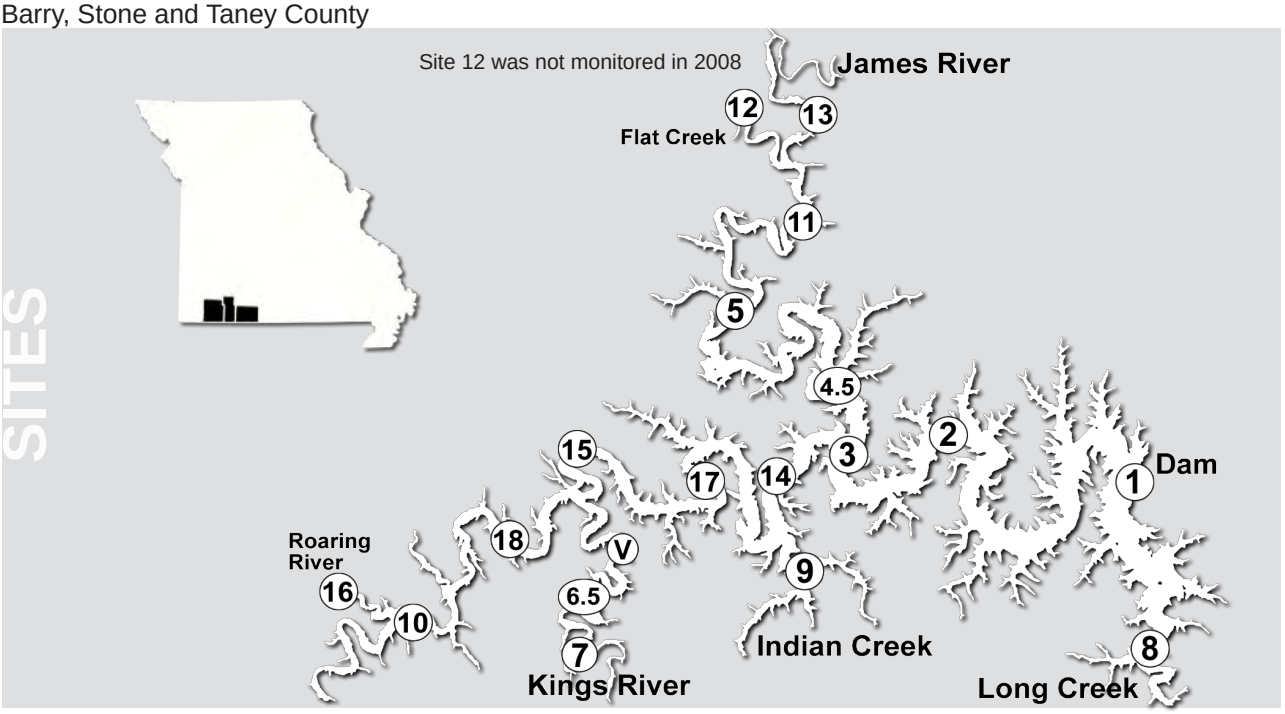
Table Rock Lake

Barry, Stone and Taney County

SITES



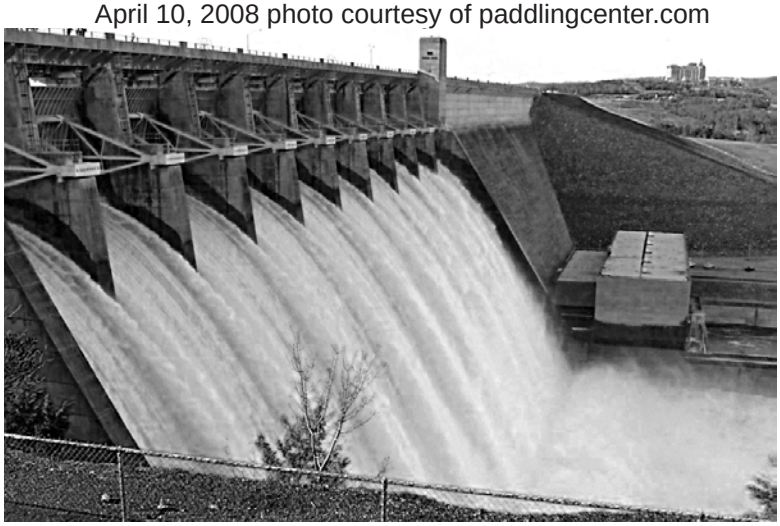
The extremely high water levels in Table Rock Lake during the 2008 sample season made for interesting data. Care should be taken when comparing among sites as not everyone was able to monitor during the exact same period. Sample collections started on April 7 at one site, while another site was not sampled until mid-July. Also, the number of samples collected varied enough to influence comparisons, with minimum and maximum number of samples ranging from four to nine.

2008 SUMMARY

During normal years, water quality in the main lake displays low variability, with only minimal differences among sites. This was not the case in 2008. Phosphorus and chlorophyll displayed the most site-to-site variability; with average phosphorus values ranging from 5µg/L (Site 1) to 21µg/L (Site 14). Chlorophyll also varied among sites by a factor of four, with average values ranging from 2.9µg/L (Site 18) to 11.5µg/L (Site 1). There was also more variability than normal at some sites during the course of the sample season. Site 3, which was sampled on nine occasions between April 7 and September 16 was the most variable of main lake sites (most likely because it was sampled over a longer period of time in 2008 than any other main lake site). At this site individual phosphorus measurements ranged by a factor of 9 (9 - 82µg/L) and the chlorophyll maximum was >11 times the minimum (2.9 – 33.4µg/L).

