Draft Final report

Sediment assessment of Lakes 11 and 31 (City of Naples)

Final report submitted to:
City of Naples

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I. Introduction

The City of Naples requested limnological work to be performed on three of their stormwater lakes (lake 11, 19 and 31). One of the lakes (11, see below) has undergone studies in 2008 (MACTEC, 2008[1]) as well as in 2012 (Thomas, 2013a[2]). Along with lake 22 (Thomas, 2013b[3]), lake 11 already was eutrophic with significant amount of organic sediment and flocculent on its bed. Sediment often exceeded the soil cleanup target levels (SCTLs) for some metals. This lake as well as lake 22 were good candidates for dredging. Lake 22 was then dredged, reshaped and planted with natives within its littoral as well as riparian zone. Surrounding watershed improvements were also implemented, e.g. the use of pervious asphalt to improve the drainage. Most of the lakes within the City's limits are indeed old (well over 30 years of age; Pers. Comm. From the City of Naples) and have never been dredged. Thus, as for Lake 22, the City seeks data-driven insights to restore the original flood mitigation and ecological filtration of its lakes. Measures including lake dredging, bank restoration, shoreline restoration/re-shaping as well as bioremediation such as littoral planting will be therefore considered as restoration measures.

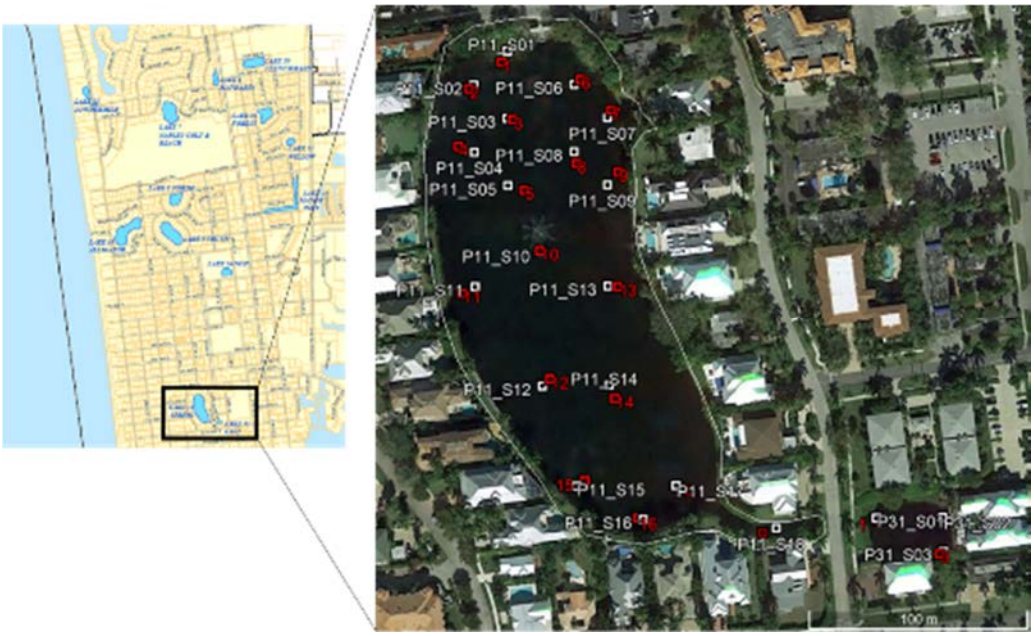


FIGURE 1. Lakes 11 and 31 and their planned (white) and actual (red) coring locations (squares).

[1] MACTEC. 2008. Spring Lake. Report of the surface water and sediment testing, Naples, Collier County, Florida. Mactec project 6787-08-1859.

[2] Thomas S. 2013. Bathymetry and sediment characterization of Spring Lake, City of Naples, FL. Streets and Stormwater, City of Naples FL.

[3] Thomas S. 2013. Bathymetry and sediment characterization of Lake Manor, City of Naples, FL. Streets and Stormwater, City of Naples FL.

II. Methods

1. Study sites and coring locations

The two stormwater lakes are located within the City of Naples. Lake 11 (5.4 acres; 17R 420019m E 2891385m N) and 31 (0.77 acres; 17R 420182m E 2891270m N) were visited and their sediment cored from March through April 2020, additionally, they were cored again in early May 2020 to be in compliance with the sampling hold time required by the NELAC Certified laboratory. A total of 18 and 3 core locations were selected for lakes 11 and 31 respectively and the sediment cores were composited as outlined in TABLE 1.

TABLE 1. Coring names and locations of lakes 11 and 31. The table is also showing how the cores were planned to be composited. Numbers in parentheses in the "composited" column refer to the sediment cores which did not have enough sediment to be composited with the other cores (where applicable). Refer to the methods section for more insight.

Lake #	Core #	Sample ID	Easting (m)	Northing (m)	Composited
11	1	P11_S01	419998	2891488	(1),2,3
	2	P11_S02	419983	2891476	
	3	P11_S03	420003	2891462	
	4	P11_S04	419978	2891450	4,5
	5	P11_S05	420008	2891430	
	6	P11_S06	420034	2891480	6,7
	7	P11_S07	420048	2891466	
	8	P11_S08	420032	2891442	8,9
	9	P11_S09	420051	2891438	
	10	P11_S10	420015	2891403	10,11
	11	P11_S11	419979	2891383	
	12	P11_S12	420019	2891344	12
	13	P11_S13	420050	2891386	13
	14	P11_S14	420049	2891335	14
	15	P11_S15	420035	2891298	15,16
	16	P11_S16	420059	2891281	
	17	P11_S17	420083	2891292	17,(18)
	18	P11_S18	420116	2891273	
31	1	P31_S01	420169	2891279	1,(2),3
	2	P31_S02	420199	2891279	
	3	P31_S03	420197	2891263	

2. Field methods

The collection of the sediment was done from a Tracker TOPPER™ 1436 aluminum Jon boat using a homemade PVC handheld corer equipped with a one-way check valve and a machined PVC boot adapter to securely couple a clear extruded 3.5" OD acrylic 1/8" thick barrel. The barrels came in various lengths to accommodate the sediment thickness. The station locations were preloaded in a handheld Garmin GPSMAP 64st GNSS unit with GPS, GLONASS and WAAS enabled. At each station, the boat was anchored at both ends and coring was proceeded from either the port or starboard side. Prior to core, the water depth was sounded. Next, a sediment core was taken by pushing the acrylic core vertically into the lake's bed until refusal. The barrel containing the core was then hauled to the surface, plugged at both

ends and a visual description of the various sediment strata were recorded. Photographs of the sediment core in its barrel along with the core's visual characteristics were then taken against a white background using a rugged 12-megapixel Olympus TG-1iHS camera. The core was then extruded from bottom up and strata were then described and measured again. These cores characteristics are presented in TABLE 3. The flocculent stratum defined as material which flows and does not free stand was measured but discarded. Only the "sediment" stratum defined as organic material, silt or other materials (sometimes clay) which obviously settled above the sand, limestone, or marl was kept and eventually combined with other sediment materials from other station(s) (cf. TABLE 1 for further details). In the event of core composition, special care was taken so that the amount of material taken at each location was roughly equivalent in volume. The materials underneath the sediment were described, their strata widths measured and discarded.

3. Sediment parsing

The sediment was thoroughly mixed with a silicone spatula in either a plastic or a metal mixing bowl depending on the type of analyses performed. Part of the sediment was then conditioned in glass jars provided by Pace Analytical Laboratories (www.pacelabs.com) and kept on ice in an enclosed cooler. The remainder of the sediment was kept in doubled zip-lock™ bags which were also chilled in the cooler. Once the samples arrived at the laboratory, the sediment was kept in a walk-in refrigerator until being shipped overnight in a cooler packed with ice to Pacelabs in Pompano Beach. The sediment in plastic bags were transferred into 1L plastic specimen jars and kept in the walk-in refrigerator at 5ºC until being processed at FGCU.

4. Outsourced NELAC laboratory (www.pacelabs.com) methods (TABLE 2)

TABLE 2. Methods used by Pacelabs.

Analyte	Method
Nitrogen, Ammonia	EPA 350.1
Nitrogen, Kjeldahl, Total	EPA 351.2
Phosphorus, Total (as P)	EPA 365.4
Arsenic	EPA 6010
Arsenic, SPLP	
Barium	
Barium, SPLP	
Cadmium	
Cadmium, SPLP	
Chromium	
Chromium, SPLP	
Copper	
Copper, SPLP	
Lead	
Lead, SPLP	
Selenium	
Selenium, SPLP	
Silver	
Silver, SPLP	
Petroleum Range Organics	FL-PRO

Analyte	Method
Mercury, SPLP	EPA 7470
Mercury	EPA 7471
4,4'-DDD	EPA 8081
4,4'-DDE	
4,4'-DDT	
Aldrin	
Chlordane (Technical)	
Dieldrin	
Endosulfan I	
Endosulfan II	
Endosulfan sulfate	
Endrin	
Endrin aldehyde	
Endrin ketone	
Heptachlor	
Heptachlor epoxide	
Methoxychlor	
Toxaphene	
alpha-BHC	
beta-BHC	
delta-BHC	
gamma-BHC (Lindane)	

Analyte	Method
PCB-1016 (Aroclor 1016)	EPA 8082
PCB-1221 (Aroclor 1221)	
PCB-1232 (Aroclor 1232)	
PCB-1242 (Aroclor 1242)	
PCB-1248 (Aroclor 1248)	
PCB-1254 (Aroclor 1254)	
PCB-1260 (Aroclor 1260)	
1-Methylnaphthalene	EPA 8270
2-Methylnaphthalene	
Acenaphthene	
Acenaphthylene	
Anthracene	
Benzo(a)anthracene	
Benzo(a)pyrene	
Benzo(b)fluoranthene	
Benzo(g,h,i)perylene	
Benzo(k)fluoranthene	
Chrysene	
Dibenz(a,h)anthracene	
Fluoranthene	
Fluorene	
Indeno(1,2,3-cd)pyrene	
Naphthalene	
Phenanthrene	
Pyrene	

a. Nutrients

Sediment nutrients were analyzed using the following EPA methods: EPA 350.1 (ammonia), EPA 351.2 (Total Kjeldahl Nitrogen, TKN) and EPA 365.4 (Total Phosphorus, TP).

b. Organochlorine pesticides and polychlorinated biphenyls (PCBs, Polyvinyl chloride)

Organochlorine pesticides and PCBs were analyzed using the EPA 8081 and 8082 methods respectively.

c. Polynuclear Aromatic Hydrocarbons (PAHs)

PAHs were analyzed using the EPA low level method 8270.

d. Total Recoverable Petroleum Hydrocarbons (TRPH)

TRPH were analyzed using the FDEP approved Florida Petroleum Residual Organic (FL-Pro) method and targets the detection of aromatic hydrocarbons in a carbon chain range of C8-C40.

e. Resource Conservation and Recovery Act (RCRA) metals (8) and copper

The 8 RCRA metals and copper were measured using the EPA methods 7471 and 6010.

f. Synthetic Precipitation Leaching Procedure (SPLP) on RCRA metals and copper

SPLP was done using the EPA leachate method 1312 and the analyzes performed using the EPA methods 7470 and 6010 for the 8 RCRA metals and copper.

5. FGCU laboratory methods

a. Water, organic, inorganic contents and bulk density

Water, organic and inorganic contents were determined using the ASTM D2974-87 method whilst the bulk density was determined using the ASTM D4531-86 method.

b. Grain size analysis

The grain size analysis of each sample was determined using the wet sieving method following the ASTM D 422 for particles larger than 75µm and D1140 for materials finer. Additionally, each sample was run in a Malvern Mastersizer 3000 for a more precise grain size analysis.

c. Atterberg limits for liquid limit, plasticity limit and plasticity index

Sediment liquid limit (LL), plasticity limit (PL) and plasticity index (PI) were determined using the ASTM D4318 method.

6. Mapping

Mapping of the data, when provided, was made using Surfer 17 (www.goldensoftware.com) using the Kriging method and appropriate variogram to interpolate spatially the data.

III. Results

1. Field characterization of sediment

The floc and sediment of lake 11 were 9.9±S.D.6.7 cm and 11.5±S.D.9.2 cm thick respectively. The floc often had filamentous algae and vegetation debris (leaves, twigs and alike) in the north portion of the lake. The sediment also had some leaves and filamentous algae (which turned black with sediment depth) in the north portion of the lake as well as some fibrous peat in it. The sediment was very dark and appeared to be organic rich with often some sand in it. The sediment was highly heterogenous at some locations in both thickness and strata characteristics. The sediment was most often sitting on a layer of sand of various grain size but mostly fine sand of various tints. Spatially, there is more floc from north to south but with less floc in the canal connecting lake 11 to 31. The sediment thickness shows roughly the same trend as for the floc but with especially less sediment on the center east of the lake as well as in its upper north portion. The canal had little sediment whilst the mouth of it had more.

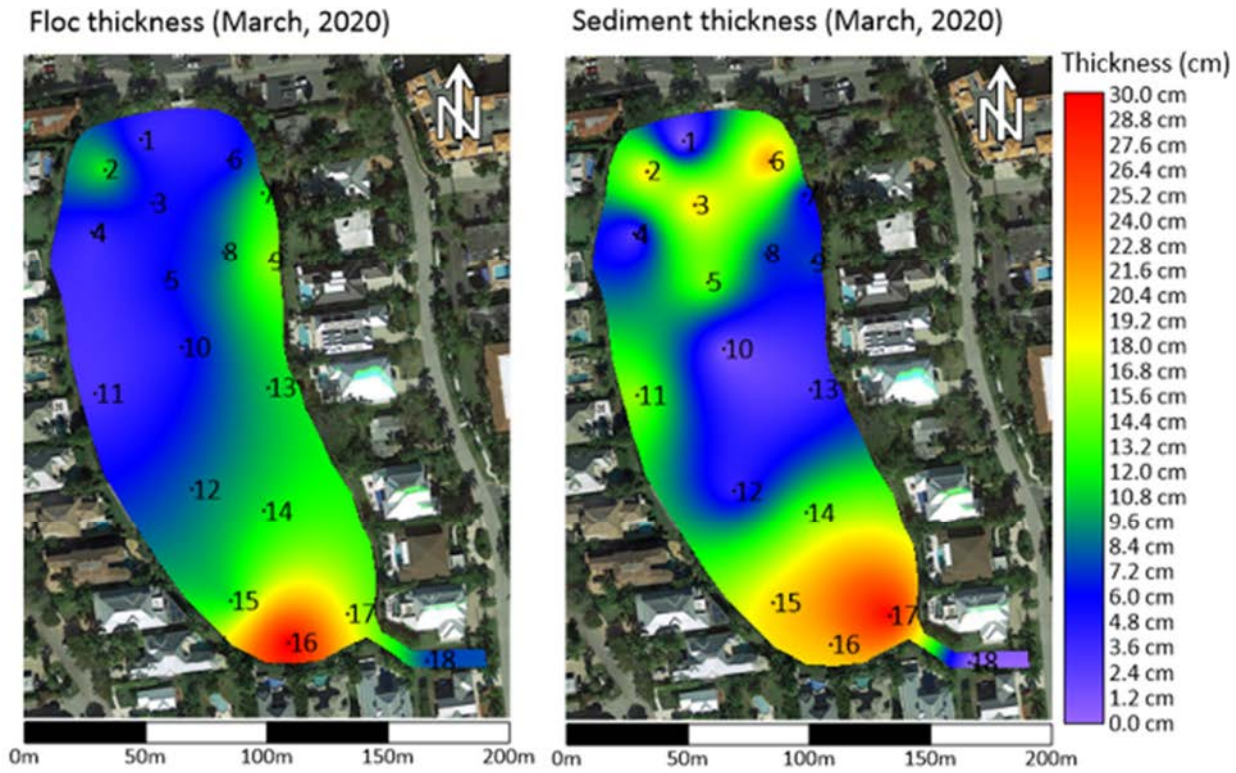


FIGURE 2. Floc and sediment thicknesses in lake 11.

TABLE 3. Sediment characteristics of lake 11 measured in the field.

