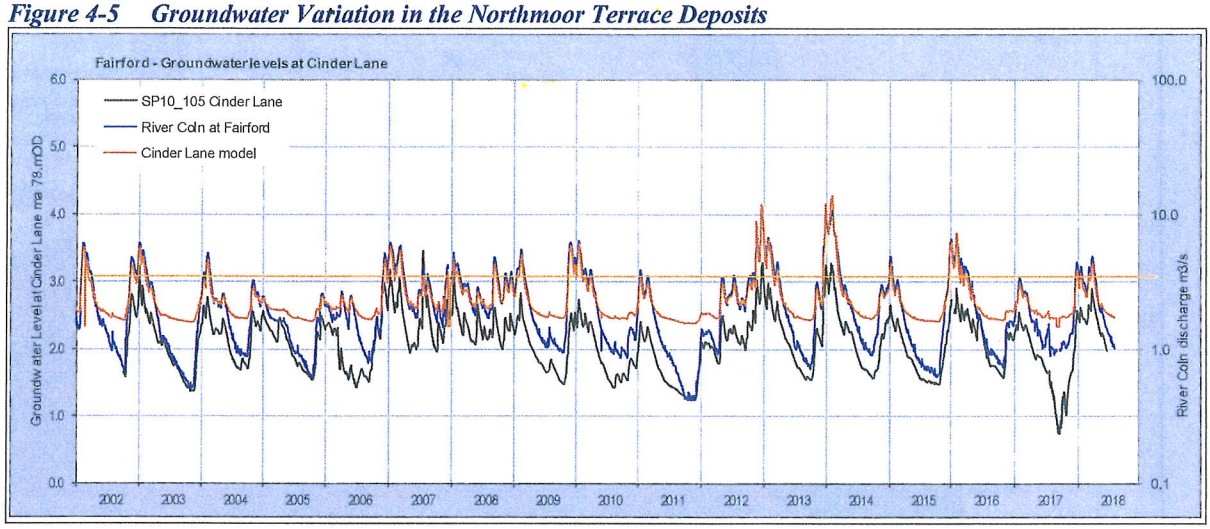
maximum groundwater levels only, and does not accurately portray summer and drought water levels. The following records of stage and mean daily discharge were analysed:

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

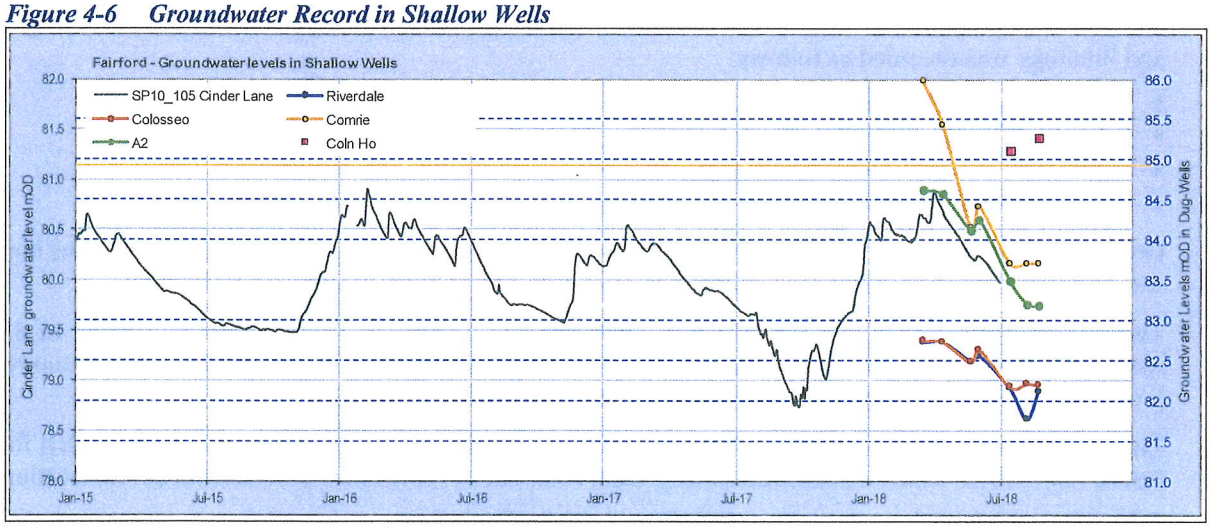
Figure 4-5 Groundwater Variation in the Northmoor Terrace Deposits



