



Proposed Iron Augmentation Site on West Rush Lake, June 16, 2008



Proposed Iron Augmentation Site on East Rush Lake, June 16, 2008

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# Evaluation of Proposed Rush Lake, Chisago County, Iron Augmentation Sites For Curlyleaf Pondweed Control

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*Pre-Treatment Conditions Collected on June 16, 2008*

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# Proposed Curlyleaf Pondweed Iron Augmentation Sites

Rush Lake, 2,823 acres (West Rush = 1,464 ac and East Rush = 1,359 ac) in Chisago County, has impaired water quality and areas of heavy growth of curlyleaf pondweed. On May 29, 2007 areas where curlyleaf pondweed was topping out on Rush Lake were mapped by Blue Water Science (Figure 1). Topping out conditions (shown in red) are associated with nuisance curlyleaf conditions.

Proposed iron augmentation sites to control heavy growth are shown with yellow dots. In West Rush Lake a 1-acre area has been delineated (W1) and in East Rush, a 2-acre area has been delineated (E1). A total of 3 acres have been delineated as proposed sites for iron augmentation with iron filings. Reference sites (W2 and E2) would not be treated, but would be monitored.

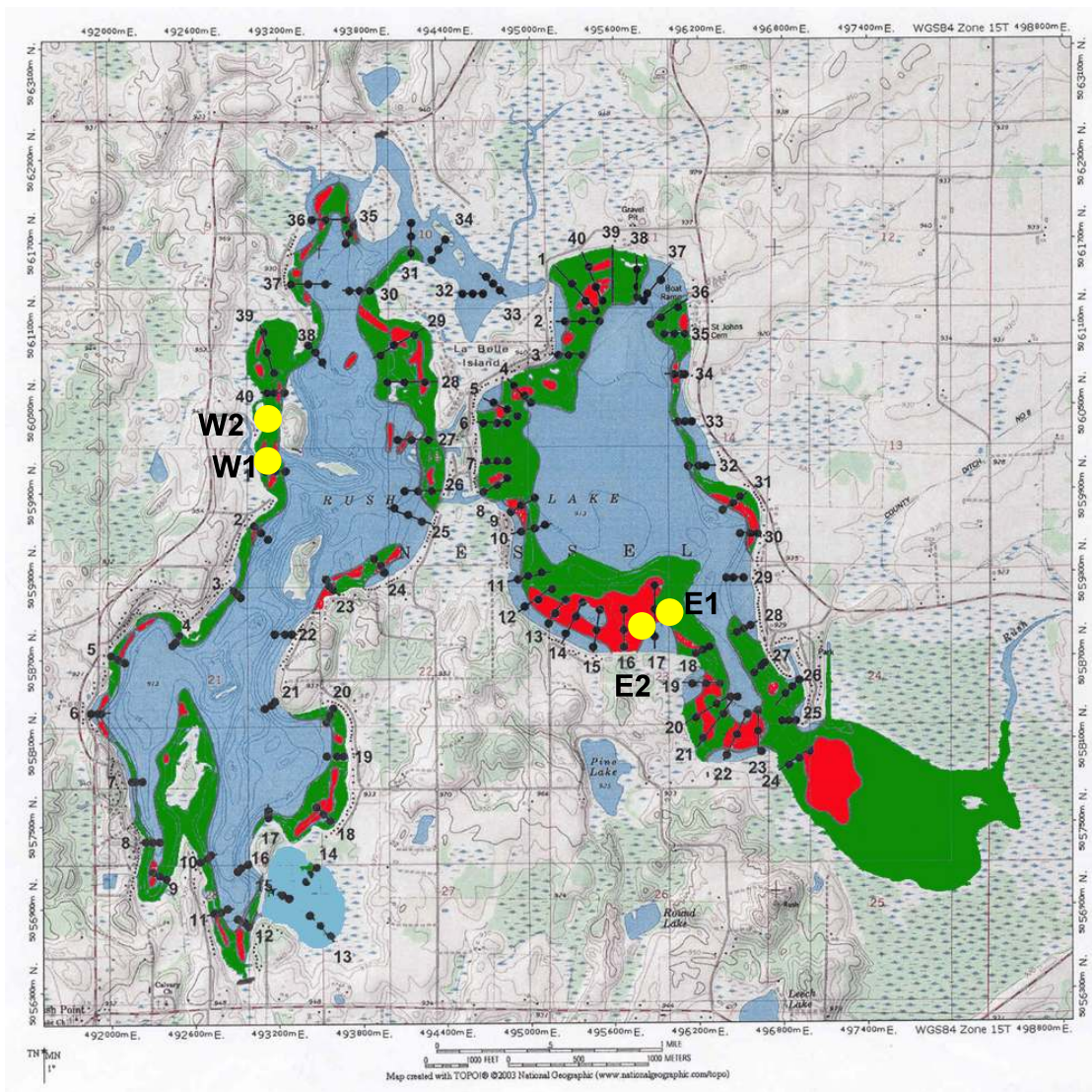


Figure 1. Curlyleaf pondweed distribution is shown in green and red. Curlyleaf pondweed topping out in Rush Lake on May 29, 2007 is shown in red. Proposed curlyleaf pondweed iron treatment sites are shown with yellow dots. Aquatic plant transects for each lake with black dots representing aquatic plant survey sample sites from 2007.



