Winter 2020

National Water Resources Plan – Draft Framework Plan

Technical Appendices

Appendix C
Supply Assessment

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Data Disclaimer:

This document uses best available data at time of writing. Some sources may have been updated in the interim period. As data relating to population forecasts and trends are based on information gathered before the Covid 19 Pandemic, monitoring and feedback will be used to capture any updates. The National Water Resources Plan will also align to relevant updates in the National Planning Framework.

1.1 Introduction

To accurately plan for future water availability, we need to have a good understanding of the water available to be put into supply. This appendix describes the assessment of or existing sources and sets out the methodology for determining the Deployable Output (DO) for each Water Resource Zone (WRZ).

DO represents the maximum quantity of water output from a water source or a group of sources that can be sustained under specific design conditions. The UK Water Industry Research Ltd (UKWIR) WR27 Water Resources Planning Tools (2012): Summary Report defines DO as follows.

> “
> Deployable Output
>
> **The output for specified conditions and demands of a commissioned source, group of sources or water resources system** as constrained by: hydrological yield; licensed quantities; environment (represented by licence constraints); pumping plant and/or aquifer properties; raw water mains and/or aqueducts; transfer and/or output main; treatment; water quality and levels of service.
> ”

DO is calculated for each of the planning scenarios, described in Appendix C. Figure 1-1 below illustrates the hierarchy of constraints assessed to derive the DO. If the DO is limited by hydrological factors, it will vary across the planning scenarios, generally with more water available in winter and less in summer. This means the DO will be higher in Winter Critical Periods than in Dry Year Critical Periods.

The “hydrological yield” is the water in the natural catchment at the abstraction point in a drought event with a return period equivalent to a given Level of Service. The “allowable abstraction” is an estimate of the water that can be taken from the source, whilst maintaining the required environmental flow, which is required to maintain the WFD objectives.

As outlined in Appendix I, in respect of the new abstraction licensing framework, we have assumed that current abstractions will be issued with licences that permit their current level of operation, unless there are specific reasons not to be identified during the licensing process. Therefore, the DO for existing sources will be constrained to either the hydrological yield, the existing abstraction rate or the Water Treatment Plant (WTP) capacity. However, we anticipate any new developed abstractions will maintain required environmental flows. The DO for new abstractions will be constrained to the allowable abstraction as opposed to the hydrological yield, if the allowable abstraction is less than the hydrological yield, and the WTP capacity.

Figure 1-1 shows that the hydrological yield and the allowable abstraction are at the top of the hierarchy of constraints, when determining DO, as these two relate to raw (untreated) water availability. The other constraints to determining DO are limitations in processing and handling this raw water.

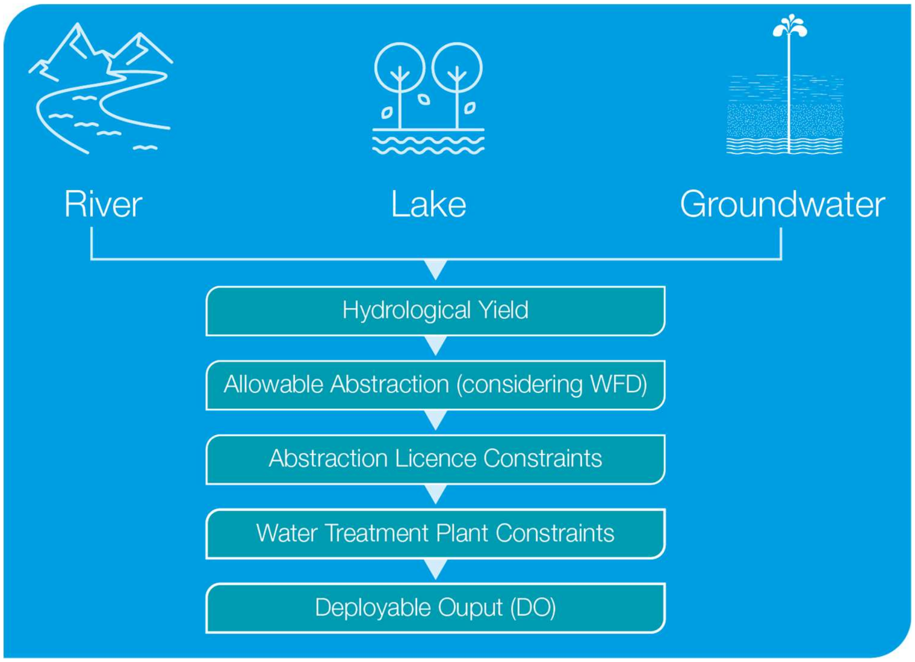


Figure 1-1 Hierarchy of DO constraints

For WRZs, which rely on one or two sources in a simple arrangement, the DO can be determined from a straightforward assessment of the hydrological yield, allowable abstraction and Water Treatment Plant (WTP) infrastructure. In more complex WRZs, where we use different sources and source types, we need to undertake a behavioural analysis by creating models of the system. These water resource models use long records of daily data to determine the DO of the system as a whole.

This Appendix sets out to:

- Describe the methodologies used to determine the hydrological yield and allowable abstraction at our sources; and
- Explain the water resource modelling for complex systems.

1.2 Methodology

To determine the hydrological yield and allowable abstraction, we must first understand the hydrology of the catchments draining to our surface water sources and the hydrogeology of our groundwater sources.

1.2.1 Surface water

Surface water sources supply 83% percent of our total supply, either from rivers or lakes. The amount of raw water available for abstraction at a surface water source is dependent on the interaction of rainfall and evaporation patterns with several catchment characteristics, such as its size, location, altitude, land use and soil features. Table 1-1 summarises these characteristics and outlines the impact they may have on the quantity of raw water available for abstraction.

Table 1-1 Surface water catchment characteristics

Catchment Characteristic	Impact on Water Available
Catchment size	The larger the catchment the greater the amount of water available for abstraction
Catchment location	If a catchment is located in the west of Ireland is likely to experience more rainfall than a catchment in the east of Ireland. Therefore, a catchment in the west is likely to have more water available than a similar sized catchment in the east

Catchment Characteristic	Impact on Water Available
Catchment altitude	If a catchment is located in high ground it is likely to experience more rainfall than a low-lying catchment. Therefore, a catchment located in high ground is likely to have more water available than a similar sized low-lying catchment.
Catchment Ground Conditions and Topography	During a rainfall event a percentage of rain is absorbed in the ground while the remaining rain runs off the local streams and rivers, this is known as runoff. The percentage of runoff is dependent on the ground type, for example gravel solid will have a lower percentage runoff than saturated clay. The percentage of runoff influences the amount of water available for abstraction, for example, there will be a significant volume of volume of water available for abstraction after the rainfall event in catchments with a high runoff rate. However, the drop off in water available after the rainfall event will be less dramatic as water stored in the soil will be released into the streams and rivers. Similarly, to ground conditions, catchment topography will impact the rate of runoff, with steeper catchment having a higher rate of runoff than shallower catchments.
Catchment Physical Features	Physical features in the catchment such as lakes and karst features will influence the water available in the catchment. If there is a lake or a series of lakes upstream of an abstraction point there will be less variability in the water available at the abstraction point as the lake or lakes will store water during heavy rainfall events making less water available for abstraction immediately after a rainfall event but providing more water for abstraction in the days following the rainfall event by flow from the storage in the lake. Karst features can reduce or increase the water available for abstraction by diverting flow away or to the catchment depending on the individual feature and the topography. Where karst features are present in a catchment a case by case analysis needs to be carried out to determine the influence the karst feature has on the water available in the catchment.

