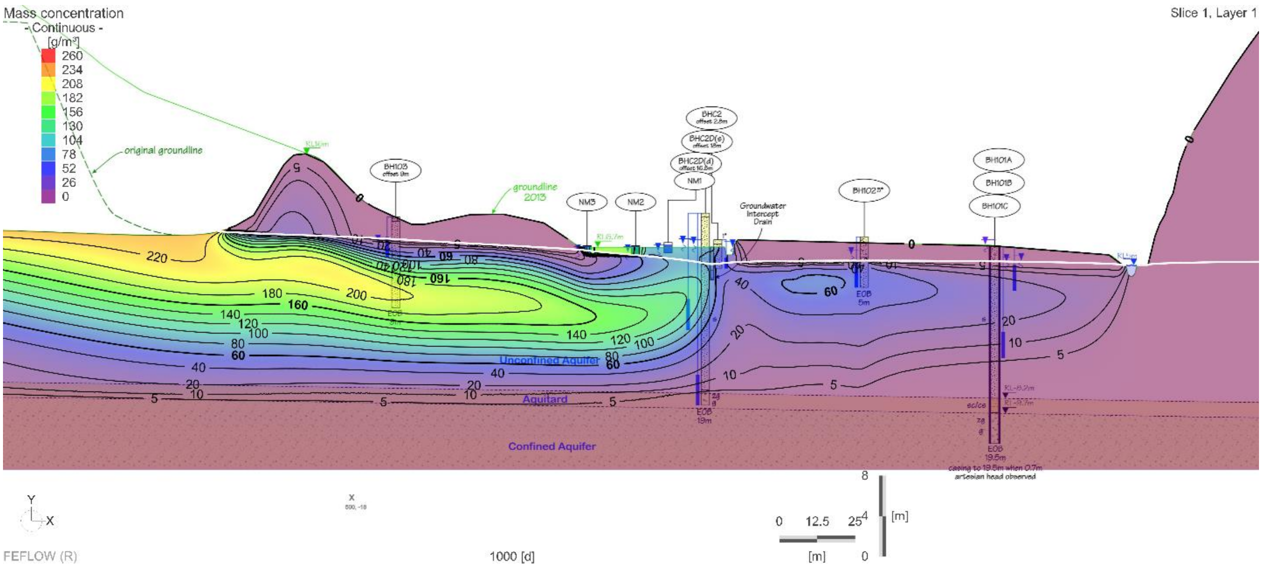
Report

Numerical Groundwater Modelling Report and BPO Engineering Design

Levin Landfill, Hōkio Beach Road, Levin



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Levin Landfill, Hōkio Beach Road, Levin

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Executive Summary

Earthtech Consulting Limited (Earthtech) has been appointed by the Horowhenua District Council (HDC) to carry out a detailed hydrogeological assessment of groundwater contamination from the unlined “Old Landfill” area of the Levin Landfill site and provide sufficient information for a Best Practicable Option (BPO) engineering solution to progress to consenting stage.

This report presents the results of numerical modelling of the ammoniacal-nitrogen (NH_4-N) contamination plume within the groundwater system, which is significant for environmental effects. The modelling aims to assess the effectiveness of the proposed groundwater intercept drain and provide the Best Practical Option (BPO) remedial works design.

The proposed groundwater intercept drain consists of a 200*m* long subsoil drain with a fabric-wrapped drainage metal intake. The drain is to be constructed in two stages, with Stage 1 consisting of the 100*m* long central section. Intercept drain design details are presented in this report and include access for rodding and flushing maintenance. Pumping from a central pumping chamber would take place to lower the groundwater table to RL5*m* to match the level of the Hōkio Stream.

A FEFLOW finite-element groundwater model has been set up to simulate both flow and mass transport. The model inputs have been determined from the site investigations and published information. Calibration has been carried out to match the predicted groundwater levels and NH_4-N concentrations against the values measured in 2023. The calibrated groundwater model includes the past 52-*year* record of leachate concentrations progressing through the groundwater system, as it simulates the time period between initial refuse placement commencing in 1971 through to 2023.

Forward analyses were carried out to predict the future movement of leachate within the groundwater system. Models were run with and without the proposed intercept drain. Results show that the 200*m* long intercept drain is very efficient in capturing approximately 90% of the NH_4-N which would have reported into the Hōkio Stream. Additionally, the discharge of NH_4-N into the Northern Farm Drain and adjacent swampy area ceases, as these areas would no longer receive groundwater discharge due to lowering of groundwater levels around the intercept drain.

The proposed 200*m* long intercept drain with an efficiency of approximately 90% provides an effective method of near total capture of NH_4-N discharge into the Northern Farm Drain and a high material reduction in the discharge to the Hōkio Stream. This complies with the BPO requirements of the Environment Court Order (19 December 2019) and Discharge Permit 6010 cl. 2A(a). Intercept drain pumping volumes and concentrations are provided with respect to treatment and management of the abstracted water for BPO design.

This report provides proof of concept for the groundwater intercept drain. We recommend that this BPO design proceeds to consenting, comprising a 200*m* long drain constructed with a staged approach.

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1. Introduction

Earthtech Consulting Limited (Earthtech) has been appointed by the Horowhenua District Council (HDC) to carry out a hydrogeological assessment of groundwater contamination from the unlined “Old Landfill” area of the Levin Landfill site.

A first hydrogeological assessment report was completed in May 2023 (Earthtech, 2023a), followed by a second report in November 2023 (Earthtech, 2023b) that presented the results of field investigations and a conceptual groundwater model for the site. The conceptual groundwater model incorporated geological and groundwater conditions, groundwater and surface water interactions, contamination plume extents, and the mechanism of contamination transport within groundwater below the site.

This report presents the results of numerical modelling of the groundwater contamination plume. Groundwater modelling has been carried out in the finite element software FEFLOW, focusing on the ammoniacal-nitrogen (NH_4-N) leachate indicator, which is critical for environmental effects. The model aims to assess the effectiveness of a proposed groundwater intercept drain and provide a Best Practical Option (BPO) remedial works design.

For clarity, when this report refers to the ‘contaminant’, ‘contamination’, ‘transport’ or ‘mass’, it refers to NH_4-N.

This report is one of a series of two reports which are to be provided as follows:

i) Conceptual Groundwater Model (Earthtech, 2023b)
ii) Numerical Groundwater Flow and Contaminant Transport Modelling and Remedial Works Design (this report)

2. Model Inputs

Model inputs have been obtained from the site-specific information presented in Earthtech (2023b) and from published information. All the inputs have been verified as part of the model calibration. The model section location is shown in Figure 1.

2.1 Flow Settings

2.1.1. Permeability

Permeability of the dune sand aquifer has been assessed through site-specific testing, which is presented in Earthtech (2023b). This testing gave a permeability range between 0.85*m*/*d* to 4.4*m*/*d*, with an average of 2.39*m*/*d*.

The modelling has adopted a sand aquifer permeability of 3.15*m*/*d*, which is the average of BH101A, BH101B, and BH103. Results from BH102 have been excluded, as this bore is an outlier in terms of both permeability and the measured NH_4-N concentrations in water samples. Results from BH104 have not been included, as this bore is distant from the model section location.

The adopted dune sand permeability is also within the 1.7*m*/*d* to 5.2*m*/*d* range estimated for the site and presented in Tonkin and Taylor (2019).

Permeability of the aquitard and gravel aquifer layers have been obtained from published information (Freeze and Cherry, 1979).

Permeability is the most sensitive setting for groundwater flow and is considered to be well supported by field investigation information and verified during model calibration. Adopted permeability settings are shown in Table 1.

2.1.2. Anisotropy

Permeability in the vertical direction is less than permeability in the horizontal direction, which results in anisotropy (anisotropy = horizontal permeability/vertical permeability).

Anisotropy has been assessed based on inspection of the drilling core obtained during the site-specific testing and typical values expected for the soil materials present on the site. The drilling core indicated that the dune sands are massive with little observable layering, indicating low anisotropy. Anisotropy settings were also verified during model calibration. Adopted anisotropy settings are shown in Table 1.

2.1.3. Recharge outside of Landfill Footprint

Recharge entering the dune sand aquifer through the ground surface is a proportion of rainfall. Annual rainfall at the site has been adopted as 1,054*mm/yr* (30-*year* annual average at the Levin weather station, obtained from https://cliflo.niwa.co.nz/).

Earthtech has carried out extensive groundwater studies in similar dune sand aquifers at Matarangi, Pauanui, and Cooks Beach on the Coromandel Peninsula. These studies showed that dune sand aquifer recharge is generally 20% of rainfall.

Further information is available from PDP (2021), which presents a regional groundwater model of the Lake Horowhenua and Levin areas. The model extended from the Tararua foothills east of Levin to the coast, approximately 15*km* wide by 28*km* long. The PDP (2021) model indicated recharge between 365*mm/yr* to 730*mm/yr* (35% to 70% of rainfall) around the Levin Landfill site. We consider that this recharge is more representative of the larger area, which includes blind gullies between sand dunes where recharge will be very high. By comparison, at the Levin Landfill site, recharge is expected to be in the range of 15% to 25% of rainfall as run-off can easily be removed by the Northern Farm Drain and Hōkio Stream.

Based on the above, recharge at 20% of rainfall (210*mm/yr*) has been adopted outside the landfill area. The recharge setting reflects winter conditions, as the recharge has been checked against and calibrated to winter groundwater levels measured in September and October 2023. Recharge settings are shown in Figure 2.

2.1.4. Recharge within Landfill Footprint

Recharge within the landfill footprint is reduced due to the landfill cap and increased run-off. We understand that the cap constructed on the unlined landfill Area 1 (the subject of this study) is very similar to the cap installed on the recently closed and lined landfill Area 2. Therefore, recharge and leachate production for both areas is expected to be similar.

Leachate volumes produced by the lined landfill area are generally between 15m^3/d to 30m^3/d, for a lined area of approx. 80,000m^2. This indicates that recharge through the landfill is between 68*mm/yr* to 137*mm/yr*, which is 6% to 13% of rainfall. The recharge assessment at 6% to 13% of rainfall is considered to be appropriate, given that the landfill capping consists of sandy materials. For comparison, published recharge values vary between 6% to 10% of rainfall for closed and partially capped landfills (Christensen et al., 1992).

Based on the above, recharge at 10% of rainfall (102*mm/yr*) was adopted within the landfill area and verified during model calibration. Recharge settings are shown in Figure 2.

2.1.5. Groundwater Levels

Measured groundwater levels are another model input. Groundwater level information for bores located near the model extremities is used to define constant head boundaries (e.g. BHD3(r) located near the left model boundary has been used to define the groundwater elevation in this area). Model constant head boundary conditions are shown in Figure 2.

Where measured groundwater levels are internal to the model (i.e. not used to define boundary conditions), these are used as calibration targets. Calibration is discussed in Section 4.
The groundwater levels adopted for both the boundary conditions and calibration targets are winter levels, measured in September and October 2023. These levels are shown on Figure 5 of Earthtech (2023b).

2.2 Mass Transport Settings

2.2.1. Attenuation Mechanisms

Attenuation describes the physical and chemical processes which reduce contaminant concentrations across time and distance. These processes have been modelled in FEFLOW and include:

i. Dilution
ii. Sorption
iii. Dispersion
iv. Diffusion

2.2.2. Dilution

Dilution occurs through a combination of rainfall recharge and groundwater through-flow. These effects are defined by the permeability and recharge settings previously described.

2.2.3. Sorption

Sorption describes the contaminant binding to soil particles, which slows (retards) the contaminant velocity. Sorption is also a function of flow velocity and soil type, with clays and silts having higher sorption effects.

Earthtech (2023b) provides velocities of various leachate contaminants, with a chloride velocity of 14.3*m/yr* and a NH_4-N velocity of 5.3*m/yr* based on the contaminant arrival times at the on-site groundwater monitoring bores. Chloride is not affected by sorption and generally follows advective flow. The difference between the chloride and NH_4-N velocities is considered to be primarily due to sorption, although other chemical and mechanical processes may have a small effect. The difference in velocities shows that sorption is occurring as part of the NH_4-N transport.

FEFLOW uses Henry Sorption Coefficients, or the “Henry Constant”, to model sorption. An initial estimate of the Henry Constant was made using the chloride and NH_4-N velocities as follows:

$$\text{Retardation factor } (R_f) = \frac{\text{non-sorbing contaminant velocity}}{\text{sorbing contaminant velocity}}$$

$$R_f = \frac{14.3\,m/yr \text{ chloride velocity}}{5.3\,m/yr \text{ NH}_4\text{-N velocity}} = 2.15$$

$$\text{Partition coefficient } (K_{ds}) = \frac{\text{effective porosity}}{\text{dry bulk density}}(R_f - 1)$$

Adopting:

- Effective porosity = 0.15 (Table 1)
- Dry bulk density = 1.6t/m^3 (assumed for loose to medium dense dune sands)

$$K_{ds} = \frac{0.15}{1.6}(2.15 - 1) = 0.11 ml/g$$

Henry Constant $(H_c) = K_{ds} \times$ solid density

Adopting:

- Solid density = 2.65t/m^3 (assumed)

$H_c = 0.11 \times 2.65 = 0.29$ (initial estimate, modified during calibration)

Trial calibration runs made with H_c = 0.29 quickly indicated that higher sorption was required, as the contaminant plume was spreading too quickly. By trial and error, in conjunction with adjusting the model dispersivity settings, H_c = 1.91 was adopted for the dune sands. Adopting a slightly greater Henry Constant is conservative in terms of the intercept drain efficiency, as it reduces natural contaminant plume dispersion.

The H_c = 1.91 setting was also applied to the gravel aquifer. Please note that the model prediction of intercept drain efficiency is not sensitive to sorption in the gravels.

Sorption for the aquitard is expected to be much higher than the dune sands and was determined from published information. Kelsey (2014) presents the results of laboratory batch tests carried out for NH_4-N at the Bonny Glen landfill in Marton. This testing provided K_{ds} values of 30*ml/g* and 8*ml/g* for silty clay (loess) and siltstone, respectively. Adopting the lowest of these values and multiplying by the adopted solid density provides H_c = 21 for the aquitard layer. Please note that the model prediction of intercept drain efficiency is not sensitive to sorption in the aquitard.

Sorption and dispersion are the two most sensitive parameters for mass transport in FEFLOW, and have been verified during calibration. Adopted Henry Constants for each soil unit are summarised in Table 1.

2.2.4. Dispersion

Dispersion describes the mechanical mixing of the contaminant as it moves through different flow paths between soil particles. Some flow paths are faster than others, which results in mechanical mixing of water with different contaminant concentrations.

FEFLOW uses longitudinal and transverse dispersivity to model dispersion effects. Dispersivity is known to be a difficult parameter to estimate in advance and is often determined during the calibration process.

Rausch et al. (2006) provides a plot of longitudinal dispersivity for different flow path lengths based on available laboratory and field investigation data. For the flow path length between the Levin Landfill and Hōkio Stream, the plot indicates that longitudinal dispersivity is expected to be in the range of 2*m* to 10*m*. During the calibration process, it was determined that a longitudinal dispersivity of 5*m* was appropriate in conjunction with the other transport parameters.

Transverse dispersivity is generally 10 to 20 times smaller than longitudinal dispersivity, but can be up to 100 times smaller in the vertical direction (Rausch et al., 2006). A transverse dispersivity of 0.1*m* (50 times smaller than longitudinal dispersivity) was adopted during the calibration process. Site monitoring records show that the contamination plume is mostly concentrated in the upper part of the dune sand aquifer, and the very low vertical dispersivity is required to limit vertical spread of the plume in the model.

Dispersion and sorption are the two most sensitive parameters for mass transport in FEFLOW, and have been verified during calibration. Adopted dispersivity settings for each soil unit are summarised in Table 1.

2.2.5. Diffusion

Molecular diffusion of a solute in a fluid is caused by random molecular motion due to the kinetic energy of the solute.

Diffusion does not significantly vary, and is between $1e^{-9} m^2/s$ to $2e^{-9} m^2/s$ for major cations in groundwater. This analysis has adopted a diffusion setting of $1e^{-9} m^2/s$ for all soil layers. The model results are not sensitive to diffusion.

2.2.6. Effective Porosity

Effective porosity has been determined from published information (Freeze and Cherry, 1979) and Earthtech (2023b). Adopted effective porosity settings for each soil unit are presented in Table 1.

2.3 NH_4-N Concentrations

2.3.1. Source Concentration from Unlined Landfill

The NH_4-N source concentration emanating from the unlined old landfill changes with time during landfill operations and after landfill closure. The old unlined landfill is reported to have been in operation between 1971 to 2004.

The biodecomposition of waste in a landfill is widely understood, with much literature describing phases or stages of landfill age and the changes in leachate quality with time. New Zealand's Technical Guidelines for Disposal to Land (Rev 3, WasteMINZ, 2022) describes such stages and sources the United Kingdom's Department of Environment's (1991) graphical interpretation of changes in leachate composition over time.

As part of the Bonny Glen Landfill consenting, Fraser Thomas (2013) prepared an assessment of the change in NH_4-N concentrations with time for municipal waste. Their prediction was based on long-term leachate concentration monitoring records for existing landfills in the North Island.

During the Levin Landfill model calibration process, different combinations of peak leachate concentrations and changes in concentration with time were trialled. It was found that the Fraser Thomas (2013) assessment provided a reasonable match to the concentrations measured in the Levin groundwater monitoring bores in 2023. Additionally, the peak NH_4-N concentration of 1,900g/m^3, which occurred during the landfill operational stage, is expected to be conservative based on published information which provides typical peak concentrations of 1,500g/m^3 (Christensen et al. 1992).

The Fraser Thomas (2013) graph of leachate concentration changes with time was prepared for a 60-*year* landfill operational period and has been adapted for the Levin Old Landfill 33-*year* operational period. The adopted NH_4-N source concentration time-history is shown in Figure A.

In FEFLOW, the landfill source concentration is applied as a time-variable mass concentration boundary condition assigned to the base of the landfill footprint. Source concentration settings are shown in Figure 2.

Further site verification is provided by the NH_4-N concentrations measured in leachate collected from the lined Class 1 area of the Levin Landfill, which closed in 2021. This provided an NH_4-N concentration of 646g/m^3 in October 2023, which is within the range of 950g/m^3 to 590g/m^3 for the first half of the early aftercare period shown in Figure A.

