Asiantaeth yr Amgylchedd Cymru
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Investigation into the impact of sewage effluent discharges on water quality in the Freshwater East area, Pembrokeshire

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Gareth Farr	Technical Officer Project Manager	Environment Agency Wales
Martin Doherty	Technical Specialist Main Reviewer	Environment Agency Wales
Rod Thomas	Senior Environment Officer	Environment Agency Wales
James Perry	Environment Officer	Environment Agency Wales
Simon Hughes & Alex Lewis	Geophysics	Terradat Geophysics
Fieldwork undertaken 15-18th January 2012 and 12th June 2012		

Environment Agency Wales. 2012. Hydrogeological assessment of Freshwater East, Pembrokeshire. Internal Report.

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Executive summary

Dwr Cymru/Welsh Water has been subject to a request to for the installation of mains sewerage in Freshwater East. This was initially made by residents in the form of a Section 101A, part of the Water Industry Act 1991. In December 2011 the Welsh Government served a notice on Dwr Cymru/Welsh Water as mains sewerage had not been installed. Following this Environment Agency Wales was asked to gather evidence on the impact of sewage effluent on water quality in the area. This report presents the first detailed water features survey and water quality analysis undertaken at Freshwater East.

The Freshwater East village is divided into three main **surface water catchments;** these are called Burrows, Lake and Freshwater East River. The risks to water quality within each are varied, although the majority of sewage effluent disposal occur within the Burrows catchment.

Geophysical techniques in the Burrows catchment identified that there was between 5-7m of blown sand beneath a survey line below the Devon Court flats. In the Lake catchment at the rear of Jason Road there are much thinner red soils overlying bedrock. Localised areas of clay rich deposits do occur and these may result in ineffective soakaways or ponding of sewage effluent.

Water quality analyses did not indicate any areas of significant contamination. Nitrate levels exceeded the drinking water standard (11.3mg/l N) at only one site, and ammonia, phosphate and boron levels were all below, or close to the lower limits of detection. Total coliform levels only exceeded the bathing water guideline at one site. Bathing water quality has been classed as excellent since 1999. Algae were also collected but no harmful blue green algae were identified. Microbial Source Tracking analysis did not detect any human bacteroidetes.

The investigation suggests that localised areas of impermeable soils and poorly maintained sewage treatment systems are the main cause of historic and current issues relating to the localised ponding of sewage effluent , however the data does not show significant or widespread areas of water contamination.

1. Introduction

The aim of the investigation is to gather hydrogeological information (primarily water quality) for the Freshwater East area. The data was used to improve the conceptual understanding of the hydrogeology in the Freshwater East area, and to determine if the effluent discharges from individual homes pose a risk to environmental receptors such as groundwater, surface water and bathing waters. There are no private drinking water supplies in the area, with all properties being served by mains drinking water.

The conceptual model was underpinned by the following:

- a detailed water features survey
- comprehensive water quality baseline analysis
- delineation of surface water catchments
- geophysical investigation

Freshwater East is subject to a section S101A process (request for installation of mains sewerage) and Dwr Cymru / Welsh Water (DCWW) have been instructed by the Welsh Government to install mains sewerage. A petition with 103 signatures was submitted to the Welsh Government by residents of Freshwater East who are opposed to the scheme. Faber Maunsel (DCWW's consultants) concluded that there is no duty under the S101A process for DCWW to install mains sewerage. DCWW failed to install mains sewerage and a notice was served on them by Welsh Government in December 2011. Subsequent to this Environment Agency Wales (EAW) was instructed by the Welsh Government to undertake this water quality investigation.

Although three detailed surveys of the type and location of private sewage treatment systems have been carried out over the last ten years (DCWW 2000 and Faber Maunsell 2005 & 2009) only limited evidence as to the impact of these systems on water quality has been collected.

2. Freshwater East

Freshwater East is a small coastal village located in Pembrokeshire, West Wales. It contains residential properties and numerous holiday homes although the exact numbers of each type are not known. There is one public house which is located on Jason Road.

3. Summary of previous work by Dwr Cymru / Welsh Water

Since the section S101A process was initiated the following reports have been completed:

- Dwr Cymru, 2000. Water Industry Act Section 101A. Report on Freshwater East
- Faber Maunsell, 2005. Dwr Cymru Welsh Water Section 101A Assessment
- Faber Maunsell, 2009. Dwr Cymru Welsh Water Section 101A Assessment

Detailed surveys of all properties and the location of their private sewage treatment systems were made, and all known surface outbreaks of effluent were recorded.

The 2009 report concluded that:

- **There is no duty under Section 101A of the Water Industry Act 1991 to provide public sewerage for any properties in this locality.**

Some of the other conclusions were:

- Bathing water quality in Freshwater East bay is classed as excellent by EAW
- Neither inland or coastal waters appear to be impacted by pollution problems emanating from the locality
- No evidence of pollution was observed during any site visits
- It is unlikely that there are any significant adverse effects on any of the local environmentally designated sites
- Problems are generally related to maintenance issues

Although DCWW and Faber Maunsell provided detailed information on the location and type of private sewerage treatment systems they failed to collect any detailed water quality data or expand our understanding of the geology and hydrogeology of the area.

The main areas where the existing reports lack information are:

- Water Features Survey: no detailed survey was undertaken. Identifying where springs occur gives an insight into the hydrogeology and allows water quality samples to be obtained.
- Water Quality: only one sample was collected, at the base of the cliffs. No water quality issues were reported.
- Percolation Tests: The only records are two failed tests to the rear of Jason Road and one test at 'Sunblest' with a Vp of 17s/mm.
- Conceptual understanding: little consideration was given to attempting to understand the area first before considering which properties were considered to be in an area deemed 'at risk'.

This report provides further information on these points.

4. Water Features Survey

The water features survey (WFS) was undertaken on the 16th of January 2012 by Gareth Farr and Rod Thomas of Environment Agency Wales (see Figure 1 and Appendix 1).

It is only during winter or after sufficient recharge that many of the water features such as springs, streams and dune slacks are active. During other times of the year recharge to the aquifer is limited such that many of the water features, such as slacks are absent and springs may have reduced flows.

The WFS included all accessible surface water and groundwater features within the Freshwater East area. In addition all drains, culverts and ditches were surveyed and where possible water quality samples were collected.

There are no private water supplies in the area and all homes are supplied with mains drinking water.

5. Geological Summary

Sid Howells (Countryside Council for Wales - Geologist) provided an introductory geological site walkover on the 15th of January 2012. In addition to this, his detailed observations and local knowledge were used to gain a better local understanding of the bedrock and superficial geology.

The bedrock geology (Figure 2) comprises Silurian and Lower Devonian strata, which are classed as secondary aquifers. The geology is faulted and orogenic earth movements have resulted in the beds dipping at near vertical or subvertical angles, with a EEN-SSW strike. Where faults occur the displacement maybe up to 50m (Sid Howells pers comms) putting Silurian strata in contact with the Devonian Lower Old Red Sandstone.

The faulting within the bedrock is most obvious to the east of the beach, where several fault derived gullies have formed. There are probably faulted structures within the bedrock elsewhere in Freshwater East however the superficial deposits prevent these from being observed.

The overlying layer of clay rich soliflucted deposits lie directly upon both the Silurian and Devonian strata. The thickness of the soliflucted deposits vary with the greatest thicknesses occurring below the blown sands.

The blown sand deposits (Figure 4 & 5) which overly the soliflucted deposits are wide ranging in their distribution and thickness. The blown sands are visible and form the dunes and burrows at Freshwater East. Onshore winds have led to sands being blown over the crest of the ridge (marked by Jason Road). Blown sand deposits are thicker at the western end of Jason Road and appear to be thinner or non existent at the eastern end.

6. Surface water catchments

There are three surface water catchments in the Freshwater East area (Figure 3) called Burrows, Lake and Freshwater East Stream. The catchments will dictate the direction of surface water, shallow soil water and groundwater flow. It is in the Burrows catchment that the majority of sewage effluent is discharged. Effluent will generally follow the same flow path as surface water within each catchment.

Shallow groundwater flow is largely governed by the surface water catchments although it is also possible that groundwater can cross surface water catchments via faults and fractures in the bedrock aquifer. Therefore surface water catchments should not be used to define groundwater catchments, although they do give some understanding into flow paths for sewage effluent.

Burrows catchment: This covers the majority of Freshwater East and is the principal focus of this study. The majority of homes and private sewage treatment systems are found here. Blown sand deposits dominate the area, however the underlying clay rich soliflucted deposits and bedrock also outcrop at the surface. The soliflucted layer may create a low permeability horizon between the sands and bedrock geology. The predominant landuse in the area is residential, with small amounts of agriculture in the east. Groundwater within the Burrows catchment drains mainly towards the coast, discharging diffusely across the face of the dune system, and at springs at the eastern end of the beach.

Lake catchment: This differs from the Burrows catchment as it is covered with soils from the Manod association, and there are less blown sand deposits. The catchment is underlain by Silurian and Devonian Old Red Sandstone strata. Surface water flows are to the north and not towards the coast in contrast to flow in the Burrows catchment. There are fewer residential properties, and low intensity agriculture dominates the upper part of the catchment north of Jason Road. It is likely that several of the Jason Road properties will drain into this catchment and not the Burrows catchment.

Freshwater East Stream catchment: This is the largest of the three catchments however it is not thought that properties in Freshwater East are posing a threat to the water quality. It is landuse and discharges within this catchment that probably have the main control on the water quality, however there is also a storm water overflow for the treatment plant at the caravan site. It is not thought that private sewage treatment systems in the Burrows catchment pose a risk to water quality in the Freshwater East stream which discharges to the coast at the western end of the beach.

7. Geophysical investigation

Terradata (Cardiff) carried out geophysical investigations in the area on the 18th of January 2012. Electrical resistivity using a 2m line spacing, seismic refraction and ground penetrating radar were the techniques used.

The main aims were to investigate the:

- depth of the soil / blown sands overlying the bedrock
- geological structure beneath the blown sands
- depth to the water table within the blown sands

Two sections were prepared (Figures 6 & 7).

Section 1 – Jason Road West

This comprised a 140m survey line (Figure 6) running almost east west behind the houses at the eastern end of Jason Road. This line was used to follow the rear of the properties where ponded effluent has been observed. Five hand augured holes were also made to compliment the geophysical work.

Investigations proved that the thickness of soil behind the houses ranged from 30-45 cm with bedrock encountered below. However in the area behind Eastfield (Site 21 – foul effluent) a 1.9m depth of clay was encountered. This would explain why foul effluent was ponding on the ground surface at this location.

Section 2 – Devon Court

This comprised a 220m survey line (Figure 7) running north-south, starting at the public footpath by Devon Court Flats and extending down towards the coast. The location of this line was based upon the requirement for a straight line profile down through the dunes. It is also downgradient of perhaps the largest sewage treatment system in Freshwater East, that serving the Devon Court flats.

No hand augured holes were made along this section, mainly due to time constraints but also due to the limited operational depth of the hand auger (2-3m) which could only partially penetrate the thicker blown sand deposits.

The section shows there is a relatively even depth of blown sand (some 5-7m) above the bedrock, in the area below Devon Court flats. In the approximate location where the property 'Wavecrest' used to stand, the seismic survey detected another layer. This is either a layer of soliflucted clay or saturated blown sand.

8. Water Quality

Where possible and where sites were accessible water quality samples were collected. In total 23 water quality samples were collected and the results are presented in Table 1. Only one of these samples was from an area of ponded sewage effluent (Site 21). The first survey samples came from all three surface water catchments and were collected between 17th – 18th of January 2012 in line with the Environment Agency Sampling Protocol ES006. The samples were transported the same day to the Environment Agency Laboratory in Starcross where analyses were undertaken and results were then stored on the Environment Agency's 'WIMS' database. A second survey was undertaken on 12th June 2012.

The **historical water quality** data at Freshwater East is limited to samples collected from the Freshwater East stream (WIMS 86212), which flows onto the western end of the beach, and to summer bathing water samples (WIMS 39029), also collected by EAW. This data will be discussed in the 'Freshwater East Stream catchment' section below.

The **bathing water quality** monitoring and recent Bathing Water Profile (EA, 2012) show that Freshwater East beach has achieved a 'Higher' water quality standard between 1999 – 2011.

Surprisingly, considering the concern about private sewage treatment systems only one water quality sample had previously been collected within the Burrows or Lake catchments. The sample collected in June 2004 (Faber Maunsell, 2009) was obtained at the 'Beach Waterfall' (equivalent to Site 14 in this investigation) and the analysis showed there was no nutrient enrichment.

For the current investigation each water sample was analysed for the major and minor ions, selected metals, nutrients (nitrate, phosphate, orthophosphate) and bacteriological contaminants. Boron was analysed as a known tracer for detergent effluent. Each sample was collected as close to the source (often the spring head) as possible, with the samples being returned to the laboratory the same evening.

Survey 1 Results

Water Quality in the Burrows catchment: Fifteen water samples were collected. There was no visible evidence of sewage pollution, such as ponding of sewage effluent. Nitrate values range from 2.69 – 10.9 mg/l as N. Phosphate results are only above detection in the springs below Devon Court (Sites 3&4) at 0.0567mg/l and 0.0575mg/l respectively and within the small dune slack (Site 6) at 0.0539mg/l. Ammonia results are below the detection limit in all samples except for Site 11 where a value of 0.035mg/l was recorded.

A total coliform limit of 500 cfu 100 ml^{-1} was used to highlight water samples that may have been impacted by sewage effluent in this and other catchments. This limit is the same as the recommended guideline limit used for freshwater and bathing waters, however it should be noted that the mandatory upper limit for bathing waters is 10,000 cfu 100 ml^{-1}.

The recommended coliforms limit of 500 cfu 100 ml^{-1} was breached at two locations (Sites 27 & 14) within the Burrows catchment. Site 27 is the spring at the eastern end of Jason Road with total coliforms of 818 cfu 100 ml^{-1}. Site 14 is the main beach waterfall at

the eastern end of the beach where total coliforms were recorded at 12000 cfu 100 ml^{-1}. In addition both of the beach springs (Sites 12 & 13) close to the beach waterfall (Site 14) recorded total coliforms >100 cfu 100 ml^{-1}. The catchment for the beach waterfall (Site 14) extends up to the houses to the south of Jason Road, however none of the springs which supply this waterfall (sites 18-20) recorded total coliforms greater than 100 cfu 100 ml^{-1}.

All the results for boron were below the level of detection of 100ug/l.

Water Quality in the Lake catchment: Six water quality samples were collected from the Lake catchment. There was clear evidence of sewage pollution at one location to the rear of Eastfield (Site 21), where the septic tank was overflowing and/or the soakaway was ineffective.

Nitrate concentrations ranged from 1 – 14.2 mg/l as N, averaging 7.4mg/l. Other than from the direct sample of sewage effluent phosphate concentration ranged from <0.02 – 0.172mg/l. The Holy Well (Site 26) and the springs at the top of the Springfield Stream (Sites 22, 23 & 25) all have concentrations above the limit of detection. Ammonia was below the limit of detection (0.03mg/l) in all six samples.

Total coliforms breached the limit of 500 cfu 100 ml^{-1} at one spring, Site 23 (this does not include the sample of sewage at site 21). The spring registered 550 cfu 100 ml^{-1} and is the first spring downgradient of the area where the sewage pollution was recorded.

All the results for boron were below the level of detection of 100ug/l.

Water Quality in the Freshwater East Stream catchment: As mentioned above, the main sample point at Freshwater East is the stream which flows onto the western end of the beach. The flow of water from the Lake catchment on the Freshwater East beach is far greater than that from the Burrows or Lake catchment. Total coliforms of 550 cfu 100 ml^{-1} breached the initial guideline limit of 500 cfu 100 ml^{-1}. However it is not thought that any of the properties located within Freshwater East will drain into this catchment or contribute to water quality at the point where the Freshwater East Stream enters the beach.

Survey 2 Results

The round 2 sampling has shown that the major and minor ions appear to have remained consistent at all sites. There were no large changes in the levels of nitrate or phosphate between the initial samples in round , in January, and round 2 in June, 2012. Nitrates are elevated above drinking water standards at one location (Site 27) and close to the standards at sites 22 and 25.

Ammonia is below the detection limit in the majority of samples as in round 1. Only the Freshwater East River showed detectable levels of ammonia.

9. Microbial Source Tracking MST

Microbial Source Tracking (MST) was undertaken on all samples during round 2. Site 21 (the area of ponded sewage effluent) and site 22 (head of Springfield stream) were not re sampled. The sampling was undertaken by Gareth Farr, Matt O'Brien and Lucy Tooher of Environment Agency Wales.

MST can indicate if bacteroidetes present are from human or ruminant (animal) sources. The method gives a qualitative (absent or present) answer rather than a quantitative answer. MST is a useful tool but should not be solely used for decision making. It should be considered as a guide and not proof of the source of bacteroidetes.

Although the relevant laboratory procedures carry United Kingdom Accreditation Service (UKAS) accreditation, the quantitative reporting of gene copy numbers is not covered by the UKAS accreditation. The uncertainty of measurement of the laboratory testing has been assessed; however in the real world situation is unknown. Until this has been further evaluated, the microbial source-tracking data should not be considered as quantitative.

10. Water Quality Summary

The results indicate that there is no evidence of significant water quality issues in the Freshwater East area. Nitrates are elevated above drinking water standards at one location (Site 27). This spring is likely to have its catchment in an agricultural area. Ammonia is below the detection limit in 20 of the 23 samples. Boron is below the detection limit of <100ug/l in all samples.

Where total coliforms are elevated, for example in the beach waterfall (Site 14) further investigation during periods of peak occupancy in the village would provide valuable additional information. The relatively small flow of this water feature (1.3 l/s) and subsequent dilution in sea water will however reduce any potential impacts on the bathing waters.

The results of the MST analysis can only be used in a qualitative manner and in conjunction with other evidence. **The MST analysis did not detect any human bacteroidetes.**

The MST analysis only detected ruminant (animal) bacteroidetes at three sites. These sites were Site 10 Main Outflow of Freshwater East River, Site 23 Springfield Spring 1 and Site 27 Spring near Eastfield.

Site	Site 2	Date Time	Geology	Catchment	EC 25C	Temp oC	BOD 5 Day ATU	Alkalinity to pH 4.5 as CaCO3	Ammoniacal Nitrogen as N	Nitrite as N mg/l	Nitrogen : Total Oxidised as	Nitrate-N mg/l	Orthophosphate, reactive as P mg/l	Phosphate : Total as P mg/l	Sodium mg/l	Calcium mg/l	Magnesium mg/l	Potassium mg/l	Chloride mg/l	Bicarb HCO3 mg/l	Sulphate as SO4 mg/l	Solids, Suspended at 105 C	Hardness mg/l	Iron, Dissolved ug/l
1	Historic Private Water Supply Well for village	12/06/2012 @ 12:35	Devonian ORS	Burrows	460	10.8	1	149	<.03	<.004	6.15	6.15	0.029	0.032	25	68	4.97	1.69	39	182	15.4	3.02	190	<30
1	Historic Private Water Supply Well for village	17-Jan-12 @ 15:22	Devonian ORS	Burrows	260	11.2	<1	145	<.03	<.004	10.6		0.023	<.02					50.1			<3		<30
3	Devon Cour Spring 1	12/06/2012 @ 9:45	Devonian ORS	Burrows	610	11.6	<1	221	<.03	<.004	6.14	6.14	<.02	0.0684	29.4	99.4	8.57	1.55	46.2	270	20.2	108	283	<30
3	Devon Cour Spring 1	17-Jan-12 @ 16:00	Devonian ORS	Burrows	620	11	<1	226	<.03	<.004	6.78	6.78	<.02	0.0567	30	100	8.81	1.65	46.4	276	18.4	132	286	<30
4	Devon Court Spring 2	12/06/2012 @ 9:52	Devonian ORS	Burrows	630	11.8	<1	226	<.03	<.004	6.74	6.74	<.02	0.0244	31	99.5	7.94	1.69	48.4	276	22	26.8	281	<30
4	Devon Court Spring 2	17-Jan-12 @ 16:05	Devonian ORS	Burrows	650	10.7	<1	228	<.03	<.004	6.85	6.85	<.02	0.0575	30.1	101	7.89	1.79	49	278	19.8	233	285	<30
6	Dune Slack 1 (small)	17-Jan-12 @ 10:56	Blown Sands	Burrows	760	9	2	278	<.03	0.016	8.32	8.3	<.02	0.0539	34.9	114	14.5	2.14	66	339	24.5	20.3	344	<30
8	Dune Slack 2 (Lagre)	12/06/2012 @ 9:27	Blown Sands	Burrows	640	15.4	1	231	<.03	0.057	3.24	3.18	<.02	<.02	33.9	98	11.4	0.589	58.2	282	20.9	6.27	292	<30
8	Dune Slack 2 (Lagre)	17-Jan-12 @ 11:05	Blown Sands	Burrows	680	5.2	1	246	<.03	0.026	4.58	4.55	<.02	<.02	34.6	99	11	1.49	62.8	300	20.6	<3	292	<30
9	Bypass Road Highway Drain into Freshwater East river	17-Jan-12 @ 10:36		Burrows	680	10.7	<1	224	<.03	<.004	5.46	5.46	<.02	<.02	34.2	99.2	9.16	1.78	62.2	273	24	<3	285	<30
10	Main Outflow Freshwater East River at footbridge	12/06/2012 @ 8:55			410	11.5	<1	117	0.061	0.072	5.23	5.16	0.074	0.111	24	44	9.6	2.59	37		14	6.77	149	
10	Main Outflow Freshwater East River at footbridge	17-Jan-12 @ 10:30		FwEast Stream	400	7	<1	113	0.04	0.046	5.92		0.038	0.0602	25.4	45.4	9.48	2.18	40.7		14.4	4.63		186
11	Junction of sand and soliflucted material	12/06/2012 @ 14:21	Blown Sands	Burrows	540	16.1	<1	223	<.03	<.004	<.2	<.196	<.02	<.02	34.8	80.8	5.69	0.14	45.1	272	12.8	<3	225	<30
11	Junction of sand and soliflucted material	17-Jan-12 @ 12:53	Blown Sands	Burrows	530	9	1	207	0.035	<.004	2.69	2.69	<.02	<.02	30	76.3	6.74	1.98	55.7	253	11.5	<3	218	<30
12	Beach Spring 1 (same as site 13)	17-Jan-12 @ 12:12	Silurian Gray SST	Burrows	650	10.8	<1	227	<.03	<.004	5.4	5.4	<.02	<.02	33.3	97.7	9.1	1.54	57.3	277	19.6	17.4	281	<30
13	Beach Spring 2 (Tufa Gray Sandstone Formation) Same as Site 12	12/06/2012 @ 10:19	Silurian Gray SST	Burrows	630	12.1	<1	223	<.03	<.004	4.01	4.01	<.02	<.02	33.1	93.6	9.13	1.28	56.7	272	20.1	5.87	271	<30
13	Beach Spring 2 (Tufa Gray Sandstone Formation) Same as Site 12	17-Jan-12 @ 12:09	Silurian Gray SST	Burrows	640	10.7	<1	229	<.03	<.004	5.31	5.31	<.02	<.02	33.1	97.7	9.05	1.5	58.2	279	19.5	4.25	281	<30
14	Beachwaterfall (main flow to eastern part of beach)	12/06/2012 @ 10:28	Devonian ORS	Burrows	620	12.3	<1	220	<.03	<.004	5.86	5.86	<.02	<.02	36.2	91.4	10.9	1.26	57.6	268	22.4	9.47	273	<30
14	Beachwaterfall (main flow to eastern part of beach)	17-Jan-12 @ 12:11	Devonian ORS	Burrows	660	9.5	1	223	<.03	<.004	7.1	7.1	<.02	<.02	35.6	95.5	11	1.48	60.9	272	22.4	27.4	284	<30
15	Beach Spring 3	12/06/2012 @ 10:39	Devonian ORS	Burrows	660	12.7	<1	190	<.03	<.004	6.02	6.02	<.02	<.02	50.6	78.5	11	1.87	83.3	232	25.1	<3	241	<30
15	Beach Spring 3	17-Jan-12 @ 12:36	Devonian ORS	Burrows	670	10.2	<1	184	<.03	<.004	6.82	6.82	<.02	<.02	46.4	80.9	10.3	1.39	85.1	224	24	<3	244	52.6
16	Beach Spring 4	12/06/2012 @ 10:46	Devonian ORS	Burrows	670	11.9	<1	171	<.03	<.004	6.36	6.36	<.02	<.02	51.7	77.4	10.6	1.3	91.6	209	25.8	<3	237	<30
16	Beach Spring 4	17-Jan-12 @ 12:50	Devonian ORS	Burrows	690	10.8	<1	170	<.03	<.004	6.99	6.99	<.02	<.02	49.6	78.3	10.2	1.29	90.7	207	25.3	<3	237	<30
18	Spring 1 (flows to Beach Waterfall)	12/06/2012 @ 11:02	Devonian ORS	Burrows	240	11.5	<1	228	<.03	<.004	5.47	5.47	<.02	0.0555	33.4	97.6	10.4	1.46	57.1	278	21.3	103	287	<30
18	Spring 1 (flows to Beach Waterfall)	17-Jan-12 @ 11:56	Devonian ORS	Burrows	560	11.2	<1	232	<.03	<.004	6.91	6.91	<.02	<.02	34.1	99.4	9.86	1.56	57.5	283	21.5	<3	289	<30
19	Spring 2 (flows to Beach Waterfall)	12/06/2012 @ 11:13	Devonian ORS	Burrows	240	11.5	<1	239	<.03	<.004	6.32	6.32	<.02	<.02	34.3	102	11.4	1.11	55.6	292	22.2	9.52	302	<30
19	Spring 2 (flows to Beach Waterfall)	17-Jan-12 @ 11:42	Devonian ORS	Burrows	690	11.3	<1	243	<.03	<.004	7.5	7.5	<.02	<.02	34.1	101	11.1	1.25	57.2	296	22.2	6.73	298	<30
20	Spring 3 (flows to Beach Waterfall)	12/06/2012 @ 11:22	Devonian ORS	Burrows	680	11.6	<1	235	<.03	<.004	6.85	6.85	<.02	<.02	36.7	96.2	11.8	1.35	56.7	287	23.5	8.07	289	<30
20	Spring 3 (flows to Beach Waterfall)	17-Jan-12 @ 11:36	Devonian ORS	Burrows	690	11.6	<1	238	<.03	<.004	7.65	7.65	<.02	<.02	35.5	97.4	11.7	1.46	58.3	290	23.2	20.2	291	<30
21	Eastfield FOUL EFFLUENT overflow	17-Jan-12 @ 14:32	n/s	Lake	280		114	222	14.6	<0.1	<1	<.9	2.22	3.37	26.5	75.1	5.42	1.62	44	271	15.7	223	210	<30
22	Springfield Stream Close to head	17-Jan-12 @ 14:30	Devonian ORS	Lake	210	11	2	86	<.03	<.004	11.3	11.3	0.021	0.0634	29	50.3	7.58	1.13	47.6	105	11.8	38.5	157	<30
23	Springfield Stream Spring 1	12/06/2012 @ 13:55	Devonian ORS	Lake	480	11.2	<1	189	<.03	<.004	3.84	3.84	0.023	0.0388	26	72.5	6.98	1.16	34.8	231	14.5	23.9	210	<30
23	Springfield Stream Spring 1	17-Jan-12 @ 14:28	Devonian ORS	Lake	470	10.6	<1	174	<.03	<.004	4.46	4.46	0.037	0.0377	27.2	67.8	6.92	1.28	36.4	212	14.8	124	198	35.2
24	Springfield Stream Spring 2	12/06/2012 @ 13:47	Devonian ORS	Lake	480	10.9	<1	197	<.03	<.004	3.72	3.72	<.02	<.02	22.3	75.6	7.12	1.12	31.4	240	10.9	<3	218	<30
24	Springfield Stream Spring 2	18-Jan-12 @ 09:45	Devonian ORS	Lake	450	10.6	<1	176	<.03	<.004	3.89	3.89	<.02	<.02	22.2	69.9	6.4	1.13	32.1	215	10.7	<3	201	<30
25	Springfield Stream Spring 3	12/06/2012 @ 13:35	Devonian ORS	Lake	320	11.1	<1	68	<.03	<.004	8.38	8.38	0.027	0.0298	26	32.6	7.95	0.86	40.1	83	12	10.5	114	<30
25	Springfield Stream Spring 3	18-Jan-12 @ 09:40	Devonian ORS	Lake	320	10.9	<1		<0.03	<0.004	11.1	11.1	0.025	0.0881	27.5	35.2	8.4	1.04	43.5	75.6	12.3	128	122	2.17
26	Holy Well	12/06/2012 @ 12:53	ORS/Blown Sand	Lake	550	11.3	<1	211	<.03	<.004	5.7	5.7	0.152	0.164	24.1	85.3	8.28	2.44	36.1	257	13.6	<3	247	<30
26	Holy Well	17-Jan-12 @ 11:46	ORS/Blown Sand	Lake	560	11	<1	217	<.03	<.004	5.77	5.77	0.166	0.172	24	87	7.78	2.42	34.5	265	12.5	<3	249	<30
27	Spring near Eastfleid flowing into Burrows catchment	12/06/2012 @ 13:14	Devonian ORS	Burrows	450	11.9	<1	96	<.03	0.005	11.5	11.5	<.02	0.0301	28.5	54	6.31	1.06	49.7	117	11.2	13.3	161	<30
27	Spring near Eastfleid flowing into Burrows catchment	17-Jan-12 @ 13:51	Devonian ORS	Burrows	450	8.9	<1	91	<.03	<.004	14.2	14.2	<.02	<.02	29.1	54.5	6.43	1.11	50.9	111	11	6.3	163	<30

Site	Site 2	Date Time	Geology	Catchment	Manganese Dissolved ug/l	Iron ug/l	Manganese ug/l	Boron ug/l	IonicBalance %	Coliforms, Faecal : Presumptive : Membrane Filtration	Streptococci, Faecal : Presumptive : Membrane Filtration	Coliforms, Total : Presumptive : Membrane Filtration	Bact Human CN lgN/0_1l	Bact Rumnt CN lgN/0_1l	E_coli C-MF NO/100ml	IE Conf CFU/0_1l	Human Bacteroidetes	Ruminant Bacteroidetes
1	Historic Private Water Supply Well for village	12/06/2012 @ 12:35	Devonian ORS	Burrows	<10	<30	<10		0.96				<2	<2	54	<10	Absent	Absent
1	Historic Private Water Supply Well for village	17-Jan-12 @ 15:22	Devonian ORS	Burrows	<10					27	< 10	81						
3	Devon Cour Spring 1	12/06/2012 @ 9:45	Devonian ORS	Burrows	<10	1240	70.2		2.97				<2	<2	<10	<10	Absent	Absent
3	Devon Cour Spring 1	17-Jan-12 @ 16:00	Devonian ORS	Burrows	<10	1690	216	<100	2.67	18	< 10	63						
4	Devon Court Spring 2	12/06/2012 @ 9:52	Devonian ORS	Burrows	<10	324	19.2		1.35				<2	<2	118	91	Absent	Absent
4	Devon Court Spring 2	17-Jan-12 @ 16:05	Devonian ORS	Burrows	<10	383	27.7	<100	1.45	18	< 10	18						
6	Dune Slack 1 (small)	17-Jan-12 @ 10:56	Blown Sands	Burrows	<10	<30	<10	<100	0.412	117	< 10	153						
8	Dune Slack 2 (Lagre)	12/06/2012 @ 9:27	Blown Sands	Burrows	<10	<30	<10		2.74				<2	<2	72	<10	Absent	Absent
8	Dune Slack 2 (Lagre)	17-Jan-12 @ 11:05	Blown Sands	Burrows	<10	<30	<10	<100	0.39	63	420	63						
9	Bypass Road Highway Drain into Freshwater East river	17-Jan-12 @ 10:36		Burrows	<10	<30	<10	<100	0.795	< 10	< 10	< 10						
10	Main Outflow Freshwater East River at footbridge	12/06/2012 @ 8:55				489	66.5		n/a				<2	5.8	135	45	Absent	Present
10	Main Outflow Freshwater East River at footbridge	17-Jan-12 @ 10:30		FwEast Stream	62.4	389	65.4	<100		670	27	636						
11	Junction of sand and soliflucted material	12/06/2012 @ 14:21	Blown Sands	Burrows	<10	<30	<10		0.0436				<2	<2	<10	<10	Absent	Absent
11	Junction of sand and soliflucted material	17-Jan-12 @ 12:53	Blown Sands	Burrows	<10	68.7	<10	<100	3.58	< 10	< 10	< 10						
12	Beach Spring 1 (same as site 13)	17-Jan-12 @ 12:12	Silurian Gray SST	Burrows	<10	84.1	<10	<100	1.16	117	54	144						
13	Beach Spring 2 (Tufa Gray Sandstone Formation) Same as Site 12	12/06/2012 @ 10:19	Silurian Gray SST	Burrows	<10	<30	<10		0.962				<2	<2	18	55	Absent	Absent
13	Beach Spring 2 (Tufa Gray Sandstone Formation) Same as Site 12	17-Jan-12 @ 12:09	Silurian Gray SST	Burrows	<10	85.6	<10	<100	0.655	144	18	171						
14	Beachwaterfall (main flow to eastern part of beach)	12/06/2012 @ 10:28	Devonian ORS	Burrows	<10	<30	<10		1.12				<2	<2	18	<10	Absent	Absent
14	Beachwaterfall (main flow to eastern part of beach)	17-Jan-12 @ 12:11	Devonian ORS	Burrows	<10	224	15.4	<100	0.743	690	36	12000						
15	Beach Spring 3	12/06/2012 @ 10:39	Devonian ORS	Burrows	<10	<30	<10		0.208				<2	<2	<10	64	Absent	Absent
15	Beach Spring 3	17-Jan-12 @ 12:36	Devonian ORS	Burrows	<10	<30	<10	<100	0.91	54	54	81						
16	Beach Spring 4	12/06/2012 @ 10:46	Devonian ORS	Burrows	<10	<30	<10		0.164				<2	<2	<10	<10	Absent	Absent
16	Beach Spring 4	17-Jan-12 @ 12:50	Devonian ORS	Burrows	<10	45.2	<10	<100	0.329	< 10	< 10	< 10						
18	Spring 1 (flows to Beach Waterfall)	12/06/2012 @ 11:02	Devonian ORS	Burrows	<10	261	11.4		1.5				<2	<2	<10	<10	Absent	Absent
18	Spring 1 (flows to Beach Waterfall)	17-Jan-12 @ 11:56	Devonian ORS	Burrows	<10	152	<10	<100	0.64	< 10	< 10	< 10						
19	Spring 2 (flows to Beach Waterfall)	12/06/2012 @ 11:13	Devonian ORS	Burrows	<10	53.3	<10		1.94				<2	<2	<10	<10	Absent	Absent
19	Spring 2 (flows to Beach Waterfall)	17-Jan-12 @ 11:42	Devonian ORS	Burrows	<10	33.4	<10	<100	0.0102	27	< 10	27						
20	Spring 3 (flows to Beach Waterfall)	12/06/2012 @ 11:22	Devonian ORS	Burrows	<10	<30	<10		0.856				<2	<2	18	27	Absent	Absent
20	Spring 3 (flows to Beach Waterfall)	17-Jan-12 @ 11:36	Devonian ORS	Burrows	<10	<30	<10	<100	0.189	54	< 10	36						
21	Eastfield FOUL EFFLUENT overflow	17-Jan-12 @ 14:32	n/s	Lake		<30	<10	<100	6.03	490000	50000	1636364						
22	Springfield Stream Clsoe to head	17-Jan-12 @ 14:30	Devonian ORS	Lake	15.9	2000	1090	<100	3.63	72	< 10	180						
23	Springfield Stream Spring 1	12/06/2012 @ 13:55	Devonian ORS	Lake	<10	54	<10		0.147				<2	4.4	650	18	Absent	Present
23	Springfield Stream Spring 1	17-Jan-12 @ 14:28	Devonian ORS	Lake	<10	591	16.6	<100	0.349	520	< 10	550						
24	Springfield Stream Spring 2	12/06/2012 @ 13:47	Devonian ORS	Lake	<10	<30	<10		0.368				<2	<2	54	<10	Absent	Absent
24	Springfield Stream Spring 2	18-Jan-12 @ 09:45	Devonian ORS	Lake	<10	<30	<10	<100	0.844	< 10	< 10	< 10						
25	Springfield Stream Spring 3	12/06/2012 @ 13:35	Devonian ORS	Lake	<10	73.8	<10		1.41				<2	4.53	144	<10	Absent	Absent
25	Springfield Stream Spring 3	18-Jan-12 @ 09:40	Devonian ORS	Lake	<30	352		27	2.17	<10	<10	<10						
26	Holy Well	12/06/2012 @ 12:53	ORS/Blown Sand	Lake	<10	<30	<10		1.01				<2	<2	<10	<10	Absent	Absent
26	Holy Well	17-Jan-12 @ 11:46	ORS/Blown Sand	Lake	<10	<30	<10	<100	0.85	< 10	< 10	< 10						
27	Spring near Eastfleid flowing into Burrows catchment	12/06/2012 @ 13:14	Devonian ORS	Burrows	<10	34.9	<10		1.19				<2	<2	390	310	Absent	Present
27	Spring near Eastfleid flowing into Burrows catchment	17-Jan-12 @ 13:51	Devonian ORS	Burrows	<10	59	<10	<100	0.497	730	18	818						

11. Algal Samples

Algae were only recorded and collected at two small beach springs (Sites 12 & 13). These sites located to the east of the beach issue from the Devonian and Silurian bedrock aquifer. Samples were collected and sent to the Environment Agency Laboratory in Llanelli for analysis by Julie Gething (see Appendix 2).

Two types of algae were identified:

- ***Enteromorpha compressa*** an inhabitant of brackish waters was collected from the rocks below the springs. It is a bright green branching tubular algae. Brown diatoms were attached to some of the larger filaments of *Enteromorpha*.
- ***Cladophora sp*** is a dark green branching filamentous algae. *Cladophora* is commonly called blanket weed and high coverage is associated with elevated nutrients in freshwaters. The sample also contained numerous diatoms, some attached to the algae.
- **No blue-green algae or other potentially harmful algae** were found in either sample.

12. Percolation tests

There is only one result from a previous percolation test in the Freshwater East area. The table below summarises this test and two failed tests undertaken in 2005 by C.J Associated Ltd for Faber Maunsells' 2009 report.

Receiving strata	Catchment	Vp	Location	date
Blown sands	Burrows	17	Verge opposite Sunblest	2005
Manod Soils over Devonian ORS	Lake	n/a	Rear of Springfield	2005
Manod Soils over Devonian ORS	Lake	n/a	Rear of Drishane	2005

In general it can be assumed that the unsaturated blown sand deposits offer very fast percolation values; this is confirmed by the results from the verge opposite Sunblest, which recorded a Vp of 17mm/second. This value is close to the lowest (or fastest percolation) recommended value of 15mm/second.

The tests at the rear of Springfield and Drishane properties were cancelled due to the shallow depth of soil so no percolation values are available.

No percolation tests were carried out during this investigation. However it was noted that sewage effluent was ponding on the surface at Site 21 and this was related to a very localised clay rich area. No ponding was observed at the rear of Drishane, however the rear of Springfield was not visited. No ponding of effluent was observed in the Burrows catchment.

Where there is an insufficient depth of soil, or ponding is seen then further percolation tests will probably confirm the unsuitability of the receiving strata for soakaways. However very fast percolation test results (such as from the blown sand deposits) should not instantly be considered a risk to the environment. Although the sand may provide fast

percolation values the depth of sand should also be considered as this will allow further attenuation of effluent. Geophysics has shown there is between 5 and 7m depth of blown sand in some areas of Freshwater East.

13. Conceptual understanding

The strong influence of the structural geology on the hydrogeology was clear during the water features survey. Silurian and Devonian strata dip nearly vertically and strike approximately east-west. Faults bring these different rock types next to each other and provide important structural controls on how and where groundwater is likely to find preferential flow paths.

Faulting has created several faulted gullies or valleys. Many of the faults are associated with springs, which issue directly from the Devonian Old Red Sandstone. The springs emerge both at the top of the Burrows and Lake catchments and also close to or near the beach.

Diffuse groundwater discharges occur at the base of the dunes and are visible at mid tide level. During the 16th of January 2012 a wet area in the mid tide level of the beach was observed. However elevated conductivity levels suggest the water was seawater rather than a groundwater discharge.

It was not possible to assess the amount of diffuse groundwater flow from the Burrows catchment, however this maybe the main route for groundwater discharging from the blown sand aquifer.

Table 2. Geological Units and Hydrogeological observations

		Hydrogeological Notes
Soils	Manod Association	Manod Association soils overly most of the Devonian Old Red Sandstone strata. The soils are not much more than a metre thick. They are common in the Lake catchment.
Superficial	Wind blown sand	Groundwater flow is intergranular and where the soliflucted material is absent the sands will be in hydraulic continuity with the underlying bedrock. Springs from the bedrock issue into the dunes and may also recharge the sand aquifer. Groundwater levels in the blown sands are probably responsible for the slack formation to the west of the dunes. The blown sands can lie directly over the bedrock or can be separated by a clay rich layer. The sand deposits range between 5-7m depth below the Devon Court flats.
	Soliflucted stony clay	Cliff sections show clay rich layers up to 3m in thickness with tufa deposits at base. The deposits form a low permeability base, in some areas, to the blown sand deposits, and cover the underlying solid geology. The deposits may not form a consistently impermeable layer however groundwater flow maybe impeded through this unit.
Devonian	Congigat Pit Sandstone Formation	This formation underlies the Lake Catchment and has more sandstone units than the Moor Cliff formation. Groundwater flow is mainly via faults, fractures and along bedding planes. Sandstones may offer a more permeable horizon for intergranualr flow.
	Moor Cliffs Formation	Less permeable mudstones and calcretes. Groundwater flow via faults, fractures and along bedding planes.
	Freshwater East Formation	Groundwater flow via faults, fractures and along bedding planes.
Silurian	Gray Sandstone Group	Groundwater flow via faults, fractures and along bedding planes. Springs issuing from this formation can be seen at the eastern end of the beach.

14. Conclusions

- Water quality sampling was first undertaken during January 2012 when occupation of residential properties is at its lowest. A second survey was conducted in June when any impact from the discharge of sewage effluent could be expected to be greater due to higher occupancy of properties.

- Three main surface water catchments have now been identified in the Freshwater East area. The catchments are also associated with different risks to water quality which are;

  Burrows Catchment - main risks are private sewage treatment systems and limited agriculture in far east of the catchment.

  Lake Catchment - main risks are agriculture and private sewage treatment systems.

  Freshwater East Stream Catchment - main risks ar agriculture and storm sewage overflow pipe.

- Historically the main water quality issues have been related to blue green algal blooms in the outflow of the Freshwater East river. Freshwater East beach has however received the 'higher' water quality standard since 1999 for its bathing water quality.

- N**o blue-green algae or other potentially harmful algae** were identified during this study.

- The local variability of the soils and small clay rich areas may lead to sewage ponding or poor soakaways. In addition it is thought that poor management of treatment systems rather than the suitability of the ground is responsible for outbreaks of sewage effluent.

- Total faecal coliforms exceeded the bathing water standard at one site only, the beach waterfall (Site 14).

- Total faecal coliforms did not exceed the bathing water standard at any of the remaining water quality sample points.

- Ammonia is below the limit of detection in 19 out of 23 samples taken during survey 1.

- Boron is below the detection limit in all samples where it was analysed.

- MST analysis did not identify any humanoid bacterial markers. Where bacteroidetes were found they appear to be of animal origin.

- The water quality data does not show significant or widespread areas of water contamination.

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Welsh Government Meeting on Freshwater East Section 101A
http://new.wales.gov.uk/topics/environmentcountryside/epq/waterflooding/sewers/provisionpublic/;jsessionid=0K2zTMQG12TGz0NBHJBVqJKDWvn1JpFZhZ2Gc6pMtybLTyqhr4ZH!271184192?lang=en

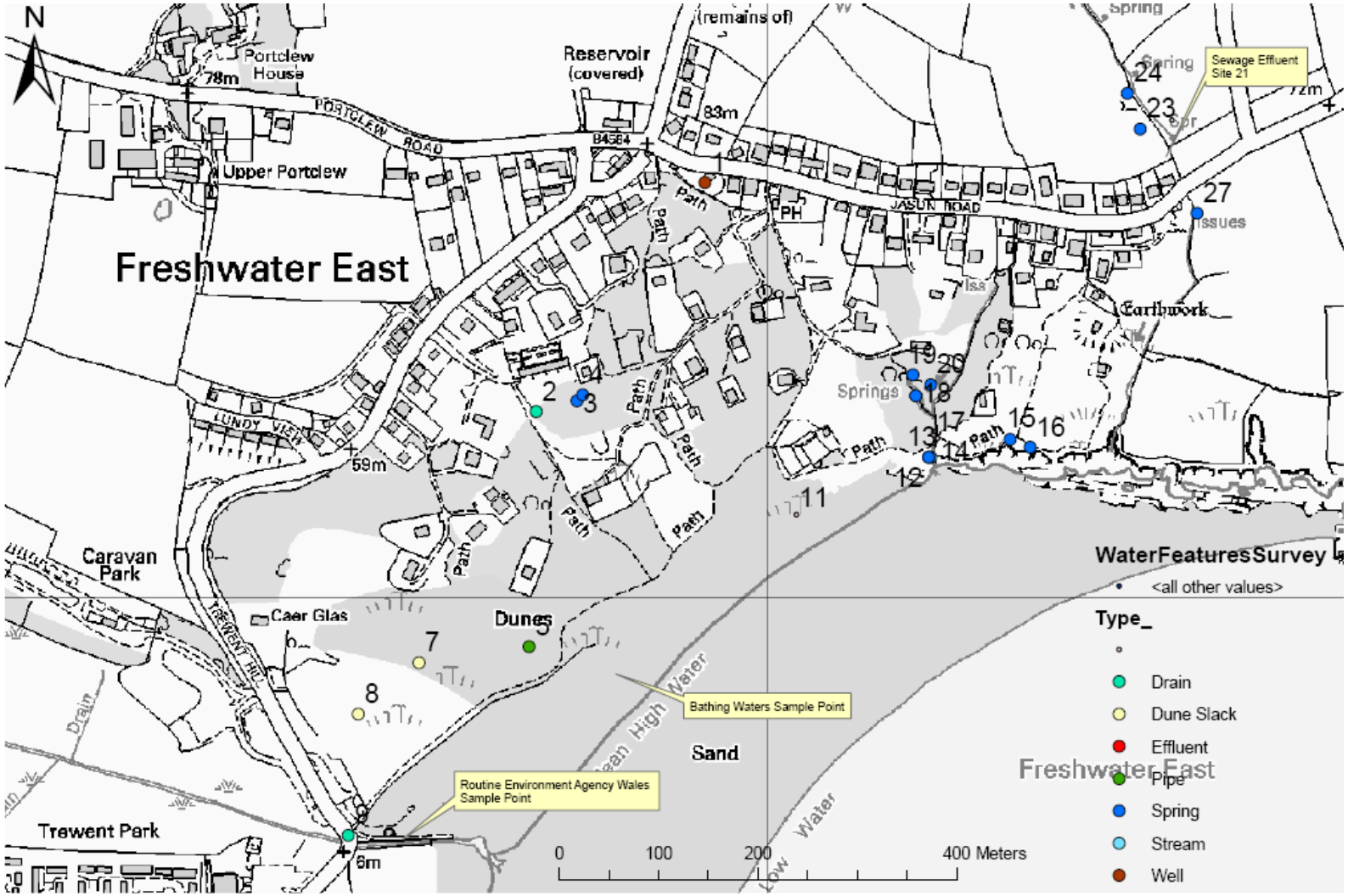

Figure 1. Water Features Survey Locations (OS Basemap)

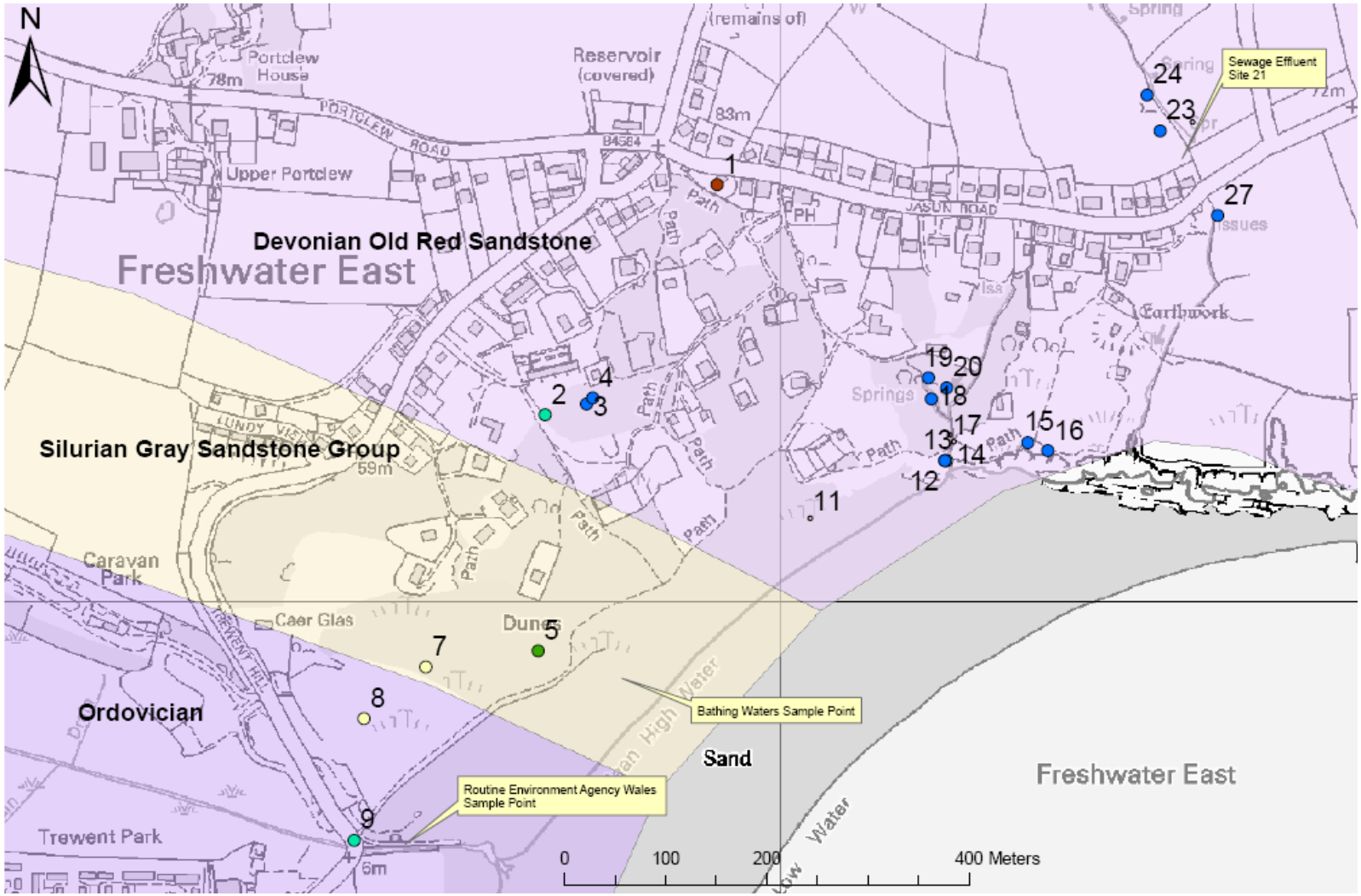
N
Portclew House
78m
Reservoir (covered)
(remains of)
83m
PORTCLEW ROAD
B4584
Upper Portclew
Devonian Old Red Sandstone
Freshwater East
Silurian Gray Sandstone Group
59m
Caravan Park
Caer Glas
Dunes
Ordovician
Trewent Park
5m
Sand
Freshwater East
Bathing Waters Sample Point
Routine Environment Agency Wales Sample Point
Sewage Effluent Site 21
JASON ROAD
PH
Springs
Earthwork
Path
0
100
200
400 Meters
1
2
3
4
5
7
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Figure 2. Bedrock geology (BGS 1:50,000)

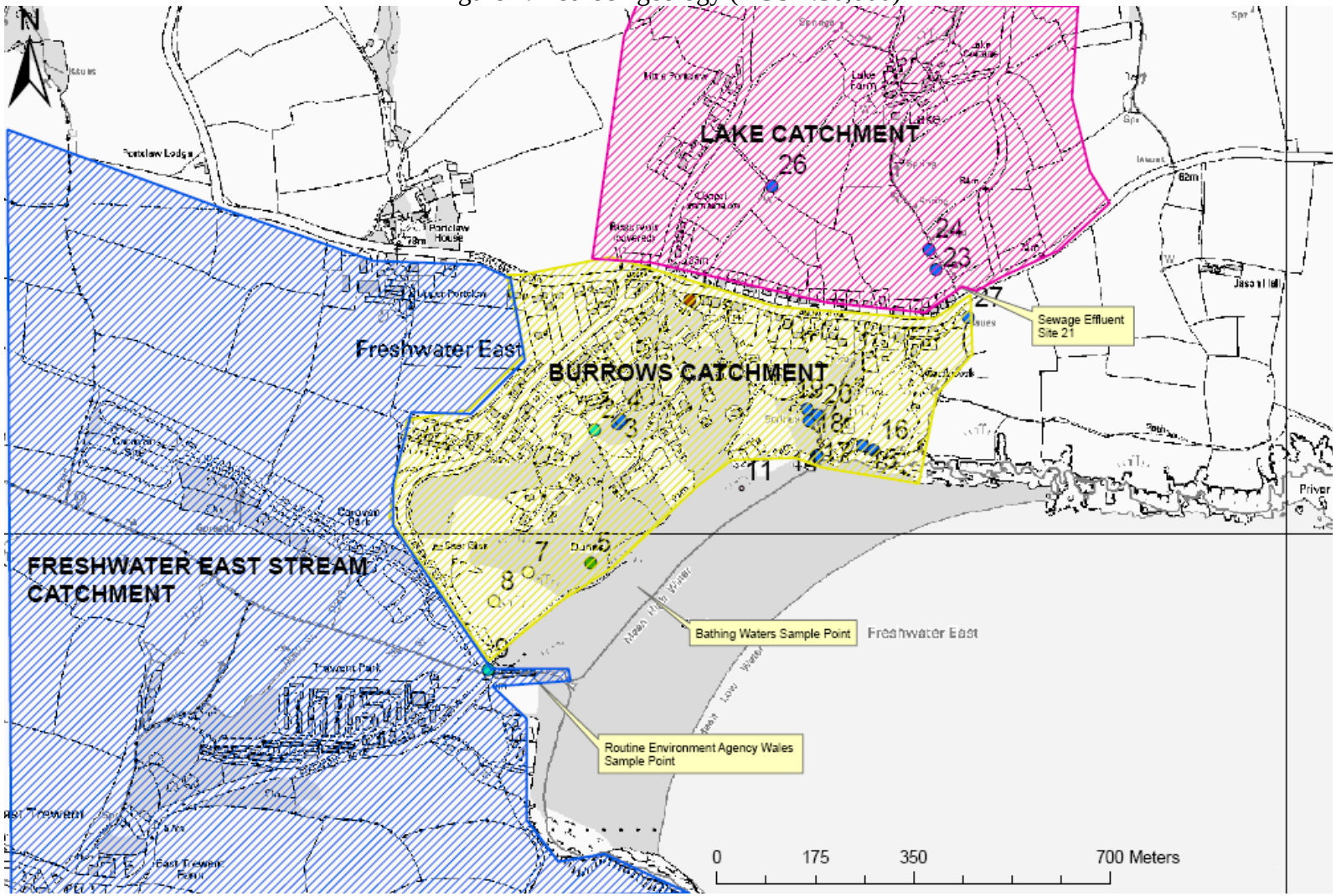

Figure 3: Proposed surface water catchments (OS Basemap)

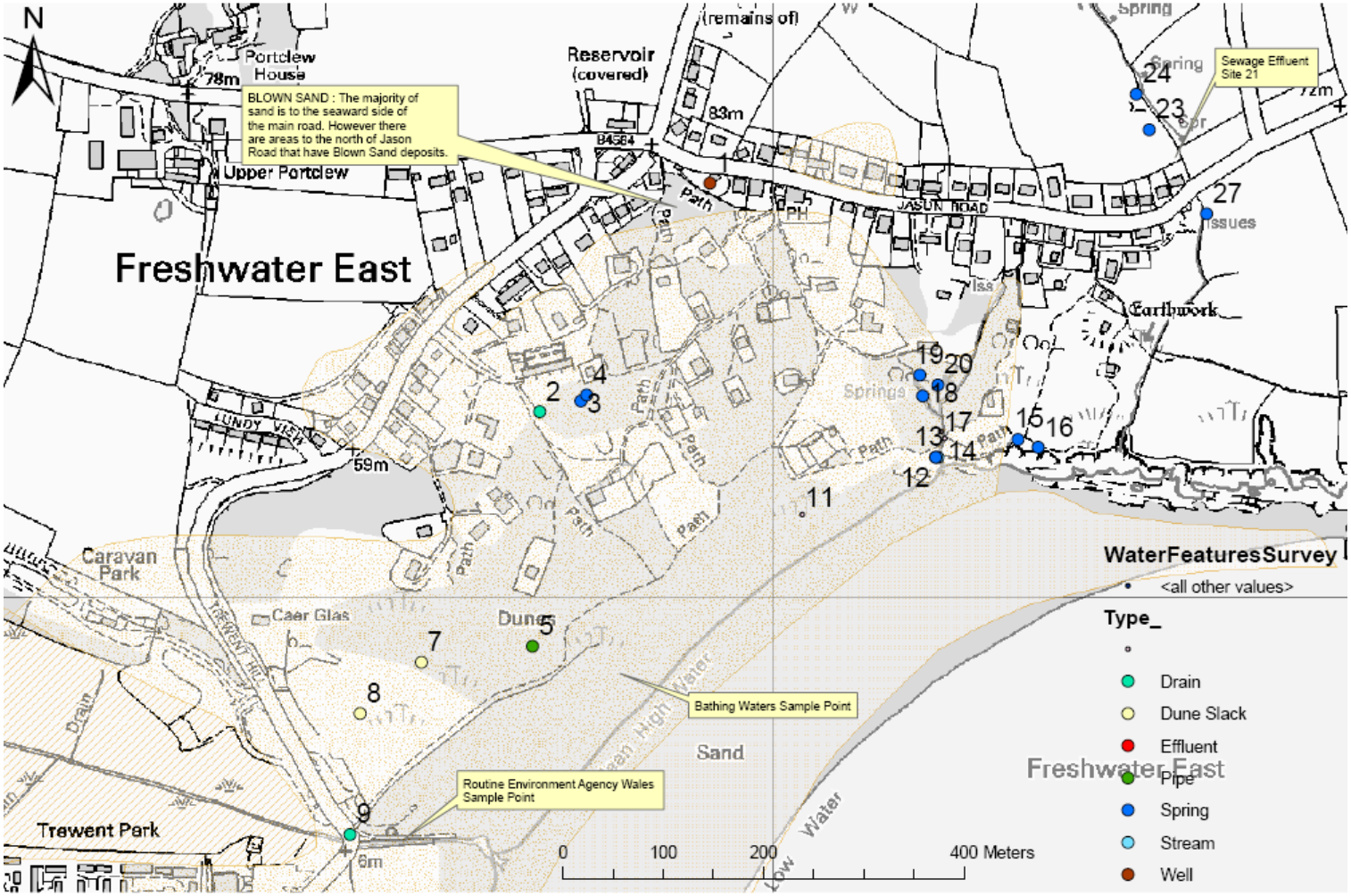

Figure 4. Superficial geology (Blown Sands) BGS 1:50K Superficial Map

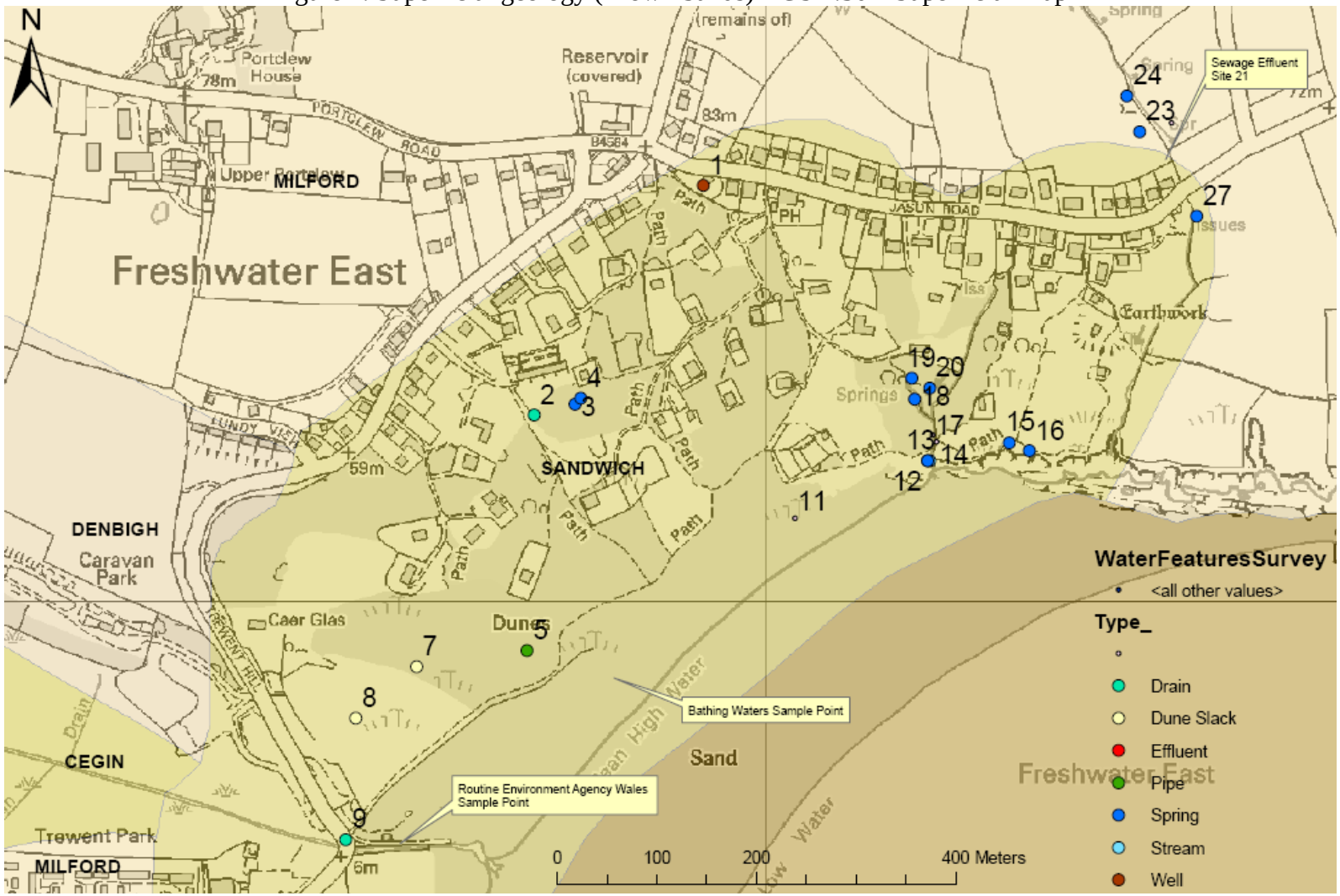

Figure 5: Soils. National Soils Research Institute 1:50K

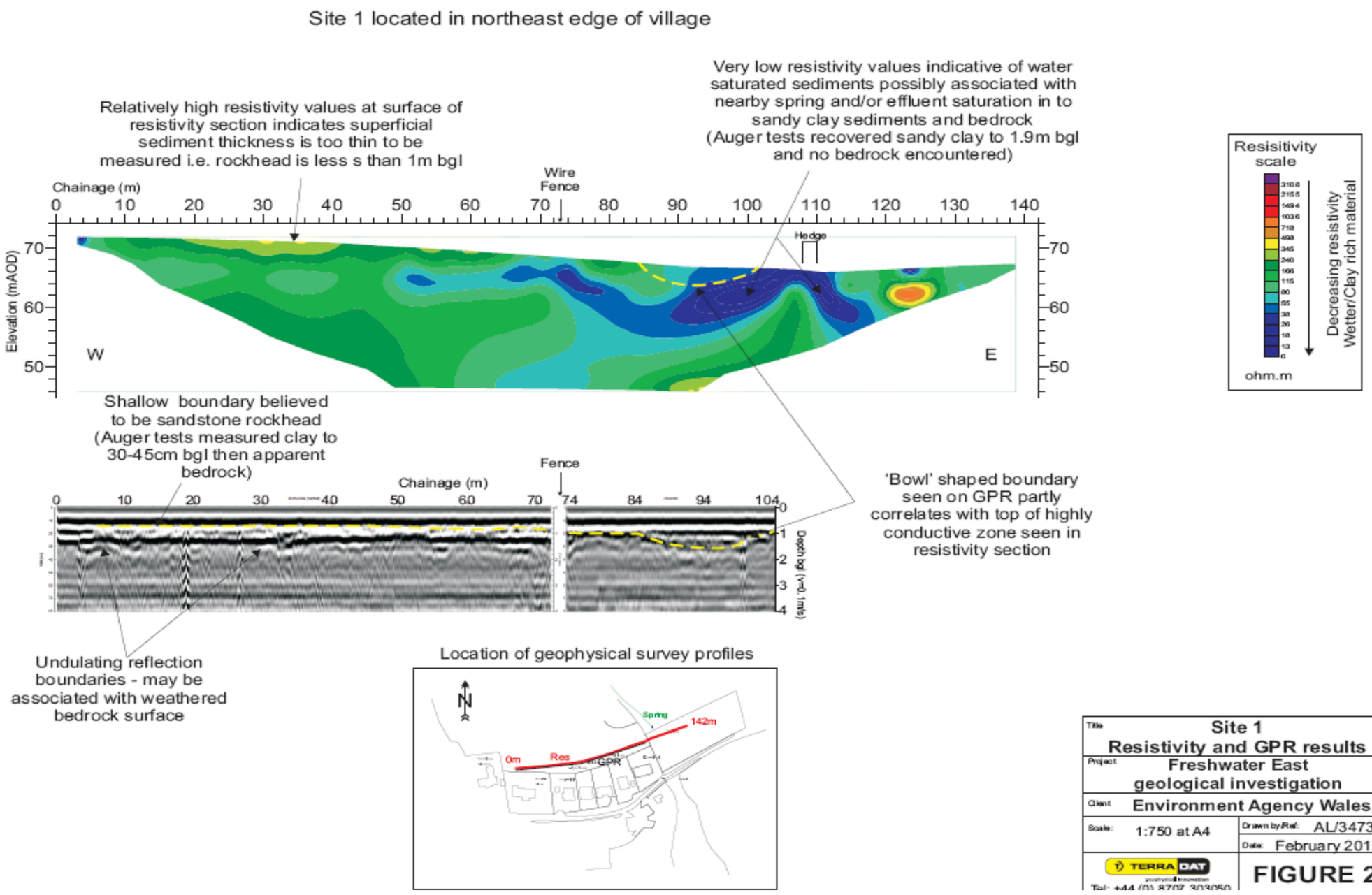

Figure 6 : Geophysical Cross Section 1. Rear of Jason Road

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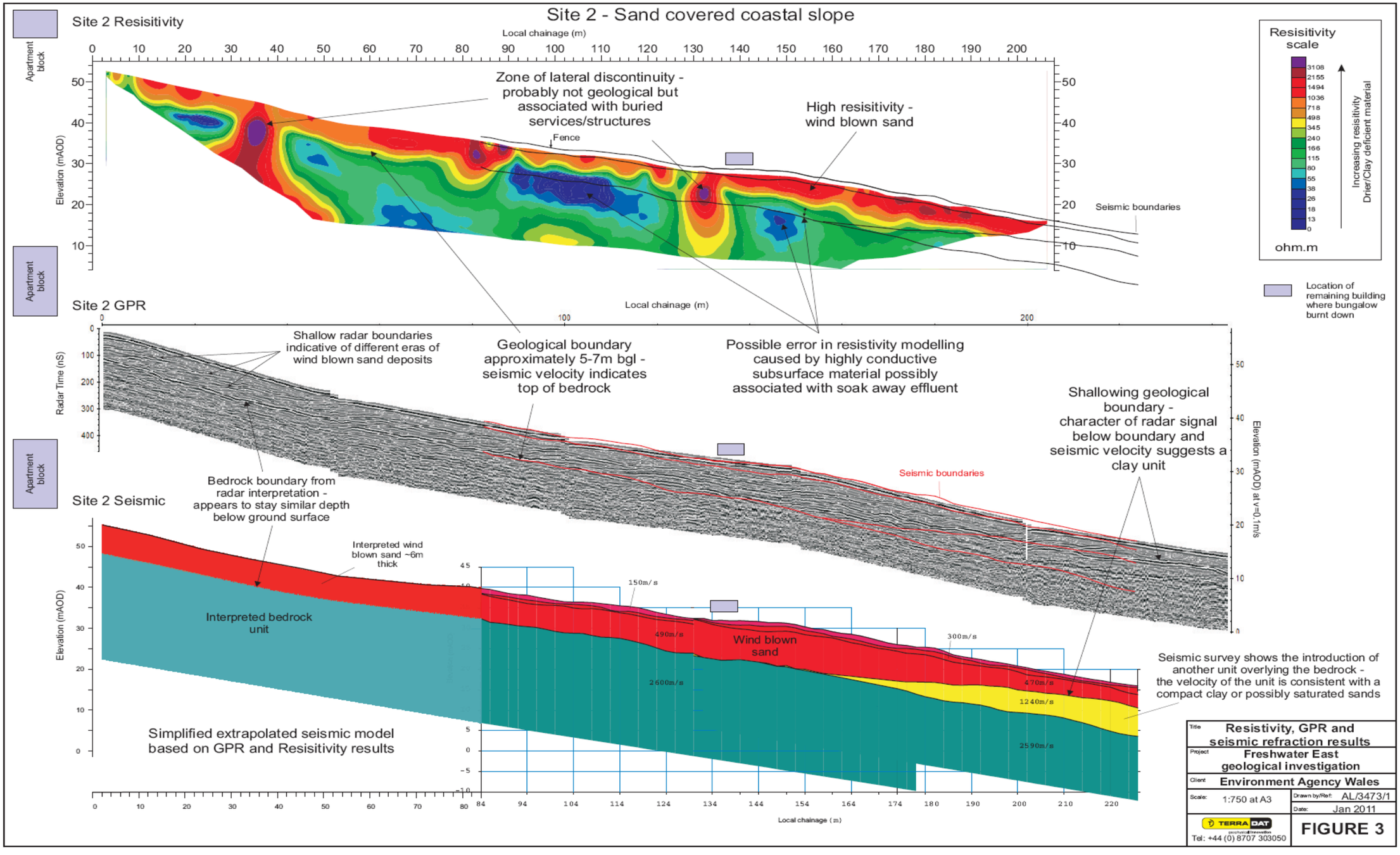

Figure 7 : Geophysical Cross Section 2. Devon Court Flats.