Summary of Passive Flux Meter Deployments at Pelaez Ranch

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Palaez Ranch Phosphorous Flux Measurements

The following data on groundwater and phosphorous flux is based on deployment of 18 Passive Nutrient Flux Meters (PNFM) at the Pelaez Ranch, four around each wetland and ten at the cross section of a ditch. See Figure 1 for well locations. Water table levels were recorded for ten of the wells. The PNFM's at the Pelaez Ranch were deployed for a period of 33 days.

At the Pelaez Ranch, monitoring wells were constructed with an inside joint protruding into the well requiring the standard PNFM design to be modified (Hatfield et al., 2004; Annable et a;., 2005) . A nine foot perforated, plastic sleeve with a second three foot plastic sleeve located around the bottom end of the longer sleeve was used to assist in inserting the PNFM. The nine foot and three foot sleeves were inserted into the well. Then a plastic sleeve covered PNFM was inserted into the well through the nine foot plastic sleeve. This allowed the PNFM to slide easily into the well at the constricting joints and still fit snuggly to the well walls due to the multiple layers of perforated plastic. See Figure 2 for a cross section of the installed PNFM.

The water flux profiles based on the PNFM deployments for each of the wetlands at the Pelaez Ranch are provided in Figures 3. Darcy velocities range from 0 to 7 cm/day with an average of 3.5 cm/day. Pelaez wells PTFM1-10 provide phosphate flux along a transects near the ditch which drains the wetland and surrounding areas. The water flux along well transects parallel to the ditch is shown in Figure 4. The Darcy velocities are more uniform with an average of 6.5 cm/day. The water flux along the transect perpendicular to the ditch is shown in Figure 5. The phosphate flux in wells around wetlands 1 and 4 are provided in Figure 6 & 7. Mass flux rates average 1.5 mg/m2/day. Figure 8 indicates there that there are higher phosphate fluxes on the east side of the ditch than the west side and on average the phosphate flux is higher along the ditch then in the wetlands. The left side of the transect shows a trend of similar to Pelaez wetland 4 where the phosphate flux increase with depth. This variation in phosphate flux maybe due to land practices or different water flux between the sides of the ditch.

Basin Wide Loads Based on Local Flux Measurements

The field data collected from six wetlands (two at Paleaz, two at Larson and two at Beaty) were used to calculate a basin-wide estimate of the total amount of phosphorus exchange between groundwater and isolated wetlands. The amount of phosphorus that could be reduced to Lake Okeechobee by detaining more water in the wetlands and surrounding groundwater for a longer period of time was estimated to be similar to the measured fluxes. To estimate the mass of phosphate that could potentially be reduced from the load reaching Lake Okeechobee the phosphate flux values measured at the six wetlands were applied to the priority basins of the Lake Okeechobee watershed.

The priority basins, S-65E, S-65D, S-154 and S-191 have consistently produced the highest levels of phosphorus concentrations of all the tributary basins to Lake Okeechobee (SFWMD and USEPA, 1999). The priority basins have abundant cow calf operations. The priority basins account for 12% of the land area in the Lake Okeechobee watershed (Figure 9), and 35% of the phosphorus entering the lake (Dunne, et al., 2006). The Lake Okeechobee Action Plan of 1999 states that if the priority basins met their target loads the phosphorus loading into Lake Okeechobee could be reduced by over 100 tons per year (SFWMD and USEPA, 1999).

Basin Wide Phosphorus Calculations for Isolated Wetlands

By using the characteristics of the six wetlands studied, an estimate of the amount of phosphorus produced by the all the wetlands located within the priority basins was calculated.

Seven percent of the land surface in the priority basins is reported as isolated wetlands (Dunne, et al., 2006). The priority basin's total area is 974 square miles (SFWMD and USEPA, 1999). Therefore there is an estimated 68 square miles of isolated wetlands within the priority basins. The average area of the study wetlands was determined by area measurements collected at each site. The average area of the six wetlands was 7,900 square meters. This average site wetland would indicate approximately 22,400 individual isolated wetlands in the priority basins.

By taking the average and range of phosphate mass flux shown in Table 3 and using the duration of gradients surrounding the wetlands the average exchange between the wetlands and groundwater can be calculated (Table 4). Multiplying by the number of individual isolated wetlands estimated for the basin, the estimated mass load average and range is calculated (Table 5). The phosphate mass load estimated represents the priority basin's total phosphate mass load between isolated wetlands and groundwater. This calculation produces phosphorus mass load range for the priority basins of 2.6 to 14 metric tons per year with an average of 4.69 metric tons per year.

Based on other studies, if the detention of water in the isolated wetlands is capable of decreasing the mass load approximately 4 to 20 percent then between 0.10 to 2.77 metric tons per year will not reach Lake Okeechobee, see Table 4.1 (Zhang, et al., 2006). South Florida Water Management District studies indicate that small on-site wetlands can potentially remove between 25 to 80% of the phosphorus they receive which would increase the anticipated phosphorus removal seen in Table 4.1 (SFWMD and USEPA, 1999). The Lake Okeechobee Annual Report for 2005 indicated that retaining water on a 410 acre wetland reduces phosphorus by 1.2 metric tons per year, a 71% reduction (Grey, et al., 2005).

