The Grayland Ditch

An Evaluation of the Effectiveness of Best Management Practices in Preventing Pesticides from Entering Cranberry Bog Drainage Ditches

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Summary

During 1996, 1998, 2002, and 2009, the Washington State Department of Ecology (Ecology) sampled for pesticides in surface water draining cranberry growing areas near Grayland on the Washington coast. Ecology found concentrations of three organophosphate pesticides in excess of water quality criteria: azinphos-methyl (Guthion™), chlorpyrifos (Lorsban™), and diazinon.

For the past few years, cranberry farmers have been implementing best management practices (BMPs) to reduce concentrations of organophosphate pesticides in adjacent surface waters. The 2009 Ecology study presented an evaluation of BMP effectiveness in reducing pesticide levels during peak application periods. Three sites each were sampled in both Grays Harbor County Drainage Ditch No. 1 and Pacific County Drainage Ditch No. 1. These two ditches are collectively known as the Grayland Ditch. Samples were collected one week prior to pesticide application, during the week of peak application, and two weeks following application.

Although progress had been made regarding the number and level of detections, concentrations of chlorpyrifos and diazinon continued to exceed state water quality standards. A large majority of the cranberry growers in the Grayland area are employing BMPs, but a small number of growers have yet to implement them. Abandoned bogs or bogs not actively farmed, but harvested have also not implemented the BMPs. Lack of detectable concentrations of azinphos-methyl in the 2009 study was likely due to the cancellation of registered uses on cranberries. Increased usage of chlorpyrifos and diazinon, due to the loss of azinphos-methyl, did not consistently show corresponding increases in detectable concentrations in the current sampling project.

Chlorpyrifos and diazinon have been continually detected above state water quality standards and federal National Recommended Water Quality Criteria (NRWQC) over the last 17 years. This requires the Washington State Department of Agriculture (WSDA) to follow the guidance described in the *Washington State Pesticide Management Strategy for Water Quality Protection* (Cook and Cowles, 2009). WSDA is the State Lead Agency for pesticide registration in Washington as delegated by EPA under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). WSDA began sampling the water in the Grayland Ditch in 2012 and continued to sample until the project was completed in Spring of 2015.

Purpose and Goals

Study Area

A major cranberry growing area in Washington State is located between Grayland (Grays Harbor County) and North Cove (Pacific County) on the Washington Coast. Grays Harbor County and Pacific County each manage a ditch system, known as the Grayland Ditch. The Grayland Ditch drains these cranberry growing areas as well as residential properties. Precipitation runoff from woodland areas east and upslope of the cranberry bogs also feeds into the ditches. These ditches originate near the Grays Harbor/Pacific County line, west of Highway 105 (Figure 1).

Grays Harbor County Drainage Ditch No. 1 (GHCDD-1) flows north for approximately 2.8 miles, draining water from around the county line through the Grayland area, and discharges to the South Bay of Grays Harbor. Pacific County Drainage Ditch No. 1 (PCDD-1) flows south for approximately 5 miles, from the county line, and discharges to the North Cove of Willapa Bay. Figure 1 shows the locations of GHCDD-1 and PCDD-1.

Background

In Washington State, drainage ditches such as the Grayland Ditch are designated as surface waters of the state. As such, state water quality standards apply (Chapter 173-201A WAC). Washington State water quality standards are the basis for protecting and regulating the quality of surface waters. Section 303(d) of the federal Clean Water Act requires Washington State every three years to prepare a list of all surface waters in the state for which beneficial uses – such as for drinking, recreation, aquatic habitat, or industrial use – are impaired by pollutants. Ecology's assessment of waters to be placed on the 303(d) list is guided by federal laws, state water quality standards, and state policy.

In 1994 and 1995, Ecology identified several pesticides frequently detected at concentrations exceeding Washington State or federal water quality standards in the Grayland Ditch (Davis et al., 1997). The resulting 303(d) listings include chlorpyrifos and diazinon, as well as DDT and its metabolites (4,4´-DDD, 4,4´-DDE).[1] Azinphos-methyl was found above federal water quality criteria, but there is not a corresponding state water quality criterion. As a result, azinphos-methyl was not put on the Washington State 303(d) list. However, due to the number of detections above the federal NRWQC, azinphos-methyl was still considered a chemical in need of further investigation.

Local cranberry growers responded to these listings by sponsoring research and development of BMPs for their growing operations. Use of BMPs to reduce pesticide levels in Grayland Ditch began in 1994 (Pacific Conservation District and the Pacific Coast Cranberry Research Foundation, 1999).

A 1996 study conducted by Ocean Spray (Frantz et al., 1997) investigated the effectiveness of several different BMPs for use in the Grayland area cranberry bogs using rubidium chloride (RbCl) as a surrogate for pesticides. The study was able to show cribbing (lining) and covering of ditches within and bordering cranberry bogs was the most effective BMP. Cribbing and covering reduced the interior and perimeter ditch concentrations of RbCl to non-detection levels at the study's detection limit of 100 µg/L.

At the time of the BMP effectiveness study, approximately one-half of the growers were implementing BMPs. By 2000, approximately 95% of the Grayland area cranberry growers were using at least one BMP for reducing pesticide pollution (Rountry, 2008).

To track the progress of the implemented BMPs, Ecology conducted studies to evaluate potential reduction in pesticide concentrations (Anderson and Davis, 2000; Coots, 2003, Anderson 2009). Results of the studies showed reductions in pesticide levels present in the ditches. However, the concentrations of pesticides continued to exceed water quality standards.

[1] DDT registration was cancelled in the United States in 1972 and it is considered a legacy pesticide.

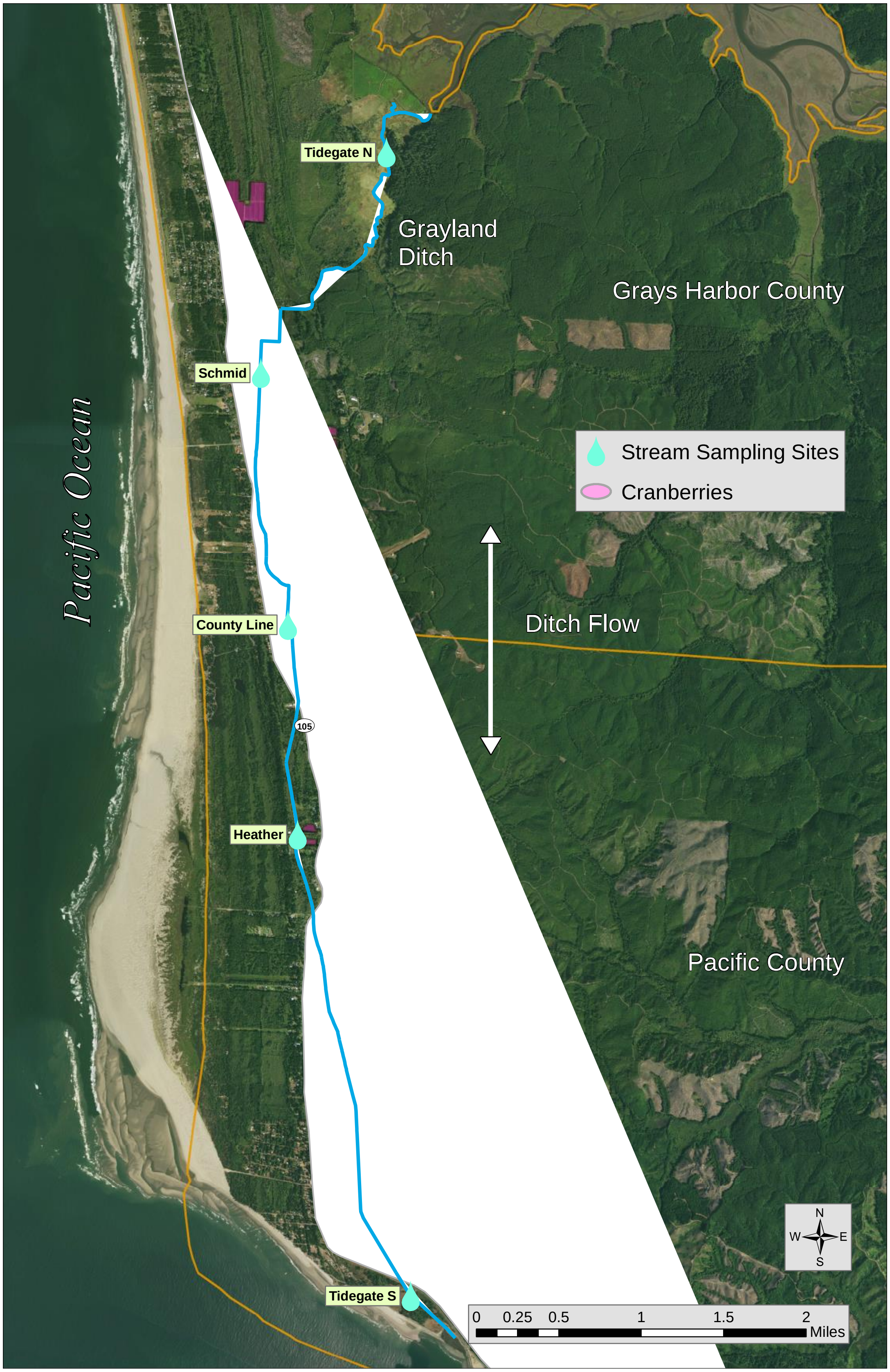

Figure 1: Grays Harbor Ditch study area

In 2010, WSDA staff were contacted by the cranberry growers on the Grayland Ditch system and asked to provide technical expertise to address the ongoing water quality concerns. In 2011, WSDA staff gathered information from the growers on pesticide application timing, application rates, and rate of BMP implementation across farms. Using this information, WSDA staff conducted baseline sampling during the spring 2012 application period (April 15 – May 31). The results of this initial sampling showed most portions of the ditch exceeded water quality standards for chlorpyrifos and diazinon. Based on these test results, WSDA followed up with a pesticide application records request to all cranberry growers in the Grayland Ditch area for the 2012 pesticide application season.

It was determined the most effective way to make reductions was to continue supporting development and implementation of BMPs and to re-evaluate pesticide concentrations with future sampling. To help with implementation of BMPs, the Natural Resource Conservation Service, Pacific and Grays Harbor Conservation Districts, and other organizations have provided growers with technical assistance and grants.

The evaluation of pesticide concentrations in the Grayland Ditch was conducted by WSDA. Under the guidance of the *Washington State Pesticide Management Strategy for Water Quality Protection* and the authority of WAC 16-232-400/450, WSDA began a three year water sampling project in 2013. The project continued through the Spring 2015 pesticide application season.

As a State Lead Agency, WSDA reviews pesticides occurring in surface and groundwater at concentrations approaching or exceeding human health or ecological reference points. If the pesticide(s) are determined to pose a risk to surface water and/or groundwater quality, the development and implementation of management measures is required. A response matrix detailing WSDA’s approach to assessing pesticide detections in surface and groundwater is provided in Appendix One of the *Washington State Pesticide Management Strategy for Water Quality Protection*.

By the time WSDA began sampling, the water quality results within cranberry growing area of Grayland had already passed response levels 1 and 2 of the response matrix contained within the

"*Strategy*". This placed the response at level 3 and could result in implementation of mandatory BMPs. As stated in Bicki et al. (2003), ditch lining and covering BMPs are effective when properly implemented.

Under the *Washington State Pesticide Management Strategy for Water Quality Protection*, WSDA will coordinate with Ecology and, if needed, Washington State Department of Health to implement the management strategies.

Methods

Sampling Design

The sampling was conducted by WSDA's Natural Resources Assessment Section (NRAS) staff.

WSDA sampling sites differ somewhat from previous sites sampled by Ecology. A new site, Tide Gate North, was added to the monitoring program to better capture runoff from all cranberry bogs draining into GHCDD. In addition the Grange Road and Jacobson Road sites were removed from the study. The Schmid Road, County Line Road, Heather Road, and Tide Gate South sites remained unchanged for a total of five sampling locations (see Figure 1 and Table 1).

Table 1 . Sampling locations and descriptions for GHCDD-1 and PCDD-1.

Station Name	Latitude	Longitude	Description
GHCDD-1			
Tide Gate North	46.83611	-124.07705	Upstream side of bridge on GHCDD-1
Schmid Road	46.8161	-124.0916	Upstream side of bridge on GHCDD-1
County Line Road	46.7938	-124.0866	Upstream side of culvert on GHCDD-1
PCDD-1			
Heather Road	46.7758	-124.0777	Upstream side of bridge on PCDD-1
Tide Gate South	46.7372	-124.0688	Upstream of tide gate on PCDD-1

Datum NAD 1983

For 2012, WSDA obtained only water samples. Beginning in 2013, WSDA began measuring ambient surface water quality for temperature, pH, conductivity, dissolved oxygen (DO), and turbidity. Stream flow measurements were also taken beginning in 2013. Water samples were collected for laboratory analysis of organophosphate pesticides and total suspended solids (TSS).

