Appendix 49 Hydrological Setting and Understanding – Myara North and Holyoake

Hydrological setting and understanding – Myara North and Holyoake

Pinjarra Alumina Refinery Revised Proposal

Alcoa of Australia Limited

22 December 2021

→ The Power of Commitment

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Executive summary

Aims and issues

Alcoa of Australia Limited (Alcoa) is proposing to increase production at the Pinjarra Alumina Refinery (Refinery) by 5 per cent from 5.0 million tonnes per annum (Mtpa) to 5.25 Mtpa and transition the Huntly Bauxite mine to the proposed Myara North and Holyoake mine regions (the Proposal). The Proposal is located in the Peel region of Western Australia (WA), approximately 100 km south-east of Perth.

The Proposal will be subject to environmental impact assessment under Part IV of the WA *Environmental Protection Act 1986* (EP Act), and the *Environment Protection Biodiversity Conservation Act 1999* (EPBC Act). The environmental impact assessment will be via a Public Environmental Review (PER).

The aim of this report is to present an understanding of the hydrological setting (surface water and groundwater) and identify potential impacts on the hydrology of the Myara North and Holyoake regions from bauxite mining.

The generalised effects from bauxite mining are recognised as decreased evapotranspiration of water stored within the subsurface beneath the mining footprint (vegetation clearing and shallow pits), until such time as rehabilitation and vegetation recovery restores the water balance to pre-mining conditions.

The decreased evapotranspiration has potential to cause a local rise, or mounding in groundwater levels, initially beneath the cleared areas, but which will migrate/dissipate towards the groundwater discharge boundaries. Discharge will occur if groundwater rises are such that there is connection with the valley floor (e.g.: surface water drainage lines). A rise in groundwater levels may also cause associated changes in surface water quality via discharge of groundwater (which often has higher TDS than surface water) into the surface water systems.

The increase in groundwater discharge may adversely impact the beneficial use of the groundwater, which at Myara North and Holyoake proposed mining regions, comprises the groundwater dependent ecosystems (GDEs), the aquatic ecology associated with drainage lines of the areas, and drinking water supply (surface water collection in dams and reservoirs).

Scope of work

This hydrological understanding is based on assessment of previous reporting, published research, publications of the Bauxite Hydrology Committee, Alcoa's and DWER's groundwater data base (over 400 monitoring bores), and installation, testing and monitoring of 33 newly installed monitoring bores within the Myara North and the Holyoake mine regions.

Generalised hydrological site setting

The hydrological profile comprises inferred shallow surficial material (lateritic/pisolitic/sands/loams), with a probable thickness of 1 to 2 metres, which may thicken in the valley floors and drainage lines (unit not characterised). The surficial sediments are underlain by a 10 to 30 metres of lower permeability clayey saprolite weathering profile, which grades sharply into granite basement.

The presence of surficial sediments (including soils and vegetation) promotes infiltration of rainfall into the subsurface (surface water runoff is). The surficial unit is most not a laterally continuous hydrogeological unit, as variable permeable (low to high), reflective of the lithology and sediment transportation history.

The infiltrated rainfall is inferred to partition into patchy (i.e. non-contiguous) shallow subsurface lateral flow within the near-surficial, mostly unsaturated sediments, and downwards (deep) drainage which recharges the deeper regional groundwater.

Where hydraulically connected to the drainage lines, groundwater discharges into drainage lines and can combine with quickflow components at times.

The regional groundwater, intersected at depths (during drilling by GHD) coincides with more permeable zones at the transition between the saprolite and bedrock (average hydraulic conductivities of 0.6 m/day at Myara North and 0.3 m/day at Holyoake), although the broader Darling Range data indicates a wider range of values.

Myara North hydrological site setting

Assessment of long-term groundwater level trends in 24 Myara North Alcoa monitoring bores, with suitable data, indicates that a total of 22 of the monitoring wells exhibit declining groundwater levels, with an average of a 4.5 metre decline over the period (1990 to 2020). Total dissolved solids(TDS) in groundwater over the same period were stable, with an average of approximately 300 mg/L.

Monitoring bores (Alcoa and newly installed GHD bores) are slotted at the transition zone between the saprolite and bedrock (10 to 30 meters below ground level), therefore little information exists on shallow groundwater.

In general, on the elevated areas on hills and ridges, the depth to regional groundwater is typically 15 to 30 meters below ground level (saprolitic permeable zones), while in the valley floors and in the creek lines (where GDEs are present), the depth to groundwater is generally between 2 to 5 meters below ground level.

Regional groundwater is inferred to migrate from the hills towards the lower lying drainage lines, and groundwater seepage is expected to occur at shallow depths to groundwater

minimal-assessment of surface water flow monitoring data, located within the mid/lower parts of the Myara North catchments, indicates that surface water flows are relatively short-lived following winter rains (ceasing to flow within 2 to 3 weeks).

Together with shallow subsurface flow, groundwater is also considered to have an important part in supporting the potential GDEs and contributing to streamflow, via maintenance of groundwater levels typically within 2 to 3 meters of the base of the drainage lines in upper parts of the catchments but may also contribute to streamflows particularly in the lower parts of the catchments.

Holyoake hydrological site setting

The newly installed monitoring (17 in total), bores, generally positioned within and close to the drainage lines and valley floors (where GDEs are located), indicate the depth to groundwater is generally greater than 10 meters below ground level and the valley floor level (no shallow surficial bores are installed).

Hydrographs from six Alcoa monitoring wells (positioned outside the Holyoake development boundary) indicate declining groundwater levels with an average decrease of approximately 9 metres over the monitoring period (1990 to 2020). There is insufficient long-term monitoring data inside the Holyoake mine region to draw conclusions on salinity trends, however the average TDS derived from Alcoa monitoring bores and newly installed GHD monitoring wells is approximately 400 mg/L. Long-term data from nearby catchments indicate a general stability in groundwater salinities with declining groundwater levels.

The depth to water in the valley floors (>10 metres) indicates that the potential GDEs are not solely supported by regional groundwater discharge, and are more likely the result of seasonal saturation of a shallow perched aquifer in the valley floor.

Surface water groundwater interaction

Seasonal (winter) rainfall increases the overall storage of water in the catchment and, in more incised catchments towards the west of the Darling Range, results in seasonal creek flows when groundwater connects with the valley floor. In broader valley forms in the eastern parts of the Darling Range, saturation of a perched shallow aquifer in the flatter parts of the valley floor is associated with streamflow. The streamflows are relatively short- they generally cease within a few weeks or months.

Streamflows comprise the baseflow and quickflow components, the proportion of which changes through the seasonal streamflow event. Quickflow components (surface runoff and interflow) dominate during the initial and possibly peak flow stages while baseflow dominates during the later stages, including the recession part of the streamflow curve.

Surface water and available groundwater hydrographs are well aligned and show the seasonal peaks suggesting a synchronised interaction between surface and subsurface flow systems.

The relationship between rainfall events, groundwater level increases and streamflow occurrences is considered relatively straightforward and well established. A simple analytical model was developed to explore the relative contributions of quickflow and baseflow components, including groundwater recharge, constrained by TDS of two principal end-members (quickflow and baseflow). Streamflow data from the Jack Rocks gauge spanning the period 1981 to 1999 (the best available dataset for the two mine regions) was used for this assessment.

This work indicates that a relatively wide range of baseflow contributions (examples included in this report range between 18 to 50% of streamflow) is possible, consistent with the more recent research (e.g., Grigg and Kinall, 2020). Recharge rate changes directly affect the baseflow contribution, hence any changes to recharge rates through land use interventions will affect streamflows where there is connection between groundwater and the valley floor.

Understanding of mining impacts to development areas

The literature review and an assessment of a former mining region (herein) indicates increased streamflows (7% to 30% of rain) and increased groundwater levels of close to 5.5 meters because of bauxite mining and land clearing. This supports that a local rise, or mounding in groundwater levels, will accompany mining and migrate/dissipate towards the groundwater discharge areas.

Rises in groundwater levels beneath the mining regions may also be accompanied by increases in shallow subsurface flow, because of excavations of any laterally continuous surficial layer during mining and migration through the surficial layers where in hydraulic connection with any accumulated in-pit waters.

Salinity impacts, to the potential GDEs, aquatic ecology and drinking water supplies (via surface water flows) from increased groundwater levels and groundwater discharge (due to mining) are not anticipated, given that soils of the area possess a low salt storage, and that groundwater salinities are low and stable over the long-term (average salinities Myara North 300 mg/L and Holyoake 400 mg/L).

Recommendations:

Given the potential for mining activities to have some effect on the potential GDEs and wetlands, through increases in water levels and groundwater discharge, it is recommended to undertake predictive estimates (e.g. through groundwater modelling) to quantify the magnitude and duration of these effects.

Where the predictive estimates indicate a change in groundwater levels and discharge is within the historic range, then adverse impacts to the potential GDEs and ecological setting are not anticipated.

However, consideration should be given to a potential shift in the ecological community composition and terrestrialisation of potential GDEs in response to natural decadal-scale change in rainfall (and water levels) as identified during the period of long-term declining groundwater levels (1990 to 2020). This may be followed by subsequent adaptation of the potential GDEs to declined groundwater levels (i.e. potential transition to more dryland composition).

Where the predictive estimates indicate a change in groundwater levels and discharge is outside the historic range, an assessment of the sensitivity of the potential GDEs to increases in groundwater levels and increased discharge over the duration of mining impacts should be carried out, to evaluate the consequence and likelihood of impacts.

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Acronyms

Abbreviations	Definition
ANZG	Australia New Zealand Guidelines
BoM	Bureau of Meteorology
CMB	Chloride mass balance
CRD	Cumulative Rainfall Departure
DE	Development Envelope
DWER	Department of Water and Environmental Regulation
EC	Electrical Conductivity
EPA	Environmental Protection Authority Western Australia
EP Act	Environmental Protection Act 1986
EPBC Act	Environmental Protection and Biodiversity Conservation Act
ESD	Environmental Scoping Document
FPC	Forests Products Commission
GDE	Groundwater Dependent Ecosystem
GSWA	Geological Society of Western Australia
ha	Hectares
HRZ	High Rainfall Zone
IRZ	Intermediate Rainfall Zone
km	Kilometres
mBGL	Metres Below Ground Level
µS/cm	Microsiemens Per Centimetre
mg/L	Milligrams Per Litre
ML	Megalitre
NTU	Nephelometric Turbidity Units
PER	Public Environmental Review
SWL	Standing Water Level
TDS	Total Dissolved Solids

1. Introduction

1.1 Project introduction

Alcoa of Australia Limited (Alcoa) is proposing to increase production at the Pinjarra Alumina Refinery (Refinery) by 5 per cent from 5.0 million tonnes per annum (Mtpa) to 5.25 Mtpa and transition the Huntly Bauxite mine to the proposed Myara North and Holyoake mine regions (the Proposal), which is presented in Appendix A, Figure A-1. The Figure shows that the Myara North region lies adjacent and north of the existing Myara mining operations. The Proposal is located in the Peel region of Western Australia (WA), approximately 100 km south-east of Perth.

The Proposal will be subject to environmental impact assessment under Part IV of the WA *Environmental Protection Act 1986* (EP Act), and the *Environment Protection Biodiversity Conservation Act 1999* (EPBC Act). The environmental impact assessment will be via a Public Environmental Review (PER).

The EPA have identified Inland Waters as a preliminary key environmental factor, noting that the proposed mining areas lie over catchments for public drinking water reservoirs.

Alcoa has engaged GHD to prepare the environmental approval documentation and supporting technical studies (the Project) for the Alcoa Proposal under the EP Act and EPBC Act. The study area includes Myara North and Holyoake mine regions.

1.2 Purpose and context of this report

As part of the environmental approval documentation, the aim of this report is to present the available information on the hydrological setting and the conceptual understanding of potential impacts on the hydrological systems and receptors due to bauxite mining.

This report relies on the following information and data sources, which are referenced throughout the report:

– Desktop review for the Myara North and Holyoake mine regions (GHD 2021), based on studies/reviews previously undertaken by Alcoa for the Bauxite Hydrology Committee, published research related to the area, geological information from public sources and monitoring data.
– GHD's field hydrological investigations comprising:
    - Installation of surface water monitoring instruments at six locations at Myara North and three locations at Holyoake (GHD 2020)
    - Installation of 18 groundwater monitoring bores at Myara North and 17 at Holyoake (GHD 2020)
    - Monitoring, baseline surface water and groundwater conditions from August 2020 to February 2021 ((GHD 2021(a))

Alcoa has supported studies to assess the potential impacts of its mining activities on the Darling Range Jarrah Forest environment since the 1970s, previously in association with the former Water and Rivers Commission as part of the *Joint Intermediate Rainfall Zone Research Program*.

This research was overseen by the Bauxite Hydrology Committee, formerly a subcommittee of the MMPLG, which was suspended in 2014.

The research has had a significant focus in understanding the relationship between rainfall, runoff, groundwater levels, and salinity in the region with respect to mining and other land uses

A summary of the findings of this research and other key studies is chronicled, along with their gaps and limitations with respect to the proposed mining areas, is presented in Appendix H.

1.3 Limitations

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Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

2. Project site setting

2.1 Project locations and overview

This surface water and groundwater study relates to the expansion of mining and infrastructure to Alcoa's Myara North and Holyoake mine regions, known collectively as Huntly. The location of the Myara North and Holyoake mine regions and boundaries are presented in Figure A-2 and Figure A-3.

The proposed Myara North mine region is situated to the northern boundary of the Huntly mine and is located within Jarrahdale State Forest 22, south east of the town of Jarrahdale. It lies predominantly in the Shire of Serpentine-Jarrahdale with a portion in the City of Armadale. Myara North mine region is bounded by the Monadnocks Conservation Park to the north-east and the Serpentine National Park to the west (Figure A-2).

State Forest 22 in the Myara North mine region is managed for multiple uses including drinking water production, timber production and recreation. Alcoa previously mined near Jarrahdale from 1963 to 1998.

Construction in Myara North mine region is scheduled to occur about 2023 (pending receipt of applicable approvals), with operations occurring from about 2025 to 2030. Mining within the existing Myara mine region is expected to decrease upon commencement of mining in the Myara North mine region, albeit some rehabilitation activities will still be occurring in the existing areas. A plan showing the proposed bauxite mining footprint areas is presented in Figure A-4. The development of these new mining areas will require new processing hubs, overland conveyors, haul roads, heavy vehicle access roads, public access roads, power generation and transmission equipment and supporting infrastructure.

A mine plan is yet to be developed for the Holyoake mine region. On completion of mining at Myara North, a move to the Holyoake region is planned with construction to commence from about 2028 with mining operations from about 2030.

2.2 Overview of Alcoa's bauxite mining process

Alcoa's bauxite mining process comprises the following steps:

– Pre-mining environmental and heritage surveys.
– Exploration/resource drilling to identify ore bodies suitable for mining.
– Vegetation clearing and salvage of timber by the Forest Products Commission.
– Topsoil and overburden removal including ripping or drilling and blasting of caprock. Material is stockpiled or used directly for rehabilitation.
– Mining of bauxite (excavation of blasted and ripped ore material), haul road transport and associated crushing and conveying to the refineries.
– Rehabilitation to jarrah forest by removing compaction of pit floors, re-contouring the surface, returning of gravels and soil, seeding, planting, and fertilising.

Bauxite is found as horizontal shallow ore bodies averaging 3.5 metres in depth and in aerial extent varying from approximately 0.5 to 150 hectares (ha). Mining of bauxite is characterised by a mosaic of shallow and widespread mine voids linked to a centrally-located crusher by a network of haul roads.

The topsoil and overburden vary in depth from 0 to 1.5 m, with the underlying bauxite ore consisting of 1 to 4 metres of friable material and in some cases a cemented layer or duricrust.

Mine clearing is integrated with forest harvesting through Alcoa's working arrangements with the Forest Products Commission (FPC), along with other third parties, to maximise wood residue re-use practices. Alcoa completes removal of forest residue through burning, scraping and excavation.

After mining, rehabilitation is undertaken with the intention of restoring a functioning jarrah forest ecosystem that can support pre-mining land uses. Typically, up to 10 years are considered for the process of vegetation re-establishment and return to pre-mining hydrological conditions. Around 100 different plant species are planted as seeds sourced from the surrounding forest within defined provenance zones or from nursery-raised recalcitrant seedlings.

During rehabilitation, the pits are designed to grade compatibly with the surrounding terrain and ripping of the pit floor is done to 1.5 m depth to remove compaction. After replacing the topsoil and overburden in sequence, the area is ripped again to 0.8 m along the contour to prepare for seeding and facilitate infiltration and reduced erosion.

2.3 Generalised effects of mining on hydrological systems

Given reduced evapotranspiration and potential for increased rainfall infiltration, bauxite mining has been recognised as potentially causing a rise in groundwater levels (due to vegetation clearing and terrain modification) that may have the following effects:

– Changes in volumes of groundwater discharge into rivers and creeks – causing alteration to flow regime
– Water logging of surface soils causing salt build-up in soils through increased evaporation (probably only in localised terrain depressions) – these are however subject to seasonal flushing
– Mobilisation of salts, where stored within the soil profile (this is more prominent in areas east of 1,100 mm isohyet), but not expected to be a major factor in Myara North and Holyoake catchments
– Changes in proportion of groundwater discharge into rivers and creeks
– Waterlogging or saturation of soils – causing increased erosion and sediment load to rivers and creeks
– Waterlogging or saturation of dieback risk areas and vegetation/root systems – causing an increased risk of dieback transmission and stress to vegetation

Changes to the groundwater flow regime and quality have potential to affect the following receptors were confirmed as present within the areas potentially affected by mining,

– Riparian vegetation
– Potential groundwater dependent ecosystems (GDEs)
– Aquatic fauna and flora
– Drinking water quality and irrigation/stock water use.

Following successful rehabilitation and establishment of pre-mining hydrological conditions, rainfall recharge will reduce and groundwater levels return close to natural conditions (if similar climatic conditions prevail), which is anticipated to occur over decadal time frames. Where depressions in place of some former mine pits remain in the landscape they may facilitate enhanced recharge through time-limited accumulation (ponding) of water.

2.4 Generalised site setting

2.4.1 Climate

Western Australia's south west region has a 'Mediterranean' type climate characterised by typically high winter rainfalls and an intense summer drought.

The nearest Bureau of Meteorology (BoM) Station to the Myara North mine region is the Serpentine Main Dam Station (No. 009115), which is within the mine region. This station only has rainfall data from 1963 to 2016. The next closest station (Karnet Station, no. 009111) is 4 km south of the mining region and has rainfall data from 1963 to 2020, as well as temperature and solar exposure data.

The nearest station to Holyoake mine region is Dwellingup Station (No. 009538) which is 7 km from the region, and 40 km south of Karnet Station. This site has measured rainfall, evaporation, and solar radiation data from 1935 to 2020.

Given the proximity of the three stations, this review presents data from Karnet Station as representative of both Myara North and Holyoake. Monthly statistics for the site since its inception are shown in Figure 2-1, and SILO[1] point data was extracted annual rainfall plotted in Figure 2-2.

The mean monthly maximum temperature ranges from 15.8°C in July to 30.9°C in January. Average annual evaporation (1,520 mm) typically exceeds average annual rainfall (1,153 mm), albeit rainfall exceeds evaporation during winter and shouldering months.

Western Australia's south west region has undergone a 15 to 20% reduction in rainfall since the 1970s, as illustrated in Figure 2-2 (Petrone, et al. 2010). This trend has been forecast to continue with a further 2% to 14% reduction predicted by 2030. Temperature increase and potential evapotranspiration are also forecast to increase by 0.7°C and 2 to 3%, respectively (CSIRO 2009, DoW 2015).

Rainfall in the Darling Range is also known to decline with distance inland. The 1,100 mm annual rainfall isohyet (High Rainfall Zone or HRZ) and the 900 to 1,100 mm annual rainfall isohyet (Intermediate Rainfall Zone or IRZ) have been identified in research as defining features the relevance of which is discussed in Section 3 (Hydrogeological setting) and Section 4 (Surface water)

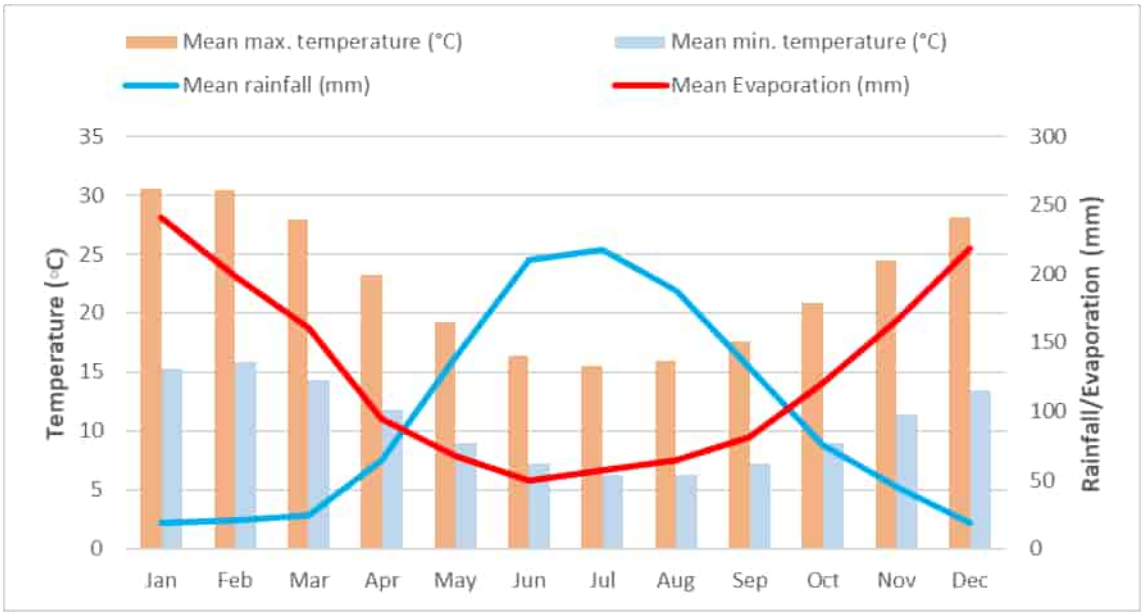


Figure 2-1 Monthly climate statistics at Karnet Station (Years 1965-2020)

[1] Rainfall, temperature, and evaporation data sourced from the SILO data downloaded from https://legacy.longpaddock.qld.gov.au/silo/ppd/ on 5 June 2020. Point data from the SILO climate database (Queensland Department of Science, 2015) provides a continuous daily climatic record for a given point with gaps infilled based on interpolation of records from nearby weather stations.

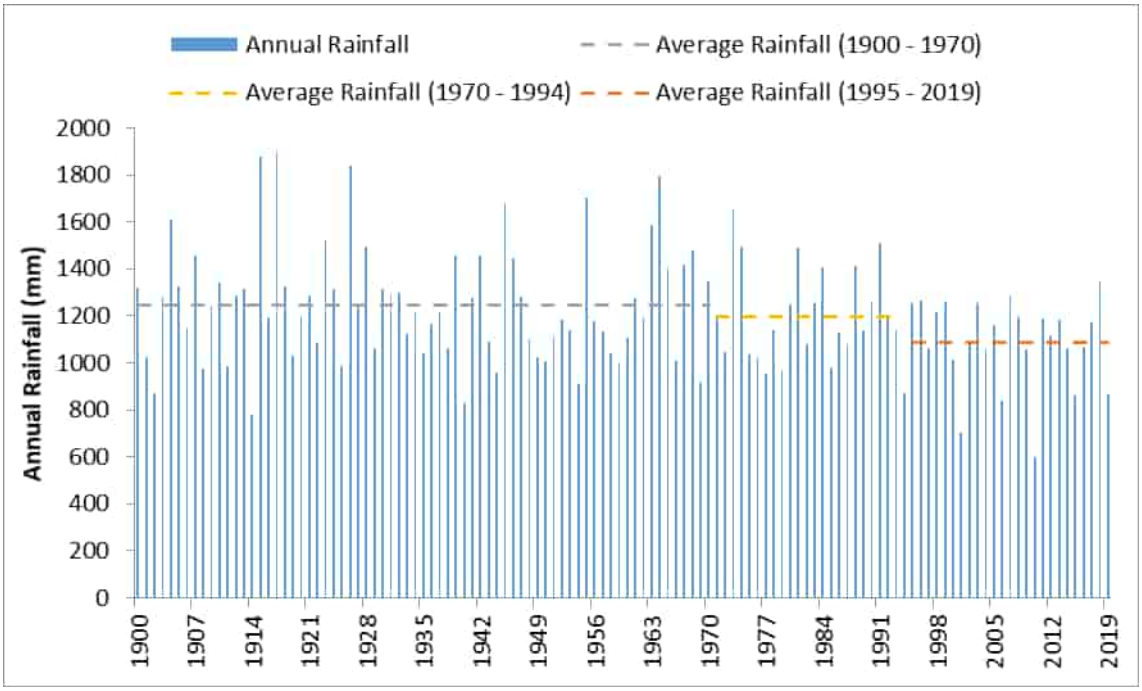


Figure 2-2 Annual rainfall at Karnet Station

2.4.2 Soils

The Huntly Mine (including Myara North and Holyoake mine regions) lies within the Darling Plateau, an undulating lateritic plateau. Soils have developed over the granitic terrain in a typical laterite profile with sand and gravelly topsoils which transition into a saprolite zone of weathering.

Soils typically comprise gravels, sands and loams including a discontinuous cemented layer or duricrust mostly in mid- to upper-slopes, merging with underlying mottled and pallid saprolite clays. Coarse gravels can be found on the upper slopes, trending to finer gravels downslope and sands near the valley floor, dominated by loams and clay loams (Churchward and Dimmock 1989).

Of hydrological significance, root channels penetrating vertically via fissures and discontinuities in the cemented layer and deep into the clay zones are a consistent feature in the lateritic profiles. These channels form preferential flow paths (bypass recharge) and are understood to form potentially large vertical fluxes into groundwater systems (A. H. Grigg 2017, McFarlane, Grigg and Daws 2017, Turner and Johnston 1987)

The ‘dry flats’ and ‘wet flats’ are broadly consistent with alluvial deposits, developed along major drainage lines and creeks which may contain finer fraction especially in their downstream sections. The ‘dry flat’ term includes both the edge of the valley floor and permanently dry’ slightly elevated part of the flat. The ‘wet flat’ is the part of the valley floor which is waterlogged during winter. The soil profile is sometimes missing along the deeply incised drainage lines or at elevated highs formed by the granite outcrops.

2.4.3 Landforms and topography

The Huntly Mine is situated within the Darling Plateau, at 240 m AHD to 370 m AHD. The area is characterised by lateritic profiles (>30 m depth), formed from the in-situ weathering of basement rock. The laterite surface is flat to undulating, dissected by streams and extending through a zone of variable thickness to weathered bedrock.

Landforms have been described by Churchwood and McArthur (1980) mapped as part of vegetation complexes of the south west forest region ((Mattiske and Havel 1998). Table 2-1 presents the landform descriptions and mapped extent over the Myara North and Holyoake mine regions and the landform distribution is presented in Figure A-5 and Figure A-6 respectively.

The landforms over Myara North mine region are predominantly “lateritic uplands interspersed by Yarragil” minor valleys with swampy floors (Table 2-1).

Table 2-1 Myara North and Huntly landforms

Landform name	Landform description	Myara North area (ha)	Holyoake area (ha)
Cooke	Hills rising above general plateau level; mainly mantled by laterite but with some rock outcrop	435	69
Dwellingup	Gently undulating landscape with duricrust on ridges; sands and gravels in shallow depressions	7582	5715
Goonaping	Shallow upland valleys with grey sands and some swamps	304	-
Murray	Deeply incised valleys with red and yellow earths on slopes; narrow alluvial terraces.	1746	64
Pindalup	Valleys of the central part of the plateau; gravelly duplex soils on slopes; some rock outcrop; grey sands, duplex yellow soils and orange earths in broad floors.	35	-
Yarragil	Valleys of the western part of the plateau; sandy gravels on the slopes; orange earths in swampy floors.	7346	4322
Total		17,449	10,170

However, on the southern boundary of the Myara North mine region, "Murray" landform occupies major valleys along the Serpentine River, while in the upper catchments the "Cooke" upland hills and rock outcrops occur as pockets along the eastern portion of the region, together with "Goonaping" sandy upland valley deposits occur in shallow depressions

The landforms over Holyoake mine region are less diverse than Myara North and comprise almost totally (99%) "Dwellingup" lateritic upland and "Yarragil" minor valley landforms (Figure A-6)

2.4.4 Regional geology

Myara North and Holyoake mine regions are within the Yilgarn Craton granite basement area. The regional geology of the area has been mapped by the Geological Society of Western Australia (GSWA) and is presented in Figure A-7.

The bedrock outcrops over less than 10% of the region, as an extensive layer of Cainozoic lateritic profile developed over the basement. A typical lateritic profile in the Darling Range is distinctly zoned. The laterite has been derived from the weathering of parent rock and consists of a ferruginous or aluminous hard cap layer which overlies a pallid, and often mottled kaolinitic zone of varied thickness (saprolite). The transition zone between the fresh basement and saprolite is referred to as saprock.

The laterite layer hosts the bauxite resources which are proposed to be mined. Development of bauxite ore has been especially pronounced along the flanks and upper slopes of ridges. In the lower lying valleys, the occurrence of bauxite is limited (eroded). The lateritic (bauxite) horizon is on average 2 to 3 m thick for granite-derived bauxite.

Younger age tholeiitic quartz dolerite dykes also intrude the Archaean basement. The dykes are generally 10 m thick although the width can vary widely. These dykes generally follow eastwest to northwest to southeast directions. Observations of outcrops along the railway cutting near Jarrahdale suggest significant differences between the profile developed over metagranites and dolerites. These are related to the dominance or preservation of quartz in the profile developed over the metagranite whereas it is almost totally absent from the profile developed over the dolerite.

2.4.5 Hydrogeology

The groundwater host rocks of the Myara North and Holyoake regions predominantly comprise the weathered and fresh Archaean crystalline rocks. In addition, more recent sediments are incised into the basement rocks, coincident with existing drainage or palaeodrainage lines.

The understanding of the generalised hydrogeology of the Myara North and Holyoake regions comprises several aquifer units:

– Shallow weathered zone aquifer: comprising lateritic caprock and shallow gravely to sandy sediments which represents seasonal aquifers of variable connectivity. Given sufficient thickness can possess significant storage, infiltration and flow capability.
– Deep weathered zone aquifer (saprolite), an aquifer of some storage potential, but limited bulk permeability (comprising clays). The clayey nature of this zone can be interspersed by macropore features developed along deep root systems which were subsequently filled with more clastic material.
– Transition zone between the fresh basement and saprolite, referred to as saprock, which typically has enhanced permeability.
– Fractured bedrock aquifer, permeability and yields are dependent on facture development and connectivity of the fractures .
– Structural features, such as faults and dolerite dykes, may have enhanced permeability along their strike.

Groundwater has been an active part of lateritisation process, particularly in development of cemented ferruginous hardcap (duricrust) often encountered on the surface. Formation of duricrust has been driven by groundwater flow and capillary action which led to precipitation of iron minerals leached from the weathered bedrock. Duricrust can also form in valley floors due to accumulation of iron brought by groundwater flow and its precipitation due to evapotranspiration or exposure to the surface (reduction of partial CO_2 pressure).

In addition to the above, where drainage lines are sufficiently developed, and have eroded the basement material, sediments, typically alluvial, have accumulated in the lower lying areas. The permeability of the sediments is variably distributed and related to lithology, depth and degree of weathering.

Groundwater levels generally mimic topography, such that groundwater level is highest in areas of highest topography and lowest in areas of lowest topography. Where groundwater levels intersect the base of the creek drainage groundwater discharges provide baseflow, following winter rains (which top up aquifer storage and elevate groundwater levels).

Substantial amount of groundwater is removed by evapotranspiration. The tree cover of the jarrah forest removes water stored and/or transmitted in unsaturated and saturated zones. Root systems of some trees reportedly go to 40 m below ground although the primary effect of evapotranspiration active predominantly within the first ten metres.

Groundwater (and surface water) derived from the Myara North mine region primarily discharges into the Serpentine Dam, but also includes several smaller catchments in the far north where the discharge is to the north towards the Wungong Dam (14 km to the north west), Gooralong Brook and a small part of the Myara North mine region drains towards the Pipehead Dam (Figure A-10).

In the Holyoake mine region, groundwater (and surface water)discharges towards the South Dandalup Dam. In the far south of the Holyoake mine region, the catchments drain to the south of the South Dandalup Dam and towards the Murray River (Figure A-11).

2.4.6 Surface water hydrology

The Myara North and Holyoake mine regions are part of the Darling Plateau, which is characterized by sharply incised drainage lines forming dense drainage networks in the western, higher rainfall zone (HRZ), with these transitioning to open, flat-floored valleys in the eastern, lower rainfall zone (IRZ) (Churchward and Dimmock, The soils and landforms of the northern jarrah forest 1989).

An overview of the major surface water catchments within the Myara North mine region is provided in Figure A-10. The Serpentine River, originates to the east of the Myara North mine region, flowing north-west along the southern boundary towards the Serpentine Dam. 39 Mile Brook is the largest tributary of the Serpentine River within the Myara North mine region, draining to the north-east of the reservoir.

Other significant tributaries of the Serpentine River include Banksia Gully and Goldmine Gully, with numerous first- and second-order tributaries. Gooralong Brook drains north, then northwest through Jarrahdale townsite, connecting with the Serpentine River downstream of the Serpentine Pipehead Dam. The northern part of Myara North mine region is drained by smaller tributaries that converge downstream as the Wungong Brook, which flow to the Wungong Brook Dam.

The South Dandalup River is the largest watercourse in the Holyoake mine region (Figure A-11), originating to the east and flowing west to the South Dandalup Dam. Along the southern boundary of the Holyoake region Swamp Oak Brook and Davis Brook drain towards the Murray River.

Some of the larger streams in the high rainfall zone (HRZ) have previously exhibited perennial flows (baseflow). However, the drying climate discussed in Section 2.4.1 has caused a significant reduction in streamflow, leading to a shift from perennial to ephemeral streams and a decline in the runoff coefficient in recent decades.

These declines have been observed as a step-change response to below-average rainfall years (Petrone, et al. 2010, Hughes, Petrone and Silberstein 2012). For the Upper Serpentine catchment, a further decline in streamflow of 24% has been forecast by 2030, compared to the historical (1997 to 2007) average streamflow (Silberstein, et al. 2012).

Groundwater storage is a key factor influencing the step-change response in streamflow, as it acts as the catchment “memory”. Where permanent groundwater levels fall below the stream bed and become ‘disconnected’ after low rainfall years, this step-change in streamflow is observed. Unless above-average annual rainfalls persist, these streams will thereafter only flow after saturation has occurred causing runoff and infiltration to occur (Kinal and Stoneman 2012, Petrone, et al. 2010)

2.4.7 Surface water bodies

The Landgate Medium Scale Topo Water Polygon dataset identifies several water bodies within and in proximity to the Myara North mine region (Figure A-10). The largest of these are the Serpentine Dam and Serpentine Pipehead Dam, both perennial reservoirs, which form part of the Water Corporations Integrated Water Supply System (IWSS) supplying drinking water to the Perth metropolitan region.

Non-perennial marshes are mapped as occurring within the mid and upper 39 Mile Brook valley floors, in the mid catchment valley floor of Goldmine Gully and in the unnamed eastern tributaries. A non-perennial swamp is also mapped in the unnamed eastern tributaries.

Downgradient of the Holyoake mine region, the largest mapped water body is the South Dandalup Dam, a perennial reservoir, and part of the Water Corporations IWSS. Other water bodies distributed primarily through the central part of the Holyoake mine region are identified as non-perennial swamps.

2.4.8 Mapped wetlands

The Myara North mine region is located at the eastern extent of the Department of Biodiversity Conservations and Attractions *Geomorphic Wetlands Swan Coastal plain dataset*. The mapping classifies wetlands present within valley floors as palusplain or floodplain flats, and headwater swamps as sump or dampland basins. The geomorphic wetland mapping classifies wetlands as conservation category where they are relatively intact.

The north-western portion of the Myara North region has some mapped geomorphic wetlands which occur within the Gooralong Brook, Serpentine Pipehead Dam and Serpentine River catchments (Figure A-10). The wetlands are, with some mapped as conservation category reflecting their lack of clearing and relatively intact nature.

Ephemeral damplands occur within the valley floors of some tributaries. The unmapped valley floors and swamps present within the Myara North and Holyoake mine regions have similar environmental values as those classified as conservation category, reflecting the lack of clearing of the wetlands except for occasional roads or access tracks.

2.4.9 Existing beneficial water use and environmental receptors

At a regional scale the existing water use and environmental receptors include:

– Drinking water supply – the Huntly Mine Operations occur within the catchment areas of public drinking (surface) water supply reservoirs.
– Potential groundwater dependent ecosystems - terrestrial ecosystems that rely on the subsurface presence of groundwater. These include riparian and phreatophytic terrestrial vegetation (which access groundwater at less than 10 m), which has a seasonal or occasional dependence on groundwater.

– Aquatic ecosystems that rely on surface or near surface expression of groundwater. This includes the surface watercourses that receive groundwater flow, groundwater fed springs and swamps within the study area and their respective biological and environmental values.

The beneficial water uses for Myara North and Holyoake mine regions are described in more detail below.

Public drinking water supply reservoirs

The Myara North and Holyoake mine regions intersect the catchment areas of public drinking water supply reservoirs, including:

– Serpentine Dam and Serpentine Pipehead Dam (Myara North)
– Wungong Brook Dam (Myara North)
– South Dandalup Dam (Holyoake).

The reservoirs form part of the Water Corporation's Integrated Water Supply System (IWSS) supplying drinking water to the Perth metropolitan region and are managed in accordance with their respective Drinking Water Source Protection Plan. The Serpentine Dam is also used for storage of groundwater and desalination sources from the IWSS.

Potential groundwater dependent ecosystems

In parts of the jarrah forest, riparian vegetation is considered to be a potential GDE, particularly where groundwater contributes to baseflow or where the groundwater level is within 10 m of the natural ground surface.

At a regional scale, vegetation types across the Northern Jarrah Forests are mapped based using key indicator species and site conditions. Potential regional-scale groundwater dependent ecosystems are associated with the following vegetation complexes that contain indicator vegetation species:

– Swamp complex
– Stream zones of the Yarragil and Murray complexes
– Swamp areas in the Yarragil 2 complex.

Potential groundwater dependent ecosystems were delineated from detailed flora and vegetation assessment of the Myara North and Holyoake mine regions by Mattiske (2021a). The potential GDEs are presented in Figure A-8 and Figure A-9 for Myara North and Holyoake mine regions respectively.

Aquatic fauna values

Limited historic aquatic fauna surveys were completed for parts of the Myara North mine region as part of the Wungong Catchment Trial (WRM 2013). Aquatic fauna values from these surveys as well as surveys of other catchments across wider Northern Jarrah Forests region were used to inform a desktop assessment of the aquatic fauna values of the Myara North and Holyoake mine regions (WRM 2020)

The Myara North and Holyoake mining regions are expected to support similar diversity of aquatic habitats, which are likely to be dominated by first-order seasonal creeklines and ephemeral headwater swamps/damplands (Inflow Dependent Ecosystems) with aquatic fauna communities expected to be characterised by a high degree of seasonality and high level of species endemicity.

(WRM 2020) identified that in higher rainfall years, baseflow in higher-order streams may maintain isolated pool refuges over summer.

Other known aquatic fauna values of the Myara North mine region include seasonal habitat for fish, crayfish and stygal amphipods. The Serpentine River, along the southern boundary of the Myara North mine region supports populations of EPBC Act listed (Carter's freshwater mussel *Westralunio carteri*) and protected (Minute freshwater snail *Glacidorbis occidentalis*) species.