Literature estimates for phosphate reduction from water detention in isolated wetlands range from 4 to 80% of the wetlands phosphorus stored in the wetland. With such a broad range it is obvious that more studies are needed to confirm the effectiveness of water detention in isolated wetlands to reduce phosphate loads. However, the reduction of 100 metric tons per year of phosphate that the Lake Okeechobee Action Plan of 1999 discusses is out of the range of the above estimates (SFWMD and USEPA, 1999). SFWMD and USEPA may also have taken into consideration other phosphate BMPs.

Basin Wide Phosphorus Calculations for Drainage Ditches

Similar to isolated wetlands, drainage ditches can serve as a source for phosphorus exchange with groundwater. The phosphate flux measurements obtained from the ditch transect at Pelaez Ranch were used as a representative measurement of phosphate flux along drainage ditches in the Lake Okeechobee priority basins. By using an estimate of the length of ditches in the priority basins and multiplying by the phosphate discharge flux the mass load of phosphate from drainage ditches in the priority basins was estimated. The average and the range of phosphate mass flux from wells PTFM3 to PTFM8, which run parallel to the drainage ditch. To determine the phosphate mass load in the priority basin the total length of drainage ditches was required. Estimates of the total length of drainage ditches were sparse. The greatest ditching density found for unimproved pastures, improve pasture, intensively managed pastures and citrus and row crops was 18 km/km^2 (Haan, 1995). To determine the maximum amount of phosphorus from the drainage ditches it was assumed that all of the area in the priority basins has the greatest ditching density for land uses. By multiplying the ditching density by the area of the priority basins a drainage ditch length of 45,000 km was determined. Steinman and Rosen describe the total linear meters of canals in the watershed north of Lake Okeechobee to be 4,000 km (Steinman and Rosen, 2000). Calculating the mass loads with each estimate of ditch length results in very different numbers. Both estimates of drainage ditch length were used in order to create a range of possible phosphate mass loads from drainage ditches into Lake Okeechobee.

To obtain a mass load, the discharge area the drainage ditches was required. The discharge area was found by using the one meter depth that the PNFM measured and multipling it twice to represent each side of the drainage ditch. This provides a phosphate mass load of 4 and 31 metric tons per year with an average of 18 metric tons per year, Table 4.2.

Using the larger drainage ditch length of 45,000 km, the phosphate mass load range increased to 22 to 362 metric tons per year, see Table 4.3. From the estimates of phosphate loads from drainage ditches in Lake Okeechobee is shown that there was a greater opportunity in reducing the phosphate from drainage ditches than from isolated wetlands.

Conclusions

Using the phosphate flux from the six isolated wetlands studied basin wide estimates for phosphate mass loads from wetlands and drainage ditches were calculated. Using literature as a guide the reduction of phosphate mass loads to Lake Okeechobee from isolated wetlands was calculated. From these calculations it was shown that the drainage ditches and isolated wetlands may contribute the same range of phosphate mass loads to Lake Okeechobee. However depending on the drainage ditch length used the drainage ditches may play a substantially larger part in phosphate mass loads than previously thought. The phosphate mass load from isolated wetlands was calculated to range from 2.6 to 14 metric tons per year while the drainage ditches contributed 2 to 360 metric tons per year. To help reduce the range of phosphate mass load for drainage ditch and provide a more accurate estimate an up to date drainage ditch total length in the priority basins should be established. Also the isolated wetlands and ditches are inundated about 3 months out of the year (SFWMD, 2007). These seasonal variations may decrease the phosphate mass load from both the isolated wetlands and drainage ditch.

By reducing the tributaries with the highest phosphorus loads the most progress will be seen in restoring Lake Okeechobee's water quality. Hiscock reported a change in phosphorus retention in wetlands from 61% in 1991 to 31% in 2003 and blamed decreased phosphate assimilation potential for the reduction (Hiscock, et al., 2003). Thus the wetland soils phosphate assimilation capacity may need to be taken into consideration during further studies. Rapid, inexpensive soil tests, such as tests for phosphate and organic matter testing for bioavailable phosphate in top sediments, could be used on drainage ditch sediments to identify the areas with greater potential to release or retain phosphate (Sallade and Sims, 1997). Further field studies involving the PNFM can help to narrow the range of phosphate mass loading and reduction. The use of PNFM before and after a detention structure is erected at an isolated wetland can provide a more accurate picture of the effects an isolated wetland has on phosphorus loading.

