FEHILY TIMONEY

CONSULTANTS IN ENGINEERING, ENVIRONMENTAL SCIENCE & PLANNING

NEW INN HISTORICAL LANDFILL SITE

TIER 3 ENVIRONMENTAL RISK ASSESSMENT HISTORICAL LANDFILL AT NEW INN, CO. GALWAY

Prepared for: Galway County Council

Comhairle Chontae na Gaillimhe
Galway County Council

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J5 Plaza, North Park Business Park,
North Road, Dublin 11, D11 PXT0, Ireland

T: +353 1 658 3500 | E: info@ftco.ie

CORK | DUBLIN | CARLOW

www.fehilytimoney.ie

TIER 3 ENVIRONMENTAL RISK ASSESSMENT

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Abstract: This report represents the findings of a Tier 3 assessment carried out at New Inn Historical Landfill, Co. Galway, conducted in accordance with the EPA Code of Practice for unregulated landfill sites.

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF FIGURES

Page

LIST OF TABLES

1. INTRODUCTION

1.1 Overview

Fehily Timoney and Company (FT) was appointed by Galway County Council (GCC) to carry out and prepare a Tier 3 risk assessment for New Inn historical landfill located at New Inn, Co. Galway. This Tier 3 refers to the:

- GCC Tier 1 risk assessment findings and classifications.
- Tier 2 Site investigation and testing and risk assessment (FT, 2020).

All FT risk assessments were carried out in accordance with the Environmental Protection Agency (EPA) Code of practice (CoP) - Environmental Risk Assessment for Unregulated Waste Disposal Sites guidance document.

1.2 Tier 1 Risk Classification

The Tier 1 Risk Assessment determined that the maximum risk score for New Inn Historical Landfill was 70%, resulting in a risk classification of **High (Class A)**. The highest score of 70% was applied to source-pathway-receptor (SPR) 8, referring to the potential of leachate migration to surface water receptor. With the exception of SPR1 (risk of leachate migration to surface water via combined groundwater and surface water pathways) which had a score of 42% (Moderate) all other risks were calculated to be low (<40%).

1.3 Tier 2 Site Investigation

FT completed a Tier 2 environmental risk assessment report. The report included site investigations, works included the following elements:

- Topographical Survey
- Geophysical survey (2D resistivity, EM31 Ground Conductivity and seismic refraction profiling)
- Installation of 2 No. groundwater monitoring wells
- Trial pits excavations
- Monitoring of groundwater at new and existing wells, surface water and landfill gas monitoring
- Factual reporting.

The findings of the site investigation found the waste comprised mixed municipal waste material that was deposited in a single infill area with an estimated footprint of 2,600 m^2. Trial pitting confirms waste material is relatively close to the surface, generally located underlaying topsoil with a shallow layer of made ground capping material present (average: 0.85m, min: 0.2m, maximum 1.6m thickness). The waste body does not have a fully engineered cap. A deposited waste volume of 10,400 m^3 was estimated based on site investigations. Applying an assumed waste density of 1.6 tn/m^3 this equates to 16,640 tonnes of waste.

1.4 Tier 2 Risk Classification and Tier 3 SPRs

The Tier 2 site investigation and risk assessment concluded that the risk rating of the site was Low (Class C). Applying the EPA scoring matrix, the highest single risk rating for the site was calculated to be 33% for source-pathway-receptor (SPR) linkage 8, which refers to leachate migration through a surface water pathway to surface water receptor.

The Tier 2 risk scores are presented in Table 1-1.

Table 1-1: Tier 2 SPR and Selected Tier 3 SPRs

SPR No.	Linkage	Normalised Score	Justification
Leachate migration through combined groundwater and surface water pathways			
SPR1	Leachate => surface water	23%	GSI describes the groundwater vulnerability as High to extreme. Intrusive S.I and geophysical survey suggest only a narrow band of overburden exits between the base of waste material and bedrock and potentially the underlying groundwater aquifer. The bedrock groundwater is classified by GSI as 'Locally important gravel aquifer - Lg' and 'Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones – LI'. Land drains are present at the site, and potential direct surface water pathway to the Raford River. The Raford_020 river (Status: Moderate) potential receptor.
SPR2	Leachate => SWDTE	12%	Raford River Bog NHA (Site Code: 000321), is located c.800m to the north-west of the site at its closest point.
Leachate migration through groundwater pathway			
SPR3	Leachate => human presence (private well)	31%	GSI describes the groundwater vulnerability as High to extreme. Intrusive S.I and geophysical survey suggest only a narrow band of overburden exits between the base of waste material and bedrock and potentially the underlying groundwater aquifer. The bedrock groundwater is classified by GSI as 'Locally important gravel aquifer - Lg' and 'Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones – LI'. No buildings or structures are located directly above estimated waste footprint area. Nearest residential dwellings are located less 50m south of the waste body.
SPR4	Leachate => GWDTE	10%	Raford River Bog NHA (Site Code: 000321), is located c.800m to the north-west of the site at its closest point.
SPR5	Leachate => Aquifer	19%	'Locally important gravel aquifer - Lg' and 'Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones – LI'.
SPR6	Leachate => Public Supply	31%	ZOC Rhynn Killeeneen protection area is located north of the site.
SPR7	Leachate => Surface Water	21%	The Raford_020 river (Status: Moderate) is located to the north of and may be hydrologically linked to the site.

SPR No.	Linkage	Normalised Score	Justification
Leachate migration through surface water pathway			
SPR8	Leachate => Surface Water	33%	Land drains are present at the site, and potential direct surface water pathway to the Raford River.
SPR9	Leachate => SWDTE	17%	Raford River Bog NHA (Site Code: 000321), is located c.800m to the north-west of the site at its closest point.
Landfill gas migration pathway (lateral & vertical)			
SPR10	Landfill Gas => Human Presence	25%	Nearest residential dwellings are located less 50m south of the waste body.
SPR11	Landfill Gas => Human Presence	0%	No buildings or structures are located directly above estimated waste footprint area.

1.4.1 Leachate migration to public water supply via groundwater pathway (SPR6)

A risk score of 31% was calculated for the SPR6 linkage which referred to leachate migration to public water supply.

The public water supply Zone of Contribution (ZOC), the ZOC Rhynn-Killeeneen is located north of the site. The ZOC encompasses sections of the Raford River (as a surface water fed drinking water supply) and is also located north of the site.

Although the defined ZOC does not encompass the historical landfill site, taking a precautionary approach it was determined that the site may still pose a potential risk to groundwater quality and drinking water quality via the locally important gravel aquifer at the site and in order to further assess the potential risk it is included in this Tier 3 DQRA.

The 'G131 New Inn' source protection area is in New Inn c. 0.95km to the north-east of the identified waste body and relates to a groundwater fed drinking water supply.

Groundwater monitoring conducted as part of the Tier 2 site investigation showed elevated concentrations of ammoniacal nitrogen, chloride, sodium and elevated conductivity when compared to upgradient wells and groundwater quality standards. This indicated that migration of leachate may be occurring and could be impacting on groundwater quality downgradient.

1.4.2 Leachate migration to surface water via and surface water pathways (SPR8)

Historical landfills were constructed adopting the approach of "dilution and dispersion". New Inn historical landfill does not include an engineered basal lining system. Presence of leachate at the landfill presents potential of the migration of pollutants from the site to the Raford River.

The Raford River forms part of a ZOC relating to a group water scheme water supply, taking a precautionary approach the potential impact on the water quality of this river is included in this Tier 3 assessment to further examine any potential risk.

2. TIER 3 QUANTITATIVE RISK ASSESSMENT

2.1 Tier 3 Overview

A Tier 3 assessment includes some form of quantitative risk assessment (QRA) either as a Generic Quantitative Risk Assessment (GQRA) or as a Detailed Quantitative Risk Assessment (DQRA).

