CURRAGHINALT GOLD PROJECT: ABSTRACTION LICENCE APPLICATION (SURFACE WATER)

Prepared For

Dalradian Gold Limited (DGL)

Report Prepared by

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U7511

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CURRAGHINALT GOLD PROJECT: ABSTRACTION LICENCE APPLICATION (SURFACE WATER)

1 INTRODUCTION

This report is prepared in support of the application for an Abstraction Licence for surface water from the proposed Curraghinalt Mine, adjacent to 80 Mullydoo Road, Greencastle, County Tyrone, BT79 7QP (Irish Grid Co-ords E258418, N383902) ('the Site').

An abstraction licence is required by the project in accordance with Water Abstraction and Impoundment (Licensing) Regulations (Northern Ireland) 2006 (2006 No 482) (hereafter "the 2006/482 Regulations").

Two abstraction licences are being sought by DGL for the project:

- one for abstraction of surface water and storage in the Clean Water Pond (this application); and
- one for abstracted mine water through dewatering of the underground mine and storage within the West Pond.

This document provides supporting information for the application for abstraction of surface water from upstream of the proposed infrastructure site. Section 2 of this report provides details required by the official application form that could not be written into the form. Section 3 provides supporting information to the application including background details on the project, its setting, the site wide water balance, and summaries of the assessments informing the application. If additional information is required, the assessments form part of the Curraghinalt Project Planning Application and are publicly available.

2 APPLICATION FORM CONTENT

2.1 Abstraction of water (Form Section 4.2)

Local name/Townland	Irish Grid Reference	Source type	Use	Map/Schematic label
Pollanroe Burn catchment, Teebane West, near Greencastle, County Tyrone	E 258564.10 N 384620.93	Diversion of surface run off	Industrial process water and maintaining minimum flow in Pollanroe Burn.	Figure 2-1

Surface water run-off from the north of the proposed infrastructure site will be collected in the North Diversion Berm and directed to the Clean Water Pond (Figure 2-1). The Clean Water Pond has a capacity of 40,260 m^3. The primary use of water from the Clean Water Pond will be to provide a source of fresh water for the process plant. Overflow from the pond will also be used to maintain a minimum flow in the Pollanroe Burn (compensation flow) if necessary (Section 2.2.1). The pond will be excavated below ground level, so water will not be impounded by a man-made structure, meaning the pond will not be governed by reservoir legislation.

Natural surface water runoff to the Clean Water Pond will not be managed. The ponds will provide a degree of attenuation, but the catchment upstream of these ponds will not be developed and no change in greenfield runoff rates is proposed. Excess water from the Clean Water Pond will be allowed to spill from the pond and will be directed to the Pollanroe Burn via a culvert.

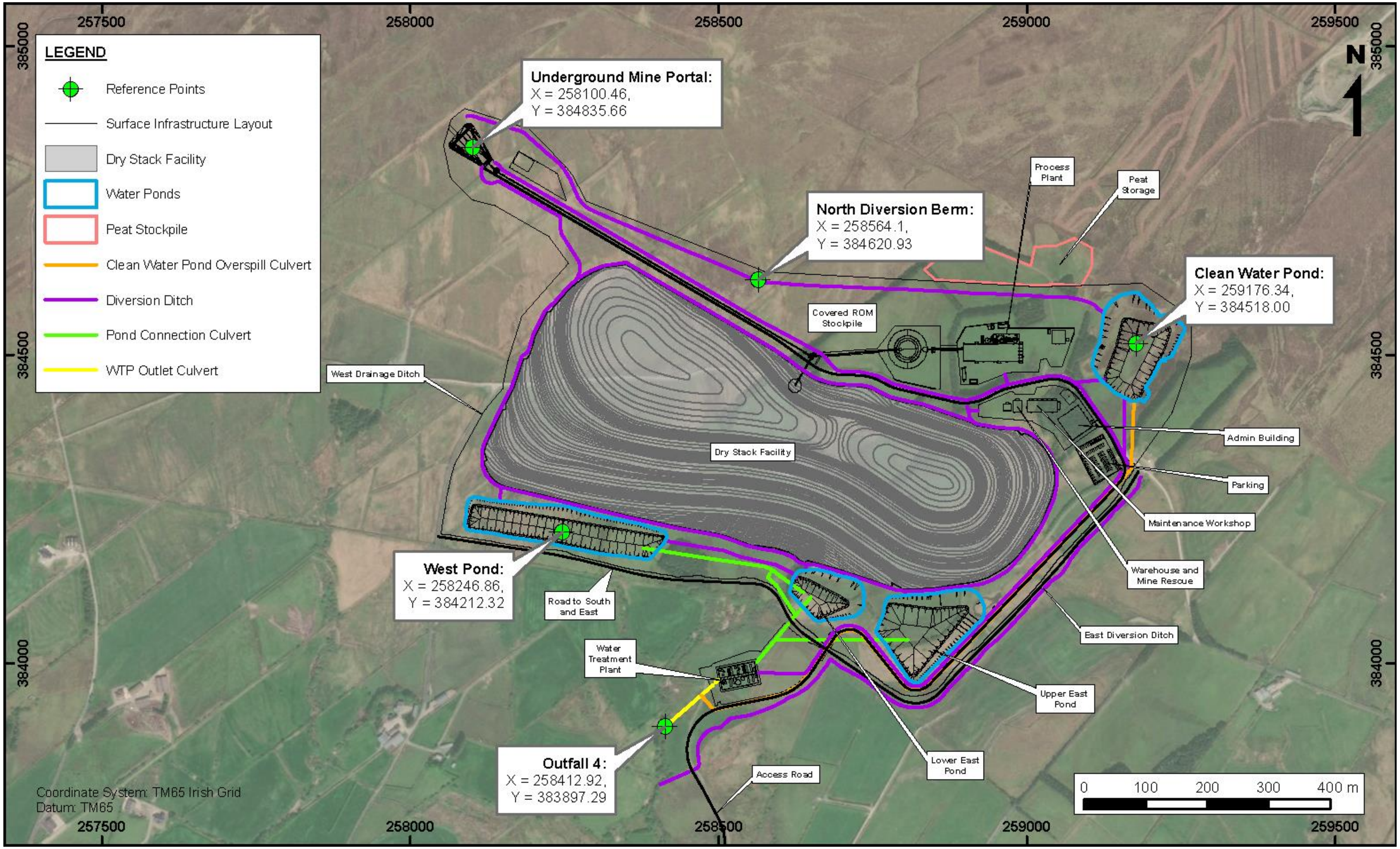

Figure 2-1: Groundwater abstraction and discharge locations

2.2 Calculations of abstraction volumes (m3) per day (Form Section 5.1)

The total maximum volume of abstracted water and frequency of operation (Form Section 5.0) is 2,250m³/day, although there is predicted to be only a 1% chance of this volume being reached. Natural runoff is expected to be substantially lower than this for most of the operational period, as shown in Figure 2-2.

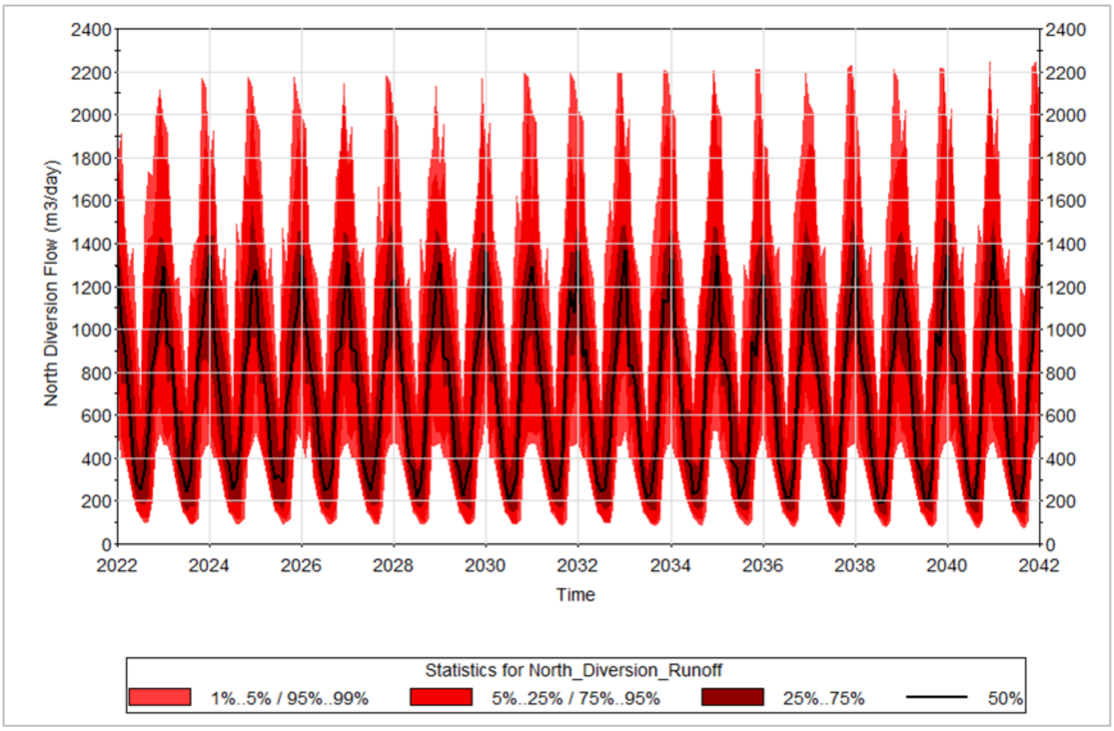

Figure 2-2: Predicted natural runoff flows to the North Diversion Berm

Surface water abstraction volumes will be the same as natural runoff volumes north of the proposed infrastructure site. Run off volumes have been calculated using a site-wide water balance model, presented as Appendix A. The model has been developed within the GoldSim modelling software, which is an industry standard for mine water management, and run using time varying and stochastic inputs. Results are presented as probability distributions and provide an indication of the likelihood of occurrence of different model results (e.g., treatment rates) based on a series of model iterations that consider climatic variability based on observed rainfall data from the closest UK Met Office rain gauge (Lough Fea). Further detail on the site wide water balance is presented in Section 3.3.

Figure 2-2 shows the likelihood of different flow rates in each month of the mine life. Abstraction volumes are predicted to vary on a seasonal basis, with higher runoff during winter months (average high of approximately 1,300 m³/hr) and lower runoff during summer months (average low of approximately 200 m³/day). Maximum flows, with less than 5% chance of occurrence, could reach 2,250 m³/hr.

2.2.1 Water return (Form Section 5.3)

Water is managed at the proposed infrastructure site in an integrated manner, maintaining separation of contact and non-contact water. The site-wide water balance models the expected inflows to and outflows from the project but does not track the proportion of each inflow source at outflow locations. The information below regarding water return is therefore presented at a site-wide level, as this is most relevant to understanding effects on the receiving environment. A schematic illustrating site wide water management is presented in Figure 3-3.

Return volumes have been calculated using a site-wide water balance model (Appendix A). The model has been developed within the GoldSim modelling software, which is an industry standard for mine water management, and run using time varying and stochastic inputs. Results are presented as probability distributions and provide an indication of the likelihood of occurrence of different model results (e.g., treatment rates) based on a series of model iterations that consider climatic variability based on observed rainfall data from the closest UK Met Office rain gauge (Lough Fea). Further detail on the site wide water balance is presented in Section 3.3.

Water not used in the processing plant will be directed from the Clean Water Pond via a culvert to an outfall on the Pollanroe Burn (shown as Outfall 4[1] on Figure 2-1). Predicted outflows from the Clean Water Pond to the Pollanroe Burn are shown in Figure 2-3.

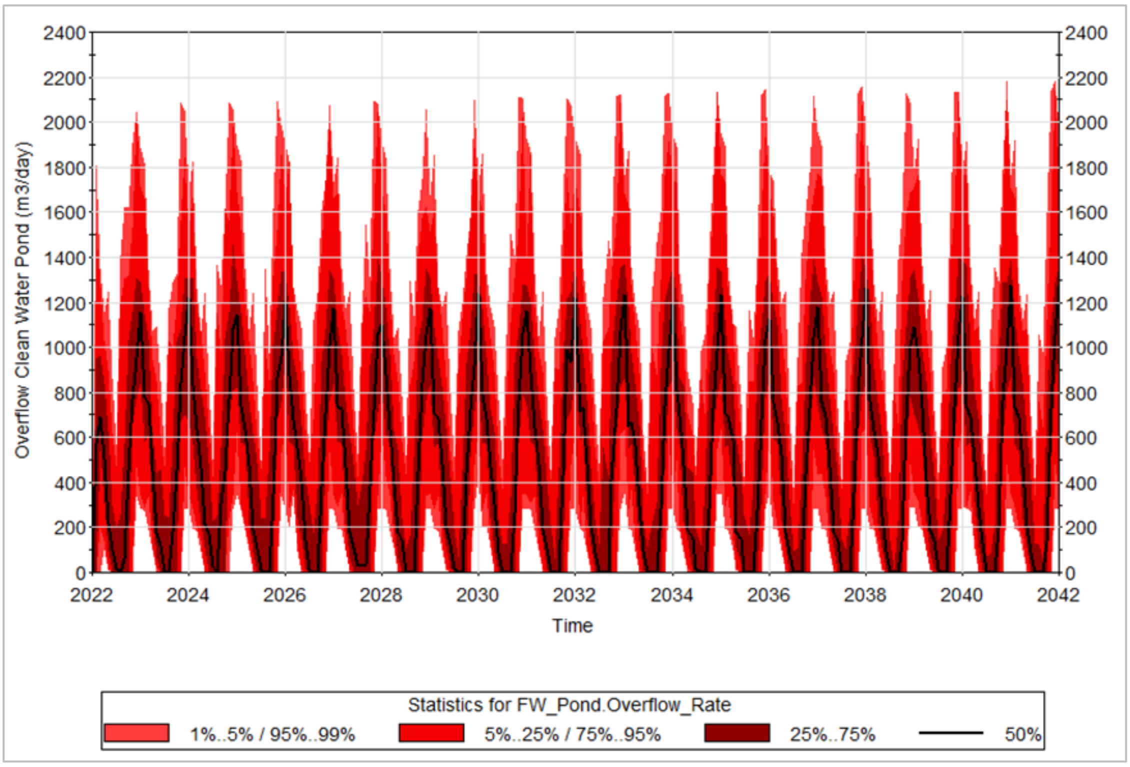

Figure 2-3: Predicted outflows from Clean Water Pond to the Pollanroe Burn

In addition to discharges from the Clean Water Pond, the Pollanroe Burn will receive other inputs from the mine development, including:

- discharge from the water treatment plant, which will be released at the same outfall as the overflow from the Clean Water Pond;
- underdrainage from the DSF and management ponds upstream of the water treatment plant outfall;

[1] This corresponds with the Schedule 6 outfall numbering system.

- non-contact water from the Eastern Diversion Ditch, which will be discharged 100m downstream of the water treatment plant outfall (Figure 2-1); and
- natural run off from surrounding fields.

The impact of changes to water quantity (stream flow) in the Pollanroe Burn as a result of the project have been assessed as part of the Curraghinalt EIA process. The residual impacts were considered ‘not significant’ for construction, operation and closure phases. The discharge application for the proposed infrastructure site demonstrates that water quality compliance criteria in the Owenreagh River will be met.

2.3 Storage of Abstracted Water (Form Section 6)

Abstracted water will be stored in the Clean Water Pond (Figure 2-1). The capacity of the Clean Water Pond, which represents the maximum possible quantity of water stored is 40,260 m^3. Excess water will be allowed to spill from the pond and will be routed to the Pollanroe Burn.

3 SUPPORTING INFORMATION (SECTION 8)

3.1 Background to the Project

The Curraghinalt Project is located in County Tyrone in Northern Ireland, approximately 15 km northeast of the town of Omagh, 7 km east of the village of Gortin, and between the settlements of Rouskey and Greencastle. Access to the project is via a number of highways and local roads, including the B48 from Omagh to Gortin, and the B46 from Gortin to Greencastle.

The Project is comprised of five project sites (areas). These are shown on Figure 3-1 and include the proposed infrastructure site (Area A), the proposed mineral extraction area (Area B), the existing surface infrastructure site (Area C), the passing bays on the Camcosy Road (Area D) and the proposed mineral exploration area (Area E). These areas combine to create the application site. Key surface infrastructure components of the project within the application site are shown in Figure 3-1 and include:

- An underground mine, that will be accessed via a portal;
- A mineral process plant consisting of a covered coarse ore stockpile and process plant building;
- A clean water storage pond;
- A dry stack facility (DSF), including drainage and water management ponds;
- A paste backfill facility (PBF) which will be located underground within Area B;
- Ancillary infrastructure and services required to support the activities (administrative buildings, mobile maintenance shop, warehouse facilities, mine dry, parking, site roads, water supply, water treatment plant and telecommunications); and
- Connections, where technically feasible, to offsite infrastructure including the Northern Ireland road network, the electrical grid, along with the water supply networks in the area of the mine.

A planning application was submitted for the project in November 2017 to Department for Infrastructure (DfI), specifically the Strategic Planning Division (SPD). In line with the requirements of Planning (Environmental Impact Assessment) Regulations (Northern Ireland) 2015, the application included an Environmental Statement (ES) to report the findings of the Environmental Impact Assessment (EIA) process undertaken for the proposed development. As part of the Environmental Impact Assessment (EIA) process carried out for the Curraghinalt Project, a series of specialist water studies were carried out. These include:

- a site wide water balance;
- a groundwater impact assessment; and
- a surface water impact assessment.

These studies were updated in 2020 to reflect the latest project design. This section provides a brief overview of the 2020 assessments and the key findings from the updated reports. The study area for the assessments is shown in Figure 3-2. The assessments demonstrate there is no adverse impact on the aquatic environment from the abstraction, in terms of shortages of supply, increased pollution through reduced dilution or damage to habitats dependent on the water body.

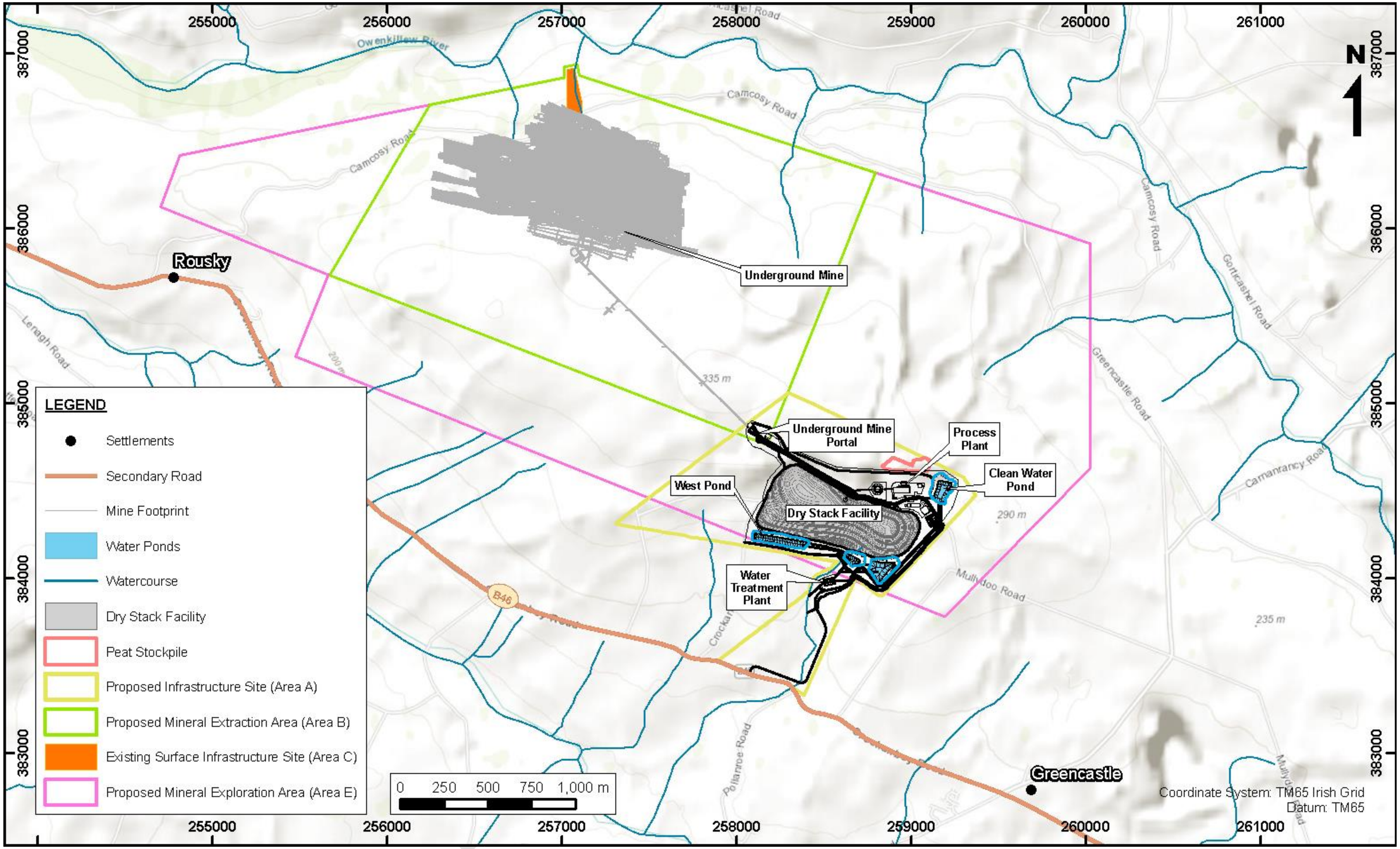

Figure 3-1: Project location and overview of project sites

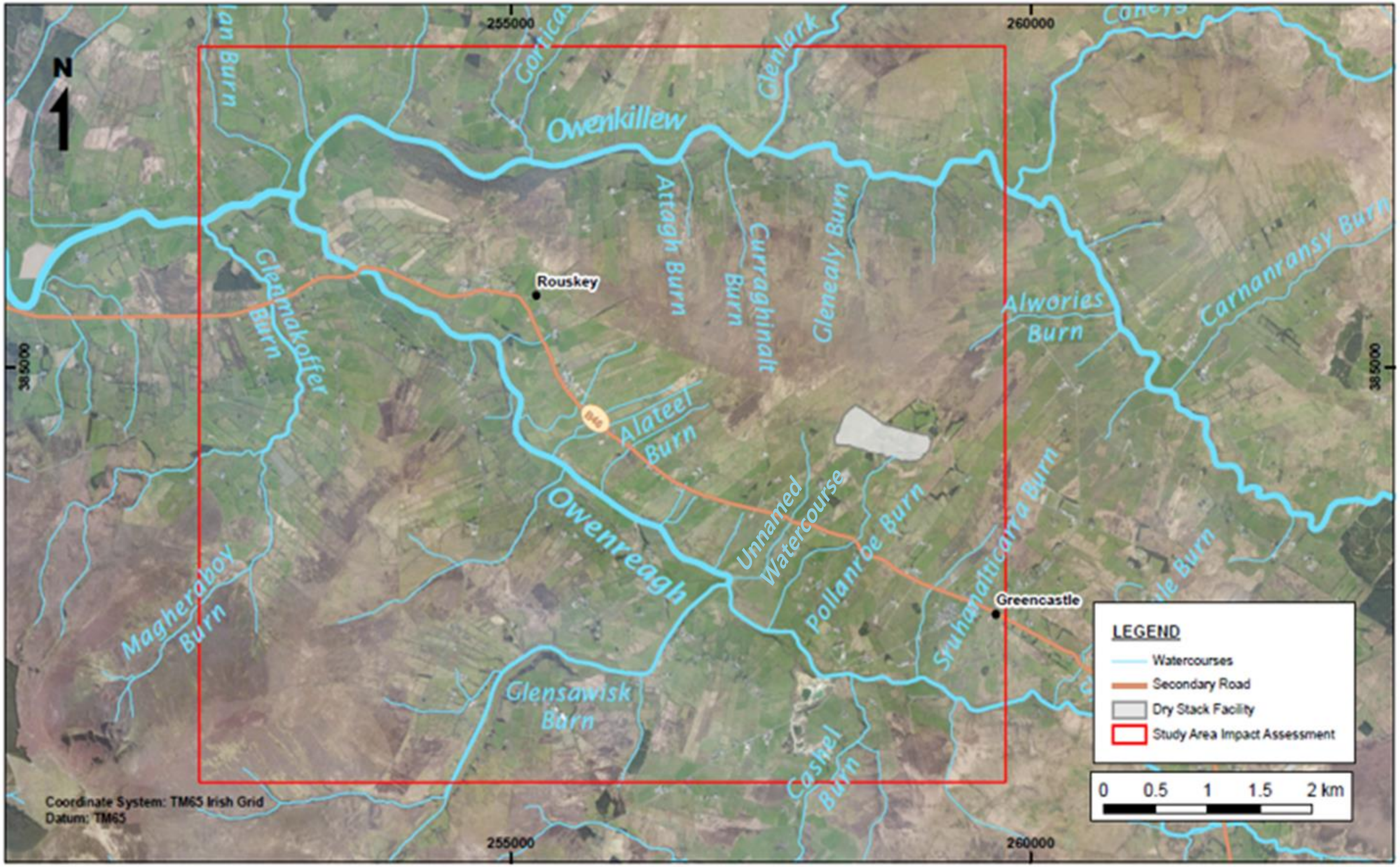

Figure 3-2: Surface water quantity and quality study area

3.2 Setting of the Project

The Curraghinalt Project is located on the southern edge of the Sperrin Mountains, an upland region in Northern Ireland. The area is characterised by relatively high annual rainfall, in the order of 1,300 mm per annum, with high seasonality, with the wettest period between October and January and the driest period between April and July.

The application site is located within an area comprising a topographic ridge that includes the high points of Mullydoo (325 m above ordnance datum – AOD), Crocknamoghil (335 m AOD) and Crockanboy Hill (287 m AOD). The ridge forms the drainage divide between the Owenkillew and Owenreagh Rivers, which originate in the upland areas of the Sperrin Mountains further to the east of the proposed mine and infrastructure areas.

There are number of sensitive features in the project environment that have been taken into account in the design of the project. Key features are as follows:

- The project is located in the Sperrin Mountain Area of Outstanding Natural Beauty (AONB);
- The Owenkillew and Owenreagh Rivers are within the River Foyle and Tributaries Special Area of Conservation (SAC), which supports a significant presence of Atlantic salmon (*Salmo salar*) and otter (*Lutra lutra*);
- The Owenkillew River is also a SAC, which incorporates the Owenkillew River Area of Special Scientific Interest (ASSI) as well as Drumlea and Mullan Woods ASSI and Owenkillew and Glenelly Woods ASSI, and it features the largest population of freshwater pearl mussel (*Margaritifera margaritifera*) in Northern Ireland, as well as extensive beds of Stream Water Crowfoot (*Ranunculus penicillatus ssp penicillatus*);
- The Owenreagh River, upstream of Cashel Bridge, is a ASSI for the feature of freshwater pearl mussel (NIEA, 2018);

Much of the higher ground across the ridge is covered with peat of varying thickness and quality, supporting blanket bog and wet heath habitats that are recognised as priority habitats in Northern Ireland and are also listed under Annex I of EU Habitats Directive.

The predominant land use on the topographic ridge between the Owenkillew and Owenreagh Rivers is farming, comprised of multiple small farm holdings. The farmland is rough grazing land predominantly for poultry and sheep. Residential dwellings and commercial properties in the vicinity of the project are predominantly clustered around the settlements of Rouskey to the west and Greencastle to the south east of the development. Residential properties are also situated along the major roads in the area, including the B46 Crockanboy Road, but are not present along the topographic ridge.

3.3 Summary of Site-Wide Water Balance

The overall aims for water management at the Curraghinalt Project can be summarised in three main concepts;

- Capture, storage and treatment of all water that contacts mining activities/infrastructure and which could have poor water quality.
- Limit natural runoff from outside of the proposed Infrastructure site from contacting mine infrastructure to reduce water volumes needing to be treated.

- Capture of clean (non-contact) surface water runoff from upslope of the proposed infrastructure site and within the proposed infrastructure site to be available for use as fresh water in mining operations. Ore processing requires a fresh water input and most of this can be provided by treated contact water, but there is a need for additional fresh water.

A site-wide water balance was prepared for the project (Appendix A) to calculate operational water levels/volumes in the water management ponds and required water treatment rates. Through this, the water balance consolidates inflows and outflows for the project.

The model scenarios are run stochastically as a Monte Carlo analysis. For each scenario, the water balance model is run for 100 'realisations' of the mine life (i.e., 20-year mine life). In each realisation, the model selects annual runoff, precipitation and evaporation inputs from the 54 year record from the Lough Fea rainfall time series. In this way, the model cycles through all possible combinations of rainfall years for each year of mine operation. This also factors in predicted climate change impacts over the anticipated 20 year mine life. In each realisation, other parameters (e.g., maximum treatment rate and pond sizes) remain the same. At the end, there are 100 sets of model results and these results are presented as probabilities (e.g., probability of water shortage in any month within the mine life).

The benefit of such a modelling approach is that results consider a full range of climatic conditions and runs are not restricted to simple inputs (e.g., average rainfall in every year, or dry weather in every year).

Results are presented as monthly averages. This is typical for a water balance model as many of the model inputs are based on a monthly time step (e.g., the evolution of the DSF is discretised on a yearly basis and mine water inflows on a monthly basis). However, a model sensitivity run was undertaken using daily hydrological inputs to test the model response to sub-monthly variations in hydrological inputs. The storm water calculations are also based on daily (24-hour) storm durations.

Schematics of the site water balance and annual mean and 95%ile water volumes have been prepared for Years 6, 12 and 20 of the mine life, selected to provide an illustration of how water management will change over time with an increasing DSF and changes to the dewatering rate from underground workings. Year 12 is provided in Figure 3-3 for illustrative purposes and to show how water is managed within the proposed infrastructure site.

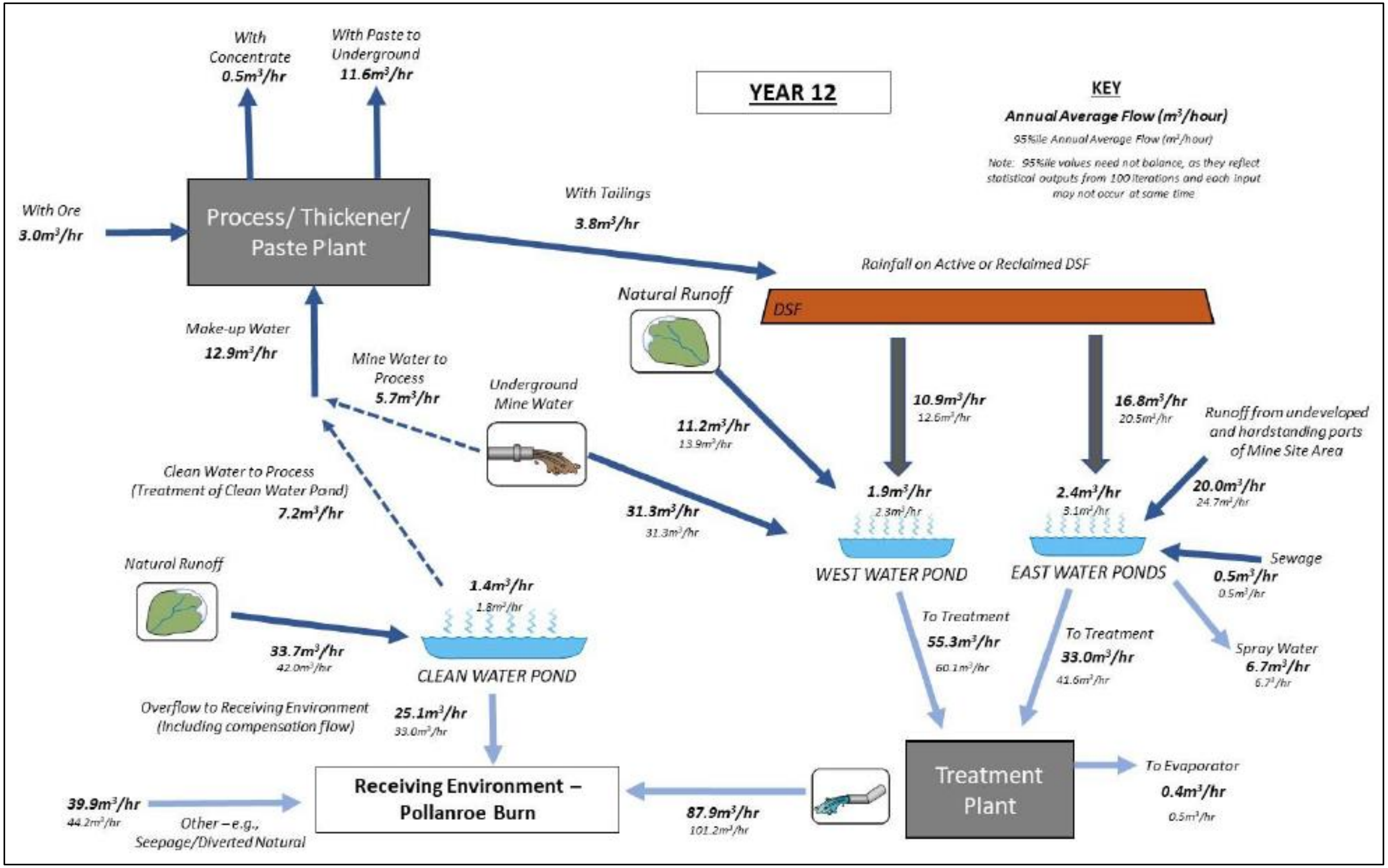

Figure 3-3: Water Balance Schematic with Annual Average Flow Rates – Year 12

3.4 Summary of Groundwater Impact Assessment

The approach for the groundwater impact assessment is based on guidance for impact assessment for mining applications internationally and on standard methodologies applied for groundwater risk assessment based on guidance relevant to the United Kingdom (UK). Assessing changes to groundwater resources is part of the Water Framework Directive (WFD) and important in terms of understanding the effects the mine could have to future abstractions and wider groundwater resources.

