Dan Albrecht

From: Kristen Balschunat <kristen@winooskinrcd.org>
Sent: Thursday, April 25, 2019 3:45 PM
To: Ann Costandi; Chelsea Mandigo; Tim Grover; Tom Dipietro; Chris Robinson; Lbeaudoin@town.milton.vt.us; James Sherrard; Karen Adams; Jenna Olson; llackey@btv.aero; Claire.Forbes@uvm.edu; Jennifer.Callahan@vermont.gov; Dan Albrecht; Dave Allerton
Cc: Gianna Petito
Subject: MEMO: Homework for Water Quality Sampling Discussion
Attachments: Stream Team 2018 Water Quality Monitoring Report_FINAL (1).pdf; 2019 RRST LaRosa Proposal.docx.pdf; Screenshot 2019-04-25 at 3.34.06 PM.png

MEMO: Homework for Water Quality Sampling Discussion
TO: CCRPC MS4 Subcommittee
FROM: Kristen Balschunat, Stream Team Coordinator

Hello MS4 representatives. I'm writing to give you some "homework" in preparation for our discussion about the Stream Team water quality monitoring at the May MS4 meeting. Please come prepared with the answers to the six questions at the end of this email so we can have a productive discussion. My District Manager, Gianna, will also be there to help share how we interpreted the data and what further analysis could be done.

Some background - the LaRosa Partnership is a state-funded program that pays for the cost of processing samples at the lab. We submit a proposal annually outlining our sites, parameters and goals. This year LaRosa published four main sampling goals that they are willing to fund (see attached screenshot from RFP) Of note ... long term monitoring for the sake of long term monitoring is no longer supported. If we've been monitoring the same site on an impaired brook for 7 years, maybe it's time to switch it up by moving upstream to identify a source or selecting a new stream altogether.

Now it's time for you to reflect on which of those goals could be achieved in your town. Consider the following

1. Are there any water-related maps that may be helpful to bring to the table for this discussion?
2. What makes the waters in your town unique?
3. What are the top 3 ways people in your town interact with streams?
4. Which stream(s) are impaired? Do you know the main sources contributing to that impairment? What questions do you have about this stream?
5. Does your town have any BMP installations planned in the next 3 years? If so, where?
6. Which stream in your town is the healthiest? How can we promote it's continued success?

For your reference, here is a link to the Site Map from 2018 (working on final edits for 2019).
https://drive.google.com/open?id=1K98F4bBO2E6p5lLKgSw7bxRSpQlzoo8Q&usp=sharing

We are looking forward to a good discussion. Let me know if you have questions beforehand. We hope this meeting will set us up with a plan for the next 3-5 years of monitoring, so we appreciate the time you put into preparing. Also attached for your reference is 2018 Final Report and 2019 LaRosa Proposal (nearly approved - waiting for final paperwork).

Best,

Kristen
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Kristen Balschunat (she/her)

Table 1. LaRosa Analytical Service Grant Monitoring Categories

The table below includes information on the five typical LaRosa Partnership monitoring designs that have been conducted over the years. The goal is to provide additional guidance for volunteer water quality monitoring groups and recommend a more standardized approach to sampling design. This will support meeting the Vermont DEC's Watershed Management Division (WSMD) monitoring goals and the goals for local watershed groups. Many sampling programs may be able to achieve multiple goals though their programs.

Waterbody Status, Spatial or Temporal - Baseline monitoring/Stressor ID - has the goal of identifying the conditions of waters across a basin or related to a specific stressed, high quality water, or waters above and below a WWTF. Sampling programs can target more than one of these goals and can serve to engage watershed groups in understanding water quality issues. Monitoring can be done on a regular schedule and does not require the targeting of high flow events although such sampling could be helpful to understand some pollutants generally tied to runoff (phosphorus/sediment).

Source ID monitoring spatial, temporal or flow based - has the goal of identifying sources of pollution impacting downstream waters. Monitoring can be broken down into parameters and water quality issues where targeting high flow events is not necessary and where targeting high flow events is strongly recommended for effectively identifying source areas. As a first cut, the areas where monitoring high flows is essential are those where the goal is to identify sources of phosphorus loading impacting lakes, sediment sources, and to a lesser degree nitrogen loading to Long Island Sound. The key to identifying pollutant sources is an iterative approach working upstream from waterbodies that have known elevated levels to bracket potential sources on larger streams and to sample smaller tributaries to narrow down the location of primary source areas. Through this iterative approach monitoring can be an ongoing effort over many years including sampling to measure impact of project implementation to determine success in reducing pollutant levels.

Swimming Hole Monitoring - has the goal of monitoring active swimming holes to provide the public information as to when it's safe to swim. This is a priority for swimming holes where sampling has not been done, is limited or have ongoing elevated levels of E. coli. Sampling is generally done weekly and the results are posted on-site at the swimming hole and through other means to notify the public.

Evaluation of a treatment or management practice (Experimental studies) – The LaRosa Partnership Program supports scientific studies conducted by, or in partnership with volunteer watershed groups. These studies have focused on the effectiveness of implementation practices at improving water quality, but other studies could be considered if they are of significant interest and importance in helping the Watershed Management Division with our monitoring goals. WWTF sampling to determine effectiveness can only be conducted during base flow periods. Monitoring can be done for one to three years to document existing conditions. This can be repeated in the future timed with the VTDEC-MAPP assessment phase of the planning cycle or changes in watershed that might increase loading.

RETHINK RUNOFF

Volunteer Water Quality Monitoring Analytical Services: *Rethink Runoff Stream Team*

Proposal for 2019 LaRosa Partnership Program

Submitted: 2/7/19

This proposal requests laboratory services for the Rethink Runoff/Stream Team volunteer water quality monitoring program. The Rethink Runoff Stream Team (RRST) is a project that engages citizens across a nine-municipality area (Burlington, Essex, Essex Junction, Milton, Shelburne, South Burlington, Williston, Colchester and Winooski) to implement projects that reduce nonpoint source pollution and stormwater volume at the local level. The program is managed by Municipal Separate Storm Sewer designated towns of Chittenden County (MS4 Committee) and run by the Winooski Natural Resources Conservation District.

1) Description of the project waters

The proposed sampling sites for 2019 include locations on Alder Brook, Allen Brook, Centennial Brook, Indian Brook, Engelsby Brook, Mallets Creek, Morehouse Brook, Muddy Brook, Munroe Brook, Potash Brook and Sunderland Brook. All eleven of these watersheds contain densely, developed urban and suburban areas. All streams, except for Allen Brook, have been identified as stormwater impaired by the VT DEC. Our data consistently shows high phosphorus and chloride levels above the EPA standard. Allen Brook is not listed as impaired so we hope to provide data to the Town of Milton so informed decisions can be made to maintain the good water quality. More details about specific sites and reasons for sampling can be found on page 2.

2) Needs for the data and intended data usage

RRST exists to inform the public about water quality concerns, and to inspire the adoption of behaviors that reduce the stormwater footprint of urban and suburban areas. Chittenden County is the most developed county in the state so it is important for residents to understand their contribution to the health of Lake Champlain. RRST can more effectively achieve the goal of public education by showing evidence about how developed lands impact stream health.

RRST goals for stream monitoring are as follows:

1. Build upon the current dataset to determine long-term trend conditions at each stream site.
2. Inform towns about effectiveness of BMP implementation and/or monitor impacts of new urban development.
3. Monitor higher quality waters to watch for signs of degradation
4. Inform communities about the condition of these streams, to inspire adoption of practices and behaviors that reduce nonpoint source pollution and stormwater volume.

RETHINK RUNOFF

3) Sample Collection Methods

Sampling Sites: The table below summarizes the site locations. This year RRST proposes to add one new sampling site at Allen Brook and to abandon the following sites due to challenging access, multiple sampling efforts at the same site or the recommendation of our basin planner: Potash 40, Bartlett 10 and Munroe 10. The coordinates of the Morehouse sites will be slightly adjusted to capture the data desired by the City of Winooski for BMP analysis.

Stream	***Location***	***Site ID***	***Sampling Reason***	***Types of Samples***	***Lat / Long***
Centennial Brook	Grove Street in Burlington	Centennial 10	Long Term monitoring since 2012	TP, Chloride	44.48453, -73.18423
	Patchen Road in Burlington	Centennial 20	Monitoring since 2017	TP, Chloride	44.47402, -73.17334
Indian Brook	Essex High School	Indian 10	Long Term monitoring since 2012	TP, Chloride	44.49668, -73.11093
	Lang Farm in Essex	Indian 20	Long Term monitoring since 2012	TP, Chloride	44.50442, -73.09190
Malletts Creek	McMullen Road	Malletts 10	Long Term monitoring since 2012	TP, Chloride	44.60855, -73.10693
Munroe Brook	Spear & Webster Intersection	Munroe 20	Monitor impact of new housing development upstream. Monitored since 2012	TP, Chloride, Turbidity	44.38984, -73.20103
Morehouse Brook	Landry Park Winooski - Pine Grove Terrace Branch	Morehouse PGT	Town of Winooski will install a detention pond this year. Monitor effectiveness.	TP, Chloride, Turbidity	44.50081, -73.194
	Landry Park - Industrial Park Branch	Morehouse IPB	Compare two branches of Morehouse brook	TP, Chloride, Turbidity	44.50015, -73.1937
Muddy Brook	River Cove Road in Williston	Muddy 10	Long Term monitoring since 2012	TP, Chloride	44.47293, -73.13505
	Exact location TBD	Muddy 20	Monitor effectiveness of new town easements in watershed	TP, Chloride	Needs scoping
	Van Sicklen Road in Williston	Muddy 30	Long Term monitoring since 2012	TP, Chloride	44.42823, -73.14622
Potash	Kindness Court	Potash 10	Long Term monitoring since	TP,	44.44572,

Brook	in South Burlington		2012	Chloride	-73.21348
	Farrell Street in South Burlington	Potash 20	Long Term monitoring since 2012	TP, Chloride	44.44660, -73.20415
	Dorset Street in South Burlington	Potash 30	Long Term monitoring since 2012	TP, Chloride	44.45150, -73.17849
Engelsby Brook	Pine St in Burlington	Engelsby 10	Long Term monitoring since 2012	TP, Chloride	44.45627, -73.21394
	Redstone Campus in Burlington	Engelsby 20	Monitoring since 2017	TP, Chloride	44.46654, -73.19741
Sunderland Brook	Pearl St Park in Essex Junction	Sunderland 10	Part of Town of Essex chloride Study	TP, Chloride	44.50179, -73.12983
	Just above Rte 2/7 culvert in Colchester	Sunderland 20	Part of Town of Essex chloride Study	TP, Chloride	44.51685, -73.20421
Sunnyside Brook	Near Hercules Rd. Colchester	Sunnyside 10	Brook impaired for chloride, awaiting TMDL	TP, Chloride	TBD
Allen Brook	Milton	Allen 10	Currently NOT stormwater impaired. Will monitor for changes	TP, Chloride, Turbidity	TBD - needs scoping
Alder Brook	Off of Rte 289 in Essex	Alder 10	Part of Town of Essex chloride Study	TP, Chloride	44.51742, -73.06559

Sampling Timeline: Grab samples will be collected on five bi-weekly dates throughout the summer, to be consistent with the timeframe used in previous years. RRST proposes sampling take place on the Tuesday mornings of **June 24th, July 9th, July 23th, August 6th, and August 20st.** Samples will be submitted to the lab no later than 2pm on those dates. RRST also proposes sampling to be carried out during two rain events at six sites during the summer and will give the lab notice the day before sampling and submission to the lab.

Samples: RRST will take two samples at all stream sites to be analyzed for Total Phosphorus (TP) and Chloride (Cl-). Turbidity (TSS) will only be sampled at four sites. Volunteers will also collect field and duplicate samples for quality assurance. These will account for 10% of the entire sample amount. Duplicates and blanks will allow for errors in handling during sample collection and laboratory analysis to be pinpointed, respectively. RRST calculates **308 samples** will be returned to the lab for analysis over the course of the summer sampling period. (230 bi-weekly samples, 28 rainy day samples, 25 duplicates, 25 blanks)

Sample collection: RRST will hold a half-day training to teach volunteers how to properly sample and follow procedures for dropping of samples at the laboratory. Volunteers will be trained using the exact guideline and steps taught by the LaRosa training in the spring.

4) Description of how resulting data will be summarized and reported:
RRST will prepare a report summarizing the data using the appropriate template(s) provided by the VT DEC Watershed Management Division. An additional report will be prepared for the general public as appendix to the full report, which will contain visual graphs and tables depicting pollutant concentration over time and whether sites exceed EPA standards for each pollutant. The full report will be submitted to the VT DEC Watershed Management Division and partners, and the general report to the public via our newsletter (over 450 people subscribed), press release, social media, Rethink Runoff tabling and project events, and the Rethink Runoff website (www.rethinkrunoff.org)

5) Anticipated outcomes and efforts to inform the local public of project results:
The goal of RRST is to inspire a clean water culture in Chittenden County. We anticipate that as more community members learn about water quality concerns affecting local streams and lakes, the more they become empowered to reduce their stormwater footprint. This year RRST will host a Build Your Own Rain Barrel Workshop, a Stream Cleanup and two stormdrain mural projects. We will use these platforms to share our data and also give people the opportunity to engage in solutions. The most important message we can share is that every individual is responsible for the health of the streams in their watersheds.