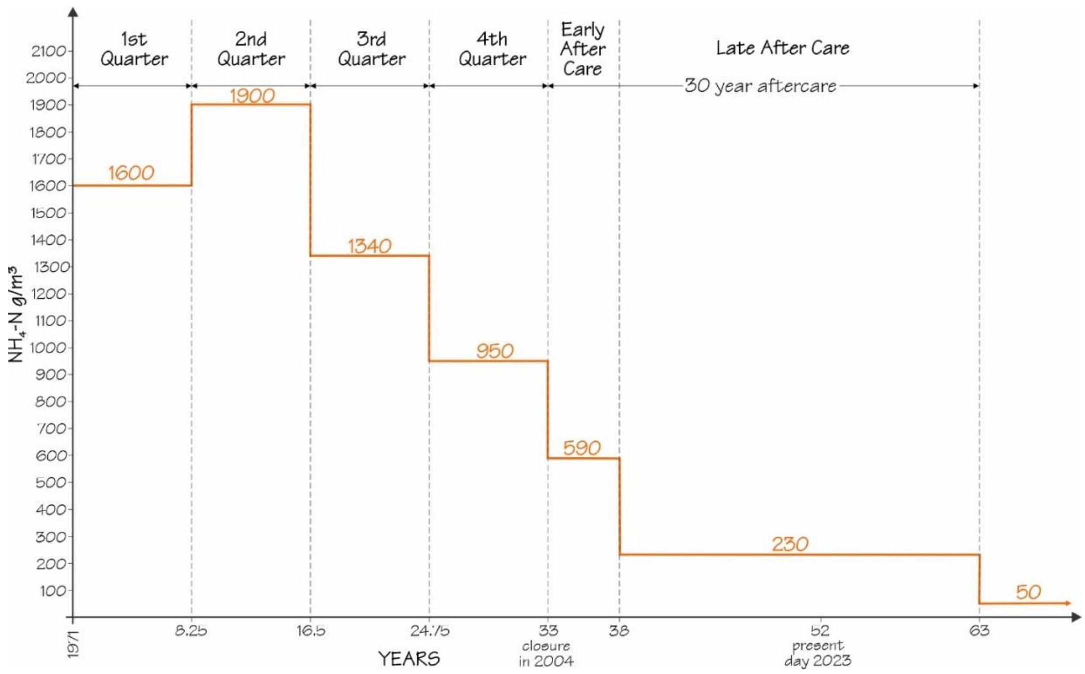

Figure A: Adopted landfill source concentration time-history

2.3.2. Background NH_4-N Concentrations

A naturally occurring groundwater background NH_4-N concentration of $0.2 g/m^3$ has been adopted based on field investigation information presented in Earthtech (2023b). Background concentration settings are shown in Figure 2.

3. Modelling Approach

3.1 Modelling Methodology

A 2D groundwater model has been developed in the software FEFLOW (version 8.0). FEFLOW is a 2D/3D finite element groundwater program developed by WASY Institute for Water Resources Planning and Systems Research in Germany, and is capable of running coupled flow and mass transport models under both steady state and transient conditions. Earthtech has been using FEFLOW since 2007 and considers it suitable for the modelling purpose.

Only NH4-N contaminant transport has been simulated, as this parameter is critical for effects on the environment.

The modelling process is shown in Figure B, and commences with a first modelling run simulating the time between landfill operations commencing in 1971 and the current condition in 2023. Iterative calibration is carried out by adjusting the model settings such that the 2023 model predicted groundwater levels and mass concentrations are a reasonable match to the 2023 site monitoring information provided in Earthtech (2023b). Two forward analysis predictive runs are then carried out to simulate conditions after 2023, comparing the difference in contamination reporting to the environment with and without the proposed groundwater intercept drain.

3.2 Model Setup and Boundary Conditions

The FEFLOW model extends from south of the unlined landfill area, to the topographical surface water divide to the north of the Hōkio Stream. The extent and location of the groundwater model section is shown in Figure 1. The section location was selected as it runs through the centre of both the NH4-N concentration plume (shown in Figure 10 of Earthtech, 2023b) and landfill footprint, in conjunction with the shortest distance to the Hōkio Stream.

The model boundary conditions and setup are presented in Figure 2. Specific model inputs are further described in Section 2 of this report.

The 2D modelling is considered appropriate for the proposed horizontal intercept drain and the uniform local flow field present at the site. The model runs through the critical location where maximum concentrations are being measured.

The FEFLOW model setup is summarised as follows:

i. General Settings:

- Groundwater flow and mass transport modelled in a 2D confined model.
- Mass transport modelled under transient conditions, and groundwater flow modelled under steady state conditions.
- Model includes the dune sands, aquitard, and gravels underlying the site down to RL-15*m* (refer to Earthtech, 2023b for geological descriptions and sections). Lumped input parameters are adopted within each of the units.
- The model includes a 1*m* thick lower permeability layer (impedance layer) across the base of the swampy ground and Northern Farm Drain, representing the deposition of silty and organic materials through this area.

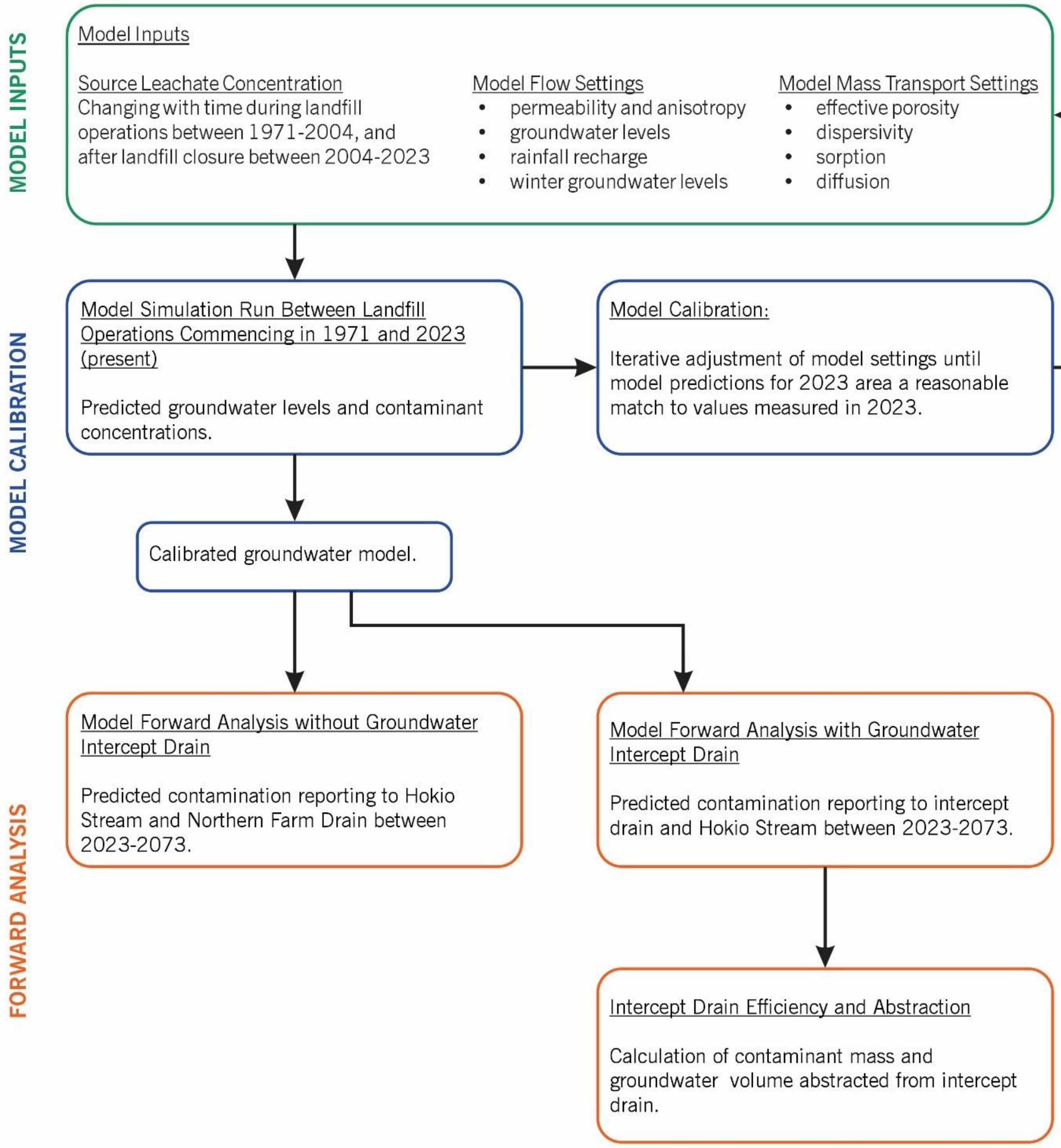

Figure B: Flow chart of groundwater modelling process

- Triangular finite element mesh variably discretised, with element sizes generally between 0.4*m* to 0.05*m* through the landfill footprint to just north of the Hōkio Stream. The finest 0.05*m* mesh size is adopted for areas where contamination is entering and leaving the model, and where changes in groundwater flow occur (i.e. the contacts between geological layers). Mesh size up to 1.5*m* north of the Hōkio Stream and south of the landfill footprint.

- Model northern boundary at the surface water divide to the north of the Hōkio Stream. The surface water divide is expected to approximate the groundwater divide in this area.

- Model southern boundary set 150*m* to the south of the landfill footprint.

- The extent of the model to the north and south are settings to avoid artificial edge effects and are not expected to influence the groundwater intercept drain predictions.

- The large sand dune under the landfill footprint (shown in Section B-B' of Earthtech, 2023b) has not been simulated. This is conservative as the model simulates the leachate source in direct contact with groundwater, and any attenuation of the contaminant in the unsaturated zone is ignored.

ii. Model groundwater flow settings:

- Model permeability and anisotropy settings determined from field investigation information and model calibration (refer to Table 1).

- Constant head boundary set at the left (southern) side of the model, at the levels given by BH3D(r), which are RL12.77*m* in the sand aquifer and RL12.45*m* in the gravel aquifer.

- Constant head boundary set at the right (northern) side of the model at a level of RL5.62*m*, calculated from the horizontal hydraulic gradient.

- Constant head boundary assigned along the base of the model, representing the change in groundwater head through gravel aquifer based on the horizontal hydraulic gradient. Constant head boundary grades linearly from RL12.45*m* at the right side to RL5.62*m* at the left side.

- Rainfall recharge of 210*mm*/*yr* assigned to the ground surface outside of the landfill footprint. Rainfall recharge of 102*mm*/*yr* assigned within the landfill footprint. Recharge settings reflect winter conditions, as recharge calibrated to observed winter groundwater levels.

- Seepage face modelled through the swampy ground, set at an elevation of RL6.8*m* to RL6.7*m* based on site survey data. The seepage face allows water to leave the model based on the set elevation, but cannot contribute water into the model.

- Constant head boundary set at RL6.5*m* at the Northern Farm Drain. Boundary constrained so it can only remove water from the model, and cannot contribute water into the model. This head boundary is slightly higher than the surveyed drain invert of RL6*m*.

- Constant head boundary set at RL5*m* at the Hōkio Stream, based on site survey data. Boundary constrained so it can only remove water from the model, and cannot contribute water into the model.

- For the models simulating the intercept drain, this is set as a constant head boundary at an elevation of RL5m. Boundary constrained so it can only remove water from the model, and cannot contribute water into the model.

iii. Model mass transport settings:

- Convective mass transport equation adopted. This setting is required as it allows for accurate calculation of the contaminant mass leaving through the model boundary conditions (i.e. mass leaving through the Hōkio Stream, intercept drain, etc.). The disadvantage of this setting is that the contamination plume is able to spread more easily both laterally and vertically through the model (i.e. concentration contour lines are further apart). This is conservative in terms of the intercept drain efficiency predictions as it allows more mass to pass under the intercept drain, but prevents matching of the timing of breakthrough curves against field measurements (as contaminants arrive earlier but concentrations increase at a slower rate).

- Model effective porosity, dispersivity, sorption, and diffusion settings determined from published information and model calibration.

- Constant mass concentration boundary condition of $0.2g/m^3$ set at the model left and right boundaries, and across the base of the model. This represents the background NH_4-N concentration naturally occurring in groundwater in the area, which enters the groundwater model.

- Constant mass concentration boundary condition of $0g/m^3$ set at the model ground surface outside of the landfill footprint, representing zero NH_4-N in rainfall recharge.

- Constant mass concentration boundary condition set under the landfill footprint which varies with time, as described in Section 2.3.1.

- Constrained mass concentration boundaries set through the swampy area, Northern Farm Drain, and Hōkio Stream. These boundary conditions allow mass to freely leave the model at any concentration as required to satisfy the flow and transport equations. Mass cannot enter the model at these boundaries, as no water inflow is permitted.

- For the models simulating the intercept drain, this is set as a constrained mass boundary which allows mass to freely leave the model, but cannot contribute mass into the model.

4. Model Calibration

Model calibration was carried out by iteratively adjusting the various model inputs described in Section 2, within expected ranges as supported by site investigations and published information. The locations of the bores which have been used in the calibration are shown in Figure 1, and geological cross sections are presented in Earthtech (2023b).

The calibration objective is to adjust the model inputs so that a reasonable match is achieved between the modelled and measured winter groundwater levels and NH_4-N concentrations in 2023. Calibration of mass and flow has been carried out simultaneously, as the flow settings affect mass concentrations. Although all input parameters were tweaked and/or tested, the main parameters which were adjusted as part of the calibration process were the input source concentration, dispersivity, sorption, and recharge.

The calibration model begins in 1971 at the commencement of landfilling and simulates a 52-*year* period ending in 2023. As such, the completed calibrated model includes the 52-*year* record of leachate concentrations progressing through the groundwater system.

The model calibrated settings are shown in Table 1 and Figure 2.

Table 1: Adopted Model Settings

Model Setting	Dune Sands	Aquitard	Gravels	Impedance Layer in Swampy Area
Permeability *(m/d)*	3.15	$8.64e^{-3}$	86.4	$8.64e^{-3}$
Anisotropy *(horiz./vertical permeability)*	3	4	3	4
Specific Yield [1]	0.14	$1e^{-4}$	$1e^{-4}$	0.14
Effective Porosity	0.15	0.18	0.13	0.18
Henry Constant	1.91	21	1.91	1.91[2]
Longitudinal Dispersivity *(m)*	5	5	5	5
Transverse Dispersivity *(m)*	0.1	0.1	0.1	0.1
Diffusion *(m^2/s)*	$1e^{-9}$	$1e^{-9}$	$1e^{-9}$	$1e^{-9}$

[1] FEFLOW input is specific storage, which is specific yield divided by layer thickness (1/*m*)

[2] Higher sorption conservatively not assigned to impedance layer

In terms of the groundwater flow part of the calibration, winter (September-October) groundwater levels measured in ten shallow and deep monitoring bores were used as calibration targets. The groundwater levels adopted as calibration targets are shown in Figure 5 of Earthtech (2023b). The hydraulic head scatter plot is presented in Figure C and shows that a good match is achieved between the predicted and measured groundwater levels (the closer the points are relative to the blue line, the better the calibration).

Flow calibration statistics are as follows:

i. *RMS* (root mean square) = 0.34*m*
ii. *RN* (normalised mean) = $RMS / (H_{max} – H_{min})$ = 5%

The model is considered to be adequately calibrated for flow with *RN* < 10%. The calibrated hydraulic heads are shown in Figure 3.

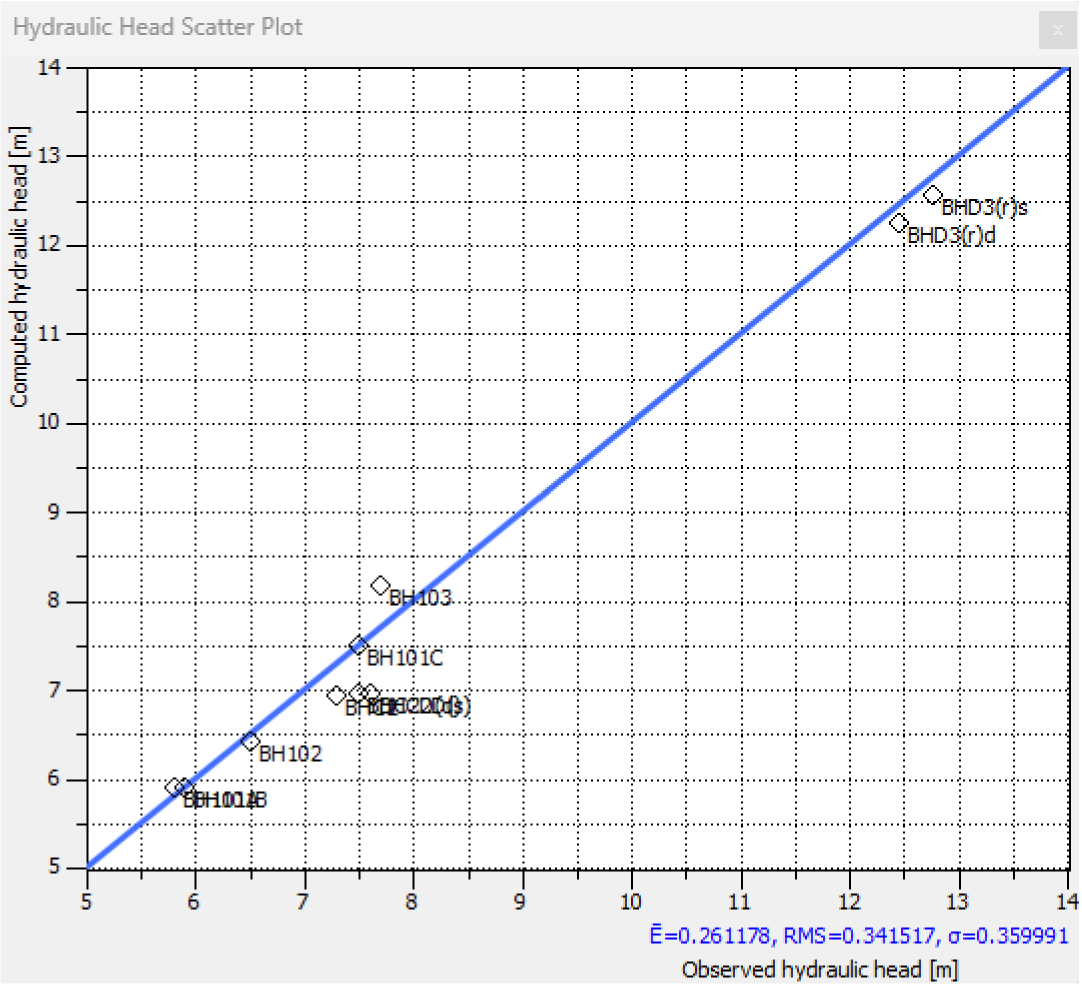

Figure C: Calibration hydraulic head scatter plot (time = 52yrs, which is the present day)

In terms of the mass transport part of the calibration, NH_4-N concentrations measured in 11 shallow and deep monitoring bores were used as calibration targets. The concentrations adopted as calibration targets are shown in Figures 5 and 6.2 of Earthtech (2023b). BH102 was excluded, as this is an outlier in terms of the data set. The mass concentration scatter plot is presented in Figure D and shows that a reasonable match is achieved between the predicted and measured groundwater levels.

