Assessment of Water Quality Conditions: Agassiz National Wildlife Refuge, 2012

Agassiz National Wildlife Refuge
22996 290th St. NE
Middle River, MN 56737-9754

Prepared by:
Josh Eash
U.S. Fish and Wildlife Service
Region 3
Division of Biological Resources
5600 American Blvd W
Bloomington, MN 55437
Correspondence: josh_eash@fws.gov

Cover photo: Thief River flowing into Agassiz National Wildlife Refuge

Credit: Dawn MacDonald, USFWS. August, 2012

Table of Contents

List of Figures

List of Tables

Executive Summary

In the summer of 2012, the U.S. Fish and Wildlife Service initiated water quality sampling on inlets, outlets and within-pool portions of Agassiz Pool, Agassiz National Wildlife Refuge's (NWR) largest wetland impoundment. The sampling was conducted in conjunction with on-going continuous water monitoring efforts measuring the volume and quality of waters entering and within Agassiz Pool. Current water quality monitoring was initiated in response to potential threats identified by two recent studies which measured sediment and nutrient loading within Agassiz Pool, its tributaries and outlets (Schottler and Engstrom, 2011; USGS, 2012). The goal of current water quality monitoring at Agassiz NWR is to: 1) track trends in water quality and quantity conditions relative to Watershed and Refuge management actions and 2) provide a better understanding of sediment and nutrient dynamics within Agassiz Pool.

Drought conditions during the 2012 sampling period allowed for the measurement of water quality conditions within Agassiz Pool with very little influence from incoming or outgoing flows. These data may be important in the future when comparing nutrient cycling capabilities under various water level management scenarios.

Water monitoring data, aerial imagery and on-site inspections coordinated with the drawdown of Agassiz Pool in 2012 indicate extensive sheet flow, vegetation disturbance and discrete periods of channel formation and sediment scour within Agassiz Pool. Further monitoring is necessary to understand the relationship between Pool levels, the management of the Ditch-11 Outlet WCS and streamflow. However, the initial results suggest that the 2012 drawdown was effective in removing water, drying soils and disturbing vegetation and soils in an isolated area around the Main WCS.

Sampling results for all sites in 2012 produced predictably low Total Suspended Sediment (TSS) concentrations due to the lack of runoff during the sampling period. Samples collected in the non-flowing waters of Agassiz Pool produced consistently low TSS concentrations, while samples from the inlet, channel and outlets sites varied widely. Relative to the other samples, Ditch-11 and the Agassiz Pool North Channel (within Pool) samples produced consistently high TSS concentrations when sampled.

The ratio of inorganic to organic material within sampled sediments was found to be primarily inorganic at inlet and outlet sites (sites with active streamflow) and primarily organic at in-Pool (non-flowing) sites. In 2012, TSS concentrations were so low that the composition of sediments is considered less significant than it would be during periods of high sediment transport.

Water samples analyzed for various forms of nitrogen and phosphorus at inlet and outlet sites were consistent with data collected by the USGS in 2008-2010 (2012). Although some concentrations were slightly elevated, sample results were for the most part, below the available state standards for each constituent. In-Pool samples, along with continuous water quality parameter data indicate a wetland system with pronounced primary and secondary production. Although this type of nutrient cycling is normal for wetlands, the dramatic changes in water chemistry over short periods of time in Agassiz Pool may indicate accelerated cycling due to an excess of nutrients in the system. This condition should continue to be closely monitored to better define the range of water chemistry changes in the Pool and

to consider potential impacts for habitats and wildlife. Of particular concern is the influence of nutrient concentrations and availability in exotic narrow leaf cattail production and the potential for large algal blooms if the current nutrient dynamics were to shift, especially with elevated concentrations of Total Nitrogen (TN) and Soluble Reactive Phosphorus (SRP). It is likely that large volumes of nitrogen and phosphorus are contained within Refuge ditch and wetland substrate, meaning that the availability of these constituents may be slow to reflect any changes in management or upstream best management practices.

Assessment of Water Quality Conditions: Agassiz National Wildlife Refuge, 2012

Background

In the summer of 2012, the U.S. Fish and Wildlife Service initiated water quality sampling on inlets, outlets and within-pool portions of Agassiz Pool, the Refuge's largest wetland impoundment. The sampling was conducted in conjunction with on-going continuous water monitoring efforts measuring the volume and quality of waters entering and within Agassiz Pool. Current water quality monitoring was initiated in response to potential threats identified by two recent studies which measured sediment and nutrient loading within Agassiz Pool, its tributaries and outlets (Schottler and Engstrom, 2011; USGS, 2012). The goal of current water quality monitoring at Agassiz NWR is to: 1) track trends in water quality and quantity conditions relative to Watershed and Refuge management actions and 2) provide a better understanding of sediment and nutrient dynamics within Agassiz Pool. As new management strategies are implemented to improve wildlife habitat through the reduction of sediment inputs, previously deposited inorganic sediment, and an overall improvement of water quality, it is important that water quality monitoring continues to serve as a tool by which to evaluate the effectiveness of these strategies. By measuring the response of sediment and nutrient dynamics to Refuge actions, it will help to inform future refuge planning, management actions and infrastructure design.

Methods

Water quality grab samples were collected within Agassiz Pool and at its associated inlets and outlets during the 2012 open water seasons by sampling once during each of the following months: June, July, August, and September. Ten discrete water quality sampling sites were identified across the Refuge, the three continuous monitoring gages, two outflow sites, and five random sites within Agassiz Pool where samples were collected during each monthly sampling effort (inlets and outlets were only sampled if streamflow was present). Water temperature, specific conductance, DO, pH, and turbidity were continuously measured by water quality sondes installed at streamflow gages, whereas point measurements were performed at all other sites using a hand-held sonde. Samples were analyzed for total nitrogen, nitrate, ammonia, soluble reactive phosphorus (SRP), and total phosphorus (TP). Samples were also analyzed for the concentration of total suspended solids (TSS) and the ratio of inorganic to organic material contained within each TSS sample. Samples were collected downstream of the outflow water control structures (Ditch-11 Outflow and Thief River Outflow sites), at the three gages (Thief River, Ditch-11, Agassiz Pool), and at the random Agassiz Pool sites (Agassiz Pool Site #1-5; Fig. 1) to determine the concentration of nutrients and suspended solids and to determine the type of sediment (i.e., wetland substrate or inorganic sediment). Streamflow measurements were conducted at the inflow and outflow sample sites in conjunction with sample collection.