This Tier 3 report further examines the Tier 2 (see Table 1-1) SPR linkages in relation to the following:

- SPR6 Leachate migration to public water supply via groundwater pathway (31%)
- SPR8 Leachate migration to surface water body via surface (33%).

Based on the outcomes of the GQRA/DQRA, suitable remediation measures and associated costs are determined, if required.

The 2020 site investigation findings and Tier 2 assessment concluded that the New Inn site presents a **low risk** to the environment, however with the presence of water supplies within 1km of the site and evidence of leachate migration from the site a DQRA was deemed necessary to further assess the potential risks to these receptors in this Tier 3 assessment.

This Tier 3 assessment report uses the following DQRAs to further assess the risks to surface waters, groundwater and to human receptors via gas migration:

- An assessment of the impact of leachate generation and migration to the groundwater supply based on potential contribution of the site to the groundwater supply based on estimated leachate generation rates and typical groundwater abstraction rates.
- An assimilative capacity assessment and a mass balance calculation were carried out to predict the potential impact on surface water quality from a leachate discharge to the Raford River.

Based on the outcomes of the DQRA, suitable remediation measures and associated costs are presented in Section 3. of this report.

The DQRAs rely on information gathered as part of the Tier 2 investigations. Relevant environmental characteristics considered in evaluating the site and carrying out this Tier 3 investigation are discussed in Section 2.2.

2.2 Existing Geological, Hydrogeological and Hydrological Environment

The risks to surface water drinking water supplies and groundwater drinking water supplies were identified as the primary potential environmental risks associated with the site. The application of the EPA risk calculation and scoring methodology is reliant on understanding the geological, hydrogeological and hydrological characteristics of the site and the surrounding environment.

An accurate understanding and rating of the geological, hydrogeological and hydrological characteristics of the site and environment are directly linked to determining the primary source-pathway-receptor linkages and potential impacts/risks associated with the site. The Tier 2 site investigation and risk assessment provided a firmer understanding of the site and surrounding environs. A summary of the relevant environmental characteristics considered in evaluating the site and carrying out this Tier 3 investigation are discussed below.

The historical landfill area was originally estimated by GCC to be approximately 1.5Ha and is in the ownership of Galway County Council however site investigation identified the waste to be only 2,600 m^2 (0.26Ha) in area. The historical landfill is located within the site of a former quarry that subsequently filled. The site is located adjacent to the R348, Athenry to Ballinasloe Road. The Raford River is located north of the site. New Inn town is located east of the site. There are no dwellings located within the site, however there is a housing located less than 50m south-east of the site.

The quaternary sediments at the site comprise gravels derived from limestones. During the installation of boreholes, the presence of made ground, sand, gravel, clay and limestone was recorded. At trial pits where waste material was not encountered natural materials (not made ground) was described as primarily sand and gravel soils.

The underlying bedrock at the site comprises the Lucan Formation (LU), described as dark limestone and shale. Bedrock was encountered during the installation of wells GW01 and GW02, at depths of 5.9m bgl (73.12 mAOD) and 4.4m bgl (73.92 mAOD) respectively.

The bedrock groundwater aquifer at the site is classified as being 'Locally important gravel aquifer - Lg' and 'Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones - LI'.

GSI mapping shows record of a well, located c.1km from the site and relates to a group water scheme. There are no Groundwater Drinking Water Protection Areas within the site boundary according to GSI. However, the Zone of Contribution (ZOC) Rhynn Killeeneen is located to the north of the site. The ZOC encompasses sections of the Raford River (as a surface water contributor to the supply) and located north of the site. The 'G131 New Inn' source protection area is located in New Inn, less than 1km from the site to the north-east. Other groundwater protection zones in the region are located over 5km from the site.

An EPA groundwater monitoring station ('New Inn No.1') is located at New Inn for the purpose of monitoring groundwater quality of the GWDTE-Rahasane Turlough groundwater body. Summary monitoring data provided by the EPA shows that groundwater quality is achieving standards for total ammonia, conductivity and nitrate but is failing to achieve quality standards for Chloride and ortho-phosphate, with respect to lower threshold values.

The GSI mapping shows that the groundwater body (GWB) underlying the site is the Rahasane Turlough GWDTE (SAC000322), a poorly productive bedrock aquifer. The most recent (2013-2018) Water Framework Directive quality status for the GWB is 'Good'. The WFD risk to groundwater quality was most recently classified as 'At Risk'.

The GSI Online mapping data set identifies the vulnerability of groundwater to contamination within the site area as being high (H). Groundwater vulnerability does vary considerably in the area changing from 'rock at or near surface' to 'low', north-east of the site.

The site is located within the Galway Bay South East catchment (Hydrometric Area: 29), Raford_SC_010 sub-catchment and Raford_020 sub-basin. The nearest surface water feature to the site is a small river (EPA Name:Raford_020 river) (Status: Moderate) which is located to the north/northeast of the site and flows in an east-west direction eventually converging with the Kilcolgan River (EPA Name) (Status: Bad) c.16km downstream of the site before discharging into Dunbulcaun Bay, south-west of New Inn town. Review of available mapping indicates and a survey of the site show the presence of land drains along the boundaries and in proximity to the site which indicate that there may be direct surface water connection e.g. land drains, ditches etc. between the landfill area and the River Raford.

Routine surface water quality monitoring is conducted by GCC at Bellafa Bridge monitoring station, on the BALLYMABILLA_010 river (a tributary of the Raford River) located c.500m downstream of the site and is the nearest EPA surface water monitoring station to the site. The most recent biological Q-Rating of surface water quality at this location (2018) was Q4, Good status. There is no record of upstream monitoring close to the site. Monitoring is also conducted at Raford Bridge c.5.5km west-south-west and downstream of the site on the Raford River. The most recent water quality status assigned for the Raford_020 river by the EPA was 'moderate'.

2.2.1 New Inn Groundwater Supply

In 2018, a formal Source Protection Zone (SPZ) report was prepared by Tynan Environmental and Geological Survey Ireland (GSI) for the New Inn Group Water Scheme and provides details on the characteristics and operation of this water supply and surrounding environment (see Appendix 1). The defined Group Scheme Preliminary Source Protection Area/Zone of Contribution is located c.0.95 km from the historical landfill waste body.

Historically, nine production wells have been drilled for this group scheme water supply however at the time of preparing the ZOC report only seven remain with three boreholes utilized for pumping (BH2, BH4 and BH6). The report states that these three wells are abstracting an average of 307 m^3/day from the shallow locally important sand and gravel aquifer. In May 2017, usage of the water supply reduced from an estimated average of 680 m^3/day between July 1996 - 1999 to 307 m^3/day. The water supply scheme serves approximately 385 domestic connections and 156 non-domestic connections. The wells are pumped automatically via a level response switch in the raw water reservoir (before treatment) which has a storage capacity of c.33m^3. The raw water is pumped through a treatment system to a reservoir (640m^3 capacity) located in Lisnamoultan (c. 2km from New Inn). The treatment system comprises a three-medium pressure filter, ultra-violet (UV) disinfection and residual chlorine disinfection.

The three wells are located in the grounds of a community centre on the western edge of New Inn village. A map extract obtained from the SPZ report showing the locations of the abstraction wells is presented in Figure 2-1.

Figure 2-1: Location of New Inn Supply Wells

The abstraction rates for wells BH2, BH4 and BH6 were estimated to be 184 m^3/day, 61 m^3/day and 61 m^3/day respectively. The reported yields (m^3/d) (based on current sustainable rate) are stated as being *'184 in conjunction with BHs 4 and 6; 660 in conjunction with BH1'* with respect to BH2 and 61 m^3/day for boreholes BH4 and BH6.

