MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

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2007-2008 Bush River Shallow Water Monitoring Data Report

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2007-2008 Bush River
Shallow Water Monitoring Data Report

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EXECUTIVE SUMMARY

The Bush River watershed drains 117 square miles of land in Harford County, Maryland. All three major subwatersheds of the Bush River have been listed by the State of Maryland as impaired waterways, and the watershed as a whole is considered a high priority for restoration. Causes of impairment include elevated levels of nutrients, suspended sediments, and toxic substances that are harmful to aquatic organisms and degrade the ecosystem. The Maryland Department of Natural Resources (DNR), in partnership with the Harford County Government and the National Oceanic and Atmospheric Administration (NOAA), therefore began a water quality criteria assessment of the Bush River in 2003 as part of its Shallow Water Monitoring Program. Two fixed Continuous Monitoring stations, configured to record measurements every fifteen minutes, were set up in the Bush River watershed to quantify the effects of nutrient and sediment pollution and associated algal blooms on water clarity and the living resources within the waterways.

This report contains the results of Continuous Monitoring for the Bush River during 2007 and 2008. (Results from previous years may be found in the 2003-2006 Bush River Shallow Water Monitoring Data Reports, available online at http://mddnr.chesapeakebay.net/eyesonthebay/publications.cfm) The Bush River watershed is becoming increasingly urbanized as approximately 35% of the land within the watershed has been developed and impervious surface area (roads, rooftops, parking lots) has increased to around 11%. These surfaces facilitate the flow of stormwater runoff directly into streams and are a major cause of the spikes in the amount of discharge following heavy precipitation events that were seen in the Bush River during 2007 and 2008. These high runoff events carry large concentrations of sediment and nutrients into the waterways and led to sharp decreases in water clarity. Furthermore, two large sanitary sewer overflows in the Bush River watershed in 2008 had measurable impacts on water clarity. Aside from high runoff events, water clarity was slightly better in 2007 than in 2008, which may have contributed to larger areas of submerged aquatic vegetation (SAV) in 2007. In both years, however, the vast majority of water clarity readings were at levels considered detrimental to SAV growth.

Nutrients discharged into waterways can also fuel large algal blooms. When algae die, the decomposition process consumes significant amounts of dissolved oxygen in the water. Low dissolved oxygen levels can be harmful to aquatic organisms. The Continuous Monitoring program, which measures algal levels by quantifying chlorophyll within the water, found that algal blooms in the Bush River were infrequent and short in duration during 2007 and 2008. Heavy precipitation and a related sanitary sewer overflow coincided with a brief bloom in the spring of 2007. A bloom of *Karlodinium veneficum*, a phytoplankton with potentially toxic properties, occurred in the autumn of 2008. Thus, with the exception of the mid-summer months when water was the warmest, dissolved oxygen levels generally remained at healthy levels during 2007 and 2008.

Introduction

Temporally Intensive Monitoring

In 2007 and 2008, Maryland DNR was contracted by Harford County, Maryland to conduct temporally intensive water quality monitoring on the Bush River. The Continuous Monitoring component of the Shallow Water Monitoring Program is designed to acquire temporal records of water quality data at shallow water stations throughout the Chesapeake and Maryland Coastal Bays. The purpose of the program is to characterize water quality and habitat conditions to assess compliance with the Environmental Protection Agency's (EPA) Chesapeake Bay ambient water quality criteria for dissolved oxygen, water clarity, and chlorophyll (US EPA, 2003). Maryland DNR deployed and maintained YSI 6600™ datasondes, (multi-parameter logging instruments), at 49 Continuous Monitoring sites in 2007 and 46 sites in 2008 spread across 19 Chesapeake Bay tributaries and water bodies. Four Coastal Bay sites were also monitored during these two years. The following water quality data parameters were collected at 15-minute intervals during deployment: water temperature, salinity, dissolved oxygen, fluorescence (used to estimate chlorophyll concentration), pH, and turbidity, which is a measure of water clarity. Data from salinity, chlorophyll, and turbidity readings were also used to calculate an additional measure of water clarity called the coefficient of light attenuation (K_d; US EPA, 2007), which estimates how far light travels through the water column.

Pigment, Nutrient, Suspended Solids, and Secchi Samples

Data concerning pigments, nutrients, and suspended solids were obtained by DNR staff during deployment of Continuous Monitoring datasondes. Discrete whole water samples were collected to measure chlorophyll *a*, pheophytin, total suspended solids, volatile suspended solids, ammonium, nitrite, nitrate, total dissolved nitrogen, particulate nitrogen, phosphate, particulate phosphate, total dissolved nitrogen, and particulate carbon. Silicate was also measured in 2007 but not in 2008 samples. Datasondes were removed and replaced with freshly calibrated instruments on a biweekly basis. At the time of each instrument replacement, Secchi disk depth and photosynthetically active radiation (PAR) measurements were recorded for use in additional calculations of K_d.

Bush River Continuous Monitoring

In 2007, Continuous Monitoring data were collected at two sites in the Bush River: Otter Point Creek (XJG7035) and Lauderick Creek (XJG4337) (Figure 1). The Otter Point Creek Continuous Monitor was fixed 0.3m above the bottom sediments and deployed from January 1st to December 10th (Table 1). A second Continuous Monitor was deployed in Lauderick Creek from March 20th to October 30th (Table 1), and was suspended from a float, 1m below the water's surface.

Several gaps in collected data occurred in 2007 due to suspension of monitoring activities and mechanical problems. At Otter Point Creek, the site was temporarily removed between January 18th and March 5th due to the threat of ice related damage. There were also several occasions during which the datasonde was not submerged due to low tidal conditions, particularly early and late in the year, and did not collect valid data. Causes of other data gaps of note at Otter Point

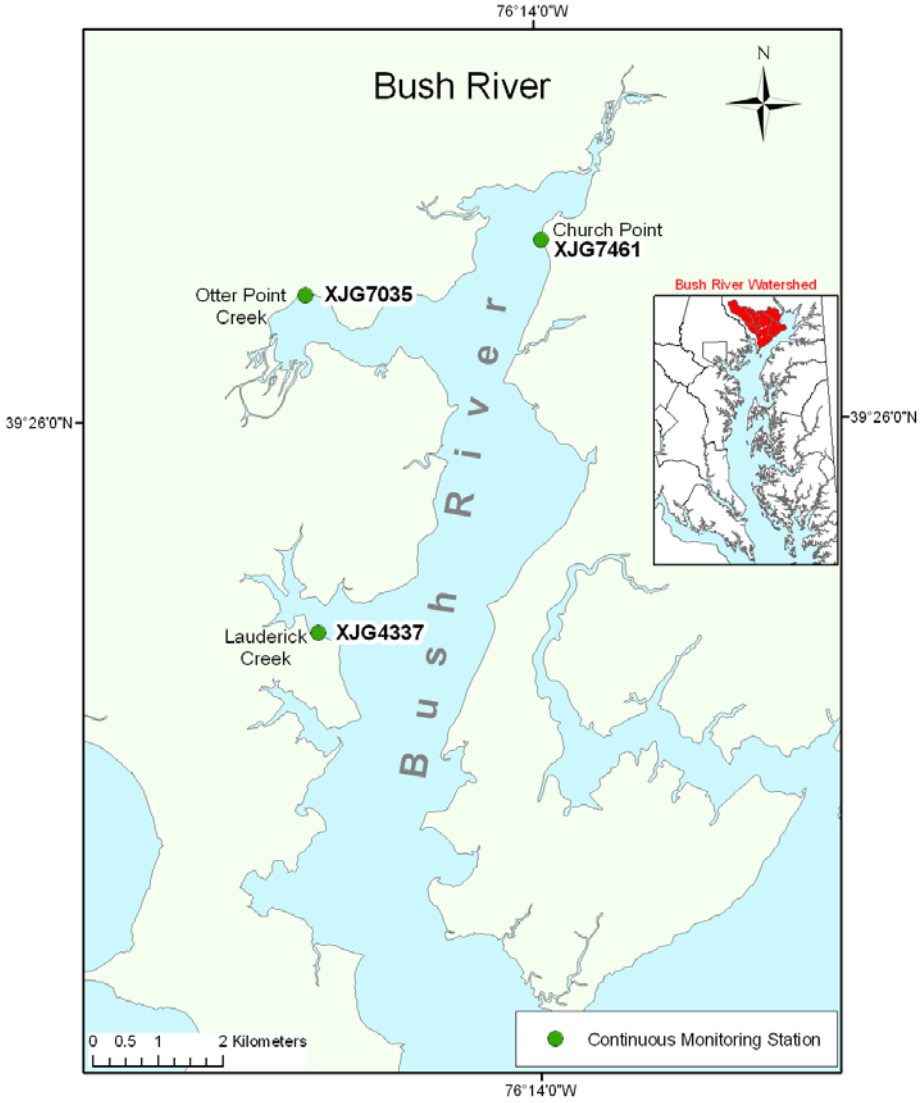

Figure 1. Map of Bush River Continuous Monitoring sites for 2007 (Otter Point & Lauderick Creeks) and 2008 (Otter Point Creek and Church Point).

Creek include: a datasonde power failure from May 6th to May 7th; dissolved oxygen probe failure from May 12th to May 15th; and dissolved oxygen data that did not meet quality-control thresholds from August 6th to August 8th. At Lauderick Creek, causes of data gaps include: turbidity probe wiper malfunctions from May 20th to May 29th, June 22nd to June 26th, and July 3rd to July 10th; chlorophyll probe wiper malfunctions from August 5th to August 8th, August 16th to August 17th, and September 2nd to September 3rd; and dissolved oxygen data that did not meet post-calibration thresholds from August 19th to August 23rd.

In 2008, data collection at the Otter Point Creek site was continued, while data collection at the Lauderick Creek site ceased. The automated water quality measurement instrumentation used at the Lauderick location was moved to Church Point (XJG7461) in order to expand Continuous Monitoring coverage of the Bush River watershed (Figure 1). The Otter Point Creek Continuous Monitor was fixed 0.3m above the bottom sediments and deployed from February 5th to December 4th (Table 1). The monitor at Church Point was deployed from April 1st to October 30th (Table 1), and was suspended from a float, 1m below the water's surface.

2008 gaps in collected data at Otter Point Creek included several occasions when datasonde probes were exposed to air due to tidal conditions, the removal of the datasonde between March 6th and April 1st due to low water levels and ice conditions, and a datasonde power failure from November 18th until monitoring ended on December 4th. At Church Point, causes of data gaps include: chlorophyll probe wiper malfunctions from June 27th to June 30th and September 13th to September 16th; turbidity probe wiper malfunctions from August 17th to August 18th and September 9th to September 16th, and inaccurate pH readings due to excessive fouling on probe from September 14th to September 16th.

The Otter Point Creek site was funded through a cooperative agreement with NOAA's National Estuarine Research Reserve System (NERRS) Program. The Harford County Government provided funding for the Continuous Monitoring equipment, nutrient analyses, and maintenance of the Lauderick Creek and Church Point sites.

Bush River Continuous Monitoring data are archived on DNR's "Eyes on the Bay" website, www.eyesonthebay.net. The interface allows users to view and download data and graphs of current and archived water quality measurements. Table 1 displays a timeline for the Bush River Continuous Monitoring sites, including related weather events, sanitary sewer overflows in the watershed that were reported to the Maryland Department of the Environment (http://www.mde.state.md.us/Programs/WaterPrograms/overflow/index.asp), and harmful algal blooms.

	Dates	Events and Details
2007	1-Jan	Continuous Monitoring begins at Otter Point Creek
	18-Jan	Continuous Monitoring stopped at Otter Point Creek due to threat of icing
	5-Mar	Continuous Monitoring resumes at Otter Point Creek
	15-16-Mar	Winter Storm impacts Mid-Atlantic region
	20-Mar	Continuous Monitoring begins at Lauderick Creek
	28-Mar	Sanitary sewer overflow due to blockage; 1,800 gallons; Village of Thomas Run; Bynum Run subwatershed
	14-15-Apr	Nor'Easter impacts Mid-Atlantic region
	15-Apr	Sanitary sewer overflow due to heavy rainfall; 1,000 gallons; Abington; Bush Creek subwatershed
	30-Oct	Continuous Monitoring ends at Lauderick Creek
	10-Dec	Continuous Monitoring stops at Otter Point Creek
2008	5-Feb	Continuous Monitoring begins at Otter Point Creek
	9-Feb	Sanitary sewer overflow due to blockage; 500 gallons; Foxborough Farms offsite; Bynum Run subwatershed
	6-Mar	Continuous Monitoring stopped at Otter Point Creek due to low water levels and ice conditions
	1-Apr	Continuous Monitoring resumes at Otter Point Creek
	1-Apr	Continuous Monitoring begins at Church Point
	22-Apr	Sanitary sewer overflow due to blockage; 720 gallons; Riverside; Church Creek subwatershed
	12-May	Heavy rain and flooding across central Maryland
	23-Jul	Heavy rain and flooding across central Maryland
	6-Sep	Tropical Strom Hanna impacts Mid-Atlantic region
	26-Sep	Sanitary sewer overflow due to mechanical failure; 17,000 gallons, Forest Hill; Winters Run subwatershed
	26-Oct	Sanitary sewer overflow due to mechanical failure; 1,250 gallons; Bel Air; Bynum Run subwatershed
	30-Oct	Continuous Monitoring stopped at Church Point
	7-Nov	Sanitary sewer overflow due to structural failure; 400 gallons; Otter Point Creek subwatershed
	10-Nov	*Karlodinium veneficum* detected at Otter Point Creek site: 1,143 cells/ml
	18-Nov	Datasonde power failure at Otter Point Creek
	4-Dec	Continuous Monitoring stopped at Otter Point Creek due to threat of icing
	30-Dec	Sanitary sewer overflow due to blockage; 1,425 gallons; Church Creek subwatershed

Table 1. Timeline of Continuous Monitoring and related events.

Yearly Precipitation and Discharge Events

Precipitation increases run-off into waterways, which can lead to a higher discharge of nutrients that fuels algal blooms, decreases water clarity, and, therefore, suppresses SAV growth. Precipitation in 2008 was substantially greater than in 2007 (Figure 2), while discharge events into waterways were higher in 2007 (Figure 3).

In 2007, precipitation at Baltimore Washington International (BWI) Thurgood Marshal Airport was substantially below normal, totaling approximately 7-inches below the 135-year average

(Figure 2a). April and October showed the highest amounts of precipitation, which coincided with the two highest discharge events measured at the USGS Otter Point Creek Gage Station near Edgewood, MD. (Figure 3a).

In 2008, total precipitation was approximately 3-inches greater than the 135-year average, with six months experiencing higher than average precipitation (Figure 2b). This pattern translated into an increased number of spikes in discharge for 2008 (Figure 3b) compared to 2007, but the net volume of discharge was lower than that in 2007. The four biggest discharge events at Otter Point Creek Gage Station in 2007 were higher than all discharge events in 2008 (Figure 3) and mean flow of discharge was higher in 2007 (65.0 cubic feet per second – cfs) than in 2008 (53.4 cfs). This pattern also held during the growing season of April through October (2007: 50.9 cfs; 2008: 45.0 cfs), when discharge events can have the greatest effect on SAV growth.

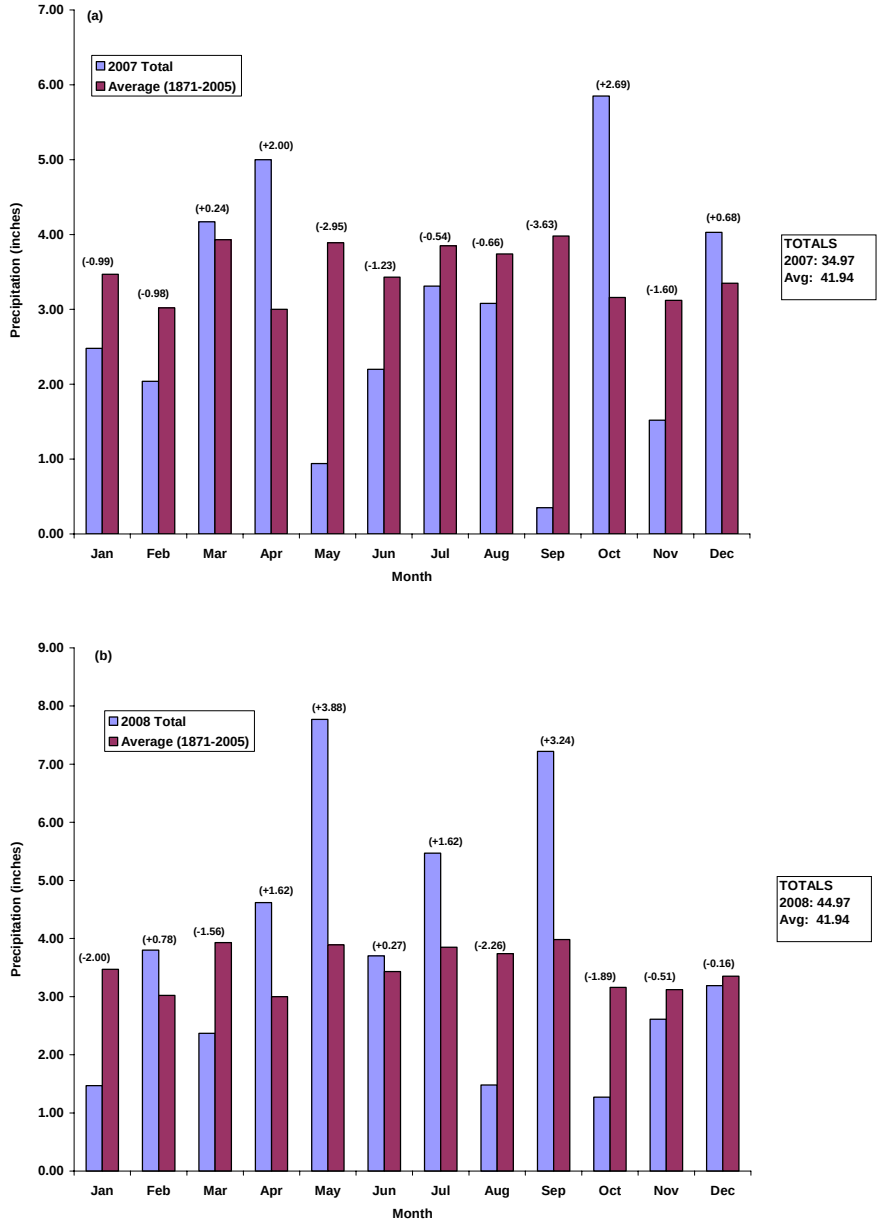

Figure 2. Total monthly precipitation at BWI Marshal Airport compared to 135-year averages for (a) 2007 and (b) 2008. (Values in parentheses indicate departures from average.)

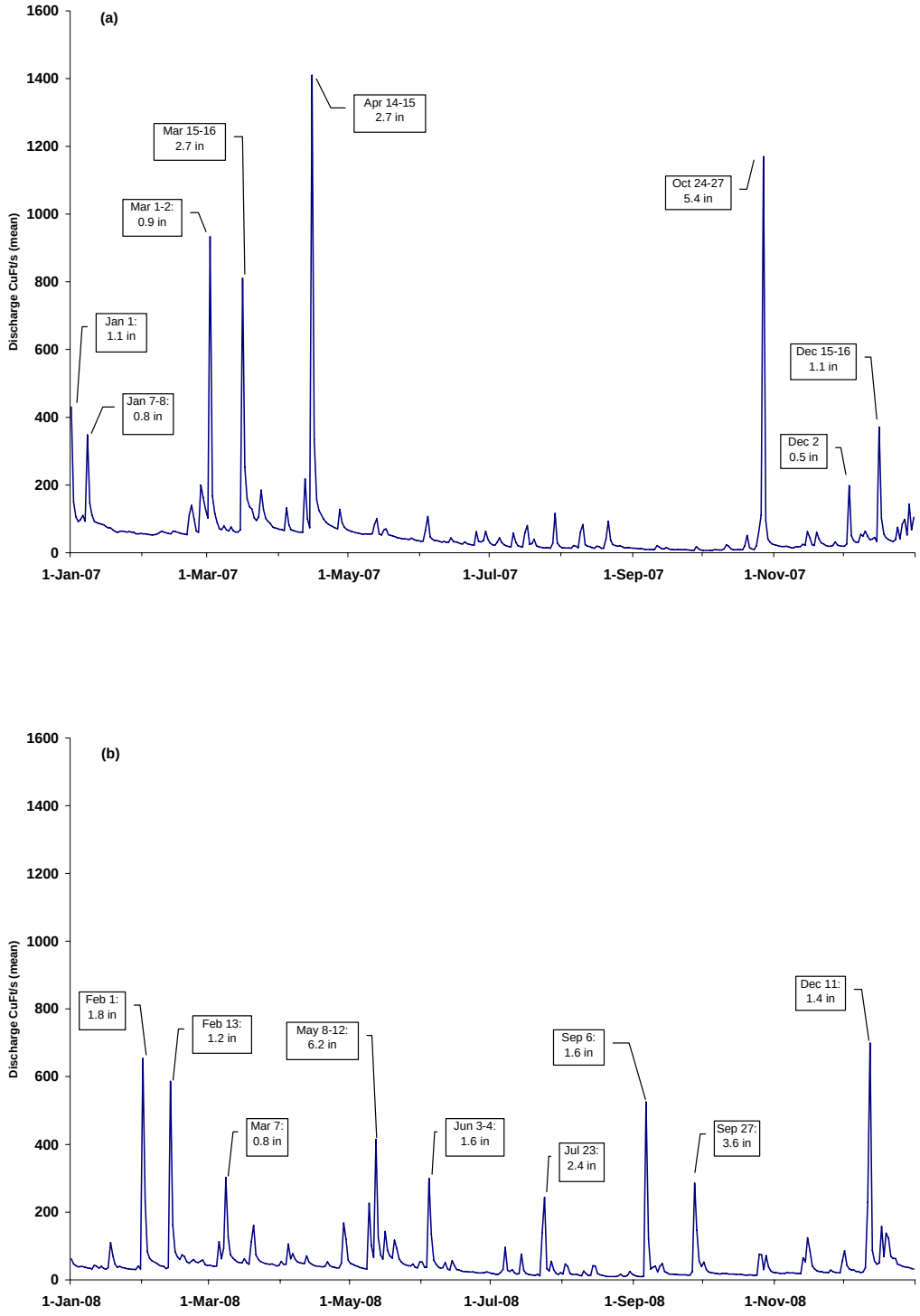

Figure 3. Daily discharge in cubic feet per second measured at USGS Gaging Station 01581757 on Otter Point Creek near Edgewood, MD in (a) 2007 and (b) 2008. (Boxes indicate precipitation events at BWI Marshall Airport that coincided with spikes in discharge.)

Continuous Monitoring Data

Water Temperature

In both 2007 and 2008, water temperature at all Bush River Stations rose predictably as air temperatures increased during the summer months (Figure 4). Otter Point Creek reached a peak of approximately 34°C between June and August in both 2007 and 2008. Church Point displayed a similar pattern in 2008 while Lauderick Creek, which is located further downstream than the other two sites and, therefore, receives a greater influx of water from the Chesapeake Bay, peaked at around 31°C in August, 2007.

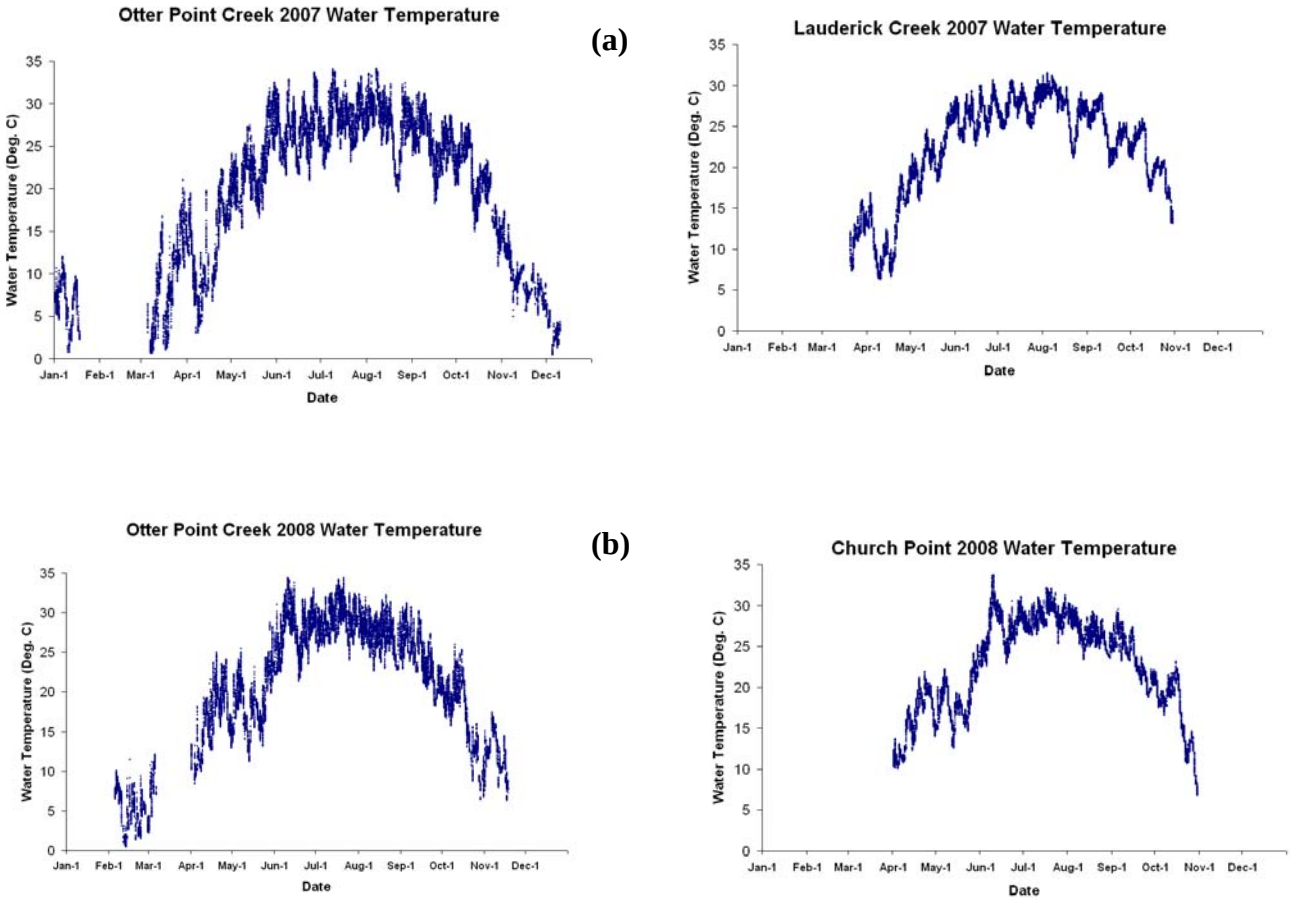

Figure 4. Water temperature at Bush River Continuous Monitoring sites during (a) 2007 and (b) 2008.

