Soil properties at archaeological site, 3 Parramatta Square,

153 Macquarie Street, Parramatta

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Report to Casey & Lowe

A sign of early cultivation: breaking open a clod to reveal a v-shaped inclusion of the dark historic topsoil, wedged into the pale yellowish grey subsurface. Probably made by a hoe, this feature may have been along a planting line. Some of the original dark topsoil was also found intact, in a low-lying part of the site, preserved by burial under a layer of fill.

Introduction

The soil was examined on 26/11/15, 4/12/15 and 3/2/16, exposed in several pits, some of which were sampled for chemical analysis. The site sits at the junction of an alluvial terrace of the Parramatta River (450 m to the north) and the base of rising ground to the south. Previous studies at other sites on the terrace have revealed a wide range of soil profiles, with features related not only to the landscape and land uses of the early colonial period but also to much earlier landscapes.

Geotechnical investigations on the terrace nearby have revealed that, in the geological past, the bedrock below the alluvial sediments has been gouged out to below the current sea level (see figure 1, from Lawrie, 1982). There are two depressions in the bedrock, probably corresponding to older locations of the riverbed. Only 50 m away from the site, deep coring prior to the construction of the multi-level car park in Horwood Place north of Macquarie Street found "extremely weathered" shale bedrock at a depth of 12 m, 3.95 m below sea level (Jeffery and Katauskas, 1978). The downcutting of the bedrock occurred during the Pleistocene, a period when sea levels fluctuated and was often lower than at present.

Above the weathered shale are many layers of sandy and clayey alluvial sediments beneath the terrace. These layers of younger alluvial sediments were deposited as the sea level rose, after the downcutting phase. In the southern part of the site the alluvial sediments gradually thin out and rest on a layer of ancient deeply weathered mottled clay.

The soil profiles developed in the top metre and a half of these sediments were examined with the objective of understanding their depositional history, and how features of the profile might have been affected or modified by human activity.

Of the eight profiles inspected 5 were sampled for laboratory testing (at sites 1,2,3,5 and test trench 18). Four more soil samples were collected for testing by Casey and Lowe from the area near the old creek line. All samples were analysed at the Wollongbar laboratories of the NSW Dept. of Primary Industries for a range of major nutrients and trace metals. Phosphorus sorption testing was done at the Scone laboratory of the Soil Conservation Service.

Landscape and Geology

The site has a very gentle slope down to the north west, towards an early colonial drain that appears to have followed the route of a former natural drainage line heading to the north east. The current elevation is between 10 m and 12.5 m AHD. Because of later deposition of fill, (depicted in the Douglas Partners 2015 geotech report in the cross-sections A-A" and D-D') the surface at the time of clearing and settlement was about a metre lower and the drainage pattern of the lower northern part of the site, across the wavy, undulating surface of the alluvial terrace, was erratic, with several small, probably natural, depressions. Even though they no longer carry water (due to a succession of infilling activities which have raised the surface of the site), the wetter or poorly drained areas in the former low-lying parts of the site have distinctive soil profile features. The soil around these former depressions may have a darker, thicker topsoil, with a grey or pallid subsoil, with mottling or dark iron/manganese-rich concretions. Modern drainage structures can alter the natural pattern of water movement, often drying out areas that were once frequently waterlogged, and making other previously dry areas wetter.

The landscape rises gradually towards the south east corner of the site. A borehole here (Groundtest P/L, 1978), at the north east corner of the former library building, found the shale bedrock only 5.4 m below the surface, under a layer 1.8 m thick of "shaley clay", which is probably the weathered zone above the harder bedrock.

Above it was a layer 0.8 m thick of grey and brown mottled clay containing shale gravel. This represents a very old colluvial layer, most likely derived from the shale hillside immediately upslope. Over the top of this was a thick layer of stiff red brown and grey mottled clay containing ironstone gravel. This deeply weathered layer 2 m thick is probably Pleistocene in age (it could be older), and may have formed either on the old colluvium, or on a very old deposit of alluvial sediments. This dense impermeable mottled clay (described as residual clay in the 2015 geotech report) was exposed by excavation at the south east corner of the site (photo 1). The top of this ancient clay slopes down towards the north west , covered by an increasingly thick layer of younger alluvial sediments, which replace it completely in the northwest and northern part of the site along Macquarie Street. The northern edge of this ancient residual clay was eroded away by the river during a period of downcutting, probably during a time of low sea level.

