
MAC SWP4

MARILLANA CREEK WETTING FRONT MODELLING

Prepared for

BHP

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EXECUTIVE SUMMARY

A GoldSim water balance model of the detrital aquifer along a tributary of Marillana Creek between the proposed MAC SWP4 surplus water discharge point and Flat Rocks Springs was prepared to simulate surplus water discharge rates of 30ML/d, 50ML/d, 60ML/d and 80ML/d over 5 year and 10 year discharge periods.

The detrital aquifer was divided longitudinally into 28 no. x 1km model cells, with infiltration to the model cells allowed across the low flow channel inundation area, which had been defined by previous 2D surface water modelling exercises. Losses from the system which were modelled included surface water evaporation, increased evapotranspiration, lateral seepage to the surrounding tertiary detrital or basement aquifer and seepage to the CID aquifer. The wetting front reaches a steady state (ceases to propagate further downstream) once the total losses equal the discharge rate.

A Base Case Model was created using AQ2's best approximation of model parameters. For all discharge rates modelled in the Base Case Model, the wetting front is predicted to reach Flat Rocks Springs within 10 years of discharge commencement. For the 50ML/d, 60ML/d and 80ML/d scenarios, the wetting front is predicted to reach Flat Rocks within 5 years of discharge commencing. For the 30ML/d scenario, the discharge is predicted to reach Flat Rocks Springs in about 5.5 years.

The maximum discharge rate which is estimated to be able to be discharged to the discharge point and not impact have a wetting front reaching Flat Rocks Springs is 23ML/d.

Although the Base Case Model contained the best estimate of parameters and process, inherent uncertainty in the rate of seepage loss from the creek alluvium arises from two key processes:

1. The rate and volume of seepage water that can be drained in the CID aquifer (i.e. once the CID aquifer is at capacity, no further seepage loss can occur. This reflects uncertainty in the process of CID drainage.
2. The rate at which water can infiltrate from the creek into the underlying CID. This reflects uncertainty in the estimates of permeability that have adopted for the alluvium.

The Process Uncertainty in point 1 was assessed by calculating the maximum transmission of additional water which could be possible through the CID between Flat Rocks and Yandi pits W0 and W1 (12ML/d). The Parameter Uncertainty in point 2 was addressed by developing probability distributions for the hydraulic conductivity values used by the model. A Monte Carlo Model was run for 100 model iterations (each iteration sampling a different hydraulic conductivity value from the probability distribution). The Monte Carlo Model was run for a scenario where the CID transfer capacity was not constrained, and a scenario where the transfer capacity was constrained to a value of 12ML/d.

The Constrained CID Monte Carlo Model and Base Case Model results were generally consistent, with the wetting front predicted to reach Flat Rocks Springs within 10 years of discharge commencement for the 50ML/d, 60ML/d and 80ML/d scenarios. For the 30ML/d scenario, it is predicted that there is a greater than 75% likelihood that the wetting front would not reach Flat Rocks.

A number of simplifying assumptions were made to allow what is a complex process to be modelled. Key simplifying assumptions which may impact the outcome of the model include:

- Simplified modelling of CID and lateral groundwater seepage losses.
- Filling of model cells evenly across the model footprint.
- Evapotranspiration function used to apply anticipated increased evapotranspiration rates due to the increased availability of water.

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1 BACKGROUND

Dewatering at BHP's Mining Area C is predicted to result in surplus water. A range of surplus water management solutions have been developed for the site, including MAR systems, infiltration basins and creek discharge systems.

A further surplus water management option is being considered by BHP – discharge of surplus water from Mining Area C into the Marillana Creek catchment at the Great Northern Highway (upstream of Flat Rocks). BHP would like to estimate the “wetting front” that may develop along Marillana Creek from Mining Area C dewatering discharge. The wetting front includes the area where groundwater levels rise to the base of the creek and extent of surface water inundation along the creek.

Previous estimates of the wetting front were made (by Surface Water Solutions) by inputting the discharge rate into a 2D Surface Water Model to track the flow path through the catchment with assumed infiltration rates from the surface into the alluvium/detritals. This approach did not include any constraints imposed by groundwater storage and as such may represent the upper range of the capacity of the creek system to accept infiltration (and therefore under-predict the wetting front extent).

BHP would like a further assessment of the wetting front, taking account of constraints imposed by infiltration capacity and groundwater storage, to assess the timing associated with propagation of the wetting front and the likelihood of the wetting front reaching the Flat Rocks Area. The current approach will include a more rigorous assessment of hydrological processes in the unsaturated zone and the associated storage in the unsaturated zone along Marillana Creek.

1.1 Model Scenarios

The following surplus water discharge rates have been considered in this assessment:

- 30ML/d for duration of 5 and 10 years;
- 50ML/d for duration of 5 and 10 years;
- 60ML/d for duration of 5 and 10 years; and
- 80ML/d for duration of 5 and 10 years.

A Base Case Model was completed to assess the wetting front for these discharge scenarios. Uncertainty in the rate of seepage loss from the creek arises from two key processes within the Base Case Model:

- The rate and volume of seepage water that can be drained by the CID aquifer (i.e. once the CID aquifer is at capacity, no further seepage loss can occur). This reflects uncertainty in the process of CID drainage.
- The rate at which water can infiltrate from the creek into the underlying CID. This reflects uncertainty in the estimates of permeability / infiltration rates that have adopted for the tertiary detritals.

Uncertainty about the flow processes modelled and the model parameters that were adopted was subsequently addressed through a Monte Carlo Analysis of the system.

2 MODEL OVERVIEW

The wetting front model was developed using the GoldSim software package. GoldSim is a Monte Carlo simulation software package, that allows users to create customised models based on built-in functions within the software. The software is well suited for water balance projects, and because the calculations are only set once, and then run through every time-step, it is computationally more efficient than MS Excel, in this instance, where the formulas are defined every time step. The Monte Carlo simulation also allows users to use input parameters which are defined as a probability distribution (sampled randomly in different model iterations) rather than as a constant number to allow model results to be calculated as a probability distribution.

The wetting front model simulates a water balance of the detrital aquifer along the Marillana Creek discharge tributary each timestep, where the difference between calculated water inputs and outputs represents the change in water storage at each time step.

An overview of the model cell layouts is shown in Figure 1.

2.1 Geology Overview

The model layout is shown in relation to the geology map in Figure 2. The geology has been determined from a combination of published geological mapping (GSWA 250K geological map), remote imagery (Google Earth and Landsat TM 8) and BHP's Leapfrog geological model. BHP's geological model was used (in particular) to assess the location of the CID in subcrop.

2.2 Conceptual Model

The conceptual model of the creek discharge system is summarised as follows:

- Discharged water will flow along the defined low flow channel of a tributary to Marillana Creek, which becomes increasingly defined downstream as it forms Marillana Creek.
- Water infiltrates the ground surface over the wetted area into the quaternary alluvium and tertiary detrital aquifers (named detritals within this report).
- The unsaturated portion of the detritals beneath the drainage line has storage capacity to accommodate the infiltration and this is derived from the specific yield.
- Water is lost from the system due to the following processes:
 - Seepage loss laterally into the adjacent formation (basement or tertiary detritals)
 - Seepage into the CID aquifer system
 - Enhanced evapotranspiration due to increased water availability
 - Evaporation from discharge water expressed above ground level
- Once the infiltration has filled the available storage within an area (model cell), the infiltration rate in that cell is restricted to the losses from the cell, which results in the wetting front propagating further downstream.

As such, the following key water fluxes have been included in the model:

- Infiltration from dewatering discharge into the detrital storage
- Seepage from the detrital storage into adjacent basement or tertiary detrital aquifers
- Seepage from the detrital storage into the CID
- Increase evapotranspiration losses
- Evaporation from ponded water

The conceptual model is summarised schematically in Figure 3.

2.3 Model Setup

The model covers the alluvial aquifer between the discharge point and Flat Rocks Springs. Given groundwater is at surface at Flat Rocks Springs, it was assumed there is no storage available for any discharge reaching this point to infiltrate. The model domain was split into 28 cells (Cell 1 to Cell 28), with each model cell representing a 1km length of the discharge drainage line (27km in total covered). The discharge point is located in the centre of Cell 1. Each model cell assumes at most 1km of detritals either side of the drainage channel can contribute to storage of infiltration. If basement mapping from the 250k State Geology map occurred within 1km of the drainage line, the model width was restricted to cover only the width of detritals between the drainage line and the basement (i.e. <1km). Where the detritals extend more than 1km from the creek, it is assumed groundwater outflow will dissipate any groundwater rise.

Input parameters for each model cell were defined, as discussed in Section 3. An overview of the model setup is shown in Figure 1 (plan) and Figure 3 (conceptual model).

The model was run on a daily time step, however the model is currently setup such that other timesteps may be adopted. The daily timestep was selected so that the magnitude of fluxes in and out of model cells is significantly less than the available storage within a single cell. The model arbitrarily starts on the 1st January, which impacts the timing of evaporative losses from the model.

2.4 Model Simplifications and Assumptions

The following key simplifications and assumptions have been made to allow what is a complex process to be simulated within the water balance model:

- Rainfall over the model and creek runoff has not been modelled. The evapotranspiration rate which has been applied to the model represents an estimated increase in evapotranspiration above normal rates due to the increased availability of water (and potential increases in surface water extent, vegetation density and vegetation water use). The simplifying assumption is that the water balance of the current system is in equilibrium, such that evapotranspiration rates are matching rainfall and creek infiltration rates.
- The specific yield of the CID, quaternary alluvium, tertiary detritals and calcrete units are all similar, such that they have been modelled as a combined unit with regards to available unsaturated zone storage capacity.
- The hydraulic conductivity of the tertiary detritals and calcrete zones are similar, such that they have been treated as the same unit when lateral seepage away from the model cell has been calculated.
- Storage with the model cells are filled from the bottom, with infiltration to the cell spread evenly across the footprint of each model cell (i.e. no localised groundwater mounding within the cell). This removed the need for multiple parallel cells to be used across the creek area.
- Surface water travel times haven't been taken into account, such that on Day 1 of the model, the wetting front has extended to point where the discharge rates match the required initial infiltration area. This reduces the need to model above ground storage within the creeks.
- Unsaturated storage changes outside of the model have not been modelled, in particular with respect to the capacity for lateral seepage to be received. To account for the impact of reducing seepage rates with time, a simplifying assumption has been adopted which assigns an estimated boundary condition for head/gradient driven flow, with the location of the boundary condition shifting further away from the model boundary with time (effectively, reducing the seepage rate with time). The maximum head driving this flow is assumed to

be 5m, and the boundary condition is assumed to reach its maximum distance from the cell after 700 days (refer Section 3 for further information).

- Model cells are all 1km in length with a rectangular shape, with the model layout conceptually a straight rectangular channel. However, the path of the creek low flow channel isn't straight and therefore some model cells overlap in areas and have gaps in other areas (refer Figure 1).

