ASSESSMENT OF THE BURIAL ENVIORONMENT AT BROOKLYN GARAGE, ALCESTER, WARWICKSHIRE: A REVIEW OF THE DATA COLLECTED BETWEEN MARCH AND MAY 2008

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INVESTOR IN PEOPLE

Project 3176
Report 1628

Contents

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1. Background

There is good preservation of wood and other organic material beneath the development site at Brooklyn Garage, Alcester, Warwickshire. This data analysis is to provide a baseline for the properties of the burial environment, and suggest guidelines to indicate where intervention may be required to preserve the burial environment, should changes from the baseline data occur.

1.1 Reasons for the project

The project has been requested by Archaeological Services and Consultancy Ltd on behalf of Green Villa Developments: Midland Ltd in response to a brief prepared by Warwickshire County Council (dated November 2006). Further guidance has been provided by English Heritage (Moffett, L, 7 February 2006 *Groundwater monitoring – list of basic points to include when specifying work*). The brief resulted from a successful planning application to Stratford on Avon District Council (reference number 06/00625/FUL). This proposed a mixed residential and retail development and is considered by the curator to have the potential to affect an archaeological site and the permission is conditional on implementation of a programme of archaeological works.

1.2 Project parameters

The brief gives detailed requirements and the proposal addresses one item. "Groundwater monitoring, before, during, and following construction should be integral to the mitigation strategy. This report addresses groundwater monitoring before construction commenced.

1.3 Aims

The aims of the project were to provide a baseline statement on the burial conditions of deposits (subject of this report), and to track any changes during and after construction (subject to one or more subsequent reports). The project would also utilise existing, or provide, infrastructure to monitor ground conditions before, during and after construction (WHEAS 2008, 2).

2. Methods

2.1 Summary of existing information on the site

The archaeological background to the site (National Grid reference SP 08817 57343) is given in the brief (section 2). The Service has also received other information relating to the site.

- GRM 2004 *Site appraisal for land at Brooklyn Ford, Priory Road, Alcester,* Ground Risk Management Limited, September 2004, reference P2714/F.1

- Hawtin, T, 2006 *Archaeological evaluation: Brooklyn, Priory Road, Alcester, Warwickshire*, Archaeological Services and Consultancy Ltd, reference 760/APR/2

- Hunn, J, 2007 *Brooklyn, Priory Road, Alcester, Warwickshire, project design for archaeological mitigation on behalf of Green Villa Developments*, Archaeological Services and Consultancy Ltd, reference 860/APR/01

There are no groundwater abstraction licenses within 500m of the site (GRM 2004, 5).

The site is at risk from flooding and lies within the flood plain of the River Arrow (GRM 2004, 5).

Geotechnical survey indicated made ground to depths of between 0.5-2.0m, with alluvium and river terrace deposits up to a depth of 4.7m (or more), and contained organic material. Groundwater was recorded at depths of between 0.94-1.9m during August (GRM 2004, 11) and as the readings were taken in August may be assumed to vary to lesser depths at other times of the year. Depths of groundwater were again recorded on 8 June 2007 and varied between 1.08 and 1.68m. Groundwater flows towards the River Arrow (GRM 2004, 12), which lies to the east of the site.

2.2 Fieldwork methodology

2.2.1 Monitoring parameters

The level of the groundwater is measured in the three boreholes by removing the sampling tube and lowering a probe, on a tape graduated in millimetres, into the borehole. The probe sounds when wet, and the depth is read from the tape. The depths can be converted to height O.D. for comparison between boreholes. The levels of the boreholes have not yet been measured.

Water droplets on the inner wall of the borehole tube may cause too short a depth to be measured. The depth is monitored at the point of recording, and measurements are repeated where the data is inconsistent.

The rate of flow of the groundwater restricts the rate of pumping from WS6 and WS7, and this can influence the ORP results. If the water supply is exhausted, air will be pumped through the tube, which can cause oxidation of the sample, and change the ORP value. A low flow rate for purge and testing has been established to prevent the exhaustion of the water supply. The water flow in BH3 is much higher and a high purge rate is used in this case.

The pH, ORP (redox potential), temperature and conductivity have been measured by pumping water from the boreholes through a flow cell, within which the measurement electrodes are located. The total dissolved solids (TDS) and salinity are derived by the instrument from the conductivity value. The full description of the method is set out in the document, ‘Alcester Groundwater Test Procedure’

Redox data is conventionally quoted with the Standard Hydrogen Electrode (SHE) as the reference. This electrode is difficult to use in practice, and the ORP probe uses an inbuilt silver/silver chloride reference electrode. To convert these measurements to the standard form, it is necessary to add 222mV to the readings obtained. (pers comm James Cheetham). This correction has been applied to the data presented in the mV/pH plots in Figures 10-13.

The ORP values vary with pH, and to examine the variation over time, values must be adjusted to a standard value of pH, using the equation below.

$Eh=Ep+222+59(7-pH)$ (pers comm James Cheetham)

Where Eh is the corrected redox potential in mV

Ep is the measured redox potential in mV

The values presented in Figure 3 have been treated in this way.

As discussed in Cheetham (2006), the data can be divided into categories as presented in Table 1 and this approach has been used to assess the variation in data over time.

Table 1 Categories of redox potential

Oxidation/Reduction status	Range of redox potential
Oxidised	+400 mV
Moderately reduced	+100 to +400 mV
Reduced	-100 to +100 mV
Highly reduced	-300 to -100 mV

(Derived from Patrick and Mahapatra 1968)

2.2.2 Water analysis

Chemical analysis of water samples has been undertaken by external specialists, Severn Trent Laboratories (STL).

3. Results

3.1 Locations

The three boreholes are located towards the edges of the development site. Borehole BH3 is in the entrance of the site and WS6 is to the rear of existing buildings alongside the site. These two locations are documented as the wetter zones beneath the site. WS7 is to the rear of the development site, close to the supermarket car park and located close to the site of the Roman Granary. This is recorded as being in a drier zone of the site. As these boreholes were put in for other purposes and are being re-used, we have not analysed the soils from these locations.

3.2 Piezometer readings

The water levels are presented in Figure 1. These data have not been adjusted for height at this time. There is a little variation in level over time but there have also been significant changes in the reference points as the well heads have been removed and the top of the wells eroded during the course of these measurements, and no firm conclusions can be drawn from the results.

3.2.1 Temperature measurements

The weather was recorded on each visit and is presented in Table 2.

Table 2:- Weather conditions and other influential factors on monitoring days.

07/03/08	Weather overcast and dry
19/03/08	Weather overcast and occasional light drizzle. Leaking tap on wall pouring water down WS6. May also influence other boreholes.

04/04/08	Weather overcast and dry. All wellheads machined off and rubble contamination
18/04/08	Weather windy and dry
29/04/08	Weather overcast with occasional showers
13/05/08	Weather hot and dry. BH6 covered with hardcore, then uncovered by digger driver for testing, and trench for services installed less than 0.5m from BH3
22/05/08	Weather hot and dry

The temperature data for the groundwater (see Figure 2) show a gradual increase until mid May, as could be expected.

3.2.2 ORP Results

Variation in ORP with time

The ORP data is more limited than the other data because a new probe was purchased for this project, which proved to be faulty after a few weeks of testing. The data over time from the replacement probe is shown in Figure 3. The data have been corrected to the Standard Hydrogen Electrode, and adjusted for pH.

All the data fall in the moderately reduced category (see Table 1), and the variation over time is moderate, but it is not realistic to get meaningful standard deviations from the limited data available.

3.2.3 Range of pH values

The variation in pH over time is presented in Figure 5.The pH values collected prior to this work commencing are also shown, with the data from this work from March 2008. The values are close to neutral, within the range of 6.5 and 7.3 for all boreholes in the present work. BN3 is slightly more alkaline than the other boreholes.

3.2.4 Conductivity

The conductivity data shows much higher values for WS7 than the other two boreholes. This is consistent with the high levels of sulphate in WS7, established by chemical analysis. The variation over time shows reasonable consistency. The drop in conductivity for all boreholes shown on 18th April ’08, and the subsequent slow recovery to previous values, may indicate intrusion of groundwater from heavy rain prior to that test.

3.2.5 Water sample analysis (Figures 7-12)

Sulphate and sulphide

Levels of sulphate in the BH3 and WS6 were close, at around 35 miligrams per litre (mg/l) in WS6 and 35 to 40 mg/l in BH3. They also both show an initial drop in sulphate concentration, possibly because the boreholes had been contaminated during flooding in 2007, and subsequent purging may have removed this contamination. The results for borehole WS7 at 1040-1110 mg/l are about thirty times the level for BH3 and WS6. This has been consistent throughout the test period.

Sulphate levels are low (typically less than 3mg/l) in all boreholes, although all three boreholes initially showed higher levels.

Nitrate and nitrite and ammonia

Nitrite levels were below the detection levels of 0.1mg/l for all samples.

The nitrate levels were more variable, with values between 0.3 and 0.8mg/l in WS6 and WS7. BH3 had higher levels of 2.5-3.5mg/l. All three boreholes had lower nitrate values initially, stabilising out after a few weeks of purging and sampling.

Ammoniacal nitrogen levels have also fallen throughout the period of testing and in recent weeks, the level in all three boreholes has been below the detection level of 0.03mg/l.

4. Recommendations

The period for monitoring is at the minimum recommended and the results above, and recommendations below, need to recognise that variation in future readings may reflect normal changes and not necessarily relate to changes resulting from construction activity (Ian Panter pers comm).

The ORP data presented in Figure 3 and in Table 3 falls into the moderately reduced category on the scale indicated in Patrick and Mahapatra (1968). This suggests that the water is drawn more widely than from the strata in the burial environment, where good preservation has been seen. The data probably represents an averaged data between the burial environment and some level of surface contributions, and this is re-enforced by the variation in sulphate levels observed over time, where surface water contributions are indicated.

Table 3:- Corrected ORP values

Borehole/date	18/4/08	29/4/08	13/5/08	22/5/08
BN3	225.87	186.29	172.57	233.13
WS6	306.51	290.87	290.82	187.15
WS7	269.87	232.61	272.87	262.48

ORP value = Ep+ 222 +59*(pH-7)

The limited volume of data for ORP does not lend itself to a control chart based on mean and standard deviations (see for example Western Electric Rules), but it is possible to suggest a pragmatic level where change from the baseline could be defined as significant.

Table 4:- As measured ORP values

Borehole/date	18/4/08	29/4/08	13/5/08	22/5/08
BN3	8	-54	-63	7
WS6	91	73	70	7
WS7	52	23	55	57

It is practically more useful to work with the as collected data, as this can be monitored in the field. This data is presented in Figure 4 and in Table 4. An increase to less reducing conditions of 50mV would appear to give a realistic indicator of change occurring, giving as measured action levels of

BH3 at 60mV as measured

WS6 at 140mV as measured

WS7 at 110 mV as measured.

It is suggested that one reading at this level should trigger a repeat measurement after one week and if that again gives the high level reading, action should be taken, by contacting the client and the curator.

Water levels should also continue to be monitored with more stable ground/datum levels established and any significant drop in water level trigger a similar action.

Changes in conductivity (greater than 30%) and changes in pH of greater than 7.8 and less than 6.0 where also considered as a trigger for similar action, but have not been recommended as very good preservation can occur with very low pH and for mildly alkaline conditions, and the complexities of urban site militate against using conductivity in many circumstances (Ian Panter pers comm).

5. Acknowledgements

The report, *Assessment of the burial environment at Street's Garage, Droitwich, Worcestershire,* (ref.: 63350, June 2006), compiled by James Cheetham from Wessex Archaeology, has been used as the framework for further data analysis presented in this document.

I am grateful for the support provided by James Cheetham in the conversion of data to the standard format.

I am also grateful for support and advice offered by Lisa Moffett, Regional Scientific Advisor from English Heritage, and for the review provided by Ian Panter of York Archaeological Trust.

6. Personnel

The fieldwork and report preparation was led by Christine Elgy. The project manager responsible for the quality of the project was Simon Woodiwiss. Ian Panter (York Archaeological Trust commented on an earlier version of this report.

7. Bibliography

Cheetham, J (2006) *Assessment of the burial environment at Street's Garage, Droitwich, Worcestershire*, unpublished report Wessex Archaeology ref.: 63350

GRM 2004 *Site appraisal for land at Brooklyn Ford, Priory Road, Alcester*, Ground Risk Management Limited, September 2004, reference P2714/F.1

Hawtin, T, 2006 *Archaeological evaluation: Brooklyn, Priory Road, Alcester, Warwickshire*, Archaeological Services and Consultancy Ltd, reference 760/APR/2

Hunn, J, 2007 *Brooklyn, Priory Road, Alcester, Warwickshire, project design for archaeological mitigation on behalf of Green Villa Developments*, Archaeological Services and Consultancy Ltd, reference 860/APR/01

Patrick, W H and Mahapatra, I C (1968). Transformation and availability to rice of nitrogen and phosphorous in waterlogged soils. *Advances in Agronomy* **20**: 323-359.

Figures

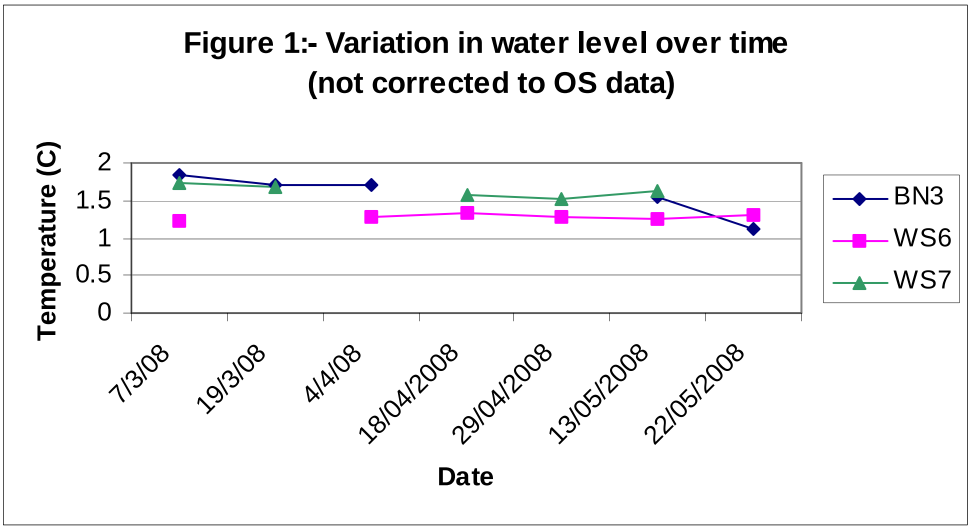
Figure 1:- Variation in water level over time
(not corrected to OS data)
Temperature (C)
2
1.5
1
0.5
0
7/3/08
19/3/08
4/4/08
18/04/2008
29/04/2008
13/05/2008
22/05/2008
Date
BN3
WS6
WS7

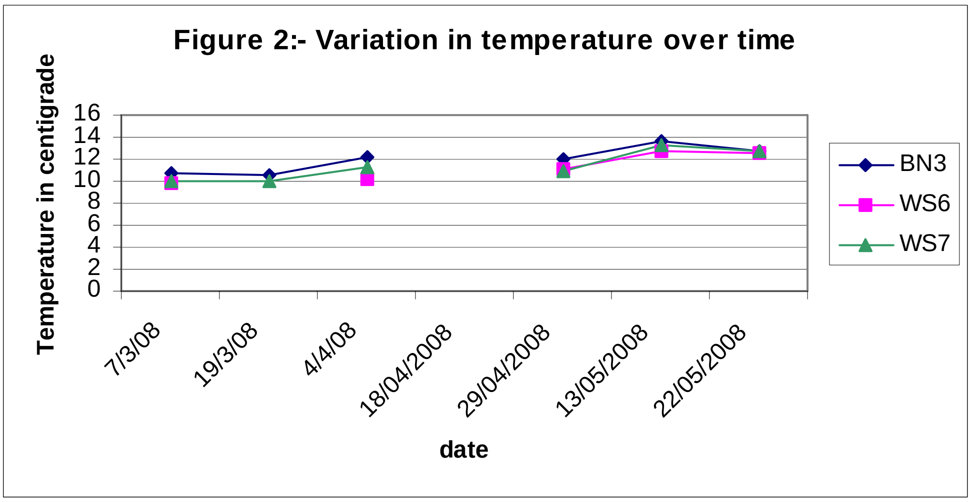
Figure 2:- Variation in temperature over time
Temperature in centigrade
16
14
12
10
8
6
4
2
0
7/3/08
19/3/08
4/4/08
18/04/2008
29/04/2008
13/05/2008
22/05/2008
date
BN3
WS6
WS7

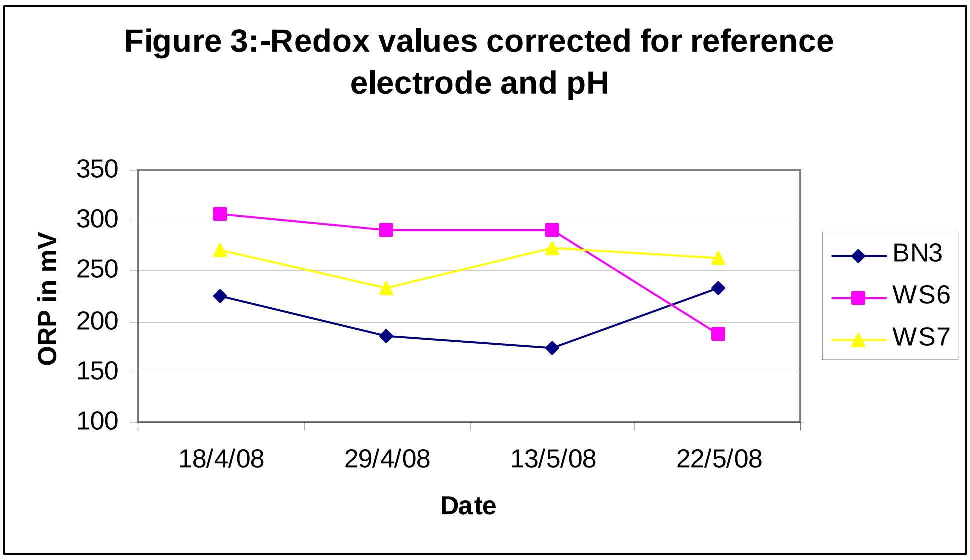
Figure 3:-Redox values corrected for reference electrode and pH
ORP in mV
350
300
250
200
150
100
18/4/08
29/4/08
13/5/08
22/5/08
Date
BN3
WS6
WS7

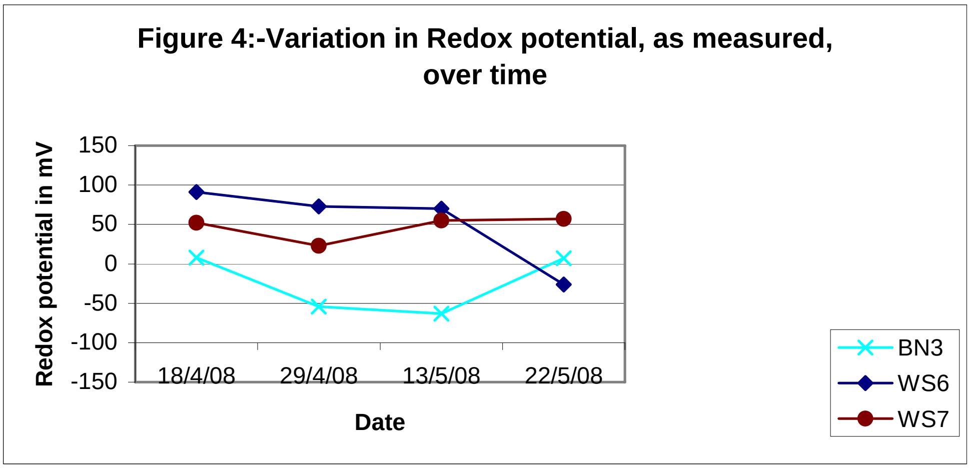

Figure 4:-Variation in Redox potential, as measured, over time

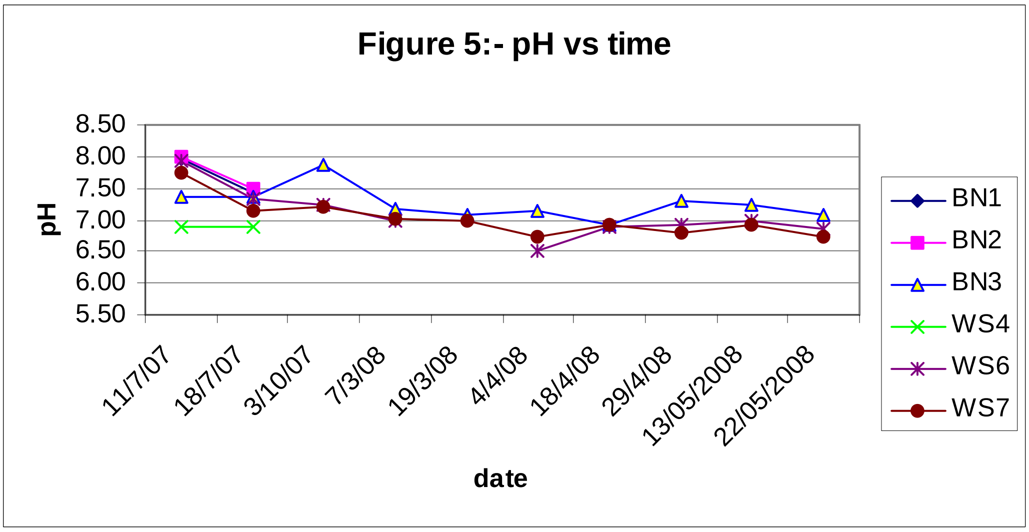

Figure 5:- pH vs time

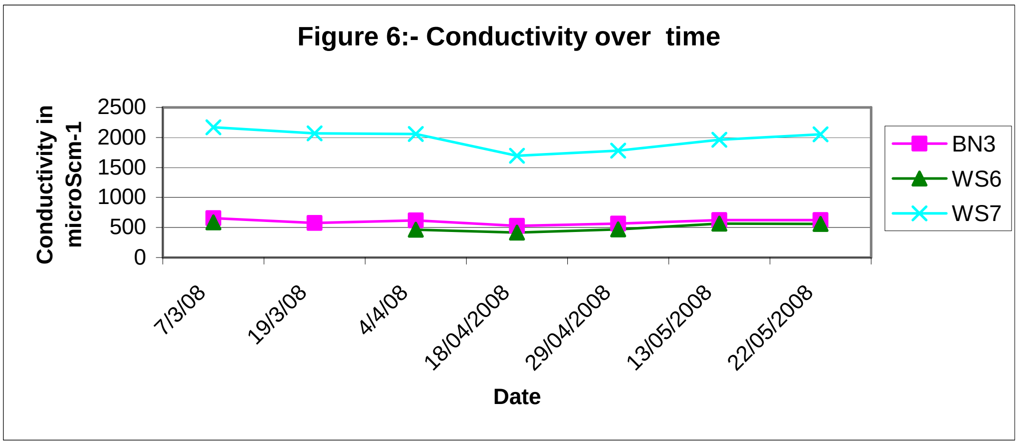

Figure 6:- Conductivity over time

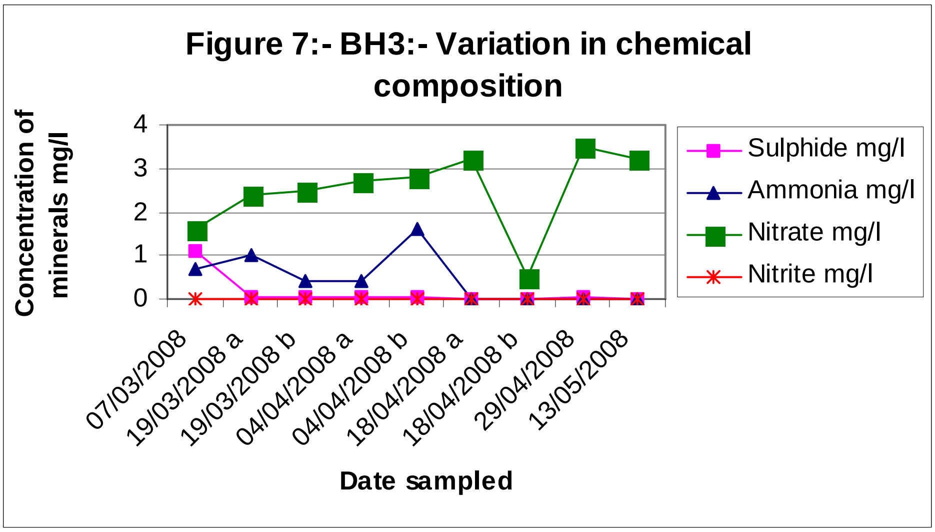
Figure 7:- BH3:- Variation in chemical composition
Concentration of minerals mg/l
4
3
2
1
0
07/03/2008
19/03/2008 a
19/03/2008 b
04/04/2008 a
04/04/2008 b
18/04/2008 a
18/04/2008 b
29/04/2008
13/05/2008
Date sampled
Sulphide mg/l
Ammonia mg/l
Nitrate mg/l
Nitrite mg/l

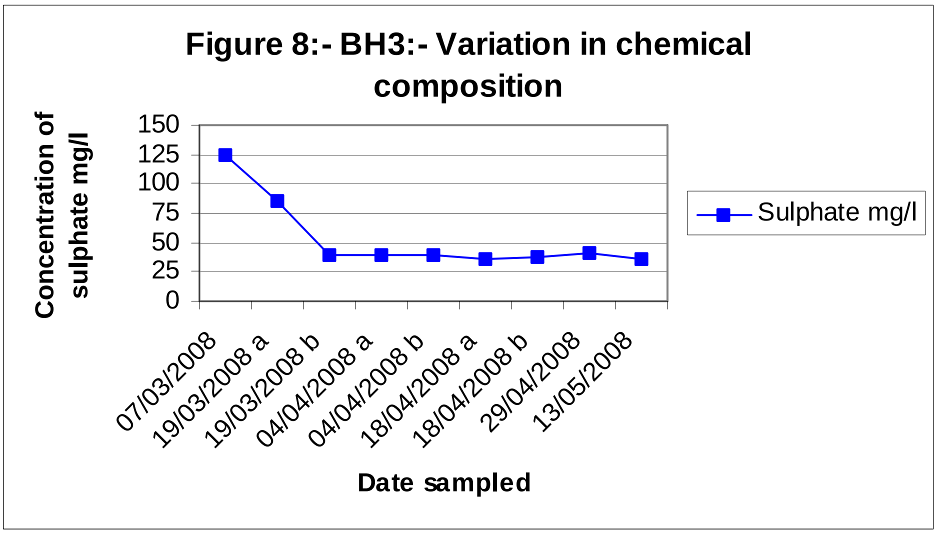
Figure 8:- BH3:- Variation in chemical composition
Concentration of sulphate mg/l
150
125
100
75
50
25
0
07/03/2008
19/03/2008 a
19/03/2008 b
04/04/2008 a
04/04/2008 b
18/04/2008 a
18/04/2008 b
29/04/2008
13/05/2008
Date sampled
Sulphate mg/l

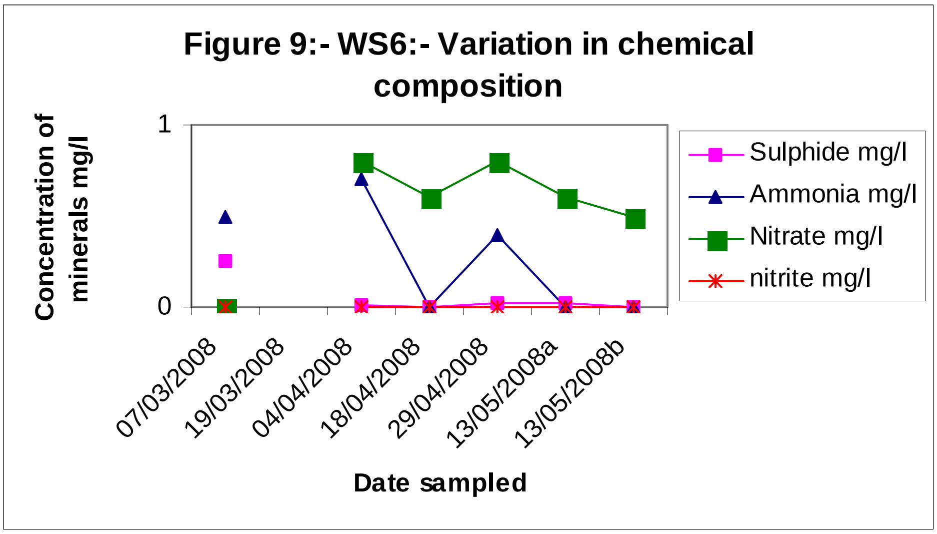
Figure 9:- WS6:- Variation in chemical composition
Concentration of minerals mg/l
1
0
07/03/2008
19/03/2008
04/04/2008
18/04/2008
29/04/2008
13/05/2008a
13/05/2008b
Date sampled
Sulphide mg/l
Ammonia mg/l
Nitrate mg/l
nitrite mg/l

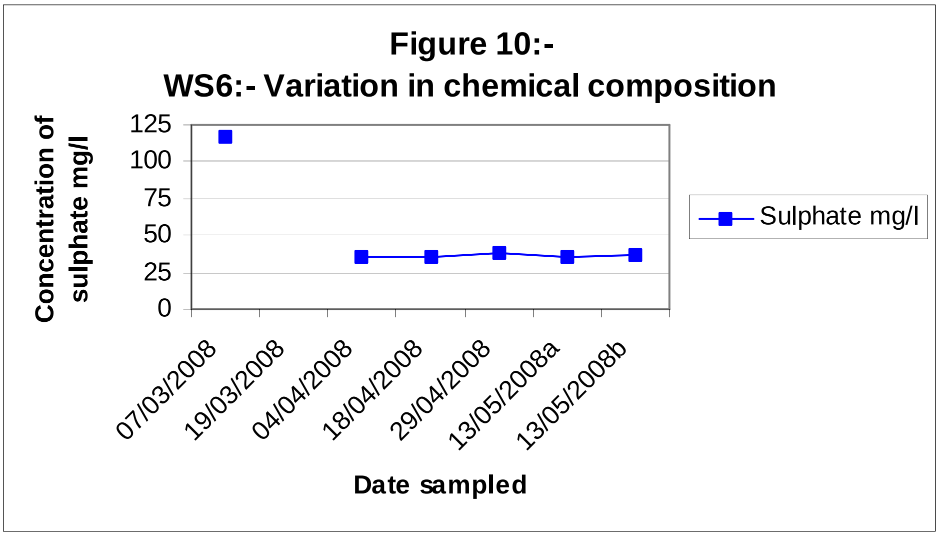
Figure 10:-
WS6:- Variation in chemical composition
Concentration of sulphate mg/l
125
100
75
50
25
0
07/03/2008
19/03/2008
04/04/2008
18/04/2008
29/04/2008
13/05/2008a
13/05/2008b
Date sampled
Sulphate mg/l

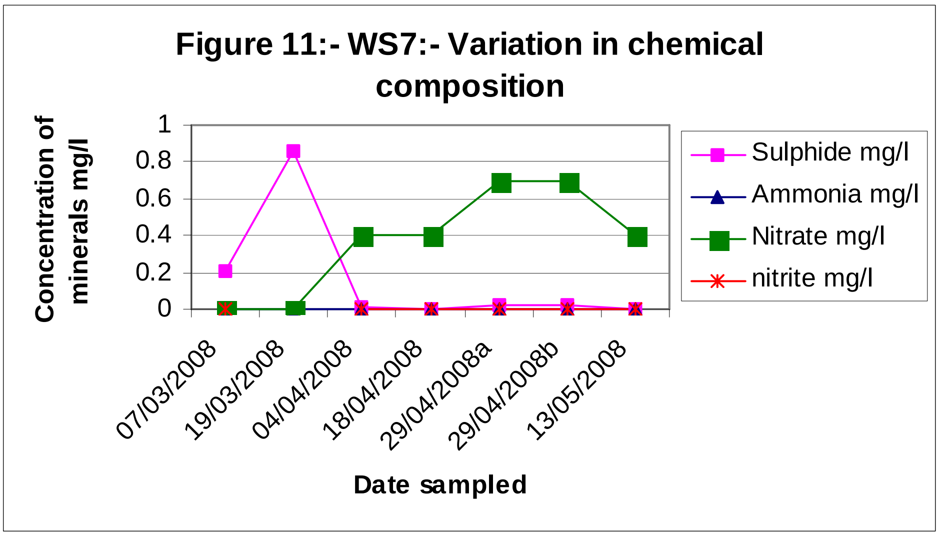
Figure 11:- WS7:- Variation in chemical composition
Concentration of minerals mg/l
1
0.8
0.6
0.4
0.2
0
07/03/2008
19/03/2008
04/04/2008
18/04/2008
29/04/2008a
29/04/2008b
13/05/2008
Date sampled
Sulphide mg/l
Ammonia mg/l
Nitrate mg/l
nitrite mg/l

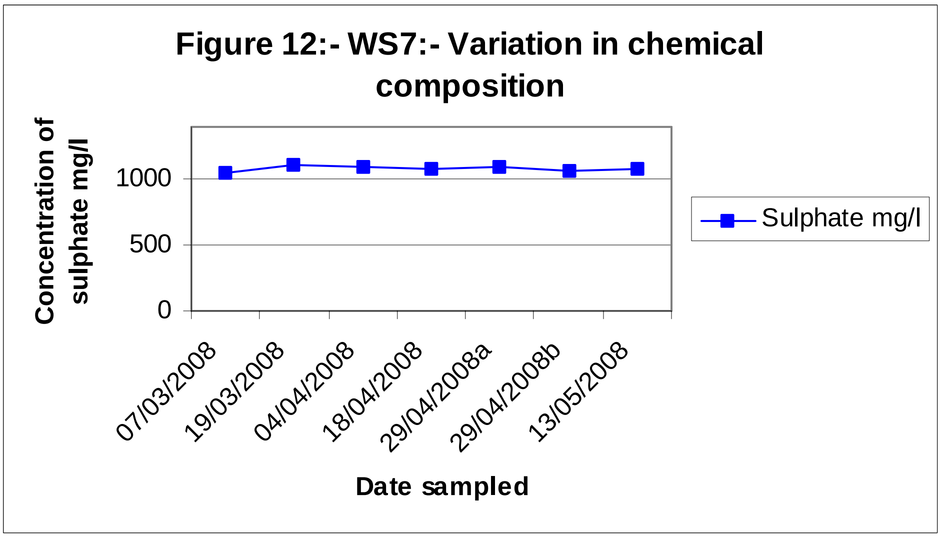
Figure 12:- WS7:- Variation in chemical composition
Concentration of sulphate mg/l
1000
500
0
07/03/2008
19/03/2008
04/04/2008
18/04/2008
29/04/2008a
29/04/2008b
13/05/2008
Date sampled
Sulphate mg/l

Appendix 1

Report number COV/ 501972/2008

07/03/08	Ammoniacal nitrogen mg/l	Nitrate mg/l	Nitrite mg/l	Sulphate mg/l	Sulphide mg/l
BH3	0.7	1.6	<0.1	125	1.1
WS6	0.5	<0.3	<0.1	117	0.25
WS7	<0.3	<0.3	<0.1	1050	0.21

Report number COV/ 501992/2008

19/03/08	Ammoniacal nitrogen mg/l	Nitrate mg/l	Nitrite mg/l	Sulphate mg/l	Sulphide mg/l
BH3	1.0	2.4	<0.1	85	0.05
BH3 repeat	0.4	2.5	<0.1	39.7	0.06
WS7	<0.3	<0.3	<01	1110	0.86

Report number COV/ 505905/2008

04/04/08	Ammoniacal nitrogen mg/l	Nitrate mg/l	Nitrite mg/l	Sulphate mg/l	Sulphide mg/l
BH3 (a)	0.4	2.7	<0.1	39.4	0.04
BH3 (b)	1.6	2.8	<0.1	38.9	0.03
WS6	0.7	0.8	<0.1	35.5	0.01
WS7	<0.3	0.4	<0.1	1090	0.01

Report number COV/ 509782/2008

18/04/08	Ammoniacal nitrogen mg/l	Nitrate mg/l	Nitrite mg/l	Sulphate mg/l	Sulphide mg/l
BH3 (a)	<0.3	3.2	<0.1	35.8	0.02
BH3 (b)	<0.3	0.5	<0.1	36.9	0.02
WS6	<0.3	0.6	<0.1	34.8	<0.01
WS7	<0.3	0.4	<0.1	1080	<0.01

Report number COV/ 512135/2008

29/04/08	Ammoniacal nitrogen mg/l	Nitrate mg/l	Nitrite mg/l	Sulphate mg/l	Sulphide mg/l
BH3 (a)	<0.3	3.5	<0.1	40.2	0.03
WS6	0.4	0.8	<0.1	38.2	0.02
WS7a	<0.3	0.7	<0.1	1100	0.02
WS7b	<0.3	0.7	<0.1	1060	0.02

Report number COV/ 515591/2008

13/05/08	Ammoniacal nitrogen mg/l	Nitrate mg/l	Nitrite mg/l	Sulphate mg/l	Sulphide mg/l
BH3	<0.3	3.2	<0.1	35.8	0.02
WS6 (a)	<0.3	0.6	<0.1	34.8	0.02
WS6 (b)	<0.3	0.5	<0.1	36.9	<0.01
WS7	<0.3	0.4	<0.1	1080	<0.01