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United Utilities

Water for the North West

United Utilities

North West Transfer Strategic Resource Option

Gate 2: Assessment of Options Involving Groundwater Abstractions

Wood Group UK Limited – August 2022

Report for

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1. Introduction

1.1 Overview

The United Utilities (UU) North West Transfer (NWT) Strategic Resource Option (SRO) is one of 17 solutions promoted by Ofwat in the PR19 Final Determination to identify new strategic water resources to meet projected supply deficits as a consequence of population growth and climate change. The NWT SRO is a combination of the United Utilities Sources (UUS) and Vyrnwy Aqueduct (UUVA) SROs, as presented at Gate 1. Both the UUS and UUVA SROs have progressed through Gate 1 (July 2021) of the Regulators' Alliance for Progressing Infrastructure Development's (RAPID) gated process and UU is now preparing its Gate 2 submission for a combined NWT SRO.

At Gate 1, feasible sub-options for the NWT SRO were identified by UU and were subject to overarching environmental assessments. UU is now working towards its Gate 2 submission, the purpose of which is to enable detailed feasibility, concept design and multi-solution decision-making, building on the work undertaken during Gate 1.

In order to inform the Gate 2 submission, sub-option-specific evidence-collection and assessments are being undertaken. These also take account of updated design information, and of regulator feedback (during Gate 1, including RAPID's Gate 1 decision, and during the preparation of the Gate 2 submission). An Evidence and Assessment Scoping Report was produced (Wood, 2022), to set out the scope of evidence collection and assessment required for each sub-option. This included:

- Informal scoping of the topics[1] that require specific evidence collection and assessment for the purposes of informing the overarching environmental assessments and UU's Gate 2 submission. All topics will receive appropriate consideration at future stages (for example, as part of any EIA), but with the focus at Gate 2 on effects that cannot be readily avoided and/or mitigated, and those which have the potential to influence the selection of the options ultimately taken forward as part of the scheme and/or affect the overall feasibility of the scheme.
- The informal scoping identified the following key topics for specific evidence collection and assessment: aquatic ecology; invasive non-native species (INNS); water quantity; water quality. For each option, a scope of work for each of those key topics was identified. This covered:
  - Evidence collection that should commence in Gate 2, but may continue beyond the Gate 2 submission date;
  - Assessment that should be undertaken to inform the Gate 2 submission;
  - Assessments that are likely to be required beyond the Gate 2 submission.

[1] Taking into account the topics listed in the Environmental Assessment of Plans and Programmes Regulations 2004 and The Town and Country Planning (Environmental Impact Assessment) Regulations 2017, as well as those topics adopted for the purposes of the SEA of UU's WRMP24

The purpose of this report is to present the evidence collection and assessment for the sub-options involving groundwater abstractions, to inform UU's Gate 2 submission. Based on the outcome of the assessments, it also includes recommendations for work required beyond Gate 2.

This report sits alongside report *Gate 2: Assessment of Options Involving Surface Water Abstractions* (Wood, 2022). The evidence and assessment from both reports is then used to inform the over-arching assessments including the Habitats Regulations Assessment (HRA), Water Framework Directive (WFD) assessment and the Integrated Environmental Assessment Report (IEAR).

1.2 Introduction to the North West Transfer Solution

The NWT SRO solution promotes cost-efficient source sub-options, selected to facilitate transfer volumes by the release of raw water directly from Lake Vyrnwy into River Vyrnwy or transferred through a new River Vyrnwy bypass pipeline into the River Severn as part of the Severn Thames Transfer (STT) SRO. The NWT SRO provides new sources to be brought online if water were to be transferred out of region by the STT, maintaining resilience for customers in the North West. The NWT SRO comprises two principal components:

- New sources to offset water transferred out of region from Lake Vyrnwy as part of the STT SRO; and
- Enabling works on the Vyrnwy Aqueduct to allow treated water from regional UU sources to be transferred by pumping into the Vyrnwy Aqueduct to maintain customer supplies (for transfer volumes greater than 50 Ml/d).

As of June 2022, a total of 14 sub-options are proposed for the NWT SRO (13 source options and one enabling works option). The source sub-options are geographically spread across UU's supply area and include groundwater and river abstractions.

This report presents sub-option-specific evidence and assessment, in relation to the sub-options of the NWT scheme that involve abstractions from groundwater. The eight relevant options are introduced in **Table 1.1**. Their location and setting are described in **Section 2**.

Table 1.1 NWT SRO Groundwater Options assessed in this report

Sub-Option ID	Sub-Option Name	Summary Description	Sub-Option Capacity (Ml/d)	New or existing Abstraction	Groundwater management unit	Groundwater Body
WR102b	[✂]	[✂]	17	Existing - increase within licence	Liverpool Speke and Halewood	Lower Mersey Basin and North Merseyside Permo-Triassic Sandstone Aquifers GB41201G101700
WR105a	[✂]	[✂]	4.5	Existing - increase within licence	South Warrington	
WR106b	[✂]	[✂]	8.45	Existing - increase within licence	South Warrington	
WR107a	[✂]	[✂]	10	New	Kirkby Ormskirk	
WR107b	[✂]	[✂]	12	Existing - increase within licence	Kirkby Ormskirk	
WR149	[✂]	[✂]	13	Existing - increase within licence	Warrington and West Glaze	
WR111	[✂]	[✂]	9	Variation on existing licence	Dean & Bollin	Manchester and East Cheshire Permo-Triassic Sandstone Aquifers GB41201G101100
WR113	[✂]	[✂]	3	Existing - increase within licence	Dean & Bollin	

1.3 Scope of assessment

Context

This report sets out the evidence and assessment relating to the potential impacts on the environment of the options involving abstractions from groundwater. These assessments are targeted towards understanding the feasibility of the options, as required for UU's Gate 2 submission to RAPID. Principally, this involves understanding the potential influence of the abstractions on Water Framework Directive classification elements, including the potential for impact on surface water features (including rivers and wetlands). These are key considerations for informing the overarching assessments, in particular the WFD assessment and the HRA. The assessment also identifies further evidence collection and assessment that will be required beyond the Gate 2 submission, to provide more targeted and detailed understanding.

Regional groundwater models already exist for the relevant area, but they are out of date and not suitable for use for immediate assessment of the sub-options. As a result, the approach taken in this report is to use the best currently-available information (including the model conceptualisation and development work undertaken by ESI (2004 and 2009), alongside other information sources) to present updated regional and local conceptual models, as relevant to each individual sub-option.

These are informed qualitative assessments, designed as an interim solution to inform the understanding of feasibility and risks as required for the Gate 2 submission. They will inform work beyond Gate 2, when updated data, groundwater and river flow modelling will test and refine the conceptual model and quantify the spatial and temporal variations in the water balance and abstraction impacts on receptors. It is anticipated that this work will include the update and use of two existing groundwater models that cover the area under investigation:

- Lower Mersey and North Merseyside Water Resources Study (ESI, 2009);
- Manchester and East Cheshire Water Resources Study (ESI, 2004).

The scope of assessment for this report is set out in more detail below.

Scope of assessment of groundwater options

The Gate 2 feasibility assessment for the groundwater abstraction sub-options focusses on improving the conceptualisation of the key environmental impacts regarding water quantity and water quality. For this stage of work the approach to the assessment has been framed around Water Framework Directive (WFD) groundwater classification quantitative status and risk tests screening (Environment Agency, 2019). as outlined in **Table 1.2**.

For each sub-option, a hydrogeological conceptual model has been developed from the available spatial datasets and from literature review, to identify the potential linkages between increased abstraction and likely impact on groundwater, dependent surface water bodies, Groundwater Dependent Terrestrial Ecosystems (GWDTE)s and risks of saline intrusion. This is targeted to understanding the risks associated with the individual options (with a comprehensive review of the regional conceptualisation to be undertaken as part of the groundwater model updates mentioned above).

Table 1.2 Approach to the Gate 2 assessment: WFD quantitative status and risk screening

Classification element	Relevance to the groundwater options
Dependent surface water body status	Increased groundwater abstraction can affect river flows, as a result of changes to groundwater levels and flows and resulting changes to groundwater-surface water connectivity. Updated groundwater models are not currently available, therefore spatial and temporal abstraction impacts on individual river water bodies have not been characterised in this report. Assessment of potential impact on surface water bodies is based on conceptualisation from available spatial data including current groundwater levels, geology, potential groundwater -surface water interaction (depth to groundwater), current WFD WB status and observations from the catchment walkovers.
Groundwater dependent terrestrial ecosystem test	Increased groundwater abstraction can affect wetland habitats that are wholly or partly dependent on groundwater supply, as a result of changes to groundwater levels and flows. In this report, assessment is based on conceptualisation of the potential hydrological connection and whether drawdown of the water table associated with groundwater abstraction could lead to lowered water levels within identified receptors.
Saline intrusion	Groundwater abstraction close to the coast can cause or contribute to saline intrusion into groundwater. In addition, some parts of the Permo-Triassic sandstone aquifer are vulnerable to saline intrusion caused by upwards movement (upconing) of saline water present at depth in the aquifer (Griffiths et al., 2003 and 2005). The Lower Mersey Basin and North Merseyside Permo-Triassic Sandstone Aquifers WFD assessment indicates that they are At Risk of saline intrusion. For this report, the reasons underlying the 'At Risk' status have been investigated and sources vulnerable to saline intrusion have been identified for further assessment.
Water balance	Increased groundwater abstraction alters the water balance of groundwater bodies and the discrete Groundwater Management Units (GWMUs) contained within them. For this report, the Environment Agency's water availability assessment summary is presented. The detail of these calculations has not been provided at GWMU scale and so no further quantification has been attempted for this report. The water availability assessment has been compared to the sub-option capacity and the utilisation profiles provided by UU. This presents an indication (based on the current availability calculations) of the capability of the GWMU to support the proposed abstraction quantities.
Chemical elements	While the physical impacts described above could, in theory, result in changes to groundwater quality, many such changes are likely to be small and/or to depend upon the specific details of the options when implemented. These aspects are not considered in any detail the Gate 2 stage. The saline intrusion (chemical) test and the components of the chemical trends assessment are exceptions in this regard and are considered in the Gate 2 assessment in conjunction with the quantitative elements of the saline intrusion test.

1.4 Structure of this report

Within this report,

- **Section 2** discusses the baseline hydrogeological setting and regional conceptualisation of the groundwater resources and receptors within the area;

- **Section 3** provides the findings of the Gate 2 assessment for each sub-option, and presents recommendations for the sub-option (if appropriate) and for future evidence collection and assessment; and
- Conclusions and recommendations for work beyond Gate 2 are given in **Section 4**. This includes a summary of all surface water bodies and wetlands that should be subject to further evidence collection and/or assessment.

2. Regional conceptualisation

2.1 Topography, land use and water courses

The NWT SRO groundwater sub-options are located in the Mersey and Merseyside area, between Liverpool and Manchester and to the south of Greater Manchester (**Figure 2.1**).

The area is relatively flat and low lying with ground levels predominantly below 40 mAOD (**Figure 2.2**). Topography varies from close to sea level along the Mersey Estuary and rises to around 150 mAOD at Tytherington in the east. Elevations increase to over 250 mAOD to the north and east of the area in the South Pennines and north Peak District. Surface water drains from the areas of higher elevation south and westwards towards the River Mersey.

Most of the groundwater sub-options are situated in urban or suburban catchments, particularly along the River Mersey and the Estuary Coast.

The river systems are shown on **Figure 2.2,** the dominant surface water feature is the River Mersey and its estuary with most of the watercourses in the area draining to the Mersey and its estuary:

- To the north of the Mersey channel, watercourses draining southwards to the Mersey and the estuary include (from west to east) the Glaze Brook, Sankey Brook, Ditton Brook.
- To the south of Manchester around the Tytherington and Woodford sources, the key rivers are the River Dean and Bollin, which join to form a tributary to the River Mersey flowing northwest to join the Mersey to the east of Lymm.
- The River Weaver, a northward flowing tributary to the Mersey, drains the area to the west and south of the Walton and Daresbury sources.

In the north Merseyside area the River Alt and Downholland Brook drain northwards into the Irish Sea.

There are a number of significant canals running through the area, including the Leeds and Liverpool Canal, Manchester Ship Canal, Bridgewater Canal, and the Macclesfield Canal. The Manchester Ship Canal is of particular hydrogeological significance as it cuts into the Permo-Triassic sandstone in places, so may be in direct contact with groundwater (Gebbett, 2003; Griffiths et al., 2003). Further investigation is required to confirm if this is the case for any other canals in the area.

2.2 Geology and hydrogeology

The regional British Geological Survey (BGS) 1:625k scale bedrock and superficial geology underlying the area under investigation is shown on **Figure 2.3** and **Figure 2.4** respectively.

The main bedrock aquifer in the area is the Sherwood Sandstone Group, classified by the Environment Agency as a Principal Aquifer. It is overlain and confined by the Mercia Mudstone Group which includes lower permeability mudstones and siltstones. In the Lower Mersey Basin the Mercia Mudstone group is present to the south of the River Mersey and extends southwards to the centre of the Cheshire Basin. In the north Merseyside Area, the Mercia Mudstone is present to the north west of Ormskirk (ESI, 2009). To the north and east the sandstones outcrop against the

faulted boundary of the older Carboniferous Coal Measures. A summary of the bedrock geology and aquifer properties in the area is given in **Table 2.1**. More detailed BGS 1:50k scale mapping is shown on the conceptual model figures in **Section 3**, including the extent of the confining Mercia Mudstone Group.

Table 2.1 Bedrock geology and aquifer properties

Age	Group	Formations	General lithological description	Aquifer designation and hydrogeological characteristics*
Triassic	**Mercia Mudstone Group**	*West of Manchester:* Sidmouth Mudstone Formation Tarporley Siltstone Formation *South of Manchester:* Bollin Mudstone Member Tarporley Siltstone Formation	Mudstones and siltstones interbedded with thin sandstone beds	Secondary B Aquifer Low permeability aquitard. With water bearing sandstone layers acting as perched aquifers
Triassic	**Sherwood Sandstone Group**	Helsby/ Ormskirk Sandstone Formation Wilmslow Sandstone Formation Chester Pebble Beds Formation Kinnerton Sandstone Formation	Well-sorted, fine to medium grained sandstones. Mudstone bands increase towards the top of the sequence. Pebbly horizons and carbonate cements. Layers and lenses of siltstone	Principal Aquifer Permeable, high storage layered aquifer. Locally heterogeneous and anisotropic
Permian	**Cumbrian Coast Group**	Manchester Marls Formation	Red marl with thin limestone and dolomite beds	Secondary B Aquifer Low permeability aquitard
	Appleby Group	Collyhurst Sandstone Formation	Red and orange fine to medium-grained sandstone	Principal Aquifer
Carboniferous	**Coal Measures Supergroup**	Pennine Middle Coal Measures Formation and South Wales Middle Coal Measures Formation	Mudstone, siltstone, sandstone, coal, ironstone and ferricrete	Secondary A Aquifer Variable
		Lower Coal Measures Formation and South Wales Lower Coal Measures Formation	Mudstone, siltstone, sandstone, coal, ironstone and ferricrete	Secondary A Aquifer Variable

* Environment Agency aquifer designation from https://magic.defra.gov.uk/ accessed 19/05/22

There is limited outcrop of the sandstone aquifer in the area due to extensive coverage by thick superficial deposits (**Figure 2.4**). These are dominated by Glacial Till which varies from a few

metres in thickness to over 50 m within glacial channels in the bedrock (ESI, 2009). A map of the thickness of the superficial deposits reproduced from ESI (2009) is presented in **Figure 2.5.**

Other superficial deposits include glaciofluvial deposits, river terrace gravels, alluvium, as well as man-made deposits due to extensive urbanisation and local peat deposits.