ID_Station	UTM X (m)	UTM Y (m)	water depth (cm)	Tot. core length (cm)	Floc. Length (cm)	Sed. Length (cm)	Core description
P11_S01	419998	2891488	33	15.0	3.5	0.0	green filamentous algae on top, 11cm gray-tan sand
P11_S02	419983	2891476	111	41.0	12.0	19.5	green/black filamentous algae on top, 19.5cm of peat with some vegetation debris, 7 cm of gray sand, 3.5 cm of brown-tan sand
P11_S03	420003	2891462	136	44.0	5.5	19.5	19.5cm of black sediment with peat, 19cm of tan sand
P11_S04	419978	2891450	147	24.5	3.5	2.5	2.5cm black sediment, , 14.5cm of tan sand, 2cm of gray sand (Note: high core variability. Second core had 19cm of black sediment, 20cm of light tan sand
P11_S05	420008	2891430	129	25.0	6.0	15.0	15cm of black sediment, 1cm of gray sand
P11_S06	420034	2891480	121	43.0	5.0	22.0	16cm of tan sand, black sediment w/some peat
P11_S07	420048	2891466	98	52.0	12.0	5.5	sediment has sand and organic matter, leaf matter, sticks. 29.5cm part sand brown, light grey with organic material, another peat layer on bottom about 5cm thick
P11_S08	420032	2891442	156	25.5	8.5	7.0	dark brown sediment with leaves. Brown/dark grey fine sand: 10cm
P11_S09	420051	2891438	127	45.0	15.5	7.5	dark brown sediment speckled w/sand+peat. Fine sand, dark brown mixed w/organic matter: 22 cm
P11_S10	420014.9	2891403	120	20.5	5.0	1.0	light brown sediment speckled with sand. Sand is light grey with organics 14.5 cm
P11_S11	419979.3	2891383	99	18.5	3.0	15.5	dark to very light grey sand mottled with organic matter/leaves/shell fragments/ floc is dark brown/fibrous
P11_S12	420019.2	2891344	178	44.0	8.5	4.0	dark brown floc, sediment layer is dark brown, some leaf matter, 31 cm sand is dark gray with mottled black sediment and leaf matter
P11_S13	420050.4	2891386	147	41.0	10.5	3.0	floc light brown slightly fibrous, sediment light fibrous brown with shell. Sand light grey to white mottled with organic matter (18cm)
P11_S14	420048.9	2891335	196	40.0	11.5	14.0	dark brown floc that transitions to a lighter brown w/ white calcite shell fragments. 14 cm of dark brown, smooth sediment. 12.5 cm of redish-brown sand with fine grain.
P11_S15	420035.1	2891298	173	41.0	11.5	19.5	dark-tan peat with clippings of leaves. 10cm of grey sand mottled w/organic matter.
P11_S16	420059.1	2891281	158	66.0	31.0	21.0	dark-brown peat with leaf fragments at the top. 14cm sand is dark grey with some leaf fragments.
P11_S17	420083.1	2891292	174	48.0	17.5	30.0	blackish-brown peat with leaf fragments. 0.5cm or sand light tan with tints of grey.
P11_S18	420116.1	2891273	68	18.0	7.5	0.0	No sediment. Dark gray sand with green filamentous algae 10.5cm. Light grey was mixed as well as pockets of leaves.
		average:	132	36.2	9.9	11.5	
		S.D.	41	14.0	6.7	9.2	

The floc and sediment of lake 31 were 5.5±S.D.1.3 cm and 5.8±S.D.5.1 cm thick respectively. The floc had lots of vegetation debris and, when available, the sediment also held not well decomposed leafy materials. Fine sand was underlying the sediment at all sites.

TABLE 4. Sediment characteristics of lake 31 measured in the field.

ID_Station	UTM X (m)	UTM Y (m)	water depth (cm)	Tot. core length (cm)	Floc. Length (cm)	Sed. Length (cm)	Description of bottom of core (not muck)
P31_S01	420169	2891278.84	187	27.0	5.0	9.5	sediment very leafy and fibrous partialy, poorly decayed greenish brown color. Sand 12.5cm
P31_S02	420199	2891278.88	113	24.0	7.0	8.0	floc green/brown. Sediment fibrous green mixed with algae+sand+ organic material. 9cm of sand light tan/brown
P31_S03	420197	2891263.37	150	27.0	4.5	0.0	floc light brown poorly decayed vegetation. sediment peat like not well decayed. 22.5cm Interspersed with pockets of muddy sand with no defined layering.
		Average	150	26.0	5.5	5.8	
		S.D.	37	1.7	1.3	5.1	

2. Sediment grain size, D60, D30, D10 and plasticity limits

Sediment textures class in lake 11 varied from silt loam to loam and fine sandy loam. There were discrepancies between the D values measured with the Malvern and the wet sieving. Wet sieving shows that, in average, 60 percent of the particulate was less than 0.15±S.D.0.05mm in size. It was most often not possible to get the size of the particulate for the D30 (average 0.12±S.D.0.04mm) or it was impossible to determine the D10 because most of the particles were very fine and thus went through the size 200 (i.e., 0.074mm pore size) sieve. The Malvern provides the following averages of 0.23±S.D.0.05mm, 0.07±S.D.0.03mm, 0.02±S.D.0.00mm and 0.006±S.D.0.001mm for Dx(90), Dx(60), Dx(30) and Dx(10) respectively. Liquid limits were in average 59.7±S.D.9.2% and the plasticity limit was 39.1±S.D.5.3% for a plasticity index of 20.7±S.D.6.7%.

TABLE 5. Sediment grain size, D90, D60, D30, D10 and plasticity limits for the sediment in lake 11. Dx values were measured with the Malvern. Acronyms in the table headers: vfs= very fine sand, fs= fine sand, ms= medium sand, cs= coarse sand, vcs= very coarse sand.

Sample #	D60	D30	D10	Dx (10)	Dx (30)	Dx (60)	Dx (90)	Liquid Limit	Plasticity Limit	Plasticity Index	Clay	Silt	Sand	vfs	fs	ms	cs	vcs	Soil texture class
#	mm	mm	mm	mm	mm	mm	mm	%	%	%	%	%	%	%	%	%	%	%	
P11__S02/03	0.07	ND	ND	0.005	0.01	0.04	0.21	68.4	40.0	28.4	13.09	50.33	36.58	16.61	12.95	6.64	0.38	0	silt loam
P11__S04/05	0.18	0.09	ND	0.008	0.02	0.09	0.26	56.0	38.9	17.1	6.33	40.79	52.9	21.06	20.96	10.12	0.76	0	fine sandy loam
P11__S06/07	0.15	ND	ND	0.005	0.02	0.06	0.22	57.8	39.1	18.7	10.87	44.74	44.43	18.93	17.9	7.41	0.19	0	loam
P11__S08/09	0.16	ND	ND	0.007	0.02	0.10	0.26	53.3	37.5	15.9	8.2	37.49	54.27	19.86	23.22	10.34	0.85	0	fine sandy loam
P11__S10/11	0.26	0.15	ND	0.009	0.03	0.13	0.34	41.8	35.1	6.6	5.73	35.55	58.65	16.61	24.15	14.98	2.85	0.06	fine sandy loam
P11__S12	0.16	ND	ND	0.005	0.02	0.05	0.18	61.7	39.6	22.1	11.62	50.14	38.2	18.56	15.84	3.8	0	0	silt loam
P11__S13	0.16	ND	ND	0.006	0.02	0.07	0.27	58.4	31.2	27.2	10.38	43.71	45.91	17.93	16.68	10.11	1.19	0	loam
P11__S14	0.1	ND	ND	0.005	0.01	0.04	0.19	67.5	39.6	27.9	11.25	52.72	36.04	17.05	14.01	4.98	0	0	silt loam
P11__S15/16	ND	ND	ND	0.006	0.02	0.04	0.17	75.0	51.9	23.1	9.47	56.58	33.94	18.8	10.54	4.56	0.04	0	silt loam
P11__S17	0.13	ND	ND	0.006	0.02	0.06	0.18	57.4	37.8	19.5	9.63	48.22	42.14	22.17	16.14	3.83	0	0	loam
average	0.15	0.12	NA	0.006	0.02	0.07	0.23	59.73	39.07	20.66									
S.D.	0.05	0.04	NA	0.001	0.00	0.03	0.05	9.21	5.25	6.68									

TABLE 6. Sediment grain size, D90, D60, D30, D10 and plasticity limits for the sediment in lake 31. Dx values were measured with the Malvern. Acronyms in the table headers: vfs= very fine sand, fs= fine sand, ms= medium sand, cs= coarse sand, vcs= very coarse sand.

Sample #	D60	D30	D10	Dx (10)	Dx (30)	Dx (60)	Dx (90)	Liquid Limit	Plasticity Limit	Plasticity Index	Clay	Silt	Sand	vfs	fs	ms	cs	vcs	Soil texture class
#	mm	mm	mm	mm	mm	mm	mm	%	%	%	%	%	%	%	%	%	%	%	
P31__S01/03	0.27	0.15	ND	0.01	0.02	0.09	0.29	47.1	33.6	13.5	5.66	42.72	51.63	20.75	18.21	10.44	2.19	0.04	sandy loam

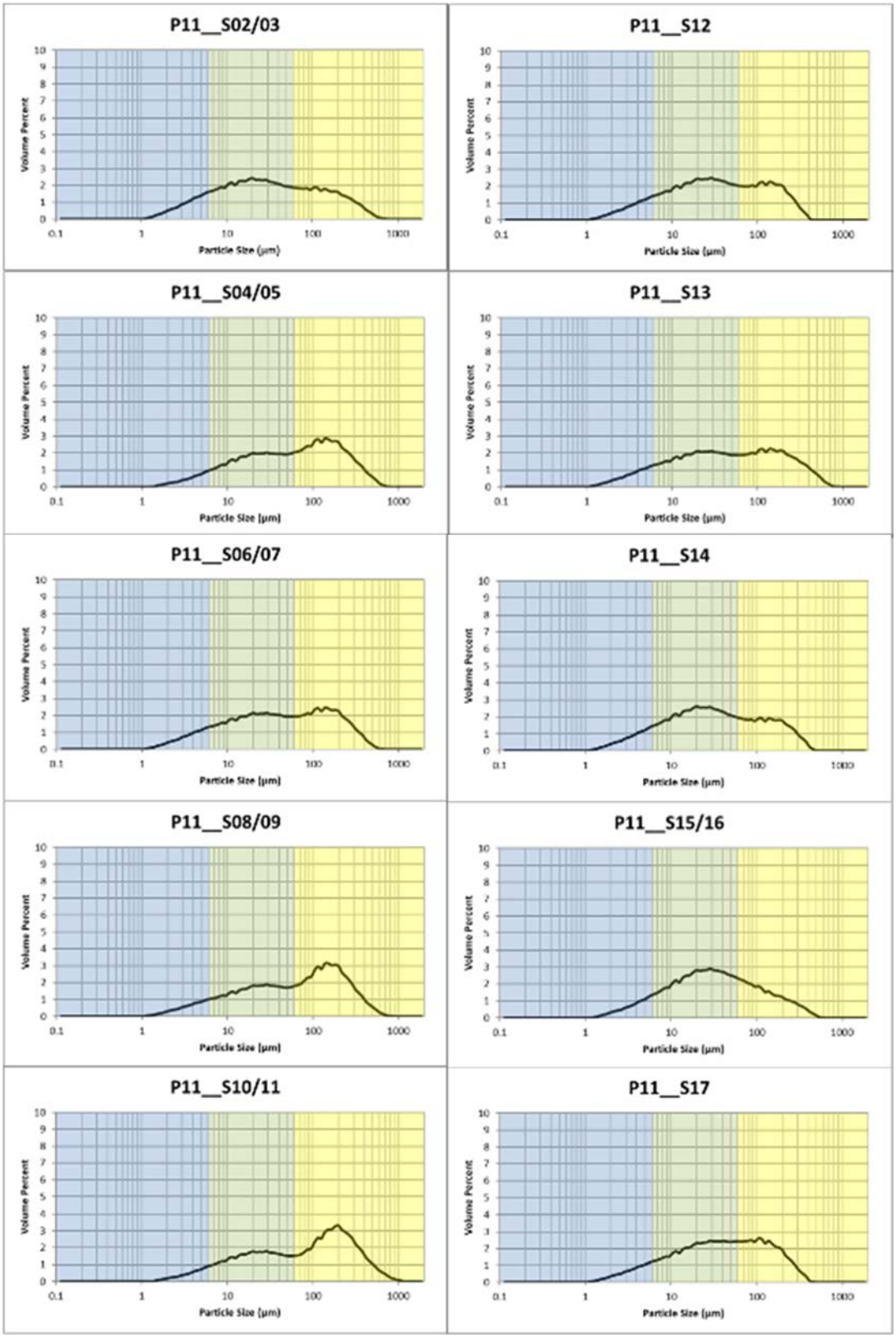


FIGURE 3. Grain size distribution of the sediment in lake 11.

The sediment texture class for lake 31 was sandy loam and its D60 and D30 were 0.27mm and 0.15mm while D10 could not be determined. The Malvern figures were 0.29mm, 0.09mm, 0.02mm and 0.01mm for Dx(90), Dx(60), Dx(30) and Dx(10) respectively. The liquid limit was in average 47.1% and the plasticity limit was 33.6% for a plasticity index of 13.5%.

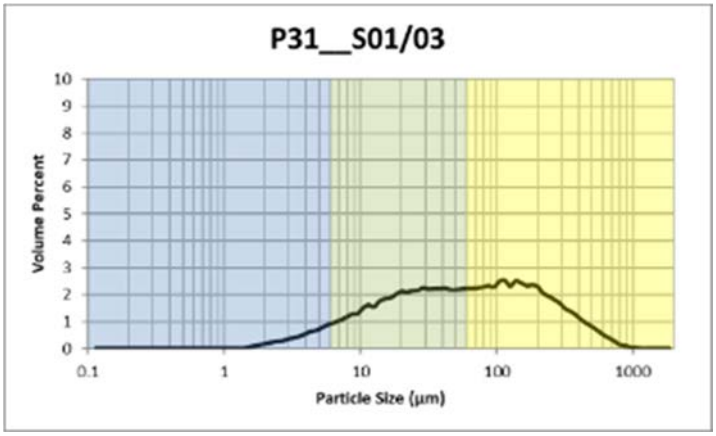


FIGURE 4. Grain size distribution of lake 31.

3. Sediment bulk density, water and organic contents

Sediment fresh bulk density was in average 1.20±S.D.0.05 g/ml and 1.32 g/ml for lakes 11 and 31 respectively. The average water content in lake 11 was 75%±S.D.7% whilst it was 62% in lake 31. The average organic content was 18%±S.D.5% in lake 11 and was higher than in lake 31 with 10% of organic content.

TABLE 7. Sediment bulk density, water and organic contents in lake 11.

pond	Sample #	bulk density FW	bulk density DW	water content	organic content	Inorganic content
#	#	g/ml	g/ml	%	%	%
11	P11__S02/03	1.21	0.24	80.4	25.3	74.7
11	P11__S04/05	1.23	0.38	69.2	19.7	80.3
11	P11__S06/07	1.20	0.28	76.5	13.4	86.6
11	P11__S08/09	1.24	0.34	72.7	15.5	84.5
11	P11__S10/11	1.30	0.48	63.3	7.9	92.1
11	P11__S12	1.19	0.30	74.5	20.1	79.9
11	P11__S13	1.20	0.31	74.6	16.9	83.1
11	P11__S14	1.14	0.21	81.3	21.7	78.3
11	P11__S15/16	1.12	0.15	86.5	24.3	75.7
11	P11__S17	1.21	0.33	73.1	17.2	82.8
	average	1.20	0.30	75.2	18.2	81.8
	S.D.	0.05	0.09	6.5	5.2	5.2

Table 8. Sediment bulk density, water and organic contents in lake 31.

pond	Sample #	bulk density FW	bulk density DW	water content	organic content	Inorganic content
#	#	g/ml	g/ml	%	%	%
31	P31__S01/03	1.32	0.50	61.82	10.16	89.84

4. Sediment water leachates

For both lakes, barium levels were below the set criterion for groundwater (not set criterions for freshwater and saltwater). For cadmium, the values were below the set criterion for groundwater and saltwater (no criterion for freshwater).

For Lake 11, arsenic levels always exceeded the criterion for groundwater and half the occurrences for freshwater/saltwater which shared the same criterion. Chromium levels were below the criterion for groundwater but were higher than the criterion for freshwater and a third of the occurrences for saltwater. Copper levels were in excess for saltwater only (no criterion for freshwater and no exceedance for groundwater) whilst lead levels were in excess for groundwater and saltwater criterions (no criterion for freshwater). When above the detection level, mercury leachates were in excess for both freshwater and saltwater, but all values were below the criterion for groundwater. Selenium and silver leachates were below the detection limits in all samples which were larger than the criterions for both freshwater and saltwater (i.e., no conclusions can be drawn). However, selenium and silver leachates detection limits were well below the criterion for groundwater.

For Lake 31, the arsenic level exceeded the criterion for groundwater for freshwater/saltwater. The chromium level was below the criterion for groundwater but was higher than the criterion for freshwater only. The copper level was in excess for saltwater only whilst the lead level was in excess for groundwater and saltwater criterions. Mercury leachates was under the detection limit which was higher than the limits for both freshwater and saltwater, but below the criterion for groundwater. Selenium and silver leachates were below the detection limits which were larger than the criterions for both freshwater and saltwater (i.e., no conclusions can be drawn). However, selenium and silver leachates detection limits were well below the criterion for groundwater.

Table 9. Synthetic precipitation leaching procedure for various metals in lake 11 and 31. "U" stands for undetected whilst "I" is denoted when the reported value is greater than or equal to the laboratory method detection limit but less than the laboratory practical quantitation limit. "NA" is used when there is not a set criterion. Cells in yellow indicate when the value exceeds the leachability based on groundwater criteria limits. Bold values indicate when the value exceeds the freshwater surface limit and when underlined, when it exceeds the saltwater surface limit.