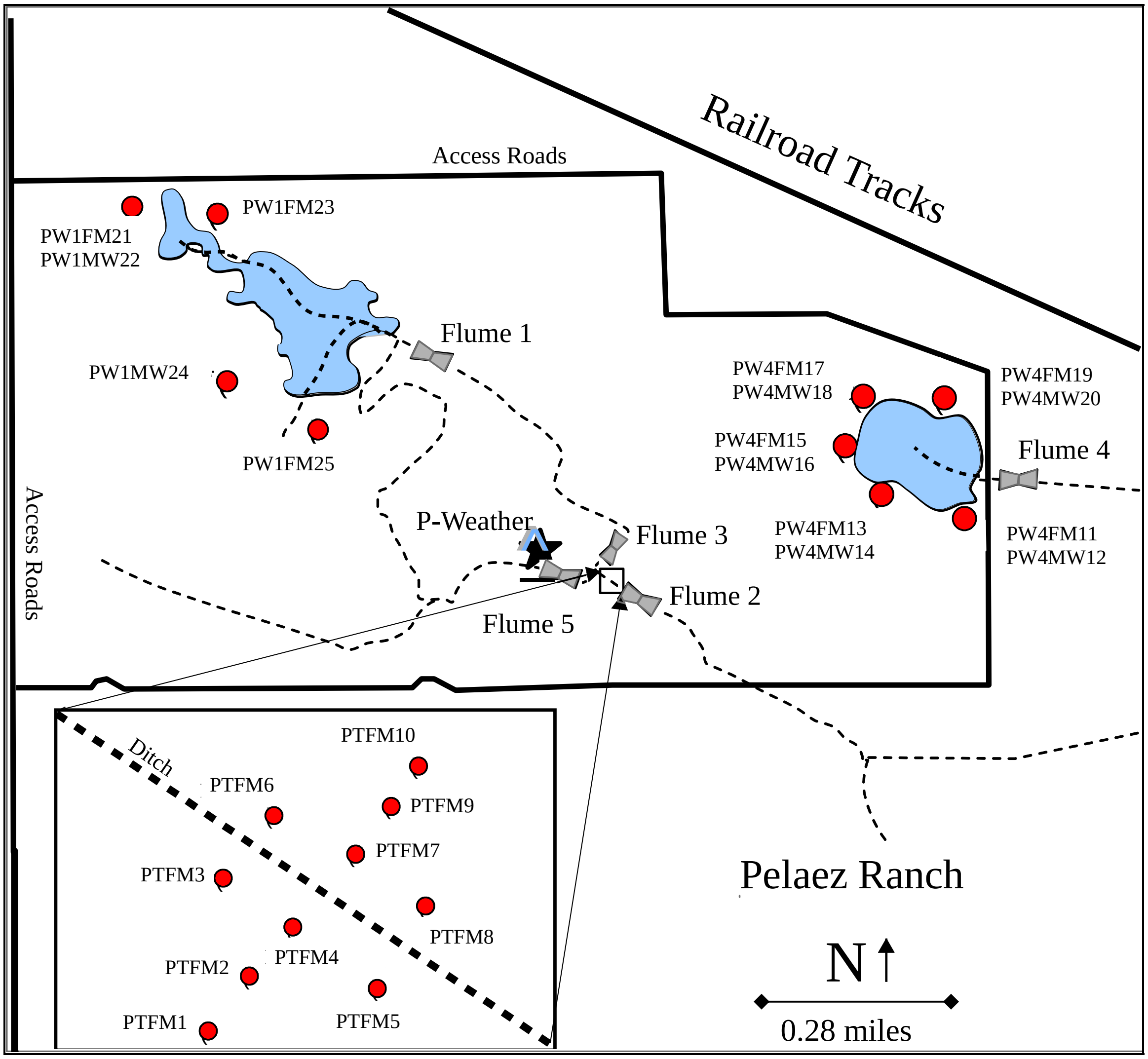

Figure 1: Pelaez Ranch - All the flux meter (FM) well contained PNFM and only wetland 4 contained a transducer in the wetland.

