Stantec **Memo**

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File:	Lake Mackay Inundation and Water Balance Modelling Memorandum	Date:	October 7, 2021

Lake Mackay Inundation and Water Balance Modelling Memorandum **Reference: 30003336.200**

1.0 INTRODUCTION AND AIMS

Agrimin Limited (Agrimin) are proposing to develop the Lake Mackay Potash Project (the Project) into a Sulphate of Potash (SOP) operation. The Project is located on Lake Mackay (the Lake), approximately 450 km south of Halls Creek and comprises 12 tenements totalling 4,370 km^2. The Project is constrained in the east by the Western Australian (WA) and Northern Territory (NT) border.

Agrimin proposes to extract hypersaline groundwater from the lakebed sediments, via a network of shallow trenches that will extend to an average depth of 4.5 m below the surface. Brine will flow along these trenches into a series of evaporation ponds located in the western part of the lake, to precipitate SOP-bearing salts. The salts will be wet harvested and pumped to an adjacent process plant, producing SOP as dry granular product, with distribution via a proposed port facility in Wyndham. The Project has a Definitive Feasibility Study (DFS) operational plan for a 20-year mine life.

The hydrological processes on Lake Mackay, including interactions between surface water and groundwater, are complex. To increase understanding of these processes, under baseline and operational scenarios, Agrimin commissioned Stantec Australia Ltd (Stantec) to undertake rainfall and satellite imagery analyses of Lake Mackay and to develop a water balance for the lake using GoldSim (GoldSim Technology Group 2018). Collectively, data analyses and modelling aimed to address knowledge gaps in relation to:

1. Regional rainfall patterns and their relationship to inundation of the lake.
2. Inundation frequency, surface water extent and duration of inundation on the lake.
3. Baseline and operational (Project) water balance scenarios for the lake.
4. Potential climate change impacts on the water balance of the lake during operations.

This memorandum details the outcomes of this work under three separate, albeit complementary sections comprising; 1) rainfall data analysis, 2) satellite imagery analysis, and 3) water balance modelling using GoldSim.

2.0 METHODS

2.1 RAINFALL DATA ANALYSIS

2.1.1 Review of BoM and SILO Data

To understand the regional patterns of rainfall, long-term rainfall data were collated from several weather stations in the vicinity of Lake Mackay (**Table 1, Figure 1**). These included the following Bureau of Meteorology (BoM) stations:

- Balgo Hills (Station No. 4577193), Billiluna (Station No. 002051, Rabbit Flat (Station No.) and Sturt Creek (Station No. 002029), located to the north of the lake;
- Walungurru Airport (Station No. 015664) and Giles (Station No. 013017) to the south of the lake;
- Vaughan Springs (Station No. 015554)to the east of the lake; and
- Additional records from the Lake Mackay weather station installed by Agrimin in 2017 and located on the southern shoreline of the lake.

BoM weather stations Ngulupi (Station No. 13027, located approximately 170 km north of the lake) has not been operational since 2006 and Tjukurla (Station No. 13041, located approximately 180 km south of the lake) since 2007 (BoM 2021), and were not investigated further. No weather stations are located to the west of the lake for over 500 km.

A summary of the weather stations and their location in relation to Lake Mackay is presented in **Table 1.** Three of these stations have rainfall records for 60 years or more (Balgo Hills, Sturt Creek and Vaughan Springs), while the remainder of the stations have rainfall records for less than 50 years. Sturt Creek has the longest historic records, dating back to 1899. However, rainfall data are patchy, with a paucity of records for some periods.

Table 1: Weather stations in proximity to Lake Mackay.

Weather Station	Station Number	Operation	Location	Rainfall Records (Years)	Distance from Lake Mackay
Lake Mackay (Trial Ponds Area)	N/A	2017-Current	-22.71 128.65	3	Lake Mackay southern shoreline
Walungurru Airport (Kintore)	015664	1998-Current	-23.27 129.38	22	~80 km south-east
Vaughan Springs	015554	1960-Current	-22.3 130.85	60	~160 km east
Rabbit Flat	015666	1996-Current	-20.18 130.02	24	~220 km north-east
Balgo Hills	013007	1940-2015	-20.14 127.99	74	~230 km north
Giles Meteorological Office	013017	1956-Current	-25.03 128.3	64	~260 km south
Billiluna	002051	1971-Current	-19.56 127.66	49	~315 km north
Sturt Creek	002029	1899-Current	-19.16 128.16	121	~330 km north

Available BoM records from weather stations contained a number of data gaps. Where possible and relevant, Scientific Information for Land Owners (SILO) patched point data were used to generate complete, long-term daily rainfall sequences. SILO is a daily time series of meteorological data at point locations, consisting of station records that have been supplemented by interpolated estimates where observed data are missing.

Daily total and annual total rainfall data from each station were analysed to identify long-term patterns and trends in relation to the inundation of Lake Mackay. Linear regression analysis was undertaken on annual rainfall totals for each station, completed in Microsoft Excel using the trend line function.

2.1.2 Review of Climate Change Predictions

A review of the available published literature on predicted climate change for Australia was undertaken. This information was assessed and the key projections and confidence levels where relevant to Lake Mackay were summarised in this memorandum.

2.1.3 Limitations

Only one BoM station is located less than 100 km from Lake Mackay, with local site representation of long-term rainfall data considered limited. While Lake Mackay provides the closest records, this weather station has only been operational for 3.5 years and therefore does not provide information on rainfall trends over time. Due to the sparse availability of data, future climate change projections in the region in which the lake is located have higher uncertainty.

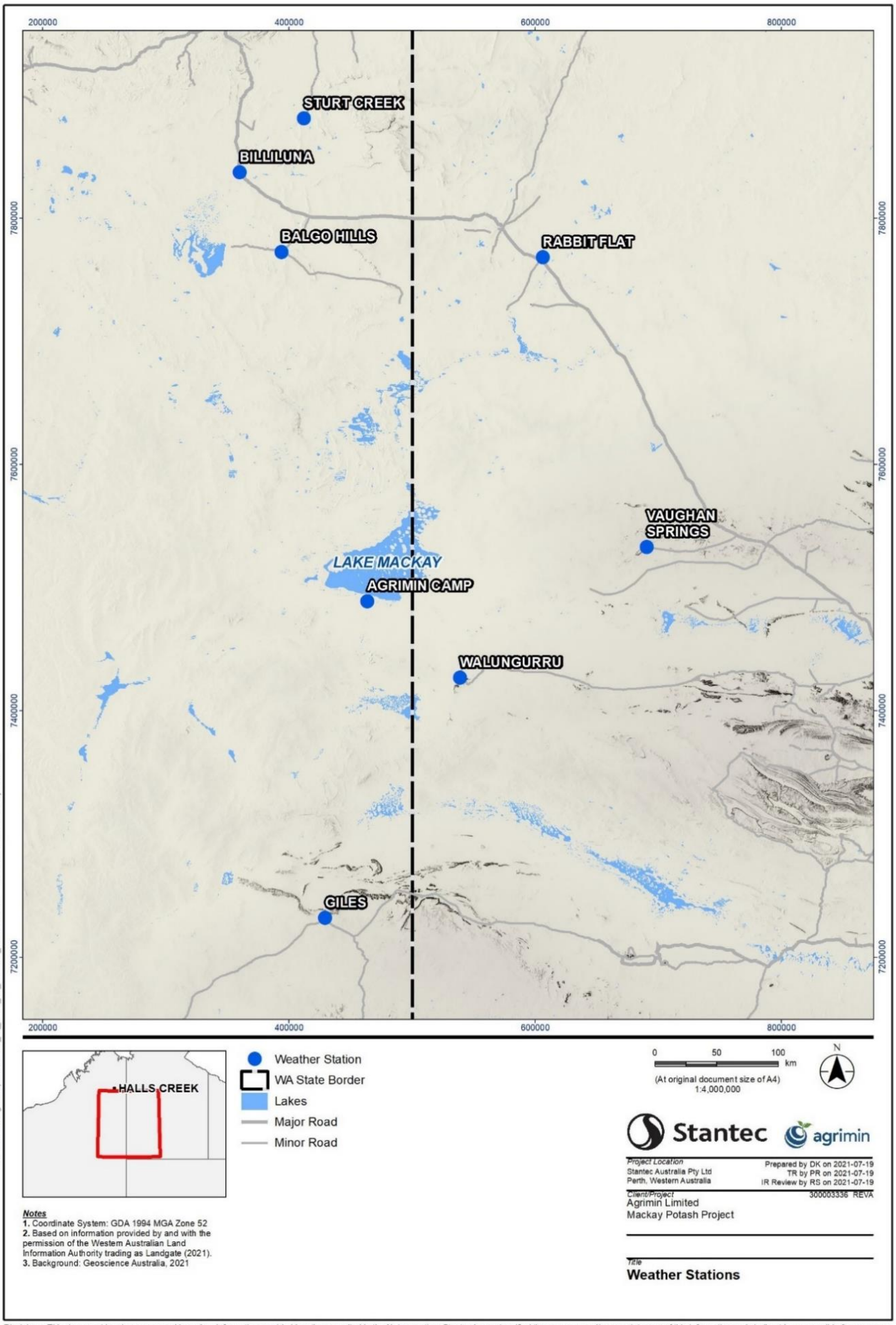

Figure 1: Location of weather stations in comparison to Lake Mackay.

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2.2 SATELLITE IMAGERY ANALYSIS

2.2.1 WOfS and DEA Waterbodies

The Water Observations from Space (WOfS) database of Geoscience Australia displays historical surface water observations derived from satellite imagery for all of Australia from 1987 to present day. Using Australia-wide Landsat 5 and Landsat 7 satellite imagery, WOfS maps the presence of surface water in each available image, using the water classification algorithm described by Mueller *et al.* (2016). This tool provides a reliable approach to visually analyse the extent and occurrence of surface water at Lake Mackay (**Figure 2**). These water observations are summed on a per-pixel basis to create a percentage water presence for every pixel. This data are available as a summary layer for all observations, or summed by season, by year, or as individual water observations.

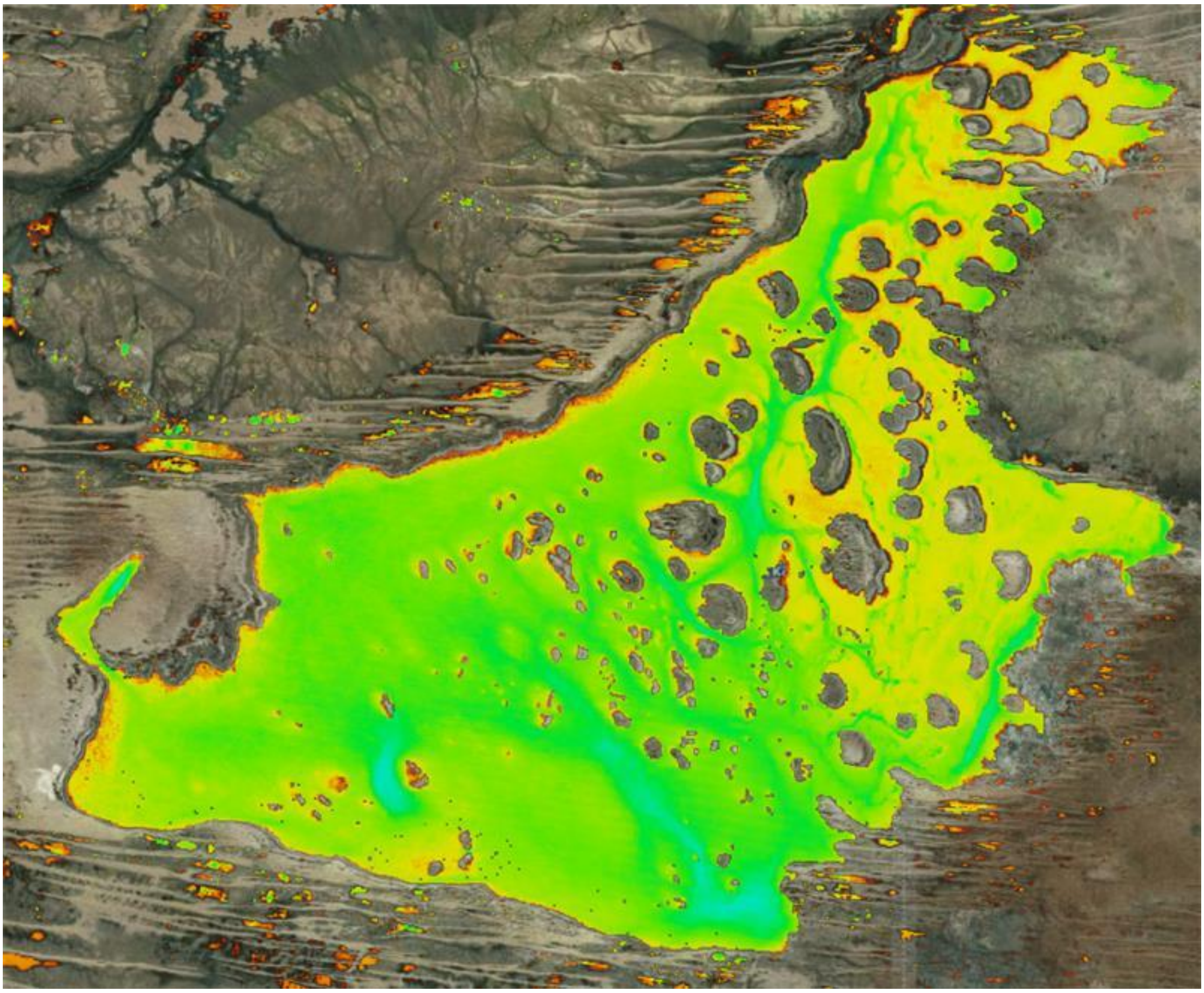

Figure 2: Lake Mackay with WOfS overlay (blue hues are where surface water is detected most often).

The DEA Waterbodies platform uses the WOfS product to map waterbodies across Australia, based on a threshold of water being present at least 10% of the time (Krause *et al.* 2021). It also provides a timeline of surface water cover using individual water observations. While this tool functions effectively for most waterbodies in Australia, it is not well suited to a temporary system such as Lake Mackay, where several areas of the lake fall below the 10% threshold of water presence over time. The derived timeline of water cover is also based on observations where at least 80% of the waterbody is covered by 'good' pixels where reliable point data are available.

This limitation is problematic for large areas such as Lake Mackay as the full extent of the lake is not always covered by the imaging swath of the satellite, and the scan-line corrector issue on Landsat 7 also greatly reduces the available coverage. Therefore, a large number of WOfS have been excluded from the available default models, reducing their temporal resolution. In addition, salt crust is often misclassed as cloud cover in the automated classifications, leading to many more valid observations not being included.

Specific to this work, a custom protocol was developed, to incorporate a significantly increased number of WOfS in the analysis. This substantially increased the spatial and temporal resolution to improve the accuracy and understanding of the inundation regime of Lake Mackay.

2.2.2 Satellite Imagery

To investigate the timing and duration of historic inundation events at the lake, an analysis was carried out using archived satellite data. This consisted of imagery from the Landsat 5, 7 and 8 satellites, and more recent data from Sentinel-2a and -2b satellites (**Table 2**).

Table 2: Satellites used to obtain imagery for analysis.

Satellite	Start Year	Repeat Cycle at Equator
Landsat 5	March 1984	16 days
Landsat 7	April 1999	16 days
Landsat 8	February 2013	16 days
Sentinel 2A	June 2015	10 days*
Sentinel 2B	March 2017	10 days*

*Note: * comprises a constellation of two polar-orbiting satellites placed in the same sun-synchronous orbit, phased at 180° to each other. (a Sentinel image at a given location could be obtained at 5 day repeat cycles).*

Imagery data were analysed using the Open Data Cube (ODC) and imagery products made available by Digital Earth Australia (DEA). Analysis was carried out in the DEA Sandbox Jupyter Lab environment. The specific products used in this analysis were the Water Observations from Space (WOfS) Summary Layer, Water Observation Feature Layers (WOFLs), and Sentinel-2 Analysis-Ready Data (ARD). The following tasks were undertaken:

1. The extent of Lake Mackay was first defined by using a 1% threshold on the WOfS summary layer instead of the default 10% to capture the lake's boundary at a higher accuracy.
2. All available WOFLs that covered Lake Mackay were then accessed – even those with partial coverage of the Lake. For each WOFL, pixels with uncertain data were masked out (as classified by the WOfS data).
3. The overall visible extent of the Lake in each image was given by this pixel count, and the overall extent with water was calculated by summing the pixels classified as water within the Lake boundary.
4. Any WOFLs that had less than 45% of the total lake surface visible were removed from the analysis.
5. Finally, Any WOFLs that had greater than 30% of the area outside the Lake classified as clouds were removed from the analysis.

To assist in filling some gaps in the Landsat imagery data and improve the cadence of recent observations, Sentinel-2 imagery data were used to calculate water cover from mid-2015 until present (**Figure 3**). Sentinel-2A and Sentinel-2b together provide a ~5-day repeat cycle, improving the chances of valid observations of the Lake between Landsat passes (every ~16 days) (**Table 2**). While DEA does not provide a Sentinel-2 WOfS data product, it was possible to custom fit this calculation using Sentinel-2 ARD and the WOfS algorithm provided by DEA in the ODC environment. Using the same workflow as described above (points 1-5), each available image of the lake was used to calculate inundation extent and was merged with the Landsat data to provide an overall time series with greater cadence after mid-2015.

Gaps in the time series between valid observations were filled using a linear interpolation to estimate inundation during these times. From this, a percentage inundation threshold was used to define inundation events, and the duration of each event was calculated as the number of days the inundation remained above that threshold. The percentage of time the Lake remained dry was also calculated, taking into account miscalculation errors (erroneous pixels) of between 1% to 5%.

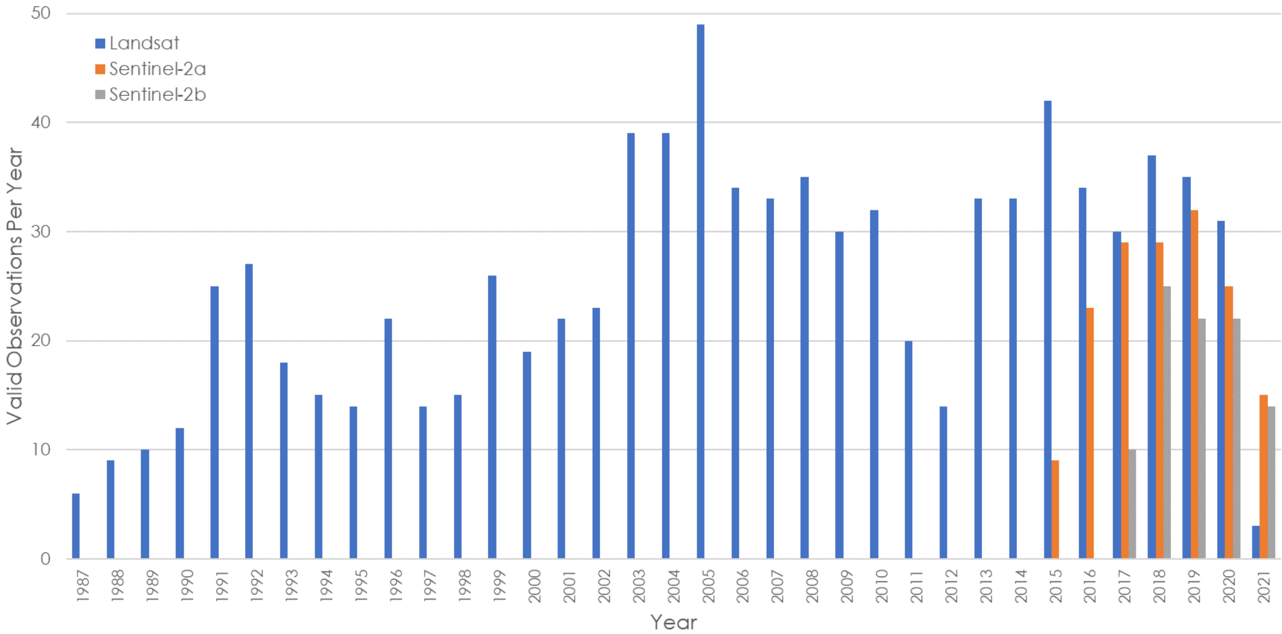

Figure 3: Number of valid observations from Landsat and Sentinel satellites over the years use for model development.

2.2.3 Limitations

Given the significant dependence on availability and condition of satellite imagery, the methods outlined above have several limitations. The repeat cycle of the Landsat satellites used is either eight or 16 days depending on time period; therefore, some minor inundation events may have been missed entirely if the event duration was shorter than the rotation period of the satellite. The start dates, end dates, and maximum inundation levels of some captured events are also likely to have been missed.

The satellite swath (the area the sensor detects) can change with each consecutive pass and therefore some passes did not have the entire lake included. An arbitrary threshold of 45% was used to remove any WOFLs that covered less than that amount of the lake. Accordingly, 1245 WOFLs were removed from the analysis. Clouds are a major obstacle to optical remote sensing. A threshold of 30% was used to remove WOFLs with high cloud cover. Accordingly, a further 182 WOFLs were removed from the analysis for high cloud cover. Both of these exclusions increase missing start and end points, maximum percent covers and even entire inundation events at the lake. In addition, 27 WOFLs were removed due to duplicate dates where both Landsat and Sentinel images were available for the same day.

Once these thresholds were applied, 1135 valid observations comprising 880 Landsat, 162 Sentinel 2a and 93 Sentinel 2b observations remained to construct a time series of inundation (**Figure 3**). This compared to the 164 valid observations provided by the DEA Waterbodies dataset.

While the inclusion of other satellites such as Sentinel-3 may have filled some gaps, there are logistical issues associated with the much coarser resolution of other satellite products, differing spectral bands and availability within the Open Data Cube.

2.3 WATER BALANCE MODELLING

2.3.1 GoldSim Modelling

Stantec developed a daily water balance model in GoldSim (v.12.1), which is a dynamic, probabilistic simulation software package (GoldSim Technology Group 2018). GoldSim was employed to simulate the hydrological processes at Lake Mackay, using relevant data and information from previous studies on surface hydrology, hydrogeology and infiltration. However, given the sizeable geographical area and limited data for the surrounding catchment, the modelling relied on simplified assumptions of regional and local hydrological processes. A conceptual model was developed as a basis for the model (**Figure 4**).