Mass transport calibration statistics are as follows:

i. *RMS* (root mean square) = 51.3g/m^3
ii. *RN* (normalised mean) = $RMS/(C_{max} - C_{min})$ = 24%

The model is considered to be acceptably calibrated for mass transport with *RN* = 24%. The calibrated mass concentrations are shown in Figure 4.

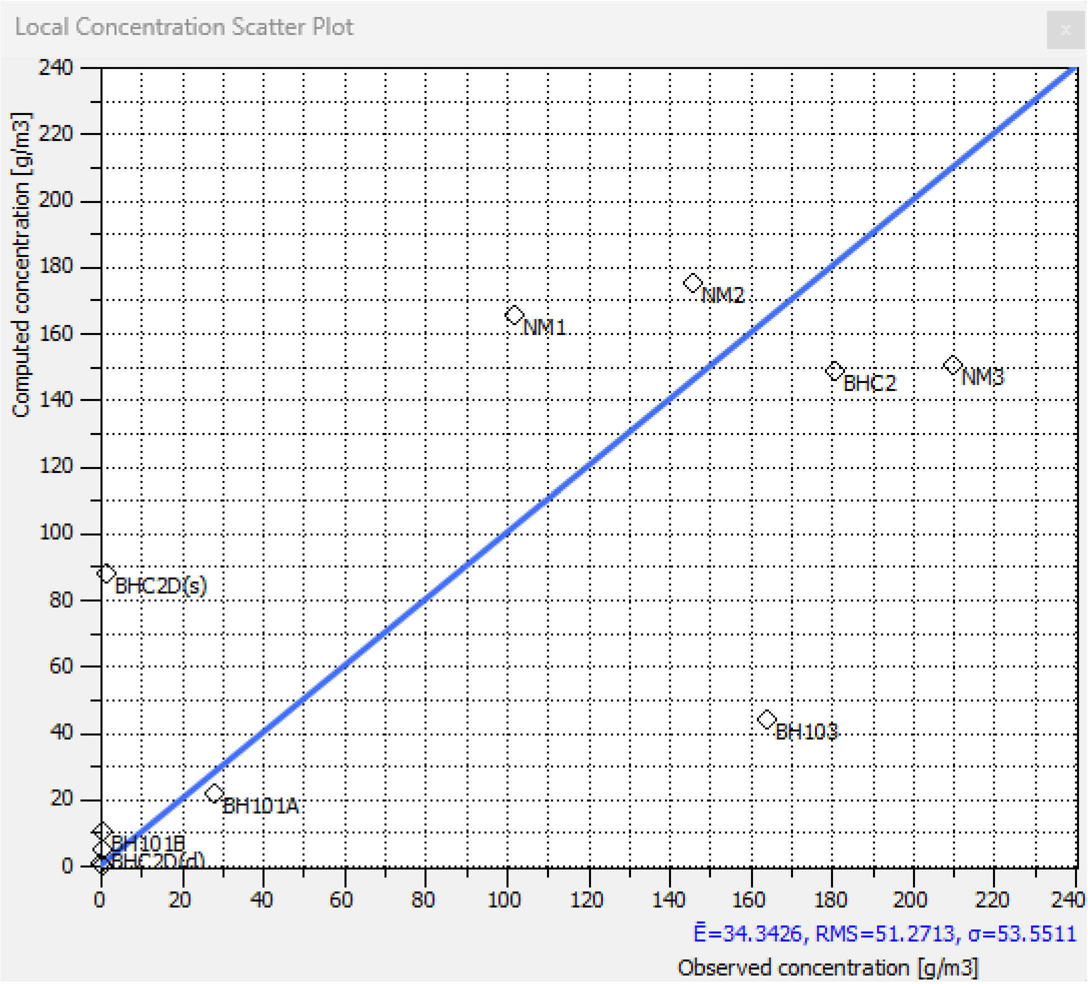

Figure D: Calibration mass concentration scatter plot (time = 52yrs, which is the present day)

There is considerable scatter in the Figure D mass concentration plot, which is expected given the difficulty in calibrating mass concentrations over a time period of 52-*years* for a lumped parameter model. Comments on the calibration scatter plot are as follows:

i. The four shallow monitoring locations in the swampy area (NM1, NM2, NM2 and BHC2) are centred on the blue line in Figure D. Figure 4 shows that concentration gradients around the swampy area are steep, so while the individual bores are influenced by edge effects, overall they match the average concentration at the swampy area.

ii. BH103 is expected to be influenced by 3D topography effects – in the model it is located in close proximity to the groundwater table, where concentration gradients are steep, and the concentration predicted for BH103 is lower due to the nearby clean water rainfall recharge boundary.

iii. BHC2D(s) is predicting a much higher concentration than was measured. This is because there is some downwards spread of the contamination plume in the model, whereas the field measurements indicate the plume remains in the upper part of the dune sand aquifer. The modelled plume vertical spread is a result of the convective mass transport equation, transverse dispersivity and sorption settings in the model. While efforts have been made to reduce the plume vertical spread during the calibration process, some vertical spread remains. This is conservative in terms of the intercept drain efficiency prediction, as it results in more contamination passing under the intercept drain and reporting to the Hōkio Stream.

iv. If BH103 and BHC2D(s) are removed from the scatter plot, the *RN* would become 15%, which is much closer to the typically accepted target of $RN \leq 10\%$.

Table 2 shows the model input settings in terms of their sensitivity. The highly sensitive parameters have the greatest influence on the model predictions, but are considered to be well-defined based on field investigation information and model calibration process.

Table 2: Model Input Parameter Sensitivity

Sensitivity	Model Flow Inputs	Model Mass Transport Inputs
Highest Sensitivity	Permeability	Dispersion and Sorption
↓	Anisotropy	Source Concentration
	Recharge	Effective Porosity
Lowest Sensitivity	Constant Head Boundary Settings	Diffusion

Overall, the model is considered to be adequately calibrated as the general distribution of mass concentrations matches the field observations with:

i. The NH_4-N mass transport predominantly occurring in the upper half of the dune sand aquifer, consistent with the field observations.

ii. The highest NH_4-N concentrations are centred on the swampy area and Northern Farm Drain, consistent with the field observations (Figure 10 of Earthtech, 2023b). This shows that the swampy area and Northern Farm Drain are already acting to intercept some of the contamination spreading from the unlined landfill due to their drainage influence in the flow field.

iii. The model shows the $10 g/m^3$ NH_4-N contour intercepting the Hōkio Stream under current conditions. This is consistent with the field observations which have recorded recent increases in NH_4-N concentrations in the stream.

5. Groundwater Intercept Drain

5.1 Intercept Drain BPO Design Requirements

A groundwater intercept drain was proposed in Earthtech (2023a) for the purpose of intercepting and abstracting the leachate contaminants before they report into the Hōkio Stream.

Proposed engineering requirements, supported by the modelling findings, of the groundwater intercept drain are shown in Figures 7 to 8. Engineering details and notes on the drain staging are provided in Section 7.4 of this report.

The intercept drain is to be constructed in two stages, with Stage 1 consisting of the 100*m* long central portion of the drain, located to extend across the area with the highest measured NH_4-N concentrations. Stage 2 involves the addition of 60*m* and 40*m* of drain on the western and eastern ends of Stage 1, respectively, to complete the full 200*m* length. It is anticipated that Stage 2 would be constructed approximately five years following Stage 1.

The two-stage approach has the benefit of allowing a period of a few years for the verification of pumping volumes and contaminant interception effects. The scope and timing of Stage 2 construction may be optimised, and groundwater modelling predictions updated, using information obtained during Stage 1 operation.

5.2 Model Results

This section describes the model results, which indicate conditions at the critical section location through the centre of the contaminant plume with the highest NH_4-N concentrations.

Forward analysis models were run with and without the groundwater intercept drain to calculate the drain efficiency in capturing contamination mass which would have otherwise reported into the Hōkio Stream and Northern Farm Drain. These models simulate conditions from 2024 to 2124, over the next 100 *years*.

Without the intercept drain, Figure 5 shows the predicted future progression of the contaminant plume towards the Hōkio Stream. Figures E and F respectively show the NH_4-N concentrations entering the Hōkio Stream and Northern Farm Drain (including the swampy area which discharges into the Northern Farm Drain) with time. Although a proportion of the contamination is intercepted by the Northern Farm Drain, the NH_4-N concentration entering the Hōkio Stream through groundwater inflow is predicted to peak at $18 g/m^3$ in 2045 at the critical section location.

With the intercept drain, Figure 6 shows the progression and interception of the contaminant plume. The majority of the plume is collected and removed by the groundwater intercept drain. Figure E shows that the mass entering the Hōkio Stream is predicted to reduce to $2 g/m^3$ in 2045 (the time when the peak concentration would have occurred if the groundwater drain was not installed). Figure F shows that contamination discharge into the Northern Farm Drain ceases, as this drain would no longer receive groundwater discharge.

The difference between the two curves in Figure E indicates that the intercept drain is approximately 90% efficient in capturing the peak concentration which would have reported into the Hōkio Stream.

The BPO remedial works need to comply with the following:

Environment Court Order – Discharge Permit 6010, section 2A

2A. … the Permit Holder must complete an assessment of leachate remediation options (and a BPO) to:

(a) cease, or if cessation is not feasible, materially reduce the discharge of leachate to the Tatana Drain [renamed the Northern Farm Drain] and Hokio Stream; or

(b) if neither of the options in (a) are feasible then options to offset effects within the Hōkio catchment and if that is not feasible or possible options to compensate effects within the Hōkio catchment or outside of it (either option through an ecological package).

Cessation of plume discharge to the stream is not practical. The proposed intercept drain, with an efficiency of approximately 90%, provides an effective method of near-total capture of discharge into the Northern Farm Drain (with total capture over the effective length of the intercept drain) and a material reduction in the discharge to the Hōkio Stream.

Figure G shows the change in NH_4-N concentration in the intercept drain at the critical section location. This shows that concentrations are initially high, and reduce with time due to both removal of the existing contamination plume and reduction in the landfill source concentration.

Further comments on the intercept drain efficiency are as follows:

i. The benefit of the proposed intercept drain is two-fold:

- Contamination mass is physically removed from the groundwater system by pumping from the intercept drain.

- As a result of the pumping, the groundwater table is nearly flat between the intercept drain and the Hōkio Stream (as both drain to RL5*m*). This means that groundwater flow between the intercept drain and the Hōkio Stream is significantly slowed. The slower groundwater movement allows for additional dilution of the NH_4-N concentrations which are already present between the intercept drain and the Hōkio Stream. This additional dilution effect is incorporated in the model through the recharge settings.

ii. Due to the shape of groundwater drawdown around the drain, the influence of the intercept drain extends approximately 50*m* beyond the drain location. The intercept drain zone of influence is shown in Figure 7 for the 200*m* long Stage 2 drain, which indicates:

- The zone of influence extends 50*m* to the north of the drain location. This means that contamination which has already passed up to 50*m* north of the intercept drain location is still able to be collected.

- The zone of influence of the intercept drain extends approximately 50*m* to either end of the drain location, providing an effective 300*m* interception length for the 200*m* long Stage 2 drain, or a 200*m* interception length for the 100*m* long Stage 1 drain.

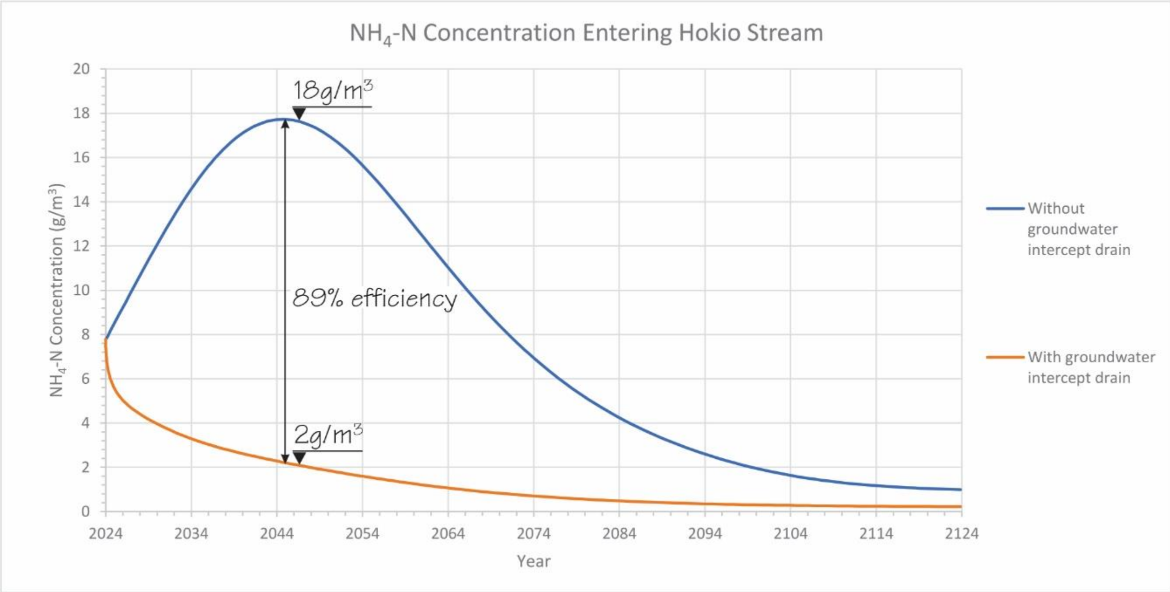

Figure E: Future prediction of NH_4-N concentration entering the Hōkio Stream, with and without the Groundwater Intercept Drain, peak concentration for critical section location (note that Figure 5B shows the $20g/m^3$ contour line intersecting a small area of the Hokio Stream. The Figure E graph tracks concentrations with time for all the nodes on the right side and underside of the stream, which is why the peak concentration in Figure E is slightly less than Figure 5B.)

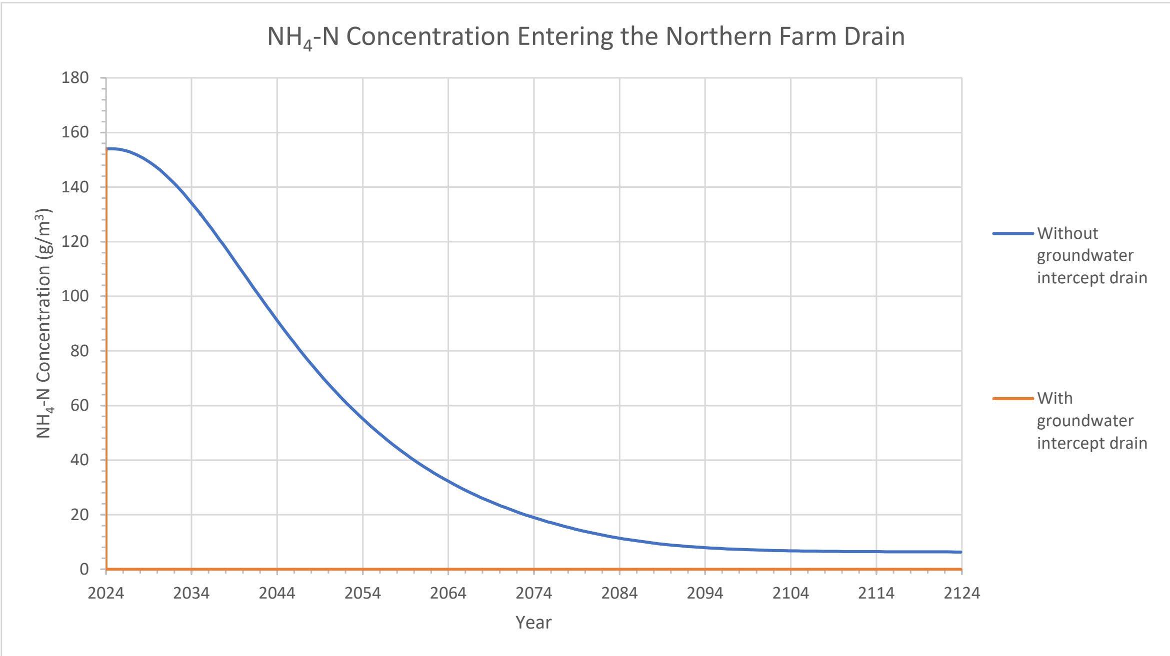

Figure F: Future prediction of NH_4-N concentration entering the Northern Farm Drain (including the Swampy Area), with and without the Groundwater Intercept Drain, peak concentration for critical section location

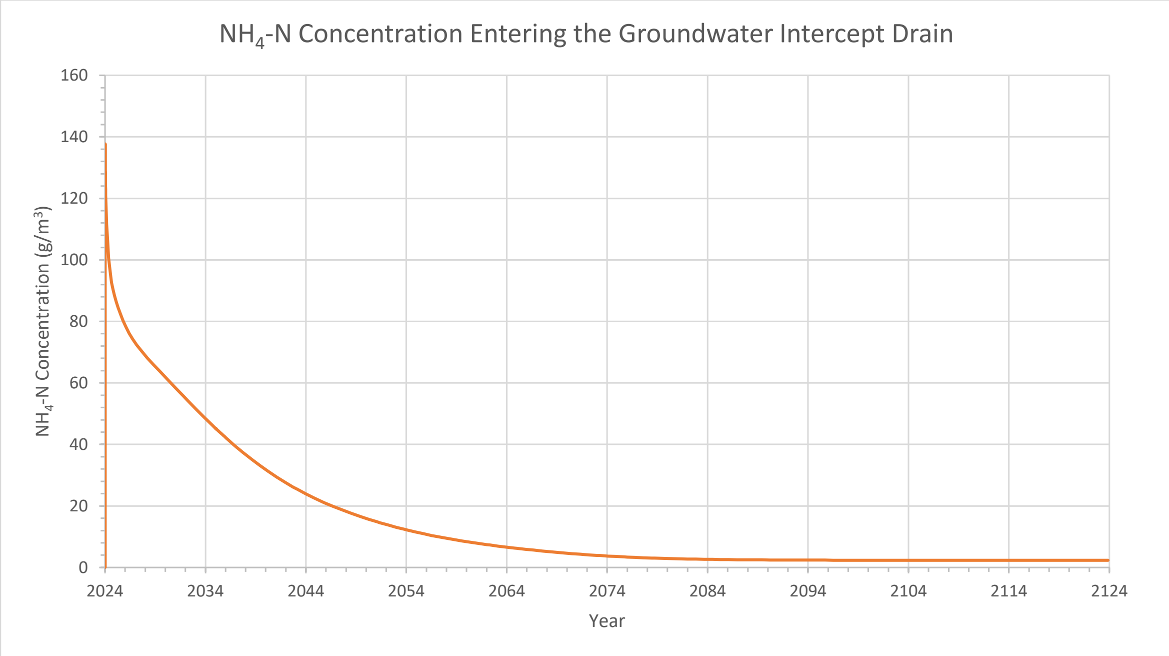

Figure G: Future prediction of NH_4-N concentration entering the Groundwater Intercept Drain, peak concentration for critical section location

Figure E indicates that a 50-*year* drain operational design life is required. The 50-*year* duration is conservative and is based on existing surface water effects being acceptable at the Hōkio Stream HS3 monitoring location (i.e. without interception, an approximately 50-*year* long period is required for concentrations entering the Hōkio Stream to return to the current levels). Concentrations at HS3 are lower than HS2 due to dilution in the stream.

Pumping from the intercept drain is predicted to result in drying of the swampy area and Northern Farm Drain, and also an interception effect on groundwater baseflows entering the Hōkio Stream (due to reduced groundwater contribution into the stream from the south). These effects will need to be considered in terms of intercept drain groundwater take and diversion consent.

5.3 Results for the 200m Long Stage 2 Intercept Drain

The previous section presents the groundwater model results which apply to the critical cross-section location through the centre of the contamination plume with highest NH_4-N concentrations. However, NH_4-N concentrations vary along the effective length of the intercept drain. This section provides the model results for the 200*m* long Stage 2 groundwater intercept drain.

The NH_4-N concentrations approximate parabolic shape for an east-west cross-section running along the intercept drain effective length. Using the trapezium method, the average NH_4-N concentration for the parabola is assessed as 52% of the peak concentration in late 2023. It is noted that this proportion will change with time; therefore, it is necessary to apply a factor of safety to the predicted concentrations for BPO design (discussed in Section 6.2).

The assessed average NH_4-N concentrations entering the Hōkio Stream and the Northern Farm Drain over a 300*m* reach (effective intercept length of a 200*m* long drain) are shown in Figures H and I, respectively. As shown in Figure 7, the 300*m* effective intercept length covers most of the area where NH_4-N concentrations were measured to be > $20 g/m^3$ along the drain alignment in late 2023.

Figure J shows the assessed average concentration leaving the groundwater intercept drain outlet pipe for treatment or management.

The 200*m* long Stage 2 intercept drain is predicted to be approximately 90% efficient in capturing the NH_4-N concentration exiting the Old Landfill which would have reported into the Hōkio Stream.

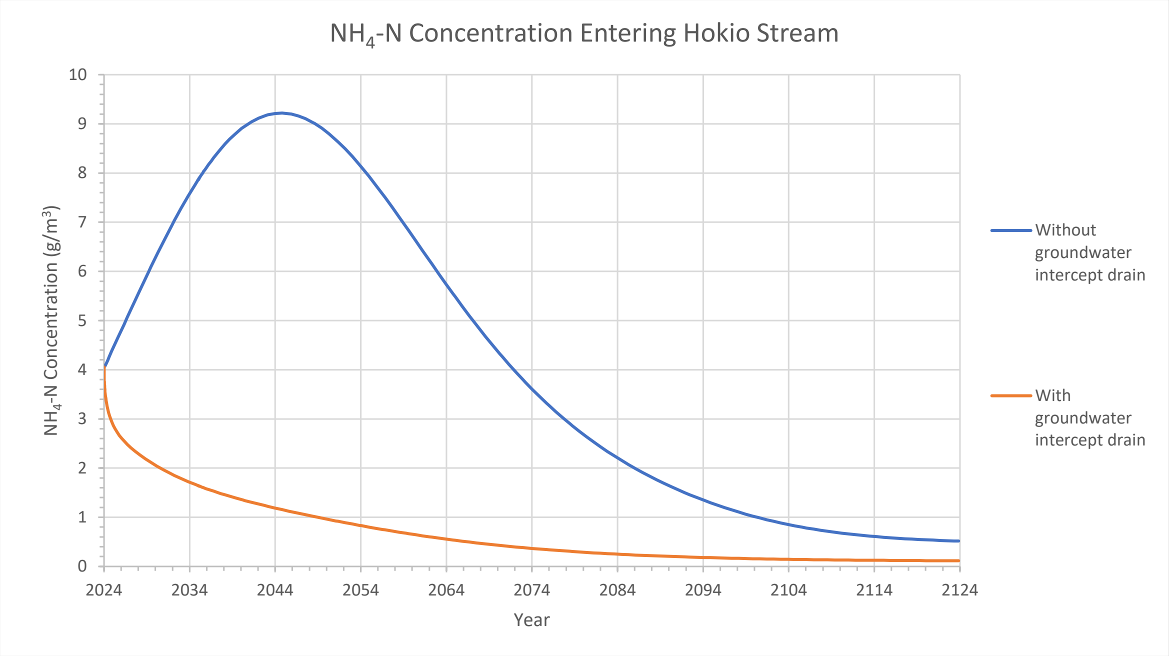

Figure H: Future prediction of average NH_4-N concentration entering the Hōkio Stream, with and without the Stage 2 Groundwater Intercept Drain, over a 300m intercept length

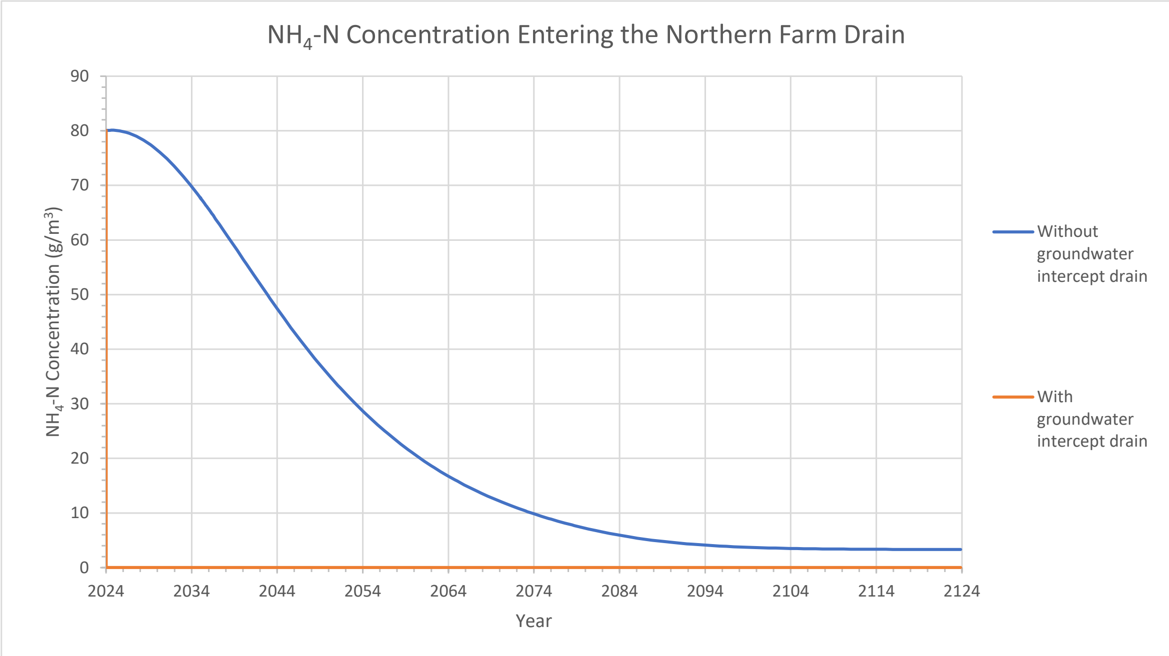

Figure I: Future prediction of average NH_4-N concentration entering the Northern Farm Drain (including the Swampy Area), with and without the Stage 2 Groundwater Intercept Drain, over a 300m intercept length

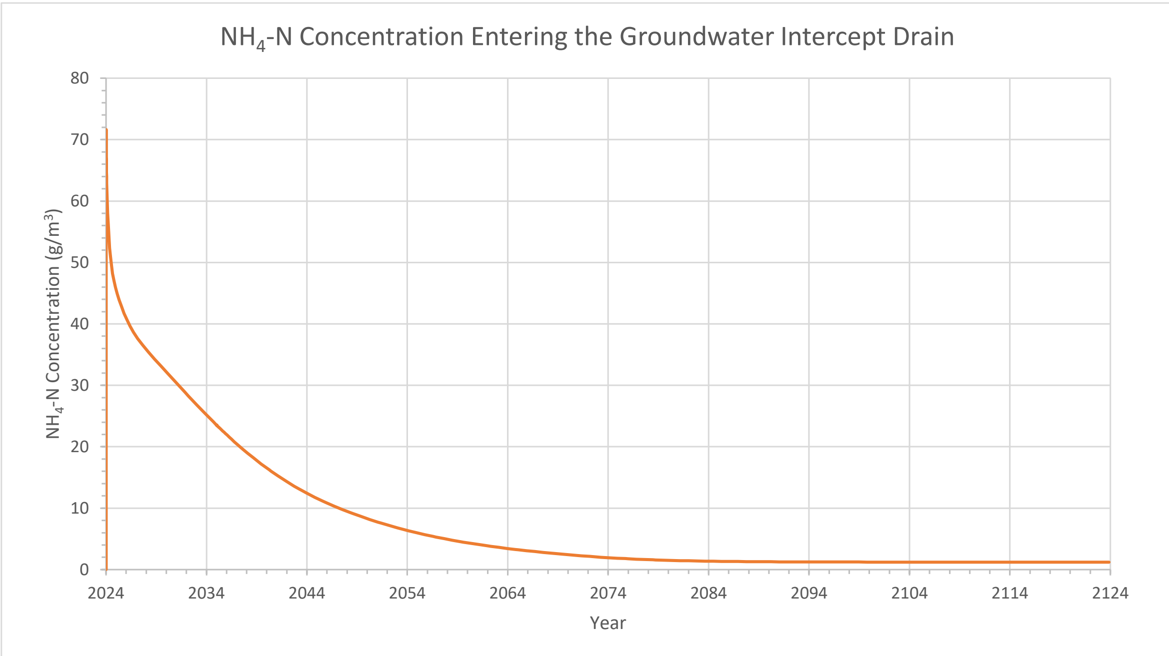

Figure J: Future prediction of NH_4-N concentration pumped from the Stage 2 Groundwater Intercept Drain

5.4 Results for the 100m Long Stage 1 Intercept Drain

This section provides the model results for the 100*m* long Stage 1 groundwater intercept drain.

The NH_4-N concentrations approximate parabolic shape for an east-west cross-section running along the intercept drain effective length. Using the trapezium method, the average NH_4-N concentration for the parabola is assessed as 68% of the peak concentration in late 2023. As previously noted, this proportion will change with time.

The assessed average NH_4-N concentrations entering the Hōkio Stream and the Northern Farm Drain over a 300*m* reach (for direct comparison with the graphs in Section 5.3) are shown in Figures K and L, respectively. The shorter 100*m* long drain provides an effective intercept length of 200*m*, which covers most of the area where NH_4-N concentrations were measured to be > 60g/m^3 along the drain alignment in late 2023. The NH_4-N concentrations entering the Hōkio Stream and the Northern Farm Drain are increased compared to the Stage 2 drain extent, as some lower concentration contaminant is able to pass to the east and west of the drain capture area.

Figure M shows the assessed average concentration leaving the groundwater intercept drain outlet pipe for treatment or management. Concentrations are higher than for Stage 2, as the Stage 1 drain targets the area of highest concentrations.

The 100*m* long Stage 1 intercept drain is estimated to be approximately 70% efficient in capturing the NH_4-N concentration exiting the Old Landfill which would have reported into the Hōkio Stream. The reduced efficiency is due to the shorter drain length, with some contaminant able to pass to the east and west of the drain. The reduction in efficiency from 90% for a 200*m* long drain to 70% for a 100*m* long drain is limited, as the contaminant which is able to pass around the 100*m* long drain has much lower concentration.

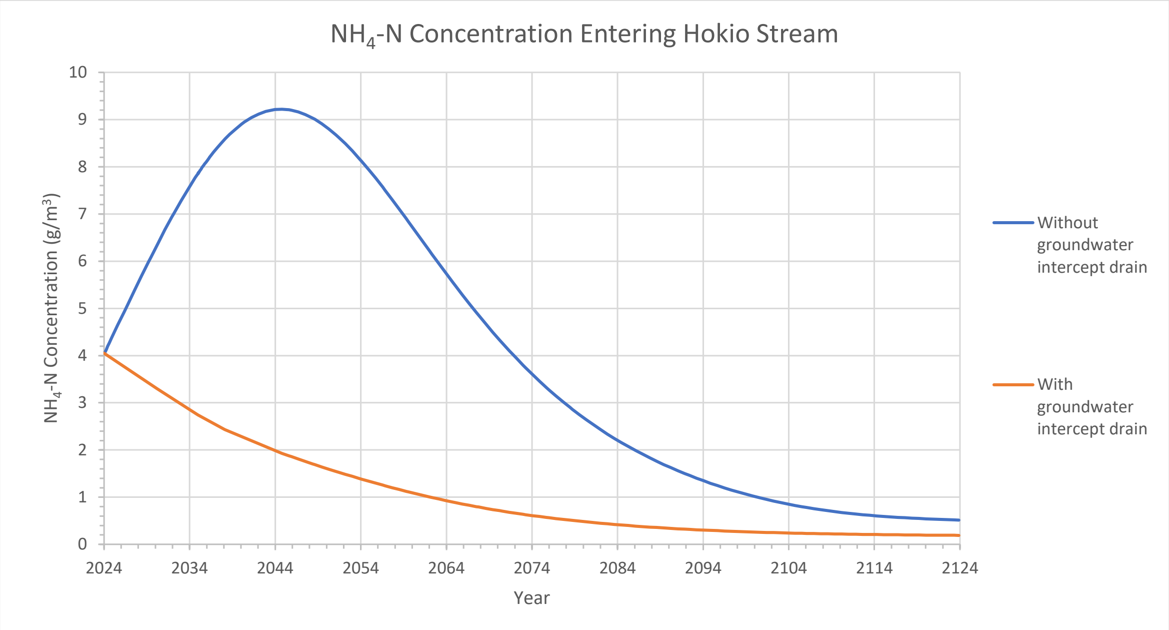

Figure K: Future prediction of average NH_4-N concentration entering the Hōkio Stream, with and without the Stage 1 Groundwater Intercept Drain, over a 300m intercept length

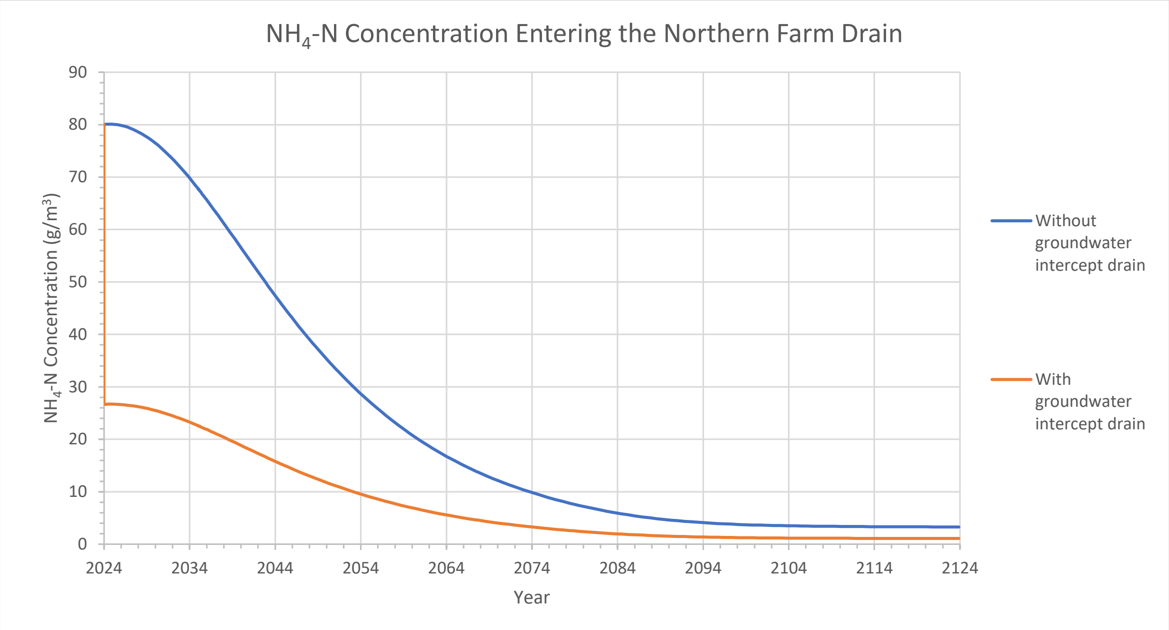

Figure L: Future prediction of average NH_4-N concentration entering the Northern Farm Drain (including the Swampy Area), with and without the Stage 1 Groundwater Intercept Drain, over a 300m intercept length

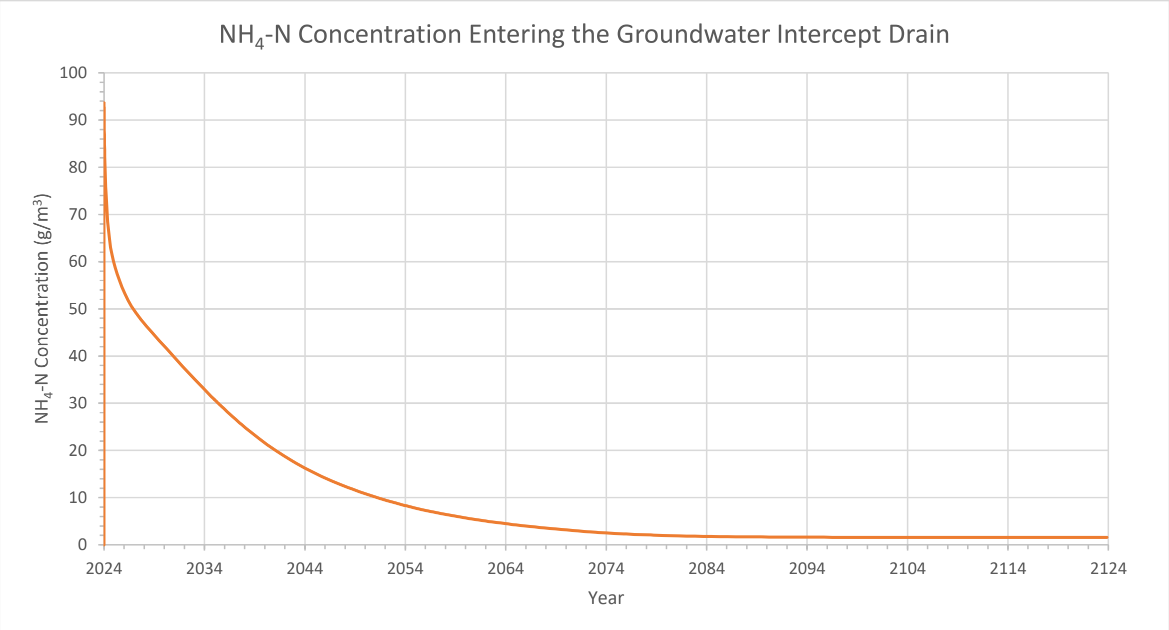

Figure M: Future prediction of NH_4-N concentration pumped from the Stage 1 Groundwater Intercept Drain

Constructing the intercept drain in stages is important to enable verification of pumping volumes and contaminant interception effects. To limit the Stage 1 drain reduced efficiency, Stage 2 is proposed to be constructed within a relatively short five year period.

6. Parameters for the BPO Engineering Design

6.1 Groundwater Pumping Volumes

Groundwater inflows will be initially high when pumping from the intercept drain first commences. There will be a four-month to six-month time period for the removal of aquifer storage before the groundwater abstraction volumes stabilise with the groundwater drawdown level achieving the design of RL5*m*.

It is proposed to size the pump and treatment system for long-term abstraction volumes. Sizing the pump for the initial higher inflows during the four-month to six-month transient period would result in redundant capacity under long-term conditions. During the initial transient time period, pumping volumes, concentrations, and groundwater levels will need to be monitored. Pump settings are expected to require adjustment until the system stabilises, such that the capacity of the pump and the treatment system is not exceeded.

Long-term groundwater abstraction volumes (for a drain pumping level controlled at RL5*m*) for BPO design are as follows:

i. For Stage 1: FEFLOW predicted steady state groundwater abstraction = 1.38$m^3/d/m$ *length* × 100*m* drain length, plus 83m^3/d radial flow from both ends of the drain = 221m^3/d, say 220m^3/d for winter conditions.

ii. For Stage 2: FEFLOW predicted steady state groundwater abstraction = 1.38$m^3/d/m$ *length* × 200*m* drain length, plus 83m^3/d radial flow from both ends of the drain = 359m^3/d, say 360m^3/d for winter conditions.

iii. To account for ground condition and modelling uncertainty, we recommend that a factor of safety of +/- 30% be applied to the FEFLOW predicted groundwater abstraction. A flow uncertainty analysis should be carried out as part of detailed design.

iv. Therefore, the final Stage 2 pumping and treatment systems should be designed to accommodate groundwater abstraction volumes between 250m^3/d and 470m^3/d, with a best estimate winter groundwater abstraction volume of 360m^3/d.

6.2 NH_4-N Mass Abstraction

Figures J and M show the change in intercept drain NH_4-N concentrations with time for Stages 2 and 1, respectively. These graphs essentially show the NH_4-N concentration at the intercept drain pump outlet pipe, which is an average of the full drain effective length.

Initial concentrations are high as the intercept drain will be installed near the peak of the existing contaminant plume. Concentrations reduce with time as the existing contamination plume is abstracted, and also as the landfill source concentration reduces.

For NH_4-N treatment and management, we recommend the following for BPO design:

i. The treatment or management system be sized to accommodate concentrations over the first 50 *years* of pumping. After this time, concentrations entering the Hōkio Stream will have returned to the values measured in late 2023.

ii. A factor of safety of +/- 30% should be added to the abstracted concentrations shown in Figures J and M, to account for ground condition and modelling uncertainty. A concentration uncertainty analysis should be carried out as part of detailed design.

iii. Therefore, the treatment and management system should be design to accommodate the Figure J best estimate concentrations, with a range of +/- 30%.

7. Best Practicable Option (BPO) Engineering

7.1 BPO Aim

The proposed remedial works need to achieve a material reduction of leachate discharged from the old unlined landfill (entering into the Tatana / Northern Farm Drain and the Hōkio Stream).

7.2 BPO Engineering Options

7.2.1. Brief Overview of Previous BPO Options Explored

HDC engaged Tonkin and Taylor (T&T) to undertake a leachate Best Practicable Options (BPO) assessment for the Levin (unlined) Landfill in 2019. In the report (Tonkin and Taylor, 2019), a summary of possible BPO options (11 in total) aimed at reducing leachate generation was provided. These options included engineering solutions that could be combined to mitigate leachate generation at the source as well as the effects of leachate migration from the unlined landfill.

It is thus important to mention these early options as follows:

Options to reduce leachate generation:

- Options 1 to 4: Capping of the landfill and improvements to existing capped areas
  Note: this was carried out by HDC as an early BPO implementation stage in 2023.

- Option 5: Surface water drainage improvements
  Note: drainage improvements were carried out across the surface capping construction as part of the above mentioned early stage BPO works in 2023.

- Option 6: Perimeter drain improvements

<u>Options to capture leachate:</u>

- Option 7: Groundwater interceptor trench
  It can be noted that this BPO option has been developed following detailed investigations carried out during 2023 by Earthtech, to progress to implementation.

- Option 8: Pump and treat shallow groundwater

- Option 9: Install leachate collection system in the original landfill

<u>Options to reduce leachate impacts:</u>

- Option 10: Constructed wetlands around Tatana Drain (Northern Farm Drain)

- Option 11: Addressing and repairing seeps
  Note: this was deemed as of high importance by HDC, and detailed site walk-overs of the old landfill have been conducted by experienced landfill specialists of both Stantec and Earthtech, with HDC's solid waste staff. While no seeps have been identified, areas of potential concern have been identified, filled, and capped by HDC's contractor (in early 2024).

7.2.2. BPO Options Brought Forward

The detailed investigation works have enabled a final BPO recommendation for a groundwater extraction trench to be developed. Several options for this BPO required clarity, which were discussed at a 'Think Tank' meeting held at HDC's offices on 25 January 2024 between HDC technical and senior management members, and technical expertise from Stantec and Earthtech.

For the ‘think tank’ the following assessment criteria was adopted:

BPO OPTIONS ASSESSMENT CRITERIA:	
Legal Context	Conformance with Environment Court Order – Discharge Permit 6010 cl. 2A(a)
Compliance Context	No significant increases in the concentrations between monitoring sites HS1A and HS3 for parameters exceeding the Trigger values contained in Table C1 at Site HS3 NH_4-N < 2.1*g*/*m*^{3}; 0.4*g*/*m*^{3} average
Consenting Context	Would a consent be obtainable within an acceptable timeframe and with acceptable technical ease?
Environmental Context	Low to minor environmental impacts
Social Acceptance Context	Iwi perspective/NLG perspective/general public perspective
Technical Context	Technically difficult or, complex or straightforward of implementing option with a high or low likelihood of success
Financial Context	What are the indicative capital (Capex) costs and operational (Opex/O&M) costs

The BPO options for the leachate collection trench solution were as follows:

‘Think Tank’ BPO Options (Groundwater Interceptor Trench)		
BPO Description	Description	‘Think Tank’ Decisions
BPO 1	Do nothing.	Not a consideration by HDC – out.
BPO 2	Do nothing but provide ecological package offsets.	Not preferred since material reduction not achieved. Possible partial fallback option.
BPO 3*	Full trench (200*m*) extraction and 100% (360*m*^{3}/*day*) discharge to sewer.	Best Option to achieve objectives - with staged construction, i.e. 100*m* trench (Stage 1) + 100*m* (Stage 2) trench.
BPO 4	Full trench (200*m*) extraction and complete on-site treatment.	Treatment effectiveness unknown without treatability trials, and potentially high challenges on discharge consent.
BPO 5	Partial trench extraction (say 100*m*) and 100% discharge to sewer.	Capture efficiency reduced due to shorter drain length, which increases the contamination reporting to the Hokio Stream.
BPO 6	Partial trench extraction (say 100*m*) and on-site treatment (and re-use/irrigation on site).	Same as above (BPO 5), treatment effectiveness unknown without treatability trials and probable consenting complications.
BPO 7	Partial or full trench extraction and discharge via dedicated line or road tankers to "The Pot".	Excessively high cost, complex, and consenting concerns – out.
BPO 8	Partial or full-scale extraction, combined discharge to sewer and on-site treatment.	Doesn’t achieve objectives, consenting challenges – out.

*selected BPO Option for implementation.

7.3 Extraction System Design

The groundwater intercept drain design has been optimised to maximise the extraction of contaminant mass which would have otherwise reported into the Hōkio Stream and the Northern Farm Drain. The epicentre of highest concentrations of the NH_4-N plume are some 150*mg/ℓ* to 210*mg/ℓ* (recorded at the NM3 location on 21 September 2023). Ammoniacal-nitrogen is potentially toxic to plants at 50*mg/ℓ* to 150*mg/ℓ* and fish life at levels of approximately 2*mg/ℓ*. Thus, this BPO focuses on reducing or removing ammoniacal-N from the receiving (and received) environment.

7.3.1. Drain Details

Proposed details of the groundwater intercept drain are shown in Figures 7 and 8 and are summarised as follows:

- 200*m* long subsoil drain, located to intercept the majority of the contaminant concentration plume.
- Drain to be constructed in two stages, with Stage 1 consisting of the 100*m* long central portion of the drain. Stage 2 involves the addition of 60*m* and 40*m* of drain at the western and eastern ends of the Stage 1 drain, respectively.
- The intercept drain (Stages 1 and 2) would be continuously pumped with a level or pressure-controlled switch set to an elevation of RL5*m* (i.e. the groundwater level is not to be lowered below RL5*m*). This is to match the water level in the Hōkio Stream to provide interception efficiency. The drain pumping level at RL5*m* will also not result in a stream depletion effect. The RL5*m* drain pumping level will also ensure capture of leachate-impacted groundwater from the swampy ground above the Northern Farm Drain.
- The drainage metal intake zone of the intercept drain is to remain submerged at all times to prevent clogging due to iron precipitation. Therefore, the intake has been specified between RL4.5*m* to RL3.5*m*, and is to be fully wrapped in a filter geotextile to prevent sand ingress.
- Intercept drain constructed with a 150*mm* diameter slotted PVC pipe, which is to be laid horizontally without grade. The required drainage gradient will occur within the pipe and drainage aggregate.
- Access to all pipes is to be provided for rodding and flushing maintenance.

Stage 1 would be constructed as soon as possible after obtaining the required consent. Stage 2 is anticipated to be constructed approximately five years following the completion of Stage 1.

The Stage 2 drain scope and timing may be updated based on observation and updated modelling predictions of the Stage 1 drain performance.

The intercept drain has been detailed following similar groundwater drains which have been installed for long-term groundwater control in dune sands under an extensive area of Matarangi on the Coromandel Peninsula. The Matarangi drains have worked successfully since 2004, provided that regular maintenance and flushing are carried out.

7.3.2. Drain Location Options

The proposed location of the Groundwater Intercept Drain, shown in Figure 7, runs parallel to the property boundary fenceline. Existing ground level rises to approximately RL11.5*m* along the fence line to the east, as shown in Figure 8, therefore necessitating an 8*m* to 9*m* deep excavation. Groundwater level is at approximately RL7*m* to RL7.5*m*, thus requiring dewatering for excavation to a depth of some 4*m* to 4.5*m* (to approximately RL3*m*). This would require a wide, stepped-type excavation to ensure safe working conditions, with possible use of shoring, sheet piles, or similar.

An alternative alignment for the proposed Groundwater Interceptor Drain could be immediately to the south on the lower-lying ground, as shown in Figure N below.

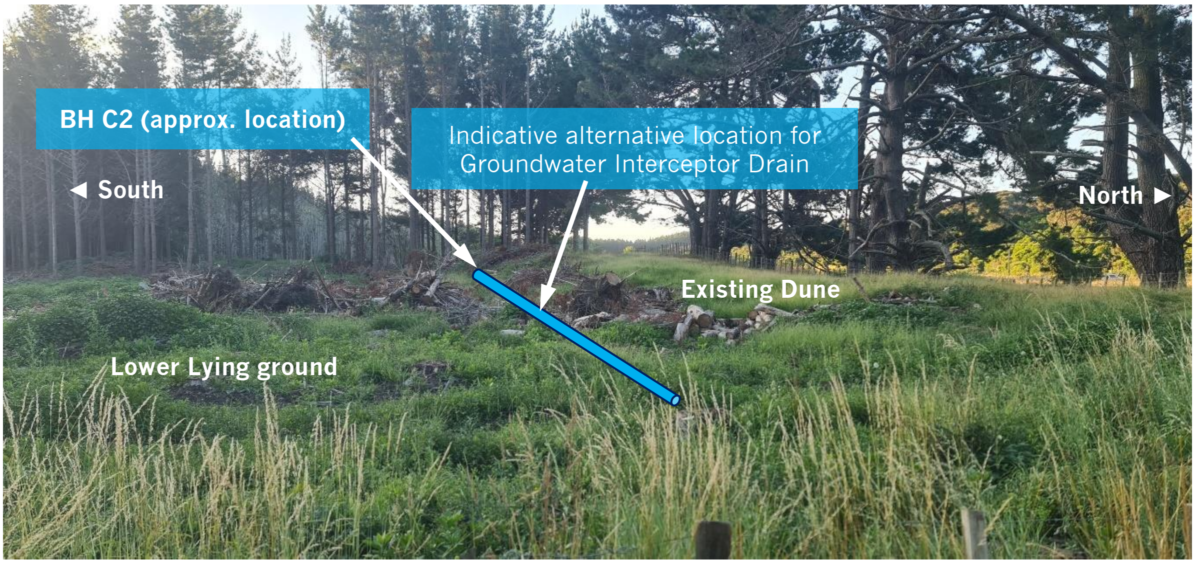

Figure N: Ground along the northern boundary of the Levin Landfill Site, viewing westwards from the entrance access road to the site. The northern perimeter fenceline is visible in the photograph (mid-right), running along the northern boundary.

7.4

7.4 Process Design Aspects

As concentrations will vary with time, the BPO gives consideration to providing an efficient and cost-effective design with a recommended staged approach, as described in Section 5.1.

We understand from recent communication with HDC's wastewater management technical staff that the Wastewater Treatment Plant (WwTP) currently accepts an inflow of some 7*Mℓ/day* (7,000m^3 per day) with an NH_4-N concentration of approximately 39g/m^3. The proposed interceptor trench will thus influence this concentration influent slightly, calculated as follows:

- Current NH_4-N concentration: 39g/m^3
- Current NH_4-N loading:
  - (7,000 x 39) ÷ 10^3 = 273*kg* NH_4-N/day
  - Plus 360m^3/*day* from proposed interceptor trench, groundwater mix NH_4-N = assume 70g/m^3 (note that short-term concentrations up to 95g/m^3 are predicted at the commencement of pumping)
  - i.e. additional loading: (360 x 70) ÷ 10^3 = 25*kg* NH_4-N/*day*
  - Therefore, future NH_4-N concentration at WwTP:
  - (25 + 273) ÷ [(7,000 + 360)] x 10^3) = 40.5g/m^3 (+3.9%)

8. Conclusions and Recommendations

The above has provided proof of concept for the groundwater intercept drain. We recommend that this BPO design, comprising a 200*m* long drain constructed with a staged approach, proceeds to consenting.

9. References

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WasteMINZ (2022)	Technical Guidelines for Disposal to Land (Rev 3, WasteMINZ, 2022)

NOT FOR CONSTRUCTION

Note: All drawings are to be approved (initialled) before final issue.