3. Myara North hydrological setting

3.1 Introduction

This section (and Section 4) presents the understanding of the hydrogeological setting based on the following sources, which are refenced throughout text:

– Published and publicly available information (e.g., GSWA)
– Reports and published studies/literature provided by Alcoa, as presented in Appendix H
– Alcoa's groundwater database (groundwater levels and salinity information, filtered for bore locations within 5 km of the original Project envelopes: in total 360 monitoring bores for Myara North and 76 for Holyoake)
– Groundwater drilling, installation and testing and monitoring of bores (GHD 2020)
– Surface and groundwater baseline monitoring report (GHD 2021(a))

3.2 Geological units

In addition to general geological information on the Darling Range, understanding of key hydrostratigraphic units was supported by installation and hydraulic testing (slug tests) of groundwater monitoring wells by GHD at both Myara North and Holyoake mine regions. Detailed geological logs are presented in (GHD 2020) and are not produced herein.

Most Alcoa monitoring bores are located in topographically elevated areas (between 250 and 350 m AHD), and specifically in previously active research areas east of the 1,100 m isohyet in the IRZ. A comparatively smaller number of monitoring bores are located within the low-lying areas, below 250 m AHD (less than 10%) and creek lines, and west of the 1,100 isohyet.

GHD installed 18 groundwater monitoring wells at Myara North in 2020 (GHD 2020). A summary of details of the monitoring bores are presented in (Table 3-2). A review of the geological logs indicates a broadly consistent lithology profile that was identified across Myara North with a typical weathering profile as follows:

– **Lateritic/ duricrust/surficial sediments:** 1 to 4.5 m thick, comprising minor soils, loams sands pisolite and cemented duricrust or laterites. Lateritic caprock is hard to very hard and often strongly cemented with pisolitic nodules.
– **Saprolite**: highly variable depths from 1 to 29 m thickness, comprising clays derived from weathered basement. Generally, saprolite clays are mottled or pallid towards the top becoming darker with depth reflecting the weathered bedrock lithology.
– **Weathered zone:** weathered basement zone is characterised by decreasing clay content, an increasing brittle rock texture/relict features (saprock) which grades sharply into basement rocks, with a thickness of less than 2 to 4 m. Groundwater flows occur in this zone and is often pressurised.
– **Crystalline basement**: depth to basement varies from 6 to 28.5 mBGL. Basement rocks are dominantly granitoids with intrusions of dolerite.

3.3 Hydrogeological units

Shallow aquifer/interflow

Where surficial sediments are present (excluding areas of basement outcrop) sufficient rainfall inputs potentially saturate these relatively permeable surficial materials (laterite/pisolitic/sands/loams).

Any excess water perched in the sediments above the less permeable underlying saprolite clay, is subject to short-term flows in the direction of the topographical slope towards drainage lines, in addition to a component of downwards seepage through the saprolite clay into the underlying regional aquifer.

Churchward and Dimmock (1989) presented a generalised soil profile of the northern jarrah forest, in which a schematic and description indicated a shallow soil profile (e.g.: 1 to 3 metres thick), which transmits shallow subsurface water flows. The generalised surficial profile comprises:

– **Topographically elevated areas**: lateric duricrust (which may be vuggy and permeable)
– **Middle slope:** sandy gravels/pisolitic (moderate permeability)
– **Lower slope/valley:** sands grading into loamy deposits (medium to low permeability):

The continuity/permeability of the surficial sediments and capacity to transmit infiltrated rainfall is not well understood in the Myara North area, however a broad distinctionis based on mapped soil/vegiation types (Figure A-5).

Due to the inferred large heterogeneity and likely discontinuity of the surficial sediments and weathering zone materials, the interflow may often not form continuous shallow perched aquifer. As a consequence, these shallow flows are conceptualised as a temporary patchwork of locally occurring flows, largely non-contiguous, but activated by winter rainfalls and able to support – in short-term – discharge to drainage lines/streamflows.

Conceptually, this interflow component is also likely to merge with baseflow in the slopes surrounding the drainage lines, where these drainage lines intersect the regional water table.

Deeper aquifer units

The understanding of deeper aquifer units is based on the drilling by GHD, which identified the presence of a saprolitic clay profile (underling the surficial sediments)– deemed as having a low permeability. Groundwater yields during drilling were identified at the transitional zone and interface between the saprolitic clays and the basement.

The monitoring bore slotted intervals were set based on the observations related to water strikes, and the hydraulic testing of the aquifer zone based on slug testing methodology (GHD 2021(a)) are summarised and presented in Figure 3-1.

3.4 Hydraulic properties

GHD conducted slug testing on the installed monitoring bores, to obtain field estimates of hydraulic conductivity in the Myara North and Holyoake mine regions. Based on this testing, Figure 3-1 indicates an average hydraulic conductivity of close to 0.6 m/day for the transition zone, within a range of <0.05 to 1.2 m/day (saprolite clays which overlie the transition zone are inferred to have low hydraulic conductivities at less than 0.001 m/day, saprolite clays were not hydraulically tested).

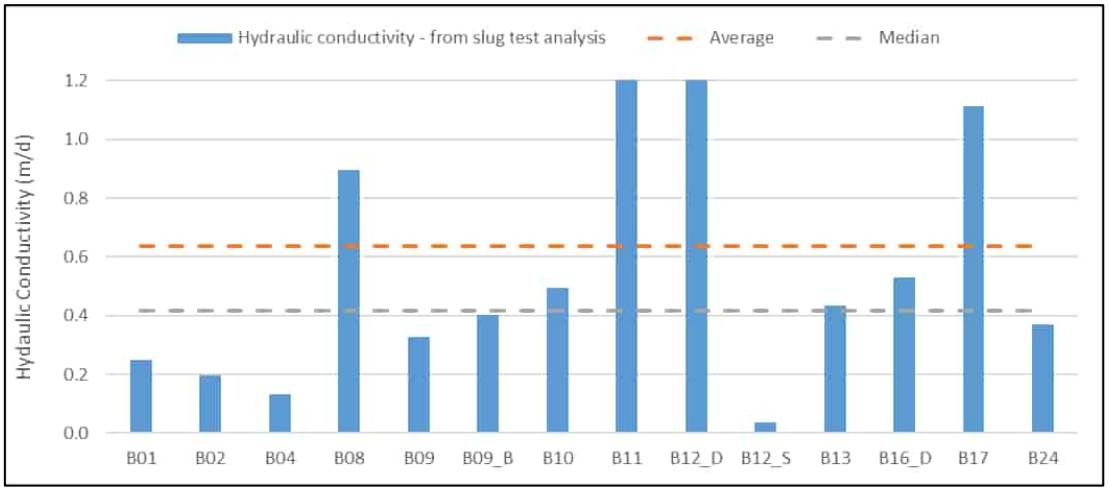


Figure 3-1 Myara North hydraulic conductivity results (from slug tests)

In absence of aquifer testing data (other than slug testing) from the Myara North mine region a reference is also made to a regional summary of predominantly hydraulic conductivity data presented in Raper and Croton (1996). This work is an internal report for Alcoa “on the hydraulic properties of Darling Range soils” and was initiated to provide parameter values for initial modelling studies.

The summary provides the following estimates of hydraulic conductivity (K):

- Upper slopes: 0.06 to 10 m/d, with representative values approximately 0.5 m/d. The gravelly sands vary between 3 to 20 m/d with average of 6.8 m/d
- Mid-slopes tend to have less permeable soil cover of less than 0.2 m/d.
- The valley floors have “heavier” soils between 001 to 1.6 m/d.
- Duricrust is described as not highly permeable but with vertical holes of higher permeability. They are described as constituting 15 % of the horizontal area of the layer. The friable zone below the duricrust have typically K = 0.2 to 1 m/d, with occasional presence of low permeability clays.
- Saprolite (mottled and pallid zones), because of its high clay content is less permeable with a representative value of 0.01 m/d.
- The weathering zone between the fresh crystalline basement and saprolite has representative hydraulic conductivity of 0.225 m/d (similar to slug testing results)
- Hydraulic conductivity (horizontal) of the deep aquifer “may be highly variable on the local scale but appears to be uniform at the regional scale” (Raper & Croton, 1996). Pumping tests conducted in the Darling Range (five tests in total but not in the Myara North mine region) indicate geometric mean of hydraulic conductivity of 0.59 m/d (0.17 to 1.6 m/d). The average vertical hydraulic averages between 0.1 and 0.22 m/d.

The average storativity reported by Raper and Croton (1996) is 0.013, with a range of values between 0.0037 to 0.1.

3.5 Groundwater levels and flow

The location of the monitoring bores for Myara North is presented in Figure A-8 (Appendix A), and the hydrographs from the monitoring bores are presented in Appendix B (including salinity data/graphs).

The average depth to groundwater (averaged over the full length of the record) for Myara North monitoring bores is presented on Figure A-14. The topographical elevation against groundwater levels (m AHD) is presented in Figure 3-2.

The Figure A-14 and Figure 3-2indicate groundwater levels reflect topography. In the elevated areas on hills and ridges, the depth to water is typically 15 to 30 meters below ground level; while in the valley floors (where GDEs are present) and in the creek lines, the depth the groundwater from the available monitoring wells is typically less than 3 to 5 meters (Figure A-14). Depth to groundwater may be shallower within the drainage lines, in areas downgradient of the monitoring bores and areas towards the Serpentine Dam.

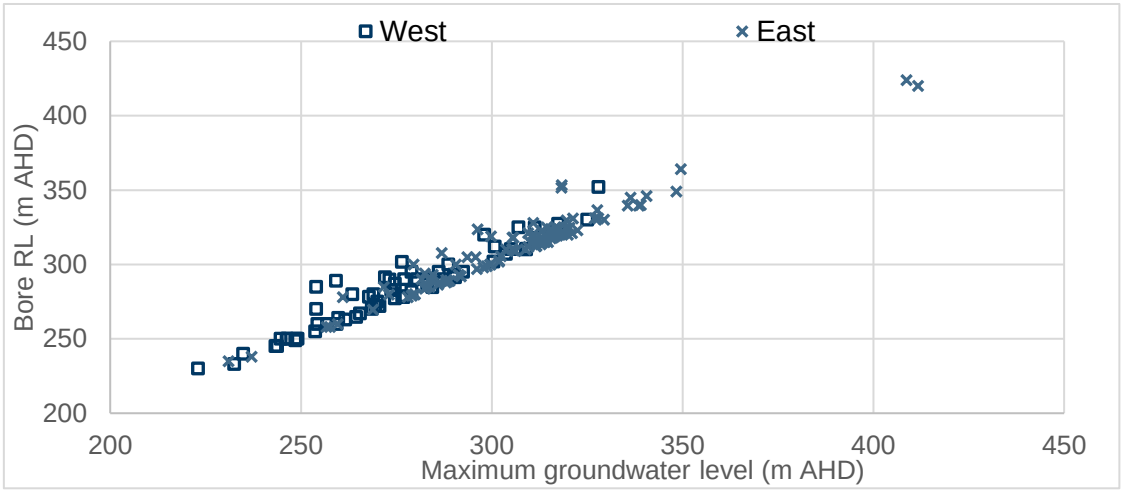


Figure 3-2 Comparison of measured maximum groundwater levels and ground elevation (Myara North monitoring bores)

The relationship between ground elevations and groundwater levels is typical of the topographically driven groundwater flow system (Toth 2009). Regional groundwater flows towards the valley floors and creek lines, where discharge of groundwater is inferred to occur through evapotranspiration in the riparian zones and/or discharge as surface water flow.

Long-term groundwater level trends and observations

From the monitoring data presented in Appendix B a selected subset of monitoring data was chosen where the subset satisfies the following conditions:

– long-term groundwater water levels (two to three decades) are available
– groundwater levels which have recently acquired data (e.g.: 2020/2021)
– salinity data which exhibits historic and recently acquired data.

The remaining monitoring bore data (Appendix B) which do not satisfy the conditions above were of limited value to adequately assess long-term trends up to and including 2021, given that much of the data was short-term and/or was limited to older decades (including 1980s, 1990s, and to a lesser extent 2000s).

The selected subset of time series data for groundwater levels, salinity and cumulative rainfall departures (CRD) is presented graphically for the Myara North monitoring bores, in Appendix C,

The graphical data has also been assessed and the results summarised and in Table 3-1, which shows estimated average trend values, based on observations/estimates (e.g.: enveloping surface).

The selected monitoring well graphs (Appendix C) and the summary table (Table 3-1) present the following features and long-term trends:

– Most bores show a strong seasonal variation in groundwater levels, typically varying over an annual cycle by between 1 to 5 metres (Appendix C) in response to natural recharge events**.** They confirm that recharge occurs during every winter season.
– Monitoring bores typically show declining groundwater levels since 1990s. They reflect the changing rainfall patterns as shown in the cumulative rainfall departures, which also appear to be declining since 1990s Appendix C). The summary data presented in (Table 3-1) indicates that all but one monitoring bore shows declining groundwater levels of between 1 to 10 meters since the 1990s, with an average decline of close to 4.5 m (since the 1990s), i.e. on average about 1.5 m per decade.
– Monitoring bores outside of the Myara North mine region (to the south) where mining occurred show increases in water levels in response to clearing and mining. Bore MK42132A, for example, recorded a water level increase of approximately 14 m after 2017. While part of this would be related to seasonal variations, the large component of the increase is associated with clearing. Based on available pre-2020 data. Following mining the water level receded but not completely to pre-clearing levels.

Table 3-1 Myara North - summary of groundwater level trends and salinity (summary of Appendix C information)

Monitoring well ID	Groundwater levels			Groundwater salinity		
	1990 SWL (mBGL) [1]	2020 SWL (mBGL) [1]	Change SWL (m)	1990 TDS (mg/l) [1]	2020 TDS (mg/L) [1]	Change TDS (mg/L)
MJ38033A	3	4	-1	500	800	300
MJ38034A	6	10	-4	400	200	-200
MJ39222A	4	10	-6	200	400	200
MJ40121A	2	6	-4	2000	500	-1500
MJ41081A	7	5.5	1.5	ND	ND	ND
MK382511A	3	3	0	1500	500	-1000
MK39171A	1	2	-1	200	200	0
MK39181A	4	8	-4	400	400	0
MK39191A	2	10	-8	400	500	100
MK40102A	5	15	-10	ND	ND	ND
MK40111A	4	8	-4	300	300	0
MK40181A	2	10	-8	250	300	50

Monitoring well ID	Groundwater levels			Groundwater salinity		
	1990 SWL (mBGL) [1]	2020 SWL (mBGL) [1]	Change SWL (m)	1990 TDS (mg/l) [1]	2020 TDS (mg/L) [1]	Change TDS (mg/L)
MK40182A	5	15	-10	100	250	150
MK40191A	2	8	-6	400	500	100
MK40251A	10	14	-4	NA	NA	NA
MK40252A	15	25	-10	NA	NA	NA
MK40261A	3	5	-2	150	100	-50
MK41041A	2	5	-3	200	200	0
MK41061A	10	15	-5	1550	1590	0
ML40092A	3	4	-1	400	300	-100
ML40093A	2	4	-2	300	300	0
ML40131A	4	6	-2	250	300	50
ML40271A	20	25	-5	NA	NA	NA
ML41011A	10	20	-10	NA	NA	NA

Notes: [1]: average values estimated from graphs observations (semi-quantitative); ND: not applicable, no data or unreliable data

New monitoring sites – short-term groundwater level observations

The locations of new groundwater monitoring bores, labelled with prefix “B” installed at 16 locations in central and western areas of the Myara North mine region are presented in Figure A-8. The monitoring bore installation summary details are presented in Table 3-2 (geological logs presented in GHD 2020). The hydrographs and salinity data are presented in Appendix D.

The hydrographs indicate some seasonal declines in groundwater levels coinciding with summer periods, averaging close to two meters.

Of the 16 monitoring wells, a total of two sites BH16 and BH12 were installed with shallow and deep monitoring bores. Continuous groundwater levels data collected from BH12S and BH12D is presented in Figure 3-3 (no data logger data for BH16S and BH16D).

The logger data indicates the following:

– The groundwater levels reduce by 3.5 m over the four months of monitoring in both the deep (screened at 18.5 m to 24.5 m below ground level) and shallow (screened at 0.5 to 3.5 m below ground level) monitoring bores (indicative of upward hydraulic head), highlighting the recession of groundwater levels between the end of the winter 2020 and the summer 2021.
– Shallow and deep monitoring bores show a similar response to rainfall events, and together with the similarly receding levels support the conclusion that the shallow and deep parts of the aquifer are hydraulically connected.

The groundwater level logger data for BH12S and BH12D is an example of the regional groundwater supporting the potential GDEs (potential GDE locations are presented in Figure A-8).

In contrast at B16S and B16D locations, the adjacent mapped potential GDE is not considered to be supported by the regional groundwater, given that the hydrographs, presented in Figure 3-4, indicate an upper perched unit (2 to 5 meters of hydraulic potential) of ephemeral very fresh water (85 mg/L TDS) which dissipates approaching summer.

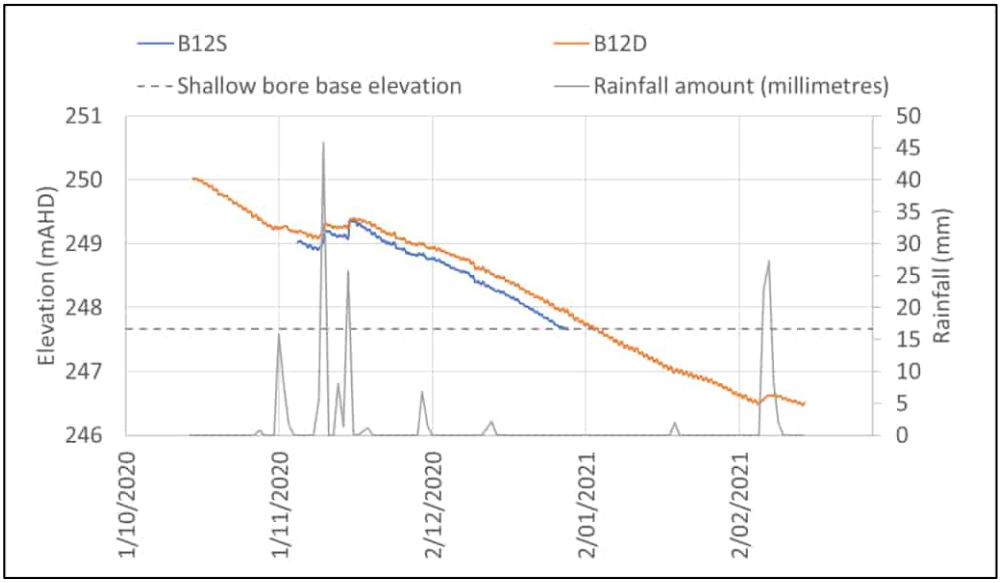


Figure 3-3 B12S and B12D groundwater levels (logger data) and rainfall

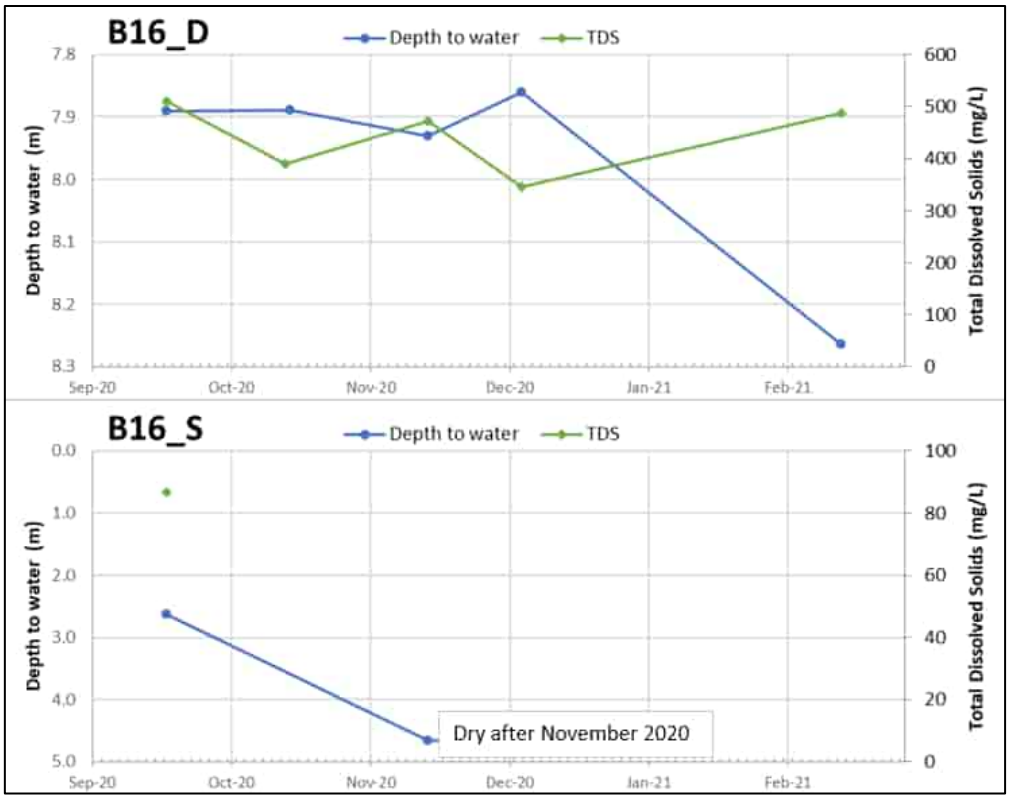


Figure 3-4 B16S and B16D groundwater levels and salinity data

Table 3-2 Myara North 2020 installed monitoring well installation details

Location	MGA GDA94		Total depth (mBGL)	Screen top (mBGL)	Screen bottom (mBGL)	Static water level (mbtoc)[1]
	Easting	Northing				
B01	424,054	6,390,718	7.7	4.4	7.7	4.38
B02	424,192	6,388,696	28.5	22.5	28.5	15.92
B03	426,806	6,387,108	23.9	17.9	23.9	24.23
B04	424,015	6,386,978	36	29.2	35.2	22.54
B07	428,234	6,386,651	8	5	8	4.95
B08	425,573	6,384,809	13.1	7.1	13.1	4.10
B09	424,805	6,383,732	3.2	0.7	3.2	3.10
B09_B	422,941	6,381,445	8.9	5.9	8.9	7.84
B10	429,106	6,381,269	21.5	15.2	21.2	10.79
B11	426,113	6,381,245	14.1	11	14.0	7.35
B12_D	419,714	6,379,933	24.5	18.5	24.5	1.73
B12_S	424,142	6,379,814	3.5	0.5	3.5	1.86
B13	426,917	6,377,918	18.5	9.4	18.4	1.94
B16_D	419,640	6,377,768	17.5	11.5	17.5	7.88
B16_S	420,847	6,376,506	4	1	4	DRY
B17	422,958	6,375,535	10.7	4.7	10.7	7.07
B18	422,522	6,372,129	8.2	1.8	7.8	7.85
B24	424,054	6,390,718	24.9	12.3	24.3	2.92

Note [1] – water level measurements taken during water quality sampling (16/10/2020)

3.6 Groundwater salinity

Long-term TDS trends and observations

The salinity data for the total number of Myara North monitoring bores is presented graphically in Appendix B and the location of the monitoring bores is presented in Figure A-8 (Appendix A).

From the 360 locations of monitoring bores, a total of 24 monitoring bores have sufficient timeseries data with which to review salinity trends over three decades (1990 to 2020). The salinity data for these 25 monitoring wells is presented graphically (together with hydrographs) in Appendix C.

The salinity temporal trends, which has been approximated from the graphs (in Appendix C), have also been summarised and presented in Table 3-1 (where sufficient data is available).

The salinity data (Appendix C and Table 3-1) indicate the following:

– A total of 6 monitoring bores show stable salinity, 4 have decreasing trend, while 8 bores show an increasing salinity.
– The average change in salinity is a decrease of 100 mg/L over the 3 decades of monitoring (1990 to 2020), although the data possess a high standard deviation (400 mg/L, indicating ahigh variability).

Spatial trends in TDS

The average salinity data for all available monitoring bores (Alcoa and GHD bores) within Myara North mine region, has been presented statistically as box and whisker plots in Figure 3-5. To indicate potential east-west spatial trends, the average salinity data has been additionally divided and grouped into 5 km north-south orientated windows (Figure 3-5)

Salinity increases from 200 mg/L evident in the western parts of the Myara North mine region, to 400 mg/L in the eastern parts of the area. The range of salinity (see percentiles) also increases eastwards. This salinity data trend (increasing eastwards) is consistent with the reducing rainfall and increasing evaporation associated with the eastern areas.

The average monitoring bore salinity data has also been presented and plotted based on the bore locations in Figure A-15.

Most of the monitoring bores show a TDS generally less than 300 mg/L, with a generalised increased salinity, exhibiting isolated occurrences, within the south-eastern catchments (consistent with the reduced rainfall associated with the eastern areas).

The isolated occurrences suggests that the increased salinities at these locations are not reflective of the regional catchment conditions, but indicative of local-scale variability which may also reflect the monitoring bore integrity and potentially ingress of shallow evaporative waters into the deeper slotted intervals (no monitoring bore completion details logs for Alcoa bores).

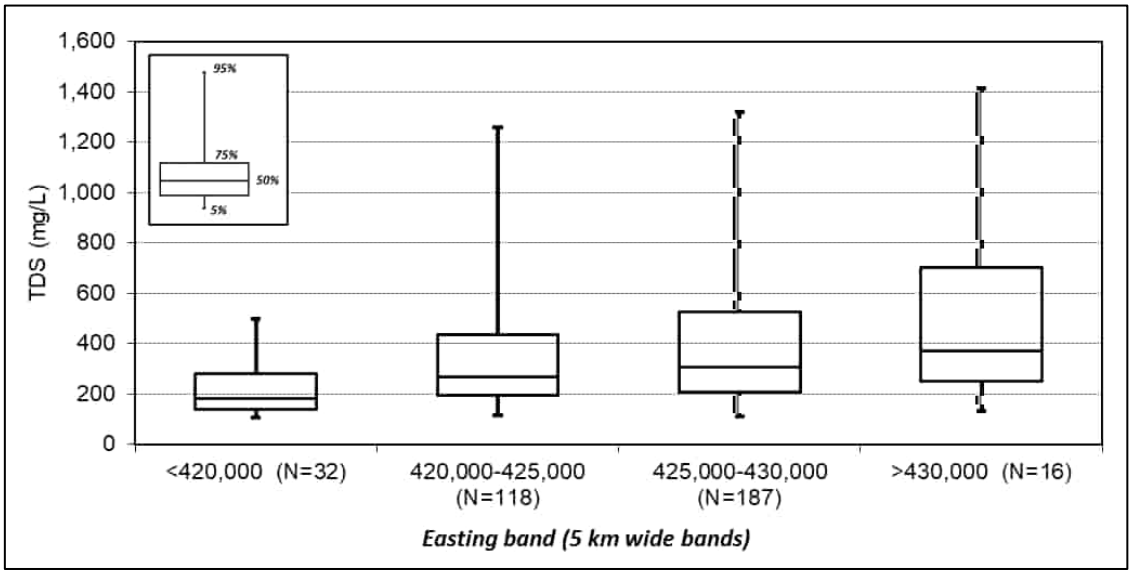


Figure 3-5 Groundwater salinity box and whisker plot (grouped by bore's Easting)

3.7 Recharge and discharge

Groundwater recharge and discharge are important processes for both groundwater and surface flows, including streamflows. Recharge is not possible to measure directly, however several techniques have been in use to estimate recharge rates at catchment scale. Recharge is also a parameter highly susceptible to climate change – and to mining impacts that involve landscape changes such as vegetation clearing.

Groundwater recharge and discharge are influenced by two distinct processes (Leaney 2011):

– The natural propensity of the land to recharge or discharge in accordance with its inherent geological and geomorphic character (i.e. the groundwater flow system and the unsaturated zone)
– The water balance of the land given dynamic interactions between climate and vegetation (which varies in space and time)

Land use and climate often varies seasonally but also at longer scales including over several decades. The land use and climate-related changes, also at multi-decadal scale, in the Darling Range with respect to water resources have been subject of several studies for example in Del Park (Grigg and Hughes 2018), an area adjacent to the South Dandalup Dam.

Recharge rates are driven by the ability of the portion of rainfall reaching the watertable after the rainfall event and contribute to groundwater flow. Soil and regolith physical properties and texture, in particular their permeability and thickness and the counteracting effects of evaporation and transpiration are the principal components determining the recharge rate.

Recharge in the context of the Darling Range geology is likely to be affected:

– Shallow soil composition, presence of laterite duricrust and their spatial continuity
– Presence of relatively thick saprolite which is relatively clayey with low permeability but is known to be interspersed by root system which provide preferential path for deep drainage
– Basement outcrops (i.e. missing saprolite and laterite weathering)
– Depth to watertable (assumed to be large in elevated areas and small in valley floors and drainage lines)
– Presence and density of transpiring vegetation
– Presence of surface flows
– Climate changes, specifically rainfall volumes, frequency and duration

Due to the variability of these factors the recharge rates are intuitively spatially and temporarily widely variable. They vary from season to season up to multi-decadal scale. A detailed attribution and specification of recharge rates that takes into account their relative contribution and interaction requires a spatially distributed framework and parameterisation. There are a number of models developed for the purpose of disaggregation of rainfall into its terrestrial flow components, both surface and subsurface.

An example of such an approach is the work of Rassam and Littleboy (Identifying the Lateral Components of Drainage Flux in Hill Slopes 2003), which partitions excess soil water into lateral and vertical pathways, based on HYDRUS-2D modelling of the duplex soil system where a coarse layer overlies a fine layer. It is therefore suited to the Myara North region in which relatively coarser soils (sands, sandy loams) overlie a clayey saprolite profile. Another advantage is that this conceptualisation and implementation removes the limitation of other one-dimensional models which tend to overpredict vertical deep drainage (recharge). This approach is proposed for the numerical modelling implementation.

Simple approaches of estimating include chloride mass balance (CMB) method (e.g. Leaney et al, 2011); or estimation of recharge from a runoff event using the recession part of the streamflow measurements based on Rutledge and Daniel (Rutledge and CC 1994).

The CMB method uses groundwater chloride concentrations and chloride atmospheric deposition and based on several assumption based on chloride conservatism and rainfall being the only source of chloride (i.e. not geologically based sources). In upland areas such as the Darling Range there may be a requirement to account for chloride exported by runoff (or perhaps shallow surface flow such as interflow. Experience from other sites however indicates that the uncertainty associated with runoff considerations will be small compared to the uncertainty in chloride deposition.

For the purposes of this assessment groundwater chloride values from upland areas (Cooke and Dwellingup landforms) were used to avoid possible bias from chloride evapoconcentration in the riparian and valley floor zones. Chloride concentrations were estimated from more widely available electrical conductivity (EC) values since there is strong correlation between chloride and EC (producing Cl values between 82 and 109 mg/L).

Chloride deposition values were taken from the national dataset which mapped the chloride deposition (both wet and dry) by fitting to a model relating the chloride deposition to the distance from the coast in Davies and Crosbie (Davies 2014). Based on that mapping the chloride deposition rate in the Myara North mine region varies between 56 kg/h/yr to 42 kg/ha/yr, decreasing from the western to eastern boundary of the development envelope. The recharge rate estimates based on these deposition rates are 45 to 61 mm/yr.

3.8 Surface watercourses

The Myara North mine region comprises three dominant catchment areas:

– Most of the Myara North mine region (129 km^2 or 74%) lies within the Serpentine Dam catchment area, including the main tributaries 39 Mile Brook, Banksia Gully and Goldmine Gully. The Serpentine River runs adjacent the southern boundary of the Myara North area. Linear hydrographic mapping of the Myara North mine region identifies a further eight (8) tributaries that are second order streams and above, and a further twelve (12) first order tributaries that discharge directly into the Serpentine River and Serpentine Dam.
– The north-western portion of Myara North mine region (25 km^2, 14%) is drained by Gooralong Brook which joins the Serpentine River downstream of the Serpentine Pipehead Dam.

– The northern portion of Myara North mine region (21 km^2, 12%) includes the Chandler Road sub-catchment and Cobiac sub-catchments which flows in a north and north-westerly direction, converging as the Wungong River and flowing towards the Wungong Reservoir.

There are several flow gauging sites relevant to the Myara North mine region, details of which are summarised in Table 3-3 and illustrated in Figure A-10.

There are large areas of the proposed mining catchment for which no flow gauging data is available. Additional gauging stations will be installed as part of the mine expansion.

Table 3-3 Gauging stations relevant to Myara North

Site ID	Site name	Flow record	Catchment area (km^2)	Average annual flow (ML/yr)
Serpentine Catchment				
614035	River Road	1982 to 1998 2008 to 2019	243	5,572
614031	Jack Rocks	1981 to 1998 2006 to 2016	55	3,660
Wungong Brook Catchment				
616041	Wungong Brook – Vardi Rd	1981 to 2020	81	7,368
616124	Wungong Brook – Chandler Rd	2005 to 2014	18	1,208
616058	Wungong Brook – Cobiac Rd	1992 to 2016	4	202

3.9 Surface water flow data

Long-term trends in annual flow

The 614035 River Road (Serpentine River) upstream of the Myara North mine region and 614031 Jack Rocks (39 Mile Brook) gauging stations provide a robust annual flow dataset from the early 1980s to 1998, and again from the mid to late 2000s through to late 2010s (Figure 3-6). Site 616041 Vardi Road (Wungong Brook) has a near continuous flow dataset from 1981 to present (Figure 3-7).

The step change in rainfall discussed in Section 2.4.1 is reflected in observed step changes in streamflow, whereby annual average streamflows after 2000 were significantly lower than the preceding period (Figure 3-6, Figure 3-7).

Long-term trends in flow seasonality

The long-term flow data available for the River Road (Serpentine River) and Jack Rocks (39 Mile Brook) gauging stations was used to generate box and whisker plots presented below as

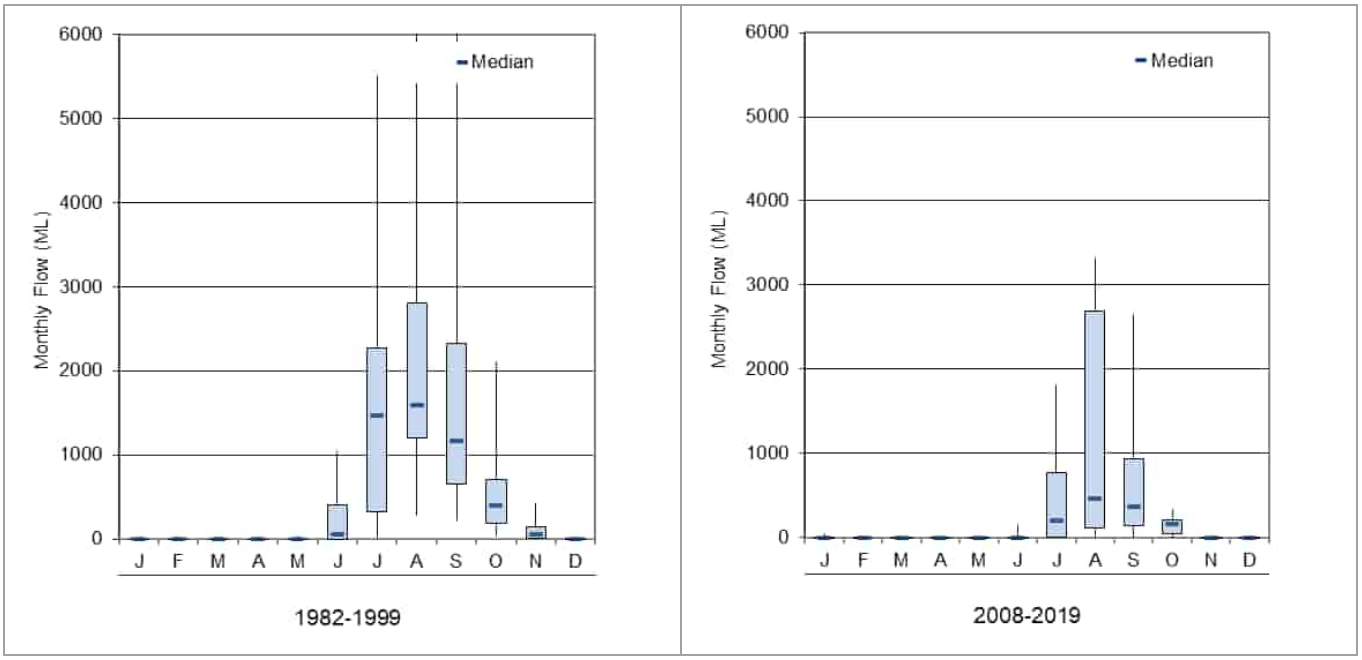


Figure 3-8 and Figure 3-9 respectively. The plots group the monthly flow data by the observed step changes in annual streamflow (pre 2000, post 2000).

The post 2000 flow data (

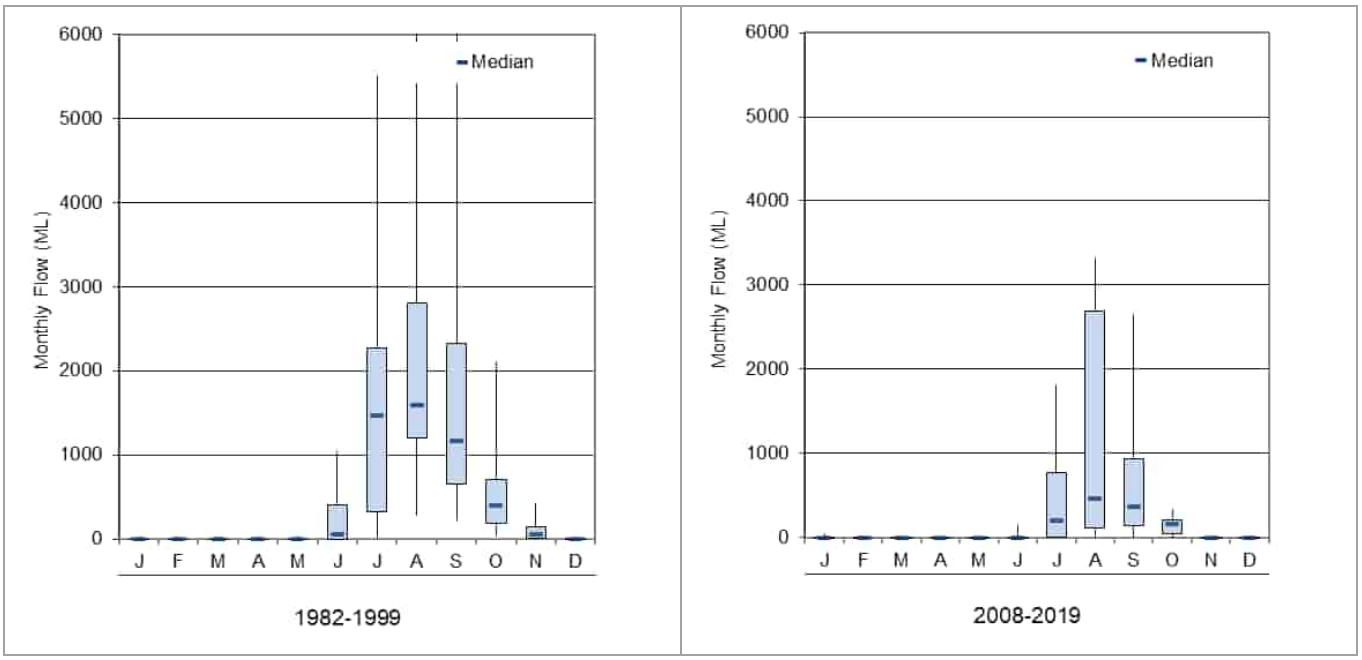


Figure 3-8 and Figure 3-9) show a delay in flow commencement and typically earlier cease to flow, in comparison to the pre 2000 flow data.

Short-term trends in surface water flows

During the 2020 baseline monitoring period flow conditions at surface water sampling locations were recorded during monthly surface water sampling events (GHD 2021(a)). Surface water level loggers were installed late September at six Myara North surface water monitoring locations, five at the downstream extent of representative catchments prior to discharge to the Serpentine River or Serpentine Dam, and one in the Serpentine River downstream of the conveyor crossing.

The observed surface water flow conditions during surface water monitoring events identifies that surface water flow was present in August preceding logger installation at one site (site 6141125, downstream end of Goldmine Gully).