The superficial deposits are classed as Secondary A and Secondary (undifferentiated) aquifers by the Environment Agency. Perched water levels may occur in lenticular sand and gravel deposits within or above the Glacial Till. Elsewhere, where the superficial deposits are dominated by sand and gravel deposits directly overlying the Sherwood Sandstone, the two may be in hydraulic continuity (ESI 2004 and 2009). The superficial deposits are likely to have an important role in confining or semi-confining the Sherwood Sandstone, and controlling and limiting recharge to it (ESI, 2009). Geological cross sections for the area have been exported from the ESI reports and are displayed in **Figures 2.6a** and **2.6b**.

2.3 Abstractions and discharges

Figure 2.7 shows the NWT groundwater options, WFD Groundwater Bodies, their breakdown into the Environment Agency's Groundwater Management Units (GWMU)s, and Source Protection Zones (SPZs) defined by the Environment Agency to protect drinking water abstractions from pollution. The GWMUs that each of the groundwater options are located in are also referenced in **Table 1.1**.

It can be seen from **Figure 2.7** that much of the sandstone aquifer both at outcrop and subcrop is protected by merged SPZ3 total catchment zones. Minimum radius circles drawn for many of the SPZ2 outer protection zones (400 day travel time) suggest a confined aquifer conceptualisation for many of the abstractions. One Drinking Water Safeguard Zone (Groundwater) has been designated, to the south of the UU Kenyon and Croft Boreholes.

The locations of active consented discharges in the area are displayed on **Figure 2.10** and **Figure 2.11**. The majority of discharges are to surface water.

2.4 Groundwater levels, flow and groundwater-surface water interaction

Historical groundwater abstraction for public water supply and industry from the aquifer, in particular from the Lower Mersey Basin and Central Liverpool, caused water levels to drop to several tens of metres below sea level over the late 19th Century and 20th Centuries (ESI, 2009). Effective aquifer management on the part of the EA, UU and their predecessors, has caused rebound in groundwater levels in many regions, and therefore the slowly responding sandstone aquifer is likely to be still in non-equilibrium conditions.

The Environment Agency regional groundwater level contours for the Permo-Triassic sandstone aquifer are shown in **Figure 2.8**, for conditions in 2017. **Figure 2.9** illustrates the depth to the regional piezometric surface in the sandstone which has been calculated from these 2017 groundwater level contours and OS Terrain DTM data.

The groundwater contours show that groundwater levels in the sandstone mirror topography, generally flowing west and southwest from areas of higher ground to discharge along the coast and estuary. A groundwater mound is observed just to the east of Liverpool associated with the

higher topography and recharge to the sandstone outcrop here. Localised cones of depression are apparent in the piezometric surface associated with groundwater abstraction boreholes. Steps in the water table have been drawn coinciding with mapped faults along many of the GWMU boundaries, suggesting that these may act as a barrier to flow (ESI, 2004). Areas at or below 0 mAOD may be at risk of saline intrusion (in particular along the estuary coastline at Liverpool).

White and blue areas on **Figure 2.9** show where groundwater may be close to or above ground level, with upwards vertical head gradients through the superficial deposits, which may allow discharge of baseflow to watercourses, particularly to the Alt and Ditton Brook, but also in the lower reaches of the Rivers Bollin and Dean, depending on the nature of the superficial cover and hydraulic connection.

Reference to the Lower Mersey Basin Groundwater Modelling report (ESI, 2009), suggests that potential areas of groundwater/surface water interaction with sandstone groundwater exist in the top of the River Alt catchment, in the Ditton Brook and also in the top of the Sankey Brook. Potential for surface water interaction with shallow groundwater in the Superficial Deposits is more widespread, particularly in the Alt, Sankey Brook and Glaze Brook catchments.

As part of the Manchester and East Cheshire Water Resources Study (ESI, 2004), spot gauging surveys were completed by the Environment Agency for the River Bollin and the River Dean. These results suggest that both rivers were gaining baseflow at this time as they crossed the sandstone aquifer. The Lower Mersey Basin Groundwater Modelling report (ESI, 2009) also indicates potential for sandstone groundwater to interact with the bottom of the Weaver and Bollin catchments.

2.5 Risks of saline intrusion

The salinity of groundwater in the Permo-Triassic sandstone of East Manchester and Merseyside shows a wide variation and is influenced by a range of hydrogeological processes (Griffiths et al., 2003 and 2005). In areas adjacent to the Mersey Estuary and the Manchester Ship Canal, groundwater salinity may be increased by the intrusion of saline water from the estuary into the aquifer. This occurs where groundwater abstraction reduces groundwater heads in the onshore area below sea level, as observed by reversal of hydraulic gradients at the coast and therefore intrusion of saline water, around Warrington, Widnes and Liverpool in the 1900's (ESI, 2009).

Areas where groundwater levels are below sea level are shown on **Figure 2.9**. Where these areas border the coastline, such as at Liverpool Docks, intrusion of seawater is likely to be occurring (groundwater level contour drawn at -10 mAOD here). This process is dynamic, responding to the balance of recharge and abstraction from the aquifer (Griffiths et al., 2005).

Elevated salinity may also be observed in groundwater further inland. The mechanisms generating elevated salinity inland are principally the upwards movement (upconing) of saline water from depth in the aquifer and dissolution of evaporite minerals from within the Mercia Mudstone Group. Both processes are interrelated and the geochemistry that results from mixing between fresh water, modern sea water and older palaeowaters or formation waters is often complex (Griffiths et al., 2005). In addition, local geological factors such as the thickness of superficial cover over the aquifer and presence of faults, may also influence the presence/depth of saline water in the aquifer (Tellam, 1996).

The EA's most recent (2019) assessment of the Lower Mersey Basin and North Merseyside Permo-Triassic Sandstone and Manchester and East Cheshire Permo-Triassic Sandstone groundwater

bodies (GB41201G101700 and GB41201G101100) indicates poor quantitative and chemical status as a result of saline intrusion. However, Reasons for Not Achieving Good Status (RNAGS) for both water bodies indicate a natural source for the salinity, which in the case of the Lower Mersey Basin, may be technically unfeasible to address. Both water bodies are assessed as being At Risk of deterioration due to saline intrusion.

2.6 Groundwater resource availability

The Environment Agency's current assessment of groundwater resource availability across the area under investigation was not provided for this Gate 2 assessment at the GWMU scale. The Environment Agency published abstraction licencing strategies for the Lower Mersey and Alt, and for the Upper Mersey, were last updated in 2013 (Environment Agency 2013a and 2013b). These provide an assessment of the water available by groundwater management unit, summarised in **Table 2.2**.

Updated screening work has been undertaken recently in March 2022 by the Environment Agency to evaluate the groundwater sub-options based on groundwater resource availability at that scale, which they have provided. This is discussed for each sub-option in **Section 3**.

Table 2.2 Environment Agency assessment of groundwater management unit resource availability*

GWMU	Licence restriction*	Reason for restriction*	Amount available (Ml/d)*	EA updated screening comments (March 2022)**
Liverpool Speke	Restricted Water Available	Saline Intrusion	34.5	Recent actual surplus
Halewood	Restricted Water Available	Over licensed on water balance & Saline Intrusion	0	
South Warrington	Restricted Water Available	Over licensed on water balance & Saline Intrusion	0	>2.9 Ml/d would over-abstract GWMU
Kirkby Ormskirk	Restricted Water Available	Over licensed on water balance	0	GWMU overlicensed but recent actual surplus
Warrington	Restricted Water Available	Over licensed on water balance & Saline Intrusion	0	>4 Ml/d would over-abstract GWMU
West Glaze	Water Not Available	Over abstracted on water balance	-28.7	
Dean & Bollin	Restricted Water Available	Over licensed on water balance	0	GWMU overlicensed but recent actual surplus

*Data from Environment Agency (2013a) and (2013b)
**From Environment Agency water availability summary by sub-option, provided to UU in March 2022

The majority of the GWMUs in the study area were assessed in 2013 as 'Restricted Water Available'. Here, more groundwater abstraction is licensed than the amount available, but recent actual

abstractions are lower than the amount available, and/or there are known local impacts likely to cause saline intrusion, but with management options in place.

An assessment of 'Water Not Available' was made in 2013 for the West Glaze GWMU, such that more groundwater is being abstracted in the long term, based on recent actual rates, than the amount available. The recent Environment Agency March 2022 screening of the sub-option in this area - WR149 Lightshaw - which includes boreholes in both the Warrington and West Glaze GWMUs, comments that '>4 Ml/d would over-abstract GWMU'. Further detail is not given as to how this is calculated across the two GWMUs (see **Section 3** for further discussion on a sub-option scale).

The Environment Agency has provided an updated assessment of groundwater resource availability calculations at the WFD Groundwater Body scale for this Gate 2 assessment. These data indicate that Fully Licensed abstraction exceeds the available resource, but that some water may be available under Recent Actual conditions. However, these numbers are not directly relatable to the March 2022 GWMU screening assessment received previously, hence the provenance of both calculations needs to be clarified. The Groundwater Body scale resource availability assessment and the distribution of abstractions, and associated impacts, in relation to the SRO sub-option locations needs to be considered in more detail and together with saline intrusion risks (**Section 2.5**), using regional groundwater and river flow models.

As per the WFD groundwater balance test methodology (Environment Agency, 2019 WFD Groundwater Balance Test – see **Section 1.2** and **Table 1.2**), any proposed increases in abstraction must maintain Good WFD status in the groundwater body (such that the available groundwater resource exceeds the recent actual long term average abstraction).

Recommendations for future groundwater and river flow modelling to test and quantify the available groundwater resource, and the spatial and temporal variations in the water balance, are outlined in **Section 4**.

2.7 WFD river water body classification

The current (2019) ecological status of WFD River Water Body Catchments in the area under investigation is displayed in **Figure 2.10** and the classification of the hydrological regime (river flows and morphological condition) in each WFD Water Body Catchment is shown in **Figure 2.11**.

The majority of WFD River Water Body Catchments are classed as Moderate ecological status, with some assessed as Poor or Bad status. All WFD River Water Body Catchments are classed as Supports Good or High hydromorphological status. These Environment Agency classification data suggest that failure to achieve good ecological status is thus primarily related to factors other than the hydrological regime - such as chemical failures. Further details of the status of WFD River Water Body Catchments around the groundwater options are given in **Section 3**.

It is important to recognise that most of the river water bodies potentially impacted by the sandstone groundwater abstraction options are also subject to flow influences associated with many other surface water abstractions and discharges. Many of the water bodies are designated as heavily modified and a few (River Dean) are associated with headwater reservoir operation. This surface water dominated context explains why the pressures associated with recent actual groundwater abstraction are not causing current environmental flow low non-compliance failures, as assessed at the outflow points of the river water bodies.

However, the focus for assessing the potential role which these sources could play as sub-options to provide additional peak resources during dry periods is to consider the flow deterioration risks associated with increasing abstraction beyond current rates. There will also need to be more local scrutiny of the impacts of peak pumping on local river reaches and tributaries within the river water bodies – upstream of the outflow points on the main channels where impacts may be offset by sewage treatment works discharges in these urbanised catchments.

The Environment Agency's National Framework analysis of water resources pressures into the future has also highlighted the potentially significant reductions in low flows which may be associated with climate change which are particularly marked in Wales and down the western half of England Environment Agency, 2020). By considering the need to raise the level of "environmental ambition", emphasising the requirement to meet river flow targets, and projecting how resources may be further squeezed by the climate and population growth into the future, the Environment Agency has challenged the water companies to set out a long term "environmental destination" which increases the intensity of the spotlight on these sub- Options. Out of the list of groundwater sub-options currently under consideration, the Environment Agency has indicated to UU that there may be a need to consider some reductions in Fully Licensed annual limits at Lymm, Croft, Landside, Lightshaw, Kenyon, Woodford and Tytherington.

The general hydrogeological context of the groundwater sub-options – a high storage slowly responding sandstone aquifer which typically has limited direct connectivity with the surface – offers good prospects for being able to realise short term increases in pumping without significant low flow impacts. However, use of updated regional groundwater models which also need to incorporate a fully routed simulation of total river flows will clearly be essential to demonstrate the acceptability of these options with respect to local impacts in the context of the Agency's future environmental ambition challenge.

2.8 Designated nature conservation sites

Designated sites potentially at risk from drawdown due to increased groundwater abstraction include wetland habitats that are wholly or partly dependent on groundwater supply. In addition, there is potential for sites dependent on river flows to be impacted, if they rely on watercourses that could be affected by changes to surface-groundwater interactions as a result of increased groundwater abstraction.

Nationally and internationally designated sites including Special Conservation Areas (SACs), Special Protection Areas (SPAs), RAMSAR sites, Sites of Special Scientific Interest (SSSI) and National Nature Reserves (NNRs) have been considered. Those identified by the Environment Agency as potentially being GWDTEs due to the presence of relevant wetland vegetation communities are shown in **Figure 2.12**. Individual sites are discussed in **Section 3** with respect to the risk posed by each option.

3. Assessment of Environmental Risks Associated with NWT SRO Groundwater Options

This section presents assessments for each option individually, drawing on the conceptual information set out in **Section 2**. The assessments focus on interpreting the conceptual understanding in the context of risks to WFD compliance and is presented in the following sub-sections. Supporting detailed conceptual figures of the area surrounding the groundwater options show, with annotations:

- BGS 1:50k scale mapped bedrock and superficial geology, and faults;
- Rivers;
- Environment Agency GWMUs;
- Environment Agency regional groundwater level contours in the Sherwood Sandstone aquifer for 2017;
- Source Protection Zones;
- WFD surface water body hydromorphological classification;
- Designated sites.

A summary table is given in **Section 4**.

3.1 WR102b: [✂]

The hydrogeological conceptualisation of the area surrounding the boreholes at [✂], groundwater option WR102B, is shown on **Figure 3.1**. [✂] is in the Liverpool Speke GWMU and [✂] sources are in the Halewood GWMU. The two GWMUs are separated by a northwest to southeast trending fault, the Croxteth Fault. The bedrock geology in this area is made up of the layered Sherwood Sandstone Group, with extensive faulting resulting in these layers being offset. To the north-east of the sources, the Pennine Lower Coal Measures subcrops against a faulted boundary, marking the extent of the Sherwood Sandstone aquifer (as shown on **Figure 2.3**).