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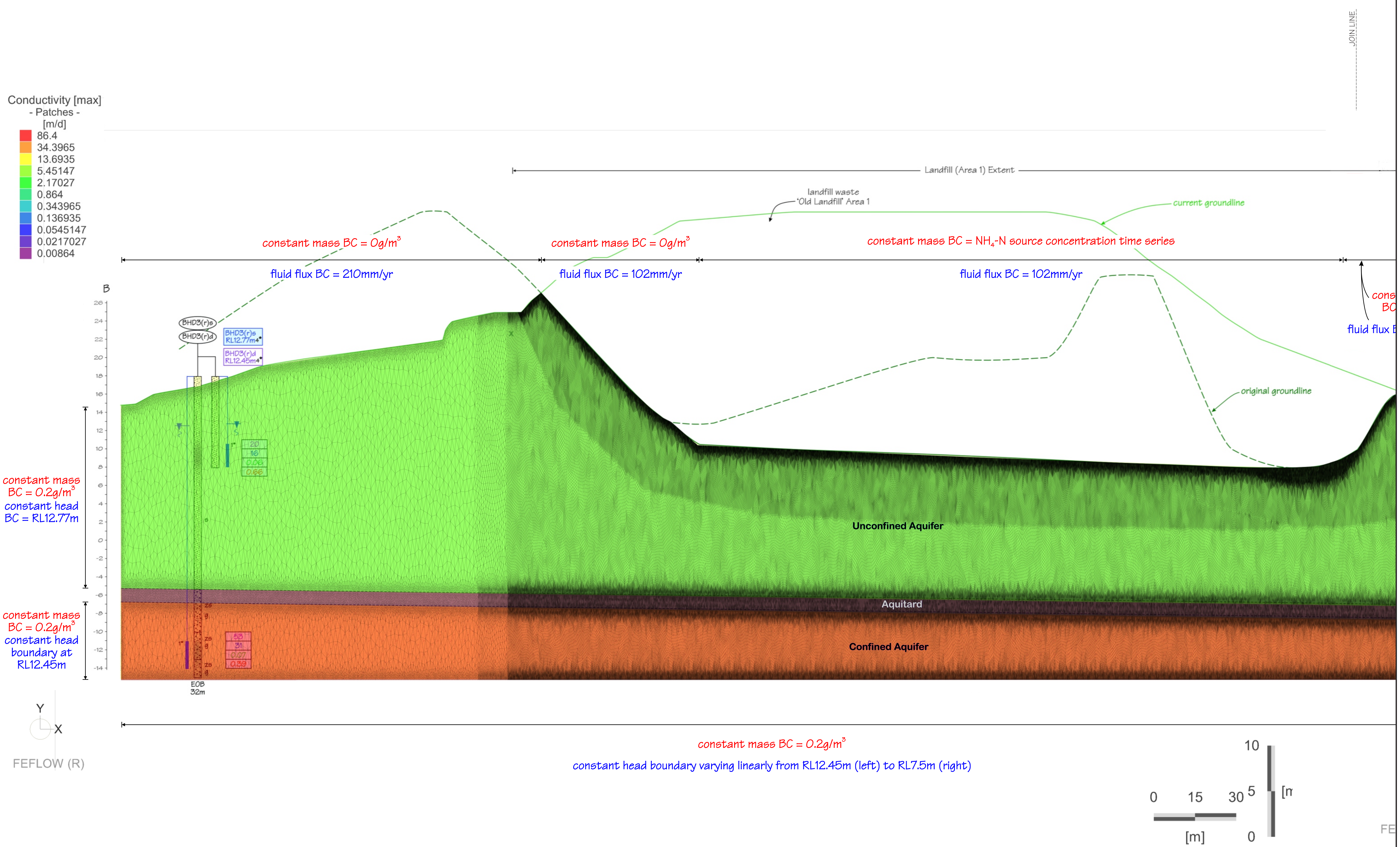
LEVIN LANDFILL
HOKIO BEACH ROAD, LEVIN
Horowhenua District Council

Feflow Model Section Loction

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	15-12-23	FOR GROUNDWATER MODELLING REPORT	M.W	M.W	S.SW	MLW

DRAWING NO.: FIG. 1
REF: 10009-R3
SCALE: 1:4000
CRS: NZTM
DATUM:



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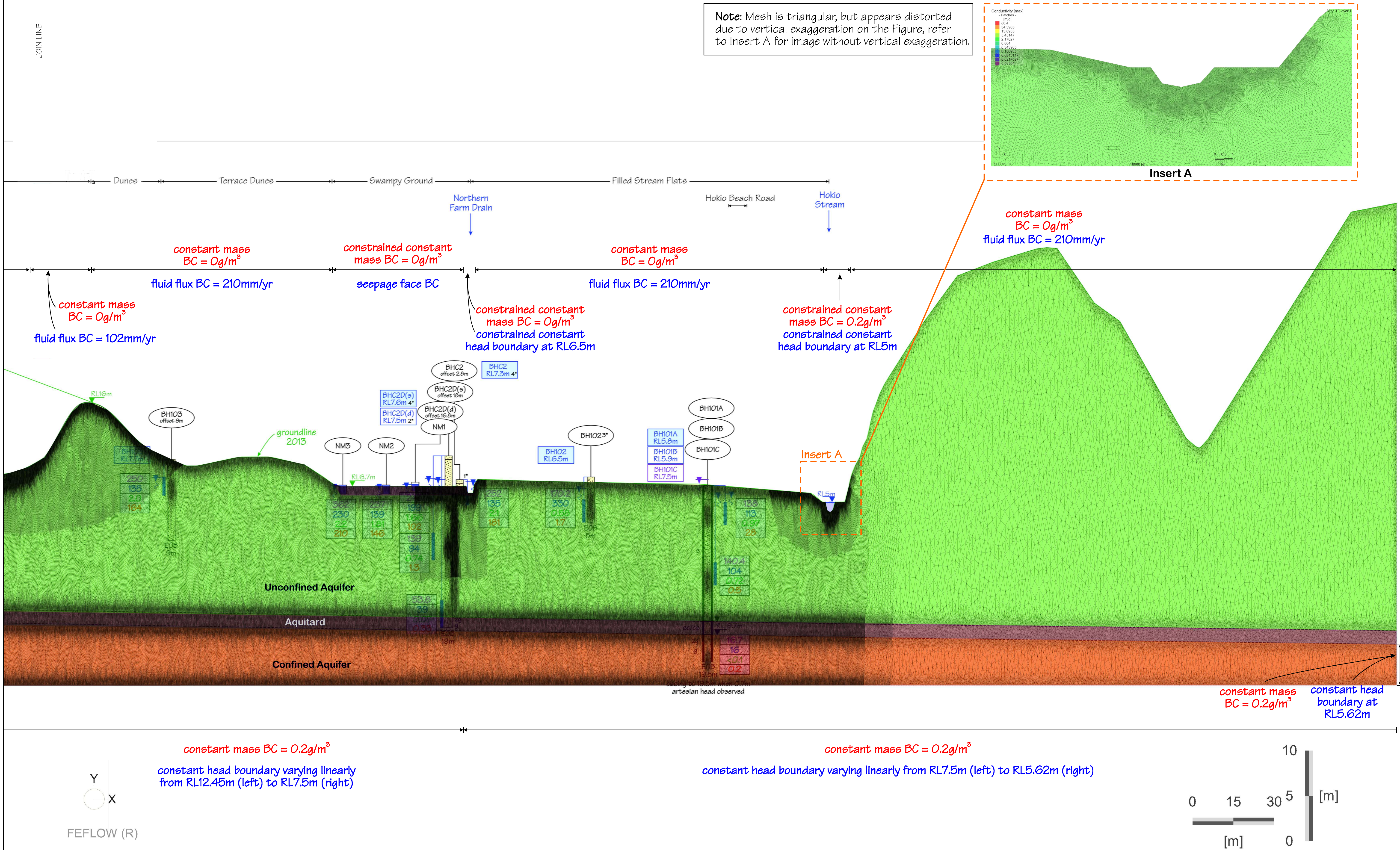
Feflow Model Setup and Finite Element Mesh - Page 1 of 2

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	15-12-23	FOR GROUNDWATER MODELLING REPORT	M.W	M.W	S.SW	MLW

DRAWING NO.: FIG. 2
REF: 10009-R3
SCALE: nts
CRS:
DATUM:



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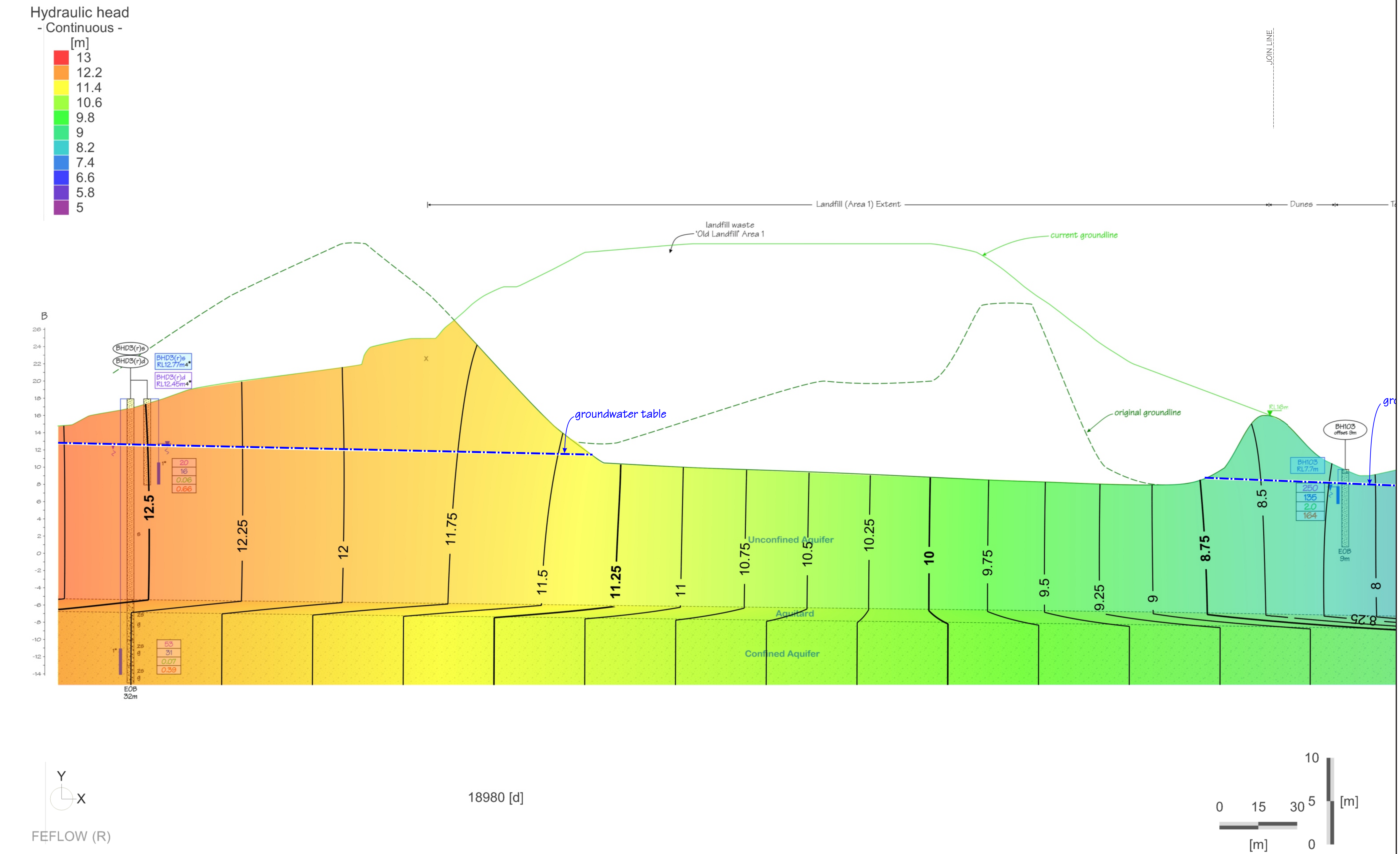
Feflow Model Setup and Finite Element Mesh - Page 2 of 2

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	15-12-23	FOR GROUNDWATER MODELLING REPORT	M.W	M.W	S.SW	MLW

DRAWING NO.: FIG. 2
REF: 10009-R3
SCALE: nts
CRS:
DATUM:



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Model Flow Calibration - Page 1 of 2

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	15-12-23	FOR GROUNDWATER MODELLING REPORT	M.W	M.W	S.SW	MLW

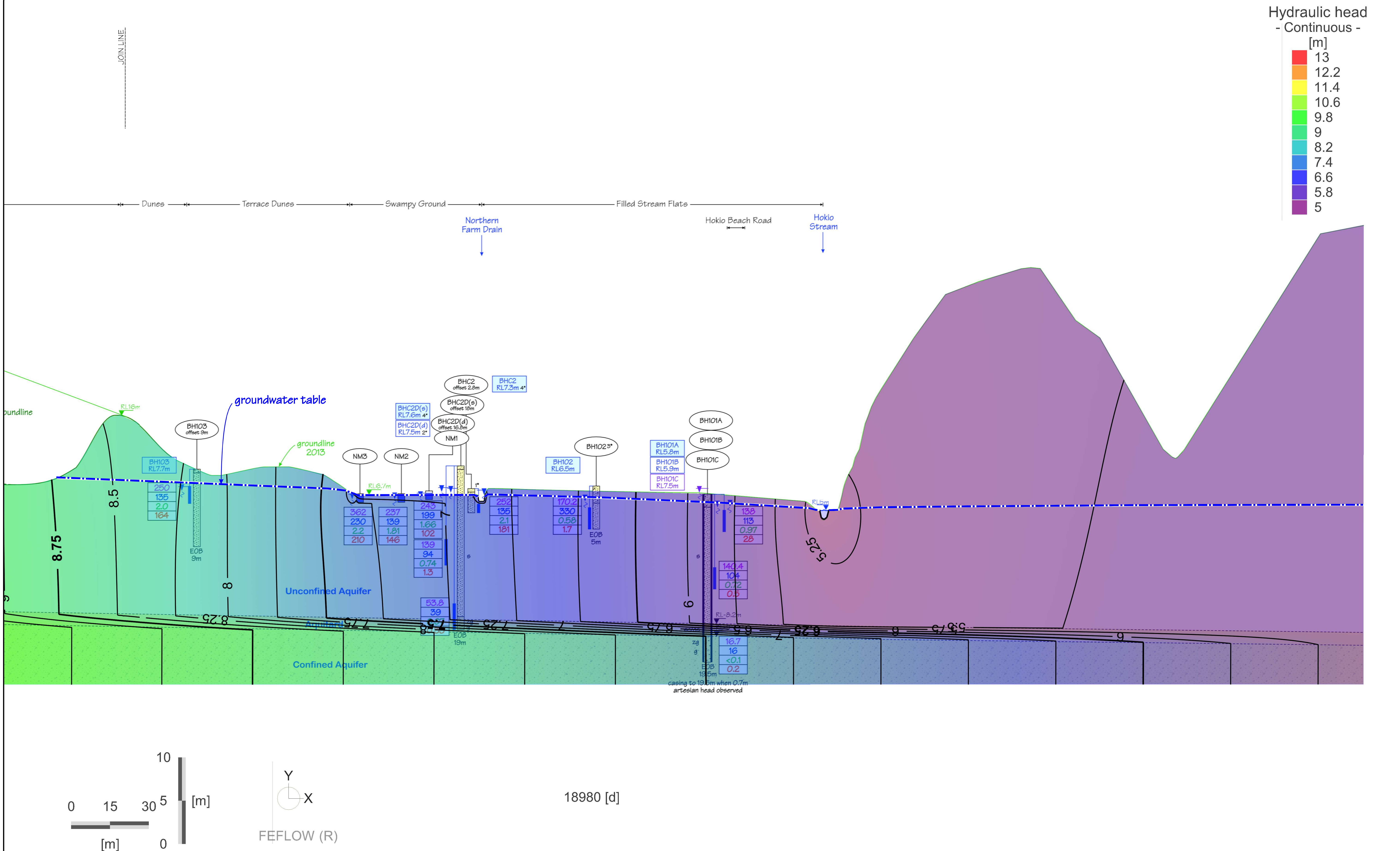
DRAWING NO.: FIG. 3

REF: 10009-R3

SCALE: nts

CRS:

DATUM:



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Model Flow Calibration - Page 2 of 2

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	15-12-23	FOR GROUNDWATER MODELLING REPORT	M.W	M.W	S.SW	MLW

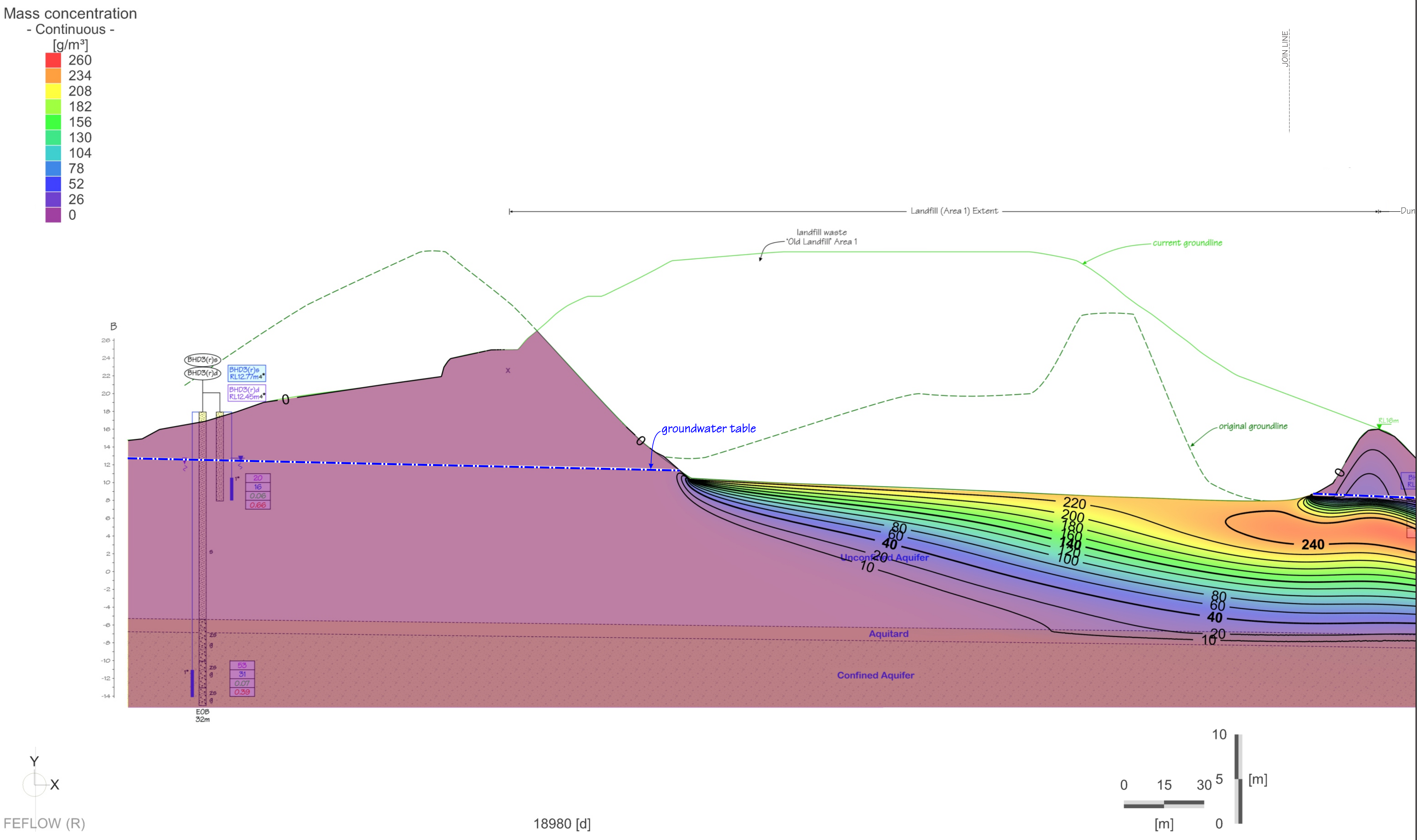
DRAWING NO.: FIG. 3

REF: 10009-R3

SCALE: nts

CRS:

DATUM:



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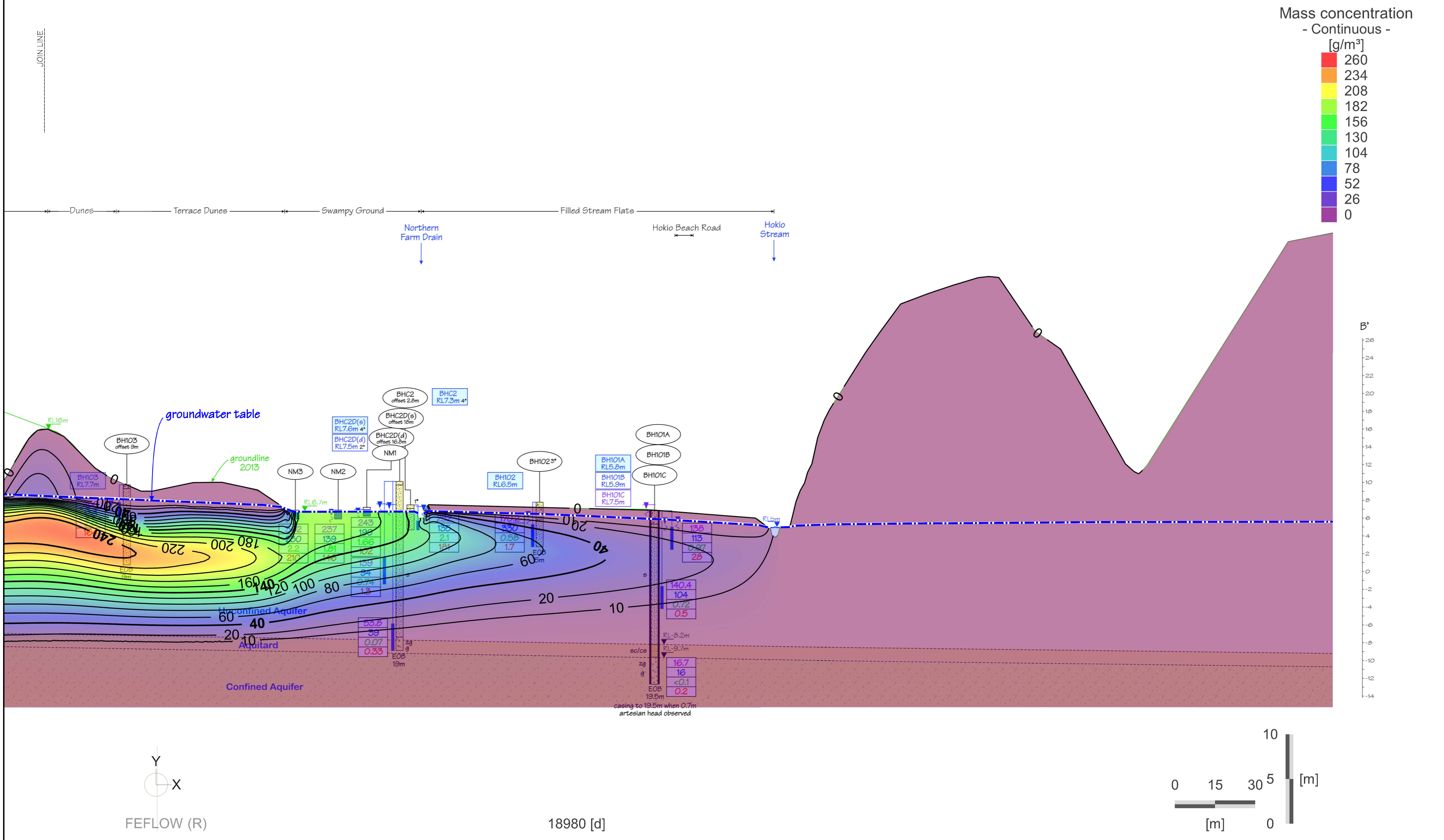
Model Mass Transport Calibration - Page 1 of 2

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	15-12-23	FOR GROUNDWATER MODELLING REPORT	M.W	M.W	S.SW	MLW

DRAWING NO.: FIG. 4
REF: 10009-R3
SCALE: nts
CRS:
DATUM:



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Model Mass Transport Calibration - Page 2 of 2

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	15-12-23	FOR GROUNDWATER MODELLING REPORT	M.W	M.W	S.SW	MLW

DRAWING NO.: FIG. 4
REF: 10009-R3
SCALE: nts
CRS:
DATUM:

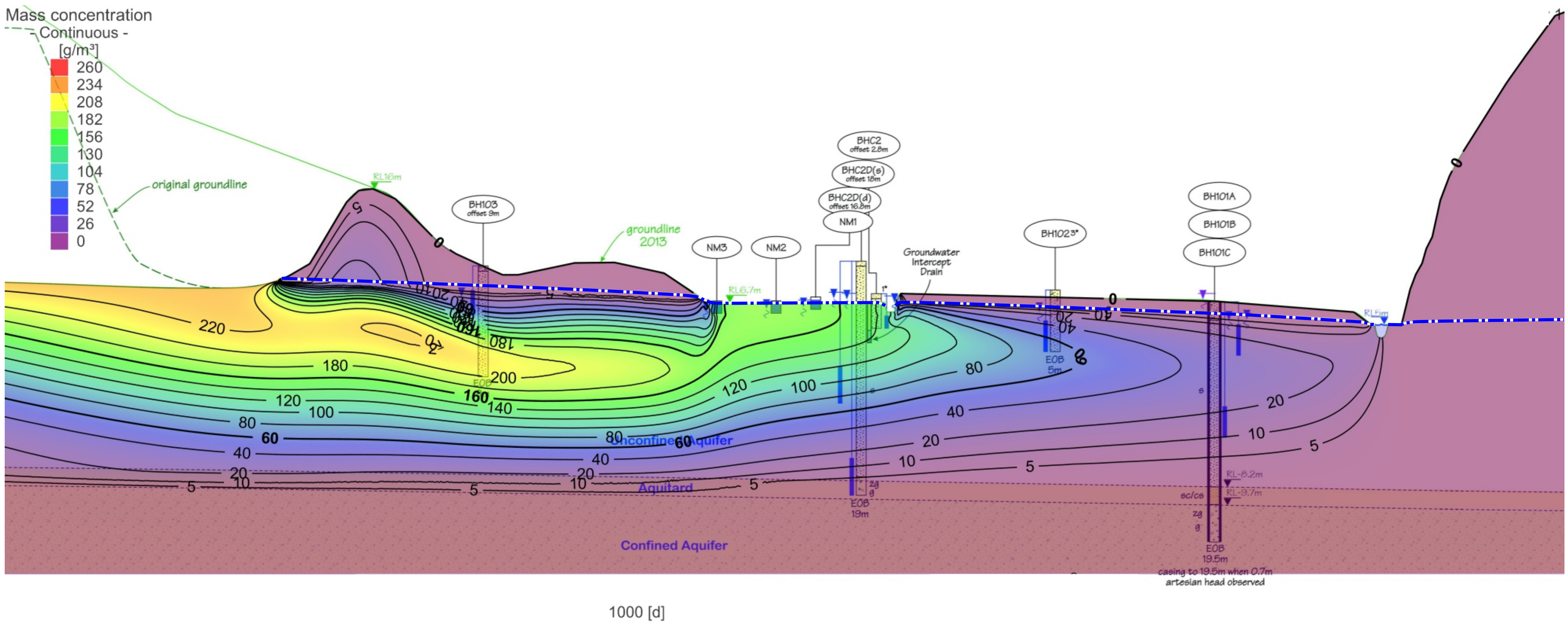

Figure 5A: Mass Concentration Estimation at 1,000 Days
approx. 2026

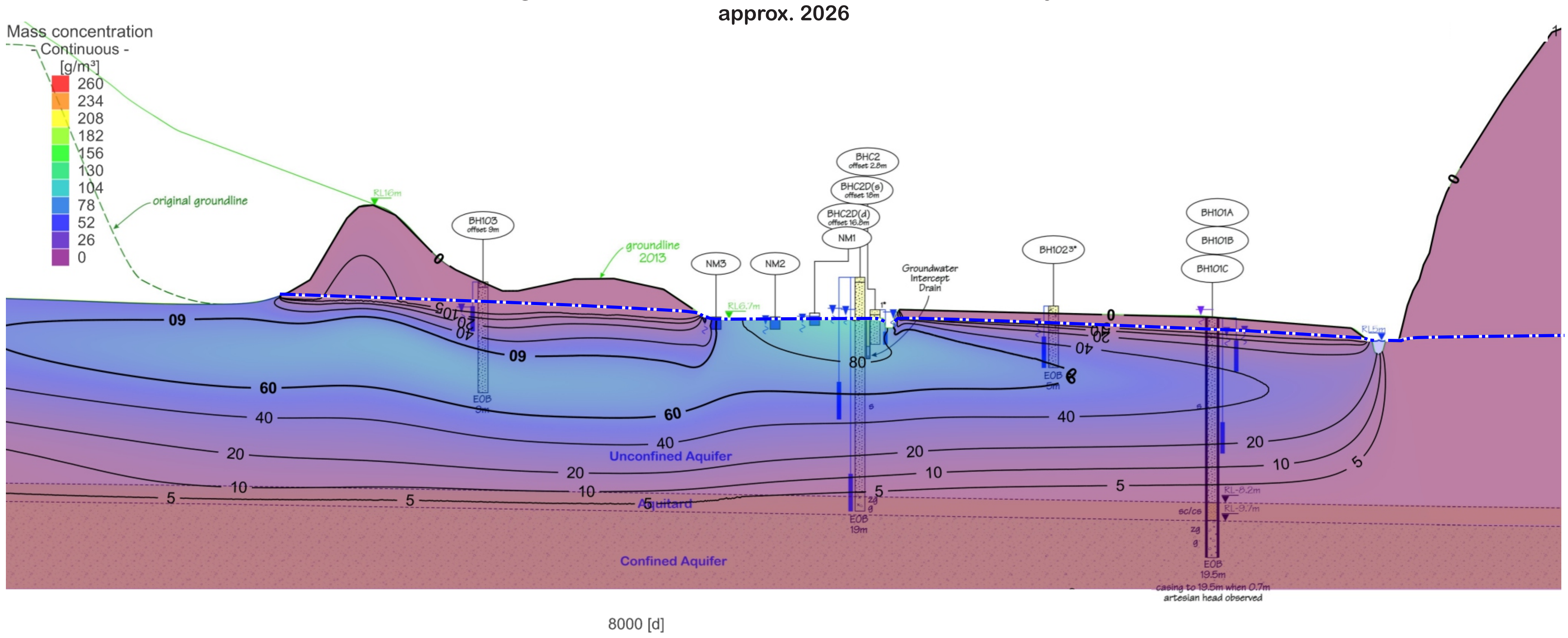

Figure 5B: Mass Concentration Estimation at 8,000 Days
approx. 2045 (Peak Mass Concentration entering Hokio Stream)

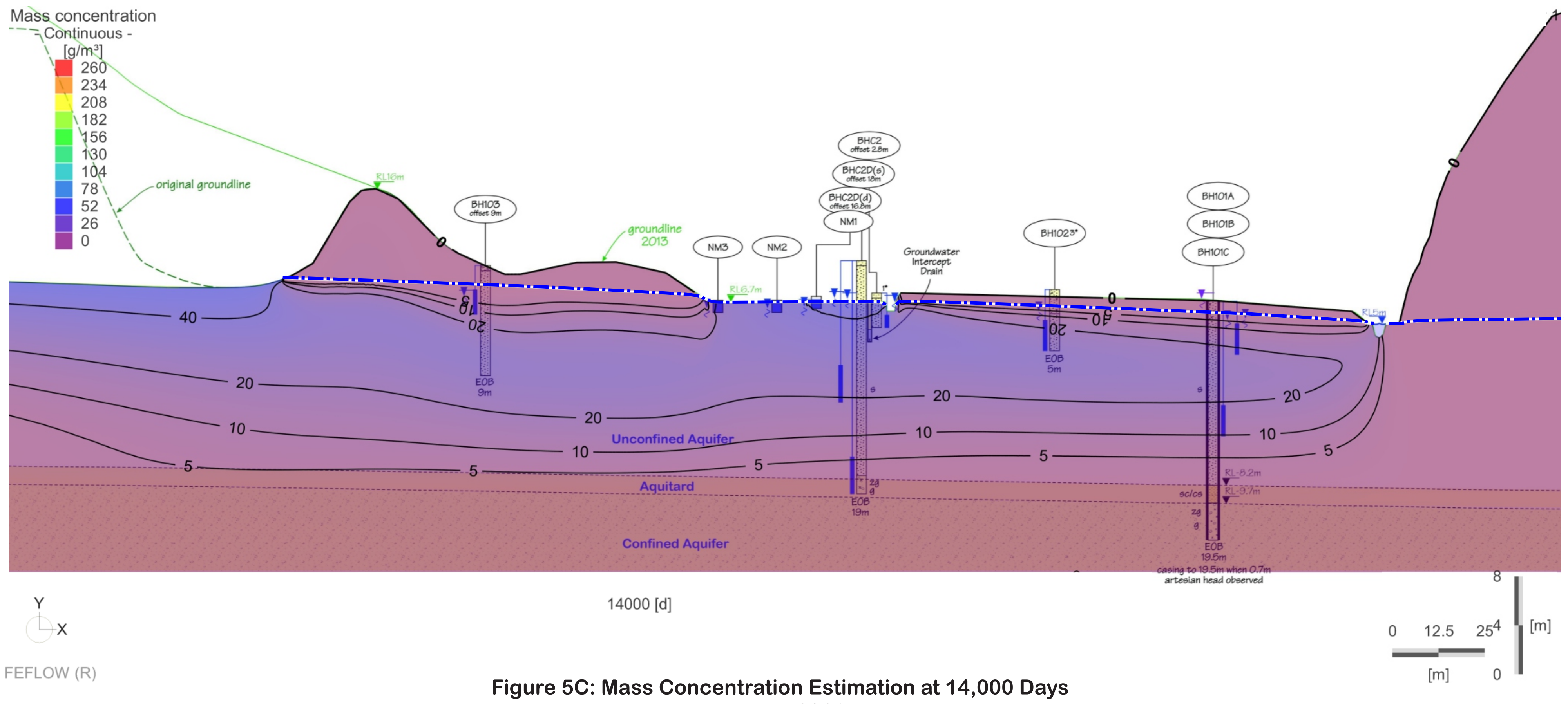

Figure 5C: Mass Concentration Estimation at 14,000 Days
approx. 2061

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Future Prediction without Groundwater Intercept Drain

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	15-12-23	FOR GROUNDWATER MODELLING REPORT	M.W	M.W	S.SW	MLW

DRAWING NO.: FIG. 5
REF: 10009-R3
SCALE: nts
CRS:
DATUM:

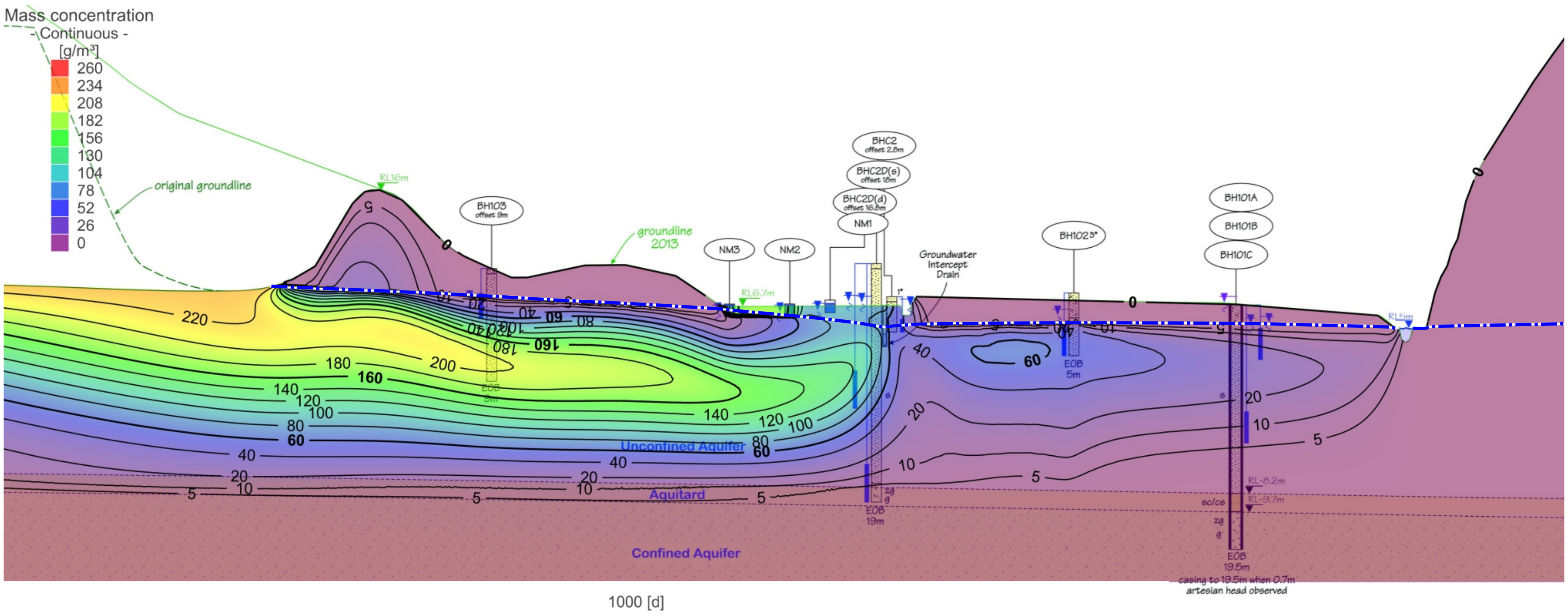

Figure 6A: Mass Concentration Estimation at 1,000 Days
approx. 2026

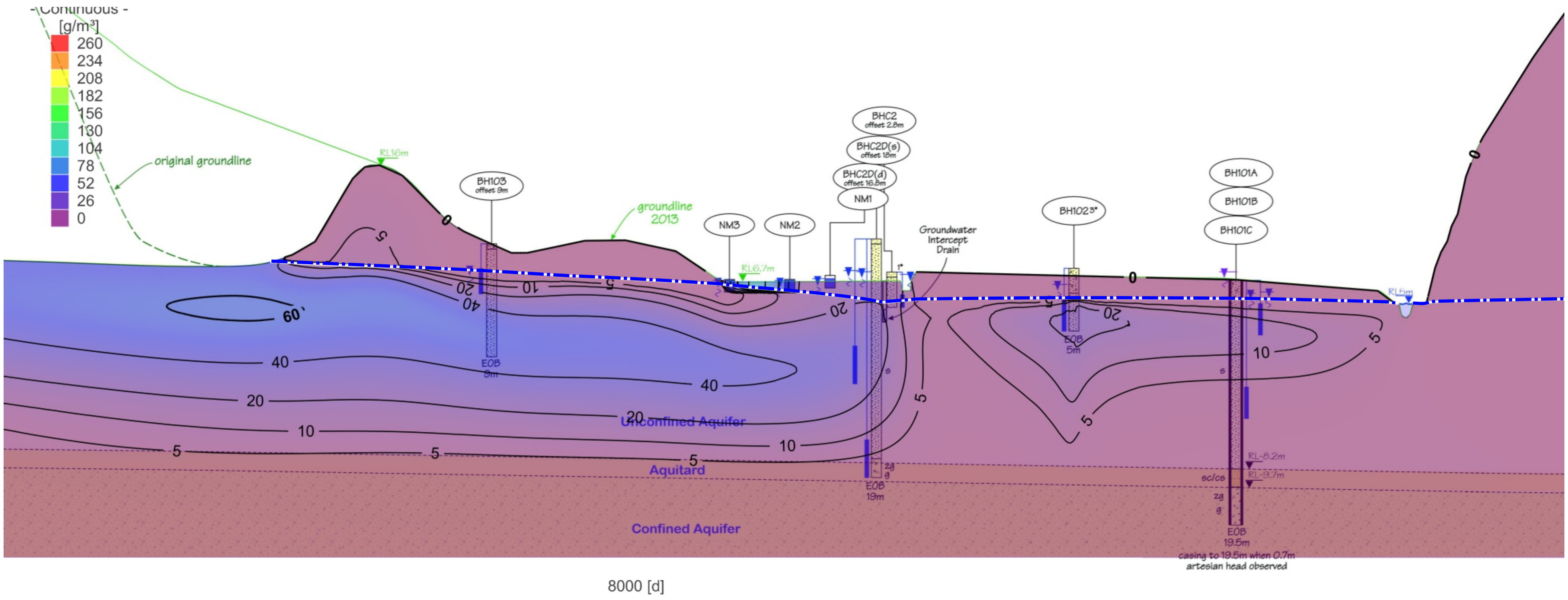

Figure 6B: Mass Concentration Estimation at 8,000 Days
approx. 2045

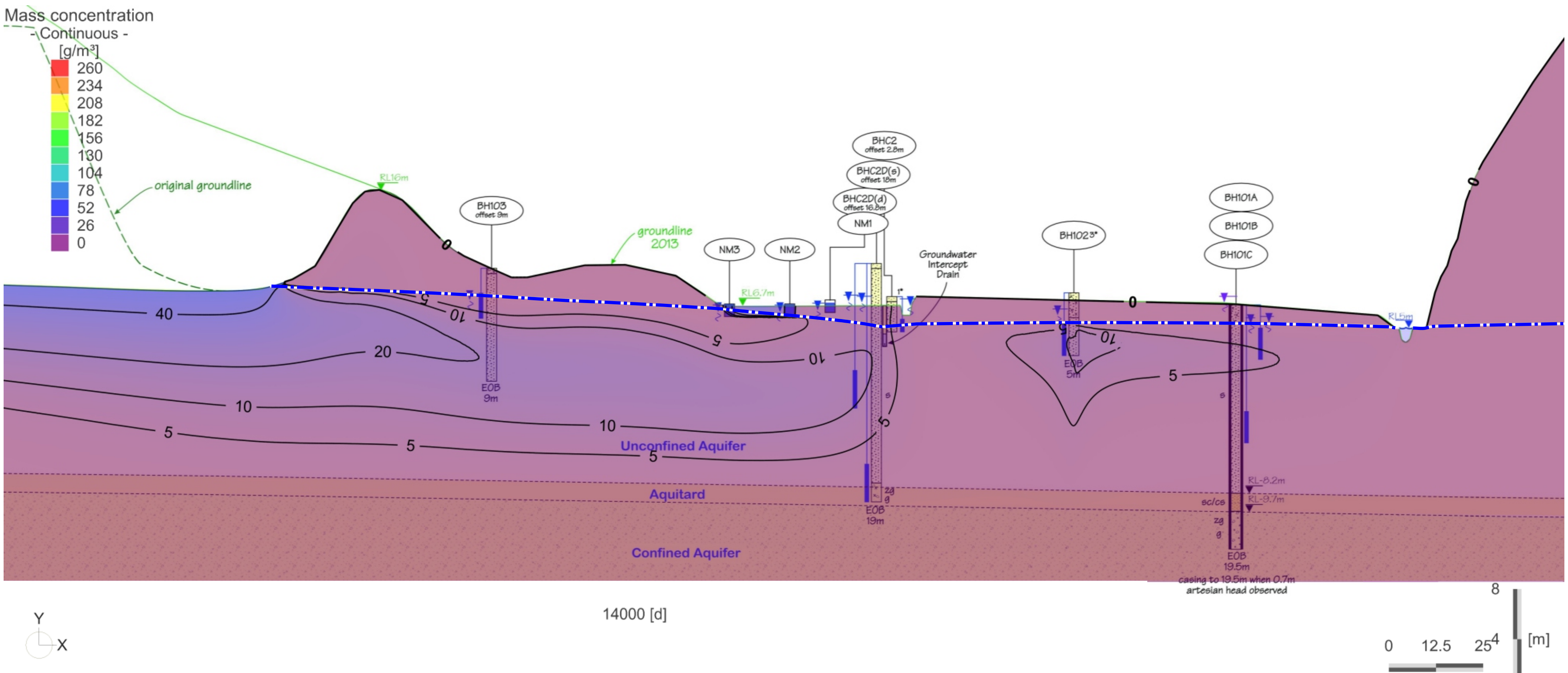

Figure 6C: Mass Concentration Estimation at 14,000 Days
approx. 2061

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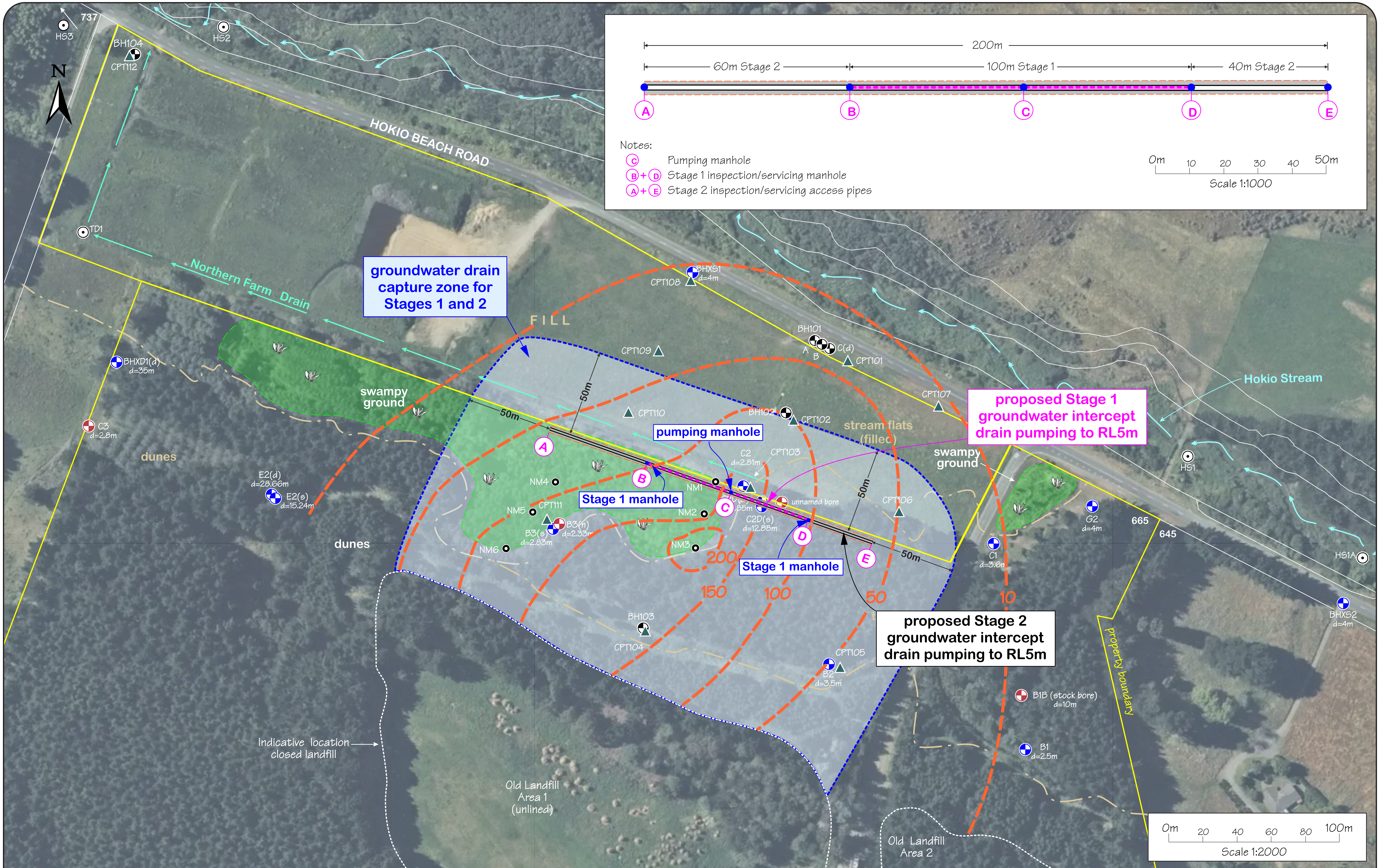
Future Prediction with Groundwater Intercept Drain

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	15-12-23	FOR GROUNDWATER MODELLING REPORT	M.W	M.W	S.SW	MLW

DRAWING NO.: **FIG. 6**
REF: 10009-R3
SCALE: nts
CRS:
DATUM:



FOR BPO DESIGN

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Groundwater Intercept Drain Location and Capture Zone

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	15-12-23	FOR BPO DESIGN	M.W	M.W	S.W	MLW
B	08-02-24	UPDATE TO INCLUDE STAGE 1 EXTENT	M.W	M.W	M.W	MLW

DRAWING NO.: FIG. 7
REF: 10009-R3
SCALE: as shown
CRS:
DATUM:

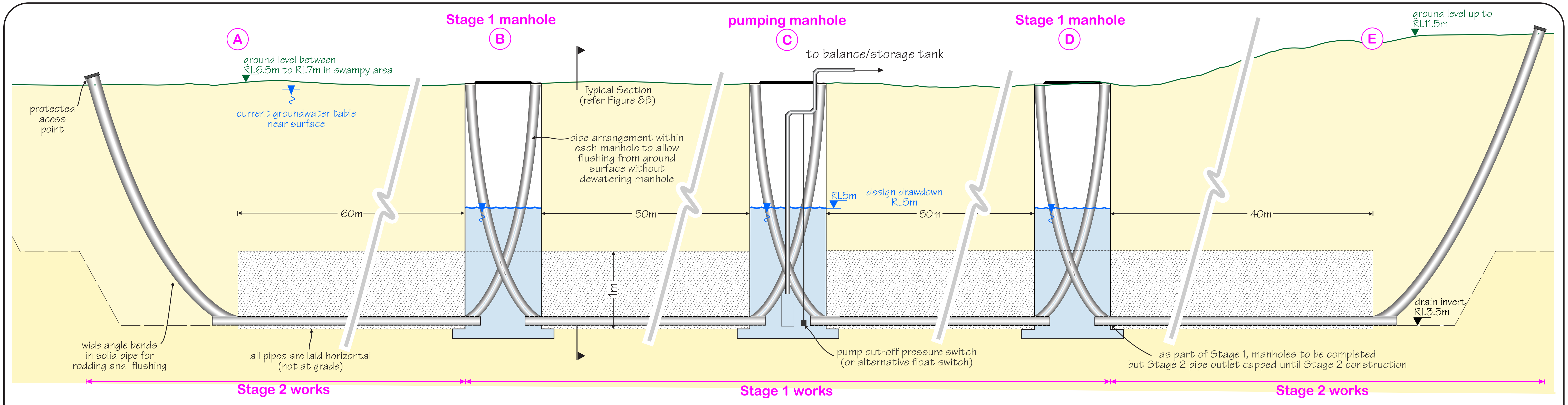

Figure 8A: Typical Long Section Through Points A to E

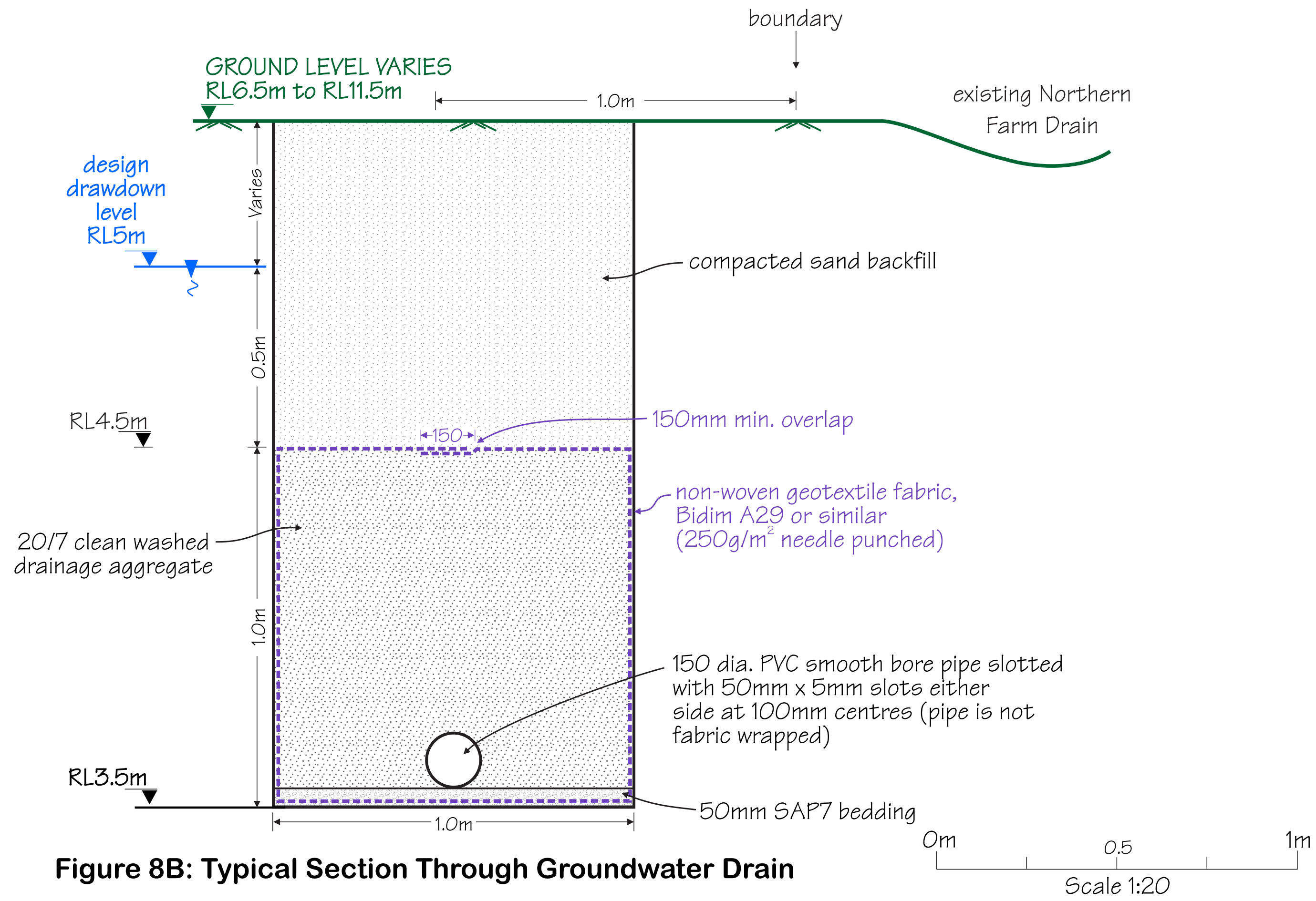

Figure 8B: Typical Section Through Groundwater Drain

CONSTRUCTION NOTES:

1. Trench excavation will require control of groundwater inflows using a well point (or similar) system.
2. Peat, topsoil, silts or other unsuitable materials are expected in the cut at the western part of the drain. Temporary stability of the cut to be appropriately managed to enure safe working conditions.
3. Bedding, fabric and pipe invert to be inspected prior to backfilling.
4. Pipe to be cleaned of all foreign matter prior to installation.
5. Entire subsoil drainage system to be jet blasted on completion to satisfaction of engineer.
6. Drains not to be used for temporary surface or groundwater controls. If trench becomes flooded during construction all silt and contaminated materials to be removed to engineers approval.
7. All bends to be long radius to allow for flushing. Inspection and access points to be no further than 100m apart.
8. Subsoil drain system to be flushed within 12 months of completion. Following this, regular maintenance flushing to be carried out every one to two years, stretching out to a maximum of once every five years as required.
9. It is noted that construction with dewatering of contaminated groundwater in open trenches at least 3m deep is a challenging task. It is recommended that contractor discussions and feedback on the construction method be obtained prior to detailed design being progressed.

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Groundwater Intercept Drain Design

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	15-12-23	FOR BPO DESIGN	M.W	M.W	S.SW	MLW
B	01-02-24	UPDATE TO INCLUDE STAGE 1 EXTENT	M.W	M.W	M.W	MLW

DRAWING NO.: FIG. 8

REF: 10009-R3

SCALE: as shown

CRS:

DATUM: