Curlyleaf Pondweed on April 27, 2015 in Medicine Lake

Curlyleaf Pondweed Delineation and Assessment for Medicine Lake, Plymouth, Minnesota in 2015

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Pre-Herbicide Plant Evaluation:	May 6	April 22	April 24	April 17	May 4	April 22	April 20	April 28	April 9	May 13	May 16	April 27
Herbicide Application:	**May 8-11**	**April 19, 21**	**April 18**	**no herbicide**	**May 12**	**May 1**	**April 23**	**May 9**	**May 10**	**May 23**	**May 22**	**May 1**
Post Herbicide Plant Evaluation and/or Curlyleaf Assessment	June 14	June 2	May 25	April 27, May 30	June 9	June 12	June 4	June 16	June 5	June 21	June 25	June 9
Herbicide Use:	1,668 gallons 317 ac treated	1,400 gallons 325 ac treated	1,400 gallons 325 ac treated	0 gallons (no herbicides used)	345 gal 80 ac treated	415 gal 62 ac treated	194 gal 29 ac treated	98.5 gal 14.7 ac treated	405 gal 59 ac treated	155 gal 30.9 ac treated	305 gal 47.0 ac treated	352 gal 59.4 ac treated

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Curlyleaf Pondweed Delineation and Assessment for Medicine Lake, Plymouth, Minnesota in 2015

Summary

In Medicine Lake in 2015, in the early season curlyleaf pondweed delineation on April 27, 2015 growth was heavier compared to 2013. Based on this delineation, about 60 acres of curlyleaf were treated on May 1, 2015. A curlyleaf assessment was conducted on June 9, 2015 after the herbicide treatment and it was found that curlyleaf was controlled in all of the treated areas (Table S1).

Table S1. Curlyleaf pondweed treatment history in Medicine Lake from 2004-2015.

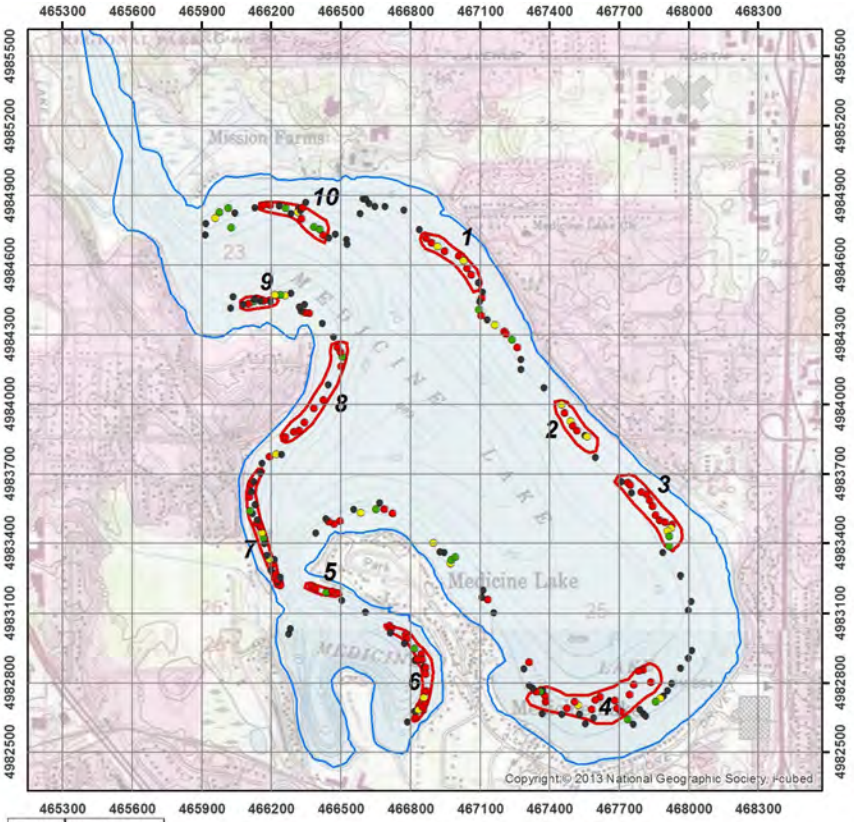
Year	Acres Treated with an Endothall Herbicide	Curlyleaf Control Result
2004	317	Complete control.
2005	325	Complete control.
2006	325	Complete control.
2007	0	Moderate to heavy regrowth.
2008	79.8	Good control.
2009	62.0	Good control.
2010	29.1	Good control.
2011	14.7	Limited control.
2012	59	Good control.
2013	30.9	Limited control in south end with moderate to heavy growth, fair to good control in north end.
2014	47.0	Good control
2015	59.3	Good control

In Medicine Lake, a general curlyleaf growth pattern has emerged over the years based on early season yearly monitoring. Curlyleaf pondweed in Medicine Lake appears to exhibit heavy growth in roughly the same areas at several locations on an annual basis. The areas of heavy growth are in the north and south ends and in the eastern side of the southwest lobe of the lake. In other areas, there are years of heavy growth and then years of light growth in similar locations. The boom and bust growth cycles of curlyleaf pondweed in these specific areas are not well understood. It appears lake sediment conditions indicate an average long-term growth potential but predicting annual light or heavy growth of curlyleaf pondweed based on early season scouting remains challenging.

Recommendations for 2016: Heavy curlyleaf growth can hinder navigation and the curlyleaf dieback contributes nutrients to the water column that could be used by algae. This type of curlyleaf growth is the kind of growth that is considered for control. In 2016, if heavy curlyleaf growth is predicted based on an early season delineation, up to a maximum of 60 acres of heavy growth could be considered for treatment. In the future, for delineating areas to treat, the cumulative experience in Medicine Lake indicates if there are five or more curlyleaf stems collected on a rake sample in April or May there is a strong likelihood of heavy curlyleaf growth in that area in June. This approach can be used to help delineate areas for treatment.