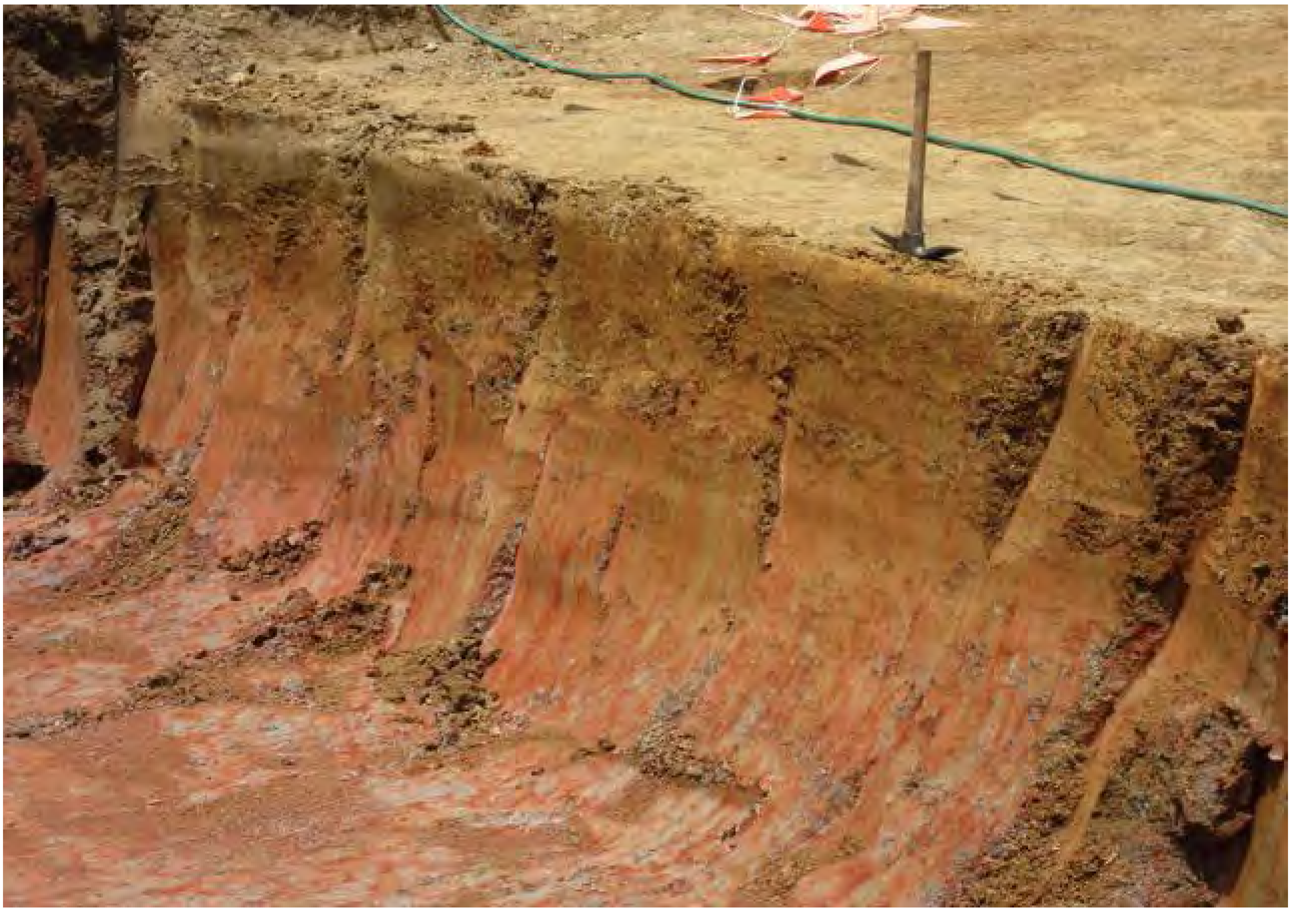

Photo 1: This large pit 1.2 m deep in front of the north east corner of the old library exposed two layers of dense clay. Above the lower red and grey mottled zone is a gradual change to a yellow brown clay that was observed as a subsoil in many places across the whole site. The lack of a clear or abrupt boundary here suggests that the yellow brown clay was formed naturally from the older deeper clay, possibly by a climatic change, or simply by being much closer to the soil surface at some point in the past.

Similar dense mottled clay was observed at about the same elevation (9 m AHD) at the former Parramatta hospital site (Lawrie, 2005), 600 m away and adjacent to the river. This old mottled clay has a significant effect on profile drainage; its very low permeability seriously impedes downward movement, producing perched water tables in the layers above it, particularly where there might be depressions in its upper surface. A linear depression in the upper surface of this clay, and in the yellow brown clay above it, was close to the route of a small natural waterway that flowed from the west and south west through the northern part of the site and across Macquarie street on the eastern side of the former Civic Place intersection (see the Casey & Lowe TOSS diagram).

Deeper in the profile groundwater movement is influenced by the underlying geological formations (Douglas Partners, 2017), including the presence of sandy more permeable sediments in the lower part of the alluvial deposits and the presence of a small near-vertical dyke of volcanic rock. This deeper watertable is influenced by rainfall but does not appear to rise upwards enough to influence soil profile drainage close to the surface (Douglas Partners, 2017); it is too deep to have affected plant growth during the colonial period.

