CRYSTAL LAKE SUMMER 2002 WATER QUALITY

24 February 2003
(Revised for website December 2005)

William Wilcox,
Water Resource Planner, Martha's Vineyard Commission

Background and Environmental Setting:
Crystal Lake is a 12-acre, fresh-water pond with a moderate density residential development pattern in its watershed (see Figure 1 for locus). Over the past 20 years it has experienced a dramatic increase in Phragmites reed along the perimeter at the expense of cattail and other wetland plants. Periodically, aquatic pondweed (*Potamegeton sp*.) and filamentous green algae have become excessive leading to harvesting projects circa 1983 and in 1995 and an attempt to limit its re-growth with a bacterial treatment annually from 1997 through 1999. The 1983 harvest was the most successful, suppressing the re-growth for about 10 years. These projects were carried out by the East Chop Association, owners of the perimeter of the Lake. Each of the other attempts failed to limit growth of the target weed.

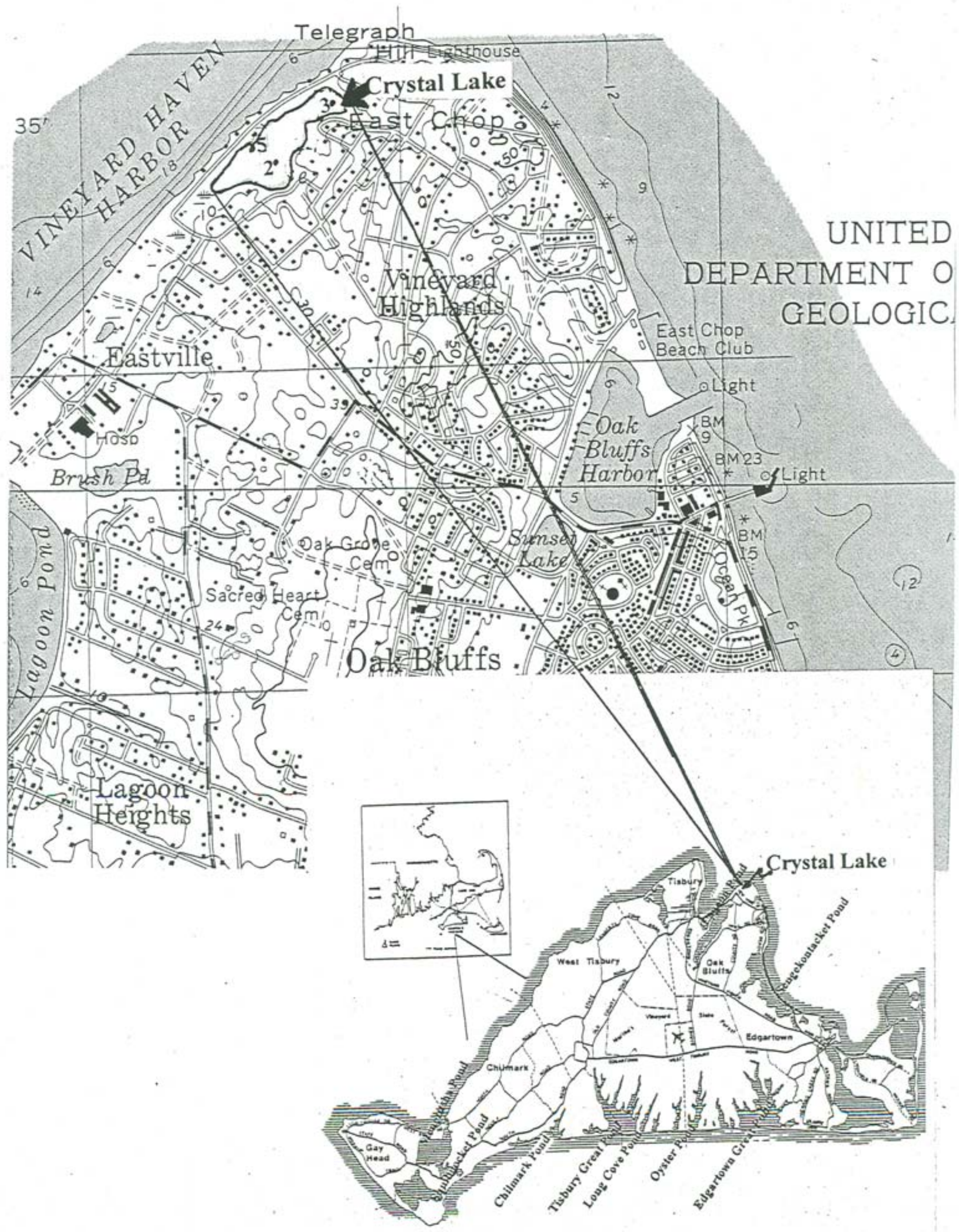
Aquatic weed control activities were carried out in summer 2002 and 2003 including spraying emergent Phragmites reed with Rodeo and treating underwater Potamegeton with Aquathol K (Endothall). In order to compensate for the release of nutrients from the decaying vegetation, a treatment with alum was planned to bind nutrients and prevent a microscopic algae bloom.

To assist the East Chop Association in meeting the Oak Bluffs Conservation Commission Order of Conditions, the MVC and the RSVP Senior Environment Corps agreed to collect water quality field data and samples for nutrient analyses. Samples were collected on 17 June, 28 July, 13 August and 28 August 2002 at sample stations where similar data was collected in previous years (see Figure 1 for locations).

The summer of 2002 was unusual in that rainfall was less than 1 inch during the July and August sampling period as measured at the Edgartown National Weather service observation station. A late August rain, coming after the 28 August samples, contributed to a total for the two months of 1.5 inches, some 5.5 inches less than the average precipitation. As a result, in addition to lower rainfall and storm runoff input to the pond, groundwater input would have been reduced. As the fresh water input carries considerable nitrogen with it, nitrogen additions to the nutrient budget during the growing season would have been lower than in an average year.

Sample Handling:
The samples were refrigerated, filtered through 0.45-micron cellulose acetate filters for dissolved nutrient analyses and forwarded to the lab of Kathy Krogslund (Univ. of Washington Marine Chem. Lab) within 24 hours of collection. Samples were also filtered through GFF and GFC filters for particulate nutrients and chlorophyll *a* analyses. Samples were also collected on 13 and 28 August for total and dissolved aluminum analyses by the Barnstable County Health Laboratory. This was done to assure that aluminum levels were not at toxic levels.

