Appendix F

SMAST Report – Sediment Nutrient Flux and Oxygen Demand

SMAST University of Massachusetts Dartmouth
The School for Marine Science and Technology

Technical Report

Merrimack River Sediment Nutrient Regeneration
2009 Sampling Season

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Introduction and Background: As part of the USACE Upper Merrimack and Pemigewasset River Study Field Sampling Program, Coastal Systems Program scientists at the School for Marine Science and Technology within UMASS-Dartmouth assessed sediment nutrient regeneration (recycling) along the Bristol - Franklin, NH reach of the Merrimack River. Sediment regeneration was assayed by incubating undisturbed sediment cores in the vicinity of the three major impoundments to determine the contribution of organic matter decomposition and nutrient remineralization in River sediments, as it relates to the overall nutrient budget of the river system. Release of remineralized nutrients from sediments can contribute a significant internal load to aquatic systems and is often a critical component of the nutrient balance and associated water quality models. Rates of sediment nutrient release can vary greatly with external organic matter loading, especially in systems receiving waste water. Further, the hydrodynamics of an aquatic system can create spatial heterogenities. In river systems this frequently is associated with impoundments behind dams which slow water velocities, thus concentrating organic matter deposition in small areas of deep water, which also can be affected by summer stratification. In addition, summer time temperatures can create thermoclines which severely limit the mixing of atmospheric oxygen into the bottom waters near the sediment surface. This situation may lead to bottom water anoxia, which changes regeneration rates by favoring anaerobic microbial communities over aerobic microbial communities. In the absence of oxygen, these microbial communities, use alternative respiratory pathways including nitrate, manganese and most importantly for fresh water systems, iron oxides (as electron acceptors).

The oxygen status of the overlying water to the sediments fundamentally controls phosphorus regeneration by structuring the biogeochemistry of the sediments. Phosphorus release under oxic waters tends to be relatively low, with remineralized inorganic phosphorus being mediated by oxidized iron minerals (e.g. iron oxyhydroxides), which bind some of the phosphorus before it can be released to the overlying waters. Under prolonged (days) anoxic conditions this binding process ceases and previously bound phosphorus can also be released. The result is a short-term large release of inorganic phosphorus to overlying waters, frequently with significant effects on aquatic productivity and trophic status.

Phosphorous release under anaerobic conditions from freshwater sediments has 3 phases (Figure 1). Phase 1 represents micro-aerobic and anaerobic microbial regeneration processes modified by changing sediment reduction-oxidation (redox) conditions and competitive inhibition by other available respiration pathways (Figure 2). Phase 2 represents anaerobic microbial regeneration of organic phosphorus and chemical release of inorganically bound phosphate. Phase 3 represents anaerobic microbial regeneration of remaining labile organic matter in the sediment after release of chemically bound phosphorus has ceased. Each of the three phases has clear implications for management strategies. Phase 1.) Bacteria classed as facultative anaerobes are primarily responsible for sediment iron reduction. The term facultative denotes that these bacteria may use a variety of oxidized molecules for respiration; the choice of molecule is a function of potential energy yield and relative concentration. The first five electron acceptors used in microbial respiration pathways are shown below in order of decreasing energy yield:

Oxygen: O_2
Nitrate: NO_3^-
Manganese: Mn^{4+}
Iron: Fe^{3+}
Sulfur: SO_4^{2-}.

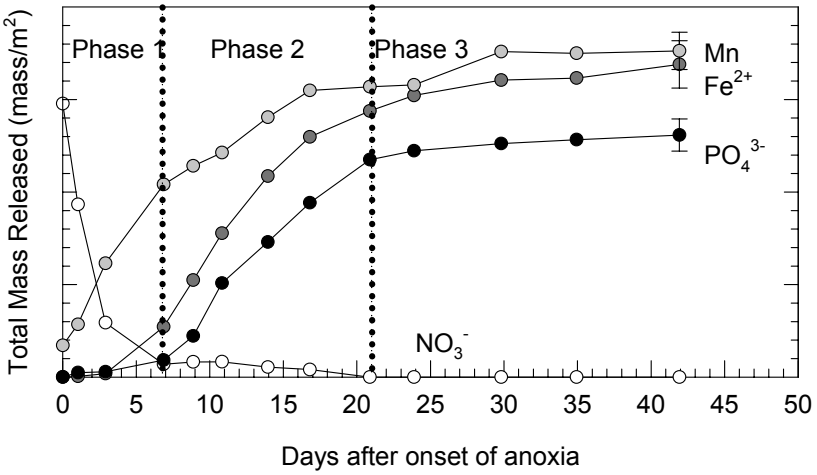

Figure 1. Illustration of time dependent changes in sediment core headspace concentrations of ions involved in respiration pathways. The headspace is anoxic at the start of the time-course (open circles=nitrate). The ion fluxes can be divided into 3 phases relative to phosphate flux. Phase 1 = initial hypoxic and anaerobic decomposition attenuated by sediment iron; Phase 2 = chemical release of iron bound phosphate + anaerobic decomposition; Phase 3 = anaerobic decomposition in the absence of significant sediment iron.

Thus, in the absence of oxygen, nitrate will be used as the dominant electron acceptor in the respiration of organic matter. When nitrate concentrations are too low, manganese becomes the dominant electron acceptor and so on down the list. Within the sediment column these different respiration pathways exist simultaneously, but occur at successively lower depths in the sediment (Figure 2). Only after the iron reducing zone reaches the sediment surface can inorganic phosphorus release occur (Phase 2). The concentration thresholds for switching to less energetic electron acceptor pathways vary from place to place, and because they depend upon many additional factors including organic matter quality, respiration rate, sediment porosity and tortuosity, must be determined empirically.