2.5 Process Uncertainty

2.5.1 CID Aquifer Hydraulics and Groundwater Flow

There are many simplifying assumptions with respect to 3D flow in both the vadose and saturated zone to allow simulation with the GoldSim model (as outlined above). The modelled flow has therefore been verified by another method to reduce the uncertainty in the groundwater flow processes within the model. A simple analytical equation of maximum transmission capacity of the CID based on hydraulic gradients between the causeway and W0 and W1 pits has been developed to check transmission assumptions (of water within the CID aquifer) within the GoldSim model. Once the alluvium is saturated during surplus water discharge, water will percolate from the alluvium into the underlying aquifers. The Weeli Wollie aquifer is low permeability and will not accept large volumes of water. The CID is a transmissive aquifer and could accept large volumes of water where the alluvium is in hydraulic connection with the CID aquifer. However, the hydrogeological properties of the CID aquifer impose limits on the volume of groundwater that could potentially flow through the aquifer; specifically:

- The CID aquifer dimensions (width and depth) will control the cross-sectional area through which flow can occur. These can be reasonably estimated from geological mapping, experience at the existing Yandi mine and the Leapfrog geological model that BHP have developed. The aquifer dimensions are in the order of 600m (w) and 60m (thickness).
- The aquifer hydraulic conductivity will control the rate at which groundwater can move through the aquifer. This can be reasonably well estimated from 20 years of operating experience at the Yandi mine and several specific groundwater studies and calibrated groundwater models. The hydraulic conductivity is in the order of 10m/d.
- The hydraulic gradient (i.e. the change in groundwater level along the aquifer) provides the energy for groundwater flow. The hydraulic gradient can be estimated from measured water levels from BHP's existing monitoring bores that extend from the mine upstream of the Yandi Causeway. The hydraulic gradient can also be inferred from the presence of groundwater fed pools and from the location of dewatered pits. The existing hydraulic gradient in the CID aquifer upstream of the mine is in the order of 0.005. This gradient steepens in the CID aquifer north of the Yandi Causeway due to dewatering at W1.

The physical properties of the CID will not change as a result of surplus water discharge. However, the hydraulic gradient that is driving flow may change as a result of changes in groundwater level where infiltration occurs. Two hydraulic gradient scenarios have been considered:

- Infiltration into the CID at the Yandi Causeway brings groundwater levels up to the invert level of the creek (i.e. water levels in the CID aquifer reach ground surface). Dewatering continues at W1 and groundwater levels are maintained at the base of mining. Based on the measured topographic level at the Causeway and water levels in BHP's monitoring bores at W1, this would result in a water level change of 70m over 5500m and a gradient of 0.013.

- Infiltration into the CID at the Yandi Causeway brings groundwater levels up to the invert level of the creek (i.e. water levels in the CID aquifer reach ground surface). Dewatering extends to W0 and groundwater levels are maintained in W0 at the same base of mining as at W1. Based on the measured topographic level at the Causeway and extending the water levels in BHP's monitoring bores at W1 into the W0 area, this would result in a water level change of 70m over 2500m and a gradient of 0.028.

The above two scenarios present the maximum hydraulic gradient that can foreseeably influence groundwater flow in the CID aquifer from Marillana Creek into the Yandi mining area. The estimates of maximum potential groundwater flow have been made using a Darcy calculation and are summarised in Table 1.

There is existing groundwater flow in the CID aquifer towards the Yandi mine that must also be considered. For a water balance, over the long-term, the existing flow must form part of the groundwater volume that flows from the Causeway area towards the mine. Thus, the ability of the CID aquifer to drain surplus water discharge from the alluvium is the net of the maximum potential groundwater flow and the pre-existing groundwater flow. Table 1 shows the calculation of the existing groundwater flow and the net maximum groundwater flow that is foreseeable in the CID aquifer should infiltration be such that groundwater levels at the Causeway are maintained at the invert level of the creek.

The hydrogeological setting of the CID and its ability to drain infiltration from Marillana Creek towards the mine workings is illustrated in Figure 4.

Table 1: Estimates of Additional Groundwater Drainage in CID

Parameter / Estimate	Average	Remarks
CID Transmissivity (m ² /d)	800 – 1,000	from BHPs Leapfrog Model and Permeability from BHPs SEA
CID width (m)	600 - 800	from BHPs Leapfrog Model
Hydraulic gradient to W1	0.013	calculated from creek invert @ Causeway, mining RL and distance to W1
Hydraulic gradient to W0	0.028	calculated from creek invert @ Causeway, mining RL and distance to W0
Potential Groundwater Flow		
Max Groundwater Flow to W1	8,000m ³ /d	application of Darcy eqn.
Max Groundwater flow to W0	17,000m ³ /d	application of Darcy eqn.
Existing Groundwater Baseflow	5,200m ³ /d	Existing throughflow in CID channel based on observed WLs
Max Additional Drainage to W1	3ML/d	Calculated by difference (potential - existing)
Max Additional Drainage to W0	12ML/d	Calculated by difference (potential - existing)

Summarily, without considering any limitations on the ability of surplus water in Marillana Creek to percolate into the CID aquifer, then:

- Natural (existing) groundwater flow is in the order of 5ML/d.
- The CID aquifer could drain a maximum of 3ML/d additional water from the alluvium with the hydraulic gradients induced by mining at W1.

- The CID aquifer could drain a maximum of 12ML/d of additional water from the alluvium with the hydraulic gradients that may be induced by mining at W0.
- When the dewatering system at Yandi is turned off (i.e. closure), then the hydraulic gradient will decrease as groundwater levels in the mine area recover. The flow of groundwater from the alluvium into the CID will reduce and more surplus water will run further downstream along the channel of Marillana Creek.
- Should infiltration be insufficient to maintain groundwater levels at the invert of the creek, then the hydraulic gradient will be lower and there will be less groundwater flow from Marillana Creek to the Yandi mine area along the CID aquifer.

2.5.2 Assumptions and Limitations

The calculations above, of maximum drainage through the CID aquifer, assume water levels in the aquifer are at ground surface from Yandi Causeway upstream (i.e. upstream of the Causeway, the CID aquifer is "full"). In practice, there is an area in the aquifer between the Causeway and the pools upstream in Marillana Creek where the groundwater levels in the CID aquifer have been affected by dewatering with water levels being up to 10mbgl. Over this area, there is storage capacity in the CID aquifer that will be replenished by surplus water infiltration in addition to the flow of groundwater to the north (towards the mine). Thus, for a period of time, the maximum potential drainage from the creek into the CID aquifer will be higher and comprise both groundwater flow to the mine area and storage replenishment. A simple calculation of the geometry of this storage capacity in the CID suggests that for all infiltration scenarios, it will be filled within 1-year (and within 3 months if infiltration rates are at the higher end of the estimated range).

The estimate of between 3ML/d and 12ML/d of additional drainage from Marillana Creek into the CID are mediated by the increased hydraulic gradients that have been induced by mine dewatering. Thus, it is implicit in these estimates, that the hydraulic gradients are maintained by pumping all of the additional inflow from the mine workings in the area from where the gradient has been calculated i.e:

- dewatering an additional 3ML/d from W1 or
- dewatering an additional 12ML/d from W0.

These additional volumes would need to be managed within the Yandi dewatering system.

2.6 Parameter Uncertainty

2.6.1 Potential Limitations on Surplus Water Percolating into the CID Aquifer

In addition to the process uncertainty, there is also uncertainty in the parameters adopted in the model. The uncertainty is associated with the permeability and infiltration capacity of the different formations within the model. Generally, hydraulic conductivity follows a log-normal distribution. To test the impact of parameter uncertainty, the following has been completed:

- Base Case Model – run with best estimates of parameters
- Monte Carlo Model – Monte Carlo analysis completed, with probability distribution functions for permeability and infiltration rates developed (see discussion below) and randomly sampled by the model for each model iteration.
- Sensitivity Analysis – the starting groundwater elevations within the Base Case Model have been lowered by 1m and 2m to determine reflect uncertainty in the upstream groundwater monitoring and what impact this has on the model results.

The permeability of the detritals is the most uncertain parameter with respect to controlling seepage loss from the creek into the underlying CID. 378 estimates of permeability are available from:

- Analysis of 4 pumping tests on shallow monitoring bores (Golder 2012).
- Derived estimates from 48 particle size distribution analyses (PSD) undertaken as part of the Yandi CCO Creek Diversion study (AQ2 2018).
- 326 estimates made by 4DG during a site walkover for the Yandi Creek surplus water discharge assessment.

Estimates of detrital permeability are summarised in Table 2 below.

Table 2: Estimates of Tertiary Detrital Permeability

K (m/d)	Freq.	Freq %	Remarks
5 - 10	234	62%	232 4DG estimates + 2 pumping test estimate
1 - 5	86	23%	85 4DG estimates + 1 pumping test estimate
0.5 - 1	10	3%	9 4DG estimates + 1 PSD (AQ2) estimate
<0.5	48	13%	47 PSD (AQ2) estimates + 1 pumping test estimate
Total	378	100%	

Based on the data there appears to be a method bias with the majority of 4DG estimates being in the range 1 – 10m/d and the majority of PSD-based estimates derived by AQ2 being in the range 0.1 – 1m/d. There are also geographical differences which may contribute to the differences. The range in estimates is such that it is not possible to construct a meaningful log-normal probability distribution around a mean or central tendency value. Rather, a uniform distribution has been adopted with permeability of the detritals ranging between 0.1 and 10m/d.

The permeability of the basement rocks within which the creek channel is incised is also uncertain and this will influence the rate at which water can dissipate from the detritals into the surrounding geology (Weeli Wolli Formation). The Weeli Wolli Formation is generally accepted to be a low-permeability aquitard with minor local permeability associated with fractured rock. This has been approximated with a log-normal distribution for permeability; the adopted mean (true-value) was 0.01m/d and the true standard deviation was 0.01m/d.

3 MODEL INPUT DATA AND FUNCTIONS

The following main input data and calculation functions were developed for each model cell:

- Water Storage and Water Level
- Infiltration Area and Infiltration Rate
- Basement/Detrinals Seepage Rate
- CID Seepage Rate
- Evapotranspiration Rate
- Evaporation Rate

Each of these items is discussed in more detail below, noting that in some instances different input values and calculation functions were used for the Base Case and Monte Carlo model runs.

3.1 Water Storage and Water Level

The GoldSim model runs a water balance on the storage contained within the detrital aquifer. At each time step, the difference between water additions and losses represents the change in stored water volume for the time step.

AQ2 assessed the geology of the model domain utilising the BHP provided LeapFrog model and published GSWA 250K geological mapping. Based on the data assessed, the following parameters were determined for the mid-point of each model cell (shown in Table 3):

- Water table elevation (believed to be interpolated within the LeapFrog model from measured water levels at either end of the model) – used to define the base of the model cell.
- Base of creek – used to define the top of the model cell.
- Tertiary detritals width – taken to be a maximum total width of 2km but constrained to a lower width if basement was present (as per Figure 2) within 1km either side of the creek. Used as the width of the model.
- A specific yield of 15% has been applied to the detritals across the model.

A stage-storage table was calculated for each cell at 1m elevation increments above the water table using the dimensional data described above, a model cell length of 1km and the specific yield. This table assumes that each model cell is rectangular (with 1km lengths). The stage-storage table for each cell is referenced by the GoldSim model to lookup the water elevation which would result from a calculated storage volume.

At each time step, the GoldSim model calculates the volume of water stored in the cell and uses the stage-storage lookup table to calculate a predicted water elevation. An inherent assumption within this approach is that all water which infiltrates reports directly to the base of the cell and is spread evenly across the whole cell (i.e. no localised mounding).

Note that the inferred water table within the LeapFrog model was at or above the elevation of the creek base in some cells. For these cells, the water table was assigned to be 1m below the creek base within the model to allow some storage to receive infiltration in the model.