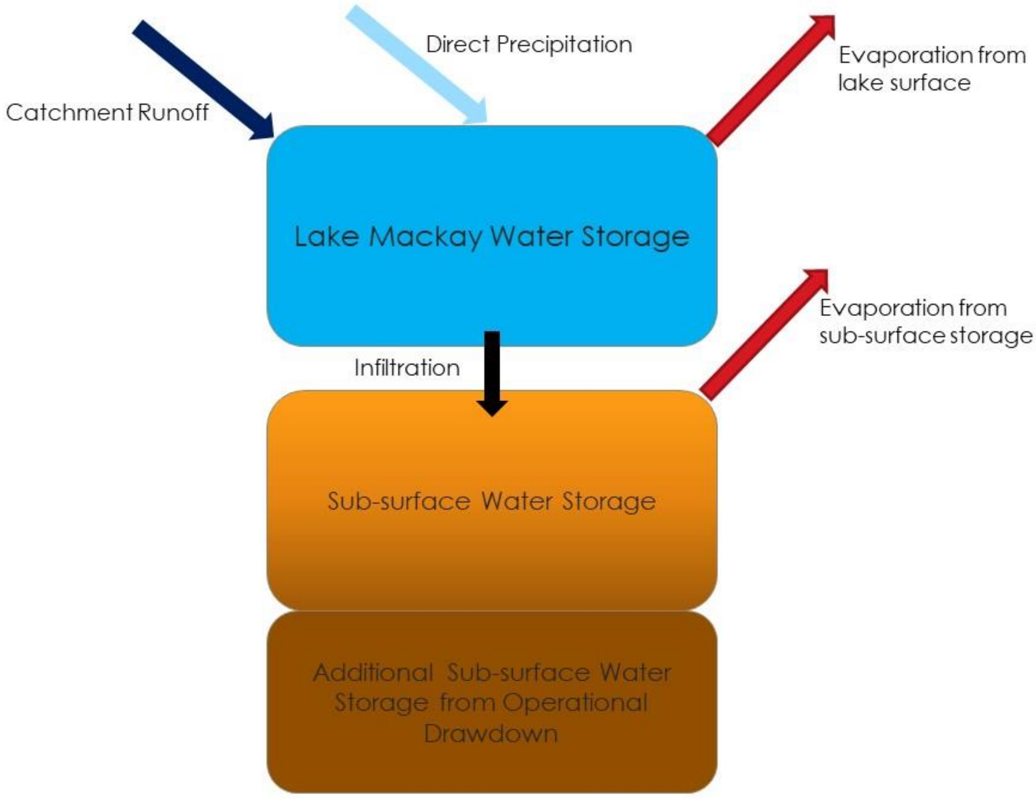

Figure 4: Conceptual model of Lake Mackay water balance model.

2.3.2 Base Case Scenario

A base case scenario was developed using available data, to determine the daily water fluxes and changes in surface area inundation, volume and water level for Lake Mackay. The lake capacity was modelled as a surface store and a sub-surface storage. The surface water capacity (**Appendix A**) was estimated from the topographical digital elevation model (DEM) data, which was derived for previous hydrological modelling of the lake (Stantec 2021a).

The maximum capacity of the sub-surface store was calculated as the surface area of the lake multiplied by the depth of the unsaturated zone multiplied by the air-filled porosity. The air-filled porosity was determined for the four lake recharge (infiltration) and evapotranspiration zones. This was based on the recharge assessment previously completed by Stantec (2020c), with an areally-weighted average value used in the model (Error! Reference source not found.).

The inflows to the lake consisted of direct precipitation on the lake surface and runoff from the surrounding catchment. The outflows from the lake included evaporation from the surface pond and the sub-surface store. It was considered that water will only pond on the surface of the lake once the storage capacity of the subsurface store is exceeded or the daily infiltration capacity is exceeded.

Stantec (2020a) documented spatial variation of localised infiltration varying from 1 mm/hr to 5000 mm/hr, with total daily infiltration typically varying between 50 to 100 mm (Error! Reference source not found.). The GoldSim modelling assumed that the maximum daily infiltration was 75 mm.

2.3.3 Inputs and Model Parameters

The rainfall and evaporation data for the model were sourced from the SILO database of Australian Climate data. The GoldSim model was run as a deterministic simulation for the period January 1960 to July 2021. The model was initially run from 1920, but the period from 1920 to 1960 generated few runoff events. This is likely due in part to the lack of operational weather stations in the region during this time (the data from which SILO rainfall is generated). While the operational mine life is approximately 20 years (plus seven years' recovery), the 6-year simulation provided an additional period of climate variability to assess the potential impact of operations. The model parameters are shown in Error! Reference source not found..

Table 3: GoldSim model parameters.

Parameter	Value	Description	Source
Lake Surface Area	302600 ha	Surface Area of lake at maximum elevation	(Stantec 2021a)
Catchment Area	19300 km^2	Percentage of catchment contributing to runoff into lake	(Stantec 2021a)
Pan Factor	0.7	Factor applied to convert pan evaporation (measured) to lake surface evaporation	Estimated from regional climate data
Runoff Coefficient	0.075	Dimensionless coefficient relating the amount of runoff to the rainfall depth	Estimated from regional studies
Unsaturated Evaporation Factor	0.25	Reduces the rate of evaporation from the sub-surface store	Estimated from regional climate data
Unsaturated Zone thickness	0.5 m	Depth to groundwater table	Estimated from groundwater monitoring data and modelling (Stantec 2020a)
Airfilled porosity above water table	14%	Proportion of soil volume that is filled with air	(Stantec 2020c)

2.3.4 Verification

There was insufficient monitoring data available to perform a detailed calibration of all the parameters used in the GoldSim water balance model. However, the base case model was verified against the inundation analysis derived from the satellite imagery. Event specific comparisons between the modelled and satellite imagery analysis is shown in **Appendix B**.

The surface area duration (SAD) curve for the GoldSim model and the satellite imagery analyis, based on the daily model simulation results from 1988 to 2021 is shown in **Figure 5**. The SAD shows that the model simulates a shorter overall duration of inundation than indicated by the satellite imagery analysis. In addition, the model predicts a maximum surface area of 77% of maximum extent (compared with 100%). This was likely attributed to the use of a constant runoff coefficient, which may vary over time, increasing substantially during wet seasons where multiple large, rainfall events result in saturated catchment conditions.

However, despite the lack of input data and simplified parametrisation, the GoldSim model was able to adequately simulate the overall lake water balance in response to rainfall events. The model supports the comparison of operational and base case scenarios.

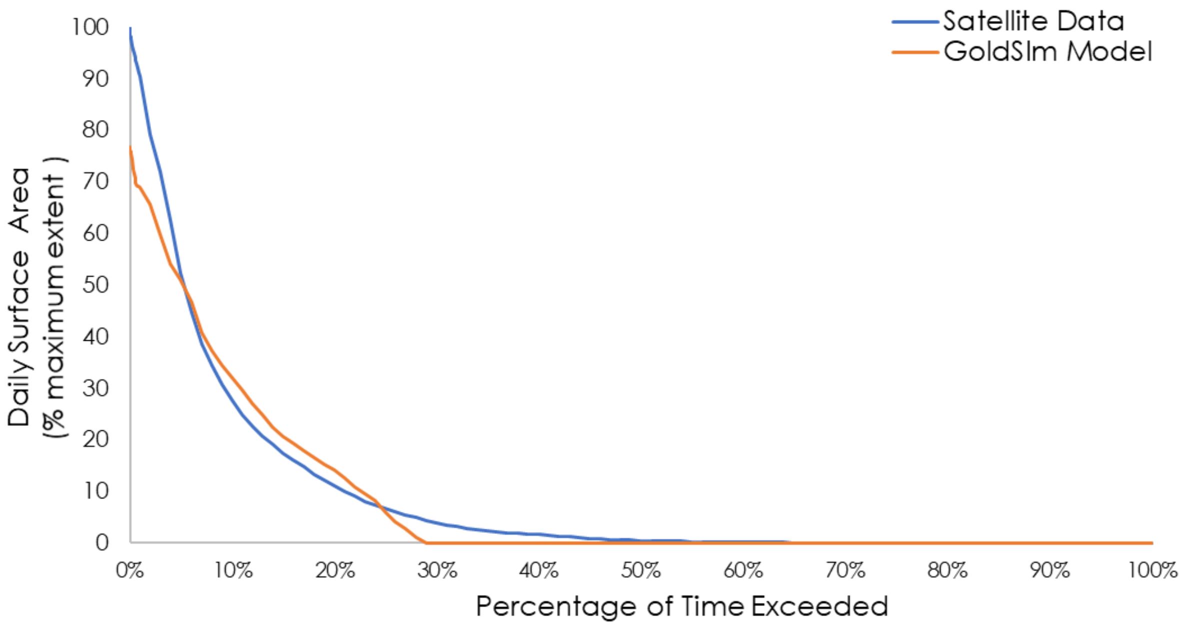

Figure 5: Surface area duration curve (SAD) for the GoldSim model vs satellite imagery analysis data.

2.3.5 Operational Scenario

In addition to the base case scenario, an operational scenario was developed to assess the impact of the proposed operations on the extent and persistence of lake inundation. This scenario accounted for the increased depth of the unsaturated zone due to the expected drawdown effects of brine extraction for the Project. The operational scenario uses the same input data and model set up as the base case with the following changes:

- Four recharge zones were established based on field testing, laboratory testing and HYDRUS 1D modelling, shown in **Figure 6**, with the highest infiltration in the eastern portion of the lake due to the sandy gypsiferous composition;
- Annual drawdown was calculated at each 50 m x 50 m cell in the DFS groundwater model (Stantec 2020a) and then averaged over the for recharge zones;
- Average annual change in storage was then determined by multiplying the drawdown by the specific yield of the brine production interval in each cell to determine the additional available subsurface storage volume due to mine operations, which was then averaged over the four recharge zones (**Figure 7**);
- The air-filled porosity between ground level and 0.5 m depth was reduced from 14% to 19% to account for the increased depth in the unsaturated zone, adapted from the results presented in Stantec (2020c)

To simulate variable climatic conditions during the 20-year operational life and 7-year recovery period, the rainfall data (1960 to 2021) were shifted by 1 year to produce 61 different climate sequences. These data were then input into the GoldSim model to give 61 different water level result realisations for Lake Mackay. The modelling results are presented in **Section 3.3**.

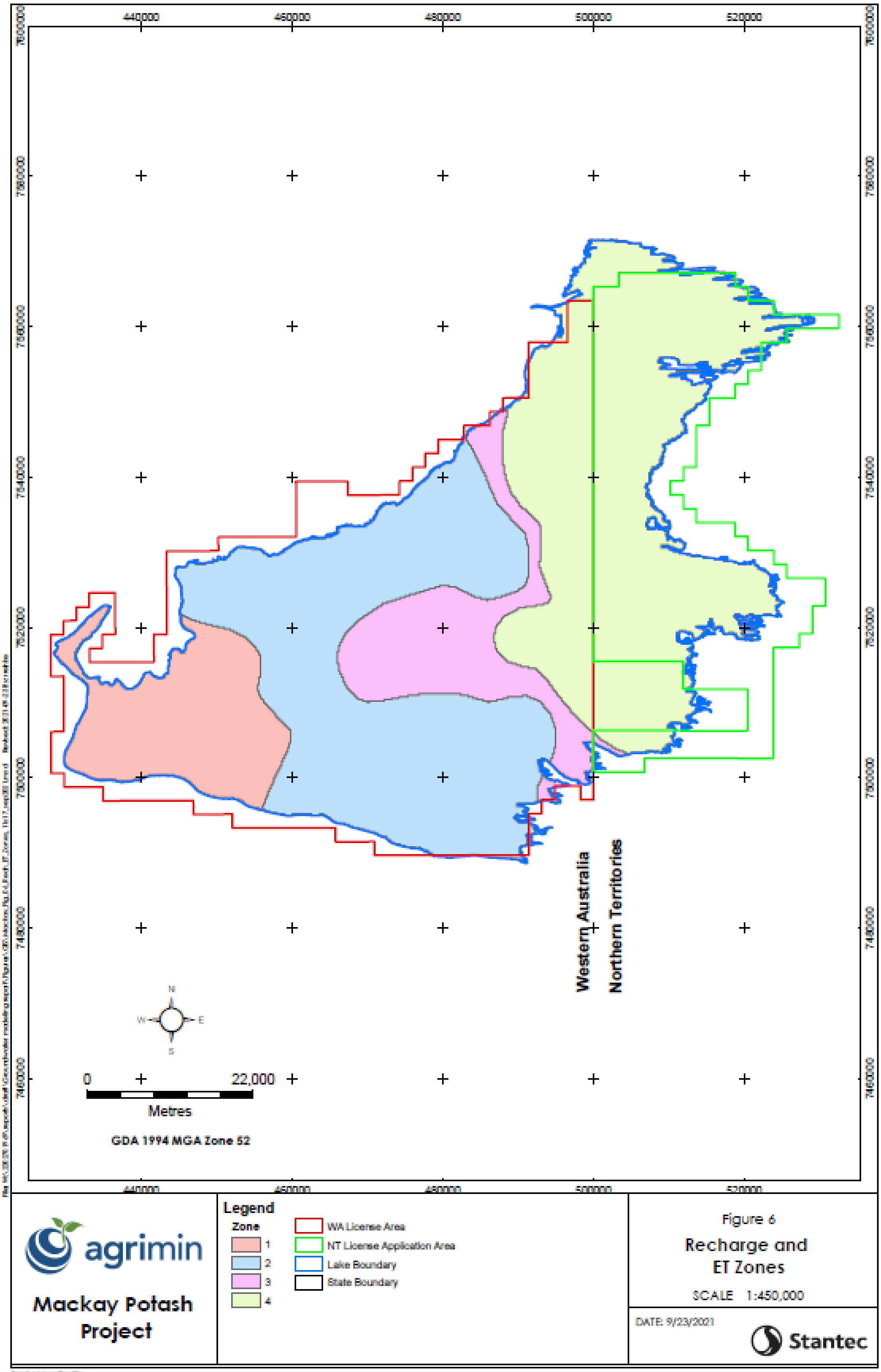

Figure 6: Lake Mackay recharge (infiltration) and evapotranspiration zones from Stantec (2020a).

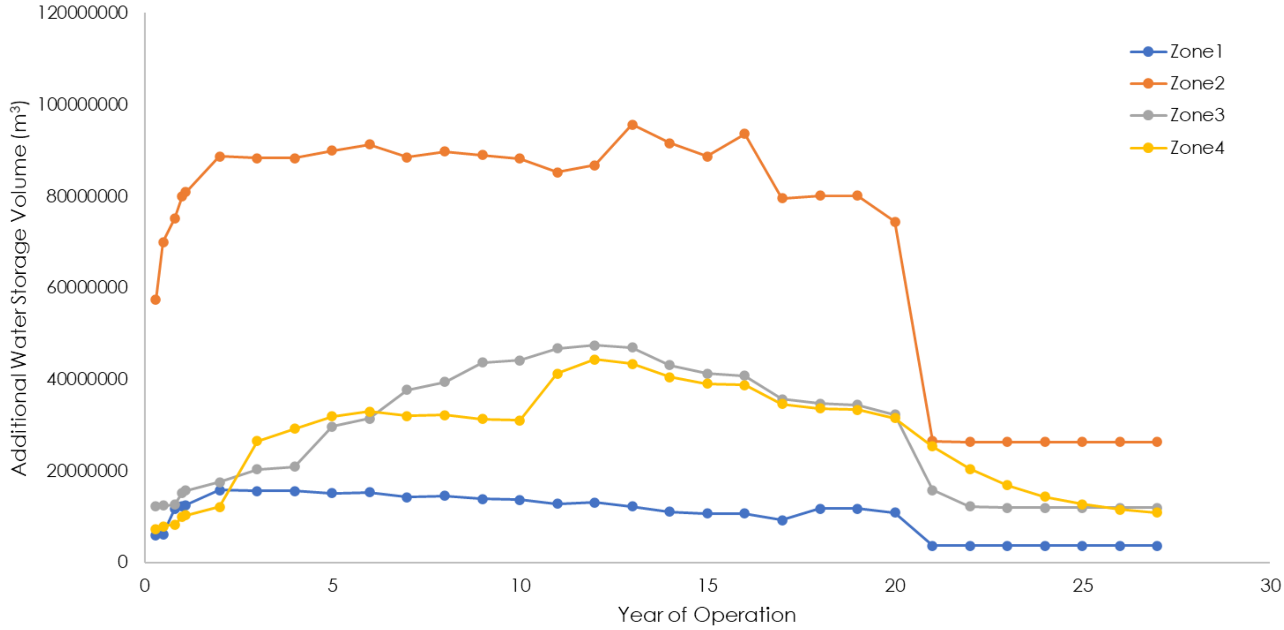

Figure 7: Projected groundwater storage volume fluctuations during operations.

2.3.6 Limitations

The GoldSim model incorporates the available data relevant to Lake Mackay. However, given the vast lake and catchment area it has been necessary to use a simplistic representation of complex, highly variable and unpredictable hydrological processes . The GoldSim water balance model was limited by the availability and quantity of input data. In the absence of relevant rainfall and monitoring data, generalised parameters have been applied across the entire area, limiting the accuracy of the model. Rainfall is a key input to the water balance; however, the rainfall records for the region are sparse and limited in the immediate vicinity of Lake Mackay.

Additional uncertainties in the model may relate to:

- Lack of streamflow data to calibrate the runoff from the catchments and inflows;
- The stage-storage relationships assigned to operational scenarios account for constructed ponds but do not account for the presence of bunds around the trenches;
- Inaccuracies in the terrain data used to generate the stage-storage-surface area curves for the lake;
- Discrepancies in the measurement and estimation of the evaporation; and
- Simplified assumptions around the ground water flux surrounding the lake.

3.0 RESULTS

3.1 RAINFALL DATA ANALYSIS

3.1.1 Geographical Trends

Annual rainfall throughout the region, in the vicinity of Lake Mackay is highly variable. The mean annual rainfall to the north of the lake is comparatively higher than areas located to the south and east. The average annual rainfall of the four BoM weather stations north of the lake (Sturt Creek, Rabbit Flat, Balgo Hills and Balliuna) is approximately 435 mm, while to the south it is approximately 290 mm (Giles), to the east it is approximately 297 mm (Vaughan), and at nearby Walungurru it is approximately 271 mm (BoM 2021).

This trend is consistent with the rainfall gradient across Australia, where annual average rainfall decreases from the coast, towards the centre of the continent. The four BoM weather stations to the north of the lake fall within the 400 to 600 mm isohyets zone, while Giles (located south of the lake) lies within the 200 to 300 mm isohyet zone, and the lake is situated across both of these zones (**Figure 8**).

Gridded BoM Intensity-Frequency-Duration (IFD) data show less pronounced spatial variation in individual storm events (BoM 2016). The 72-hour, 1% Annual Exceedance Probability (AEP) event varies from a low of 257 mm in the southeast corner to a high of 277 mm in the northeast corner of the lake. The 6-hour, 10% AEP event varies from 69 mm to 72 mm across the same extents.

3.1.2 Long-term Trends

Over the past century, and especially after the 1970s, long-term rainfall observations show an increase in the summer rainfall (wet season) over northwest Western Australia (Smith 2004), while rainfall in central west of the state has exhibited comparatively weaker trends. Since 1958, there has been an overall increase in rainfall at the regional scale, largely attributed to increasing cyclonic activity, bringing onshore moist tropical flow to the Pilbara coast and inland (Fierro and Leslie 2013). Increased rainfall may also be related to changing patterns in monsoonal weather and frontal systems (Dey *et al.* 2019).

Rainfall trends since 1958 in the wet season months of November to April in central west Western Australia are primarily associated with El Niño–Southern Oscillation (ENSO), and with the southern annular mode (SAM) further inland (Fierro and Leslie 2013). However, increased rainfall north and northwest of Lake Mackay has been linked to an increase in the growth rate of the northwest cloud bands and an increase in the variability of the Madden-Julien Oscillation (Bates *et al.* 2010).

Linear regression of total annual rainfall data indicates variable long-term patterns throughout the region. Rainfall at Sturt Creek (**Figure 9A-B**), Balgo Hills (**Figure 9C-D**), and Giles (**Figure 10E-F**) shows an increase in total annual rainfall over time. At Sturt Creek and Balgo Hills, daily records (**Figure 9A-C**), which date back to the late 1950's, also indicate an increased frequency of rainfall events above 50 mm since 2000, particularly evident in the most recent records. In contrast, total annual rainfall at Rabbit Flat (**Figure 9G-H**) and Vaughan (**Figure 10A-B**) shows a long-term decreasing trend, while patterns are not evident at Billiluna (**Figure 9C-D**), Walungurru (**Figure 10E-F**) and the Agrimin Lake Mackay stations (**Figure 10G**), due to a paucity of records.

The Australian Rainfall and Runoff (ARR) data hub includes interim climate change factors for application to precipitation depths. Factors are presented for a range of Representative Concentration Pathways (RCPs). ARR recommends RCP4.5 and RCP8.5, with 2050 predicted global temperature increases ranging from 1.5 to 2.0°C. The resulting increase in precipitation intensities or depths for the lake area ranges from 7.7% to 10.3% (Ball *et al.* 2019). The impacts on rainfall patterns is unclear, and ARR recommends that spatial patterns, temporal patterns, space-time patterns, and areal reduction factors should be the same as derived under existing climatic conditions until credible further studies are completed showing otherwise (Ball *et al.* 2019). Whilst rainfall intensities for individual events are expected to increase over time, a drier climate will also result in a decrease in soil moisture and a corresponding increase in soil losses, potentially offsetting the impact on runoff. Where climate change impacts cannot be effectively predicted, as is the case in the Lake Mackay catchment, ARR suggests recognising the additional uncertainty in simulation results until further studies are completed (Ball *et al.* 2019).

3.1.3 Major Rainfall Events

The highest annual rainfall totals recorded to date across all of the weather stations occurred in 1974 and in 2001 (**Figure 9A-H, Figure 10A-G**). Totals during 1974 ranged from 782 mm (Giles) to 1,133 at Vaughn, and in 2001 from 795 mm (Balgo Hills) to 1,106 mm at Sturt Creek. Rainfall totals were also above 750 mm at all stations (except for Giles) in 2000, indicating two successively wet years throughout the region (BoM 2021), partially related to tropical cyclone (TC) activity at the end of this year.

At Walungurru Airport, the closest BoM weather station to Lake Mackay, only patchy rainfall records are available, since 1998 (**Figure 10E-F**). Of these, the highest annual total of 500 mm was recorded in 2014. There have also been two days that have recorded totals in excess of 100 mm (in March 2006 and December 2016). Rainfall was not associated with TCs and was attributed to localised storm systems (BoM 2021). Similarly, there are limited records available for the Agrimin Lake Mackay weather station, with the highest daily rainfall of 50 mm recorded in February 2021 (**Figure 10G**).

The timing of TCs or ex-TCs traversing through the region has shown some correlation with major rainfall events. As Lake Mackay is located more than 800 km inland from the ocean, most TCs do not reach the lake. However, the paths of several remnant TCs have passed within the vicinity of the lake since 1899 according to historic records (**Figure 11**), including:

- TC Gwen passed directly over the lake as a Tropical Low in 1967
- TC Alan passed south-east of the lake as a Category 1 in 1976;
- TC Jane passed south of the lake as a Category 1 in 1983;
- TC Gertie passed south of the lake as a Tropical Low / Category 1 in 1995; and
- TC Sam passed north of the lake as a Category 1 in 2000/2001 (NOAA 2021).

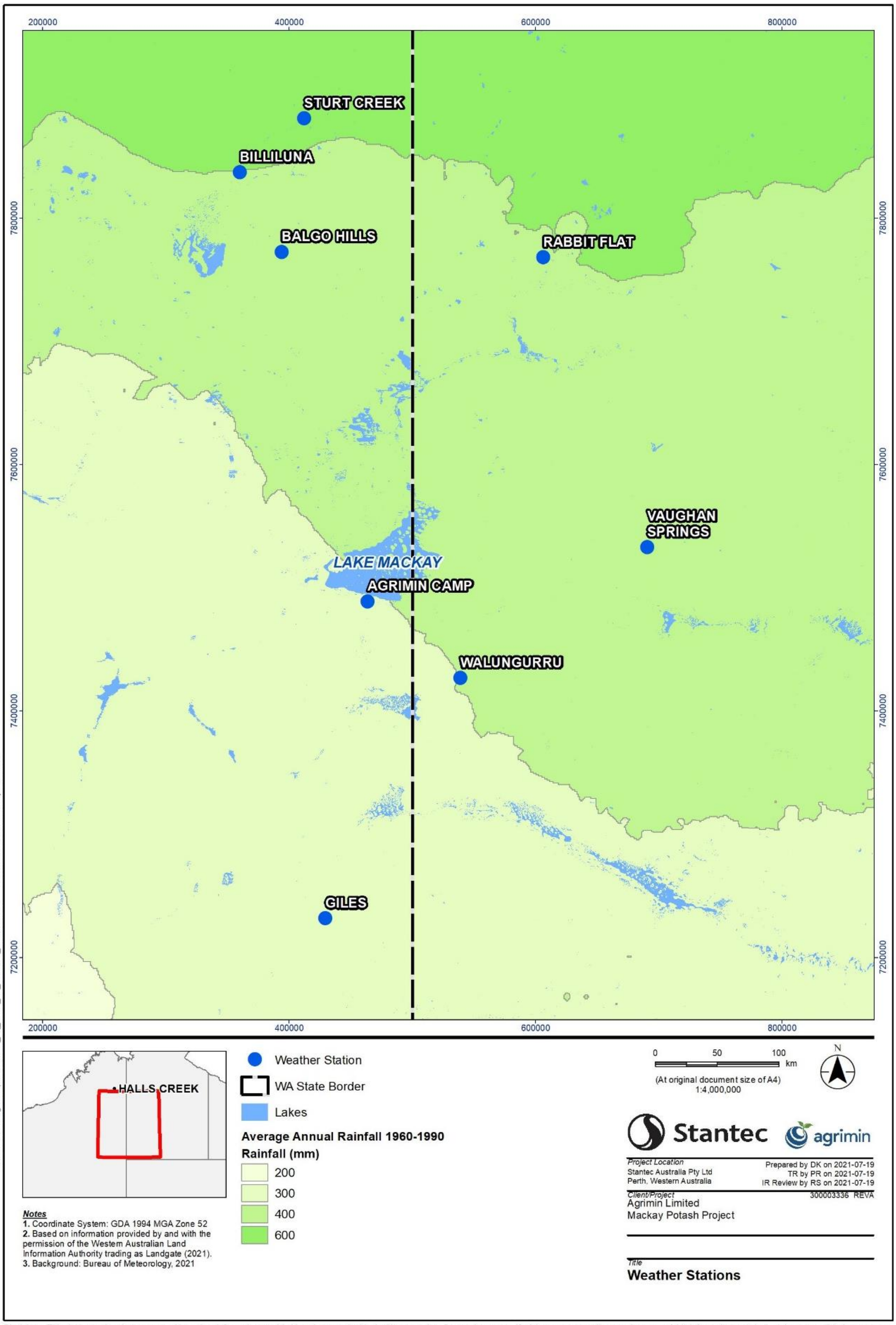

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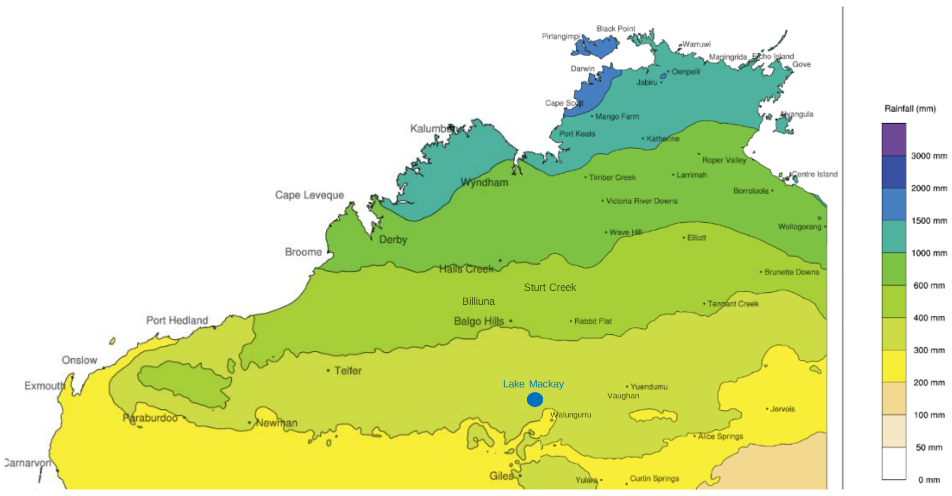
Figure 8: Average annual rainfall isohyets and the location of BoM weather stations in the vicinity of Lake Mackay (Source: Bureau of Meteorology, 2021).



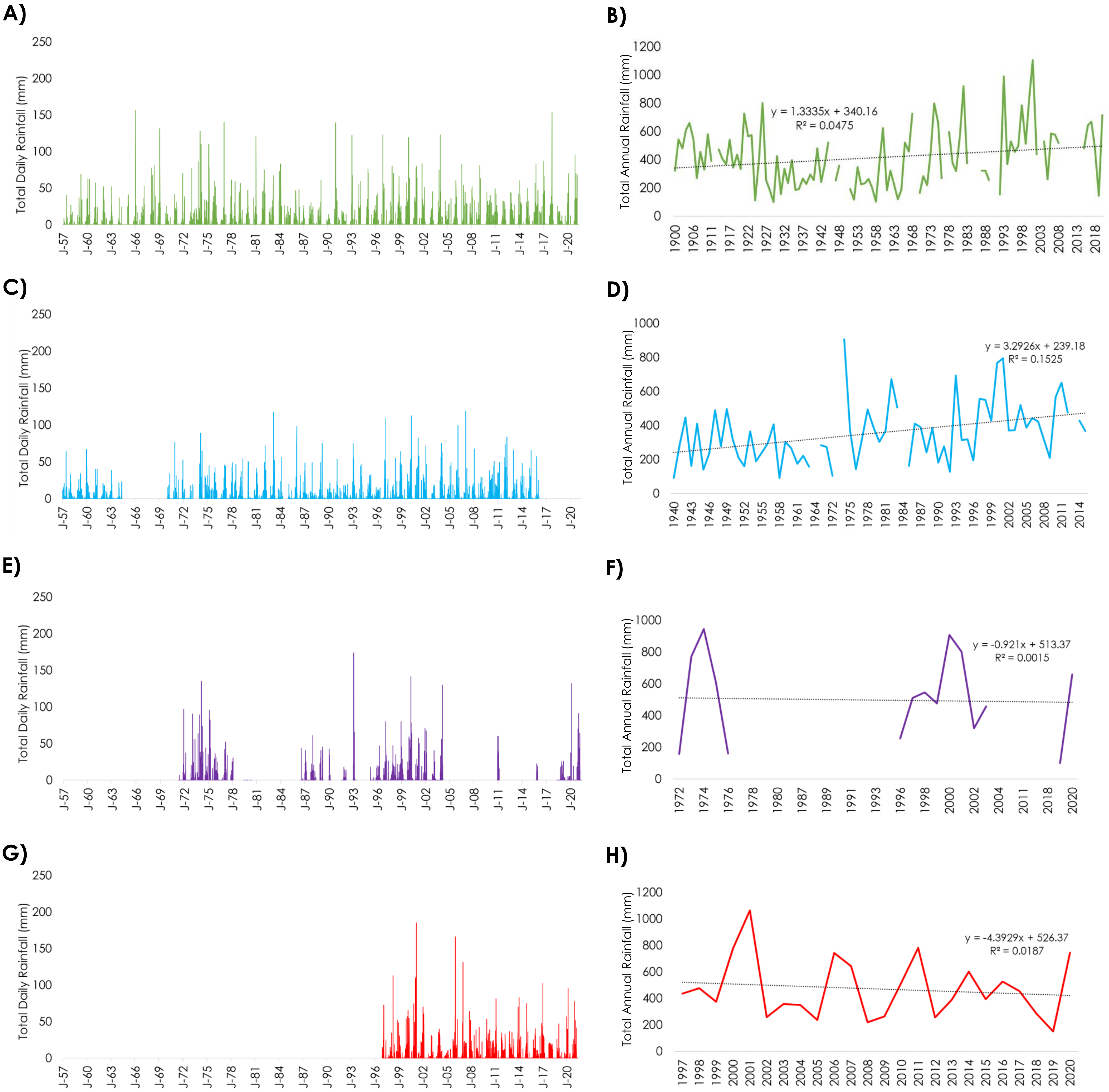


Figure 9: Rainfall daily totals (left) and regression analysis of annual rainfall totals (right) from BoM weather stations north of Lake Mackay. (A-B) Sturt Creek, (C-D) Balgo Hills, (E-F) Billiuna, and (G-H) Rabbit Flat (Source: Bureau of Meteorology, 2021).

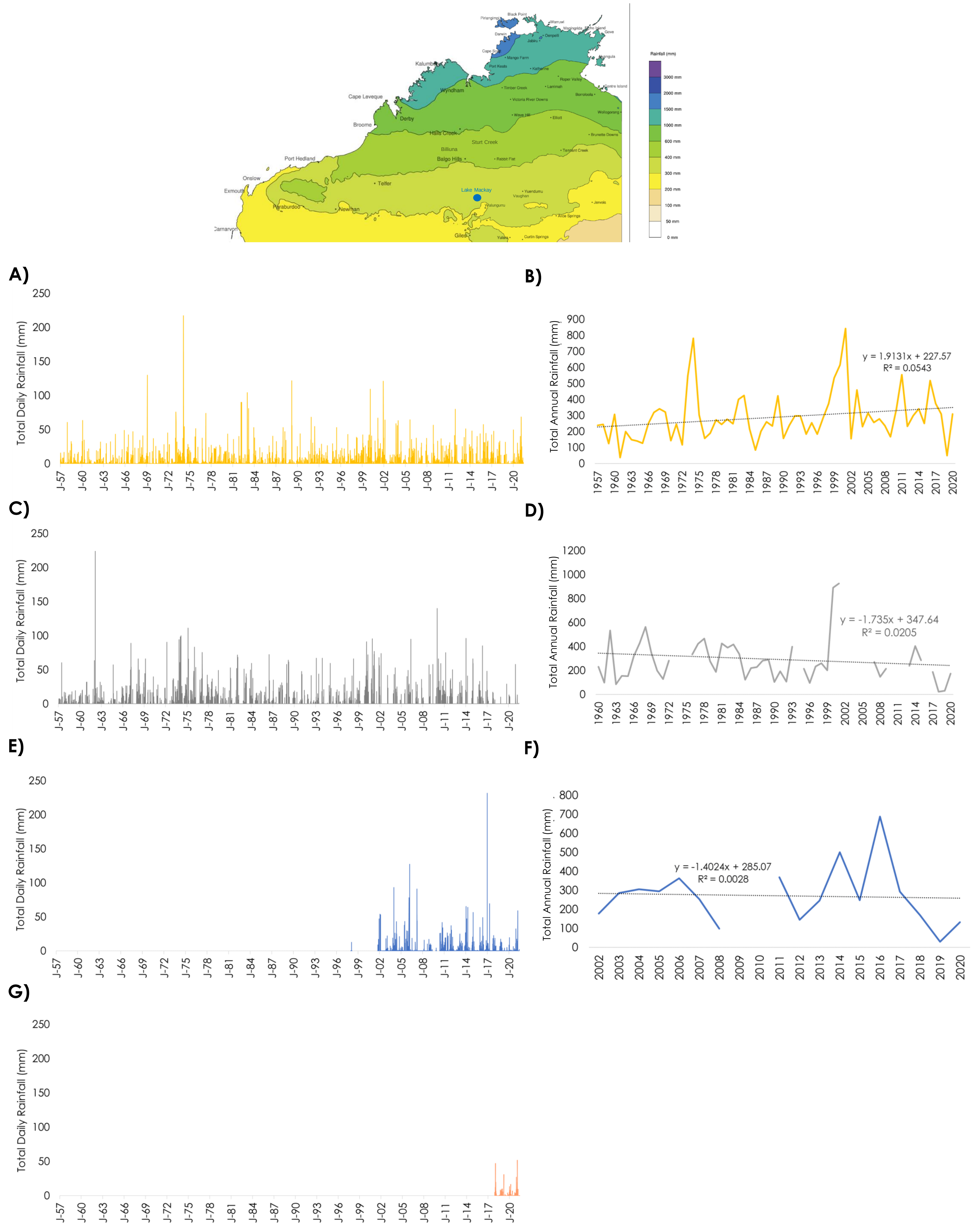


Figure 10: Historic rainfall daily totals (on left) and annual rainfall totals (right) from BoM weather stations south and east of Lake Mackay. (A-B) Giles, (C-D) Vaughan Springs, (E-F) Walungurru (Source: Bureau of Meteorology, 2021), and (G) Agrimin Lake Mackay.

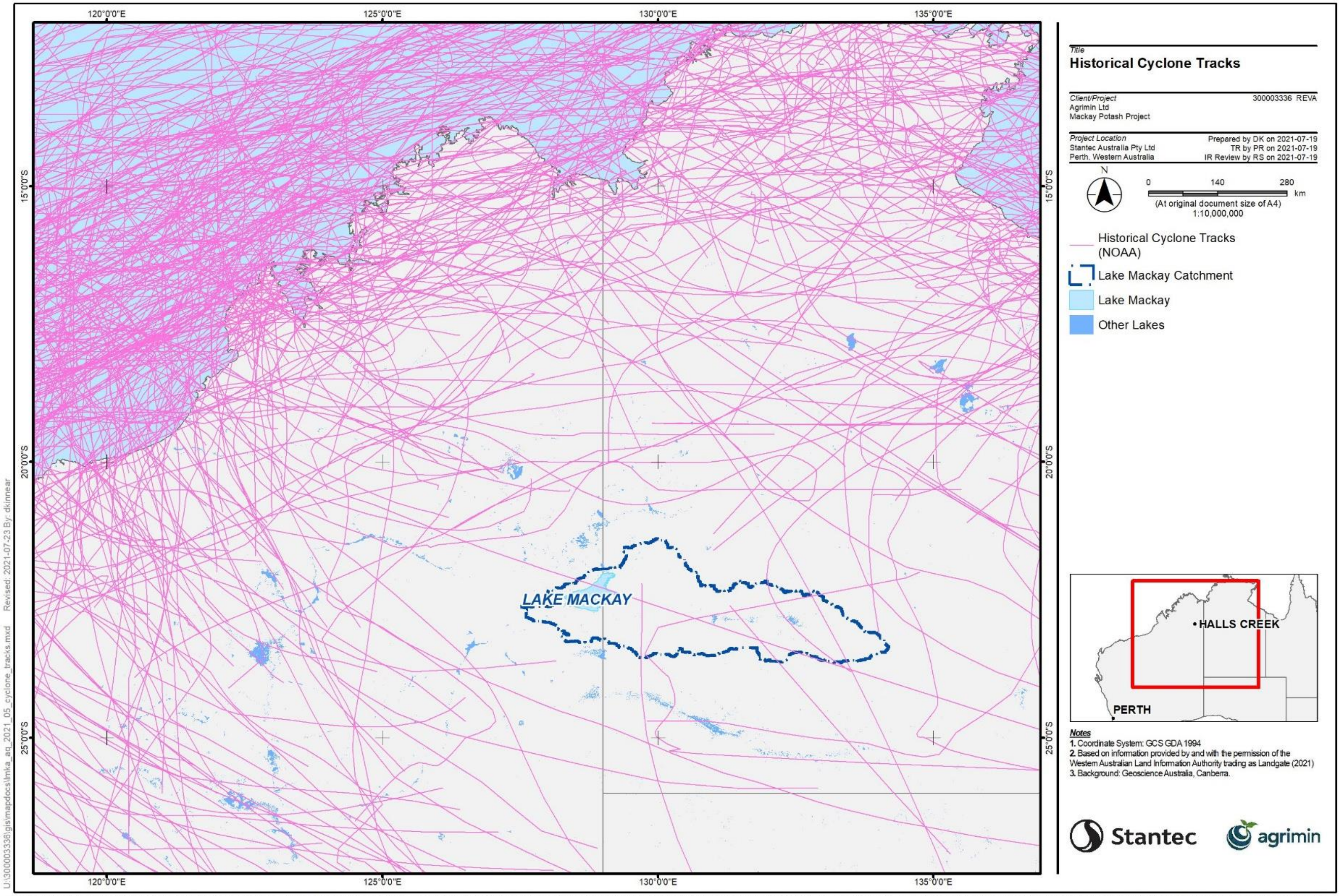


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Figure 11: Cyclone pathways in the vicinity of Lake Mackay between 1899 and 2020 (Source: National Oceanic and Atmosphere Administration, 2021).

Although cyclone intensity decreases over land, the resulting tropical lows from these TCs have caused heavy rainfall in the region, evident from the rainfall data recorded from regional BoM weather stations. These extreme rainfall events have caused the inundation of Lake Mackay and resulted in historic recharge of other lakes in the region, including Lake Surprise and Lake Lewis. Some events have also resulted in the extensive sheet flow of water across the lower Tanami Desert (Duguid *et al.* 2005). Most recently, from February to March 2020, TC Esther (Category 1 / Tropical Low), delivered substantial rainfall further north of Lake Mackay; however, no substantial rainfall was recorded at the lake.

Overall, TCs make a significant contribution to rainfall in the region, and the interannual and spatial variability of cyclones and storm fronts strongly affect the reliability of rainfall. There is also some evidence that the frequency of the most intense cyclones has increased (NOAA 2021). Since 1967, at least six TCs have come within the vicinity of Lake Mackay (NOAA 2021). However, these have been categorised as Category 1 cyclones or Tropical Lows, weakening as they move inland from the coast.

3.1.4 Rainfall and Lake Inundation

The contribution and relevance of rainfall patterns throughout the region should be interpreted with caution, in relation to inundation events at Lake Mackay. Drainage and catchment mapping indicate that the four BoM stations north and Giles to the south, fall outside of the lake's effective surface water catchment area (**Figure 12**). Climate conditions at Walungurru Airport are likely to be most similar to the lake, given the relatively flat terrain and limited topographical relief. However, comparison to the Agrimin Weather Station on the margins of the lake suggest there is limited correlation between stations, with the exception of extremely wet years such as 1974 and 2001 (BoM 2021). This reflects the highly variable spatial distribution of rainfall throughout the region.

The lakebed covers an area of approximately 3,500 km^2 and measures approximately 100 km east to west and 100 km north to south. The total modelled catchment area for Lake Mackay is approximately 87,000 km^2 and extends more than 550 km east into the MacDonnell Ranges (Stantec 2020b). However, it is considered that the actual catchment area that contributes to the lake's surface inundation is much more localised and comprises approximately half the size (Agrimin 2018). The Lake Mackay basin is internally draining with no outflow, and there are only a small number of ephemeral watercourses on the margins (mostly the southeast) that drain and potentially contribute to surface runoff in the lake during extreme rainfall (Stantec 2020b). The dune systems around the lake also impede surface water movement, with drainage paths meandering longitudinally. While there are several large, and numerous smaller playas further to the west, they are unlikely to discharge surface flow to Lake Mackay (Stantec 2020b). Surface water contribution to the lake via concentrated tributary channel inflows and sheet flow from the surrounding catchment is limited by the surrounding topography and soil characteristics.

The most significant contributor to surface water in Lake Mackay is direct precipitation on the surface of the lake during large rainfall events; however, a comparison of lake levels to the historic rainfall records indicates that there is not necessarily a consistent correlation between rainfall and lake levels. In broad terms, hydrological modelling indicates that the lake appears to fill when monthly precipitation recorded at Walungurru Airport reaches approximately 250 mm (Stantec 2020b). In some cases, this rainfall total occurs in a single day, whereas in other instances it may occur over 72 hours, one week, or one month (Stantec 2020b). Temporal and spatial variability in rainfall patterns throughout the region and their relevance to inundation is difficult to quantify, with satellite imagery analysis better suited for developing an understanding of hydrological processes.

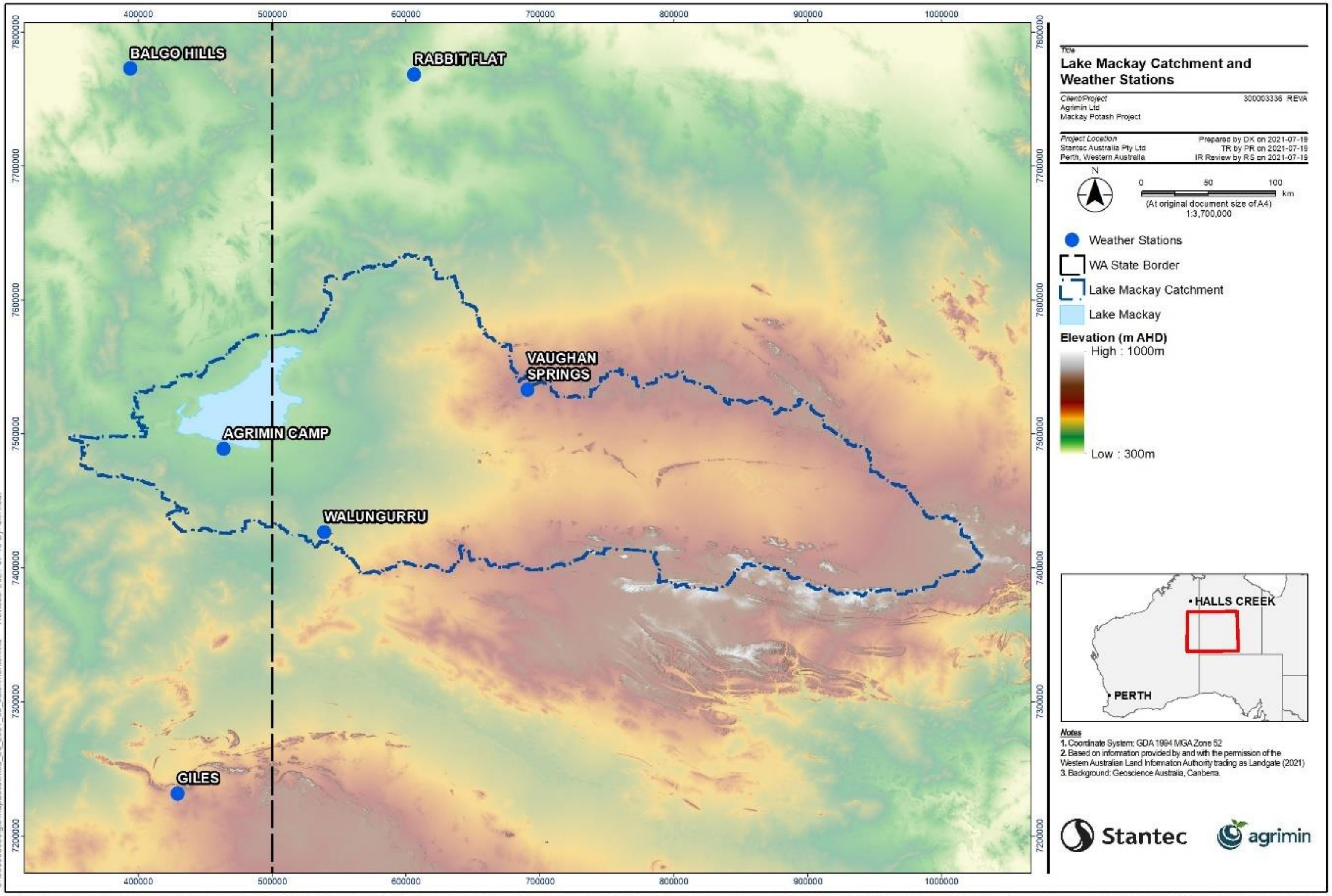

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Figure 12: Lake Mackay catchment and location of weather stations.

3.1.5 Climate Change Predictions

Changes in rainfall in north-west Australia are predicted to be minor compared to the current natural interannual variability; however, there is generally low confidence in the projections. Climate models for the Kimberley region, north of Lake Mackay, predict that annual rainfall changes may be less than or equal to 1% of current variations (Moise 2015). In contrast, global climate models adopted for the Pilbara region, project a decrease in future rainfall in the west and an increase in eastern areas (Charles *et al.* 2013).

However, statistical testing of long-term rainfall data across Western Australia indicates a significant upward trends in rainfall over most of the central and northern regions (Department of Water 2015). The closest weather data included in this analysis comprised stations >750 km from Lake Mackay and therefore specific patterns of rainfall change are largely unknown.

For the purpose of assessing climate change impacts throughout Australia, the continent has been grouped into eight National Resource Management (NRM) clusters, which correspond to broad-scale climate and biophysical regions (Watterson *et al.* 2015). Lake Mackay is located in the Rangelands cluster and Rangelands North sub-cluster (**Figure 13**). Key outcomes for future rainfall predictions for the Rangelands cluster (Watterson *et al.* 2015) are as follows:

- in the near future (2030), natural variability is projected to predominate over trends due to greenhouse gas emissions;
- changes to rainfall are possible, however the direction of change cannot be confidently projected given the spread of model results;
- the RCP8.5 scenario suggests a small decrease in median annual rainfall (-4%) in the 2090 simulation, however, overall, the inter-model changes are comparable to the natural decadal variability that has been observed over the past century;
- changes to annual and summer rainfall late in the century are possible, but the direction of change cannot be confidently projected given the spread of model results;
- increased intensity of extreme rainfall events is projected, with high confidence;
- understanding of the physical processes that cause extreme rainfall, coupled with modelled projections, indicate with high confidence a future increase in the intensity of extreme rainfall events, although the magnitude of the increases cannot be confidently projected; and
- time spent in drought is projected to increase over the course of the century, with medium confidence.

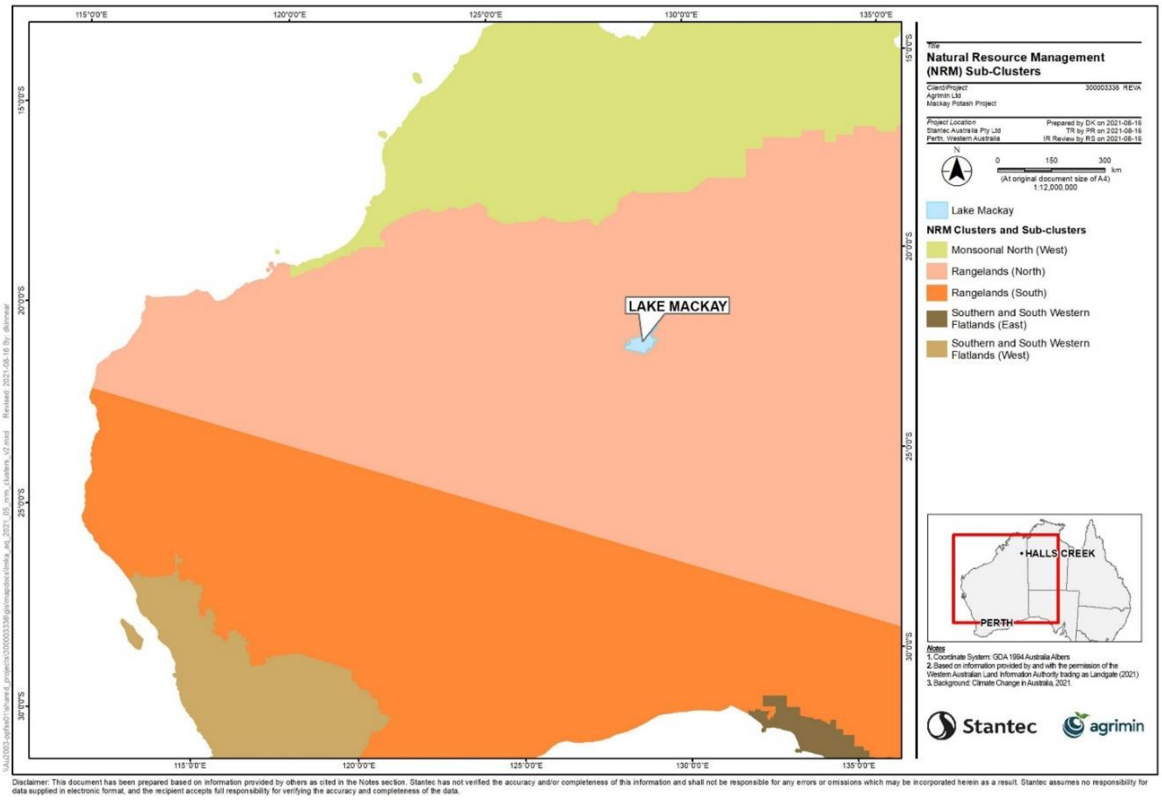

Figure 13: Natural Resource Management (NRM) sub-clusters in relation to Lake Mackay.

3.2 SATELLITE IMAGERY ANALYSIS

3.2.1 Inundation Events

Lake Mackay is a large, ephemeral salt lake in the central part of Australia that is predominantly dry. According to the analysis of satellite imagery and considering potential misclassification errors, the lake is dry approximately 60% to 75% of the time. When inundated, following large rainfall events, there is a high degree of variability in the frequency, extent and distribution of surface water on Lake Mackay. The volume and duration of inundation is also driven by the duration and intensity of the rainfall event and spatial distribution of precipitation in relation to the lake's surface and catchment areas. During the more frequent, albeit minor inundation events, prevailing winds and seasonality (temperature and evaporations rates) also have a strong influence on surface water (Stantec 2020b).

The topography at the lake and immediate surrounds is subdued and flat, with lakebed elevations ranging from approximately 364 mAHD in the west to 360 mAHD in the east (Stantec 2020b). While records of surface water depth for Lake Mackay are limited, it is likely that the NT portion of Lake Mackay is deeper (Duguid *et al.* 2005). On the WA side of the lake, this correlates to the deepest areas occurring in the south east, close to the NT border (**Figure 13**). Satellite imagery also indicates that the south-eastern portion of the lake is typically inundated for longer periods after large rainfall events and is often the last part of the lake to dry out at the end of the hydroperiod (**Figure 13**). Based on available satellite imagery and hydrological modelling, the lake appears to fill to an average depth of approximately 2 m once every 5 to 10 years (Stantec 2020b). This depth inundates most of the visible lake perimeter (Stantec 2020b).

Interpolated inundation extent (measured as percentage surface area cover), according to the analysis of satellite imagery over time, shows several broad trends since 1987. Prior to 2000, the lake was dry most years, with only short periods of inundation, usually occurring around February to March, where <20% of the lake was inundated (**Appendix C**). In addition, from 1987 to 2000, there was only one event that correlated to more than 50% inundation of the lake in 1993 (**Figure 15**).

During the wettest years (post 2000), Lake Mackay has generally begun to fill in December, with inundation often peaking between February and March (**Appendix C**), due to top-up events associated with tropical lows and storm events. Water levels have then gradually decreased from April, corresponding to reduced rainfall, before the lake has dried completely and persisting through to November. However, interannual variation is also evident, with inundation extent showing substantial seasonal variation (**Appendix C**).

From 2000 to 2021 inundation events were much more regular, with 20 events recorded (**Figure 15, Figure 16**). The largest and longest was associated with well-above average annual rainfall recorded consecutively in 2000 and 2001. Rainfall records were available for Balgo Hills (north of the lake) and reported an annual total of 768 mm in 2000, followed by another 796 mm in 2001. Surface water subsequently persisted on the lake from December 2000 to early March 2002, peaking in April 2001 (**Figure 15**). There were several periods of above average monthly rainfall during this period and rainfall was often widespread, well beyond the Lake Mackay catchment area. In addition, TC Sam passed to the north of the lake as a Category 1 in late 2000 and early 2001, contributing to heavy rainfall.

The satellite imagery suggests that water levels of over 2 m occurred throughout most of the playa during 2000 and 2001, potentially reaching up to 4 m in the south-eastern part of the basin, spilling into the riparian vegetation zone (Stantec 2020b). Satellite imagery also shows the lake was inundated to an extent of over 80% for more than six months in 2001, reaching 100% inundation on several occasions throughout the 2000 to 2001 period (**Appendix C**). No other event over the 34-year historic record has resulted in 100% inundation of the lake for this extended period (**Figure 15**). However, based on rainfall records for the region, it is likely that a similarly large event occurred at the end of 1973, persisting into 1974 and potentially longer, prior to when satellite imagery is available. Based on the available records, flooding of the lake for more than 12 months appears to represent an AEP between 5% and 2%, equivalent to between a 1:20 or a 1: 50 year flood event (Stantec 2020b).

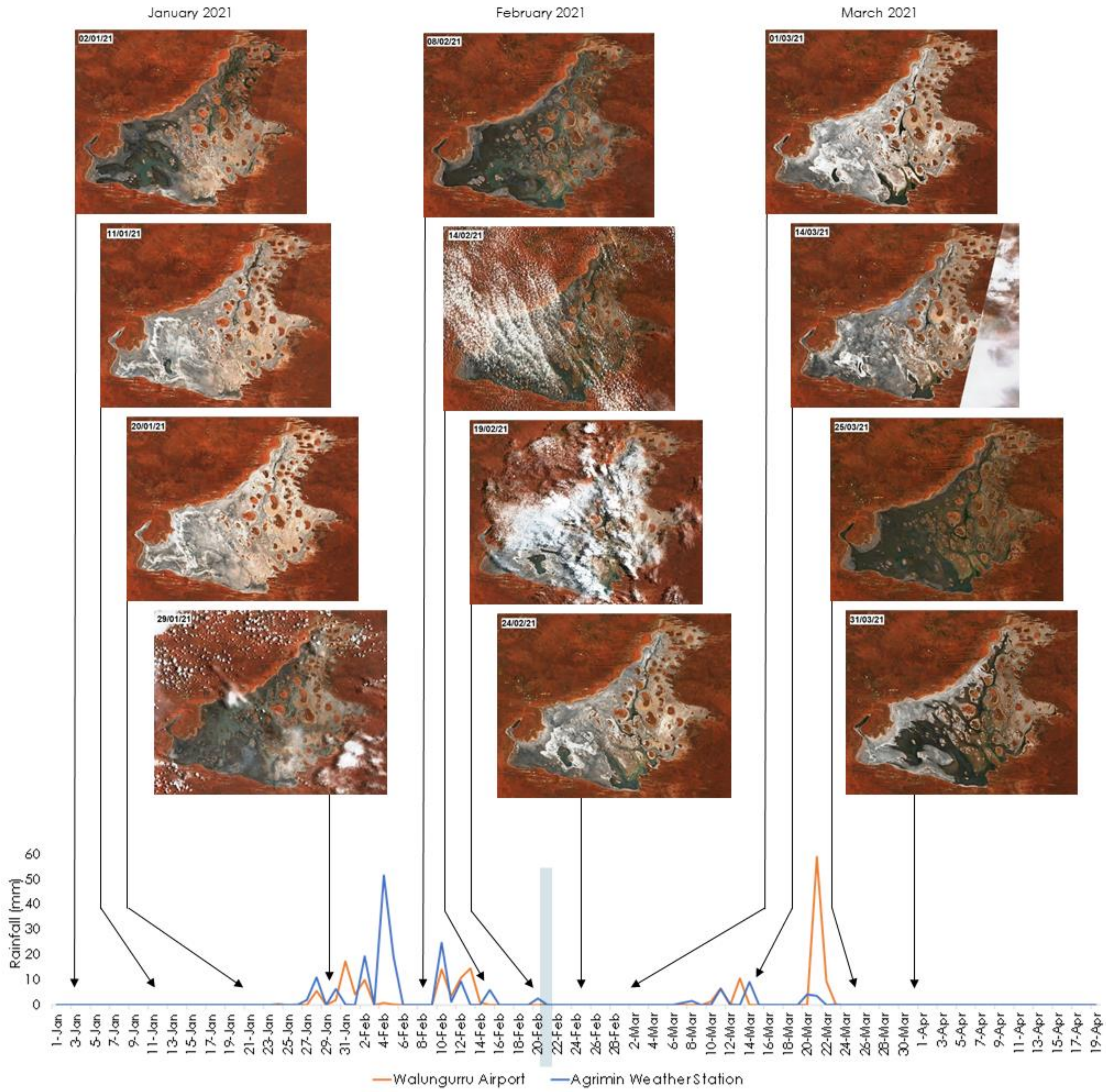

Figure 14: Satellite imagery and rainfall data (Walungurru Airport and Agrimin Lake Mackay weather stations) in 2021, indicating south eastern area inundation.

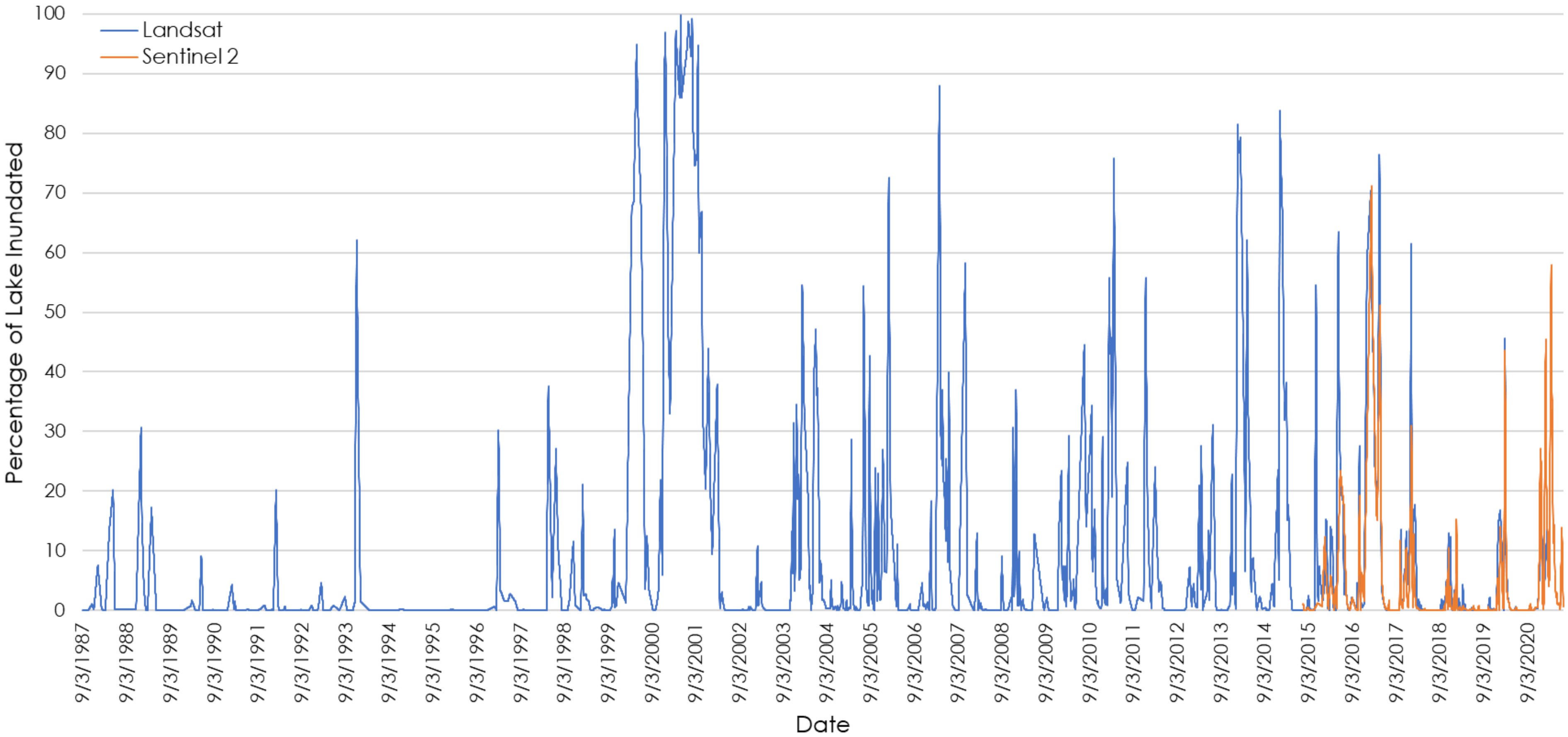

Figure 15: Comparison of percentage inundation values from Landsat and Sentinel imagery at Lake Mackay from 1987 to 2021.

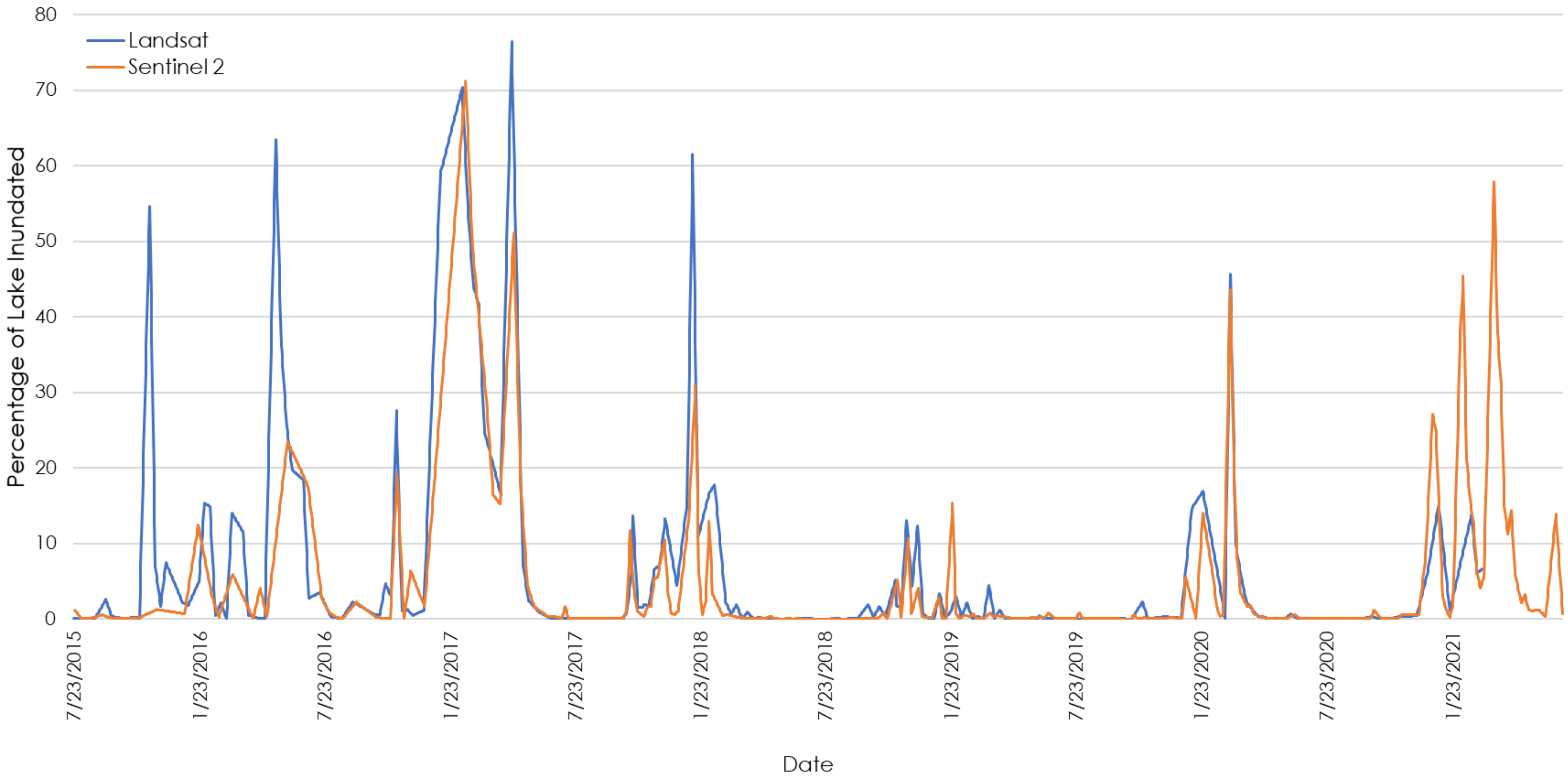

Figure 16: Comparison of percentage inundation values from Landsat and Sentinel imagery at Lake Mackay from 2015 to 2021.

3.2.2 Surface Area Extent and Duration

Surface area duration (SAD) curves were developed for Lake Mackay (**Figure 17A-F**), which shows the cumulative time (%) the lake was inundated (% surface area). Based on all available data over time (since 1987), the SAD curve (**Figure 17A**), indicates the lake is rarely inundated completely (100%) for any significant length of time. The lake also dries rapidly following peak inundation events, and typically water retention only occurs over a short duration. For example, 75% lake inundation may occur for approximately 2.5% of the time, while 20% lake inundation may occur for approximately 14% of the time (**Figure 17A**).

In comparison, the SAD curves of the five largest inundation events (early and late in 2000, one in 2014, 2015 and 2016), following above average annual rainfall show a contrasting trend (**Figure 17B-F**). During the largest of the inundation events, Lake Mackay retained water for a longer duration before drying out. The drying process was then more gradual, compared to typical, low rainfall years when the lake is predominantly dry. A comparison of December 2000 and February 2000 indicated the lake was inundated to >80% surface area for more than 45% and 20% of the time, respectively (**Figure 17B-C**). In comparison this was less than 10% of the time in January 2014 and January 2015 at the 80% inundation extent (**Figure 17E-F**). In comparison 60% of the surface area was inundated for approximately 35% of the time in December 2016 (**Figure 17D**).

A time-dependent version of the SAD curve, known as a short-time surface area duration (STSAD) plot was also generated to investigate surface inundation extent and duration (**Figure 18**). This plot also demonstrates that 2000 to 2001 was a period of increased inundation for Lake Mackay, and the more frequent occurrence of inundation events post 2000 is supported by the satellite imagery analysis. The lake has been partially inundated, relatively consistently from 2003 until 2018. The plot also captured the beginning of the large rainfall event that occurred in early 2021, where >180 mm rainfall was recorded at the Lake Mackay weather station, the duration of which was 56 days.

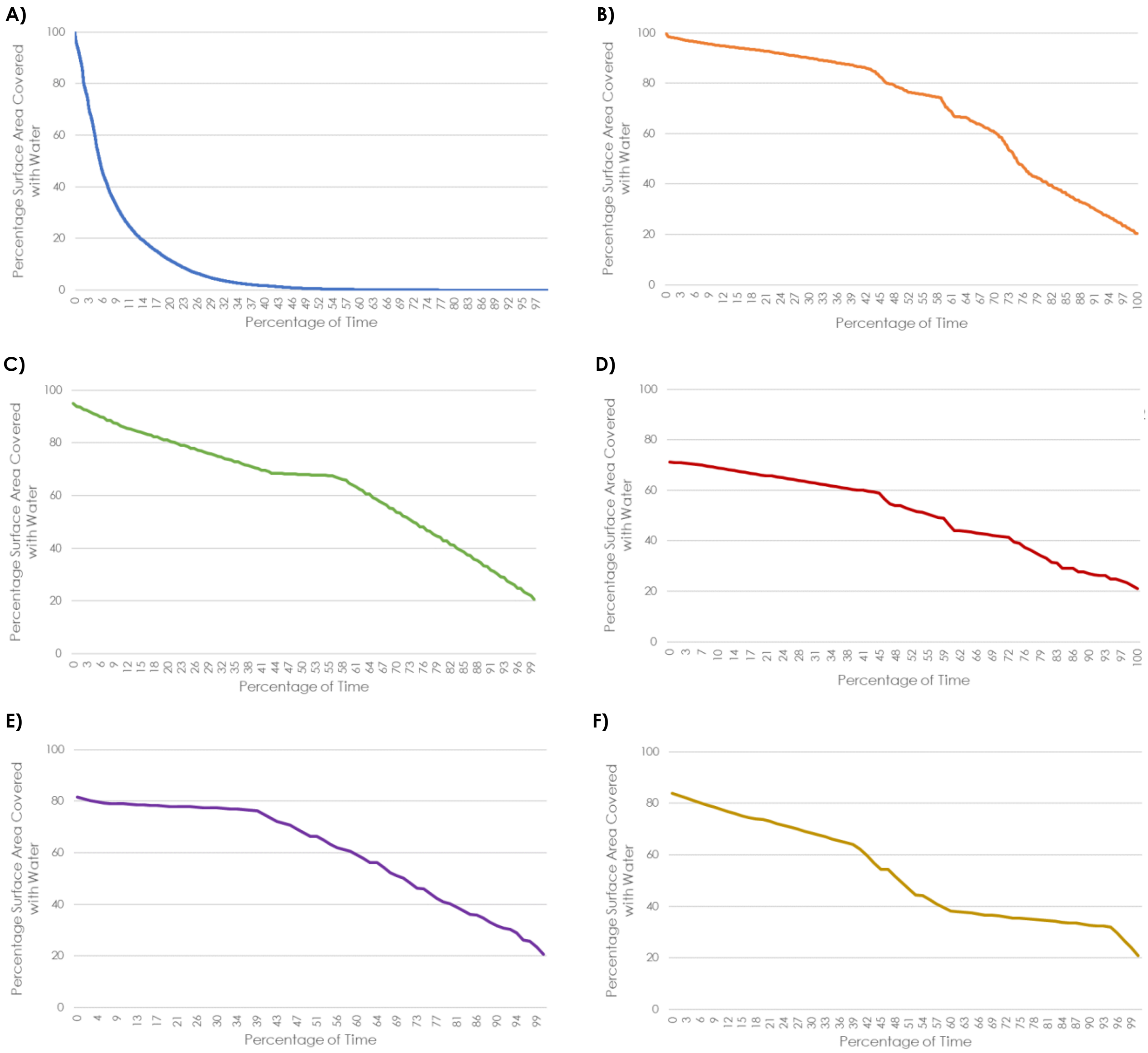

Figure 17. Lake Mackay SAD curves for; (A) all available data (since 1987), compared to the five most substantial inundation events, (B) December 2000, (C) February 2000, (D) December 2016, (E) January 2014, and (F) January 2015.

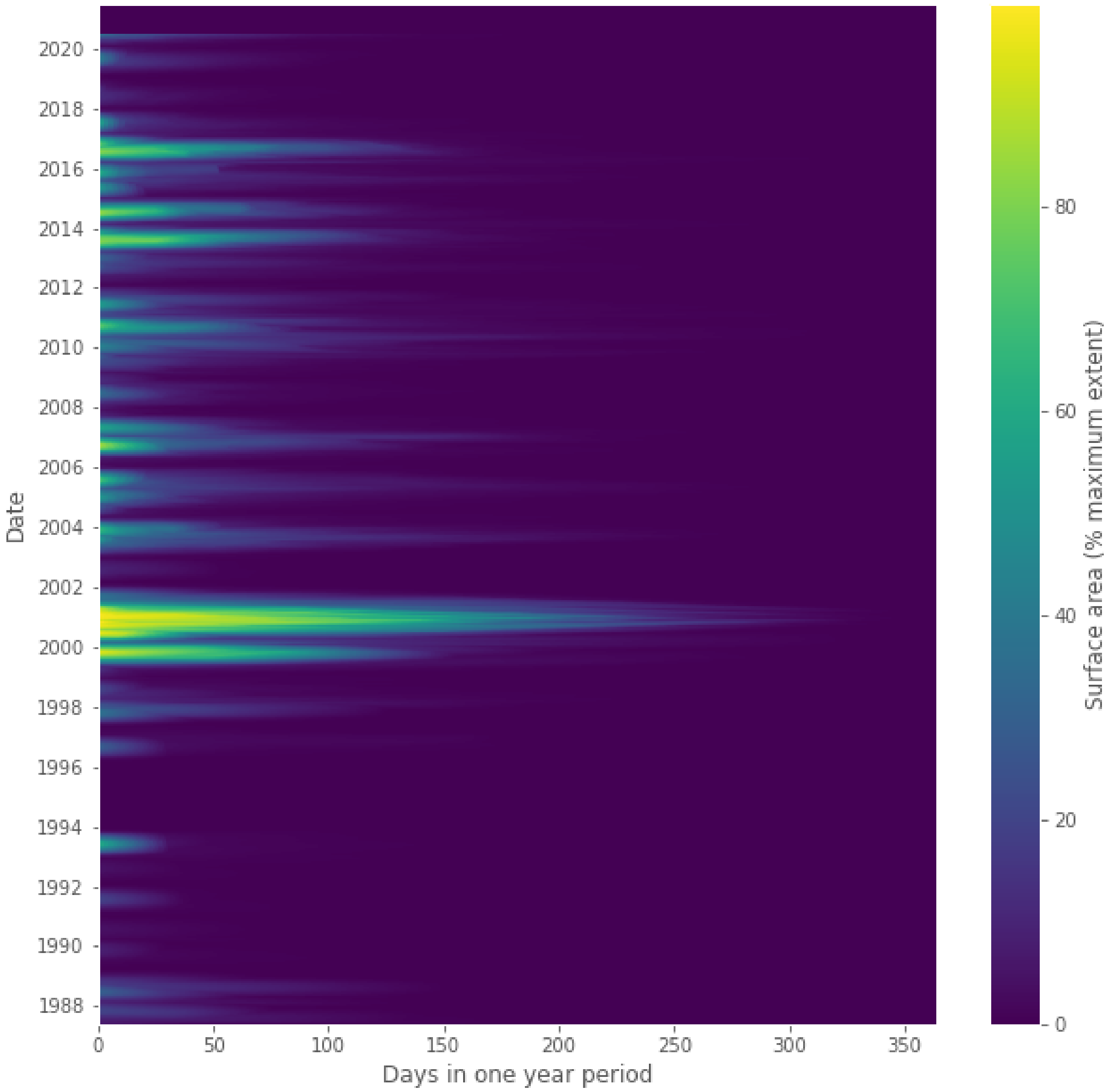

Figure 18. Short-time surface area duration (STSAD) plot for Lake Mackay (yellow is increased % surface area inundation).

3.2.3 Frequency and Duration of Inundation Events

The number and duration of discrete inundation events under different percentage inundation thresholds (20%, 50% and 75%) were calculated for Lake Mackay, based on approximately 5-year interval periods (**Table 4**). Over the last 34 years (since 1987), there have been 58 discrete inundation events at the 20% inundation threshold, of which 21 exceeded the 50% threshold and nine exceeded the 75% threshold (**Table 4**). The 20% and 50% threshold inundation events have a typical duration of >25 days, compared to the 75% threshold (<20 days). The shorter duration at the 75% threshold is likely due to rapid infiltration or evaporation (Stantec 2020c), with only the south east portion of the lake appearing to retain water for longer periods. Regardless, these average durations are substantially influence by the large 2000 to 2001 inundation event (**Table 4**).

An increase in the number of events and the average duration of each event is evident across all three thresholds (20%, 50% and 75%) post 2000, following trends observed from the analysis of satellite imagery and SAD curves. This was supported by linear regression (**Figure 19A-C**), and was most prominent at the 50% inundation threshold (R^2=0.87), and to a lesser extent also occurred for the 20% and 75% thresholds (R^2=0.53 and 0.39, respectively) (**Figure 19A-C**). The duration of inundation also shows a general increasing trend at the 20% inundation threshold; however, it is interrupted by largest inundation event recorded between 2000 and 2001. At the 20% and 75% thresholds, trends in duration were also limited due to the influence of the 2000 to 2001 event (**Figure 19A-C**). For the largest events, trends are less clear, due to their rarity and the corresponding paucity of records.

Table 4. Number and duration of discrete inundation events at Lake Mackay under different unundation thresholds.

Time Range	20 % Inundation Threshold		50 % Inundation Threshold		75 % Inundation Threshold	
	Number of Events	Average Duration (Days)	Number of Events	Average Duration (Days)	Number of Events	Average Duration (Days)
1987 – 1989*	2	10	0	0	0	0
1990 - 1994	2	18	1	10	0	0
1995 - 1999	4	13	0	0	0	0
2000 - 2004	9	78	4	100	4	67
2005 - 2009	13	17	4	11	1	7
2010 - 2014	17	21	5	16	2	15
2015 - 2019	7	35	6	17	2	6
2020 – 2021*	4	15	1	4	0	0
Total	58	-	21	-	9	-
Average^	-	26	-	26	-	19

*Note: yellow shading indicates includes 2000 to 2001 inundation event; * indicates records incomplete for this time period; ^ indicates weighted average based on groupings.*

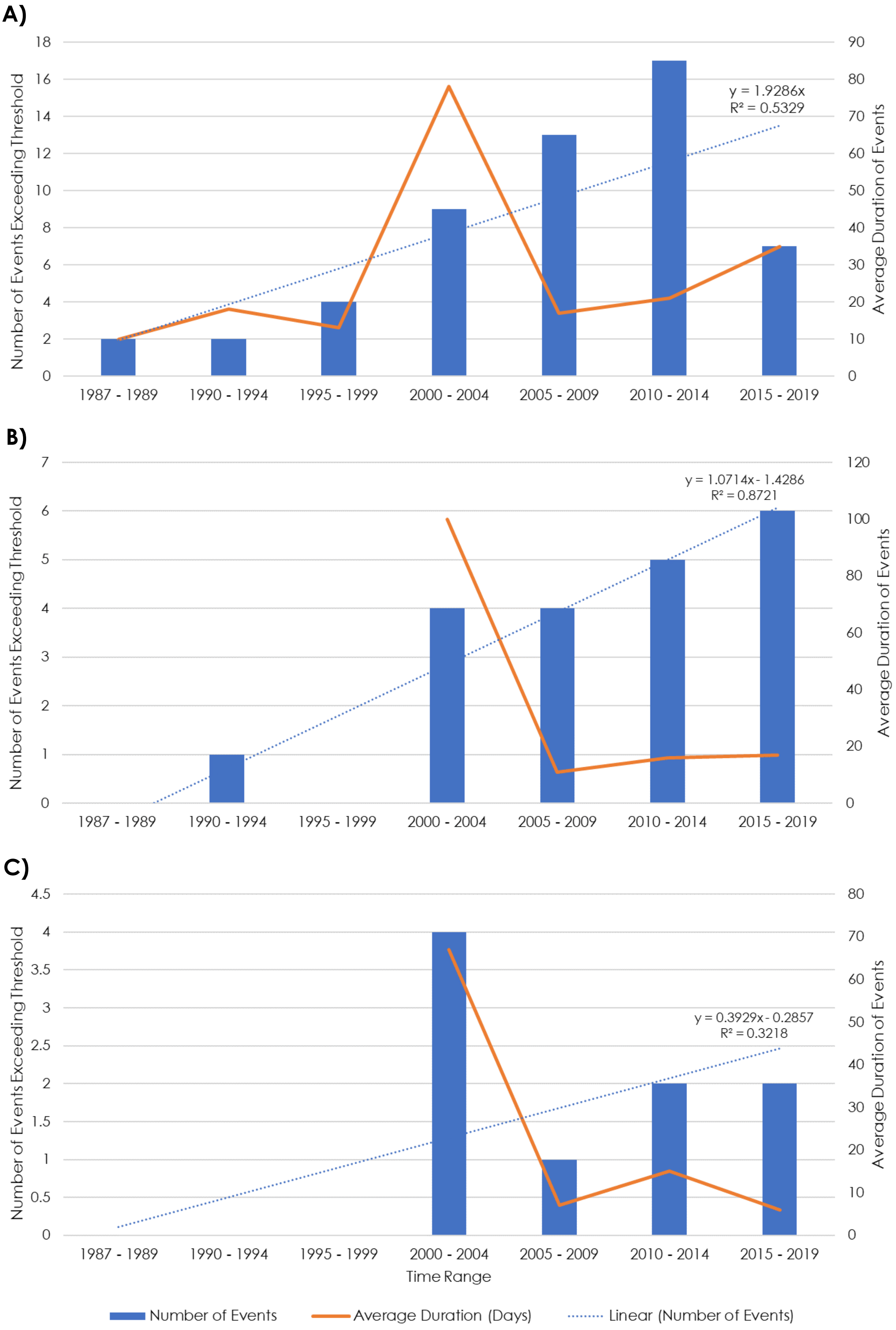

Figure 19: Number and duration of inundation events exceeding (A) 20%, (B) 50%, and (C) 75% thresholds at Lake Mackay since 1987.

3.3 GOLDSIM WATER BALANCE MODEL

3.3.1 Daily Time Series and SADS

Based on the GoldSim modelling results, the daily time series graphs (1960 to 2021) indicate that the largest inundation event at Lake Mackay commenced in November 1973. This aligns with historic rainfall data from this period but occurred prior to available satellite imagery. The peak inundation surface area extent during this period was 80% (due to model limitations) and water persisted on the lake for 640 days. The longest simulated inundation event occurred from 1999 to 2002, when modelling showed that the lake was continuously inundated for 866 days (**Figure 20**).

Overall, the daily time series of model results (**Appendix D**) shows that under the operational scenario there is a reduction in the frequency of the short-duration, smaller (generally less than 20% inundation extent) pond forming events. This operational impact was less significant when the antecedent catchment conditions were wet.

The SAD curve based on the GoldSim model demonstrates the daily time series data in **Figure 21**, with decadal scale results provided in **Appendix E**. The SAD shows that using the 1960 to 2021 climate data, surface water ponding occurred at Lake Mackay approximately 27% of the time for the base case scenario. This is comparable to the satellite imagery analysis, which estimated conditions were dry 60% to 75% of the time. In comparison, under the operational scenario, this was reduced to 18%. The difference reduces to just 0.5% at 50% surface area inundation before converging to the same maximum inundation of approximately 80% surface area extent (**Figure 21**).

3.3.2 Base Case and Operational Scenarios

The discrete inundation events (>25% threshold) for the model scenarios are shown in **Table 5**. Following the largest flood event which commenced in November 1973, the modelling indicated that there was less than a 2% reduction on the maximum surface area inundated, and the duration of inundation decreased by only 5%. For events smaller than 40% surface area inundation, on average, the peak inundation percentage was reduced by 30% for the operational scenario and the duration was reduced by approximately 40%

The average number of events above a range of lake inundation threshold percentages, are summarised for the base case and operational scenario in **Table 6.** The tabulated values are represented conceptually in **Figure 22A-D**. In addition, changes in the duration of inundation for these scenarios at >20% inundation threshold are presented in **Table 7**, with comparison to satellite and modelled scenarios provided in **Table 8.** More broadly, the modelled results indicate that in the larger events (while rare), where inundation extent and duration is greatest, there is negligible difference between the baseline and operational scenarios (**Table 5**). The GoldSim modelling results can be summarised as follows:

- Under a base case scenario there would be 10 events greater than 20% lake inundation and one event greater than 60% inundation during the life of mine, while under an operational scenario, there would be seven events greater than 20% lake inundation and one event greater than 60% inundation (**Table 6**);
- Under a base case scenario groundwater levels tend to fluctuate from approximately 0.4 to 0.7 mbgl throughout the wet and dry season, respectively, based on data collected during the 2019 period (**Figure 22A-B**), while under an operational scenario, this is expected to increase to approximately 1.1 to 1.4 mbgl, on average throughout the seasons and across the lake by year 10 of operations (Agrimin Ltd 2020), with a corresponding reduction in surface water levels during inundated conditions (**Figure 22D-C**);
- The presence of the constructed ponds was incorporated into the stage-volume relationship for the operational scenarios and was found to be negligible; the effect of the bunds around the trenches on the stage-volume relationship was not included, because the effect is temporary and results in a number of individual stage-volume relationships that could not be effectively modelled in GoldSim;
- At >20% inundation threshold, the change in the duration (in days) of inundation events is also considered minor between the base case and operational scenarios, with less than a one days' difference modelled during the 1974 and 2001 events (**Table 7**), and only one less event of duration >24 days predicted during operations (**Table 8**);
- Changes under operational conditions during the larger inundation events are considered negligible, due to limited frequency of occurrence and the minor reduction in surface water extent and duration; and
- While there may be additional storage created in the lakebed sediments by operations (drawdown), this storage is filled during wetter years, with a limited effect during large inundation events and almost complete recovery expected within two years following cessation of the Project, and complete recovery predicted by year 7 (**Figure 7**).

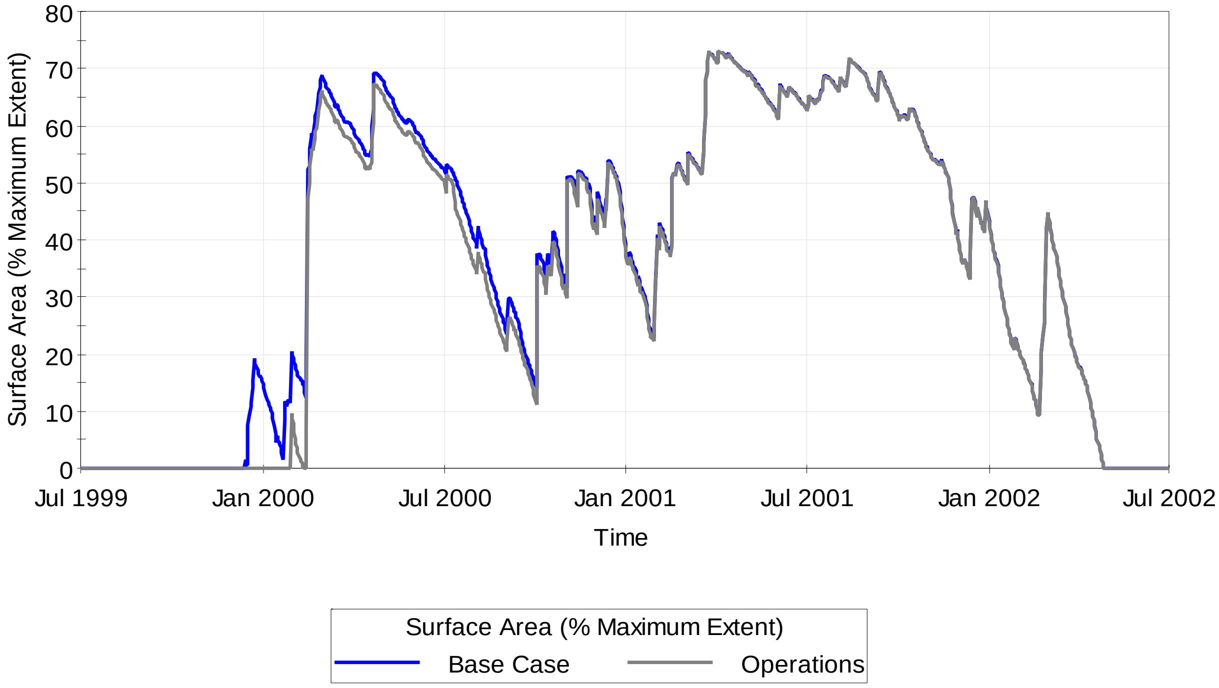

Figure 20. Modelled Lake Mackay surface area extent July 1999 to July 2002.

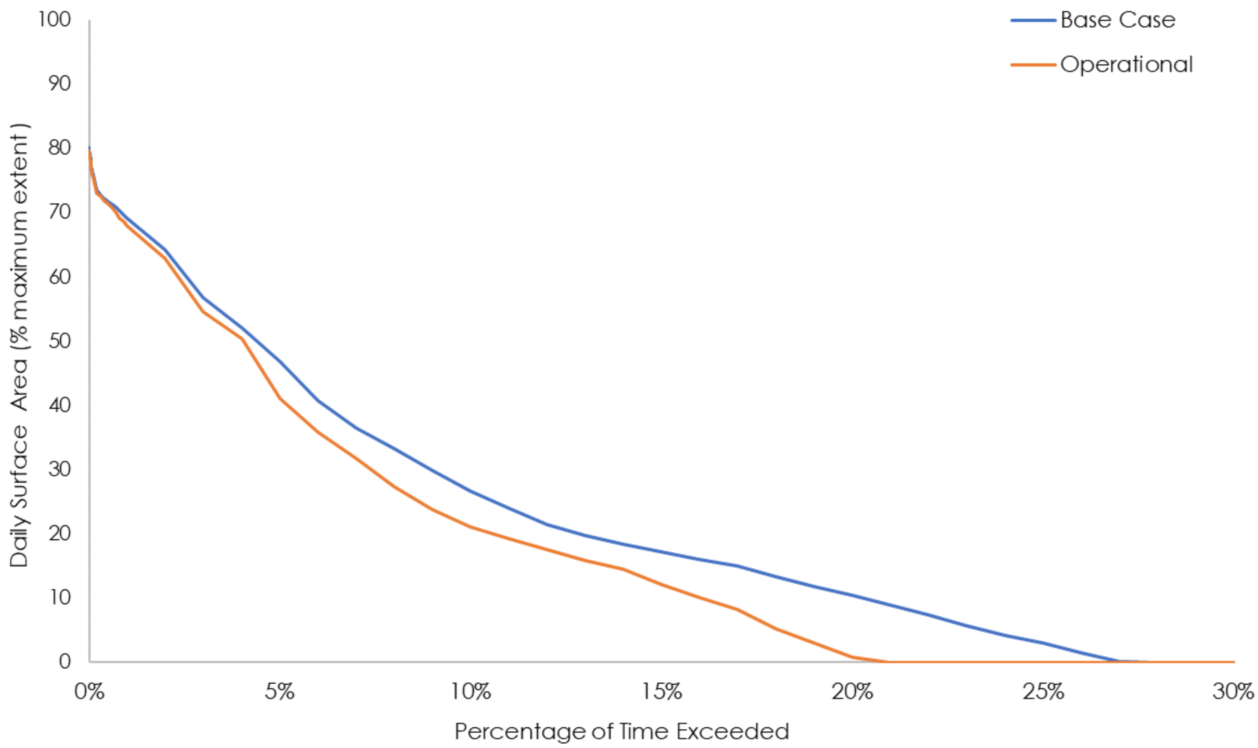

Figure 21. Surface Area Duration Curve (SAD) for the GoldSim model scenarios.

Table 5. Modelled maximum inundation and duration of discrete inundation events at Lake Mackay.

Event Start Date	Base Case		Operational	
	Maximum % Inundation	Flood Duration (Days)	Maximum % Inundation	Flood Duration (Days)
Nov-73	80.0	677	79.0	640
Dec-99	73.2	866	73.1	831
Dec-16	71.7	577	66.5	406
Jan-82	58.6	476	53.4	401
Mar-89	58.6	122	50.8	87
Jan-07	58.3	173	54.8	130
Jan-14	52.5	114	39.2	84
Dec-03	52.4	267	44.1	263
May-10	42.8	459	42.1	416
Dec-98	42.6	158	34.6	108
Jan-06	42.2	123	18.9	75
Jan-81	40.7	105	22.6	79
Feb-77	38.9	110	20.7	75
Oct-11	38.1	175	38	175
Dec-20	35.5	168	26.7	92
Jan-62	33.1	68	12.25	18
Feb-67	25.2	210	17.5	72

Table 6. Modelled average number of inundation events above thresholds for 20 year mine life (plus seven year recovery).

Event Threshold (% extent of Inundation)	Base Case Scenario	Operational Scenario
20	10	7
25	7	5
30	6	4
50	3	2
60	1	1
75	<1	<1

Table 7. Modelled duration of inundation events >20% threshold for 20 year mine life (plus seven year recovery).

Event Start Date	Base Case Duration (Days)	Operational Scenario Duration (Days)
Jan-74	527	527
Feb-77	60	14
Jan-81	68	19
Feb-82	227	213
Mar-89	77	58
Dec-98	81	49
Jan-00	742	741
Dec-03	150	131
Feb-06	62	17
Jan-07	100	78
Jul-10	245	217
Nov-11	55	55
Jan-14	67	59
Dec-16	165	155
Dec-20	45	26

Table 8. Comparison of duration of inundation events >20% threshold for satellite and modelled scenarios.

Duration of Events (Days) >20% Inundation Threshold	Satellite Imagery Analysis	Base Case Scenario (GoldSim)	Operational Scenario (GoldSim)
Events >24 days	21	11	10
Events >65 days	6	8	5

3.3.3 Climate Change

The climate change predictions for the region that comprises Lake Mackay are generally uncertain. However, time spent in drought is projected to increase, with medium confidence, while there is increased intensity of extreme rainfall events projected with high confidence (Watterson *et al.* 2015). While reduced antecedent moisture in the lake and surrounding catchment may result in fewer small inundation events, GoldSim modelling showed that Project operations will have a negligible impact on the lake's water balance during larger inundation events (>50% extent and multiple-day duration).

These large events are considered most important for biota as they result in decreases in surface water salinity due to the volume of freshwater entering the lake. Lower salinities provide a cue for the emergence of aquatic biota and high biological productivity, supporting higher order consumers, including waterbirds, referred to as the boom cycle of temporary inland waters (Taukulis *et al.* 2014; Taukulis *et al.* 2012). Specifically, the lake is likely to provide important waterbird foraging and breeding habitat when the lake holds water for the longest periods (>20% threshold and >65 days duration), which allows adequate time for foraging, nesting and breeding behaviours (Stantec 2021b). Across the satellite imagery analysis and GoldSim modelling, the difference in the number of these events ranged from six to eight under the baseline scenario, with only a minor reduction to five events under the operational scenario (**Table 8**).

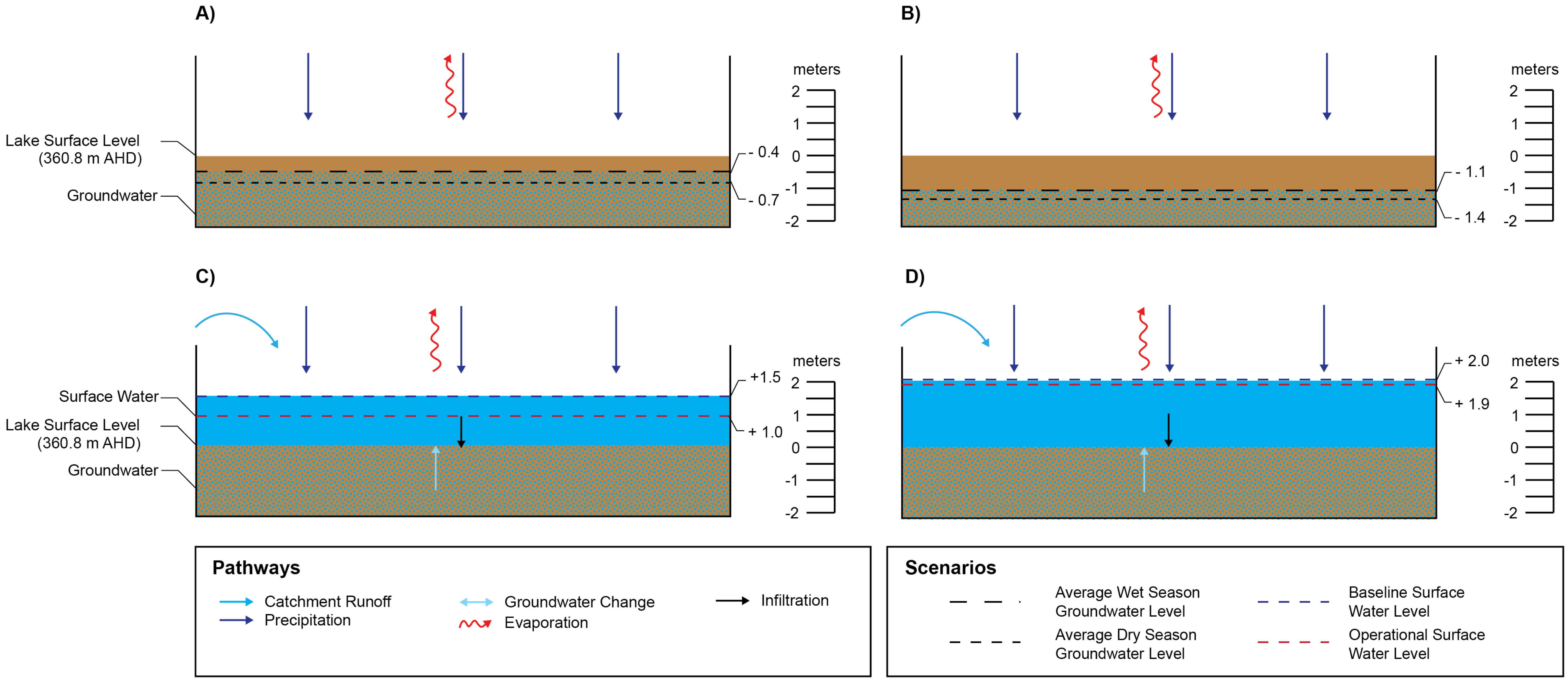

Figure 22: Conceptual diagrams for Lake Mackay during dry conditions under (A) baseline, and (B) operational (year 10) scenarios, and during inundated conditions under baseline and operational scenarios at (C) surface water level expected to be exceeded 25% of the time, and (D) maximum surface water level.

4.0 SUMMARY

4.1 RAINFALL

Rainfall records for the region for several of the weather stations in the vicinity of Lake Mackay are available for more than 60 years, although the data is considered patchy. North of the lake receives more rainfall, with the annual average of these stations approximately 435 mm/year, compared to stations south and east of the lake (approximately 300 mm/year or less). There is limited correlation between the Lake Mackay level and rainfall measured at regional weather stations. Rainfall in the region exhibits high spatial and temporal variability, with the exception of extremely wet years such as 1974 and 2000. During these years, the historic records indicate annual rainfall totals were between 750 mm to more than 1,000 mm throughout the area, associated with wet season storm events and tropical cyclone activity.

There is limited contribution to the lake's inundation via tributaries, inflows, interflow and infiltration. The most significant contributor is direct precipitation on the surface of Lake Mackay during large rainfall events, associated with tropical lows or cyclones traversing the region. Rainfall generally falls during the wet season, received during varying time periods (less than one day to more than one month). Approximately six tropical cyclones (classified as Category 1 / Tropical Low) have passed in the vicinity of Lake Mackay since 1899.

Climate change scenarios predict an increase in drought periods with moderate confidence, although increased intensity of extreme rainfall events is also projected with high confidence. In addition, while not specific to Lake Mackay, long-term rainfall data across Western Australia indicate statistically significant upward trends in summer rainfall over most of the northern and central regions of Western Australia. This is likely related to increasing cyclonic activity and intensity off the coast. Several weather stations in the vicinity of Lake Mackay also show increasing annual rainfall totals, however, interannual variation is evident. Where climate change impacts cannot be effectively predicted, as is the case in the Lake Mackay catchment, there may be additional uncertainty in simulation results until further studies are completed.

4.2 INUNDATION

According to the analysis of satellite imagery, Lake Mackay is dry approximately 60% to 75% of the time. When inundated, following large rainfall events, there is a high degree of variability in the frequency, extent and distribution of surface water, influenced by the spatial distribution and intensity of rainfall, as well as prevailing winds and evaporation. Hydrological modelling indicates that the lake appears to fill to an average of approximately 2 m, once every 5 to 10 years, which inundates most of the visible perimeter of the lake. The deepest areas with the longest retention times occur on the WA side of the lake in the southeast.

Interpolated inundation extent (%), based on the analysis of satellite imagery showed that prior to 2000, the lake was dry most years, with only short periods of surface ponding, usually occurring around February to March. Post 2000, inundation to various extents was more regular, with the lake typically beginning to fill in December, often peaking between February and March, with water levels gradually decreasing and drying out completely.

The five largest, discrete inundation events (based on SAD curves) occurred in early and late 2000, 2014, 2015 and 2016. Of these, the largest and longest event was associated with well-above average annual rainfall recorded in the latter part of 2000 (>750 mm), with extremely wet conditions persisting throughout 2001. Elevation data indicates that water levels of over 2 m occurred throughout most of the playa during this period, with depths of up to 4 m in the south-eastern part of the basin, spilling into the riparian vegetation zone. Inundation extent reached 100% of the lakebed and was more than 80% for over six months during this period. It is also likely a similar event occurred in 1973 to 1974, which was not captured by satellite imagery.

The analysis of the number and duration of discrete inundation events at Lake Mackay at different percentage inundation thresholds since 1987 indicated there has been a general increase, which was most prominent at the 50% threshold. There have been more than 55 discrete inundation events recorded at the 20% inundation threshold, of which 21 and nine events exceeded the 50% and 75% thresholds, respectively. The average duration of these inundation events is more than 25 days for the 20% and 50% thresholds, and less than 20 days for the 75% threshold. In addition, at 50% inundation threshold, 20 of the 21 events occurred post 2000.

In summary, while the hydroperiod shows a high degree of interannual variation, larger inundation events are considered rare, with smaller events occurring more frequently. Both rainfall and the frequency of inundation have increased at Lake Mackay in the last 20 years. Regardless, the lake typically dries rapidly unless top-up events occur over the course of the wet season, although the south eastern portion of the lake holds water for longer.

4.3 OPERATIONAL SCENARIO

In comparison to the satellite imagery analysis, the long-term GoldSim modelling typically followed similar trends in the inundation extent and duration on Lake Mackay, although the results under-predicted the maximum extent of surface water in the largest events. Base case and operational scenarios were also generally closely correlated, particularly during the largest events. Therefore, the model adequately simulated the overall lake water balance in response to rainfall events and supports the prediction of operational versus a base case scenario.

The GoldSim model outputs indicated that the proposed operations will not significantly impact Lake Mackay's overall water balance and can be summarised as follows:

- The lake is typically dry and only holds water for only approximately 27% of the time;
- There may be an average decrease in groundwater levels across the lake by approximately 0.7 m by year 10 of operations;
- A minor reduction may be observed in the number of smaller inundation events (<20% inundation extent) that cause ponding on the lake, corresponding to a 10% decrease in the time the lake holds water; and
- During larger inundation events (which are rare), there will be negligible impacts on the frequency, maximum extent, depth and duration of surface water on the lake.

4.3 CLIMATE CHANGE SCENARIO

Climate change predictions for the region include a projected increase in drought periods as well as increased intensity of extreme rainfall events. Together with potential influence of operations from the Project, this may have a temporary effect in reducing the number of minor inundation events over the life of mine. However, current projections indicate that large inundation events will not be substantially affected, maintaining the lake's hydrological processes, productivity and ecological values, particularly as providing important habitat for waterbirds.

The predicted increase in extreme rainfall events, which is also evident in rainfall and satellite imagery analysis (post 2000), may offset potential changes associated with operations and changes in soil moisture within the catchment. Recovery of groundwater levels to baseline conditions post operations is expected to mostly occur within two years (complete recovery is expected by year 7) of cessation, corresponding to minor, temporary disturbance to the lake from the Project.

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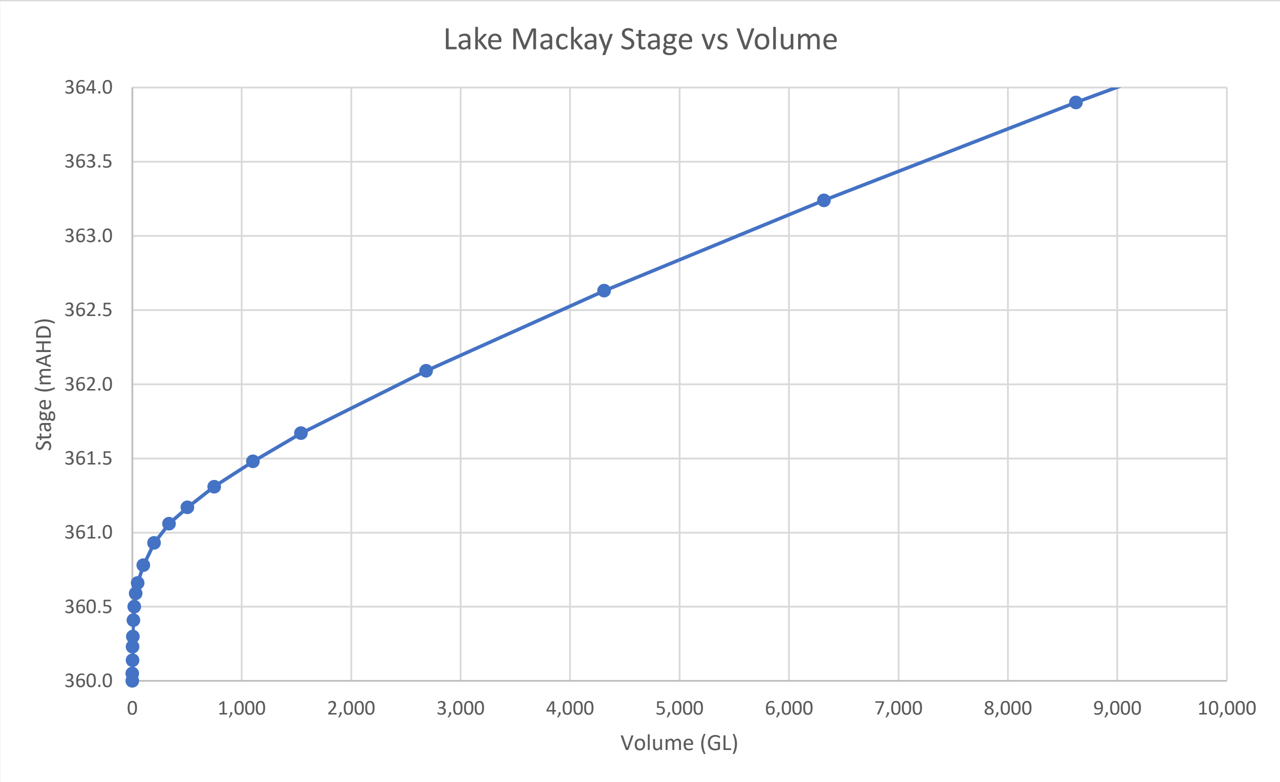
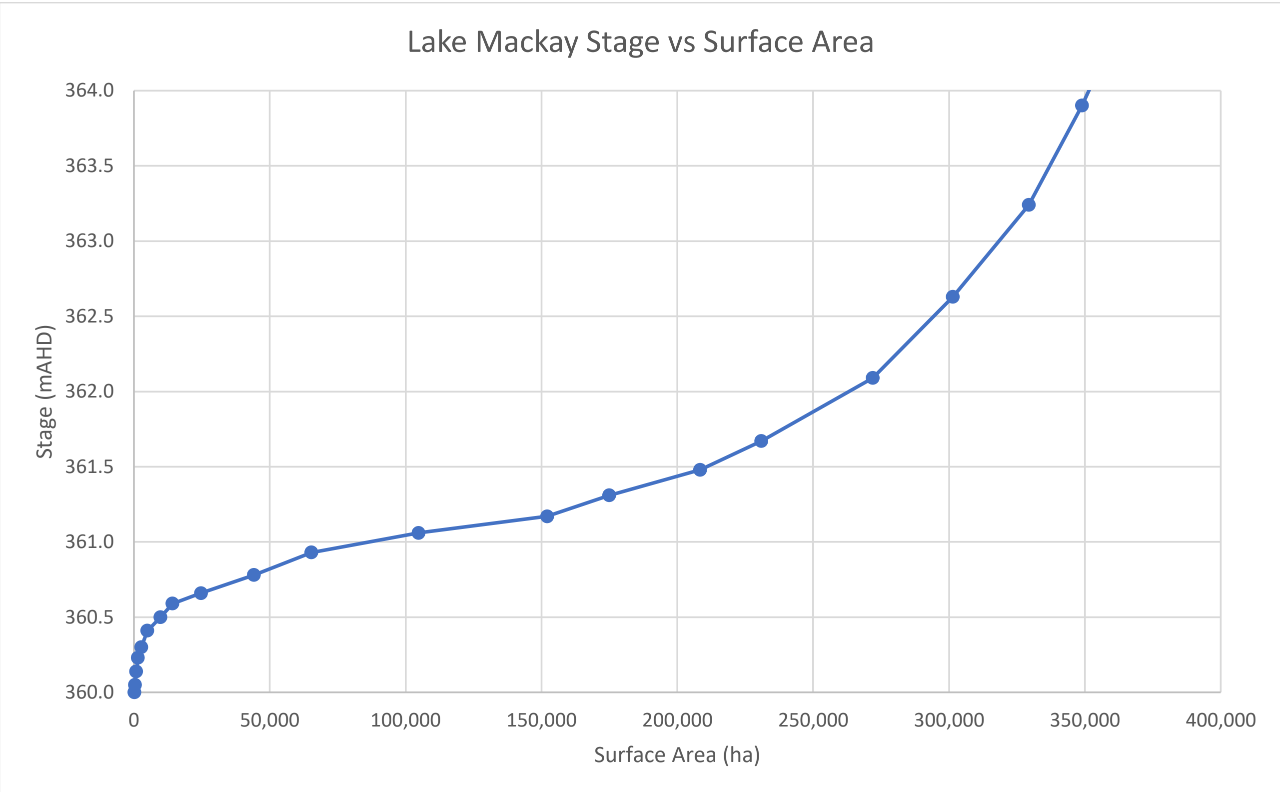
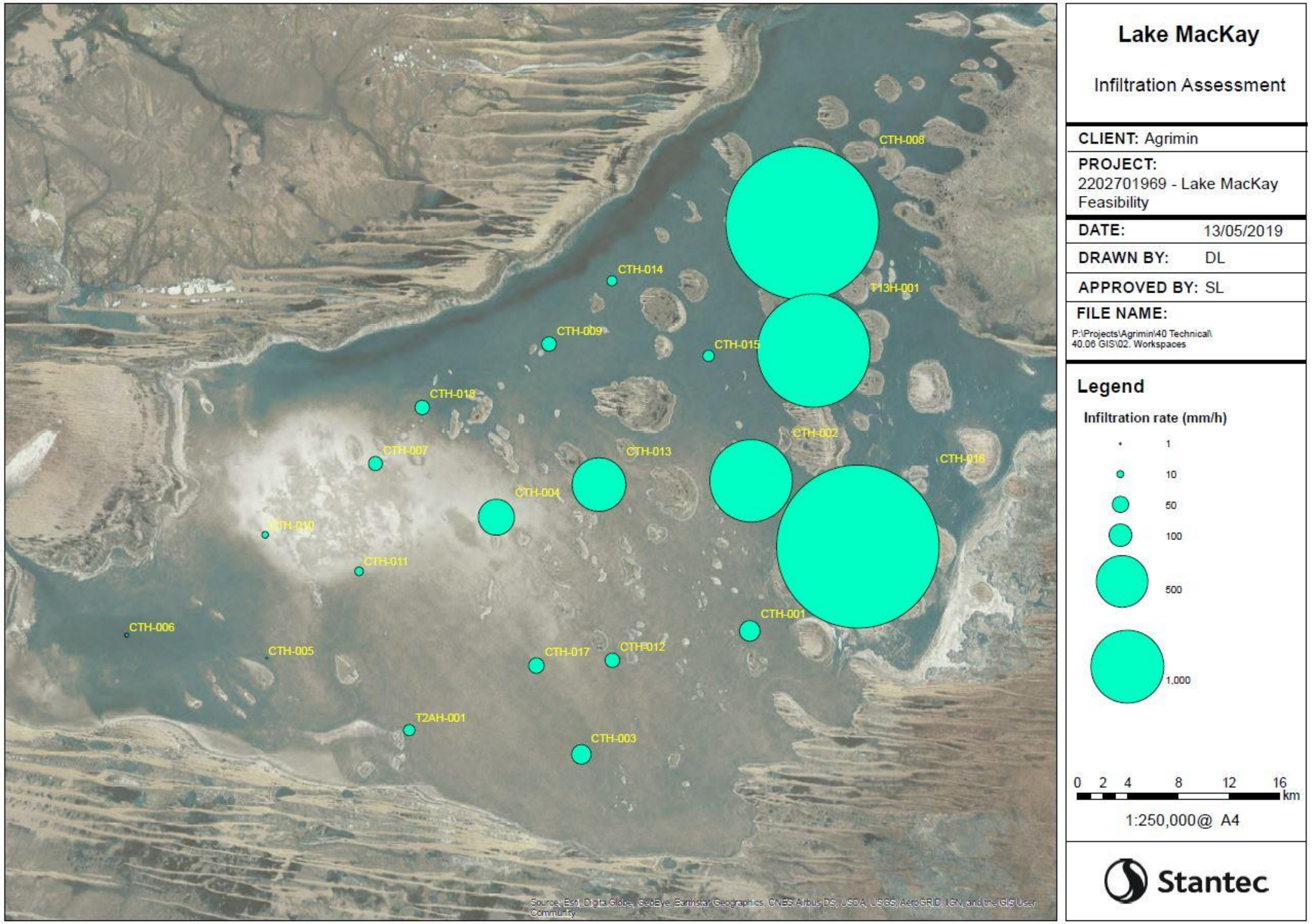
APPENDIX A:
LAKE MACKAY STORAGE AND SURFACE AREA CURVE


Lake Mackay Stage vs Volume
Stage (mAHD)
364.0
363.5
363.0
362.5
362.0
361.5
361.0
360.5
360.0
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
Volume (GL)

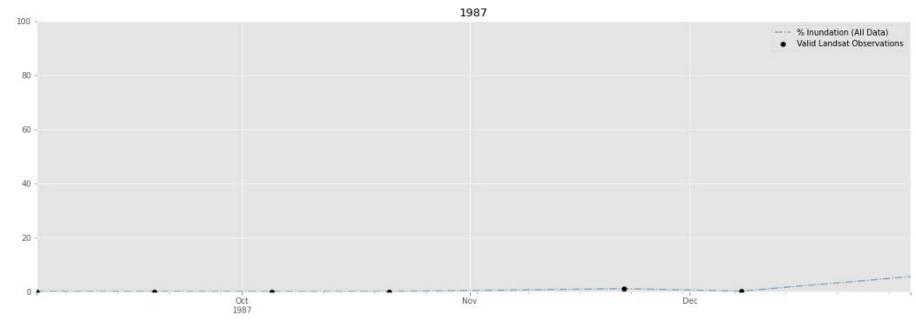

Lake Mackay Stage vs Surface Area
Stage (mAHD)
364.0
363.5
363.0
362.5
362.0
361.5
361.0
360.5
360.0
0
50,000
100,000
150,000
200,000
250,000
300,000
350,000
400,000
Surface Area (ha)

APPENDIX B:
LAKE MACKAY INFILTRATION RATES (STANTEC 2020C)


CTH-008
CTH-014
T13H-001
CTH-009
CTH-015
CTH-018
CTH-002
CTH-007
CTH-013
CTH-016
CTH-004
CTH-010
CTH-011
CTH-001
CTH-006
CTH-005
CTH-017
CTH-012
T2AH-001
CTH-003
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Lake MacKay
Infiltration Assessment
CLIENT: Agrimin
PROJECT: 2202701969 - Lake MacKay Feasibility
DATE: 13/05/2019
DRAWN BY: DL
APPROVED BY: SL
FILE NAME: P:\Projects\Agrimin\40 Technical\ 40.06 GIS\02. Workspaces
Legend
Infiltration rate (mm/h)
1
10
50
100
500
1,000
0 2 4 8 12 16 km
1:250,000@ A4
Stantec

APPENDIX C:
ANNUAL INUNDATION PERCENTAGE OF LAKE MACKAY (1987 TO 2021)

1987



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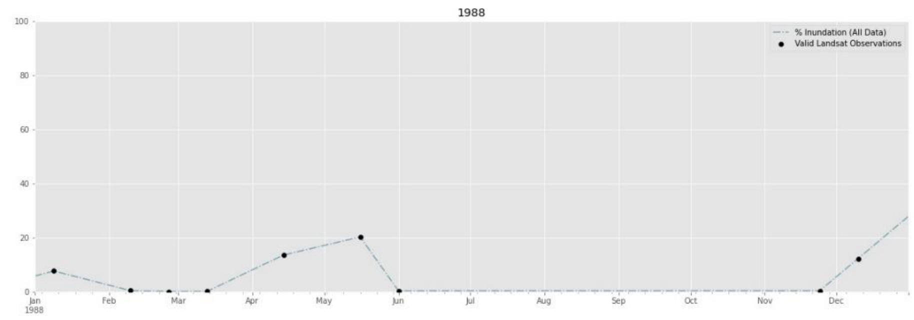
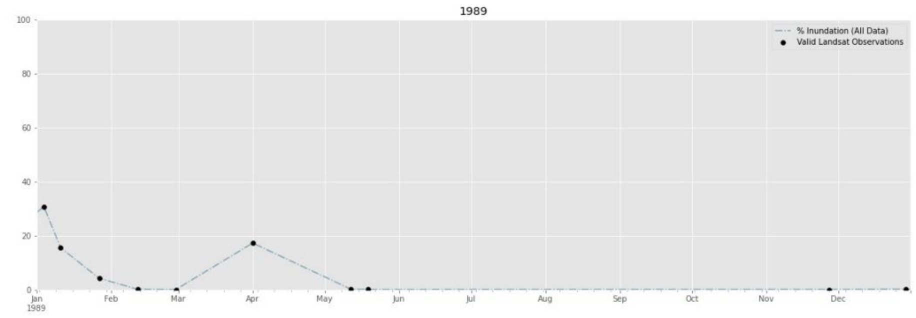
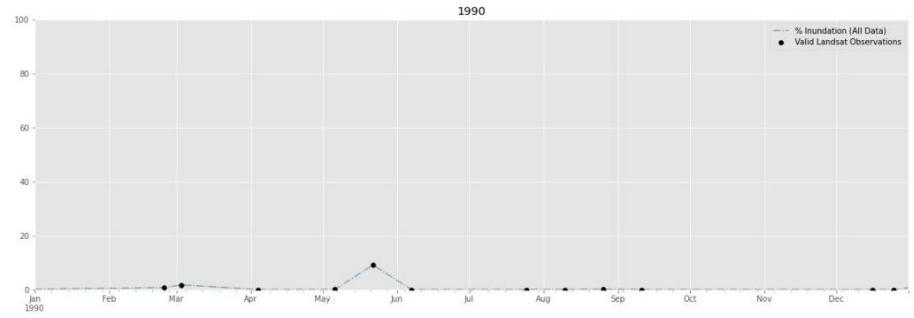


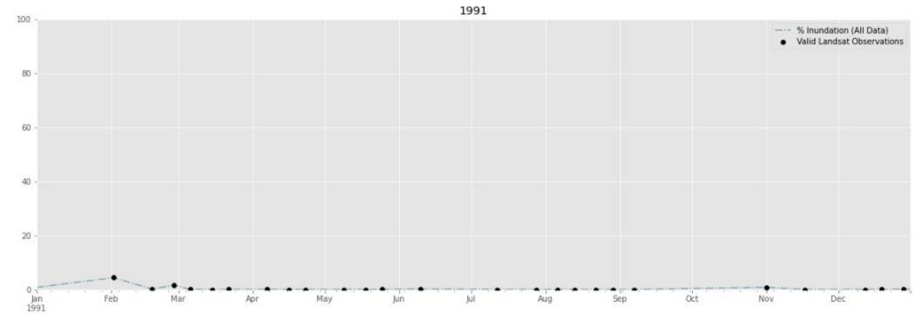
1989



1990



1991



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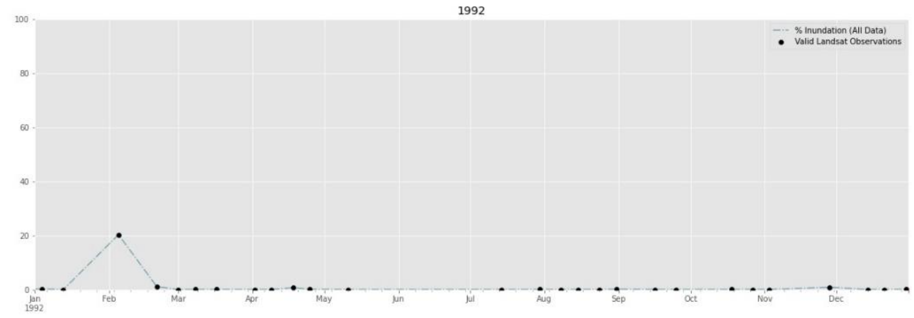

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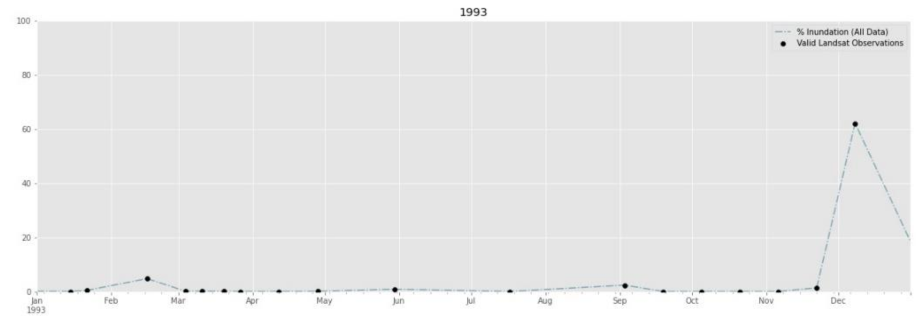

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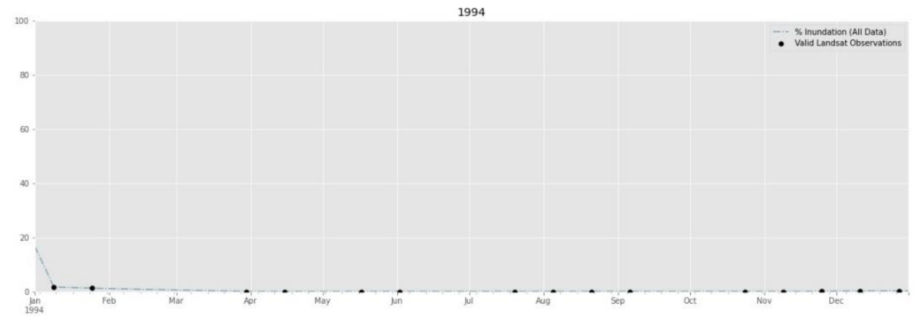
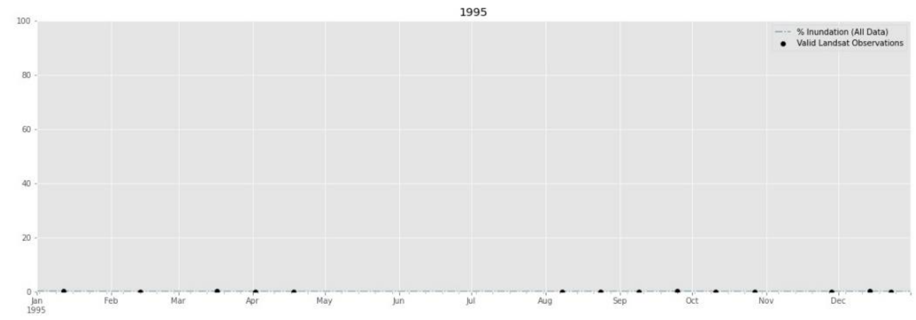
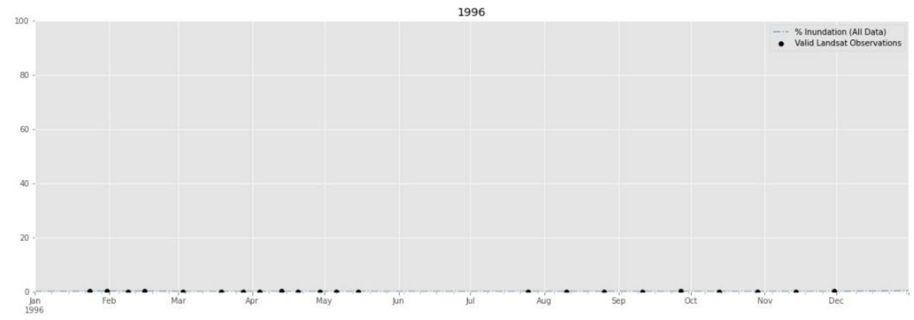


1995



1996



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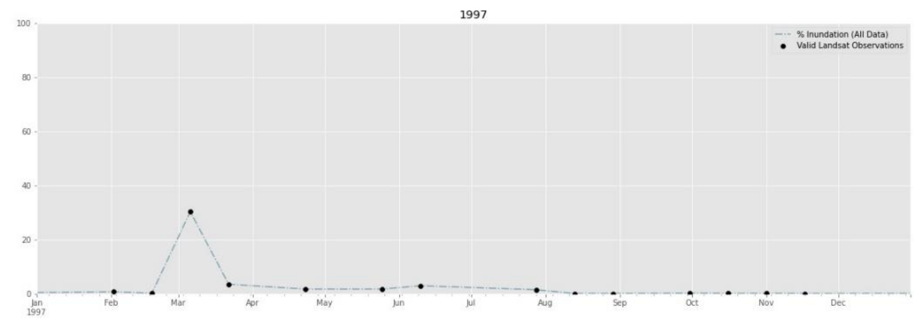

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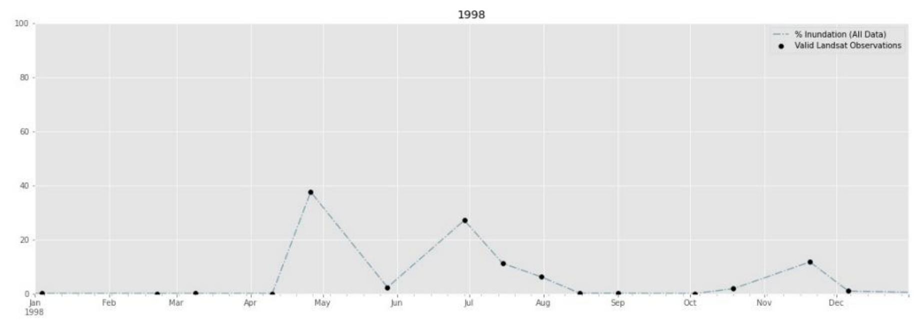

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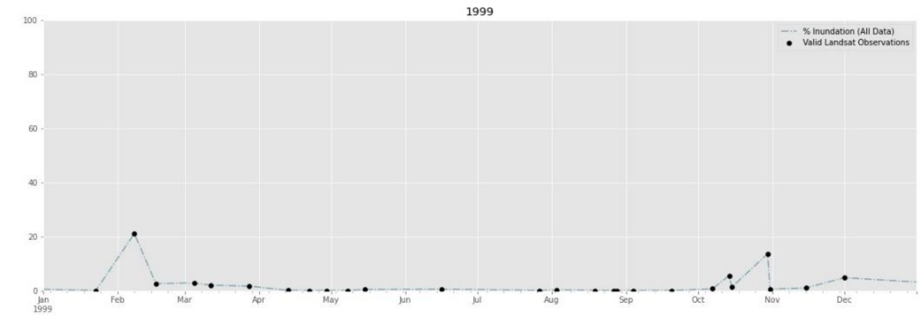

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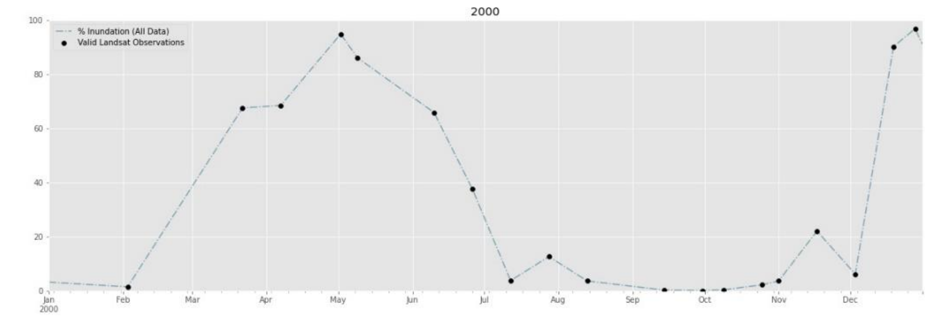

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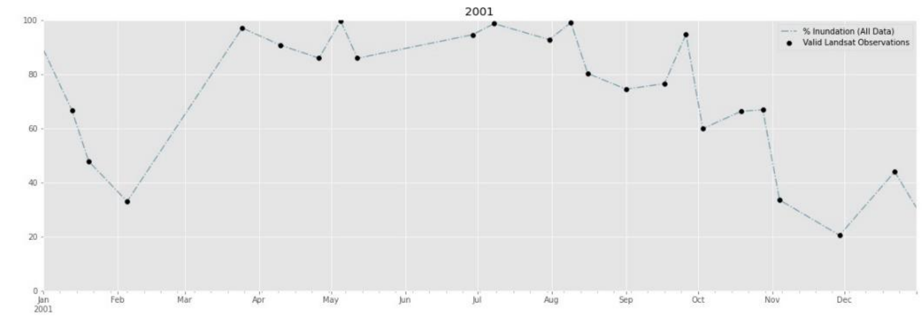

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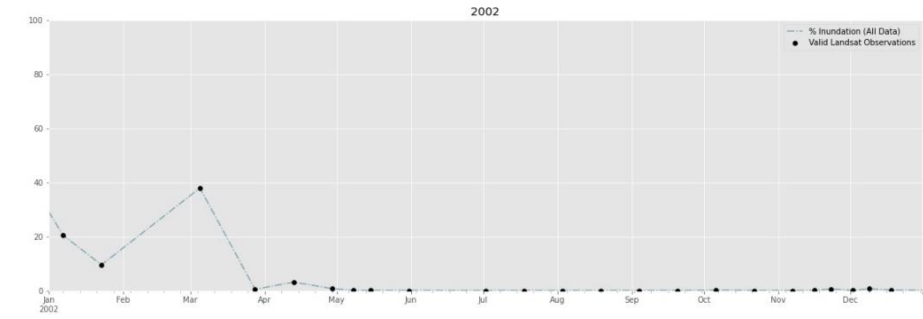

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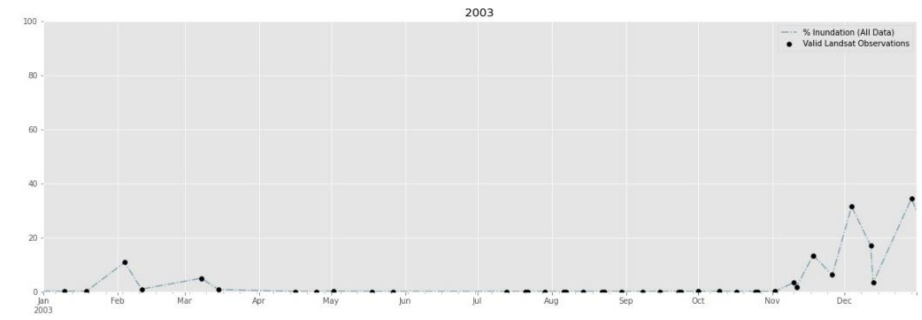

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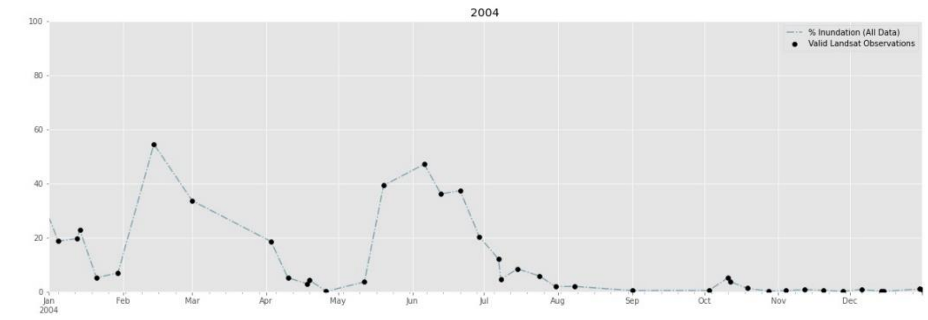

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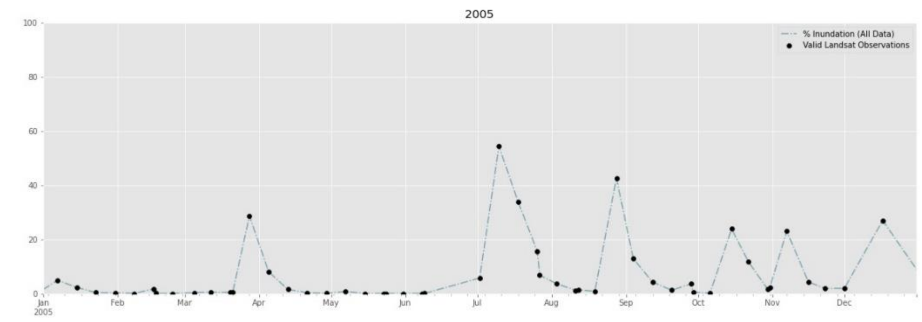

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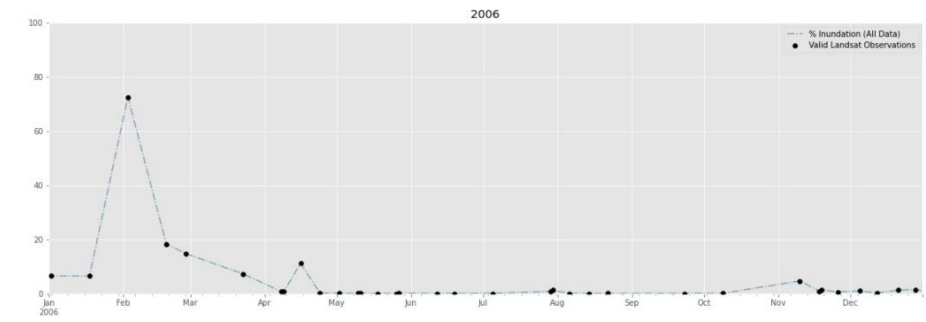

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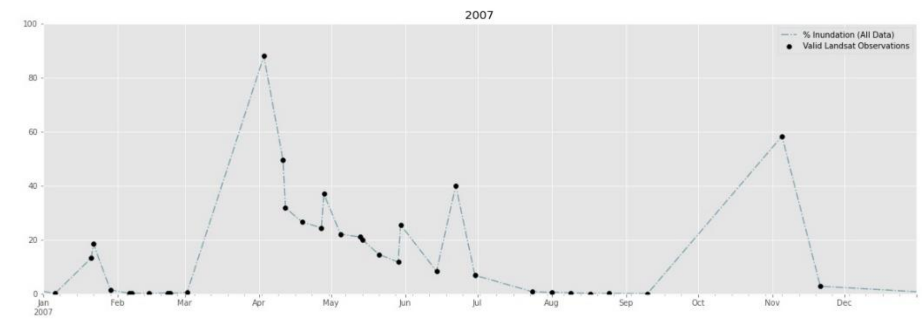

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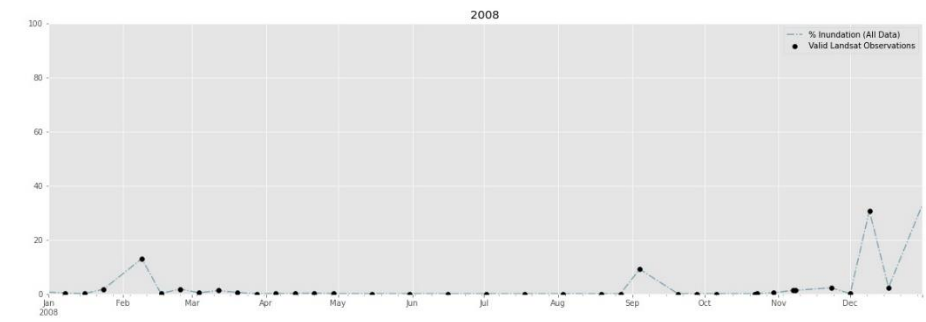
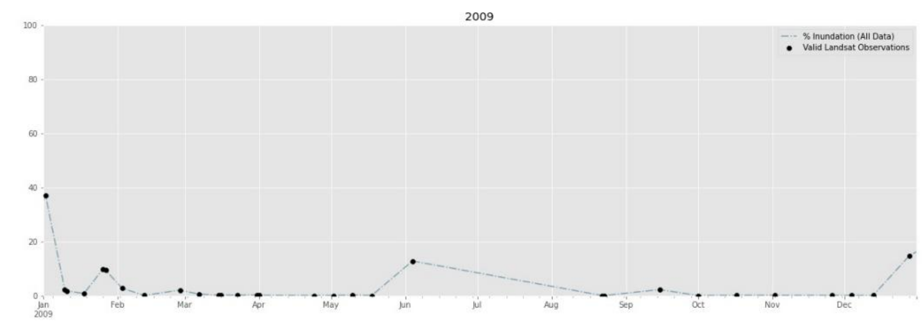


2009



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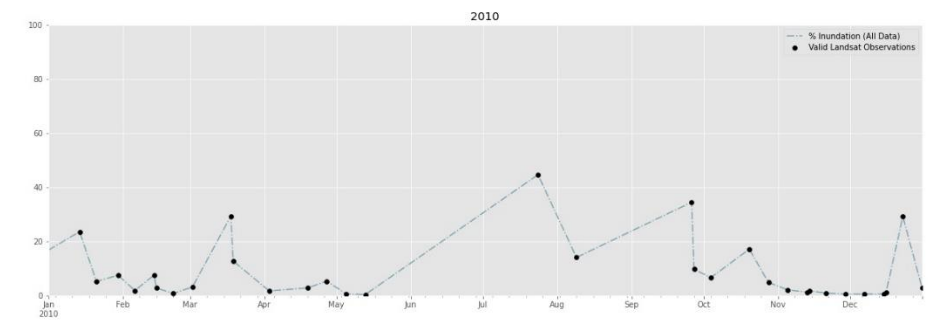

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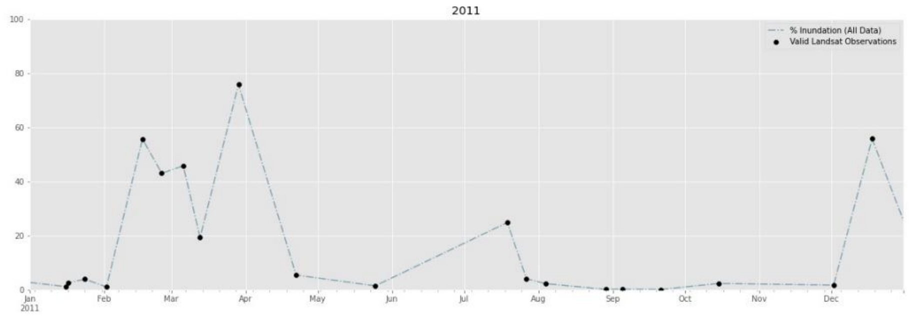

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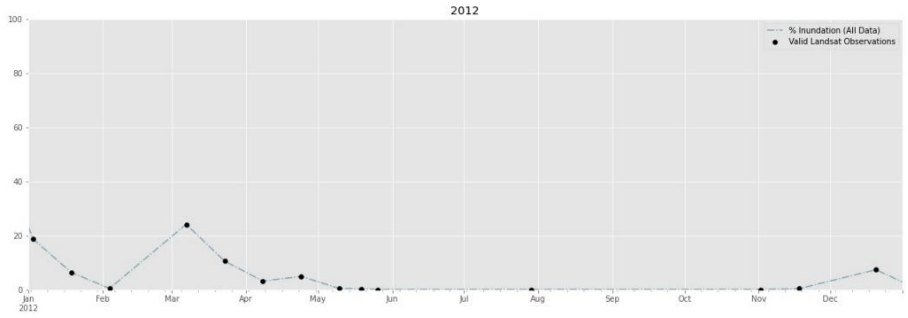
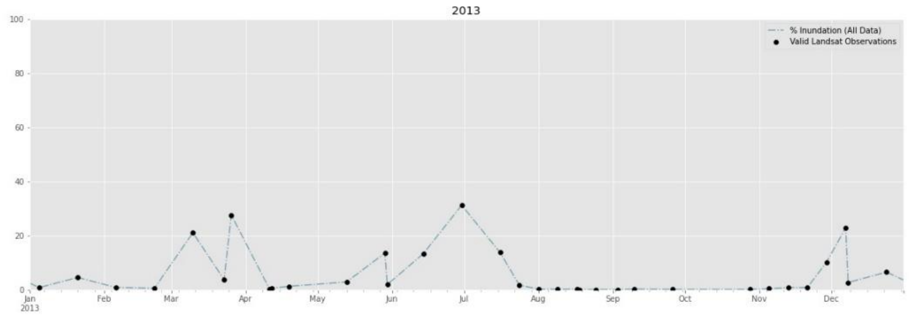


2013



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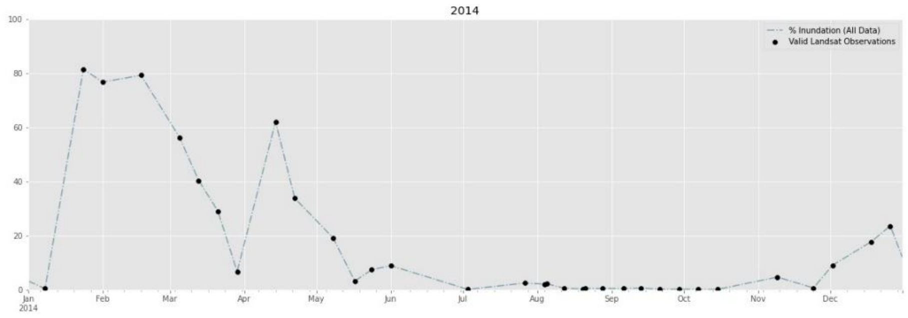
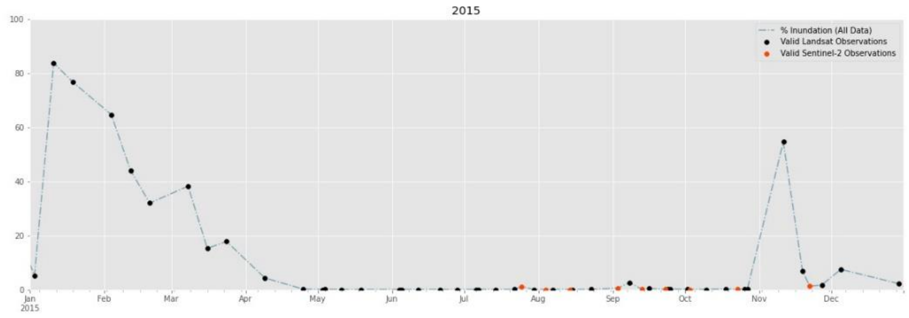
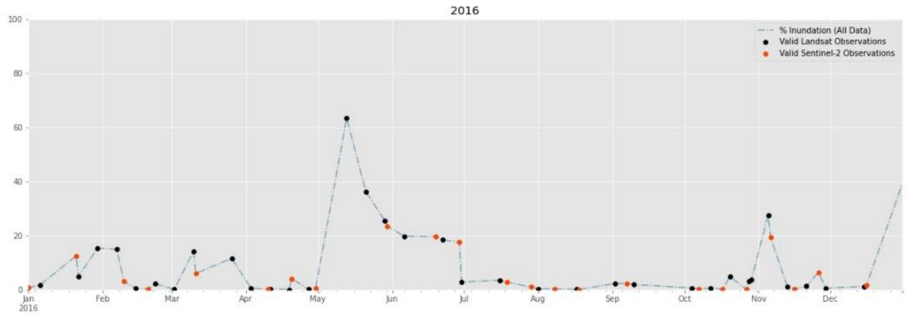


2015



2016



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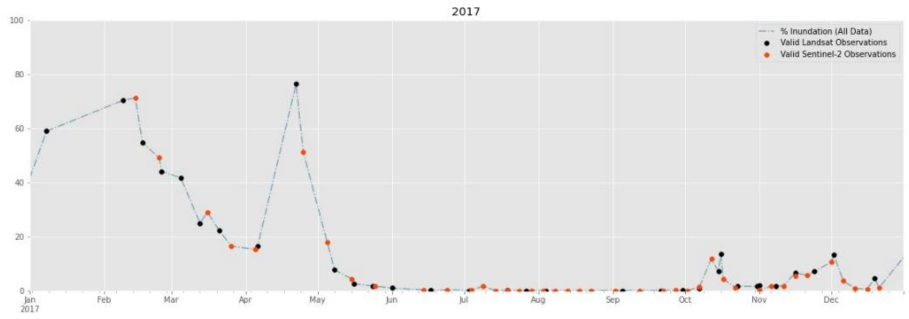
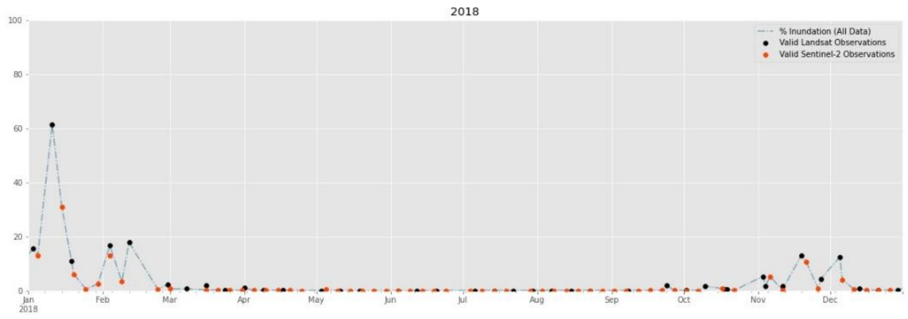
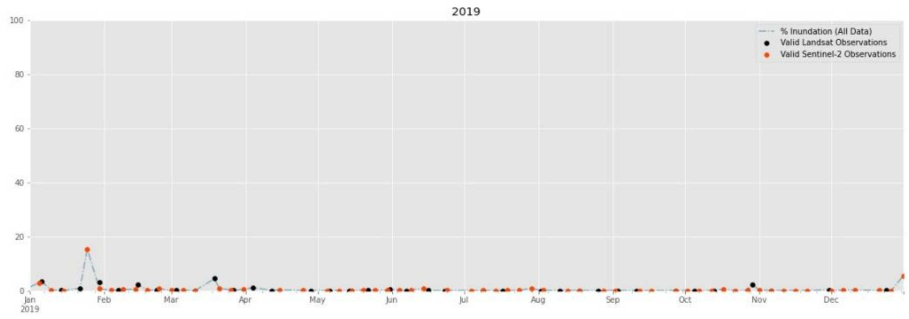


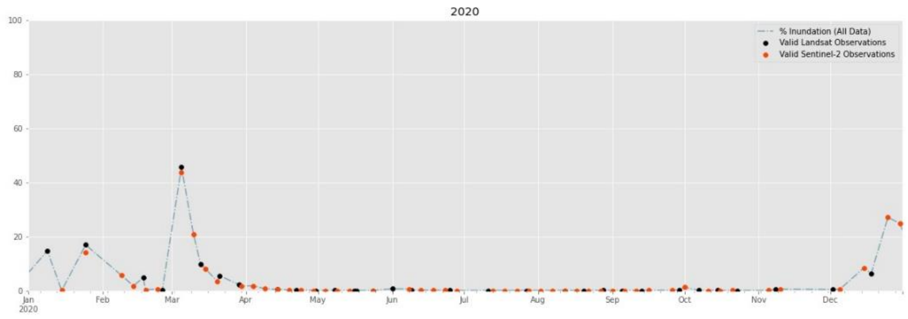
2018



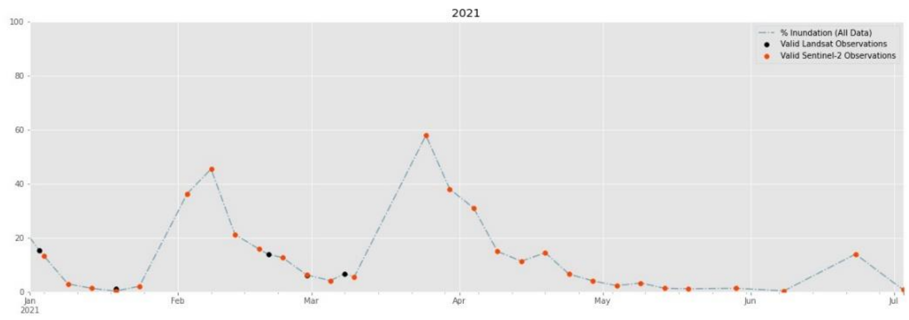
2019



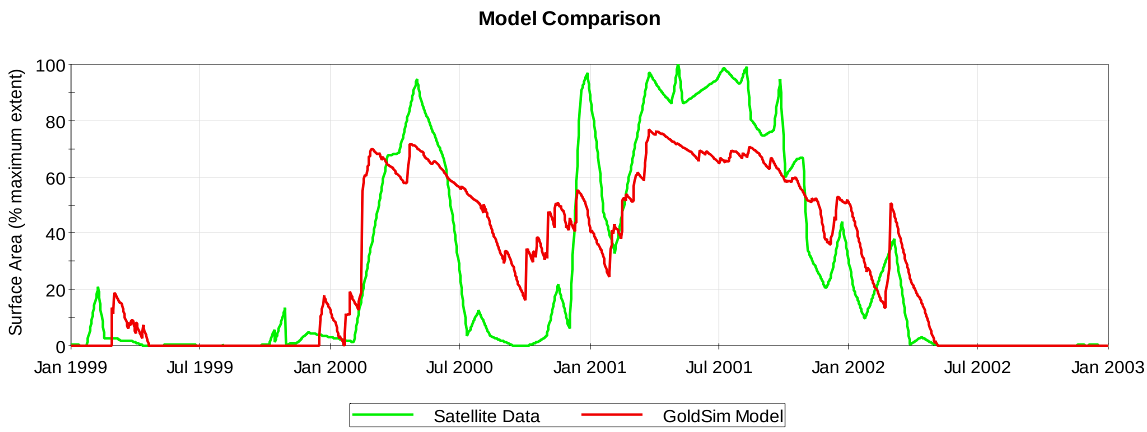
2020

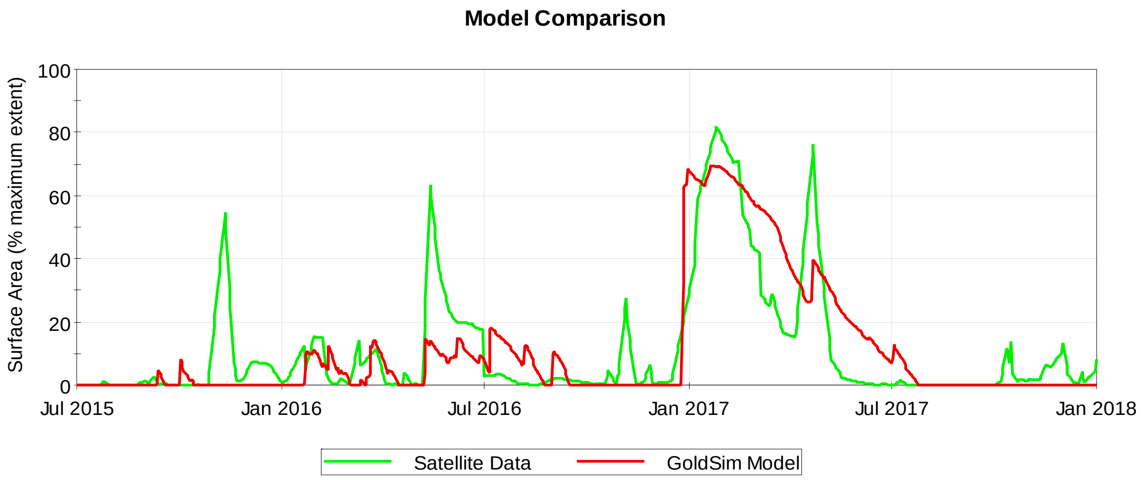


2021

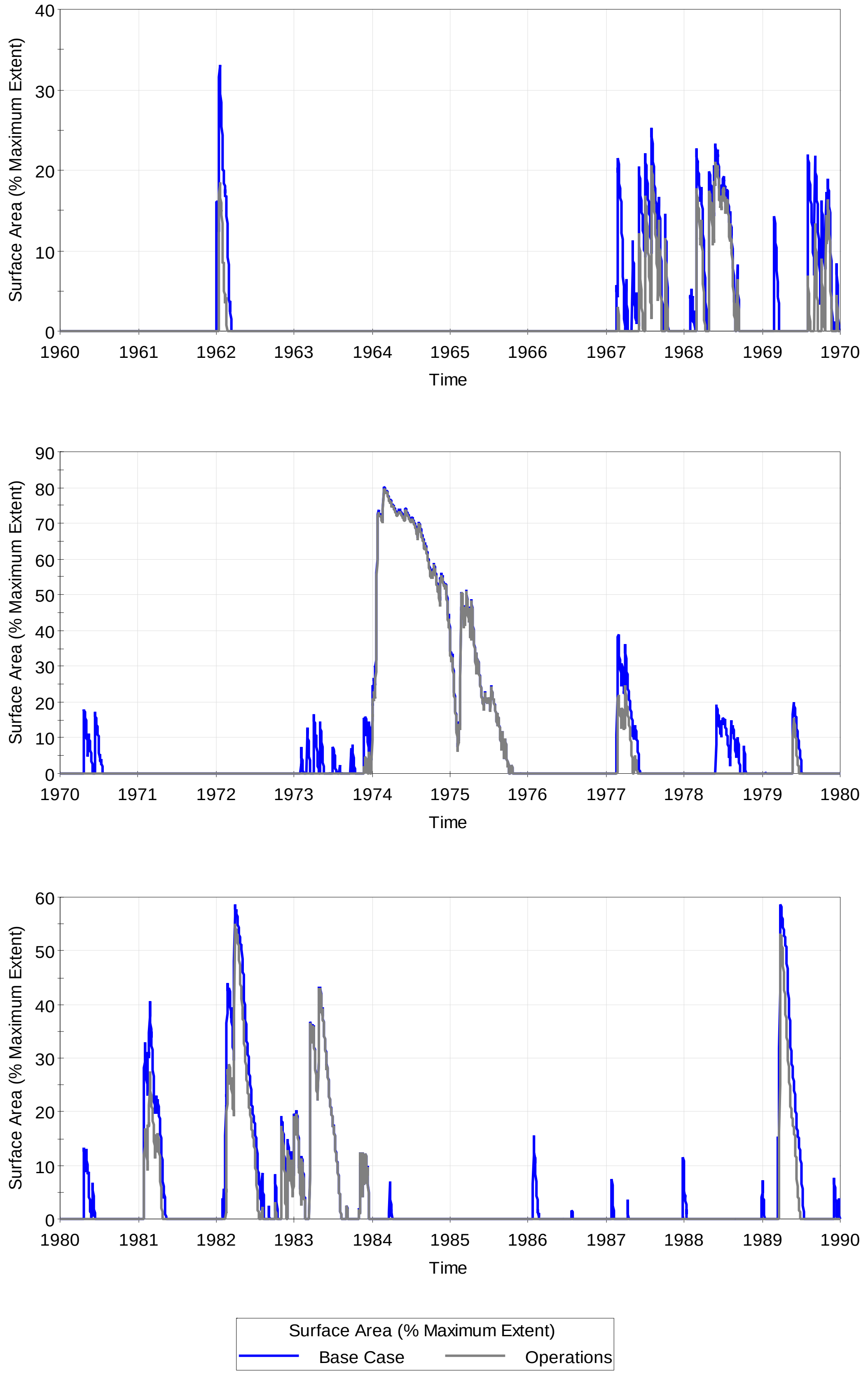


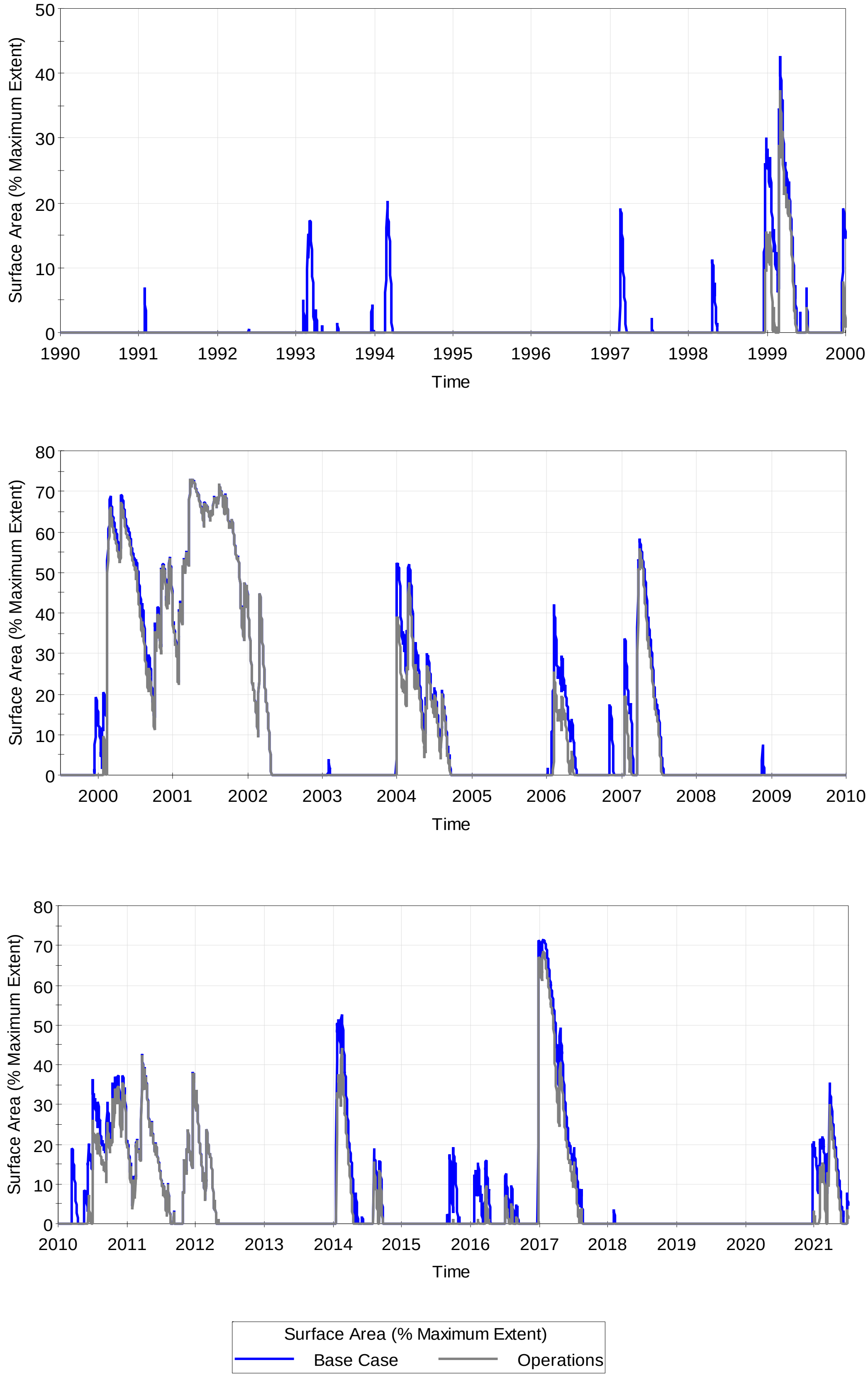
APPENDIX D: GOLDSIM WATER BALANCE MODEL COMPARISON WITH SATELLITE IMAGERY ANALYSIS


Model Comparison
Surface Area (% maximum extent)
100
80
60
40
20
0
Jan 1999
Jul 1999
Jan 2000
Jul 2000
Jan 2001
Jul 2001
Jan 2002
Jul 2002
Jan 2003
Satellite Data
GoldSim Model


Model Comparison
Surface Area (% maximum extent)
100
80
60
40
20
0
Jul 2015
Jan 2016
Jul 2016
Jan 2017
Jul 2017
Jan 2018
Satellite Data
GoldSim Model

APPENDIX E:
GOLDSIM WATER BALANCE MODEL RESULTS (BY DECADE)


Surface Area (% Maximum Extent)
Time
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
Base Case
Operations


Surface Area (% Maximum Extent)
0
10
20
30
40
50
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
Time
Surface Area (% Maximum Extent)
0
10
20
30
40
50
60
70
80
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Time
Surface Area (% Maximum Extent)
0
10
20
30
40
50
60
70
80
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Time
Surface Area (% Maximum Extent)
Base Case
Operations