



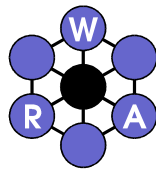
# Fairford Town Council

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## Groundwater Monitoring and Review of Flood Risk at Fairford

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**Approved Final Report  
November 2018**



**Water Resource  
Associates**

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Cover photographs: Spring in field off Lovers Lane, cable-tool rig drilling borehole B5, A2 core and well-head completion.

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## Summary

### Preamble

Situated in a river basin within the Cotswold Water Park, Fairford has historically suffered many flooding incidents, from overspill from the River Coln but also groundwater, surface water and sewage flooding. Flooding from these other sources has continued since the EA flood alleviation scheme for the River Coln was carried out in 2013, and further investigation was required.

An important part of determining the potential for groundwater emergence or flooding is in understanding the underlying geology and the potential for it to store and transmit groundwater. The geology and hydrology of Fairford is extremely complex; it includes superficial deposits of sands and gravels which may indicate areas more vulnerable to groundwater flooding as a result of prolonged rainfall raising groundwater levels, and also underlying bedrock of much lower permeability, mudstone and limestone which can prevent or reduce infiltration of groundwater from superficial deposits. Fairford also has many springs, where groundwater emerges to the surface, and this gives potential for surface water flooding. There is also a gradient, running roughly NW to SE, which determines the direction of surface water flow. Interaction between these factors increases the potential for flooding. It is likely that groundwater in the superficial layers is recharged by infiltration from rain, runoff and surface water, and also via groundwater from underlying aquifers. This means that when flooding occurs it is slow to subside. It is concluded that SuDS solutions using infiltration are unlikely to be effective in the low-lying areas to the south of the town because of frequent high groundwater levels.

### Background

The Fairford Neighbourhood Development Plan [NP] was rejected in 2017 by the Examiner partly on the grounds that “insufficient hard evidence” had been provided to support the strategy that future housing development should be located on land away from the River Coln. The NP Steering Group therefore commissioned this hydrological study to provide that hard evidence, through the investigation and monitoring of groundwater levels in areas representative of proposed development at Fairford. The work also included a review of documents produced by other consultants and utilities relating to recent flooding in the town.

It was accepted by FTC that the River Coln flood risk has been improved through construction of a new bund and other infrastructure by the Environment Agency in 2013.

### Scope and Objectives

The focus of work has been to gain an understanding of groundwater levels so that future development planning can be sited in appropriate places which are not subject to high groundwater levels, so that can infiltration schemes can operate effectively, using CIRIA guidelines to keep maximum groundwater levels at least 1 m below the bottom of soakaways.

### Mapping and Geology

#### Topography

LiDAR data and geological mapping was used to investigate lineaments and micro-relief of the town area which would help in locating monitoring sites and interpreting characteristics of proposed development sites.

#### Geology

The Fairford town area is underlain successively by Oxford Clay, Kellaways Sand, Kellaways Clay, Cornbrash Limestone and Forest Marble mudstone. The hydrogeology of the Fairford town area is dominated by the interaction between Cornbrash, Terrace deposits, alluvium and the River Coln, and the buried geological boundary between the Cornbrash limestone and Kellaway Clay is located just south of the urban area.

The Cornbrash Formation is part of the Great Oolite Group and consists of intercalated limestone and marl up to 4.5 m thick with local anomalies, and forms a well-dissected gently-sloping landscape with a uniform dip of one degree.



Superficial deposits consist of river alluvium, glacial head deposits in two valleys on the west side of town, then three terrace deposits [old alluvium]: Northmoor, Summertown-Radley and Hanborough. Most of the town area south of London Road and Horcott Road is characterised by up to 5 m of the Northmoor sand and gravels. The Summertown-Radley terrace is confined to higher areas on the west side of along Cirencester Road and south through Burdocks. There are some remnant higher level terraces of little significance for local groundwater.

#### Water Supply

Until 1946, Fairford used to be supplied by a spring issuing from the Cornbrash, at the junction with Forest Marble under Fairford Old Mill with an average yield of 155 m<sup>3</sup>/d [1.8 l/s]. Houses which were not included in this network were dependent on wells 2.7 to 3 m deep in the gravel deposits and Cornbrash across the town.

The supply was then replaced by a Thames Water groundwater supply using boreholes from deeper limestone in the Great Oolite Group, leaving the Cornbrash essentially unexploited in the present-day. Groundwater levels in the Burdocks observation well show the impact of groundwater abstraction.

### Groundwater Investigation and Monitoring

#### New Observation Boreholes

Three boreholes were drilled in the town area to identify lithology, groundwater presence and thickness of gravel and limestone, terminating in the upper part of Forest Marble mudstone.

- A2 on the edge of the Coln House rugby pitch, to investigate the Summertown-Radley terrace deposits; GL 91.4 mOD; 0-2.8 mbgl superficial deposits, 2.8-7.2 mbgl Cornbrash limestone.
- B2 at the end of St Marys Drive, to investigate groundwater conditions in the Cornbrash limestone; GL 91.2 mOD; 0-1.6 mbgl superficial, 1.6-3.7 mbgl Cornbrash limestone.
- B5 at the junction of Lovers Lane and Leafield Road to investigate Cornbrash springs in the field at that point; GL 94.0 mOD; 0-0.7 mbgl superficial, 0.7-3.4 mbgl Cornbrash limestone.

The boreholes were cased and equipped with sensor-loggers and monitored for six months.

#### Well Inventory

Reconnaissance-inventory was carried out of wells and springs in the area, and five dug-wells dipped monthly. This information was supplemented by historical records obtained from BGS and the Environment Agency for three sites:

- 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]

### Groundwater Assessment

#### Groundwater in the Great Oolite and Borehole A2

There is a national index monitoring site at Ampney Crucis which provides the longest local record of 60 years, free from abstraction influence. This borehole is 61 m deep with groundwater level generally within the Forest Marble, and it recorded the highest groundwater levels in 2014, 1982 and 1965, confirming that the 2018 monitoring at Fairford has not been done under extreme conditions. The overall range in GWL at Ampney Crucis is 6.07 m, while the average range is 3.085 m, 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 2018 range recorded at A2 in Fairford is 1.74 m [83.2 to 84.94 mOD], and regression analysis was used with caution to extend the A2 record using the Ampney Crucis data, showing that average range in groundwater levels at A2 would be 2.3 m, with a maximum value of 85.9 mOD, and freeboard of 1.4 m below ground level of 87.3 mOD.

#### Groundwater in Superficial Deposits

The Northmoor terrace outcrops in a broad arc through Horcott and Fairford town south of London Road into the industrial estate and gravel workings. Groundwater levels are monitored by a 4.6m deep borehole at Cinder Lane with a 16-year record. Although groundwater maxima occurred in the winters of 02/03, 06/07, 07/08, 12/13, 13/14, the highest level occurred 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] and ground level is 83.31 mOD. Maximum groundwater levels were simulated for the period 1991-2018, using the available record for the River Coln at Fairford, which showed a T200 freeboard of 1.2 m at Cinder Lane.

Likewise, groundwater levels were simulated for the dug-well records using the Mar-Aug 2018 monitoring period and records at Cinder Lane, Burdocks and Ampney Crucis.

#### Cornbrash Groundwater

The Cornbrash limestone is relatively thin and although water levels appear to be high during most winters, the formation dewateres during spring-summer, falling to levels controlled by groundwater in the Coln valley. Two wells in the Cornbrash were monitored and Comrie was dry by 17-July despite having over 2 m of water in the well in winter. Likewise, springs at the junction of Lovers Lane and Leaffield Road were flowing in winter, but they also dried up over the same period. Boreholes B2 and B5 were drilled to confirm water levels and the thickness of the Cornbrash in this area.

Since Meysey Hampton abstraction was reduced in 2004, the borehole at Burdocks overflows in winter: however, it would appear that the Forest Marble mudstone prevents vertical rise into the Cornbrash.

#### Maximum Groundwater Levels

Extreme value frequency analysis was carried out at Fairford select sites in order to assess potential groundwater flooding and freeboard with reference to the 1 in 200-yr groundwater level [T200]. This showed that levels would exceed ground level at Riverdale and Comrie. While this is likely to be true of the Northmoor terrace, it is geologically less likely at the higher-level Cornbrash site where groundwater maxima will be depressed by peripheral spring discharge, as with the Ampney Crucis record. It can be concluded however that groundwater levels in the Cornbrash will be close to the surface in T200 conditions.

In contrast, the Summertown terrace analysis shows that groundwater rise is contained with more than a metre of freeboard under T200 conditions.

### Implications for Development

#### Summertown-Radley Terrace

This terrace deposit of 3.0 to 4.4 m thickness and underlying Cornbrash has permanent groundwater and represented by data from A2 and Coln House dug-well. Although groundwater levels are closer to the surface at Coln House dug-well, the area is unlikely to experience groundwater flooding and maximum levels remain well below ground surface.

Part of the F50 site along the southern boundary and south-west boundary will experience high groundwater levels, where the area lies along the boundary with the Northmoor terrace deposits and valley of the Dudgrove Brook. There is scope for infiltration schemes in the northern portion of F50 and area to the north.

#### Northmoor Terrace

Groundwater in the Northmoor Terrace reflects the regime of the River Coln and this will dominate F44. Although Horcott Road forms local high ground which may impede the entry of floodwater directly from the river, F44 is low-lying [83 to 84 mOD], and river flood level is 84.0 mOD, which suggests that F44 would be vulnerable to groundwater emergence from the alluvial deposits. No area can be considered suitable at this location.

The other Northmoor terrace sites are located east of the river at F15, F38, F39C, F39D and F52. These sites may be represented by data for Cinder Lane and the Keble Fields ground investigation. Cinder Lane showed a freeboard of 1.2 m under T200 conditions, particularly where Northmoor deposits overlie the Cornbrash limestone. This suggests that F15 and F39D satisfy requirements and the development area could be larger, whereas parts of sites F39C and F52 are likely not to have sufficient freeboard. F38 is closer to the monitoring well at Riverdale which showed a risk of groundwater flooding in T200 conditions.

#### Cornbrash outcrop

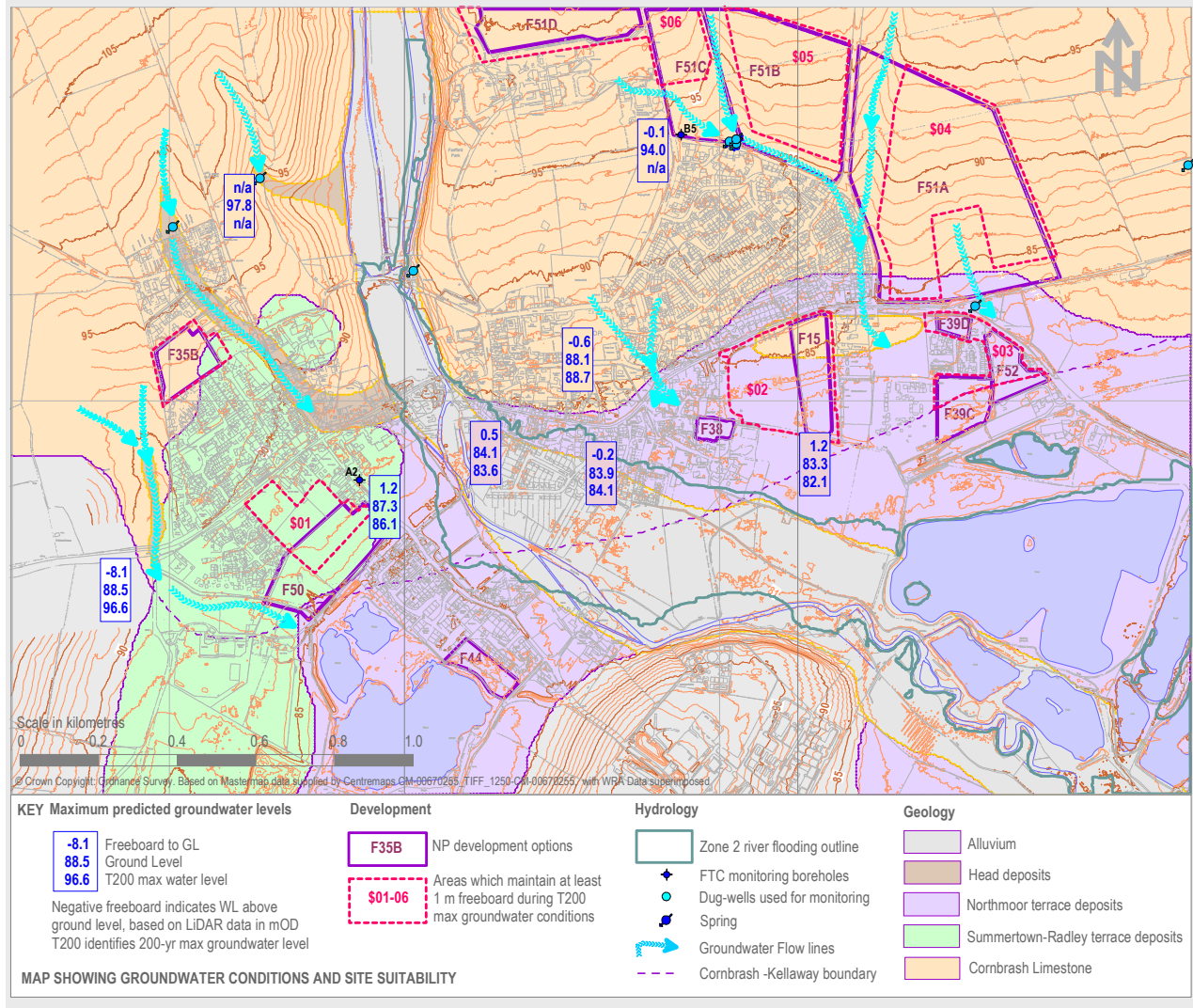
In general terms, the Cornbrash outcrop area is characterised by groundwater levels close to the surface during winter which give rise to numerous springs, followed by progressive dewatering of the formation during the spring and summer recession. Evidence of groundwater discharge was confirmed in the shallow valley infilled with head deposits west of Dynevor Place, which follows a route under Milton Farm and into the Coln. The Milton site F35B is distant from this dry valley, so should have reasonable freeboard during times of high groundwater, as confirmed in the dug-well at Dynevor Place.



At the Leaffield sites F51A-C, groundwater levels are artesian and close to the surface during winter at several locations, and geological data was provided by boreholes B2 and B5. The low-lying parts of this area do not achieve the desired freeboard, and would be subject to groundwater flooding.

Fairford Park site 51D is at a higher elevation and should achieve the required freeboard. Groundwater flowlines have been drawn to identify areas which would be expected to have higher aquifer permeability and high groundwater levels during flood conditions.

The following figure shows the groundwater conditions and site suitability.



## Conclusions

Fairford has experienced significant fluvial flooding from the River Coln and Court Brook on a number of occasions and with a changing climate it is likely that such events will become more common. There have also been floods from surface runoff and from an overwhelmed sewer system.

As part of future planning, developers would fund independent studies to ascertain what additional sewerage works would be required to support proposed new development. This would take the form of scoping studies to identify the work required and cost of improvement which would then be undertaken by Thames Water.

There is no scope for SuDS drainage using infiltration in low-lying areas associated with the Coln alluvial corridor due to frequent high groundwater levels. In such conditions, attenuation storage ponds provided as a SuDS solution can only take the form of shallow depressions which would require significant land.

Ideally development would be directed away from the Coln and Court Brook corridor.

CIRIA guidelines emphasise that effective SuDS infiltration schemes would ensure that groundwater levels are at least 1 m below the bottom of soakaways. For sensitive sites at the preliminary planning stage, developers would provide a flood risk assessment with infiltration tests to confirm the suitability or otherwise of that site.

## Glossary of Units, Terms and Abbreviations

m	metres
mm	millimetres
m bgl	metres below ground level
mOD	metres above Ordnance Datum
m AOD	metres above Ordnance Datum
Ha	hectare
catchment	area drained by a river
river gauging	point on the river where the rate of discharge is measured
GW	Groundwater
RWL	Rest water level
GWL	Groundwater level
T	Return period in years
T200	1 in 200-year event
GL	Ground Level
WT	Well Top
LiDAR	Surveying method using pulsed laser light
CIRIA	Construction Industry Research and Information Association
Freeboard	Vertical distance from water level to another reference point [usually ground level]
GIS	Geographic Information System
SMD	Soil Moisture Deficit
Soakaway	Cavity which allows water to drain into the ground rather than a sewer or mains drain pipe
GCC	Gloucestershire County Council
LLFA	Lead Local Flood Authority
LFRMS	Local Flood Risk Management Strategy
uFMfSW	Updated Flood Maps for Surface Water [Environment Agency]
BGS	British Geological Survey
EA	Environment Agency
CDC	Cotswold District Council
NP	Neighbourhood Development Plan
LNR	Local Nature Reserve
SFRA	Strategic flood risk assessment
WILD	Water with Integrated Local Delivery [Project with Cotswold Water Park]
SuDS	Sustainable drainage systems



## Glossary of Hydrogeological Terms

**Alluvium.** An unconsolidated accumulation of fluvially-deposited sediments, including sands, silts, clays, or gravels [typically deposited by rivers and streams in a valley bottom].

### Aquifer -

[1] A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs [after Lohman and others, 1972].

[2] A geologic formation, group of formations, or part of a formation capable of yielding a significant amount of groundwater to wells or springs. Any saturated zone created by uranium or thorium recovery operations would not be considered an aquifer unless the zone is or potentially is [1] hydraulically interconnected to a natural aquifer, [2] capable of discharge to surface water, or [3] reasonably accessible because of migration beyond the vertical projection of the boundary of the land transferred for long-term government ownership and care [10 CFR Part 40 Appendix A].

[3] A formation, a group of formations, or a part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs [10 CFR Part 960.2].

[4] A zone, stratum, or groups of strata that can store or transmit water in sufficient quantities for a specific use [30 CFR Part 710.5].

[5] Geological formation, groups of formations, or part of a formation, that is capable of yielding a significant amount of water to a well or spring [40 CFR Parts 146.03; 260.10; 270.2].

[6] A geologic formation, group of formations, or portion of a formation capable of yielding usable quantities of groundwater to wells or springs [40 CFR Part 257.3-4].

### Artesian

Artesian groundwater refers to water in a confined aquifer which, when penetrated by a borehole, rises under hydrostatic pressure to a point above the top of the aquifer. Depending on the depth of the aquifer, the water may or may not overflow onto the ground surface. The word artesian comes from the town of Artois in France, the old Roman city of Artesium, where the best-known overflowing artesian wells were drilled in the Middle Ages. The level to which water will rise in artesian aquifers is called the piezometric surface.

### Confined aquifer -

[1] An aquifer bounded above and below by confining units of distinctly lower permeability than that of the aquifer itself [ASCE, 1985].

[2] An aquifer containing confined groundwater [ASCE, 1985].

[3] An aquifer bounded above and below by impermeable beds or by beds of distinctly lower permeability than that of the aquifer itself; an aquifer containing confined groundwater [40 CFR 260.10].

**Groundwater** [1] all subsurface water as distinct from surface water [ASCE, 1985].

[2] All water which occurs below the land surface. It includes both water within the unsaturated and saturated zones [NRC, 1985].

**Drawdown** [1] The vertical distance the water elevation is lowered or the reduction of the pressure head due to the removal of water [after ASCE, 1985].

[2] The decline in potentiometric surface at a point caused by the withdrawal of water from a hydrogeologic unit [after Heath, 1984]

**Head, static** - The height above a standard datum of the surface of a column of water [or other liquid] that can be supported by the static pressure at a given point. The static head is the sum of the elevation head and the pressure head [after Lohman and others, 1972].

**Hydraulic head** - The height above a datum plane [such as sea level] of the column of water that can be supported by the hydraulic pressure at a given point in a ground water system. For a well, the hydraulic head is equal to the distance between the water level in the well and the datum plane [ASCE, 1985].

**Hydrograph** - A graph relating stage, flow, velocity, or other characteristics of water with respect to time [after ASCE, 1985].

**Impermeable** - A characteristic of some geologic material that limits its ability to transmit significant quantities of water under the head differences ordinarily found in the subsurface [after ASCE, 1985].

**Infiltration** - The downward entry of water into the soil or rock [SSSA, 1975].

**Permeability** - The property of a porous medium to transmit fluids under an hydraulic gradient.

**Permeability coefficient** - The rate of flow of water through a unit cross-sectional area under a unit hydraulic gradient at the prevailing temperature [field permeability coefficient] or adjusted to a temperature of 150C [60-F] [ASCE, 1985].

**Piezometer** - A device used to measure groundwater pressure head at a point in the subsurface.

**Piezometric surface** - Potentiometric surface - An imaginary surface representing the static head of groundwater, defined by the level to which water will rise in a tightly cased well [after Lohman and others, 1972].



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# 1 Introduction

## 1-1 Background

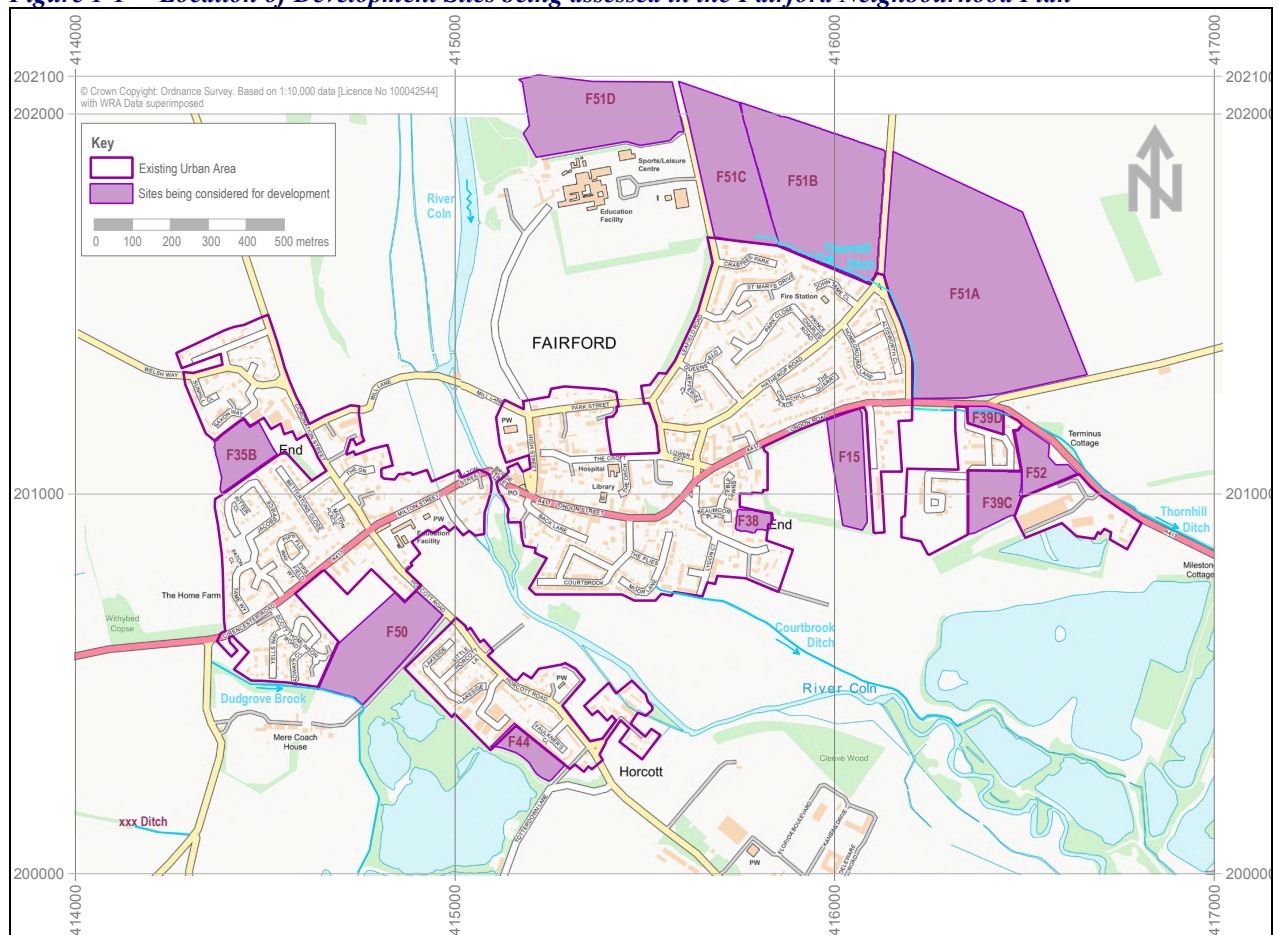
This report has been prepared following the scope of the FTC terms of reference included in [Appendix A](#), taking into consideration a revised outline of sites under assessment.

The Fairford Neighbourhood Development Plan [NDP] was recently rejected by the examiner partly on the grounds that “insufficient hard evidence” had been provided to support the strategy that future housing development should be located on land away from the River Coln and river terrace deposits. The NDP Steering Group therefore commissioned this hydrological study to provide that hard evidence, through the investigation and monitoring of groundwater levels in areas representative of proposed development at Fairford. The work also included a review of documents produced by other consultants and utilities relating to recent flooding in the town.

It would appear that the River Coln flood risk has been improved through construction of a new bund and other infrastructure by the Environment Agency in 2013. The risk of localised surface water flooding at East End was significantly reduced when Thames Water cleared drains under London Road and cleared Court Brook in 2017. So, the focus of this assignment has been assessment of the groundwater levels in and around the town of Fairford, with particular attention to the south-west and north-east perimeters of the town.

The location of development being considered for the Fairford Neighbourhood Plan is shown in [Figure 1-1](#). The sites being assessed conform with the CDC Local Plan.

**Figure 1-1 Location of Development Sites being assessed in the Fairford Neighbourhood Plan**



## 1-2 Objectives and Scope of Work

The scope of the work has included the following key activities:

- Collation and review of all relevant geological, hydrological and hydrogeological data and documentation available from the Environment Agency, the British Geological Survey and other relevant bodies, including records of groundwater and surface water levels, geological map and memoir, borehole records and flood-related reports.
- Reconnaissance of the town area to identify existing water wells and springs, discussion with owners and retrieval of records where possible, to produce an inventory of data and water levels.
- Analysis of LiDAR data and geological mapping to investigate lineaments and micro-relief of the town area and help locate proposed monitoring sites.
- Drilling of small diameter exploratory boreholes in two areas to determine water levels and formation thickness of the Cornbrash limestone and Summertown sand and gravel deposits.
- Construction of piezometers at two exploratory borehole sites for groundwater level monitoring.
- Installation of water level sensors and data loggers in a secure manner.
- Groundwater level monitoring for a period of three months.
- Hydrogeological analysis of long-term historical groundwater records and correlation with data captured by the new piezometers for prediction of conditions at potential development sites shown in [Figure 1-1](#).
- Preparation of a draft report describing the results of the work, for comment by FTC.
- Preparation of a final report addressing FTC comments.

The main focus of the assignment has been on groundwater, but the report also includes a review of previous studies to assess comparative risk of surface flooding for sites close to the river and those further away.