Table Rock Lake with all 10 flood gates open

April 10, 2008 photo courtesy of paddlingcenter.com



2008 Table Rock Summary Data

TP = Total Phosphorus;
TN = Total Nitrogen;
CHL = Chlorophyll

Main Lake Sites		10	18	15	17	14	3	2	1
	# of samples	7	6	4	7	7	9	5	5
Secchi (inches)	Mean	92	114	86	78	88	85	73	58
	Min	50	86	68	62	42	29	63	39
	Max	116	190	111	104	120	138	84	76
TP (µg/L)	Mean	13	10	16	15	21	19	11	5
	Min	10	5	9	10	11	9	9	3
	Max	23	14	20	24	39	82	14	9
TN (µg/L)	Mean	390	335	488	466	573	648	483	358
	Min	280	220	350	320	350	380	350	210
	Max	670	540	690	730	1060	1250	730	680
CHL (µg/L)	Mean	6.8	2.9	7.6	10.1	9.5	10.6	11.4	11.5
	Min	2.4	0.1	5.7	6.1	1.7	2.9	7.6	6.1
	Max	13.6	7.6	9.8	15.0	19.8	33.4	17.1	18.4

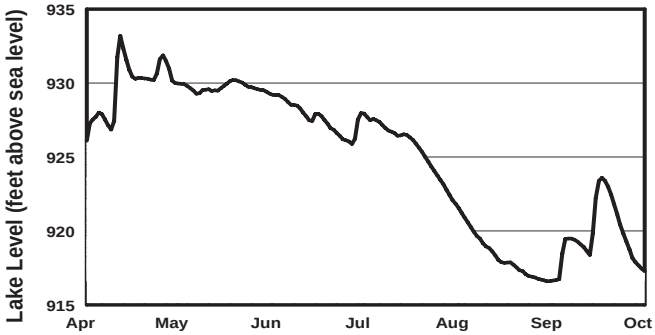
		James River Arm				Kings River Arm		Indian Creek	Roaring River	Long Creek
Tributary Sites		13	11	5	4.5	7	6.5	9	16	8
	# of samples	7	8	4	8	7	7	7	7	8
Secchi	Mean	36	41	66	67	29	47	78	42	57
	Min	23	32	49	48	4	13	33	30	23
	Max	53	66	88	88	63	70	116	54	99
TP (µg/L)	Mean	64	51	25	22	35	28	21	24	29
	Min	36	33	18	13	8	14	13	19	17
	Max	130	142	35	79	195	154	63	36	136
TN (µg/L)	Mean	1028	849	571	759	608	563	589	626	856
	Min	540	410	390	370	430	350	320	380	560
	Max	1730	1740	990	1750	1110	980	910	2240	1810
CHL (µg/L)	Mean	33.6	30.8	15.7	10.5	13.7	14.2	8.5	7.0	12.6
	Min	18.6	12.3	7.4	3.4	4.0	6.5	2.6	0.5	4.3
	Max	48.6	77.8	24.1	22.6	32.2	29.4	32.1	17.2	23.7

Main Lake – 2008 Season

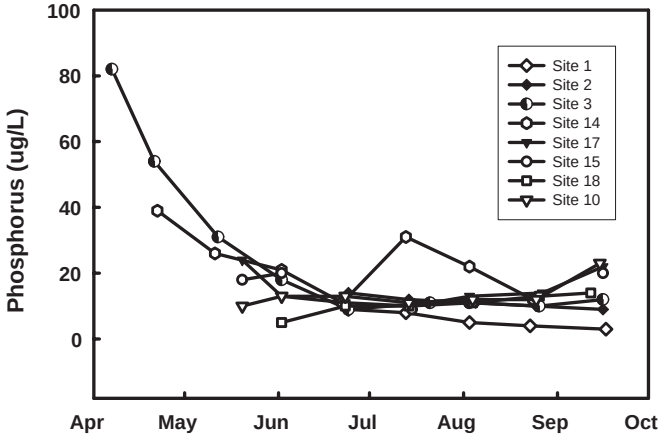
Phosphorus in the Main Lake – The highest phosphorus values measured in 2008 were from samples collected in April at Sites 3 and 14. By mid-May, when sampling started at many of the other main lake sites, phosphorus levels at these two sites had decreased and were comparable to values measured throughout the main lake. Phosphorus levels were similar at all of the sites through August, with the exception of Site 14 which displayed a spike in July. Towards the end of the sample season, phosphorus values were higher at upper lake sites (TP >20 µg/L), moderate in the mid-lake region (10-15 µg/L) and low at the dam (<5 µg/L).

Nitrogen in the Main Lake – The pattern of nitrogen concentrations across the main lake in 2008 was similar to that seen for phosphorus, with the highest values being measured early in the season. Nitrogen levels decreased to normal concentrations more gradually than did phosphorus. This is quite likely due to phosphorus being bound to inorganic suspended solids particles which would settle out of the water column fairly fast. Nitrogen often enters the lake in a dissolved form not tied to particulate matter, so sedimentation is more gradual.

