Final report

Limnological health assessment of Seven Sanibel Island ponds

Final report submitted to:
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A. Introduction

Seven ponds located within the barrier island of Sanibel, Collier County, Florida, were selected to be studied for their water quality and sediment characteristics. Such ponds besides one (Beach Villa) have a long history of cultural eutrophication and are, as such, a major concern for the City of Sanibel Island.

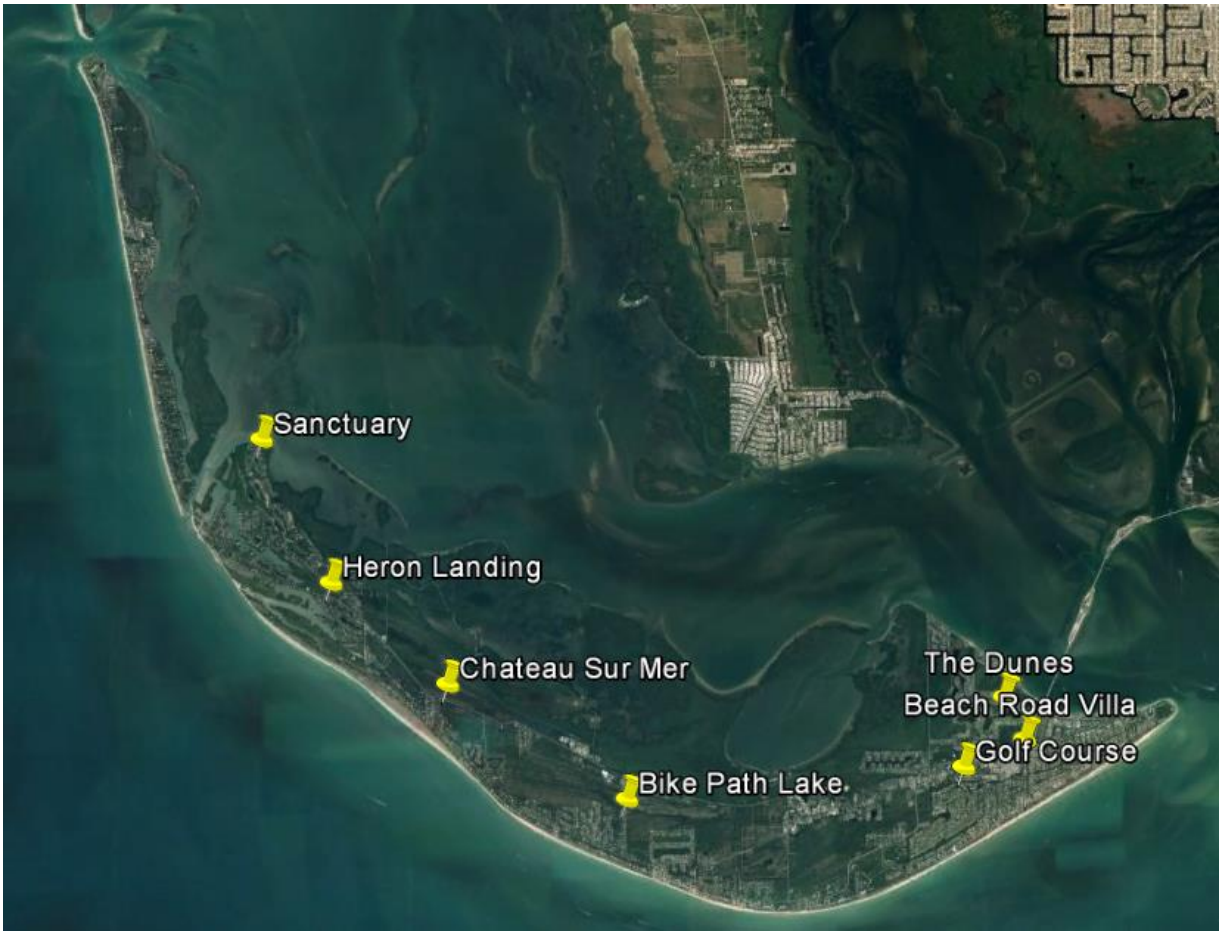


Figure 1.Ponds studied within Sanibel Island. Photo courtesy of Google Earth Pro.

B. Objectives

The objectives were to i) survey the ponds for their bathymetry, bottom hardness and submerged aquatic vegetation (SAV) using Sonar technology then to ii) select water quality and sediment coring stations so that iv) water quality be assessed once in a year in the heart of the dry season and iv) that the sediment/floc be characterized for thickness as well as nutrients contents. The City of Sanibel would then use such data summarized in this report to develop management plans customized for each pond.

C. Pond mapping

1. Methods

The bathymetry, bottom hardness and submerged aquatic vegetation (SAV) cover were done from a boat equipped with a Lowrance HDS 7 sonar connected to a 200 Khz transponder placed about 10cm below the surface. The boat traveled throughout each pond by making concentric paths which distance between paths varied from 5m to 25m depending on the pond's surface area. The position of the transponder below the surface was compensated for when the maps were generated using the Kriging method (linear variogram using an interpolation grid made of square cells of 0.5m) using the software Surfer 12 (www.goldensoftware.com). Sonar depths below 0.5m to 0.7m were automatically rejected because of the high noise generated by the transponder in very shallow water. The elevation of the surface of the pond was measured with a Trimble™ 3D R8 GNNS the day the bathymetry was made so that all depths referenced initially to the water surface were adjusted to NAVD'88 elevation. A wooden post made of a 2 by 4 treated lumber was also placed in the pond the day of the sonar deployment (the yellow star in all maps generated) and its apex NAVD'88 elevation was also determined so that a staff gage can be affixed to it on a later date. Once the bathymetric map done, volume and surface computations against a known NAVD'88 elevation of the water surface were made to generate NAVD'88 to volume, surface area and mean depth conversions (see in Appendix 1 for such relationships). The bathymetric maps were used to select the water quality station so that it would be placed in the deepest locale of the pond (yellow diamond in the maps).

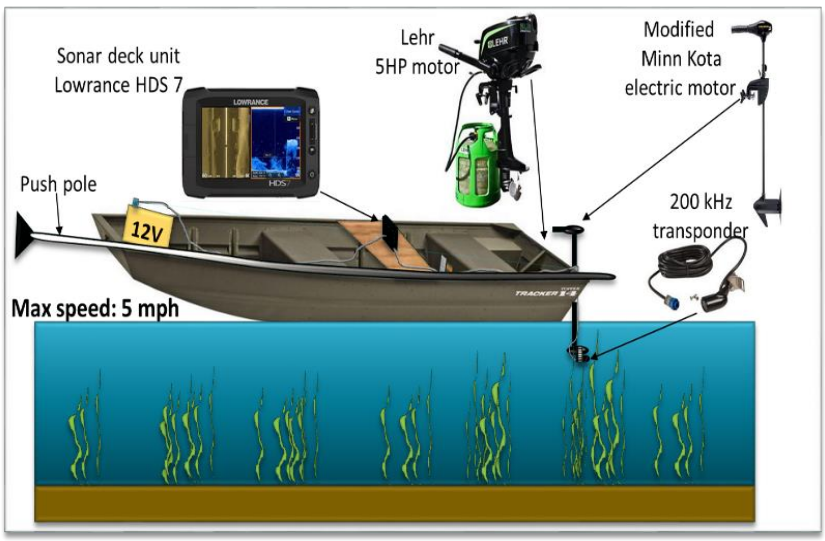


Figure 2. Sonar and boat setup. In addition, a Trimble 3D R8 GNNS was used to determine the NAVD'88 elevation of the surface water the day of the bathymetry.

Bottom hardness was determined by applying the proprietary algorithms from www.cibiobase.com. The hardness is a relative value running from 0 (very soft) to 1 (very hard) which reflects the sediment thickness located on the pond's bed in shallow water. Because the frequency used by the transponder, the signal is strong enough to penetrate well the sediment when the water is ideally less than 2-3m deep. For better penetration of the echo generated by the sonder, a lower frequency transponder should normally be used but this transponder could not then be used to determine SAV cover. The sharpness of the echo on the bottom is evaluated by the algorithm so that bottom hardness (sharp echo on the bottom= high hardness) is

estimated. Bottom hardness is not determined when too much SAV is present so that those sounding points are dropped automatically by the algorithm. The bottom hardness map was used to select the positions of the coring stations.

SAV was determined by measuring the SAV's height (as measured by the echo of the acoustic signal sent through the water column) and the its relative height compared to the water depth. As such a plant that would occupy 80% of the water column would return an 80% biovolume SAV.

2. Maps

i. Beach Villa pond

When visited, Beach Villa pond surface water was 0.247m NAVD'88. The volume of the pond was then 414m^3 for a planar surface area of 522m^2 and a mean depth of 0.8m.

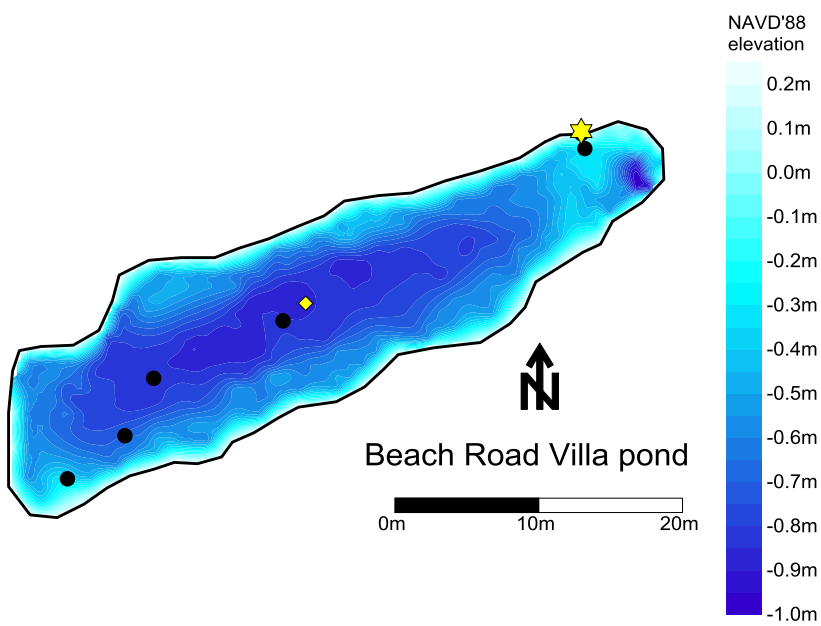


Figure 3. Bathymetry of Beach Villa pond.

The average bottom hardness of Beach Villa pond was around 0.3. The yellow portion of the map (bottom hardness around 0.3) is most accurate as the softer surrounding sediment around was extrapolated since the algorithm ran dropped out most of the depths in the shallow portion of the pond or when SAV was present. The SAV cover was found especially in the northeast corner as well as in the deepest portion of the pond.

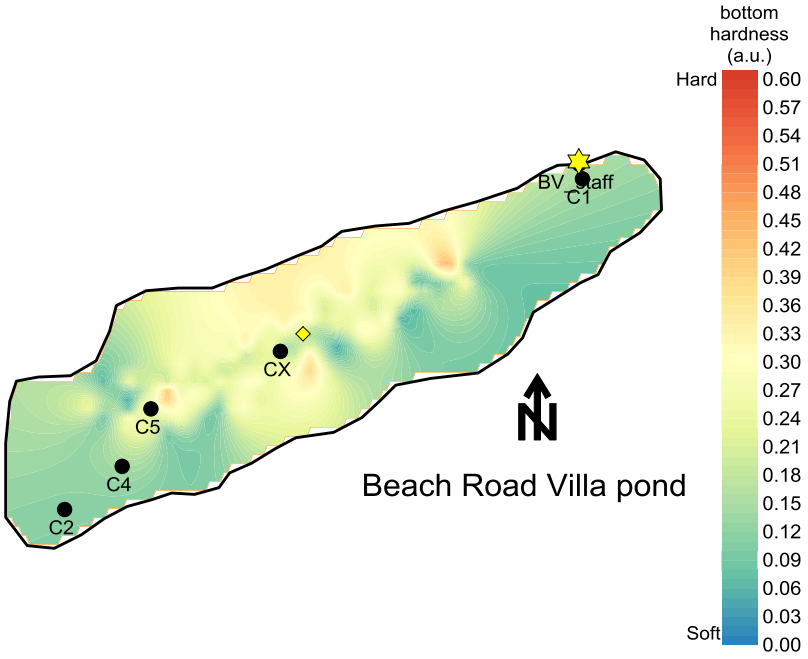


Figure 4. Bottom hardness of Beach Villa pond

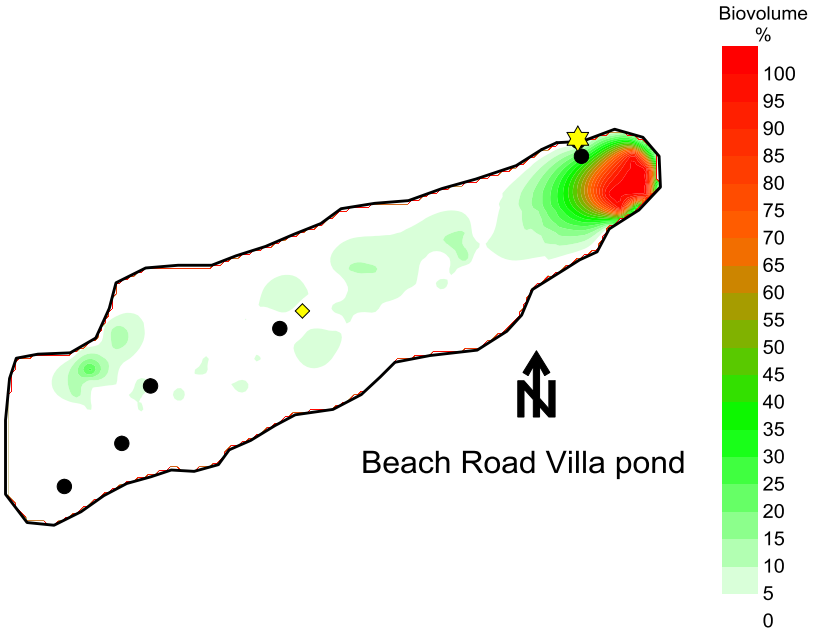


Figure 5. SAV cover in Beach Villa pond

ii. Bike Trail pond

When visited, Bike Trail pond surface water was -0.5m NAVD'88. The volume of the pond was then 27,055m^3 for a planar surface area of 15,007m^2 and a mean depth of 1.8m. The average bottom hardness of Bike trail pond was 0.39 as calculated with surfer and this was quite uniform all over the pond. The SAV cover was very sparse and limited to the shelf.

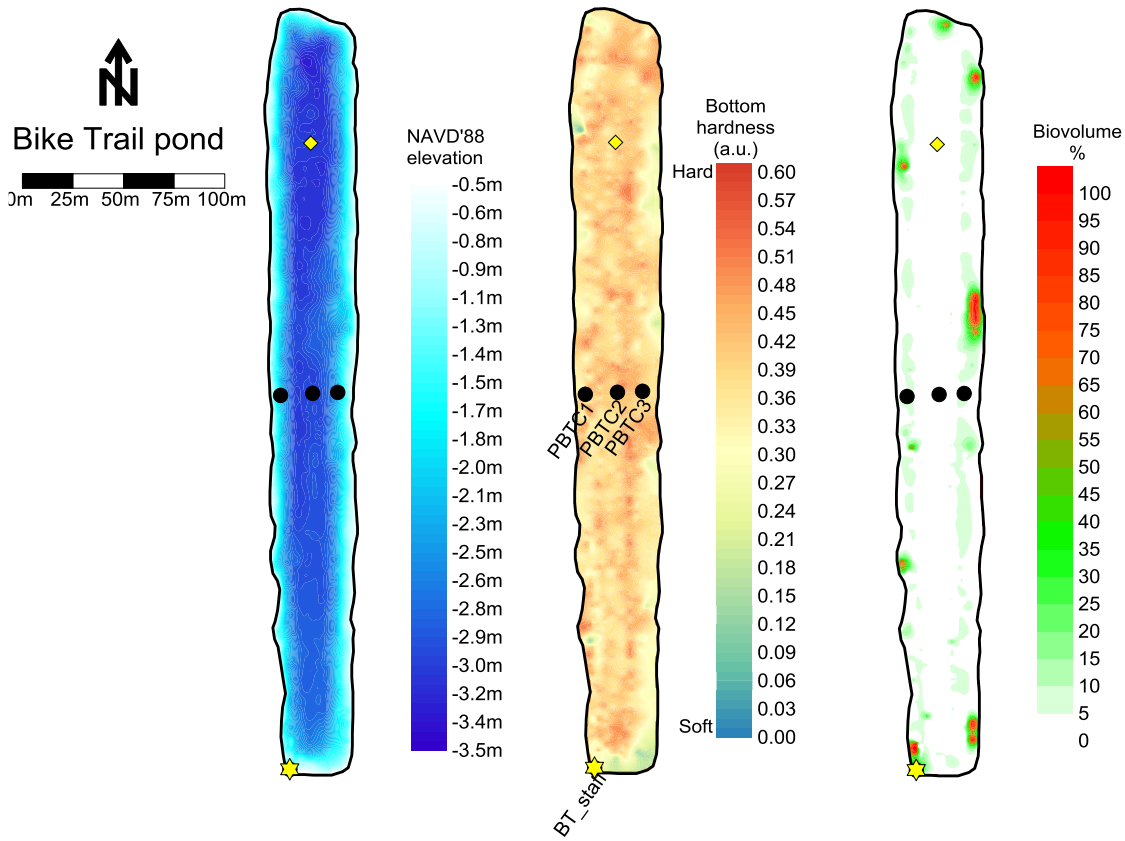


Figure 6. From left to right Bathymetry, bottom hardness and SAV cover of Bike Trail pond

iii. Chateau-Sur-Mer pond

When visited, Chateau-Sur-Mer pond surface water was -0.27m NAVD'88. The volume of the pond was then 9,791m^3 for a planar surface area of 8,219m^2 and a mean depth of 1.2m.

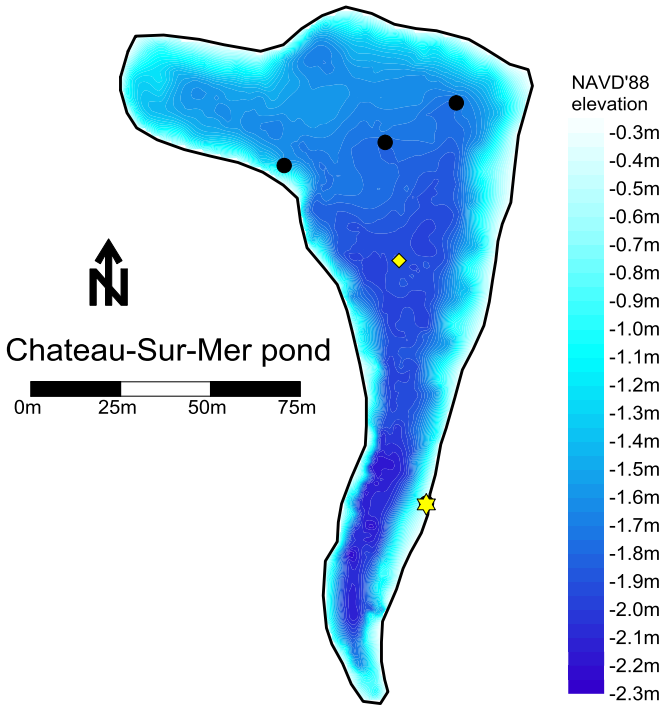


Figure 7. Bathymetry of Chateau-Sur-Mer pond

The average bottom hardness of Chateau-Sur-Mer pond was 0.37 as calculated with surfer and this was quite uniform all over the pond beside at the vicinity of the north east and central west corners where the hardness was around 0.09-0.15. SAV cover was found in very localized spots of the shelf as well as in low density in the deepest portions of the pond

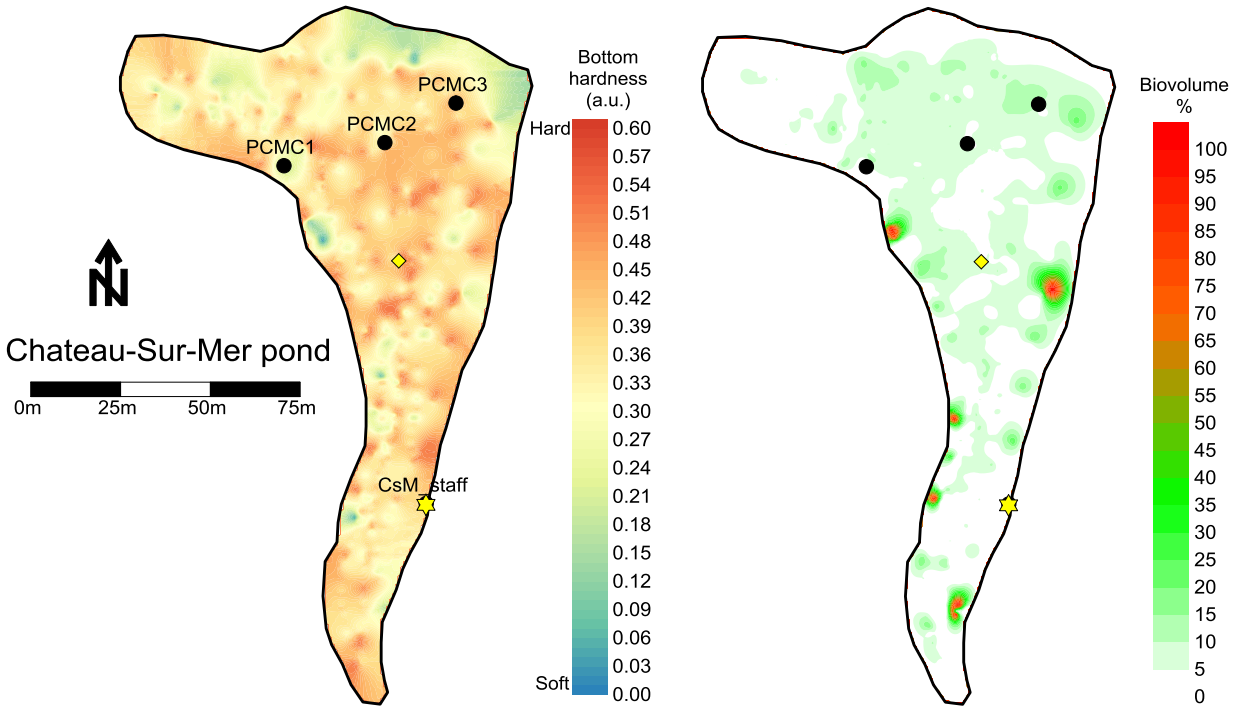


Figure 8. From left to right, bottom hardness and SAV cover in Chateau-Sur-Mer pond

iv. Golf Course pond

When visited, Golf Course pond surface water was 0.247m NAVD'88. The volume of the pond was then 12,679m^3 for a planar surface area of 8,218m^2 and a mean depth of 1.6m.

