Water Resource Benefits of Working With Natural Processes

Final Idle and Torne Report
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Revision History

<table>
<thead>
<tr>
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Contract
This report describes work commissioned by Sean Arnott, on behalf of the Environment Agency, by an email dated October 2019. The Environment Agency’s representative for the contract was Sean Arnott. Iain Craigen, Emily Christopherson, Abigail Speakman, Alexander Jones, Susan Wagstaff and Barry Hankin of JBA Consulting carried out this work.

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Purpose
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### Abbreviations

<table>
<thead>
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<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEP</td>
<td>Annual Exceedance Probability</td>
</tr>
<tr>
<td>AoI</td>
<td>Area of Interest</td>
</tr>
<tr>
<td>BFI</td>
<td>Baseflow Index</td>
</tr>
<tr>
<td>BGS</td>
<td>British Geological Survey</td>
</tr>
<tr>
<td>CEH</td>
<td>Centre of Ecology and Hydrology</td>
</tr>
<tr>
<td>DEM</td>
<td>Digital Elevation Model</td>
</tr>
<tr>
<td>DWSZ</td>
<td>Drinking Water Safeguard Zones</td>
</tr>
<tr>
<td>DTM</td>
<td>Digital Terrain Model</td>
</tr>
<tr>
<td>ELJ</td>
<td>Engineered Log-Jam</td>
</tr>
<tr>
<td>ET</td>
<td>Evapotranspiration</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information Systems</td>
</tr>
<tr>
<td>HER</td>
<td>Hydrologically Effective Rainfall</td>
</tr>
<tr>
<td>HYPE</td>
<td>Hydrological Predictions for the Environment</td>
</tr>
<tr>
<td>IFRM</td>
<td>Integrated Flood Risk Management</td>
</tr>
<tr>
<td>JBA</td>
<td>Jeremy Benn Associates</td>
</tr>
<tr>
<td>LiDAR</td>
<td>Light Detection And Ranging</td>
</tr>
<tr>
<td>LWD</td>
<td>Large Woody Debris</td>
</tr>
<tr>
<td>NERC</td>
<td>National Environment Research Council</td>
</tr>
<tr>
<td>NFM</td>
<td>Natural Flood Management</td>
</tr>
<tr>
<td>PC</td>
<td>Priority Catchment</td>
</tr>
<tr>
<td>RAF</td>
<td>Runoff Attenuation Feature</td>
</tr>
<tr>
<td>SAC</td>
<td>Special Area of Conservation</td>
</tr>
<tr>
<td>SCS</td>
<td>Soil Conservation Service</td>
</tr>
<tr>
<td>SMD</td>
<td>Soil Moisture Deficit</td>
</tr>
<tr>
<td>SUDS</td>
<td>Sustainable Urban Drainage Systems</td>
</tr>
<tr>
<td>WFD</td>
<td>Water Framework Directive</td>
</tr>
<tr>
<td>WWNP</td>
<td>Working With Natural Processes</td>
</tr>
<tr>
<td>WWNP CS</td>
<td>WWNP Mid/Upper-Catchment Storage Potential</td>
</tr>
<tr>
<td>WWNP FZ</td>
<td>WWNP Lower Catchment Floodplain Zone Potential</td>
</tr>
<tr>
<td>WWNP FROP</td>
<td>WWNP Lower Catchment Floodplain Reconnection Potential</td>
</tr>
<tr>
<td>WWNP LCM</td>
<td>WWNP Arable and Grassland Land Cover Management Potential</td>
</tr>
<tr>
<td>WWNP SPS</td>
<td>WWNP Slowly Permeable Soils Potential</td>
</tr>
<tr>
<td>WWNP RAF</td>
<td>WWNP Runoff Attenuation Features Potential</td>
</tr>
<tr>
<td>WWNP RZ</td>
<td>WWNP Mid/Upper-Catchment Riparian Zone Potential</td>
</tr>
</tbody>
</table>
**Glossary**

Annual exceedance probability - the probability of a flood of a particular magnitude, or greater, occurring in any given year.

Gaining watercourse – a waterbody which has increasing flow with distance downstream due to discharge of groundwater baseflow into the surface watercourse.

Flood Zone 2 – an Environment Agency dataset predicting areas of land assessed as having between a 1 in 100 and 1 in 1,000 annual probability of river flooding (1% – 0.1%), or between a 1 in 200 and 1 in 1,000 annual probability of sea flooding (0.5% – 0.1%) in any year.

Losing watercourse – a waterbody which has decreasing flow with distance downstream due to leakage of flow from the surface watercourse to the ground. Watercourses may be both gaining and losing at different times and locations.
1 Introduction

1.1 Background

JBA were commissioned by the Environment Agency to undertake research into Working With Natural Processes (WWNP) and groundwater. This follows considerable work on working with natural processes and flood management, also known as natural flood management (NFM). The focus of this project was to investigate the potential for WWNP to augment water resources, particularly groundwater, so that findings can be considered as part of the Environment Agency’s updated Abstraction Licensing Strategy. This project focussed on nine Environment Agency Priority Catchments which comprise areas of significant water demand. However, the findings are applicable throughout England.

An overall project report is available separately and includes the following:

- Literature and WWNP review;
- Data review;
- Generic conceptualisation of WWNP and groundwater;
- Mapping methodology;
- Overall project findings and recommendations.

This report presents the findings regarding an Area of Interest (AoI) within the Idle and Torne Priority Catchment and includes the following:

- Section 1 – Introduction;
- Section 2 – Catchment overview: a description of the AoI;
- Section 3 - Site visit and local knowledge of the system;
- Section 4 – Conceptual model;
- Section 5 - Identifying potential WWNP and groundwater recharge areas;
- Section 6 – Recommendations.

In order to obtain a detailed on-the-ground understanding of: the catchment, current challenges, what measures are currently implemented, those planned, and potential for further work; specific AoI were defined for each Priority Catchment in discussion with Environment Agency staff. These AoI are representative of the wider Priority Catchment and were chosen for their potential for WWNP. The findings for the AoI are likely to be applicable in the wider Priority Catchment and in other similar areas in England. However, in the wider Priority Catchment where different soils, geology and hydrogeology are present then other additional WWNP measures may also be applicable. The other Priority Catchment reports and the wider overall project report will provide useful information about a wider range of WWNP and groundwater measures.

1.2 Using the Project Outputs

The project focusses on WWNP measures that should improve water resources through a range of measures aimed particularly at increasing: soil infiltration rates; groundwater recharge rates; aquifer storage and summer baseflows. To that end, the project has produced a series of GIS outputs which signpost where different interventions would be more favourable to improving water resources (see Section 5). The project recognises that broad objectives can be set at a national or regional level, however prioritisation of the implementation of interventions will need additional input from a range of stakeholders to identify local considerations. This may include: how interventions may work with other projects; or that improving low flows in systems with limited baseflow input; or improving water quality (e.g. sediment and nutrient levels) are particular concerns. In other areas maximising infiltration into principal aquifers may be the main driver. The individual outputs
for this project identify where specific WWNP processes can be enhanced with interventions and this can be combined with local knowledge and decisions on objectives to drive implementation.