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

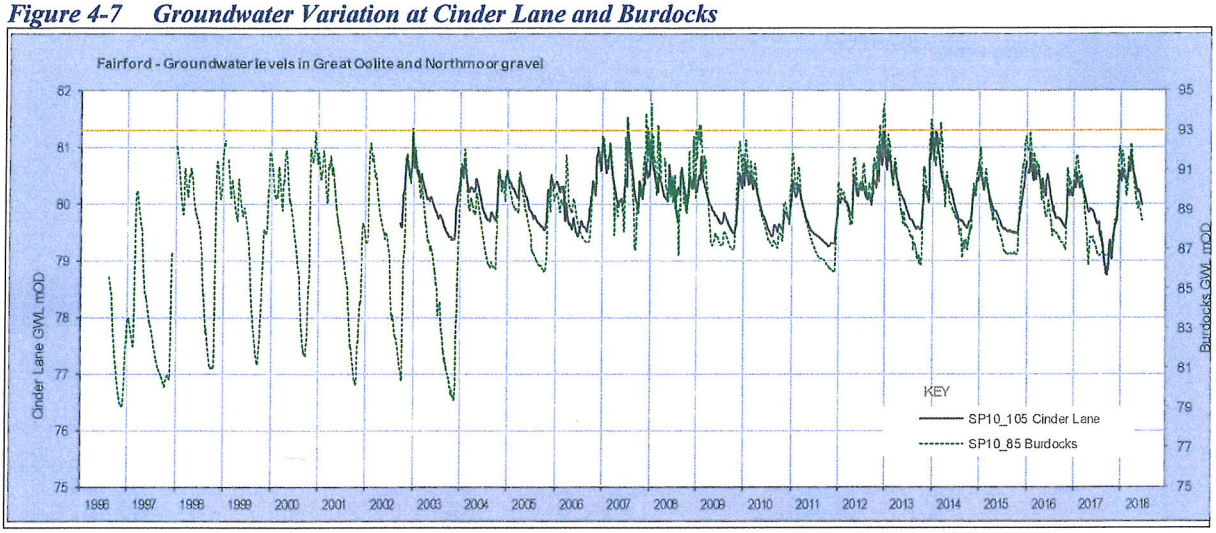


4-2-4 Groundwater Level in the Cornbrash

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	**-0.15**
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	**-0.60**
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	**-8.08**
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

