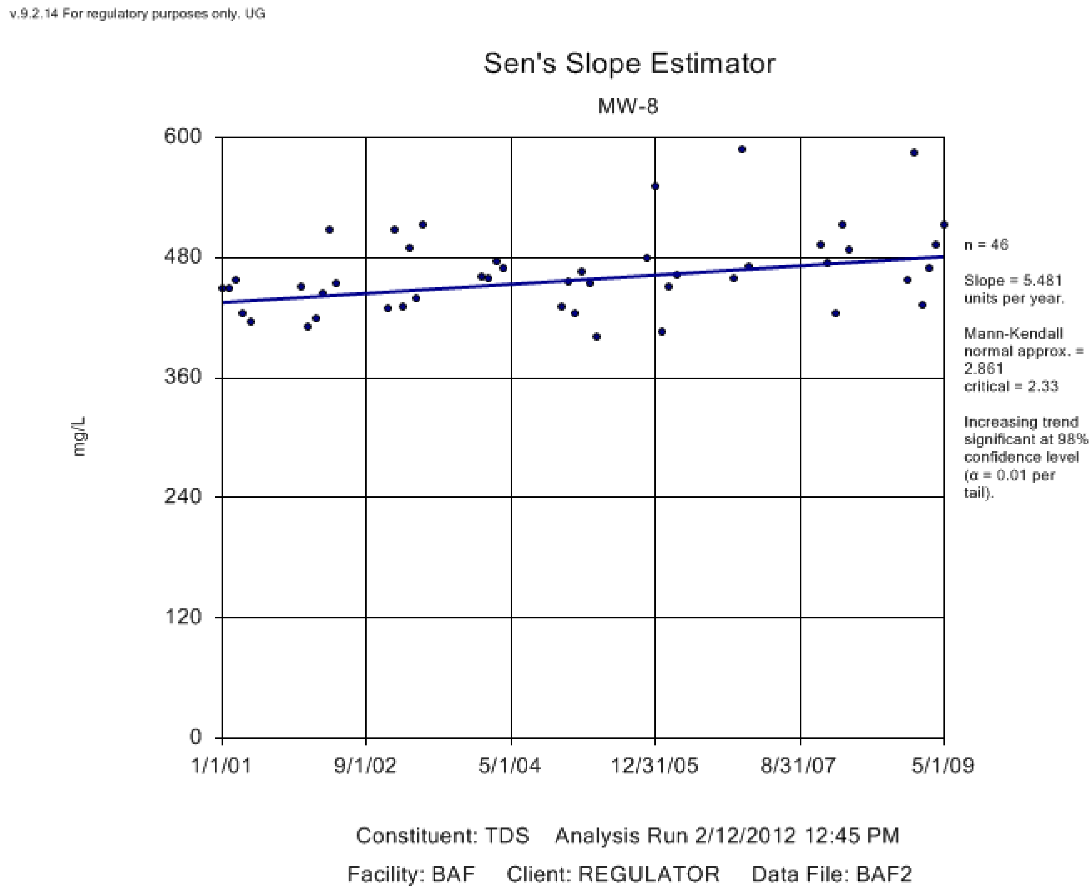

Figure D.17 Trend for BAF MW-8 using TDS Values.

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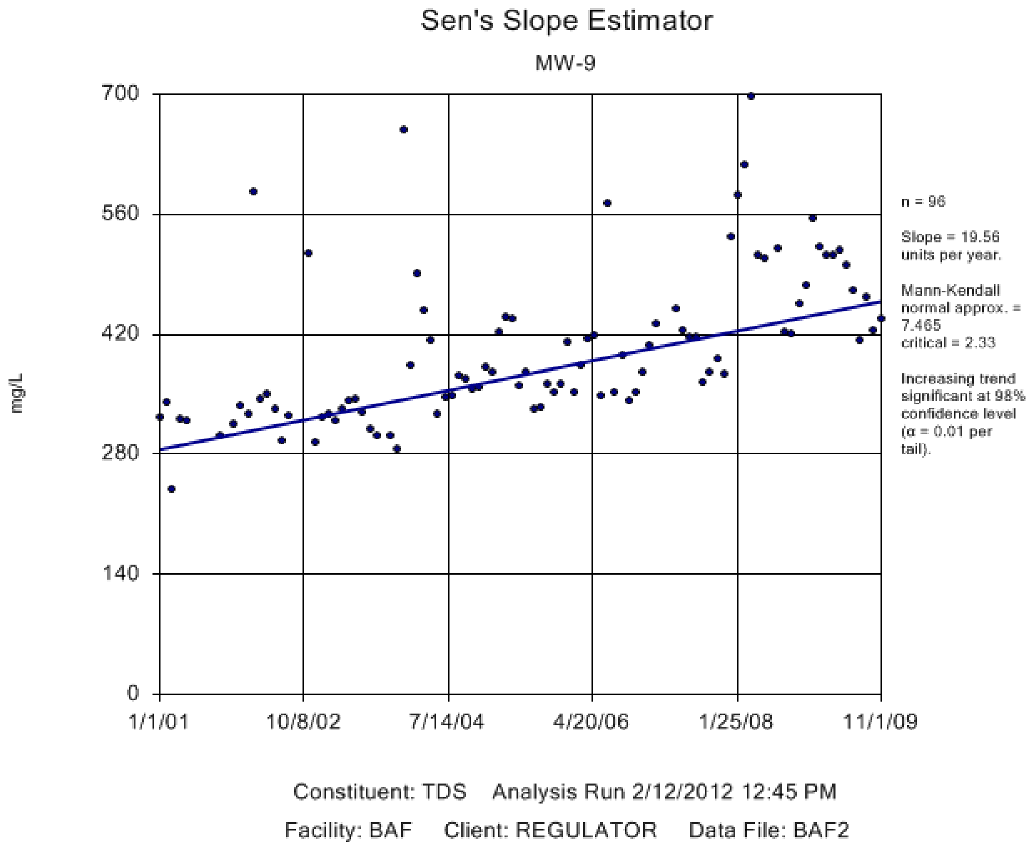

Figure D.18 Trend for BAF MW-9 using TDS Values.

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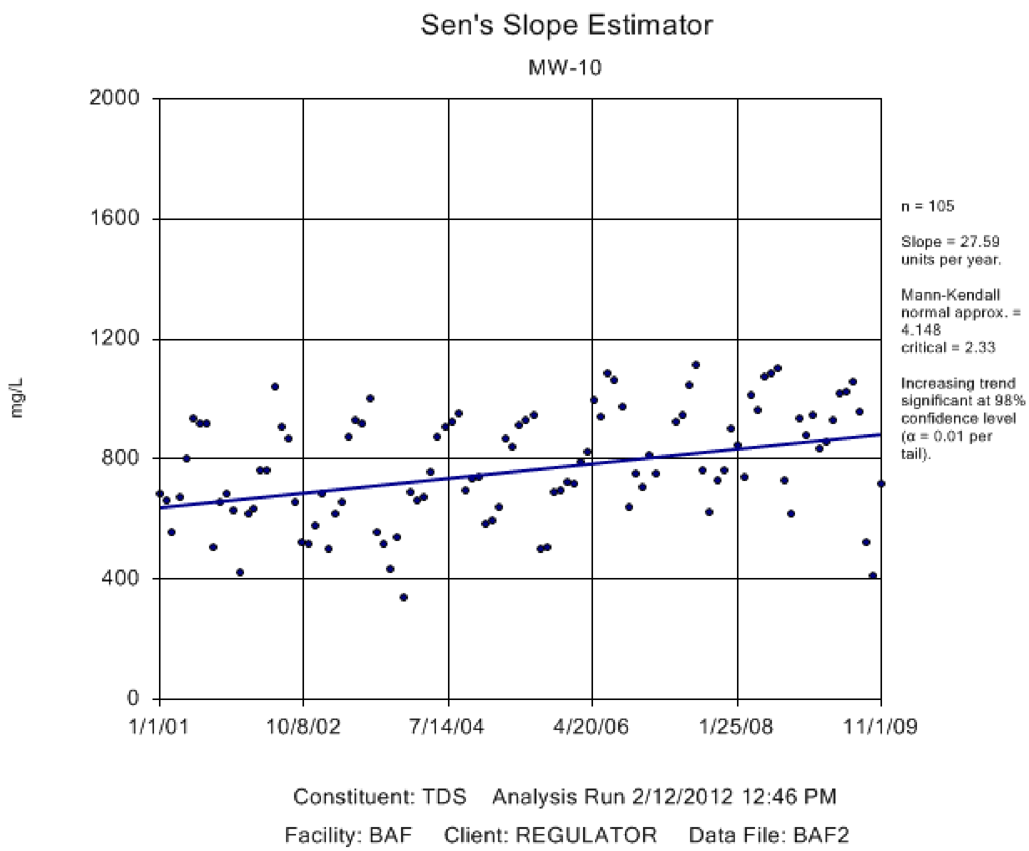

Figure D.19 Trend for BAF MW-10 using TDS Values.

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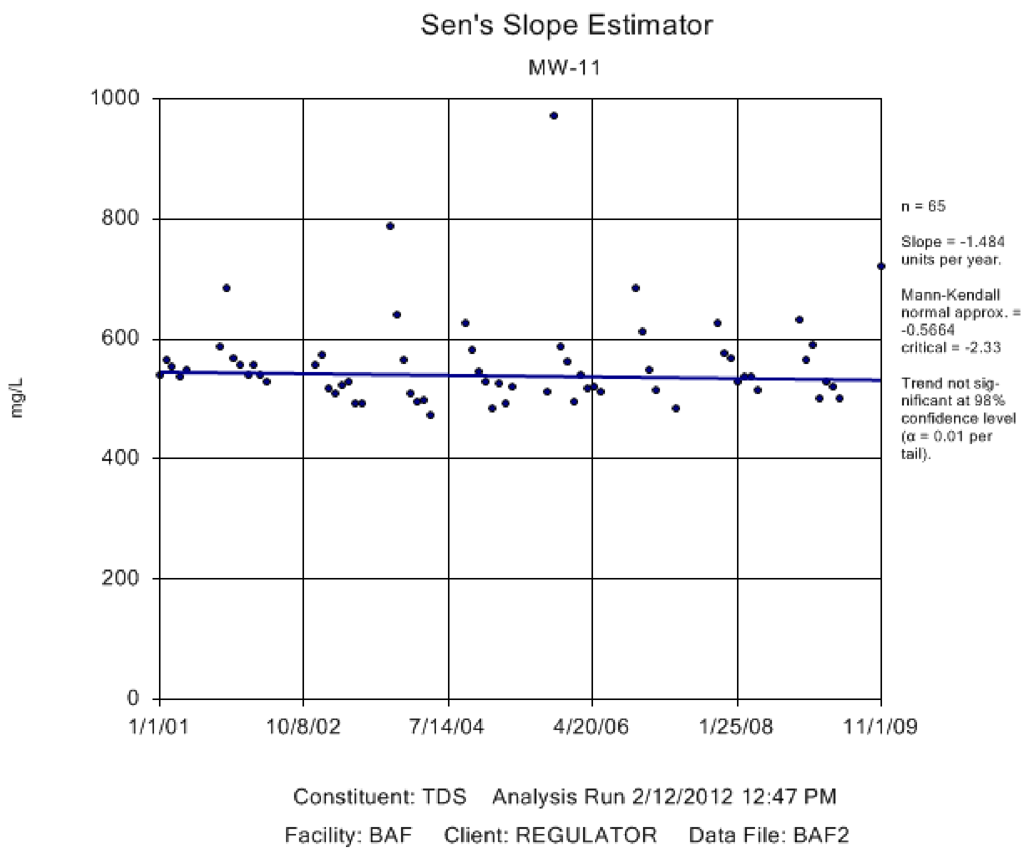

Figure D.20 Trend for BAF MW-11 using TDS Values.

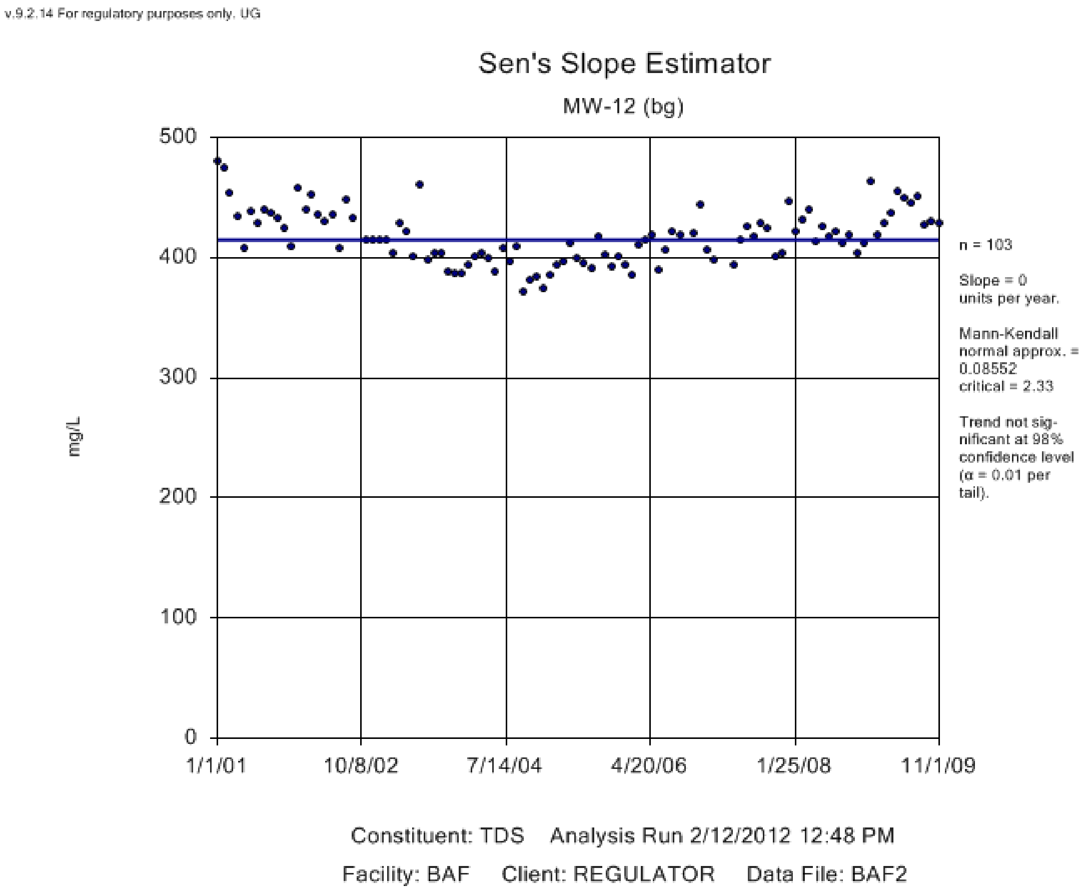

Figure D.21 Trend for BAF MW-12 using TDS Values.

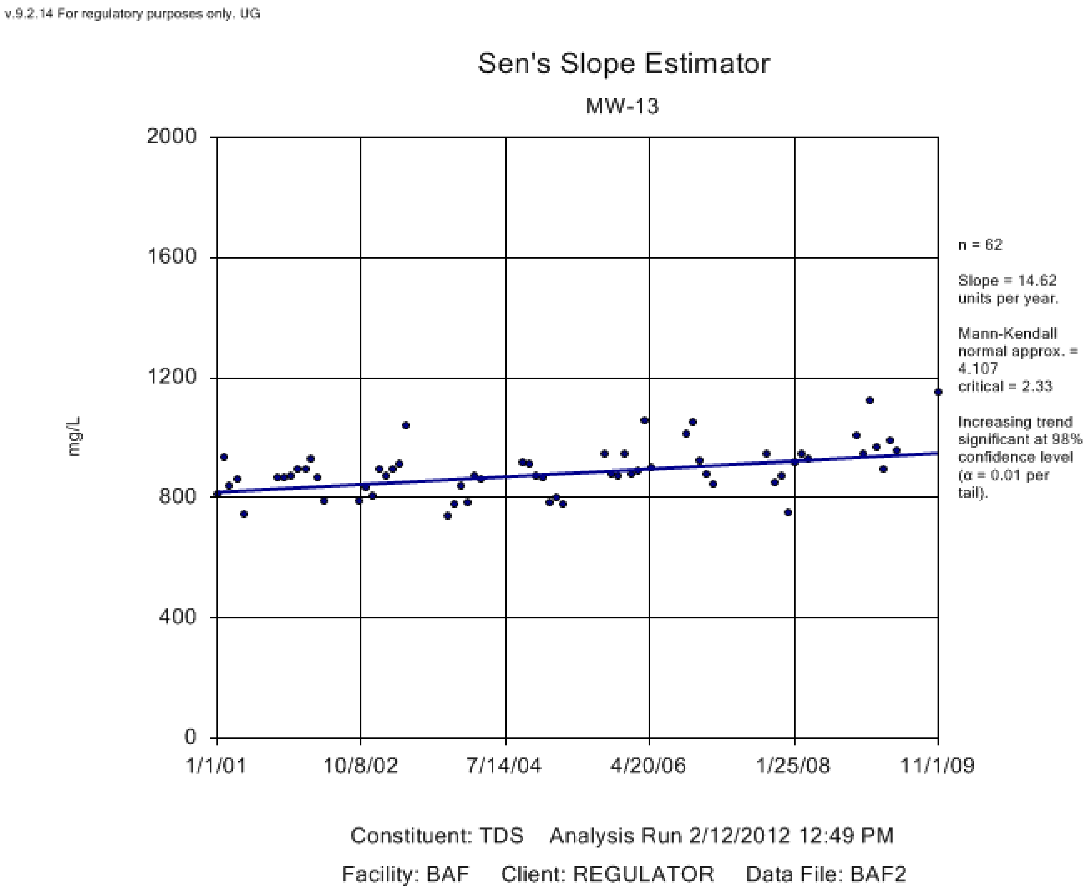

Figure D.22 Trend for BAF MW-13 using TDS Values.