Sample #	Arsenic, SPLP	Barium, SPLP	Cadmium, SPLP	Chromium, SPLP	Copper, SPLP	Lead, SPLP	Selenium, SPLP	Silver, SPLP	Mercury, SPLP
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
P11_S02/03	0.0479	0.0727	0.0013	**0.0484**	0.218	0.354	0.0085 U	0.0010 U	**0.00048**
P11_S04/05	**0.0587**	0.0581	0.0016	**0.027**	0.363	0.438	0.0085 U	0.0010 U	**0.00051**
P11_S06/07	**0.0564**	0.0658	0.0012	**0.0442**	0.737	0.278	0.0085 U	0.0010 U	**0.00048**
P11_S08/09	0.0233	0.0293	0.00073 I	**0.0321**	0.154	0.149	0.0085 U	0.0010 U	**0.00041**
P11_S10/11	**0.0668**	0.0368	0.00033 U	0.0049 I	0.0216	0.0318	0.0085 U	0.0010 U	0.000090 U
P11_S12	0.0320	0.0958	0.0011	**0.0667**	0.131	0.169	0.0085 U	0.0010 U	**0.00043**
P11_S13	**0.0518**	0.0497	0.0014	**0.0481**	0.144	0.256	0.0085 U	0.0010 U	**0.00051**
P11_S14	0.0431	0.0542	0.0017	**0.0626**	0.247	0.321	0.0085 U	0.0010 U	**0.00078**
P11_S15/16	**0.0840**	0.0917	0.0020 I	**0.0749**	0.260	0.487	0.0085 U	0.0010 U	0.00090 U
P11_S17	0.0214	0.0966	0.00047 I	**0.0291**	0.0871	0.0646	0.0085 U	0.0010 U	0.00090 U
P31_S01/03	**0.0678**	0.0673	0.0010	**0.0329**	0.624	0.157	0.0085 U	0.0010 U	0.00090 U
Leachability Based on Groundwater Criteria (mg/l)	0.01	2	0.005	0.1	1	0.015	0.05	0.1	0.002
Freshwater surface criteria (mg/l)	0.05	NA	NA	0.011	NA	NA	0.005	0.00007	0.000012
Saltwater surface criteria (mg/l)	0.05	NA	0.0093	0.05	0.0029	0.0085	0.071	0.0004	0.000025

Exceeds Leachability Based on Groundwater Criteria Limits

Exceeds freshwater surface criteria

Exceeds saltwater surface criteria

5. Sediment petroleum range organics

For both lakes, the petroleum range organics were well below the leachability criterion for groundwater as well as for the direct exposure for both residential and commercial limits.

Table 10. Petroleum range organics analyzed in the sediment from lakes 11 and 31. "U" indicates "concentration below the method detection limit (MDL)". Residential and commercial direct exposure limits are from Table 2 of Chapter 62-777, FAC.

Sample #	Petroleum Range Organics
#	mg/kg
P11_S02/03	53.4 U
P11_S04/05	44.8 U
P11_S06/07	40.4 U
P11_S08/09	29.2 U
P11_S10/11	27.8 U
P11_S12	47.4 U
P11_S13	46.7 U
P11_S14	47.7 U
P11_S15/16	76.9 U
P11_S17	35.1 U
P31_S01/03	20.7 U
Leachability Based on Groundwater Criteria (mg/kg)	340
Direct Exposure Residential (mg/kg)	460
Direct Exposure Commercial/Industrial (mg/kg)	2,700

Exceeds Leachability Based on Groundwater Criteria Limits

Exceeds Direct Exposure Residential Limits

Exceeds Direct Exposure Commercial/Industrial Limits

6. Sediment non-carcinogenic PAHs

For both lakes, none of the analytes analyzed for non-carcinogenic PAHs were above the set criteria for either their leachability based on groundwater nor do they exceed direct exposures for both residential and commercial.

TABLE 11. Sediment non-carcinogenic PAHs analyzed in the sediment from lakes 11 and 31. "U" indicates "concentration below the method detection limit (MDL)". "I" indicates concentration between the MDL and the practical quantification limit (PQL). Residential and commercial direct exposure limits are from Table 2 of Chapter 62-777, FAC.

	Soil Non-Carcinogenic PAHs										
Sample #	Naphthalene	1-Methylnaphthalene	2-Methylnaphthalene	Acenaphthene	Acenaphthylene	Anthracene	Benzo(g,h,i)perylene	Fluoranthene	Fluorene	Phenanthrene	Pyrene
#	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
P11_S02/03	0.13 U	0.15 U	0.15 U	0.13 U	0.12 U	0.14 U	0.22 I	0.40	0.14 U	0.13 U	0.36 I
P11_S04/05	0.10 U	0.12 U	0.11 U	0.10 U	0.093 U	0.11 U	0.37	0.59	0.11 U	0.098 U	0.51
P11_S06/07	0.12 U	0.13 U	0.13 U	0.12 U	0.11 U	0.12 U	0.17 I	0.30 I	0.12 U	0.11 U	0.28 I
P11_S08/09	0.094 U	0.11 U	0.10 U	0.094 U	0.086 U	0.097 U	0.069 U	0.090 U	0.098 U	0.090 U	0.086 U
P11_S10/11	0.067 U	0.077 U	0.074 U	0.067 U	0.061 U	0.069 U	0.065 I	0.14 I	0.070 U	0.064 U	0.12 I
P11_S12	0.13 U	0.15 U	0.14 U	0.13 U	0.12 U	0.13 U	0.095 U	0.12 U	0.14 U	0.12 U	0.12 U
P11_S13	0.12 U	0.13 U	0.13 U	0.12 U	0.10 U	0.12 U	0.084 U	0.11 U	0.12 U	0.11 U	0.11 U
P11_S14	0.15 U	0.18 U	0.17 U	0.15 U	0.14 U	0.16 U	0.11 U	0.15 U	0.16 U	0.15 U	0.14 U
P11_S15/16	0.20 U	0.23 U	0.22 U	0.20 U	0.18 U	0.21 U	0.15 U	0.19 U	0.21 U	0.19 U	0.19 U
P11_S17	0.097 U	0.11 U	0.11 U	0.098 U	0.089 U	0.10 U	0.071 U	0.093 U	0.10 U	0.093 U	0.089 U
P31_S01/03	0.065 U	0.074 U	0.072 U	0.065 U	0.059 U	0.067 U	0.048 U	0.063 I	0.068 U	0.062 U	0.060 U
Leachability Based on Groundwater Criteria (mg/kg)	1.2	3.1	8.5	2.1	27	2500	32000	1200	160	250	880
Direct Exposure Residential (mg/kg)	55	200	210	2400	1800	21000	2500	3200	2600	2200	2400
Direct Exposure Commercial/Industrial (mg/kg)	300	1800	2100	20000	20000	300000	52000	59000	33000	36000	45000

Exceeds Leachability Based on Groundwater Criteria Limits

Exceeds Direct Exposure Residential Limits

Exceeds Direct Exposure Commercial/Industrial Limits

7. Sediment carcinogenic PAHs

Benzo (a) pyrene equivalent and Benzo(a)pyrene were on occasion in exceedance for residential exposure especially at the locations near the north of lake 11. Lake 31 did not have any exceedances.

*TABLE 12. Soil carcinogenic PAHs in lakes 11 and 31. "**" stands for leachability values not applicable whilst "#" codes for a Direct Exposure value not applicable except as part of the Benzo(a)pyrene equivalent. "U" indicates "concentration below the method detection limit (MDL)". "I" indicates concentration between the MDL and the practical quantification limit (PQL). Residential and commercial direct exposure limits are from Table 2 of Chapter 62-777, FAC.*

Sample #	Benzo(a)pyrene	Benzo(a) anthracene	Benzo(b)fluoranthene	Benzo(k) fluoranthene	Chrysene	Dibenz(a,h)anthracene	Indeno(1,2,3-cd)pyrene	Benzo (a) pyrene equivalent
#	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	(mg/kg)
P11_S02/03	0.27 I	0.22 I	0.40	0.14 I	0.32 I	0.090 U	0.19 I	0.40
P11_S04/05	0.43	0.28 I	0.65	0.25 I	0.47	0.083 I	0.32	0.64
P11_S06/07	0.25 I	0.19 I	0.30 I	0.17 I	0.26 I	0.078 U	0.15 I	0.35
P11_S08/09	0.068 U	0.078 U	0.073 U	0.073 U	0.087 U	0.063 U	0.063 U	0.077
P11_S10/11	0.082 I	0.070 I	0.12 I	0.052 U	0.094 I	0.045 U	0.059 I	0.13
P11_S12	0.094 U	0.11 U	0.10 U	0.10 U	0.12 U	0.087 U	0.087 U	0.11
P11_S13	0.083 U	0.096 U	0.089 U	0.090 U	0.11 U	0.077 U	0.077 U	0.094
P11_S14	0.11 U	0.13 U	0.12 U	0.12 U	0.14 U	0.10 U	0.10 U	0.12
P11_S15/16	0.15 U	0.17 U	0.16 U	0.16 U	0.19 U	0.14 U	0.14 U	0.17
P11_S17	0.070 U	0.081 U	0.076 U	0.076 U	0.090 U	0.065 U	0.065 U	0.079
P31_S01/03	0.047 U	0.054 U	0.052 I	0.051 U	0.060 U	0.044 U	0.043 U	0.056
Leachability Based on Groundwater Criteria (mg/kg)	8	0.8	2.4	24	77	0.7	6.6	**
Direct Exposure Residential (mg/kg)	0.1	#	#	#	#	#	#	0.1
Direct Exposure Commercial/Industrial (mg/kg)	0.7	#	#	#	#	#	#	0.7

Exceeds Leachability Based on Groundwater Criteria Limits

Exceeds Direct Exposure Residential Limits

Exceeds Direct Exposure Commercial/Industrial Limits

8. Sediment VOAs TRPHs and metals

Arsenic was found to be in exceedance for direct exposure residential limits in both lakes. It was on two occasions exceeding the limits for commercial as well. For lake 11, chromium was in exceedance for its leachability to the groundwater (location P11_S15/16).

TABLE 13. Sediment VOAs TRPHs and metals analyzed in the sediment from lakes 11 and 31. "NS" indicates "Not Sampled".

	Soil VOAs TRPHs & Metals									
Sample #	Benzene	Ethyl-benzene	Toluene	Tolal Xylenes	MTBE	TRPHs	Arsenic	Cadmium	Chromium	Lead
#	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
P11_S02/03	NS	NS	NS	NS	NS	53.4 U	**12.9**	**0.53**	**22.7**	**135**
P11_S04/05	NS	NS	NS	NS	NS	44.8 U	**11.0**	**0.41**	**11.1**	**111**
P11_S06/07	NS	NS	NS	NS	NS	40.4 U	**10.5**	**0.48**	**19.1**	**111**
P11_S08/09	NS	NS	NS	NS	NS	29.2 U	**1.2 I**	0.096 U	**3.4**	**13.5**
P11_S10/11	NS	NS	NS	NS	NS	27.8 U	**9.1**	**0.39**	**9.5**	**106**
P11_S12	NS	NS	NS	NS	NS	47.4 U	**6.1**	**0.38**	**28.9**	**55.4**
P11_S13	NS	NS	NS	NS	NS	46.7 U	**10.1**	**0.48**	**17.5**	**81.9**
P11_S14	NS	NS	NS	NS	NS	47.7 U	**10.7**	**0.72**	**36.1**	**152**
P11_S15/16	NS	NS	NS	NS	NS	76.9 U	**31.0**	**1.1**	**43.7**	**230**
P11_S17	NS	NS	NS	NS	NS	35.1 U	**5.7**	**0.30**	**26.6**	**41.7**
P31_S01/03	NS	NS	NS	NS	NS	20.7 U	**7.1**	**0.21**	**9.9**	**33.5**
Leachability Based on Groundwater Criteria (mg/kg)	.007	.6	.5	.2	.09	340	*	7.5	38	*
Direct Exposure Residential (mg/kg)	1.2	1500	7500	130	4400	460	2.1	82	210	400
Direct Exposure Commercial/Industrial (mg/kg)	1.7	9200	60000	700	24000	2700	12	1700	470	1400
Exceeds Leachability Based on Groundwater Criteria Limits										
Exceeds Direct Exposure Residential Limits										
Exceeds Direct Exposure Commercial/Industrial Limits										

9. Sediment TRPH and TRPH fractions

Only soil TRPHs using the Florida Petroleum Organic Method (FLPRO) were analyzed by the outsourced laboratory. None of the aliphatic and aromatic hydrocarbons were analyzed as they all were reported as "Not Sampled" (NS). Soil TRPHs (FLPRO) did not exceed the set criteria for leachability based on groundwater criteria limits and direct exposures for both residential and commercial.

TABLE 14. Soil TRPH (FLPRO method) in the sediment of lakes 11 and 31.

Sample #	TRPHs (FLPRO) (mg/kg)
P11_S02/03	53.4 U
P11_S04/05	44.8 U
P11_S06/07	40.4 U
P11_S08/09	29.2 U
P11_S10/11	27.8 U
P11_S12	47.4 U
P11_S13	46.7 U
P11_S14	47.7 U
P11_S15/16	76.9 U
P11_S17	35.1 U
P31_S01/03	20.7 U
Leachability Based on Groundwater Criteria (mg/kg)	340
Direct Exposure Residential (mg/kg)	460
Direct Exposure Commercial/Industrial (mg/kg)	2700

10. Sediment nutrients

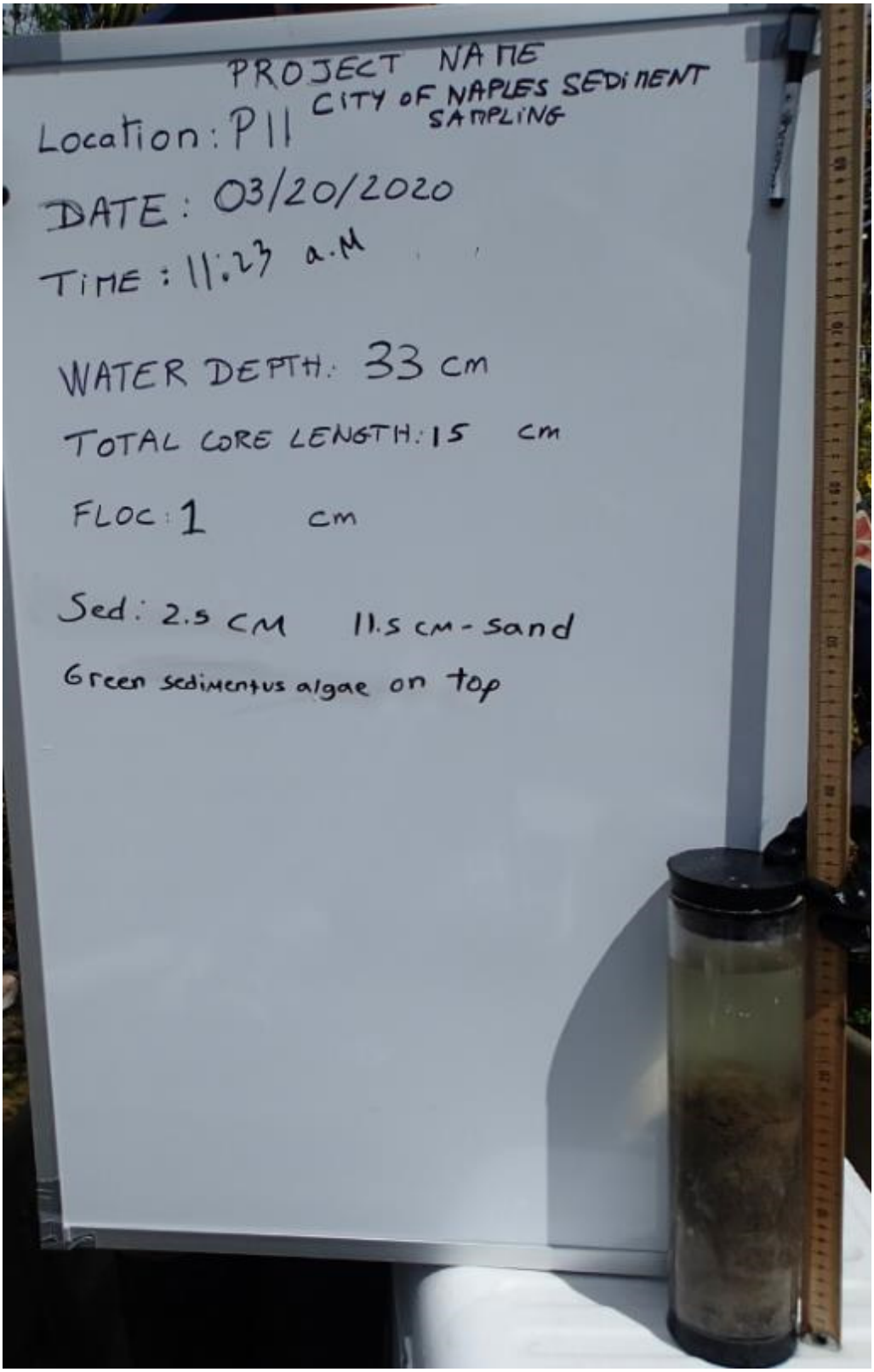
Sediment nutrients were highly variable spatially. Average TKN was 2100±S.D.1767 mg/kg and 1530 mg/kg in lakes 11 and 31 respectively. These figures were 487±S.D.570 and 116 for TP. These are high values and reflect the eutrophication of both lakes as well as the organic rich sediment and floc.