Curlyleaf Pondweed Delineation and Assessment For Medicine Lake, Plymouth, Minnesota in 2015

Early Season Delineation, April 27, 2015: The entire nearshore area of Medicine Lake was surveyed and specific sampling and notes were taken at 242 sites on April 27, 2015. Curlyleaf pondweed stem densities had a wide range with the stems collected with a rake sample often numbering greater than 5 stems per rake with a maximum of 30 stems/rake. Areas where curlyleaf was sampled with 5 or more stems per rake were delineated for treatment. A rake typically samples an area of about 0.1 m^2. Therefore stem densities ranged from 10 stems/m^2 up to 300 stems/m^2. Based on the April 27, 2015 scouting results, treatment areas were delineated for a herbicide application. A delineation map is shown in Figure 1. Delineation methods are listed in the appendix.



Id	CLP Acre
1	5.03
2	4.59
3	8.1
4	16.33
5	1.05
6	4.71
7	4.9
8	7.83
9	1.73
10	5.08

59.3 Acres Total

Figure 1. Curlyleaf pondweed density based on stems per rake sample at sample sites on April 27, 2015 is shown with green dots = light potential growth, yellow dots = moderate potential growth, and red dots = heavy potential growth. Black dots = sample location. Curlyleaf was treated in the 10 red circled areas totaling about 60 acres on May 1, 2015.

Curlyleaf Pondweed Treatment, May 1, 2015: Ten treatment areas with a total treatment area of 59.4 acres were treated using 352 gallons of an endothall herbicide at a concentration of 1.5 ppm on May 1, 2015. A treatment map with boat tracks used to deliver herbicides is shown in Figure 2.

Figure 2. Curlyleaf pondweed treatment map for 2015. Treatment was conducted on May 1, 2015 by Lake Restoration. The red line is the path the boat took when it was traveling around Medicine Lake. The solid red areas is the location of the herbicide app (map supplied by Lake Restoration).

Follow-Up Curlyleaf Pondweed Assessment, June 9, 2015: On June 9, 2015, the entire nearshore area of Medicine Lake as well as the 10 treatment areas were surveyed about 5 weeks after an herbicide treatment and sites of curlyleaf growth were noted. A total of about 60 acres of curlyleaf were treated on May 1, 2015 and the objective of the assessment was to determine if the herbicide treatment was successful and if curlyleaf was present in untreated areas (Figure 3). Survey results found good control in the 10 treatment areas with some light curlyleaf growth present in several of the treatment areas.