The ZOC was delineated based on a combination of hydrogeological mapping and inferences and geological boundaries. Although only three of wells are operational the ZOC was defined assuming potential use of the other open wells.

The boundaries of the ZOC are shown Figure 2-2.

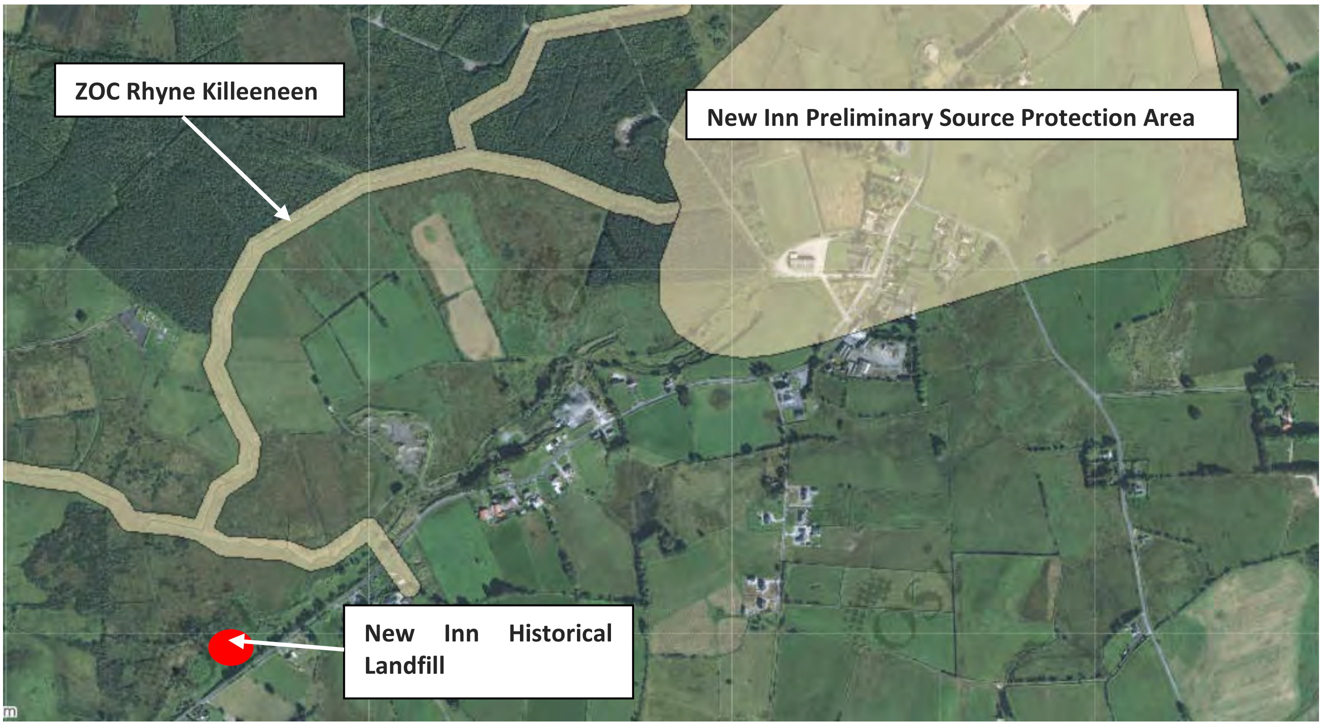

Figure 2-2: GSI mapping extract showing Group Scheme ZOC and Protection Areas

The GSI assessment also reviewed monitoring data of the raw, untreated groundwater from combinations of BH2, BH3 BH4 and BH6 and a single sample from BH S1, comparing results to both the drinking water limits (as per S.I No. 122 of 2014) and the groundwater quality threshold values (as per S.I No. 9 of 2010).

Monitoring results show the presence of total coliforms and faecal coliforms in concentrations above the drinking water limits, however these are likely associated with septic tanks and agricultural organic wastes, with the highest concentrations occurring in Spring-Summer due to land spreading of organic wastes. There were 8 exceedances of the of the drinking water limit of 0 cfu/100 ml, for clostridium perfringens.

Chloride was detected slightly above the groundwater regulations threshold value of 24 mg/l in one sample, with a concentration of 26.53 mg/l. Ammonium was found to be below both the drinking water limit of 0.3 mg/l NH_4 and the groundwater threshold value, with the exception of exceedances in one sample taken from BH S1.

The potassium:sodium ratio was found to be slightly above the applied indicator level of 0.4 in a single sample with a measured ration of 0.6. The report states that the background potassium:sodium ratio in most Irish groundwater is less <0.4 and often <0.3. The higher ratio was indicative of contamination by plant organic matter e.g. slurry.

The monitoring results of the 2017 BH2, BH4 and BH6 combined sample did not show any other naturally occurring elements present at concentrations considered harmful to human health.

With the exception of recorded biological contamination (total coliforms and faecal coliforms) water quality is generally good. Both of these contaminants are not attributable to leachate migration from the historical landfill.

An EPA groundwater monitoring station ('New Inn No.1') is located at New Inn for the purpose of monitoring groundwater quality of the GWDTE-Rahasane Turlough groundwater body.

Summary monitoring data provided by the EPA shows that groundwater quality is achieving standards for total ammonia, conductivity and nitrate but is failing to achieve quality standards for Chloride and ortho-phosphate. A summary of the baseline concentrations for the 2010 - 2015 trend period (2012 baseline) are presented in Table 2.1.

Table 2-1: Summary of EPA Monitoring Data at New Inn No.1 GW Station

Parameter	2012 baseline concentration	2018 Concentration
Ammonia-Total (as N) (mg/l)	0.018	0.028
Chloride (mg/l)	26.849	26.6
Conductivity@25oC (uS/cm)	728.667	705.667
Nitrate (as NO_3) (mg/l) (mg/l)	9.147	5.610
Ortho-phosphate (as P) (mg/l)	0.033	0.035

2.3 Conceptual Site Model (CSM)

A revised conceptual site model has been prepared as part of the Tier 2 assessment and is included below for reference. The revised CSM illustrates the identified potential groundwater and surface water pathways from the site.