1.3 Idle and Torne Priority Catchment and Area of Interest

The catchment of the Idle and Torne rivers covers an area of approximately 1,200km². The Idle drains a catchment area of 880km² and the Torne, 330km². An Area of Interest (AoI) has been defined to the southeast of Worksop within the headwaters of the Idle covering 127km². The Sherwood Sandstone outcrops over 710km² of the 1,200km² total Idle and Torne catchment. The groundwater body is in long-term deficit because of over-abstraction. This has led to no additional water being available for growth and river baseflows have been reduced, which has consequently impacted river flows, habitats and ecology. As a result, the groundwater body has been closed to further consumptive abstraction since the early 1990s and is at ‘Poor Status’ under the WFD. The following description and conceptual model focusses on the AoI, but wider aspects of the catchment are highlighted where relevant.
2 Catchment Overview

2.1 Topography and Surface Water Drainage

The overall catchment is predominantly a mid to lowland catchment. Most watercourses flow in a north-eastward direction. The AoI terrain is approximately 150m AOD in the south and west of the AoI and declines to a level of approximately 50m AOD to the north-east.

There are four Water Framework Directive (WFD) river waterbody catchments within the 127km² AoI: Maun, Meden, Poulter, Millwood Brook. The River Maun flows along the southern boundary of the AoI in a north-easterly direction. The River Meden flows through the centre of the AoI in the same direction, and the River Poulter is the most northern river within the AoI and also flows in a north-eastern direction. The Carburton dam is situated upstream of the River Poulter within the AoI. The River Poulter becomes confluent with the River Maun immediately prior to entering the River Idle over the Sherwood Sandstone in Nottinghamshire.
Figure 2-1: Topography and surface drainage within Idle and Torne AoI

The Chesterfield Canal is also located within the Idle and Torne catchment but outside of the AoI. The canal enters the catchment to the west of Worksop and through Retford, it then enters the River Trent and thus has hydrological interaction with the Idle and Torne catchment. Canals are generally lined and perched above local surface and groundwaters. Many of the minor valleys in the AoI have no mapped surface water features which is indicative of a highly permeable geology setting. However, it is possible that there is local agricultural or forestry drainage and local drainage ditches which are not mapped. Forestry typically has a reasonably dense drainage network. However, the areas of ancient woodland forestry, such as Sherwood Forest are likely to have very limited drainage and runoff.

There has been extensive coal mining in the East Midlands, which largely ceased by 2000 and so any associated subsidence is likely to have occurred by 2005. However, this may
have historically impacted upon ground levels, watercourse profiles and historical level data (ESI, 2012). Evidence from the site visit suggests that subsidence has been significant.

2.2 Soil and geology

2.2.1 Soils
The soils in the AoI are almost exclusively freely draining acid sandy soils and freely draining slightly acid sandy soils. There are very small areas of naturally wet very acid sandy and loamy soils, and loamy clayey floodplain soils with naturally high groundwater around the surface watercourses and freely draining slightly acid loamy soils in the more upgradient areas. The soils reflect the underlying geology which in the AoI is nearly entirely bedrock sandstone.

Figure 2-2: Soil type within Idle and Torne AoI
2.2.2 Superficial Geology

Whilst there are only limited superficial deposits within the AoI as illustrated in the figure below, there are considerable thicknesses of superficial deposits within the wider Idle and Torne catchment as indicated in the subsequent table. This should be borne in mind if transferring findings from the AoI to the wider catchment.

![Superficial geology map of Idle and Torne AoI](Image)

**Figure 2-3: Superficial geology within Idle and Torne AoI.**
Table 2-1: Superficial geology in the wider Idle and Torne catchment (Source Shepley and Soley 2009)

<table>
<thead>
<tr>
<th>Age</th>
<th>Generic Name</th>
<th>Thickness</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent V</td>
<td>Made Ground (1)</td>
<td>Variable</td>
<td>Anthropogenic deposits.</td>
</tr>
<tr>
<td></td>
<td>Warp (2)</td>
<td>Up to 1m</td>
<td>Made ground formed by flooding land and the artificial deposition of laminated silt and clay.</td>
</tr>
<tr>
<td>Flandrian V</td>
<td>Peat (3)</td>
<td>0-4.5m</td>
<td>Peat</td>
</tr>
<tr>
<td></td>
<td>Alluvium (4)</td>
<td>3-8m</td>
<td>River flood plain deposits</td>
</tr>
<tr>
<td></td>
<td>Blown Sand (5)</td>
<td>0-4m, 8 in places</td>
<td>Fine-grained wind-blown sand that commonly underlies Peat in the east of the area</td>
</tr>
<tr>
<td>Probably late</td>
<td>River Terrace</td>
<td>0-8m, 15 in places</td>
<td>Sand and gravel with some clay</td>
</tr>
<tr>
<td>Devensian G</td>
<td>Head (7)</td>
<td>0-3m</td>
<td>Generally sandy and gravelly clay, dependent on the surrounding deposits, caused by solifluxion during and at the end of the last glacial interval.</td>
</tr>
<tr>
<td></td>
<td>Glaciolacustrine Deposits (sand) (8)</td>
<td>0-1m</td>
<td>Sand with silt and clay deposited in the Pro-glacial Lake Humber or when the lake had just drained.</td>
</tr>
<tr>
<td></td>
<td>Glaciolacustrine Deposits (silt and clay) (9)</td>
<td>0-8m</td>
<td>Also called the Hemingbrough Formation or 25ft Drift (silt and clay) Pro-glacial lake deposits formed in Lake Humber when the present estuary was blocked with ice.</td>
</tr>
<tr>
<td></td>
<td>Glaciolacustrine Deposits (basal sand) (10)</td>
<td>0-3m</td>
<td>Silty and clayey sand</td>
</tr>
<tr>
<td></td>
<td>Glaciofluvial Deposits (11)</td>
<td>0-5m</td>
<td>Sand and gravelly sand with silt and clay interdigitating with the other glaciolacustrine sediments in places.</td>
</tr>
<tr>
<td>Ipswichian</td>
<td>Older River Gravel (Doncaster area) (12)</td>
<td>5-15m</td>
<td>Sand and gravel</td>
</tr>
<tr>
<td>Pre-Ipswichian</td>
<td>Older Glaciofluvial Deposits (13)</td>
<td>0-16m generally 0-10m</td>
<td>Well-sorted sand and gravel with abundant pebbles derived from the Sherwood Sandstone Group bedrock.</td>
</tr>
<tr>
<td>Possibly Anghian</td>
<td>Older Till (Doncaster area) (14)</td>
<td>0-9m</td>
<td>Bouldery, cobbly and gravelly sandy clay deposited from ice.</td>
</tr>
<tr>
<td>Pre-Anghian or</td>
<td>Buried Channel Deposits (15)</td>
<td>Up to 58m</td>
<td>Deposits filling deep incised buried valleys, mainly sand and gravel at base overlain by thick laminated silt and clay.</td>
</tr>
</tbody>
</table>

Numbers after unit name refer to items in the text below.