## Proposed Rush Lake Iron Augmentation Demonstration Sites

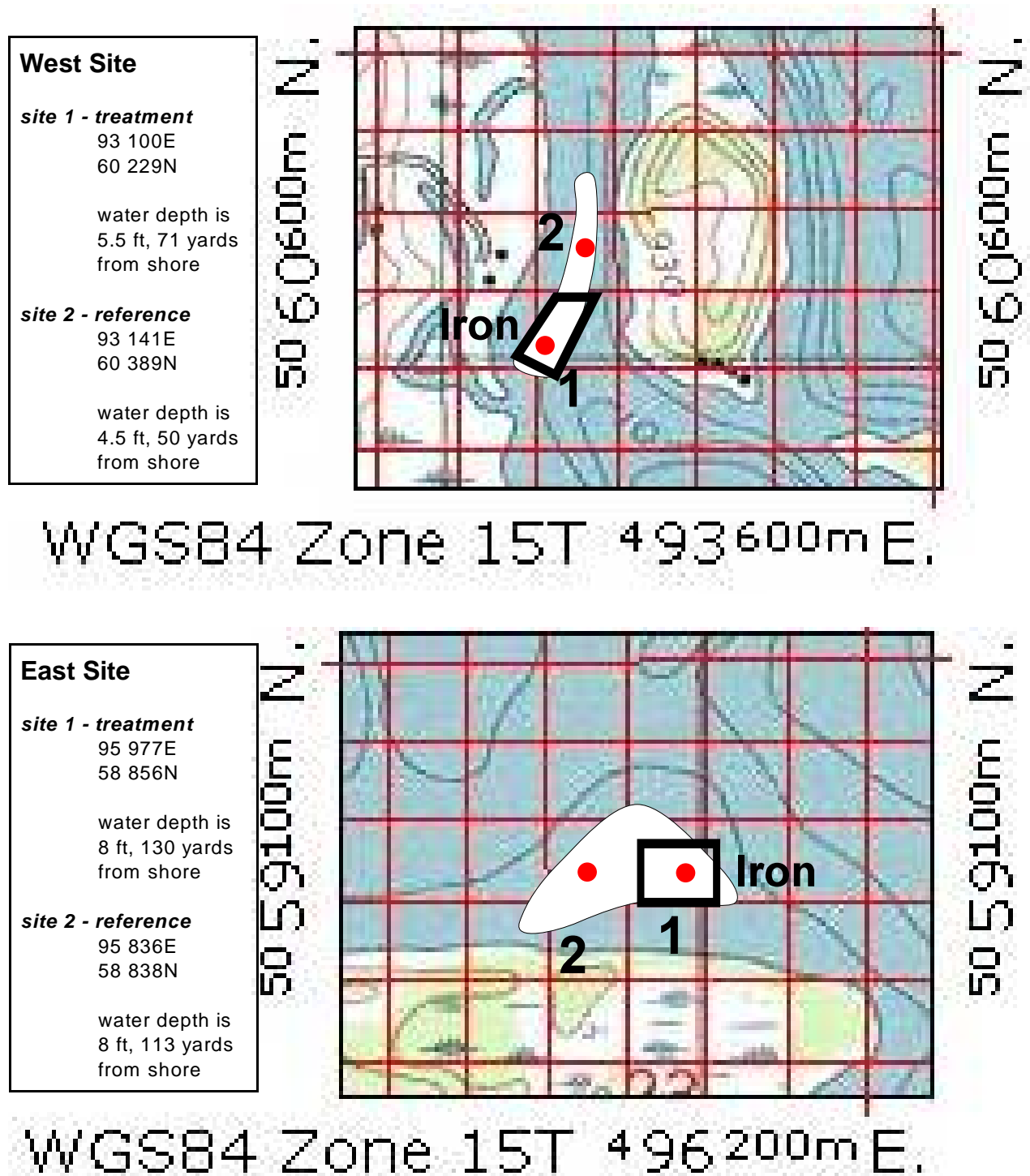


Figure 2. Location maps for curlyleaf iron augmentation sites. White areas indicate heavy growth of curlyleaf pondweed. Red dots indicate a GPS coordinate within the test site. In West Rush, a 1-acre plot is delineated and in East Rush, a 2-acre plot is delineated. The untreated areas will serve as reference areas and will be monitored along with the treatment site.

**Curlyleaf Conditions:** A total of 400 acres of curlyleaf pondweed was estimated to be topping out at the surface in late May of 2007 based on a line transect aquatic plant survey conducted by Blue Water Science. In June of 2008 areas of heavy growth of curlyleaf pondweed were revisited. Major heavy growth areas in West Rush and in East Rush were selected and curlyleaf stem densities and biomass were determined.

Two sites in West and two sites in East Rush Lake were evaluated in detail. Stem densities were determined by quadrat samples and lake sediment samples were collected for analysis. Results show there was heavy curlyleaf growth at all four of the sites (Table 1). These data indicate the selected sites are good candidates for sediment iron augmentation because all are within areas of heavy curlyleaf growth.

**Table 1. Summary of curlyleaf pondweed conditions on June 16, 2008 in proposed iron treatment sites in Rush Lake.**

	West Rush		East Rush		Curlyleaf Heavy Growth Criteria
	Site 1	Site 2	Site 1	Site 2	
Stem Density Average (stems/m <sup>2</sup> ) (n=20/site)	546	429	426	468	greater than 400
Biomass Average (grams dry wt/m <sup>2</sup> )(n=3/site)	164 (no turions)	154 (no turions)	298 (no turions)	267 (no turions)	greater than 300 (with turions)