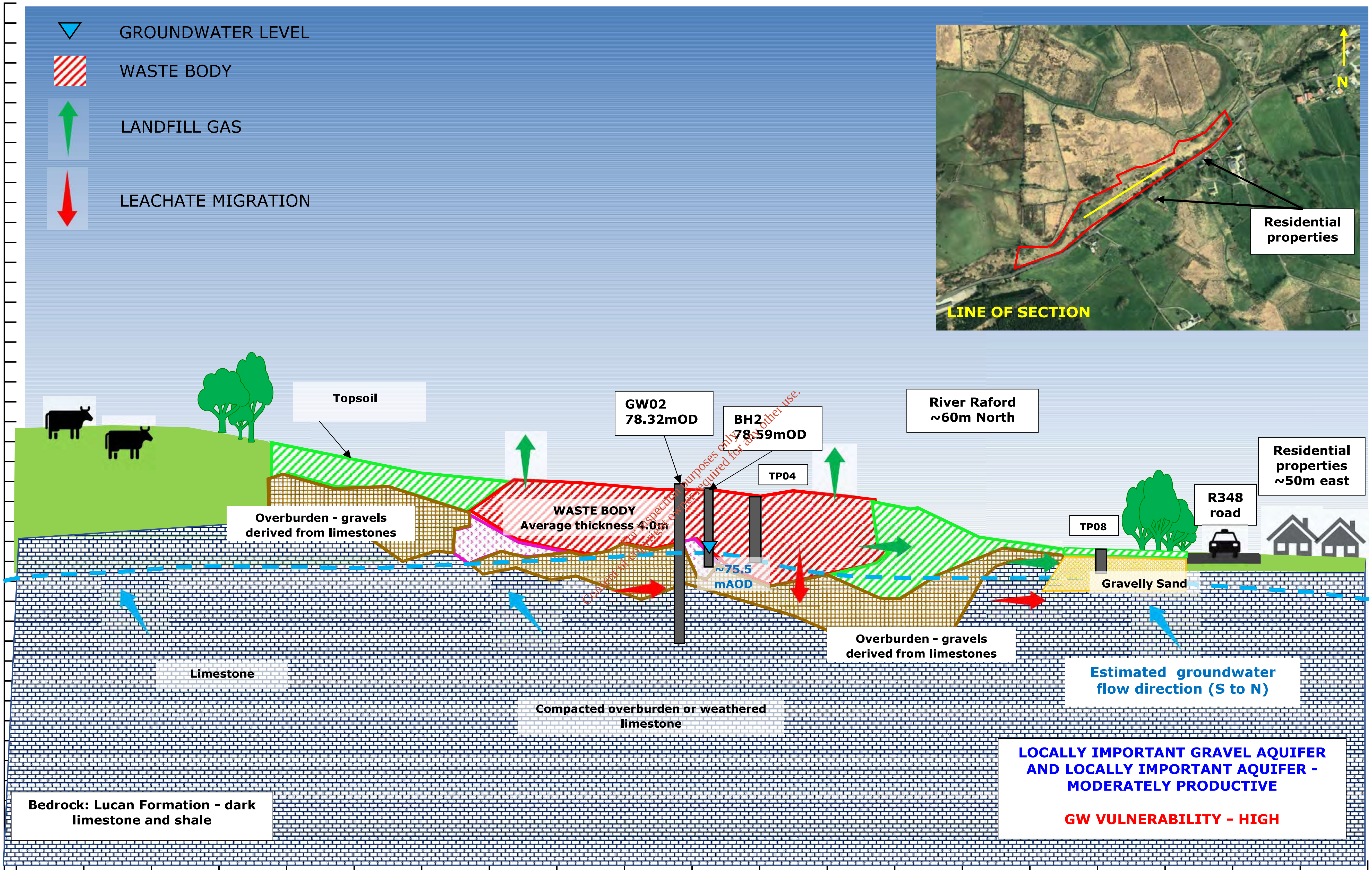

FIGURE 2.3a NEW INN HISTORIC LANDFILL CONCEPTUAL SITE MODEL

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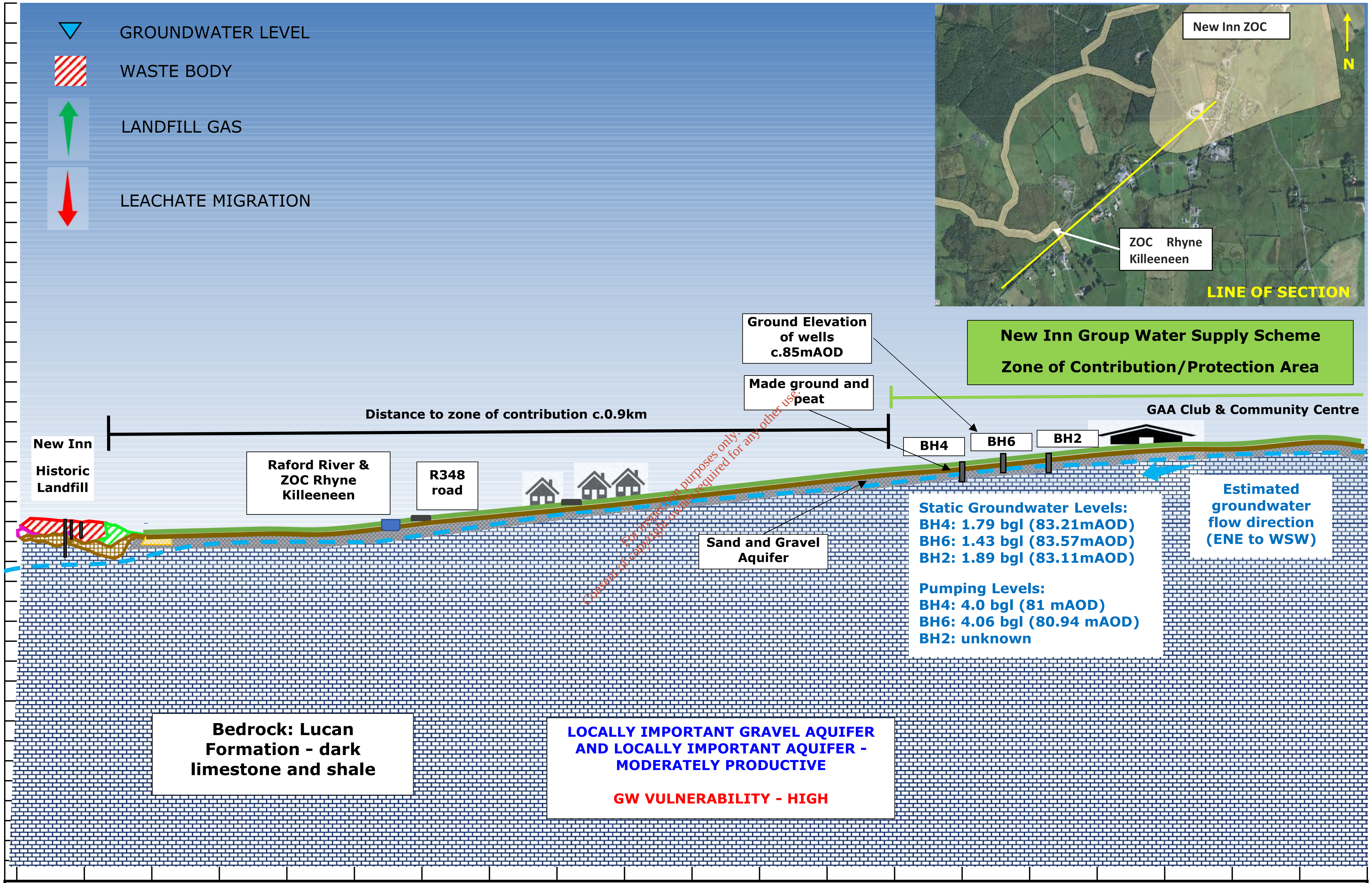

FIGURE 2.3b NEW INN HISTORIC LANDFILL CONCEPTUAL SITE MODEL

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2.4 Impact of Leachate on Groundwater and Water Supply

The bedrock groundwater aquifer at the site is classified as being 'Locally important gravel aquifer - Lg' and 'Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones - Ll'. The aquifer vulnerability is classified as being high at the site, indicating that the aquifer at this location is highly vulnerable to and highly influenced by rainwater infiltration at the site, and as subsequently by any pollutants migrating vertically to the bedrock/gravel aquifer. The generation of leachate via infiltration of rainwater through the shallow soil cap and underlying waste and migration of that leachate to the underlying groundwater and possible migration to surface water is a risk.

In July and August 2020, as part of the Tier 2 site investigation static groundwater levels within groundwater monitoring wells BH01 (existing), BH04 (existing), GW01, GW02 and leachate well BH02 were measured on two occasions yielding average static water/leachate levels of 74.5 mAOD, 72.3 mAOD, 73.3 mAOD, 73.1 mAOD and 75.5 at each well respectively. Groundwater level measurements, when compared against waste depths as per trial pit logs, indicates that the groundwater table is below the base of waste material.

The generation and subsequent vertical migration of leachate is driven predominantly by rainfall percolation inputs through the waste body as opposed to the lateral movement of groundwater through the waste body.

2.4.1 Potential Leachate Generation and Contribution

In quantifying the potential impact that the leachate generated at the historical landfill may have on the groundwater or surface water receptors it is important to estimate the quantity of leachate or contaminated groundwater produced at the site.

The vertical infiltration of rainfall above the site to the underlying groundwater aquifer is determined by the groundwater recharge rate at this site. The recharge coefficient applied by GSI for the area varies from 42.5% to is 85%, based on the classification of the subsoil permeability as high, high groundwater vulnerability, and the underlying aquifer being classified as a locally important sands and gravel aquifer. The recharge coefficient of 42.5% is applied where the 'hydrogeological setting description' is described as 'sands and gravel aquifer overlain by poorly drained soil'. The recharge coefficient of 85% is applied where 'hydrogeological setting description' is described as 'sands and gravel aquifer overlain by well-drained soil'. Applying these recharge coefficients to an effective rainfall rate of 724 mm/yr equates to recharge rate of 308 mm/year and 615 mm/year.

The potential leachate generation has been estimated applying these recharge coefficients.

Leachate Generation at 42.5% recharge

42.5% x 724mm/year = 308 mm/year or 0.308m/year (available rainfall for recharge over the landfill area

Aquifer Recharge Volume = Recharge x area of landfill

Aquifer Recharge Volume = 0.308 m/year x 2,600 m^2[estimated waste footprint area]

Aquifer Recharge Volume over landfill area = 801 m^3/year ***[2.2 m^3/day] [0.025l/s]***

Leachate Generation at 85% recharge

85% x 724mm/year = 615 mm/year or 0.615 m/year (available rainfall for recharge over the landfill area

Aquifer Recharge Volume = Recharge x area of landfill

Aquifer Recharge Volume = 0.615 m/year x 2,600 m^2[estimated waste footprint area]

Aquifer Recharge Volume over landfill area = 1,599 m^3/year ***[4.4 m^3/day] [0.05 l/s]***

The GSI mapping shows that the groundwater body (GWB) underlying the site is the Rahasane Turlough GWDTE (SAC000322), a poorly productive bedrock aquifer. This groundwater body is recorded as being 330 km^2 in area. The New Inn historical landfill waste footprint was determined to be 2,600 m^2 in area based on the findings of the site investigation. This accounts for <0.1% of the groundwater body, indicating that the generation of leachate and migration to the underlying is unlikely to have an impact on groundwater quality regionally, however the risk to groundwater quality locally remains.

The New Inn water supply abstracts on average of 307 m^3/day. Based on the leachate generation calculations shown above, assuming all groundwater was contributing to the water supply source, the estimated volume of aquifer recharge over the landfill area would be contributing **0.7% - 1.4%** of the daily drinking water supply provided by the New Inn water supply.

This determination shows the risk of landfill leachate negatively impacting the drinking water quality of the New Inn Water Supply is low with likely significant dilution of any leachate entering the ZOC and groundwater supply.

The New Inn ZOC Report also indicates the following static groundwater levels and pumping depths at abstractions wells BH2, BH4 and BH6. A comparison of groundwater levels and pumping against levels measured at groundwater monitoring wells located at the historical landfill shows that the landfill is located downgradient of the New Inn water abstraction wells and is therefore highly unlikely to contribute to the New Inn water supply source.

This is consistent with the New Inn ZOC as defined and shown in Figure 2-2.

Table 2-2: New Inn Abstraction Wells Groundwater Levels vs Landfill Groundwater Monitoring Wells

Abstraction Wells	Static Groundwater Level (mbgl)	Static Groundwater level (mAOD)[1]	Pumping Level (mbgl)	Pumping level (mAOD)
BH4	1.79	83.21	4.0	81
BH6	1.43	83.57	4.06	80.94
BH2	1.89	83.11	unknown	unknown
Landfill Groundwater and Leachate Monitoring Wells	**Static Groundwater Level (mbgl)**	**Static Groundwater level (mAOD)[1]**	**Pumping Level (mbgl)**	**Pumping level (mAOD)**
GW01	5.695	74.5	n/a	n/a
GW02	5.24	72.3	n/a	n/a
BH02	3.135	73.1	n/a	n/a

Note 1: estimated groundwater level in mAOD is based on the ZOC reports assumed ground level of 85 mAOD for each well (wells were not surveyed).

2.5 Impact of Leachate on Receiving Surface Waters

The potential impact of leachate migration to the Raford River and the ZOC Rhynn Killeeneen to the north of the site was identified as being a potential risk associated with the historical landfill. Although surface water monitoring did not indicate that the site was causing a deterioration in water quality, the proximity and sensitivity of the river (as a ZOC for a drinking water supply) to potential emissions from the site and surface drainage connections required further assessment.

2.5.1 Potential Leachate Generation and Discharge

In this assessment leachate breakout/discharge rate is based on the estimated leachate generation rates shown in Section 2.4.1. This assessment represents a worst-case scenario whereby it is conservatively assumed that the entire volume leachate is entering the river and at the same rate that it is being generated. This calculation does not take into account attenuation of pollutants within the underlying geology and groundwater and further dilution and dispersion of leachate that may occur downgradient of the site which would otherwise reduce the rate of pollutant discharge to the receiving waterbody.

To assess the potential efficacy of an improved cap on the waste material, the leachate discharge rate, based on a significantly reduced rate of rainfall percolation to the site is calculated. For the purpose of this calculation an assumed reduced recharge of 10% is applied. This assumes that 90% of rainfall to the site does not contact the underlying waste and therefore does not contribute to leachate generation.

Leachate Generation at 10% recharge

10% x 724mm/year = 72.4 mm/year or 0.0724 m/year (available rainfall for recharge over the landfill area)

Aquifer Recharge Volume = Recharge x area of landfill
Aquifer Recharge Volume = 0.0724 m/year x 2,600 m^2[estimated waste footprint area]
Aquifer Recharge Volume over landfill area = 188.24 m^3/year **[0.52 m^3/day] [0.006 l/s]**

The potential impact of the site on this receiving waterbody was determined by conducting an assimilative capacity assessment and mass balance calculation with ammoniacal nitrogen chosen as a representative potential pollutant. The leachate breakout/discharge rate is based on the above estimated leachate generation rates. It is assumed that all leachate is entering the river.

2.5.2 Assimilative Capacity Assessment

The following analysis was applied to determine the assimilative capacity of the receiving waterbody, see Appendix 2.

Table 2-3 shows the assimilative capacity of receiving waters in relation to ammoniacal nitrogen to be **0.12 kg/day**:

Table 2-3: Raford River Assimilative Capacity Assessment

Assimilative capacity (AC) = (C_{max} – C_{back}) x F95 x 86.4 kg/day		
Where:	Value	Source
C_{max} = maximum permissible concentration (EQS – 95%ile value) (mg/l)	0.14	95%-ile 'good' status threshold as per S.I No. 77 of 2019 - European Union Environmental Objectives (Surface Waters) (Amendment) Regulations 2019
C_{back} = background upstream concentration (mg/l mean value)	0.048	No EPA monitoring station location upstream of the site therefore the average of 2020 FT monitoring results for upstream location SW01 (0.0237 mg/l, 0.0726 mg/l) was applied
F95 = the 95%ile flow in the river (m^3/s)	0.0148[1]	Obtained from online EPA Hydrotool for river segment/catchment upstream of site.
Assimilative Capacity kg/day	**0.12**	AC (kg/day) = (0.14 - 0.065) x 0.019 x 86 .4

Note 1: *background concentration applied is based solely on two individual grab samples and therefore may not account for seasonal variations in concentrations.*

2.5.3 Potential Impacts of Leachate Breakouts on Receiving Surface Waters

To determine potential impact that leachate surface breakouts from the landfill could have on the assimilative capacity of the receiving surface water body, the mass of ammoniacal nitrogen discharging from the site is calculated applying the equation:

Mass Emission (kg/day) = Discharge Flow (m^3/day) x Concentration (mg/l) /1000
Assumed criteria:

- *Flow range of assumed leachate breakouts:* *2.2m^3/day, 4.4m^3/day and 0.52 m^3/day*
- *Concentration of ammonia in leachate:* *22 mg/l ammoniacal nitrogen (maximum concentration measured at leachate well BH02)*
- *Significant pollution threshold if:* *> S.I. No. 77 of 2019 ('Good' status 95%-ile 0.140 mg/l)*

As shown in Table 2-3 this calculation conservatively assumes low flow conditions (95%-ile) flow conditions within the receiving river. In applying the 95%-ile flow, the assessment assumes the worst-case scenario whereby minimum dilution of the discharge is assumed within the receiving river waterbody.

Assumed leachate breakout and discharge flows (*2.2m^3/day, 4.4m^3/day and 0.52 m^3/day*) based on potential leachate generation rates (as per Section 2.4.1) were applied and the percentage of the assimilative capacity removed following discharge to the receiving water was also calculated (Daily Mass Emission ÷ Assimilative Capacity).

A conservative discharge ammoniacal nitrogen concentration of 22 mg/l (maximum ammoniacal nitrogen concentration detected in 2020 monitoring at leachate well BH02) was assumed for this calculation.

This concentration is within the range of typical ammonia concentration in MSW landfill leachate. The calculated mass emissions and the impacts on the assimilative capacity, for assumed discharge rates based on potential generation rates at the site (see Section 2.4.1) of the receiving water are shown in Table 2-4.

2.5.4 Mass Balance Assessment

A mass balance calculation determines the potential change in ammonia concentration within the receiving water downstream of the discharge. The following calculation as shown in Table 2-4 was applied.

Table 2.4: Mass Balance Calculation

<table>
<tr><th colspan="4">T = (FC + fc)/(F + f)</th></tr>
<tr><td colspan="3">Where:</td><td>Source</td></tr>
<tr><td>F is the river flow upstream of the discharge (95%ile flow m^3/s);</td><td colspan="2">0.0148</td><td>Obtained from online EPA Hydrotool for river segment upstream of site</td></tr>
<tr><td>C is the concentration of pollutant in the river upstream of the discharge (mean concentration in mg/l);</td><td colspan="2">0.048</td><td>No EPA monitoring station location upstream of the site therefore average of 2020 FT monitoring results for upstream location SW01 (0.0237 mg/l, 0.0726 mg/l) was applied</td></tr>
<tr><td rowspan="3">f is the flow of the discharge (m^3/s);</td><td>0.00003</td><td>2.2 m^3/day</td><td rowspan="3">Assumed discharge rate based on conservative estimates of leachate generation and breakout to surface water</td></tr>
<tr><td>0.00005</td><td>4.4 m^3/day</td></tr>
<tr><td>0.00005</td><td>0.52 m^3/day</td></tr>
<tr><td>c is the maximum concentration of pollutant in the discharge (mg/l);</td><td colspan="2">22</td><td>Maximum concentration detected in groundwater monitoring well BH02</td></tr>
<tr><td>T is the concentration of pollutant downstream of the discharge.</td><td colspan="2">Varies for discharge flows</td><td>n/a</td></tr>
<tr><td>Water Quality Standard (mg/l)</td><td colspan="2">0.140</td><td>'Good' Status 95%-ile as per S.I No. 77 of 2019 (95% of results are below this concentration)</td></tr>
</table>

Table 2.5: Assimilative Capacity and Mass Balance Calculation Results

Assumed Leachate Breakout Flow (m^3/day)	Daily Mass Emission (kg/day) assuming ammoniacal nitrogen concentration 22 mg/l	% Impact Breakout has on of Assimilative Capacity (% consumed) [2]	Estimated Downstream Concentration Ammoniacal nitrogen (mg/l)
2.2	0.048	41%	0.086
4.4	0.097	82%	0.123
0.52	0.011	9.7%	0.057

Note 1: *Water quality standard as per S.I. No. 77 of 2019 ('Good' status 95%-ile 0.140 mg/l).*
Note 2: *Assimilative capacity estimated to be 0.12 kg/day ammonia (Table 2-3)*

2.5.5 Discussion of Results

Table 2-5 results show that at leachate discharge flow rates of 2.2 and 4.4 m^3/day the predicted downstream concentrations are compliant with S.I. No. 77 of 2019 'Good' status 95%-ile (<0.140 mg/l) with predicted downstream concentrations of 0.086 mg/l (79% increase) and 0.123 mg/l (156% increase) respectively.

This corresponds with the assimilative capacity calculation which determined that, assuming low flow conditions in the river at discharge rates of 2.2 and 4.4 m^3/day, 41% and 82% of the assimilative capacity of the Raford River for ammoniacal nitrogen/total ammonia would be consumed.

Whilst there was no evidence of leachate breakouts on site, this assessment shows there is potential for a leachate breakout flows to consume a significant proportion of the assimilative capacity of downstream waters, but only at hypothetical conservative, higher discharge rates. However, despite this the predicted downstream concentration of ammoniacal nitrogen (as per mass balance calculation) remains below the water quality threshold limit.

The application of the reduced rainfall, infiltration rate (with an improved engineered cap) of 0.52 m^3/day shows that the predicted downstream concentrations remains below the 95%-ile threshold value of 0.140 mg/l ammoniacal nitrogen with predicted downstream concentrations of 0.057 mg/l ammoniacal nitrogen at a discharge concentration of 22 mg/l ammoniacal nitrogen. This equates to a 19% increase in ammoniacal nitrogen concentrations against the applied background concentration.

This corresponds with a low 9.7% consumption of the river's assimilative capacity for ammoniacal nitrogen showing that with the installation of an engineered cap achieving a significant reduction in rainfall infiltration to the waste body, the potential impact to surface water quality is reduced.

Although the most recent water quality status for the Raford_020 section of the Raford River is moderate, based on monitoring conducted at Raford Bridge, c.5.5km west-south-west and downstream of the historical landfill, this classification is based on the classification of 'moderate' quality with respect to 'ecological status or potential'. All other monitoring parameters and categories e.g. nutrient conditions, pH, ammonium, dissolved oxygen etc. achieved 'pass' or 'high' quality standards. EPA monitoring results at this station show a 2017 total-ammonia concentration of 0.021 mg/l, lower than those predicted above.

2.6 Conclusions

The aim of this Tier 3 assessment was to examine (quantitatively) the potential impact of the historical landfill site on the receiving environment i.e. leachate generation/migration upon groundwater and surface quality and associated drinking water supplies in the area.

2.6.1 Impact of Leachate to Groundwater and Water Supply

The potential contribution of groundwater and leachate to the public water supply aquifer was estimated.

A comparison of measured static groundwater levels at groundwater monitoring wells located at the historical landfill and groundwater levels and pumping levels of the New Inn abstraction wells confirms that the historical landfill is located downgradient of the water supply and is therefore not contributing to the water supply. Further calculations based on estimated groundwater recharge at the site and typical pumping rates at the public water supply it was calculated that groundwater, and potentially leachate could contribute 0.7% - 1.4% to public drinking water supply.

There is a very low to negligible risk of leachate generated at the site negatively impacting on the water quality of the New Inn water supply.

Although there is no significant risk to the water quality of the New Inn water supply or risk to groundwater quality on a regional scale from the site groundwater and leachate monitoring conducted as part of the Tier 2 did indicate that there is a source of pollutants i.e. leachate remaining at the site which may be directly impacting on groundwater quality locally.

2.6.2 Impact of Leachate of Surface Water

The assimilative capacity assessment and mass balance calculations indicated that:

- Although no leachate breakout was observed at the site the modelled leachate breakout (at assumed discharge rates) has the potential to impact on water quality downstream of the site but only at higher hypothetical discharge rates. However, the predicted downstream concentrations remain below the surface water quality threshold.
- At the applied discharge concentration, the modelled discharges have the potential to consume a proportion of the assimilative capacity of the Raford River with respect to ammoniacal nitrogen, 41% to 82% at discharge rates of 2.2 m^3/day to 4.4 m^3/day. However, it is not likely for discharge rates to reach 4.4 m^3/day. The calculations applied conservatively assume that all leachate generated at the site is instantaneously and continuously discharged to the river with no dilution of contaminants between the site and the river.
- The installation of a lower permeability cap limiting the infiltration rate to the landfill yielded a reduction in leachate generation and subsequently a reduction in both the impact on assimilative capacity and predicted downstream ammoniacal nitrogen concentrations.

2.6.3 Site Capping

Trial pitting confirms waste material is relatively close to the surface, generally located underlaying topsoil with a shallow layer of made ground capping material present (average: 0.85m, min: 0.2m, maximum 1.6m thickness). The waste body does not have a fully engineered cap.

3. REMEDIAL ACTION PLAN

Based on the findings of the modelling exercises and quantitative risk assessment the following measures are proposed to mitigate the identified risks to surface waters from leachate.

3.1 S-P-R Linkages

Following comprehensive desktop review, a site investigation and a Tier 2 assessment identified the primary source-pathway-receptors (S-P-R) linkages for the site to be leachate migration through surface water pathways and groundwater pathways. Proposed remedial measures for each of these linkages are discussed below.

3.1.1 Leachate Migration through ground water pathway (SPR6)

This Tier 3 assessment determined that given the relatively low rates of potential leachate generation at the historical landfill compared to the abstraction rates of the New Inn drinking water supply the generation and migration of this leachate is unlikely to negatively impact on the quality of the drinking water. Any migration of leachate to the groundwater supply would be diluted.

However, groundwater and leachate monitoring at the site does indicate that the site may be having an adverse impact on groundwater quality at a local level. The overall objective of the Water Framework Directive (WFD) is to prevent the deterioration of the status of groundwater. Furthermore, the European Union Environmental Objectives (Groundwater) Regulations 2010, as amended, outline duties of public authorities with respect to promoting compliance with the requirements of the regulations including to;

'…take all reasonable steps including, where necessary, the implementation of programmes of measures, to:

a) ***prevent or limit****, as appropriate, the input of pollutants into groundwater and prevent the deterioration of the status of all bodies of groundwater;*

b) *protect, enhance and restore all bodies of groundwater and ensure a balance between abstraction and recharge of groundwater with the aim of achieving good groundwater quantitative status and good groundwater chemical status by not later than 22 December 2015;*

c) *reverse any significant and sustained upward trend in the concentration of any pollutant resulting from the impact of human activity in order to progressively reduce pollution of groundwater;*

d) *achieve compliance with any standards and objectives established for a groundwater dependant protected area included in the register of protected areas established under Regulation 8 of the 2003 Regulations by not later than 22 December 2015, unless otherwise specified in the Community legislation under which the individual protected areas have been established.'*

Regarding the *'Prevention and Control of Groundwater Pollution'* the regulations also state that '*Point source discharges and diffuse sources liable to cause groundwater pollution shall be controlled so as to prevent or limit the input of pollutants into groundwater.'*

In order to ***limit*** further leachate generation at the site and subsequent migration of leachate downgradient of the site landfill capping works at the site are proposed (see Section 3.1.2.1). This will also serve to restore the site for future use i.e. agriculture and grazing.

3.1.2 Leachate Migration through surface water pathway (SPR8)

The Raford River was identified as being a potential receptor for any discharge from the site. Although application of the EPA risk screening tool generated a low risk score for SPR8, as the Raford River forms part of a drinking water supply Zone of Contribution (ZOC) namely the Rhyne Killeeneen ZOC, to further examine the potential risk it was considered as part of this Tier 3 assessment.

The assimilative capacity assessment and mass balance calculation determined that, under a worst-case scenario there is a potential for a discharge from the site to negatively impact on the water quality of the Raford River.

In order to mitigate or eliminate this potential risk remedial measures are proposed. As indicated, the primary cause of leachate generation at the site is through vertical infiltration of precipitation through the waste body, and subsequent lateral migration from the site. The following mitigation measures proposed to reduce potential leachate generation at the site and the risk to the Raford River.

3.1.2.1 Landfill Capping

The proposed capping works will be subject to Certificate of Authorisation, detailed design and agreement with existing site users and private landowner(s) and will be cognisant of the future site use.

A landfill cap is proposed for the site. The landfill cap will be designed in accordance with the EPA Landfill design manual for inert landfills. The capping will typically consist of the following:

- 200mm Topsoil Layer
- 800mm Sub Soil

The proposed landfill cap will reduce the generation of leachate via percolation of rainwater and subsequently the potential migration of leachate to groundwater and surface water.

The site will be reprofiled to promote surface run off and limit percolation of precipitation to the waste body subsequently limiting leachate generation.

The capping design should be consistent with the future uses of the site for agricultural grazing purposes. The sub soil layer will therefore be adequately specified to ensure it is free draining to support grazing.

3.1.3 Landfill Gas Management

The installation of a landfill cap can have the secondary effect of altering the preferential pathway for landfill gas migration. A shallow soil cap directly above the waste may be currently causing passive, diffuse vertical migration of landfill gases, limiting the potential for lateral migration of gas outside of the waste body. The complete capping of a landfill can inhibit vertical migration and cause increased lateral migration of landfill gases.

As such, as the proposed remediation of the site includes the construction of an appropriately design landfill cap additional measures are required to reduce the risk of lateral migration to nearby human receptors.

It is proposed that passive ventilation measures be used to mitigate the risk of landfill gas migration. The proposed measures are discussed in further detail below.

3.1.3.1 Passive Ventilation

It is proposed that a passive gas collection trench is installed along the south eastern boundary of the waste body with a series of vertical standpipes venting to atmosphere at c.2m above the final ground level.

The vertical standpipes will provide a preferential pathway for LFG to escape to atmosphere mitigation risks associated with migration to offsite receptors.

Installed ventilation standpipes will include a carbon filtration packs to "scrub" any odour and low concentrations of methane from the landfill gas prior to venting. Wind driven rotating cowls will also be used to induce a negative pressure within the standpipe improving potential LFG flow.

3.1.4 Environmental Monitoring: Existing Locations

It is recommended that groundwater and surface water monitoring continue at existing monitoring locations at the site specifically:

- Groundwater (Groundwater Quality and Landfill Gas Migration):
  - GW01 (upgradient)
  - GW02 (downgradient)
  - BH01 (upgradient)
- Surface Water (Surface Water Quality):
  - SW1 (upgradient)
  - SW2 (downgradient)
- Leachate (Leachate Quality):
  - BH02 (in waste)
- Landfill Gas
  - BH02 (in waste)

Continued environmental monitoring should be undertaken on an annual basis up until the recommendations of the Certificate of Authorisation are known and remediation works are complete.

Monitoring data should be available prior to detailed remediation design to confirm the findings of this report and for use post remediation as baseline data for comparative analysis.

3.1.5 Environmental Monitoring: Proposed New Locations

The following additional groundwater locations are recommended:

- GW03 – Downgradient Receptor (>50m <100m Downgradient of Waste Body)

The following additional landfill gas monitoring locations are recommended:

- LFG1– between the identified waste body and houses to the south-east of the site, adjacent to the R348 road.

3.1.6 Proposed Groundwater, Surface Water, Leachate and Landfill Gas Monitoring Regime

The EPA Landfill Monitoring landfill manual outlines recommended, minimum monitoring requirements for ground and surface waters. These parameters are shown in Table 5-1 below and are as presented in Table C.2 of the EPA's *Landfill Manuals - Landfill Monitoring, 2nd Edition (2003).*

Groundwater monitoring shall be carried out at existing wells BH01, GW01, GW02 and proposed well GW03, surface water monitoring at existing surface water monitoring locations SW1 (upstream) and SW2 (downstream) and leachate monitoring at BH02 in accordance parameters listed in Table 3-1.

Landfill gas monitoring will be conducted at existing leachate well BH02 and proposed landfill gas monitoring well LFG1.

Table 3-1: Parameters for Monitoring of Groundwater and Surface Water

Monitoring Parameter[1]	Frequency	Surface Water	Groundwater	Leachate	Landfill Gas
Location		**SW1, SW2**	**GW01, GW02, BH01, GW03**	**BH02**	**BH02, LFG1**
Fluid Level	Bi-annual	-	-	-	
Flow Rate		-	-	-	
Temperature		✓	✓	✓	
Dissolved Oxygen		✓	-	-	
pH		✓	✓	✓	
Electrical Conductivity[2]		✓	✓	✓	
Total suspended solids		✓	-	-	
Total dissolved solids		-	✓	-	
Ammonia (as N)		✓	✓	✓	
Total oxidized nitrogen (as N)		✓	✓	✓	
Total organic carbon		-	✓	-	

[1] Tables D.1 and D.2 of the EPA Landfill Monitoring manual recommend guideline minimum reporting values for parameters.

[2] Where saline influences are suspected, a salinity measurement should also be taken.

Monitoring Parameter[1]	Frequency	Surface Water	Groundwater	Leachate	Landfill Gas
Location		**SW1, SW2**	**GW01, GW02, BH01, GW03**	**BH02**	**BH02, LFG1**
Biochemical Oxygen Demand		✓	-	✓	
Chemical Oxygen Demand		✓	-	✓	
Metals[3]		✓	✓	✓	
Total Alkalinity (as $CaCO_3$)		✓	✓	-	
Sulphate		✓	✓	✓	
Chloride		✓	✓	✓	
Molybdate Reactive Phosphorous[4]		✓	✓	✓	
Cyanide (Total)		✓	✓	✓	
Fluoride		✓	✓	✓	
Landfill Gas		-	-	-	✓
Methane (CH_4)					
Carbon Dioxide (CO_2)					
Oxygen (O_2)					
Atmospheric Pressure					
Temperature					

3.2 Remediation Design

The preliminary remediation design is presented in the following drawings:

- P2282-0000-0102-0001 Drawing Schedule (New Inn Historic Landfill)
- P2282-0102-0001 Site Location Map (New Inn Historic Landfill)
- P2282-0102-0002 Existing Site Survey (New Inn Historic Landfill)
- P2282-0102-0003 Proposed Landfill Capping Area (New Inn Historic Landfill)
- P2282-0102-0004 Existing & Proposed Monitoring Points (New Inn Historic Landfill)
- P2282-0702-0001 Proposed Passive Gas Venting System (New Inn Historic Landfill)
- P2282-0902-0001 Sections A - A, B - B & Passive Gas Vent Typical Detail (New Inn Historic Landfill)

Drawings are included in Appendix 3 to this document.

[3] Metals for analysis should include calcium, magnesium, sodium, potassium, iron, manganese, cadmium, chromium (total), copper, nickel, lead, zinc, arsenic, boron and mercury.

[4] Total Phosphorus should be measured in leachate samples where colorimetric interference is likely.

3.2.1 Objectives of the Proposed Remediation Plan

Whilst quantitative risk assessments determined the risks associated with leachate impacting receiving surface and groundwaters to be low, remedial capping works are recommended to ensure the site complies with the Landfill Directive and Environmental Protection Agency (EPA) publication landfill manual - Landfill Site Design which for a non-hazardous landfill requires a capping of at least 1m total thickness. As per the EU groundwater regulations discharge of pollutants to groundwater should be limited and protection of groundwaters ensured.

The proposed remediation plan objectives will be to:

- Facilitate use of land for agricultural purposes.
- Reduce deep percolation inputs into the waste body to reduce the volume of leachate being produced through reprofiling of the site and installation of a 1m thick cap, as shown on Drawing nr. P2282-0102-0003 and P2282-0902-0001.
- Facilitate passive management of landfill gas via the proposed cap to encourage oxidation by using the gas drainage system and a dedicated venting outlet as shown on Drawing nr. P2282-0702-0001.
- Monitor potential leachate migration at existing upgradient and downgradient wells and proposed additional downgradient well, as shown on Drawing nr. P2282-0102-0004.

In the event that subsequent landfill gas emissions increase beyond those observed during the Tier 3 assessment, appropriate control measures shall be selected in accordance with the EPA Guidance document: *Management of Low Levels of Landfill Gas*

3.3 Remediation Cost Estimates

The following section outlines the potential costs associated with the remediation of the site. The costs estimate is limited to “once-off” civil and mechanical and electrical works.

Long term costs associated with maintenance, license compliance and environmental liabilities are not considered.

The cost estimate for New Inn Historical Landfill was prepared based on similar recent works completed by FT. The remediation cost estimate is presented in Table 3.2. The proposed remediation works are in line with the EPA Landfill Design manual recommendations as presented previously.

Table 3-2: Remediation Cost Estimate for New Inn Historical Landfill

Item	Quantity	Unit	Rate, €	Cost
Design				
Allowance for New Monitoring Well Installation	1	Rate	€6,000.00	€6,000.00
Detailed Design and Supervision	1	Rate	€20,000.00	€20,000.00

Item	Quantity	Unit	Rate, €	Cost
General Site Clearance and Demolition Works	***1.45***	***ha***		
General Site Clearance	1.45	ha	€4,000.00	€5,800.00
Excavation Works	14500	m^2		
Excavation of Existing Capping for Reuse/Filling	14500	m^3	€1.50	€21,750.00
Landfill Capping Works	2600			
Preparation of Surfaces	2600	m^2	€0.50	€1,300.00
Importation of 800mm Subsoil Capping Layer	2600	m^2	€10.50	€27,000.00
Importation of 200mm Topsoil Capping Layer	2600	m^2	€3.50	€9,100.00
Allowance Landfill Gas Collection Trench	220	m	€150.00	€33,000.00
Allowance for Passive Gas Vents	4	nr	€2,000.00	€8,000.00
Miscellaneous				
Landscaping Allowance	1	Sum	€3,600.00	€3,600.00
Sub-Total 1				**€135,850.00**
Add 10% Contractor Prelims	10.0%			€13,585.00
Sub-Total 2				**€149,435.00**
Add 12.5% Contingency	12.5%			€18,679.00
Grand Total (excl VAT)				**€168,114.00**

In making this Cost Estimate FT advises the following:

- FT used rates over the period 2018 to 2019 for similar tendered works items where possible and has used engineering judgement to estimate rates & sums where similar rates were not available.
- Management of hazardous materials was not allowed for.
- Pricing was based on a concept design; no detailed designs were prepared.

- The cost estimate assumes that materials to be imported are readily available from local sources.
- The cost estimate excludes VAT.
- The cost estimate excludes in/deflation.
- The estimate includes for a level of contingency as indicated.

Prices may change subject to prevailing market conditions.