Salinity

In 2007, salinity levels for both the Otter Point Creek and Lauderick Creek monitoring sites were within their normal annual ranges during the spring and early summer (Figure 5a). Levels then increased substantially during the late summer and early fall as May through September experienced below normal precipitation (Figure 2a), which reduced flow conditions and allowed higher salinity waters from the Chesapeake Bay to move upriver. Salinity levels at Lauderick Creek began steadily increasing around the end of May and peaked at 6.4 parts per thousand (ppt) on October 24th. The Otter Point Creek site is located further upstream (Figure 1) and it, therefore, takes longer for the higher salinity waters of the Chesapeake Bay to influence levels than at Lauderick Creek. Thus, salinity levels at Otter Point Creek did not begin steadily rising until August and peaked at 3.9ppt on October 18th. Levels at both sites decreased following a substantial precipitation and discharge event beginning October 24th (Figure 3a).

In 2008, salinity levels for both the Otter Point Creek and Church Point sites remained low for most of the spring and summer (Figure 5b) as April through July was wetter than normal (Figure 2b). Levels at both sites began increasing during a dry August, dropped slightly following a wet September, and increased steadily through late October and early November. Church Point salinity levels peaked at 5.3ppt on October 25th and Otter Point Creek levels peaked at 5.5ppt on November 10th.

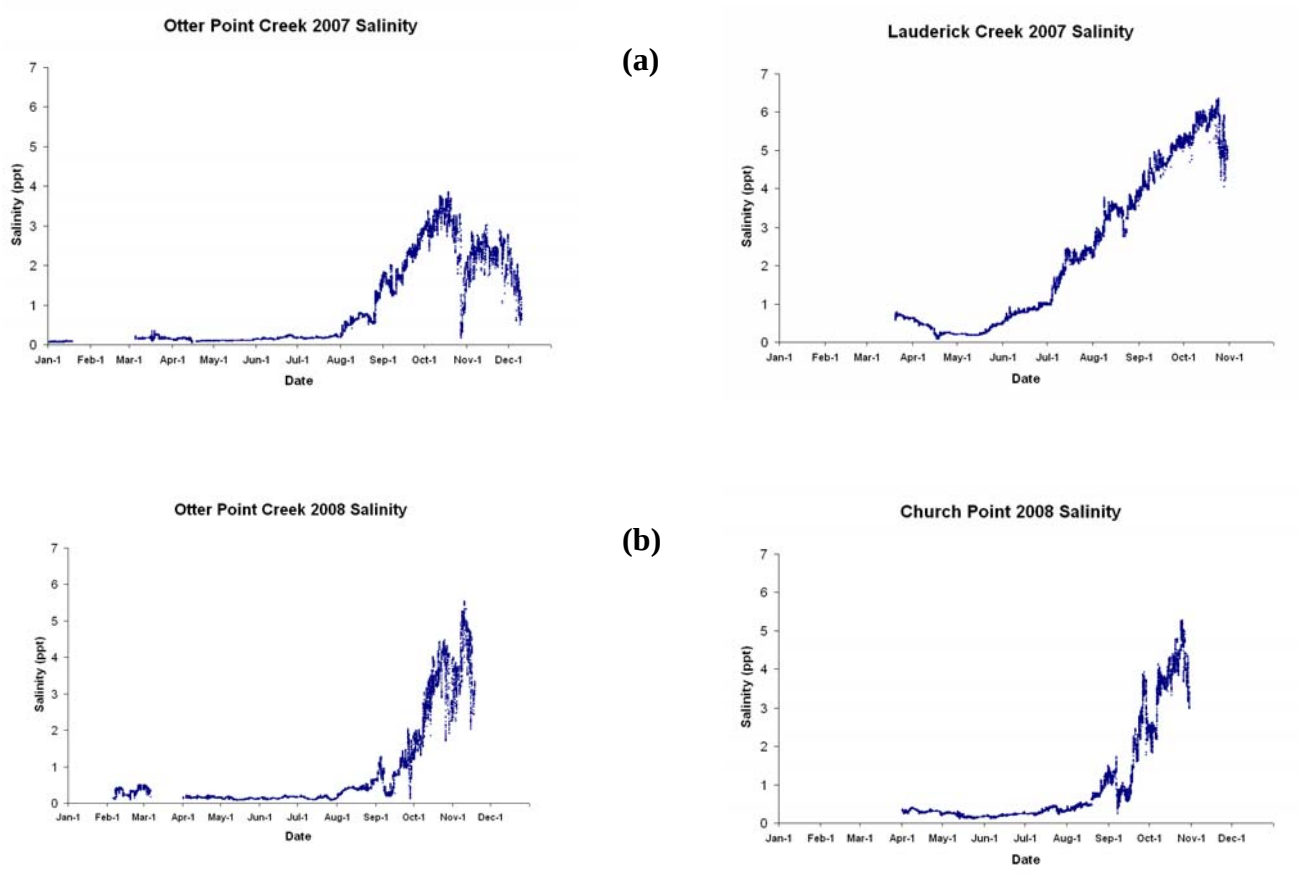

Figure 5. Salinity levels at Bush River Continuous Monitoring sites during (a) 2007 and (b) 2008.

Dissolved Oxygen

In 2007, dissolved oxygen for both Lauderick Creek and Otter Point Creek exhibited expected declines during the summer months (Figure 6a) because warmer water cannot dissolve oxygen as readily as colder water. Greater variability in dissolved oxygen levels was also seen at Otter Point Creek, indicating that this site is more affected by nutrients and associated algal blooms that affect dissolved oxygen levels than the site at Lauderick Creek, which is further downstream and experiences more mixing with water from the Chesapeake Bay. Both sites, however, experienced relatively few days of dissolved oxygen concentrations below 5 milligrams per liter (mg/l) (Table 2), which can be detrimental to the survival of juvenile fish (US EPA, 2003), perhaps due to the absence of large, harmful phytoplankton blooms such as those seen in 2003 and 2004 on the Bush River.

Dissolved oxygen concentrations at Otter Point Creek experienced a high of 18.38mg/l on June 30th, and a low of 0.86mg/l on July 30th. In general, however, dissolved oxygen levels were concentrated around 8-10mg/l during the summer months with 10.3% of 7,838 valid readings below 5mg/l between July and September. At the Lauderick Creek site, dissolved oxygen concentrations reached a high of 14.93mg/l on March 27th. Levels then dipped to below 10mg/l in early April, which coincided with a 1,800 gallon sanitary sewer overflow that took place in the Bush River watershed on March 28th (Table 1). Dissolved oxygen levels then rebounded to

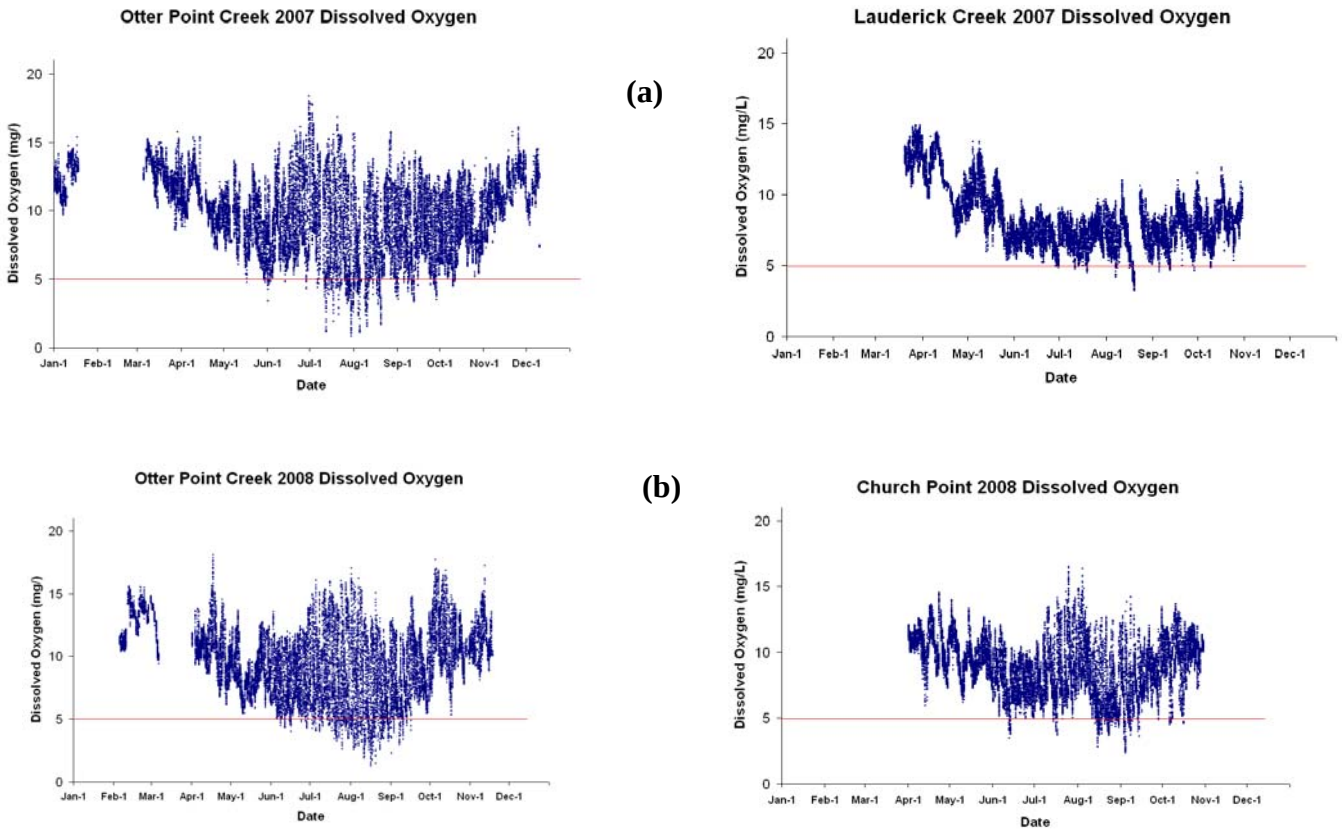

Figure 6. Dissolved oxygen levels at Bush River Continuous Monitoring sites during (a) 2007 and (b) 2008.

(Red line indicates threshold below which levels can lead to ecosystem stress.)

approximately 15mg/l on April 10th, before dropping again to around 7mg/l following a Nor'Easter and related sanitary sewer overflow that impacted the region in mid-April. Levels also dropped as water temperatures heated through the summer (Figure 4a) to a low of 3.31mg/l on August 19th. Levels during the summer were concentrated around 7-8mg/l with 2.5% of 8,487 valid readings below 5mg/l between July and September.

In 2008, both Continuous Monitoring sites were located relatively closer to the head waters than the mouth of the Bush River (Figure 1) and exhibited similar variability to each other in dissolved oxygen levels (Figure 6b). Otter Point Creek also experienced more days with dissolved oxygen concentrations below 5mg/l (Table 2) than in 2007, perhaps because of the higher levels of precipitation (Figure 2) and more frequent spikes in discharge events (Figure 3) in 2008.

Dissolved oxygen concentrations at Otter Point Creek experienced a high of 18.11mg/l on April 17th, and a low of 1.32mg/l on August 16th. In general, however, dissolved oxygen levels were again concentrated around 8-10mg/l during the summer months and 10% of 8,450 valid readings between July and September were below 5mg/l. At the Church Point site, dissolved oxygen concentrations reached a high of 16.52mg/l on July 25th and a low of 2.41mg/l on September 4th. Levels during the summer were concentrated around 8-9mg/l and 5.5% of 7,240 valid readings between July and September were below 5mg/l.

Furthermore, two sanitary sewer overflows in the Bush River watershed (Table 1), a 17,000 gallon overflow on September 26th and a 1,250 gallon overflow on October 26th, coincided with drops in dissolved oxygen levels at both sites. At Otter Point Creek, levels dropped from approximately 12mg/l on September 24th to 5.5mg/l on September 29th, and from approximately 12mg/l on October 25th to 7.8mg/l on October 27th. At Church Point, levels dropped from approximately 10mg/l on September 24th to below 5mg/l on September 28th, and from greater than 10mg/l on October 25th to 7.4mg/l on October 27th.

Continuous Monitoring Site	2007	2008
Otter Point Creek		
Dissolved Oxygen less than 5 mg/l	10.33%	10.01%
Dissolved Oxygen less than 3.2 mg/l	1.62%	1.17%
Lauderick Creek		
Dissolved Oxygen less than 5 mg/l	2.47%	N/A
Dissolved Oxygen less than 3.2 mg/l	0%	N/A
Church Point		
Dissolved Oxygen less than 5 mg/l	N/A	5.46%
Dissolved Oxygen less than 3.2 mg/l	N/A	0.37%

Table 2. Dissolved Oxygen criteria failure at Otter Point Creek, Lauderick Creek, and Church Point during July through September, 2007 and 2008. *(3.2mg/l is the EPA threshold for open-water fish and shellfish use; US EPA, 2003.)*

Chlorophyll

In 2007 at both Continuous Monitoring sites, there were very few chlorophyll readings greater than 50 micrograms per liter (µg/l), which are indicative of significant algal blooms, or 100µg/l, which indicates severe blooms (Figure 7a and Table 3). Lauderick Creek showed brief spikes in chlorophyll in late March and early May, while Otter Point Creek experienced a brief spike in late October. The late-March peak of approximately 100µg/l at Lauderick Creek coincided with a sanitary sewer overflow on March 28th, and a drop in dissolved oxygen levels in early April (Figure 6a). A substantial proportion of chlorophyll readings during the wet spring, however, were greater than 15µg/l (Table 3), a threshold above which detrimental effects on aquatic ecosystems may occur. Of 6,893 valid readings at Lauderick Creek between March and May, 87% were greater than 15µg/l. At Otter Point Creek, 29.8% of 7,103 valid readings between March and May were greater than 15µg/l.

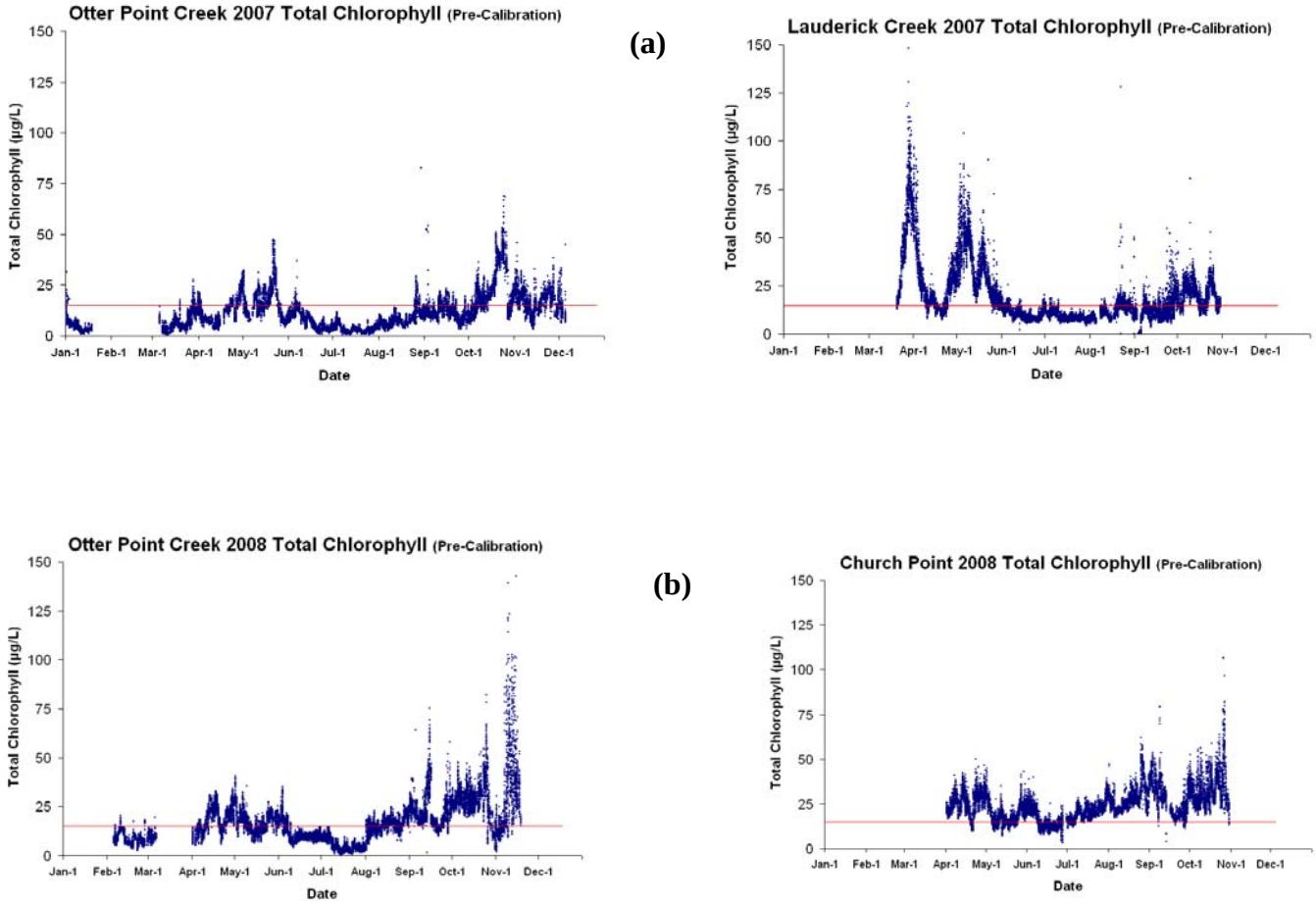

Figure 7. Total chlorophyll levels at Bush River Continuous Monitoring sites during (a) 2007 and (b) 2008.

(Red line indicates threshold above which levels may have harmful effects on aquatic ecosystems.)

In 2008, chlorophyll levels generally remained below 50µg/l until late August and early September when both sites experienced a series of algal blooms that lasted into November (Figure 7b). A much higher proportion of readings at Otter Point Creek were greater than 15µg/l than were measured in 2007 (Table 3). Of 5,740 valid readings between March and May and 8,449 valid readings between July and September, 58.8% and 47.8% respectively were greater than 15µg/l. A peak of greater than 100µg/l in mid-November also coincided with a harmful algal bloom of *Karlodinium veneficum* that was detected at the Otter Point Creek site (Table 1). At Church Point, of 4,864 valid readings between March and May and 8,173 valid readings between July and September, 83.6% and 96.4% respectively were greater than 15µg/l.

Continuous Monitoring Site	Months	2007	2008
Otter Point Creek			
Readings greater than 15µg/l	Mar - May	29.75%	58.80%
	July - Sept	6.82%	47.78%
Readings greater than 50µg/l	Mar - May	0%	0%
	July - Sept	0.06%	0.33%
Readings greater than 100µg/l	Mar - May	0%	0%
	July - Sept	0%	0%
Lauderick Creek			
Readings greater than 15µg/l	Mar - May	86.99%	N/A
	July - Sept	14.99%	N/A
Readings greater than 50µg/l	Mar - May	21.01%	N/A
	July - Sept	0.10%	N/A
Readings greater than 100µg/l	Mar - May	0.26%	N/A
	July - Sept	0.01%	N/A
Church Point			
Readings greater than 15µg/l	Mar - May	N/A	83.56%
	July - Sept	N/A	96.38%
Readings greater than 50µg/l	Mar - May	N/A	0.02%
	July - Sept	N/A	0.65%
Readings greater than 100µg/l	Mar - May	N/A	0%
	July - Sept	N/A	0%

Table 3. Chlorophyll criteria failure at Otter Point Creek, Lauderick Creek, and Church Point in 2007 and 2008.

pH

In 2007, the variability of Otter Point Creek pH measurements was larger than the variability at Lauderick Creek (Figure 8a). Otter Point Creek was also generally more alkaline than Lauderick Creek, which follows the pattern seen in previous years. Of note, pH at both sites dropped dramatically in mid-April following an influx of fresh water into the system from a Nor'Easter (Table 1) and associated discharge event (Figure 2). Lauderick Creek dropped from 9.3 on April 10th to 7.1 on April 23rd, while Otter Point Creek dropped from 9.5 on April 10th to 6.9 on April 24th. Also, Otter Point Creek experienced a spike in pH between mid-June and the end of July. Such spikes often indicate the presence of a blue-green (*Microcystis* sp.) algal bloom, which currently cannot be detected with the fluorometers used to measure chlorophyll on the Continuous Monitoring datasondes deployed on the Bush River. However, low dissolved oxygen levels at Otter Point Creek in July and August (Figure 6a) provide further evidence of a phytoplankton bloom and subsequent die-off.

In 2008, Otter Point Creek and Church Point displayed similar variability and pH levels (Figure 8b). Both Continuous Monitoring sites showed a dip in pH in mid-May following a heavy rain (Table 1) and discharge event (Figure 2) and a spike in pH levels in July and August. This spike on Otter Point Creek was lower in magnitude, however, than the one observed in 2007 (Figure 8a).

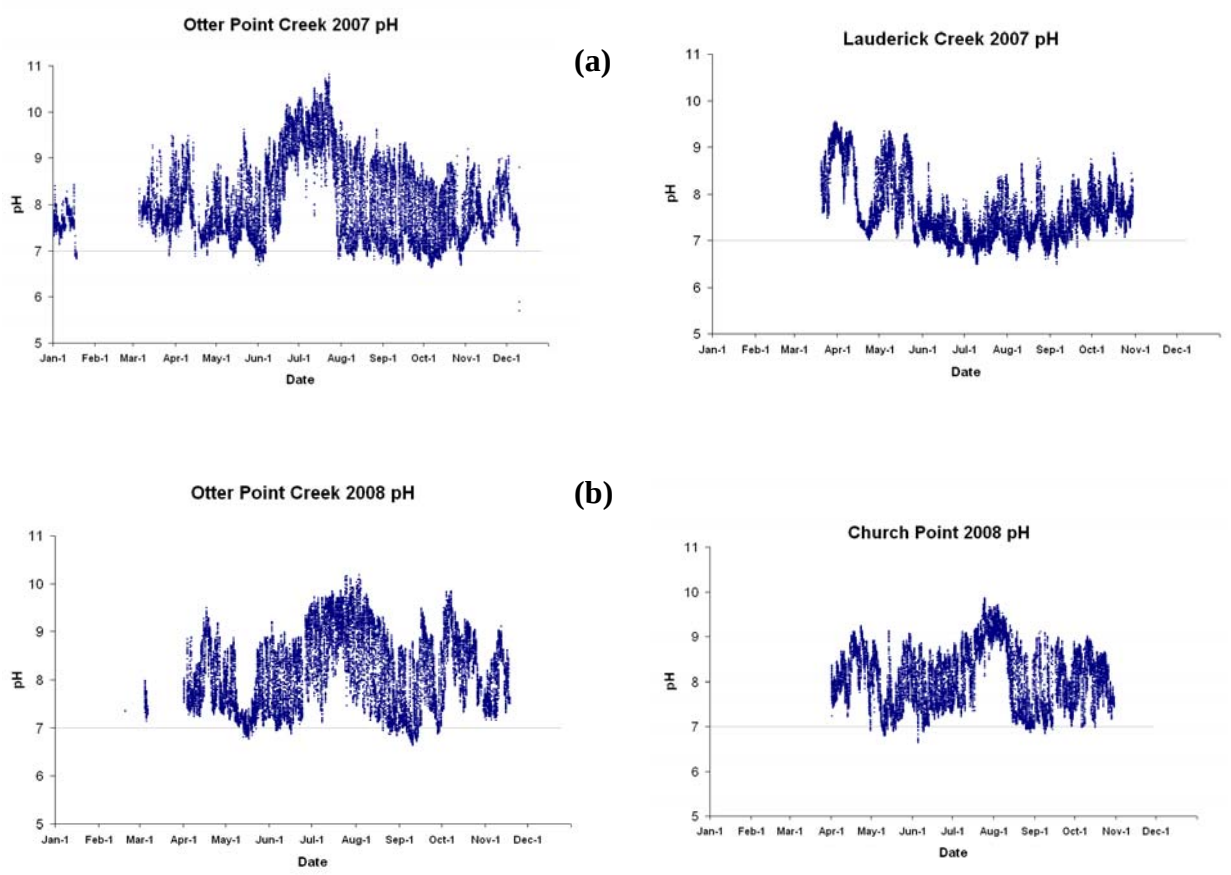

Figure 8. pH levels at Bush River Continuous Monitoring sites during (a) 2007 and (b) 2008.