Dunes Wastewater Treatment Plant Nitrate Trends

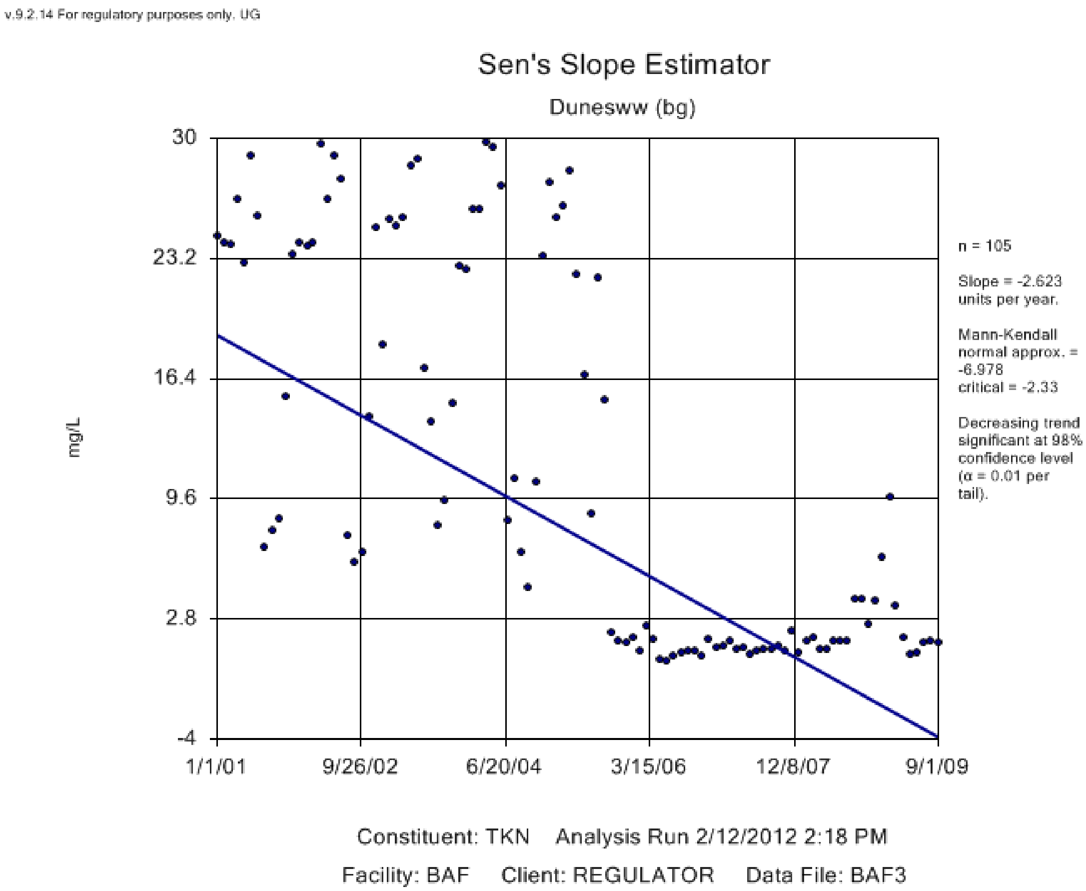

Figure D.23 Trend for Dunes WWTP Wastewater using Total Kjeldahl Nitrogen (TKN) Values.

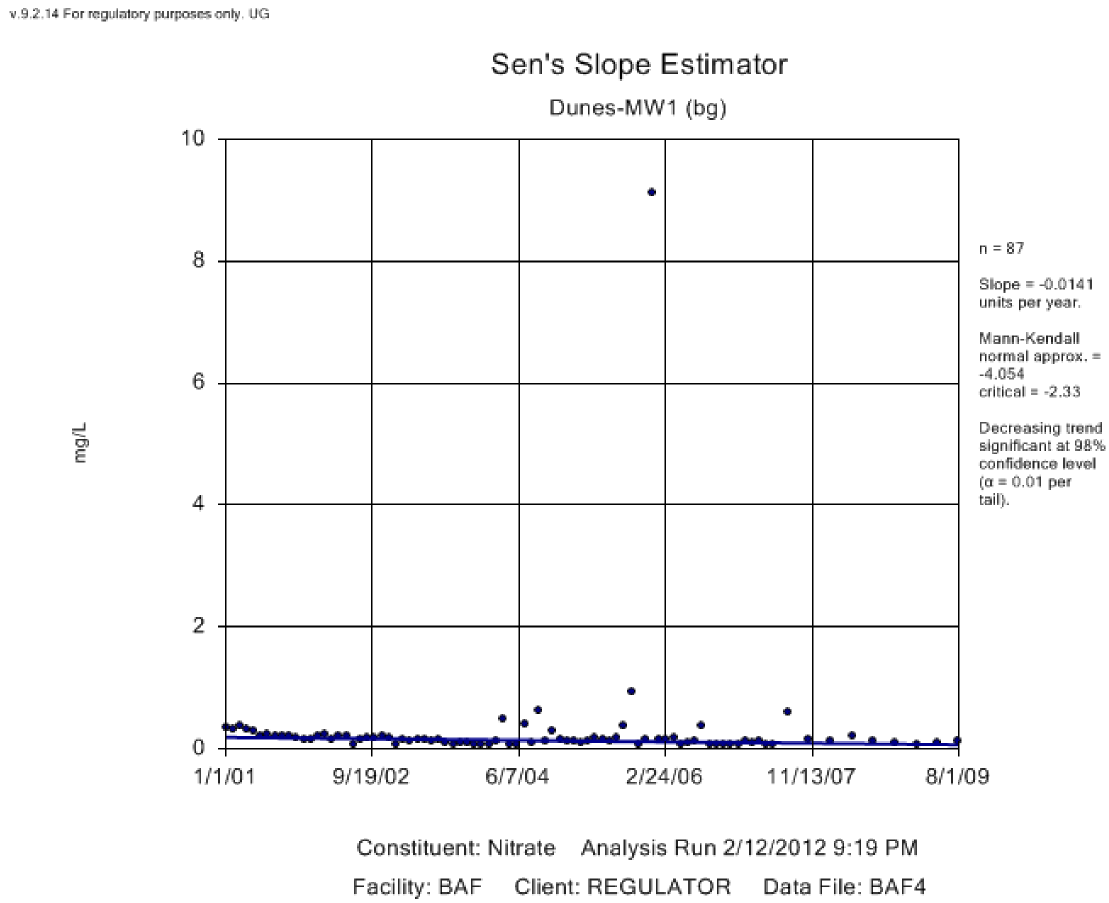

Figure D.24 Trend for Dunes WWTP Well MW-1 using Nitrate Values.

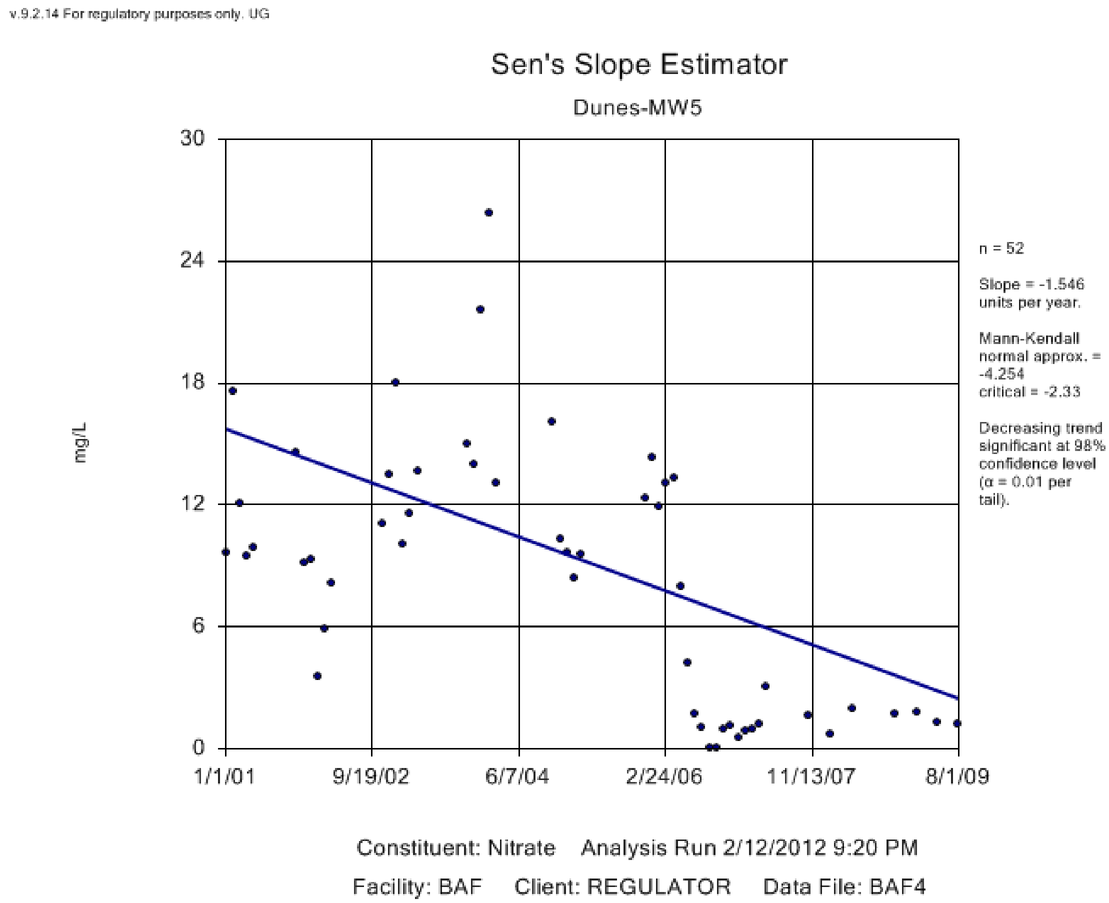

Figure D.25 Trend for Dunes WWTP Well MW-5 using Nitrate Values.

Dunes WWTP Total Dissolved Solids (TDS) Trends

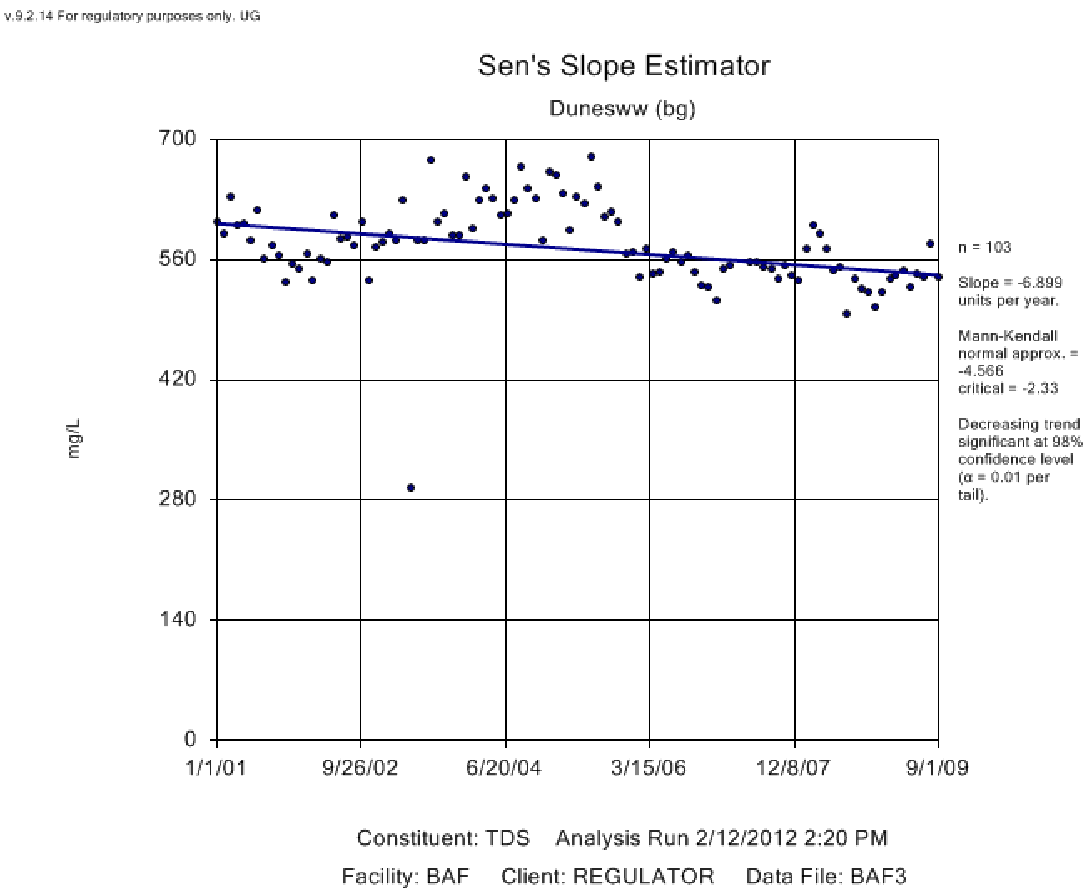

Figure D.26 Trend for Dunes WWTP Wastewater using TDS Values.

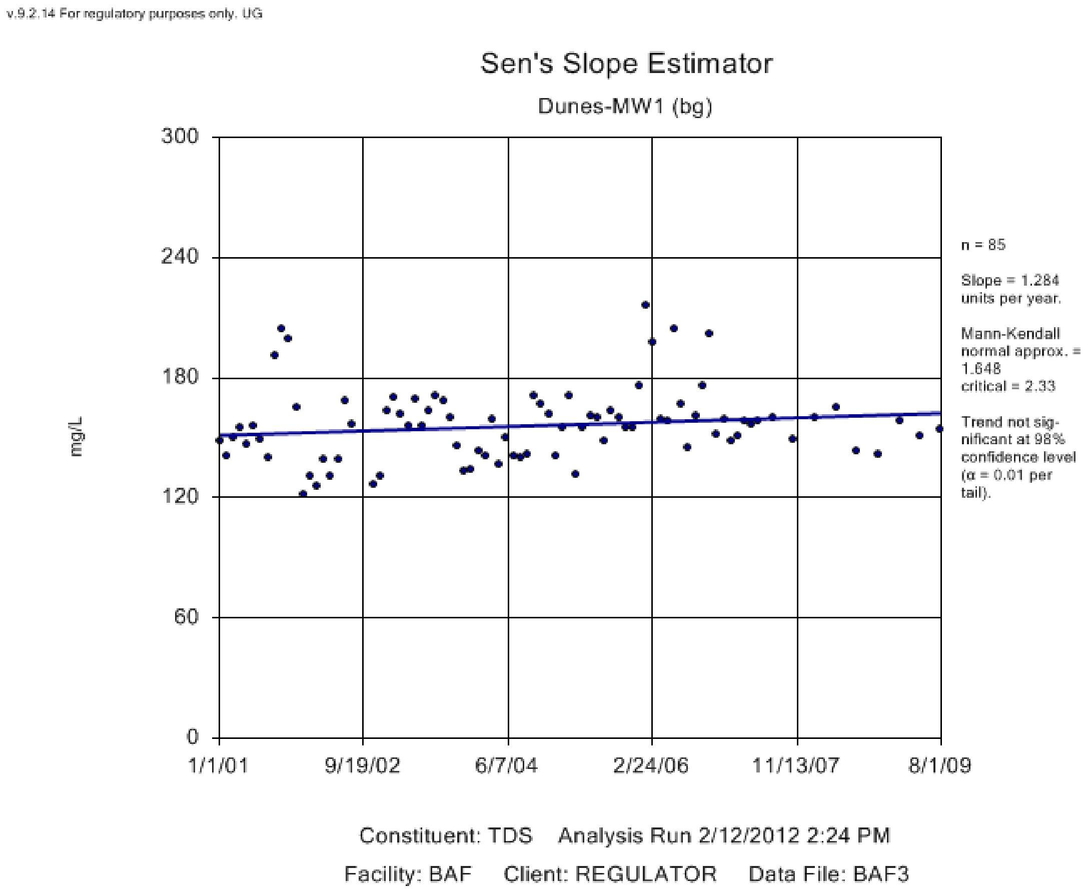

Figure D.27 Trend for Dunes WWTP MW-1 using TDS Values.