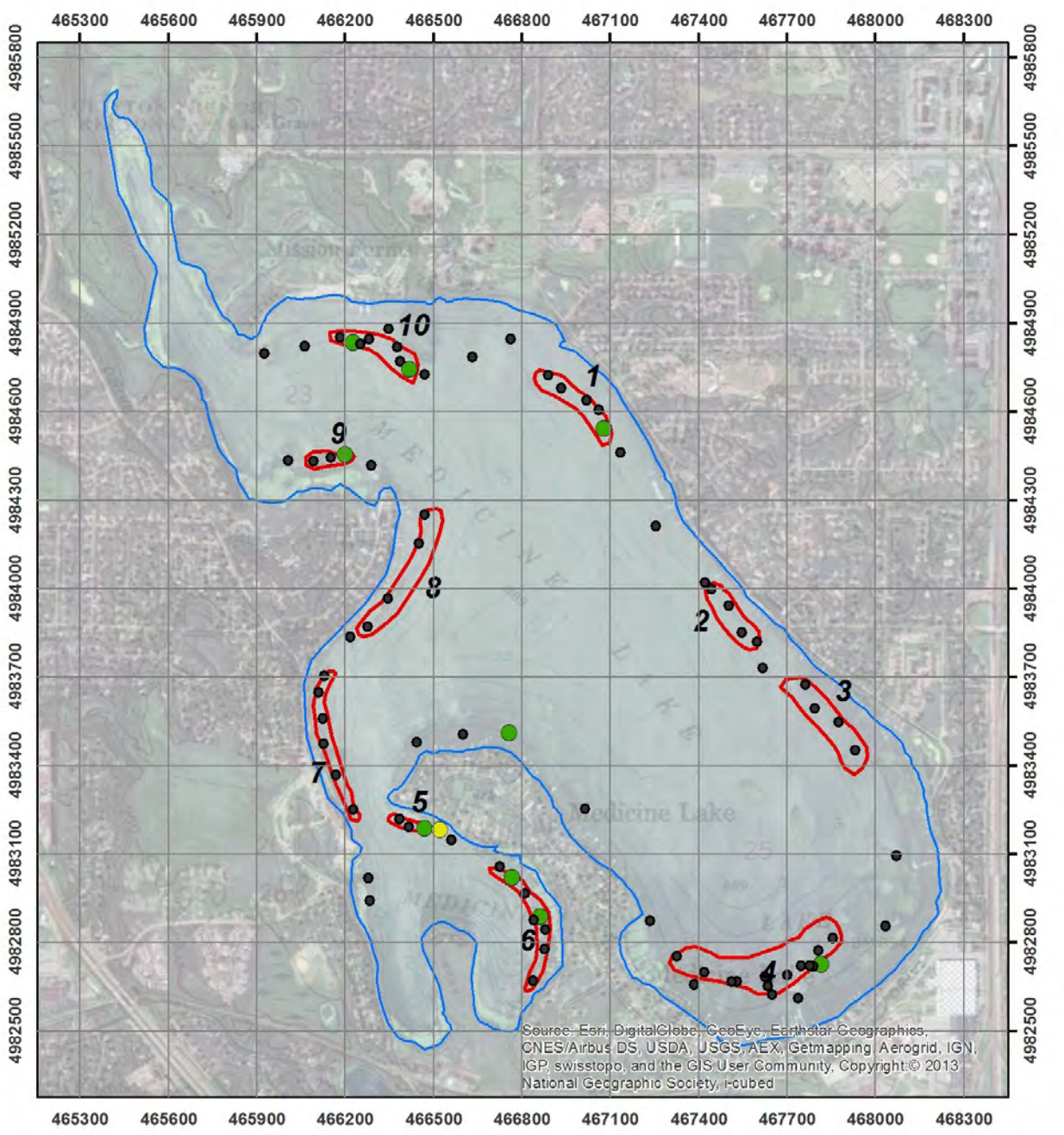


Figure 3. Curlyleaf pondweed density at various sites on June 9, 2015 is shown with black shading = no curlyleaf pondweed sampled, green shading = light growth, and yellow shading = moderate growth. Curlyleaf pondweed was treated on May 1, 2015.

Eurasian Watermilfoil Status, June 9, 2015: Eurasian watermilfoil (EWM) was also sampled on June 9, 2015 and was found to be widely distributed around Medicine Lake (Figures 4 and 5). The heaviest EWM was observed in the south end of Medicine Lake (Figure 4).

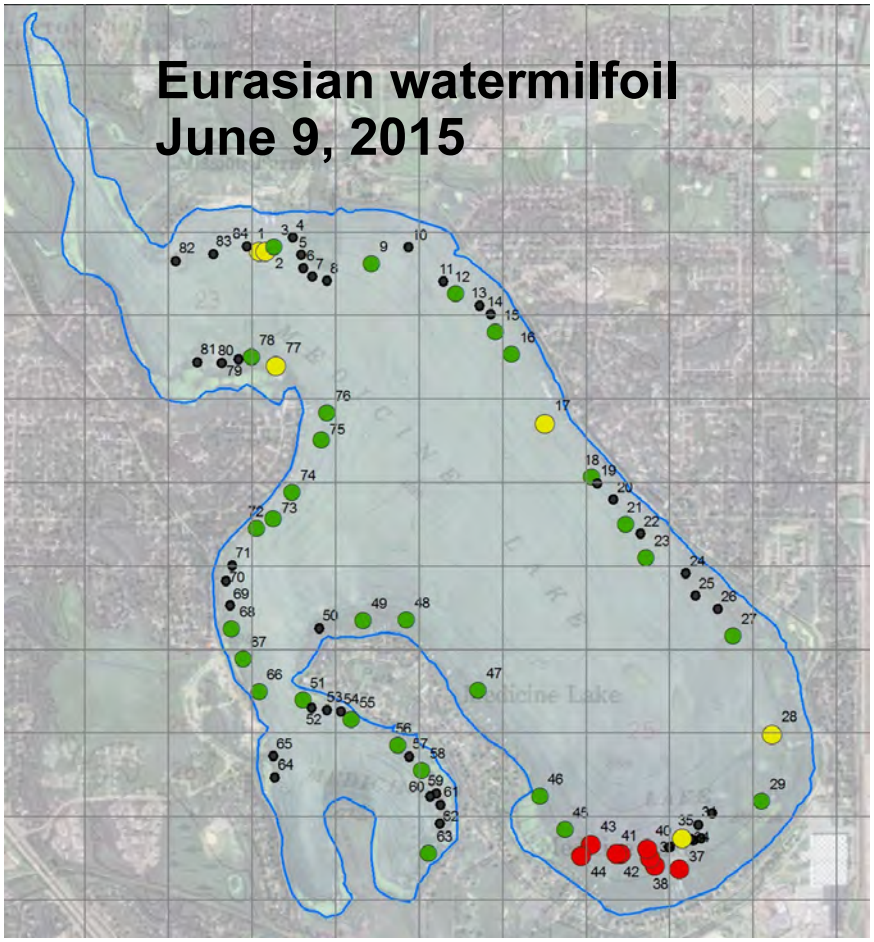


Figure 4. Sample sites and EWM observed locations and colored densities.
Key: green dots = light growth, yellow dots = moderate growth, red dots = heavy growth, and black dots = sample site.

Figure 5. [left] Eurasian watermilfoil in Medicine Lake on June 9, 2015.
[right] Submersed EWM close to the surface on June 9, 2015.

Curlyleaf Pondweed Treatment and Response in 2015: In 2004, there was significant curlyleaf pondweed growth in Medicine Lake. This was the first year of an aggressive curlyleaf treatment program that ran from 2004-2006. There was no treatment in 2007 and curlyleaf started to grow back. Partial treatments have occurred from 2008-2015. In 2015, 59.4 acres were delineated and treated (Figures 6 and 7) and there was good control of heavy growth of CLP (Figure 8).