(Line indicates neutral pH.)

Turbidity and Coefficient of Light Attenuation (K_d)

Turbidity is one parameter of water clarity and is quantified by measuring how much light is reflected from suspended particles in the water. Lower turbidity values indicate less reflection and, therefore, clearer water. In 2007, Lauderick Creek experienced less variability and generally lower overall turbidity levels than Otter Point Creek (Figure 9a). Both Continuous Monitoring sites experienced spikes and declines in turbidity levels following weather patterns and discharge events, although the overall magnitude of change was lower at the Lauderick Creek site. Turbidity levels went above 1000 nephelometric turbidity units (NTUs) once at Otter Point Creek following a winter storm in mid-March (Table 1). A Nor'Easter that impacted the mid-Atlantic region in mid-April (Table 1) led to a high volume discharge event (Figure 2a) and a spike in turbidity with levels reaching 185.6 NTUs at Lauderick Creek and 258.1 NTUs at Otter Point Creek. Otter Point Creek also experienced a turbidity spike in mid-July that coincided with a spike in pH (Figure 8a), potentially indicating a blue-green algal bloom. Levels then declined and leveled off through a dry summer and Otter Point Creek experienced spikes again in late October and early December following high volume discharge events (Figure 2a).

Although 2008 was a wetter year than 2007 (Figure 2) leading to more frequent spikes in discharge (Figure 2), overall volume from discharge events was lower in 2008, which may have led to the more consistent levels of turbidity observed at the two Continuous Monitoring sites (Figure 9b). Church Point experienced brief spikes over 100 NTUs in April, June, August, and October and Otter Point Creek dropped to below 10 NTUs in July. Both sites, however, exhibited turbidity levels between 20 and 50 NTUs for the majority of the year.

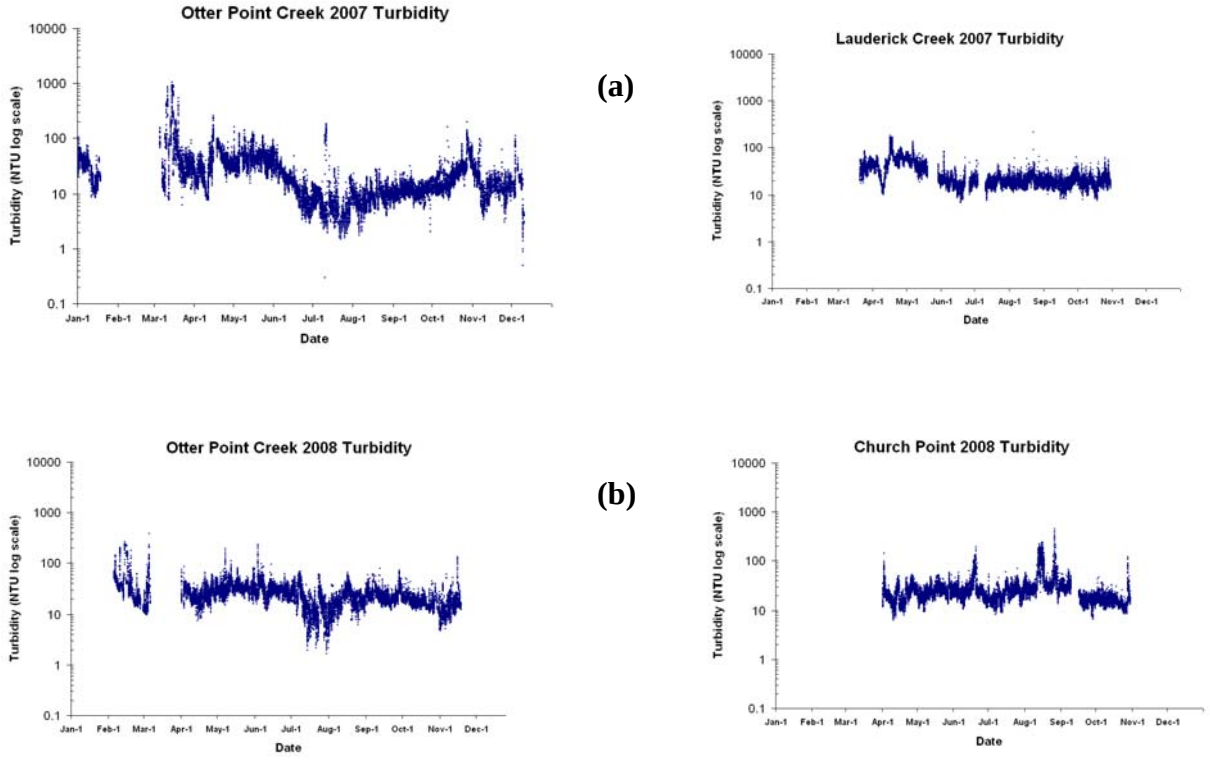

Figure 9. Turbidity levels at Bush River Continuous Monitoring sites during (a) 2007 and (b) 2008.

Furthermore, two autumn sanitary sewer overflows in the Bush River watershed (Table 1) coincided with increases in turbidity at each site. Following a sanitary sewer overflow on September 26th, turbidity levels at Otter Point Creek increased from approximately 14 NTUs on September 24th to 74 NTUs on September 28th. Following a sanitary sewer overflow on October 26th, turbidity levels at Church Point increased from approximately 10 NTUs on October 25th to 121.6 NTUs on October 28th.

Another measure of water clarity is the coefficient of light attenuation (K_d). This coefficient measures how far light can travel down the water column and is calculated using salinity, chlorophyll, and turbidity data (US EPA, 2007). Clearer water has lower K_d values while murky or cloudy water has higher values. For the Continuous Monitoring sites on the Bush River, K_d values less than or equal to 2.1 are considered optimal for SAV growth. During the SAV growing season (April through October) in both 2007 and 2008, the vast majority of K_d values were greater than 2.1 (Table 4). In 2007, over 72% of 18,586 valid readings at Otter Point Creek and over 99% of 17,679 valid readings at Lauderick Creek resulted in K_d values greater than 2.1. In 2008, water clarity further declined as over 94% of 19,023 valid readings at Otter Point Creek and almost 100% of the valid readings at Church Point resulted in K_d values greater than 2.1.

Continuous Monitoring Site	2007	2008
Otter Point Creek		
K_d greater than 2.1	72.53%	94.32%
Lauderick Creek		
K_d greater than 2.1	99.51%	N/A
Church Point		
K_d greater than 2.1	N/A	99.83%

Table 4. Coefficient of light attenuation failure (K_d) at Otter Point Creek, Lauderick Creek, and Church Point during April through October, 2007 and 2008.

Submerged Aquatic Vegetation (SAV) in the Bush River

SAV or underwater grasses are an important component of estuarine ecosystems. They provide habitat for juvenile fish and shellfish, supply food for waterfowl, oxygenate the water, and help stabilize bottom sediments. Since 1984, SAV total area and density within the Bush River has been quantified annually (with the exception of 1988) by the Virginia Institute of Marine Science (VIMS),

Total area of SAV in 2007 increased by 98% from the previous year to 643 acres. Over 65% of this acreage consisted of high density beds (Figure 10) and 6 different species (*Ceratophyllum demersum*, *Elodea canadensis*, *Hydrilla verticillata*, *Myriophyllum spicatum*, *Vallisneria americana*, *Zannichellia palustris*) were present in 2007. Total area decreased by 19% to 519 acres in 2008. Over 52% of this acreage consisted of high density beds and all species from 2007, with the exception of *Zannichellia palustris*, were present.

The decrease in SAV acreage between 2007 and 2008 may be partly explained by greater water clarity in 2007. At the Otter Point Creek Continuous Monitoring site, chlorophyll levels were lower (Table 3) and K_d values indicate there were more optimal light conditions within the water column to facilitate SAV growth (Table 4) in 2007 than in 2008. K_d values in 2007 were also much improved as compared to 2006 (see data supplement for the 2006 Bush River Newsletter: http://mddnr.chesapeakebay.net/eyesonthebay/documents/Bush_River_sup.pdf), which may have facilitated the expansion in SAV acreage.

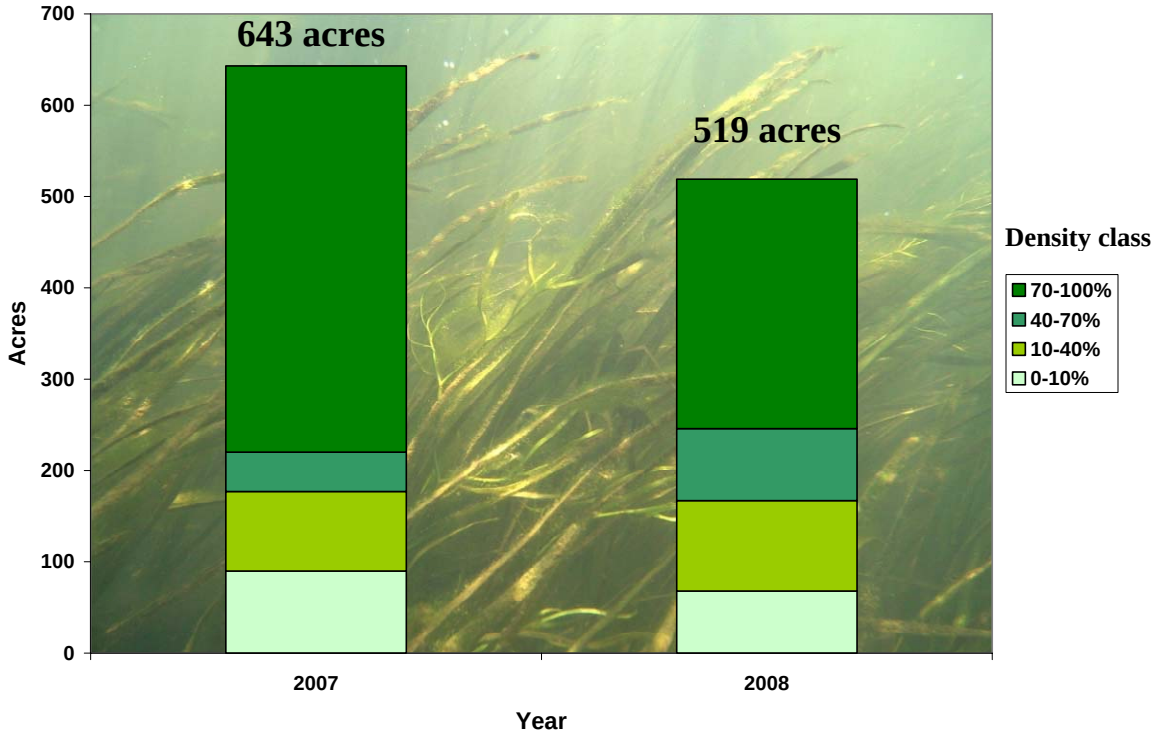

Figure 10. Total area and density of SAV in the Bush River during 2007 and 2008.

Pigments, Nutrients, Suspended Solids, and Secchi Data

Bi-weekly grab samples of water were taken at each of the two Continuous Monitoring stations on the Bush River when the YSI meters were exchanged. Secchi depth, a measure of water clarity, was also recorded at the time of the grab sample.

For the grab samples, the water was processed in the field using vacuum filtration, and the resulting particulate and filtrate samples delivered to laboratories for analysis of pigments, nutrients, and suspended solids. Chlorophyll *a* and pheophytin were analyzed by the Maryland Department of Health and Mental Hygiene (DHMH) Environmental Chemistry Division. Suspended solids and nutrient samples were analyzed at the University of Maryland's Chesapeake Biological Laboratory (CBL) Nutrient Analytical Services Laboratory (NASL). For details on methods, procedures, analysis and detection limits, refer to the Quality Assurance Project Plan (QAPP) for the Shallow Water Monitoring Program. This document can be found at http://mddnr.chesapeakebay.net/eyesonthebay/documents/swm_qapp_2006.pdf. Results of the nutrient analyses, suspended sediments, and pigments are presented in Appendix A. In Appendix A, Tables A1 through A8 list the data values, and Figures A-1 through A-18 present the data graphically.

Ambient water quality data (dissolved oxygen, pH, salinity, and water temperature) were collected concurrently with the grab samples. These values are presented in Appendix A in Tables A9 to A12 and also in Figures A-19 to A-22. These water quality parameters are usually measured at multiple depths at each station. In the graphs, the data range for each parameter is represented by a vertical bar for each sample date. The connecting line intersects each bar at the average value for the station on that date.

For the Otter Point Creek station (XJG7035), the data record extends back to the year 2003. Plots of the available pigment, nutrient, and suspended solids variables over this extended time period are presented in Appendix B (Figures B1 through B18).

Conclusion

Shallow water monitoring, consisting of temporally intensive Continuous Monitoring, provides a critical function for assessing the health of Maryland's tidal waters in areas historically lacking water quality information. Not only is this information used for characterizing the health of shallow water habitats, but also to: 1) assess newly developed Chesapeake Bay water quality criteria for dissolved oxygen, water clarity and chlorophyll in shallow water habitats; 2) determine attainment or non-attainment of shallow water habitats for their designated uses; 3) assess SAV habitats and identify potential SAV restoration sites, 4) provide information to better understand ecosystem processes and the impact of extreme events (e.g. hurricanes, high flows, sanitary sewer overflows) in shallow water and open water environments; 5) provide data for calibrating the Bay Eutrophication and Watershed Model.

References

U. S. Environmental Protection Agency. 2003. *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries.* EPA 903-R-03-002. Region III Chesapeake Bay Program Office, Annapolis, Maryland.

U. S. Environmental Protection Agency. 2007. *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries – 2007 Addendum.* EPA 903-R-07-003. CBP/TRS 285/07. Ambient Water Quality Criteria for Dissolved Oxygen Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tributaries Region III Chesapeake Bay Program Office, Annapolis, Maryland.

Appendix A

Results of laboratory and ambient water quality analyses for:
Lauderick Creek (Station XJG4337)
Otter Point Creek (Station XJG7035)
Church Point (Station XJG7461)

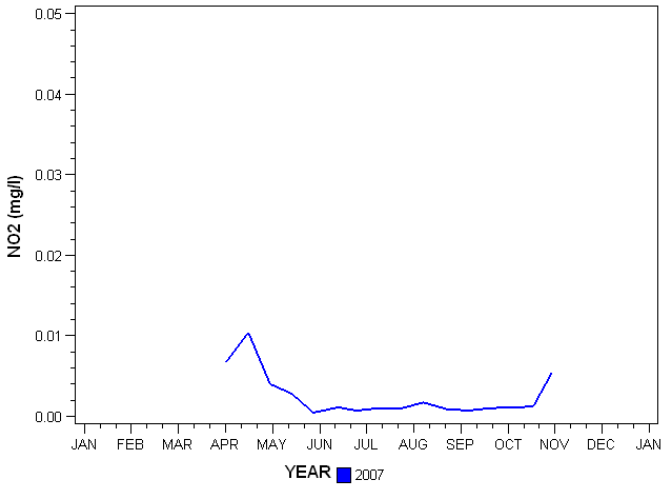

Figure A-1a. Nitrite concentrations at Lauderick Creek.

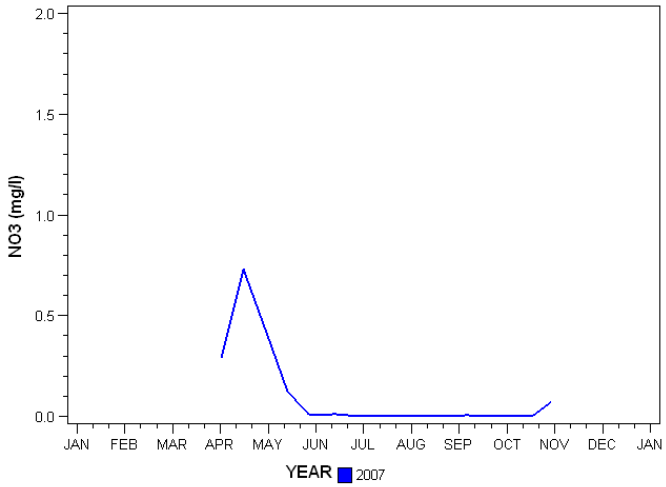

Figure A-2a. Nitrate concentrations at Lauderick Creek.

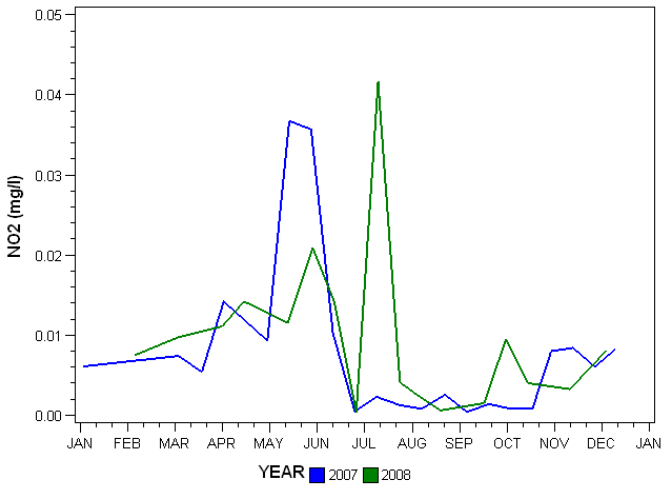

Figure A-1b. Nitrite concentrations at Otter Point Creek.

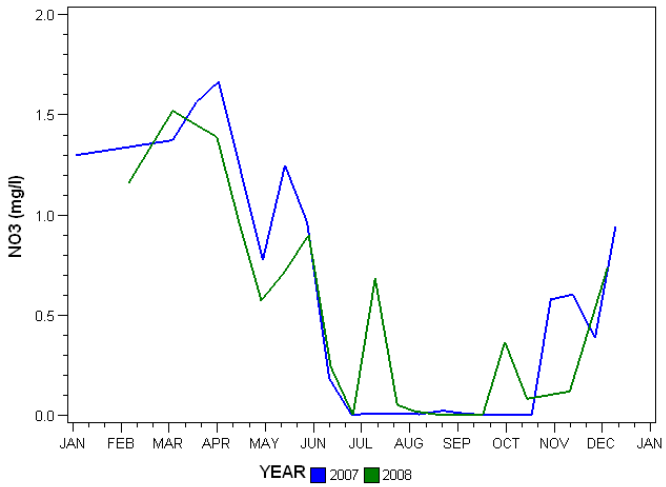

Figure A-2b. Nitrate concentrations at Otter Point Creek.

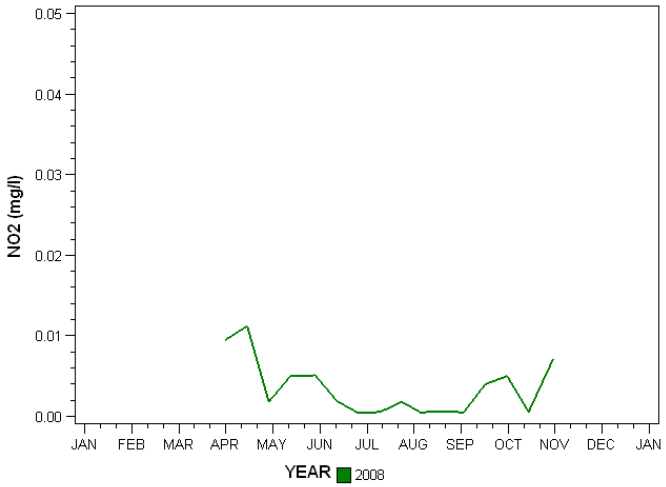

Figure A-1c. Nitrite concentrations at Church Point.

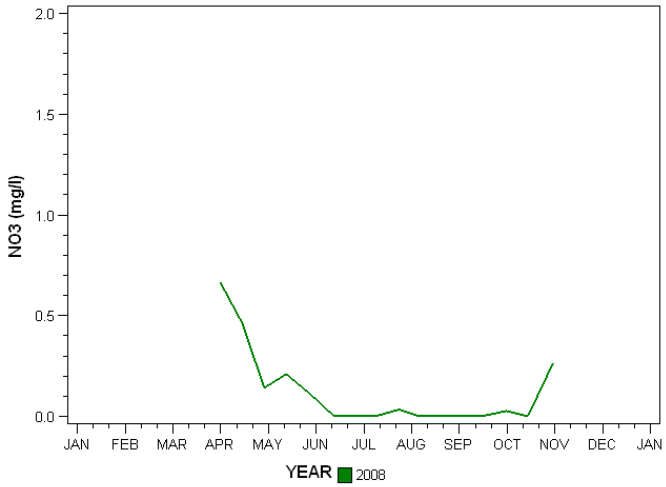

Figure A-2c. Nitrate concentrations at Church Point.

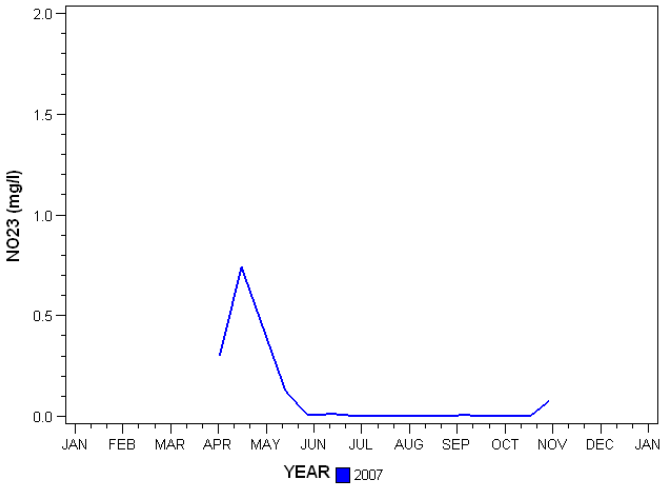

Figure A-3a. Nitrite + Nitrate concentrations at Lauderick Creek.

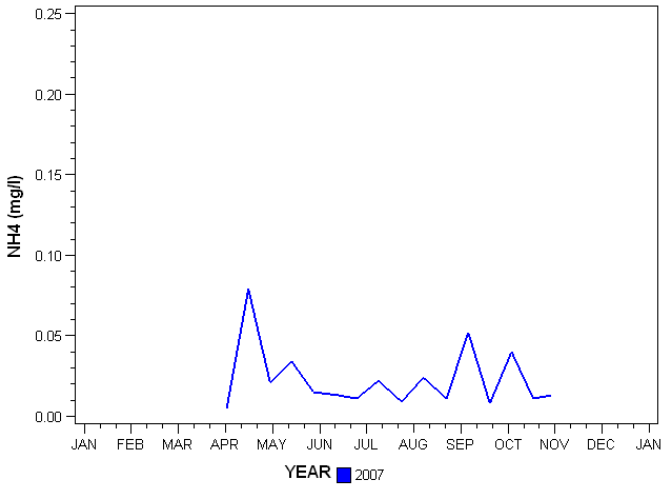

Figure A-4a. Ammonium concentrations at Lauderick Creek.

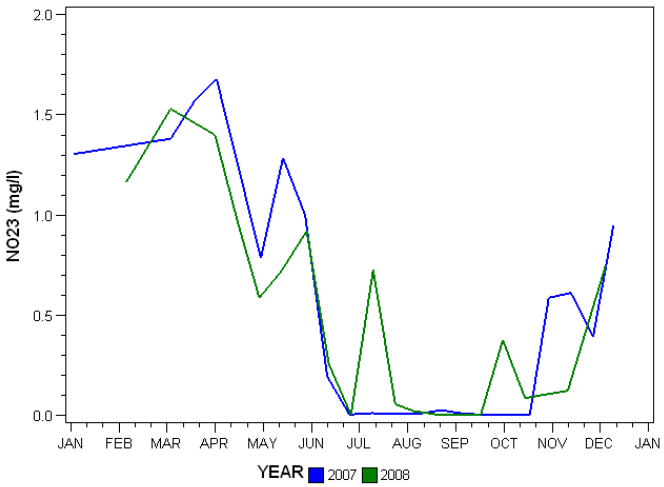

Figure A-3b. Nitrite + Nitrate concentrations at Otter Point Creek.

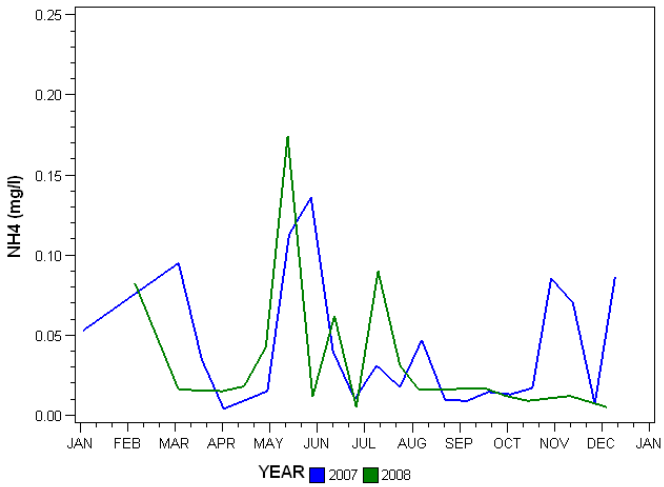

Figure A-4b. Ammonium concentrations at Otter Point Creek.

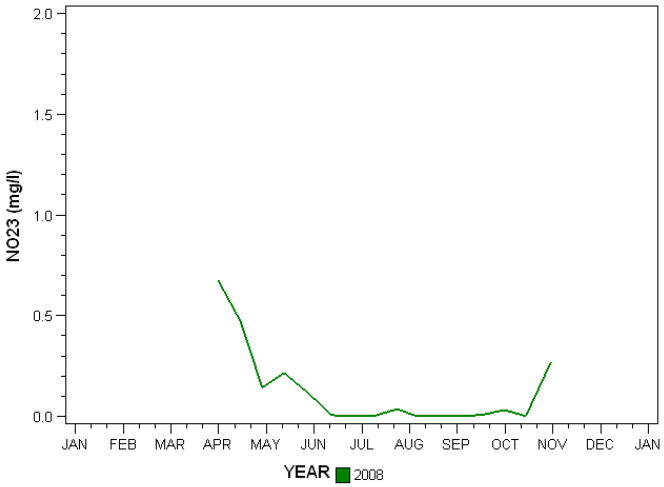

Figure A-3c. Nitrite + Nitrate concentrations at Church Point.

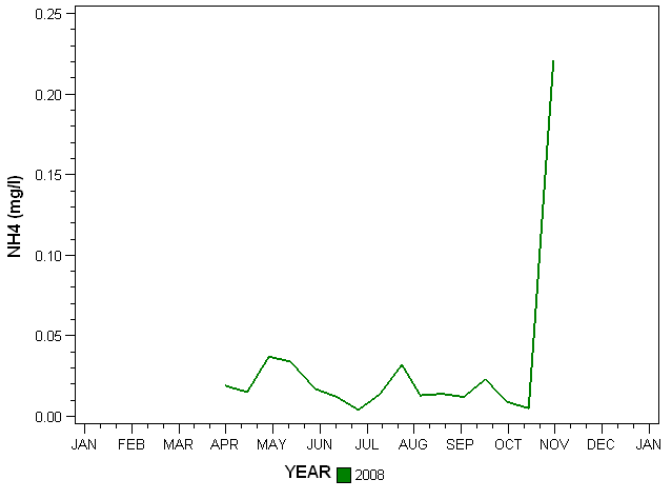

Figure A-4c. Ammonium concentrations at Church Point.

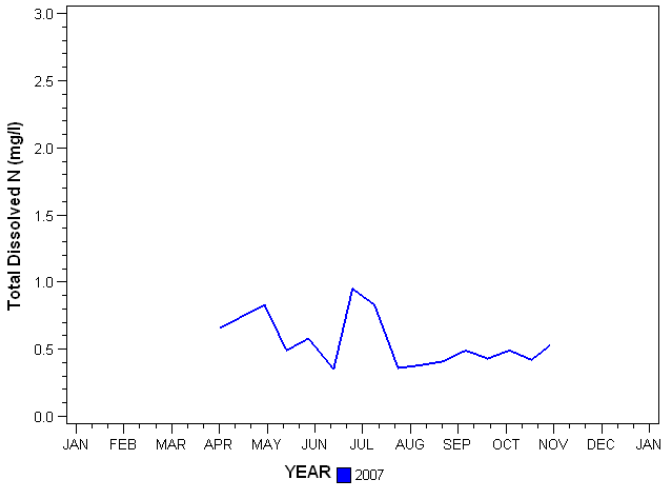

Figure A-5a. Total dissolved nitrogen concentrations at Lauderick Creek.

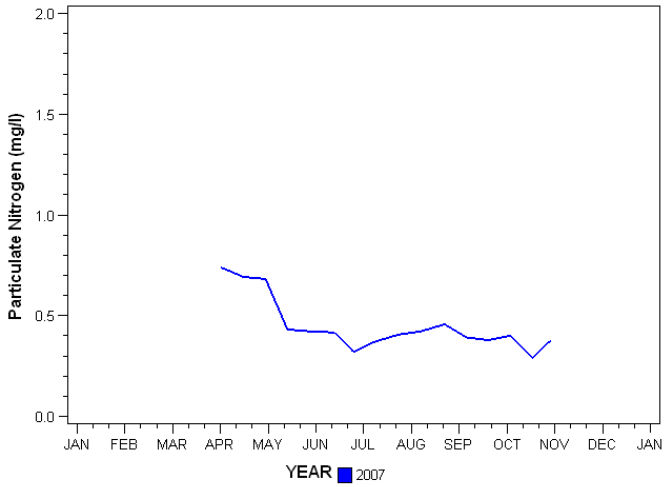

Figure A-6a. Particulate nitrogen concentrations at Lauderick Creek.

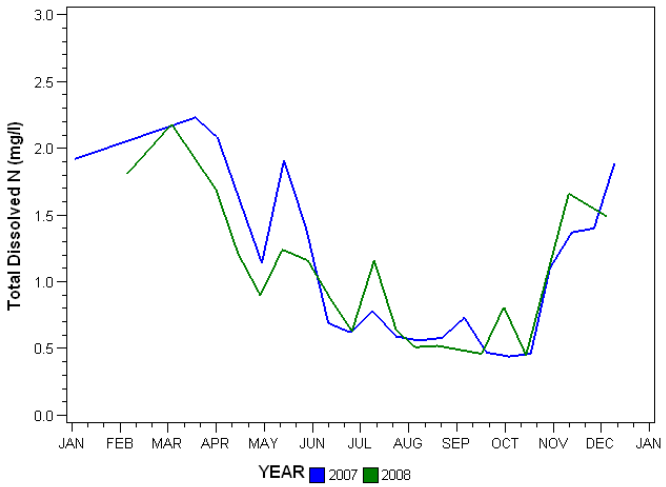

Figure A-5b. Total dissolved nitrogen concentrations at Otter Point Creek.

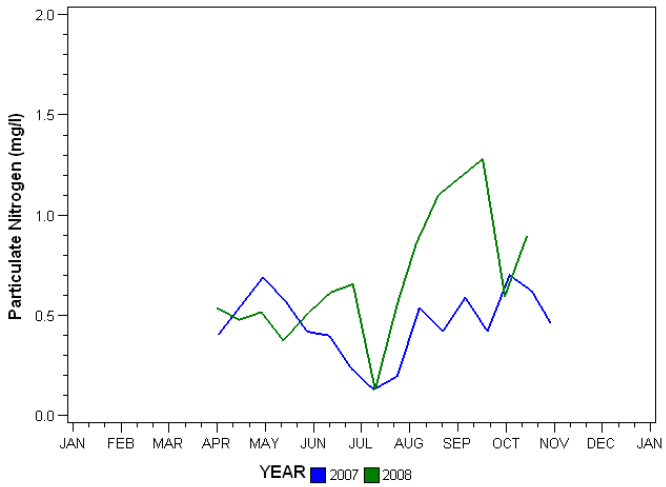

Figure A-6b. Particulate nitrogen concentrations at Otter Point Creek.

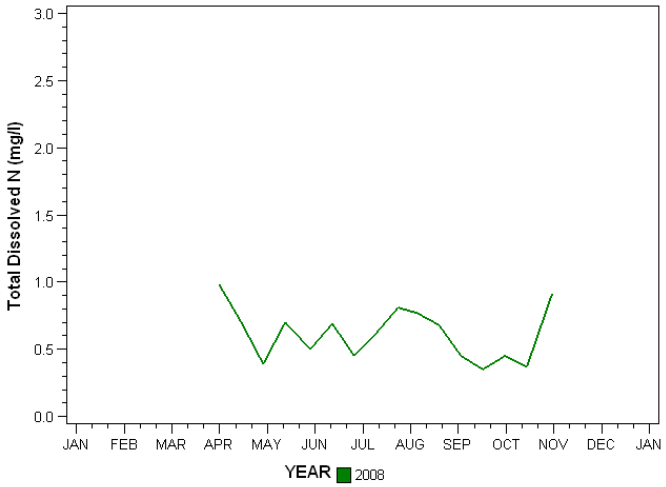

Figure A-5c. Total dissolved nitrogen concentrations at Church Point.

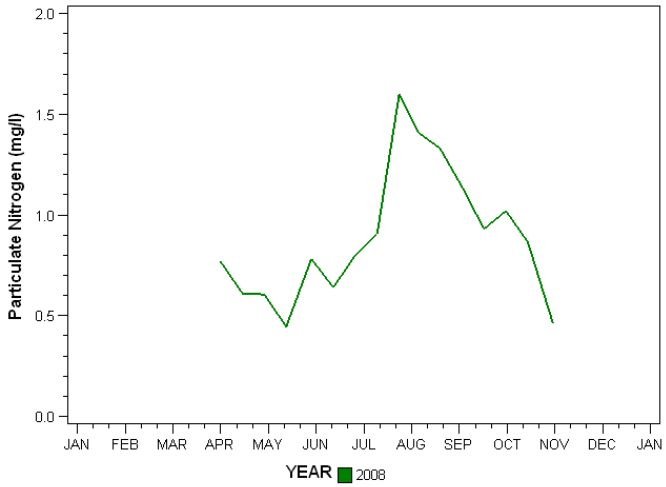

Figure A-6c. Particulate nitrogen concentrations at Church Point.

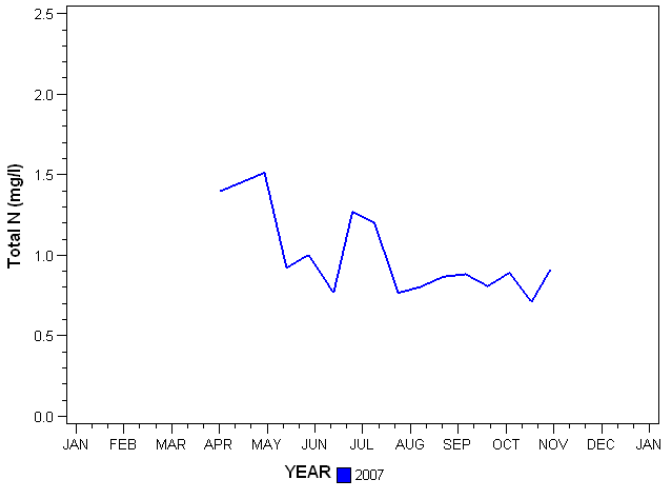

Figure A-7a. Total nitrogen concentrations at Lauderick Creek.

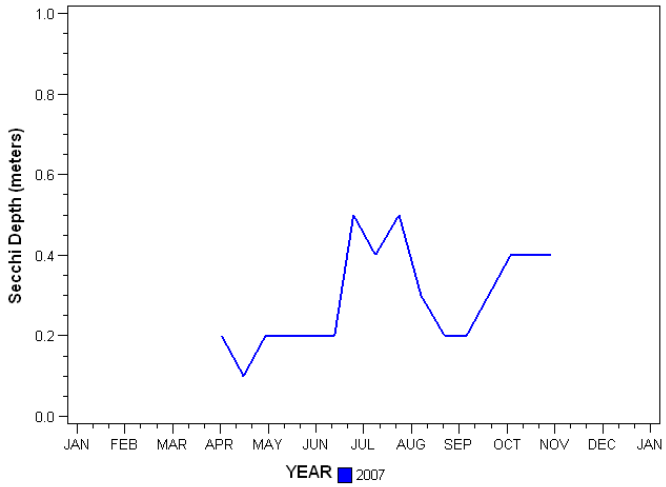

Figure A-8a. Secchi depth at Lauderick Creek.

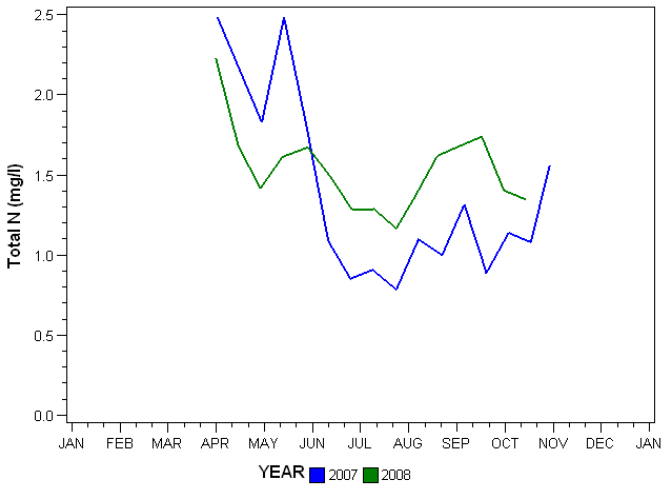

Figure A-7b. Total nitrogen concentrations at Otter Point Creek.

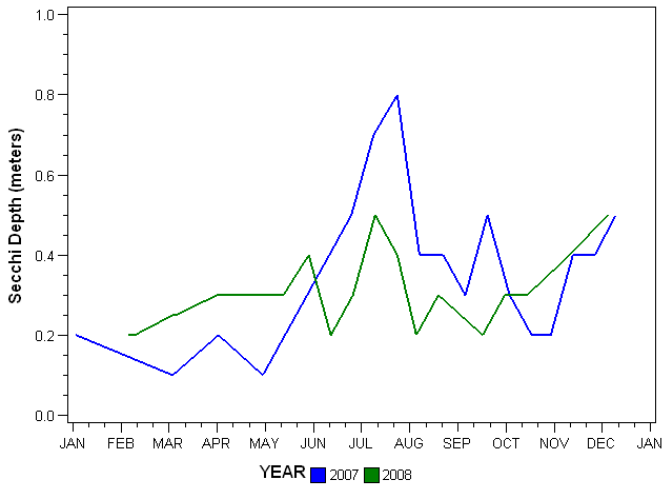

Figure A-8b. Secchi depth at Otter Point Creek.

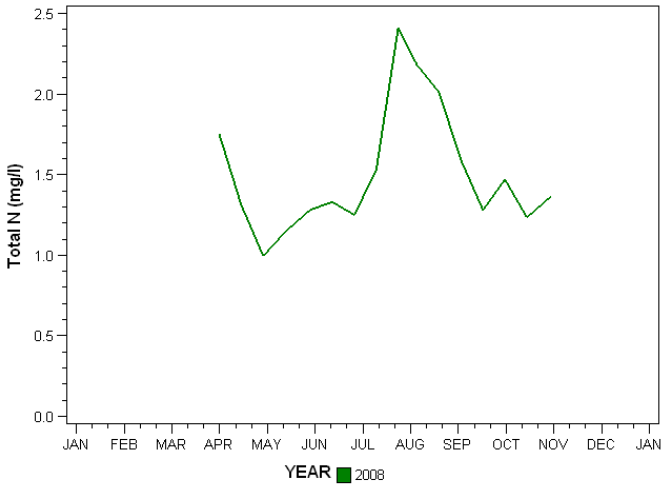

Figure A-7c. Total nitrogen concentrations at Church Point.

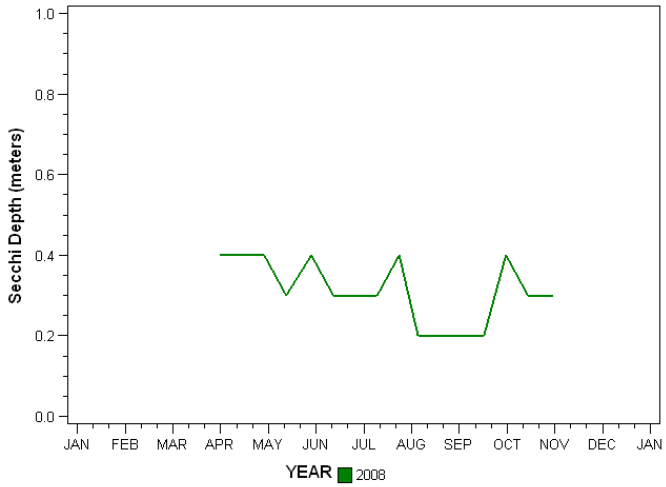

Figure A-8c. Secchi depth at Church Point.

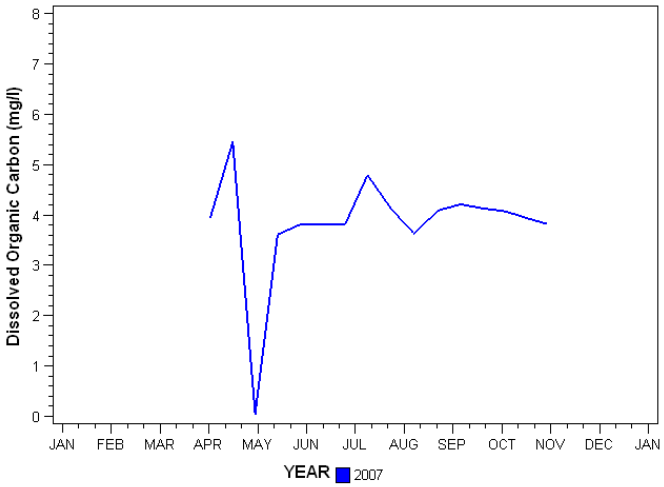

Figure A-9a. Dissolved organic carbon concentrations at Lauderick Creek.

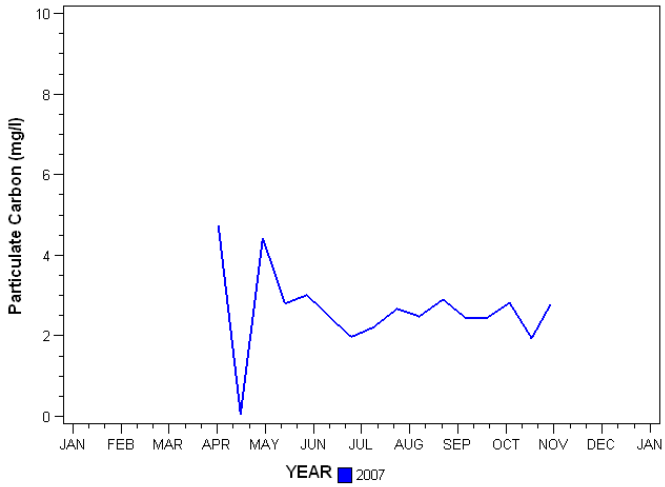

Figure A-10a. Particulate carbon concentrations at Lauderick Creek.

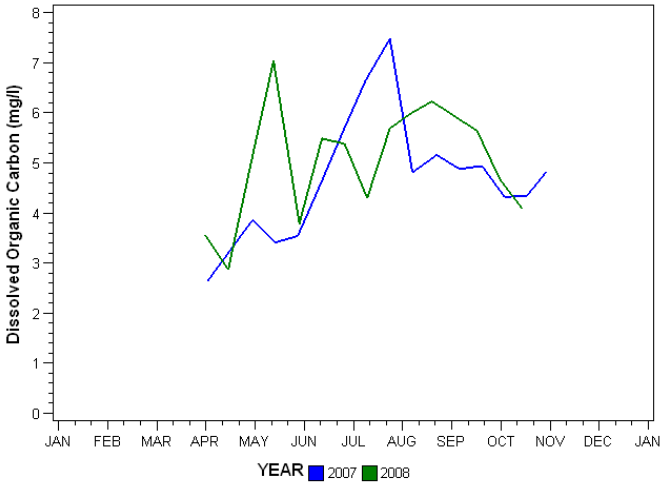

Figure A-9b. Dissolved organic carbon concentrations at Otter Point Creek.

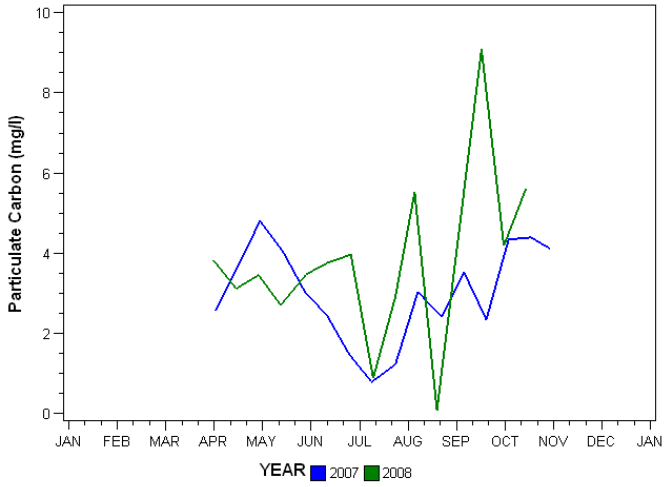

Figure A-10b. Particulate carbon concentrations at Otter Point Creek.

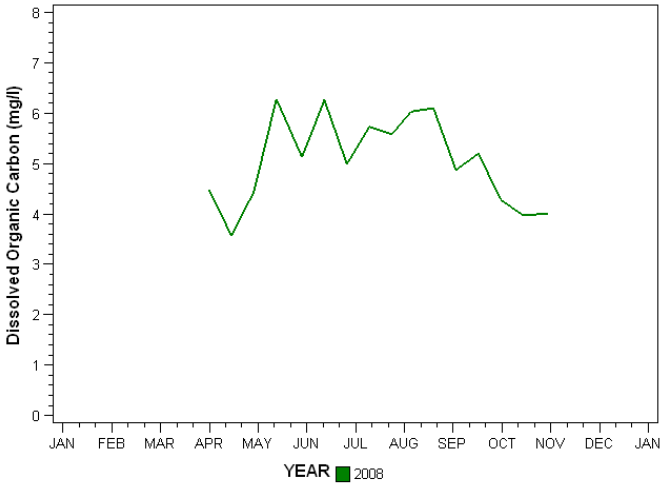

Figure A-9c. Dissolved organic carbon concentrations at Church Point.

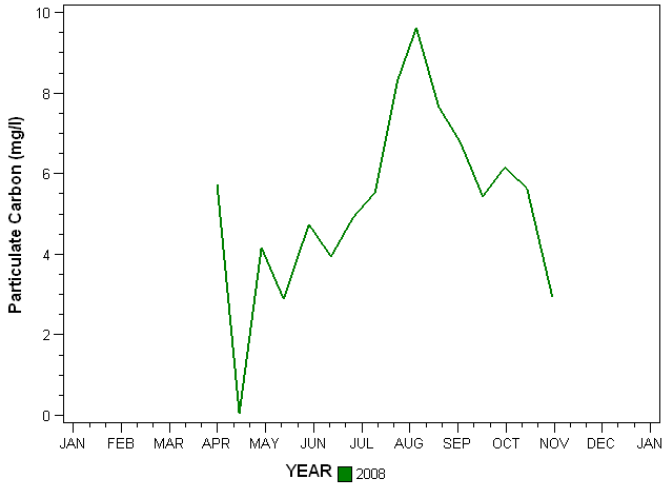

Figure A-10c. Particulate carbon concentrations at Church Point.

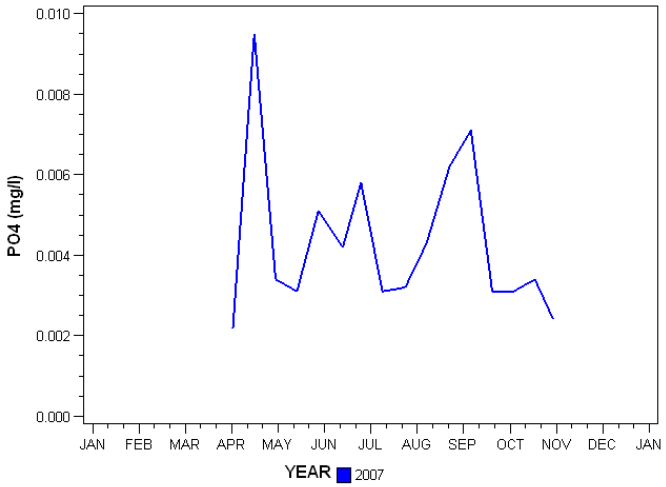

Figure A-11a. Phosphate concentrations at Lauderick Creek.

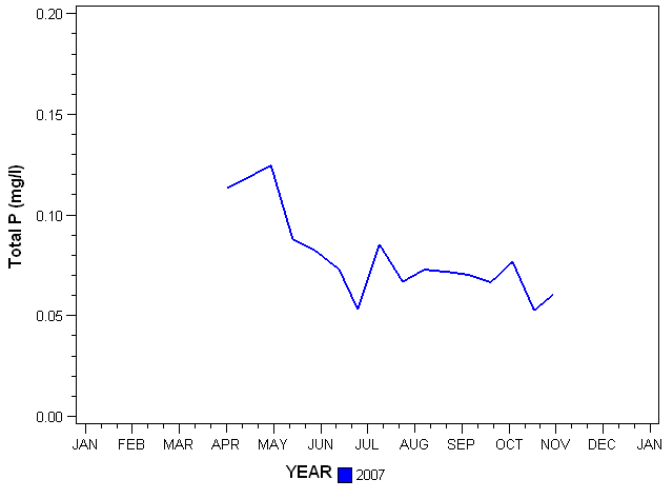

Figure A-12a. Total phosphorus concentrations at Lauderick Creek.

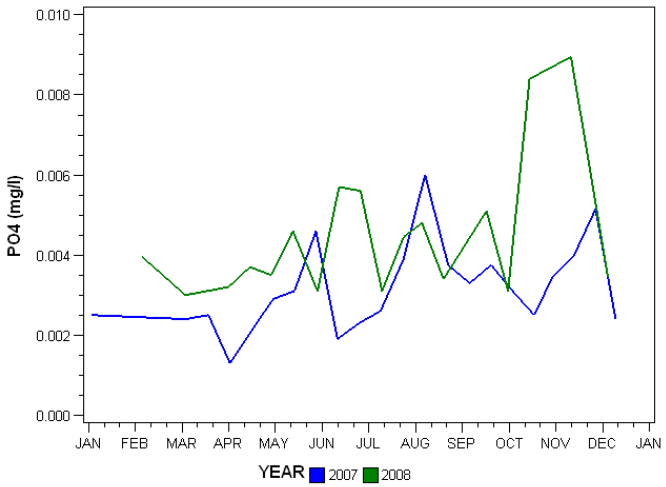

Figure A-11b. Phosphate concentrations at Otter Point Creek.