The data will also be available for Vermont DEC staff. Examples of how this data could be used by VT DEC include 1) assisting the tactical basin planner in where source concerns areas may be/where potential water quality projects could have a positive impact, or 2) identifying where further monitoring may be needed to ascertain if a stream site should be included on VT's 303d list.

6) Implementation plans leading to beneficial improvement in project waters:
RRST exists to inform and educate. The 2019 data report will be provided to each town's planning commission and stormwater department so that it can be taken into consideration during flow restoration plans development or updates. This report will also be made available to VT DEC.

7) Contact Information

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This document was prepared by the Winooski Natural Resources Conservation District, who is contracted by Chittenden County's Ms4 Committee to run the RRST program

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This document was prepared by the Winooski Natural Resources Conservation District, who is contracted by Chittenden County's Ms4 Committee to run the RRST program

2018 Water Quality Monitoring Report

Monitoring Team

The Rethink Runoff Stream Team (formerly known as the Chittenden County Stream Team) is a program that engages citizens across a nine-municipality region to implement projects that reduce non-point source pollution and stormwater volume at the local level. The participating towns are Burlington, Colchester, Essex, Essex Junction, Milton, Shelburne, South Burlington, Williston, and Winooski. The Water Quality Monitoring program is managed by the Chittenden County Regional Planning Commission Clean Water Advisory Committee MS4 subcommittee, coordinated by the Winooski Natural Resources Conservation District, and made possible through the support of the Vermont Department of Environmental Conservation LaRosa program. This report describes the results from the 2018 collection season; the seventh, consecutive year data was collected by this volunteer-led stream water quality monitoring effort in Chittenden County.

When, Where, and What the Stream Team Monitors

The Rethink Runoff Stream Team (RRST) has collected biweekly water quality samples at several pollutant "impaired" or "stressed" stream sites in Chittenden County since 2012. These urban or suburban streams suffer from excessive nutrient loads, sodium chloride, sedimentation, high temperatures, bacteria, and/or other pollutants. Samples were collected on six different dates in 2018: on five, scheduled bi-weekly dates and on one unscheduled "high-flow" date (i.e. during a rain event). High-flow sampling provides a snapshot of the potentially, elevated or diluted pollutant-loads moving through these systems when it rains. Samples were analyzed for turbidity, total phosphorus, and chloride at all 23 sites.

Biweekly sampling dates occurred on July 10th, July 24th, August 7th, and August 21st and September 4th, and all regular bi-weekly sampling occurred during dry/baseflow conditions. The proposed sampling dates (originally 6/26/18-8/21/18) were pushed two weeks later due to staff turnover within WNRCD to give the new Stream Team coordinator time to prepare for the volunteer training and sampling season. One rainy day sampling event occurred on August 18th at sites on Indian, Muddy, Potash, Centennial and Morehouse brooks. Table 1 indicates total rainfall in inches for the day of sampling and the day immediately preceding sampling. While baseflow sampling days all had less than 0.5 inches of rainfall, freshet sampling on August 18th had 1.65 inches.

Report prepared by: Kristen Balschunat & Gianna Petito
Winooski Natural Resources Conservation District

Funded by: LaRosa Partnership, VT Department of Environmental Conservation Watershed Management Division

Table 1. Average regional rainfall, in inches, for the preceding day and day of sampling. Rainfall data for each day was gathered from several station sites across the sampling region (Burlington, Colchester, and Essex) and a daily mean was calculated. Daily means were then summed for the preceding and day-of sampling events. Rainfall data was collected from the National Oceanic and Atmospheric Administration through their daily summaries maps: https://gis.ncdc.noaa.gov/maps/ncei/summaries/daily The specific sampling sites and their locations are listed in Table 2. A map of the sites is shown in Figure 1.

Date	Total Rainfall (inches)
07/10/18	0.4
07/24/18	0.3
08/07/18	0.362
08/18/18	1.65 (freshet)
08/21/18	0
09/04/18	0.2

Table 2. Rethink Runoff Stream Team 2018 Water Quality Sampling Sites. Note that sites located further up a streamshed are labeled with high numbers except at Sunderland where this labeling was switched and Sunderland 20 is actually downstream of Sunderland 10. Stream Team will look into fixing this labeling anomaly with our records and those of the lab starting next field season.

Stream	*Location*	*Site ID*	*Lat / Long*
Centennial Brook	Grove Street in Burlington (by the parking lot for Schmanska Park)	Centennial 10	44.48453, -73.18423
	Patchen Road in South Burlington (through cemetery)	Centennial 20	44.47402, -73.17334
Indian Brook	Parking lot B of Essex High School	Indian 10	44.49668, -73.11093
	Lang Barn in Essex	Indian 20	44.50442, -73.09190
Malletts Creek	McMullen Road	Milton 10	44.60855, -73.10693
Munroe Brook	Route 7 and Bay Road (by Red Apple Motel)	Munroe 10	44.40532, -73.21735
	Spear & Webster Intersection (just south of Kwiniaska Golf Course)	Munroe 20	44.38984, -73.20103
Morehouse Brook (One new site: 20)	Landry Park Winooski (Eastern trib)	Morehouse 10	44.50035, -73.19226
	Landry Park Winooski (main branch - west of Morehouse 10)	Morehouse 20	44.50041, -73.19444

Muddy Brook (20- site changed)	River Cove Road in Williston	Muddy 10	44.47293, -73.13505
	S. Brownell Road Williston	Muddy 20	44.44196, -73.13228
	Van Sicklen Road in Williston	Muddy 30	44.42823, -73.14622
Potash Brook (40 - site changed)	Kindness Court in South Burlington near Humane Society	Potash 10	44.44572, -73.21348
	Farrell Street in South Burlington near Klinger's Bakery	Potash 20	44.44660, -73.20415
	Dorset Street in South Burlington	Potash 30	44.45150, -73.17849
	Kimball Ave South Burlington	Potash 40	44.45394, -73.14809
Engelsby Brook	Pine St in Burlington near Champlain Elementary Community Gardens	Engelsby 10	44.45627, -73.21394
	Behind UVM Redstone Campus in Burlington	Engelsby 20	44.46654, -73.19741
Alder Brook (new)	Off Chapin Road in Essex	Alder 10	44.51742, -73.06559
Bartlett Brook (new)	By Shearer Chevrolet in South Burlington	Bartlett 10	44.42596, -73.21345
Sunnyside Brook (new)	Mountain View Drive in Colchester	Sunnyside 10	44.50654, -73.17823
Sunderland Brook (new)	In Pearl Street Park in Essex Junction	Sunderland 10	44.50179, -73.12983
	Off Pine Island Road in Colchester	Sunderland 20	44.51685, -73.20421

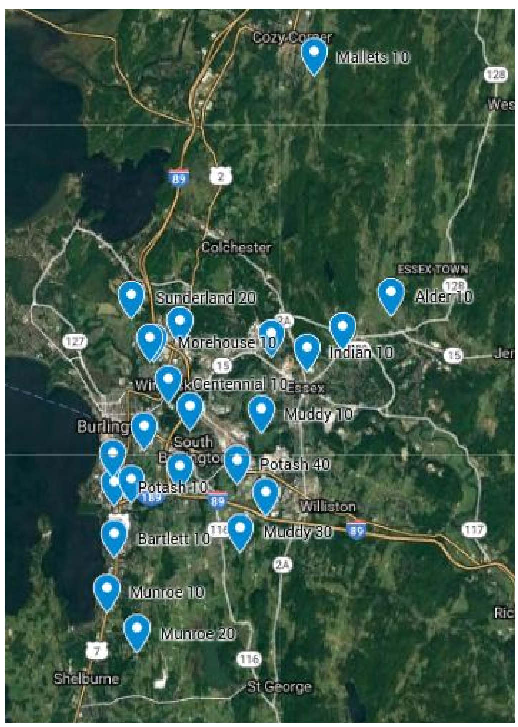


Figure 1: 2018 Rethink Runoff Stream Team Sample Sites. An interactive version of this map is available here:

https://drive.google.com/a/winooskinrcd.org/open?id=1K98F4bBO2E6p5lLKgSw7bxRSpQlzoo8Q&usp=sharing

Phosphorus Results

Phosphorus is an essential nutrient for plants and animals that is naturally limited in most freshwater systems. Even a modest increase can set off a chain of undesirable events, such as algal blooms, accelerated plant growth, low dissolved oxygen, and the subsequent die off of aquatic life. Although phosphorus occurs naturally in soils and rocks, additional phosphorus enters waterways through runoff from sources such as fertilized lawns and cropland, pet waste, failing septic systems, animal manure from storage areas or livestock access, wastewater treatment plants, and streambank erosion.

Phosphorus sample results continue to be high across all sampling sites. The VT 2016 water quality standard for phosphorus in Class B warm water medium-gradient streams is 27 µg/L but the mean 2018 phosphorus level for every site exceeded this standard (see Table 2).

Table 3. 2018 RRST Phosphorus Results Summary: Mean phosphorus levels in µg/L during both baseflow (dry) and high-flow (rain) sampling events in 2018. Values exceeding the Vermont chronic chloride standard of 27 µg/L are shown in red. Sites denoted with an * had at least one sampling date in which blank or dupe results were flagged. Recalculated means with this data removed resulted in very similar values such that it was decided to keep them for descriptive statistics reporting purposes. Raw data is presented in Appendix C.

Location	Mean Phosphorus during Baseflow - Dry Conditions	Phosphorus during Rain Event
Alder 10*	102.06	--
Bartlett 10	57.02	--
Centennial 10	50.94	88.9
Centennial 20*	62.44	--
Englesby 10*	82.12	--
Englesby 20	98.56	--
Indian 10	41.66	180
Indian 20	97.48	--
Mallets Creek 10	39.68	--
Morehouse 10	30.9	48.8
Morehouse 20	35.86	76.5
Muddy 10	50.4	--
Muddy 20	41.6	--

Muddy 30	116.46	92.3
Munroe 10*	60.86	--
Munroe 20	88.96	--
Potash 10	44.66	--
Potash 20	35.82	--
Potash 30	89.58	--
Potash 40	318.54	--
Sunderland 10	92.94	--
Sunderland 20	55.26	--
Sunnyside 10	27.36	--

Phosphorus levels in Chittenden County Streams 2012-2018
Since the onset of this monitoring program in 2012, mean concentrations of phosphorus during baseflow have remained notably above the 27 µg/L standard at all stream sites. In fact only 7 out of the 23 sites sampled have ever exhibited phosphorus concentrations below this standard (Indian 20, Malletts 10, Morehouse 10 and 20, Potash 10 and 20, and Sunnyside 10). Out of these 7, only one site (Sunnyside 10) reports a median below the standard but the 1-yr sampling mean still falls above the standard (see Table 2 above). Sites of notable historic levels include Engelsby 20, Muddy 10, 20 and 30, Munroe 20, Potash 40, and Sunderland 10.