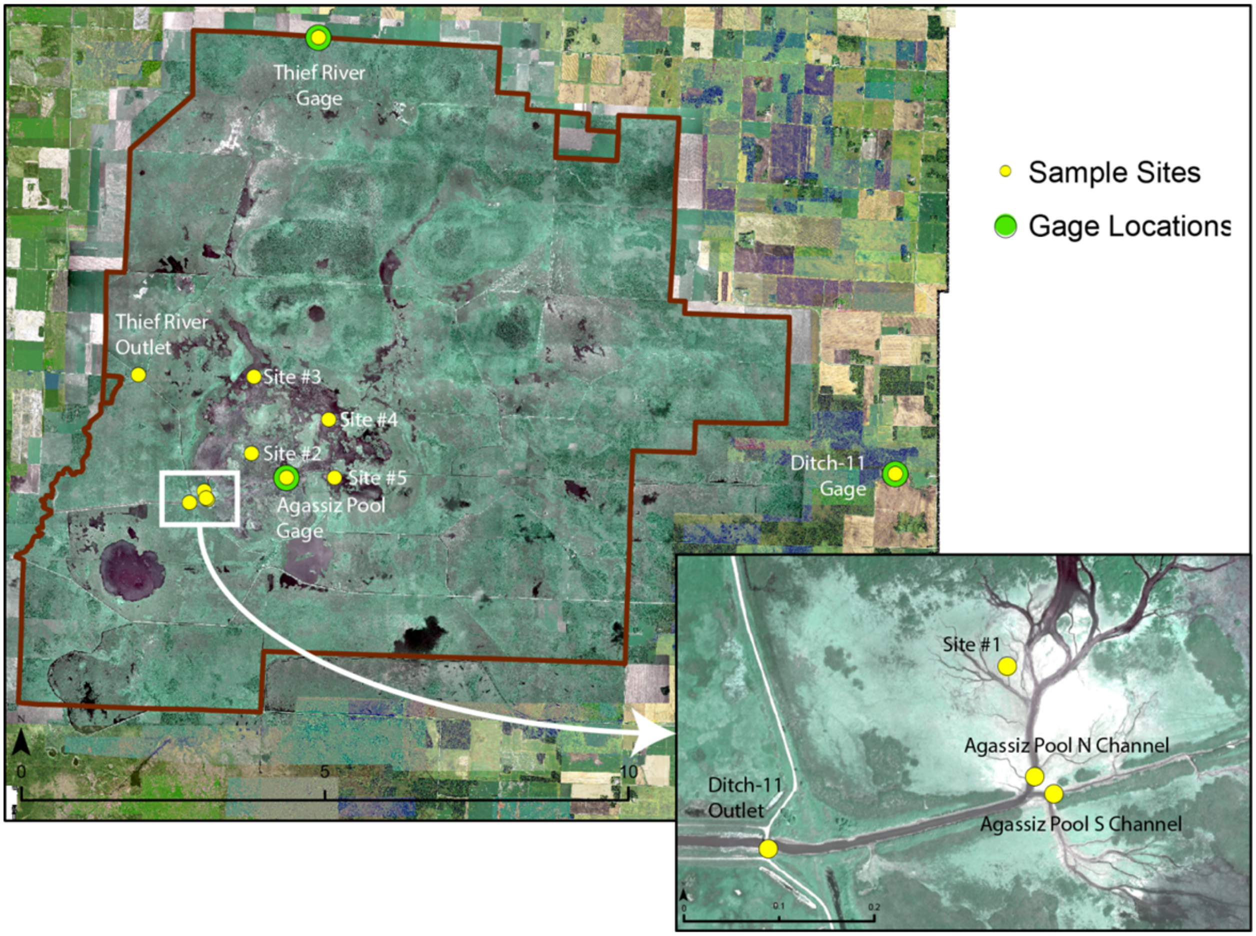

Figure 1: 2012 water monitoring gage and sampling sites on and near Agassiz NWR.

Over the course of the summer, 27 samples were collected at 12 different sites (Appendix A). The randomly selected Agassiz Pool sites (#1-5 and Agassiz Pool gage; Fig. 1) were sampled once each in June and July before the drawdown of the Pool prevented access to those sites. After the Pool was largely dewatered, during the August and September sampling, two additional sites were selected and sampled from drainage pathways formed within Agassiz Pool (Agassiz Pool North Channel and Agassiz Pool South Channel; Fig. 1). The water control structure (WCS) located on the Ditch-11 Outlet (Fig. 1) of Agassiz Pool was closed in June and July due to dry conditions, and was therefore only sampled in August and September when discharge was occurring. Likewise, the Thief River Outlet (Fig. 1) WCS was only open during the September trip, which represents the only sample from this site. Continuous monitoring gage sites on the Thief River near Gatzke and Ditch 11 near Grygla (Fig. 1) were sampled during all four months.

Precipitation

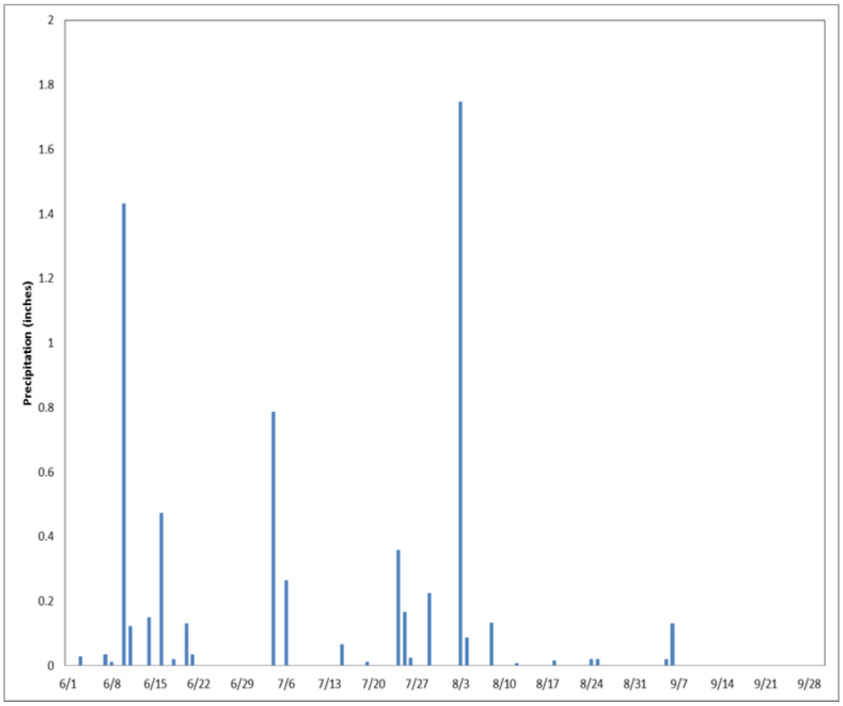

Figure 2: Daily precipitation (in inches) June – September, 2012. Agassiz NWR RAWS station, Goodridge 12 NNW, MN US GHCND:USW00004994

The summer of 2012 was marked by drought conditions across much of the Midwest which included Agassiz NWR. Although there was some precipitation during the sampling period, the rain that did fall was infrequent and in small amounts. The total rainfall from June 1 to September 30, 2012 was only 6.5 inches as measured at the Agassiz NWR weather station. For comparison, average monthly totals from June through September for the city of Thief River Falls are approximately 11.6 inches.

Surface Water

Drought conditions throughout the late-spring and summer months produced lower than normal flows on both of the primary tributaries to Agassiz Pool, resulting in a shortage of water for achieving some wetland management objectives. In order to sustain aquatic habtiats in Agassiz Pool both outlet structures remained closed throughout the summer to maintain adequate water depth and distribution (Fig. 3). Flows downstream of the Refuge were also much lower than normal due to the drought, as can be seen from the USGS streamflow data on the Thief River at Thief River Falls located approximately 10 miles downstream of the Agassiz Pool outlet (Fig. 4). On August 1, 2012

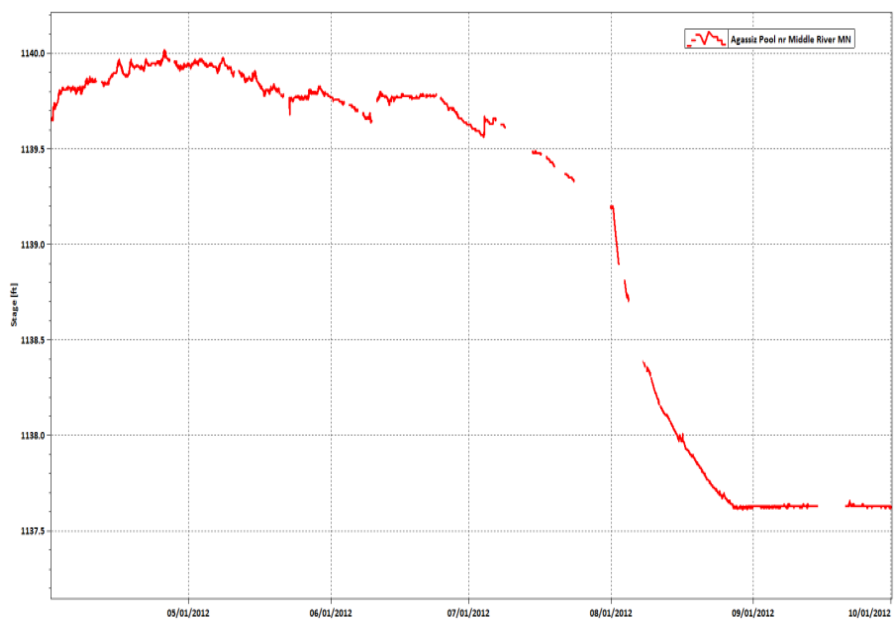

Figure 3: Agassiz Pool hydrograph April-September 2012.

Refuge staff initiated a drawdown of Agassiz Pool in accordance with their 2012 habitat management plans. The initial pulse of water discharging through the Ditch-11 Outlet produced high flows downstream for a short period of time (10 days with flows >100 cubic feet per second at USGS Thief River near Thief River Falls gage) and the entire pool drained to the extent possible in approximately 1 month (Fig. 4).