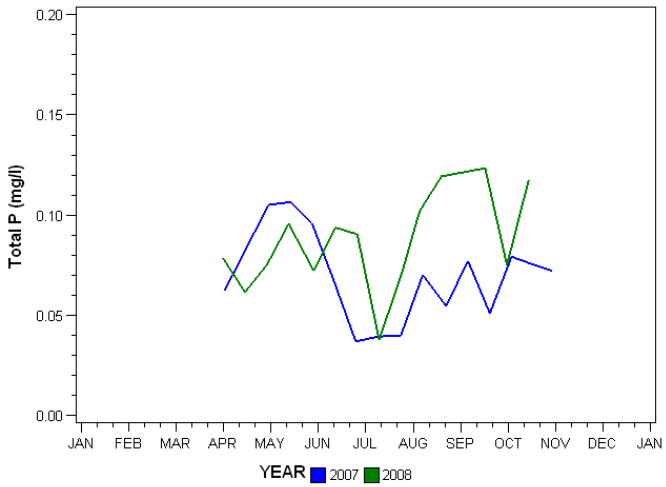

Figure A-12b. Total phosphorus concentrations at Otter Point Creek.

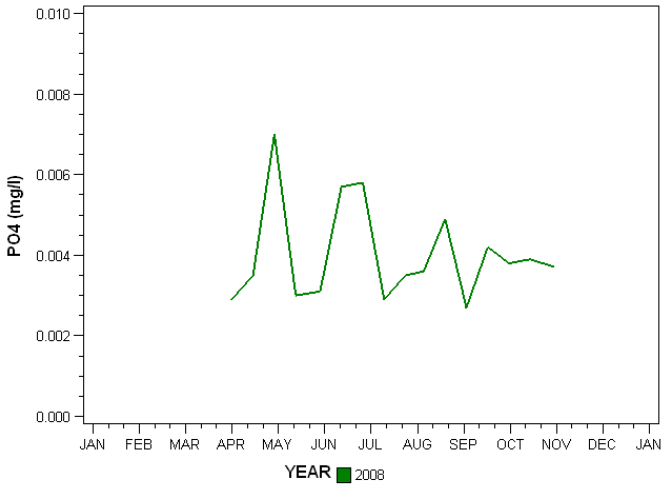

Figure A-11c. Phosphate concentrations at Church Point.

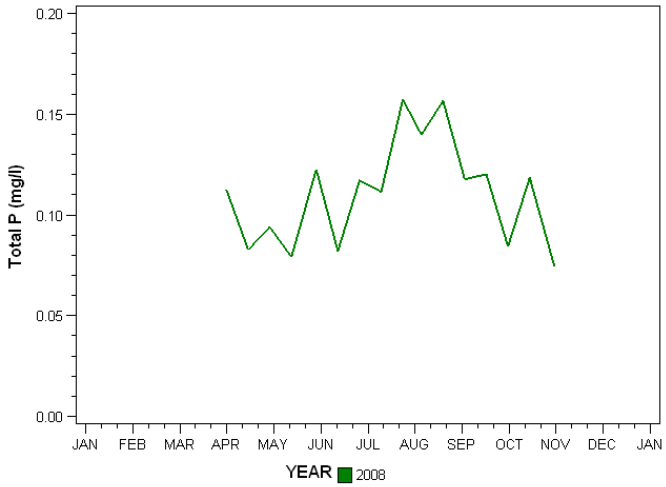

Figure A-12c. Total phosphorus concentrations at Church Point.

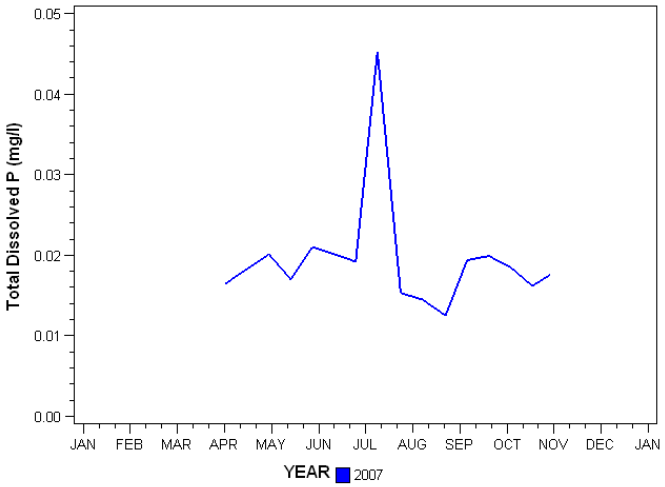

Figure A-13a. Total dissolved phosphorus concentrations at Lauderick Creek.

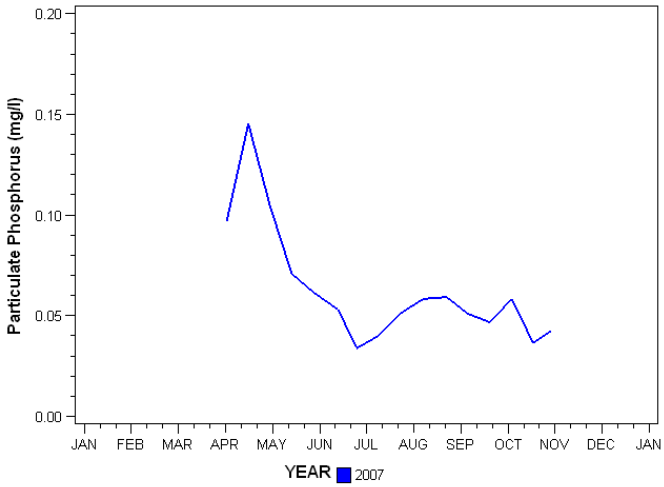

Figure A-14a. Particulate phosphorus concentrations at Lauderick Creek.

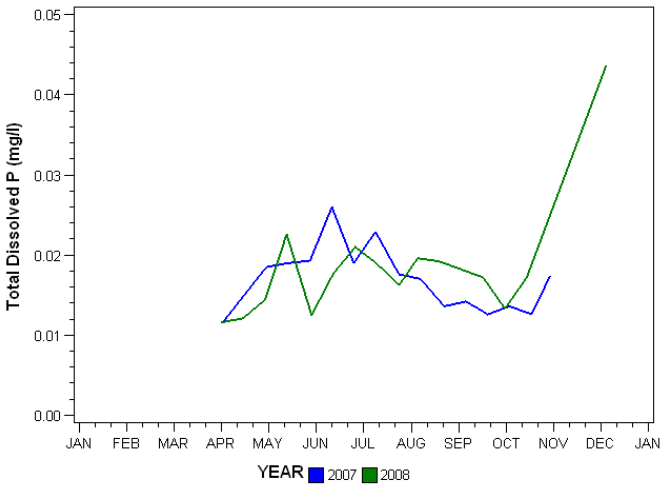

Figure A-13b. Total dissolved phosphorus concentrations at Otter Point Creek.

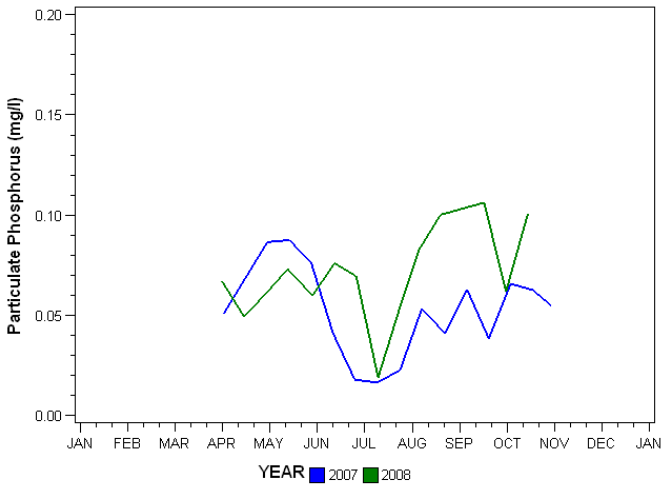

Figure A-14b. Particulate phosphorus concentrations at Otter Point Creek.

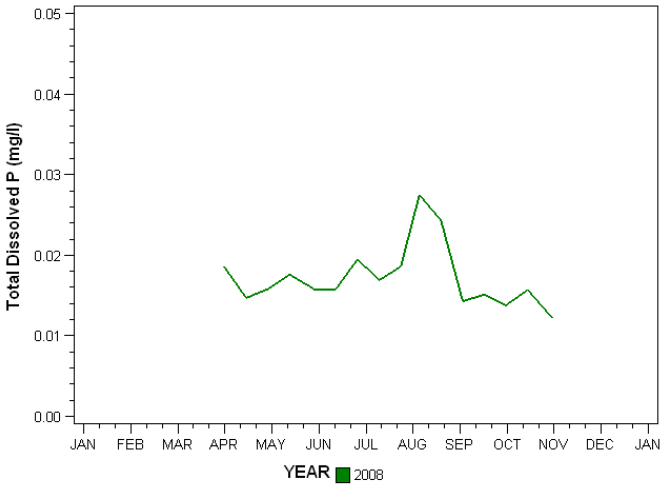

Figure A-13c. Total dissolved phosphorus concentrations at Church Point.

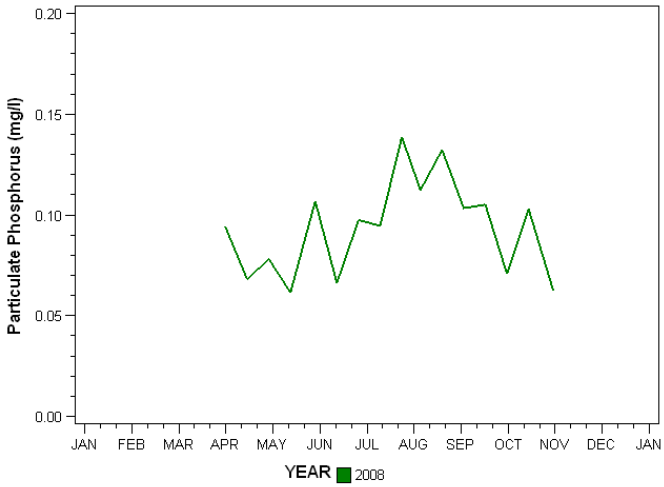

Figure A-14c. Particulate phosphorus concentrations at Church Point.

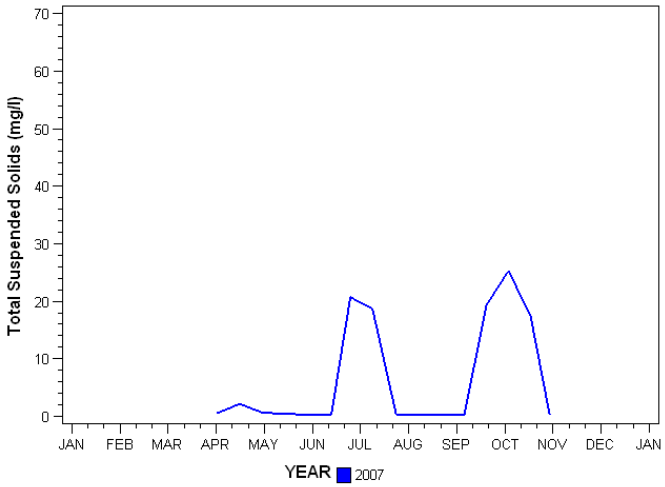

Figure A-15a. Total suspended solids concentrations at Lauderick Creek.

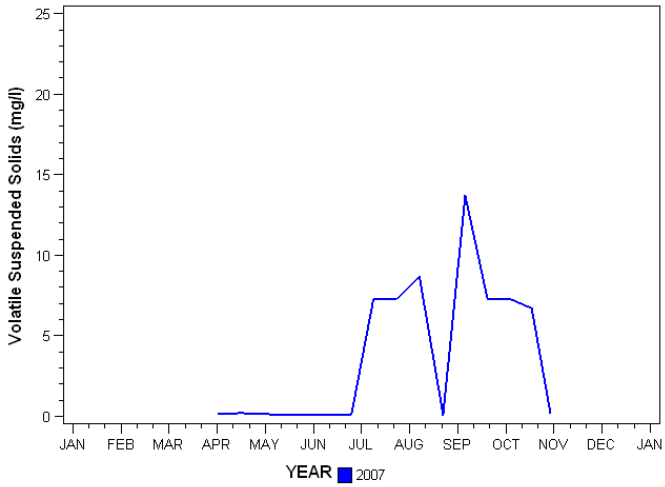

Figure A-16a. Volatile suspended solids concentrations at Lauderick Creek.

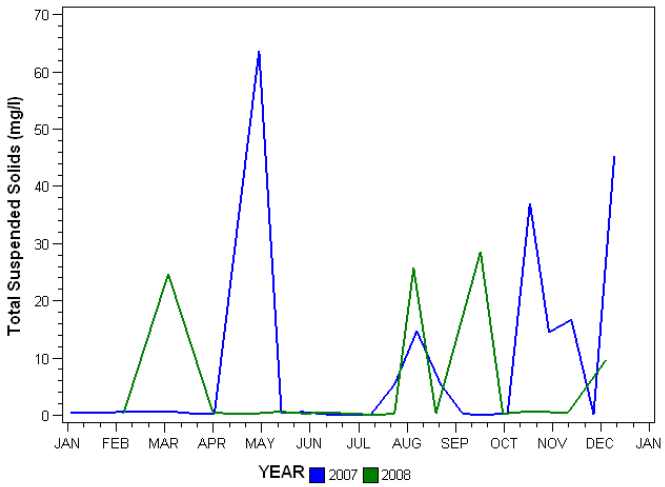

Figure A-15b. Total suspended solids concentrations at Otter Point Creek.

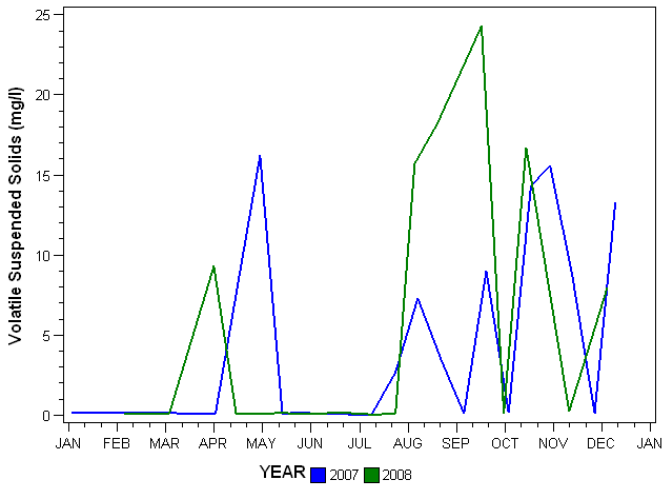

Figure A-16b. Volatile suspended solids concentrations at Otter Point Creek.

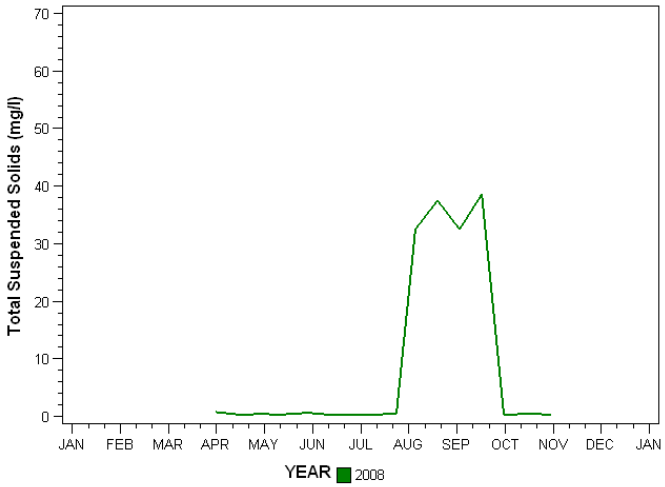

Figure A-15c. Total suspended solids concentrations at Church Point.

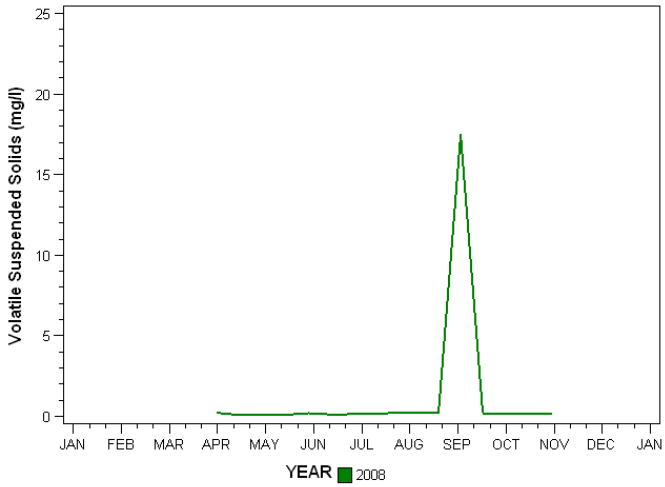

Figure A-16c. Volatile suspended solids concentrations at Church Point.

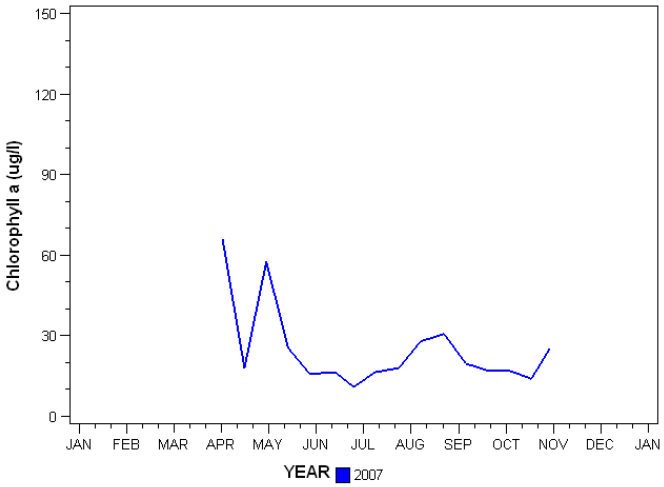

Figure A-17a. Chlorophyll *a* concentrations at Lauderick Creek.

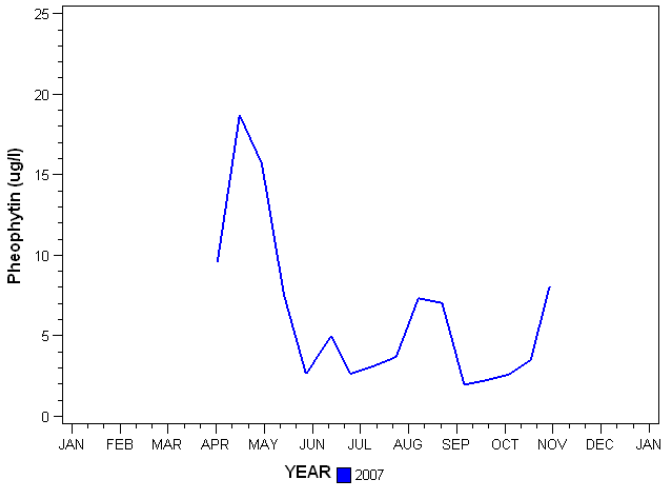

Figure A-18a. Pheophytin concentrations at Lauderick Creek.

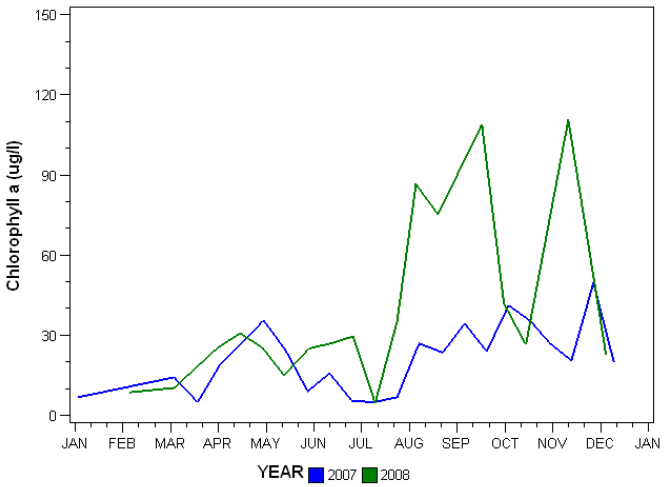

Figure A-17b. Chlorophyll *a* concentrations at Otter Point Creek.

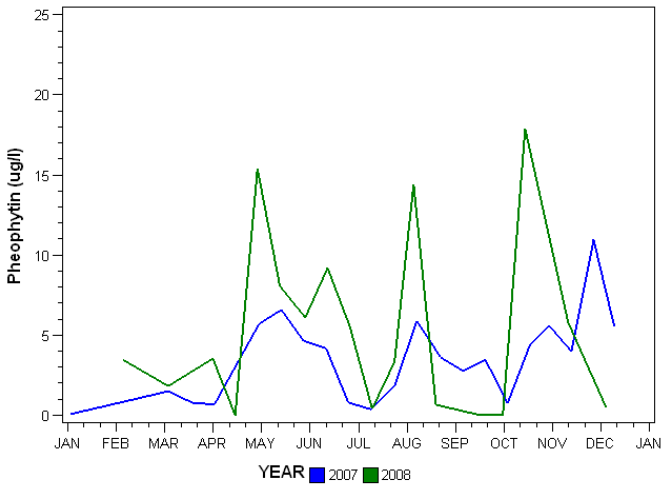

Figure A-18b. Pheophytin concentrations at Otter Point Creek.

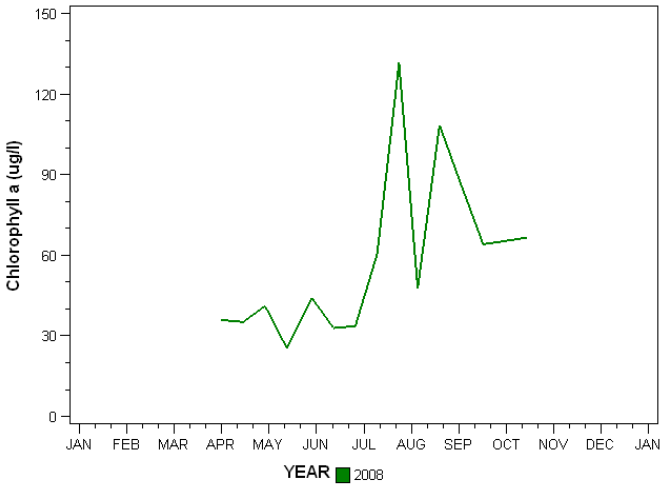

Figure A-17c. Chlorophyll *a* concentrations at Church Point.

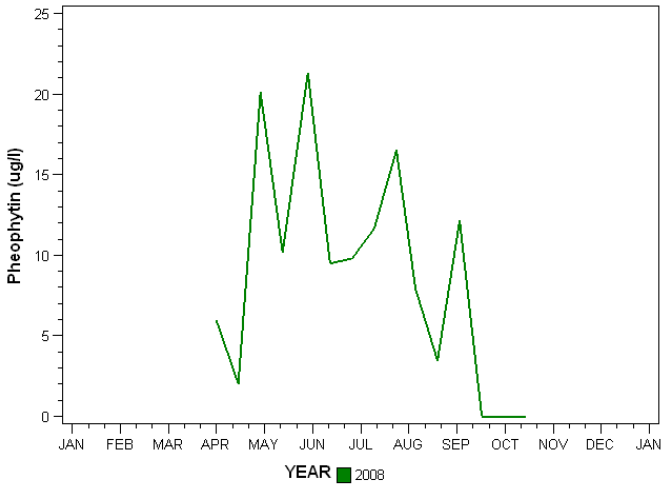

Figure A-18c. Pheophytin concentrations at Church Point.

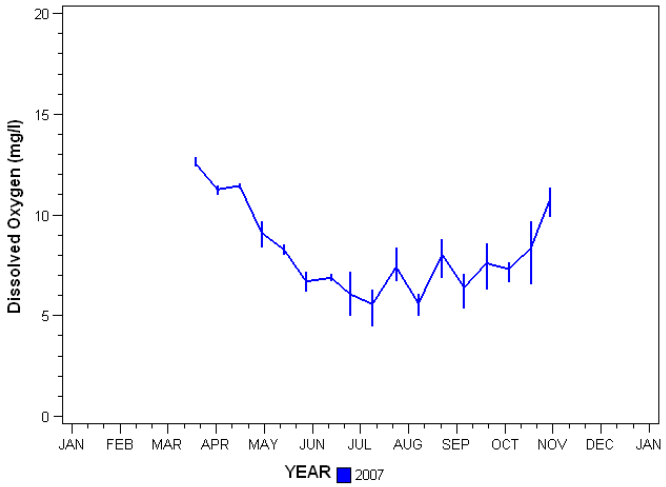

Figure A-19a. Dissolved oxygen concentrations at Lauderick Creek.

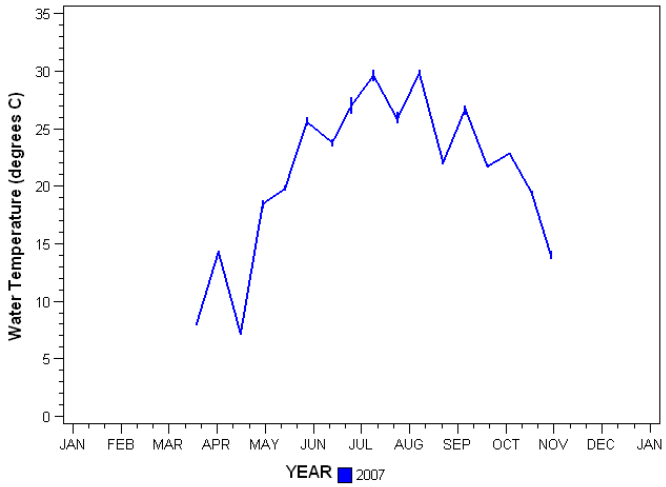

Figure A-20a. Water temperatures at Lauderick Creek.

