PROJECT

REVISED WATER BALANCE MODELLING, TWEED SAND PLANT EXPANSION, CUDGEN, NEW SOUTH WALES

PREPARED FOR

HANSON CONSTRUCTION MATERIALS PTY LTD

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SYNOPSIS This report describes the methodology and results of revised water balance modelling undertaken for the proposed expansion of the Hanson Construction Material's Tweed Sand Plant located in Cudgen, New South Wales. The revised water balance model was prepared to satisfy relevant aspects of a submission from the Department of Planning Industry and Environment – Water Division and the Natural Resource Access Regulator with respect to surface and groundwater take and licensing.

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SUMMARY

Hanson Construction Materials Pty Ltd (Hanson) commissioned Gilbert & Sutherland Pty Ltd (G&S) to prepare a water balance assessment for the proposed expansion of its Tweed Sand Plant (TSP) located in Cudgen, New South Wales ('the site').

This report updates and supersedes the water balance modelling information presented in G&S's March 2021 report '*Surface Water Assessment, Tweed Sand Plant Expansion, Cudgen, New South Wales'*, which was Appendix B of the Tweed Sand Plant Environmental Impact Statement (EIS) submitted in early 2021.

This report was prepared to address relevant items from NSW Department of Planning, Industry and Environment's (DPIE) 18 June 2021 correspondence titled *Hanson Tweed Sand Plant Expansion (SSD-10398), Environmental Impact Statement (EIS)* with respect to surface and groundwater take and licensing. Specifically, the report addresses item 1.1.1 a) of that correspondence that required the Proponent to:

> *a) define the licensable take of water consistent with that described in the NSW Aquifer Interference Policy (AIP) (2012) and provide a strategy to obtain the entitlement.*

and item 1.2.1 c) ii, which provided the Proponent the opportunity to avoid the need for a surface water entitlement through:

> *ii. redesign of the lakes outlet system to enable them to be detention basins during a flood event and that any water captured can be released immediately after.*

In consideration of the highly connected surface and groundwater environments at the site, and following a comprehensive review of the methodologies adopted for determination of groundwater take across a wide range of industries in NSW, a detailed water balance model was prepared to address the items above.

A revised water balance model was developed for the catchment and resulting lake levels verified against continuously monitored lake water levels over a 16-month period in 2020-2021. Following verification, the water balance model was subsequently used to estimate the anticipated hydrological behaviour of the lake, local

catchment discharge and groundwater exchange for each future phase of the development.

With respect to groundwater take (item 1.1.1 a) of the DPIE Correspondence), the model results indicate that:

- There will be no net annual groundwater take in Phases 1 through to 9 of the development.
- The annual groundwater take is highest in Phase 11, with a licensable quantity of 121 ML/year.
- Groundwater take due to the removal of sand via the dredging process is assessed to be 319ML/yr (318.86ML/year) based on a maximum extraction rate of 950,000 tonnes per annum.

Based on Hanson's current holding of 109ML an additional ~210ML (319ML - 109ML) would be required at the commencement of the Project (Phase 5) to permit immediate dredging at the proposed maximum rate of 950,000 tonnes per annum. When dredging proceeds to Phase 10 and 11 of the Project a further 121ML would be required.

It is noted that the approval for the existing TSP MOD1 approval contains the following condition with respect to water licensing:

> *The Applicant must ensure that it has sufficient water for all stages of the development, and if necessary, adjust the scale of operations under this consent to match its available water supply.*

Under the same or a similar condition attached to the proposed TSP expansion project, approval of the Project prior to purchase of the full volumetric requirement would mean the dredging rate would need to be limited to correspond with the volume of groundwater entitlement held by the operation at that time. Extraction of Phases 10 and 11 could likewise be conditional upon obtaining the requisite entitlement needed for these phases.

With respect to surface water entitlements (item 1.2.1 c) ii of the DPIE Correspondence), the lakes' outlet system was redesigned to allow the basins to approximate the function of a detention basin through all stages of the development such that any water received from external catchments and/or during flood events is not captured by the extraction lakes but rather is released to the receiving environment.

The model results indicate that:

- The hydrological regime with respect to runoff generated in the portion of the catchment external to the site is maintained at the overall catchment discharge point for all phases of the development.
- The weir outlet level for the south lake (incorporating the existing lake) is currently (and will remain) at RL 1.0 mAHD, whilst the outlet weir for the north lake will be constructed at RL 0.5 mAHD.
- With adoption of these outlet characteristics, the lake(s) only capture and store a volume of runoff equal to or less than that which is generated from within the site.
- There is no quantifiable surface water take and therefore need to acquire a surface water entitlement for the development.

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1 Introduction

Hanson Construction Materials Pty Ltd (Hanson) commissioned Gilbert & Sutherland Pty Ltd (G&S) to prepare a water balance assessment for the proposed expansion of its Tweed Sand Plant (TSP) located in Cudgen, New South Wales ('the site').

This report updates and supersedes the water balance modelling information presented in G&S's March 2021 report 'Surface Water Assessment, Tweed Sand Plant Expansion, Cudgen, New South Wales' (Appendix B of the Tweed Sand Plant Environmental Impact Statement (EIS) submitted in early 2021.

This report was prepared to address relevant items from NSW Department of Planning, Industry and Environment's (DPIE) 18 June 2021 correspondence titled '*Hanson Tweed Sand Plant Expansion (SSD-10398), Environmental Impact Statement (EIS)*' with respect to surface and groundwater take and licensing. Specifically, this report addresses item 1.1.1 a) of that correspondence that required the Proponent to:

> *a) define the licensable take of water consistent with that described in the NSW Aquifer Interference Policy (AIP) (2012) and provide a strategy to obtain the entitlement.*

and item 1.2.1 c) ii. Which provided the Proponent with the opportunity to avoid the need for a surface water entitlement through:

> *ii. redesign of the lakes outlet system to enable them to be detention basins during a flood event and that any water captured can be released immediately after.*

This revised report addresses the following to inform our response to the above items:

- quantification of the groundwater exchange into and out of the lake on an annual (water year) basis;
- analysis of the surface water hydrologic regime to demonstrate that there is no take and that all runoff generated external to the site is subsequently discharged to the downstream environmental and not captured or held in the lake.

In respect of item 1.2.1 c) ii, it is noted that as the lakes are wet and permanently contain water, their operation as strict detention basins is not practicable. Irrespective of what outlet system is selected to control discharge with the intent of operating as a detention basin, whenever there is water stored below the lowest detention outlet, there is the potential for this water to leave the lake through both evaporation and seepage at rates which cannot be artificially controlled. These natural processes create available storage below the lowest detention outlet.

When rainfall or runoff next enters the lake, it will first fill up that storage deficit (permanently capturing that volume of water) and only the component of storage above the lowest detention outlet can be immediately released. In fact, the only way to avoid such a storage deficit occurring below the detention outlets and ensure the lake remains full to the lowest outlet at all times would be to drop the detention outlet to below the lowest anticipated groundwater level within the soil store and rely on groundwater ingress to maintain the level in the lake. This would, in turn, cause significant and undesirable groundwater impacts, which also is not practicable.

To address this item, this report presents a solution that demonstrates maintenance of the hydrological regime with respect to runoff generated external to the site. That is, irrespective of how much external catchment runoff enters the lakes, the site has been designed to ensure that the total catchment discharge (on an annualised basis) always remains equal to or higher than the discharge generated from the portion of the catchment external to the site.

The proposed solution ensures that the lake(s) only capture and store a volume of runoff equal to or less than that which is generated from within the site. Accordingly, by implementing the solution described herein, the proposed development requires no surface water entitlement.

1.1 Site surface water management system

Operations at TSP have been designed and are managed to minimise impacts to onsite and offsite surface water environments.

The TSP extraction lake forms a groundwater window. Overburden (material above the sand resource and groundwater table) is removed periodically and stockpiled onsite for later use in site rehabilitation. All extraction below the groundwater table is via dredge, negating the need for any dewatering activities.

For the purpose of acid sulfate soil management, materials extracted from the lake are processed through the site's wash plant with excess water and fines returned to the lake via the fines return pipeline.

There are no offsite water transfers and surface waters in the lake are hydraulically isolated from the external drainage lines under normal (i.e. not flooded) conditions, thereby minimising the potential for offsite impacts. Water required for operational purposes (such as dust suppression) is sourced from the lake to minimise the use of clean (potable) water.

Analysis of surface water quantity management (including site drainage, flooding and water releases) is also provided in the *'Flood and Stormwater Assessment'* (Burchills, 2021).

1.2 Water supply and use

Water is required to be used for dust suppression on the site's internal roads and for other minor onsite uses (such as equipment washdown).

To avoid the use of potable water for operational purposes, water for dust suppression is sourced from the extraction lake with an appropriate licence relevant to the volumetric take in place. The volume of water used for dust suppression is minimised to ensure that ponding of water or the generation of runoff is avoided. Approximate volumes for this water use are provided in the site's water balance.

Since all water extracted during the dredging process is either passively infiltrated as groundwater recharge (in the area of the wash plant) or immediately returned to the lake in solution with the separated fines, any hydraulic losses from the lake and groundwater are limited to evaporation.

The impacts of rainfall and evaporation are considered in the site's water balance. Further consideration of water take due to the extraction of sand via the dredging process is provided in Section 3.4.2 and 4.4.1.

1.3 Climate data analysis

To assess the lake's long term hydrological behaviour, a water balance assessment was performed using meteorological data sourced from the Scientific Information for Land Owners (SILO) climate database, which is hosted by the Queensland Government's *The Long Paddock* website.[1] This online facility generates a climatic profile for a given length of time based on a number of records in the site vicinity.

In the case of the TSP site, the rainfall records date from 1889 to the present. Evaporation records commenced in 1970 (with numerically generated daily averages used prior to that time).

The water balance model used 51.5 years of data from 1 January 1970 to 30 June 2021. Annual reporting statistics were based on water years (from 1 July to 30 June) as this correlated with the return period for ongoing annual reporting and corresponds with a 'water year'.[2] The initial 6 months of the model (1 January to 30 June 2020) were excluded from the calculation of annual reporting statistics.

Table 1.3.1 (on the following page) provides statistics for the daily time-step rainfall and evaporation data used in the model.

[1] https://www.longpaddock.qld.gov.au/silo/

[2] A water year starts on 1 July and ends on 30 June in the following year.

Table 1.3.1 Annual rainfall and evaporation statistics for model dataset

	Rainfall (mm)	Evaporation (mm)
Minimum	967	1,295
5th percentile	1,019	1,348
20th percentile	1,245	1,446
Median	1,758	1,535
80th percentile	2,196	1,652
95th percentile	2,492	1,707
Maximum	3,319	1,778
Average	1,742	1,529

On average, rainfall exceeds evaporation, however the rainfall depth in any given year is much more variable than the evaporation.

A more detailed analysis of the meteorological records on a monthly basis indicates that evaporation generally exceeds rainfall for the months of July through to January, with a relative excess in precipitation occurring between February and June.

It must be noted that these qualifications are based on medians derived from the long-term data and the rainfall can be higher or lower than the evaporation in any given month.

Table 1.3.2 presents net rainfall-evaporation differential statistics for each calendar month within the dataset.

Table 1.3.2 Net monthly rainfall and evaporation differential (mm) for model dataset

Month	20th percentile	Median	80th percentile
July	-63	-18	62
August	-100	-59	8
September	-126	-86	-37
October	-120	-56	5
November	-112	-50	29
December	-122	-45	84
January	-96	-11	113
February	-61	40	210
March	-41	37	212
April	-47	30	155
May	-25	54	156
June	-24	21	133
Total	-359	334	770

The data indicates that for any given calendar month, evaporation exceeds rainfall in at least 20 percent of years and, similarly, rainfall exceeds evaporation in at least 20 percent of years (with the exception of September where rainfall only exceeds evaporation in 7 percent of years).

2 Water balance model description and overview

A spreadsheet-based water balance model was established to characterise the anticipated long-term hydrological behaviour of the lake and surrounding surface and groundwater environments, including:

- fluctuations in the lake water surface level and storage volume;
- frequency and size of overflow events;
- evaporative losses;
- total catchment discharge;
- groundwater (soil moisture store) levels; and
- groundwater exchange.

An initial (existing case) model was set up up to represent current site conditions and to allow for estimation of seepage behaviour through verification of the modelled water level against continuous lake level data recorded with an onsite data logger between March 2020 and July 2021.

Following quantification of suitable seepage rates, a long-term model was established for the entire 51 water year period for which climate data is available. This model was then used to examine the anticipated hydrological behaviour for each of the eight phases of lake expansion works.

Sections 2.1 to 2.3 provide a summary of the algorithms used in the water balance model calculations and Section 2.4 provides details of each of the inputs and elements used in those calculations.

2.1 Lake surface water balance

The model adopted a simple algorithm to calculate changes in the volume of water stored in the lake on a daily basis:

$$V_{end} = V_{ini} + V_{sin} - V_{sout} - V_{ev} + V_{ra} + V_{ro} - V_{use} - V_{over}$$

where:

V_{end}	=	End day stored volume
V_{ini}	=	Initial volume
V_{sin}	=	Seepage into lake
V_{sout}	=	Seepage out of lake
V_{ev}	=	Evaporation
V_{ra}	=	Direct rainfall on lake
V_{ro}	=	Catchment surface runoff into lake
V_{use}	=	Site water usage
V_{over}	=	Lake overflow

For modelling purposes, the lake has been assumed to be a closed loop with respect to inflows, and that no daily external flows into the lake occur, with the exception of direct runoff from the local contributing catchment. In practice, this means the water balance does not take into consideration large flood events where the surrounding land floods and fills the lake to capacity.

2.2 Groundwater level estimation

The model estimates changes to the groundwater level using an algorithm to calculate the soil moisture storage level on a daily basis:

$$h_{end} = h_{ini} + h_{inf} - h_{etrans} - h_{sin} + h_{sout} - h_{decay}$$

where:

h_{end}	=	End day soil moisture storage level
h_{ini}	=	Initial soil moisture storage level
h_{inf}	=	Soil moisture level change from rainfall infiltration
h_{etrans}	=	Soil moisture level change from evapotranspiration
h_{sin}	=	Seepage into lake
h_{sout}	=	Seepage out of lake
h_{decay}	=	Decay in soil moisture storage level to equilibrate with Tweed River

The groundwater store is an open system and is hydraulically connected to the Tweed River.

2.3 Infiltration and surface runoff

For rainfall on land areas within the model catchment, it has been assumed that all water will infiltrate into the soil moisture store until it becomes saturated. Any excess rainfall will generate surface runoff draining either to the lake or to the catchment discharge point.