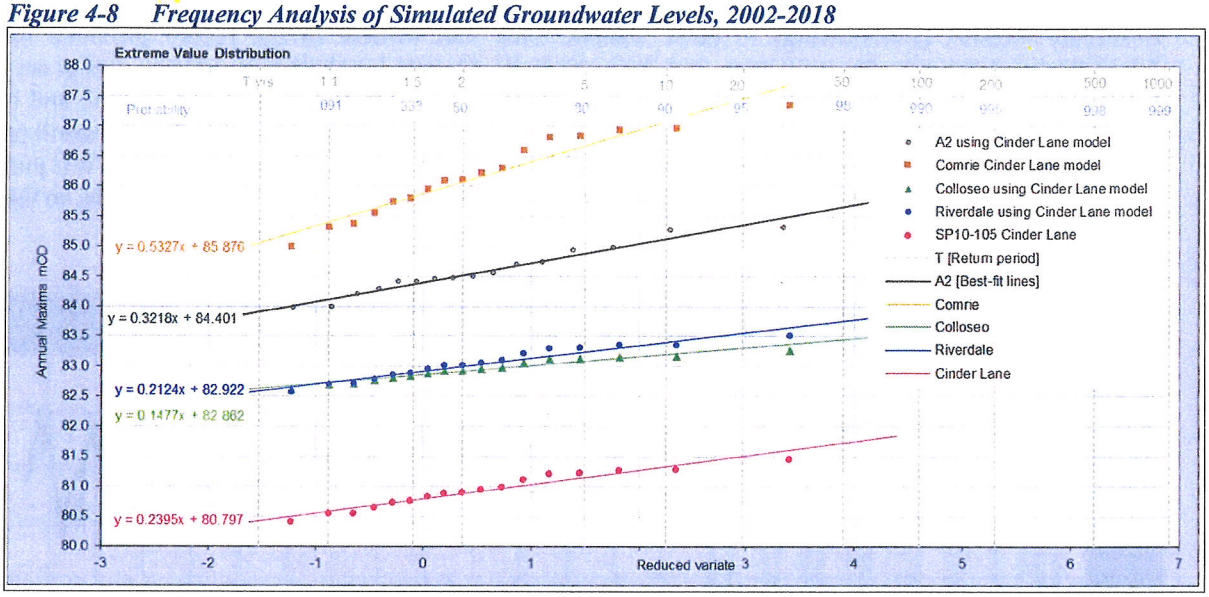
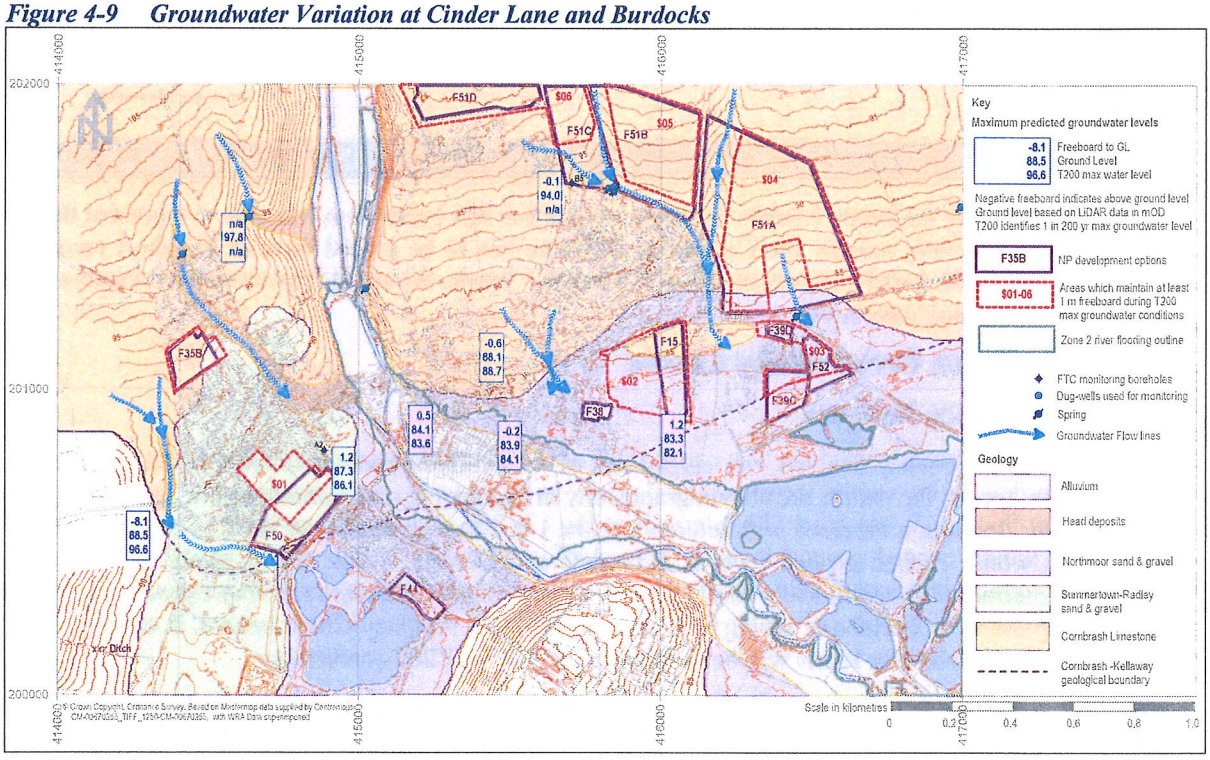


Figure 4-9 Groundwater Variation at Cinder Lane and Burdocks



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 Leafield Road area. At Milton, information was obtained from a dry well at Dynevor Place, and at Leafield 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 Cornbrash 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.