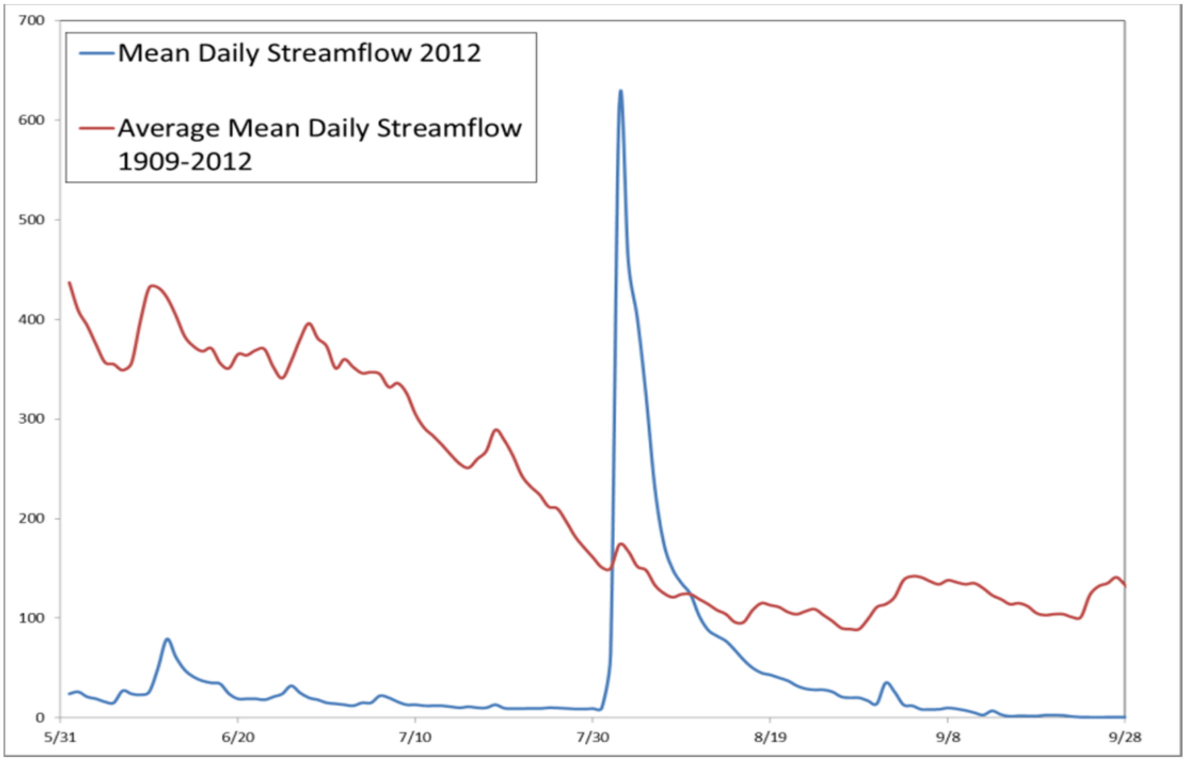

Figure 4: ***Daily precipitation (in inches) June – September, 2012. Agassiz NWR RAWS station, Goodridge 12 NNW, MN US GHCND:USW00004994***

The drawdown within the pool caused significant disturbance to emergent wetland vegetation and substrate in the immediate vicinty of the Ditch-11 Outlet. The head differential created between water surface elevations in the main ditch system extending upstream of the Ditch-11 Outlet and water surface elevations within Agassiz Pool appear to have created velocities sufficient to flatten vegetation and scour multiple networks of channels (Fig. 5).

Figure 5: USFWS hydrologic technician Jaime Nielsen inspects vegetation disturbance and scoured channels within Agassiz Pool on August 8, 2012.

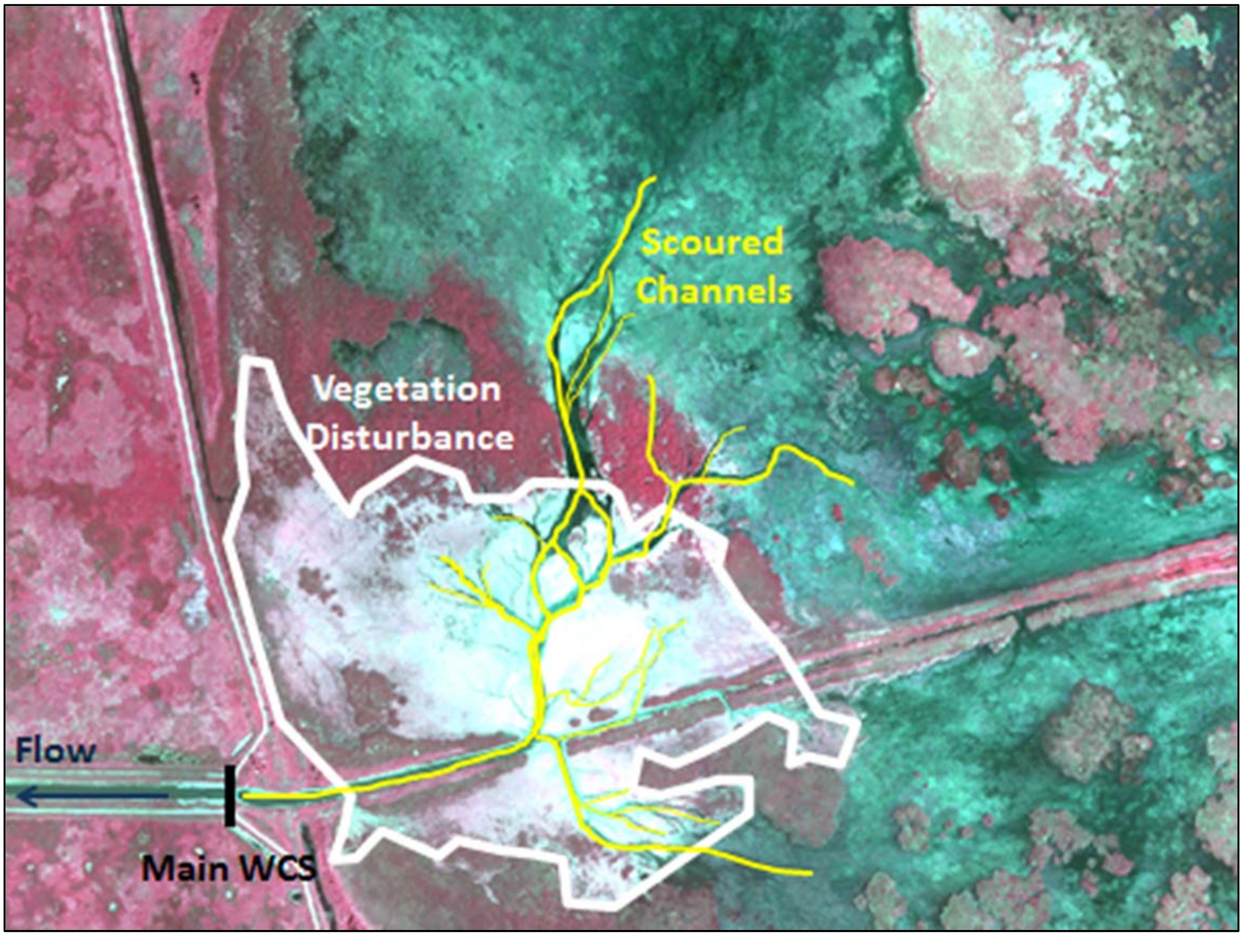

Figure 6: ***USFWS infrared imagery of Agassiz Pool and the Main WCS on August 7, 2012 approximately 7 days after the radial gates were opened to initiate a drawdown of the Pool. Areas of flattened and/or scoured vegetation are evident along with channels eroded through the wetland substrate.***

On the ground inspections and aereial imagery of these areas suggest a period of high velocity sheetflow spanning a large area around the Ditch-11 Outlet as water levels within the ditch began to drop lower than the surrounding pool water level. The sheetflow had velocities sufficient to flatten large areas of vegetation and undoubtedly transport large volumes of unconsolidated organic substrate from these areas of the Pool (Fig. 6). By August 7, conditions had transitioned to consolidated flow within discrete channels as water levels within the pool had dropped below the landsurface elevation, thus resulting in a reduction in head differential.

