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SMITH GRANT
Environmental Consultancy
LLP

Partnership No: OC 300776

FORMER BRYMBO STEELWORKS

THE WONDER BANK

CONTAMINATION CERTIFICATION REPORT

For: Brymbo Developments Limited

May 2007

R754-R07/Final

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1. Introduction

1.1. Brief

1.1.1. Smith Grant LLP (SGP) was appointed by Brymbo Developments Ltd (BDL) as Environmental Consultant to advise on the environmental aspects of the reclamation and redevelopment of the former Brymbo Steelworks, Brymbo, Wrexham (NGR: SJ297528).

1.1.2. The former steelworks site has been divided into a number of discrete reclamation and development modules. This following report forms the Contamination Certification Report specifically for the Wonder Bank module. The module incorporates both a former licenced waste tip area formed by excavating long trenches within the plateau area of the Wonder Bank itself, along with an adjacent area of naturally regenerated woodland referred to as the Wonder Bank Remainder.

1.2. Background

1.2.1. Brymbo Steelworks closed in 1990 after some 200 years of iron and steel production. Following closure much of the structure and plant were cleared and the site remained largely derelict. The site was subsequently acquired from United Engineering Steels Ltd. (UES) by Brymbo Developments Limited (BDL), specifically to undertake the reclamation and redevelopment of the site.

1.2.2. Details of the original reclamation scheme were submitted to Wrexham County Borough Council (WCBC) in December 1995 with Planning Approval being granted in November 1997 (ref: CB00016).

1.2.3. The original planning approved scheme covered an approximate area of 95 ha and included the coal recovery of approximately 200,000 tonnes by opencast working. This scheme was not implemented as originally envisaged.

1.2.4. Following discussions between BDL and WCBC to find a scheme to ensure the redevelopment and regeneration of the site, a revised scheme was drawn up based largely on the original planning permission. The revised scheme resulted in:

- Approximately 20 ha of the original 95 ha of BDL ownership to be redeveloped and remain in the ownership of BDL. The extent of the opencast working and coal recovery was to be reduced to about 90,000 tonnes;

- The remaining land areas, largely unreclaimed or undevelopable, to be transferred into the ownership of WCBC who would be responsible for the redevelopment and regeneration works on these areas, supported by a Land Reclamation Grant (LRG) from the Welsh Development Agency (WDA).

1.2.5. It was subsequently agreed, in July 2004, that BDL would act as contractor for the LRG reclamation works with WCBC as managing agent on behalf of the WDA.

1.2.6. Reclamation works commenced on the main site in October 2003 following earlier demolition activities by WCBC in a number of areas. The overall reclamation scheme has evolved since the preparation of the revised scheme in 2001 in on-going consultation with all the relevant bodies (WCBC, Local Liaison Committee, Environment Agency Wales (EAW), Welsh Development Agency (WDA) etc).

1.2.7. The site has been divided into a number of distinct development areas, depending on the nature of the proposed redevelopment:

- Wonder Bank – partial informal open space
- Heritage Module – tourism / leisure
- Central, Southern, Western, Northern (2) Development Modules - housing
- Central Development Northern Module (CDNM) - school
- Spine Road - infrastructure
- Northern (1) and Longer Term Development Modules – industrial / commercial
- North Western Development Module (NWDM) – learning, information and resource centre

1.2.8. The overall reclamation strategy across the main site principally involves the:

- Excavation and replacement of steelworks wastes to permit the classification and stabilisation of these materials;
- Regrading of natural soils and made ground to form development plateaux and landscaped batters;
- Stabilisation of the underlying ground affected by historical mining;
- Segregation and controlled storage of unsuitable materials away from future development zones; and,
- Provision of uncontaminated and physically suitable capping materials on development and landscaped areas.

1.2.9. The strategy also provided for the stabilisation of the slopes and capping of the Wonder Bank. Under the terms of Condition No. 32 of the overall planning permission a scheme relating to the capping and remodelling of the Wonder Bank was submitted to WCBC by BDL and subsequently approved. It is currently proposed to prevent public access to the Wonder Bank area itself for the immediate future with the adjoining area, the Wonder Bank Remainder, providing informal public open space.

1.2.10. A Contamination Certification Report is to be provided for each individual development zone on completion of the reclamation activities. The following report deals specifically with all of the Wonder Bank modules. Reclamation activities commenced in this area in May 2005 and earthworks and regrading of the slopes were substantially completed by February 2006.

1.3. Roles and Responsibilities

1.3.1. Reclamation and redevelopment works have been undertaken by BDL. SGP has been retained as Environmental Consultant by BDL since 1995 and information provided by SGP has been extensively used in the design of the reclamation strategy for the overall site, both in relation to potential environmental impacts during the works and on completion.

1.3.2. The role of SGP during the reclamation of Brymbo Steelworks has included the:

- Identification of the nature and extent of contamination across the site;

- Provision of advice on appropriate reclamation and remediation measures across the site;
- Routine dust and controlled waters monitoring;
- Placement of full-time chemist on site to observe activities and collect samples as required and in accordance with environmental monitoring plans and agreements;
- Liaison and correspondence with the relevant regulatory authorities as necessary;
- Additional sampling, analysis and monitoring as required across the site;
- Production of Contamination Certification Reports for the individual reclamation modules for provision to the relevant parties.

1.3.3. Scott Wilson Limited (SWL) have been retained by BDL to advise on geotechnical issues such as compaction operations, slag expansivity, ground stability, locations and capping of coal shafts etc.

1.3.4. The Planning Authority and Environmental Health Authority (responsible for contaminated land regulation) is Wrexham County Borough Council. The EAW is responsible for waste regulation and environmental protection, particularly with respect to controlled waters.

1.4. Site Location and Boundaries

1.4.1. The former steelworks site is located at Brymbo, 4.5 km to the west of Wrexham. The main site occupies an elevated position on the west side of a north-south valley extending between The Lodge and Brymbo. The works were mostly constructed on a plateau formed from tipped slag and quarry overburden which projects out from the original valley side at a height of about 195 m AOD.

1.4.2. The main site occupies an area between the village of Brymbo to the north, the valley and villages of The Lodge and Broughton to the east, the village of Tanyfron to the south and Ty Cerryg, a former opencast coal site, to the west. The site boundaries are formed by Brake Road, Blast Road, Gwalia Road and Mount Hill to the north; New Road, and Kent Road to the east; and Brymbo Link Road and Tanyfron to the south and west.

1.4.3. The Wonder Bank Module is located in the northwestern area of the former steelworks site as shown on Drawing D001. The Wonder Bank Module

forms a roughly triangular shaped former colliery spoil tip that projects eastwards from the flank of the hillside and is effectively comprised of two separate areas: the Wonder Bank itself and the Wonder Bank Remainder. The layout of the site pre-reclamation is shown in Drawing D02 and post-reclamation Drawing D10. The main Wonder Bank itself comprises a former licenced tip area (enclosed within a security fence) along with the eastern and southeastern slopes outside the security fence. The adjoining land to the west is referred to as the Wonder Bank Remainder. This following report considers both areas of land.

1.4.4. The area is bound by open farmland to the immediate west (area known as The Stryt); Penrhos electricity sub-station to the immediate south; the Ty-Cerryg former opencast site to the southeast; the Western Slopes and Heritage Area to the northwest and residential properties on Brake Road to the north. The southern end of the Wonder Bank narrows to form a ridge running southwards and around to the west of the sub-station. A public footpath runs across the site within the Wonder Bank Remainder. Two other public footpaths run along the toe of the eastern slopes, bordering the Module. The Wonder Bank Module comprises an area of about 6.1ha.

2. Sources of Information

2.1. Document List

2.1.1. A large number of documents relevant to the environmental status and overall reclamation scheme of the main site have been produced by several parties since the closure of the works. A list of the key documents considered most relevant to this report is provided in Appendix C.

2.1.2. The Wonder Bank itself has been subject to a number of intrusive investigations and previous reports, prepared principally by Northern Consultants Ltd (NECL), SGP and WCBC. These have been referred to to provide background information on the site history and conditions prior to the onset of remediation works.

Table 1: Summary of Previous Investigations

Date	Title		Description
	Hydrotechnica Ltd	[no details available]	Installation of 4 groundwater monitoring boreholes (3 downgradient / east of tip; 1 upgradient / west of tip)
1991	Northern Environmental Consultants Ltd (NECL)	Contaminated Land, Investigation of the Duck Pond and Wonder Bank Areas of Brymbo Steelworks, Wrexham, Clwyd	Excavation of 19 trial pits to maximum depth of 5m bgl (BM9-BM28); collection and analysis of 75 soil samples
1995	Smith Grant Partnership (SGP)	Brymbo Steelworks Site Contamination Assessment; Ref:R31-R02 (Volumes 1 and 2)	Excavation of 5 boreholes to maximum of 20m bgl (WBB1 – WBB5); collection and analysis of 20 soil samples including 10 samples for leachate testing.
2003	Wrexham County Borough Council	Site Investigation Works on Wonder Bank and Site of the Former Coke Ovens: Laboratory Analysis of Soil / Water Samples [contains drillers logs and analytical results; summary report / risk assessment not produced]	Excavation of 3 boreholes to maximum depth of 17m bgl (WBBH1 – WBBH3); groundwater and gas monitoring wells; collection and analysis of 25 soil samples; 9 rounds of gas monitoring

Date	Title		Description
2005	Smith Grant Partnership	[not previously reported]	Excavation of 7 trial pits to maximum depths of 1m bgl (TP121005WB1 – TP121005WB7) in areas external to the security fenced area; collection and analysis of 7 soil samples

2.1.3. A scheme detailing the proposed capping and remodelling of the Wonder Bank was provided by BDL to WCBC and subsequently approved (written confirmation dated 7 January 2005). Additional documents and correspondence prepared by SGP in relation to the reclamation and subsequent monitoring of the Wonder Bank include:

- Wonder Bank Gas Monitoring Plan, ref: R754-N14, December 2004
- Subsequent correspondence with WCBC regarding gas monitoring results

2.1.4. Copies of these and other key correspondence with the Regulatory Authorities are provided in Appendix H.

3. Environmental Setting

3.1. Topography

3.1.1. The Wonder Bank comprises a former colliery spoil tip projecting eastwards from the hillside. The top of the bank is essentially a plateau located at 258m AOD, the central area of which is provided with a security fence and which was the former licenced waste disposal area. The hillsides drop steeply down to about 234-236m AOD to the north, east and southeast, the northern slopes being heavily vegetated with mature trees. As part of the reclamation the eastern slopes have been re-buttressed and an access ramp constructed up the eastern corner of the slopes from the main reclamation site.

3.1.2. The Wonder Bank Remainder is generally level (part of the tip plateau pre-tipping), apart from the peripheral slopes, and is covered with scrubland and mature trees. There are a number of heavily vegetated raised mounds across the area which may be residual construction and demolition waste.

3.2. Geology

3.2.1. The main site overlies Middle Coal Measures strata (Bettisfield Formation) predominantly of mudstones, with sequences of thin siltstones and sandstones, coal seams and seat earths. The coal seams and iron-rich sandstones have been extensively worked in the area. The strata have a generally uniform dip to the eastsoutheast of between 1v : 6h and 1v : 8h.

3.2.2. The Brymbo Fault is mapped as running roughly NNW-SSE across the centre of the main site, lying at least 250m to the east of the Wonder Bank. The fault was seen in the opencast workings as a narrow well-defined break, and throws down the strata by about 140m to the west. On the west side of the fault the Cefn Sandstone outcrops whilst to the east are the typical sequences of Coal Measures strata. Geological mapping shows that the Wonder Bank overlies Coal Measures sandstone under its western side, and Bettisfield Formation under its eastern side.

3.2.3. Drift deposits of Boulder Clay may have originally overlain parts of the site, however, it is now generally thin or absent from the slopes. The majority of the main site is underlain by variable depths of fill material created by the deposits of colliery waste and slag to facilitate the expansion of the works over the years. The stratigraphy of the Wonder Bank is described in detail

later, however, it generally comprises at least 20m of tipped colliery spoil.

3.3. Hydrology

3.3.1. There are no natural surface watercourses within 100m of the site. The area of the main site potentially falls into the catchment of two tributary systems: to the north is the Afon Cegidog (~1.0 km from the Wonder Bank) that joins the Afon Alun at Cefn y Bedd and to the south is the Afon Gwenfro (~1.6 km from the Wonder Bank) that joins the Afon Clywedog in Wrexham. The Gwenfro is fed by the Lodge Stream, which runs down the valley along the eastern boundary of the main site. The stream forms the closest surface watercourse to the Wonder Bank, lying about 850m to the southeast.

3.3.2. The Gwenfro and Cegidog are classed by the EAW as having GQA levels of B (good) and A (very good) respectively. The Lodge Stream is unclassified under the GQA scheme.

3.3.3. Drainage on the main site is via direct run-off from the slopes, through man made drains and channels constructed during previous uses of the site or by infiltrating the ground and moving through a saturated zone beneath the site. Prior to reclamation it is considered likely that the majority of drainage on the Wonder Bank Module moved via infiltration. Drainage on the undisturbed areas is still predominantly via infiltration. However, the presence of the recently placed compacted mudstones over the enclosure area of the former tip has now resulted in low permeability and surface run-off to the perimeter drainage, and thence to the newt ponds located in the Heritage Module at the north-eastern base of the Wonder Bank, or to the west during periods of heavy rainfall; further details on current drainage are provided in Section 8.

3.4. Hydrogeology

3.4.1. The area of the former steelworks is underlain by a minor aquifer (the Coal Measures) of variable permeability as shown on the Environment Agency Groundwater Vulnerability Map (Sheet 16, West Cheshire). This geological formation can contain locally significant quantities of groundwater which may provide baseflow to local rivers. Groundwater within the overall reclamation site has been found within perched water tables in the fractured sandstone strata and old workings and in hollows above superficial boulder clay.

3.4.2. Generally the original fill on the reclamation site is highly permeable and

rapidly transmits precipitation water downwards to the base. Seepages have been noted at the base of the slag slopes above the Lodge prior to the reclamation works in this area.

3.4.3. Groundwater is likely to be present at substantial depth within the bedrock below the Wonder Bank. The area has been extensively mined in the past and the historic underground workings are likely to form a large interconnected system or 'pool' with multiple voids of varying sizes linked to each other and the surface environment, possibly at significant distance from the site itself. Drainage pathways are unknown but could be to the north via old mine workings and mine drainage discharges to the Afon Cegidog in the Ffrith valley, to the east via old mineworkings to mine discharges to the Afon Alun near Cefn-y-Bedd, to the east down gradient through sandstone units to the natural springs in the Lodge area feeding the Lodge stream or to the south via the Tan-y-Fron Adit and discharging to the Afon Gwenfro.

3.4.4. The height of groundwater across the site generally decreases from an average of 203m AOD on the west side of the Brymbo Fault to 148m AOD on the east side of the fault.

3.4.5. A number of boreholes have been installed across the main site over time which have permitted the measurement of groundwater depth. The closest to the Wonder Bank were boreholes HT1 and HT2 located at the base of the eastern / northeastern slopes. Measurements over a number of years have shown that the groundwater in these locations was at an average depth of 230m AOD and 231m AOD (3.54 – 4.84m bgl). The shallow nature of the groundwater encountered indicates this represents perched groundwater within the residual glacial deposits in this area.

3.4.6. The Supply Borehole (located 80m to the northeast) has a resting water table at an average depth of 69m bgl within the Coal Measures strata. Boreholes 318 and 401 (also referred to as 318a), located within the former Ty Cerryg opencast site and 310m to the southeast both have average water depths of 203m AOD (36m bgl).

3.4.7. The groundwater in the area is not currently abstracted locally and the site does not lie within a Source Protection Zone.

3.5. Mining

3.5.1. Information provided by BDL based on several earlier investigations of the geology and mining history of the steelworks site and detailed in the Regeneration Strategy in 1995 (Drawing BY7, Geology) indicated the presence of three possible mine shafts within the site relating to the former Wonder Pit (refs: 2B/117, 18 and 19). Shaft 18 is shown to be in the northwest corner of the enclosed area. Shafts 2B/117 and 19 are shown in the northwest and western areas of the Wonder Bank Remainder area (see Drawing D002). All three shafts are marked on the historical maps as disused by 1899; shaft 18 is not marked by 1912, the area being covered by railway lines. Shaft 19 is not marked by 1967. There is no other information available regarding the shafts and they are not believed to have been capped or treated. However, shaft 18, located within the enclosure area, is shown to have been overtipped by 1912, before the use of the area for the disposal of blast furnace sludges.

but infilled with colliery shale?

3.6. Neighbouring Development

3.6.1. The Wonder Bank is located in the northwestern corner of the former steelworks site. To the immediate west lies open farmland. A row of cottages (Mount Pleasant Cottages) are located to the immediate west of the site across Brymbo Road. The cottages lie at closest 40m from the module boundary and 170m from the security fence. The former Ty Cerryg opencast coal site, which now comprises agricultural grazing land having been back filled and landscaped in the 1970s, lies to the immediate southeast of the site. Penrhos Electricity Sub-station lies to the immediate south, partially enclosed by the southern ridge of the site. A second row of cottages on Brake Road lie within 10m of the base of the northern slopes and 54m from the security fence, beyond which lies the residential development of Brymbo.

3.6.2. The northeastern slopes drop down to an area formally referred to as the 'Duck Pond', now located within the Heritage Module. Further northeast the ground drops again to a series of former railway sidings also within the Heritage Module.

3.6.3. Offa's Dyke, a Scheduled Ancient Monument, runs north to south across the eastern end of the Wonder Bank, a remnant being present in the southeast corner. The Dyke has been damaged by the construction of the colliery spoil mound. The Dyke continues northwards across the 'Duck Pond' and

Heritage Area and southwards across the western area of the former Ty Cerryg open cast site (see Drawing D06).

4. Site History and Development

4.1. Brymbo Steelworks

4.1.1. Information regarding the historical development of the site has been generated from a number of sources during the course of the development of the reclamation scheme including historical County Series and Ordnance Survey maps, discussions with former employees and a review of undated former works plans. Historical maps showing the development of the Wonder Bank are provided in the Appendices.

4.1.2. Industry commenced at the main site in the late 18th Century with the establishment of an ironworks, and coal and ironstone mines. Progressive development of the ironworks and expansion into steel production over a period of about 200 years resulted in the present overall size of the site. Growth tended to be in an eastwards and southwards direction from the original works which was centred upon the blast furnaces and colliery (now within the Heritage Module).

4.1.3. Principal buildings and development across the site associated with the operation of an iron and steelworks included blast furnaces, mineral railways and sidings, colliery buildings, billet mill, opencast coal workings, coke ovens and by products plants (although smaller than associated with modern steelworks sites), water treatment plants, machine shops, waste tips etc.

4.1.4. The smelting of iron and refining of steel produced large volumes of slag wastes, much of which could not be re-used and had to be tipped alongside the sites of production. Other wastes were produced in substantial volumes and these included ash from coal fired boilers and reheating furnaces, retort bricks, moulding sands, flue dusts and soot and general works wastes. These were interspersed within the slags in the waste tips. After 1974 when waste tips required licensing disposal took place in two locations: the Works Tip and the Wonder Bank.

4.1.5. Production on site ceased in 1990 and the full plant was decommissioned by December 1990.

4.2. Wonder Bank

4.2.1. The earliest available historical maps show that in 1873 (Drawing D003) the Wonder Bank was occupied by the Wonder Pit with associated colliery spoil tips, two associated coal and iron shafts and a mineral railway line running southwards into the site. The Wonder Pit mine is understood to have ceased operation in the 1940s following the establishment of the Blast Pit to the east. An old shaft is also marked in the northwestern corner with associated tipping. An area of shafts and tipping slightly further westwards was identified as Mount Pleasant. A second mineral railway line ran east-westwards across the northern edge of the site linking Mount Pleasant Colliery and Brymbo Iron and Steelworks to the east. By 1899 (Drawing D004) expansion of the Wonder Tip has occurred with the site accessed via mineral railways lines from the south rather than north and west.

4.2.2. During the 1900s (Drawing D005) tipping at the Wonder Pit is shown to extend further northwards in spurs. The shafts are marked as 'old'. By 1967 (Drawing D006) the site is shown to occupy a similar topography to that currently; all railway lines have been removed and an overhead electricity line runs NNW-SSE across the site to the electricity sub-station to the south. The 1984 map (Drawing D007) shows the central security fence in place along with an access track running into the site from the northwest entrance off the junction of Brymbo Road and Brake Road.

4.2.3. It is reported that from the early 1900s the steelworks used the Wonder Pit for the disposal of coal waste products, namely coal slurry/washings. This material is understood to have been tipped in the mid to north areas with tipping in the west area also occurring after 1912. Between 1960 and 1980, blast furnace sludges were disposed of into several sludge lagoons or trenches which were excavated in the southern part of the (subsequently) fenced enclosure on top of the tip. Two further lagoons were also sited at the northern end and northeastern margins of the enclosure. The trenches were approximately 46m long, 3.6m wide and 2.7m deep. Sludge waters were allowed to drain into the underlying spoil mass and in 1980, after cessation of tipping, the sludge dried out and the trenches were covered over with colliery spoil. With the introduction of the Control of Pollution Act 1974, a Waste Disposal Licence was obtained permitting the disposal of the thickened gas washing slurry into the trenches. The slurry was formed by mixing furnace fume dusts with waste lubricating oil to produce a sludge which typically

comprised 35% oil, 12% quicklime, 8% iron oxide, 1% zinc and 0.3% lead. The Waste Disposal Licence was returned in 1990 to the issuing authority (Wrexham Maelor Borough Council).

4.2.4. Burning of tip materials was also reported to have occurred historically which was either brought under control or burnt itself out.

4.3. Surrounding Land

4.3.1. As noted above the Wonder Bank is located in the northwestern corner of the former steelworks. Principal historical areas within the steelworks in proximity to the Wonder Bank include:

- Heritage Area – former railway sidings including an area formally known as the 'Duck Pond' at the base of the northeastern slopes; to form informal public open space;
- WDM – former railway sidings and Slag Reduction Company; now reclaimed and being developed to residential use; 380m to the southeast;
- NWDM – former coke ovens and by-products plant; remediation works complete and being redeveloped to a learning, information and resources centre; 240m to the northeast;
- Eastern Slopes – predominantly slag waste; to be regraded and stabilised for informal public open space; 650m to the east.

4.3.2. Ty Cerryg, a former opencast site, lies immediately to the southeast. The area was infilled and returned to agricultural use in the 1970s.

4.3.3. Penrhos Electricity Sub-station, to the immediate south, was constructed sometime between 1938 and 1963, originally built to supply the former steelworks. Other developments in the general surrounding area include Mount Pleasant Colliery about 100m to the northwest.

4.4. Contaminative uses

4.4.1. The Wonder Bank largely comprises colliery spoil, particularly burnt shales, derived from the Wonder Pit and Blast Pit. Later tipping within a fenced plateau area included coal slurry and washings, and between 1960 – 1980 included blast furnace slurries comprising fume dusts and lubricating oils. The tipping activities will have given rise to elevated metals, sulphates etc typically associated with coal mining wastes along with lubricating oils and other steelworks waste such as metals, arsenic and sulphates.

5. Previous Site Investigation Findings

5.1. Description

5.1.1. A number of intrusive investigations have been undertaken on, or included, the Wonder Bank as listed in Section 2. These reports have been referred to to provide background information on the original status of the site prior to the remediation works.

5.1.2. The boreholes installed by SGP (1995) and WCBC (2003) were concentrated within the area historically subject to the steelworks waste disposal, within the security fenced area. Trial pits BM18-BM20 and BM22-28 excavated by NECL (1991) were similarly within the security fenced area. Trial pits BM17 and BM21 were excavated within the Wonder Bank but beyond the security fenced area to the south and east respectively.

5.1.3. Trial pits BM9 - BM16 were excavated within the area now referred to as the Wonder Bank Remainder located to the west and south of the fenced area. Additional background information on the undisturbed areas of the Wonder Bank Remainder and areas to the south of the enclosure was obtained through a series of additional trial pits excavated by SGP in 2005 (121005WB1 – 121005WB7).

5.1.4. The locations of all the trial pits and boreholes are shown on Drawing D008. Copies of all the borehole and trial pit logs relevant to the Wonder Bank are provided in Appendix D.

5.2. Physical

Wonder Bank

5.2.1. The intrusive investigations identified the Wonder Bank area to consist of up to a maximum of 17.50m depth of made ground typically comprising colliery shale, ash, foundry slag and bricks. The ground was typically loose becoming compact at depth. Natural ground was not encountered at the surface in any locations across the area.

5.2.2. The pre-reclamation ground in the vegetated areas within the enclosure (BM18, 22, 10 and 26) typically comprised an upper layer of shale, slag and ash further underlain by carbonaceous shales, baked shales, coal, slag, cinders, coke and ash.

5.2.3. The upper ground surface in the areas lacking or poor in vegetation within

the enclosure comprised loose to compact slag, shale and cinder gravel with ash, silt, brick, scrap metal and occasional wood and polythene. A crushed steel drum was reported in BM24. These materials were underlain by a variable made ground comprising carbonaceous/carboniferous shales and burnt shales, ash, coke, slag and bands of very fine coal/shale.

5.2.4. Visible oil contamination was noted in a number of locations, namely in BM21, BM22 and BM23 between near surface and 5m bgl. A black sludge was recorded in WBBH2 from 3.50m to 5.00m bgl and WBBH3 from 0.5m to 1.80m bgl. An oily odour was also noted in BM24, 25 and 27 within the enclosed area. These observations correspond with the reported excavation of trenches into the colliery spoil to depths of 2.7m below original surface level for the disposal of oil and flue dust sludges.

5.2.5. Natural ground was encountered in three of the boreholes, and possibly in an additional three. The ground comprised a hard red/brown sandstone at depths of 16-17.50 m bgl. A layer of boulder clay overlying the sandstone was reported in one location, WBBH3, in the southwestern area of the enclosure.

5.2.6. The ground conditions encountered in the boreholes excavated in the area are summarised below in Table 1.

Table 2: Summary of Ground Stratigraphy – Wonder Bank

Borehole Reference	Nature of Made Ground	Depth of Made Ground (m bgl)	Natural Strata	Depth of Borehole (m bgl)
WBB1	Loose/compact ashes, bricks and colliery waste with pieces of sandstone	16.40	Sandstone	20.00
WBB2	Ash, bricks, colliery waste	17.50	Possible sandstone	18.50
WBB3	Ash fill underlain by ash and metal slag with colliery waste	16.90	Possible sandstone	18.00
WBB4	Ash and colliery waste	16.00	Sandstone	18.00
WBB5	Ash, colliery waste with occasional slag	16.90	Possible sandstone	18.00
WBBH1	Ash slag with foundry waste and colliery waste	At least 15.00	Not proven	15.00
WBBH2	Ash, slag and foundry waste with black sludge encountered at 3.50-5.50m further underlain by colliery spoil and red shale	At least 9.00	Not proven	9.00

Borehole Reference	Nature of Made Ground	Depth of Made Ground (m bgl)	Natural Strata	Depth of Borehole (m bgl)
WBBH3	Colliery spoil with dry black sludge at 0.20-1.80m	15.60	Stiff boulder clay underlain by sandstone-	17.00

Note:

WBB1 – 5: Boreholes installed on behalf of SGP, 1995

WBBH1 – 3: Boreholes installed on behalf of WCBC, 2003 (WBBH2 grouted back up due to nature of ground encountered)

The WCBC boreholes were initially referred to as WB1-WB3 in the borehole logs but WBBH1-WBBH3 in the analysis schedule

Wonder Bank Remainder

5.2.7. The area external to the enclosure is generally heavily vegetated with shrubs through to mature trees.

5.2.8. The ground generally comprised in the order of 0.5m of loose, silty clayey, shaley 'soil' with occasional slag, bricks and ash. Underlying this upper layer the fill generally became more carbonaceous with depth with coaly shale, bands of baked shale with coal, silt, sand, clay and ash and occasional slag/clinker. Visible oils or other hydrocarbons were not encountered in any of the locations to the west of the enclosure other than a possible oily odour recorded in BM13.

5.3. Groundwater Conditions

5.3.1. All of the trial pits across the site were noted to be dry other than minor seepages reported in BM13, BM15 and BM22 at 0.9m, 2.4m and 1.7m respectively. The boreholes were similarly noted to be dry other than a slow seepage at 0.4m in WBB3 and at 0.5m in WBBH1 .

5.3.2. It is likely these seepages represent local perched surface water infiltrations within the fill materials and are not indicative of a continuous water table across the site.

5.4. Soil Contamination

5.4.1. A comprehensive summary of all the previous chemical analysis is provided in Appendix F.

Wonder Bank

5.4.2. A total of 92 soil samples collected from variable depths from within the Wonder Bank Tip area have been subject to a variety of chemical analysis

during the various investigations. These are summarised below in Table 2 and have been differentiated between near-surface (0.0 – 0.5m bgl) and deeper soils (>0.5m bgl).

5.4.3. Although not directly relevant to the site the results have been initially compared to the CLEA SGVs for 'residential without plant uptake' criteria, where available, to provide information on the level of contamination present. Where SGVs are unavailable comparison has initially been made to the criteria adopted for the residential areas in the main site previously agreed with WCBC to provide initial screening assessment criteria.

Table 3: Summary of Soil Chemical Analysis – Wonder Bank Tip Area

Determinand	Range (no. of samples)		Assessment Criteria	No. of Exceedances (near surface soils / deeper soils)
	Near Surface Soils (0.0 – 0.5 m bgl)	Underlying Soils (>0.5m bgl)		
pH	5.7-9.6 (18)	7.2-11.9 (73)	<3 United Utilities	none / none
Arsenic	<1-67 (18)	<1-115 (74)	20 CLEA SGV	14 / 47
Boron (water soluble)	<1-13 (5)	<0.3-10.0 (41)	3 ICRCL	3 / 12
Cadmium	<1-350 (18)	0.5-258 (74)	30 CLEA SGV	5 / 12
Chromium	43-1,305 (5)	12-2,059 (42)	200 CLEA SGV	3 / 22
Mercury	<1 (5)	<0.1-1.1 (42)	8 CLEA SGV	none / none
Nickel	37-1,256 (18)	15-3,030 (74)	75 CLEA SGV	11 / 38
Lead	109-39,625 (18)	10-41,750 (74)	450 CLEA SGV	14 / 46
Copper	42-1,987 (18)	15-1,575 (74)	130 ICRCL	12 / 42
Zinc	116-131,775 (18)	24-66,250 (74)	300 ICRCL	17 / 59
Total sulphate	490-8,015 (18)	150-31,021 (73)	2,400 BRE SD1	6 / 33
Sulphide	<1-1,473 (18)	<0.5-787 (74)	none	-
Total cyanide	<1-250 (18)	<<1-164.7 (73)	none	-
Free cyanide	<1-14 (7)	- (0)		
Phenols	<0.01-4.8 (18)	<0.01-13.8 (73)	10 United Utilities	none / 1
Toluene extractable matter (%)	0.33-8.40 (13)	0.1-27.6 (50)	none	-
TPH	42,000 (1)	<10-55,000 (10)	4,000 TPHCWG	1 / 7
EPH	82-81,939 (5)	84-772,939 (22)	4,000 TPHCWG	3 / 12
PRO (µg/kg)	<10-232 (3)	<10-39,506 (22)	none	-
Benzene (µg/kg)	<10 (3)	<10-1,071 (22)	none	-

Determinand	Range (no. of samples)		Assessment Criteria	No. of Exceedances (near surface soils / deeper soils)
Toluene (µg/kg)	<10-17 (3)	<10-1,640 (22)	3,000 CLEA SGV	none / none
Ethylbenzene (µg/kg)	<10 (3)	<10-406 (22)	9,000 CEA SGV	none / none
Xylene (µg/kg)	<10-18 (3)	<101,498 (22)	none	-
Total PAH	0.5-106 (4)	<0.126 (31)	none	-
Naphthalene	0.1-3.5 (4)	<0.05-9.87 (22)	9.7 CLEA SSAC	none / 1
Benzo(a)pyrene	0.01-11.8 (4)	<0.1-6.3 (22)	0.9 CLEA SSAC	2 / 7
Total PCB (ug/kg)	<1-8,870 (10)	<1-27,590 (30)	none	-
Asbestos	nfd (3)	fd	fd	none / 1
Calorific Value (kJ/kg)	- (0)	7,528-13,704 (7)	none	-

All concentrations expressed as mg/kg unless stated otherwise

Nfd – no fibres detected; fd – fibres detected

5.4.4. pH of the soils typically ranged from moderately to highly alkaline, with one sample being acidic. The typical range was 7 – 9 with 11no. samples recording a pH >9 and 1no. pH <6. The highly alkaline samples were associated with the slag and oily samples. The single acidic sample was taken from an area outside the enclosure.

5.4.5. The soils are variably contaminated by particularly elevated concentrations of lead, zinc and sulphates and to a lesser extent by arsenic, cadmium, chromium, copper, and nickel. These were present in both the shallow and deeper soils. Mercury and selenium were generally below limits of detection or present at low concentrations. Total cyanide was similarly present at relatively low concentrations.

5.4.6. A small fibrous sample collected by NECL from BM24 at 4.1m bgl was confirmed as containing chyrosotile asbestos. However, asbestos fibres were not detected within any of the 25 samples collected by WCBC. Extensive potential asbestos containing materials were not noted on the site.

5.4.7. The samples have been subject to various hydrocarbon analyses. The initial analysis undertaken by NECL comprised toluene extractable matter (TEM) with subsequent TLC analysis on those samples containing TEM in excess of 0.5% (5,000 mg/kg). Analysis conducted by SGP in 1995 included total petroleum hydrocarbons (TPH) and total PAH whereas that undertaken in

2005 comprised EPH (DRO) and PAHs (16 speciated). Analysis undertaken by WCBC in 2003 included petroleum range organics (PRO), diesel range organics (EPH (DRO)), BTEX (benzene, ethylbenzene, toluene and o/p-xylene) and speciated PAHs.

5.4.8. Oils were encountered in the majority of locations within the enclosure and particularly in WBBH2 where a black oily sludge was encountered at 3.50 – 5.00m bgl. Concentrations were recorded as 77% at 2.5 – 3.0m, 48% at 4.0 – 4.5m and 2.5% at 8.0 – 8.5m. The laboratory descriptions confirm the oils as typically comprising heavy engineering or lubricating oils with occasional lighter mineral oils. Petrol range organics and BTEX were present in WBBH2, up to a maximum of 39.5 mg/kg of PRO and 1.1 mg/kg of benzene, and to a lesser extent in WBBH3. Concentrations of PAHs were relatively low with maxima of 9.9 mg/kg and 11.8 mg/kg of naphthalene and benzo(a)pyrene respectively.

5.4.9. The WCBC 2003 investigation indicated decreasing oil content within the fills at depth. The SGP 1994 investigation however, did detect greater levels of hydrocarbons at depth with 5.5% by weight in WBB% (at 13m) and 0.5% in WBB1 (at 14 – 16.4m). The variations may be due to the differing analytical techniques used. It is noted however that the underlying sandstone in WBB1 was not significantly contaminated.

5.4.10. A total of 25 soil samples were submitted by NECL for PCB analysis which were detected in the range <0.001 – 27.59 mg/kg, the maximum concentrations being detected in BM24. Of the 10 samples submitted by SGP for PCB analysis, PCBs (noted to be Aroclor 1254) were only detected in WBBH5 at 1.2 mg/kg at 5m bgl and 1.5 mg/kg at 13m bgl (limit of detection higher than that for NECL). PCBs were undetected in the analysis undertaken by WCBC. Variations in the results obtained are likely to the influenced by differing analytical techniques. Analysis undertaken on behalf of NECL and SGP was noted as for 'total PCBs' but to varying limits of detection, where as that undertaken by WCBC was for 7 PCB congeners. In addition, it is noted in the NECL report that due to the extent of oil contamination in some of the samples, interferences may have occurred producing 'false positive' results. It is also likely that PCBs may have been retained largely in the upper parts of the tips or have undergone significant attenuation as they migrated downwards.

5.4.11. The results indicate that although occasional concentrations of PCBs may be found in the oil contaminated sludges, PCBs are not widespread in the tip.

5.4.12. The calorific analysis undertaken on several coaliferous / ashy samples indicated a potential combustion hazard in some areas, some results exceeding 10 kJ/kg.

5.4.13. The summary above shows that the contamination with metals and oils was present within both the near surface soils and those present at depth as expected based on the historical information on the site.

Wonder Bank Remainder

5.4.14. A total of 35 soil samples collected from within the Wonder Bank Remainder area have been subject to a variety of chemical analysis. These are summarised below in Table 3 and again have been differentiated between near-surface (0.0 – 0.5m bgl) and deeper soils (>0.5m bgl).

5.4.15. As for the Wonder Bank the results have initially been compared to the CLEA SGVs for 'residential without plant uptake' criteria, where available to provide preliminary screening assessment criteria.

Table 4: Summary of Soil Chemical Analysis – Wonder Bank Remainder

Determinand	Range (no. of samples)		Assessment Criteria	No. of Exceedances (near surface soil / deeper soils)
	Near Surface Soils (0.0 – 0.5m bgl)	Underlying Soils (>0.5m bgl)		
pH	6.2-8.5 (12)	4.6-10.5 (23)	<3 United Utilities	none / none
Arsenic	3-60 (12)	4-66 (21)	20 CLEA SGV	7 / 10
Boron (water soluble)	<1-3 (5)	-(0)	3 ICRCL	1 / -
Cadmium	0.5-3.0 (12)	0.5-4 (21)	30 CLEA SGV	none / none
Chromium	35-1391 (5)	- (0)	5,000 CLEA SSAC	none / -
Hexavalent chromium	<3-4.2 (5)	- (0)	130 CLEA SGV	none / -
Mercury	<1 (5)	- (0)	8 CLEA SGV	none / -
Nickel	3-463 (12)	20-64 (21)	150 CLEA SSAC	2 / 2

Determinand	Range (no. of samples)		Assessment Criteria	No. of Exceedances (near surface soil / deeper soils)
	Near Surface Soils (0.0 – 0.5m bgl)	Underlying Soils (>0.5m bgl)		
Lead	43-502 (12)	40-905 (21)	450 CLEA SGV	2 / 2
Selenium	<3-12 (7)	- (0)	260 CLEA SGV	none / -
Copper	32-242 (12)	42-154 (21)	130 ICRCL	2 / 1
Zinc	44-1,492 (12)	105-1,270 (21)	300 ICRCL	4 /7
Total cyanide	<1-9 (12)	<1-130 (21)	none	- / -
Free cyanide	<1 (5)	<1-12 (3)	none	- / -
Thiocyanate	<1-2 (5)	<1 (1)	none	- / -
Total sulphate	355 – 4,070 (7)	220 – 3,170 (21)	2,400	1 / 3
Acid soluble sulphide	<1 – 80 (12)	<1 – 120 (21)	none	-
Total phenols	<0.01-5.0 (12)	<1-3.2 (21)	10 United Utilities	none / none
TEM (% w/w)	0.02 – 0.26 (7)	<0.02-0.42 (21)	none	-
EPH (DRO)	82-5,846 (5)	- (0)	4,000 TPHCWG	1 / -
Total PAH	0.45-14.7 (5)	-	none	-
Naphthalene	0.1-2.4 (5)	-	9.7 CLEA SSAC	none
Benzo(a)pyrene	0.02-0.86 (5)	-	0.9 CLEA SSAC	none

Notes:

All concentrations are in mg/kg unless stated otherwise

TEM – toluene extractable matter

5.4.16. The soils within the Wonder Bank Remainder were noted to be contaminated principally with arsenic, up to a maximum of 60mg/kg, and to a lesser extent nickel, lead, copper and zinc, both with the near-surface and deeper soils.

5.4.17. Elevated concentrations of cyanides and phenols were not encountered.

5.4.18. Elevated EPH was detected in one location, WB4 at 5,846 mg/kg. The laboratory analysis describes the hydrocarbons as 'lube oil'. Banded breakdown of the hydrocarbon analysis for WB3 and WB4 shows the hydrocarbons to be predominantly in the heavier end (low toxicity) as below:

Table 5: Banded hydrocarbon breakdown for WB3 and WB4

Hydrocarbon Bands	WB3 (mg/kg)	WB4 (mg/kg)
C10 – 12	10	10
>C12 – 16	46	120
>C16 – 21	137	102
>C21 - 40	1,034	5,614
Total C10 - 40	**1,227**	**5,846**

5.4.19. The samples did not however contain any visual evidence of oil contamination and concentrations of the indicator compounds, naphthalene and benzo(a)pyrene, were below the relevant assessment criteria. Concentrations of total PAHs (16 speciated) were low indicating the hydrocarbons to be present predominantly as the low toxicity aliphatics. Concentrations of toluene extractable matter were low and in the range <0.02 – 0.26% (=2,600 mg/kg). The hydrocarbons are therefore possibly of natural origin within the bituminous Coal Measures rocks. PAH source diagnosis indicates the PAHs to be of pyrolitic / coal origin.

5.4.20. The deeper (>0.5m) soils were similarly found to be contaminated by arsenic and zinc with occasional elevated lead and copper. Elevated cadmium and nickel concentrations however were not detected and analysis has not been undertaken for mercury and chromium. pH values of the soils ranged from acidic (4.6 – ash fill with metal and slag; 1.2 – 3.2m bgl) to highly alkaline (10.5 – silty sandy fill; 0.4 – 1.70m bgl). Toluene extractable matter was generally low and in the range of <0.02 – 0.42 % (= 4,200 mg/kg).

5.5. Leachate Analysis

5.5.1. A selection of the samples (10 in total) collected by SGP in 1995 from within the tip plateau (fenced) area were submitted for leachate analysis. Analysis was undertaken for a wide range of metals, total cyanides and phenols and the results are summarised below in Table 4. The results have been compared to the site specific leachate criteria previously agreed with the EAW for a range of contaminants considered to be of most concern at the site following a P20 risk assessment undertaken by SGP.

5.5.2. With respect to other potential contaminants which may have been present, the results were also compared with other relevant guidelines including the UK EQS Standards and the Water Supply (Water Quality) Regulations 2000, commonly referred to as the UK Drinking Water Standards (DWS), although these are not be directly applicable to the site and location.

Table 6: Summary of Leachate Analysis

Determinand	Range (ug/l)	Assessment Criteria	Exceedances
Arsenic	<10	50 EQS	none
Cadmium	<5	400 SGP P20	none
Chromium	<10 – 10	6950 SGP P20	none
Mercury	<1	1 EQS	none
Nickel	<10	200 EQS	none
Lead	<10	2340 SGP P20	none
Zinc	<10	3860 SGP P20	none
Selenium	<10	10 EQS	none
Copper	<10 - 10	112 EQS	none
Sulphide	<50	250 EQS	none
Sulphate (mg/l)	8 – 430	400 EQS	1 (WBB 1/3)
Total cyanide (mg/l)	<0.05 – 0.51	0.05 UK DWS	1 (WBB5/2)
Phenols	<50	30 EQS	none

Notes:

All concentrations in ug/l unless stated otherwise

EQS – Environmental Quality Standard

SGP P20 – Criteria established following P20 risk assessment

UK DWS – UK Drinking Water Standard

5.5.3. None of the samples contained leachable metals / metalloids in exceedance of the assessment criteria and were generally all below the relevant limit of detection. Sulphates were present up to a maximum of 430 mg/l. Elevated total cyanide was detected in one sample which at 0.51 mg/l is in exceedance of the UK Drinking Water Standard and indicates the presence of leachable cyanide. This standard is particularly stringent however as it is established for drinking water and is not necessarily indicative of a significant risk being posed to groundwater.

5.6. Radiation and Temperature

5.6.1. A survey was undertaken in 1995 to determine whether any of the materials within the site were emitting radiation significantly above the background levels for the area. When compared with the regional background variation there was no evidence to suggest that any of the materials present within the site posed significant radiological hazards.

5.6.2. Combustion of the colliery spoil materials have been reported in the past however there has been no evidence of combustion in the last 10 years. Evidence of sub-surface heating was observed by NECL in 1992 during trial pit excavations in TP23, TP24, TP25 and TP27 with fill material becoming warm to touch from about 3m bgl. A white efflorescent speckling was noted in TP25 in the warm fill matrix. Measurements were therefore taken by SGP in 1995 of the strata temperatures from within the boreholes during drilling and during the post-drilling gas survey to provide an indication of possible combustion in the fill materials.

5.6.3. Slightly elevated temperatures, ranging up to 20.2°C (WBB2) were recorded within the boreholes. Given the recorded presence of up to 11.0% carbon dioxide in this area, the known past history of combustion in the tip and previously measured calorific values, it was considered that localised heating may be continuing to take place.

5.7. Dioxins

5.7.1. Two of the soil samples collected from the Wonder Bank in 1995 confirmed the presence of dioxins at significant concentrations at 2.42 and 1.62 ng TEQ/g associated within the wastes within the tip. The dioxins were found to be strongly sorbed onto the organic minerals within the soil and hence not capable of being leached out by rainfall.

5.8. Groundwater Quality

5.8.1. A single groundwater sample was collected from WBBH1 by WCBC in 2003 (all other locations being dry). The sample was alkaline (pH 9.77) and contained elevated chromium with low levels of other metals, PAHs and no detectable PRO / BTEX.

5.8.2. The groundwater encountered was perched within the fill materials at shallow depth and there was no evidence of any seepages from the foot of the slopes around the Wonder Bank. The potential however for the tip to drain via the underlying sandstone and / or coal workings cannot be discounted.

5.8.3. Groundwater within the main site and surrounding area was assessed prior to the on-set of reclamation activities (Summary Review of Baseline Water Quality Prior to Commencement of Works, October 2003, Ref: R175-R13). Groundwater quality has subsequently been reviewed on an annual basis

along with regular monitoring of the nearby surface watercourses and mine adit drainage.

5.8.4. The groundwater within the main site was found to be of generally poor quality, both due to the natural poor quality of groundwater within Coal Measures and arising from the long industrial history of the site. The EAW has agreed that the groundwater beneath and around the site is not considered a sensitive receptor in its own right and is not likely to be used as a supply of potable water in the foreseeable future. The groundwater is considered primarily as a pathway to other sensitive receptors.

5.8.5. The key boreholes located potentially downgradient of the Wonder Bank that may be indicative of migration of hydrocarbon contamination (namely BH318, BH401, Supply Well, HT1 and HT2), both at shallow and deep depths, were sampled and analysed for a range of organic determinands on a number of occasions as part of the site wide assessment prior to the reclamation activities. Analysis has included GRO/BTEX, EPH, VOCs, SVOCs, PAHs (16 speciated) and PCBs.

5.8.6. EPH has occasionally been detected in all the boreholes up to a maximum of 517 ug/l in the Supply Well in October 2004. More specific targeted analysis (PAHs speciated, VOCs, SVOCs and PCBs) however has not detected any determinands in excess of the LOD on any occasion. Results of EPH analysis can be subject to positive influences by the presence of naturally occurring humic acids and an elevated EPH result is not necessarily indicative of hydrocarbon contamination being present. Although an assessment criteria of 10 ug/l of dissolved hydrocarbons in water is often referred to, this is established as a standard for drinking water quality at consumers taps and is overly conservative with respect to groundwater quality, particularly in the absence of any abstraction points. An alternative criteria specified for hydrocarbons of 1,000 ug/l for surface water intended for treatment (A3) for drinking water purposes (EC Water for Human Consumption Directive 80/778/EEC) is considered more appropriate. This criteria has not been exceeded on any occasion. The annual groundwater assessment has not therefore found any evidence of a deep lateral spread of a contamination plume of hydrocarbons from the Wonder Bank.

5.9. Ground Gas

5.9.1. The trial pits and boreholes did not encounter any significant quantities of biodegradable materials other than some local occurrences of wood and cardboard.

5.9.2. Gas concentrations of methane, carbon dioxide and oxygen were recorded by SGP in 1995 in boreholes WBB1-WBB5 on one occasion and by WCBC in 2003/4 within boreholes WBBH1 and WBBH3 on nine occasions. WBBH2 was abandoned and not monitored as it had been drilled into one of the disposal trenches. A detailed summary of the results is provided in Appendix G which is summarised below in Table 5.

Table 7: Summary of Previous Gas Monitoring Results

Determinand	Range (%v/v)
Methane	<0.1
Carbon Dioxide	<0.1 – 11.0
Oxygen	5.4 – 21.0

5.9.3. Methane was not detected in any of the boreholes in excess of the limit of detection of 0.1% v/v.

5.9.4. Elevated carbon dioxide concentrations were recorded in a number of boreholes with corresponding depleted oxygen levels. These indicated the possible presence of biodegradable or combustible material within the tip or may have been due to the underlying Coal Measures and historical mine workings.

6. Environmental Risk Assessment

6.1. Site Conceptual Model

6.1.1. In order to provide a systematic risk assessment to develop an appropriate remediation strategy, a conceptual model of the site was developed. This took into account the likely requirements of the site development, including technical, commercial, practical and sustainability issues.

6.1.2. The conceptual model of the site following development is based on three elements: landuse (which introduces various receptors), fate and transport of contaminants, and contaminant toxicology (DEFRA / EA, CLR report 10).

6.1.3. *Landuse*

Current proposals are for the Wonder Bank Remainder area to form informal public open space. The site is crossed by three public footpaths. Formal landscaping of this area is not proposed, the land being left to natural recolonisation. A public footpath crosses the site from northwest – southeast, the location of which is shown in Drawing D02.

The area of the former licensed tip itself (the area within the security fence) is to remain enclosed with no authorised public access. The eastern slopes of the Wonder Bank will not be enclosed as such but extensive planting, low fencing and the steep banks will minimise public access. Two public footpaths run along the base of these slopes – the locations of which are shown in Drawing D02.

In this respect the key receptors or targets considered to be at risk are the health of future human users of the Wonder Bank Remainder area and public footpaths and those gaining unauthorized access to the Wonder Bank; nearby residential properties; and water resources.

6.1.4. The site setting is not considered particularly sensitive with respect to local groundwater or surface waters due to the old industrial setting, poor natural water quality in the Coal Measures and distance to receptors. However the local aquifer does provide baseflow to surface watercourses, notably the Lodge Stream, and via mine drainage discharges, the Afon Cegidog and Afon Gwenfro. It has been previously agreed with the EAW that due to historical contamination and the effects of mineworking, the aquifer is

primarily considered as a pathway between source zones and surface water receptors, rather than as a sensitive receptor in its own right.

6.1.5. *Contaminant toxicology*

The investigations of the Wonder Bank plateau (fenced) area identified heavy metals and oils as the principal contaminants of concern which were found to be widely dispersed throughout the full depth of the fill material within the tip itself. The tipped materials were found to extend close to the eastern / southern eastern flanks.

A number of metals that may pose a risk to human health via ingestion and / or inhalation, principally arsenic, lead and nickel, were detected in the Wonder Bank Remainder area. Elevated hydrocarbons were encountered in isolated locations, although visual oils were not present and the hydrocarbons were confirmed to be of low toxicity heavy end aliphatics (possibly of natural origin within Bituminous Coal Measures). Copper and zinc were also present within the Wonder Bank Remainder at concentrations that may pose a risk to plant growth up to maximum concentrations of 242 mg/kg and 1,492 mg/kg respectively, although no damage to the extensive vegetation in this area was observed.

Gas monitoring confirmed the absence of any methane generation within the tip. Elevated carbon dioxide and depleted oxygen had been detected, which were considered to be possibly associated with localised heating within the tip. The underlying Coal Measures and historical mine workings may also give rise to elevated levels of ground gases.

6.1.6. *Fate and transport of contaminants*

Leaching tests of the materials confirmed that the metal contamination was relatively immobile. However, in the absence of a capping layer the potential did exist for metals to leach out of the soils into the nearby surface waters and groundwater. Similarly, the absence of a cover may have given rise to potential migration via dust blow. However, the presence of extensive vegetation across the site would minimise the risk of dust blow to only occurring during any earthworks on the site.

Dioxins are highly hydrophobic and resistant to leaching. The dioxins detected within the tip were found to be strongly sorbed onto the organic

minerals within the soil minimising the potential for leaching. The principal route for any migration of dioxins is via physical erosion of the eastern flanks exposing the underlying waste materials and dust blow during any ground disturbance. The emission of dioxins from underground fires is also a consideration.

Heavy oils of the nature present within the tip are similarly relatively immobile and unlikely to give rise to a widespread plume of hydrocarbon contamination. There is no evidence of on-going migration through the spoil or any break-out of liquids through the tip surface or sides. Monitoring of the groundwater and receiving surface watercourses by BDL, and subsequently SGP, have not identified any evidence of significant migration from the tip of volatile or soluble hazardous substances.

Ground gas will always migrate along the path of least resistance, always following routes that ultimately lead to the atmosphere. Thus lateral movements will only predominate over vertical upwards movements where such upwards movements are impeded by overlying impermeable strata or by temporary obstructions such as waterlogged topsoil or snow / frost affected areas. In the absence of an impermeable cover across the tip ground gas migration was therefore most likely to occur direct to surface.

6.2. Human Health / Built Development

Wonder Bank

6.2.1. The conceptual model identified significant hazards in the tipped materials within the enclosure arising primarily from oils and PCBs. Significant human health risks were potentially posed via direct contact or ingestion of exposed or near-surface contaminated soils by any members of the public gaining unauthorized access to the enclosure area. Dust blow was a possibility in any areas of restricted vegetation growth although much of the site was being naturally colonized. Any dioxins / furans present were likely to be strongly sorbed onto carbonaceous and clay minerals and oils in the fill and hence were unlikely to migrate into the surrounding environment and impact human health unless combustion or dust-raising occurred.

6.2.2. The slightly elevated temperatures recorded at depth within the Wonder Bank Tip suggested that localised heating may have been continuing to take place. The recorded temperatures indicated that care was needed during

any works on the tip. Provision of capping would serve to reduce the supply of oxygen into the tip and subsequently inhibit combustion. Provision of a cap would also serve to prevent any direct contact with, and dust generation of, the contaminated surface materials. Given the nature of the materials within the tip and potential combustion hazards, development of the Bank was not proposed.

6.2.3. Although no oil seepages were evident on the eastern flanks of the tip the potential existed for erosion / failure of the pre-reclamation steep slopes resulting in direct exposure to / release of the deposited sludges.

6.2.4. The remediation strategy therefore provided for the provision of an impermeable cap to provide a cover to the contaminated materials; and supporting of the over-steep eastern slopes to improve long term stability.

6.2.5. Aspects relating to the potential risks associated with ground gas were presented in the landfill Gas Monitoring Plan, Ref: R754-N14, dated December 2004. Given the topography and geology, any risks to the residential properties on Brymbo Road and at Mount Pleasant were considered to be low in the tip's undisturbed state. However, capping of the tip may encourage gas accumulation and lateral migration towards these properties, and hence a programme of post-capping gas monitoring was proposed.

Wonder Bank Remainder

6.2.6. Elevated levels of a number of determinands (namely arsenic, nickel and lead) were noted within the near-surface soils that may pose a risk to human health through ingestion, direct contact or inhalation of wind-blown dust.

6.2.7. Although the near-surface soils across the area comprised variable made ground with some shales, ash, slag and rubble, given the overall varied nature it is not possible to identify specific zones. As the entire area is to provide informal open space the area is treated as a single averaging area and mean value tests have therefore been undertaken for arsenic, nickel and lead within the near-surface soil samples. The US95 for arsenic is in exceedance of the SGV at 34 mg/kg (SGV 20 mg/kg) and for nickel marginally in exceedance of the SSAC at 168 mg/kg (SSAC 150 mg/kg). The detected concentrations of lead pass the mean value test (calculated as

detailed in CLEA CLR7). For each determinand the maximum values are within the distribution with no outliers identified.

6.2.8. The SSAC for nickel has been previously calculated in agreement with WCBC for use on the batters of the housing areas within the main site. An SSAC can be calculated for arsenic on the same basis, namely reducing the exposure frequency of a child of 6 years to 3.5 days a week, resulting in a SSAC of 40 mg/kg. These criteria however are not directly relevant to the informal public access to the site. In particular, the area is extensively vegetated with minimal exposed soils reducing the likelihood of regular direct exposure through ingestion and/or inhalation. In addition, the SSACs are based on the most critical receptor being a child aged 0 – 6 years, with an exposure frequency of 182 days/year for oral ingestion, whereas given the site location and informal undeveloped nature it is unlikely to be extensively utilized by this age group.

6.2.9. On this basis, risks to human health in the Wonder Bank Remainder area are considered to be low due to the limited use of the area, and the presence of extensive dense vegetation minimising the potential for direct contact with near-surface soils or for dust blow. No remedial works are therefore deemed necessary for this area of the site. Should more formal development of the site be proposed including provision of new footpaths, play areas etc, more detailed risk assessment should be undertaken with the possible provision of remedial measures.

6.2.10. Although copper and zinc were detected at concentrations that may pose a risk to plant growth, the area is extensively vegetated with no evidence of plant damage. Remedial works may however be necessary should formal landscape planting be proposed.

6.3. Controlled Waters Risk Assessment

6.3.1. The principal risk posed to the surrounding environment by the contaminated materials within the tip was the long term potential for mobile soil contamination, leaching into controlled waters, i.e. the underlying aquifer, Lodge Stream or other watercourses via mine drainage channels by infiltration through and run-off from the contaminated materials. Leaching tests, however, suggested contaminants to be relatively immobile.

6.3.2. Existing risks to surface waters appeared to be minimal, although the potential for short-term releases resulting from remedial works were noted. Monitoring of the Lodge Stream undertaken by both WCBC and SGP pre- and during the main site reclamation works had not shown any significant levels of hydrocarbons in surface waters, suggesting that there was not significant migration along this pathway.

6.3.3. Risks to groundwater could not be discounted although monitoring had not identified a significant plume of contamination that may be attributable to the Wonder Bank. With respect to the remainder of the steelworks, it has been previously acknowledged by EAW that groundwater below the site is principally important as a pathway for pollutants rather than as a target in its own right. This is because groundwater quality has been impacted historically as a result of the local industries, most importantly by coal mining, and that natural contamination is also likely to restrict the value of the resource. It was therefore considered that, whilst it would be desirable to minimise on-going pollution of groundwater, widespread treatment of groundwater was unlikely to be justifiable or feasible.

6.3.4. The provision of an impermeable cap as outlined above would serve to minimise infiltration through the wastes and reduce any potential future impacts on the groundwater. Doming of the cap would encourage surface run-off into perimeter drainage.

7. Remediation Strategy

7.1. Works Specification

7.1.1. Given the nature of the materials within the Wonder Bank, a strategy of minimum disturbance together with remodeling of the eastern side slopes to improve stability and capping of the surface plateau to minimise infiltration and oxygen entry was recommended by SGP. The works comprised:

- remodeling of the over-steep eastern side slopes to improve their stability;
- provision of low permeability cap to surface plateau to minimise water infiltration and air entry;
- shaping of the capping to promote run-off;
- collection of run-off in perimeter drainage;
- repair / replacement of security fencing to former licenced waste area;
- stabilisation of slopes by soiling and vegetation establishment.

7.1.2. The conceptual model did not identify any specific remedial requirements to the Wonder Bank Remainder for the proposed end-use.

7.1.3. As required under Planning Condition 32, a scheme relating to the capping and remodeling of the Wonder Bank was submitted by BDL to, and approved by, WCBC.

7.2. Wonder Bank Principal Actions

7.2.1. BDL commenced remedial works on the Wonder Bank in May 2004 and the majority of works were complete by February 2006. Capping of the plateau area was undertaken between 11th May and 1st June 2005. Works have involved the following principal actions;

- removal of existing vegetation on eastern slopes;
- construction of an access ramp to the plateau;
- buttressing of the eastern slopes by placement of colliery spoil / coal measures rocks and compaction;
- construction of domed low permeability cap (1 – 2m depth of material) over the existing security fenced area plateau;
- construction of perimeter drainage and connection to main site drainage;
- provision of tree shreddings mulch to minimise drying out of the clay cap;

- provision of up to 0.5m replacement soil cover to eastern slopes and grassing / planting of shrubs and trees.

7.2.2. Capping of the plateau was undertaken using reworked mudstones excavated from the main site (see SWL report: Wonderbank Capping; Construction Certification Report, D101082/GEO/1531A, Nov 2005).

7.2.3. The original scheme submitted to WCBC included for the rebutressing of the majority of the eastern slopes, construction of an access ramp to the plateau via the southeastern slope and possible re-alignment of the footpaths at the base of the slopes. The works ultimately undertaken involved the re-butressing of the over steep eastern-most slopes and construction of an access ramp via the easternmost slope to the eastern corner of the plateau. The original alignment of the footpaths was retained. The northern and southern parts of the Wonder Bank slopes did not exhibit substantial instability, were generally well-vegetated by grass and scrub woodland, and were retained in their undisturbed state.

7.2.4. The re-worked eastern slopes have not been provided with a cap, but have received replacement soil cover and subsequent re-planting.

7.3. Supervision of Remedial Works

7.3.1. The role of SGP during the remediation of the Wonder Bank was principally to undertake:

- daily inspections of all earthworks for contamination / pollution;
- visual inspections of any suspect or exposed materials;
- visual inspections of the capping material;
- sampling where appropriate;
- implementation of a programme of gas monitoring.

7.4. Validation Methodology

7.4.1. A gas monitoring programme was agreed with WCBC to enable confirmation that the remedial works did not result in increased risks to nearby properties through increasing gas migration. During placement of the cap a series of 6no. paired gas monitoring wells were installed on the upper edge of the plateau (external to the enclosed area) using cable percussion techniques. The locations of the boreholes are shown in Drawing D009.

7.4.2. The boreholes were installed with response zones of 1m – 5m (BH1A, BH2B, BH3A, BH4B, BH5B, BH6B) and 5m – to base of the fill (BH1D, BH2A, BH3B, BH4A, BH5A, BH6A). The borehole logs / standpipe installation

details and a summary of ground conditions are attached in Appendix E. All the boreholes encountered a variable ash fill with clinker and foundry brick to depths of 7.4m (BH6A) to 24.4m bgl (BH3A). As anticipated the made ground was shallower across the western edge of the site becoming deeper to the east and northeast due to the plateau projecting eastwards from the naturally sloping hillsides. Bedrock was proven in each of the deeper boreholes and comprised mudstone in BH2A and BH3B and sandstone in BH1D, BH4A, BH5A and BH6A, all associated with the underlying Coal Measures. The ground conditions are consistent with earlier investigations which identified tipped materials to depths of up to 20m within the main Wonder Bank area.

7.4.3. None of the boreholes encountered any sludge or chemical wastes, confirming the boreholes to be located beyond the perimeter of the areas historically subject to tipping of oil and flue dusts. Chemical analysis of a number of soil samples collected from a range of depths (full details included within Appendix F) confirmed the soils to be free of substantial hydrocarbon contamination (maximum EPH: 1,275 mg/kg; PAH 21.58 mg/kg). Metals / metalloids contamination was limited to elevated zinc with marginal arsenic contamination. Particularly high concentrations of total sulphate (maximum 34,790 mg/kg) were encountered at depth.

7.4.4. A series of 9 hand-driven shallow probes (response zone 1 - 1.5m bgl) were also installed at the base of the Wonder Bank facing the properties on Brake Road in February 2005. The probes were installed at an approximate spacing of 20m.

7.4.5. The probes and boreholes were monitored initially on a fortnightly basis from installation, reducing to monthly after 11 monitoring rounds. Monitoring was conducted by a SGP representative for relative borehole pressure, gas flow rate and concentrations of methane, carbon dioxide, carbon monoxide, oxygen, hydrogen sulphide, carbon monoxide and VOCs. The temperature within the boreholes was also monitored on a number of occasions. Due to time constraints it was not possible to obtain extensive monitoring data from the boreholes prior to the on-set of works to confirm the background gassing regime. However, 7 data sets were available for the probes prior to the placement of the cap and 2 during capping earthworks.

7.4.6. Groundwater was not encountered within any of the installations and hence, groundwater monitoring has not been undertaken. However, as part of the on-going reclamation works across the main site the Lodge Stream has been subject to daily and weekly sampling and monitoring (undertaken monthly since March 2007). In addition, four mine adits deemed to possibly receive drainage from the site have been subject to monthly monitoring and all residual boreholes on site to annual monitoring as part of a site-wide assessment. In addition, boreholes BH318, BH401 and the Supply Well, potentially downgradient of the Wonder Bank, were monitored in July 2005 on completion of the capping.

8. Validation Sampling and Testing

8.1. Capping Layer

8.1.1. 40 samples of the clay capping material were submitted to permeability tests by Bureau Veritas under constant head conditions in a triaxial cell in accordance with Environment Agency R&D Technical report P1-398/TR/2: Jan 2002. The samples recorded permeability in the range of 3.8×10^{-12} – 5.6×10^{-10} m/s and are significantly within the agreed criteria for the capping material (10^{-9} m/s). Full details are provided in the Scott Wilson Wonderbank Capping, Construction Certification Report (Ref: D101082/GEO/1531A, November 2005).

8.2. Batters

8.2.1. 6 samples (221105WB1 – 221105WB6) were collected of the replacement near-surface soils placed on the eastern batters prior to planting of trees and shrubs and subject to a variety of chemical analysis as summarised below in Table 6.

8.2.2. The results have been compared to those criteria referred to previously with respect to the Wonder Bank Remainder (residential without plant uptake).

Table 8: Summary of Soil Chemical Analysis – Replacement Soils on Eastern Slopes

Determinand	Range	Assessment Criteria	No. of Exceedances of Near Surface Soils
No. of samples	5	-	-
pH	6.7 – 7.9	<3 United Utilities	none
Arsenic	10 - 12	20 CLEA SGV	none
Boron (water soluble)	<1 - 1	3 ICRCL	none
Cadmium	<1 - 2	30 CLEA SGV	none
Chromium	30 - 324	5,000 CLEA SSAC	none
Hexavalent chromium	<3 - 6	130 CLEA SGV	none
Mercury	<1	8 CLEA SGV	none
Nickel	23 - 49	150 CLEA SSAC	none
Lead	98 - 198	450 CLEA SGV	none
Selenium	<3	260 CLEA SGV	none

Determinand	Range	Assessment Criteria	No. of Exceedances of Near Surface Soils
Copper	19 - 52	130 ICRCL	none
Zinc	172 - 582	300 ICRCL	none
Total cyanide	<1	none	-
Free cyanide	<1	none	-
Thiocyanate	<1-3	none	-
Acid soluble sulphide	<50	none	
Total phenols	<0.01 – 0.08	10 United Utilities	none
EPH (DRO)	204 - 474	4,000 TPHCWG	none
Total PAH	1,735 – 5,202	none	-
Naphthalene	0.14 – 1.29	9.7 CLEA SSAC	none
Benzo(a)pyrene	0.06 – 0.16	0.9 CLEA SSAC	none

Notes:

All concentrations are in mg/kg unless stated otherwise

8.2.3. None of the replacement soils contained any determinands in excess of the agreed assessment criteria.

8.3. Ground Gas – Pre-Capping

8.3.1. The shallow probes were monitored on 7 occasions on a fortnightly basis prior to the completion of capping. Due to time constraints it was not possible to undertaken any monitoring of the boreholes prior to completion of the capping.

8.3.2. The results of the monitoring have been compared to the following Generic Assessment Criteria (GAC).

Table 9: Generic Assessment Criteria for Ground Gas

Contaminant	GAC	Receptors	Note	Reference
Methane	≥1% v/v or >0.07 l/hr	Property	Explosive; 20% of lower explosive limit	Assessing Risks Posed by Hazardous Ground Gases to Buildings, CIRIA C659, 2006; EA Guidance on the Management of Landfill Gas, 2004
Carbon Dioxide	≥1.5% v/v[1] or >0.07 l/hr	Human Health	Asphyxiant; Causes physiological problems above 1.5%	As above
Oxygen	≤18% v/v	Human Health	Lack causes asphyxiation	Guidance Note EH40 Occupational Exposure Limits
Hydrogen Sulphide	10 ppm 8hr twa	Human Health	Toxic	As above

Contaminant	GAC	Receptors	Note	Reference
Carbon Monoxide	30 ppm 8hr twa	Human Health	Toxic	As above
VOCs	1 ppm (based on benzene 8 hr twa)	Human Health	Toxic	As above (gives limits for individual VOCs)

1 EA guidance provides trigger concentration for carbon dioxide of 1.5% *above background levels*; CIRIA guidance provides trigger concentration of 5%

8.3.3. The results of the monitoring have initially been compared to the trigger levels for methane and carbon dioxide respectively above background concentrations as recommended by the EA at off-site landfill monitoring wells. There are no guideline limits for carbon monoxide and hydrogen sulphide in relation to ground gases and hence the HSE long term exposure limits of 30ppm and 10ppm have been referred to. An exposure limit is similarly not established for VOCs. Landfill gas can contain a wide range of VOCs and other trace components (Investigation of the composition and emissions of trace components in landfill gas, EA, R&D Technical Report p1-438/TR). A GAC of 1ppm for VOCs has been used based on the HSE 8 hour time weighted average for benzene and chlorobenzene, which provide the most conservative guideline limit for potential landfill gas components.

8.3.4. A temperature of 10°C is used by the EA (CLEA Update Briefing Note 2: table 3) as an annual average for a UK surface soil based on a mean annual average UK air temperature of 7 – 11°C. Although not site-specific or applicable to soils at depth, this has been used as an initial reference value.

8.3.5. Methane was undetected (<0.1 % v/v) in any of the probes. Carbon dioxide was detected in the range <0.1% - 1.2% (PH6). The levels were not in excess of 5% on any occasion. The levels of carbon dioxide corresponded to slightly depleted levels of oxygen with concentrations <18% v/v being detected in PH6 and PH7. Significant relative pressures were not detected.

8.3.6. Carbon monoxide, hydrogen sulphide and VOCs were undetected in any location (CO and H_2S <1 ppm; VOCs <0.1 ppm).

Table 10: Summary of Ground Gas Monitoring Results

	CH4 (%)		CO2 (%)		O2 (%)		Carbon Monoxide (ppm)		VOCs (ppm)		Temp (°C)	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Probeholes - Pre-capping[1]												
1	<0.1	<0.1	<0.1	0.4	19.2	20.8	<1	<1	<0.1	<0.1	-	-
2	<0.1	<0.1	<0.1	<0.1	19.8	20.8	<1	<1	<0.1	<0.1	-	-
3	<0.1	<0.1	<0.1	0.2	19.3	20.9	<1	<1	<0.1	<0.1	-	-
4	<0.1	<0.1	<0.1	0.7	18.7	20.7	<1	<1	<0.1	<0.1	-	-
5	<0.1	<0.1	<0.1	0.4	19	20.9	<1	<1	<0.1	<0.1	-	-
6	<0.1	<0.1	<0.1	1.2	16.3	21.1	<1	<1	<0.1	<0.1	-	-
7	<0.1	<0.1	<0.1	0.9	17.1	20.8	<1	<1	<0.1	<0.1	-	-
8	<0.1	<0.1	0.2	0.9	19.1	20.8	<1	<1	<0.1	<0.1	-	-
9	<0.1	<0.1	<0.1	0.3	18.9	20.7	<1	<1	<0.1	<0.1	-	-
Probeholes - Post-capping[1]												
1	<0.1	<0.1	<0.1	6.5	16	21.5	<1	5	<0.1	<0.1	-	-
2[2]	-	-	-	-	-	-	-	-	-	-	-	-
3	<0.1	<0.1	<0.1	5.3	8.3	21.8	<1	<1	<0.1	<0.1	-	-
4	<0.1	<0.1	<0.1	1.9	18.0	21.7	<1	<1	<0.1	8.7	-	-
5	<0.1	<0.1	<0.1	5.1	12.1	21.4	<1	7	<0.1	<0.1	-	-
6	<0.1	<0.1	<0.1	4.6	12.5	21.9	<1	6	<0.1	<0.1	-	-
7	<0.1	<0.1	<0.1	3.9	12.8	22.1	<1	4	<0.1	<0.1	-	-
8	<0.1	<0.1	0.3	1.4	18.2	21.4	<1	5	<0.1	<0.1	-	-
9	<0.1	<0.1	0.1	1.7	17.4	22.5	<1	5	<0.1	<0.1	-	-
Boreholes												
Post-capping												
BH1A (shallow)	<0.1	<0.1	1.1	7.0	8.8	18.9	<1	7	<0.1	<0.1	10.2	14.1
BH2B (shallow)	<0.1	<0.1	<0.1	4.8	14	21.3	<1	5	<0.1	<0.1	4.9	14.0
BH3B (shallow)	<0.1	<0.1	2.3	5.2	10	17.5	<1	4	<0.1	0.5	14.1	18.9
BH4B (shallow)	<0.1	<0.1	1.4	6.9	8.8	19.7	<1	3	<0.1	<0.1	14.4	18.3
BH5B (shallow)	<0.1	<0.1	3.6	9.3	2.3	18	<1	5	<0.1	1.4	11.1	15.4
BH6B (shallow)	<0.1	0.1	<0.1	1.3	18.7	21.6	<1	4	<0.1	<0.1	9.1	12.1
BH1B (deep)	<0.1	<0.1	0.5	3.2	13.3	21.1	<1	3	<0.1	<0.1	11.3	13.4
BH1D (deep)[4]	<0.1	<0.1	<0.1	3.5	15.1	21.5	<1	<1	<0.1	<0.1	10.7	11.8
BH2A (deep)	<0.1	0.1	<0.1	2.3	14.9	21.4	<1	4	<0.1	<0.1	5.7[3]	14.6[3]
BH3A (deep)	<0.1	0.1	<0.1	12.5	1.3	22.5	<1	5	<0.1	2.3	17.9	21.1
BH4A (deep)	<0.1	<0.1	<0.1	11.9	3.8	20.8	<1	3	<0.1	<0.1	18.5	23.5
BH5A (deep)	<0.1	<0.1	<0.1	8.2	5	21.5	<1	5	<0.1	1.4	11.7	17.1
BH6A (deep)	<0.1	<0.1	<0.1	1.4	19	22.3	<1	3	<0.1	0.6	9.1	12.1

Note:

1 Capping of the plateau commenced on 11.05.06; capping was completed on 1.06.06; it was not possible to install the boreholes prior to the commencement of capping works

2 PH2 vandalised and unable to be monitored from 20.04.05

3 BH2A – temperature only monitored on one occasion due to a blockage in the pipe; 4 BH4D – monitored since 7.11.05

8.4. Ground Gas – Post-Capping

Probes

8.4.1. The probeholes and boreholes have been monitored on 19no. occasions since completion of the capping. Corrected for site altitude of 258m AOD, the atmospheric pressure will typically be about 26mb below that at sea level, giving 2 occasions when the atmospheric pressure was below 1000 mb at sea level.

8.4.2. During this period carbon dioxide was detected in all the probes and was in the range <0.1 – 6.5% (PH1), with concentrations in excess of 1.5% being detected in all the probes other than PH8. The elevated carbon dioxide corresponded to depleted oxygen which was detected at a minimum of 8.3% in PH3. Concentrations of carbon dioxide were noted to increase during the period June 2005 – January 2006. Levels from January 2006 onwards returned to low levels similar to those recorded previously in early 2005 (pre-capping) with a potential rise again noted in June 2006. The area of installation is highly vegetated and it is thought the increase in carbon dioxide generation may have arisen due to rotting of the extensive leaf litter during the summer / autumn months rather than necessarily indicative of enhanced carbon dioxide migration from the tip.

8.4.3. VOCs remained undetected in all the locations other than PH4 where concentrations of <0.1 – 8.7ppm were recorded. The highest concentrations were detected in May / June 2005, with all results since August 2005 (15 rounds of data) being below 3ppm, and generally <1ppm.

8.4.4. Carbon monoxide was similarly detected in the majority of locations and up to a maximum of 7ppm in PH5. All concentrations however were greatly below the GAC of 30ppm. Hydrogen sulphide remained undetected (<1 ppm).

Boreholes - Shallow

8.4.5. Methane was only detected on one occasion in any of the shallow boreholes. At 0.1% (BH6B) this is below the GAC and not considered significant.

8.4.6. Carbon dioxide has been detected in excess of 1.5% on occasion in all the shallow boreholes other than BH6B where the levels have been consistently

in the range <0.1 – 1.3%. The levels of carbon dioxide across the boreholes have generally followed a similar trend (other than BH4B) as demonstrated in the attached graphs (Appendix G) with the maximum of 9.3% recorded in BH5B. The available data does not indicate any particular overall increasing trends other than a slight increase in BH2AB towards the end of the monitoring period. Gas flow rates have been low with a maximum of 0.8l/hr with no appreciable increases. The resulting maximum carbon dioxide limiting volume flow is 0.04 l/hr (BH5B)(equivalent to Characteristic Situation 1 as per CIRIA C639). Low levels of oxygen have similarly been recorded on occasion in all the boreholes, other than BH6B, to a minimum of 2.3% (BH5B).

8.4.7. VOCs were present on occasion in only two boreholes (BH3B and BH5B) where a maxima of 0.5 ppm and 1.1 ppm were recorded. These levels are not considered significant. Carbon monoxide has been detected at similar levels across all the shallow boreholes and is in the range <1-7 ppm which are greatly below the GAC.

8.4.8. Elevated temperatures have been recorded within the shallow boreholes and were recorded to a maximum of 18.9°C in BH3B and 18.3°C in BH4B. The lowest temperatures were recorded in BH6B which at 9.6 - 12.1°C are at normal levels. No overall increases in temperatures have been observed since capping.

8.4.9. BH6A/6B is located the closest to the housing on Brymbo Road, the other boreholes all being at least 200m distant.

Boreholes - Deep

8.4.10. Methane has only been present in two deep boreholes on two isolated occasions with 0.1% recorded in BH2A and BH3A. This is not considered significant.

8.4.11. Carbon dioxide has been detected in excess of 1.5% on occasion in all the deep boreholes, other than BH6A where the levels have been consistently in the range <0.1-1.4%. The levels of carbon dioxide present have generally been greater, but more variable, than in the shallow boreholes, with a maximum of 12.5% recorded in BH3A. Gas flow rates have been low and generally similar to those in the shallow boreholes other than a single

recording of 1.8l/hr in BH5B. The resulting maximum carbon dioxide limiting volume flow is 0.08 l/hr (BH5B). None of the boreholes show an indication of any overall increasing trends in gas generation. Low levels of oxygen have similarly been recorded on occasion in all the boreholes, other than BH6A, to a minimum of 1.3% in BH3A.

8.4.12. VOCs have been detected on isolated occasions in three of the deep boreholes (BH3A, BH5A and BH6A) with a maximum of 2.3 ppm recorded in BH3A. VOCs have not been detected in excess of 1 ppm since July 2005. Carbon monoxide has been detected at similar levels across all the deep boreholes and at similar levels to those encountered in the shallow boreholes, and is in the range <1-5 ppm which are below the GAC.

8.4.13. Elevated temperatures have been recorded at depth within the deep boreholes, at levels greater than the adjacent shallow boreholes, to a maximum of 23.5°C in BH4A and 21.1°C in BH3A, with the lowest temperatures being recorded in BH6A. The greatest temperatures in BH4A and BH3A were noted at about 10m depth within the boreholes. There have been no appreciable increases in temperature during the monitoring period.

Summary

8.4.14. The gas monitoring undertaken has demonstrated that the capping of the tip has not resulted in increased generation of methane gas with methane remaining either undetected (<0.1 %) or only present at low concentrations (0.1%) in any of the probes or boreholes.

8.4.15. The highest levels of carbon dioxide, along with depleted oxygen, have been detected in the deep boreholes to the immediate north and northeast of the tip (BH3A, BH4A and BH5A), located on the deepest edge of the tip, up to a maximum of 12.5%. Lower levels, although elevated, have been recorded in the shallow boreholes on the north / northeastern and western edges of the tip. These concentrations are broadly similar to those detected during previous investigations which recorded a maximum of 11% carbon dioxide. The recorded gas concentrations are generally highly variable but other than a possible small increase in concentrations in the shallow borehole BH2B (on the southern most point of the tip) to a maximum of 4.8% no overall increasing trends within the boreholes have been noted.

8.4.16. Increase in carbon dioxide was noted in the majority of probes during June 2005 – January 2006 up to a maximum of 5.3%, with levels subsequently returning to previous pre-capping concentrations. This is believed to be possibly due to rotting of the extensive leaf litter in the area rather than necessarily indicative of enhanced migration from the tip. The concentrations detected are also within those typically encountered in land overlying Coal Measures and are not indicative of an increased risk to the housing along Brake Road.

8.4.17. The absence of detectable methane and elevated carbon dioxide in BH6A / 6B, the boreholes to the northwest of the tip, demonstrate the absence of any significant gas migration in the direction of the residential properties along Brymbo Road.

8.4.18. VOCs have generally been undetected in the boreholes, other than on isolated occasions, with no appreciable increases since completion of the capping. VOCs were detected in the probe PH4, located at the base of the tip, during capping operations in May 2005 (at a maximum of 8.7 ppm). Concentrations in this location subsequently decreased with a maximum of 2.6 ppm being recorded since July 2005. VOCs were not detected in any of the other probes and there were no visual signs of any hydrocarbon contamination in this area that may have given rise to the VOCs. Although the GAC has been referred to, this is based on the benzene 8hr occupational limit. As benzene would only be a small component of the total VOC present, if present at all as it is highly volatile, these subsequent levels are not considered to be of concern.

8.4.19. Depleted levels of oxygen have been detected in all boreholes, other than BH6A, indicating a reduced future risk of ground combustion.

8.4.20. Elevated temperatures have been recorded at depth within the deep boreholes at similar levels to earlier investigations and suggesting possible on-going localised heating may be taking place. However, no appreciable increases since capping have been observed. Similarly, there is no evidence of elevated carbon monoxide which is a key indicator of ground combustion.

8.5. Waters

8.5.1. A single surface water sample was collected of the perimeter tip drainage (WB Drain) in March 2006 and submitted for comprehensive analysis. No determinands were detected in exceedance of the criteria agreed with the EAW in relation to the closest watercourse to the site (Lodge Stream). Mineral oils and PAHs (16 speciated) were undetected.

8.5.2. Groundwater samples were collected from the residual boreholes BH318, BH401 and the Supply Well in July 2005 following completion of the capping and in October 2005 and 2006 as part of the site wide assessment (HT1 and HT2 were no longer present). The samples were submitted for comprehensive analysis including PAH (16 speciated), EPH, GRO / BTEX, PCBs, VOCs and SVOCs. The levels of organic determinands were all below the relevant limit of detection in all cases other than naphthalene in BH318 and BH401 in October 2005 which at 0.34 ug/l and 0.33 ug/l are substantially below the EQS (10 ug/l). All key metal determinands were also below the relevant assessment criteria. The results therefore do not indicate the presence of any contamination migration from the Wonder Bank.

8.5.3. Post-completion weekly inspections and field monitoring have been undertaken of the Lodge Stream from October 2003 to March 2007, with sampling of the Lodge Stream for chemical analysis. Monthly sampling and analysis is presently on-going. Monthly samples were collected from a series of mine adits to assess potential impact of groundwater discharges from the site from October 2003 to December 2006. Additional sampling was, and will continue to be, undertaken as necessary in response to the data obtained and / or visual observations. The monitoring programme will continue until such a time as agreed with EAW.

8.5.4. The monitoring has not identified the presence of any contaminants at any location that may be attributed specifically to the Wonder Bank.

9. Completion Assessment

9.1. Residual Environmental Risk Assessment

9.1.1. The Wonder Bank principally comprises colliery spoil with ash, clinker and oil contaminated sludges. The made ground material contains elevated heavy metals, particularly lead and zinc, and heavy oils. Development of the Wonder Bank is not proposed and the main plateau tip area is to remained enclosed with no unauthorized access. Remedial works have incorporated the placement of low permeability capping to the former waste licensed area and buttressing of the worst affected parts of the eastern slopes. Provision of the capping will ensure that any members of the public gaining unauthorized access will not come into contact with the underlying waste materials and the risk to public health is therefore limited. The spread bark mulch will help minimise drying out of the cap until the newly planted shrubs etc across the cap are established.

9.1.2. The eastern slopes have been buttressed by the placing of additional colliery spoil and Coal Measures rock, provided with at least 0.5m clean soil cover, grass seeded and tree planting. Once established the vegetation will help prevent erosion of the banks and subsequent potential exposure of the underlying contaminated materials. The reduced slope angles and placement of soils will also serve to reduce air entry, to prevent potential combustion within the tip.

9.1.3. The northern and southern sections of the eastern slopes have not been re-butressed as part of the works. The northern section remains heavily vegetated with no indications of exposure of underlying materials or bank erosion. Part of the southern section is relatively free of vegetation with some signs of erosion and with colliery spoil evident at the surface. No oils are visible in this area. This area of slope will be subject to vegetation stabilisation and management under the wider landscape / aftercare management of the site and will eventually be available as informal open space.

9.1.4. The Wonder Bank Remainder is to provide informal public open space. The extensive dense vegetation in this area will minimise any public exposure to any near-surface contaminated materials.

9.1.5. The gas monitoring undertaken during 2005 – 2006 does not indicate the presence of any increased risks to either vegetation on the bank slopes or nearby buildings and their occupants. The monitoring has demonstrated that the capping of the tip has not resulted in increased generation of methane gas with methane remaining either undetected (<0.1 %) or only present at low concentrations (0.1%) in any of the probes or boreholes. No overall increases in the concentrations of carbon dioxide have been noted in the boreholes. Although fluctuations of carbon dioxide have been observed in the probes at the base of the tip this is thought to be primarily due to rotting of extensive leaf litter in this area rather than increased migration from the tip.

9.1.6. Temperature measurements suggest minor on-going localised heating may be occurring at depth. Maintenance of the security fence will help minimise public access.

9.1.7. Materials present within the tip, beneath the cap, may contain potentially leachable contaminants. The impermeable cap will serve to reduce rainwater infiltration into subsurface material and thus reduce any on-going contamination. The domed cap will direct surface run-off to the perimeter drain to prevent ponding and potential damage to the cap. Surface run-off is directed eastwards to the ponds in the Heritage Module. Groundwater monitoring of residual boreholes downgradient of the Wonder Bank has not identified any organic contamination that may be attributable to the residual materials. The weekly monitoring of the Lodge Stream and monthly mine adit monitoring has similarly not indicated any migration of pollutants from the Wonder Bank.

9.2. Development / Management Requirements

9.2.1. There is no proposed development within the Wonder Bank Module. The integrity of the remediation works depends on maintenance of the low permeability cap to the tip, and prevention of soil erosion by managing site drainage and enhancing / maintaining vegetation cover to stabilize the soil slopes. The residual contaminants are persistent and will require containment for the foreseeable future. Regular (annual) inspections, to include gas and temperature measurements and collection / analysis of water samples from the downstream Newt Ponds, are recommended.

9.2.2. Formal landscaping of the Wonder Bank Remainder is not required given the existing dense vegetation cover.

9.3. Contingent Environmental Liabilities

9.3.1. It is considered that the Wonder Bank has been remediated substantially in accordance with the WCBC planning requirements and as agreed with statutory consultees, such as EAW. The contaminated soils within the former tip have been overlain by 1 – 2m low permeability mudstone/clay materials and are deemed not to pose a significant threat to human health or surface waters environmental receptors. No objections to the existing use of the site from WCBC or EAW are anticipated by SGP on soil quality issues.

9.3.2. Due to the poor quality of the groundwater in the general area of the site (arising from the historical mining activity resulting in increased weathering of rocks bearing naturally occurring contaminants) and lack of any important local abstractions, the EAW accepts that the groundwater beneath and around the site is not considered a receptor in its own right. It is therefore considered unlikely that any future environmental impairment liability will arise from groundwater quality below the Wonder Bank.

9.4. Statutory / Regulatory Approvals

9.4.1. The investigations and reclamation strategy across the site have all been agreed in on-going consultation with WCBC Planning and Environmental Protection Department and EAW since 1995.

9.4.2. Information has been (and is continuing to be) provided to the EAW and WCBC throughout the course of the overall reclamation works. Copies of principal correspondence between SGP and the Regulatory Authorities specifically regarding the reclamation works and validation testing in the Wonder Bank or considered directly relevant are included in Appendix H.

10. Conclusions and Recommendations

10.1. SGP has inspected the remediation works carried out on the Wonder Bank and is satisfied that these have substantially complied in all material respects with the strategy recommendations as approved by Wrexham County Borough Council, and that contaminated soils and other deleterious materials in the area do not pose a significant risk to public health or the environment.

10.2. The plateau cap is underlain by colliery spoil and flue dust sludges which were placed during the operation of the steelworks. The low permeability clay cap provides protection against human contact with, or surface erosion of, the contamination within the colliery wastes. The tree bark mulch should be maintained across the cap to prevent drying out of the clay until such a time as the vegetation is established. The cap also serves to minimise air entry into the tip.

10.3. Although the residual contaminated materials may potentially pose a pollution risk to underlying groundwaters as a result of infiltration and leaching, groundwater monitoring has not found evidence of an historic contamination plume arising from the Wonder Bank. The materials within the bank are relatively immobile and the low permeability cap will minimise infiltration into the underlying materials thereby reducing the potential for future contamination migration.

10.4. SGP concludes that the appropriate and necessary remedial works have been substantially completed and that the Wonder Bank will be suitable in due course for use as informal public open space.

10.5. On-going management of the Module will be necessary to ensure maintenance of the integrity of the remediation works. This should comprise management of the site drainage, maintenance of the low permeability cap and enhancing / maintenance of the vegetation on the side slopes. Regular (annual) inspections, to include gas and temperature measurements and collection / analysis of water samples from the downstream Newt Ponds, are recommended.

10.6. Smith Grant LLP reserves the right to alter any of the foregoing information, recommendations or conclusions, in the event of new information being provided and in the light of changes to legislation, guidelines and responses by the statutory and regulatory authorities.

10.7. Limitation

This report has been prepared by Smith Grant LLP for the use of Brymbo Developments Ltd and any other person to whom Smith Grant LLP gives a collateral warranty pursuant to its appointment by Brymbo Developments Ltd. Transfer of benefit of this report will be permitted to one further assignee without the written permission of Smith Grant LLP. All reasonable skill, care and diligence has been exercised within the timescale and budget available, and in accordance with the technical requirements of the brief given by and developed with Brymbo Developments Ltd. Notwithstanding the efforts made by Smith Grant LLP in undertaking the assessment and preparing this report, it is possible that other ground conditions and contamination as yet undetected may exist. Reliance on the findings of this report must therefore be limited accordingly. Such reliance must be based on the whole report and not on extracts which may lead to incomplete or incorrect conclusions when taken out of context