FIGURE 1 STUDY LOCUS



Sample Station Locations:
Sample stations were selected to coincide with locations that have been sampled over the years. The three stations used were CRY2, CRY3 and CRY5. These are located on the attached map (Figure 1). The label CRY1 was used for blind duplicate samples that were

drawn from the same bottle as one of the other stations, processed similarly and sent out to assess the accuracy of the lab.

Treatment Schedule:
Herbicide treatment occurred on 20 June 2002. Aquathol treatment was applied to the southern two-thirds (approximately) of the pond leaving Silvey's Cove untreated. A total of 27.5 gallons was applied. Application was even throughout the treated portion of the pond. Phragmites treatment with Rodeo at 42 ounces total was applied to areas identified as Sections A, C, D and E.

During the follow up visit, it was discovered that the pondweed in Silvey's Cove was killed back even though this area had not been treated. Apparently prevailing southwest winds had circulated enough Aquathol into that end of the pond to kill the pondweed.

On July 12, 275 gallons of alum was added to the pond to suppress the growth of phytoplankton. The quantity had been determined by bench tests with Crystal Lake water to maintain pH between 6 and 9 units.

Field Data:
In the field, an YSI-85 meter was used to record specific conductivity, temperature and dissolved oxygen in vertical profile and a separate sample was collected at the surface for analysis for pH. The YSI meter is self-calibrating for dissolved oxygen and specific conductivity and was checked regularly during the sampling season against conductivity standards to assure accuracy. Field data is tabulated in Table 1.

On 28 July, dissolved oxygen saturation varied from 98 to 115 percent at mid-morning. Specific conductivity was between 508 and 522 micro-Siemens and temperature was between 23.6 and 24.7 centigrade. Conductivity levels are high for freshwater ponds probably due to the proximity of the Lake to marine waters from which the Lake is separated by a barrier beach. No stratification was indicated and oxygen saturation at the bottom was in the same range as reported above. Surface pH was between 6.57 and 7.76.

On 13 August, dissolved oxygen saturation ranged between 95 and 112 percent again except at the station at the north end of the pond (CRY3) where it was about 92 percent. Temperature varied from 27.4 to 28.4 centigrade. Specific conductivity varied from 472 at the bottom to 578 at the surface at sample station 5, was right around 580 at station 2 and at the north end varied from 591 at the surface to 567 at the bottom. Surface pH varied between 6.45 and 6.55 at the three stations.

On 28 August, dissolved oxygen saturation was again between 93 and 98 percent. Specific conductivity was about 500 micro-Siemens throughout. Temperature varied only between 22.9 and 23.1 degrees centigrade. The surface water tested between 6.11 and 6.81 pH units.

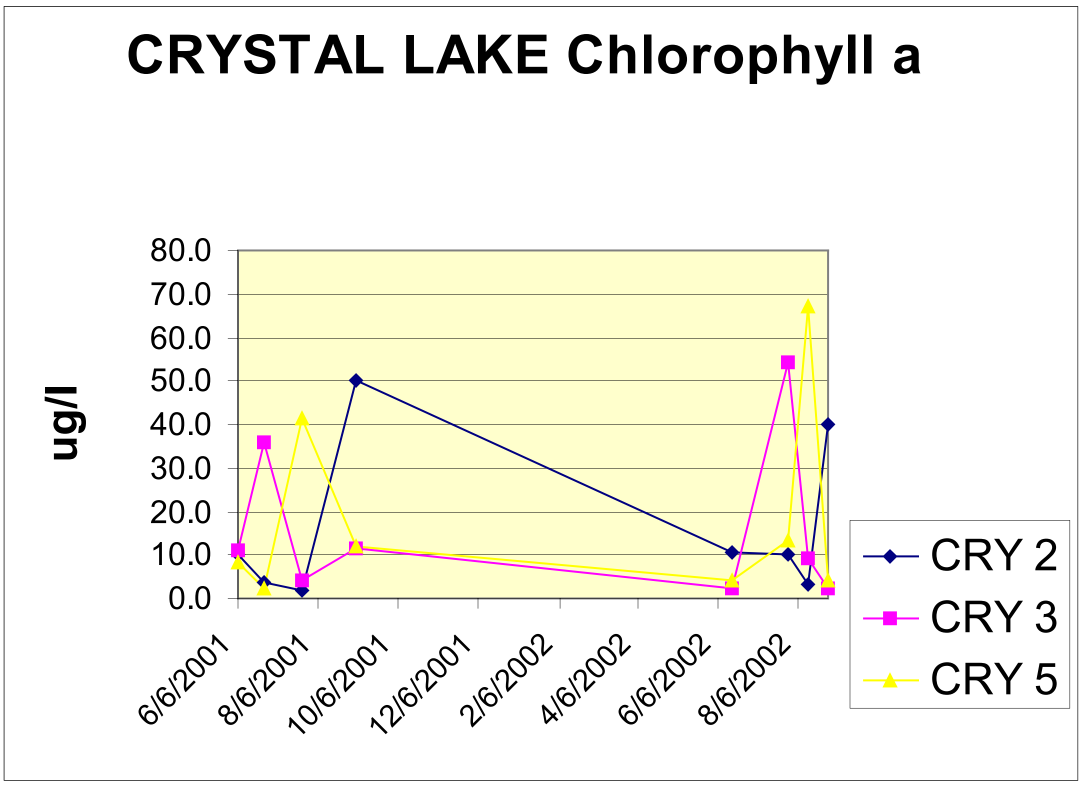
In summary, the field data indicate that hypoxic (low dissolved oxygen) conditions did not develop. Despite the addition of alum, surface water pH remained in an acceptable range. No strong stratification developed during the four visits. However, in early September, the pond did develop a severe algae bloom lending it a pea green color as discussed below. Blooms at this time of year have occurred frequently in the past. If field data had been collected during that time frame, a different picture may have resulted.

Aluminum Analyses:
Alum was used to bind nutrients that might be released from the decaying vegetation caused by the weed control program to suppress the development of a microscopic algae bloom. If available in the water column in the range of 10's of milligrams per liter, the aluminum can be toxic to fish and benthic invertebrates. A safe level for fish is reported to be less than 50 milligrams per liter. To assure that toxic levels did not develop, samples were collected, acidified and Groundwater Analytical performed the aluminum analyses (Method 6010B). On 13 August aluminum concentrations were all below the minimum detection limit of 0.2 milligrams per liter at all three stations for both total and dissolved aluminum. On the 28th of August, Station 2 tested at 0.3 milligrams per liter for dissolved aluminum but Total Aluminum was below the reporting level. There is some likelihood of an error with the Station 2 result as the total aluminum result should at least be the same as the dissolved result. This could result from contamination during the filtration process or in the sample bottles provided or an error in the testing process. Samples from Station 3 and 5 were below the detection limit. The data indicates there was little risk to aquatic organisms. Lab results are attached to this report.

pH Results:
Samples were collected for pH analyses using a Thermo Orion Model 230a meter provided by the University of Washington Marine Chemistry Lab. This device has auto calibration and temperature compensation. The unit was checked against standards before each use to assure accuracy. The readings varied from 6.57 to 7.76 on July 28. On August 13 the readings ranged from 6.45 to 6.55 at the three sample stations. On August 28 the values varied from 6.11 to 6.81. All values recorded are within the acceptable range and typical of lakes found in weakly soluble sediment with little carbonate.

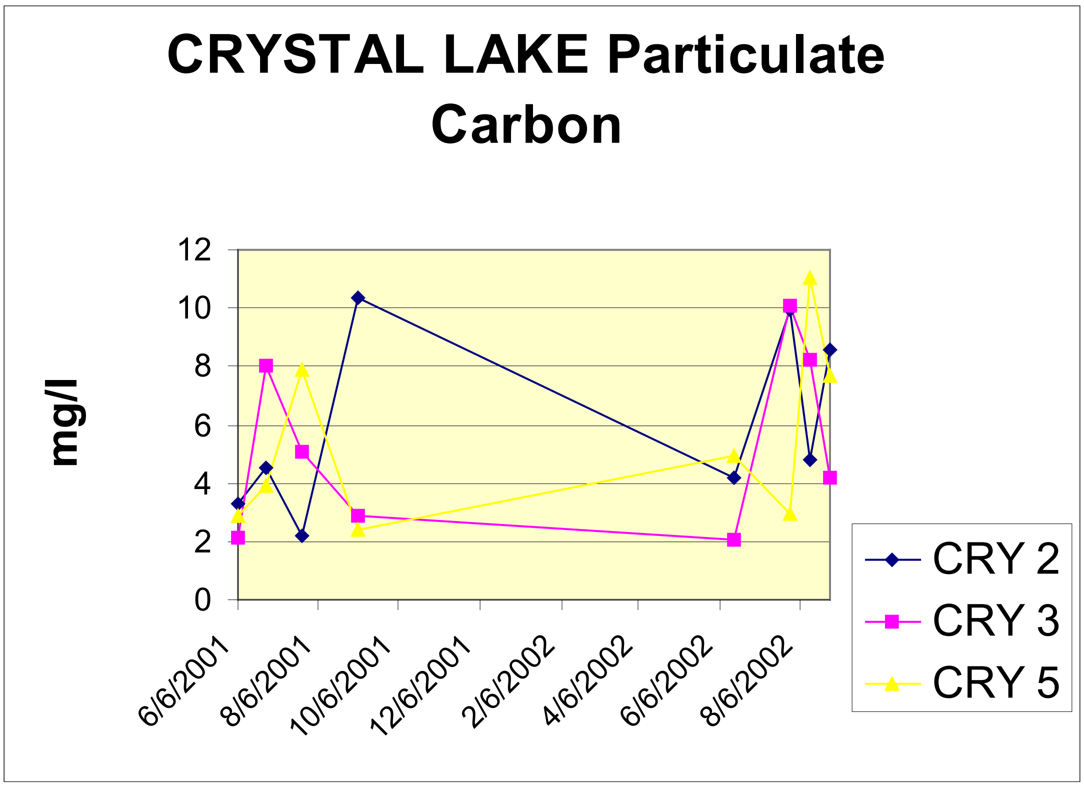
Chlorophyll Content:
The lab data for the three post-treatment sample rounds discussed here and the June 17, pre-treatment samples are included in Table 2 and displayed in Figure 2. It is desirable for chlorophyll concentrations to remain below 10 micrograms per liter (ug/L) and average around 3 to 5 ug/L. Chlorophyll *a* levels remained near the limit during the herbicide treatment and following the alum treatment. However, in late August an algae bloom developed with chlorophyll *a* levels rising to 35 to 40 micrograms per liter. This bloom continued through most of the month of September as noted by visual observation only. No samples were collected during September.

FIGURE 2:



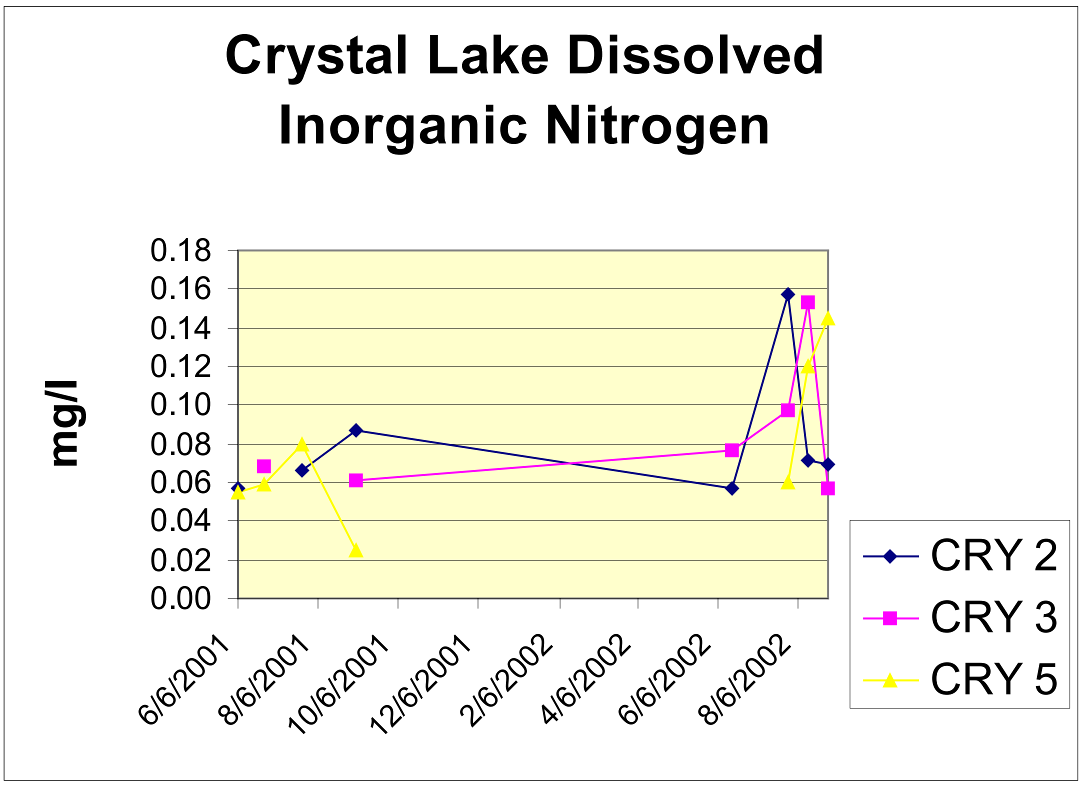
The onset of the bloom is also indicated by the particulate data in Table 2 and, for the carbon component, in Figure 3. Although only Carbon (C) is displayed in Figure 3, both Hydrogen (H) and Nitrogen (N) concentration in particulates nearly doubled between the 13 and 28 August sample rounds. This indicates a dramatic increase in microscopic organisms and/or fragments of plant material in the water column. Units shown are milligrams per liter (mg/l) or parts per million.

