Eastleigh Hydrological Sensitivity Study

Task 1

Revised Report

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This report describes work commissioned by Eastleigh Borough Council. Eastleigh Borough Council's representative for the contract was Graham Tuck. Eleanor Haresign and Susan Wagstaff of JBA Consulting carried out this work.

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Purpose

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1 Introduction

1.1 Background

Eastleigh Borough Council (EBC) commissioned JBA Consulting to identify the hydrological sensitivities within the north of Eastleigh Borough, with particular regard to the proposed North of Bishopstoke link road (NBLR) route.

The EBC Local Plan includes strategic development of housing within the northern sector of the borough and requires the relevant transport infrastructure to determine the housing capacity. The location of the development and the NBLR are within close proximity of the River Itchen SAC, which constitutes an ecological and hydrological constraint to development. This study advises on the alignment of this NBLR with regard to hydrological sensitivities.

Any changes in hydrology resulting from the NBLR could have an impact on the water quality and flows within the catchment and potentially cause a significant impact on the River Itchen SAC, especially when viewed in-combination with the sites allocated within the Draft Local Plan and permitted developments discharging into the Itchen catchment.

1.2 Objectives

The purpose of this report is produce a hydrological conceptual model to provide an understanding of flow systems and a holistic picture of the water in the lower River Itchen catchment tributaries and, in particular, the hydrological sensitivities within the north of the Eastleigh Borough. This takes into account physical, hydrochemical and geological data related to groundwater systems, springs and surface water flows to assess the sensitivity of the water environment.

Hydrological sensitivity can be expressed in terms of:

- The hydrological processes that are important to the headwaters and the associated streams;
- How the headwaters are fed from the surrounding area (including whether the water enters via surface or ground water routes, is fed by springs or is a combination of all three); and
- The ecological value of the waterbody.

This report constitutes the delivery of Task 1 of the Eastleigh Hydrological Sensitivity Study. This report does not address flood risk, flood plain compensation or sustainable urban drainage systems, which are considered in detail in Task 2 and Task 3 of this study.

1.3 Report Structure

The report first outlines the catchment setting of the area of the proposed development and its hydrological significance. Baseline data for the geology, hydrogeology and hydrology are then presented. These data provide the basis for the development of a conceptual model of the water environment with regard to the hydrological sensitivity. The implications of this conceptual understanding are discussed, and recommendations made regarding the proposed NBLR route on the hydrological functions of the area.

Map figures are provided in Appendix A.

2 Catchment Setting

The proposed NBLRlies predominantly within the catchment of the River Itchen (Figure 1), and approximately traverses a route from the B3037 east of Fair Oak (between Pembers Hill and Stroudwood Dairy Farm) and extending north west towards Crowdhill and towards the River Itchen. It crosses Bow Lake tributary towards Brambridge where it turns south west along the existing B3335 to cross the River Itchen towards Highbridge and join the A335 at Allbrook.

The entire River Itchen is designated Site of Special Scientific Interest (SSSI) and Special Area of Conservation (SAC). The SAC has a Chalk-fed stream and river, fen meadow, flood pasture and swamp habitats, with associated invertebrates, fish, birds and mammals[1]. Its qualifying habitats are water courses of plain to montane level with floating vegetation often dominated by water-crowsfoot. It has qualifying species including *A*tlantic salmon, brook lamprey, bullhead, otter, southern damselfly and white-clawed crayfish.

At and downgradient of the project area, units 87-102 of the SSSI constitute much of the river valley, and comprise mainly 'Neutral Grassland - Lowland', with most having a status of 'Unfavourable - Recovering'. The overall status of the SSSI is 'Unfavourable - Recovering'. Historic trends have been for a decrease in flow velocities and increased siltation, affecting macrophyte cover. Inappropriate water levels, with siltation and abstraction cited as problems, are noted more recently, with discharges causing reduced water quality.

The river and stream conditions required by the SSSI are that the natural flow regime should be maintained to assist with the natural geomorphology that supports the features of interest. In addition, it is imperative to manage the water and sediment quality to minimise pollution, effluents and organics entering the river.

The eastern extent of the project area for the NBLR lies within the catchment of the River Hamble, which flows to the south east of the River Itchen and, in its lower reaches below Botley, is designated as the Upper Hamble Estuary and Woods SSSI. It is designated for its saltmarsh, reedswamp and semi-natural woodland. The overall status of the SSSI is 'Favourable'.

These two rivers drain into the Solent and Southampton Special Protection Area (SPA) and Ramsar, or the Solent Maritime SAC.

The Itchen catchment has been the subject of much hydrogeological/hydro-ecological investigation over many years. As a Chalk-fed catchment with river flows vulnerable to over-abstraction from groundwater as well as surface water, and being of international environmental importance, significant catchment management now exists. The EA Catchment Management Strategy[2] (CAMS) outlines that public water supply is the largest consumptive demand and is equally split between groundwater and surface water.

In terms of water resource availability, surface water is not available for licencing in the Itchen and groundwater has restricted availability for licencing over the River Itchen Chalk groundwater body. Further downgradient, the Central Hants and Bracklesham Group groundwater body has groundwater available for licensing.

The EA's Review of Consents process identified a need for a "hands off flow" (stopping abstraction from the four groundwater public water supplies when river flows fall below 198 Ml/d) to help protect the ecology of the River Itchen SAC. This has implications for Southern Water's supply-demand balance in their western area, including the Hampshire South Water Resource Zone.

As well as a "hands off flow" condition existing for abstraction, the EA's Candover and Alre Groundwater Augmentation Schemes augment the Itchen at times of low flow. However, concerns exist for the potential of the scheme to impact on the ecology of the chalk river headwaters[3].

The Hampshire County Council (HCC) Surface Water Management Plan[4] (SWMP) addresses surface water flood risk to identify flooding hotspots along with potential solutions.

1 https://necmsi.esdm.co.uk/PDFsForWeb/Citation/2000227.pdf
2 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/289879/LIT_2494_0c58d2.pdf
3 https://www.hiwwt.org.uk/sites/default/files/files/Reports/120806_Augmentation_Report_vf.pdf
4 http://documents.hants.gov.uk/flood-water-management/EastleighSWMPReport.pdf

3 Baseline

3.1 Introduction

This section provides outline baseline information used to develop the conceptual model of the groundwater and surface water system in the Itchen catchment tributaries' headwaters, presented in Section 4.

3.2 Data Sources

3.2.1 Desk Study

The desk study reviewed the following sources of information:

- existing published and readily online soils, geological, hydrogeological, hydrological and Ordnance Survey information, including regional borehole logs and hydrogeological information (e.g. the Environment Agency (EA) and the local authority, EBC; and
- details of the proposed development provided by EBC.

Table 3-1: Sources of Information

Topic	Source of data and information
Climate: Rainfall	Flood Estimation Handbook (Centre of Ecology and Hydrology, 1999), CEH Hydrometric Register
Topography: Elevation, relief	OS Open Data, Terrain 50 DTM, LiDAR 2m DTM (EA Open Data); and, Aerial photography (Google Earth and Bing Maps).
Geology: Solid and drift, Soils	BGS Bedrock and Superficial Deposits Mapping (Scale 1:50,000), Sheet 315 Southampton, 1987 BGS digital geology mapping; BGS online borehole database (BGS website); BGS online Lexicon (BGS website); Soil Survey of England and Wales, 1983. Soil Map of England and Wales; and BGS UK Soils Map Viewer http://mapapps2.bgs.ac.uk/ukso/home.html
Groundwater: Hydrogeology, aquifer properties, Source Protection Zones and groundwater levels	Hydrogeology Scanned Maps (BGS website); Aquifer classification (Environment Agency website); Groundwater vulnerability (Environment Agency website); Source Protection Zones (Environment Agency website); Licensed abstractions (Environment Agency website); Groundwater quality (Environment Agency website; ESI, 2006); and Major Aquifer properties manual (Jones et al., 2000). EA - Consultation
Surface Water: Surface water features, water quality.	EA - Consultation Forestry Commission (FC)
Water resources: private water supplies, licensed abstractions	EBC – Consultation EA - Consultation

3.2.2 Site Walkover

The site inspection took place on 20th June 2017 by a JBA hydrogeologist, and included the observation, verification and documentation of the pre-identified headwater locations, as requested by EBC, as well as some watercourses and surface water features following discussion with FC.