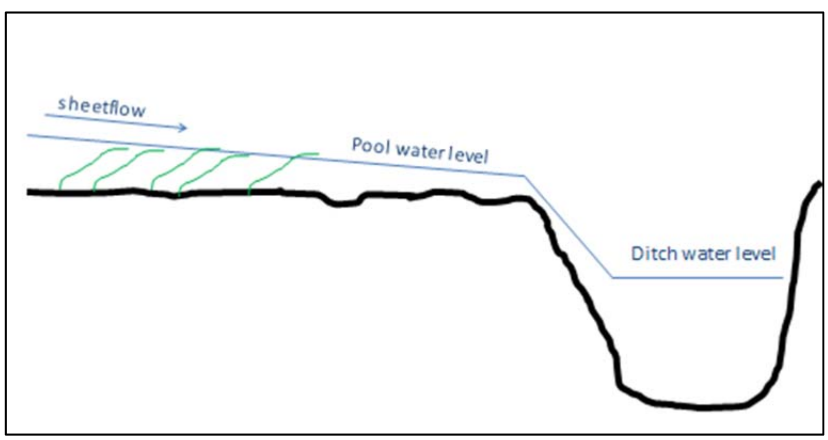

Figure 7: Diagram of hypothetical water surface profile within Agassiz Pool during periods of sheet flow.

Infrared imagery displayed an area of vegetation disturbance of approximately 100 acres and the scour channels extended as far as 0.6 miles into the Pool from the Ditch-11 Outlet (Fig. 6). This anecdotal evidence, along with observations from Refuge staff, suggest that there may be a critical Pool elevation relative to radial gate (Ditch 11 Outlet strucutre) opening which lowers water level within the Ditch-11 Outlet ditch while water level within the Pool is still above the surrounding landsurface (Fig. 7).

Water Chemistry

Total Suspended Solids (TSS)

TSS concentrations were generally low for all samples analyzed in 2012. This is not surprising given the drought conditions and limited runoff occurring during the sampling period. With very low flows on both inflow sampling sites, erosion and subsequent transport of sediments from agricultural fields and/or ditch banks upstream was unlikely during this period. However, the September sample at the Ditch-11 gage site does show slightly elevated concentrations which may correspond with some isolated rainfall at the time the samples were collected.

TSS values found in 2012 ranged from approximately 1 mg/L to 27 mg/L across all samples (Fig. 8). While samples collected in the non-flowing waters of Agassiz Pool produced consistently low TSS concentrations (3.9 mg/L to 0.9 mg/L), samples collected from the inlet, within pool channels and outlets sites varied widely. Relative to the other samples, Ditch-11 produced consistently high TSS concentrations throughout the year, ranging from approximately 7mg/L to 19.5 mg/L (Fig. 8). The Agassiz Pool North Channel sample site also produced relatively high TSS concentrations, ranging from 14.3 mg/L to 26.8 mg/L during the drawdown of Agassiz Pool. Questions still remain regarding the timing and degree of sediment transport. In the future, additional streamflow information will be necessary to evaluate potential scour conditions and to calculate loads for comparisons between inlet and outlet sites.

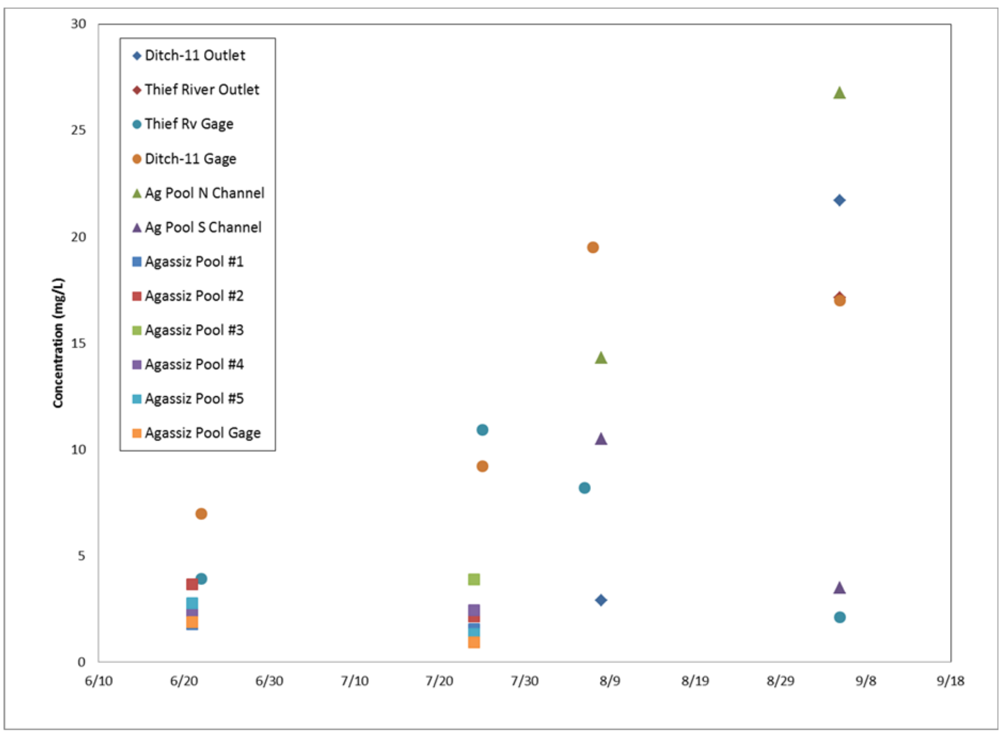

Figure 8: Agassiz 2012 Total Suspended Solids Concentrations from all sites.

The range in TSS concentrations from samples collected in 2012 correlate reasonably well with the approximate median values from U.S. Geological Survey (USGS) suspended sediment values from 2008-2010 for inlet sites. Outlet sites sampled in 2012 showed a significantly lower range in TSS concentrations than the approximate USGS median values (Table 1). The USGS (2012) did not collect in-pool samples. It should be noted that the USGS analyzes for total suspended sediment, which only includes inorganic particles, as opposed to the total suspended solids (TSS) analysis performed on 2012 samples which includes both inorganic and organic components.

The Minnesota Pollution Control Agency's (MPCA) draft aquatic life TSS criteria for the Central River Nutrient Region is 30 mg/L (MPCA, 2011). The Thief River is identified as a central region watershed in the MPCA 2010 Regionalization of Minnesota's Rivers for Application of River Nutrient Criteria (MPCA, 2010). TSS standards must not be exceeded more than 10% of the time over a multiyear data window; the assessment season is April through September. None of the samples collected in 2012 exceeded the 30 mg/L TSS criteria.

Agassiz NWR straddles two Minnesota ecoregions: the Red River Valley ecoregion and the Northern Minnesota Wetlands ecoregion. The MPCA lists the 50th percentile for TSS concentrations in streams of the Northern Minnesota Wetlands ecoregion as 11 mg/L, while the Red River Valley ecoregion's 50th percentile is 50 mg/L (MPCA, 2010).

Table 1: Total Suspended Solids concentrations from 2012 sampling at Agassiz, USGS 2008-2010 results and water quality standards.

Site	2012 Range in TSS (mg/L)	Approx. USGS median value (mg/L)	TSS criteria (mg/L) (lakes and streams respectively)	2012 sample values exceeding criteria
Inlets	2.109 – 19.50	10[1]	30[2]	N/A
Agassiz Pool	0.933 – 26.77	--	30[2]	N/A
Outlets	2.90 – 21.712	35[1]	30[2]	N/A

[1]USGS, 2012. **Note: USGS analyzed suspended sediment (only inorganic component), not total suspended solids.**
[2]MPCA, 2011.

Organic vs Inorganic Sediments

To determine the inorganic versus organic composition of solid particles within water samples, a loss on ignition (LOI) analysis was performed on most of the samples collected in 2012. Overall, TSS concentrations were fairly low for all samples which lowered the significance of the inorganic versus organic components of the sediment being transported into, out of or within Agassiz Pool.

Samples collected at Agassiz Pool sites #1-5 showed a relatively low percentage of inorganic sediment, ranging between 15% and 30%. Only one LOI sample was obtained for each of these sites (June). Agassiz Pool gage site samples from June and July show a more even mix of sediment content with around 50% comprised of inorganic particles for both samples (Fig. 9). The higher amount of inorganic materials in the gage site samples may be due to bed disturbance associated with checking the gage (staff would have been wading in the water whereas other within-Pool site samples were collected off of the air boat deck). The results from the Agassiz Pool sites are consistent with expectations for a greater composition of organic matter in suspension when Pool water levels are managed in a more static state.

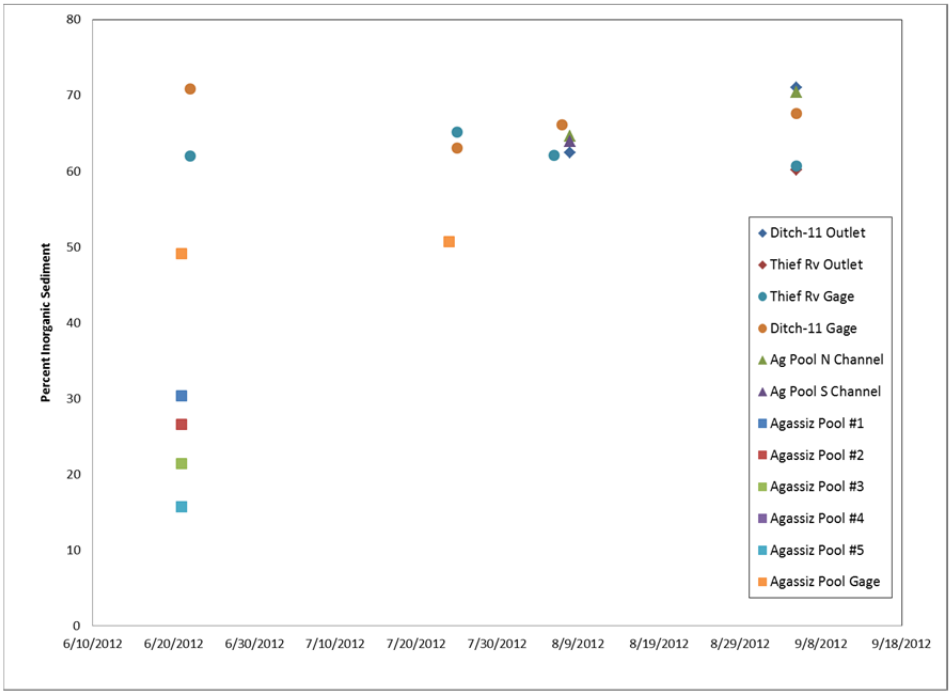

Figure 9: Agassiz 2012 Percentage of inorganic sediment within water samples.

Agassiz Pool North and South Channel alternate site samples were collected as the only option after the western 1/3 of Agassiz Pool, including the Pool's only airboat launch site, dried up due to the drawdown and drought conditions. Erosion was evident in these channels with noticeable velocity as the veins emptied into the main ditch system in front of the Ditch-11 Outlet WCS. Course to fine grain aggregate was evident in these channels and the LOI analysis confirms the transport of more inorganic sediments. Samples from August and September show an inorganic concentration of approximately 65-70% (Fig. 9). The banks of the channels were approximately 2-3 feet deep and largely unstable. Due to the depth and location of the channels it is unclear as to whether the inorganic sediments transported out of the Pool during the drawdown are from recent (i.e., past 70 years) deposits associated with agricultural runoff and ditch bank erosion or if they are part of the wetland substrate that was in place prior to Refuge establishment.

Using lakes from the Northern Glaciated Plains ecoregion as a comparison for Agassiz Pool sample results (similar comparisons for Northern Minnesota Wetlands ecoregion are unavailable), shows that TSS concentrations can be quite high in the lakes of the Northern Glaciated Plains with individual values ranging as high as 110 mg/L, of which 82 % was inorganic suspended solids, when sampled on very windy days. However, in contrast, other lakes in this ecoregion were found to have TSS concentrations predominately comprised of organic suspended solids, such as algae (Heiskary et al., 2003; MPCA, 2005).

On average, total suspended sediment concentrations for lakes of the Northern Glaciated Plains are between 10-30 mg/L during the summer months (MPCA, 2005). This comparison appears to fit well with the higher percent of organic material found in the June samples from Agassiz Pool. Results suggest that TSS within the Pool is primarily comprised of plant and insect tissue.

All sampled inlets, outlets and within-Pool scours showed inorganic concentrations ranging from 60-71% (Fig. 9). This means that during the sampling periods the majority of both inflowing and outflowing sediments to Agassiz Pool were of inorganic composition. The samples collected at the Thief River and Ditch-11 gage sites showed similar percentages of inorganic sediments. For most samples, the Ditch-11 gage site had a slightly higher percentage of inorganic sediment when compared to the Thief River gage samples. Ditch-11 gage site percentages also varied more across the four samples than did the percentages from the Thief River.

The North and South Agassiz Pool channels compared well with the Ditch-11 Outlet site in terms of inorganic percentages. Both the North Channel and the Ditch-11 Outlet site showed similar trends during both August and September samples (Fig. 9). This was expected, due to the fact that the North Channel likely constituted the majority of outflow through the Ditch-11 Outlet radial gates during both the August and September visits.

Nitrogen

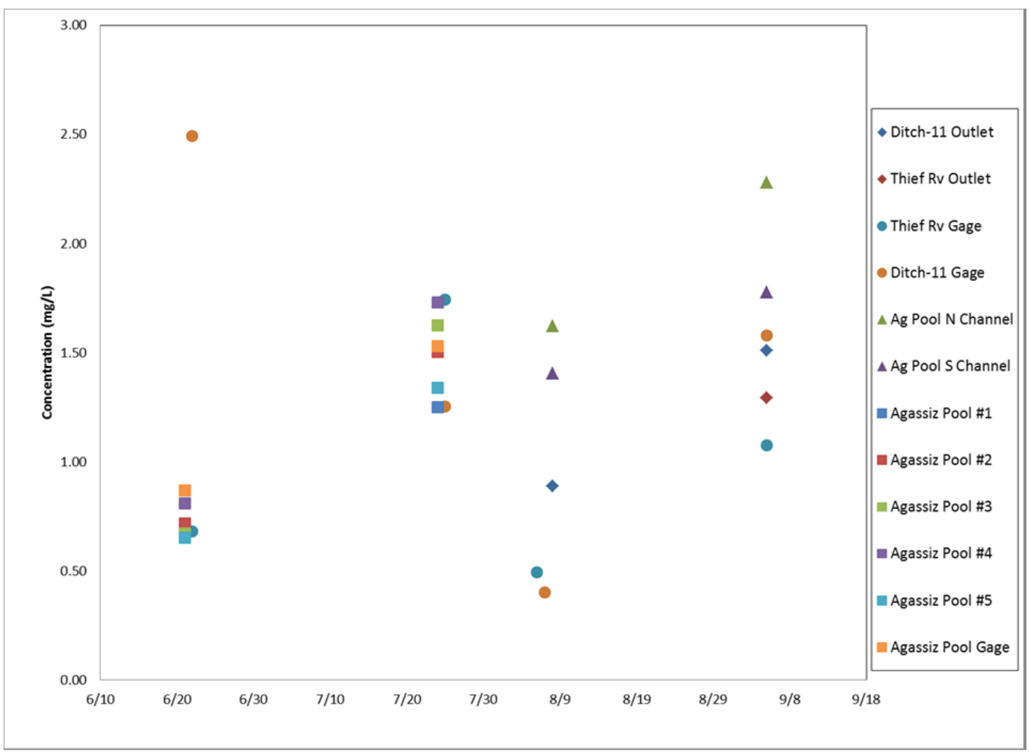

Figure 10: Agassiz 2012 Total Nitrogen concentrations in mg/L for all sites.

Total Nitrogen (TN)
Minnesota does not have water quality criteria or standards for total nitrogen concentrations. Results from 2012 sampling suggest that the inflows, outflows and within-pool systems of Agassiz NWR are not 'nitrogen limited', meaning that biotic productivity is not limited by the availability of nitrogen.

