WAT-PS-10 Assigning Groundwater Assessment Criteria for Pollutant Inputs – Draft for Consultation

Annex 3 Recommended assessment approach

For activities that SEPA consider pose a high hazard, a site-specific risk assessment is required to determine if the objectives have been met. This annex sets out SEPA's recommended approach for undertaking such an assessment.

The Standards that will require assessment will depend on the nature of the substance and whether the assessment relates to current / new activities or to historical land contamination.

Table 3 sets out which groundwater standards apply when undertaking assessment of impacts on the water environment. Note that other criteria may also be taken into account when setting compliance limits or deriving remedial targets (see Section 7).

Table 1 - Overview of applicable groundwater standards for impact assessment

Type of Substances	Hazardous Substance Input Standard	Groundwater Pollution Standard	Groundwater Status Standard
Hazardous Substances	Always	Only for historical land contamination where Hazardous Substance has already entered groundwater	Only for historical land contamination where Hazardous Substance has already entered groundwater
Non-Hazardous Substances	Not applicable	Always	Only for surface waters, abstractions and GWDTEs

A3.1 General approach

The recommended assessment methodology is based on a source-pathway-receptor approach, adopting a phased approach using the following tiers:

Tier 1 Compare source concentrations with relevant standards

Tier 2 Compare predicted concentrations at the relevant assessment point with the relevant standards taking into account dilution only

Tier 3 Compare predicted concentrations at the relevant assessment point with the relevant standards taking into account natural attenuation

Dilution (Tier 2) does not apply to the Hazardous Substance Input Standard since this standard applies at the base of the unsaturated zones, immediately prior to entry into groundwater.

Table 2 - Overview of applicable assessment tiers for groundwater standards

Assessment Tier		Hazardous Substances Input Standard	Groundwater Pollution Standard	Groundwater Status Standard
1	Screening	Yes	Yes	Yes
2	Dilution	No	Yes	Yes
3	Natural attenuation	Yes	Yes	Yes

The level of detail required for the assessment should be proportional to the risk posed by the source and the sensitivity of the receptors. If site-specific data is not available, conservative assumptions based on literature values should be adopted. All relevant assumptions must be stated and justified.

SEPA recommends that site-specific risk assessments are undertaken by groundwater professionals with appropriate qualifications and experience.

A3.1.1 Pollutant linkages

The generally accepted procedure for assessing risks to water quality is to use the concept of source-pathway-receptor linkages.

The movement of a substance in the subsurface varies according to the physical and chemical characteristics of the substance and the local hydrogeological regime. Characterising the fate and transport of an input requires development of a site-specific conceptual model. In this context, a conceptual model is the identification and characterisation of the process and/or processes which cause migration of the substance(s) between source and receptor(s), together with the major limits and boundaries on these processes.

Factors that must be considered include:

- properties and geometry of the source
- unsaturated and, if required, saturated zone migration and attenuation
- receptors that could be affected
- where the potential impact will be assessed
- what assessment limit to use.

A3.1.2 Source characterisation

The source(s) must be characterised as part of the conceptual model. Both the geometry and the composition of the source must be considered.

For proposed new inputs (i.e. not yet built), the source area should be characterised based on the system design and specification.

For existing inputs, the source area should be characterised based on the available evidence, which might include:

- Details of the system design and construction (if known) for active discharges (e.g. soakaways) or for engineered systems (e.g. PPC landfills)

- Desk study and / or ground investigation in accordance with BS5930:2015 +A1:2020 and BS10175:2011+A1:2013 for historical passive inputs (e.g. land contamination).

A3.1.3 Pathway characterisation

The pathway(s) between the point of entry to groundwater and the relevant receptors must be characterised as part of the conceptual model.

Constraints on contaminant migration may be taken into account provided they are appropriately justified. There may be physical constraints on contaminant migration, such as hydraulic barriers to groundwater flow or major discharge zones such as the sea or a river. Consideration should also be given to the potential for preferential pathways (natural or man-made) to exist that may influence contaminant migration.