Some logger installation sites that were dry in August prior to logger installation had upstream locations with flowing surface water, including 6141121 at downstream end of Banksia Gully (upstream site SN01 had flowing water present) and SW03 at downstream end of 39 Mile Brook (upstream sites TN14/614031 and TN34 had flowing water present).

The short water level logger record for selected monitoring location is presented in Figure 3-10. The water level logger record identifies varying water level response for the selected Myara North sites. Flows in the minor unnamed tributary (SW04) are rapid and flashy. Flows at other locations are more sustained with a general decline towards cease to flow ranging from early October in Banksia Gully (6141121) and late October in 39 Mile Brook (SW03).

Surface water was present at site SW05 (minor tributary to Serpentine Pipehead Dam) on all monitoring occasions between August 2020 and January 2021. Upwelling of water observed during the January 2021 sampling event inferred the presence of a local groundwater source.

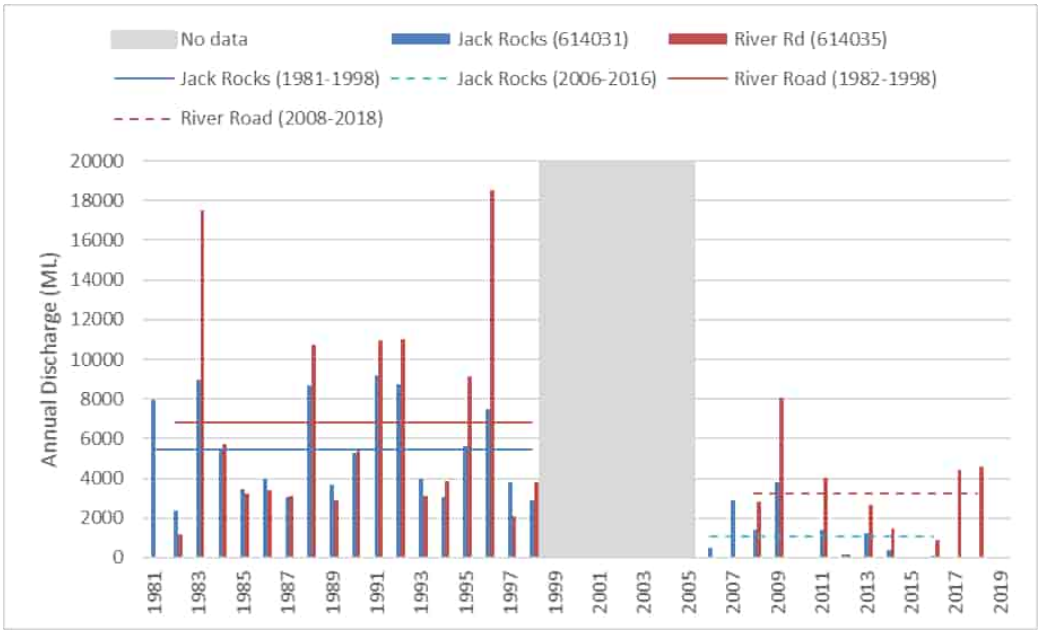


Figure 3-6 Annual flows at relevant Serpentine catchment gauging stations

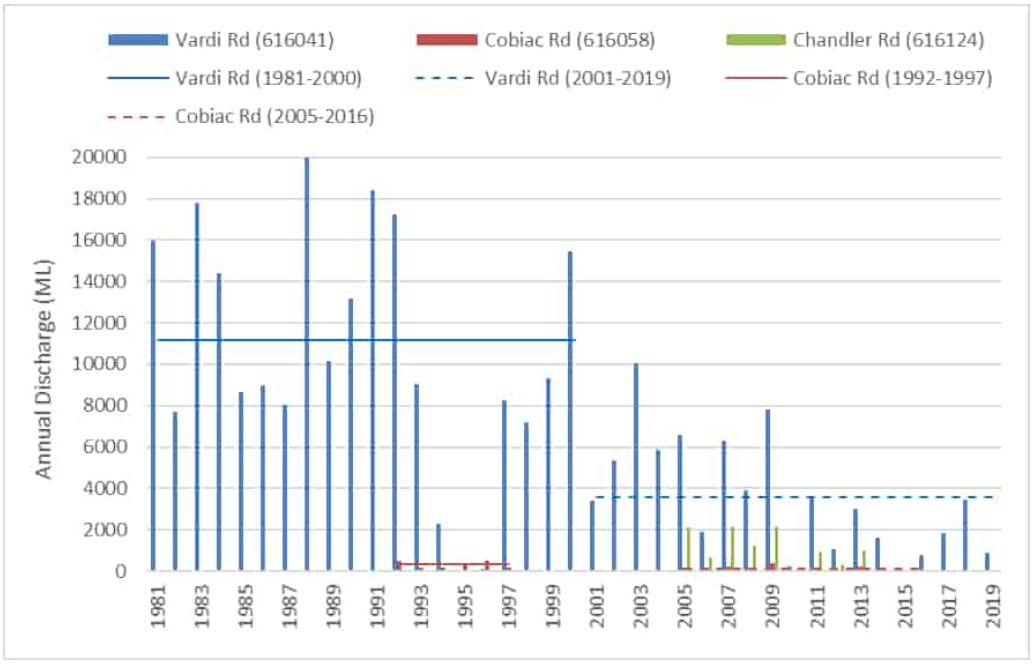


Figure 3-7 Annual flows at relevant Wungong catchment gauging stations

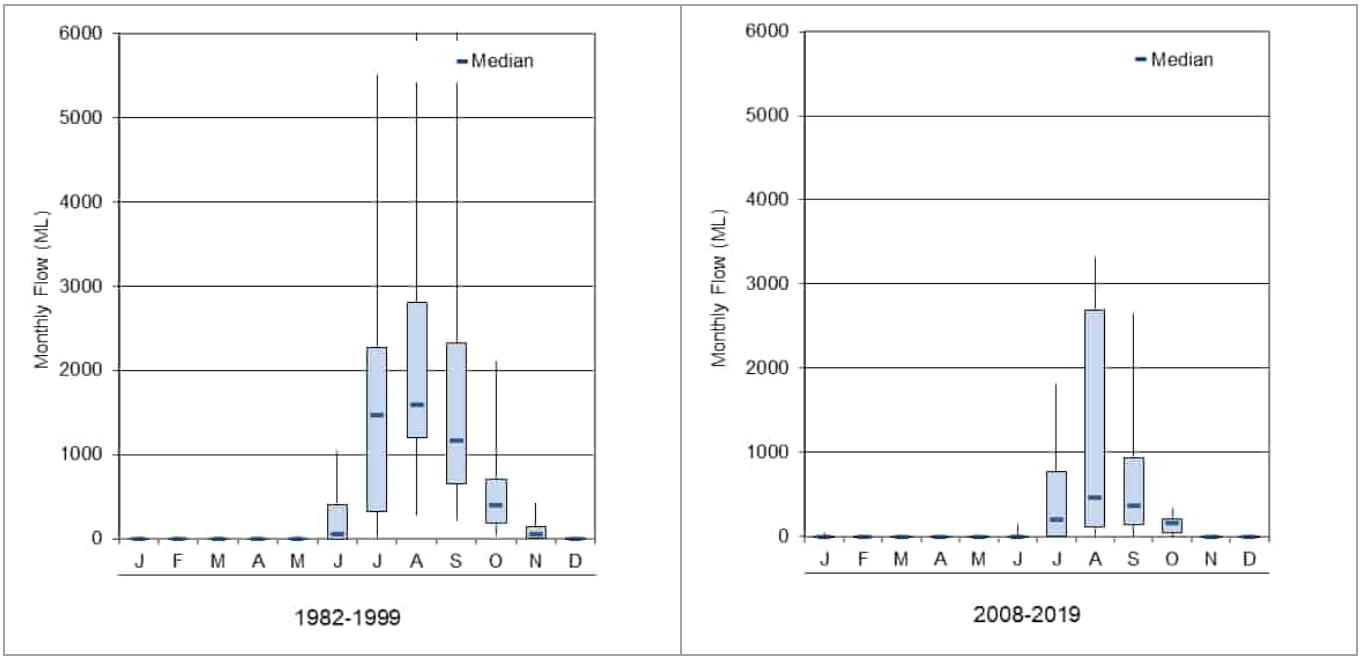


Figure 3-8 Flow seasonality – River Road (Serpentine River) for periods 1982-1999 and 2008-2019

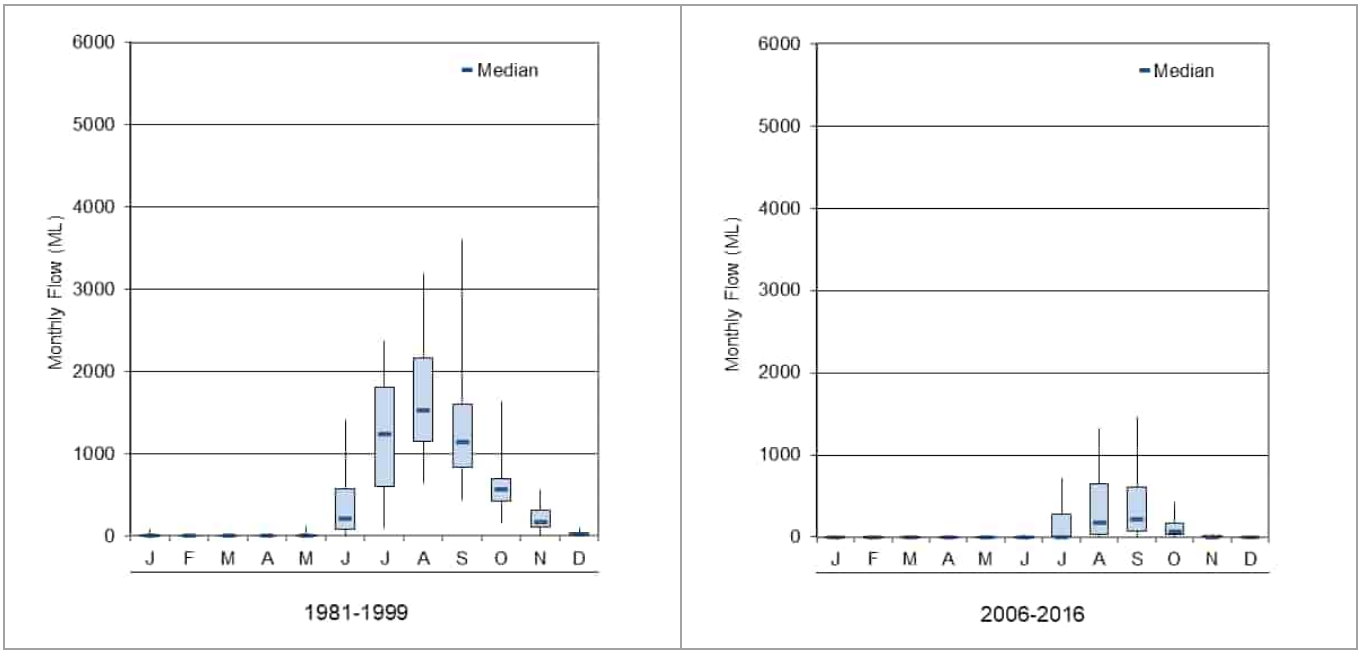


Figure 3-9 Flow seasonality – Jack Rocks (39 Mile Brook) for periods 1981-1999 and 2006-2016

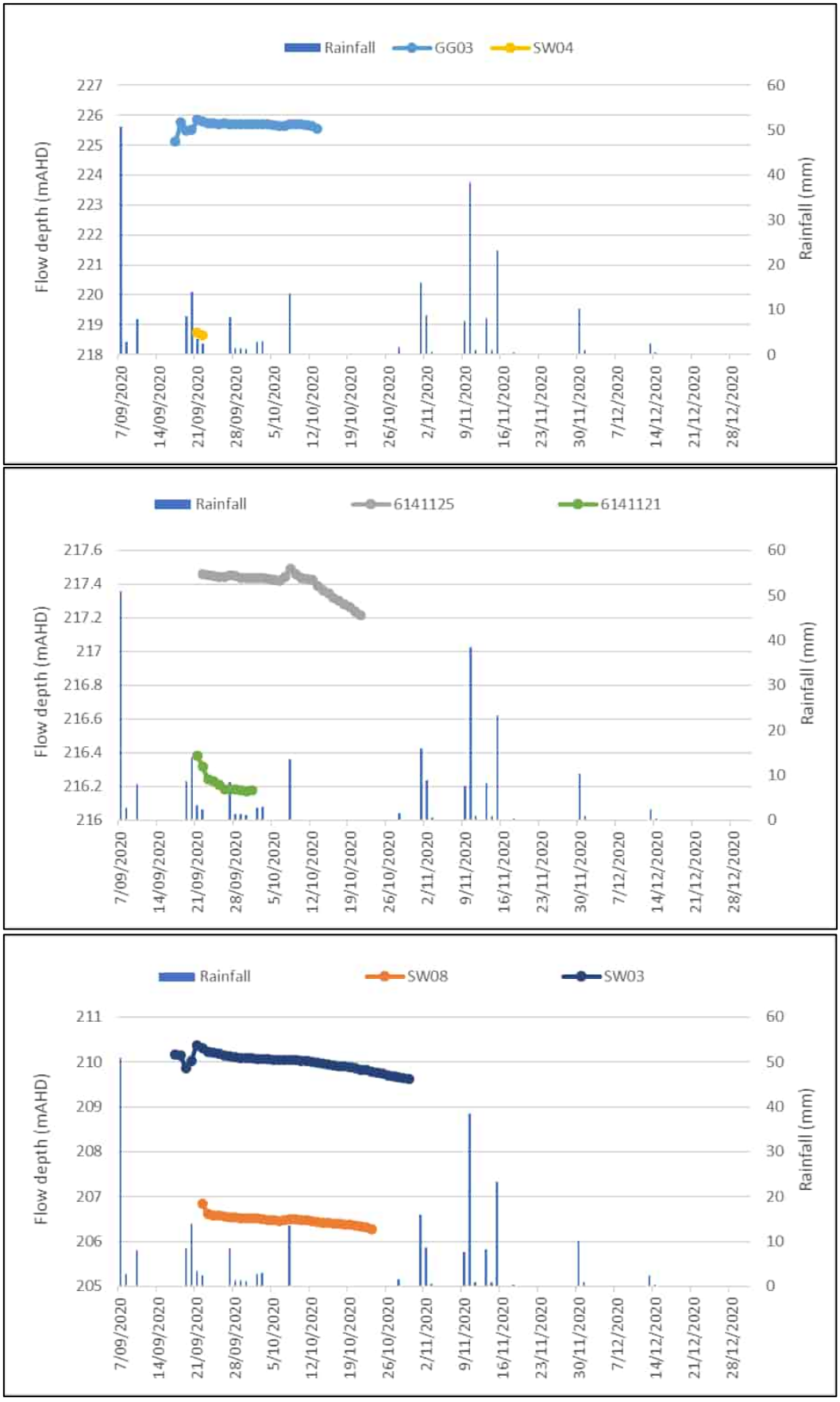


Figure 3-10 Myara North logged water levels (from date of installation)

3.10 Surface water quality

Historic water quality data

Surface water quality monitoring data across the Myara North mine region has historically been gathered by Alcoa and DWER.

The spatial distribution and frequency of Alcoa water quality monitoring data varies widely across the Myara North mine region, with historical focus on research catchments and proposed mining catchments. Data extends from the mid to late 1970s to the early to mid 1990s for the northern and central catchments. Data for most subcatchments east of the 1,100 mm isohyet extends from the early 1980s to late 1990s. Two sites have data from the early 1990s to 2020, site SN04 on a minor eastern tributary and site SN07 on the Serpentine River at River Road gauging station.

DWER data across the Myara North mine region ranges from short periods in the 1970s, with more extensive data from the mid 1970s through mid 1980s and mid 1990s.

The spatial distribution of historic monitoring locations within Myara North and immediate surrounds are presented in Figure A-11, noting the period of record for many sampling locations is not continuous with observed gaps in data for some parameters.

Summary statistics tables of water quality parameters are presented in Appendix Fand salinity (as EC) for selected sites are presented in Appendix G. Site selection for plots is based on representative up and downstream sites with higher parameter count and wider period of record.

Surface water salinity is classified as fresh (less than 500 mg/L TDS) in the surface water tributaries west of the 1,100 mm isohyet, with maximum TDS of 486 mg/L reported for site TN14 (Jack Rocks) on 39 Mile Brook (Table F-1 Appendix F). For tributaries east of the 1,100 mm isohyet, the maximum TDS typically exceeds 500 mg/L (Table F.1).

Electrical conductivity values identify comparable median values across the Myara North mine region, however an increase in maximum electrical conductivity values is recorded for tributaries east of the 1,100 mm isohyet.

Plots of EC for the available period of record (generally ending in 1990s) for representative Alcoa and DWER monitoring locations (typically upstream and downstream sites on key tributaries) (0), support the minor increase in surface water salinity in the eastern extent of the Myara North mine region.

Available pH data (Appendix F) indicates that median pH of all tributaries is neutral with some tributaries' minimum pH values in the acidic range.

Baseline water quality data

Baseline surface water sampling events were completed monthly between August 2020 and January 2021. Two electrical conductivity loggers were installed at the downstream extent of two significant tributaries east of the 1,100 mm isohyet.

The monthly sampling events indicate fresh water conditions across the Myara North mine region, with electrical conductivity ranging from 174 µS/cm (SW04, September 2020) and 587 µS/cm (SN02, October 2020). An outlier of 2,790 µS/cm was recorded from site SN02 with the sample noted to have been collected from a standing pool. Monitoring identified moderately acidic pH conditions across all sites.

The electrical conductivity logger record at Banksia Gully (site 6141121) was limited to four days due to rapid decline in water levels at this site below the logger installation height. EC during the limited logger record was stable with an average EC of 167.1 µS/cm.

The logger record for Goldmine Gully (site 6141125) was four weeks with the logged EC steadily rising during this period, ranging between 236.2 and 377.6 µS/cm.

3.11 Conceptual understanding of surface water and groundwater connectivity

Introduction

Given the shallow depth to groundwater beneath the lower lying drainage lines at Myara North mine region (see section 3.5), surface water and groundwater are inferred as hydraulically connected within the drainage lines (and potentially springs), valley floors (wetlands, damplands) and the water reservoir (Serpentine Dam).

Streamflow is supported by both regional groundwater flow and the shallow subsurface surface “interflow” and limited surface runoff (See Section 3.3), although the relative contribution from each varies and is not well established.

The following section evaluates the evidence to support the contribution from both the regional groundwater aquifer “baseflow” and the shallow subsurface surface flows “interflow.”

Evidence of relative contributions based on surface water flow data

The location of the relevant surface water monitoring points for the Myara North mine region which have suitable long-term data with which to interpret contributions of baseflow and interflow are presented in Figure A-11.

Of the three surface water monitoring points relevant to Myara North, one location was excluded from this assessment (610435) given that the catchments and flow data is collected from both within and areas outside the Myara North mine region catchment (Serpentine River), and as a consequence surface water flow and quality could not be exclusively attributed to the Myara North mine region catchments (Figure A-10).

The available surface water flow rates and salinity data from the two monitoring sites 39 Mile Brook - Jack Rock surface monitoring point (614031), and Wungong Brook – Cobiac (616058) (see Figure A-11) are presented in Figure 3-11 to Figure 3-14.

These figures show long-term data together with a short-term subset of the data, to review (seasonal) streamflow response to rainfall.

Streamflows are relatively short-lived based on observations from available datasets. Following seasonal winter rains, they cease to flow within two to three weeks following the peak surface water flows (Figure 3-12 and Figure 3-14).

The short duration of streamflow indicates that it is derived from low storage discharge components, surface runoff and interflow with lesser baseflow components. Past this point (2 to 3 weeks following the peak) any surface water flows likely become solely dependent on contribution from baseflow (not observable on graphs).

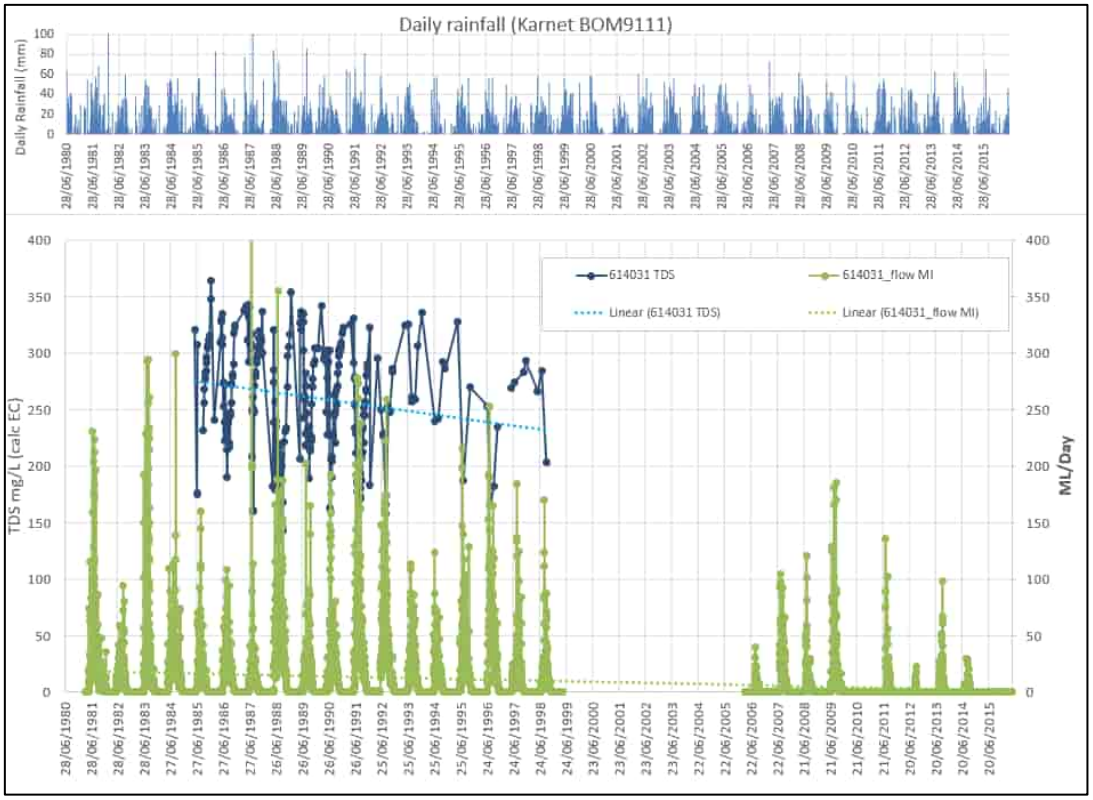


Figure 3-11 *39 Mile Brook - Jack Rocks (614031) Myara North salinity and surface water flow data*

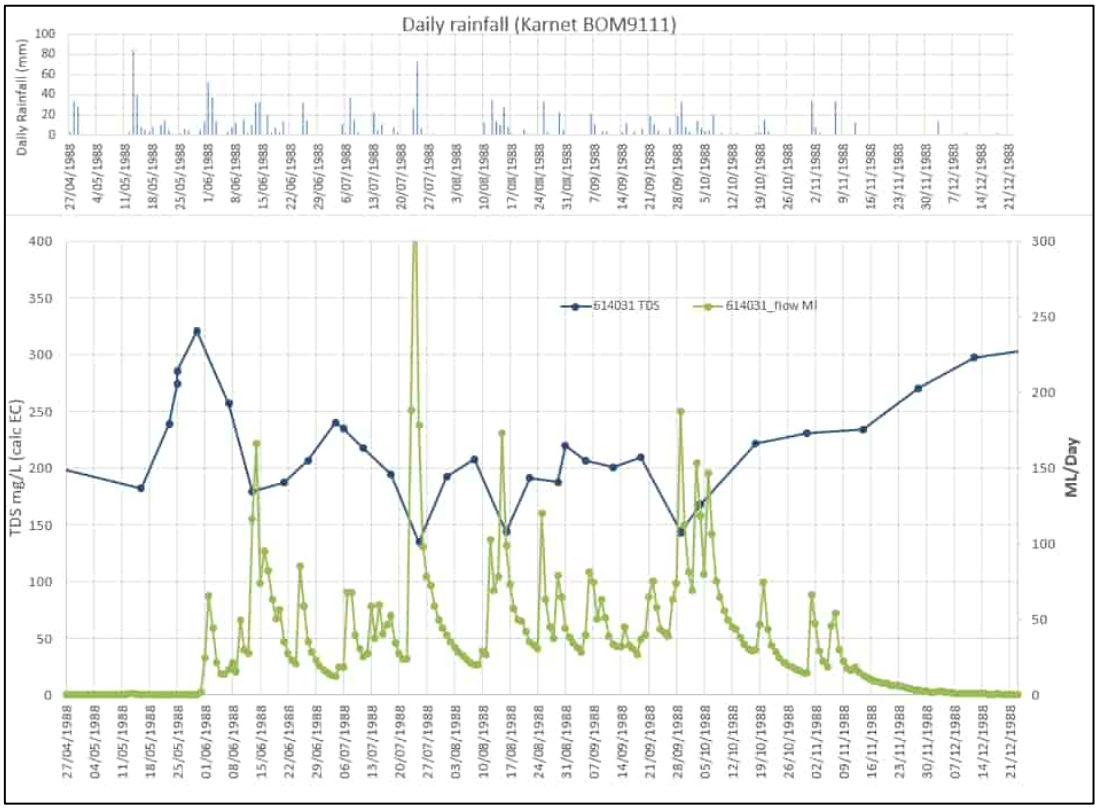


Figure 3-12 *39 Mile Brook - Jack Rocks (614031) Myara North rainfall, salinity and surface water flow rates for selected period (1988)*

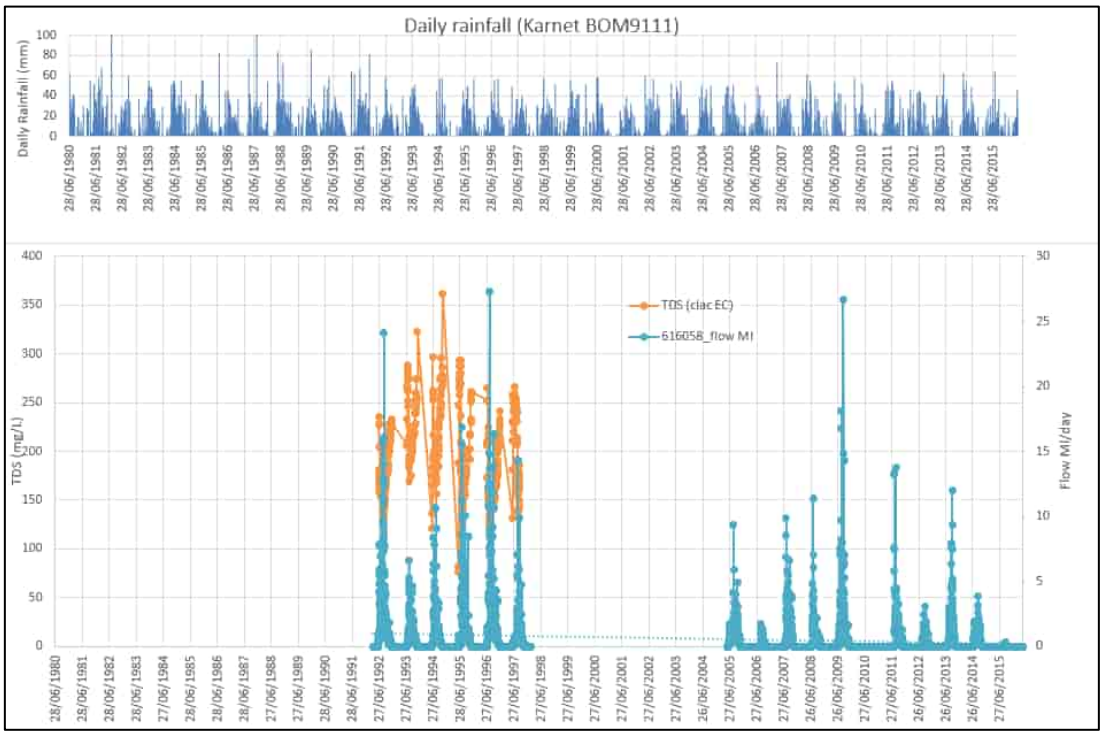


Figure 3-13 Wungong Brook - Cobiac (616058) Myara North rainfall, salinity and surface water flow rates

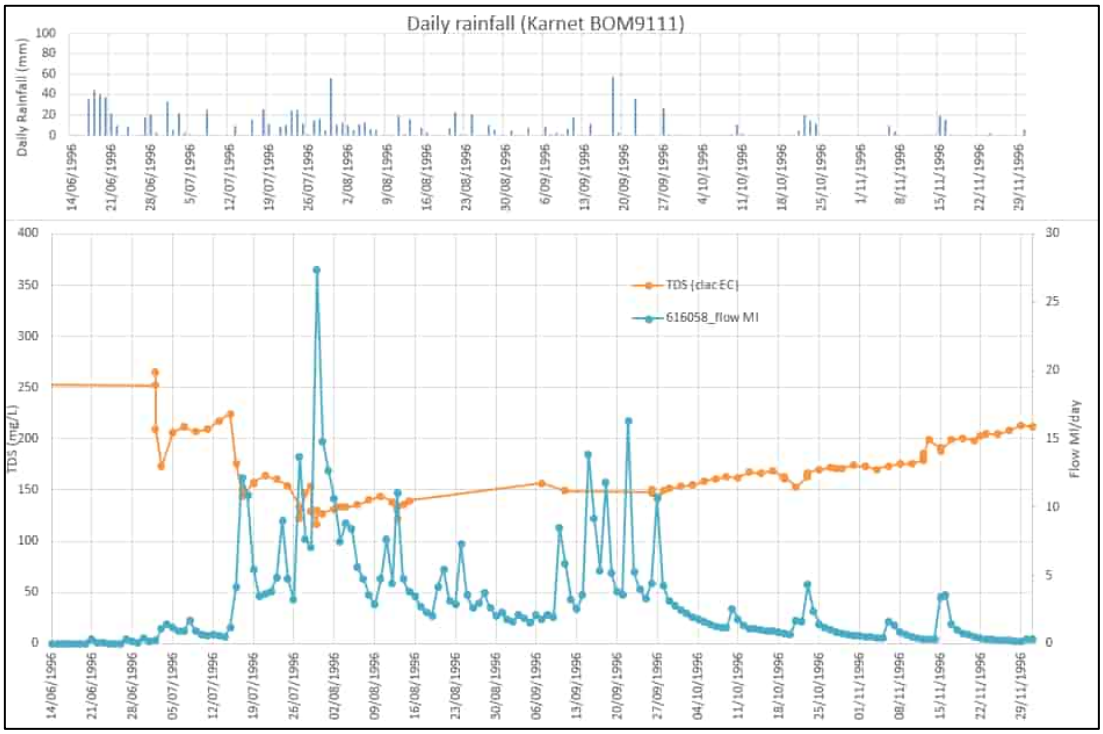


Figure 3-14 Wungong Brook - Cobiac (616058) Mayra North rainfall, salinity and surface water flow rates for selected period (1996)

Groundwater levels and surface flows exhibit similar seasonal behaviour. An example is shown using the Jack Rocks flow gauge data (614031) and the monitoring bore located adjacent to the gauge, MJ40122A (Figure A-11 for gauge location and Figure A-8 for bore location).

Figure 3-16 shows that peak surface flow rates (614031) are coincident with seasonally elevated groundwater levels - the levels of which are at ground level adjacent to the drainage line (MJ40122A). The data supports that surface water flows are likely to be subject to discharge from the regional groundwater (as baseflow) together with the quickflow components. Further, based on the slow decline in groundwater levels as summer approaches, interflow appears typically short lived while baseflow is likely to extend weeks to months following the winter rains and peak aquifer storage.

Evidence of relative contributions based on surface salinity data

In similarity to observed flow variations, seasonal streamflow salinity variations are also well indicated in the available data.

Streamflow and groundwater level data presented in Figure 3-16, with a reasonable data density during the 1990 and 1992 period, indicates that winter surface water flows at Jack Rocks gauge (614031) have low TDS values at around 150 mg/L, due to the dilution from quickflow components. Outside of major winter events, TDS rises to around 320 mg/L more typical of groundwater in the area, which provides diminishing baseflow as summer approaches (regional groundwater) until cessation of flow.

Based on the slow decline in groundwater levels as summer approaches, quickflow components are short lived while baseflow is likely to extend weeks to months following the winter rains and peak aquifer storage.

Streamflow salinity data can also provide indications of the prevailing flow regimes as presented in Figure 3-15. The figure shows the relationship between the recorded streamflows and TDS at the Jack Rocks gauge (614031). The data indicates a relatively stable range of TDS at low flow rates and then linear decrease in TDS with rising flow rates. Below average flow rates of 0.05 m^3/s, the recorded TDS ranges between 280 and 345 mg/L. It is reasonable to assume that at these flow rates practically all contribution is coming from groundwater as baseflow, and when the flow rate exceeds 0.05 m^3/s, the quickflow components increase their contribution to streamflow.

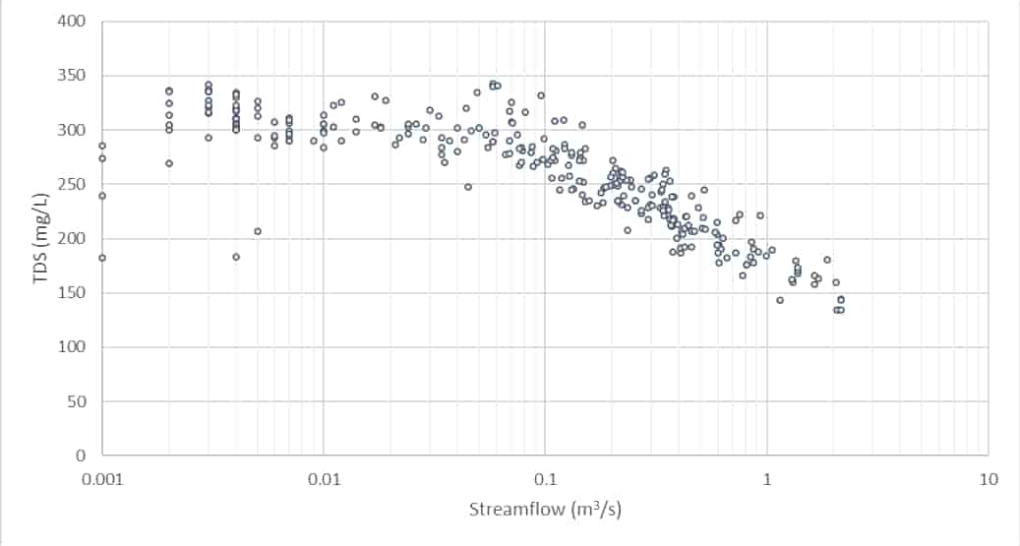


Figure 3-15 Jack rocks gauge (614031), relationship between average daily flow rates and TDS

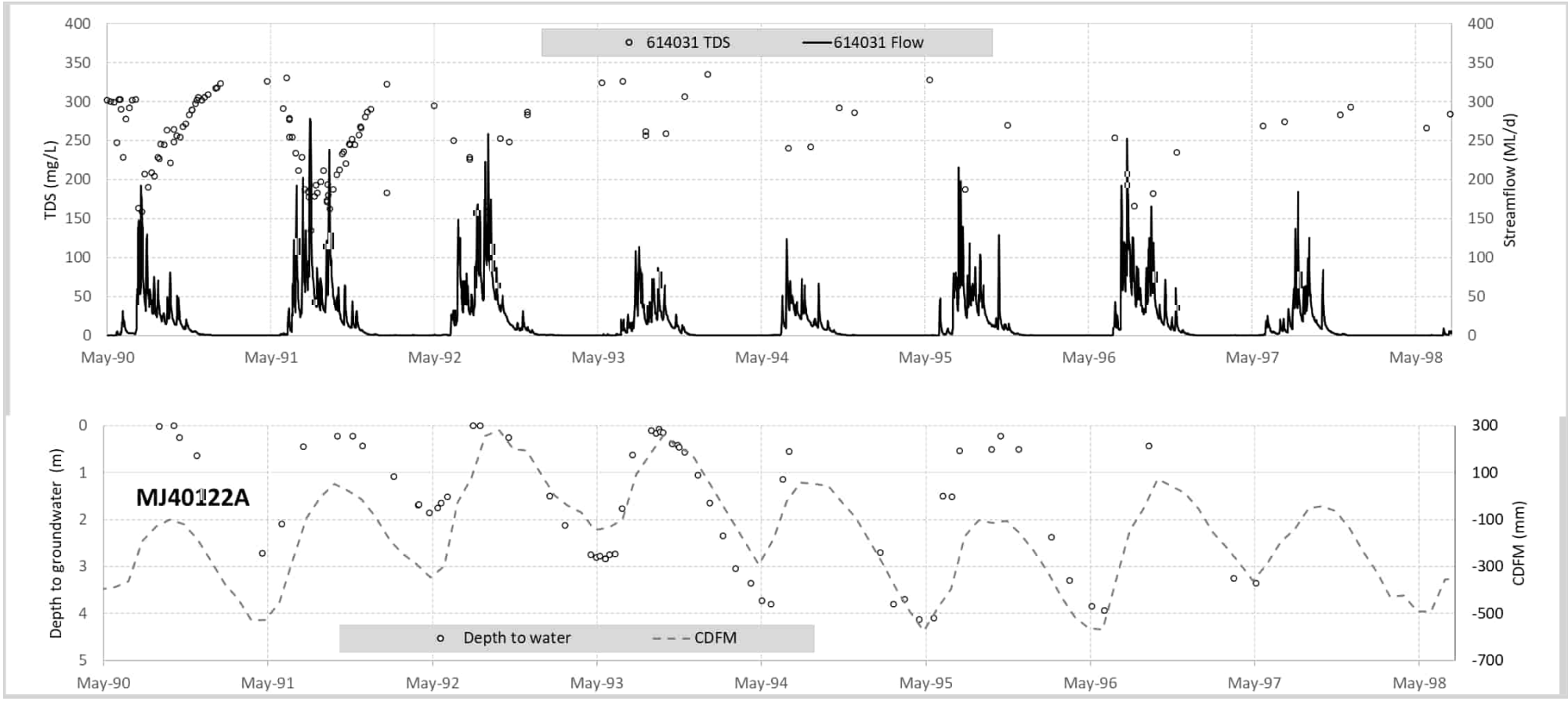


Figure 3-16 Example of streamflow and groundwater level response to seasonal rainfall (Jack Rocks gauge and bore MJ40122A)

Conditions that support baseflow

Given the shallow depth to groundwater in areas beneath the potential GDEs and wetlands (See Section 3.5), the regional groundwater is inferred to support the potential GDEs and wetlands, particularly during the summer months in absence of surface water flows.

As long as groundwater level surrounding the drainage lines fall below the creek level (which would lead to hydraulic disconnection), or the groundwater flow gradient reduces such that the incoming flow is completely removed by riparian evapotranspiration, groundwater continues to discharge into the creek, or via a sufficiently shallow watertable, support the riparian zone and associated vegetation communities.

Estimation of quickflow and baseflow components

The following presents a simple case calculation, using TDS and streamflow to estimate the relative contribution from quickflow (including interflow and runoff) and baseflow to the streamflow, demonstrated on Jack Rocks gauge data, which has a reasonable density of flow and EC data during 1980s and 1990s observation period.

The analysis, based on two primary reservoirs uses the principle that a flowing water body is a mixture of waters of two different origins (and associated salinities). It is an example of a more parsimonious and rapid conceptual models based on a significant surface water groundwater interaction. The quickflow and baseflow contributions are calculated by solving a reservoir water balance which accounts for time-varying recharge.

Estimation is based on an example of several similar approaches, in this case on Gonçalvès et al (Gonçalvès 2021) who presented a methodology that uses hydrochemical data to constrain various streamflow components (they refer to baseflow and interflow as surface/hypodermic flow). Their methodology uses major ions to characterise hydrochemical end-members and also assumes fast responding reservoir to runoff and the near-surface flows; and slower responding reservoir to baseflow. This approach does not use conceptual reservoir cascade typical for some other approaches.