Figure 3:



Nutrient Data:
Nitrogen data is included in Table 2 and in Figure 4. A substantial increase in dissolved nitrogen occurred between the July 29 and August 28 sample rounds. As there was little rainfall during that time period the sources are probably sediment release, decay of aquatic vegetation and groundwater. A late summer increase in nitrogen concentration has been found to occur in previous years. The nitrogen increase was largely ammonium but nitrate and nitrite also increased. Total nitrogen concentration also increased substantially but more so between the two August samples. Orthophosphate decreased from late July to mid-August but then increased once again by late August.

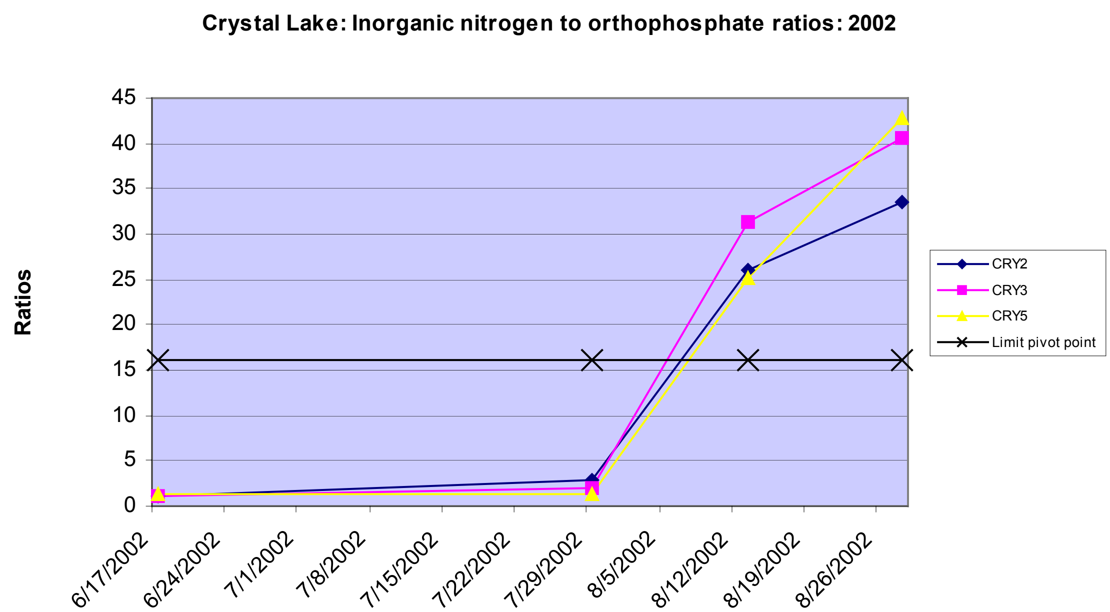
Figure 4



Nutrient Limitation of Plant Growth: Changes in the concentration of phosphorus and nitrogen caused the pond to shift from a nitrogen-limited condition before August 13 to a phosphorus-limited condition on 13 August and through the end of the month. The growth limit is an indication of what key nutrients necessary for plant growth are lacking in the water column and thereby retarding the growth of phytoplankton and algae that are not rooted and must take nutrients directly from the water. The ratio of dissolved nitrogen to phosphorus equal to 16 is the pivot point between a nitrogen-limited situation (ratio less than 16) and a phosphorus limited one (ratio greater than 16).

On August 13, an increase in ammonium concentration altered the ratio to well in excess of 16 indicating phosphorus limitation. By August 28 increased amounts of orthophosphate were in the water column but the amount of ammonium had also increased dramatically so that the ratio continued to indicate phosphorus limitation. This is shown in Figure 5 where the ratio shifts from less than 16 (nitrogen limited condition) to more than 16 (phosphorus limited condition).

Figure 5:



Silica probably was limiting during mid-June for those phytoplankton that require it for growth (diatoms) but does not appear to be limiting during the remainder of the sampling period. This has greater implication for growth of phytoplankton than for rooted plants.

Trophic State: Trophic state is an indication of the biomass in a pond system. The trophic state is often described by terms such as mesotrophy and eutrophy but a numerical index was created by Carlson using the amount of chlorophyll and total phosphorus in the water column and the Secchi depth. These correlate to the total amount of algal biomass in the pond. The Trophic State Indices (TSI) range from 0 to

100 with the higher numbers indicating increasing productivity and larger amounts of biomass in the system.
For more information on the TSI go to http://dipin.kent.edu/tsi.htm

In Table 2, the TSI are calculated for nitrogen, phosphorus and chlorophyll. The chlorophyll indices vary from mid-40's in June and again in mid-August up to the mid-60's in late August. These are indicative of a mesotrophic system shifting to a eutrophic system. Eutrophic systems are characterized by an excess of either or both of microscopic and larger plants. The eutrophic condition leads to a cascade of other problems that we perceive as poor water quality including low or no dissolved oxygen that may cause fish kills and algal scum and odors. The total phosphorus and nitrogen TSI indicates a system that is always eutrophic. No Secchi readings were taken due to the thick macrophytes (pondweed) that masked the disk at the station locations.