1.2.2 The hydrological conditions at the point of the abstraction

The interactions of the catchment characteristics and the climatic conditions give rise to a pattern of flows that can vary from location to location. We summarise this variation in Flow Duration Curves (FDCs). An FDC describes the percentage of time that flow is likely to equal or exceed a specific percentile. For example, the 95th percentile flow, denoted as Q95, is the flow rate equalled or exceeded for 95% of the time at that site.

Figure 1-2 compares example FDCs for some catchment types in Ireland. The recorded flows for each FDC have been divided by the mean flow in the catchment to allow a like-for-like comparison.

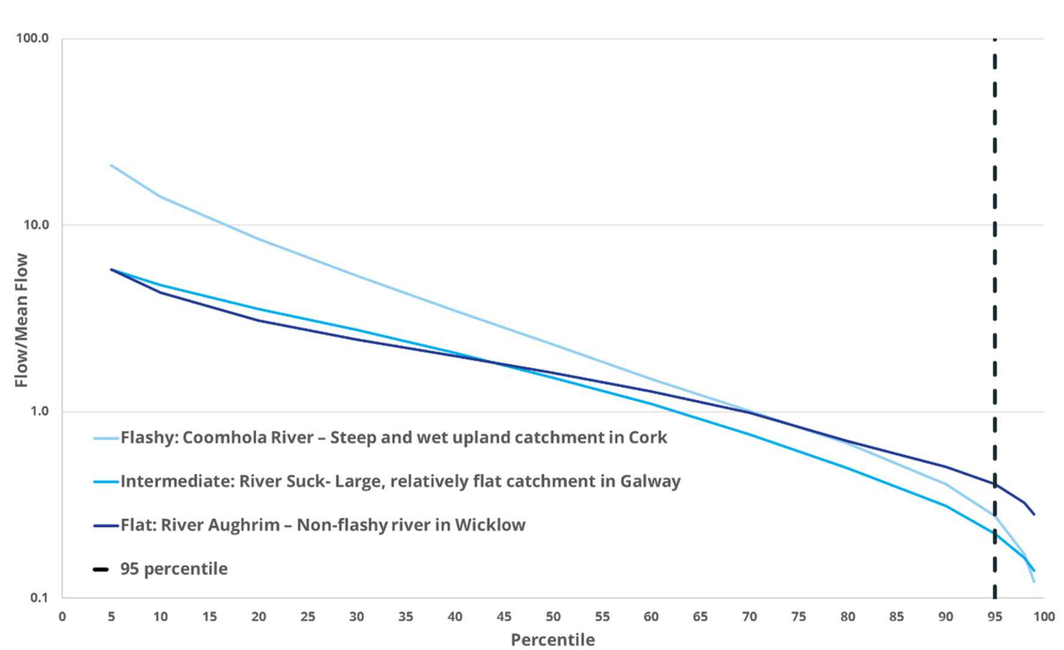


Figure 1-2 Example of a Flow Duration Curve

As the FDC provides an overview of the catchment hydrology, it can be used to provide an understanding of the potential water available for abstraction. FDCs are also used as a basis for describing environmental flows. The best way of creating an FDC is from a long-term record of flow measurements at the site of interest, although very few yield assessments at abstraction points can be developed in this way, due to data limitations. In these instances, we need to develop an estimated FDC for our abstraction points by using sites that we determine have similar hydrological characteristics.

1.2.3 Estimating the Flow Duration Curve

The different methods which can be used to determine FDCs are described below, alongside an outline of the method adopted for this project.

1.2.3.1 Transposition method

The transposition method provides an estimated flow series and FDC at a stream location by transposing the flow series from a gauged catchment. The physical characteristics of a catchment are matched to those of a catchment, where flows are measured at a gauging station. The flow record of the ‘donor’ site is then adjusted to account for the catchment size and annual rainfall differences between the two sites.

1.2.3.2 Rainfall-runoff method

Rainfall-runoff models can provide the best representation of a catchment. Although they require much more comprehensive data than other approaches to develop and calibrate, they allow us to estimate flow beyond the record of the gauging station, if there is available rainfall data. They can also be used to look at the impacts of climate change, using model outputs from global and/or regional climate models.

1.2.3.3 Comparison of methods

All the methods described above have their own strengths and weaknesses. For example; limitations include:

- The EPA online application cannot be used for small catchments;
- There are limited gauges available to support the transposition method; and
- Extensive data is required for the rainfall-runoff method.

To deliver a nationally consistent approach in developing our plan, the transposition methodology has been used to determine the hydrological conditions at the point of the abstractions and ultimately, to determine the yield. This method was selected as it represents a good balance between accuracy and a method suitable for application at a nationwide scale.

1.2.3.4 Detail of the transposition method

The transposition method has been adopted for the project as it provides us with an estimated flow series and FDC at each surface water source by transposing the flow series from a gauged catchment. An overview of the process is provided in Figure 1-3. As noted, this method was selected as it represents a good balance between accuracy and a method suitable for application at a nationwide scale.

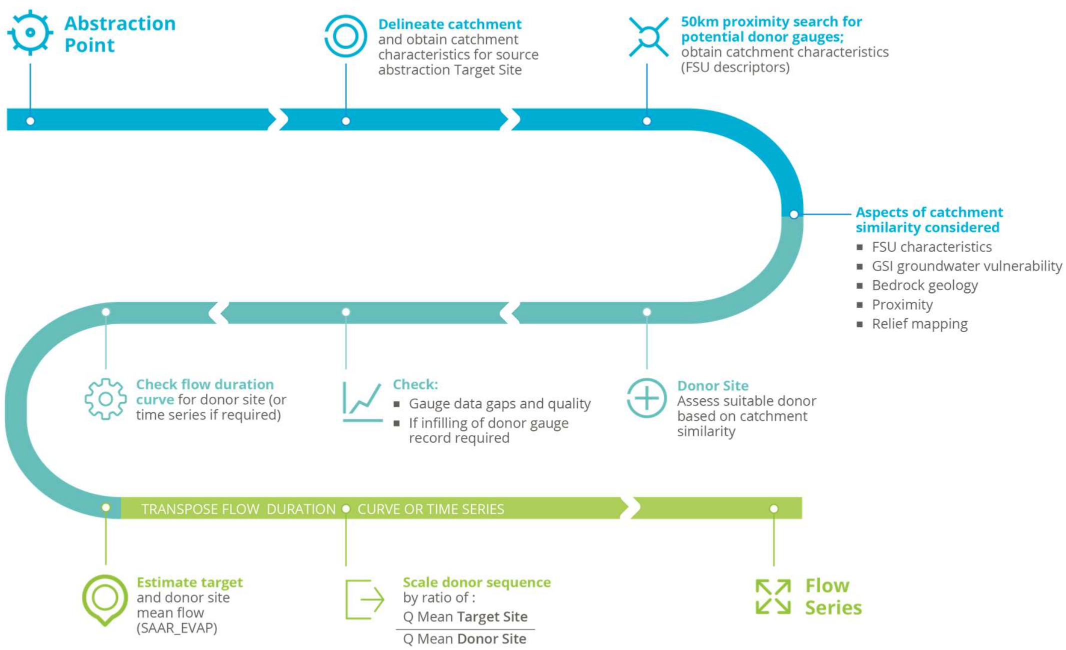


Figure 1-3 Transposition flow chart

The flow-time series for the catchment of interest is determined by transposing flows from a hydrologically similar catchment, giving us a flow series. While the flow series can be used to calculate the FDC, the flow series itself provides a greater level of detail than the FDC and can be analysed for sequences of prolonged low flow and to determine the water available at the source.