**Table 2. June 16, 2008: Individual quadrat results for curlyleaf pondweed stem density (stems/m<sup>2</sup>).**

Sample	East Rush Site 1 95 977 E 58 856N just before point, natural shoreline 130 yards from shore 8 ft water depth		East Rush Site 2 95 836 E 58 838N Brown house, last house before natural area 113 yards from shore 8 ft water depth		West Rush Site 1 93 100 E 60 229N next to landing 71 yards from shore 5.5 ft water depth		West Rush Site 1 93 141 E 60 389N 1 <sup>st</sup> mobile home after natural shoreline 34 yards from shore 4.5 ft water depth	
	1	2	1	2	1	2	1	2
1	280	230	470	560	600	560	670	240
2	580	300	750	320	660	460	610	560
3	360	340	450	430	420	730	380	580
4	450	400	310	560	740	520	680	330
5	520	340	610	510	540	420	550	530
6	610	360	730	450	540	650	360	290
7	510	510	500	440	630	410	510	270
8	330	420	420	310	530	510	590	390
9	560	530	380	400	430	390	190	310
10	470	410	280	480	700	470	430	110
Average (stems/m <sup>2</sup> )	467	384	490	446	579	512	497	361
Site Average (stems/m <sup>2</sup> )	426 (n=20)		468 (n=20)		546 (n=20)		429 (n=20)	

## West and East Rush Lake Curlyleaf Conditions, June 16, 2008



**Figure 3. Nuisance surface matting and underwater views of curlyleaf pondweed stem densities in West Rush Lake (top) and East Rush Lake (bottom) in the proposed sediment iron treatment area. Stem densities are rated as heavy growth (heavy growth conditions are defined on the next page, Table 3).**

### Table 3. Curlyleaf Pondweed Growth Characteristics

(source: Steve McComas, Blue Water Science, unpublished)

#### Light Growth Conditions

Plants rarely reach the surface.

Navigation and recreational activities are not generally hindered.

Stem density: 0 - 160 stems/m<sup>2</sup>

Biomass: 0 - 50 g-dry wt/m<sup>2</sup>

Estimated TP loading: <1.7 lbs/ac



*MnDNR rake sample density equivalent for non-nuisance conditions: 1, 2, or 3.*

#### Moderate Growth Conditions

Broken surface canopy conditions.

Navigation and recreational activities may be hindered.

Lake users may opt for control.

Stem density: 100 - 280 stems/m<sup>2</sup>

Biomass: 50 - 85 g-dry wt/m<sup>2</sup>

Estimated TP loading: 2.2 - 3.8 lbs/ac



*MnDNR rake sample density equivalent for light nuisance conditions: 3 or 4.*

#### Heavy Growth Conditions

Solid or near solid surface canopy conditions.

Navigation and recreational activities are severely limited.

Control is necessary for navigation and/or recreation.

Stem density: 400+ stems/m<sup>2</sup>

Biomass: >300 g-dry wt/m<sup>2</sup>

Estimated TP loading: >6.7 lbs/ac



*MnDNR rake sample density has a scale from 1 to 4. For heavy nuisance conditions where plants top out at the surface, the scale has been extended: 4.5 is equivalent to a near solid surface canopy and a 5 is equivalent to a solid surface canopy.*

## Existing Rush Lake Sediment Conditions at the Proposed Treatment Sites:

Lake sediment samples were collected on June 16, 2008 at the proposed iron treatment sites.

Two sediment samples were collected at each site for a total of 8 samples. Results are shown in Table 4.

**Table 4. June 16, 2008: Lake sediment data for treatment sites. Soil chemistry results are reported as  $\mu\text{g}/\text{cm}^3$ -dry which is equivalent to ppm except for organic matter (%) and pH (standard units)(Analysis conducted by the University of Minnesota Soils Lake, St. Paul, MN).**

Sample Number	Sample Depth (Ft)	Bulk Density - dry (g/cm <sup>3</sup> )	O.M. (%) by L.O.I.	pH	Bray-P (ppm) (corr)	Olsen-P (ppm) (corr)	K (ppm) (corr)	Ca (ppm) (corr)	Mg (ppm) (corr)	Boron (ppm) (corr)	NH <sub>4</sub> -N (ppm) (corr)	Fe (ppm) (corr)	Cu (ppm) (corr)	Mn (ppm) (corr)	Zn (ppm) (corr)	SO <sub>4</sub> -S (ppm) (corr)
E1	6	1.11	1.9	7.6/8.0	0.95	8.06	26	2965	119	0.32	3.18	46	0	28	0	64
E1R	6	1.12	1.9	7.8	0.96	6.70	31	3038	124	0.38	2.87	44	0	29	0	65
E2	8	1.01	2.9	7.7	0.86	6.91	29	2879	115	0.47	3.28	56	1	20	1	121
E2R	8	1.04	2.7	7.6	0.88	8.81	32	2937	107	0.50	3.35	55	1	21	1	109
W1	5	0.56	14.5	7.7	0.47	4.73	27	1892	126	0.30	5.63	35	0	21	0	57
W1R	5	0.52	15.6	7.7	0.44	3.97	33	1719	116	0.28	4.14	35	0	19	0	62
W2	5	0.52	12.9	7.8	0.44	5.28	25	1600	82	0.27	4.04	29	0	19	0	30
W2R	5	0.48	13.4	7.9	0.41	5.27	10	1459	70	0.21	3.45	25	0	20	0	25

## Rush Lake Sediment Conditions Associated with Curlyleaf Growth

**Characteristics:** Lake sediment characteristics associated with light, moderate, and heavy growth of curlyleaf pondweed are shown in the top half of Table 5. Rush Lake sediment results from 8 samples are shown in the lower half of the table. Sediment characteristics indicate a moderate to high potential for Rush Lake sediments to support heavy growth of curlyleaf pondweed in the proposed treatment sites in Rush Lake.

**Table 5. Sediment conditions that are correlated with curlyleaf growth characteristics.**

Site	pH (su)	Bulk Density (g/cm <sup>3</sup> dry)	Organic Matter (%)	Fe:Mn Ratio	Potential for Heavy Curlyleaf Pondweed Growth
Light to Moderate Growth	6.2 - 6.8	0.9 - 1.04	5 - 11	4.6 - 5.9	Low - Medium (green or yellow)
Heavy Growth	>7.7	<0.51	>20	<1.6	High (red)
E1	7.8	1.11	1.9	1.6	High
E1Rep	7.8	1.12	1.9	1.5	High
E2	7.7	1.01	2.9	2.8	Medium
E2Rep	7.6	1.04	2.7	2.6	Medium
W1	7.7	0.56	14.5	1.7	Medium
W1Rep	7.7	0.52	15.6	1.8	Medium
W2	7.8	0.52	12.9	1.5	High
W2Rep	7.9	0.48	13.4	1.3	High

# Impact of Iron Filings Applied to Lake Sediments

Research findings indicate that naturally occurring iron-rich sediments support light to moderate growth of curlyleaf pondweed while native aquatic plants are relatively unimpacted. Along with the high iron content, a sediment pH less than 7.7 is also correlated with light to moderate growth of curlyleaf pondweed (McComas, unpublished).

All indications are that adding iron filings to lake sediments mimics what is found in natural lake sediments that have a high iron content and a light growth of curlyleaf pondweed.

To put the iron augmentation in perspective, Rush Lake sediments are used as an example. Results from Rush Lake sediment analysis indicate the sediment density is between 0.5 to 1.0 g/cm<sup>3</sup>-dry. Based on a 1-acre area, to a depth of 12 inches (30 cm), the dry weight of the sediments would be 660 tons/ac to 1,320 tons/ac. For comparison, Rush Lake sediments are less dense than typical agricultural soils which weigh about 1,500 tons/ac to a depth of 12 inches.

In other research, lake sediment analysis of Minnesota lake sediments finds they have an iron content of up to 5% (Jones and Bowser 1978)\*. If the total iron content of Rush Lake sediments was 5%, then there would be between 33 tons to 66 tons of iron/lake acre (to a sediment depth of 12 inches).

However, not all the iron in the lake sediments is available. Rush Lake sediment analysis of available iron found that the available iron ranges from 25 ppm to 50 ppm which would be equal to 66 pounds to 132 pounds per acre. This indicates in Rush Lake that only about 0.1% of the iron is available for impacting curlyleaf.

By adding iron filings to the lake sediment, the amount of active iron increases. Typically about 1.5 tons of iron filings/acre are added to lakes. This would add about 4% additional iron to the total amount of iron that is already present in the sediments. Adding 1.5 tons of iron filings/acre is equivalent to adding a layer of iron that is 0.1 mm thick to the lake sediment surface. The iron filings are about the size of table salt grains.

In lakes with naturally occurring iron (high enough to control curlyleaf pondweed), no adverse impacts to the biota are typically registered and are rarely tested. The impact to the biota of adding iron filings to lake sediments has not been thoroughly investigated. However, acute impacts have not been observed in other lakes with iron filing additions and limited data collection indicates native plants and fish appear to be unimpacted (McComas unpublished).

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\*Jones, B.F. and C.J. Bowser. 1978. The mineralogy and related chemistry of lake sediments. In: Lerman, A. (Ed), Lakes: chemistry, geology, physics. Springer, Berlin. pp 179-235.



## Monitoring the Iron Augmentation Sites and Reference Sites

It is anticipated that iron augmentation will occur in the winter of 2009, with a 1-acre site in West Rush and a 2-acre site in East Rush at a rate of 3,000 pounds of iron per acre. At each iron augmentation site there is an adjacent reference site that will not be treated with iron.

Pre-treatment curlyleaf stem densities, curlyleaf biomass, and lake sediments were collected on June 16, 2008 at treatment and reference sites on West and East Rush.

For the next three summers (2009, 2010, 2011) curlyleaf stem densities and curlyleaf biomass will be monitored at the treatment sites and at the reference sites. Sediment samples will also be collected from each site for the next three years.

A summary of sampling activities is shown in Table 6.

**Table 6. Annual monitoring in the iron augmentation areas for 2009, 2010 and 2011.**

	West Rush		East Rush	
	W1. Iron Site	W2. Reference Area	E1. Iron Site	E2. Reference Area
Curlyleaf stem counts (collected by scuba diving)	20 quadrats	20 quadrats	20 quadrats	20 quadrats
Curlyleaf biomass (minimum 150 stems)	150+	150+	150+	150+
Aquatic plant survey (point intercept in areas)	yes	yes	yes	yes
Sediment samples	1	1	1	1