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Memo

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May 8, 2007

To: Bill Immich, City of Plymouth

From: Steve Grumann, Earth Tech

Subject: **Mill Pond Baseline Water Quality Assessment Technical Memorandum**

This technical memorandum summarizes the results of the baseline water quality sampling completed by Earth Tech during the summer and fall of 2006, at the Mill Pond located in Plymouth, Wisconsin. Components of the water quality sampling conducted by Earth Tech included field measurements (temperature, pH, dissolved oxygen, conductivity and water transparency) and laboratory analysis (total phosphorus and chlorophyll-*a*).

SAMPLING METHODOLOGY

Water samples were collected by Earth Tech during four sampling events (June, July, August, and October) at two locations in Mill pond and two locations on Mullet River (Figure 1, Attachment A). Sample containers used were shipped in a sealed cooler from the State Hygienic Lab in Madison, WI to the Earth Tech office in Sheboygan, WI. Water samples were collected according to the Wisconsin Department of Natural Resources (WDNR) collection protocols with the following activities.

- Prior to arriving at the site, all field measurement equipment was examined to verify that it was in good operating condition. The sampling equipment was washed with an aqueous cleaner, using elevated temperature and pressure as appropriate. In the field, after each use, the sampling equipment was rinsed well with sample water before readings were taken.

- Sample preservatives and containers were prepared and used as necessary to comply with United States Environmental Protection Agency (USEPA) requirements for the analytes of interest.

- Sample labels were completed at the time of sample collection, noting the site identification, sample location, sample interval (as appropriate), preservative, sample analysis, and sample date.

- For each sample collected, the applicable sampling procedure was recorded in the field notes or on a Sampling Data Sheet. Laboratory chain-of-custody documentation and procedures were followed.

A small water craft was used by two Earth Tech employees to the Sample Stations 2 and 3 to obtain water samples in Mill Pond. While at the stations, sample containers were gently submerged into the water and allowed to fill. Preservation of the appropriate samples was done immediately after collection. Water quality field parameter measurements were taken at each

sample station after all water samples were acquired. GPS coordinates of each location were collected and recorded using a hand-held GPS unit (Trimble GeoXT™).

Water samples from Stations 1 and 4 were obtained by an Earth Tech employee who waded into the Mullet River. The employee gently waded from downstream working upstream to minimize disturbance of the sediments. Once in the thalweg of the stream, water samples were collected by submerging the sample containers until full. Preservation of the appropriate samples was done immediately after collection. Water quality field parameter measurements were taken at each sample station after all water samples were acquired. GPS coordinates were collected at each station.

All samples were shipped on ice in a sealed cooler to the State Hygienic Lab for chemical analysis following appropriate chain-of-custody procedures.

RESULTS

Table 1, in Attachment B, presents the water quality sample results for the four Stations for each of the four sample events. Charts 1 through 4 in Attachment C show the trends for temperature, pH, dissolved oxygen, and conductivity, respectively, through the sampling period. Temperature, dissolved oxygen, pH and conductivity values were within the normal range for inland lakes and impoundments.

Secchi disc readings could only be measured at Station 3, because the secchi disc was visible all the way down to the substrate at Stations 1, 2, and 4. Chart 5 shows the measurements for secchi disk readings at Station 3 through the sampling period. The water was less clear in July and August, which is typical for lakes in Wisconsin. In late summer, more algae and plankton are suspended in the water column because the nutrient levels are higher in mid to late summer.

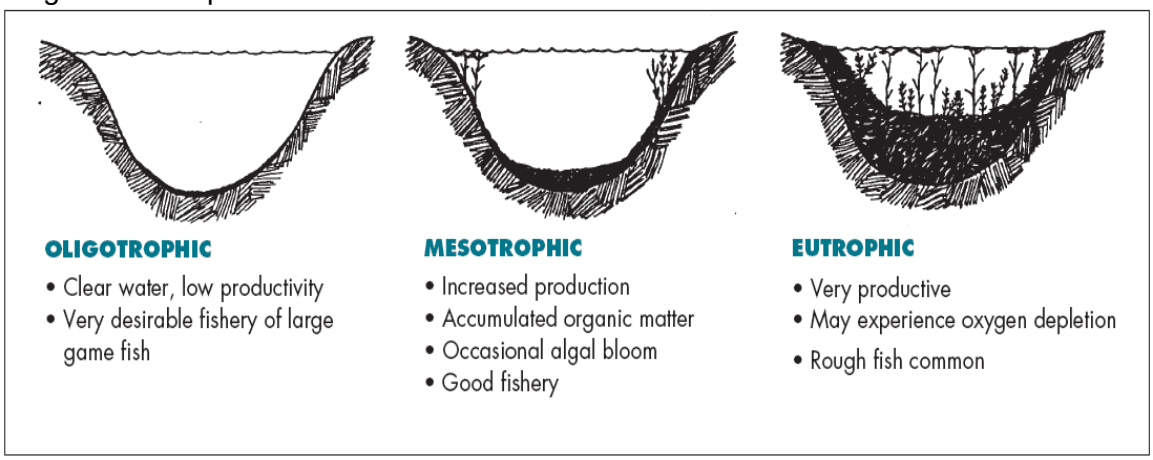
Chart 6 shows the trend for total phosphorus through the sampling period. Total phosphorus levels peaked in July at all stations and were higher at Stations 2, 3, and 4 than Station 1. Total phosphorus and chlorophyll-*a* levels were considerably higher at Stations 2, 3, and 4 than at Station 1, the upstream station. This result indicates that a considerable amount of phosphorus is entering Mill Pond from the area directly adjacent to pond rather than from upstream.