Attenuation processes in the unsaturated and saturated zone between the source and the receptor may be taken into account provided they are appropriately justified (see A3.4 for further details). Degradation should only be assumed to occur where hydrogeological conditions indicate that it is likely to occur. Both the original contaminant and its daughter products should be taken into account in the assessment.

A3.1.4 Receptor characterisation

The key receptors requiring consideration include:

- Groundwater (for hazardous substances only)
- Potential future groundwater resources (for both hazardous and non-hazardous substances)
- Surface waters
    - Rivers and streams
    - Lochs
    - Coastal and transitional waters
- Existing abstractions
- Groundwater dependent terrestrial ecosystems.

A3.1.5 Calculation of average annual concentrations

The following guidelines are recommended to be adopted when calculating annual average concentrations for comparison with the groundwater standards.

a) Annual averages in source concentrations and loadings may be calculated on both a temporal and spatial basis.
b) Annual averages in concentrations in groundwater at the assessment point should be calculated on a temporal basis only. Spatial averaging within the plume is not recommended.
c) The minimum number of data points required will vary on a site-specific basis, taking into account the variability of the dataset and the level of risk to the water environment. Any potential seasonal or other temporal variations in the dataset should be taken into account.
d) Parameters varying by more than two orders of magnitude are usually recommended to be calculated using a geometric mean, rather than an arithmetic mean.
e) Values that are less than the limit of detection should be assumed to be equal to the limit of detection.
f) Potential outliers should only be excluded from the dataset if there is supporting evidence available to justify their omission, such as a documented problem with the sampling /analysis or results of more detailed statistical analysis. Caution in the treatment of outliers is particularly required when assessing small datasets.
g) When undertaking probabilistic predictive modelling, the 50%ile value is not necessarily equivalent to the annual average. SEPA recommend the 95%ile value is usually appropriate for comparison with the relevant standard.

Alternative statistical approaches may be acceptable provided they are appropriately justified.

A3.2 Tier 1 Screening

Tier 1 assessments involves comparison of concentrations within the source with the relevant groundwater standards.

If the source concentration does not exceed any of the relevant groundwater standards then no further assessment is required.

If the source concentration does exceed the relevant standards, the assessment should proceed to Tier 2.

A3.3 Tier 2 QRA (dilution only)

Tier 2 assessment requires a quantitative risk assessment (QRA) to determine whether dilution is sufficient to prevent the standards being exceeded.

This requires comparison of input loading rates with the hydrogeological regime to assess potential dilution.

The methodology for the assessment of dilution varies depending on the receptor being assessed. This section sets out the recommended approach for each type of receptor.

If the Tier 2 assessment indicates that there is potential for the relevant standard to be exceeded, either currently or in the future, even once dilution is taken into account, then the assessment should progress to Tier 3.

A3.3.1 Input loading

The load of contamination being added to groundwater per day from the source should be calculated. This requires consideration of the nature and geometry of the source and the rate at which substances will enter groundwater.

The geometry of the source area should be based on the spatial extent of:

- Active discharge to ground; or
- Leachable substances in soils or wastes; or
- Non-aqueous phase liquid (NAPL).

The nature of the source will influence how the loading rate to groundwater (concentration x flow rate) should be estimated – see Table 5. Both concentration and flow rate should be considered as annual averages, except for abstractions for human consumption where maximum values should be used.

The use of site-specific infiltration and recharge rates is preferred. Literature vales will require adequate justification.

Source composition and concentrations may change over time. Temporal trends in source concentrations may be taken into account in predictive modelling of future impacts provided this can be appropriately justified.

Table 3 - Estimation of source input loading rates

Source Type	Concentration	Flow Rates
Active discharge to ground	Effluent concentration (measured or calculated)	Discharge rate
Leachable soils or wastes	Leachable concentration (measured[1] or calculated)	Recharge rates multiplied by source area for sources located above water table Groundwater flux passing through source for sources located below water table
NAPL	Solubility limit[2]	Recharge rates multiplied by source area for NAPL located above water table Groundwater flux passing NAPL located at or below water table

A3.3.2 Accounting for upgradient groundwater quality

A3.3.2.1 Naturally elevated background concentrations

Where the background groundwater upgradient of the site being assessed contains naturally elevated concentrations, then site-specific values may be adopted in accordance with Annex 2.4 instead of applying the Hazardous Substance Input Value and Threshold Value set out in Annex 2.1.