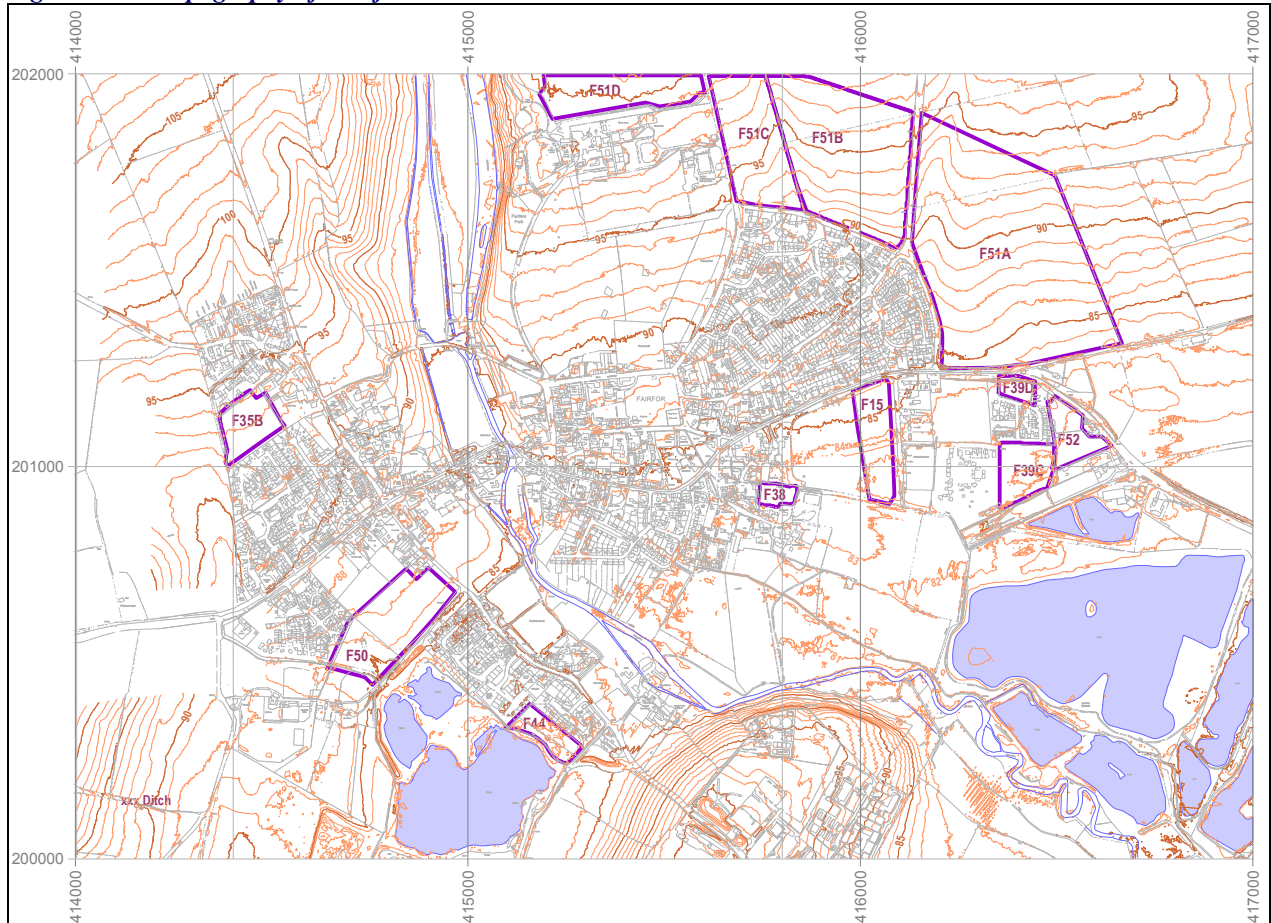
## 2 Reconnaissance, Mapping and Well Inventory

### 2-1 Topographic Mapping

Use was made of LiDAR data and geological mapping to investigate lineaments and micro-relief of the town area which would help in locating monitoring sites and characteristics of proposed development sites.

The relevant LiDAR data-tiles were downloaded from the Environment Agency website and processed using GIS software to produce a digital terrain model and contouring for the study area. Together with Ordnance Survey Mastermap data, this topographic information provides a base-map for the investigation and is shown in [Figure 2-1](#), using a 1 m contour interval.

**Figure 2-1 Topography of Fairford Town Area**



### 2-2 Rainfall and Recharge

Various types of hydrological data were acquired from the British Geological Survey and Environment Agency with a view to supplementing the local information obtained by observation during the 6-month project monitoring period, Mar-Aug 2018. Location of the monitoring sites is shown in [Figure 2-2](#).

The local data-gathering was put into context using rainfall records from Lechlade [1913-2018], Kempsford [1961-2018], and the Thames model rainfall and infiltration simulation for the Cotswold-West area [1920-2018]. Relevant characteristics are shown in [Table 2-1](#) and listing of all sites is provided in [Appendix B-2](#).

Total winter percolation in the Oct-Mar period, which conditions the start-point of monitoring, totalled 276.1 mm compared with 306.5 mm in an average year and 7.8 mm in a dry winter. Likewise, model rainfall of 420.8 mm is close to the long-term mean of 432.4 mm for the same 6-month period. This confirms that groundwater levels during the 2017-2018 recharge period would be expected to be close to or slightly below-average. Groundwater recession during the period of project monitoring would therefore have provided a

reasonable representation of water level variation. It was only from June onwards that the region suffered a prolonged period of zero or low rainfall which would affect groundwater levels through the summer.

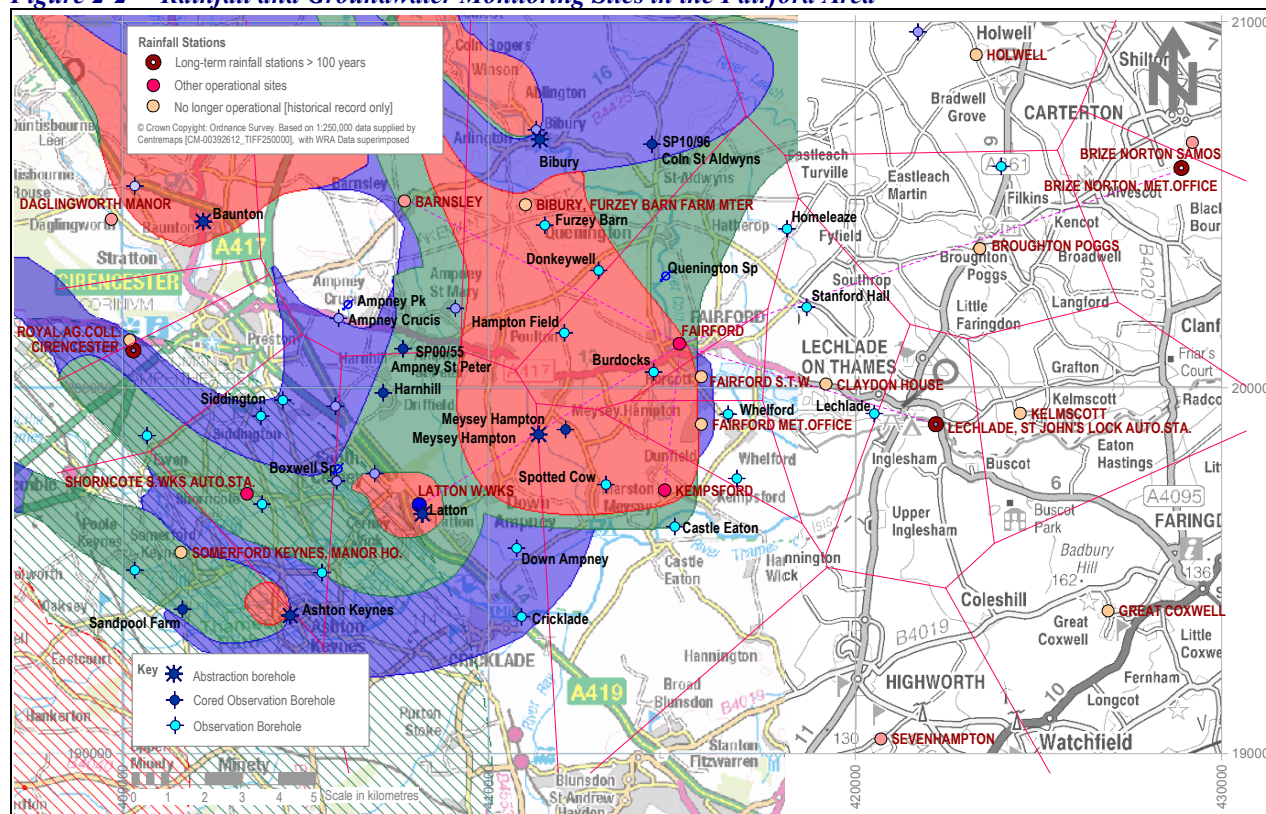
**Table 2-1 Rainfall and Infiltration Statistics affecting the Monitoring Period**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
<b>Lechlade</b>													
2017	69.1	31.3	40.2	6.5	72.6	29.0	79.6	41.4	47.6	21.9	52.2	97.3	588.7
2018	66.1	25.8	93.5	50.8	62.4								
min	7.2	2.1	3.1	1.0	5.3	5.9	2.7	1.1	6.6	4.4	6.8	11.9	358.6
max	157.1	116.3	158.0	147.3	153.2	151.6	176.1	147.2	142.2	150.3	182.6	130.8	992.4
mean	60.6	44.8	47.4	46.2	55.8	50.0	54.0	60.3	53.2	62.6	64.1	64.9	659.6
<b>Rainfall for Cotswold West</b>													
2017	75.4	41.0	51.6	11.0	62.7	69.4	74.1	53.7	62.6	33.0	56.1	107.9	698.5
2018	77.5	32.7	113.6	55.6	82.5	2.9							364.8
min	8.3	2.8	2.1	2.5	5.6	2.9	5.6	2.7	4.0	6.7	8.5	13.3	364.8
max	210.0	164.4	168.0	171.3	181.5	159.1	201.4	161.7	162.1	163.9	215.6	200.8	1157.5
mean	79.5	56.6	56.6	55.7	65.3	57.3	62.7	70.2	67.1	75.4	82.4	82.0	806.3
<b>Areal Infiltration for Cotswold West</b>													
2017	69.4	28.2	27.6	0.5	5.2	5.7	6.7	3.0	5.5	3.6	7.8	92.7	255.9
2018	72.0	24.9	75.1	20.0	8.8	0.0							200.8
min	3.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	2.8	1.8	101.6
max	202.9	146.3	148.0	101.6	106.3	49.7	109.3	58.1	109.1	139.4	180.5	188.9	679.3
mean	72.6	45.7	30.5	16.4	10.1	7.3	7.3	8.2	14.7	26.8	59.1	71.9	368.6

**Note:** The Cotswold-West model cell is referenced as 6010 in EA Thames Region water resources situation reports and data-sets.

**Key:** Winter recharge period Project monitoring period

**Figure 2-2 Rainfall and Groundwater Monitoring Sites in the Fairford Area**



Groundwater source protection zones shown by colour shading: 1 red, 2 green, 3 blue.

[Ampney Crucis and Whelford unaffected by abstraction]

## 2-3 Geology of the Fairford Town Area

### 2-3-1 Mapping and Formations

The solid geology of the Fairford town area consists of the following units:

- Oxford Clay Formation - mudstone.
- Kellaways Sand Member - sandstone and siltstone, interbedded.
- Kellaways Clay Member - mudstone.
- Cornbrash Limestone.
- Forest Marble Formation predominantly mudstone, greenish grey, variably calcareous and intercalated with sandy cross-bedded limestone lower in the sequence.

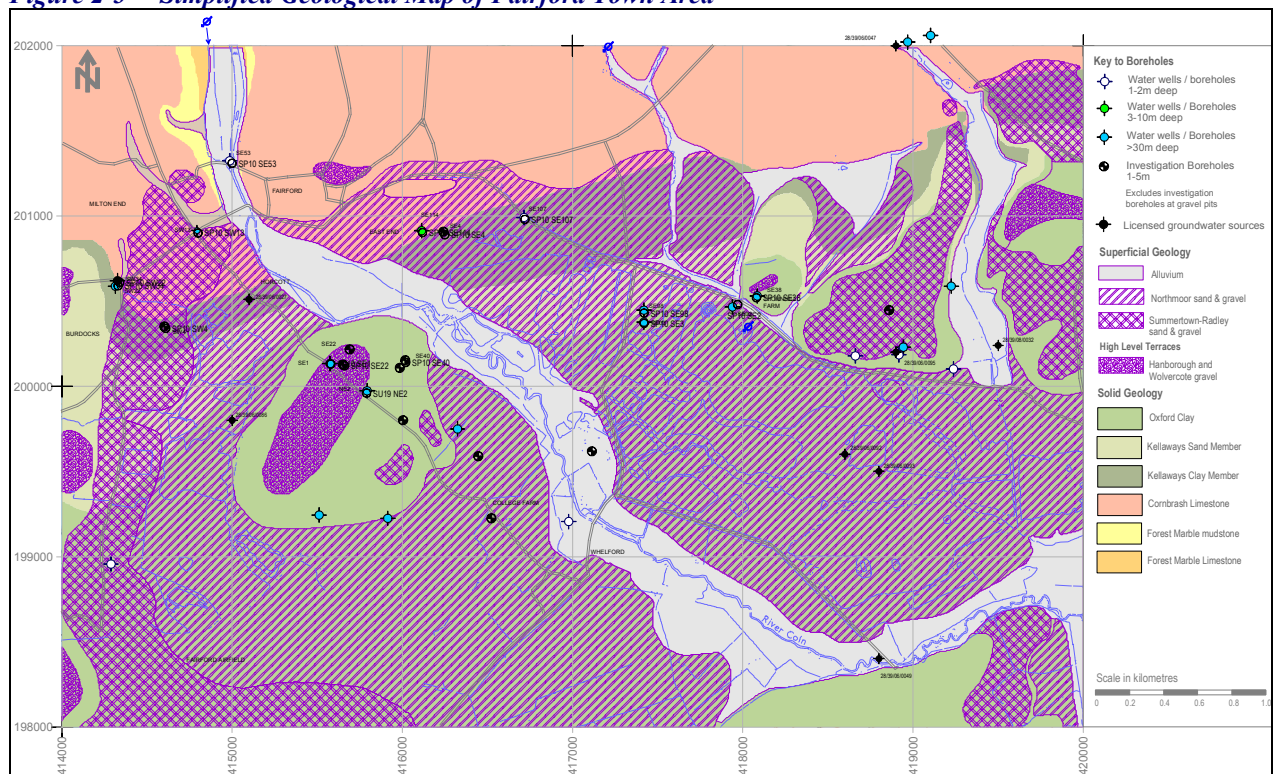
The hydrogeology of the Fairford town area is dominated by the Cornbrash Formation and the interaction of river and groundwater level in the various sand and gravel deposits. The geological boundary between the Cornbrash limestones and Kellaway Clay Formation is located just south of town, roughly travelling south where the sand and gravel deposits begin. The outcrop of different geologies is shown in [Figure 2-3](#).

The Cornbrash Formation is part of the Great Oolite Group and consists of a complex sequence of limestones interbedded with marls and well-known for local anomalies which do not conform to the usual succession. The outcrop forms a well-dissected gently-sloping landscape with a fairly uniform dip of one degree.

The limestones found through drilling at Fairford are pale grey to ochreous brown, argillaceous and sandy, containing fine-grained shell debris. The drill cuttings were typically a coarse brown sand mixed with ochreous silty-clay.

It is reported that the thickness of the Cornbrash is 3 to 4.5 m. In a borehole at Meysey Hampton, the thickness is 4.4 m, and a distinction is made between a sandier upper layer and lower fine limestone layer, but the difference may not be apparent in terms of lithology at some locations. The georeference section is located at Shipton-on-Cherwell Cement Works Quarry, 4.4 km north-northwest of Kidlington, Oxfordshire, where there is a complete sequence exposed, up to about 3 m thick.

**Figure 2-3 Simplified Geological Map of Fairford Town Area**



Based on OS 1:50,000 scale raster base-map and simplification of geological data from various sources

The BGS lexicon of named rock units describes the lithology of the Cornbrash Formation as follows:



“Limestone, medium- to fine-grained, predominantly bioclastic wackestone and packstone with sporadic peloids; generally and characteristically intensely bioturbated and consequently poorly bedded, although better bedded, commonly somewhat arenaceous units occur in places, particularly in the upper part. Generally bluish grey when fresh, but weathers to olive or yellowish brown. Thin argillaceous partings or interbeds of calcareous mudstone may occur”.

The lower boundary is generally a sharp, disconformable non-sequence, where bioclastic limestone rests on mudstone of the Forest Marble Formation.

The superficial deposits of the Fairford town area consists of the following units:

- Alluvial deposits of clay, silt, sand and gravel form a corridor along the River Coln valley.
- Head deposits of clay, silt, sand and gravel formed in a periglacial environment fill shallow valleys on the west side of town.

These are followed in age by the following Thames river terrace deposits:

- Northmoor Sand and Gravel Member
- Summertown-Radley Sand and Gravel Member
- Hanborough Gravel Member

Most of the town area south of London Road and Horcott Road is characterised by up to 5 m of the Northmoor sand and gravels and this is the lowest of the terrace deposits. The Summertown-Radley terrace is confined to higher areas on the west side of town north and south of Cirencester Road and in the Burdocks area.

There are some remnant higher level terraces of the Hanborough and Wolvercote group on the top of Horcott and at the junction of Leafield Road and Park Street. These have little consequence for local groundwater.

## 2-3-2 Local Information

Information on lithology was obtained from the BGS archive, and some of the data from old boreholes in the area are summarised in [Table 2-1](#). This provided a number of useful references, in particular the borehole logs for the Retreat [now Coln House School], Cinder Lane and Burdocks, and further details are provided in [Appendix E](#).

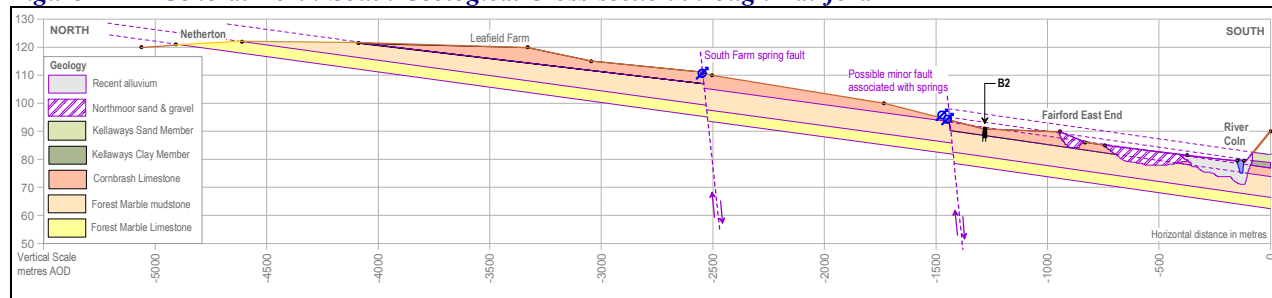
**Table 2-2 List of Historical Wells and Boreholes in the Fairford Area**

Site name	Easting	Northing	Depth m	BGS Ref	GL m aMSL	Cons Date	Terr- ace	Kell- away	Cb	FM clay	FML l/st	White l/st	RWL mbgl
The Retreat Fairford	414800	200900	35.66	SP10 SW13	86.8	1924	1.5	n/a	0.0- 2.1	2.1- 6.4	6.4- 13.1	-	2.13
Fairford Football club	416119	200903	4.70	SP10 SE114			4.7	-	-	-	-	-	2.36
Beaumont Farm	416250	200890	4.00	SP10 SE4				4.9	-	-	-	-	
EA Burdocks geophysical log	414340	200610	79.00	SP10 SW22	88.95	1982			0.0- 6.5	6.5- 14.5	14.5- 36.5	36.5- 48.0	3.30
EA Burdocks Obs BH	414330	200590	79.00	SP10 SW34	89.45	1982			0.0- 6.5	6.5- 14.5	14.5- 36.5	36.5- 58.0	3.30
Fairford old mill	415000	201310	-2.00	SP10 SE53					spring				
Burdocks [Summertown]	414610	200340	4.60	SP10 SW4	88.7	1971	0.2- 4.1	4.1- 4.5	4.5-	-	-	-	
Fairford : New Chapel Electronics	416720	200980	3.96	SP10 SE107		1984	0.0- 3.96	-	-	-	-	-	

Key: Cb Cornbrash, FM Forest Marble, FML Forest Marble limestone, l/st Limestone, RWL Rest water level, GL Ground level

A North-South geological section from Quenington across Fairford Park through Fairford town to Horcott has been interpreted in [Figure 2-4](#). This exemplifies the thin nature of the Cornbrash Limestone and the fact that the thickness is expected to be fairly similar across the area due to the slope and dip.



**Figure 2-4 General North-South Geological Cross-section through Fairford**

Note. Line of cross-section shown in Appendix Figure C-1.

## 2-4 Historical Use of Groundwater for Supply

Part of the parish of Fairford used to be supplied by an undertaking belonging to R Barker of Fairford Park. The source of supply was a spring issuing from the Cornbrash, where it is thrown out by the Forest Marble under Fairford Old Mill. The water was piped to reservoirs and tanks at Milton End 150 m<sup>3</sup>/d, 91 m<sup>3</sup>/d, Manor Farm 6 m<sup>3</sup>/d, Fairford Park 18 m<sup>3</sup>/d, Farhill Farm 5 m<sup>3</sup>/d and Leaffield Farm 5 m<sup>3</sup>/d. The daily average quantity of water supplied by the spring was 155 m<sup>3</sup>/d [1.8 l/s]. Houses which were not included in this network supply were dependent on wells in the gravel deposits and Cornbrash across the town. In the centre of Fairford, these were reported to be 2.7 to 3 m deep and the water level reflecting changes in discharge in the River Coln [Wells and springs of Gloucestershire, p92].

On the side of Waitenhill, where gravel rests on Oxford Clay, a spring used to be exploited and the water pumped into a 10 m<sup>3</sup> tank from where it gravitated to Burdocks and two lodges. A second spring at the locality supplied Waitenhill Farm buildings and did not fail until the drought of 1921.

Another spring was reported issuing from the Cornbrash near Barrow Elm Farm and there were numerous wells in the Cornbrash dotted about the fields. The Fairford Mill spring was used until approximately 1946. These have all been replaced by a new Thames Water groundwater supply using boreholes from deeper limestone in the Great Oolite Group, leaving the Cornbrash essentially unexploited in the present-day. Groundwater levels can therefore be expected to be at natural rest levels, except on the west side of town where groundwater abstraction will have an impact on groundwater levels beneath the Forest Marble.

### 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 mAOD	WellTop mAOD	Depth m bWT	Dia mm	Stick-up 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 mAOD	WellTop mAOD	Depth m bWT	Dia mm	Stick-up 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	-	-	-

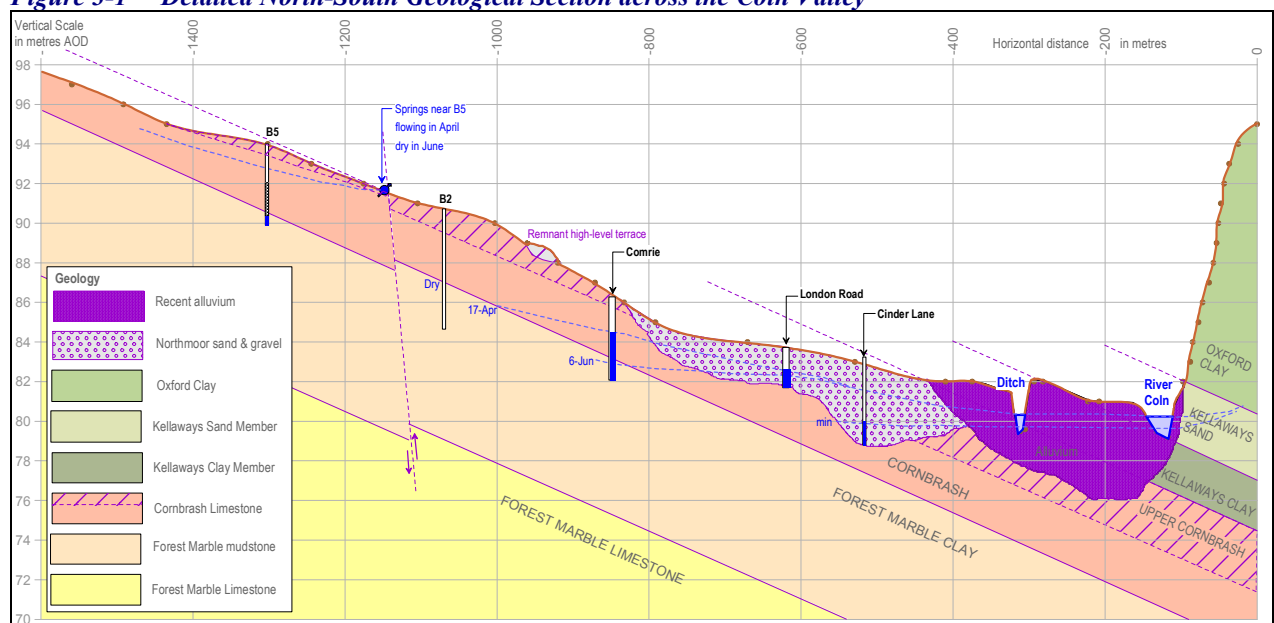
A mixture of daily and weekly groundwater levels was acquired as follows:

- 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

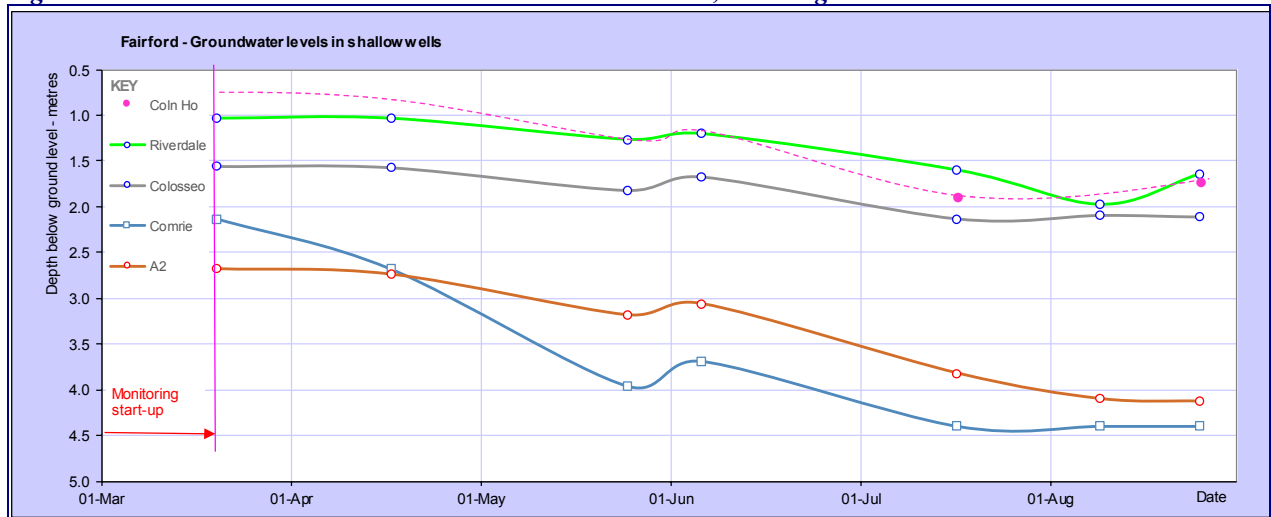
The drilling of A2 and B2 was completed in March 2018 and borehole B5 in August 2018, giving a 6-month record at A2. Monitoring involved monthly dipping and download of the data-loggers with corrections made for barometric pressure and sensor drift relative to dipped values. The groundwater recession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

The dug-well hydrographs are shown in 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.