Defining Phase 1 is critical to nutrient management for two important reasons. First, it is a transition period that defines the minimum period of anoxia required to mobilize sediment pools of adsorbed phosphorus (i.e. time for sorbed phosphorus to be released). Second, this phase defines the competitive inhibitions between alternative electron acceptors which control whether *in situ* anoxia is likely to result in accelerated sediment phosphorus release. The most important among these alternate electron acceptors is nitrate, often found elevated in fresh water systems as a result of discharges from WWTF's and non-point nitrogen sources. Within the Upper Charles River (Charles River Watershed Alliance, 2005) it is believed that nitrate from WWTF point

discharges may entirely prevent anaerobic sediment phosphorus release through competitive inhibition.

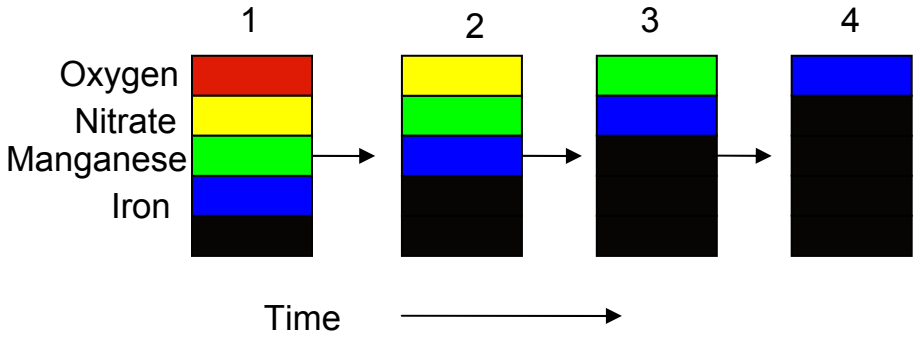

Figure 2. Typical changes in sediment redox status during Phase 1. Bars represent a sediment core, black indicates sediment volume dominated by methanogenisis and sulfate reduction. Vertical zonation of respiration pathways in an oxidized sediment (1) and the upward movement of these zones through time as conditions become more reducing. Through time (left to right) oxygen is depleted (2), nitrate is depleted and reduced soluble manganese is released into the water column (3), finally manganese is depleted and microbially reduced iron along with attached phosphate is released into the water column.

Phase 2 falls within the steep middle portion of the curve, where iron is actively reduced and released into the headspace along with the previously bound phosphate, and thus represents the sum of anaerobic decomposition of phosphorus containing organic matter and the release of phosphate previously bound to iron. This phase provides information on the magnitude of the pool of sediment bound phosphate which will be released to overlying waters under a sufficiently long anoxic event. After release into the water column this phosphorus mass is available to migrate downstream and potentially impact down gradient reaches of the river. In addition this phase may provide clues to the frequency and duration of previous anoxic events.

Phase 3 is of very long duration and consists primarily of phosphorus remineralization under anoxic conditions and oxidized iron is no longer present to bind inorganic phosphorus before release to overlying waters. Phase 3 allows prediction of phosphorus release in river reaches, generally impoundmnets, which can stratify and develop anoxic bottomwaters lasting for most of the summer. Under these conditions after the Phase 2 loss of bound phosphorus, internal sediment loading to the water column may be dominated by phase 3 phosphorus release throughout most of the warmest and most productive months of August and early September.

The sediment nutrient regeneration analysis undertaken for the Merrimack River focused on directly quantifying each of the 3 phases of release in an effort to support nutrient modeling efforts and to provide resource managers with linkages between water quality parameters, primarily oxygen levels, and patterns of sediment nutrient release.

Sediment Sampling sites within the Merrimack River: Samples were collected from sites coincident with water quality sampling stations previously occupied by CDM staff. The sediment collection sites were located upstream from dams to provide a potential gradient of nutrient regeneration associated with increasing depth and decreasing water velocity moving from the "river" into the impoundment above each dam. When access to a specific location was

impossible (e.g. restricted areas), or when coring conditions were unsatisfactory (e.g. boulders or fallen trees) sediment locations were adjusted to provide samples representative of that area of river.. The two most important reasons for adjusting the station locations were the inability to place boats and divers within the restricted area behind the dam and the presence of cobbles and boulders and trees on the bottom. Sediment cores were collected from the three impoundments (figures 3-6) on September 1 and September 2, 2009 under relatively high flow conditions. Cores were transported in vibration dampened chambers at *in situ* temperatures to Franklin, NH for incubation. Following incubation under aerobic conditions, the cores were placed in a gimbaled system to minimize disturbance and transported to the Coastal Systems laboratory for a long-term incubation under anaerobic conditions. Changes in oxygen (aerobic only), nitrate, ammonium, ortho-phosphate, total dissolved phosphorus, dissolved iron, and dissolved manganese were measured within the headspace overlying the sediment surface in time course. Rates of exchange are determined as changes in concentration over time, see below.

In addition to collecting sediment cores, water column profiles of oxygen were collected at each impoundment as well as bottom water nutrient and chlorophyll samples. Water column samples were collected to determine *in situ* nutrient and oxygen concentrations to better inform the interpretation of sediment regeneration results.

Water column measurements: Water column profiles of temperature and oxygen (Table 1) showed oxygen concentrations at or near air saturation values. The largest depletion of oxygen was seen at 4 m at MRK 8 where oxygen concentrations were 90% of air saturation. Low chlorophyll concentrations ($\leq 1 \mu g\ L^{-1}$; Table 2) coupled with high water clarity (secchi depth >0.5 times total water depth) are consistent with the observed low rates of water column oxygen uptake or respiration (Table 2) and with water column dissolved oxygen at or near air saturation. Despite a modest temperature stratification of the waters of this impoundment, dissolved oxygen concentrations were only 10% below air saturation in the bottom water. Although this level of depletion is insufficient to affect sediment regeneration rates it does indicate the role of sediment oxygen demand in this basin.

Water column nutrients (Table 2) showed inorganic N:P (nitrate+nitrite+ammonium:phosphate) ratios higher than typical fresh water N:P ratios. Nitrate + nitrite represented the largest pool of inorganic nitrogen indicating the oxidation of ammonium within the river system and the likely importance of upstream wastewater outfalls to nitrogen balance. In general the water quality parameters indicate a healthy aquatic ecosystem consistent with an oligotrophic or mesotrophic designation.