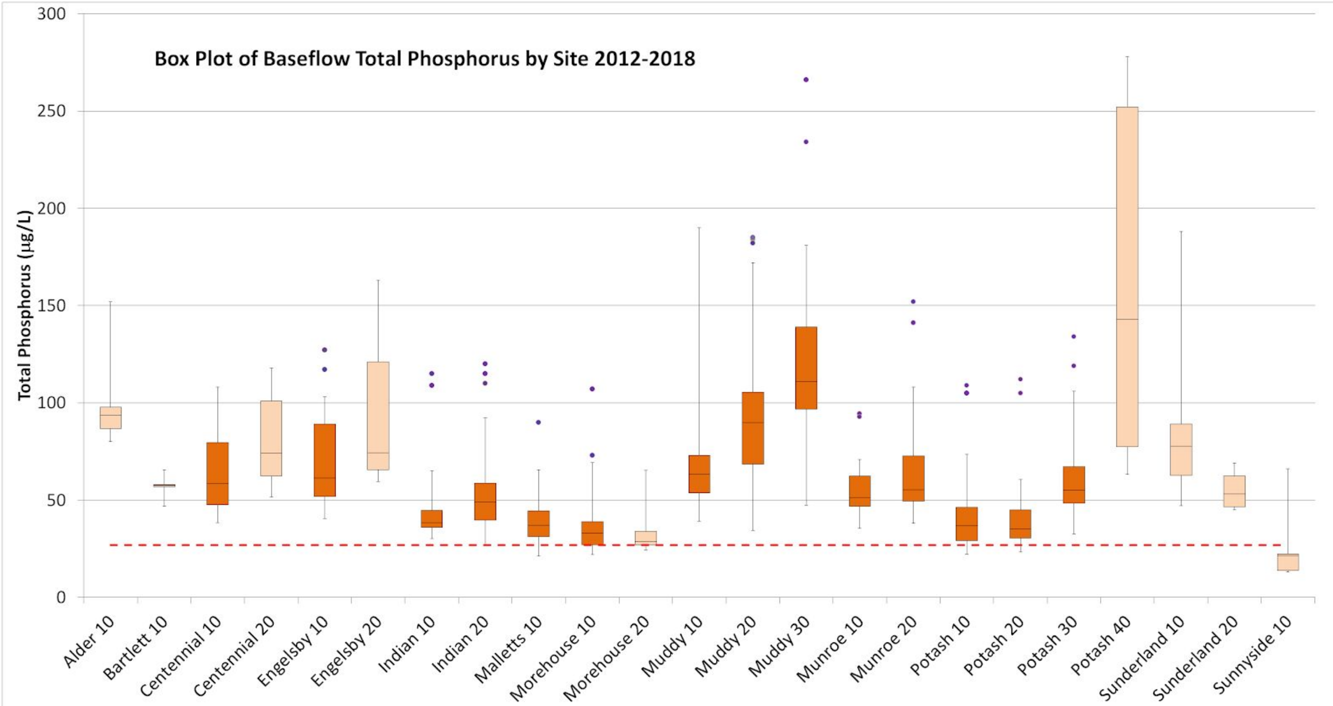


Figure 2. Comparison of total phosphorus levels across sites 2012-2018. Box plots indicate first and third quartiles and median values of total phosphorus concentrations for all sites. These values were calculated including sampling dates that may or may not have associated flagged dupe or blank samples. Lighter colored boxes indicate 1-2 years of sampling data, darker boxes indicate 6-7 years of sampling data. Dots indicate outliers which were identified as equal to or greater than 2 times the site's standard deviation. Red line indicates Vermont's 2016 Water Quality Standard of 27 micrograms/L.

Figure 2 suggests that phosphorus levels increase as sampling moves upstream. To test this hypothesis, RRST used scatter plots to graph phosphorus data over time by stream and ran statistical analyses on 8 streams that had more than one sampling site. Of the 8 streams that have more than one sampling location, 6 indicated a statistically significantly different value of phosphorus between sites, all of which presented statistically significantly higher concentrations of total phosphorus upstream . Table 4 summarizes the results of these tests. Appendix D summarizes statistics and graph visualizations. This result was somewhat surprising and merits more consideration since we assumed that total phosphorus increased in concentration as water moves downstream and more inputs are introduced.

Table 4 Statistical Results of Phosphorus trends along stream lengths. Statistical tests selected because data either had too small a sample size or was not normally distributed and therefore it was not appropriate to do a Paired T-test. While Wilcoxon Signed Rank recognizes dependent samples as could be the case up and down the same stream, the Kruksal-Wallis was the best tool available to reporter but it assumes independent samples so results should be seen with caution. Location of higher concentration was estimated through graphing. Note that all values and sampling dates were included in analysis as long as they could be paired (in the case of the Wilcoxon Signed Rank), including outliers and those flagged with dupe or blank concerns.

Stream	# of Sites	Statistical Test Used	Statistically significant difference?	Location of higher concentration?
Centennial	2	Wilcoxon Signed Rank	Y	Upstream
Engelsby	2	Wilcoxon Signed Rank	N	--
Indian	2	Wilcoxon Signed Rank	Y	Upstream
Morehouse	2	Wilcoxon Signed Rank	N	--
Munroe	2	Wilcoxon Signed Rank	Y	Upstream
Sunderland	2	Wilcoxon Signed Rank	Y	Upstream
Muddy	3	Kruksal-Wallis	Y	Upstream
Potash	4	Kruksal-Wallis	Y	Upstream

Figure 2 also suggests that Muddy Brook has shown consistently high levels of Phosphorus as compared to other sites including some extremely high outliers. Interestingly, temporal data is suggesting a non-significant downward trend of Phosphorus concentrations at sites Muddy 20 and Muddy 30 with Muddy 10 holding relatively constant. This is unique to Muddy Brook and it’s not clear what land use changes or restoration efforts could have contributed to this. Figures 3 and 4 show the suggested trends for Muddy 20 and 30 respectively.

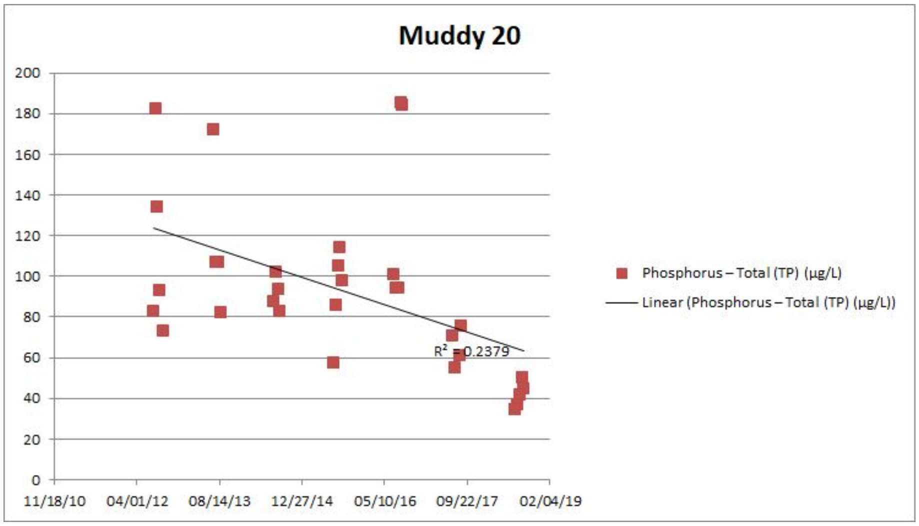


Figure 3. Total Phosphorus in Muddy 20 since 2012. Scatter plot visually suggests a downward trend but R2 of the best fit line is still only about 0.24 and not significant.

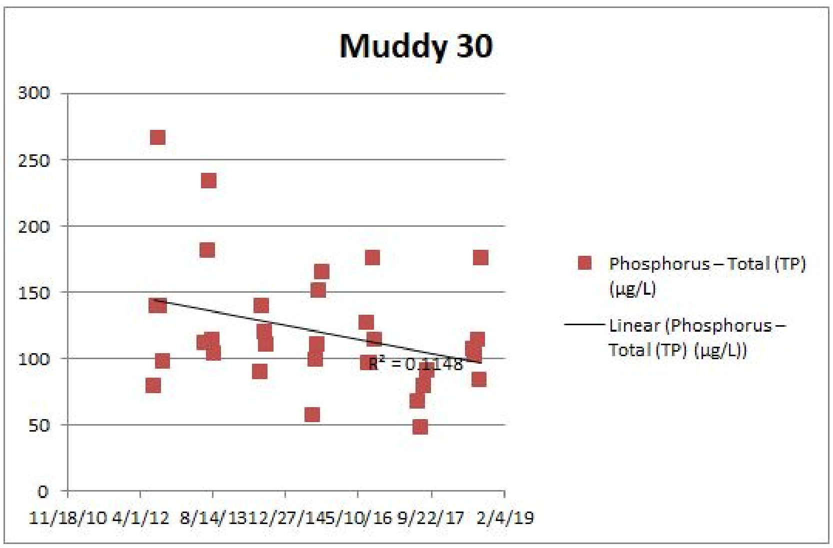


Figure 4. Total Phosphorus in Muddy 30 since 2012. Scatter plot visually suggests a downward trend but R2 of the best fit line is still only about 0.12 and not significant.

Chloride Results

Chloride is a component of salt found naturally in minerals and in oceans. While a low level of instream chloride can originate from natural sources, higher levels are generally due to the use of deicing salts. Elevated chloride levels in surface waters can negatively impact the health and reproduction of aquatic species, according to the Vermont Surface Water Management Strategy. The Stream Team took grab samples of chloride, which do not provide adequate data to label a stream impaired or acute, however, the data acts as a spot check. For reference, the Environmental Protection Agency's (EPA) and State of Vermont's (VT) current water quality standard for chloride is 230 mg/L (chronic criteria) and 860 mg/L (acute criteria). 230 mg/L is the highest concentration of chloride to which aquatic life can safely be exposed for one hour once every 3 years. 860 mg/L is the highest concentration of chloride to which aquatic life can safely be exposed for four consecutive days once every 3 years.

Table 5. 2018 RRST Chloride Results Summary: This table depicts mean chloride levels in mg/L during baseflow (dry) and high-flow (rain) sampling events in 2018. Values exceeding the Vermont chronic chloride standard of 230 mg/L are shown in red. No sites had a sampling date in which blank or dupe results were flagged for chloride. Raw data is presented in Appendix C.

Location	Mean Chloride in Dry Conditions Only	Chloride during Rain Events
Alder 10	10.93	--
Bartlett 10	256	--
Centennial 10	728	248
Centennial 20	176.2	--
Englesby 10	401.8	--
Englesby 20	711.8	--
Indian 10	257.6	41.55
Indian 20	180.5	--
Mallets Creek 10	50.09	--
Morehouse 10	133.17	38.65
Morehouse 20	490.1	111
Muddy 10	231.2	--
Muddy 20	596	--
Muddy 30	34.2	35.7
Munroe 10	341.4	--
Munroe 20	169.54	--
Potash 10	570.4	--
Potash 20	600.2	--
Potash 30	330	--

Potash 40	737.1	--
Sunderland 10	187.2	--
Sunderland 20	168.2	--
Sunnyside 10	773	--

While in 2017 only thee sampled brooks presented mean values above of 230 mg/L, in 2018 nine brooks presented exceedances although this increase is partially attributed to the addition of new sampling sites of concern. Similar to 2017, chloride levels were higher during baseflow conditions in the majority of cases which is suspected to be due to dilution. Chloride grab sample levels exceeded 860 mg chloride/L, in Centennial 10 and Engelsby 20 in 2018. Both streams exceeded this value on 7/10/18 and 7/24/18. This is the first time this value was surpassed in any individual sample over this seven year period. This could result in a need for more continuous monitoring at these sites to gain continuous-flow data.

Chloride levels in Chittenden County Streams 2012-2018

Since the onset of this monitoring program, mean chloride levels at Centennial 10 and Potash 10, 20 and 30 have remained notably above 230 mg/L standard. Recently added sampling sites have also presented alarmingly high data including Engelsby 20, Morehouse 20, Potash 40, and Sunnyside 10.

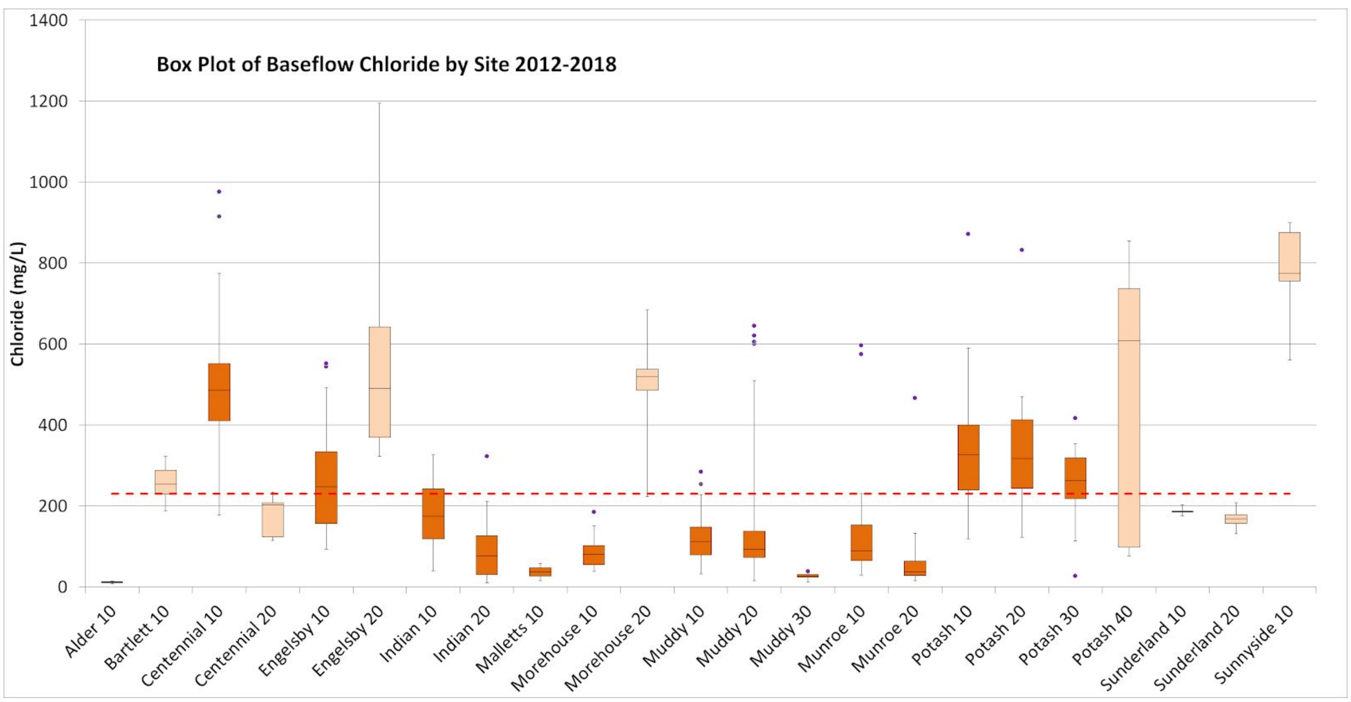


Figure 5 - Comparison of Chloride levels across sites 2012-2018. Box plots indicate first and third quartiles and median values of chloride levels (mg/L) for all sites. Lighter colored boxes indicate 1-2 years of sampling data, darker boxes indicate 6-7 years of sampling data. Dots indicate outliers which were identified as equal to or greater than 2 times the site's standard deviation. EPA's and Vermont's standard for 4-day average chloride levels (230 mg/L) is shown by the red line.

There is not as clear a link between location in the watershed and chloride levels as there is for phosphorus levels but several streams presented statistically significantly different chloride levels across sampling sites. Of the 8 streams that have more than one sampling location, 7 indicated a statistically significantly different value of Chloride between sites. This information could be useful in pin-pointing chloride pressure points along the stream length for intervention purposes. Table 6 summarizes the results of these statistical tests. Appendix E summarizes statistics and graph visualizations.

Table 6 Statistical Results of Chloride trends along stream lengths. See Table 4 note for details.

Stream	# of Sites	Statistical Test Used	Statistically significant difference?	Location of higher concentration?
Centennial	2	Wilcoxon Signed Rank	Y	Downstream
Engelsby	2	Wilcoxon Signed Rank	Y	Upstream
Indian	2	Wilcoxon Signed Rank	Y	Downstream
Morehouse	2	Wilcoxon Signed Rank	Y	Upstream
Munroe	2	Wilcoxon Signed Rank	Y	Downstream
Sunderland	2	Wilcoxon Signed Rank	N	--
Muddy	3	Kruksal-Wallis	Y	Midstream (site 20)
Potash	4	Kruksal-Wallis	Y	Unclear

Chloride data from this sampling program suggests that of the 14 sites that have been sampled for 6 or more years, chloride levels are trending upwards in 10 of them (Centennial 10, Engelsby 10, Indian 10 and 20, Malletts 10, Muddy 30, Munroe 10 and 20,and Potash 10 and 20). These trends are not statistically significant but highlight an important stressor to monitor closely. Appendix F documents graphs of these trends.

Aggregated data also suggests a general increasing trend in chloride. Figure 6 below shows that e mean, median, and standard deviation values have all increased slightly over time.

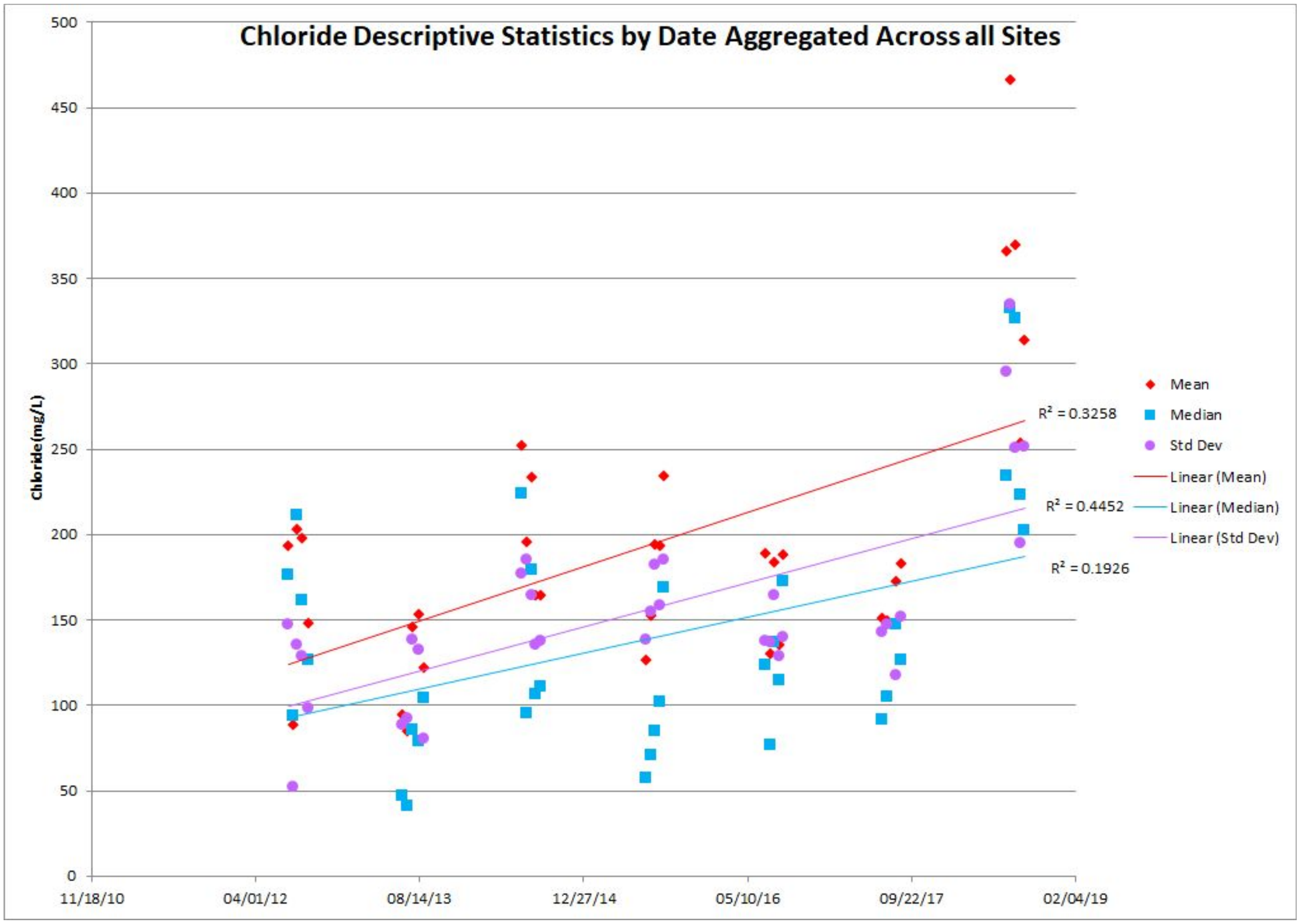


Figure 6. Descriptive Statistics for chloride data gathered across sites aggregated by date. Each sampling date since June 2016 had chloride values across sites averaged to determine mean, median, and standard deviation for the entire sampling area.

Turbidity Results

The turbidity of a water sample refers to its cloudiness. This measurement is based on the amount of algae, microbes, and sediment suspended in the water. High turbidity levels can negatively impact aquatic life by raising water temperature, decreasing forage and cover, and harming gill function, and has the potential to increase the presence and number disease-causing organisms. Turbidity measurements can also be used as an indicator for erosion and increased nutrient levels in streams. The Vermont Water Quality Standards state that turbidity should not exceed 10 NTU (nepholometric turbidity units) in cold-water fish habitat and 25 NTU in warm-water fish habitat.

Table 7. 2018 RRST Turbidity Results Summary. Mean turbidity levels in NTU baseflow (dry) and high-flow (rain) sampling events in 2018. Overall mean values exceeding the Vermont standard of 25 NTU are shown in red. Raw data is presented in Appendix C.

Location	Mean Turbidity in Dry Conditions Only	Turbidity during Rain Event
Alder 10	30.9	--
Bartlett 10	11.402	--
Centennial 10	5.198	18.2
Centennial 20	3.462	--
Englesby 10	6.92	--
Englesby 20	2.242	--
Indian 10	7.738	64.9
Indian 20	9.104	--
Mallets Creek 10	4.772	--
Morehouse 10	5.938	8.52
Morehouse 20	2.816	21.3
Muddy 10	6.252	--
Muddy 20	5.928	--
Muddy 30	17.68	11.5
Munroe 10	6.724	--
Munroe 20	18.9	--
Potash 10	4.868	--
Potash 20	1.488	--
Potash 30	10.782	--
Potash 40	39.32	--
Sunderland 10	8.032	--

Sunderland 20	10.106	--
Sunnyside 10	11.044	--

Mean baseflow turbidity levels did not exceed the VT Water Quality standard for turbidity of 25 nephelometric units (NTU) for warm-water fish habitat in 2018 except at Potash 40 and Alder 10. This represents an increase of two sites as compared to 2017 but one of these sites was newly added in 2018. As suspected, turbidity concentrations were mostly higher during rain events, and surpassed standards on Indian Brook alone.

Turbidity Levels in Chittenden County Streams 2012-2018

Mean, baseflow turbidity values have only rarely exceeded the VT standard for warm-water streams of 25 NTU over the seven year sampling period. Of note, however, is the high turbidity recorded for new sampling sites Alder 10 and Potash 40. Higher turbidity in Alder 10 is not surprising because the site is comparatively more agricultural with a couple farms and potential field runoff nearby. Turbidity has not been included in sampling support requests for the 2019 field season but will be revisited in 2020.

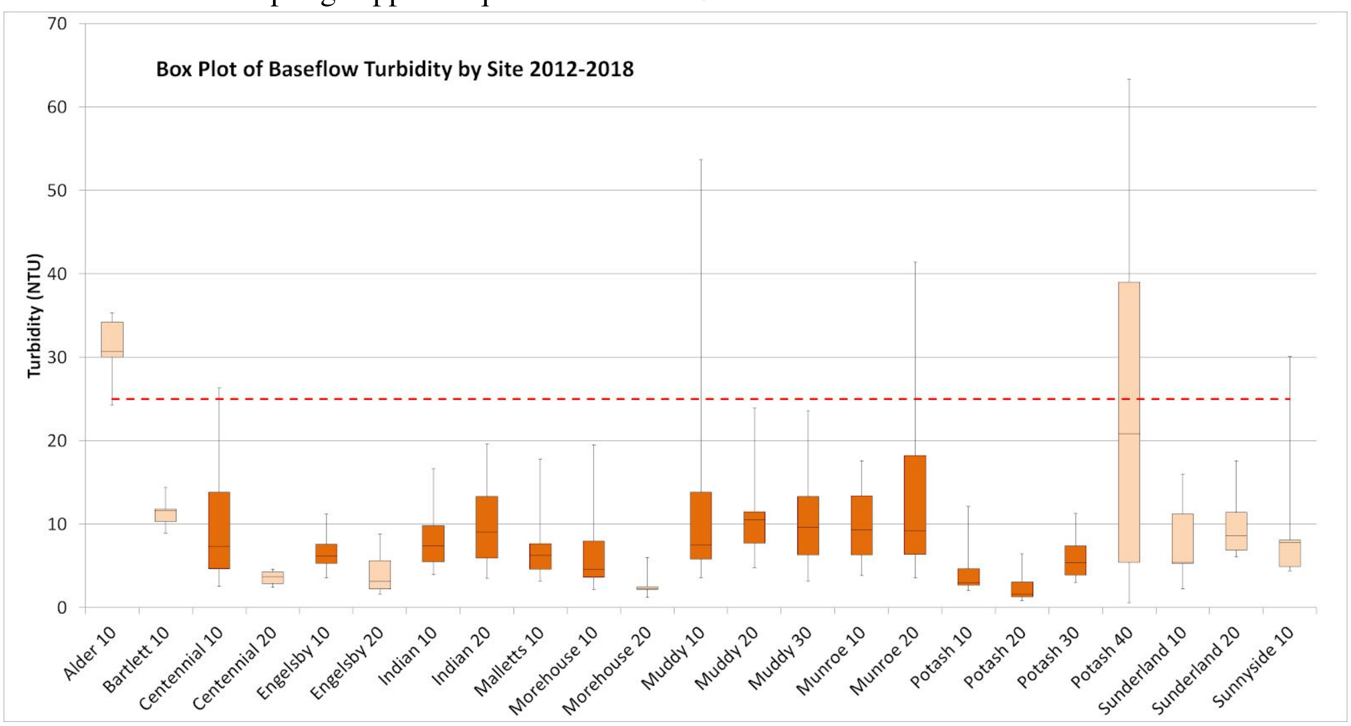


Figure 7 - Comparison of turbidity levels 2012-2018 during baseflow (dry) conditions. The standard proposed by the State of Vermont for mean turbidity at baseflow in medium gradient, warm water streams (25 NTU) is indicated by the red line. These values were calculated including sampling dates that may or may not have associated flagged dupe or blank samples.

Importantly, it was challenging to secure valid turbidity data for the 2018 sampling season. Appendix A will reveal a mean relative percent difference between duplicate and actual samples above the acceptable 15%. Some but not all of this was due to having very low sample values in relation to test sensitivity.