Discussion and Conclusions:
In previous years, the pond was typically limited by phosphorus until July or August when nitrogen became limiting. This was not the case in 2002. Possible causes of the reversal of previous patterns include the lack of rain in July and August (1.5 inches total, more than 5.5 inches below average) and the record low water table levels through the spring and summer. However, as rain and groundwater are important sources of nitrogen, the lack of precipitation through July and August does not support an increase in nitrogen in the pond from those sources. Releases of nitrogen from decay of herbicide treated plant material and/or from bottom sediment are also possible sources of nitrogen.

Chlorophyll values measured in late August (and probably continuing through September) were no worse than those measured in 1998 when chlorophyll concentrations varied from 20 to 60 micrograms per liter through the pond on 18 August. In July and again in October 1997, chlorophyll concentrations approached 20 micrograms per liter. These years are not fully comparable with 2002 though as in-pond dissolved inorganic nitrogen in '97 and '98 was much lower than 2002 and rainfall in both '97 and '98 was above average whereas it was well below average in 2002 for those months. During 2002, Upper Lagoon Pond also displayed an algal bloom with chlorophyll concentrations from mid-August through mid-September from 40 to 194 micrograms per liter (3 samples).

Clearly there was a significant algae bloom from late August through September. The question of the cause(s) of the algae bloom is a complex one and not easily answered. The large increase in ammonium concentration in late August coincided with the onset of this algae bloom as indicated by the chlorophyll and particulate nutrient concentration. The concentration of inorganic nitrogen (DIN- includes ammonium) in late August 2002, exceeded values seen in previous years in late summer by a factor of 2 to 10. The implication is that a larger or a different source of dissolved nitrogen was present in 2002 compared to previous years.

Orthophosphate also increased in late August to concentrations that were similar to those seen in late summer in previous years.

The treatment program was a significant deviation from previous years and it seems reasonable that the release of nutrients from the dying pondweed in 2002 may have driven the algae bloom. The alum treatment aimed at sequestering the nutrients needed for a bloom was apparently not adequate. The algae blooms seen in 1997 and 1998, may have resulted from natural senescence of the pondweed in late summer releasing nutrients to support an algae bloom. As in Crystal Lake, the Upper Lagoon bloom in 2002 followed a die off of rooted plants in early to mid-July and may have been driven by that release of nutrients. Never the less, the 2002 chlorophyll and particulate values are undesirable.

The developing algae bloom did not cause a lack of oxygen in the water column (hypoxia) during the 13 and 28 August sampling rounds. It is possible that, as the bloom continued into September, hypoxia could have developed but we do not have data to support that contention.

Accuracy of the data:
Blind duplicate samples were sent out during the June, July and late August sample rounds. These duplicate samples contained water from one or more of the sample stations processed and analyzed in the same manner. As can be seen from comparing the results for CRY1 with the results for the station that it duplicates, the lab accuracy was quite good.

Recommendations:

- The algae bloom that developed in late August and continued through September is unacceptable. A second alum treatment may be desirable next season during early to mid-August to avoid a repeat of the 2002 algae bloom. In 2003, the treatment may generate fewer nutrients because it will be treating only the re-growth of the pondweed killed back in 2002. This may in itself result in less algal growth. This possibility should be discussed with the consultant before the project schedule is planned to identify the best approach to nutrient control to suppress the algal bloom.
- RSVP volunteers should take Secchi readings at each visit even if measured off-station where there is clear water.
- RSVP volunteers should be on the pond between 8:30 and 9:00 a.m. to acquire the overnight dissolved oxygen saturation values.
- An additional sampling round in mid-September should be added to observe the late onset of an algae bloom if one occurs.
- The pond system can be characterized as eutrophic. Efforts to reduce the input of nutrients particularly phosphorus are needed.

Acknowledgements:
Kathy Krogslund, Marine Chemistry Lab, provided free sample analyses. This is a value in excess of $1000. Kathy also provided the pH meter. Bill Walker and Bob Ford, RSVP Senior Environment Corps, collected the samples and field data.

Key to Attached Table:

PO4-P Orthophosphate one of the macronutrients required for growth of phytoplankton the base of the food chain. Phosphate is added to the system from runoff, nearby septic systems and by release from bottom sediments when the dissolved oxygen is removed from the water column.

Si(OH)4-Si Silicate a nutrient required for certain plankton that utilize it in their skeletons such as diatoms. Silicate is added to the system by demineralization of sediment or plankton skeletons.

NO3-N Nitrate- a highly soluble macronutrient utilized in phytoplankton growth. Nitrate is added to the system from acid rain, septic systems and fertilizers.

NO2-N Nitrite- also a highly soluble macronutrient as is nitrate.

NH4-N Ammonium- a somewhat less mobile macronutrient that may be added from septic systems that are near or in the groundwater or by release from decaying organic matter.

DIN Dissolved Inorganic Nitrogen This is the sum of nitrate, nitrite and ammonium.

DIN/PO4 The ratio of DIN to orthophosphate. Generally, when the ratio is less than 16 nitrogen is deficient in the system for the growth of phytoplankton and when it is greater than 16 phosphorus is deficient for their growth.

TP Total phosphorus. The sum of orthophosphate plus organic forms of phosphorus both dissolved and as particulate matter.

TN Total Nitrogen. The sum of DIN plus organic forms of nitrogen both dissolved and as particulate matter.

Chl a Chlorophyll a This is found in all green plants including phytoplankton and serves as an indicator of the biomass of microscopic organisms in the water column.

C counts, wgt., and mg/lMeasures of the amount of carbon in the particulate matter in the water column. This is also an indicator of the amount of biomass in the water column.

H counts, wgt., and mg/l Measures of the amount of hydrogen in the particulate matter in the water column. This is also an indicator of the amount of biomass in the water column.

N counts, wgt., and mg/l Measures of the amount of nitrogen in the particulate matter in the water column. This is also an indicator of the amount of biomass in the water column.

Trophic State Indices (TSI) A numerical rating of the amount of biomass in the water column that is derived from chlorophyll (chloro), Secchi depth (Secchi) and total phosphorus (Total P).

Secchi depth A measure of the transparency of the water column derived from the depth that a standard black and white disk can be seen from the boat.