The timing of the sampling focused on the most intensive application periods for insecticides in the cranberry bogs. Intensive application of insecticides typically occurs during the spring and again in the middle of July. Many factors influence the start of pesticide applications. To achieve the target sample collection windows, WSDA staff queried the cranberry growers regarding pesticide application timing, application rates, and rate of BMP implementation across farms. WSDA also conducted a pesticide application record request for the 2012 pesticide application season. In typical years insecticide applications occur twice, once in late spring

(April-May) and again immediately after removal of the honey bees used for pollination. Removal of the bees is weather dependent, but in the past has occurred around the middle of July.

The sampling schedule was determined using prior studies and information gathered by WSDA. Samples were obtained beginning the week of April 22, 2013 and sampling continued through the week of May 20. Samples were also obtained July 8 through July 25. Sampling in 2014 began on April 17 and was completed on July 31. Sampling for 2015 began on April 23 and was completed on May 13. The laboratory analysis for 2012 and 2013 was conducted by ALS Environmental (ALS) under contract. The laboratory analysis for 2014 and 2015 was conducted by Pacific Agricultural Laboratory (PAL) also under contract.

Quality Objectives and Data Criteria

Quality objectives for this project were to obtain data of sufficient quality and quantity so it can be used to assess the current concentrations of chlorpyrifos and diazinon in the Grayland Ditch system; and subjectively evaluate the effectiveness and extent of implemented BMPs. This was be accomplished by comparing data from this study to data collected from previous studies. These objectives were achieved through careful planning and adherence to procedures described in the project Quality Assurance Project Plan (QAPP).

Field Procedures

Field measurements of temperature, pH, conductivity, DO, and turbidity were adapted from Ecology Standard Operating Procedures (SOP) (Nipp, 2006; Swanson, 2007; Ward, 2007a, 2007b) and the manufactures instruction manual. All field parameters were measured at the sampling site by field staff using a Hydrolab Quanta® multi-parameter probe (table 2).

Table 2. Measurement quality objectives for conventional parameters measured by field meters or determined by a standard method.

Parameter	Method/Equipment	Field Replicate MQO	Reporting Limits
Water Temperature	Hydrolab Quanta™	±0.2°C	-5.0°C
Conductivity	Hydrolab Quanta™	±1% of reading ±1 count	0.1 mS/cm
pH	Hydrolab Quanta™	±0.2 s.u.	2 s.u.
Dissolved Oxygen	Hydrolab Quanta™	±0.2 mg/L	0.1 mg/L
Turbidity	Hydrolab Quanta™	±0.5% of reading ± NTU	0 NTU

MQO – measurement quality objectives, s.u. – standard unit, Nephelometric Turbidity Units (**NTU**)

The Hydrolab Quanta ™ was calibrated before each field use by using commercially available reagents and in accordance with the manufacturer's instructions.

Stream flow measurements were obtained using a Marsh-McBirney flow meter, an OTT MF Pro electromagnetic flow sensor and a top-setting rod. Flow SOP was adapted from Ecology's *Measuring and Calculating Stream Discharge v1 1EAP056*.

Lab Procedures

All surface water samples were collected as grab samples using a pole sampler. Surface water sampling SOPs were adapted from Ecology SOPs described in EAP003 *Sampling of Pesticides in Surface Waters* (Anderson, 2006) and EAP015 *Manually Obtaining Surface Water Samples* (Joy, 2006) (table 3). The water samples were sent to ALS in Kelso, WA or PAL in Portland, OR for analysis.

Results from the laboratories included case narratives describing QA/QC procedures used during analysis. These QA/QC results included holding times, instrument calibrations, method blanks, matrix spikes, laboratory duplicates, laboratory control samples, and surrogate spikes. Case narratives describing the quality of the data are available upon request. ND and U were data qualifiers used to indicate non detection of the target analytes.

Transfer blanks were analyzed to evaluate the potential for contamination. Transfer blanks were prepared using blank water supplied by ALS. Laboratory. Water was transferred from its container at the sampling site to a new sample container. No target analytes were detected in transfer blanks.

The sample results were compared to available water criteria in Table 4.

Table 3. Available water quality criteria.

Chemical	Type	Common Name	WAC		NRWQC	
			Acute	Chronic	CMC	CCC
Chlorpyrifos	Organophosphate	Lorsban	0.083 µg/L	0.041 µg/L	0.083 µg/L	0.041 µg/L
Diazinon	Organophosphate	(several)	--	--	0.17 µg/L	0.17 µg/L

WAC – Washington Administrative Code (Chapter 172-201A)
CMC – criteria maximum concentration
CCC – criteria continuous concentration

Sample Results for 2012 and 2013

In 2012 only water samples were obtained. Beginning in 2013 both water samples and ambient data were collected. The water samples in 2012 and 2013 were analyzed for the presence of diazinon and chlorpyrifos. The results are shown in tables 5 and 6.

Site	Date	Chlorpyrifos µg/L	Diazinon µg/L
Tidegate N	4/22/2012	ND	ND
Schmid	4/22/2012	ND	ND
County Line	4/22/2012	ND	ND
Heather	4/22/2012	ND	ND
Tidegate S	4/22/2012	ND	ND
Tidegate N	5/9/2012	ND	ND
Schmid	5/9/2012	ND	ND
County Line	5/9/2012	ND	ND
Heather	5/9/2012	ND	ND
Tidegate S	5/9/2012	ND	ND
Tidegate N	5/15/2012	ND	0.22
Schmid	5/15/2012	ND	0.43
County Line	5/15/2012	ND	ND
Heather	5/15/2012	ND	0.23
Tidegate S	5/15/2012	ND	3
Tidegate N	5/22/2012	ND	1.3
Schmid	5/22/2012	0.28	1.8
County Line	5/22/2012	ND	ND
Heather	5/22/2012	ND	3.8

Tidegate South	5/22/2012	0.36	4
Tidegate North	5/29/2012	ND	ND
Schmid	5/29/2012	0.25	ND
County Line	5/29/2012	0.52	ND
Heather	5/29/2012	ND	0.36
Tidegate South	5/29/2012	0.63	0.36

Table 4. 2012 diazinon and chlorpyrifos detections

In 2012, diazinon was detected at each site at least twice. All detections were above the NRWQC maximum/continuous concentration of 0.17 µg/L. Chlorpyrifos was detected at four sites. All detections were above the State Acute and Chronic concentrations of 0.083 µg/L.

Site	Date	Diazinon µg/L	Chlorpyrifos µg/L
Tidegate North	4/25/2013	ND	ND
Schmid	4/25/2013	ND	ND
County Line	4/25/2013	ND	ND
Heather	4/25/2013	ND	ND
Tidegate South	4/25/2013	ND	ND
Tidegate North	5/1/2013	ND	ND
Schmid	5/1/2013	ND	ND
County Line	5/1/2013	ND	ND
Heather	5/1/2013	ND	ND
Tidegate South	5/1/2013	ND	ND
Tidegate North	5/8/2013	ND	ND
Schmid	5/8/2013	ND	ND
County Line	5/8/2013	ND	ND
Heather	5/8/2013	ND	ND
Tidegate South	5/8/2013	ND	ND
Tidegate North	5/15/2013	ND	ND
Schmid	5/15/2013	ND	ND
County Line	5/15/2013	0.59	ND
Heather	5/15/2013	ND	ND
Tidegate South	5/15/2013	ND	0.23
Tidegate North	5/22/2013	SITE NOT AVAILABLE	
Schmid	5/22/2013	ND	ND
County Line	5/22/2013	0.21	ND
Heather	5/22/2013	ND	ND
Tidegate South	5/22/2013	ND	ND
Tidegate North	7/9/2013	ND	ND

Schmid	7/9/2013	ND	ND
County Line	7/9/2013	ND	ND
Heather	7/9/2013	ND	ND
Tidegate South	7/9/2013	ND	ND
Tidegate North	7/18/2013	ND	ND
Schmid	7/18/2013	0.24	ND
County Line	7/18/2013	0.43	ND
Heather	7/18/2013	1.9	ND
Tidegate South	7/18/2013	0.3	ND
Tidegate North	7/25/2013	ND	ND
Schmid	7/25/2013	ND	ND
County Line	7/25/2013	0.44	ND
Heather	7/25/2013	ND	ND
Tidegate South	7/25/2013	ND	ND

Table 5 2013 diazinon and chlorpyrifos detections

In 2013, diazinon was detected seven times at four sites. All detections were above the NRWQC maximum/continuous concentration of 0.17 µg/L. Only one detection (Heather on 7/18) was substantially above the NRWQC at levels similar to those observed in 2012. Chlorpyrifos was detected at one site once in 2013. This detection was well above the State Acute and Chronic concentration of 0.083 µg/L.

Ambient Data for 2012 and 2013

Washington State water quality standards for conventional water quality parameters are set forth in Chapter 173-201A of the WAC. Water bodies are required to meet water quality standards based on the designated uses of the water body. When designated uses are not specified for a particular water body, then default designated uses are used to identify appropriate water quality criteria. The Grayland Ditch does not have specified designated uses, so the default becomes (1) salmonid spawning, rearing, and migration, and (2) primary contact recreation. There is no documented use by, or presence of, any salmon species in Grayland Ditch (WDFW, 2010). The numeric pH criteria for the above designated uses should be within the range of 6.5 to 8.5, with a human-caused variation of less than 0.5 standard units. The ambient data collected is shown in Figures 2 through 20. Ambient data was not available for all sites for all sampling events. Data was unavailable for a variety of reasons such as limited access, water depth or equipment failure. The tabular data for all measurements is available in Appendix C.

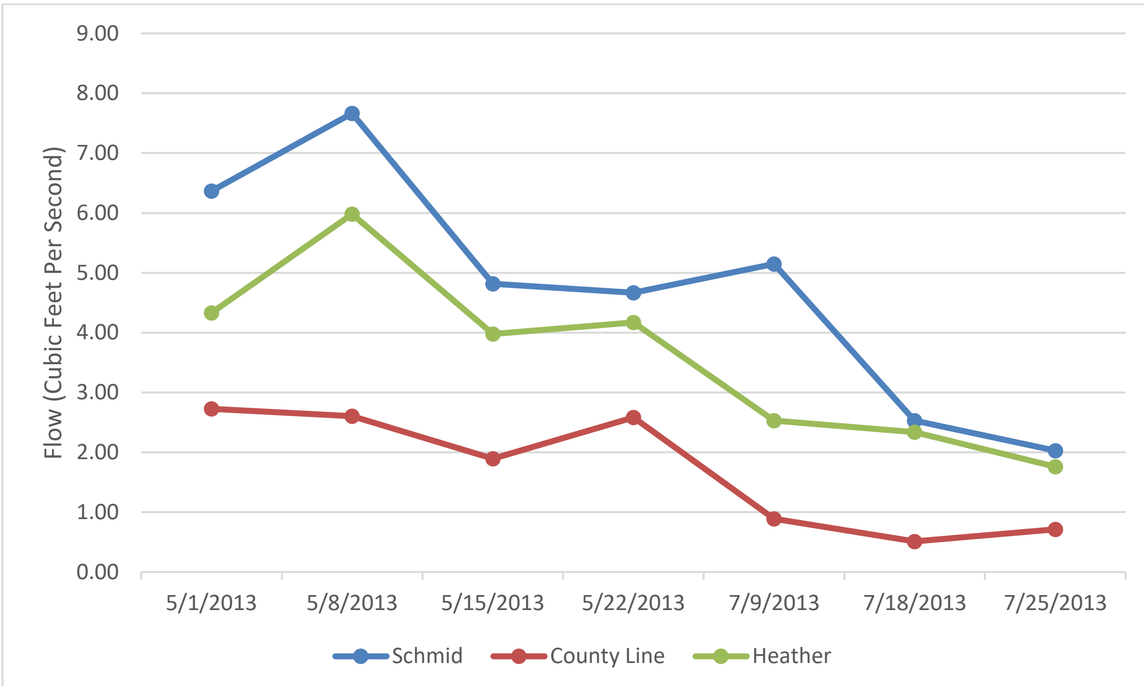

Figure 2: Flow (cubic feet per second).

Stream discharge (flow) was measured at three sites in 2013. Discharge peaked on 5/8 and declined as the year progressed. The low flow in this system indicates a chance for increased pesticide exposure to aquatic invertebrates and non-anadromous fish.