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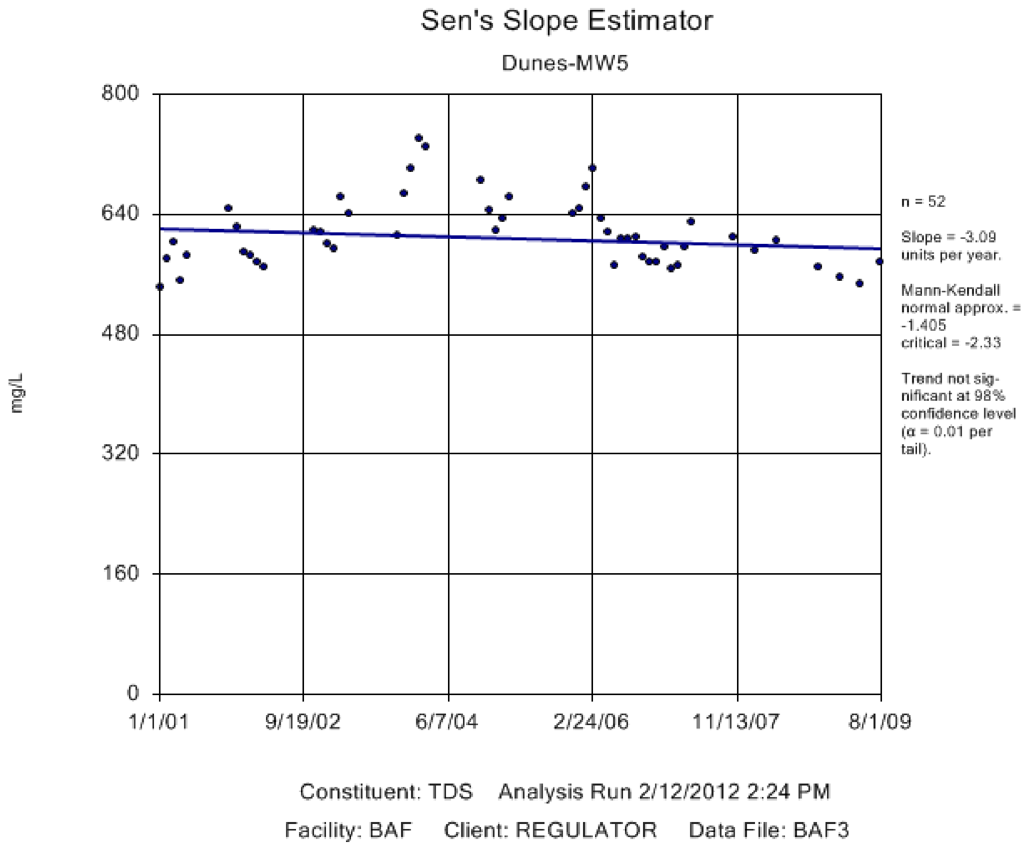

Figure D.28 Trend for Dunes WWTP MW-5 using TDS Values.

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Appendix E. Discharge Monitoring Report (DMR) Data for BAF

Table E-1. BAF Process Wastewater Quality (mg/L), 2001-09.

Date	TKN	Ammonia	Ca	Cl	Mg	P	K	Na	FDS	SO_4	Bicarbonate
Jan-01	89	31.2	13	121	14	17.2	205	153		18.5	598
Feb-01	70	36									
Mar-01	68	32									
Apr-01	62	31.3	9	54	9	12.4	146	155		13	600
May-01	51	23									
Jun-01	43	19									
Jul-01	45	13.9	11	141	7.3	10	125	176		23	458
Aug-01	52	20									
Sep-01	47	24									
Oct-01	46	22	8.1	131	7.2	8.4	137	176		22	489
Nov-01	52	21									
Dec-01	62	24	12	146	12	13.5	159	172		22	518
Jan-02	9	3									
Feb-02	58	24	11	164	9	11.7	162	18		20	518
Mar-02	67	25.8									
Apr-02	50	27.9									
May-02	45	20.8	9	145	6.9	10.6	130	140		18.1	360
Jun-02	46	27.8									
Jul-02	1.9	1									
Aug-02	81	28.3	5.4	117	7.7	19.5	194	145		29	493
Sep-02	57.9	25.6									
Oct-02	70	31									
Nov-02	84	29	13.7	123	10.9	15	174	141		81	419
Dec-02	72	30									
Jan-03	80	32									
Feb-03	86	33	13.2	103	12.4	17.5	204	154		31	606
Mar-03	70.8	27.4									
Apr-03	83.2	32.5									
May-03	66	27.6									

Date	TKN	Ammonia	Ca	Cl	Mg	P	K	Na	FDS	SO_4	Bicarbonate
Jun-03	32	19	6	109	7.5	14.9	186	135		18.7	487
Jul-03	28.8	17									
Aug-03	34	22	5.5	15.6	5.5	7.7	118	106		5	478
Sep-03	76	27.7									
Oct-03	108	41									
Nov-03	80	25.4	8.5	109	8.6	16.2	185	138		19.6	504
Dec-03	67	30									
Jan-04	51	0.5									
Feb-04	57.1	31.4	9.8	146	7.8	12.4	145	177		25	477
Mar-04	75	41									
Apr-04	62	32									
May-04	57	41	8.3	141	8.3	13.4	161	125		12.4	385
Jun-04	41.7	17.8									
Jul-04	0.1	0.1									
Aug-04	37	22									
Sep-04	29	17									
Oct-04	44	23									
Nov-04	65	54	8.3	107	9	13.9	185	134		19	502
Dec-04	54	22									
Jan-05	63	27	8.9	208	9.1	15.8	169	215		9.5	530
Feb-05	86	43									
Mar-05	49.2	21.6									
Apr-05	54	29									
May-05	83	30.8	8.3	76.6	8.7	29.1	150	129		17.5	466
Jun-05	76	53									
Jul-05	0.1	0.5									
Aug-05	64.3	22.8	79	418	49	67	813	813		105	3047
Sep-05	50.9	33.9									
Oct-05	38.2	19.7									
Nov-05	38.6	25.1	6.3	98	6.1	7.7	123	138		13.5	422
Dec-05	48.5	30.4									
Jan-06	56.7	28.8									
Feb-06	36.6	32.2	7.2	104	6.7	8.8	123	128		14.4	388
Mar-06	58.1	31.3									

Date	TKN	Ammonia	Ca	Cl	Mg	P	K	Na	FDS	SO_4	Bicarbonate
Apr-06	85.8	40.9									
May-06	85	37.4	10.4	125	10	15.4	176	167		17.2	557
Jun-06	57.6	42.6									
Jul-06	64.9	29.6									
Aug-06	37.8	13.1									
Sep-06	48.7	19.9	8.3	139	7.6	18.4	147	447	722	14.2	469
Oct-06	41.3	21.5							663		
Nov-06	77.7	28.9							814		
Dec-06	67.2	35.2							764		
Jan-07	46.5	16.1							618		
Feb-07	48.5	13.7							701		
Mar-07	68.1	25.6	8.6	114	8.8	13	184	524	685	15.6	693
Apr-07	54.4	20.1							592		
May-07	57.6	22.7							587		
Jun-07	52.3	27.3							636		
Jul-07	13.4	4.3							291		
Aug-07	24.6	7.9							542		
Sep-07	33.2	13.5	7	137	5.2	6.9	97.2	175	587	16.1	407
Oct-07	74.4	27.2							741		
Nov-07	54.9	20.1							695		
Dec-07	77.9	30.8							878		
Jan-08	83.2	30.3							817		
Feb-08	83.2	35.6							869		
Mar-08	97.3	36.4	15.6	159	11.6	18.2	217	167	908	20.1	581
Apr-08	49.4	7.9							662		
May-08	86.8	41.1							885		
Jun-08	52.6	28.3							651		
Jul-08											
Aug-08	42.3	14.6							513		
Sep-08	37.3	9.3	7.4	111	5.3	6.8	96.1	142	581	15.3	365
Oct-08	34.9	12.2							623		
Nov-08	42.4	11.6							538		
Dec-08	25.6	5.8							471		
Jan-09	27.5	13.2							377		

Date	TKN	Ammonia	Ca	Cl	Mg	P	K	Na	FDS	SO_4	Bicarbonate
Feb-09	41.5	17.5							663		
Mar-09	59	8.4	8	99.7	7.5	10	123	126	497	16.4	393
Apr-09	43	13.4							580		
May-09	25.2	8.4							438		
Jun-09	28.5	8.2							570		
Jul-09	45.1	19.7							641		
Aug-09	18.4	6							433		
Sep-09	22.6	12.4	6.9	80	4.4	5.7	74.1	120	463	12.4	323
Oct-09	43.1	14.4							531		
Nov-09	39.5	21.3							565		
Mean	53.93	23.69	11.51	129.03	9.76	15.07	176.15	190.90	626.11	22.91	570.10
Max	108	54	79	418	49	67	813	813	908	105	3047
Min	0.1	0.1	5.4	15.6	4.4	5.7	74.1	18	291	5	323

See Appendix A for definitions of abbreviations in the header row.

Table E-2. BAF Well MW-1 Groundwater Quality Data (mg/L), 2001-09.

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Jan-01	0.5	1.5	2.1	3.6	199	125	5	14	33	10	4.1	
Feb-01	0.5	1.5	1.9	3.4	217							
Mar-01	0.5	0.5	2.2	2.7	205							
Apr-01	0.5	1.5	1.8	3.3	213	121	3	15	38	11	4.1	
May-01	0.5	1.5	1.5	3	218							
Jun-01	0.5	1.5	2.2	3.7	213	128	6.6	14	33	10	4.2	
Jul-01	0.5	1.5	2.8	4.3	193							
Aug-01	0.6	1.5	2.8	4.3	203							
Sep-01	0.5	1.5	2.9	4.4	206							
Oct-01	0.5	1.5	2.2	3.7	207	128	6	14	31	10	4.1	
Nov-01	0.5	3.9	1.8	5.7	208							
Dec-01	0.5	1.5	2.1	3.6	198							
Jan-02	0.5	2	2	4	205							
Feb-02	0.8	1.5	2.1	3.6	205	142	7.3	13	30	10	2.3	
Mar-02	0.5	1.5	2	3.5	212							
Apr-02	0.5	1.5	2.2	3.7	207							
May-02	0.5	1.5	2.2	3.7	222	139	14	13.7	32.4	10.1	4.1	
Jun-02	0.5	1.5	1.9	3.4	209							
Jul-02	0.5	1.5	2	3.5	183							
Aug-02	0.5	1.5	1.9	3.4	219	119	6	14	30.7	10	4.2	
Sep-02	0.5	1.5	1.5	3	199							
Oct-02	0.5	1.5	1.3	2.8	195							
Nov-02	0.5	1.5	1.6	3.1	177	113	3	13.6	27.2	9	3.8	
Dec-02	0.5	1.5	1.5	3	188							
Jan-03	0.5	1.5	1.8	3.3	196							
Feb-03	0.5	1.5	1.8	3.3	195	121	5	13	28.4	9.3	4.1	
Mar-03	0.6	1.5	1.7	3.2	206							
Apr-03	0.5	1.5	2	3.5	206							
May-03	0.5	1.5	1.9	3.4	221	114	3	12.6	31.2	10.1	3.6	
Jun-03	1.6	1.5	2.8	4.3	209							
Jul-03	0.6	1.5	2.8	4.3	236							
Aug-03	0.5	1.5	2.5	4	202	131	5	13.7	33.1	10.5	4.1	

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Sep-03	0.6	1.5	2.1	3.6	209							
Oct-03	0.5	1.5	1.4	2.9	195							
Nov-03	0.5	1.5	1	2.5	188	115	3	12.1	26.7	8.9	1.6	
Dec-03	0.5	1.5	1.2	2.7	188							
Jan-04	0.5	1.5	1.3	2.8	190							
Feb-04	0.5	1.5	1.2	2.7	188	130	9	12.4	31	10.1	3.8	
Mar-04	0.5	1.5	1.4	2.9	202							
Apr-04	0.5	1.5	1.7	3.2	193							
May-04	0.5	2	2.2	4.2	200	128	3	11.4	31.4	10.2	3.9	
Jun-04	0.5	1.5	1.6	3.1	187							
Jul-04	0.5	1.5	1.8	3.3	212							
Aug-04	0.5	1.5	1.8	3.3	191							
Sep-04	0.5	1.5	1.6	3.1	196							
Oct-04	0.5	1.5	1.2	2.7	196							
Nov-04	0.5	1.5	1.1	2.6	175	117	5.8	12	28.6	9.3	3.3	
Dec-04	0.5	1.5	1.4	2.9	171							
Jan-05	0.5	1.5	1.6	3.1	184	121	6.7	11.9	31.2	10.1	3.2	
Feb-05	0.5	1.5	1.7	3.2	183							
Mar-05	0.5	1.5	1.6	3.1	201							
Apr-05	0.5	1.5	1.6	3.1	197							
May-05	0.4	1.5	1.6	3.1	199	124	6	12.8	33.9	11.3	3.7	
Jun-05	0.3	1.5	1.6	3.1	189							
Jul-05	0.3	1.5	2	3.5	186							
Aug-05	0.29	0.65	1.4	2.05	186	129	1	13.3	26	9.2	3.6	
Sep-05	0.4	0.65	2	2.65	177							
Oct-05	0.3	0.7	1.7	2.4	187							
Nov-05	0.3	0.7	1	1.7	186	121	1	12.7	28.8	10.3	4.4	
Dec-05	0.3	0.7	1.1	1.8	180							
Jan-06	0.3	0.7	0.9	1.6	191							
Feb-06	0.3	0.7	1.4	2.1	177	123	2	13.7	28.4	10.2	4.9	
Mar-06	0.3	0.7	2.2	2.9	195							
Apr-06	3	2.5	2.5	5	203							
May-06	0.3	0.7	3.3	4	213	6	2	13.2	32	10.9	4.7	

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Jun-06												
Jul-06		1	3.9	4.9	230	135	5	14.2	39.5	12.7	3.3	
Aug-06	0.1	0.7	4.4	5.1	233							
Sep-06		0.7	2.8	3.5	229							
Oct-06		1.1	2.8	3.9	210							
Nov-06	0.1	0.7	2.5	3.2	230							
Dec-06		0.7	2	2.7	212							
Jan-07		0.7	2.3	3	206							
Feb-07	0.1	0.7	2.3	3	196							
Mar-07												
Apr-07												
May-07	0.1	0.7	2.6	3.3	199							
Jun-07		0.7	2.6	3.3	199							
Jul-07		0.7	2.4	3.1	202	134	2	11	31.3	10.2	3.9	5.3
Aug-07	0.1	2.9	2.8	5.7	219							
Sep-07		0.7	2.8	3.5	201							
Oct-07		0.7	2.6	3.3	211							
Nov-07	0.1	0.7	1.8	2.5	186							
Dec-07		0.7	1.5	2.2	201							
Jan-08		0.7	1.5	2.2	211							
Feb-08	0.1	0.7	1.5	2.2	204							
Mar-08		0.7	1.7	2.4	207							
Apr-08		0.7	2.8	3.5	224							
May-08	0.1	0.5	3.3	3.8	216							
Jun-08		2.7	2.7	5.4	225							
Jul-08		0.5	1.9	2.4	213	213	2.3	12.3	34.7	11.2	4.9	4.8
Aug-08	0.1	0.5	2.4	2.9	223							
Sep-08		0.5	1.5	2	221							
Oct-08		0.5	1.5	2	218							
Nov-08	0.1	0.5	1.7	2.2	207							
Dec-08		0.5	1.4	1.9	198							
Jan-09		1.5	1.4	2.9	243							
Feb-09	0.1	0.9	1.4	2.3	198							

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Mar-09		0.5	1.7	2.2	208							
Apr-09		0.5	3.1	3.6	210							
May-09	0.1	0.5	2.9	3.4	218							
Jun-09		1	2.7	3.7	235							
Jul-09		1	3	4	265	148	2.1	14.5	39.3	12.3	4.1	6.4
Aug-09	0.1	0.5	2.2	2.7	233							
Sep-09		0.5	1.7	2.2	215							
Oct-09		0.5	1.6	2.1	194							
Nov-09	0.1	0.5	1.5	2	203							
Mean	0.46	1.20	2.00	3.20	204.23	125.00	4.59	13.12	31.63	10.28	3.84	5.50
Max	3	3.9	4.4	5.7	265	213	14	15	39.5	12.7	4.9	6.4
Min	0.1	0.5	0.9	1.6	171	6	1	11	26	8.9	1.6	4.8

See Appendix A for definitions of abbreviations in the header row.

Table E-3. BAF Well MW-2 Groundwater Quality Data (mg/L), 2001-09.