Dsi/PO4 The ratio of silicate to orthophosphate. Generally, when the ratio is less than 16 silicate is deficient in the system for the growth of plankton that use it in their skeletons and when it is greater than 16 phosphorus is deficient for their growth

CRYSTAL LAKE

TABLE 1 2002 Field Data SEC &MVC

DATE	Time	Station#	DEPTH	DO	DO	Sp. Cond.	Temp	pH
				mg/l	% Sat.	microS	C	
			meters					
07/28/02	11:05 AM	2	0.25	9.33	111	512	24.1	6.74
07/28/02	11:05 AM	2	**1**	9.17	105	511		
07/28/02	11:05 AM	2	**1.5**	9.35	104.7	510		
07/28/02	10:45 AM	3	0.25	9.59	115.1	522	24.7	7.76
07/28/02	10:45 AM	3	**0.5**	9.43	113.5	518		
07/28/02	10:45 AM	3	**0.75**	9.32	112.2	516		
07/28/02	11:35 AM	5	0.25	8.86	98	510	23.7	6.57
07/28/02	11:35 AM	5	**1**	7.98	102.6	508	23.7	
07/28/02	11:35 AM	5	**2**	7.54	95.6	508	23.6	
08/13/02	12:05 PM	2	0.25	8.79	112.8	581	28	6.51
08/13/02	12:05 PM	2	**1**	8.85	106.1	581	28	
08/13/02	12:05 PM	2	**2**	8.55	107.5	576	28	
08/13/02	12:25 PM	3	0.25	7.36	92.6	591	28.4	6.55
08/13/02	12:25 PM	3	**0.5**	7.08	92	574	28.4	
08/13/02	12:25 PM	3	**0.75**	7.24	91.3	567	28.4	
08/13/02	11:50 AM	5	0.25	8.74	98.3	578	27.4	6.45
08/13/02	11:50 AM	5	**1**	8.84	95.2	474	27.4	
08/13/02	11:50 AM	5	**2**	7.77	97.6	472	27.4	
08/28/02	09:00 AM	2	0.25	8.35	95.4	500	22.9	6.81
08/28/02	09:00 AM	2	**1**	8.4	97.5	500	22.9	
08/28/02	09:00 AM	2	**2**	8.23	97.1	500	22.9	
08/28/02	09:30 AM	3	0.25	8.2	96.1	500	23.1	6.79
08/28/02	09:30 AM	3	**0.5**	8.18	95.3	500	23.1	
08/28/02	09:30 AM	3	**0.75**	8.14	93.2	500	23.1	
08/28/02	10:00 AM	5	0.25	8.34	96.4	500	22.9	6.11
08/28/02	10:00 AM	5	**1**	8.06	96.2	500	22.9	
08/28/02	10:00 AM	5	**2**	8.28	98.1	500	22.9	

TABLE 2: Crystal Lake Nutrient Data

Sta. #	Date	Lab	PO4 uM/L	SiO4 uM/L	NO3 uM/L	NO2 uM/L	NH4 uM/L	DIN uM/L	pH Range top to bottom	CH a uG/L	Phaeo. uG/L	FO/FA Ratio
1	9/12/95		0	1.76	0.01		0.92	0.93		11.58	0.33	
1	11/6/96	UW	0.03	3	0.12	0.03	0.4	0.55	9.3	2.11	0.23	2.03
1	4/14/97	UW	0.01	0.08	0.15	0.02	0.38	0.55	9.25 to 9.32	2.58	1.64	1.64
1	7/14/97	UW	0.08	8.96	0.44	0.06	0.76	1.26	10.9 to 10.8	15.88	13.84	1.54
1	10/6/97	UW	0.12	15.33	0.01	0.03	0.92	0.96	10.8 to 8.99	32	7.04	1.94
1	4/13/98	UW	0.04	1.07	0.37	0.04	0.81	1.22	8.1 to 8.5	3.67	2.26	1.59
1	6/1/98	UW	0.09	1.5	0.67	0	0.47	1.14	9.7 to 9.6	13.77	10.78	1.54
1	8/18/98	UW	0.12	9.8	0	0.04	0.66	0.7	10.3	62	15.83	1.76
1	7/6/99	UW	0.1	3.65	0.15	0.04	0.78	0.97	9.5 to 7.6	4.2	1.75	1.68
1	8/17/99	UW	0.05	17.73	0.13	0.05	1.08	1.26	9.6 to 7.9	8.18	0.65	1.89
1	9/13/99	UW	0.11	10.84	0.12	0.04	0.76	0.92	9.8 to 9.2	3.07	2.57	1.52
2	9/12/95		0.24	1.32	0.27		0.88	1.15		66.08	0.64	
2	11/6/96	UW	0.03	5.35	0.12	0.03	0.23	0.38	9.1 to 9	1.63	0.37	1.93
2	4/14/97	UW	0	0.12	0.31	0.02	0.78	1.11	9.38 to 9.39	2.37	1.17	1.17
2	7/14/97	UW	0.06	12.6	0.01	0.05	1.4	1.46	11.55 to 11.78	13.93	8.72	1.63
2	10/6/97	UW	0.08	16	0.02	0.03	1.01	1.06	10.6 to 8.4	9.58	1.87	1.96
2	4/13/98	UW	0.04	0.85	0.25	0.03	0.77	1.05	8.2 to 8.5	4.47	2.22	1.64
2	6/1/98	UW	0.05	1.65	0.55	0	0.49	1.04	9.9 to 8.3	9.39	9.5	1.48
2	8/18/98	UW	0.14	12.41	0	0.03	0.61	0.64	10.3 to 9.8	23.92	9.63	1.68
2	7/6/99	UW	0.09	3.76	0.17	0.03	2.24	2.44	9.7 to 7.7	6.59	1.42	1.79
2	8/17/99	UW	0.04	21.27	0.11	0.06	0.97	1.14	9.4 to 7.7	0.79	8.5	1.08
2	9/13/99	UW	0.1	15.13	0	0.02	0.66	0.68	9.9 to 7.3	4.17	3.84	1.5
2	7/19/00	UW	0.09	15.3	0.38	0.03	0.66	1.07	9.4 to 9.1	4.712		