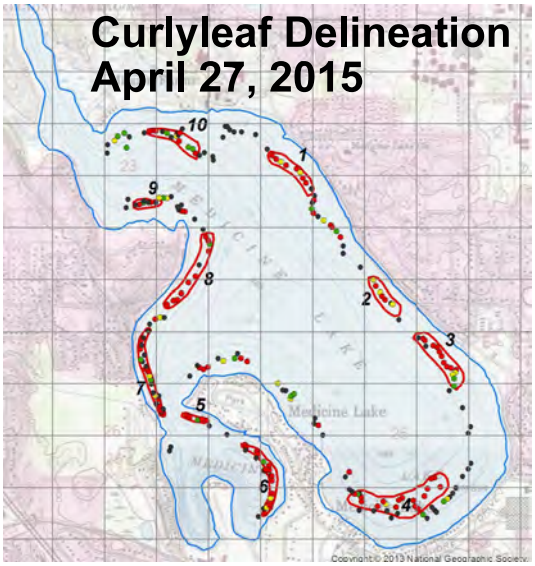


Figure 6. Curlyleaf delineation on April 27, 2015 are shown with dots. Green dots = light potential growth, yellow = moderate potential growth, and red dots = heavy potential growth. Black dots = sample site.

Curlyleaf Treatment of 59.4 acres on May 1, 2015

Figure 7. Treatment areas are shown with red lines.

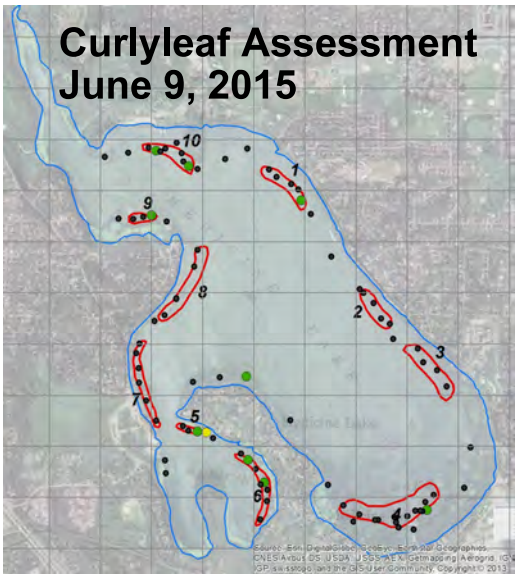


Figure 8. Curlyleaf density on June 9, 2015 is shown with dots. Green dots = light growth, yellow dots = moderate growth, and black dots = no growth. Red circled areas show the treatment areas.

Table 1. Observations of curlyleaf pondweed density for April 27 and June 9, 2015.

Site	Pre-Treatment, April 27, 2015		Site	Post Treatment, June 9, 2015								
	Depth (ft)	CLP stems on Rake Sampler		Depth (ft)	Curlyleaf Density (scale 1 to 5)	CLP Stems on Rake Sampler	EWM	Chara	Coontail	Water stargrass	FA	No plants
1	4		1	7	1	1	3					
2	5	7	2	6			3					
3	6	4	3	5			2					
4	6	1	4	3								1
5	6	1	5	4								1
6	7	8	6	6								1
7	7		7	7	1	3						
8	5		8	5								1
9	5		9	6			2				3	
10	6		10	4								1
11	5		11	6					2		2	
12	3		12	6			2		1		1	
13	4		13	6					2			
14	4		14	6								1
15	4		15	6	1	1	1					
16	4		16	4			1				1	
17	4		17	6			3		2			
18	4		18	7			2		3			
19	5	15	19	6					2			
20	6	7	20	5					2			
21	7	3	21	8			1					
22	7	5	22	3								1
23	6	6	23	8			2		2			
24	6	3	24	3					3			
25	7	8	25	12								1
26	7	18	26	6					2			
27	4		27	5			2		2			
28	5		28	5			3		1			
29	6	4	29	3			2				1	
30	6		30	7					3			
31	6	2	31	8								1
32	8	6	32	7	2	7			5			
33	8		33	7					3			
34	9	3	34	7					2			
35	10	7	35	7			3					
36	8	13	36	8					3			
37	7	2	37	5			5					
38	7	8	38	5			4		2			
39	5		39	7			4					
40	6		40	7			4		2			
41	10		41	7			4					
42	6	3	42	8			4					
43	7	10	43	7			4					
44	8	3	44	4			5					
45	8	8	45	5			1					
46	8	7	46	4			1		4		4	
47	8		47	8			1		3			
48	6	3	48	5	1	1	1					
49	5		49	5			1		2		2	
50	6		50	6								1
51	6	6	51	6			1					
52	7	9	52	11								1
53	11		53	10	1	1						
54	6	15	54	6	3	10						
55	6	12	55	6			1		3			
56	8	6	56	3			2			2		
57	9	18	57	4	1	3						
58	10	4	58	5			1		3			
59	9	12	59	4	1	3			3			
60	6	11	60	9								1
61	5	8	61	4				1	3			
62	6	3	62	5					2			
63	7	3	63	5			1		3			
64	5	1	64	8								1
65	6	1	65	8								1
66	7		66	6			1		2			
67	5		67	4			2					
68	5		68	4			1					
69	8		69	12								1
70	5		70	6					2			
71	5		71	10								1
72	6		72	5			2		1		1	
73	6		73	5			2					
74	7		74	5			1		1			
75	7		75	5			2					
76	7	3	76	7			2		1			
77	6	1	77	4			3					
78	9	5	78	6	1	4	2		2			
79	10	6	79	11								
80	10	4	80	11					1			
81	9	18	81	4					5			
82	8	30	82	4					4		4	
83	7		83	9								
84	7		84	9			3					
85	6											
86	6											

Table 1. Observations of curlyleaf pondweed density for April 27 and June 9, 2015.