The transposition method involves selecting a suitable donor catchment, based on similar catchment descriptors (for example, land use, geology, soils, average rainfall) and proximity to the target site. A scaling factor is then applied to the donor sites' flow sequence to transpose it to the target site. The scaling factor, at its most basic, may just be based on the ratio of catchment area sizes. A more robust approach was however applied for this study, where the donor flow series was scaled to provide a target flow series by the relative size of their respective mean flows.

Ideally, the time series at the target site should be scaled from an adjacent donor catchment, which would have experienced similar rainfall patterns and would have a continuous flow record which covers a few drought years. Therefore, the following criteria are key when assessing suitable potential donor catchments:

- Hydrological characteristics;
- Proximity to point of interest with comparable annual average rainfall; and
- Length of flow record, and number of gaps in the flow record.

The first two points above refer to the suitability of the donor catchment based on hydrological similarity. The last point above refers to the quality of the time series that would be obtained from the gauge.

The transposition method is limited by the number of gauged catchments, length of record available and gaps in the datasets. Figure 1-4 illustrates the record lengths and data gaps in the flow series for all monitoring gauges in Ireland of suitable quality for use when considering low flows. This figure shows that, within the 163 of suitable accuracy at low flows, there are only 11 gauges with records that predate 1970 (longer than 50 years), and in general, there are significant gaps in the datasets. Therefore, there is uncertainty associated with the estimated flow series and FDCs.

During the summer 2018 drought, we collected level and flow data at approximately 140 of our most sensitive abstractions. This is the first opportunity to collect data in drought conditions since 1995. This data will be analysed and used to further develop our understanding of the water available at our sources.

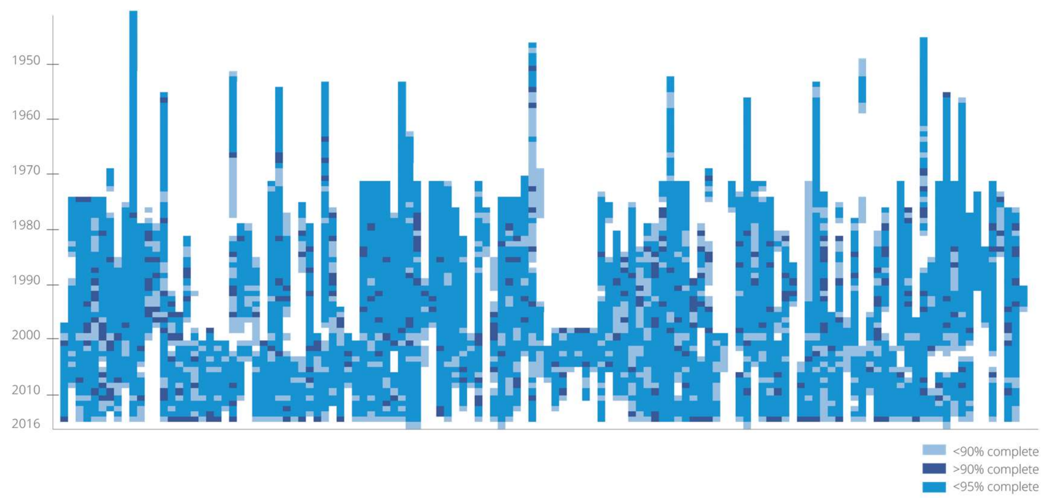


Figure 1-4 Summary of gauged records with sufficient data in a year to make it useful for analysis

To address gaps in the records, the flow series records are infilled by analysing the flow series of additional gauges local to the catchment of interest and scaling flows from these gauges for the period of the gap. This process can require flows to be scaled from several local gauges to create a continuous flow series at the donor site. Figure 1-5 overleaf, illustrates a time series where three gauges were used to create a continuous flow series with a 63-year duration.

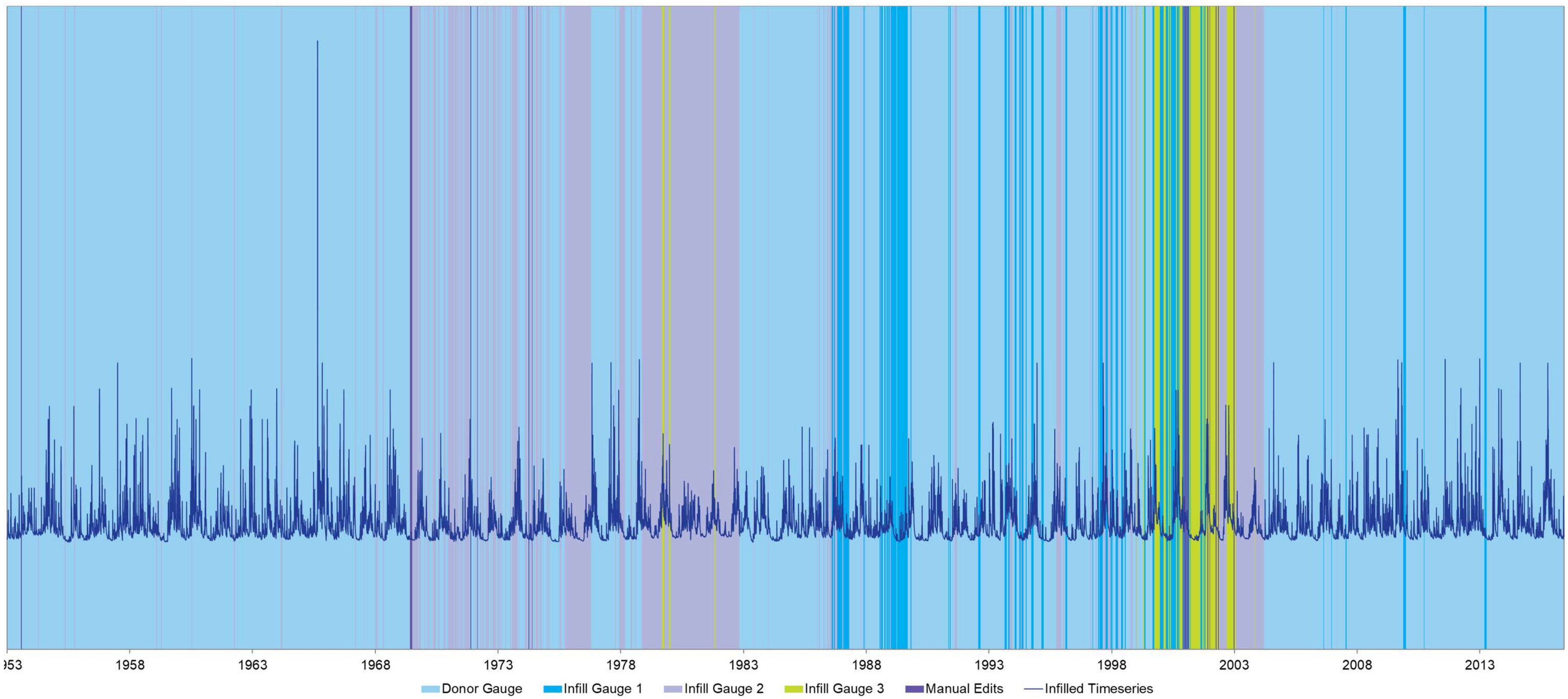


Figure 1-5 Infilling of time series

1.2.4 Groundwater

Groundwater sources supply 17% of our total supply, either from boreholes, springs or infiltration galleries.

An aquifer map of Ireland is included in Figure 1-6, which shows that the majority of Ireland is occupied by poorly productive aquifers, meaning large rates of abstraction at a single point are often impossible. Most of the bedrock is relatively poor at storing and transmitting groundwater, while areas underlain by karstified limestone (shaded blue) can be highly productive but prone to surface contamination, due to shallow overburden, the fractured nature of the rock and the presence of subsurface conduits.