The depth of rainfall that infiltrates into the soil is calculated by:

$$P_{inf} = MIN[P_{tot}, (h_{max} - h_{ini}) \times p_o]$$

where:

P_{inf}	=	Precipitation lost as infiltration
P_{tot}	=	Total precipitation
h_{max}	=	Maximum soil moisture storage level (at saturation)
h_{ini}	=	Initial soil moisture storage level
p_o	=	Soil porosity

The depth of rainfall that generates surface runoff is subsequently calculated by:

$$P_{ro} = P_{tot} - P_{inf}$$

where:

P_{ro}	=	Depth of runoff
P_{tot}	=	Total precipitation
P_{inf}	=	Precipitation lost as infiltration

3 Model inputs and assumptions

3.1 Lake and catchment properties

3.1.1 Lake geometry

The existing lake area for the verification model was measured from a June 2020 Nearmap image of the site. For each development phase, the lake-full area was estimated from the development Concept Plan (Drawing No. Z19163-F119 prepared by Zone Planning Group and included in Appendix 1).

For both the verification model and each development phase, the lake was modelled with a constant area throughout the range of active storage depths. Whilst it is acknowledged that the lake internal batters will not be vertical, sensitivity testing within the model indicated that the assumption of a constant area has no material impact on modelling outcomes.

As the lake depths are variable, for modelling purposes, a total depth of 2.0 m below full storage was included as this covers the full range of anticipated water surface variation during the 51 year model period. As such the modelled lake volumes are the storage volume above this reference level, rather than the total volume of water contained within the lake.

Based on an analysis of 16 months of surface water logger data collected in the lake, it has been estimated that the existing lake holds water up to an elevation of RL 1.0 mAHD. Accordingly, this has been adopted as the existing overflow weir level for the southern lake. It has been assumed that the overflow weir for the southern lake will remain at the elevation for all phases of the development.

For the northern lake (commencing in Phase 10), an overflow weir level of RL 0.5 mAHD has been adopted in order to achieve the optimal outcome with reference to maintenance of the existing hydrological regime.

Table 3.1.1.1 shows the modelled lake full areas adopted for each phase of development.

Table 3.1.1.1 Lake areas for each development phase

Phase	South lake area (ha)	North lake area (ha)	Total lake area (ha)
Existing	29.8	-	29.8
Phases 1-4	39.0	-	39.0
Phase 5	72.9	-	72.9
Phase 6	101.5	-	101.5
Phase 7	113.2	-	113.2
Phase 8	130.8	-	130.8
Phase 9	154.5	-	154.5
Phase 10	154.5	20.3	174.8
Phase 11	154.5	43.4	197.9

It is noted that in Phases 10 and 11, a separate northern lake is formed. For these phases, the lake area for the southern lake remain the same as for Phase 9 and the table presents the areas for the northern lake as well as total areas for both lakes. Details of the stage-storage relationship for each lake phase is tabulated in Appendix 2.

Stage-storage relationships derived for each development phase are included in Appendix 3.

3.1.2 Catchment areas

The overall catchment area for water balance modelling purposes was taken from the Burchills Engineering Solutions 'Flood and Stormwater Assessment' (October 2021) and comprises an area of approximately 688 hectares (ha). Whilst the catchment area draining to the lake varies from phase to phase, this total area allows for a consistent comparison of catchment discharge to be made across all phases of the development.

The total catchment area comprises a site area of 236 ha and an external catchment area of 452 ha. For surface water licensing purposes, runoff generated from the external catchment (whether contributing to the lake or not) needs to be maintained at the overall catchment discharge point, whereas runoff generated within the site can (and will) be impacted by the expansion of the lake.

The existing lake is surrounded by discontinuous bunding, and thus a small additional catchment area may contribute surface runoff to the lake. As the southern lake expands to the south, diversion drains for a portion of the external catchment to the southeast of the southern lake will be consumed by the lake itself and this catchment will contribute runoff to the lake from Phase 6 onwards.

For each development phase, the contributing catchment for the southern lake has been determined in reference to the catchment plans in Burchills *'Flood and Stormwater Assessment'* and available LiDAR survey throughout the expansion area.

The northern lake (in Phases 10 and 11) has been assumed to be fully isolated from external catchment runoff (with the exception of regional flood flows not addressed by the water balance). The only surface water entering the north lake is direct rainfall on the lake itself.

Table 3.1.2.1 shows the modelled catchment areas draining to and bypassing the lake for each phase of development. It is noted that in Phases 10 and 11, a separate northern lake is formed. For these phases, the catchment areas for the southern lake remain the same as for Phase 9 and the table presents the areas for the northern catchment as well as total areas for both lakes.

3.1.3 Lake discharge and overflow

There is no formal bunding surrounding the existing lake and none is proposed throughout the expansion of the southern lake or for the northern lake in the later phases of the project. Both lakes are proposed to be constructed with 10-metre wide weir outlets to permit discharge to the receiving environment. The weir outlet level for the south lake (incorporating the existing lake) is currently and will remain at RL 1.0 mAHD, whilst the outlet weir for the north lake will be constructed at RL 0.5mAHD.

Lake discharge was assumed to occur when the daily water level (following all other inputs and outputs) exceeds the full storage level (set by the respective lake weir outlet levels). Whilst no formal bunding will contain water above this level, an analysis of the weir flow capacity indicates that the weir for each lake has sufficient capacity to discharge any water entering the lake up to depths of at least 0.3 m above the lake surface, within 24 hours.

Given that the bunding is discontinuous and the lake will quickly spill in multiple locations in addition to the weir, it is reasonable to assume that both lakes will be able to release any water (generated within the local catchment) in excess of their full storage capacity within 24 hours. This does not necessarily include regional floodwaters passing across the lake which the water balance

Table 3.1.2.1 Lake catchment areas for each development phase

Phase	South lake catchment area (ha)	North lake catchment area (ha)	Total lakes catchment area (ha)	Catchment area bypassing lakes (ha)
Existing	45.3	-	45.3	642.3
Phases 1-4	45.3	-	45.3	642.3
Phase 5	86.9	-	86.9	600.7
Phase 6	167.8	-	167.8	519.7
Phase 7	179.1	-	179.1	508.5
Phase 8	196.8	-	196.8	490.8
Phase 9	218.6	-	218.6	469.0
Phase 10	218.6	20.3	239.0	448.7
Phase 11	218.6	43.4	262.0	425.6

model does not address. Accordingly, given the daily timestep of the model, it has been assumed that all water entering the lake will discharge and the water level drop back to the weir level within a single model timestep.

3.2 Rainfall and runoff

3.2.1 Rainfall and evaporation

Rainfall directly onto the lake and evaporation from the lake surface were adopted from the climate data described in Section 1.3.

3.2.2 Catchment runoff

Surface runoff depths were calculated using the method described in Section 2.3. For each phase, separate runoff calculations were undertaken for:

- The catchment draining to the south lake
- The catchment bypassing the lake(s) to calculate total catchment discharge.
- The entire external catchment (whether contributing to the lake or not) for comparison to the total catchment discharge.

3.3 Groundwater properties

3.3.1 Soil moisture store

The soil moisture store (SMS) has been modelled with a flat grade throughout the entire catchment, i.e. a single groundwater level has been adopted across the entire catchment and the model does not estimate local drawdown in the immediate vicinity of the lake nor does it consider the influence of higher ground levels at the upstream limits of the local catchment. The SMS is topped up by infiltration from rainfall on the catchment surface and drawn down by evapotranspiration and by seepage to the Tweed River via a network of existing agricultural drains. Groundwater seepage into and out of the lake has been included in the model to examine its influence on the lake hydrology, however the influence of this seepage on the soil store is negligible.

The bottom of the modelled SMS has been set at 0.1 mAHD (limited by the hydraulic influence of the Tweed River) and 1 mAHD (the full storage level of the lake). The top of the modelled SMS has been set at RL1.0 mAHD, which corresponds within the full storage level of the existing and much larger southern lake. Much of the land within the catchment lies around this RL and exhibits localised areas of surface water ponding following rain.

3.3.2 Infiltration

The primary mechanism for topping up the SMS is through infiltration from rainfall on the catchment surface. The porosity of the soils within this zone has been assumed to be 0.3. Consequently, for every 10 mm of rainfall, the SMS will rise by 30 mm until it reaches saturation, at which point surface runoff is generated.

3.3.3 Evapotranspiration

Evapotranspiration from the SMS was calculated using the FAO56 evapotranspiration depths from the SILO dataset described in Section 1.3. Similar to the infiltration, the evapotranspiration was required to be scaled by the porosity to determine its influence on the SMS. Furthermore, it was assumed that evapotranspiration can only draw down 95% of the SMS, such that the limiting depth to which evapotranspiration can occur was set at 0.145 mAHD.

3.3.4 Seepage to the Tweed River

The Tweed River is a major influence on the near surface groundwater level in the vicinity of the site. When the soil moisture store is high (following rainfall), the hydraulic grade between the groundwater table and the surface water levels in the agricultural drainage network and the Tweed River itself, will drive seepage from the groundwater table to the drains and eventually the river as the system attempts to reach a natural equilibrium. This results in a gradual lowering (or decay) of the groundwater level overtime, limited by the water levels in the drains and river.

The Tweed River is tidal, with a Mean Sea Level in the vicinity of the site being approximately 0.1mAHD. The agricultural drainage network is connected to the Tweed River through tidal gates, meaning that the water level in the drains can drop to the bottom of the tide and not refill as the tide rises. Mean Low Water in the vicinity of the site is approximately -0.2mAHD. Accordingly, it is anticipated that during direr periods, the groundwater would form a dynamic equilibrium with the river system at around -0.2 to 0.1 mAHD.

The decay rate was initially estimated[3] and iteratively adjusted to achieve verification of the modelled behaviour against field data. A rate of 0.003 m/day was adopted in the model.

3.3.5 Seepage into and out of the lake

The lake is a groundwater window and seepage can occur both into and out of the lake, depending on the hydraulic grade between the lake water level and the surrounding groundwater level.

To determine whether seepage was occurring either into or out of the lake, the modelled groundwater level was compared to the modelled lake level on the same day.

Where the groundwater level was higher than the lake, the height of seepage interface (for seepage into the lake) was assumed to be equal to 20 percent of the difference in water levels. Where the lake was higher than the groundwater level, the seepage interface (for seepage out of the lake) was assumed to be 50 percent of the difference in water levels. These differing assumptions for the height of the seepage interface reflect the differing nature of the phreatic surface within the soils store when the flows are being driven by either the groundwater or the surface water body, and were derived iteratively through the model verification process.

The surface area over which seepage occurs has been calculated using the product of the lake perimeter and the height of the seepage interface.

A seepage rate of 9 m/day (or 375 mm/hour) was adopted based on the sandy nature of the soils.

3.3.6 Initial lake and groundwater conditions

Surface and groundwater levels have been monitored at the site monthly by TSP since 2008. From this data, the average of recorded lake levels is 0.381 mAHD, this was adopted as the initial lake level in the model. For each groundwater bore that has been in operational throughout the entire monitoring period, an average groundwater level was calculated, and subsequently an overall average groundwater level across all bores was calculated to be 0.368 mAHD, which was adopted as the initial groundwater level in the model.

Notwithstanding the above estimates, it is noted that the first 6 months of the model period (January to June 1970) has been excluded from reporting outcomes and is considered sufficient to account for any model start-up effects.

3.4 Site operations

3.4.1 Site water usage

During Phases 1 to 6, while the processing plant remains in its current location, a daily reuse volume of 24kL has been applied for watering of internal roads for dust suppression when the daily rainfall is up to 25 mm. If the daily rainfall exceeds 25 mm, it has been assumed that dust suppression water would not be required. This water use is incorporated into the water balance model.

From Phase 7 onwards, once the plant has been relocated, the site's internal roads will be sealed and therefore water for dust suppression of these roads will no longer be required.

3.4.2 Water entrained in the dredging process

The TSP expansion proposes a sand extraction rate of 950,000 tonnes per annum which equates to 487,180 m^3 of insitu sand per annum.[4]

The dredger utilised at TSP operates on a sand to water ratio of 1:3 (i.e. 25% sand to 75% water) with the product stream flowing to the onshore hydrocyclone for processing and continual return of the entrained water to the extraction lake.

If 487,180 m^3 of sand is processed through the dredge/hydrocyclone each year, three times as

[3] Initial estimates based on review of available information and information contained in the following reference;
Juan Enciso, Assistant Professor and Extension Specialist; Xavier Peries, Extension Associate; Luis A. Ribera, Assistant Professor and Extension Economist; and Dean Santistevan, Field Engineer (USDA-NRCS, Colorado) *'Understanding and Installing Drainage Systems.*

[4] The field geologists handbook provides an insitu bulk density for sand of 1.95g/cm^3 which equates to 1.95t/m^3.

much water must be involved in the process equating to 1,461,538 m³ of water. This equates to 1,462 ML of water cycled from the lake to the hydrocyclone and back to the lake in the sand extraction process. As this water is immediately returned to the lake, it has been excluded from the modelling, however the groundwater drawn into the lake due to sand extraction is accounted for in Section 4.4.1.

The water entrained in the dredging process is a combination of lake water (accumulated over previous years) and groundwater drawn into the lake to replace extracted sand. The continuous process of extraction and return (and the relatively small influence of the dredge compared to the size of the lake system) means that the dredging process avoids groundwater drawdown.

Groundwater drawn into the lake to replace the extracted sand removed via dredge is included in the calculation of overall take. Lake water entrained in the dredging process should not be included as groundwater take as this represents double-accounting for the intake of water that occurred (and was licenced to occur) in the previous year.

4 Results and discussion

4.1 Existing case model verification

As noted in Section 2, an existing case model was established to characterise the hydrological response of the lake to rainfall, to estimate suitable parameter to represent groundwater behaviour in the model and to verify those results against recorded lake level data from 3 March 2020 to 5 July 2021.

The existing case model was run over a shorter modelling period, from 1 January 2000 to 5 July 2021. Only the results corresponding to the period of logger data were used for model verification, however the longer timeframe was modelled to minimise the influence of any numerical effects of initial conditions applied to the model.

It is noted that, whilst monthly lake levels have been recorded on site since 2008, model verification over a longer period was not undertaken. This was due to the dynamic nature of the onsite operations, such that the landform (lake and catchment areas) adopted in the model differs in extent from that which would have been in place when the historical records were collected. Given these considerations, comparing model results based on the current landform against field results from previous and varying landforms is not an appropriate verification tool.

A comparison of the recorded and modelled lake water levels as well as the modelled groundwater level is provided in Figure A3.1 (in Appendix 3).

In addition to a visual comparison of modelled water levels to the surface water logger data, verification of the hydraulic interaction between the lake and groundwater table was undertaken through a review of the modelled lake and groundwater levels at times corresponding with potentiometric plots of field levels collected between May and October 2020. A copy of the potentiometric plots is included in Appendix 4.

In reference to each monitoring round represented in the potentiometric plots, the lake and groundwater levels were extracted from the model on the date(s) of the monitoring. From this, average lake and groundwater levels were calculated corresponding with each monitoring round to determine whether the model was indicating active seepage into or out of the lake at the time of monitoring. Table 4.1.1 presents the modelled levels and a comparison of the flow direction to that seen in the potentiometric plots.