Chart 7 shows the trend for chlorophyll-*a* through the sampling period. Chlorophyll-*a* levels were lowest at all stations in June, but increased considerably at all but Station 1 as the summer progressed. The additional input of phosphorus is a likely cause of the increase in chlorophyll-*a*, a measure of plant productivity.

Trophic status index

Trophic State Index (TSI) is a measurement for characterizing a lake's trophic state. The term "trophic status" refers to the level of productivity in a lake. Productivity refers to the amount of nutrients, plant, and fish biomass. Productivity and trophic state of lakes are typically classified into three categories: oligotrophic, mesotrophic and eutrophic, and are described and illustrated in Diagram A below.

Diagram A. Trophic States of Lakes



Source: University of Wisconsin Extension, Understanding Lake Data

Carlson's Trophic State Index (TSI) is one means available to examine the relationship between total phosphorus, chlorophyll-*a*, and secchi disk readings in a lake, and its overall productivity. The WDNR has modified Carlson's equations to form a Wisconsin Trophic Status Index (WSTI) to better suit lakes in Wisconsin. Individual WTSI values for this study were calculated from the following WTSI equations:

$$\text{Secchi: } WSTI_{SD} = 60 - (14.4 \ln SD),$$

$$\text{Total P: } WSTI_{P} = 28.2 + (7.73 \ln TP), \text{ and}$$

$$\text{Chlorophyll a: } WSTI_{CHL} = 34.8 + (7.56 \ln CHL),$$

where SD = secchi depth in meters, TP = total phosphorus in parts per billion (ppb), and CHL = chlorophyll-*a* in ppb.

The WTSI results are presented in Table 2 in Attachment B. Chart 8 presents the trends for WTSI through the sampling period. According to WDNR, the WTSI values for the four stations were typical for eutrophic lakes, except for the chlorophyll-*a* at Station 1, which was typical for a mesotrophic lake. Based on these measurements, Mill Pond should be considered a eutrophic system, meaning that it is very nutrient rich, containing abundant organic matter. The relationship among chlorophyll-*a* and total phosphorus WTSI's in 2006 suggests that there is a high volume of algal biomass within the downstream end of the pond, with some limiting factor in the upstream end of the pond, such as the current of the river or nitrogen levels in the water.

CONCLUSIONS

Baseline water quality results suggest that Mill Pond is a eutrophic system, receiving concentrations of phosphorus that is degrading its water quality. Phosphorus entering the Mill

Pond from both the watershed of the Mullet River and from the adjacent landscape are likely to promoting the high density of macrophytes in the pond and the algal blooms the occur in the summer. Limiting the phosphorus entering the pond should positively affect the aquatic health and aesthetics of Mill Pond.

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ATTACHMENT A – FIGURES

FIGURE 1 – WATER QUALITY SAMPLING LOCATIONS

Source: USDA WI Farm Agency NAIP 2005, Earth Tech 2006

Spatial Reference: GCS_North_American_1983

Figure 1 - Water Quality Sampling Locations, 2006

Mill Pond Project
City of Plymouth
Sheboygan County, Wisconsin

December 8, 2006

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ATTACHMENT B – TABLES

TABLE 1 – WATER QUALITY RESULTS SUMMARY

TABLE 2 – TROPHIC STATUS INDEX (TSI) RESULTS SUMMARY

Table 1

Water Quality Results Summary
Mill Pond
Plymouth, Wisconsin

Station	Date	Parameters						
		Temp (C)	pH	DO (mg/L)	Cond. (µmhos/cm)	Secchi (m) *	Total P (µg/L)	Chl a (µg/L)
Upstream (Station 1)	6/26/06	18.8	8.5	12.3	696	NA	64	3.89
	7/25/06	20.6	8.3	9.5	681	NA	86	4.32
	8/23/06	16.8	7.8	8.7	719	NA	61	2.54
	10/12/06	6.9	6.9	8.3	705	NA	44	1.44
Pedestrian Bridge (Station 2)	6/26/06	20.2	8.4	8.5	704	NA	78	5.74
	7/25/06	22.6	7.3	6.6	717	NA	123	6.45
	8/23/06	18.6	7.6	5.6	731	NA	98	14.6
	10/12/06	7.1	6.8	8.3	697	NA	49	27
Deep spot Mill Pond (Station 3)	6/26/06	20.3	8.1	6.5	683	1.07	94	10.9
	7/25/06	25	7.5	5.9	743	0.52	141	124
	8/23/06	22.7	7.2	4.6	766	0.61	93	32.2
	10/12/06	6.9	6.8	8.1	657	0.91	50	28.5
Downstream (Station 4)	6/26/06	20.2	8.1	7.2	682	NA	88	8.58
	7/25/06	25.9	8.3	7.9	698	NA	127	57.2
	8/23/06	22.6	7.5	6.5	737	NA	120	42.5
	10/12/06	6.5	6.8	8.1	658	NA	53	60.3

Notes:
* Secchi disc visibility reached the sediment at Stations 1, 2, and 4.