Times series decomposition of streamflow, in this case using monthly time scale, has been applied. The decomposition requires estimation of two parameters, recharge and quickflow rates (the latter can be understood as runoff coefficient accounting for surface runoff and interflow). The presence of two “calibration” parameters is the reason for an understandable non-uniqueness of estimation when using different conceptual assumptions. Variations in recharge rate, in particular, are explored since they are relevant to the mining impact assessment process.

In this case we present the following possible realisations which yield similar streamflow timeseries results:

– “Low baseflow”, and low recharge rate realisation (in this case 46 mm/yr recharge rate)
– “High baseflow” – and higher recharge realisation (in this case 113 mm/yr recharge rate)
– Baseflow aligned with the CMB recharge estimate (in this case 56 mm recharge rate)
– Baseflow aligned with the CMB recharge estimate and peak flows

The first three realisations match the observed and simulated average annual streamflow rate (at the expense of sufficient match of peak flows); the fourth realisation provides a better match of peak flows but overpredicts the average annual streamflow rate.

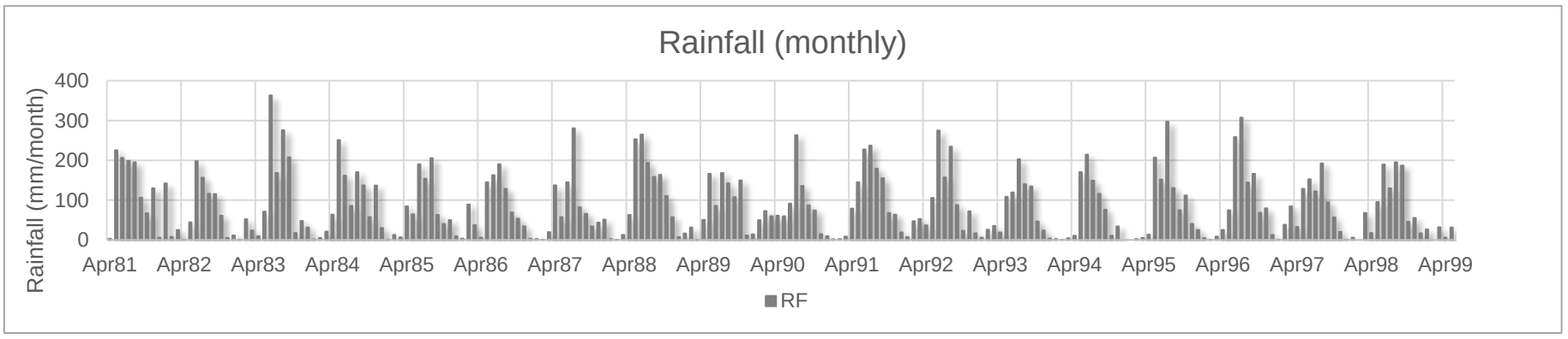
In absence of detailed hydrochemical data for the Jack Rocks gauge, TDS is applied as the additional constraint. Assuming the average TDS values for the two end-members, runoff/near-surface flow (i.e. quickflow) and baseflow, at 150 and 350 mg/L, conceptually viable realisations of the relative contribution of these two flow components during 1981 to 1991 winters were derived.

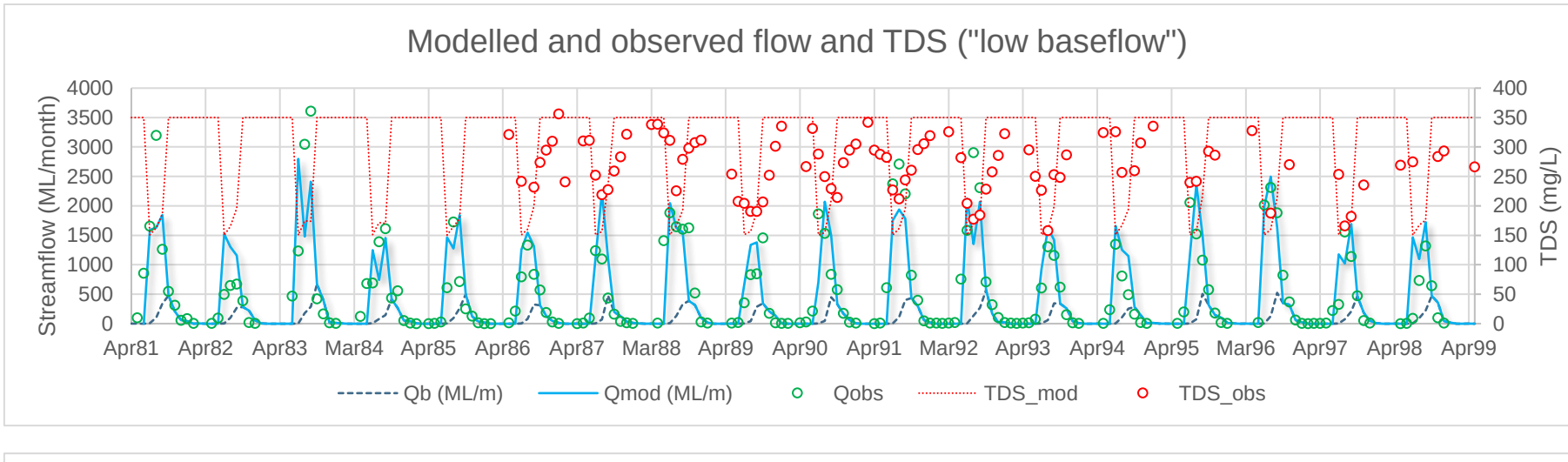
The time series results of simulated realisations for winter flows of 1981 and 1991 obtained using this approach (based on Gonçalvès et. al., 2021) are presented in Figure 3-17.

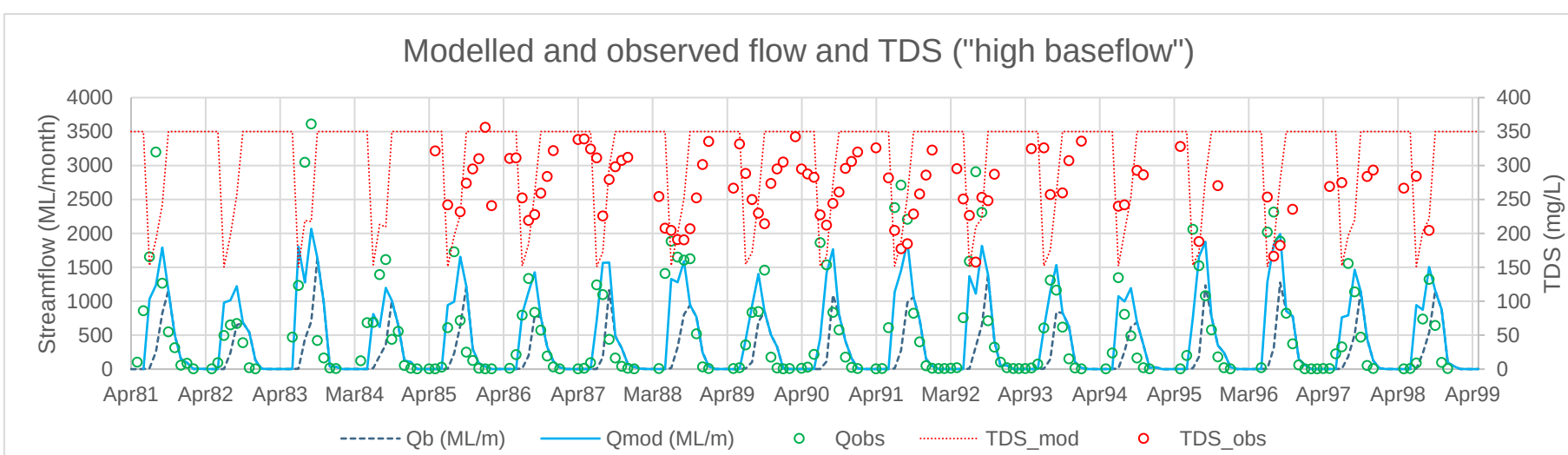
The presented realisation example results indicate the following:

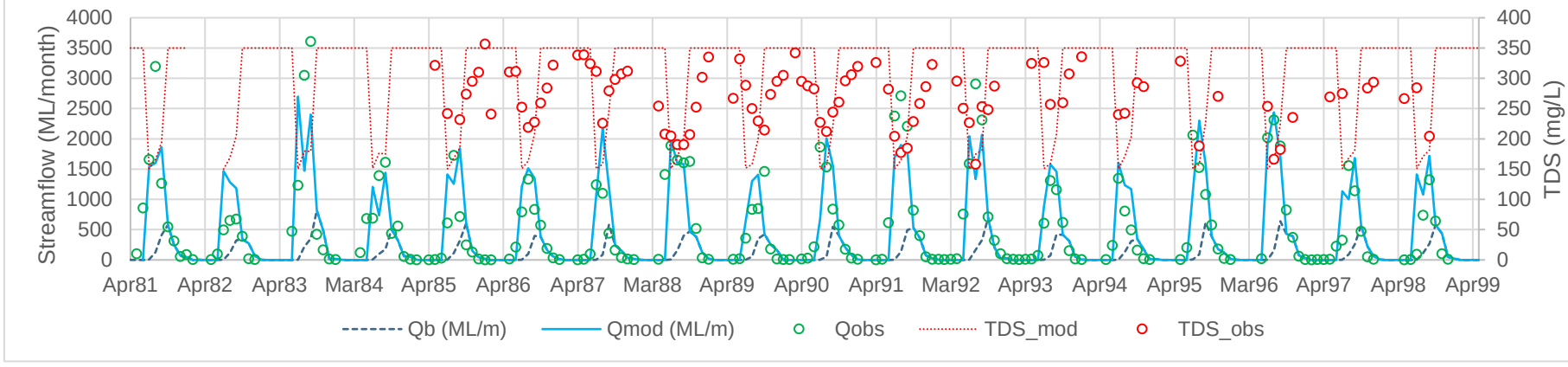
– A reasonable match between measured and calculated data (both flows and TDS) using parsimonious analytical model supports a relatively representation of streamflow components. All presented realisations have similar correlation between observed and simulated results, with coefficient of variation R^2 varying between 0.71 and 0.77 (Figure 3-18).

- Peak flows in simulated timeseries are often under-represented (e.g. winters of 1981, 1983, 1991, 1992. It is possible to match peak flows by increasing quickflow proportion (bottom plot in Figure 3-18), however this would lead to higher than observed annual average flow (by 30%). It needs to be taken into account that monthly steps are evaluated in this approach, with averaging potentially skewing the results to some degree. There is also uncertainty associated with measured flows, for example Gonçalvès et. al. (2021) also assumed 30% errors associated with streamflow measurements. The point however is not the absolute accuracy of the results, rather the ability of this simple relationship, constrained by TDS, to reproduce the streamflow trends with relative ease.
- The results also indicate that using a range of recharge rate values it is possible to obtain similar streamflow results, even when constrained by TDS. The recharge rate in this case varied between 46 and 113 mm/yr (Table 3-4), with the balance of streamflow supplied from quickflow (mainly interflow) components. In these evaluated realisations baseflow contributes between 18.5 to 50% of streamflow. This range could be potentially even larger given that the analytical solution can accommodate it and produce plausible streamflow estimates. Baseflow proportion is likely to vary more during shorter timesteps, e.g. quickflow would be dominant during the initial phases of the streamflow event, while baseflow will be dominant in the receding part of the event. This is also reflected in the simulated realisations (Figure 3-17) in which the streamflow peak precedes the baseflow peak.
- The TDS constraint helps the attribution of flows although the simulated TDS during the recession part of the streamflow event rises faster than observed. This is interpreted, to some degree at least, as the effect of averaging.
- The simple analytical relationship indicates that recharge rates over the 55 km^2 Jack Rocks gauge catchment could vary at least within 46 to 113 mm/yr, i.e. producing 2.5 to 6.2 GL/yr. Applying this range of recharge rates to the entire Myara North development envelope would yield on average 7.8 to 19.3 GL/yr of recharge.
- Streamflow from Jack Rocks gauge represents an average of 5.4 GL/yr in which baseflow proportion is 1.1 to 2.7 GL/yr. The remaining recharge will contribute to groundwater storage and/or be removed by evapotranspiration. The actual evapotranspiration for the area based on Bureau of Meteorology is 500 to 600 mm/yr. If evapotranspiration only took place in GDE areas, which cover 26% of the project development envelope, the theoretical output through evapotranspiration at 500 mm/yr would be 8.8 GL/yr. Total groundwater recharge is thus well within the evapotranspirative capacity of the area and consequently evapotranspiration is the major component of groundwater discharge. Should the baseflow component of the Jack Rocks be extrapolated to the mine development envelope, evapotranspiration would represent 50 to 82% of groundwater discharge.









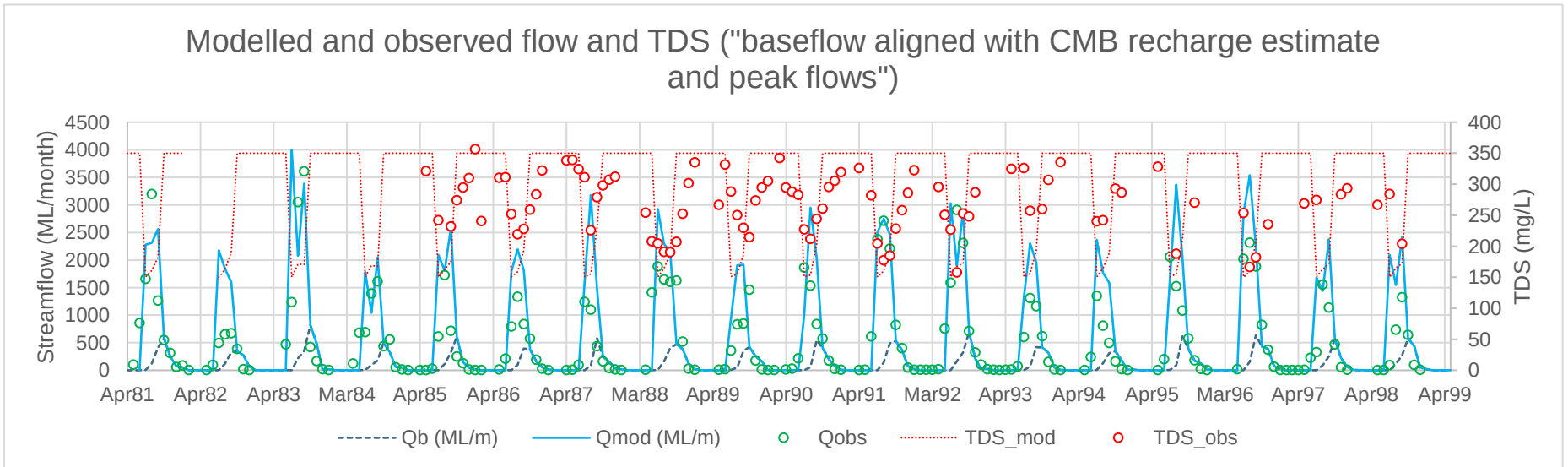
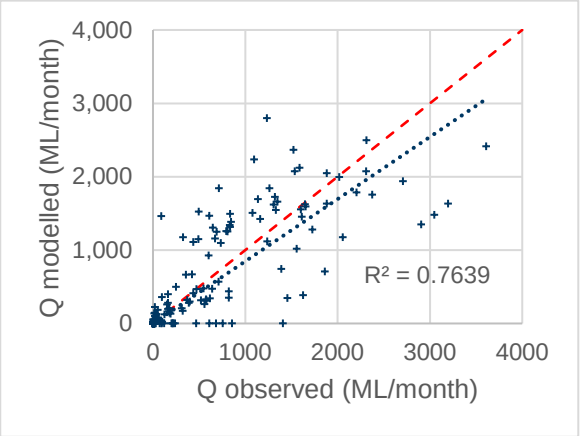
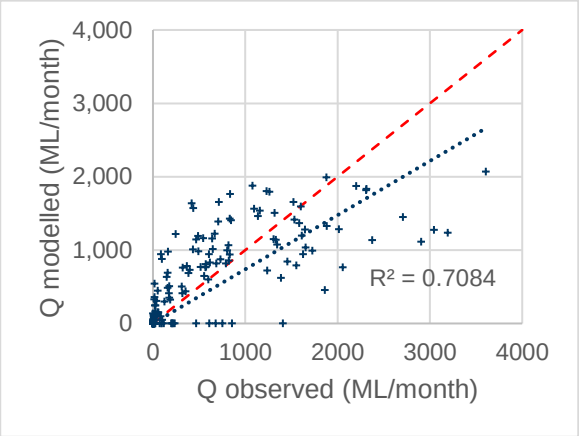


Figure 3-17 ***Application of simple analytical TDS-constrained baseflow-quickflow models to represent measured streamflows at Jack Rocks gauge (Qb – baseflow; Qmod – modelled streamflow; Qobs – observed streamflow; TDS_mod – modelled TDS; TDS_obs observed TDS)***

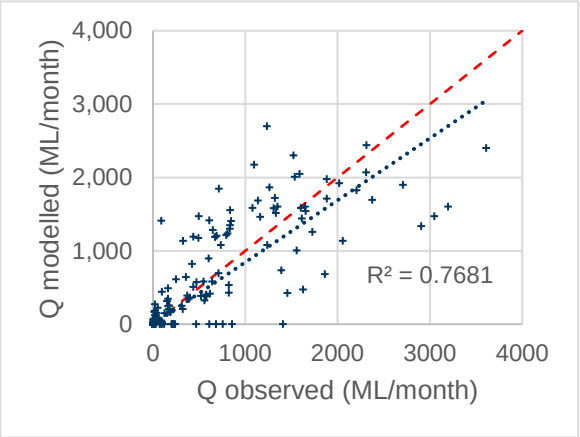
Low baseflow (46 mm/yr) realisation



High baseflow (113 mm/yr) realisation



Baseflow (25 mm/yr) aligned with CMB recharge estimate



Baseflow (25 mm) aligned with CMB recharge estimate, matched to peak flows

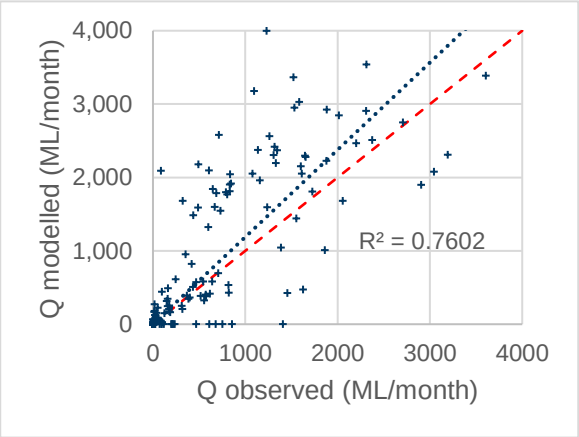


Figure 3-18 ***Observed vs estimated streamflow (red line denotes 1:1, blue line denotes linear trend) for Jack Rocks gauge***

Table 3-4 ***Summary of realisations of recharge and baseflow estimate, Jack Rocks gauge***

Realisation	Area recharge (mm/yr)	Area recharge (% of rainfall)	Baseflow (mm/yr)	Baseflow (% of streamflow)	Baseflow (% rainfall)
“Low” baseflow	46	4.5	20	21	2.0
“High” baseflow	113	11.0	49	50	4.8
Aligned with CMB recharge	56	5.5	25	25	2.4
Aligned with CMB and peak flows	56	5.5	25	18	5.5

4. Holyoake hydrological setting

4.1 Hydrostratigraphic units

The information for interpretation of the hydrostratigraphy is based on the installation of 17 groundwater monitoring bores at Holyoake mine region in 2020 (GHD 2020). The summary details of the monitoring wells are presented in Table 4-2. A review of geological logs (GHD 2020) indicates a thicker lateritic profile and increased depth to bedrock than the Myara North mine region, with a generalised profile as described below:

- **Lateritic/ duricrust caprock**: 1 to 7.5 m deep with an average of 1 to 2 m. The caprock comprises of minor soils with pisolites gravels and cemented duricrust or laterites and is less developed than Myara North.
- **Saprolite clays**: variable thicknesses from 1 to 32 m, clays are mottled or pallid towards the top becoming darker with depth reflecting weathered bedrock lithology.
- **Weathered zone**: weathered basement zone is characterised by a gravelly texture and decreasing clay content, with a typical thickness of 1 to 3 metres.
- **Granitoid basement**: depth to basement varied from 6 to 36 mBGL. In general, granite was intersected. Two notably shallower bores intercepted a quartz vein/alteration and dolerite intrusion whereas one deep bore recorded a schist at 33.5 m.

4.2 Hydraulic properties

Slug testing was used to obtain indications of hydraulic conductivity (GHD 2021(a)). The results are summarised and presented in Figure 4-1. The water strikes and slotted intervals, were generally identified and installed within the transition zone from weathered bedrock to basement materials.

The hydraulic conductivity ranges from <0.1 to just over 1.0 m/day with an average of 0.3 m/day as shown in Figure 4-1. The average hydraulic conductivity (K) at Holyoake is lower in comparison to results from the Myara North mine region. The range of potential K values is likely to be larger (see discussion of regional results in Section 3.4).

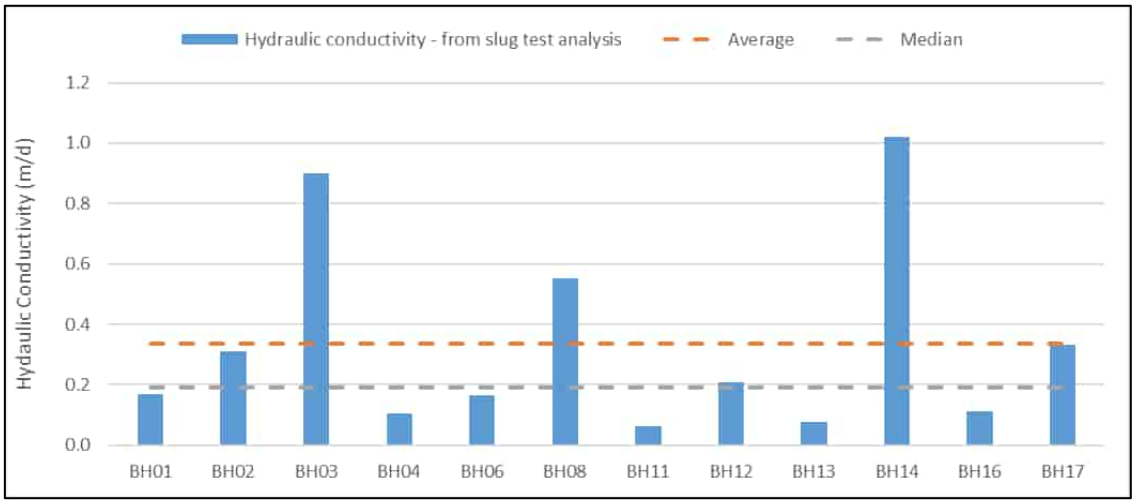


Figure 4-1 Holyoake slug testing results (hydraulic conductivity)

4.3 Groundwater levels and flow

The location of the monitoring bores for Holyoake mine region is presented in Figure A-9 (Appendix A), and the hydrographs from the total number of Holyoake monitoring bores is presented in Appendix B (including salinity data/graphs).

The average depth to groundwater (averaged over the full length of the record) for Holyoake monitoring bores is presented on Figure A-16.

The newly instated monitoring bores, which are located close to, or within the valley floors/ creek lines, indicate that the depth to groundwater is generally greater than 10 metres below ground level (valley floor level), with 1 of the 17 locations exhibiting depth to groundwater levels less than 5 metres (BH12). The average depth to water is 14.5 metres below ground level.

Although the data is relatively short-term (end of summer 2020), this depth to water data indicates that the mapped potential GDEs are more likely the result of seasonal saturation of a shallow perched aquifer in the valley floor (Fordyce, et al. 2007) .

At a regional scale, an inferred relationship between topography and depth to groundwater indicates that groundwater flows towards the north west, where groundwater discharges into riparian zones of the lower lying drainage lines (no monitoring bores in the western areas), including the lower lying areas of the South Dandalup Dam and associated lower lying tributaries (e.g.: South Dandalup River). Groundwater will be mostly lost to evapotranspiration by vegetation that can access the water table, which is located primarily along the major drainage lines.

Long-term groundwater level trends and observations

The location of Alcoa's monitoring bores at Holyoake mine region are shown on Figure A-9. Of these monitoring bores a total of six bores have longer-term monitoring data together with more recent data (2020/21), available for an indication of long-term groundwater trends.

The hydrographs (and salinity data) for these six bores are presented in Appendix C, and a table summarising the trends is presented in Table 4-1. The groundwater levels of the six monitoring bores show an average declining groundwater levels since 1990s, of close to 9 meters, which reflect the reducing rainfall patterns (see CRD), declining since 1990s (Appendix C).

Table 4-1 Holyoake summary of groundwater level trends and salinity (extract of Appendix C information)

Monitoring well ID	Groundwater levels			Groundwater salinity		
	1990 SWL (mBGL)[1]	2020 SWL (mBGL) [1]	Change SWL (m)	1990 TDS (mg/l) [1]	2020 TDS (mg/L) [1]	Change TDS (mg/L)
MJ46071A	10	17	-7	250	300	50
MJ46071B	10	17	-7	ND	ND	ND
MK46051A	17	22	-5	ND	ND	ND
MK46101A	10	25	-15	150	200	50
MK49162A	9	20	-11	2000	2000	0
ML49131A	10	20	-10	1000	1400	400

Notes: 1: average values estimated from graphs observations (semi-quantitative); ND: Not applicable, no data or unreliable data.

New monitoring bores short-term groundwater level response

A summary of the new monitoring bore installation details is provided in Table 4-2, and the bore locations shown on Figure A-9. The hydrographs and salinity data for the new Holyoake mine region bores, prefixed "BH" is presented in Appendix D.

The data shows that the groundwater levels reduce over the monitoring period (October 2020 to February 2021), consistent with a seasonal change from late winter groundwater highs to summer groundwater lows.

The average seasonal groundwater level decline for all new bores is 0.7 m, significantly less than Myara North mine region (1.9 m for Myara North bores), which may reflect the observations in Myara North and Holyoake mine regions that bores with shallower depth to water, tend to have a greater seasonal range in groundwater levels.

Table 4-2 Holyoake monitoring well installation summary and water levels

Location	MGA GDA94		Total depth (mBGL)	Screen top (mBGL)	Screen bottom (mBGL)	Static water level (mbtoc)[1]
	Easting	Northing				
BH01	424,054	6,390,718	29.5	20.5	29.5	8.55
BH02	424,192	6,388,696	17.5	12.5	17.5	12.02
BH03	426,806	6,387,108	40.2	28.2	40.2	20.48
BH04	424,015	6,386,978	29.7	23.7	29.7	15.69
BH05	428,234	6,386,651	14.2	12.2	14.2	11.34
BH06	425,573	6,384,809	40.3	34.3	40.3	25.27
BH07	424,805	6,383,732	18	12	18	12.29
BH08	422,941	6,381,445	19	13	19	8.35
BH09	429,106	6,381,269	28.2	22.2	28.2	13.93
BH10	426,113	6,381,245	18.2	12.2	18.2	17.22
BH11	419,714	6,379,933	33	13.5	22.5	
BH12	424,142	6,379,814	6.1	3.1	6.1	4.19
BH13	426,917	6,377,918	34	28	34	18.29
BH14	419,640	6,377,768	38.6	26.6	38.6	20.73
BH15	420,847	6,376,506	9.3	4.2	8.2	8.81
BH16	422,958	6,375,535	34	28	34	22.13
BH17	422,522	6,372,129	25.2	19.2	25.2	13.59

Note [1] – Water level measurements taken during water quality sampling (20/10/2020)

4.4 Groundwater salinity

Long-term TDS trends and observations

The salinity data for the total number of Holyoake monitoring bores is presented graphically in Figure 4-2 and the location of the monitoring bores is presented in Figure A-9(Appendix A).

Of these 72 locations, a total of six monitoring wells have sufficient time series data with which to review salinity trends over three decades (1990 to 2020). The salinity data for these 6 monitoring wells is presented graphically (together with hydrographs) in Appendix E.

The salinity temporal trends, which has been approximated from the graphs (in Appendix E) have also been summarised and presented in Table 4-1 (where sufficient data is available). The salinity data is limited, but where the data exists for the three monitoring points, the data may show an increasing salinity, but may also be within seasonal variations (lack of seasonal data).

Spatial trends in TDS

The average salinity data for the total number of monitoring bores (Alcoa and GHD bores) based on monitoring bores within Holyoake mine region and those located outside but close to the eastern boundary of the Holyoake mine region (see Figure A-17), has been presented in Figure 4-2.

The statistical box and whisker plots indicate average of approximately 400 mg/L over the Holyoake mine region. The average monitoring bore salinity data has also been presented and plotted based on the monitoring bore locations in Figure A-17. Given the wide spacing and low numbers of the monitoring bores within the Holyoake area, conclusions cannot be reliably drawn on spatial distribution tends.

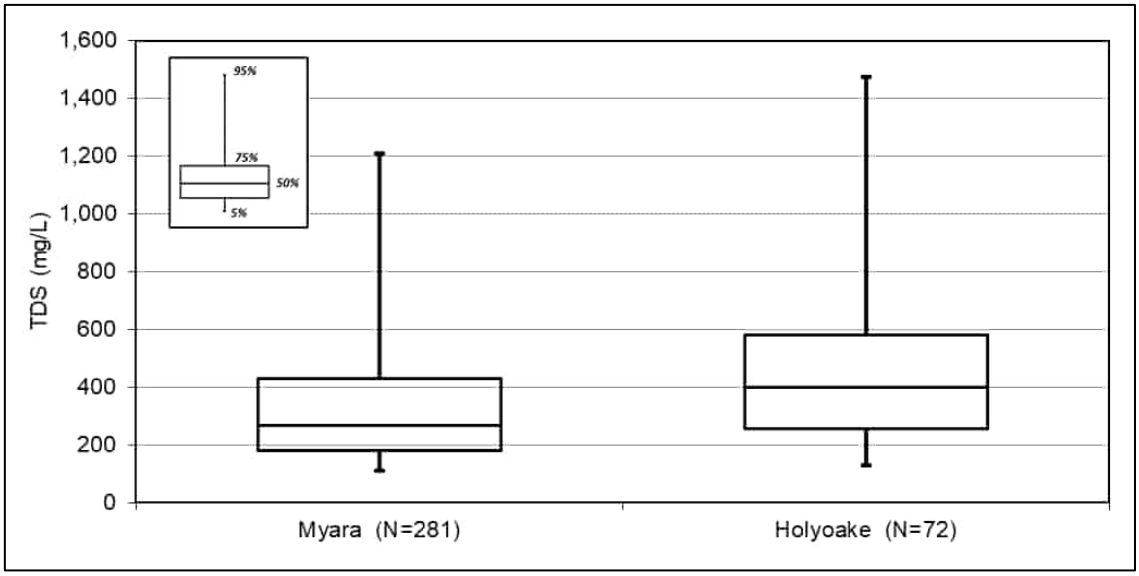


Figure 4-2 Groundwater salinity box and whisker plot for Myara and Holyoake regions

4.5 Water courses

The Holyoake mine region comprises two dominant catchment areas:

– The majority of the Holyoake mine region (67 km^2 or 66%) lies within the South Dandalup Dam catchment. This part of the Holyoake drains either into the main tributary of South Dandalup River or one of four of its tributaries. The South Dandalup Dam catchment extends well beyond the Holyoake mine region boundary.

– The south-western portion of the Holyoake mine region drains south to the Murray River catchment, in one of two tributaries, Davies Brook and Swamp Oak Brook.

There are six flow gauging sites relevant to the Holyoake region, details of which are summarised in Table 4-3 and illustrated in Figure A-11.

The majority of flow gauging stations relevant to Holyoake hold around 15 years of data from mid 1980s through to late 1990s. The Gordon Rd site is the exception, with a 30-year record available from 1988 to 2018.

Table 4-3 Gauging sites relevant to Holyoake

Site ID	Site name	Flow record	Catchment area (km^2)	Average annual flow (ML/yr)
Murray River and tributaries				
614045	Chadoora (Swamp Oak Tributary)	1984 to 1997	5	20
614047	Davis Brook – Murray Valley Plntn (Murray River Tributary)	1954 to 2002	66	6407
614006	Baden Powell (Murray River)	1952 to 2020	6737	244,189
South Dandalup Tributary				
614043	Pindalup	1984 to 1998	7	59
614059	Skeleton Road	1988 to 1998	19	2519
614060	Gordon Catchment	1988 to 2018	2	17

4.6 Surface water flow data

Long-term trends in surface water annual flow

Long-term annual flow data for the Holyoake region is restricted to the Gordon catchment for the South Dandalup River (Figure 4-3). The Baden Powell gauging station is the only other site in proximity to the Holyoake mine region, with data from other stations predating 2000.

As with surface water flows in the Myara North region there is an observed step change in streamflow in the Gordon catchment after 2000 (Figure 4-3), with similar step changes observed in Baden Powell annual flow data (data not shown).

Long-term trends in surface water flow seasonality

Similar to the long-term trends in flow seasonality in the Myara North region the box plots of monthly flow data (grouped by pre 2000 and post 2000) for Gordon (South Dandalup River) show a delay in flow commencement and they typically cease to flow earlier after 2000 (Figure 4-4).

Short-term trends in surface water flows

As with the Myara North mine region, observed flows at Holyoake mine region surface water sampling locations were recorded during monthly surface water sampling events (GHD 2021(a)). Surface water level loggers were installed late September at three Holyoake mine region surface water monitoring locations, two representing the downstream extent of representative catchments, and one downstream of the Holyoake mine region in the Murray catchment.

Surface water flow observations during monthly sampling events identified variable conditions across the Holyoake mine region. Multiple sites were observed to be dry during all monthly sampling events (including logger location HSW03, a minor eastern tributary at site 6141470 and a minor tributary inflow to the South Dandalup Dam at site 6141325).

The most downstream site of the central tributary through the Holyoake MDE (site 6141340) was also dry during all sampling events, while its upstream location at site SD31 was observed to be flowing on one sampling event (September 2020).

Flowing water was present in August preceding logger installation at sites 6141005 and HSW05. Some sites upstream of the site HSW05 reported surface flow conditions in late October surface water sampling (site HSW01 and site 6141349), as well as November (site HSW01), extending beyond the cease to flow at HSW05 in mid October.

Varying water level response to seasonal rainfall events was observed in the limited logger record. Rainfall totalling 18.4 mm over 4 days (27 to 30/09/2020) was insufficient to prevent water level decline to cease to flow at site HSW05, with water levels also declining at site 6141005. A 30.8 mm rainfall event on the 8/10/2020 results in a brief return of flows at site HSW05, and maintains flows at site 6141005 until cease to flow in mid October.

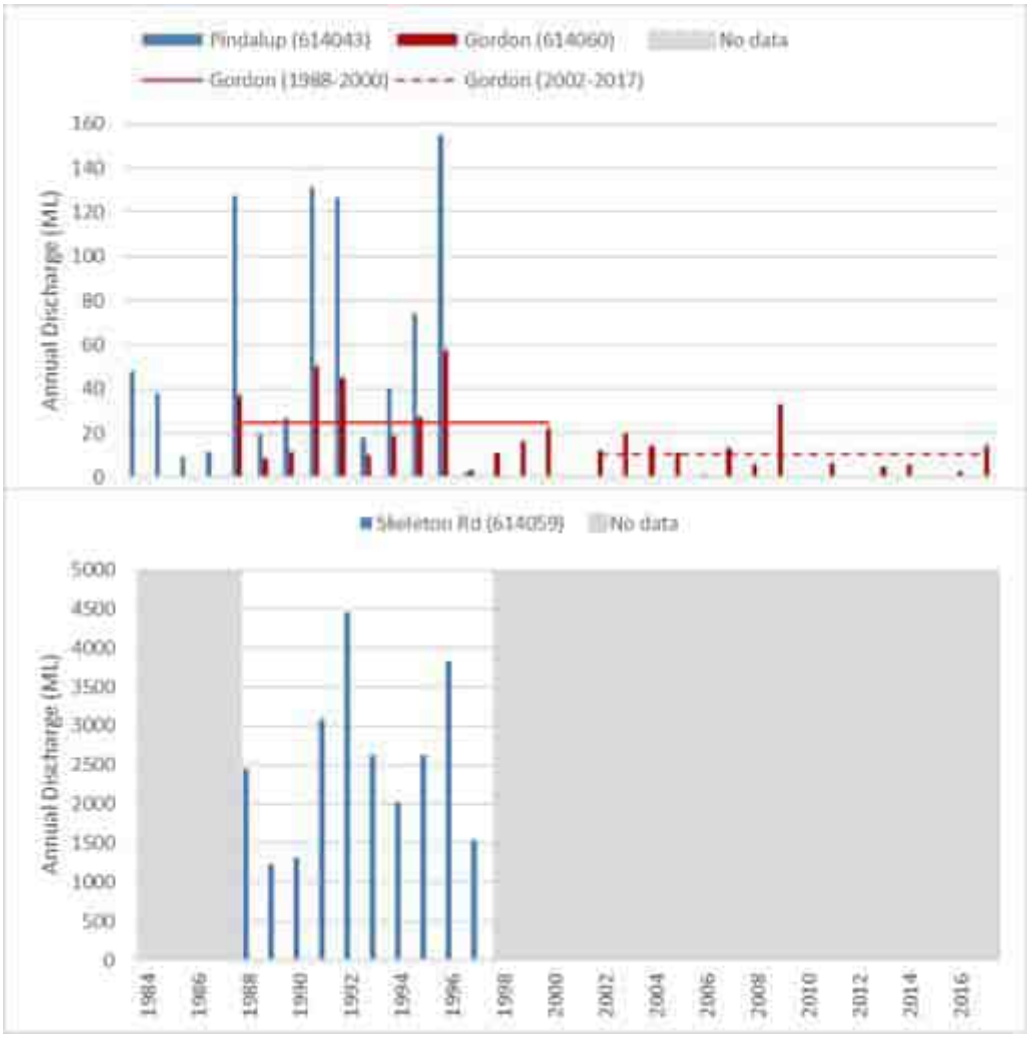


Figure 4-3 Annual flows at relevant South Dandalup catchment gauging stations

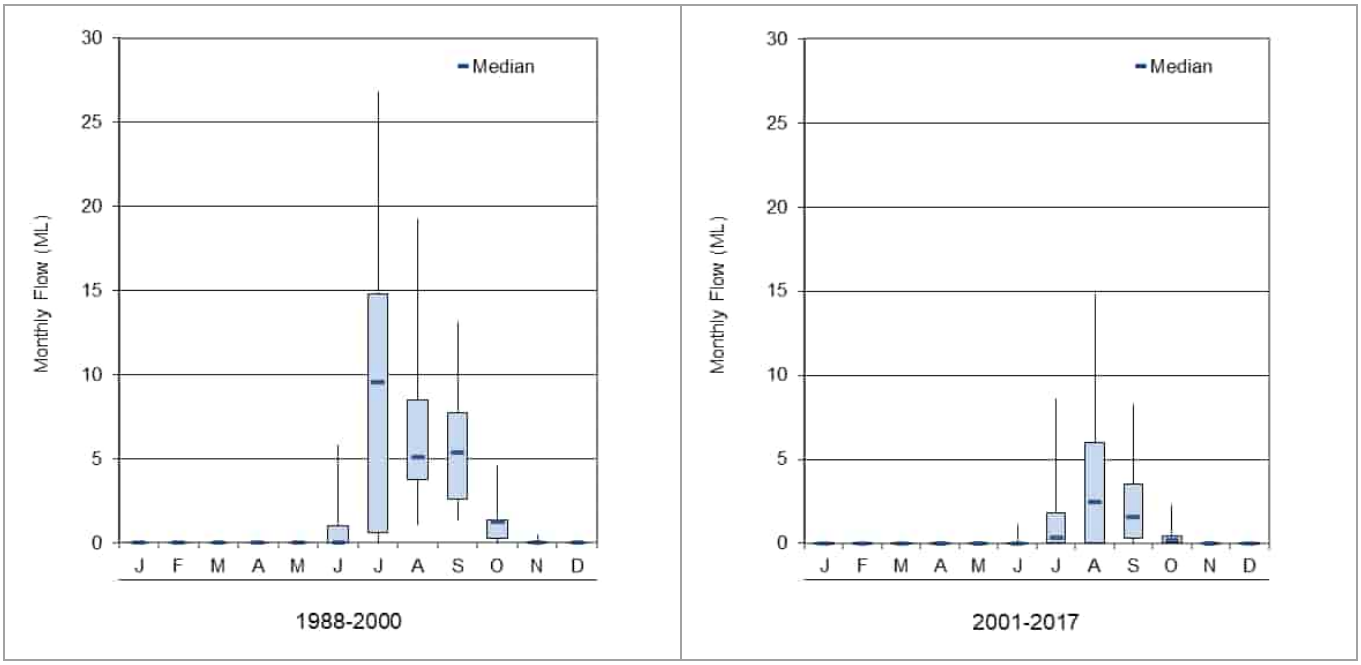


Figure 4-4 Flow seasonality – Gordon (South Dandalup) for periods 1988-2000 and 2001-2017

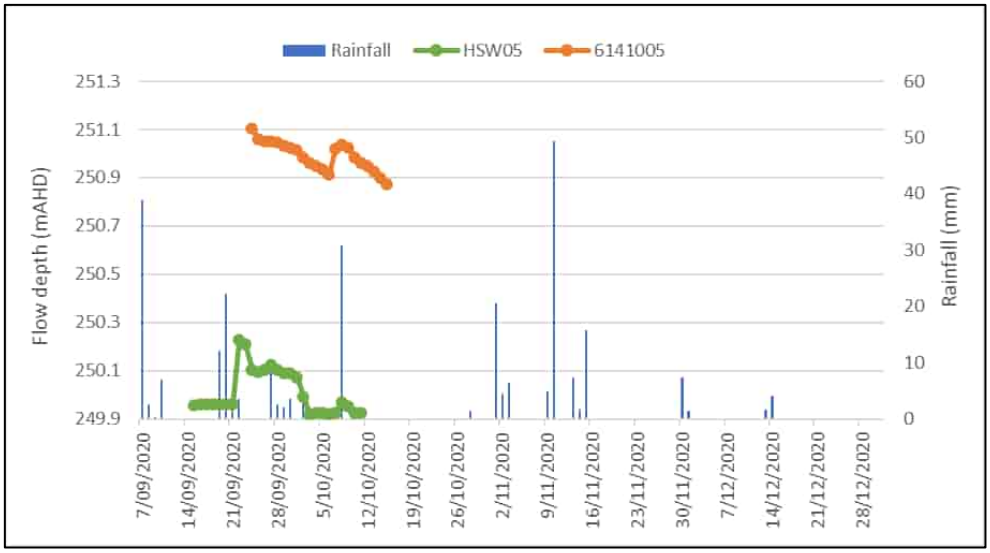


Figure 4-5 Holyoake logged water levels (from date of installation)

4.7 Surface water quality

Historic water quality data

Surface water quality monitoring within the proposed Holyoake mining region has primarily been carried out DWER. Alcoa monitoring in this region is limited to one site on Davis Brook (DV04) with sufficient data for review.