Site	Pre-Treatment, April 27, 2015	
	Depth (ft)	CLP stems on Rake Sampler
89	8	15
90	9	5
91	8	4
92	9	4
93	8	6
94	5	
95	5	
96	7	
97	8	3
98	8	11
99	8	10
100	6	
101	4	
102	8	4
103	9	7
104	11	
105	11	2
106	9	10
107	8	
108	6	
109	9	
110	11	8
111	7	
112	8	4
113	6	
114	9	
115	7	3
116	9	1
117	11	1
118	10	
119	10	
120	6	3
121	6	13
122	7	10
123	11	
124	6	1
125	9	3
126	12	
127	6	12
128	6	10
129	7	8
130	11	
131	12	
132	10	6
133	9	18
134	10	2
135	8	12
136	9	12
137	13	
138	13	
139	4	6
140	9	6
141	13	
142	4	12
143	4	8
144	13	
145	4	2
146	4	5
147	7	3
148	10	
149	5	
150	6	4
151	6	9
152	4	14
153	11	
154	8	5
155	7	25
156	3	8
157	8	15
158	12	
159	10	
160	6	3
161	4	15
162	5	10
163	9	3
164	7	6
165	9	
166	11	
167	9	6
168	4	
169	7	5
170	12	
171	5	5
172	3	
173	7	10
174	12	

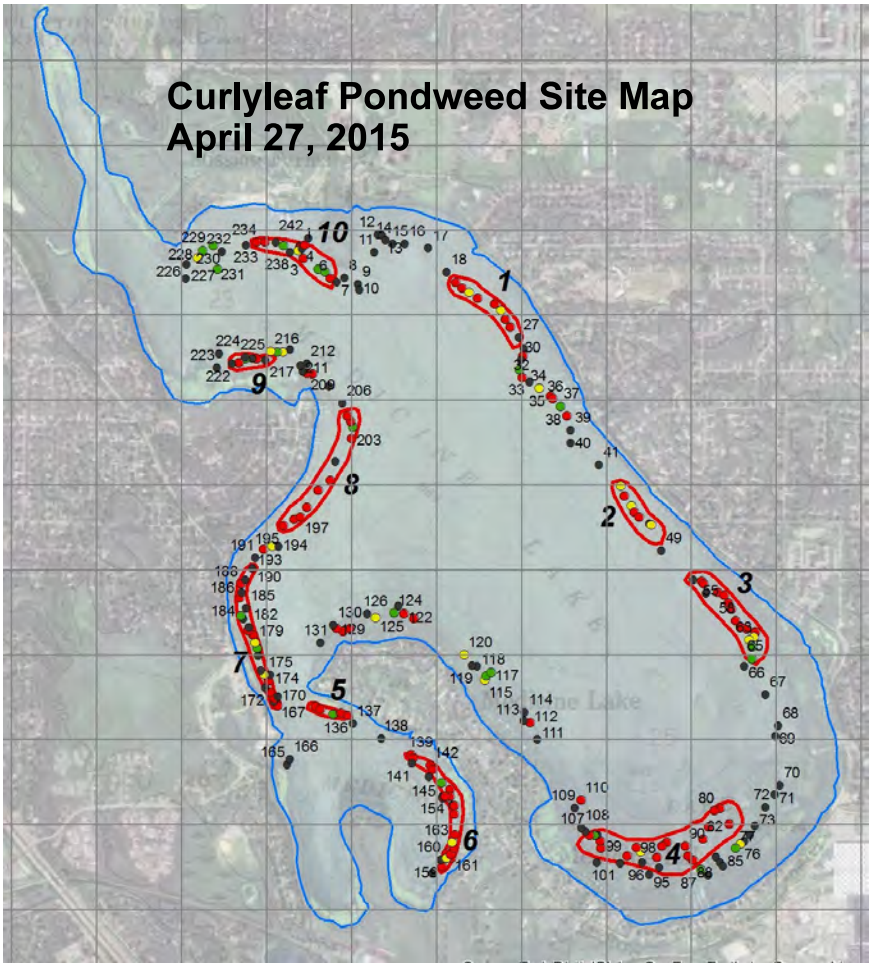
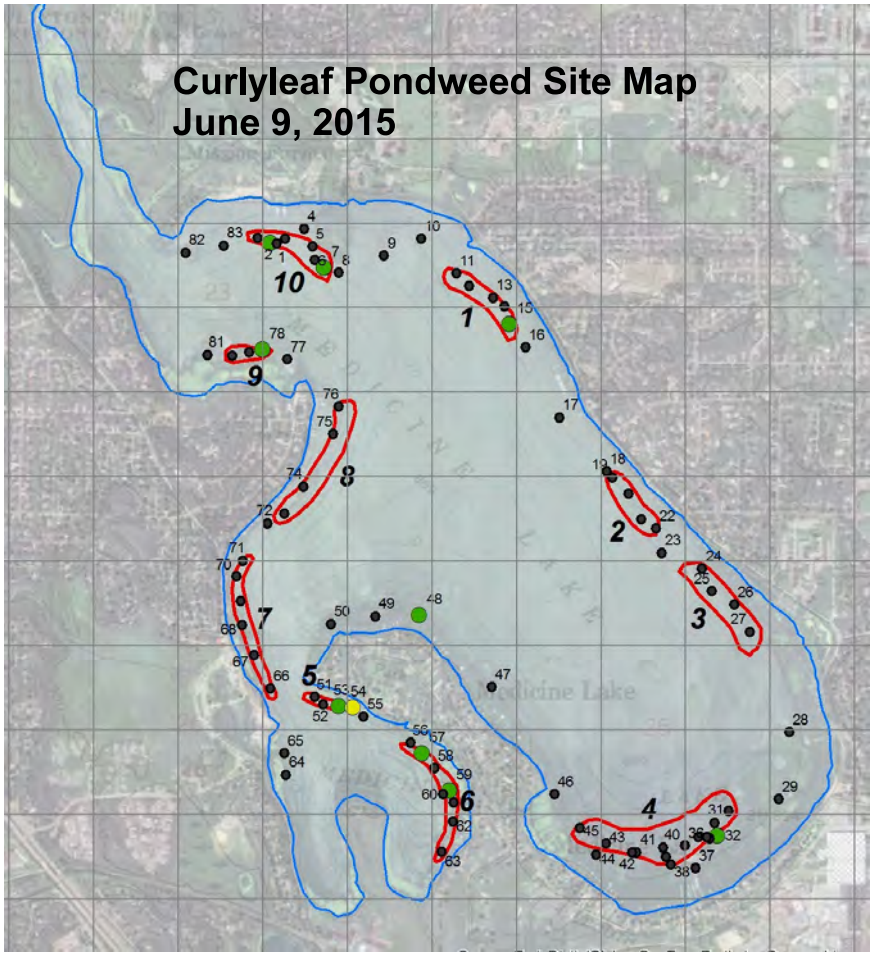