A3.3.2.2 Elevated background concentrations due to anthropogenic contamination

The groundwater standards apply irrespective of any background anthropogenic contamination already present in the groundwater.

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[1] In accordance with BS EN 18772:2014 for soils or BS EN 12457:2002 for wastes.

[2] Where mixtures of substances are present within a NAPL, the solubility of the individual substances may be adjusted in accordance with Raoult's Law.

Where background groundwater concentrations upgradient of the site being assessed are already impacted by anthropogenic contamination[3], this must be taken into account during the quantitative risk assessment process. SEPA recognises that levels of background contamination are often not within the control of site owners or operators. However, groundwater resources do not have an infinite capacity to accept inputs before the groundwater becomes no longer suitable for future potable use.

If the background contamination does not yet exceed the relevant groundwater pollution or status standard, the input being assessed must not result in the standard being exceeded. The ability of the groundwater to accept additional inputs will be constrained. Upgradient groundwater concentrations should be taken into account when calculating acceptable source concentrations, including consideration of any significant temporal trends. Natural attenuation within both the unsaturated zone and the saturated zone may be taken into account provided this can be adequately justified.

If the background contamination already exceeds the relevant groundwater pollution or status standard, significant additional inputs will not be permitted. The input concentration must not exceed the standard at the point of entry into groundwater. Natural attenuation within the unsaturated zone only may be taken into account provided this can be adequately justified.

The input to groundwater being assessed must not result in the groundwater body becoming poor status or prevent a groundwater body already at poor status from being restored.

Additionally the input to groundwater being assessed must not result in any additional adverse impact to surface waters, abstractions or wetlands.

A3.3.3 Assessing impacts on future groundwater resources

When assessing impacts on future groundwater resources, the combined area of both the source and the predicted maximum extent of the associated downgradient

[3] This includes impacts to upgradient groundwater quality due to anthropogenic atmospheric emissions.

plume (see Figure 5) should be compared with the relevant assessment areas (1 ha for pollution or 20 ha for status).

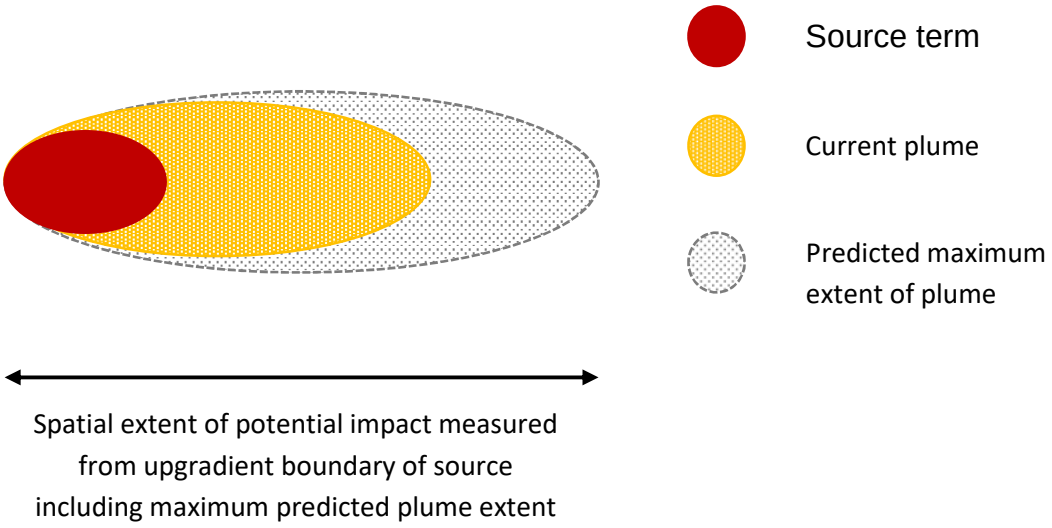

Figure 1 - Assessing spatial extent of potential impacts on future groundwater resources

For the purposes of this assessment, the edge of the plume will be considered to be the point at which the concentration is equal to the Threshold Value[4].