The highest concentrations of TN, and the only sites measured above 2 mg/L, were found at the Ditch-11 gage site in June and the North Channel Agassiz Pool site in September (Fig. 10). The elevated concentrations found at the Ditch-11 gage site in June may correlate with agricultural fertilizer applications upstream or some other isolated input of nutrients adjacent to the ditch system. Various forms of nitrogen (inorganic and organic) are likely entering Agassiz Pool, many of which become bio-available and are digested and converted to various forms of biomass within the Pool. Due to this production we would expect that TN outputs from the Pool may be high as well, but will be primarily organic forms of nitrogen. Between the June and July samples, an increase in TN concentrations can be seen within the Pool which is likely associated with biotic production. Elevated concentrations on the North Channel, or any of the samples associated with water flowing out of Agassiz Pool, is likely associated with biotic production within the pool (organisms and their tissue are in elevated concentrations within the water column).

Total nitrogen concentrations for Agassiz Pool inlets and outlets, respectively, compare well with approximate median concentrations measured by the USGS between 2008-2010 (2012; Table 2).

Table 2: Total Nitrogen Concentrations from 2012 sampling at Agassiz, USGS 2008-2010 results and water quality standards.

Site	2012 Range in TN (mg/L)	Approx. USGS TN median value (mg/L)	TP criteria (mg/L) (lakes and streams respectively)	2012 sample values exceeding criteria
Inlets	0.40 – 2.49	1.5[1]	N/A	N/A
Agassiz Pool	0.65 – 2.28	--	N/A	N/A
Outlets	0.89 – 1.51	1.5[1]	N/A	N/A

[1]USGS, 2012.

Nitrate

Minnesota's draft acute nitrate criteria (maximum standard) for the support of aquatic life is 41 mg/L nitrate-N for a 1-day duration, while the draft chronic value is 4.9 mg/L nitrate-N for a 4-day duration (MPCA, 2010). The U.S. Environmental Protection Agency's (EPA) maximum contaminant level (MCL) for nitrate-N in drinking water is 10 mg/L.

Nitrate concentrations from all samples collected in 2012 were well below the state of Minnesota's draft acute and chronic standards for the support of aquatic life and also below the EPA's drinking water contaminant level. All values were consistently very low, except the June sample at Ditch-11 (1.779 mg N/L) which constitutes the majority of the higher TN concentration measured from this sample and may suggest an input of agricultural fertilizer from upstream. As a whole, nitrate concentrations from samples collected in 2012 are consistent with nitrate concentrations measured by the USGS in 2008-2010 (2012; Table 3).

Table 3: Nitrate concentrations from 2012 sampling at Agassiz, USGS 2008-2010 results and water quality standards.

Site	2012 Range in NO_3 (mg N/L)	Approx. USGS median value NO_3 (mg N/L)	NO_3 (mg N/L) chronic exposure criteria	2012 sample values exceeding criteria NO_3 (mg N/L)
Inlets	0.000 – 1.779	0.4[1]	4.9[2]	N/A
Agassiz Pool	0.003 – 0.015	--	4.9[2]	N/A
Outlets	0.006 – 0.022	0.06[1]	4.9[2]	N/A

[1]USGS, 2012

[2]MPCA, 2010

Un-ionized Ammonia

Minnesota water quality standards for un-ionized ammonia are 0.04 mg N/L (Minnesota Office of the Revisor of Statues 7050.0220, 2012). Un-ionized ammonia concentrations for most samples collected during the summer of 2012 were calculated using NH_4 mg N/L, field measurements of water temperature and pH, and the formula recommended by Minnesota state statues (Minnesota Office of the Revisor of Statues 7050.0222, 2012), which determines chemical speciation as a function of pH and temperature. Some samples lacked the corresponding water quality parameter measurements and therefore concentrations could not be computed for these samples (June: Agassiz Pool 1-5 and Ditch-11 gage; August: Agassiz Pool North and South Channel). Results from these computations show that un-ionized ammonia concentrations were below state standards for most samples except for August samples collected at Agassiz Pool sites 3 and 4(Table 4; Appendix A). USGS sampling in 2008-2010 did not produce any un-ionized ammonia concentrations in excess of the 0.04 mg N/L standard (USGS, 2012).

Table 4: Un-ionized ammonia concentrations from 2012 sampling at Agassiz, USGS 2008-2010 results and water quality standards.

Site	2012 Range in NH_3 (mg N/L)	Approx. USGS values NH_3 (mg N/L)	NH_3 (mg N/L) criteria	2012 sample values exceeding NH_3 (mg N/L) criteria
Inlets	0.0018 – 0.0173	<0.04[1]	0.04[2,3]	N/A
Agassiz Pool	0.0008 – 0.0689	<0.04[1]	0.04[2,3]	Agassiz Pool 3&4 (July)
Outlets	0.0002 – 0.0116	<0.04[1]	0.04[2,3]	N/A

[1]USGS, 2012

[2]Minnesota Office of the Revisor of Statues 7050.0220, 2012

In-situ monitoring of water quality parameters at the Agassiz Pool gage site show dramatic fluctuations in pH and dissolved oxygen concentrations (Fig. 11). Due to the fact that un-ionized ammonia concentrations are influenced by the pH and temperature of the water column, it is not surprising that there were fluctuations in the un-ionized ammonia concentrations and that those samples collected during periods of high pH and high water temperature (late afternoon to early evening during the summer months) occasionally exceeded state standards. These data suggest that un-ionized ammonia concentrations experience daily diurnal trends where photosynthesis and primary aquatic organism (algae, plants, etc.) production during summer days converts CO_2 to O_2 thereby creating super oxygenated (high dissolved oxygen) and very basic (high pH)water, along with higher concentrations of un-ionized ammonia. Conversely, at night, when photosynthesis cannot occur due to a lack of sunlight, secondary production occurs whereby bacteria consume large amounts of O_2. This results in lower dissolved oxygen, pH and un-ionized ammonia by the start of the next day. It is important to note that un-ionized ammonia can be oxidized to nitrate in a biologically mediated reaction which is most prone to occur during high concentrations of dissolved oxygen. Similarly, un-ionized ammonia also volatilizes at the air-water interface, most commonly at pH levels above 9.0. Conversion and uptake would likely be highest in flowing waters. Therefore the unstable qualities of un-ionized ammonia help to regulate its concentrations within Agassiz Pool and make it highly unlikely that higher concentrations would be transported downstream.

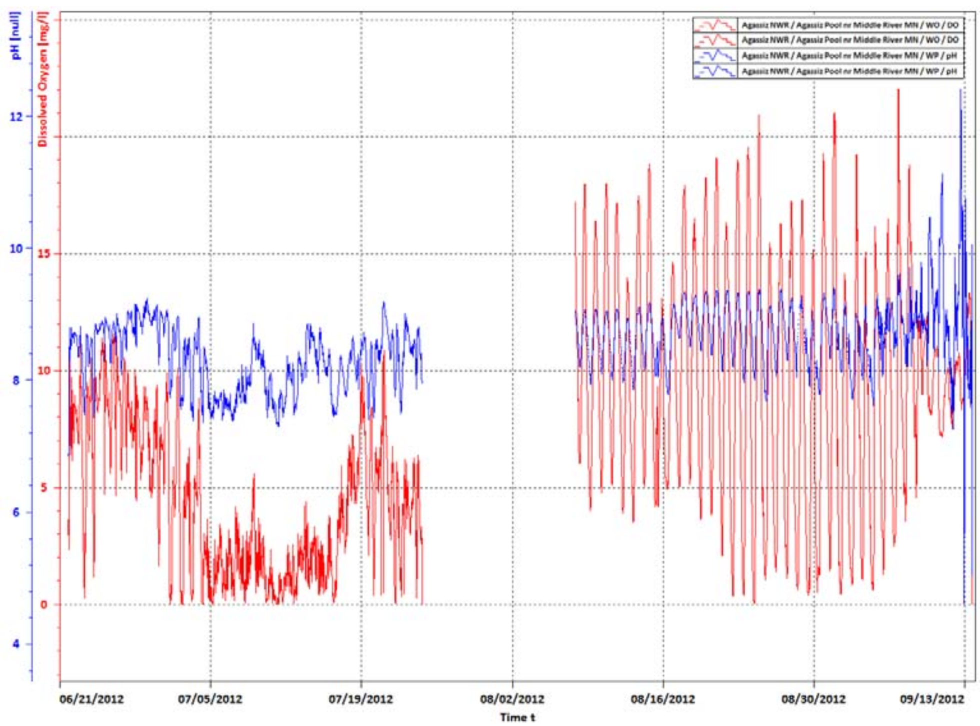

Figure 11: Preliminary continuous data (recorded every 30 min) for pH and dissolved oxygen concentrations (mg/L) measured at the Agassiz Pool gage site for June 1 – September 30, 2012.

Phosphorus

Total Phosphorus (TP)

The MPCA has not developed eutrophication standards for shallow lakes in either of the ecoregions within which the Refuge is located (Red River Valley and Northern Minnesota Wetlands). Therefore, for comparison purposes, results of TP concentrations for samples collected in Agassiz Pool during 2012 were evaluated based on the Minnesota water quality standards of 0.09 mg/L for shallow lakes in the Northern Glaciated Plains ecoregion (Minnesota Office of the Revisor of Statues 7050.0222, 2012) which is consistent with comparisons made by the USGS (USGS, 2012). Inlet sites were compared with EPA water quality recommendations of 0.05 mg/L threshold for streams flowing into lakes (EPA, 1986), while the outlet sites were evaluated based on Minnesota's draft Central River Nutrient Region Recommended Criteria of 0.10 mg/L (MPCA, 2013) (MPCA, 2010).

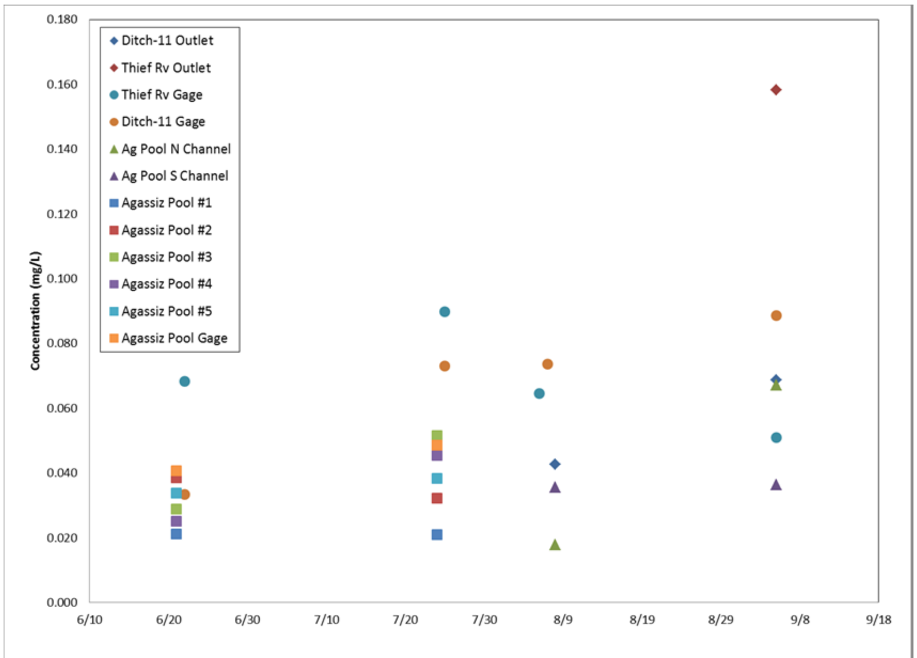

Figure 12: Agassiz 2012 Total Phosphorus concentrations in mg/L for all sites.

Inlet sites exceeded the EPA's recommended concentration of 0.05 mg/L for streams entering lakes for 7 out of the 8 samples collected at the Thief River and Ditch-11 gage sites which is consistent with the concentrations found by the USGS on these waterways in 2008-2010 (Table 5; USGS, 2012). None of the samples collected within Agassiz Pool exceeded the standards for shallow lakes in the Northern Glaciated Plains ecoregion (Table 5). Lastly, only the September sample collected at the Thief River Outlet site exceeded the draft Minnesota TP standards for Central Region Rivers (Table 5), which was also consistent with USGS findings (USGS, 2012).

At this time it is unknown as to why TP concentrations are elevated in the inlets and outlets to Agassiz Pool. It is likely that much of the phosphorus in the system is bound to sediments and that even higher concentrations may be found during periods of high sediment transport, such as heavy runoff or Agassiz Pool drawdown. Further monitoring is necessary to define the relationship between TP inputs, outputs and in-Pool nutrient dynamics under various water level regimes.

Table 5: Total phosphorus concentrations from 2012 sampling at Agassiz, USGS 2008-2010 results and water quality standards.

Site	2012 Range in TP (mg/L)	Approx. USGS median value (mg/L)	TP criteria (mg/L) (lakes and streams respectively)	2012 sample values exceeding criteria
Inlets	0.033 – 0.09	0.07[1]	0.05[2]	All 7 samples, except D-11 (June)
Agassiz Pool	0.018 – 0.067	--	0.09[3]	N/A
Outlets	0.043 – 0.158	0.09[1]	0.10[4]	Thief WCS (Sept) – 0.158

[1]USGS, 2012

[2]EPA, 1986

[3]Minnesota Office of the Revisor of Statues 7050.0222, 2012

[4]MPCA, 2013 Central River Nutrient Region Recommended Criteria

Soluble Reactive Phosphorus (SRP)

Soluble reactive phosphorus, as phosphate (PO_4), is one of the biologically available fractions of phosphorus in water. It is a dissolved, inorganic form of phosphorus which is readily available for uptake by algae, plants or other organisms. Elevated SRP levels are often associated with extensive algal blooms, unless the system is limited in nitrogen. There are no water quality standards for SRP concentrations in Minnesota by which to compare Agassiz NWR results. When comparing 2012 results with USGS data it should be noted that the USGS used a slightly different technique to analyze for the biologically available fraction of phosphorus (orthophosphate) in water samples collected at Agassiz between 2008 and 2010.

Samples from all sites showed moderate levels of SRP, with concentrations ranging from below the detection limit of 0.007 mg/L to 0.048 mg/L. Agassiz Pool sites, including the channels sampled during drawdown, showed very low levels of SRP and ranged from below the detection limit of 0.007 mg/L to 0.018 mg/L. Samples from the outlet sites showed slightly higher SRP concentrations with a range over three samples of 0.013 to 0.0329 mg/L, with the highest concentration (0.0329 mg/L) found at the Thief River Outlet. The median value of ortho-phosphorus measured by the USGS at the outlet sites was lower at approximately 0.008 (Table 6). Inlets sites sampled during 2012 displayed substantially lower SRP concentrations than the median value for ortho-phosphorus found by the USGS of approximately 0.18 mg/L. Samples collected at the Thief River gage site displayed the highest concentrations of SRP found across all sites during the 2012 sampling, with a concentration of 0.048 mg/L in June (Table 6).

Most streams in Minnesota exceed SRP concentrations of 0.02 to 0.025 mg/L and TN concentrations of 0.25 to 0.3 mg/L, a combination of which is associated with unlimited growth potential for benthic algae (MPCA, 2013). Samples from both the inlet and outlet sites indicated elevated concentrations of SRP, while concentrations within the Pool appear to be relatively low. Lower SRP concentrations in the Pool likely indicate that biotic activity is rapidly consuming large volumes of the available phosphorus. If concentrations within the Pool were to increase dramatically there may be potential for large algal blooms.

Table 6: Soluble reactive phosphorus concentrations from 2012 sampling at Agassiz NWR, USGS 2008-2010 results and water quality standards.

Site	2012 Range in SRP (mg/L)	Approx. USGS median SRP value (mg/L)	SRP criteria (mg/L) (lakes and streams respectively)	2012 sample values exceeding criteria
Inlets	0.014 – 0.048	0.18[1]	N/A	N/A
Agassiz Pool	0.007 - 0.018	--	N/A	N/A
Outlets	0.013 - 0.0329	0.008[1]	N/A	N/A

[1]USGS, 2012

Summary

Drought conditions during the 2012 sampling period allowed for the measurement of water quality conditions within Agassiz Pool with very little influence from incoming or outgoing flows. These data may be important in the future when comparing nutrient cycling capabilities under various water level management scenarios.

Water monitoring data, aerial imagery and on-site inspections coordinated with the drawdown of Agassiz Pool in 2012 indicate extensive sheet flow, vegetation disturbance and discrete periods of channel formation and sediment scour within Agassiz Pool. Further monitoring is necessary to understand the relationship between Pool levels, the management of the Ditch-11 Outlet WCS and streamflow. However, the initial results suggest that the 2012 drawdown was effective in removing water, drying soils and disturbing vegetation and soils in an isolated area around the Main WCS.

Sampling results for all sites in 2012 produced predictably low TSS concentrations due to the lack of runoff during the sampling period. Samples collected in the non-flowing waters of Agassiz Pool produced consistently low TSS concentrations, while samples from the inlet, channel and outlets sites varied widely. Relative to the other samples, Ditch-11 and the Agassiz Pool North Channel samples produced consistently high TSS concentrations when sampled. In the future, additional streamflow information will be necessary to evaluate potential scour conditions and to calculate loads for comparisons between inlet and outlet sites.

The sediment ratio was found to be primarily inorganic at inlet and outlet sites (sites with active streamflow) and primarily organic at in-Pool, non-flowing sites. In 2012, TSS concentrations were so low that the composition of sediments is considered less significant than it would be during periods of high sediment transport.

Water samples analyzed for various forms of nitrogen and phosphorus at inlet and outlet sites were consistent with data collected by the USGS in 2008-2010 (2012). Although some concentrations were slightly elevated, sample results were for the most part, below the available state standards for each constituent. In-Pool samples along with continuous water quality parameter data indicate a wetland system with pronounced primary and secondary production. Although this type of nutrient cycling is normal for wetlands, the dramatic changes in water chemistry over short periods of time in Agassiz Pool may indicate accelerated cycling due to an excess of nutrients in the system. This condition should continue to be closely monitored to better define the range of water chemistry changes in the Pool and to consider potential impacts for habitats and wildlife. Of particular concern is the influence of nutrient concentrations and availability in exotic narrow leaf cattail production and the potential for large algal blooms if the current nutrient dynamics were to shift, especially with elevated concentrations of TN and SRP. It is likely that large volumes of nitrogen and phosphorus are contained within Refuge ditch and wetland substrate, meaning that the availability of these constituents may be slow to reflect any changes in management or upstream best management practices.

References

Heiskary, S., H. Markus, and M. Lindon. 2003. Shallow lakes of southwestern Minnesota: status and trend summary for selected lakes. MPCA.

Minnesota Office of the Revisor of Statutes, Minnesota Administrative Rules: 7050.0220, 2012. https://www.revisor.mn.gov/rules/?id=7050.0220

Minnesota Office of the Revisor of Statutes, Minnesota Administrative Rules: 7050.0222, 2012. https://www.revisor.mn.gov/rules/?id=7050.0222

Minnesota Pollution Control Agency, 2010. Aquatic Life Water Quality Standards Technical Support Document for Nitrate: Triennial Water Quality Standard Amendments to Minn. R. chs. 7050 and 7052 DRAFT for External Review, November 12, 2010. http://www.pca.state.mn.us/index.php/view-document.html?gid=14949

Minnesota Pollution Control Agency, 2011. Aquatic Life Water Quality Standards Draft Technical Support Document for Total Suspended Solids (Turbidity): 2011 Triennial Water Quality Standard Amendments to Minn. R. chs. 7050 and 7052. http://www.pca.state.mn.us/index.php/view-document.html?gid=14922

Minnesota Pollution Control Agency, 2005. Minnesota Lake Water Quality Assessment Report: Developing Nutrient Criteria. Third Edition. http://www.pca.state.mn.us/index.php/view-document.html?gid=6503

Minnesota Pollution Control Agency, 2013. Minnesota Nutrient Criteria Development for Rivers: Draft. http://www.pca.state.mn.us/index.php/view-document.html?gid=14947

Minnesota Pollution Control Agency, 2010. Regionalization of Minnesota's Rivers for Application of River Nutrient Criteria: Environmental Analysis and Outcomes. http://www.pca.state.mn.us/index.php/view-document.html?gid=14948

Schottler, S.P., and Engstrom, D.R., 2011. Sediment loading and sources to Agassiz National Wildlife Refuge: St. Croix Watershed Research Station Final Report.

U.S. Environmental Protection Agency, 1986. Quality Criteria for Water. http://water.epa.gov/scitech/swguidance/standards/criteria/aqlife/upload/2009_01_13_criteria_goldbook.pdf

U.S. Geological Survey, 2012. Assessment of Nutrients and Suspended Sediment Conditions in and near the Agassiz National Wildlife Refuge , Northwest Minnesota, 2008-2010. http://pubs.usgs.gov/sir/2012/5112/sir2012-5112.pdf

Appendix A

Table 7: Water quality concentrations from 2012 sampling at Agassiz NWR.

2012 Sample Date	Site	Stream-flow	TSS mg/L	% Inorganic TSS	TP mg/L	TN mg/L	NH4 mg N/L	NO3 mg N/L	SRP mg PO_4/L	NH3 mg N/L
6/21	Agassiz Pool Site #1	--	1.800	30.331	0.021	0.71	0.075	0.006	0.007	--
7/24	Agassiz Pool Site #1	--	1.557	--	0.021	1.25	0.031	0.003	0.014	0.0008
6/21	Agassiz Pool Site #2	--	3.680	26.631	0.038	0.72	0.084	0.005	0.011	--
7/24	Agassiz Pool Site #2	--	2.142	--	0.032	1.50	0.031	0.004	0.013	0.0037
6/21	Agassiz Pool Site #3	--	2.666	21.418	0.029	0.67	0.081	0.007	0.011	--
7/24	Agassiz Pool Site #3	--	3.910	--	0.051	1.62	0.113	0.006	0.011	0.0689
6/21	Agassiz Pool Site #4	--	2.366	15.723	0.025	0.81	0.087	0.009	0.010	--
7/24	Agassiz Pool Site #4	--	2.448	--	0.045	1.73	0.084	0.003	0.012	0.0475
6/21	Agassiz Pool Site #5	--	2.768	15.715	0.034	0.65	0.089	0.009	0.013	--
7/24	Agassiz Pool Site #5	--	1.320	--	0.038	1.34	0.071	0.006	0.013	0.0033
6/21	Agassiz Pool Gage	--	1.898	49.118	0.041	0.87	0.100	0.015	0.018	0.0065
7/24	Agassiz Pool Gage	--	0.933	50.698	0.049	1.53	0.108	0.003	0.011	0.0214
8/8	Agassiz Pool N Channel	N/A	14.300	64.599	0.018	1.62	--	--	--	--
9/5	Agassiz Pool N Channel	N/A	26.767	70.383	0.067	2.28	0.094	0.005	0.0092	0.0143
8/8	Agassiz Pool S Channel	N/A	10.500	63.949	0.036	1.40	--	--	--	--
9/5	Agassiz	N/A	3.503	--	0.036	1.78	0.040	0.000	0.0123	0.0057

	Pool S Channel									
8/8	Ditch-11 Outlet	N/A	2.900	62.401	0.043	0.89	0.000	0.006	0.0204	0.0002
9/5	Ditch-11 Outlet	N/A	21.712	71.007	0.069	1.51	0.117	0.006	0.0132	0.0116
9/5	Thief River Outlet	N/A	17.142	60.187	0.158	1.29	0.232	0.022	0.0329	0.0059
6/22	Ditch-11 Gage	8.70	6.972	70.892	0.033	2.49	0.133	1.779	0.023	--
7/25	Ditch-11 Gage	N/A	9.224	63.047	0.073	1.25	0.037	0.008	0.027	0.0024
8/7	Ditch-11 Gage	1.21	19.50	66.119	0.074	0.40	0.018	0.005	0.0204	0.0056
9/5	Ditch-11 Gage	N/A	16.992	67.571	0.089	1.58	0.124	0.002	0.0196	0.0049
6/22	Thief River Gage	3.77	3.911	61.985	0.068	0.68	0.147	0.020	0.048	0.0119
7/25	Thief River Gage	0.92	10.917	65.155	0.090	1.74	0.050	0.017	0.042	0.0056
8/6	Thief River Gage	3.58	8.200	62.089	0.065	0.49	0.055	0.007	0.0275	0.0173
9/5	Thief River Gage	2.80	2.109	60.709	0.051	1.08	0.030	0.000	0.0147	0.0018