Table 2

Trophic Status Index (TSI) Results Summary
Mill Pond
Plymouth, Wisconsin

Site	Date	Secchi Disk TSI [1]	Total Phosphorus TSI	Chlorophyll-*a* TSI
Station 1 (Upstream)	6/26/06	*NA*	*60.3*	*45.1*
	7/25/06	*NA*	*62.6*	*45.9*
	8/23/06	*NA*	*60.0*	*41.8*
	10/12/06	*NA*	*57.5*	*37.6*
	Average	*NA*	*60.1*	*42.6*
Station 2 (Pedestrian Bridge)	6/26/06	*NA*	*61.9*	*48.0*
	7/25/06	*NA*	*65.4*	*48.9*
	8/23/06	*NA*	*63.6*	*55.1*
	10/12/06	*NA*	*58.3*	*59.7*
	Average	*NA*	*62.3*	*52.9*
Station 3 (Deep spot)	6/26/06	*59.0*	*63.3*	*52.9*
	7/25/06	*69.4*	*66.5*	*71.2*
	8/23/06	*67.1*	*63.2*	*61.0*
	10/12/06	*61.4*	*58.4*	*60.1*
	Average	*64.2*	*62.8*	*61.3*
Station 4 (Downstream)	6/26/06	*NA*	*62.8*	*51.0*
	7/25/06	*NA*	*65.6*	*65.4*
	8/23/06	*NA*	*65.2*	*63.1*
	10/12/06	*NA*	*58.9*	*65.8*
	Average	*NA*	*63.1*	*61.3*

Notes:
[1] = Secchi disk readings not available for Stations 1, 2, and 4 because the disk was visible to the bottom of the pond at these locations.

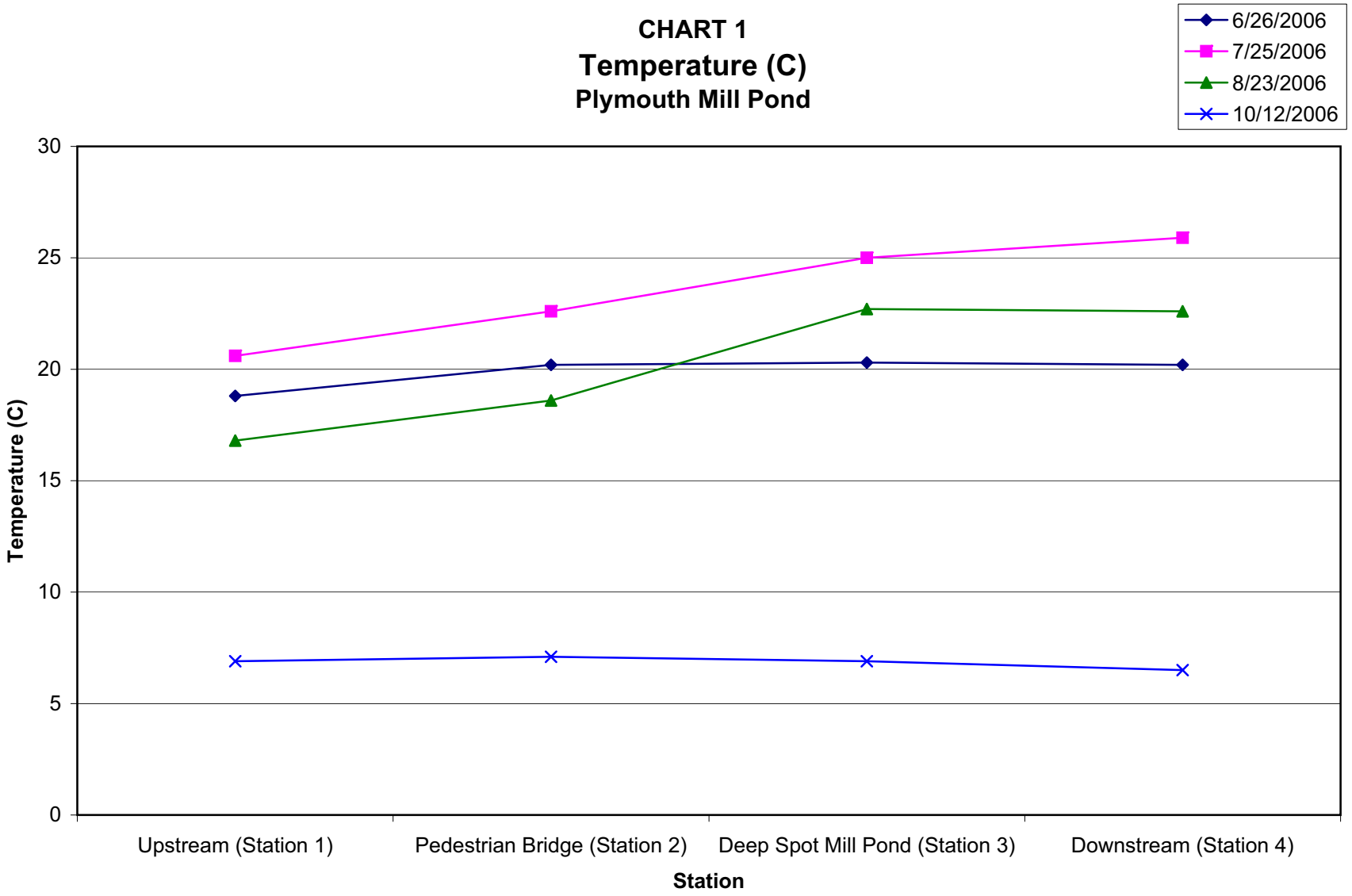
ATTACHMENT C – CHARTS

CHART 1 – TEMPERATURE TRENDS
CHART 2 – Ph TRENDS
CHART 3 – DISSOLVED OXYGEN TRENDS
CHART 4 – CONDUCTIVITY TRENDS
CHART 5 – SECCHI DISC READING TRENDS
CHART 6 – TOTAL PHOSPHORUS TRENDS
CHART 7 – CHLOROPHYLL-*a* TRENDS
CHART 8 – WTSI TRENDS

CHART 1

Temperature (C)

Plymouth Mill Pond



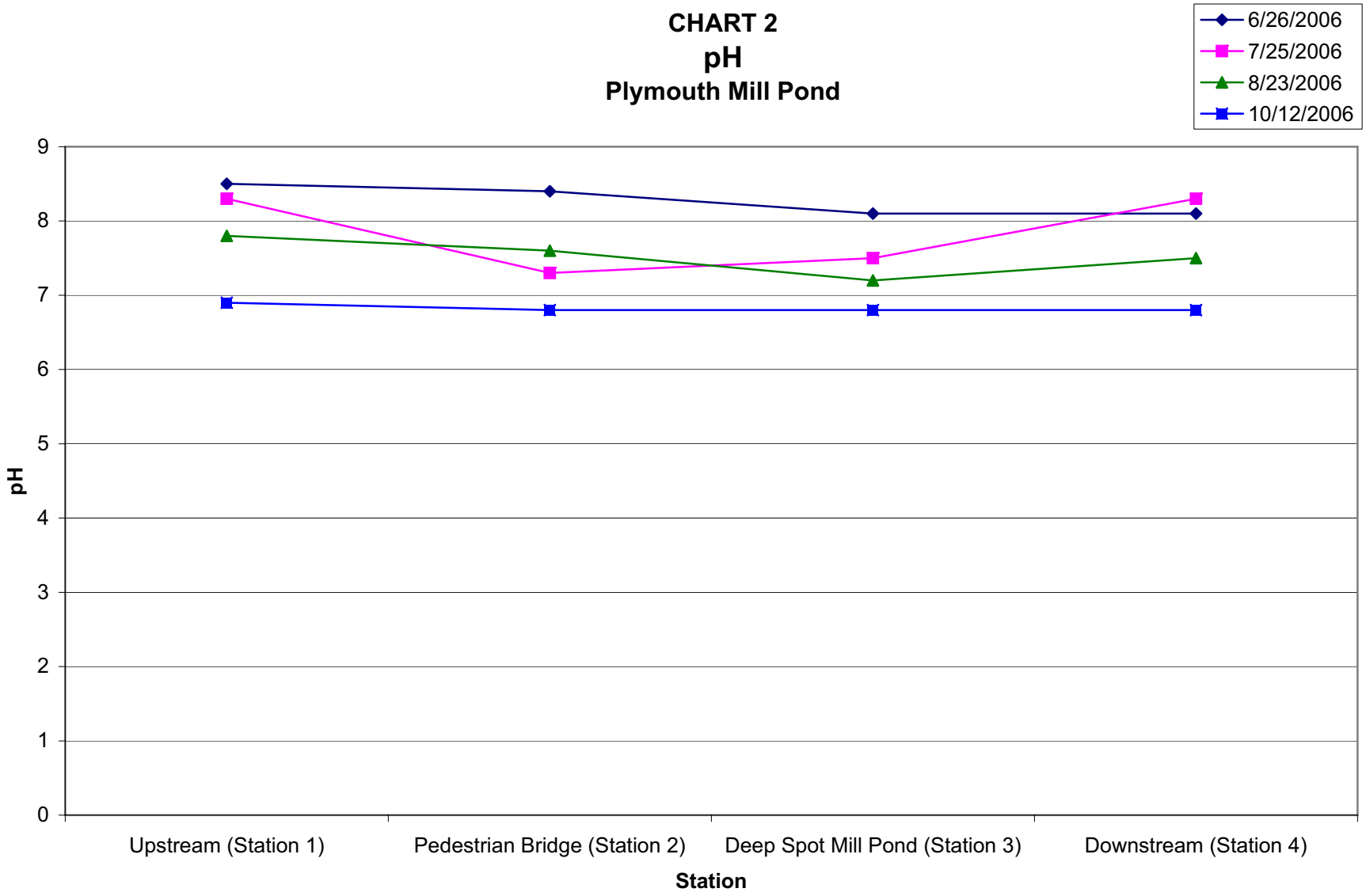


CHART 2
pH
Plymouth Mill Pond
6/26/2006
7/25/2006
8/23/2006
10/12/2006
9
8
7
6
5
4
3
2
1
0
pH
Upstream (Station 1)
Pedestrian Bridge (Station 2)
Deep Spot Mill Pond (Station 3)
Downstream (Station 4)
Station