2	8/29/00	UW	0.12	61.63	0	0.02	0.86	0.88		5.989		
2	5/2/01	UW	0.0011	0.074	1.5	0.22142857	16.5	18.221429		10.2366		
2	6/6/01	UW	0.0011	0.1078	0.22142857	0.05714286	1.3214286	1.6		10.0853		
2	6/26/01	UW								3.9025		
2	7/24/01	UW	0.00214697	0.16854747	0.06073564	0.04472414	0.6893279	0.7947877		1.869		
2	9/4/01	UW								50.08		
2	6/17/02	UW	0.01092468	0.13063446	0	0.035814	0.8475056	0.8833196		10.63		
2	7/29/02	UW	0.0069	0.148	0	0.02142857	1.4071429	1.4285714		10.266		
2	8/13/02	UW	0.002	0.2	0.64285714	0.03571429	2.9214286	3.6		3.274		
2	8/28/02	UW	0.00526789	0.20014888	1.24801393	0.32283436	11.07366	12.644508		39.848		
3	9/12/95		0.05	0.71	0.04		0.92	0.96				
3	11/6/96	UW	0.03	10.43	0.04	0.03	0.3	0.37	9.4	2.58	0.27	2.04
3	4/14/97	UW	0.01	0.16	0.15	0.02	0.81	0.98	9.78 to 10.1	2.34	2.16	2.16
3	7/14/97	UW	0.06	10.09	0.01	0.05	0.67	0.73	11.9 to 12	20.76	9.32	1.7
3	10/6/97	UW	0.07	18.61	0.03	0.03	0.92	0.98	10.5 to 10.3	13.57	2.63	1.96
3	4/13/98	UW	0.02	0.84	0.23	0.03	0.7	0.96	8.4 to 8.6	3.93	2.07	1.63
3	6/1/98	UW	0.09	2.84	0.53	0	0.51	1.04	9.7 to 9.5	10.91	1.11	1.87
3	8/18/98	UW	0.17	16.57	0	0.03	0.86	0.89	10.5 to 9.6	25.04	10.73	1.67
3	7/6/99	UW	0.1	3.69	0.11	0.04	0.86	1.01	9.8 to 9.6	11.68	3.14	1.76
3	8/17/99	UW	0.02	19.45	0.05	0.04	0.86	0.95	9.4	1.79	4.59	1.27
3	9/13/99	UW	0.18	20.42	0	0.05	0.87	0.92	9.6 to 7.9	11.51	5.03	1.67
3	7/19/00	UW	0.08	14.55	0.27	0.04	0.77	1.08	9.8 to 8.9	5.727		
3	8/29/00	UW	0.06	31.5	0	0.03	1.17	1.2	9.5	8.108		
3	5/2/01	UW	0.0014	0.071	1.564285710	0.21428571	14.1	15.878571		10.9832		
3	6/6/01	UW	0.0039	0.1164	0.21428571	0.05	2.1357143	2.4		11.524		
3	6/26/01	UW								4.011		
3	7/24/01	UW	0.00213703	0.19587949	0.05682971	0.04472414	0.5136521	0.615206		2.3898		

3	9/4/01	UW								54.4		
3	6/17/02	UW	0.01105531	0.16105618	0	0.0398575	0.8945391	0.9343966		8.185		
3	7/29/02	UW	0.0093	0.148	0	0.02857143	1.2357143	1.2642857		9.04		
3	8/13/02	UW	0.0016	0.174	0.5	0.05714286	2.9428571	3.5		2.327		
3	8/28/02	UW	0.00536195	0.19014143	2.95239929	0.05970221	12.566786	15.578888		35.685		
4	9/12/95											
4	11/6/96	UW										
4	4/14/97	UW	0.01	0.08	0.15	0.02	1.04	1.21	10.0 to 10.2	2.32	2.21	2.21
4	7/14/97	UW	0.08	9.95	0.01	0.06	0.83	0.9	12	18.69	9.38	1.68
4	10/6/97	UW	0.1	19.45	0.26	0.24	4.9	5.4	10.2 to 8.8	13.38	2.22	1.99
4	4/13/98	UW	0.04	0.83	0.71	0.03	1.48	2.22	8.2 to 8.3	1.59	5.16	1.23
4	6/1/98	UW	0.07	4.19	0.5	0.01	0.55	1.06	9.2 to 9	15.02	0.86	1.91
4	8/18/98	UW	0.12	5.75	0	0.06	0.66	0.72	9.1	14.46	8.15	1.61
4	7/6/99	UW	0.14	3.8	0.14	0.03	0.87	1.04	9.7 to 9.1	33.53	14.76	1.67
4	8/17/99	UW	0.03	20.36	0.04	0.03	0.91	0.98	9.5	1.28	9.27	1.12
4	9/13/99	UW	0.18	18.05	0	0.04	1.44	1.48	9.9	9.78	6.82	1.57
5	9/12/95											
5	11/6/96	UW										
5	4/14/97	UW	0.01	0.24	0.31	0.02	1	1.33	9.1	2.13	1.51	1.51
5	7/14/97	UW	0.04	3.62	0.22	0.04	3.53	3.79	11.16 to 11.12	11.62	13.89	1.46
5	10/6/97	UW	0.06	16.76	0.11	0.18	5.63	5.92	10.8 to 9.9	11.22	1.95	1.98
5	4/13/98	UW	0.02	0.81	0.54	0.03	1.18	1.75	8.4	4.65	2.36	1.64
5	6/1/98	UW	0.05	2.99	0.44	0	0.49	0.93	9.7	9.7	1.37	1.84
5	8/18/98	UW	0.1	7.1	0	0.03	0.59	0.62	9.8 to 9.1	12.93	3.6	1.75
5	7/6/99	UW	0.07	3.09	0.15	0.03	0.81	0.99	9.7 to 6.9	3.28	1.3	1.69
5	8/17/99	UW	0.03	23.91	0.09	0.05	1.26	1.4	9.5 to 7.6	0.26	13.73	1.02

5	9/13/99	UW	0.1	9.03	0	0.02	1.9	1.92	9.8	10.11	3.63	1.71
5	7/19/00	UW	0.12	12.85	0.12	0.03	0.81	0.96	8.8 to 8.7	5.371		
5	8/29/00	UW	0.14	6.52	0	0.02	0.85	0.87	9.6 to 8.7	8.017		
5	5/2/01	UW	0.0014	0.0791	1.52857143	0.22142857	15.65	17.4		11.8303		
5	6/6/01	UW	0.0014	0.107	0.27142857	0.05	3.6285714	3.95		13.2995		
5	6/26/01	UW								4.1832		
5	7/24/01	UW	0.00191836	0.17765815	0.05292379	0.04472414	2.7820661	2.8797141		4.6578		
5	9/4/01	UW								67.32		
5	6/17/02	UW	0.01159845	0.15121386	0	0.03956871	1.1269926	1.1665613		9.462		
5	7/29/02	UW	0.0098	0.13	0	0.02857143	0.8928571	0.9214286		4.186		
5	8/13/02	UW	0.0016	0.204	0.57142857	0.15	2.2	2.9214286		2.496		
5	8/28/02	UW	0.00507975	0.19807837	1.535719290	0.27861043	13.697397	15.511726		41.608		
2d	8/18/98		0.13	14.28	0	0.03	0.93	0.96				