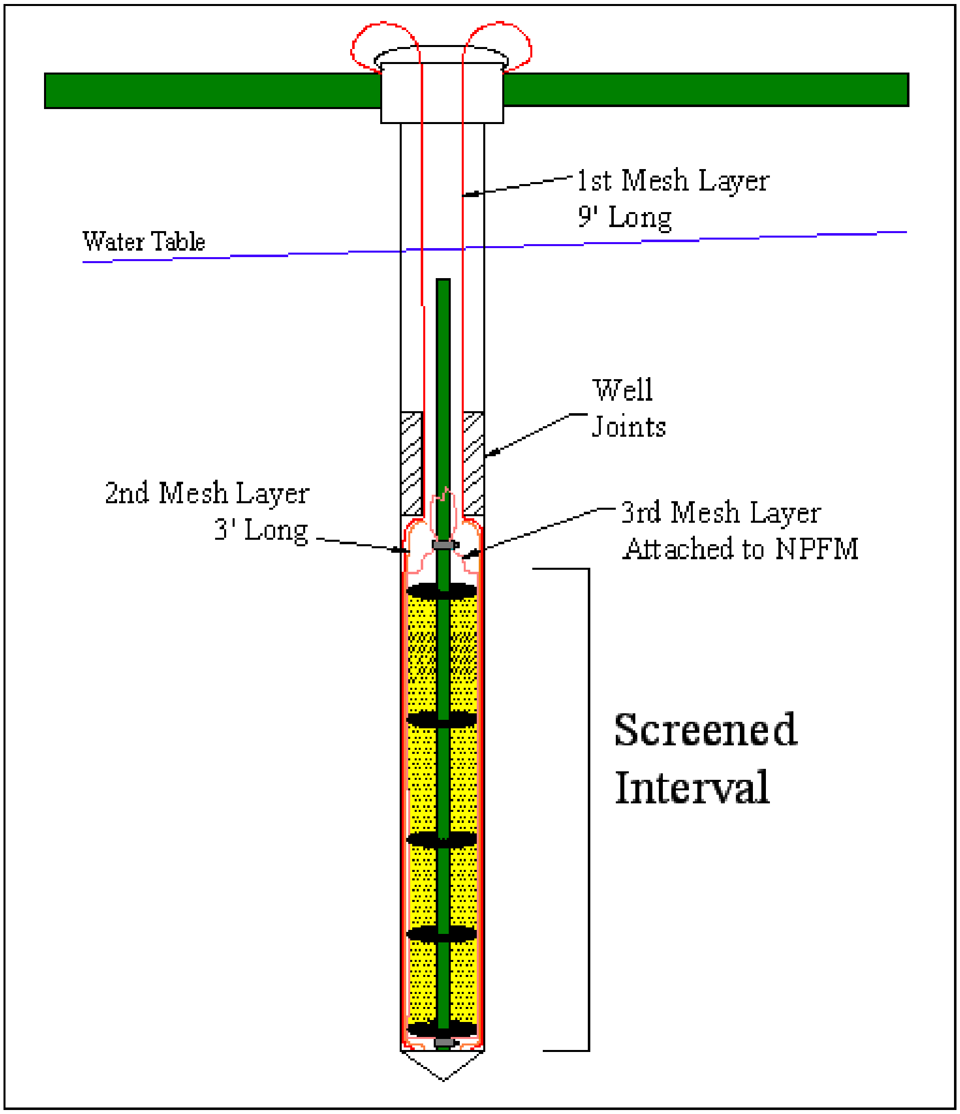

Figure 2: Cross section of PNFM installation at Pelaez Ranch.

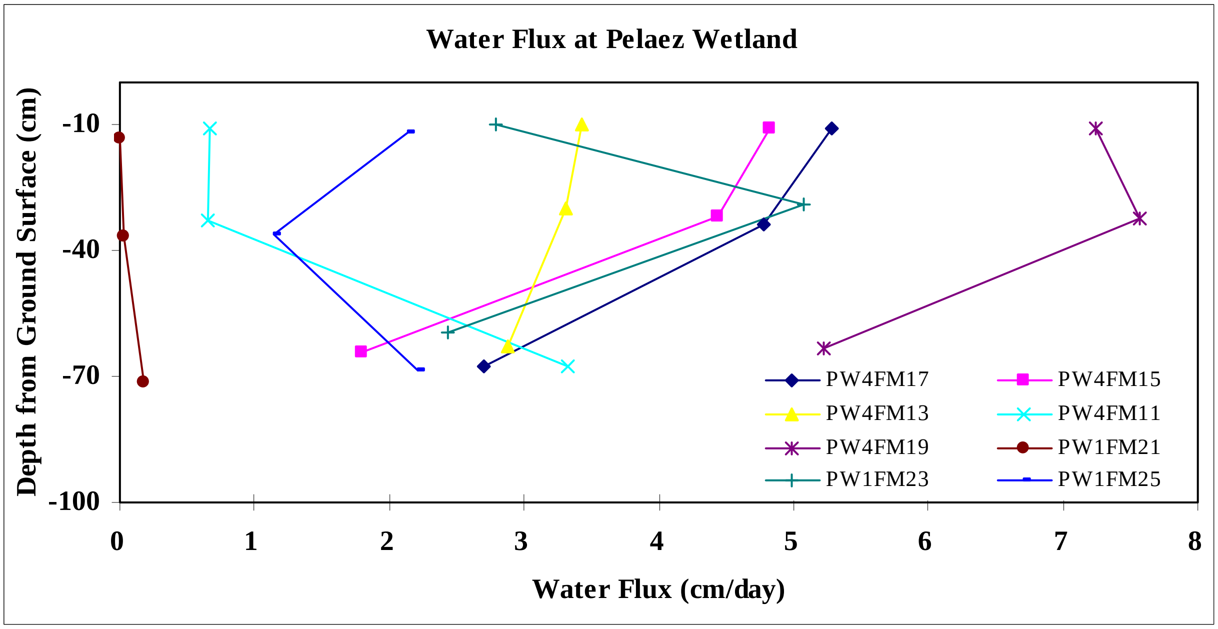

Figure 3: Water flux verse depth at Pelaez wetland for each well location.