In general, there is a reasonable match between the modelled flow direction and that indicated on the potentiometric plots. The only exception is on 11-12 August, where the model predicts a higher groundwater level than the lake level (driving seepage into the lake) whilst the potentiometric plot indicates seepage out of the lake.

Table 4.1.1 Comparison of modelled flow regime to potentiometric plots

	Water balance model			Potentiometric
Monitoring date(s)	Average lake level (mAHD)	Average groundwater level (mAHD)	Flow direction	Flow direction
6-7 May 2020	0.75	0.61	Out of lake	Out of lake
17-18 June 2020	0.67	0.65	Out of lake	Out of lake
16 July 2020	0.63	0.59	Out of lake	Out of lake
11-12 August 2020	0.75	0.86	Into lake	Out of lake
26-27 August 2020	0.69	0.66	Out of lake	Out of lake
9-10 September 2020	0.62	0.54	Out of lake	Out of lake
22 September 2020	0.57	0.49	Out of lake	Out of lake
7-8 October 2020	0.41	0.23	Out of lake	Out of lake

The water balance indicates the groundwater level is higher than the lake level from 25 July 2020 to 23 August 2020 (inclusive).

The SILO rainfall data used for the water balance indicates the following daily rainfall totals from 24-27 July 2020, respectively: 25.2, 30.7, 79, 14.1 – a total of 149mm over 4 days which pushed the groundwater level from 0.52mAHD (23 July) to 0.99 mAHD (on 27 July 2020) – almost saturating the soil store but just insufficient to generate runoff in the model. A further 18.7mm was recorded over 7-8 August, further topping up the soil store and maintaining the modelled groundwater level higher than the lake.

The logger did pick up a corresponding increase in lake level at the same time, confirming there was rainfall in the local catchment at that time (rather than something in the SILO data that did not occur at the site), however the jump in the logger level was less than the jump in the modelled lake water level so it is possible the rainfall event at the site was less than that in the SILO data and the modelled response in terms of ground and lake levels is more than the physical response at the site.

If this was the case, the observed groundwater levels may have peaked lower and dropped sooner than the model indicates, and as such the outward flow regime could have restored itself sooner. (Note: after commencement of modelling in May 2020, we don't get a consistent regime of flow into the lake for an extended period again until mid-December 2020 following a much more substantial rainfall event).

Notwithstanding this difference, and based on the review described above, the model is considered to provide a reasonable representation of the physical response of the lake and groundwater to climatic influences and of the interaction between the lake and surrounding groundwater table.

4.2 Water balance model results

The water balance model was run for the 51 year model period for each of the development phases previously described in Section 3.1. Key results of the model across each development phase are described in the following sections.

4.2.1 Lake water level fluctuations

The modelled long term lake levels for each phase of the development are presented on Figures A3.2 to A3.9 (in Appendix 3). Table 4.2.1.1 presents statistics on the range of anticipated lake levels for each phase of the development. Note that these statistics have been calculated based on the water level the lake would reach each day prior to any discharge or overflow.

The median modelled water level in the southern lake is anticipated to remain relatively steady through to its completion in Phase 9, though the estimated range of water levels in the lake will increase by the time the south lake is completed.

Table 4.2.1.1 Modelled lake water surface elevation statistics

Development Phase	Water surface elevation (mAHD)							
	Minimum	5th %ile	20th %ile	Median	80th %ile	95 %ile	Maximum	Average
Phases 1-4	-0.23	0.00	0.15	0.50	0.84	0.98	1.38	0.49
Phase 5	-0.30	-0.01	0.15	0.49	0.86	0.98	1.41	0.49
Phase 6	-0.35	-0.02	0.16	0.50	0.89	0.99	1.60	0.50
Phase 7	-0.36	-0.02	0.16	0.51	0.89	0.99	1.57	0.50
Phase 8	-0.36	-0.02	0.16	0.51	0.88	0.99	1.55	0.50
Phase 9	-0.37	-0.01	0.16	0.51	0.88	0.99	1.51	0.50
Phase 10 (south)	-0.38	-0.02	0.15	0.48	0.86	0.99	1.50	0.49
Phase 10 (north)	-0.22	0.02	0.15	0.44	0.50	0.51	0.89	0.35
Phase 11 (south)	-0.39	-0.02	0.15	0.47	0.85	0.98	1.50	0.48
Phase 11 (north)	-0.31	-0.01	0.14	0.41	0.50	0.51	0.89	0.33

Once construction of the northern lake commences, the water levels in the southern lake will drop by up to 0.04 m as the north lake expands (this is likely due to a local depression in the groundwater elevation as a result of the northern lake full storage level being 0.5 m lower than the southern lake).

The median modelled water level in the northern lake is approximately 0.04 to 0.06 m lower than the southern lake. This is primarily a result of the lower weir outlet level set for the north lake, however the absence of any external catchment draining to the north lake may also be a factor.

4.2.2 Groundwater level fluctuations

The modelled long term groundwater levels for each phase of the development are also presented on Figures A3.2 to A3.9 (in Appendix 3). Table 4.2.2.1 presents statistics on the range of anticipated groundwater levels throughout each phase of the development to provide a basis for estimating the impact of the development on groundwater levels within the catchment.

Similar to the water levels in the southern lake, the median modelled groundwater level remains relatively stable throughout the southern lake expansion up to the completion of Phase 9.

As construction of the lower northern lake takes place in Phases 10 and 11, the median groundwater level is anticipated to reduce by up to 0.05 m. This can be attributed to the lower design full storage level in the northern lake resulting in some localised groundwater drawdown. (Note: separate groundwater modelling has been undertaken to better quantify both the extent and magnitude of this drawdown.)

4.2.3 Frequency and extent of lake discharge

Table 4.2.3.1 provides a summary of the number and percentage of model years during which any lake discharge occurs, the total number of days of discharge throughout the 51 year model period and the average number of days of discharge for years in which it occurs.

Table 4.2.3.1 Lake discharge behaviour

Phase	No. of model years discharge occurs	Percent of years discharge occurs	Total no. of discharge days	Average discharge days in discharge years
1-4	23	45.1 %	263	11.4
5	24	47.1 %	286	11.9
6	28	54.9 %	388	13.9
7	27	52.9 %	386	14.3
8	27	52.9 %	378	14.0
9	27	52.9 %	370	13.7
10 (north)	25	49.0 %	346	13.8
10 (total)	49	96.1 %	6,162	125.8
11 (north)	25	49.0 %	330	13.2
11 (total)	49	96.1 %	4,572	93.3

Table 4.2.2.1 Modelled groundwater elevation statistics

Development Phase	Groundwater elevation (mAHD)							
	Minimum	5th %ile	20th %ile	Median	80th %ile	95 %ile	Maximum	Average
Phases 1-4	0.09	0.12	0.16	0.54	0.88	0.98	0.99	0.53
Phase 5	0.08	0.12	0.16	0.54	0.88	0.98	1.00	0.53
Phase 6	0.08	0.12	0.17	0.55	0.88	0.98	1.00	0.53
Phase 7	0.08	0.12	0.17	0.55	0.88	0.98	1.00	0.54
Phase 8	0.07	0.12	0.17	0.55	0.88	0.98	1.00	0.54
Phase 9	0.06	0.12	0.17	0.55	0.88	0.98	1.00	0.54
Phase 10	0.05	0.12	0.17	0.51	0.86	0.97	1.00	0.52
Phase 11	0.04	0.12	0.16	0.50	0.85	0.97	1.00	0.51

The model results indicate that discharge from the south lake is predicted to occur in approximately 50 percent of years (or every second year) throughout the entire life of the development and continuing after completion when the lakes are in their final form. For each year when there is some discharge, the average number of days of active discharge is 11-14 days.

The north lake, with its lowered weir outlet, will discharge much more frequently and in almost all (96%) years. There is only an absence of discharge during the driest years. During discharge years, the north lake will spill much more frequently, with discharge occurring for between 93 and 126 days per year – or 1 in every 3 to 4 days.

At times when discharge from the lake does occur, the volume of discharge from the site is highly variable, based on the size of the rainfall event and the lake condition prior to the event (influenced by rainfall in the preceding month. However, anecdotally a trend may be observed that suggests that as the lake increases so does the volume of overflow lost from the lake. Furthermore, during the larger discharge events related to significant rainfall events, it is likely that such events may result in localised flooding, that may add additional flows into the lake that are not represented by the water balance model. These additional flows will still discharge from the lake as set by the weir height.

Table 4.2.3.2 shows the average annual volume of discharge (over all model years) for comparison to surface water inflows (rainfall and runoff) to the lake. As the lake increases in area, the volume of lake discharge will increase.

It is important to note that these results only represent lake discharge volumes, not overall catchment discharge. Overall catchment discharge and maintenance of the external catchment hydrological regime is discussed separately in Section 4.3.

During expansion of the southern lake (Phases 1-9), discharge over the weir accounts for 9 to 16 percent of all surface water inflows to the lake. Once construction of the northern lake commences, this increases to approximately 20 percent across both lakes in Phases 10 and 11.

4.2.4 Lake surface evaporation

The climate data analysis presented in Section 1.3 shows that, on average, annual rainfall depths exceed annual evaporation depths at the site.

Table 4.2.4.1 (following page) compares the average annual volume of evaporation to the lake's average annual surface water inflows (rainfall and runoff).

Table 4.2.3.2 Average annual lake discharge volumetric results

	Lake discharge (ML)			Surface water inflows (ML)			Lake discharge as proportion of surface inflows (%)		
Phase	South lake	North lake	Total	South lake	North lake	Total	South lake	North lake	Total
1-4	64	-	64	704	-	704	9 %	-	9 %
5	128	-	128	1,325	-	1,325	10 %	-	10 %
6	333	-	333	2,034	-	2,034	16 %	-	16 %
7	350	-	350	2,237	-	2,237	16 %	-	16 %
8	375	-	375	2,544	-	2,544	15 %	-	15 %
9	405	-	405	2,948	-	2,948	14 %	-	14 %
10	376	240	616	2,932	354	3,276	13 %	68 %	19 %
11	361	384	745	2,924	756	3,680	12 %	51 %	20 %

Table 4.2.4.1 Average annual evaporation

Phase	Evaporation (ML)			Surface water inflows (ML)			Evaporation as proportion of surface inflows (%)		
	South lake	North lake	Total	South lake	North lake	Total	South lake	North lake	Total
1-4	598	-	598	704	-	704	85 %	-	85 %
5	1,119	-	1,119	1,325	-	1,325	84 %	-	84 %
6	1,559	-	1,559	2,034	-	2,034	77 %	-	77 %
7	1,738	-	1,738	2,237	-	2,237	78 %	-	78 %
8	2,009	-	2,009	2,544	-	2,544	79 %	-	79 %
9	2,373	-	2,373	2,948	-	2,948	80 %	-	80 %
10	2,373	312	2,685	2,932	354	3,276	81 %	88 %	82 %
11	2,373	667	3,040	2,924	756	3,680	81 %	88 %	83 %

Across all future phases of the development, evaporation accounts for approximately 77 to 85 percent of all rainfall and runoff entering the southern lake and just under 90 percent of rainfall and runoff entering the northern lake.

When considering both lake evaporation and surface water discharge together, these account for 93 to 94 percent of all surface water inflows to the southern lake across all phases. The remaining inflows leave the lake via seepage into the soil moisture store, indicating that the south lake is and will remain a net groundwater recharge window throughout all phases of the project.

From Phase 10 onwards, discharge and evaporation are equivalent to 139 to 156 percent of all surface water inflows, indicating that the additional discharge is coming from groundwater seeping into the northern lake. Overall, for Phases 10 and 11, discharge and evaporation together exceed surface water inflows by approximately 3 percent, meaning there will be a small groundwater take once the northern lake is constructed.

4.3 Overall surface water hydrology

To address surface water licensing requirements, estimates of water take (if any) need to be quantified. For this purpose, surface water take would be defined as the capture of runoff generated external to the site without its subsequent release to the downstream receiving environment. The modelling has been used to quantify annual runoff volumes generated within the catchment but external to the site and compare these to the overall catchment discharge. Any deficit between the total catchment discharge and the runoff generated external to the site would be considered as a take, requiring the appropriate licence.

Of the overall 688 ha catchment, 452 ha is external to the site. For each phase of the development, Table 4.3.1 details the average annual volume of runoff from the external catchment for comparison to the average annual total catchment discharge.

Table 4.3.1 Comparison of average annual external catchment runoff to total catchment discharge

Phase	External catchment runoff (ML)	Total catchment discharge (ML)
Phases 1-4	1,801	2,519
Phase 5	1,799	2,521
Phase 6	1,815	2,502
Phase 7	1,815	2,393
Phase 8	1,812	2,344
Phase 9	1,807	2,282
Phase 10	1,695	2,478
Phase 11	1,640	2,290

The results above show that, on average, the hydrological regime with respect to runoff from the external catchment is maintained and there is no take. Appendix 5 presents the results for each Water Year in the model for each phase and demonstrates that maintenance of the external catchment hydrology is achieved for all model years and that there is no surface water take.

4.4 Quantification of groundwater exchange

The lake exists in a dynamic state with the surrounding groundwater environment, meaning there is almost constant seepage occurring either into or out of the lake depending on the hydraulic grade between the lake and the groundwater table. To address groundwater licensing, we have calculated the net volume of groundwater seeping into the lake for each year (i.e. the annual groundwater take) within the model period (where a negative value indicates the lake is operating as a recharge window).

Table 4.4.1 provides the average annual groundwater take and the corresponding 95% confidence interval surrounding that value for each development phase. The results confirm that during expansion of the existing southern lake (up to Phase 9), the lake will act as a net groundwater recharge window.

Table 4.4.1 Estimated annual groundwater take

Phase	Average (ML)	95 % CI (ML)	95 % CI limits (ML)
Phases 1-4	-30	± 38	-68, 8
Phase 5	-63	± 67	-130, 4
Phase 6	-123	± 87	-210, -36
Phase 7	-136	± 96	-232, -40
Phase 8	-145	± 110	-245, -35
Phase 9	-153	± 128	-281, -25
Phase 10	30	± 124	-94, 154
Phase 11	121	± 126	-5, 247

The regime changes when extraction commences in the northern lake for Phase 10 and 11. Based on this, the maximum licensable take across all phases of the development with respect to seepage into the lake is 121 ML.

4.4.1 Groundwater take due to removal of sand

Groundwater take due to removal of sand via the dredging process can be accounted for through the inclusion of the volume of groundwater that would theoretically enter the lake to replace the volume previously consumed by the sand. This calculation is shown in Table 4.4.1.1. It shows that with a net annual extraction of approximately 455,512 m³ and a sand porosity of ~30%, the groundwater take due to removal of sand via the dredging process would approximate 319 ML/yr (318.86 ML per annum).