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Jan-01	0.7	1.5	8.6	10.1	647	334	61	120	74	27	5.6	
Feb-01	0.5	1.5	9.8	11.3	662							
Mar-01	0.5	1.5	13.2	14.7	654							
Apr-01	0.5	1.5	22.2	23.7	1389	324	52	130	85	30	5.9	
May-01	0.5	1.5	20.5	22	709							
Jun-01												
Jul-01												
Aug-01												
Sep-01												
Oct-01	0.5	1.5	13.7	15.2	692	400	67	135	72	28	5.6	
Nov-01	0.5	1.5	12.9	14.4	697							
Dec-01	0.8	1.9	19	20.9	706							
Jan-02	0.5	1.5	16.9	18.4	712							
Feb-02	0.5	1.5	17.3	18.8	707	433	66	123	75	30	4.2	
Mar-02	0.5	1.5	19.1	20.6	717							
Apr-02	0.5	1.5	18.5	20	695							
May-02	0.5	1.5	16.3	17.8	683	409	76	125	67.9	24.4	5.6	
Jun-02	0.5	1.5	17	18.5	717							
Jul-02												
Aug-02												
Sep-02												
Oct-02												
Nov-02												
Dec-02	0.5	1.5	23.1	24.6	708							
Jan-03	0.5	1.5	20.7	22.2	692							
Feb-03	0.5	1.8	20.3	22.1	674	320	25	121	70.6	27.7	5.9	
Mar-03	0.5	1.5	14.2	15.7	653							
Apr-03	0.5	1.5	13	14.5	683							
May-03	0.5	1.5	11.7	13.2	683	316	64	113	64.2	25.3	5.3	
Jun-03												
Jul-03												
Aug-03												

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Sep-03												
Oct-03	0.5	4	12.4	16.4	653							
Nov-03												
Dec-03												
Jan-04												
Feb-04												
Mar-04	0.5	1.5	12.3	13.8	650							
Apr-04	0.5	1.5	10.5	12	625							
May-04												
Jun-04												
Jul-04												
Aug-04												
Sep-04												
Oct-04	0.5	1.5	8.6	10.1	662							
Nov-04	0.9	1.5	9.4	10.9	637	321	69	120	64.4	26.2	4.6	
Dec-04	0.5	1.5	10.7	12.2	622							
Jan-05	0.5	1.5	10.5	12	623	622	59.6	116	66.2	25.6	4.5	
Feb-05	0.5	1.5	10.3	11.8	609							
Mar-05	0.5	1.5	10.2	11.7	618							
Apr-05	0.5	1.5	9.3	10.8	619							
May-05												
Jun-05												
Jul-05												
Aug-05												
Sep-05												
Oct-05	0.3	0.7	22.7	23.4	689							
Nov-05	0.3	0.7	12.9	13.6	666	365	61	113	78.2	31.8	7.1	
Dec-05	0.3	1	9.5	10.5	657							
Jan-06	0.3	0.7	9.6	10.3	637							
Feb-06	0.3	0.9	9.6	10.5	606	318	65	115	67.4	27.3	6.6	
Mar-06	0.3	1.9	9.5	11.4	625							
Apr-06	0.3	2.8	9.6	12.4	627							
May-06	0.4	1.3	9.2	10.5	637		64	121	66.4	26.2	6.2	
Jun-06												

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Jul-06												
Aug-06	0.1	0.9	8.4	9.3	422							
Sep-06												
Oct-06												
Nov-06	0.1	1.7	9.3	11	641							
Dec-06		0.9	9.1	10	658							
Jan-07		0.7	9.3	10	635							
Feb-07	0.1	0.7	9.1	9.8	580							
Mar-07												
Apr-07												
May-07	0.1	1.8	7.3	9.1	574							
Jun-07		0.7	4	4.7	571							
Jul-07												
Aug-07												
Sep-07		0.7	4.6	5.3	580							
Oct-07		0.7	3.7	4.4	588							
Nov-07	0.1	0.9	1.9	2.8	549							
Dec-07		0.7	1.4	2.1	541							
Jan-08		0.7	1.1	1.8	573							
Feb-08	0.1	0.7	1.3	2	559							
Mar-08		0.7	1.1	1.8	559							
Apr-08		0.7	0.8	1.5	556							
May-08	0.1	0.5	0.8	1.3	551							
Jun-08												
Jul-08		0.5	0.4	0.9	563	295	63.4	102	53.2	21.1	7.4	23.9
Aug-08	0.1	0.5	1.6	2.1	529							
Sep-08		0.5	1.6	2.1	537							
Oct-08		0.5	1.3	1.8	545							
Nov-08	0.1	0.6	1.4	2	530							
Dec-08		0.5	2.5	3	552							
Jan-09		1.5	2.1	3.6	601							
Feb-09	0.1	0.5	2.1	2.6	548							
Mar-09		0.5	2.5	3	544							
Apr-09		1.7	2.6	4.3	549							

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
May-09	0.1	0.5	1.6	2.1	537							
Jun-09												
Jul-09												
Aug-09												
Sep-09		0.5	3.6	4.1	543							
Oct-09		1	2.2	3.2	549							
Nov-09	0.1	3.3	2.3	5.6	555							
Mean	0.39	1.24	9.20	10.45	628.84	371.42	61.00	119.54	69.58	26.97	5.73	23.90
Max	0.9	4	23.1	24.6	1389	622	76	135	85	31.8	7.4	23.9
Min	0.1	0.5	0.4	0.9	422	295	25	102	53.2	21.1	4.2	23.9

See Appendix A for definitions of abbreviations in the header row.

Table E-4. BAF Well MW-3 Groundwater Quality Data (mg/L), 2001-09.

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Jan-01	0.5	1.5	2.5	4	572	283	61	116	56	23	7	
Feb-01	0.5	1.5	3.3	4.8	569							
Mar-01	0.5	1.5	5.4	6.9	582							
Apr-01	0.5	1.5	5.1	6.6	591	313	57	122	63	24	7.2	
May-01	0.5	1.5	4	5.5	595							
Jun-01	0.5	1.5	2.5	4	564	231	61	120	55	23	7.2	
Jul-01												
Aug-01												
Sep-01												
Oct-01												
Nov-01												
Dec-01												
Jan-02	0.5	1.5	2.8	4.3	529							
Feb-02	0.6	1.5	3	4.5	507	391	64	114	48	22	5.2	
Mar-02												
Apr-02	0.5	1.5	4.5	6	563							
May-02	0.5	1.5	6.3	7.8	552	391	79	114	48.6	22	6.7	
Jun-02	0.5	1.5	6	7.5	562							
Jul-02												
Aug-02												
Sep-02												
Oct-02												
Nov-02												
Dec-02												
Jan-03												
Feb-03	0.5	2.6	5.6	8.2	548	273	71	112	50.6	23.9	7	
Mar-03	0.8	2.1	5.5	7.6	541							
Apr-03	0.9	1.5	5.1	6.6	579							
May-03	0.7	1.5	5.2	6.7	572	266	61	101	45.8	22.1	6.9	
Jun-03												
Jul-03												
Aug-03												

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Sep-03												
Oct-03												
Nov-03												
Dec-03												
Jan-04												
Feb-04												
Mar-04												
Apr-04	0.5	1.5	4.7	6.2	541							
May-04												
Jun-04												
Jul-04												
Aug-04												
Sep-04												
Oct-04												
Nov-04												
Dec-04												
Jan-05												
Feb-05												
Mar-05	0.5	4.3	4.7	9	528							
Apr-05	0.5	1.5	4.6	6.1	521							
May-05	0.6	1.5	4.6	6.1	544		65	118	59.4	25.6	7.8	
Jun-05												
Jul-05												
Aug-05												
Sep-05												
Oct-05												
Nov-05												
Dec-05												
Jan-06												
Feb-06												
Mar-06												
Apr-06	0.3	1.9	4.2	6.1	527							
May-06	0.3	1.3	13.4	14.7	555	6	62	112	53.1	22.6	7.6	
Jun-06	0.3	0.7	14.6	15.3	583							

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Jul-06		1.6	14.9	16.5	572	325	64	111	49.7	23.3	5.9	
Aug-06	0.1	0.9	10.7	11.6	594							
Sep-06		0.7	12.9	13.6	564							
Oct-06		1.5	12.3	13.8	559							
Nov-06	0.1	1.1	12.6	13.7	583							
Dec-06		0.82	12.4	13.22	565							
Jan-07		0.7	4.3	5	531							
Feb-07	0.7	0.7	2.7	3.4	506							
Mar-07												
Apr-07												
May-07	0.1	0.7	2.2	2.9	520							
Jun-07		0.7	2.2	2.9	532							
Jul-07		2.3	1.7	4	543	295	57.6	108	46.5	20.6	6.9	26.1
Aug-07	0.1	1.9	2.7	4.6	541							
Sep-07		0.7	5.5	6.2	535							
Oct-07		0.7	4	4.7	538							
Nov-07	0.1	0.7	4.2	4.9	524							
Dec-07		0.83	4.1	4.93	525							
Jan-08		0.7	1.5	2.2	534							
Feb-08	0.1	0.7	1.8	2.5	519							
Mar-08		0.7	2.1	2.8	518							
Apr-08		0.7	2.4	3.1	524							
May-08	0.1	0.5	2.1	2.6	554							
Jun-08		2.1	1.4	3.5	536							
Jul-08		0.5	1.8	2.3	538	275	65	106	49	22	8.8	24.6
Aug-08	0.1	0.5	1.8	2.3	539							
Sep-08		0.5	2.1	2.6	525							
Oct-08		0.6	2.3	2.9	519							
Nov-08	0.1	0.8	2.7	3.5	517							
Dec-08		0.5	2.7	3.2	520							
Jan-09		1.5	1.6	3.1	590							
Feb-09	0.1	0.5	0.9	1.4	513							
Mar-09		0.5	0.8	1.3	515							
Apr-09		0.5	1.4	1.9	509							

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
May-09	0.1	0.5	1	1.5	522							
Jun-09		1.6	1.6	3.2	545							
Jul-09		0.5	0.7	1.2	547	291	65.7	110	49	20.5	6.7	23
Aug-09	0.1	0.5	0.8	1.3	535							
Sep-09		0.5	1.1	1.6	551							
Oct-09		0.6	1.1	1.7	521							
Nov-09	0.1	0.5	1	1.5	537							
Mean	0.38	1.15	4.32	5.47	544.02	278.33	64.10	112.62	51.82	22.66	6.99	24.57
Max	0.9	4.3	14.9	16.5	595	391	79	122	63	25.6	8.8	26.1
Min	0.1	0.5	0.7	1.2	506	6	57	101	45.8	20.5	5.2	23

See Appendix A for definitions of abbreviations in the header row.

Table E-5. BAF Well MW-6 Groundwater Quality Data (mg/L), 2001-09.

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Jan-01	0.9	1.5	40.7	42.2	1321	796	101	151	228	83	9.1	
Feb-01	0.5	1.5	29.4	30.9	1320							
Mar-01	0.5	1.5	22.7	24.2	1239							
Apr-01	0.5	1.5	17.8	19.3	555	818	106	147	219	80	9.1	
May-01	0.5	1.5	17.4	18.9	1225							
Jun-01	1.5	1.5	16.5	18	1266	799	95	139	207	79	9.2	
Jul-01	0.5	1.5	14.5	16	1228							
Aug-01	0.9	1.5	22.4	23.9	1235							
Sep-01	0.5	2.7	47.1	49.8	1309							
Oct-01	0.6	1.5	39.4	40.9	1245	327	110	147	206	79	8.9	
Nov-01	0.5	1.5	50.2	51.7	1358							
Dec-01	0.6	1.5	66.5	68	1433							
Jan-02	0.5	1.5	61.7	63.2	1435							
Feb-02	0.6	1.5	51.4	52.9	1341	853	100	146	201	80	7	
Mar-02	0.5	1.5	41.2	42.7	1298							
Apr-02	0.5	1.5	40.3	41.8	1214							
May-02	0.5	1.5	53.1	54.6	481	604	103	136	180	70.4	6.1	
Jun-02	0.5	2.7	36	38.7	1300							
Jul-02	0.5	1.5	29.4	30.9	1264							
Aug-02	0.5	1.5	43	44.5	1331	713	123	152	219	87.1	9.8	
Sep-02	0.5	1.5	45.2	46.7	1347							
Oct-02	0.5	1.5	44.2	45.7	1330							
Nov-02	0.5	3.7	32.4	36.1	1291	669	146	137	199	78.4	8.1	
Dec-02	0.5	1.5	26.5	28	1267							
Jan-03	0.5	1.5	26.2	27.7	1290							
Feb-03	0.5	1.8	27.5	29.3	1318	742	133	137	200	79	8.9	
Mar-03	0.6	1.5	35.1	36.6	1331							
Apr-03	0.5	1.5	40.4	41.9	1298							
May-03	0.5	1.5	53.4	54.9	1415	695	125	127	197	76.5	8	
Jun-03	1.3	1.5	59.4	60.9	1461							
Jul-03	0.6	1.5	65.8	67.3	1400							
Aug-03	1.2	1.5	71	72.5	1430	678	132	139	209	79.5	8	

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Sep-03	0.7	1.5	68.8	70.3	1389							
Oct-03	0.5	5	88.5	93.5	1458							
Nov-03	0.9	1.5	99.2	100.7	1487	640	107	145	204	85.4	6.5	
Dec-03	0.5	2.4	88	90.4	1462							
Jan-04	0.5	1.5	60.8	62.3	1393							
Feb-04	0.5	1.5	44.4	45.9	1327	780	139	138	202	80.9	8.2	
Mar-04	0.5	2.9	38	40.9	1299							
Apr-04	0.5	1.5	10.5	12	1323							
May-04	0.5	2.5	44.2	46.7	1288	717	129	126	196	76.6	7.9	
Jun-04	0.7	1.5	47.1	48.6	1301							
Jul-04	0.6	1.5	47.8	49.3	1309							
Aug-04	0.5	1.5	60	61.5	1381							
Sep-04	0.5	1.5	63.8	65.3	1369							
Oct-04	0.5	1.5	67.9	69.4	1349							
Nov-04	0.5	1.5	70.7	72.2	1348	607	97	136	200	77.3	7.5	
Dec-04	0.5	1.5	62	63.5	1282							
Jan-05	0.5	1.9	52	53.9	1248	622	113	126	184	72	7.1	
Feb-05	0.5	1.5	45	46.5	1178							
Mar-05	0.5	1.5	34.8	36.3	1193							
Apr-05	0.5	1.5	30.2	31.7	1156							
May-05	0.5	1.5	27.7	29.2	1147	637	121	137	184	76.5	7.9	
Jun-05	0.3	3.6	25.3	28.9	1085							
Jul-05	0.3	1.9	22.7	24.6	1121							
Aug-05	0.29	2.98	25.6	28.58	1130	681	95	126	176	69.7	8	
Sep-05	0.45	1.03	38.3	39.33	1203							
Oct-05	0.3	0.7	53	53.7	1246							
Nov-05	0.3	0.7	27.2	27.9	1146	708	128	129	184	72.3	8.9	
Dec-05	0.3	0.95	67.1	68.05	1258							
Jan-06	0.3	0.7	58.3	59	1271							
Feb-06	0.3	0.88	52.9	53.78	1173	630	125	131	179	70.8	8.9	
Mar-06	0.3	2.1	52	54.1	1146							
Apr-06	0.74	5.6	44.4	50	1196							
May-06	0.7	1	43.6	44.6	1164	6	110	130	178	70.6	8.9	

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Jun-06	0.3	1	41.6	42.6	1119							
Jul-06		1	3.9	4.9	1181	635	114	128	173	68.4	6.7	
Aug-06	0.1	0.9	48.4	49.3	1157							
Sep-06		0.7	50.5	51.2	1150							
Oct-06		0.7	48.4	49.1	1167							
Nov-06	0.1	1.8	44.4	46.2	1153							
Dec-06		1	56.3	57.3	1193							
Jan-07		0.7	58	58.7	1263							
Feb-07	0.1	1.9	50	51.9	1097							
Mar-07												
Apr-07												
May-07	0.1	2.9	40.5	43.4	1044							
Jun-07		2.2	43.4	45.6	1121							
Jul-07		1.1	14.5	15.6	1152	616	90	122	157	62.9	7.7	28.6
Aug-07	0.1	1.2	30.8	32	1099							
Sep-07		1	25.4	26.4	1099							
Oct-07		1.4	28.5	29.9	1174							
Nov-07	0.1	2.3	35.3	37.6	1272							
Dec-07		2.5	37.4	39.9	1312							
Jan-08		2.8	41.4	44.2	1418							
Feb-08	0.1	2.9	44.8	47.7	1346							
Mar-08		2.5	47.1	49.6	1402							
Apr-08		2.3	45.6	47.9	1379							
May-08	0.1	2.7	41.5	44.2	1280							
Jun-08		5.1	36.7	41.8	1400							
Jul-08		3.7	40.3	44	1484	612	210	138	210	83	11.2	57.7
Aug-08	0.1	3.3	41.8	45.1	1445							
Sep-08		4.2	44.3	48.5	1579							
Oct-08		5	42.2	47.2	1478							
Nov-08	0.1	4.6	42.3	46.9	1533							
Dec-08		3.2	42	45.2	1491							
Jan-09		1.5	42.6	44.1	1663							
Feb-09	0.1	3.2	44.1	47.3	1494							

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Mar-09		4.2	45.6	49.8	1506							
Apr-09		5.7	41.3	47	1492							
May-09	0.1	3.9	39.6	43.5	1575							
Jun-09		3.4	37.6	41	1596							
Jul-09		2.8	39.6	42.4	1509	575	206	147	225	88.1	9	66.6
Aug-09	0.1	1.9	41.2	43.1	1477							
Sep-09		3.8	39.6	43.4	1478							
Oct-09		4.2	40.5	44.7	1394							
Nov-09	0.1	4.1	41.2	45.3	1467							
Mean	0.47	2.09	43.33	45.42	1295.63	646.40	122.32	136.68	196.68	77.06	8.26	50.97
Max	1.5	5.7	99.2	100.7	1663	853	210	152	228	88.1	11.2	66.6
Min	0.1	0.7	3.9	4.9	481	6	90	122	157	62.9	6.1	28.6

See Appendix A for definitions of abbreviations in the header row.

Table E-6. BAF Well MW-8 Groundwater Quality Data (mg/L), 2001-09.

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Jan-01	0.1	1.5	18.4	19.9	448	103	74	21	73	30	3.6	
Feb-01	0.5	1.5	18	19.5	449							
Mar-01	0.5	1.5	18.7	20.2	457							
Apr-01	0.5	1.5	18	19.5	423	114	59	19	71	30	3.5	
May-01	0.5	1.5	18.1	19.6	415							
Jun-01												
Jul-01												
Aug-01												
Sep-01												
Oct-01												
Nov-01												
Dec-01	0.7	1.5	21.8	23.3	450							
Jan-02	0.5	1.5	18.4	19.9	410							
Feb-02	0.5	1.5	18.2	19.7	419	124	79	18	64	30	1.6	
Mar-02	0.5	1.5	38.2	39.7	443							
Apr-02	0.5	1.5	18	19.5	508							
May-02	0.5	1.5	20.4	21.9	453	124	89	17.3	59.7	28.9	2.8	
Jun-02												
Jul-02												
Aug-02												
Sep-02												
Oct-02												
Nov-02												
Dec-02	0.5	1.5	20.2	21.7	428							
Jan-03	0.5	1.5	19.5	21	508							
Feb-03	0.5	2.6	20.5	23.1	430	99	80	17.5	61.1	29	3.5	
Mar-03	0.5	1.5	17.8	19.3	489							
Apr-03	0.5	1.5	17.7	19.2	438							
May-03	0.5	1.5	20.5	22	512	75	79	15.2	56.4	27.7	2.8	
Jun-03												
Jul-03												
Aug-03												

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Sep-03												
Oct-03												
Nov-03												
Dec-03												
Jan-04	0.5	1.5	20.5	22	460							
Feb-04	0.5	1.5	21.1	22.6	458	116	83	17.7	67.8	32	3.1	
Mar-04	0.5	1.5	19.8	21.3	476							
Apr-04	0.5	1.5	19.9	21.4	469							
May-04												
Jun-04												
Jul-04												
Aug-04												
Sep-04												
Oct-04												
Nov-04												
Dec-04	0.5	1.5	19.1	20.6	430							
Jan-05	0.5	1.5	20.4	21.9	455	105	86	16.9	66.6	31.5	2.5	
Feb-05	0.5	1.6	20.9	22.5	423							
Mar-05	0.5	1.5	20.5	22	466							
Apr-05	0.5	1.5	19.9	21.4	453							
May-05	0.4	1.5	19.4	20.9	400		78	17.7	65.5	33.3	2.9	
Jun-05												
Jul-05												
Aug-05												
Sep-05												
Oct-05												
Nov-05												
Dec-05	0.3	0.95	20	20.95	478							
Jan-06	0.3	0.7	18.1	18.8	551							
Feb-06	0.3	0.7	19.2	19.9	406	113	88	19.9	64.6	31.7	4.3	
Mar-06	0.3	1.9	19.3	21.2	451							
Apr-06	0.3	1.3	18.3	19.6	462							
May-06												

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Jun-06												
Jul-06												
Aug-06												
Sep-06												
Oct-06												
Nov-06												
Dec-06		0.82	18.6	19.42	458							
Jan-07		0.7	19	19.7	588							
Feb-07	0.1	1.1	20	21.1	470							
Mar-07												
Apr-07												
May-07												
Jun-07												
Jul-07												
Aug-07												
Sep-07												
Oct-07												
Nov-07												
Dec-07		1.42	18.5	19.9	492							
Jan-08		1.7	16.6	18.3	474							
Feb-08	0.1	1.7	15.5	17.2	423							
Mar-08		1.8	14.9	16.7	513							
Apr-08		1.5	15.6	17.1	488							
May-08												
Jun-08												
Jul-08												
Aug-08												
Sep-08												
Oct-08												
Nov-08												
Dec-08		1.8	17.9	19.7	457							
Jan-09		1.5	16.5	18	584							
Feb-09	0.1	2	16.3	18.3	432							

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Mar-09		2	17	19	468							
Apr-09		3	19.2	22.2	492							
May-09	0.1	1.9	19.1	21	512							
Jun-09												
Jul-09												
Aug-09												
Sep-09												
Oct-09												
Nov-09												
Mean	0.42	1.53	19.21	20.73	464.54	108.11	79.50	18.02	64.97	30.41	3.06	
Max	0.7	3	38.2	39.7	588	124	89	21	73	33.3	4.3	
Min	0.1	0.7	14.9	16.7	400	75	59	15.2	56.4	27.7	1.6	

See Appendix A for definitions of abbreviations in the header row.

Table E-7. BAF Well MW-9 Groundwater Quality Data (Mg/L), 2001-09.

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Jan-01	0.5	1.5	20.8	22.3	322	129	16	17	46	23	2.4	
Feb-01	0.5	1.5	22	23.5	341							
Mar-01	0.5	1.5	22.3	23.8	239							
Apr-01	0.5	1.5	21.5	23	321	124	5	17	49	20	2.4	
May-01	0.5	1.5	21.3	22.8	318							
Jun-01												
Jul-01												
Aug-01												
Sep-01												
Oct-01	0.9	1.5	20.9	22.4	302	126	20	19	34	26	4.2	
Nov-01												
Dec-01	0.5	1.5	21.7	23.2	314							
Jan-02	0.5	1.5	20.7	22.2	337							
Feb-02	0.5	1.5	21.4	22.9	327	117	16	16	43	22	0.4	
Mar-02	0.5	1.5	38.2	39.7	586							
Apr-02	0.5	2.1	22.1	24.2	345							
May-02	0.5	1.5	24.3	25.8	350	149	24	17.3	391	25	2.9	
Jun-02	0.5	1.5	21.9	23.4	333							
Jul-02	0.5	1.5	20.8	22.3	295							
Aug-02	0.5	1.5	20	21.5	324	136	17	17.9	31.7	24.6	4.2	
Sep-02												
Oct-02												
Nov-02	0.5	1.5	36	37.5	513	116	19	16.9	31.8	25.9	3.5	
Dec-02	0.5	1.5	20.4	21.9	293							
Jan-03	0.5	1.5	21	22.5	323							
Feb-03	0.5	1.8	23.6	25.4	327	121	15	16.3	39.3	22.8	2.8	
Mar-03	0.5	3.7	22.7	26.4	318							
Apr-03	0.5	1.5	23	24.5	333							
May-03	0.5	2	23.4	25.4	343	120	15	15.3	38.4	23.9	2.8	
Jun-03	0.8	1.5	22.1	23.6	345							
Jul-03	0.6	1.5	21.3	22.8	328							
Aug-03	1.5	3	18.9	21.9	309	149	14	18.5	33.3	25	3.8	

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Sep-03	0.6	1.5	20	21.5	302							
Oct-03												
Nov-03	1.1	1.5	20.8	22.3	301	124	11	18.1	33	25.8	2	
Dec-03	0.5	1.5	21.6	23.1	286							
Jan-04	0.5	1.5	45.6	47.1	659							
Feb-04	0.5	1.5	29.5	31	384	131	36	18.4	48.3	29.7	3.2	
Mar-04	0.5	1.5	38.4	39.9	491							
Apr-04	0.5	1.5	36.7	38.2	447							
May-04	0.5	1.5	33.9	35.4	413	121	43	17.7	52.5	31.2	3.3	
Jun-04	0.5	1.5	24.8	26.3	326							
Jul-04	0.6	1.5	24.7	26.2	347							
Aug-04	0.5	1.5	24.5	26	348							
Sep-04	0.5	1.5	23.9	25.4	371							
Oct-04	0.5	1.5	26	27.5	367							
Nov-04	0.5	1.5	25.2	26.7	356	114	25	17.1	38.5	29.1	3.2	
Dec-04	0.5	1.5	25.4	26.9	357							
Jan-05	0.5	1.5	30.9	32.4	382	116	30	18.4	50.8	32.1	2.9	
Feb-05	0.5	1.7	32.7	34.4	376							
Mar-05	0.5	1.5	36.3	37.8	423							
Apr-05	0.5	1.5	33.4	34.9	440							
May-05	0.4	1.5	33.6	35.1	437	116	32	19.2	58.5	32.8	2.7	
Jun-05	0.3	2.4	27.5	29.9	360							
Jul-05	0.3	1.5	29.8	31.3	376							
Aug-05	0.29	1.16	25.5	26.66	333	128	16	19.1	35.1	27.3	3.6	
Sep-05	0.4	1.03	23.7	24.73	334							
Oct-05	0.32	1.54	30.2	31.74	361							
Nov-05	0.3	0.7	24.8	25.5	351	127	22	18.5	36.9	29.5	4.3	
Dec-05	0.3	0.7	28.4	29.1	361							
Jan-06	0.3	0.7	27.2	27.9	410							
Feb-06	0.3	0.7	28.9	29.6	352	119	28	19.8	45.8	30.7	4.3	
Mar-06	0.3	1.3	28.5	29.8	384							
Apr-06	0.3	3.4	29.7	33.1	414							
May-06	0.5	1.7	31.5	33.2	418	6	34	18.8	51.6	30.5	3.7	
Jun-06	0.3	1	27.4	28.4	348							

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Jul-06		1.6	14.9	16.5	572	129	23	18.8	40.3	28.4	2.9	
Aug-06	0.1	0.9	25.2	26.1	351							
Sep-06		0.7	24.2	24.9	395							
Oct-06		0.7	23.4	24.1	343							
Nov-06	0.1	1.2	25.2	26.4	351							
Dec-06		1.12	25.5	26.62	376							
Jan-07		1.2	29.6	30.8	407							
Feb-07	0.1	1.2	36.2	37.4	431							
Mar-07												
Apr-07												
May-07	0.1	2.1	37.5	39.6	450							
Jun-07		1.6	29	30.6	425	126	23.4	17.9	41	30.2	3.9	6.3
Jul-07		1.5	27	28.5	417							
Aug-07	0.1	0.7	27.9	28.6	417							
Sep-07		0.7	27.8	28.5	364							
Oct-07		1.3	28	29.3	375							
Nov-07	0.1	1.8	27.4	29.2	391							
Dec-07		2.02	27.2	29.22	373							
Jan-08		1.8	42.1	43.9	534							
Feb-08	0.1	2.2	50.8	53	583							
Mar-08		2	49.1	51.1	618							
Apr-08		1.9	51.2	53.1	697							
May-08	0.1	2.5	42.4	44.9	512							
Jun-08		4.2	37.2	41.4	508							
Jul-08												
Aug-08	0.1	2.8	32.6	35.4	519							
Sep-08		2.7	31.6	34.3	423							
Oct-08		3.8	31.1	34.9	421							
Nov-08	0.1	3.5	33.7	37.2	456							
Dec-08		2.5	34	36.5	477							
Jan-09		1.5	37.7	39.2	554							
Feb-09	0.1	3	39.7	42.7	522							
Mar-09		3	44.2	47.2	512							
Apr-09		3.2	47.3	50.5	512							

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
May-09	0.1	2.8	38	40.8	518							
Jun-09		0.8	29.6	30.4	500							
Jul-09		2	33.8	35.8	471	122	35.3	20.1	50.7	36.3	4.2	7.9
Aug-09	0.1	2	33	35	412							
Sep-09		3	24.1	27.1	463							
Oct-09		2.7	32.9	35.6	424							
Nov-09	0.1	2.2	32.6	34.8	437							
Mean	0.43	1.74	29.04	30.78	402.21	120.26	22.60	17.96	57.41	27.47	3.20	7.10
Max	1.5	4.2	51.2	53.1	697	149	43	20.1	391	36.3	4.3	7.9
Min	0.1	0.7	14.9	16.5	239	6	5	15.3	31.7	20	0.4	6.3

See Appendix A for definitions of abbreviations in the header row.

Table E-8. BAF Well MW-10 Groundwater Quality Data (mg/L), 2001-09.

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Jan-01	0.5	1.5	47.9	49.4	682	137	66	44	97	37	5.5	
Feb-01	0.5	1.5	47	48.5	658							
Mar-01	0.5	1.5	39.2	40.7	553							
Apr-01	0.5	1.5	51.6	53.1	671	135	61	45	109	40	5.5	
May-01	0.5	1.5	64.2	65.7	797							
Jun-01	0.5	1.5	75.1	76.6	931	146	89	50	125	48	7.6	
Jul-01	0.5	1.5	69.6	71.1	916							
Aug-01	0.5	1.5	67	68.5	916							
Sep-01	0.5	1.5	30.4	31.9	506							
Oct-01	0.5	1.5	45.6	47.1	656	116	70	45	95	37	5.3	
Nov-01	0.5	1.5	49.1	50.6	680							
Dec-01	1.1	1.5	41.4	42.9	627							
Jan-02	0.5	1.5	20.5	22	419							
Feb-02	0.5	1.5	47.5	49	616	142	70	43	89	38	3.3	
Mar-02	0.5	1.5	46.9	48.4	632							
Apr-02	0.5	3.3	65.4	68.7	760							
May-02	0.5	1.5	60.8	62.3	761	174	83	45.6	102	43.4	4.9	
Jun-02	0.5	1.5	99.3	100.8	1039							
Jul-02	0.5	1.5	72.5	74	908							
Aug-02	0.5	1.5	64.4	65.9	866	164	93	52.3	117	45.9	7.5	
Sep-02	0.5	1.5	44.6	46.1	652							
Oct-02	0.5	1.5	34	35.5	521							
Nov-02	0.5	1.5	36	37.5	513	157	52	40.6	72.7	31.1	4.8	
Dec-02	0.5	1.5	38.7	40.2	574							
Jan-03	0.5	1.5	46.4	47.9	680							
Feb-03	0.5	1.5	34.3	35.8	498	135	49	36.9	66.3	29.4	4.1	
Mar-03	0.5	1.5	44.2	45.7	617							
Apr-03	0.5	1.5	44.9	46.4	653							
May-03	0.5	1.5	53.3	54.8	872	146	82	41.5	100	42	4.8	
Jun-03	0.8	1.5	64.5	66	925							
Jul-03	1.1	1.5	71.1	72.6	917							
Aug-03	1.1	1.5	62.5	64	1002	153	116	53.1	127	50	7.1	

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Sep-03	0.6	1.5	36	37.5	557							
Oct-03	0.5	1.5	34.3	35.8	517							
Nov-03	0.9	1.5	26.2	27.7	431	127	38	34.1	58.4	26.4	1.7	
Dec-03	0.5	1.5	37.8	39.3	538							
Jan-04	0.5	1.5	24.8	26.3	339							
Feb-04	0.5	1.5	44.4	45.9	688	149	76	43.2	95.1	39.8	4.8	
Mar-04	0.5	1.5	42.7	44.2	660							
Apr-04	0.5	1.5	44.7	46.2	673							
May-04	0.5	1.8	53.7	55.5	756	156	91	42	107	44	5.5	
Jun-04	0.5	1.5	58.8	60.3	873							
Jul-04	0.5	1.5	65	66.5	906							
Aug-04	0.5	1.5	63.2	64.7	924							
Sep-04	0.5	1.5	61.5	63	951							
Oct-04	0.5	1.5	50.4	51.9	695							
Nov-04	0.5	1.5	51	52.5	732	131	81	41.8	96.9	41.6	4.5	
Dec-04	0.5	1.5	47.8	49.3	736							
Jan-05	0.5	1.5	36	37.5	582	131	64	40.5	93.9	40.3	4	
Feb-05	0.5	1.5	45	46.5	591							
Mar-05	0.5	1.5	49.8	51.3	637							
Apr-05	0.5	1.5	60.5	62	865							
May-05	0.4	1.5	60.3	61.8	837	145	97	50.9	129	53.3	6.1	
Jun-05	0.3	1.5	65.7	67.2	909							
Jul-05	0.3	2.1	68.9	71	928							
Aug-05	0.29	1.52	58.4	59.92	946	149	79.9	50.6	128	51.6	7	
Sep-05	0.4	1.31	28.1	29.41	500							
Oct-05	0.3	0.7	33.2	33.9	504							
Nov-05	0.3	0.7	38.8	39.5	688	142	68	40.7	91.4	39.3	5.7	
Dec-05	0.3	0.95	46.2	47.15	696							
Jan-06	0.3	0.7	45.5	46.2	724							
Feb-06	0.3	0.88	64.2	65.08	716	135	96	46.8	113	48.2	6.4	
Mar-06	0.3	2.4	76.2	78.6	790							
Apr-06	0.3	2.8	58	60.8	822							
May-06	0.4	0.7	69.6	70.3	997	6	117	51.7	142	56.2	7.5	
Jun-06	0.3	1.5	69	70.5	936							

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Jul-06		1.27	75.6	76.87	1081	150	140	53.8	147	57.2	6.5	
Aug-06	0.1	0.9	81.3	82.2	1064							
Sep-06		0.7	68.5	69.2	974							
Oct-06		0.7	41.1	41.8	640							
Nov-06	0.1	1.2	51	52.2	749							
Dec-06		1.64	53	54.64	705							
Jan-07		1.5	54	55.5	812							
Feb-07	0.1	1.6	56	57.6	747							
Mar-07												
Apr-07												
May-07	0.1	2	68	70	921							
Jun-07		1.8	68	69.8	944							
Jul-07		0.7	66.3	67	1042	169	98	48	139	54.8	7.5	45.9
Aug-07	0.1	0.7	65.2	65.9	1112							
Sep-07		0.9	51.8	52.7	759							
Oct-07		1.3	38.6	39.9	621							
Nov-07	0.1	1.4	46.5	47.9	727							
Dec-07		2.4	48.8	51.2	758							
Jan-08		1.9	56.4	58.3	899							
Feb-08	0.1	1.9	56	57.9	843							
Mar-08		2.1	47.3	49.4	736							
Apr-08		2.1	56.8	58.9	1011							
May-08	0.1	2.5	60.1	62.6	962							
Jun-08		5.5	58.8	64.3	1071							
Jul-08		3.3	59.8	63.1	1085	160	130	49.5	150	58	9.3	50.7
Aug-08	0.1	3.9	57.1	61	1103							
Sep-08		2.6	40.8	43.4	727							
Oct-08		3.4	33.8	37.2	616							
Nov-08	0.1	3.6	49.2	52.8	931							
Dec-08		2.3	47.3	49.6	876							
Jan-09		1.5	48.4	49.9	942							
Feb-09	0.1	3.7	47.4	51.1	831							
Mar-09		3.4	53	56.4	856							
Apr-09		3	57.1	60.1	930							

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
May-09	0.1	2.5	54.7	57.2	1018							
Jun-09		3.4	53.6	57	1020							
Jul-09		2.3	55.8	58.1	1055	162	120	50.7	157	59.2	7.9	59.1
Aug-09	0.1	1	54.9	55.9	954							
Sep-09		2.7	21.7	24.4	520							
Oct-09		2.9	21.9	24.8	412							
Nov-09	0.1	3.6	37.7	41.3	714							
Mean	0.43	1.76	51.99	53.75	775.52	140.68	85.08	45.65	109.91	44.47	5.79	51.90
Max	1.1	5.5	99.3	100.8	1112	174	140	53.8	157	59.2	9.3	59.1
Min	0.1	0.7	20.5	22	339	6	38	34.1	58.4	26.4	1.7	45.9

See Appendix A for definitions of abbreviations in the header row.

Table E-9. BAF Well MW-11 Groundwater Quality Data (mg/L), 2001-09.

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Jan-01	0.5	1.5	19	20.5	539	309	27	40	96	38	5.6	
Feb-01	0.5	1.5	19.4	20.9	564							
Mar-01	0.6	1.5	17.9	19.4	553							
Apr-01	0.5	4.1	17.7	21.8	536	313	16	38	99	38	5.6	
May-01	0.5	1.5	16.3	17.8	547							
Jun-01												
Jul-01												
Aug-01												
Sep-01												
Oct-01	0.5	1.5	27.9	29.4	586	146	41	39	101	42	5.7	
Nov-01	0.5	1.5	40.2	41.7	684							
Dec-01	0.5	1.5	25	26.5	566							
Jan-02	0.5	7.2	20.3	27.5	555							
Feb-02	0.5	1.5	18.9	20.4	540	270	31	36	87	38	3.6	
Mar-02	0.5	1.5	20	21.5	555							
Apr-02	0.5	1.5	19.5	21	539							
May-02	0.5	1.5	15.2	16.7	527	320	31	35	82.9	36.2	4.9	
Jun-02												
Jul-02												
Aug-02												
Sep-02												
Oct-02												
Nov-02												
Dec-02	0.5	1.5	25.9	27.4	556							
Jan-03	0.5	1.5	21.7	23.2	572							
Feb-03	0.5	2.6	19.6	22.2	517	270	31	33.7	79.4	34.8	5.3	
Mar-03	0.5	2.1	17.7	19.8	507							
Apr-03	0.5	1.5	17	18.5	521							
May-03	0.6	1.5	14.7	16.2	527	272	21	29.7	76.8	33.2	4.6	
Jun-03	0.7	1.5	17.1	18.6	493							
Jul-03	0.7	1.5	17.1	18.6	493							
Aug-03												

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Sep-03												
Oct-03												
Nov-03	0.9	1.5	52.4	53.9	787	226	65	40.8	122	52.9	4.4	
Dec-03	0.5	1.5	36.8	38.3	640							
Jan-04	0.5	1.5	24.4	25.9	565							
Feb-04	0.5	1.5	21.4	22.9	509	274	34	32.5	85.5	36.7	5	
Mar-04	0.5	1.5	18.6	20.1	494							
Apr-04	0.5	1.5	16	17.5	497							
May-04	0.5	1.5	13.5	15	472	282	24	29	77	32.8	4.9	
Jun-04												
Jul-04												
Aug-04												
Sep-04												
Oct-04	0.5	1.5	41.8	43.3	624							
Nov-04	0.5	1.5	29.5	31	580	238	46	33.5	95.7	41.1	5.1	
Dec-04	0.5	1.5	46.6	48.1	545							
Jan-05	0.5	1.5	20	21.5	527	249	29	29.8	84.1	35.8	4.3	
Feb-05	0.5	1.6	18.6	20.2	483							
Mar-05	0.5	1.5	17.6	19.1	524							
Apr-05	0.5	1.5	15.7	17.2	491							
May-05	0.3	1.5	13.9	15.4	520	268	21	32.1	83.3	36.9	4.7	
Jun-05												
Jul-05												
Aug-05												
Sep-05												
Oct-05	0.3	0.7	18.1	18.8	510							
Nov-05	0.3	0.7	55	55.7	971	222	82	39.7	145	62.2	7.3	
Dec-05	0.3	1.5	22.9	24.4	586							
Jan-06	0.3	0.7	20.2	20.9	560							
Feb-06	0.3	0.7	18.2	18.9	494	256	32	32.4	84.9	37.1	6	
Mar-06	0.3	2.4	17.3	19.7	539							
Apr-06	0.5	3.1	16.5	19.6	518							
May-06	0.6	1.7	16.3	18	520	6	27	31	85.6	36.4	5.6	
Jun-06	0.3	1.5	20.7	22.2	512							

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Jul-06												
Aug-06												
Sep-06												
Oct-06												
Nov-06	0.1	1	34.1	35.1	684							
Dec-06		1.6	27.8	29.4	611							
Jan-07		1.2	21.6	22.8	546							
Feb-07	0.1	1.3	19.3	20.6	514							
Mar-07												
Apr-07												
May-07	0.1	2.2	13.1	15.3	483							
Jun-07												
Jul-07												
Aug-07												
Sep-07												
Oct-07												
Nov-07	0.1	1.9	30.2	32.1	624							
Dec-07		1.7	23.1	24.8	576							
Jan-08		1.9	17.8	19.7	566							
Feb-08	0.1	1.5	16.7	18.2	528							
Mar-08		1.5	15.4	16.9	536							
Apr-08		1.2	14.5	15.7	537							
May-08	0.1	1.8	13.4	15.2	514							
Jun-08												
Jul-08												
Aug-08												
Sep-08												
Oct-08												
Nov-08	0.1	3.2	23.8	27	631							
Dec-08		2.3	19.6	21.9	565							
Jan-09		1.5	16	17.5	590							
Feb-09	0.1	1.6	14	15.6	500							
Mar-09		2.4	14.5	16.9	527							
Apr-09		1.8	14.3	16.1	520							

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
May-09	0.1	1	11.7	12.7	499							
Jun-09												
Jul-09												
Aug-09												
Sep-09												
Oct-09												
Nov-09	0.1	4	28.5	32.5	721							
Mean	0.42	1.75	21.68	23.43	557.18	245.06	34.88	34.51	92.83	39.51	5.16	
Max	0.9	7.2	55	55.7	971	320	82	40.8	145	62.2	7.3	
Min	0.1	0.7	11.7	12.7	472	6	16	29	76.8	32.8	3.6	

See Appendix A for definitions of abbreviations in the header row.

Table E-10. BAF Well MW-12 Groundwater Quality Data (mg/L), 2001-09.

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Jan-01	0.5	1.5	7.9	9.4	480	320	13	34	87	31	4.7	
Feb-01	0.5	2.2	7.4	9.6	474							
Mar-01	0.5	1.5	6.8	8.3	454							
Apr-01	0.5	1.6	6.6	8.2	434	309	10	35	89	31	4.7	
May-01	0.5	1.5	6.4	7.9	407							
Jun-01	0.5	1.5	7.1	8.6	438	284	14	31	73	28	4.7	
Jul-01	0.5	2.2	7.3	9.5	428							
Aug-01	0.5	1.5	8.5	10	440							
Sep-01	1	1.5	7	8.5	437							
Oct-01	0.5	1.5	7.2	8.7	433	293	17.4	33	77	29	4.6	
Nov-01	0.5	1.5	7	8.5	424							
Dec-01	0.5	1.5	6.7	8.2	409							
Jan-02	0.5	1.5	6.4	7.9	457							
Feb-02	0.5	2	7.3	9.3	439	355	19	33	75	30	2.6	
Mar-02	0.5	1.5	7.3	8.8	452							
Apr-02	0.5	1.5	6.8	8.3	435							
May-02	0.5	1.5	7.2	8.7	429	309	21	32.1	72.4	28.3	4.1	
Jun-02	0.5	1.5	7.2	8.7	435							
Jul-02	0.5	1.5	6.6	8.1	407							
Aug-02	0.5	1.5	6.9	8.4	448	339	20	31.5	73.6	28.1	4.8	
Sep-02	0.5	1.5	7	8.5	432							
Oct-02												
Nov-02	0.5	1.5	6.8	8.3	415	277	16	30.7	69.8	27.5	4.3	
Dec-02	0.5	4.5	6.8	11.3	415							
Jan-03	0.5	1.5	6.4	7.9	415							
Feb-03	0.5	1.5	6.2	7.7	415	277	14	30.8	68.2	26.6	4.5	
Mar-03	0.5	2.1	6.2	8.3	403							
Apr-03	0.5	1.5	6.1	7.6	428							
May-03	0.5	1.5	6.1	7.6	422	270	9	26.9	66.3	25.5	3.8	
Jun-03	0.9	1.5	6.5	8	401							
Jul-03	0.5	1.5	6.9	8.4	461							
Aug-03	6.3	1.5	1.1	2.6	398	275	16	29.8	69.4	26.2	4.2	

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Sep-03	0.6	1.5	7.7	9.2	403							
Oct-03	0.5	1.5	7.5	9	403							
Nov-03	0.9	1.5	6.9	8.4	388	260	14	30.3	68.1	26.4	2.4	
Dec-03	0.5	1.5	6.8	8.3	386							
Jan-04	0.5	1.5	6.7	8.2	387							
Feb-04	0.5	1.5	6.8	8.3	393	276	16	30.8	69.6	26.8	3.9	
Mar-04	0.5	1.5	6.9	8.4	400							
Apr-04	0.5	1.5	7	8.5	403							
May-04	0.5	1.5	7.3	8.8	399	270	15	28	68	26	4.2	
Jun-04	0.5	1.5	7.1	8.6	388							
Jul-04	0.5	1.5	7.1	8.6	407							
Aug-04	0.5	1.5	7.7	9.2	396							
Sep-04	0.5	1.5	7.2	8.7	409							
Oct-04	0.5	1.5	7	8.5	371							
Nov-04	0.5	1.5	7.5	9	381	250	10	28.7	67.6	26	3.7	
Dec-04	0.5	1.5	6.7	8.2	384							
Jan-05	0.5	1.5	6.9	8.4	374	249	17	30	70	27	4.3	
Feb-05	0.5	1.5	7.5	9	385							
Mar-05	0.5	1.5	7	8.5	394							
Apr-05	1.7	1.5	7.2	8.7	396							
May-05	0.3	1.5	7.4	8.9	412	261	15	31	74.3	29.4	3.9	
Jun-05	0.3	1.5	7.2	8.7	399							
Jul-05	0.3	1.5	8	9.5	395							
Aug-05	0.29	1.16	6.9	8.06	390	270	12	29.9	65.6	26.2	3.9	
Sep-05	0.4	0.75	7	7.75	417							
Oct-05	0.3	0.7	6.7	7.4	402							
Nov-05	0.3	0.7	7.1	7.8	392	271	14	28.9	65.6	26.7	4.7	
Dec-05	0.3	0.95	6.4	7.35	400							
Jan-06	0.3	0.7	6.2	6.9	393							
Feb-06	0.3	0.7	6.5	7.2	385	259	17	30.9	68.9	27.5	5.1	
Mar-06	0.3	2.1	6.8	8.9	410							
Apr-06	0.3	2.5	6.7	9.2	414							
May-06	0.3	0.7	7.2	7.9	418	6	16	30	72.8	28	4.6	
Jun-06	0.3	1.5	7.1	8.6	389							

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Jul-06		0.7	7.5	8.2	406	286	14	29.3	71.3	27.6	3.3	
Aug-06	0.1	0.9	8.4	9.3	422							
Sep-06		0.7	6.9	7.6	419							
Oct-06												
Nov-06	0.1	1.2	7.1	8.3	420							
Dec-06		1.49	7	8.49	443							
Jan-07		0.7	7	7.7	406							
Feb-07	0.1	1	7.4	8.4	398							
Mar-07												
Apr-07												
May-07	0.2	1.3	7.7	9	394							
Jun-07		1.1	7.6	8.7	414							
Jul-07		1.9	7.1	9	426	303	10.8	27.2	69.4	27.6	4.2	12.6
Aug-07	0.1	0.7	7.2	7.9	417							
Sep-07		1.1	7.3	8.4	428							
Oct-07		1	7.2	8.2	424							
Nov-07	0.1	1.7	6.7	8.4	400							
Dec-07		1.1	6.5	7.6	403							
Jan-08		1.7	6.8	8.5	446							
Feb-08	0.1	1.2	7.1	8.3	422							
Mar-08		1.1	7.3	8.4	431							
Apr-08		1	7.3	8.3	439							
May-08	0.1	1.6	7	8.6	413							
Jun-08		3.4	6.1	9.5	425							
Jul-08		1.3	7	8.3	417	277	11.1	27.8	73.4	28.4	5.3	11.7
Aug-08	0.1	1.4	6.5	7.9	421							
Sep-08		1.3	6.6	7.9	412							
Oct-08		0.7	6.5	7.2	419							
Nov-08	0.1	1.3	6.5	7.8	403							
Dec-08		1.1	6.2	7.3	411							
Jan-09		1.5	6.2	7.7	463							
Feb-09	0.1	0.7	6.4	7.1	419							
Mar-09		1.8	6.8	8.6	428							
Apr-09		2.4	7.1	9.5	436							

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
May-09	0.1	2.3	6.6	8.9	455							
Jun-09		3.7	6.2	9.9	449							
Jul-09		1.5	6.6	8.1	445	304	10.9	30.2	76.9	29.1	4.5	11.7
Aug-09	0.1	0.5	6.6	7.1	451							
Sep-09		0.5	6.4	6.9	427							
Oct-09		1.2	6.4	7.6	430							
Nov-09	0.1	1.2	6.1	7.3	428							
Mean	0.50	1.46	6.88	8.33	416.87	274.00	14.49	30.43	72.09	27.76	4.20	12.00
Max	6.3	4.5	8.5	11.3	480	355	21	35	89	31	5.3	12.6
Min	0.1	0.5	1.1	2.6	371	6	9	26.9	65.6	25.5	2.4	11.7

See Appendix A for definitions of abbreviations in the header row.

Table E-11. BAF Well MW-13 Groundwater Quality Data (mg/L), 2001-09.

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Jan-01	0.5	1.5	58.5	60	810	125	123	27	126	59	3.6	
Feb-01	0.5	2.2	56.2	58.4	931							
Mar-01	0.5	1.5	55.8	57.3	837							
Apr-01	0.5	1.5	55.4	56.9	861	126	125	28	133	60	3.6	
May-01	0.5	1.5	53.6	55.1	741							
Jun-01												
Jul-01												
Aug-01												
Sep-01												
Oct-01	0.5	1.5	59.6	61.1	865	233	134	29	133	66	3.7	
Nov-01	0.5	1.5	62.5	64	867							
Dec-01	0.5	1.5	60.6	62.1	872							
Jan-02	0.5	1.5	58.1	59.6	894							
Feb-02	0.5	1.5	59	60.5	896	206	141	27	126	64	1.6	
Mar-02	0.5	1.5	62.9	64.4	927							
Apr-02	0.5	1.5	56.7	58.2	867							
May-02	0.5	1.5	47.1	48.6	789	178	120	26	112	57.9	2.9	
Jun-02												
Jul-02												
Aug-02												
Sep-02												
Oct-02	0.5	1.5	58	59.5	788							
Nov-02	0.5	1.5	56.6	58.1	831	123	144	26.2	122	63.1	3.5	
Dec-02	0.5	1.5	54.3	55.8	803							
Jan-03	0.5	1.5	54.2	55.7	895							
Feb-03	0.5	1.5	56.7	58.2	871	133	13	26.2	123	63.9	3.6	
Mar-03	0.5	1.5	54	55.5	894							
Apr-03	0.5	1.5	52.3	53.8	913							
May-03	0.5	1.5	54	55.5	1040	130	141	23.9	123	62.7	3.1	
Jun-03												
Jul-03												
Aug-03												

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Sep-03												
Oct-03												
Nov-03	0.9	1.5	42	43.5	739	177	104	25.8	117	60.8	1.6	
Dec-03	0.5	1.5	45.2	46.7	778							
Jan-04	0.5	1.5	50	51.5	836							
Feb-04	0.5	1.5	47.4	48.9	783	190	110	26.6	125	63.7	3.1	
Mar-04	0.5	1.5	50.5	52	870							
Apr-04	0.5	1.5	40.5	42	858							
May-04												
Jun-04												
Jul-04												
Aug-04												
Sep-04												
Oct-04	0.5	1.5	51.2	52.7	914							
Nov-04	0.5	1.5	50.4	51.9	910	145	127	26.2	131	67.9	3.1	
Dec-04	0.5	1.5	47.8	49.3	873							
Jan-05	0.5	1.5	46.8	48.3	867	154	116	27	128	67	27	
Feb-05	0.5	1.7	45.3	47	783							
Mar-05	0.5	1.5	43.8	45.3	802							
Apr-05	0.9	1.5	38	39.5	778							
May-05												
Jun-05												
Jul-05												
Aug-05												
Sep-05												
Oct-05	0.3	0.7	28	28.7	943							
Nov-05	0.3	0.7	47.5	48.2	878	141	132	26.5	134	70.2	4.2	
Dec-05	0.3	1	44	45	873							
Jan-06	0.3	0.7	49.3	50	947							
Feb-06	0.3	1.2	52.5	53.7	876	149	175	27.4	133	69.7	4.3	
Mar-06	0.3	1.1	67.7	68.8	886							
Apr-06	0.3	1.9	45.9	47.8	1054							
May-06	0.7	0.7	45.5	46.2	898	6	132	26.4	133	70.7	3.8	
Jun-06												

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
Jul-06												
Aug-06												
Sep-06												
Oct-06		0.7	46.9	47.6	1010							
Nov-06	0.1	1.4	45.6	47	1051							
Dec-06		1.5	45.8	47.3	922							
Jan-07		1.2	42.1	43.3	879							
Feb-07	0.1	1.4	40.5	41.9	843							
Mar-07												
Apr-07												
May-07												
Jun-07												
Jul-07												
Aug-07												
Sep-07												
Oct-07		1.6	41.5	43.1	944							
Nov-07	0.1	1.6	40.4	42	850							
Dec-07		2.5	40.4	42.9	872							
Jan-08		2.1	39.6	41.7	749							
Feb-08	0.1	1.3	41.2	42.5	918							
Mar-08		1.8	40.1	41.9	945							
Apr-08		1.5	40.8	42.3	926							
May-08												
Jun-08												
Jul-08												
Aug-08												
Sep-08												
Oct-08												
Nov-08	0.1	3.5	46.6	50.1	1003							
Dec-08		3.1	45.2	48.3	946							
Jan-09		1.5	42.4	43.9	1121							
Feb-09	0.1	3	42.2	45.2	965							
Mar-09		3.3	41.2	44.5	893							
Apr-09		3.6	42.1	45.7	989							

Date	Ammonia	TKN	NO_3	Total N	TDS	Bicarbonate	Cl	Na	Ca	Mg	K	SO_4
May-09	0.1	2.5	42.8	45.3	954							
Jun-09												
Jul-09												
Aug-09												
Sep-09												
Oct-09												
Nov-09	0.1	5.3	45.6	50.9	1148							
Mean	0.43	1.68	48.68	50.37	891.39	147.73	122.47	26.61	126.60	64.44	4.85	
Max	0.9	5.3	67.7	68.8	1148	233	175	29	134	70.7	27	
Min	0.1	0.7	28	28.7	739	6	13	23.9	112	57.9	1.6	

See Appendix A for definitions of abbreviations in the header row.

Appendix F. Discharge Monitoring Report (DMR) Data for the City of Moses Lake Dunes WWTP

Ecology manually checked the City of Moses Lake Dunes WWTP data for accuracy against the paper DMR reports for January 2003 – September 2009. DMRs during January 2001 – December 2002 are archived and therefore were not manually verified.

Table F-1. Comparison of Wastewater and Groundwater Quality Data at the Dunes WWTP (mg/L), January 2001 – September 2009.

Date	WWTP Effluent			Well MW-1 upgradient			Well MW-5 downgradient		
	TKN (as N)	NO2+NO3 (as N)	Total N (as N)	TKN (as N)	NO2+NO3 (as N)	Total N (as N)	TKN (as N)	NO2+NO3 (as N)	Total N (as N)
Jan-01	24.5	0.09	24.59	0.7	0.34	1.04	0.6	9.63	10.23
Feb-01	24.1	0.07	24.17	0.3	0.33	0.63	0.3	17.6	17.9
Mar-01	24	0.08	24.08	0.3	0.37	0.67	0.3	12.1	12.4
Apr-01	26.5	0.07	26.57	0.3	0.33	0.63	0.3	9.45	9.75
May-01	22.9	0.61	23.51	1.3	0.28	1.58	1	9.93	10.93
Jun-01	29	0.34	29.34	0.4	0.21	0.61			
Jul-01	25.6	0.4	26	0.3	0.23	0.53			
Aug-01	6.8	6.37	13.17	2.6	0.21	2.81			
Sep-01	7.8	1.52	9.32	0.3	0.21	0.51			
Oct-01	8.5	3.93	12.43	0.3	0.22	0.52			
Nov-01	15.4	1.82	17.22	0.3	0.19	0.49	0.3	14.6	14.9
Dec-01	23.4	0.35	23.75	0.3	0.15	0.45	0.3	9.12	9.42
Jan-02	24.1	0.16	24.26	0.3	0.16	0.46	0.4	9.28	9.68
Feb-02	23.9	0.14	24.04	0.3	0.21	0.51	0.5	3.55	4.05
Mar-02	24.1	0.16	24.26	0.3	0.23	0.53	0.3	5.85	6.15
Apr-02	29.7	0.07	29.77	0.3	0.15	0.45	0.3	8.13	8.43
May-02	26.5	0.27	26.77	0.3	0.21	0.51			
Jun-02	29	0.31	29.31	0.3	0.2	0.5			
Jul-02	27.7	0.19	27.89	0.6	0.06	0.66			
Aug-02	7.5	7.11	14.61	0.3	0.14	0.44			
Sep-02	6	5.36	11.36		0.19	0.19			
Oct-02	6.6	7.89	14.49		0.17	0.17			
Nov-02	14.2	1.69	15.89	0.4	0.2	0.6	0.4	11.1	11.5
Dec-02	24.9	0.21	25.11	0.5	0.18	0.68	0.4	13.5	13.9
Jan-03	18.3	0.14	18.44	0.8	0.07	0.87	0.3	18	18.3
Feb-03	25.4	0.1	25.5	0.3	0.15	0.45	0.3	10.1	10.4
Mar-03	25	0.07	25.07	0.3	0.13	0.43	0.3	11.6	11.9
Apr-03	25.5	0.07	25.57	0.3	0.14	0.44	0.3	13.7	14

Date	WWTP Effluent			Well MW-1 upgradient			Well MW-5 downgradient		
	TKN (as N)	NO2+NO3 (as N)	Total N (as N)	TKN (as N)	NO2+NO3 (as N)	Total N (as N)	TKN (as N)	NO2+NO3 (as N)	Total N (as N)
May-03	28.4	0.27	28.67	0.3	0.14	0.44			
Jun-03	28.8	0.2	29	0.3	0.12	0.42			
Jul-03	17	0.53	17.53	0.3	0.16	0.46			
Aug-03	13.9	2.19	16.09	0.3	0.1	0.4			
Sep-03	8.1	2.81	10.91	0.3	0.08	0.38			
Oct-03	9.5	6.78	16.28	0.3	0.09	0.39			
Nov-03	15	1.64	16.64	0.3	0.1	0.4	0.3	15	15.3
Dec-03	22.8	0.14	22.94	0.3	0.07	0.37	0.7	14	14.7
Jan-04	22.6	0.07	22.67	0.3	0.08	0.38	0.3	21.6	21.9
Feb-04	26	0.09	26.09	1.3	0.07	1.37	0.3	26.4	26.7
Mar-04	26	0.34	26.34	0.3	0.13	0.43	0.8	13.1	13.9
Apr-04	29.8	0.13	29.93	0.03	0.48	0.51			
May-04	29.5	0.26	29.76	0.3	0.07	0.37			
Jun-04	27.3	0.64	27.94	0.3	0.07	0.37			
Jul-04	8.4	2.62	11.02	0.3	0.39	0.69			
Aug-04	10.7	1.65	12.35	0.3	0.11	0.41			
Sep-04	6.6	8.41	15.01	0.3	0.63	0.93			
Oct-04	4.6	11.35	15.95	0.3	0.12	0.42			
Nov-04	10.5	4.28	14.78	0.3	0.29	0.59	0.3	16.1	16.4
Dec-04	23.3	0.85	24.15	0.3	0.14	0.44	0.3	10.3	10.6
Jan-05	27.5	0.2	27.7	0.3	0.12	0.42	1.1	9.64	10.74
Feb-05	25.5	0.15	25.65	0.3	0.13	0.43	0.3	8.4	8.7
Mar-05	26.2	0.8	27	0.3	0.11	0.41	0.3	9.61	9.91
Apr-05	28.2	0.07	28.27	0.3	0.12	0.42			
May-05	22.3	3.18	25.48	0.3	0.17	0.47			
Jun-05	16.6	6.57	23.17	0.3	0.15	0.45			
Jul-05	8.7	5.17	13.87	0.8	0.12	0.92			
Aug-05	22.1	2.09	24.19	0.3	0.17	0.47			
Sep-05	15.2	2.08	17.28	0.3	0.38	0.68			
Oct-05	2	10.79	12.79	0.3	0.93	1.23			
Nov-05	1.5	8.95	10.45	0.3	0.07	0.37			
Dec-05	1.4	10.53	11.93	2.2	0.15	2.35	0.8	12.3	13.1
Jan-06	1.7	7.43	9.13	0.5	9.13	9.63	0.4	14.3	14.7
Feb-06	1	4.94	5.94	0.3	0.16	0.46	0.3	11.9	12.2
Mar-06	2.4	4.3	6.7	0.3	0.14	0.44	0.3	13.1	13.4
Apr-06	1.6	2.96	4.56	0.4	0.17	0.57	0.3	13.3	13.6
May-06	0.5	2.81	3.31	0.3	0.07	0.37	0.3	8.01	8.31
Jun-06	0.4	0.46	0.86	0.3	0.1	0.4	0.3	4.24	4.54

Date	WWTP Effluent			Well MW-1 upgradient			Well MW-5 downgradient		
	TKN (as N)	NO2+NO3 (as N)	Total N (as N)	TKN (as N)	NO2+NO3 (as N)	Total N (as N)	TKN (as N)	NO2+NO3 (as N)	Total N (as N)
Jul-06	0.7	0.38	1.08	0.3	0.12	0.42	0.6	1.72	2.32
Aug-06	0.9	2.27	3.17	0.4	0.37	0.77	0.4	1.03	1.43
Sep-06	1	4.13	5.13	0.3	0.07	0.37	0.3	0.07	0.37
Oct-06	1	2.07	3.07	0.3	0.07	0.37	0.3	0.07	0.37
Nov-06	0.7	2.41	3.11	0.3	0.07	0.37	0.3	0.97	1.27
Dec-06	1.6	1.1	2.7	0.3	0.07	0.37	0.3	1.11	1.41
Jan-07	1.2	0.41	1.61	0.3	0.07	0.37	0.3	0.58	0.88
Feb-07	1.3	2.33	3.63	0.3	0.12	0.42	0.6	0.85	1.45
Mar-07	1.5	0.9	2.4	0.3	0.09	0.39	0.3	0.95	1.25
Apr-07	1.1		1.1	0.8	0.12	0.92	0.3	1.19	1.49
May-07	1.2		1.2	0.3	0.07	0.37	0.4	3.04	3.44
Jun-07	0.8	0.36	1.16	0.5	0.08	0.58			
Jul-07	1	0.24	1.24						
Aug-07	1.1	0.75	1.85	0.3	0.61	0.91			
Sep-07	1.1	0.42	1.52						
Oct-07	1.3	0.58	1.88						
Nov-07	1	0.33	1.33	0.3	0.15	0.45	0.3	1.62	1.92
Dec-07	2.1	0.35	2.45						
Jan-08	0.9	0.17							
Feb-08	1.5	0.36	1.86	0.3	0.12	0.42	0.3	0.69	0.99
Mar-08	1.7	0.88	2.58						
Apr-08	1.1	1.49	2.59						
May-08	1.1	0.44	1.54	0.3	0.22	0.52	0.3	2	2.3
Jun-08	1.5	0.76	2.26						
Jul-08	1.5	0.96	2.46						
Aug-08	1.5	0.72	2.22	0.3	0.13	0.43			
Sep-08	3.9	0.31	4.21						
Oct-08	3.9	1.31	5.21						
Nov-08	2.5	1.86	4.36	0.3	0.09	0.39	0.4	1.71	2.11
Dec-08	3.8	0.78	4.58						
Jan-09	6.3	0.68	6.98						
Feb-09	9.7	1.62	11.32	0.8	0.08	0.88	0.6	1.8	2.4
Mar-09	3.5	0.34	3.84						
Apr-09	1.7	1.5	3.2						
May-09	0.8	1.44	2.24	0.3	0.11	0.41	0.5	1.3	1.8
Jun-09	0.9	0.53	1.43						
Jul-09	1.49	0.65	2.14						
Aug-09	1.5	2.45	3.95	0.3	0.12	0.42	1.2	1.2	2.4

Date	WWTP Effluent			Well MW-1 upgradient			Well MW-5 downgradient		
	TKN (as N)	NO2+NO3 (as N)	Total N (as N)	TKN (as N)	NO2+NO3 (as N)	Total N (as N)	TKN (as N)	NO2+NO3 (as N)	Total N (as N)
Sep-09	1.4	0.77	2.17						
Mean	11.65	1.92	13.65	0.41	0.28	0.68	0.42	8.28	8.70
Max	29.8	11.35	29.93	2.6	9.13	9.63	1.2	26.4	26.7
Min	0.4	0.07	0.86	0.03	0.06	0.17	0.3	0.07	0.37

Table F-2. Wastewater Quality at the Dunes WWTP (mg/L), January 2001 – September 2009.

Date	TKN (as N)	Nitrate (as N)	Total N (as N)	P	TDS
Jan-01	24.5	0.09	24.59	4.2	603
Feb-01	24.1	0.07	24.17	4.09	590
Mar-01	24	0.08	24.08	4.4	632
Apr-01	26.5	0.07	26.57	4.38	599
May-01	22.9	0.61	23.51	4.47	601
Jun-01	29	0.34	29.34	4.56	583
Jul-01	25.6	0.4	26	4.61	618
Aug-01	6.8	6.37	13.17	1.98	560
Sep-01	7.8	1.52	9.32	1.51	576
Oct-01	8.5	3.93	12.43	3.26	564
Nov-01	15.4	1.82	17.22	3.78	534
Dec-01	23.4	0.35	23.75	3.84	555
Jan-02	24.1	0.16	24.26	4.72	549
Feb-02	23.9	0.14	24.04	4.29	566
Mar-02	24.1	0.16	24.26	3.52	535
Apr-02	29.7	0.07	29.77	4.37	561
May-02	26.5	0.27	26.77	4.36	557
Jun-02	29	0.31	29.31	0.4	612
Jul-02	27.7	0.19	27.89	4.11	584
Aug-02	7.5	7.11	14.61	1.88	585
Sep-02	6	5.36	11.36	2.57	576
Oct-02	6.6	7.89	14.49	3.39	603
Nov-02	14.2	1.69	15.89	2.98	536
Dec-02	24.9	0.21	25.11	3.71	575
Jan-03	18.3	0.14	18.44	5.68	581
Feb-03	25.4	0.1	25.5	5.21	589
Mar-03	25	0.07	25.07	9.61	583
Apr-03	25.5	0.07	25.57	4.98	628
May-03	28.4	0.27	28.67	0.07	293
Jun-03	28.8	0.2	29	5.89	582
Jul-03	17	0.53	17.53	4.11	582
Aug-03	13.9	2.19	16.09	3.99	676
Sep-03	8.1	2.81	10.91	0.9	604
Oct-03	9.5	6.78	16.28	3.55	614
Nov-03	15	1.64	16.64	2.75	587
Dec-03	22.8	0.14	22.94	4.43	588
Jan-04	22.6	0.07	22.67	4.21	656
Feb-04	26	0.09	26.09	4.03	595
Mar-04	26	0.34	26.34	3.87	628

Date	TKN (as N)	Nitrate (as N)	Total N (as N)	P	TDS
Apr-04	29.8	0.13	29.93	5.14	643
May-04	29.5	0.26	29.76	4.06	630
Jun-04	27.3	0.64	27.94	3.86	612
Jul-04	8.4	2.62	11.02	4.16	613
Aug-04	10.7	1.65	12.35	3.91	628
Sep-04	6.6	8.41	15.01	3.61	667
Oct-04	4.6	11.35	15.95	3.5	642
Nov-04	10.5	4.28	14.78	3.66	630
Dec-04	23.3	0.85	24.15	3.7	582
Jan-05	27.5	0.2	27.7	4.36	662
Feb-05	25.5	0.15	25.65	0.68	659
Mar-05	26.2	0.8	27	3.15	636
Apr-05	28.2	0.07	28.27	3.92	593
May-05	22.3	3.18	25.48	6.87	633
Jun-05	16.6	6.57	23.17	3.94	625
Jul-05	8.7	5.17	13.87	4.96	680
Aug-05	22.1	2.09	24.19	4.59	645
Sep-05	15.2	2.08	17.28	3.48	609
Oct-05	2	10.79	12.79	3.58	615
Nov-05	1.5	8.95	10.45	3.7	604
Dec-05	1.4	10.53	11.93	3.52	566
Jan-06	1.7	7.43	9.13	3.09	568
Feb-06	1	4.94	5.94	2.94	540
Mar-06	2.4	4.3	6.7	3.32	573
Apr-06	1.6	2.96	4.56	3.32	543
May-06	0.5	2.81	3.31	3.19	545
Jun-06	0.4	0.46	0.86	3.03	561
Jul-06	0.7	0.38	1.08	2.41	568
Aug-06	0.9	2.27	3.17	4.37	557
Sep-06	1	4.13	5.13	3.65	565
Oct-06	1	2.07	3.07	2.58	545
Nov-06	0.7	2.41	3.11	2.15	530
Dec-06	1.6	1.1	2.7	1.99	528
Jan-07	1.2	0.41	1.61	1.23	512
Feb-07	1.3	2.33	3.63	2.46	549
Mar-07	1.5	0.9	2.4	2.41	553
Apr-07	1.1		1.1	2.37	
May-07	1.2		1.2	2.43	
Jun-07	0.8	0.36	1.16	3.05	556
Jul-07	1	0.24	1.24	2.01	556

Date	TKN (as N)	Nitrate (as N)	Total N (as N)	P	TDS
Aug-07	1.1	0.75	1.85	1.76	551
Sep-07	1.1	0.42	1.52	1.51	548
Oct-07	1.3	0.58	1.88	1.17	537
Nov-07	1	0.33	1.33	0.86	552
Dec-07	2.1	0.35	2.45	1.21	542
Jan-08	0.9	0.17	1.07	0.6	536
Feb-08	1.5	0.36	1.86	1.06	573
Mar-08	1.7	0.88	2.58	2.25	599
Apr-08	1.1	1.49	2.59	3.51	590
May-08	1.1	0.44	1.54	2.4	572
Jun-08	1.5	0.76	2.26	3.83	547
Jul-08	1.5	0.96	2.46	4.08	551
Aug-08	1.5	0.72	2.22	3.92	496
Sep-08	3.9	0.31	4.21	2.69	538
Oct-08	3.9	1.31	5.21	1.42	525
Nov-08	2.5	1.86	4.36	2.64	522
Dec-08	3.8	0.78	4.58	1.62	504
Jan-09	6.3	0.68	6.98	1.23	522
Feb-09	9.7	1.62	11.32	5.21	537
Mar-09	3.5	0.34	3.84	2.41	541
Apr-09	1.7	1.5	3.2	4.22	546
May-09	0.8	1.44	2.24	2.68	528
Jun-09	0.9	0.53	1.43	1.66	544
Jul-09	1.49	0.65	2.14	2.28	540
Aug-09	1.5	2.45	3.95	6.54	579
Sep-09	1.4	0.77	2.17	2.91	540
mean	11.65	1.92	13.53	3.32	575.95
max	29.8	11.35	29.93	9.61	680
min	0.4	0.07	0.86	0.07	293

Table F-3. Upgradient (Well MW-1) Groundwater Quality at the Dunes WWTP (mg/L), January 2001 – September 2009.

Date	MW1									
	Bicarbonate	Calcium	Magnesium	Chloride	Ammonia (as N)	TKN (as N)	No_2+NO_3 (as N)	Phosphorus Total	Sodium	TDS
Jan-01					0.07	0.7	0.34	0.07		148
Feb-01					0.07	0.3	0.33	0.07		141
Mar-01	82	58	26.3	0.5	0.07	0.3	0.37	0.7	138	150
Apr-01					0.07	0.3	0.33	0.07		155
May-01					0.07	1.3	0.28	0.09		147
Jun-01					0.07	0.4	0.21	0.07		156
Jul-01					0.07	0.3	0.23	0.07		149
Aug-01					0.07	2.6	0.21	0.07		140
Sep-01					0.07	0.3	0.21	0.07		191
Oct-01					0.07	0.3	0.22	0.7		204
Nov-01					0.07	0.3	0.19	0.07		199
Dec-01					0.07	0.3	0.15	0.07		165
Jan-02					0.07	0.3	0.16	0.07		122
Feb-02					0.07	0.3	0.21	0.07		131
Mar-02	84	13.4	9.73	2.2	0.07	0.3	0.23	0.07	9.13	126
Apr-02					0.07	0.3	0.15	0.07		139
May-02					0.07	0.3	0.21	0.07		131
Jun-02					0.07	0.3	0.2	0.07		139
Jul-02					0.07	0.6	0.06	0.07		168
Aug-02					0.07	0.3	0.14	0.07		157
Sep-02		13.2					0.19		8.33	
Oct-02					0.07		0.17			
Nov-02					0.07	0.4	0.2			127
Dec-02					0.07	0.5	0.18			131
Jan-03					0.08	0.8	0.07			163

Date	MW1									
	Bicarbonate	Calcium	Magnesium	Chloride	Ammonia (as N)	TKN (as N)	No_2+NO_3 (as N)	Phosphorus Total	Sodium	TDS
Feb-03		13			0.08	0.3	0.15		8.16	170
Mar-03		13.4			0.07	0.3	0.13			162
Apr-03					0.07	0.3	0.14			156
May-03					0.07	0.3	0.14			169
Jun-03					0.07	0.3	0.12			156
Jul-03					0.15	0.3	0.16			163
Aug-03		14.3	10		0.08	0.3	0.1		7.68	171
Sep-03					0.07	0.3	0.08			168
Oct-03					0.07	0.3	0.09			160
Nov-03					0.07	0.3	0.1			146
Dec-03					0.07	0.3	0.07			133
Jan-04					0.07	0.3	0.08			134
Feb-04		14.4	9.47		0.07	1.3	0.07		8.82	143
Mar-04					0.07	0.3	0.13			141
Apr-04					0.07	0.03	0.48			159
May-04					0.16	0.3	0.07			137
Jun-04					0.07	0.3	0.07			150
Jul-04					0.07	0.3	0.39			141
Aug-04		14.3	9.4		0.07	0.3	0.11		9.14	140
Sep-04					0.07	0.3	0.63			142
Oct-04					0.25	0.3	0.12			171
Nov-04					0.07	0.3	0.29			167
Dec-04					0.07	0.3	0.14			162
Jan-05					0.17	0.3	0.12			141
Feb-05					0.07	0.3	0.13			155
Mar-05					0.07	0.3	0.11			171
Apr-05					0.07	0.3	0.12			132

Date	MW1									
	Bicarbonate	Calcium	Magnesium	Chloride	Ammonia (as N)	TKN (as N)	No_2+NO_3 (as N)	Phosphorus Total	Sodium	TDS
May-05					0.07	0.3	0.17			155
Jun-05					0.07	0.3	0.15			161
Jul-05					0.07	0.8	0.12			160
Aug-05					0.07	0.3	0.17			148
Sep-05					0.07	0.3	0.38			163
Oct-05					0.07	0.3	0.93			160
Nov-05					0.07	0.3	0.07			155
Dec-05					0.07	2.2	0.15			155
Jan-06					0.07	0.5	9.13			176
Feb-06		15.3	10.2		0.07	0.3	0.16		8.34	216
Mar-06					0.09	0.3	0.14			198
Apr-06					0.07	0.4	0.17			159
May-06					0.07	0.3	0.07			158
Jun-06					0.3	0.3	0.1			204
Jul-06					0.07	0.3	0.12			167
Aug-06		15.3	10.4		0.07	0.4	0.37		8.8	145
Sep-06					0.1	0.3	0.07			161
Oct-06					0.07	0.3	0.07			176
Nov-06					0.07	0.3	0.07			202
Dec-06					0.07	0.3	0.07			152
Jan-07					0.07	0.3	0.07			159
Feb-07		15.7	10.7		0.07	0.3	0.12		8.25	148
Mar-07					0.07	0.3	0.09			151
Apr-07					0.07	0.8	0.12			158
May-07					0.07	0.3	0.07			157
Jun-07					0.15	0.5	0.08			158
Jul-07										

Date	MW1									
	Bicarbonate	Calcium	Magnesium	Chloride	Ammonia (as N)	TKN (as N)	No_2+NO_3 (as N)	Phosphorus Total	Sodium	TDS
Aug-07		16.2	11.2		0.07	0.3	0.61		9.5	160
Sep-07										
Oct-07										
Nov-07					0.07	0.3	0.15			149
Dec-07										
Jan-08										
Feb-08		15.2	10.5		0.07	0.3	0.12		8.3	160
Mar-08										
Apr-08										
May-08					0.21	0.3	0.22			165
Jun-08										
Jul-08										
Aug-08		17.4	10.7		0.07	0.3	0.13		8.25	143
Sep-08										
Oct-08										
Nov-08					0.07	0.3	0.09			142
Dec-08										
Jan-09										
Feb-09		17.4	11		0.07	0.8	0.08		9.25	158
Mar-09										
Apr-09										
May-09					0.07	0.3	0.11			151
Jun-09										
Jul-09										
Aug-09		14.5	9.7		0.07	0.3	0.12		10.4	154
Sep-09										
Mean	83.00	17.56	11.48	1.35	0.08	0.41	0.28	0.13	17.36	156.51

Date	MW1									
	Bicarbonate	Calcium	Magnesium	Chloride	Ammonia (as N)	TKN (as N)	No_2+NO_3 (as N)	Phosphorus Total	Sodium	TDS
Max	84	58	26.3	2.2	0.3	2.6	9.13	0.7	138	216
Min	82	13	9.4	0.5	0.07	0.03	0.06	0.07	7.68	122

Table F-4. Downgradient (Well MW-5) Groundwater Quality at the Dunes WWTP (mg/L), January 2001 – September 2009).

Date	MW5									
	Bicarbonate	Calcium	Magnesium	Chloride	Ammonia (as N)	TKN (as N)	NO_2 +NO_3 (as N)	Phosphorus Total	Sodium	TDS
Jan-01						0.6	9.63	0.07		543
Feb-01					0.07	0.3	17.6	0.08		581
Mar-01	320	13.6	9.35	66.6	0.07	0.3	12.1	0.13	98	603
Apr-01					0.07	0.3	9.45	0.2		551
May-01					0.07	1	9.93	0.24		585
Jun-01										
Jul-01										
Aug-01										
Sep-01										
Oct-01										
Nov-01					0.07	0.3	14.6	0.2		647
Dec-01					0.07	0.3	9.12	0.18		622
Jan-02					0.07	0.4	9.28	0.16		590
Feb-02					0.07	0.5	3.55	0.16		584
Mar-02	310	55.3	24.8	69.7	0.07	0.3	5.85	0.11	109	577
Apr-02					0.07	0.3	8.13	0.13		570
May-02										
Jun-02										
Jul-02										
Aug-02										
Sep-02										
Oct-02										
Nov-02					0.07	0.4	11.1			618
Dec-02					0.07	0.4	13.5			616
Jan-03					0.11	0.3	18			600

Date	MW5									
	Bicarbonate	Calcium	Magnesium	Chloride	Ammonia (as N)	TKN (as N)	NO_2 +NO_3 (as N)	Phosphorus Total	Sodium	TDS
Feb-03		58.1	23.7		0.07	0.3	10.1		100	594
Mar-03					0.07	0.3	11.6			662
Apr-03					0.07	0.3	13.7			640
May-03										
Jun-03										
Jul-03										
Aug-03										
Sep-03										
Oct-03										
Nov-03					0.07	0.3	15			612
Dec-03					0.17	0.7	14			668
Jan-04					0.07	0.3	21.6			701
Feb-04		66.7	27.2		0.07	0.3	26.4		130	740
Mar-04					0.07	0.8	13.1			729
Apr-04										
May-04										
Jun-04										
Jul-04										
Aug-04										
Sep-04										
Oct-04										
Nov-04					0.07	0.3	16.1			686
Dec-04					0.07	0.3	10.3			646
Jan-05					0.07	1.1	9.64			619
Feb-05					0.07	0.3	8.4			634
Mar-05					0.07	0.3	9.61			663
Apr-05										

Date	MW5									
	Bicarbonate	Calcium	Magnesium	Chloride	Ammonia (as N)	TKN (as N)	NO_2 +NO_3 (as N)	Phosphorus Total	Sodium	TDS
May-05										
Jun-05										
Jul-05										
Aug-05										
Sep-05										
Oct-05										
Nov-05										
Dec-05					0.07	0.8	12.3			640
Jan-06					0.07	0.4	14.3			647
Feb-06		52.7	21.6		0.07	0.3	11.9		115	677
Mar-06					0.07	0.3	13.1			700
Apr-06					0.07	0.3	13.3			634
May-06					0.07	0.3	8.01			616
Jun-06					0.07	0.3	4.24			572
Jul-06					0.07	0.6	1.72			608
Aug-06		50	18.3		0.7	0.4	1.03		122	608
Sep-06					0.08	0.3	0.07			610
Oct-06					0.07	0.3	0.07			583
Nov-06					0.07	0.3	0.97			577
Dec-06					0.07	0.3	1.11			577
Jan-07					0.07	0.3	0.58			596
Feb-07		47.1	16.1		0.07	0.6	0.85		132	567
Mar-07					0.07	0.3	0.95			571
Apr-07					0.07	0.3	1.19			595
May-07					0.07	0.4	3.04			629
Jun-07										
Jul-07										

Date	MW5									
	Bicarbonate	Calcium	Magnesium	Chloride	Ammonia (as N)	TKN (as N)	NO_2 +NO_3 (as N)	Phosphorus Total	Sodium	TDS
Aug-07										
Sep-07										
Oct-07										
Nov-07					0.07	0.3	1.62			609
Dec-07										
Jan-08										
Feb-08		45.8	17		0.1	0.3	0.69		120	592
Mar-08										
Apr-08										
May-08					0.25	0.3	2			604
Jun-08										
Jul-08										
Aug-08										
Sep-08										
Oct-08										
Nov-08					0.07	0.4	1.71			570
Dec-08										
Jan-09										
Feb-09		50	17.8		0.07	0.6	1.8		120	555
Mar-09										
Apr-09										
May-09					0.07	0.5	1.3			547
Jun-09										
Jul-09										
Aug-09		44.2	14.9		0.07	1.2	1.2		138	575
Sep-09										
Mean	315.00	48.35	19.08	68.15	0.09	0.42	8.28	0.15	118.40	614.23

Date	MW5									
	Bicarbonate	Calcium	Magnesium	Chloride	Ammonia (as N)	TKN (as N)	NO_2 +NO_3 (as N)	Phosphorus Total	Sodium	TDS
Max	320	66.7	27.2	69.7	0.7	1.2	26.4	0.24	138	740
Min	310	13.6	9.35	66.6	0.07	0.3	0.07	0.07	98	543