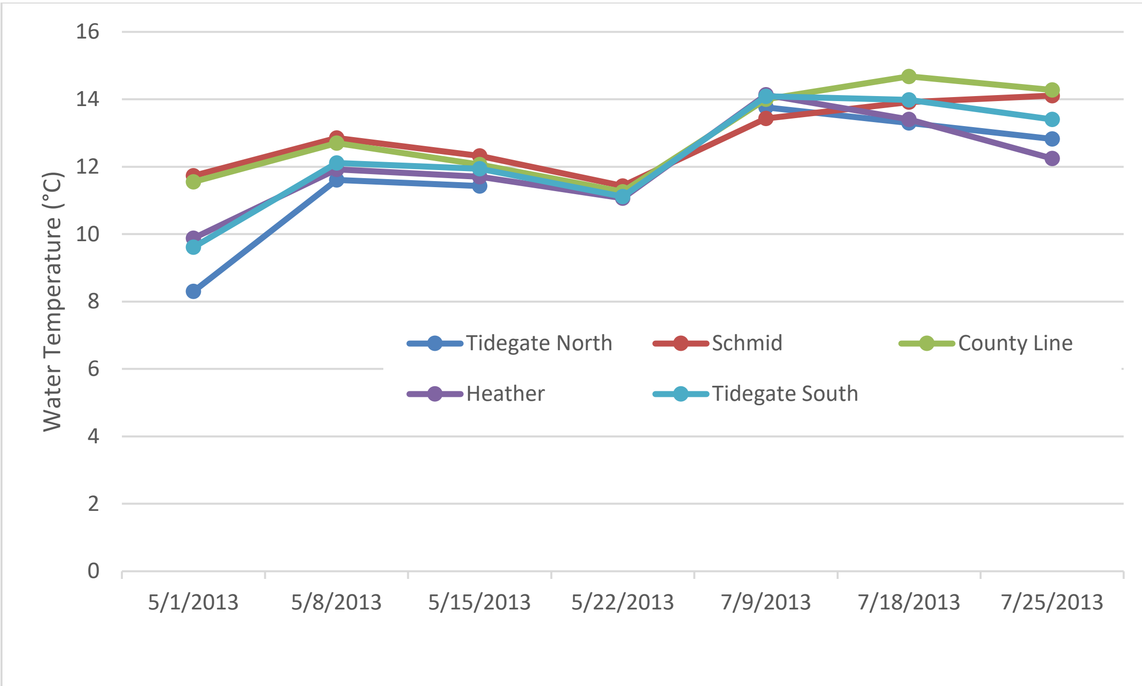

Figure 3: Water Temperature (degrees C)

Water temperature varied from just above eight degrees (C) in April to approximately fourteen degrees in July. All of these temperatures are within the range to support aquatic life. This ditch system has an abundance of riparian plantings and shade to mediate water temperature.

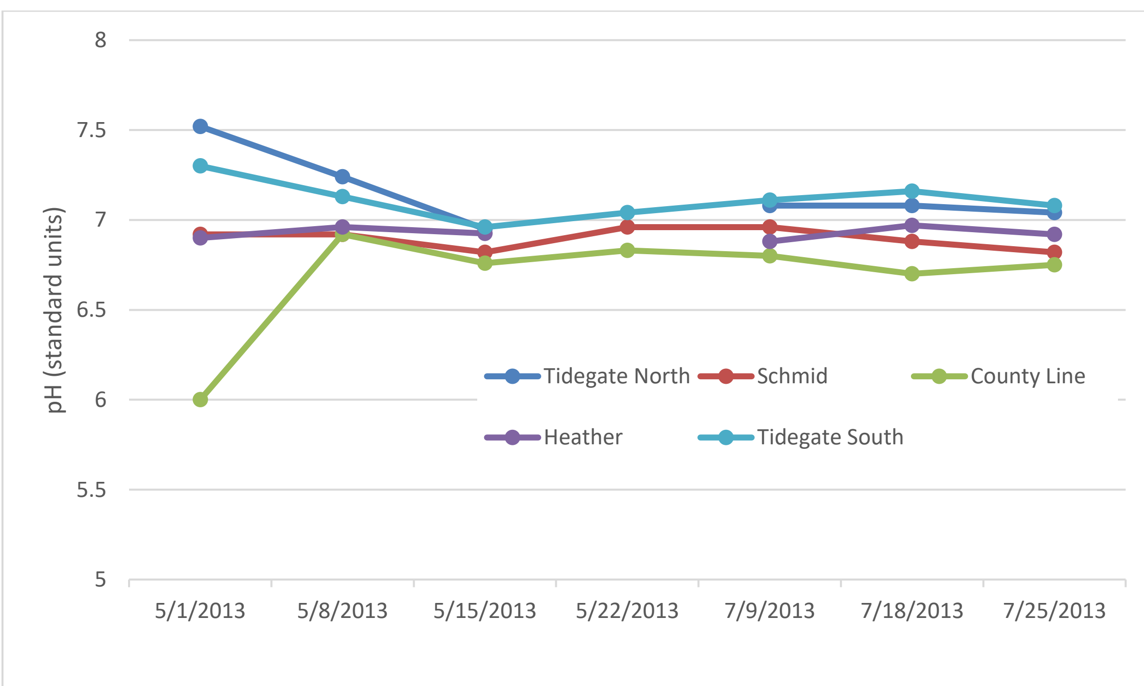

Figure 4: pH (standard units)

The pH as measured was most often within the aquatic criteria. The County Line reading on 5/1 was the single exception. The pH generally tended towards slightly acidic. The water in the Grayland Ditch primarily comes from wetlands and bog drainage which are typically acidic.

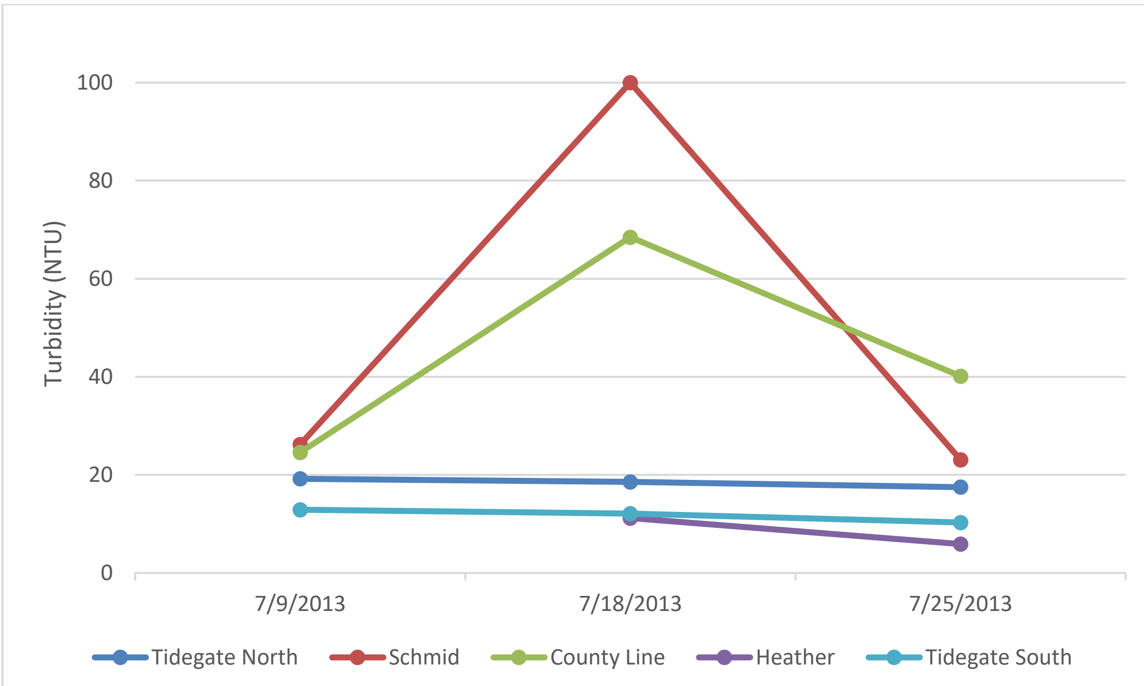

Figure 5: Turbidity (NTU)

Turbidity was measured using the Hach Hydrolab Quanta® beginning with the July site visits. The Schmid and County Line sites showed considerable variability between visits. Turbidity was measured in the field during all sampling events in 2014 and 2015.

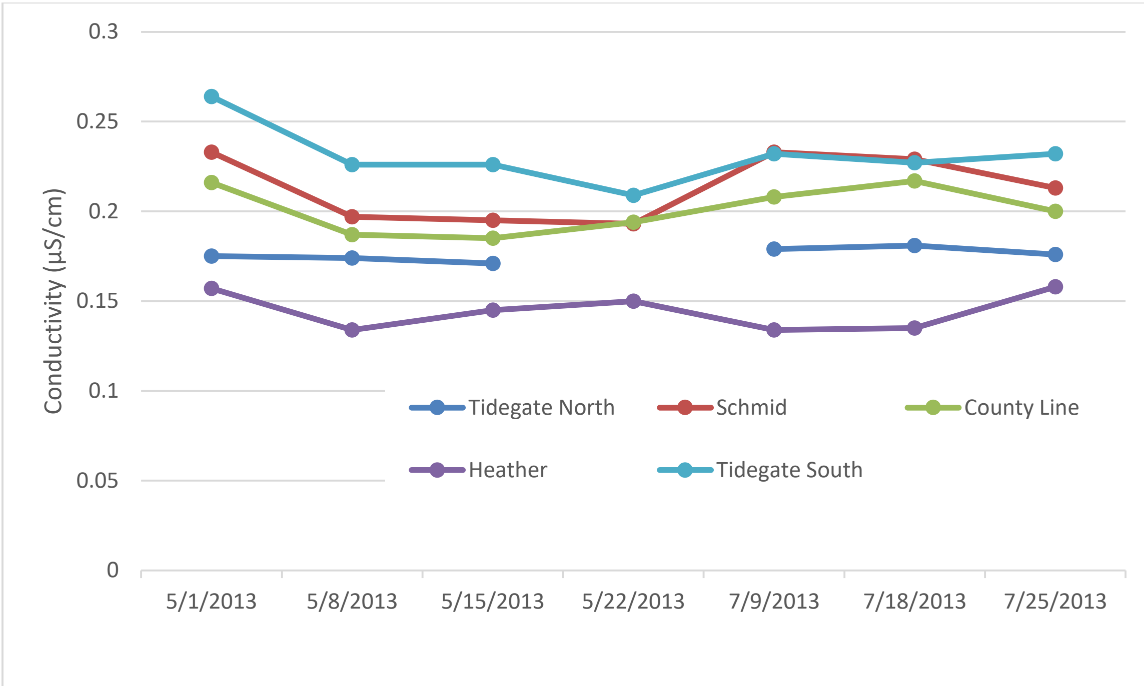

Figure 6: Conductivity (µS/cm)

Conductivity measurements showed considerable variability between the sampling sites. The measurements indicate the presence of salt water, at least in small amounts, throughout the Grayland Ditch system. This is expected and observed in other tide gate protected ditch systems.

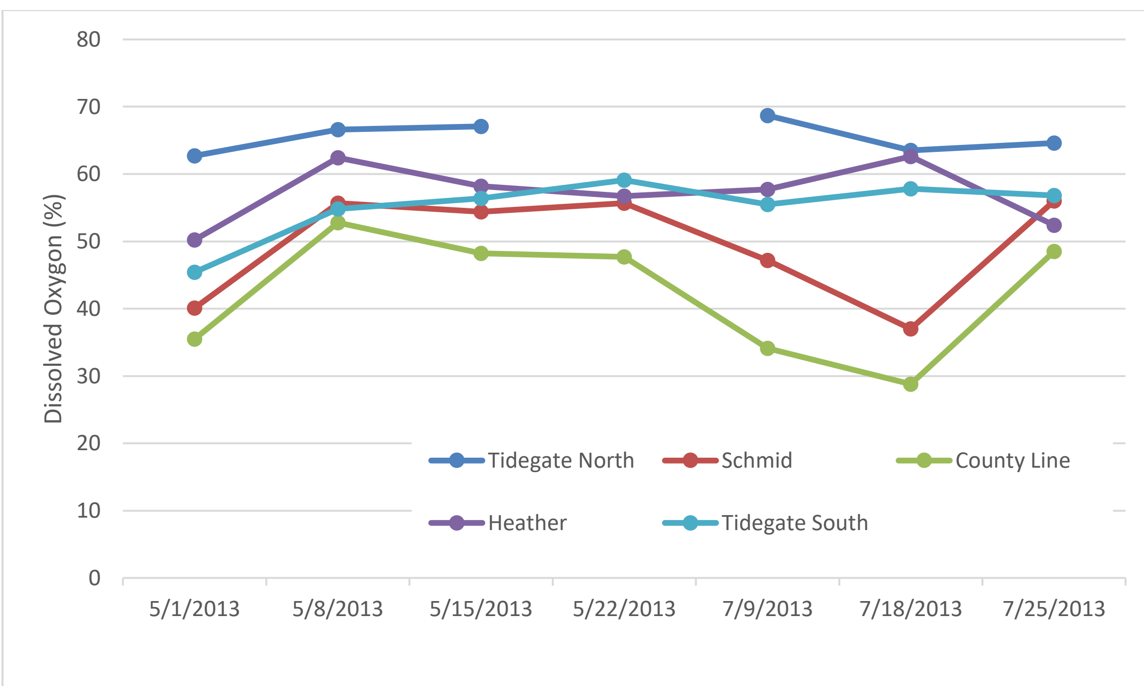

Figure 7: Dissolved Oxygen (%)

The dissolved oxygen levels were generally low and did not meet any of the criteria for salmonid habitat.