This adds to the Stream Team's resolve to remove this parameter from future sampling activities for the time being.

Turbidity was statistically significantly different along only two streams (Morehouse and Potash). The Morehouse site results, while significant, both fell under the water quality standards such that the difference is of less interest to the research team. In contrast, Potash 40 presented turbidity levels which both exceeded water quality standards and were significantly different from other sites along that brook. The sampling team suspects this could be due to the unique hydrology of Potash 40 which is located among a complex of artificial wetlands within an industrial park. The water has no noticeable flow rate or direction and presents less as a stream and more as a marsh. It is suspected that in-stream sampling practices might disturb a lot of bottom sediment in such a setting thereby leading to higher turbidity readings. Considering this, Potash 40 has been removed from the 2019 sampling program.

Visualization revealed no notable trends in turbidity data over time and it is therefore not currently recognized as a high priority threat.

Conclusion

The Rethink Runoff Stream Team has monitored chloride, phosphorus, and turbidity in various, stormwater impaired streams in Chittenden County for the past seven consecutive years (2012-2018). The 2018 season's results are similar to those obtained over the past six years, and indicate that all stream sites have sustained phosphorus levels well above the Vermont standard and that chloride is becoming a prevalent and growing concern.

Phosphorus levels in almost all sampled streams have remained two to four times the Vermont water quality standard of 27 µg/L. Muddy Brook continues to maintain high levels of phosphorus although values are potentially trending downwards. Six streams sampled also showed statistically significantly higher concentrations of total phosphorus upstream as opposed to downstream which presents an opportunity to explore localized stressors. It's important to consider that while phosphorus levels are presenting high in many sites, turbidity levels are low. This provides some clues as to sources of phosphorus and should inform phosphorus reduction efforts. For example, it is possible these high phosphorus values can be attributed to more urban-like runoff such as car wash detergents, liquid lawn fertilizers, and pet waste.

Chloride levels continue to surpass standards in several streams, most notably at Centennial 10, Engelsby 20, Morehouse 20, Potash 40, and Sunnyside 10. For the first time in Stream Team's sampling history, chloride levels exceeded the EPA's and VT's acute standard of 860 mg chloride/L on the same two sampling dates at both Centennial 10 and Engelsby 20. As mentioned in prior year reports it is suspected that Engelsby's high levels are due to a nearby parking lots on the UVM campus but further assessments should consider rising stressors across the sampling region at all sites of concern.

Low turbidity values in most sites reveal this does not appear to be a significant stressor in the Chittenden County area although research team should consider potential sediment inputs upstream of

Alder 10 for remediation. After seven years of showing minimal concern, turbidity will be abandoned at most locations in the 2019 season.

There will be a few sampling adjustments made to the 2019 sampling effort. Potash 40 will be removed because of its unique and confounding hydrological conditions that complicates data analysis. Munroe 10 seems to be located physically too close to Munroe 20 to be giving any valuable information on landscape impacts so it will similarly be abandoned. Munroe 20 will be kept, however as a valuable data point because a housing development is planned and will be implemented upstream soon. Finally, Bartlett 10 will be removed because it is already sampled by a team from UVM.

It became clear this year that, moving forward, the Stream Team needs explicit guidance and documented practices in the QAPP for dealing with outliers and data points whose duplicates or blanks were flagged. For 2018 analysis all data points were included because those whose duplicates or blanks were flagged, still had values less than two standard deviations from the mean. Outliers, similarly, only presented when multi-year data was assessed such that for 2018-specific descriptive statistics, all data points were included. Given the small sampling sizes, however, (5 - 6 data points per site per year) this may not be a reliable practice for future analysis and consultation will be sought from the La Rosa Partnership for technical guidance on this practice.

Finally, it is the goal of this team to improve outward reporting of these data such that each stream could eventually receive some type of scorecard and summary sheet across the multiple parameters evaluated. We expect that scoring, and then ranking streams holistically is one step towards simplifying where to direct remediation efforts.This may be attempted in the 2019 report.

Appendix A. Quality Assurance Measures for phosphorus, chloride, and turbidity sampling in 2018.

RPD Analysis				
Date	Location	Test	RPD (%)	
07/10/18	Munroe 20	Chloride (mg/L)	0.00	
		TP(ug P/L)	17.52	
		Turbidity (NTU)	7.92	
	Muddy 10	Chloride (mg/L)	0.59	
		TP(ug P/L)	4.96	
		Turbidity (NTU)	3.79	
	Engelsby 10	Chloride (mg/L)	1.61	
		TP(ug P/L)	71.28	
		Turbidity (NTU)	1.00	
07/24/18	Potash 20	Chloride (mg/L)	0.48	
		TP(ug P/L)	0.00	
		Turbidity (NTU)	18.62	
	Muddy 30	Chloride (mg/L)	1.20	
		TP(ug P/L)	0.98	
		Turbidity (NTU)	2.96	
	Indian 10	Chloride (mg/L)	3.28	
		TP(ug P/L)	0.78	
		Turbidity (NTU)	2.57	
08/07/18	Potash 30	Chloride (mg/L)	0.00	
		TP(ug P/L)	0.91	
		Turbidity (NTU)	7.76	
	Munroe 10	Chloride (mg/L)	0.87	
		TP(ug P/L)	10.23	
		Turbidity (NTU)	20.16	
	Indian 20	Chloride (mg/L)	0.49	
		TP(ug P/L)	4.08	
		Turbidity (NTU)	20.61	
08/21/18	Potash 40	Chloride (mg/L)	0.70	
		TP(ug P/L)	2.81	
		Turbidity (NTU)	52.12	
	Malletts 10	Chloride (mg/L)	1.94	
		TP(ug P/L)	0.60	
		Turbidity (NTU)	4.62	
	Bartlett 10	Chloride (mg/L)	0.78	
		TP(ug P/L)	1.69	
		Turbidity (NTU)	5.22	
09/04/18	Sunderland 10	Chloride (mg/L)	1.00	
		TP(ug P/L)	9.52	
		Turbidity (NTU)	33.93	
	Morehouse 10	Chloride (mg/L)	2.80	
		TP(ug P/L)	12.66	
		Turbidity (NTU)	89.69	
	Centennial 20	Chloride (mg/L)	0.81	
		TP(ug P/L)	24.39	
		Turbidity (NTU)	38.43	
Mean RPD		Parameter	Actual	Target
		Chloride (mg/L)	1.10	≤5
		TP(ug P/L)	10.83	≤30
		Turbidity (NTU)	20.63	≤15

Appendix B. Project Completeness
Project proposal anticipated 5 dates for baseflow sampling across 23 sites (115 samples per parameter) as well as 2 rain dates sampling across 5 sites (10 samples per parameter). This is a total of 125 samples per parameter not including duplicates and blanks.

Parameter	Number of Samples Anticipated (not including blanks and Dupes) = 23 sites*5 sampling dates	Number of Valid Samples* Collected and Analyzed	Percent Complete
Chloride	125	121	97%
Total Phosphorus	125	116	93%
Turbidity	125	117	94%

*"Valid sample" includes all samples not flagged by issues that arose from blank or dupe results

Appendix C. Individual Sample Results. Boxes highlighted in yellow indicate issue flagged by inconsistent blank result. Boxes highlighted in red indicate sample whose duplicate is notably different in value. All values included in graphing and statistical analyses of 2018 report.

Sample Number	Location	Date	Chloride (mg/L)	TP(ug P/L)	Turbidity (NTU)
181280-01	Alder 10	7/10/2018	12	152	35.3
181398-01	Alder 10	7/24/2018	13.4	97.8	24.3
181538-01	Alder 10	8/7/2018	9.73	86.7	30
181652-01	Alder 10	8/21/2018	7.82	80.1	34.2
181809-01	Alder 10	9/4/2018	11.7	93.7	30.7
181280-02	Alder 10 Blank	7/10/2018	< 2	5.48	< 0.2
181280-03	Bartlett 10	7/10/2018	229	57.8	11.6
181398-02	Bartlett 10	7/24/2018	322	56.8	10.3
181538-02	Bartlett 10	8/7/2018	288	65.7	14.4

181652-02	Bartlett 10	8/21/2018	254	46.9	11.8
181809-02	Bartlett 10	9/4/2018	187	57.9	8.91
181652-03	Bartlett 10 Field Dup	8/21/2018	256	47.7	11.2
181398-04	Centannial 10 Blank	7/24/2018	< 2	< 5	< 0.2
181280-04	Centennial 10	7/10/2018	915	46.4	3.79
181398-03	Centennial 10	7/24/2018	976	57.7	7.39
181538-03	Centennial 10	8/7/2018	775	40.9	3.2
181629-01	Centennial 10	8/18/2018	248	88.9	18.2
181652-04	Centennial 10	8/21/2018	430	47.7	6.08
181809-03	Centennial 10	9/4/2018	544	62	5.53
181280-05	Centennial 10 Blank	7/10/2018	< 2	< 5	< 0.2
181280-06	Centennial 20	7/10/2018	234	74.1	2.88
181398-05	Centennial 20	7/24/2018	202	62.3	3.7
181538-04	Centennial 20	8/7/2018	207	51.6	2.43
181652-05	Centennial 20	8/21/2018	114	66.6	3.74
181809-05	Centennial 20	9/4/2018	124	57.6	4.56
181538-05	Centennial 20 Blank	8/7/2018	< 2	9.17	0.5
181809-04	Centennial 20 Dup	9/4/2018	123	73.6	3.09
181280-07	Engelsby 10	7/10/2018	492	102	6.05
181398-06	Engelsby 10	7/24/2018	544	44.4	5.94
181538-06	Engelsby 10	8/7/2018	480	51.9	4.36
181652-06	Engelsby 10	8/21/2018	296	117	14.1

181809-06	Engelsby 10	9/4/2018	197	95.3	4.15
181398-07	Engelsby 10 Blank	7/24/2018	< 2	< 5	< 0.2
181280-08	Engelsby 10 Field Dup	7/10/2018	500	48.4	5.99
181280-09	Engelsby 20	7/10/2018	1030	103	3.12
181398-08	Engelsby 20	7/24/2018	1195	121	2.56
181538-07	Engelsby 20	8/7/2018	642	129	1.58
181652-07	Engelsby 20	8/21/2018	370	74.2	2.25
181809-07	Engelsby 20	9/4/2018	322	65.6	1.7
181538-08	Engelsby 20 Blank	8/7/2018	< 2	< 5	< 0.2
181280-10	Indian 10	7/10/2018	288	38.9	14.5
181398-09	Indian 10	7/24/2018	300	38.5	3.94
181538-09	Indian 10	8/7/2018	326	37.8	5.46
181629-02	Indian 10	8/18/2018	41.55	180	64.9
181652-08	Indian 10	8/21/2018	140	43.2	4.96
181809-08	Indian 10	9/4/2018	234	49.9	9.83
181652-09	Indian 10 Blank	8/21/2018	< 2	< 5	< 0.2
181398-10	Indian 10 Field Dup	7/24/2018	310	38.8	3.84
181280-11	Indian 20	7/10/2018	131	115	13.6
181398-11	Indian 20	7/24/2018	322	110	6.63
181538-10	Indian 20	8/7/2018	206	120	5.92
181652-10	Indian 20	8/21/2018	55.5	68.3	11.8
181809-09	Indian 20	9/4/2018	188	74.1	7.57

181809-10	Indian 20 Blank	9/4/2018	< 2	< 5	0.23
181538-11	Indian 20 Field Dup	8/7/2018	205	125	7.28
181809-11	Mallets 10	9/4/2018	54.5	44.4	4.61
181280-12	Malletts 10	7/10/2018	48.15	41.2	6.25
181398-12	Malletts 10	7/24/2018	57	36.7	3.22
181538-12	Malletts 10	8/7/2018	47.35	42.6	4.28
181652-11	Malletts 10	8/21/2018	43.45	33.5	5.5
181652-12	Malletts 10 Field Dup	8/21/2018	44.3	33.7	5.76
181280-13	Morehouse 10	7/10/2018	136	32.9	10.2
181398-13	Morehouse 10	7/24/2018	185	26.2	6.18
181538-13	Morehouse 10	8/7/2018	150	26	2.18
181629-03	Morehouse 10	8/18/2018	38.65	48.8	8.52
181652-13	Morehouse 10	8/21/2018	49.85	32.4	3.59
181809-12	Morehouse 10	9/4/2018	145	37	7.54
181280-14	Morehouse 10 Blank	7/10/2018	< 2	< 5	< 0.2
181809-13	Morehouse 10 Dup	9/4/2018	141	42	19.8
181280-15	Morehouse 20	7/10/2018	537.5	27.1	5.99
181398-14	Morehouse 20	7/24/2018	684	24.4	1.23
181538-14	Morehouse 20	8/7/2018	486	65.3	2.48
181629-04	Morehouse 20	8/18/2018	111	76.5	21.3
181652-14	Morehouse 20	8/21/2018	223	28.5	2.18
181809-14	Morehouse 20	9/4/2018	520	34	2.2

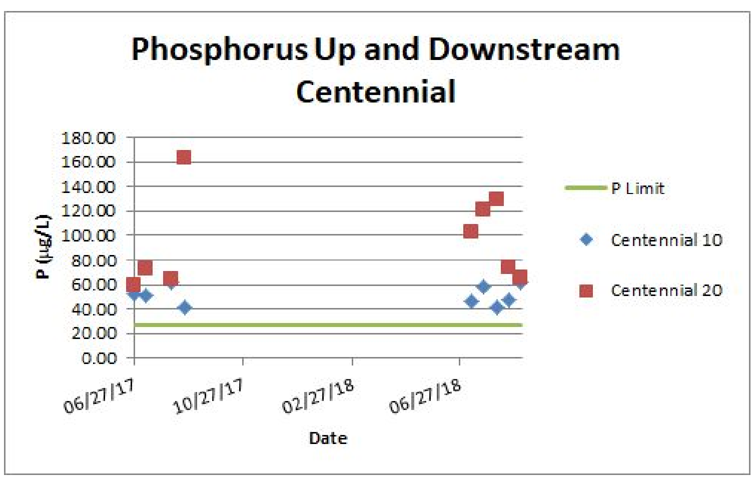
181629-05	Morehouse 20 Blank	8/18/2018	< 2	< 5	0.22
181280-16	Muddy 10	7/10/2018	170	55.1	7.5
181398-15	Muddy 10	7/24/2018	220	51.8	6.87
181538-15	Muddy 10	8/7/2018	228	43.1	4.11
181652-15	Muddy 10	8/21/2018	254	49.8	6.31
181809-15	Muddy 10	9/4/2018	284	52.2	6.47
181398-16	Muddy 10 Blank	7/24/2018	< 2	< 5	0.23
181280-17	Muddy 10 Field Dup	7/10/2018	171	57.9	7.79
181280-18	Muddy 20	7/10/2018	645	34.5	4.97
181398-17	Muddy 20	7/24/2018	620	36.9	4.77
181538-16	Muddy 20	8/7/2018	600	41.8	5.9
181652-16	Muddy 20	8/21/2018	510	50.2	7.72
181809-16	Muddy 20	9/4/2018	605	44.6	6.28
181538-17	Muddy 20 Blank	8/7/2018	< 2	< 5	< 0.2
181280-19	Muddy 30	7/10/2018	31.2	107	21.1
181398-18	Muddy 30	7/24/2018	33.4	102	13.3
181538-18	Muddy 30	8/7/2018	34	114	13.9
181629-06	Muddy 30	8/18/2018	35.7	92.3	11.5
181652-17	Muddy 30	8/21/2018	38.25	84.3	16.5
181809-17	Muddy 30	9/4/2018	34.15	175	23.6
181652-18	Muddy 30 Blank	8/21/2018	< 2	< 5	< 0.2
181398-19	Muddy 30 Field Dup	7/24/2018	33	103	13.7

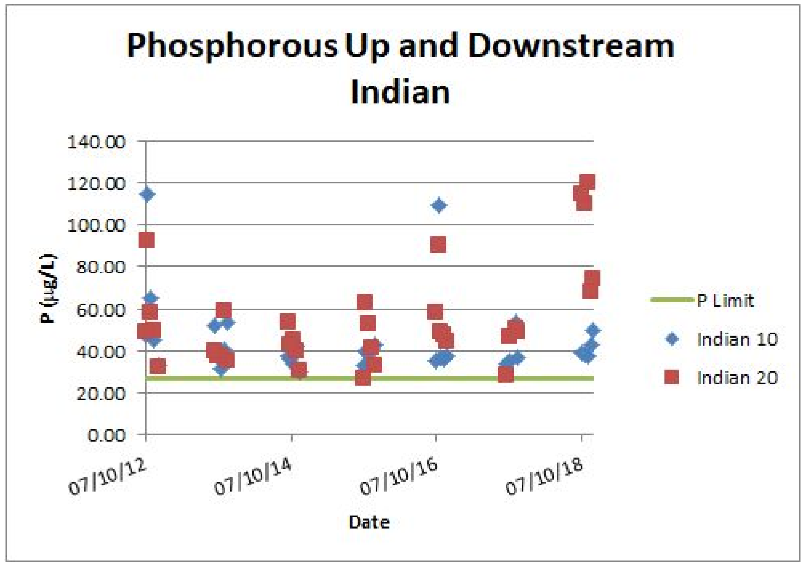
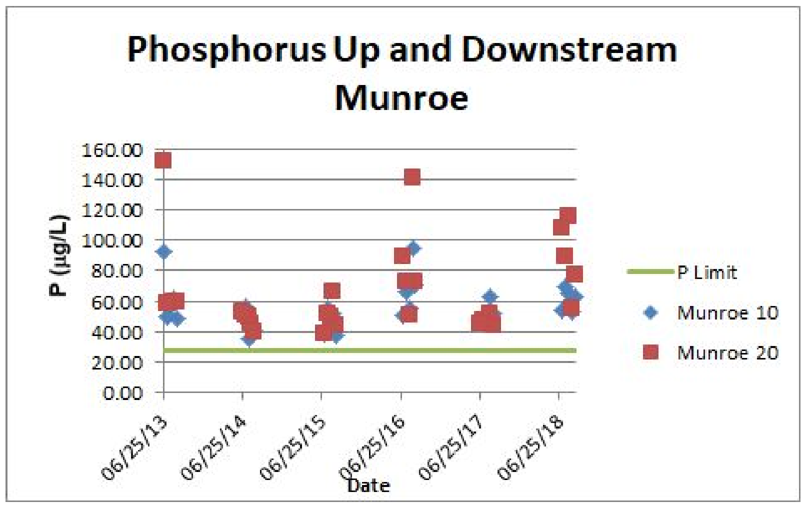
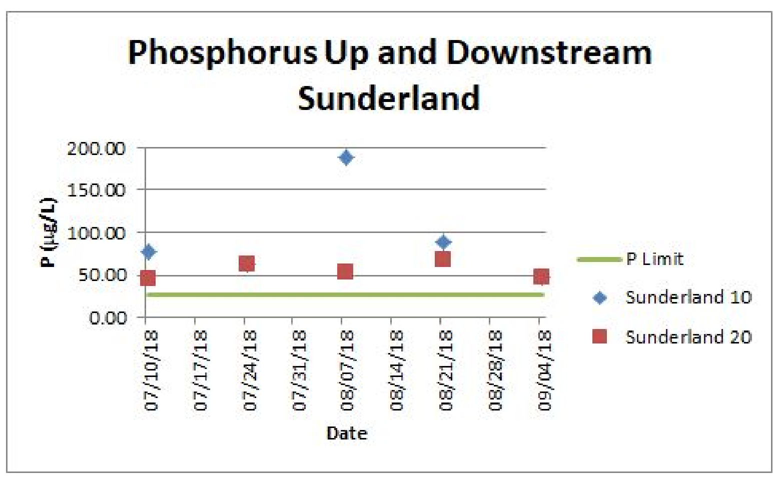
181280-20	Munroe 10	7/10/2018	230	54.4	5.25
181398-20	Munroe 10	7/24/2018	596	69.5	8.69
181538-19	Munroe 10	8/7/2018	575	64.9	8.25
181652-19	Munroe 10	8/21/2018	152	52.6	5.28
181809-18	Munroe 10	9/4/2018	154	62.9	6.15
181809-19	Munroe 10 Blank	9/4/2018	< 2	7.58	< 0.2
181538-20	Munroe 10 Field Dup	8/7/2018	570	71.9	10.1
181280-21	Munroe 20	7/10/2018	92.9	108	30.2
181398-21	Munroe 20	7/24/2018	466	88.8	33.9
181538-21	Munroe 20	8/7/2018	132	116	9.2
181652-20	Munroe 20	8/21/2018	63	55.2	6.7
181809-20	Munroe 20	9/4/2018	93.8	76.8	14.5
181280-22	Munroe 20 Field Dup	7/10/2018	92.9	90.6	27.9
181280-23	Potash 10	7/10/2018	490	32	2.84
181398-22	Potash 10	7/24/2018	872	31.6	2.39
181538-22	Potash 10	8/7/2018	484	41.4	4.09
181652-21	Potash 10	8/21/2018	416	74.3	12.1
181809-21	Potash 10	9/4/2018	590	44	2.92
181280-24	Potash 20	7/10/2018	470	31.7	0.98
181398-23	Potash 20	7/24/2018	832	30.3	1.12
181538-23	Potash 20	8/7/2018	416	33.8	1.02
181629-07	Potash 20	8/18/2018	187	74	8.71

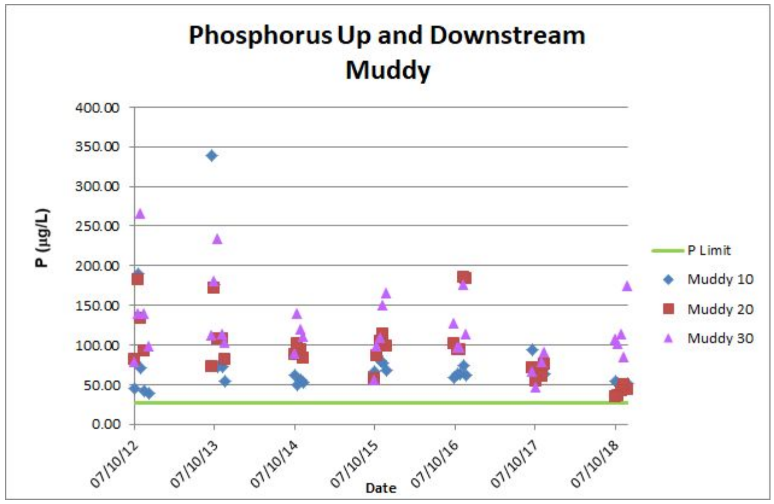
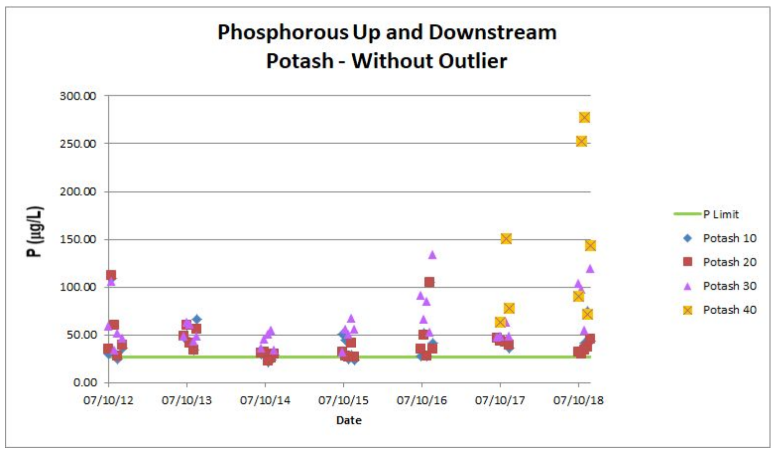
181652-22	Potash 20	8/21/2018	460	37.8	1.39
181809-22	Potash 20	9/4/2018	823	45.5	2.93
181398-24	Potash 20 Field Dup	7/24/2018	828	30.3	1.35
181280-25	Potash 30	7/10/2018	338	104	3.13
181398-25	Potash 30	7/24/2018	332	98	3.39
181538-24	Potash 30	8/7/2018	416	55.1	4.09
181652-23	Potash 30	8/21/2018	348	71.8	32
181809-23	Potash 30	9/4/2018	216	119	11.3
181538-25	Potash 30 Field Dup	8/7/2018	416	54.6	4.42
181280-26	Potash 40	7/10/2018	607.5	252	50.2
181398-26	Potash 40	7/24/2018	736	277.8	39
181538-26	Potash 40	8/7/2018	855	847.8	23.3
181652-24	Potash 40	8/21/2018	720	72.1	20.8
181809-24	Potash 40	9/4/2018	767	143	63.3
181652-25	Potash 40 Field Dup	8/21/2018	715	70.1	12.2
181280-27	Sunderland 10	7/10/2018	176	77.8	11.2
181398-27	Sunderland 10	7/24/2018	185	62.7	5.41
181538-27	Sunderland 10	8/7/2018	186	188	16
181652-26	Sunderland 10	8/21/2018	187	89.2	2.24
181809-25	Sunderland 10	9/4/2018	202	47	5.31
181652-27	Sunderland 10 Blank	8/21/2018	< 2	< 5	< 0.2
181809-26	Sunderland 10 Dup	9/4/2018	200	51.7	7.48