A Tier 3 (detailed) appraisal was required for the groundwater level and flow assessment for dewatering due to the complexity of the mine's life cycle through construction to closure. This enabled the model to reflect that underground mine dewatering is a transient and 3-dimensional process with the aquifer taking time to react to changes in storage. The groundwater simulation was implemented using the USGS groundwater modelling code MODFLOW, within the user interface Groundwater Vistas Version 6.

Due to the changes in groundwater conditions with depth, the model assesses groundwater drawdown in five layers. These are as follows (in increasing depth from surface) and are described in more detail in Table 3-1:

- Layer 1 peatland, alluvium and glaciofluvial material on the northern side of the ridge sloping towards the Owenkillew River;
- Layer 2 heavily weathered basement rock;
- Layer 3 moderately fractured basement rock;
- Layer 4 fresh bedrock (upper); and
- Layer 5 fresh bedrock (lower).

The groundwater model provided a numerical assessment of the risks of mine dewatering to surface water baseflows, groundwater-related abstractions and peatland. The groundwater model was also used to provide inputs to the groundwater quality assessment. The mine design is based on the resource estimate and has been used for the simulation (herein referred to as the 'Initial Mine Design') as this provides a conservative representation of the mine for impact assessment purposes.

The dewatering model has been used to provide predictions of changes to groundwater levels near the end of the operational life of the mine, when the mine is deepest and dewatering activities are at a peak. This represents the maximum groundwater level impact expected, though the onset of the impact would occur earlier in the operational phase gradually increasing as the underground mine development progresses. In terms of assessing mine dewatering effects, the threshold for a change in groundwater level beyond which a receptor is considered as impacted is 0.1 m in peatland areas and 5% level change in well water level at groundwater abstractions.

Table 3-1: Model layers, thicknesses and associated hydraulic testing results

Model Layer	Groundwater Unit Description	Thickness (m)	Bottom Elevation (masl)	Number of Hydraulic tests	Hydraulic Conductivity; geometric mean (m/day)*
1	Peatland	1 – 6.5	+80 to +440	6	2.96E-04
	Alluvium	1 – 10		4	1.67E+00
	Glaciofluvial	1 - 4		1	9.07E+00
2	Heavily weathered basement rock	9 - 19	+70 to +420	24	3.59E-02
3	Moderately fractured basement rock	30	+40 to +390	16	5.27E-03
4	Fresh bedrock (upper)	130	+90 to +260	14	9.47E-04 [Bedrock] 1.71E-03 [Faults]
5	Fresh bedrock (lower)	550 - 910	-650	22	1.09E-05 [Bedrock] 1.64E-04 [Faults]

* Averages for bedrock; includes fault zone tests

A Tier 3 (detailed) approach to risk assessment was also applied for groundwater quality but this is not discussed further as it is not considered relevant to the abstraction licence applications.

The impact from the groundwater impact assessment that is of relevance to the abstraction licence application is as follows:

- Potential impact of changes to groundwater levels from dewatering of the mine on groundwater abstractions, surface water and peat (referenced as Impact GW02 in ES documentation)

A summary of this impact is provided below.

3.4.1 Potential impact of changes to groundwater levels from dewatering of the mine on groundwater abstractions, surface water and peat

Dewatering of the mine will result in a drawdown of surrounding groundwater resources. Assessing changes to groundwater resources is part of the Water Framework Directive (WFD) and important in terms of understanding the effects the mine could have to future abstractions and wider groundwater resources.

Groundwater resource changes are expressed in terms of groundwater drawdown in the five layers of the model. Model predictions for operations are presented for the end mine life, when the mine is at its maximum development size. The expected changes are as follows:

- Layer 1: No phreatic (water table) drawdown is predicted in Layer 1 for the area of the underground mine, which is overlain by blanket bog peatland. No drawdown is predicted in any area of peatland or alluvium.
- Layer 2: Phreatic drawdown in the weathered bedrock areas between the peat and alluvium and is predicted to generally reach around 0.5m adjacent to the mine boundary, but up to 10m where faults have been simulated.

- Layer 3 and Layer 4: The drawdown represented in Layer 3 of the groundwater model is *piezometric drawdown.* Piezometric drawdown represents the change in water pressure in the rock at that depth interval, but not necessarily a change in saturation state at the phreatic water level. Piezometric drawdown is expected to be 0.5 m to the south of the mine and to the north below the edge of the Owenkillew River course. Layer 4 is similar to Layer 3 though extending slightly further.
- Layer 5: Forecast piezometric drawdown in the fresh bedrock occurs across a much wider lateral area but does not translate to dewatering in shallower weathered units or the upper superficial deposits.

In summary, drawdown occurs to a greater extent at depth than in shallow model layers. This is due to mining occurring largely at depth, and the effects of high recharge and higher permeably in the uppermost bedrock layer. The drawdown in the aquifer layer at depth is not usually phreatic drawdown, but rather piezometric drawdown.

Once dewatering activities cease at the end of operations, the groundwater impacts will begin to reverse and groundwater levels will return to near natural conditions around 15 years post-closure.

Forecast changes to existing groundwater abstraction wells

Of the 32 abstractions with a known depth inside the area of potential drawdown, three are predicted to experience drawdown impacts, considered as drawdown exceeding 5% of overall well depth:

- Abstraction ID 5 (well) is located inside the infrastructure development area and will be removed as part of the development.
- Abstraction ID56 (spring) is predicted to run dry relatively early in the mine development (<5 years into operation).
- Abstraction ID 11 (field well used for livestock) is predicted to run dry 7 to 9 years into operation.
- Abstraction ID 112 (well) is DGL owned and can be decommissioned.
- Abstraction ID 121 (well) is listed as disused.

For wells with an unknown depth inside the zone of influence of the mine, two are predicted to have a drawdown exceeding the 5% criteria when a well depth of 200 m is assumed. Both wells are listed as disused. As wells with such depths are not typical in this area, it is considered unlikely these wells will be impacted.

As this modelling reflects a conservative scenario, on-going monitoring during mining will be required to determine whether groundwater levels significantly change in the well. DGL has committed to offer to replace any abstractions significantly derogated by the operation.

Forecast changes to river and burn baseflow

Changes in baseflow were assessed for watercourses within the mine extraction area; namely the Owenkillew River, the Curraghinalt Burn, the Attagh Burn, and Glenealy Burn. For the Curraghinalt Burn and Attagh Burn, changes as a result of dewatering represents approximately 3% of the mean summer flow, as under natural conditions baseflow from the bedrock is estimated to make relatively little contribution to the overall flow in the streams. For the Owenkillew River, Owenreagh River and Glenealy Burn changes in baseflow relative to mean summer flow are well below 1%. Based on this review, these changes in surface water baseflow are considered to be not significant.

Forecast changes to peatland water levels

Much of the peatland on the northern side of the ridge comprises blanket bog habitat, which is supported by high rainfall as opposed to groundwater flow, therefore the likely risks to the peatland from mine dewatering are low. However, upland peat areas in stream valleys could potentially be in hydraulic continuity with weathered bedrock groundwater and therefore more susceptible to dewatering impacts.

At the end of operations when mine dewatering will be at its peak, no phreatic drawdown is predicted in Layer 1 of the groundwater model for the peat and river alluvium above the underground mine. As much of the peatland comprises blanket bog habitat which is supported by high rainfall as opposed to groundwater flow, no impacts are expected on peatland from mine dewatering.

Summary

Although sensitivity of the receptors assessed is high, the magnitude of the residual impact is judged to be low due to the minor nature of the changes to groundwater abstractions, surface water baseflows and peat and the impact is not significant.

<table>
<tr><th colspan="3">Impact GW02: Potential impact of changes to groundwater levels from dewatering of the mine on groundwater abstractions, surface water and peat</th></tr>
<tr><td>Impact characteristics</td><td>Initial impact</td><td>Residual impact</td></tr>
<tr><td>Type (+ / - /neutral)</td><td>Negative</td><td>Negative</td></tr>
<tr><td>SIGNIFICANCE</td><td>Not significant</td><td>Not significant</td></tr>
<tr><td colspan="3">Project design measures
• Exploration boreholes will be backfilled will grout or low permeability sealing material and fracture zones will be sealed following drilling to reduce groundwater inflows.
• Future exploration tunnels within the mineral exploration area will be below a depth of 100 m below ground level
Mitigation measures
• Groundwater levels will be monitored throughout construction and operation
• Future mine excavations will be reviewed against buffer zones for abstractions
• Water depths and total well depths will be obtained for private abstractions with currently unknown depths where possible
• DGL will replace any abstractions significantly derogated by the operation</td></tr>
</table>

3.5 Summary of Surface Water Impact Assessment

The study area for the surface water impact assessment is shown in Figure 3-2. It includes the small watercourses (Pollanroe Burn, Unnamed Watercourse, Curraghinalt Burn, Attagh Burn and Glenealy Burn) potentially impacted by mining activities as well as the Owenreagh and Owenkillew Rivers. The sensitivities of the watercourses considered in this assessment to changes in water quantity are outlined in Table 3-2.

Table 3-2: Sensitivity of watercourses for surface water quantity assessment

Watercourse	Sensitivity	Basis
Pollanroe Burn and minor tributaries	Low	Minor watercourse with limited ecological value. No flood alleviation benefits or important morphological diversity (i.e., is small upland watercourse)
Unnamed Watercourse and minor tributaries	Low	Minor watercourse with limited ecological value. No flood alleviation benefits or important morphological diversity (i.e., is small upland watercourse)
Owenreagh River, main channel	High	Important sensitive and protected ecosystem
Curraghinalt Burn and minor tributaries	Low	Minor watercourse with limited ecological value. No flood alleviation benefits or important morphological diversity (i.e., is small upland watercourse)
Attagh Burn and minor tributaries	Low	Minor watercourse with limited ecological value. No flood alleviation benefits or important morphological diversity (i.e., is small upland watercourse)
Glenealy Burn and minor tributaries	Low	Minor watercourse with limited ecological value. No flood alleviation benefits or important morphological diversity (i.e., is small upland watercourse)
Owenkillew River, main channel	High	Important sensitive and protected ecosystem

The surface water impact assessment quantifies the effects of the project on four hydrological parameters:

- Annual runoff and flow pathways;
- Monthly flow conditions;
- Low flow conditions; and
- Flood flow conditions.

The effects assessment focused on quantifying changes in the hydrological parameters. The WFD requires river morphology (which includes flow and water level) to be protected to meet the ecological objectives of the Directive and for watercourses to maintain Good standard. UKTAG[2] (2008) developed standards to define a 'maximum permitted change from natural flow' for watercourses, with the change referring to a reduction, rather than an increase in flow. Increases in flow are generally considered neutral or positive in terms of ecological status, as long as the increases do not increase flood risk or cause changes to channel morphology. This assessment has considered flow change reference values for Good Status, salmonid watercourses.

[2] UKTAG is the UK Technical and Advisory on the Water Framework Directive

The key driving concept behind Planning Policy Statement 15 Planning and Flood Risk ("PPS 15", DOENI, 2006) is that development should not place the development at risk of flooding or increase flood risk to others. Therefore, the assessment considers whether development will increase flood flows in watercourses downstream and if there is an increase, the impact on downstream flood risk is considered.

The method for calculating changes in flow conditions from the proposed infrastructure site was based on a water balance model based on GoldSim modelling software. The quantitative model makes stochastic based predictions, on a monthly time step, of surface water flows at the proposed infrastructure site and downstream locations over a range of climatic conditions.

The surface water impact assessment also uses predictions from the project groundwater model to assess impacts of underground mining on baseflows to the watercourses around the mine site area. Details of the groundwater modelling are presented in Section 3.4.

The impact from the surface water impact assessment that is of relevance to the abstraction licence application is as follows:

- Potential impact on surface water flow in the Pollanroe Burn, Unnamed watercourse and Owenreagh River due to construction, operation and closure of proposed infrastructure site (referenced as Impact SW01 in ES documentation).

A summary of this impact is provided below.

3.5.1 Potential impact on surface water flow in the Pollanroe Burn, Unnamed watercourse and Owenreagh River due to construction, operation and closure of proposed infrastructure site

Construction

Construction will last two years and involve a number of activities that will disturb the natural ground surface, cover the headwaters of minor tributaries to the Pollanroe Burn and will increase runoff rates in the proposed infrastructure site. Mitigation is embedded in the proposed construction works with the aims of controlling runoff rates and managing sediment.

The construction activities at the proposed infrastructure site will be divided into two stages. Stage 1 will last 2 months and will include isolated construction sites that will be limited in size. Runoff will be managed through local attenuation measures. The short time scale of these works and their scale will result in negligible change in stream flows.

At the end of the first stage the West Pond and water treatment plant will be completed. This means that during Stage 2, runoff from construction areas within the main mine site will be routed to the pond and then treated in the water treatment plant before discharge to the Pollanroe Burn. In a similar way to water management during operations, runoff rates will be managed through attenuation in water management ponds and releases through the water treatment plant. Impacts on stream flows are predicted to be similar to those assessed for the operations phase (see below).

Overall, with mitigation the impacts on surface water in the Pollanroe Burn are predicted to be neutral or positive with a negligible magnitude in the early part of construction, increasing to neutral or positive with a major or medium magnitude at the end of construction, consistent with the impacts predicted for operations.

The residual impact on flows in the Pollanroe Burn, Owenreagh River and downstream reaches of the Owenkillew and Lough Foyle tributaries is negligible with mitigation measures in place.

Operation (average annual and monthly flows)

During operation, the project will result in an increase in average annual and monthly flows and low flow conditions within the Pollanroe Burn, and a decrease in flood flows. Water volumes in the Pollanroe catchment will be increased from a pre-development scenario by the following activities:

- Diversion of runoff from 0.07 km² (5%) of the natural catchment of the Unnamed watercourse due to construction of infrastructure within this area (Figure 3-4);
- Pumping of mine water from the underground workings to the West Pond, prior to treatment and discharge to the Pollanroe Burn; and
- Piping of municipal freshwater to the site to be used for drinking water, toilets and showers will enter the East Pond as treated sewage discharge and will be treated again in the water treatment plant before discharge to the Pollanroe Burn.

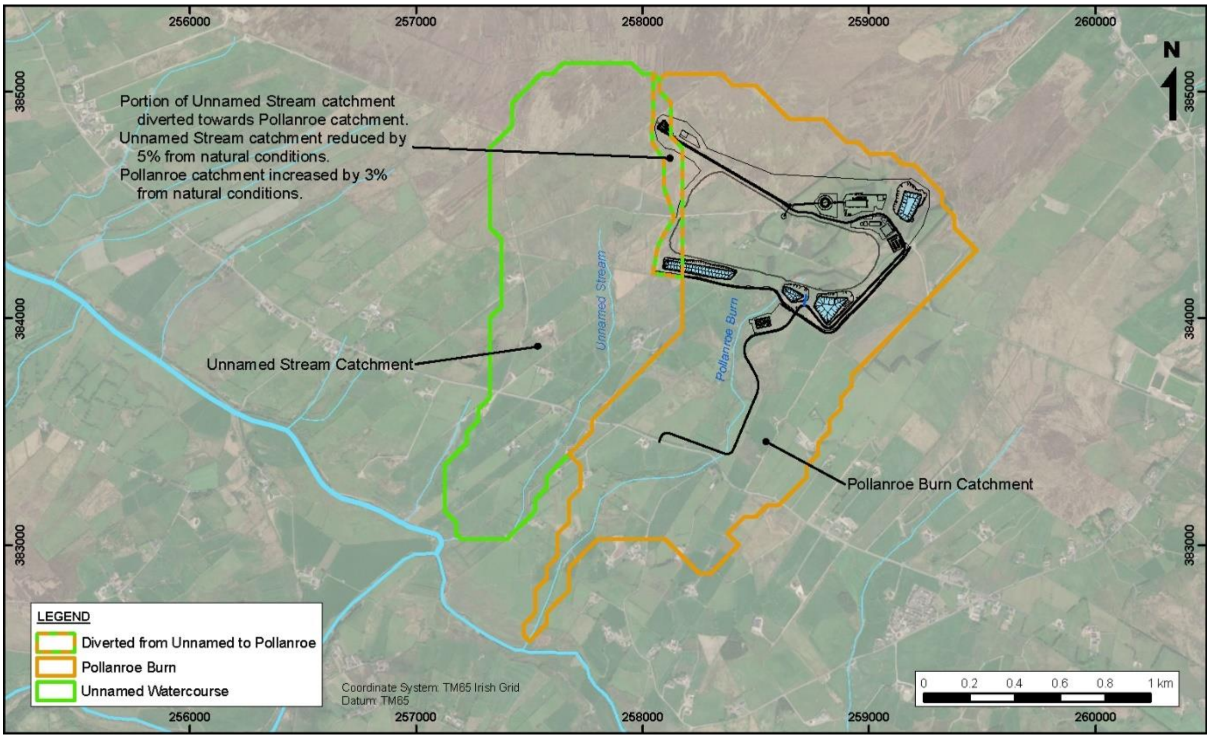

Figure 3-4: Pollanroe and Unnamed watercourse catchments, showing diversion of headwaters of Unnamed watercourse

The changes to the catchment areas will reduce flows in the Unnamed Watercourse by an amount proportional to the loss in catchment area. The total catchment of the Unnamed Watercourse at its confluence with the Owenreagh River is 1.39 km², meaning there will be an approximate 5% decrease in flows in this watercourse where it joins the Owenreagh River.

Runoff rates in the catchment of the Pollanroe Burn will be controlled by the presence of water management infrastructure included in the project design (including the Northern Diversion Berm, West Drainage Ditch, Eastern Diversion Ditch, West and East ponds, and Clean Water Pond) that captures and retains contact surface water within water management ponds. Following treatment at the water treatment plant, contact water will be discharged at an outfall on the Pollanroe Burn downstream of the water treatment plant. The outfall will also discharge overflow from the Clean Water Pond. The location of the outfall is shown on Figure 2-1.

In addition to water treatment plant outfall discharge, the Pollanroe Burn will receive underdrainage from the DSF and ponds upstream of the outfall, diverted non-contact water from the Eastern Diversion Ditch 100m downstream of the water treatment plant outfall and run off from the access road discharged at greenfield rates after attenuation and treatment in SuDS.

Considering the inflows above, annual average flows in the Pollanroe Burn at the water treatment plant outfall are expected to be approximately 40 L/s across the years modelled (Year 6, Year 12 and Year 20 of operation). This represents an increase of 22-27% from average annual pre-development flow conditions at the water treatment plant outfall. The increased runoff rates within the proposed infrastructure area, diversion of part of the Unnamed Watercourse catchment and underground mine water inputs will more than offset the flows diverted in the Eastern Diversion Ditch. Increases will be highest in summer months.

At the location where the Eastern Diversion Ditch flow enters the Pollanroe Burn, 100m downstream of the water treatment plant outfall, there will be a larger increase in post-development flows compared to baseline conditions. The increase in annual average flows is predicted to increase by around 38 to 42% across the years modelled, with summer flows increasing by 100 to 130%.

The predicted increase in annual average flows is lower at the mouth of the Pollanroe Burn immediately upstream of the confluence with the Owenreagh River, ranging from 23-25% across the years modelled, with increases up to 77% during summer months. Monthly flows at this location are also expected to increase when compared with pre-development conditions, but to a lesser extent than at the water treatment plant outfall.

Predicted pre- and post-development flows for the three assessment points on the Pollanroe Burn in Year 12 of operation are presented in Table 3-3.

Table 3-3: Predicted pre- and post-development flows in Pollanroe Burn in Year 12 of operation

	Downstream of WTP outfall			Downstream from the Eastern Diversion Ditch outfall			At the mouth		
Month	Baseline flow (L/s)	Flow in Operations (L/s)	Difference (%)	Baseline flow (L/s)	Flow in Operations (L/s)	Difference (%)	[c]Baseline flow (L/s)	Flow in Operations (L/s)	Difference (%)
January	59.7	68.0	13.9	62.2	80.6	29.6	102.4	120.5	17.7
February	36.0	43.9	21.8	37.5	51.5	37.1	61.7	75.2	21.8
March	36.4	45.5	24.9	37.9	53.0	39.7	62.4	76.9	23.2
April	32.5	40.4	24.4	33.9	47.4	39.9	55.7	69.1	24.0
May	22.0	29.7	35.2	22.9	34.2	49.3	37.7	48.3	28.1
June	12.5	21.8	74.1	13.1	24.4	87.3	21.5	33.6	56.5
July	9.4	20.2	113.8	9.8	22.5	128.2	16.2	28.6	76.7
August	10.5	20.1	91.2	11.0	22.3	103.8	18.0	29.2	62.4
September	18.8	28.7	52.8	19.6	32.7	67.4	32.2	45.4	41.2
October	34.1	43.8	28.5	35.5	51.4	44.8	58.4	74.9	28.3
November	49.6	57.8	16.5	51.6	68.4	32.5	85.0	101.9	19.9
December	49.1	56.6	15.3	51.2	66.7	30.4	84.2	101.4	20.4
[a]Annual (L/s)	33.5	42.5	26.8	34.9	49.6	42.1	57.4	72.0	25.4
[b]Runoff (mm)	887.5	1262.9	42.3	887.6	1194.3	34.6	887.5	1075.8	21.2

a Average of monthly average flows

b Runoff is total annual flow divided by catchment area.

c In the table, baseline flows are different for different years. This reflects the changes in rainfall and evaporation rates due to climate change. Changes are also influenced by the stochastic modelling approach used in the Water Balance Model, where there will be slight differences in averages based on the combination of climatic conditions that are selected for each year in each model run.

Although the percentage increases in annual and monthly average flows seem high, the volumes are low when compared to baseline high flow conditions. During average flow periods when the flows in the channel are predicted to increase from baseline conditions, flows will be retained in the channel, well below the top of bank. The increase in flow will result in an increase in water levels of a few centimetres. There will be no increase in flood risk. Flow rates and flow velocities during this time will be much less than would be experienced by the channel in flood flow conditions. During high flow conditions, flows in the channel will be reduced from baseline conditions, due to flow attenuation within the site

Increased average flows in the Pollanroe Burn are expected to result in an increase of flows in the Owenreagh River downstream of the confluence with the burn. Flows in the Owenreagh River are expected to increase by 0.9-1% for annual average flows when compared to baseline conditions. Monthly increases range from 0.5% in winter months to 2.4% in summer months. The predicted increase in flows in the Owenreagh River downstream of the Unnamed watercourse is lower than downstream of the Pollanroe Burn. Downstream of the Unnamed watercourse, there is predicted to be a 0.7% increase in annual flows and 0.4-1.8% increase in monthly flows. This is due to the diversion of part of this catchment to the Pollanroe.

Operation (low flows and flood flows)

In terms of low flow conditions, summer baseflows in the Pollanroe Burn will be supported by discharges from the water treatment plant or a minimum flow will be discharged from the proposed infrastructure site consistent with the 95%ile annual low flow in the Pollanroe Burn to retain flow in the burn (around 5 L/s at the outfall). However, water balance modelling predicts discharges from the water treatment plant will be lowest during the first year of operations at 7 L/s and then after that the rate will be above 8.3 L/s (30 m^3/hour) including during the summer. In addition, groundwater modelling indicates flows of 6.1 L/s in the DSF and water management pond under drains will discharge to the Pollanroe Burn. Therefore, the results would indicate that low flows in the Pollanroe Burn would be higher than baseline conditions during operations. The increase in low flow conditions in the Pollanroe Burn will result in a positive but negligible change in low flow conditions in the Owenreagh River.

For flood flow conditions, no untreated discharges would occur from the mine water management ponds up to and including the 1 in 1000 year 24-hour storm event. Predicted flood flows from a range of return periods show that, during operations, attenuation of water on the mine site would result in a decrease of peak flood flows in the Pollanroe Burn.

Table 3-4: Comparison of baseline and post-development flood flows in Pollanroe Burn

Storm event return period (years)	Baseline flood flow (m^3/s)	Post-development flood flow (m^3/s)	Difference (m^3/s)	Difference (%)
Pollanroe Burn at outfall- 0.81 km^2				
2	0.91	0.61	-0.30	-33
5	1.19	0.78	-0.41	-34
10	1.44	0.94	-0.51	-35
25	1.83	1.17	-0.66	-36
50	2.21	1.40	-0.81	-36
100	2.66	1.68	-0.98	-37
Pollanroe Burn at mouth - 2.04 km^2				
2	2.28	1.99	-0.30	-13
5	3.00	2.59	-0.41	-14
10	3.63	3.12	-0.51	-14
25	4.61	3.95	-0.66	-14
50	5.57	4.76	-0.81	-15
100	6.71	5.72	-0.99	-15

In terms of the effect on the Owenreagh River downstream of the Pollanroe Burn, flood flows are predicted to be around 1 to 1.5% lower than under baseline conditions, reducing downstream flood risk.

Operation (summary)

The diversion of flows from the Unnamed watercourse to the Pollanroe Burn results in a decrease in flows in the Unnamed watercourse under all flow conditions. This has a positive effect during flooding as peak flows are reduced, but a moderate or major adverse magnitude during low and average flow conditions. As the Unnamed watercourse is a low sensitivity watercourse, the overall significance of the impact is considered minor. Additional mitigation is not proposed.

The increase in annual average, monthly average and low flows in the Pollanroe Burn is not expected to result in out of bank flows, bank erosion or deterioration of ecological habitats. Conversely, the modified flow regime supports the maintenance of flows in the small watercourse. Considering this and the reduction in flood flows, the impact is considered neutral or positive. Changes to the Owenreagh River, downstream reaches of the Owenkillew River and Lough Foyle and tributaries are negligible.

Closure

At mine closure, the proposed infrastructure site will be returned as close to greenfield conditions as is practical. Over time it is predicted that flows in the Pollanroe Burn will return to baseline conditions, post-closure, with the main difference being the increased catchment to the Pollanroe Burn, due to the diversion of a small part of the Unnamed Watercourse catchment to the Pollanroe.

Given that the reach of the Pollanroe Burn potentially impacted by a reduction in catchment area and flow during closure is very short (around 100m) and for the rest of the catchment average and low flows are predicted to be increased or very similar to baseline during closure, the impacts of the development on flows in the Pollanroe Burn are predicted to be neutral or positive.

Impact SW01: Potential impact on surface water flow in the Pollanroe Burn, Unnamed watercourse and Owenreagh River due to construction, operation and closure of proposed infrastructure site		
Impact characteristics	**Initial impact**	**Residual impact**
Type (+ / - /neutral)	Neutral	Neutral
SIGNIFICANCE (Pollanroe Burn)	Not significant	Not significant
SIGNIFICANCE (Unnamed watercourse)	Not significant	Not significant
SIGNIFICANCE (Owenreagh River)	Not significant	Not significant
Project design measures • Stream crossings for access road to be designed to pass 1 in 100 year flow. • Contact water will be captured in ponds and treated prior to discharge to Pollanroe Burn. • Water management ponds will be constructed below ground surface level so there is no water stored by man-made structures. • Mine water management ponds will be designed to hold the 1 in 1000 year, 24-hour storm with no discharge under normal operating conditions. • Ponds have a spillway or other structure that will allow excess water to leave the ponds in a controlled manner to control any spills for events in excess of the design condition. **Mitigation measures** • Measures to control runoff during construction will be outlined in the Construction Environmental Management Plan, a final version of which will be agreed prior to the start of construction activities. • Water management ponds will be retained at closure to attenuate flood flows		

For and on behalf of SRK Consulting (UK) Limited

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APPENDIX

A SITE WATER BALANCE 2020 UPDATE

Dalradian Gold Limited

Curraghinalt Gold Mine Project

Site Water Balance – 2020 Update

October 2020

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1 Introduction

Kaya Consulting Ltd. has been commissioned by Dalradian Gold Limited (DGL) through SRK Consulting UK (SRK) to undertake water balance calculations for the proposed Curraghinalt Gold Mine in Northern Ireland, to support the Environmental Impact Assessment (EIA). The Curraghinalt site is located in the Sperrin Mountains, an upland region in Northern Ireland.

The water balance is based on the mine site layout, dry stack designs and process plant water balance information provided by others and described in detail elsewhere. Key information required for the water balance is summarised in this report, with appropriate references to the source documents.

This report replaces the Water Balance Report in the 2017 ES (Appendix C4, Annex A) by updating the information and allowing the assessments and information to be reviewed in the one report. There is duplication of earlier information that remains unchanged. The concept and models remain the same.

The calculations are based on monthly inputs so are suitable for general water management at the site. Calculations are reliant on inputs from other study contributors on key water balance components of the site. This includes;

- Process water circuit – JDS Engineering and Canenco
- Dry Stack Facility (DSF) area – SRK Consulting
- Water management infrastructure design – JDS Engineering and Hoy-Dorman
- Underground mine dewatering – SRK Consulting
- Water Treatment Plant – JDS Engineering

The report also provides estimates of runoff volumes for short-lived (hourly and daily) storm events and assesses the water storage capacity of key water management ponds.

The purpose is to calculate operational water levels/volumes in the water management ponds and to calculate required water treatment rates to maintain water levels in the ponds at appropriate operational levels, required for flood water management. Design of the water management infrastructure is not part of this assessment and this work is being undertaken by JDS Engineering and Hoy-Dorman as noted above.

This report is based on the mine life and mine layout which supports the EIA and Planning Application for the site.

It is assumed that the mine life extends for 20 years, with operations commencing on 1st January in the first year of operations.

This report focusses on the Proposed Infrastructure Site to the south of the study area. The Proposed Infrastructure Site is situated in the headwaters of two small watercourses (Pollanroe Burn and Unnamed Watercourse) that drain to the Owenreagh River, which is a main tributary of the Owenkillew River.

1.1 Key Changes from the Environmental Statement

The overall water management plan for the mine (see Section 2.1) remains the same as presented in the ES 2017 water balance (Environmental Statement Volume 3, Appendix C4, Annex A). The major processing change at the mine site in 2019 is the removal of cyanide processing of ore at the site; the ore is now pre-processed at the site and trucked offsite for final processing. This has limited impact on the water balance at the site but removes any risk of cyanide contamination. The process water balance is updated in the light of this change in ore processing and the new process water balance is included in this report.

There have been changes in the final shape of the Dry Stack Facility (DSF). This has resulted in small changes in the overall size of the DSF and the final topography. Further seepage analysis was also undertaken in support of the DSF design and this is discussed in more detail in Section 3.5.1.

The extent of the underground mine has been changed and groundwater modelling of water inflows to the underground workings has been updated. The new underground water inflows are incorporated in this updated water balance.

The following other changes have been made:

- Hydrological inputs for undeveloped areas (natural runoff) have been improved following further analysis of baseline flow data collected between 2017 and end 2019. This work has been augmented by a review of regional data and rainfall-runoff modelling. The updated approaches are presented in Chapter 3
- Hydrological inputs (runoff and seepage) for the DSF have been updated following work undertaken by SRK (2020b)
- Climate change is explicitly considered in model inputs, based on UKCP18 climate predictions (https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/about) and DFI (2019)
- An error in the sewage production rate in the 2017 water balance has been corrected (see Environmental Statement Volume 3, Appendix C4, Annex A, Section 5 for sewage values used in the 2017 water balance). In addition, sewage is now treated near source and then discharged to one of the on-site water management ponds before being passed through the main mine Water Treatment Plant. In the ES 2017 report sewage was discharged directly to the Pollanroe Burn after treatment in the dedicated sewage treatment plant (see Environmental Statement Volume 3, Appendix C4, Annex A, Section 2,1 for description of approach in ES 2017 report)
- The capacity of the end of line Reverse Osmosis (RO) Water Treatment Plant (WTP) has been increased to 300 m^3/hour from 200 m^3/hour to provide additional treatment capacity at the site

2 Proposed Infrastructure Site

This chapter outlines the general water management plan for the Proposed Infrastructure Site and process plant water requirements used in the model.

There are no significant changes to the management of surface water at the Proposed Infrastructure Site. The key small-scale changes are:

- In the 2017 water balance it was proposed to discharge treated sewage (treated by standard sewage treatment methods) directly to the Pollanroe Burn. Treated sewage will now be discharged to the East Pond, where it will pass through the Reverse Osmosis Water Treatment Plant (WTP) before discharge to the Pollanroe Burn. Effectively the sewage will be treated twice, but the purpose is to combine all treated water so that it is passed through the WTP and can be regulated at one location.
- Fresh water for the mine process can be provided from the Clean Water Pond or treated water from the WTP. In the 2017 water balance an assumption was made that excess water from the WTP would be pumped to the Clean Water Pond before overflowing to the Pollanroe Burn. This was a simplification within the model that did not impact the overall water balance. In this water balance the model routine has been updated so that water from the WTP is discharged directly to the Pollanroe Burn, with water pumped to the Clean Water Pond only if there is a shortage in that pond. Clean water for the process is taken from the Clean Water Pond where available, before water is pumped from the WTP. This change does not impact the overall water balance or discharges from the site but removes an over-simplification in the flow pathways in the 2017 model.
- There have been small changes in the catchment areas reporting to water management ponds, due to changes in the DSF. Hence, these catchment areas are updated and the presentation of these catchment areas (see Table 1) is simplified compared to the 2017 report to focus on key types of catchment (natural, hardstanding etc,) that are discussed in Chapter 3. This change makes it easier to cross-reference the catchment areas to the catchment type and method used to calculate flows for that catchment.
- A small clarification has been made in the design of the under-drains of the DSF in that there will be manhole access for water quality testing at the downstream end of the drain, but water in the under-drain will flow to the Pollanroe Burn as before.
- There are changes to the process water balance at the site, due to the change in the process method. This has changed the water demands of the process, which is outlined in Section 2.1. The structure of this section is also changed compared to the 2017 report to reflect the new simpler process and to aid clarity.

Other changes to the general layout drawings for the mine site, which do not impact on the water balance, are not discussed in this report.

2.1 Proposed Infrastructure Site Layout and Catchments

The Proposed Infrastructure Site is shown in Figure 1. This area will include the following infrastructure:

- Processing Plant, Stockpile, Haul Road, Crusher, Warehouse and Workshop, Admin Building and Car Park
- DSF Area
- Mine Water Management Ponds; East Ponds (Upper and Lower) and West Pond
- Clean Water Pond
- Access Road to Mine Site

The aims of the water management plan can be summarised in three main concepts;

1. Capture, storage and treatment of all water that contacts mining activities/infrastructure and which could have poor water quality.
2. Limit natural runoff from outside of the Proposed Infrastructure Site from contacting mine infrastructure to reduce water volumes needing to be treated.
3. Capture of clean (non-contact) surface water runoff from upslope of the Proposed Infrastructure Site to be available for use as fresh water in the process plant. Where possible water used in the process will be untreated mine water to limit the need for fresh water inputs.

Design of the water management infrastructure has been undertaken by JDS Engineering and Hoy-Dorman.

The Proposed Infrastructure Site will be bounded to the north, east and west by berms and associated ditches which will capture natural surface water runoff from upslope of the Proposed Infrastructure Site and route it away from contacting with mine site infrastructure (refer to Figure 2).

Flows from the north of the Proposed Infrastructure Site will be routed to a Clean Water Pond located to the north-east of the mine site area. Water will be stored in the Clean Water Pond (capacity of 40,260 m^3) to provide a source of additional make-up water for the processing of ore and to maintain a minimum flow in the Pollanroe Burn (compensation flow). Water will be discharged from the Clean Water Pond to the main project outfall to the Pollanroe Burn and the pond will have a spillway to allow free overflow during extreme events.

The diversion berm along the eastern edge of the Proposed Infrastructure Site will capture surface water from hillslopes located on the eastern side of the catchment and route it around the periphery of the mine to ultimately discharge into the Pollanroe Burn on the slopes below. A diversion ditch along the western edge of the DSF will capture surface water runoff from the slopes on the western side of the catchment and will route it to the West Pond.

Runoff landing within the mine site area will be routed through a series of ditches to the three water storage ponds:

- Upper East (52,870 m^3 capacity) and Lower East Ponds (9,973 m^3 capacity) receive surface water runoff from the mine infrastructure area and runoff seepage from the eastern part of the DSF.
- West Pond (38,855 m^3 capacity) receives runoff and seepage from the western part of the DSF and runoff from the West Diversion Ditch. Excess water from the underground workings (not used in the process or tailings paste plant) will be pumped to the West Pond.

Runoff entering the ponds will need to be treated before discharge. The ponds are provided with spillways for emergency safety conditions. However, during operations there should be zero uncontrolled discharge from these ponds. Storm water storage in these facilities is discussed in Appendix 1.

A WTP will be located to the south of the East and West Ponds. Water from the treatment plant will be pumped to the Clean Water Pond (if water levels in the pond are low) or to the Pollanroe Burn at the outfall point close to the treatment plant. All water released to the Pollanroe Burn will need to be of sufficient quality to meet the site discharge consent.

The treatment plant proposed at the site will be based on RO technology, with a two stage RO system to meet water quality requirements at the site. The plant is being designed by JDS Engineering. The proposed system will include a crystalliser to limit the volume of the plant effluent. Many RO systems have a brine waste, but the proposed system will have a solid residue with water losses of less than 0.5% of the inflow to the treatment plant.

Drinking and other sanitary water will be provided by a piped mains water supply. Sewage will be treated using standard methods and the liquid effluent from this process with be discharged to the East Pond, from where it will pass through the RO treatment plant, before discharge to the Pollanroe Burn. Drinking, sanitary water and sewage will be kept on a separate system to the mine water management system up until the point of discharge to the Upper East Pond.

The DSF has been designed by SRK Consulting (SRK (2020c). During construction of the mine, waste rock from the creation of the underground mine access will be used to form a Starter Dam along the southern (downslope) edge of the DSF area (See Figure 3). This will provide a base for deposition of the tailings through the mine life. This Starter Dam will be comprised of unreactive rock and will be vegetated and reclaimed along the south facing side. In the model these areas are considered as having runoff conditions similar to natural conditions, as distinct from the tailings areas within the DSF. The DSF will then be progressively developed from east to west across the mine site, with Figure 3 illustrating the approximate evolution of the facility over time. The facility will have a series of internal drains and water flowing through the internal drains will be captured and routed to the East and West Ponds. The facility will also have a basal liner, with an under-drain below the facility. The under-drain will receive any residual water seepage from the facility through the liner as well as local groundwater. The under-drain will have manhole access for water quality testing, but it is assumed that water in the under-drain will flow to the Pollanroe Burn.

The catchment areas flowing to each part of the mine are summarised in Table 1 and Figure 2.

The evolution of the DSF in terms of catchment areas draining to the East and West Ponds are outlined in Table 2 to Table 4.

The DSF will be progressively reclaimed and will be covered by an engineered cover comprising a 0.3 m thick layer of dry stack tailings blended with bentonite clay. This will be topped by 0.5 to 1 m thick layer of soil material that will be vegetated. The reclamation will occur on an annual basis during the summer months, with two-thirds of the DSF assumed to be reclaimed by the end of Mine Life. For more information on the DSF refer to the Dry Stack Facility Feasibility Design Report (Appendix G to the Mine Waste Management Plan (including two addendums 2019 and 2020).

Water management infrastructure that will convey contact water within the site has been designed for the 1 in 1,000-year 24-hour storm event (based on FEH 2013 rainfall depths, Stewart et al., 2012). Other water management infrastructure will be designed for the 1 in 1000-year event (internal drainage within the Proposed Infrastructure Site) and 1 in 100-year event (access road outside of Proposed Infrastructure Site).

Table 1: Summary of key catchments draining to East and West Ponds

Catchment	West Pond Catchments (m^2)	East Ponds Catchments (m^2)
DSF Area (see Table 1)	125,700	145,980
Natural Catchments (non-hardstanding)	61,145	142,745
Mine infrastructure (hardstanding)		38,542
Pond Areas	18,400	24,300
TOTAL	**205,245**	**351,568**
	TOTAL	**556,813**

Table 2: Evolution of catchments draining to West Pond. Table gives areas at end of given year

Year	West Pond Catchments						
	[a]Non-Hardstanding Catchment (m^2)	Hardstanding Areas (m^2)	Pre-developed Dry Stack (m^2)	Active Dry Stack (m^2)	Reclaimed Dry Stack (m^2)	Pond Area (m^2)	Total (m^2)
-1	61,145	0	125,700	0	0	18,400	205,245
1	61,145	0	125,700	0	0	18,400	205,245
5	61,145	0	125,700	0	0	18,400	205,245
9	61,145	0	62,850	62,850	0	18,400	205,245
11	61,145	0	31,425	94,275	0	18,400	205,245
20	61,145	0	0	75,420	50,280	18,400	205,245

a Includes Starter Dam as outlined in the text

Table 3: Evolution of catchments draining to Upper East Pond. Table gives areas at end of given year

Year	Upper East Pond Catchments						
	[a]Non-Hardstanding Catchment (m^2)	Hardstanding Areas (m^2)	Pre-developed Dry Stack (m^2)	Active Dry Stack (m^2)	Reclaimed Dry Stack (m^2)	Pond Area (m^2)	Total (m^2)
-1	122,355	38,542	129,880	0	0	16,700	307,477
1	122,355	38,542	129,880	0	0	16,700	307,477
5	122,355	38,542	35,717	94,163	0	16,700	307,477
9	122,355	38,542	9,741	25,976	94,163	16,700	307,477
11	122,355	38,542	4,871	30,847	94,163	16,700	307,477
20	122,355	38,542	0	9,741	120,139	16,700	307,477

a Includes Starter Dam as outlined in the text

Table 4: Evolution of catchments draining to Lower East Pond. Table gives areas at end of given year

Year	Lower East Pond Catchments						
	[a]Non-Hardstanding Catchment (m^2)	Hardstanding Areas (m^2)	Pre-developed Dry Stack (m^2)	Active Dry Stack (m^2)	Reclaimed Dry Stack (m^2)	Pond Area (m^2)	Total (m^2)
-1	20,391	0	0	0	16,100	7,600	44,091
1	20,391	0	0	0	16,100	7,600	44,091
5	20,391	0	0	0	16,100	7,600	44,091
9	20,391	0	0	0	16,100	7,600	44,091
11	20,391	0	0	0	16,100	7,600	44,091
20	20,391	0	0	0	16,100	7,600	44,091

a Includes Starter Dam as outlined in the text

2.2 Mine Water / Process Water Demands

The Process Water Balance has been updated since the ES submission. The Process Water Balance has been developed by Canenco and is outlined in Appendix 2. The key components of the Process Water Balance have been included in the site-wide water balance model, particularly where the Process Balance interacts with other mine components. Where there is recycling of water within the process this is not explicitly modelled in the water balance presented in this report as it does not impact on the surface water management at the site, i.e., this is water that is cycled within the process plant buildings.

The process proposed includes grinding and flotation of the mined ore, as well as tailings preparation and a paste plant prior to the management of tailings in the DSF and underground. As a result, there is only a minor change to the overall water requirement in the process as many of the components of the process remain as before.

The process requires 156.7 m^3/hour of water. Of this 140.8 m^3/hour is recycled and re-used within the process plant. Water leaves the process in the following ways;

- with the ore concentrate shipped from the mine (0.5 m^3/hour);
- with the paste production process for tailings sent to underground (11.6 m^3/hour); and
- with the tailings sent to the DSF (3.8 m^3/hour).

Of this only the water with the tailings can eventually report to the East or West Ponds.

This loss of water from the process needs to be balanced by a water inflow of 15.9 m^3/hour. For reference the ES water balance had a water requirement for the process of 19.16 m^3/hour. Some of this water needs to be fresh water (non-mine contact), while other water can be recycled from other sources within the mine site. In detail:

- 7.2 m^3/hour needs to be fresh water, either from the Clean Water Pond or treated water. The preferred source of fresh water is from the Clean Water Pond, as it can flow to the process plant through gravity.
- 5.7 m^3/hour can be pumped directly from the underground workings and be used untreated
- 3 m^3/hour enters the process with the ore itself, i.e., it is also sourced from underground workings and is untreated

The fresh water is used for mixing with reagents (3.7 m^3/hour) and as Gland Water (3.5 m^3/hour).

These requirements are assumed to be constant through the mine life based on the average rate of ore production. The production rate is constant through the life of mine (LOM) with small variations each year. Those variations do not materially affect the modelling.

There are water requirements for spray water for dust suppression during dry periods for the DSF. Spray water will also be used within the process to manage dust. This water will only be applied within the mine area and mine water can be used for this purpose. It could be taken from any of the water management ponds, but for the purpose of modelling it is taken from the East Pond. The spray water is 10m^3/hour for summer months and 5 m^3/hour for non-summer months.

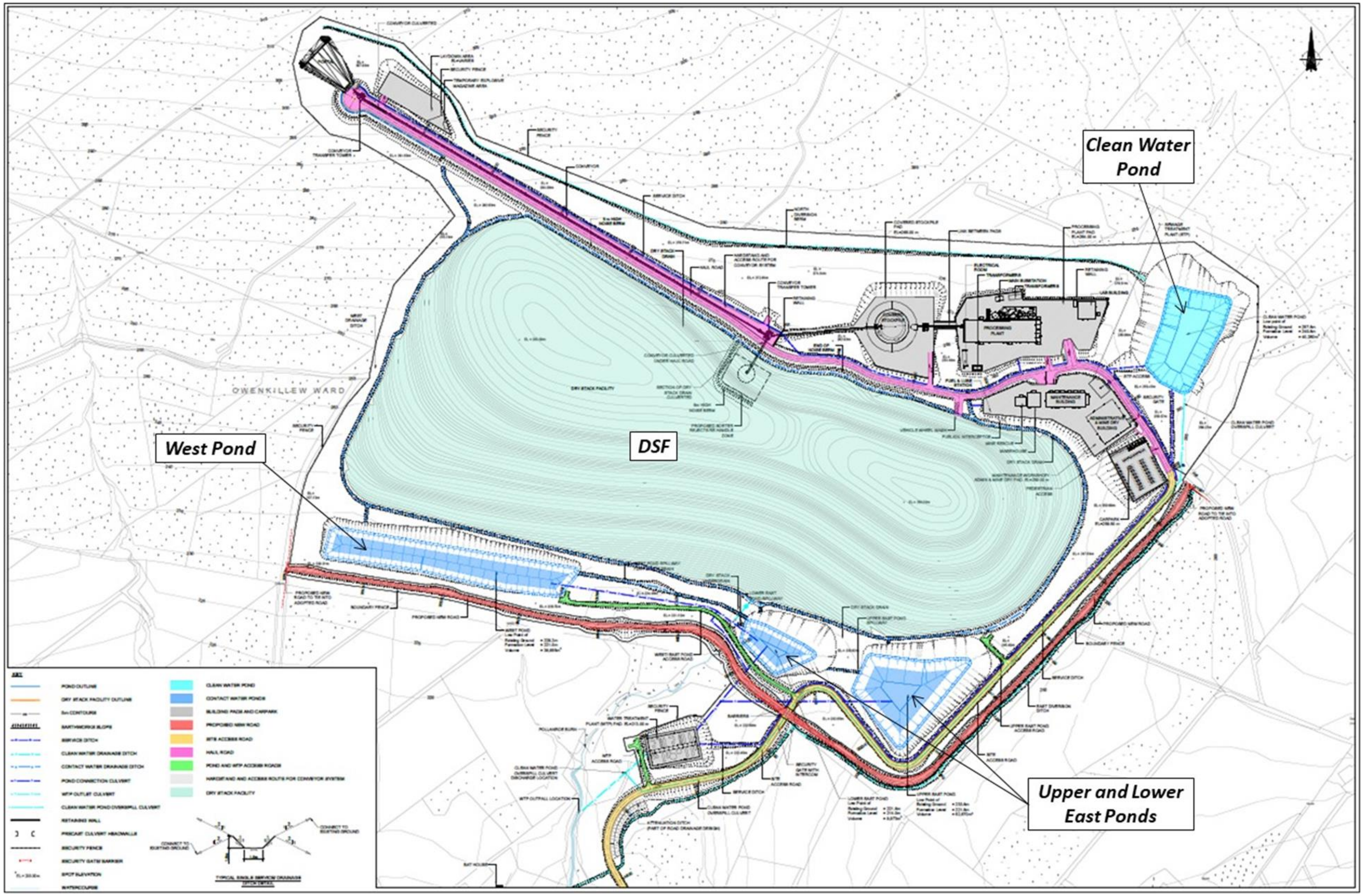


Figure 1: **Proposed Infrastructure Site (Hoy Dorman Drawing 2016021-P-CIV-004 (A) General Site Layout Plan)**

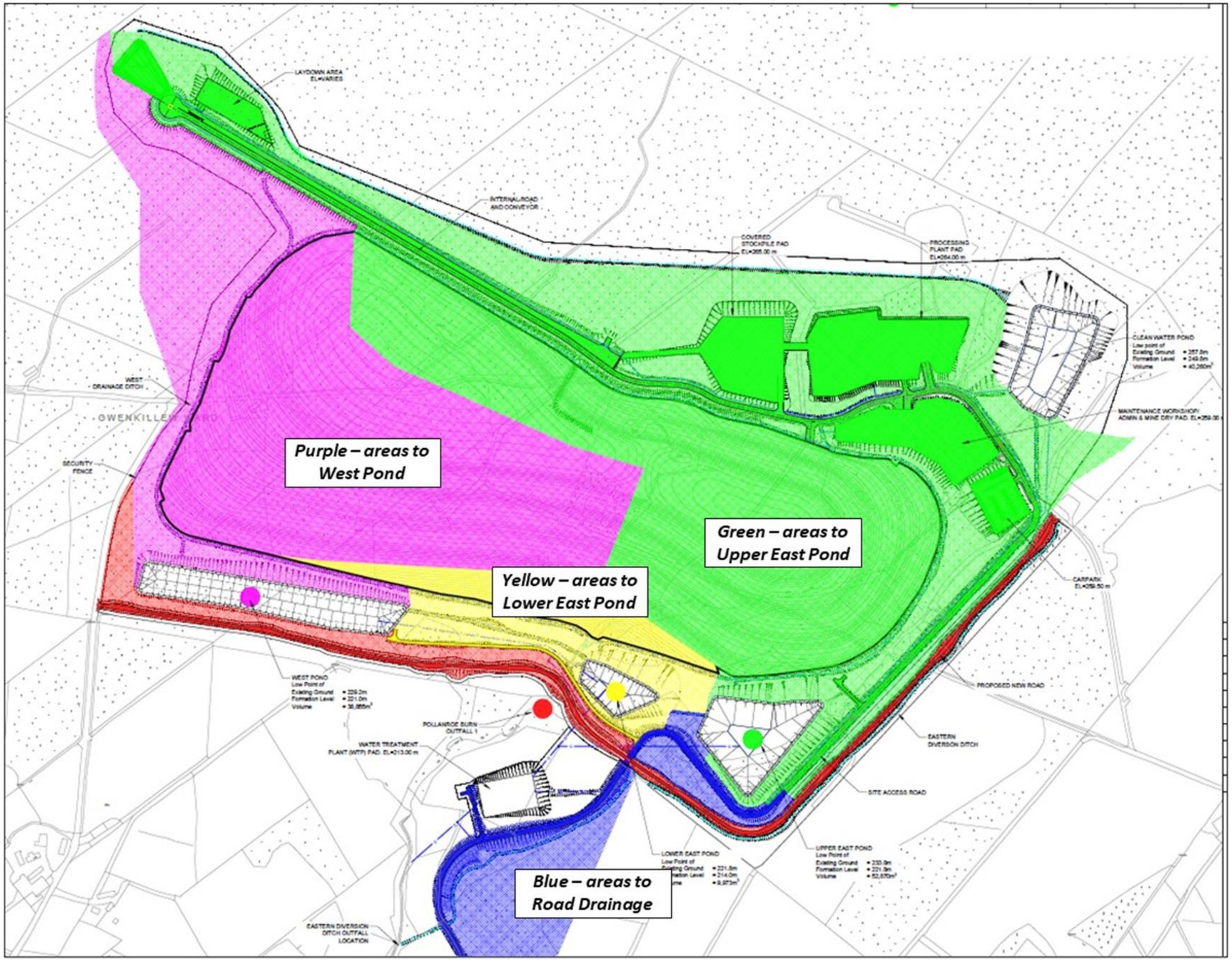


Figure 2: **Proposed Infrastructure Site (Excerpt from Hoy Dorman Drawing 2016021-P-CIV-300 Drainage Catchments Areas Rev B)**

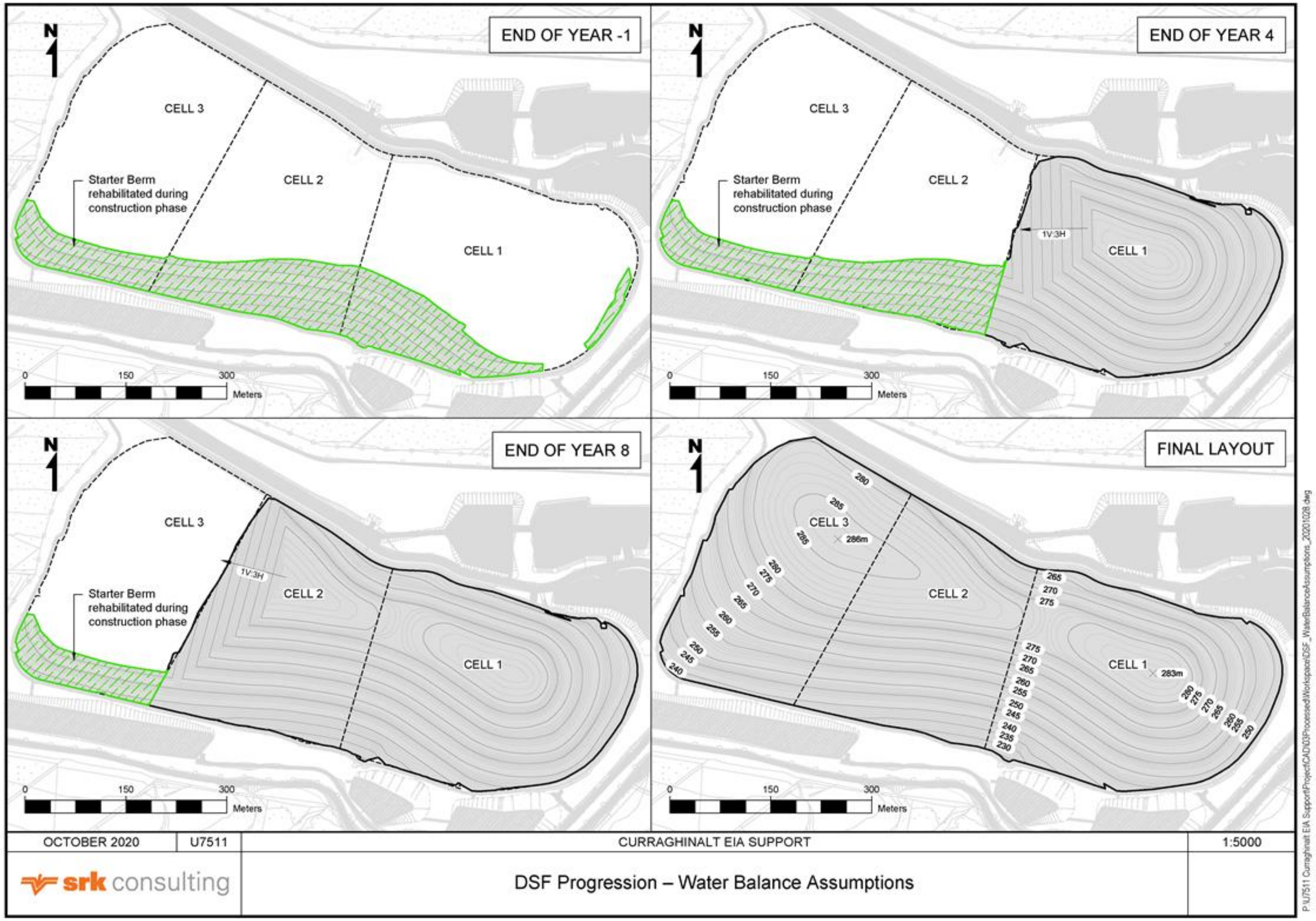


Figure 3: **Evolution of Dry Stack Facility – final layout is shown in Figure 1**

3 Hydrological Inputs

This chapter outlines methods and values used to generate the hydrological inputs to the water balance model. The main focus of the study is on surface water but estimates for seepage inflows from the DSF are also included. Information on groundwater inflows to the underground mine are provided in Chapter 4.

Predictions of monthly flow rates from the mine site area and surrounding catchments are based on:

- Analysis of gauged flow data for watercourses close to the mine site. This includes data collected as part of the baseline monitoring program and from DfI Rivers national gauged flow data set.
- Development of methods for calculating runoff for mine site areas, i.e., from the DSF area and natural (peat dominated) catchments.
- Standard UK Wallingford Hydrosolutions LowFlows2 software (https://www.hydrosolutions.co.uk/software/lowflows2/), for catchments close to the site. The LowFlows2 data is additional information used in this assessment compared to the 2017 report. This dataset provides estimates of flow duration curves for ungauged watercourses throughout the UK and is a suitable dataset to be compared to the available on site data. Its use improves the quality of flow inputs to the model.

As the water balance works on inputs provided on a monthly time step, the analysis focusses on annual and monthly totals. However, a model sensitivity run was also undertaken using daily hydrological inputs to test the model response to sub-monthly variations in hydrological inputs. The storm water calculations (Appendix 1) are also based on daily (24-hour) storm durations.

For surface water runoff there are four key types of catchment at the mine site;

1. Natural undisturbed catchment areas.
2. Active DSF. These are the parts of the DSF area which are undergoing active creation. These are composed of exposed, un-vegetated tailings and waste rock.
3. Re-claimed DSF. Once active deposition has been completed the dry stack areas will be reclaimed through the placing of a soil cover.
4. Plant site and roads. Hardstanding areas or disturbed ground with higher runoff totals.

The approaches taken in the water balance report to calculate runoff and seepage rates to the water management ponds are described below, after an initial description of key precipitation and evapotranspiration data. As the updates to the methods used to calculate surface water runoff at the site use these precipitation and evapotranspiration data sets their discussion is moved earlier in this chapter compared to the 2017 report.

3.1 Precipitation Data

Annual and monthly precipitation parameters for the site are based on analysis of UK Met Office monitoring data at Lough Fea, which is the closest station to the project area. The site is located at a similar elevation to the mine site so is considered a good analogue for the site. The UK National River Flow Archive (NRFA, https://nrfa.ceh.ac.uk/) provides daily calculated rainfall totals for selected UK flow gauging stations, with data available for the Owenkillew River at Crosh. NRFA data was also obtained and compared to the Lough Fea information, showing a good fit. Gaps in the Lough Fea data set were filled using data from the NRFA data and the annual totals at Lough Fea were calculated with these gaps filled. Annual rainfall totals are shown in Figure 4. The average annual rainfall total (hydrological year) at the Lough Fea gauge is 1,347 mm, which is slightly higher than the value of 1,336 mm used in the 2017 water balance report.

The UK Flood Estimation Handbook (FEH) also provides estimates of annual precipitation for catchments throughout the UK, with the SAAR (Standard Annual Average Rainfall) value for the Pollanroe Burn at 1,367mm, close to that at Lough Fea, showing a good correlation between standard data sources.

The monthly average distribution of rainfall is shown in Table 5 and Figure 5.

More information on the approach to modelling inter-annual variations in rainfall is provided in Section 3.6.

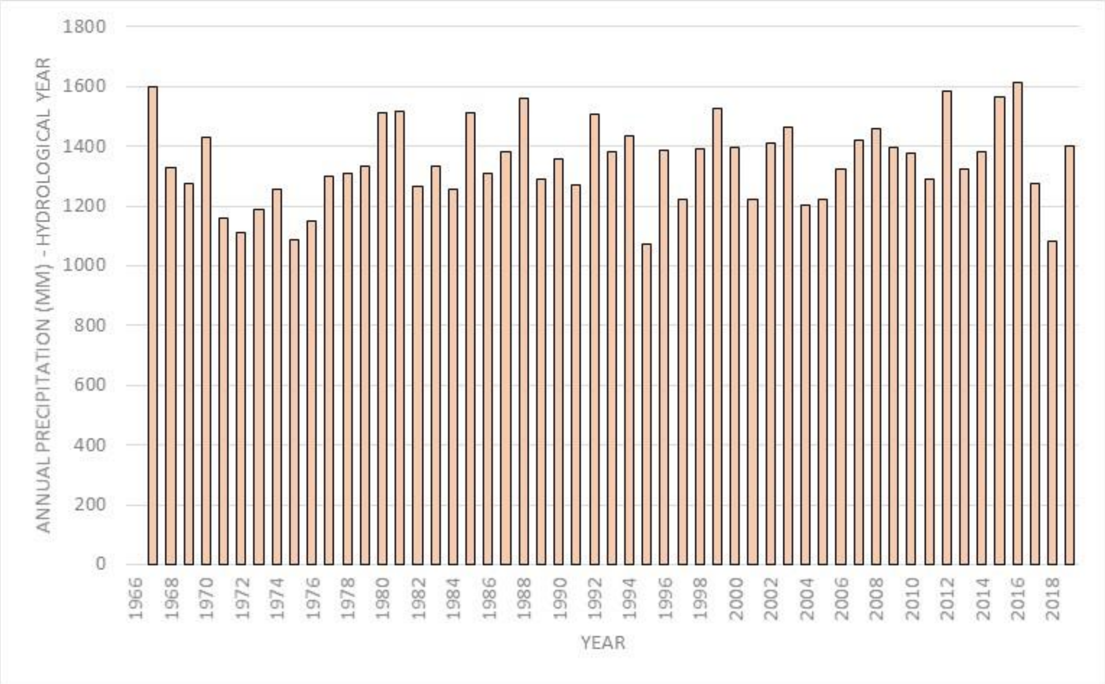


Figure 4: Lough Fea – Annual Precipitation Data

3.2 Evaporation Data

Evaporation from open water ponds and potential evapotranspiration (PE) from exposed mine site areas are based on the following approaches

- Calculation of PE from met station data collected at the mine site meteorological station (5 years of data)
- Calculation of long-term PE records (for comparison with long-term precipitation records) based on meteorological data from Lough Fea. This data was then scaled to provide similar average conditions to the site data

PE was calculated using the Oudin et al. (2005) approach that was developed specifically for the purpose of generating evapotranspiration records for hydrological modelling for sites with limited evaporation or other meteorological site data.

The average PE from the site data was calculated as 457 mm/year, with the monthly distribution of values provided in Table 5. Daily and monthly totals were calculated for the period 1966 to 2019 based on Lough Fea temperature data where available (1981 to 2019), with time series for earlier years based on a relationship between annual precipitation and annual PE developed using the 1981 to 2019 data. Open water pond evaporation was set equivalent to PE for the purpose of this model, due to limited other information and given the small surface areas of ponds relative to the overall site area.

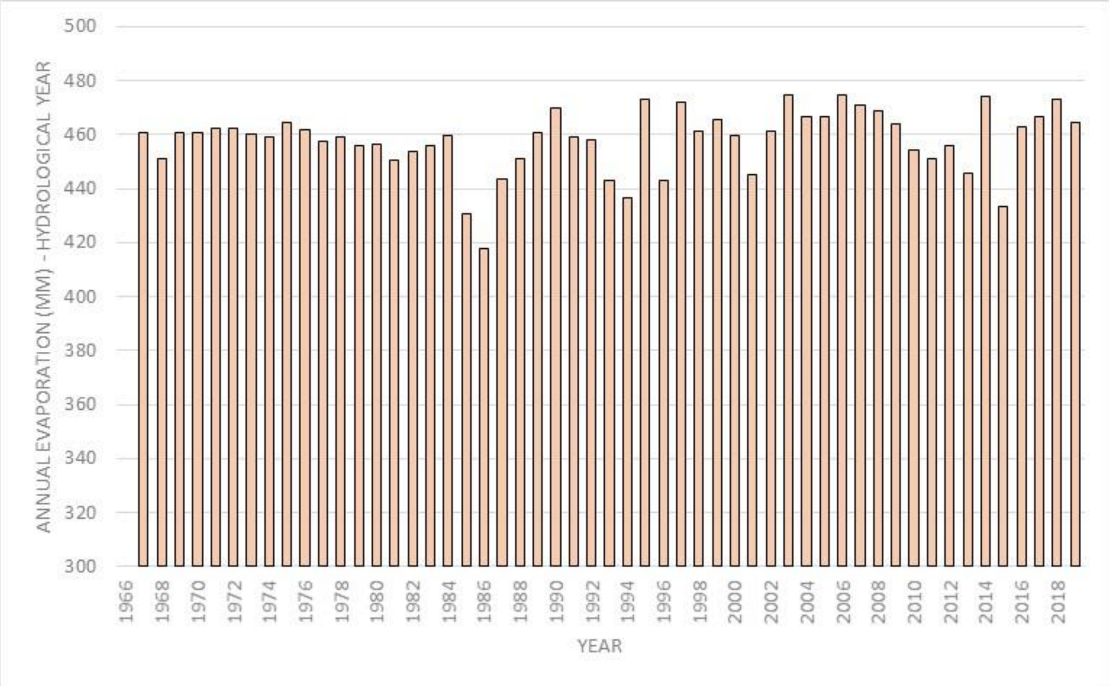


Figure 5: **Lough Fea – Annual Evapotranspiration Data based on Oudin et al. (2005) methods**

3.3 Natural Catchment Runoff

Calculation of stream flows and runoff rates for the catchments and watercourses located close to the site are based on (i) twelve flow gauging stations constructed and operated for this project, (ii) review of regional flow monitoring stations operated by the UK government and (iii) standard national methods of flow estimation (i.e., LowFlows2 and FEH).

Runoff rates from natural surfaces at the site are based on data obtained for small catchments (e.g., Pollanroe Burn) close to the site. Within the site baseline flow data set, flows are measured on five streams where the upstream catchment is less than 25km^2 in size;

- FLO1 – Curraghinalt Burn, 1 km^2
- FLO2 – Glenealy Burn, 1 km^2
- FLO4 – Glenlark Burn, 21.9 km^2
- FL11 – Sruhanalticarra Burn, 1 km^2
- FL13 – Pollanroe Burn, 1 km^2

Annual average runoff rates for these catchments range from 762 mm to 1,047 mm, with a median of 849 mm, with the results for FL13 being an outlier with significantly higher runoff than the other sites. As discussed in the Surface Water Baseline Report, there are issues with low flow measurement at FL13 due to changes in bed form over time.

Within the DfI Rivers data set there are no stations with catchments < 100 km^2 near to the site. In the 2017 ES extrapolation of data from larger catchments to the onsite stations produced estimates of runoff for the Pollanroe Burn of between 700 – 900 mm per year. For this update flow duration curve outputs from the LowFlows2 software were also obtained. LowFlows2 calculates flow duration curves for any ungauged catchment in the UK, with the method calibrated against observed data at gauged sites. There is uncertainty with LowFlows2 outputs for small (<25 km^2) catchments, given the limited number of gauging stations on small catchments and the impact of local conditions on flow conditions for small watercourses. Therefore, the LowFlows2 data should be compared/calibrated against site data, of the type collected as part of the baseline assessment. The resultant flow values used in this assessment for small catchments are based on comparison between LowFlows2, site data and hydrological modelling calibrated against the on-site data. This approach provides a robust method that utilises on-site data and national methods to produce typical flow conditions for natural catchments at the site and for the Pollanroe Burn.

LowFlows2 results are considered more representative for larger watercourses, and this is borne out by the good comparison of baseline flow data for the Owenreagh River (53.5 km^2, at the junction with Pollanroe Burn) with the LowFlows2 results, which are discussed in more detail in Section 3.9. This allows the LowFlows2 data to be used to develop flow duration curves for the Owenreagh River at the site.

The flow duration curves for the five gauging stations at the site are compared to the LowFlows2 results in Figure 7, with flow data normalised by area to allow comparison of data from different sized catchments. The data shows that all of the sites, apart from FL13, appear to fit reasonably well with the LowFlows2 data from the Owenreagh and Pollanroe Burns, with the Pollanroe Burn having slightly higher flow per unit area compared to the Owenreagh. Following additional review there is uncertainty with the data at FL13 due to the presence of a relatively mobile bed at the gauged site and a culvert downstream of the site that results in difficulties in accurately calculating low flows. Excluding data from FL13 and averaging the flow duration curves for the other 4 sites, gives the average flow duration curve in the lower graph in Figure 9. It shows a generally good fit against the LowFlows2 data, especially in the range 40%ile to 95%ile (graph is log scale).