Table 1. Observations of curlyleaf pondweed density for April 27 and June 9, 2015.

Site	Pre-Treatment, April 27, 2015	
	Depth (ft)	CLP stems on Rake Sampler
175	4	3
176	4	
177	5	
178	5	2
179	6	3
180	8	6
181	6	4
182	12	
183	9	
184	5	1
185	14	
186	7	18
187	13	
188	6	5
189	15	
190	16	
191	5	
192	5	5
193	7	3
194	12	
195	4	9
196	8	10
197	6	6
198	5	12
199	5	12
200	8	10
201	5	
202	9	10
203	9	1
204	8	6
205	8	9
206	8	
207	12	
208	10	7
209	5	4
210	4	
211	4	
212	12	
213	5	
214	4	3
215	5	2
216	5	3
217	4	
218	7	7
219	12	
220	8	1
221	10	9
222	11	
223	4	
224	8	
225	10	
226	4	
227	4	
228	4	3
229	4	1
230	6	1
231	9	1
232	8	
233	9	
234	8	6
235	6	10
236	5	
237	5	2
238	5	
239	5	3
240	5	
241	4	4
242	3	



Curlyleaf Pondweed Growth Characteristics in April and June 2015

The methods for predicting the expansion and growth of curlyleaf pondweed for the early growing season to the late growing season is ongoing. In Medicine Lake, curlyleaf growth in 2015 in April is lighter than it will be in June. In the June 9, 2015 assessment it was observed that curlyleaf was controlled at all treatment areas.

April 27, 2015 | **June 9, 2015**

Figure 9. [left] Curlyleaf stem densities in April (top) are typically moderate to heavy. Curlyleaf at this rake density would be expected to produce heavy growth in June. This site was scheduled for treatment. Native aquatic plants were common at many locations, here coontail at a density of a 3 (bottom).
[right] Curlyleaf on June 9, 2014 (top). Coontail growth was abundant in many areas of Medicine Lake (bottom).

Curlyleaf Pondweed Treatment Areas from 2008-2015

2008 Curlyleaf Treatment - 80 acres

2009 Curlyleaf Treatment - 62 acres

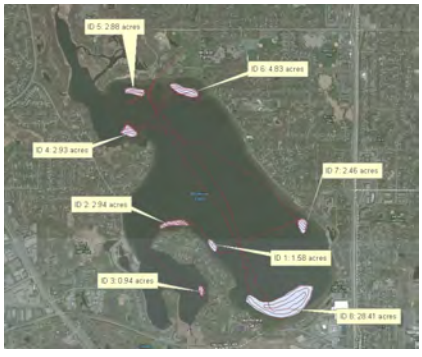
2010 Curlyleaf Treatment - 29.1 acres

2011 Curlyleaf Treatment - 14.7 acres

2012 Curlyleaf Treatment - 59 acres

2013 Curlyleaf Treatment - 30.9 acres

2014 Curlyleaf Treatment - 47 acres



2015 Curlyleaf Treatment - 59.4 acres

Tracking Curlyleaf Pondweed Density at Four Locations from 2004-2015

Curlyleaf stem densities at four locations were evaluated with scuba diving and quadrat sampling in 2015 (Figures 10 and 11). These same four locations have been checked since 2004. In 2015, at the long-term curlyleaf monitoring sites, Sites 1, 3, and 4 were treated (Figure 11, right). Curlyleaf growth was light at these sites.

Table 2. Curlyleaf pondweed stem densities at four sites in Medicine Lake in 2015.

		April 27, 2015	June 9, 2015
		Curlyleaf Stems (stems/m^2)	Curlyleaf Stems (stems/m^2)
Site 1	6 ft	70	14
	9 ft	90	15
Site 2	6 ft	440	0
	9 ft	140	0
Site 3	6 ft	20	7
	9 ft	480	2
Site 4	6 ft	680	0
	9 ft	190	0
Average		260	4.8
6 ft average		300	5.3
9 ft average		230	4.3

Figure 10. A quadrat is a square frame laid down on the bottom. All plant stems within the 0.1 m^2 square are counted.

2015 Curlyleaf Treatment - 59.4 acres

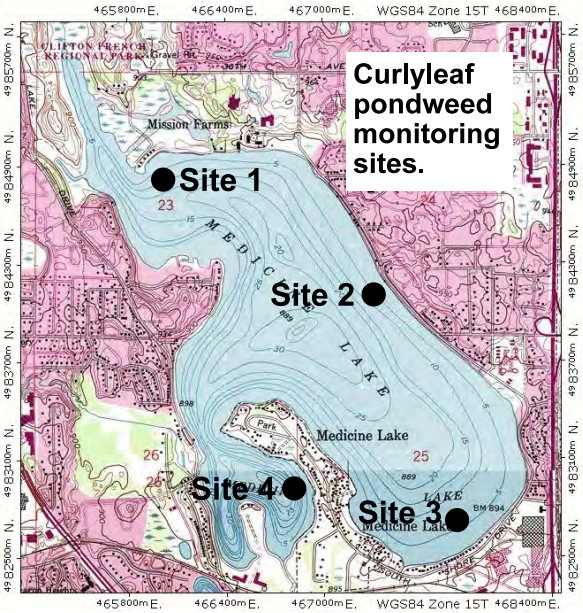


Figure 11. [left] Curlyleaf treatment areas are shown with light shading.
[right] Curlyleaf monitoring sites to collect stem densities are shown with black dots.