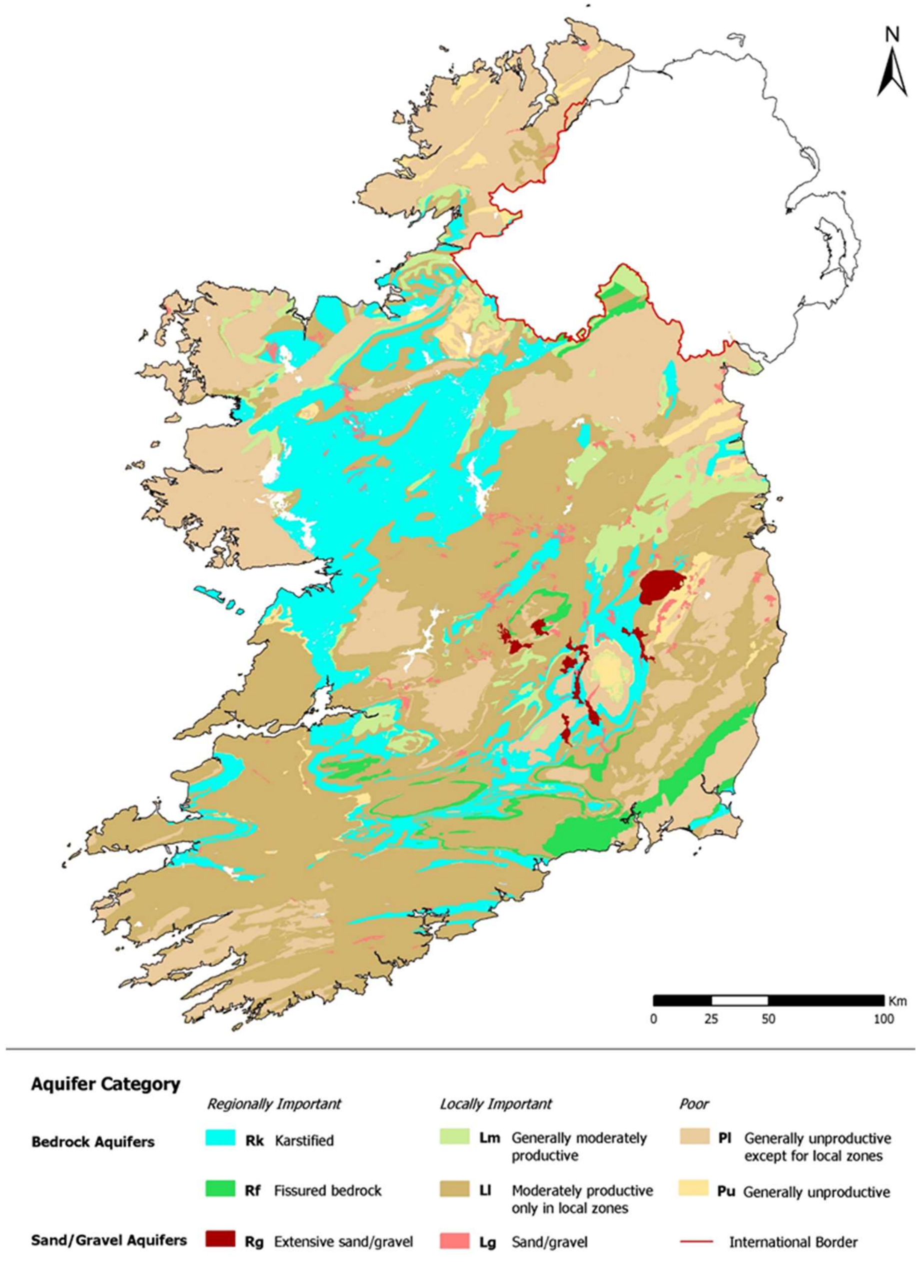


Figure 1-6 Map categorising bedrock and sand gravel aquifers in Ireland

This Geological Survey Ireland (GSI) map has classified and mapped nine aquifer categories across the country. The broad criteria used to determine aquifer categories include hydrogeological data, the presence of large springs, geology and stream density. The classification also includes sand and gravel, shaded in maroon, where deposits meet specific criteria.

Additionally, GSI usefully grouped and summarised the aquifer categories into high-level groupings that succinctly describe the broad types:

- Sand/gravel (Rg, Lg);
- Karstic (Rk, Lk, Rkc, Rkd);
- Productive fissured bedrock (Rf, Lm); and
- Poorly productive bedrock (Ll, Pl, Pu).

These general types can be considered as groundwater systems that have similar properties with a good indication of resource, extent and risk. Table 1-2 below describes the nine aquifer categories.

Table 1-2 Groundwater catchment characteristics

Aquifer type and geology	Impact on water available
Regionally Important (R) Aquifers	Generally dominated by relatively pure fractured limestones or clean sorted sands and gravels; sufficiently productive to be able to yield regionally important abstractions or "excellent" yields (>400m³/d) from boreholes or springs. The continuous aquifer unit generally has an area of >25km². Karstified bedrock **(Rk)** – may be further characterised as either Rkc (conduit flow) or Rkd (diffuse flow) Fissured bedrock **(Rf)** Extensive sand and gravel **(Rg)**
Locally Important (L) Aquifers	Generally dominated by impure limestones, shales, sandstones, granite and other rock types; moderately productive capable of yielding locally important abstractions (smaller public water supplies or group water schemes for villages/small towns) or "good" yields (100–400m³/d) from boreholes or springs. Bedrock which is generally moderately productive **(Lm)** Bedrock which is moderately productive only in local zones **(Ll)** Sand and gravel **(Lg)**
Poor (P) Aquifers	Generally dominated by impure limestones, shales, sandstones, granite and other rock types; normally capable of yielding only "moderate" or "low" yields (<100m³/d) from wells or springs to supply single houses, small farms or small group water schemes. Bedrock which is generally unproductive except for local zones **(Pl)** Bedrock which is generally unproductive **(Pu)**
Locally Important Karstified bedrock (Lk)	Generally similar to Rk but with a smaller continuous area (<25km²). While the karst properties imply that this aquifer can supply "excellent" yields, the smaller size limits the amount of recharge available to meet abstractions.[1]

The bedrock is covered by different types of subsoil of varying degrees of thickness. This subsoil helps protect groundwater and is a controlling factor on the amount of recharge, (that is, water returning to groundwater from runoff) from the rainfall on the land surface. Climate is another controlling factor on recharge rates, and the effective rainfall greatly reduces from west to east across the country.

[1] Kelly, Hunter Williams, Misstear and Motherway (2015) 'Irish Aquifer Properties – A reference manual and guide' Prepared on behalf of the Geological Survey of Ireland and the Environmental Protection Agency, available from: https://www.gsi.ie/NR/rdonlyres/FD633EB9-4F71-4ADE-B3CD-DFB403AD201B/0/IrishAquifersPropertiesAreferencemanualandguideVersion10March2015.pdf

The groundwater sources that contribute to the public water supplies are located in all of these aquifer types. We need to define the catchment area of a groundwater source to understand its yield. We refer to this as the Zone of Contribution (ZOC).

Zone of Contribution (ZOC)

Land area that contributes water to the well or spring.

It is important to realise that springs have a natural catchment, as they are fundamentally driven by gravity, whereas catchment areas to boreholes relate to a number of hydrogeological factors, including recharge and abstraction rate.

The definition of ZOCs has a long history in Ireland, and many have been defined for many of the public water supplies by the GSI, EPA and Irish Water.

GSI hosts data, maps and reports with respect to ZOCs on their website for the majority of those defined to date. The EPA's groundwater monitoring infrastructure comprises many of Irish Water's public water supplies, and the EPA hosts reports relating to those supplies on their website, as part of the information they provide on those sources.

1.2.4.1 Definition of Zones of Contribution – Methodology

Basic hydrogeological principles govern the definition of ZOCs for groundwater sources. In Ireland, the acknowledged schemes and documents that outline the methodologies include:

- Groundwater Protection Schemes (Department of Environment, Community and Local Government, GSI and EPA, 1999)
- Advice Note Number 7. Source Protection and Catchment Management (EPA, 2011).

To date, the ZOCs have been developed on a site-by-site basis, which has proved time-consuming. We have decided to apply a tiered approach and undertake a simplified assessment to delineate ZOCs for all our sources now. We will then target specific sites to study in more detail, based on source size or local issues.

The simple methodology considers groundwater flow, recharge and the area required to support the abstraction from long-term groundwater recharge. This is based on a similar methodology that was used for the definition of ZOCs for the EPA groundwater monitoring network (Kelly, 2010)[2].

1.3 Yield assessments

1.3.1 Surface water

Section 1.2 above provides an overview of how to obtain a flow series at a catchment of interest. This section outlines how the flow series and FDCs can be used to determine the hydrological yield and allowable abstraction.

1.3.1.1 Hydrological yield

The hydrological yield is calculated following the Institute of Hydrology Report No. 108 Low flow estimation in the United Kingdom Methodology.

[2] Kelly, C. 2010. Delineating Source Protection Zones and Zones of Contribution for Monitoring Points. IAH Groundwater Conference. Tullamore.

This methodology uses the observed relationship between normal and very low flows at long-term gauging sites in the UK to extrapolate a relationship at ungauged sites based on basic catchment information. Whilst not calibrated for Ireland, the similarities in catchment characteristics mean the relationships are likely to transfer with an acceptable level of accuracy. This method requires the following information to determine the yield at various return periods for river sources:

- Catchment area;
- Seasonal annual average rainfall for the catchment;
- Q95, the flow in a flow series which is equalled or exceeded 95% of the time;
- Qmean, the mean flow of a flow series; and
- Slope of the FDC.

For lake and reservoir sources, consideration needs to be given to the storage available in the lake to determine the yield. Therefore, the following additional information is required:

- Surface area of the lake;
- Potential Evaporation from the surface of the lake;
- Compensation flow; and
- Usable storage (the volume between the Top Water Level and the lowest level the lake or reservoir can be drawn down to, that is, emergency or dead storage)

At present, the lack of data available on storage volumes in natural lakes is a significant cause of uncertainty. This will form part of the programme of work for further investigation prior to the development of the next National Water Resources Plan.

1.3.1.2 Allowable abstraction

As discussed in Appendix G there is currently no definitive legislation or guidance available within Ireland for considering the ecological limit of acceptable abstraction from streams or rivers in terms of hydrological regime alteration. A number of projects are determining Ireland specific methods but at present, we are making assumptions based on the broadly similar hydrological conditions in the UK.

Within the UK, the standards for abstraction have been established as technical guidance by UKTAG, which comprises the Environment Agency, Natural Resources Wales, Scottish Environmental Protection Agency and Northern Ireland Environment Agency. The UKTAG standards have been used by Irish Water to understand what the future implications may be.

The standards permit a degree of modification from natural conditions, with the allowable variation from natural conditions decreasing at the lower flows. These standards are only a supporting element of the overall ecological status indicator, and the EPA may allow physical monitoring data to override the assessment for existing abstractions. We assume that new abstractions will be licensed only in accordance with these standards.

The standards for “Good” ecological status waterbodies vary depending on the river typology and the time of year. More restrictive limits apply between April and October, compared to the period between November and March; refer to Table 1-3 and Table 1-4. The standards for “High” ecological status waterbodies are more onerous and are presented in Table 1-5.

The river typology is the categorisation of a watercourse depending on its altitude, catchment size and dominant geology. The EPA has provided the river typology for all catchments in Ireland as outlined in Figure 1-7.

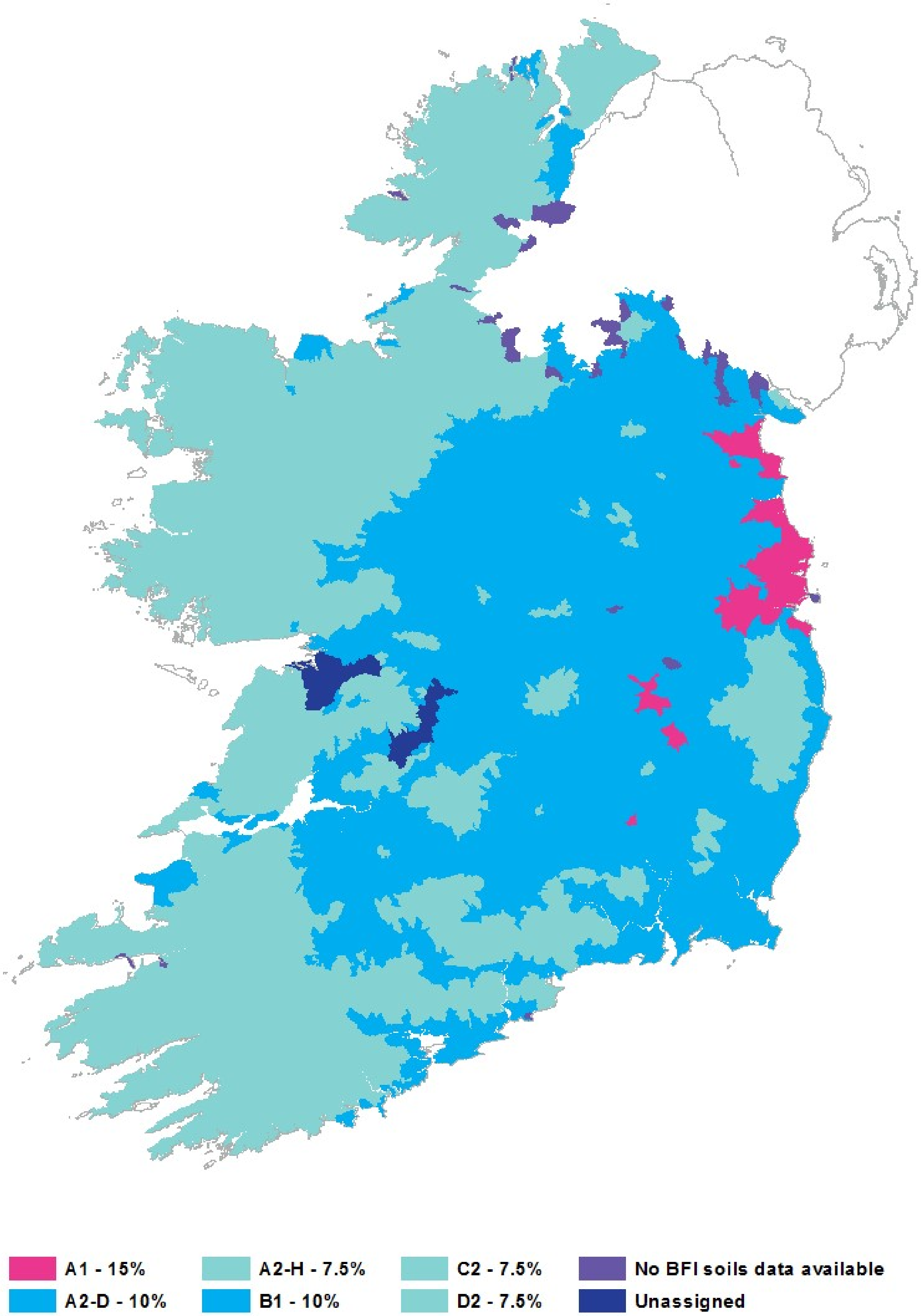


Figure 1-7 River types and Q95 allowable abstraction percentage of natural flow to achieve "Good" status

Table 1-3 Allowable abstraction standards for “Good” status watercourses for April to October.

River typology	Season	Allowable percentage abstraction			
		Flow > QN60	Flow > QN70	Flow > QN95	Flow < QN95
A1	April – October	30	25	20	15
A2, B1, B2, C1, D1	April – October	25	20	15	10
A2, C2, D2	April – October	20	15	10	7.5
Salmonid spawning and nursery areas	April – October	25	20	15	10

Table 1-4 Allowable abstraction standards for “Good” status waterbodies for November to March

River typology	Season	Allowable percentage abstraction			
		Flow > QN60	Flow > QN70	Flow > QN95	Flow < QN95
A1	November – March	35	30	25	20
A2, B1, B2, C1, D1	November – March	30	25	20	15
A2, C2, D2	November – March	25	20	15	10
Salmonid spawning and nursery areas	April – October	25	20	15	10

Table 1-5 Allowable abstraction standards for “High” status watercourses

Types	Allowable Percentage Abstraction	
	Flows > QN95	Flows < QN95
All types	10	5

Using the UKTAG guidance, the process of risk-assessing an abstraction for compliance with the WFD standards and this potential for future licensing is as follows:

- Determine the FDC for the watercourse;
- Determine the WFD waterbody status and river typology;
- Calculate the allowable abstraction in accordance with UKTAG standards for the given waterbody status; and
- Obtain a range of allowable abstractions across the flow percentiles.

This process provides an allowable abstraction regime for a river source across the FDC.

The UKTAG method for determining the allowable abstraction for lakes requires detailed bathometry and water level data, which are not widely available. Instead, the methodology set out in a 2009 report by the EPA[3] was used to determine the ecological limit of abstraction at lakes. This method sets the threshold for abstraction from lake sources at 10% of the Q50 of the rivers flowing into the lake.

[3] Eastern River Basin District Project Abstractions - National POM/Standards Study Revised Risk Assessment Methodology for Surface Water Abstractions from Lakes, January 2009

1.3.1.3 Example

Figure 1-8 illustrates the FDC for an example site. The allowable abstraction for the site for April to October and November to March are shown in the figure as curved lines below the FDC. The allowable abstraction from April to October is lower than that for November to March, which is typical.

Figure 1-9 shows more detail of the bottom-right corner of the FDC for flows less than Q90 for the example site. In this figure, the hydrological yield can be seen as a static line (colour: pink-dash). This is the yield from the catchment that will provide the 1 in 50 Level of Service (LoS). For this site, the yield is higher than allowable abstraction for flows less than approximately Q93.5 between April and October. Therefore, if this was a new abstraction, the yield at this site would be curtailed to the allowable abstraction between April and October for flows less than Q93.5, unless we were able to demonstrate that a greater abstraction would not have an impact on the ecological status of the watercourse. Ecological surveys would be required to demonstrate this.

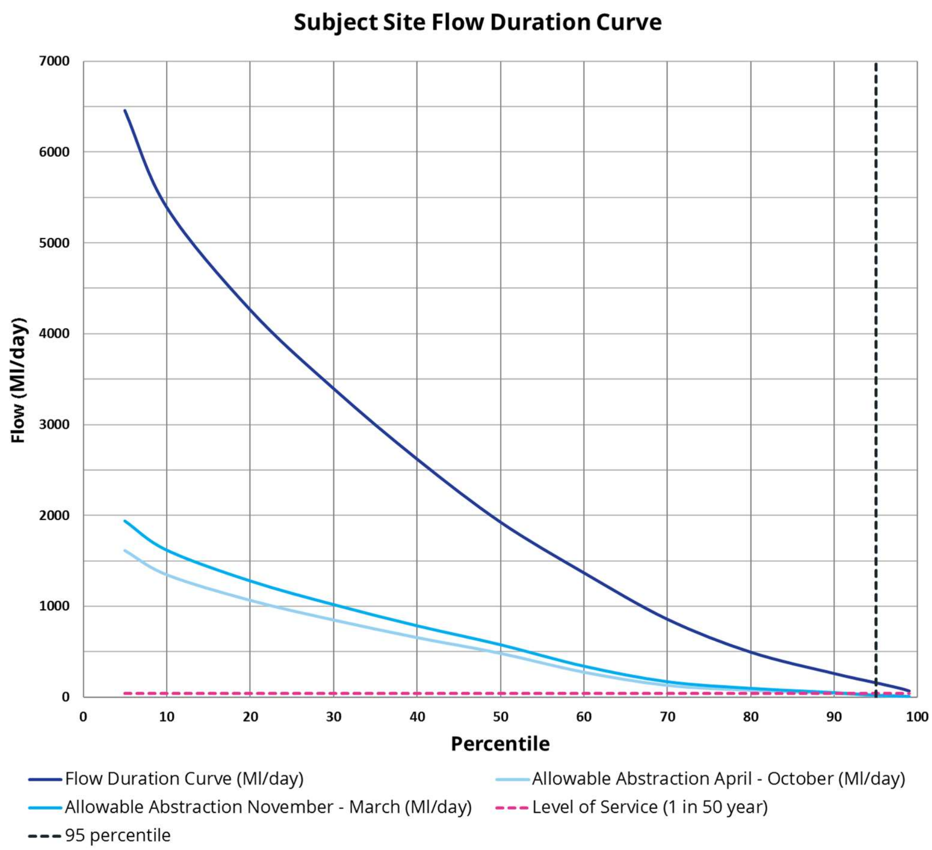


Figure 1-8 Flow Duration Curve compared to allowable abstraction and yield across all percentiles

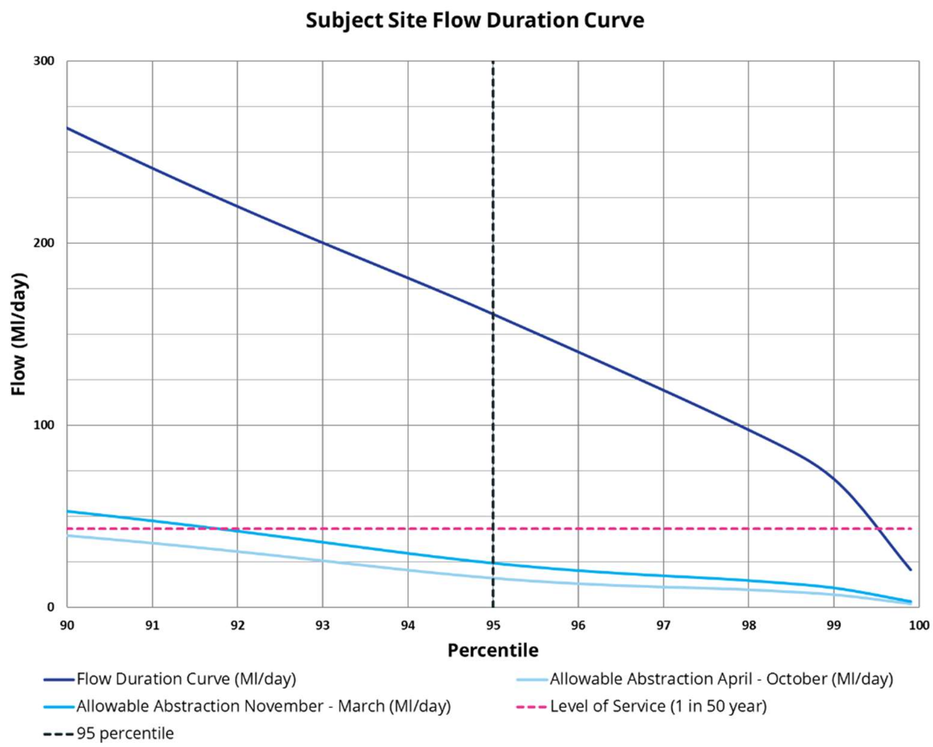


Figure 1-9 Flow Duration Curve compared to allowable abstraction and yield Q90 – Q100

1.3.2 Groundwater

Section 1.2.4 above provides an overview of groundwater resources in Ireland, how they are categorised, how groundwater contributes to Irish Water assets, and the importance of and overall approach in determining ZOCs for sources.

The defined ZOC provides an estimate of the reliability of the yield, which can be compared to the current production or future demand scenarios. The abstraction rate is an important piece of information that influences the definition and the estimates of yield. In the established schema, ZOC delineation requires an abstraction plus 150% to estimate yield, the potential to expand or meet future demand scenarios or critical dry weather periods.

Note that the yield is based on the known abstraction rate which is governed by a number of factors including the borehole construction and configuration.

"Yield" is a term that is used in the context of how much water can be abstracted from a borehole. It ordinarily refers to the normal abstraction possible in a 24-hour period. The yield depends on the aquifer, borehole dimensions and configuration, pump size, pump setting and pump efficiency, weather conditions, and can vary seasonally or over a longer period of time, owing to other factors such as over-abstraction, chemical reactions or pump behaviours. For instance, yield can decline owing to oxidation of iron, which can clog pumps and borehole screens.

After drilling a borehole, the aquifer and borehole are both tested to determine hydraulic properties such as transmissivity, permeability and storage. The abstraction rate and drawdown are monitored, and the reliable long-term yield of the borehole is estimated from the test observations. The methodologies and associated assumptions are described in detail in several hydrogeological text books, for example *Water Wells and Boreholes* by Misstear *et al*. (2017).

It is likely that most, if not all, of the existing boreholes have undergone some form of testing and have also been in operation for some time. There are some reports available however in most cases, there is no reliable information on the tests carried out. The test that were completed were often 72-hour tests with the barest information recorded. It was normal practice to simply see, based on the driller's estimate of yield, anticipated abstraction rate and the pump that was installed for the test, what sort of yield could be obtained from the borehole.

The current abstraction rate is useful as it is often related to that first primitive test and is also the rate established over a period of time, which normally has not declined. Thus, there is a correlation between the existing abstraction rate and long-term yield. Therefore, for examining the existing groundwater assets, establishing ZOCs and accurate information on yield can provide useful information on determining yields. Comprehensive hydrogeological reports, of which there are many for the major well fields, normally describe yield.

1.3.2.1 Yield

The ZOCs are spatial approximations based on available information on the source, interpretations of topography, geology, groundwater flow, vulnerability, chemistry and water quality.

A water balance is conducted, using the abstraction rate (150%) and recharge (estimated from the GSI recharge maps). This water balance provides an area needed to supply the yield and can be compared to the delineated ZOC to see how much bigger or smaller the ZOC area is than the area required by the water balance. Thus, the sustainability or safe yield, which does not impact the ecological status can be described.

The assumptions need to be described and a statement made regarding the conceptual model of the source and its ZOC. This is important to put into context the yield, reliability and, particularly, to highlight any issues and uncertainties. For instance, a ZOC that is much larger than the current abstraction may suggest that the potential yield or current yield is safe and sustainable. However, that may be misleading as, for instance, borehole configuration may be constrained and limit any production, or insufficient information may have been available to define a more appropriate ZOC.

On the other hand, a ZOC may be much smaller than the current abstraction. That is, the area alone cannot provide sufficient replenishment of a groundwater abstraction. This could be, for example, because the borehole is next to a river and it is actually the river that is providing much of the recharge.

WFD obligations require the achievement of “Good” groundwater status. The tests under which groundwater status is tested include a quantitative test, which is done under a water balance test and requires information on the abstraction. The EPA carries out this performance test. In this way, the WFD can influence abstraction, where groundwater status is “Poor” or “At Risk”. Estimates of individual yields do not need to reference this water balance test, however regional assessments of groundwater yields and proposed abstractions would be required to adhere to WFD requirements.

1.4 Calculation of Deployable Output

Determining the hydrological yield and allowable abstraction of sources is the starting point for determining the DO. As outlined in Figure 1-1 however, DO is also influenced by Water Treatment Plant (WTP) constraints.

1.4.1 Water Treatment Plant Constraints

The WTP and the trunk main system transferring water from the plant to the distribution system have their own maximum capacities. Similarly, for groundwater sources the borehole configuration will have an associated maximum capacity. These maximum capacities will ultimately limit the volume of water that can be obtained from the source.

1.4.2 Process Losses

Process Losses are incurred through the treatment process as water from the source is treated at a WTP to ensure it is safe for human consumption. Process Losses represent a loss to the DO and are a function of the treatment type at the WTP.

The three main types of WTP operated by Irish Water are:

- WTP which include some type of chemical coagulation and filtration process, where losses would be moderate to high;
- WTP which just have filtration plus disinfection, where losses would be moderate to low; and
- WTP which have disinfection only where losses would also be moderate to low.

The Process Losses for the various treatment types are outlined in Table 1-6 below.

Table 1-6 Percentage Process Losses accounted for the different treatment types

Water Treatment Plant treatment type	Process Losses (%)
Coagulation, flocculation, clarification and filtration (includes waste residuals)	7.5
Filtration and disinfection	3
Disinfection only	1

1.4.3 Licence constraints

As discussed in Appendix G, abstraction licenses are not common in current operations but, where applicable, the restrictions have been incorporated in our planning. We have assumed that current abstractions will be issued with licenses that permit their current level of operation. Therefore, for existing sources, we have set the constraint on the DO as the lesser of the current operation or the hydrological yield, rather than the allowable abstraction. However, if we were considering a new source, we would set the constraint on the DO as the allowable abstraction.

1.4.4 Calculation of Deployable Output – Simple WRZs

In simple WRZs, when the hydrological yield and allowable abstraction of a source are estimated, the DO is determined as the lesser of: the hydrological yield, the allowable abstraction, any licence constraint and the WTP production capacity, less the Process Losses.

For example, if the allowable abstraction from a watercourse is 40Ml/d and the WTP and distribution system has a capacity to treat and distribute 10Ml/d, then the DO is 10Ml/d. If the process losses at the WTP are 3%, then a 10.3 Ml/d abstraction of raw water is required to produce 10Ml/d for supply. In this same example, if there is an abstraction licence in place with a limit of 7.5Ml/d, the DO reduces to 7.3Ml/d (i.e. 7.5Ml/d minus 3% process losses as the licence restricts raw water abstraction).

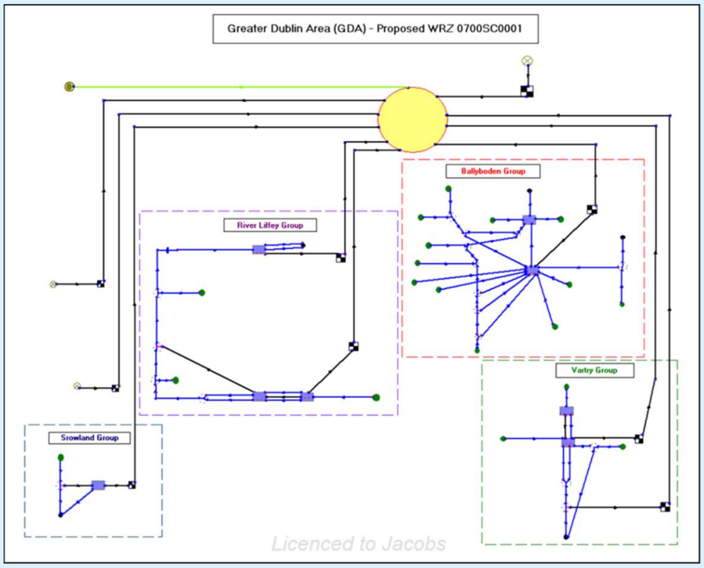
Deployable Output is firstly calculated for the current scenario. However, to feed into the Supply Demand Balance (SDB) over the 25-year horizon, estimates of supply in 2044 will also be required. This has been carried out by taking into consideration potential climate change impacts to the hydrological yield and allowable abstraction, which is discussed in Appendix F.

1.4.5 Calculation of Deployable Output – Complex WRZs

In complex WRZs where we have a number of sources and/or types of sources which have a different response to low-flow conditions, water resource models are required to calculate the DO as a result of combined operation. We have adopted an industry standard modelling tool called Aquator to develop our strategic systems. The model allows us to represent the current water supply system and derives the combined yield of the selected sources within each system assuming a “conjunctive use” within a Water Resource Zone. For example, if a WTP is supplied by both river and lake sources, raw water is abstracted from the river source during high flows only and from the lake source when flows in the river are below a certain threshold; the combined yield of the two sources could be higher than the sum of yields, if they were considered independently.

A summary example of the Aquator model approach is given in Box 1, based on the model developed for the GDA.

Box 1 Aquator Model of the GDA WRZ



As the GDA WRZ is a complex network consisting of nine individual water supplies, the supply has been modelled using a water resource planning tool known as Aquator. The Aquator model enables us to assess the deployable output for the combined supplies for all weather conditions (normal, dry, drought and winter), for an appropriate level of service.

The Aquator model simulates all of the existing and planned sources within the GDA WRZ to assess the capability of these resources to supply increasing levels of demand, and determines the deployable output from our sources for a target level of service. As outlined in the Volume 1 Report, we are working towards delivering a 1 in 50 Level of Service. Due to the strategic importance of water supply in the GDA, the impact to customers and to potential future investment if we cannot guarantee supply without outages, the proposed deployable output includes an allowance for 14 days reserve storage at Poulaphuca and Vartry reservoirs. This limits the potential impact of a failure of one of our large WTPs during a Dry Year Critical Period or Dry Year Annual Average.

The Aquator model was used to develop the deployable output for the following scenarios:

- **2019 with current capabilities,**
- **2022 with planned works implemented, and**
- **2055 with climate change impacts applied.**

The results for these scenarios were incorporated to determine the deployable output for intermediate years. The baseline model considers all abstractions operating as per current arrangements outlined in Table A9.3.2.1. To understand the sensitivity of our current supplies to external factors such as climate change and potential tighter abstraction legislation, we have also run these various scenarios through the model.

1.5 Summary of water availability in Ireland

As noted, the hydrological yield and allowable abstraction have been determined for all 293 surface water sources in Ireland. Figure 1-10 and Figure 1-11 demonstrate the split of sources.

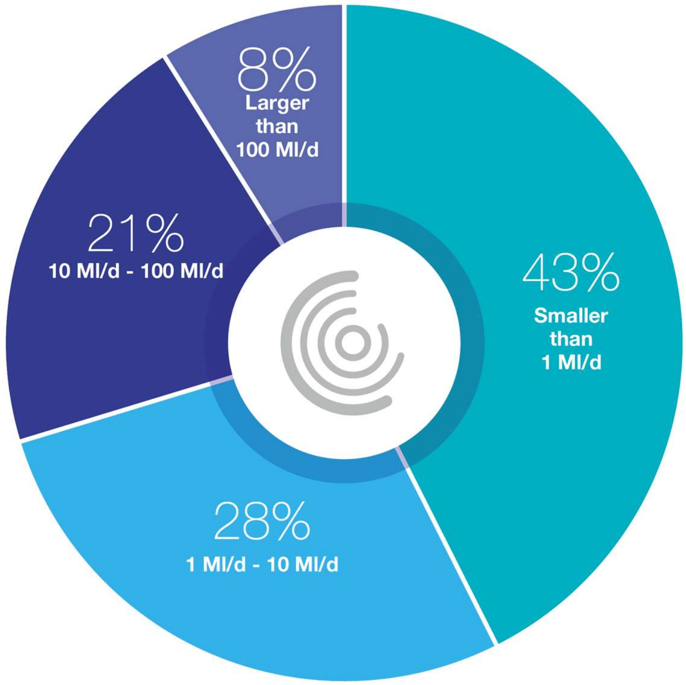


Figure 1-10 Percentage of sources by "hydrological yield"

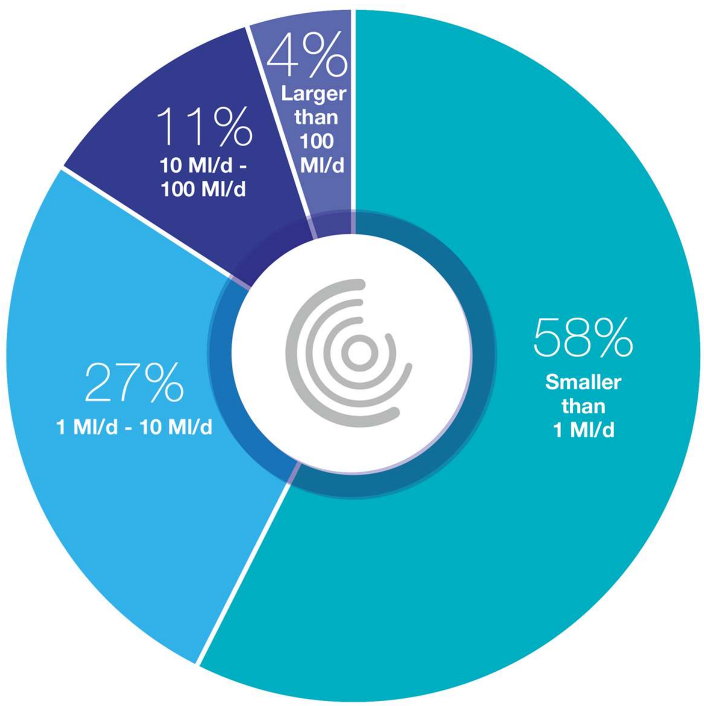


Figure 1-11 Percentage of sources by "allowable abstraction"

1.6 Steps to improve supply assessment

As noted previously, there are only a small number of gauges in surface water sources with records greater than 50 years in Ireland. There are also a limited number of gauges located in small catchments, where we have abstractions. More gauging stations and longer records of data would reduce the uncertainty associated with the flow estimates at our sources and give us a better understanding of local hydrology and the water available for abstraction.

The most robust method to determine hydrological conditions of a proposed abstraction location is to obtain site-specific gauging, which can be used to scale a flow record from a suitable nearby gauge. This level of detail, along with modelling of the potential effect the abstraction will have on water levels, may be required in instances, where an abstraction may impact a Habitats Directive site or where there is no suitable hydrologically similar gauged catchment. Collecting this type of data could take several years to complete.

One of the most important steps with respect to groundwater supply assessment is to develop continuous source water level and flow monitoring to calculate deployable output estimates from direct observations.