To further assess the site data and to try to extrapolate the period of record at these gauges to a longer period record, simple rainfall-runoff models of each of the small gauged catchments was constructed using a catchment water balance model (Australian Water Balance Model AWBM, Broughton, 2004, see Surface Water Baseline Report, 2020 for more information on the model set-up and calibration). The models were calibrated for each gauged site and a single set of calibrated parameters was then used to calculate a long term (1966 – 2019) flow time series based on the observed and calculated precipitation and PE data described in Sections 3.1 and 3.2. A comparison between the modelled flow duration curve, the observed flow duration curve and data from LowFlows2 are shown in Figure 8, illustrating a reasonably good fit between all the data sources. The modelled curve is similar to that for the Pollanroe Burn from LowFlows2 and is slightly higher flows than the curve based on observed flows. Compared to the site data the use of the modelled flow time series is likely slightly conservative, in that it produces higher flow volumes within the water balance.

The monthly flow distribution is shown in Table 5 and Figure 6. A summary of the flow statistics for an example 1 km^2 catchment is provided in Table 6.

The model output is used as an input to the water balance for any natural, undeveloped surfaces. On average the runoff total predicted by the model was 898 mm, equivalent to 67% of mean annual precipitation. The annual variation in runoff (compared to precipitation) in the input dataset is shown in Figure 9. The average value used in the updated water balance is higher than the average of 700 mm used in the 2017 ES water balance.

A key low flow condition is the 95%ile flow, which is the flow that is exceeded for 95% of the time annually. The mine water management plan requires that a minimum compensation flow will be discharged from the mine site area to provide at least the pre-development 95%ile flow for the Pollanroe Burn at the mine site outfall, to maintain flows in the watercourse downstream of the mine. The 95%ile flow from the LowFlows2 analysis is 3.9 $l/s/km^2$ from LowFlows2 and 4.6 $l/s/km^2$ from the site data. In the 2017 ES water balance the 95%ile flow was calculated as 4.2 $l/s/km^2$. As the 2017 ES value is mid-way between the other two estimates, it is retained for the updated water balance, giving a 95%ile flow at the mine outfall of 3.52 L/s or 12.7 m^3/hour.

Table 5: Monthly flow and rainfall percentages

Month	Percentage flow in each month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Runoff %	13.4	10.2	10.1	7.4	6.1	4.5	3.5	4.9	6.1	9.5	11.4	12.9
Rainfall %	10.6	7.9	8.3	6.4	6.7	6.6	6.7	8.1	8.2	9.9	10.0	10.6
PE %	1.4	2.3	5.1	8.6	13.8	17.2	18.6	15.2	9.5	5.0	2.1	1.2

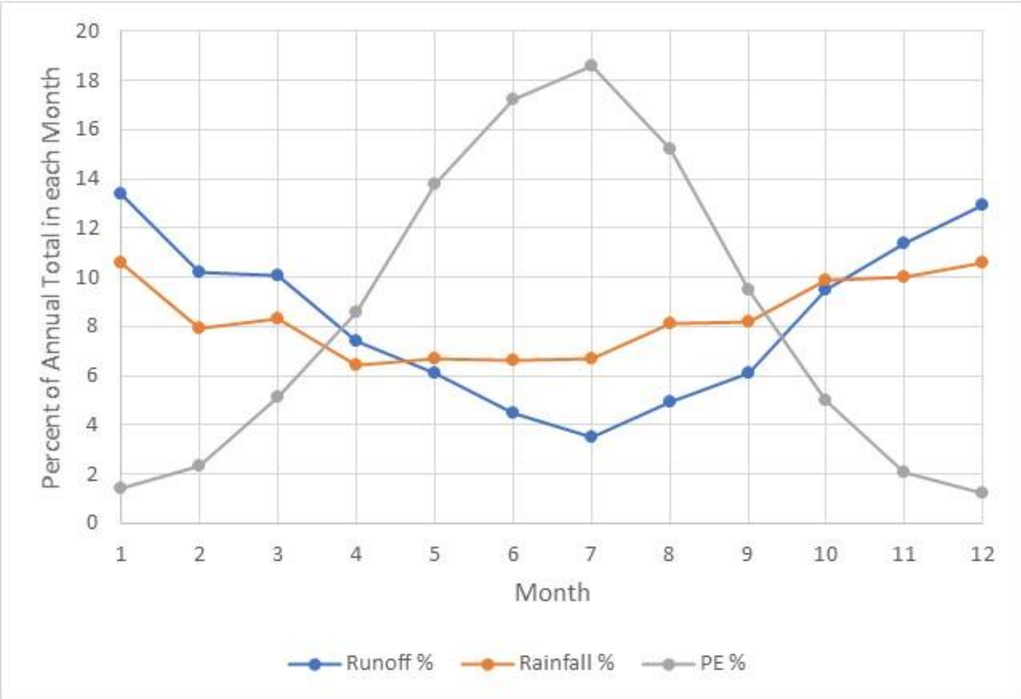
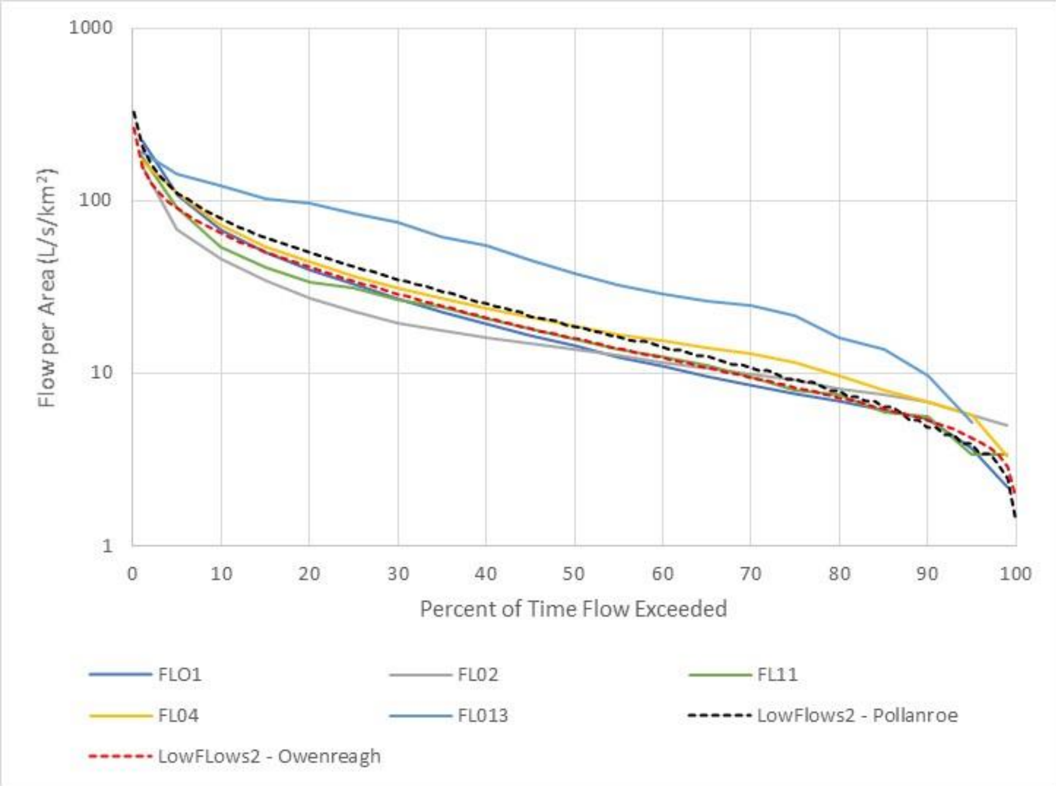


Figure 6: Comparison of monthly runoff and precipitation distributions



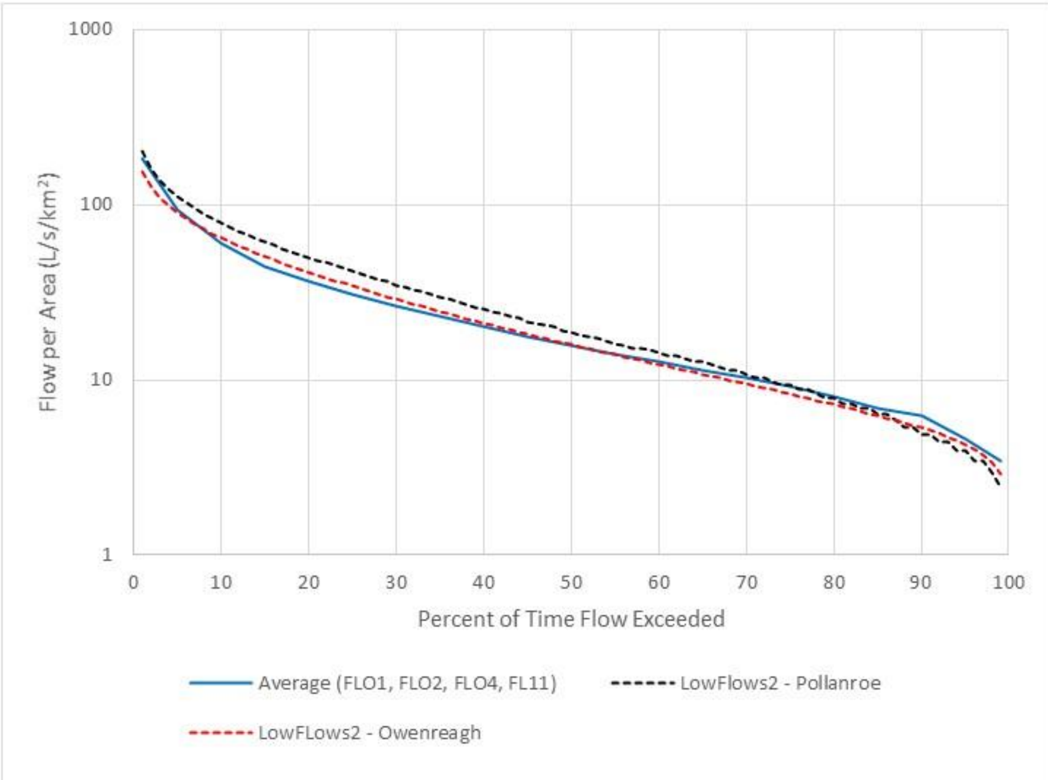


Figure 7: **Comparison of flow duration curves for onsite flow monitoring stations and LowFlows2 results**

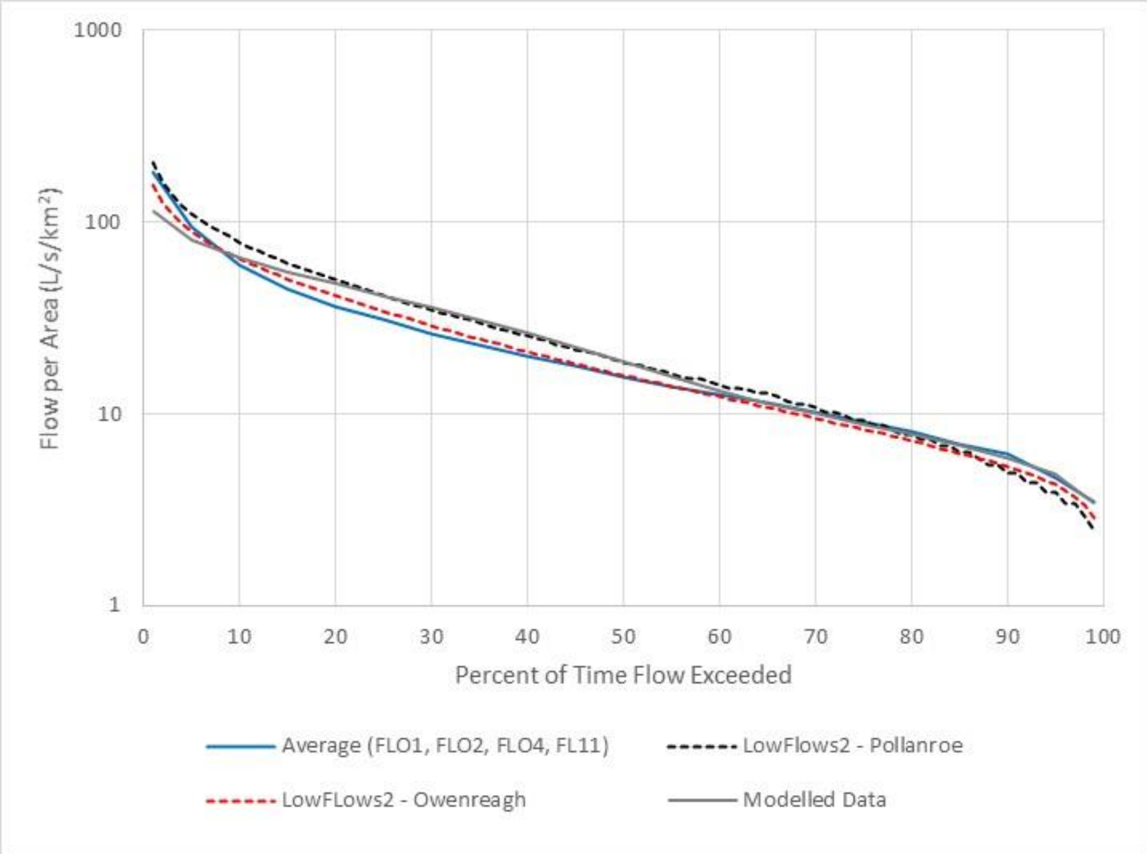


Figure 8: Comparison of flow duration curves used in assessment

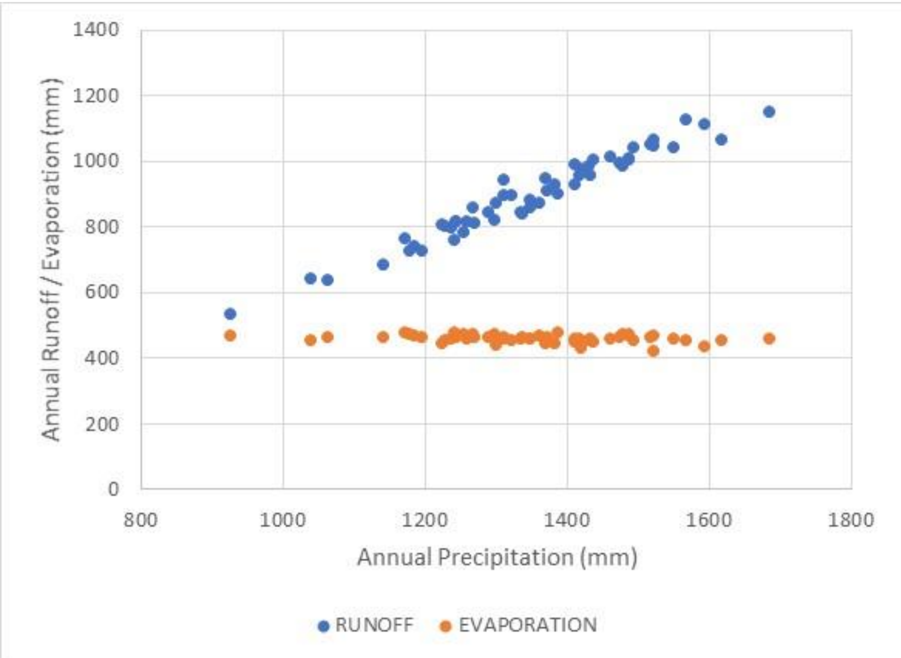


Figure 9: Comparison of Modelled Annual Runoff with Annual Precipitation

Table 6: Flow Duration Curve for Natural Catchment

Percent of Time Flow Exceeded	Model Input (l/s/km^2)
99%	3.5
95%	4.8
90%	5.9
85%	6.9
80%	7.8
75%	8.9
70%	10.1
65%	11.4
60%	13.1
55%	15.6
50%	18.6
45%	22.2
40%	26.4
35%	31.0
30%	35.8
25%	41.3
20%	47.7
15%	55.1
10%	65.0
5%	80.5
1%	112.8
Mean	28.5

3.4 Runoff from Disturbed Mine Site Areas

Disturbed mine site areas include the process plant, offices and associated parking areas. In the water balance model all runoff from these areas is routed to the East Pond.

It is assumed that these areas have an annual runoff rate 20% greater than that of the natural catchments, which themselves have high runoff rates. Therefore, runoff from areas of hardstanding are just over 80% of annual precipitation. This approach is considered a reasonable and conservative approach for representing annual and monthly runoff rates over the varied surfaces within the mine site area, that will include unpaved roads, hard standing areas and roofs. There will be drainage features associated with the mine site area (pipe work, swales and other SuDS) that will manage the runoff rates. Therefore, the runoff rate suitable for monthly flow calculations will be expected to lie between the runoff from natural catchments (around 65%) and runoff rates from disturbed areas during storm events (around 90%), with a value of just over 80% providing this balanced value. In the model the calculated natural runoff is scaled by 1.2 to provide inputs for the disturbed site areas. The model sensitivity to this input is considered in the sensitivity assessment with a further 20% variation in the runoff rate.

3.5 DSF Infiltration and Runoff Rates

The DSF will be comprised of a mix of waste rock and non-reactive tailings. The DSF is designed with waste rock forming a starter embankment along the southern edge of the facility with the area to the north filled with a mix of waste rock and non-reactive tailings, but predominantly with tailings. There will be a basal liner that will prevent infiltration to the subsurface and a series of drains within the facility that will route water seeping into the DSF to one of the water management ponds. Surface water will be routed to the north of the facility as it is constructed, from where it will be routed to one of the water management ponds. The DSF areas will be progressively reclaimed, with the mine material capped by mixed tailings and bentonite clay, topped with a soil cover. The sequencing of the formation of the DSF is summarised in Figure 3 and Table 2 to Table 4.

Details of the DSF design are provided in the Dry Stack Design Report (Appendix G to the Mine Waste Management Plan (including two addendums 2019 and 2020, including SRK (2020c)).

Detailed modelling of infiltration, seepage and runoff from the DSF has been undertaken (SRK 2020b), which is an update from the 2017 water balance, which used infiltration and runoff rates which were based on standard design parameters and not site-specific modelling work. The new inputs have the following runoff and infiltration rates from the active and reclaimed DSF for a year with average precipitation.

- Active DSF
  - % of annual precipitation as infiltration to DSF and then to water management ponds = 22%
  - % of annual precipitation as surface runoff to water management ponds = 60%
  - Total of infiltration and runoff = 82% of annual precipitation
- Reclaimed/Closed DSF
  - % of annual precipitation as infiltration to DSF and then to water management ponds = 12.5%
  - % of annual precipitation as surface runoff to water management ponds = 50%
  - Total of infiltration and runoff = 62.5% of annual precipitation

In the 2017 water balance the model considered 30% infiltration and 36% runoff for the active DSF. The updated modelling predicts higher runoff rates and an overall higher percentage of the annual precipitation reporting to the water management ponds as runoff and infiltration. In the 2017 water balance it was assumed that 75% of annual precipitation reported to the water management ponds, but this was not based on an assumed runoff rate for the reclaimed surface. The values used in this report are based on modelling of the reclaimed surface and are close to the runoff rates used for natural catchments.

The rest of the water is lost to evaporation at the surface and seepage through the basal liner (see Section 3.5.1). There is also a contribution from drain down of tailings water that is discussed in Section 3.5.2.

Runoff rates are predicted to be high for the active DSF due to the near saturated water content of deposited tailings. In addition, new tailings will be progressively deposited on the surface of the DSF so that the upper layers will remain saturated even in dry weather conditions.

Inputs to the water balance model were based on the same soil water accounting method (SWAC) used in SRK (2020b) and developed as an addition to the seepage/groundwater model. The model was run for the full precipitation and evapotranspiration time series outlined in Sections 3.1 and 3.2. Outputs from this model are used to generate monthly runoff and seepage rates in response to the precipitation and evapotranspiration inputs. The same input data sets were used in the SWAC method as were used to generate surface water flows in Section 3.3. These runoff and seepage values were then applied to the relevant active or reclaimed areas of the DSF within the water balance model.

3.5.1 Seepage through Basal Layer of the DSF

The seepage through the basal layer of the dry stack is predicted to be 1.19 m^3/day (SRK 2020b) near the end of operations, falling to 0.74 m^3/day once the facility is closed. These are best estimate predictions with conservative (upper) values of 2.25 m^3/day for operations and 1.33 m^3/day for closure.

The rate of seepage in any one year of operations will depend on the surface area of the DSF and its height. Crudely the seepage rate during operations is 0.14% of annual precipitation, or 1.9 mm/year. For closure it is 0.09% or 1.2 mm/year. These values are applied in the water balance model to any active or closed part of the DSF. The seepage value at the end of mine life from the DSF was predicted to be around 1.06 m^3/day as the water balance model provides a more refined modelling of the balance between active and reclaimed areas of the DSF than in the dry stack seepage modelling work (with the reclaimed areas producing lower seepage rates than active areas by the end of mine life). The water balance predictions are then scaled to match the values in SRK (2020b).

The seepage rates calculated through the basal layer of the DSF are lower than in the 2017 water balance, which considered 1.3% of annual precipitation for the active DSF and 0.57% for the reclaimed areas of the DSF. The seepage rates have been refined through the introduction of formalized drains and refined seepage modelling presented in SRK (2020b). The seepage rates through the liner are not sensitive to changes in annual precipitation but are controlled by the water content of the tailings at the base of the DSF. Therefore, the predictions in the model are not varied year on year with changing precipitation.

Seepage through the basal layer of the DSF will report to under drains and then to the Pollanroe Burn. The under drains will also receive natural groundwater from under the DSF and the water management ponds.

3.5.2 Drain Down of Tailings Water

Drain down is the process by which water held in the pore water of the tailings when it is deposited on the DSF flows out of the DSF over time due to gravity. In the 2017 water balance model drain down was considered to contribute 5,960 m^3 of water every year during operations, falling to close to zero once the DSF was reclaimed. The calculation of drain down has been improved for this report, based on laboratory test work on the grain size and moisture content of deposited tailings. One combined calculation of drain down for the active and reclaimed DSF has been made and as a result, the calculation of drain down is presented as a separate section in this report.

Tailings will arrive at the DSF with a moisture content of around 15.8% by weight. The tailings will be reworked at the DSF and compacted, at which point they will have a reduced moisture content of 14.7% by weight, with excess water either running off the DSF or infiltrating. The residual water content of the tailings over time is calculated to be 6% by volume (or 4% by weight), with the remaining water being released from the pores of the tailings over time is a process termed “drain down”.

From the Process Water Balance there is an average of 3.76 m^3/hour (see Section 2.1) leaving the process plant with the tailings, i.e., 32,940 m^3/year. After reworking at the DSF the volume of water held in the tailings is 30,450 m^3/year at deposition for 176,000 tonnes of tailings per year. Therefore, around 2,490 m^3/year of water will be released from the DSF during the deposition of the tailings. A conservative assumption is made that this water runs off the DSF to one of the water management ponds.

Assuming a residual tailings water content of 6% by volume, this gives a final water content of 7,350 m^3 for the annual tailings mass. Therefore, the water released through drain down will be 23,100 m^3 for every 176,000 tonnes of deposited tailings.

The release of water from drain down will not be constant. Modelling of the DSF suggests that drain down of tailings water will be substantially complete 5 to 8 years after the end of operations. A seepage curve for the toe drain of the DSF was calculated as part of the DSF seepage assessment (SRK 2020b). This curve was then scaled to the total drain-down volume in the DSF, producing a curve shown in Figure 10. The model showed drawdown flows from the DSF to the water management ponds increasing through the life of mine, reaching a peak of 23,100 m^3/year at the end of operations and then falling rapidly after the end of operations.

As discussed at the beginning of this section, the drain down volumes are larger than considered in the 2017 water balance, due to improved understanding of the tailings material and its performance in the DSF.

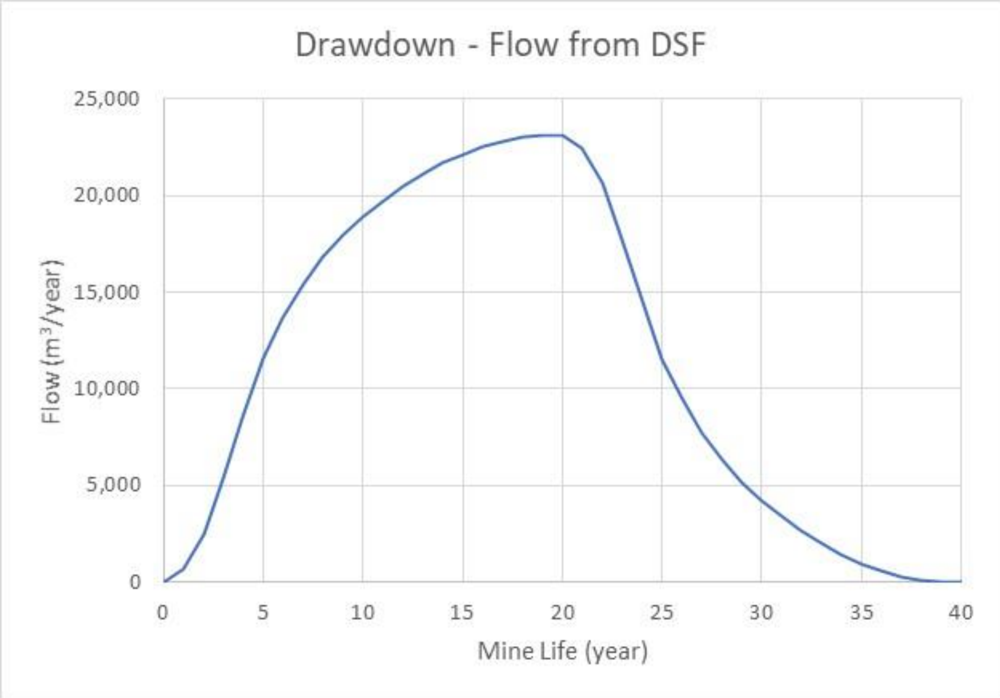


Figure 10: Water released from tailings pore water in drain down

3.6 Approach to Modelling Annual Variation in Rainfall

Initial water balance runs considered the annual variations in rainfall by representing the annual totals as statistical distributions and then assigning the rainfall into monthly totals based on the average monthly rainfall distribution discussed in Table 8. This approach has advantages as it allows the modeller control on the statistics of the annual rainfall totals, but it does tend to smooth out natural variations in monthly rainfall, i.e., it uses an average monthly distribution of rainfall that does not pick up significant variation from that average.

The model simulations presented in this report were based on the 54 years of observed rainfall at Lough Fea (refer to the Climate Baseline Report). The rainfall data was used to calculate monthly runoff totals for each of the key catchment types in the model (e.g., natural, active DSF). This produced 54 annual runoff records and the model is able to select each of these years at random to create variable climate conditions for the 20 years of mine life. The filling of gaps in the Lough Fea data (as outlined in Section 3.1) has resulted in more complete set of rainfall data and one with years with higher rainfall than used in the 2017 ES.

This approach allows for a more robust representation of observed variation in monthly rainfall totals but is limited by the available rainfall data series. As the proposed mine life is 20 years, the use of a 54-year time series data is considered robust to assess likely climatic variability during the mine life. The input time series contains one year with >1 in 200-year dry annual runoff totals and around three more with precipitation equivalent to a 1 in 10 dry year or less. In terms of wet years, the historical period contains four years with between 1 in 20 and 1 in 50 wet year precipitation and one with around a 1 in 80-year wet year, all based on fitting the annual totals to a normal distribution.

As a result, the data provides an acceptable range of wet and dry conditions.

The stochastic modelling approach selects annual rainfall, runoff and evaporation data sets on an annual basis (January to December). Checks were made on the impact of selecting annual series based on a hydrological year (October to September). The differences in model predictions between these two approaches were 0 to 2%, illustrating there was no significant difference between the two methods. The stochastic approach (by running 100 iterations of the mine life) means that a full range of hydrological conditions within the data set is considered in the model runs whether calendar or hydrological years are considered as the starting point for the inputs.

The approach taken to model annual variations in rainfall remain effectively the same in this report, compared to the 2017 water balance. The same Monte Carlo approach is taken. The two differences between the approaches taken in 2017 and the current report are:

- In 2017 the Monte Carlo method randomly selected a start year from within the Lough Fea rainfall time series and then in subsequent years the rainfall followed the observed sequence of rainfall years from that start year. In the current report the Monte Carlo method selects a year of rainfall from any of the available years of data at Lough Fea and there is no requirement to maintain the observed sequence of rainfall from the dataset. This approach is considered more robust as it allows a wider range of different rainfall time series as input into the stochastic model.
- The precipitation time series from Lough Fea has been updated with data from the years between the 2017 report and the end of 2019 and a review of the precipitation data was undertaken (see Section 3.1) which resulted in the infilling of gaps within the data based on NRFA rainfall totals. This provides a more complete input time series to the model.

3.7 Modelling of Climate Change

- A more explicit representation of the impacts of climate change are included in this water balance report compared to the assessment undertaken in 2017. In 2017 it was assumed that the life of mine was sufficiently short such that the effects of climate change would not be significant. However, with the release of updated climate predictions for the UK (UKCP18), it was felt that these should be taken forward into the water balance modelling. Therefore, the model inputs are adjusted to take into account the predicted climate change impacts on precipitation and evapotranspiration, and therefore runoff.
- Precipitation and evaporation inputs to the hydrological and groundwater flow estimates used in the water balance were adjusted to take account of the effects of climate change during the life of mine. The most up to date quantitative climate change predictions for the UK are provided within the UK Climate Projections (UKCP18) dataset
- (https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/download-data).

- The UKCP18 data provides estimates of the effect of future climate change on a range of meteorological variables (e.g., air temperature, precipitation, etc.). These estimates are based on a range of climate model scenarios, which are strongly dependent on future global greenhouse gas emissions. The scenarios used for the UKCP18 predictions are representative concentration pathways (RCPs), which consider a range of assumptions around future population, economic development and the possibility of greenhouse gas emission mitigation. The four scenarios considered within the dataset have differing changes in air temperature by 2081-2100 (Table 7), chosen to represent a range of potential alternative futures with various outcomes.

Table 7: RCP increase in global mean surface temperature averaged over 2081-2100 compared to the pre-industrial period (1850-1900)

Representative Concentration Pathway (RCP)	Change in air temperature (°C) by 2081-2100 (best estimate, 5-95% range)
RCP2.6	1.6 (0.9 – 2.3)
RCP4.5	2.4 (1.7 – 3.2)
RCP6.0	2.8 (2.0 – 3.7)
RCP8.5	4.3 (3.2 – 5.4)

RCP2.6 represents a pathway with a strong reduction in greenhouse gas emissions, whereas RCP8.5 represents a pathway with unmitigated greenhouse gas emission growth. RCP4.5 and RCP6.0 represent pathways with varying levels of greenhouse gas emission mitigation and are considered median scenarios.

Estimates of future climate change are provided in the UKCP18 dataset as probabilistic projections ranging from 5 to 95%, which indicate how strongly the evidence from observations and modelling support alternative future climate outcomes. There is more evidence for predicted outcomes near the centre of the distribution (i.e., 50%) than near the tail ends (i.e., 5 and 95%). The projection outcome considered for this assessment is the 50% central estimate, considered to have a 50% chance of being exceeded.

UKCP18 air temperature and precipitation anomalies have been extracted for a 25 km^2 grid cell encompassing the project site. Results are presented for RCP4.5 and RCP8.5 emissions scenarios. There is no clear guidance as to what would be a 'best estimate' of future climate change projections. However, a scenario with median emissions (RCP4.5 or RCP6.0) with a 50% chance of exceedance could be considered a reasonably likely scenario; alternatively, a scenario with high emission (RCP8.5) and a 50% chance of exceedance could be considered a reasonably conservative upper limit scenario.

Table 8 shows the average monthly precipitation anomalies (%) for emissions scenarios RCP4.5 and RCP8.5 for four benchmark years (2040, 2060, 2080 and 2100). The values are calculated for set benchmark years as the average of the yearly values 5 years before and after these dates in order to remove some of the inter-annual variation in the yearly datasets. For example, the monthly 2040 anomalies are the average monthly anomalies between 2035 and 2045. The last benchmark year – 2100 – was taken directly from the UKCP18 dataset for 2098, as this is the latest projection year available.

This approach was taken as analysis of the raw annual anomalies (monthly data) from UKCP18 showed inter-annual variability within the general trends of wetter winters and drier summers, e.g., the percentage change in monthly rainfall oscillating up and down from year to year. These inter-annual changes reflect the modelling work used in the calculation of the climate predictions and reflect variabilities in the modelling rather than reflecting the climate trends. Therefore, to extract the key climate trends and the remove the inter-annual effects of the raw data the averaging approach outlined in the previous paragraph was taken.

Evaporation time series for the site were calculated using the Oudin (2015) method using long-term temperature records from the Met Office gauge at Lough Fea supplemented by data from global datasets (MEERA2 from NASA, 2020). These values were then adjusted to be consistent with calculated annual average values calculated using data from the on-site meteorological station. Table 9 shows the average monthly potential evaporation anomalies (%) for the same emissions scenarios and three benchmark years (2040, 2060 and 2080).

In order to estimate monthly and daily future projections of precipitation and potential evaporation, anomalies between benchmark years were linearly interpolated and applied on a daily timestep using the monthly anomalies for every day in the corresponding month. To estimate precipitation between 2100 and 2120 (beyond the timescale of the UKCP18 data), the same rate of change as between 2080 and 2100 was extended to 2120. For evaporation, the same rate of change between 2060 and 2080 was applied to daily evaporation between 2080 and 2120.

The water balance model was run for the period 2022 to 2042, i.e., operational period only. The percentage changes were applied to the precipitation and evaporation inputs to the hydrological and model discussed in Sections 3.1 and 3.2, such that the inputs to the water balance take account of the impact of climate change through the mine life. This is an update from the approach used in the 2017 EIA water balance model, where no climate change impacts were considered.

Table 8: Average monthly precipitation anomalies (%) for UKCP18 RCP4.5 and RCP8.5 scenarios

Month	RCP4.5				RCP8.5			
	2040	2060	2080	2100	2040	2060	2080	2100
Jan	5.1	8.1	9.0	10.6	6.2	11.0	14.1	18.8
Feb	6.8	8.8	10.9	10.2	7.5	10.6	15.3	15.9
Mar	0.9	2.7	3.3	0.45	1.2	3.3	3.8	2.3
Apr	5.1	3.9	9.2	11.8	4.6	3.6	8.0	11.0
May	0.6	-12.3	-4.0	-18.9	0.4	-12.4	-4.0	-19.3
Jun	-7.0	-11.1	-16.1	-21.9	-7.7	-12.7	-19.2	-26.1
Jul	-8.7	-18.5	-12.5	-26.9	-9.6	-21.5	-18.0	-33.4
Aug	-14.2	-21.1	-13.5	-29.8	-15.2	-23.6	-18.1	-34.2
Sep	-10.7	-3.6	-6.5	-17.3	-11.0	-4.4	-7.5	-19.3
Oct	1.6	4.0	11.8	9.9	2.3	5.9	15.4	15.6
Nov	4.1	8.6	18.1	13.6	5.0	10.3	21.7	18.7
Dec	7.8	7.0	13.7	1.0	8.8	10.0	18.9	9.8

Table 9: Average monthly evaporation anomalies (%) for UKCP18 RCP4.5 and RCP8.5 scenarios

Month	RCP4.5			RCP8.5		
	2040	2060	2080	2040	2060	2080
Jan	11.6	15.0	20.8	13.8	20.7	31.1
Feb	10.0	12.5	17.5	10.8	16.7	25.8
Mar	7.1	9.3	12.5	8.6	13.6	20.0
Apr	4.7	8.0	9.6	5.9	11.0	15.7
May	6.5	8.4	12.1	7.6	11.8	18.7
Jun	4.2	7.1	10.1	5.5	9.9	15.0
Jul	4.9	8.0	13.2	6.0	12.1	20.4
Aug	6.1	9.1	13.8	7.4	12.8	20.9
Sep	7.8	10.7	15.7	9.4	15.1	23.9
Oct	6.7	9.9	13.9	8.3	13.9	21.0
Nov	6.9	9.9	14.9	8.9	13.9	21.8
Dec	8.7	13.6	16.6	10.7	18.1	25.6

3.8 Flood Storage Requirements

Flood volume calculations are provided in Appendix 1. These are updated from the 2017 report to take account of the small changes in catchment areas at the mine site between the 2017 and present studies.

The East and West Ponds will need to be operated so that there is sufficient freeboard in the ponds (i.e., available, free storage between the operational water level and overtopping level of the ponds) to accommodate a 24 hour, 1 in 1000-year storm event. Calculated storage volumes for the 24 hour, 1 in 1000-year event are:

- East Ponds 27,550 m3
- West Pond 15,970 m^3

The calculations assume that the treatment plant is operating during the event and is able to remove water from the pond at a rate of 300 m^3/hour. However, the results are not overly sensitive to this assumption, as outlined in Appendix 1. Based on DFI (2019) a 20% increase in peak flows in rivers by 2080 is recommended for Northern Ireland with 20% increase in rainfall for drainage design over the same period. Therefore, by 2040 (end of mine life) rainfall totals for flood storage might have increased by around 6.7% (although likely less as the rate of increase is not linear). The water balance model predictions of the available flood storage at the end of mine life are assessed compared to the calculated storage volumes, including the potential impact of climate change.

3.9 Flows in Pollanroe Burn and Owenreagh River

A discussion of the data sets used in the calculations of flows in the Pollanroe Burn and Owenreagh River is provided in Section 3.3. The methods are updated from the 2017 water balance and improved through the inclusion of additional site data, regional analysis (gauged and LowFlows2 data) and modelling (for Pollanroe Burn).

Flows in the Pollanroe Burn and Owenreagh River downstream of the site are based on the following assumptions;

- Flows in the Pollanroe Burn downstream of the site are calculated using the same approach for natural catchments within the mine site area, as this approach was developed using gauged data from small catchments close to the mine site and is appropriate for the Pollanroe. There is 0.164 km^2 natural catchment entering the Pollanroe upstream of the mine site outfall (i.e., catchment to the east of the edge of the mine site, diverted around the east of the mine to the Pollanroe Burn). There is a further 1.2 km^2 catchment between the outfall and the mouth of the Pollanroe Burn. Post-development the total catchment (undeveloped and mine site area) draining to the mouth of the Pollanroe Burn is larger than the pre-development catchment as a small part of the catchment of the watercourse to the west of the Pollanroe is diverted towards the Pollanroe, increasing the Pollanroe catchment at its mouth by around 10%, i.e. from 2.05 km^2 to 2.26 km^2. The model compares pre- and post-development flows in the watercourse.
- Flows in the Owenreagh River are based on gauged flow data for the Owenreagh River, collected as part of the surface water baseline assessment, and the LowFlows2 data for the river, The flow duration curves for the gauged sites and LowFlows2 are compared in Figure 11. The observed flow data fits well with the LowFlows2 results for the Owenreagh, especially for FLO6 and FLO9. The average of FLO6 and FLO9 is plotted against the LowFlows2 data in the final figure, with the flow duration curve from the observed and LowFlows2 data summarised in Table 10.

Monthly average flows for the Pollanroe Burn and Owenreagh River are provided in Table 11 to illustrate the significant differences in flows between the two watercourses, illustrating the significantly larger flows in the Owenreagh River compared to the Pollanroe Burn.

Compared to the 2017 water balance, this report focusses on calculating the impacts on flows in the Pollanroe Burn and then takes the differences between the pre- and post-development flows and calculates the impact on the Owenreagh River. Although results are provided for average monthly flows, which is the same as the approach in the 2017 water balance, results are also provided for the annual flow duration curve in each watercourse. The flow duration curve provides a fuller representation of the distribution of flows during the year in both watercourses and the use of the flow duration curve provides additional information on the impact of the development on flows in the Pollanroe Burn and Owenreagh River that is provided through the comparison of monthly average flows only, i.e., it provides an indication of the impact over the full range of flow conditions through a typical year.

Table 10: Flow Duration Curve for Owenreagh River at Pollanroe Burn

Percent of Time Flow Exceeded	LowFlows2 (l/s/km²)	Observed Site Data (l/s/km²)	Average of Two Data Sets (l/s/km²)
99%	2.9	3.7	3.3
95%	4.3	4.9	4.6
90%	5.3	5.9	5.6
75%	8.3	8.6	8.4
50%	15.9	14.4	15.2
25%	34.3	30.8	32.6
10%	64.6	72.8	68.7
5%	90.0	114.6	102.3
1%	155.4	175.4	165.4
Mean	27.6	28.3	28.0

Table 11: Monthly average flows for key watercourses

Month	Average Monthly Flow (l/s)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
[a]Pollanroe Burn at Mouth	89.9	75.7	67.7	51.3	40.9	31.2	23.5	32.9	42.3	63.7	79.0	86.5
[b]Owenreagh upstream of Pollanroe	2,576	2,131	1,798	1,169	812	610	558	791	1,079	1,880	2,125	2,434
[c]Owenreagh at Mouth	4,300	3,557	3,002	1,952	1,356	1,018	932	1,320	1,801	3,139	3,547	4,064

a 2km² catchment

b 53.5km² catchment

c 85.5km² catchment

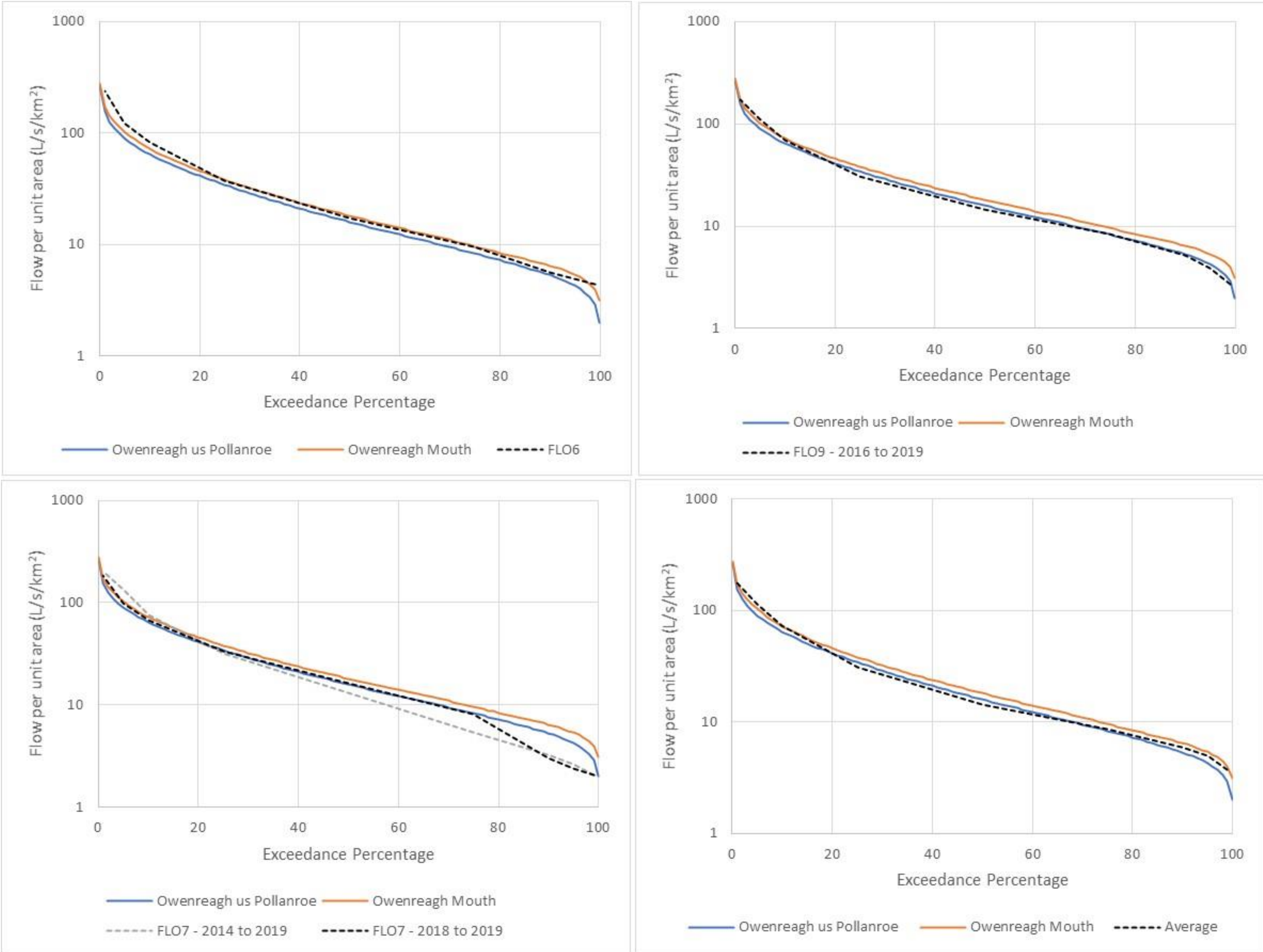


Figure 11: Comparison of gauged and LowFlows2 data for Owenreagh River

4 Groundwater and Mine Water Inflows

The groundwater and mine water inflows were included in the 'Hydrological Inputs' section of the 2017 water balance. However, it is more appropriate that these inflows are considered separately to the other surface water inputs in Chapter 3. The groundwater model in support of the development of the underground mine has been fully updated for the 2019 mine plan and the results of this new modelling (SRK 2020a) are provided in this chapter. Overall, the mine water flow rates are increased from the 2017 water balance, but the updated groundwater modelling considers a wider range of sensitivity analyses than were undertaken for the 2017 ES. These included modelling with climate change included in the groundwater recharge calculations.

The groundwater model is described in detail in SRK (2020a). The groundwater model was run for a base case scenario and then a series of sensitivity runs that considered variations in key model parameters. The base case was run with and without the impacts of climate change, simulated through adjusting the precipitation and evaporation inputs to take account of the impact of climate change (as outlined in Section 3.7). The base case groundwater model predictions for the groundwater inflow to the underground mine workings (with climate change) are used as the base case scenario in the water balance model. These results are considered conservative as they provide mine inflow rates that are generally higher than the 90^{th} percentile (P90) of all the sensitivity runs. The base case and sensitivity results (P10, P50 and P90) are shown in Figure 12, with a full description of the runs provided in SRK (2020a).

The sensitivity of the water balance to the mine water inflows is tested (Chapter 7) based on scenarios with base case +20% and -40%, shown in Figure 12. As the base case is already considered a conservative, high flow scenario, the simulation with +20% flow considers a scenario that has higher flows than predicted in the groundwater model sensitivity analysis. The scenario with -40% flow encompasses the P10 sensitivity analysis results. The use of this range of groundwater inflow rates to the mine will test the site water balance in terms of both conservative high and low inflow rates constrained by the groundwater modelling assessment.

The base case groundwater inflow rate (average annual flow rate) to the underground mine workings with and without climate change are summarised in Table 12. Water pumped from the underground workings can be used in the process plant with the unused water pumped to the West Pond. The flow rate from underground to the process plant is 5.71 m^3/hour.

Figure 12 also shows the monthly underground flow rates from the groundwater model, again for the base case with and without climate change. The water balance model is simulated with the monthly flow rates to provide a representation of seasonal variations in groundwater flows.

Natural groundwater will also enter under-drains for the DSF and water management ponds. The flow rate of natural water to the under-drains is shown in Figure 13. This includes water from under drains to the DSF and the site water management ponds (east, west and clean water ponds). This water will mix with water seeping through the basal liner of the dry stack facility (predicted to be around 1.06 to 1.19 m^3/day, Section 3.5.1) and enter the Pollanroe Burn.

Groundwater modelling also predicts changes to flows to the Pollanroe Burn during operations as a result of the lowering of the local groundwater table as the underground mine develops. This will reduce groundwater-fed baseflows to the burn. In addition, modelling predicts there will be a change in the water balance of peat in the headwaters of the Pollanroe Burn, where more rain water is held in peatlands than in the Curraghinalt and Attagh Burn valleys. Groundwater modelling identifies areas of peat in the valley bottoms where the lowering of the groundwater table will result in a vertical flow through the base of the peat into groundwater. This will not impact on the water content of the peat as this loss of water will be balanced by inputs from rainfall, however, it will mean that some rainfall that would have converted to runoff in the catchment will now be held within the peat, lowering flows in the burn. On average the reduction in flows to the Pollanroe Burn due to these processes will be around 0.67 L/s.

The peat losses are predicted to occur in the uplands to the north of the main mine site, so are applied to the flows entering the Clean Water Pond. Groundwater-fed baseflow losses are distributed through the catchment, based on inflowing area. They are included in the calculations of flows to the underdrain of the DSF (including groundwater flows to the water management ponds and Clean Water Pond), therefore in the model they are applied to catchments downstream of the mine site area, in proportion to the catchment area, relative to the whole Pollanroe Burn catchment.

Table 12: Underground water inflow rates – base case with climate change

Year	Underground flow – Annual Average (m^3/hour)	
	m^3/hour	change/s
1	24.7	6.9
2	36.5	10.2
3	30.8	8.6
4	30.8	8.5
5	30.7	8.5
6	32.8	9.1
7	40.7	11.3
8	40.7	11.3
9	36.8	10.2
10	36.1	10.0
11	40.4	11.2
12	37.1	10.3
13	41.0	11.4
14	35.5	9.9
15	39.1	10.9
16	38.5	10.7
17	41.0	11.4
18	35.8	10.0
19	35.8	9.9
20	35.3	9.8
21	35.1	9.7
22	35.3	9.8
23	34.8	9.7

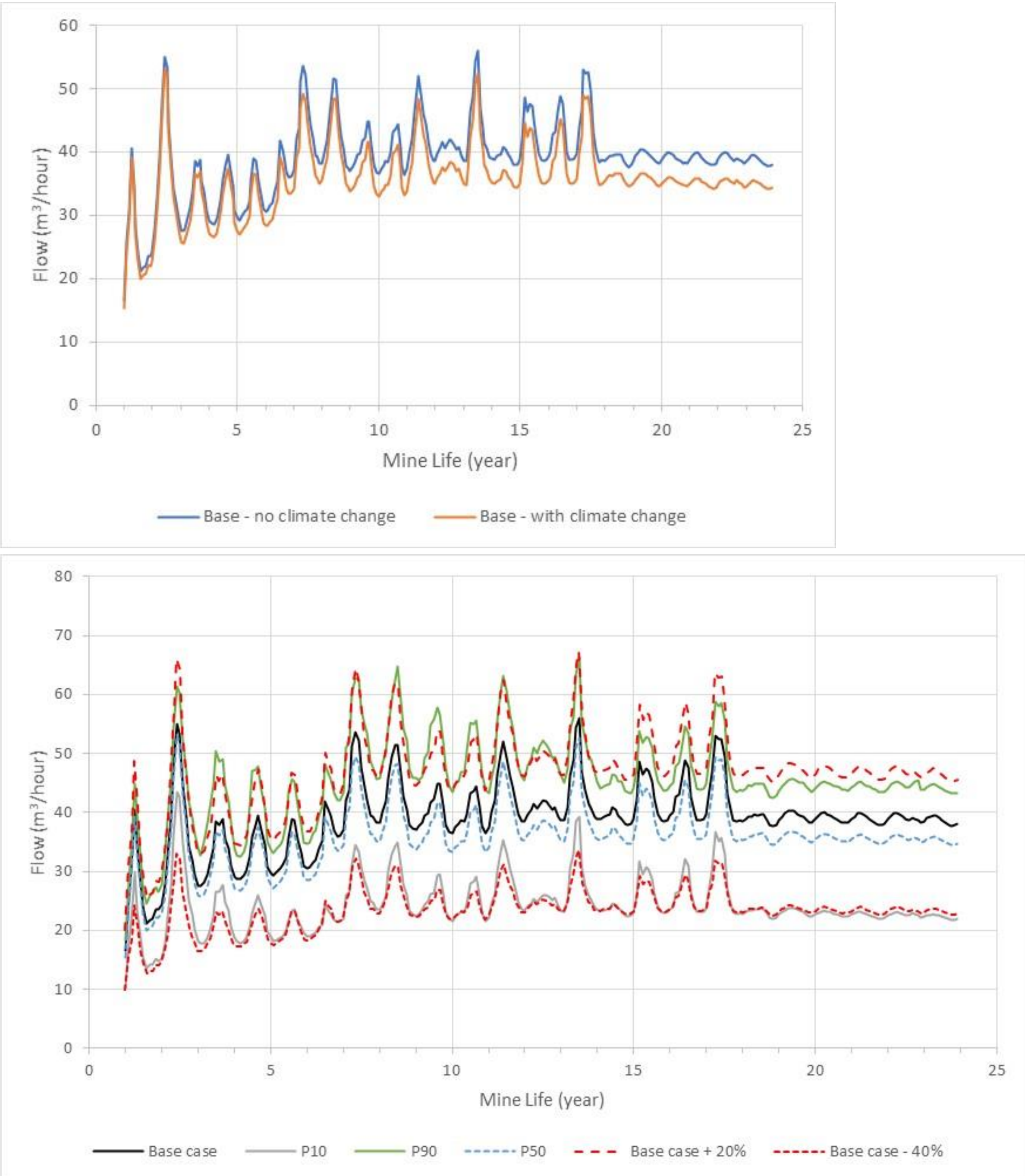


Figure 12: **Upper: Comparison of Base Case Groundwater Inflows to Underground Mine, with and without impact of climate change. Lower: Sensitivity Results for Groundwater Inflows to Underground Mine**

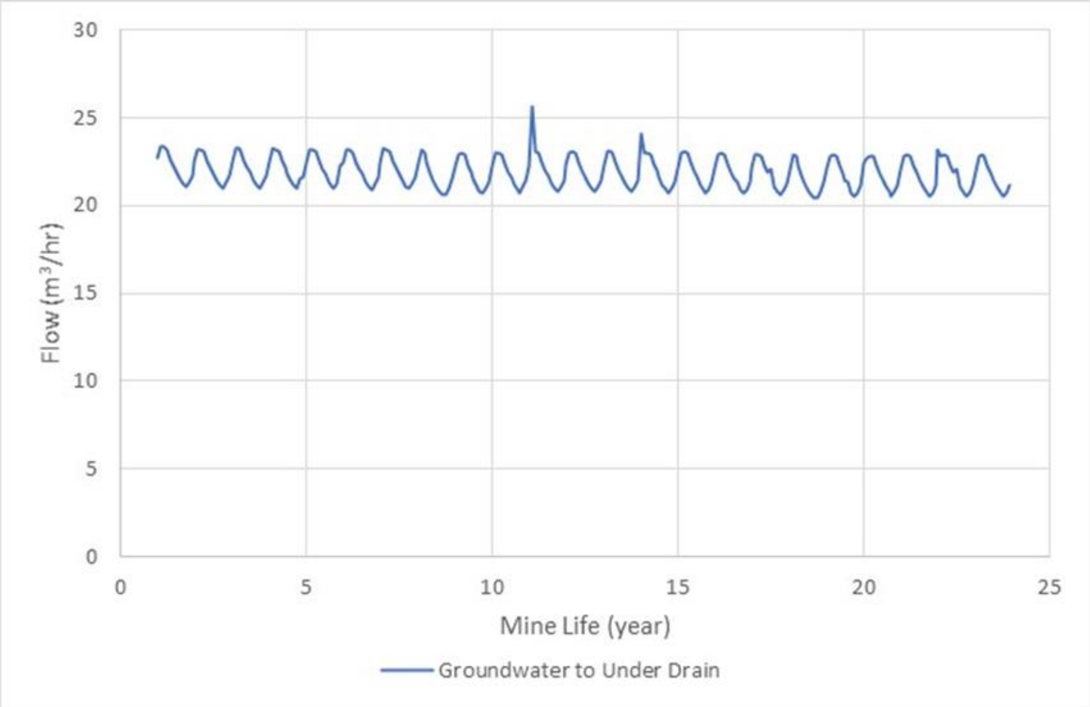


Figure 13: Natural Groundwater Inflows to Under Drain that Flows to Pollanroe Burn

5 Model Set-up

Key model inputs are summarised in Table 13.

The model is run for the Base Case scenario summarised in Table 13 and outlined in previous sections. Sensitivity runs are discussed in Chapter 7.

The model has been developed within the GoldSim modelling software, which is an industry standard for mine water management.

The model scenarios are run stochastically as a Monte Carlo analysis. For each scenario, the water balance model is run for 100 'realisations' of the mine life (i.e., 20-year mine life). In each realisation, the model selects annual runoff, precipitation and evaporation inputs from the 54 year record from the Lough Fea rainfall time series. In this way, the model cycles through all possible combinations of rainfall years for each year of mine operation. In each realisation, other parameters (e.g., maximum treatment rate and pond sizes) remain the same. At the end, there are 100 sets of model results and these results are presented as probabilities (e.g., probability of water shortage in any month within the mine life).

The benefit of such a modelling approach is that results try to consider a full range of climatic conditions and runs are not restricted to simple inputs (e.g., average rainfall in every year, or dry weather in every year).

As with any model the accuracy of the results depends on the quality of the inputs. For a stochastic model run the ability of the model to predict the range of possible outcomes depends on the how accurately the inputs can represent the full range of natural variability.

For the base model, the model inputs are based on monthly data, although the model is run on a shorter time step to allow more accurate interpolation of results within each monthly period and to more accurately calculate operations within the mine water management plan (e.g., treatment rates) that can be varied on a sub-monthly time step. Results are presented as monthly averages. This is typical for a water balance model as many of the model inputs are based on a monthly time step (e.g., the evolution of the DSF is discretised on a yearly basis and mine water inflows on a monthly basis). However, a model sensitivity run was undertaken using daily hydrological inputs to test the model response to sub-monthly variations in hydrological inputs. The storm water calculations (Appendix 1) are also based on daily (24-hour) storm durations.

Table 13: Summary of key model inputs for Base Case

Model Parameter or Method	Description
Physical/Hydrological Parameters	
Mine Life	20 years (From 1st January 2022 to end 2041)
Pond Volumes	Clean Water Pond = 40,260 m^3 Upper East Pond = 52,870 m^3 Lower East Pond = 9,973 m^3 West Pond = 38,855 m^3 Within the model the Upper and Lower East Ponds are modelled as a single unit for simplicity and to avoid uncertainties associated with modelling flows from the larger to the smaller pond. During operations, flows from the two ponds will be controlled to maintain flood storage freeboard in the two ponds.
Runoff Rates	Consistent with rates and methods described in Chapter 3.
Catchment Areas	Based on Tables 1 to 5
Mine Water Inflows from Underground Mine	Consistent with rates and methods described in Chapter 4.
Freeboards in East and West Ponds	Ponds will be operated to maintain pond volumes to around 25% of the full volume. Water levels will rise above this level during extended periods of rainfall, but this will provide a buffer between the normal operating level and the maximum level for flood management. The pond levels will remain below the level that provides sufficient flood storage to allow retention of a 24-hour, 1 in 1,000-year rainfall event without spilling to the environment. Storage calculations are provided in Appendix 1.
Water Management	
Mine Water Demand	15.9 m^3/hour of additional water required for paste plant and process. Derived from underground mine water, Clean Water Pond or treated mine water. Of this ○ 7.16 m^3/hour needs to be fresh water ○ 5.71 m^3/hour can be pumped directly from the underground workings and be used untreated ○ 3.03 m^3/hour enters the process with the ore itself, i.e., it is also from underground workings and is untreated
Maximum Treatment Rate	300 m^3/hour The model calculates the treatment rate required to keep the water levels in the East and West Ponds at the normal operating level.
Discharge of Treated Water	Treated water from the WTP is either pumped to the Clean Water Pond (when the pond is not full) or discharged to the Pollanroe Burn.
Compensation Flow	A compensation flow is discharged from the Clean Water Pond to maintain discharges from the site at a minimum of 12.7 m^3/hour, equivalent to the 95%ile flow for the mine site area. This is to maintain flows in the watercourse downstream of the mine. If discharges from the treatment plant to the Pollanroe Burn exceed 12.7 m^3/hour there is no compensation flow discharge.
Seepage from Impoundments	Included in downstream flow calculations, but not included in site water balance as volumes are small compared to the overall balance.

6 Model Results – Base Case

The model was run for the Base Case scenario, outlined in Table 13.

The following key model results are considered:

- Water Shortage. Make-up water is required for the Process Plant and can be obtained from treated water or fresh water stored in the Clean Water Pond. The model predicts if there is a risk of water shortage at the site.
- Uncontrolled Overspill from East or West Ponds. Uncontrolled spills of untreated water from the East or West Ponds will need to be avoided during operations.
- Calculation of water treatment rates required to provide water for process and to keep water levels in East and West Ponds below the required level to provide storm water storage.
- Predicted discharge rates from the mine site to be used in water quantity and water quality sections of the EIA.

6.1 Base Case - Annual Averages

A schematic of the site water balance and annual mean and 95%ile water volumes is provided in Figure 13 to Figure 15 for years 6, 12 and 20 of the mine life, selected to provide an illustration of how water management will change over time with an increasing DSF and changes to the dewatering rate from underground workings. A summary of key water transfers is provided in Table 14 to Table 17 for each year of operations. Results are given as the mean annual and 95%ile values produced from each of the modelled climatic scenarios.

Predicted annual average treatment rates (mean and 95%ile) are summarised in Table 15 and Table 17.

The maximum annual average treatment rate is predicted to be 91.8 m^3/hour, with the maximum 95%ile at 105.1 m^3/hour, both around the middle of the mine life, due to peak periods of predicted inflows from the underground mine.

Note results are presented for the mean flow rates in this report, compared to the 50%ile flows in the 2017 EIA. This change was made following discussions with regulators and a review of the results presented in the 2017 water balance. Mean values are considered easier to interpret than the 50%ile values and mean values are the required inputs into water quality calculations for the assessment of the impact of discharges from the WTP on the water quality of the Owenreagh River.

6.2 Base Case - Monthly Results

Results for key model outputs are provided in Figure 16 to Figure 22. The graphs show monthly averaged outputs from the model based on the 100 climatic scenarios undertaken. The black line on the graphs shows the median result from all the scenarios, with the coloured bands showing the upper and lower extents of the model predictions. These higher and lower values have a lower probability of occurrence, with the probability shown by the colour.

The key results from the Base Case scenario are;

- The model predicts no shortages of water for any model scenario. There is sufficient fresh water within the treated water volume and Clean Water Pond to provide make-up water to the mine site, Figure 11.
- The model predicts that the ponds can be operated with water levels maintained below the level required to provide storage for a 1 in 1,000 year, 24-hour storm with no overtopping. Modelling shows that significantly more storage can be provided in the ponds than is required, more than enough to account for climate change impacts on flood storage or inflow volumes. The available water storage buffers in the ponds are shown in Figure 18 to Figure 21, relative to the required flood storage volume.
- The maximum treatment rate of 300 m^3/hr is not reached as an average for any one month within the model, with rates reaching an average of 220 m^3/hour during the wettest months, see Figure 16.

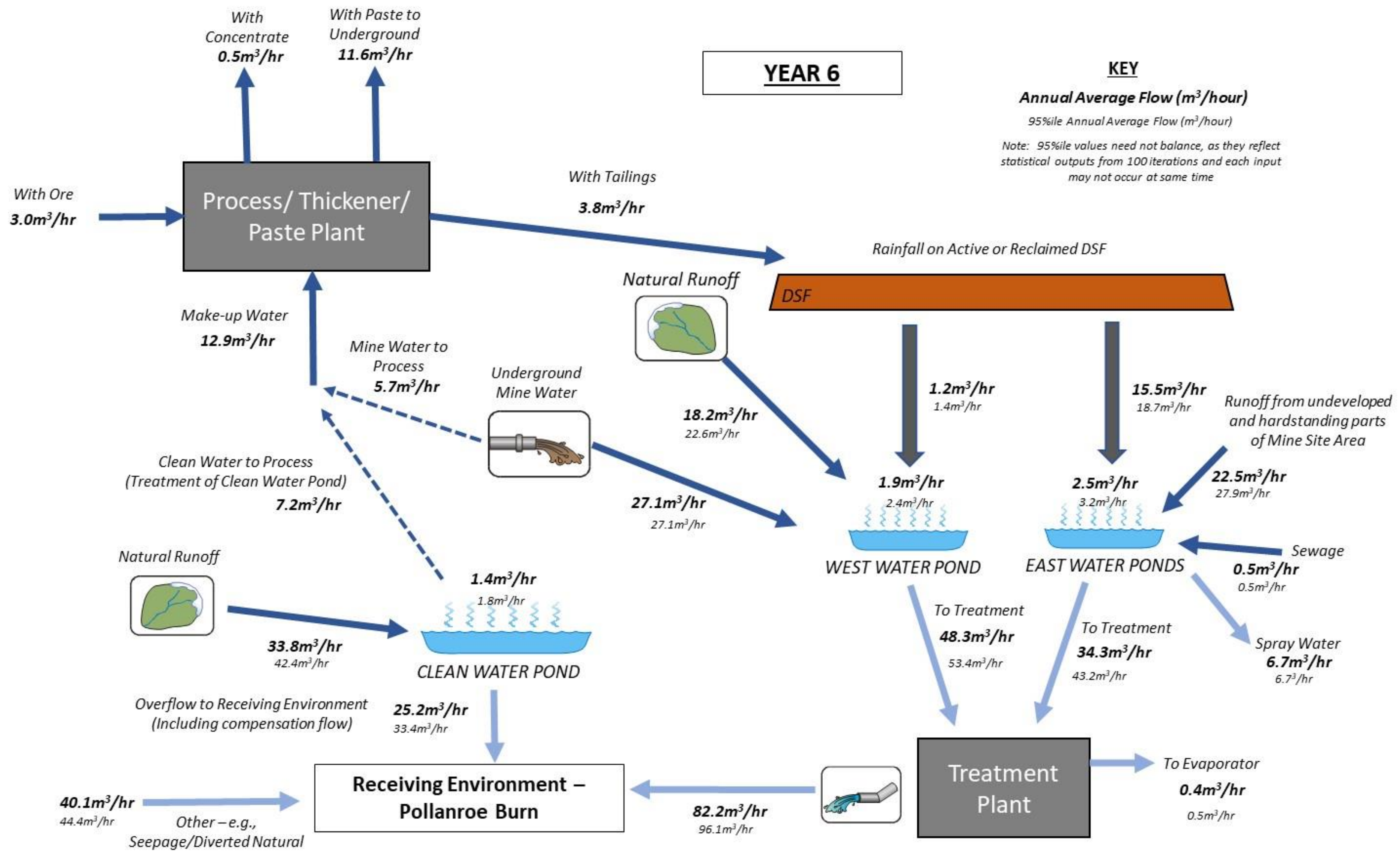


Figure 14: Water Balance Schematic with Annual Average Flow Rates – Year 6

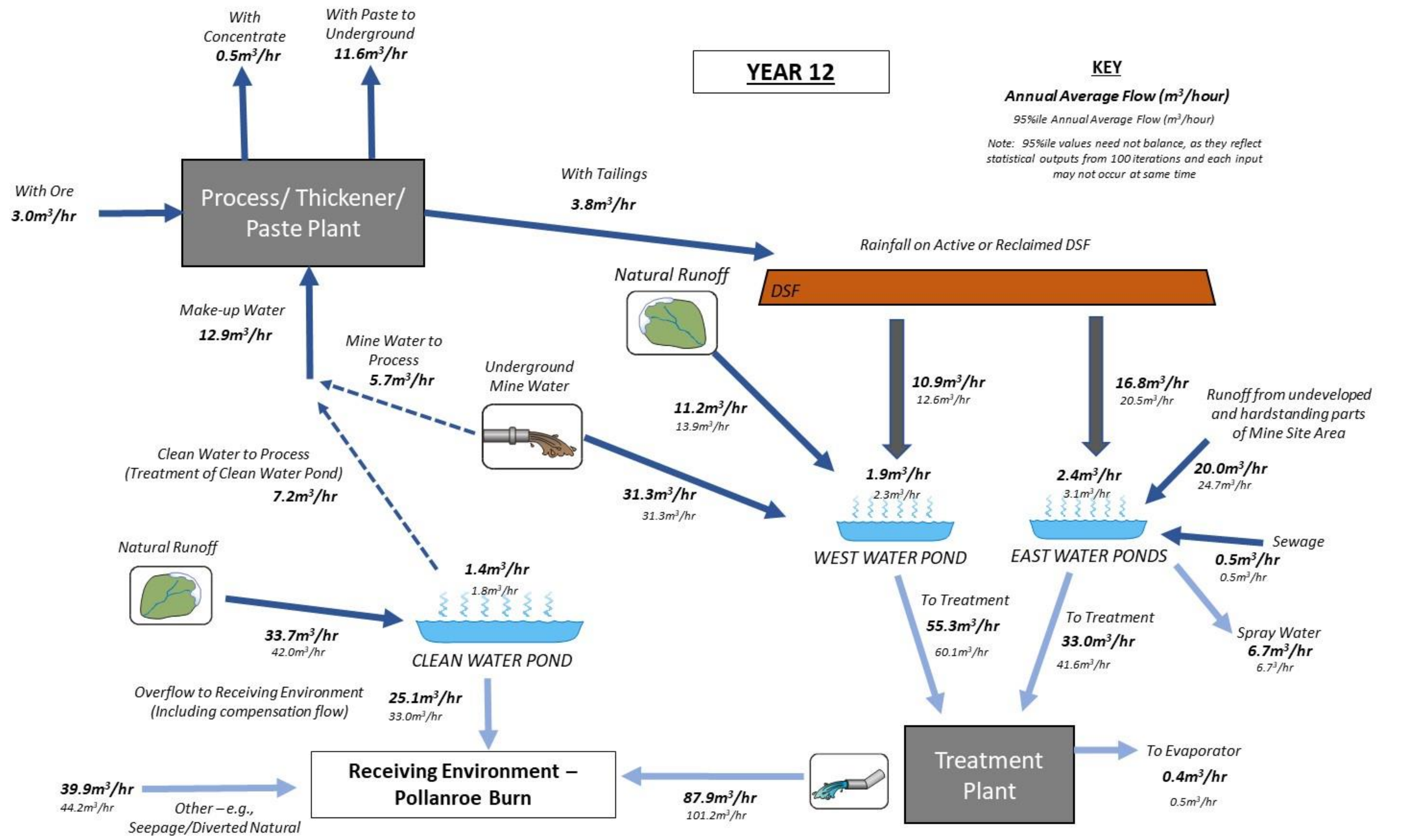


Figure 15: **Water Balance Schematic with Annual Average Flow Rates – Year 12**

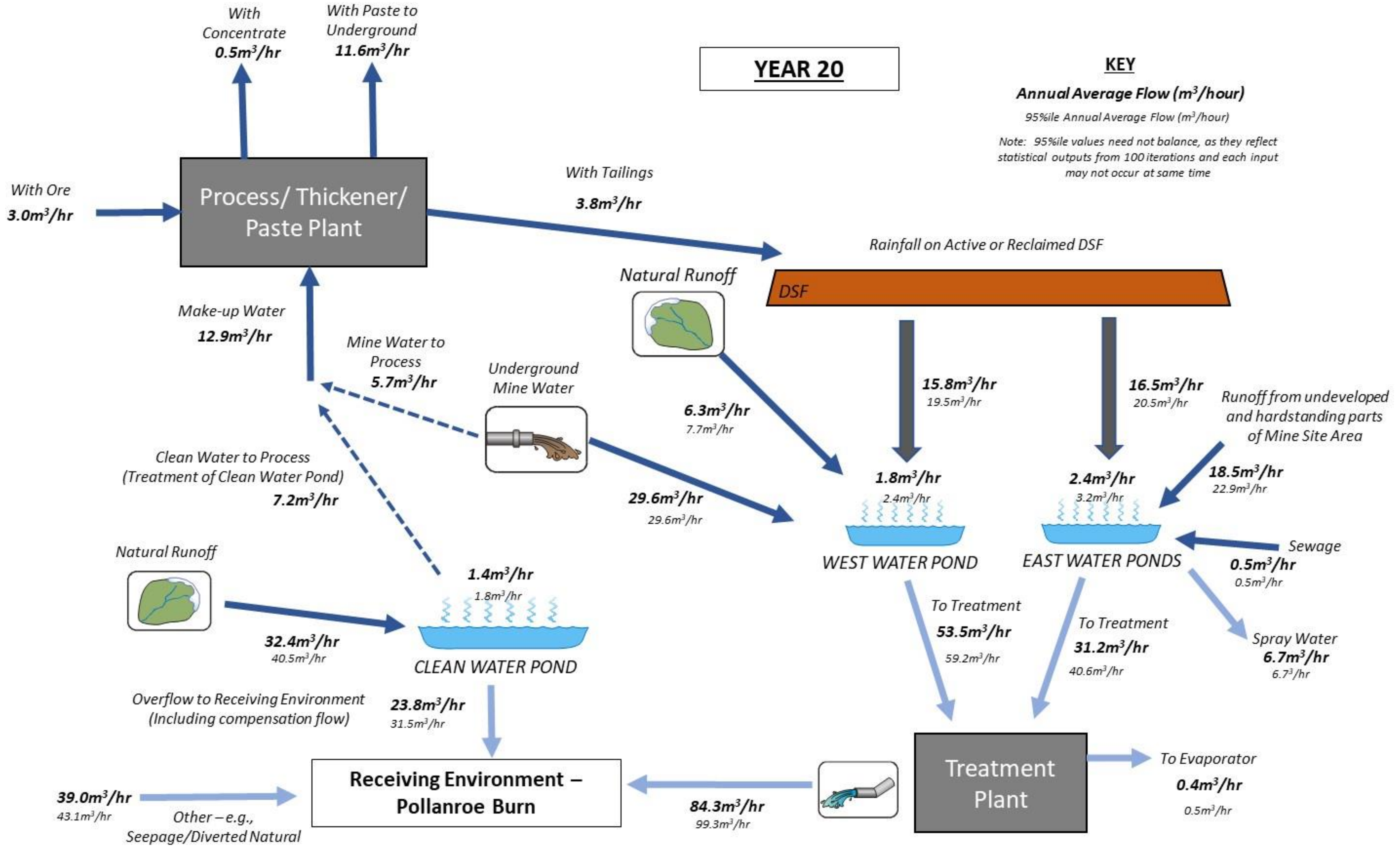


Figure 16: Water Balance Schematic with Annual Average Flow Rates – Year 20

Table 14: Annual average flow rates (m³/hour) – mean model result for Base Case

Year	East Pond							West Pond				
	Inflow (m³/hr)					Outflow (m³/hr)		Inflow (m³/hr)				Outflow (m³/hr)
	Seepage / Runoff DSF	Natural Runoff	Net Rainfall on Pond	Sewage	Mine Site Runoff	To Treatment	To Spray Water	Seepage / Runoff DSF	Natural Runoff	Mine Water (UG Dewatering)	Net Rainfall on Pond	To Treatment
Year 1	1.7	13.3	2.5	0.5	19.4	29.8	6.7	0.0	19.2	19.0	1.9	39.9
Year 2	3.7	11.8	2.4	0.5	18.9	30.5	6.7	0.0	18.6	30.8	1.8	51.3
Year 3	7.1	9.8	2.5	0.5	19.6	32.8	6.7	0.0	19.3	25.1	1.9	46.4
Year 4	10.4	7.2	2.4	0.5	19.1	33.0	6.7	0.0	18.9	25.1	1.8	45.8
Year 5	13.8	4.9	2.4	0.5	19.2	34.1	6.7	0.0	19.0	25.0	1.9	45.8
Year 6	15.6	3.3	2.5	0.5	19.2	34.3	6.7	1.2	18.2	27.1	1.9	48.3
Year 7	15.6	2.6	2.4	0.5	18.8	33.1	6.7	3.4	16.2	35.0	1.8	56.4
Year 8	15.6	1.9	2.4	0.5	18.6	32.3	6.7	5.5	14.5	35.0	1.8	56.8
Year 9	16.0	1.3	2.4	0.5	18.7	32.2	6.7	7.8	13.1	31.1	1.8	53.7
Year 10	16.4	0.9	2.4	0.5	19.0	32.5	6.7	9.3	12.2	30.4	1.8	53.7
Year 11	16.8	0.9	2.5	0.5	19.3	33.2	6.7	10.2	11.9	34.7	1.9	58.6
Year 12	16.8	0.8	2.4	0.5	19.2	33.0	6.7	10.9	11.2	31.3	1.9	55.3
Year 13	16.6	0.7	2.4	0.5	18.9	32.4	6.7	11.5	10.6	35.3	1.8	59.2
Year 14	16.7	0.6	2.4	0.5	18.8	32.3	6.7	12.2	10.0	29.8	1.8	53.8
Year 15	16.9	0.5	2.4	0.5	18.7	32.4	6.7	13.0	9.4	33.4	1.8	57.6
Year 16	17.1	0.4	2.4	0.5	18.9	32.6	6.7	13.7	9.0	32.8	1.8	57.3
Year 17	16.5	0.3	2.3	0.5	18.2	31.2	6.7	13.9	8.0	35.3	1.7	59.0
Year 18	16.9	0.2	2.4	0.5	18.8	32.1	6.7	14.9	7.7	30.1	1.8	54.5
Year 19	17.1	0.1	2.4	0.5	19.0	32.4	6.7	15.6	7.1	30.1	1.8	54.6
Year 20	16.5	0.0	2.3	0.5	18.4	31.2	6.7	15.9	6.3	29.6	1.8	53.5

Note: Main water transfers shown only. Results are based on statistical analysis of multiple model runs, so values may not always balance (i.e., inflows and outflows to East Pond may not balance). However, models balance within each model simulation.

Table 15: Annual average flow rates (m^3/hour) – mean model result for Base Case

Year	Other Flows (m^3/hr)											
	Water in Treatment	Loss to Treatment Waste	Treated Water to PP	Unused Treated Water for Discharge	Clean Water Pond to Process	Clean Water Pond Overflow	Natural Catchment Outfall	Seepage from DSF	Underdrains to Pollanroe	Pollanroe at Outfall	Pollanroe at Mouth	Pollanroe at Mouth Pre-Dev
Year 1	69.7	0.3	0.1	69.2	7.1	22.3	18.1	0.05	22.2	131.8	239.4	209.1
Year 2	81.8	0.4	0.0	81.4	7.2	24.6	17.7	0.05	22.1	145.8	250.5	203.5
Year 3	79.1	0.4	0.0	78.7	7.2	25.8	18.3	0.05	22.1	145.0	253.6	211
Year 4	78.8	0.4	0.0	78.4	7.2	25.0	17.9	0.05	22.1	143.4	249.5	206.2
Year 5	79.9	0.4	0.0	79.5	7.2	25.1	18.0	0.05	22.1	144.7	251.4	207.2
Year 6	82.6	0.4	0.0	82.2	7.2	25.2	18.0	0.05	22.1	147.5	254.1	207.2
Year 7	89.6	0.4	0.0	89.1	7.2	24.4	17.6	0.05	22.1	153.2	257.4	202.5
Year 8	89.1	0.4	0.0	88.7	7.2	24.1	17.4	0.05	21.7	151.9	255.0	200.4
Year 9	85.8	0.4	0.0	85.4	7.2	24.2	17.5	0.05	21.9	149.0	252.6	201.5
Year 10	86.2	0.4	0.0	85.8	7.2	24.8	17.8	0.05	21.9	150.2	255.6	204.8
Year 11	91.8	0.5	0.0	91.4	7.2	25.3	18.1	0.05	22.2	157.0	264.2	208.5
Year 12	88.3	0.4	0.0	87.9	7.2	25.1	17.9	0.05	22.0	152.8	259.1	206.7
Year 13	91.6	0.5	0.0	91.2	7.2	24.5	17.7	0.05	22.0	155.4	260.1	203.5
Year 14	86.0	0.4	0.0	85.6	7.2	24.4	17.6	0.05	22.0	149.5	253.8	202.6
Year 15	90.0	0.4	0.0	89.5	7.2	24.4	17.5	0.05	21.9	153.3	257.2	202.1
Year 16	89.9	0.4	0.0	89.4	7.2	24.6	17.7	0.05	21.9	153.6	258.6	204
Year 17	90.1	0.5	0.0	89.7	7.2	23.4	17.0	0.05	21.9	152.0	253.1	196.6
Year 18	86.6	0.4	0.0	86.1	7.2	24.6	17.6	0.05	21.5	149.8	254.2	203
Year 19	87.0	0.4	0.0	86.6	7.2	24.8	17.8	0.05	21.8	150.9	256.2	204.7
Year 20	84.7	0.4	0.0	84.3	7.2	23.8	17.3	0.05	21.8	147.1	249.4	199

Note: Main water transfers shown only. Results are based on statistical analysis of multiple model runs, so values may not always balance (i.e., inflows and outflows to East Pond may not balance). However, models balance within each model simulation.

Table 16: Annual average flow rates (m^3/hour) – 95%ile model result for Base Case

Year	East Pond							West Pond				
	Inflow (m^3/hr)					Outflow (m^3/hr)		Inflow (m^3/hr)				Outflow (m^3/hr)
	Seepage / Runoff DSF	Natural Runoff	Net Rainfall on Pond	Sewage	Mine Site Runoff	To Treatment	To Spray Water	Seepage / Runoff DSF	Natural Runoff	Mine Water (UG Dewatering)	Net Rainfall on Pond	To Treatment
Year 1	2.1	16.5	3.2	0.5	24.0	38.4	6.7	0.0	23.7	19.0	2.4	44.8
Year 2	4.2	14.1	2.9	0.5	22.6	38.2	6.7	0.0	22.3	30.8	2.2	55.7
Year 3	8.5	11.5	3.2	0.5	23.1	39.9	6.7	0.0	22.8	25.1	2.4	50.3
Year 4	12.0	8.3	3.0	0.5	22.4	39.5	6.7	0.0	22.2	25.1	2.3	49.5
Year 5	16.6	6.0	3.2	0.5	23.9	44.2	6.7	0.0	23.6	25.0	2.4	51.4
Year 6	18.7	4.1	3.2	0.5	23.8	43.2	6.7	1.4	22.6	27.1	2.4	53.4
Year 7	18.7	3.2	3.1	0.5	23.0	42.4	6.7	4.0	19.9	35.0	2.3	61.6
Year 8	17.9	2.3	2.9	0.5	22.2	39.9	6.7	6.3	17.3	35.0	2.2	61.1
Year 9	19.7	1.6	3.2	0.5	23.8	41.8	6.7	9.5	16.6	31.1	2.4	59.3
Year 10	18.7	1.1	3.0	0.5	22.2	40.1	6.7	10.6	14.2	30.4	2.3	58.1
Year 11	19.9	1.1	3.1	0.5	23.7	41.6	6.7	11.7	14.6	34.7	2.3	63.3
Year 12	20.0	1.0	3.1	0.5	23.7	41.6	6.7	12.6	13.9	31.4	2.3	60.1
Year 13	20.1	0.8	3.1	0.5	22.9	40.9	6.7	13.4	12.8	35.3	2.3	64.2
Year 14	20.2	0.7	3.0	0.5	22.8	41.2	6.7	14.2	12.1	29.8	2.3	58.9
Year 15	20.4	0.6	3.1	0.5	22.9	41.3	6.7	15.1	11.5	33.4	2.3	62.8
Year 16	20.7	0.5	3.2	0.5	22.8	41.2	6.7	16.5	10.8	32.8	2.4	62.4
Year 17	19.3	0.4	2.9	0.5	21.9	38.3	6.7	16.2	9.6	35.3	2.2	63.3
Year 18	20.9	0.3	3.2	0.5	23.4	40.8	6.7	18.1	9.6	30.1	2.4	59.8
Year 19	21.0	0.2	3.2	0.5	23.4	40.9	6.7	18.9	8.8	30.1	2.4	59.9
Year 20	20.5	0.1	3.2	0.5	22.8	40.6	6.7	19.5	7.7	29.6	2.4	59.2

Note: Main water transfers shown only. Results are based on statistical analysis of multiple model runs, so values may not always balance (i.e., inflows and outflows to East Pond may not balance). However, models balance within each model simulation.

Table 17: Annual average flow rates (m³/hour) – 95%ile model result for Base Case

Year	Other Flows (m³/hr)											
	Water in Treatment	Loss to Treatment Waste	Treated Water to PP	Unused Treated Water for Discharge	Clean Water Pond to Process	Clean Water Pond Overflow	Natural Catchment Outfall	Seepage from DSF	Underdrains to Pollanroe	Pollanroe at Outfall	Pollanroe at Mouth	Pollanroe at Mouth Pre-Dev
Year 1	83.2	0.4	0.1	82.7	7.1	30.4	22.5	0.05	22.2	157.7	290.9	258.5
Year 2	93.8	0.5	0.0	93.4	7.2	31.2	21.1	0.05	22.1	168.4	295.1	243.5
Year 3	90.2	0.5	0.0	89.7	7.2	32.1	21.6	0.05	22.1	165.5	293.6	248.8
Year 4	89.0	0.4	0.0	88.5	7.2	30.9	21.0	0.05	22.1	162.5	286.9	242
Year 5	95.7	0.5	0.0	95.2	7.2	33.4	22.4	0.05	22.1	174.3	309.5	257.5
Year 6	96.6	0.5	0.0	96.1	7.2	33.4	22.3	0.05	22.1	174.0	306.6	257.3
Year 7	103.9	0.5	0.0	103.4	7.2	32.0	21.6	0.05	22.1	180.1	310.3	248.2
Year 8	101.0	0.5	0.0	100.5	7.2	30.5	20.8	0.05	21.7	174.3	299.3	239.8
Year 9	101.2	0.5	0.0	100.7	7.2	33.2	22.3	0.05	21.9	178.0	310.2	256.5
Year 10	98.3	0.5	0.0	97.8	7.2	30.4	20.8	0.05	21.9	173.0	300.7	239.2
Year 11	104.9	0.5	0.0	104.4	7.2	33.1	22.2	0.05	22.2	182.0	314.3	256.1
Year 12	101.7	0.5	0.0	101.2	7.2	33.0	22.2	0.05	22.0	178.4	310.1	255.8
Year 13	105.1	0.5	0.0	104.6	7.2	31.7	21.4	0.05	22.0	179.7	306.8	246.7
Year 14	100.1	0.5	0.0	99.6	7.2	31.7	21.4	0.05	22.0	175.6	304.7	246.6
Year 15	104.2	0.5	0.0	103.7	7.2	31.8	21.5	0.05	21.9	179.6	308.8	247.1
Year 16	103.4	0.5	0.0	102.8	7.2	31.6	21.4	0.05	21.9	178.6	307.4	246.3
Year 17	101.6	0.5	0.0	101.1	7.2	30.0	20.5	0.05	21.9	173.5	295.4	236.7
Year 18	100.5	0.5	0.0	100.0	7.2	32.6	22.0	0.05	21.5	175.6	305.8	252.8
Year 19	100.8	0.5	0.0	100.3	7.2	32.5	22.0	0.05	21.8	176.3	306.8	252.8
Year 20	99.8	0.5	0.0	99.3	7.2	31.5	21.3	0.05	21.8	174.8	303.4	245.7

Note: Main water transfers shown only. Results are based on statistical analysis of multiple model runs, so values may not always balance (i.e., inflows and outflows to East Pond may not balance). However, models balance within each model simulation.

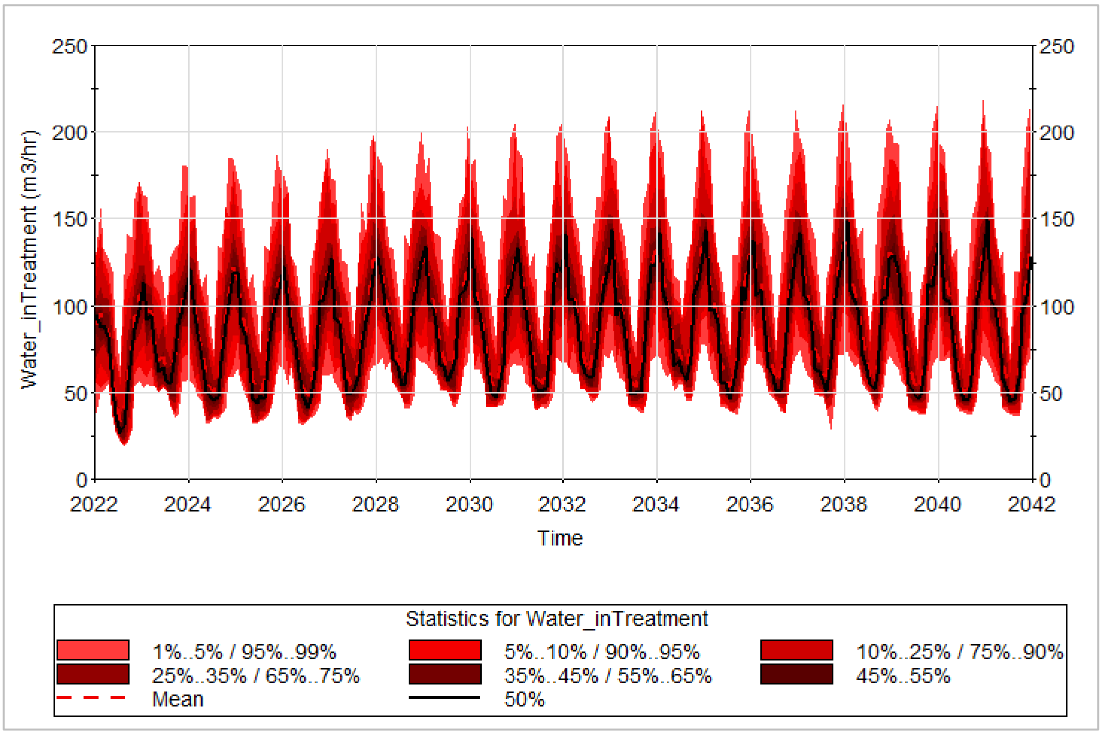


Figure 17: **Monthly average treatment rate for Base Case run**

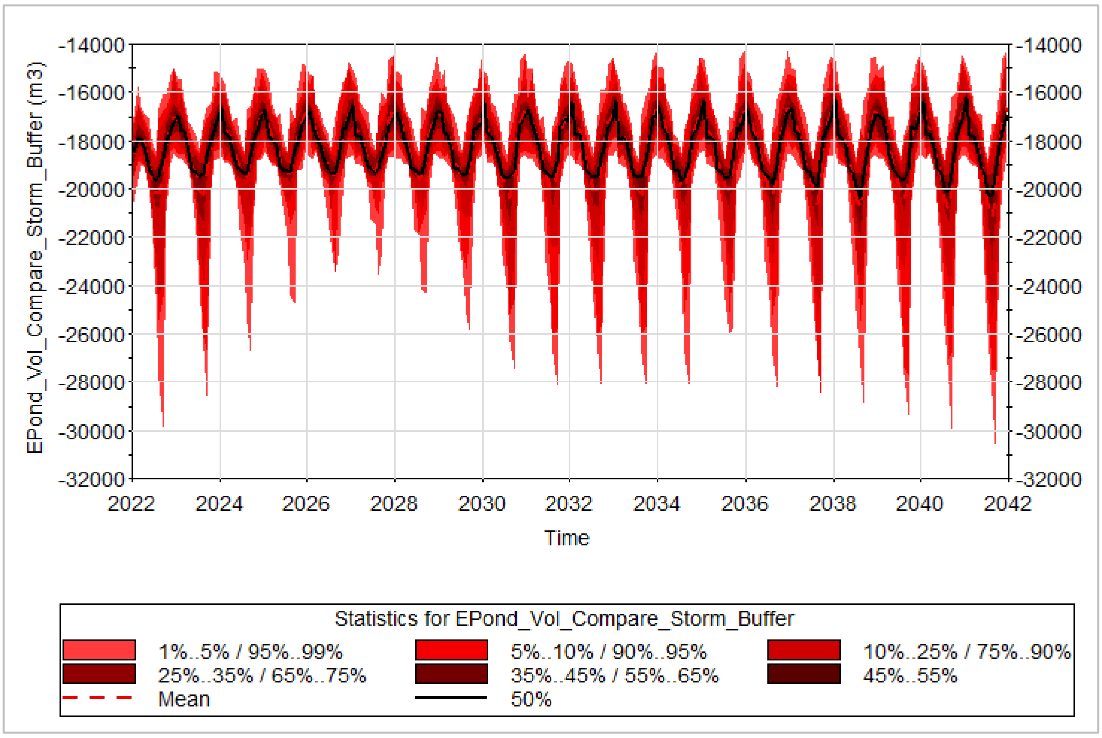


Figure 18: **Monthly average volume in East Ponds compared to buffer required for Storm Water Management. A value of zero shows pond is at level that provides 1 in 1000-year storm water storage. Values below zero show more storage is provided than is required.**

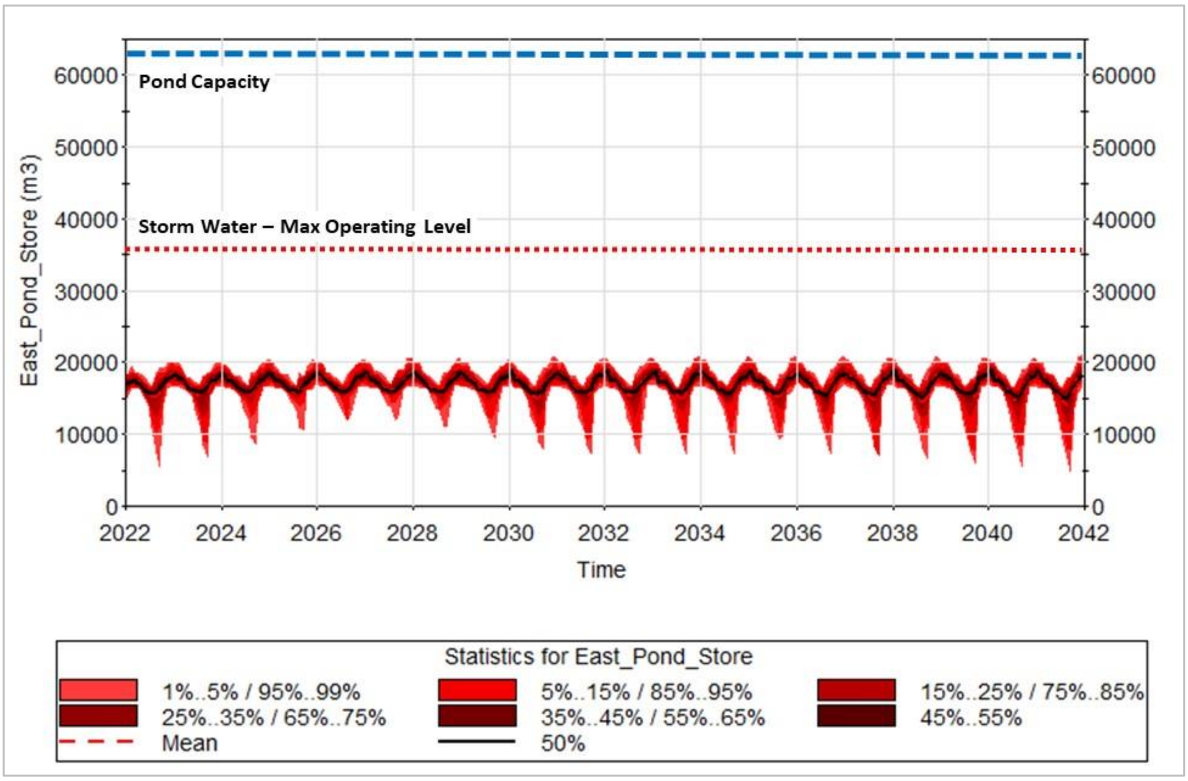


Figure 19: **Monthly average volume in West Pond compared to full and storm water buffer**

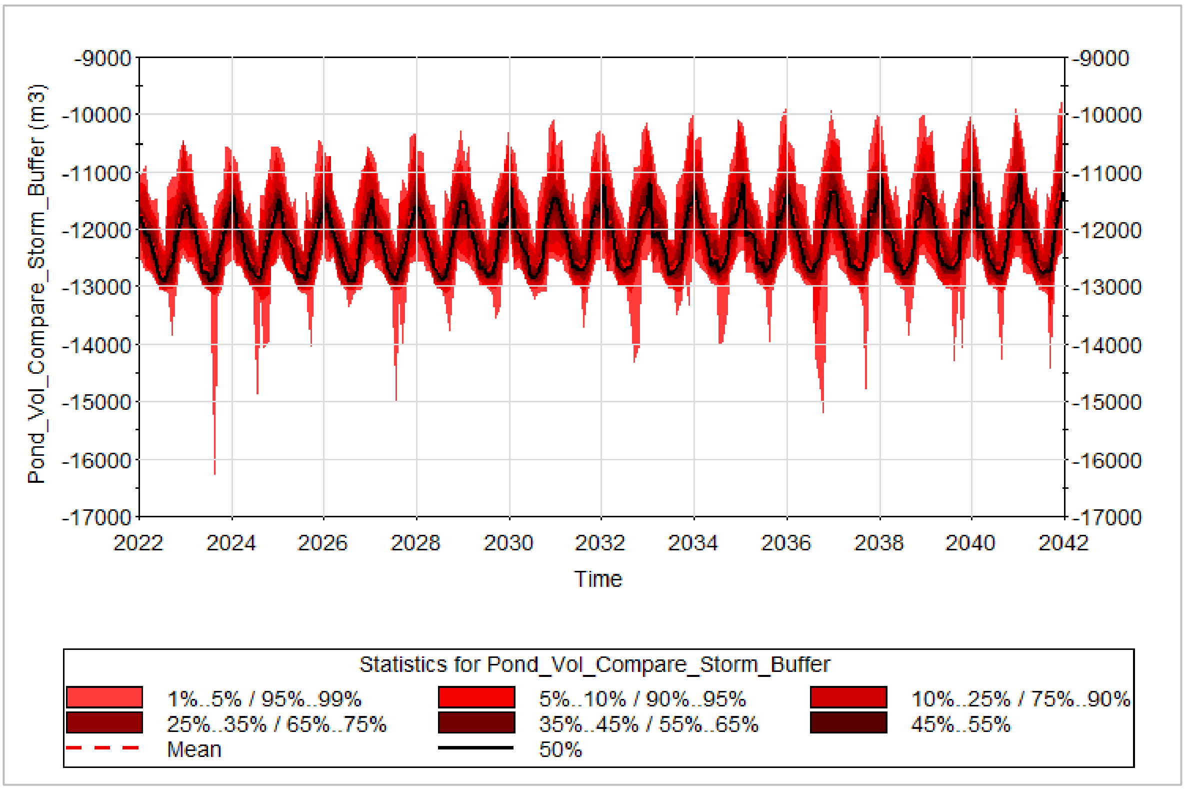


Figure 20: **Monthly average volume in West Pond compared to buffer required for Storm Water Management. A value of zero shows pond is at level that provides 1 in 1000-year storm water storage. Values below zero show more storage is provided than is required.**

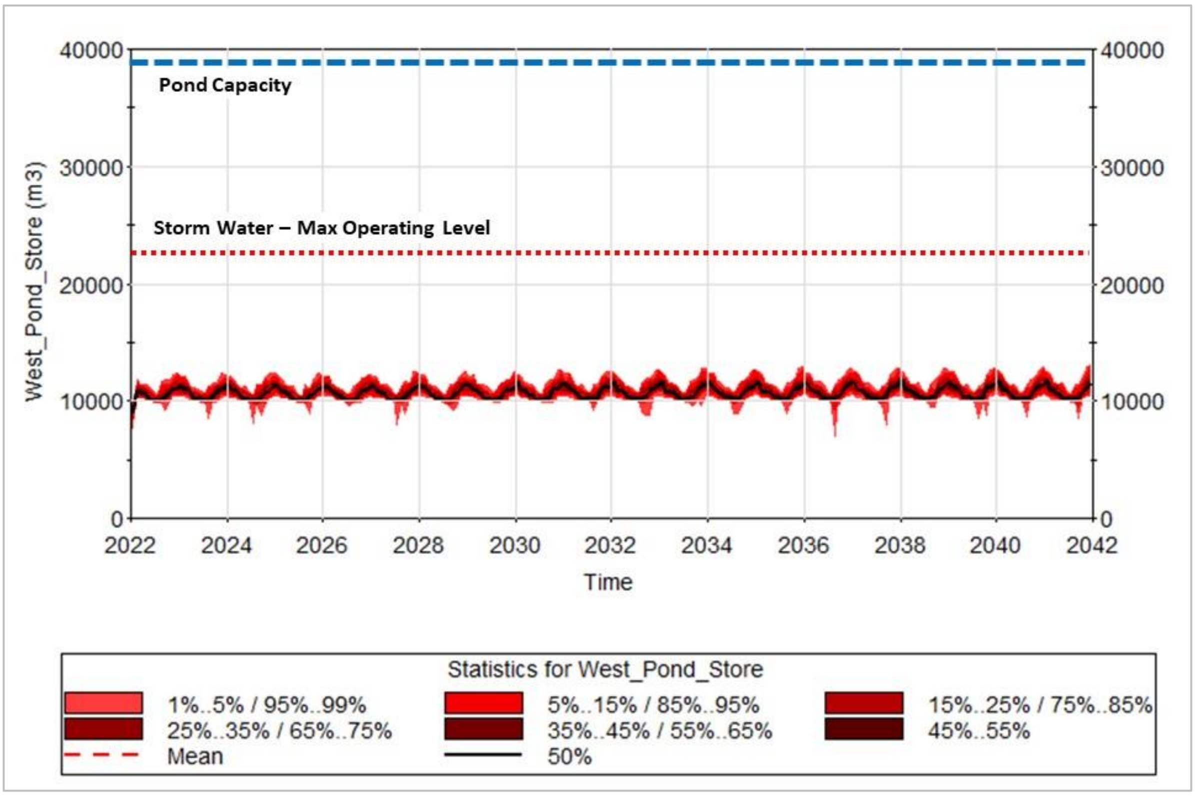
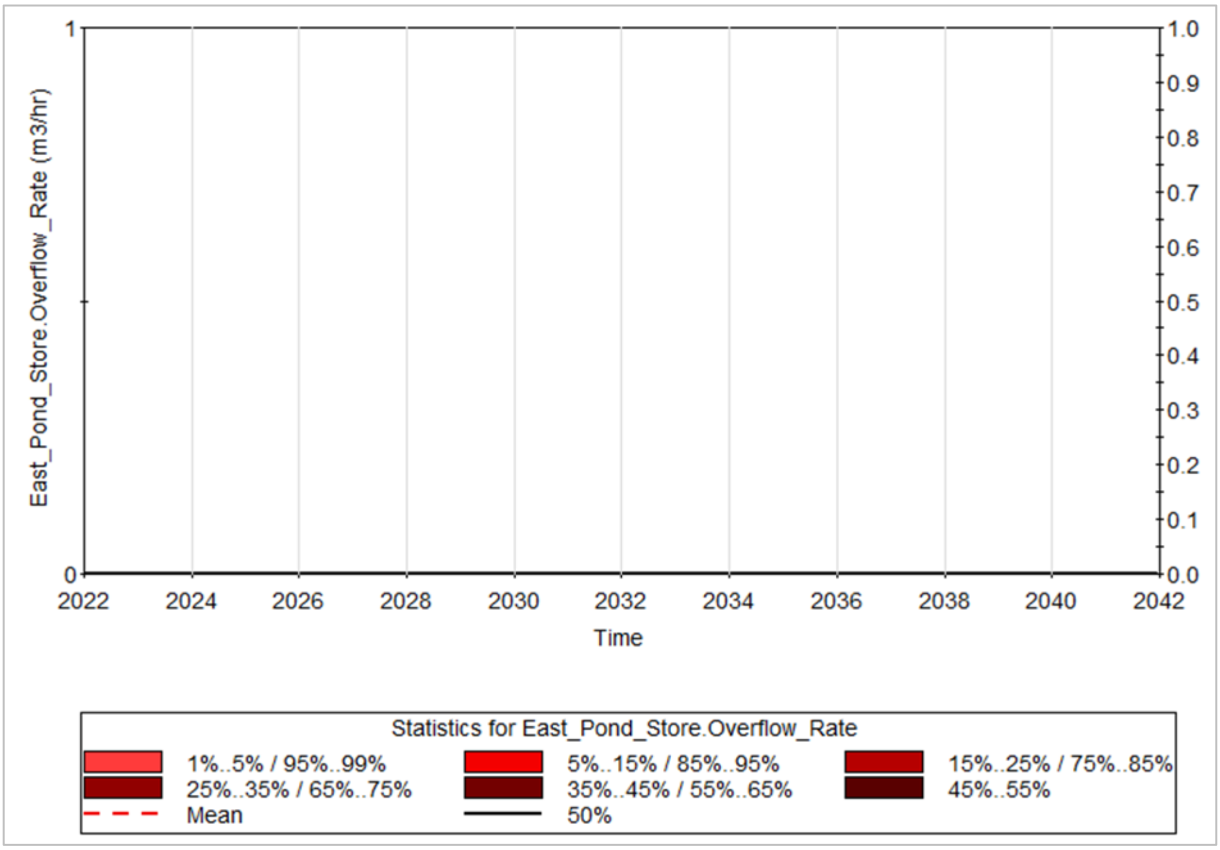


Figure 21: Monthly average volume in West Pond compared to full and storm water buffer



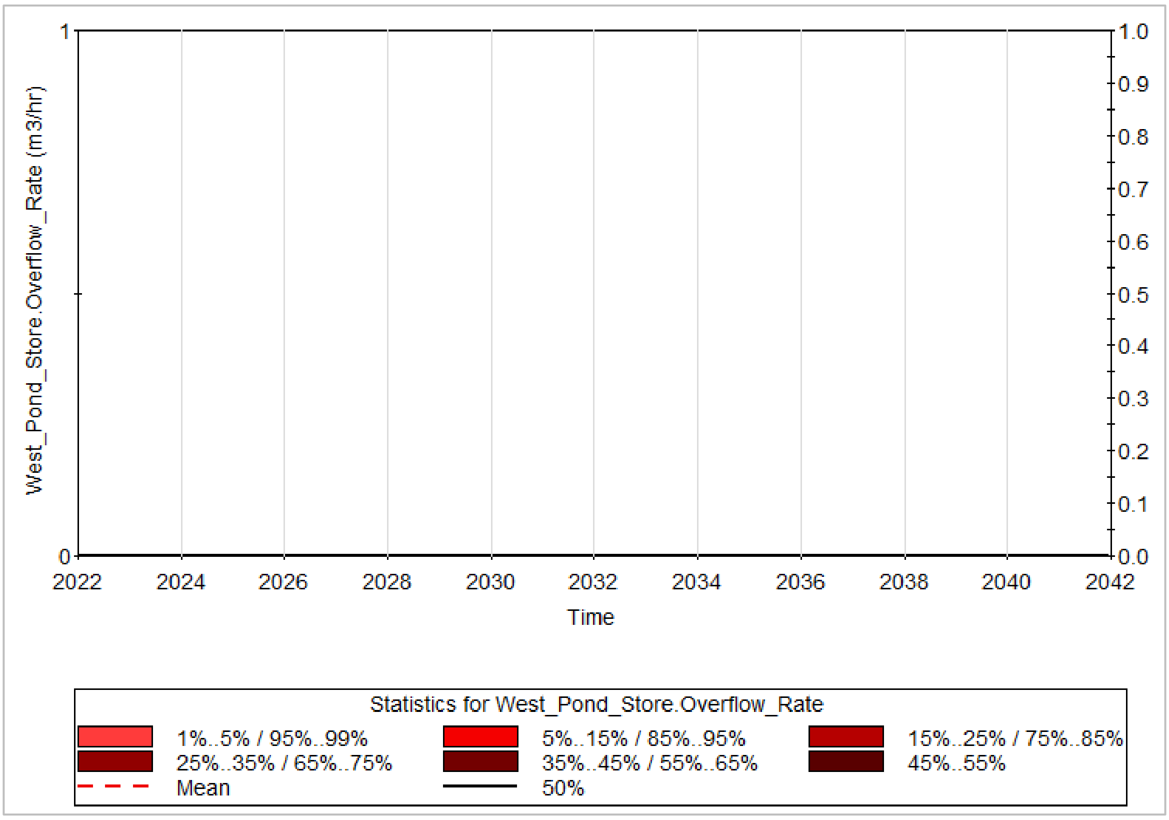


Figure 22: **Monthly average East Ponds overflow (top) and West Pond overflow (bottom). Both are zero for all simulations**

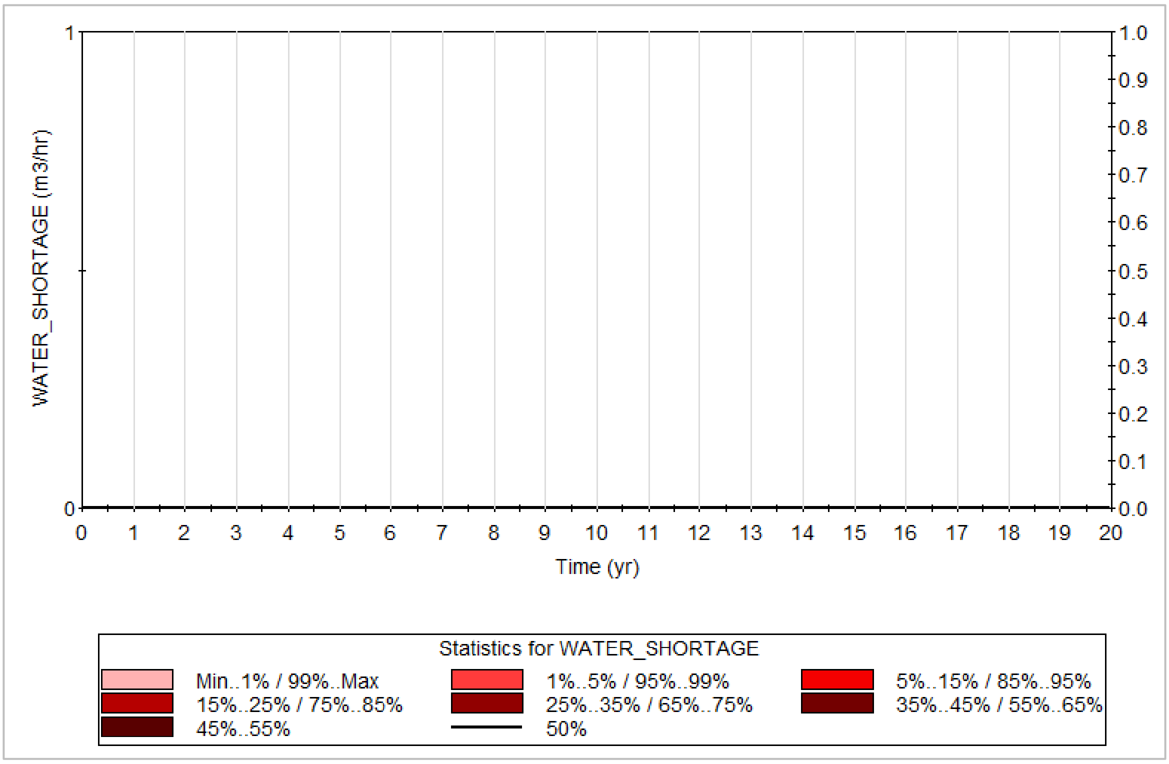


Figure 23: **Monthly average Water Shortage at mine (bottom). Values are zero for all simulations**

7 Sensitivity Runs

A series of sensitivity runs were undertaken to assess the impact of key model inputs on predictions and the robustness of the water balance.

A model sensitivity analysis provides an illustration of the effect of changing key model parameters on key model outputs (in this case; treatment rates, risk of water shortages or pond overtopping). By re-running the model for a range of scenarios and changing one input parameter for each model run, the effect of each input on the model results can be isolated in order to illustrate how the model varies/performs due to variations in that parameter. If model parameters are varied within the range of possible input values, then a sensitivity analysis can be used to identify which of the parameters provides the greatest uncertainty to the prediction (i.e., which produces the largest change in the results). These parameters can then be reviewed by the modeller to see if the design is robust to changes in these inputs. It is possible to vary more than one parameter at a time, but this can hide the relative impact of each parameter. However, conservative runs (see Section 7-5) are included that vary more than one parameter, following a similar approach to that in the 2017 report

More sensitivity runs are considered in this report compared to the 2017 water balance. As a result, the sensitivity runs section of the report is restructured to group the sensitivity runs based on the type of changes made to the base model simulation. The following groups of runs were considered:

1. Sensitivity to changes in key model hydrological or other flow inputs, e.g., runoff rates, mine water inflows, climate change effects. This includes a simulation based on daily hydrological inputs
2. Sensitivity to changes in process water demands
3. Sensitivity to changes in mine infrastructure, e.g., size of ponds, maximum treatment rate
4. Sensitivity to water management options
5. Conservative sensitivity runs considering combinations of key model parameters

The impact of the changes is considered in terms of:

- Predicted increase in average treatment rates
- Whether the calculations predict a risk of water shortage at the site
- Whether the calculations predict a risk of overtopping of the West or East Ponds

7.1 Sensitivity to Changes in Key Model Hydrological or Other Flow Inputs

The following runs were considered:

- Run S1-1 - Sensitivity to uncertainty in runoff conditions by increasing all rainfall/runoff by 20%, which is considered a reasonable uncertainty range and would result in the average rainfall total for the sensitivity run being equivalent to an approx. 1 in 10 wet year in the base case.
- Run S1-2 - Sensitivity to uncertainty in runoff conditions by decreasing all rainfall/runoff by 20%, which is considered a reasonable uncertainty range and would result in the average rainfall total for the sensitivity run being equivalent to an approx. 1 in 10 dry year in the base case.
- Run S1-3 - Sensitivities to underground mine water inflow, with rates increased by 20%.
- Run S1-4 - Sensitivities to underground mine water inflow, with rates decreased by 40%.
- Run S1-5 – Sensitivity to climate change assumption though use of more conservative RP8.5 climate predictions.
- Run S1-6 – Sensitivity to hydrological input time step, with model run with daily hydrological inputs.
- Run S1-7 – Sensitivity to hydrological input time step, with model run with daily hydrological inputs and 20% increase in runoff rates.

Sensitivities to changes in the groundwater and DSF seepage flows in the DSF under drain are considered in the Surface Water Impact Assessment (SWIA). The DSF seepage flows (average and high estimates) are very small compared to the overall water balance and groundwater flows in the under drain do not have implications for the site water balance. Any implications of these flows on downstream water quality are considered in the SWIA.

The results are presented in Table 18. Increasing runoff by 20% increases the average treatment rates as would be expected, but pond water levels are shown to be able to be kept below the flood storage requirements, illustrating the base model provides conservative assumptions with respect to providing flood storage on site, to reduce the risks of any uncontrolled spills.

Reducing runoff results in lower treatment rates but does not result in a water shortage on site. There is an excess of water on site either as a result of runoff, underground mine water and pond storage.

Changing the underground water inflows produces expected changes in treatment rates. Underground water flows are effectively an underlying baseflow to the water management ponds, so any increase or decrease in flows would have a direct influence on the average treatment rates.

Modelling with RP8.5 climate change inputs results in limited change to the 95%ile annual average treatment rates, but does impact average rates in winter months (increase in treatment with increased rainfall) and summer months (decrease in treatment with lower rainfall and higher PE). There is a higher risk of lower pond volumes in the summer months, but the model does not predict any shortages.

The base case model (monthly inflows) was then run with daily hydrological inputs, based on the hydrological modelling approaches discussed in Sections 3.3 and 3.5. The base case model was run on a monthly time step to be consistent with uncertainties in other model inputs (underground water, DSF evolution etc) and as the purpose of the modelling is to assess an overall water balance for the mine and not to model daily operations. However, a sensitivity run with daily inflows was undertaken to test whether the model was sufficiently robust when dealing with more event-based inputs (e.g., to consider months where most of rainfall is confined to first week of month and not distributed through the month). Key results are provided in Table 18, which show that the results from the daily model are very similar to those in the Base Case model, as no water shortages are predicted, flood storage requirements are maintained and average treatment rates are similar. More detailed results are provided in Figure 24 and Figure 26.

Figure 24 presents the variation in daily treatment rates. The results show that the average rate is similar to the scenarios with monthly inflows; however, the daily model shows periods when the maximum treatment rate would be required in selected winter months and where treatment could fall to zero under some dry weather conditions. Figure 25 and Figure 26 show the impact that this has on storage volumes and the flood storage buffer in the East and West Ponds. The modelling shows there are periods when the storage is less than predicted in the monthly model, but the storage never falls below the volume required to be maintained for flood storage.

Overall, the results of the daily model confirm those from the monthly model, indicating that the modelling and water management proposals are robust under both inputs.

Table 18: Sensitivity Results for Section 7.1

Run Number	Sensitivity Run	Shortage of Water	[a]Encroachment on Flood Storage	Maximum annual average (95%ile) treatment		
				Years 1 to 6 (m^3/hour)	Years 7 to 12 (m^3/hour)	Years 13 to 20 (m^3/hour)
Base	Base	No	No	96.6	104.9	105.1
S1-1	Runoff +20%	No	No	97.3	106.4	106.7
S1-2	Runoff -20%	No	No	95.0	103.4	103.6
S1-3	Underground inflow +20%	No	No	103.1	113.0	113.3
S1-4	Underground inflow -40%	No	No	83.4	88.8	88.7
S1-5	Climate Change at RP8.5	No	No	96.5	104.9	105.1
S1-6	Daily hydrological timestep	No	No	93.8	105.3	104.4
S1-7	Daily hydrological timestep + Runoff +20%	No	No	107.3	115.3	113.1

a Defined as pond water levels encroaching into flood storage buffer

Note – Model results are from stochastic modelling and are the 95%ile of 100 model simulations. Therefore, small changes in treatment rate may result from changes under specific climate conditions

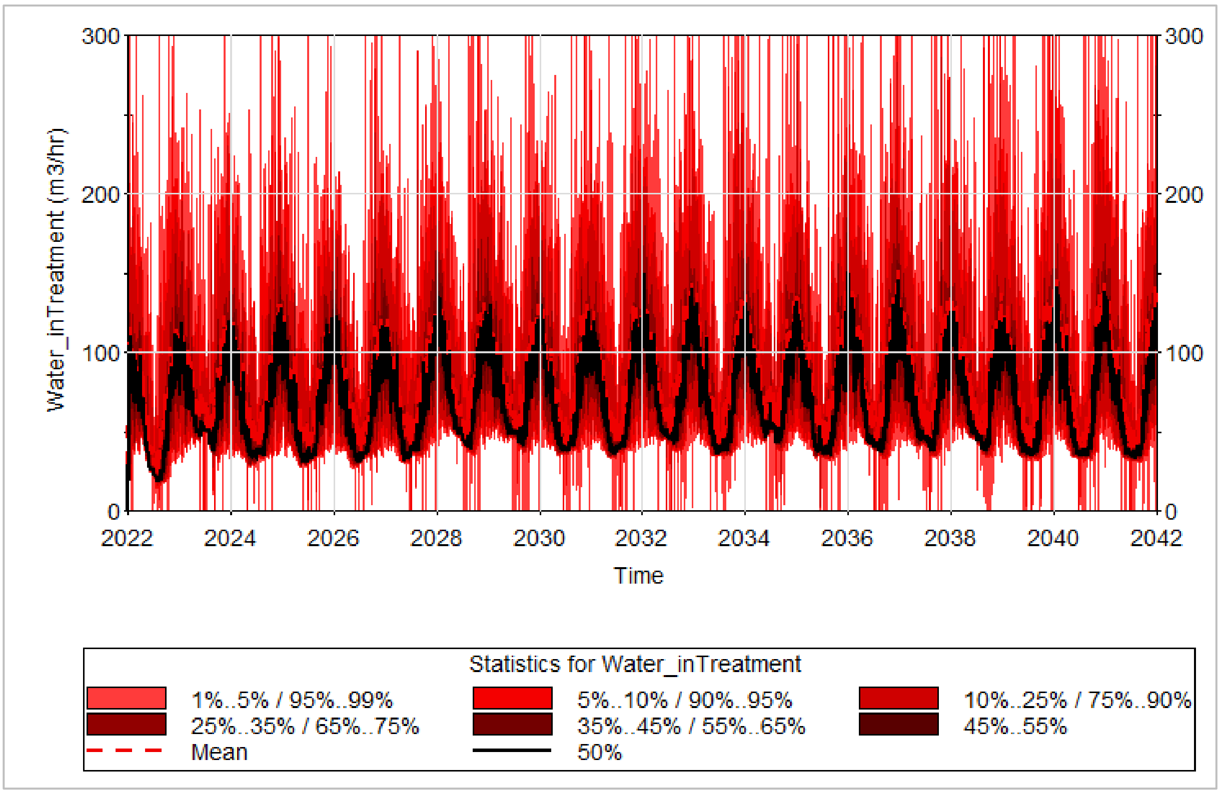
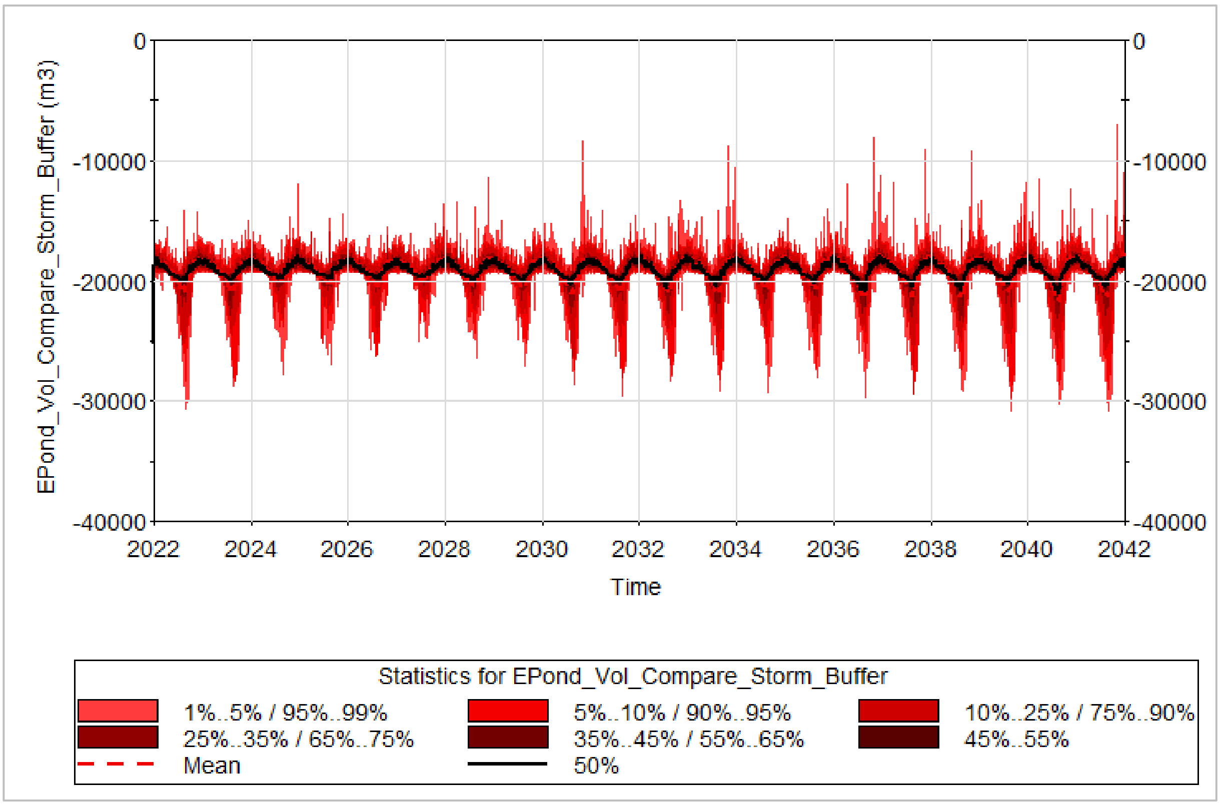


Figure 24: Daily treatment rates from Sensitivity Run S1-6



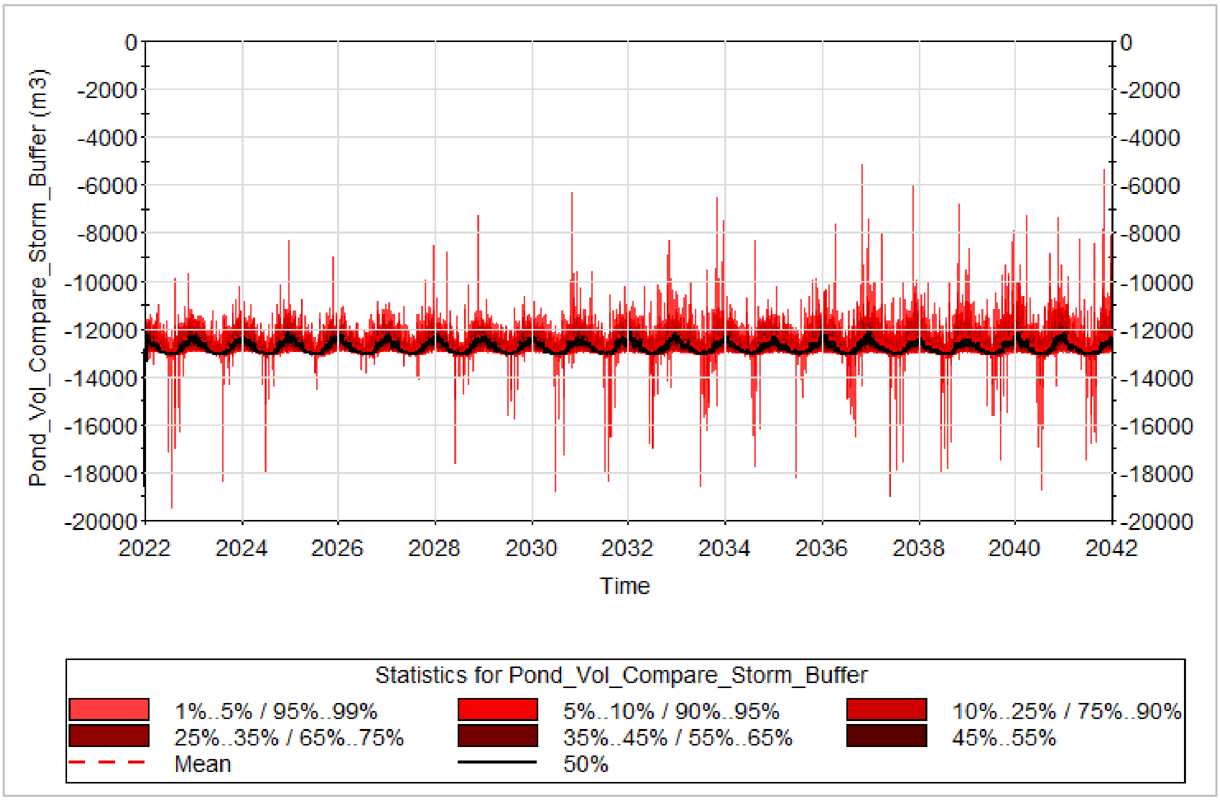
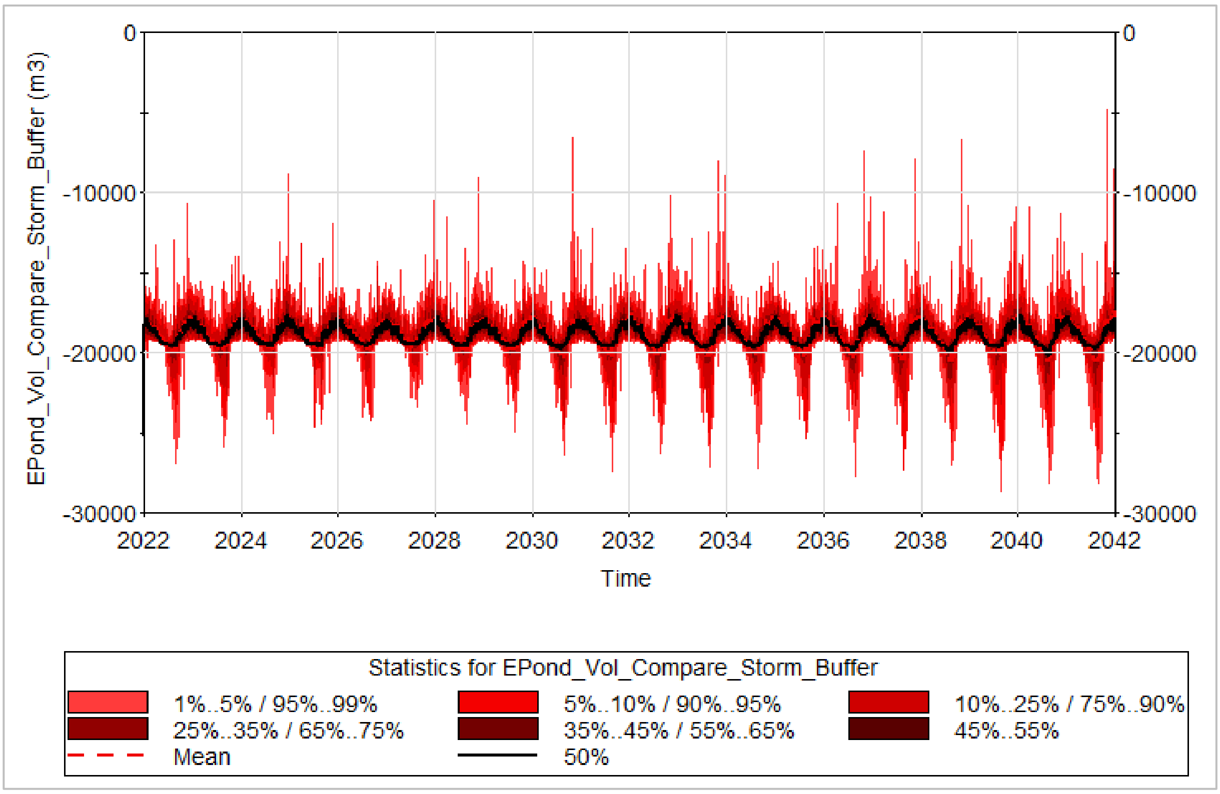


Figure 25: Storm Water Buffer in East Pond (upper figure) and West Pond (lower figure) from Sensitivity Run S1-6



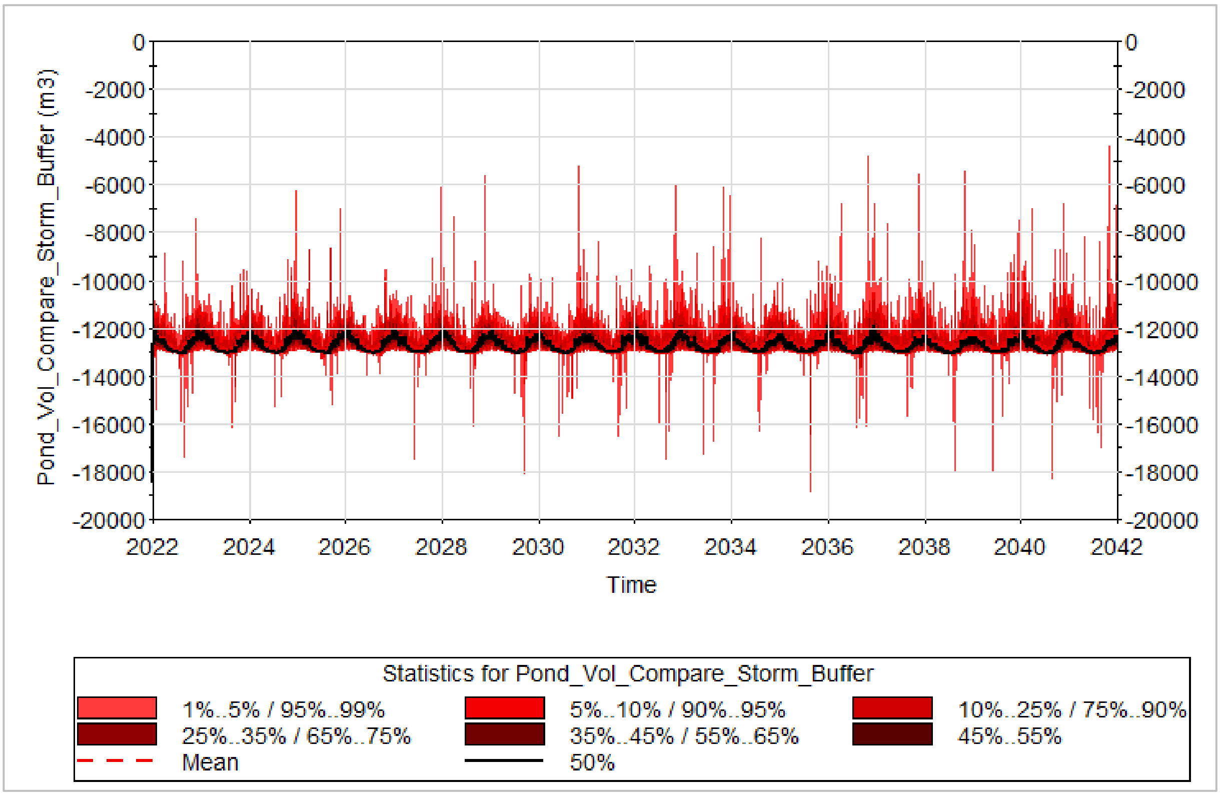


Figure 26: Storm Water Buffer in East Pond (upper figure) and West Pond (lower figure) from Sensitivity Run S1-7

7.2 Sensitivity to changes in process water demands

The following run was considered;

- Run S2-1 - Sensitivity to make-up water requirements, with fresh water requirement increased by 50%

The model results are provided in Table 19. Increased fresh water demands has no impact on treatment rates. The overall fresh water demand is low compared to the water volumes on site and the treatment rate.

Table 19: Sensitivity Results for Section 7.2

Run Number	Sensitivity Run	Shortage of Water	[a]Encroachment on Flood Storage	Maximum annual average (95%ile) treatment		
				Years 1 to 6 (m^3/hour)	Years 7 to 12 (m^3/hour)	Years 13 to 20 (m^3/hour)
Base	Base	No	No	96.6	104.9	105.1
S2-1	Fresh Water Requirement increased by 100%	No	No	96.6	104.9	105.1

a Defined as pond water levels encroaching into flood storage buffer

Note – Model results are from stochastic modelling and are the 95%ile of 100 model simulations. Therefore, small changes in treatment rate may result from changes under specific climate conditions

7.3 Sensitivity to changes in mine infrastructure

The following runs were considered:

- Run S3-1 - Sensitivity to uncertainties in maximum treatment rate by decreasing by 50%, i.e., half the base case maximum treatment.
- Run S3-2 - Sensitivities to uncertainties in maximum treatment rate by increasing by 50%.
- Run S3-3 - Sensitivities to treatment plant loss to evaporator, with losses increased from <0.5% to 2.5%
- Run S3-4 - Sensitivity to requirement for additional storm water storage in the onsite ponds, with the storage requirement increased by 50%, considered a significantly large increase in flood storage.

Model results are presented in Table 20. Decreasing the maximum treatment rate to 150 m^3/hr results in a risk of spillage from the water management ponds. This indicates the importance of the treatment rate to the water management plan.

Increasing the treatment rates increases the redundancy in the water treatment plant but does not impact on the modelled annual average rates.

Increasing the loss to the evaporator with the solid residue in the RO Water Treatment Plant has no significant impact on the water management, although there would be a slightly lower discharge from the site to the Pollanroe Burn.

Providing additional storm water storage has no measurable impact as the Base Case already shows that the ponds can be operated with significantly more flood storage than is required. The additional storage provided is greater than the potential increase in flood volumes due to climate change (6.7%) by the end of the mine life. This sensitivity run also considers a +50% storage volume, well in excess of the additional storage due to climate change.

Table 20: Sensitivity Results for Section 7.3

Run Number	Sensitivity Run	Shortage of Water	[a]Encroachment on Flood Storage	Maximum annual average (95%ile) treatment		
				Years 1 to 6 (m^3/hour)	Years 7 to 12 (m^3/hour)	Years 13 to 20 (m^3/hour)
Base	Base	No	No	96.6	104.9	105.1
S3-1	Max. Treatment Rate decreased by 50%	No	**Yes**	94.4	104.9	103.3
S3-2	Max. Treatment Rate increased by 50%	No	No	96.6	104.9	105.1
S3-3	Increased Loss to Evaporator	No	No	96.6	104.9	105.1
S3-4	Additional storm water storage	No	No	96.6	104.9	105.1

a Defined as pond water levels encroaching into flood storage buffer

Note – Model results are from stochastic modelling and are the 95%ile of 100 model simulations. Therefore, small changes in treatment rate may result from changes under specific climate conditions

7.4 Sensitivity to water management options

The following runs were considered;

- Run S4-1 - Diversion from West Pond
- Run S4-2 - Natural runoff from DSF released

The Base Case model assumes that runoff from the natural catchment to the west of the site (West Diversion) and that runoff from areas of the DSF that are undeveloped are both routed to the West Pond. The purpose of this was to:

(i) capture and treat all water potentially contracting the mine area; and

(ii) take a conservative approach to make sure that the water treatment rate and water management ponds are sized to accommodate the full mine area.

However, it would be possible to consider water management options whereby water from these undeveloped areas are discharged to the Pollanroe Burn directly with no treatment, assuming regulators are content that this water would be clean and not in contact with mining activities.

Two sensitivity runs were undertaken to see the impact of diverting these catchments to the Pollanroe Burn. It is noted that runoff from reclaimed areas of the DSF are still routed to the water management ponds and treated before discharge in these scenarios.

Results of the sensitivity analysis are summarised in Table 21. The show the reduction in treatment rates predicted if these water management options were implemented. The options would also change the resultant flows in the Pollanroe Burn. The assessment shows that the proposed water treatment capacity and pond volumes are conservative and allow for capture and treatment of all water within the mine site area.

Table 21: Sensitivity Results for Section 7.4

Run Number	Sensitivity Run	Shortage of Water	[a]Encroachment on Flood Storage	Maximum annual average (95%ile) treatment		
				Years 1 to 6 (m^3/hour)	Years 7 to 12 (m^3/hour)	Years 13 to 20 (m^3/hour)
Base	Base	No	No	96.6	104.9	105.1
S4-1	Divert Natural Runoff in Western Diversion Channel to Pollanroe	No	No	88.9	97.2	97.8
S4-2	Divert Natural Runoff and Pre-development DSF discharged to Pollanroe	No	No	74.0	90.4	92.6

a Defined as pond water levels encroaching into flood storage buffer

Note – Model results are from stochastic modelling and are the 95%ile of 100 model simulations. Therefore, small changes in treatment rate may result from changes under specific climate conditions

7.5 Conclusions and Discussion of Conservative Sensitivity Runs

The sensitivity model runs presented above highlighted two key model inputs that had the largest impacts on the water balance model:

(i) the rainfall and runoff totals; and

(ii) the flow rate from underground dewatering to the West Pond.

The treatment rate is also a key model parameter, but it is assumed that this would be increased to meet the water management requirements at the mine.

The volume of freeboard maintained in the East and West Ponds to manage storm water storage is also an important variable, although the sensitivity analysis indicated that an increase to the storage volumes could be achieved without an increase to the maximum treatment rate.

Two conservative model runs were also considered (S5-1 and S5-2) that combined changes to multiple model parameters.

Simulation S5-1 considered a conservative, wet condition with higher rainfall rates and higher mine dewatering inflows. The results showed the increased inflows could be managed with the current proposed treatment rate.

Simulation S5-2 considered conservative, dry conditions with higher storm water storage (i.e., less water held in the ponds), reduced rainfall and runoff, and increased fresh water requirement for the plant. This run indicated there was no predicted shortage of water during the mine life, suggesting that the balance is robust in terms of available water for the process.

Table 22: Sensitivity Results for Section 7.5

Run Number	Sensitivity Run	Shortage of Water	[a]Encroachment on Flood Storage	Maximum annual average (95%ile) treatment		
				Years 1 to 6 (m^3/hour)	Years 7 to 12 (m^3/hour)	Years 13 to 20 (m^3/hour)
Base	Base	No	No	96.6	104.9	105.1
S5-1	Conservative Wet Weather Run, with increased runoff rates (+20% on all surface water inflows) and mine water inflows (+20%)	No	No	104.7	114.5	114.9
S5-2	Conservative Dry Weather Run with increased flood storage requirement (+50%), reduced surface water runoff (-20%) and increased freshwater demand (+100%)	No	No	95.0	103.4	103.6

a Defined as pond water levels encroaching into flood storage buffer

Note – Model results are from stochastic modelling and are the 95%ile of 100 model simulations. Therefore, small changes in treatment rate may result from changes under specific climate conditions

8 Predictions of Impact on Flows in the Pollanroe Burn and Owenreagh River

This chapter looks at the potential impact of the development on flows in the Pollanroe Burn and Owenreagh River for the Base Case scenario.

The water balance model provides predictions of monthly flow conditions in the Pollanroe Burn and Owenreagh Rivers, based on the modelling approaches provided in Section 3.1. The stream flow predictions will be used to predict downstream impacts of the mine site on flows and water quality in the Pollanroe Burn and Owenreagh River.

A summary of flow predictions for the pre-development and post-development scenarios for the Pollanroe Burn (at its mouth) are presented in Table 23 and Figure 27. The modelled approach to calculating flows in the Pollanroe Burn was outlined in Section 3.3. Post-development flows in the Pollanroe Burn will be higher than at present under average and low flow conditions. The impacts on average annual and monthly flows (Table 23) are similar to those presented in the 2017 water balance. The impact on annual flows was 26% in Year 6 in the 2017 study and it is now 22.6%. On a monthly basis the impact is predicted to be slightly less during wet months than in 2017 and more during summer months compared to 2017 (higher flows are predicted in summer months than before). These changes are primarily due the review of the baseline hydrology for the Pollanroe Burn that has changed the baseline flow rates in the watercourse from those used in 2017. Flows will be lower under flood flow conditions, due to flood waters during heavy rainfall being stored within the water management ponds on site, before being released at a rate controlled by the capacity of the WTP. These impacts are discussed in more detail in the surface water impact assessment. Generally, increases in low and average flow conditions would be considered a positive change as it reduces the potential for the stream drying. Decreasing peak flows is also normally considered as positive, reducing the risk of flooding downstream and reducing the risk of erosion within the channel.

The Owenreagh River is significantly larger than the Pollanroe Burn. The impact on the Owenreagh River flows are outlined in Table 24. The predicted change is flows in the Owenreagh just downstream of the Pollanroe Burn is a maximum of 2.4% in July (Year 12), falling to less than 1% in winter months. By the mouth of the Owenreagh River the predicted change in flows is 1.5% in July (Year 12), falling to around 0.5% in winter months. As for the Pollanroe Burn the predicted changes are consistent with those in the 2017 water balance.

As noted, these results are consistent with and similar to the results presented in the 2017 water balance report. The overall impacts on the Pollanroe Burn and Owenreagh River remain the same, i.e., increases in average and low flow conditions in the Pollanroe, with decreases in flood flows. Minor changes to flows are predicted in the Owenreagh River due to the difference in scale of the catchment of the mine site (around 0.5 km^2) and the catchment of the Owenreagh River upstream of the Pollanroe (53.5 km^2) and Owenreagh River at its mouth (85.5 km^2).

Table 23: Water Balance Model Flow Predictions in Pollanroe Burn at its Mouth

Pollanroe Burn Confluence with Owenreagh River	Year 6			Year 12			Year 20		
Month	[b]Baseline flow (L/s)	Flow in Operations (L/s)	Difference (%)	[c]Baseline flow (L/s)	Flow in Operations (L/s)	Difference (%)	[c]Baseline flow (L/s)	Flow in Operations (L/s)	Difference (%)
January	97.8	113.3	15.9	102.4	120.5	17.7	104.7	124.0	18.4
February	68.2	79.9	17.2	61.7	75.2	21.8	66.8	82.7	23.7
March	67.4	78.8	17.0	62.4	76.9	23.2	64.5	79.5	23.3
April	48.5	59.9	23.3	55.7	69.1	24.0	49.3	62.3	26.4
May	28.5	37.7	32.2	37.7	48.3	28.1	30.9	40.7	31.9
June	22.7	32.8	44.7	21.5	33.6	56.5	21.5	32.2	50.0
July	18.9	30.1	59.5	16.2	28.6	76.7	14.9	25.5	71.8
August	27.1	40.4	49.3	18.0	29.2	62.4	14.7	25.4	73.1
September	36.7	51.3	40.1	32.2	45.4	41.2	23.7	32.9	39.0
October	56.9	67.3	18.4	58.4	74.9	28.3	57.5	71.8	24.8
November	67.9	82.9	22.1	85.0	101.9	19.9	66.2	81.6	23.3
December	88.9	104.4	17.4	84.2	101.4	20.4	88.0	105.6	20.0
Annual (L/s)	57.6	70.6	22.6	57.4	72.0	25.4	55.3	69.3	25.3
[a]Runoff (mm)	889.8	1054.9	18.6	887.5	1075.8	21.2	854.6	1035.6	21.2

a Runoff is total annual flow divided by catchment area. Percentage change in annual runoff is not the same as percentage change in flow as catchment area is different during operations and closure, compared to baseline as part of the Unnamed Watercourse catchment is diverted to Pollanroe Burn. Higher post-development totals reflect higher runoff from disturbed areas within mine site area and additional flows from underground water and sewage

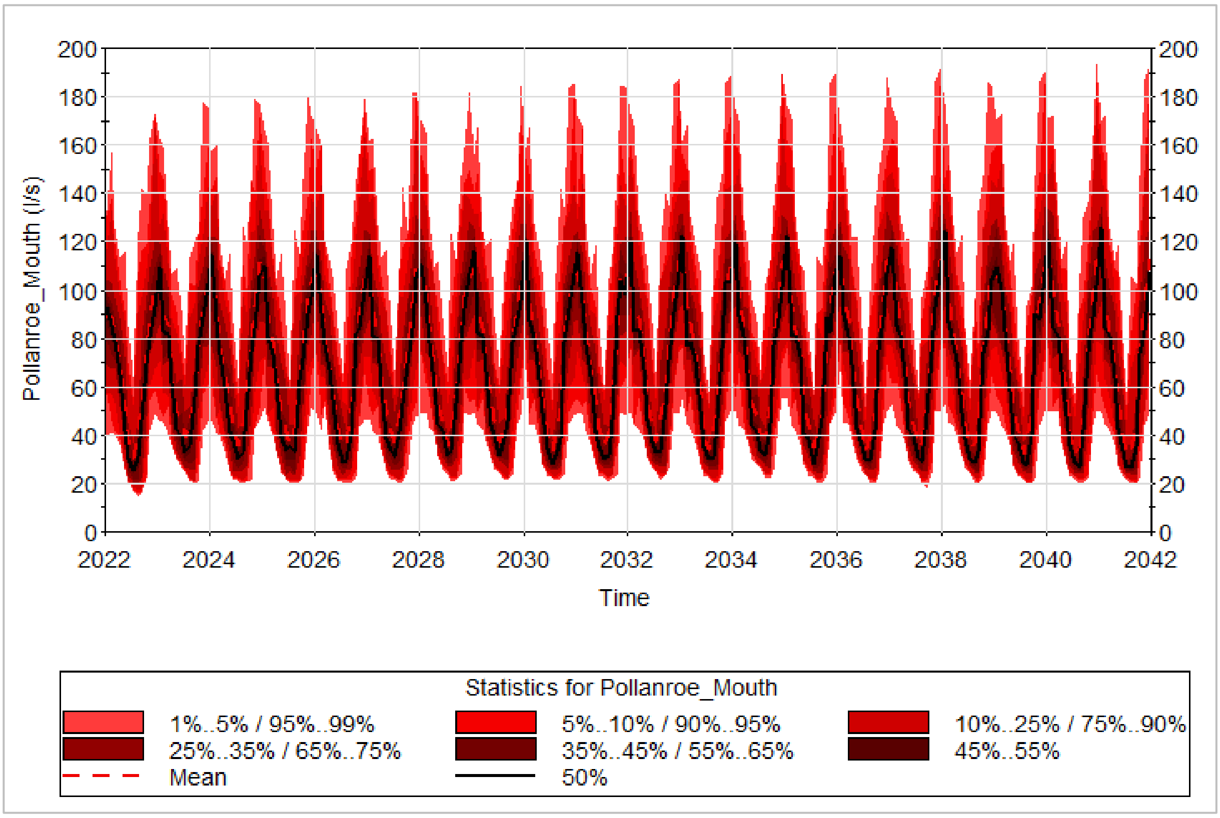
b In the table baseline flows are different for different years. This reflects the changes in rainfall and evaporation rates due to climate change. Flow rates in winter months are predicted to increase, while rates in summer are predicted to decrease. Changes are also influenced by the stochastic modelling approach used in the Water Balance Model, where there will be slight differences based on the combination of climatic conditions that are selected for each year in each model run.

Table 24: Water Balance Model Flow Predictions in Owenreagh River downstream of Pollanroe Burn

Owenreagh downstream of Pollanroe Burn	Year 6			Year 12			Year 20		
Month	[b]Baseline flow (L/s)	Flow in Operations (L/s)	Difference (%)	[b]Baseline flow (L/s)	Flow in Operations (L/s)	Difference (%)	[b]Baseline flow (L/s)	Flow in Operations (L/s)	Difference (%)
January	2,673	2,689	0.6	2,707	2,725	0.7	2,747	2,766	0.7
February	2,205	2,217	0.5	2,229	2,243	0.6	2,275	2,291	0.7
March	1,850	1,862	0.6	1,850	1,865	0.8	1,859	1,874	0.8
April	1,216	1,228	0.9	1,235	1,249	1.1	1,245	1,258	1.0
May	831	841	1.1	840	851	1.3	833	843	1.2
June	612	622	1.7	597	609	2.0	579	590	1.9
July	545	556	2.1	516	528	2.4	480	490	2.2
August	747	761	1.8	676	688	1.7	591	601	1.8
September	1,017	1,032	1.4	926	939	1.4	802	811	1.2
October	1,850	1,860	0.6	1,785	1,801	0.9	1,696	1,710	0.8
November	2,170	2,185	0.7	2,188	2,205	0.8	2,170	2,186	0.7
December	2,531	2,546	0.6	2,561	2,578	0.7	2,611	2,629	0.7
Annual (L/s)	1,523	1,536	0.9	1,510	1,524	1.0	1,491	1,505	0.9
[a]Runoff (mm)	868.4	874.3	0.7	861.0	867.8	0.8	850.1	856.6	0.8

a Runoff is total annual flow divided by catchment area. Percentage change in annual runoff is not the same as percentage change in flow as catchment area is different during operations and closure, compared to baseline as part of the Unnamed Watercourse catchment is diverted to Pollanroe Burn. Higher post-development totals reflect higher runoff from disturbed areas within mine site area and additional flows from underground water and sewage

b In the table baseline flows are different for different years. This reflects the changes in rainfall and evaporation rates due to climate change. Flow rates in winter months are predicted to increase, while rates in summer are predicted to decrease. Changes are also influenced by the stochastic modelling approach used in the Water Balance Model, where there will be slight differences based on the combination of climatic conditions that are selected for each year in each model run.



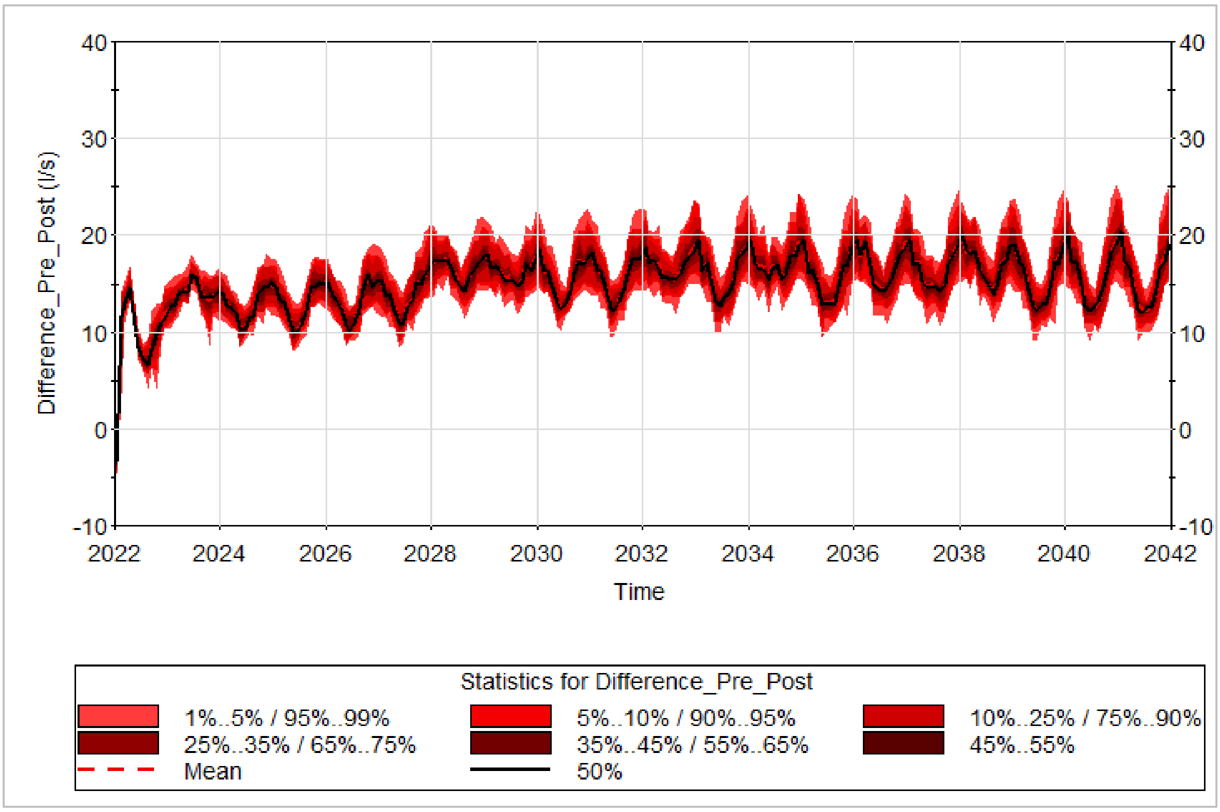


Figure 27: Model Output showing predicted monthly flow difference between baseline and operational flows at the mouth of the Pollanroe Burn

9 Risks and Uncertainties

Risks and uncertainties associated with key model inputs and model results are discussed below.

9.1 Rainfall and Approach to Modelling Climate Variability

The rainfall inputs to the model are based on observed rainfall at the closest appropriate UK Met Office rain gauge to the site. Modelling is based on a stochastic approach that utilises the natural variability in the observed rainfall record. As the rainfall record is 54 years long and the mine life modelled is only 20 years, the data is considered appropriate to provide a robust assessment of the effect of climatic variability on the water balance. Small changes were made to the rainfall record and method for selecting annual rainfall time series in the stochastic model, both of which are considered improvements over the 2017 report.

The model also explicitly considered the impacts of climate change on rainfall and evapotranspiration, based on the UKCP18 climate change predictions. Climate change was not explicitly modelled in the 2017 water balance.

The model was run with the East and West Pond water levels drawn down to allow capacity for the storage of flood waters (1 in 1,000 years, 24-hour storm). With an increased water treatment rate compared to the 2017 report, the model predicted that the pond water levels could be operated with more than sufficient flood storage for the design storm. Although the base model was run using a monthly time step, as in 2017, a sensitivity run was undertaken using a daily input for surface water flows. This run also predicted sufficient flood storage, providing some confidence that the approach taken in robust.

Sensitivity runs were undertaken changing runoff rates by 20% from their base case values (this increased/decreased both wet and dry years by 20%). With the use of 54 years of data and an additional model test changing runoff by a further 20% the modelling is considered to provide a robust test of the water balance at the mine. Irrespective, and consistent with any water balance study, there remain uncertainties associated with the variability in the local climate.

9.2 Storm Water Storage Assumptions

The modelling has assumed that the mine water ponds will be operated at a level that will retain at least a freeboard equivalent to a calculated 1 in 1000 year 24-hour rainstorm. As noted above, with an increased water treatment rate compared to the 2017 report, the model predicted that the pond water levels could be operated with more than sufficient flood storage for the design storm. The flood storage requirements are around 43% of the total pond capacities.

In the case of water approaching the spill level of the pond, contingency measures include termination of mine dewatering and pumping excess water to the underground workings, to be stored until the end of the flood event. Appropriate pumps should be sized and installed on site.

The ponds will also contain overspill weirs or culverts to route any excess water to the Pollanroe Burn without flooding of the site or failure of the ponds. The impact of an uncontrolled spill is considered in the surface water impact assessment. It is noted that water quality modelling in the ES predicted that dilution during the 1 in 1000 year event would mean that if multiple very extreme events were to occur one after another, then a release of water from the ponds would not result in significant downstream effects in terms of water quality.

After a flood event the water management ponds will need to be drained down to the operating level. It is noted with respect to drain down that the design flood event is a 1 in 1000 year 24-hour event, therefore, it will need to be drained down over multiple days after the event, i.e., if the full volume were discharged in less than 24 hours this would release downstream water at a higher rate than in the original event.

9.3 Water Treatment Capacity

The water treatment capacity at the mine was guided by the water balance results, so that the capacity allowed compliance with the storm water storage requirements at the mine site and was able to deal with the mine water demand (providing water for process) and all inflows to the water management ponds.

The treatment rate has been increased from 200 m^3/hour to 300 m^3/hour compared to the 2017 water balance, to provide additional capacity to deal with flood events and to provide contingencies during normal operations. This increased treatment rate allows the water management ponds to be operated at a lower level than with the lower treatment rate.

This modelling assumed the treatment plant was working during the flood event. However, the treated volume during the event (300 m^3/hour for 24 hours = 7,200 m^3) can be accommodated within the ponds with the water management modelled in the Base Case.

9.4 Clean Water Pond Design and Risk of Water Shortages

The modelling presented in this report indicates a low risk of water shortages impacting the mine operation. However, this depends on a number of assumptions, but especially those related to the runoff able to reach the Clean Water Pond, meteorological conditions modelled, mine dewatering volumes and mine water demand requirements. There is sufficient water within the mine dewatering volumes to provide sufficient water for the process (after treatment). A risk of water shortage remains if climatic conditions and mine operations are not consistent with the modelled assumptions and are outside of the model sensitivity runs.

The contingency for process plant water is to make use of piped fresh water in the process.

9.5 Compensation Flow

The compensation flow released from the Clean Water Pond has been set at the 95%ile low flow in the Pollanroe Burn. This is a standard approach, but there may be site specific requirements which may be demanded by regulators during the permitting process, e.g., to try and maintain higher flows in the burn. Given the model predicts that average and low flow rates in the Pollanroe Burn are above baseline conditions, there is confidence that any requirement for increased flows could be met at the mine site. As outlined in Figure 27 the model predicts 95%ile flows in the Pollanroe Burn will increase by almost 100% during operations.

9.6 Engineering Designs (Water Management and Dry Stack)

Designs of engineered structures on site (e.g., ponds, channel, buildings, road and DSF) have been undertaken by others. We have been reliant on information provided by others on the sizing and operations of these structures. Changes to the designs have been incorporated into this water balance update.

10 Summary and Conclusions

This report describes a water balance for the Curraghinalt Gold Mine in Northern Ireland. The water balance updates and replaces a water balance report submitted with the 2017 ES. There have been a number of changes to the mine site that impact the water balance, and these are summarised in Section 1.1. The key changes are the removal of ore processing at the site that has reduced the mine fresh water demand and an increase in the capacity of the site WTP. In addition, improvements have been made to a number of inputs to the water balance calculations due to the collection of additional data since the 2017 report (e.g., stream flow and rainfall data) and due to updates to calculation of model inputs, such as improved infiltration and seepage modelling of the DSF and improved surface water runoff calculations. The balance is based on current best estimates of surface water runoff at the mine site, the current process water balance and mine infrastructure plans.

The calculations are based on a monthly input dataset, so are suitable for general water management at the site. However, storm water requirements are based on a 24-hour duration storm and a sensitivity run has been undertaken with daily hydrological inputs to test how robust the model is to the monthly time step. The model is used to:

- Provide inputs to geochemical calculations
- Assess and review maximum water treatment rates
- Assess whether there is sufficient water to provide make-up for the process
- Provide flow estimates for discharges from the mine to be used in the EIA

The model was developed within the GoldSim modelling software and run using time varying and stochastic inputs. Results are presented as probability distributions and provide an indication of the likelihood of occurrence of different model results (e.g., treatment rates) based on a series of model iterations that consider climatic variability based on observed rainfall data from the closest UK Met Office rain gauge.

Overall, the conclusions made in the 2017 water balance report remain. Predictions based on model Base Case (best estimate) inputs indicate that there is a low risk of water shortage at the mine site and a low risk of spillage of untreated mine water. A storm water storage volume has been calculated for the East and West Ponds and the model predicts that the pond water levels can be operated with more than sufficient flood storage volume available above the operational water of the ponds as free storage.

Simple annual water balances are presented in Figure 15 and Figure 16. Predictions of key outputs are provided on a monthly time step.

Sensitivity model runs in Chapter 7 provide an indication of the impact of model uncertainties on water balance predictions. The assessment shows that the water management plan, proposed water treatment capacity and pond volumes are robust to changes in model inputs. There may be options to reduce flow rates to the water management ponds in the future, but the approach taken is conservative and considers the management of runoff from the full site area.

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Appendix 1: Storm Runoff Calculations

Runoff from the mine infrastructure area and DSF will be routed to the East and West Ponds. Runoff will be attenuated within these ponds, then pumped through the Water Treatment Plant before discharging to the Clean Water Pond or Pollanroe Burn. When receiving mine waters, all ponds have been designed to;

- Provide storage of untreated water as a buffer for storm water runoff; and
- Provide storage of untreated water that can be treated and then used in the mine site as clean water.

The key objective is for there to be no discharges of untreated contact water from the mine site.

The ponds have been designed to attenuate runoff from a 1 in 1000-year storm event. A sensitivity run is presented in the main report that checks the storage against a 1 in 1000 year + 50% event. This is substantially greater than the normal 20% uplift that is considered in Northern Ireland for flood events under climate change. Design storm volumes have been calculated using the Wallingford Procedure, based on catchment areas and runoff coefficients outlined in Table A1 1.

Rainfall data is based on FEH 2013 data from the FEH Web Service, with values given in Table A1 2.

The outflow from the ponds is limited to 300 m^3/hour (83.3 l/s), which is the maximum treatment rate within the Water Treatment Plant. The 2-year greenfield runoff rate for the mine site area is calculated as 3.7 l/s/ha, based on IH124 (with SAAR = 1398 mm, SOIL = 0.30).

A total of 0.557 km^2 (55.7 ha) is being routed to the East and West Ponds, giving a 2-year greenfield runoff rate of 206 l/s for the site area. As treatment rates are limited to 83.3 l/s from this part of the site, the post-development discharge from the site area will be less than 2-year greenfield rates.

Table A1 1: Storm Water Runoff Calculations

Catchment	West Pond Catchments (m^2)	[a]East Ponds Catchments (m^2)	Runoff Co-efficient
DSF Area (see Table 1)	125,700	145,980	0.75
Natural Catchments (non-hardstanding)	61,145	142,745	[b]0.56
Mine infrastructure (hardstanding)		38,542	0.9
Pond Areas	18,400	24,300	1
TOTAL	**205,245**	**351,568**	**-**
	TOTAL	**556,813**	**-**

a Combined Upper and Lower East Pond Catchments
b Based on SPRHOST of 56% for catchment

Storage volumes for the East Ponds are provided in Table A1 3, with values for the West Pond in Table A1 4.

Calculations indicate a peak storage volume for a 1 in 1,000 year 24-hour storm to be;

- East Ponds 27,550 m^3
- West Pond 15,970 m^3

The volumes for a 100 year, 24-hour event are 16,770 m^3 and 9,590 m^3 for the East and West Ponds respectively. Therefore the 1,000-year storm storage volumes are significantly more than 20% greater than required for the 100 year + 20% storm storage.

The ponds will need to be operated with at least the storage volumes highlighted above (1,000-year event) available above the operating water level.

Further contingency measures for extreme events are discussed in Section 3.3 of the main report.

Table A1 2: Rainfall Totals (mm)

Storm Duration (min)	Return Period (years)							
	2	5	10	20	30	50	100	1000
5	2.9	4.6	6.4	7.9	8.8	10.1	11.9	-
10	4.3	7.1	9.9	12.0	13.6	15.5	18.5	-
15	5.4	8.8	11.9	14.9	16.7	19.2	23.1	-
30	7.7	12.2	16.2	20.4	22.9	26.4	31.9	-
60 (1 hour)	10.3	16.7	21.7	26.8	30.0	34.5	41.4	72.6
120 (2 hours)	14.3	21.4	26.7	32.4	36.0	40.9	48.7	85.3
240 (4 hours)	19.1	26.9	32.7	38.8	42.8	48.2	56.6	95.6
360 (6 hours)	22.4	30.6	36.6	43.0	47.2	52.9	61.8	101.8
720 (12 hours)	29.1	38.1	44.7	51.7	56.1	62.4	72.1	113.7
1440 (24 hours)	37.6	47.7	55.0	62.7	67.7	74.5	84.9	128.3

Table A1 3: Flood storage volumes (m^3) for East Ponds

Storm Duration (min)	Return Period (years)							
	2	5	10	20	30	50	100	1000
60 (1 hour)	1,393	2,338	3,068	3,817	4,292	4,953	5,962	10,542
120 (2 hours)	1,861	2,910	3,683	4,520	5,049	5,773	6,915	12,292
240 (4 hours)	2,326	3,474	4,324	5,217	5,802	6,603	7,835	13,565
360 (6 hours)	2,571	3,782	4,657	5,600	6,207	7,056	8,359	14,236
720 (12 hours)	2,835	4,159	5,127	6,156	6,806	7,728	9,153	15,264
1440 (24 hours)	2,644	4,123	5,200	6,336	7,063	8,064	9,593	15,969

Table A1 4: Flood storage volumes (m^3) for West Pond

Storm Duration (min)	Return Period (years)							
	2	5	10	20	30	50	100	1000
60 (1 hour)	2,379	3,976	5,210	6,477	7,280	8,398	10,104	17,847
120 (2 hours)	3,192	4,966	6,273	7,688	8,583	9,807	11,738	20,829
240 (4 hours)	4,025	5,965	7,403	8,913	9,902	11,256	13,340	23,028
360 (6 hours)	4,484	6,531	8,012	9,607	10,633	12,068	14,272	24,208
720 (12 hours)	5,069	7,307	8,944	10,683	11,783	13,341	15,750	26,084
1440 (24 hours)	5,020	7,522	9,343	11,263	12,492	14,184	16,770	27,551

Natural surface water runoff to the Clean Water Pond will not be managed. The ponds will provide a degree of attenuation, but the catchment upstream of these ponds will not be developed and no change in greenfield runoff rates is proposed. Excess water from the Clean Water Pond will be allowed to spill from the pond and will be routed to the Pollanroe Burn.

No attenuation is proposed for surface water runoff diverted around the edges of the mine site through the East Diversion Berm. The catchments flowing to these diversion structures will be undeveloped.

Appendix 2: Process Plant Water Management Memo

canenco

Memo

To:
From:
CC: [redacted]
Date: May 28, 2020
Re: Process Plant Water Management Strategy

Summary

This memo will provide a brief description of the water requirements and sources for the Curraghinalt Mine Process Plant. The key changes from the original process are:

- Removal of on site processing using cyanide. A concentrate will now be prepared and this will be trucked from site for final processing elsewhere.

Process Water Management Strategy

Within the process plant water is required for the following purposes:

- Reagent Mixing (clean water – fresh water sourced from the clean water pond or water treatment plant (WTP)
- Gland Water (clean water – fresh water sourced from clean water pond or WTP)
- Process Water (recycled or mine water) for
    - Grinding
    - Flotation
    - Concentrate Thickening and Filtration
- Tailings Thickening and Filtration
- Tailings Paste Production

Based on the proposed production rate, a freshwater input of approximately 7.2 m^3/hour is required for mixing of reagents and gland water for pump seals. This will be supplied from the Clean Water Pond or treated water from the site WTP.

An input of ~5.7 m^3/hour of mine water is required for general process water to balance system reallocations. Water also enters the process with the feed material at ~3.0m^3/hour.

Water is removed from the system with the concentrate trucked from site at ~0.5 m3/hour, with underground backfill using tailings at ~11.6 m3/hour and tailings sent to the surface Dry Stack Facility (DSF) at ~3.8 m3/hour.

The total water entering the process is ~156.7 m3/hour. External inputs, (clean water, feed moisture and mine water) account for ~15.9 m3/hour, which means that ~140.8 m3/hour is recycled within the system. This water is recovered from the tailings and concentrate thickening and filtration processes, with canenco

Memo

~15.0m3/hour from the concentrate thickener and ~120.1 m3/hour from the tailings thickener and paste plant combined.

The general process water management strategy is to recycle as much water as possible to reduce the requirement for clean water.

Clean water inputs, in order of preference for use in the process plant would be provided from:

1. Water from the WTP, which would be pumped to the Process Plant
2. Water from the Clean Water Pond

The current water management strategy assumes all contact water sources, (including building run-off, DSF run-off, etc...) will be routed to one of the water management ponds on site where it will be treated before use.

Non-fresh water inputs will be sourced from groundwater pumped from the underground mine. The data to date indicates there is sufficient mine water through the life of mine to provide the required inputs to the process.

Clean water is also required for spraying for dust suppression on roads around and within the process plant pad areas. For the Feasibility Study that is current understood to be approximately 10 m^3/hour in summer and 5 m^3/hour in winter.

References

1. 20190628 – DALCUR003 – WB – Rev J.xls