Curlyleaf Pondweed Densities at Four Sites from 2004 - 2015: A summary of curlyleaf pondweed stem densities from the four permanent sample sites that have been monitored since 2004 is shown in Table 3. Stem densities at all four sites were high at the start of the curlyleaf control program in 2004 (Table 3). Stem densities were measured on May 6, 2004 and this was the reference condition. After three years of aggressive herbicide treatment with over 300 acres treated per year (in 2004, 2005, and 2006), stem densities had declined when early season stem densities from 2007 - 2015 were compared to the May 6, 2004 measurements (Table 3).

The three consecutive years of herbicide treatment (2004, 2005, 2006) reduced the early season curlyleaf stem densities in Medicine Lake. Curlyleaf was not treated in 2007 and the late season curlyleaf stem densities increased at 3 out of 4 sites. Early season stem densities increased in 2008 compared to 2007 indicating curlyleaf stem density was coming back in 3 out of 4 sites that were not treated in 2007. Two sites were treated in 2008 with good control. At the untreated Site 4, curlyleaf increased from the early to late season sampling. In 2009, three sites were treated, and late season curlyleaf growth was light at all four monitoring sites including monitoring Site 2 which was not treated. In 2010, three sites (1, 3, and 4) were treated and Site 2 was not treated. Curlyleaf pondweed stem densities were light at all four monitored sites (Table 3 and Figure 12).

In 2011, the same three sites were treated that were treated in 2010 and 2009. However, in 2011, curlyleaf stem density control was not nearly as effective as compared to 2009 and 2010. In 2012, Sites 1, 3, and 4 were treated and viable curlyleaf was not observed in the late survey (Table 3). At Site 2, curlyleaf was not treated directly, but stem densities decreased from April to June. In 2013, Sites 1 and 3 were treated (Table 3). Curlyleaf was at low to moderate densities before treatment. In the late survey, curlyleaf increased in density at all four sites, including Site 3, which was treated.

In 2014, early season curlyleaf densities were low compared to 2004. Late season densities were low at the three treated sites. At Site 2, the untreated site, curlyleaf growth did not increase and actually appeared to decrease from early season to late season measurements.

In 2015, early season curlyleaf densities were low compared to 2004. Late season densities were low at the all treated sites. At Site 2 and Site 4, no curlyleaf was found in the June survey (Table 3 and Figure 12).

Table 3. Summary of curlyleaf pondweed stem densities for early (typically April) and late season (typically June) conditions for individual sites. Sites that were not treated are shown in blue shading.

		Sites (average of 6 ft and 9 ft depths)(#/m^2)				Average (all sites)
		1	2	3	4	
2004	early	667	680	611	273	558
	late	2	2	0	0	1
2005	early	304	408	27	385	281
	late	0	0	0	0	0
2006	early	31	114	130	68	86
	late	0	16	73	25	29
2007	early	8	16	9	23	14
	late	61	80	152	15	77
2008	early	131	83	18	20	63
	late	0	59	0	402	116
2009	early	43	21	3	49	29
	late	4	0	0	5	2
2010	early	13	1	9	32	14
	late	0	11	39	39	12
2011	early	24	2	28	89	36
	late	171	8	155	149	121
2012	early	415	214	480	278	347
	late	0	214	0	0	0.6
2013	early	29	38	52	57	44
	late	73	56	280	194	151
2014	early	3	32	29	51	29
	late	1	8	5	1	8
2015	early	8	29	25	44	26
	late	15	0	5	0	5

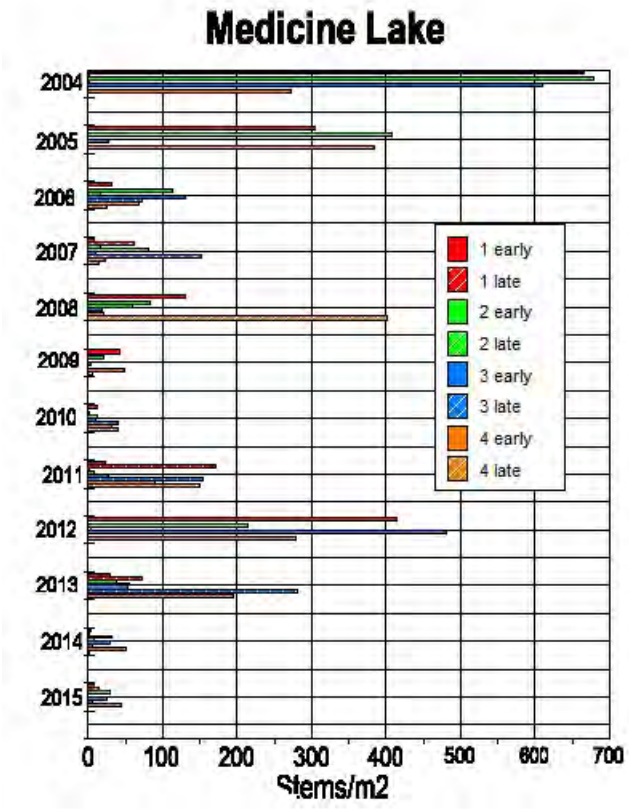


Figure 12. Medicine Lake curlyleaf pondweed stem densities from 2004-2015 for four sites for early and late spring conditions. Initial stem densities were high in 2004.

Discussion and Recommendations for 2016

Aquatic plant management in Medicine Lake keeps evolving. A 3-year lake-wide curlyleaf pondweed (CLP) control program treated between 317 to 325 acres was conducted in 2004, 2005, and 2006. This was a CLP distribution control strategy where all curlyleaf was treated with the objective to restrict curlyleaf by diminishing or depleting all turions in the lake. Then in 2007 no curlyleaf was treated. During the 2007 growing season, curlyleaf re-growth was uneven but significant with some areas showing light growth and other areas approaching heavy growth.

Much was learned from this aggressive CLP distribution control program, chiefly, that a three-year lake-wide treatment would not keep curlyleaf from coming back in Medicine Lake. Starting in 2008, the CLP distribution control strategy changed to a CLP biomass control strategy, where only the heavy curlyleaf growth was treated using selective treatments. This CLP biomass control strategy has been employed from 2008 through 2015.

Selective treatments of 29 to 80 acres from 2008 to 2010 were effective for controlling heavy CLP growth. In 2011, 14.7 acres were treated and heavy CLP growth resulted in about 65 acres. This selective treatment attempt was not very effective. In 2013, a total of 30.9 acres of CLP was treated with some heavy growth of CLP observed in the south end of the lake. In 2014, 47 acres of CLP were treated. In 2015, about 60 acres of Clp were treated.

The 65 acres of heavy curlyleaf growth observed in 2011 is about the maximum that has been found in Medicine Lake in years past and is not likely to be greater than that amount, although curlyleaf growth could be present in other areas, but at light to moderate levels. A likely curlyleaf treatment range for 2016 is between 30 to 60 acres.

Predicting the exact acres of heavy growth with subsequent early season herbicide treatments remains challenging. It is recommended that in 2016, early season scouting should be combined with previous growth history and lake sediment information to delineate areas to treat. The CLP biomass control strategy which just treats areas of heavy growth is a more cost-effective and ecologically-sound option than the CLP distribution management strategy which treats all curlyleaf, regardless of growth status.

There appears to be a potential for ongoing heavy curlyleaf growth in specific areas in Medicine Lake (Figure 13). Lake sediment sampling results from 2009 have been used to predict lake bottom areas that have the potential to support three types of curlyleaf pondweed plant growth: light, moderate, or heavy based on the key sediment parameters of pH, the Fe:Mn ratio, sediment bulk density, and organic matter (McComas, unpublished). Curlyleaf pondweed growth is predicted to produce a combination of moderate growth (where plants may occasionally top out in a broken canopy) and heavy growth (mostly a solid canopy) in Medicine Lake. The north and south ends of the lake appear to be conducive to heavy growth with some areas of heavy growth in the southwestern lobe.

Predicted Curlyleaf Pondweed Growth Based on Lake Sediments

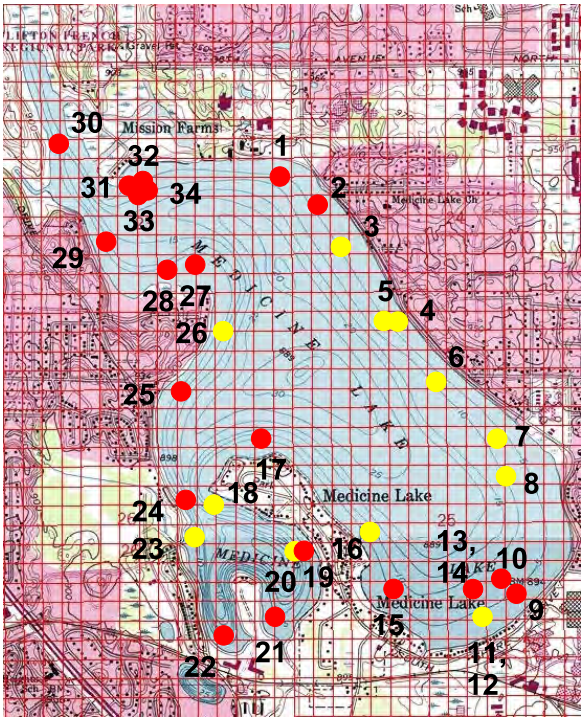


Figure 13. Sediment sample locations are shown with a circle. The circle color indicates the type of curlyleaf pondweed growth predicted to occur at that site. Key: green = light; yellow = moderate; red = heavy.

APPENDIX

Curlyleaf Delineation Methods

At the time of the spring curlyleaf delineations, only a fraction of the peak curlyleaf biomass is present. For spot treatments, the areas to be treated had to be delineated prior to curlyleaf developing peak biomass. Curlyleaf stem counts on a rake sampler were used to identify areas that had a potential to produce dense curlyleaf. After a short sweep of about 1-foot (30 cm), 4 curlyleaf stems or more per rake sample generally indicated some plants had developed runners and would likely produce heavy growth in the next few weeks. Alternatively, sites where 3 stems or less were collected per rake sample were not predicted to produce dense growth at the peak growing period. These areas were not treated. This delineation method was used for spot lake treatments in Gleason Lake and has worked for other lakes as well (McComas et al, 2015).

McComas, S.R., Y.E. Christianson, and U. Singh. 2015. Effects of curlyleaf pondweed control on water quality and coontail abundance in Gleason Lake, Minnesota. Lake and Reservoir Management. 31:109-114.