CHART 3

Dissolved Oxygen (mg/L)

Plymouth Mill Pond

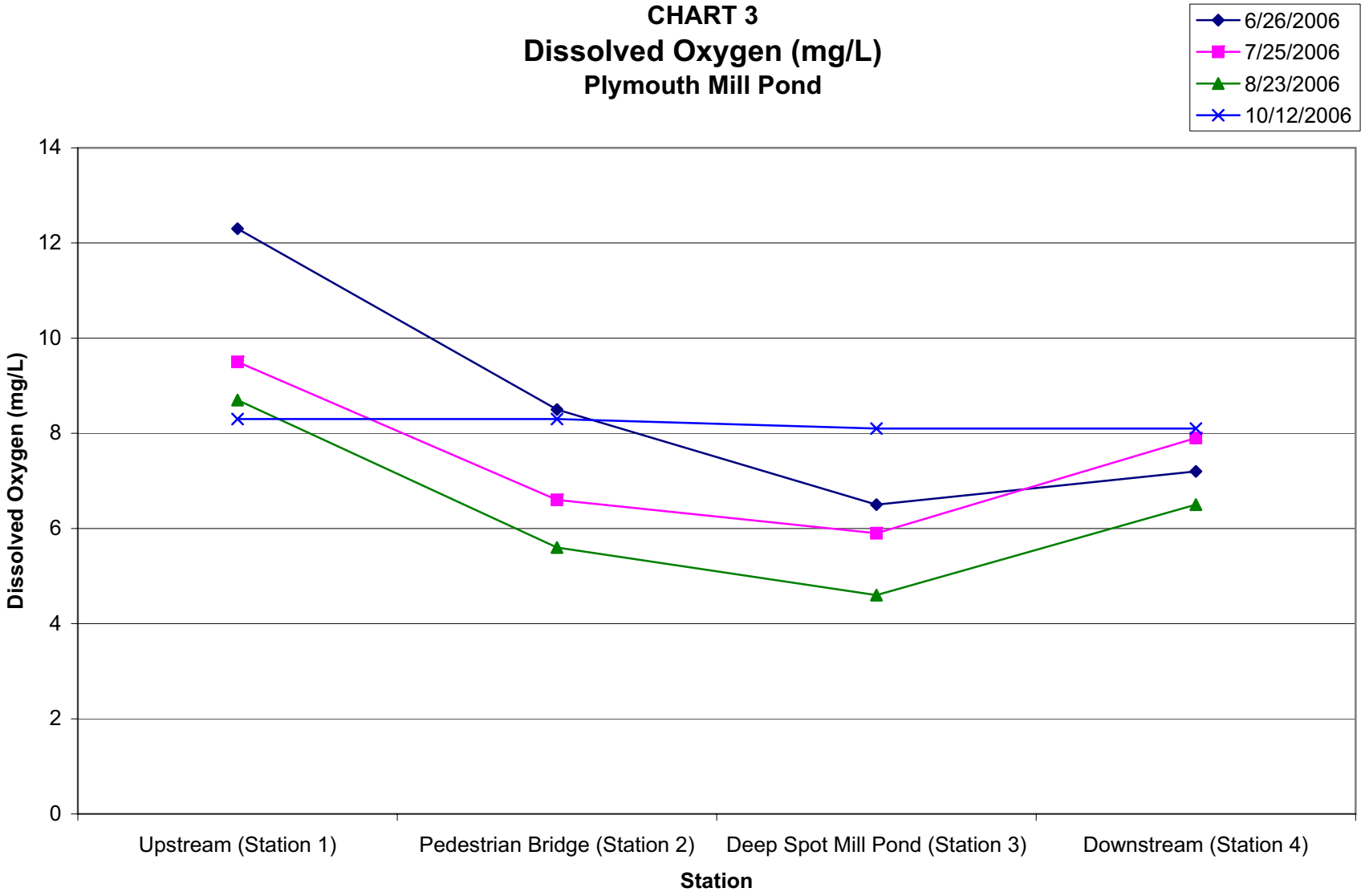


CHART 4

Conductivity (µmhos/cm)

Plymouth Mill Pond

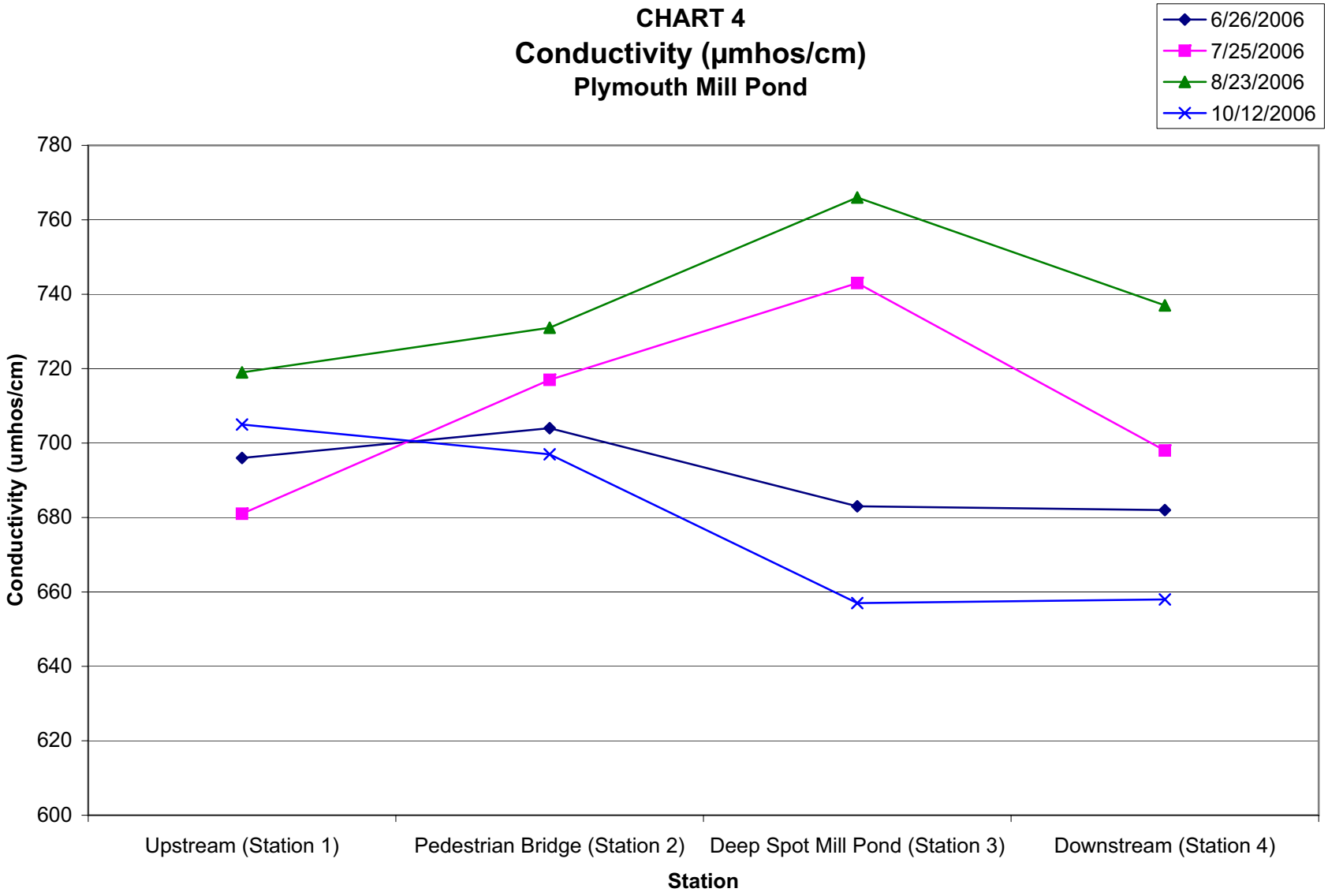


CHART 5

Secchi Depth (m)

Plymouth Mill Pond

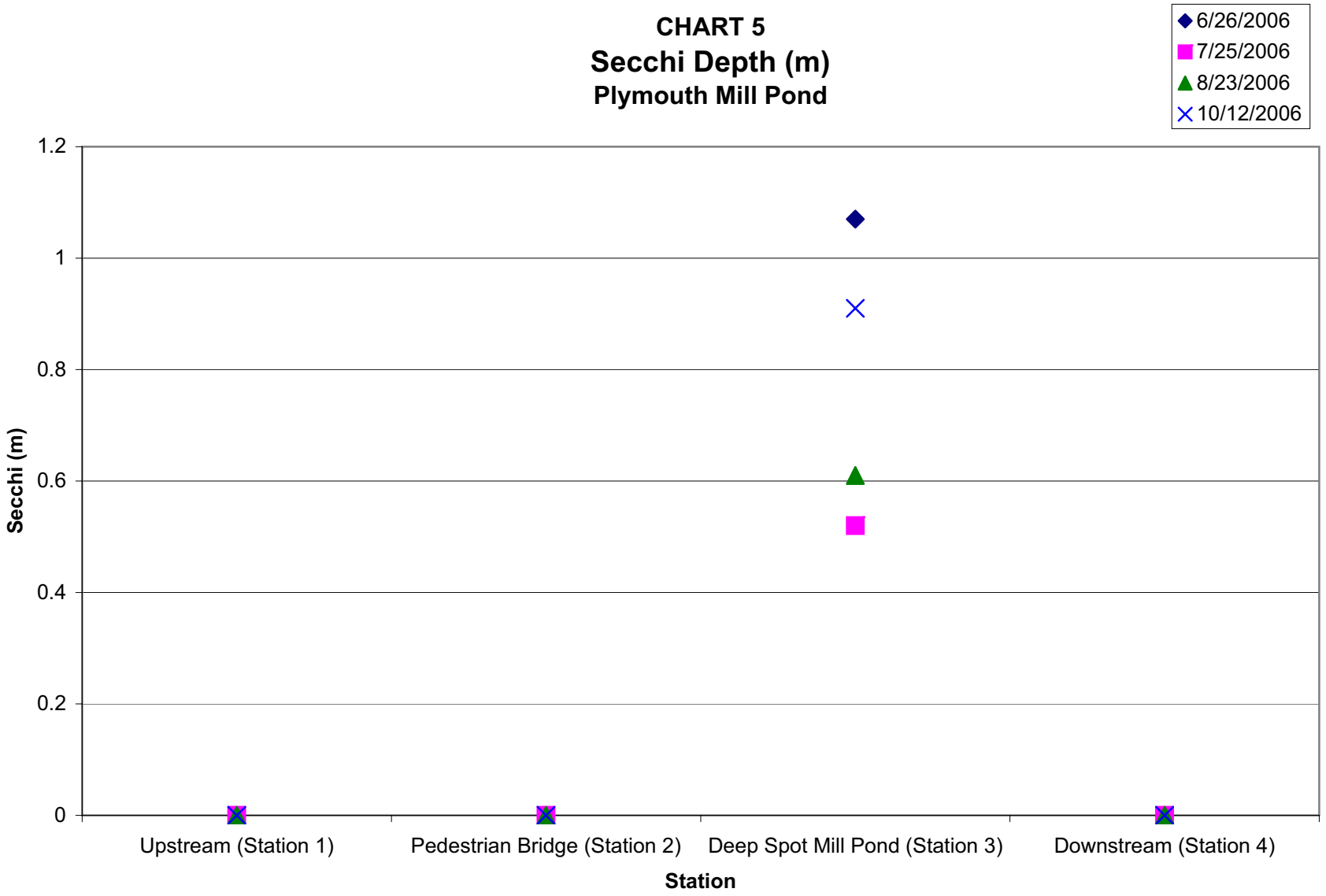


CHART 6

Total Phosphorus (µg/L)

Plymouth Mill Pond

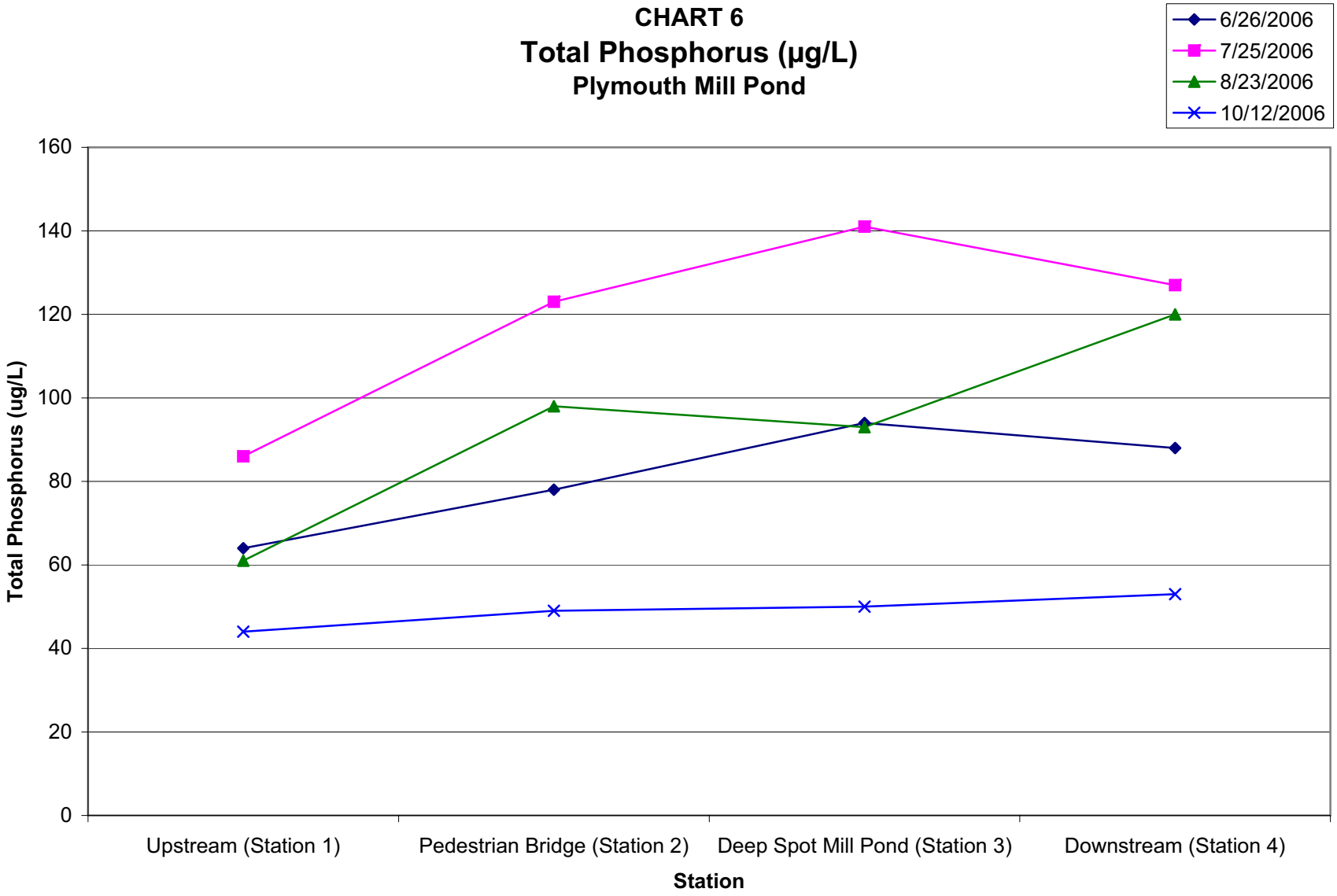


CHART 7

Chlorophyll a (µg/L)

Plymouth Mill Pond

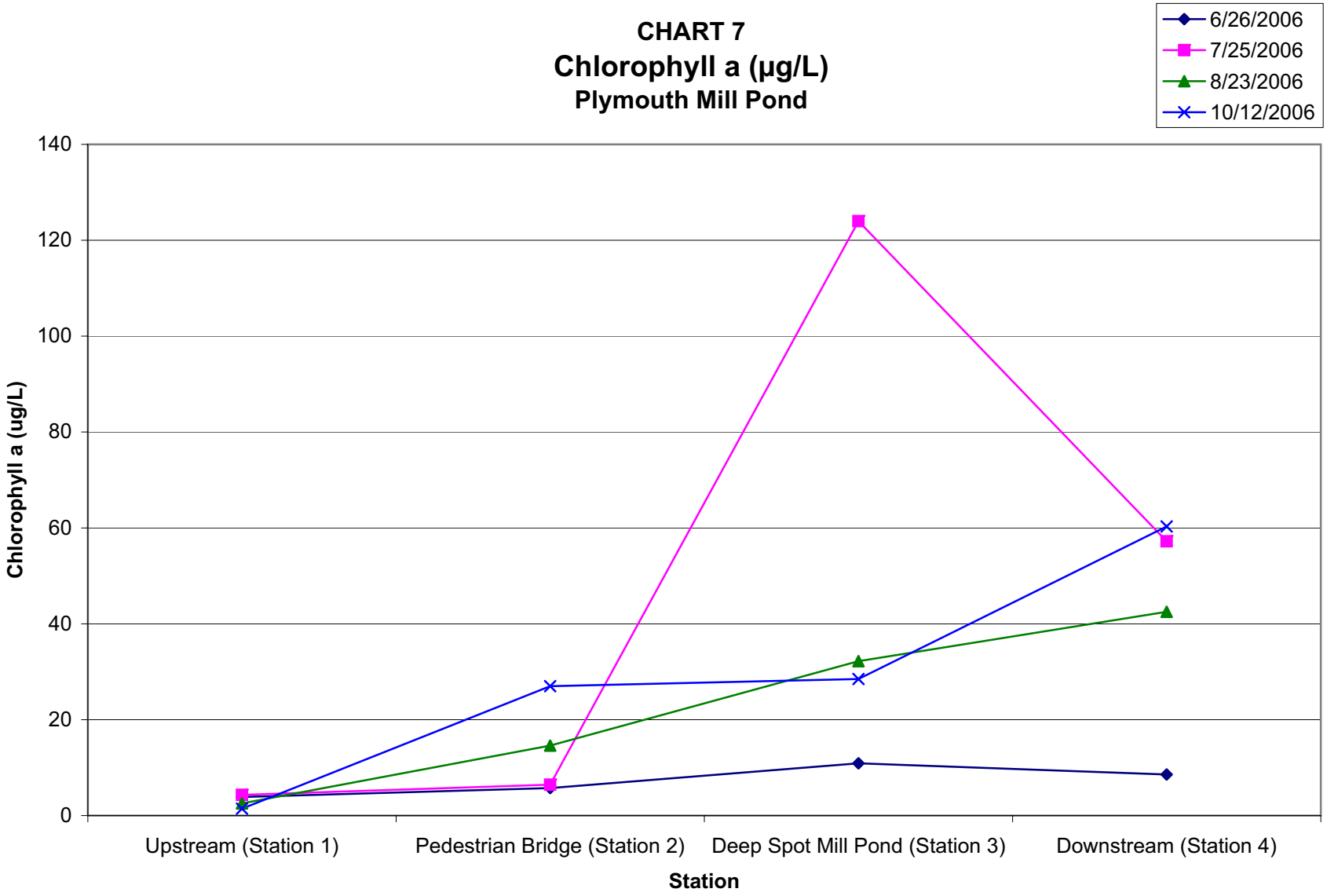


CHART 8

Phosphorus, Chlorophyll a, and Secchi Depth TSI

Plymouth Mill Pond