Table 1. Water column profiles of dissolved oxygen and temperature. Data was collected at the same location as the bottom water nutrient samples. Total station depth and secchi depth are included for reference.

Station ID		MRK 2		Station ID		MRK 5		Station ID		MRK 8
Total Depth (m)		4.82		Total Depth (m)		7.04		Total Depth (m)		5.9
Secchi Depth (m)		3.15		Secchi Depth (m)		3.4		Secchi Depth (m)		3.2
Depth (m)	DO (μM)	Temp (°C)		Depth (m)	DO (μM)	Temp (°C)		Depth (m)	DO (μM)	Temp (°C)
0.15	292.3	19.3		0.15	294.8	19.5		0.15	294.5	20.3
2	274.8	18.7		2	297.3	17.6		2	296.7	18.5
4	299.8	17.6		4	292.6	17.5		5.5	266.3	18.1

Table 2. Water quality measurements from each of the impoundments sampled. Water samples were collected 0.5 m from the sediment surface.

Station ID	NH_4^+ (μM)	PO_4^{3-} (μM)	NO_3^- (μM)	TDN (μM)	TDP (μM)	Chl a (μg/L)	Pheo a (μg/L)	Winkler DO (μM)	WC Respiration (μM/Day
MRK2	1.24	0.15	7.12	29.54	0.22	0.5	0.8	256.8	4.95
MRK5	0.68	0.10	7.22	24.49	0.23	0.5	0.7	267.4	4.89
MRK8	0.68	0.10	7.61	22.92	0.18	1.0	0.5	261.2	4.31

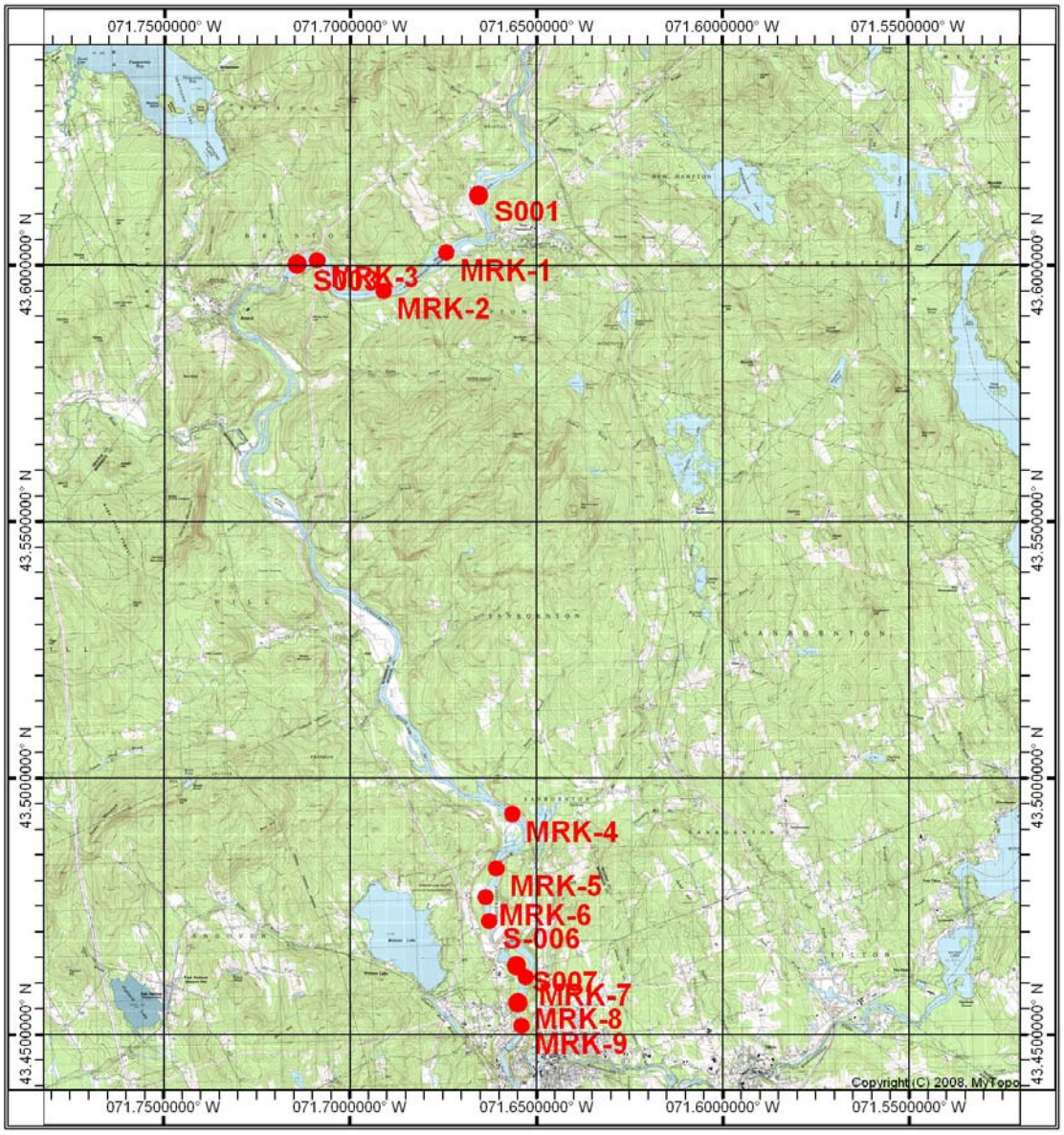

Figure 3. Overview of Merrimack River study area extending from Bristol, NH south to Franklin, NH.