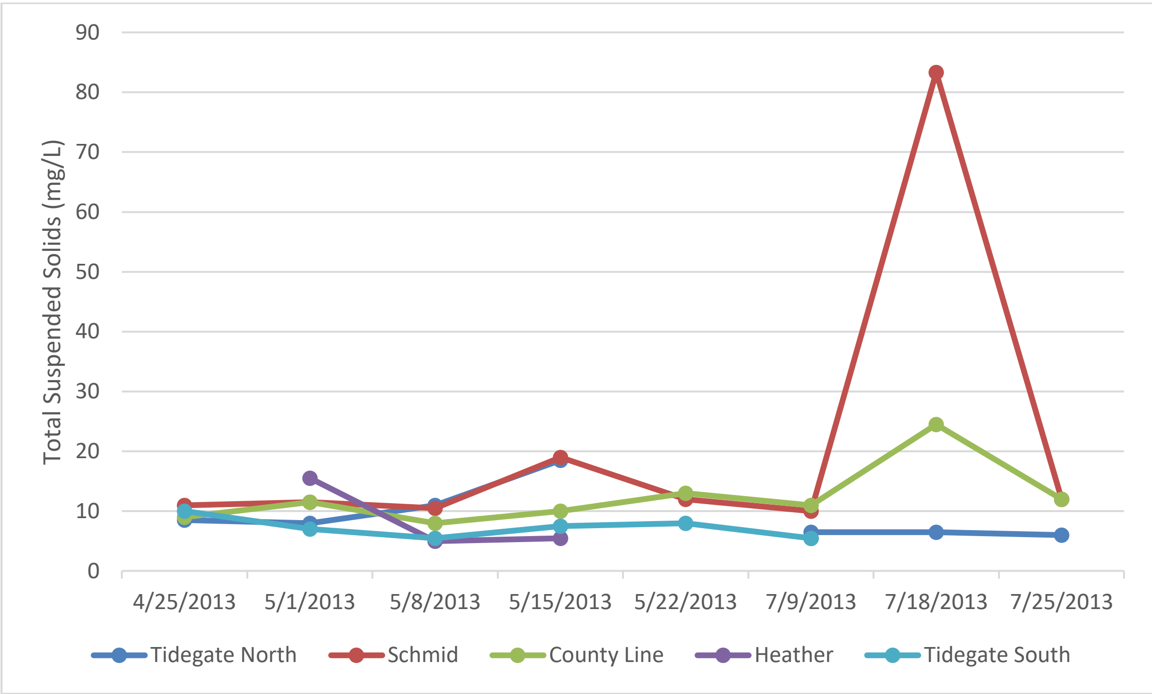

Figure 8: Total Suspended Solids (mg/L)

Water samples were obtained from most site visits and tested for total suspended solids. While there was a certain amount of variability between the samples, the Schmid sample on 7/18 was extremely high. Turbidity was also sampled in the field on 7/18/2013. This sample was also very high. This anomalous result may be a natural occurrence or may be due to errors in the sampling technique.

The number of detections of both diazinon and chlorpyrifos declined, from previous studies conducted by Ecology, during the first two years of WSDA's sampling. The concentrations detected have also generally declined, although all detections are still above State and Federal water quality levels.

Three factors may be contributing to the decline in chlorpyrifos and diazinon detections:

1. The BMPs (cribbing and covering the ditches) is slowly increasing on all or most of the bog ditches and may be functioning properly. This would indicate the BMPs are successful in decreasing pesticide concentrations in the ditch system.
2. Diazinon and chlorpyrifos may not be used as much as they were in the past. This could indicate a decline in the number of applications and/or the applied rate of these pesticides.
3. A combination of one and two.

A stated purpose of this study is to evaluate the effectiveness of the cribbing and covering BMP around the Grayland Ditch. Implementation of the required BMPs should keep the majority of applied pesticide residues from entering the waters of the state. If diazinon and chlorpyrifos are being phased out, then continued testing for only diazinon and chlorpyrifos would not be a good indicator for determining the effectiveness of the BMPs. WSDA made an effort to identify all or most of the pesticides used in the production of cranberries and expanded the water sampling testing in the 2014 and 2015 application seasons to include more of the pesticides applied. This was accomplished by moving the sample analysis to PAL in Portland, OR. PAL was able to analyze for the expanded chemical list at a cost the WSDA budget could bear. PAL had previously worked with a number of cranberry growers on a project through WSU Extension. PAL had developed a cranberry profile of active ingredients (table X) that could be utilized for WSDA's project.

Sample Results for 2014 and 2015

Active Ingredient	Type	Active Ingredient	Type
acephate	Insecticide	acetamiprid	Insecticide
carbaryl	Insecticide	chlorothalonil	Fungicide
chlorpyrifos	Insecticide	clothianidin	Insecticide
chlorantraniliprole	Insecticide	diazinon	Insecticide
difenoconazole	Insecticide	imidacloprid	Insecticide
methamidophos	Insecticide	methoxyfenozide	Insecticide
propiconazole	Fungicide	spinetoram	Insecticide
thiamethoxam	Insecticide		

Table 6: PAL cranberry profile used for 2014 and 2015 WSDA sampling

Sample Date	Analytes	Tidegate North	Tidegate South	Heather	County Line	Schmid
4/17/2014	Imidacloprid	0.079	0.120	0.400	0.180	0.074
	Methoxyfenozide	0.170	0.210	0.370	0.240	0.130
	Chlorantraniliprole				0.070	0.330
4/24/2014	Imidacloprid	0.690	0.120	0.210	0.170	0.630
	Methoxyfenozide	0.160	0.280	0.220	0.170	0.200
5/7/2014	Imidacloprid			0.081	0.170	0.095
	Methoxyfenozide	0.063	0.081	0.088		0.063
	Chlorothalonil					**2.400**
5/15/2014	Acephate	2.000	11.000	3.000	2.500	5.100
5/22/2014	Acephate					1.600
	Diazinon		**0.180**			
5/29/2014	Diazinon	**0.240**	**0.310**	**0.095**	**0.700**	**0.280**
	Chlorpyrifos	0.200	0.160			0.440
	Chlorthalonil			**51.000**		
7/10/2014	Diazinon	**0.320**	**0.570**	**0.440**		**0.300**
7/17/2014	Diazinon	0.150	**0.190**		**0.330**	**0.800**
7/24/2014	Diazinon				**0.440**	**0.180**
	Chlorantraniliprole					**0.210**
7/31/2014	Chlorpyrifos		0.072			
	Diazinon				**0.210**	0.073
	EPA Office of Pesticide Programs Aquatic Life Benchmarks					
Analytes	**Fish Acute**	**Fish Chronic**	**Invert Acute**	**Invert Chronic**		
Acephate	416,000	5,760	550	150		
Carbaryl	13.1	16.5	4,200	560		
Chlorantraniliprole	> 600	110	4.9	4.5		
Chlorpyrifos	0.83	0.57	0.05	0.04		
Chlorothalonil	5.25	3	1.8	0.6		
Diazinon	45	<0.55	0.11	0.17		
Imidacloprid	> 41,500	1,200	34.5	1.05		
Methoxyfenozide	> 2100	530	25	6.3		

Table 7: 2014 sample results and EPA aquatic life benchmarks. Aquatic life benchmark exceedances in bold

During the summer of 2014 the Pesticide Management Division Compliance Team conducted extensive technical assistance inspections with almost all the cranberry growers in the Grayland area. The purpose of these inspections was to inspect all aspects of the cranberry growing operations involving pesticides. Pesticide storage, record keeping, irrigation/chemigation systems, and the status of cribbing and covering were the principle focus of the inspections. Growers were informed verbally and in writing of areas needing correction. Growers were given the rest of the 2014 growing season through the winter and to the beginning of the 2015 pesticide application season to make repairs and/or enhancements to the cribbing and covering and to the 2016 application season for any chemigation system repairs.

Due to the thoroughness of these inspections by the Compliance Team, NRAS decided to only sample during the 2015 spring application season. Sampling during July would not present further evidence of the success of the Compliance efforts or the adequacy of the established BMPs.

Sample Date	Analytes	Tidegate North	Tidegate South	Heather	County Line	Schmid
4/23/2015	Imidacloprid	0.071	0.320	0.093		0.130
	Acetamiprid		0.110			
	Methoxyfenozide		0.330	0.080		0.070
4/29/2015	Chlorpyrifos		0.150	0.220		
	Chlorantraniliprole		0.061			0.080
	Methoxyfenozide		0.086	0.110		0.072
	Acephate			1.200	3.600	1.100
	Carbaryl			0.062		
	Imidacloprid			0.079		
5/6/2015	Diazinon	**0.680**	**0.230**			**1.300**
	Acephate	4.400	22.000	2.400	1.700	7.700
	Methoxyfenozide	1.700	0.064			3.200
	Carbaryl		0.520	0.072		
	Chlorantraniliprole			0.063		0.074
5/13/2015	Chlorpyrifos		0.350			
	Diazinon		**0.500**	0.077		0.068
	Acephate		4.100	1.900		2.500
	Carbaryl		0.820	0.440	0.130	0.094
	Methoxyfenozide					0.300

EPA Office of Pesticide Programs Aquatic Life Benchmarks						
Analytes	**Fish Acute**	**Fish Chronic**	**Invert Acute**	**Invert Chronic**		
Acephate	416,000	5,760	550	150		
Carbaryl	13.1	16.5	4,200	560		
Chlorantraniliprole	> 600	110	4.9	4.5		
Chlorpyrifos	0.83	0.57	0.05	0.04		
Chlorothalonil	5.25	3	1.8	0.6		
Diazinon	45	<0.55	0.11	0.17		
Imidacloprid	> 41,500	1,200	34.5	1.05		
Methoxyfenozide	> 2100	530	25	6.3		

Table 8: 2015 sample results. Aquatic life benchmark exceedances in bold

Ambient Data for 2014 and 2015

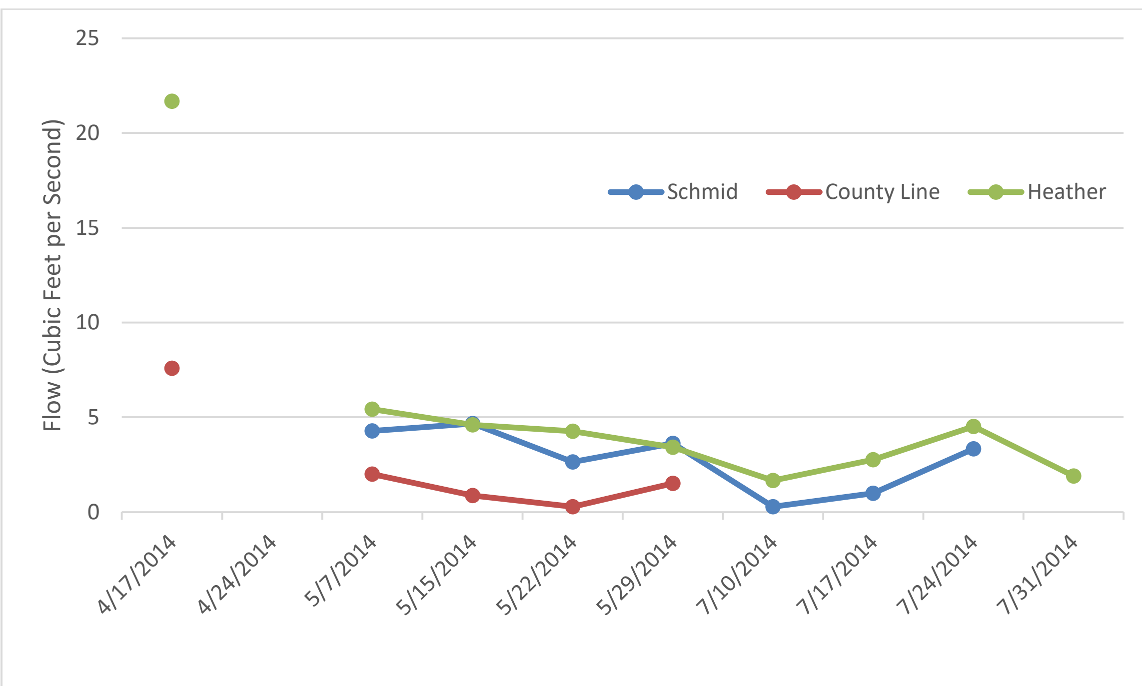

Figure 9: 2014 flow (feet per second)

Flow was measured at Schmid, County Line and Heather. On 4/17 at Schmid and 4/24 at all sites, the water levels were very high. Field staff determined the levels were too high to measure flow and posed an unsafe condition for entry, therefore, flow was not measured at those times. After 5/29 at County Line, the water was not moving and flow could not be measured.