ESI (2009) reported that the southern part of the Croxteth Fault, and an associated sub-parallel fault zone, in the vicinity of the UU sources acts as a barrier to flow within the aquifer. Superficial deposits in this area are dominated by Glacial Till, which is low permeability and semi-confines the aquifer where it is present. However, there are some windows in the superficial deposits, including approximately 1 km to the west of Belle Vale, meaning that there is direct recharge into the sandstone aquifer. Regional groundwater flow direction in the sandstone aquifer is south towards the River Mersey. ESI (2009) report that the rest water level (RWL) in [✂] is artesian when not pumping. The unused [✂] is artesian and RWL in the [✂] is close to ground level.

The ESI (2009) report indicates that the upper reaches of the Ditton Brook flow across the sandstone and superficial deposits and may receive some baseflow when water levels are high. To the south, the lower reaches of the Ditton Brook are underlain by thick superficial deposits and appear disconnected from the groundwater system.

WFD dependent surface water body screening

[✂] are located in the Netherley Brook WFD river water body and [✂] in the Ditton Brook (Halewood to Mersey Estuary) WFD river water body. The Netherley Brook is a tributary of the Ditton Brook, the Dog Clog Brook joins the Netherley Brook from the east just above its confluence with the Ditton Brook. The Prescot Brook joins the Dog Clog Brook from the north upstream of the Ditton Brook. Below the confluence with the Netherley Brook, the Ditton Brook flows southeast to the Mersey near Widnes. All water bodies, except the Prescot Brook, are classed as heavily modified. The current WFD status of these water bodies is summarised in **Table 3.1**.

In order to assess the hydrological regime the Environment Agency WRGIS assigns impacts from groundwater abstractions to water bodies. In the data provided:

- 5% of abstraction impacts from [✂] are assigned to the Ditton Brook (Halewood to Mersey Estuary) water body; and
- The remaining 95% of abstraction impacts from [✂] and 100% of the impacts from [✂] are assigned to the downstream Mersey transitional water body.

No notes are provided by the Environment Agency with the WRGIS data but this distribution of impacts is likely to reflect the complexity of the hydrogeology due to the faulting, the small nature of the water courses in the immediate vicinity of the abstractions, plus the large thickness of Glacial Till deposits overlying the sandstone aquifer. These will limit local abstraction impacts on surface water bodies such that the abstraction impact is almost entirely felt downstream on the discharge of groundwater at the coast to the Mersey Estuary.

The WRGIS 'IMPFAC' for these sources is 1, such that there is no reduction in abstraction impacts conceptualised at times of low flow (i.e. no accounting for how drawing on groundwater storage may reduce impacts on surface water bodies at these times).

Table 3.1 WFD dependent surface water body screening: Groundwater Option WR102b*

Water body	Ecological status	Biological quality	Physico-chemical quality	Hydro-morph. regime	Chemical status	RNAG
Netherley Brook Water Body ID GB112069060680	Moderate	Bad	Moderate	Supports Good	Fail (Mercury, PDBE)	Diffuse source pollution (urban and transport), point sewage discharge (water industry), Physical modification via land drainage and urbanisation (Invertebrates)
Ditton Brook (Halewood to Mersey Estuary) Water Body ID GB112069061390	Moderate	Bad	Moderate	Supports Good	Fail (Mercury, PFOS, PDBE, Cypermethrin)	Diffuse source pollution (urban and transport, agriculture and rural land management), point source (sewage discharge – water industry), Physical modification (flood protection, urbanisation - invertebrates)
Mersey Water Body Water Body ID GB531206908100	Moderate	Moderate	Moderate	Supports Good	Fail (Benzo(g-h-i)perylene, Heptachlor and cis-Heptachlor epoxide, Mercury, PBDE, Dichlorvos)	Diffuse source pollution (contaminated land and contaminated water body bed sediments - industry, water industry)
Prescot Brook (Logwood Mill Brook) Water Body ID GB112069060710	Poor	Poor	Moderate	Supports Good	Fail (Mercury, PBDE, Cypermethrin)	Diffuse source pollution (urbanisation, contaminated land, abandoned mine, poor livestock management, point source pollution (misconnections, private sewage treatment), physical modification (urbanisation, flood protection structures)
Dog Clog Brook (including Mill Brook) Water Body ID GB112069060690	Moderate	Moderate	Moderate	Supports Good	Fail (Mercury, PFOS, PBDE, Cypermethrin)	Diffuse source pollution (poor soil and nutrient management, abandoned mine), point source pollution (private sewage treatment)

* Based on Catchment Data Explorer data from https://environment.data.gov.uk/catchment-planning/ accessed 20/05/2022. 2019 classification. RNAG Reasons for Not Achieving Good; PDBE Polybrominated diphenyl ethers; PFOS Perfluorooctane sulphonate.

As stated above, regional groundwater levels indicate that there is the potential for Ditton Brook, as well as the lower reaches of its tributaries the Prescot Brook and Dog Clog Brook, to gain baseflow as well as runoff and interflow as these watercourses pass over the sandstone subcrop, where upward hydraulic gradients are mapped. However, the predominantly low permeability glacial till superficial cover, and its thickness and nature will limit the hydraulic connection between the sandstone and river in all but the upper reaches of the Ditton Brook.

Linkages between abstraction and groundwater dependent terrestrial ecosystems

SSSIs and GWDTE's close to option WR102B are listed in **Table 3.2,** and shown on **Figure 2.12** and **Figure 3.1**.

There is only one designated site flagged for further investigation within [✂] This is the **Mersey Estuary SSSI/SPA/Ramsar**, which is located approximately 5.5 km to the southwest. This SSSI is not classed as a GWDTE, although may receive groundwater discharging at freshwater seepages, emerging from/through the superficial deposits, and may be indirectly influenced via changes to freshwater flows entering the estuary. While it is not expected that this environment is particularly sensitive to the sandstone groundwater in terms of direct interactions, a change in the overall amount of freshwater entering the Mersey Estuary may require further consideration. This is further discussed in **Section 2.11 of Appendix B** and is assessed in the **Habitats Regulations Assessment (HRA)**.

Table 3.2 SSSIs and GWDTEs within 10 km of option WR102b

Site Name	Description*	Distance to source (km)	Sub-Option Sources	Potential hydrological connection for further assessment
Mersey Estuary SSSI/SPA/Ramsar	Intertidal sand and mudflats. Internationally important site for wildfowl	5	[✂]	Y?
New Ferry SSSI	Intertidal sand and mudflats interspersed with shingle and cobbles. Supports national important populations of birds	9	[✂]	N – located on the other side of the estuary on the Wirral peninsula

*Data from https://designatedsites.naturalengland.org.uk/ Accessed 20/05/2022.

Risks of saline intrusion

The Liverpool Speke and Halewood GWMUs where these abstractions are located have restricted water availability and one of the reasons for this is risk of saline intrusion (Environment Agency, 2013a). These groundwater management units border the Mersey Estuary and there is connection between the aquifer and the estuary in this area (Griffiths et al., 2005). Saline intrusion from the estuary is a risk if the groundwater balance for these GWMUs changes.

The boreholes identified in option WR102b are located [✂] meaning that they are unlikely to be directly affected by intrusion of water from the estuary. However, abstraction in these areas could affect the groundwater balance that controls saline intrusion in parts of the GWMUs closer to the coast.

Groundwater levels at the [✂] boreholes are understood from UU to flow artesian when the boreholes are not pumped (data from WR102b PBD, June 2022). Pumping data for the [✂] borehole indicates that water level drawdown may be large when pumped. Both these factors suggest that there is a potential risk to water quality at these boreholes linked to upwards movement (upconing) of saline water from depth. There has been no recent monitoring of groundwater quality at these boreholes.

Groundwater Balance

Table 3.3 gives details of current and potential fully licensed abstraction rates for this groundwater option, together with proposals for future abstraction rates.

The proposals here are to increase abstraction within the current licensed quantity. The option has a maximum capacity of 17.0 Ml/d, however the anticipated utilisation of option WR102b, as provided from UU's water resource modelling (**shown in Appendix A**), shows that in an average year, the rate of abstraction would peak in summer at 15.7 Ml/d, with a minimum of approximately 4.3 Ml/d in winter. For the '1 in 500 year drought' scenario, the option may be utilised at its maximum capacity for a number of months through the spring, summer and early autumn.

The Environment Agency assessment of groundwater resource availability has indicated that this may exceed the groundwater resource available within the groundwater management units, particularly at Greensbridge Lane (Liverpool Speke and Halewood GWMUs located within the Lower Mersey Basin and North Merseyside Permo-Triassic Sandstone groundwater body). Proposals will be further evaluated beyond Gate 2 as part of the planned updates to the Lower Mersey & North Merseyside groundwater model.

Table 3.3 Current and proposed abstraction: Groundwater Option WR102b

Source	Licence	Recent Actual abstraction (Ml/d)*	Fully Licensed abstraction (Ml/d)*	Proposed option capacity (Ml/d)*	Proposed Ml/d available unconstrained **	Comment**
[✂]	2569028013	0.0	4.3	17.0 (total)	8.2	Comment from Env. Agency: 8.2 Ml/d = 5.5 (lic. rate from Belle Vale) + 2.7 (available within surplus for Greensbridge). Stockswell dropped
[✂]	2569028014	0.0	4.1			
[✂]	2569028012	0.0	11.31			

* From UU data provided 21/06/2022. Fully Licensed abstraction is the annual licence quantity expressed as Ml/d equivalent.
**From Environment Agency water availability summary, provided to UU in March 2022

3.2 WR105a [✂]

The hydrogeological conceptualisation of the area around the [✂] Boreholes, groundwater option WR105A, is shown on **Figure 3.2**. The [✂] boreholes are in the South Warrington GWMU. The bedrock geology in this area is made up of the layered Sherwood Sandstone Group, which is overlain to the east and south of the Lymm source by the Mercia Mudstone Group which confines

the sandstone. Superficial deposits in this area are dominated by Glacial Till and glaciofluvial deposits, which are low permeability and semi-confine the aquifer where they are present. Other superficial deposits present in the area include alluvium along the Bollin and Tidal Flat Deposits around the River Mersey. These deposits are thick, following a buried channel between Warrington and Speke. The Lymm Boreholes [✂] of the Till to the [✂] of the River Mersey. Glaciofluvial deposits are present in the Mersey channel to the north and the Shirdley Hill Sand formation, these deposits are expected to be in hydraulic continuity with the aquifer. ESI (2009) indicates potential for groundwater-surface water interaction with the superficial and Sandstone aquifers in this area. Regional groundwater flow direction is west towards the River Mersey with relatively shallow levels to the north of Lymm.

The two Lymm Boreholes [✂]. ESI (2009) note that to the west of the Lymm Boreholes, the Bridgewater Canal cuts in to the Helsby Sandstone and some leakage to/from the canal is possible. There is also known connection between the sandstone and the Manchester Ship Canal for approximately 8 Km as it passes south of Warrington which provides a strong control on local groundwater heads (ESI, 2009).

WFD dependent surface water body screening

The Lymm Boreholes are not located in a WFD river water body, but lie in the catchment of the Bradley/Sow Brook, which flows north to the Manchester Ship Canal. The adjacent and upgradient Bollin (Ashley Mill to Manchester Ship Canal) WFD river water body to the east is drained by the River Bollin, which flows into the River Mersey to the north of the Bridgewater Canal.

Environment Agency WRGIS data assign abstraction impacts from the Lymm Boreholes entirely to water body GB212069061522; a coast marginal catchment within which there are no WFD designated rivers and no formal outflow points, and downstream of which is the estuary. This water body is not found in the Environment Agency's Catchment Data Explorer. No notes are provided by the Environment Agency with the WRGIS data but this type of impact distribution is thought to reflect the partially to fully confined nature of the aquifer in this area, with a large thickness of low permeability Glacial Till at Lymm and to the north, as well as the presence of the Mercia Mudstone to the east over much of the Bollin surface water body. This limits local abstraction impacts on surface water bodies, such that the abstraction impact is not felt until further downstream where the aquifer discharges at the coast.

The WRGIS 'IMPFAC' for these abstractions is 1, indicating that there is no reduction in conceptualised abstraction impacts at times of low flow (i.e. no accounting for how drawing on groundwater storage may reduce impacts on surface water bodies at these times).

Regional groundwater level contours, which follow topography here, suggest that the sandstone aquifer in this catchment discharges groundwater northwest to the Mersey (and potentially to the Manchester Ship Canal and Bridgwater Canal, depending on the nature and thickness of the superficial cover). There is not expected to be significant regional groundwater flow southwards into the confined zone where the Mercia Mudstone Group (Tarporley Siltstone Formation and Bollin Mudstone Member) overlies and confines the sandstone.

Linkages between abstraction and groundwater dependent terrestrial ecosystems

SSSIs and GWDTE's close to option WR105A are listed in **Table 3.4** and shown on **Figure 2.12** and **Figure 3.2**. Those marked for further investigation include:

- The **Woolston Eyes SSSI**, which supports a variety of wetland habitats. The connection of water levels in the lagoons with the river and with underlying groundwater may be limited by low permeability silt and will be different for each of the individual water bodies. Regionally, the Sherwood Sandstone discharges groundwater to the River Mersey and the estuary here, so there is potential for some degree of hydraulic connection with groundwater as well as surface water, which could affect the site to some extent. This is further explained in **Section 2.4 of Appendix B**. Further information is required regarding local water levels at the site and observation borehole data before this site can be scoped out for further assessment.
- **Risley Moss SSSI**: The confined sandstone piezometric surface lies within the overlying superficial deposits and may be above the base of the peat deposits, resulting in an upward head gradient. Regional groundwater levels are also known to be recovering, so that upward head gradients may be greater now than in 2017. Therefore, there is some potential for the Risley Moss to be supported by lateral interflow from the superficial cover in continuity with the sandstone aquifer. This is further discussed in **Section 2.5 of Appendix B**. Further information is required regarding local water levels at the site and observation borehole data before this site can be scoped out for further assessment.
- The **Rixton Clay Pits SSSI / SAC** is located in a disused quarry on superficial deposits overlying the Bollin Mudstone Member of the Mercia Mudstone and not therefore directly connected to the Sherwood Sandstone aquifer. However, Environment Agency regional sandstone groundwater contours here are at the same elevation as topography at the site (see **Figure 3.2**), indicating that there can be artesian upwards head gradients in the sandstone. Groundwater in the Sherwood Sandstone aquifer has the potential to be in continuity with overlying superficial deposits and therefore may indirectly support water levels at the site to some extent. This is further explained in **Section 2.3 of Appendix B**.
- **Rostherne Mere SSSI** formed from subsidence because of the dissolution of underlying salt deposits in the Sidmouth Mudstone Formation. Although the site is expected to be hydraulically isolated by the very low permeability mudstone, recent assessments conducted for HS2 have indicated that the hydrogeology of this area is complex[2] and so Rostherne Mere has not been scoped out at this stage. This is further explained in **Section 2.9 of Appendix B**. Further information is required regarding local water levels at the site and observation borehole data before this site can be scoped out for further assessment.

[2] Pers. comm. Jane Wilson/ Paul Thomas, Natural England, 20/7/22

Table 3.4 SSSIs and GWDTEs within 10 km of option WR105a

Site Name	Description*	Distance to source (km)	Sub-Option Sources	Potential hydrological connection for further assessment
Woolston Eyes SSSI	Operational raised large lagoons, open water and mud, used for depositing dredgings from the Manchester Ship Canal. Wetland habitat important for breeding birds	2	Lymm	Y- More data needed before site can be screened out.
Rixton Clay Pits SSSI and SAC	Disused quarry in Glacial Till (boulder clay deposits). Mosaic of water-filled hollows and clay banks which now support a diversity of habitats	3	Lymm	Y- This will be further investigated
Risley Moss SSSI	Raised bog system, open water and peatland. Developed in natural depression in the glacial deposits. Water levels have been raised to regenerate an active mire surface	5	Lymm	Y- Unlikely but this will be further investigated. More data needed before site can be screened out.
Rostherne Mere SSSI	Open water and peatland site developed in a deep hollow in the glacial superficial cover. Formed by subsidence as a result of the dissolution of underlying salt deposits in the Sidmouth Mudstone Formation.	6	Lymm	Y – complex hydrogeology due to subsidence. Further data needed to draw conclusions
Dunham Park SSSI	Ancient pasture-woodland or park-woodland with a number of species of trees	5.5	Lymm	N – situated on a small isolated faulted block of Sherwood Sandstone and not connected to the main aquifer
The Mere, Mere SSSI	Open water and peatland site including two lakes developed in natural depressions in the glacial superficial cover overlying the Sidmouth Mudstone Formation.	7	Lymm	N – disconnected from the sandstone aquifer
Tatton Meres SSSI	Open water and peatland site developed in natural depressions in the glacial superficial deposits overlying the Sidmouth Mudstone Formation. Consists of two meres and includes fen, flushed acidic grassland and woodland.	9	Lymm	N – disconnected from the sandstone aquifer

*Data from https://designatedsites.naturalengland.org.uk/ Accessed 25/05/2022.

Risks of saline intrusion

The South Warrington GWMU where the Lymm Boreholes are located has restricted water availability due to risk of saline intrusion (Environment Agency, 2013a). In the case of this source, the risk is likely to be linked to upwards movement (upconing) of saline water from depth rather

than intrusion from the Mersey Estuary. No specific information has been made available for these boreholes for this assessment.

Groundwater Balance

Table 3.5 gives details of current and potential fully licensed abstraction rates for this groundwater option, together with proposals for future abstraction rates.

The proposals here are to increase abstraction to the current licensed quantity of **9 Ml/d.** The current operating capacity of the boreholes is 4.5 Ml/d (due to WTW constraints), resulting in an option capacity of 4.5 Ml/d. This option is not currently included in the Preferred Portfolio as part of UU's water resource modelling. UU has advised that, if this option were to be used, its utilisation profile would be similar to that for option WR113, which is shown in **Appendix A**. When applied to option WR105a, in an average year the rate of abstraction would peak in summer at 6.9 Ml/d, with a minimum of approximately 1.4 Ml/d in winter. For the '1 in 500 year drought' scenario, the option may be utilised at its maximum capacity for a number of months through the spring, summer and early autumn.

The Environment Agency assessment of groundwater resource availability has indicated that this may exceed the groundwater resource available within the groundwater management unit (South Warrington GWMU located within the Lower Mersey Basin and North Merseyside Permo-Triassic Sandstone Aquifers groundwater body). Proposals will be further evaluated beyond Gate 2 as part of the planned updates to the Lower Mersey & North Merseyside groundwater model.

The [✂] Boreholes have been flagged by the Environment Agency as 'at risk' from environmental destination. Further investigation is required as to the nature and potential of implication of this risk.

Table 3.5 Current and proposed abstraction: Groundwater Option WR105a

Source	Licence	Recent Actual abstraction (Ml/d)*	Fully Licensed abstraction (Ml/d)*	Proposed quantity (Ml/d)*	Proposed Ml/d available unconstrained**	Comment**
[✂]	2569021011	4.5	9.1	9.1	2.9	>2.9 Ml/d would over-abstract GWMU, but licence exists for 9 Ml/d

* From UU data provided 21/06/2022. Fully Licensed abstraction is the annual licence quantity expressed as Ml/d equivalent.
**From Environment Agency water availability summary, provided to UU in March 2022.

3.3 WR106b: [✂]

The hydrogeological conceptualisation of the area around the boreholes at [✂], groundwater option WR106b, is shown on **Figure 3.3**. The [✂] boreholes are in the South Warrington GWMU. The bedrock geology in this area is made up of the layered Sherwood Sandstone Group and is overlain to the south by the Mercia Mudstone Group. There are several northwest to southeast trending faults along this boundary which are indicated by ESI (2009) as having a significant impact on groundwater flow. Superficial deposits are thick to the north of this area, due to the presence

of a buried valley beneath the Mersey between Warrington and Speke. This is predominantly made up of Glacial Till deposits, which are generally low permeability and are overlain by Tidal Flat Deposits around the River Mersey. However, to the north of Daresbury and to the east of Walton there are small windows in this superficial cover, meaning there is direct recharge into the sandstone aquifer. Additionally, the Shirdley Hill Sand formation is mapped to the north of the sources, these deposits are expected to be in hydraulic continuity with the aquifer. ESI (2009) indicates potential for groundwater-surface water interaction with the Superficial and Sandstone aquifers in this area. Regional groundwater flow in the sandstone is towards the north/north-west towards the Mersey.

[✂]. ESI (2009) note that in this area the Bridgewater Canal cuts in to the Helsby Sandstone and some leakage to/from the canal is possible. There is also known connection between the sandstone and the Manchester Ship Canal for approximately 8 Km as it passes south of Warrington which provides a strong control on local groundwater heads (ESI, 2009).

WFD dependent surface water body screening

The two boreholes at [✂] are located just to the [✂] of the Bridgewater Canal and are not in a WFD river surface water body. The borehole at [✂] is located within the Keckwick Brook WFD river water body. The Keckwick Brook flows northwards to the Manchester Ship Canal. It is also intersected by the Bridgewater Canal. The Keckwick Brook WFD river water body is classed as heavily modified. Its current WFD status is summarised in **Table 3.6.**

Environment Agency WRGIS data assign the abstraction impacts from the [✂] Boreholes entirely to water body GB212069061522; a coast marginal catchment within which there are no WFD designated rivers and no formal outflow points, and downstream of which is the estuary. No notes are provided by the Environment Agency with the WRGIS data but such an impact distribution is thought to reflect the complexity of the faulted geology the small nature of the water courses within the water body and the large thickness of superficial deposits in the area around the Mersey Channel, which could limit local abstraction impacts on surface water bodies.

The WRGIS 'IMPFAC' for these abstractions is 1, indicating that there is no reduction in abstraction impacts conceptualised at times of low flow (i.e. no accounting for how drawing on groundwater storage may reduce impacts on surface water bodies at these times).

Table 3.6 WFD dependent surface water body screening: Groundwater Option WR106b*

WFD Surface Water body	Ecological status	Biological quality	Physico-chemical quality	Hydro-morph. regime	Chemical substances status	RNAG
Keckwick Brook Water Body ID GB112068060520	Moderate	Bad	Moderate	Supports Good	Fail (Mercury, PDBE)	Diffuse source (urban, agriculture, rural) Physical modification leading to barriers (urban and transport)

* Based on Catchment Data Explorer data from https://environment.data.gov.uk/catchment-planning/ accessed 20/05/2022. 2019 classification. RNAG Reasons for Not Achieving Good; PDBE Polybrominated diphenyl ethers; PFOS Perfluorooctane sulphonate.

Similarly to the setting of [✂] Boreholes, regional groundwater level contours suggest that the sandstone outcrop and subcrop in this catchment discharges groundwater north/northwest to the Mersey Estuary (and potentially to the Manchester Ship Canal and Bridgewater Canal), depending on the nature and thickness of the superficial cover. There is not expected to be significant groundwater flow southwards into the confined zone where the Mercia Mudstone Group (Tarporley Siltstone Formation and Bollin Mudstone Member) overlies the sandstone.

Linkages between abstraction and groundwater dependent terrestrial ecosystems

SSSIs and GWDTE's close to option WR106b are listed in **Table 3.7** and shown on **Figure 2.12** and **Figure 3.3**.

There is no hydrological connection to any designated sites south of the Walton and Daresbury abstractions because the Mercia Mudstone Group overlies and confines the Sherwood Sandstone Group at depth here, and therefore these are not listed in **Table 3.7**.

Those marked for further investigation include:

- The **Woolston Eyes SSSI** approximately 5km distant, which supports a variety of wetland habitats. The connection of water levels in the lagoons with the river and with underlying groundwater may be limited by low permeability silt and will be different for each of the individual water bodies. Regionally, the Sherwood Sandstone discharges groundwater to the River Mersey and the estuary here, so there is potential for some degree of hydraulic connection with groundwater as well as surface water, which could affect the site to some extent. This is further explained in **Section 2.4 of Appendix B**. However, it is thought unlikely that abstraction for this option will impact Woolston Eyes SSSI based on the distance from the abstraction and the WRGIS abstraction impact distribution. Further information is required regarding local water levels at the site and observation borehole data before this site can be scoped out for further assessment.
- The **Mersey Estuary SSSI/SPA/Ramsar**, approximately 5km distant, which may receive groundwater discharging at freshwater seepages, emerging from/through the superficial deposits. This is further discussed in **Section 2.11 of Appendix B**.

It is not expected that these environments are particularly sensitive to any increases in abstraction at Walton and Daresbury, although a change in the overall amount of freshwater entering the Mersey Estuary is recognised as a potential risk, and is assessed in the **Habitats Regulations Assessment (HRA)**.

Table 3.7 SSSIs and GWDTEs within 10 km of option WR106b

Site Name	Description*	Distance to source (km)	Sub-Option Sources	Potential hydrological connection for further assessment
Woolston Eyes SSSI	Operational large raised lagoons, open water and mud, used for depositing dredgings from the Manchester Ship Canal. Wetland habitat important for breeding birds	5	Walton	Y- Unlikely based on distance from abstraction and WRGIS abstraction impact distribution, more

Site Name	Description*	Distance to source (km)	Sub-Option Sources	Potential hydrological connection for further assessment
				data needed before option can be scoped out.
Mersey Estuary SSSI/SPA/Ramsar	Intertidal sand and mudflats. Internationally important site for wildfowl	5	Daresbury	Y – based on location downgradient, WRGIS abstraction impact distribution, potential for combined impact on freshwater discharge
Red Brow Cutting SSSI	Cutting of Tarporley Siltstone Formation. Notified for geological interest	1	Daresbury	N – Geological interest only

*Data from https://designatedsites.naturalengland.org.uk/ Accessed 25/05/2022.

Risks of saline intrusion

The South Warrington GWMUs where these abstractions are located has restricted water availability due to risk of saline intrusion (Environment Agency, 2013a). In the case of these boreholes, the risk is likely to be linked to upwards movement (upconing) of saline water from depth or dissolution of evaporite minerals due to proximity to the Mercia Mudstone Group outcrop rather than intrusion from the Mersey Estuary. UU's Deployable Output assessment for the [✂] borehole indicates that water quality does change with depth in this location, which is a constraint on pumping rates. The Drinking Water Safety Plan for [✂] also identifies saline intrusion as a risk. The EA's licence for this borehole requires quarterly quality monitoring, presumably linked to risk of rising salinity.

Groundwater Balance

Table 3.8 gives details of current and potential fully licensed abstraction rates for this groundwater option, together with proposals for future abstraction rates.

The proposals here are to increase borehole capacity to the maximum current daily licensed quantity to a total of **8.45 Ml/d**. This option is not currently included in the Preferred Portfolio as part of UU's water resource modelling. UU have advised that, if this option were to be used, its utilisation profile would be similar to that for option WR149, which is shown in **Appendix A**. When applied to option WR106b, in an average year this would result in the rate of abstraction peaking in summer at 6.7 Ml/d, with a minimum of approximately 1 Ml/d in winter. For the '1 in 500 year drought' scenario, the option may be utilised at its maximum capacity for a number of months through the spring, summer and early autumn.

The Environment Agency assessment of groundwater resource availability has indicated that this may exceed the groundwater resource available within the groundwater management unit (South Warrington GWMU located within the Lower Mersey Basin and North Merseyside Permo-Triassic Sandstone groundwater body). Proposals will be further evaluated beyond Gate 2 as part of the planned updates to the Lower Mersey & North Merseyside groundwater model.

Table 3.8 Current and proposed abstraction: Groundwater Option WR106b

Source	Licence	Recent Actual abstraction (Ml/d)*	Fully Licensed abstraction (Ml/d)*	Proposed quantity (Ml/d)*	Proposed Ml/d available unconstrained**	Comment**
[✂]	2568004008	0.0	3.4	8.45 (total)	2.9	>2.9 Ml/d would over-abstract GWMU, but licence exists for 8.4 Ml/d
[✂]	2568004016	0.0	3.4			

* From UU data provided 21/06/2022. Fully Licensed abstraction is the annual licence quantity expressed as Ml/d equivalent.
** From Environment Agency water availability summary, provided to UU in March 2022

3.4 WR107a: [✂]

The hydrogeological conceptualisation of the area around [✂] Boreholes, groundwater option WR107a, is shown on **Figure 3.4**. The [✂] boreholes are in the Kirkby Ormskirk GWMU. The bedrock geology in this area is made up of the layered Sherwood Sandstone Group, which is overlain to the north and west by the Singleton Mudstone Member of the Sidmouth Mudstone Formation (Mercia Mudstone Group) which confines the sandstone. To the east of the sources, the Pennine Lower Coal Measures subcrops against a faulted boundary, marking the extent of the Sherwood Sandstone aquifer (as shown on **Figure 2.3**). Superficial cover is relatively thick in this area, with most of the sandstone subcrop overlain by Glacial Till (which is mostly low permeability) and the Shirdley Hill Sand Formation. Where this is present, it is likely to be in hydraulic continuity with the Sherwood Sandstone Group aquifer. ESI (2009) indicates the potential for groundwater-surface water interaction with the sandstone to the north of this area and with the Superficial deposits in the areas where the Shirdley Sandstone is mapped around the UU sources. Regional groundwater flow in the sandstone is towards the coast.

WFD dependent surface water body screening

The boreholes at [✂] are located within the Downholland (Lydiate/Cheshires Lines) Brook WFD river water body, which is drained by the Downholland Brook and is classed as heavily modified. Its current WFD status is summarised in **Table 3.9**.

These abstractions will be regulated by new abstraction licences, and therefore there is as yet no Environment Agency WRGIS assignment of groundwater abstraction impacts to water bodies.

Table 3.9 WFD dependent surface water body screening: Groundwater Option WR107a*

WFD Surface Water body	Ecological status	Biological quality	Physico-chemical quality	Hydro-morphological regime	Chemical substances status	RNAG
Downholland (Lydiate/ Cheshires Lines) Brook Water Body ID	Moderate	Moderate	Moderate	Supports Good	Fail (Mercury, PFOS, PDBE)	Point source (sewage discharge), Physical modification (agricultural and land management)

* Based on Catchment Data Explorer data from https://environment.data.gov.uk/catchment-planning/ accessed 20/05/2022. 2019 classification. RNAG Reasons for Not Achieving Good; PDBE Polybrominated diphenyl ethers; PFOS Perfluorooctane sulphonate.

In this area, rivers issue radially from the higher ground to the Mersey Estuary to the south, and to the coast to the north and west.

Where it flows across the Sherwood Sandstone Group, over much of its length the Downholland Brook has the potential to be in hydraulic connection with the bedrock aquifer as the superficial cover here is dominated by the Shirdley Hill Sand Formation. Whilst regional groundwater levels indicate that the Downholland Brook is mainly perched above and disconnected from the main saturated aquifer, the layered nature of the Sherwood Sandstone Group means that there is the potential for the Brook to receive perched water from higher horizons, together with shallow interflow and runoff from the superficial Shirdley Hill Sand Formation and Till.

Regional groundwater levels indicate that there is the potential for the lower reaches of the Downholland Brook to gain baseflow from the sandstone aquifer, with shallow groundwater levels and upward hydraulic gradients, before it flows off onto the Mercia Mudstone Group.

Pumping in this area has resulted in two cones of depression in the piezometric surface with regional lowering of the water table in the north of the GWMU. Historically the Downholland Brook may have received more groundwater discharge from the sandstone in its lower reaches.

The Leeds and Liverpool Canal runs along the northern and western boundary of the GWMU; further review is required to investigate the potential for interaction of the canal with the groundwater environment in this area.

Linkages between abstraction and groundwater dependent terrestrial ecosystems

SSSIs and GWDTE's close to option WR107a are listed in **Table 3.10** and shown on **Figure 2.12** and **Figure 3.4**.

Of these, it is recommended that **Martin Mere, Burscough SSSI and SPA** is assessed further. Martin Mere is a low-lying wetland complex, which supports habitats of grassland and marsh as well as a number of migrant birds. The site is characterised by deep peat surrounded by the superficial Shirdley Hill Sand Formation, overlying the faulted contact of the Tarporley Siltstone Formation (Mercia Mudstone Group) and the Helsby Sandstone Formation at the edge of the sandstone block. It therefore may be supported by northward flowing groundwater issuing from the margin of sandstone and also runoff and lateral interflow from superficial deposits, although the extent of interaction between groundwater in the Permo-Triassic sandstone aquifer and groundwater in the superficial deposits is uncertain. This is further discussed in **Section 2.8 of Appendix B**. There is the potential for abstraction at [✂] boreholes to flatten the northwards regional hydraulic gradient and affect groundwater discharge to the site.

Table 3.10 SSSIs and GWDTEs within 10 km of option WR107a

Site Name	Description*	Distance to closest source (km)	Sub-Option Sources	Potential hydrological connection for further assessment
Martin Mere, Burscough SSSI and SPA	Wetland complex	8	[✂]	Y
Downholland Moss SSSI	Arable field and a small birch woodland (geological interest)	9	[✂]	N – geological interest only – sequence of changing tidal flat, lagoonal and perimarine palaeoenvironments
Mere Sands Wood SSSI	Planted oakwood of geological interest	10	[✂]	N – geological interest only (Shirdley Hill Sand)
Ravenhead Brickworks SSSI	Nationally important geological site for exposures of Late Carboniferous Westphalian succession	9	[✂]	N – geological interest only

*Data from https://designatedsites.naturalengland.org.uk/ Accessed 25/05/2022.

Risks of saline intrusion

The Kirkby Ormskirk groundwater management unit where these abstractions are located has restricted water availability but saline intrusion is not indicated as a risk factor in the EA's assessment (Environment Agency, 2013a). However, saline intrusion by upwards movement (upconing) of water from depth may still be a risk in this area. Factors controlling the risk will include the degree of aquifer confinement, the depth of the boreholes and drawdown associated with the required abstraction rate. This risk should be given further consideration once the updated groundwater balances and model is available.

Groundwater Balance

Table 3.11 gives details of current and potential fully licensed abstraction rates for this groundwater option, together with proposals for future abstraction rates.

The proposals here are to commission two existing unused boreholes to provide a total of **10 Ml/d**, keeping abstraction within the groundwater resource available within the groundwater management unit under current rates of abstraction (the Kirkby Ormskirk GWMU located within the Lower Mersey Basin and North Merseyside Permo-Triassic Sandstone groundwater body). This option would require a new abstraction licence.

The option has a maximum capacity of 10 Ml/d, however the anticipated utilisation of option WR107a, as provided from UU's water resource modelling (shown in **Appendix A**), shows that in an average year, the rate of abstraction would peak in summer at 4.9 Ml/d, with a minimum of

approximately 0.1 Ml/d in winter. For the '1 in 500 year drought' scenario, the option may be utilised at its maximum capacity for a number of months through the summer and early autumn.

Further evaluation of the water balance will be undertaken beyond Gate 2 as part of the planned updates to the Lower Mersey & North Merseyside groundwater model.

Table 3.11 Current and proposed abstraction: Groundwater Option WR107a

Source	Licence	Recent Actual abstraction (Ml/d)*	Fully Licensed abstraction (Ml/d)*	Proposed quantity (Ml/d)*	Proposed Ml/d available unconstrained**	Comment**
[✂]	N/A (new source)	0	0	10 (total)	10	GWMU over-licensed but 10 Ml/d available within recent actual surplus
[✂]	N/A (new source)	0	0			

* From UU data provided 21/06/2022. Fully Licensed abstraction is the annual licence quantity expressed as Ml/d equivalent.
** From Environment Agency water availability summary, provided to UU in March 2022.

3.5 WR107b: [✂]

The hydrogeological conceptualisation of the area around the boreholes that comprise groundwater option WR107b is shown on **Figure 3.5**. The Randles Bridge, Knowsley and Primrose Hill boreholes are in the Kirkby Ormskirk GWMU. The bedrock geology in this area is made up of the layered Sherwood Sandstone Group, which is overlain to the northwest by the Singleton Mudstone Member of the Sidmouth Mudstone Formation (Mercia Mudstone Group) which confines the sandstone. To the east of the sources, the Pennine Lower Coal Measures subcrops against a faulted boundary, marking the extent of the Sherwood Sandstone aquifer (as shown on **Figure 2.3**). Superficial cover is relatively thick in this area, with most if the sandstone subcrop overlain by Glacial Till (which is mostly low permeability) and the Shirdley Hill Sand Formation. Where this is present, it is likely to be in hydraulic continuity with the Sherwood Sandstone Group aquifer. Regional groundwater flow in the sandstone is towards the coast.

WFD dependent surface water body screening

The borehole at [✂] is located within the upper reaches of the Three Pool's Waterway WFD river water body catchment, which flows northwards to discharge to the outer reaches of the Ribble Estuary. The [✂] boreholes are all located in the Croxteth/Knowsley Brook WFD river water body. Croxteth/Knowsley Brook is a tributary of the Alt, which flows into the Alt Estuary south of Formby. Both water bodies are classified as heavily modified in their hydromorphology. The current WFD status of these water bodies is summarised in **Table 3.12**.

Environment Agency WRGIS data assign and distribute the abstraction impacts from these sources as follows:

- The impacts from the boreholes at [✂] are assigned to the Alt river water body;

- The impacts from the borehole at [✂] are assigned to AP4, Alt at Kirkby (the Alt US Bull Bridge water body); and
- The impacts from the boreholes at [✂] are assigned to the Mersey Mouth coastal water body.

No notes are provided by the Environment Agency with the WRGIS data but this type of abstraction impact distribution could indicate a large thickness of superficial deposits limiting local abstraction impacts on surface water bodies, such that the abstraction impact is felt further downstream.

The WRGIS 'IMPFAC' for these sources is 1, indicating that there is no reduction in abstraction impacts conceptualised at times of low flow (i.e. no accounting for how drawing on groundwater storage may reduce impacts on surface water bodies at these times).

Table 3.12 WFD dependent surface water body screening: Groundwater Option WR107b*

WFD Surface Water body	Ecological status	Biological quality	Physico-chemical quality	Hydro-morphological regime	Chemical substances status	RNAG
Three Pool's Waterway Water Body ID GB112070064830	Moderate	Poor	Moderate	Supports Good	Fail (Mercury, PFOS, PDBE)	Point source (sewage discharge – water industry), Diffuse source (agriculture and rural), physical modification
Croxteth/ Knowsley Brook Water Body ID GB112069060610	Moderate	Poor	Moderate	Supports Good	Fail (Mercury, PDBE)	Point source contamination and physical modification associated with urbanisation
Alt Water Body ID GB112069060580	Moderate	Poor	Moderate	Supports Good	Fail (Mercury, PFOS, PDBE, Tributyltin)	Point source contamination (sewage discharge – water industry, misconnections, physical modifications – urban and transport, agriculture and land management)
Alt US Bull Bridge Water Body ID GB112069061441	Moderate	Bad	Moderate	Supports Good	Fail (Mercury, PFOS, PDBE, Tributyltin, Cypermethrin)	Diffuse source (urban and transport, agriculture and rural land management), Point source (sewage discharge, water industry)

*Based on Catchment Data Explorer data from https://environment.data.gov.uk/catchment-planning/ Accessed 18/05/2022. 2019 classification. RNAG Reasons for Not Achieving Good; PDBE Polybrominated diphenyl ethers; PFOS Perfluorooctane sulphonate.

The boreholes within this option are located in the same area and hydrogeological setting as [✂] (**Section 3.4)**, spread across the GWMU. Regional groundwater flows west and north to discharge

at the coast and to the lower River Alt. Groundwater pumping in the area has resulted in two cones of depression in the piezometric surface, with regional lowering of the water table in the north of the GWMU near to [✂].

The watercourses in this area are all generally perched above the regional water table in the sandstone aquifer and therefore hydraulically disconnected, although will receive runoff and shallow lateral interflow from the superficial deposits (especially where the Shirdley Hill Sand Formation is found), depending on the nature and thickness of the superficial deposits.

As the Croxteth/Knowsley Brook flows past [✂] and joins the Alt, regional sandstone groundwater levels are close to or above ground level such that there is the potential for the Alt to gain groundwater baseflow from the aquifer, with upward hydraulic gradients. Here the sandstone is overlain by the superficial Shirdley Hill Sand Formation and may have a good hydraulic connection with the river. In its bottom reaches, where the Superficial Deposits are underlain by the Mercia Mudstone, the Alt is very low lying and highly engineered with an extensive pumped drainage system to protect farmland from flooding.

The Leeds and Liverpool Canal runs along the northern and western boundary of the GWMU; further review is required to investigate the potential for interaction of the canal with the groundwater environment in this area.

Linkages between abstraction and groundwater dependent terrestrial ecosystems

SSSIs and GWDTE's close to option WR107B are listed in **Table 3.13** and shown on **Figure 2.12** and **Figure 3.5.** Those marked for further investigation include:

- The closest GWDTE, SSSI and SPA is **Martin Mere, Burscough** which is 5 km north-east of [✂]. Martin Mere is a low-lying wetland complex, which supports habitats of grassland and marsh as well as a number of migrant birds. The site is characterised by deep peat surrounded by the superficial Shirdley Hill Sand Formation, overlying the faulted contact of the Tarporley Siltstone Formation (Mercia Mudstone Group) and the Helsby Sandstone Formation at the edge of the sandstone block. It therefore may be supported by northward flowing groundwater issuing from the margin of sandstone and also runoff and lateral interflow from superficial deposits, although the extent of interaction between groundwater in the Permo-Triassic sandstone aquifer and groundwater in the superficial deposits is uncertain. This is further discussed in **Section 2.8 of Appendix B**. There is the potential for abstraction at Primrose Hill borehole to flatten the northwards regional hydraulic gradient and affect groundwater discharge to the site.
- The intertidal mud, sandflats and dunes of the **Sefton Coast SSSI** are also designated as an NNR and SAC. This site receives groundwater discharging at freshwater seepages, emerging from/through the superficial deposits. This site has been scoped out for further investigation because previous work has established that there is a very low permeability clay and silt layer that acts as a no-flow boundary, isolating the dune systems from the underlying sandstone aquifer. This is further discussed in **Section 2.10 of Appendix B**.

Table 3.13 SSSIs and GWDTEs within 10 km of option WR107b sources

Site Name	Description*	Distance to closest source (km)	Sub-Option Sources	Potential hydrological connection for further assessment
Martin Mere, Burscough SSSI / SPA	Wetland complex	5	[✂]	Y
Downholland Moss SSSI	Arable field and a small birch woodland (geological interest)	6	[✂]	N – geological interest only – sequence of changing tidal flat, lagoonal and perimarine palaeoenvironments
Mere Sands Wood SSSI	Planted oakwood of geological interest	8	[✂]	N – geological interest only (Shirdley Hill Sand)
Sefton Coast SSSI	Intertidal mud, sandflats and dunes	8	[✂]	N - The dunes are thought to be hydraulically isolated from the bedrock aquifer.
Mersey Narrows SSSI	Estuary – open water, saltmarsh, grasslands, sand and mudflats	9.5	[✂]	N – located on the other side of the estuary on the Wirral peninsular
Mersey Narrows & North Wirral Foreshore SPA	Located at the mouths of the Mersey and Dee estuaries. Intertidal habitats, man-made lagoons and extensive intertidal flats	9	[✂]	N – located on the other side of the estuary on the Wirral peninsular
Stanley Bank Meadow SSSI	Damp unimproved neutral grassland	9.5	[✂]	N (disconnected, on Carboniferous strata)

*Data from https://designatedsites.naturalengland.org.uk/ Accessed 25/05/2022.

Risks of saline intrusion

The Kirkby Ormskirk groundwater management units where these abstractions are located has restricted water availability but saline intrusion is not indicated as a risk factor in the EA's assessment (Environment Agency, 2013a). However, saline intrusion by upwards movement (upconing) of water from depth may still be a risk in this area. Factors controlling the risk will include the degree of aquifer confinement, the depth of the boreholes and drawdown associated with the required abstraction rate. This risk should be given further consideration once the updated groundwater balances and model is available.

Groundwater Balance

Table 3.14 gives details of current and potential fully licensed abstraction rates for this groundwater option, together with proposals for future abstraction rates.

The proposals here are to increase abstraction to a maximum of **12 Ml/d**, but keeping abstraction within the licenced quantity and groundwater resource available within the groundwater management unit under current rates of abstraction (the Kirkby Ormskirk GWMU located within the Lower Mersey and North Merseyside groundwater body).

The option has a maximum capacity of 12 Ml/d, however the anticipated utilisation of option WR107b, as provided from UU's water resource modelling (shown in **Appendix A**), shows that in an average year, the rate of abstraction would peak in summer at 9.7 Ml/d, with a minimum of approximately 1.2 Ml/d in winter. For the '1 in 500 year drought' scenario, the option may be utilised at its maximum capacity for a number of months through the summer and early autumn.

Further evaluation of the water balance will be undertaken beyond Gate 2 as part of the planned updates to the Lower Mersey & North Merseyside groundwater model.

Table 3.14 Current and proposed abstraction: Groundwater Option WR107b

Source	Licence	Recent Actual abstraction (Ml/d)*	Fully Licensed abstraction (Ml/d)*	Proposed quantity (Ml/d*	Proposed Ml/d available unconstrained**	Comment*
[✂]	2569031024	0.0	7.96	12 (total)	12 (total)	GWMU over-licensed but 12 Ml/d available within recent actual surplus
[✂]	2569031016	0.0	5.68			
[✂]	2670101003	0.0	9.09			

* From UU data provided 21/06/2022. Fully Licensed abstraction is the annual licence quantity expressed as Ml/d equivalent.
** From Environment Agency water availability summary, provided to UU in March 2022.

3.6 WR149: [✂]

The hydrogeological conceptualisation of the area around the boreholes at [✂], groundwater option WR149, is shown on **Figure 3.6**. [✂] Borehole is included for completeness because it has been considered in the option identification, but UU have deemed that reinstating this abstraction is not feasible due to the high salinity of water here. All the boreholes are in the Warrington and West Glaze GWMU. The bedrock geology in this area is made up of the layered Sherwood Sandstone Group, with extensive faulting resulting in these layers being offset. It is likely that these faults may act as barriers to flow within the aquifer. To the north of the sources, the Pennine Lower Coal Measures subcrops against a faulted boundary, marking the extent of the Sherwood Sandstone aquifer. Superficial cover is dominated by Glacial Till and glaciofluvial deposits, which are thick and have low permeability, but there are some small gaps in this to the west of [✂] boreholes which allows direct recharge into the sandstone aquifer. Within this area, regional groundwater generally flows southwards towards the Mersey.

WFD dependent surface water body screening

The source at [✂] is located within the Hey/Borsdane Brook WFD surface water body, which is a tributary of the Glaze. The Glaze subsequently flows southwards to the Manchester Ship Canal. The [✂] sources are both located in the Spittle Brook WFD surface water body, which lies to the west of the Glaze catchment, and flows south to the River Mersey. [✂] Borehole is located in the Glaze WFD surface water body.

All three water bodies are classified as heavily modified in their hydromorphology. Their current WFD status is summarised in **Table 3.15.**

Environment Agency WRGIS data assign abstraction impacts from [✂] entirely to water body GB212069061522; a coast marginal catchment within which there are no WFD designated rivers and no formal outflow points, and downstream of which is the estuary. This waterbody cannot be found in the Environment Agency's Catchment Data Explorer. No notes are provided by the Environment Agency with the WRGIS data but this type of impact distribution is thought to reflect the geological complexity of the area and an interpretation that large thickness of low permeability Glacial Till superficial deposits which overlie the sandstone aquifer over most of this area, limiting local abstraction impacts on surface water bodies, such that the abstraction impact is not felt until much further downstream where the sandstone aquifer discharges at the coast.

The WRGIS 'IMPFAC' for these abstractions is 1, indicating that there is no reduction in abstraction impacts conceptualised at times of low flow (i.e. no accounting for how drawing on groundwater storage may reduce impacts on surface water bodies at these times).

Table 3.15 WFD dependent surface water body screening: Groundwater Option WR149*

WFD Surface Water body	Ecological status	Biological quality	Physico-chemical quality	Hydro-morphological regime	Chemical status	RNAG
Hey/Borsdane Brook Water Body ID GB112069064520	Moderate	Moderate	Moderate	Supports Good	Fail (Mercury, PDBE)	Diffuse source (abandoned mine, urbanisation) Point source (sewage discharge – water industry), Physical modification
Pennington Brook (Glaze) Water Body ID GB112069060760	Moderate	Poor	Moderate	Supports Good	Fail (Mercury, PFOS, PBDE, cypermethrin)	Diffuse source (urbanisation, sweater discharge). Physical modification (urbanisation, barriers, flood protection)
Glaze Water Body ID GB112069061420	Bad	Bad	Moderate	Supports Good	Fail (Mercury, PDBE, PFOS, Cypermethrin)	Diffuse source (urban and transport, agriculture and rural) Point source (sewage discharge – water industry

WFD Surface Water body	Ecological status	Biological quality	Physico-chemical quality	Hydro-morphological regime	Chemical status	RNAG
						Physical modification (barriers)
Spittle Brook Water Body ID GB112069061020	Moderate	Poor	Moderate	Supports Good	Fail (Mercury, PDBE)	Diffuse source (urban and transport, agriculture and rural) Physical modification (urban and transport)

* Based on Catchment Data Explorer data from https://environment.data.gov.uk/catchment-planning/ Accessed 18/05/2022. 2019 classification. RNAG Reasons for Not Achieving Good; PDBE Polybrominated diphenyl ethers; PFOS Perfluorooctane sulphonate.

Within this area, regional groundwater generally flows southwards towards the Mersey and may discharge baseflow to the lower reaches of the Spittle Brook and Glaze where regional groundwater levels are close to or above bed levels, depending on the local nature and thickness of the superficial deposits (a mixture of glaciofluvial deposits, till, peat and alluvium, with significant Made Ground). ESI (2009) suggest that interaction in the bottom of the Spittle Brook would be limited by the Superficial deposits.

In the upper reaches, watercourses are perched above and disconnected from regional sandstone water levels, receiving runoff and shallow interflow from the superficial deposits which is dominated by glaciofluvial deposits. Seepages from perched water in the layered sandstone may also locally support watercourses.

Linkages between abstraction and groundwater dependent terrestrial ecosystems

SSSIs and GWDTE's close to option WR149 are listed in **Table 3.16** and shown on **Figures 2.12** and **Figure 3.6.** The risk of drawdown impacts will depend on the spread of abstraction between the four sources. Those marked for further investigation include:

- The **Abram Flashes SSSI** is located 1.5km from the borehole at [✂]. Regional sandstone groundwater levels here are mapped as being well below topography with an existing cone of depression in the water table to the east. However, given the formation of the wetland within areas of subsided land due to mining, further site data should be sought to understand whether lowering of sandstone groundwater levels at [✂] could lead to an impact on water levels at the site. This is further explained in **Section 2.6 of Appendix B**. NE have noted that the site is largely connected with surface waters around the brook, but cannot be ruled out for groundwater dependence[3].
- At **Risley Moss, Holcroft Moss, and Astley & Bedford Mosses SSSIs** (which are all included in the Manchester Mosses SAC) the confined sandstone piezometric surface lies within the overlying superficial deposits and may be above the base of the peat deposits, with an upward head gradient. NE have noted that for the peat to stay wet

[3] Pers. comm. Jane Wilson/ Paul Thomas, Natural England, 20/7/22

at Astley and Bedford Mosses, the underlying sand and gravel needs to be kept saturated[4]. Regional groundwater levels are also known to be recovering, so that upward head gradients may be greater now than in 2017. Therefore, there is some potential for the sites to be supported by lateral interflow from the superficial cover in continuity with the sandstone aquifer. This is further discussed in **Section 2.5 of Appendix B**.

- It is unlikely that **Highfield Moss SSSI** is connected to the sandstone aquifer as regional groundwater levels here are well below ground level. However, due to the complex hydrogeology in this area as a result of historic shallow mine-working and the proximity of [✂] Borehole, local groundwater level monitoring data will be reviewed to confirm this. This is further discussed in **Section 2.7 of Appendix B**.
- **Woolston Eyes SSSI** along the Mersey supports a variety of wetland habitats. The connection of water levels in the lagoons with the river and with underlying groundwater may be limited by low permeability silt and will be different for each of the individual water bodies. Regionally, the Sherwood Sandstone discharges groundwater to the River Mersey and the estuary here, so there is potential for some degree of hydraulic connection with groundwater as well as surface water, which could affect the site to some extent. This is further explained in **Section 2.4 of Appendix B**.
- The **Rixton Clay Pits SSSI / SAC** is located on the Bollin Mudstone Member of the Mercia Mudstone and not therefore directly connected to the Sherwood Sandstone aquifer. However, Environment Agency regional sandstone groundwater contours here are at the same elevation as topography at the site (see **Figure 3.2**), indicating that there are artesian upwards head gradients in the sandstone. Groundwater in the Sherwood Sandstone aquifer has the potential to be in continuity with overlying superficial deposits and therefore may indirectly support water levels at the site to some extent. This is further explained in **Section 2.3 of Appendix B**.
- The **Bryn Marsh & Ince Moss SSSI** is located 4.5 km from the borehole at [✂] and is thought unlikely to be hydraulically connected to the sandstone aquifer. NE have noted that they believe the sites to be dependent on alluvial groundwater[5]. This is a fragment of the historically much larger area of Ince Moss. Although the Natural England citation references the development of this lowland raised mire over 'tills and late-glacial flood gravels overlying Triassic sandstones of the Sherwood Sandstones Group'[6], this remaining fragment of the Ince Moss lies on peat overlying Coal Measures based on BGS 1:50k mapping. Regionally, sandstone groundwater flow is southwards in this area with little flow expected northwards laterally into the Coal Measures (or overlying superficial deposits) and there is unlikely to be much interaction of groundwater and surface water in this area. However, given the formation of the wetland within areas of subsided land due to mining, the hydrogeology is complex and further site data should be sought to understand

[4] Pers. comm. Jane Wilson/ Paul Thomas, Natural England, 20/7/22

[5]

[6] https://designatedsites.naturalengland.org.uk/PDFsForWeb/Citation/1005647.pdf

whether lowering of sandstone groundwater levels at [✂] could lead to an impact on water levels at the site. This is further explained in **Section 2.6 of Appendix B**.

It is understood[7] that a number of these sites are to be incorporated into a new Wigan Flashes NNR. This includes the Abram Flashes SSSI, Ince Moss SSSI, Bryn Marsh SSSI and surrounding areas of local designation.

Table 3.16 SSSIs and GWDTEs within 10 km of option WR149

Site Name	Description*	Distance to closest source (km)	Sub-Option Sources	Potential hydrological connection for further assessment
Highfield Moss SSSI	Wet lowland heath and valley mire, underlain by peat and overlying Sherwood Sandstone. Peat vegetation and acidic marshy grassland	1.5	[✂]	Y- Unlikely but will be further investigated
Risley Moss SSSI/GWDTE (part of Manchester Mosses SAC)	Raised bog system, open water and peatland. Developed in natural depression in the glacial deposits. Water levels have been raised to regenerate an active mire surface	3	[✂]	Y- Further site data needed to draw conclusions
Holcroft Moss SSSI/GWDTE (part of Manchester Mosses SAC)	Peat bog occupying several small depressions in the Upper Terrace of the glacial deposits	4	[✂]	Y- Further site data needed to draw conclusions
Woolston Eyes SSSI	Operational large, raised lagoons, open water and mud, used for depositing dredgings from the Manchester Ship Canal. Wetland habitat important for breeding birds	6	[✂]	Y- Further site data needed to draw conclusions
Abram Flashes SSSI	Wetland underlain by tills and glacial flood gravels overlying Sandstone. Shallow open water-bodies formed through flooding of land subsided through mining	1.5	[✂]	Y- Further site data needed to draw conclusions
Astley & Bedford Mosses SSSI / GWDTE (part of Manchester Mosses SAC)	Lowland raised mire developed over tills and Late-glacial flood gravels overlying Triassic sandstones of the Sherwood Sandstones Group. Peat bog	5.5	[✂]	Y- Further site data needed to draw conclusions
Bryn Marsh & Ince Moss SSSI	Wetlands, part of the 'Wigan Flashes' which are the result of flooding of coal mining subsidences.	4.5	[✂]	Y- Unlikely but further site data needed to draw conclusions

[7] Pers. comm. Jane Wilson, Natural England, 19/5/22

Site Name	Description*	Distance to closest source (km)	Sub-Option Sources	Potential hydrological connection for further assessment
Rixton Clay Pits SSSI / SAC	Disused quarry in glacial boulder clay deposits. Mosaic of water-filled hollows and clay banks which now support a diversity of habitats	5.5	[✂]	Y- Unlikely but will be further investigated
Stanley Bank Meadow SSSI	Damp unimproved neutral grassland	8	[✂]	N- (disconnected, on Carboniferous strata)

*Data from https://designatedsites.naturalengland.org.uk/ Accessed 25/05/2022.

Risks of saline intrusion

The [✂] boreholes are located in the Warrington GWMU, which has restricted water availability according to the Environment Agency's abstraction licensing strategy (Environment Agency, 2013a). The [✂] boreholes are located in the West Glaze GWMU, which has no water available. One of the reasons for the restriction on water availability in the Warrington unit is known occurrence of saline intrusion (Environment Agency, 2013a). In the case of these boreholes, the risk is likely to be linked to upwards movement (upconing) of saline water from depth or transfer from Coal Measures & workings, adjacent to the east. This is identified as a specific risk in UU's Deployable Output assessment for the [✂] boreholes. Landside borehole was abandoned, due to the increased salinity, attributed to saline upwelling.

Groundwater Balance

Table 3.17 gives details of current and potential fully licensed abstraction rates for this groundwater option, together with proposals for future abstraction rates.

The proposals here are to increase abstraction within the current licensed quantity to a total of **13.0 Ml/d**. The option has a maximum capacity of 13.0 Ml/d, however the anticipated utilisation of option WR149, as provided from UU's water resource modelling (shown in **Appendix A**), shows that in an average year, the rate of abstraction would peak in summer at 10.8 Ml/d, with a minimum of approximately 1.6 Ml/d in winter. For the '1 in 500 year drought' scenario, the option may be utilised at its maximum capacity for a number of months through the spring, summer and early autumn.

The EA assessment of groundwater resource availability has indicated that this may exceed the groundwater resource available within the groundwater management units (Warrington and West Glaze GWMUs located within the Lower Mersey Basin and North Merseyside Permo-Triassic Sandstone groundwater body). Proposals will be further evaluated beyond Gate 2 as part of the planned updates to the Lower Mersey & North Merseyside groundwater model.

The [✂] boreholes have been flagged by the Environment Agency as 'at risk' from environmental destination. Further investigation is required as to the nature and potential of implication of this risk.

Table 3.17 Current and proposed abstraction: Groundwater Option WR149

Source	Licence	Recent Actual abstraction (Ml/d)*	Fully Licensed abstraction (Ml/d)*	Proposed quantity (Ml/d)*	Proposed Ml/d available unconstrained**	Comment**
[✂]	2569023003	0	6.84	13.0 (total, but 0 from Landside)	4	>4 Ml/d would over-abstract GWMU, but licence exists for 17.5Ml/d. Quality issues at Croft.
[✂]	2569016049	0	6.85			
[✂]	2569025043	0	3.81			
[✂]	2569023005	3.3	4.55			

* From UU data provided 21/06/2022. Fully Licensed abstraction is the annual licence quantity expressed as Ml/d equivalent.
** From EA water availability summary, provided to UU in March 2022.

3.7 WR111: [✂]

The hydrogeological conceptualisation of the area around [✂] Borehole, groundwater option WR111, is shown on **Figure 3.7**. The [✂] Borehole is in the Dean and Bollin GWMU. The bedrock geology in this area is made up of the layered Sherwood Sandstone Group, with extensive faulting resulting in these layers being offset. The borehole is located just to the [✂] of one of these north-south trending faults. To the east of the sources, the Pennine Lower Coal Measures subcrops against a faulted boundary, marking the extent of the Sherwood Sandstone aquifer and to the west the Bollin Mudstone Member (Mercia Mudstone Group) overlies the sandstone, confining the aquifer. Superficial deposits in this area are dominated by thick Glacial Till and glaciofluvial deposits, which are low permeability and semi-confine the aquifer. Regional groundwater flow in the sandstone aquifer is towards the north-west, towards the River Mersey and groundwater levels are relatively deep (between 50 and 100 mAOD).

WFD dependent surface water body screening

[✂] Borehole is located in the Dean (Bollington to Bollin) WFD surface water body, which is a tributary of the River Bollin. The Bollin subsequently flows northwest to the Manchester Ship Canal. The Dean water body is not classed as artificial or heavily modified. Its current WFD status is summarised in **Table 3.18**.

Environment Agency WRGIS data assign abstraction impacts from [✂] distributed locally between the Bollin (Source to Dean), Dean (Bollington to Bollin) and the much further downstream, Mersey (upstream of Manchester Ship Canal) water bodies:

- 10% of impacts from the [✂] Borehole are assigned to AP12, Bollin (Macclesfield STW);
- 10% of impacts are assigned to AP14, Dean at Stanneylands Gauging Station; and

- 80% of impacts are assigned to AP11, Mersey Ashton-on-Mersey Gauging Station, which is the most downstream AP on the Mersey (upstream of the estuary).

No notes are provided by the Environment Agency with the WRGIS data but this type of impact distribution is thought to reflect a large thickness of Glacial Till and glaciofluvial superficial deposits in this area, plus the presence of the Mercia Mudstones in the lower reaches, which limit local abstraction impacts on surface water bodies, such that the abstraction impact is mostly felt much further downstream on the discharge of groundwater to the River Mersey.

The WRGIS 'IMPFAC' for this source is 1, indicating that there is no reduction in abstraction impacts conceptualised at times of low flow (i.e. no accounting for how drawing on groundwater storage may reduce impacts on surface water bodies at these times).

Table 3.18 WFD dependent surface water body screening: Groundwater Option WR111*

WFD Surface Water body	Ecological status	Biological quality	Physico-chemical quality	Hydro-morphological regime	Chemical substances status	RNAG
Dean (Bollington to Bollin) Water Body ID GB112069061360	Poor	Poor	Good	Supports Good	Fail (Mercury, PDBE, Cypermethrin)	Phosphate (Agriculture and rural land management), point sewage discharge (water industry), Barriers - ecological discontinuity (Fish)
Bollin (Source to Dean) Water Body ID GB112069061320	Moderate	Moderate	Moderate	Supports Good (2014 last assessment)	Fail (Benzo(g-h-i)perylene, Mercury, PDBE)	Phosphate (Urban, Agriculture and rural land management), point sewage discharge (water industry), Physical modification (water industry)
Mersey (upstream of Manchester Ship Canal) Water Body Water Body ID GB112069061030	Moderate	NA	Moderate	Supports Good	Fail (Benzo(b)fluoranthene, Benzo(g-h-i)perylene, Benzo(k)fluoranthene, Mercury, PFOS, PDBE, Cypermethrin)	Diffuse source (agricultural and rural and management, urban and transport) Point source (sewage discharge, water industry)

*Based on Catchment Data Explorer data from https://environment.data.gov.uk/catchment-planning/ Accessed 18/05/2022. 2019 classification. RNAG Reasons for Not Achieving Good; PDBE Polybrominated diphenyl ethers; PFOS Perfluorooctane sulphonate.

Regional groundwater levels indicate that the River Dean and the Bollin may gain some baseflow as well as runoff and interflow as it passes over the sandstone subcrop, which may vary spatially depending on the nature and thickness of the superficial deposits (Till, glaciofluvial deposits and alluvium). The downstream reaches flow over the Bollin Mudstone and are therefore unlikely to be directly impacted by the abstraction.

Linkages between abstraction and groundwater dependent terrestrial ecosystems

SSSIs and GWDTE's close to option WR107b are listed in **Table 3.19** and shown on **Figure 2.12** and **3.7**.

No sites have been marked for further investigation for option WR111. Sites within 10 km of the source were investigated for potential hydrological connection (see Table 3.22). Initially Lindow Common SSSI was scoped in for further investigation, however following further review (see **Section 2.2 in Appendix B**) the site was determined to be predominantly supported by rainfall, surface water drainage and shallow interflow from superficial deposits and to be disconnected from the sandstone aquifer.

Table 3.19 SSSIs and GWDTEs within 10 km of option WR111 source

Site Name	Description*	Distance to source (km)	Sub-Option Sources	Potential hydrological connection for further assessment
Lindow Common SSSI	Lowland heath: wet and dry heath, bog, open water and scattered scrub and woodland	6	[✂]	N – disconnected from sandstone aquifer
Cotterill Clough SSSI	Incised ravine cut into the Bollin Mudstone Member. Diverse clough woodland with associated stream habitat	9	[✂]	N – disconnected from sandstone aquifer
Alderly Edge SSSI	Geological exposures of ores in mine workings	4.5	[✂]	N – Geological interest only

* From https://designatedsites.naturalengland.org.uk/ accessed 19/05/22.

Risks of saline intrusion

The Dean and Bollin GWMU where this abstraction is located has restricted water availability, but saline intrusion is not indicated as a risk factor in the EA's assessment (Environment Agency, 2013b). However, saline intrusion by upwards movement (upconing) of water from depth may still be a risk in this area if abstraction wells are deep and draw down water levels significantly.

Groundwater Balance

Table 3.20 gives details of current and potential fully licensed abstraction rates for this groundwater option, together with proposals for future abstraction rates.

The proposals here are to increase abstraction above the current daily licensed quantity to a peak daily total of **12 Ml/d**, but keeping the annual average to a maximum of 9.1 Ml/d.). The option has a maximum capacity of 12 Ml/d, however the anticipated utilisation of option WR111, as provided from UU's water resource modelling (shown in **Appendix A**), shows that in an average year, the rate of abstraction would peak in summer at 9 Ml/d, with a minimum of approximately 2.5 Ml/d in winter. For the '1 in 500 year drought' scenario, the option may be utilised at its maximum capacity for a number of months through the spring, summer and early autumn, keeping abstraction within the groundwater resource available within the groundwater management unit (Dean & Bollin GWMU located within the Manchester and East Cheshire groundwater body

Further evaluation of the water balance will be undertaken beyond Gate 2 as part of the planned updates to the East Cheshire groundwater model.

The [✂] borehole has been flagged by the Environment Agency as 'at risk' from environmental destination. Further investigation is required as to the nature and potential of implication of this risk.

Table 3.20 Current and proposed abstraction: Groundwater Option WR111

Source	Licence	Recent Actual abstraction (Ml/d)*	Fully Licensed abstraction (Ml/d)*	Proposed quantity (Ml/d)*	Proposed Ml/d available unconstrained**	Comment**
[✂]	2569019040	0.2	9.1	12 (peak daily, 9.1 annual average)	11	Impacts on surface water; GWMU over-licensed but 11 M/d available within recent actual surplus.

* From UU data provided 21/06/2022. Fully Licensed abstraction is the annual licence quantity expressed as Ml/d equivalent.
** From EA water availability summary, provided to UU in March 2022.

3.8 WR113: [✂]

The hydrogeological conceptualisation of the area around the [✂] Boreholes, groundwater option WR113, is shown on **Figure 3.8**. [✂] borehole is in the Dean and Bollin GWMU. The bedrock geology in this area is made up of the layered Sherwood Sandstone Group, with north-south faulting resulting in these layers being offset. To the east of the sources, the Pennine Lower Coal Measures subcrops against a faulted boundary, marking the extent of the Sherwood Sandstone aquifer and to the west the Bollin Mudstone Member (Mercia Mudstone Group) overlies the sandstone, confining the aquifer. Superficial deposits in this area are dominated by thick Glacial Till and glaciofluvial deposits, which are low permeability and semi-confine the aquifer. Regional groundwater flow in the sandstone aquifer is towards the north-west, towards the Bollin and the River Mersey. Groundwater levels are relatively deep (between 80 and 120 mAOD).

WFD dependent surface water body screening

[✂] Boreholes are located in the Bollin (Source to Dean) WFD surface water body, which flows in to lower reaches of the Bollin, and then to the Manchester Ship Canal. This water body is classed as heavily modified. Its current WFD status is summarised in **Table 3.21**.

Environment Agency WRGIS data assign abstraction impacts from [✂] distributed locally between the Bollin (Source to Dean), adjacent Dean (Bollington to Bollin) and the much further downstream, Mersey (upstream of Manchester Ship Canal) water bodies:

- 10% of impacts from the [✂] Boreholes are assigned to AP12, Bollin (Macclesfield STW);
- 10% of impacts are assigned to AP14, Dean at Stanneylands Gauging Station; and
- 80% of impacts are assigned to AP11, Mersey Ashton-on-Mersey Gauging Station, which is the most downstream AP on the Mersey (upstream of the estuary).

No notes are provided by the Environment Agency with the WRGIS data but this type of abstraction impact distribution could reflect a large thickness of superficial deposits limiting local abstraction impacts on surface water bodies, such that the abstraction impact is mostly felt much further downstream on the discharge of groundwater to the River Mersey where the river may be in good continuity with the sandstone aquifer.

The WRGIS 'IMPFAC' for this source is 1, indicating that there is no reduction in conceptualised abstraction impacts at times of low flow (i.e. no accounting for how drawing on groundwater storage may reduce impacts on surface water bodies at these times).

Table 3.21 WFD dependent surface water body screening: Groundwater Option WR113*

WFD Surface Water body	Ecological status	Biological quality	Physico-chemical quality	Hydro-morphological regime	Chemical substances status	RNAG
Bollin (Source to Dean) Water Body ID GB112069061320	Moderate	Moderate	Moderate	Supports Good (2014 last assessment)	Fail (Benzo(g-h-i)perylene, Mercury, PDBE)	Phosphate (Urban, Agriculture and rural land management), point sewage discharge (water industry), Physical modification (water industry)
Dean (Bollington to Bollin) Water Body ID GB112069061360	Poor	Poor	Good	Supports Good	Fail (Mercury, PDBE, Cypermethrin)	Phosphate (Agriculture and rural land management), point sewage discharge (water industry), Barriers - ecological discontinuity (Fish)
Mersey (upstream of Manchester	Moderate	NA	Moderate	Supports Good	Fail (Benzo(b)fluoranthene, Benzo(g-h-	Diffuse source (agricultural and rural and management, urban and transport)

WFD Surface Water body	Ecological status	Biological quality	Physico-chemical quality	Hydro-morphological regime	Chemical substances status	RNAG
Ship Canal) Water Body Water Body ID GB112069061030					i)perylene, Benzo(k)fluoranthene, Mercury, PFOS, PDBE, Cypermethrin)	Point source (sewage discharge, water industry)

* Based on Catchment Data Explorer data from https://environment.data.gov.uk/catchment-planning/ Accessed 18/05/2022. 2019 classification. RNAG Reasons for Not Achieving Good; PDBE Polybrominated diphenyl ethers; PFOS Perfluorooctane sulphonate.

To the south, the Dane (Clough Brook to Cow Brook) WFD surface water body is assessed as 'Does not support Good', based on Hydrological Regime due to surface water abstraction. This catchment overlies the mudstone, siltstone and sandstone of the Morridge Formation in the Millstone Grit Group, which is stratigraphically below the Coal Measures and hydrogeologically disconnected from the Sherwood Sandstone.

Within the Bollin (Source to Dean) WFD surface water body, regional groundwater flows north and west from areas of higher topography. The upper Bollin is perched above and disconnected from regional sandstone water levels, receiving runoff and shallow interflow from the superficial deposits which is dominated by glaciofluvial deposits. As the river flows towards Wilmslow it may start to gain sandstone baseflow where regional groundwater levels are close to topography, although the hydraulic connection between the river and aquifer will depend on the local nature of the superficial deposits (till, glaciofluvial deposits and alluvium).

Linkages between abstraction and groundwater dependent terrestrial ecosystems

SSSIs and GWDTE's close to option WR113 are listed in

Table 3.22 and shown on **Figure 2.12** and **Figure 3.8**.

No sites have been marked for further investigation for option WR113. Sites within [✂] of the source were investigated for potential hydrological connection (see Table 3.22). Initially both Danes Moss SSSI and Lindow Common SSSI were scoped in for further investigation, however following further review (see **Sections 2.1 and 2.2 in Appendix B**) both sites were determined to be predominantly supported by rainfall, surface water drainage and shallow interflow from superficial deposits and to be disconnected from the sandstone aquifer.

Table 3.22 SSSIs and GWDTEs within 10 km of option WR113*

Site Name	Description	Distance to source (km)	Sub-Option Sources	Potential hydrological connection for further assessment
Danes Moss SSSI	Cut-over raised mire, developed in a natural depression in the glacial deposits	5	[✂]	N- not connected to

Site Name	Description	Distance to source (km)	Sub-Option Sources	Potential hydrological connection for further assessment
				sandstone aquifer.
Lindow Common SSSI	Lowland heath: wet and dry heath, bog, open water and scattered scrub and woodland	10	[✂]	N - not connected to sandstone aquifer.
Alderly Edge SSSI	Geological exposures of ores in mine workings	6	[✂]	N – geological interest only
Goyt Valley SSSI / South Pennine Moors SAC	Moorlands overlying the Carboniferous Millstone Grits and Coal Measures. Extensive blanket bogs, marshes, water fringed vegetation, fens.	9	[✂]	N - not connected to sandstone aquifer.

* From https://designatedsites.naturalengland.org.uk/ accessed 19/05/22.

Risks of saline intrusion

The Dean and Bollin GWMU where these abstractions are located has restricted water availability but saline intrusion is not indicated as a risk factor in the EA's assessment (Environment Agency, 2013b). However, saline intrusion by upwards movement (upconing) of water from depth may still be a risk in this area if abstraction wells are deep and draw down water levels significantly.

Groundwater balance

Table 3.23 gives details of current and potential fully licensed abstraction rates for this groundwater option, together with proposals for future abstraction rates.

The proposals here are to increase abstraction within the current licensed quantity by **3 Ml/d**, but keeping abstraction within the groundwater resource available within the groundwater management unit (Dean & Bollin GWMU located within the Manchester and East Cheshire groundwater body). The option has a maximum capacity of 3 Ml/d, however the anticipated utilisation of option WR113, as provided from UU's water resource modelling (shown in **Appendix A**), shows that in an average year, the rate of abstraction would peak in summer at 2.3 Ml/d, with a minimum of approximately 0.4 Ml/d in winter. For the '1 in 500 year drought' scenario, the option may be utilised at its maximum capacity for a number of months through the spring, summer and early autumn.

Further evaluation of the water balance will be undertaken beyond Gate 2 as part of the planned updates to the East Cheshire groundwater model.

The [✂] borehole has been flagged by the Environment Agency as 'at risk' from environmental destination. Further investigation is required as to the nature and potential of implication of this risk.

Table 3.23 Current and proposed abstraction: Groundwater Option WR113

Source	Licence	Recent Actual abstraction (Ml/d)*	Fully Licensed abstraction (Ml/d)*	Proposed quantity (Ml/d)*	Proposed Ml/d available unconstrained**	Comment**
[✂]	2569018050	1.9	4.1 annual, 6.82 daily	4.9	3	GWMU over-licensed but 3 Ml/d possible within recent available surplus. Possible impacts on surface water

* From UU data provided 21/06/2022. Fully Licensed abstraction is the annual licence quantity expressed as Ml/d equivalent.
** From EA water availability summary, provided to UU in March 2022.

4. Summary and next steps

4.1 Summary

A summary of the WFD compliance screening of the NWT groundwater options is given below in **Table 4.1**, which has been shaded to indicate the potential risks to the water environment from increased groundwater abstraction.

For work beyond Gate 2, the dependent surface water body screening indicates that the impacts of groundwater abstraction are expected to be a particular focus for the Ditton Brook and its tributaries, the Alt, the Dean, the Bollin, and also the lower reaches of the Downholland Brook, Croxteth/Knowsley Brook and possibly the Spittle Brook and Glaze. Further detail is provided about individual water bodies for each option in Section 4.2. At this stage, no distinction has been made in level of risk between options for this test, as an improved quantified assessment is required, through the use of an updated groundwater model.

A number of SSSIs / GWTDEs have been flagged in the screening for further assessment beyond Gate 2 to improve the understanding of drawdown risks to water levels and ecology in these conservation sites. See **Section 4.2** for a full summary of sites. This is conservative at this stage as many of these sites are relatively far (several kilometres) from the options under consideration and the impacts of sandstone groundwater abstraction on water levels and on ecology may not be significant in reality.

The risk of saline intrusion, including upwards movement of saline water (upconing) or intrusion from the sea, has been flagged for all groundwater options. For WR107a, WR107b, WR111 and WR113, this is a precautionary conclusion, pending the improved understanding that should be gained through updated groundwater modelling. For WR102b, WR105a, WR106b and WR149, saline intrusion is already recognised as a risk in the groundwater management units within which these abstractions are located, and hence these have been assigned a higher level of risk.

Water availability has also been flagged as a risk for all groundwater options. This is based on the currently available information regarding the proposed options and the available groundwater resource. The EA have provided updated assessments of groundwater resource availability at the Groundwater Body scale. This data indicates that Fully Licensed abstraction exceeds the available resource, but that some water may be available under Recent Actual conditions. However, these numbers are not directly relatable to the summaries of water availability data at the GWMU level, provided by the EA in March 2022. Some further reconciliation may be required. At this stage, those abstractions which were identified in the Environment Agency's March 2022 water availability summary as having water available within the Recent Actual surplus are lighter blue, while those identified as being over-abstracted are highlighted darker blue.

For Gate 3, the distribution of abstractions and abstraction impacts in relation to the SRO option locations needs to be considered in more detail by numerical modelling and in association with saline intrusion risks. Updates to existing models provide a mechanism for detailed review of Environment Agency resource availability assumptions and further assessment using groundwater and river flow modelling.

Table 4.1 Risks relating to WFD compliance for the NWT Groundwater Options

Option ID	Name	Option Capacity (Ml/d)	Dependent surface water body status	Groundwater dependent terrestrial ecosystem test	Saline intrusion test	Water availability
WR102b	[✂]	28.3	Surface water bodies potentially in connectivity have been identified. Further assessment required.	No GWDTEs identified	CAMS (2013) lists restricted water available due to saline intrusion	Latest Environment Agency update indicates GWMU over-licensed, with insufficient water available for option. To be reviewed.
WR105a	[✂]	9	Surface watercourse with potential connectivity is not a WFD water body.	GWDTES potentially in connectivity have been identified. Further assessment required.	CAMS (2013) lists restricted water available due to saline intrusion	Latest Environment Agency update indicates GWMU over-licensed, with insufficient water available for option. To be reviewed.
WR106b	[✂]	8.45	Surface water bodies potentially in connectivity have been identified. Further assessment required.	GWDTES potentially in connectivity have been identified. Further assessment required.	CAMS (2013) lists restricted water available due to saline intrusion	Latest Environment Agency update indicates GWMU over-licensed, with insufficient water available for option. To be reviewed.
WR107a	[✂]	10	Surface water bodies potentially in connectivity have been identified. Further assessment required.	GWDTES potentially in connectivity have been identified. Further assessment required.	No specific risk identified, but to be reviewed	Latest Environment Agency update indicates GWMU over-licensed, but with sufficient water available (within licence) for option. However, new licence required. To be reviewed.
WR107b	[✂]	12	Surface water bodies potentially in connectivity have been identified. Further assessment required.	GWDTE potentially in connectivity has been identified. Further assessment required.	No specific risk identified, but to be reviewed	Latest Environment Agency update indicates GWMU over-licensed, but with sufficient

Option ID	Name	Option Capacity (Ml/d)	Dependent surface water body status	Groundwater dependent terrestrial ecosystem test	Saline intrusion test	Water availability
						water available (within licence) for option. To be reviewed.
WR149	[✂]	13.3	Surface water bodies potentially in connectivity have been identified. Further assessment required.	GWDTES potentially in connectivity have been identified. Further assessment required.	CAMS (2013) lists restricted water available due to saline intrusion	Latest Environment Agency update indicates GWMU over-licensed, with insufficient water available for option. To be reviewed.
WR111	[✂]	12	Surface water bodies potentially in connectivity have been identified. Further assessment required.	No GWDTEs which are potentially in connectivity have been identified.	No specific risk identified, but to be reviewed	Latest Environment Agency update indicates GWMU over-licensed, but with sufficient water available (within licence) for option. However, licence variation required. To be reviewed.
WR113	[✂]	3	Surface water bodies potentially in connectivity have been identified. Further assessment required.	No GWDTEs which are potentially in connectivity have been identified.	No specific risk identified, but to be reviewed	Latest Environment Agency update indicates GWMU over-licensed, but with sufficient water available (within licence) for option. To be reviewed.

Key to Table 4.1:

Lowest risk			Highest risk

4.2 Recommendations

This report has provided an assessment of the likely feasibility of the groundwater options included in the NWT scheme, in relation to their risks to the water environment. Further work is recommended in order to improve the understanding of these risks, in two key areas:

- In order to better quantify impacts on groundwater, and resulting groundwater-surface water interactions, the relevant regional groundwater models should be updated. This process has already been initiated, and is further discussed below;
- For surface water bodies and wetlands that have been identified as having the potential to be impacted by the proposed abstractions, environmental monitoring should be undertaken. The purpose of this will be to understand potential environmental impacts that could result from reduced baseflows to the watercourses. Relevant water bodies are set out below, with an outline scope of work.

Ultimately, these two strands of work will converge, allowing a quantified assessment of impact on river flows and/or groundwater levels, which will inform the associated environmental assessments. This will be combined with further groundwater evidence collection, for example including UU's water quality data, DO/source reliable output assessments and drinking water safety plans.

Groundwater modelling

Groundwater and river flow modelling is recommended, to update and refine the conceptual model and quantify the spatial and temporal variations in the water balance and abstraction impacts on receptors. This will include refinement of a spatially distributed recharge model to simulate the fate of rainfall as it passes to runoff, recharge and shallow interflow, with detailed conceptualisation of the nature of the superficial cover influencing how recharge passes to the underlying aquifer and how groundwater interacts with surface water.

A range of scenarios will be run to assess the spatial and temporal impact of additional groundwater abstraction at the proposed sources on groundwater levels, river flows, SSSI/GWDTEs, the water balance and risks of saline intrusion.

As part of this work, the EA's current assessment of groundwater resource availability at the GWMU scale will be reviewed and compared with model outputs, including recharge, allowances for the groundwater flows required to support dependent surface water ecosystems, groundwater flows out across the coast and the long term average abstraction from the groundwater body.

The overview hydrogeological conceptualisation presented in this feasibility assessment will be tested and refined during the modelling, in particular the understanding of:

- The spatial pattern of groundwater-surface water interaction across the area, including areas where rivers may lose and gain baseflow. Further data collation may be undertaken, including the latest regional sandstone groundwater level contours from the EA, and site work to undertake targeted spot flow surveys and bed elevation surveys (e.g. for the Bollin, Dean, Ditton Brook, Alt, Downholland Brook, Spittle Brook, Glaze). This would aid the future calibration of the model and build confidence in its outputs.

- The lined - or unlined - nature of the canals that cross the area to determine whether these are likely to leak to the aquifer or receive inflows of groundwater, and what component of the water balance this represents.
- The hydraulic behaviour of fault zones as barriers to groundwater flow, and where faults may influence flow accretion and control the spatial extent of any abstraction impacts.
- The influence of the nature of the superficial deposits on groundwater levels in the Sandstone aquifer and interaction between the sandstone and the overlying deposits.
- The importance of any areas of sandstone excluded from the EA GWMU area to the aquifer water balance.
- The boundaries of the sandstone aquifer and lateral flow across these – in particular the Carboniferous Coal Measures and the Mercia Mudstone Group.

Environmental monitoring and assessment

Impacts on rivers

While it will not be possible to draw conclusions about impacts from the groundwater abstractions on surface waters with certainty until the groundwater model is available, the assessments presented in this report assist in targeting surface water monitoring in reaches most likely to interact with the regional sandstone aquifer. The water bodies that are most likely to be impacted are identified in **Table 4.2**. The table includes some commentary about likely spatial distribution of impact, as well as some context provided from a series of walkover surveys that were recently conducted in the area.

A full record of the walkover surveys may be found in Appendix C to the report "Assessment of environmental impacts of NWT river abstractions" (Wood, 2022). The scope of the surveys sought to capture the water bodies that might be impacted by abstraction, although the project programme dictated that they be planned and undertaken in advance of this report and associated assessment being completed. As a result, there are a few differences between the locations that were visited and those identified in **Table 4.2**. Gaps in understanding will be addressed by a future stage of surveys (as described below).

It is recommended that, in order to be prepared for Gate 3 and beyond, hydrological and ecological monitoring should commence in the relevant reaches. The scope of monitoring will be set out in detail in the Environmental Monitoring Plan accompanying the Integrated Environmental Assessment Report (IEAR), with locations targeted using the summaries in **Table 4.2**. The following types of habitat and ecological monitoring are recommended:

- Further targeted geomorphology and physical habitat surveys, using the MoRPH methodology. These should be targeted within and downstream of reaches with likely connectivity to the regional sandstone. In addition, surveys should be undertaken at macroinvertebrate sample sites;
- Macroinvertebrate and macrophyte sampling should continue at existing locations sampled by the Environment Agency. The proposed sampling network should be reviewed with the Environment Agency to confirm which they will be monitoring, and which should be sampled by UU;

- An improved understanding of fish populations in the catchments should be established by eDNA surveys.

In addition, spot flow surveys and bed level surveys will be critical for a full understanding of the connectivity of surface water bodies to the underlying regional sandstone aquifer. While some were carried out for the original groundwater model development, this should be fully reviewed so that any gaps in knowledge can be filled. This should be considered comprehensively as part of the planned groundwater model development projects, which are beyond the scope of this report.

Table 4.2 Surface water bodies to be considered for evidence collection

Option	Relevant river water bodies	Comments
WR102b	Dog Clog Brook GB112069060690 Prescot Brook GB112069060710 Netherley Brook GB112069060680 Ditton Brook GB112069061390 Mersey Estuary GB531206908100	[✂]
WR105a	Bradley Brook / Sow Brook (non-WFD water body) Bollin (Ashley Mill to Manchester Ship Canal) GB112069061382	[✂]
WR106b	Keckwick Brook GB112068060520	[✂]
WR107a	Downholland (Lydiate/ Cheshires Lines) Brook (GB112069060640)	[✂]
WR107b	Three Pool's Waterway GB112070064830 Croxteth/Knowsley Brook GB112069060610 Alt US Bull Bridge GB112069061441	[✂]
WR149	Hey/Bordsane Brook GB112069064520 Pennington Brook (Glaze) GB112069060760 Glaze GB112069091420 Spittle Brook GB112069061020	[✂]
WR111	Dean (Bollington to Bollin) GB112069061360 Bollin (Source to Dean) GB112069061320	[✂]

Option	Relevant river water bodies	Comments
WR113	Dean (Bollington to Bollin) GB112069061360 Bollin (Source to Dean) GB112069061320	[✂]

Impacts on GWDTEs and other relevant water-dependent sites

This report has reviewed sites with national and international designations to identify those that could potentially be impacted by the scheme. This has focussed mainly on groundwater-dependent designated sites (GWDTEs), but also considers sites that could be impacted by resulting changes to surface water flows. The GWDTEs are summarised in **Table 4.3**. Additional literature review (**Appendix B)** and engagement with the EA and NE has been undertaken for the second issue of this report to provide more detail on the potential impacts on these sites from the proposal groundwater sub-options. However, for many sites there remains low level of certainty about the extent to which the identified sites are likely to be connected to the regional sandstone aquifer, and hence may be impacted by the abstractions. Any sites with international designations will be assessed within the **HRA**.

Downstream sites that could be affected by changes to river flow and/or direct seepage include:

- The **Mersey Estuary SSSI, SPA and Ramsar**. Six options lie in the Mersey catchment, including WR102b, WR105a, WR106b, WR149, WR111 and WR113. The potential impact of these options on designated features of the Mersey Estuary will be considered individually and in combination (including in-combination with relevant surface water options) in the **HRA**.
- The **Ribble and Alt estuary SPA and Ramsar** (comprising **parts of the Ribble Estuary SSSI and Sefton Coast SSSI**). Two options lie in the upstream catchment of the Alt Estuary and/or Ribble Estuary, including WR107a and WR107b. The potential impact of these options on designated features in the Alt and Ribble Estuaries will be considered individually and in-combination (including in-combination with relevant surface water options) in the **HRA**. Parts of the Ribble Estuary SSSI are also a Marine Conservation Zone.

Table 4.3 GWDTEs to be subject to further review

Option	Potentially relevant GWDTEs	Comments
WR102b	None identified	-
WR105a1	Woolston Eyes SSSI	[✂]
	Rixton Clay Pits SSSI and SAC	[✂]
	Risley Moss SSSI	[✂]

Option	Potentially relevant GWDTEs	Comments
	Rostherne Mere SSSI	
WR106b	Woolston Eyes SSSI	[✂]
WR107a	Martin Mere SSSI and SPA	[✂]
WR107b	Martin Mere SSSI and SPA	[✂]
	Sefton Coast SSSI, SAC and NNR	[✂]
WR149	Abram Flashes SSSI	[✂]
	Component SSSIs of Manchester Mosses SAC, including Risley Moss SSSI, Holcroft Moss SSSI, Astley & Bedford Mosses SSSI	[✂]
	Highfield Moss SSSI	[✂]
	Woolston Eyes SSSI	[✂]
	Rixton Clay Pits SSSI and SAC	[✂]
	Bryn Marsh & Ince Moss SSSI	[✂]
WR111	None identified	-
WR113	None identified	-

5. References

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Figures

Appendix A
Modelled option utilisation

This appendix shows the modelled utilisation rates for each source, as provide by United Utilities from their water resource modelling. Two of the options assessed in this report are not included in the Preferred Portfolio and hence do not appear in these tables. UU have advised that, if the remaining two options were to be used, their utilisation would be likely to be similar to:

- WR105a Lymm boreholes- use would be similar to the profiles provided for WR113 Tytherington boreholes;
- WR106b Walton & Daresbury boreholes- use would be similar to the profiles provided for WR149 Lightshaw boreholes.

Appendix B
Technical note: GWDTE Literature Review