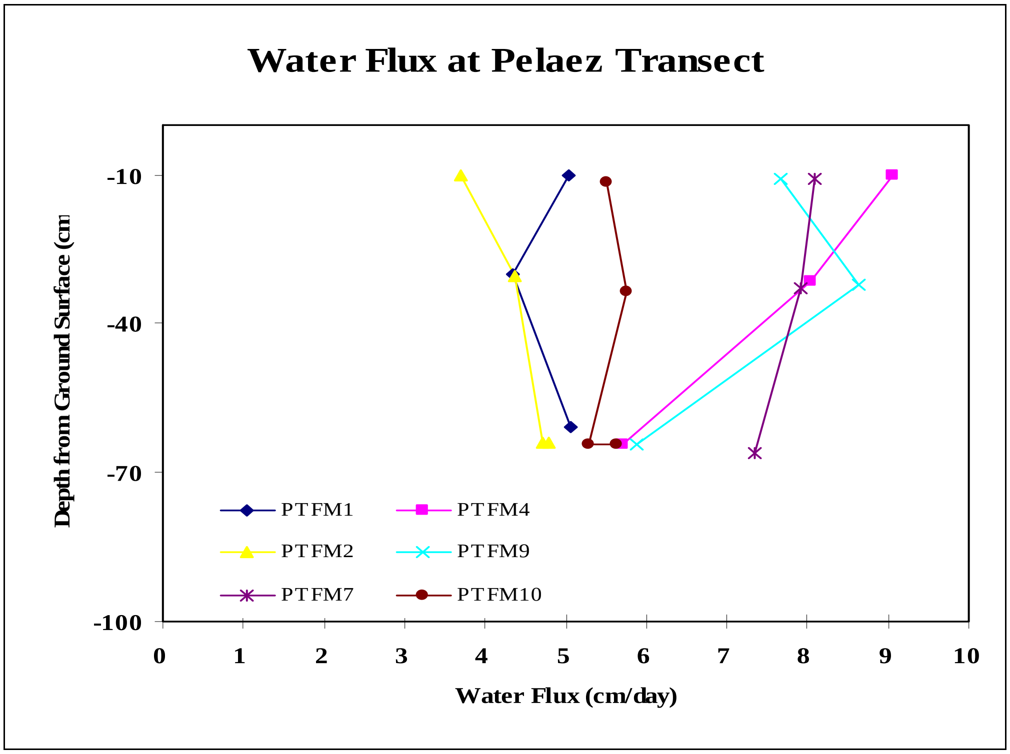

Figure 4: Water flux verse depth at Pelaez transects along the ditch.

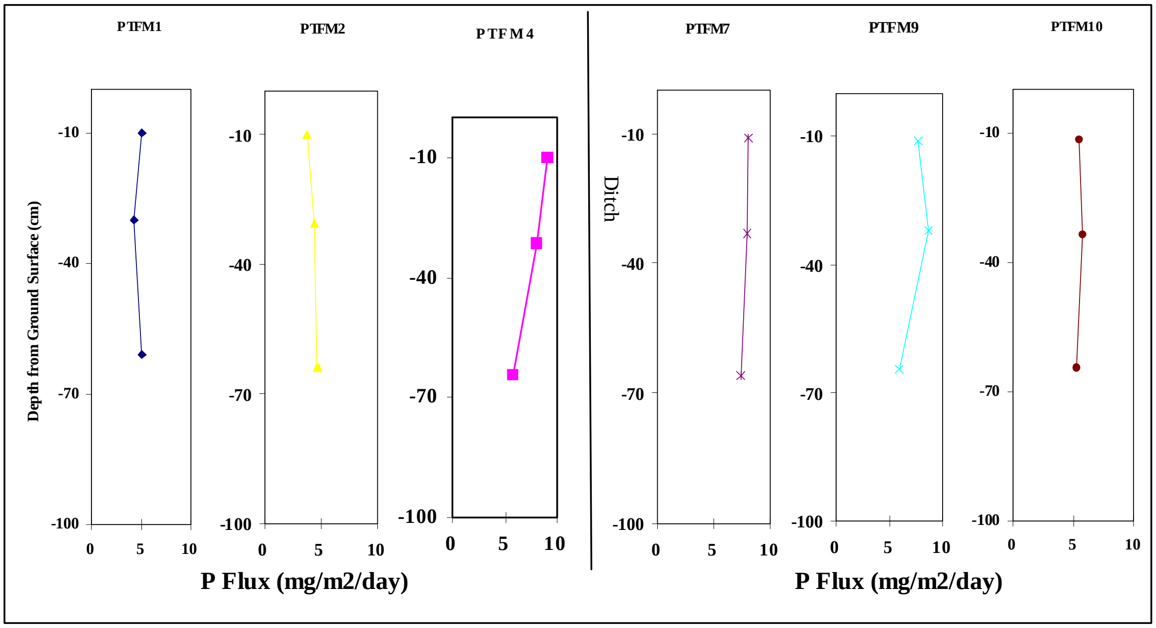

Figure 5: Water flux verse depth at Pelaez transect crossing the ditch.

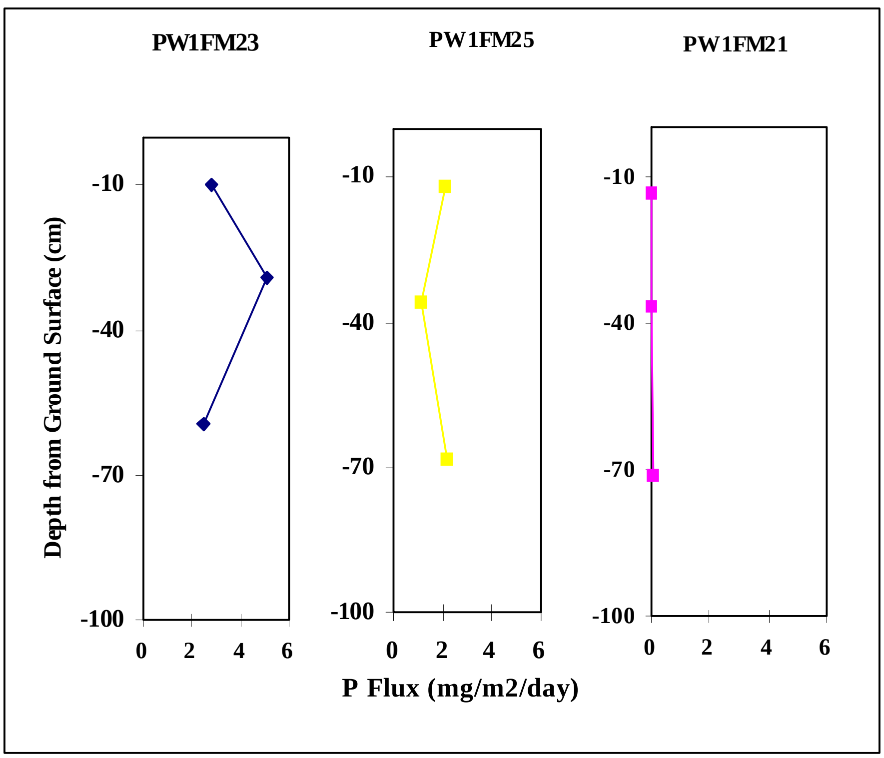

Figure 6: Pelaez wetland 1 phosphate flux verse depth at each well location.

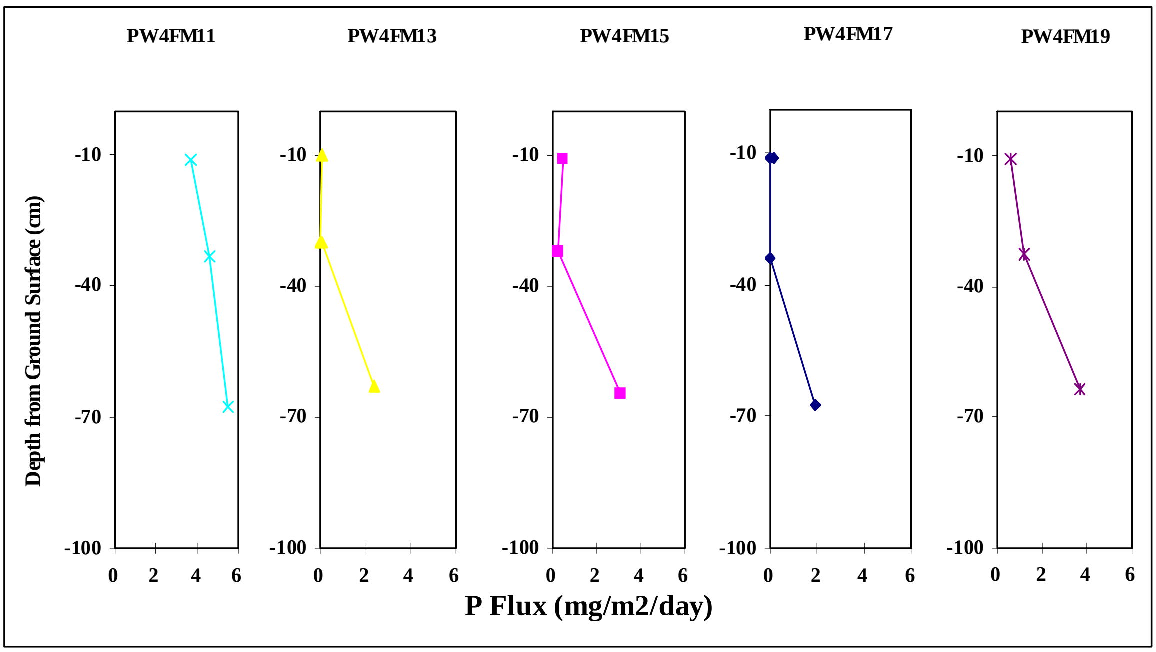

Figure 7: Pelaez wetland 4 phosphate flux verse depth at each well location.

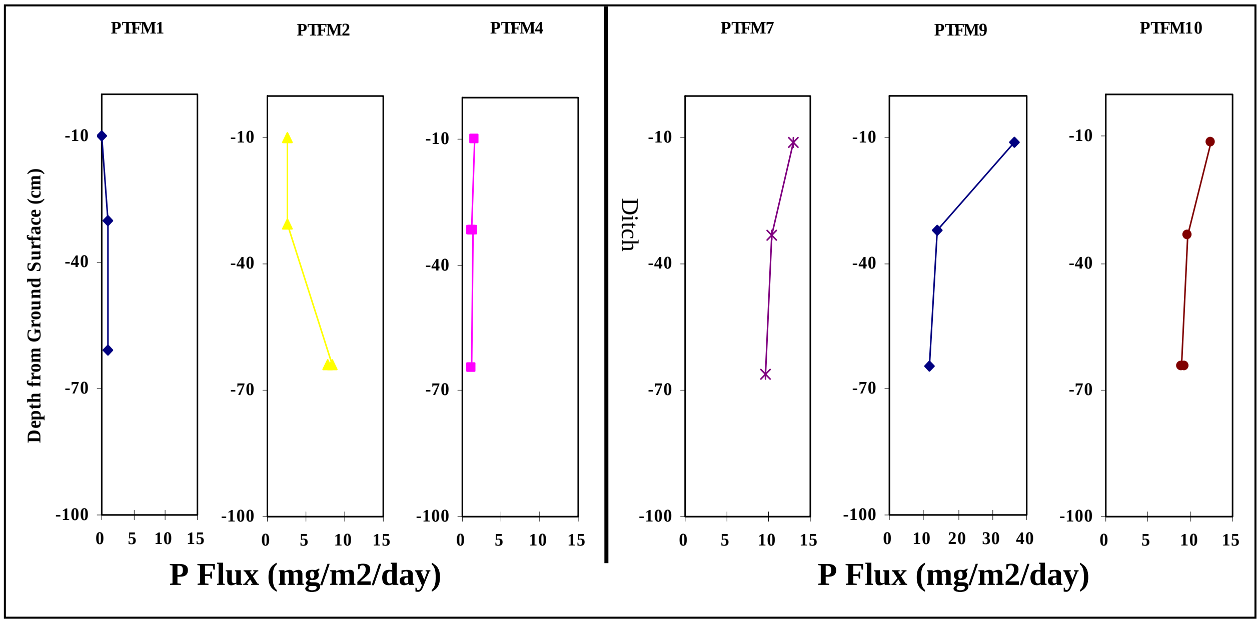

Figure 8: Pelaez transect phosphate flux verse depth at each well location. Note: The axis for phosphate flux on well PTFM9.

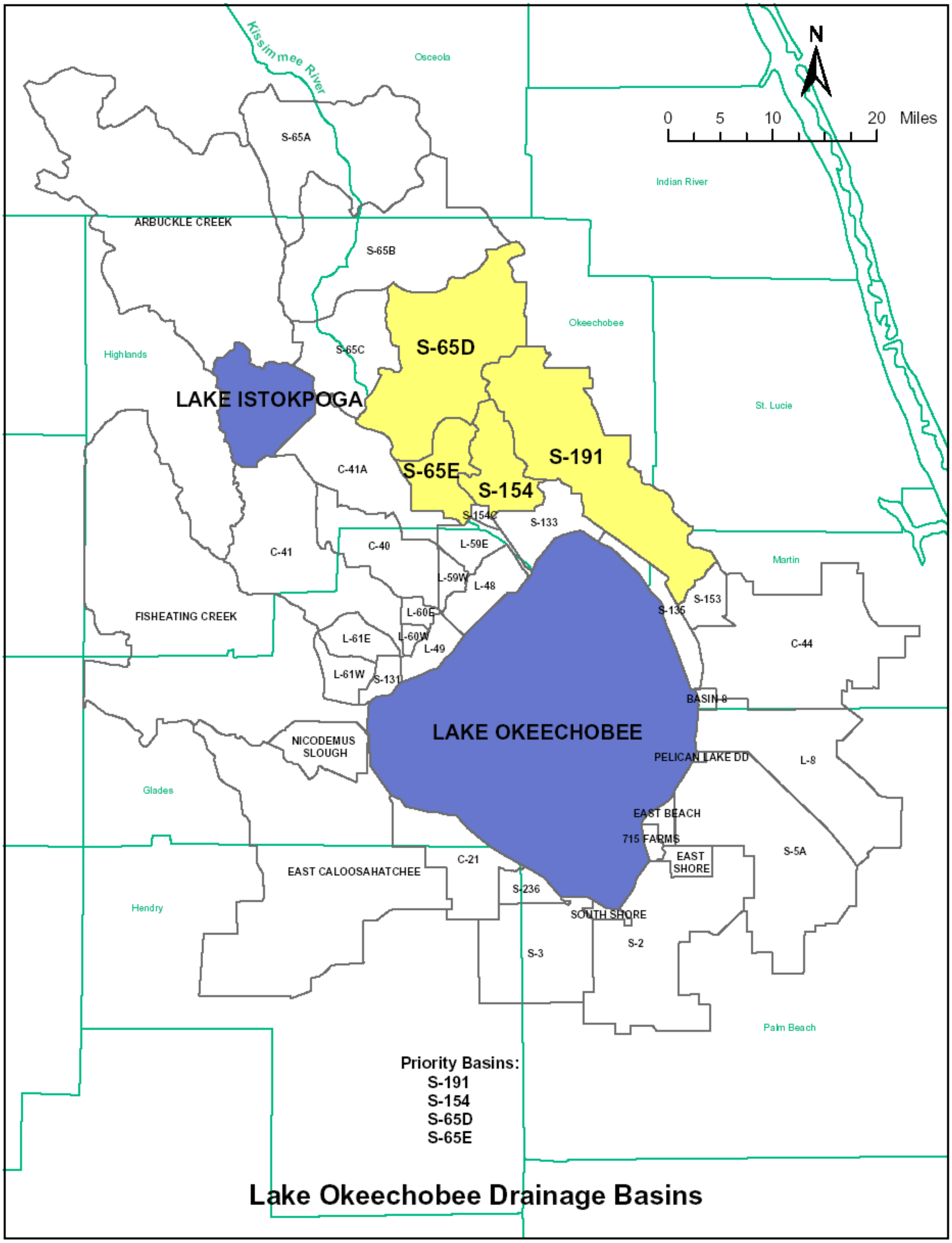
Kissimmee River
Osceola
N
0 5 10 20 Miles
Indian River
S-65A
ARBUCKLE CREEK
S-65B
Okeechobee
Highlands
S-65C
S-65D
LAKE ISTOKPOGA
St. Lucie
S-191
C-41A
S-65E
S-154
S-154C
S-133
C-41
C-40
L-59E
Martin
L-59W
L-48
S-153
S-135
FISHEATING CREEK
L-60E
L-61E
L-60W
C-44
L-49
L-61W
S-131
BASIN 8
NICODEMUS SLOUGH
LAKE OKEECHOBEE
PELICAN LAKE DD
L-8
Glades
EAST BEACH
715 FARMS
S-5A
C-21
EAST SHORE
EAST CALOOSAHATCHEE
S-236
Hendry
SOUTH SHORE
S-2
S-3
Palm Beach
Priority Basins:
S-191
S-154
S-65D
S-65E
Lake Okeechobee Drainage Basins

Figure9: Lake Okeechobee drainage basins. The yellow basins are priority basins (SFWMD, 2007).

Wetland ID	J_{c*} mg/m^2/day	Mass Load mg/day	Mass Load Average of Well mg/day	Mass Load Average of Wetland mg/day
PW1FM25	2.1	3921.9		
	1.1	2100.3		
	2.2	4041.6		
	1.8	3247.3		
	1.7	3129.7	3288.2	
PW1FM23	2.8	5112.5		
	5.1	9296.0		
	2.4	4439.8		
	3.4	6282.8	6282.8	
PW1FM21	0.0	0.0		
	0.0	0.0		
	0.0	66.6		
	0.2	323.6		**PW1**
	0.1	130.1	104.1	3225.0
PW4FM19	0.6	593.3		
	1.2	1148.7		
	3.7	3565.6		
	1.8	1769.2	1769.2	
PW4FM17	0.2	172.2		
	0.0	0.0		
	0.0	0.0		
	1.9	1897.0		
	0.6	632.3	540.3	
PW4FM15	0.5	466.3		
	0.2	193.7		
	3.1	2976.2		
	1.2	1212.0	1212.0	
PW4FM13	0.0	38.1		
	0.0	35.1		
	0.1	73.4		
	2.4	2319.3		
	0.8	809.3	655.0	
PW4FM11	3.7	3644.9		
	4.6	4472.2		
	5.5	5410.2		**PW4**
	4.6	4509.1	4509.1	1447.6

Table 1: Mass flux for each section in each PNFM and mass load estimates using the areas of the wetland.

Wetland	Average Phosphate Mass Load g/day
LW1	2.74
LW2	1.24
BW1	1.26
BW2	0.82
PW1	3.23
PW4	1.45

Table 2: Summary table of the average phosphate mass load per wetland (LW – Larson wetland; BW – Beaty wetland)..

Wetland	Gradient In days	Gradient Out days	Phosphate In grams	Phosphate Out grams	Cumulative Phosphate grams
LW1	4.0	30.0	11.0	82.2	93.1
LW2	1.5	32.5	1.9	40.2	42.1
BW1	4.0	30.0	5.1	37.9	43.0
BW2	1.0	33.0	0.8	27.0	27.8
PW4	0.0	33.0	0.0	47.8	47.8

Table 3: Number of days water gradient was into and out of the wetlands and grams of phosphate measured throughout deployment period.

Wetlands	PNFM Measurement Mass Flux mg/m2/day	Mass Flux found from Darcy Velocity and TP Concentration mg/m2/day
LW1	7.46	64.06
LW2	2.09	8.02
BW1	2.83	14.82
BW2	1.83	7.22
PW1	1.75	--
PW4	1.74	0.12
Average	2.71	5.898

Table 4: Mass flux measurements estimated from the PNFM and gradient calculations.

Phosphate Mass Flux Range	Phosphate Mass Load Range
mg/m2/day	(metric tons/year)
1.50	2.59
2.71	4.69
8.00	13.84

Table 5: Basin wide estimates of phosphate mass loading and reduction from isolated wetlands.

Phosphate Mass Flux Range	Phosphate Mass Load Range (Using two 1 meter cross sections)
mg/m2/day	(metric tons/year)
1.36	3.97
6.32	18.46
10.93	31.91

Table 6: Basin wide estimates of phosphate mass loading from drainage ditches using a conservative drainage ditch length.

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