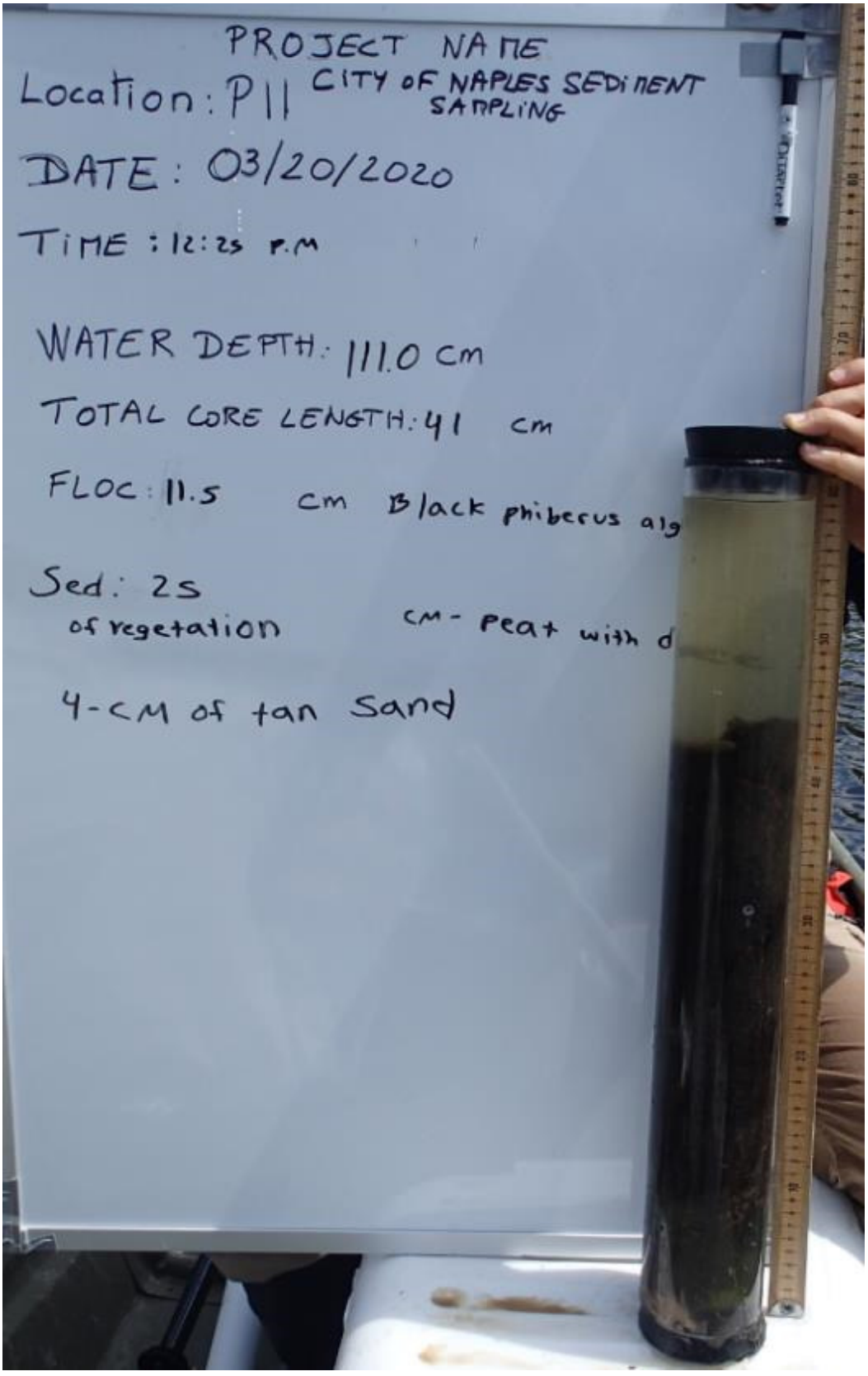
11. Sediment other contaminants

The organochloride dieldrin concentration was found to be in exceedance for all the sediment samples of both lakes for its leachability based on groundwater criteria limits only. Although there are no criteria for the leachability of copper to the groundwater, copper exceeded the direct exposure for residential on two occasions (samples P11_S10/S11 and P11_S14).

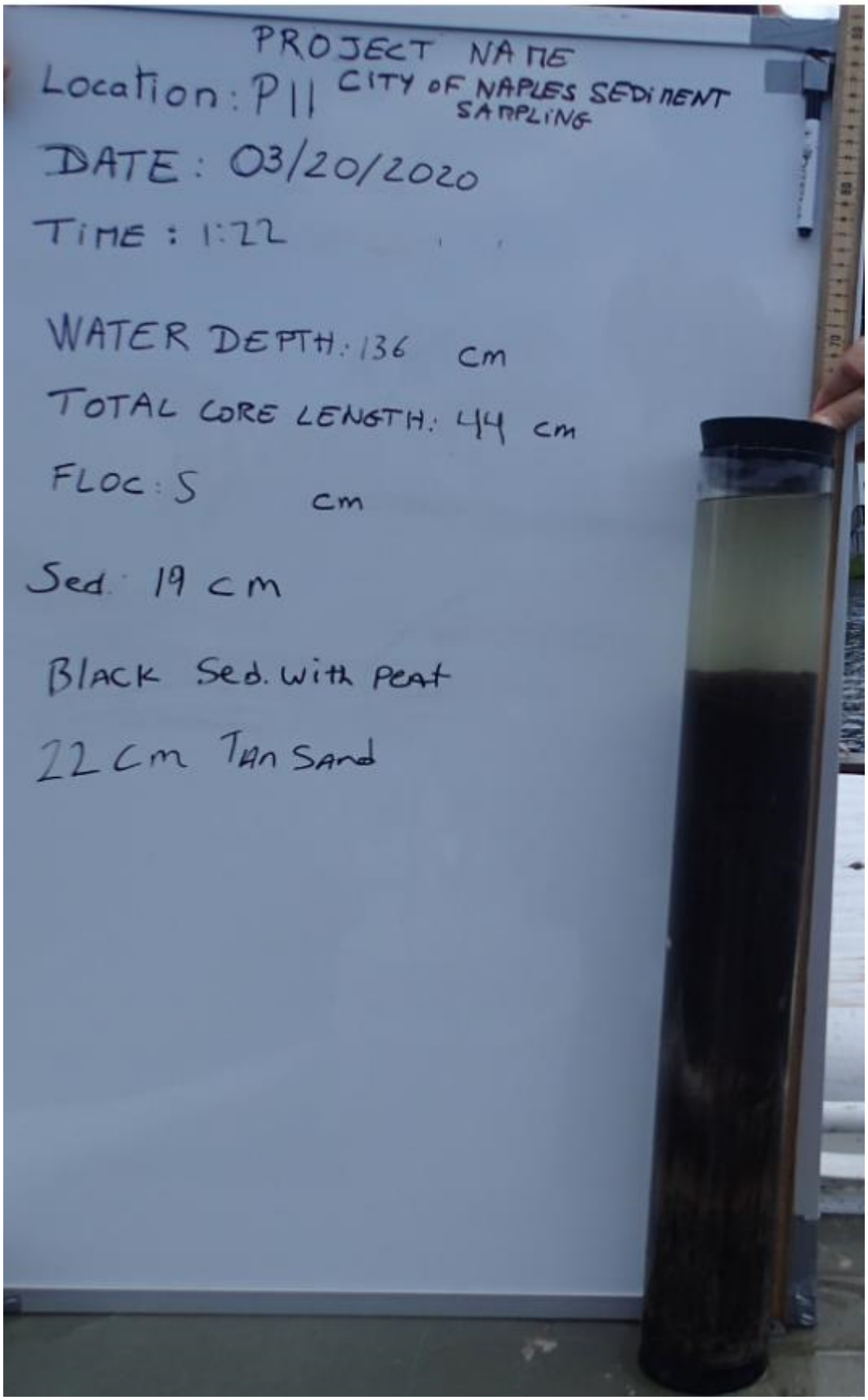
Appendices: Pictures of the sediment cores

P11_S01

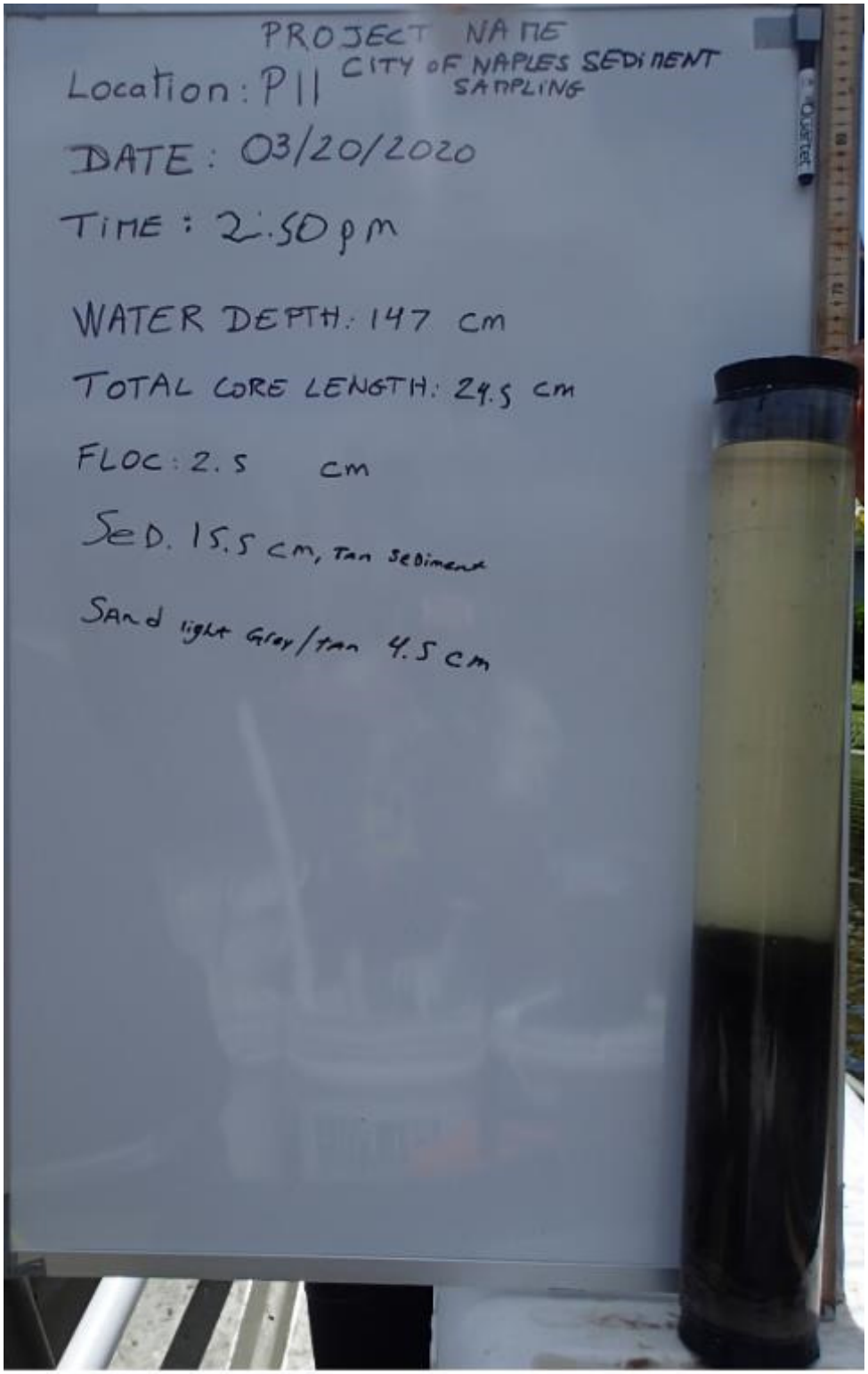



PROJECT NAME
CITY OF NAPLES SEDIMENT SAMPLING
Location: P11
DATE: 03/20/2020
TIME: 12:25 P.M
WATER DEPTH: 111.0 cm
TOTAL CORE LENGTH: 41 cm
FLOC: 11.5 cm Black phibecus alg
Sed: 25
of vegetation
cm - peat with d
4-cm of tan Sand

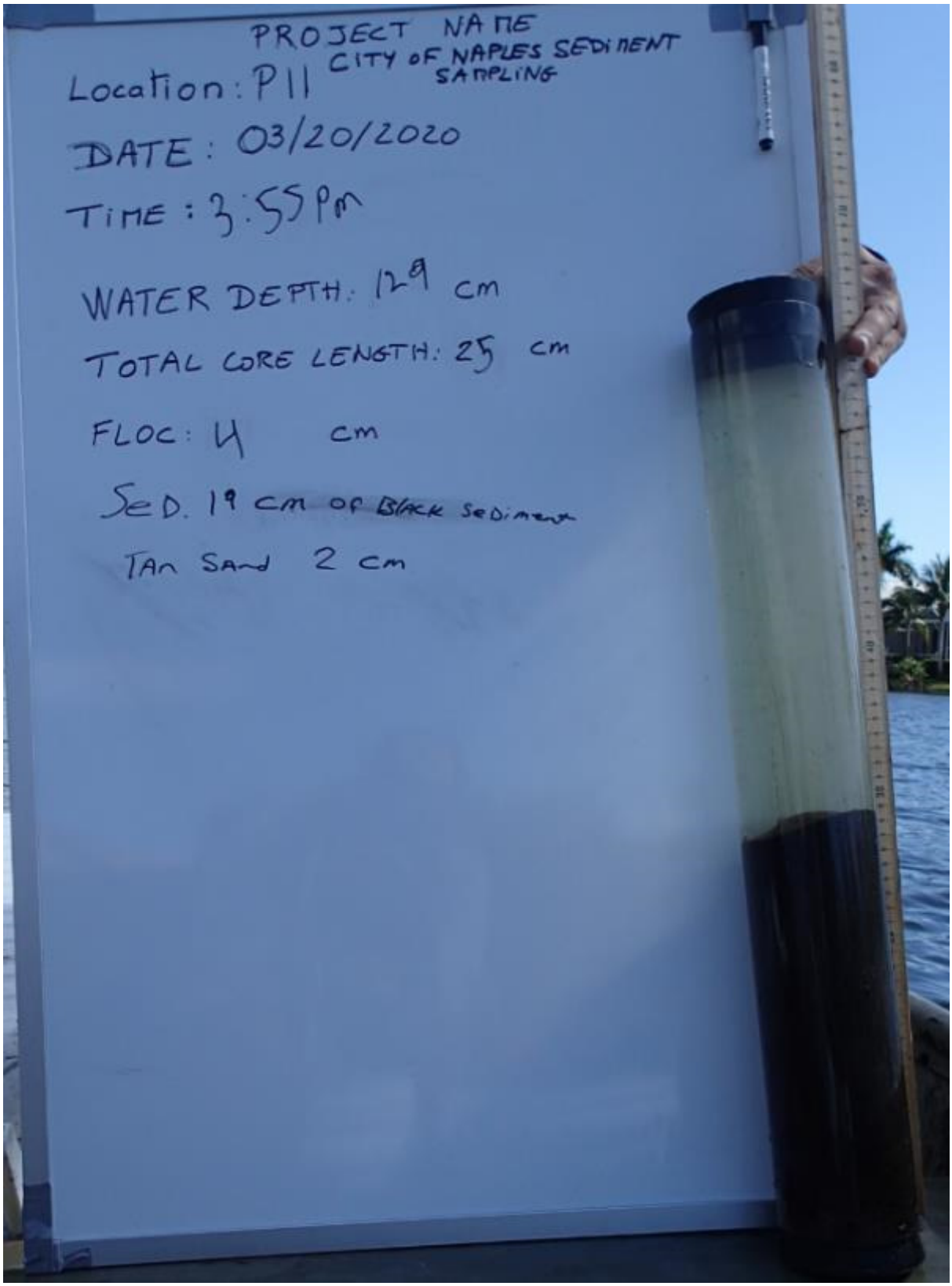
P11_S03


PROJECT NAME
CITY OF NAPLES SEDIMENT SAMPLING
Location: P11
DATE: 03/20/2020
TIME: 1:22
WATER DEPTH: 136 cm
TOTAL CORE LENGTH: 44 cm
FLOC: 5 cm
Sed. 19 cm
Black Sed. with Peat
22 cm Tan Sand

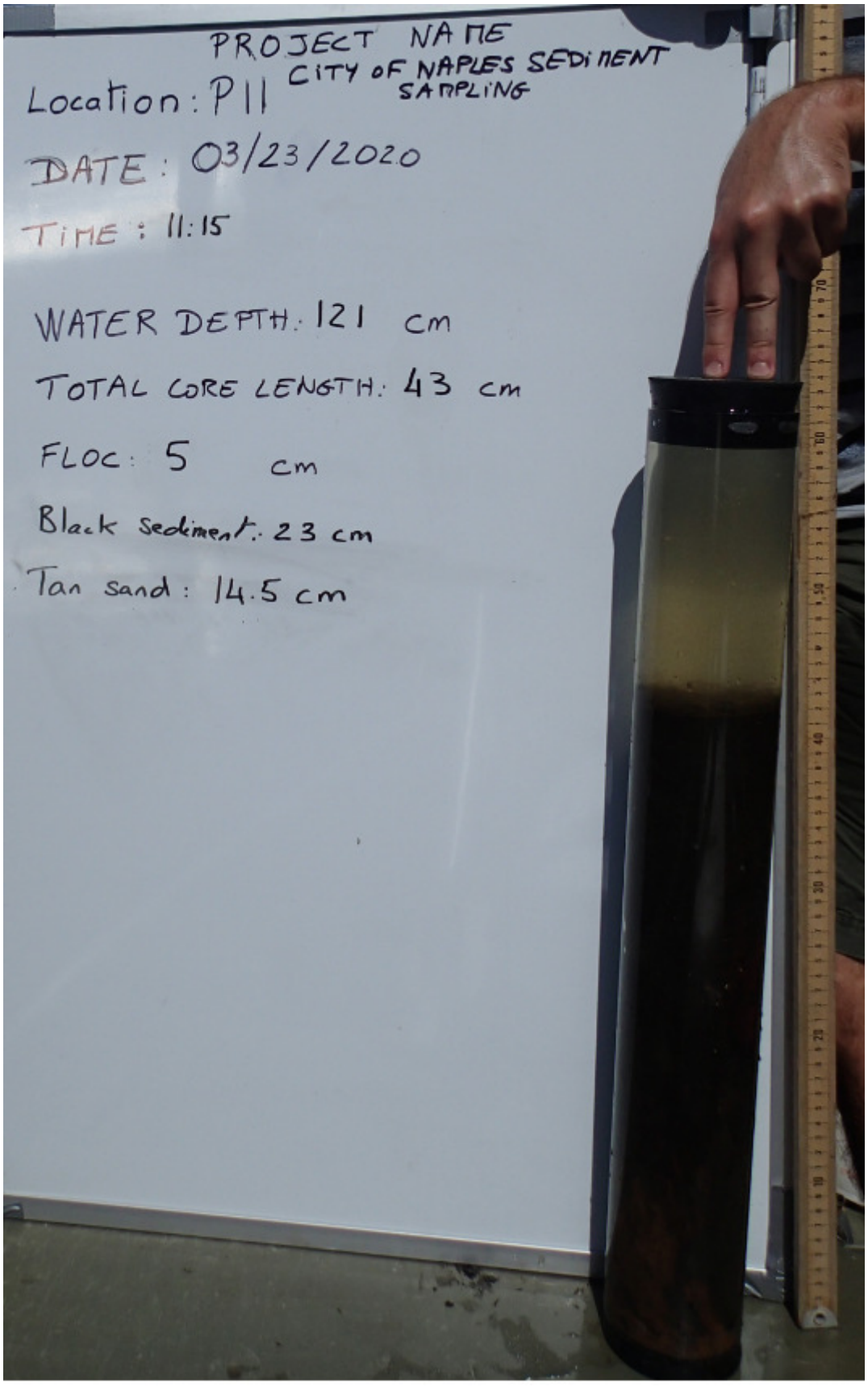
P11_S04


PROJECT NAME
CITY OF NAPLES SEDIMENT SAMPLING
Location: P11
DATE: 03/20/2020
TIME: 2:50 pm
WATER DEPTH: 147 cm
TOTAL CORE LENGTH: 24.5 cm
FLOC: 2.5 cm
SED. 15.5 cm, Tan sediment
Sand light Gray/tan 4.5 cm
Quartet

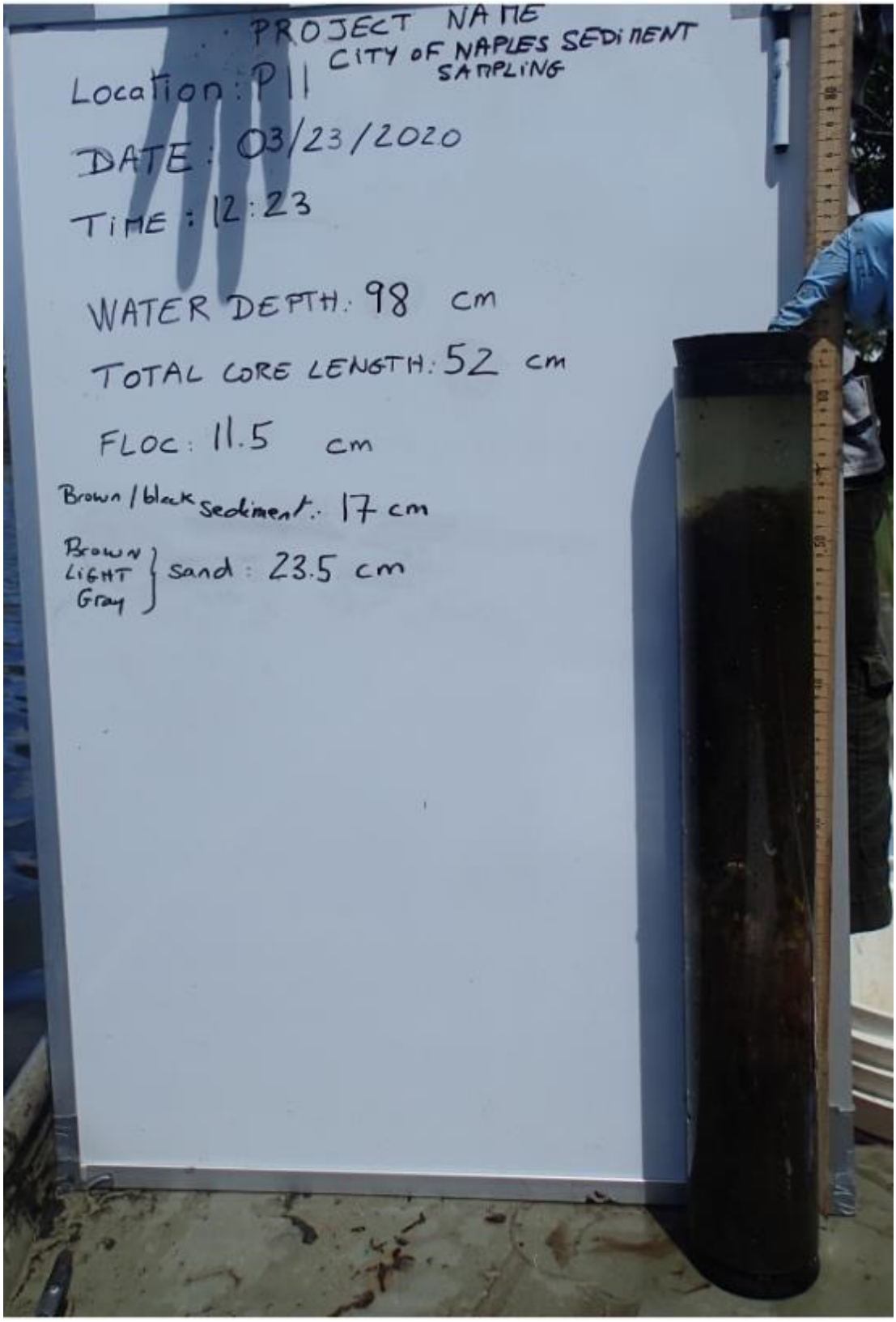
P11_S05


PROJECT NAME
CITY OF NAPLES SEDIMENT SAMPLING
Location: P11
DATE: 03/20/2020
TIME: 3:55 PM
WATER DEPTH: 129 cm
TOTAL CORE LENGTH: 25 cm
FLOC: 4 cm
SED. 19 cm of BLACK sediment
TAN SAND 2 cm

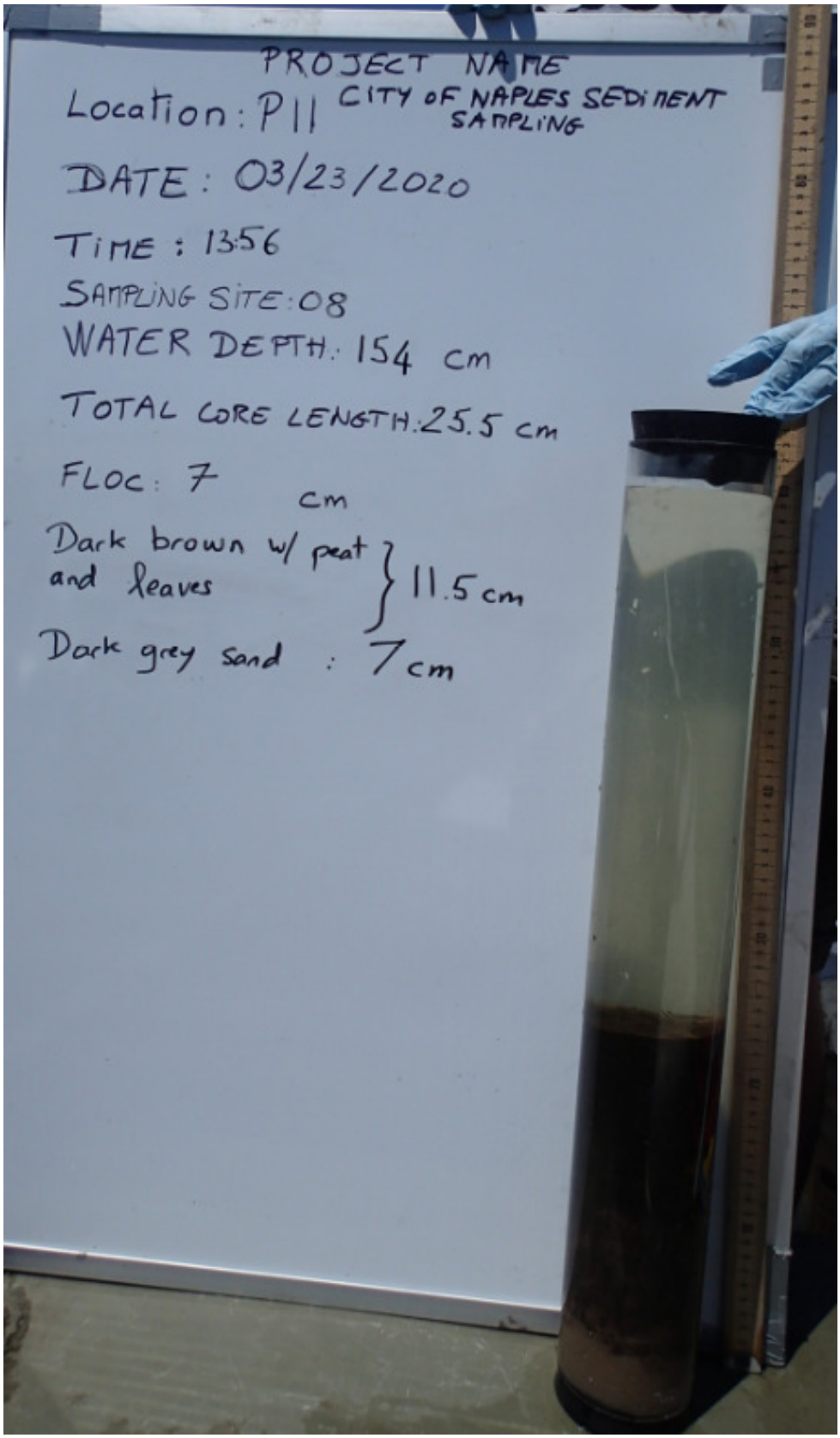
P11_S06


PROJECT NAME
CITY OF NAPLES SEDIMENT SAMPLING
Location: P11
DATE: 03/23/2020
TIME: 11:15
WATER DEPTH: 121 cm
TOTAL CORE LENGTH: 43 cm
FLOC: 5 cm
Black Sediment: 23 cm
Tan sand: 14.5 cm

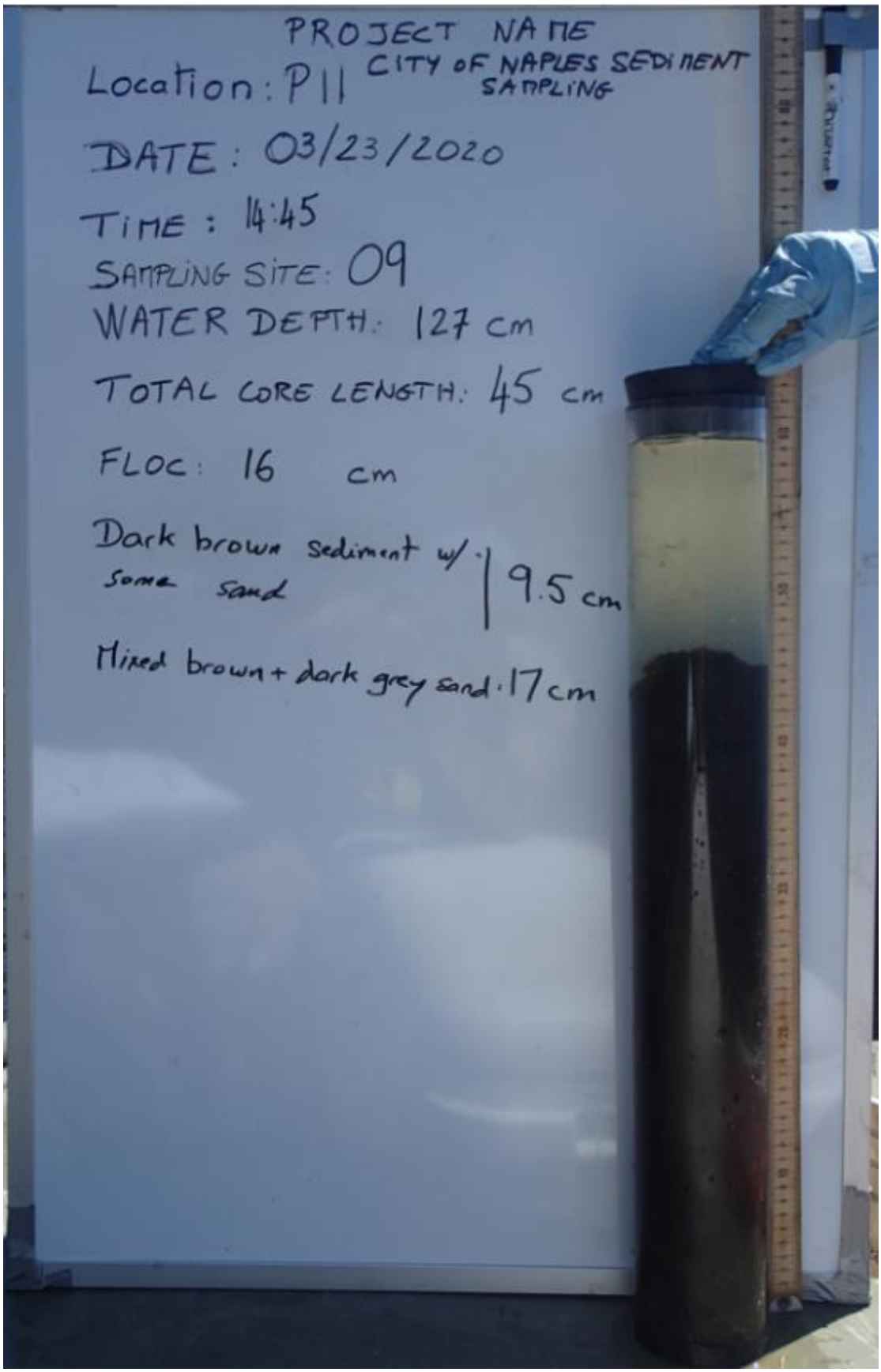
P11_S07


PROJECT NAME
CITY OF NAPLES SEDIMENT SAMPLING
Location: P11
DATE: 03/23/2020
TIME: 12:23
WATER DEPTH: 98 cm
TOTAL CORE LENGTH: 52 cm
FLOC: 11.5 cm
Brown/black sediment: 17 cm
Brown Light Gray sand: 23.5 cm

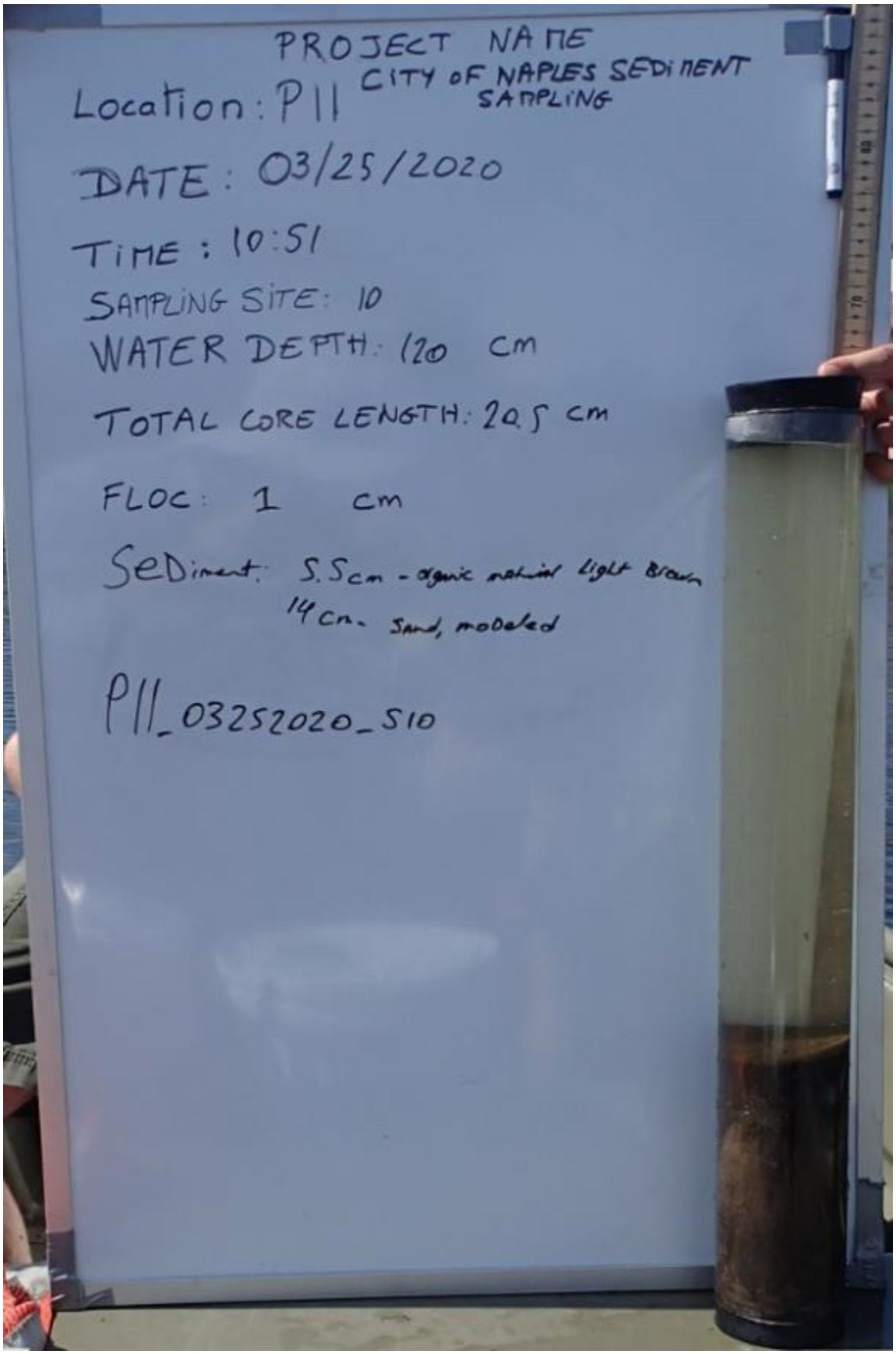
P11_S08. Note: water depth is 156, not 154cm.



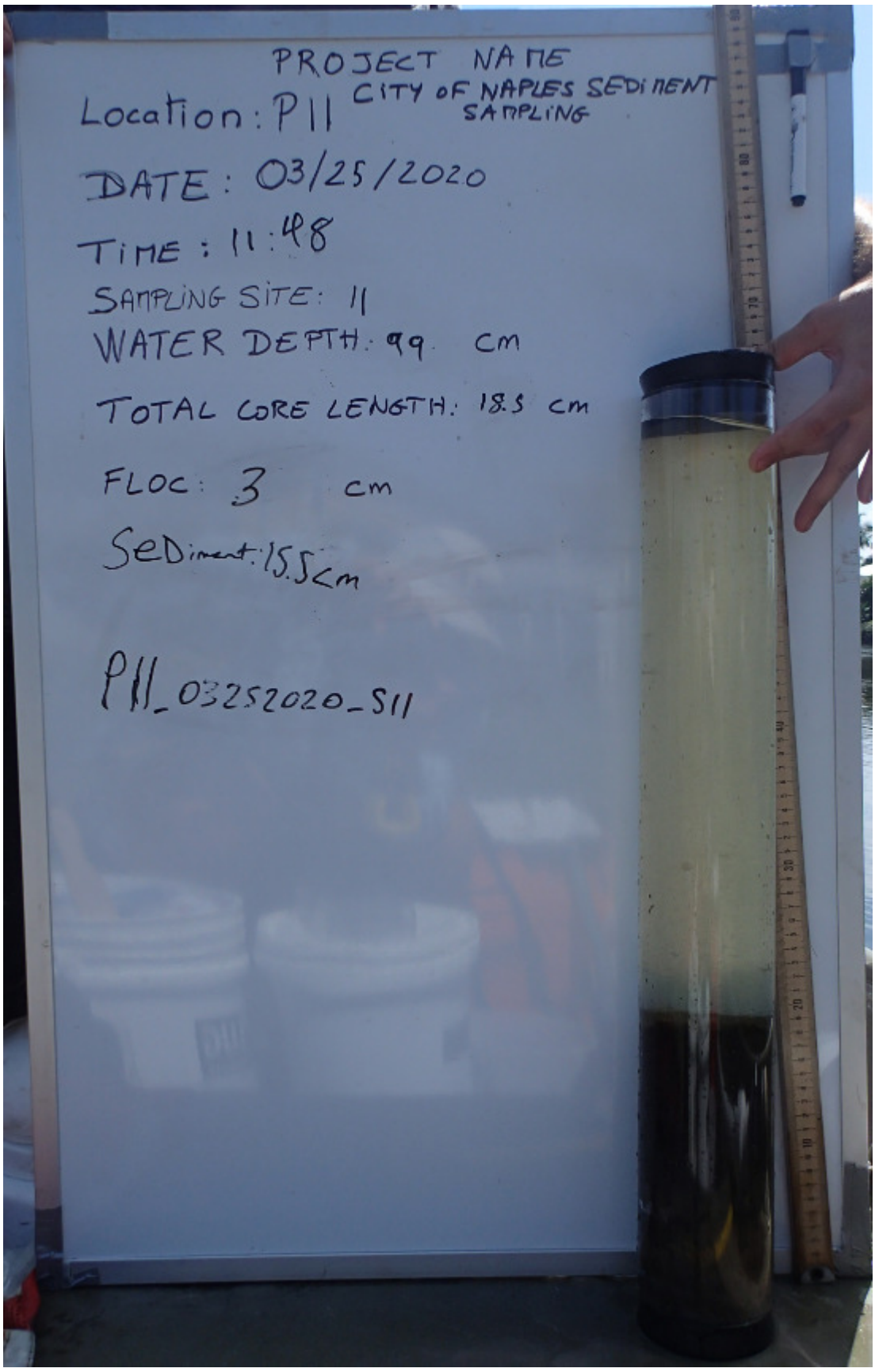
P11_S09


PROJECT NAME
CITY OF NAPLES SEDIMENT SAMPLING
Location: P11
DATE: 03/23/2020
TIME: 14:45
SAMPLING SITE: 09
WATER DEPTH: 127 cm
TOTAL CORE LENGTH: 45 cm
FLOC: 16 cm
Dark brown sediment w/ some sand | 9.5 cm
Mixed brown + dark grey sand: 17 cm

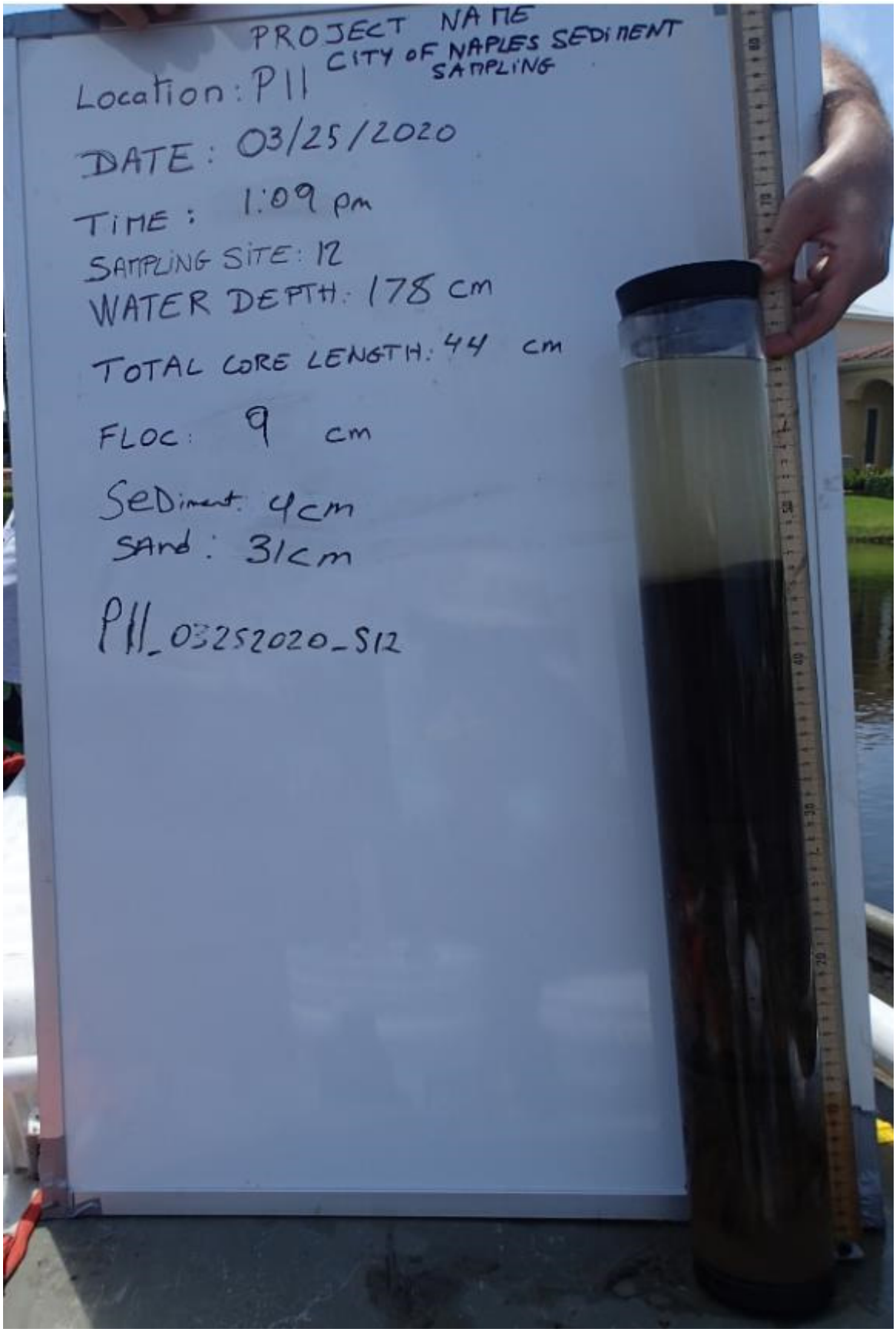
P11_S10


PROJECT NAME
CITY OF NAPLES SEDIMENT SAMPLING
Location: P11
DATE: 03/25/2020
TIME: 10:51
SAMPLING SITE: 10
WATER DEPTH: 120 cm
TOTAL CORE LENGTH: 20.5 cm
FLOC: 1 cm
SEDiment: 5.5cm - organic material light brown
14 cm. Sand, molded
P11_03252020_S10

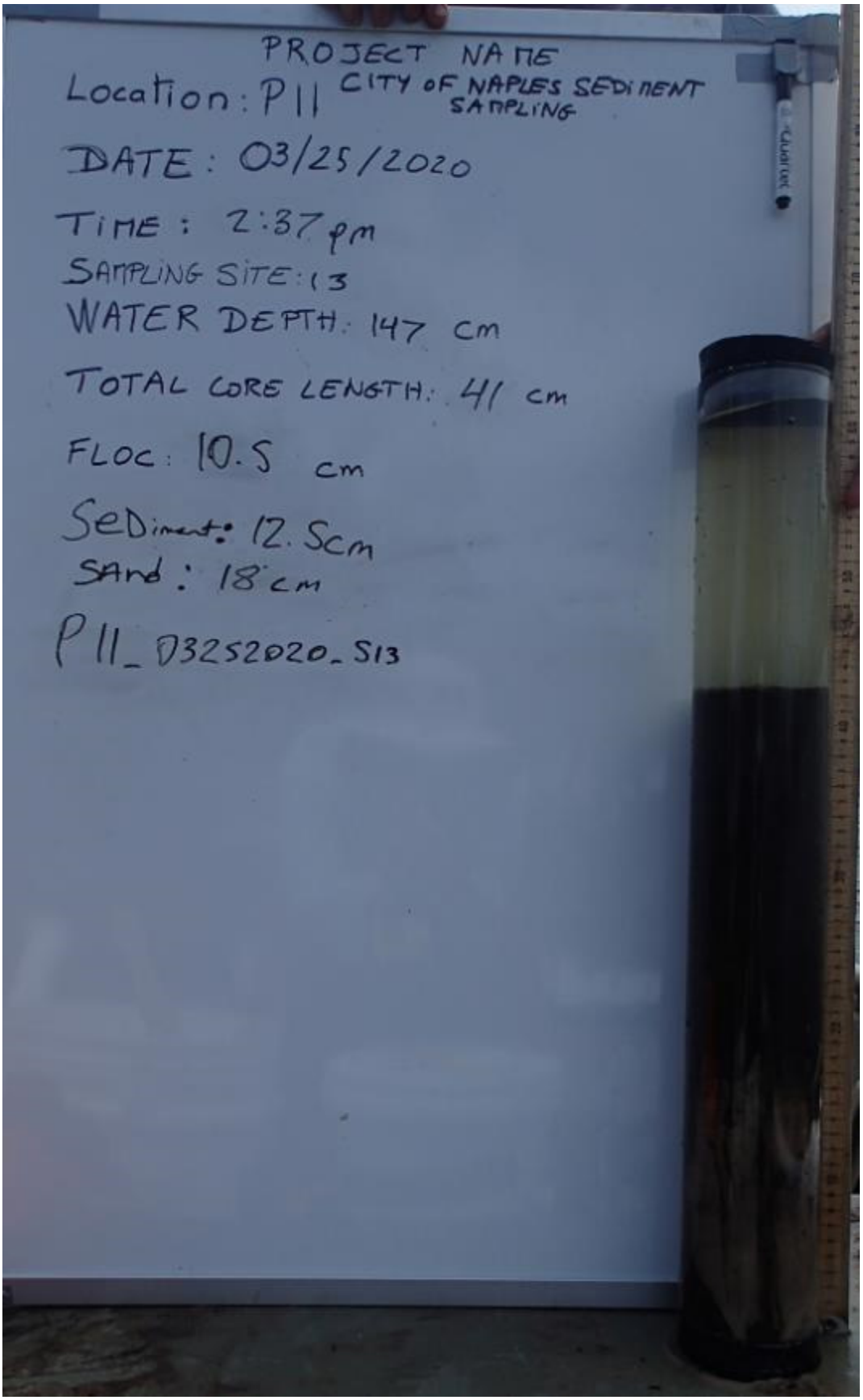
P11_S11


PROJECT NAME
CITY OF NAPLES SEDIMENT SAMPLING
Location: P11
DATE: 03/25/2020
TIME: 11:48
SAMPLING SITE: 11
WATER DEPTH: 99 cm
TOTAL CORE LENGTH: 18.5 cm
FLOC: 3 cm
SEDIMENT: 15.5 cm
P11_03252020_S11