A further site visit, on 15th May 2018, allowed inspection of selected tributary watercourses of the River Itchen further downstream between the headwaters and their confluence with the River Itchen, to address queries from the EA relating to the first draft of this report.

3.2.3 Consultation

A consultee response with relevance to the water environment was received from the EA. In summary, the main issues the EA may have with any proposals for the NBLR in terms of hydrological sensitivity will be focused around the following topics:

- Any crossing of the floodplain and thus associated floodplain storage compensation;
- Any impacts on conveyance and flow routes of flood and surface water;
- Potential surface water disposal methods such as SuDs; and
- Water quality and pollution prevention methods.

The EA has also provided feedback to the early drafts of this report and its comments have been accommodated in this final version.

3.3 Location and Topography

The project area is located immediately north of the Bishopstoke-Fair Oak conurbations, in Hampshire (Figure 1). It occupies high ground between the River Itchen to the west and the B3354 to the east, and between the B3037 to the south and the B3335 at Highbridge.

Elevations range from ~10 mAOD in the south to a maximum of 62 mAOD in the central part of the site, within Stoke Park Wood, and to ~20 mAOD in the north close to the Itchen. Elevations are lowest along the course of the River Itchen and the undulating countryside continues beyond the eastern part of the area of interest (Figure 2).

3.4 Land Use

The conurbation of Bishopstoke lies between Stoke Park Wood and the River Itchen and extends eastwards towards Fair Oak. Stoke Park Wood is a Forestry Commission managed woodland, with public access footpath amenities. In the northern part of the project area the land use comprises a mixture of arable and grazing, interspersed with localised areas of woodland. Woodland areas are highlighted on Figure 1. A series of ponds lies east of Stoke Common and is utilised as a fish farm.

3.5 Catchment and Climate

Rainfall has not been recorded on site. The nearby gauging station at Highbridge & Allbrook (total, station; 42010) has historic Met Office data available, and is located on the River Itchen just west of the project area (Figure 3). The EA gauging station identified from the UK Hydrometric Register (2008) nearest the project area is located on the Itchen at Highbridge & Allbrook Total. The most recent data from this station indicates a SAAR of 834 mm for the period 1961-1990.

The Flood Estimation Handbook (FEH) also includes long-term average rainfall data for catchments in the UK. For the project area, the Standard Annual Average Rainfall (SAAR) ranges from ~800-830 mm/yr

At the time of the site visit (June 20, 2017) there had been a sustained period of dry weather and there was a heat-wave on-going.

The Flood Estimation Handbook gives the Standard Percentage Runoff (SPR) for the project area as being approximately 30-40%. The SPR is the percentage of rainfall responsible for the short-term increase in river flow during and/or following a rainfall event. However, this varies across the site, with SPR values within Stoke Park Wood at ~30 %, increasing to the east up to 50% on the Horton Heath Stream. These values are indicative of normal runoff associated with underlying low permeability strata.

FEH values for SPR in the north of the project area are closer to ~15% but this likely reflects the Chalk geology much further north of the project area, than at the project area itself.

3.6 Geology and Soils

3.6.1 Introduction

The BGS mapped bedrock and superficial geology of the site and surrounding area is illustrated in Figure 4 and Figure 5, respectively.

3.6.2 Bedrock

The borough of Eastleigh lies within the eastern part of the Hampshire Basin geological region, a broad basin filled with bedrock Tertiary clays and sands, which overlie Cretaceous Chalk at depth. In the area of Bishopstoke/Fair Oak, the bedrock of the London Clay Formation outcrops. This comprises stratigraphy of the Eocene London Clay member. The London Clay mainly comprises bioturbated, or poorly laminated, blue-grey or grey-brown, slightly calcareous, silty to very silty clay, clayey silt and sometimes silt, with some layers of sandy clay. It includes a few thin beds of shells and fine sand partings or pockets of sand, which commonly increase towards the base and towards the top of the formation.

This is underlain by the Whitecliff Sand Member (sand silt and clay, with lenticular bodies of sand), which lies to the north, and other in isolated outcrops; and a few isolated outcrops of the Durley Sand Member (sandy clay and sand silt) adjacent to and northwards of the Whitecliff Sand Member to the east of Fair Oak.

The London Clay Formation is overlain to the south by the Wittering Formation (a greyish brown laminated clay, running northwest-southeast just south of Bishopstoke, which is part of the Bracklesham Group.

To the north of the London Clay lies the Lambeth Group (formerly the Woolwich and Reading Beds), comprising vertically and laterally variable sequences mainly of clay, some silty or sandy, with some sands and gravels, minor limestones and lignites and occasional sandstone and conglomerate. This overlies the Tarrant Chalk Member (formerly the Upper Chalk), a soft white chalk with relatively widely spaced but large flint seams.

The solid geology stratigraphy is highlighted in Table 3-2, taken from BGS 1:50,000 mapping.

Table 3-2: Hampshire Basin Solid Geology stratigraphy

Period	Epoch	Formation
Palaeogene	Eocene	Wittering Formation
		Durley Sand Member
		Whitecliff Sand Member
		London Clay Formation
		Lambeth Group
Cretaceous	Late Cretaceous	Tarrant Chalk Member

Some geological information is confirmed by BGS boreholes on their online viewer[5]:

- Borehole (SU51NW/4[6]) within the east of the project area identifies London Clay from 3.6-92 mbgl;
- Bagshot Sands (Whitecliff Sand Member) occurs at 3 mbgl (SU41NE321[7]) and 5.7 mbgl (SU41NE270/A-F[8]) in boreholes at Fair Oak;
- Borehole scan SU51NW8[9] sets out a generalised vertical section comprising a range of local boreholes;
- Further north, nearer the northern extent of the London Clay extent, at Stoke Park Farm (SU42SE59[10]), London Clay extends to 45 mbgl;
- Borehole scan SU42SE58[11] indicates the Chalk was encountered at 55.2mbgl; and
- In the north west of the project area close to the River Itchen, borehole scan (SU42SE35[12]) comprises clay from 0.7 mbgl to its base at 10 mbgl.

5 http://mapapps2.bgs.ac.uk/geoindex/home.html
6 http://scans.bgs.ac.uk/sobi_scans/boreholes/416318/images/10749781.html
7 http://scans.bgs.ac.uk/sobi_scans/boreholes/15952510/images/15270842.html
8 http://scans.bgs.ac.uk/sobi_scans/boreholes/409412/images/10741210.html
9 http://scans.bgs.ac.uk/sobi_scans/boreholes/416322/images/10749787.html
10 http://scans.bgs.ac.uk/sobi_scans/boreholes/412154/images/10745247.html
11 http://scans.bgs.ac.uk/sobi_scans/boreholes/412153/images/10745245.html
12 http://scans.bgs.ac.uk/sobi_scans/boreholes/412130/images/10745215.html

The lower Itchen tributaries have their headwaters primarily on London Clay outcrops.

3.6.3 Superficial

The river valleys feature alluvium deposits, both within the main River Itchen to the west of the project area and along the course of Bow Lake. There are also river terrace deposits, which occur within the wider Itchen valley, and extends eastwards through Bishopstoke. An isolated head deposit of gravel, sand, silt and clay exists in Fair Oak. Nonetheless, much of the project area has no mapped drift cover, and all the headwaters arise in drift-free areas.

3.6.4 Artificial Deposits

Some areas of artificial deposits exist within Fair Oak and Bishopstoke urban areas and to the east of Bishopstoke, on the lower lying areas.