The spatial distribution of existing monitoring locations in the Holyoake mining region and immediate surrounds is presented in Figure A-13.

Electrical conductivity values are predominantly available for sites on the main and minor tributaries of the South Dandalup River, with median EC ranging from 169 µS/cm (site 614060) to 699 µS/cm (site 6141005, limited data from 1972 and 1975).

Limited pH data is available for gauging locations which indicates that median pH of tributaries is neutral.

Baseline water quality data

Monthly baseline surface water sampling events were also completed between August 2020 and January 2021 at Holyoake. Three electrical conductivity loggers were installed, with one on the main branch of the South Dandalup River, one on a major South Dandalup tributary in the north-west, and one downstream of the Holyoake mining region within the Murray catchment.

Electrical conductivity during monthly sampling events typically ranged between 122 µS/cm (BF20, August 2020) and 384 µS/cm (DV04, September 2020) indicating fresh water.

As with the limited historic pH record, the baseline data for Holyoake indicates neutral pH.

4.8 Assessment of surface water and groundwater interaction

The location of the relevant surface water monitoring points at Holyoake is presented in Figure A-13. The figure shows that the catchments and surface water flow data is exclusively collected from areas outside the Holyoake area and catchments, and as a consequence the surface flow data could not be used to develop a region-specific understanding of groundwater or quickflow contribution to surface flow at Holyoake mining region.

The newly installed monitoring bores (GHD 2020) within the creek line of the Holyoake mine region indicate the average depth to water is 14.5 meters below ground level (See section 4.3), and supports that in the upper part of the catchments, the mapped GDEs are not exclusively supported by regional groundwater levels, and quickflow

components (or perched conditions as described by Fordyce et al, 2007) may provide the majority of water for the GDEs.

The depth to groundwater is shallower within the drainage lines in located down-gradient of the monitoring bores and towards the tributaries of the South Dandalup Dam, where groundwater discharges and supports the GDEs.

5. Understanding of impacts due to bauxite mining

5.1 Observation on historical groundwater level changes of previously mined area at Myara

Introduction

This section presents an assessment of groundwater levels in previously mined areas proximal to the Myara North area (not within MDE) and is aimed at correlating groundwater level changes to bauxite mining related activities.

An area of previous mining has been selected for the groundwater level assessment given the proximity to the Myra North mining region and that the area exhibits the suitable spatial coverage of monitoring wells, coincident with previously mined areas (see Figure A-8 for location).

The selected area and monitoring well locations are presented in Figure I1 (Appendix I) which shows the area of this assessment and outline of former mining (2011 to 2019).

Establishment of background groundwater levels

With respect to the monitoring bores considered removed from the influence of mining (see Table 5-1 for list), a review of the hydrographs and CRD in Appendix Indicates the following:

the seasonal changes in rainfall are reflected in both the CRD data and the groundwater levels

a downwards bulk shifting of the CRD from 2015 onwards compared to the groundwater level data, indicates a departure of groundwater levels to that of the CRD (see graph MK41252A for annotation. the downwards bulk shifting of CRD data, compared to the groundwater levels evident on the graphs is not considered a reflection of the conditions local to the assessment area (weather station located 28 km to the south).

Based on an approximation, derived from the enveloping surfaces of the hydrographs, Table 5-1 indicates that excluding one monitoring well (deep monitoring well MK42281A), five monitoring wells indicate an overall average increase of 1.5 meters over the decade of interest (2010 to 2020).

As part of an overall naturally declining groundwater trend over 3 decades from 1990 to 2020 (see Section 3.5,) the approximated 1.5 metre groundwater level increase over the decade of interest (2011 to 2019) is considered to reflect an apparent increase in groundwater levels, and the natural conditions local to area (not influenced by previous mining).

Changes in groundwater levels due to mining:

The list of monitoring wells considered within the influence of mining is presented in Table 5-1 and the groundwater levels and CRD data is presented graphically in Appendix I.

The groundwater level change attributed to mining is based on an approximation of changes to groundwater levels in the decade of interest (2010 to 2020), and removal of the natural changes in groundwater levels.

Of the available nine monitoring wells, Table 5-1 indicate a rise in groundwater levels above that which is considered attributable to bauxite mining, from a minimum of 0.5 meters to a maximum of 10.5 meters, with an average increase of 5.5 meters.

Estimates of changes in evapotranspiration:

The estimates for decreased evapotranspiration (equivalent to increases in rainfall infiltration or recharge) due to mining is presented in Table 5-2. These estimated mining effects on the water table are derived from average increase of the water table per year (derived from Table 5-1), and adoption of a range of likely porosities.

Where monitoring bores are outside of the mining parcel (e.g.:100 to 200 meters) the groundwater level rise noted in these bores is typically reduced, given that the groundwater mound beneath the mining parcel dissipates during groundwater flow towards the bore. Where monitoring bores are outside from the mining parcels (and mining parcels are small) these bores have been excluded from calculations to derive the increase of rainfall infiltration due to mining (see Table 5-2.).

Where the monitoring bores are located directly hydraulically downgradient and close to the mining parcel (see Figure I1, I the groundwater mound will migrate towards the bore and provide an approximation for groundwater level rise beneath the mining parcel. However, these groundwater level increases are probably a reflection of a minimum increase given that mound dissipation will occur beneath the mining parcel during rainfall infiltration and during mound migration. Consequently, the recharge rate figures provided in Table 5-2 are an underestimate of the rates attributable within the parcel.

Nevertheless, the calculations relating to five monitoring bores considered suitable, indicates that the increase in rainfall infiltration beneath the mining parcels is considered as a minimum close to 160 mm (assumed porosity 0.2), which represents close to 14% increase in rainfall infiltration beneath the mining parcel (average rainfall 1,100 mm).

Table 5-1 Monitoring bores and groundwater level information summary

Monitoring Bore ID	Groundwater level change (m/decade)*	Groundwater level change attributed to mining (m/decade)*	Screened interval (m BGL)	Mining dates **	Distance to mining (meters)
Monitoring bores removed from the influence of mining:					
MK41252A+	+ 1.5	N/A	6.0 to 12.0	N/A	N/A
MK42031A	+ 1.5	N/A	8.2 to 14.2	N/A	N/A
MK42071A	ND (dry bore)	N/A	3.8 to 4.5	N/A	N/A
MK42151A	+ 1.2	N/A	9.8 to 15.8	N/A	N/A
MK42161A	+ 1.5	N/A	6.9 to 10.9	N/A	N/A
MK42281A	- 2 (minus)	N/A	23.0 to 26.0	N/A	N/A
ML42251A	ND (SW input?)	N/A	5.7 to 8.7	N/A	N/A
ML43012A	+ 2	N/A	5.0 to 9.0	N/A	N/A
Monitoring bores within the influence of mining:					
MK42131A	ND (dry bore)	N/A	4.5 to 6.6	2013	0
MK42132A	+ 12	+ 10.5	16.6 to 22.1	2013, 2016	115
MK42171A	+ 2	+ 0.5	5.6 to 11.1	2013, 2014	150
MK42211A	+ 2	+ 0.5	9.9 to 15.9	2013	72
MK42251A	+ 4	+ 2.5	9.9 to 15.9	2013	30
MK43041A	+ 10.5	+ 9	14.5 to 26.5	2010, 2013	50
MK43071A	+ 11	+ 9.5	16.6 to 22.6	2011	0
MK43072A	+ 9	+ 7.5	8.4 to 14.4	2011	50
ML43011A	+ 3.5	+ 2	16.1 to 28.1	2011	310
ML43051A	+ 3.0	+ 1.5	7.3 to 13.3	2011	250

+ mining commenced in 2019 at a distance of 460 meters, bore deemed not influenced by mining

* approximated groundwater level change (+/- 0.5 meters) in the decade following mining (e.g.: 2010 to 2020)

ND: Data unreliable

N/A not applicable

mBGL : meters below ground level (source Alcoa)

** date indicates approximate clearing and mining start date (source Alcoa)

Table 5-2 Summary of rainfall infiltration increase due to mining

Monitoring Bore ID	Bores located within mining groundwater stream lines	Groundwater level change m/year	Rainfall recharge mm/year @ porosity 0.05	Rainfall recharge mm/year @ porosity 0.1	Rainfall recharge mm/year @ porosity 0.2
MK42132A	Yes	1.05	53	105	210
MK42171A	No	-	-	-	-
MK42211A	No	-	-	-	-
MK42251A	Yes	0.25	13	25	50
MK43041A	Yes	0.9	45	90	180
MK43071A	Yes	0.95	48	95	190
MK43072A	Yes	0.75	38	75	150
ML43011A	No	-	-	-	-
ML43051A	No	-	-	-	-
Average		***0.78***	***39***	***78***	***156***

Yes: bores considered influenced by groundwater mounding beneath the mining area - groundwater mound direction predominantly towards the monitoring bore

No: bores not considered as predominantly influenced by groundwater mounding beneath the mining or not influenced by mounding.

- not applicable

5.2 Catchment response to land clearing – literature summary

Introduction

This section presents a summary of the measurable effects that clearing of vegetation (bauxite mining and forest management) has on streamflow on experimental catchments located on the Darling Range some of them in the vicinity but not within the Myara North or Holyoake mining regions.

Decreased evapotranspiration of soil pore water, because of land clearing - including bauxite mining and forest harvesting is recognised as causing increases in catchment streamflow and increases in groundwater discharge areas within drainage lines (Grigg 2017).

The literature and information, presented in Appendix H was reviewed to obtain the following relevant and related data (where available):

– area of catchment cleared, and the related
– increases in measured streamflow

The information of percentage cleared area was taken directly from the published sources. Where the changes to leaf area index information (LAI) were presented in the literature, the percentage area of cleared catchment was not estimated.

Results

The information based on the literature review (primarily derived from Bari and Ruprecht 2003), has been summarised and presented in Table 5-3, in addition the data in Table 5-3 has been plotted and presented in Figure 5-1.

Grigg (2017) identified little difference in streamflow response between mining areas and areas subject to intensive thinning treatment. As a consequence, the bauxite mining and forest thinning effects on streamflow have been presented together Figure 5-1.

A review of the literature and data (Table 5-3 and Figure 5-1) shows following key points:

– The estimates of natural catchment groundwater outflow, measured via streamflow (control catchments where no clearing occurred) were found to vary considerably from 0.7% to 27% of rainfall (Bari and Ruprecht 2003), however, Table 5-3 indicates an average of 10.6%, which is close to 9.6% recorded for Jack Rocks in Myara North during 1981 to 1999.
– A reasonable correlation exists between streamflow increases (% of rainfall) compared to cleared area (%), with a linear R-squared value of 0.8 (value not shown on Figure 5-1). Presumably, where more densely forested areas are cleared, the effects on streamflow increases would be more pronounced, and visa-versa.
– There appears to be an upper limit to increases in streamflow, of close to 30% of rainfall based on 100% clearing (Figure 5-1).
– Studies have shown that bauxite mining results in peak increases to surface water flow of between 8% to 23% of rainfall, followed by a return to, or below, pre-mining flow conditions roughly 11 to 15 years after mining (Ruprecht and Stoneman 1993; Bari and Ruprecht 2003; Croton and Reed, 2007; Grigg 2017).
– Studies in the Intermediate Rainfall Zone, for example in the Cameron catchment (e.g. Croton et al. 2011) showed little effect of mining on streamflow. In areas where regional groundwater resides below the valley floor, additional recharge was observed insufficient to raise groundwater levels sufficiently enough to produce or increase baseflow. This effect may at least partly occur in the Holyoake region, where measured groundwater levels were shown to be comparably deeper (i.e. typically more than 10 m below ground level). For that catchment it was suggested that a rainfall year above 1,150 mm would be needed to produce streamflow.

Table 5-3 Summary of clearing % and catchment response.

Clearing type	Catchment name	Cleared (%)	Streamflow (% of rain)	Streamflow increase (% of rain)
Catchments where clearing was not undertaken:				
Jarrah forest *	(eight catchments)	none	10.6	0
Catchments where clearing was undertaken:				
Cleared for Agri (1977)	Wights [1)]	100	*ND*	32
Cleared for Agri	Lemon [3)]	54	*ND*	17
Clear felled - 80% basal area	Hansen [1)]	80	*ND*	19
Clear felled - 60% basal area	Higgins [1)]	60	*ND*	12
Clear felled - 60% basal area	Jones [1)]	60	*ND*	8
Bauxite mining	Del Park [1)]	30	*ND*	8
Bauxite mining	Seldom seen [1)]	34	*ND*	20
Bauxite mining	More Seldom Seen[1)]	62	*ND*	20

* Water yield from the eight forested control catchments highly variable, (standard deviation of 9%, No = 8)

1) High rainfall zone (>1,100 mm), 2) Intermediate rainfall zone (900 to 1,000 mm), 3) low rainfall zone (<700 mm)

ND = No data or information

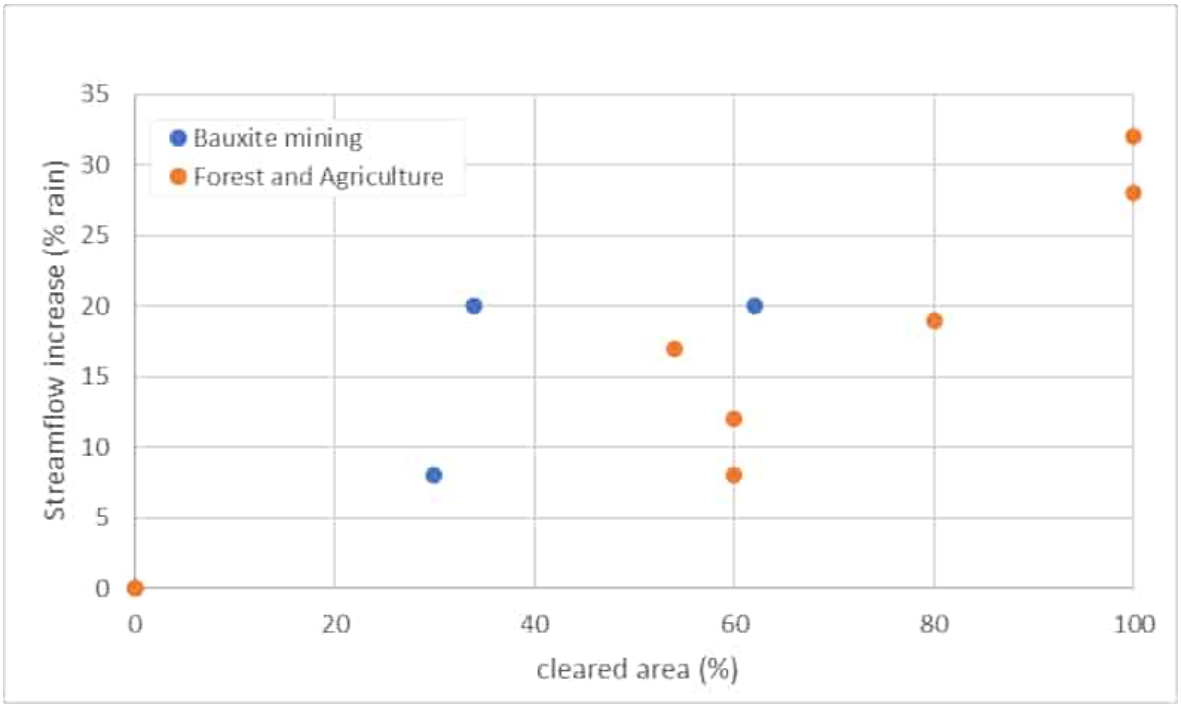


Figure 5-1 Relationship between cleared area (%) and increases in streamflow (% rainfall)

5.3 Key conceptual components of stream and aquifer interaction at Myara North and Holyoake

5.3.1 Introduction

The GDEs, wetlands, and aquatic ecology are the key ecological receptors to any changes in the hydrological system - such as groundwater level rise and increases or decreases in groundwater discharge, which may occur through vegetation clearing and bauxite mining activities. Also included are the drinking water reservoirs which are situated at the downgradient parts of the catchment.

Section 2.4.8 and 2.4.9 presents a description and location of the mapped and inferred GDEs and wetlands, which occupy the topographical low points and drainage lines of the Myara North and Holyoake proposed mining regions.

The following sections present the relevant hydrological conceptual models and discuss the potential hydrological impacts to the GDEs and wetlands as a consequence of bauxite mining.

5.3.2 Hydrological scenarios relating to GDEs source water

Presentation of generalised hydrological scenarios

The sources that support the GDEs through shallow groundwater flows or discharge to surface water flow have been conceptualised as follows.

Three potential surface and subsurface sources of water which may support the GDEs and wetlands are considered (Figure 5-2):

– **Surface runoff** – the proportion of rainfall flowing down-slope on the surface. It is short-term and proportionally small due to rainfall infiltration into the subsurface and roughness due to forestation. The shallow sediments have spatially variable permeability which is higher than that of the underlying saprolite profile.
– **Occasional near-surface flow in variably-saturated shallow subsurface** – a patchwork of shallow subsurface flow within lateritic material/sands/gravels, which may discharge into the creek or riparian zone or merge with baseflow. This component of flow represents occurrences of lateral flow through otherwise mostly

unsaturated zone, perched above the less permeable saprolite clays or basement material of low permeability. The proportion of flow may occasionally exfiltrate (for example on encountering outcrop, or less permeable soil) and then infiltrate again, or removed by e.g., evaporation or evapotranspiration.

– **Baseflow - groundwater discharge** where the topographic low points (e.g., creeks, wetlands) intersect the regional groundwater table. For shorter periods after rainfalls the flow overcomes evapotranspiration in the riparian zone and discharges as baseflow into the stream.

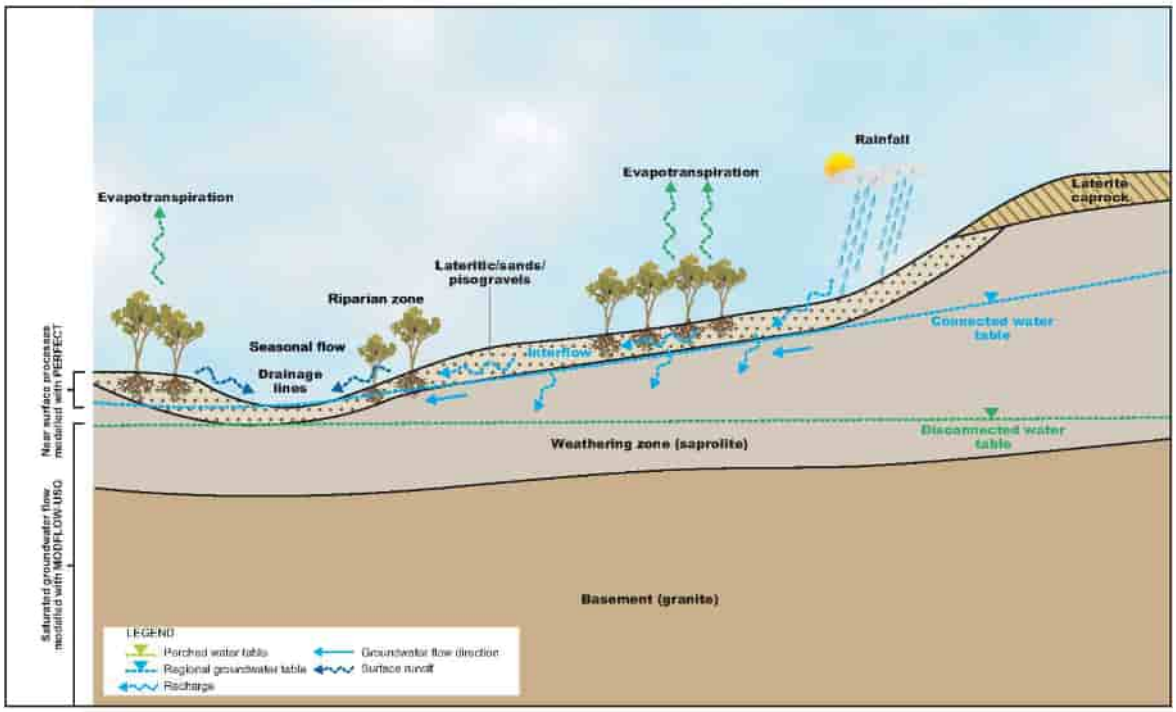


Figure 5-2 Conceptual representation of surface water groundwater interaction

Previous studies relating to hydrological scenarios

The key outcomes from available published sources regarding the understanding of relative contributions to streamflow from groundwater and interflow, are summarised as follows:

– Churchward and Dimmock (1989) presented a generalised soil profile of the northern jarrah forest, in which a schematic and description indicated a shallow soil profile (e.g.: 1 to 3 metres thick), which transmits shallow subsurface water flows. The generalised surficial profile comprises:
  - **Topograhically elevated areas**: lateritic duricrust (which may be vuggy and permeable)
  - **Middle slope**: sandy gravels/pisolitic (moderate permeability)
  - **Lower slope/valley**: sands grading into loamy deposits (medium to low permebility):

– Where present and relatively continuous, this shallow soil profile is underlain by clayey saprolite (which have low permeability), or occasionally granite basement subcrops facilitating perched shallow subsurface flow down the topographical gradient towards the valley floor and drainage lines (interflow or groundwater flow where regional watertable is shallow). The lateral extent and permeability of the surficial soils is not known in detail within the Myara North and Holyoake mining regions, however the broad distinction can be based on distribution of land systems associated with mapped soil and vegetation complexes (Figure A-5 and Figure A-6).

– (Grigg and Kinal 2020) presented a summary of references relating to a hydrological conceptual model describing shallow subsurface flow developed in laterally extensive shallow surficial materials (regolith). The shallow surface material which exhibits high infiltration rates, is underlain by clayey saprolite with low permeability, and is presented as an important flow path for supporting streamflows in the Darling Range. The authors evaluated geochemical and hydrological information, and presented an alternate conceptual model relating to streamflows to groundwater discharge and concluded the "*direct contribution of groundwater to streamflow in laterite catchments of the Darling Range in south-western Australia is far more variable across*

catchments and through time than has previously been acknowledged". This variability is also supported by a simple analytical model of the Jack Rock gauge streamflows presented in Section 3.11.

5.4 Understanding of risk of bauxite mining impacts on receptors

Groundwater level change and impacts to GDEs

Bauxite mining involves vegetation clearing which decreases evapotranspiration losses via interception and transpiration and promotes shallow and deep infiltration. The Leaf Area Index (LAI) values for typical jarrah forest areas of 1.5 to 1.7 will effectively decrease to zero.

Localised changes to the terrain morphology (shallow mine pits) may result in time-limited ponding (accumulation of water in the pit) after the rainfall events, possible interruption of local quickflow processes which enhances the deep drainage.

Bauxite mining at Myara North and Holyoake will cause a combination of local groundwater level rises, or mounding, initially beneath the mined/cleared areas. They will rapidly dissipate outside of mining pits towards the discharge boundaries where GDEs and wetlands are located.

Where groundwater level rises beneath the GDEs are small (e.g., 0.5 to 1 metre) and short lived, the increase is unlikely to be of significance, given the natural variability of seasonal groundwater level changes and the fact that increases in groundwater levels are offset by the observed long-term declining trend in groundwater levels (see Section 5.1) These small changes in groundwater levels are also unlikely to cause a considerable/measurable increase of groundwater discharge as baseflow.

Small changes in groundwater levels and discharge can be expected where the mining footprint is relatively small within the catchment and is located some distance from the potential GDE and wetland receptors (e.g., greater than 500 meters).

However, groundwater mounding effects on the potential GDEs, wetlands and aquatic ecology of the streams, will be more pronounced where groundwater level rises on top of natural variations are larger (e.g., 2 to 5 meters) and increases in discharge occur, such as potential GDEs and wetlands located close to the mining footprint (e.g., less than 200 to 300 meters), or where the mining footprint is large compared to the catchment area.

Following mining, rehabilitation of mining pits will result in gradual re-establishment of vegetation and associated water uptake. Some effects of ponding may remain where pits leave local depressions in the area topography and promote localised infiltration if re-establishing vegetation does not fully intercept or transpire available water. The LAIs for rehabilitated areas are slightly higher (approximately 2) as estimated by Lu et al. (2001), but were also shown to be larger than 2 (McFarlane et al. 2017). It is likely that some of the differences between Alcoa-supplied rehab LAI and forest LAI estimated by Lu et al is down to methodological differences

Changes to runoff components are also likely to occur (due to the terrain morphology changes) but are expected to be minor.

Water quality risks derived from soil salinity

A review and summary of the relevant investigations and literature (Appendix H) from Darling Range, relevant to salinity indicates the following:

– Soil investigations in the 1980s identified a gradual increasing spatial trend in soil salt content between high rainfall areas (HRZ) and lower rainfall areas (IRZ) on the Darling Plateau (Slessar, Murray and Passchier 1983, Tsykin 1989). Low soil salt storages were identified within the soils in areas within and to the west of the HRZ (Tsykin 1989).
– Predictive large-scale rainfall-runoff modelling, undertaken by DWER, was considered conservative and overestimated the impacts of mining, but has nonetheless indicated it was unlikely there will be a significant salinity response due to Alcoa's mining in the IRZ under current rainfall regimes. (DWER 2019).

Given the locations of Myara North and Holyoake mining regions mostly reside within or are to the west of the HRZ, the literature indicates that salt storage within the soils is low, and that the risk of mobilisation of salts from

soil storage, during mining and potential changes to the hydrological system is considered low (rising groundwater levels).

Water quality risks derived from increased groundwater discharge

The groundwater salinity information presented in Section 3.6, indicates that the average salinity of the groundwater increases from west to east, within both the Myara North and Holyoake mining regions , from an average of close to 200 mg/L in the western parts to an average of close to 400 mg/L in the eastern parts (based on 5 km spaced north-south windows).

The groundwater salinity trend data from the Myara North, from 25 monitoring wells (see section 3.6) indicates that although the data in a number of the bores is variable (possible well integrity issue) the groundwater salinity of the Myara North region appears to be relatively stable over the three decades of monitoring (1990 to 2020).

Given that the groundwater salinity is moderately fresh and appears stable in concentration over the long-term, where groundwater discharges into the lower lying drainage lines, mining effects and any increased groundwater discharge should be minor in terms of increased risk of salinity impacts on the GDEs and drinking water supply. This is due to a potential increased proportion of groundwater discharge into the streams during mining (due to groundwater level rise) with the minor increase in the salinity of streamflows and water remaining fresh.

Given that the soils of the have a low salt storage the risk of mobilisation of salts from soil storage and associated increase of TDS in discharge is considered low (rising groundwater levels).

6. Summary of findings

Generalised hydrological site setting

Regional groundwater, intersected at depths within the deep saprolite weathering profile (drilling by GHD) coincides with more permeable zones at the transition between the saprolite and the granitic bedrock (average hydraulic conductivities of 0.3 m/d at Myara North and 0.6 m/d at Holyoake).

Regional groundwater is inferred to flow in the direction of the topographical gradient towards the groundwater discharge boundaries, which include evapotranspiration from riparian zones and shallow groundwater areas; and seasonal (winter) discharge into creeks.

The less permeable clayey saprolite zone is overlain by discontinuous shallow surficial material, comprising laterite (caprock) in elevated areas, grading into pisolite and sands/loams within the lower lying valley areas. Although the thickness, continuity and lateral extent over the proposed Myara North and Holyoake mining areas is spatially not well defined, the existing information suggest that surficial sediments have a thickness of 1 to 3 metres. Given the inferred lack of continuity the surficial material do not always comprise a contiguous permeable unit.

Where present, the surficial sediments transmit shallow subsurface water flows (perched above saprolite clays) during winter rainfall, in the direction of the topographical slope, and towards the discharge boundaries (e.g., drainage lines), where this discharge supplements surface water flows. Such a flow is considered to be patchy and non-contiguous and its geometry hard to constrain by the existing data. Grigg (2017) argued that such shallow flow is largely limited to lower slopes abutting the valley floors.

Myara North hydrological site setting.

In Myara North's elevated areas on hills and ridges, the depth to water is typically 15 to 30 m below ground level, while in the valley floors and in the creek lines (where potential GDEs are mapped), the depth the groundwater is generally less than or between 2 to 5 meters below ground level in higher rainfall (or lower LAI) areas, but can be deeper in the lower rainfall parts of the jarrah forest catchments. The mapped potential GDEs can also be associated with a shallow perched but leaky system in the valley floor which gets waterlogged in winter but desiccates in summer (Fordyce et al. 2007).

Assessment of the long-term groundwater level trends in 24 Myara North Alcoa monitoring bores, with suitable long-term data, indicates that a total of 22 of the monitoring wells exhibit declining groundwater levels, with an average of a 4.5 metre decline over the period (1990 to 2020). The salinity over the similar period - the average of 24 monitoring wells, is indicated as stable, with perhaps a slight decrease of 100 mg/L indicated over the period (standard deviation of 400 mg/L). The average groundwater salinity derived from Alcoa and newly installed GHD monitoring bores (No.18) is close to 300 mg/L.

The monitoring bores (Alcoa and GHD bores) are primarily screened at the transition zone between the saprolite and bedrock, but two recently installed surficial monitoring bores, located in two separate subcatchments within Myara North mine region, (nested with deeper bores), indicate two conceptual scenarios: 1) shallow groundwater supported by regional groundwater levels, and 2) shallow groundwater perched above regional groundwater.

To elucidate surface water and groundwater connectivity, surface water flow monitoring data (two sites within the Myara North mid/lower catchment), indicates that streamflows are relatively short-lived following winter rains, ceasing to flow within 2 to 3 weeks following peak surface water flows. These "quickflow" components, together with salinity streamflow data support derivation of streamflow from the shallow subsurface with limited storage, such as through surficial sediments and runoff during winter rainfall (TDS 150 mg/L) and discharge of regional groundwater during low rainfall periods (TDS 350 mg/L).

Holyoake hydrological site setting

The 2020 installed monitoring bores (17 in total), generally positioned within and close to the drainage lines and valley floors (where GDEs are located), indicate the depth to groundwater is generally greater than 10 m below ground level (in the valley floor settings). These newly installed monitoring bores and the several available older

Alcoa monitoring bores located outside the development boundary, are both screened at the transition zone between the saprolite and bedrock. No shallow zone monitoring bores were installed.

Hydrographs from six Alcoa monitoring wells (positioned outside the Holyoake development boundary) indicate declining groundwater levels with an average of close to nine metre decrease over the period of monitoring (1990 to 2020).

There is insufficient long-term monitoring data to draw conclusions on groundwater salinity trends, however the average TDS derived from Alcoa monitoring bores and newly installed GHD monitoring wells is close to 400 mg/L.

The depth to water in the valley floors (>10 metres) indicates that the recently mapped potential GDEs are better characterised as occurring on shallow perched groundwater systems which are sustained in winter by rainfall and dry up in summer. Regional groundwater supports the potential GDEs mostly in low-lying areas along the western boundary of the Holyoake region (closer to South Dandalup Dam) but generally lacks connection to the valley floors in other parts of the catchment.

Surface water flow monitoring data is limited, and inferences related to streamflow response and conceptual models could not be drawn (e.g. relative proportion of baseflow and quickflow components).

Surface water groundwater interaction

Seasonal (winter) rainfall increases the overall storage of water in the catchment and results in seasonal creek flows. The streamflows are relatively short-lived – they generally cease within a few weeks or months.

Streamflows comprise the baseflow and quickflow components, the proportion of which in the streamflow changes through the seasonal streamflow event. The quickflow components (surface runoff and interflow) dominate during the initial and possibly peak flow stages while baseflow dominates during the later stages, including the recession part of the streamflow curve.

Surface water and available groundwater hydrographs are well aligned and show the seasonal peaks suggesting a synchronised interaction between surface and subsurface flow systems.

The relationship between rainfall events, groundwater level increases and streamflow occurrences is considered relatively straightforward and well established. A simple analytical model was developed to explore the relative contributions of quickflow and baseflow components, including groundwater recharge, constrained by TDS of two principal end-members (quickflow and baseflow). Streamflow data from the Jack Rocks gauge spanning 1981 to 1999 period 9the best available dataset for the two development areas) was used for this assessment.

This work indicates that a relatively wide range of baseflow contributions (examples included in this report range between 18 to 50% of streamflow) is possible, consistent with the more recent research (e.g. Grigg and Kinall, 2020). The recharge rate changes directly affect the baseflow contribution, hence any changes to recharge rates through land use interventions will affect streamflows.

Assessment of potential mining impacts

The effects of mining and land clearing on the groundwater levels, groundwater discharge zones and streamflows have been presented in former studies (e.g. Grigg, 2017; Bari and Ruprecht, 2003). In analogue catchments, located on the Darling Range, vegetation clearing and bauxite mining caused an increase in streamflow (7% to 30% of rain) deemed as due to an increase in groundwater levels and the associated increase in groundwater discharge, measured as streamflow.

An assessment of a former mining area located on the southern boundary of the Myara North study area (see Section 5.1), indicates rising water levels following bauxite mining, close to a minimum of 5.5 m averaged across nine groundwater monitoring wells, despite the overall declining groundwater trend attributed to decrease of rainfall over the last three decades.

The data and information on Myara North mining region (data is sparse for Holyoake region but some inferences can be made from neighbouring experimental catchments) indicates that streamflows are supported by both quickflow (interflow+ runoff) and baseflow components, but that the relative contributions to streamflow in each subcatchment is not sufficiently understood (in particular where streamflow data is not available).

The effects of open cut mining exhibit as follows:

1. Excavations of any laterally continuous surficial layer during mining redirect larger volume (then during pre-mining phase) of water to deep drainage.
2. Local groundwater level rises, or mounding, initially beneath the mined/cleared areas, will increase groundwater storage and will gradually dissipate outside of mining pits towards the discharge boundaries where some of the potential GDEs and wetlands are located.

When considering impacts from bauxite mining, conceptual models which incorporate streamflows derived from quickflow components and deeper regional groundwater discharge should be considered when developing the understanding of risk to the receptors across numerous sub-catchments and wider site (until site-based evidence indicates otherwise)

Observable and distinguishable salinity impacts to the GDEs, aquatic ecology and drinking water supplies (via surface water flows) from raised groundwater levels and groundwater discharge (due to mining) are not anticipated, given that soils of the area have a naturally low salt storage.

Minor salinity changes in streams during mining may occur as a result of increased proportion and volume of groundwater discharging as baseflow. However, groundwater TDS is still relatively low and stable over the long-term (average salinities Myara North 300 mg/L and Holyoake 400 mg/L) and a slight rise of TDS due to potential increase in regional groundwater discharge should not impact the beneficial use of surface water.

Recommendations:

Given the potential for mining activities to influence the potential GDEs and wetlands, through rising water levels and groundwater discharge during mining, it is recommended to quantify the magnitude and duration of effects at these receptors through numerical modelling of conjunctive groundwater and surface water flow.

Where the predictive estimates indicate a change in groundwater levels and discharge is within the historic range, then effects on the potential GDEs are not anticipated. Where reviewing the historical range, consideration should be given to the declining groundwater levels over the long-term commensurate with a potential shift in the ecological communities and adaptation and accommodation of the GDEs these to lower groundwater levels.

Mining has the potential to reduce or reverse the currently on-going decline in groundwater levels and increase surface water flows, including flows into the reservoirs (Serpentine, and less so for South Dandalup). Confirmation of these effects would benefit from installing gauges near the inflow points of major drainages, with high-density measurements of flows and EC.

An assessment of the sensitivity of the potential GDEs to increases in groundwater levels and increased discharge over the duration of mining impacts should be undertaken to evaluate the likelihood of impacts to the ecological setting.