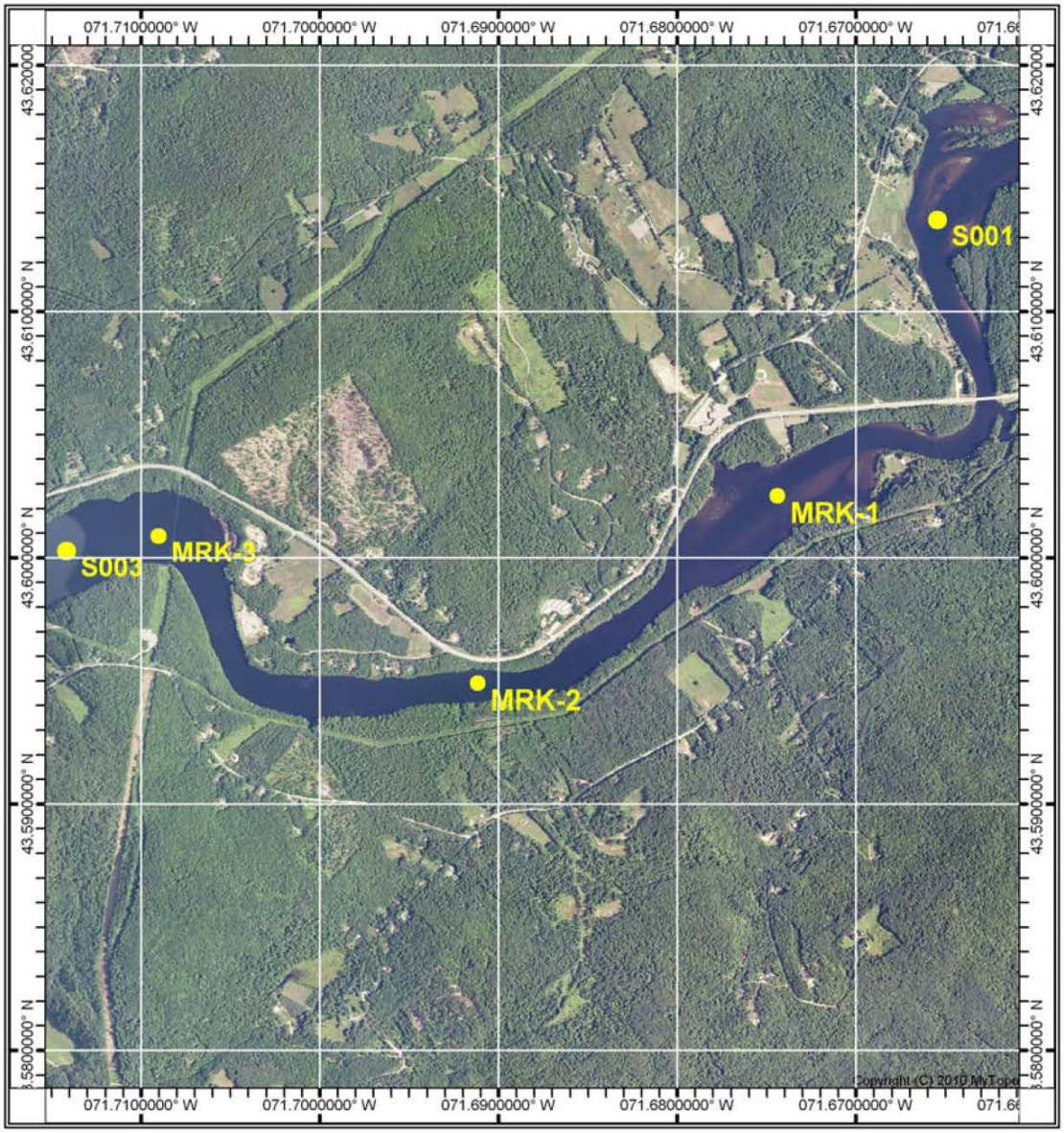

Figure 4. Sediment coring locations within the Ayers Island Reservoir. CDM water quality monitoring stations are denoted with "**S00#**" when different from sediment coring locations denoted with "**MRK-**".