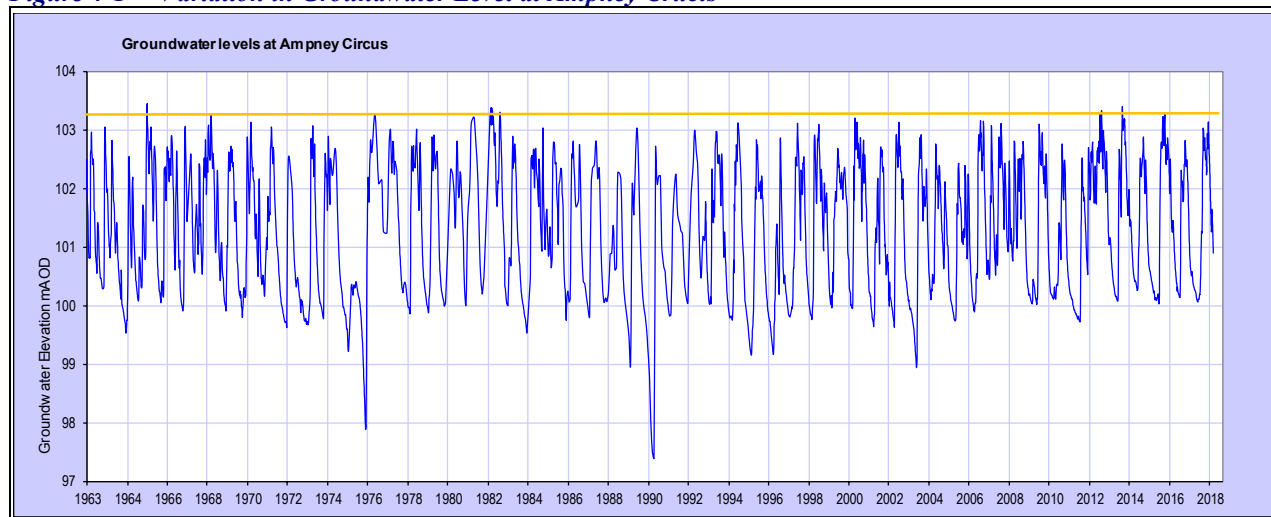
This section looks at the results of the groundwater monitoring and reviews available hydrological data, examining the correlation of short-term records with long-term groundwater records in order to predict seasonal fluctuation and the range in groundwater levels at the sites of interest.

### 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.

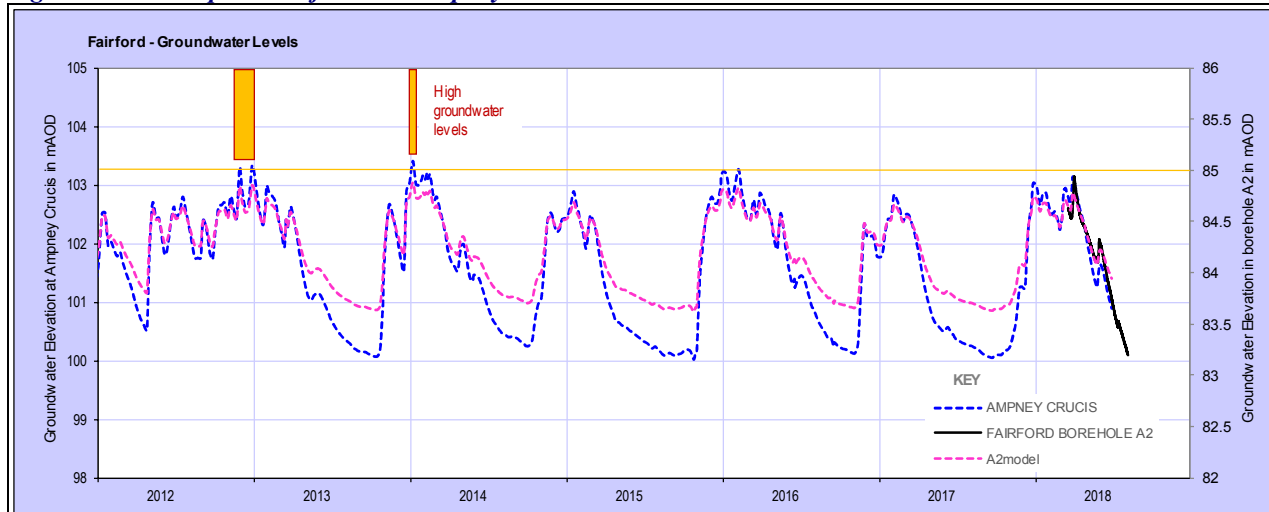
The 12 highest groundwater levels have been summarised in [Table 4-2](#), using a threshold value of 103.2, identifying three years [2014, 1982, 1965] with particularly high levels which may have triggered groundwater flood events. Although top of borehole is 109.52 mOD, maximum values do not greatly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

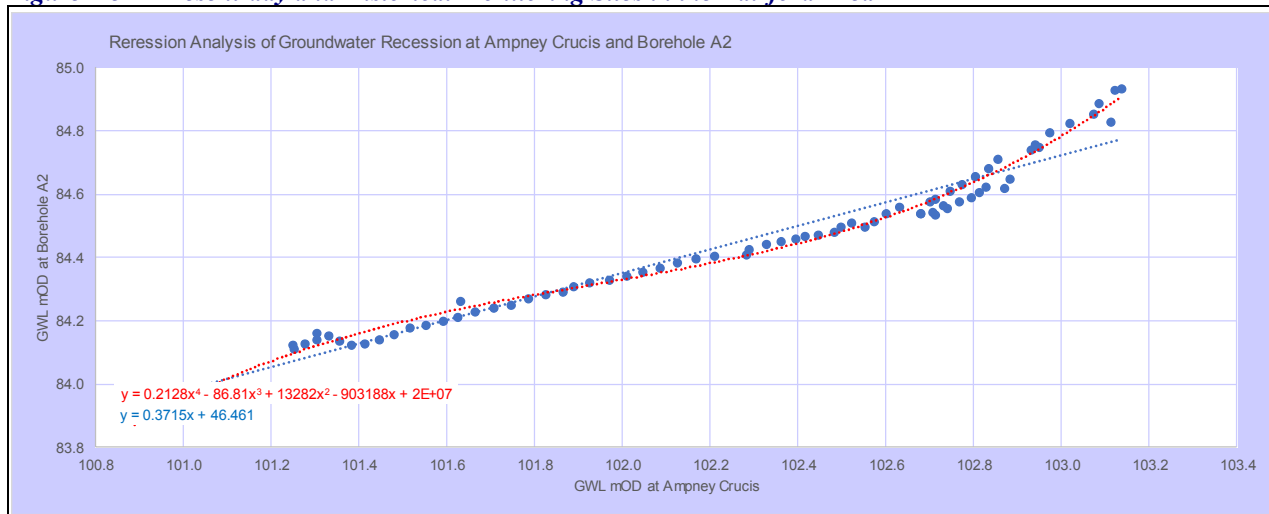


**Figure 4-2 Comparison of A2 and Ampney Crucis Observed Groundwater Levels**

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].

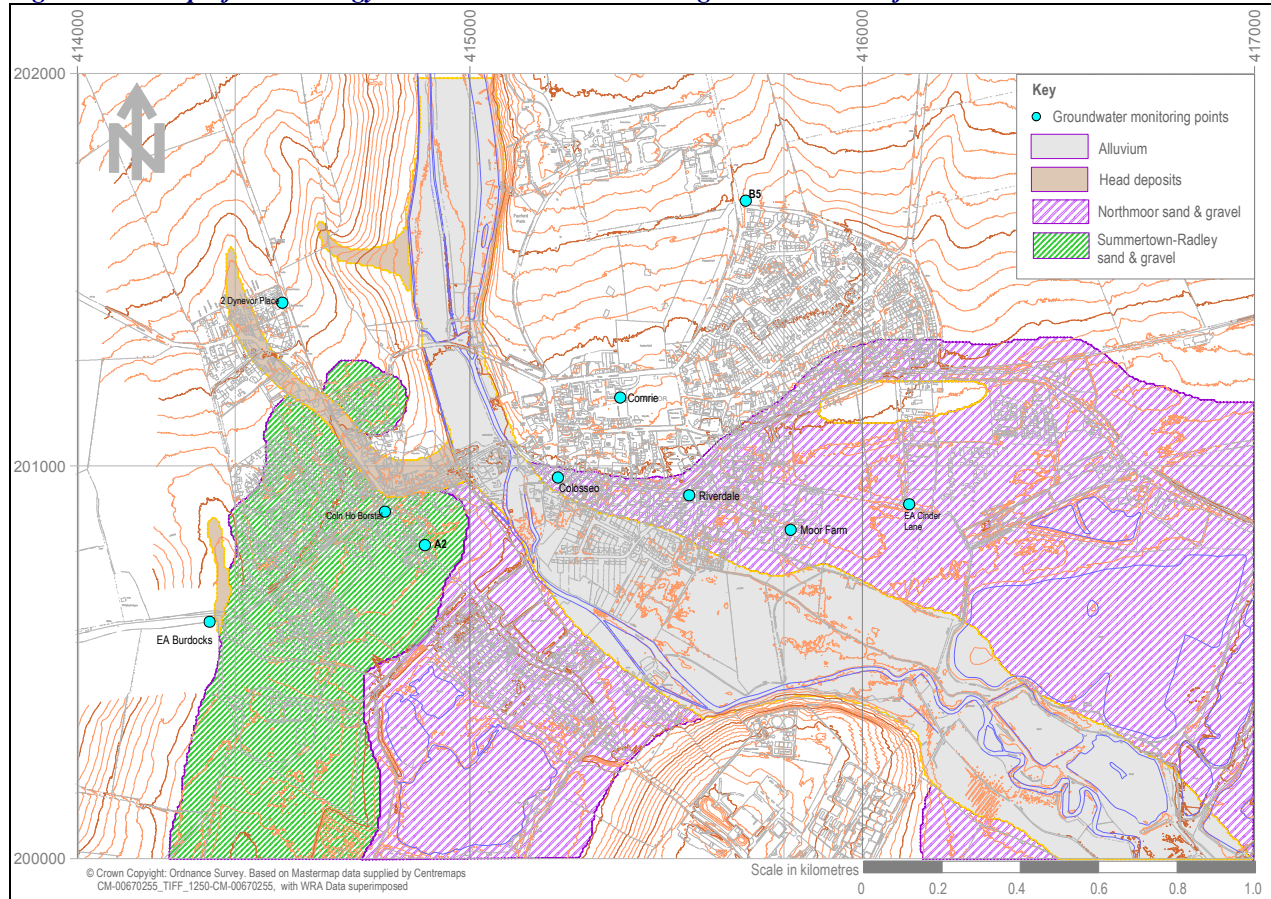
The simple regression analysis shown in [Figure 4-3](#) may be used with caution to extend the water level record using the Ampney Crucis data. Using this equation, the average range in groundwater levels at borehole A2 would be of the order of 2.3 m while a maximum value might be 85.9 mOD, which leaves 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**

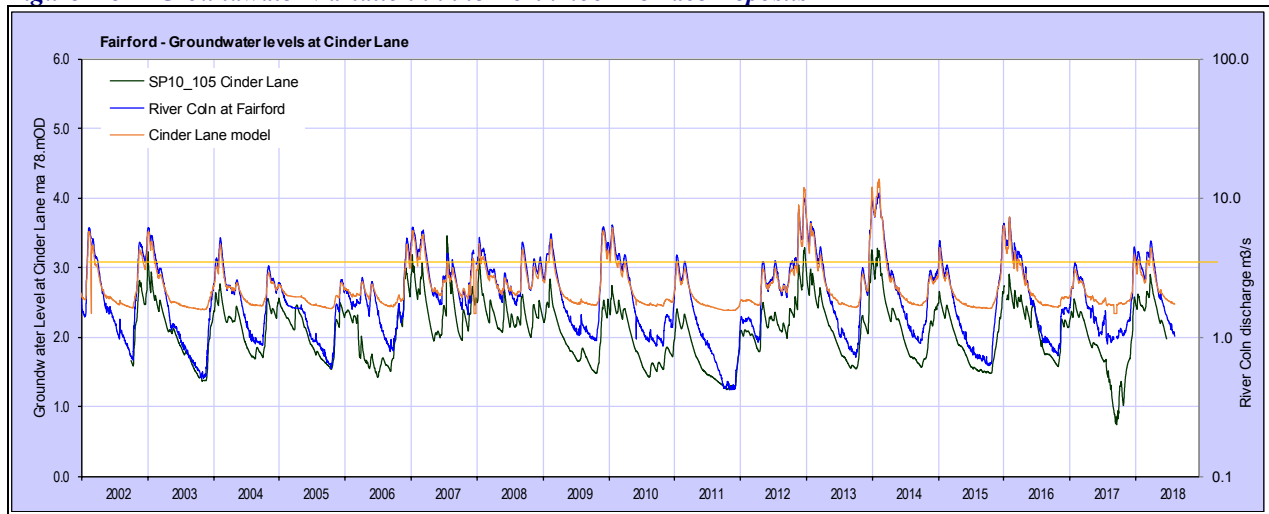
Date	GWL	Date	GWL	Date	GWL
02-Jan-03	81.230	16-Jan-08	81.120	07-Feb-14	81.272
10-Jan-07	81.181	29-Dec-12	81.283		
22-Jul-07	81.452	07-Jan-14	81.250		

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

maximum groundwater levels only, and does not accurately portray summer and drought water levels. The following records of stage and mean daily discharge were analysed:

- 39110 – River Coln at Fairford [415000, 201200], feb1991-jul2018.
- 39020 – River Coln at Bibury [412100, 206200], jan1963-aug2018.

**Figure 4-5** Groundwater Variation in the Northmoor Terrace Deposits



#### 4-2-3 Groundwater Level in Shallow Wells

The project included monitoring in four dug-wells in the town area, and the record for Mar-Aug 2018 has been compared with the long-term monitoring sites at Cinder Lane, Burdocks and Ampney Crucis. Comparison with the Cinder Lane hydrograph is shown in [Figure 4-6](#). As would be expected, the groundwater recession in 2018 at all sites is comparable, and the sites show the start of the autumnal rebound after mid-August.

**Figure 4-6** Groundwater Record in Shallow Wells

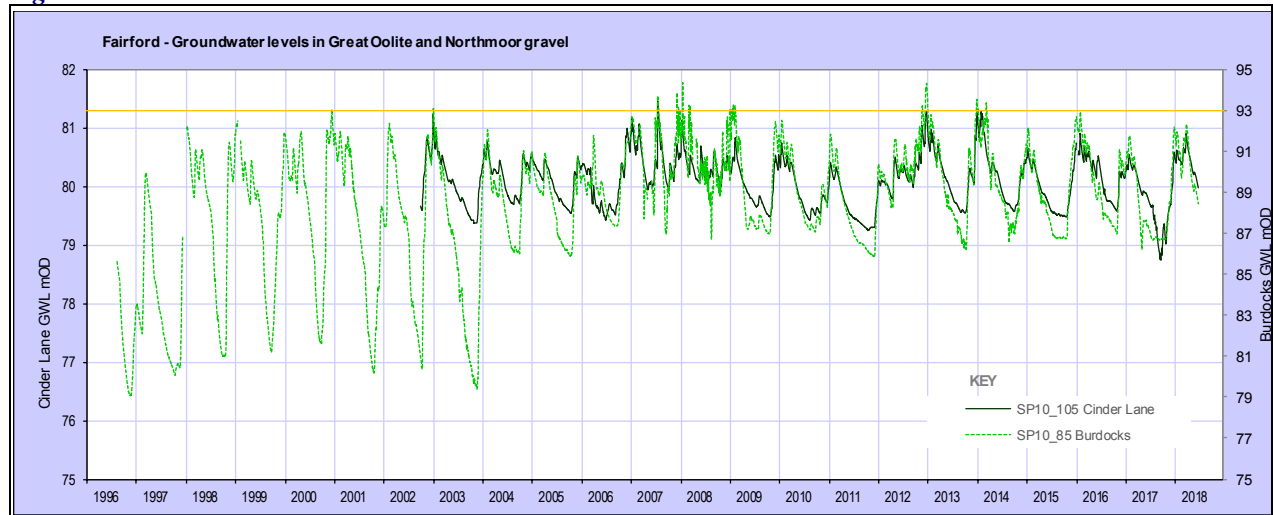


#### 4-2-4 Groundwater Level in the Cornbrash

The Cornbrash limestone is relatively thin and although water levels appear to be high during most winters, the formation can dewater during summer months. Two wells were inventoried and monitored [Comrie and Dynevor Place] and they were both dry by 17-Jul despite having over 2 m of water in the well in winter. Likewise, springs at the junction of Lovers Lane and Leafield Road flow in winter to feed the Thornhill Brook, but they also dry up over the same period. No doubt, for this reason, the Cook Trust decided to backfill an old well at the Orangery near its Estate offices in Fairford Park.

Although classified as the Great Oolite Group, the degree of connectivity between the deeper limestones and Cornbrash is not known. It would appear that the Forest Marble mudstone is sufficiently thick and laterally continuous to provide a significant barrier to vertical movement, so that the borehole at Burdocks becomes positively artesian [overflowing] in most winters. This was evident in the record provided by the Environment Agency in file comments such as “reset to 91.32, note borehole now artesian, not as accurate when artesian”. In fact, in recent years, the logger needs regular resetting due to this feature, and really requires reconstruction of the well-head to install a longer length of tubing. The other feature worth noting is the impact of Meysey Hampton abstraction in the record up to Dec-2003, when presumably TWU pumped less from this source. The pre-2003 pumping would have depressed the peak groundwater levels, so that the observation borehole overflowed to a lesser extent. The details are shown in [Figure 4-7](#).

**Figure 4-7 Groundwater Variation at Cinder Lane and Burdocks**



The confinement of the Forest Marble limestone means that this borehole is less able to represent the aquifer of interest in Fairford, namely the Cornbrash. Reliance has to be placed then on the short records from boreholes and shallow wells in the Cornbrash [Dynevor, Comrie, B2 and B5] to attempt to examine seasonal fluctuation in groundwater level.

### 4-3 Maximum Groundwater Levels

#### 4-3-1 Frequency Analysis

Extreme value frequency analysis was carried out of the available records in order to estimate maximum groundwater levels: the results are shown graphically in [Figure 4-8](#), and summarised in [Table 4-4](#). Potential groundwater flooding is assessed with reference to the 1 in 200-yr groundwater level [T200], and this shows that levels would exceed ground level at Riverdale and Comrie. While this is likely to be true of the Northmoor terrace, it is geologically less likely at the higher-level Cornbrash site where groundwater maxima will be depressed by peripheral spring discharge, as with the Ampney Crucis record. It can be concluded however that groundwater levels will be close to the surface in T200 conditions.

**Table 4-3 Summary of Maximum Predicted Groundwater Levels [mOD] for Fairford Town**

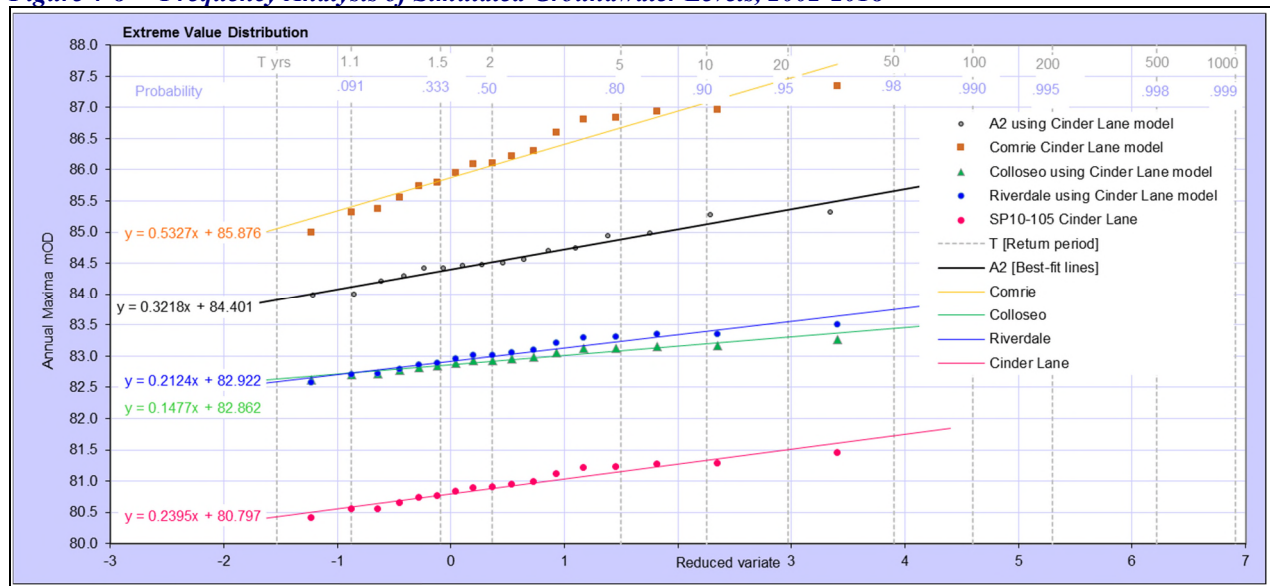
Site	Max mOD	T500	T200	T100	T50	T25	T10	T2	T200 - max	GL mOD	Free-board
Cinder Lane	81.45	82.29	82.07	81.90	81.73	81.56	81.34	80.88	0.61	83.30	1.24
Riverdale	83.75	84.24	84.05	83.90	83.75	83.60	83.40	83.00	0.30	83.90	<b>-0.15</b>
Colosseo	84.30	83.78	83.64	83.54	83.44	83.33	83.19	82.92	-0.66	84.10	0.46
Comrie	88.10	89.19	88.70	88.33	87.95	87.58	87.07	86.07	0.60	88.10	<b>-0.60</b>
A2	84.94	86.40	86.11	85.88	85.66	85.43	85.13	84.52	1.16	87.30	1.19
Burdocks	94.34	97.36	96.58	95.98	95.39	94.79	93.98	92.37	2.24	88.50	<b>-8.08</b>
Ampney Circus	103.45	103.91	103.76	103.65	103.54	103.43	103.27	102.97	0.31	109.50	5.74

Note: Negative freeboard indicates groundwater levels above ground level. Confidence limits have been shown on graphs in [Appendix B-4](#).

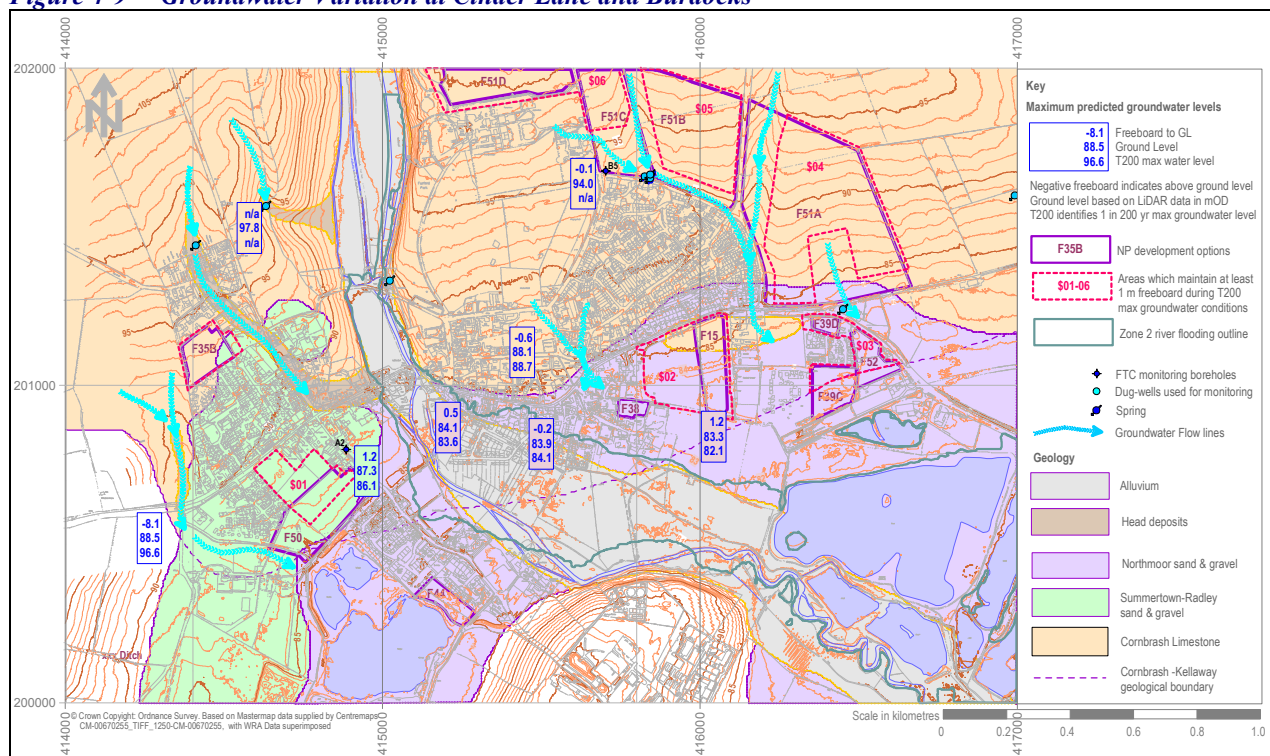


In contrast, the higher Summertown terrace shows that groundwater rise is contained with more than a metre of freeboard under T200 conditions. These results have been mapped in [Figure 4-9](#).

**Figure 4-8 Frequency Analysis of Simulated Groundwater Levels, 2002-2018**



**Figure 4-9 Groundwater Variation at Cinder Lane and Burdocks**



The importance of the analysis in this section is to allow an estimate of potential maximum groundwater levels which lie beyond the elevations observed during the period of monitoring in 2018. The predicted values should be used as a guide rather than providing definitive values, and they allow some useful conclusions.

The characteristics of different parts of Fairford town are now discussed by geological formation, with particular reference to the freeboard available at maximum groundwater levels, to assess the comparative risk of groundwater flooding and to examine whether drainage schemes such as SuDS would be able to operate effectively. CIRIA guidelines emphasise that effective SuDS infiltration schemes should ensure that groundwater levels are at least 1 m below the base of soakaway pits or trenches.

## 4-4 Implications for Development

### 4-4-1 Summertown-Radley Terrace

This terrace is generally an area where seasonally there is permanent groundwater at shallow depth above the Forest Marble Formation, and the maximum values remain well below the ground surface. The area is characterised by the new A2 borehole and the well at Coln House West, where the terrace thickness varies from 3.0 to 4.4 m respectively overlying Cornbrash limestone to a depth of about 7 m bgl.

Groundwater levels are closer to the surface in the vicinity of Coln House West than at A2. In conclusion, this area can be considered as generally an area with perennial groundwater in the terrace and underlying Cornbrash, and is unlikely to experience groundwater flooding.

Although this area would seem to be the area with best characteristics, there is only one site F50 identified for assessment in the planning proposals. Parts of this site along the southern boundary and south-west boundary will experience high groundwater levels, where the area lies along the boundary with the Northmoor terrace deposits and valley of the Dudgrove Brook.

The area with optimal scope for SuDS and free of groundwater flooding is the area immediately to the north of F50 and the northern portion of the proposed development site: this optimal area is designated \$01 in [Figure 4-9](#).

### 4-4-2 Northmoor Terrace

Groundwater levels in the Northmoor Terrace deposits in general reflect the regime of the River Coln, being masked and delayed further away from the main river channel.

There is only one site shown west of the River Coln in the Horcott area at F44. Although no groundwater data were retrieved during the monitoring for that area, the area is low-lying [83 to 84 mOD] and of a similar elevation to the Cinder Lane borehole [83.3 mOD]. Cinder Lane was modelled to have a freeboard of 1.2 m at T200 conditions. Horcott Road forms a ridge between the river and old gravel workings to the west of F44, which implies that groundwater discharge in the lake due west of the proposed site would then control the hydraulic head in the terrace deposits. As river flood level on the other side of the road is of the order of 84.0 mOD, this would suggest that F44 would be vulnerable from both the impact of this flood level and backing-up of groundwater entering the lake, to the extent that the site would in fact flood.

Unlike F50, no area can be considered suitable at this location.

The majority of the proposed development sites in the Northmoor terrace deposits are located east of the river and south of London Road: F15, 38, 39C, 39D and 52.

These sites benefit from having data at Cinder Lane, Chapel Electronics and the newly-constructed housing estate at Keble Fields [Ground investigation for Kensington & Edinburgh Estates, by Hydrock July 2014]. The simulation at Cinder Lane indicates that there would remain a freeboard of 1.2 m under T200 conditions, particularly where Northmoor deposits overlie the Cornbrash limestone. This would suggest that the majority of site F15 and F39D satisfy this condition, whereas parts of sites F39C and F52 are likely not to have freeboard.

Site F38 [due north of Moor Farm] is closer to the monitoring well at Riverdale [London Road] which was modelled to show that there would be no freeboard and a risk of groundwater flooding in T200 conditions.

An indication has again been shown in [Figure 4-9](#) of open areas which would retain more than a metre of freeboard in the predicted flood conditions. The areas are designated \$02 and \$03.

### 4-4-3 Cornbrash

There are two areas of town, to the west and east of the Coln valley, where proposed development has been designated in ground underlain directly by Cornbrash Limestone. The area on the west side of town is generally known as Milton and the area to the east is the Leaffield Road area. At Milton, information was obtained from a dry well at Dynevor Place, and at Leaffield Road, geological information was supplemented using two boreholes, B2 and B5. Unfortunately, a six-month record of groundwater levels was not collected



from these sites, as B2 has not been equipped with piezometer tubing, and B5 was only drilled in August 2018. Monitoring of the B5 borehole will provide further data to refine the assessment of sites F51A-C

In general terms, the Combrash outcrop area is characterised by groundwater levels close to the surface during winter followed by progressive dewatering of the formation during the spring and summer recession. Lithological discontinuities in the formation cause ephemeral springs to occur, of which there are group between B2 and B5 and there is also evidence of springs or groundwater discharge in the shallow valley infilled with head deposits west of Dynevor Place, which follows a route under Milton Farm and into the Coln.

Site F35B lies away from the line of this dry valley, so should have reasonable freeboard during times of high groundwater.

The broad corridor of cultivated land between Leafield Road and London Road [F51A-C] is characterised by groundwater levels close to the surface during winter and at several locations, the groundwater discharges at springs or causes fields to become waterlogged. The low-lying parts of this area do not achieve the desired freeboard, and special drainage considerations would be required should those areas be developed. An indicative line is again provided using the designation \$04.

Finally, site 51D in Fairford Park is at a generally higher elevation and should achieve the required freeboard. Groundwater flowlines have been drawn on [Figure 4-9](#): as a general principle, areas adjacent to and at the outlet of those flow-paths would be expected to have higher aquifer permeability and high groundwater levels during flood conditions.

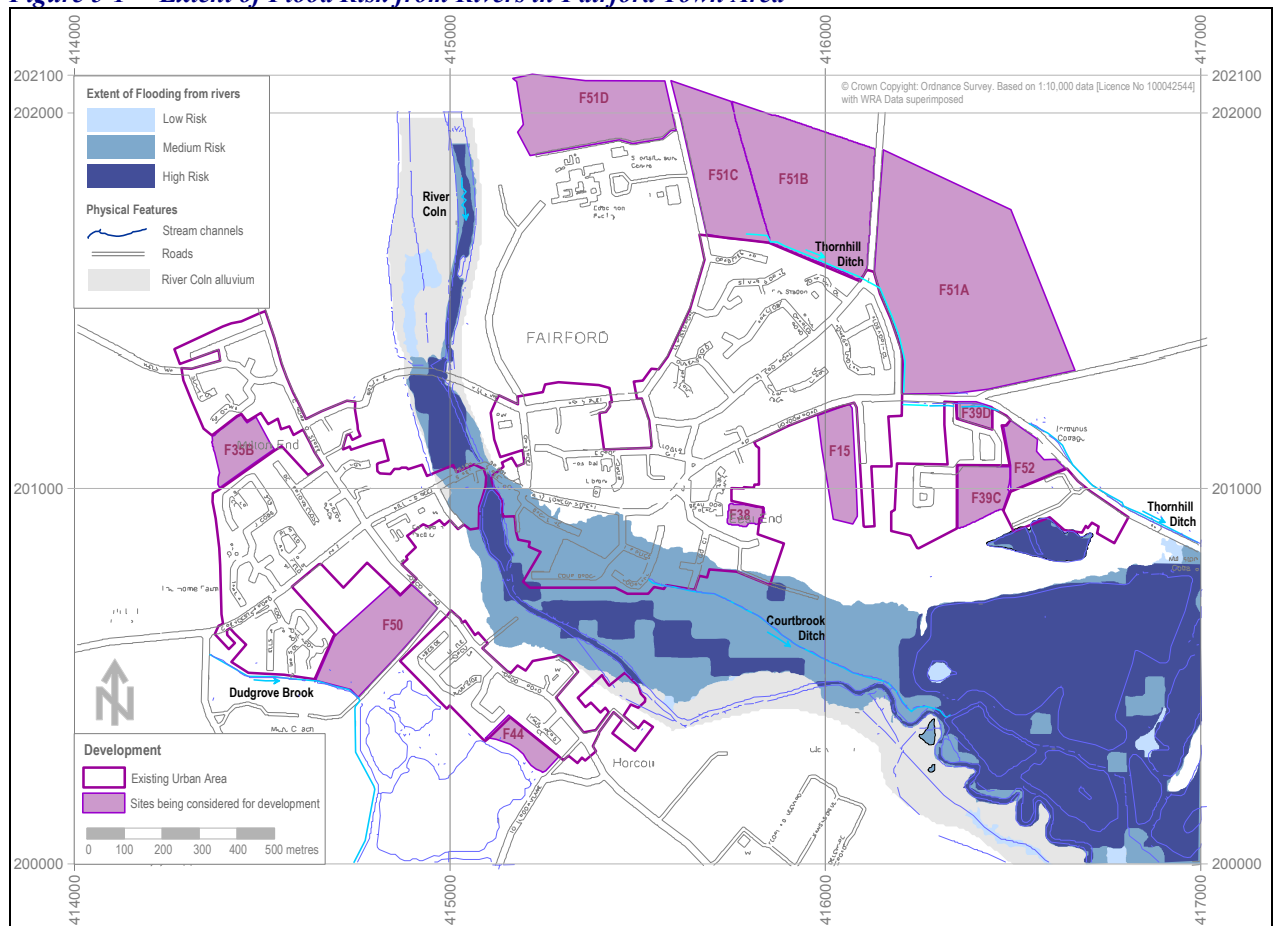
## 5 Surface Water Review

### 5-1 General

A review has been made of the results of work carried out by the Environment Agency, Thames Water and Gloucestershire Highways, and validity of the conclusions reached. A review has also been made of the design flood adopted by the Environment Agency for the Fairford Flood Alleviation Scheme on the River Coln.

Fairford is located on the River Coln that drains a catchment of 129 km<sup>2</sup> upstream of the town. This flows from the Cotswolds limestones from just east of Cheltenham in a south easterly direction and meets the gravel beds of the Upper Thames valley at Fairford. Because the area to the west and south of the town centre is a broad flat floodplain, there is an extensive area at risk from fluvial flooding as shown in [Figure 5-1](#), and the area of old gravel workings to the south east of the town is particularly vulnerable. The outer 1% flood risk line corresponds very closely to the areas of the town that were flooded in the July 2007 flood [described in the Environment Agency report on 2007 flood], and this is within flood zone 3 and hence not suitable for development.

**Figure 5-1** *Extent of Flood Risk from Rivers in Fairford Town Area*



**Key:** Simplified sketch based on Environment Agency Flood Map: dark blue indicates areas with a greater than 3.3% annual risk of flooding [1:30 years] and the pale blue area has risk of 3.3% to 1% [between 1:30 and 1:100 years].

GCC is the Lead Local Flood Authority (LLFA) under the Flood and Water Management Act 2012, and has responsibilities for investigating and reporting flooding incidents and managing flood risk from surface water, groundwater and ordinary watercourses (non-main rivers). GCC's Local Flood Risk Management Strategy [LFRMS, 2014] states that it has delegated the consenting and enforcement role to district councils such as CDC, and has updated the consenting and enforcement protocol in partnership with them. Its Annual Progress and Implementation Plan 2017/18 for Fairford records the number of properties affected as greater than 100, with 50 to 75 properties at high risk [based on the Environment Agency's updated Flood Maps for

Surface Water, uFMfSW]. It classifies the flood risk as High and also records ‘Scheme complete ‘for the Environment Agency river flood alleviation scheme at Fairford.

Gloucestershire SuDS Design & Maintenance Guide notes that some areas of the Cotswolds can be affected by high groundwater levels, and those sites would be investigated using infiltration tests. This is likely to be the case in planned development at Fairford.

The GCC Groundwater Intermediate Assessment for South Cotswold District [Atkins, April 2015] reports the following: “Groundwater level data have indicated that there is the potential for groundwater levels to be above, at or approaching the ground level in a number of locations (including Fairford). The lower lying land to the south of the Cotswold District is shown to have areas that have a higher potential risk of groundwater flooding due to a combination of low gradient land, the presence of superficial deposits with a high percentage coverage of sands and gravels and underlying mudstones, together with historic flooding.”

Dudgrove Brook drains the W side of Fairford into Horcott lakes [old water-filled gravel workings on the south side of Horcott] and then collects discharge from the lakes, and from land drains from the fields around, and runs across the Fairford Air Base and across gravel workings before discharging into the River Coln at Dudgrove. Because of previous flooding problems and the sensitivity of the site, this discharge is released at a limited controlled rate, which is regulated by Environment Agency [Information provided by FTC].

Court Brook was the original town sewer, and the ditch runs at a lower level than the River Coln.

The CDC report discusses the flood pressure on sensitive areas in and around Fairford with a number of key paragraphs from their report repeated below:

*7.5.1 The main area in the District which has particularly complex flood risk issues is the Cotswold Water Park. The Environment Agency has advised that any further development in this area will require further work to fully appreciate the complex fluvial, groundwater and lake interactions. Without a full appreciation of this interaction, development should not go ahead.*

*8.6 Application of the Sequential Approach to Other Sources of Flooding.*

*8.6.1 Development proposals in any location [Flood Zones 1, 2, 3a and 3b] must take into account the likelihood of flooding from sources other than rivers and the sea [where applicable]. The principle of locating development in lower risk areas should therefore be applied to other sources of flooding.*

*8.6.2 The information collated within the SFRA has identified areas in which risk from other sources of flooding is likely to be an important consideration. The Council should therefore use the Sequential Approach to steer new development away from areas at risk from other sources of flooding, as well as fluvial.*

*8.6.3 The SFRA has highlighted areas where information of flooding from other sources is currently poorly understood or will require further refinement in the future. Of particular relevance is the fact that the Environment Agency now requires further investigation/mapping of surface water flooding to be carried out as part of a Level 2 SFRA, to ensure that potential allocations can be Sequentially Tested against this source of flooding.*

The Pitt report on the 2007 floods identified Fairford as one of the areas worst-affected by surface water flooding and where properties were also affected by sewer flooding. The report states “on 20<sup>th</sup> July 2007 Exceptionally heavy rainfall fell onto already saturated ground resulting in quick, widespread flooding from a variety of sources, not just watercourses. As well as extremely high river flows, it is important to note that surface water, sewer and groundwater flooding played a considerable role in the summer flood event, adding to the complications. Drains and sewers were overwhelmed by the intense and prolonged rainfall, rapidly causing flooding”. The report went on to state that there were a number of discrepancies in the Environment Agency flood maps in the Cotswold area and that “consultation with EA staff has indicated that there is a complex relationship between the river Coln, Court Brook [draining from Fairford] and existing gravel pits. This is an area where development is underway and is also proposed. It should be highlighted that there is a need for further modelling work in this area”.

During the 2007 flood Fairford suffered from both overflowing of the River Coln and also from surface runoff from fields and paved areas and the sewerage system was overwhelmed during the event. The Hyder post-flood report of 2008 summarised the flood problems experienced and proposed a number of remedial actions which in most cases have now been implemented.

Similarly, the Thames Water Strategy study report identified a number of problems within the town where sewers had been overwhelmed during heavy rainfall events and some of these issues have subsequently been resolved with a major survey of the piped sewerage system undertaken recently. Some of the remaining sewer problems arise from infiltration of high groundwater levels into the system, a major problem because of the alluvial and terrace gravels which underly much of the town. Other problems arise from surface water mis-connections and surface runoff from roads and public spaces finding their way into the system.

## **5-2 SuDS**

Urban sustainable drainage systems [SuDS] are current ‘best practice’ for new urban development with the objective of minimising the impacts upon the local pre-development drainage regime. This may be achieved through the use of permeable areas to encourage infiltration or through construction of attenuation ponds to restrict runoff from the site to less than the original ‘green field’ rate.

Thames Water suggests that SuDS solutions using infiltration are unlikely to be effective in the low-lying areas to the south of the town because of frequent high groundwater levels. In their CDC Strategic Flood Risk Assessment report, JBA also suggest that SuDS drainage using infiltration is unlikely to be feasible for those areas to the south and southeast of Fairford. Thus, it is likely that SuDS drainage in such areas would only be possible through the use of quite significant areas of shallow attenuation ponds because of the high groundwater levels in these areas; attenuation ponds would have to be shallow to avoid ingress of groundwater and hence would have to occupy a significant portion of any site.

Some SuDS designs may aim to raise the ground level which would have the following result:

- i) Reduction in floodplain storage and conveyance capacity thereby increasing flood risk elsewhere.
- ii) Risk of increasing run-off and flooding elsewhere, although reducing flood risk on the site itself.
- iii) Improved viability of infiltration systems due to the increased margin above the maximum groundwater level.
- iv) Improved freeboard for attenuation storage, thereby reducing the land area required.
- v) Increased elevation and visual impact of the development on the landscape.

Such schemes imply raising ground levels significantly over large areas, which would generally be impractical or unacceptable.

## 6 Conclusions

### 6-1 Groundwater

- 6-1-1 The Summertown-Radley terrace deposit and underlying Cornbrash has permanent groundwater and represented by data from A2 and Coln House dug-well. Although groundwater levels are closer to the surface at Coln House dug-well, the area is generally unlikely to experience groundwater flooding and maximum levels remain well below ground surface for SuDS schemes.
- 6-1-2 Part of the F50 site along the southern boundary and south-west boundary will experience high groundwater levels, where the area lies along the boundary with the Northmoor terrace deposits and valley of the Dudgrove Brook.
- 6-1-3 Groundwater in the Northmoor Terrace reflects the regime of the River Coln which dominates F44. Although Horcott Road forms local high ground, F44 is low-lying and vulnerable to groundwater flooding. No area can be considered suitable at this location.
- 6-1-4 The other Northmoor terrace sites are located east of the river at F15, F38, F39C, F39D and F52. Represented by Cinder Lane F15 and F39D satisfy requirements and could be larger, whereas parts of sites F39C and F52 are likely not to have sufficient freeboard. F38 is closer to the monitoring well at Riverdale which showed a risk of groundwater flooding in T200 conditions.
- 6-1-5 The Cornbrash outcrop area is characterised by groundwater levels close to the surface during winter which give rise to numerous springs, followed by progressive dewatering of the formation during the spring and summer recession. Evidence of groundwater discharge was confirmed in the shallow valley infilled with head deposits west of Dynevor Place, which follows a route under Milton Farm and into the Coln. The Milton site F35B is distant from this dry valley, so should have reasonable freeboard during times of high groundwater, as confirmed in the dug-well at Dynevor Place.
- 6-1-6 At the Leaffield sites F51A-C, groundwater levels are artesian and close to the surface during winter at several locations, and geological data was provided by boreholes B2 and B5. The low-lying parts of this area do not achieve the desired freeboard, and would be subject to groundwater flooding.
- 6-1-7 Fairford Park site 51D is at a higher elevation and should achieve the required freeboard. Groundwater flowlines have been drawn to identify areas which would be expected to have higher aquifer permeability and high groundwater levels during flood condition.
- 6-1-8 The suitability of possible development sites has been summarised in [Table 6-1](#) by applying the CIRIA guideline that the base of soakaways should be built at least 1 metre above maximum groundwater level.

**Table 6-1 Suitability of Development Sites from a Groundwater Perspective**

Site	Description	Geology	Suitability	Map Area <sup>1</sup>	Comment
F_15	Jones Field	Northmoor	Full	\$02	
F_35B	Land behind Milton Farm	Cornbrash	Full	F_35B	
F_38	Land east of Beaumoor Place	Northmoor	No	n/a	
F_39C	Field SE of Keble Fields	Northmoor	Partial	n/a	Northern part only
F_39D	Land at London Road (Bovis)	Northmoor	Full	\$03	
F_44	Land at Faulkners Close	Northmoor	No	n/a	
F_50	Land West of Horcott Road	Summertown-Radley	Partial	\$01	Northern part only
F_51A	Land East of Leaffield Road	Cornbrash	Partial	\$04	Avoid flow-paths
F_51B	Land East of Leaffield Road	Cornbrash	Partial	\$05	Avoid flow-paths
F_51C	Land East of Leaffield Road	Cornbrash	Partial	\$06	Avoid flow-paths
F_51D	Land West of Leaffield Road	Cornbrash	Full	\$06	
F_52	Land West of Terminus Cottage	Northmoor	Partial	n/a	Northern part only

Note. <sup>1</sup> Map reference refers to [Figure 4-9](#).



## **6-2    *Floods and SuDS***

- 6-2-1 Fairford has experienced significant fluvial flooding from the River Coln and Court Brook on a number of occasions and with a changing climate it is likely that such events will become more common.
- 6-2-2 There have also been floods from surface runoff and also from an overwhelmed sewer system. As part of any further development developers should contribute to significant improvement in the sewer system.
- 6-2-3 There is no scope for SuDS drainage using infiltration in the low-lying areas associated with alluvial deposits of the Coln valley due to frequent high groundwater levels.
- 6-2-4 Attenuation storage ponds in low-lying areas provided as a SuDS solution can only take the form of shallow depressions that would require significant land.
- 6-2-5 Ideally development should be directed away from the Coln and Court Brook corridor.

## 7 References and Source of Information

7-1	Foul & Surface NE Fairford A0	pdf	583 192
7-2	GW_Flood_Report_update_2007	pdf	3 482 201
7-3	WRA-FRA&SUDs Drainage-October 2016-v.3.1	pdf	3 954 682
7-4	360_Bishop2	pdf	3 655 098
7-5	CAMS_3201_c09752	pdf	4 231 387
7-6	CEH_GWFlood_Risk_2007_update	pdf	3 238 026
7-7	Drought Plan Appendix A DRAFT	pdf	173 309
7-8	Drought Plan Appendix D DRAFT	pdf	777 344
7-9	Fairford Drainage Strategy v2FR 260218 [003]	pdf	6 825 673
7-10	Fairford-Flood-Alleviation-Scheme	pdf	2 896 811
7-11	Microsoft Word - 2079 fairford cover pdf	pdf	1 579 337
7-12	phelps-ppt-ILD-IASC-2017	pdf	3 782 330
7-13	Thames Water Draft Drought Plan 2016 FINAL	pdf	2 837 976
7-14	Thames_Water_Situation_Report_January_2018	pdf	1 615 583
7-15	Thames_Water_Situation_Report_September_2017	pdf	1 515 756
7-16	WILD Project _www-FWAG SouthWest	pdf	449 934
7-17	WILD_Final_Summary_012017	pdf	12 385 322
7-18	Fairford meeting record 31 Oct 2016 v2.1	docx	1 625 591
7-19	Fairford Town Council - Drainage - Issues and Actions v2	docx	15 792
7-20	FTC - Drainage - Documents and Events v2	docx	18 238
7-21	N Plan v2 Ch.2 Neighbourhood area-pach-comments	docx	299 628
7-22	N Plan v2 Ch.2 Neighbourhood area	docx	296 660
7-23	Summary of Flood Alleviation Measures and Outstanding Issues - v1	docx	18 371
7-24	Appendix-1-SA-review-AECOM-	pdf	429 673
7-25	Appendix-B-Fairford-map	PDF	323 785
7-26	Atkins-GWflooding_26_2_14	pdf	445 878
7-27	Atkins-hydrogeo_imp_assesst-kempsford	pdf	460 767
7-28	DSR.05 LOW RES	pdf	6 517 644
7-29	Fairford-DrainageStrategy	pdf	3 993 748
7-30	Fairford-Neighbourhood-Plan-Pre-Sub-FINAL	pdf	3 828 018
7-31	Fairford-Neighbourhood-Plan-Reg-16-submission-Feb-2017	pdf	5 232 627
7-32	Fairford-Neighbourhood-Site-Assessment-Report-FINAL	pdf	1 111 914
7-33	Fairford_WILD	pdf	9 232 109
7-34	Figure 1-2 - Site Assessment_280618	pdf	277 611
7-35	FNP-Site-Assessment-Report-Feb-2017-Final	pdf	1 052 604
7-36	FNPgreenspaces	pdf	3 747 647
7-37	FPW_Appeal_Appendices	pdf	1 298 398
7-38	GWMPBishopsSuttonActionPlan	pdf	428 941
7-39	HMS.02 Med Res	pdf	13 774 388
7-40	Hyder-report-2007-floods	pdf	3 446 557
7-41	Hyder2008-App5-fairford	pdf	201 340
7-42	Identified Sites Map Reg16	pdf	993 876
7-43	JBA - Vale of White Horse District Council - Water Cycl	pdf	3 692 082
7-44	JBA-Water-Cycle-Study-August-2015	pdf	9 379 491
7-45	JBA_Strategic-Flood-Risk-Assessment-SFRA-Level-2-Appendices-June-2014	pdf	711 278
7-46	K & E F.R.A.	pdf	1 189 718
7-47	k & E hydrology extra 2015	pdf	6 725 730
7-48	K & E soakaway results + disclaimer Nov 13	pdf	933 548
7-49	Manor Farm Kempsford FRA.F1	pdf	38 035 874
7-50	Manor Farm Kempsford H&HIA.F1	pdf	110 102 492
7-51	NPPF-2115548	pdf	413 421
7-52	Reg-16-Pre-Submission-document-FDP-Evidence-base-Final	pdf	227 145

7-53	SHELAA Context Map	pdf	1 337 632
7-54	16_01492_Comply-Part_1_Ground_Investigation_Report-1079763	pdf	6 463 182
7-55	16_01492_Comply-Part_1a_Ground_Investigation_Report-1079765	pdf	3 522 494
7-56	16_01492_Comply-Part_2_Ground_Investigation_Report-1079688	pdf	3 491 356
7-57	16_01492_Comply-Part_3_Ground_Investigation-1079800	pdf	6 231 808
7-58	16_01492_Comply-Part_3a_Ground_Investigation-1079799	pdf	577 662
7-59	16_01492_Comply-Part_4_Ground_Investigation_Report-1079793	pdf	418 642
7-60	16_01492_Comply-Part_4a_Ground_Investigation_Report-1079796	pdf	7 230 457
7-61	14_04847_Rem-Design_Access_Statement-759588	pdf	1 862 189
7-62	14_04847_Rem-Location_Plan-759580	pdf	507 873
7-63	14_04847_Rem-Proposed_Site_Plan_338a06-1003-836575	pdf	952 612
7-64	14_04847_Rem-Site_Survey-759589	pdf	531 807
7-65	13_03097_Out-Flood_Risk_Assessment-623088	pdf	3 826 408
7-66	16_01766_Out-Flood_Risk_Assessment-945167	pdf	3 647 700
7-67	16_01766_Out-Flood_Risk_Assessment-945168	pdf	3 377 999
7-68	16_01766_Out-Flood_Risk_Assessment-945169	pdf	2 139 275
7-69	16_01766_Out-Flood_Risk_Assessment-946957	pdf	7 193 830
7-70	12_02133_Ful-Part_1_Drainage_Strategy-497511	pdf	4 386 193
7-71	12_02133_Ful-Part_1_Flood_Risk_Assessment-497500	pdf	4 668 900
7-72	12_02133_Ful-Part_2_Flood_Risk_Assessment-497501	pdf	8 367 091
7-73	12_02133_Ful-Part_3_Flood_Risk_Assessment-497502	pdf	184 823
7-74	12_02133_Ful-Part_4_Flood_Risk_Assessment-497503	pdf	168 687
7-75	13_01116_Comply-Landscape_Ecological_Management_Plan-585205	pdf	9 986 725
7-76	16_01766_Out-Geophysical_Survey-945177	pdf	3 749 565
7-77	Fairford, Whelford, Kempsford & Lechlade; Floods Review July 2007. Environment Agency March 2008.		
7-78	Review and Response to the Summer 2007 Floods in the Cotswold District, Second Phase Report, 25 July 2008. Report No: 0002-NE02933-WXR-04, Hyder Consulting.		
7-79	Learning lessons from the 2007 floods; An independent review by Sir Michael Pitt. Cabinet Office, June 2008.		
7-80	Strategic Flood Risk Assessment for Local Development Framework, Level 1, Volume 1 – FINAL, September 2008. Report to Cotswold District Council by Halcrow Group Limited.		
7-81	Fairford Drainage Strategy, Stage 1 – Initialise/Prepare. Thames Water		
7-82	Strategic Flood Risk Assessment, Final Report, June 2014. Report to Cotswold District Council by JBA Consulting.		
7-83	Water Cycle Study, Phase I Study [Incorporating Water Quality Assessment – Phase II], August 2015. Report to Cotswold District Council by JBA Consulting.		
7-84	WILD, Fairford, Floods Incident Map together with associated Spreadsheet of Incident Details, June 2016.		
7-85	GCC: Gloucestershire Groundwater Management Plan, Groundwater intermediate assessment for South Cotswold District, Apr 2015 [Atkins 5125400/COT/001]		
7-86	GCC: Local flood risk management strategy, annual progress and implementation plan 2015-16.		

## Appendix A Terms of Reference

### Introduction

This document provides an outline scope of work required by Fairford Town Council [FTC] from consultants, Water Resource Associates [WRA] for the proposed investigation and monitoring of groundwater levels in areas of proposed development at Fairford. The work also covers a review of documents produced by its consultants and utilities related to flooding in the town.

The Fairford Neighbourhood Development Plan [NDP] was recently rejected by the inspector partly on the grounds that insufficient hard evidence had been provided to support the strategy that future housing development should be located on land away from the River Coln and river terrace deposits. The NDP Steering Group is therefore commissioning a hydrological study to provide that hard evidence.

### Objectives of the Assignment

The scope of the work will include:

- Review of relevant reports, maps and documents such as geological map and memoirs, borehole records and flood-related reports.
- Collation and review of all relevant geological, hydrological and hydrogeological data and documentation available from the Environment Agency [EA], the British Geological Survey [BGS] and other relevant bodies, including records of groundwater and surface water levels.
- Reconnaissance of the town area to identify existing water wells and springs, discussion with owners and retrieval of records where possible, to produce an inventory of data and water levels.
- Analysis of LiDAR [mapping] data and geological mapping to investigate lineaments and micro-relief of the town area and help locate proposed monitoring sites.
- Drilling of small diameter exploratory boreholes in two areas to determine water levels and formation thickness of the Cornbrash limestone and Summertown sand and gravel deposits.
- Construction of piezometers at two exploratory borehole sites for groundwater level monitoring.
- Installation of water level sensors and data loggers which are secure from vandalism.
- Groundwater level monitoring for a period of three months [December 2017 to February 2018].
- Hydrogeological analysis of long-term historical groundwater records and correlation with data captured by the new piezometers for prediction of conditions at the Development Sites listed in Appendix 1.
- Preparation of a draft report describing the results of the work, for comment by FTC.
- Preparation of a final report addressing FTC comments.

The overall assignment will focus on groundwater, but will also include a review of all previous studies to define comparative risk of surface flooding for sites close to the river and those further away.

The area of study is shown in Figure 1. A definitive list of development sites is given in Appendix 1. The study will investigate and report the comparative risk of flooding and groundwater levels in those areas. The consultant should be aware of two residential developments under construction, namely the Bloor2 and Bovis estates.

### Task 1 Data acquisition, reconnaissance and Mapping

Relevant reports in the possession of FTC or Cotswold District Council [CDC] will be provided and supplemented where possible by other documents prepared either by Thames Water [TW] or Gloucestershire County Council [GCC] on the matter of flooding in the town.

Complete records of hydrological data will be requested from the two main organisations monitoring groundwater and surface water in the area, namely the Environment Agency and Thames Water. This will include but not be limited to acquisition of water level time series at the following locations:

- Cinder Lane Borehole
- River Coln Flow Gauge
- Ampney Crucis Borehole

The consultant will identify wells and springs in the study area which may provide important information on the seasonal variation in groundwater levels in different geological formations. This will be done using BGS records as a starting-point, then following up leads by on-foot reconnaissance talking to residents, with the support of FTC where

possible. Water levels will be measured and historical records retrieved when feasible, to produce an inventory of data and water levels.

The relevant LiDAR data-tiles will be downloaded by the consultant from the Environment Agency website and processed using GIS software to produce a digital terrain model and contouring for the study area. This topographic information will be overlain on geological mapping to investigate lineaments and micro-relief of the town area and help improve the siting of proposed groundwater monitoring points.



**Figure 1 Fairford Town Study Area and Monitoring Sites**

## Task 2 Exploratory Drilling and Piezometer Construction

The aim of the drilling and piezometer construction is to establish the thickness of formations and variation in groundwater level at two proposed sites, designated as follows:

- Site A will be 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 Member of the Quaternary Period.
- Site B will be located on the north-eastern edge of town at the end of St Marys Drive, to establish groundwater conditions in the Cornbrash limestone.

If these locations are considered to be inappropriate by the consultant, or if there are difficulties in obtaining landowner permission, the consultant will advise on alternative siting to achieve the aims of characterising and monitoring the two geological formations.

The drilling of the two boreholes will be carried out using small diameter and lightweight drilling rigs, at size sufficient to identify the lithology of samples retrieved from the borehole and to allow for piezometer construction.

The maximum drilling depth will be dictated by the underlying clay formation, and allowance should be made to penetrate the clay layer by at least 0.3 metres.

At Site A, the anticipated geological succession will be:

- 0.0 - 4.0m Summertown sand and gravel
- 4.0 - 9.0m Cornbrash Limestone

- 9.0 - 9.3m Forest Marble mudstone [clay]

At Site B the anticipated geological succession will be

- 0.0 - 6.0m Cornbrash Limestone
- 6.0 - 6.3m Forest Marble mudstone [clay]

The anticipated drilling depth will therefore not exceed 10 m, and the more complex drilling will occur at Site A, which may have two separate groundwater levels, one in the sand and gravel deposits and another level in the Cornbrash limestone, unless the two formations have hydraulic continuity.

It may be appropriate to install two piezometers in the same borehole at Site A, in order to monitor groundwater levels in each aquifer. This option should be investigated by the consultant, and the appropriate drilling and construction method identified.

Each piezometer will be equipped with a groundwater level sensor and data-logger, housed securely in a small concrete chamber at the head of the borehole and protected by a steel plate which can be locked and opened for ease of access during the monitoring activities.

### Task 3 Groundwater Level Monitoring and Hydrogeological Analysis

Once the field activities and piezometer construction has been completed, the two monitoring sites will be maintained during a period of three months. This will involve monthly download of the data-loggers to ensure accuracy and to carry out manual observation of water levels to verify logger accuracy.

If other wells and groundwater features in the town and vicinity are deemed to be important by the consultant, arrangements should also be made to include those sites in the monitoring campaign.

On completion of the groundwater monitoring period, the consultant will process and analyse all hydrological data collated, including the output from the data-loggers at piezometers A and B, and examine 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 development sites of interest.

The final result will provide a frequency analysis of groundwater levels, and identify the freeboard available for residential development. The freeboards will be compared between different development sites to make a comparative risk of groundwater flooding and to examine whether drainage schemes such as SuDS would be able to operate effectively.

### Duration of the Assignment and Deliverables

Duration of the proposed assignment will be five months, divided into two main stages. The bulk of the work will be done in the first month, and this will then be followed by monitoring activities, analysis and reporting. The two stages are expected to be divided as follows between the two stages:

Stage 1 will take three months to complete, and will involve data acquisition, reconnaissance, mapping, drilling, piezometer construction, groundwater monitoring, hydrogeological analysis and preparation of a draft report. This report will be submitted before the **end of March 2018**.

Stage 2 will involve a review of the results of the work by FTC, facilitated by a presentation and meeting in Fairford. FTC may wish to follow up queries raised during the meeting, or not addressed in the draft report, and would provide the consultant with comments so that a final version of the consultant's report can be prepared for submission by the **end of May 2018**. The final report will be used to substantiate the revised NDP and provide quantified evidence of groundwater at appropriate locations.

All data collated and used in the study will be provided in electronic form, together with two bound hard-copies of the report and copy in digital form.

The study will be carried out for a Lump Sum fee, against work identified in a brief proposal to be submitted no later than **12<sup>th</sup> December 2017** for a start date in **early January 2018**. The cost should be broken down into the individual work components, and allow for the submission of regular progress bulletins and a final presentation of the conclusions to the client.

FTC will arrange with respective landowners the necessary permissions for the consultant to enter land and carry out the exploratory drilling and piezometer construction. This will include the arrangement to subsequently monitor water levels during the project duration.



**TOR APPENDIX 1 – Potential Development Sites**

SHLAA Ref	FNP Ref	Site Location
F_15	x	Jones's Field (Morgan Hall Field)
F_20A	x	Land south of Cinder Lane
F_35B	x	Land behind Milton Farm
F_39A	x	Land off London Road (FTFC Practice Ground)
F_39B	x	Fairford Town Football Club football ground site
F_39C	x	Field South East of Keble Fields (Bovis).
F_44	x	Land behind Faulkners Close
F_45	x	Land south of Morgan Hall
F_50	x	Land west of Horcott Road
F_51A	x	Land east of Hatherop Road
F_51B	x	Land west of Hatherop Road
F_51C	FNP 16	Land east of Leafield Road
F_2	FNP 19	Lower Croft
x	FNP 22 (vii)	Land off Rhymes Lane
x	FNP 3	Land at East End (SHLAA ref F_38)
x	x	Jones Field west of Cinder Lane

**UPDATE OF SITE ASSESSMENT DURING THE COURSE OF THE PROJECT:**

NB: The following seven sites were excluded from the study, since they had already been developed or are no longer in scope: F\_20A, F\_39A, F\_39B, F\_45, F\_2, FNP-22, FNP-3.

Furthermore, the following four sites were added:

- F\_38 Land East of Beaumoor Place
- F\_39D Land at London Road [Bovis]
- F\_51D Land West of Leafield Road
- F\_52 Land West of Terminus Cottage

## Appendix B Hydrological Data and Analysis

### B-1 Well Inventory

Ref	Address	Owner / contact	Easting	Northing	GL m AOD	WellTop m AOD	Depth m bWT	Dia mm	Stick-up 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	-	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	Borehole A2	FTC	414911	200812	87.30	87.30	6.70	50	0.00
9	Borehole B2 [backfilled]	FTC	415908	201604	91.20	91.20	4.47	50	0.00
10	Borehole B5	FTC	415704	201675	94.00	94.00	4.10	50	0.00
11	Thornhill Farm	New owner	418080	200520	80.30	80.30	8.84	950	0.00
12	Cinder Lane observation BH	Environment Agency	416118	200900	83.31	83.95	4.60	200	0.64

Ref	GL m AOD	WellTop m AOD	Depth m bWT	Dia mm	Stick-up WT-GLm	Monitoring in 2018: RWL in metres bgl						
						20-Mar	17-Apr	25-May	06-Jun	17-Jul	09-Aug	25-Aug
1	83.90	83.90	1.90	700	0.00	1.030	1.030	1.264	1.200	1.600	1.980	1.640
2	83.90	83.90	-	-	0.00	-	-	-	-	-	-	-
3	83.65	84.40	2.85	-	0.75	1.560	1.575	1.820	1.675	2.130	2.090	2.110
4	86.20	86.75	4.32	780	0.55	2.130	2.680	3.960	3.690	4.400	4.400	4.400
5	83.00	83.00	1.34	-	0.00	dry	-	-	-	-	-	-
6	88.00	88.00	-	-	0.00	-	-	-	-	-	-	-
7	87.00	87.00	4.33	800	0.00	-	-	-	-	1.895	-	1.730
8	87.30	87.30	6.70	50	0.00	2.680	2.740	3.183	3.060	3.820	4.100	4.130
9												
10	94.00	94.00	4.10	50	0.00	-	-	-	-	-	-	-
11	80.30	80.30	8.84	950	0.00	-	0.820	-	-	-	-	-
12	83.31	83.95	4.60	200	0.64	3.00	-	-	-	-	-	-

Ref	Address	Location	Access	Condition. Dipping Point
1	Riverdale. London Road	Rear west of property	Steel manhole cover	manhole cover [edge]
2	2 Eastbourne Terrace	In sitting room	Removable glass plate	
3	Colosseo Restaurant, London Rd	Behind bar	Removable wooden cover	Top of well, bar side
4	Comrie [Dovecote House]	In garden	Walled and grided but open	max WL 1m bwh. Top of well, south side
5	Moor Farm	In garden by wall	Steel manhole cover	dry, part full of sand
6	Well House, 2 Coronation Street	Inaccessible	Located inside the house	-
7	Coln Ho Reform School -front yard	No opening in well-head	Concrete caisson	
8	Borehole A2	Rugby Club field	14mm socket wrench	New: Top of casing
10	Borehole B5	Woodland on Lovers Lane	Allen key	
11	Thornhill Farm	Inside the main farm bldg	Glass cover in kitchen floor	Recently cleaned out max WL 0.41m below kitchen floor
12	Cinder Lane observation BH	Corner of Football ground	Through FTC gate	Good. Top of casing

**B-2 GeolIndex Archive**

Id	Location Id	Depth [m]	Built	Aquifer	East	North	Start	Contin	End
SP10/24	Fairford Deer Park	2.5	1941	Alluvium	414980	202290	-	-	-
SP10/85	Fairford Burcotts	79.0	1982	Great Oolite Formation	414330	200590	-	-	-
SP10/52	Horcutt Lane Fairford	35.8	1924	Great Oolite Group	414800	200900	-	-	-
SP10/100	Fairford Chapel Electronics	4.0		River Terrace Deposits	416720	200980	-	-	-
SP10/105	Fairford Football Club	4.6	2002	River Terrace Deposits	416119	200903	-	-	-
SP10/31	Thornhill Farm Fairford	30.5	1955	Great Oolite Formation	418080	200510	-	-	-
SP10/46	Pittam Boring Quenington	39.9	1935	Great Oolite Formation	414190	203310	-	-	-
SP10/104	Leafield Farm Quenington	75.0	1996	Great Oolite Formation	415580	203900	-	-	-
SP10/80	Barrow Elm Cottage	3.4		Combrash Formation	416710	203900	-	-	-
SP10/103	Milton Farm, Fairford	75.0	1995	Great Oolite Formation	414250	202240	-	-	-
SP10/5B	H.J.Godwins Works Quenington	38.1	1933	Great Oolite Formation	414330	204360	-	-	-
SP10/45	E.Of Crossroads Cottages Quenington	30.5	1929	Great Oolite Formation	413700	204100	-	-	-
SP10/70	Mawley Farm Quenington	76.2	1961	Inferior Oolite Group	413450	203930	-	-	-
SP10/84	Donkeywell Farm Quenington	106.7		Great Oolite Group	412840	203420	-	-	-
SP10/54	Donkey Well Buildings	97.5	1973	Inferior Oolite Group	412750	203400	1973	1973	1980
SP10/4	Donkeywell Buildings	45.7		Great Oolite Formation	412710	203410	1963	1963	1980
SP10/23	Honeycombe Leaze Quenington	44.2	1925	Great Oolite Formation	412690	202280	-	-	-
SP10/102	Homleaze Farm Hatherop	58.0		Great Oolite Formation	417400	204300	-	-	-
SP10/1	South Farm Quenington	25.6	1935	Great Oolite Formation	417140	203100	-	-	-
SP10/2	South Farm Southrop	34.1	1954	Great Oolite Formation	417760	202530	1954	1975	1980
SP10/26	Southrop Manor Lechlade	31.7	1949	Great Oolite Formation	419530	202490	1949	1975	1977
SP10/60	Stanford Hall Lechlade	54.9	1946	Great Oolite Formation	419090	202030	-	-	-
SP10/25	Stanford Hall	54.9		Great Oolite Group	418960	202000	-	-	-
SP10/65	Waitenhill House Fairford	66.0	1954	Great Oolite Formation	413030	200400	-	-	-
SU19/3	Marston Hill Farm			Unknown	412940	199800	-	-	-
SU19/4	Marston Hill Farm	35.1	1949	Multiple Aquifers	412930	199820	-	-	-
SP10/28B	Magpies Farm, Meysey Hampton	18.3	1930	Great Oolite Group	412840	200370	-	-	-
SP10/28A	The Three Magpies Marston Maisey	15.2	1930	Great Oolite Formation	412680	200370	-	-	-
SU19/38	Manor House Meysey Hampton	4.6		River Terrace Deposits	411920	199860	-	-	-
SU19/32A	The Old Rectory Meysey Hampton	29.3	1935	Cornbrash Formation	411800	199850	-	-	-
SU19/32B	The Old Rectory Meysey Hampton	21.9	1937	Forest Marble Formation	411730	199900	-	-	-
SU19/30	Manor Farm Meysey Hampton	27.4	1945	Forest Marble Formation	411700	199970	-	-	-
SU19/78	The New Rectory Meysey Hampton	28.2	1935	Forest Marble Formation	411650	199990	-	-	-

### B-3 Rainfall Data

#### Appendix B-3-1 List of Rainfall Stations in the Vicinity of Fairford

RAIN_NO	STN_NAME	EASTING	NORTHING	ELEVATION	FIRSTYEAR	MACHDATA	LAST YEAR	FREQ_OBS
248128	Cirencester, Royal Ag.Coll.	4002	2013	135	1875	1882	1915	
248113	Cirencester	4003	2011	133	1951	1961		daily
248300	Somerford Keynes, Manor Ho.	4016	1955	91	1925		1945	
249124	Stratton	4016	2037	131	1968	1968	1969	
249150	Cirencester, Cripp's Mead	4019	2023	111	1902		1922	
249134	Cirencester, The Firs	4019	2031	107	1870		1884	
249145	Cirencester, Chesterton Grove	4022	2009	123	1956	1957	1986	daily
249142	Cirencester, Somerford Rd	4022	2012	115	1941	1941	1956	
249159	Cirencester, Dollarward Ho.	4022	2021	111	1890		1924	
249147	Cirencester, Chesterton Lane Mter	4026	2010	100	1980	1981	1983	daily
249141	Cirencester, Gwynfa	4028	2017	108	1923	1923	1941	
248332	Shorncliffe S.Wks Auto.Sta.	4034	1971	94	1993			daily
249175	South Cerney Met.Office	4050	1993	111	1965	1965	1967	
249515	Waterton House	4065	2013	110	1939		1952	
249447	Barnsley	4077	2051	133	1996	1996		daily
250791	Bibury, Furzey Barn Farm Mter	4110	2050	145	1977	1978	1983	daily
250123	Kempsford	4148	1972	79	1863	1875		daily
250849	Fairford	4152	2012	90	1996	1996		daily
250198	Fairford Met.Office	4158	1990	82	1968	1968	1977	daily
250858	Fairford S.T.W.	4158	2003	99	1991	1991	1996	daily
250965	Claydon House	4192	2001	76	1892		1951	
251281	Sevenhampton	4207	1904	91	1990	1990		daily
251529	Lechlade, St John's Lock	4222	1990	72	1913	1913		daily
251530	Lechlade, St John's Lock Auto.Sta.	4222	1990	72	1993			daily
252265	Holwell	4233	2091	130	1969	1971	1973	
252055	Broughton Poggs	4234	2038	84	1920		1950	
251898	Kelmscott	4245	1993	70	1930	1951	1972	
251422	Great Coxwell	4269	1939	116	1952	1958	1975	daily
252460	Brize Norton, Met.Office	4289	2060	84	1968	1968	1969	
252448	Brize Norton Met.Office	4292	2067	81	1969	1970		daily
252449	Brize Norton, Met.Office Sser	4292	2067	81	1971	1979		daily
252450	Brize Norton Samos	4292	2067	81	1995	1995		daily
252473	Bampton	4310	2029	70	1956	1969		daily

**Appendix B-3-2 Monthly Rainfall [mm] at Lechlade, 1913-2018**

YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1913	82.0	26.3	65.7	78.7	46.0	13.0	41.2	18.6	57.3	73.6	53.1	24.8	580.3
1914	9.6	50.1	89.6	21.0	23.3	48.5	80.1	45.6	22.4	52.2	107.4	117.4	667.2
1915	73.7	64.2	26.0	23.1	77.8	22.9	95.8	71.4	40.7	90.5	19.0	109.3	714.4
1916	30.0	92.8	96.8	22.3	46.2	41.2	27.4	90.0	23.9	111.2	69.7	84.0	735.5
1917	27.0	28.5	51.4	27.7	68.7	79.4	72.2	123.9	46.4	88.8	21.0	33.5	668.5
1918	66.3	31.7	21.4	74.5	47.1	17.8	93.4	40.2	112.0	35.2	44.5	57.6	641.7
1919	73.7	58.6	97.6	47.8	19.8	43.3	54.8	61.8	40.4	33.5	30.3	97.7	659.3
1920	54.8	17.6	43.7	117.9	78.4	59.8	115.3	22.5	35.9	65.9	15.3	47.3	674.4
1921	57.3	10.9	24.7	26.4	34.6	10.8	4.6	30.4	40.6	36.4	47.8	34.1	358.6
1922	51.2	67.8	50.3	67.5	25.5	38.3	89.5	103.3	31.8	19.0	34.3	67.6	646.1
1923	33.2	89.4	53.1	48.5	26.6	7.5	38.3	56.5	63.0	101.7	25.9	70.0	613.7
1924-1930 missing													
1931	34.9	44.7	4.1	74.9	113.5	88.6	75.3	75.0	38.8	16.8	81.9	29.1	677.6
1932	52.9	3.1	47.2	66.5	153.2	23.8	76.0	33.0	83.1	118.5	41.3	16.3	714.9
1933	41.8	80.9	70.5	32.8	29.3	52.9	41.7	34.9	82.1	54.4	18.2	11.9	551.4
1934	47.3	4.9	43.5	54.1	18.7	36.9	36.9	35.9	38.4	35.5	43.4	121.6	517.1
1935	13.9	49.3	11.5	87.8	36.9	90.1	17.3	41.0	112.5	112.1	118.4	75.0	765.8
1936	75.1	43.8	47.6	26.7	15.1	51.0	114.4	8.7	63.0	41.0	75.0	65.8	627.2
1937	89.9	116.3	63.2	76.7	63.2	41.4	46.3	13.8	50.6	84.5	31.1	47.7	724.7
1938	71.1	21.3	6.4	1.4	45.7	28.1	42.8	96.0	70.5	80.6	70.7	59.1	593.7
1939	114.9	24.9	36.0	82.6	34.2	48.8	124.2	40.0	40.3	99.1	117.2	44.6	806.8
1940	73.0	50.8	53.6	44.7	47.3	15.3	73.7	2.4	27.7	68.5	182.6	30.0	669.6
1941	73.3	64.6	73.1	25.7	31.4	46.3	55.8	85.1	18.8	37.4	63.2	43.0	617.7
1942	80.1	19.2	53.0	27.3	111.8	5.9	46.4	85.3	41.2	81.5	53.8	92.4	697.9
1943	110.3	23.6	27.0	17.7	65.7	40.9	31.3	56.7	28.8	73.7	42.1	24.7	542.5
1944	42.6	22.9	8.6	46.5	15.7	42.3	54.6	47.2	61.9	88.4	112.3	37.7	580.7
1945	44.7	52.2	22.9	26.8	58.9	84.5	48.5	57.8	40.6	84.9	6.8	92.3	620.9
1946	48.3	59.5	23.4	39.4	89.0	73.9	25.8	128.6	76.7	25.0	125.0	42.8	757.4
1947	36.3	33.9	158.0	61.2	40.6	35.8	58.7	11.3	35.0	9.9	35.9	49.5	566.1
1948	128.8	27.6	23.6	51.5	105.8	42.1	30.6	91.2	51.7	71.3	40.3	88.0	752.5
1949	27.3	24.9	38.2	36.1	63.7	11.0	71.7	44.3	51.4	145.3	75.6	29.0	618.5
1950	11.3	113.3	25.0	50.7	63.7	39.2	99.2	84.2	87.7	15.9	123.3	41.7	755.2
1951	70.7	89.2	96.6	63.4	64.1	30.3	24.1	124.9	77.5	28.6	139.3	51.9	860.6
1952	44.9	12.5	62.5	42.2	69.1	39.7	7.6	134.9	24.9	103.9	96.2	54.5	692.9
1953	18.1	30.3	24.9	42.5	43.1	35.8	65.6	75.8	56.6	74.2	27.0	15.8	509.7
1954	37.0	59.7	61.1	6.9	48.2	92.7	46.0	90.7	56.7	58.9	120.5	47.5	725.9
1955	57.0	39.2	36.4	12.2	103.1	74.1	5.9	16.0	18.2	37.1	34.8	77.4	511.4
1956	88.6	4.2	9.2	43.6	6.2	60.2	55.9	114.6	99.3	54.2	20.7	113.6	670.3
1957	52.0	85.2	58.4	8.5	43.3	39.2	62.8	84.4	77.4	52.0	45.7	48.7	657.6
1958	72.7	84.1	28.8	20.2	63.1	99.4	63.5	82.1	89.5	63.8	68.5	91.0	826.7
1959	101.2	2.1	74.4	67.5	18.3	23.7	47.0	61.0	6.6	41.2	44.1	130.8	617.9
1960	102.3	53.2	30.2	22.7	40.0	94.7	85.8	67.4	95.5	145.2	118.3	104.3	959.6
1961	84.7	71.0	3.1	89.1	28.6	38.4	57.5	43.6	60.5	72.0	33.0	113.4	694.9
1962	92.3	10.7	35.6	55.7	53.0	7.4	53.2	103.3	95.6	21.3	54.0	61.4	643.5
1963	28.8	8.3	94.2	64.0	44.9	90.9	45.0	68.7	47.2	49.9	133.3	23.6	698.8
1964	16.3	26.0	91.1	61.1	68.2	65.7	21.3	19.0	23.9	33.7	44.7	54.6	525.6
1965	66.3	4.1	55.0	44.6	77.7	71.2	76.2	46.3	82.5	15.8	75.3	122.1	737.1
1966	39.7	106.1	12.5	100.4	50.6	42.4	68.6	82.8	42.7	148.0	42.6	76.2	812.6
1967	42.9	93.5	40.9	34.2	124.4	40.5	43.2	51.3	73.8	150.3	35.8	68.0	798.8
1968	69.4	31.9	23.7	60.2	64.9	95.7	141.3	67.5	109.2	65.4	51.3	71.4	851.9
1969	59.7	45.7	54.5	29.3	122.8	18.5	46.6	91.6	29.2	7.8	60.4	61.5	627.6
1970	65.8	43.2	46.3	58.1	28.4	63.5	53.7	108.9	42.7	22.0	126.8	27.8	687.2
1971	111.3	24.3	43.1	69.1	44.2	122.7	6.3	74.6	22.2	91.8	56.8	31.7	698.1
1972	55.7	55.6	59.8	55.6	76.7	34.1	32.7	14.1	32.4	20.7	46.1	85.7	569.2
1973	27.4	15.1	11.4	51.5	53.8	98.0	70.1	28.4	43.2	28.2	29.5	31.2	487.8
1974	79.1	76.7	31.5	7.5	24.8	51.7	33.4	78.5	117.6	49.8	69.4	36.8	656.8
1975	80.1	37.6	73.9	30.7	30.0	10.7	55.7	26.1	87.1	13.0	38.5	23.2	506.6
1976	18.4	19.1	24.2	10.1	31.2	22.6	53.7	26.9	104.5	106.7	51.2	85.5	554.1



YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1977	64.5	114.3	51.9	37.2	42.8	102.9	8.1	147.2	11.6	35.0	47.9	62.1	725.5
1978	63.1	38.8	44.2	45.9	24.5	31.3	89.9	30.2	19.8	4.4	20.6	99.4	512.1
1979	40.3	42.9	87.8	41.6	118.2	37.3	13.5	71.5	13.8	44.7	49.4	110.5	671.5
1980	36.3	46.4	80.9	17.2	19.6	87.1	52.2	80.8	60.6	62.2	41.8	36.2	621.3
1981	30.1	20.6	114.1	30.8	84.9	40.4	47.4	40.2	113.8	67.8	35.9	84.4	710.4
1982	54.5	39.3	82.2	25.8	13.4	72.8	27.7	33.5	64.1	75.8	84.7	61.5	635.3
1983	45.8	14.0	42.2	82.4	103.0	15.3	47.1	15.3	54.7	42.1	35.6	52.4	549.9
1984	97.7	30.2	38.5	1.0	76.5	25.2	12.5	27.0	74.9	48.9	127.4	45.8	605.6
1985	46.0	43.0	55.6	25.7	105.9	107.7	40.9	94.1	13.6	31.8	37.9	100.9	703.1
1986	72.6	7.8	57.8	60.5	64.7	16.1	33.6	77.5	30.9	65.0	86.8	69.5	642.8
1987	10.4	48.5	57.0	57.3	35.6	98.2	36.4	30.6	38.0	138.7	63.4	34.1	648.2
1988	100.1	42.4	53.8	27.8	43.3	55.2	96.7	50.4	43.1	55.3	27.0	14.6	609.7
1989	30.8	61.5	46.8	64.0	9.5	37.5	37.8	38.7	34.7	71.2	45.2	129.6	607.3
1990	62.6	83.0	15.9	26.5	5.3	41.4	17.1	29.5	31.4	49.7	26.3	59.7	448.4
1991	69.5	21.5	62.1	55.3	9.8	79.7	62.5	2.0	55.5	38.6	62.5	12.9	531.9
1992	32.6	22.4	38.8	48.4	45.0	35.3	97.4	101.8	85.2	65.0	131.8	53.5	757.2
1993	73.9	4.1	27.3	58.9	126.7	49.0	55.1	26.9	59.1	89.0	36.2	94.3	700.5
1994	85.3	58.4	38.5	43.2	83.9	12.9	34.7	39.9	64.3	55.4	51.9	76.6	645.0
1995	110.7	72.2	36.5	20.0	46.5	8.3	13.2	1.1	142.2	48.9	61.7	98.4	659.7
1996	33.4	58.3	33.5	51.3	27.7	32.2	24.6	71.3	24.2	42.7	67.7	21.1	488.0
1997	7.2	70.2	10.9	22.9	52.1	64.3	15.2	105.5	12.2	50.3	75.7	65.6	552.1
1998	67.7	9.7	63.1	109.7	45.2	98.1	24.0	27.4	-	113.4	60.1	73.9	692.3
1999	104.9	26.6	32.3	53.4	68.8	79.2	2.7	97.9	96.3	58.7	42.9	84.4	748.1
2000	18.6	75.2	14.2	147.3	82.0	41.7	23.8	64.4	92.7	110.4	97.7	109.8	877.8
2001	58.7	71.5	75.7	77.3	33.3	28.2	58.7	96.6	20.2	69.4	33.4	20.3	643.3
2002	67.4	77.6	35.2	47.1	66.7	50.5	131.0	37.3	16.7	126.2	116.8	101.7	874.2
2003	71.8	20.4	25.3	38.7	55.7	38.2	64.2	11.7	14.3	27.4	86.5	78.5	532.7
2004	77.3	30.6	43.7	74.1	47.6	35.9	46.4	140.6	34.4	127.1	34.2	52.0	743.9
2005	28.7	17.8	55.9	56.5	38.1	56.6	54.8	40.8	40.9	65.8	51.3	61.4	568.6
2006	19.9	31.8	71.7	30.3	94.6	8.4	74.1	32.8	117.4	66.1	113.3	89.2	749.6
2007	90.5	82.9	55.7	3.5	111.8	107.8	176.1	43.6	20.1	83.4	51.3	89.9	916.6
2008	106.9	21.6	73.9	33.7	106.8	84.3	118.0	91.2	82.3	38.3	80.0	39.4	876.4
2009	58.9	-	22.9	43.5	40.1	47.2	84.1	60.2	7.4	54.3	117.7	74.4	610.7
2010	67.0	54.7	49.7	23.2	27.6	27.2	23.4	128.0	32.3	46.8	55.6	25.2	560.7
2011	56.0	-	11.0	2.9	32.1	51.4	37.5	52.2	40.9	30.4	30.9	91.7	437.0
2012	50.8	27.7	22.9	123.1	50.5	151.6	75.3	95.4	66.8	84.5	114.3	129.5	992.4
2013	81.2	38.9	65.8	24.1	56.0	20.9	37.0	20.3	48.5	96.1	54.8	118.5	662.1
2014	157.1	105.8	30.0	58.5	Data missing		25.4	75.4	20.3	67.5	97.1	56.9	694.0
2015	79.3	41.4	21.6	17.1	59.2	22.7	75.0	57.7	32.4	46.3	92.3	-	545.0
2016	74.2	65.3	75.9	71.9	-	74.4	11.3	58.4	45.2	14.4	91.7	21.6	604.3
2017	69.1	31.3	40.2	6.5	72.6	29.0	79.6	41.4	47.6	21.9	52.2	97.3	588.7
2018	66.1	25.8	93.5	50.8	62.4	Data missing							298.6
min	7.2	2.1	3.1	1.0	5.3	5.9	2.7	1.1	6.6	4.4	6.8	11.9	358.6
max	157.1	116.3	158.0	147.3	153.2	151.6	176.1	147.2	142.2	150.3	182.6	130.8	992.4
Mean	60.6	44.8	47.4	46.2	55.8	50.0	54.0	60.3	53.2	62.6	64.1	64.9	659.6

**Appendix B-3-3 Monthly Rainfall [mm] for Thames Model Cotswold West Area**

YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1920	96.4	26.9	80.1	144.4	63.9	81.7	135.5	40.2	50.1	84.2	24	73.9	901.3
1921	73.8	9.3	40	30	50.9	7.5	11.1	59.8	46.6	38.4	57.8	47.4	472.6
1922	91.6	94.9	65.9	94.9	22.6	27.6	128.3	136.3	58.1	22.2	50.3	107.5	900.2
1923	51.6	155.3	61.6	72.4	45.2	9	60.2	63.7	76	144.8	53	94.3	887.1
1924	103.6	18	34.9	92.4	181.5	68.3	117.3	81.5	138.2	129	69.8	123	1157.5
1925	51.5	112.5	15.2	53.4	102.8	3	93.2	76.4	108.9	89.8	47.7	77.5	831.9
1926	114.4	62.6	17.1	94.2	100.2	67.8	66.5	40.1	37.4	73.6	185.9	14.5	874.3
1927	90.2	100	87.9	51.6	38.6	94.1	94.7	115.9	162.1	47.8	76.4	92.1	1051.4
1928	122.2	64.2	68.1	26.3	22.3	74	70.6	65.7	24.6	142.5	92.1	77.3	849.9
1929	33.1	16.9	2.1	34.2	59.4	35	39.7	49.7	12.7	118.9	215.6	200.8	818.1
1930	131.4	13.8	49.1	85.2	43.9	56.6	94.7	72.8	101.8	52.8	116.9	100.9	919.9
1931	47.4	64.4	5.3	95	117.2	96.9	100.3	123.5	61	20.5	114.9	36.9	883.3
1932	75.7	3.6	55.6	81.8	166.9	33.1	65.5	78.2	88.2	126.4	51.9	25	851.9
1933	63.4	104.4	80.2	32.1	47.1	51.9	42.1	23.5	65.9	73.1	27.6	13.3	624.6
1934	67	10.8	62.9	69.3	20.7	48	30.4	51	63.1	42.6	49.9	175.1	690.8
1935	21.8	71.6	12.2	121.6	50.2	99.3	19.9	44.1	134	123.8	158.4	103.2	960.1
1936	102.8	62.1	61	55.7	19.8	89.4	153.4	12.9	128.4	39.3	76.9	87.7	889.4
1937	111.9	131.3	96.8	91.7	66.5	49.1	57	18	49.7	94.1	39.8	62.3	868.2
1938	89	23.1	8.4	2.5	53.7	34.3	61.5	90.7	74.7	98.6	89.5	100.1	726.1
1939	160.3	39.5	51.9	89.2	29.1	62.3	128.1	55.9	33.2	113.6	126.3	55.8	945.2
1940	77.2	60.6	64.2	48	50.5	18.1	93.6	2.7	31.5	113.4	196.1	41.7	797.6
1941	81.3	84.4	78.9	28.9	51	64.8	91.8	117.4	18.3	54.5	73.5	54.1	798.9
1942	96.3	20.1	58.8	34.5	116.5	8.5	56.1	115.3	43.9	86.6	55.5	110.3	802.4
1943	142.9	35.6	27	22.5	82.1	55.5	22.6	61.7	52.1	70.2	48.7	32.6	653.5
1944	55.4	28.1	8.5	43.5	35.9	68.5	68.5	65.5	82.7	119.3	130.1	61.8	767.8
1945	54.9	62.6	28.3	31.9	66.1	82.2	41.3	50	44.1	91.8	8.5	116.6	678.3
1946	64.2	64.8	25.1	50.3	88	74.7	31.8	153.2	108.3	22.5	163.5	68.3	914.7
1947	54	40.4	168	67.7	46	42.4	71.2	13.3	53.9	11.6	38.9	54.6	662
1948	146.5	29.9	32.3	64	115.2	66.5	27	106.2	73.6	86.9	34.3	107.8	890.2
1949	33.9	37.6	44	49.4	72.5	14.7	33.7	29.5	67.1	151.5	82.1	34.1	650.1
1950	12.2	150.1	35.5	58.6	74.1	51.4	97	105.2	106.2	17	151.8	44.4	903.5
1951	87.9	110.2	115.1	89.6	81.1	27.4	36.7	147.3	92.7	26.3	188.3	67.1	1069.7
1952	60.9	18.8	79.3	58.1	76.4	46.7	8.7	123.7	32.3	115	111.2	79.1	810.2
1953	28	49	31.4	60.2	60.9	59.9	95.7	92.8	71.9	76.3	28.5	22.5	677.1
1954	38.1	70.8	73.9	9.2	64.1	109.6	65	110.7	90.9	82.1	163.2	62	939.6
1955	69.2	44.8	46.6	27	122.1	91.9	5.6	13.4	28.9	44.5	68.2	81	643.2
1956	113	10.7	18.4	49.1	16.8	64.8	53.8	134	87.6	49.7	24.6	109.1	731.6
1957	63.9	91.7	70.3	9.7	36.6	48.4	103.3	135.3	108.6	54.9	51.3	68.5	842.5
1958	85.2	101.5	36.1	22.3	80.3	99.9	76.4	78.9	100.5	74.9	83.3	90.3	929.6
1959	119.6	2.8	83.9	80.4	33.5	33.6	46	43.7	4	55.2	66.2	153.5	722.4
1960	123.2	66.6	37.4	22.6	56.4	92.5	111.5	90.3	122.1	155.1	123.5	105.4	1106.6
1961	88.9	65.2	4.2	122.8	28	38.3	71.2	55.4	63.5	76.2	32.2	108.6	754.5
1962	101.7	13.4	31.1	64	58.5	6.1	36.3	135.9	83.6	25.1	69.2	64.3	689.2
1963	31.2	15.8	98.2	63.4	41.9	99.6	54.9	82.2	53.6	47	148.7	26.9	763.4
1964	19.9	28.7	80.1	59.4	61.5	65.3	24.6	18.9	19.9	36.2	45.1	77.5	537.1
1965	79.8	7.8	63.8	50.5	61.6	73.7	100.2	42.4	107.3	15.8	74.4	148.6	825.9
1966	43.7	98.8	23.4	93	63.2	42.4	61.5	86.4	30.3	115.7	51.4	93.2	803
1967	52.3	95.8	57.6	29.8	159.6	31.2	40	53.4	95.5	163.9	50	81.2	910.3
1968	71.3	41.8	29.9	66.9	73.9	110.8	123	59	134.4	71	62.5	89.5	934
1969	75.8	54.3	60.6	43.4	124	32.9	64.1	96.8	27.7	10.5	80.6	79.2	749.9
1970	93.6	59.7	53.7	67.4	36.9	74.4	68.4	86.5	61	24.6	161	36.3	823.5
1971	128.9	25.6	61.3	56.7	52	123.6	35.1	102.5	17.5	86.3	73.6	35.2	798.3
1972	86.5	79	73.9	52.6	74.6	49.9	33.1	24.6	37.4	31.1	58.4	138.1	739.2
1973	36.8	21.8	17.4	64.7	64.4	85.8	89.7	39.3	51.8	30.3	35.2	39.9	577.1
1974	109.4	111.8	36.7	8.2	32.5	55.1	52.5	97.1	139.5	56.9	92.3	49.8	841.8
1975	99.9	42.3	103.1	41.3	29.1	9.8	54.9	33	81.5	17.6	46.6	36.4	595.5
1976	23.9	31.8	33	12.4	40.5	25.8	19	38.1	135.2	111.6	54.7	100.9	626.9
1977	80.5	142.9	70.3	42.4	49	125.7	10.6	161.7	16.3	46.8	70.2	87.2	903.6



YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1978	93.1	54.4	66	50.9	26.8	40.2	109.8	59.4	28.5	6.7	29.1	145.9	710.8
1979	66	56.9	133.4	48.3	140.6	31.4	22.6	78.5	26.3	47.9	64.2	149.6	865.7
1980	63.7	66.8	100.3	22.1	28.6	98.7	60.2	74.2	72.5	83.3	56.1	57.7	784.2
1981	36.3	33.7	137.2	51.9	97.5	29.9	38.6	44.5	150	80.1	43.6	99.5	842.8
1982	63	45.9	102.2	27.4	25.4	108.3	39.8	55	90.2	90.8	99.9	84.4	832.3
1983	70.6	19.9	52.3	92.5	128.4	14.3	65.9	21.9	82.1	52.1	49.6	66	715.6
1984	114.6	45.4	47.2	6.1	66.8	25.4	11.5	56.5	113	78.2	152.9	60.9	778.5
1985	60.3	46.6	64	42	86.5	143.6	54.3	92	20.2	60.8	51.9	111.3	833.5
1986	102.9	9.4	67.2	70.3	84.6	30.7	45.1	118.5	22.7	73.5	108.5	92.6	826
1987	11.3	49.4	73.5	59.6	44.4	111.2	58.2	32.2	37.5	152.4	78.8	41	749.5
1988	129.6	49.8	79.7	34.6	48	41.1	115.5	70.5	46.7	69.1	32.5	19	736.1
1989	37.3	81.9	66.3	81.2	19.7	44.7	32	54.2	52.8	103.7	50.1	145.6	769.5
1990	98.2	122.5	14.5	35.4	5.6	61.6	28.4	27.8	39.5	63.8	31.9	81.7	610.9
1991	89.4	35.2	70.3	68.4	12.8	105.2	81.7	11.7	56	55.5	93.7	18.8	698.7
1992	68.5	31.3	52.9	71.3	58.2	56.8	98.3	129.9	77.8	69.5	138.4	71.2	924.1
1993	115.9	10.5	27.9	81.3	95.3	59.9	73.7	31.4	97.2	90.5	57.6	134.5	875.7
1994	110.9	75.2	64.3	51.3	90.7	22.5	27.2	48.5	96.7	72.1	67.4	115.9	842.7
1995	143.6	92.4	46.4	23	61.5	10.7	22.8	3.2	126.2	64	82.2	102.1	778.1
1996	51	67.8	47.7	53.4	40.6	17.6	38.7	68.2	27.2	60.5	84.1	36.3	593.1
1997	8.3	98.4	14.9	27.5	77.4	83.1	29.4	124.8	24.1	68.6	102.1	87.6	746.2
1998	96.8	12.1	86.3	120	29.3	109.9	23.6	35.2	106.4	135	70.2	83.4	908.2
1999	141	34.5	53.3	82.1	85.7	66.2	5.9	112.6	118.5	73.5	52.8	127.4	953.5
2000	29	90.8	21.8	171.3	83	32.5	41.7	56.6	107.7	154.3	143.6	146.4	1078.7
2001	67.4	82.8	93.2	108.9	41.4	29.6	71.9	76.6	53.2	116.5	46.2	29	816.7
2002	91.8	119.2	44.2	47.2	84.6	56.5	92.6	35.7	24.6	155.3	132.2	113.8	997.7
2003	81.9	25.6	36.1	49.9	59	49.1	84.8	10.3	19.7	42.7	97	92.5	648.6
2004	101.9	32.4	56.3	88.2	47.7	44	53.3	136.8	49.7	148	45	46.8	850.1
2005	35.8	26.7	66.3	58.3	44.4	40.8	47.5	39.7	53.2	94.7	81.7	76.4	665.5
2006	21.4	34.4	84.2	30.1	121.1	14.7	72.9	61.7	112.8	88.4	112.7	119.8	874.2
2007	91.7	98.1	74.7	5.1	142.8	129.3	201.4	45.9	31.7	74.2	96.8	83.6	1075.3
2008	121.8	31.6	100.1	47.8	96.4	61.6	131.5	104.5	116.1	49.5	83.6	54.7	999.2
2009	77	60.3	30.2	42.5	50.7	55.8	99.6	75	26.8	67.2	159.2	87	831.3
2010	90.2	54.9	61.7	24	42.9	38.2	31	134.8	45.8	60.6	62.1	35.5	681.7
2011	65.8	64.8	10.4	4.9	44.9	57.9	45.9	52.7	40.7	38.9	39.1	96.4	562.4
2012	55.6	24.6	26.5	139	51.2	159.1	105.1	109.4	72.8	100.1	148.6	153.1	1145.1
2013	82.7	44.9	75.3	29.1	75	27.9	38.9	30.9	56.6	145.5	65.5	135.5	807.8
2014	210	164.4	43.7	58.2	70	27.7	36.2	99.3	5.5	90.1	95.7	45.9	946.7
2015	85.5	52.9	27.8	15	61.4	37.7	69.3	62.9	41.2	63.3	92.8	117.1	726.9
2016	108.5	74.9	97.8	47.9	65.8	65.5	13.8	41.3	50.3	15.9	96.7	31.4	709.8
2017	75.4	41	51.6	11	62.7	69.4	74.1	53.7	62.6	33	56.1	107.9	698.5
2018	77.5	32.7	113.6	55.6	82.5	2.9	-	-	-	-	-	-	364.8
min	8.3	2.8	2.1	2.5	5.6	2.9	5.6	2.7	4.0	6.7	8.5	13.3	364.8
max	210.0	164.4	168.0	171.3	181.5	159.1	201.4	161.7	162.1	163.9	215.6	200.8	1157.5
avg	79.5	56.6	56.6	55.7	65.3	57.3	62.7	70.2	67.1	75.4	82.4	82.0	806.3

**Appendix B-3-4 Monthly Areal Infiltration [mm] for Thames Model Cotswold West Area**

YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1920	83.4	11.7	41.5	99.5	4.9	6.4	26.4	2.7	5.2	40.3	13.2	65.2	400.4
1921	61.4	2.3	5.4	2	3	0	0	3.9	5.1	4.5	7.8	6.2	101.6
1922	51.9	81.6	37.7	43.8	2.4	0.7	13.2	34.8	13.3	2	41.9	99.6	422.9
1923	46.7	142	37.9	35	1.4	0.4	4.9	5.5	8.6	76.3	49.1	90.7	498.5
1924	99.5	1.8	11.2	30.1	106.3	28.2	10.5	6.2	87.4	105.5	58.6	116.9	662.2
1925	42.7	96.6	1.1	3.6	8	0	9	5.9	26	62.9	44.2	74.5	374.5
1926	106.6	49.2	1.4	19.6	41.9	4.7	4.8	2	3.4	9.4	159.2	11.8	414
1927	81.8	88.6	47.1	25.6	1.5	7.2	7.3	28.9	109.1	26.2	69.8	86.5	579.6
1928	114.6	52.4	33.1	4.3	0.7	4.4	7.6	5	2.6	38.4	80.6	74.3	418
1929	28.5	10.6	0	2.5	4.8	1.2	2.4	3.3	0.8	15.9	174.1	188.9	433
1930	121.2	7.2	28.5	29.5	1.7	5.1	8.2	5.5	11.7	19.8	105.4	95.5	439.3
1931	45.6	51.5	0	16.4	32.8	26.6	8.4	58.1	13.7	2.3	96.8	31	383.2
1932	73.3	0.3	12.8	25.7	105.8	3.5	5.4	9.7	19.7	101.5	40.3	21.4	419.4
1933	63	93.5	54.6	2.8	3.2	2.8	2	1.5	7.7	9	3.8	1.8	245.7
1934	50.4	4.1	41.8	15.1	1	3.8	1.2	3.5	6.4	4.4	7.3	129.6	268.6
1935	15.6	51.3	2.1	51.5	3.8	6.5	0.9	3.7	14.8	88	151.4	100	489.6
1936	95.2	50.1	32.7	12.1	0.6	8.6	26	0.1	51.8	10.3	69	80.9	437.4
1937	105.7	116.4	74.3	46.2	4.9	3.4	6.2	1.1	4.6	13	33	60.4	469.2
1938	76.5	6.4	1.8	0	4.2	1.7	4.9	9.1	8.7	30.4	79.3	97.3	320.3
1939	152.3	27.3	21.4	33	2.1	3.9	11.1	5.3	3.4	56.9	115.5	51.6	483.8
1940	76.5	50.6	36.2	2.7	2.2	0.1	6.8	0	1.6	14.6	162.6	36.9	390.8
1941	78.5	74.3	52.6	10.5	2.9	6.5	5.7	9.2	1.2	6.1	58.8	49.2	355.5
1942	90.1	13	35.8	13.7	9.1	0	3.2	11.6	4	43.9	53.5	104.4	382.3
1943	137.6	29.8	3.2	0.4	7.5	2.3	0.3	4.3	4.6	9.2	6.4	16.3	221.9
1944	48.4	17.1	0.5	4.5	2.3	5.3	5.5	6.4	9.3	81.3	123	60.6	364.2
1945	51.2	55	2.2	2.9	5.1	6	2.3	3.5	3.2	13.7	2.8	114.4	262.3
1946	61.9	50.5	7	4.8	9.1	4.8	1.3	44.6	73.4	2.5	144.7	68.3	472.9
1947	51.2	35	148	24.6	3	1.9	3.9	0.6	5.7	1.1	5.4	7.5	287.9
1948	115.2	21.5	3.7	6.2	12.4	9.5	1	11.2	19.2	44.9	31.2	107.4	383.4
1949	28.3	24.6	25.2	4.8	5.7	0.5	2.7	1.9	8.2	40.5	72.9	30.2	245.5
1950	7	140	10.4	4.3	8	3.4	9.5	8.9	41.7	2.2	142.3	43.9	421.6
1951	84.4	99.3	88.2	56.7	6.2	0.8	2.3	15.9	40.5	5.8	180.5	56.7	637.3
1952	57.9	13.3	45.7	18.6	20.7	3.3	0	12.8	1.8	46.1	107.5	79	406.7
1953	25.4	43.2	3.4	10.6	5	4	7.6	9.6	8.3	51.7	20.3	21.7	210.8
1954	34.7	64.1	45.8	3.4	5.4	34.5	4.5	24.3	29.7	62.2	160.1	59.8	528.5
1955	66.8	38	19.6	2.1	21.6	41.4	0.1	0.2	1.9	5.2	9.6	49.9	256.4
1956	109.2	6.2	5.5	5.2	0.6	4.7	4	13.2	34.2	24.1	17.1	107.6	331.6
1957	60.1	85.3	42.7	0.7	2.6	3.6	9	31.6	56.6	34.2	48.9	67.9	443.2
1958	83.5	88.6	10	5.8	6.6	13.7	5.6	6.9	45.3	57.3	79.9	90.3	493.5
1959	119.6	0.2	52.4	30	2.2	0.8	3.8	4	0.3	6.6	9.6	118.4	347.9
1960	122	57	9.3	5	5.7	9.1	11.4	13.9	80.8	139.4	120.3	105.4	679.3
1961	83.7	55	0	49.4	4.3	4	6.8	4	7	9.3	10.7	108.6	342.8
1962	96.5	5.8	3.5	17.6	4.1	0	1.8	15.5	9.3	4.6	64.9	64.1	287.7
1963	30.8	12	67.9	24.7	1.5	7.7	3.9	7.3	5.4	6.1	140.7	26.5	334.5
1964	17	15.7	61.5	4.7	5.3	14.2	0.6	0.5	1.5	4.1	6.3	42	173.4
1965	76.2	0.4	33.7	4.7	4.9	6.5	17.5	3.1	39.9	1.6	63.5	148.5	400.5
1966	41	87.6	6.7	37.7	14.4	1.9	4.3	8.8	2.5	37.8	42.9	86.6	372.2
1967	50.8	81.8	33.2	2.2	56	2.3	1.9	3.6	10.1	107.7	48.2	81.2	479
1968	65.2	36.7	2	6.6	5.8	15	67.2	4.7	54.9	50.5	57.5	88.6	454.7
1969	70.1	44.3	43.6	3.3	34.3	1.5	6.9	9.6	2.6	0.8	36.3	75.3	328.6
1970	91.4	48.4	19.6	21.6	2.3	6.9	4.6	9.2	6.3	2.3	105.3	33.9	351.8
1971	125.6	15.3	36.2	6.9	3.7	38.9	1.4	10.4	1.5	26.6	68.2	29.6	364.3
1972	81.6	65.4	41.1	15.7	5.5	2.3	1.6	1.5	4.8	3.8	8.1	105.7	337.1
1973	33.6	13.8	2.9	6.1	4.1	10.3	13.5	3.8	5.3	3.6	6.5	36.4	139.9
1974	95.9	96.7	20.4	0.2	1.6	4.7	3.7	9.5	15.9	31.3	82.7	37.7	400.3
1975	86.3	37.5	72.3	4.7	1.7	0.3	4.3	0.7	9.2	1.7	6.7	5.2	230.6
1976	3	3.8	3.5	0.7	1.7	1.5	0	4	16.9	31.5	49.1	100.6	216.3
1977	76.2	130.9	37.4	2	3.5	48.1	0.1	48.2	1.2	5.1	45	80.7	478.4

YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1978	85.3	40.8	25.7	6.1	1.2	2.1	12	4.8	2.1	0	4	111.9	296
1979	63.9	45.7	103	9.7	44.9	1.5	1.7	7.5	2.3	5.6	8.7	133.2	427.7
1980	62.7	57.4	66.7	7.6	1.4	7.3	4.7	7.4	8.2	15.9	39.1	50.1	328.5
1981	30.7	17.4	103.3	7.2	29.6	5	2.1	5.1	35.8	56.8	31.2	97.8	422
1982	59.2	31.8	77.7	2.8	0.4	8.3	3.3	3.6	10.8	25.9	91.1	79.3	394.2
1983	55.1	6.4	20.3	40.9	63.7	0.1	6.8	1.1	8.6	5.9	7.2	53.1	269.2
1984	106	32.6	16.2	0	5.8	1.4	0	3.8	13.2	9.8	119.6	60.9	369.3
1985	56.4	39.1	31.5	11.8	8.7	48.7	4	6.8	1.7	8	28.2	104.9	349.8
1986	93.8	6.8	22.8	30.6	7.2	2.3	2.8	13.5	2.7	9.7	95.3	84.8	372.3
1987	8.6	36.1	41	34.5	2.6	9.9	4.6	1.3	2.4	63.9	70	33.4	308.3
1988	121.8	45	34.7	2.6	2.8	2.4	10.3	6.2	4.4	8.8	22.7	13	274.7
1989	31.2	65.5	40.6	33.2	1.3	2.9	2.5	4.8	5.8	13.6	7.5	130.9	339.8
1990	88.7	99.1	1.1	1.8	0	4.5	1.8	1.5	3.5	7.8	4.4	11.9	226.1
1991	63.8	26.4	50.2	7.1	0.7	8.4	7.9	0.1	5.9	6.6	62.1	14	253.2
1992	63.2	18.6	5.7	17.6	5	5	10.1	13.5	21.1	44.7	126.5	69.4	400.4
1993	102.9	1.2	2.8	29	9.7	3.9	5	2.4	11.6	57	43.3	124.3	393.1
1994	103	64	19.3	23.4	7.6	0.8	0.8	3.3	10.3	9.6	49.7	109.3	401.1
1995	133.6	76.8	22.8	1.7	5.2	0.1	0.8	0	15.4	8.7	35.4	99	399.5
1996	46	54.8	24.1	5.8	2.2	0.5	1.2	5.6	2.7	6.8	11.2	6.9	167.8
1997	7.5	79.6	0.7	3	5.6	6.2	1.2	13.2	1.6	8.8	68.4	80.7	276.5
1998	89.5	1.3	49.5	71.2	1.7	9.1	0.6	2.3	11.6	55	59.9	78	429.7
1999	129.4	18.2	24.9	29.6	11.4	8.1	0	11.4	14	40.2	36.2	116.6	440
2000	23.9	69.6	6.7	101.6	7.6	1.7	1.9	3.7	12.3	108.7	128.9	140.1	606.7
2001	64.6	73.8	67.5	56	2.7	1.7	6	5.6	3.9	14	23.7	26.1	345.6
2002	84.9	98.3	22.6	3.9	6.2	4.5	8.8	1.9	2.6	63.5	119.3	108.8	525.3
2003	73.2	16.6	27.2	3.9	3.1	3.5	6.3	0.3	1.2	5.5	13.6	54.1	208.5
2004	90.5	26.9	16	18.6	16.5	3.8	4.5	12.6	3.4	51.7	32	42.9	319.4
2005	20.3	11.7	36.2	9.6	3.1	2.2	3.6	2.6	5.1	11.9	19.4	72.3	198
2006	18.4	24.3	45.9	2.1	19.7	0	6.3	4.1	13.3	10.2	92.1	110.2	346.6
2007	79.1	80.2	52.2	0	19.5	41.2	109.3	3.4	3	13.6	80.1	76.1	557.7
2008	107.6	21.9	53.7	3	9.7	13.7	20.2	17.1	76.4	5.5	58.6	54.7	442.1
2009	74	57.3	11.1	2.9	3.1	4.6	7.8	7.5	3	7.7	97.4	86.6	363
2010	90.2	49.4	29.1	10.7	3.7	2.6	1.4	14.7	4.3	6.9	18.4	35.2	266.6
2011	64.9	59.1	0.7	0	3.5	3.7	2.8	4	2.1	4	4.9	13.4	163.1
2012	36.8	17.5	11.2	63.6	17	49.7	40.4	9.4	21.9	71.2	140.9	151.3	630.9
2013	79.6	41.4	55.3	2.1	5.9	0.8	2.8	1.3	5.8	18.4	50.5	126.6	390.5
2014	202.9	146.3	13.2	5.6	4.5	1.3	2.2	10.1	0.1	10.6	44.7	41.7	483.2
2015	75.5	44.4	3.3	0.3	4.6	3.2	4.8	5.6	4	8.3	19.5	102.3	275.8
2016	103.5	64.3	64	13	5.9	3.5	0	3.3	4.8	1.7	13.9	16.4	294.3
2017	69.4	28.2	27.6	0.5	5.2	5.7	6.7	3	5.5	3.6	7.8	92.7	255.9
2018	72	24.9	75.1	20	8.8	0	-	-	-	-	-	-	200.8
min	3.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	2.8	1.8	101.6
max	202.9	146.3	148.0	101.6	106.3	49.7	109.3	58.1	109.1	139.4	180.5	188.9	679.3
avg	72.6	45.7	30.5	16.4	10.1	7.3	7.3	8.2	14.7	26.8	59.1	71.9	368.6

Note: The Cotswold-West model cell is generally referenced as 6010 in Environment Agency water resources situation reports for the Thames region.

## B-4 Hydrological Analysis

Figure B-4-1 Cinder Lane annual maxima, 2002-2018

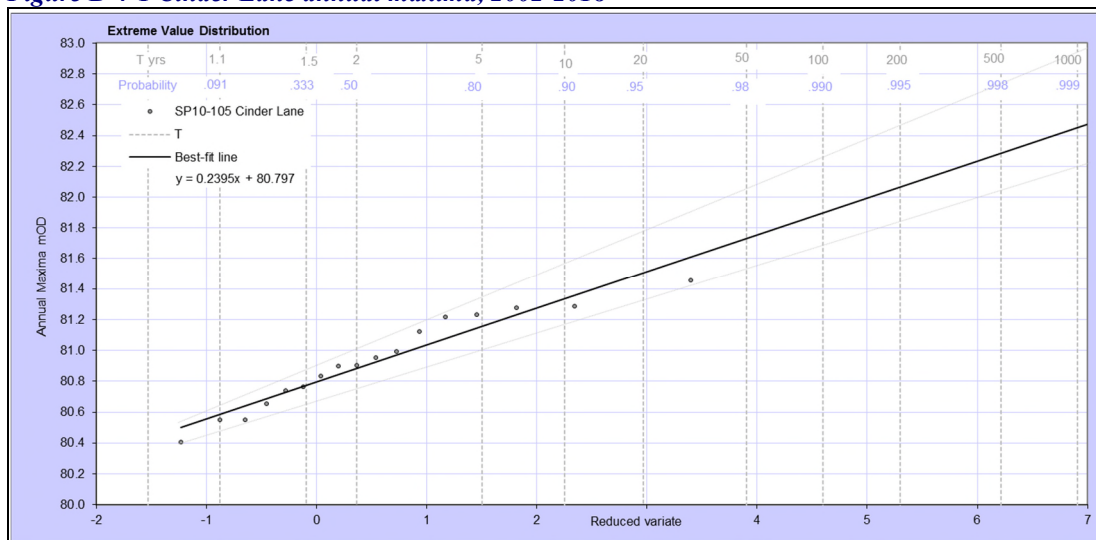
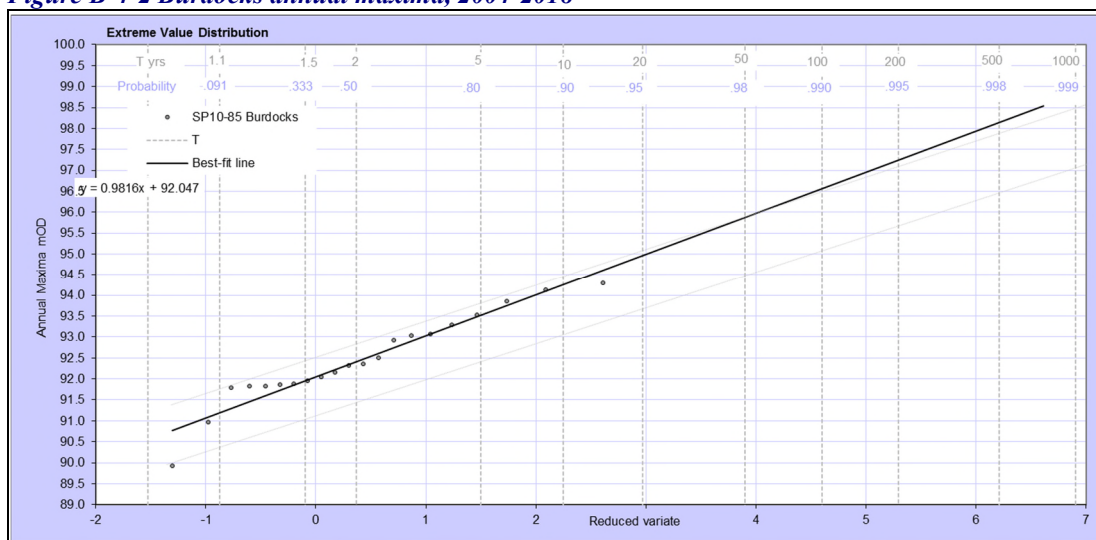
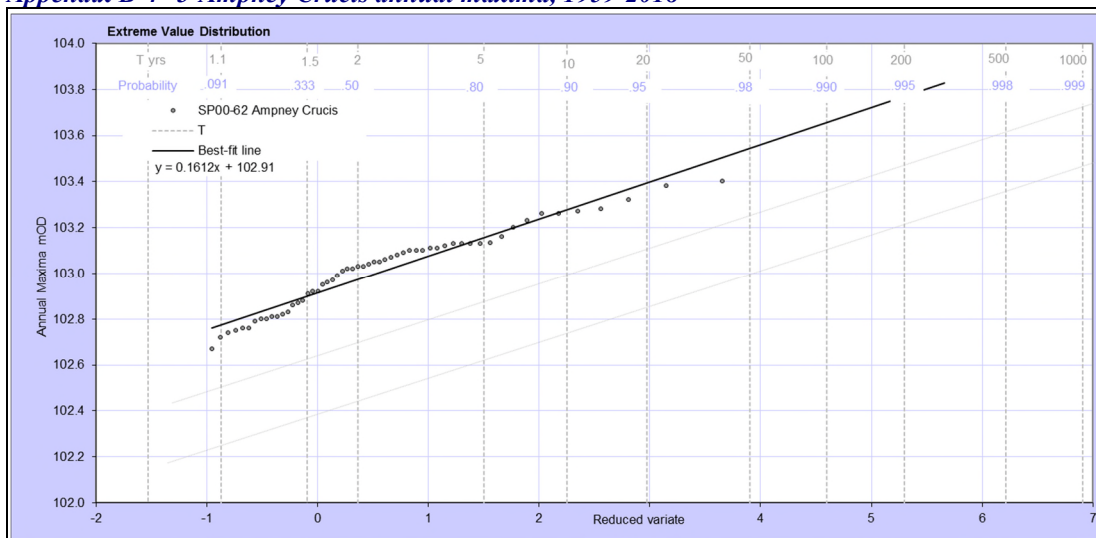
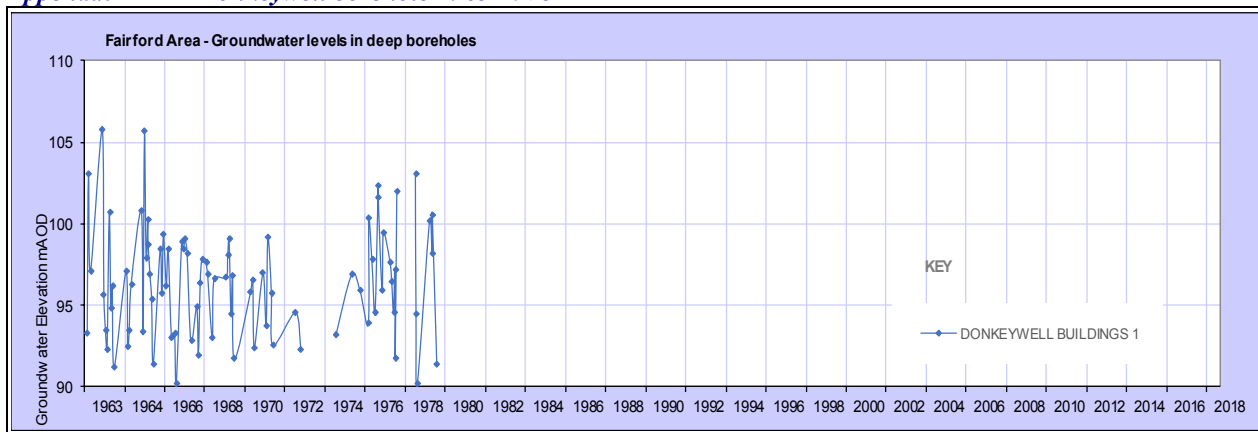
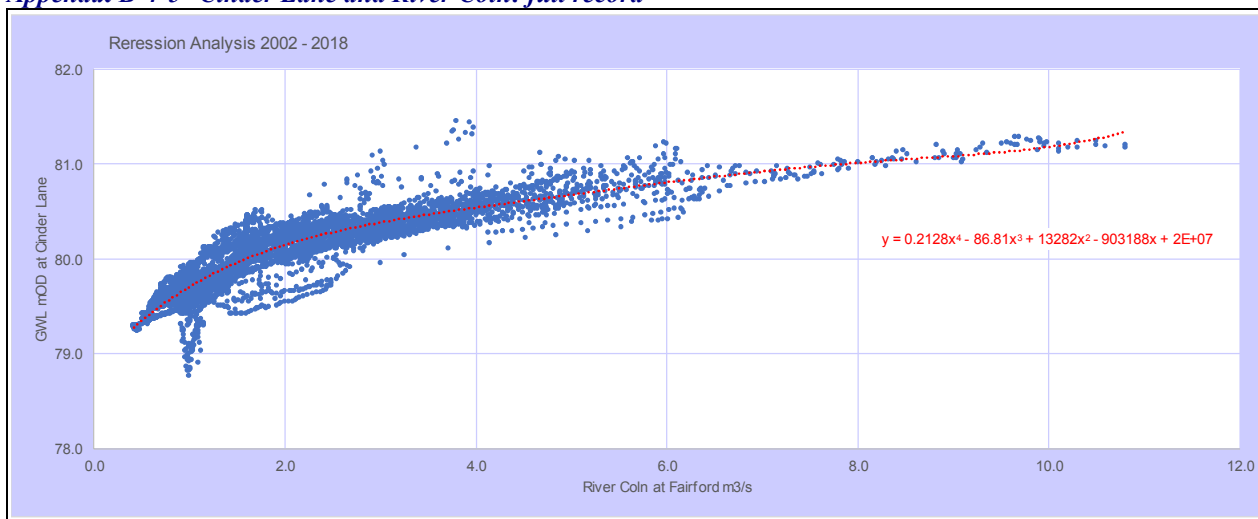
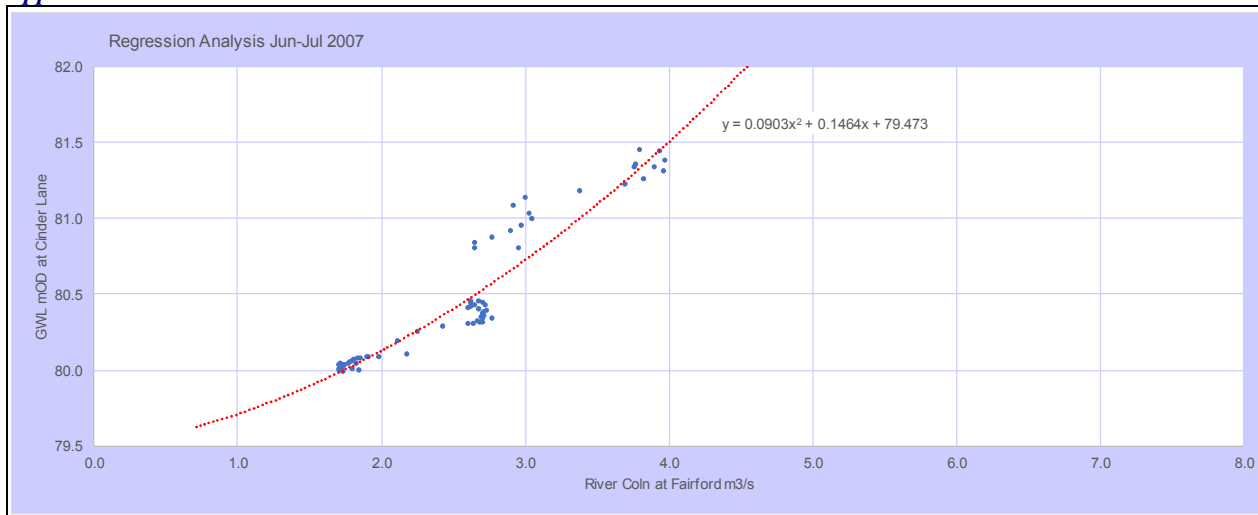


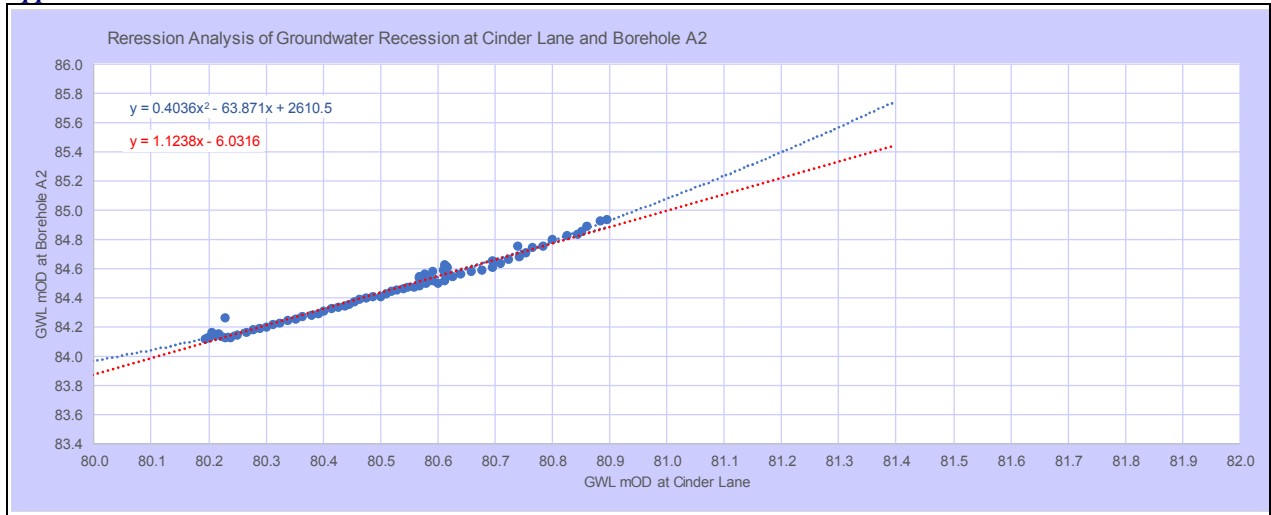
Figure B-4-2 Burdocks annual maxima, 2004-2018



Appendix B-4--3 Ampney Crucis annual maxima, 1959-2018

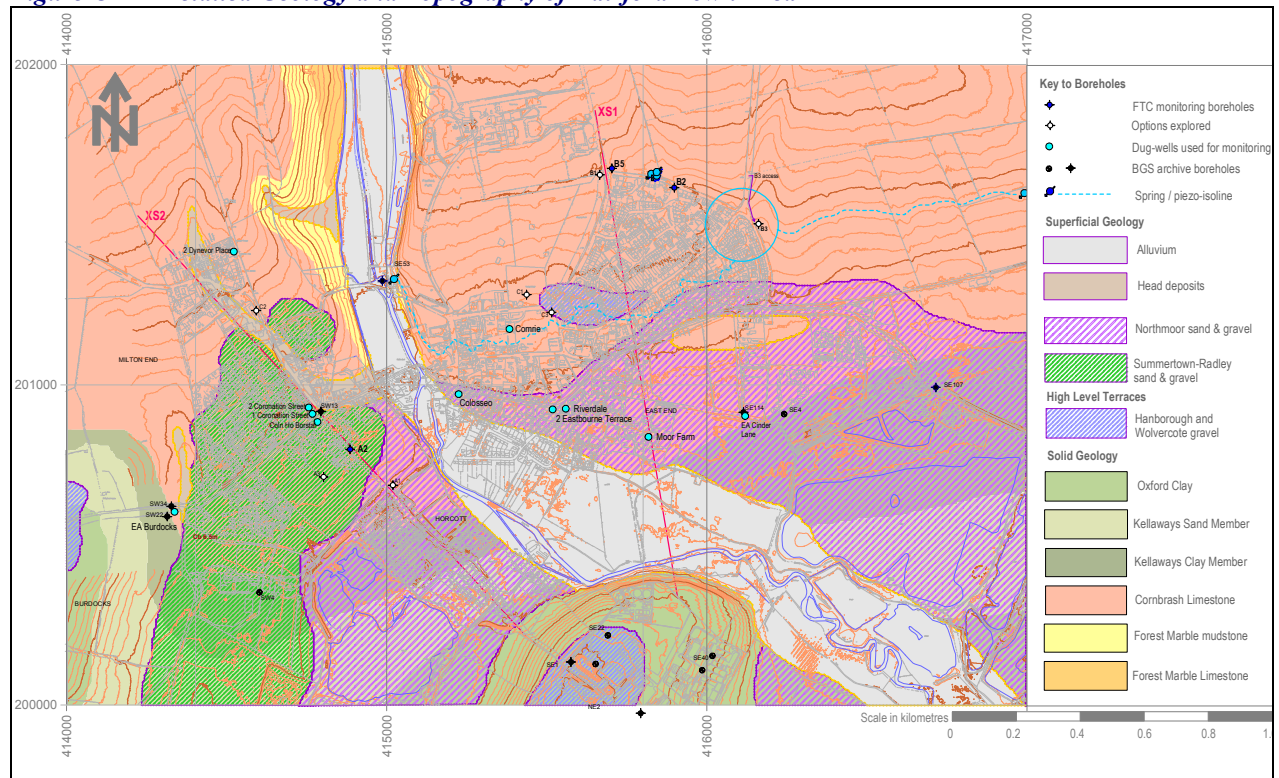


**Appendix B-4-4 Donkeywell borehole 1963-1978****Appendix B-4-5 Cinder Lane and River Coln: full record****Appendix B-4-6 Cinder Lane and River Coln: Summer 2007**

**Appendix B-4-7 Cinder Lane and Borehole A2**

## Appendix C Detailed Maps

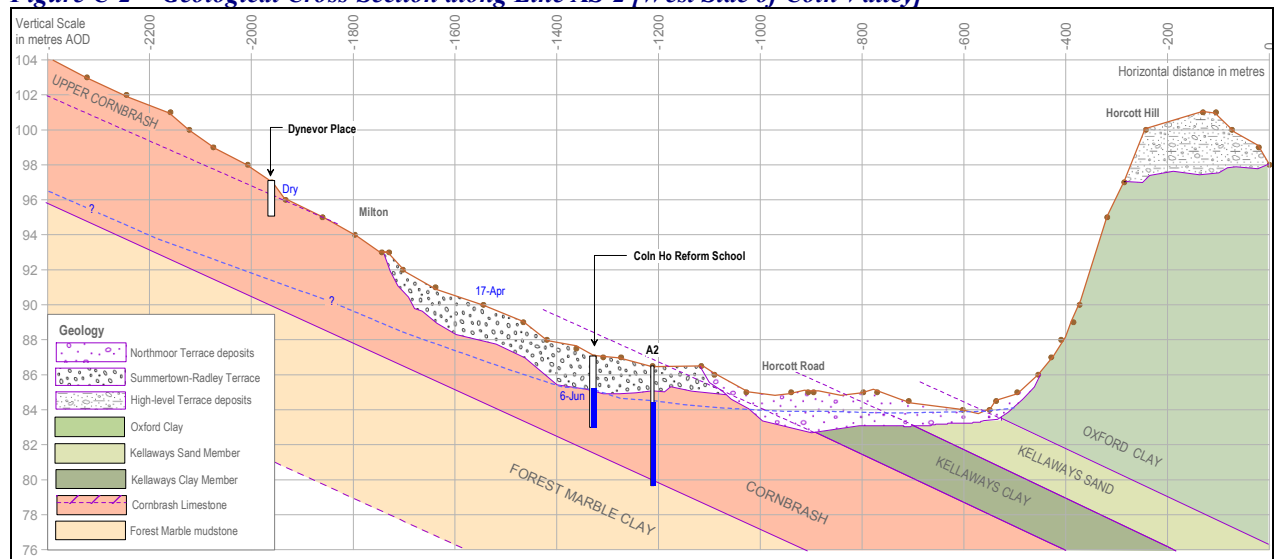
**Figure C-1 Detailed Geology and Topography of Fairford Town Area**



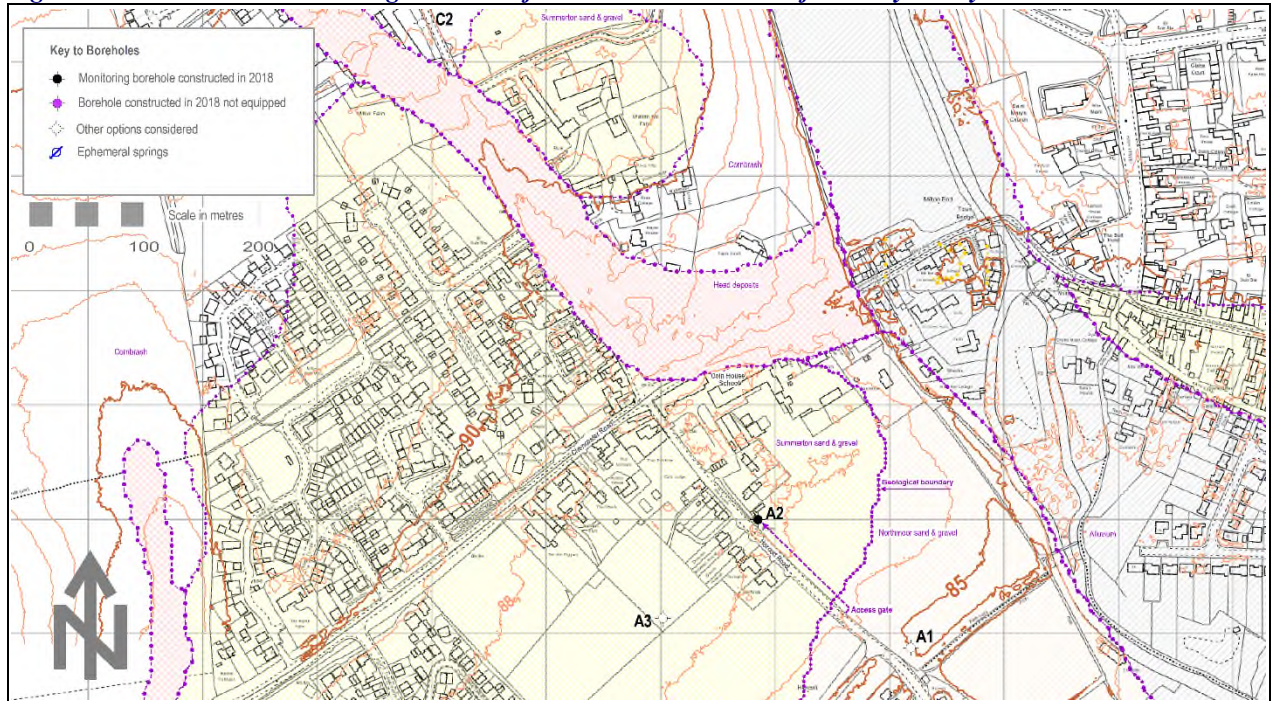
Superimposed on OS Mastermap extract, showing wells and boreholes

Shows location of interpreted cross-sections XS1 and XS2, drawn in [Figure 3-1](#) and [Figure C-2](#).

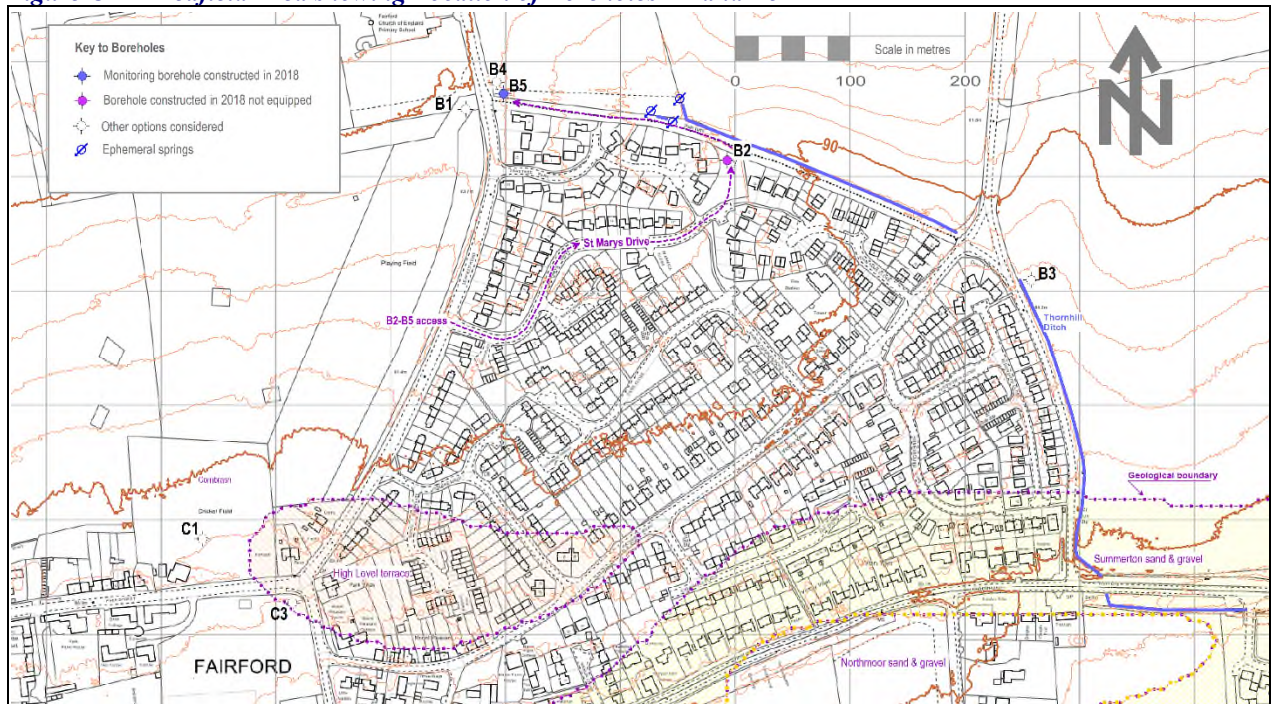
**Figure C-2 Geological Cross-Section along Line XS-2 [West Side of Coln Valley]**

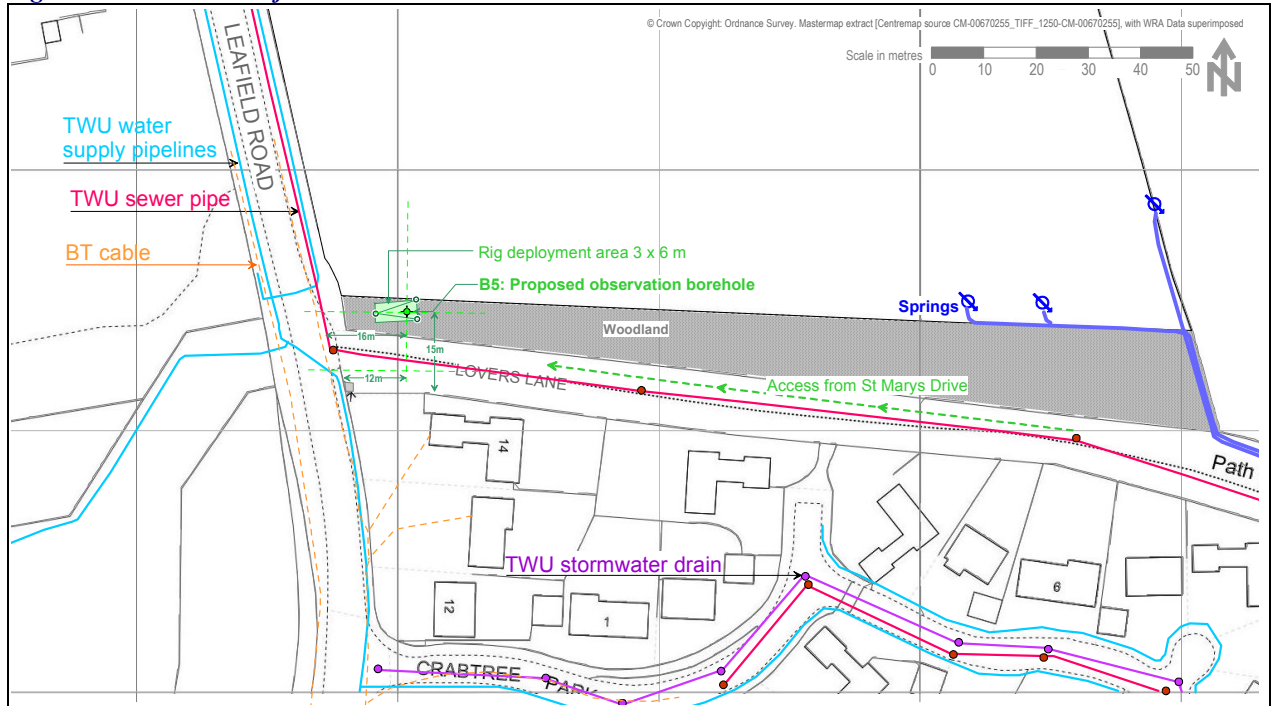


***Figure C-3 Horcott Area showing Location of Borehole A2 and Head-filled Dry Valley***



***Figure C-4 Leaffield Area showing Location of Boreholes B2 and B5***



**Figure C-5 Location of Borehole B5**

## Appendix D Reconnaissance Photo-Log

### *D-1 Reconnaissance Photographs and Environment Agency Boreholes*



D-1 Springs on Lovers Lane



D-2 Springs at head of Thornhill Brook



D-3 Cinder Lane borehole SP10-105



D-4 Dudgrove Brook



D-5 Burdocks borehole SP10-85



D-6 Donkeywell borehole SP12762 03418

*D-2 Monitoring Boreholes*



D-7 Drilling Borehole A2



D-8 Borehole A2 cuttings



D-9 Drilling Borehole B5



D-10 Borehole A2 monitoring point



D-11 Borehole B5 monitoring point



D-12 Cornbrash cuttings from Borehole B5

*D-3 Well Inventory*



D-13 Coln House West: well located to left of doorway



D-14 Well interior at Coln House West



D-15 Well-head at Coln House West



D-16 Well-head at 2 Dynevor Place



D-17 Dynevor Place: well on raised part of side-garden



D-18 Dug-well interior at 2 Dynevor Place



D-19 Dug-well at Comrie: well-head



D-20 Dug-well at Manor Farm: interior backfilled



D-21 Dug-well at Manor Farm: well-head



D-22 Dug-well at Riverdale: interior



D-23 Dug-well at Riverdale: well-head



D-24 Dug-well at Colloseo: well-head



D-25 Dug-well at Colloseo: interior

## Appendix E Drilling Logs

### E-1 Observation Borehole Geology and Construction Details

Figure E-1 Borehole A2 Details

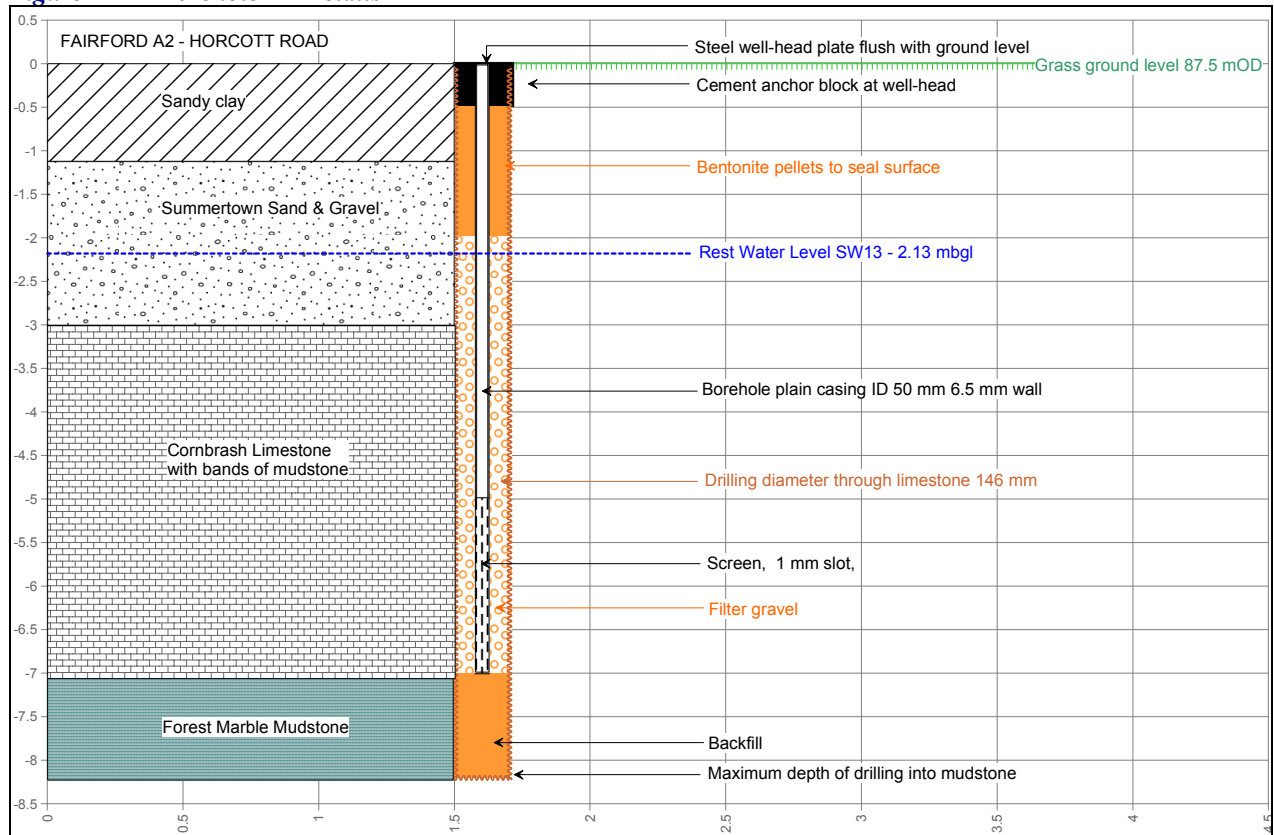
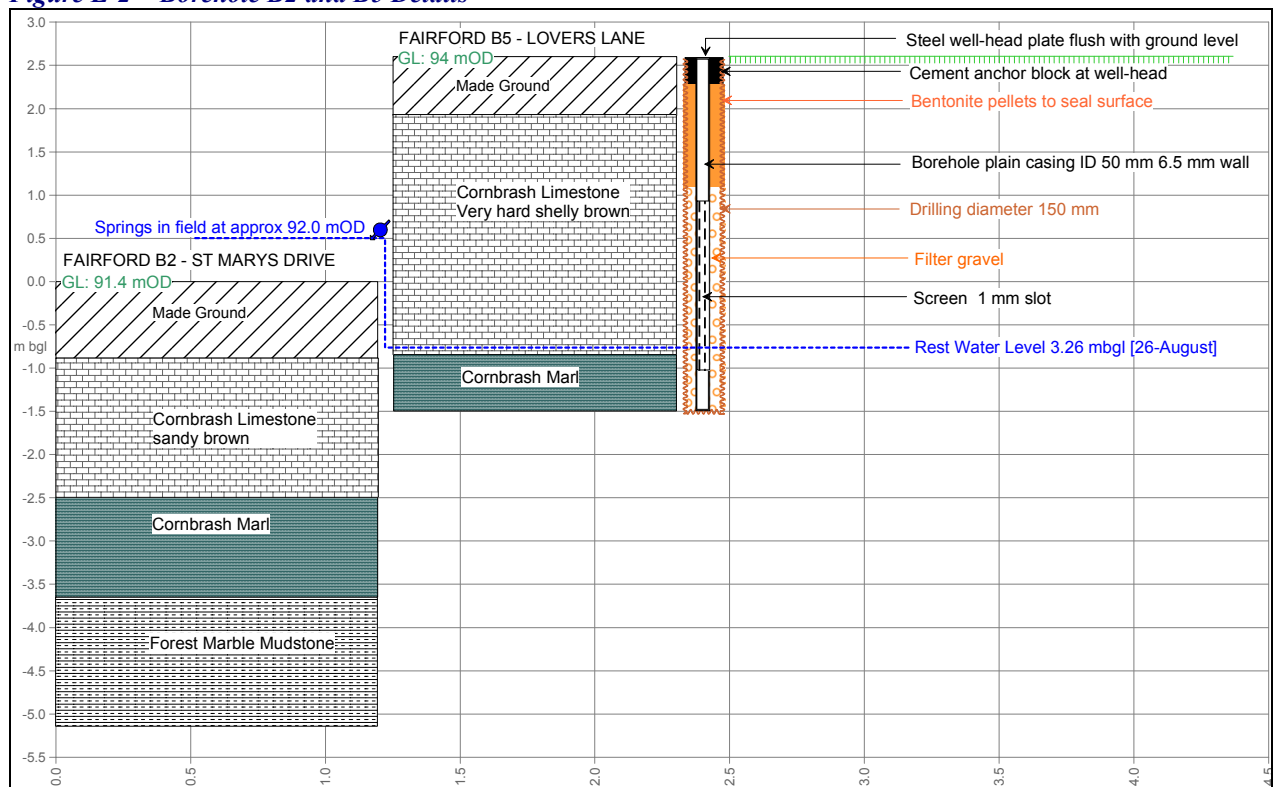


Figure E-2 Borehole B2 and B5 Details



## E-2 CCGI Borehole Logs

### Logging



CC Ground Investigations Ltd

The logging of soils and rocks has been carried out in general accordance with BS 5930:2015.

### Sample type

B	Large disturbed sample
C	Core run
CS	Rotary core sub-sample
D	Small disturbed sample
ES	Environmental sample
SPT	Standard penetration test carried out using split spoon (split spoon sample retained)
SPT C	Standard penetration test carried out using solid cone (no sample retained)
U70 or U100	Undisturbed sample followed by nominal diameter of sample. (Taken using thick-walled open-tube sampler – OS-TK/W)
UT100	Undisturbed sample followed by nominal diameter of sample. (Taken using thin-walled open-tube sampler – OS-T/W)
W	Water sample





### Water levels

Initial Water Strike	Level after monitoring	Standing Level/No groundwater encountered
		<b>3.00m/Dry</b>









### Insitu Testing

























S 30	Denotes SPT undertaken using split spoon followed by N Value (EN ISO 22476-3:2005+A1:2011)
C 30	Denotes SPT undertaken using solid cone followed by N Value (EN ISO 22476-3:2005+A1:2011)
*240	Denotes SPT where full test drive has not been completed and linearly extrapolated N value reported
**	Denotes no effective penetration (Linearly extrapolated N value > 1000)
H 30	Hand shear vane. Direct reading in kPa

### Sample range


	Undisturbed sample		Core run		U(T)100 Undisturbed Samples		Rotary core sub-sample
---	--------------------	---	----------	---	-----------------------------------	---	---------------------------

### Installation Details

	Porous Tip		Screened Standpipe		Bentonite seal
	Plain standpipe		Granular response zone		Concrete
	Grout		Backfill with arisings		

Soils	Rocks		
	Sedimentary	Metamorphic	Igneous
 Made ground	 Chalk		
 Boulders and cobbles	 Limestone	 Coarse-grained	 Coarse-grained
 Gravel	 Conglomerate	 Medium-grained	 Medium-grained
 Sand	 Breccia	 Fine-grained	 Fine-grained
 Silt	 Sandstone		
 Clay	 Siltstone		
 Peat	 Mudstone		
	 Shale		
	 Coal		
	 Pyroclastic (volcanic ash)		
	 Gypsum, Rocksalt etc.		



CC Ground Investigations Ltd								Borehole No.		
<h1>ROTARY BOREHOLE LOG</h1>								A2		
Telephone: 01452 739 165, Fax: 01452 739 220, Email: Info@CCGround.co.uk								Sheet 1 of 2		
Project Name: Fairford Observation Wells				Project No:		Co-ords: E N		Hole Type		
				C5964				DS+RC		
Location: SITE A2 and B2				Level: mAOD		Scale		1 : 56.25		
Client: Water Resource Associates LLP				Dates: Start: 01/03/2018 End: 01/03/2018		Logged By		TH		
(m)	Water Levels	Core Run, Samples & Testing		Core Run & Sample	TCR SCR RQD	Install	Description	Depth (m)	Level (mAOD)	Legend
1		No/Type	Depth (m)	Result			Grass over firm friable dark brown slightly sandy CLAY with frequent roots and rootlets (<2mm).	0.30		
							Firm friable brown slightly gravelly slightly sandy calcareous CLAY with rare roots and rootlets (<2mm). Gravel is angular to sub-rounded fine to coarse of limestone.	0.70		
		C	1.10 - 2.50		100% 0% 0%		Light brown sandy very clayey angular to sub-rounded fine to coarse GRAVEL of limestone.	1.10		
							Light brown slightly gravelly slightly silty SAND with occasional comminuted shell fragments (<10mm). Gravel is sub-angular fine of limestone.	(1.40)		
2										
		C	2.50 - 4.00		100% 22% 7%		Light greyish brown slightly sandy angular to sub-rounded fine to coarse GRAVEL of limestone. 2.75m: 1No. sub-rounded cobble of limestone.	2.50		
3							Light brown gravelly very clayey SAND locally tending to slightly gravelly sandy clay. Gravel is sub-angular to sub-rounded fine to medium of limestone.	2.80		
							Weak light greyish brown and light brown shelly LIMESTONE. Discontinuities are horizontal locally sub-vertical intersecting very closely to closely spaced stepped and undulating rough with light brown clayey sand infill (<2mm) and brown staining.	3.00		
								(0.65)		
4		C	4.00 - 5.50		100% 75% 51%		Firm light brown locally greyish brown slightly gravelly sandy CLAY. Gravel is sub-angular to sub-rounded fine to coarse of limestone.	3.65		
								4.00		
5							Weak light greyish brown and light brown shelly LIMESTONE. Discontinuities are horizontal locally sub-vertical intersecting very closely to closely spaced stepped and undulating rough with light brown clayey sand infill (<2mm) and brown staining.	(0.75)		
		C	5.50 - 7.00		100% 100% 88%		4.25-4.60m: 1No. sub-vertical discontinuity stepped rough with slightly clayey sand infill (<2mm) and brown staining.	4.75		
6							4.65-4.75m: 1No. thin bed of firm light brown sandy clay.	(2.40)		
							Medium strong locally weak grey locally light brown shelly LIMESTONE with occasional voids (<40mm). Discontinuities are horizontal closely spaced undulating and stepped rough with light brown or grey slightly clayey sand infill (<2mm).			
7		C	7.00 - 8.20		100% 92% 71%		4.75-4.95m: 1No. vertical discontinuity undulating rough with orangish brown staining.	7.15		
							5.15-5.20m: 1No. very thin bed of grey very clayey sand.			
							5.50-7.15m: With rare voids (<30mm).			
8							6.10-6.25m: 1No. thin bed of stiff grey slightly gravelly slightly sandy clay. Gravel is sub-angular to sub-rounded of limestone.	(1.05)		
							6.25-7.10m: discontinuities are horizontal closely to medium spaced.	8.20		
							Extremely weak thickly laminated grey MUDSTONE locally tending to very stiff silty clay. discontinuities are horizontal and sub-horizontal very closely to closely spaced undulating smooth with clay smear.			
9							7.60-8.20m: with rare lenses (<20mm) very closely to closely spaced of light grey limestone.			
							Borehole completed at 8.20m			
<p>EQUIPMENT: Hand digging tools. Fraste Multi-drill PL(G) track mounted rig.  METHOD: Hand dug inspection pit: 0.00-0.80m. Dynamic sampling using 128mm sample barrel: 0.80-1.10m. Waterflush rotary coring using T6-146 coring barrel: 1.10-8.20m.  CASING: 168mm diameter to 1.00m.  GROUNDWATER: None encountered prior to using water flush during drilling process.  INSTALLATION: Borehole backfilled with bentonite pellets: 7.15-8.20m. Granular filter pack: 7.00-7.15m. 50mm ID HDPE slotted pipe with washed gravel response zone and geo-sock: 5.00-7.00m. Plain 50mm ID HDPE pipe with washed gravel response zone: 2.00-5.00m and bentonite pellet seal: 0.2-2.00m. Flush 150mm steel cover set in concrete: 0.20-0.00m. Gas valve fitted.  REMARKS: Driller notes loss of flush from 2.50-7.00m.</p>										
Groundwater:						Hole Progress:				
Date	Strike Depth (m)	Casing Depth (m)	Depth After Observation (m)	Date	Hole Depth (m)	Casing Depth (m)	Water Depth (m)			
				01/03/2018 17:00	8.20	1.00				



CC Ground Investigations Ltd								Borehole No. <b>B2</b>		
<h1 style="margin: 0;">ROTARY BOREHOLE LOG</h1>										
Telephone: 01452 739 165, Fax: 01452 739 220, Email: Info@CCGround.co.uk										
Project Name: Fairford Observation Wells					Project No: <b>C5964</b>		Co-ords: E N		Hole Type DS	
Location: SITE A2 and B2							Level: mAOD		Scale 1 : 56.25	
Client: Water Resource Associates LLP							Dates: Start: 20/03/2018 End: 20/03/2018		Logged By EC	

(m)	Water Levels	Core Run, Samples & Testing			Core Run & Sample	TCR SCR RQD	Install	Description	Depth (m)	Level (mAOD)	Legend
		No/Type	Depth (m)	Result							
1							MADE GROUND (Grass over): Soft locally firm orangish brown slightly gravelly slightly sandy silty calcareous CLAY. Gravel is angular to sub-angular fine to coarse of limestone and rare porcelain. 0.00-0.05m: Occasional rootlets (<5mm). 0.70m: Low cobble content. Cobbles are angular of limestone.	(0.90)			
2							Firm dark orangish brown slightly gravelly slightly sandy silty calcareous CLAY. Gravel is angular to sub-angular fine to coarse of limestone. 1.60-1.63m: Sandy.	(0.80)			
3							Light yellowish brown and orangish brown sandy slightly clayey angular to sub-angular fine to coarse GRAVEL of limestone with low cobble content. Cobbles are sub-angular of limestone.	(0.80)			
4							Firm orangish brown locally mottled light grey slightly gravelly slightly sandy silty calcareous CLAY. Gravel is angular to sub-angular fine to coarse of limestone.	(0.70)			
5							Firm tending to stiff thinly laminated orangish and greyish brown locally mottled light grey slightly gravelly slightly sandy silty calcareous CLAY. Gravel is angular to sub-angular fine to coarse of limestone.	(0.50)			
6							Stiff thinly laminated grey silty calcareous CLAY with rare lenses (<1mm) of light grey silty fine sand.	(1.90)			
7											
8											
9											

EQUIPMENT: Hand digging tools. Comacchio MC305 multi-purpose tracked rig.

METHOD: Hand dug inspection pit: 0.00-1.00m. Dynamic sampling using 128mm sample barrel: 1.00-6.00m.

CASING: 168mm diameter to 3.70m

GROUNDWATER: Groundwater encountered at 2.30m and rose to 2.10m after 20 minute monitoring period.

INSTALLATION: Borehole backfilled with bentonite pellets: 4.50-6.00m. 50mm ID HDPE slotted pipe with washed gravel response zone and geo-sock: 1.60-4.50m. Plain 50mm ID HDPE pipe with washed gravel response zone: 1.50-1.60m and bentonite pellet seal: 0.10-1.50m. Flush 150mm steel cover set in concrete: 0.10-0.00m. Gas valve fitted.

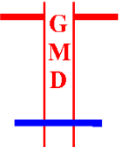
  

<b>Groundwater:</b> Date: 20/03/18    Strike Depth (m): 2.30    Casing Depth (m):    Depth After Observation (m): 2.10				<b>Hole Progress:</b> Date: 20/03/2018 17:00    Hole Depth (m): 6.00    Casing Depth (m): 3.70    Water Depth (m): 2.10			
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CC ROTARY LOG C5964.GPJ CCGI GINT STD ACS 4 0.GDT 34/18



## E-3 GMD Drilling Log and Samples

	<b>Groundwater Monitoring &amp; Drilling Ltd</b> 1 Adeane Road, Chalgrove Oxfordshire OX44 7TQ	<b>DRILLING LOG</b>		<b>BOREHOLE No. B5</b>
<b>Equipment &amp; Methods</b> Pilcon Wayfarer shell and auger rig 150 mm diameter		<b>Location</b> LOVERS LANE, FAIRFORD OXFORDSHIRE GL7 4LS		
<b>Water levels</b> Water added to bail RWL on 26/08/18 = 3.26 mbgl Chiselling from 1.80 mbgl		<b>Grid Reference:</b> 415701, 201673		
		<b>Ground level:</b> 94.0 m AOD		
		<b>Datum level:</b> Well top is 0.06 m below ground level		
<b>Carried out for</b> Fairford Parish Council		<b>Date</b> 25/8/18-26/08/18		
<b>Description</b>	<b>Thickness m</b>	<b>Depth m</b>	<b>Reduced Level</b>	
Brown [7.5YR4/2] hard dry stony SOIL becoming moist dark brown [7.5YR] and slightly stony between 0.35 m and 0.50 m and brown [7.5YR5/4] at 0.6 m	0.70	0.70		
Strong brown [7.5YR5/8] clayey light grey [5Y7/1] hard rubbly limestone.	1.10	1.80		
Hard LIMESTONE light grey [[5Y7/1] with some Brownish yellow [10YR6/6] CLAY	1.60	3.40		
Firm-stiff dark grey [N4] CLAY	0.50	4.10		
<b>Completion</b>		<b>Length</b>		
Inspection cover set in 0.25 m concrete surround with Allen key access Bentonite pellets Pack -2- 5 mm  60 mm OD x 50 mm ID PVC plain casing 60 mm OD x 50 mm ID PVC screen with 1 mm slots 60 mm OD x 50 mm ID PVC plain casing				
		1.50		
		4.10		
		1.80		
<b>Sample No and depth [m]</b>				
B5/1 0.00 - 0.35 m B5/2 0.35 - 0.50 B5/3 0.50 - 0.60 B5/4 0.60 - 0.70 B5/5 0.70 - 1.80	B5/6 1.80 - 2.20 m B5/7 2.20 - 2.40 B5/8 2.40 - 2.75 B5/9 2.75 - 3.40 B5/10 3.40 - 4.10			

*Figure E-3 Borehole B5 Cuttings*



D-1 Borehole B5 cuttings 0.50-0.60 mbgl



D-2 Borehole B5 cuttings 0.60-0.70 mbgl



D-3 Borehole B5 cuttings 0.70-1.80 mbgl



D-4 Borehole B5 cuttings 1.80-2.20 mbgl



D-5 Borehole B5 cuttings 2.75-3.40 mbgl



D-6 Borehole B5 cuttings 3.40 – 4.10 mbgl

## E-4 BGS Archive Logs

### SP 10 SE 4 [1625 0089], near Beaumoor Farm, Fairford Block C

Surface level [+82.0 m] +269 ft, Water struck at [+79.6 m]

Shell and auger [modified] 152 mm [6. in] diameter

June 1971

Overburden 0.6• m [2.0 ft]

Mineral 4.2 in [14.0 ft]

Bedrock 0.1 m+ [0.5 ft+]

Soil, dark brown, Thickness/ Depth 0.1, 0.1

Terrace 1 deposits Clay, silty, pebbly, dark brown. Thickness/ Depth 0.5, 0.6

Sandy gravel, with a silty calcareous matrix to 1.7 m; Thickness/ Depth 4.2, 4.8m

Gravel: fine with some coarse to 2.6 in passing into fine with coarse. Predominantly sub-rounded, platy and tabular, grey and brown oolitic limestone, with some shelly oolitic limestone.

Sand: coarse and medium with a little fine, silty in the upper part. Limestone grains and quartz, buff to 1.7 m, passing into yellowish-brown matrix to 1.7 m

Kellaways Beds Mudstone, sandy and shelly, hard, brown passing into greyish-blue, 0.1, 4.9m

### SW22/SW34 GL 88.95 mAOD [SP10-85]

0 - 6.5 Cornbrash

6.5 - 14.5 Wychwood FM mudstone

14.5 - 36.5 Kemble Beds FM limestone

36.5 - 48.0 White Limestone

48 - 50 Marl

50 - 59.0 Taynton Stone

59 - 67 Stonefield Suite

67 - 79 Fullers Earth

### SW13 The Retreat [near Marlborough Arms].

Groundwater found in FM at 6.4 mbgl, tested 1.14 l/s

0-1.5 Gravel

1.5-2.7 Cornbrash

2.7-13.1 FM mudstone

13.1-31.7 FM limestone

### SE114 RWL 2.4 mbgl Fairford football club [SP10-105 EA]

RWL at 3.0 mbgl, drilling depth 4.6 mbgl. GL 83.31 mOD, 82.95 mOD, drilled 7-May-2002

0-0.1 top soil

0.1-0.4 brown clay

0.4-1.9 sandy gravelly clay

1.9-4.6 coarse sand and gravel [limestone boulder at 4 mbgl]

### SP 10 SW 4 Burdocks

Dry, drilling depth 4.6 mbgl. GL 88.7 mOD, 82.95 mOD, drilled July-1971

0-0.2 top soil / overburden

0.2-4.1 Terrace 2 [sand and gravel]

4.1-4.5 Kellaway Beds

4.5-4.6 Cornbrash [sandy-rubby limestone with shell debris, yellow-brown]

## Appendix F NP Policy Example

This appendix provides a small extract from the Benson Neighbourhood Plan, in which WRA members are also involved, and suggests that, while the Fairford NP text is correct and fit-for-purpose, it would be made more robust by including firm policies at the end of the “Geology, Topography and Hydrology” section.

The following examples may be useful.

### Extracts from Benson’s fully adopted Neighbourhood Plan [‘Made’ in 2018]

#### Drainage and Flood Risk Management

- 14.12.1 Thames Water’s Benson Drainage Strategy [2013, and updated for 2015-2020] indicates that Benson has a significant problem with the foul sewerage system being overloaded by both surface water and groundwater infiltration. The Strategy states that both urban creep [more building and loss of permeable surfaces] and climate change [which is predicted to increase the number of adverse weather events] are expected to exacerbate the problem. Thames Water quantified the rate of urban creep in Benson as ‘average’ in 2013 at 0.0879%, but flagged that their intention to escalate with the County Council if that figure increased. Furthermore, the Water Cycle Study for South Oxfordshire District Council [2016] confirmed that there is minimal or no Wastewater treatment works capacity at Benson.
- 14.12.2 Developers must work with statutory bodies to plan for the necessary wastewater management infrastructure to accommodate growth in Benson to avoid unacceptable deterioration of water quality in parish watercourses and quality of life for residents.
- 14.12.3 Flows in Benson Brook are influenced by the level of winter rainfall infiltrating down into the chalk aquifer and flowing out from late winter onwards, mainly entering the brook in a series of springs in Ewelme. During periods of peak flow, some residents along Brook Street reporting water rising up through their floors.
- 14.12.4 Developers must take account of these specific flood risks in Benson and avoid exacerbating the issue by providing adequate on-site drainage proposals. The detail of Sustainable Drainage System proposals must take account of advice from RAF Benson on the need to manage the risk of bird strike.

#### NP33

**Development proposals should include Sustainable Drainage Systems within their boundaries designed to manage the risk of surface water flooding and foul water sewer overload, and that they will not increase flood risk elsewhere in Benson.**

**Sustainable Drainage Systems should be designed to maximise the benefits of the features, taking account where possible of the Benson’s Strategy for Nature and People [See Appendix L].**

#### NP34

**Built development within areas which provide flood capacity for the built settlements will not be supported.**