Table 7.1c Validation Tests for Sidewall Samples : Eastern Boundary

Determinand	Acceptable Level	Sample Location	1	2	3	4	
		Depth (m bgl)	-0.63	-0.63 to -1.33	+1.07 to +0.37	-0.31	-1.31 t
Arsenic	40						
Cadmium+A91	3						
Chromium (total)	600						
Copper	130						
Nickel	70						
Lead	500						
Mercury	1						
Selenium	3						
Zinc	300						
Water Soluble Boron	3						
pH (units)	>5						
Total Sulphate	2000						
Total Phenols	5						
Total Cyanide	25						
Sulphide	250						
Total Petroleum Hydrocarbons	70						
Total PAH	50		157.7		76		

Notes: All concentrations in mg/kg unless otherwise stated
Depths are relative to final ground levels

Table 7.1d Validation Tests for Sidewall Samples : Western Boundary

Determinand	Acceptable Level	Sample Location	78	79	80	81	
		Depth (m bgl)	+0.35	-0.55	-1.55	-2.5	
Arsenic	40						
Cadmium	3		211.6	6.6	5.2	6.9	
Chromium (total)	600						
Copper	130						
Nickel	70						
Lead	500					77	
Mercury	1						
Selenium	3						
Zinc	300						
Water Soluble Boron	3		597				
pH (units)	>5						
Total Sulphate	2000						
Total Phenols	5						
Total Cyanide	25						
			130				
Sulphide	250						
Total Petroleum Hydrocarbons	70						
Total PAH	50						

Notes: All concentrations in mg/kg unless otherwise stated
Depths are relative to final ground levels

5	6	7	8	9		63	64	100	101
2.11	-0.91 to -1.31	-0.55	-1.45 to -2.45	-2.45 to -3.45		-2.05	-2.75 to -3.05	+0.65	-0.35

104	105	106	107	108	
+0.38	-0.62	-1.62	+0.06	-1.19	
25.9	28.7		24.3	3.2	
			625		
	367				
4.3					

Table 7.2a Validation Tests for Excavation Base (formation sample

Determinand	Acceptable Level	Sample Location	54	55	56
		Depth (m bgl)	-2.03	-0.4	-2.29
Arsenic	40				
Cadmium	3		3.4		
Chromium	600				
Copper	130				
Nickel	70				
Lead	500				
Mercury	1				
Selenium	3				
Zinc	300				
Water Soluble Boron	3				
pH (units)	>5				
Total Sulphate	2000				
Total Phenols	5				
Total Cyanide	25				
Sulphide	250				
Total Petroleum Hydrocarbons	70				
Total PAH	50				

Notes: All concentrations in mg/kg unless otherwise stated
Depths are relative to final ground levels

Table 7.2b Validation Tests for Excavation Base (formation sample

Determinand	Acceptable Level	Sample Location	102	103	112
		Depth (m bgl)	-2.61	-2.48	-1.25
Arsenic	40				
Cadmium	3		6		
Chromium	600				
Copper	130				
Nickel	70				
Lead	500				
Mercury	1				
Selenium	3				
Zinc	300				
Water Soluble Boron	3				
pH (units)	>5				
Total Sulphate	2000				
Total Phenols	5				
Total Cyanide	25				
Sulphide	250				
Total Petroleum Hydrocarbons	70				
Total PAH	50				

Notes: All concentrations in mg/kg unless otherwise stated
Depths are relative to final ground levels

s)

57	58	59	60	61	94	95	96	98	99
1.37	-1.21	-1.4	-1.54	-3.67	-1.98	-1.65	-2.35	-1.79	-2.68
					41.8				
3.6		3.7	3.9	3.4					
	84								
				6500	3300		4500		2700

)

13	115	116	117	118	119	123	129	130
34	-2.38	-2.79	-1.9	-1.93	-1.9	-1.23	no data	no data
	45.4							
								3.4
					134			
	614				394			
	5000	5600	6200	5500	8400			2300

205

7.17. Whilst STM were satisfied that these errors did not affect the validity of the bulk of the works undertaken and witnessed, Wokingham District Council had reservations regarding the accuracy of the recorded results due to the errors noted above especially the presence of high level of cadmium in one of the samples. To address this concern further samples were taken from the relevant area of the site on the 2nd February 1999 by an environmental scientist from STM. Trial pits were dug using a back hoe excavator and soil samples obtained were sent to Environmental Analysis Ltd and tested for their cadmium content. These results are presented in Table 7.3. Laboratory certificates of analysis have been included in Appendix 7. Sample locations are included in Figure 7.1.

Table 7.3 Additional Validation Testing

Sample Location	Sample Depth	Sample Description	Cadmium (mg/kg)
SGTP1	0.6	Clay Fill	2.4
SGTP2	0.5	Clay Fill	1.2
	0.8	Clay Fill (to 1m)	2.0
	1.2	London Clay	2.2
	2.0	London Clay	2.8
SGTP3	0.5	Clay Fill (to 0.8m)	**9.6**
	1.0	London Clay	2.1
	1.75	London Clay	1.9
	2.25	London Clay	**3.7**
SGTP4	0.5	Clay Fill (to 0.75m)	2.0
	1.0	London Clay	2.2
	1.1	London Clay	2.4
	2.1	London Clay	2.9

Values in bold exceeded the Clean up target of 3mg/kg

Validation Testing of Fill Materials

7.18. Fill materials were tested at source and approved for use against the specification in the method statement prior to importing to the site. Source testing results are included in Appendix 8. Additionally source materials were tested at intervals to provide quality control over the materials being deposited at the site. Samples were tested by obtaining single point samples of the material which was accepted by STM as suitable.

7.19. 450m^3 of concrete sourced on site was crushed and reused as fill material. Validation tests on this material were carried out by STATS. The results which are included in Appendix 7 have been abstracted and also shown along with other fill validation tests in Appendix 8.

Laboratories Used

7.20. All the laboratories used have UKAS (NAMAS) accreditation and were accepted by STM as suitable laboratories.

206

Table 7.2a Validation Tests for Excavation Base (formation samples)

Determinand	Acceptable Level	Sample Location	54	55	56	57
		Depth (m bgl)	-2.03	-0.4	-2.29	-1.37
Arsenic	40					
Cadmium	3		3.4			
Chromium	600					3.6
Copper	130					
Nickel	70					
Lead	500					
Mercury	1					
Selenium	3					
Zinc	300					
Water Soluble Boron	3					
pH (units)	>5					
Total Sulphate	2000					
Total Phenols	5					
Total Cyanide	25					
Sulphide	250					
Total Petroleum Hydrocarbons	70					
Total PAH	50					

Notes: All concentrations in mg/kg unless otherwise stated
Depths are relative to final ground levels

Table 7.2b Validation Tests for Excavation Base (formation samples)

Determinand	Acceptable Level	Sample Location	102	103	112	113
		Depth (m bgl)	-2.61	-2.48	-1.25	-1.34
Arsenic	40					
Cadmium	3		6			
Chromium	600					
Copper	130					
Nickel	70					
Lead	500					
Mercury	1					
Selenium	3					
Zinc	300					
Water Soluble Boron	3					
pH (units)	>5					
Total Sulphate	2000					
Total Phenols	5					
Total Cyanide	25					
Sulphide	250					
Total Petroleum Hydrocarbons	70					
Total PAH	50					

Notes: All concentrations in mg/kg unless otherwise stated
Depths are relative to final ground levels

58	59	60	61	94	95	96	98	99
-1.21	-1.4	-1.54	-3.67	-1.98	-1.65	-2.35	-1.79	-2.68
				41.8				
	3.7	3.9	3.4					
84								
			6500	3300		4500		2700

115	116	117	118	119	123	129	130
2.38	-2.79	-1.9	-1.93	-1.9	-1.23	no data	no data
45.4							
							3.4
				134			
614				394			
000	5600	6200	5500	8400			2300

8. ASSESSMENT OF FINAL SITE CONDITIONS

General

8.1. Critical factors which determine the final site conditions for a project of this type are:

(i) frequency of chemical contamination validation tests results in comparison to agreed frequencies

(ii) quality of chemical contamination validation test results in comparison to the clean up target values;

8.2. These factors are applicable to the sampling of the excavation base and side walls and the sampling of the incoming fill.

Sampling Frequency of Excavation Base and Side Walls

8.3. The total number of samples taken from the base of the excavation was 25 for a site of this size (1ha) the total number of samples is in line with good practice. This does not include the additional samples obtained by STM.

8.4. The spacing of the sampling within the base of the excavation is not in a strict pattern e.g. regular square grid or "herring bone", and the final form of the sampling location may be best described as a stratified random pattern. Guidance from Department of the Environment (now Department of Transport Environment and the Regions) provides advice on design of sample spacings ("Sampling Strategies for Contaminated Land", CLR Report 4, 1994) which provides useful tools to assess the frequency and spacing of sampling locations when designing a site investigation. However, in practice such designs will be altered due to practical access limitations and also visual assessments of the presence of contaminants made by the environmental scientist attending site. Additionally stratified random methods of selecting sample locations are valid sampling strategies which produce only slightly less accurate estimates of actual levels of contamination present (CLR Report 4). It is the number of sample locations per unit area which has the largest effect on the accuracy and dependability of the results obtained and in this case the sampling frequency was in line with good practice.

8.5. The total number of samples taken from the side walls of the excavation was 41. Many of the samples were taken in sets providing 2 or 3 samples over a range of depths. Again for a site of this size the frequency of side wall sampling is in line with good practice.

Chemical Contamination Testing of Excavation Base and Side Walls

8.6. From a review of the results the range of chemical contaminants tested was in line with best practice and suitable to detect contaminants of interest at the site based on its known industrial history.

8.7. The majority of validation tests demonstrated levels of chemical contamination to be below clean up target values. However, in some cases clean-up target values were exceeded. These are reviewed in detail below.

Arsenic and Sulphate

8.8. Arsenic levels were identified to be slightly elevated from the previous site investigation. This contamination is not typical of the activities carried out at the site. Arsenic levels may be elevated in natural soils and in this instance we conclude that this is the likely reason for the elevated levels observed (this is discussed further in Section 5). Elevated levels of arsenic were observed within samples from the London Clay in the base of the excavation. In only two instances the ICRCL Threshold Trigger Concentration for open spaces (40mg/kg), which was the clean up target adopted, was very slightly exceeded (41.8mg/kg and 45.4mg/kg). In our professional opinion these slight exceedences would not pose a risk to future site users and both values are below the Dutch Intervention Value for soils of 55mg/kg. Further in both instances the samples were obtained from the excavation base and are therefore over 1m beneath the ground level.

8.9. Sulphate levels were also elevated in a total of 11 samples all but 1 of which were obtained from the base of the excavation. Elevated sulphate levels are a known feature of London Clay. Sulphate can be a significant contaminant with respect to its effects on buried concrete structures, in this respect this is a matter for the engineer to consider when specifying concrete protection measures for underground concrete structures. It is not considered that elevated sulphate levels will have any human health implication, the ICRCL Action Trigger Concentration for gardens is 10,000 mg/kg much higher than the levels encountered in this case.

Cadmium - Excavation Base Samples

8.10. In the excavation base samples slight cadmium contamination was detected in 7 out of 25 samples (3.4, 3.6, 3.7, 3.9, 3.4, 6.0 and 3.4 mg/kg). These results were above the clean up target set of 3mg/kg equivalent to the ICRCL Threshold Trigger Concentration for housing with gardens. In all other samples the cadmium concentration was below the ICRCL Threshold Trigger Concentration. Although the clean up target was exceeded in 7 instances the level of exceedence was relatively small. For cadmium there is no ICRCL Action Trigger Concentration set thus it is a matter of risk assessment of to determine whether it is acceptable to allow the contamination to remain in place or whether its removal is indicated. The Dutch soil clean up guidelines contains an Intervention Value for cadmium of 12mg/kg a value derived from a generic risk assessment which does not account for site specific factors. Additionally in this specific case the residual contamination is greater than 1m beneath the ground surface and therefore leaving the residual traces of cadmium contamination is considered to be low risk and its presence would not affect the amenity value of the land.

Cadmium - Excavation Sidewall Samples

8.11. The following residual levels of cadmium were identified in excavation sidewall samples:

(i) northern boundary: 3 samples from 13 (4.2, 8.4, 50.7mg/kg)

(ii) southern boundary: 1 sample from 14 (4mg/kg)

(iii) eastern boundary: none from 14 samples

(iv) western boundary: 9 samples from 10 (211.6, 6.6, 5.2, 6.9, 25.9, 28.7, 24.3, 3.2, 4mg/kg)

8.12. Previous study of the site and surrounding area suggests that the cadmium contamination had arisen off site to the north west and had been transported on to the site by groundwater flow. The groundwater flow direction was identified previously by STATS geotechnical to be north

209

west to south east across the top of the London Clay. The presence of residual contamination identified on the northern boundary, especially in sample 111 (50mg/kg) does not accord with this general flow pattern. It is likely that the residual contamination in this area was due to the presence of a land drain which runs east to west across the northern boundary of the site. Thus contaminated groundwater could have been picked up at the north west corner of the site and transmitted along the northern boundary causing local ground contamination with cadmium in the vicinity of the drain run. During the original site investigation undertaken by STATS a trial pit, TP13, was excavated within 5m of sample 111. In TP 13 cadmium concentrations were 2.3 and 2.2mg/kg at 1.1 and 1.8m respectively i.e there was no evidence of cadmium contamination in this are of the site.

8.13. For the southern and eastern boundaries there was only one instance where marginal residual cadmium contamination was noted and these results will not be discussed further.

8.14. On the western boundary all but one sample showed residual cadmium contamination. These results support the view that cadmium contamination had originated off site to the west. The presence of such levels in the boundary samples is unacceptable in relation to reuse of the site for housing and further works will be required to mitigate the potential for contamination to migrate on to site.

8.15. The site works reviewed in this report relate to activities the decontaminate the internal site area of the former oil depot site and did not address the potential for the surrounding land to recontaminate the site. Contamination beyond the boundaries and present at the boundaries cannot be addressed further in the context of the works undertaken to date. Further works to prevent recontamination of the site will be reported separately by STM when such works have been undertaken. Such works are required before the site can be considered to be appropriate for a housing development.

Cadmium - Site Access from Wokingham Road

8.16. The majority of the land forming the access to the site from Wokingham Road was not included within the site remediation as results from previous site investigations undertaken by STATS Geotechnical had shown that the ground in that area of the site was not contaminated to the extent that specific remediation measures were required.

8.17. The results obtained by STATS were: TP2 0.7mg/kg (0.5m bgl), 1.8mg/kg (1.10m bgl); TP1 4.1mg/kg (0.5m bgl), 4.0mg/kg (2.10m bgl); TP14 (0.8m bgl), 3.1mg/kg (2.2m bgl). The sample locations are shown in Appendix 7 as Figure 15 extracted from the STATS site investigation report.

8.18. Records held by Wokingham District Council for soil samples obtained from adjacent land at the end of Compton Close also show that cadmium levels in soil to be generally low: Sample No. C9A 3.0mg/kg (surface soil), <0.06mg/kg (at samples from 0.3-0.6m, 0.6-1.0m and >1.0m bgl). Records for soil samples from the adjacent land to the west also show that north of this point cadmium levels in soil increase to values similar to those observed on the proposed residential site under discussion in this report.

210

Cadmium - Additional Samples

8.19. Following completion of the site works further soil samples were obtained and tested for cadmium contamination. These samples were obtained for the following reasons:

(i) Some confusion remained around the status of the cadmium results for Samples 111 and 112 where a residual concentration of 50mg/kg cadmium was originally reported for Sample 112 and then after rechecking the paper work this was corrected to be the measurement for Sample 111. As a further check additional sampling was considered appropriate.

(ii) As a high residual cadmium level remained on the northern boundary in Sample 111 further checks were made to determine whether the was any indication of significant contamination of the groundmass in the vicinity.

8.20. The results of the additional tests were given in Table 7.3 earlier. The results clearly show that:

(i) There is no substantial contamination of the groundmass within the area of the site tested;

(ii) The groundmass in the vicinity of Sample location 112 does not show evidence of significant levels of cadmium contamination;

(iii) The groundmass within the site boundary adjacent to sidewall Sample 111 shows no evidence of significant contamination with cadmium;

(iv) The results are concluded to be consistent with the validation testing results provided by STATS and consistent with the intended use of the site for residential housing with gardens.

8.21. Two of the samples from SGTP3 did show cadmium levels slightly in exceedence of clean up target, but both were below the Dutch Intervention of 12mg/kg and hence no further assessment was carried out.

8.22. The high cadmium result reported in sidewall validation Sample 111 has been discussed in section 8.13 above. The additional sampling undertaken supports the view that the result is not consistent with the level of cadmium in the surrounding land and that the groundmass is not significantly contaminated with cadmium. As stated earlier the high result in Sample 111 is likely to be associated with a small amount of residual material associated with the drainage run formerly present along the northern boundary of the site. The available evidence suggests that the volume of material contaminated is small. This evidence is:

(i) The original site investigation by STATS showed no evidence of cadmium contamination in samples obtained within 5m from the location of Sample 111.

(ii) No adjacent validation samples show similar concentrations

(iii) Additional samples obtained by STM from surrounding ground do not show similar levels.

211

8.23. It is understood that the source of cadmium contamination is located to the west of the site and there is evidence that, historically, cadmium contamination has been entering the site in the north west corner. There is no evidence to suggest that the cadmium contamination has migrated to the location of Sample 111 from the north or north west by any other route than the drainage run previously present at this location. The obvious drainage pathway for groundwater on the site is to the south and south east across the surface of the low permeability London Clay. There is no evidence that drainage of groundwater contaminated with cadmium arising off site to the west could have caused the contamination recorded in Sample 111. To have done so would have required ground water to have first migrating north onto the railway site and then changing direction and migrating south into the site. The hydrogeological pathway required would be complex and unlikely.

8.24. Hence it is concluded that the result in Sample 111 is due to a small amount of cadmium contamination remaining after the decontamination works. It is considered that the only likely means that contamination arose at this location is thorough the historic presence of a drainage run which carried drainage water contaminated with cadmium. This drain has been removed. The high cadmium result present in Sample 111 is not reflected in high cadmium results in any other samples adjacent to it which take before or after the decontamination works. This demonstrates that the contamination was never extensive in the first place and is indeed localised and minor following decontamination.

8.25. ICRCL guidance note 59/83 2nd Ed. states the following "For most contaminants, it is very difficult at present to set upper values at which the concentration [of a contaminant] would automatically be considered undesirable or unacceptable. Given the paucity of information about some contaminants and the difficulty of obtaining it for others, it is unlikely that these values could ever be derived experimentally. The assessment of risks and of the need for remedial action must therefore depend on subjective or qualitative criteria."

8.26. Our preceding assessment of risk arising for the presence of the elevated cadmium in Sample 111 is undertaken in such a manner and our conclusion is that the site is suitable for residential housing with gardens.

Copper, Nickel and Zinc

8.27. The following exceedences of the relevant clean up targets were recorded:

(i) Copper	134mg/kg in Sample 119, excavation base sample Clean up target 130mg/kg
(ii) Nickel	84mg/kg in Sample 58, excavation base sample 77mg/kg in Sample 81, sidewall sample, western boundary Clean up target 70mg/kg
(iii) Zinc	614mg/kg in Sample 115, excavation base sample 394mg/kg in Sample 119, excavation base sample 597mg/kg in Sample 78, sidewall sample western boundary 367mg/kg in Sample 105, sidewall sample western boundary Clean up target 300mg/kg

8.28. Copper, nickel and zinc are listed by ICRCL as "contaminants which are phytotoxic but not normally hazards to health".

212

8.29. In this instance there are several minor exceedences of the clean up target set for the excavation base samples (22 base samples showed no residual contamination with copper nickel or zinc). These areas of minor residual contamination have been over filled with greater than 1m of clean infill. Given the depth below ground, the level of residual contamination identified and its infrequency then the risks posed by this material are assessed as low.

8.30. With regard to residual contamination identified in samples from the western boundary of the excavation the comments made for cadmium under paragraphs 5.9 to 5.12 above apply. In that the scope of works was to decontaminate the site area and that further remedial works are required to prevent recontamination of the site.

Lead, pH and Total Cyanide

8.31. One lead exceedence of the clean up target was identified for each of these determinands in samples from the western boundary sidewall. The comment made in the previous paragraph are also applicable in this case.

Total Petroleum Hydrocarbons

8.32. There are 4 instances where the residual level of total petroleum hydrocarbons exceeded the clean up target. These results must viewed within the context of carrying out engineering works to remove the gross hydrocarbon contamination from the site. Comments on the adequacy of the remediation works with respect to the EAs requirements are reported in a letter from Glanville Consultants which is included in Appendix 2.

8.33. In two instances, samples 1 and 3 taken from a thin strip of ground along the eastern boundary, these results were available prior to the commencement of excavation works. Based on these results, it was agreed with STM that this material could remain in place to avoid the need to cut down trees present along the eastern boundary. It was viewed that these levels of hydrocarbons remained in a very limited area of land did not pose a significant environmental risk to future site users. This view is based on comparison of the levels of residual hydrocarbons encountered to the Dutch Intervention Value for mineral oils of 5000mg/kg which is set with respect to environmental protection including protection of human health. In samples 1 and 3 the levels of residual hydrocarbons identified were 157.7 and 76mg/kg respectively well below the Intervention Value.

Sampling Frequency of Imported Fill

8.34. Table 8.1 shows the total number of tests performed on incoming clay and granular fill.

Table 8.1 Testing Rates on Imported Fill

Fill Type	Volume Used (m^3)	No. of Validation Tests Carried Out	Testing Rate / $1000m^3$
Clay fill	6080	9	~1.5
Granular fill	4040	4	~1

8.35. In the method statement the rate of testing specified was 1 test per $1000m^3$. It is evident from the above table that this rate was achieved.

8.36. Additionally in respect of the reused crushed concrete 3 tests were carried out on $450m^3$ of material, well in excess of the testing rate required.

213

Chemical Contamination Testing of Imported Fill

8.37. The source tests for Maple Cross (clay fill), Knowle Hill (clay fill) and Aldermarston (clay fill) and all subsequent tests on imported clay and granular fill showed the material to be acceptable for use against the acceptance levels specified in the method statement.

8.38. The first test performed on the crushed concrete showed that the material (sample ref 120 in Appendix 8) contained an elevated concentration of total petroleum hydrocarbon. The crushed concrete itself could be seen to have surficial hydrocarbon staining in places. Two further samples of concrete were tested and both were found to be acceptable. On this basis the material was reused as fill.

Land Drainage

8.39. As part of the remediation works a land drain along the northern boundary and part way along the eastern boundary was removed. The land drain was in part reinstated with a french drain.

8.40. The final arrangement of the land drains remaining on site were:

(i) Approximately 30m of new built french drain on the northern boundary leading to the north east corner connecting into;

(ii) New built french drain extending approximately half the site width south along the eastern boundary connecting into;

(iii) Original french drain and pipe running south along the remainder of the eastern boundary to the interceptor in the south east corner of the site.

8.41. At the end of the decontamination works the interceptor was not inspected or sampled. It is recommended that these actions are included within the next stage of works.

214

9. CONCLUSIONS

9.1. The decontamination works carried out have been reviewed by Symonds Travers Morgan acting as an independent consultant. This has included review of:

(i) Site investigations

(ii) Remediation proposals

(iii) Project method statements

(iv) Environmental monitoring

(v) Decontamination validation testing.

9.2. This document provides a summary of the remediation works undertaken and in our view provides a representative account of those works and final site conditions.

9.3. In general we consider that the decontamination works have undertaken to high standard. There have been a few instances where there have been errors made in recording of soil testing results although we are satisfied that the soil testing results supplied generally reflect the actual conditions at the site. Further some details of the discharges made to foul sewer were not adequately recorded however this does not have any implications for the final site conditions achieved.

9.4. The validation testing results show that the clean up targets were achieved except in a few cases. Most significantly contamination with cadmium, nickel, lead, zinc, low pH and total cyanide in samples from the side wall along the western boundary.

9.5. In our opinion no significant sources of contamination remained within the site. However, residual contamination along the western boundary was significant and is indicative of contamination present on adjacent land which has the potential to migrate and recontaminate the site.

9.6. With regard to chemical contamination, to the best of our knowledge and belief the site is suitable for residential housing except in respect of the potential for the site to be recontaminated.

9.7. Separate remediation measures to prevent recontamination of the site from off site sources will be required to be implemented before the site is suitable for residential housing. It is also required that the drainage interceptor is inspected and sampled as part of any further works undertaken on site.

215