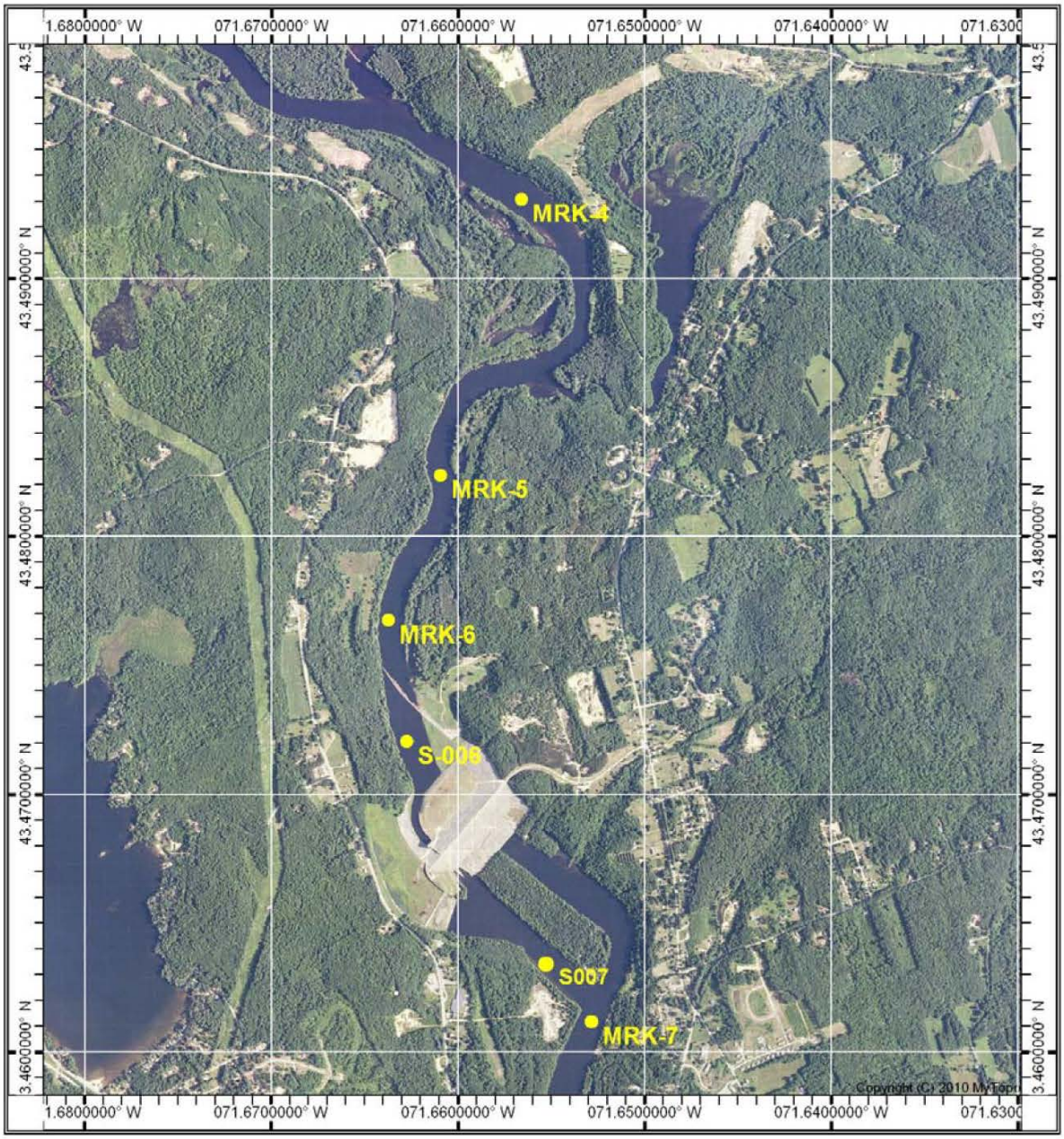

Figure 5. Sediment coring locations within the Franklin Dam Impoundment. CDM water quality monitoring stations are denoted with "**S00#"** when different from sediment coring locations denoted with "**MRK-**".

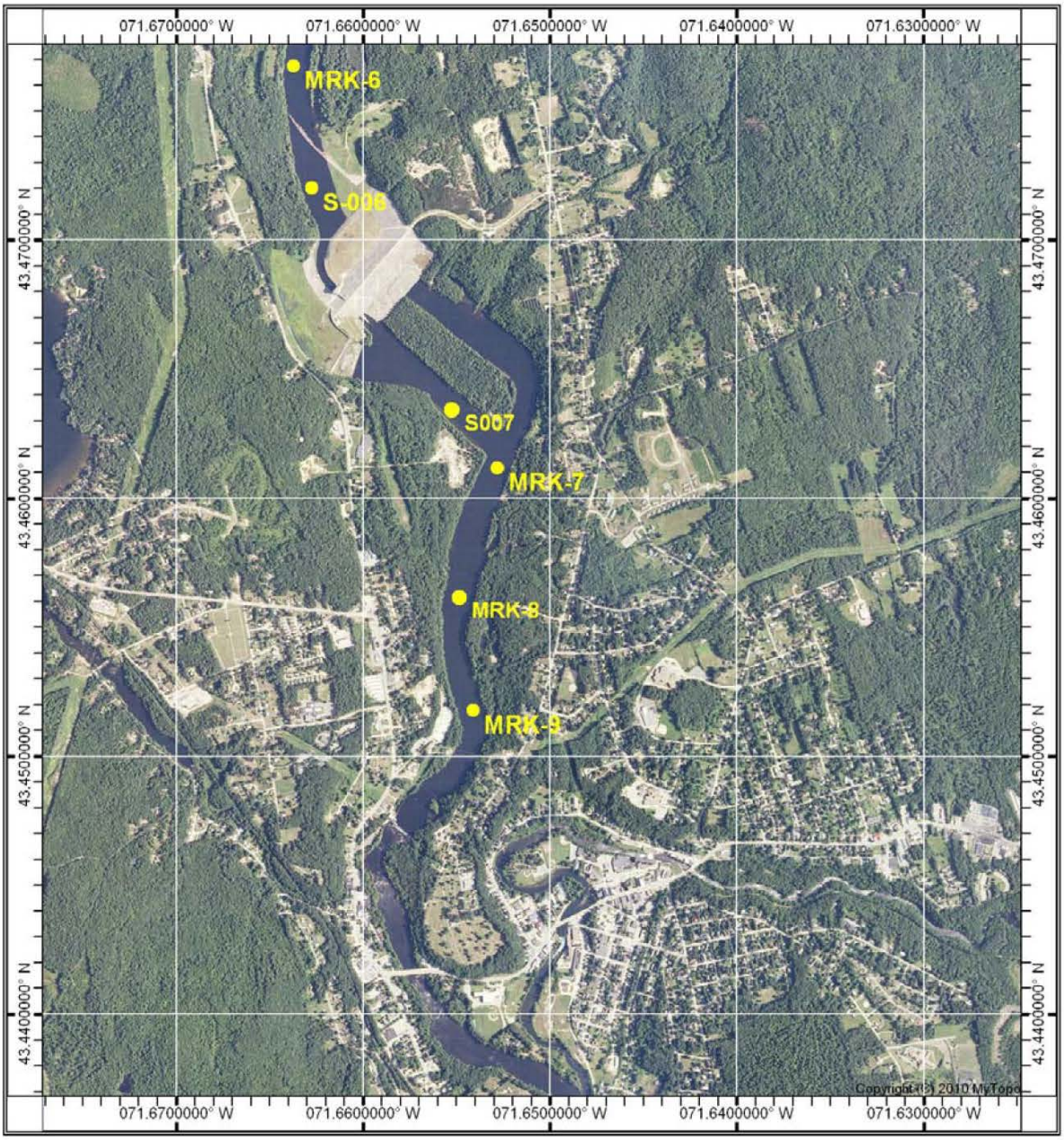

Figure 6. Sediment coring locations within the Eastman Falls Impoundment. CDM water quality monitoring stations are denoted with "**S00#**" when different from sediment coring locations denoted with "**MRK-**".