The superficial deposits have variable permeability which determines whether they act as aquifers or aquitards. The ability of the superficial sediments to accept recharge infiltration is key to how much recharge arrives at the bedrock aquifers and where the recharge arrives.
Table 2-2: Permeability of the superficial sediments (Source Shepley and Soley 2009)

<table>
<thead>
<tr>
<th>Generic Name</th>
<th>Permeability classification</th>
<th>Further hydrogeological observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Made Ground (1)</td>
<td>Permeable</td>
<td>Considered permeable because of heterogeneity</td>
</tr>
<tr>
<td>Warp (2)</td>
<td>Weakly permeable</td>
<td>Primarily cohesive silt and clay, forming a surface layer of the order of 1 to 2m in thickness. Where other weakly permeable strata underlie the Warp it is considered to be effective in reducing recharge to the underlying aquifer. Being primarily clay and silt the Warp exhibits limited storage potential.</td>
</tr>
<tr>
<td>Alluvium (3)</td>
<td>Weakly Permeable</td>
<td>River flood plain deposits are inherently variable. Limited testing [B6] indicates hydraulic conductivities to be in the range $4.55 \times 10^{-3}$ to $2.75 \times 10^{-3}$ m/d, which is confirmed by permeability tests on borehole samples [A10], which have given a range between $6.9 \times 10^{-4}$ to $3.4 \times 10^{-3}$ m/d. In central parts of the main river channels the weakly permeable material may be absent and gravel exposed but the identification of this using bathymetric data was beyond the scope of the project.</td>
</tr>
<tr>
<td>Peat (4)</td>
<td>Weakly permeable</td>
<td>Hydraulic conductivities, determined from boreholes in Hatfield Moors, are in the range $4.06 \times 10^{-4}$ to $1.12 \times 10^{-3}$ m/d when derived from falling head tests and $4.75$ to $8.55 \times 10^{-5}$ m/d when laboratory determined from core samples, representing vertical hydraulic conductivity [B6].</td>
</tr>
<tr>
<td>Blown Sand (5)</td>
<td>Permeable</td>
<td>Where this deposit is thick enough it may locally conduct a reasonable amount of lateral groundwater flow, generally overlain by Peat and Alluvium.</td>
</tr>
<tr>
<td>River Terrace Deposits (6)</td>
<td>Permeable</td>
<td>Sand and gravel with some clay, locally derived from the Glaciolacustrine Deposits, therefore relatively fine grained, but locally may conduct a reasonable amount of lateral groundwater flow where it is thick enough.</td>
</tr>
<tr>
<td>Head (7)</td>
<td>Permeable</td>
<td>The heterogeneity of the Head (both Devensian and Holocene deposits) warrant that they be classified as permeable.</td>
</tr>
<tr>
<td>Glaciolacustrine Deposits (sand) (8)</td>
<td>Permeable</td>
<td>Sand with silt and clay, commonly forming discontinuous, low ridges and generally less than 2.5m in thickness, therefore only locally utilised for water supply.</td>
</tr>
<tr>
<td>Glaciolacustrine Deposits (silt and clay) (9)</td>
<td>Weakly permeable</td>
<td>The structured nature of the laminated clays, silts and sands renders them effective as an aquitard. This is supported by triaxial and permeability tests performed on borehole samples [A10], which gave results between $2.9 \times 10^{-9}$ and $5 \times 10^{-9}$ m/d.</td>
</tr>
<tr>
<td>Glaciolacustrine Deposits (basal sand) (10)</td>
<td>Permeable</td>
<td>The deposits generally comprise bedded and well-sorted silty and clayey sand, which is up to 4m in thickness and locally may conduct a reasonable amount of groundwater.</td>
</tr>
<tr>
<td>Glaciofluvial Deposits (11)</td>
<td>Permeable</td>
<td>Sand and gravelly sand with silt and clay interdigitating with the Glaciolacustrine Deposits in places.</td>
</tr>
<tr>
<td>Older River Gravel (Doncaster area) (12)</td>
<td>Permeable</td>
<td>Sand and gravel, possibly locally confined.</td>
</tr>
<tr>
<td>Older Glaciofluvial Deposits (13)</td>
<td>Permeable</td>
<td>Well-sorted sand and gravel with abundant pebbles derived from the Sherwood Sandstone Group, likely to be in hydraulic continuity with the bedrock.</td>
</tr>
<tr>
<td>Older Till (Doncaster area) (14)</td>
<td>Permeable</td>
<td>The Older Till generally comprises weathered and decalcified bouldery, cobbly and gravelly sandy clay, which has a limited effect on inhibiting recharge.</td>
</tr>
</tbody>
</table>
The precise stratigraphy of the superficial deposits is important for determining recharge. Where superficial deposits are permeable and overlie both bedrock aquifers and aquitards then they can route recharge infiltrating over aquitards horizontally into nearby underlying aquifers.

Greater thicknesses of superficial deposits can dampen and delay the recharge signal to the underlying bedrock.

However, there are in fact very limited superficial deposits in the AoI. The majority of the area of interest has no superficial deposits and bedrock is exposed beneath the soils. There are a few very local superficial deposits which include:

- A few small areas of till – this is a mixed glacial deposit including variable amounts of clays, sands and gravels. The exact composition of the till areas in the AoI is not known.
- Alluvium comprising clay, silt, sand and gravel locally along the Rivers Poulter, Meden and Maun.
- River terrace sands and gravels along the Rivers Poulter and Maun.
- Glacial fluvial sand and gravel.
- Head: clay, silt sand and gravel deposits.

### 2.2.3 Solid Bedrock Geology

The Idle and Torne catchment is situated within the Sherwood Natural Character Area in Nottinghamshire and overlies the UK’s second largest aquifer: the Permo-Triassic Sandstone aquifer. The Lower Magnesian Limestone, Sherwood Sandstone (outcropping 710km²) and Mercia Mudstone dominate the catchment geology. A summary catchment cross-section is given in the following figure. The bedrock geology dips in an approximately easterly direction at around 12 degrees (BGS, 1966).

![Figure 2-4: Summary cross-section through the priority catchment (Source Shepley and Soley 2009)](image-url)
The following table gives a general bedrock geology summary.

### Table 2-3: Bedrock geological strata (upper most strata at top of table)

<table>
<thead>
<tr>
<th>Geology Group</th>
<th>Formation and Aquifer</th>
<th>Lithology</th>
<th>Thickness m$^3$</th>
<th>Location relative to AoI</th>
<th>Hydrogeological Properties$^4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercia Mudstone Group</td>
<td>Mercia Mudstone Tarporly Siltstone Formation</td>
<td>Mudstones and siltstones and occasional sandstones</td>
<td>0 - 253 overlies Sherwood Sandstone to west of AoI.</td>
<td>East of the AoI</td>
<td>Low productivity</td>
</tr>
<tr>
<td>Sherwood Sandstone Group</td>
<td>Chester Formation Principal Aquifer</td>
<td>Red sandstone, thickens northward.</td>
<td>60-370</td>
<td>Aol</td>
<td>Aquifer with significant intergranular flow</td>
</tr>
<tr>
<td>Zechstein Group</td>
<td>Lenton Sandstone Formation Principal Aquifer (formerly the lower Mottled Sandstone) part of the Sherwood Sandstone Group)</td>
<td>Sandstone</td>
<td>~ 20$^3$</td>
<td>Along the western edge of the AoI</td>
<td>Aquifer with significant intergranular flow</td>
</tr>
<tr>
<td>Roxby Formation (upper)</td>
<td>Red-brown calcareous gypsiferous mudstone, thickens northward. Bands of anhydrite.</td>
<td>0-80</td>
<td>Not in AoI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brotherton Formation (Upper Magnesian Limestone) Principal Aquifer</td>
<td>Dolomite and dolomitic limestones thickens northward</td>
<td>0-45</td>
<td>Not in AoI</td>
<td>Fracture flow dominated</td>
<td>Highly Productive Aquifer</td>
</tr>
<tr>
<td>Edlington Formation (Middle Permian Marls) Secondary A in AoI Secondary B to west of AoI.</td>
<td>Coarse-grained sandy and gravelly in the south becoming fine-grained siltstone and mudstone northward</td>
<td>0-70m</td>
<td>To west of AoI. Underlies Aol and separates Sherwood Sandstone from underlying Cadeby Formation</td>
<td>Rock with essentially no groundwater</td>
<td></td>
</tr>
<tr>
<td>Cadeby Formation (Lower Magnesian Limestone) Principal Aquifer</td>
<td>Thin dolomitic breccia and sandstone</td>
<td>0-130</td>
<td>To west of Aol, source of baseflow beneath Aol and for surface waters upgradient from Aol.</td>
<td>Fracture flow dominated</td>
<td>Highly Productive Aquifer</td>
</tr>
<tr>
<td>Yellow Sands Formation$^2$</td>
<td>Aeolian sands</td>
<td>0-20 (locally 50)</td>
<td>To west of Aol</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>Basal Permian Breccia$^2$ (south of model area)</td>
<td>Eroded bedrock</td>
<td>0-5</td>
<td>To west of Aol</td>
<td>n/a</td>
<td></td>
</tr>
</tbody>
</table>

Notes.
Maximum thickness, may be absent or present with less thickness across the area. Sourced from Shepley and Soley 2009.
Yellow Sands and Basal Permian Breccia modelled together as one unit in regional model.
Based on BGS Aquifer flow types and Environment Agency classification.
Within the AoI the bedrock outcrop is nearly exclusively the Sherwood Sandstone Group Chester Sandstone Formation as shown within the figure below. There is a band of the Lenton Sandstone Formation along the west of the AoI, this horizon used to be classified as part of the Sherwood Sandstone Group and is now classified within the Zechstein Group. There is a tiny slither of Zechstein Formation Edlington Group in the northwest of the area.

Figure 2-5: Bedrock geology underlying the Idle and Torne AoI
2.3 Aquifers

Bedrock Aquifers

The Idle and Torne catchments include a number of aquifers. The Magnesian Limestone Cadeby Formation within the Zechstein Group and Sherwood Sandstone Group are both classified as ‘principal’ aquifers. The deep-confined Cadeby Formation may be considered part of the Sherwood Sandstone aquifer system in the East Midlands area, where the Sherwood Sandstone outcrops. However, beneath the deep-confined Sherwood Sandstone Group the Cadeby Formation is not important (Shepley and Soley 2009). This has the implication that additional recharge to the Cadeby Formation to the west of the AoI has the possibility to benefit the Sherwood Sandstone aquifer within the AoI. The aquifer potential of the Cadeby Formation is enhanced where evaporites have dissolved from within the rock.

The following cross sections are orientated approximately West to East across the north, central and southern parts of the priority catchment with the central section through the area of interest (AoI). There is some level (pumped) drainage in the very northeast of the priority catchment where WWNP measures are not likely to significantly benefit groundwater.

Figure 2-6: Cross section through the priority catchment to the north of the AoI (Source Shepley and Soley 2009)
Figure 2-7: Cross-section centre south of Worksop, along the approximate line of the River Poulter (approx. northing 370000), source Shepley and Soley 2009.

Figure 2-8: Cross-section to south of AoI, source Shepley and Soley 2009.
The main aquifer within the area of interest is the Sherwood Sandstone principal aquifer. This covers all of the AoI except the western part of the AoI. The western part of the AoI is underlain by the Lenton Sandstone Formation: this is also classified as a principal aquifer.

**Figure 2-9: Bedrock aquifers surrounding Idle and Torne AoI**

The potential for vertical upward groundwater flow from the underlying Cadeby Formation into the Sherwood Sandstone is illustrated in the following figure. The larger blue circles indicate a greater head between the underlying Cadeby (blue) and the Sherwood Sandstone (yellow).
Figure 2-10: Groundwater levels different in the Cadeby Formation and Sherwood Sandstone, source Shepley and Soley 2009.
Superficial Aquifers

Given the limited extent of the superficial deposits within the AoI they are not likely to form significant aquifers. However, all the superficial deposits are classified as secondary A and B aquifers (see figure below) as follows:

- Glacio-fluvial sands and gravels: secondary A aquifer
- River Terrace sands and gravels deposits: secondary A aquifer
- Alluvium; clay, silt sand and gravel deposits: secondary A aquifer
- Till; diamicton sand and gravel: secondary B aquifer
- Head deposits; clay, silt sand and gravel deposits: secondary undifferentiated.

Figure 2-11: Superficial aquifers surrounding the Idle and Torne AoI
Given the reasonable permeability of the superficial deposits these aquifers are likely to be in connection with the underlying Sherwood Sandstone aquifer and can probably (with the possible exception of the till) be treated as one unit with the bedrock.

**Recharge**

Infiltration recharge estimation from groundwater modelling (1970-2004 modelling scenario) gives a fairly variable pattern of recharge including the following features:

- 100-200mm/a around the River Torne and in the north of the catchment.
- West of the catchment by the Upper Rivers Poulter, Meden and Maun recharge is 200-250mm/a.
- South of the catchment south of the River Maun recharge is locally high around 300-350mm/a.
- Locally there are low areas of recharge 0-50mm/a associated with the lower permeability Zechstein deposits and the Mercia Mudstone Group.

Comparison to the modelled recharge for the time period 2000-2012 estimates recharge levels have recently been up to 50mm/a lower in the east of the AoI but potentially fairly similar in the west of the AoI.

There is a small amount of recharge leakage from the Mercia mudstone to the Sherwood Sandstone.

The gridded 1km baseflow index across the area is shown in the figure below and indicates a fairly uniformly high baseflow index of 0.88 across most of the AoI. The baseflow index measured at the gauge on the Torne at Auckley is 0.7. Auckley is located downstream of the AoI south of Doncaster. This BFI indicates there is already a high level of recharge in the AoI.
Groundwater vulnerability is given as uniformly high across the AoI: this is indicative of the high potential for infiltration from the surface. There is no soluble rock vulnerability within the AoI. However, the Cadeby Formation to the west of the AoI is associated with potential soluble rock vulnerability and this should be considered if enhanced recharge measures are considered in this area. There may be additional vulnerability from fracturing of the Sherwood Sandstone due to subsidence.

2.4 Groundwater Mechanisms

The East Midlands and Yorkshire Groundwater model area covers most the AoI within the East Midlands part of the model (ESI, 2012). It contains a vast amount of data, only some of which is reproduced in this report where it is specifically relevant to the identification of relevant WWNP measures. For specific measures and projects proposed within the AoI or wider priority catchment and surrounding areas the model and associated documents would provide useful information.
Generally, the flow within the Sherwood Sandstone and associated deposits is intergranular through spaces between the sandstone grains; some limited flow is through fractures. In the AoI the exposure of the bedrock at the surface and the fairly uniform permeable nature of sediment means that the aquifer will be unconfined in the AoI. Geological faults are not thought to significantly impact on groundwater flows, although they are in general represented in the model as 1m thick with a hydraulic conductivity of 0.0027m/d (ESI, 2012).

**Groundwater levels**

Typical seasonal variation in water levels in the area of interest is 0-0.2m in the Sherwood Sandstone. This low seasonal variation is reflective of the high intergranular storage in the Sherwood Sandstone and any connected superficial deposits. Seasonal fluctuations in the underlying Cadeby Formation are higher up to 6m: this reflects the more fractured nature of this aquifer with lower storage.

Stream flow analysis has indicated that surface water flows generated on the Zechstein Group – the Magnesian Limestone Formation and Cadeby Group - are critical for maintaining surface water flows across the Sherwood Sandstone (Shepley and Soley 2009).

The following figure indicates modelled gaining and losing surface waters, under both wet and dry conditions. Surface waters gaining from groundwater are shown in blue and those surface waters losing to groundwater in red. Recent (in 2012) actual abstraction conditions were applied to the model. Under wet conditions there is considerably more leakage to the aquifer (red dots). These areas have the potential for enhanced recharge to the ground during wet periods and could be the focus of runoff attenuation features (RAFs). In dry conditions much of the surface water system is sustained by baseflow.
Figure 2-13: Gaining and losing surface waters
The overall water balance of the East Midlands and Yorkshire model is given below. Whilst this is a very general figure, a few points can be noted. The amount of groundwater storage varies considerably between wet and dry years. So measures to increase recharge have the potential to improve drought resilience. At times of lower than typical recharge, water abstraction is balanced by recharge and use of stored groundwater. At times of higher than average rainfall recharge, there is increased baseflow: represented by stream leakage and drains; and gains in the groundwater stored by the aquifer. Leakage from rivers to the ground (dark blue) is represented as fairly constant.

![Rainfall and Streamflow Graph](Figure 2-14: Water Balance in the EMY regional Model.){/}

### 2.5 Flooding Mechanisms

The Environment Agency Flood Map for Planning shows that there is a greater than 1% chance of flooding from rivers (fluvial flooding) along the watercourses within the Idle and Torne AoI. However, outside of the narrow valleys in the AoI, the majority of the AoI is not located within a flood zone at risk of fluvial flooding.

There are many small areas distributed throughout the AoI that are at a 1% Annual Exceedance Probability (AEP) risk of surface water flooding. These often are along narrow dry valley in the interfluves.

The JBA Groundwater Flood Risk Map predicts that the majority of the AoI comprises groundwater levels less than 0.5m below the ground surface in the 1% AEP event. This suggests that during such a magnitude event, groundwater may re-emerge close-to or at the surface over significant areas of the AoI regardless of its topography. The area between the River Poulter and River Meden to the west of the AoI is predicted to be less sensitive to groundwater flooding with levels predicted to range between 0.5m and over 5m below ground level during the 1% AEP event. However, it is noted that the high intergranular

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{Figure 5.5a: Recent actual scenario: model water balance (EMY527b_RA)}
storage in the sandstones means that very considerable recharge is required to raise groundwater levels even by 0.5m.

Figure 2-15: Flood risk predicted within Idle & Torne AoI

2.6 Land Cover

The Land Cover Map 2015 data shows the dominant land cover to be arable and horticulture land which covers 43% of the AoI. Other significant land covers in the area include broadleaf woodland (26%) followed by coniferous woodland (15%) and improved grassland (6%) (see table below for further compositions within the AoI).

The highest slopes of the AoI are typically forested with a mix of broadleaf and conifer woodland. Clumber Park, which drains towards the River Poulter comprises mixed broadleaf and coniferous woodland areas. Clipstone Forest, whilst outside the AoI itself, is a large coniferous woodland that drains into the AoI at Ollerton.

The mid-lower slopes of the AoI are typically arable and horticulture in land cover, particularly east of the A614.

A number of disused collieries are present within the AoI in the vicinity of Meden Vale and Edwinstowe (Thoresby Colliery) which may include contaminated land and therefore should be dealt with sensitively regarding any potential activities, particularly regarding increasing recharge through potentially contaminated land.
Figure 2-16: Land use within Idle and Torne AoI
Table 2-4: Land cover proportions within Idle and Torne AoI

<table>
<thead>
<tr>
<th>Land Cover</th>
<th>Percentage AoI Area (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arable and horticulture</td>
<td>42.7</td>
</tr>
<tr>
<td>Broadleaf woodland</td>
<td>25.9</td>
</tr>
<tr>
<td>Coniferous woodland</td>
<td>14.7</td>
</tr>
<tr>
<td>Improved grassland</td>
<td>5.5</td>
</tr>
<tr>
<td>Suburban</td>
<td>4.2</td>
</tr>
<tr>
<td>Heather grassland</td>
<td>2.1</td>
</tr>
<tr>
<td>Neutral grassland</td>
<td>1.3</td>
</tr>
<tr>
<td>Freshwater</td>
<td>1.2</td>
</tr>
<tr>
<td>Inland rock</td>
<td>1.1</td>
</tr>
<tr>
<td>Acid grassland</td>
<td>0.7</td>
</tr>
<tr>
<td>Urban</td>
<td>0.5</td>
</tr>
<tr>
<td>Calcareous grassland</td>
<td>0.1</td>
</tr>
<tr>
<td>Fen, marsh and swamp</td>
<td>0.1</td>
</tr>
<tr>
<td>As defined by LCM2015</td>
<td></td>
</tr>
</tbody>
</table>

2.7 WFD Status for Surface and Groundwaters

The WFD status within the AoI provides indications of the pressures on surface and groundwaters and the potential for improvements in water quality, quantity and river morphology.

Table 2-5: WFD AoI Waterbody Status\(^1\)

<table>
<thead>
<tr>
<th>Waterbody</th>
<th>Ecological Classification</th>
<th>Chemical Classification</th>
<th>Hydrological Regime Classification (continuity of flow)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maun (from Rainworth water to Poulter)</td>
<td>Moderate</td>
<td>Good</td>
<td>Does not support good status</td>
</tr>
<tr>
<td>Maun (from source to Vicar water)</td>
<td>Moderate</td>
<td>Good</td>
<td>Does not support good status</td>
</tr>
<tr>
<td>Meden (from Sookholme Brook to Maun)</td>
<td>Moderate</td>
<td>Good</td>
<td>Does not support good status</td>
</tr>
<tr>
<td>Poulter (from source to Millwood Brook)</td>
<td>Moderate</td>
<td>Good</td>
<td>Supports Good status</td>
</tr>
<tr>
<td>Poulter (from Millwood Brook to Maun)</td>
<td>Poor</td>
<td>Good</td>
<td>Does not support good status</td>
</tr>
</tbody>
</table>

Chemical classification is ‘good’ in the five WFD river body catchments within the AoI. This was because WFD chemical indicators were either classified as ‘good’ or ‘high’, with the

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\(^1\) https://data.gov.uk/dataset/41cb73a1-91b7-4a36-80f4-b4c6e102651a/wfd-classification-status-cycle-2
exception of phosphate, which was classified as ‘moderate’ in the Poulter, and ‘poor’ in the Maun².

The Hydrological Regime classification is monitored because the WFD acknowledge the quantity and dynamics of flow required for the aquatic ecosystem to continue to thrive and achieve environmental objectives. The WFD monitors the hydrological regime to ensure the waterbody is providing sufficient flow to support this³.

2.8 Abstraction Licencing Strategy Status and Pressures

The East Midlands-Yorkshire Permo-Triassic Sandstone forms a regionally important aquifer which is used for public water supply to many cities such as Doncaster, Lincoln, York and Nottingham. The aquifer also supports baseflow to the River Trent and its tributaries.

Resource availability at Q95 has been identified as unavailable for licencing. This is because recent actual flows are below the Environmental Flow Indicator.

In the Idle and Torne abstraction licencing strategy report it was highlighted that water resources are available less than 30% of the time at the catchment Assessment Points.

2.9 Other Sensitivities

Sensitive sites in the catchment can highlight areas where interventions may not be appropriate and also indicate areas where groundwater may be particularly sensitive or close to the surface. The figure included below includes a number of environmentally sensitive or potentially environmentally influencing areas.

There are five Sites of Special Scientific Interest in the AoI – Birklands and Bilhaugh, Birklands West and Ollerton Corner, Thoresby Lake, Clumber Park and Wellbeck Lake. From these, Thoresby Lake and Clumber Park are groundwater dependent terrestrial ecosystems, potentially indicating areas of groundwater discharge and where groundwater levels are close to the surface.

Birklands and Bilhaugh Special Area of Conservation site is located north of Edwinstowe. The site is dominated by broad-leaved deciduous old woodland and dead-wood habitat, a remnant of the historic Sherwood Forest.

There are 17 historic landfill sites which are clustered in the south west corner of the AoI around Market Worksop and Mansfield. There is one authorised landfill site within the most southwestern limits of the AoI.

As identified in the land cover review, a number of disused collieries are present within the AoI in the vicinity of Meden Vale and Edwinstowe (Thoresby Colliery). Impacts of coal mining beneath the Sherwood Sandstone has resulted in induced subsidence of this aquifer. However, whilst the majority of mining stopped in 2000 and it is believed that associated deformation stopped in 2005, the Thoresby Colliery previously identified closed more recently in 2015. The hydraulic conductivity of the Sherwood Sandstone has thought to have potentially increased due to subsidence of the underlying coal mining (of the Coal Measures).

There are 9 Zone 1 Source Protection Zones (SPZs), 5 Zone II SPZs and a single Zone III SPZ which intersect the AoI. Whilst the mining is at considerable depth, observations during the site visit suggested that subsidence is locally a very significant issue, resulting in new

2 https://data.gov.uk/dataset/41cb73a1-91b7-4a36-80f4-b4c6e102651a/wfd-classification-status-cycle-2

lakes (subsidence flashes); and cracking of the ground surface, especially after heavy rainfall. Impacts on some buildings have also be significant.

Figure 2-17: Sensitivities existing within Idle and Torne AoI
3 Site Visit

A site visit was undertaken by JBA with the Environment Agency and other parties on 4 February. A number of locations were visited including: Sherwood Forest (RSBP); Thoresby Estate farmland; and Clumber Park. Staff at these locations were very helpful with discussions. A number of discussions included the requirement on landowners to manage their land for key features, such as: productive agriculture; or ancient trees; or historic park land; or housing development. These land management requirements had both some synergy and opportunities and some potential conflicts with managing the same land for groundwater resources.

The table below outlines general themes from the discussion during the day.

Table 3-1: Site Visit Discussion Themes

<table>
<thead>
<tr>
<th>Catchment Features</th>
<th>Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Management</td>
<td>Water is a scarce resource in the AoI. Farmers use both borehole supplies, surface water abstraction and winter reservoirs to provide irrigation. In a dry year, they need all their abstraction licence quantities. Winter reservoirs are filled by pumping during higher flows in the winter. There might be scope for increased use of winter storage reservoirs, but for farmer uptake a high level of subsidy (e.g. 50%) might be needed. Winter reservoirs have the potential to make use of high flows water during winter months when water is available. There is also flooding in the catchment. The combination of flooding and water shortage suggest the potential for slowing down runoff and enhancing recharge.</td>
</tr>
<tr>
<td>Sherwood Forest</td>
<td>Sherwood Forest is an ancient woodland, with very limited runoff. Management has to balance managing woodland for key ancient tree features (see Figure 3-1) and also for more general environmental benefits. In terms of recharge, they have undertaken a study (Cranfield, 2019 - see literature review) on what benefits groundwater recharge and are aiming for wood pasture with around 30% tree cover (Figure 3-3). The older trees in the forest (oldest ~ 1000 years old) may in some locations have started growing when groundwater levels were higher before development of the underlying Sherwood Sandstone aquifer over 100 years ago. Higher levels of trees take more water, while more open wood pasture allows more groundwater recharge.</td>
</tr>
<tr>
<td>Mining subsidence</td>
<td>The AoI has been undermined for coal. This has resulted in subsidence, which has cracked the sandstone aquifer and resulted in fracturing at the surface. Cracks may emerge in fields, especially in wet weather. Subsidence has affected surface waters, with subsidence flashes appearing. These include a subsidence flash (or new lake) in Thoresby Estate, Perlethorpe (Figure 3-6). Groundwater levels have been rising (by approximately the subsidence amount) as a result of subsidence in historic coal mining areas. The increased fracturing of the aquifer provides a rapid recharge route from the surface – for both recharge and pollution.</td>
</tr>
<tr>
<td>Water Meadows</td>
<td>There has been some investigation of reinstating water meadows in the AoI. Local stakeholders informed that flooded meadows are situated along the River Meden where overbank flow from the river spills into these meadows and there is a large area on the floodplain available for water to be stored and infiltrated. Opportunities for interventions at old Welbeck water meadow system where a drain is located. Historically water meadows were very significant in the area. Water</td>
</tr>
</tbody>
</table>
meadows potentially have the following benefits:
- Water quality – reducing phosphorus and suspended sediment from rivers during high flow;
- Habitat – wet grassland and wading birds
- Production - sustainable grassland management
- Historic – living history
- Water resources – infiltration & aquifer recharge at high-flow and increase in aquifer storage.

There may be benefits of reduction in pathogens following flooding of fields4.

| Intensive Farming | Discussions regarding farming highlighted that the requirements of intensive farming can be in conflict with management of the soils for groundwater recharge. The following points were discussed:
- Contour working the fields increases recharge and reduces sediment runoff. However, it is difficult with large modern machinery on sloping fields – machines tip towards the lower wheel and crops such as potatoes end up at the lower side of the harvester. There may be the potential for machinery development to allow safe, effective working across slopes.
- Large machines are heavy and contribute to compaction of soil. However, large machines are needed to harvest crops (e.g. sugar beet) quickly as required by purchasers. Large machines with wide tyres to spread the load, but have the potential effect of compacting soils over a wider area, rather than just two ‘tramlines’. This results in wider or whole field compaction rather than tramlines. Farmers can use sub-soiling (running a deep tool through the soil) to break through compacted layers.
- Field size: large machines are easier to work in large fields. Smaller fields, especially with frequent hedges/tree lines/runoff barriers down slope are more effective at reducing runoff.
- Intensive farming is highly managed with crop rotation, pesticides and times of bare earth to reduce pest problems. The practices of cover cropping may not easily fit into this system without some adaptation. Cover crops which remain in the soil may not be easy to combine with harvesting methods for root vegetables which involve sieving the soil. However, benefits of cover crops for reducing runoff, reducing sediment generation and adding organic matter to the soil were recognised. |

| Land conversion | Discussions at Clumber Park included the Revitalise Project where the aim is to plant trees (copper, beech, chestnuts and pine) to create a mosaic of heathland and smaller areas of woodland plantations at the park (Figure 3-7). 2000 trees, 33km fencing and 5km of water pipes have been implemented as part of the £10 million project to achieve the reversion from arable land to wood pasture. The long-term plan at the park is to return the area to heathland, however the Forestry Commission are licensed for some parts of the park until 2100 which means areas of... |

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commercial and conifer forestry will probably remain up to this date. A larger area of open wood pasture and heathland will allow more groundwater recharge.

| Sustainable Drainage Systems (SUDs) | New housing developments were being constructed along the A614 near Thoresby. Generally housing development may reduce groundwater recharge, due to increased drainage. The conversion to impermeable land provides a potential for SUDs to be implemented to infiltrate: particularly clean water from rooftop runoff. However, concerns regarding the potential degradation of water quality if road runoff were to leak into the aquifer as groundwater were discussed. |
| Incised River Channels | The potential for raising incised river channels was discussed. Some areas of floodplain have already been connected to rivers. But there may be limitations where fields adjacent to rivers are farmed intensively. |

*Figure 3-1: Ancient tree at Sherwood forest (>1000 years old).*
Figure 3-2: Heather acid grassland within the RSPB reserve at Sherwood Forest.

Figure 3-3: Felling at Sherwood Forest for wood pasture conversion.
Figure 3-4: Rapid runoff, erosion and ponding near to Sherwood Forest (photos © Izi Banton RSPB)

The generation of rapid runoff during Storm Ciara in early 2020 near to Sherwood Forest is illustrated above. Some areas showed ponding. Runoff was concentrated down paths and low areas. It is particularly interesting that there is very limited runoff from the actual ancient woodland but adjacent arable fields (likely to originally have similar soils, geology etc.) have significant runoff. This highlights the importance of land management in the generation of runoff and the partition of rainfall between infiltration and runoff. Also illustrated is the importance of vegetation including permanent vegetation or winter cover crops in prevention of erosion. Ponding of water prior to infiltration has the potential to temporarily render areas inaccessible, see following photo.
Figure 3-5: Flooding Storm Ciara 2020 in Sherwood Forest Visitor Area (photo © Izi Banton RSPB)

Figure 3-6: Flooded grassland caused by subsidence at Thoresby Estate.
Figure 3-7: Tree planting and fencing at Clumber Park to create a mosaic of heathland and woodland.
4 Conceptual Model and Recharge Concepts

The conceptual model of the area is shown in Figure 4-1 and its location illustrated in Figure 4-2. A version incorporating how WWNP interventions could be incorporated into the landscape is shown in Figure 4-3.

The AoI lies in the mid catchment of the Idle and Torne and is characterised by small valleys in sandstone bedrock with permeable soils and limited permeable superficial deposits. There is a very strong baseflow signature in the surface waters indicative of: the high rainfall infiltration rates to the Sherwood Sandstone; the contribution of baseflow from the upstream Magnesian Limestone Cadeby Formation; and potentially the upward vertical leakage from the confined Cadeby Formation. Much of the area has been undermined and has subsided. This has resulted in lowering of the land surface relative to groundwater levels (which have risen relative to the ground) with some subsidence flashes (new lakes) appearing and cracking of the bedrock.

Much of the interfluve areas are wooded, with arable land concentrated on the valley sides. Valley bottoms are typically narrow. There is already likely to be considerable recharge from rainfall: as indicated by the high BFI HOST values present. Most significant opportunities for increasing recharge in this mid catchment area are likely to be drainage interventions to increase infiltration from surface water runoff. This would have the effect of decreasing the effective standard percentage runoff (SPR) from significant rainfall events.

There are numerous ‘dry’ valleys which could be blocked or partially blocked to enhance infiltration recharge during extreme or significant rainfall events.

There is also some scope for increasing rainfall recharge through land management. The wooded areas could potentially be managed to allow less continuous woodland, less coniferous wood compared to deciduous woodland and drainage which prioritises infiltration. The arable land could be manged for soil conservation and infiltration with measures to increase drainage pathways. Currently intensive agriculture is highly demanding of water at key stages to grow produce of the required quality. However, less intensive agriculture could have a lower water demand and less irrigation requirements.

The valley bottoms are fairly limited in extent. However, depending upon the interaction of local topography with the more regional Sherwood Sandstone groundwater table there may be potential for leakage to the sandstone from valley bottom reservoirs/lakes/ponds.
Figure 4-1: Idle and Torne AoI Conceptual Model
Figure 4-2: Conceptual Model Cross Section Relative to Superficial Geology
4.1 Existing Groundwater Models

The existing East Midlands and Yorkshire Groundwater Model covers all the AoI within the East Midlands part of this model.
5 Identifying potential WWNP and groundwater recharge areas

5.1 Estimating Recharge Potential

An assessment of the soil permeability and superficial and bedrock aquifer recharge potential has been undertaken across the AoI. This has taken into account the overlying soil drainage, superficial cover and thickness as well as both superficial and bedrock permeability and aquifer designation. More detailed information on the generation of these datasets is available within the full project report.

As previously discussed, the dominant soils across the AoI are sandy and hence the significant majority of the AoI is classified with a very high soil permeability (Figure 5-1). The exceptions to this are areas of low soil permeability within the narrow river valleys which exhibit naturally wet soil drainage.

There is very little superficial geology across the AoI, confined mostly to the river valleys as alluvium and river terrace deposits forming Secondary A designated aquifers. As shown in Figure 5-2, these have been classified with high recharge potential based on their permeability and aquifer designation. Patches of till outside these valleys form Secondary B designated aquifers although are attributed with greater thickness and hence also retain a high recharge potential. The reduction to medium superficial recharge potential in the east of the AoI can be attributed to the reduced baseflow contribution at this point in the catchment. There are no unproductive superficial aquifers designated within the AoI.

The entire AoI has been classified with a high bedrock recharge potential (Figure 5-3) due to its status as a Principal aquifer, high permeability and lack of significant superficial cover or thickness which may otherwise inhibit recharge to the bedrock.

Figure 5-1: Wider Recharge Area – Soil Permeability Class
Figure 5-2: Wider Recharge Area – Superficial Recharge Potential

Figure 5-3: Wider Recharge Area – Bedrock Recharge Potential
5.2 WWNP Potential Areas

A suite of WWNP potential areas have been delineated across the AoI based initially on the measures published in the Environment Agency’s WWNP Evidence Directory and further expanded upon based on conceptual and local understanding. The methodology outlining their production is specified within the main project report. Table 5-1 summarises the broad WWNP interventions delineated with their description and potential application based on this AoI’s local context. The suite of WWNP potential areas have been supplied as GIS features and attributed with their soil permeability, superficial and bedrock aquifer recharge potential as illustrated within the previous wider recharge area figures.
Table 5-1: Application of Screened WWNP to AoI

<table>
<thead>
<tr>
<th>WWNP Data Layer</th>
<th>WWNP Description</th>
<th>WWNP Local Context</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runoff Attenuation Features (WWNP_RAF)</td>
<td>These include local measures to intercept or divert water onto the floodplain and are most beneficial where the soils are permeable and there is underlying aquifer.</td>
<td>- Approximately 50% of features are delineated on arable/grassland land cover over very highly permeable soils and aquifers. Features such as bunds, swales and hedgerow planting may slow flows on steep topography reducing surface runoff and associated flooding, soil erosion, water quality issues and enhance infiltration and recharge. - Approximately 30% of features are delineated within woodland. Features such as large woody debris and leaky barriers sourced locally may slow flows, reduce soil erosion and promote further infiltration and recharge where ponded. However, within ancient woodland and highly permeable areas there may be limited actual runoff.</td>
</tr>
<tr>
<td>Mid/Upper-Catchment Storage (WWNP_CS)</td>
<td>These include more extensive areas than runoff attenuation features where storage and attenuation of hillslope flow pathways are most beneficial over permeable soils and underlying aquifers.</td>
<td>- Several significant surface water flow pathways situated on hillslopes above the Rivers Maun, Meden and Poulter. Features such as bunds, swales and leaky barriers may slow flows within these ephemeral pathways.</td>
</tr>
<tr>
<td>Mid/Upper-Catchment Riparian Zone (WWNP_RZ)</td>
<td>These include measures to intercept or attenuate minor watercourse corridors above the floodplain, particularly where the soils are permeable and there is underlying aquifer.</td>
<td>- A significant area of coverage is situated in the upstream reaches of the River Poulter where river restoration and floodplain reconnection may increase recharge into the superficial aquifer present.</td>
</tr>
<tr>
<td>Lower Catchment Floodplain Reconnection (WWNP_FROP)</td>
<td>These include measures to intercept or divert water onto the floodplain in areas deemed at a national-scale to have a lower watercourse connectivity and associated flood risk and are most beneficial where the soils are permeable and there is underlying aquifer. <strong>Elevated groundwater levels within the lower catchment may reduce recharge capabilities, check the attributed groundwater flood risk and seek expert advice where groundwater levels are predicted or historically known to reach close to the ground surface.</strong></td>
<td>- A significant area of features are situated beside both the Rivers Maun and Meden within the floodplain. Features such as flood meadows may slow flows, increase biodiversity and increase infiltration and recharge into both superficial and bedrock aquifers.</td>
</tr>
<tr>
<td>Lower Catchment Floodplain Zone (WWNP_FZ)</td>
<td>These include more extensive areas than floodplain reconnection measures within the wider floodplain and may be of seasonal benefit where sited over underlying aquifers. <strong>Elevated groundwater levels within the lower catchment may reduce recharge capabilities, check the attributed groundwater flood risk and seek expert advice where groundwater levels are predicted or historically known to reach close to the ground surface.</strong></td>
<td>- Features such as floodplain reconnection, river restoration and flood meadows may slow flows, increase biodiversity and increase infiltration and recharge into both superficial and bedrock aquifers.</td>
</tr>
<tr>
<td>Slowly Permeable Soils (WWNP_SPS)</td>
<td>These include areas of impeded soil permeability and superficial till cover.</td>
<td>- The few areas delineated are mostly situated over superficial till in the far east of the AoI near Elkesley. Features such as low density vegetation planting and buffer strips may slow flows permitting recharge to both superficial and bedrock aquifers.</td>
</tr>
</tbody>
</table>
| Arable & Grassland Land Cover Management (WWNP_LCM) | These include more extensive areas than slowly permeable soils defining areas of arable or grassland land cover. | - Improvement in arable land cover management such as planting cover crop, more conservative tillage such as less frequent ploughing (keeping this along contours where safe), increased sub-soiling and grass inter-crop seeding may reduce surface runoff; this may in-turn reduce associated soil erosion and water quality issues, permitting greater infiltration for potential recharge. Planting of crop types utilising lower water budgets may also reduce irrigation demand and abstraction and increase aquifer water resources.  
- Reductions in arable farming intensity, such as crop rotation, as well as carefully managed manure spreading, can improve soil organic matter and associated moisture content and drainage potential which may improve recharge.  
- Reductions in livestock density may also reduce soil compaction, reducing surface runoff and associated soil erosion and water quality issues, permitting greater infiltration and recharge. |
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<tr>
<td>Undefined</td>
<td>Areas not defined by WWNP datasets</td>
<td>- Significant areas of the AoI are managed woodland. On-going conversion of dense woodland into wood pasture and heathland may reduce water budget demand and promote greater volumes of water reaching the ground for recharge. Felled timber could be utilised locally for woody debris and leaky barrier features.</td>
</tr>
</tbody>
</table>
6 Recommendations

There is considerable scope for implementing Working with Natural Processes and groundwater within the Idle and Torne AoI and wider catchment as shown in the table above. There are already considerable initiatives being undertaken including:

- Arable reversion schemes to grassland, which generally has less runoff and more infiltration.
- Development/restoration of water meadows.
- Consideration of creating less dense forestry (wood pasture) rather than full broadleaf or conifer (most water demanding) woodland land use.

There is also scope for consideration and investigation of the following measures which are likely to be effective in the AoI and wider catchment:

- The existence of flooding within the AoI and wider catchment combined with pressures on groundwater resources means that there is scope for reducing the rate of runoff and increasing the rate of infiltration to have significant multiple benefits. All the measures suggested in the above table in the upper, middle and lower catchment areas and regarding runoff attenuation are relevant for this.
- Land management measures including soil conservation and improvement measures to decrease runoff and increase infiltration. In the Idle and Torne catchment this may include liaison and working with farmers regarding how to combine the requirements of intensive agriculture with improved soil management. Consideration of the net profitability of lower input farming (potentially with environmental incentive support e.g. Environmental Land Management Scheme (ELMS)), compared to intensive farming profitability should be investigated. There may be considerable scope for peer-to-peer farmer learning and workshops as many of the proposed land and soils management strategies are fairly new in this area (although similar measures are practiced in other parts of the country).
- Strategic consideration of crop water requirements. Some crops require more water, and water at critical times, than other less water sensitive crops.
- Research into how to undertake some soil management techniques on the types of farms in the AoI, for instance, the optimal machinery for managing sloping fields and intensive agriculture. Large heavy machinery is not highly suited to contour working sloping fields (risk of tipping over machinery, crops harvested all roll to the downslope side). But there is scope for machines to be designed to work optimally across a slope.
- In order to determine the potential impact of measures, interventions should be carefully designed and monitored (before and after). Numerical modelling of interventions may be required in order to estimate the actual change in groundwater recharge resulting from specific projects.
References
BGS 1966 Ollerton, Solid and Drift Geology map, Sheet 113.
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