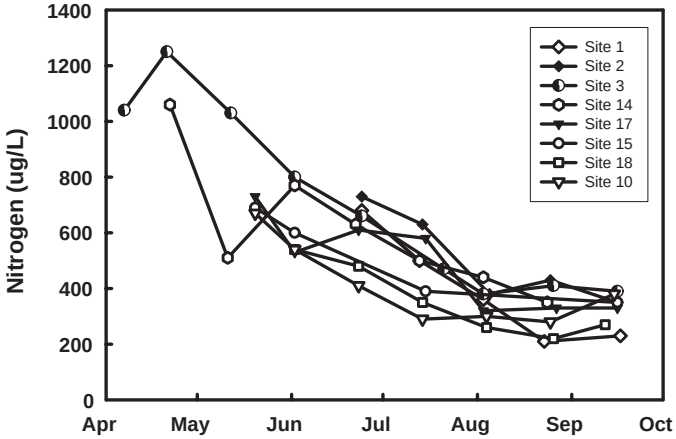
Lake Level at Table Rock Dam



Phosphorus in the Main Lake



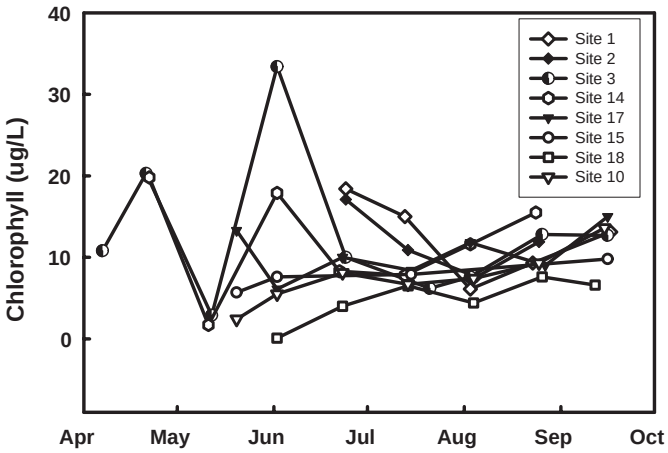
Nitrogen in the Main Lake



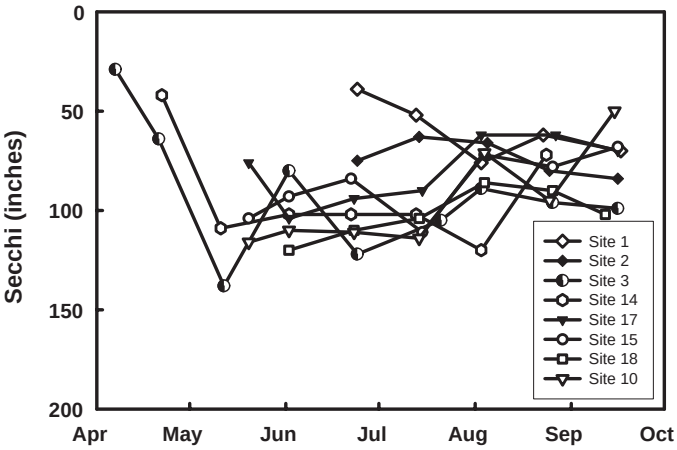
Chlorophyll in the Main Lake – While the two nutrients followed similar patterns across the 2008 sample season in the main lake, algal chlorophyll behaved differently. Some high values were measured during the early part of the season, but there was not a consistent trend towards decreasing values as the season progressed. In fact, maximum chlorophyll values at individual sites occurred in four different months, ranging from April to September. The probable reason for chlorophyll not mimicking the nutrient patterns is turbidity caused by inorganic suspended solids. These materials reduce light penetration into the lake. Without adequate light, algal cells were not able to maximize efficiency in using available nutrients. Light limitation probably kept chlorophyll levels from peaking early in the season when nutrient levels were highest.

Secchi Transparency in the Main Lake – The majority of Secchi readings collected at main lake sites in 2008 ranged between 60 and 120 inches, with no strong pattern across sites. There was a slight trend for decreased Secchi readings at the end of the sample season relative to mid-season. This decrease in clarity can be attributed to the fact that half of the sites did not register maximum chlorophyll values until late summer.

Chlorophyll in the Main Lake



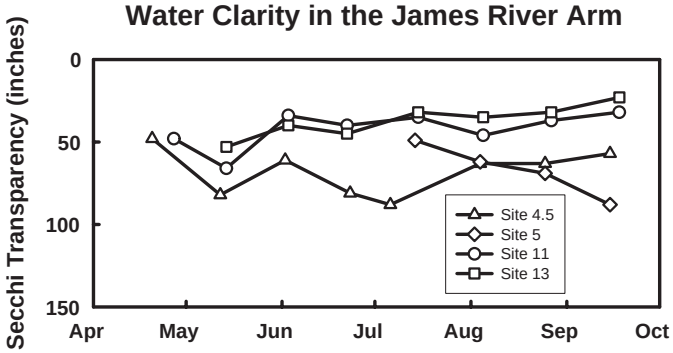
Water Clarity in the Main Lake



James River Arm – 2008 Season

The norm for water quality in the James River Arm is for a longitudinal gradient, with high nutrient and algal chlorophyll levels up-lake that decrease as site location approaches the main lake. Secchi transparency behaves in an opposing fashion relative to chlorophyll; low measurements up-lake with increased readings towards the main channel.

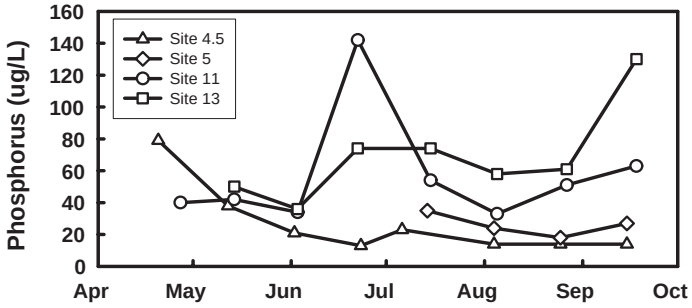
Water Clarity in the James River Arm



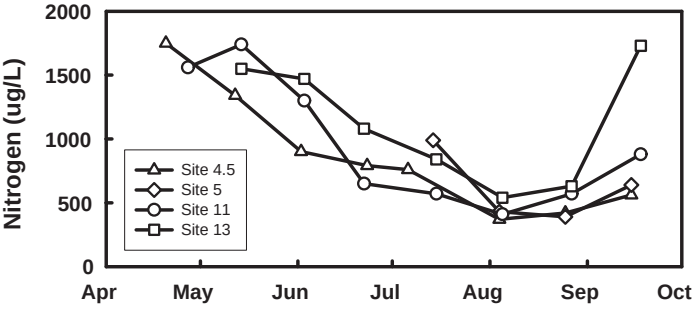
During the first half of the 2008 sample season the expected longitudinal gradient in nutrient concentrations was not identifiable. During late April, Site 4.5 which is located near the main lake channel had twice the phosphorus measured at Site 11 (79 vs. 40µg/L). Site 11 is located approximately 19 miles up-lake from Site 4.5, and generally has 2-4 times the phosphorus concentration observed at Site 4.5 (the other two sites in the James River Arm were not sampled on that first date). During the late June sample period the highest phosphorus concentration was measured at Site 11, with lower phosphorus values occurring both up and down-lake. The 142µg/L phosphorus value at Site 11 was about twice the phosphorus concentration measured up-lake at Site 13. It is most likely that this lack of a predictable longitudinal gradient occurred due to slugs of nutrient-rich water flowing through the arm associated with heavy rain events in the watershed. These slugs could be small enough in size to impact individual sites and not the whole arm on any given sample date. During August and September the predictable gradient in nutrient concentrations returned to the James River Arm.

Average chlorophyll values in the James River Arm for the 2008 sample season display the predictable gradient of maximum chlorophyll concentrations up-lake and decreasing values as site location approaches the main lake. Review of the individual sample dates shows that this longitudinal gradient was not constant through the sample season. On three sample dates the highest chlorophyll readings in the James River Arm were measured at Site 11 and not Site 13, which is the most up-lake site.

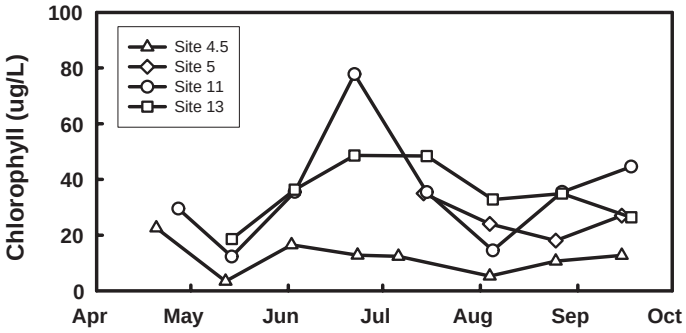
Phosphorus in the James River Arm



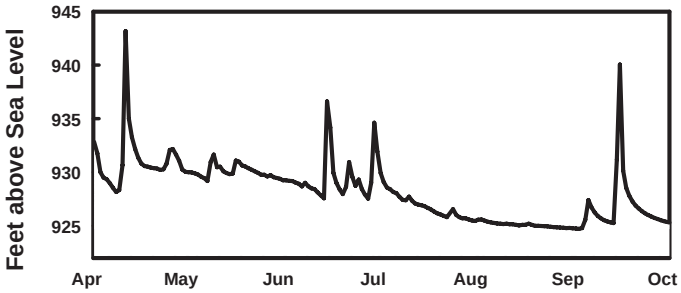
Nitrogen in the James River Arm



Chlorophyll in the James River Arm

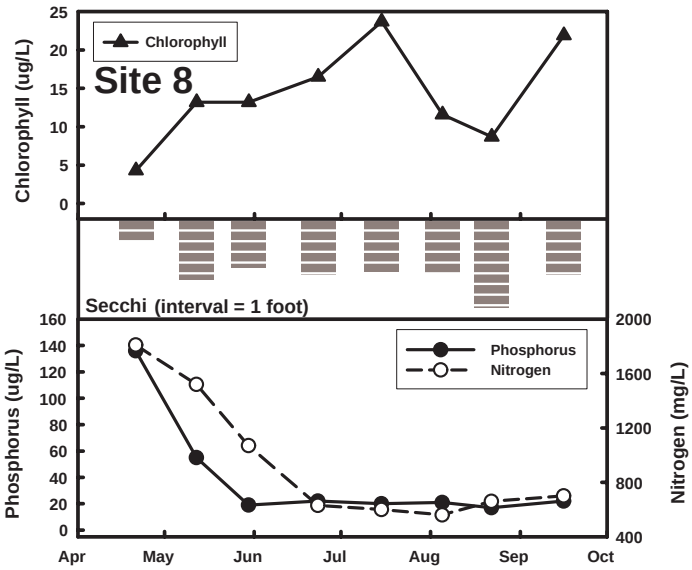


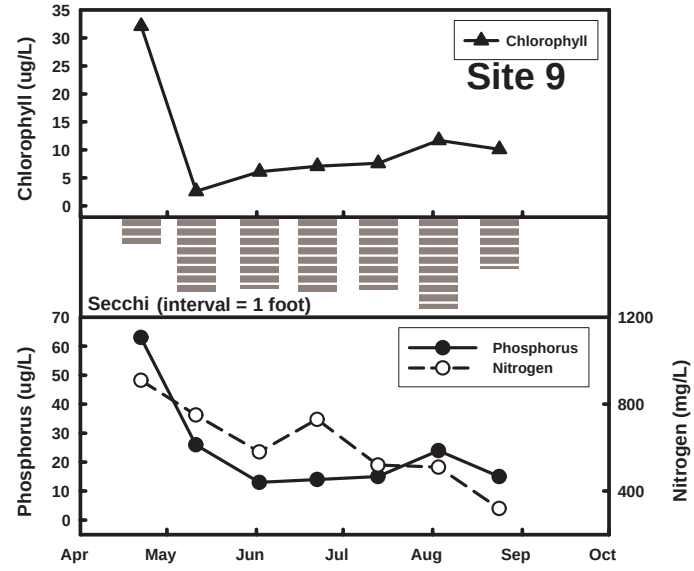
James River Level at Galena



Indian Creek (Site 9) and Long Creek (Site 8) displayed seasonal patterns for phosphorus and nitrogen similar to main lake sites. At both sites the maximum values were measured on the first sample date in late April, followed by a decrease in nutrient levels through May and fairly stable conditions the rest of the sample season. The maximum phosphorus and nitrogen values measured on the first day in Long Creek were about twice the concentration measured in Indian Creek. During the later part of the sample season nutrient levels remained slightly higher in Long Creek relative to Indian Creek.

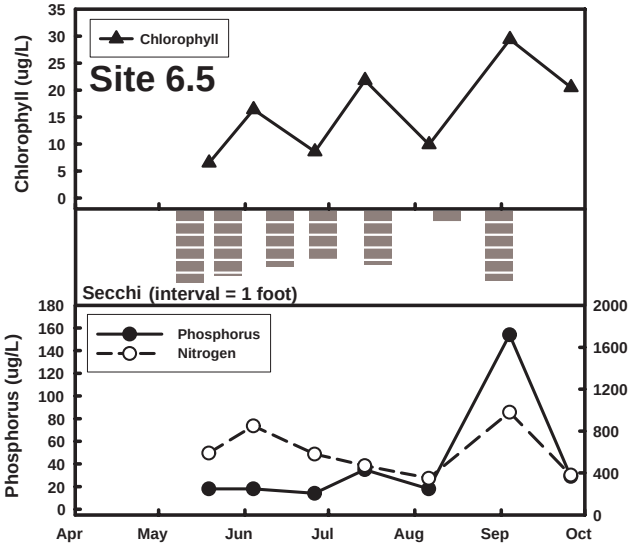
While the nutrients followed similar patterns at Sites 8 and 9, chlorophyll behaved quite differently. At Site 9 in Indian Creek the maximum chlorophyll value was measured on the first sample date, when nutrients were at their highest level. As nutrient concentrations declined and leveled out, so did chlorophyll values. In contrast, the minimum chlorophyll value measured at Site 8 in Long Creek was collected on the first sample date, again when nutrients were at their maximum. The difference in chlorophyll response to nutrients in late April at these two sites suggests that inorganic suspended solids were more prevalent in Long Creek than Indian Creek. Secchi readings support this hypothesis as Indian Creek's Secchi transparency was deeper than Long Creek's, even though chlorophyll levels in Indian Creek were much greater (>7 times those in Long Creek).