Surface Readings

Sta. #	Date	DO mG/L	Temp. Cent.	% Saturat	DIN/PO4	DSi/PO4	Tot. P uM/l	Tot. N uM/l	TROPHIC STATE I Chloro
1	9/12/95								
1	11/6/96	12.3	9	110	18.3333333	100			
1	4/14/97	11.43	11.1	107	55	8			
1	7/14/97	8.47	25.2	105	15.75	112			
1	10/6/97	13.9	16.8	149	8	127.75			
1	4/13/98		13.1		30.5	26.75			
1	6/1/98	9.75	19.7						
1	8/18/98		27.3						
1	7/6/99	9.38	26.1	115.9	9.7	36.5			

1	8/17/99	10.44	23	121.7	25.2	354.6			
1	9/13/99	11.15	25.8	144.1	8.3636364	98.5454545			
2	9/12/95				4.7916667	5.5			
2	11/6/96	12.3	9	110	12.666667	178.333333			
2	4/14/97	11.86	10.7	112					
2	7/14/97	8.7	27.3	111	24.333333	210			
2	10/6/97	12.2	16	128	13.25	200			
2	4/13/98	9.9	11.4		26.25	21.25			
2	6/1/98	9.48	20.5						
2	8/18/98	10.71	21.2						
2	7/6/99	10.27	27.4	130.1	27.1111111	41.7777778			
2	8/17/99	10.41	23.5	122.5	28.5	531.75			
2	9/13/99	12.56	25.3	152.2	6.8	151.3			
2	7/19/00	7.18	20.8	80	11.888889	170			
2	8/29/00				7.3333333	513.583333	2.55	94.12	
2	5/2/01				16564.935				
2	6/6/01				1454.5455		1.82258065	111.635714	
2	6/26/01								
2	7/24/01				370.19007		2.12186935	84.0057044	
2	9/4/01						2.79719745	142.4069	
2	6/17/02				80.855403		1.83870968	117.764286	53.7877027
2	7/29/02				207.03934		5.07096774	141.857143	53.4458955
2	8/13/02				1800		2.29032258	140.214286	42.2347824
2	8/28/02				2400.3007		2.2516129	164.714286	66.7505584
3	9/12/95				19.2	14.2			
3	11/6/96	13.3	9	119	12.333333	347.666667			

3	4/14/97	11.85	12.4	113	98	16			
3	7/14/97	11.6	26.5	146	12.166667	168.166667			
3	10/6/97	13.38	17.1	143	14	265.857143			
3	4/13/98	8.27	12.3		48	42			
3	6/1/98	8.53	21.1		11.555556				
3	8/18/98		25.7						
3	7/6/99	9.86	28.6	128.5	10.1	36.9			
3	8/17/99	10.61	23.5	124.9	47.5	972.5			
3	9/13/99	12.1	25.8	150.8	5.1111111	113.444444	NOTE: Both 3 and 4 labeled as 3		
3	7/19/00	7.99	21.1	90.3	13.5	181.875			
3	8/29/00	7.4	23.6	86.6	20	525	1.68	99.8	
3	5/2/01				11341.837				
3	6/6/01				615.38462		1.96774194	111.35	
3	6/26/01								
3	7/24/01				287.87870		2.45667987	86.9835986	
3	9/4/01						3.14034106	155.013707	
3	6/17/02				84.520153		1.76129032	114.95	51.2235945
3	7/29/02				135.9447		4.92903226	140.714286	52.1982765
3	8/13/02				2187.5		1.84516129	127.857143	38.8853287
3	8/28/02				2905.4497		2.20322581	162.857143	65.6681055
4	9/12/95								
4	11/6/96								
4	4/14/97	13.19	12.7	129	121	8			
4	7/14/97	12.5	28.2	162	11.25	124.375			
4	10/6/97	11.42	17.4	122	54	194.5			
4	4/13/98	9.37	13		55.5	20.75			

4	6/1/98	7.4	21.4						
4	8/18/98		25.8						
4	7/6/99	9.19	28.6	117.8	7.4285714	27.1428571			
4	8/17/99	10.4	24.1	124.1	32.666667	678.666667			
4	9/13/99	15.62	26.3	194.1	8.2222222	100.277778	" "" " "		
5	9/12/95								
5	11/6/96								
5	4/14/97	11.47	10.3	106	133	24			
5	7/14/97	7.9	24.6	97	94.75	90.5			
5	10/6/97	13.9	16.2	146	98.666667	279.333333			
5	4/13/98		11.2		87.5	40.5			
5	6/1/98	9.23	20.5		18.6	59.8			
5	8/18/98	8.05	20.9		6.2	71			
5	7/6/99	9.25	27.3	117.5	14.142857	44.1428571			
5	8/17/99	9.78	23.3	114.6	46.666666 7	797			
5	9/13/99	11.19	25.4	136.8	19.2	90.3			
5	7/19/00	5.95	20.9	66	8	107.083333			
5	8/29/00	6.67	22.9	78.1	6.2142857	46.5714286	1.6	98.56	
5	5/2/01				12428.571		0.78709677	39.2064516	
5	6/6/01				2821.4286		1.92258065	50.2741935	
5	6/26/01								
5	7/24/01				1501.1341		2.63168861	41.8826906	
5	9/4/01						3.87899313	75.0308392	
5	6/17/02				100.57905	13.0374172	1.87419355	118.171429	63.051881
5	7/29/02	7.98	23.7	102.6	94.023324	13.2653061	4.66774194	137.285714	29.4115905
5	8/13/02	8.84	27.4	95.2	1825.8929	127.5	1.91935484	133.071429	69.3313325
5	8/28/02	8.06	22.9	96.2	3053.6421	38.993755	2.56129032	178.642857	69.7472112

2d	8/18/98	1.7	19.8