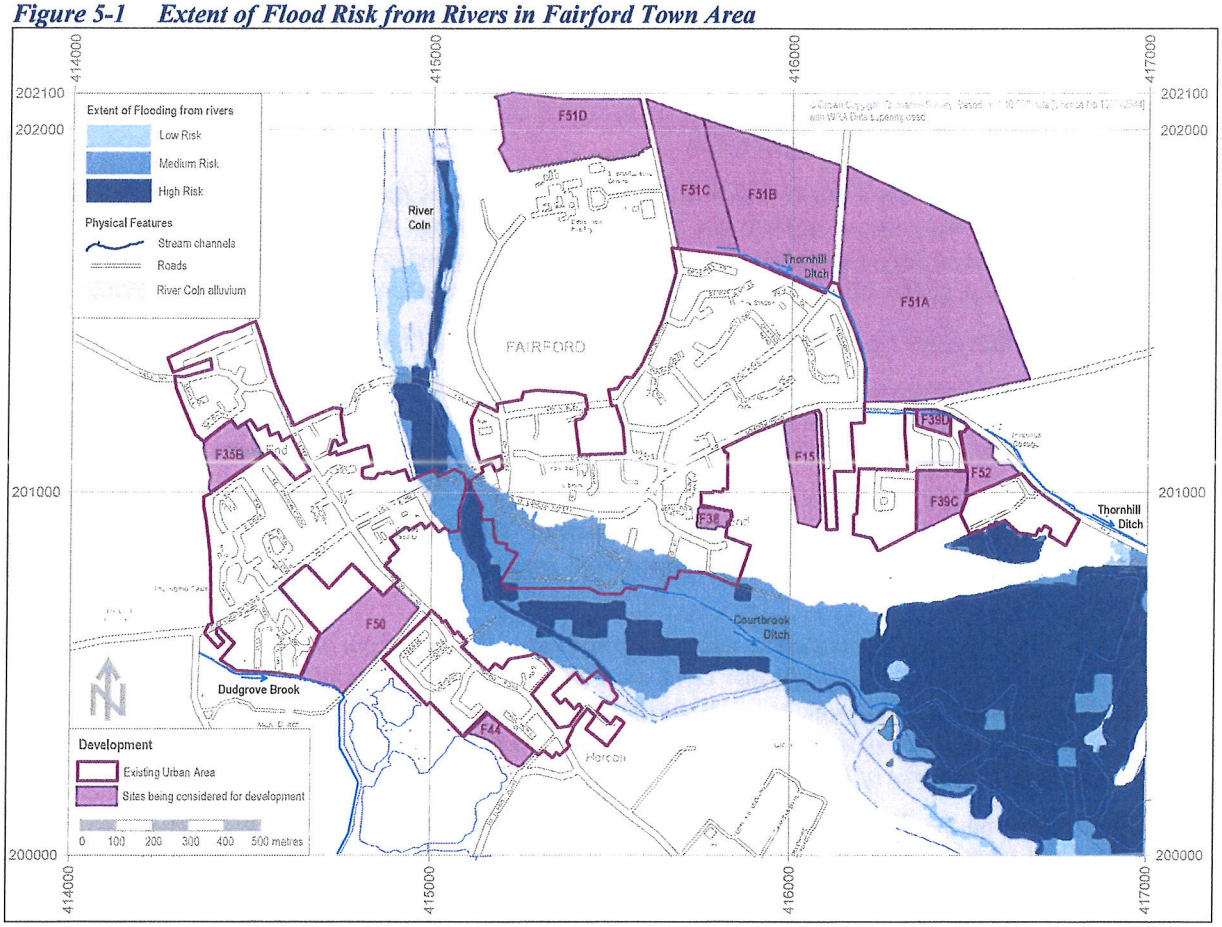
5 Surface Water Review

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^2 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 Wate, 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 20th 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*".