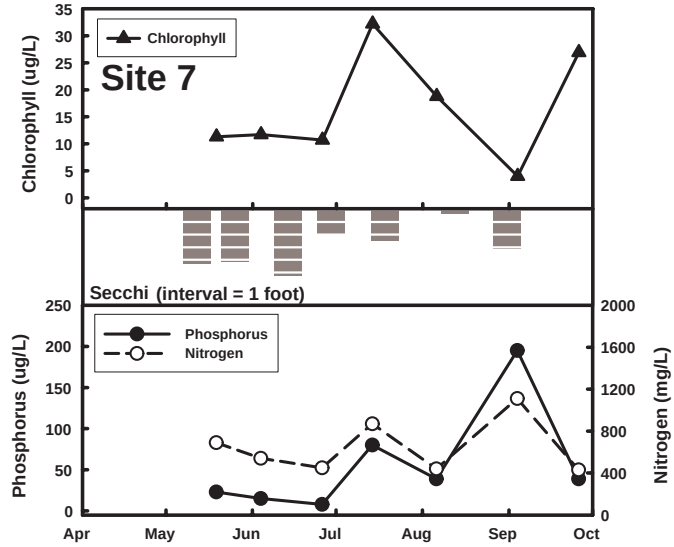




King's River Arm

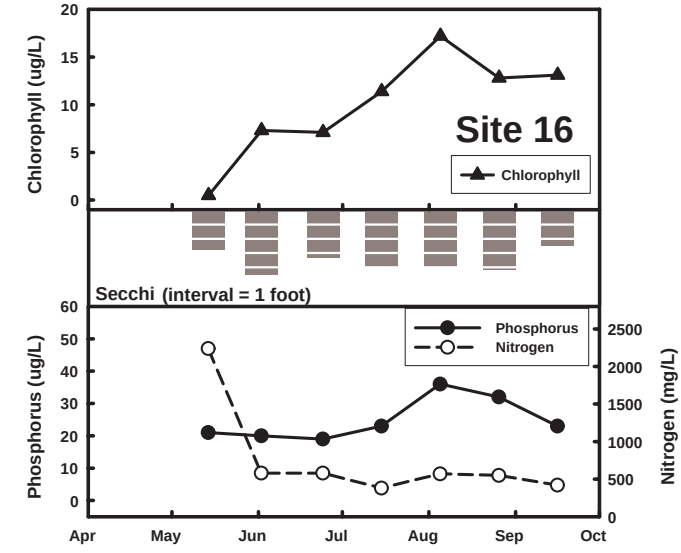
During normal years we find the phosphorus concentration at Site 7 in the Kings River Arm to be about twice that found at Site 6.5. High water levels and turbid inflows during 2008 limited the differences between these two sites. While overall mean phosphorus at site 6.5 was lower than at Site 7 (28 vs. 35 µg/L), there were two sampling occasions when this down-lake site had a higher phosphorus reading than at the up-lake site. Nitrogen and chlorophyll concentrations were, for all intents and purposes, equal at the two sites during the 2008 season. Secchi transparency was slightly deeper at Site 6.5, probably relating to lower levels of inorganic suspended solids (soil material) and not in differences in algal biomass.





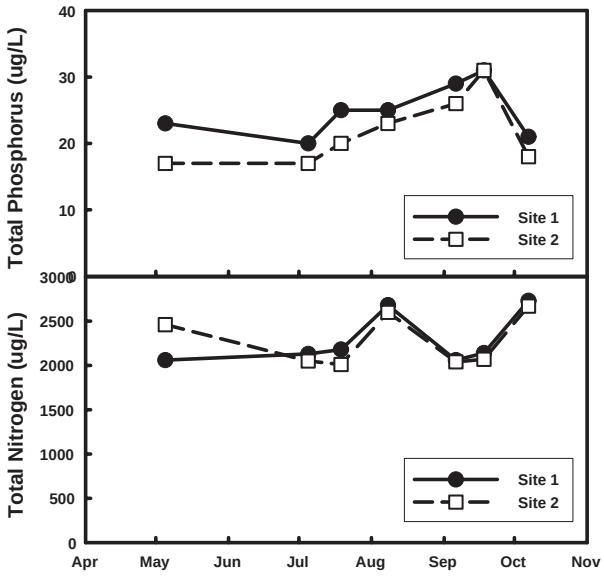
Roaring River

Site 16 in the Roaring River Arm was somewhat different from many of the other tributary sites in that the maximum phosphorus concentration measured during 2008 did not represent a substantial peak above the remainder of the data. The first sample collection occurred mid-May, so any peaks that occurred in April (when maximum phosphorus values were measured at some sites) were missed. Nitrogen on the other hand was at its maximum on the first sample date, with a value that was about four times that of the other measurements collected from this site. Algal chlorophyll was at a minimum on the first sample date, with a trend towards increasing values as the season went on.