3.6.5 Soils

Soils mapping indicates that much of the project area is underlain by soils of the Windsor Association, which are slowly permeable, seasonally waterlogged clayey soils, with mostly brown subsoils. Also present are some fine loamy over clayey and fine silty over clayey soils and, locally on slopes, clayey soils with only slightly seasonal waterlogging. The main risks to water in areas with these soils are associated with overland flow from compacted or poached fields. Organic slurry, dirty water, fertiliser, pathogens and fine sediment can all move in suspension or solution with overland flow or drain water.

Around the eastern end of Fair Oak, soils are of the Burlesdon Association, comprising deep fine loamy soils with slowly permeable subsoils and slight seasonal waterlogging associated with deep coarse loamy soils variably affected by groundwater. Some slowly permeable seasonally waterlogged loamy over clayey soils. Landslips and associated irregular terrain locally are associated with this soil type. Farmed land is drained and therefore vulnerable to pollution run-off and rapid through-flow to streams; surface capping can trigger erosion of fine sediment.

Across Stoke Park Wood itself, soils are of the Fyfield 4 Association. These comprise deep well-drained and often stoneless coarse loamy and sandy soils. Also present are some fine loamy soils with slowly permeable subsoils and slight seasonal waterlogging and some slowly permeable seasonally water logged fine loamy over clayey soils. Here, water mainly drains to local groundwater and rivers. There is a risk of water erosion.

These soils types are consistent with the SPR runoff values presented previously.

3.7 Hydrogeology

3.7.1 Bedrock Aquifer Properties

The River Itchen hydrology is largely dominated by groundwater flow due to the Chalk bedrock that underlies much of the area. However, the project area, primarily in the Lower Itchen catchment and Horton Heath Stream catchment, lies largely over the London Clay member, and is considered to be within an area of 'Rocks with essentially no groundwater'. Nonetheless, there also exposures of the Wittering Formation, Whitecliff Sand Member and Durley Sand Member within the project area, which are considered to be a Secondary A aquifer; permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of baseflow to rivers. Similarly, the Lambeth Group strata to the north of the area are a Secondary A aquifer, whilst the Chalk further north still is a Principal aquifer.

There are superficial deposits within the area that can also comprise a Secondary A aquifer. Occurring primarily along the main River Itchen as alluvium, they also occur within the project area along the course of Bow Lake. Secondary (undifferentiated) deposits exist where river terrace deposits occur.

The Baseflow Index (BFI) ranges widely across the project area. This is the proportion of total streamflow made up of baseflow (mostly groundwater input). In the area of Stoke Park Wood, values are ~0.6-0.65. However, these values are lower further east at Fair Oak, at ~0.3 while, further east still, they reduce to 0.2 in the Horton Heath Streams catchment. This suggests that in the project area, 20-60% of the flow of the local watercourses is made up of baseflow. In contrast, in the north of the project area, which reflects the dominance of groundwater flow from the Chalk,

BFI values are ~0.8. Nonetheless, certainly in the area of Stoke Park Wood, baseflow remains an important component of stream flow.

The BFI at gauging station 42010 is of 0.96 and is fairly similar to that from FEH for the wider Itchen catchment, indicating that baseflow within the region is a very high proportion of River Itchen flow, reflecting the wider Chalk catchment. However, these values also imply that baseflow is less important to the lower Itchen tributary river flows i.e. those within the project area.

In addition, it is worth noting that the lower Itchen catchment flows through a heavily urbanised area, making it more prone to flash flooding from surface water runoff and drainage systems being overwhelmed.

3.7.2 Regional Groundwater Levels

Within the project area, groundwater levels are likely to vary spatially with topography and geology.

Groundwater levels have been reported in conjunction with site investigations carried out for the Pember Hill Farm (grid reference SU 504189) proposed development for housing. A letter from CGL (ref CG/18805; August 31st, 2016) outlines the depth to groundwater encountered at ten trial pits in the vicinity. They were completed to a maximum of 3 m deep in February 2016 and ranged from being dry to encountering water at 2.0 mbgl. Groundwater appears to be influenced by site topography with groundwater flowing from west to east.

In comparison, the BGS borehole (SU51NW/4) has a rest water level reported at 28 mbgl. As such, it appears that (at least in this location), given the low permeability of the London Clay, and the fact that some trial pits were dry despite being observed during winter, the observed groundwater is shallow perched water associated with seepage from more permeable subsurface deposits.

Other BGS boreholes in the Whitecliffe Sand Member at Fair Oak report water being encountered at ~5 mbgl (SU41NE270/A-F and SU41NE321). Further north at Stoke Park Farm (SU42SE59), the rest water level is given as 24 mbgl. In the north west of the project area close to the River Itchen, borehole scan (SU42SE35) notes no water ingress to the base of the borehole at 10 mbgl.

There is anecdotal evidence of large (>10 m) and rapid fluctuations in groundwater levels in the Fair Oak area, which is believed to be due to runoff from the London Clay recharging the Whitecliff Sands, causing a rapid temporary rise in groundwater.

The EA has two groundwater monitoring boreholes close to the project area, which monitor Chalk groundwater level, in an area overlain by London Clay.

3.7.3 Regional Groundwater Quality

The site is underlain by two groundwater bodies, with the following classifications:

- Hants Central Bracklesham Group - underlies Bishopstoke and Fair Oak. Overall Good status; and
- Hants South East Bracklesham Group - in the south east part of the project area. Overall Poor status with Good Quantitative status and Poor Chemical status due to industry pressures.

The northern part of the project area, where underlain by the London Clay, is not classified as a groundwater body.

3.8 Hydrology

3.8.1 Catchment Setting

The proposed area of the NBLR extends ~6 km from north west to south east. It traverses the catchments of the main River Itchen and a lower tributary, Colden Common stream, in the north, through the Bow Lake watercourse and other tributaries of the River Itchen in the centre, and to Horton Heath Stream in the south east. Catchment boundaries and watercourses are delineated on Figure 1.

Colden Common stream has a fairly small catchment and flows southeast from the eastern extent of Colden Common village to join the Itchen just below Highbridge. Bow Lake runs largely east to west (although its catchment extends some distance to the north east), flowing to the north of Crowd Hill and through Bow Lake fish farm to join the River Itchen north of Stoke Common. Most of the small tributaries of the River Itchen arise within the vicinity of Stoke Park Wood and flow south

through Bishopstoke to join the Itchen north of the railway viaduct. Those small tributaries further east in Fair Oak also discharge via the same route to the main Itchen, via Quobleigh Pond. The tributaries in the very east of the area of interest flow into Horton Heath Stream, which joins the Upper Hamble just south of Bishop's Waltham.

The OS vector watercourse mapping shows several orphaned streams, which do not appear to flow onwards to join the main river. This appears to be primarily attributable to the OS Opendata map source, rather than being a hydrological characteristic. However, in some cases this may be because the watercourse is then culverted through an urban area, for example the tributary flowing south from Stoke Park Wood from headwaters 7 and 13 to the Itchen tributary (Figure 3) and, in other cases, it is because OS mapping does not always show up the continuity of field edge drains e.g. from headwater 1 to Bow Lake. Nonetheless, there are no mapped sinks in the area, so it is assumed that in fact full connectivity does exist. However, not all flow paths have been ground-truthed so the mapping has not been manually extrapolated.

3.8.2 Water Flows and Flooding

River flows are gauged at Allbrook on the Itchen Navigation (SU4612921122) and on the River Itchen at Highbridge (SU4673221431), which are the key strategic gauging stations for the EA against which impacts should be considered. The combined flows are used in defining the EA's licensing strategy and enforcing flow conditions.