Aerobic Sediment Nutrient Regeneration: Evaluating the sediment-watercolumn exchange results from the three impoundments: Ayers Island Reservoir, Franklin Dam and Eastman Falls showed a distinct pattern.. Overall organic matter mineralization rates (sediment oxygen demand), an indicator of organic matter deposition generally decreased moving successively downgradient. It has not been determined if this is the result of organic matter being trapped in the uppermost impoundments or if settling of organic matter is generally lower in the lower basins due to their specific depth/velocity environment. The results also indicated that sediment oxygen demand did not increase relative to each impoundment from the upgradient river channel to the basin, although organic deposition was predicted to increase with water depth and as water velocity decreased with proximity to the dams.,

Aerobic nutrient fluxes showed a pattern of decreasing flux with each successive down river impoundment similar to that seen in the sediment oxygen demand. However, there were also identifiable trends in flux rates within each impoundment as one moved down river towards each dam.

Inorganic P flux (+ or -) was not detectable except at Station MRK 3 just above the Ayers Island Impoundment Dam, where there was a small uptake by the sediments. These results are likely due to a pool of iron oxyhydroxides within the sediments and a generally well oxygenated watercolumn.

Total Dissolved P (TDP) flux generally showed a small net sediment uptake or release, except at at MRK 1 farthest upstream from the Ayers Island Dam where a significant release was observed with lesser rates of release at MRK 2, 5, and 6. Generally there was no clear trend in TDP flux approaching a dam, with rates generally uniform and low.

Sediment release rates of ammonium tracked the observed SOD rates. Sediment efflux of ammonium increased moving down stream within each impoundment and in general decreased down stream between impoundments. The middle, Franklin Dam, impoundment showed ammonium uptake at the most upstream station MRK 4. MRK 4 was the only location to show ammonium uptake. It was also the only station with observable macrofauna (mussels). In contrast, there was a clear pattern in nitrate flux, with uptake, indicative of denitrification associated with the uppermost impoundment, Ayers Island Reservoir where sediment oxygen demand was highest and the sediments were universally soft unconsolidated muds. In the lower impoundments nitrate was released from the sediments at all locations, which supported generally coarser and more oxidized sediments than associated with theAyers Island Dam sites. No obvious trend was seen in the dissolved organic nitrogen flux.

Anaerobic Sediment Nutrient Regeneration (Phase 1): This time period represents the transition from aerobic to anaerobic nutrient regeneration. This phase begins when oxygen is depleted and ends with the appearance of dissolved iron in the water overlying the sediment cores. For the Merrimack River cores, nitrate was below detection at the beginning of this phase. Phase 1 lasted 2, 7 and 10 days for Ayers Island (MRK 1, 2, 3), Franklin Dam (MRK 4, 5, 6) and Eastman Falls (MRK 7, 8, 9), respectively. Interestingly, total dissolved P and phosphate flux for all the cores showed significant increases beginning at day 2. This behavior suggests significant interaction between iron and manganese in the headspace during this phase in which micro-aerobic conditions may result in the reverse of redox status diagram (figure 2). Trace amounts of dissolved oxygen in the headspace re-oxidize the dissolved manganese; the oxidized manganese in turn is chemically reduced by the dissolved iron. The iron becomes oxidized and returns to the sediment surface.

Anaerobic Sediment Nutrient Regeneration (Phase 2): This Phase of the anaerobic incubation is dependent upon the relative concentrations of alternative electron acceptors within the sediment and overlying water column. In the absence of oxygen, the concentrations of nitrate, manganese and iron control the rate of organic matter regeneration. While the presence of nitrate and manganese controls the onset of chemical phosphate release, it is iron, which ultimately controls the aerobic chemical absorption and storage of phosphate and under anaerobic conditions the rate and quantity of chemical phosphate release. During the anaerobic incubation, release of phosphate began on day 2. Release of iron and manganese occurred at the end of phase 1 as stated above. This was likely the result of the high concentration of sediment iron, which was 120-800% higher than manganese (Table 5). The iron and phosphate flux rates were highly correlated (Figure 7). Examining the amount of iron and inorganic phosphate released indicates that the sediment has the capacity to bind on the order of 100 times more phosphate than held at present, since saturated iron-phosphate precipitates have a maximum Fe:P ratios ranging from 1-3:1, compared to a Fe:P ratio of 269:1 measured in the Merrimack River. In other words, it appears that only ~1% of the iron sorption sites presently bind inorganic phosphate at the Merrimack River study sites, which is consistent with the observed very low rates of inorganic phosphate release.

Anaerobic Sediment Nutrient Regeneration (Phase 3): This period of the anaerobic time course follows the release of iron bound phosphate and reflects on-going anaerobic remineralization in the absence of iron scavenging of dissolved phosphorus. During this period there was continued ammonium and iron release (Table 6). As noted above, the rate of ammonium release did not change over the anaerobic incubation so that Phase 2 and 3 rates were similar. However, release of dissolved iron is greatly diminished or ceases, while manganese and phosphate flux were minimal and in some cases were negative. The negative rates likely represent trace contamination of dissolved oxygen which would be easily seen in the low concentrations of phosphate, yet imperceptible in the large background concentrations of iron and manganese.

Relevance of Observed Flux Rates to the Merrimack River: Oxygen concentrations in the impoundments were not significantly depressed below air equilibration. *In situ* oxygen meters deployed by CDM during the months prior to the core collection also indicated the absence of hypoxia. However, the results of the sediment incubations indicate that if oxygen depletion were to occur in the Merrimack River basins investigated, significant phosphate flux would not occur for at least two days. Under the oxic conditions within the river waters that have been generally observed, it appears that the high concentrations of iron within the sediments effectively eliminate the release of inorganic phosphate from sediment to overlying waters.

Further interpretation of the results of the sediment incubations must consider how the sediments would behave under *in situ* conditions where the overlying water is continually exchanged. For example, nitrate was not detected within the cores at the time the anaerobic incubation was begun, but water column measurements at the collection sites showed nitrate concentrations of ~7μM within each of the impoundments. The nitrate was apparently denitrified within the sediments during the aerobic incubation period preceding anoxia. While nitrate competitively inhibits microbial iron and manganese reduction, it is unlikely given the 100-200 times greater concentration of iron and manganese in the sediments that water column nitrate could exert significant influence on the sediments. Iron and manganese would be the primary determinants of sediment phosphorus release to the overlying watercolumn. Once in the watercolumn dissolved iron would scavenge available oxygen with the

formation of iron oxide precipitate. These precipitates would, in turn, scavenge phosphate in the water column and return the phosphate to the sediment as the precipitate settled. Within the Merrimack River the presence of high iron concentrations within the sediments suggests that hypoxic/anoxic conditions, which typically deplete sediment iron pools in river impoundments, are uncommon. Unless there was extended anoxia it is unlikely that any significant impact from anaerobic chemical phosphorus release would be occur within the study reaches. However, if extended anoxic conditions were to occur, the increase in water column phosphate concentration, assuming 2 meters of affected water column would range between 0.16 μM (maximum from MRK 5) and 0.05 μM (minimum from MRK 4). This would represent an increase over observed water column concentrations of between 50 and 150%.

Table 4. Measured aerobic sediment flux rates. Sediment oxygen demand values are in units of mMol/m^2/d, all other values are given in units of µMol/m^2/d. Positive values indicate flux from sediment to overlying waters; negative values indicate uptake by the sediment. Core ID's refer to the locations in Figures 4-6, Ayers Island (MRK 1, 2, 3), Franklin Dam (MRK 4, 5, 6) and Eastman Falls (MRK 7, 8, 9).

Sediment Core ID	Sediment Oxygen Demand		Ammonium Flux		Phosphate Flux		Nitrate Flux		Total Diss. N Flux		Total Diss. P Flux	
	Rate	Std. Err.	Rate	Std. Err.	Rate	Std. Err.	Rate	Std. Err.	Rate	Std. Err.	Rate	Std. Err.
	(mMoles/m^2/d)		(µMoles/m^2/d)		(µMoles/m^2/d)		(µMoles/m^2/d)		(µMoles/m^2/d)		(µMoles/m^2/d)	
MRK1	34.9	2.0	433.6	33.3	0.0	0.0	-40.9	65.7	2186.0	480.4	134.0	33.9
MRK2	35.6	2.2	1118.5	59.2	0.0	0.0	-84.5	14.0	578.5	124.6	13.8	5.9
MRK3	29.77	3.19	1074.9	59.9	-10.1	4.0	-185.5	24.0	1039.6	285.3	-16.5	3.9
MRK3 FD	33.13	3.09	1101.8	79.8	-20.2	5.1	-221.7	18.5	1014.8	365.3	-14.8	7.1
MRK4	14.52	0.86	-108.8	23.6	0.0	0.0	212.3	9.4	398.3	74.8	-19.6	11.7
MRK5	14.9	0.8	23.6	7.5	0.0	0.0	213.2	10.0	1665.6	234.7	10.3	5.3
MRK6	17.3	0.9	125.4	44.2	0.0	0.0	145.9	13.8	791.9	236.5	18.5	3.1
MRK7	7.35	0.50	20.6	18.3	0.0	0.0	218.2	159.6	1366.6	194.9	-5.5	3.3
MRK8	6.7	0.3	29.7	43.6	-5.0	2.5	365.9	15.0	248.5	146.4	-2.5	6.6
MRK9	8.18	0.37	56.8	8.8	0.0	0.0	343.4	6.8	159.1	347.7	-1.1	1.6

Table 5. Measured anaerobic sediment flux rates associated with Phase 2. Rates represent the short chemical release phase for iron-bound inorganic phosphorus. All values are given in units of µMol/m^2/d. Positive values indicate flux from sediment to overlying waters; negative values indicate uptake by the sediment. Note that all rates, except ammonium, were calculated between day 2 and day 14 of the anaerobic incubation. Ammonium rates were constant over the entire anaerobic incubation. Core ID's refer to the locations in Figures 4-6, Ayers Island (MRK 1, 2, 3), Franklin Dam (MRK 4, 5, 6) and Eastman Falls (MRK 7, 8, 9).

Sediment Core ID	Sediment Oxygen Demand		Ammonium Flux		Phosphate Flux		Iron Flux		Manganese Flux		Total Diss. P Flux	
	Rate	Std. Err.	Rate	Std. Err.	Rate	Std. Err.	Rate	Std. Err.	Rate	Std. Err.	Rate	Std. Err.
	(mMoles/m^2/d)		(µMoles/m^2/d)		(µMoles/m^2/d)		(µMoles/m^2/d)		(µMoles/m^2/d)		(µMoles/m^2/d)	
MRK1	NA	NA	374.5	42.2	8.5	1.8	4484.5	728.0	924.0	154.7	12.2	4.0
MRK2	NA	NA	1267.8	117.9	17.9	1.6	4769.7	461.1	716.1	76.9	19.6	4.2
MRK3	NA	NA	556.8	40.0	10.8	0.4	3199.1	376.5	452.9	46.7	17.3	3.6
MRK3 FD	NA	NA	723.7	31.7	9.6	1.9	3114.9	421.5	411.7	43.5	7.1	2.0
MRK4	NA	NA	167.1	9.1	1.3	0.2	1154.7	63.6	972.6	172.4	6.4	1.4
MRK5	NA	NA	173.8	14.1	26.0	5.4	1952.4	132.6	596.3	109.9	11.3	1.6
MRK6	NA	NA	210.1	18.3	7.8	1.2	2574.4	242.4	573.8	100.5	13.6	3.6
MRK7	NA	NA	210.7	24.1	2.1	0.1	556.9	48.8	533.9	125.2	2.1	0.8
MRK8	NA	NA	87.5	6.9	2.4	0.2	536.2	72.1	422.2	66.7	4.5	1.8
MRK9	NA	NA	72.0	10.1	4.9	1.0	1505.2	120.2	777.6	163.5	9.7	3.2

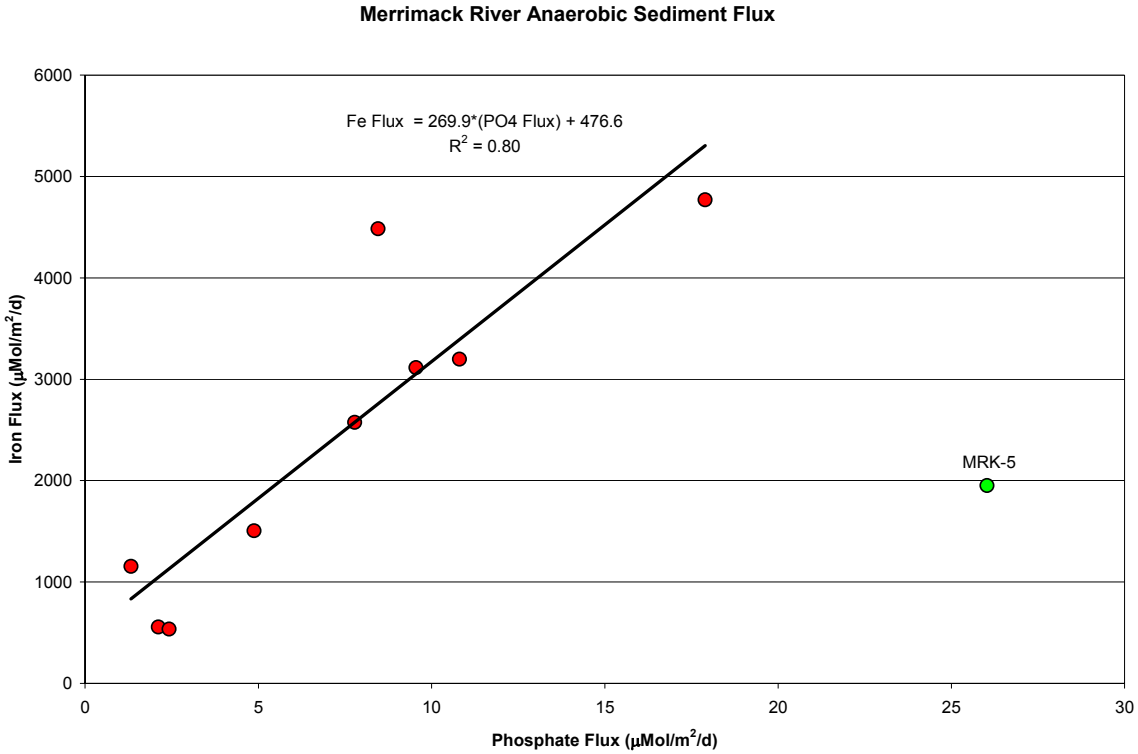

Figure 7. Anaerobic Phosphate vs. Iron flux. Except for MRK 5, which was not included in the regression and considered an outlier, phosphate and iron flux were highly correlated.

Table 6. Measured phase 3 anaerobic sediment flux rates, representing continuing microbial regeneration of sediment organic matter. All values are given in units of μMol/m^2/d. Positive values indicate flux from sediment to overlying waters; negative values indicate uptake by the sediment. Rates were calculated from measurements between day 14 and the end of the incubation (day 79) of the anaerobic incubation for all constituents except ammonium and iron. Phase 3 iron was calculated from measurements between day 30 and day 79. Core ID's refer to the locations in Figures 4-6, Ayers Island (MRK 1, 2, 3), Franklin Dam (MRK 4, 5, 6) and Eastman Falls (MRK 7, 8, 9).

Sediment Core ID	Sediment Oxygen Demand		Ammonium Flux		Phosphate Flux		Iron Flux		Manganese Flux		Total Diss. P Flux	
	Rate	Std. Err.	Rate	Std. Err.	Rate	Std. Err.	Rate	Std. Err.	Rate	Std. Err.	Rate	Std. Err.
	(mMoles/m^2/d)		(μMoles/m^2/d)		(μMoles/m^2/d)		(μMoles/m^2/d)		(μMoles/m^2/d)		(μMoles/m^2/d)	
MRK1	NA	NA	374.5	32.2	0.0	0.2	706.3	67.6	35.6	12.1	-0.9	0.3
MRK2	NA	NA	1267.8	28.3	-2.6	0.5	1026.6	168.6	113.6	15.0	-1.6	0.3
MRK3	NA	NA	556.8	24.1	-1.0	0.2	1266.9	57.8	98.1	11.6	-1.4	0.2
MRK3 FD	NA	NA	723.7	171.9	-0.2	0.1	1089.8	57.8	98.5	3.3	-0.6	0.3
MRK4	NA	NA	167.1	63.8	0.8	0.1	1154.7	63.6	51.1	12.6	-0.3	0.5
MRK5	NA	NA	173.8	23.7	-0.2	0.1	721.6	100.0	26.9	10.3	-0.4	0.1
MRK6	NA	NA	210.1	19.1	-0.1	0.1	1122.3	99.4	67.5	7.8	-0.5	0.2
MRK7	NA	NA	210.7	9.1	2.5	0.2	131.7	35.8	-20.8	3.1	0.0	0.4
MRK8	NA	NA	87.5	12.2	2.7	0.2	426.0	52.6	85.3	16.7	2.3	0.4
MRK9	NA	NA	72.0	13.8	-0.6	0.1	1345.5	75.5	128.6	51.5	-1.1	0.4