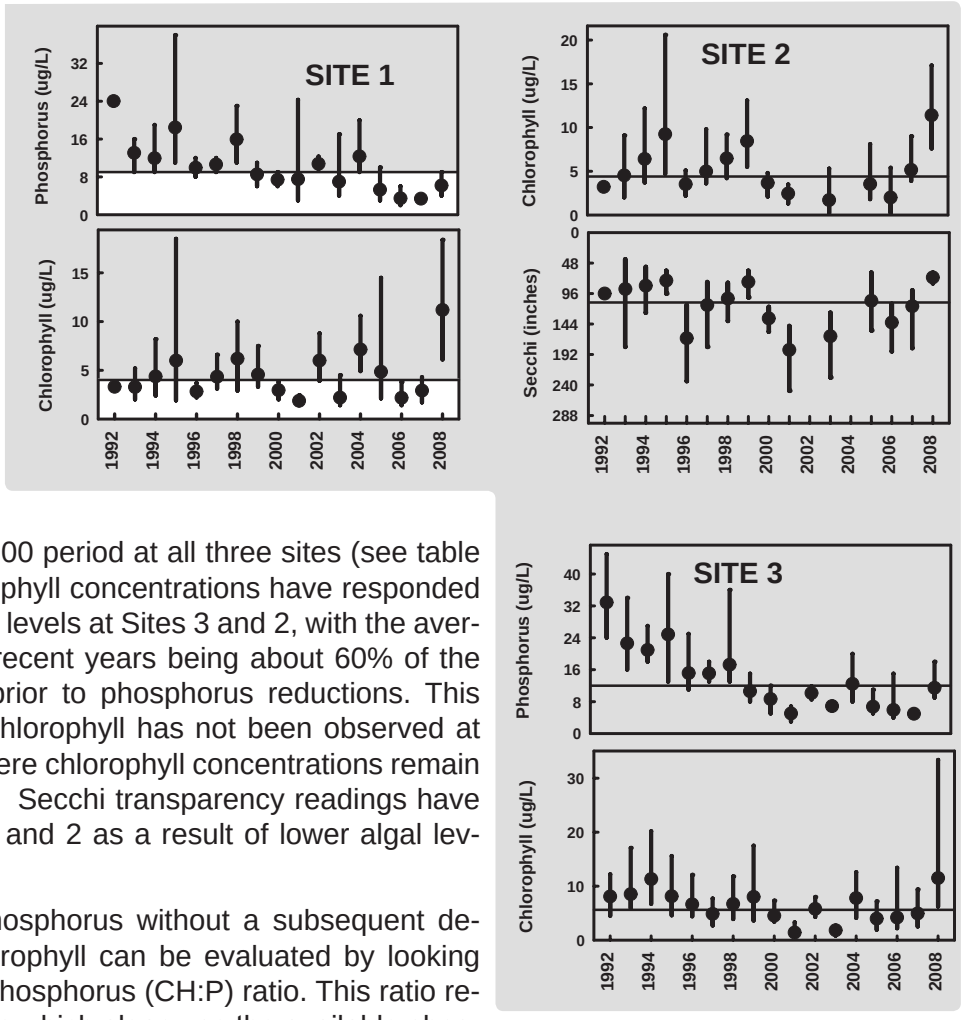
Roaring River was monitored at two stream sites, located approximately 1 and 2.5 miles upstream from the Highway 86 bridge. These sites were sampled on the same days, seven times May through October. Site 2 consistently had less phosphorus than Site 1, but the differences were minor (≈3µg/L). Nitrogen also tended to be slightly lower at Site 2 compared to Site 1, with the exception of the first sample date when nitrogen concentrations at Site 2 were about 25% higher. These data, along with those collected in 2007, indicate that water quality does not differ between the two Roaring River sites.

Phosphorus concentrations at the two sites were generally within the expected range for an Ozark stream. In contrast, nitrogen levels were extremely high with both sites averaging almost 2300µg/L nitrogen. Some of the nitrogen may be attributed to ground water inputs into the stream. Sample collections in 2004 and 2005 from Flat Creek also indicated high nitrogen levels, with the maximum values coming from an upstream site located near a spring. Another potential source of nitrogen impacting the Roaring River sites is the trout hatchery located upstream.



An interesting note is that the phosphorus values at Site 16 on Table Rock Lake (located in the Roaring River Arm) are comparable to those readings collected from the inflowing river (≈24µg/L), while nitrogen values tend to be about 25% of those measured in the inflowing river. The exception was on May 14, the first sample of the season, when nitrogen concentrations at Site 16 were 2240µg/L – a value very comparable to those measured up-river. Looking back at previously collected data from Site 16, it is common for samples collected early in the sample season to have elevated nitrogen levels (sometime the first two samples are elevated if monitoring started early enough). It is quite likely that during the early part of the season, the lake at Site 16 is still mixing and inputs coming in via the Roaring River impact surface waters where LMVP samples are collected. Sometime in May, the lake thermally stratifies at this site and inputs probably enter the lake as a sub-surface inflow, not being measured by the surface sample.

Sites 1, 2 & 3



The most obvious long-term trend in the lower main lake channel (confluence of James River to Table Rock Dam) is a decline in phosphorus concentrations. Average summertime phosphorus values for the period 2001-2008 are 50% of the averages from the 1993-2000 period at all three sites (see table below). Algal chlorophyll concentrations have responded to lower phosphorus levels at Sites 3 and 2, with the average chlorophyll for recent years being about 60% of the chlorophyll values prior to phosphorus reductions. This response of lower chlorophyll has not been observed at the dam (Site 1), where chlorophyll concentrations remain virtually unchanged. Secchi transparency readings have improved at Sites 3 and 2 as a result of lower algal levels.

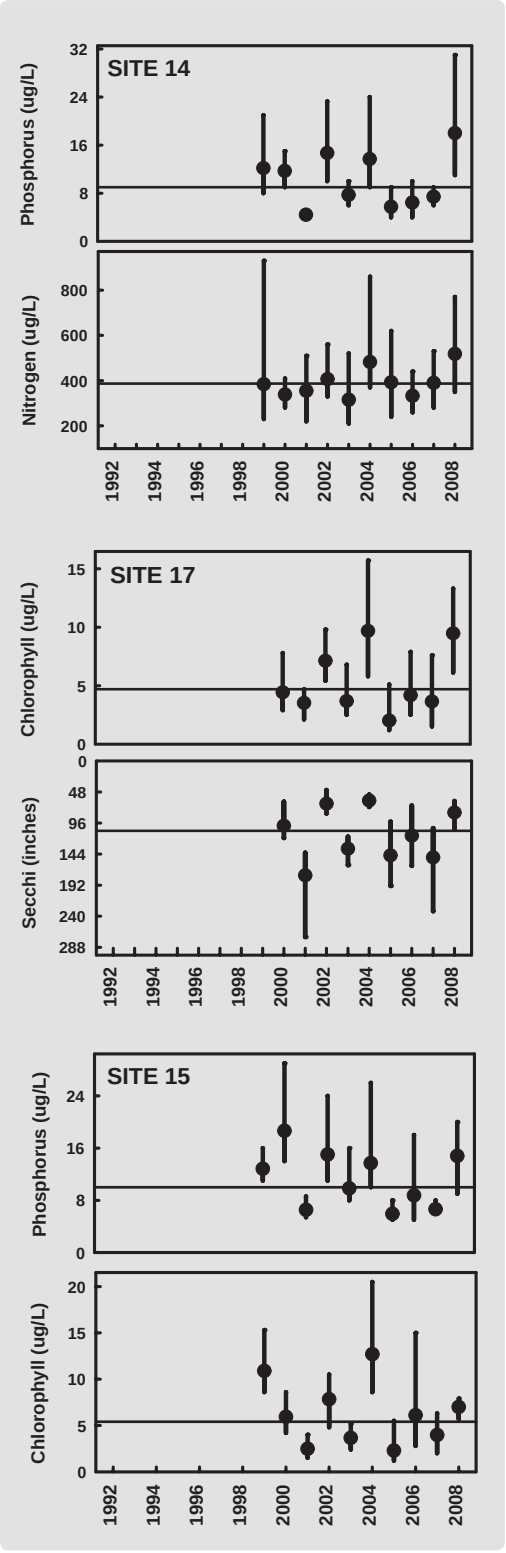
The decrease in phosphorus without a subsequent decrease in algal chlorophyll can be evaluated by looking at the chlorophyll : phosphorus (CH:P) ratio. This ratio reflects the efficiency in which algae use the available phosphorus, with a higher ratio indicating greater efficiency. Increases in CH:P ratios at Sites 3 and 2 have been fairly small, while the increase at Site 1 has been close to a doubling (.36 to .66 µg/L of chlorophyll per µg/L phosphorus). Some of the factors that could influence this increase in efficiency would include improvements in the light environment, decreased grazing by zooplankton, and shifts in the species that make up the algal community (algal species vary in both their nutrient requirements as well as the amount of chlorophyll they contain).

	Site 3		Site 2		Site 1	
	1993-2000	2001-2008	1993-2000	2001-2008	1993-2000	2001-2008
Phosphorus	16	7	14	7	12	6
Nitrogen	417	409	377	396	349	363
Chlorophyll	7.0	4.3	5.6	3.4	4.2	4.0
Secchi	83	127	102	125	131	123
N:P Ratio	26	55	27	59	30	60
CH:P Ratio	.44	.57	.40	.52	.36	.66

Sites 15, 17 & 14

Three sites are located in the main lake between the confluence with the Kings River Arm and the confluence with the James River Arm. These sites have been monitored for nine (Site 17) or ten (Sites 15 and 14) years, meaning the long-term data does not extend as far back for these sites as it does for others.

Review of the stick plots does not suggest long-term changes in any of the water quality parameters at any of the sites in this middle region of the main lake channel. The range of annual geometric mean values for all water quality parameters are extremely comparable at all three sites, indicating no real spatial difference in water quality among these sites.



Long Term Trends - Upper Main Channel and Kings River

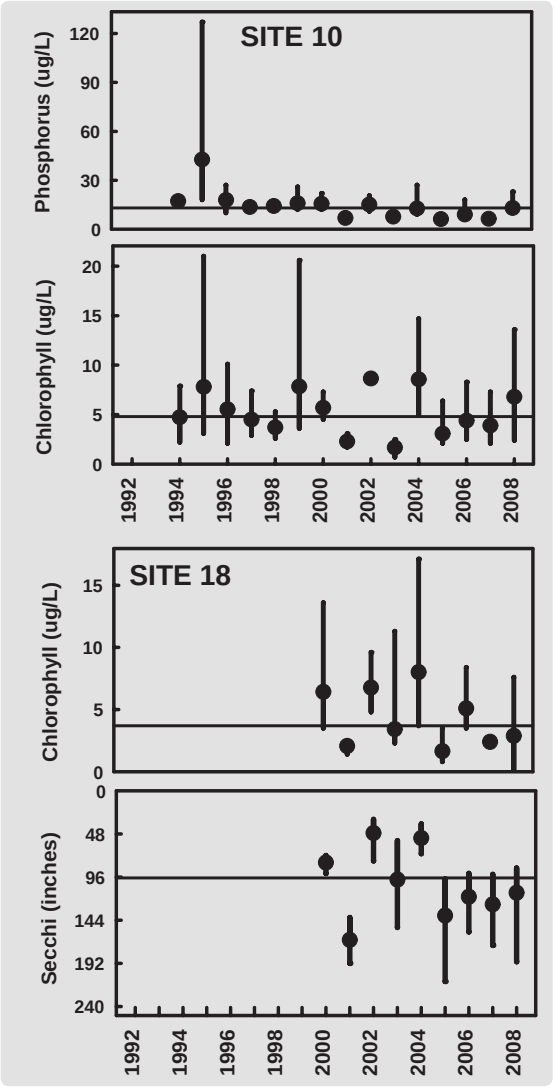
Sites 10 & 18

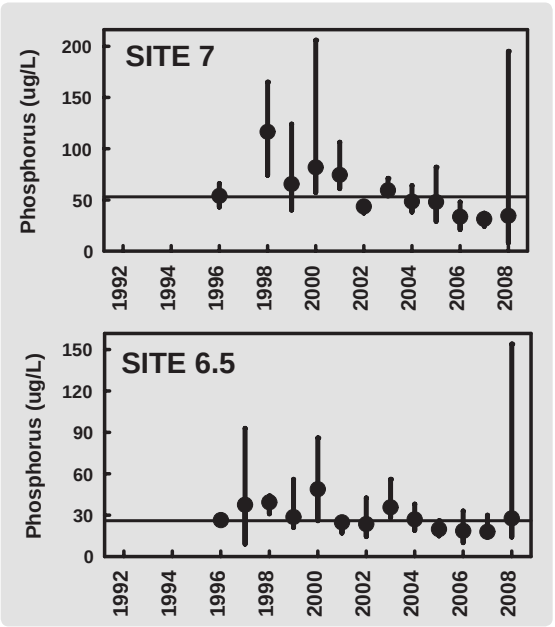
Two sites are located up-lake from the confluence of the main lake with the Kings River Arm. Neither site displays trends for changing nitrogen, chlorophyll or Secchi transparency over time. Phosphorus at Site 10 does seem to have decreased over time. The overall average for 1994-2000 was 16µg/L, while the average for 2001-2008 was only 8µg/L (Note that data from 1995 and 2002 were excluded from this analysis – 1995 represents an anomaly as two of the three measured values were higher than any other value measured at this site, -2002 was excluded because there were only two samples collected during the summer). This trend is not evident at Site 18 (or any of the mid-lake main channel sites) because these sites have not been sampled for as many years. Excluding 1995 data from Site 10 (when extremely high nutrient concentrations were measured), the two sites have very similar water quality when comparing the range of annual geometric mean values.

Sites 7 and 6.5

There is a trend towards lower phosphorus concentrations at Site 7 in the Kings River Arm. The geometric mean value for 1996-2001 was 73µg/L, while the period 2002-2008 averages 41µg/L. During the later period the variability within individual years tended to be fairly small, with the exception of 2008 when the high water led to the most variability in phosphorus levels measured at this site. There does not seem to be any changes occurring in nitrogen or chlorophyll levels, nor Secchi transparency at Site 7.

Site 6.5, down-lake from Site 7, displayed a much smaller change in phosphorus concentrations since 1996. The overall mean phosphorus value for 1996-2001 was 31µg/L compared to an average of 24µg/L for 2002-2008. Again, there did not seem to be any long-term trends for nitrogen, chlorophyll or Secchi transparency at this site.





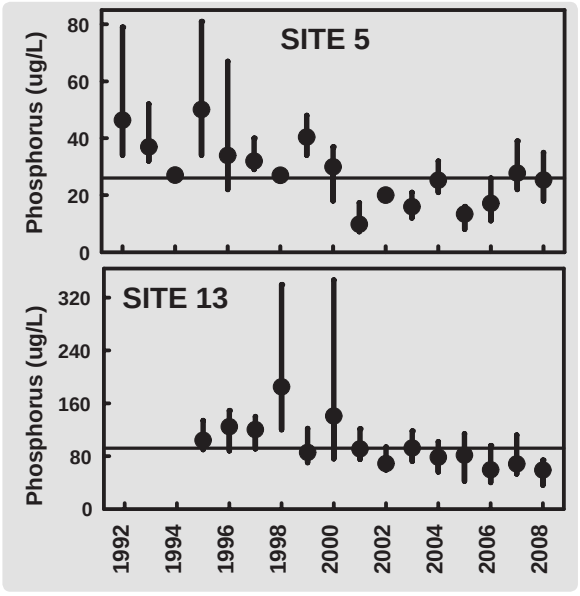
Sites 13, 11, 5 & 4.5

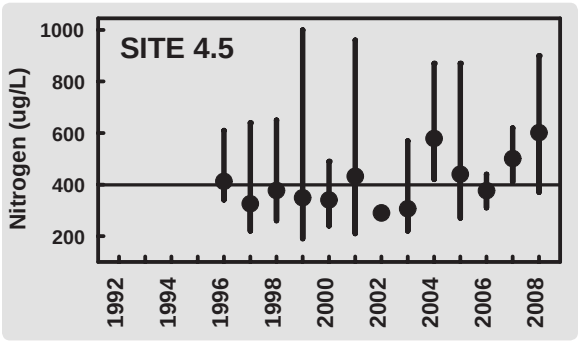
Phosphorus values have decreased at all four James River Arm sites since 2001, when Springfield's Southwest Sewage Treatment Plant started meeting regulated phosphorus release limits. The decline in phosphorus has varied from site to site, with mean phosphorus levels since 2001 being between 50-76% of previous phosphorus levels (see table below).

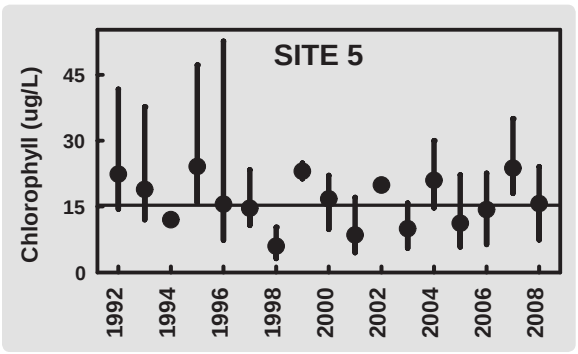
Nitrogen levels have not changed in the upper James River Arm (Sites 11 and 13), with mean nitrogen values pre- and post-2001 being virtually the same. In the lower James River Arm (Site 4.5 and 5) the mean nitrogen values post-2001 have been about 100µg/L higher than the means from prior-2001. There is quite a bit of overlap in the nitrogen data, so it is difficult to know if there is an actual trend in nitrogen levels at these two sites.

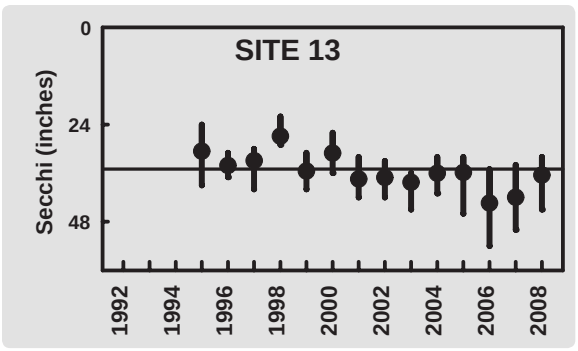
Algal chlorophyll has not mimicked the decline in phosphorus concentrations within the James River Arm, with any difference between pre- and post 2001 values being minimal. The lack of response of algal chlorophyll in the upper and middle James River Arm is not surprising because the ratios of nitrogen to phosphorus prior to 2001 were low enough to suggest that phosphorus was in excess relative to nitrogen. One change that has occurred is that maximum measured chlorophyll values at Site 5 do not seem to be as extreme since 2001. The same trend does not hold true for Sites 11 and 4.5, located up and down-lake from Site 5, respectively.

Phosphorus In the James River		
	=>2000	2001=>
Site 13	118	73
Site 11	49	38
Site 5	36	18
Site 4.5	14	9









Sites 8, 9 and 16

None of these tributary sites display obvious trends in changing water quality like those seen for phosphorus in the James River Arm. There are, however, some interesting patterns that could be indicative of trends. With continued monitoring time will tell.

Site 8 - There may be a slight trend for increased chlorophyll at Site 8 in the Long Creek Arm. The three highest summer geometric mean values have been measured since 2002, though these do not represent a substantial increase in chlorophyll. The overall average value for 1992-2001 was 5.4µg/L compared to an average of 8.6µg/L for the period since 2002. If algal chlorophyll has increased it has not been associated with any increases in nutrients. The chlorophyll:phosphorus ratios have increased with the slightly higher chlorophyll levels. This could indicate a better light environment associated with lower inorganic suspended solids levels, less grazing, or a shift in the algal community.

Site 9 – The four lowest summer geometric mean phosphorus values have been recorded during the last eight years. All of these values were <8µg/L, compared to an overall average phosphorus value of 16µg/L for the eight years previous 2001. Between these four "low" years the phosphorus levels have been normal, averaging 15µg/L.

Site 16 – Summer Secchi means during 2000-2003 were all >54 inches. During the last five years the Secchi means have been shallower (40-49 inches). This could be a trend but the differences are small enough to limit detection. The chlorophyll levels during the recent years have been lower, which should translate to deeper Secchi readings. Again the differences are small enough to hinder trend detection.