Data from the National River Flow Archive indicate a combined flow Q95 of 3.004 m^3/s and an average flow of 5.533 m^3/s[13]. Indicative data for the gauges were provided for the period 2013 to 2017. Average flows at Highbridge from Jan 2013 to July 2017 are 4.8 m^3/s, with a maximum flow of 17.9 m^3/s (Feb 2014) and minimum of 2.1 m^3/s (Oct 2013). An annual hydrograph from 2016 at Highbridge is shown in Figure 3-4 of the Geomorphology and Ecology report (Task 2 of this programme) and illustrates the relatively stable flow regime which reflects the dominance of baseflow provided by the Chalk groundwater further up the catchment. Monthly spot flow data for the Bow Lake watercourse at Stoke Common (Figure 3) have been provided by the EA for the period February 2000 to September 2011. The average value (Feb 2000-Jan 2011) is 0.13 m^3/s, and the average June value is 0.05 m^3/s.

To corroborate these values, spot flow estimates were obtained during the site visit which took place in May 2018. Prior to this time, due to prolonged spring rainfall throughout March and April, water levels in the River Itchen at Highbridge weir were relatively high (~0.5 m)[14]. This is in contrast to the water levels which were observed during the site visit in heatwave conditions in June 2017 (~0.33 m). Details about the flow gauging are contained within Appendix B. In summary, observed estimated flows across these tributaries represent, as a maximum, <14% of the Itchen Q95 flow value[15] (total of Allbrook and Highbridge), although most individual flow measurements are <5% and may in any case be augmented by pumping station discharges. As such, these flows represent a very small proportion of flow in the Itchen SAC, especially given that observed flows are likely to be relatively high and are being compared to a low flow condition for the Itchen.

Actual flow data for the Allbrook and Highbridge stations were also provided by the EA for May 15th 2018. Flow at Allbrook was 1.993 m^3/s and at Highbridge was 5.218 m^3/s, giving a total Itchen flow of 7.210 m^3/s. Observed estimated flows across the tributaries represent, as a maximum, <6% of the Itchen actual flows, with most values being <1%.

By way of validating this conclusion, the Bow Lake spot flow average value can be compared with that observed in the same location on May 20th 2018, which was 0.124 m^3/s, and is within the same order of magnitude as the historic spot flow data. This suggests that the observed flow estimates from May 2018 provide a realistic picture of the variation in flows across the catchment area of the NBLR.

Although the above data analysis provides a cautionary overview of flows across the catchment, it could be expected that, following rainfall, there may be relatively more flow from the lower permeability area, which would be likely to generate more runoff.

The EA flood map indicates that the majority of the proposed route des not cross areas of Flood Zone 3. The exception is in the north eastern part where the NBLR crosses Bow Lake where there

13 http://nrfa.ceh.ac.uk/data/station/meanflow/42010
14 http://www.gaugemap.co.uk/#!Map/Summary/1470/1617/2017-05-01/2018-05-31
15 http://nrfa.ceh.ac.uk/data/station/meanflow/42010

is a limited extent of Flood Zone 3 indicated along the watercourse, and then the River Itchen across the area of Flood Zone 2 and 3 where the existing Highbridge Road is routed.

Further details regarding flow responses are available in the JBA updated flood report for the EA (in progress). In summary, flows at 'Allbrook + Highbridge' typically remain above 90% of their peak value for 6-10 days during large floods. This is probably long enough for the river and floodplain to attain a steady state, in which the highest flows are occurring simultaneously at all locations along the river system, and all available volume of storage in the channels and floodplain is used up. The largest flow increases are seen in the lower catchment, where runoff from the lower-permeability deposits boosts the peak flow. There may also be a risk of flooding from runoff caused by intense rainfall over the local lower-permeability deposits and urban areas. Nonetheless, the degree to which properties flood also depends strongly on the presence of a pathway through the complex maze of braided channels that constitute the Itchen system.

The project area includes small watercourses that rise on the Eocene deposits and can therefore be expected to have a markedly different flood response to the main River Itchen. The HCC SWMP identifies flooding hotspot area within the region. At Bishopstoke, these include:

- Fair Oak Road - where incidents have been addressed by improving the drainage ditches capacity;
- The Itchen floodplain (Shawford to Bishopstoke) which is largely undeveloped; and
- The Bow Lake main river line, which is largely undeveloped.

For Fair Oak and Horton Heath, flood hot spots include Allington Lane, Fir Tree Lane and Botley Road to the south of the heavily urbanised area, as well as Summerlands Road within Fair Oak centre. It is noted that appropriate maintenance is required to minimise flood risk and that development should account for potential flood risk and not increase runoff rates within these areas.

3.8.3 Water Quality

The River Basin Management Plan (RBMP) for South East river basin district shows the current ecological status of the Itchen watercourses downstream of the project area:

- Itchen - Overall Good status with Good Chemical status and Good Ecological status in 2016; and
- Bow Lake - Overall Bad status with Good Chemical status and Bad Ecological status in 2016 due to pressures relating to commercial fisheries.

The Habitats Regulations Assessment Screening Report (EBC, 2015[16]) identifies that the two major discharges to the Itchen are from the Chickenhall Lane Waste Water Treatment Works (WWTW), just downgradient from Bishopstoke, and the Harestock WWTW, further north near Winchester. Historically, water quality in the Itchen was poorest in Eastleigh area, particularly for ammonia, BOD and phosphorus. Discharge consents by the EA have since been implemented to reduce the inputs of these nutrients to acceptable levels.

The proposed development area lies within a Nitrate Vulnerable Zone (2017 designation).

Water quality data are available from the EA for fifteen locations within the vicinity of Bishopstoke (Figure 3). Data are variously available from 1978 to 2000, and for a variable range of parameters. As such, in order to present meaningful data to demonstrate spatial trends, of these locations five were selected from which summary average data for a selection of parameters across the project area are highlighted in Table 3-3.

16 https://my.eastleigh.gov.uk/media/180204/Eastleigh-Issues-and-Options-draft-HRA-v3-final_SF.PDF

Table 3-3: Summary Water Quality Data

Parameter	PARK HILLS WOOD STREAM PT A (5)	BOW LAKE AT STOKE COMMON (10)	RIVER ITCHEN AT HIGHBRIDGE (11)	RIVER ITCHEN AT BISHOPSTOKE (12)	ALLINGTON STREAM AT FAIR OAK (13)
PH	7.7	7.8	8.1	8.1	7.7
T	10.4	10.9	11.3	11.3	10.4
EC	555	522	588	530	492
nitrate	3	3.5	5.3	6.2	4.3
max nitrate	8.3	15.5	7.8	14.2	6
turbidity	n/a	36	n/a	4	27
DO %	78	83	104	101	88

These data provide a brief snapshot of water quality from Bow Lake (sites 5 and 10), the main River Itchen (11 and 12) and from an Itchen tributary (13).

They indicate that water quality for tributary areas tends to experience higher turbidity and lower DO levels, indicative of the role of surface runoff for the tributaries. This is supported by greater variability in the nitrate levels seen in the tributaries, which could be anticipated to be more constant where groundwater baseflow provided a greater input to the streams. Furthermore, the lower pH and EC values of the tributaries compared to the Itchen indicate that rainfall-runoff provides a greater contribution to stream flow than groundwater. Ground water from Chalk (calcium carbonate) would be expected to have a high pH. In summary, the water quality data suggest that the quality of the Itchen tributaries is not pristine and is significantly derived from surface runoff.

3.8.4 Headwaters

Headwater streams are the smallest parts of river and stream networks, and are the part of the rivers furthest from the river's end point or confluence with another watercourse. Loss of headwater streams can impact water quality and ecology downstream.

There is little guidance to help assess the condition of headwaters and, because there are so many, monitoring all of them is impractical. Many headwater streams are prone to natural drying because they lack year-round connections to groundwater due to seasonal changes in groundwater levels, and do not have permanent flow. This can make it difficult or impossible to use traditional methods of stream health assessment. Similarly, some river reaches may vary between gaining and losing to groundwater during the year.

Indicators of headwater permanence and health include environmental indicators (rock, water, soil and chemical features of headwater streams) and living organism indicators (bryophytes, invertebrates and amphibians). In the UK, the CEH dataset 'Headwater Stream Quality' consists of modelled estimates of observed//expected Biological Monitoring Working Party (BMWP) scores for freshwater streams across Britain, based on a 1 km^2 grid. This is an index for measuring the biological quality of rivers using selected families of macroinvertebrates as biological indicators, and based on the principle that macroinvertebrates differ in their perceived sensitivity or tolerance to organic pollution i.e. nutrient enrichment. Values greater than 1 indicate high water quality. Due to the grid size, however, the resolution for examining individual headwater streams across a small area is limited. As such, to evaluate headwater sensitivity within this study, a range of baseline data are collated, and cross examined in order to better understand the sensitivity of these features.

A habitats map is not available for the project area. However, habitat surveys have been carried out across some of the headwater areas (Figure 3) (HBIC, 2016), and the NVC type can be correlated with the headwater location IDs used here. In addition, macroinvertebrate survey results give an indication of the ecological health of the headwater areas (Arcadian, 2016). In summary, it was considered that the headwater streams are of at most moderate and, more typically, low ecological value in the context of the macroinvertebrate communities that they support.

Twenty headwater locations (Figure 3) were identified by EBC for evaluation within this report with regard to their hydrological functioning, in order to better understand their sensitivity. These headwater locations were visited during the site visit (June 20th, 2017), and site photos are provided in Appendix A. Summary information for each location is provided in Table 3.

Overall, the following observations and comments are made:

- Most headwater streams arise within an area of London Clay deposits, with the exception of sites 4, 5, 6, 10, 11, 12 and 14, which arise over the Whitecliff Sand Member;
- Sites 1-6, which flow into Bow Lake flow entirely over London Clay, including the confluence portion of Bow Lake itself to the point of its own confluence with the River Itchen;
- Sites 16-20 flow entirely over London Clay, which underlies Horton Heath Stream a further kilometre downstream from site 20;
- Sites 7-15 which join the lower Itchen tributaries, cross outcrops of the Whitecliff Sand Member, and then the Wittering Formation before the tributaries join the main River Itchen channel;
- The BFI for each location was taken from catchment information from the point closest to the headwater site. In some cases, it should be noted that these values may not be particularly localised to the headwater e.g. those high values at Bow Lake sites reflect more the groundwater dependent Chalk catchment of Bow Lake. Those which were more localised values include those for sites 7 to 12, at 0.6. It is likely that those for sites 1-6 are more akin to these values, rather than ~0.8;
- Most of the headwater locations had no flowing water but the gully base remained damp. Given the BFI values, the generally low permeability bedrock and the poorly draining soils in many areas, any water observed in the headwaters is considered to be retained runoff. In the area of Stoke Park Wood, in some cases this may result from perched water within the slightly more permeable Wittering Formation supplying the headwaters;
- The two BWMP scores available for the project area are both less than 1, which suggests that water quality is only moderate, and supports the water quality data values presented earlier. This concurs with the results of the macroinvertebrate studies (Table 4 of Arcadian, 2016; Hampshire Ecological Services, 2016);
- Those habitats which are deemed to have a greater groundwater dependence tend to be those wooded sites with wet woodland e.g. W7c. However, this apparent groundwater dependence could be attributed to low permeability deposits where, instead, rainfall-runoff is retained in the gullies; and
- None of the Itchen SAC qualifying flora and fauna are observed within the headwaters or the lower Itchen tributaries.

3.9 Abstractions and Discharges

The EA provided details of abstraction licences within the vicinity of the project area. There are six groundwater licences, all for Agriculture. Basic grid references indicate that the majority of the licences are north/north east beyond the project area, and fall within the Chalk. There is one which may lie between Fisher's Pond and Stoke Park Farm, used for fisheries. Nonetheless, given its location on the London Clay, it is likely that the abstraction in fact penetrates the deeper Chalk, unless otherwise the alluvium.

As such, further details are not provided here as it is not considered that these abstractions are part of any hydrological sensitivity within the project area.

The project area does not lie within in any Source Protection Zones, which all lie to the north east, predominantly within the Chalk (Figure 4). Nonetheless, as the boundary between the London Clay and the Lambeth Group and Chalk is approached, the London Clay will become thinner and provide less protection to these underlying strata.

3.10 Missing Data

Data has been obtained from readily available sources, including data requests and online information. However, limited site-specific data are available to provide detailed interpretation about the functioning of each headwater area.

4 Lower Itchen Catchment Sensitivity

4.1 Hydrological Conceptualisation

The hydrological conceptualisation of the site is as follows:

- The project area lies in an undulating area of the lower Itchen catchment with the eastern part of the area draining into the Upper Hamble catchment. The centre of the area forms the high point, with Bow Lake watercourse forming a lower area in the north and the lower Itchen/ Upper Hamble tributaries draining to the south;
- The area is underlain by strata of the London Clay Formation in the north including the London Clay, Durley Sand Member and Whitecliffe Sand Member, with the Wittering Sand Member of the Bracklesham Group occurring to the south. There are few superficial deposits across the area of interest;
- Whilst the overall River Itchen BFI values suggest a strong groundwater component, this is coming from the Chalk aquifer, further up the catchment; the BFI values are much lower in the project area suggesting surface water plays a greater role in the lower headwaters of the project area;
- Most headwaters in the project area arise on the London Clay, which has low permeability. In conjunction with the SPR values, this suggests that much of the flow supporting headwater streams comes from surface runoff. Although the wet woodland habitats W7c are considered to be groundwater dependent, they may in fact rely on retained surface runoff on the low permeability deposits. However, the sand member formations are moderate aquifers, which may supply some perched groundwater to the headwater streams and wet woodland, particular in the area of Stoke Park Wood;
- Despite heat wave conditions within a dry period noted during the site visit in June 2017, most headwater ditches remained damp, providing further evidence of retained surface runoff combined with some localised perched groundwater supply;
- Runoff proportions may be lower than predicted due to the extent of wooded area where floor leaf cover may act to effectively attenuate runoff; and
- Water quality across the project area is moderate, as evidenced by water quality sampling, BMWP scores and other macroinvertebrate sampling. Given the low or absent flows in the headwater streams during parts of the year, these waters are unlikely to be making a significant contribution to the conditions required by the SAC River Itchen.

4.2 Water Environment Potential Receptors

The potential receptors across the project area which have the potential to be impacted by the proposed development, and their sensitivity value, include the following:

- Surface Water
    - River Itchen SAC - Very High
    - Bow Lake and headwaters - Moderate
    - River Itchen tributaries and headwaters - Moderate
    - Horton Heath Stream and headwaters - Moderate
- Groundwater
    - Principal aquifer (Chalk) - High
    - Moderate productivity aquifers (Sand Members) - High
    - Low productivity aquifers (London Clay) - Low
    - Groundwater abstractions within moderate or low permeability aquifers - Medium
    - Public water supplies and associated SPZs - High

4.3 Water Environment Likely Potential Impacts

The following types of potential (prior to mitigation) effect of the proposed NBLR upon water environment interests have been identified:

- Water Levels and Flows

- Potential adverse effects include those affecting hydromorphology including drainage patterns and surface water flows;
- During the site visit, the headwater locations were verified to be the true headwater position for each watercourse. Nonetheless, care should be taken to ensure that other currently unconnected drains are not connected to these headwaters due to the proposed NBLR. Vice versa, care needs to be taken to ensure that existing drainage pathways are not blocked, to maintain existing conditions supporting the Itchen SAC;
- Removal of wooded headwater areas may lead to increased rapid runoff rates and stream flows with potentially corresponding lower levels of slower baseflow response i.e. removal of the woodlands may make the headwaters more 'flashy'. In turn, these may cause further downstream erosion;
- Given the relatively low contribution of groundwater baseflow to the headwater streams, and perched nature of any local shallow groundwater, only in the north of the project area where the London Clay thins out over the Chalk, is care needed be taken to ensure that Chalk water levels are not disrupted by any deep excavation which fully penetrates the low permeability strata; and
- Any re-alignment of the road at the Itchen crossings close to the EA flow gauging stations could impact the ability to be able to monitor flow conditions reliably if the road crossing has any impact upon river flows. It is unlikely that river crossing construction would impact upon baseflow to the river by affecting groundwater movement, given that the Chalk bedrock is not at the surface.

- Water Quality
  - Removal of wooded headwater areas with corresponding effects on runoff rates and flows may have water quality implications for the SAC in terms of sediment and suspended solids;
  - In addition, there may be an effect on water pH from potential acidity effects resulting from woodland clearance;
  - Increased sediment loading may occur at or near watercourse crossings during the construction period;
  - Accidental spillages from site activities and/or concrete leaching arising from construction works pose a potential pollution source;
  - Whilst the SPZs lie to the north outwith the area of interest for development, given the lack of superficial deposits, any excavation in the northern area should take account of thinning out of the London Clay, and ensure that the integrity of the underlying aquifer units is maintained. Nonetheless, the available geological information suggests this does not pose a significant risk; and
  - Excavations may also have implications for water quality in nearby groundwater abstractions and a stand-off area should be maintained.

These effects may be temporary or permanent and would be assessed as part of an environmental impact assessment. Mitigation measures would have the potential to reduce or even eliminate these impacts, and should help to ensure that the features of the Itchen SAC, as well as the Upper Hamble SSSI which are the end receptors that need to be protected, can be safeguarded against potential impacts from the proposed NBLR.

Nonetheless, it is noted that the key features of the SAC are most notably affected by the Chalk-fed part of the Itchen catchment. Given these works are not taking place on the Chalk, they are not going to impact the Chalk baseflow water inputs to the Itchen SAC.

To further inform the potential impacts and the pathways along which they may occur, recommendations are made below to obtain further site-specific data for the area.

4.4 Water Environment Constraints

The identified receptors should be considered within the design of the NBLR and provide constraints which would need to be mitigated according to the level of potential impact. Figure 6 identifies the following constraints:

- An appropriate buffer around the head waters should be considered, based upon the ground conditions (including likely base flow through the ground, and overland flow), flow

conditions and hydrogeology, hydrology and hydromorphology of the water courses, to maintain the function of the head waters. These areas are broadly indicated where the NBLR does not otherwise cross the watercourse. Other constraints regarding watercourse crossings are outlined in the Task 2: Geomorphology and Ecology report;

- Areas where woodland removal is likely to affect runoff rates or water acidity within headwater areas;
- Approximate areas where London Clay is likely to be starting to thin towards the north and where excavations should therefore proceed carefully such as to avoid excavating the full thickness and into the underlying Chalk aquifer; and a suitable buffer (as indicated on Figure 6) for any groundwater abstractions.

The mapped constraints are based on the current iteration of the proposed route, as shown in Figure 6, and would be revised if the route was subsequently revised.

4.5 Recommendations

This report has gathered readily available data to inform the conceptual understanding of the hydrological functioning of the headwater stream across the area of the proposed NBLR. Further data which would support this understanding at a site-specific level could include:

- Spot flow gauging should be continued by the EA at Stoke Common on Bow Lake watercourse to provide confidence in the contribution of flows being made from this area to the main River Itchen;
- Water quality data in headwater areas - to better characterise the stream quality. In addition, it would be useful to collect further water quality data from the existing EA sampling points identified in Table 2. For example, EA WQ point 11 is located at a proposed river crossing;
- Ground investigation (e.g. auguring or installation of piezometers) to obtain more site-specific data regarding the nature of the underlying geology and hydrogeological permeability (falling head tests); and
- EA Chalk groundwater levels - obtain these data as these would indicate if there is an overall upward groundwater gradient, and how effectively groundwater levels are being confined by the London Clay.

Tests for stream flows and water quality of the headwater streams should commence as soon as possible to extend across a full annual cycle of seasons if possible.

The use of natural flood management could also be considered within the scheme design, particularly near the headwater areas, given that this part of the catchment overlies low permeability clays, and responds differently to much of the remainder of the Itchen catchment.

With regard to the comments made by the EA in their consultation response regarding flooding, SuDs and pollution prevention methods, these will be addressed in further detail during Task 2 of this programme. This will include consideration of the implications for the hydrogeomorphology of the project area and effects to the Itchen SAC.

Appendices

A Appendix - Figure List

North

Colden Common Stream

Highbridge

Brambridge

Allbrook

Bow Lake

River Itchen

Bishopstoke

Stoke Park Wood

Stoke Park Stream

Fair Oak

Fair Oak Stream

Horton Heath Stream

0 0.5 1 2 Kilometres

LEGEND

NBLR

Watercourse

River Catchment

Bow Lake

Horton Heath Stream

Itchen

Woodland

JBA consulting

FIGURE 1: Catchment Setting

North

0 0.5 1 2 Kilometres

LEGEND

NBLR

Watercourse

Elevation (mAOD)

High : 115.1

Low : 4.9

JBA consulting

FIGURE 2: Topography

North

Colden Common Stream

Bow Lake

River Itchen

Stoke Park Stream

Fair Oak Stream

Horton Heath Stream

Highbridge

Allbrook

Brambridge

Bishopstoke

Fisher's Pond

Crowdhill

Fair Oak

Horton

0 0.5 1 2 Kilometres

LEGEND

Groundwater Abstraction (location uncertain)

EA WQ Data

No data

Data available

Gauging station

Spot flow gauging location

River Headwater

Bow Lake

Horton Heath Stream

Itchen

Habitat Survey Site

NBLR

Watercourse

River Catchment

Bow Lake

Horton Heath Stream

Itchen

JBA consulting

FIGURE 3: Hydrological Features

North

SU42SE58

SU42SE35

SU42SE59

SU41NE321

SU51NW/4

Pember Hill SI

SU51NW8

SU41NE270/A

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

0 0.5 1 2 Kilometres

LEGEND

- BGS Borehole
- NBLR
- Watercourse
- Source Protection Zone

River Headwater

- Bow Lake
- Horton Heath Stream
- Itchen

Soild Geology

- WITTERING FORMATION
- WHITECLIFF SAND MEMBER
- DURLEY SAND MEMBER
- NURSLING SAND MEMBER
- LONDON CLAY FORMATION
- LAMBETH GROUP
- NEWHAVEN CHALK FORMATION
- TARRANT CHALK MEMBER

JBA consulting

FIGURE 4: Solid Geology

North

SU42SE35

SU42SE59

SU41NE321
GWL: 5 mbgl

SU51NW/4
GWL: 28 mbgl

Pember Hill SI
GWL: 2 mbgl

SU51NW8

SU41NE270/A
GWL: 5 mbgl

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Fisher's Pond

Nob's Crook

Crowdhill

Hensting

Bishopstoke

Fair Oak

Boyatt Wood

0 0.5 1 2 Kilometres

LEGEND

- BGS Borehole
- NBLR
- Watercourse

River Headwater

- Bow Lake
- Horton Heath Stream
- Itchen

Superficial Geology

- TUFA
- HEAD
- HEAD, 1
- ALLUVIUM
- RIVER TERRACE DEPOSITS (UNDIFFERENTIATED)
- RIVER TERRACE DEPOSITS, 1
- RIVER TERRACE DEPOSITS, 3
- CLAY-WITH-FLINTS FORMATION
- MADE / INFILLED GROUND

JBA consulting

FIGURE 5: Superficial Geology

North

Bow Lake

River Itchen

Colden Common

Hensting

Brambridge

Highbridge

Lord's Wood

Allbrook

Fisher's

Nob's Brook

Crowdhill

Bishopstoke

Fair Oak

EASTLEIGH

Eastleigh

Otterbourne Manor

Dell Copse

Beach Farm

Bow Park Farm

Rowlake Farm

Hurst Farm

Hurst Common Cottages

Southviews Farm

Marwell Manor

Lowhill Farm

Jamesmead Farm

Mortimer's Farm

East Horton Cottages

East Horton Farm

Knowle Hill Farm

Four Winds

West Horton Farm

Horton Park

0 0.5 1 2 Kilometres

LEGEND

- Groundwater abstraction
- Watercourse
- NBLR
- Constraint buffer
- Woodland
- Thinning London Clay

River Catchment

- Bow Lake
- Horton Heath Stream
- Itchen

JBA consulting

FIGURE 6: Water Environment Constraints

B Appendix - Spot Flow Gauging

B.1 Introduction

Spot flow gauging was carried out over a one-day period to provide an estimate of flows within the lower Itchen tributary watercourses over which the proposed NBLR lies. This was undertaken in order to address comments from the EA which sought to better understand ground and river conditions following a period of significant / prolonged rainfall. Conditions were originally observed in June 2017 followed prolonged dry weather. Whilst the weather at the time of the visit in May 2018 was dry, high rainfall during the spring led to relatively high water levels observed at the gauged Highbridge location on the Itchen, as per Figure B1.

Figure B1 - Highbridge Weir Water Levels on the River Itchen[17]

During the May 2018 site visit, it was noted at locations which were visited previously e.g. Stoke Park Wood that stream flows were greater, although the surrounding ground was not visibly wetter than during the June 2017 visit. This section describes the work that was carried out, and presents the results of the spot flow gauging.

B.2 Methodology

On May 15th 2018, numerous locations along each tributary (Colden Common stream, Bow Lake, Stoke Park stream, Fair Oak stream (all flowing to the River Itchen) and Horton Heath stream (flowing to the River Hamble)) were selected, as illustrated in Figure B2. At each location, flow estimates were made using the float method[18]. This method was selected in order to provide as many flow estimates as achievable within a one-day period, and was also suitable for lone working.

The locations were selected with readily available access, primarily at watercourse crossings on public roads or footpaths. In some cases, flow was measured through a culvert and, whilst specific hydraulic calculations exist for this scenario, the bottom slope was not known and such calculations were not feasible.

Where possible, the channel width was measured with a measuring tape although, in some cases it was necessary to make a visual estimate. Similarly, the reach over which the float was timed was estimated visually in some cases. Several depth readings were obtained where the water channel varied across its width. In some cases, the water was too shallow for the float to be used and, in these cases, a visual estimate of flow (l/s) was made. Whilst this approach has limitations regarding data accuracy, its purpose was to understand the order of magnitude of flows and the data obtained are considered to be sufficient in this regard.

17 http://www.gaugemap.co.uk/#!Map/Summary/1470/1617
18 https://www.inmtn.com/tools/float-method/

Figure B2 - Spot Flow Locations

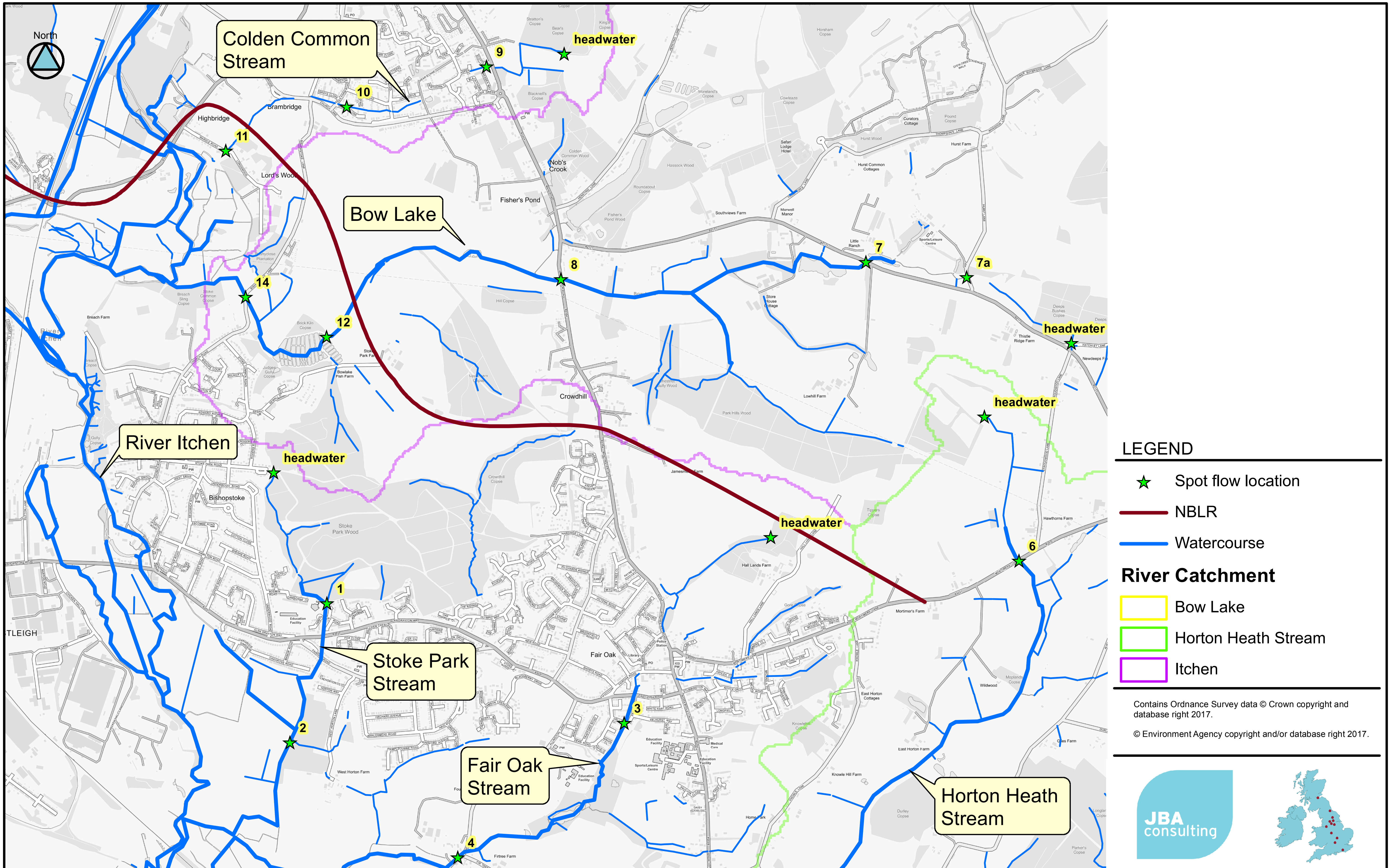


FIGURE B2: Spot Flow Locations

Repeat measurements were made where possible in order to constrain uncertainty. However, some uncertainty in the flow rates obtained remains.

B.3 Results

The site data are illustrated in Figure B3[19] (following page), and the summary data are given below in Table B1. The summary data indicate the average flows for the locations on each watercourse, and the percentage that these flows represent of the Q95 value of the River Itchen at Highbridge.

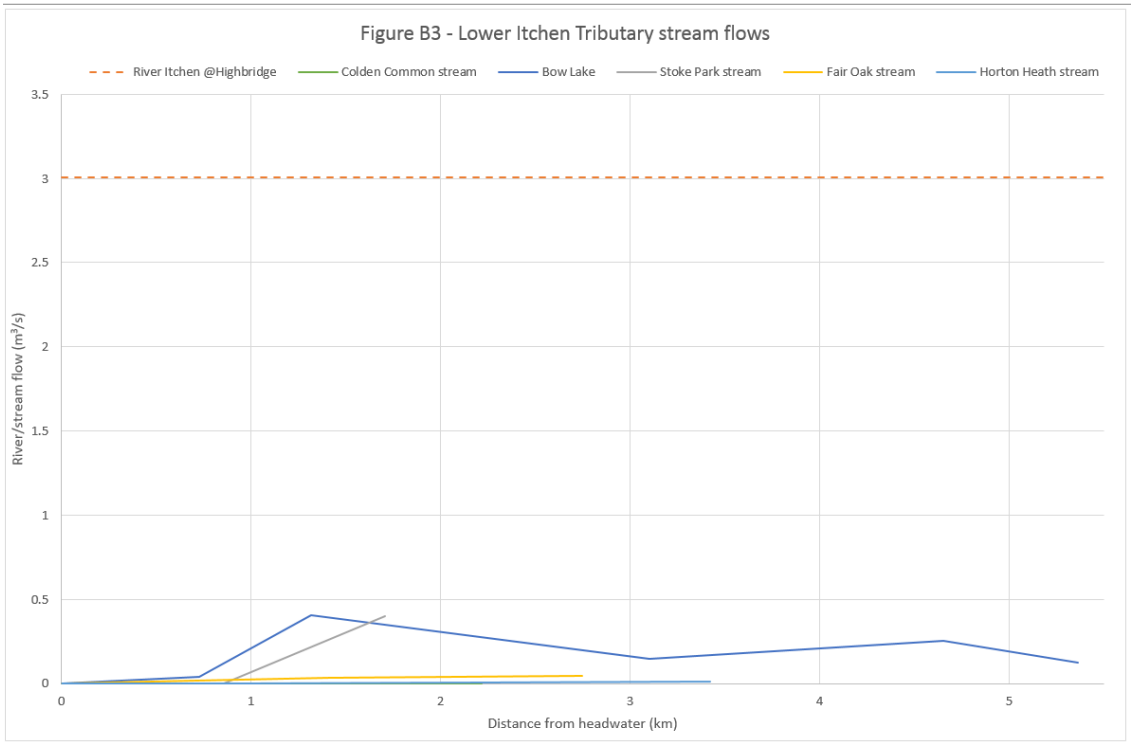
Table B-1: Summary Water Flow Data for May 15th 2018

Watercourse	Average Flow (m^3/s)	% of Itchen Q95
Colden Common stream	0.001	0.02
Bow Lake	0.20	6.61
Stoke Park stream	0.20	6.67
Fair Oak stream	0.04	1.29
Horton Heath stream	0.01	0.19

The average flows indicate that the majority of the stream flows across the catchment area relate to those in the Bow Lake and Stoke Park watercourses. The individual results show that the flows within the tributary watercourses represent <7% of Q95 flows in the Itchen. Actual flow data from the Itchen for May 15th are pending from the EA, but not available at the time of report completion.

An accretion profile of the flows at individual flow observation points with distance from the headwater location on each watercourse has been plotted in comparison to these Q95 Itchen flows, in Figure B4.

Figure B4 - Lower Itchen Tributary Stream Flows



The profiles indicate that the watercourses do not necessarily gain water steadily along its reach. However, the signal may in part reflect factors like faster flow rates occurring through a culvert[20], errors in estimating flow in culverts, flow inputs from pumping stations, and inaccuracies in estimation of channel width or reach length.

19 Site 13 missing as unable to obtain data
20 http://evidence.environment-agency.gov.uk/FCERM/en/FluvialDesignGuide/Chapter7.aspx?pagenum=4

Figure B3 - Lower Itchen Tributary Flow Data

Site	catchment	easting	northing	from headwater (km)	Depth (m) 1	2	3	4	5	average	Width (m)	Area (m2)	Float distance m	Time (s) 1	2	3	average	Surface velocity (m/s)	0.85 mid channel velocity (m/s)	Discharge (m3/s)	Discharge (l/s)	% of Itchen Q95	Comments
headwater	Colden Common stream	448854	121899	0.00																0			
9	colden1	448438	121830	0.62	0.02					0.02	0.5	0.01								0.0002	2l/5-10s?	0.01	
10	colden2	447690	121615	1.43	0.15					0.15	0.6	0.09	1	60			60.0	0.02	0.01	0.001	1	0.04	
11	colden3	447043	121380	2.22	0.1	0.15				0.125	0.5	0.0625	1	90			90.0	0.01	0.01	0.001	1	0.02	
headwater	Bow Lake	451568	120349	0.00																0			
7a	bow1	451009	120703	0.73	0.2					0.2	0.6	0.12	8	18.1	21.6		19.9	0.40	0.34	0.041	41	1.37	culvert
7	bow2	450469	120783	1.32	0.4	0.05	0.05			0.17	2.5	0.42	8	7	7		7.0	1.14	0.97	0.405	405	13.47	culvert, just below lake outlet
8	bow3	448836	120691	3.11	0.1					0.1	2	0.2	7	9	7.8	8	8.3	0.85	0.72	0.144	144	4.79	Just above pumping station? Bridge with drop
12	bow4	447582	120382	4.66	0.4					0.4	2.5	1	5	13	18	19	16.7	0.30	0.26	0.255	255	8.49	Above fish farm
14	bow5	447149	120597	5.37	0.15	0.2				0.175	2.5	0.4375	7	18	17	18	17.7	0.40	0.34	0.147	147	4.91	Below fish farm but just above pumping station?
headwater	Stoke Park stream	447299	119657	0.00																0			
1	stoke1	447583	118956	0.86	0.04	0.08	0.04			0.05	0.50	0.03	1	10			10	0.10	0.09	0.002	2	0.08	
2	stoke2	447385	118210	1.71	0.1	0.3	0.4	0.4	0.3	0.3	3.5	1.05	6	13.1	13.5	13.7	13.4	0.45	0.38	0.399	399	13.27	
headwater	Fair Oak stream	449960	119310	0.00																0			
3	fair oak 1	449175	118315	1.41	0.04	0.6	0.08	0.08	0.08	0.176	1.5	0.264	3	16	26	21	21.0	0.14	0.12	0.032	32	1.07	
4	fair oak 2	448284	117595	2.75	0.1					0.1	1	0.1	11	19.3	21.5	20.8	20.5	0.54	0.46	0.046	46	1.52	
headwater	Horton Heath stream	451104	119955	0.00																0			
6	horton1	451289	119184	0.89	0.02					0.02	1	0.02							0.00	0.0002	1l/3s?	0.01	
5	horton2	450163	117288	3.43	0.25	0.25	0.1	0.15	0.1	0.17	4	0.68	2	105			105.0	0.02	0.02	0.011	11	0.37	road bridge no culvert

It is noted that the high value at Bow Lake 2 location is likely skewed by the lake discharge occurring immediately upgradient of the flow observation point. Bow Lake sites 3 and 5 occur immediately upgradient of a mapped pumping station, and data are not available here to evaluate the contribution these make to flows. However, it appears that the changes in flow due to these pumping stations are sufficiently large to be higher than the total flow at the headwaters.

Nonetheless, the data suggests that flows increase notably down the channels, particularly Bow Lake and Stoke Park. This suggests inflows to the tributaries are occurring not just at the head waters and, therefore, that impacts on the whole hydromorphology of the tributaries should be considered in due course with regard to the wider developments that are contingent upon the proposed link road e.g. housing.

From these individual gauging points, the average value represents <4% of the Itchen Q95 flows, whilst the largest value represents <14% of Itchen Q95 flows. This takes a cautionary approach, given that the river levels are currently relatively high and the Q95 reflects a low flow condition, as well as allowing for the site-specific comments made above.

C Appendix - Headwater Photos

Headwater Site 1 – photo not possible to due to undergrowth

Headwater Site 2

Headwater Site 3

Headwater Site 4

Headwater Site 5

Headwater Site 6

Headwater Site 7

Headwater Site 8

Headwater Site 9

Headwater Site 10

Headwater Site 11

Headwater Site 12

Headwater Site 13

Headwater Site 14

Headwater Site 15

Headwater Site 16 – not visited

Headwater Site 17

Headwater Site 18 not visited

Headwater Site 19

Headwater Site 20

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