Table 3: Model Cell Parameters

Cell	Channel Base (mRL)	SWL* (mRL)	Quaternary Alluvium Width (m)	Tertiary Detritals Width (m)	Infiltration Area (km ²)	CID
C1	694	677	1000	2000	0.008	Yes
C2	690	674	1000	2000	0.015	No
C3	687	673	657	2000	0.013	Yes
C4	682	672	635	2000	0.015	Yes
C5	679	670	732	2000	0.011	Yes
C6	674	668	467	2000	0.014	No
C7	672	667	483	2000	0.014	No
C8	669	665	450	2000	0.017	Yes
C9	667	663	438	2000	0.018	No
C10	663	660	356	2000	0.014	No
C11	661	658	535	2000	0.021	Yes
C12	658	655	530	2000	0.015	Yes
C13	655	653	464	2000	0.021	Yes
C14	653	650	473	2000	0.016	Yes
C15	649	647	458	2000	0.017	Yes
C16	646	644	656	2000	0.017	Yes
C17	643	642	545	2000	0.015	Yes
C18	639	638	435	2000	0.016	Yes
C19	636	635	440	2000	0.015	Yes
C20	633	632	388	2000	0.020	Yes
C21	629	628	439	2000	0.015	Yes
C22	625	624	394	1940	0.021	Yes
C23	622	621	718	2000	0.019	Yes
C24	617	616	375	2000	0.022	Yes
C25	612	611	443	2000	0.020	Yes
C26	610	607	357	2000	0.017	Yes
C27	603	599	500	1535	0.020	Yes
C28	596	595	439	1075	0.020	Yes

* Base Case and Monte Carlo Analysis model starting water levels

3.2 Infiltration Area and Rate

3.2.1 Base Case and Sensitivity Test Models

BHP provided results and reporting from Surface Water Solutions (November 2018) surface water wetting front estimation project, which was based on completing TUFLOW and HEC-RAS 2D models of the following discharge rates long Marillana Creek:

- 15ML/d
- 30ML/d
- 45ML/d

The 2D model was run by Surface Water Solutions for the above discharge rates with the following assumed infiltration rates:

- 50mm/d
- 150mm/d
- 500mm/d

GIS results (wetted area extents) of the 2D flow modelling for some of the scenarios above were provided to AQ2 for use in this project. The predicted wetted area footprint from the 2D flood model with a 45ML/d discharge rate and 150mm/d infiltration was used by AQ2 as an estimate of the infiltration area for the model on the assumption that the 2D model results adequately map the low flow channel which surface discharge would fill when infiltrating. The area from the 45ML/d discharge and 150mm/d infiltration rate was selected as it covered the largest infiltration area of the results we had received (25km of creek length, some 2km upstream of the boundary of the GoldSim Water Balance Model) and therefore covered most of the GoldSim model cells. The infiltration area within each cell boundary was estimated based on the taking measurements from the provided GIS data.

For the downstream cells within the GoldSim model which weren't covered by the inundation mapping completed by Surface Water Solutions (Cell 27 and 28), an inundation area of 0.2km² (therefore a low flow channel width of 20m) was assumed, which generally matched the magnitude of the inundation areas for nearby model cells from the 2D model results.

A list of the approximated areas for each cell over which infiltration could occur is provided in Table 3 and was imported to GoldSim. An infiltration rate of 500mm/d was applied to each cell's infiltration area provided:

- Sufficient inflow volume from the surface discharge for the cell to meet the infiltration rate; and
- Available detrital storage has not been filled.

Within the GoldSim model, a running total of the remaining surface discharge was completed. For example, the adopted model discharge rate was applied as an inflow to Cell 1 (i.e. 30, 50, 60 or 80ML/d), with the outflow from Cell 1 being calculated as the discharge inflow rate minus the infiltration. The surface outflow from Cell 1 was taken as the surface inflow to Cell 2.

Once the detrital storage within a cell has been filled, the infiltration rate for the cell is equal to the total loss rate from the cell (i.e. the total evaporation, evapotranspiration and seepage losses).

3.2.2 Monte Carlo Model

Within the Monte Carlo Model, the infiltration rate has been altered to be a function of the tertiary detrital permeability (which is in turn defined by a probability distribution). It has been assumed that the vertical infiltration through the detritals will be 10% of the horizontal permeability value adopted (refer Section 3.3), with a minimum infiltration rate of 100mm/d assumed.

3.3 Seepage Losses

Seepage losses from the model have assumed to occur laterally through the tertiary detrital (or basement) aquifer and through an interconnected CID aquifer (where the model cell overlies or is connected to the CID). The seepage losses are a function of hydraulic conductivity values set within the model.

3.3.1 Hydraulic Conductivity

Within the Base Case and Sensitivity Analysis Models, the following hydraulic conductivity values have been adopted:

- Tertiary detritals – 4m/d
- Basement – 0.01m/d

For the Monte Carlo Model, the hydraulic conductivity values have been defined by probability distributions which are randomly sampled at the start of each model iteration, and then held constant throughout the model iteration. The hydraulic conductivity distributions were defined as follows:

- Tertiary detritals – Uniform distribution between 0.1m/d and 10m/d.
- Basement - Log-normal distribution with a mean of 0.01m/d and a standard deviation of 0.01m/d.

These distributions were based on assessments discussed in Section 2.

3.3.2 Lateral Detrital and Basement Losses

Water losses from the model detrital storage will occur laterally away from the model boundary. The model is bounded by either additional Tertiary detritals or basement geology. Within the GoldSim model, a flow loss per unit length has been estimated and then applied across both lateral model boundaries. The flow loss was estimated as follows:

- A hydraulic gradient was calculated between the lateral model boundary and a boundary condition point at each time step.
 - The change in water level for the hydraulic calculation was assumed to be the difference between the calculated cell water level at the time step and the initial water level for that cell (i.e. the water level at the boundary condition point is assumed to be unaffected by the infiltration of surplus water).
 - The distance between the cell boundary and the boundary condition location is calculated at each time step that infiltration is occurring in the model cell using Sichert's approximation of the radius of influence of changed groundwater elevation (i.e. mounding or pumping).
 - The formula uses an assumed value for the specific yield (15% for detritals and 1% for basement) and hydraulic conductivity of the aquifer into which the lateral seepage is occurring.
 - The calculation of the radius of influence limits the water level rise to a maximum of 5m.
 - The calculation of the radius of influence limits the time over which the influence develops to 700 days from the start of infiltration (i.e. after 700 days, the zone of influence was not allowed to expand any further).
- The flow out of the model was calculated using Darcy's formula assuming:
 - hydraulic gradient as calculated above
 - a constant transmissivity

Flow losses per cell (i.e. per km length of creek length) were typically between 100m³/d and 300m³/d where the boundary of the model is detritals, and less than 1m³/d when the boundary is basement.

An example time series of the seepage loss function for a typical cell is shown in Figure 5 (Cell 20 in the 80ML discharge Base Case, bounded by tertiary detritals). The following can be seen:

- No seepage occurs before infiltration to the cell starts (0.75 years approx.).
- Initial water level rises occur seepage losses to peak at just over 400m³/d.
- The seepage rate reduces with time before reaching a steady state loss of 100m³/d, 700 days after infiltration at the cell commenced.

3.3.3 CID Losses

3.3.3.1 Base Case and Sensitivity Analysis

In model cells that are connected to CID (refer to Table 3), additional losses through the CID have been allowed for. The CID loss estimate assumes that flow is limited by the ability of the detritals to transfer water to the CID (i.e. the detritals hydraulic conductivity) and not by the ability for the CID to transfer flow. The CID loss has been assumed to be 180m³/d per km of stream length (which resulted in a maximum of 4ML/d being lost to the CID across the model).

Note that storage and transfer of water within the CID aquifer has not been modelled, i.e. the seepage loss to the CID is not accounted for once it has been lost from the model cell such that the capacity for the CID to transfer the progressive accumulation of inflow towards Flat Rocks is not accounted for.

3.3.3.2 Monte Carlo Analysis

The main aim of the Monte Carlo Analysis was to address uncertainty around the adopted parameters while considering constraints which have been estimated by reviewing model process uncertainty. In particular, the process used to model losses to the CID has been altered by allowing different detrital hydraulic conductivity values to be sampled by the model (as discussed in Section 2). Although a range of detrital hydraulic conductivity values are sampled, the Process Uncertainty analysis completed estimated that the capacity for transfer of additional flow from surplus water seepage through the CID would be limited to 12ML/d (which is higher than the effective CID capacity of 4ML/d from the Base Case Model).

Two model runs were completed, one with the total capacity for the CID to receive/transfer infiltration unconstrained, and a second model where the CID transfer capacity was constrained to a maximum value of 12ML/d, as discussed in the Process Uncertainty section of the report (Section 2).

3.4 Evaporative Losses

Evaporative losses from the model occur from two processes – increased evapotranspiration due to increased availability of water and evaporation from surface inundation areas.

3.4.1 Increased Evapotranspiration

It has been assumed that currently there is a balance between water inflow (i.e. rainfall, streamflow recharge or groundwater throughflow) and evapotranspiration from the existing vegetation within the detrital aquifer system. As rainfall and creek flow are not explicitly captured within the model, an evapotranspiration rate has been applied within the model which represents the estimated increase in evapotranspiration due to additional availability of water for vegetation to use where infiltration is occurring and to allow for some increase in vegetation density. The increase in ET has been estimated based on recent AQ2 experience from Solomon where the impacts of

supplementation and vegetation water use were studied. It should be noted that the increase in vegetation density will be variable depending on geomorphic setting. The applied ET increase is less than the maximum that maybe expected to allow for some areas where the increase will be greater and other areas where the increase will be less.

The evapotranspiration (increase) loss function works as follows:

- Annual evapotranspiration increase rate of 318mm/yr when the depth to water is less than 1m, reducing to 0mm/yr when the depth to water exceeds 10m.
- The annual evapotranspiration increase rate is varied within the model on a monthly basis using average the same pattern of variation shown by average monthly average potential evaporation rates to average annual rates.
- The evapotranspiration rate is applied to the assumed quaternary alluvium widths, which vary from 1000m (500m either side of the creek) within the upper cells of the model to typically 400-500m widths through the middle and lower parts of the model.

3.4.2 Evaporation

Evaporation losses have been applied from the active infiltration area used by the model. Monthly average dam evaporation losses for Mt Newman from the Department of Agriculture (1987) were used as the evaporation loss rates.

4 LIMITATIONS

The model has the following limitations:

- The model parameters are representative of the cell mid-point only, such that the full variability of the system is not necessarily captured in the model.
- The calculated water level for each cell represents the water level at the cell mid-point and has been assumed constant across the cell area for stage/storage calculations. Initial localised mounding beneath the creek has not been modelled.
- The model assumes infiltration occurs across the full area required to match the surplus water discharge rate from the start of the model. Therefore, the time taken for initial surface water flow propagation down the creek channel has not been modelled.
- A constant loss to the CID has been assumed in the Base Case Model, but variable losses have been simulated in the Monte Carlo Model.
- In the Base Case model, no account is taken of the impact of dewatering at Yandi operations on groundwater levels in the CID or in enhanced drainage of the CID (such that its capacity to receive alluvial infiltration maybe in excess of 4,000m³/d). In the Monte Carlo model, this has been accounted for in the estimation of transmission capacity to a dewatering pit WO.
- The model cells have been spaced at 1km distances measured along the low flow channel of the creek, and each model cell has been assumed to be a rectangular shape with lateral boundaries perpendicular to the direction of stream flow at the cell mid-point. Given the sinuous geometry of the creek line, parts of the model cells will overlap and gaps between model boundaries will occur (refer Figure 1).
- Groundwater flow downstream through the alluvial aquifer has not been considered in the model. If it were incorporated in the model, it may impact the rate at which the wetting front propagates downstream, but is unlikely to impact the extent of wetting front given Flat Rocks Springs represents a constant groundwater level at surface.

5 BASE CASE - MODEL RESULTS

The Base Case model has been run for the following discharge scenarios:

- 30ML/d for a period of 5 and 10 years;
- 50ML/d for a period of 5 and 10 years;
- 60ML/d for a period of 5 and 10 years;
- 80ML/d for a period of 5 and 10 years.

Within each model run, the wetting front has been tracked. The wetting front has been defined as the last (furthest downstream) model cell which has stream flow leaving the cell to the following cell.

5.1 Results

The extent of the wetting front downstream of the discharge point for each of these scenarios is provided in Table 4 and Figure 6, noting that the Flat Rocks Spring is located at the end of the model extents, 27km downstream of the discharge point. The progression of the wetting front with time (at half year intervals) is shown in Figure 7. As shown in these figures, the wetting front reaches the end of the model (Flat Rocks Spring) in all simulations completed.

Other than the 30ML/d scenario, the wetting front extends to Flat Rocks Springs permanently (while discharge continues) once it has reached the end of the model. For the 30ML/d scenario, the wetting front seasonally oscillates between Flat Rocks Spring (during the dry season, when evaporation rates are low) and 23km downstream of the discharge point during the wet season (when evaporation rates are high). This indicates that the maximum capacity for this tributary of Marillana Creek to sustainably receive discharge water without impacting Flat Rocks is marginally less than 30ML/d.

Different discharge rates less than 30ML/d were run in the model to predict the maximum discharge rate which would not reach Flat Rocks Springs. It was found that 23ML/d was the maximum discharge rate, which matched the average daily system losses when model fluxes were reviewed (see below).

Table 4: Base Case Wetting Front Extents for Each Scenario

Discharge Rate	5 Year	10 Year
30ML/d	24km	27km
50ML/d	27km	27km
60ML/d	27km	27km
80ML/d	27km	27km

The average daily water fluxes over the 10-year model duration for each of the discharge scenarios is shown in Figure 8. The figure shows that the largest mechanism for losing the infiltrated water is via evapotranspiration (up to 12ML/d). Filling the storage in the detritals is also a significant mechanism, but note that once the storage is filled (and discharge has reached Flat Rocks), this mechanism doesn't provide any further loss of water from the model. The seepage losses and evaporation loss are smaller components of the water balance, but combined are still a significant part of the water balance (contributing up to 11ML/d of water loss).

The model balance between total dewatering discharge, infiltration to the ground and outflow to Flat Rocks Spring is summarised in Table 5 for each of the model scenarios. These numbers represent average flow rates over the 10-year model run, noting that Flat Rocks Outflow will be zero during initial periods of the model when the wetting front hasn't reached Flat Rocks.

Table 5: Base Case Water Balance Summary (Average Over 10 Years)

Discharge Rate	Infiltration	Flat Rocks Outflow
30ML/d	27ML/d	3ML/d
50ML/d	31ML/d	19ML/d
60ML/d	32ML/d	28ML/d
80ML/d	33ML/d	47ML/d

5.2 Discussion

The model results indicate that discharging greater than 30ML/d from the proposed discharge point is likely to result in surface inundation of the Marillana Creek drainage line extending from the discharge point to Flat Rocks Springs. The extent of inundation is greater than the results from the Surface Water Solutions (2018) study, which was expected given that study assumed unlimited storage for seepage within the detrital aquifer beneath the creek (i.e. the unlimited ability to dissipate infiltration).

The storage within the detrital aquifer is greater in the upper cells of the model, where the depth to groundwater is greater. Further downstream, and closer to Flat Rocks Springs, the water table is closer to the base of the creek, and there is less available storage volume to receive infiltration such that the wetting front propagates more quickly downstream once the upstream storages are full.

With regards to the impact of uncertainty on the model predictions (both wetting front extent and timing), the following should be noted:

- Storage – the available storage within the detrital aquifer is uncertain, however storage impacts the rate at which the wetting front propagates, rather than the steady state wetting front extent, which is where the dewatering discharge rate and the total loss rate (seepage and evaporative losses) are equal. For the discharge scenarios other than 30ML/d, the wetting front is predicted to reach Flat Rocks Springs within 2.5 years, which suggests that the storage would need to be significantly greater than what has been allowed for within the model for the wetting front not to reach Flat Rocks within 10 years of discharge commencement. However, the assumed available storage may have a significant impact on the timing of the wetting front propagation. Potentially there may also be some additional storage (and losses) which has not been accounted for where the wetting front passes other Marillana Creek tributaries.
- Infiltration – similar to storage, changing the infiltration rate is likely to only impact the rate of wetting front propagation as it acts to distribute the infiltration to fill the storages differently. As an example, changing the infiltration for the 30ML/d scenario to 150mm/d caused the wetting front to reach Flat Rocks Springs in 4.5 years rather than 5.5 years.
- Evapotranspiration losses – although there is uncertainty in the increase in evapotranspiration which would occur once the dewatering discharge occurs, even if the

evapotranspiration rate was doubled compared to what has been assumed in the model, it would only add an additional 10ML/d (approx.) loss capacity to the model, which would allow discharge rates to increase from less than 30ML/d to less than 40ML/d over 10 years before Flat Rocks is impacted. If the evapotranspiration losses have been overestimated, it would mean that the wetting front would reach Flat Rocks more quickly than estimated by the model.

- CID loss – the CID seepage losses currently contribute approx. 4ML/d of losses to the model. Even if this loss rate were underestimated, and the seepage loss to the CID were doubled, it would not have a significant impact on the outcomes of the model (particularly for the 50ML/d, 60ML/d and 80ML/d scenarios). Note that the estimated throughflow of the CID aquifer used in other Yandi closure studies is in the order of 4ML/d; AQ2 considers it unlikely that an increase in groundwater levels of typically around 5m would be capable of increasing the groundwater throughflow by significantly more than what has been adopted in the model.

Even when the wetting front has not reached Flat Rocks Springs, the creek discharge is still likely to have some impact on the water available at Flat Rocks after rainfall events. The inundated low flow channel area is likely to reduce the recharge rates during creek flow events and thereby increase the flow at Flat Rocks.

6 MONTE CARLO ANALYSIS RESULTS

Monte Carlo Model runs have been completed over the proposed 10-year discharge period, with 100 model iterations completed. Two model scenarios have been completed:

- Unconstrained CID Losses
- Constrained CID Losses

Results from these analyses are generally provided in terms of a probability distribution.

6.1 Unconstrained CID Losses

The Monte Carlo model was run under a scenario where the loss of surplus water discharge to the CID was not limited by the capacity of the CID to transmit water away from the water balance, but limited by the infiltration rate through the detritals into the CID.

Model results in terms of wetting front extents (Table 6) and surplus water loss rates compared with outflow rates at Flat Rocks (Table 7) are presented below. The wetting front propagation with time is plotted in Figure 9.

Table 6: Unconstrained CID Wetting Front Extents for Each Scenario

Discharge Rate	Min	25%	50%	75%	Max
5 Year Discharge					
30ML/d	3km	3km	6km	11km	27km
50ML/d	6km	9km	11km	19km	27km
60ML/d	7km	10km	12km	25km	27km
80ML/d	10km	12km	17km	27km	27km
10 Year Discharge					
30ML/d	3km	3km	6km	11km	27km
50ML/d	6km	9km	11km	20km	27km
60ML/d	7km	10km	12km	25km	27km
80ML/d	10km	12km	17km	27km	27km

Table 7: Unconstrained CID Water Balance Summary (Average Over 10 Years)

Discharge Rate	Min	25%	50%	75%	Max
Infiltration Rate					
30ML/d	25ML/d	30ML/d	30ML/d	30ML/d	30ML/d
50ML/d	26ML/d	50ML/d	50ML/d	50ML/d	50ML/d
60ML/d	26ML/d	60ML/d	60ML/d	60ML/d	60ML/d
80ML/d	26ML/d	72ML/d	80ML/d	80ML/d	80ML/d
Flat Rocks Outflow					
30ML/d	OML/d	OML/d	OML/d	OML/d	5ML/d
50ML/d	OML/d	OML/d	OML/d	OML/d	24ML/d
60ML/d	OML/d	OML/d	OML/d	OML/d	34ML/d
80ML/d	OML/d	OML/d	OML/d	8ML/d	54ML/d

6.2 Constrained CID Losses

As discussed in the Process Uncertainty assessment which has been completed, the capacity for the CID to transmit additional flow from the seepage of surplus dewatering was estimated to be less than 12ML/d on the assumption that mining of W0 occurred (compared with the Base Case limit of 4ML/d). The Monte Carlo Model was run with the total infiltration capacity into the CID limited to 12ML/d. Note that the infiltration generally took place in the upstream model cells on the assumption that CID water levels were reduced to the bottom of Yandi's W0 pit.

Model results in terms of wetting front extents (Table 8) and surplus water loss rates compared with outflow rates at Flat Rocks (Table 9) are presented below. The wetting front propagation with time is plotted in Figure 10.

Table 8: Constrained CID Wetting Front Extents for Each Scenario

Discharge Rate	Min	25%	50%	75%	Max
5 Year Discharge					
30ML/d	10km	10km	10km	17km	27km
50ML/d	27km	27km	27km	27km	27km
60ML/d	27km	27km	27km	27km	27km
80ML/d	27km	27km	27km	27km	27km
10 Year Discharge					
30ML/d	20km	22km	23km	25km	27km
50ML/d	27km	27km	27km	27km	27km
60ML/d	27km	27km	27km	27km	27km
80ML/d	27km	27km	27km	27km	27km

Table 9: Constrained CID Water Balance Summary (Average Over 10 Years)

Discharge Rate	Min	25%	50%	75%	Max
Infiltration Rate					
30ML/d	25	30	30	30	30
50ML/d	26	35	38	38	39
60ML/d	26	35	39	39	40
80ML/d	26	36	39	40	41
Flat Rocks Outflow					
30ML/d	0	0	0	0	5
50ML/d	11	12	12	15	24
60ML/d	20	21	21	25	34
80ML/d	39	40	41	44	54

6.3 Discussion

The Monte Carlo analysis model results indicate that the wetting front extents are sensitive to both the capacity of the CID to transmit seepage from the detritals, plus the assumed hydraulic conductivity of the alluvium material. Note the following:

- As discussed in Section 2, the range of detrital hydraulic conductivity values which have been considered in the probability distribution is large (0.1m/d to 10m/d), with an apparent method-bias in the calculated values. Model iterations which have adopted a higher hydraulic conductivity value would allow higher infiltration rates into the detritals, higher seepage loss rates away from the creek through the detritals and higher loss rates into the CID (in particular for the Unconstrained CID model).
- The Constrained CID model allowed approximately 3 times more seepage through the CID than the Base Case Model (12ML/d compared with 4ML/d). Results between the two models are generally consistent, with the predicted Base Case Model Flat Rocks Outflow Rates generally within the upper quartile of results from the Constrained CID Monte Carlo model, which would be expected given the lower CID transfer capacity. The wetting front extents between the Base Case and Constrained CID Monte Carlo model were also consistent.
- The results of the Unconstrained CID Monte Carlo model are not considered feasible based on the Process Uncertainty assessment which was completed (refer Section 2).
- Note that even if the CID capacity were unconstrained, the impact of the CID being able to transfer greater rates of surplus water infiltration would be a large increase in the requirements for dewatering at WO pit at Yandi.

7 WATER TABLE SENSITIVITY TEST

A sensitivity analysis was completed on the base case model by modifying the assumed starting groundwater elevations in the model. Groundwater levels were reduced uniformly across the model by 1m (Sensitivity Test A) and 2m (Sensitivity Test B).

7.1 Sensitivity Test A

Starting water levels across the Base Case model were reduced by 1m and the model was run with the 4 surplus water discharge rates used for the other assessments. The outcomes of the model are summarised in Tables 10 and 11 (to be compared with Tables 4 and 5).

Table 10: Sensitivity A - Wetting Front Extents for Each Scenario

Discharge Rate	5 Year	10 Year
30ML/d	19km	27km
50ML/d	27km	27km
60ML/d	27km	27km
80ML/d	27km	27km

Table 11: Sensitivity A - Water Balance Summary (Average Over 10 Years)

Discharge Rate	Infiltration	Flat Rocks Outflow
30ML/d	28ML/d	2ML/d
50ML/d	33ML/d	17ML/d
60ML/d	34ML/d	26ML/d
80ML/d	35ML/d	45ML/d

7.2 Sensitivity Test B

Similar to Sensitivity Test A, a second sensitivity test was run with the starting cell water levels 2m below the assumed water levels in the Base Case. Results are shown in Tables 12 and 13.

Table 12: Sensitivity B - Wetting Front Extents for Each Scenario

Discharge Rate	5 Year	10 Year
30ML/d	15km	27km
50ML/d	27km	27km
60ML/d	27km	27km
80ML/d	27km	27km

Table 13: Sensitivity B - Water Balance Summary (Average Over 10 Years)

Discharge Rate	Infiltration	Flat Rocks Outflow
30ML/d	29ML/d	1ML/d
50ML/d	35ML/d	15ML/d
60ML/d	36ML/d	24ML/d
80ML/d	37ML/d	43ML/d

7.3 Results Discussion

Comparing the results for the reduced water table elevation sensitivity tests to the results in the Base Case model runs (Section 5), has led to the following conclusions:

- The model results do not appear to be sensitive to the changes in the assumed water table in the model, either in terms of wetting front extents or loss rates across the model. The lower water table results allow slightly higher infiltration rates to occur (due to the filling of additional cell storage plus a higher head to drive seepage losses), but in all models and durations (except the 5 year 30ML/d scenario) the surplus water discharge is predicted to reach Flat Rocks.
- The additional storage provided by the lower table only delays the propagation of the wetting front, rather than causing a meaningful difference in the capacity of the creek to infiltrate and lose surplus water discharges.

8 SUMMARY

A GoldSim water balance model of the detrital aquifer along a tributary of Marillana Creek between the proposed MAC SWP4 surplus water discharge point and Flat Rocks Springs was prepared to simulate surplus water discharge rates of 30ML/d, 50ML/d, 60ML/d and 80ML/d.

The detrital aquifer was divided longitudinally into 28 no. x 1km model cells, with infiltration to the model cells allowed across the low flow channel inundation area. Losses from the system which were modelled included surface water evaporation, increased evapotranspiration, lateral seepage to the surrounding tertiary detrital or basement aquifer and seepage to the CID aquifer.

A Base Case Model was run with the best estimates of parameters adopted. For all discharge rates modelled, the wetting front is predicted to reach Flat Rocks Springs within 10 years of discharge commencement. For the 50ML/d, 60ML/d and 80ML/d scenarios, the wetting front is predicted to reach Flat Rocks within 5 years of discharge commencing. For the 30ML/d scenario, the discharge is predicted to reach Flat Rocks Springs in about 5.5 years.

The maximum discharge rate which is estimated to be able to be discharged to the discharge point and not impact have a wetting front reaching Flat Rocks Springs is 23ML/d using the Base Case Model.

Although the Base Case Model contained the best estimate of parameters and process, inherent uncertainty in the rate of seepage loss from the creek alluvium arises from two key processes:

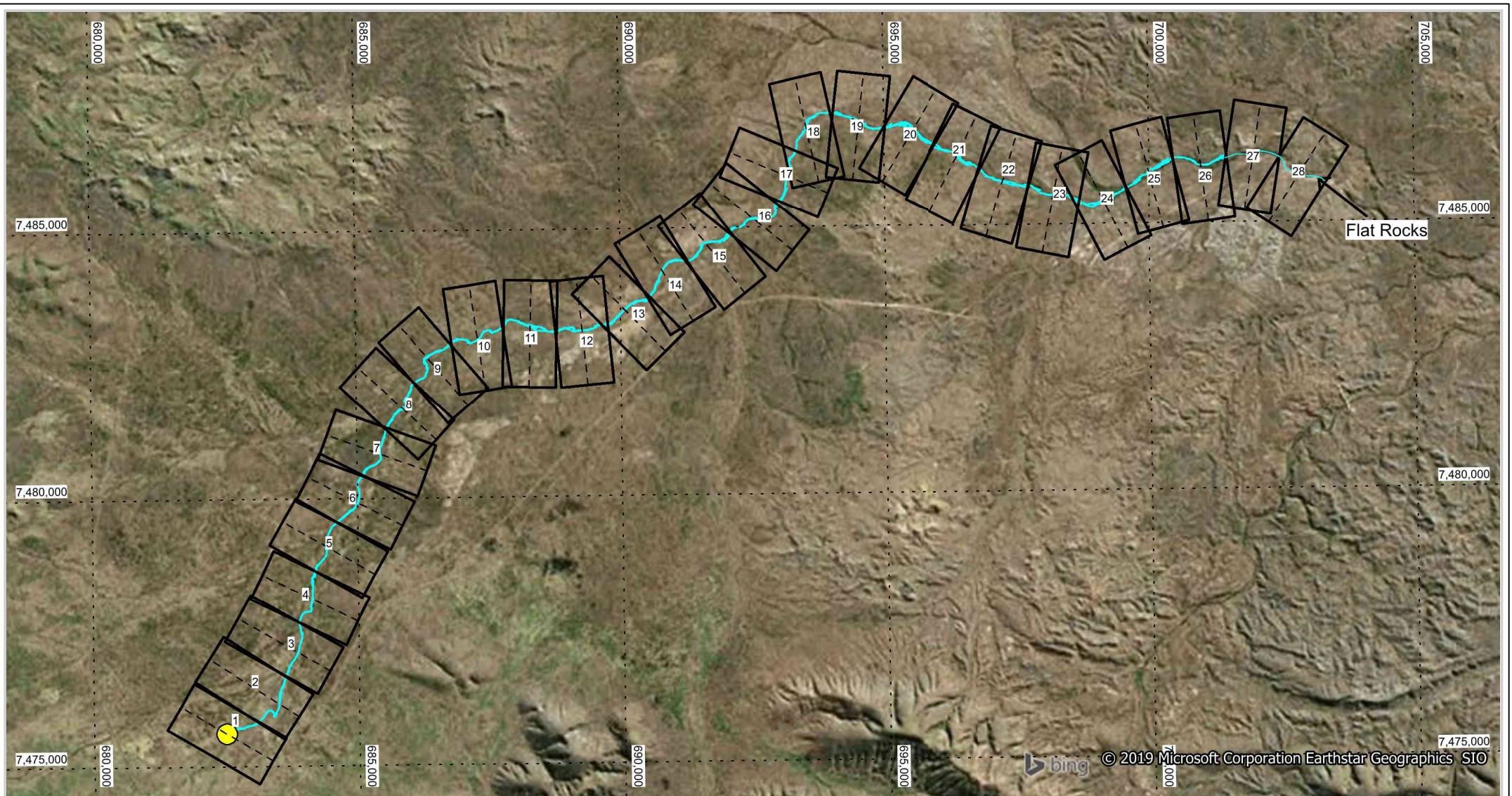
1. The rate and volume of seepage water that can be drained in the CID aquifer (i.e. once the CID aquifer is at capacity, no further seepage loss can occur. This reflects uncertainty in the process of CID drainage.
2. The rate at which water can infiltrate from the creek into the underlying CID. This reflects uncertainty in the estimates of permeability that have adopted for the alluvium.

The Process Uncertainty in point 1 was assessed by calculating the maximum transmission of additional water which could be possible through the CID between Flat Rocks and Yandi pits W0 and W1 (12ML/d). The Parameter Uncertainty in point 2 was addressed by developing probability distributions for the hydraulic conductivity values used by the model. A Monte Carlo Model was run for 100 model iterations (each iteration sampling a different hydraulic conductivity value from the probability distribution). The Monte Carlo Model was run for a scenario where the CID transfer capacity was not constrained, and a scenario where the transfer capacity was constrained to a value of 12ML/d.

The Constrained CID Monte Carlo Model and Base Case Model results were generally consistent, with the wetting front predicted to reach Flat Rocks Springs within 10 years of discharge commencement for the 50ML/d, 60ML/d and 80ML/d scenarios. For the 30ML/d scenario, it is predicted that there is a greater than 75% likelihood that the wetting front would not reach Flat Rocks.

A test of the model's sensitivity to assumed water levels within the model cells was also completed. Reducing the water levels by 1m or 2m below the Base Case assumed levels did not have a significant impact on the results from the Base Case model.

FIGURES



LOCATION MAP



Location: F:\259\4.GIS\Workspaces\005a\Figures

LEGEND

- Discharge Location
- Low Flow Channel
- Wetting Front Model Cell



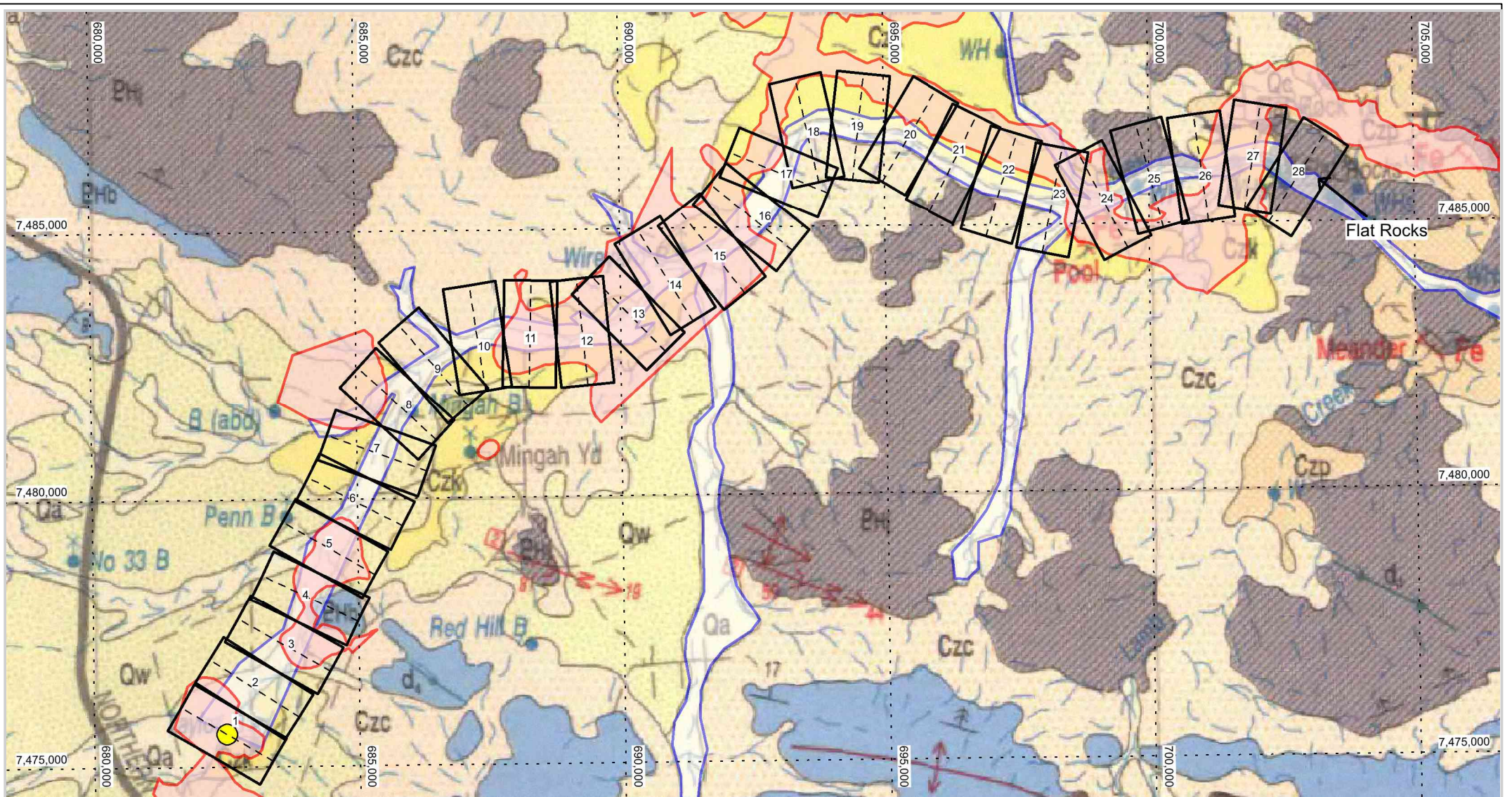
AUTHOR: MN
 DRAWN: LDS
 DATE: 20/09/2019

REPORT NO: 005a
 REVISION: A
 JOB NO: 259

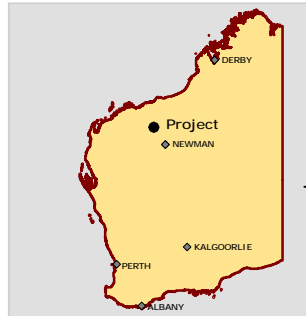
NOTES & DATA SOURCES:
 Aerial image from Bing, Microsoft Corporation 2019.
 Low flow channel based on Surface Water Solutions 2D
 Surface Water Model results up to Cell 26



FIGURE 1
**WETTING FRONT
 MODEL - CELL
 LAYOUT**



LOCATION MAP



Location: F:\259\4.GIS\Workspaces\005a Figures

LEGEND

-  Discharge Location
-  CID
-  Basement Unit
-  Wetting Front Model Cel
-  Alluvium Outcrop
-  Basement Unit



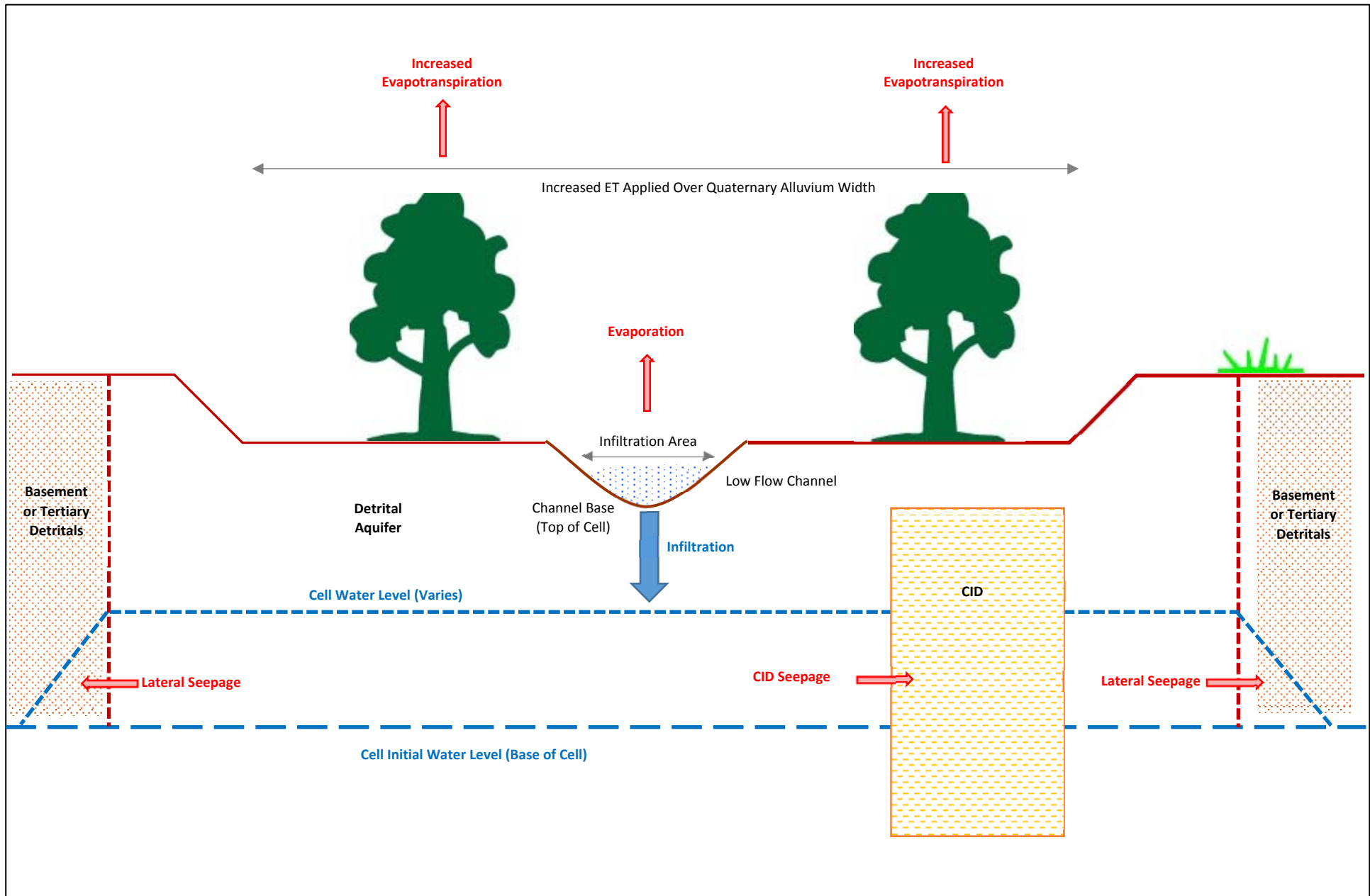
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 REVISION: A
 JOB NO: 259

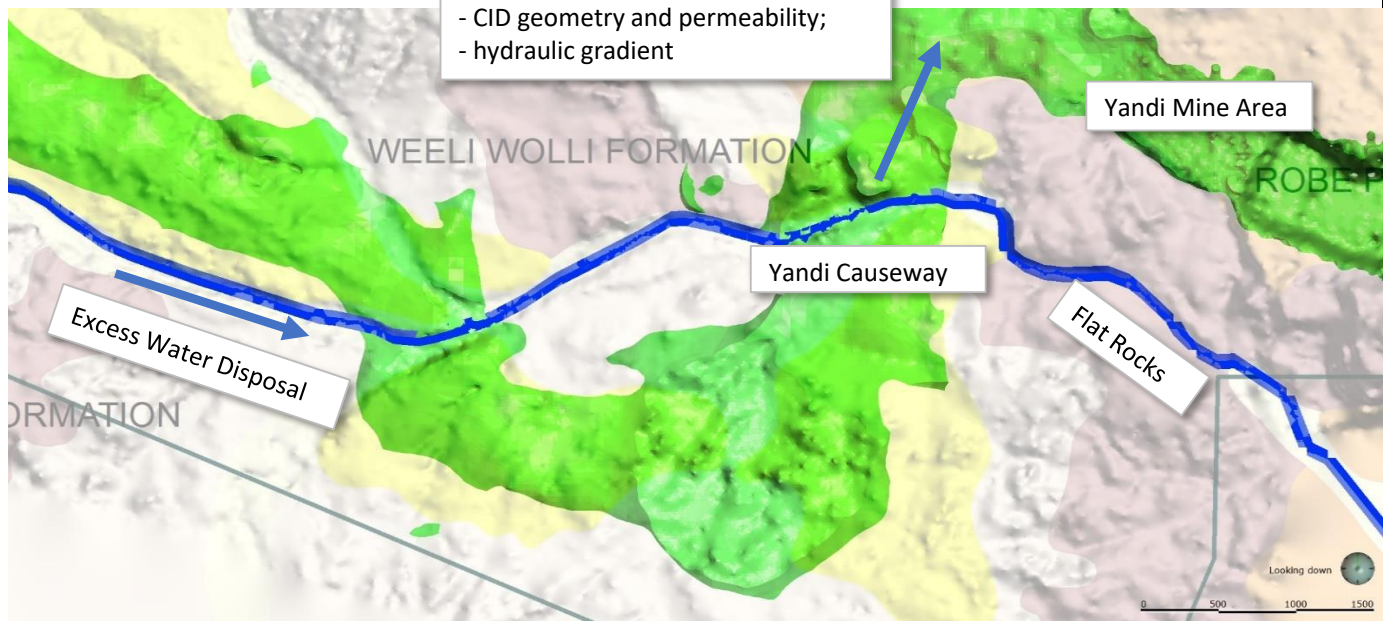
NOTES & DATA SOURCES:
 Aerial image from Bing, Microsoft Corporation 2019.
 Alluvium outcrop mapped by AQ2 from 250k Geology map
 Background Image 250k State Geology Map
 CID extents digitised from BHP Leapfrog Model



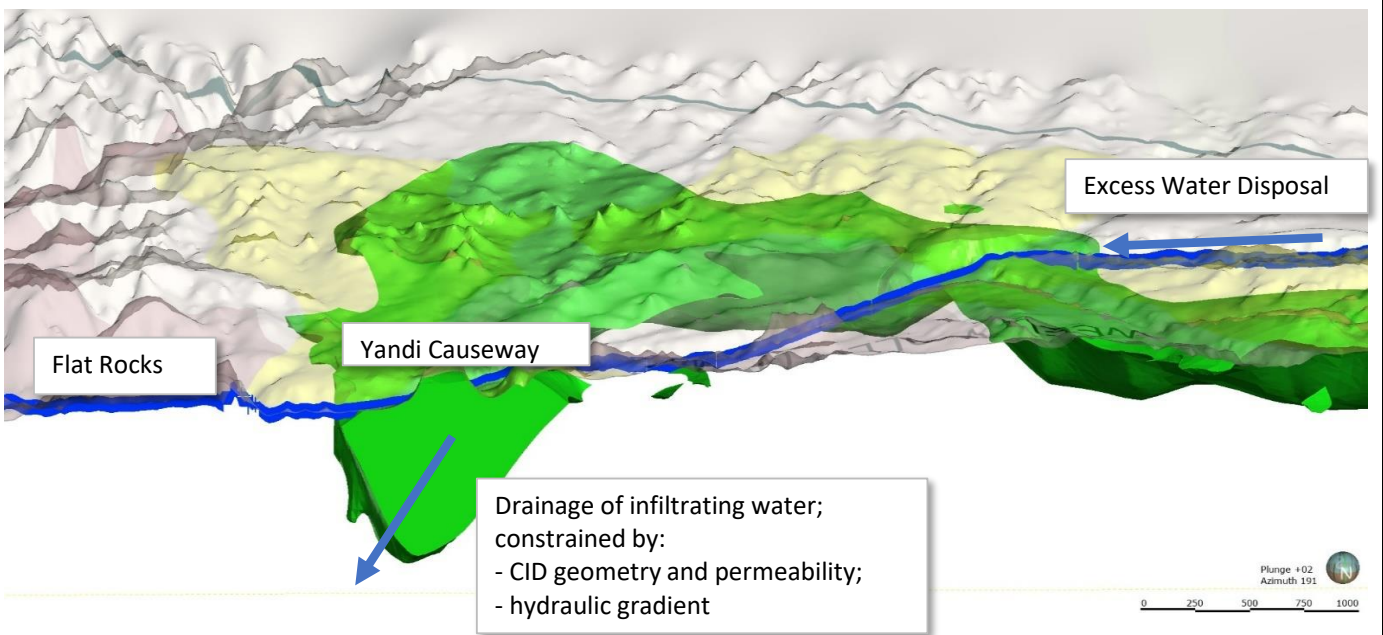
FIGURE 2
WETTING FRONT
MODEL - GEOLOGY
OVERVIEW

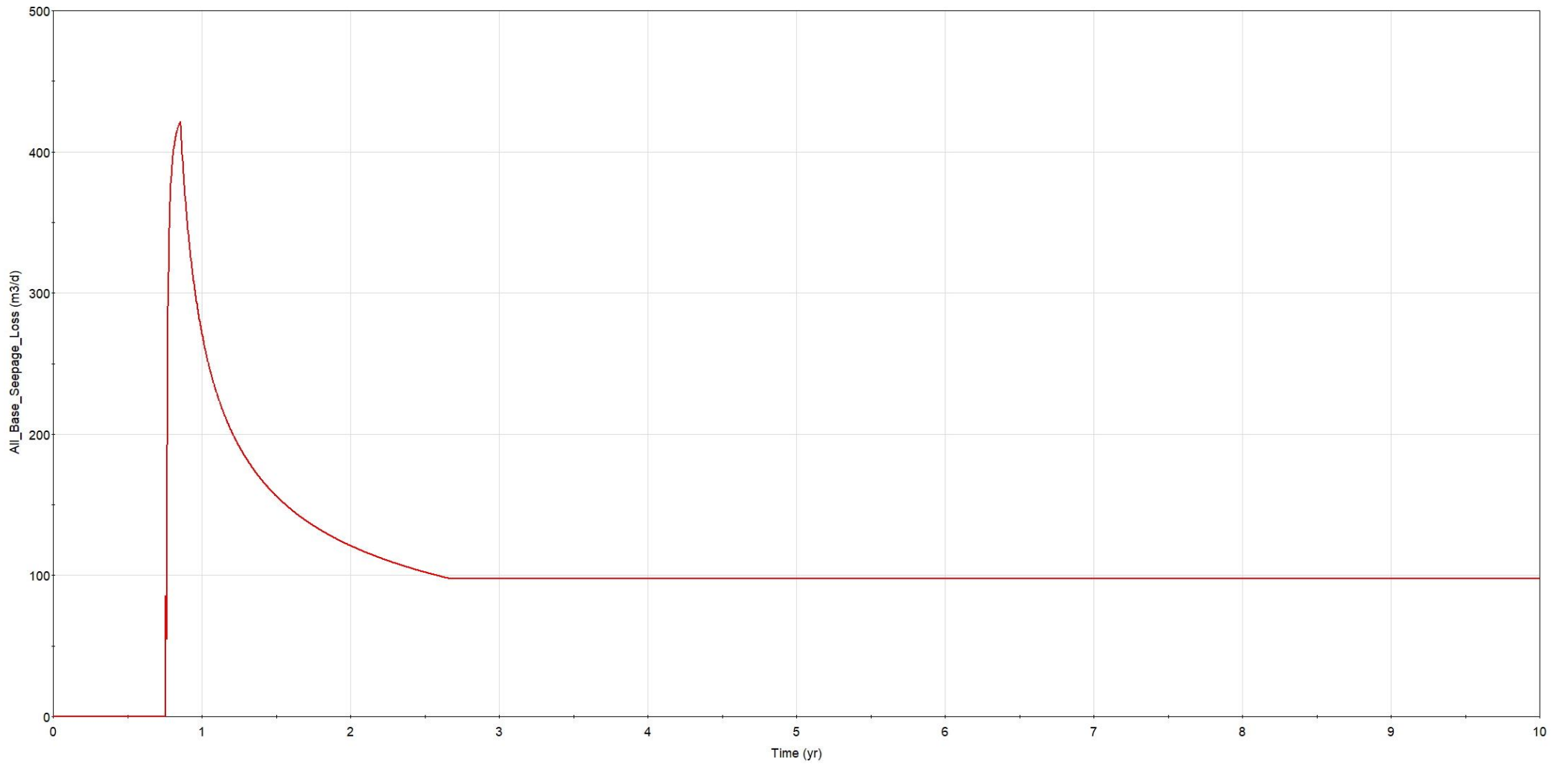


Drainage of infiltrating water;
constrained by:
- CID geometry and permeability;
- hydraulic gradient



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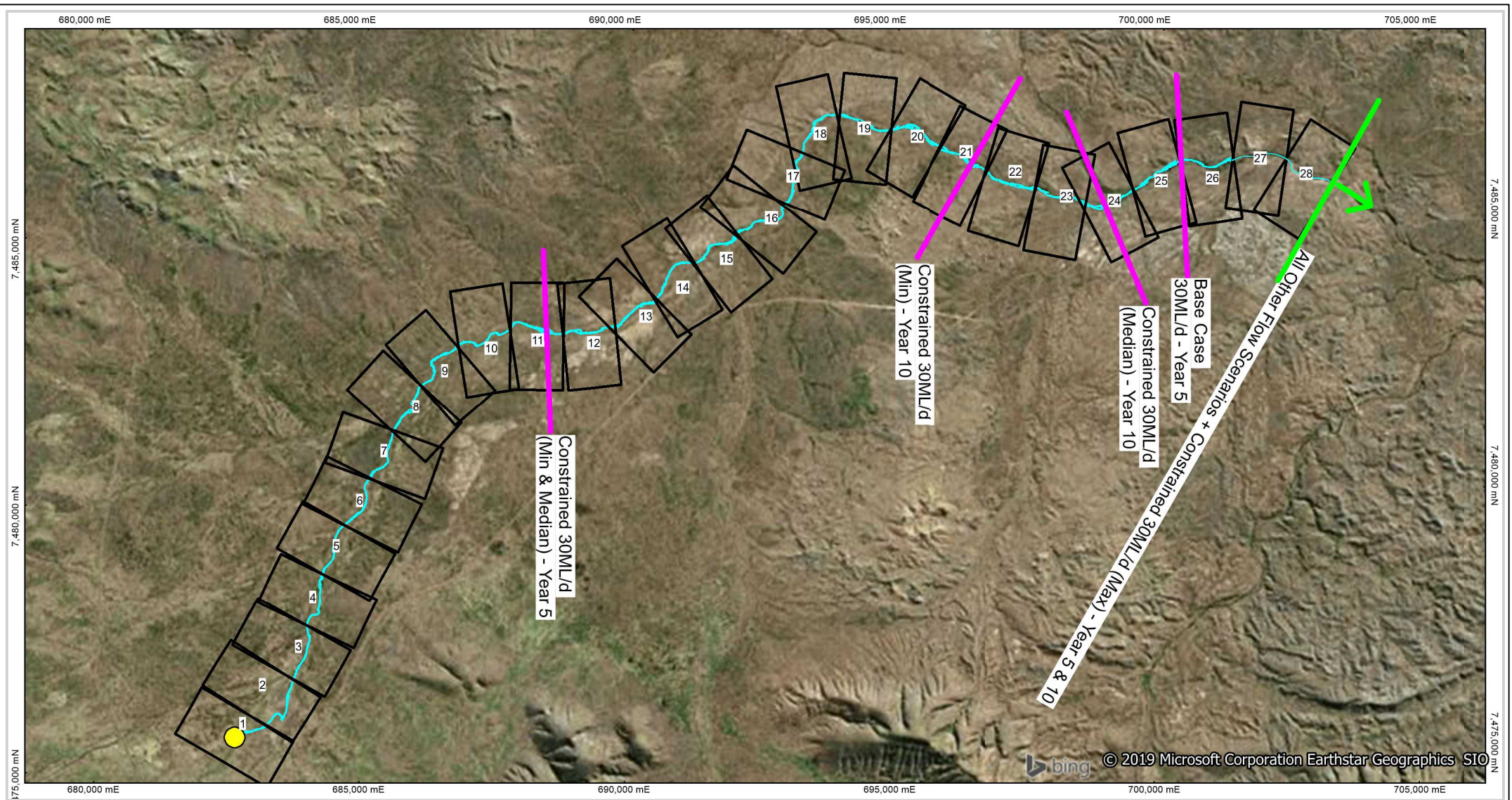


All_Base_Seepage_Loss

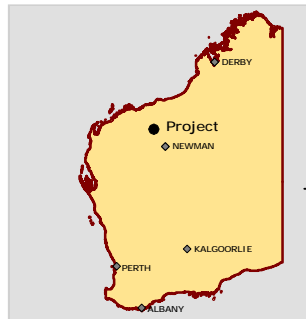


Example Detrital Seepage Loss with Time (Base Case Model - 80ML/d - Cell 20)




Figure 5



LOCATION MAP



LEGEND

-  Discharge Location
-  Low Flow Channel
-  Wetting Front Cells



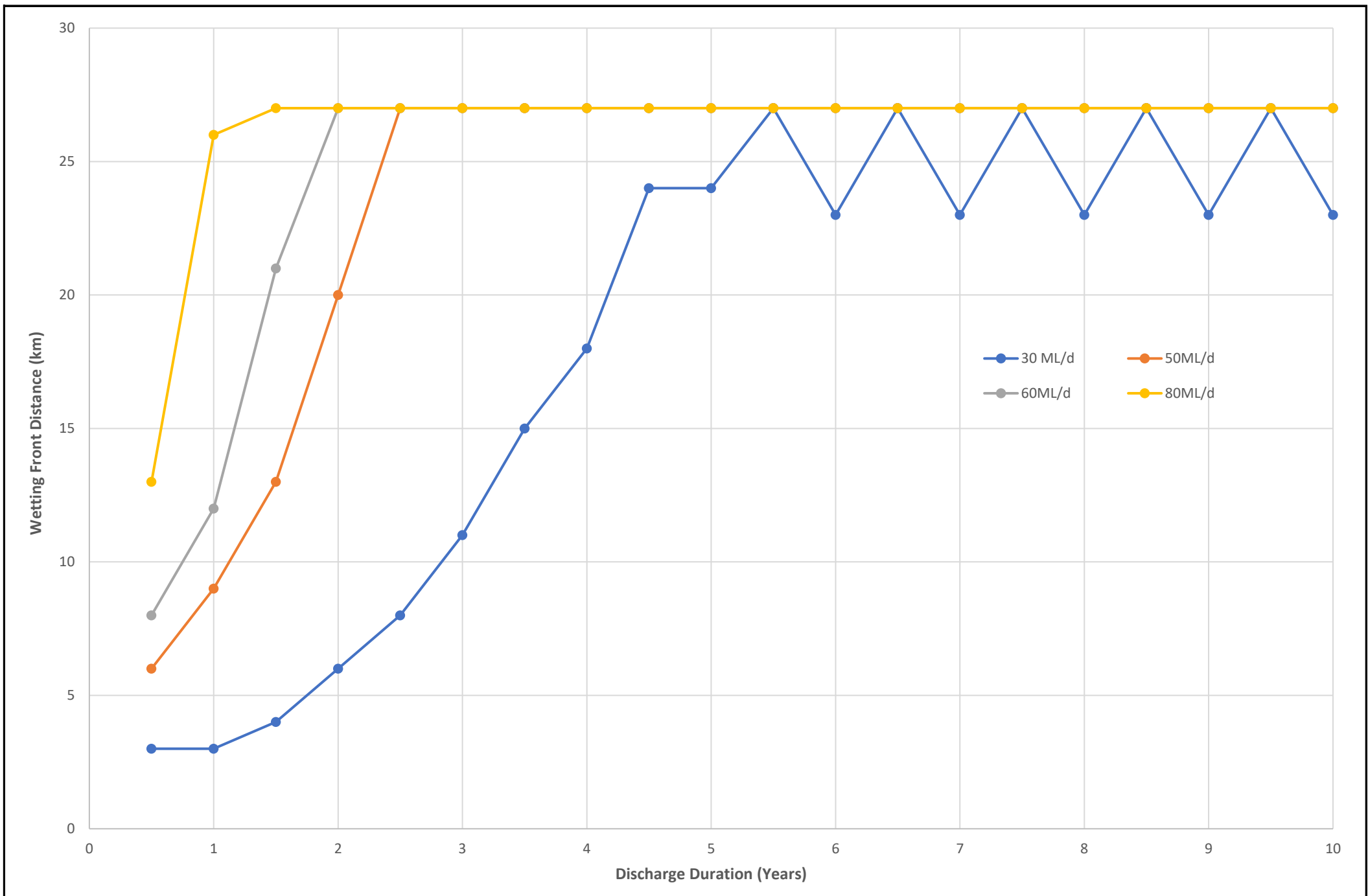
AUTHOR: MN
 DRAWN: LDS
 DATE: 18/12/2019

REPORT NO: 001b
 REVISION: 1B
 JOB NO: 259

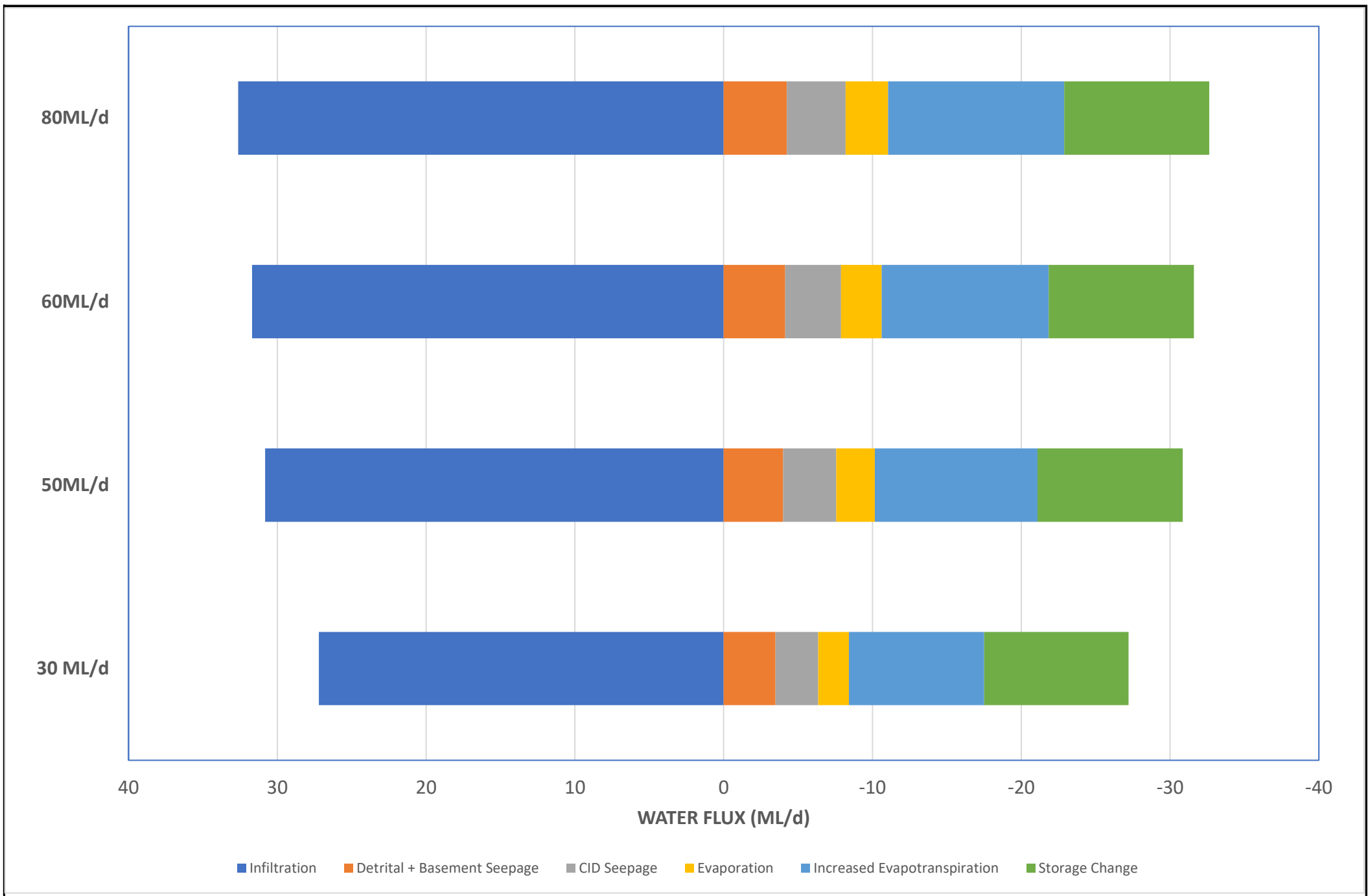
NOTES & DATA SOURCES:
 Aerial image from Bing, Microsoft Corporation 2019.
 Low flow channel based on Surface Water Solutions 2D
 Surface Water Model results up to Cell 26

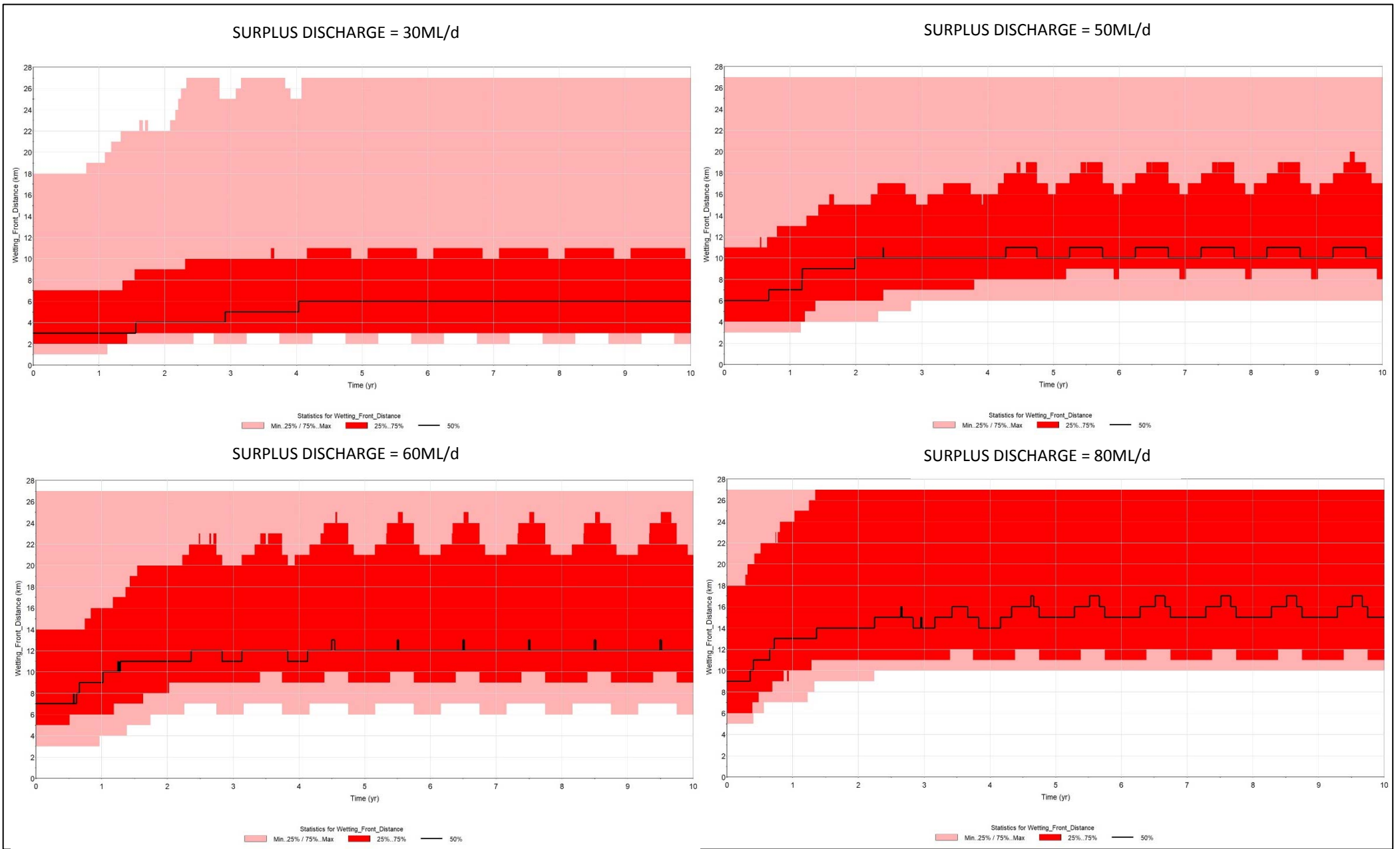


FIGURE 6
BASE CASE MODEL
PREDICTED WETTING
FRONT EXTENTS



BASE CASE MODEL - WETTING FRONT PROGRESSION FIGURE 7





UNCONSTRAINED CID – WETTING FRONT PROPAGATION

FIGURE 9