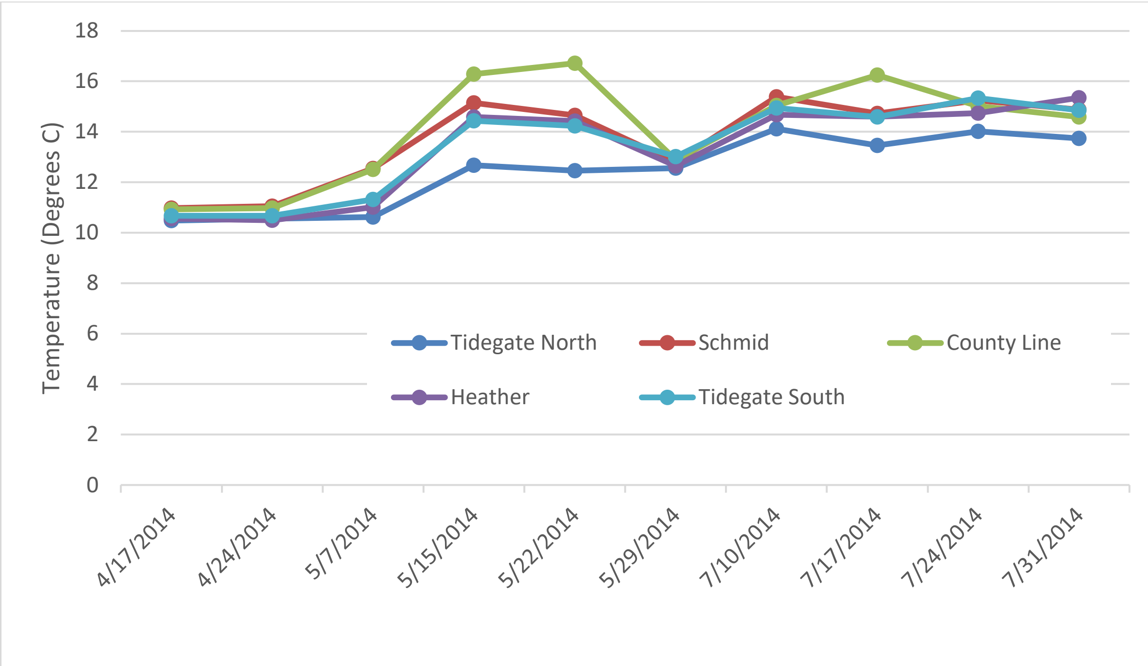

Figure 10: 2014 temperature (degrees centigrade)

Temperature measurements were obtained at all sites for all dates in 2014.

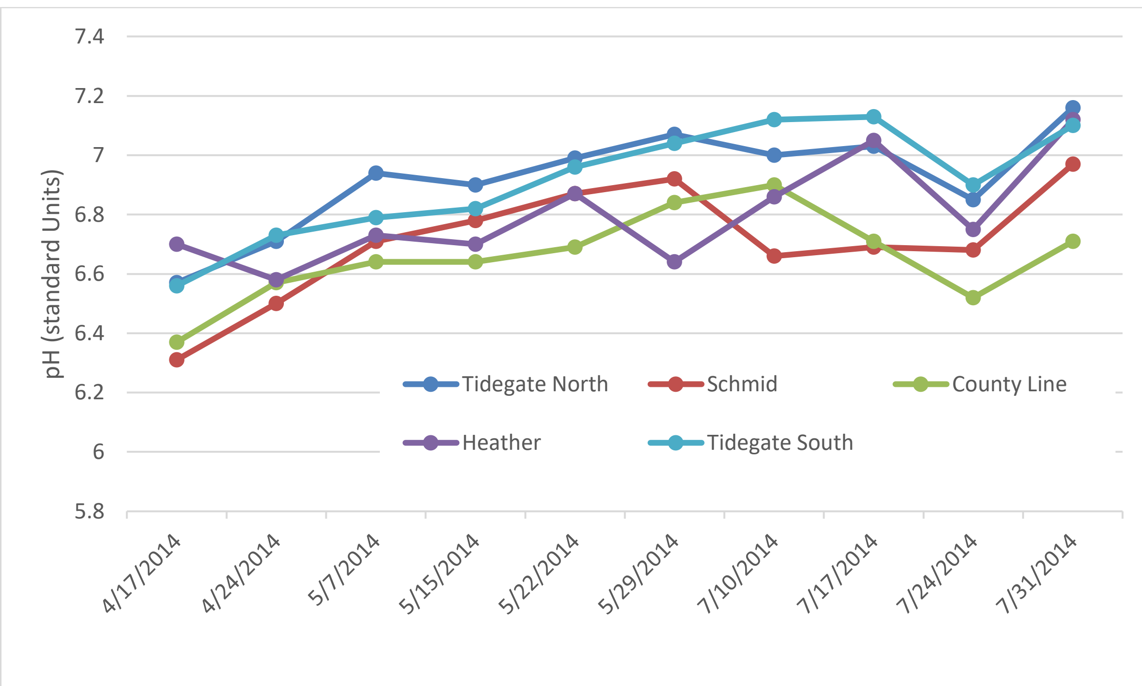

Figure 11: 2014 pH (standard units)

pH measurements were obtained at all sites for all dates in 2014.

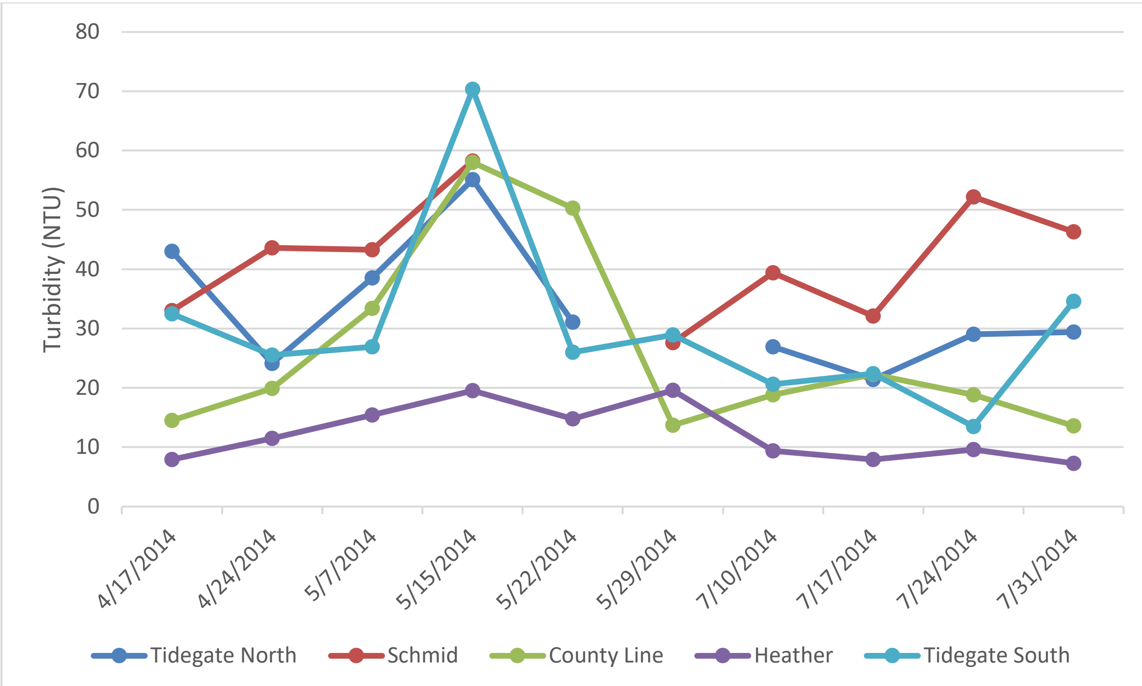

Figure 12: 2014 turbidity (NTU)

Due to equipment issues, turbidity measurements were not obtained at Schmid on 5/22 or Tidegate North on 5/29.

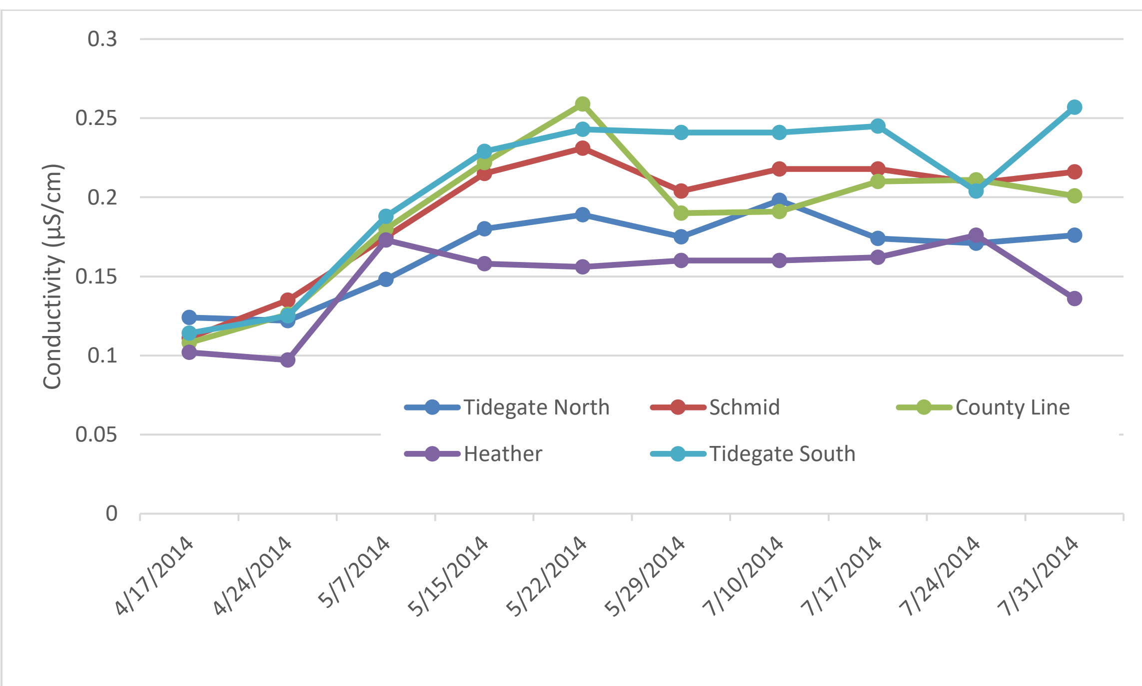

Figure 13: 2014 conductivity (µS/cm)

Conductivity measurements were obtained at all sites for all dates in 2014.