7. References

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Appendices

Appendix A

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Figure A-3 Location and boundaries of Holyoake proposed development area
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Figure A-14 Myara North depth to groundwater (meters)
Figure A-15 Myara North average bore salinity
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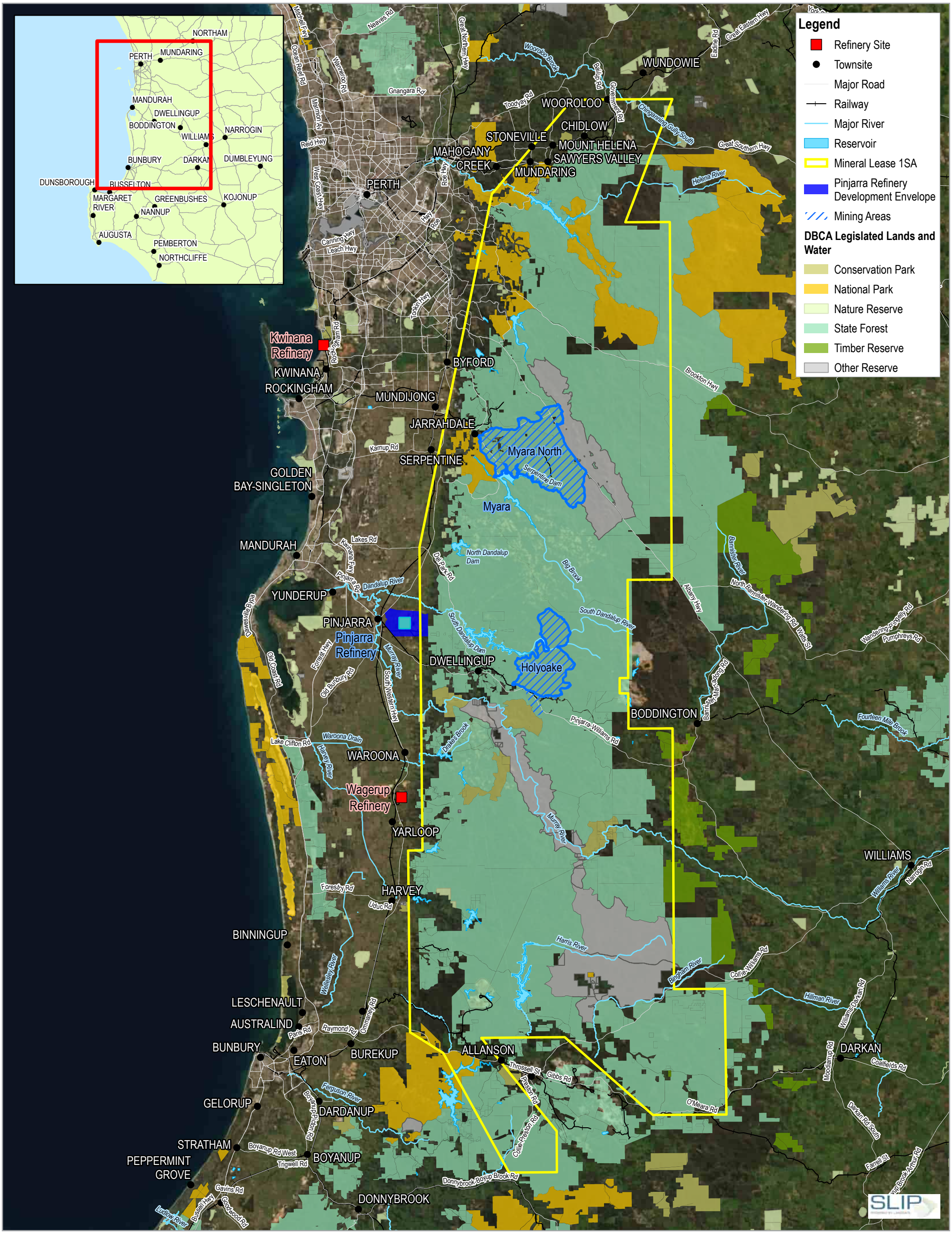
Figure A-17 Holyoake average bore salinity



Paper Size ISO A3

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Kilometres

1:600,000

Map Projection: Transverse Mercator

Horizontal Datum: GDA 1994

Grid: GDA 1994 MGA Zone 50

N

Alcoa of Australia Limited

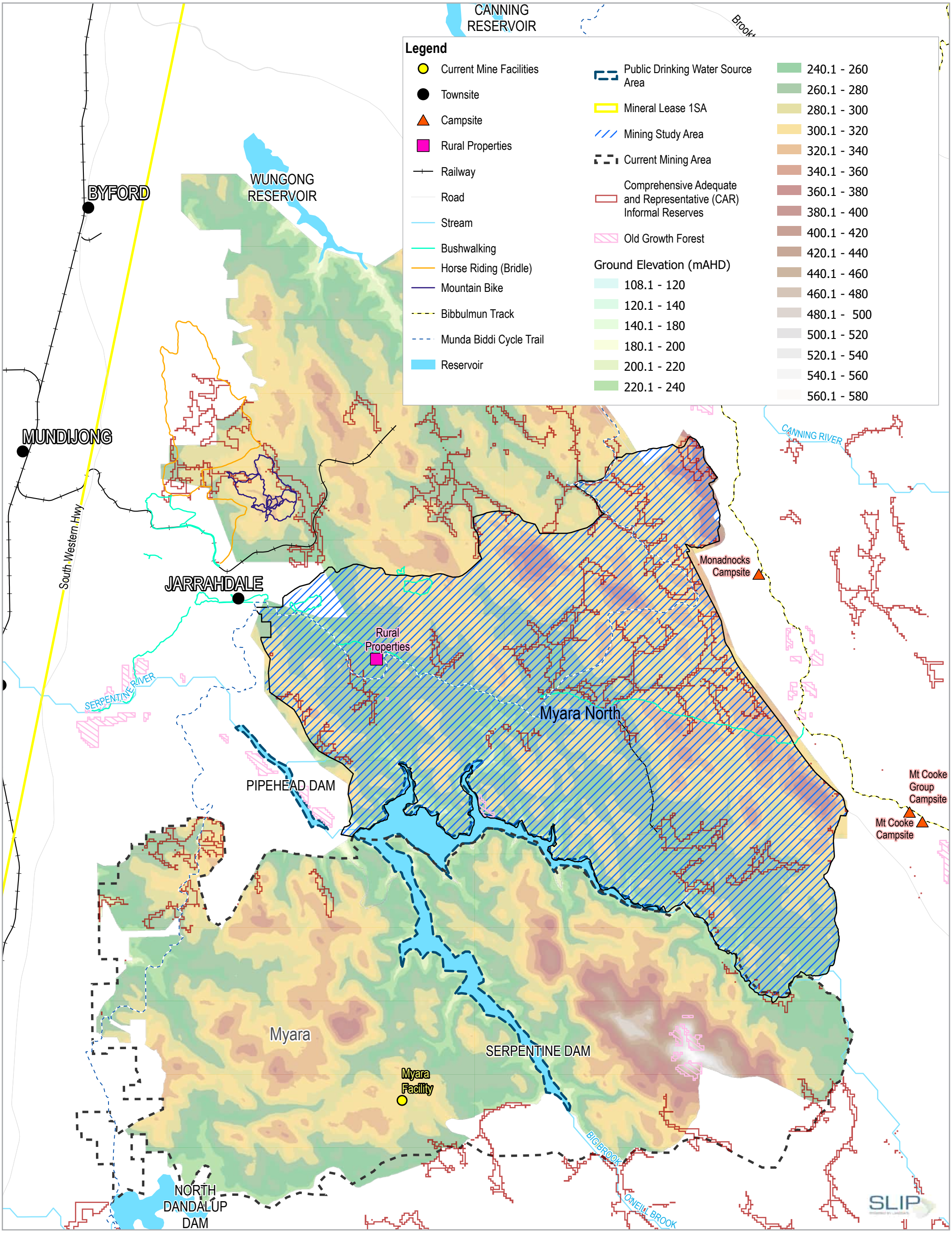
Locality Plan and Development Envelope

Project No. **12520591**
Revision No. **0**
Date **3/06/2021**

FIGURE A-1

\\ghdnet\ghd\AU\Perth\Projects\61\12520591\GIS\Maps\Working\12520591-MAP-A-SW\12520591_Hydrology_Overview_MM.aprx\12520591_001_LocalityPlanAndDevelopmentEnvelope_Rev
Print date: 03 Jun 2021 - 16:24

Data source: Alcoa: Refinery Sites, Huntly Mine boundary, Pinjarra Refinery, Development Envelope - 20200403, Holyoake Conveyor Corridor, Conveyor/Haul Road Envelope - 20200605; DBCA: Legislated Lands and Water - 20190301; DoW: Rivers, Reservoir - 2200221; Landgate: Roads - 20190128, Railway - 20190304, World Imagery: Earthstar Geographics. Created by: mmatar



Paper Size ISO A3

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Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

Alcoa of Australia Limited

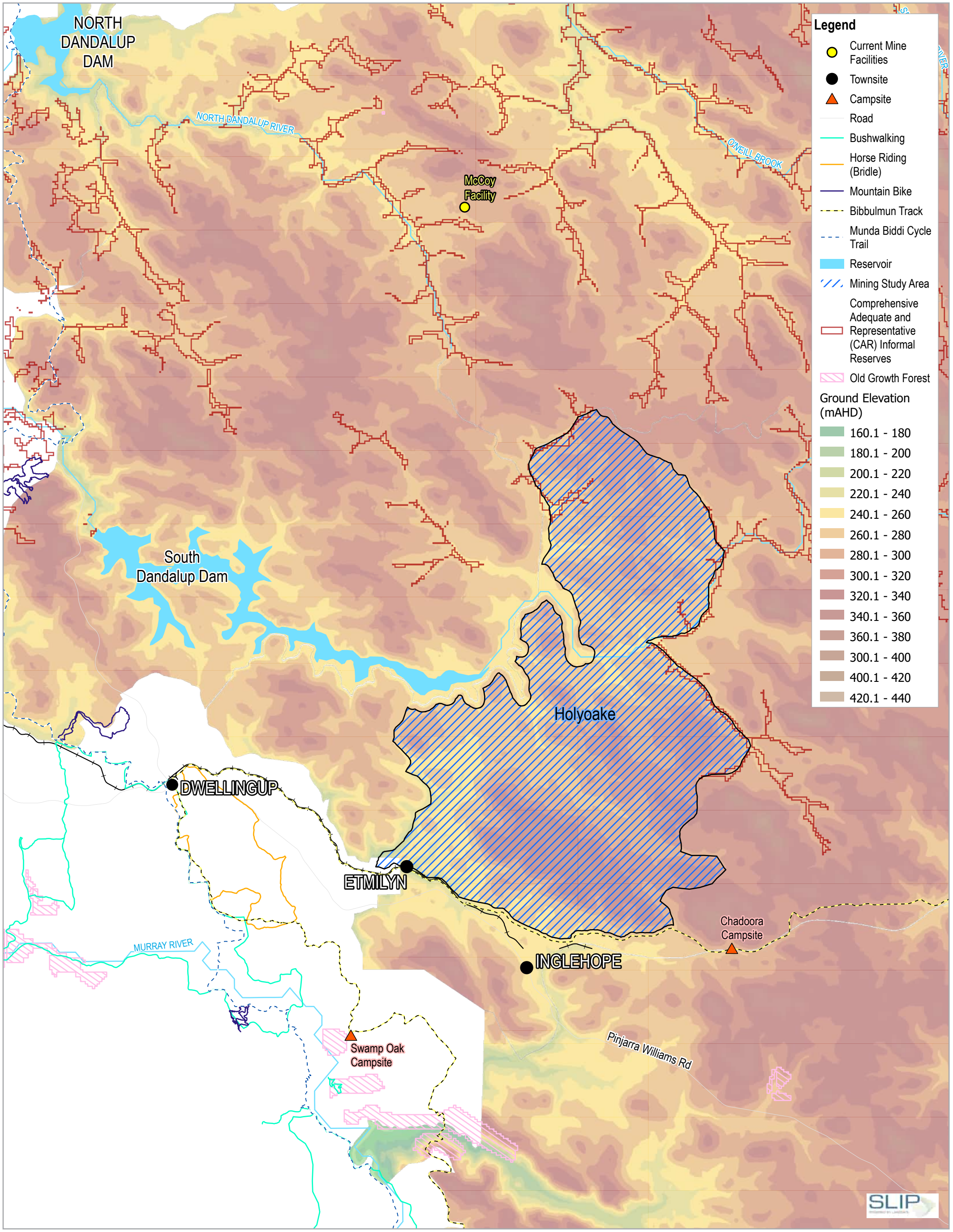
Location and boundaries of Myara North proposed development area

Project No. **12520591**
Revision No. **A**
Date **03/06/2021**

FIGURE A-2

\\ghdnet\ghd\AU\Perth\Projects\61\12520591\GIS\Maps\Working\12520591_EnvironmentalReviewDocument\12520591_EnvironmentalReviewDocument - MMatar.aprx\12520591_2-6_MyaraNorthLocalContext_RevA1
Print date: 08 Jun 2021 - 13:30

Data source: Alcoa/GHD: Refinery Sites - 20200221, Mine Development Envelope, LiDAR Elevation - 20200626 Mining Areas - 20210125; DMIRS: Mining Tenement - 20180719; DBCA: Legislated Lands and Water - 20200301; DoW: Watercourse - 20200221; Landgate: Railway - 20190304, Roads - 20190114,accessed 20200204. Created by: mmatar



Paper Size ISO A3

0 1 2 3 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

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GHD

Alcoa of Australia Limited

Locations and boundaries of Holyoake proposed development area

Project No. **12520591**
Revision No. **A**
Date **03/06/2021**

FIGURE A-3

\\ghdnet\ghd\AU\Perth\Projects\61\12520591\GIS\Maps\Working\12520591_EnvironmentalReviewDocument\12520591_EnvironmentalReviewDocument - MMatar.aprx\12520591_2-7_HolyoakeLocalContext_RevA1
Print date: 08 Jun 2021 - 13:38

Data source: Alcoa/GHD: Refinery Sites - 20200221, Mine Development Envelope, LiDAR Elevation - 20200626, Mining Areas - 20210125; DMIRS: Mining Tenement - 20180719; DBCA: Legislated Lands and Water - 20200301; DoW: Watercourse - 20200221; Landgate: Railway - 20190304, Roads - 20190114,accessed 20200204. Created by: mmatar

420,000 430,000

6,430,000 6,420,000 6,410,000

Legend

- Myara North Boundary
- Waterways
- GDE (maped by Matiske)
- 10yr mine plan Myara North
- Previous Myara bauxite mining areas

Paper Size A3

0 350 700 1,400 2,100

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

Alcoa of Australia Limited
Conceptual Model

Myara North proposed bauxite mining areas and GDEs

Job Number 12520591
Revision A
Date 22 Jun 2021

Figure A-4

G:\61\12520591\GIS\Maps\Working\12520591-Conceptual_Model\12520591_MyaraNorth 10 yr plan.mxd

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Data source: Alcoa: Myara North Boundary 20210125, Stream 20200617, Installed Wells. GHD: Installed Wells 20210218. Mattiske: GDE (Mattiske Mapping). ESRI: Imagery accessed 20200807. Created by:phamer

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

410000 415000 420000 425000 430000 435000

6430000 6425000 6420000 6415000 6410000 6405000 6400000

Legend

- Myara North boundary
- GHD monitoring bore

Vegetation complex

- Cooke Complex
- Dwellingup Complex
- Goonaping Complex
- Swamp Complex
- Helena 1 Complex
- Murray 1 Complex
- Pindalup Complex
- Yarragil 1 Complex
- Yarragil 2 Complex

Karrakup Langford Park Gooralong Myara

Paper Size ISO A3

0 1 2 3

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

Alcoa of Australia Limited

Landform distribution
Myara North development area

Project No. **12520891**
Revision No. **1**
Date **18/06/2021**

FIGURE A-5

G:\61\12520591\GIS\Maps\Working\12520591-Conceptual_Model\12520591 veg complex-BCs-MN.mxd
Print date: 18 Jun 2021 - 13:04

Data source: Data source: Alcoa:Myara North Boundary GHD: GHD monitoring bores DBCA: Vegetation complex Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community. Created by: mmatar

415000 420000 425000 430000

6395000 6390000 6385000 6380000 6375000 6370000

Legend

- Holyoake boundary
- GHD monitoring bore

Vegetation complex

- Cooke Complex
- Dwellingup Complex
- Murray 1 Complex
- Swamp Complex
- Yarragil 1 Complex
- Yarragil 2 Complex

Yarragil 2 Complex
Yarragil 2 Complex
Yarragil 2 Complex
Yarragil 2 Complex
Yarragil 2 Complex
Yarragil 2 Complex
Dwellingup Complex
Swamp Complex
Swamp Complex
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Dwellingup Complex
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Cooke Complex
Yarragil 2 Complex
Swamp Complex
Dwellingup Complex
Yarragil 1 Complex
Cooke Complex
Yarragil 2 Complex
Cooke Complex
Swamp Complex
Yarragil 1 Complex
Yarragil 1 Complex
Yarragil 1 Complex
Dwellingup Complex
Cooke Complex
Murray 1 Complex
Yarragil 1 Complex
Yarragil 1 Complex
Yarragil 1 Complex
Yarragil 1 Complex
Dwellingup Complex
Yarragil 1 Complex
Yarragil 1 Complex
Yarragil 1 Complex
Dwellingup Complex
Yarragil 1 Complex
Dwellingup Complex

Edwards Rd
Nowra Rd
Wilde Rd
Holyoake
Duncans Rd
Dillon Rd
Vardals Rd
River Rd
Park Rd
Swamp Oak Rd
Yarragil Rd
Pindalup Rd
Wuraming

Paper Size ISO A3

0 1 2 3

Kilometers

N

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

Alcoa of Australia Limited

Landform distribution
Holyoake development area

Project No. **12520591**
Revision No. **1**
Date **18/06/2021**

FIGURE A-6

G:\61\12520591\GIS\Maps\Working\12520591-Conceptual_Model\12520591 veg complex-BCs-HLY.mxd
Print date: 18 Jun 2021 - 13:04

Data source: Alcoa:Holyoake Boundary GHD: GHD monitoring bores DBCA: Vegetation complex Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community. Created by: mmatar

400,000 410,000 420,000 430,000 440,000 450,000

6,430,000 6,420,000 6,410,000 6,400,000 6,390,000 6,380,000 6,370,000

SOUTHWEST MINERALISE

Holyoake

Myara North

Geology 250k

- Quaternary Sediments
- Tertiary Sediments
- Tertiary laterite
- Granitic Rocks
- Migmatite
- Marradong Fm (Mafic Volcanics)
- Wells Fm (Felsic volcanics)
- Gneissic, Darling Scarp
- Water

Source: Esri, Maxar, GeoEye, Earthstar Geo
the GIS User Community

Paper Size A3

0 0.5 1 2 3 4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

Alcoa of Australia Limited

Regional geology of Myara North and Holyoake development areas (GSWA 250K)

Job Number	12520591
Revision	A
Date	08 Jun 2021

Figure A-7

\\ghdnet\ghd\AU\Perth\Projects\61\12520591\GIS\Maps\Working\12520591-Conceptual_Model\12520591_GSWA 250k Regional geology of Myara North and Holyoake.mxd

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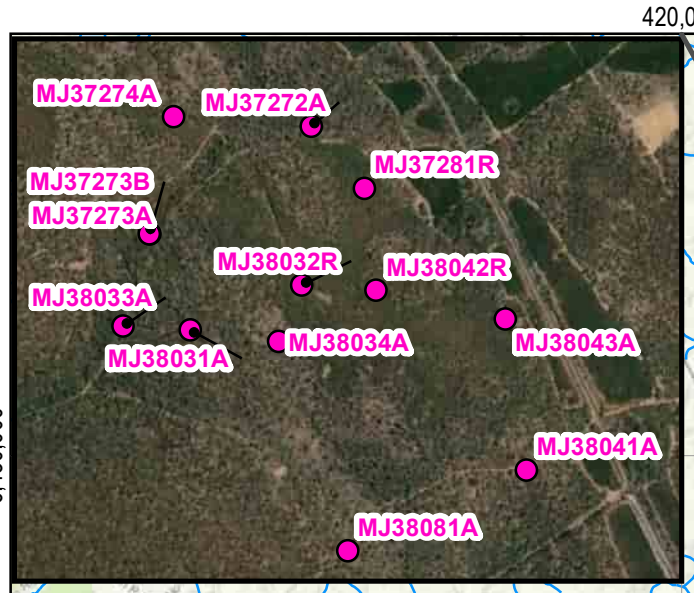

420,000

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MJ38101A
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ML40091A
ML40092A
ML40051A
ML40093A
ML40131A
MK40152A
MK40152B
MK40151A
B13
B17
B16_D
B16_S
B07
B12_D
B12_S
MJ39222A
B09
B24
B08
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MK42281A
ML42251A
ML43012A
ML43011A
ML43051A
MK43041A
MK42211A
MK42251A
MK43072A
MK43071A
Area of previous mining

Legend

- Installed Wells (GHD and Alcoa)
- Myara North Boundary
- Waterways
- GDE (Mattiske Mapping)

Paper Size A3

0 350700 1,400 2,100

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

Alcoa of Australia Limited
Conceptual Model

Myara North mining area monitoring bore location plan

Job Number	12520591
Revision	AF
Date	02 Jun 2021

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Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:sbright

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c)

422,500 425,000 427,500

6,425,000 6,422,500 6,420,000 6,417,500

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MK38218A MK38212A MK38217A MK38219A MK38251A MK38252A MK38253A MK38253B MK38254B MK38254A MK38259A
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MK40063A MK40064A MK40072A MK40071A MK40112A
MK40101A MK40111A
MK40102A

Randall Rd
Halstead Rd
Burkley Rd
Appian Rd
510 m
365 m

Legend

- Installed Wells (GHD and Alcoa)
- Myara North Boundary
- Waterways
- GDE (Mattiske Mapping)

Paper Size A3
0 350 700 1,400 2,100
Metres
N
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

Alcoa of Australia Limited
Conceptual Model

Myara North
Inset 1 to Figure A-8

Job Number	12520591
Revision	A
Date	08 Jun 2021

\\ghdnet.internal\ghd\AU\Perth\Projects\61\12520591\GIS\Maps\Working\12520591-Conceptual_Model\12520591_MyaraNorth_GDE_Wells_Insets.mxd

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Data source: Alcoa: Myara North Boundary 20210125, Streams 20200617, Installed Wells. GHD: Installed Wells 20210218. Mattiske: GDE (Mattiske Mapping). ESRI: Imagery accessed 20200807. Created by:sbright

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

420,000 430,000 440,000

6,400,000 6,390,000 6,380,000

MK43071A ML43051A

MK46121A ML46136A ML46135A MK46162A ML46133A ML46134A MK46161A ML46132A ML46131A ML46175A ML46176A ML46179A ML46171A ML46177B ML46215A ML46177A ML46211A ML46178A ML462210A ML46216A ML46214A ML46213A ML46216B ML46218A

MK45222A MK45141A MK45221A MK45211A MK46021A MJ45151A MJ45241A MK45261A MK45282A MK45281A MK45251A MK46071A MK46081B MK45251B MK46081A MJ46041A BH01 MK46061A BH02 MK45223A BH04 BH03 BH05 MM47171A BH06 BH07 MM48051A BH08 BH10 BH09 MM48211A BH11 BH12 ML49021A MK49151A MM49091A ML49171A BH14 BH13 ML49172A BH15 ML49173A MK49161A ML49281A BH16 ML49211A ML50031A ML50061A ML50161A MM50171A ML50071A BH17

Legend

- Installed Wells (GHD and Alcoa)
- Holyoake Boundary
- Waterways
- GDE (Mattiske Mapping)

Paper Size A3

0 350700 1,400 2,100

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

Alcoa of Australia Limited
Huntly Mine Extension

Holyoake groundwater monitoring bore location plan

Job Number 12520591
Revision A
Date 08 Jun 2021

Figure A-9

\\ghdnet.internal\ghd\AU\Perth\Projects\61\12520591\GIS\Maps\Working\12520591-Conceptual_Model\12520591_Holyoake_GDE_Wells.mxd

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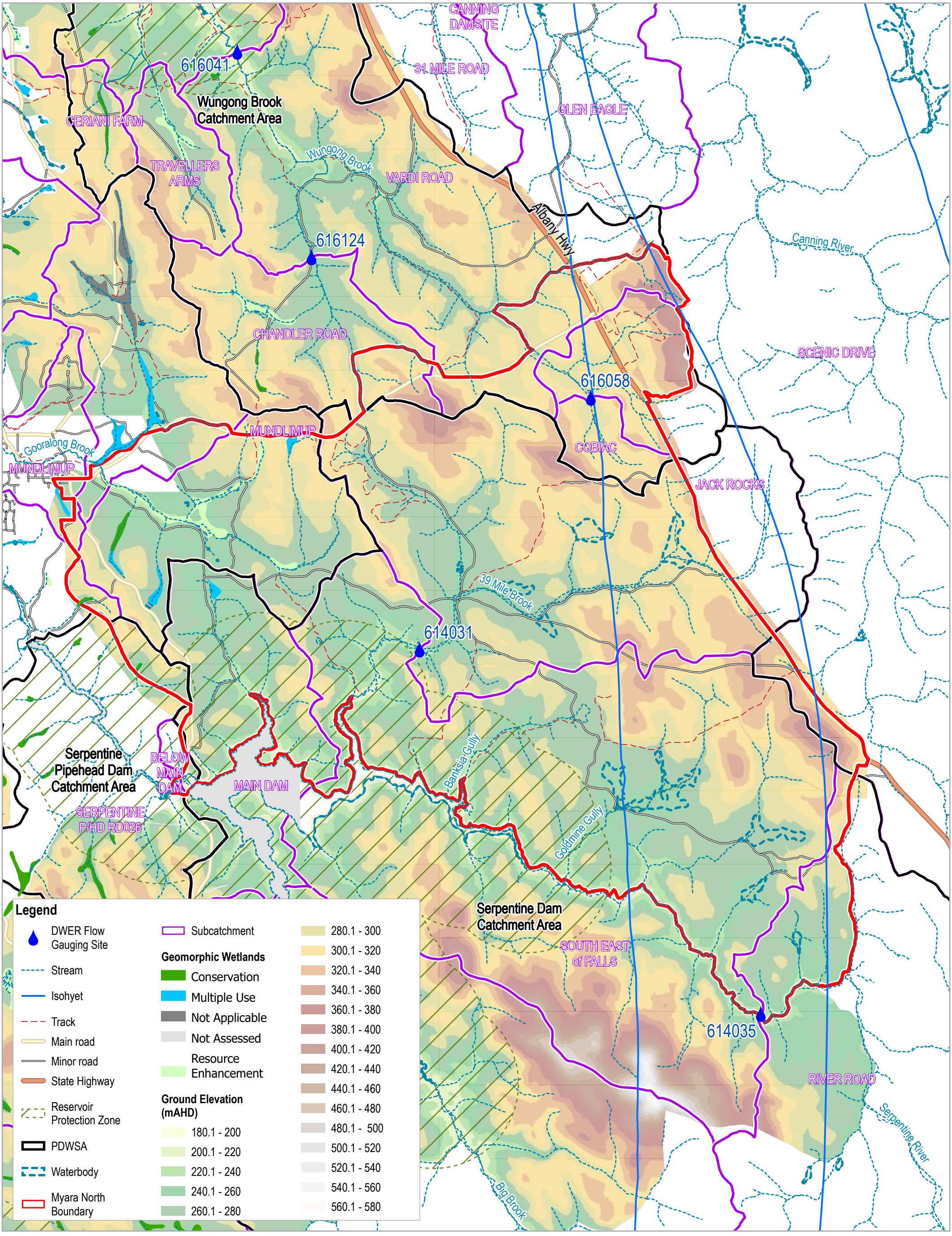
Data source: Alcoa: Myara North Boundary 20210125, Streams 20200617, Installed Wells 20210218. GHD: Installed Wells 20210218. Mattiske: GDE (Mattiske Mapping). ESRI: lagery accessed 20200807. Created by:sbright

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS



Paper Size ISO A3

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Kilometres

1:80,000

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

Alcoa of Australia Limited

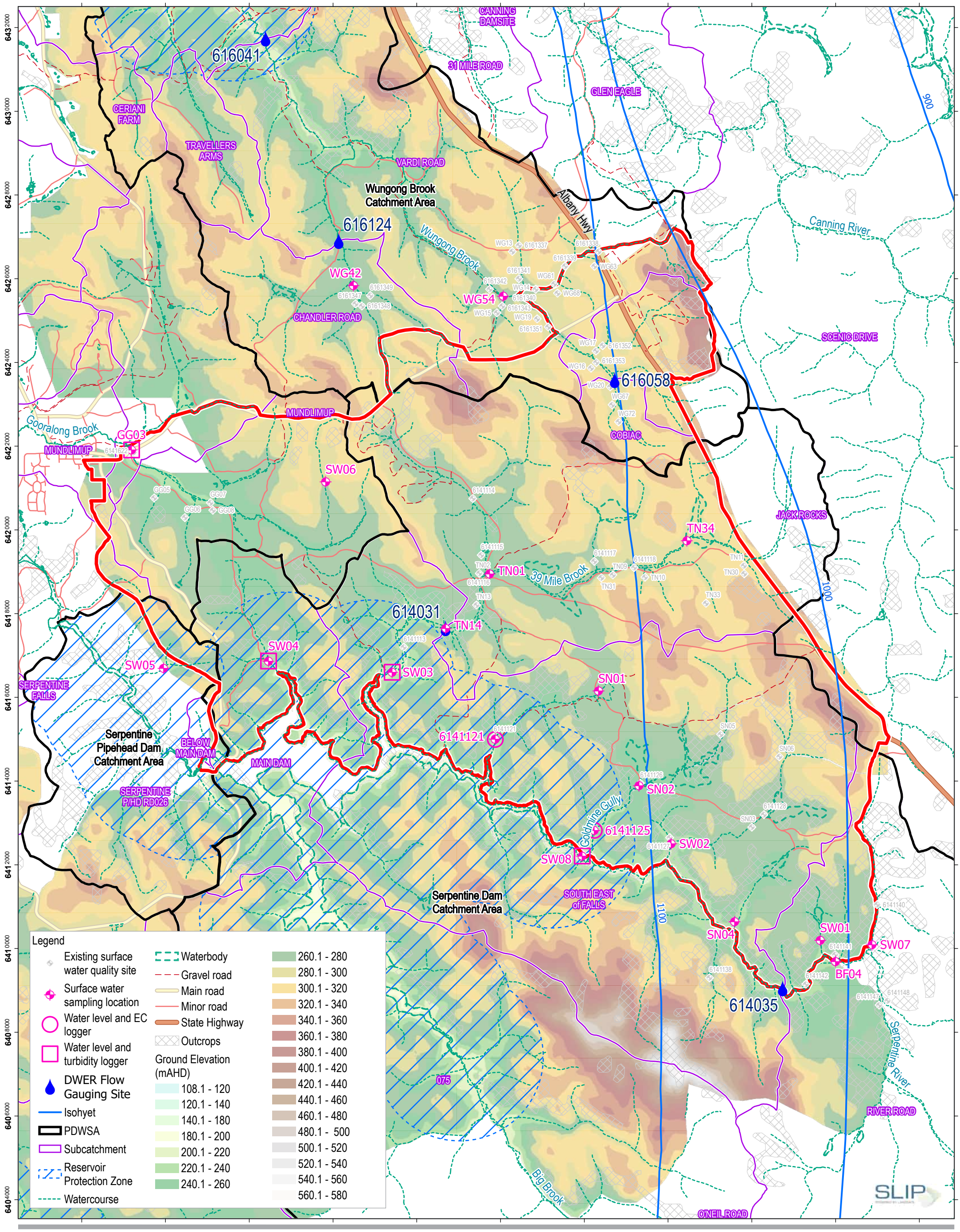
Myara North surface water features

Project No. **12520591**
Revision No. **0**
Date **8/06/2021**

Figure A-10

\\ghdnet\ghd\AU\Perth\Projects\61\12520591\GIS\Maps\Working\12520591-MAP-A-SW\12520591_Hydrology_Overview_MM.aprx\12520591_A-2_MyaraNorthCatchmentsAndDrainage_Rev0
Print date: 08 Jun 2021 - 16:23

Data source: GHD: Subcatchments - 20200624; Alcoa: Myara North Boundary - 20200618, LiDAR Elevation - 20200626, Reservoir Protection Zone, Isohyet - 20200225, Streams - 20200617; GA: SRTM - 20200526; DBCA: Geomorphic Wetlands 20200117 - DWER: SW Monitoring Sites - 20200629; DoW: PDWSA - 20160607; Landgate: Roads - 20190128, . Created by: mmatar



Paper Size ISO A3

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Kilometres

1:80,000

Map Projection: Transverse Mercator

Horizontal Datum: GDA 1994

Grid: GDA 1994 MGA Zone 50

N

GHD

Alcoa of Australia Limited

Myara North surface water monitoring locations

Project No. **12520591**

Revision No. **0**

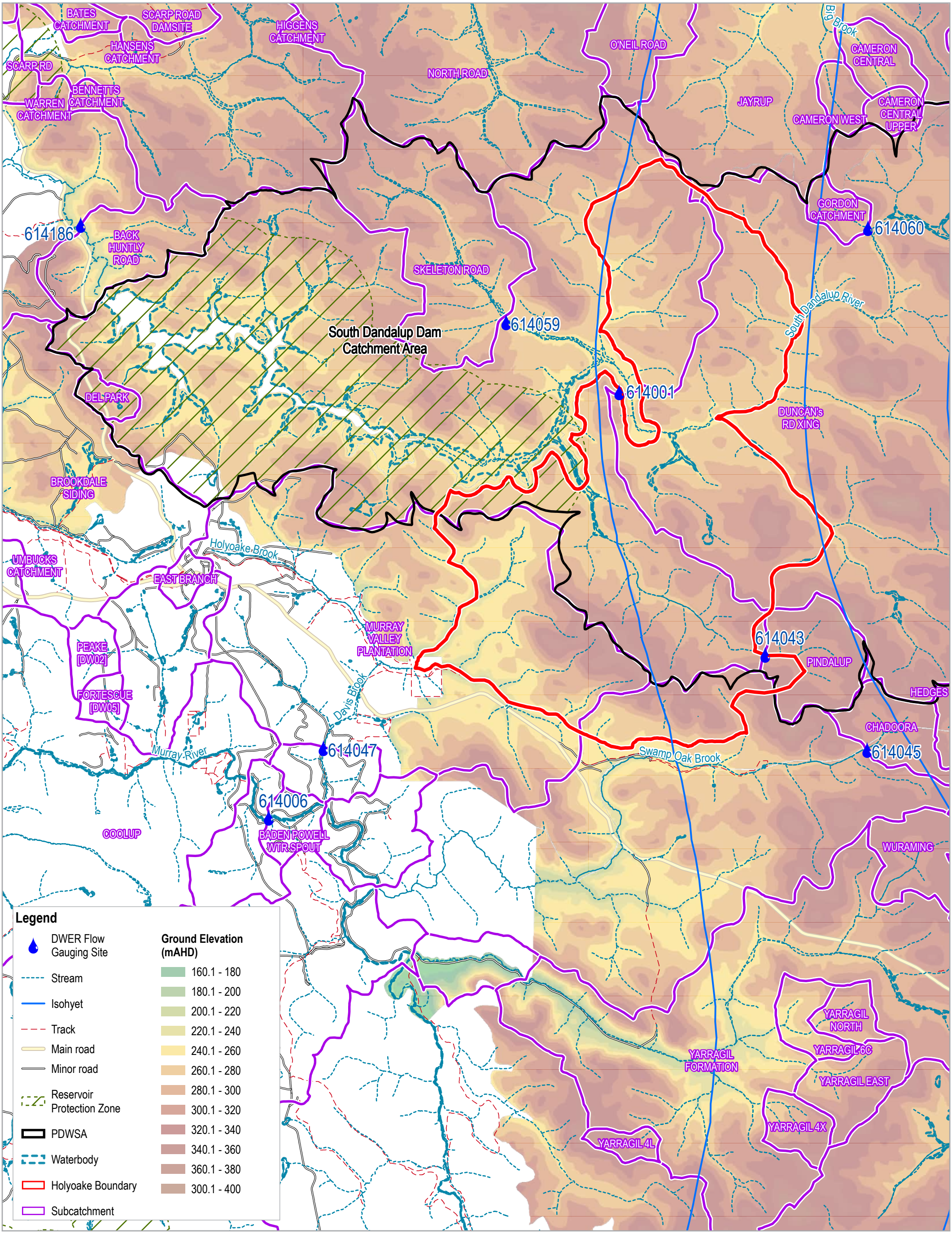
Date **8/06/2021**

Figure A-11

\\ghdnet\ghd\AU\Perth\Projects\61\12520591\GIS\Maps\Working\12520591-MAP-A-SW\12520591_Hydrology_Overview_MM.aprx\12520591_A-1_SAQP_MyaraNorthWaterMonitoringLocations_RevA

Print date: 08 Jun 2021 - 14:16

Data source: GHD: Proposed sites - 20200825, Subcatchments - 20200624; Alcoa: Myara North Boundary - 20200618, LiDAR Elevation - 20200626, Reservoir Protection Zone, Isohyet - 20200225, Streams - 20200617; GA: SRTM - 20200526; DWER: Existing Monitoring Sites - 20200629; DoW: PDWSA - 20160607; Landgate: Roads - 20190128, . Created by: mmatar



Paper Size ISO A3

0 0.5 1 1.5 2

Kilometres

1:90,000

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

Alcoa of Australia Limited

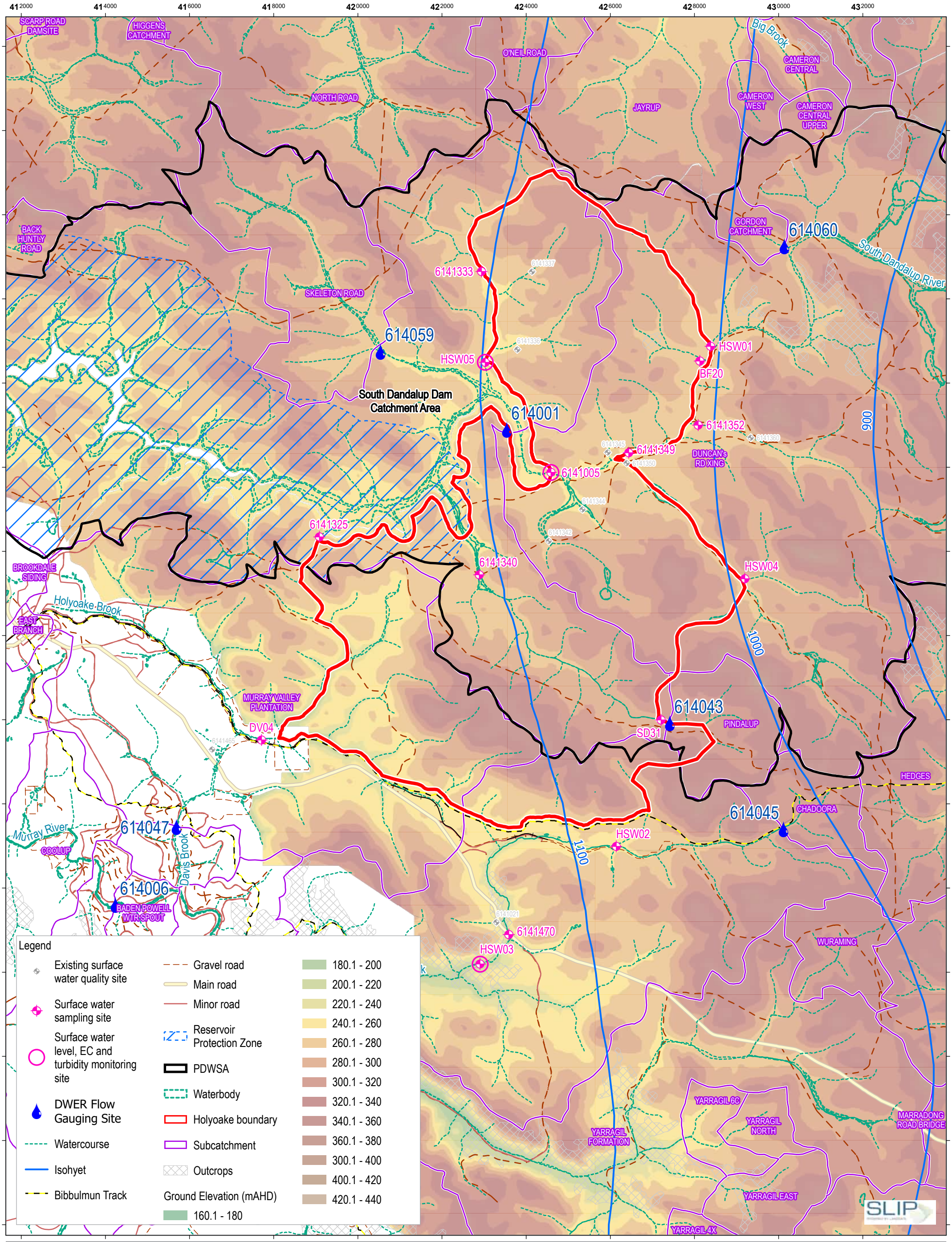
Holyoake
surface water features

Project No. **12520591**
Revision No. **0**
Date **8/06/2021**

Figure A-12

\\ghdnet\ghd\AU\Perth\Projects\61\12520591\GIS\Maps\Working\12520591-MAP-A-SW\12520591_Hydrology_Overview_MM.aprx\12520591_A-3_HolyoakeCatchmentsAndDrainage_Rev0
Print date: 08 Jun 2021 - 14:55

Data source: Alcoa: Myara North Boundary - 20200618, LiDAR Elevation - 20200626, Reservoir Protection Zone, Isohyet - 20200225, Streams - 20200617; GA: SRTM - 20200526; DWER: SW Monitoring Sites - 20200629; DoW: PDWSA - 20160607, Subcatchments - 20130902; Landgate: Roads - 20190128, . Created by: mmatar



Paper Size ISO A3

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Kilometres

1:80,000

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

Alcoa of Australia Limited

Holyoake surface water monitoring locations

Project No. **12520591**
Revision No. **0**
Date **8/06/2021**

Figure A-13

\\ghdnet\ghd\AU\Perth\Projects\61\12520591\GIS\Maps\Working\12520591-MAP-A-SW\12520591_Hydrology_Overview_MM.aprx\12520591_A-2_SAQP_HolyoakeWaterMonitoringLocations_RevA
Print date: 08 Jun 2021 - 14:39

Data source: GHD: Proposed monitoring sites - 20200825, Subcatchments - 20200624; Alcoa: Myara North Boundary - 20200618, LiDAR Elevation - 20200626, Reservoir Protection Zone, Isohyet - 20200225, Streams - 20200617; GA: SRTM - 20200526; DWER: SW Monitoring Sites - 20200629; DoW: PDWSA - 20160607; Landgate: Roads - 20190128, . Created by: mmatar

415,000 420,000 425,000 430,000

6,425,000 6,420,000 6,415,000 6,410,000

Nettleton Rd
Jarrahdale Rd
Albany Hwy
Kingsbury Dr
MOUNT RANDALL

Legend

- Myara North Boundary
- Waterways
- Roads
- Tracks
- SPZ
- 1100 mm isohyet
- Subcatchments
- GDE (Mattiske Mapping)
- Outcrop (250K)

Average Depth to Groundwater (m)

- <2.0
- 2.1 - 5.0
- 5.1 - 10.0
- 10.1 - 15.0
- 15.1 - 20.0
- 20.1 - 30.0
- 30.1 - 35.0

Paper Size A3

0 350 700 1,400 2,100

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

Alcoa of Australia Limited

Conceptual Model

Myara North depth to groundwater (metres)

Job Number	12520591
Revision	A
Date	08 Jun 2021

Figure A-14

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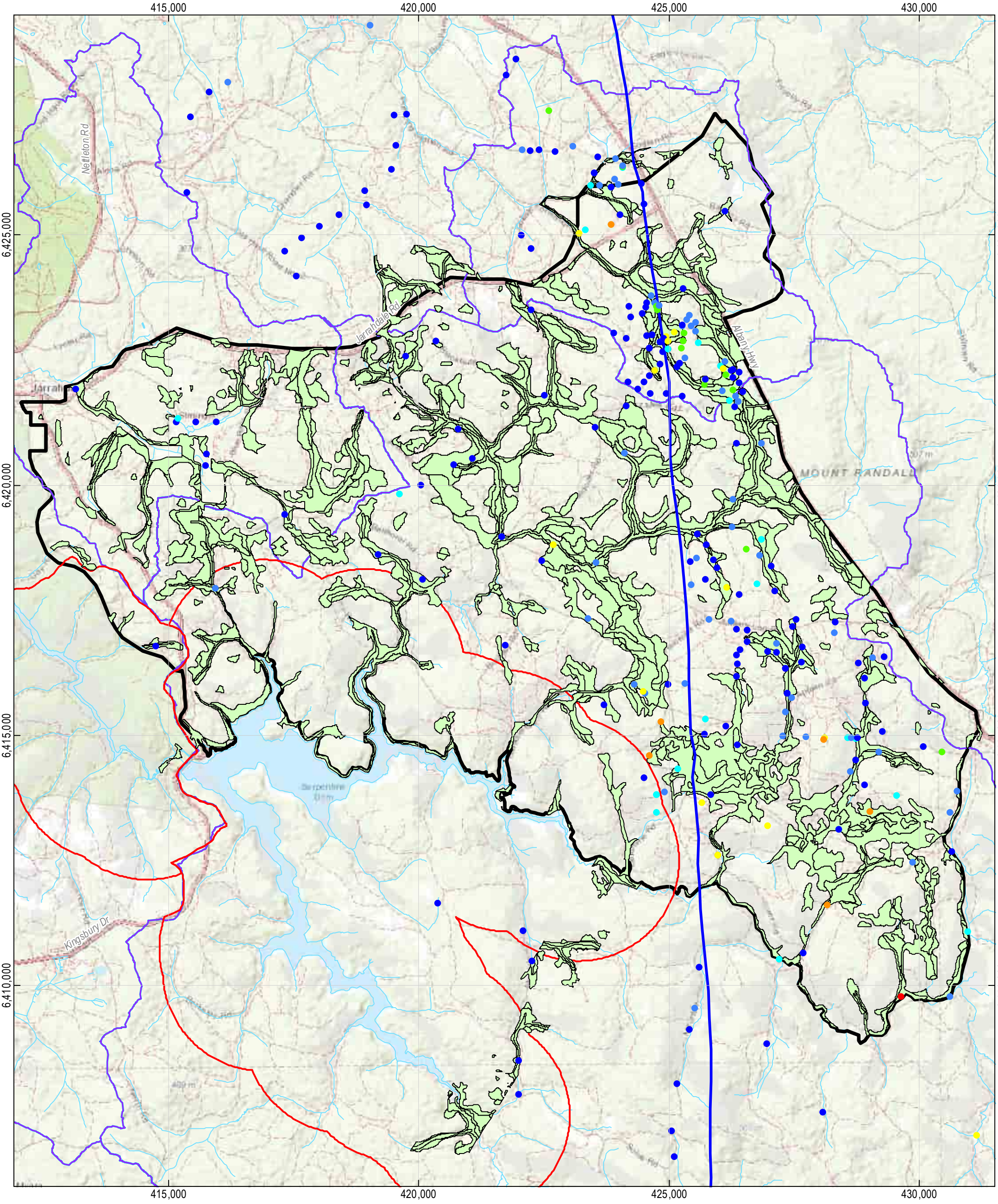
Data source: Alcoa: Myara North Bounday 20210125, Streams - 20200617, SPZ, Isohyet - 20200225 DMIRS: Outcrop (250K) DoW: Subcatchments - 20130902 Landgate: Roads - 20190128 GHD: Average Depth to Groundwater - 20210519 Mattiske:GDE (Mattiske Mapping) ESRI: Imagery accessed 20200807 Created by:mmatar

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community



Legend

- Myara North Boundary
- Waterways
- Roads
- Tracks
- SPZ
- 1100 mm isohyet
- Subcatchments
- GDE (Mattiske Mapping)
- Outcrop (250K)

TDS (mg/L)

- < 300
- 301 - 500
- 501 - 700
- 701 - 1000
- 1001 - 1500
- 1501 - 3000
- 3001- 5000

Paper Size A3

0 350 700 1,400 2,100

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

Alcoa of Australia Limited
Conceptual Model

Myara North average bore salinity

Job Number	12520591
Revision	A
Date	08 Jun 2021

Figure A-15

\\ghdnet\ghd\AU\Perth\Projects\61\12520591\GIS\Maps\Working\12520591-Conceptual_Model\12520591_Myara_Salinity.mxd

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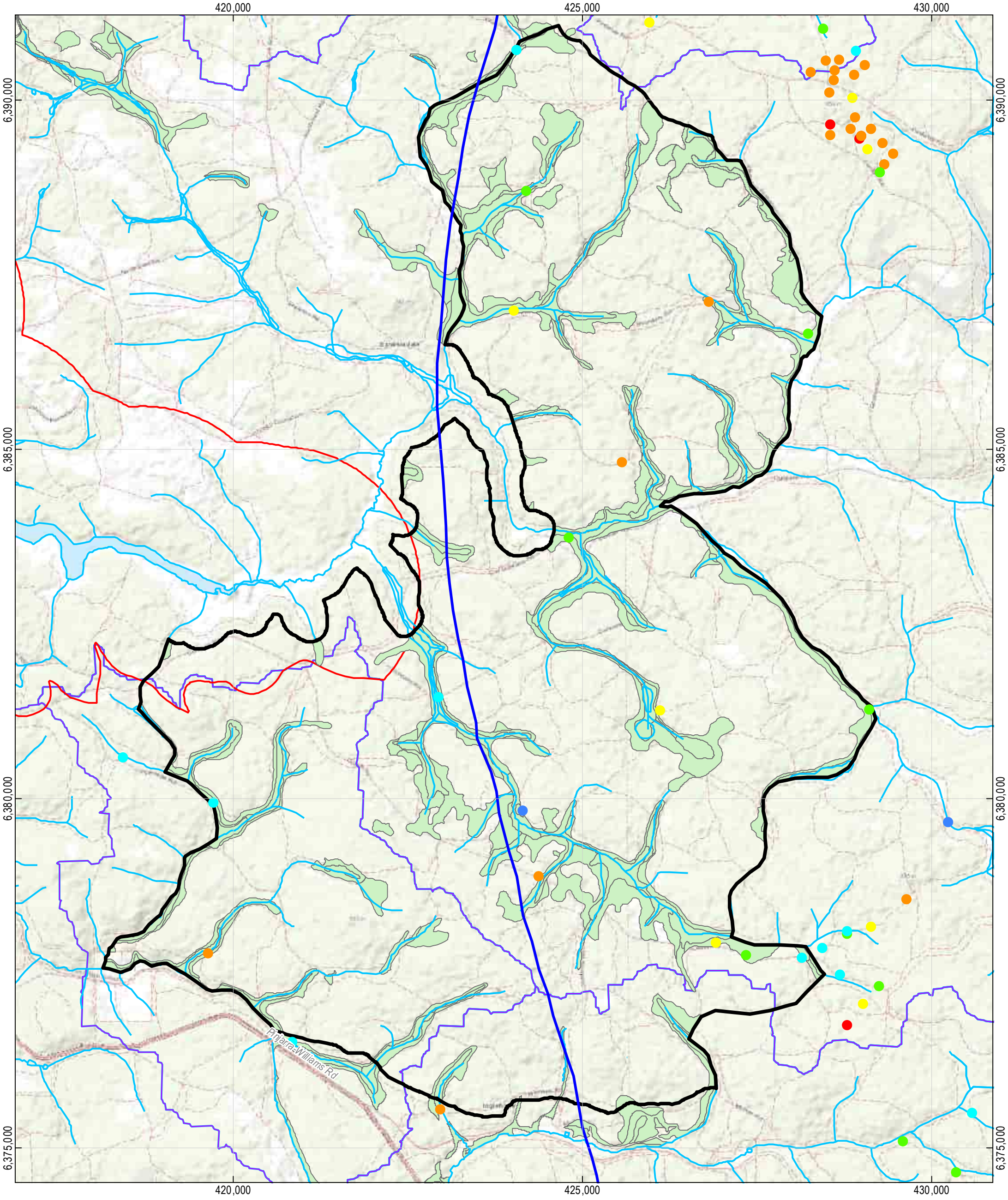
Data source: Alcoa: Myara North Bounday 20210125, Streams -20200617, SPZ, Isohyet - 20200225 DMIRS: Outcrop (250K) DoW: Subcatchments - 20130902 Landgate: Roads - 20190128 GHD: Average Bore Groundwater Salinity - 20210519 Mattiske:GDE (Mattiske Mapping) ESRI: Imagery accessed 20200807 Created by:mmatar

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c)



Legend

- Holyoake Boundary
- Waterways
- Tracks
- Roads
- SPZ
- 1100 mm isohyet
- Subcatchments
- GDE (Mattiske Mapping)
- Outcrop (250K)

Average Depth to Groundwater (m)

- < 2
- 2.1 - 5.0
- 5.1- 10.0
- 10.1 - 15.0
- 15.1 - 20.0
- 20.1 - 30.0
- 30.1 - 37.0

Paper Size A3

0 350 700 1,400 2,100

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

Alcoa of Australia Limited
Conceptual Model

Holyoake depth to groundwater (metres)

Job Number	12520591
Revision	A
Date	08 Jun 2021

Figure A-16

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Data source: Alcoa: Holyoake Bounday 20210125, Streams -20200617, SPZ, Isohyet - 20200225 DMIRS: Outcrop (250K) DoW: Subcatchments - 20130902 Landgate: Roads: - 20190128 GHD: Average Depth to Groundwater - 20210519 Mattiske:GDE (Mattiske Mapping) ESRI: Imagery accessed 20200807. Created by:mmatar

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c)

420,000
425,000
430,000
6,390,000
6,385,000
6,380,000
6,375,000
Pinjarra Williams Rd

Legend

- Holyoake Boundary
- Waterways
- Roads
- Tracks
- SPZ
- 1100 mm isohyet
- Subcatchments
- GDE (Mattiske Mapping)
- Outcrop (250K)

TDS (mg/L)

- < 300
- 301 - 500
- 501- 700
- 701 - 1000
- 1001 - 1500
- 1501 - 3000
- 3001 - 5001

Paper Size A3

0 350 700 1,400 2,100

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

Alcoa of Australia Limited
Conceptual Model

Holyoake average bore salinity

Job Number	12520591
Revision	A
Date	08 Jun 2021

Figure A-17

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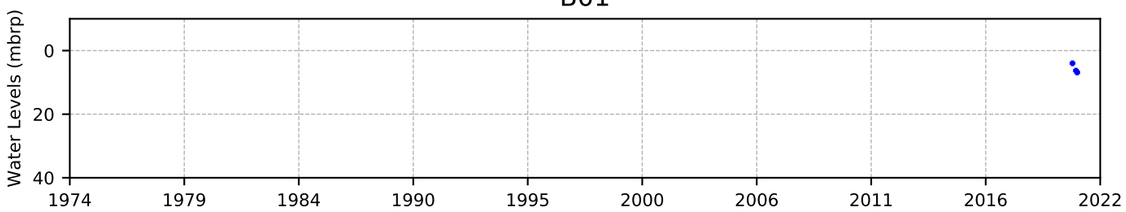
Data source: Alcoa: Holyoake Bounday 20210125, Streams -20200617, SPZ, Isohyet - 20200225 DMIRS: Outcrop (250K) DoW: Subcatchments - 20130902 Landgate: Roads - 20190128 GHD: Average Bore Groundwater Salinity - 20210519 Mattiske:GDE (Mattiske Mapping) ESRI: Imagery accessed 20200807 Created by:mmatar

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c)

Appendix B

Myara North and Holyoake monitoring bore hydrographs and salinity graphs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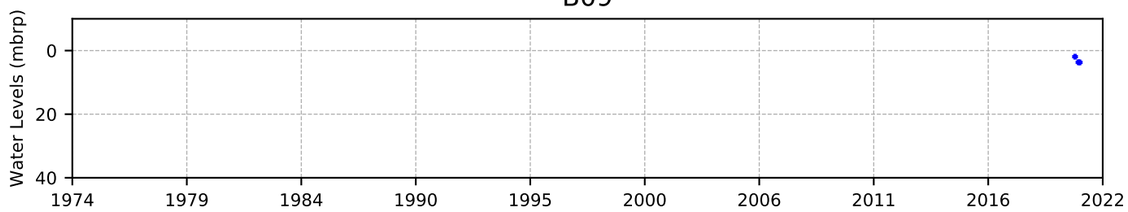
Water Levels (mbrp)
0
20
40
1974
1979
1984
1990
1995
2000
2006
2011
2016
2022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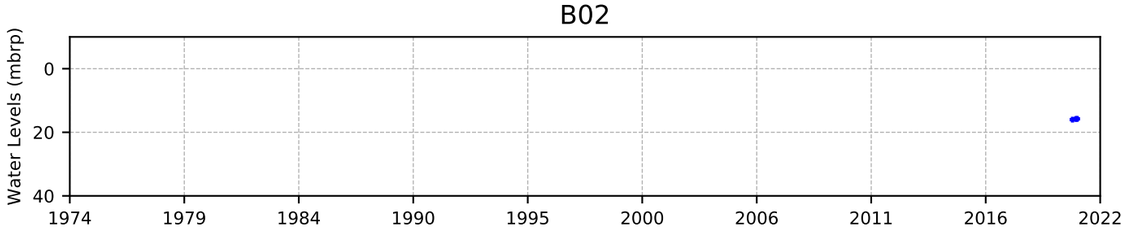
Water Levels (mbrp)
0
20
40
1974
1979
1984
1990
1995
2000
2006
2011
2016
2022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Water Levels (mbrp)
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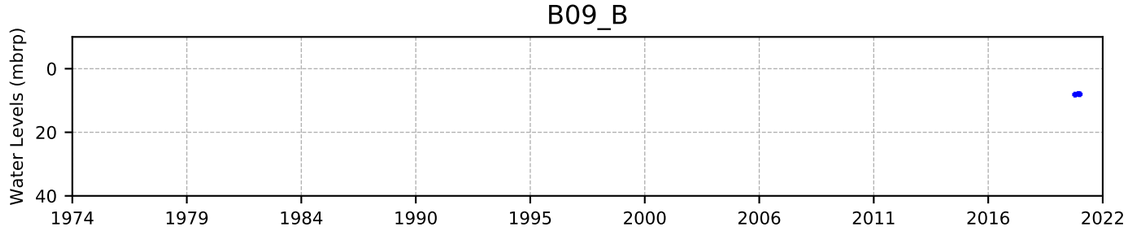
20
40
1974
1979
1984
1990
1995
2000
2006
2011
2016
2022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Water Levels (mbrp)
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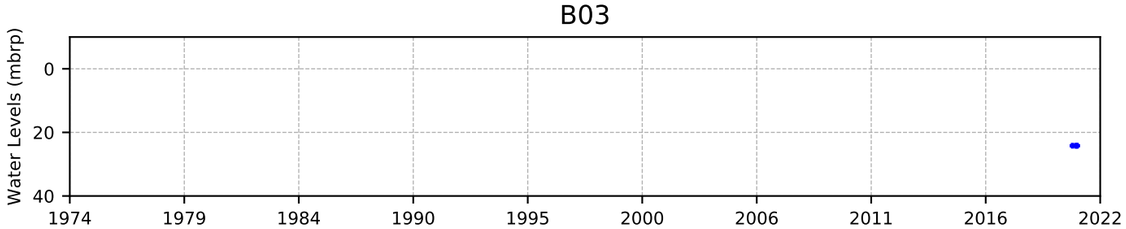
1984
1990
1995
2000
2006
2011
2016
2022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Water Levels (mbrp)
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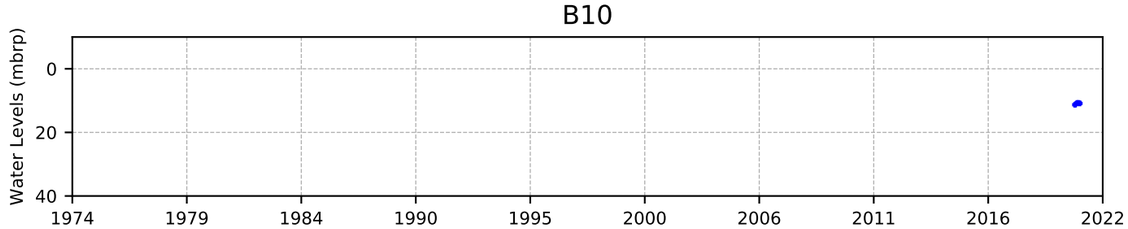
20
40
1974
1979
1984
1990
1995
2000
2006
2011
2016
2022


B10
Water Levels (mbrp)
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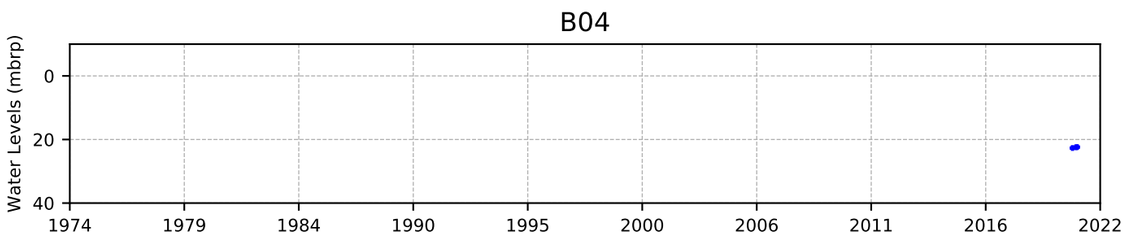
20
40
1974
1979
1984
1990
1995
2000
2006
2011
2016
2022


B04
Water Levels (mbrp)
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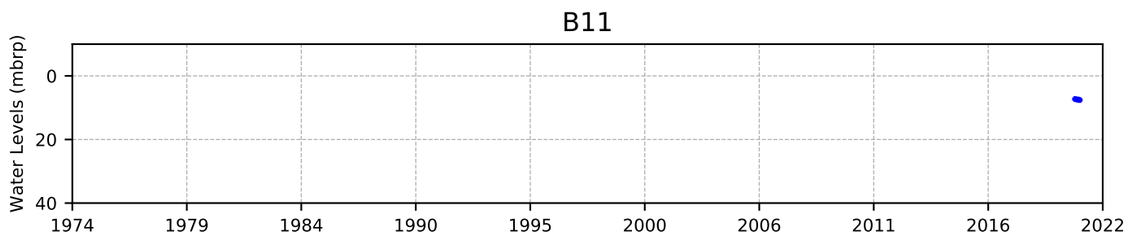
1984
1990
1995
2000
2006
2011
2016
2022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Water Levels (mbrp)
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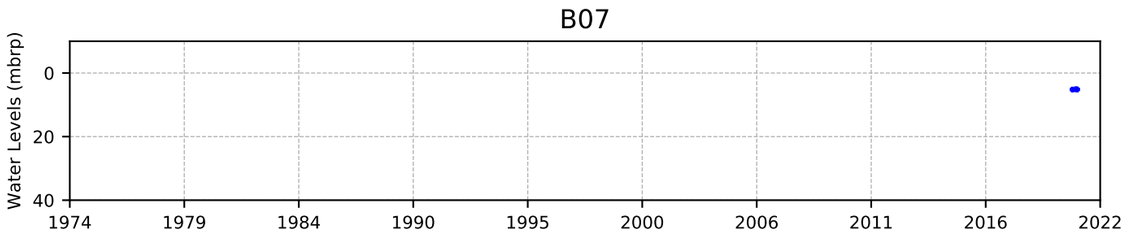
20
40
1974
1979
1984
1990
1995
2000
2006
2011
2016
2022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Water Levels (mbrp)
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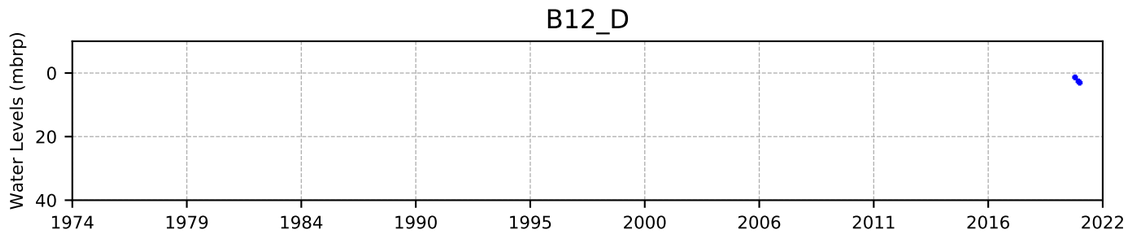
1979
1984
1990
1995
2000
2006
2011
2016
2022


B12_D
Water Levels (mbrp)
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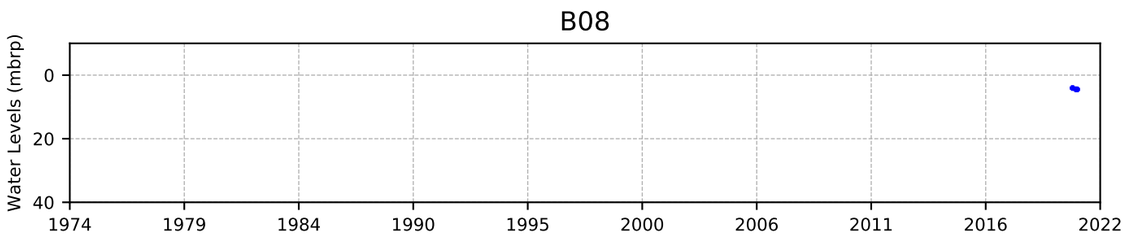
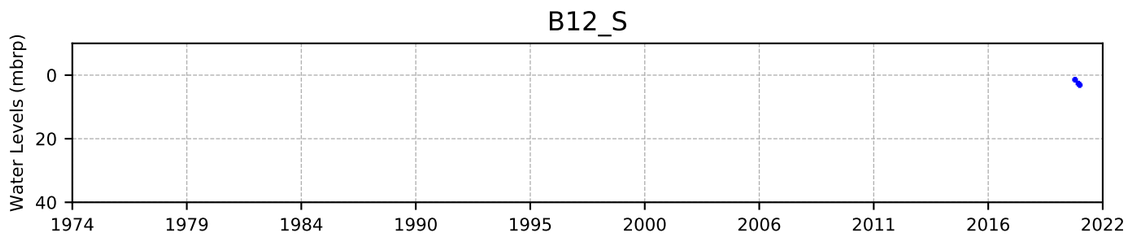
40
1974
1979
1984
1990
1995
2000
2006
2011
2016
2022