Table 4.4.1.1 Groundwater take due to removal of sand

Annual extraction (tonnes)	Insitu Bulk density	Cubic metres	Fines (returned to lake) m³	Balance extracted (m³)	Assuming Porosity (30%)	ML
950,000	1.95[5]	487,179.49	31,666.67	455,512.82	318,858.97	318.86

[5] Berkman, D.A (Compiled and Edited by). Field Geologists' Manual Fourth Edition – 2001 published by The Australasian Institute of Mining & Metallurgy .

5 Licensable groundwater take

The existing Tweed Sand Plant and proposed expansion area is located within the Tweed Brunswick Coastal Sands (TBCS) of the Tweed Coastal Sands Groundwater Management Area (GMA). Environmental water is accessed via licensed entitlements through the North Coast Coastal Sands Groundwater Source Water Sharing Plan (WSP).

The TBCS groundwater source encompasses the far North Coast of NSW, from Tweed Heads to the north and Suffolk Park to the south. Groundwater is accessed primarily for domestic use via spear pump extraction. The TSP site and proposed development footprint are located within an area with groundwaters considered to be of high environmental value.

The North Coast Coastal Sands Groundwater Source Water Sharing Plan (WSP) sets an upper extraction limit in the Tweed-Brunswick Coastal Sands (TBCS) source at 21,750 ML/year[6], and indicates that at the time of publication of the WSP, the total current water requirements for this source were 713 ML/yr.[7]

The WSP provides consideration of future water requirements including sand mining developments which are common within this GMA. It sates:

> *Based on the potential for significant development in the future, it is recommended that a significant allocation for future sand mining developments is required. The future dewatering requirements for sand mining have been estimated by DPI Water licensing and hydrology staff based on local knowledge of current and future potential for sand mining along the north coast.*

The WSP details the estimated future water requirements for sand mining operations in this GMA to be in the order of 5,000ML/yr.[8]

TSP currently holds an allocation of 109ML/yr in the TBCS source for groundwater interference/ take commensurate with the scale of its existing (pre MOD1) operation. Expansion of the operation and the proposed increase in extraction rate will necessitate an application for an additional volumetric share within the TBCS and an application for an additional Water Access Licence under the Water Management Act 2000.[9]

The volumetric requirements for groundwater licensing of the proposed TSP expansion are quantified in this revised water balance model report. The calculations indicate that:

- During expansion of the existing southern lake (up to Phase 9), the lake will act as a net groundwater recharge window.
- The surface-groundwater regime changes when extraction commences in the northern lake for Phases and 11. For these Phases groundwater seepage into the lake results in a maximum licensable take of 121 ML.
- Groundwater take due to the removal of sand via the dredging process equates to approximately 318.86ML per annum.

This equates to a total licensable groundwater take of ~ 440 ML required to complete the proposed expansion. As TSP currently holds an allocation of 109ML in the TBCS source, a further 331 ML would need to be purchased and licenced to allow for completion of the proposed development at the maximum extraction rate proposed.

5.1 Strategy for obtaining the required entitlement

Under the *Water Sharing Plan for the North Coast Coastal Sands Groundwater Sources 2016,* there are currently two pathways for the purchase of a groundwater allocation within the Tweed Brunswick Groundwater Source:

1. Controlled Allocation Order; and
2. Market-based trading of access licences and water allocations ('Open Market').

[6] Table 7 of the WSP.
[7] Table 8 of the WSP.
[8] Table 9 of the WSP.
[9] Water Management Act, NSW Government. 2000.

The most recent controlled allocation for the Tweed Brunswick Groundwater Source was held in mid 2020. If the regulator determines that this groundwater source has remaining sustainable, unallocated capacity, then another Controlled Allocation is likely be held.

At the time of preparation of this report no information was available as to the likelihood or timing of a further Controlled Allocation Order in this aquifer.

The last Controlled Allocation Order was gazetted on 29 May 2020. At that time there was 793 ML available for purchase. It is reasonable to assume that water would have been purchased from this aquifer during the controlled allocation and that less water would now be available in any subsequent rounds.

Water can also be purchased through the open market provided there is a water holder wishing to sell their allocation.

5.1.1 Proposed approach

The existing TSP operation holds Water Access Licences for a total of 109 ML, which is commensurate with the 150,000 m^3 insitu (or ~292,500 tonnes) extraction limit stated in the Development Consent issued for the project in 2006. In 2018, MOD1 for the TSP operation was approved permitting an increase in extraction up to ~256,400 m^3 insitu (or ~ 500,000 tonnes) with the condition that:

> *The Applicant must ensure that it has sufficient water for all stages of the development, and if necessary, adjust the scale of operations under this consent to match its available water supply.*

In accordance with this condition, Hanson has and will continue to extract at a rate commensurate with its current water licence allocation of 109ML until such time as an additional allocation has been purchased.

Hanson has engaged the services of a water broker to explore options for purchase of water from existing allocation holders. At the time of preparation of this report, negotiations were ongoing regarding a potential purchase of up to 100ML of groundwater in the Tweed Brunswick Groundwater Source. The water broker's work will continue in the area to source additional entitlements with the aim of incrementally increasing Hanon's water holding up to the required maximum.

Whilst information as to if/when a further Controlled Allocation will be announced for this groundwater source was not available at the time of preparation of this report, it is Hanson's intention to purchase any remaining water requirements through this process when the opportunity arises.

With respect to groundwater take (item 1.1.1 a) of the DPIE Correspondence), the model results indicate that:

- For Phases 1 to 4 (existing approved operation) and proposed Phases 5 to 9 the lake behaves as a groundwater recharge window.
- For these phases groundwater take is commensurate with the rate of sand extraction with a volume of ~319ML/yr (318.86ML) required to achieve the maximum extraction rate of 950,000 tonnes per annum[10].
- For phases 10 and 11 the surface-groundwater regime changes. For these phases net groundwater seepage into the lake results in an additional licensable take of 121 ML per annum. This additional allocation would not be required until commencement of extraction in Phases 10 and 11 (years 23 to 30 of the proposed development).

Based on Hanson's current holding of 109ML an additional ~210ML (319ML - 109ML) would be required at the commencement of the Project (Phase 5) to permit immediate dredging at the proposed maximum rate of 950,000 tonnes per annum. When dredging proceeds to Phase 10

[10] If the extraction rate is less, the volume of groundwater take would also be less and thus the extraction rate would necessarily be limited by the allocation held.

and 11 of the Project a further 121ML would be required. It is proposed that a similar Condition (as contained in MOD1) could be applied to the TSP expansion proposal such that, should the Project be approved prior to purchase of the full volumetric requirement, the dredging rate would need to be limited to correspond with the volume of groundwater entitlement held by the operation at that time.

6 Conclusions

A revised water balance model was developed for the catchment and resulting lake levels verified against continuously monitored lake water levels over a 16-month period in 2020-2021. Following verification, the water balance model was subsequently used to estimate the anticipated hydrological behaviour of the lake, local catchment discharge and groundwater exchange for each future phase of the development. With respect to groundwater take (item 1.1.1a) of the DPIE Correspondence) the model results indicate that;

- There will be no net annual groundwater take in Phases 1 through to 9 of the development.
- The annual groundwater take is highest in Phase 11, with a licensable quantity of 121 ML/year.
- Groundwater take due to the removal of sand via the dredging process is assessed to be approximately 319 ML/yr (318.86 ML/year) based on a maximum extraction rate of 950,000 tonnes per annum.

Based on Hanson's current holding of 109ML an additional ~210ML (319ML - 109ML) would be required at the commencement of the Project (Phase 5) to permit immediate dredging at the proposed maximum rate of 950,000 tonnes per annum. When dredging proceeds to Phase 10 and 11 of the Project a further 121ML would be required.

It is noted that the approval for the existing TSP MOD1 approval contains the following condition with respect to water licensing;

> *The Applicant must ensure that it has sufficient water for all stages of the development, and if necessary, adjust the scale of operations under this consent to match its available water supply.*

The same (or similar) condition could reasonably be applied to the proposed TSP expansion project such that should the Project be approved prior to purchase of the full volumetric requirement, the dredging rate would need to be limited to correspond with the volume of groundwater entitlement held by the operation at that time. Extraction of Phases 10 and 11 could likewise be conditional upon obtaining the additional entitlement needed for these phases.

With respect to surface water entitlements (item 1.2.1 c) ii of the DPIE Correspondence), the lakes outlet system has been redesigned to allow the basins to approximate the function of a detention basin through all stages of the development such that any water received from external catchments and/or during flood events is not captured by the extraction lakes but rather is released to the receiving environment. The model results indicate that:

- The hydrological regime with respect to runoff generated in the portion of the catchment external to the site is maintained at the overall catchment discharge point for all phases of the development.
- The weir outlet level for the south lake (incorporating the existing lake) is currently and will remain at RL 1.0 mAHD, whilst the outlet weir for the north lake will be constructed at RL 0.5 mAHD.
- With adoption of these outlet characteristics the lake(s) only capture and store a volume of runoff equal to or less than that which is generated from within the site.
- There is no quantifiable surface water take and therefore no need to acquire a surface water entitlement for the development.

7 Appendix 1 – Drawings

PROJECT TITLE

HANSON TWEED SAND PLANT EXPANSION PHASE 5 TO PHASE 11

ENVIRONMENTAL IMPACT STATEMENT

DRAWING TITLE

FIGURE 19: EXTRACTION PHASES

REV	DESCRIPTION	DATE	DRAWN	DESIGN	CHECK	APPROVED
A	PHASING ARRANGEMENT CHANGES - REQ. PLANNER	25/01/2021	ZP	LN	LN	LN
B	PHASING ARRANGEMENT CHANGES - REQ. PLANNER	15/10/2021	MS	LN	LN	LN

ISSUE: PRELIMINARY

CLIENT: HANSON CONSTRUCTION MATERIALS PTY LTD

BASE PROVIDED BY: SIXMAPS DCDB

MANAGER: LANCE NEWLEY

ZONE PLANNING GROUP

GOLD COAST
1638 Tweed Street, Burleigh Heads QLD 4220
PO Box 3805, Burleigh Town QLD 4220

GLADSTONE
2/172 Goondoon St, Gladstone, QLD 4680
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JOB / DRAWING NO: Z19163- F119

SHEET NO. SHEET 17 OF 21

PROJECT TITLE

HANSON TWEED SAND PLANT EXPANSION PHASE 5 TO PHASE 11

ENVIRONMENTAL IMPACT STATEMENT

DRAWING TITLE

FIGURE 20: SITE LAYOUT

REV	DESCRIPTION	DATE	DRAWN	DESIGN	CHECK	APPROVED
A	PRELIMINARY ISSUE	17/03/21	ZP	LN	LN	LN
B	PRELIMINARY ISSUE	15/10/21	MS	LN	LN	LN

ISSUE: PRELIMINARY

CLIENT: HANSON CONSTRUCTION MATERIALS PTY LTD

BASE PROVIDED BY: SIXMAPS DCDB

MANAGER: LANCE NEWLEY

ZONE PLANNING GROUP

GOLD COAST
1638 Tweed Street, Burleigh Heads QLD 4220
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JOB / DRAWING NO: Z19163- F120

SHEET NO. SHEET 18 OF 21

8 Appendix 2 – Lake stage storage details

Table A2.1 South lake properties – existing lake form

Parameter	Value
Lake surface area	29.83 ha
Lake perimeter	2417 m²
Elevation (mAHD)	Storage volume (above RL -1.0 mAHD) (ML)
-1.00	0
-0.75	75
-0.50	149
-0.25	224
0.00	298
0.25	373
0.50	447
0.75	522
1.00	597
2.00[a]	895

[a] Note: Lake does not contain water to this level. It has been included in the model to estimate peak water levels that would be reached prior to discharge, if storage above the weir was constrained to the lake area.

Table A2.2 South lake properties – Phases 1-4

Parameter	Value
Lake surface area	38.96 ha
Lake perimeter	2,746 m²
Elevation (mAHD)	Storage volume (above RL -1.0 mAHD) (ML)
-1.00	0
-0.75	97
-0.50	195
-0.25	292
0.00	390
0.25	487
0.50	584
0.75	682
1.00	779
2.00[a]	1,169

[a] Note: Lake does not contain water to this level. It has been included in the model to estimate peak water levels that would be reached prior to discharge, if storage above the weir was constrained to the lake area.

Table A2.3 South lake properties – Phase 5

Parameter	Value
Lake surface area	72.85 ha
Lake perimeter	3,689 m²
Elevation (mAHD)	**Storage volume (above RL -1.0 mAHD) (ML)**
-1.00	0
-0.75	182
-0.50	364
-0.25	546
0.00	729
0.25	911
0.50	1,093
0.75	1,275
1.00	1,457
2.00[a]	2,186

[a] Note: Lake does not contain water to this level. It has been included in the model to estimate peak water levels that would be reached prior to discharge, if storage above the weir was constrained to the lake area.

Table A2.4 South lake properties – Phase 6

Parameter	Value
Lake surface area	101.50 ha
Lake perimeter	4,307 m²
Elevation (mAHD)	**Storage volume (above RL -1.0 mAHD) (ML)**
-1.00	0
-0.75	254
-0.50	508
-0.25	761
0.00	1,015
0.25	1,269
0.50	1,523
0.75	1,776
1.00	2,030
2.00[a]	3,045

[a] Note: Lake does not contain water to this level. It has been included in the model to estimate peak water levels that would be reached prior to discharge, if storage above the weir was constrained to the lake area.

Table A2.5 South lake properties – Phase 7

Parameter	Value
Lake surface area	113.19 ha
Lake perimeter	4,773 m²
Elevation (mAHD)	**Storage volume (above RL -1.0 mAHD) (ML)**
-1.00	0
-0.75	283
-0.50	566
-0.25	849
0.00	1,132
0.25	1,415
0.50	1,698
0.75	1,981
1.00	2,264
2.00[a]	3,396

[a] Note: Lake does not contain water to this level. It has been included in the model to estimate peak water levels that would be reached prior to discharge, if storage above the weir was constrained to the lake area.

Table A2.6 South lake properties – Phase 8

Parameter	Value
Lake surface area	130.84 ha
Lake perimeter	5,521 m²
Elevation (mAHD)	**Storage volume (above RL -1.0 mAHD) (ML)**
-1.00	0
-0.75	327
-0.50	654
-0.25	981
0.00	1,308
0.25	1,635
0.50	1,963
0.75	2,290
1.00	2,617
2.00[a]	3,925

[a] Note: Lake does not contain water to this level. It has been included in the model to estimate peak water levels that would be reached prior to discharge, if storage above the weir was constrained to the lake area.

Table A2.7 South lake properties – Phases 9, 10 and 11

Parameter	Value
Lake surface area	154.52 ha
Lake perimeter	6,692 m²
Elevation (mAHD)	Storage volume (above RL -1.0 mAHD) (ML)
-1.00	0
-0.75	386
-0.50	773
-0.25	1,159
0.00	1,545
0.25	1,931
0.50	2,318
0.75	2,704
1.00	3,090
2.00[a]	4,635

[a] Note: Lake does not contain water to this level. It has been included in the model to estimate peak water levels that would be reached prior to discharge, if storage above the weir was constrained to the lake area.

Table A2.8 North lake properties – Phase 10

Parameter	Value
Lake surface area	20.33 ha
Lake perimeter	1,821 m²
Elevation (mAHD)	Storage volume (above RL -1.0 mAHD) (ML)
-1.00	0
-0.75	51
-0.50	102
-0.25	152
0.00	203
0.25	254
0.50	305
0.75	356
1.00[a]	407

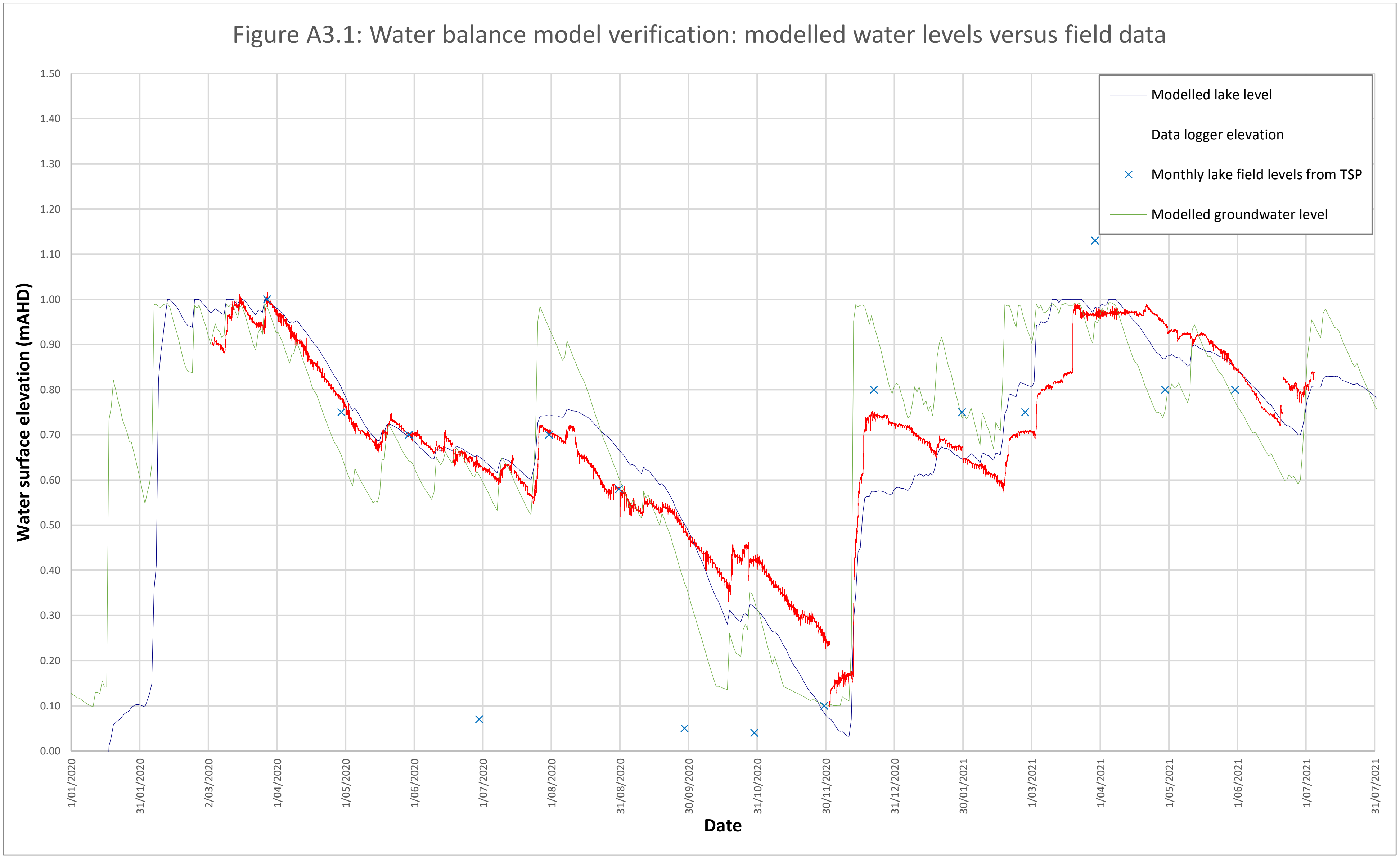
[a] Note: Lake does not contain water to this level. It has been included in the model to estimate peak water levels that would be reached prior to discharge, if storage above the weir was constrained to the lake area.

Table A2.9 North lake properties – Phase 11

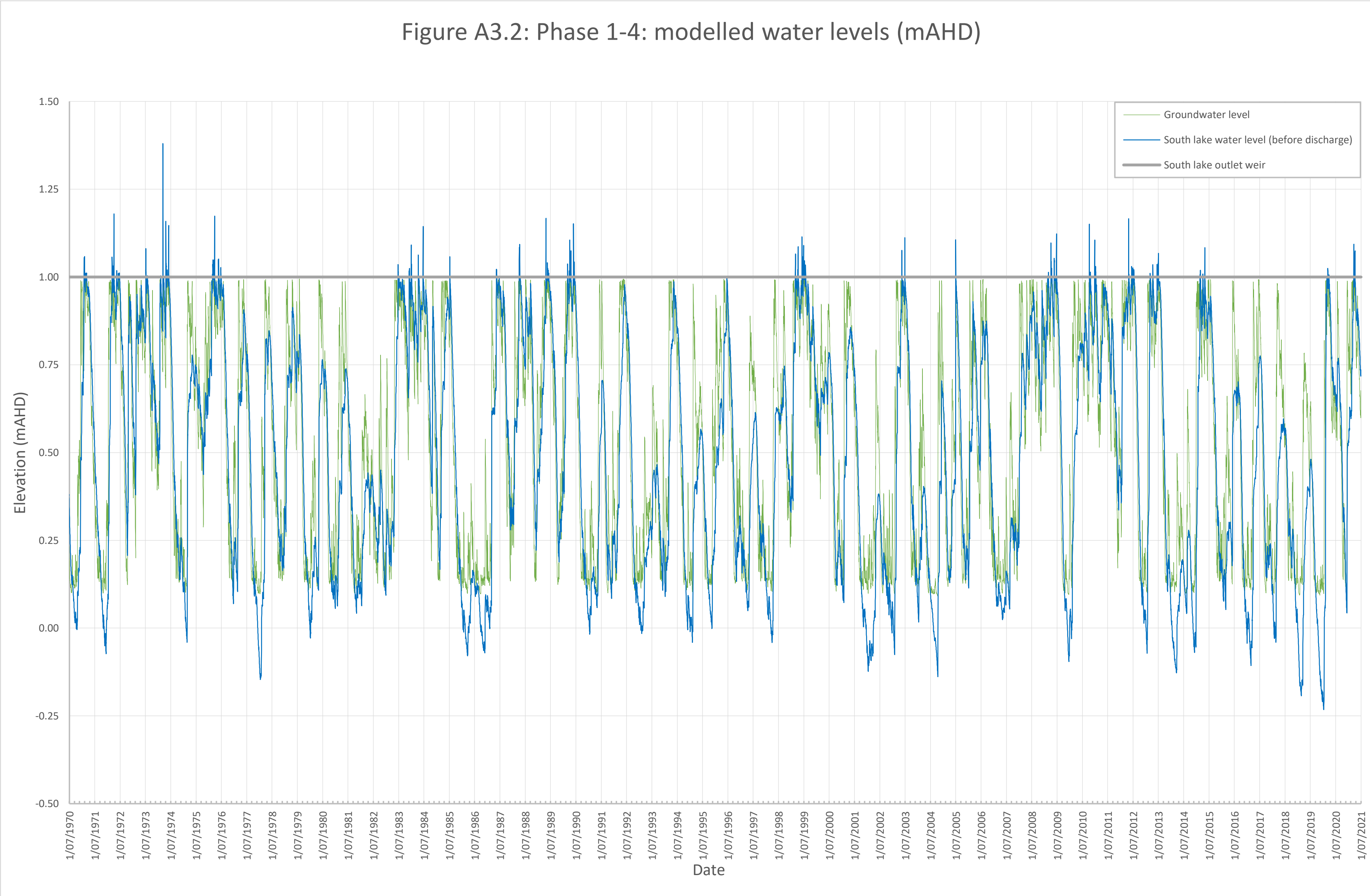
Parameter	Value
Lake surface area	43.40 ha
Lake perimeter	2,628 m²
Elevation (mAHD)	**Storage volume (above RL -1.0 mAHD) (ML)**
-1.00	0
-0.75	108
-0.50	217
-0.25	325
0.00	434
0.25	542
0.50	651
0.75	759
1.00[a]	868

[a] Note: Lake does not contain water to this level. It has been included in the model to estimate peak water levels that would be reached prior to discharge, if storage above the weir was constrained to the lake area.

9 Appendix 3 – Water surface elevation plots



12035_LakeWaterBalance_v8_Calibration_Phase0_20210928.xlsx



12035_LakeWaterBalance_v8_20210928_Phase1-4.xlsx

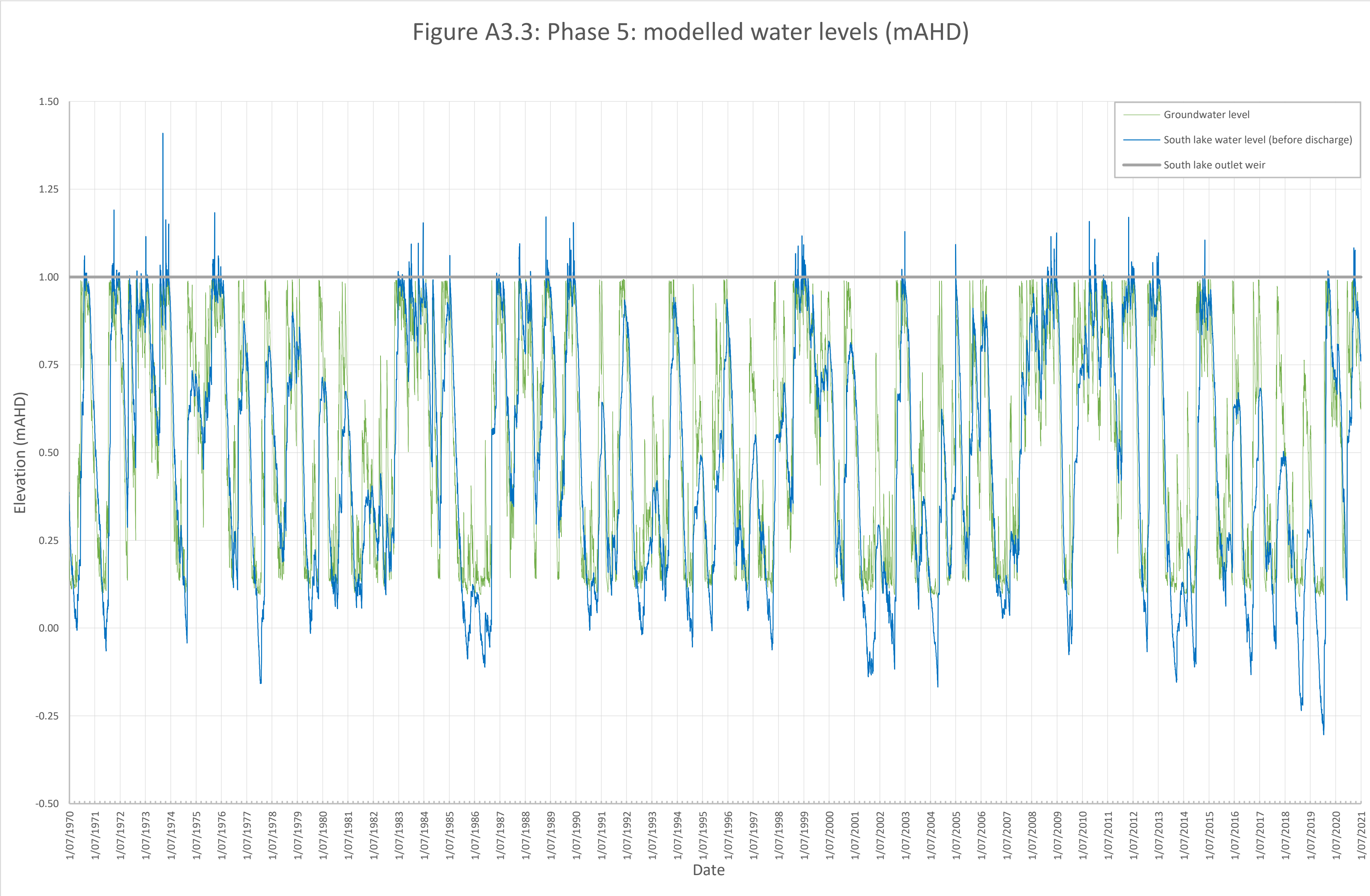


Figure A3.3: Phase 5: modelled water levels (mAHD)
1.50
1.25
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
Elevation (mAHD)
Groundwater level
South lake water level (before discharge)
South lake outlet weir
1/07/1970
1/07/1971
1/07/1972
1/07/1973
1/07/1974
1/07/1975
1/07/1976
1/07/1977
1/07/1978
1/07/1979
1/07/1980
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1/07/2010
1/07/2011
1/07/2012
1/07/2013
1/07/2014
1/07/2015
1/07/2016
1/07/2017
1/07/2018
1/07/2019
1/07/2020
1/07/2021
Date

GILBERT SUTHERLAND

Figure A3.4: Phase 6: modelled water levels (mAHD)

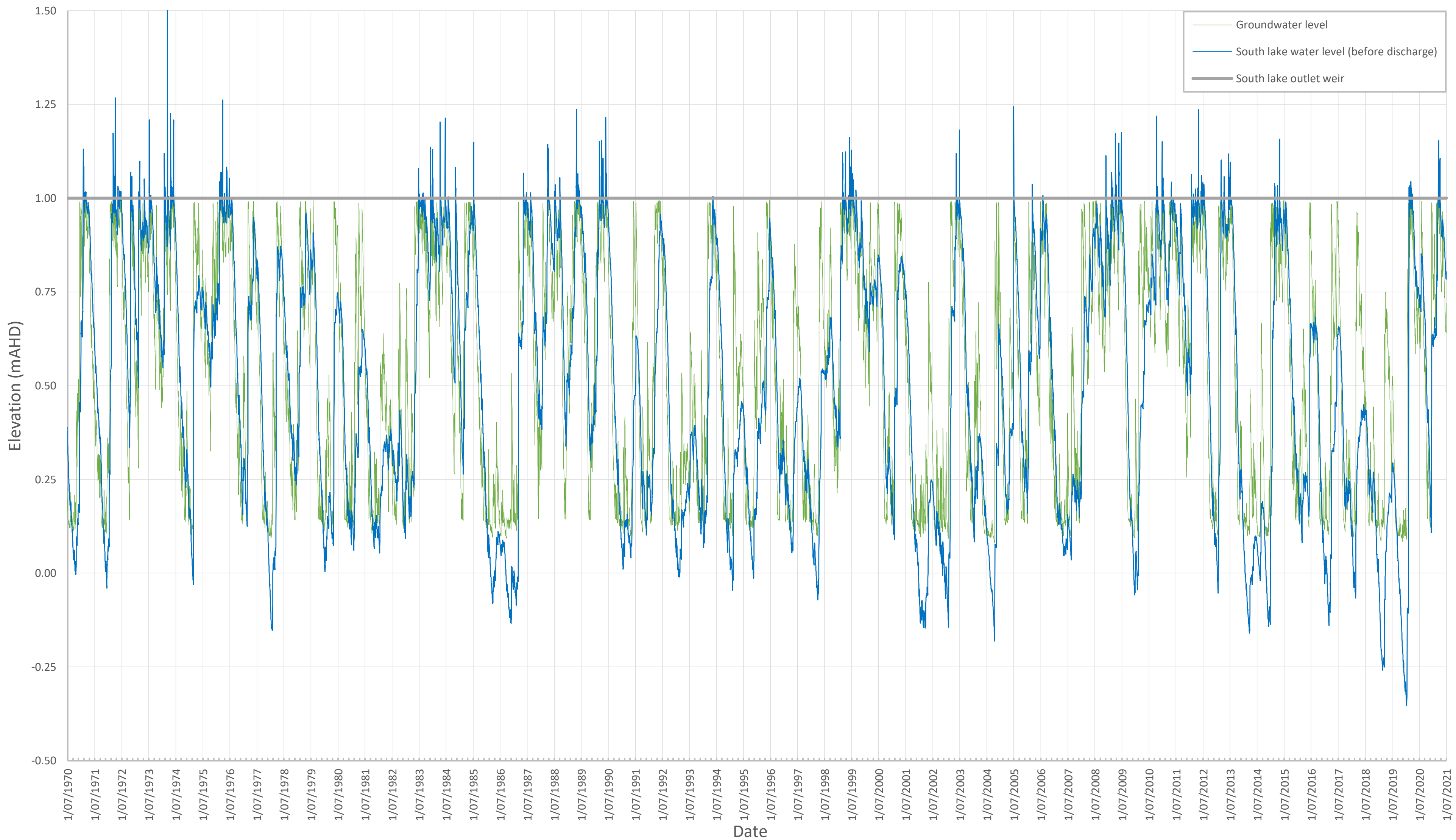
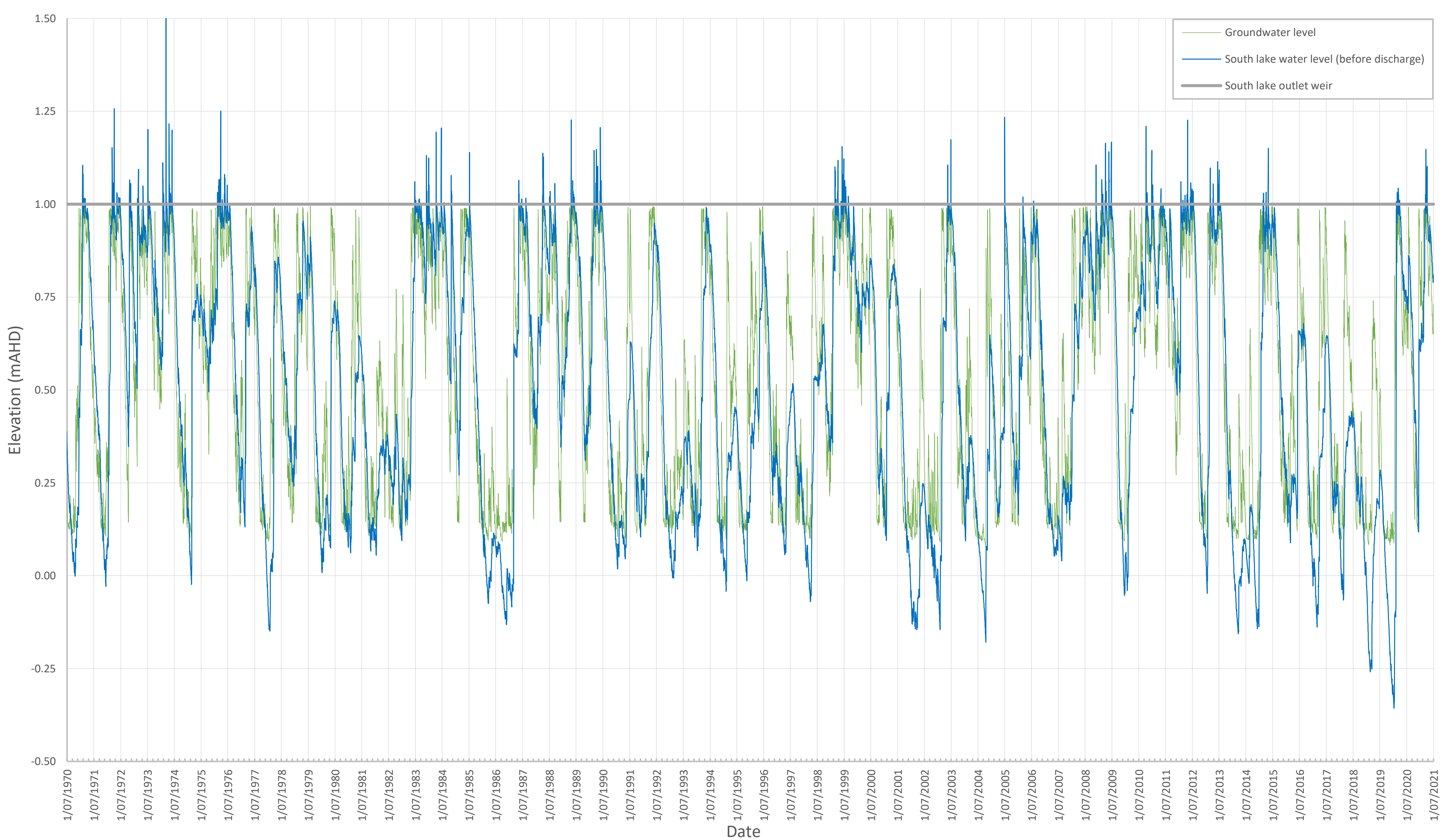


Figure A3.5: Phase 7: modelled water levels (mAHD)



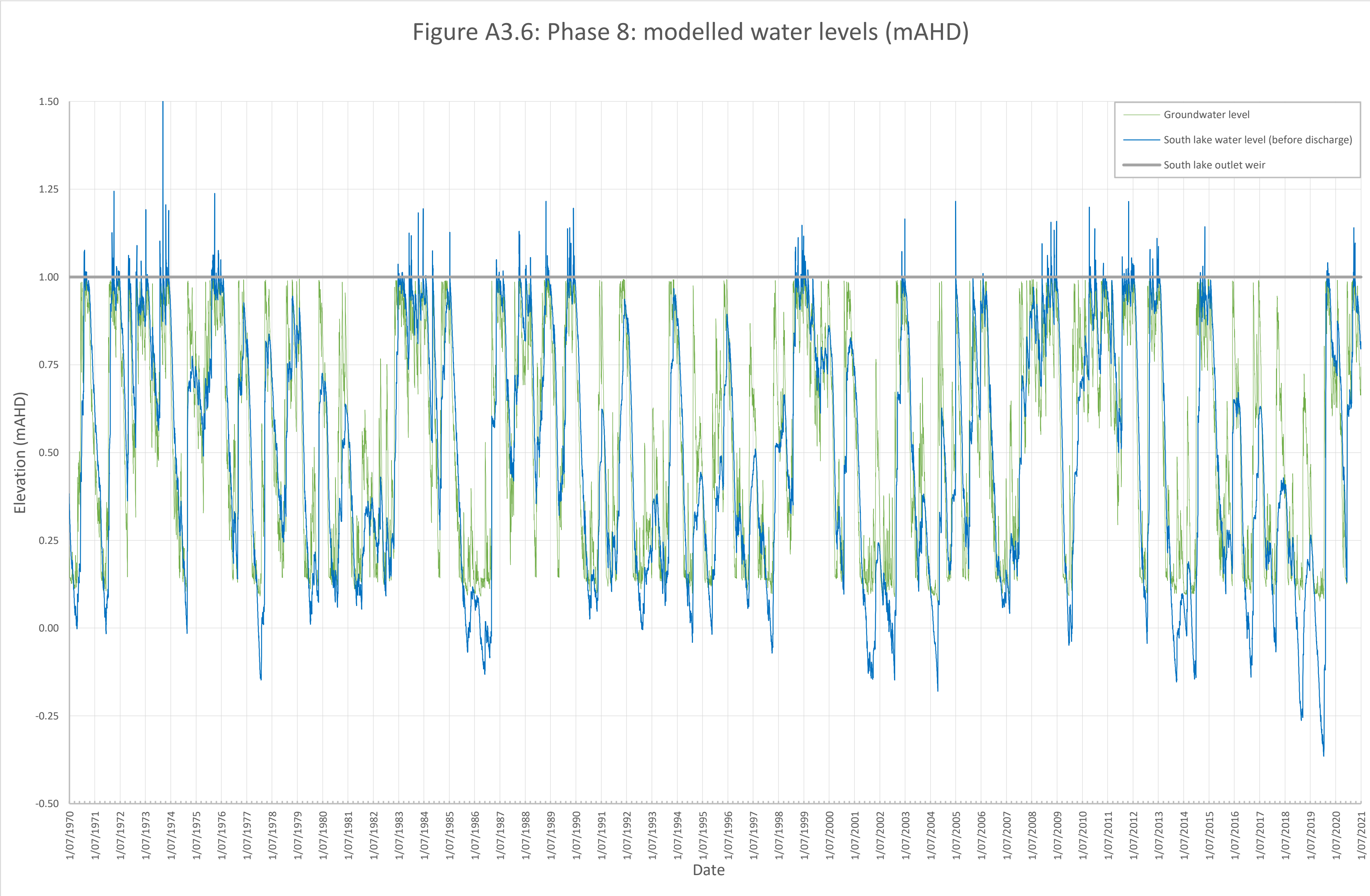


Figure A3.6: Phase 8: modelled water levels (mAHD)
Groundwater level
South lake water level (before discharge)
South lake outlet weir
Elevation (mAHD)
1.50
1.25
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
Date
1/07/1970
1/07/1971
1/07/1972
1/07/1973
1/07/1974
1/07/1975
1/07/1976
1/07/1977
1/07/1978
1/07/1979
1/07/1980
1/07/1981
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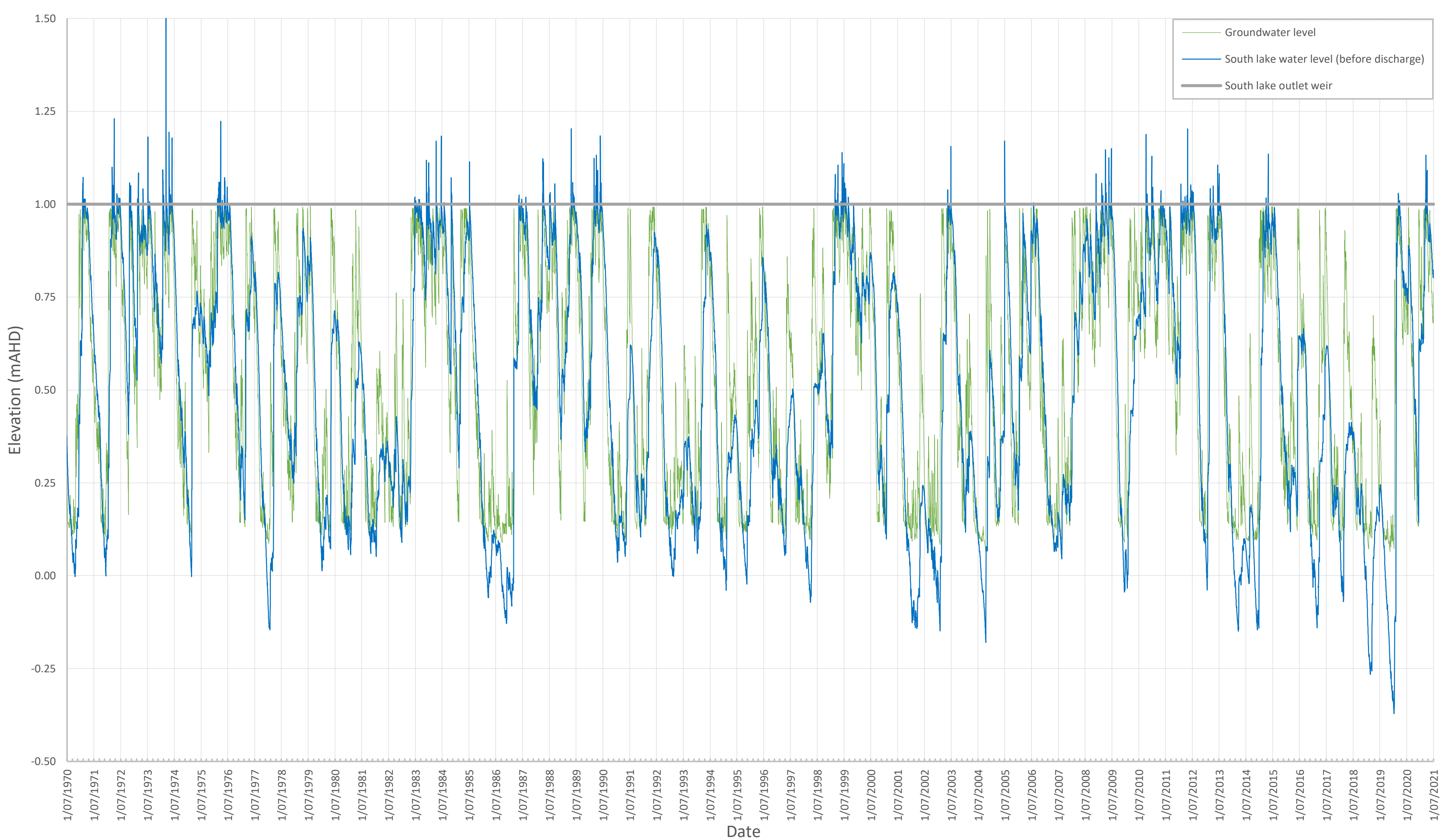
1/07/2011
1/07/2012
1/07/2013
1/07/2014
1/07/2015
1/07/2016
1/07/2017
1/07/2018
1/07/2019
1/07/2020
1/07/2021

Figure A3.7: Phase 9: modelled water levels (mAHD)



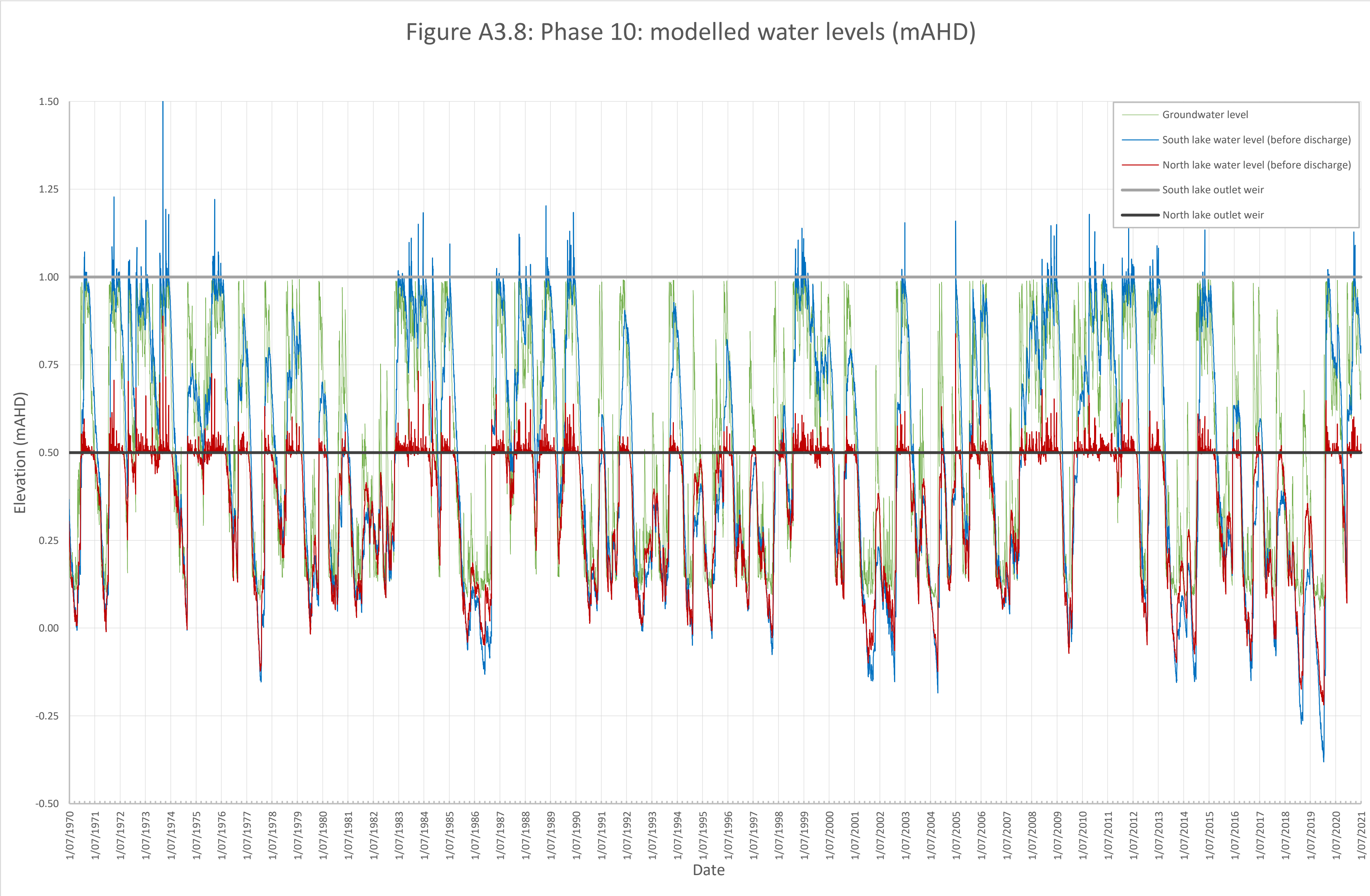


Figure A3.8: Phase 10: modelled water levels (mAHD)
Groundwater level
South lake water level (before discharge)
North lake water level (before discharge)
South lake outlet weir
North lake outlet weir
Elevation (mAHD)
1.50
1.25
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
Date
1/07/1970
1/07/1980
1/07/1990
1/07/2000
1/07/2010
1/07/2021

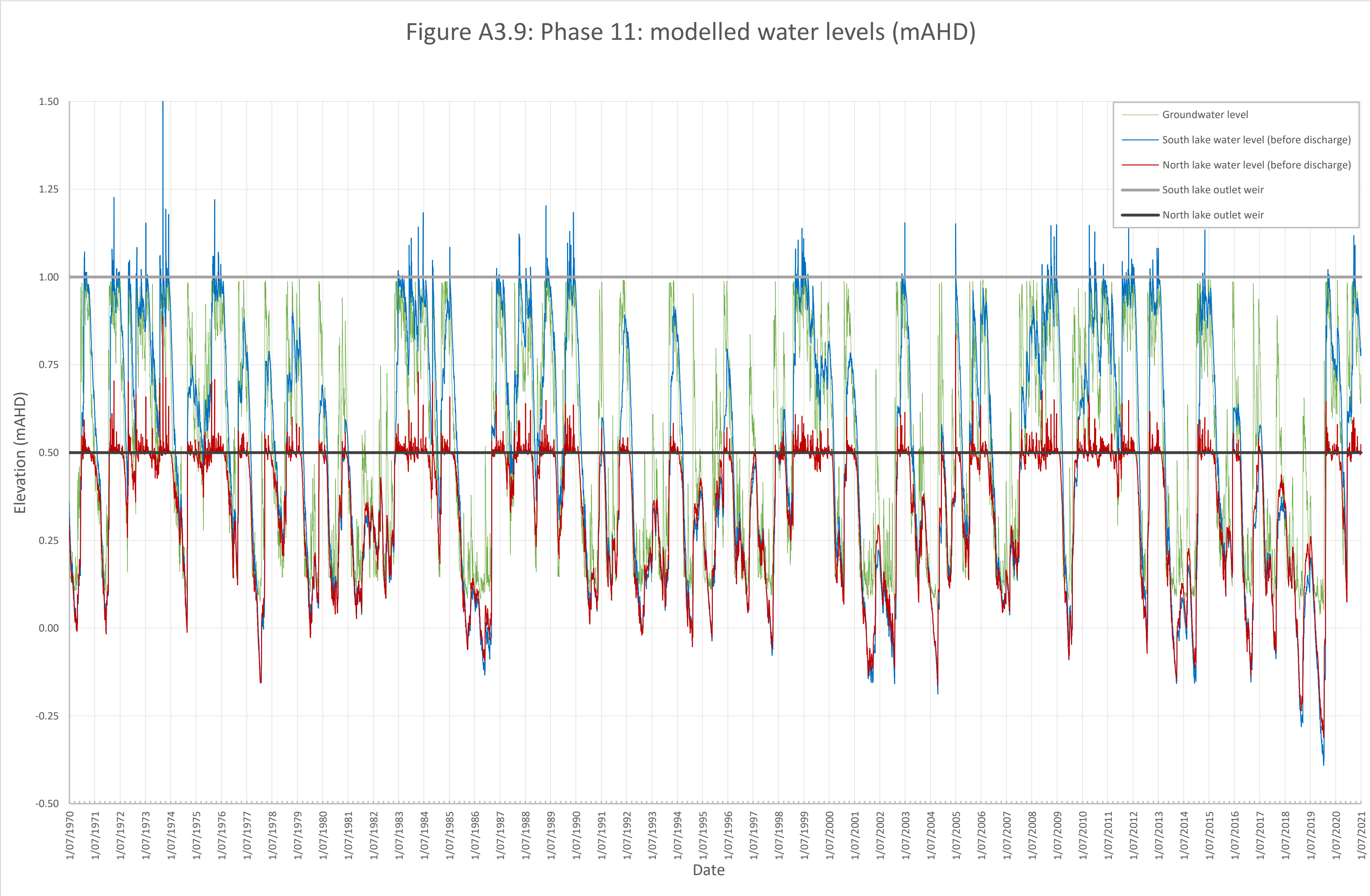


Figure A3.9: Phase 11: modelled water levels (mAHD)
Groundwater level
South lake water level (before discharge)
North lake water level (before discharge)
South lake outlet weir
North lake outlet weir
Elevation (mAHD)
1.50
1.25
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
Date
1/07/1970
1/07/1971
1/07/1972
1/07/1973
1/07/1974
1/07/1975
1/07/1976
1/07/1977
1/07/1978
1/07/1979
1/07/1980
1/07/1981
1/07/1982
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1/07/2009
1/07/2010
1/07/2011
1/07/2012
1/07/2013
1/07/2014
1/07/2015
1/07/2016
1/07/2017
1/07/2018
1/07/2019
1/07/2020
1/07/2021

10 Appendix 4 – Potentiometric plots

ORIENTATION

SCALE

0 125 250 375 500 625
metres

ROBINA

PO Box 4115 Robina QLD4230 07 5578 9944
Email robina@access.gs **www.access.gs**

LEGEND

- Groundwater bores
- Groundwater flow direction
- Groundwater level major contour (0.1 m interval) (mAHD)
- Groundwater level minor contour (0.025 m interval) (mAHD)

SOURCES

Image: Nearmap image dated 1 June 2020.

PROJECT	**CLIENT**	**DRAWING**
TWEED SAND PLANT EXPANSION	HANSON CONSTRUCTION MATERIALS PTY LTD	GROUNDWATER CONTOURS & FLOW DIRECTIONS 6 MAY 2020

SCALE	DATE	DRAWN	CHECKED	PROJECT	DRAWING	REVISION
1:12,500 @A3	3/12/2020	AJF	ELH	12035	502	-

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ORIENTATION

SCALE

0 125 250 375 500 625 metres

ROBINA

P O Box 4115 Robina QLD4230 07 5578 9944

Email robina@access.gs www.access.gs

LEGEND

- Groundwater bores
- Groundwater flow direction
- Groundwater level major contour (0.1 m interval) (mAHD)
- Groundwater level minor contour (0.025 m interval) (mAHD)

SOURCES

Image: Nearmap image dated 1 June 2020.

PROJECT	CLIENT	DRAWING
TWEED SAND PLANT EXPANSION	HANSON CONSTRUCTION MATERIALS PTY LTD	GROUNDWATER CONTOURS & FLOW DIRECTIONS 17 JUNE 2020

SCALE	DATE	DRAWN	CHECKED	PROJECT	DRAWING	REVISION
1:12,500 @A3	3/12/2020	AJF	ELH	12035	503	-

GILBERT SUTHERLAND

ORIENTATION

SCALE

0 125 250 375 500 625
metres

ROBINA

PO Box 4115 Robina QLD4230 07 5578 9944
Email robina@access.gs www.access.gs

LEGEND

- Groundwater bores
- Groundwater flow direction
- Groundwater level major contour (0.1 m interval) (mAHD)
- Groundwater level minor contour (0.025 m interval) (mAHD)

SOURCES

Image: Nearmap image dated 1 June 2020.

PROJECT	CLIENT	DRAWING
TWEED SAND PLANT EXPANSION	HANSON CONSTRUCTION MATERIALS PTY LTD	GROUNDWATER CONTOURS & FLOW DIRECTIONS 16 JULY 2020

SCALE	DATE	DRAWN	CHECKED	PROJECT	DRAWING	REVISION
1:12,500 @A3	3/12/2020	AJF	ELH	12035	504	-

GILBERT SUTHERLAND

ORIENTATION

SCALE

0 125 250 375 500 625 metres

ROBINA

PO Box 4115 Robina QLD4230 07 5578 9944

Email robina@access.gs www.access.gs

LEGEND

- Groundwater bores
- Groundwater flow direction
- Groundwater level major contour (0.1 m interval) (mAHD)
- Groundwater level minor contour (0.025 m interval) (mAHD)

SOURCES

Image: Nearmap image dated 1 June 2020.

PROJECT	CLIENT	DRAWING
TWEED SAND PLANT EXPANSION	HANSON CONSTRUCTION MATERIALS PTY LTD	GROUNDWATER CONTOURS & FLOW DIRECTIONS 11 AUGUST 2020

SCALE	DATE	DRAWN	CHECKED	PROJECT	DRAWING	REVISION
1:12,500 @A3	3/12/2020	AJF	ELH	12035	505	-

GILBERT SUTHERLAND

ORIENTATION

SCALE

0 125 250 375 500 625 metres

ROBINA

PO Box 4115 Robina QLD4230 07 5578 9944

Email robina@access.gs www.access.gs

LEGEND

- Groundwater bores
- Groundwater flow direction
- Groundwater level major contour (0.1 m interval) (mAHD)
- Groundwater level minor contour (0.025 m interval) (mAHD)

SOURCES

Image: Nearmap image dated 1 June 2020.

PROJECT	CLIENT	DRAWING
TWEED SAND PLANT EXPANSION	HANSON CONSTRUCTION MATERIALS PTY LTD	GROUNDWATER CONTOURS & FLOW DIRECTIONS 26 AUGUST 2020

SCALE	DATE	DRAWN	CHECKED	PROJECT	DRAWING	REVISION
1:12,500 @A3	3/12/2020	AJF	ELH	12035	506	-

GILBERT SUTHERLAND

ORIENTATION

SCALE

0 125 250 375 500 625 metres

ROBINA

PO Box 4115 Robina QLD4230 07 5578 9944
Email robina@access.gs www.access.gs

LEGEND

- Groundwater bores
- Groundwater flow direction
- Groundwater level major contour (0.1 m interval) (mAHD)
- Groundwater level minor contour (0.025 m interval) (mAHD)

SOURCES

Image: Nearmap image dated 1 June 2020.

PROJECT	CLIENT	DRAWING
TWEED SAND PLANT EXPANSION	HANSON CONSTRUCTION MATERIALS PTY LTD	GROUNDWATER CONTOURS & FLOW DIRECTIONS 9 SEPTEMBER 2020

SCALE	DATE	DRAWN	CHECKED	PROJECT	DRAWING	REVISION
1:12,500 @A3	3/12/2020	AJF	ELH	12035	507	-

GILBERT SUTHERLAND

ORIENTATION

SCALE

0 125 250 375 500 625 metres

ROBINA

P O Box 4115 Robina QLD4230 07 5578 9944
Email robina@access.gs **www.access.gs**

LEGEND

- Groundwater bores
- Groundwater flow direction
- Groundwater level major contour (0.1 m interval) (mAHD)
- Groundwater level minor contour (0.025 m interval) (mAHD)

SOURCES

Image: Nearmap image dated 1 June 2020.

PROJECT	CLIENT	DRAWING
TWEED SAND PLANT EXPANSION	HANSON CONSTRUCTION MATERIALS PTY LTD	GROUNDWATER CONTOURS & FLOW DIRECTIONS 22 SEPTEMBER 2020

SCALE	DATE	DRAWN	CHECKED	PROJECT	DRAWING	REVISION
1:12,500 @A3	3/12/2020	AJF	ELH	12035	508	-

GILBERT SUTHERLAND

ORIENTATION

SCALE

0 125 250 375 500 625 metres

ROBINA

P O Box 4115 Robina QLD4230 07 5578 9944
Email robina@access.gs **www.access.gs**

LEGEND

- Groundwater bores
- Groundwater flow direction
- Groundwater level major contour (0.1 m interval) (mAHD)
- Groundwater level minor contour (0.025 m interval) (mAHD)

SOURCES

Image: Nearmap image dated 1 June 2020.

PROJECT

TWEED SAND PLANT EXPANSION

CLIENT

HANSON CONSTRUCTION MATERIALS PTY LTD

DRAWING

GROUNDWATER CONTOURS & FLOW DIRECTIONS 7 OCTOBER 2020

SCALE	DATE	DRAWN	CHECKED	PROJECT	DRAWING	REVISION
1:12,500 @A3	3/12/2020	AJF	ELH	12035	509	-

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11 Appendix 5 – Review of annual surface water discharge

Table A5.1 Comparison of external catchment runoff to total catchment discharge – Phases 1-4

Water Year	External catchment runoff (ML)	Total catchment discharge (ML)	Difference (ML)
WY1971	2579	3761	1181
WY1972	3866	5660	1795
WY1973	3173	4511	1338
WY1974	8129	12115	3986
WY1975	1185	1684	500
WY1976	3762	5592	1830
WY1977	1203	1711	508
WY1978	1607	2285	678
WY1979	774	1100	326
WY1980	838	1191	353
WY1981	174	248	74
WY1982	0	0	0
WY1983	1319	1898	578
WY1984	3905	5740	1836
WY1985	2021	2873	852
WY1986	493	724	230
WY1987	2296	3291	995
WY1988	3023	4484	1461
WY1989	2611	3841	1231
WY1990	4052	6020	1968
WY1991	70	100	30
WY1992	825	1172	348
WY1993	0	0	0
WY1994	1262	1795	532
WY1995	10	14	4
WY1996	801	1139	338
WY1997	0	0	0
WY1998	443	629	187
WY1999	4545	6725	2180
WY2000	1194	1781	587
WY2001	872	1240	368
WY2002	0	0	0
WY2003	2622	3801	1179
WY2004	0	0	0
WY2005	2338	3324	986
WY2006	2441	3512	1071
WY2007	180	256	76
WY2008	856	1218	361
WY2009	4519	6663	2144
WY2010	343	487	144
WY2011	3633	5335	1702
WY2012	2964	4316	1351
WY2013	3437	4961	1524
WY2014	425	646	221
WY2015	3080	4426	1346
WY2016	640	910	270
WY2017	505	718	213
WY2018	5	8	2
WY2019	0	0	0
WY2020	3313	4745	1431
WY2021	3534	5223	1689

Table A5.2 Comparison of external catchment runoff to total catchment discharge – Phase 5

Water Year	External catchment runoff (ML)	Total catchment discharge (ML)	Difference (ML)
WY1971	2537	3522	985
WY1972	3840	5421	1581
WY1973	3291	4402	1111
WY1974	8252	12152	3900
WY1975	1161	1544	383
WY1976	3767	5493	1726
WY1977	1181	1570	389
WY1978	1560	2074	514
WY1979	751	998	248
WY1980	848	1128	280
WY1981	125	167	41
WY1982	0	0	0
WY1983	1284	1721	437
WY1984	4011	5790	1779
WY1985	2081	2767	686
WY1986	494	702	208
WY1987	2270	3041	771
WY1988	3069	4442	1373
WY1989	2679	3831	1152
WY1990	4074	5945	1871
WY1991	55	73	18
WY1992	756	1005	249
WY1993	0	0	0
WY1994	1207	1605	398
WY1995	5	7	2
WY1996	700	931	231
WY1997	0	0	0
WY1998	408	542	135
WY1999	4542	6562	2020
WY2000	1231	1802	570
WY2001	837	1112	276
WY2002	0	0	0
WY2003	2562	3517	955
WY2004	0	0	0
WY2005	2264	3011	747
WY2006	2468	3349	881
WY2007	179	238	59
WY2008	811	1079	268
WY2009	4613	6654	2041
WY2010	271	361	89
WY2011	3673	5249	1576
WY2012	3112	4367	1255
WY2013	3429	4715	1285
WY2014	425	646	221
WY2015	3044	4127	1083
WY2016	633	841	209
WY2017	434	578	143
WY2018	0	0	0
WY2019	0	0	0
WY2020	3268	4377	1108
WY2021	3557	5096	1539

Table A5.3 Comparison of external catchment runoff to total catchment discharge – Phase 6

Water Year	External catchment runoff (ML)	Total catchment discharge (ML)	Difference (ML)
WY1971	2518	3319	801
WY1972	3854	5244	1390
WY1973	3376	4330	954
WY1974	8347	12175	3829
WY1975	1158	1332	175
WY1976	3834	5518	1684
WY1977	1195	1375	180
WY1978	1538	1770	232
WY1979	778	895	117
WY1980	891	1025	134
WY1981	102	117	15
WY1982	0	0	0
WY1983	1260	1561	301
WY1984	4093	5832	1739
WY1985	2150	2650	500
WY1986	511	739	228
WY1987	2279	2818	539
WY1988	3118	4416	1298
WY1989	2739	3843	1104
WY1990	4111	5905	1794
WY1991	44	51	7
WY1992	711	818	107
WY1993	0	0	0
WY1994	1182	1365	183
WY1995	3	3	0
WY1996	628	723	95
WY1997	0	0	0
WY1998	384	442	58
WY1999	4566	6451	1884
WY2000	1271	1804	532
WY2001	830	955	125
WY2002	0	0	0
WY2003	2545	3263	717
WY2004	0	0	0
WY2005	2219	2599	380
WY2006	2545	3214	669
WY2007	219	259	40
WY2008	802	923	121
WY2009	4713	6682	1969
WY2010	222	255	33
WY2011	3710	5180	1470
WY2012	3270	4413	1143
WY2013	3442	4518	1076
WY2014	425	646	221
WY2015	3054	3848	794
WY2016	633	728	95
WY2017	390	448	59
WY2018	0	0	0
WY2019	0	0	0
WY2020	3270	4036	766
WY2021	3623	4997	1374

Table A5.4 Comparison of external catchment runoff to total catchment discharge – Phase 7

Water Year	External catchment runoff (ML)	Total catchment discharge (ML)	Difference (ML)
WY1971	2501	3243	742
WY1972	3846	5181	1334
WY1973	3407	4303	896
WY1974	8395	12193	3798
WY1975	1152	1297	145
WY1976	3838	5492	1654
WY1977	1187	1337	149
WY1978	1520	1711	191
WY1979	774	872	97
WY1980	894	1007	112
WY1981	88	99	11
WY1982	0	0	0
WY1983	1245	1503	258
WY1984	4135	5857	1722
WY1985	2167	2628	461
WY1986	513	735	222
WY1987	2271	2741	470
WY1988	3143	4424	1281
WY1989	2760	3849	1090
WY1990	4122	5890	1768
WY1991	38	43	5
WY1992	682	768	86
WY1993	0	0	0
WY1994	1158	1303	145
WY1995	0	0	0
WY1996	595	670	75
WY1997	0	0	0
WY1998	370	416	46
WY1999	4570	6404	1834
WY2000	1302	1831	529
WY2001	816	918	102
WY2002	0	0	0
WY2003	2518	3168	649
WY2004	0	0	0
WY2005	2188	2488	300
WY2006	2559	3167	608
WY2007	227	265	38
WY2008	786	884	99
WY2009	4747	6685	1938
WY2010	194	219	24
WY2011	3728	5162	1434
WY2012	3320	4438	1118
WY2013	3440	4444	1004
WY2014	425	646	221
WY2015	3045	3751	706
WY2016	631	710	79
WY2017	361	407	45
WY2018	0	0	0
WY2019	0	0	0
WY2020	3256	3907	651
WY2021	3636	4967	1330

Table A5.5 Comparison of external catchment runoff to total catchment discharge – Phase 8

Water Year	External catchment runoff (ML)	Total catchment discharge (ML)	Difference (ML)
WY1971	2469	3117	648
WY1972	3833	5078	1245
WY1973	3450	4253	802
WY1974	8467	12208	3741
WY1975	1145	1244	99
WY1976	3840	5438	1598
WY1977	1175	1277	102
WY1978	1489	1617	129
WY1979	765	831	66
WY1980	896	973	78
WY1981	64	69	6
WY1982	0	0	0
WY1983	1218	1408	190
WY1984	4196	5883	1687
WY1985	2191	2589	398
WY1986	515	726	211
WY1987	2257	2619	361
WY1988	3196	4455	1259
WY1989	2787	3848	1060
WY1990	4137	5861	1723
WY1991	27	30	2
WY1992	634	689	55
WY1993	0	0	0
WY1994	1116	1213	97
WY1995	0	0	0
WY1996	539	586	47
WY1997	0	0	0
WY1998	347	377	30
WY1999	4570	6317	1747
WY2000	1351	1870	520
WY2001	793	862	69
WY2002	0	0	0
WY2003	2475	3018	543
WY2004	0	0	0
WY2005	2134	2318	185
WY2006	2574	3079	505
WY2007	239	272	33
WY2008	755	820	65
WY2009	4793	6673	1879
WY2010	148	161	13
WY2011	3749	5119	1370
WY2012	3393	4463	1070
WY2013	3434	4323	890
WY2014	425	646	221
WY2015	3021	3590	569
WY2016	628	683	54
WY2017	318	345	27
WY2018	0	0	0
WY2019	0	0	0
WY2020	3225	3709	484
WY2021	3653	4913	1260

Table A5.6 Comparison of external catchment runoff to total catchment discharge – Phase 9

Water Year	External catchment runoff (ML)	Total catchment discharge (ML)	Difference (ML)
WY1971	2419	2946	527
WY1972	3815	4946	1131
WY1973	3532	4218	687
WY1974	8568	12227	3658
WY1975	1132	1175	43
WY1976	3849	5369	1520
WY1977	1158	1203	46
WY1978	1441	1496	55
WY1979	764	794	29
WY1980	886	920	34
WY1981	28	29	1
WY1982	0	0	0
WY1983	1178	1281	103
WY1984	4286	5917	1631
WY1985	2221	2539	318
WY1986	519	715	195
WY1987	2238	2459	221
WY1988	3267	4496	1229
WY1989	2830	3857	1027
WY1990	4159	5822	1663
WY1991	12	12	0
WY1992	560	581	21
WY1993	0	0	0
WY1994	1048	1088	40
WY1995	0	0	0
WY1996	460	478	18
WY1997	0	0	0
WY1998	310	322	12
WY1999	4572	6202	1630
WY2000	1419	1921	502
WY2001	758	787	29
WY2002	0	0	0
WY2003	2411	2823	412
WY2004	0	0	0
WY2005	2048	2127	78
WY2006	2581	2942	361
WY2007	252	267	15
WY2008	712	739	27
WY2009	4858	6653	1795
WY2010	92	95	3
WY2011	3777	5054	1277
WY2012	3492	4495	1003
WY2013	3422	4162	741
WY2014	425	646	220
WY2015	2976	3385	409
WY2016	626	650	24
WY2017	254	264	10
WY2018	0	0	0
WY2019	0	0	0
WY2020	3169	3446	276
WY2021	3658	4824	1166

Table A5.7 Comparison of external catchment runoff to total catchment discharge – Phase 10

Water Year	External catchment runoff (ML)	Total catchment discharge (ML)	Difference (ML)
WY1971	2262	2944	683
WY1972	3615	4913	1299
WY1973	3409	4271	862
WY1974	8312	12205	3892
WY1975	1108	1220	112
WY1976	3578	5294	1717
WY1977	1051	1252	201
WY1978	1376	1517	141
WY1979	665	866	201
WY1980	809	933	124
WY1981	0	86	86
WY1982	0	0	0
WY1983	1101	1281	180
WY1984	4002	5955	1953
WY1985	2041	2580	539
WY1986	484	692	208
WY1987	2153	2449	295
WY1988	3141	4588	1447
WY1989	2608	3888	1280
WY1990	3983	5898	1914
WY1991	0	37	37
WY1992	410	634	224
WY1993	0	33	33
WY1994	932	1118	186
WY1995	0	22	22
WY1996	361	480	119
WY1997	0	26	26
WY1998	266	317	52
WY1999	4368	6184	1816
WY2000	1243	2075	832
WY2001	698	868	170
WY2002	0	2	2
WY2003	2256	2781	525
WY2004	0	48	48
WY2005	1945	2053	109
WY2006	2506	2986	480
WY2007	159	280	121
WY2008	591	793	202
WY2009	4525	6616	2091
WY2010	24	163	140
WY2011	3475	5050	1575
WY2012	3234	4468	1234
WY2013	3238	4132	894
WY2014	421	692	271
WY2015	2771	3339	568
WY2016	578	672	94
WY2017	200	296	96
WY2018	0	20	20
WY2019	0	0	0
WY2020	3049	3387	338
WY2021	3492	4860	1368

Table A5.8 Comparison of external catchment runoff to total catchment discharge – Phase 11

Water Year	External catchment runoff (ML)	Total catchment discharge (ML)	Difference (ML)
WY1971	2176	2901	725
WY1972	3512	4877	1365
WY1973	3362	4290	927
WY1974	8202	12207	4005
WY1975	1096	1195	99
WY1976	3461	5284	1822
WY1977	998	1241	243
WY1978	1328	1456	127
WY1979	625	918	293
WY1980	776	908	133
WY1981	0	92	92
WY1982	0	0	0
WY1983	1052	1271	219
WY1984	3880	5990	2111
WY1985	1954	2599	644
WY1986	468	677	208
WY1987	2109	2402	293
WY1988	3085	4650	1566
WY1989	2511	3955	1445
WY1990	3901	5950	2049
WY1991	0	22	22
WY1992	323	653	330
WY1993	0	45	45
WY1994	857	1093	237
WY1995	0	30	30
WY1996	292	447	155
WY1997	0	23	23
WY1998	228	246	18
WY1999	4272	6189	1917
WY2000	1175	2157	982
WY2001	671	864	193
WY2002	0	2	2
WY2003	2151	2691	540
WY2004	0	61	61
WY2005	1860	1944	85
WY2006	2473	2982	508
WY2007	140	310	171
WY2008	524	806	282
WY2009	4373	6614	2240
WY2010	0	158	158
WY2011	3344	5050	1706
WY2012	3127	4478	1351
WY2013	3142	4071	929
WY2014	420	705	286
WY2015	2652	3254	601
WY2016	551	646	95
WY2017	182	284	101
WY2018	0	10	10
WY2019	0	0	0
WY2020	2962	3231	270
WY2021	3414	4865	1450