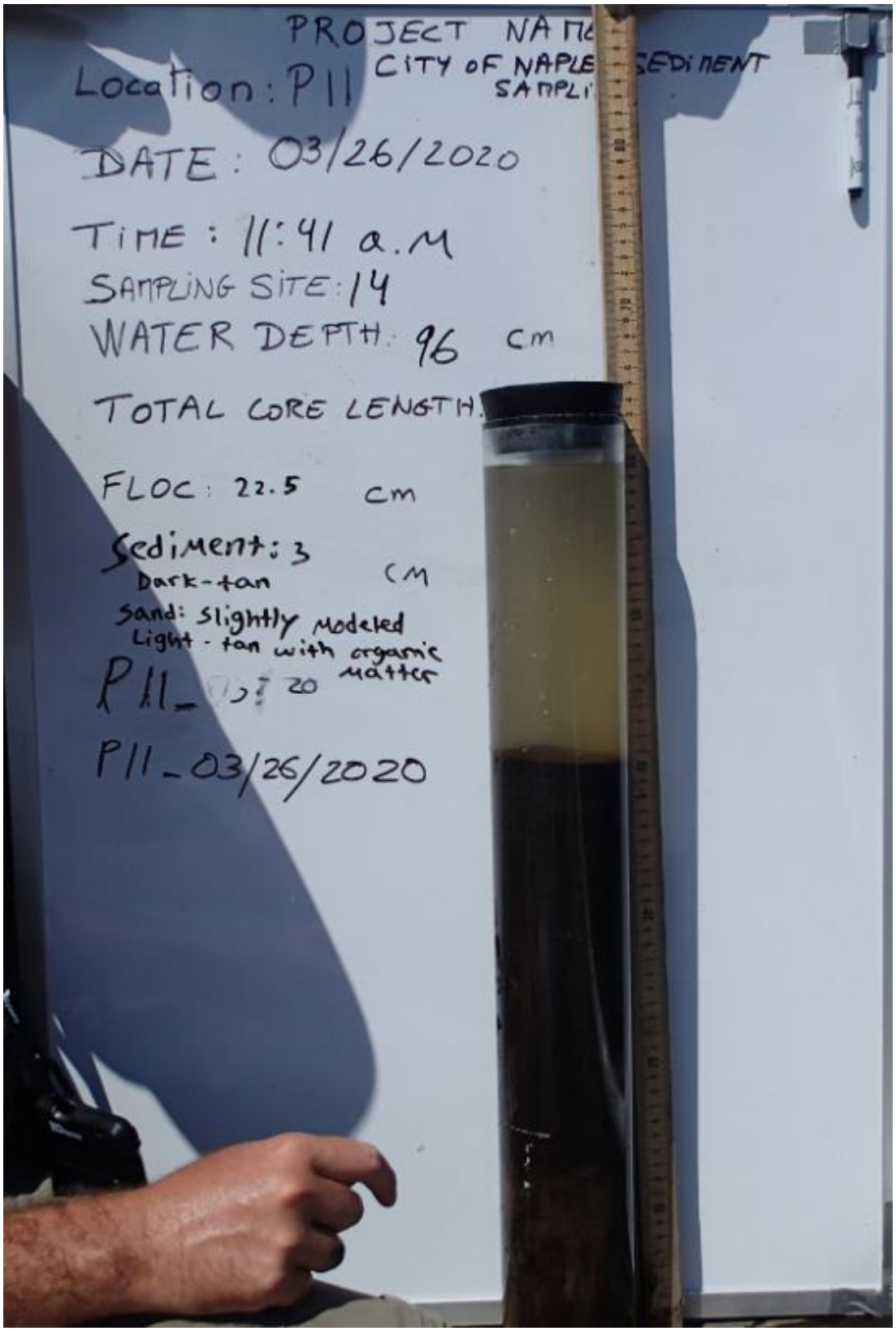
P11_S12


PROJECT NAME
CITY OF NAPLES SEDIMENT SAMPLING
Location: P11
DATE: 03/25/2020
TIME: 1:09 pm
SAMPLING SITE: 12
WATER DEPTH: 178 cm
TOTAL CORE LENGTH: 44 cm
FLOC: 9 cm
Sediment: 4cm
Sand: 31cm
P11_03252020_S12

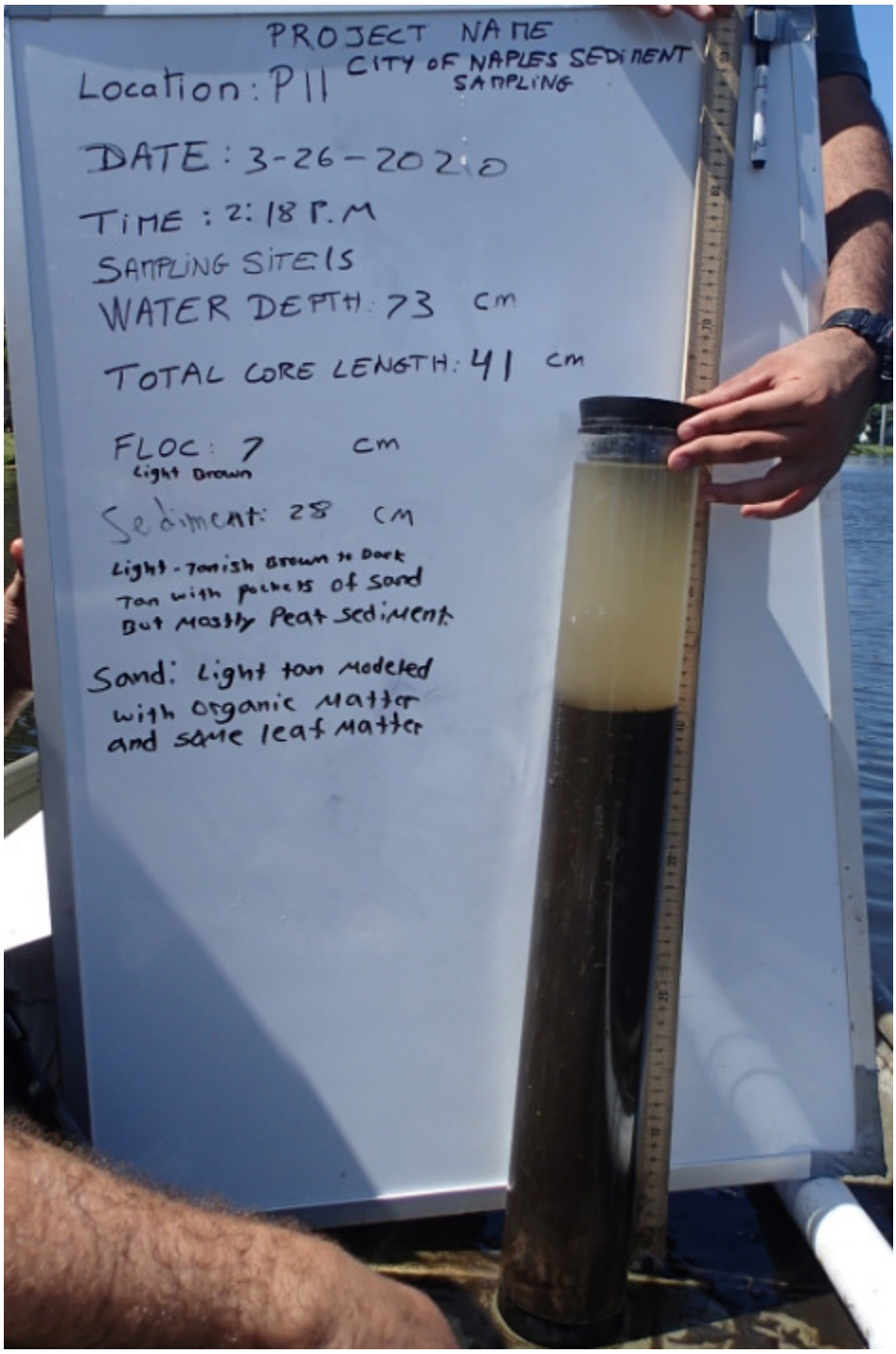
P11_S13


PROJECT NAME
CITY OF NAPLES SEDIMENT SAMPLING
Location: P11
DATE: 03/25/2020
TIME: 2:37 pm
SAMPLING SITE: 13
WATER DEPTH: 147 cm
TOTAL CORE LENGTH: 41 cm
FLOC: 10.5 cm
Sediment: 12.5cm
Sand: 18 cm
P11_03252020_S13

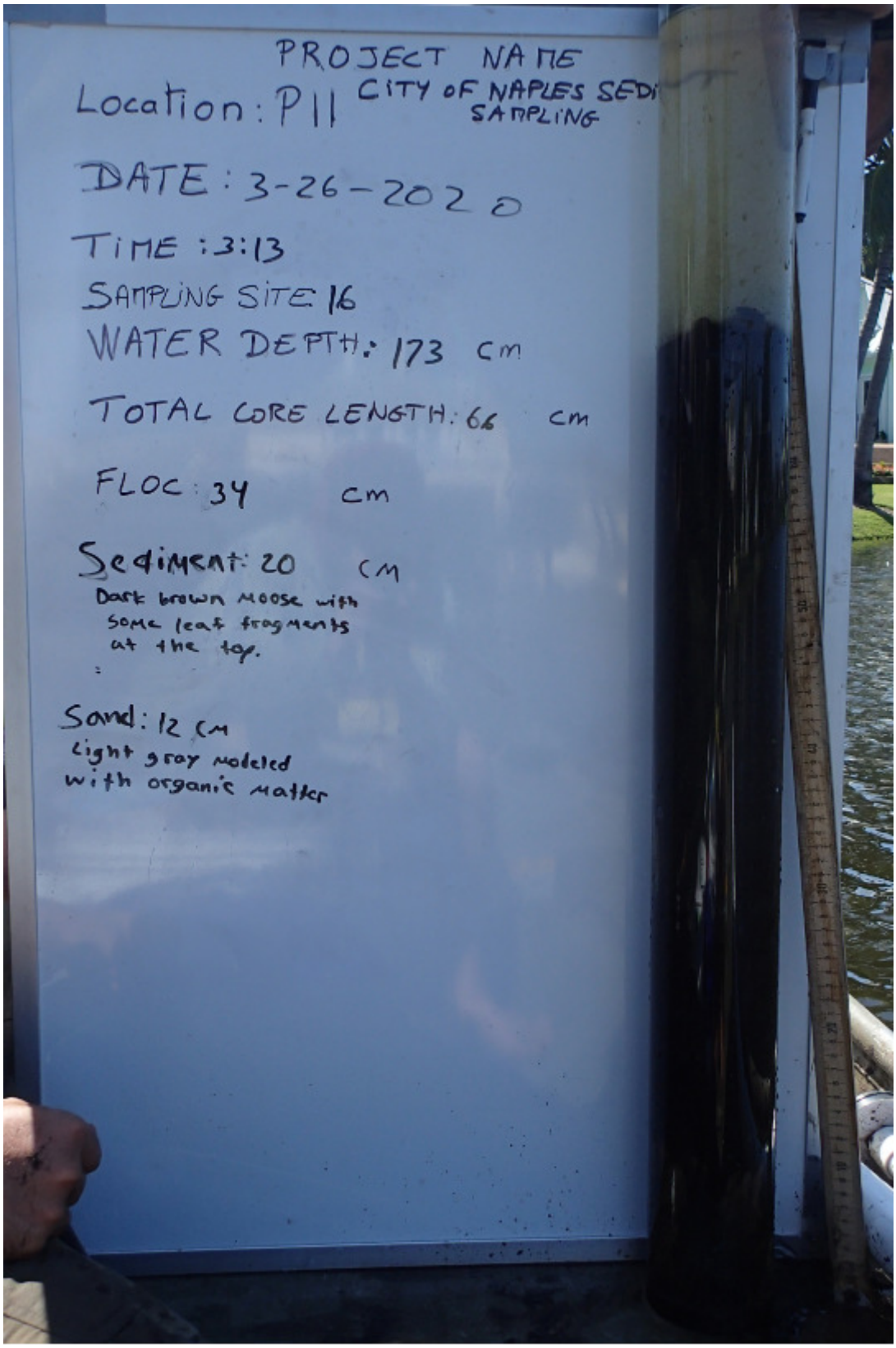
P11_S14


PROJECT NA
CITY OF NAPLE
SEDIMENT
SAMPLI
Location: P11
DATE: 03/26/2020
TIME: 11:41 a.M
SAMPLING SITE: 14
WATER DEPTH: 96 cm
TOTAL CORE LENGTH:
FLOC: 22.5 cm
Sediment: 3 cm
Dark-tan
Sand: Slightly Modeled
Light-tan with organic
matter
P11_
20
P11_03/26/2020

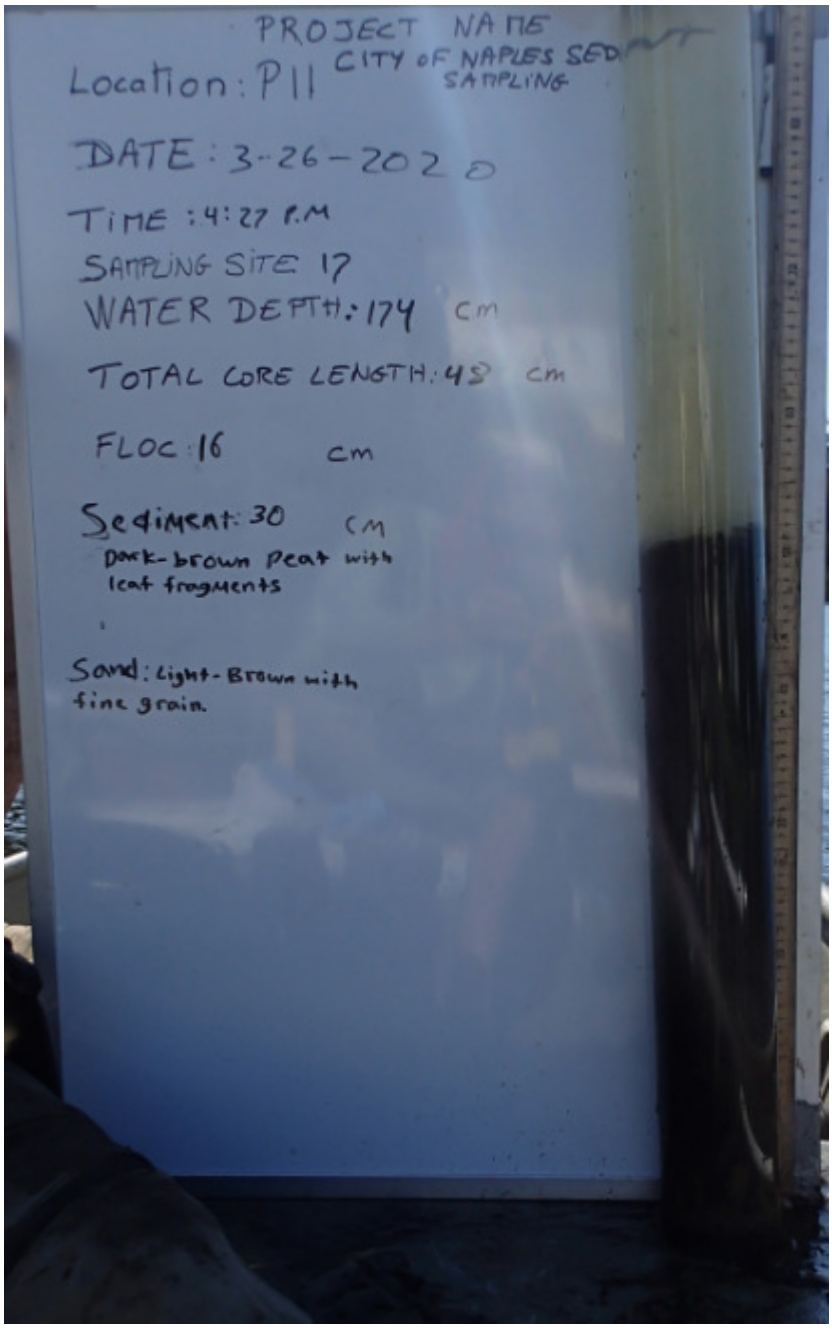
P11_S15


PROJECT NAME
CITY OF NAPLES SEDIMENT SAMPLING
Location: P11
DATE: 3-26-2020
TIME: 2:18 P.M
SAMPLING SITE: 15
WATER DEPTH: 73 cm
TOTAL CORE LENGTH: 41 cm
FLOC: 7 cm
Light Brown
Sediment: 28 cm
Light-Tanish Brown to Dark Tan with pockets of Sand But Mostly Peat Sediment
Sand: Light tan modeled with organic matter and some leaf matter