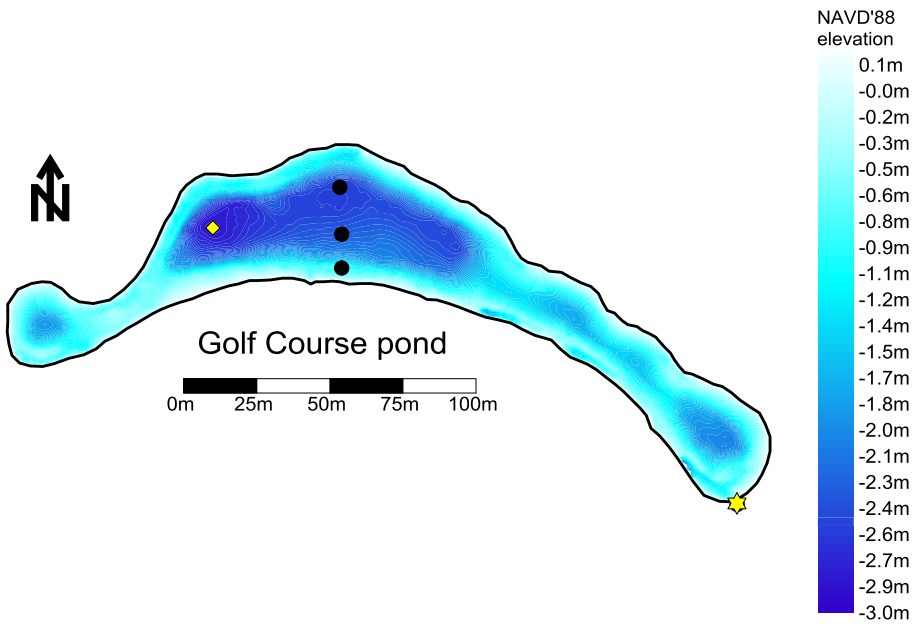


Figure 9. Bathymetry of Golf Course pond

The average bottom hardness of Golf Course pond was 0.47 as calculated with surfer with harder bottom (0.49) on the littoral zone and softer sediment (038) in the deepest portions.

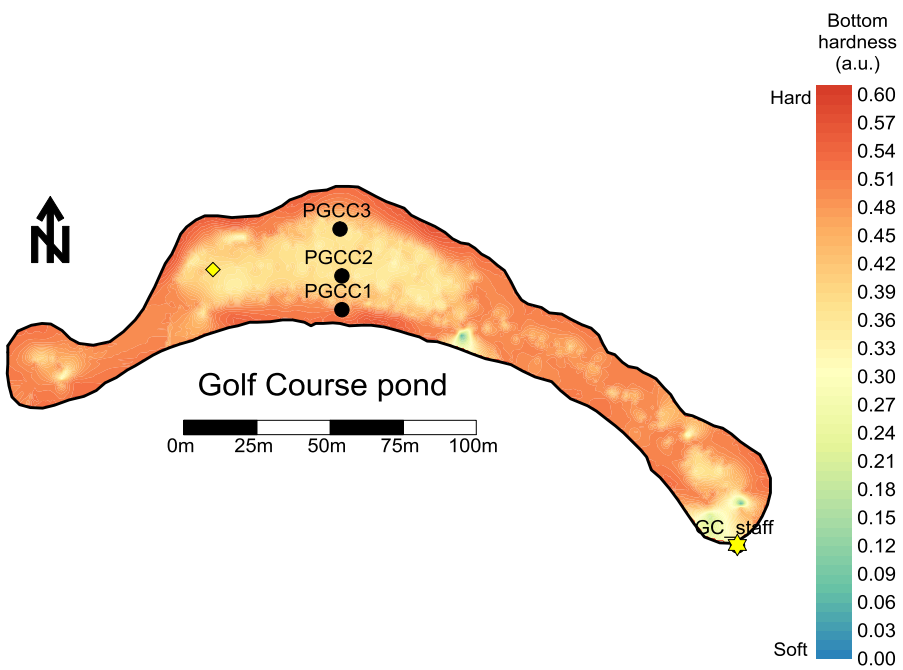


Figure 10. Bottom hardness of Golf Course pond

SAV cover was found in good density on the shelf but not in the deepest portions of the pond.

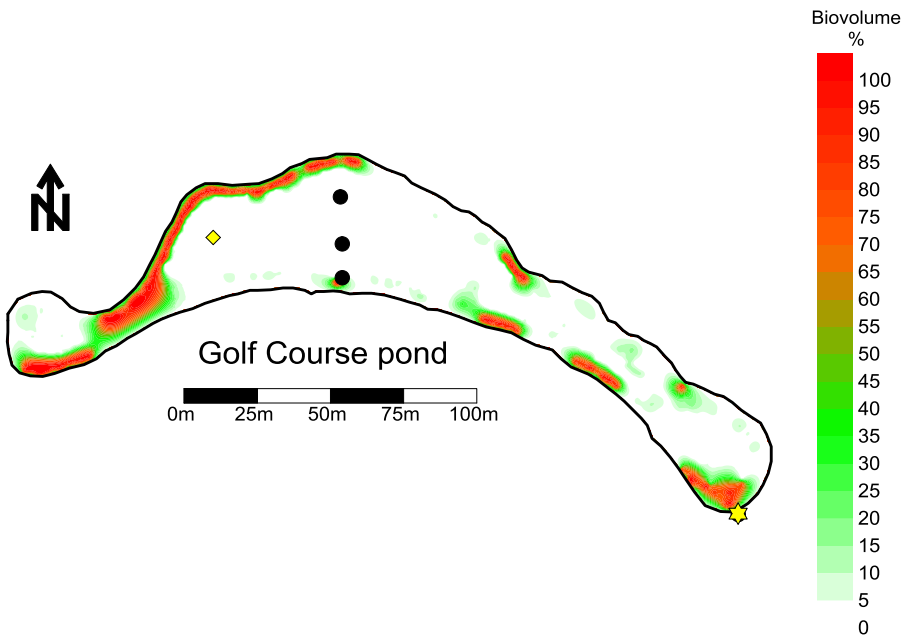


Figure 11. SAV cover in Golf Course pond

v. Heron landing pond

When visited, Heron Landing pond surface water was -0.17m NAVD'88. The volume of the pond was then 8,595m^3 for a planar surface area of 4,774m^2 and a mean depth of 1.9m.

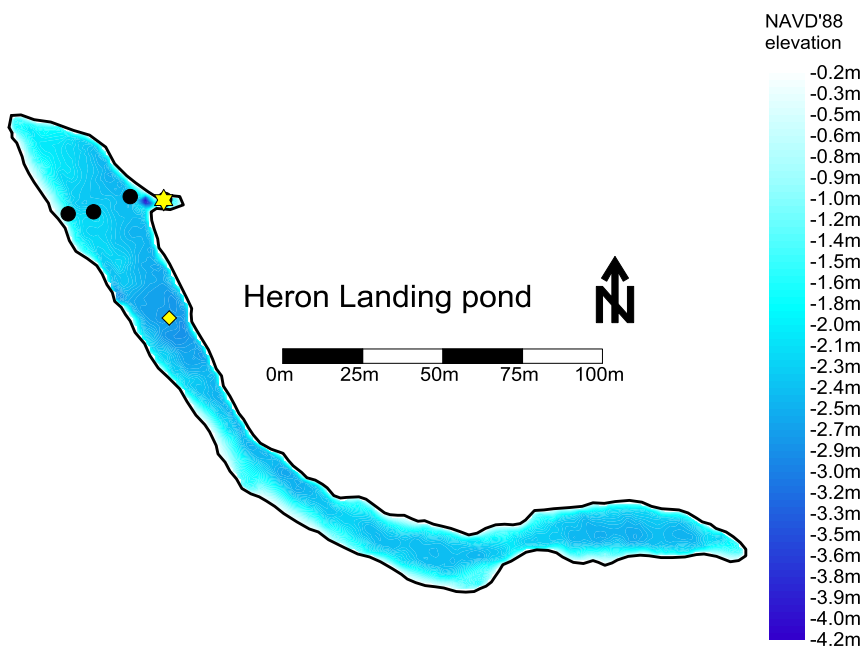


Figure 12. Bathymetry of Heron Landing pond

The average bottom hardness of Heron Landing pond was 0.44 as calculated with surfer and its bottom was harder than its shelf. SAV cover was found intermittently on the shelf but not in the deepest portions of the pond.

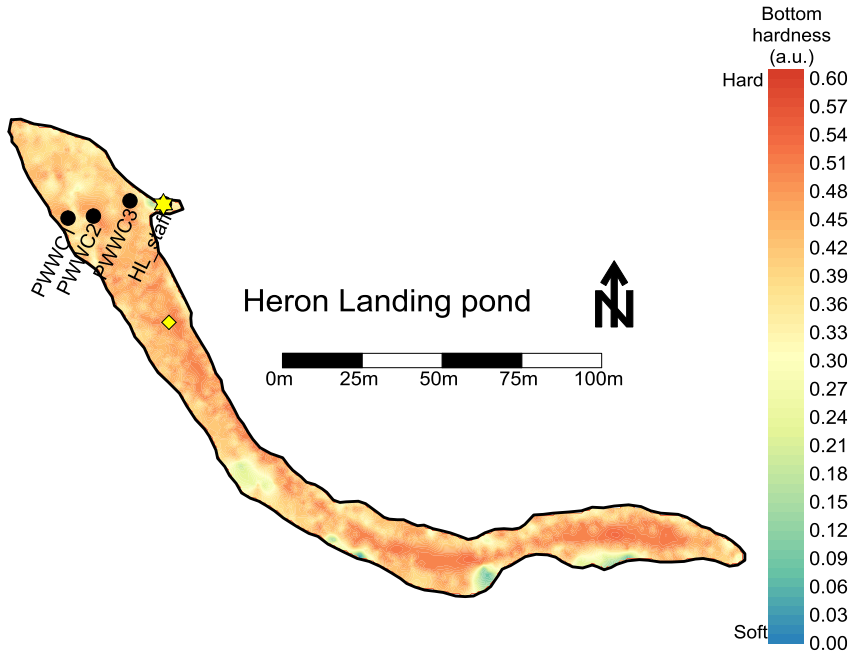


Figure 13. Bottom hardness of Heron Landing pond

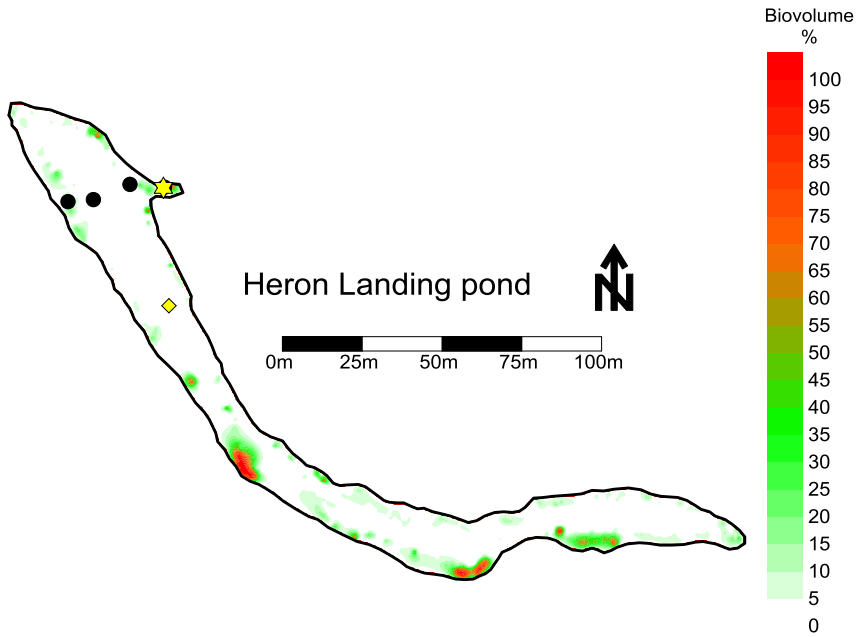


Figure 14. SAV cover in Heron Landing pond

vi. Sanctuary pond

When visited, Sanctuary pond surface water was 0.17m NAVD'88. The volume of the pond was then 9,007m^3 for a planar surface area of 4,540m^2 and a mean depth of 2.1m.
The average bottom hardness of Sanctuary pond was 0.42 as calculated with surfer and quite uniform all over beside its central east shore which had softer bottom (0.14).
SAV cover was mainly found on the shelf and especially on the eastern side of the pond.

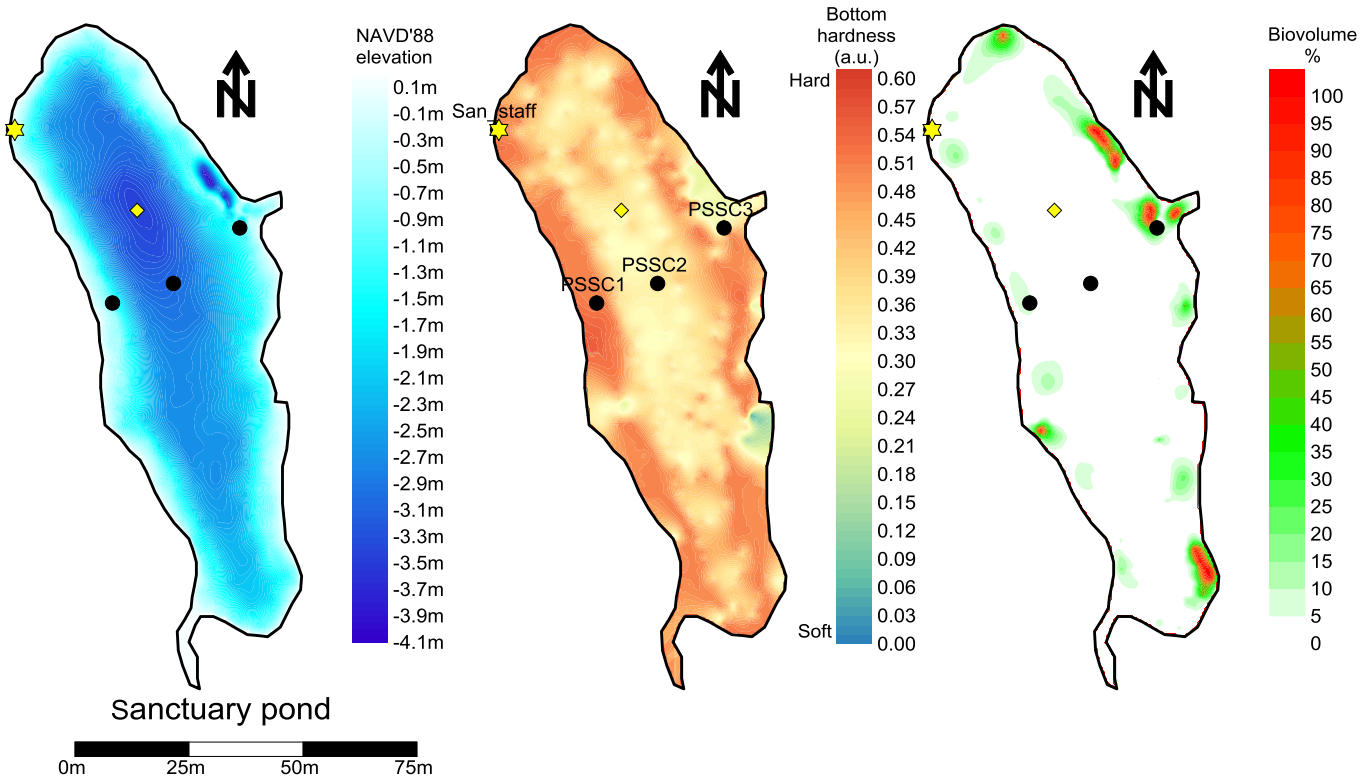


Figure 15. From left to right Bathymetry, bottom hardness and SAV cover of Sanctuary pond

vii. The Dunes pond

When visited, The Dunes pond surface water was 0.103m NAVD'88. The volume of the pond was then 207,700m^3 for a planar surface area of 81,404m^2 and a mean depth of 2.6m.

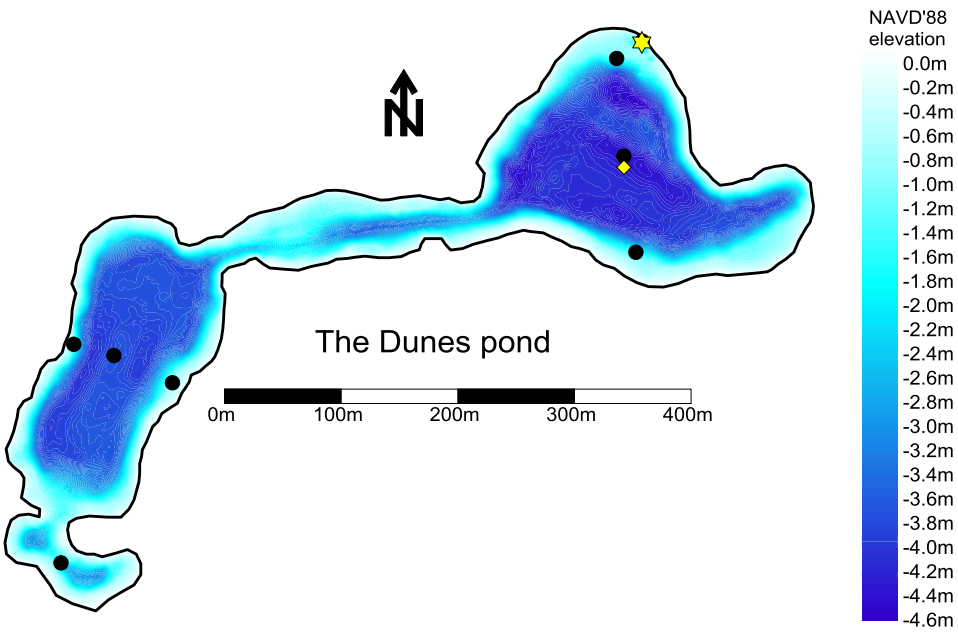


Figure 16. Bathymetry of The Dunes pond.

The average bottom hardness of The Dunes pond was 0.41 as calculated with surfer. Its shelf was considerably harder (0.5) than its deeper portions (0.3).