181280-28	Sunderland 20	7/10/2018	208	45.1	6.07
181398-28	Sunderland 20	7/24/2018	156	62.4	11.4
181538-28	Sunderland 20	8/7/2018	178	53.3	8.57
181652-28	Sunderland 20	8/21/2018	131	68.9	17.6
181809-27	Sunderland 20	9/4/2018	168	46.6	6.89
181809-28	Sunderland 20 Blank	9/4/2018	< 2	< 5	< 0.2
181280-29	Sunnyside 10	7/10/2018	900	21.5	4.91
181398-29	Sunnyside 10	7/24/2018	875	22.3	8.07
181538-29	Sunnyside 10	8/7/2018	775	13	4.37
181652-29	Sunnyside 10	8/21/2018	560	13.9	7.77
181809-29	Sunnyside 10	9/4/2018	755	66.1	30.1

Appendix D. Statistically Different Phosphorus Up and Downstream

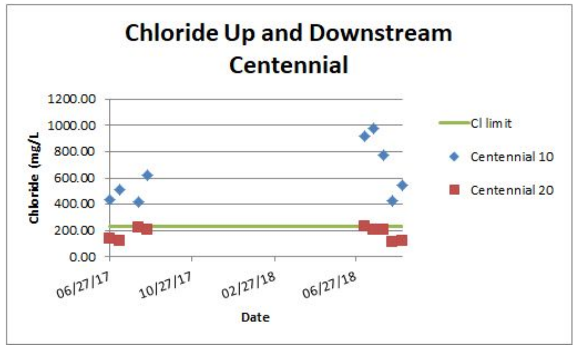
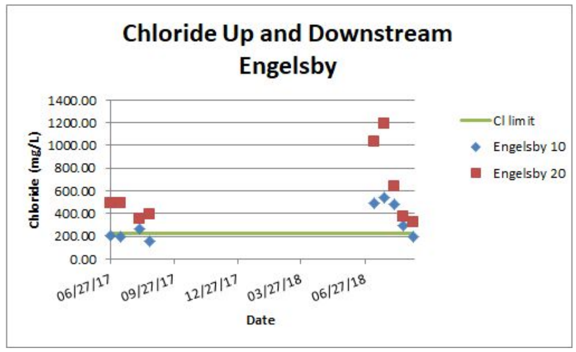
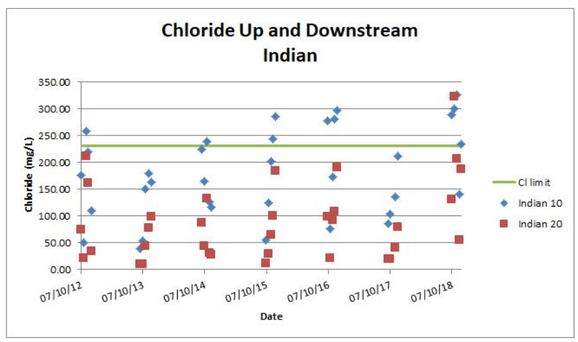
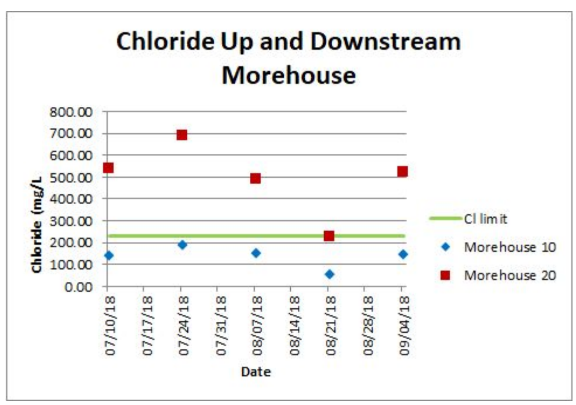
Stream	Test statistic, Critical Value, Two-tailed Alpha Value	Visualization
Centennial	0,6,0.05	

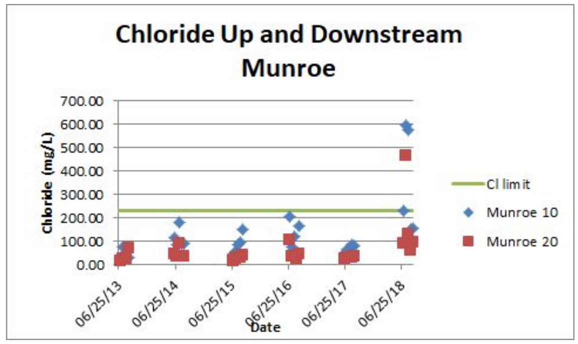
Indian	159, 187, 0.05	
Munroe	90,127,0.05	
Sunderland	0,1, 0.1	

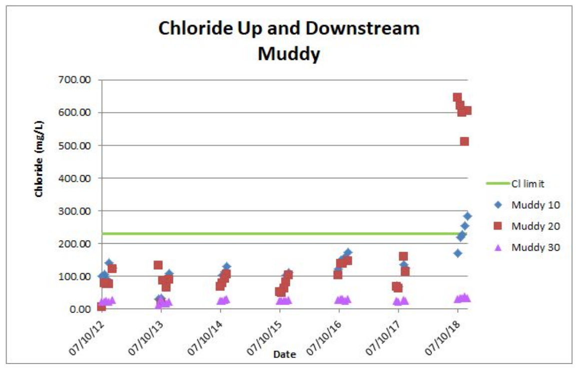
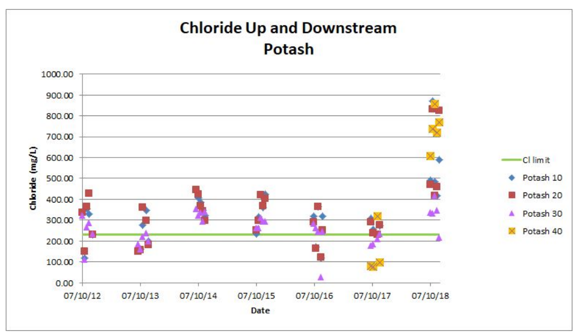
Site	K, Critical Value, Two tailed Alpha Value	Visualization
Muddy	26.85, 5.99, 0.05	
Potash	43.94, 7.81, 0.05	

Appendix E. Statistically Different Chloride Up and Downstream

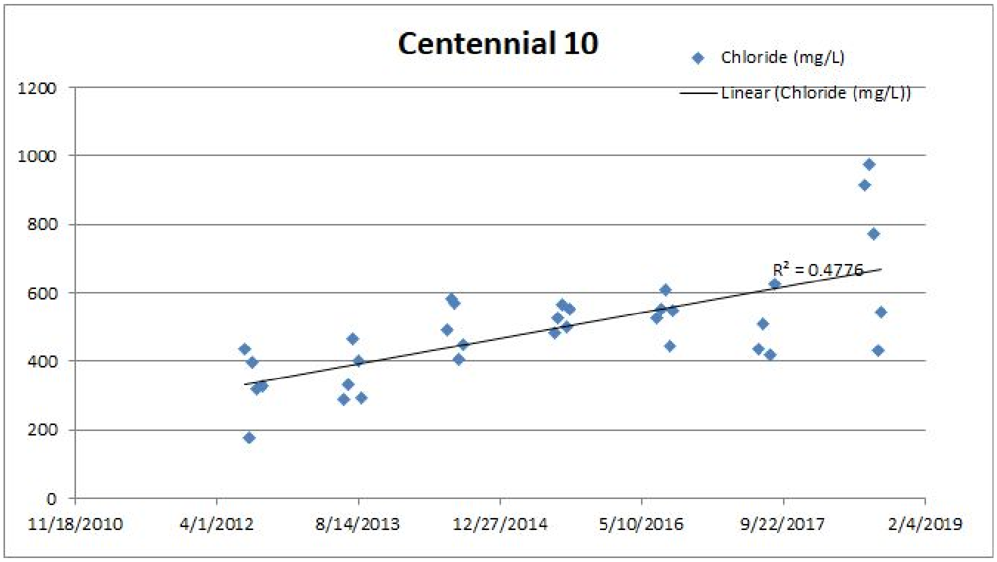
Stream	Test statistic, Critical Value, Two-tailed Alpha Value	Visualization

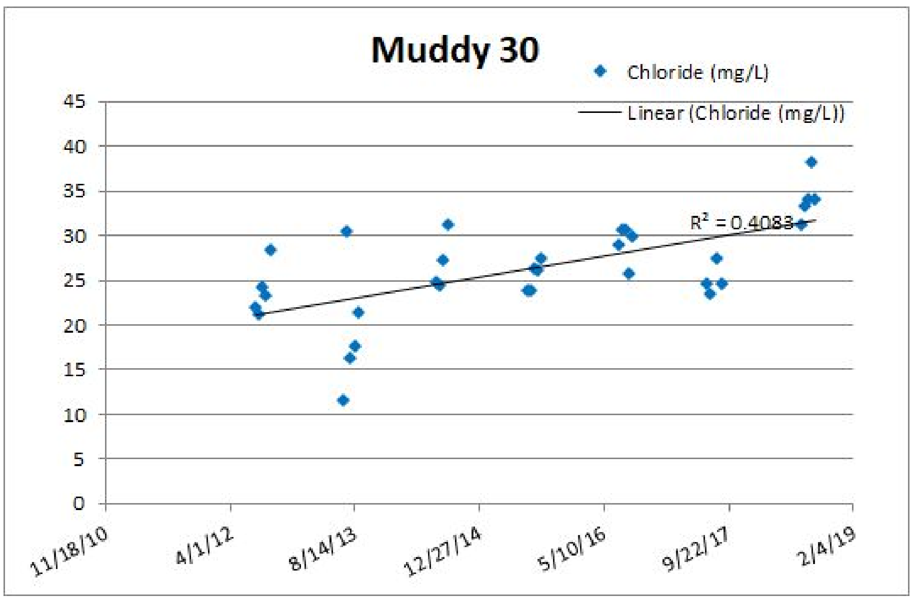
Centennial	0, 6, 0.05	
Engelsby	0, 6, 0.05	
Indian	1, 187, 0.05	
Morehouse	0, 1, 0.1	

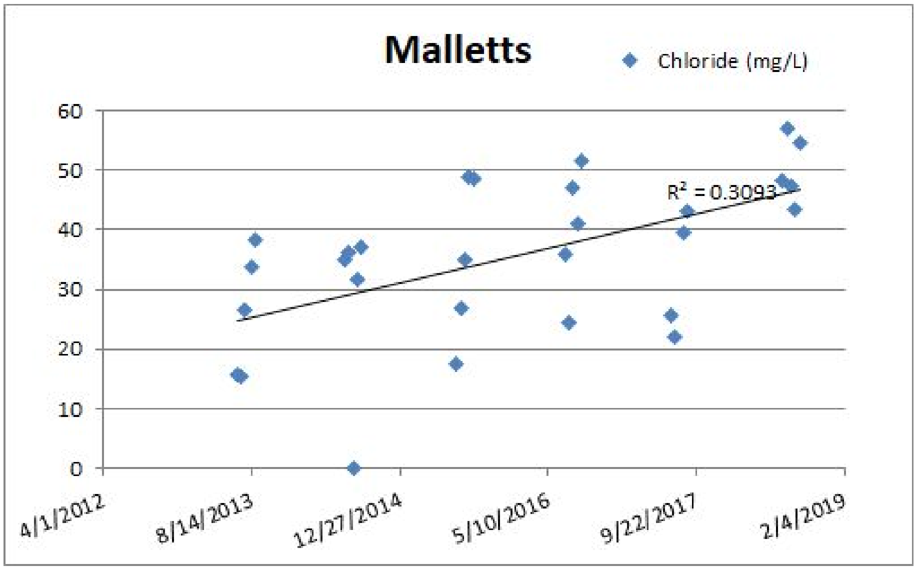
Munroe	9, 117, 0.05	

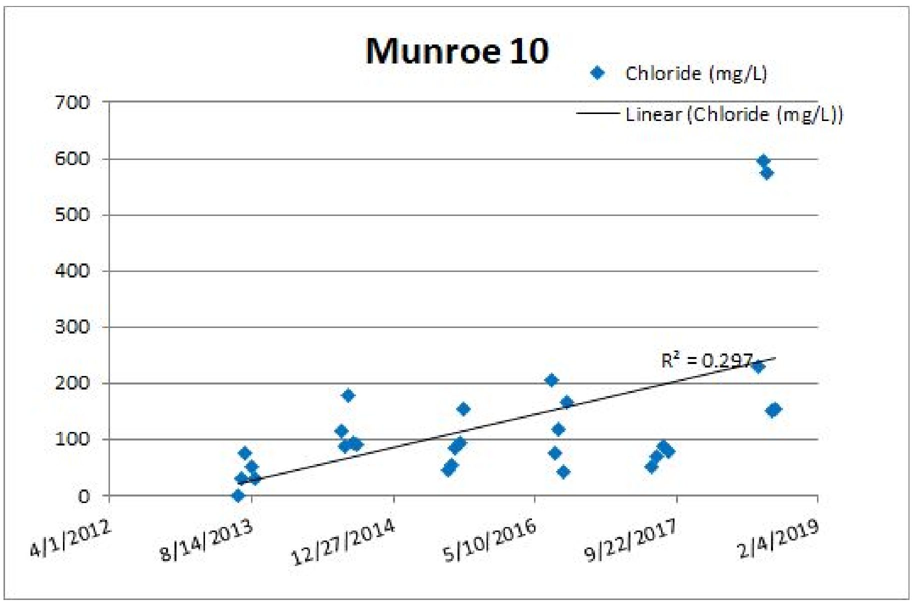
Site	K, Critical Value, Two tailed Alpha Value	Visualization
Muddy	57.23, 5.99, 0.05	
Potash	8.33, 7.81, 0.05	

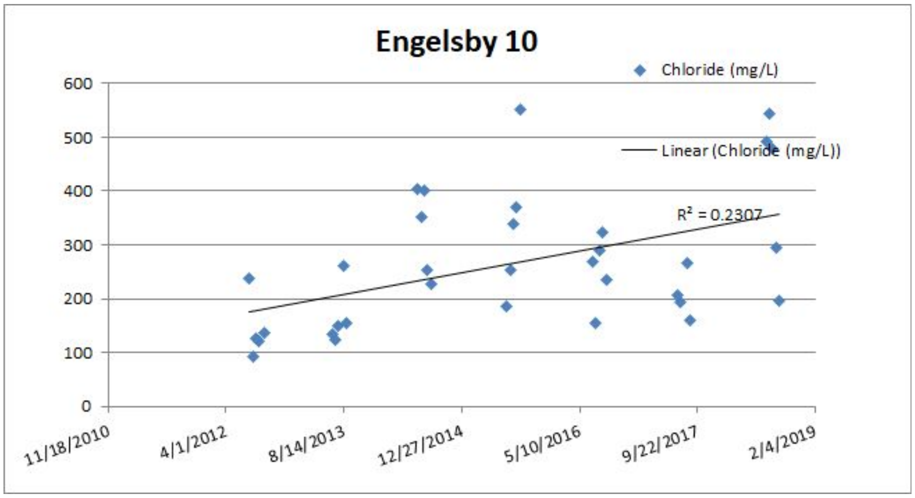
Appendix F. Notable Trends in Chloride Increases Over Time By Site. Sorted in descending order by R2 values.

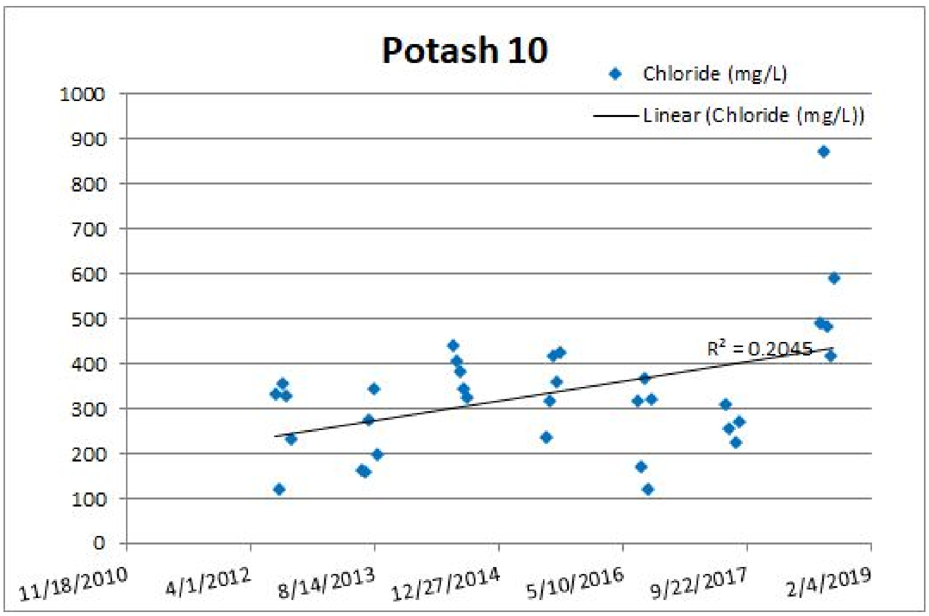

Centennial 10
Chloride (mg/L)
Linear (Chloride (mg/L))
$R^2 = 0.4776$
1200
1000
800
600
400
200
0
11/18/2010
4/1/2012
8/14/2013
12/27/2014
5/10/2016
9/22/2017
2/4/2019

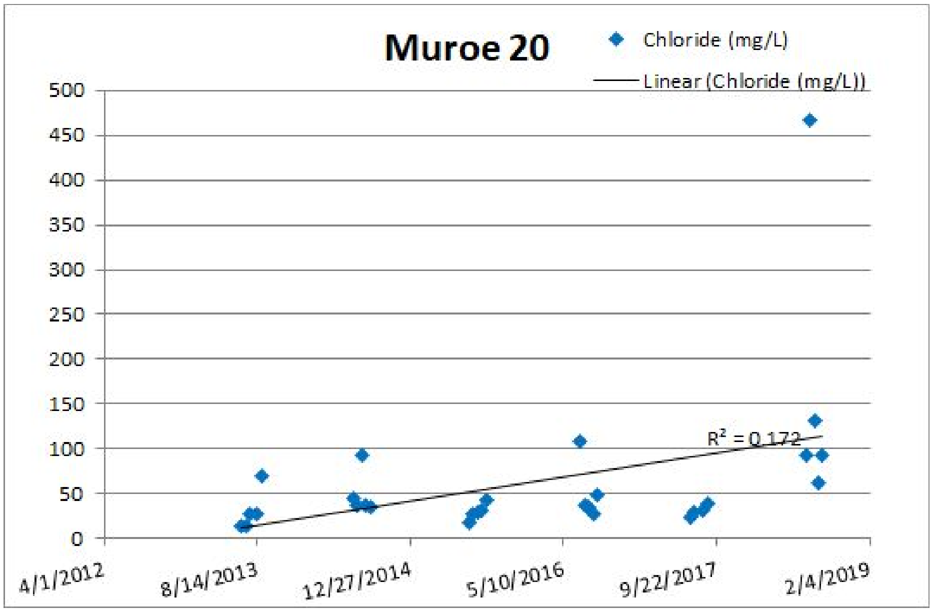

Muddy 30
Chloride (mg/L)
Linear (Chloride (mg/L))
$R^2 = 0.4083$
45
40
35
30
25
20
15
10
5
0
11/18/10
4/1/12
8/14/13
12/27/14
5/10/16
9/22/17
2/4/19

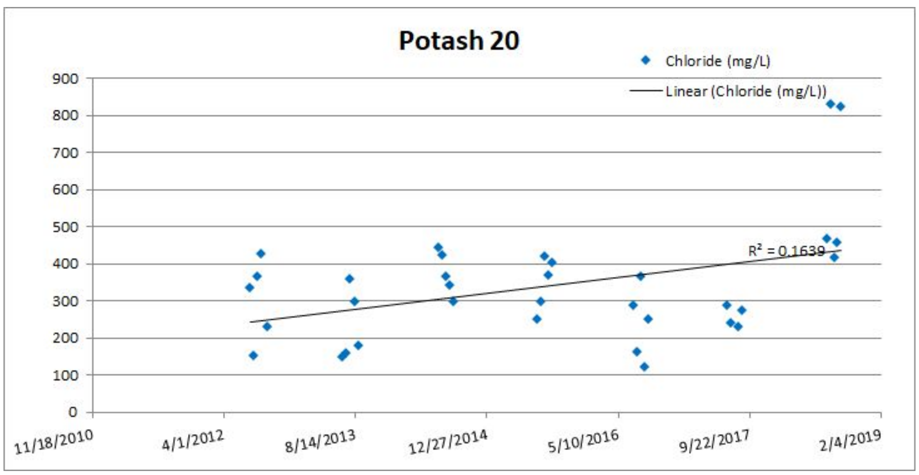

Malletts
Chloride (mg/L)
R^2 = 0.3093
60
50
40
30
20
10
0
4/1/2012
8/14/2013
12/27/2014
5/10/2016
9/22/2017
2/4/2019

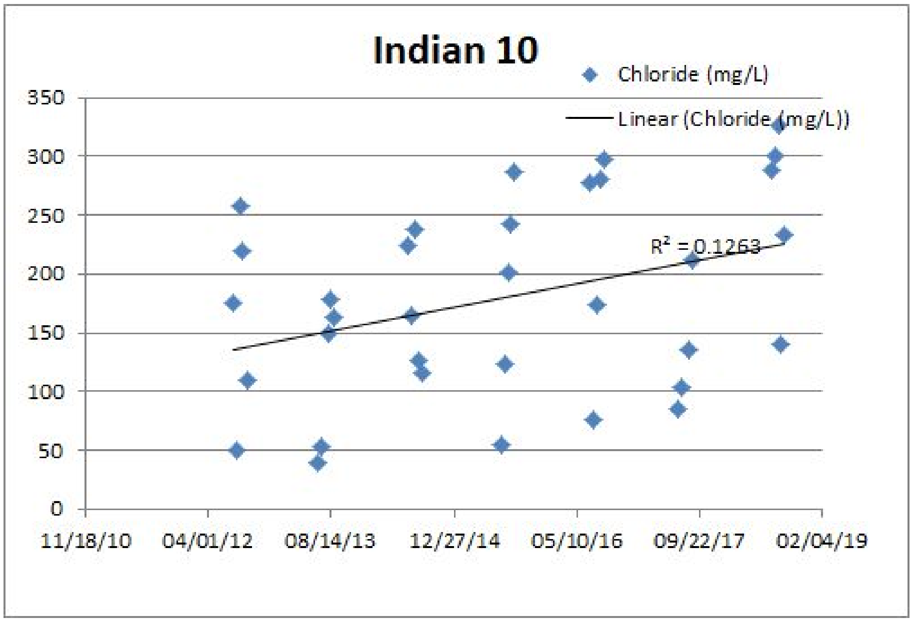

Munroe 10
Chloride (mg/L)
Linear (Chloride (mg/L))
R^2 = 0.297
700
600
500
400
300
200
100
0
4/1/2012
8/14/2013
12/27/2014
5/10/2016
9/22/2017
2/4/2019

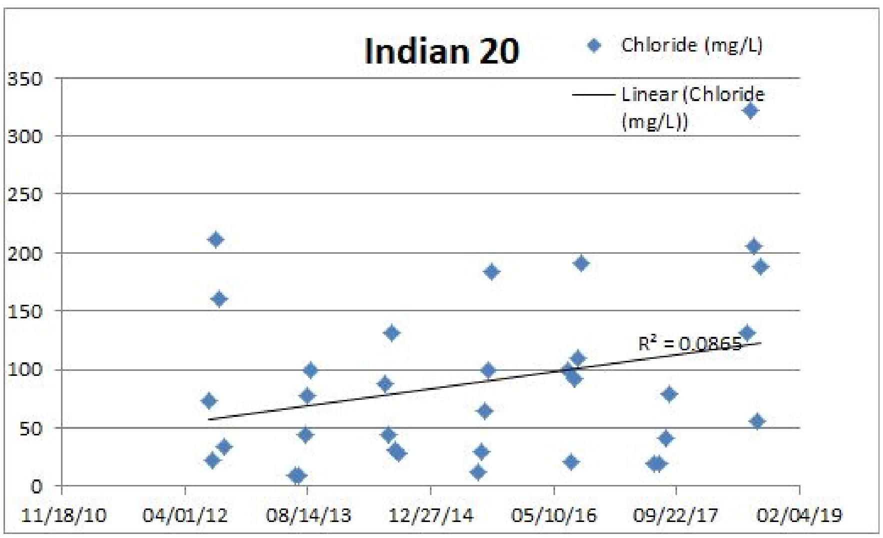

Engelsby 10
Chloride (mg/L)
Linear (Chloride (mg/L))
R² = 0.2307
600
500
400
300
200
100
0
11/18/2010
4/1/2012
8/14/2013
12/27/2014
5/10/2016
9/22/2017
2/4/2019


Potash 10
Chloride (mg/L)
Linear (Chloride (mg/L))
R² = 0.2045
1000
900
800
700
600
500
400
300
200
100
0
11/18/2010
4/1/2012
8/14/2013
12/27/2014
5/10/2016
9/22/2017
2/4/2019


Muroe 20
Chloride (mg/L)
Linear (Chloride (mg/L))
500
450
400
350
300
250
200
150
100
50
0
R² = 0.172
4/1/2012
8/14/2013
12/27/2014
5/10/2016
9/22/2017
2/4/2019


Potash 20
Chloride (mg/L)
Linear (Chloride (mg/L))
900
800
700
600
500
400
300
200
100
0
R² = 0.1639
11/18/2010
4/1/2012
8/14/2013
12/27/2014
5/10/2016
9/22/2017
2/4/2019


Indian 10
Chloride (mg/L)
Linear (Chloride (mg/L))
$R^2 = 0.1263$
350
300
250
200
150
100
50
0
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
02/04/19


Indian 20
Chloride (mg/L)
Linear (Chloride (mg/L))
$R^2 = 0.0865$
350
300
250
200
150
100
50
0
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
02/04/19