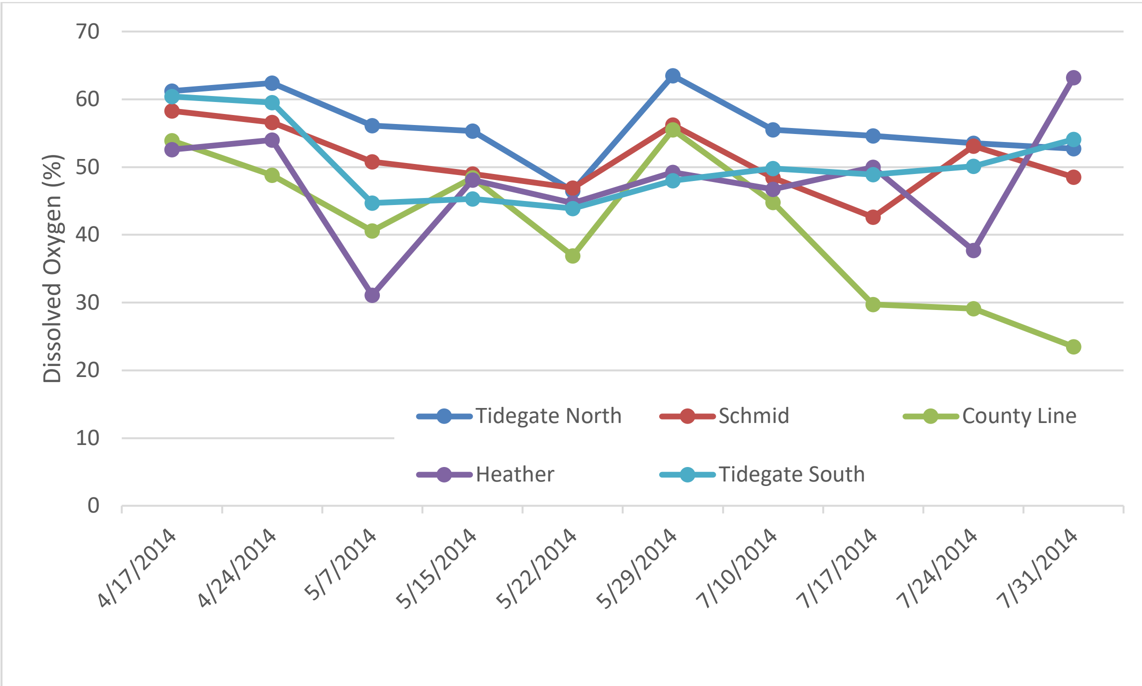

Figure 14: 2014 dissolved oxygen (percent)

Dissolved oxygen measurements were obtained at all sites for all dates in 2014.

Sampling in 2015 was conducted in the spring only. On the last day of sampling, 5/25/2015, the gate accessing Tidegate North was locked. Water samples and ambient measurements were not obtained that day.

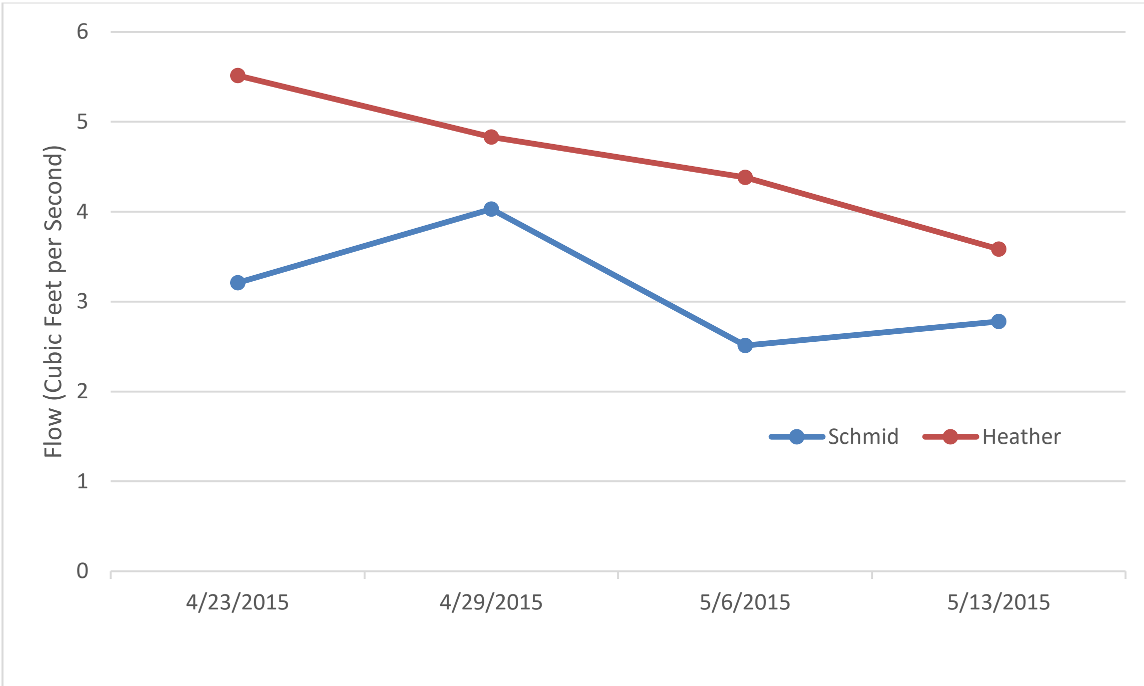

Figure 15: 2015 flow (cubic feet per second)

The flows at County Line during the 2015 sampling visits were too low to measure.

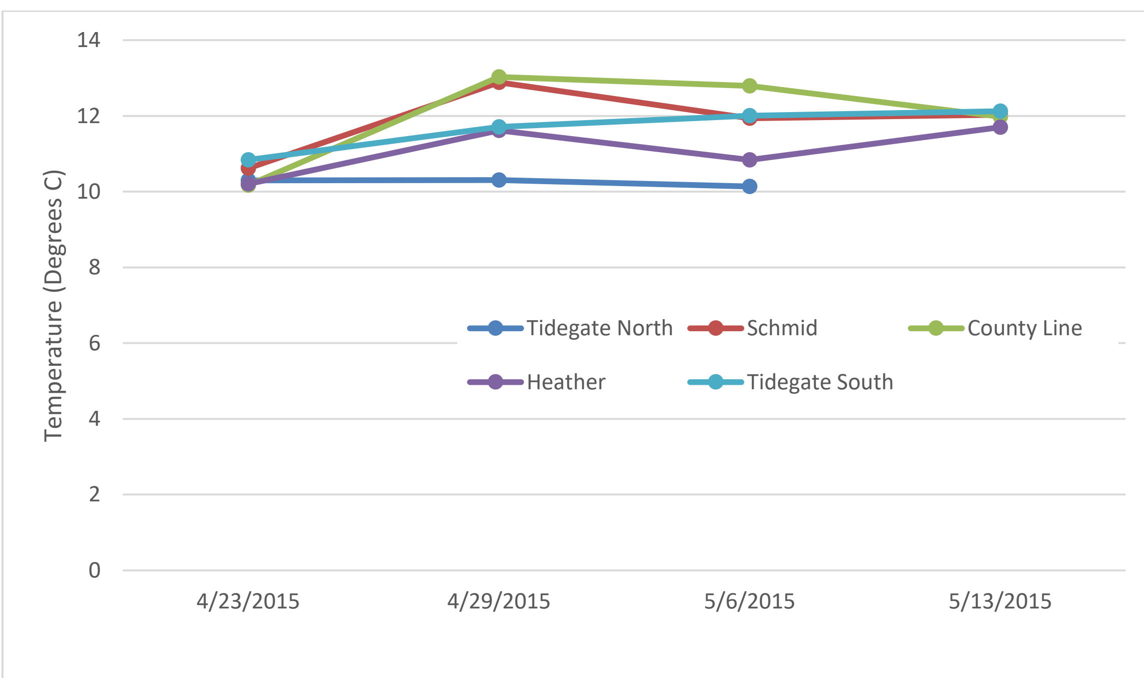

Figure 16: 2015 temperature (degrees centigrade)

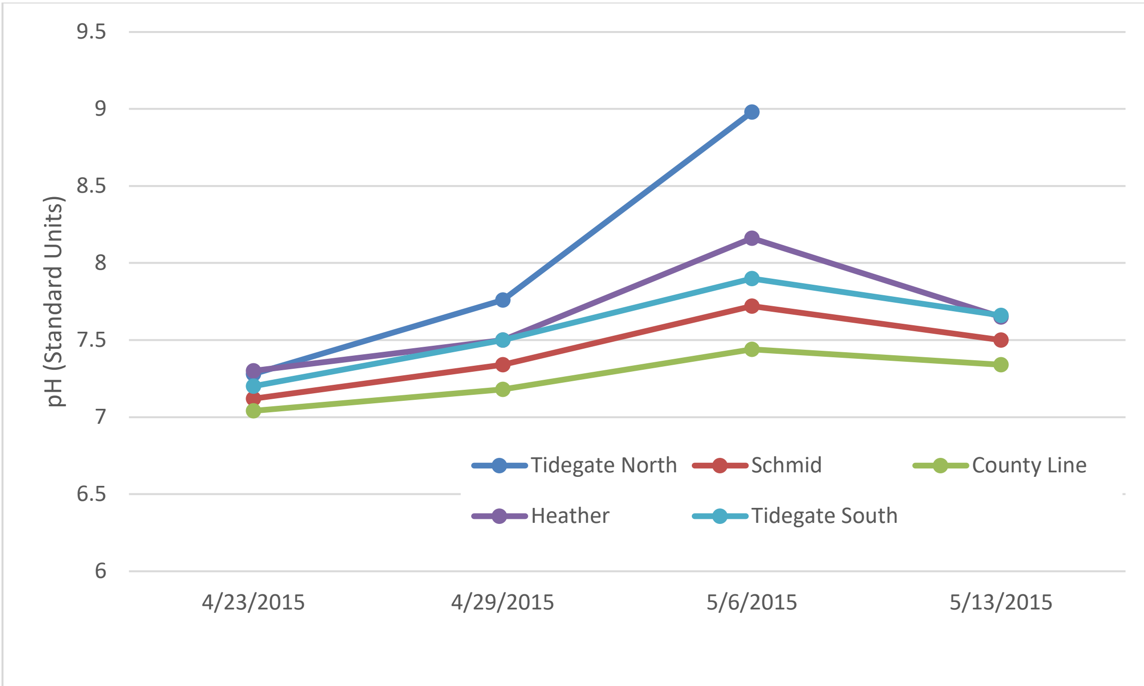

Figure 17: 2015 pH (standard units)

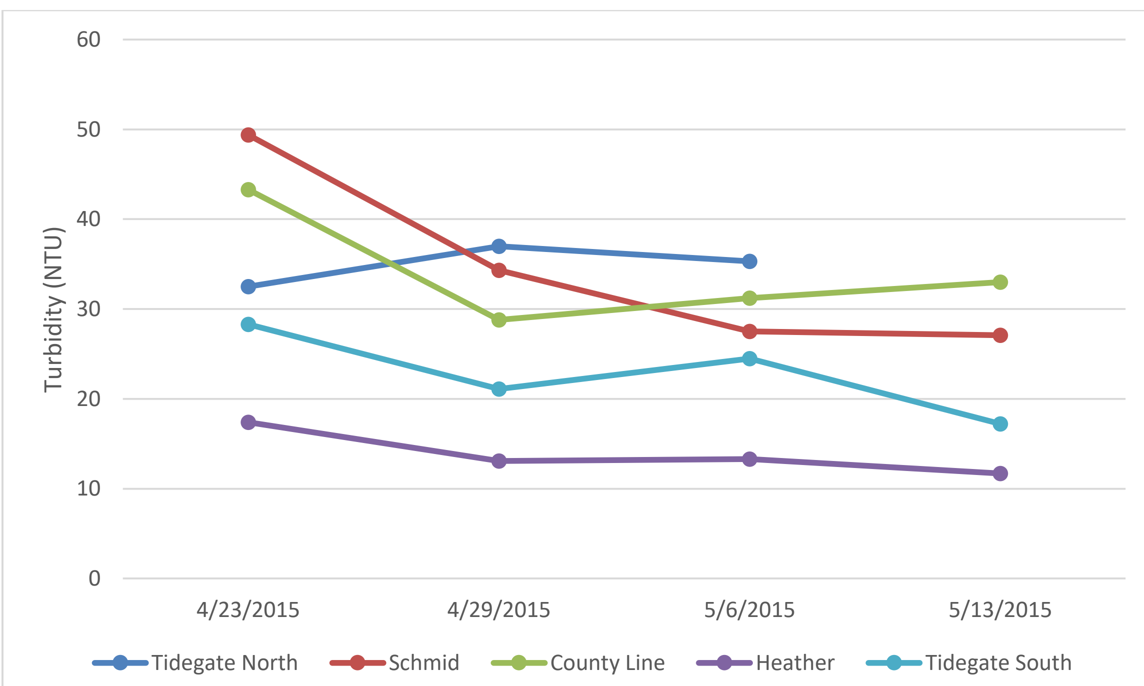

Figure 18: 2015 turbidity (NTU)

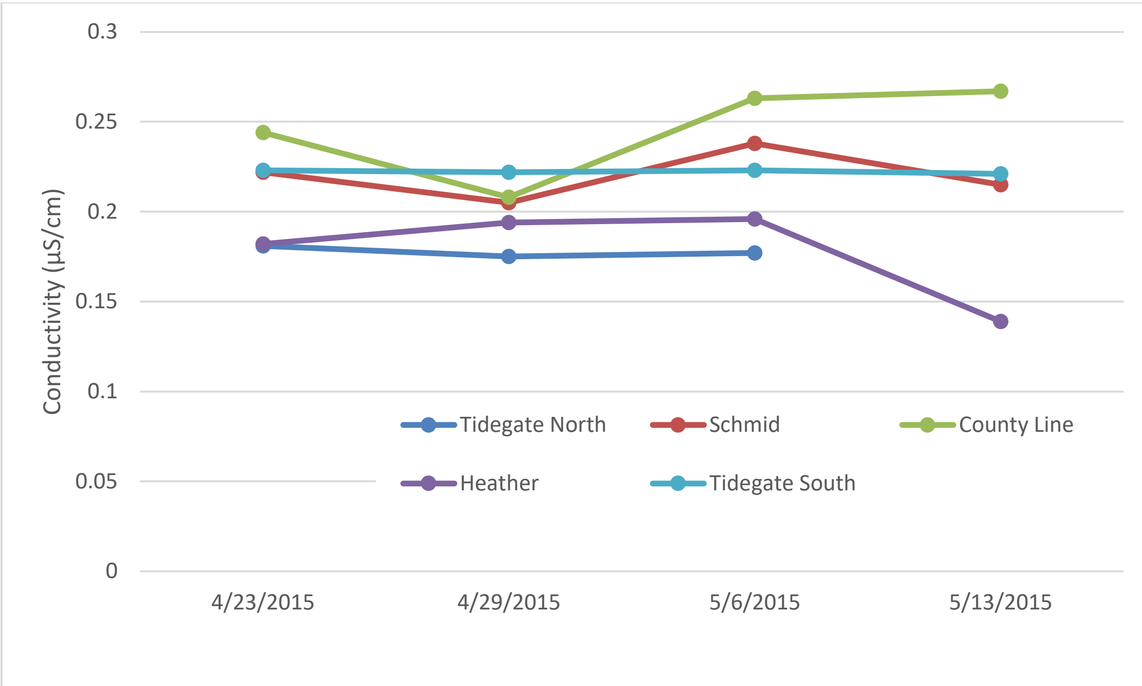

Figure 19: 2015 conductivity (µS/cm)

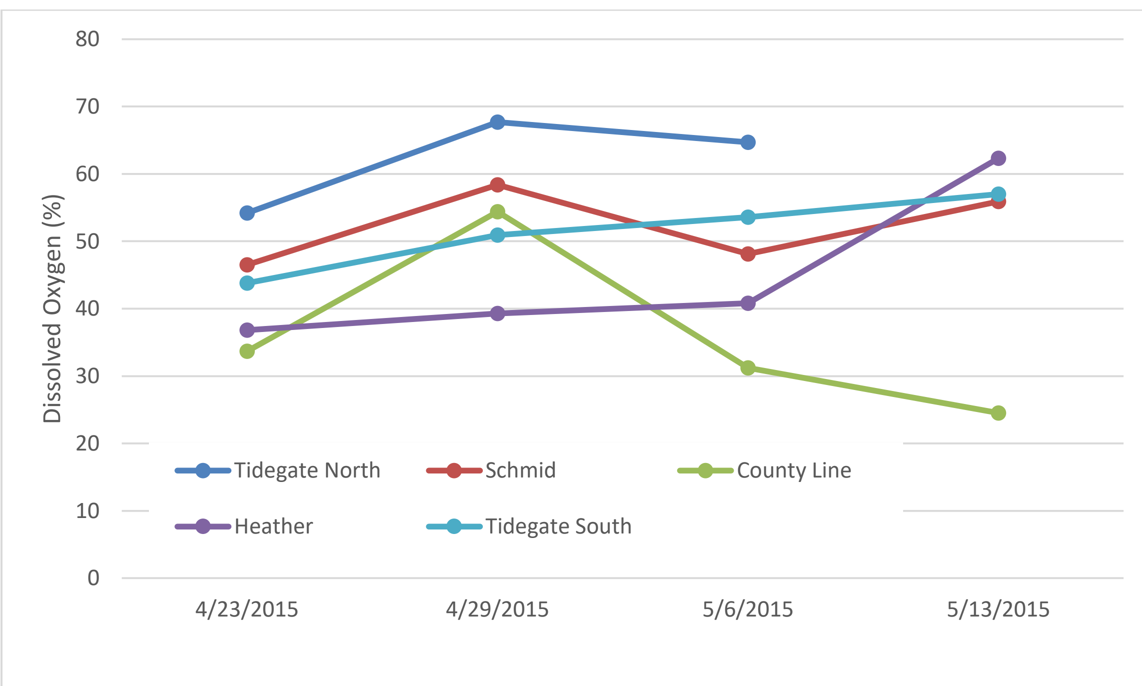

Figure 20: 2015 dissolved oxygen (percent)

Findings

Ambient water quality information indicates the Grayland ditch system has relatively consistent water temperatures, dissolved oxygen and pH levels during the spring and summer. All areas of the system show some salt water intrusion, as would be expected in a tide gate managed ditch. Although this system is high in silt and other organic material, total suspended solid samples and turbidity measurements generally indicated relatively good water clarity. Dissolved oxygen levels are consistently below aquatic life standards.

Cribbing and covering BMPs have been implemented on most (about 95%) of the ditches bordering the cranberry bogs draining into the Grayland Ditch. Water sampling test results by WSDA and Ecology have consistently shown the presence of pesticides, including chlorpyrifos and diazinon, in the Grayland Ditch. It can be concluded the BMPs, as currently established, are not adequate to prevent pesticides applied to the cranberry bogs via the irrigation systems from eventually entering the Grayland Ditch. Pesticides containing the active ingredients diazinon or chlorpyrifos are generally detected above established water quality standards. While there may be other factors besides open ditches or inadequate BMPs contributing to the contamination of the Grayland Ditch, current research does not indicate what those factors may be. Unless other factors are identified and remediated, it is the recommendation of this report the next and final step of the *Washington State Pesticide Management Strategy for Water Quality Protection* be implemented. This step would be promulgating and implementing a rule prohibiting the application of products containing diazinon or chlorpyrifos to the cranberry bogs in the area draining into the Grayland Ditch.

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Appendix A: Glossary, Acronyms, and Abbreviations

Glossary

303(d) list: Section 303(d) of the federal Clean Water Act requires Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality limited estuaries, lakes, and streams that fall short of state surface water quality standards.

Acetylcholinesterase: An enzyme that hydrolyzes the neurotransmitter acetylcholine: its action is blocked by nerve gases and certain drugs.

Carbamate insecticides: N-methyl carbamate insecticides are similar to organophosphate insecticides in that they are nerve agents that inhibit cholinesterase enzymes. However they differ in action from the organophosphate compounds in that the inhibitory effect on cholinesterase is brief. Carbamates degrade rapidly in the environment.

Clean Water Act: A federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

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.

Exceeds criteria: Fails to meet criteria.

Grab sample: A discrete sample from a single point in the water column or sediment surface.

Organophosphate pesticides: Organophosphate pesticides are all derived from phosphoric acid. They are nerve poisons which kill the target pest (usually insects). The mechanism of action is similar to carbamate insecticides, both are neurotoxins, inhibiting the enzyme acetylcholinesterase by inhibiting cholinesterase. They break down relatively quickly in the environment.

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

Pesticide: A pesticide is any substance or mixture of substance intended for preventing, destroying, repelling or mitigating any pest. Pests include nuisance microbes, plants, fungus, and animals.

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, salt waters, wetlands and all other surface waters and watercourses within the jurisdiction of Washington State.

Total Maximum Daily Load (TMDL): Water cleanup plan. A calculated or managed distribution of a substance in a waterbody designed to protect it from exceeding water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a Margin of Safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

Total suspended solids: The suspended particulate matter in a water sample as retained by a filter.

Acronyms and Abbreviations

Following are acronyms and abbreviations used frequently in this report.

BMP Best management practices
BOD Biological Oxygen Demand
CCC Criteria Continuous Concentrations
CFU Cubic Feet per Second
CMC Criteria Maximum Concentration
DO Dissolved Oxygen
Ecology Washington State Department of Ecology
EPA U.S. Environmental Protection Agency
FIFRA Federal Insecticide Fungicide Rodenticide Act
GHCDD-1 Grays Harbor County Drainage Ditch No. 1
MEL Manchester Environmental Laboratory
MQO Measurement Quality Objectives
NAD North American Datum
NOAA National Oceanic and Atmospheric Administration
NRAS Natural Resources Assessment Section
NRWQC National Recommended Water Quality Criteria
NTU Nephelometric Turbidity Units
OP Organophosphate
PCDD-1 Pacific County Drainage Ditch No. 1
QAPP Quality Assurance Project Plan
QA/QC Quality Assurance / Quality Control
RPD Relative percent difference
SOP Standard operating procedures
SU Standard Units
TSS Total Suspended Solids
WAC Washington Administrative Code
WSDA Washington State Department of Agriculture

Units of Measurement

°C degrees centigrade
mg/L milligrams per liter
s.u. standard unit
µg/L micrograms per liter (parts per billion)
µS/cm microSeimans per centimeter

Appendix B: Summarized Study Results from Common Sampling Sites, 1996-2009 (Ecology).

Location			1996	1998	2002	2009	
3	Schmid Road	Azinphos methyl	number	26	5	3	
0			detections	16	3	2	
nd			mean	0.13	0.25	0.11	
nd			range	0.010-0.73	0.004-1.2	0.033-0.20	
3		Chlorpyrifos	n	26	5	3	
3			detections	7	5	2	
0.09			mean	0.021	0.38	0.008	
0.051-0.13			range	0.003-0.016	0.0095-1.8	0.0050-0.010	
3		Diazinon	n	26	5	3	
2			detections	26	5	3	
0.76			mean	0.86	1.1	0.17	
0.034-2.2			range	0.026-5.42	0.033-4.4	0.018-0.35	
3	Grange Road	Azinphos-methyl	n	-	-	3	
0			detections	-	-	3	
nd			mean	-	-	0.13	
nd			range	-	-	0.019-0.020	
3		Chlorpyrifos	n	-	-	3	
3			detections	-	-	3	
0.14			mean	-	-	0.013	
0.089-0.21			range	-	-	0.0065-0.023	
3		Diazinon	n	-	-	3	
2			detections	-	-	3	
0.054			mean	-	-	1.9	
34-0.094			range	-	-	0.033-5.7	0.0
3	County Line Road	Azinphos-methyl	n	-	-	3	
0			detections	-	-	3	
nd			mean	-	-	0.18	
nd			range	-	-	0.020-0.30	
3		Chlorpyrifos	n	-	-	3	
3			detections	-	-	2	
0.16			mean	-	-	0.012	
.1-0.22			range	-	-	0.0067-0.020	0
3		Diazinon	n	-	-	3	
1			detections	-	-	3	
0.029			mean	-	-	0.80	
32-0.055			range	-	-	0.036-2.0	0.0

Location			1996	1998	2002	2009
PCDD-1						
Heather Road	Azinphos-methyl	number	-	-	3	3
		detections	-	-	3	0
		mean	-	-	0.11	nd
		range	-	-	0.048-0.22	nd
	Chlorpyrifos	number	-	-	3	3
		detections	-	-	3	1
		mean	-	-	0.027	0.027
		range	-	-	0.019-0.039	0.022-0.052
	Diazinon	number	-	-	3	3
		detections	-	-	3	3
		mean	-	-	0.16	0.19
		range	-	-	0.079-0.31	0.089-0.36
Jacobson Road	Azinphos-methyl	number	-	-	3	3
		detections	-	-	3	0
		mean	-	-	0.08	nd
		range	-	-	0.0079-0.22	nd
	Chlorpyrifos	number	-	-	3	3
		detections	-	-	3	2
		mean	-	-	0.39	0.046
		range	-	-	0.034-0.59	0.035-0.082
	Diazinon	number	-	-	3	3
		detections	-	-	3	3
		mean	-	-	0.31	0.21
		range	-	-	0.11-0.69	0.096-0.42
Larkin Road	Azinphos-methyl	number	26	5	3	-
		detections	23	5	3	-
		mean	0.17	0.33	0.050	-
		range	[illegible]	[illegible]	[illegible]	-
	Chlorpyrifos	number	26	5	3	-
		detections	25	5	3	-
		mean	0.44	0.59	0.028	-
		range	0.003-3.7	0.019-1.3	0.015-0.036	-
	Diazinon	number	26	5	3	-
		detections	25	5	3	-
		mean	0.28	2.4	0.48	-
		range	0.008-1.7	[illegible].033-7.0	0.20-0.64	-
Tidegate	Azinphos-methyl	number	-	-	3	3
		detections	-	-	3	0
		mean	-	-	0.06	nd
		range	-	-	0.0067-0.15	nd
	Chlorpyrifos	number	-	-	3	3
		detections	-	-	3	2
		mean	-	-	0.025	0.08
		range	-	-	0.014-0.030	0.027-0.18
	Diazinon	number	-	-	3	3
		detections	-	-	3	3
		mean	[illegible]	[illegible]	0.57[illegible]	0.13
		range	[illegible]	[illegible]	0.18-0.71	0.085-0.2[illegible]

Appendix C: Environmental (Ambient) Measurements

Location	Date	Discharge	Water Temp(°C)	pH	Turb (NTU)	Cond (µS/cm)	Cond (MS/cm)	DO(%)	DO(mg/L)	TSS (mg/L)
Tidegate North	4/25/13	NA	NA	NA	NA	NA	NA	NA	NA	8.5
Tidegate North	5/1/13	NA	8.30	7.52	NA	175	0.175	62.7	7.45	8
Tidegate North	5/8/13	NA	11.61	7.24	NA	174	0.174	66.6	7.26	11
Tidegate North	5/15/13	NA	11.43	6.95	NA	171	0.171	67.1	7.31	18.5
Tidegate North	5/22/13	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tidegate North	7/9/13	NA	13.76	7.08	19.2	179	0.179	68.7	7.11	6.5
Tidegate North	7/18/13	NA	13.30	7.08	18.6	181	0.181	63.5	6.63	6.5
Tidegate North	7/25/13	NA	12.82	7.04	17.5	176	0.176	64.6	6.88	6
Schmid	4/25/13	NA	NA	NA	NA	NA	NA	NA	NA	11
Schmid	5/1/13	6.36678	11.73	6.92	NA	233	0.233	40.1	4.41	11.5
Schmid	5/8/13	7.6644	12.85	6.92	NA	197	0.197	55.7	5.84	10.5
Schmid	5/15/13	4.8186	12.32	6.82	NA	195	0.195	54.4	5.85	19
Schmid	5/22/13	4.6652	11.43	6.96	NA	193	0.193	55.7	6.11	12
Schmid	7/9/13	5.1496	13.43	6.96	26.2	233	0.233	47.2	4.95	10
Schmid	7/18/13	2.53052	13.92	6.88	100	229	0.229	37	3.96	83.3
Schmid	7/25/13	2.02868	14.11	6.82	23.1	213	0.213	56	5.77	12

Location	Date	Discharge	Water Temp(°C)	pH	Turb (NTU)	Cond (µS/cm)	Cond (MS/cm)	DO(%)	DO(mg/L)	TSS (mg/L)
County Line	4/25/13	NA	NA	NA	NA	NA	NA	NA	NA	9
County Line	5/1/13	2.7264	11.55	6.00	NA	216	0.216	35.5	3.9	11.5
County Line	5/8/13	2.606	12.70	6.92	NA	187	0.187	52.8	5.62	8
County Line	5/15/13	1.8956	12.06	6.76	NA	185	0.185	48.2	5.18	10
County Line	5/22/13	2.5832	11.26	6.83	NA	194	0.194	47.7	5.25	13
County Line	7/9/13	0.889339	14.00	6.8	24.6	208	0.208	34.1	3.52	11

County Line	7/18/13	0.51191	14.68	6.7	68.5	217	0.217	28.8	2.74	24.5
County Line	7/25/13	0.713712	14.28	6.75	40.1	200	0.2	48.5	4.99	12
Heather	4/25/13	NA	NA	NA	NA	NA	NA	NA	NA	ND
Heather	5/1/13	4.33136	9.88	6.9	NA	157	0.157	50.2	5.76	15.5
Heather	5/8/13	5.98	11.92	6.96	NA	134	0.134	62.4	6.77	5
Heather	5/15/13	3.97925	11.70	6.925	NA	145	0.145	58.2	6.38	5.5
Heather	5/22/13	4.17075	11.07	NA	NA	150	0.15	56.7	6.37	ND
Heather	7/9/13	2.52888	14.13	6.88	NA	134	0.134	57.7	5.91	5.5
Heather	7/18/13	2.337	13.40	6.97	11.2	135	0.135	62.6	6.22	ND
Heather	7/25/13	1.75972	12.24	6.92	5.9	158	0.158	52.4	5.54	ND
Location	Date	Discharge	Water Temp(°C)	pH	Turb (NTU)	Cond (µS/cm)	Cond (MS/cm)	DO(%)	DO(mg/L)	TSS (mg/L)
Tidegate South	4/25/13	NA	NA	NA	NA	NA	NA	NA	NA	10
Tidegate South	5/1/13	NA	9.61	7.3	NA	264	0.264	45.4	5.22	7
Tidegate South	5/8/13	NA	12.11	7.13	NA	226	0.226	54.8	5.94	5.5
Tidegate South	5/15/13	NA	11.94	6.96	NA	226	0.226	56.4	6.07	7.5
Tidegate South	5/22/13	NA	11.11	7.04	NA	209	0.209	59.1	6.51	8
Tidegate South	7/9/13	NA	14.09	7.11	12.9	232	0.232	55.5	5.72	5.5
Tidegate South	7/18/13	NA	13.98	7.16	12.1	227	0.227	57.8	5.97	ND
Tidegate South	7/25/13	NA	13.40	7.08	10.3	232	0.232	56.8	5.97	ND

Temp

	4/17/2014	4/24/2014	5/7/2014	5/15/2014	5/22/2014	5/29/2014	7/10/2014	7/17/2014	7/24/2014	7/31/2014
Tidegate North	10.48	10.56	10.62	12.67	12.46	12.56	14.12	13.46	14.02	13.74
Schmid	10.98	11.05	12.54	15.14	14.65	12.8	15.38	14.73	15.25	14.88
County Line	10.93	10.98	12.51	16.28	16.72	12.89	15.04	16.24	15.02	14.59
Heather	10.56	10.49	11.01	14.58	14.42	12.65	14.68	14.6	14.74	15.35
Tidegate South	10.67	10.67	11.32	14.43	14.23	13.01	14.94	14.58	15.34	14.85

pH

	4/17/2014	4/24/2014	5/7/2014	5/15/2014	5/22/2014	5/29/2014	7/10/2014	7/17/2014	7/24/2014	7/31/2014
Tidegate North	6.57	6.71	6.94	6.9	6.99	7.07	7	7.03	6.85	7.16
Schmid	6.31	6.5	6.71	6.78	6.87	6.92	6.66	6.69	6.68	6.97
County Line	6.37	6.57	6.64	6.64	6.69	6.84	6.9	6.71	6.52	6.71
Heather	6.7	6.58	6.73	6.7	6.87	6.64	6.86	7.05	6.75	7.12
Tidegate South	6.56	6.73	6.79	6.82	6.96	7.04	7.12	7.13	6.9	7.1

Conductivity

	4/17/2014	4/24/2014	5/7/2014	5/15/2014	5/22/2014	5/29/2014	7/10/2014	7/17/2014	7/24/2014	7/31/2014
Tidegate North	0.124	0.122	0.148	0.18	0.189	0.175	0.198	0.174	0.171	0.176
Schmid	0.111	0.135	0.175	0.215	0.231	0.204	0.218	0.218	0.209	0.216
County Line	0.108	0.126	0.18	0.222	0.259	0.19	0.191	0.21	0.211	0.201
Heather	0.102	0.097	0.173	0.158	0.156	0.16	0.16	0.162	0.176	0.136
Tidegate South	0.114	0.125	0.188	0.229	0.243	0.241	0.241	0.245	0.204	0.257

Dissolved Oxygen (%)

	4/17/2014	4/24/2014	5/7/2014	5/15/2014	5/22/2014	5/29/2014	7/10/2014	7/17/2014	7/24/2014	7/31/2014
Tidegate North	61.2	62.4	56.1	55.3	46.5	63.5	55.5	54.6	53.5	52.7
Schmid	58.3	56.6	50.8	49	46.9	56.2	48.4	42.6	53.1	48.5
County Line	53.9	48.8	40.6	48.4	36.9	55.5	44.8	29.7	29.1	23.5
Heather	52.6	54	31.1	48.1	44.7	49.2	46.7	50	37.7	63.2
Tidegate South	60.4	59.5	44.7	45.3	43.9	48	49.8	48.9	50.1	54.1

Dissolved Oxygen (mg/L)

	4/17/2014	4/24/2014	5/7/2014	5/15/2014	5/22/2014	5/29/2014	7/10/2014	7/17/2014	7/24/2014	7/31/2014
Tidegate North	6.87	6.94	6.26	7.92	4.97	7.04	5.72	7.63	5.63	5.58
Schmid	6.47	6.23	5.43	6.65	4.65	6.2	4.89	5.78	5.35	5.13
County Line	5.99	5.37	4.36	6.4	4.78	6.19	4.68	3.88	2.94	2.43
Heather	5.83	5.94	3.47	6.64	4.53	5.23	4.63	6.98	3.86	6.39
Tidegate South	6.71	6.61	0.487	6.24	4.5	5.35	5.12	6.64	5.04	6.39

Turbidity

	4/17/2014	4/24/2014	5/7/2014	5/15/2014	5/22/2014	5/29/2014	7/10/2014	7/17/2014	7/24/2014	7/31/2014
Tidegate North	43	24.1	38.5	55.1	31.1		26.9	21.4	29	29.4
Schmid	33	43.6	43.3	58.2		27.6	39.4	32.1	52.2	46.3
County Line	14.5	19.9	33.4	58	50.3	13.7	18.8	22.3	18.8	13.6
Heather	7.9	11.5	15.4	19.5	14.8	19.6	9.4	7.9	9.6	7.3
Tidegate South	32.5	25.5	26.9	70.3	26	28.9	20.6	22.4	13.5	34.6

Flow

	4/17/2014	4/24/2014	5/7/2014	5/15/2014	5/22/2014	5/29/2014	7/10/2014	7/17/2014	7/24/2014	7/31/2014
Tidegate North	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Schmid	NA	NA	4.28	4.67	2.65	3.63	0.28	0.99	3.34	NA
County Line	7.58	NA	2	0.87	0.29	1.52	0	0	0	0
Heather	21.67	NA	5.42	4.61	4.26	3.42	1.66	2.77	4.52	1.91
Tidegate South	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Temp				
	4/23/2015	**4/29/2015**	**5/6/2015**	**5/13/2015**
Tidegate North	10.3	10.31	10.14	NA
Schmid	10.62	12.89	11.94	12.03
County Line	10.17	13.03	12.79	11.98
Heather	10.21	11.62	10.84	11.7
Tidegate South	10.84	11.71	12.01	12.13
pH				
	4/23/2015	**4/29/2015**	**5/6/2015**	**5/13/2015**
Tidegate North	7.28	7.76	8.98	NA
Schmid	7.12	7.34	7.72	7.5
County Line	7.04	7.18	7.44	7.34
Heather	7.3	7.5	8.16	7.65
Tidegate South	7.2	7.5	7.9	7.66
Conductivity				
	4/23/2015	**4/29/2015**	**5/6/2015**	**5/13/2015**
Tidegate North	0.181	0.175	0.177	NA
Schmid	0.222	0.205	0.238	0.215
County Line	0.244	0.208	0.263	0.267
Heather	0.182	0.194	0.196	0.139
Tidegate South	0.223	0.222	0.223	0.221
Dissolved Oxygen (%)				
	4/23/2015	**4/29/2015**	**5/6/2015**	**5/13/2015**
Tidegate North	54.2	67.7	64.7	NA
Schmid	46.5	58.4	48.1	55.9
County Line	33.7	54.4	31.2	24.5
Heather	36.8	39.3	40.8	62.3
Tidegate South	43.8	50.9	53.6	57
Dissolved Oxygen (mg/L)				
	4/23/2015	**4/29/2015**	**5/6/2015**	**5/13/2015**
Tidegate North	6.11	7.64	7.32	NA
Schmid	5.22	6.19	5.21	6.04
County Line	3.81	5.75	3.31	2.66
Heather	4.16	4.25	4.56	6.71
Tidegate South	4.88	5.55	5.79	6.23
Turbidity				
	4/23/2015	**4/29/2015**	**5/6/2015**	**5/13/2015**
Tidegate North	32.5	37	35.3	NA
Schmid	49.4	34.3	27.5	27.1
County Line	43.3	28.8	31.2	33
Heather	17.4	13.1	13.3	11.7
Tidegate South	28.3	21.1	24.5	17.2
Flow				
	4/23/2015	**4/29/2015**	**5/6/2015**	**5/13/2015**
Schmid	3.211	4.028	2.511	2.777
Heather	5.515	4.829	4.382	3.582
Tidegate North	NA	NA	NA	NA
County Line	NA	NA	NA	NA
Tidegate South	NA	NA	NA	NA