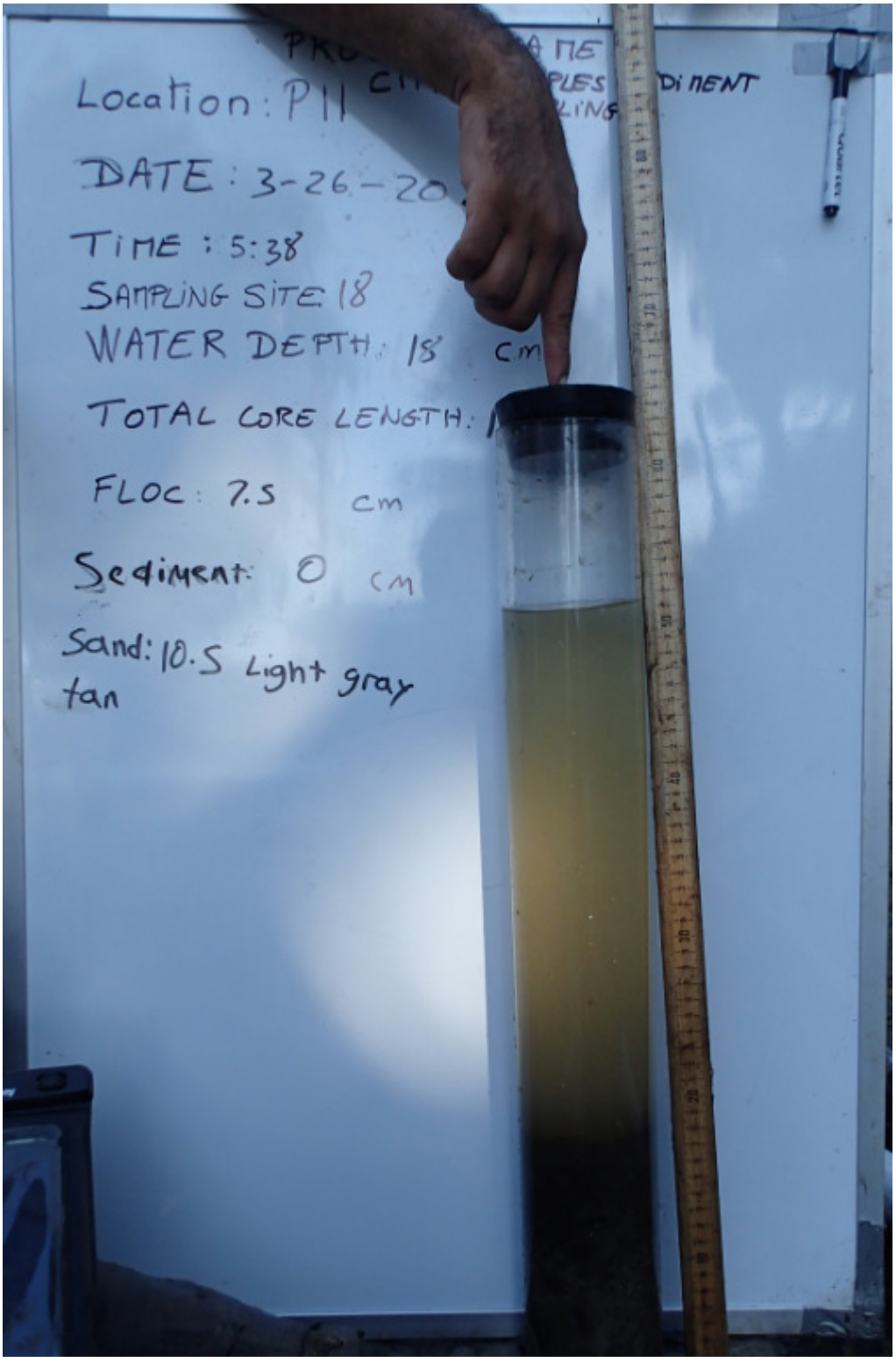
P11_S16


PROJECT NAME
Location: P11
CITY OF NAPLES SEDI
SAMPLING
DATE: 3-26-2020
TIME: 3:13
SAMPLING SITE: 16
WATER DEPTH: 173 cm
TOTAL CORE LENGTH: 66 cm
FLOC: 34 cm
Sediment: 20 cm
Dark brown MOOSE with some leaf fragments at the top.
Sand: 12 cm
Light gray modeled with organic matter

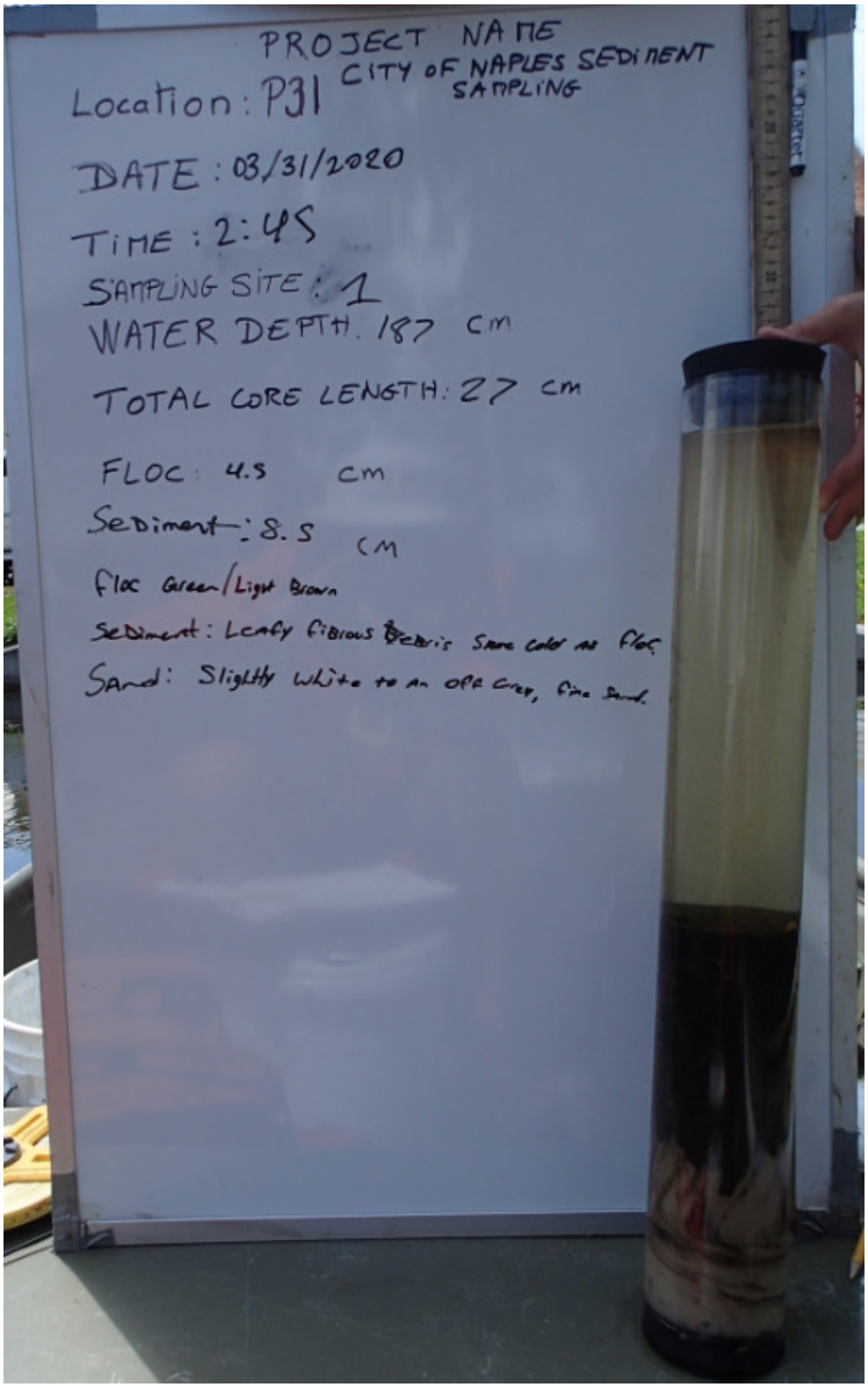
P11_S17


PROJECT NAME
CITY OF NAPLES SED
SAMPLING
Location: P11
DATE: 3-26-2020
TIME: 4:27 P.M
SAMPLING SITE 17
WATER DEPTH: 174 cm
TOTAL CORE LENGTH: 45 cm
FLOC 16 cm
Sediment: 30 cm
Dark-brown Peat with
leaf fragments
Sand: Light-Brown with
fine grain.

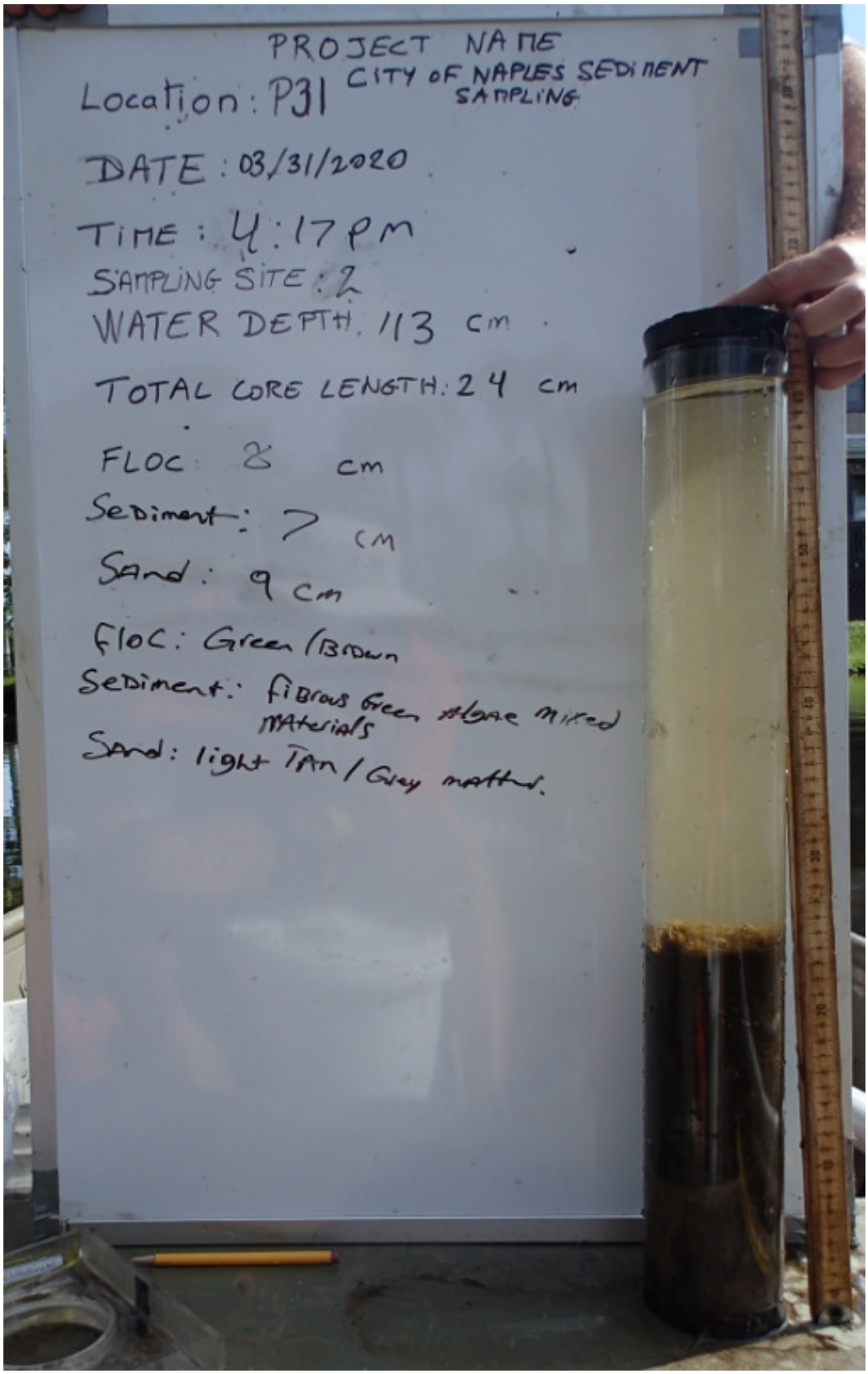
P11_S18


Location: P11
DATE: 3-26-20
TIME: 5:38
SAMPLING SITE: 18
WATER DEPTH: 18 cm
TOTAL CORE LENGTH:
FLOC: 7.5 cm
Sediment: 0 cm
Sand: 10.5 Light gray tan

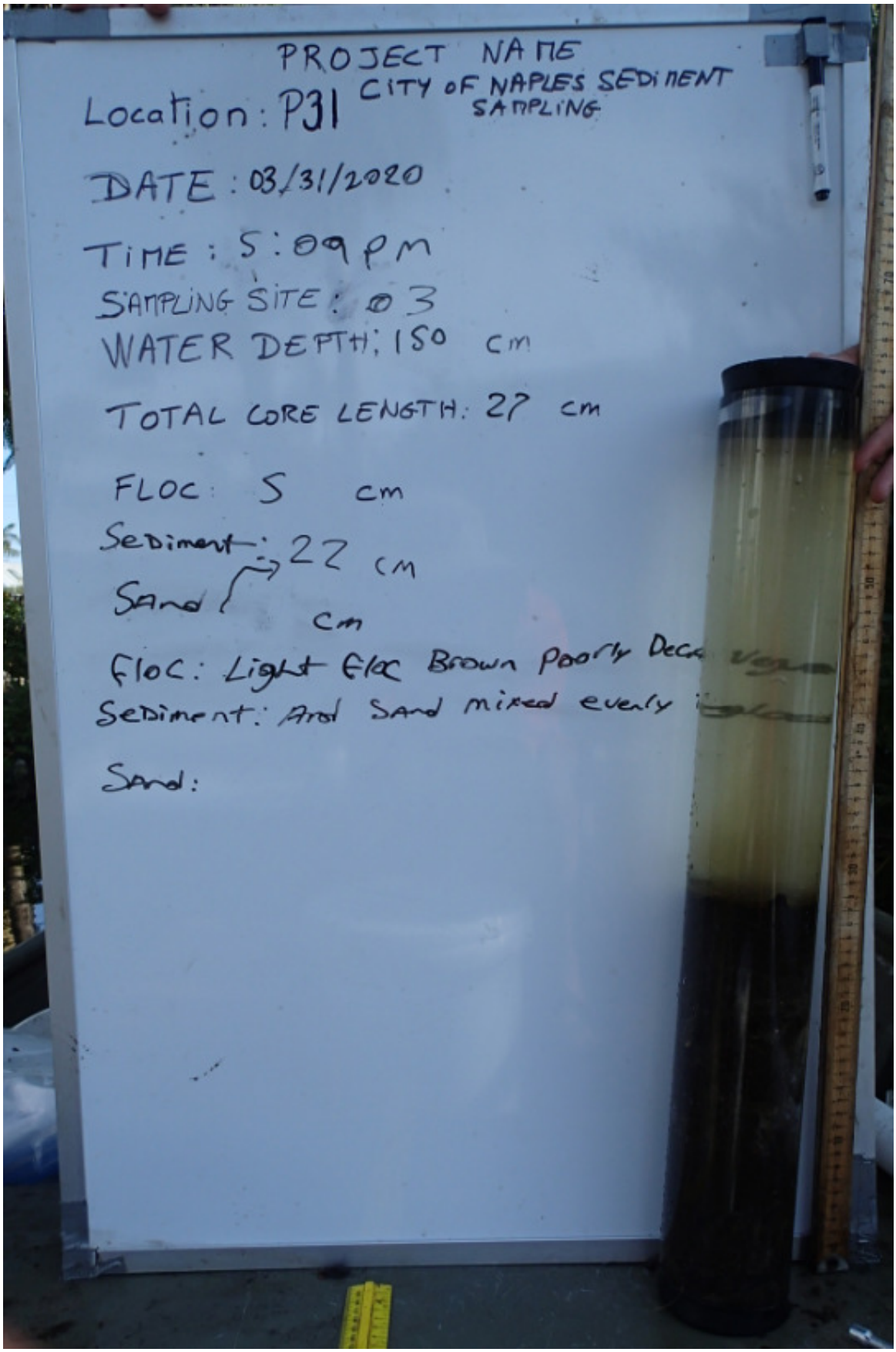
P31_S01


PROJECT NAME
CITY OF NAPLES SEDIMENT SAMPLING
Location: P31
DATE: 03/31/2020
TIME: 2:45
SAMPLING SITE: 1
WATER DEPTH. 187 cm
TOTAL CORE LENGTH: 27 cm
FLOC: 4.5 cm
Sediment: 8.5 cm
floc Green/Light Brown
Sediment: Leafy fibrous debris Same color as floc
Sand: Slightly White to an off Grey, fine Sand.

P31_S02


PROJECT NAME
CITY OF NAPLES SEDIMENT SAMPLING
Location: P31
DATE: 03/31/2020
TIME: 4:17 PM
SAMPLING SITE: 2
WATER DEPTH: 113 cm
TOTAL CORE LENGTH: 24 cm
FLOC 8 cm
Sediment: 7 cm
Sand: 9 cm
FLOC: Green/Brown
Sediment: fibrous green algae mixed materials
Sand: light TAN/Grey matter.

P11_S03


PROJECT NAME
CITY OF NAPLES SEDIMENT SAMPLING
Location: P31
DATE: 03/31/2020
TIME: 5:09 PM
SAMPLING SITE: 03
WATER DEPTH: 150 cm
TOTAL CORE LENGTH: 27 cm
FLOC: 5 cm
Sediment: 22 cm
Sand
cm
Floc: Light Floc Brown Poorly Dec
Sediment: And Sand mixed evenly
Sand: