3 Groundwater Monitoring

3-1 New Observation Boreholes

Three small diameter boreholes [150 to 200 mm] were drilled within the town area of Fairford to identify lithology, determine groundwater occurrence and formation thickness of the Cornbrash limestone and Summertown sand and gravel deposits. Drilling at all sites aimed to terminate after penetrating the upper part of Forest Marble mudstone.

Various options were evaluated, identified as A1-3, B1-5 and C1-3. The finally selected sites were:

- Site A2 located on the western edge of the Coln House School rugby pitch field [owned by GCC Education Department] north of the Horcott Road gate, to establish groundwater levels in the Summertown-Radley Sand and Gravel terrace deposits.
- Site B2 located at the end of St Marys Drive, to establish groundwater conditions in the Cornbrash limestone.
- Site B5 located on the north-eastern edge of town at the junction of Lovers Lane and Leafield Road to establish groundwater conditions up-gradient from springs in the cropped field at that point.

Sites A2 and B2 were drilled using Fraste and Comacchio rotary drilling rigs and site B5 was drilled using a Pilcon Wayfarer lightweight cable-tool percussion rig, at a drill diameter of 150 mm.

The succession at each site has been summarised in Table 3-1.

Table 3-1 Summary of Lithology in Project Boreholes A2, B2 and B5

A2: GL 91.4 mOD		B2: GL 91.2 mOD		B5: GL 94.0 mOD	
Depth m	Lithology	Depth m	Lithology	Depth m	Lithology
0.00-1.10	Clayey sand and gravel	0.00-0.90	Made ground	0.00-0.35	Made ground, lumps of limestone and clayey earth
2.50-2.80	Coarse limestone gravel and cobbles	0.90-1.60	Gravelly clay and limestone	0.35-0.70	Brown-Dark brown gritty-sandy clay with limestone cobbles
2.80-7.15	Cornbrash Limestone	1.60-3.70	Cornbrash limestone [orange brown sandy limestone	0.70-3.40	Cornbrash limestone [very hard ochreous brown sandy limestone with shells]
7.15-8.20	Forest Marble mudstone	3.70-6.00	Forest Marble mudstone [grey silty clay	3.40-4.10	Forest Marble mudstone [stiff blue-grey clay]

Two of the boreholes, A2 and B5, were completed with casing, screen, filter pack, bentonite, concrete well-head block and steel access plate, for monitoring during the project and into the future. The sites were then equipped with a Troll-100 groundwater level sensor and data-logger, housed inside the borehole and the well-head secured using bolts which can easily be opened with the appropriate spanner for monitoring activities.

3-2 Well and Borehole Inventory

Reconnaissance and inventory were carried out of wells and springs in the project area with the help of FTC, and arrangements made with owners to carry out monthly dipping at selected sites. In all, nine old dug-wells were identified, summarised in Table 3-1, of which five were selected for monitoring of the seasonal variation in groundwater levels in different geological formations. Further details of the wells are provided in Appendix B-1.

This information has been supplemented by the project boreholes and historical records obtained from the BGS and the Environment Agency for observation boreholes monitored in the area. These boreholes are summarised in Table 3-2.

Table 3-2 Fairford Town Dug-Well Inventory

Ref	Address	Owner / contact	Easting	Northing	GL	WellTop	Depth	Dia	Stick-up
					mAOD	mAOD	m bWT	mm	WT-GLm
1	Riverdale, London Road	Kevin Wigham	415557	200928	83.90	83.90	1.90	700	0.00
2	2 Eastbourne Terrace	Jason Baker	415518	200924	83.90	83.90	-	-	0.00
3	Colosseo Restaurant, London Rd	Sous Guenaoua	415223	200970	83.65	84.40	2.85	-	0.75
4	Comrie [Dovecote House]	Mr&Mrs deCourcy-Ireland	415387	201183	86.20	86.75	4.32	780	0.55
5	Moor Farm	Margaret Bishop	415870	200855	83.00	83.00	1.34	-	0.00
6	Well House, 2 Coronation Street	n/a	414756	200928	88.00	88.00	-	-	0.00
7	Coln Ho Reform School -front yard	GCC	414767	200910	87.00	87.00	4.33	800	0.00
8	Thornhill Farm	New owner	418080	200520	80.30	80.30	8.84	950	0.00
9	2 Dynevor Place	n/a	414523	201417	97.60	97.60	2.10	450	0.00

Table 3-3 Summary of Project and National Observation Boreholes in the Area

Ref	Address	Owner / contact	Easting	Northing	GL	WellTop	Depth	Dia	Stick-up
					mAOD	mAOD	m bWT	mm	WT-GLm
A2	Project Borehole A2	FTC	414911	200812	87.30	87.30	6.70	50	0.00
B5	Project Borehole B5	FTC	415704	201675	94.00	94.00	4.10	50	0.00
SP10/105	Fairford Football Club, Cinder Lane	Environment Agency	416118	200900	83.31	83.95	4.60	200	0.64
SP10/085	Fairford Burdocks	Environment Agency	414325	200605	88.50	89.1	-	-	-
SP00/062	Ampney Crucis	BGS Nat Index site	405900	201900	-	-	-	-	-
SP10/004	Donkeywell Buildings	Environment Agency	412777	203420	121.0	121.6	-	-	-

A mixture of daily and weekly groundwater levels was acquired as follows:

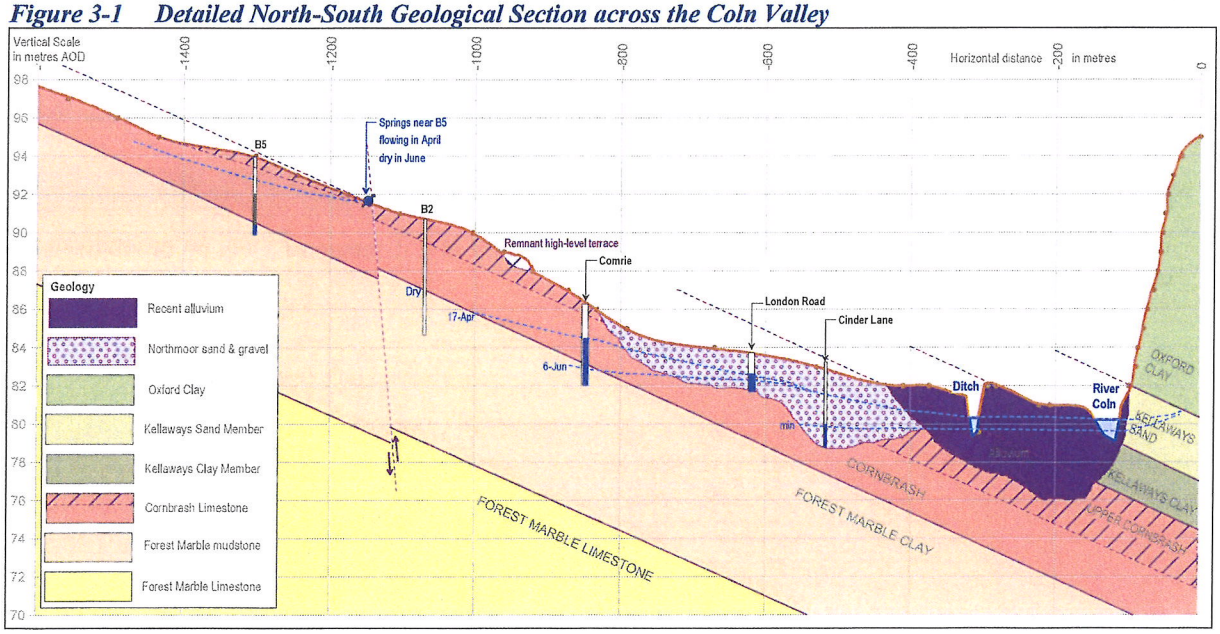
- Fairford Cinder Lane..... Oct-2002 to Jun-2018.
- Fairford Burdocks..... aug-1996 to Jun-2018.
- Ampney Crucis..... Jul-1993 to Apr-2018. Dips: Dec-1958 to May-2018.

The project borehole loggers were set at 3-hourly data interval.

3-3 Interpretation of Town Geology

The knowledge of local geology, BGS mapping and information from drilling and monitoring has allowed the interpretation of a detailed cross-section across the town area as shown in Figure 3-1. A similar cross-section has been drawn on the west side of the Coln Valley.

Figure 3-1 Detailed North-South Geological Section across the Coln Valley



Note: Exaggerated vertical scale for a strata dip of 1 degree.
Line of cross-section and detailed mapping shown in Appendix Figure C-1.

3-4 Groundwater Level Monitoring

The drilling of A2 and B2 was completed in March 2018 and borehole B5 in August 2018, giving a 6-month record at A2. Monitoring involved monthly dipping and download of the data-loggers with corrections made for barometric pressure and sensor drift relative to dipped values. The groundwater recession hydrograph is shown n Figure 3-2.

The dug-well hydrographs are shown n Figure 3-2 for the same period.

Figure 3-2 Variation in Groundwater Level in Borehole A2, Mar-Aug 2018

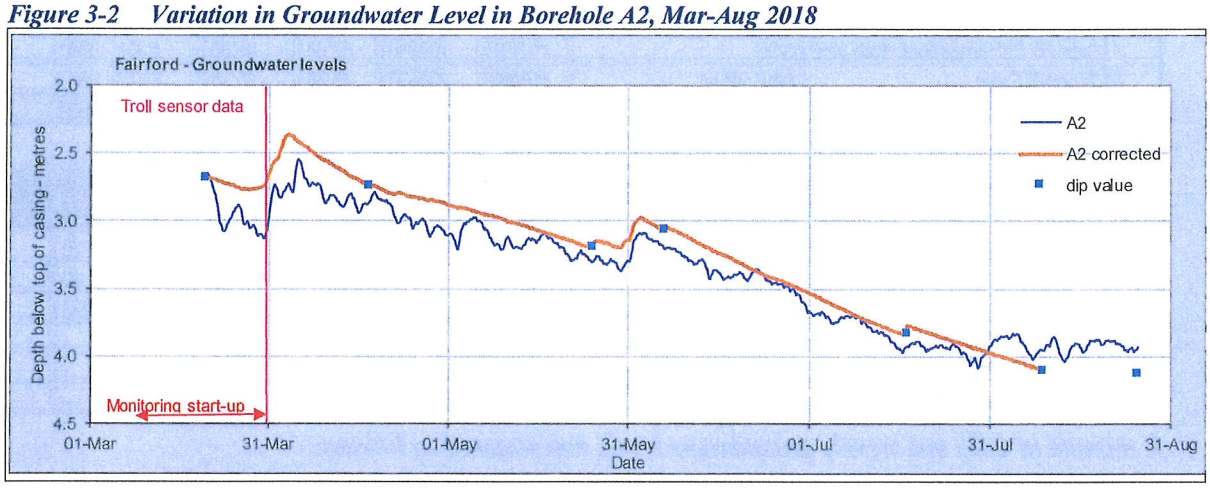
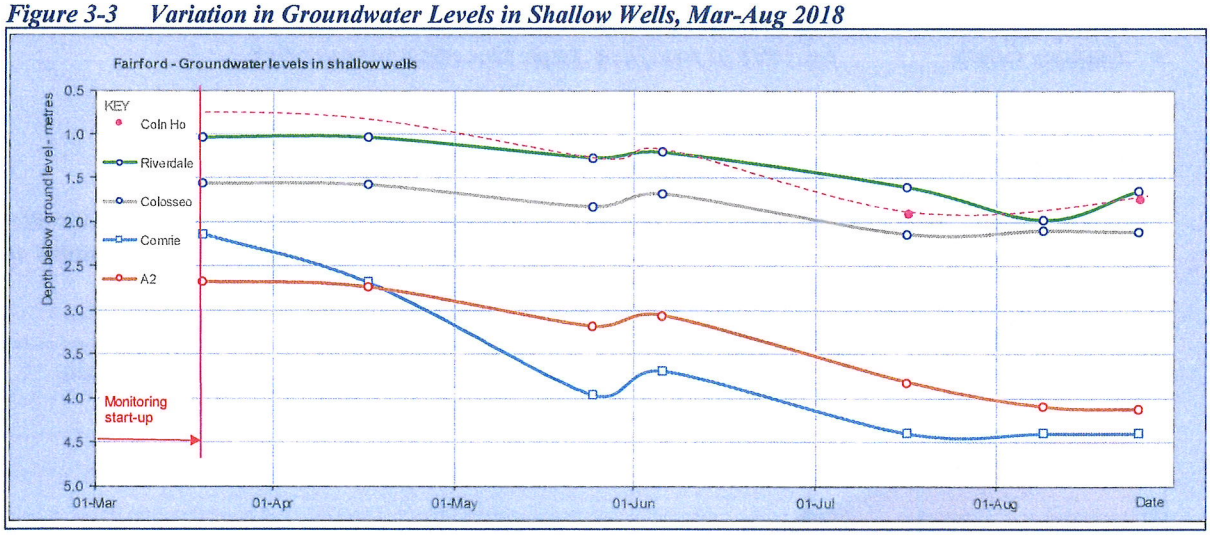


Figure 3-3 Variation in Groundwater Levels in Shallow Wells, Mar-Aug 2018



It was found that springs rise in the fields adjacent to site B2 at a distance of 75m, so groundwater level comes to the surface at that location.

4 Groundwater Assessment

4-1 Scope

The focus of the WRA assignment has been to gain an understanding of groundwater levels in Fairford, so that future development planning can be sited in appropriate places which are not subject to high groundwater levels where SuDS schemes can operate effectively. These results will then help FTC in the preparation of the Neighbourhood Plan.

The client has specifically asked for a "comparative risks assessment" for sites off Horcott Road and Leafield Road.

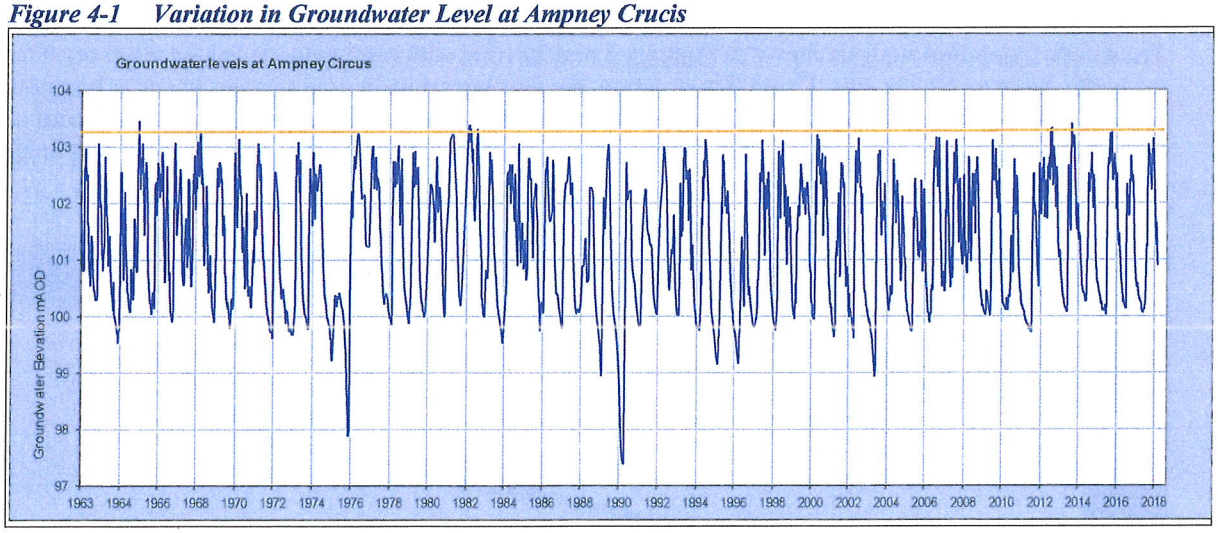
This section looks at the results of the groundwater monitoring and reviews available hydrological data, examining the correlation of short-term records with long-term groundwater records in order to predict seasonal fluctuation and the range in groundwater levels at the sites of interest.

4-2 Long-term Records

4-2-1 Groundwater Level in the Great Oolite

Groundwater Level in the Great Oolite at Ampney Crucis [SP00/62] is monitored by EA Thames as a national index site, and it provides the longest local record of 60 years, beginning in 1959, which is free from abstraction influence. The hydrograph is shown in Figure 4-1.

Figure 4-1 Variation in Groundwater Level at Ampney Crucis



This borehole is 61 m deep penetrating into Fuller's Earth, and measures groundwater level in the Great Oolite, with a rest water level generally within the Forest Marble, and considered to be unconfined.

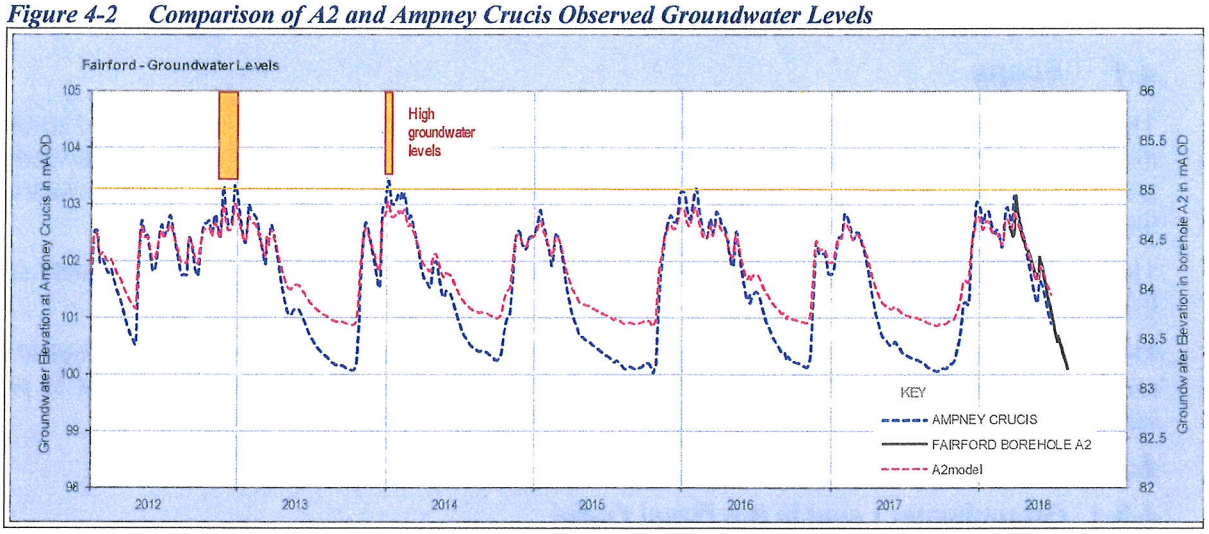
The 12 highest groundwater levels have been summarised in Table 4-2, using a threshold value of 103.2, identifying three years [2014, 1982, 1965] with particularly high levels which may have triggered groundwater flood events. Although top of borehole is 109.52 mOD, maximum values do not greatly exceed 103 mOD due to local springs.

This confirms that the recent phase of monitoring has been done following a period of average winter recharge and should serve as a reasonable indicator of the seasonal change in levels. The most recent part of the Ampney Crucis record has been used to compare the response in Fairford local wells monitored during 2018. The A2 record is plotted in Figure 4-2. The short record of groundwater levels from new monitoring wells will help the process of extrapolation of the seasonal range from existing monitoring sites.

Table 4-1 Years with Highest Groundwater Level [GWL] in mOD at Ampney Crucis

Date	GWL		Date	GWL		Date	GWL		Date	GWL
10/02/2016	103.26		10/01/2007	103.16		**12/12/1982**	**103.38**		09/02/1969	103.27
08/01/2014	**103.40**		06/11/2000	103.20		03/02/1982	103.19		**19/12/1965**	**103.45**
27/12/2012	103.32		08/05/1983	103.30		10/03/1977	103.26		29/01/1960	103.28

Figure 4-2 Comparison of A2 and Ampney Crucis Observed Groundwater Levels

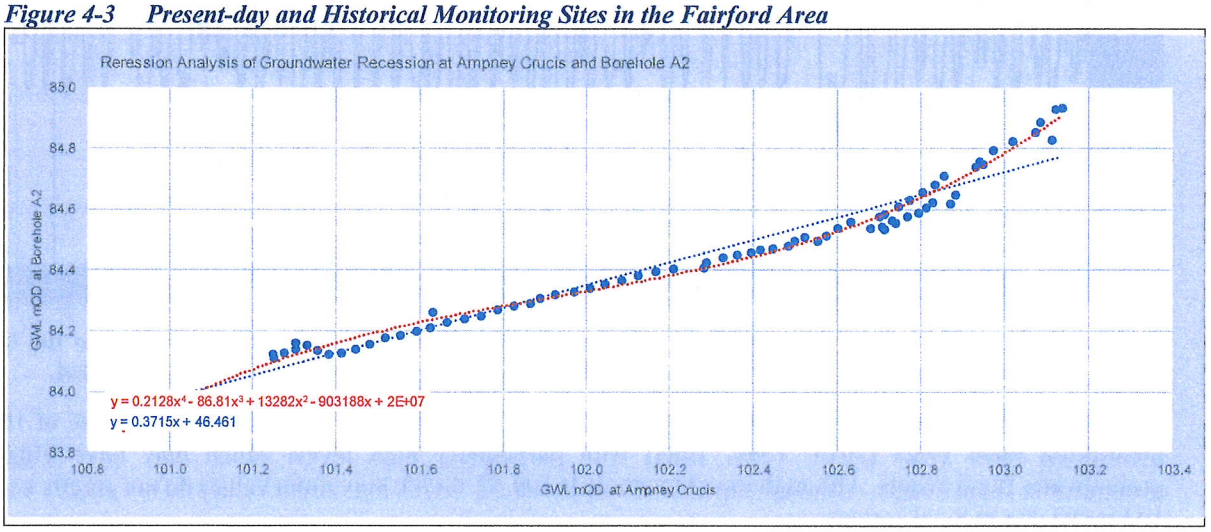


The overall range in GWL at Ampney Crucis is 6.07 m [97.38 to 103.45 mOD], while the average range is 3.085 m [100.05 to 103.135 mOD], typical of the 2017-2018 part of the record. Maximum groundwater levels may be about 1 m higher than average winter levels, if not constrained by local spring discharge.

The range recorded at A2 in Fairford is 1.74 m [83.2 to 84.94 mOD].

The simple regression analysis shown in Figure 4-3 may be used with caution to extend the water level record using the Ampney Crucis data. Using this equation, the average range in groundwater levels at borehole A2 would be of the order of 2.3 m while a maximum value might be 85.9 mOD, which leaves a freeboard of 1.4 m below ground level of 87.3 mOD. The A2 modelled time series is superimposed on observed data in Figure 4-2, showing that a reasonable representation of maximum water levels can be obtained.

Figure 4-3 Present-day and Historical Monitoring Sites in the Fairford Area

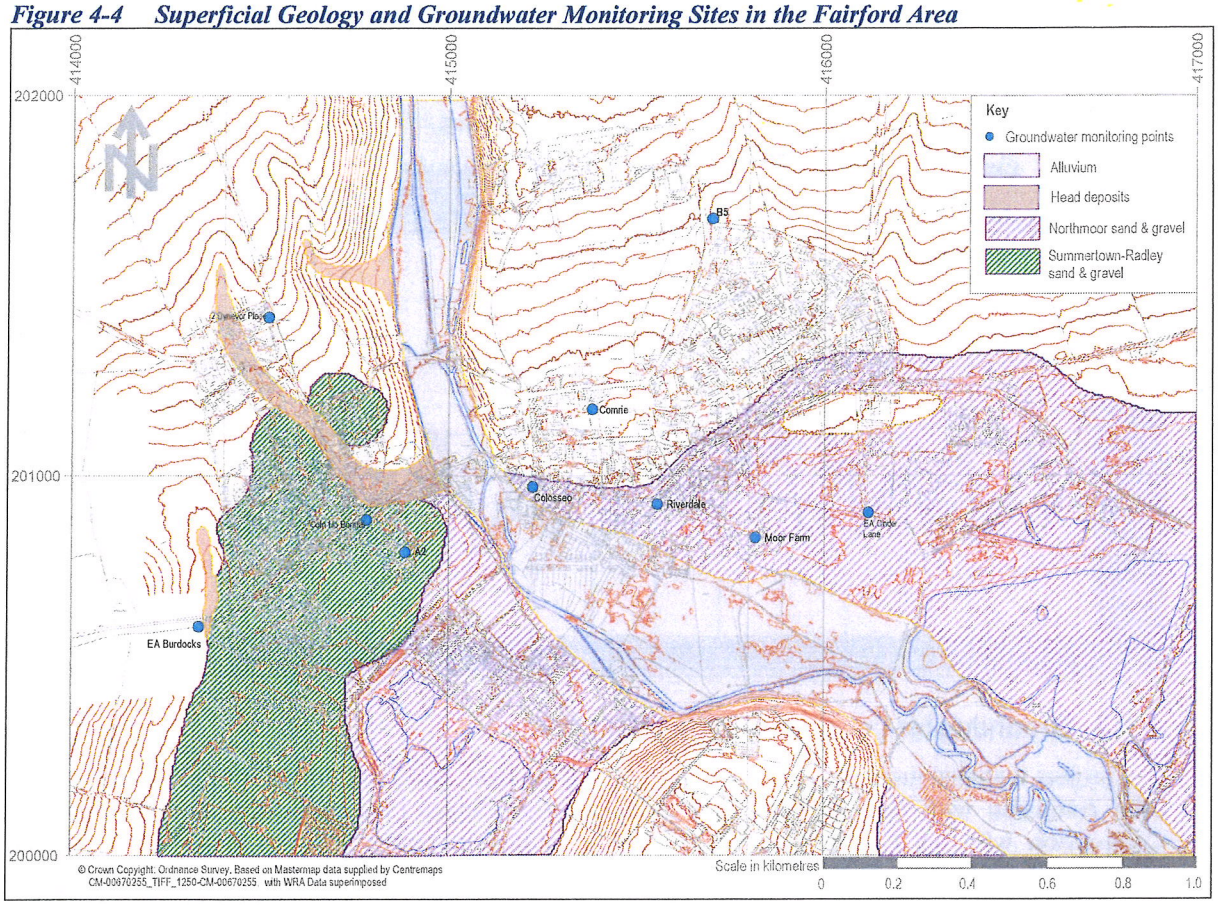


4-2-2 Groundwater Level in Superficial Deposits

There are three main belts of superficial deposit which will be characterised by different groundwater regimes. The alluvial deposits along the River Coln valley will be directly linked to changes in river level, so that, broadly speaking, temporal change in levels in the alluvium will follow river level with a slight delay.

Then there are two terrace deposits: the Northmoor sand and gravel is the lowest level terrace in the area and outcrops in a broad belt through Horcott village and Fairford town south of London Road and through the industrial estate. Groundwater levels in the Northmoor terrace are monitored by the Environment Agency in the Cinder Lane borehole and this has a 16-year record, 2002-2018. The geology and monitoring sites are shown in Figure 4-4.

Figure 4-4 Superficial Geology and Groundwater Monitoring Sites in the Fairford Area



The borehole at Cinder Lane [SP10-105] only partially penetrates sand and gravel with a depth of 4.6 m bgl and measures groundwater level in the Northmoor terrace deposits. The borehole was drilled in May 2002 and lithology was recorded as follows:

- 0.00 – 0.10 m bgl Top soil
- 0.10 – 0.40 m bgl Brown clay
- 0.40 – 1.90 m bgl Sandy gravel and clay
- 1.90 – 4.70 m bgl Coarse gravel and sand

Ground level at SP10-105 is 83.31 mOD and the well sticks up to a level of 83.95 mOD. A limestone boulder was found at a depth of 4 m during drilling, and rest water level after drilling was 80.95 mOD.

The highest groundwater levels have been summarised in Table 4-3, using a threshold value of 81.15, identifying five winter periods [02/03, 06/07, 07/08, 12/13, 13/14,] with higher-than-average groundwater levels. In addition, there were unusually high groundwater levels in July 2007.

The overall range of levels in the Northmoor gravels at Cinder Lane is 2.72 m [78.74 to 81.45 mOD] for the period 2001-2018, which demonstrates that groundwater has never reached ground level at this location.

Table 4-2 Highest Groundwater Level [GWL] in mOD at Cinder Lane

Date	GWL		Date	GWL		Date	GWL
02-Jan-03	81.230		16-Jan-08	81.120		07-Feb-14	81.272
10-Jan-07	81.181		29-Dec-12	81.283			
22-Jul-07	81.452		07-Jan-14	81.250			

The groundwater levels depicted in Figure 4-5 correlate well with the streamflow record in the River Coln, which is useful in estimating a broader range in extreme groundwater levels. Another regression equation was used to relate Cinder Lane groundwater level to Flow in the River Coln, so that a longer period of record could be simulated, 1991-2018. It should be emphasized that this model is biased towards predicting