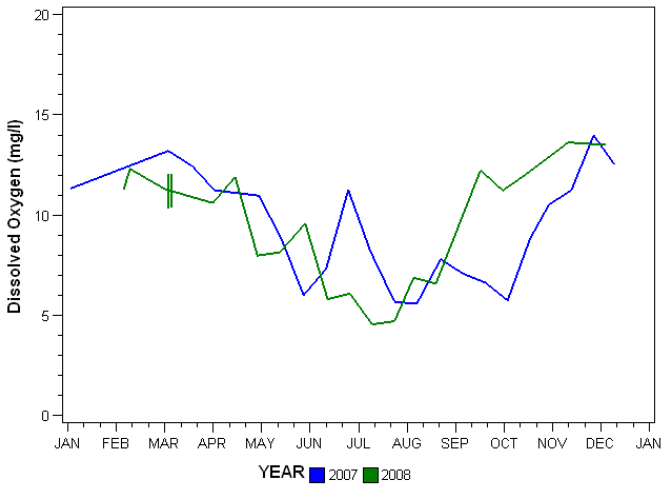

Figure A-19b. Dissolved oxygen concentrations at Otter Point Creek.

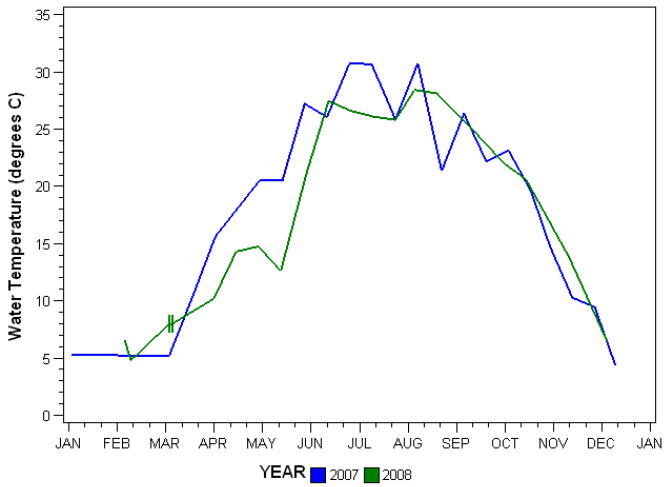

Figure A-20b. Water temperatures at Otter Point Creek.

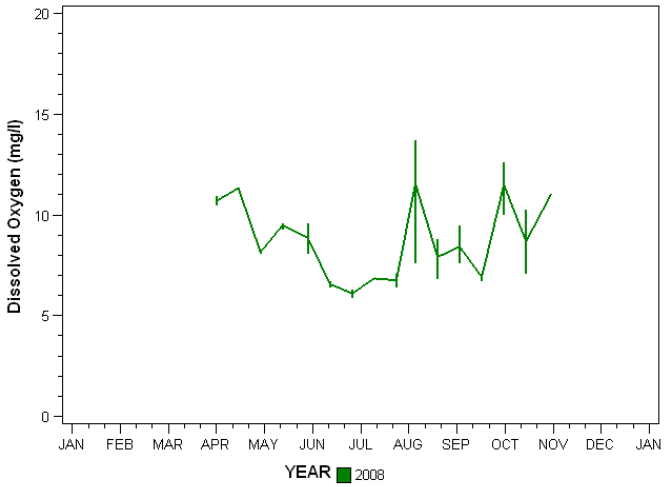

Figure A-19c. Dissolved oxygen concentrations at Church Point.

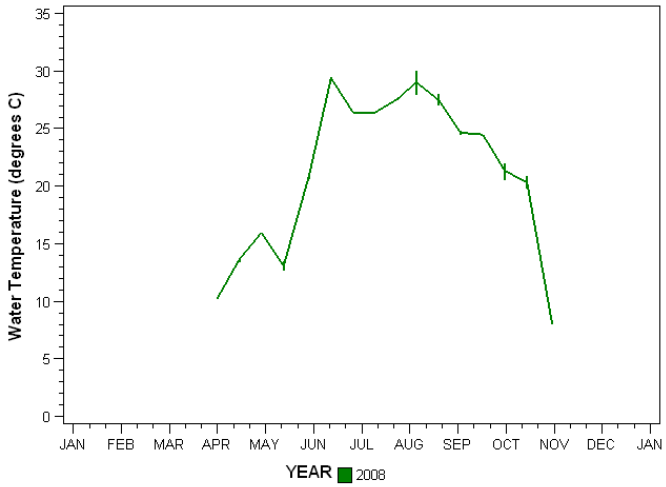

Figure A-20c. Water temperatures at Church Point.

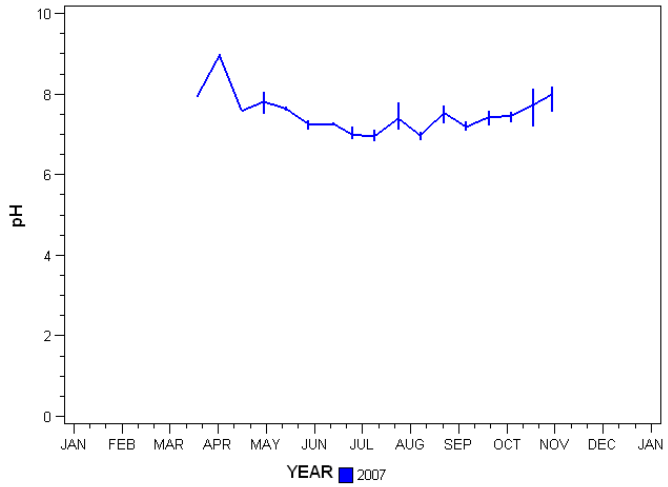

Figure A-21a. Values of pH at Lauderick Creek.

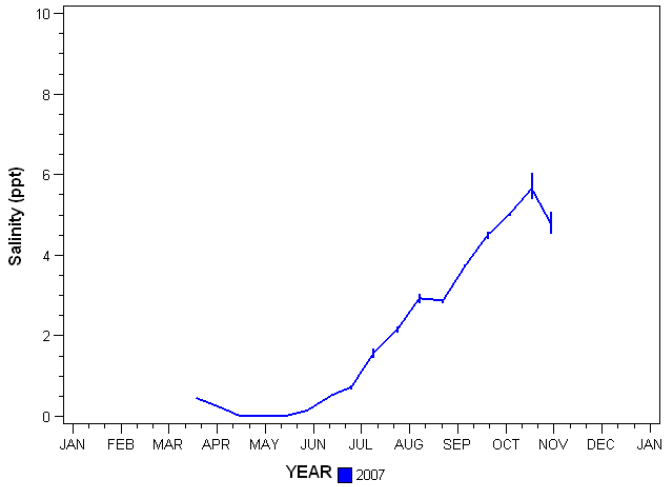

Figure A-22a. Salinity values at Lauderick Creek.

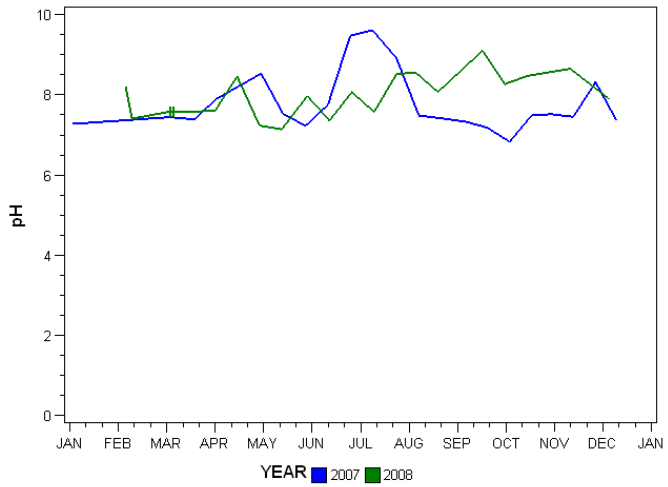

Figure A-21b. Values of pH at Otter Point Creek.

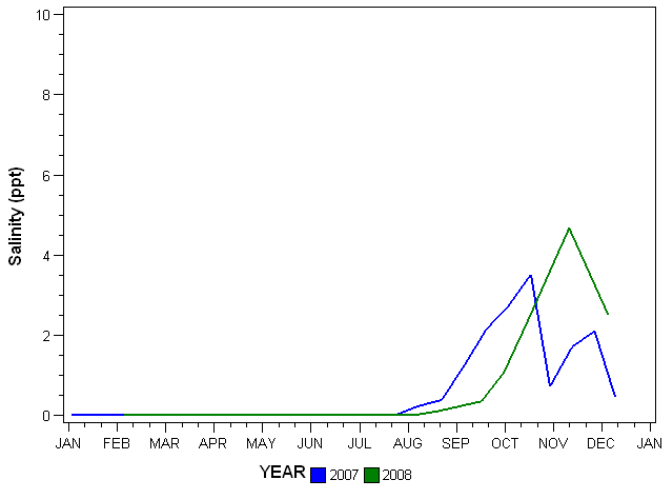

Figure A-22b. Salinity values at Otter Point Creek.

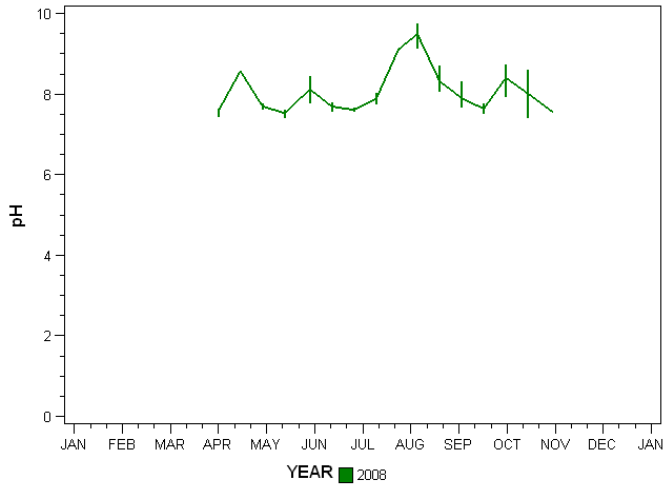

Figure A-21c. Values of pH at Church Point.

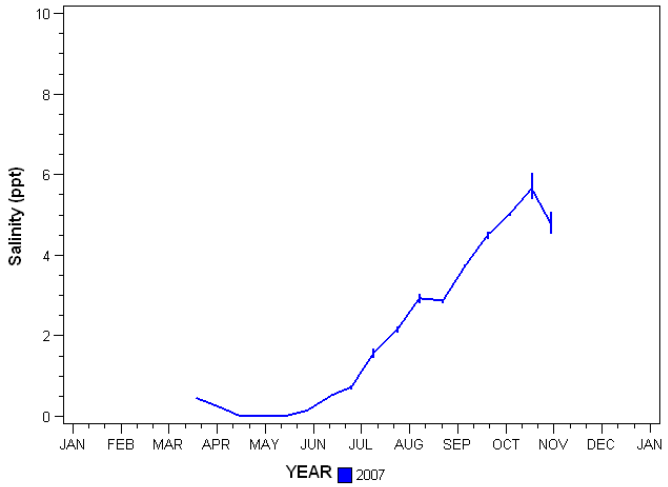

Figure A-22c. Salinity values at Church Point.

Table A1. Discrete Continuous Monitoring Data for Lauderick Creek (XJG4337) in 2007; ammonium (NH_4), nitrite (NO_2), nitrate (NO_3), nitrite + nitrate (NO23), total dissolved nitrogen (TDN), particulate nitrogen (PN), total nitrogen (TN), phosphate (PO_4), total dissolved phosphorus (TDP), particulate phosphorus (PP), total phosphorus (TP), dissolved organic carbon (DOC), and particulate carbon (PC).

Date	Depth (m)	Replicate	NH_4 (mg/L)	NO_2 (mg/L)	NO_3 (mg/L)	NO23 (mg/L)	TDN (mg/L)	PN (mg/L)	TN (mg/L)	PO_4 (mg/L)	TDP (mg/L)	PP (mg/L)	TP (mg/L)	DOC (mg/L)	PC (mg/L)
03/20/07	1	1													
04/03/07	1	1	0.005	0.0068	0.2932	0.3000	0.66	0.738	1.398	0.0022	0.0165	0.0970	0.1135	3.94	4.73
04/17/07	1	1	0.079	0.0104	0.7296	0.7400		0.692		0.0095		0.1453		5.45	0.05
05/01/07	1	1	0.021	0.0040	0.4290	0.4330	0.83	0.682	1.512	0.0034	0.0201	0.1044	0.1245	0.04	4.43
05/15/07	1	1	0.034	0.0028	0.1232	0.1260	0.49	0.431	0.921	0.0031	0.0170	0.0708	0.0878	3.61	2.80
05/29/07	1	1	0.015	0.0005	0.0050	0.0054	0.58	0.422	1.002	0.0051	0.0210	0.0616	0.0826	3.81	3.01
06/14/07	1	1	0.013	0.0011	0.0107	0.0118	0.35	0.416	0.766	0.0042	0.0200	0.0529	0.0729	3.82	2.40
06/26/07	1	1	0.011	0.0007	0.0025	0.0032	0.95	0.320	1.270	0.0058	0.0192	0.0338	0.0530	3.81	1.97
07/10/07	1	1	0.022	0.0010	0.0011	0.0021	0.83	0.372	1.202	0.0031	0.0453	0.0400	0.0853	4.79	2.21
07/25/07	1	1	0.009	0.0010	0.0016	0.0026	0.36	0.406	0.766	0.0032	0.0153	0.0515	0.0668	4.11	2.67
08/08/07	1	1	0.024	0.0017	0.0012	0.0029	0.38	0.422	0.802	0.0043	0.0145	0.0583	0.0728	3.63	2.48
08/23/07	1	1	0.011	0.0009	0.0008	0.0017	0.41	0.457	0.867	0.0062	0.0125	0.0592	0.0717	4.09	2.90
09/06/07	1	1	0.052	0.0007	0.0053	0.0060	0.49	0.392	0.882	0.0071	0.0194	0.0508	0.0702	4.21	2.45
09/20/07	1	1	0.008	0.0010	0.0008	0.0018	0.43	0.378	0.808	0.0031	0.0199	0.0467	0.0666	4.13	2.45
10/04/07	1	1	0.040	0.0011	0.0007	0.0018	0.49	0.401	0.891	0.0031	0.0185	0.0582	0.0767	4.07	2.82
10/18/07	1	1	0.011	0.0012	0.0012	0.0024	0.42	0.289	0.709	0.0034	0.0162	0.0364	0.0526	3.93	1.94
10/30/07	1	1	0.013	0.0054	0.0718	0.0772	0.53	0.380	0.910	0.0024	0.0176	0.0427	0.0603	3.82	2.78

Table A2. Discrete Continuous Monitoring Data for Otter Point Creek (XJG7035) in 2007; ammonium (NH_4), nitrite (NO_2), nitrate (NO_3), nitrite + nitrate (NO23), total dissolved nitrogen (TDN), particulate nitrogen (PN), total nitrogen (TN), phosphate (PO_4), total dissolved phosphorus (TDP), particulate phosphorus (PP), total phosphorus (TP), dissolved organic carbon (DOC), and particulate carbon (PC).

Date	Depth (m)	Replicate	NH_4 (mg/L)	NO_2 (mg/L)	NO_3 (mg/L)	NO23 (mg/L)	TDN (mg/L)	PN (mg/L)	TN (mg/L)	PO_4 (mg/L)	TDP (mg/L)	PP (mg/L)	TP (mg/L)	DOC (mg/L)	PC (mg/L)
01/03/07	0.5	1	0.053	0.0061	1.2989	1.3050	1.92			0.0025	0.0936				
03/05/07	0.2	1	0.095	0.0074	1.3736	1.3810				0.0024					
03/20/07	0.2	1	0.032	0.0055	1.5845	1.5900	2.23			0.0020	0.0584				
03/20/07	0.2	2	0.037	0.0053	1.5417	1.5470				0.0030					
04/03/07	0.4	1	0.004	0.0142	1.6658	1.6800	2.08	0.403	2.483	0.0013	0.0116	0.0508	0.0624	2.63	2.55
05/01/07	0.3	1	0.015	0.0093	0.7757	0.7850	1.14	0.688	1.828	0.0029	0.0185	0.0865	0.1050	3.86	4.80
05/15/07	0.6	1	0.119	0.0377	1.3013	1.3390	1.91	0.573	2.483	0.0036	0.0190	0.0875	0.1065	3.41	4.06
05/15/07	0.6	2	0.107	0.0358	1.1952	1.2310				0.0026					
05/29/07	0.1	1	0.136	0.0357	0.9633	0.9990	1.40	0.417	1.817	0.0046	0.0193	0.0764	0.0957	3.54	3.04
06/12/07	0.4	1	0.040	0.0103	0.1827	0.1930	0.69	0.398	1.088	0.0019	0.0260	0.0411	0.0671	4.57	2.44
06/26/07	0.3	1	0.009	0.0005	0.0019	0.0024	0.62	0.232	0.852	0.0021	0.0190	0.0178	0.0368	5.63	1.47
06/26/07	0.3	2	0.011	0.0005	0.0037	0.0041				0.0025					
07/10/07	0.4	1	0.031	0.0023	0.0079	0.0102	0.78	0.128	0.908	0.0026	0.0229	0.0163	0.0392	6.65	0.78
07/25/07	0.5	1	0.019	0.0012	0.0090	0.0102	0.59	0.194	0.784	0.0040	0.0176	0.0223	0.0399	7.48	1.22
07/25/07	0.5	2	0.016	0.0013	0.0055	0.0068				0.0038					
08/08/07	0.3	1	0.047	0.0008	0.0051	0.0059	0.56	0.537	1.097	0.0060	0.0170	0.0531	0.0701	4.81	3.03
08/23/07	0.4	1	0.011	0.0027	0.0230	0.0257	0.58	0.420	1.000	0.0054	0.0136	0.0409	0.0545	5.16	2.41
08/23/07	0.4	2	0.008	0.0024	0.0217	0.0241				0.0021					
09/06/07	0.5	1	0.009	0.0004	0.0076	0.0080	0.73	0.586	1.316	0.0033	0.0142	0.0629	0.0771	4.88	3.52
09/20/07	0.5	1	0.018	0.0016	0.0002	0.0018	0.47	0.419	0.889	0.0052	0.0126	0.0383	0.0509	4.94	2.34
09/20/07	0.5	2	0.011	0.0012	0.0008	0.0020				0.0023					
10/04/07	0.4	1	0.013	0.0008	0.0012	0.0020	0.44	0.699	1.139	0.0031	0.0136	0.0656	0.0792	4.32	4.34
10/18/07	0.3	1	0.017	0.0008	0.0012	0.0020	0.46	0.620	1.080	0.0025	0.0126	0.0626	0.0752	4.35	4.39
10/30/07	0.2	1	0.093	0.0090	0.5480	0.5570	1.10	0.459	1.559	0.0035	0.0174	0.0548	0.0722	4.83	4.11
10/30/07	0.2	2	0.078	0.0070	0.6088	0.6158				0.0034					
11/13/07	0.3	1	0.070	0.0084	0.6026	0.6110	1.37			0.0040	0.0586				
11/27/07	0.1	1	0.008	0.0052	0.3788	0.3840	1.40			0.0046	0.0647				
11/27/07	0.1	2	0.006	0.0069	0.3921	0.3990				0.0057					
12/10/07	0.3	1	0.095	0.0077	0.6512	0.6589	1.89			0.0022	0.1069				
12/10/07	0.3	2	0.078	0.0087	1.2353	1.2440				0.0026					

Table A3. Discrete Continuous Monitoring Data for Otter Point Creek (XJG7035) in 2008; ammonium (NH_4), nitrite (NO_2), nitrate (NO_3), nitrite + nitrate (NO23), total dissolved nitrogen (TDN), particulate nitrogen (PN), total nitrogen (TN), phosphate (PO_4), total dissolved phosphorus (TDP), particulate phosphorus (PP), total phosphorus (TP), dissolved organic carbon (DOC), and particulate carbon (PC).

Date	Depth (m)	Replicate	NH_4 (mg/L)	NO_2 (mg/L)	NO_3 (mg/L)	NO23 (mg/L)	TDN (mg/L)	PN (mg/L)	TN (mg/L)	PO_4 (mg/L)	TDP (mg/L)	PP (mg/L)	TP (mg/L)	DOC (mg/L)	PC (mg/L)
02/05/08	0.4	1	0.081	0.0073	1.1627	1.1700	1.81			0.0039	0.0914				
02/05/08	0.4	2	0.084	0.0077	1.1523	1.1600				0.0040					
02/09/08	0.3	1													
03/04/08	0.3	1	0.012	0.0098	1.6002	1.6100	2.18			0.0024	0.0507				
03/04/08	0.3	2	0.020	0.0097	1.4403	1.4500				0.0036					
03/04/08	0.4	1													
03/06/08	0.3	1													
03/06/08	0.3	2													
03/06/08	0.4	1													
04/01/08	0.7	1	0.015	0.0111	1.3889	1.4000	1.69	0.536	2.226	0.0032	0.0116	0.0667	0.0783	3.55	3.81
04/15/08	0.1	1	0.018	0.0142	0.9618	0.9760	1.21	0.476	1.686	0.0037	0.0121	0.0493	0.0614	2.87	3.11
04/29/08	0.4	1	0.044	0.0129	0.5721	0.5850	0.90	0.515	1.415	0.0033	0.0144	0.0607	0.0751	4.99	3.45
04/29/08	0.4	2	0.041	0.0129	0.5741	0.5870				0.0037					
05/13/08	0.5	1	0.174	0.0115	0.7085	0.7200	1.24	0.373	1.613	0.0046	0.0226	0.0730	0.0956	7.04	2.70
05/29/08	0.5	1	0.012	0.0212	0.8968	0.9180	1.16	0.512	1.672	0.0029	0.0125	0.0597	0.0722	3.79	3.47
05/29/08	0.5	2	0.011	0.0206	0.9024	0.9230				0.0033					
06/12/08	0.5	1	0.062	0.0141	0.2409	0.2550	0.88	0.614	1.494	0.0057	0.0177	0.0760	0.0937	5.49	3.77
06/26/08	0.3	1	0.005	0.0005	0.0017	0.0021	0.63	0.654	1.284	0.0050	0.0210	0.0694	0.0904	5.38	3.96
06/26/08	0.3	2	0.005	0.0003	0.0007	0.0010				0.0062					
07/10/08	0.3	1	0.090	0.0416	0.6834	0.7250	1.16	0.127	1.287	0.0031	0.0189	0.0188	0.0377	4.30	0.88
07/24/08	0.5	1	0.031	0.0045	0.0510	0.0555	0.61	0.556	1.166	0.0058	0.0156	0.0539	0.0695	5.69	2.92
07/24/08	0.5	2	0.031	0.0037	0.0491	0.0528	0.66			0.0031	0.0168				
08/05/08	0.5	1	0.016	0.0024	0.0179	0.0203	0.51	0.858	1.368	0.0048	0.0196	0.0823	0.1019	5.97	5.52
08/19/08	0.5	1	0.013	0.0006	0.0028	0.0034	0.52	1.100	1.620	0.0027	0.0192	0.1001	0.1193	6.23	0.07
08/19/08	0.5	2	0.019	0.0006	0.0033	0.0039				0.0041					
09/16/08	0.1	1	0.017	0.0015	0.0001	0.0016	0.46	1.280	1.740	0.0051	0.0172	0.1062	0.1234	5.64	9.09
09/30/08	0.5	1	0.015	0.0098	0.3542	0.3640	0.81	0.594	1.404	0.0038	0.0133	0.0617	0.0750	4.68	4.18
09/30/08	0.5	2	0.009	0.0092	0.3778	0.3870				0.0024					
10/14/08	0.3	1	0.009	0.0040	0.0817	0.0857	0.45	0.896	1.346	0.0084	0.0172	0.1005	0.1177	4.08	5.62
11/10/08	0.3	1	0.012	0.0036	0.1154	0.1190	1.66			0.0076	0.1224				
11/10/08	0.3	2	0.012	0.0029	0.1225	0.1254				0.0103					
12/04/08	0.7	1	0.006	0.0085	0.7265	0.7350	1.47			0.0035	0.0410				
12/04/08	0.7	2	0.004	0.0079	0.7531	0.7610	1.51			0.0034	0.0464				

Table A4. Discrete Continuous Monitoring Data for Church Point (XJG7461) in 2008; ammonium (NH_4), nitrite (NO_2), nitrate (NO_3), nitrite + nitrate (NO23), total dissolved nitrogen (TDN), particulate nitrogen (PN), total nitrogen (TN), phosphate (PO_4), total dissolved phosphorus (TDP), particulate phosphorus (PP), total phosphorus (TP), dissolved organic carbon (DOC), and particulate carbon (PC).

Date	Depth (m)	Replicate	NH_4 (mg/L)	NO_2 (mg/L)	NO_3 (mg/L)	NO23 (mg/L)	TDN (mg/L)	PN (mg/L)	TN (mg/L)	PO_4 (mg/L)	TDP (mg/L)	PP (mg/L)	TP (mg/L)	DOC (mg/L)	PC (mg/L)
04/01/08	1.0	1	0.019	0.0095	0.6645	0.6740	0.98	0.770	1.750	0.0029	0.0185	0.0938	0.1123	4.47	5.72
04/15/08	0.8	1	0.015	0.0112	0.4628	0.4740	0.70	0.611	1.311	0.0035	0.0147	0.0680	0.0827	3.57	0.04
04/29/08	1.0	1	0.037	0.0018	0.1412	0.1430	0.39	0.605	0.995	0.0070	0.0158	0.0781	0.0939	4.44	4.16
05/13/08	1.0	1	0.034	0.0050	0.2100	0.2150	0.70	0.445	1.145	0.0030	0.0176	0.0615	0.0791	6.28	2.89
05/29/08	1.0	1	0.017	0.0051	0.1059	0.1110	0.50	0.782	1.282	0.0031	0.0158	0.1068	0.1226	5.13	4.74
06/12/08	1.0	1	0.012	0.0019	0.0041	0.0060	0.69	0.640	1.330	0.0057	0.0158	0.0662	0.0820	6.26	3.94
06/26/08	1.0	1	0.004	0.0004	0.0017	0.0021	0.45	0.800	1.250	0.0058	0.0195	0.0975	0.1170	4.99	4.91
07/10/08	0.9	1	0.014	0.0006	0.0035	0.0040	0.62	0.908	1.528	0.0029	0.0169	0.0946	0.1115	5.73	5.54
07/24/08	1.0	1	0.032	0.0018	0.0345	0.0363	0.81	1.600	2.410	0.0035	0.0186	0.1387	0.1573	5.58	8.30
08/05/08	1.0	1	0.013	0.0005	0.0019	0.0024	0.77	1.410	2.180	0.0036	0.0275	0.1123	0.1398	6.03	9.62
08/19/08	1.0	1	0.014	0.0006	0.0015	0.0021	0.68	1.330	2.010	0.0049	0.0243	0.1323	0.1566	6.10	7.67
09/02/08	1.0	1	0.012	0.0005	0.0010	0.0015	0.45	1.140	1.590	0.0027	0.0143	0.1034	0.1177	4.87	6.76
09/16/08	1.0	1	0.023	0.0040	0.0031	0.0071	0.35	0.930	1.280	0.0042	0.0151	0.1051	0.1202	5.20	5.43
09/30/08	1.0	1	0.009	0.0050	0.0268	0.0318	0.45	1.020	1.470	0.0038	0.0138	0.0706	0.0844	4.28	6.16
10/14/08	1.0	1	0.005	0.0006	0.0009	0.0014	0.37	0.864	1.234	0.0039	0.0157	0.1028	0.1185	3.97	5.63
10/30/08	0.5	1	0.221	0.0072	0.2638	0.2710	0.91	0.461	1.371	0.0037	0.0122	0.0622	0.0744	4.01	2.94

Table A5. Discrete Continuous Monitoring Data for Chlorophyll-a, Pheophytin, Total Suspended Solids, Volatile Suspended Solids, and Secchi Disk Depth for Lauderick Creek (XJG4337) in 2007.

Date	Sample Depth (m)	Replicate	Chlorophyll-a (ug/L)	Pheophytin (ug/L)	Total Suspended Solids (mg/L)	Volatile Suspended Solids (mg/L)	Secchi Depth (m)
03/20/07	1	1					
04/03/07	1	1	65.789	9.569	0.56	0.13	0.2
04/17/07	1	1	17.942	18.690	2.16	0.20	0.1
05/01/07	1	1	57.565	15.700	0.67	0.14	0.2
05/15/07	1	1	25.418	7.551	0.39	0.09	0.2
05/29/07	1	1	15.700	2.617	0.32	0.08	
06/14/07	1	1	16.447	5.009	0.28	0.11	0.2
06/26/07	1	1	10.965	2.642	20.70	0.08	0.5
07/10/07	1	1	16.447	3.090	18.70	7.30	0.4
07/25/07	1	1	17.942	3.688	0.26	7.30	0.5
08/08/07	1	1	27.910	7.326	0.30	8.70	0.3
08/23/07	1	1	30.652	7.027	0.24	0.08	0.2
09/06/07	1	1	19.625	1.962	0.20	13.70	0.2
09/20/07	1	1	16.946	2.243	19.30	7.30	0.3
10/04/07	1	1	16.946	2.592	25.30	7.30	0.4
10/18/07	1	1	13.955	3.489	17.30	6.70	0.4
10/30/07	1	1	25.418	8.074	0.26	0.11	0.4

Table A6. Discrete Continuous Monitoring Data for Chlorophyll-a, Pheophytin, Total Suspended Solids, Volatile Suspended Solids, and Secchi Disk Depth for Otter Point Creek (XJG7035) in 2007.

Date	Sample Depth (m)	Replicate	Chlorophyll-a (ug/L)	Pheophytin (ug/L)	Total Suspended Solids (mg/L)	Volatile Suspended Solids (mg/L)	Secchi Depth (m)
01/03/07	0.5	1	6.728	0.075	0.41	0.14	0.2
03/05/07	0.2	1	14.204	1.495	0.69	0.14	0.1
03/20/07	0.2	1	4.486	0.000	0.30	0.10	
03/20/07	0.2	2	5.233	1.570			
04/03/07	0.4	1	18.690	0.673	0.27	0.09	0.2
05/01/07	0.3	1	35.511	5.700	63.70	16.20	0.1
05/15/07	0.6	1	24.671	7.775	0.62	0.11	0.2
05/15/07	0.6	2	23.923	5.383	0.36	0.13	
05/29/07	0.1	1	8.971	4.635	0.55	0.14	
06/12/07	0.4	1	15.700	4.187	0.17	0.09	0.4
06/26/07	0.3	1	5.482	0.797	0.06	0.06	0.5
06/26/07	0.3	2	5.482	0.797	0.06	0.06	
07/10/07	0.4	1	4.859	0.374	0.05	0.04	0.7
07/25/07	0.5	1	7.974	2.143	10.70	5.30	0.8
07/25/07	0.5	2	5.482	1.495	0.04	0.04	
08/08/07	0.3	1	26.914	5.881	14.70	7.30	0.4
08/23/07	0.4	1	22.926	3.588	10.70	6.70	0.4
08/23/07	0.4	2	23.923	3.638	0.10	0.06	
09/06/07	0.5	1	34.390	2.766	0.20	0.10	0.3
09/20/07	0.5	1	24.422	3.489	0.12	9.30	0.5
09/20/07	0.5	2	23.425	3.439	0.10	8.70	
10/04/07	0.4	1	41.118	0.748	0.26	0.16	0.3
10/18/07	0.3	1	35.244	4.379	37.10	14.30	0.2
10/30/07	0.2	1	28.035	5.327	28.70	18.70	0.2
10/30/07	0.2	2	26.166	5.887	0.25	12.50	
11/13/07	0.3	1	20.434	3.987	16.70	8.70	0.4
11/27/07	0.1	1	48.345	10.267	0.18	0.12	0.4
11/27/07	0.1	2	50.837	11.613			
12/10/07	0.3	1	31.399	9.420	45.30	13.30	0.5
12/10/07	0.3	2	8.473	1.645			

Table A7. Discrete Continuous Monitoring Data for Chlorophyll-a, Pheophytin, Total Suspended Solids, Volatile Suspended Solids, and Secchi Disk Depth for Otter Point Creek (XJG7035) in 2008.

Date	Sample Depth (m)	Replicate	Chlorophyll-a (ug/L)	Pheophytin (ug/L)	Total Suspended Solids (mg/L)	Volatile Suspended Solids (mg/L)	Secchi Depth (m)
02/05/08	0.4	1	8.971	2.542	0.39	0.12	0.2
02/05/08	0.4	2	8.224	4.336			
02/09/08	0.3	1					0.2
03/04/08	0.3	1	9.470	3.090	24.70	0.10	0.3
03/04/08	0.3	2	10.965	0.548			
03/04/08	0.4	1					0.3
03/06/08	0.3	1					0.3
03/06/08	0.3	2					
03/06/08	0.4	1					0.3
04/01/08	0.7	1	25.418	3.539	0.48	9.30	0.3
04/15/08	0.1	1	30.652	0.000	0.20	0.07	0.3
04/29/08	0.4	1	25.418	14.877	0.25	0.08	0.3
04/29/08	0.4	2	25.418	15.924	0.40	0.10	
05/13/08	0.5	1	14.952	8.074	0.62	0.14	0.3
05/29/08	0.5	1	25.418	6.504	0.35	0.09	0.4
05/29/08	0.5	2	24.671	5.682	0.26	0.10	
06/12/08	0.5	1	26.914	9.195	0.49	0.13	0.2
06/26/08	0.3	1	30.652	5.981	0.27	0.13	0.3
06/26/08	0.3	2	28.409	5.084	0.27	0.13	
07/10/08	0.3	1	4.486	0.399	0.10	0.04	0.5
07/24/08	0.5	1	35.885	3.364	0.24	0.10	0.4
07/24/08	0.5	2	34.390	3.289	0.19	0.09	
08/05/08	0.5	1	86.508	14.418	25.70	15.70	0.2
08/19/08	0.5	1	72.891	1.028	0.30	18.80	0.3
08/19/08	0.5	2	77.564	0.280	0.30	17.50	
09/16/08	0.1	1	108.936	0.000	28.60	24.30	0.2
09/30/08	0.5	1	41.866	0.000	0.30	0.13	0.3
09/30/08	0.5	2			0.19	0.13	
10/14/08	0.3	1	26.415	17.893	0.62	16.70	0.3
11/10/08	0.3	1	115.878	6.579	0.48	0.24	0.4
11/10/08	0.3	2	105.412	5.009			
12/04/08	0.7	1	21.431	0.897	0.18	8.70	0.5
12/04/08	0.7	2	23.923	0.000	19.30	7.30	

Table A8. Discrete Continuous Monitoring Data for Chlorophyll-a, Pheophytin, Total Suspended Solids, Volatile Suspended Solids, and Secchi Disk Depth for Church Point (XJG7461) in 2008.

Date	Sample Depth (m)	Replicate	Chlorophyll-a (ug/L)	Pheophytin (ug/L)	Total Suspended Solids (mg/L)	Volatile Suspended Solids (mg/L)	Secchi Depth (m)
04/01/08	1.0	1	35.885	5.981	0.74	0.22	0.4
04/15/08	0.8	1	35.137	2.019	0.32	0.09	0.4
04/29/08	1.0	1	41.118	20.110	0.40	0.09	0.4
05/13/08	1.0	1	25.418	10.167	0.34	0.09	0.3
05/29/08	1.0	1	44.108	21.307	0.63	0.20	0.4
06/12/08	1.0	1	32.894	9.495	0.28	0.12	0.3
06/26/08	1.0	1	33.642	9.794	0.33	0.14	0.3
07/10/08	0.9	1	60.556	11.663	0.34	0.17	0.3
07/24/08	1.0	1	131.578	16.522	0.43	0.22	0.4
08/05/08	1.0	1	47.659	7.943	32.50	0.25	0.2
08/19/08	1.0	1	108.402	3.458	37.50	0.20	0.2
09/02/08	1.0	1	85.974	12.149	32.50	17.50	0.2
09/16/08	1.0	1	64.080	0.000	38.60	0.20	0.2
09/30/08	1.0	1			0.23	0.16	0.4
10/14/08	1.0	1	66.536	0.000	0.46	0.16	0.3
10/30/08	0.5	1			0.32	0.14	0.3

Table A9. Ambient Water Quality Data for Dissolved Oxygen (D.O.), pH, Salinity, and Water Temperature for Lauderick Creek (XJG4337) in 2007 (continued on next page).

Date	Sample Depth (m)	D.O. (mg/L)	pH	Salinity (ppt)	Water Temperature (^{o}C)
03/20/07	0.5	12.4	7.95	0.45	8.0
03/20/07	1.0	13.4	7.98	0.45	8.0
03/20/07	1.5	12.4	7.94	0.46	7.9
04/03/07	0.5	11.4	8.99	0.24	14.4
04/03/07	1.0	11.5	8.96	0.25	14.4
04/03/07	1.5	11.2	8.95	0.24	14.2
04/03/07	1.9	11.0	8.90	0.24	14.2
04/17/07	0.5	11.6	7.58	0.00	7.1
04/17/07	1.0	10.5	7.58	0.00	7.3
05/01/07	0.5	9.7	8.06	0.00	18.8
05/01/07	1.0	9.2	8.04	0.00	18.4
05/01/07	1.7	8.4	7.51	0.00	18.1
05/15/07	0.5	8.4	7.70	0.00	20.1
05/15/07	1.0	8.6	7.76	0.00	19.8
05/15/07	1.5	8.2	7.60	0.00	19.6
05/15/07	2.0	8.0	7.60	0.00	19.6
05/29/07	0.5	7.2	7.35	0.14	26.0
05/29/07	1.0	6.9	7.60	0.18	25.3
05/29/07	1.3	6.2	7.12	0.14	25.3
06/14/07	0.5	7.1	7.31	0.50	24.1
06/14/07	1.0	6.5	7.16	0.48	24.0
06/14/07	1.5	6.9	7.29	0.52	23.9
06/14/07	2.0	6.9	7.24	0.56	23.5
06/14/07	2.4	6.8	7.25	0.56	23.5
06/26/07	0.5	7.2	7.20	0.66	27.8
06/26/07	1.0	5.8	7.00	0.73	26.9
06/26/07	1.5	5.0	6.88	0.78	26.3
07/10/07	0.5	6.3	7.12	1.46	30.1
07/10/07	1.0	6.0	7.14	1.49	29.7
07/10/07	1.6	4.5	6.84	1.70	29.1
07/25/07	0.5	8.4	7.80	2.07	26.5
07/25/07	1.0	7.2	7.35	2.14	25.5
07/25/07	1.7	6.7	7.12	2.23	25.5
08/08/07	0.5	6.1	7.07	2.82	30.1
08/08/07	1.0	6.1	7.37	2.94	29.8
08/08/07	1.6	5.0	6.87	3.05	29.6
08/23/07	0.5	8.8	7.72	2.91	22.3
08/23/07	1.0	9.1	7.67	2.93	21.8
08/23/07	1.5	8.4	7.29	2.90	21.9
09/06/07	0.5	7.1	7.34	3.71	27.1
09/06/07	1.0	6.9	7.20	3.77	27.2
09/06/07	1.7	5.4	7.10	3.73	26.2
09/20/07	0.5	8.6	7.59	4.41	21.7
09/20/07	1.0	8.3	7.69	4.49	21.6
09/20/07	1.5	6.3	7.23	4.60	21.8

Table A9 (continued). Ambient Water Quality Data for Dissolved Oxygen (D.O.), pH, Salinity, and Water Temperature for Lauderick Creek (XJG4337) in 2007.

Date	Sample Depth (m)	D.O. (mg/L)	pH	Salinity (ppt)	Water Temperature (^{o}C)
10/04/07	0.5	7.7	7.47	5.02	22.9
10/04/07	1.0	7.7	7.76	4.88	22.9
10/04/07	1.5	6.7	7.32	5.07	22.8
10/18/07	0.5	9.7	8.14	5.40	19.6
10/18/07	1.0	9.1	7.79	5.47	19.6
10/18/07	1.6	6.6	7.20	6.05	19.2
10/30/07	0.5	11.4	8.21	4.54	13.7
10/30/07	1.0	10.5	8.27	4.74	14.1
10/30/07	1.6	9.9	7.57	5.09	14.4

Table A10. Ambient Water Quality Data for Dissolved Oxygen (D.O.), pH, Salinity, and Water Temperature for Otter Point Creek (XJG7035) in 2007.

Date	Sample Depth (m)	D.O. (mg/L)	pH	Salinity (ppt)	Water Temperature (^{o}C)
01/03/07	0.5	11.2	7.16	0.00	5.3
03/05/07	0.2	12.7	7.57	0.00	5.2
03/20/07	0.2	12.4	7.31	0.00	10.8
04/03/07	0.4	11.2	7.79	0.00	15.6
05/01/07	0.3	11.0	8.31	0.00	20.6
05/15/07	0.6		7.50	0.00	20.5
05/29/07	0.1	6.3	7.05	0.00	27.1
06/12/07	0.4	7.6	7.69	0.00	26.3
06/26/07	0.3	11.1	9.49	0.00	30.8
07/10/07	0.4	9.6	9.99	0.00	31.0
07/25/07	0.5	6.0	8.99	0.00	25.9
08/08/07	0.3	5.8	7.63	0.19	30.4
08/23/07	0.4	7.9	7.52	0.40	21.4
09/06/07	0.5	7.3	7.44	1.22	26.4
09/20/07	0.5	6.7	7.37	2.19	22.2
10/04/07	0.4	5.8	6.74	2.72	23.2
10/18/07	0.3	8.9	7.61	3.52	19.6
10/30/07	0.2	10.5	7.53	0.72	14.4
11/13/07	0.3	11.6	7.39	1.61	10.4
11/27/07	0.1	14.1	8.04	2.06	9.5
12/10/07	0.3	12.6	7.39	0.38	4.4

Table A11. Ambient Water Quality Data for Dissolved Oxygen (D.O.), pH, Salinity, and Water Temperature for Otter Point Creek (XJG7035) in 2008.

Date	Sample Depth (m)	D.O. (mg/L)	pH	Salinity (ppt)	Water Temperature (^{o}C)
02/05/08	0.4	11.5	8.44	0.00	6.6
02/09/08	0.3	12.3	7.52	0.00	4.7
03/04/08	0.3	11.9	7.96	0.01	8.8
03/04/08	0.4	10.2	7.40	0.02	7.2
03/06/08	0.3	11.9	7.96	0.01	8.8
03/06/08	0.4	10.2	7.40	0.02	7.2
04/01/08	0.7	10.9	7.53	0.00	10.3
04/15/08	0.1				
04/29/08	0.4	8.1	7.20	0.00	14.8
05/13/08	0.5	8.2	7.00	0.00	12.6
05/29/08	0.5	9.9	8.10	0.00	21.2
06/12/08	0.5	6.0	7.35	0.00	27.5
06/26/08	0.3	6.5	8.22	0.00	26.6
07/10/08	0.3	4.8	7.62	0.00	26.1
07/24/08	0.5	4.9	8.70	0.00	25.8
08/05/08	0.5	5.6	8.15	0.00	27.6
08/19/08	0.5	6.9	8.14	0.09	28.3
09/16/08	0.1	12.4	9.26	0.53	24.2
09/30/08	0.5	11.6	8.16	1.07	22.2
10/14/08	0.3	11.9	8.42	2.27	20.6
11/10/08	0.3	13.7	8.62	4.64	13.8
12/04/08	0.5	13.5	7.91	2.52	6.4
12/04/08	0.7	1.0			

Table A12. Ambient Water Quality Data for Dissolved Oxygen (D.O.), pH, Salinity, and Water Temperature for Church Point (XJG7461) in 2008.

Date	Sample Depth (m)	D.O. (mg/L)	pH	Salinity (ppt)	Water Temperature (^{o}C)
04/01/08	0.5	10.6	7.64	0.00	10.2
04/01/08	1.0	11.4	7.24	0.00	10.4
04/01/08	1.3	10.5	7.64	0.00	10.2
04/15/08	0.5	11.3	8.58	0.00	13.8
04/15/08	0.8	11.4	8.59	0.00	13.5
04/29/08	0.5	8.1	7.78	0.00	16.0
04/29/08	1.0	8.4	7.44	0.00	15.8
05/13/08	0.5	9.6	7.62	0.00	13.5
05/13/08	1.0	9.6	7.46	0.00	13.2
05/13/08	1.5	9.3	7.54	0.00	12.7
05/29/08	0.5	9.6	8.45	0.00	21.1
05/29/08	1.0	8.2	7.90	0.00	20.6
06/12/08	0.5	6.7	7.80	0.00	29.5
06/12/08	1.0	6.7	7.74	0.00	29.3
06/26/08	0.5	5.9	7.66	0.00	26.4
06/26/08	1.0	6.7	7.61	0.00	26.3
07/10/08	0.5	6.9	8.02	0.00	26.4
07/10/08	0.9	7.2	7.86	0.00	26.4
07/24/08	0.5	6.8	9.13	0.09	27.6
07/24/08	1.0	7.3	9.25	0.11	27.6
07/24/08	1.3	6.4	9.10	0.08	27.5
08/05/08	0.5	13.7	9.76	0.08	30.0
08/05/08	1.0	13.2	9.62	0.08	29.1
08/05/08	1.3	7.6	9.14	0.10	27.9
08/19/08	0.5	8.8	8.70	0.17	28.0
08/19/08	1.0	8.8	8.33	0.31	27.8
08/19/08	1.5	6.8	8.05	0.20	27.0
09/02/08	0.5	9.5	8.31	0.86	24.8
09/02/08	1.0	8.6	7.95	0.91	24.6
09/02/08	1.3	7.6	7.71	0.90	24.5
09/16/08	0.5	7.1	7.76	0.53	24.5
09/16/08	1.0	6.9	7.77	0.59	24.4
09/30/08	0.5	12.6	8.75	2.23	22.0
09/30/08	1.0	12.4	8.59	2.28	21.5
09/30/08	1.3	10.0	7.93	2.24	20.5
10/14/08	0.5	10.3	8.60	3.21	20.9
10/14/08	1.0	6.8	7.30	3.52	19.8
10/30/08	0.5	11.0	7.56	2.74	8.0

Appendix B

Water quality data for 2003-2009 at the
Otter Point Creek (Station XJG7035)

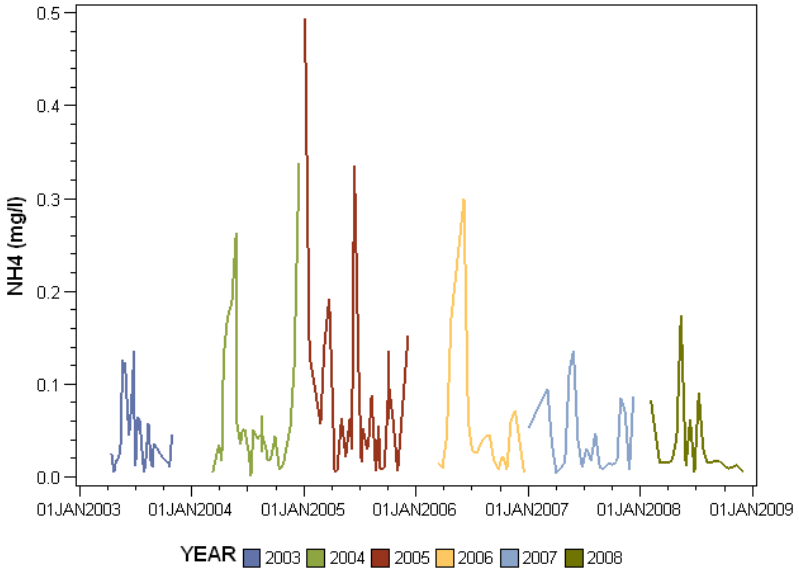

Figure B-1. Ammonium at Otter Point Creek over time.

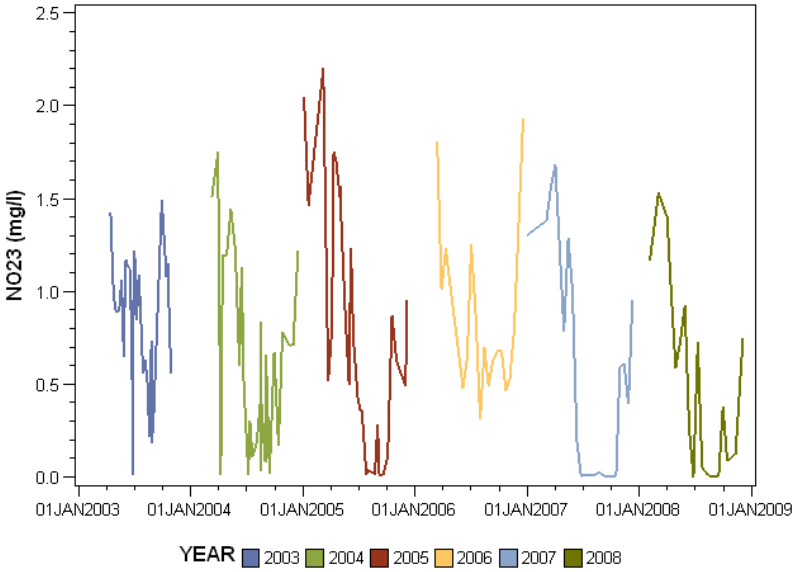

Figure B-2. Nitrite + Nitrate at Otter Point Creek over time.

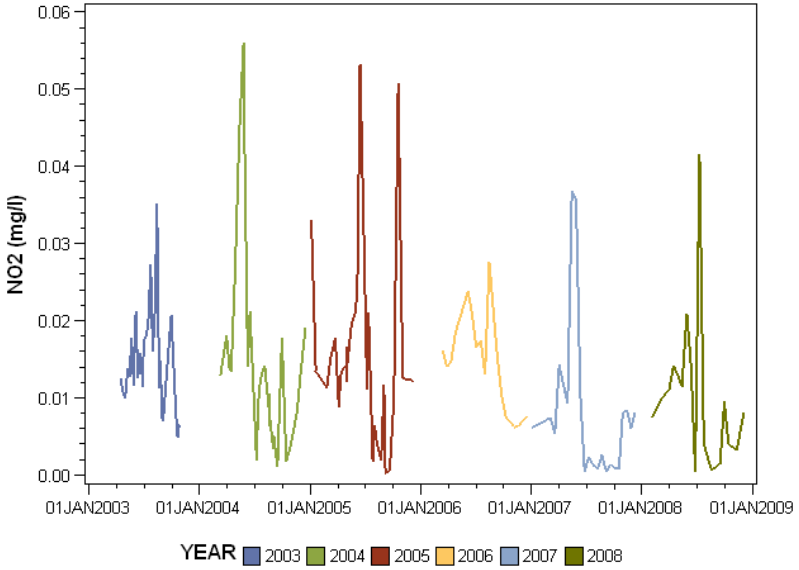

Figure B-3. Nitrite at Otter Point Creek over time.

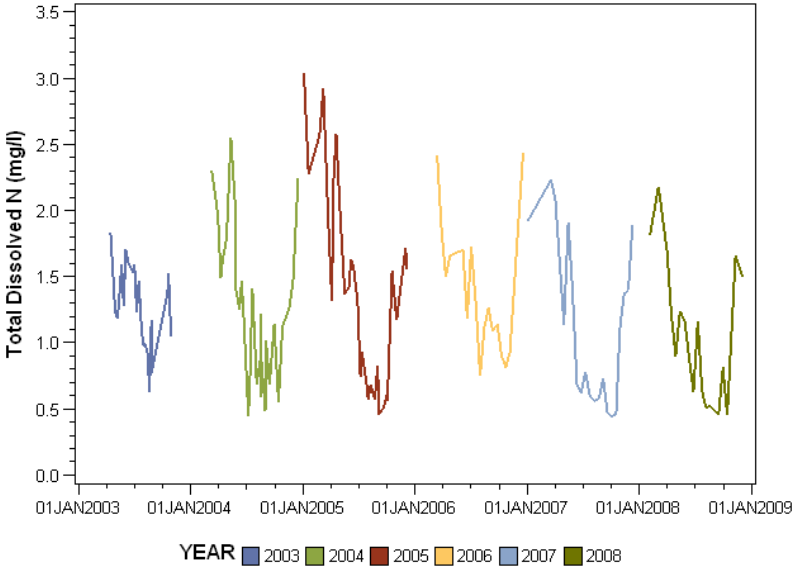

Figure B-4. Total dissolved nitrogen at Otter Point Creek over time.

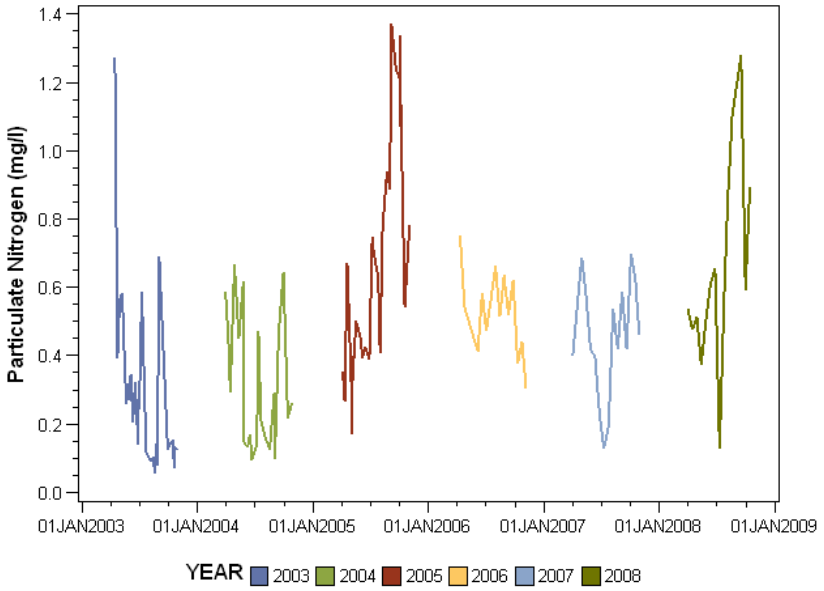

Figure B-5. Particulate nitrogen at Otter Point Creek over time.

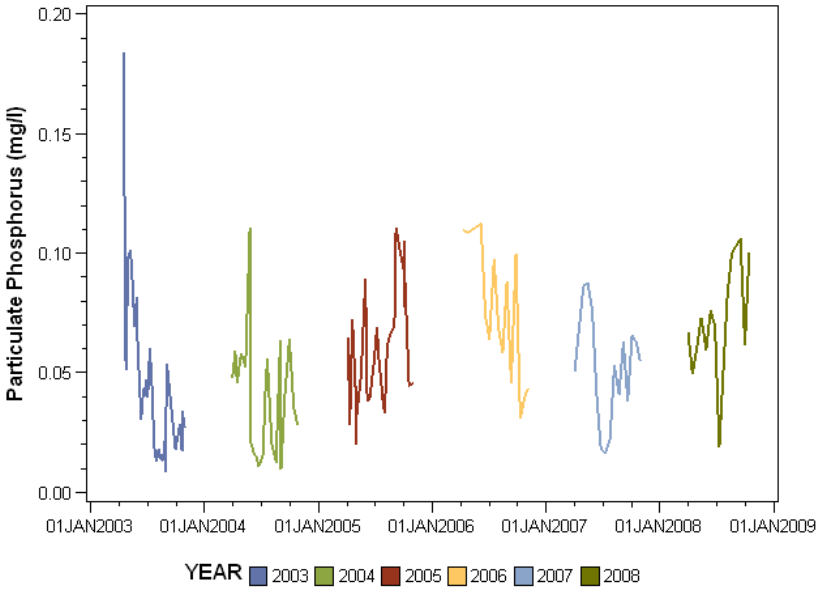

Figure B-6. Particulate phosphorus at Otter Point Creek over time.

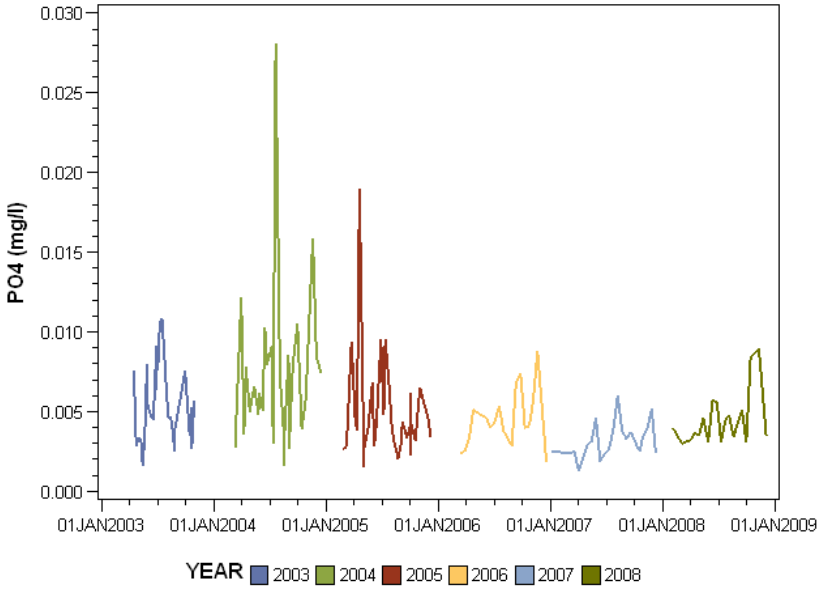

Figure B-7. Orthophosphate at Otter Point Creek over time.

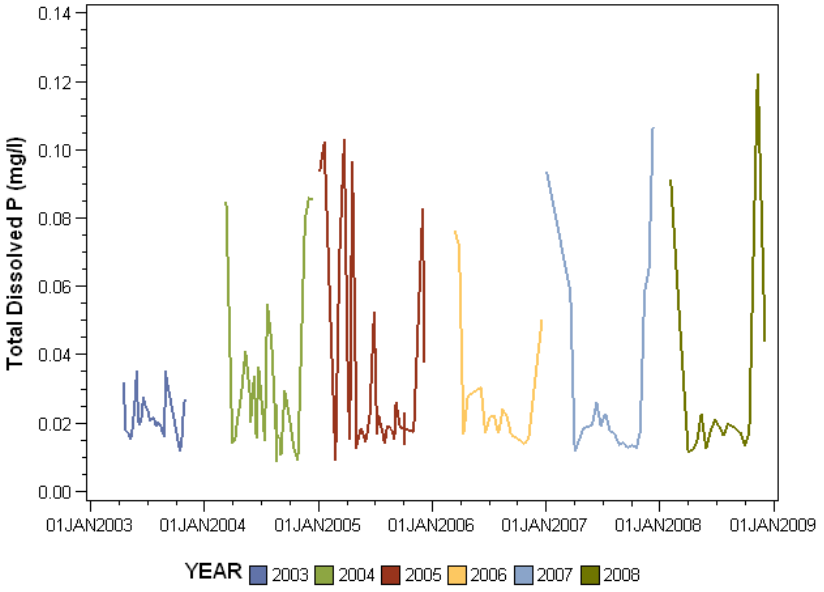

Figure B-8. Total dissolved phosphorus at Otter Point Creek over time.

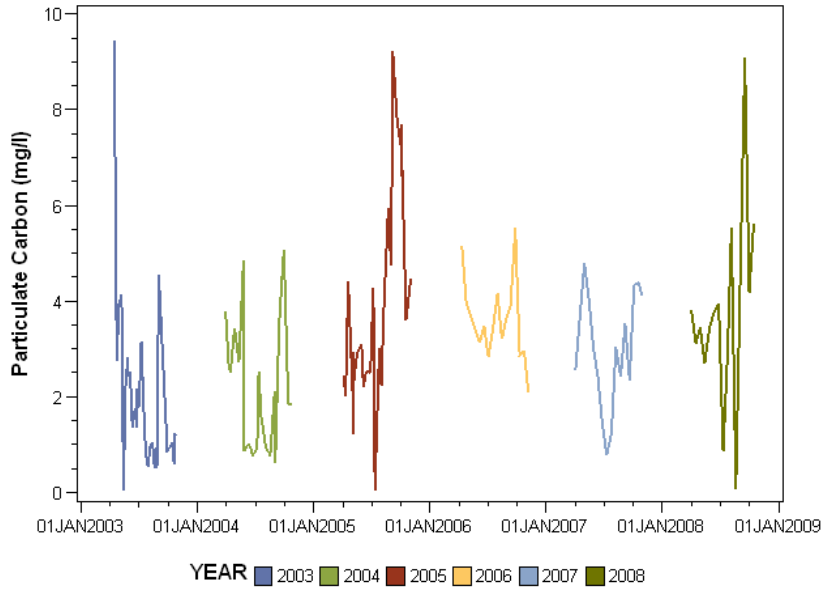

Figure B-9. Particulate carbon at Otter Point Creek over time.

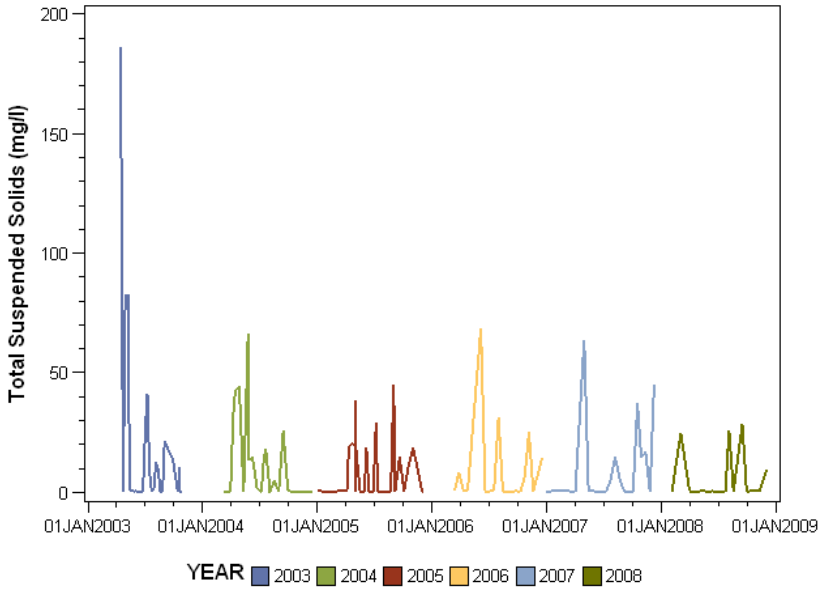

Figure B-10. Total suspended solids at Otter Point Creek over time.

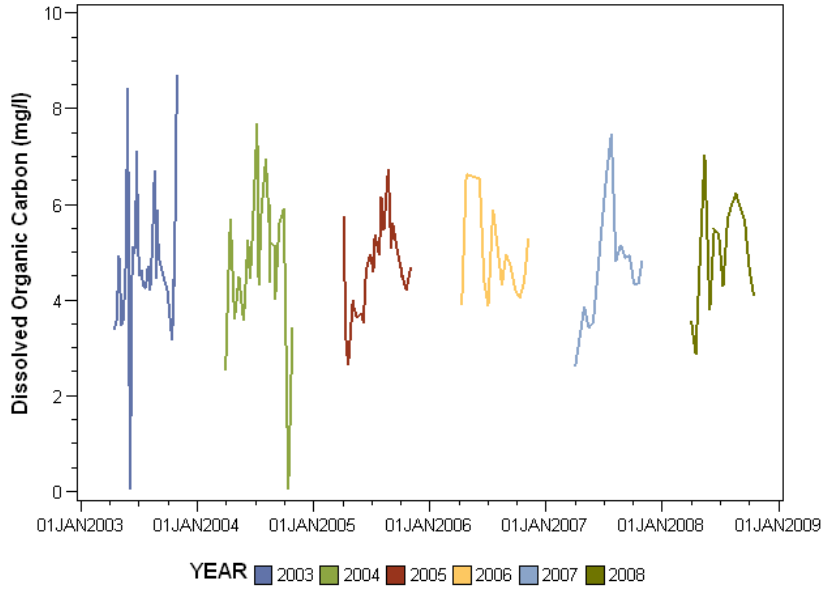

Figure B-11. Dissolved organic carbon at Otter Point Creek over time.

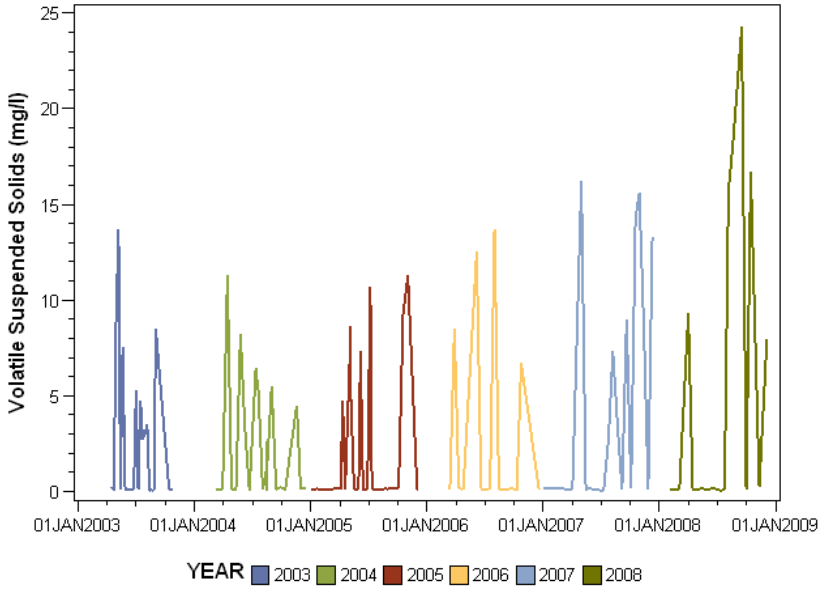

Figure B-12. Volatile suspended solids at Otter Point Creek over time.

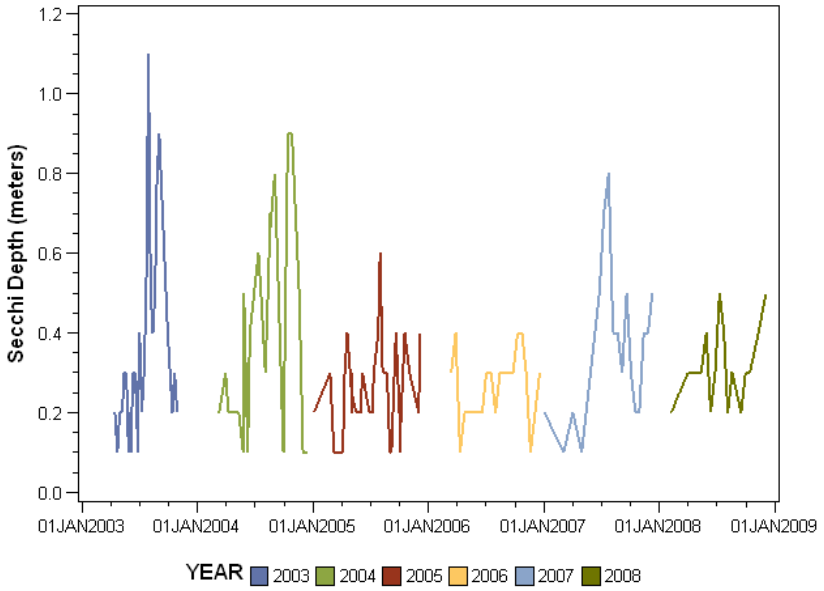

Figure B-13. Secchi disk depth at Otter Point Creek over time.

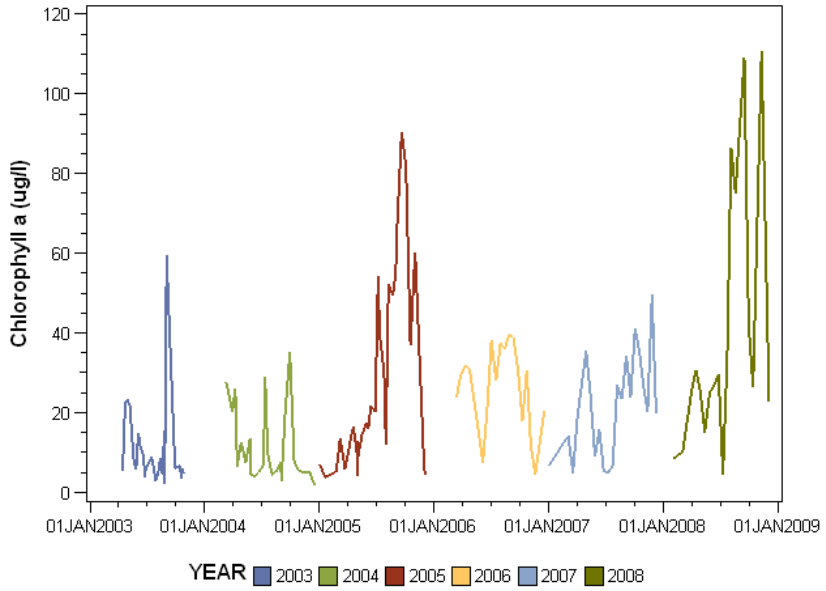

Figure B-14. Chlorophyll a at Otter Point Creek over time.

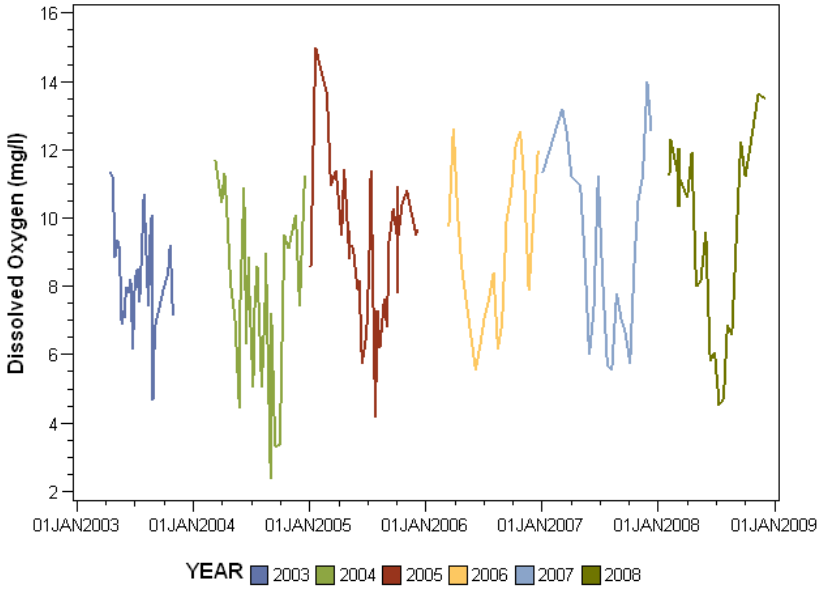

Figure B-15. Dissolved oxygen at Otter Point Creek over time.

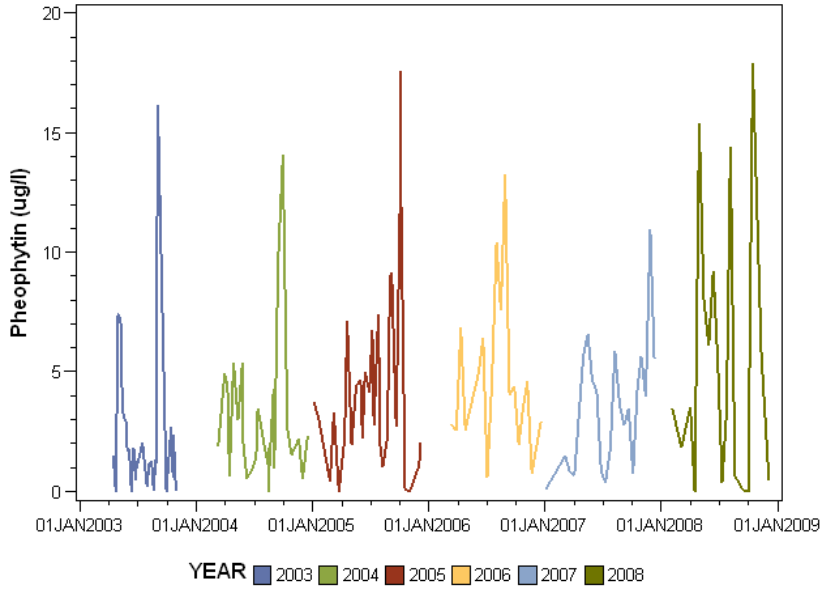

Figure B-16. Pheophytin at Otter Point Creek over time.

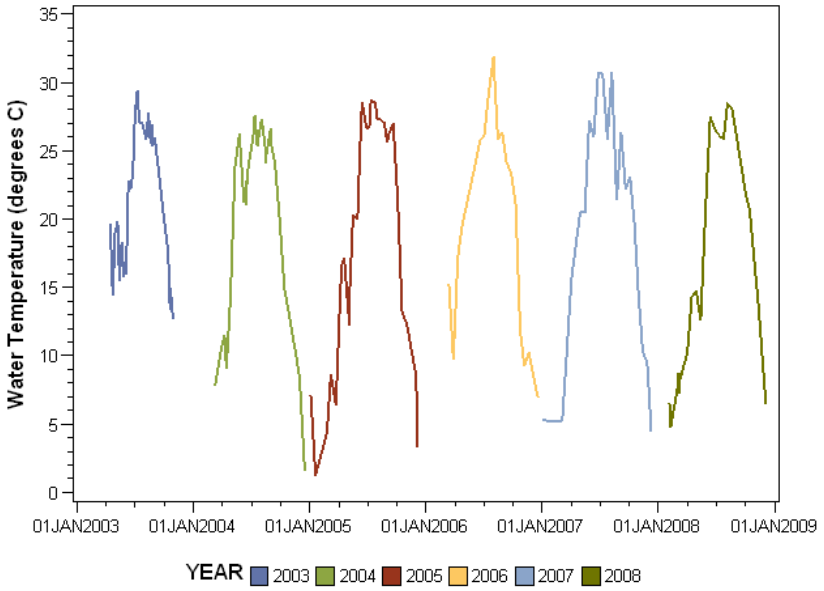

Figure B-17. Temperature at Otter Point Creek over time.

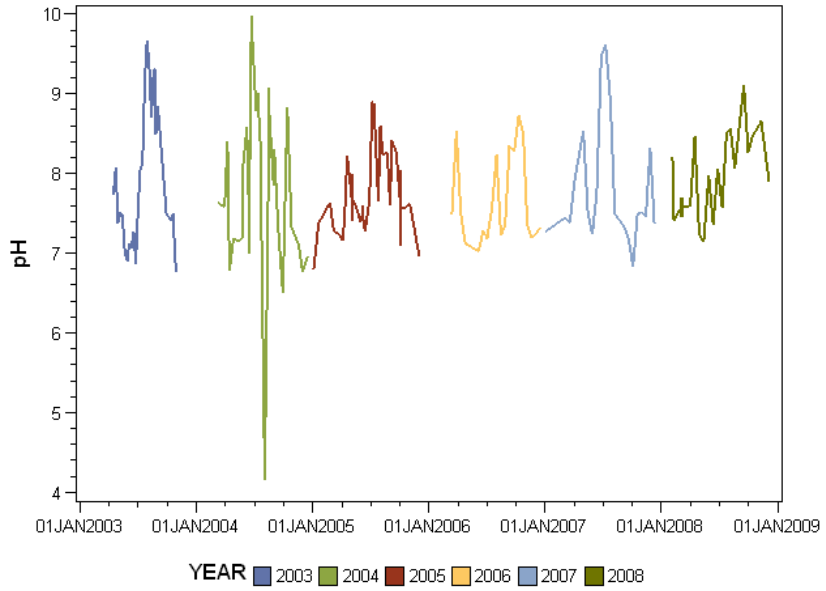

Figure B-18. pH at Otter Point Creek over time.