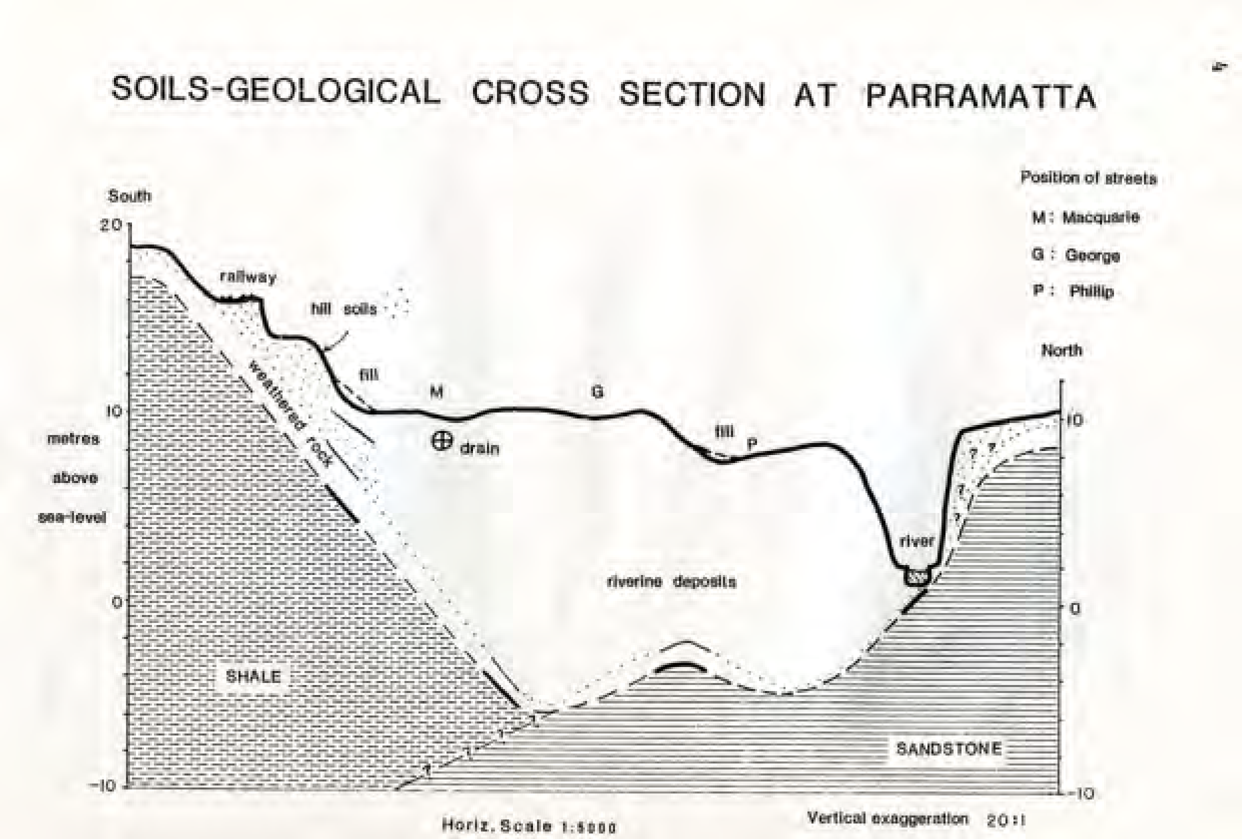

Figure 1: Surface elevation of the alluvial terrace at Parramatta and the elevation of the underlying bedrock, along a north-south cross-section between the Lennox Bridge and the railway station (from Lawrie, 1982); note the sloping surface of the shale bedrock in the proximity of Macquarie Street (diagram based on geotechnical reports from the 1970's, with surface elevations from a detailed town plan supplied by Parramatta City Council).

Soils

Natural features of soil profiles across the site: Subsoils

The top part of the underlying old mottled clay gradually changes colour, the grey mottle decreasing and being replaced by yellow-brown mottles. Occasionally some of the red-brown mottles contain strongly weathered fragments of iron-indurated shale (see photo 2). Often accompanying the colour change is a slight decrease in clay content, from a heavy to a medium clay. Moving further upwards into the root zone, the red-brown mottles become less prominent and the clay is mostly brown, especially where the slope levels out. On the rising ground to the south east the clay subsoil becomes yellow-brown (photo 3), and it goes grey in the lower areas to the north west. These colour changes reflect natural variation in the soil moisture regime that once prevailed across the landscape over a very long period of time. The dominant presence of clay in the subsoil (photo 4) stands in sharp contrast to the sandy nature of soil profiles at the Cumberland Press site (142-154 Macquarie Street) 500 metres away, near the eastern end of Macquarie Street (Lawrie, 2016), on a slightly lower part of the terrace.

Photo 2: Red brown ironstone gravel is found within a yellowish brown dense clay (IIB horizon) underneath the lighter-textured B horizon of the site 5 profile. Similar gravel was sometimes seen surrounded by red mottles in the underlying possibly Pleistocene clay, the most likely parent material of the IIB horizon.

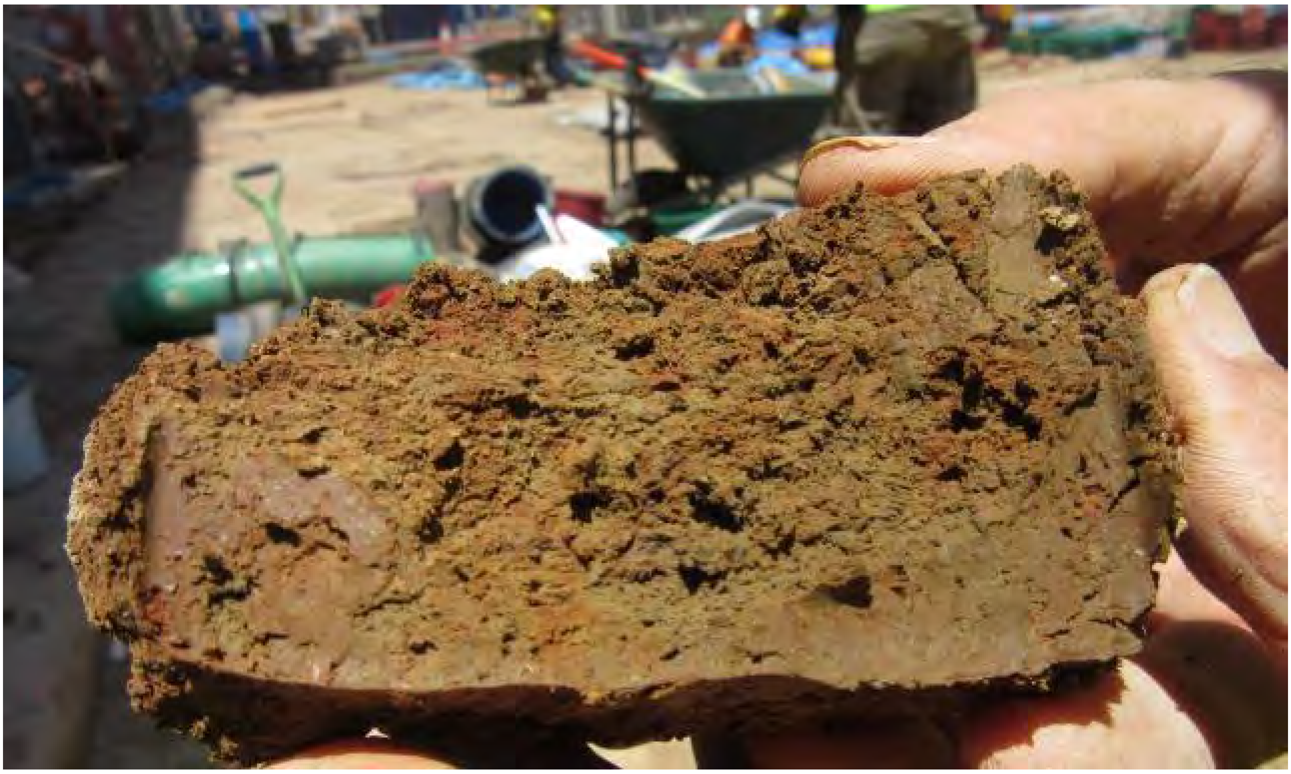

Photo 3: A piece of the dense yellowish brown clay subsoil (from the IIB horizon) with reddish brown mottles, from a depth of 20-25 cm at site 1. Clay similar to this was seen at several locations, usually at shallow depths, across the whole site.

Photo 4: A long ribbon can be moulded from a sample of the IIB horizon (from the site 1subsoil), demonstrating its high clay content.

Since it lies deep in the profile, and judging by its characteristic chemical properties, the clay (IIB) horizon (tested at sites 1, 2 and 5), appears to have been preserved largely intact. The trace metal content is low. Another property that reflects the absence of disturbance by human activity is the very low phosphorus content. In the six samples analysed from the IIB horizon the concentration of plant-available P (Colwell test) ranged from 1.3 to only 7.3 mg/kg; the range in total P was 31 to 110 mg/kg. The depletion of soil phosphorus is an indicator of strong leaching coupled with prolonged extraction, over thousands of years, by plants under natural conditions (Norrish and Rosser, 1983).

Consistent with this history is the low pH (5.1) and the dominance of exchangeable magnesium over calcium found in the underlying mottled clay (IIC horizon) at site 3. This last property can be altered by deposition on the soil surface of calcium–rich fireplace ash and then its subsequent leaching down the profile. There is some evidence of calcium enrichment due to this activity in the upper part of the IIB horizon at site 2. The longer the surface is exposed to the weather, the greater will be depth of leaching.

The IIB horizon in its natural state has a moderate to very high phosphorus sorption capacity, is less acidic (pH 6.3 to 6.5), and it contains more carbon, nitrogen, and exchangeable cations (with calcium being dominant) than the underlying mottled clay (IIC horizon); it is also slightly less dense and impermeable. The upper surface of the IIB horizon is not horizontal; it slopes down gradually from the south east to the north west, indicating that it may have formed within the upper portion of the underlying red and grey mottled clay (the IIC horizon, see photo 5).

The upper boundary of the IIB horizon clay with the overlying silty alluvial layer is generally clear and distinct, but the change to the IIC horizon below is gradual or diffuse .

Photo 5: The mottled grey dense clay of the IIC horizon from site 3, showing yellow brown mottles that are seen within the gradual transition to with the overlying IIB horizon.

Natural features of soil profiles across the site: Surface soils

Above the IIB horizon the profile is generally much more disturbed, except in lower lying depressions. There is a significant change in its composition, with a distinctly silty or fine sandy fraction that suggests it originated as an alluvial sediment.

The alluvial layer thickens in the lower part of the 3PS site (at site 2 for example), while on higher ground near the old library the darker upper part (A_1 horizon) seems to thin out and appears to have been eroded away. On the eastern boundary at site 1, the lower part of the topsoil (the A_2 horizon), a pale or a drab yellowish grey colour, appears to have been close to the soil surface during early settlement because it has been partially affected by cultivation, changing its physical features as well as its chemical properties (see photo 6).

Photo 6 (Casey & Lowe P/L): These furrows or plough lines, which date back to the 1830's, were found when the concrete roadway of Civic Place was carefully removed. This is near the old drainage line where the topsoil was once thicker, and higher in organic matter and nutrients, than on the slightly more elevated ground to the southeast. The drab yellowish grey soil appears to be from the A_2 or B horizon, with the darker, greyer soil, containing a mix of surface A_1 horizon and the upper part of the underlying A_2) in between (possibly once formed up into raised beds).

The alluvial layer at site 5, about 35 m from the drainage line, is thick enough (30 cm) to have three distinct components. Preserved under an early house (see photo 9) is the dark A_1 horizon 10-15 cm thick covering a very light grey A_2 horizon (5-10 cm thick), with a light yellowish grey layer (B horizon) underneath containing abundant rusty mottles.

Charcoal fragments are conspicuous in the A_1 horizon of site 2 (original surface at about 9.5 m AHD) and in the A_2 horizon of the more elevated site 1 (about 1-1.5 m higher). Charcoal raises the soil's carbon content without much effect on the nitrogen level.

The best preserved natural profile was seen in the Casey & Lowe test trench 18 close to Macquarie Street (photo 7). The original soil surface, quite low-lying here, only 9.14 m AHD, was protected by burial under a layer of sand about 15 cm thick that appeared to have been spread early in the colonial period. The sand had the highest pH of any sample tested (pH 7), possibly produced by runoff from lime-washed dwellings nearby. It also contained specks of charcoal and an elevated calcium content, suggesting fireplace ash deposition (the sandy fill has not been contaminated with heavy metals, suggesting it was buried early, prior to the 20^{th} cent.). Residues leached from the ash in the sandy fill appear to have also boosted the calcium level in the otherwise undisturbed historic topsoil underneath.

Photo 7: The Casey & Lowe test trench 18 soil profile has dark clayey fill covering another fill layer of yellowish light brown sand (between 45 and 55 cm depth) that has protected the grey historic topsoil underneath it. On the floor of the pit is a pale grey silty light clay, the A_2 horizon of the original profile. Its chemical properties have remained unaffected by British settlement.

Details of each soil profile, with comments on land use

-site 1: sampled 26/11/15 for Jill Comber; located 3 m from the eastern edge of 3PS, about 25 m from the southern boundary

The site 1 soil profile has a thin capping of very pale silty alluvium that sits on a dense clay, with an irregular boundary between that looks as if it has been disturbed by cultivation (photo 7). Raised nutrient levels indicate disturbance has extended into the IIB horizon below. A small amount of lead (32 mg/kg) in the topsoil is probably from lead paint.

Photo 8: Shallow pit 15 cm deep near site 1 shows the very pale silty topsoil covering the brown clay subsoil. The top of the clay has an unnatural convex shape, suggesting it was disturbed by deep cultivation (furrowed?). The topsoil contains many small dark charcoal fragments, possibly from fireplace ash. This can act like liming material, elevating the soil pH and raising the calcium level, even in the underlying clay (given enough time).

-site 5: sampled 3/2/16 for Jill Comber, located 20m south of Macquarie Street, and about 25m from the eastern edge of 3PS

Patches of the dark historic topsoil were found here, preserved beneath the remains of a c.1822 house (photo 9). The boundaries between horizons were more gradual at the site 5 profile. The light clay in the 3 horizons above the dense clay IIB horizon was friable and distinctly sandy, a difference arising most likely from the change to an alluvial soil parent material.

Photo 9: The profile sampling location at site 5 is in the centre, near the leaning spade. The grey historic topsoil becomes very pale underneath (the A_2horizon). Below this the profile gradually changes to a pale yellowish grey light clay (B horizon). A similar grey historic topsoil was seen at test trench 18 (photo 7) buried under a layer of sandy fill (which was not present at site 5) that protected the test trench 18 topsoil from nutrient enrichment. It is possible that the nutrient-rich material at site 5 was applied prior to 1822; it may have also been enriched by household dust that fell through gaps in the wooden floor of the house.

Photo 10: The yellowish grey alluvial B horizon of the site 5 profile has rusty coloured mottles along old root channels. These are a natural feature of a horizon within the root zone that is prone to intermittent waterlogging; in this profile it shows that the underlying dense clay (IIB horizon) has low permeability.

Site	Horizon	Sample depth (cm)	Description	Lab. no. WN 16 /	Nutrient status	Trace metal status
1: thin layer of alluvial terrace, at the base of slope, eastern side of 3PS	A_2 ; alluvial historic topsoil	0-5	Very light grey brown silty loam, structureless; clear irregular lower boundary	1366	Raised potassium, phosphorus, pH, calcium	Slight lead contamination
	IIB_1	10-15	Dark brown medium-heavy clay, dense, very hard when dry, weakly structured	1367	Raised potassium, slight rise in pH, calcium	Normal
	Upper IIB_2	20-25	Mottled dark reddish brown and dark brown medium clay, moderately structured	1368	Raised potassium. slight rise in pH, calcium	Normal
	Lower IIB_2	30-35	As above, slightly redder mottle	1369	Raised potassium.	Normal
5: alluvial terrace over clay, in centre of site	Historic topsoil	0-10	Dark grey light clay with fine sand; gradual lower boundary	1370	Raised phosphorus, carbon, pH, calcium	Normal
	A_2	15-20	Very pale grey light clay with fine sand; sets hard when dry	1371	Slight rise in pH and calcium	Normal
	B	20-25	Light yellowish grey light clay; abundant rusty mottles along old root channels	1372	Slight rise in pH and calcium	Normal
	IIB	40-45	Dark yellowish brown heavy clay with reddish brown mottles	1373	normal	Normal

Table 1: Summary of the features of eight samples from two soil profiles, their position in the profile, and brief comments on their nutrient and trace metal status. The laboratory numbers are from report WN16/0175.

-site 2: sampled 26/11/15, located close to Macquarie Street footpath about 20m from the eastern edge of 3PS

Under a layer of sandy mixed fill is a gradual boundary to a disturbed remnant of the original topsoil. Its phosphorus content is higher than in the cultivated topsoil at site 1, and well above the level in the topsoil of test trench 18, only about 20m away. The lead content is higher too, and the roadside location suggests that motor vehicle emissions may have contributed to the increase rather than old paint. The two horizons sampled below appear physically undisturbed but their chemical properties have been affected by minerals leached out of waste (livestock and domestic) dumped on the surface.

-site 3: sampled 26/11/15, located close to the old library on the southern edge of 3PS

The dense mottled ?Pleistocene clay (IIC horizon), like the IIB horizon clays from site1, has more exchangeable potassium than most other samples. Perhaps this is a natural feature, but leaching of potassium out of leafy bushfire ash over a long period of time can't be ruled out as a possible contributor. Apart from this feature the sample is undisturbed.

The elevated potassium content could also be related to the site location, which is on the edge of a "historic pond". The highest exchangeable potassium at 3PS was found in the pond sediment (sample 183 of the Casey & Lowe old creek line samples). Plant residues contain high amounts of potassium, and a dense proliferation of plant roots was seen in the overlying IIB horizon at site 3. The extra moisture that was once available at both sites allowed increased plant growth

Site; C &L soil sample, context number	Horizon	Sample depth (cm)	Description	Lab. no. WN 16/ 0350	Nutrient status	Trace metal status
2; 100, 16416	Alluvial historic topsoil	80-85	grey brown loam, with fragments of charcoal, broken glass and bricks	1	Raised phosphorus, pH, calcium	Slight lead contamination
-101, 16465	A_2	90-95	Light grey-brown loam	2	slight rise in phosphorus, pH, calcium	Normal
-102, 16949	Upper IIB_2	105-110	Yellow- brown medium to heavy clay	3	slight rise in phosphorus, pH, calcium	Normal
3; 103, 16256	IIC	130-135	Red-brown and grey mottled dense clay; physically undisturbed	4	Slight rise in potassium, otherwise normal	Normal

Table 2: Summary of the features of four samples from two soil profiles, their position in the profile, and brief comments on their nutrient and trace metal status. The laboratory numbers are from report WN16/0350.

-test trench 18 (see photo 7): sampled 4/12/15, located about 10m from the Macquarie Street footpath and about 12m from the former roadway of Civic Place

Under a layer of very disturbed dark clayey mixed fill was a second older layer of yellowish brown sandy fill, with a dark layer of historic topsoil about 15cm thick underneath it. This topsoil was undisturbed, crumbly and friable, with traces of iron mineralisation. All three samples had a low heavy metal content.

AP 10 Test trench 18	horizon	Sample depth (cm)	description	Lab. no. WN 16/ 0350	Nutrient status	Trace metal status
soil no. 358, context 16193;	Sandy fill	45-50	Light yellowish brown and light greyish brown sand; no gravel, no roots; structureless, with specks of fine charcoal	12	elevated pH and calcium, slight rise in phosphorus	Very low
soil no. 357, context 16224;	Buried topsoil-original A_1	58-65	Grey silty light clay, with rusty mottles, many plant roots; moderately structured with firm, crumbly aggregates	11	Normal; appears undisturbed	Normal
soil no. 356, context 16190	original A_2	65-70	Light grey silty light clay, with yellowish brown mottles along old root channels and occasional dark soft nodules (2-3mm diam.); weakly aggregated	10	Normal; appears undisturbed	Normal

Table 3: Summary of the features of the three samples from test trench 18, their position in the profile, and brief comments on their nutrient and trace metal status. The laboratory numbers are from report WN16/0350

Trace Metals

Lab.no. 160175, 13--	Site/trench	horizon	Copper mg/kg	Lead mg/kg	Zinc mg/kg	Cobalt mg/kg	Chromium mg/kg
66	1/343	Historic topsoil	8.5	32	16	7.9	29
67		IIB_1	15	20	17	6.6	33
68		Upper IIB_2	16	20	18	5.4	34
69		Lower IIB_2	17	21	18	4.9	32
70	5	Historic topsoil	5.7	10	8.6	10	11
71		A_2	4.1	15	5.6	6.2	18
72		B	5.1	12	6.3	5.4	14
73		IIB	17	19	17	6.4	33
Ref.1	Glebe	Topsoils	60	300	200	-	-
Ref.2	Sydney region	Topsoils	7.5	15	14.5	0.8	8
Ref.3	Global	Soils	30	35	90	8	70

Table 4: Heavy metal content (mg/kg) of soil samples from sites 1 and 5 in relation to local, regional and global median levels. (Ref. 1: Markus & McBratney (1996); Ref. 2: Lawrie et al (1992); Ref. 3: Bowen (1979).

All the soils seem relatively uncontaminated with trace metals. Levels of arsenic and cadmium are below detection limits (see report WN 16/0175). Concentrations of copper, lead and zinc, the three main indicators of twentieth century industrial activity, are generally moderate (see table 4). The lead content in the topsoil of site 1 is slightly elevated (relative to other topsoils in Sydney), but is near the global median level and well below the levels found in soils from the inner city suburb of Glebe. The site 5 profile, preserved under an old house, has remained uncontaminated by heavy metals.

Cobalt and chromium concentrations are also elevated compared to topsoils in the Sydney region, but not when compared to global benchmarks.

The three subsoil samples at site 1 and the sample from the IIB horizon at site 5 all have remarkably similar concentrations of trace metals, strongly suggesting a common parent material. Clay soils like these have a greater natural capacity to bind and retain metals than sandy soils.

Lab.no. 160350	Site/trench	horizon	Copper mg/kg	Lead mg/kg	Zinc mg/kg	Cobalt mg/kg	Chromium mg/kg
1	2	Historic topsoil	13	88	32	8.1	16
2		A_2	5.4	15	8.4	5.6	12
3		Upper IIB_2	12	16	13	5.7	22
4	3	IIC	21	23	12	2.1	22
12	TT18	sandy fill	1.9	4.1	4.8	5.9	3.5
11		Buried A_1	3.7	10	6.4	9.6	9.4
10		Original A_2	4.6	14	6.4	6.5	12
Ref.1	Glebe	Topsoils	60	300	200	-	-
Ref.2	Sydney region	Topsoils	7.5	15	14.5	0.8	8
Ref.3	Global	Soils	30	35	90	8	70

Table 5: Heavy metal content (mg/kg) of soil samples from sites 2, 3 and TT18 in relation to local, regional and global median levels. (Ref. 1: Markus & McBratney (1996); Ref. 2: Lawrie et al (1992); Ref. 3: Bowen (1979).

The site 2 topsoil is the only sample with any sign of heavy metal contamination. It was situated under the concrete slab next to the footpath along Macquarie Street so the lead content may have been boosted by motor vehicle exhaust fumes, when this spot was once a grassy roadside verge. The copper and zinc levels are also slightly elevated, but not to the same extent. The contamination probably occurred by the first half of the 20th century, before the soil was covered by fill half a metre thick.

Old creek line samples

Four samples near the old creek line along the western side of the site were collected for laboratory analysis to see if any of their chemical properties were altered by previous land uses (see WN 160350 for detailed results).

The "orange clay" below the drain (C&L soil no. 330, context 17893, lab. no. 9) has chemical properties consistent with an acidic clay B horizon that is largely undisturbed. Only the sulphate content seems elevated, but this is not unusual for a clay along an active drainage line.

The "creek bed" sample (C&L soil no. 321, lab. no. 8) is also acidic, and significantly, non-saline, suggesting that it was flushed regularly by the creek. Fresh water flows seem to have been a regular occurrence, providing occasional drinking water for livestock and wildlife, and also for visiting local Aboriginal groups. Other altered chemical properties (high carbon, nitrogen, phosphorus and potassium levels) are associated with additional organic matter, probably trapped by water plants like reeds and rushes. Manure dropped by livestock while drinking can also contribute to the increase. Eroded topsoil surprisingly does not seem to be a contributor, because the total of exchangeable cations is very similar to the level in the "orange clay". The trace metal content is elevated, but not excessively, suggesting that the creek did receive waters (including stormwater containing zinc from corrugated iron roofs and downpipes, and lead from old paint) well into the colonial period.

The "historic topsoil" sample (C&L soil no. 231, lab. no. 7), from the rear yard of house 4, has some chemical properties similar to the well-preserved buried topsoil at test trench 18 near Macquarie Street. Important differences, such as the higher pH and high phosphorus levels, suggest domestic waste applications. Higher salinity and exchangeable sodium levels may be associated with the sample (231) originating from a minor surface depression with impeded drainage, but soapy laundry wastewater is also a likely contributor. Trace metal concentrations (in 231) are about double those in the TT18 sample, but are not as high as those found in the "creek bed" sample (or in the disturbed historic topsoil at site 2). Metal corrosion derived from nearby buildings, dating back possibly to the later colonial period, is a likely source.

The chemical properties of the "pond sediment" (C&L sample no. 183, lab. no. 6) are also indicative of an area of closed or impeded drainage (high salinity, sulphate). The carbon content (0.44%) is much lower than in the "creek bed" sample (1.7%), so it will contain fewer plant residues, but the potassium and calcium levels are nearly twice as high. These cations are readily attached to suspended clay (which then settles out in placid water) that probably originated from eroded areas in the catchment of the pond, following cultivation. Some of the soapy wastewater dumped on the historic topsoil probably found its way into the pond, because the exchangeable sodium concentration in the pond sediment is also slightly elevated. Importantly, the phosphorus content is low, suggesting that the pond was not overloaded with livestock or human wastes. The trace metal content lies between levels in the creek bed (higher) and the historic topsoil (lower).

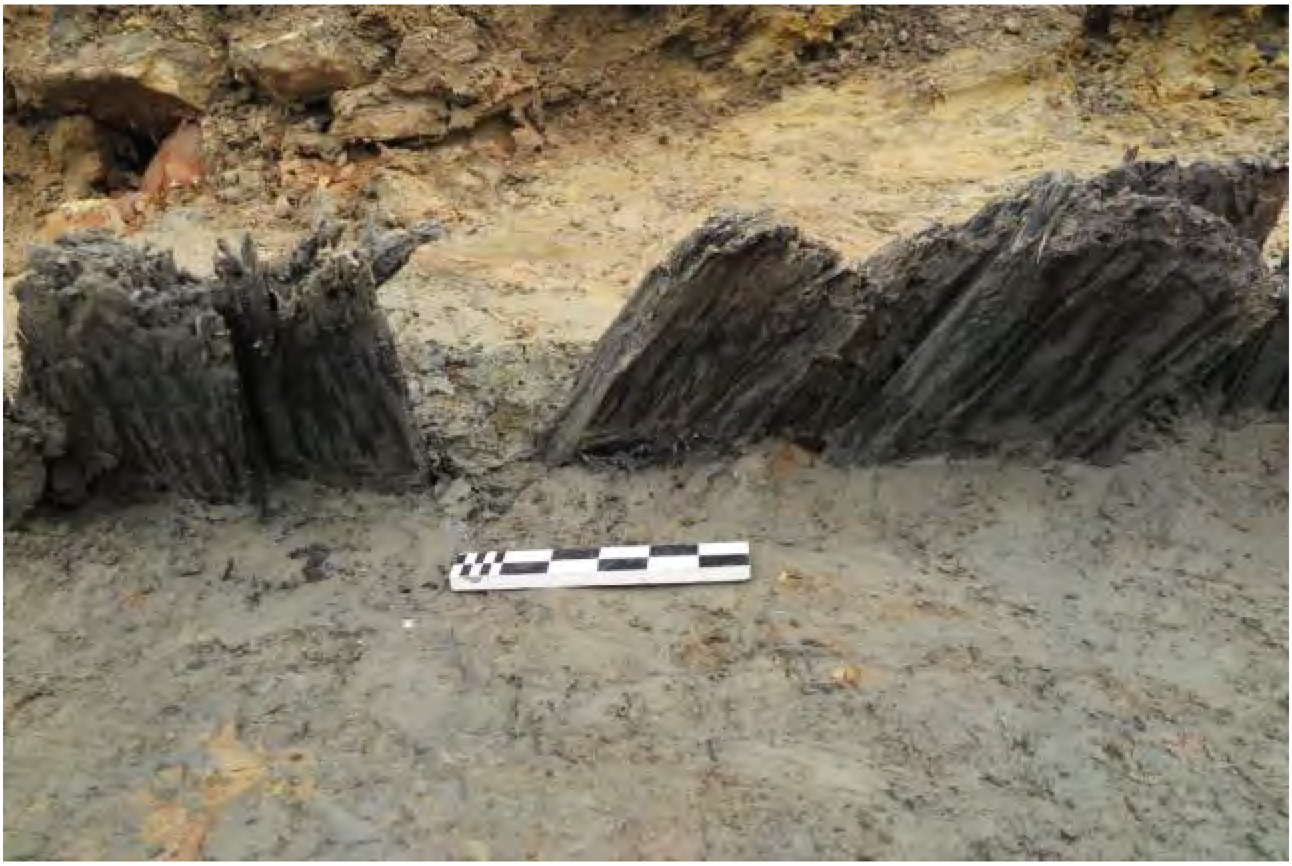

Photo 11: Timber shoring beside the drain within the creek line (Casey & Lowe photo)

Photo 12: Grey creek line clay above mottled clay (Casey & Lowe photo)

Conclusion

Silty and light clayey alluvial sediments once covered most of the archaeological site. The subsoil underneath was generally a dense clay. Much of the original dark surface soil has been heavily disturbed or removed, but the physical features of the subsurface layers appear largely undisturbed. Laboratory testing however has revealed that at most places on the site subsoil chemical properties have been altered, mainly by the downward movement of nutrients and alkaline elements leached out of material dumped on the soil surface.

The clayey nature of the soil profiles has a strong influence on drainage. Low subsoil permeability tends to push water laterally, towards any nearby depressions, or to the drainage line that once came close to the site's western boundary. This natural drainage feature must have been rather narrow because its impact on soil profile features was not seen until the excavation extended beyond the western edge. The presence of natural depressions within the confines of the site has favoured preservation (by burial) of the pre-colonial topsoil.

Most of the nutrient-rich material was probably deposited during colonial times, and continued as Parramatta started to become urbanised. One profile has a low level of lead contamination, probably arising from lead paint residues. In the creek bed sample copper and zinc levels were elevated, but not excessively. Otherwise the content of trace metals is moderate, with no obvious evidence of contamination.

The discovery of a well-preserved historic topsoil (in test trench 18) is the most significant finding, A soil with such a low phosphorus content (Colwell P 6.3 mg/kg, total P 80 mg/kg) would only provide (without adding manure) enough to supply 2 or 3 wheat crops, at a low yield of 13-14 bushels/acre, typical of the 1790's (Lawrie, 2017). Unless more phosphorus could be applied, a wheat or maize paddock would then be only suitable for grazing. A new area of virgin soil would need to be cleared for future crops, and this would make up for the loss of cropping land in themiddle of Parramatta.

Low background P levels in topsoil are rare at archaeological sites because they are easily boosted by the haphazard disposal of P-rich wastes deposited on the soil surface or incorporated by shallow tillage, usually in the early 19th century. Subsoils normally have a much lower available P content.

Organic fertilisers such as animal or poultry manure were the main sources of P applied in the early 19th century, but even this source of P was unavailable in the earliest years of settlement due to the extreme shortage of livestock. Although livestock numbers started to increase after 1795, manure remained too expensive for most farmers. The problem was described by the prominent gentleman farmer John Oxley in 1820,

> "without the assistance of manure, which is probably out of his (i.e. the pioneer farmer's) power to procure, his lands will continue decreasing in produce, so that at the end of six years, the soil will be entirely exhausted.." (from the 1820 Bigge report, quoted by King, 1948).

By that stage, 6 years of continuous wheat cropping would have removed 10-20 kg P/ha, more if the straw had been collected for chaff. If the surface soil's Colwell P concentration in its natural pre-settlement condition was around 20 mg/kg, its ability to support further cropping would probably cease until sufficient manure was added.

Similar low P levels were found in a soil at the government farm (the site in 1789 of the first successful wheat crop) during the Western Sydney Stadium archaeological study (Lawrie 2019). These data, together with total P results from other sites around Parramatta (figure 2), indicate that low P levels are common in the soils around the town.

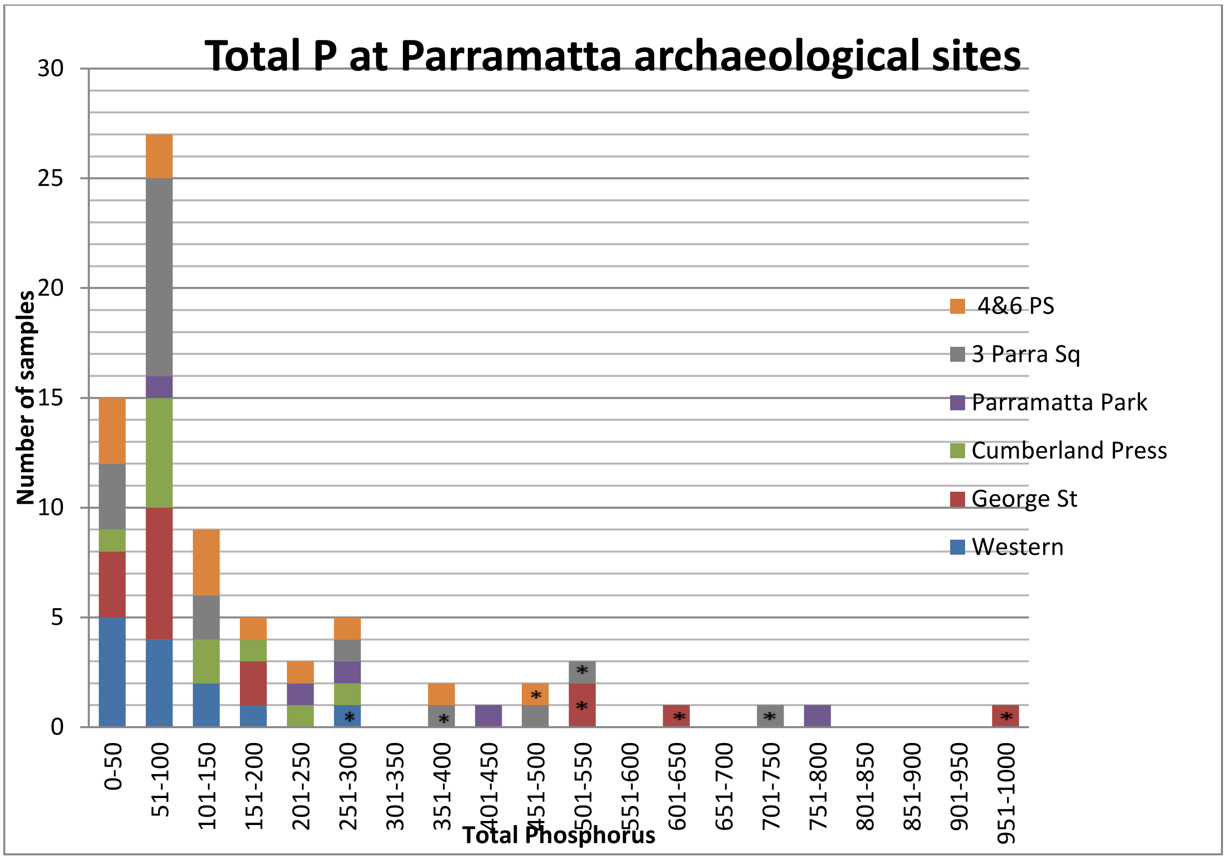

Figure 2: Total phosphorus concentrations (mg/kg) in 64 soil samples from six archaeological sites in Parramatta (P'matta Square 4 & 6, P'matta Square 3, P'matta Park, Cumberland Press, 184-188 George St and Western Sydney Stadium); * denotes samples which also had a high level of plant-available phosphorus (Colwell test >50 mg/kg) ie well above natural background, almost certainly boosted by phosphorus.

The planting lines/furrows found under the roadway (photo 7) are probably not from this very early period of cereal cultivation. Alternatively they may be later relics of cultivated raised beds, consisting of humus-rich topsoil scooped out of the intervening furrows and heaped up in between. Raised beds are commonly used by vegetable growers in backyards and market gardens, particularly where temporary waterlogging is a problem. Given their proximity to the former drainage line this kind of farming technique seems likely.

Animal manure, rich in phosphorus and potassium, was a rare and precious commodity in the early days of cropping. There is only a modest level of these two major nutrients in the topsoil from the backyard of house 4. This suggests that soil nutrient levels were still fairly low when the house was inhabited, and probably also in the nearby cultivated ground.

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Appendices-

Soil test results: WN 160175 and WN 160350 attached separately.

Soil phosphorus sorption test data: 1366-9 are from site 1, 1370-3 are from site 5.

Lab No	Method	C8B/1	
	Sample Id	P sorp (mg/kg)	P sorp index
1	1366	250	2.2
2	1367	730	5.3
3	1368	760	6.0
4	1369	750	5.7
5	1370	270	2.3
6	1371	270	2.3
7	1372	310	2.5
8	1373	760	6.0