Many commonly used quantitative risk assessment methods involve 2-dimensional equations or models that simulate a vertical cross-section of the source and plume. To aid such calculations, equivalent downgradient assessment points may be assigned, taking into account the source area geometry. The equivalent assessment point distance must be measured from the upgradient boundary of the source in the direction of groundwater flow. Thus for larger source areas, the equivalent assessment point may be located within the source area.

Equivalent assessment point distances for different source size thresholds are set out in Tables 6 and 7 for pollution and status respectively. The maximum acceptable equivalent assessment point distances are 500m for pollution and 4km for status.

Table 4 - Equivalent assessment point distance for future groundwater resource pollution standard

[4] Or natural background concentrations when this exceeds the Threshold Value.

Source width perpendicular to groundwater flow (m)	Equivalent assessment point for pollution: Distance from upgradient boundary of source (m)
<20	500
20-50	200
50-100	100
>100	50

Table 5 - Equivalent assessment point distance for future groundwater resource status standard

Source width perpendicular to groundwater flow (m)	Equivalent assessment point for status: Distance from upgradient boundary of source (m)
<50	4000
50-100	2000
100-200	1000
200-500	400
>500	200

The depth of the equivalent assessment point should be defined on a site-specific basis, taking into account the local hydrogeological setting, so as to be representative of the vertical centreline of the plume (i.e. the highest concentration in the vertical dimension). The exception to this is where the centreline of the plume is located within superficial deposits that are not classed as having future groundwater

resource potential, in which case the equivalent assessment point should be located at the top of the underlying groundwater resource receptor (see Figure 1).

If the equivalent assessment point is located beyond the coast (mean high water springs tidal limit), the future groundwater resources need not be considered as a receptor. The groundwater should be considered as a pathway to the coastal or transitional water body receptor.

If the equivalent assessment point is located on the opposite side of a large river or loch from the source, further assessment is required. If it can be demonstrated that the majority of the downgradient plume enters the surface water body as baseflow, then groundwater may be considered as a pathway rather than as having future groundwater resource potential. However, where the geological and hydrogeological evidence suggests that the majority of the plume may pass beneath the surface water feature, then future groundwater resources should be considered as a receptor. The assessment should be based on site-specific evidence obtained from site investigation and/or groundwater and surface water monitoring. In the absence of plausible site-specific evidence, SEPA recommend adopting a precautionary approach.

A3.3.4 Assessing impacts on surface waters

Surface waters are defined by the WFD as all inland waters (except groundwater); transitional water, and coastal waters. For these receptors the assessment point is located in the surface water beyond the mixing zone (i.e. taking dilution into account). The actual assessment point chosen will depend upon the type of surface water feature.

The assessment concentrations to be used for surface waters are set out in WAT-SG-53 Environmental Standards for Surface Waters.

The groundwater pollution standard for surface water impacts is considered to be exceedance of the relevant surface water quality standard in the surface water beyond the mixing zone due to groundwater inputs.

Calculation of dilution in surface waters is only required:

- If the surface water feature is located within the equivalent assessment distance set out in A3.3.3; and
- If the predicted groundwater concentrations at the point of entry to surface waters exceed the surface water assessment concentrations.

The groundwater status standard for surface water impacts comprises two elements:

- Deterioration (actual or predicted) in surface water status
    - Exceedance of the relevant surface water quality standard in the surface water body[5] beyond the mixing zone over a specified spatial extent of the water body as set out in Schedule 4 of The Scotland River Basin District (Standards) Directions 2014.
- Groundwater inputs account for at least 50% of the surface water quality impacts[6].

For surface water dilution calculations the input from groundwater should be considered as arising from a pipe discharge. Instantaneous mixing in the surface water may be assumed for the purposes of undertaking mass balance calculations.

SEPA uses the digital river network (DRN[7]) for assessing inputs into the surface water environment. Therefore, for small watercourses, the assessment point is the point at which the tributary enters the river on the DRN.

Surface water calculation methods to determine the acceptable load from groundwater depend upon the type of water body:

- **Rivers** - as described in WAT-RM-03 Regulation of Sewage Discharges to Surface Waters and WAT-SG-03 Data Analysis and River Quality Planning Models.

[5] Only water bodies used for classification under WFD will be considered; impacts on tributaries will only cause groundwater status failures if the main water body is or is predicted to be impacted to the point at which deterioration in status below Good could occur.

[6] Takes into account that 95th percentile baseflow index for Scottish water bodies is <0.5.

[7] The DRN is published by the Centre for Ecology & Hydrology (CEH) and is based on 1;50,000 Ordnance Survey mapping.

- **Lochs** – for phosphorous as described in WAT-RM-37: Regulation of Phosphorus Discharges to Freshwater Lochs[8].
- **Coastal and transitional waters** - as described in WAT-SG-11: Modelling Coastal and Transitional Discharges or alternatively as outlined below:

Dilution in coastal & transitional waters = (2 x W x TR x 100) / Q

Where:

- W – Groundwater plume width in m
- TR – Tidal range in m, i.e. height difference between mean high and low water
- Q – Groundwater seepage rate in m^3/d, i.e. rate at which groundwater emerges from ground at low tide
- Calculation assumes a mixing zone of 100m measured from low tide and two tidal cycles per day.

Alternative approaches to calculating dilution[9], including detailed hydraulic modelling, may be acceptable.

The capacity of the surface waters, taking into account other inputs, should be taken into account in accordance with WAT-RM-21 Allocation of Capacity and Protection of the Water Environment.

Please note: diffusion of poor quality groundwater through the hyporheic zone may cause harm to some sensitive species living in or on sediments (for example, fish eggs, freshwater mussels). SEPA considers that significant harm is more likely from larger sources. In order to minimise the risk to these sensitive species, we will automatically consult SNH where discharges occur in or to Special Areas of Conservation (SACs) or Special Protection Areas (SPAs), and will also consult SNH on selected point source discharges authorised by a licence or permit. Where SNH indicates the presence of a sensitive species and where an alternative EQS is defined by SNH, this will be applied at an assessment point located in groundwater immediately before entry into the surface water; that is, dilution will not be

[8] For non-nutrient inputs his can be considered to be exceeding the environmental standard over an area greater than or equal to $100x100x\pi$ m^2

[9] For example as described in Mixing in Inland and Coastal Waters by Fischer *et al* 1979.

considered. These parameters can be measured, modelled, or estimated as appropriate to the level of risk posed by the site. Compliance will be measured in groundwater immediately prior to entry into the surface water.

A3.3.5 Assessing impacts on abstractions

Where the assessment point is an existing abstraction, the assessment limit should prevent an increase in the level of purification treatment applied. This means that where treatment is not currently applied for the substance in question, the assessment limit should ensure that future treatment will not be necessary. Where treatment is currently applied to such an abstraction, the assessment limit should ensure that the level of treatment does not increase. In all cases upgradient concentrations must be taken into account.

Where an abstraction exists at or within the distance of the future groundwater resource assessment point, in addition to calculating of the concentration at the future groundwater resource assessment point, there must also be calculation of the concentration at the abstraction assessment point, prior to any treatment the abstracted water might receive. The assessment limit adopted should be such as to protect both receptors. Note that the groundwater pollution and status standards for abstractions are based on maximum, rather than annual average, values. Concentration trends must also be taken into account when assessing status.

Compliance will be measured in the abstracted groundwater (raw water) prior to any treatment this might receive.

Consultation with SEPA is recommended during assessment of impacts to existing abstractions for human consumption.

A3.3.6 Assessing impacts on groundwater dependent terrestrial ecosystems

Groundwater dependent terrestrial ecosystems (GWDTE), which are wetlands that are wholly or partially reliant on groundwater, can be damaged by contaminated groundwater.

There can be many pressures affecting a wetland, e.g. vegetation management, however this procedure only relates to chemical pressures transmitted through groundwater.

Criteria on which significant damage to a GWDTE is based is set out in EU CIS technical report no 6[10] . For example, for GWDTE that are part of the designation of Natura 2000 nature conservation sites, significant damage can equate to failure to meet conservation targets.

Groundwater nitrate threshold values are set out in the Scotland River Basin District (Standards) Directions. These values identify acceptable limits for groundwater nitrate concentrations in different wetland types at the relevant wetland assessment point. The standards are dependent on the type of GWDTE which is impacted. The wetland types are set out in these Directions.

Exceedance of these values does not automatically mean that the wetland that receives this water would be damaged, but that the risk of damage is significant.

The assessment point for the GWDTE should be:

- located at the up gradient boundary of the wetland in the relevant groundwater flow path; and
- in groundwater that is hydraulically linked to the GWDTE such that this groundwater is likely to be the irrigation source that critically supplies the GWDTE.

Where more than one groundwater layer is present at a GWDTE the vegetation composition of the GWDTE can often be used to identify the groundwater source. Advice should be sought where uncertainty exists, from a qualified wetland ecologist[11].

The nitrate standards set out in the 2014 Directions[12] should be applied to determine if the groundwater pressure is likely to be causing this significant damage where:

- a GWDTE is significantly damaged; and

[10] Technical report on groundwater dependent terrestrial ecosystems, December 2011, https://publications.europa.eu/en/publication-detail/-/publication/f7bd5cf8-c62c-41f6-8138-fe922a1f6410

[11] See Groundwater dependent terrestrial ecosystem threshold values

[12] Table 2 of Schedule 6 of The Scotland River Basin District (Standards) Directions 2014.

- in SEPA's judgment the characteristics of the damage are due to nitrate reaching the wetland from groundwater[13]; and
- there is a direct hydraulic linkage between the polluted groundwater body and the GWDTE.

Water quality standards for other pollutants specific to wetlands have not yet been developed. A qualified wetland ecologist will need to be consulted to assess if other pollutants could cause significant damage and the concentrations that may cause significant damage[14].

Compliance will be measured in groundwater immediately prior to entry into the GWDTE, with the compliance point located at the appropriate location and depth along the pathway to the GWDTE to monitor the pollutant plume.

A 3.4 Tier 3 Detailed QRA (natural attenuation)

Tier 3 assessment requires a detailed quantitative risk assessment (DQRA) to determine whether natural attenuation processes are sufficient to prevent the standards being exceeded. The DQRA must be supported by site-specific evidence obtained from site investigation and/or groundwater monitoring. Literature values may be used only if their relevance to the hydrogeological conditions at the site in question can be adequately demonstrated.

Unless previously explicitly stated otherwise (e.g. in A2.3), natural attenuation can be taken into consideration:

- In the unsaturated zone prior to entry into groundwater
- In the saturated zone between the source and the assessment point

Natural attenuation must not be taken into consideration:

- In the hyporheic zone when assessing risks to surface waters
- Within the surface water features

[13] A site specific assessment should be carried out where other (for example surface or air mediated) nitrate pressures are present to differentiate between damage caused by groundwater versus other nutrient sources

[14] pollutant criteria for water destined for human consumption may often be used to risk screen if these pollutants could cause significant damage

- Within the groundwater dependent terrestrial ecosystem

It must be noted that the subsurface has a limited and finite ability to retard contaminants. For inputs that will continue over long time scales (e.g. decades), it is recommended not to place significant reliance on retardation processes that might significantly decline, stop or be reversed.

Degradation may be considered only where the ground conditions are consistent with it plausibly occurring. The impacts of the resultant daughter products must also be taken into account.