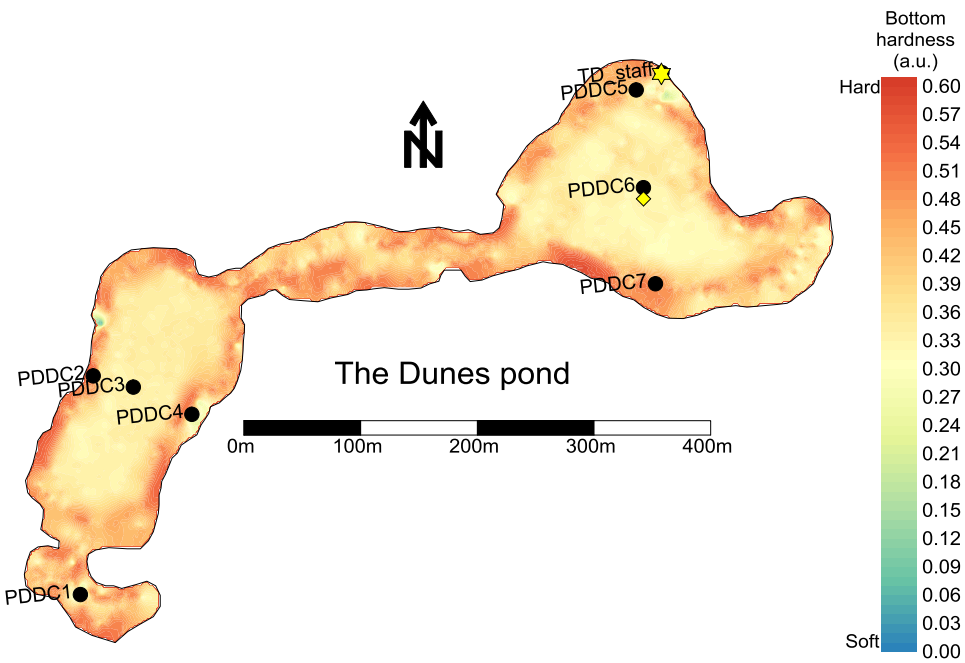


Figure 17. Bottom hardness of The Dunes pond

SAV cover was very sparse as SAV was found mainly in one spot of the north of the pond on the shelf and in the south central portion of it. Further, sporadic SAV was found in the center of the extreme south portion of the pond.

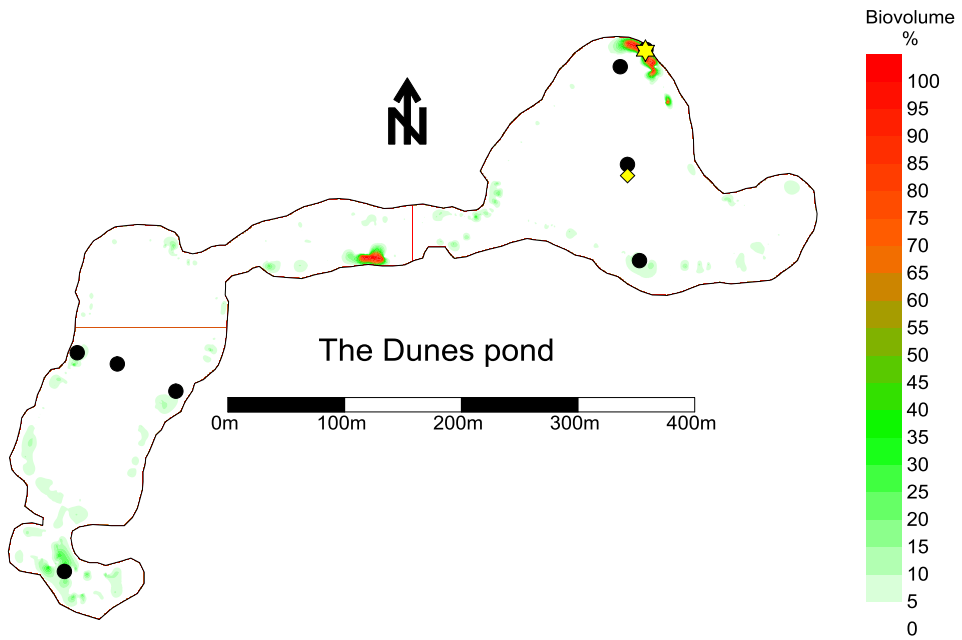


Figure 18. SAV cover in The Dunes pond

3. Conclusions

Most ponds had their water level close to 0m NAVD'88, however some ponds were substantially lower than 0m NAVD'88. Bike Trail pond was especially the lowest, followed by Chateau-Sur-Mer and Heron Landing. The other ponds had positive elevations with the Beach Villa and Golf course being the highest followed by Sanctuary and The Dunes.

The largest pond is by far The Dunes followed by Bike Trail, while Golf Course, Chateau-Sur-Mer, Sanctuary and Heron Landing are all around one hectare. Beach Villa pond is the smallest.

All ponds are shallow but the Dunes is the deepest pond followed by Sanctuary, Heron Landing and Bike Trail around 2m average depth while Chateau-Sur-Mer and especially Beach Villa are around 1m deep.

Golf course pond has the hardest bottom especially because of its shelf while Sanctuary, The Dunes, Bike Trail and Chateau-Sur-Mer had similar bottom hardness and spatial variation. Heron Landing was unique in the fact that its bottom was harder than its shelf. Beach Villa had the softest sediment but its hardness was hard to determine since nearly all the shelf data were missing in the interpolation.

Finally, SAV cover was the highest in Golf Course and Sanctuary, especially on the shelf while it was poor in all the other ponds besides Beach Villa (spotty high density on the shelf) and Chateau-Sur-Mer which had quite homogenous but low density SAV on its deepest portion.

	Elevation	Volume	Planar area	Mean depth	bottom hardness	SAV
Ponds	NAVD'88 (m)	m^3	m^2	m	a.u.	%
Beach Villa	0.247	414	522	0.8	~0.3	spotty on shelf, sparse in deep portion
Bike Path Trail	-0.5	27,055	15,007	1.8	0.39	spotty to sparse on shelf
Chateau sur Mer	-0.27	9,791	8,219	1.2	0.37	spotty on shelf, sparse in deep portion
Golf Course	0.247	12,679	8,218	1.6	0.47	fair cover on shelf
Heron Landing	-0.17	8595	4,774	1.9	0.44	spotty to sparse on shelf
Sanctuary	0.17	9,007	4,540	2.1	0.42	fair cover on shelf
The Dunes	0.103	207,700	81,404	2.6	0.41	very sparse on shelf and deeper portion

Table 1. Summary of mapping characteristics

D. Water column characteristics

Water column characteristics were assessed when the sun was around its zenith position at one location for each pond as determined subsequently to the bathymetry mapping (yellow diamond on each map). Water depth was first measured followed by the water profiling of the water column with smarTROLL multiparameter sonde (www.in-situ.com) equipped with a temperature, luminescent dissolved oxygen (DO), pH, specific conductance, oxidation-reduction (ORP) probe and a water depth sensor. The sonde was lowered in the water column at every 0.25cm waiting about 10second between each depth increment before resuming lowering the sonde at that increment until it reached the bottom. Photosynthetically active measurements (PAR) were done with a LICOR 4π Quantum type sensor connected to a LICOR 1400 meter which sensor was lowered every 0.25cm until the bottom was reached or sky conditions changed. Water clarity was also assessed with a Secchi disk and turbidity meter (Hach 2100Q, www.hach.com). All instruments were calibrated prior to getting to the sites. Such profiles were plotted in Microsoft Excel to determine whether a thermocline, oxycline and halocline/pycnocline were present as well as to determine if levels for the parameters measured were critical. Further, PAR profiles were used to determine the euphotic zone depth below which algae theoretically can no longer photosynthesize (Kirk, 2011). The Secchi disk depth was used to calculate the Trophic Status Index (TSI, Brezonik 1984).
The water column was sampled using a vertical 2.2L Beta™ Van Dorn bottle sampler at various depth intervals until 0.5m above the pond's bed. All samples were then mixed in a clean bucket so that a composite sample could be taken. Total alkalinity was then determined using a Hach kit (Model AL-DT, www.hach.com). The composite water sample was kept in an opaque 1.5L Nalgene bottle which was kept in the dark in a cooler. Within 10 hours, the water for the analysis of total phosphorus (EPA365.1) and total nitrogen (ASTM D5176) was transferred into a 125ml Nalgene bottle which was kept refrigerated until being analyzed. A 60ml subsample was additionally filtered through a Nucleopore™ 0.45µm pore size filter into an 80ml Nalgene bottle which was immediately frozen until being analyzed for dissolved nutrients: NOx (EPA353.2), NO2- (EPA353.2), NH4+ (EPA350.1) and soluble reactive phosphorus (SRP, EPA365.1). A known volume of water was further filtered onto a Whatman™ GF/F (0.7µm nominal pore size) to retain algae. The filter was then processed through acetonic extraction in a fridge for 48h to extract Chl *a* which extract was read in a spectrophotometer to determine the pigment concentration (Jeffrey and Humphrey 1975). Nutrients and Chl *a* were analyzed by Dr. Lasso de la Vega at the Water Hyacinth Control (Lee County, Florida).

1. **Water column structure and clarity**

   i. **Beach Villa pond**

The water column was well mixed in Beach Villa pond with slightly less than the lower limit of DO for fishes to be stressed (less than 5mg/l). It is anticipated that such DO levels drop even further at night as respiration prevails. pH was close to circumneutral with a drop at the vicinity of the sediment which corroborates the drop in DO there as well. Specific conductance is characteristic of freshwater and increases near the bottom because of sediment porewater influence. ORP is positive and normally drops near the bottom as DO and other elements in the oxidative state decrease. The water column is clear and allows benthic phototrophs to grow (i.e. algae and SAV).

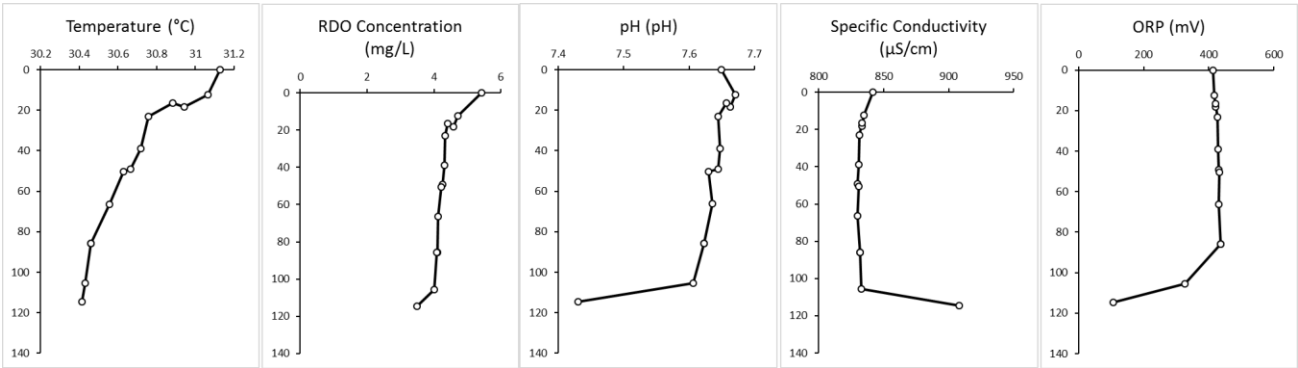


Figure 19. From left to right, water column profiles of temperature, DO, pH, specific conductance and ORP in Beach Villa pond

   ii. **Bike Trail pond**

The water column was well mixed in Bike Trail pond with less than the lower limit of DO for fishes to be stressed (less than 5mg/l). It is anticipated that such DO levels drop even further at night as respiration prevails. pH was higher than circumneutral and more in par with brackish or saline systems. pH drops at the vicinity of the sediment which corroborates the decrease in DO there as well. The specific conductance is characteristic of brackish water. ORP is positive and normally drops near the bottom as DO and other elements in the oxidative state decrease. The water clarity is sufficient enough to allow algae to grow on the bottom but it restricts SAV growth.

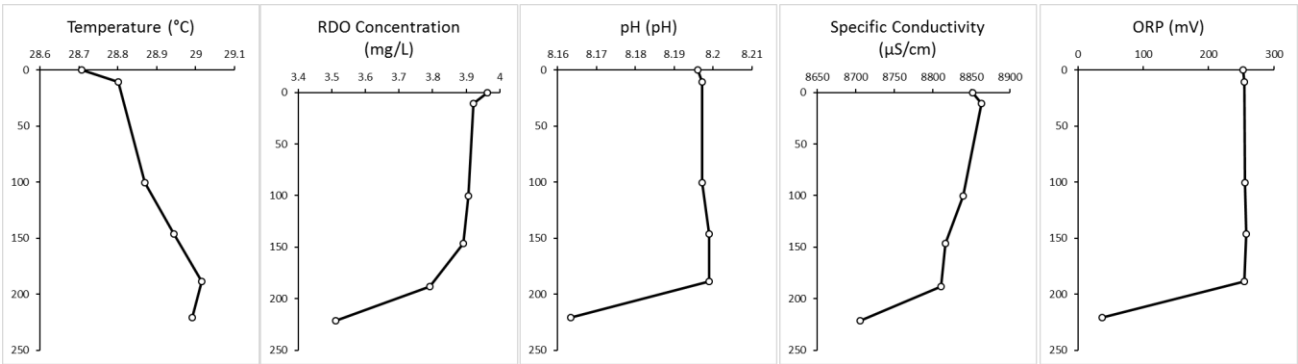


Figure 20. From left to right, water column profiles of temperature, DO, pH, specific conductance and ORP in Bike Trail pond

iii. Chateau-Sur-Mer pond

The water column was well mixed in Chateau-Sur-Mer pond with adequate to critical DO enough to stress fishes near the bottom (less than 5mg/l). It is anticipated that such DO levels drop even further at night as respiration prevails. pH was higher than circumneutral and more in par with brackish or saline systems. pH drops at the vicinity of the sediment which corroborates the decrease in DO there as well. Specific conductance is characteristic of slightly brackish water. ORP is positive and normally drops near the bottom as DO and other elements in the oxidative state decrease. Water clarity is fair but since this ponds is shallow, there is ample amount of light reaching the bottom to allow benthic algae and some SAV to grow.

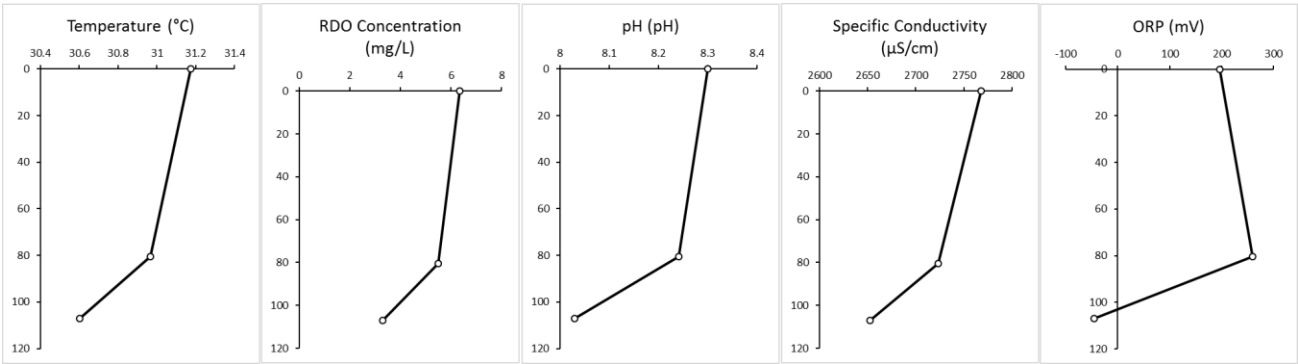


Figure 21. From left to right, water column profiles of temperature, DO, pH, specific conductance and ORP in Chateau-Sur-Mer pond

iv. Golf Course pond

The water column was well mixed in Golf Course pond. High DO in the surface representing biological production via photosynthesis would not stress fishes during the day but would decrease steeply at night as algae add their respiration to the one from the heterotrophs. Below 0.5m, an oxycline is present as DO drops to hypoxia near the bottom. Logically, the pH follows that pattern with high pH above 8.2 on the surface exhibiting supersaturation of DO. Specific conductance is characteristic of slightly brackish water. ORP is positive and normally drops near the bottom as DO and other elements in the oxidative state decrease. The water clarity is fair and allows light to reach most of the bottom thus allowing benthic and show SAV to grow especially on the shelf.

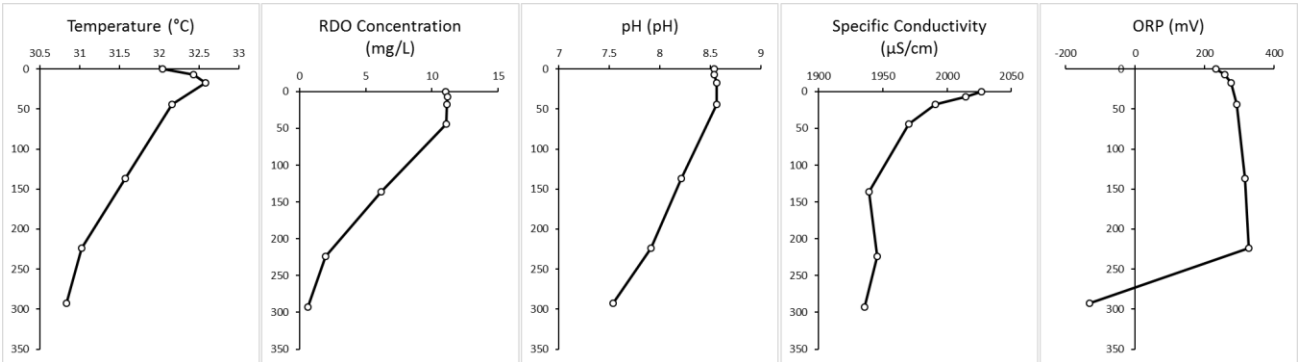


Figure 22. From left to right, water column profiles of temperature, DO, pH, specific conductance and ORP in Golf course pond

v. Heron landing pond

The water column is being destratified in Heron Landing pond since the temperature curve represents mixing occurring between the epi and hypolimnion. DO are alarming low and typical of anoxia. pH is typical of brackish and saline water which agrees with the specific conductance. Specific conductance is also lower on the surface than in deeper water and shows a weak halo/pycnocline which is being destroyed. ORP is very negative showing a very reducing environment in par with the anoxia observed. Water clarity is very poor as PAR profiles prove very challenging as light would attenuate too quickly. Particulates other than phytoplankton and likely heterotrophic bacteria and other particulates attenuate light in the water column.

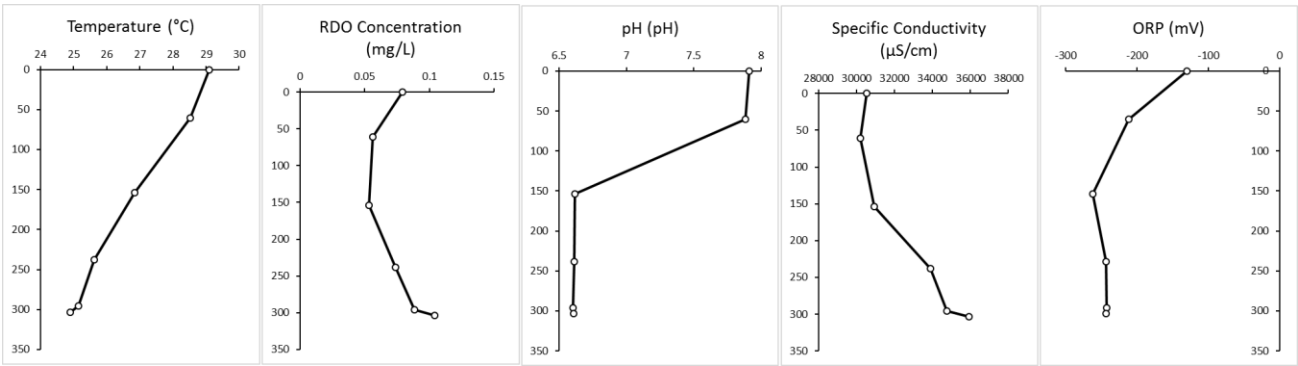


Figure 23. From left to right, water column profiles of temperature, DO, pH, specific conductance and ORP in Heron Landing pond

vi. Sanctuary pond

The water column was well mixed in Sanctuary pond. High DO throughout most of the water column reflect biological production via photosynthesis. Such a supersaturation in DO would not stress fishes during the day but DO would decrease steeply at night as algae add their respiration to the one from the heterotrophs. DO drop to hypoxia near the bottom. Logically, the pH follows that pattern with high pH above 8.2 on the surface exhibiting supersaturation of DO. Specific conductance is characteristic of slightly brackish water. ORP is positive and normally drops near the bottom as DO and other elements in the oxidative state decrease. Water clarity is mediocre linked to phytoplankton and other particulates. SAV will grow on the shallow shelf and algae can still grow in most of the pond's bottom and especially within the water body.

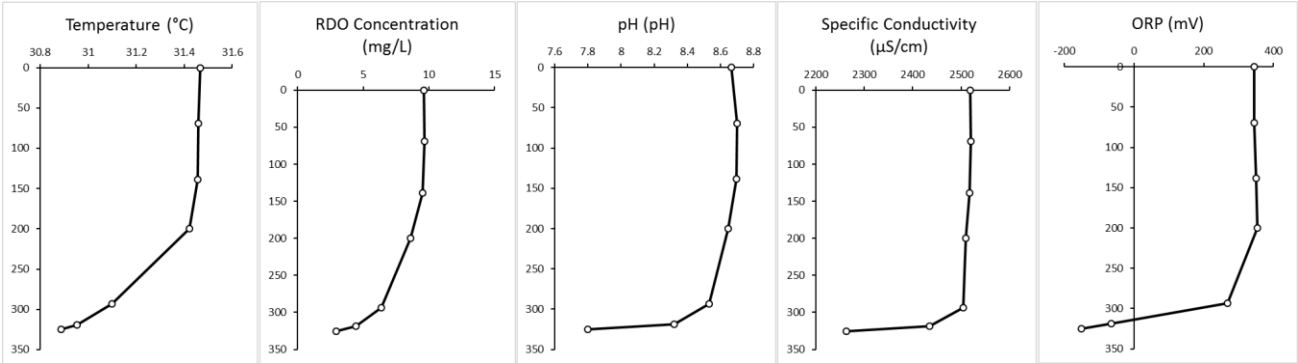


Figure 24. From left to right, water column profiles of temperature, DO, pH, specific conductance and ORP in Sanctuary pond

vii. The Dunes pond

The water column was well mixed in The Dunes pond even despite the relative deep depth. DO is too high in the surface representing biological production via photosynthesis which would not stress fishes during the day but would decrease steeply at night as algae add their respiration to one from the heterotrophs. Below 0.5m, a steep oxycline is present as DO drop to anoxia near the bottom. Logically, the pH follows that pattern but on a log scale with high pH above 8.2 on the surface exhibiting supersaturation of DO. Specific conductance is characteristic of slightly brackish water and it increases steeply over the bottom showing more saline pore sediment water. ORP is positive and normally drops near the bottom as DO and other elements in the oxidative state decrease. ORP however remains positive. Water clarity is mediocre to poor as light is attenuated by phytoplankton and other particulates. SAV growth is limited to the shallow shelf while algae should be able to grow there as well and up to 1.4m.

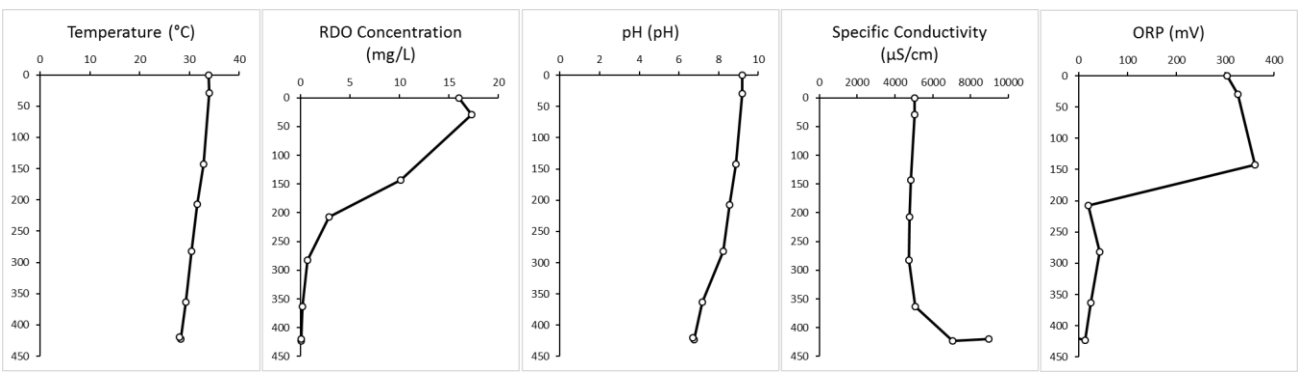


Figure 25. From left to right, water column profiles of temperature, DO, pH, specific conductance and ORP in The Dunes pond

	Mean temperature	Mean sp. cond.	Mean salinity	Mean DO	Mean DO	Mean pH	Mean ORP	Turbidity	Zeu
Ponds	ºC	µS/cm	ppt	mg/l	%	a.u.	mV	NTU	m
Beach Villa	30.7±S.D.0.2	838±S.D.21	0.42±S.D.0.01	4.31±S.D.0.45	57.9±S.D.6.2	7.62±S.D.0.06	394.1±S.D.91.1	2.3	2.8
Bike Path Trail	28.9±S.D.0.1	8815±S.D.57	4.99±S.D.0.03	3.83±S.D.0.17	51.3±S.D.2.2	8.19±S.D.0.01	218.9±S.D.89.1	24.0	2.3
Chateau sur Mer	30.9±S.D.0.3	2714±S.D.58	1.42±S.D.0.03	5.05±S.D.1.57	68.5±S.D.21.6	8.19±S.D.0.14	137.1±S.D.160.9	18.6	1.9
Golf Course	31.8±S.D.0.7	1975±S.D.37	1.02±S.D.0.02	7.61±S.D.4.68	104.5±S.D.64.7	8.26±S.D.0.41	224.9±S.D.160.4	20.3	2.1
Heron Landing	26.7±S.D.1.8	32705±S.D.2455	20.77±S.D.1.71	0.08±S.D.0.02	1.1±S.D.0.3	7.04±S.D.0.67	-222.3±S.D.47.8	111.0	NA
Sanctuary	31.2±S.D.0.3	2467±S.D.95	1.29±S.D.0.05	7.3±S.D.2.75	99.7±S.D.37.9	8.48±S.D.0.33	206.6±S.D.218.1	20.2	1.6
The Dunes	31±S.D.2.4	5690±S.D.1522	3.13±S.D.0.9	5.93±S.D.7.42	84±S.D.106	8.09±S.D.1.05	136.7±S.D.161.6	38.2	1.4

Table 2. Summary table of the water characteristics over the water column. Means ± standard deviation (S.D.) are shown where appropriate.

2. Water chemistry

i. Beach Villa pond

Beach Villa pond has relatively low nutrients levels which does not trigger large phytoplankton populations and which allow the water to remain clear. It is well balanced with nutrients and has fair water quality (mesotrophic).

	Total alkalinity	Chl*a*	NOx	NH4	TN	SRP	TP	TN/TP	Limitation	TSI(SD)	TSI(Chl*a*)	TSI(TP)	TSI(TN)	TSI(Combo)
Ponds	mg/l	µg/l	mg/l	mg/l	mg/l	mg/l	mg/l	no units	P, N, both	a.u.	a.u.	a.u.	a.u.	a.u.
Beach Villa	129.5	6.0	0.024	0.033	0.799	0.016	0.027	29.6	both	54.3	42.7	43.3	54.8	48.7
Bike Path Trail	194.0	36.9	0.040	0.061	2.571	0.071	0.021	125.4	P	84.0	68.8	38.2	79.9	63.6
Chateau sur Mer	297.0	22.3	0.039	0.041	1.576	0.037	0.078	20.3	both	68.6	61.5	62.9	69.4	65.4
Golf Course	192.0	31.6	0.016	0.062	2.423	0.048	0.117	20.7	both	64.2	66.5	70.6	78.6	68.4
Heron Landing	507.0	63.2	0.079	0.533	3.030	4.120	3.821	0.8	N	91.5	76.5	135.4	83.4	84.0
Sanctuary	269.0	49.6	0.025	0.049	1.965	0.284	0.650	3.0	N	54.3	73.0	102.5	74.1	63.6
The Dunes	258.0	66.1	0.020	1.578	4.162	0.132	0.171	24.3	both	84.6	77.2	77.6	90.3	81.9

Table 3. Summary table of the water chemistry and overall water quality assessment via the TSI.

ii. Bike Trail pond

Bike Trail pond is quite nutrients rich with especially nitrogen mostly as particulate nitrogen. Ammonia however is not at critical levels for the fish population as the water column is not reducing. Such nitrogen triggers algae blooms which lower the water clarity thus leading to a eutrophic+ pond.

iii. Chateau-Sur-Mer pond

Chateau-Sur-Mer pond has good amounts of both nitrogen and phosphorus which balance each other and contribute to the grow of a fair about of phytoplankton which attenuates water clarity. The pond has thus eutrophic+ water. Ammonia levels are not critical for the fish populations are the water is not reducing enough.

iv. Golf Course pond

Golf Course pond has very good amounts of both nitrogen and phosphorus which are in balance and which feed phytoplanktonic populations. The pond has thus eutrophic+ water but ammonia are not of concerns due to low reducing conditions.

v. Heron landing pond

Heron Landing has high total alkalinity showing an eventual good connection between the pond water and the surrounding lime rich environment. Such alkalinity could limit algal and SAV growth as carbonates dominate. Cyanobacteria however can thrive in such environments and it seems to be the case as chl *a* concentration is quite high but not enough to compensate the high biological oxygen demand of the water and likely of the sediment. Nitrogen, but especially, phosphorus (*a fortiori* as labile phosphorus) levels are especially high in this pond and drive the TSI to hypereutrophy+. The pond is limited in nitrogen which can select nitrogen fixing cyanobacteria but with such high levels of nutrients, it is doubtful that any limitation exists. Ammonia levels are high linked especially to the reducing properties of the water (i.e. low ORP).

vi. Sanctuary pond

Sanctuary pond has high nitrogen and very high phosphorus contents. Nitrogen still in not reduced to alarming levels of ammonia because of the non-reducing conditions. Such nutrients should have driven to higher phytoplanktonic populations and it is hypothesized that there is some pond management which limits the algal growth via the aerator present as well as eventually the use of xenobiotics. The water indeed remains fairly clear and thus reduces artificially the TSI to eutrophic+ (in lieu of hypereutrophic).

vii. The Dunes pond

The Dunes pond has very high nitrogen and phosphorus contents. The reducing conditions of the water (even if ORP is not negative) drive the ammonia levels high so that fish could be harmed. The nutrients, mainly in the labile form, allow algae to thrive and make the water turbid which all drive the TSI to hypereutrophic+.

3. Conclusions

A correlation matrix was run between all the parameters measured for this study (Appendix 4). As for most water bodies, salinity is a main driver of these hydrosystems since it was positively correlated with the turbidity and therefore was negatively correlated with the Secchi disk and euphotic zone depths. More saline ponds had lower temperature, lower DO, pH, ORP but higher TP, SRP, total alkalinity and NOx. Large ponds with large volume, surface area and mean depth also had larger water concentration in ammonia and TN. Water TN and Chlorophyll *a* mainly drove the TSI of all the ponds. Hypereutrophic ponds had reducing water column properties which drove ammonia to alarming levels which as bioavailable nutrients fed algae growth which reduced water clarity.
However, Sanctuary pond slightly deviates from his expected hypereutrophy because its water is likely highly managed in such a way that its water column remains relatively clear and with less phytoplankton

than one would expect. Because of its large size and despite some managements, The Dunes pond water quality is not improved, even artificially as it is the case for the much smaller Sanctuary pond.
Heron Landing also is different than the other ponds because of the extreme conditions this pond is encountering as its high biological oxygen demand masks the photosynthesis DO production.

E. Sediment characteristics

1. Methods.

Sediment coring locations were determined upon the mapping of the bottom hardness via sonar (black dots on maps). Sediment coring was performed from a Jon boat or an aluminum 14' canoe using a handheld push corer. The corer was made of interlocking 2" PVC sections upon which a clear acrylic tube of inner diameter 6.35cm (2.5") was mounted (Appendix 3). The one-way valve of the corer allowed the water to flow one way as the corer was lowered in the water column and the acrylic core pushed through the sediment. The acrylic core was pushed in the pond's bed until rebuttal and then brought to the surface. The one-way valve held the sediment material in the acrylic tube until the surface. At the surface, the base of the acrylic tube was capped with a rubber stopper #13 to create a good seal.

Once on the boat deck, the corer was uncoupled from the acrylic tube and the tube's apex was capped with a second rubber #13 stopper. A 12MP picture of the core was then taken against a white erase board with an Olympus tough TG-1 after the total sediment core length was recorded. For the cores selected for their content analysis, sediment material was extruded upward by pushing up a piston inserted at the bottom of the tube (after the basal rubber stopper was removed). Once the sediment material was flushed to the opening of the acrylic tube, the depth of the floc layer was measured to the nearest ½ cm by letting a plastic ruler sink through it under its own weight. The flocculent layer was then sampled and kept in a ziplock bag chilled in a cooler packed with crushed ice.

The sediment was then pushed upward and its thickness measured to the nearest ½ cm until either sand, peat, clay or limestone was reached. The sediment was collected in a bucket then mixed and stored in a ziplock™ bag chilled in the cooler. All the other layers underneath the sediment were characterized, measured to the nearest cm then discarded.

Once in the laboratory, part of the sediment or floc was dried until constant weight in a drying oven set at 80 ºC (DW) and then combusted at 550ºC for one hour. The ash weight was then determined (AW) and the ash free dry weight deducted (AFDW). The organic content was finally computed as AFDW/DW (ASTM D2974-87). Another fraction of the sediment or floc was dried in the oven until constant weight, then grinded to a fine powder with a Belart MICRO-MILL® grinder. A few grams of powdered sample were then sent to the SERC/FIU laboratory for the analyses of total phosphorus (TP), total carbon (TC) and total nitrogen (TN) which were reported in g/g DW or % DW. Total phosphorus in sediments was determined using the ashing/acid hydrolysis method of Solorzano and Sharp (1980) with the resulting soluble reactive phosphorus (SRP) being measured as SRP in water (EPA365.1). Sediment TC and TN were analyzed using Perkin Elmer Series II 2400 CHNS/O Analyzer (Nelson and Sommers 1996).

2. Results and discussion

Using the correlation matrix (Appendix 4), sediment and floc characteristics had poor relationships with the water quality. This normally is the case in other ponds in the region and this could be linked to the fact that

there was only one water quality assessment over the course of a hydrologic cycle whereas water sampling once a month was conducted for the other studies that our group conducted. However, when the sediment and floc data are compared to one another, it was found that for the same core, a thick layer of floc would equate to a thick layer of sediment. The nutrient contents of these two layers did not show much correlation though. Nevertheless, for both the floc and the sediment of the same core, high nitrogen content equated to high carbon and organic content. This shows that the sediment and floc were organic and thus would leach nutrients to the water column as they are degraded. The phosphorus content did not exhibit this pattern but this could be linked to the fact that the analysis of TP was not made through a TP fractionation process which is long, costly and laborious but which would have allowed to separate the various forms of P found in the core and especially tease apart the labile and refractory forms of P.

Overall, the combined sediment and floc accumulation in all the ponds was less than 30cm which is the arbitrary threshold that has been arbitrarily used to determine whether dredging ought to be necessary. Thus, based upon this figure, it appears that all the ponds have not reached that threshold yet. Beside Chateau-Sur-Mer with an overall low sediment and floc accumulation (7.2cm in average), all ponds have accumulated about the same amount of sediment regardless of their current TSI (9.3 to 12.8 cm in average). The Dunes pond had very long sediment accumulation on its shelf but this was compensated for by a much higher sediment accumulation pass the littoral zone.

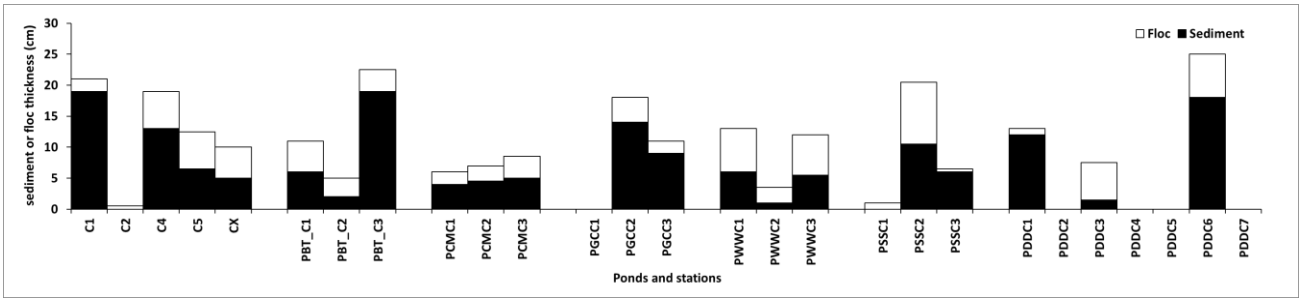


Figure 26. Sediment and floc accumulation for all the ponds at their stations selected for coring.

Nutrient content in the sediment is also a factor to consider for dredging and overall management decisions. Beside the relatively low sediment and floc accumulation, the amount of nutrients appears to be high when compared to other ponds in Lee and Collier counties and mainly located within Bayside Bay Creek Community Development Districts (CDDs referred as Pelican Landing in Estero and Bonita Springs, Thomas, 2015).

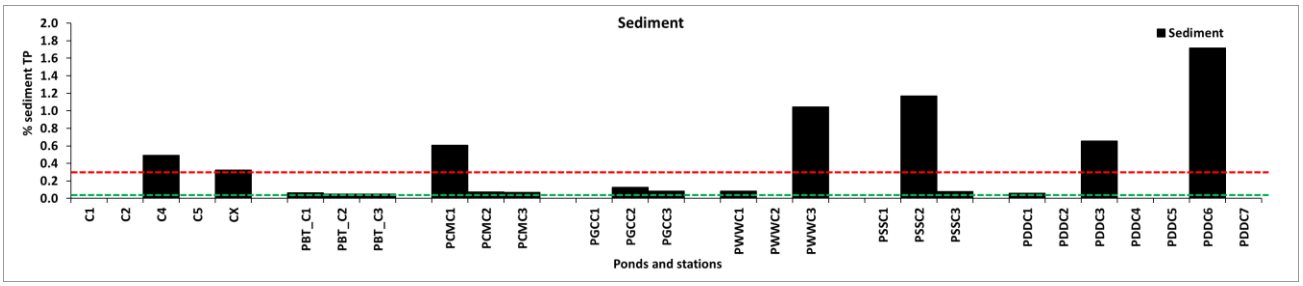


Figure 27. TP content in the sediment (2% TP equates to 20,000µg/g). The red dotted line refers to the average TP content in the sediment of golf course ponds in Pelican Landing development. The green dotted line refers to the most pristine ponds (abutting a Preserve) in the same development.

It is noteworthy to point out that sediment nutrient has often more P than for the floc. This is unusual but might be linked that most P is refractory in the sediment and less refractory in the floc. Thus, the P content of the muck of the ponds studied is high, especially for the floc TP content alone.

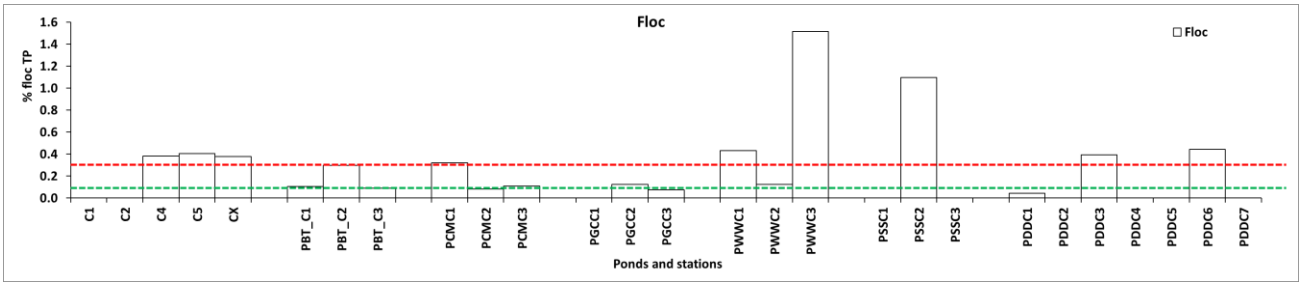


Figure 28. TP content in the floc (2% TP equates to 20,000µg/g). The red dotted line refers to the average TP content in the floc of golf course ponds in Pelican Landing development. The green dotted line refers to the most pristine ponds (abutting a Preserve) in the same development.

Sediment and floc TN (as well as TC and organic content since these are all highly correlated, so they are implicitly discussed below) were also higher than other ponds in Lee and Collier Counties. TN was more in the floc than in the sediment and has high potential for leaching back into the water column and create algae blooms (especially since the TSI is driven mainly by TN and Chlorophyll *a*). Besides for Golf Course pond, the sediment in the golf course ponds (The Dunes and Sanctuary) had high maxima.

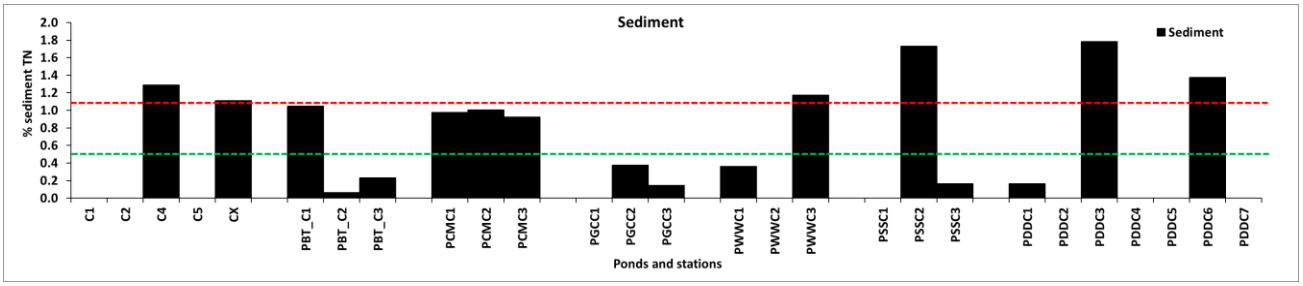


Figure 29. TN content in the sediment. The red dotted line refers to the average TN content in the sediment of golf course ponds in Pelican Landing development. The green dotted line refers to the most pristine ponds (abutting a Preserve) in the same development.

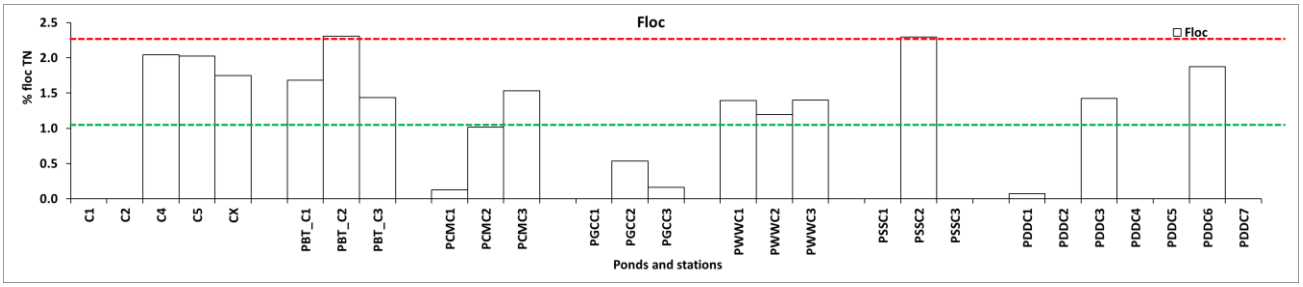


Figure 30. TN content in the floc. The red dotted line refers to the average TN content in the floc of golf course ponds in Pelican Landing development. The green dotted line refers to the most pristine ponds (abutting a Preserve) in the same development.

This was also the case for Beach Villa pond which could be linked to the high leaf litter deposits which were found in great abundance in the cores. TN in the floc was especially high except for the Golf Course pond which overall and regardless of the nutrient considered had the “healthiest” muck.

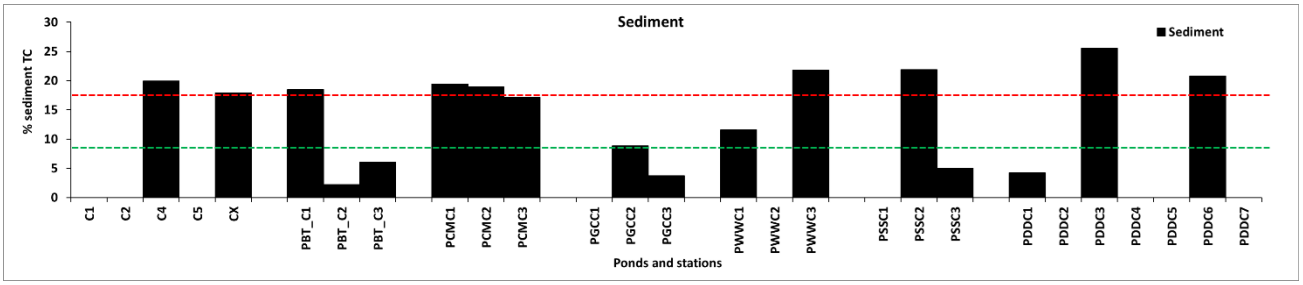


Figure 31. TC content in the sediment. The red dotted line refers to the average TC content in the sediment of golf course ponds in Pelican Landing development. The green dotted line refers to the most pristine ponds (abutting a Preserve) in the same development.

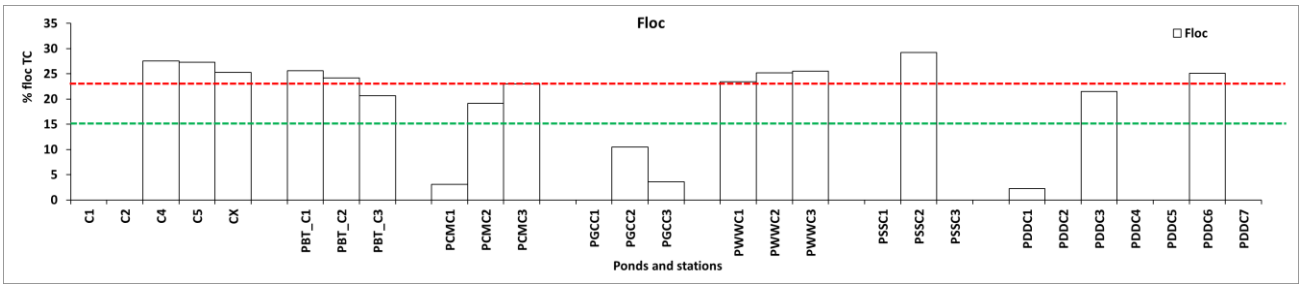


Figure 32. TC content in the floc. The red dotted line refers to the average TC content in the floc of golf course ponds in Pelican Landing development. The green dotted line refers to the most pristine ponds (abutting a Preserve) in the same development.

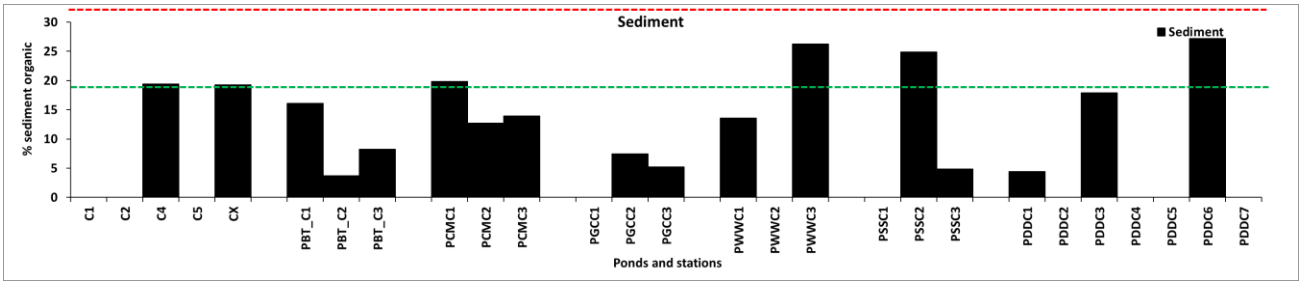


Figure 33. Organic content in the sediment. The red dotted line refers to the average organic content in the sediment of golf course ponds in Pelican Landing development. The green dotted line refers to the most pristine ponds (abutting a Preserve) in the same development.

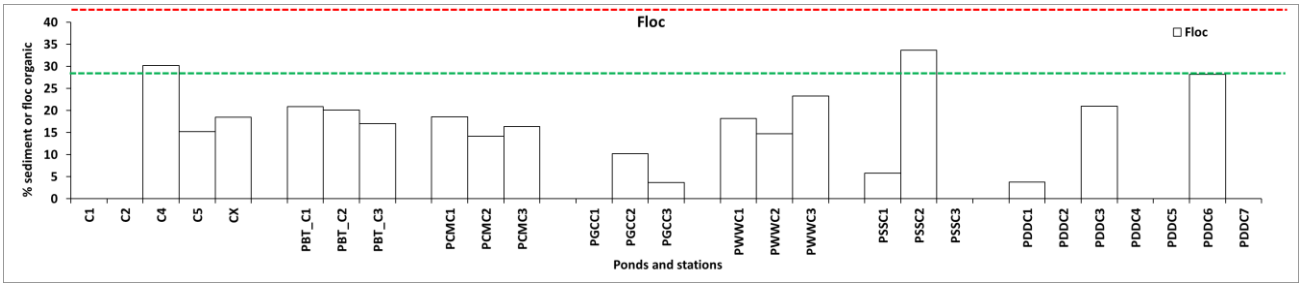


Figure 34. Organic content in the floc. The red dotted line refers to the average organic content in the floc of golf course ponds in Pelican Landing development. The green dotted line refers to the most pristine ponds (abutting a Preserve) in the same development.

F. Closing thoughts

A principal component analysis (PCA) was run in Primer-e 7 (www.primer-e.com) to assess how similar the ponds were from one another while considering all the parameters discussed in this study (cf. Appendix 4 for correlation matrix and Appendix 5 for the values of these parameters). All parameters were kept (even the redundant ones) so that the observed grouping in the hyperspace but reduced to a 3-axis volume encompassing for 79.3% of the variation are accurate. Another PCA was run when the redundant variables (those with a positive or negative correlation over 80%) were removed but ponds did not group (PCA not shown).

The two first axes of the PCA (ran on a normalized matrix after transformations were made to approach data normality) represented 63.5% of the hyperspace variability and with three axes, 79.3% of the variability was represented. The PCA shows that Bike Trail, Chateau-Sur-Mer and Sanctuary were most similar especially when the two first axes (1 and 2) were considered. Salinity is mainly representing axis 1 positively while temperature represents it negatively. Axis 2 represents positively the sediment and floc thickness and negatively the volume of the pond. Finally, axis 3 is mostly driven positively by the bottom hardness and negatively by the sediment and floc nutrients.

In this tri-dimensional scale, Heron Landing stands apart because of its high salinity while the Dunes is especially different because of its large size. Bike Trail, Chateau-Sur-Mer and Sanctuary are most similar while Beach Villa and especially Golf Course are distant from this group.

Overall, most of the ponds studied had nutrients issues whether these nutrients were found in the water column (all ponds but Beach Villa) or in the sediment or floc (all ponds besides Chateau-Sur-Mer). Beach Villa likely receives most of its nutrients via leaf litter because the pond is small and surrounded by trees, and has in consequence higher coarse organic particulates inputs (in the sense of the River Continuum concept, Vannote et al. 1980). Such inputs should be limited over time as these would eventually turn the system eutrophic. Most ponds had high levels of nutrients in the sediment and floc and since these two parameters reflect a much longer term than the water column analyses, there is evidence of cultural eutrophication especially from P as well as N. Efforts should be made to limit such nutrients loading. Some small ponds especially could benefit from local dredging done using the bottom hardness maps provided. For the larger ponds like The Dunes, intense aeration which would benefit aerobic digestion should be envisaged. The nutrients released from aeration should be captured by littoral planting which would benefit from clearer water. Flocculation of the particulates in the water would immediately improve water clarity and could be done in conjunction of aeration and planting.

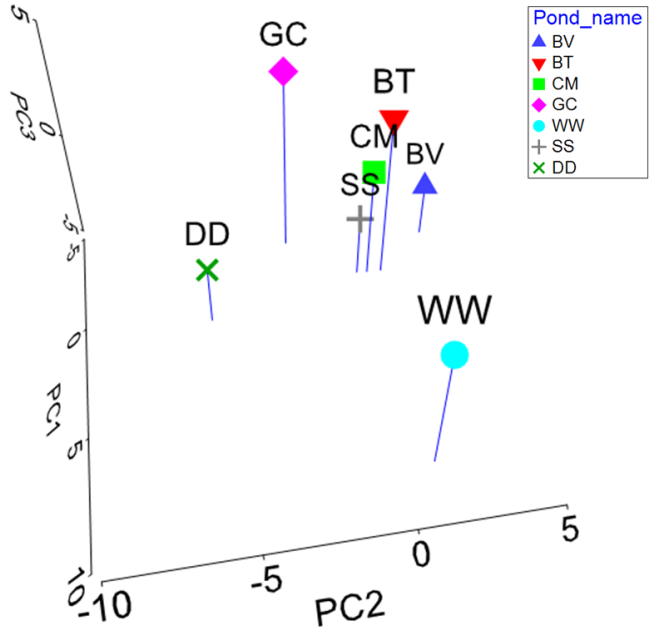


Figure 35. Pond grouping subsequent to running a PCA on all the parameters from this study (see Appendix 5 for these parameters). BV= Beach Villa, BT= Bike Trail, CM=Chateau-Sur-Mer, GC= Golf Course, WW=Heron Landing, SS= Sanctuary and DD= The Dunes.

References

Jeffrey, S.W., Humphrey, G.F. 1975. New spectrophotometric equations for determining chlorophyll *a*, b, c1 and c2 in higher plants, algae and natural phytoplankton. – Biochem. Physiol. Pflanz. 167: 191-194.

Brezonik P.L. 1984. Trophic state indices: rationale for multivariate approaches. Lake and Reservoir Management. in Proc. 3rd Annu. Conf. North Am. 441-445 Lake Manage. Soc. 18-23 Oct. 1983. Knoxville, Tenn. EPA 440/5-84-001. U.S. Environ. Protection Agency (EPA), Washington, D.C

Kirk J.T.O. 2011. Light and photosynthesis in aquatic ecosystems. New York, USA: Cambridge University Press

Nelson D.W. and, Sommers L.E., 1996. Total carbon, organic carbon, and organic matter. In: Methods of Soil Analysis, Part 2, 2nd ed., A.L. Page et al., Ed. Agronomy. 9:961-1010. Am. Soc. of Agron., Inc. Madison, WI.

Schreiber U., Schliwa U., and Bilger W. 1986. Continuous recording of photochemical and non-photochemical chlorophyll fluorescence quenching with a new type of modulation fluorometer. Photosynthesis Research 10: 1-62.

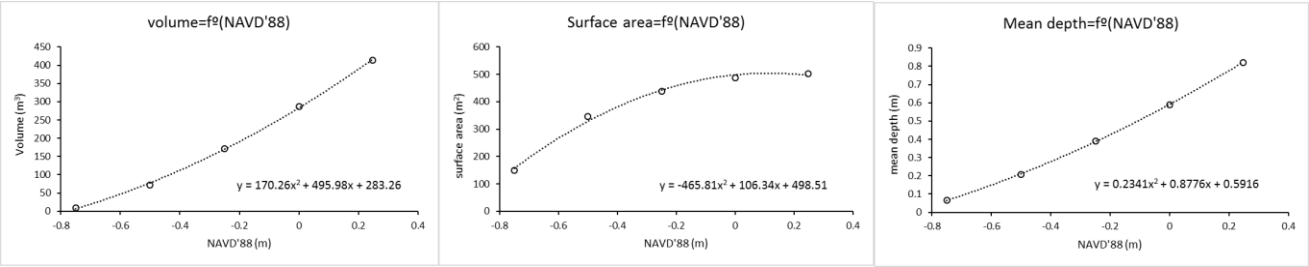
Solorzano L. and Sharp J.H., 1980. Determination of Total Dissolved Phosphorus and Particulate Phosphorus in Natural Waters. Limnology and Oceanography, 25, 754-758.

Vannote R. L., Minshall G.W., Cummins K.W., Sedell J.R. and Cushing C.E. 1980. The River Continuum Concept. Canadian Journal of Fisheries and Aquatic Sciences 37:130-137.

Appendix 1. Morphometric relations

These relationships relate the water level elevation expressed in NAVD'88 with the volume, the surface area of pond bed and the mean depth. The elevation of the top portion of the wooden post is provided as well as the elevation of the water level when the bathymetry was conducted.

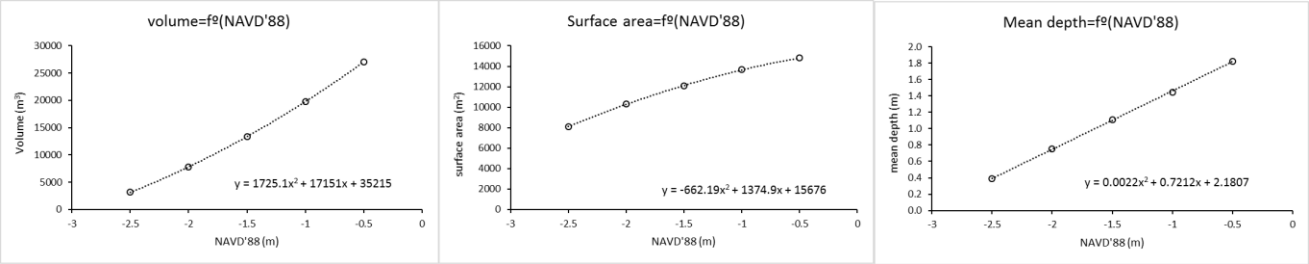
1. Beach Villa pond (2/15/17)



Appendix1_ 1. Morphometric relations for Beach Villa pond

Water level: 0.247m, top of post 1.307m

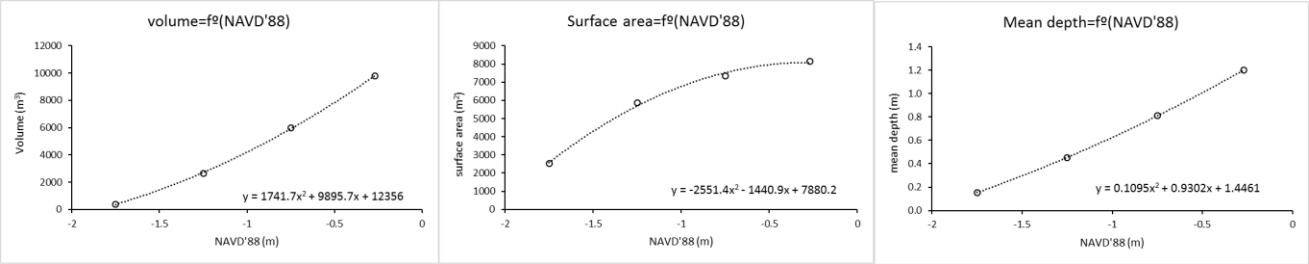
2. Bike Trail pond (2/17/17)



Appendix1_ 2. Morphometric relations for Bike Trail pond

Water level: -0.5m, top of post 0.450m

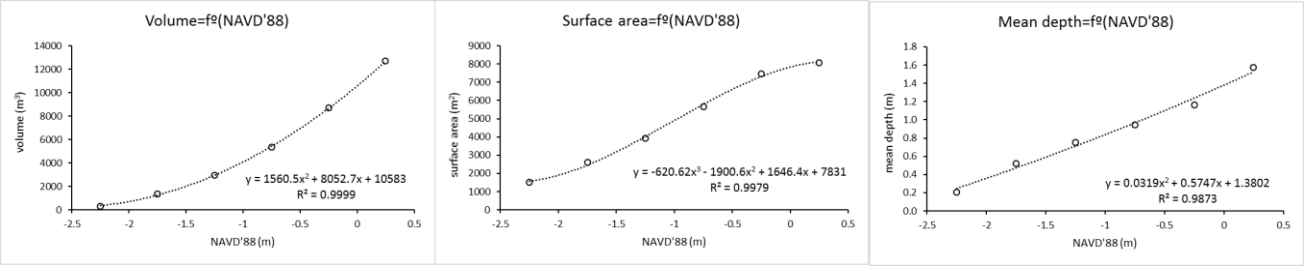
3. Chateau-Sur-Mer pond (2/15/17)



Appendix1_ 3. Morphometric relations for Chateau-Sur-Mer pond

Water level: -0.267m, , top of post 0.563m

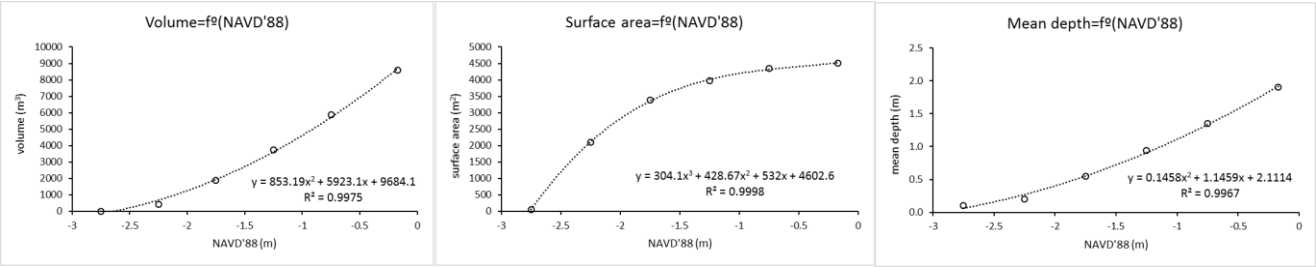
4. Golf Course pond (2/17/17)



Appendix1_ 4. Morphometric relations for Golf Course pond

Water level: 0.247m, top of post 1.442m

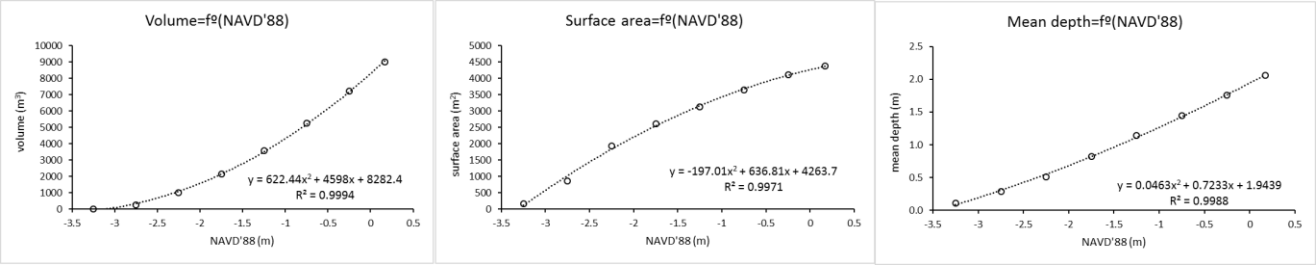
5. Heron Landing pond (3/22/17)



Appendix1_ 5. Morphometric relations for Heron Landing pond

Water level: -0.166m, top of post 0.234m

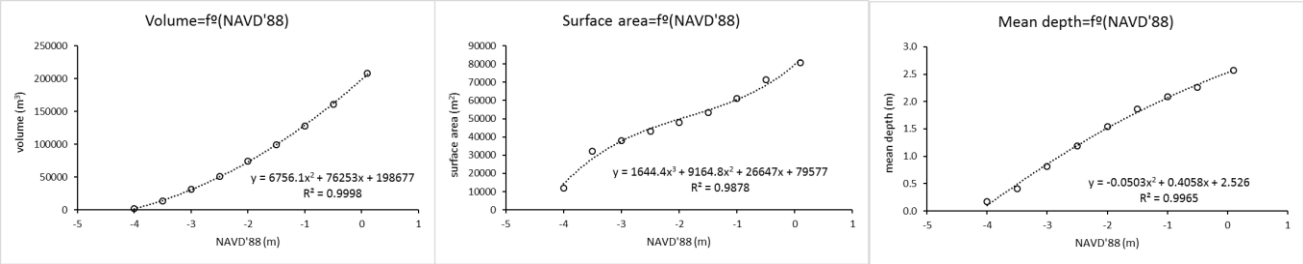
6. Sanctuary pond (3/6/17)



Appendix1_ 6. Morphometric relations for Sanctuary pond

Water level: 0.166m, top of post 0.686m

7. The Dunes pond (3/6/17)

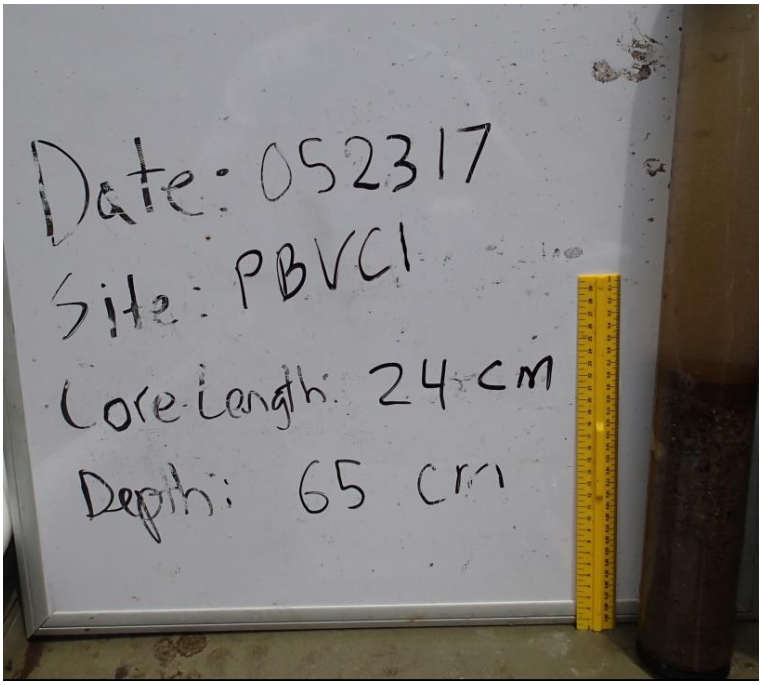


Appendix1_ 7. Morphometric relations for The Dunes pond

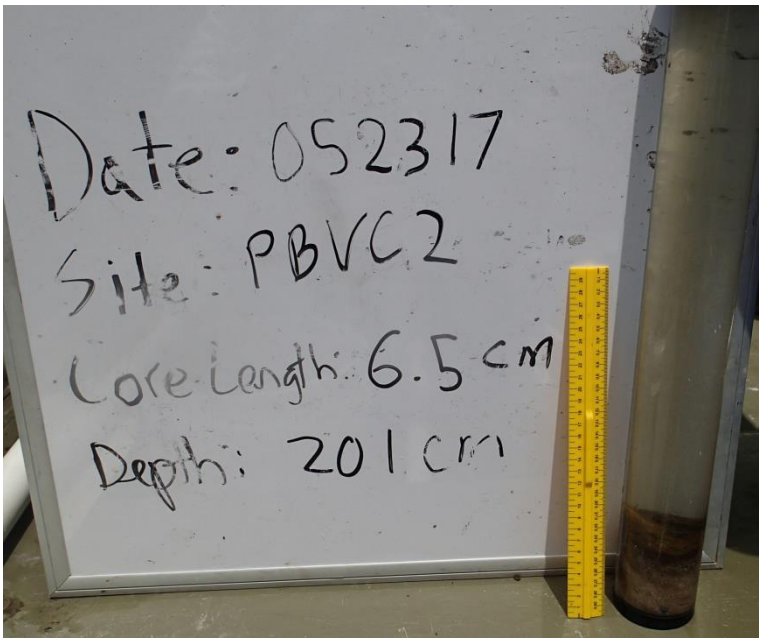
Water level: 0.103m, top of post 0.623m

Appendix 2. Pictures of cores.

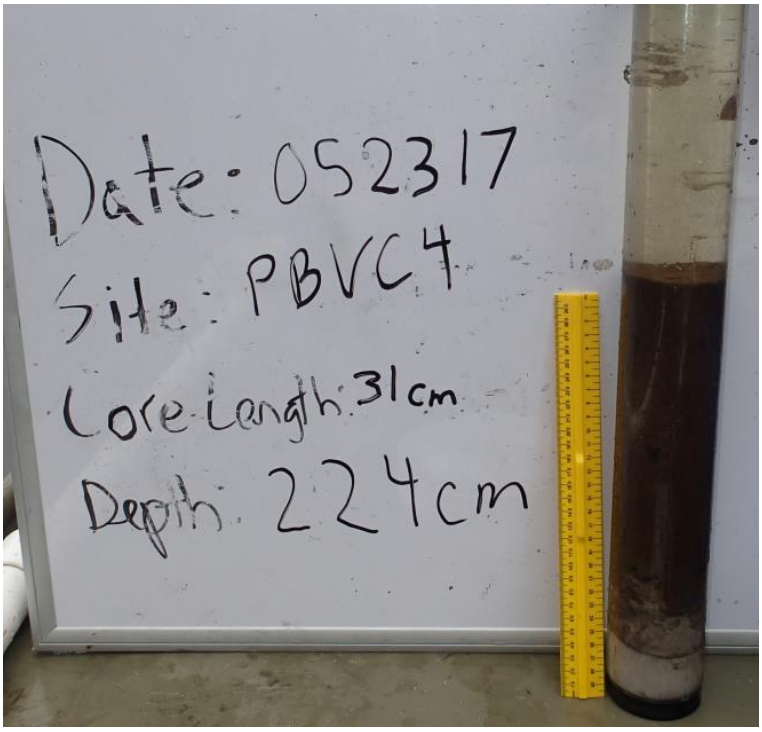
1. Beach Villa pond (2/15/17)



Appendix2_ 1. Core 1, Beach Villa pond.

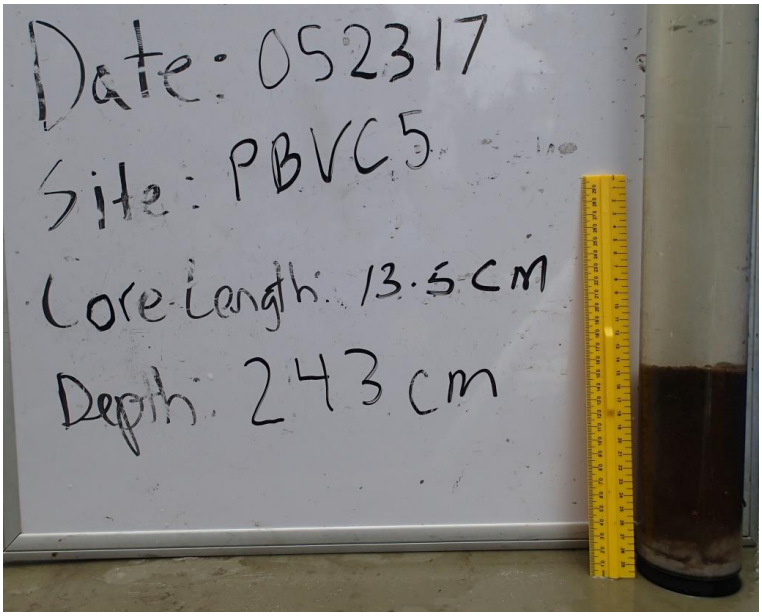


Appendix2_ 2. Core 2, Beach Villa pond.

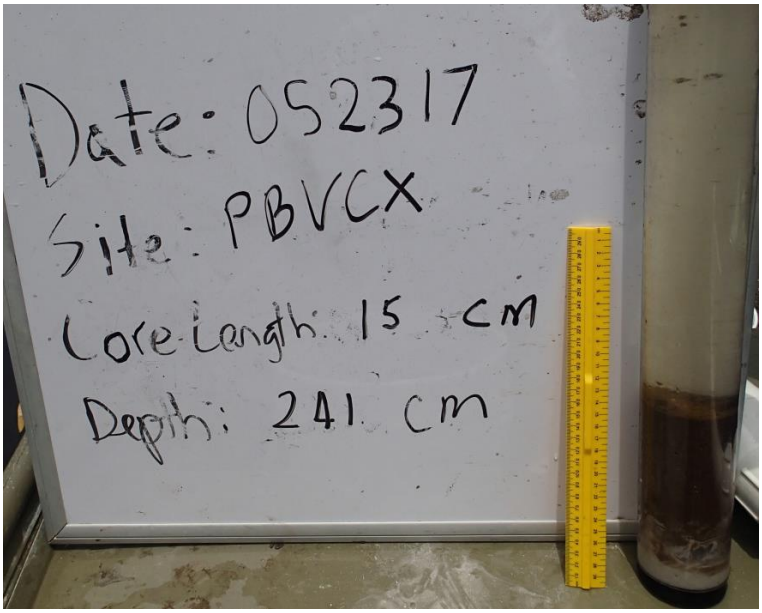


Appendix2_ 3. Core 4 in Beach Villa pond

Appendix2_ 4. Closeup of sedimentary material in core 4, Beach Villa pond.

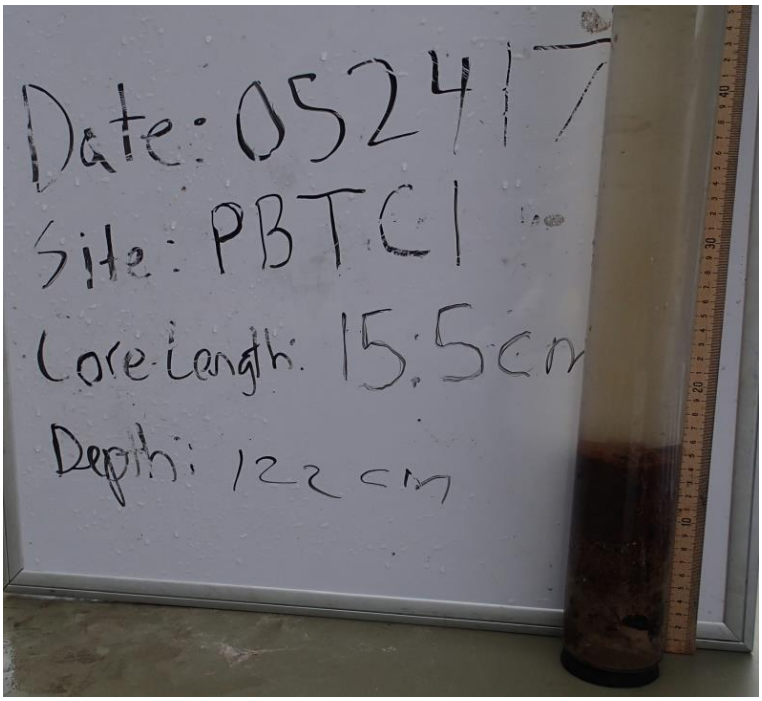


Appendix2_ 5. Core 5, Beach Villa pond.

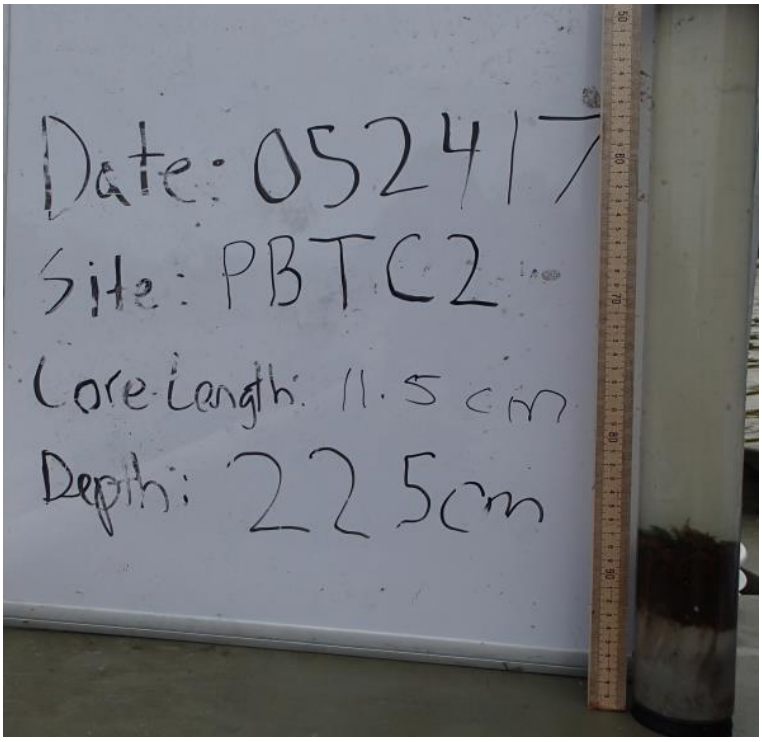


Appendix2_ 6. Core X, Beach Villa pond.

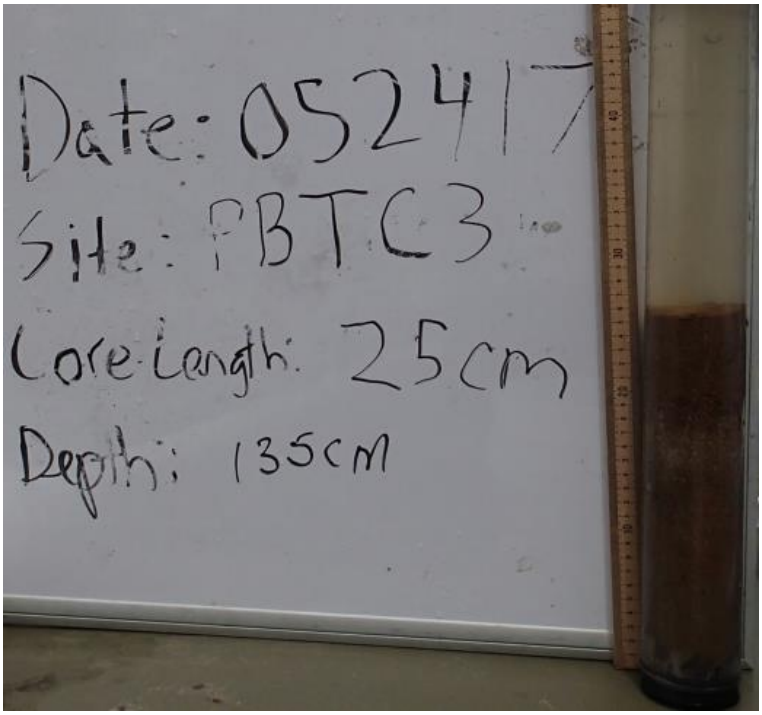
2. Bike Trail pond (2/17/17)



Appendix2_ 7. Core 1, Bike Trail pond.

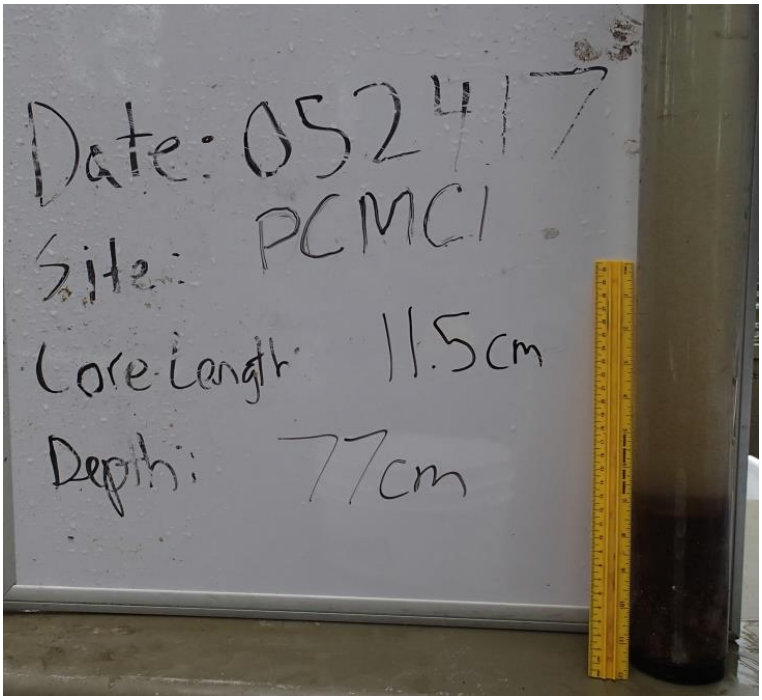


Appendix2_ 8. Core 2, Bike Trail pond.

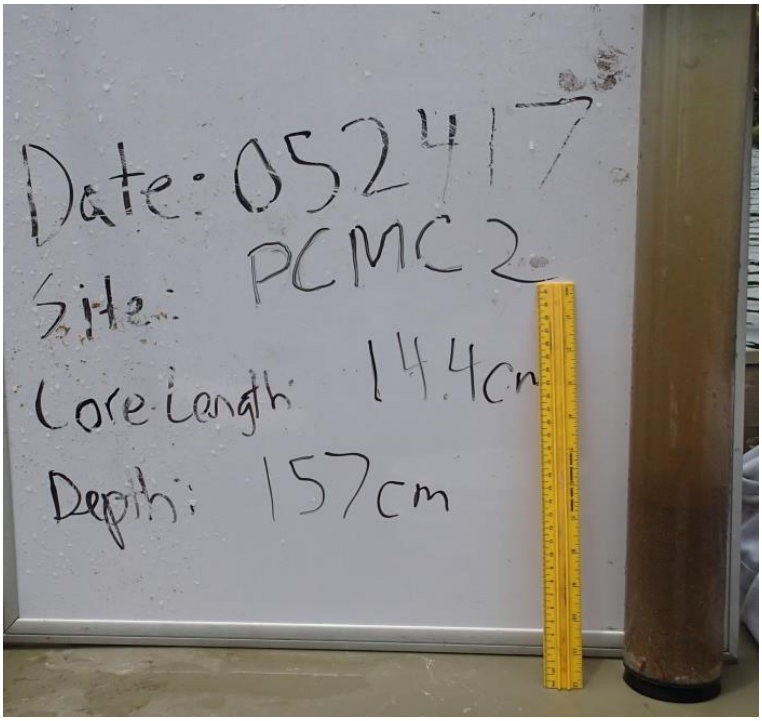


Appendix2_ 9. Core 3, Bike Trail pond.

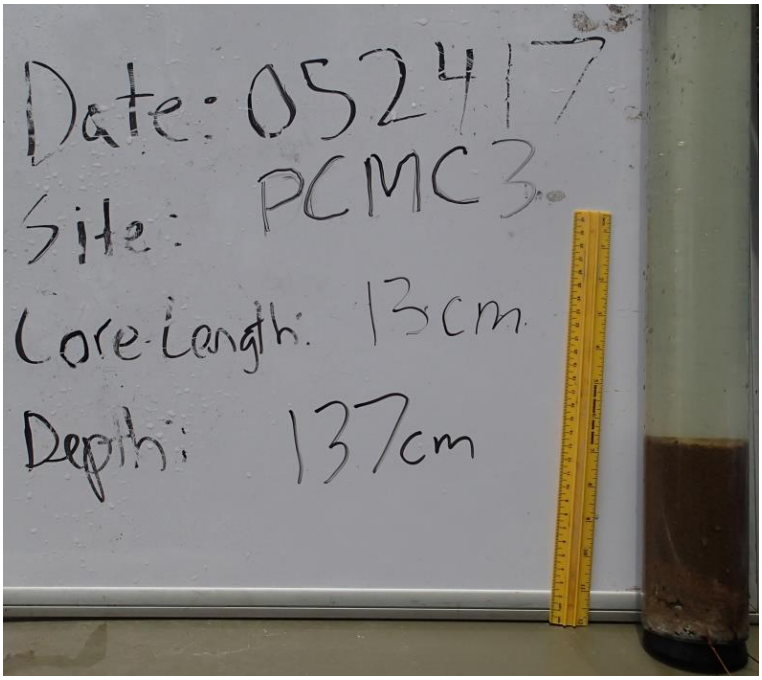
3. Chateau-Sur-Mer pond (2/15/17)



Appendix2_ 10. Core 1, Chateau-Sur-Mer pond.



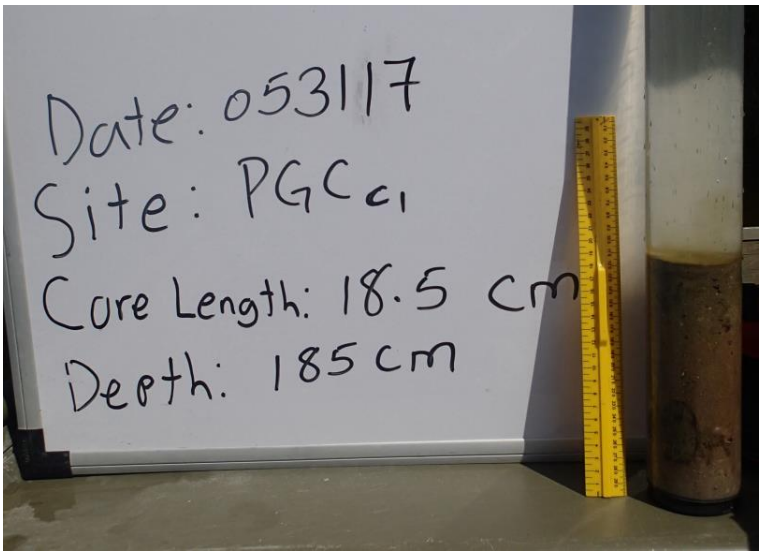
Appendix2_ 11. Core 2, Chateau-Sur-Mer pond.



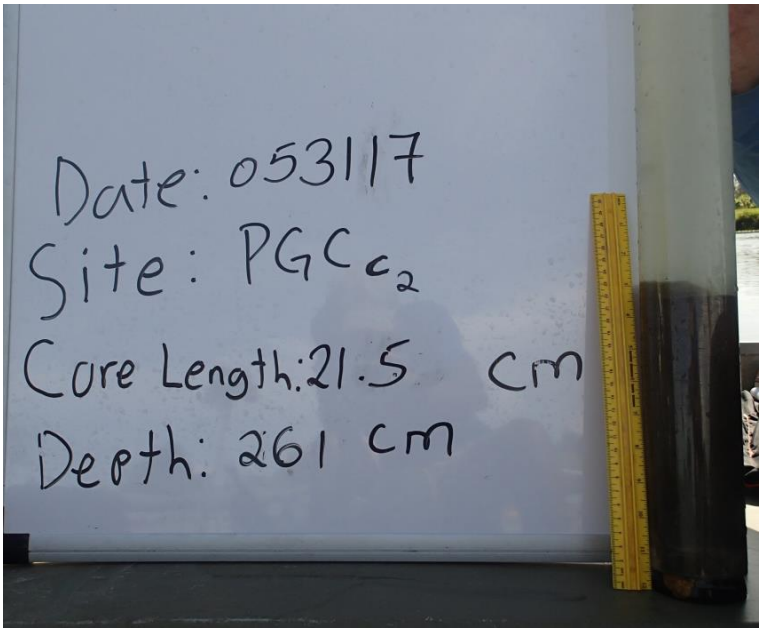
Appendix2_ 12. Core 3, Chateau-Sur-Mer pond.

Appendix2_ 13. Closeup of sedimentary material in core 3, Chateau-Sur-Mer pond.

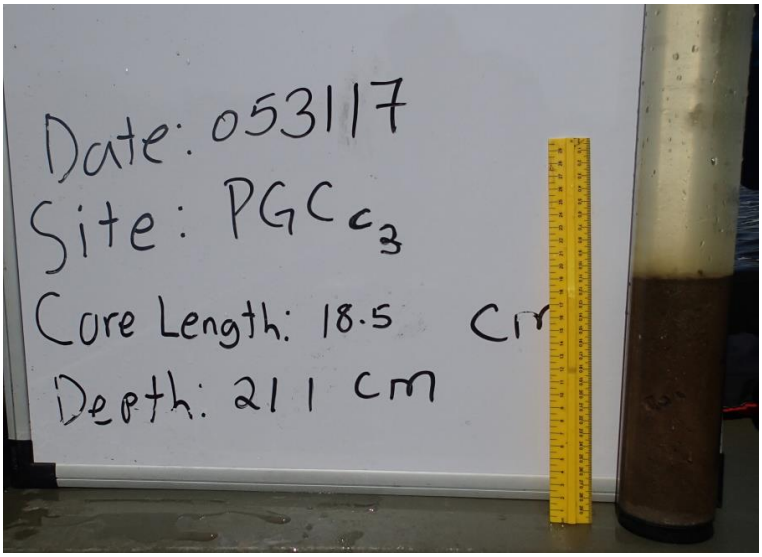
4. Golf Course pond (2/17/17)



Appendix2_ 14. Core 1, Golf Course pond.

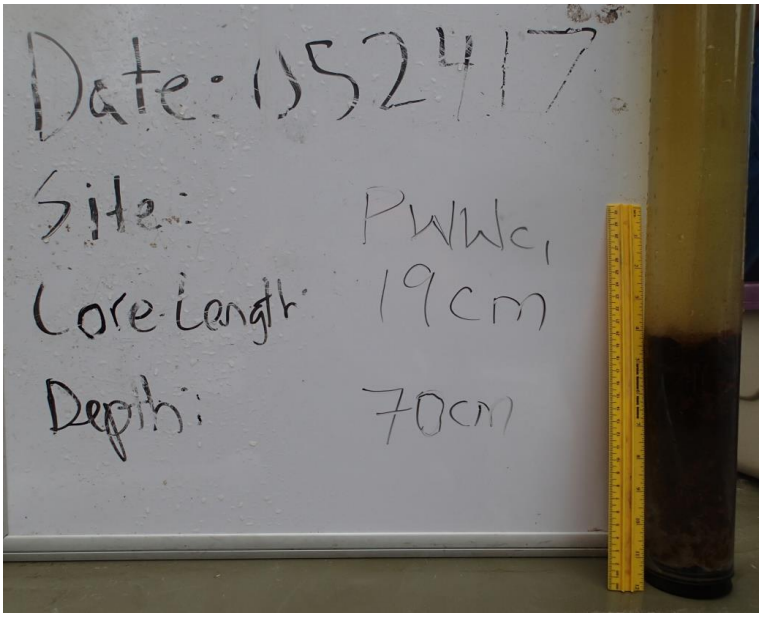


Appendix2_ 15. Core 2, Golf Course pond.

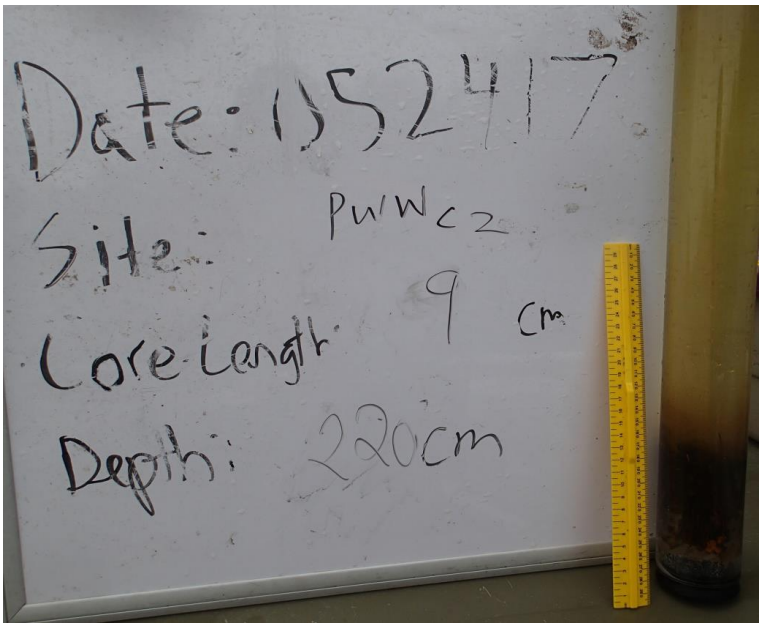


Appendix2_ 16. Core 3, Golf Course pond.

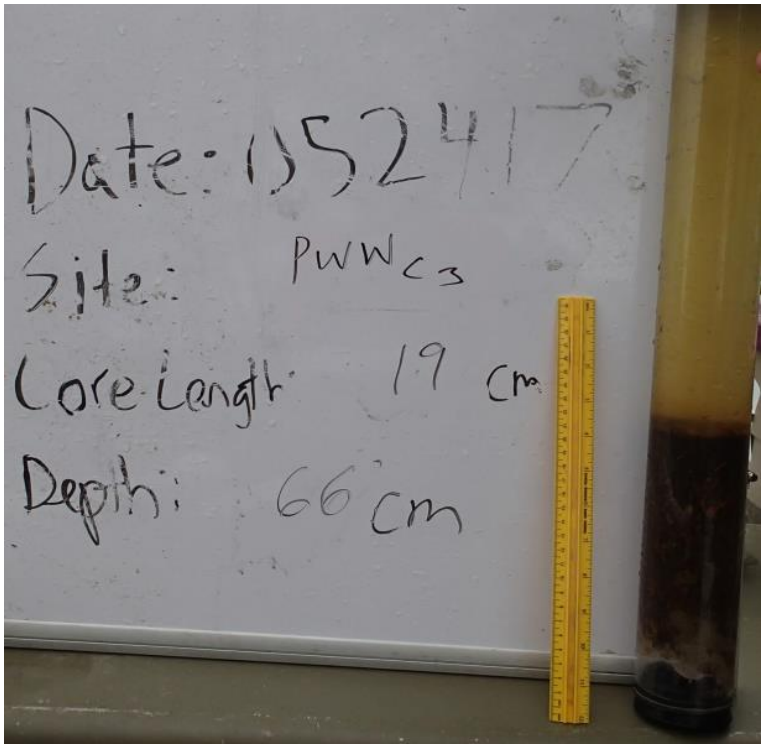
5. Heron Landing pond (3/22/17)



Appendix2_ 17. Core 1, Heron Landing Pond

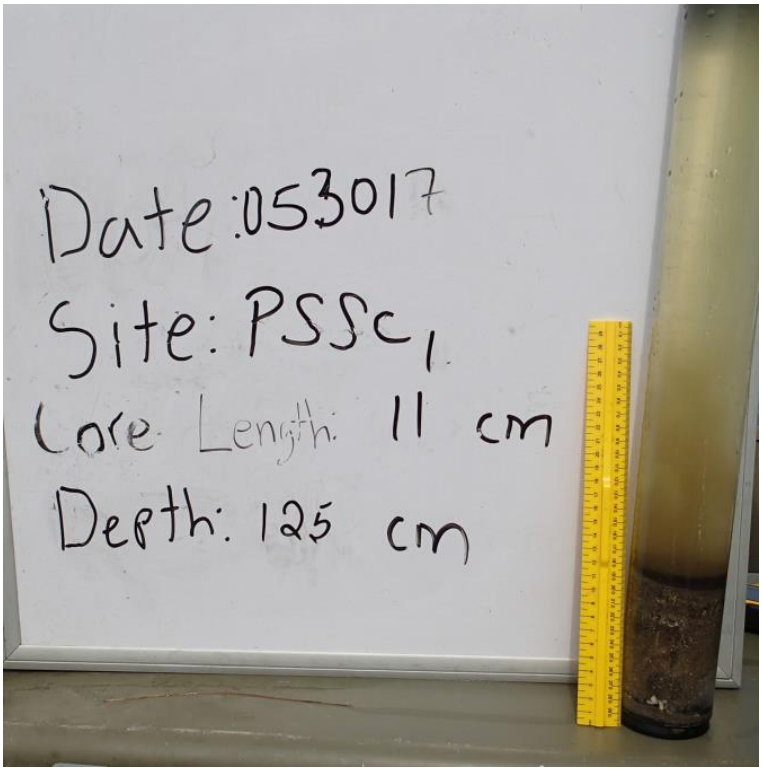


Appendix2_ 18. Core 2, Heron Landing Pond

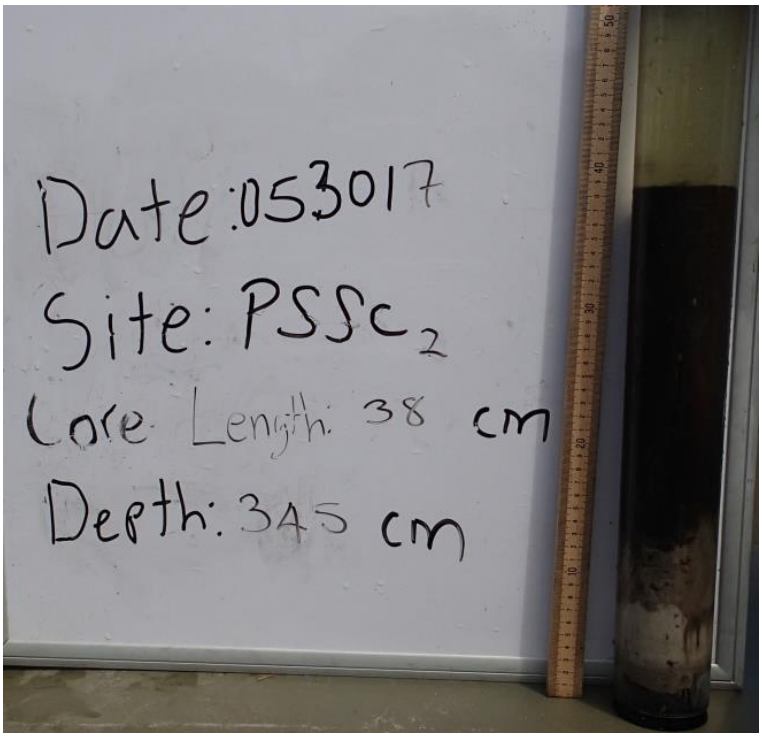


Appendix2_ 19. Core 3, Heron Landing Pond

6. Sanctuary pond (3/6/17)

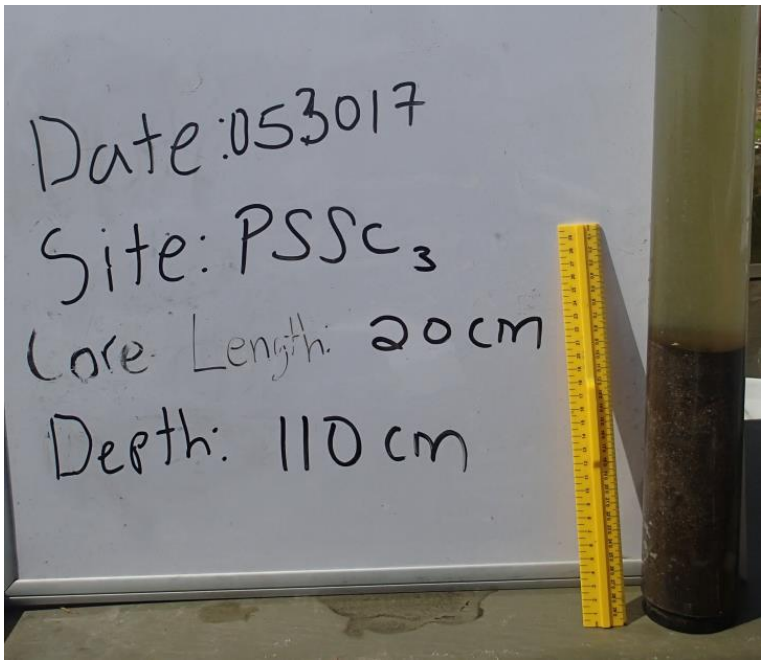


Appendix2_ 20. Core 1, Sanctuary Pond



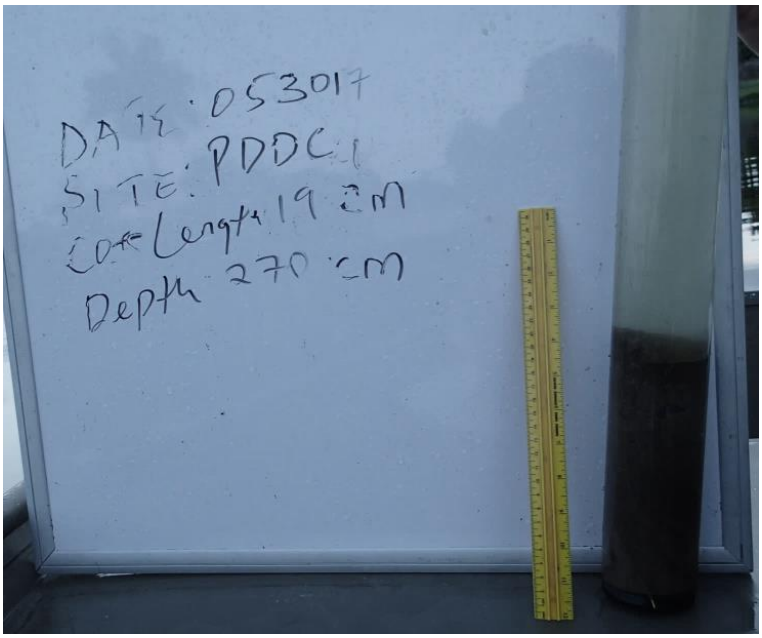
Appendix2_ 21. Core 2, Sanctuary Pond

Appendix2_ 22. Closeup of sedimentary material in core 2, Sanctuary Pond

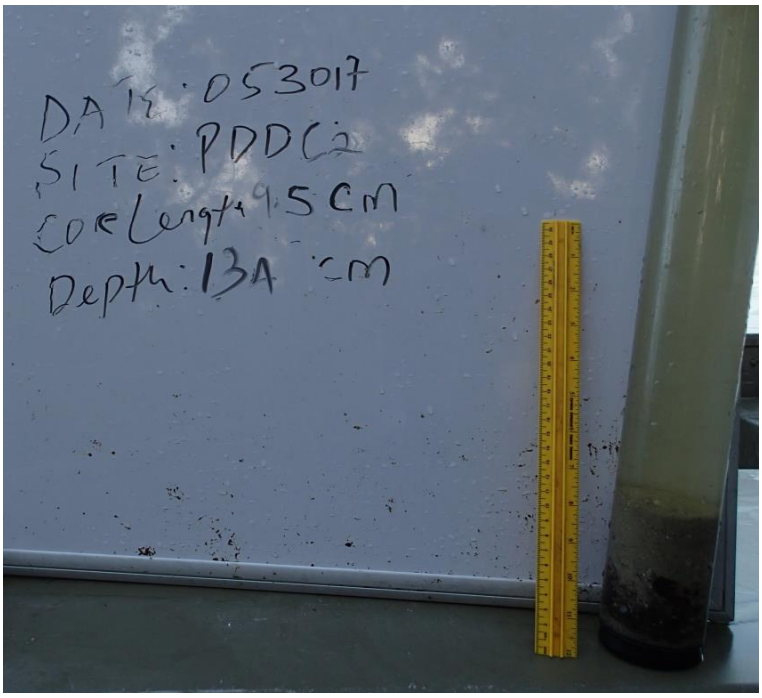


Appendix2_ 23. Core 3, Sanctuary Pond

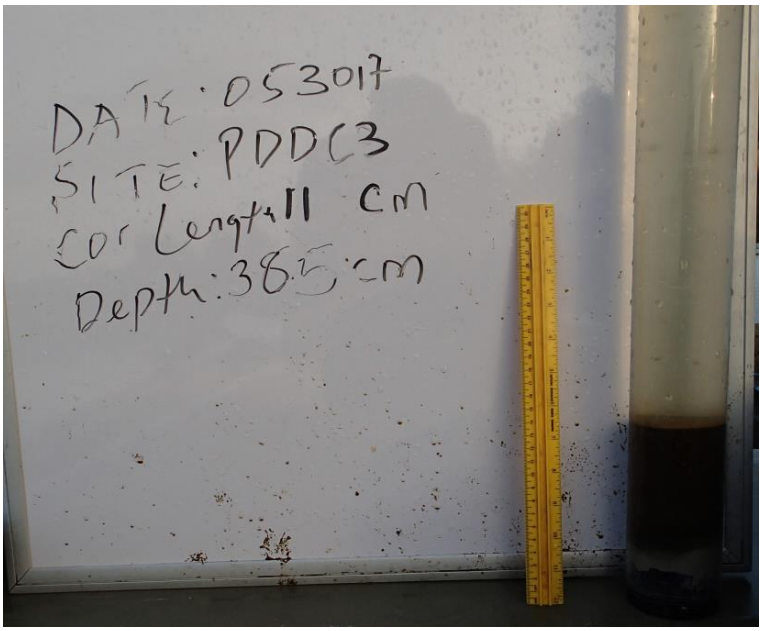
7. The Dunes pond (3/6/17)



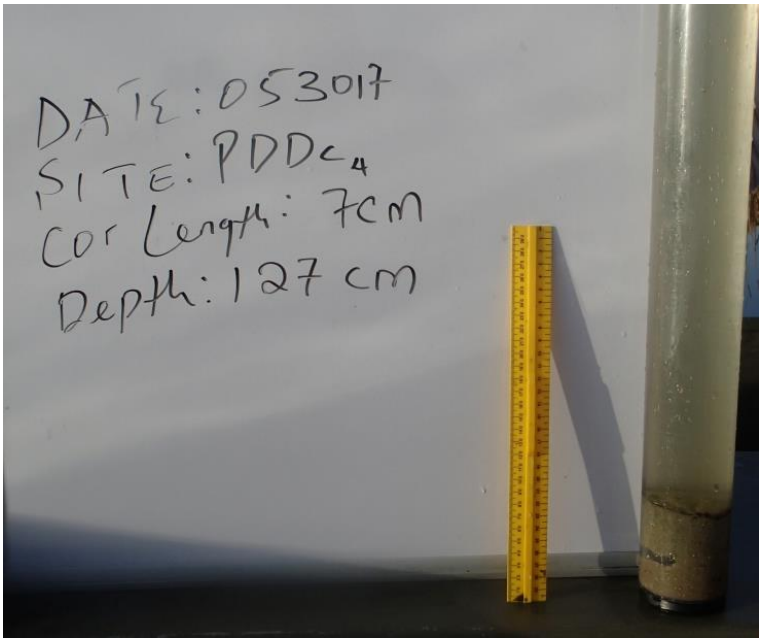
Appendix2_ 24. Core 1, The Dunes Pond



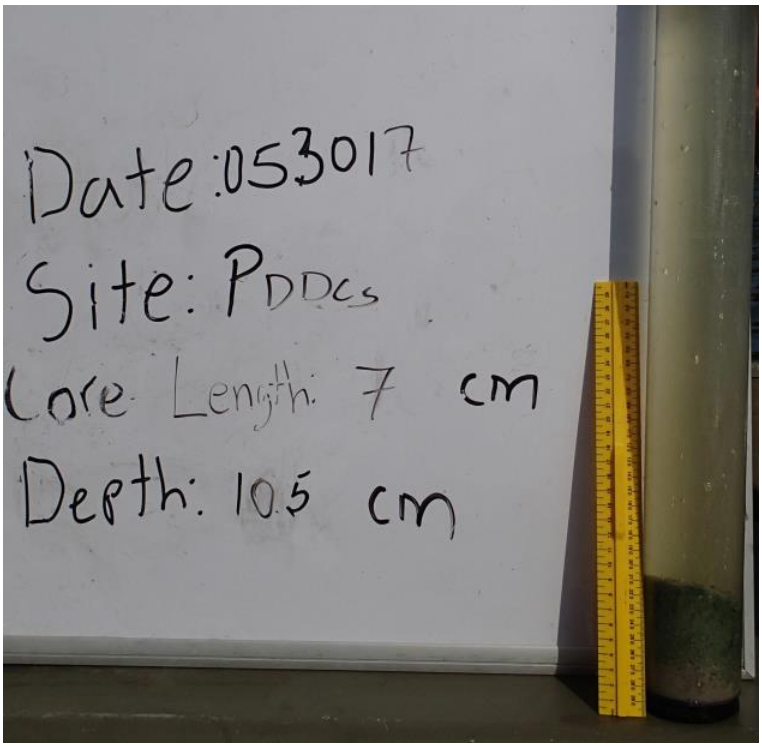
Appendix2_ 25. Core 2, The Dunes Pond



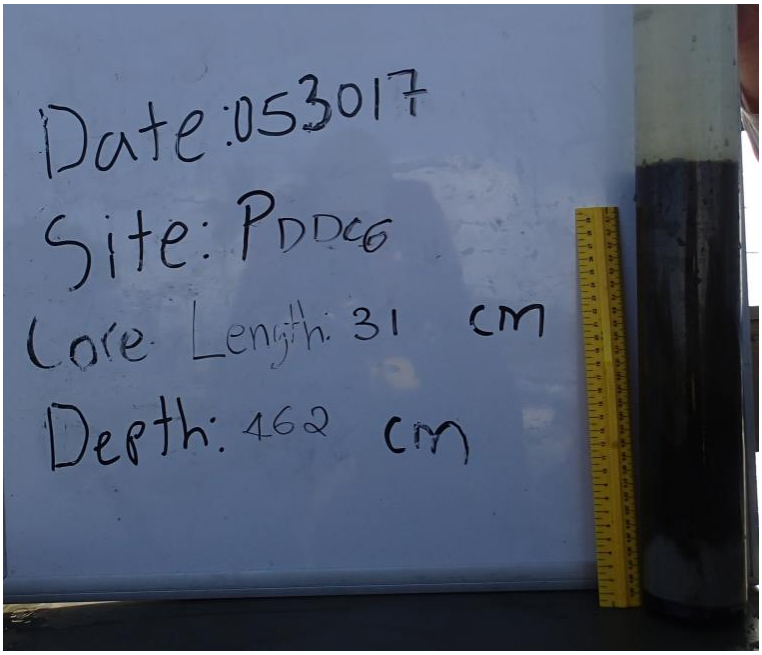
Appendix2_ 26. Core 3, The Dunes Pond



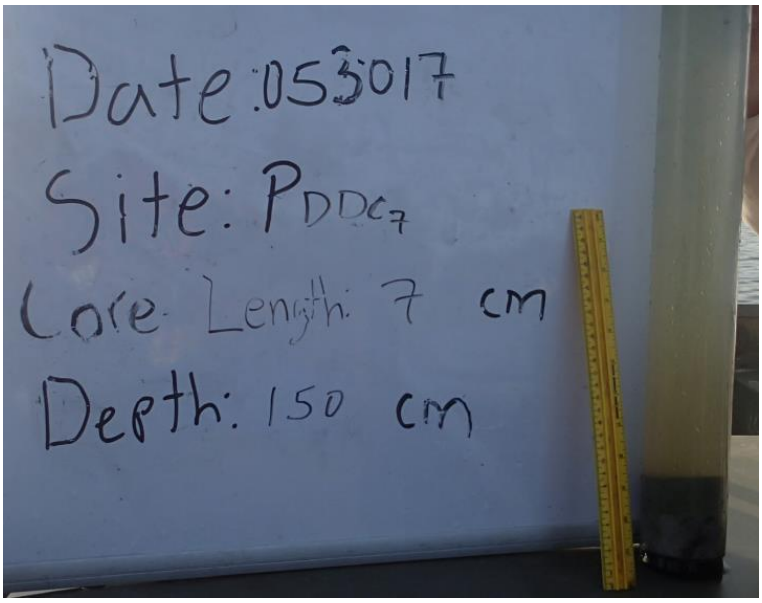
Appendix2_ 27. Core 4, The Dunes Pond



Appendix2_ 28. Core 5, The Dunes Pond

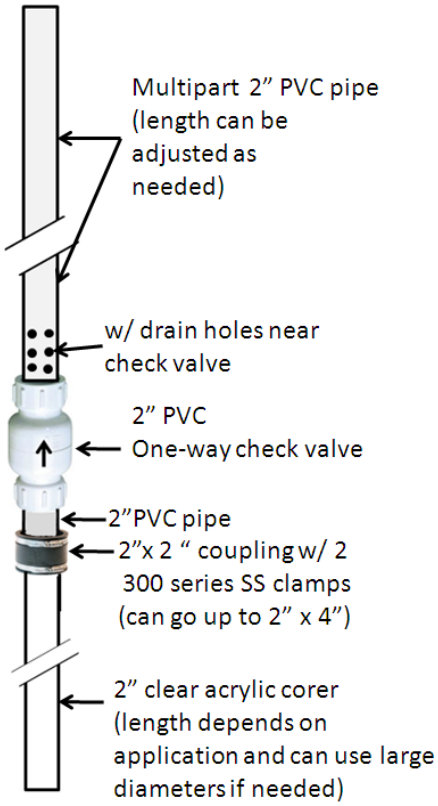


Appendix2_ 29. Core 6, The Dunes Pond



Appendix2_ 30. Core 7, The Dunes Pond

Appendix 3. Corer design



The piston consists of a 2" one-way check valve (Mfg# 101-108HC). This piston features spring-loaded poppet and stainless-steel spring with O-ring seal.

The arrow on the check valve shows that water can move only in one direction (upward in our case). The length of the clear acrylic core used depends on the intended depth of the core. Retrieving 2-m cores with this system is not a problem.

Depending on the water depth, the length of pipe above the check valve can be adjusted.

Once the corer is assembled, it is lowered until the sediment is reached, then pushed down to the desired depth, then pulled up to the surface. The water inside the pipe above the check valve is drained through the drain holes.

With the clear acrylic (or CAB) corer still in the water, a rubber is inserted at the open end, and then the corer is lifted outside the water.

The acrylic core is separated from the coupling using an electric screwdriver.

Appendix 4. Similarity matrix showing the correlations between the different parameters measured

	NAVD	Vol	SA	Mean Depth	bed_hard	Temp	cond	sal	DO	pH	ORP	Turb	Zeu	SD	Zmax	AT	Chla	NOx	NH4+	TN	TP	SRP	TNvTP	TSI	Core_Z	Floc_I	Sed_I	Floc_sed_I	Sed_TP	Sed_N	Sed_C	Floc_TP	Floc_N	Floc_C	Sed_org
Vol	12%																																		
SA	8%	100%																																	
Mean Depth	-3%	70%	70%																																
bed_hard	3%	12%	13%	63%																															
Temp	59%	18%	18%	-10%	-10%																														
cond	-39%	-8%	-9%	26%	35%	-93%																													
sal	-37%	-9%	-10%	25%	35%	-93%	100%																												
DO	53%	18%	19%	11%	14%	95%	-86%	-86%																											
pH	9%	13%	16%	18%	13%	77%	-79%	-80%	88%																										
ORP	37%	-5%	-5%	-42%	-54%	74%	-91%	-91%	66%	59%																									
Turb	-27%	6%	5%	40%	48%	-83%	97%	97%	-75%	-73%	-96%																								
Zeu	22%	18%	20%	-14%	-32%	86%	-97%	-98%	83%	85%	89%	-96%																							
SD	65%	-44%	-47%	-49%	-37%	63%	-65%	-64%	56%	36%	69%	-67%	49%																						
Zmax	40%	84%	83%	69%	39%	14%	4%	4%	20%	-1%	-9%	18%	1%	-35%																					
AT	-31%	-3%	-3%	35%	45%	-71%	87%	87%	-65%	-58%	-98%	92%	-88%	-54%	-3%																				
Chla	-10%	56%	56%	93%	66%	-38%	57%	56%	-10%	-14%	-70%	70%	-48%	-61%	59%	65%																			
NOx	-58%	-29%	-29%	2%	14%	-94%	93%	93%	-92%	-75%	-85%	86%	-91%	-57%	-30%	85%	35%																		
NH4+	12%	94%	93%	72%	20%	-7%	22%	22%	-8%	-17%	-33%	36%	-15%	-55%	85%	26%	70%	-2%																	
TN	-14%	78%	78%	89%	62%	-25%	41%	39%	-10%	-6%	-53%	53%	-27%	-76%	80%	40%	88%	14%	84%																
TP	-16%	-18%	-20%	21%	37%	-82%	95%	96%	-76%	-78%	-89%	95%	-99%	-42%	-1%	91%	54%	88%	15%	28%															
SRP	-21%	-17%	-19%	18%	34%	-85%	97%	98%	-81%	-83%	-90%	96%	-100%	-48%	0%	90%	52%	90%	16%	29%	99%														
TNvTP	-64%	1%	4%	-4%	-22%	-17%	-13%	-15%	-9%	23%	32%	-28%	32%	-31%	-10%	43%	-20%	-5%	-18%	3%	-39%	-34%													
TSI	-18%	53%	53%	32%	10%	68%	-59%	-59%	-31%	-25%	-84%	79%	-59%	-78%	56%	75%	89%	46%	71%	89%	60%	60%	-27%												
Core_Z	71%	54%	52%	32%	-15%	-81%	70%	71%	-78%	-67%	-45%	57%	-72%	-8%	-42%	52%	12%	78%	-28%	-20%	73%	72%	-4%	-10%											
Floc_I	-30%	-50%	-53%	-14%	-34%	17%	-41%	-41%	18%	19%	70%	-56%	44%	33%	-15%	-77%	-63%	-38%	-51%	-44%	-50%	-47%	66%	-72%	-62%										
Sed_I	3%	-34%	-34%	-47%	-34%	-26%	0%	0%	-24%	-17%	39%	-21%	3%	25%	-34%	-41%	-49%	6%	-59%	-49%	-7%	-4%	58%	-63%	29%	-1%									
Floc_sed_I	-13%	-55%	-56%	-48%	-37%	2%	21%	22%	-7%	-23%	-30%	34%	-25%	-3%	50%	38%	61%	5%	71%	43%	33%	29%	-58%	44%	25%	11%	49%	87%							
Sed_TP	40%	58%	54%	56%	2%	-4%	12%	-13%	-19%	12%	-10%	6%	28%	0%	2%	38%	-5%	-6%	34%	-17%	-3%	-5%	-40%	-15%	3%	10%	-37%	-65%	-51%						
Sed_N	26%	30%	27%	-8%	-66%	12%	-13%	-13%	-9%	-19%	12%	-10%	6%	28%	0%	2%	-5%	-6%	34%	-17%	-3%	-5%	-40%	-15%	3%	10%	-37%	-50%	-31%	71%					
Sed_C	5%	16%	14%	-20%	-61%	-15%	14%	15%	-39%	-45%	-16%	15%	-22%	6%	-15%	29%	-5%	26%	29%	-18%	21%	22%	-43%	-1%	-30%	25%	-50%	-36%	-31%	59%	92%				
Floc_TP	26%	-19%	-22%	29%	12%	-18%	27%	27%	-8%	-11%	-26%	29%	-34%	34%	-12%	41%	39%	24%	-5%	-6%	47%	39%	-48%	7%	-9%	57%	-36%	21%	6%	49%	60%	35%	23%		
Floc_N	-5%	-18%	-21%	1%	-47%	-19%	-1%	-1%	-14%	-1%	22%	-12%	4%	36%	-28%	-11%	-2%	7%	-19%	-30%	3%	-1%	19%	-42%	-6%	60%	21%	6%	-48%	-17%	29%	43%	25%	66%	
Floc_C	-11%	-25%	-28%	-2%	-44%	-42%	25%	25%	-40%	-28%	-3%	13%	-24%	23%	-32%	15%	6%	34%	-16%	-27%	30%	27%	6%	-27%	-26%	79%	6%	45%	36%	47%	39%	93%	72%	46%	
Sed_org	10%	10%	6%	-8%	-48%	-38%	39%	40%	-55%	-63%	-32%	39%	-47%	2%	-7%	45%	13%	44%	31%	-9%	48%	48%	-47%	10%	-31%	51%	-48%	6%	69%	85%	93%	40%	47%	58%	
Floc_org	-26%	3%	1%	-2%	-64%	-40%	19%	19%	-46%	-30%	-1%	9%	-15%	4%	-24%	11%	4%	32%	8%	-16%	17%	16%	16%	-21%	-29%	62%	-5%	27%	43%	68%	63%	47%	85%	90%	71%

Appendix 5. Parameters fed to the PCA.

	BV	BT	CM	GC	WW	SS	DD
NAVD'88 (m)	0.25	-0.50	-0.27	0.25	-0.17	0.17	0.10
Volume (m3)	414	27055	9791	12679	8595	9007	207700
Planar Surface area (m2)	522	15007	8219	8218	4774	4540	81404
Mean Depth (m)	0.80	1.80	1.20	1.60	1.90	2.10	2.60
Bottom hardness (a.u.)	0.30	0.39	0.37	0.47	0.44	0.42	0.41
Temperature (ºC)	30.70	28.89	30.92	31.81	26.69	31.25	31.01
Specific conductance (µs/cm)	838.46	8814.56	2714.40	1974.74	32705.18	2466.82	5690.12
Salinity (PSU)	0.42	4.99	1.42	1.02	20.77	1.29	3.13
DO (mg/l)	4.31	3.83	5.05	7.61	0.08	7.30	5.93
pH (a.u.)	7.62	8.19	8.19	8.26	7.04	8.48	8.09
ORP (mV)	394.14	218.86	137.06	224.85	-222.29	206.59	136.66
Turbidity (NTU)	2.31	24.00	18.60	20.30	111.00	20.20	38.20
Euphotic zone depth (m)	2.77	2.30	1.92	2.11	N.D.	1.59	1.37
Secchi disk depth (cm)	121	45	75	87	35	121	44
Water depth at station (cm)	233	235	152	316	265	233	441
Total Alkalinity (mg CaCO3eq/l)	129.50	194.00	297.00	192.00	507.00	269.00	258.00
Chl*a* (µg/l)	6.04	36.91	22.28	31.57	63.18	49.56	66.10
NOx (mg/l)	0.02	0.04	0.04	0.02	0.08	0.03	0.02
NH4+ (mg/l)	0.03	0.06	0.04	0.06	0.53	0.05	1.58
TN (mg/l)	0.80	2.57	1.58	2.42	3.03	1.96	4.16
TP (mg/l)	0.03	0.02	0.08	0.12	3.82	0.65	0.17
SRP (mg/l)	0.02	0.07	0.04	0.05	4.12	0.28	0.13
TN/TP	29.57	125.39	20.33	20.71	0.79	3.02	24.34
TSI (a.u.)	48.67	63.63	65.42	68.43	84.00	63.64	81.91
Depth at coring station (cm)	194.80	160.67	123.67	219.00	118.67	193.33	233.29
Floc thickness (cm)	3.90	3.83	2.67	2.00	5.33	3.83	2.00
Sed thickness (cm)	8.70	9.00	4.50	7.67	4.17	5.50	4.50
Floc+ sediment thickness (cm)	12.60	12.83	7.17	9.67	9.50	9.33	6.50
Sediment TP (%)	0.41	0.06	0.25	0.11	0.56	0.62	0.81
Sediment TN (%)	1.20	0.45	0.97	0.26	0.77	0.95	1.11
Sediment TC (%)	18.91	8.89	18.50	6.27	16.68	13.44	16.84
Floc TP (%)	0.39	0.16	0.17	0.10	0.69	1.10	0.29
FlocTN (%)	1.94	1.81	0.89	0.35	1.33	2.30	1.12
Floc TC (%)	26.69	23.49	15.07	7.01	24.68	29.21	16.26
Sediment organic content (%)	19.34	9.35	15.50	6.33	19.92	14.89	16.52
Floc organic content (%)	21.28	19.33	16.36	6.95	18.75	19.71	17.65

Table 4. Summary table of all the parameter studied and ran into the PCA. Some are averages. N.D. denotes as non-determined. BV= Beach Villa, BT= Bike Trail, CM=Chateau-Sur-Mer, GC= Golf Course, WW=Heron Landing, SS=Sanctuary, DD=The Dunes.