B08
Water Levels (mbrp)
0
20
40
1974
1979
1984
1990
1995
2000
2006
2011
2016
2022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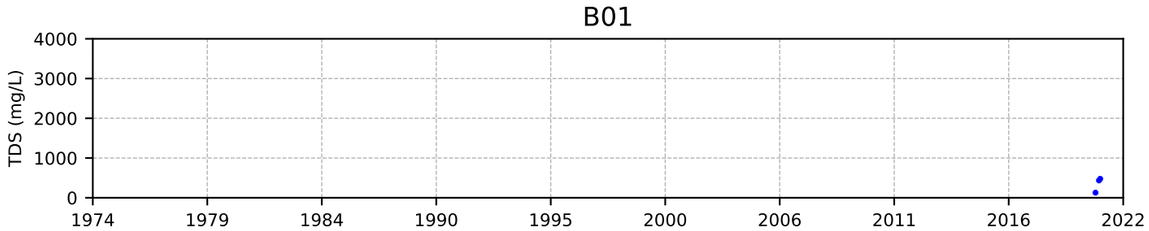
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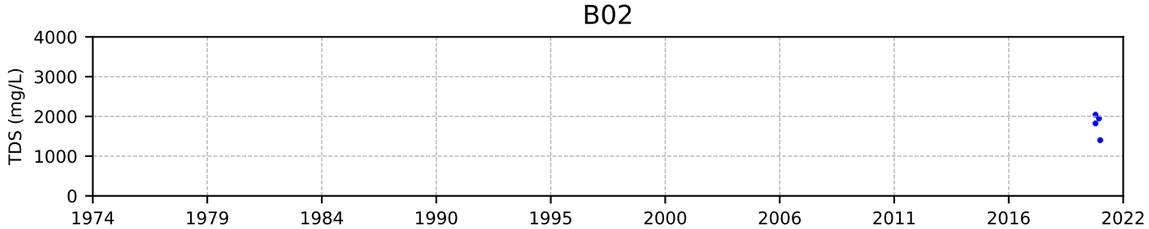
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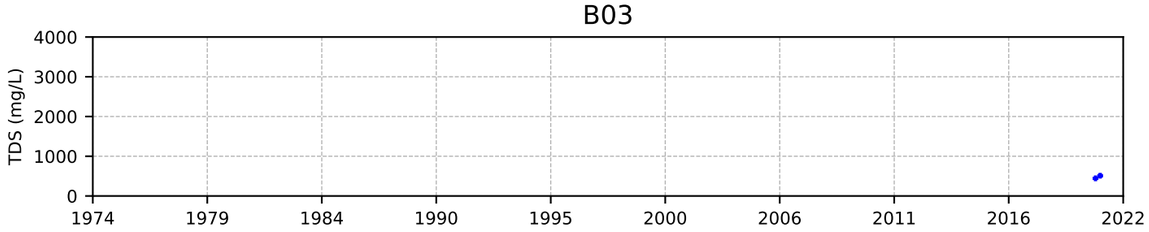
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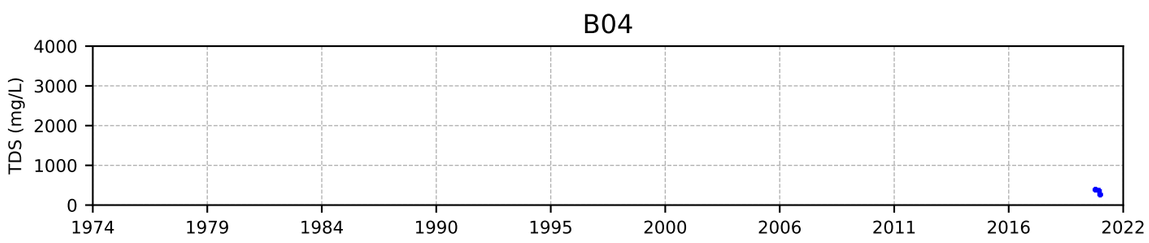
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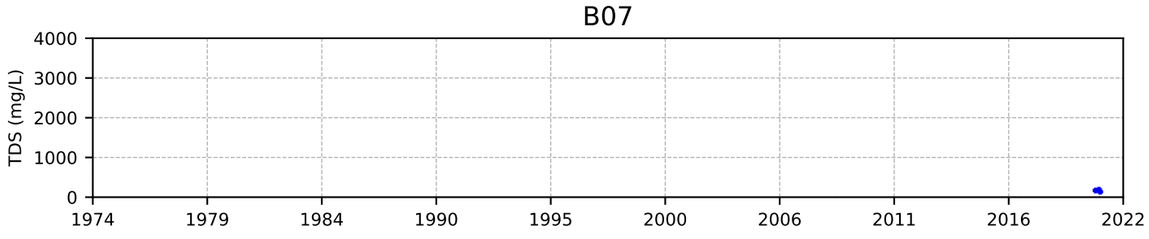
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TDS (mg/L)
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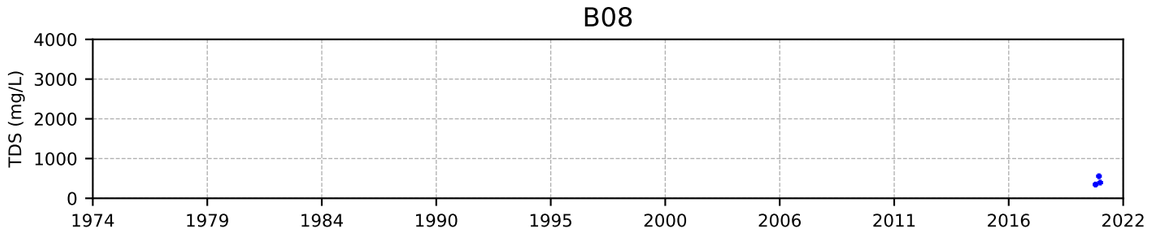
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TDS (mg/L)
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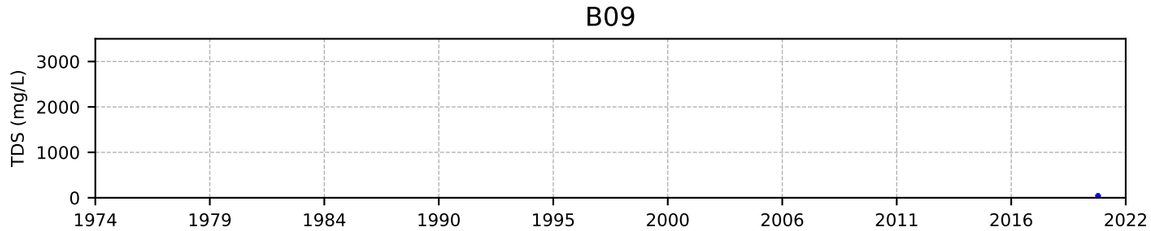
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TDS (mg/L)
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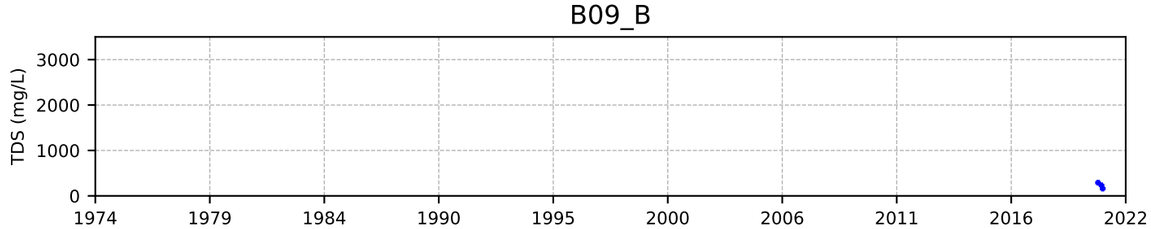
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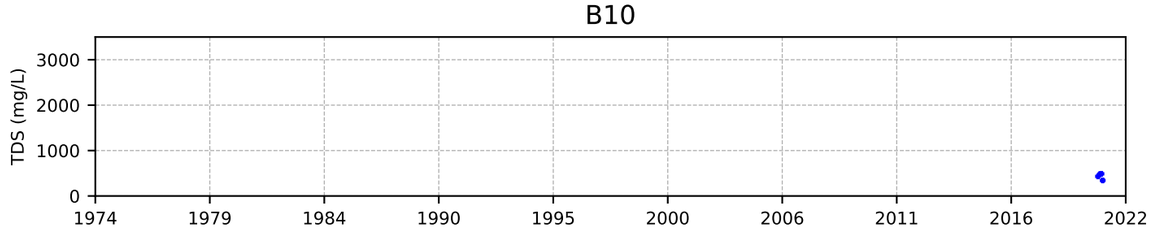
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TDS (mg/L)
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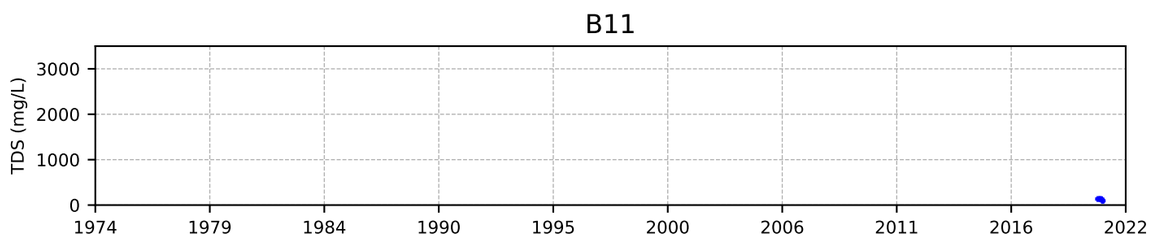
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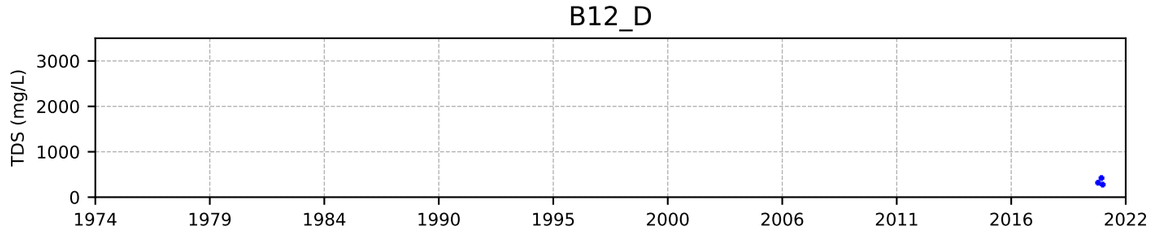
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TDS (mg/L)
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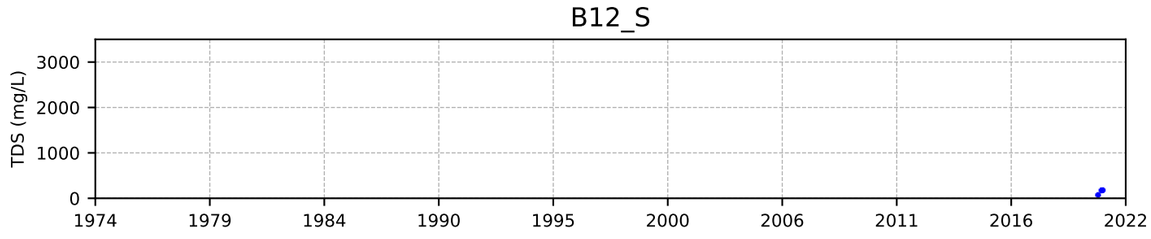
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TDS (mg/L)
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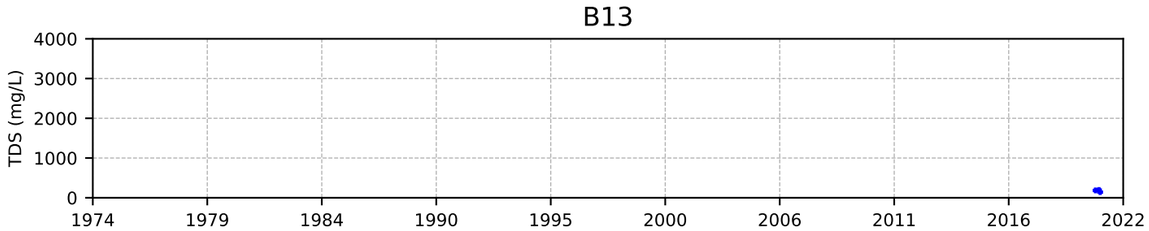
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TDS (mg/L)
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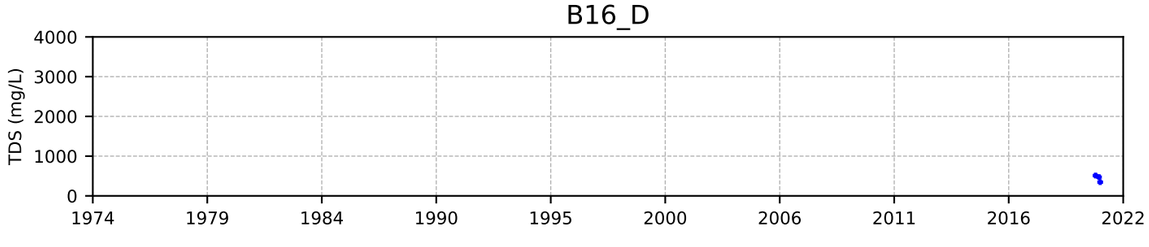
B16_D
TDS (mg/L)
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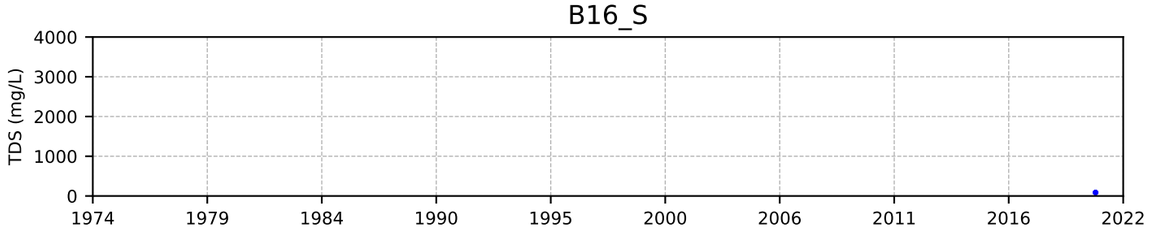
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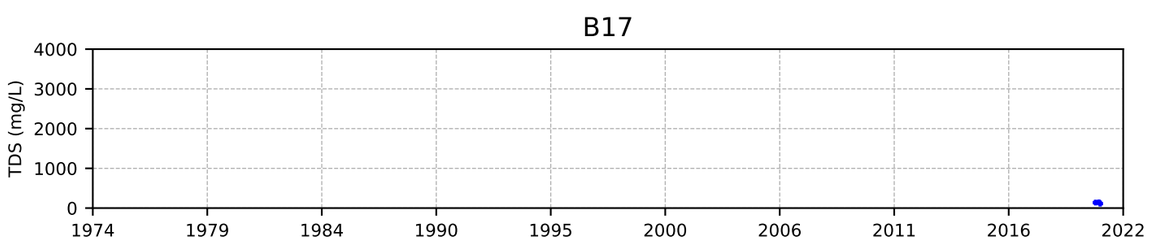
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TDS (mg/L)
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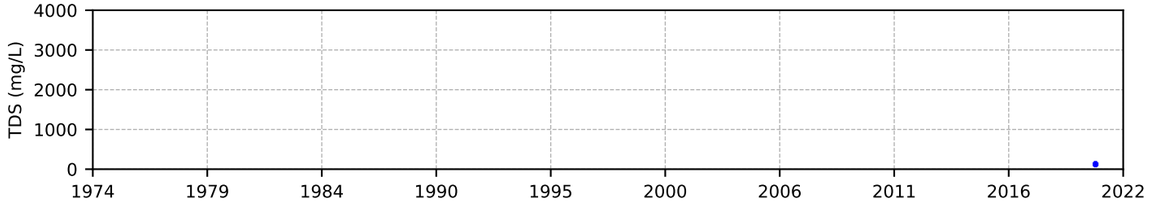
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TDS (mg/L)
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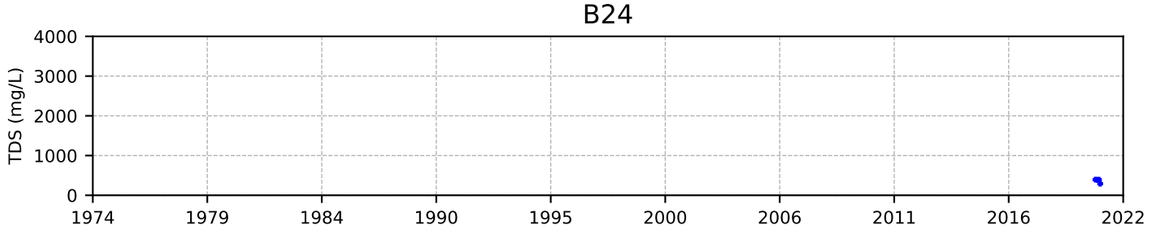
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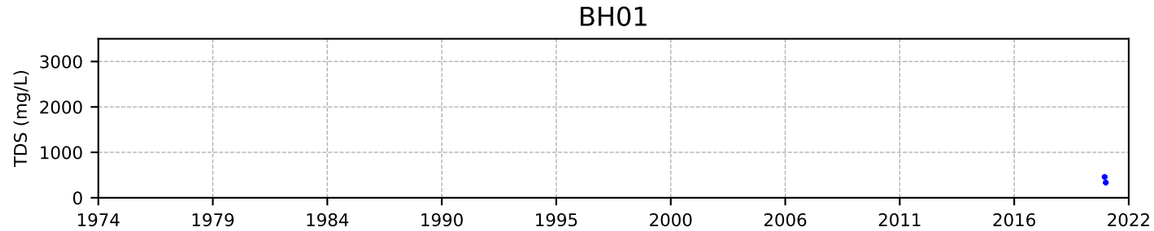
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TDS (mg/L)
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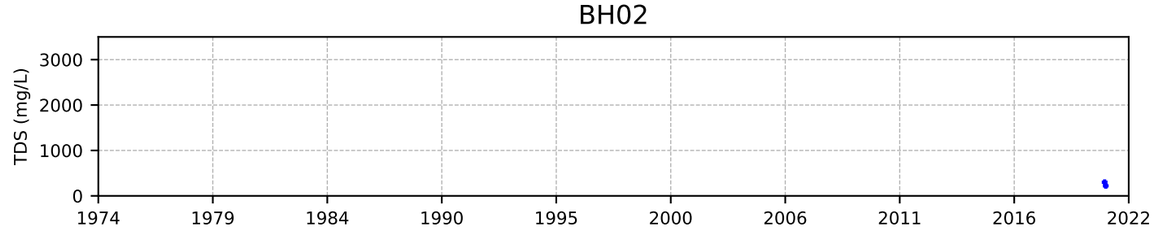
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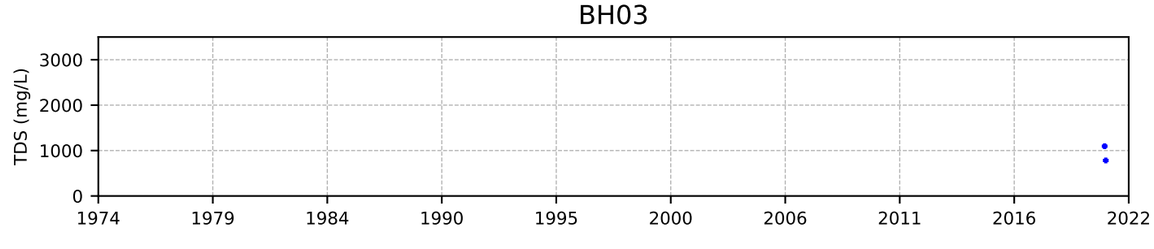
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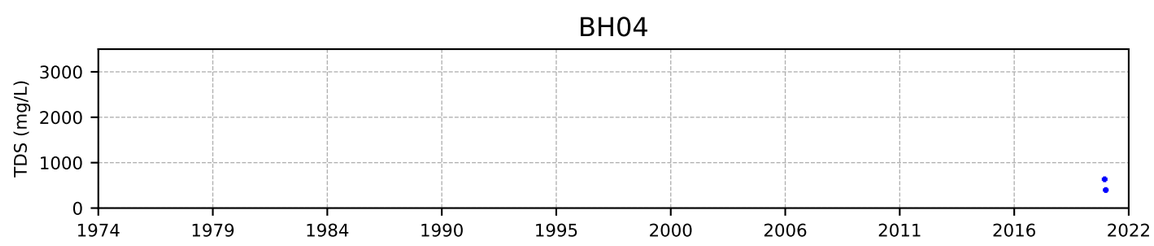
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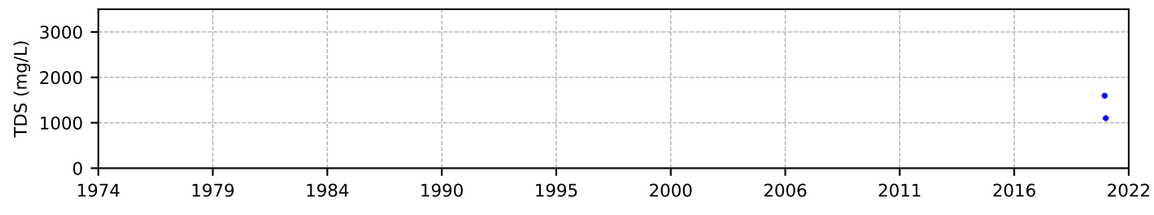
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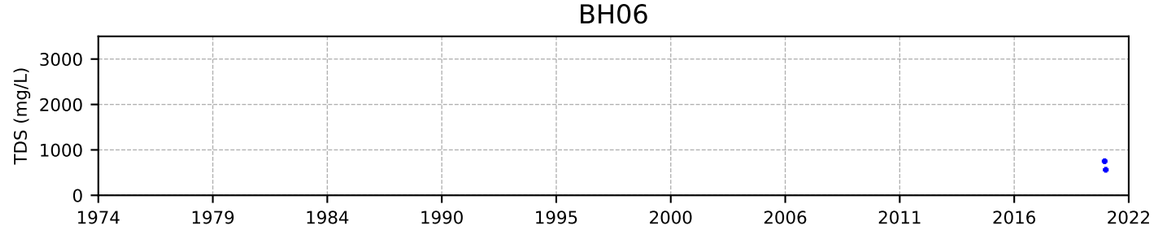
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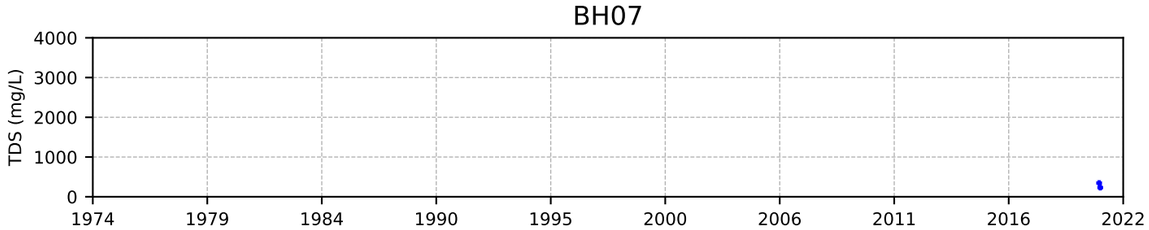
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TDS (mg/L)
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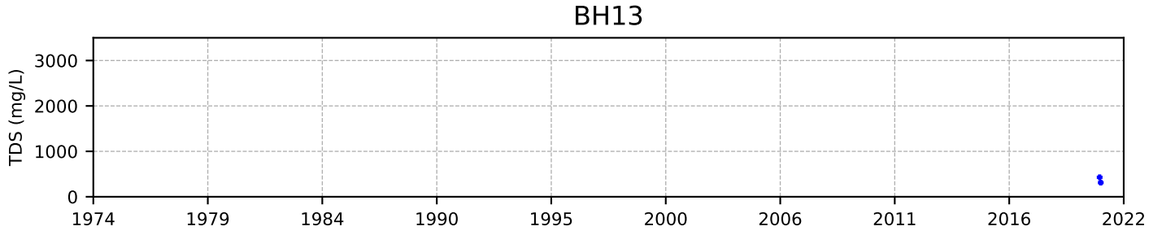
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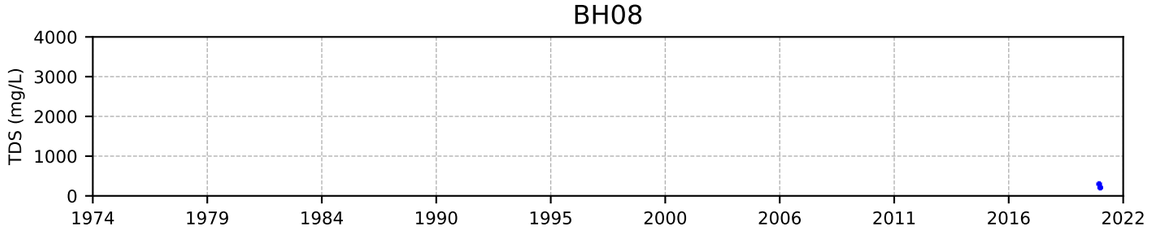
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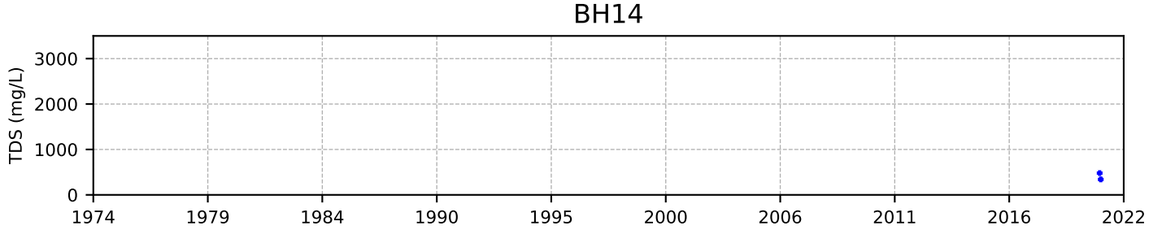
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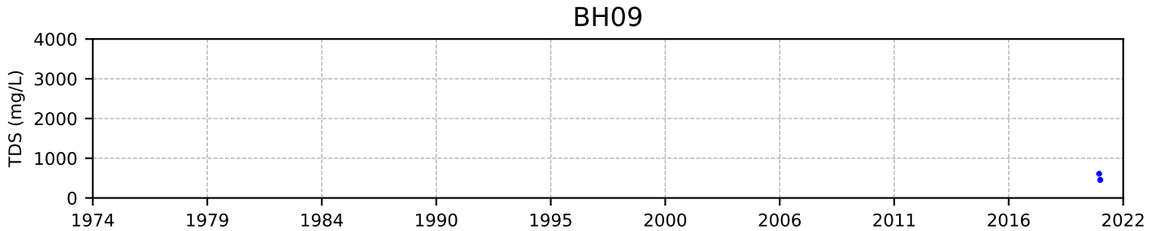
BH09
TDS (mg/L)
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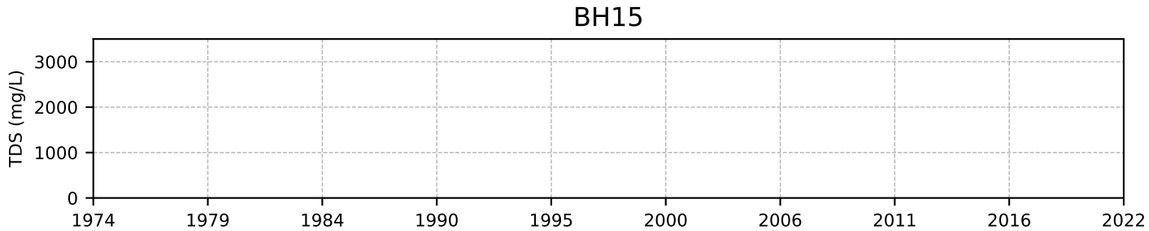
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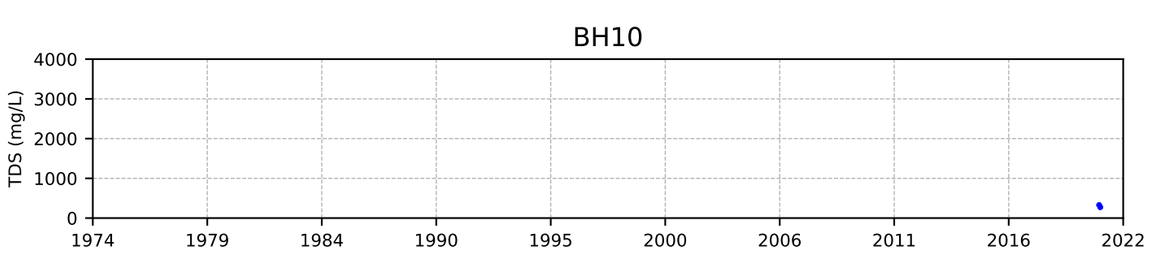
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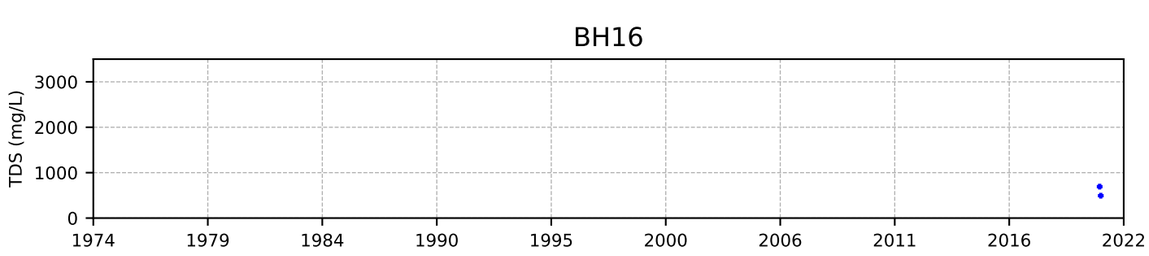
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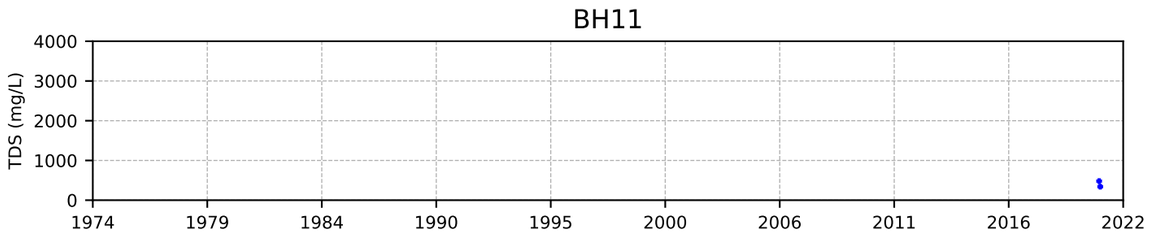
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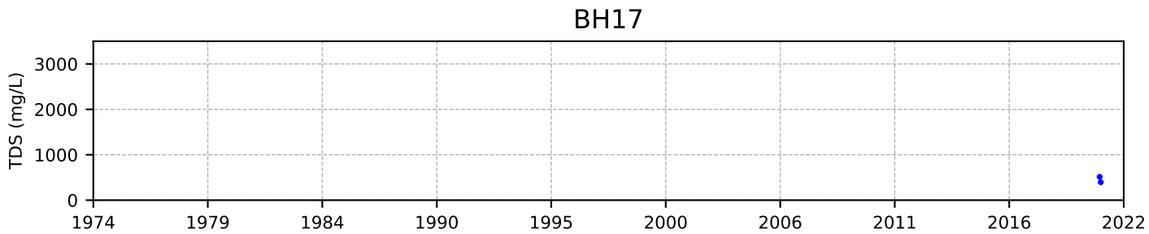
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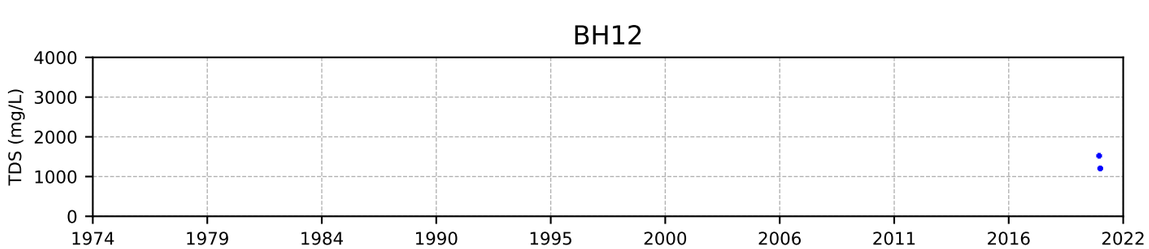
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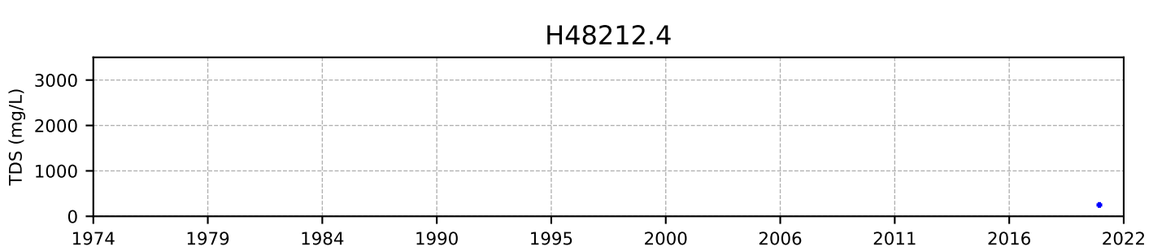
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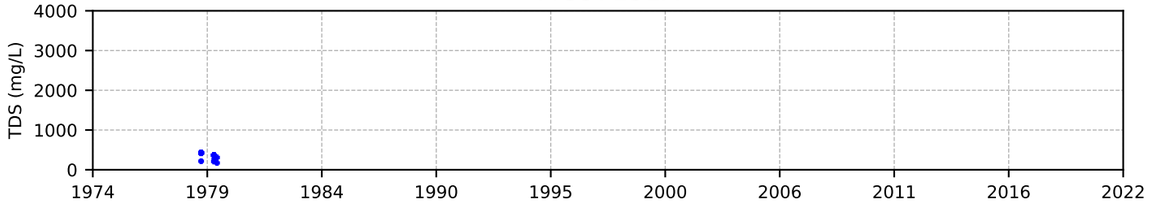
MG37151A
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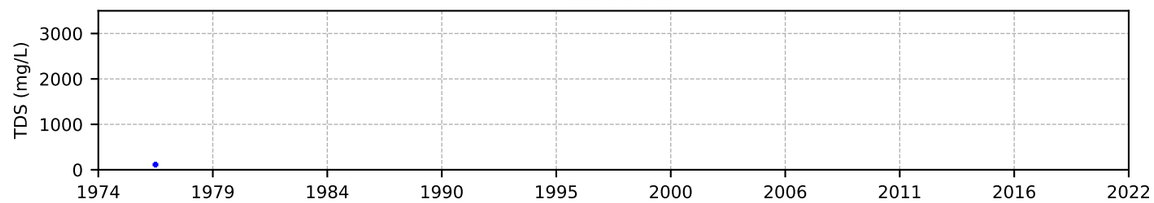
MG38161A
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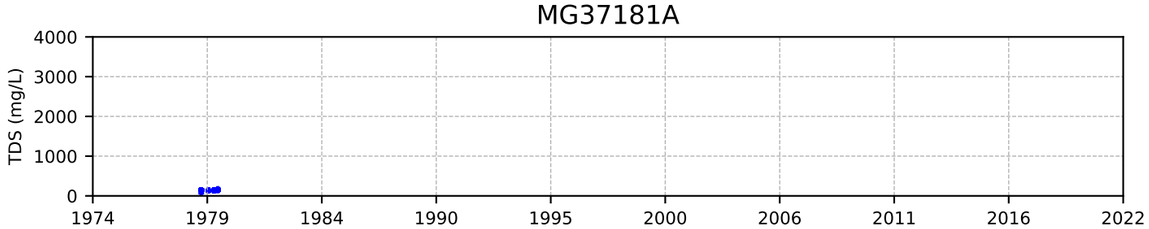
MG37181A
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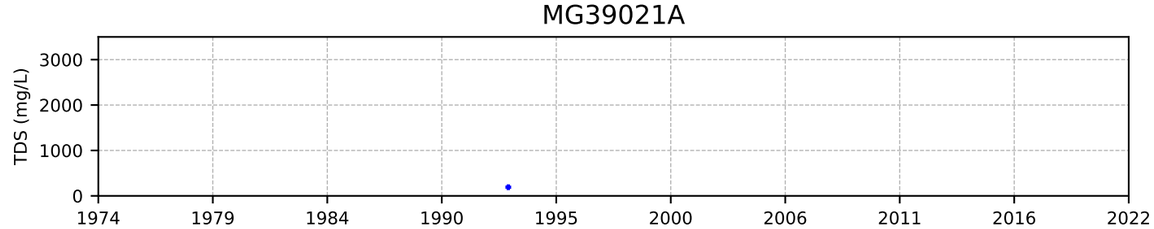
MG39021A
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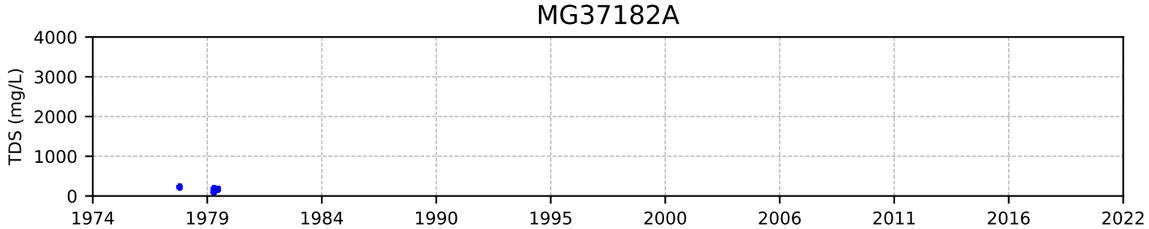
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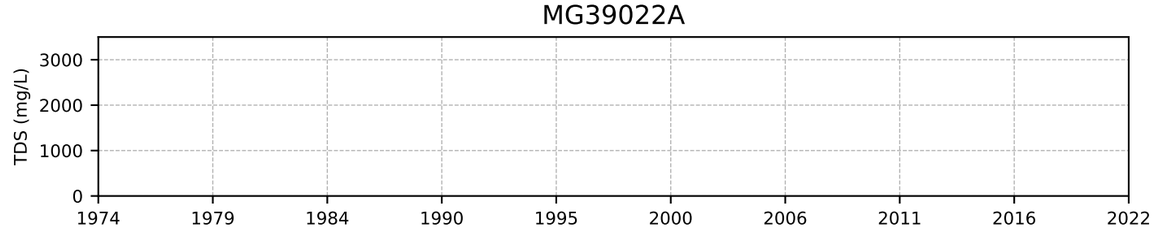
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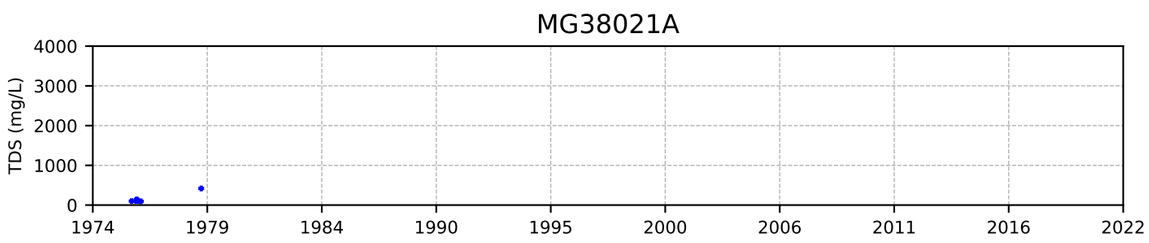
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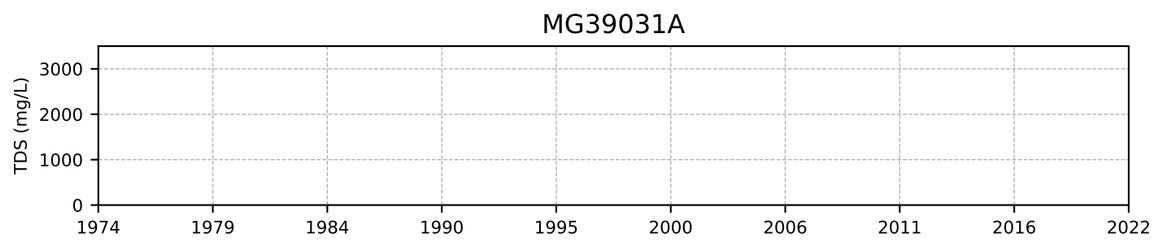
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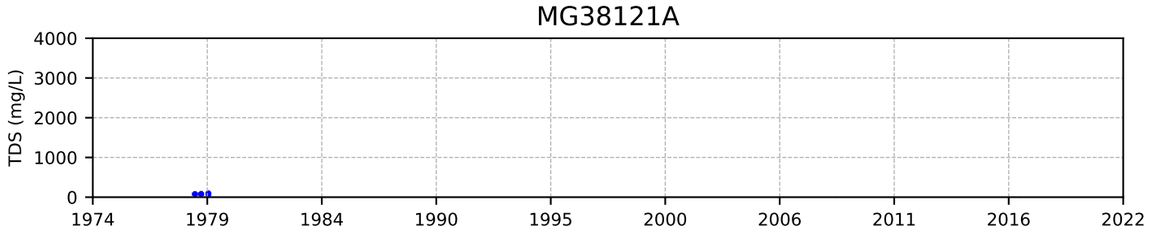
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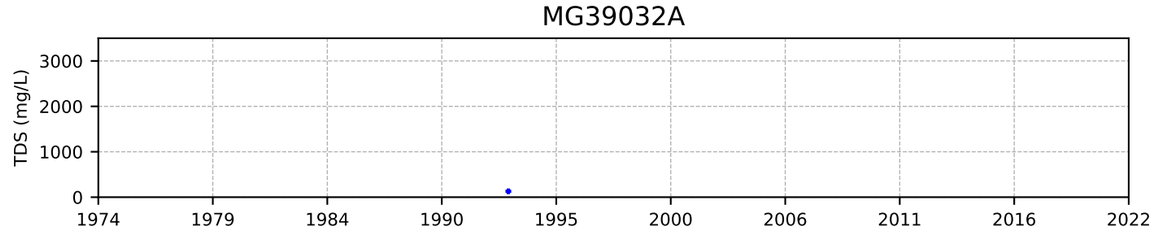
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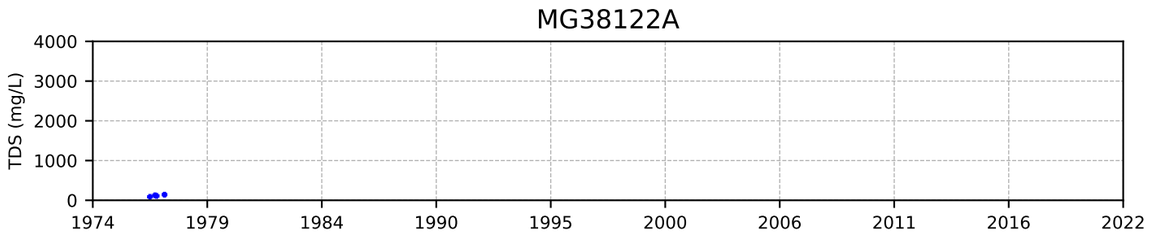
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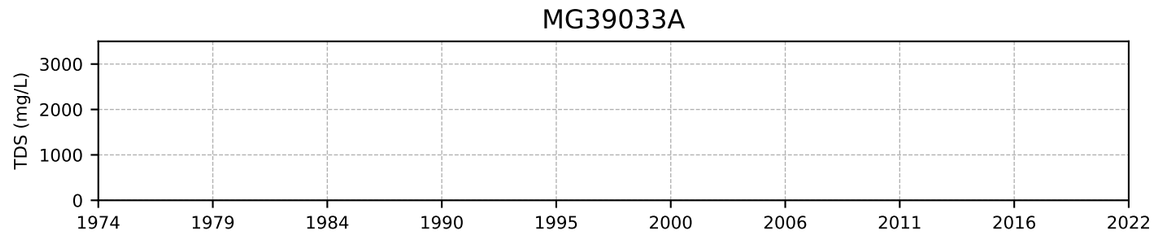
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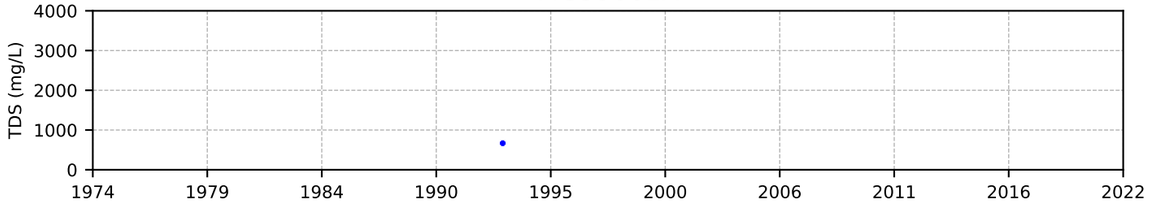

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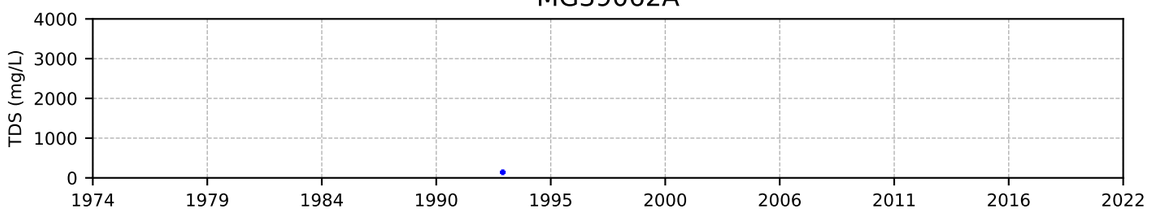

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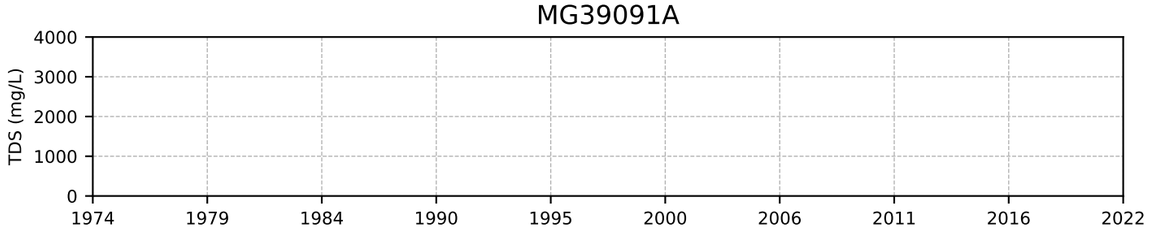

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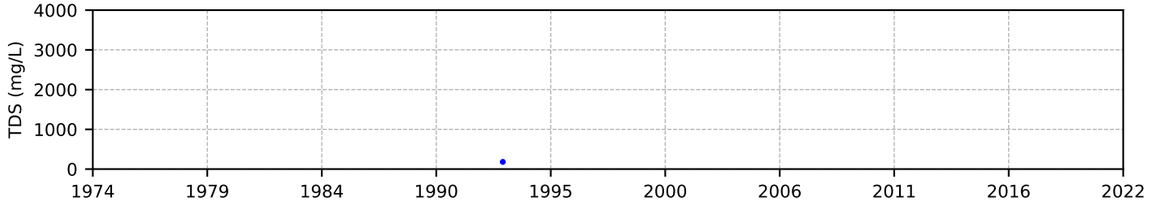

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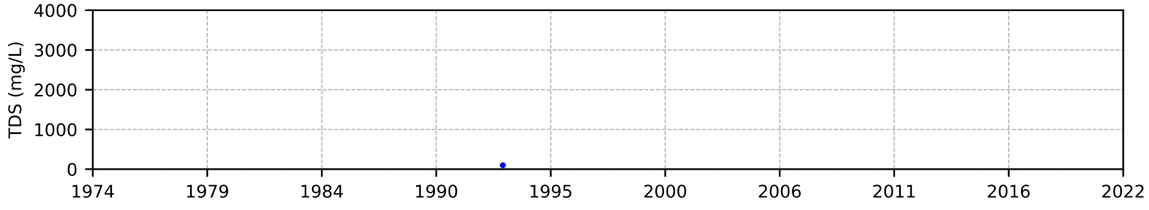

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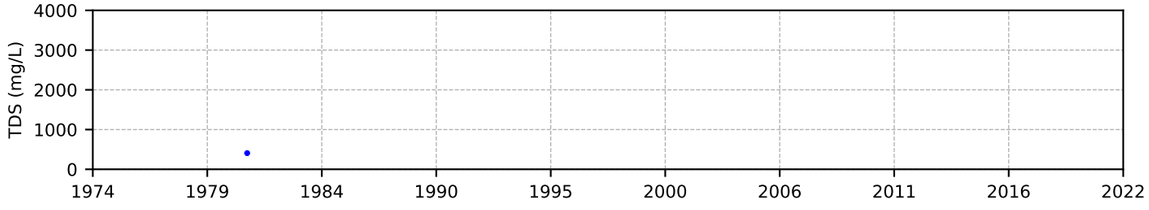

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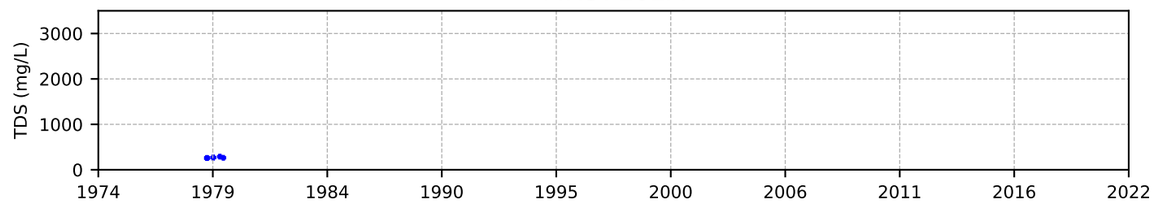

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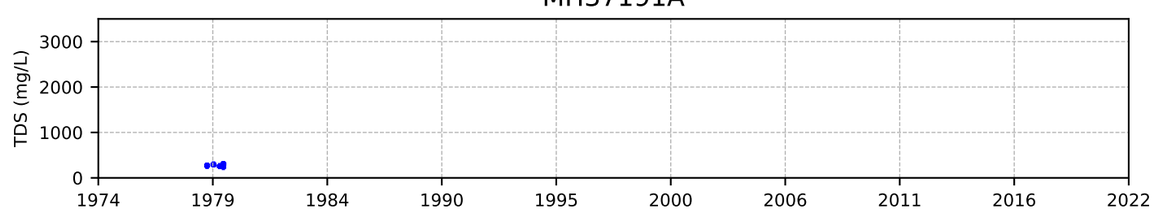

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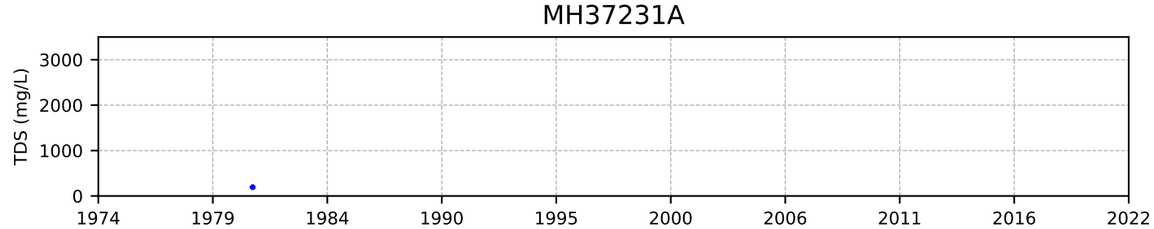

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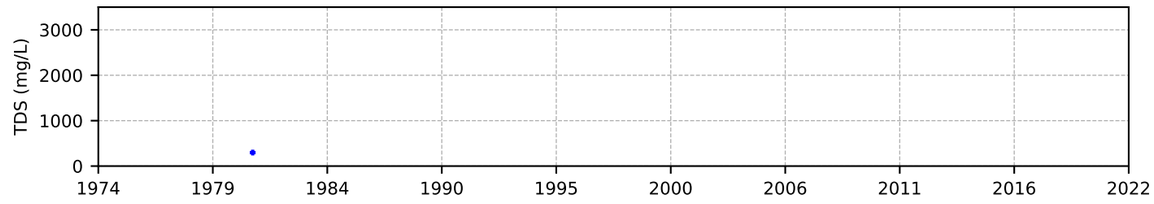

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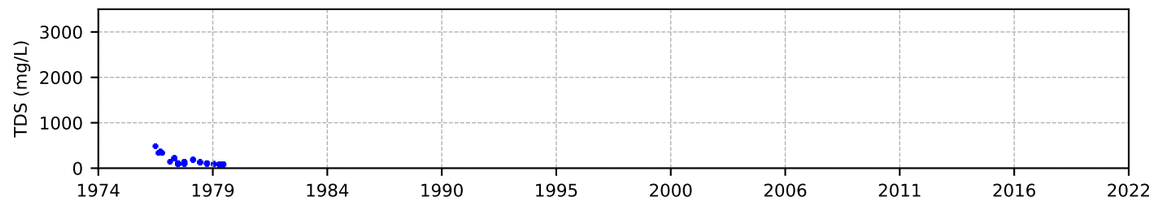

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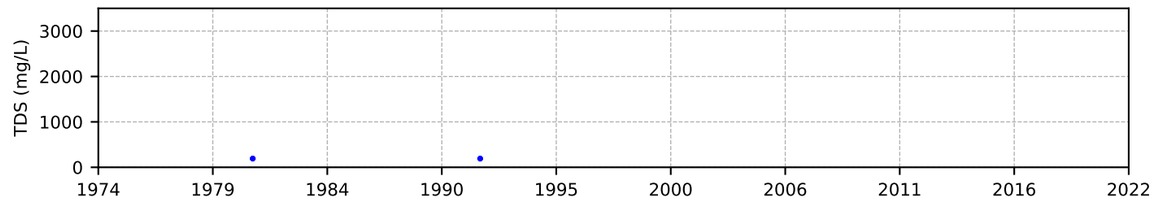

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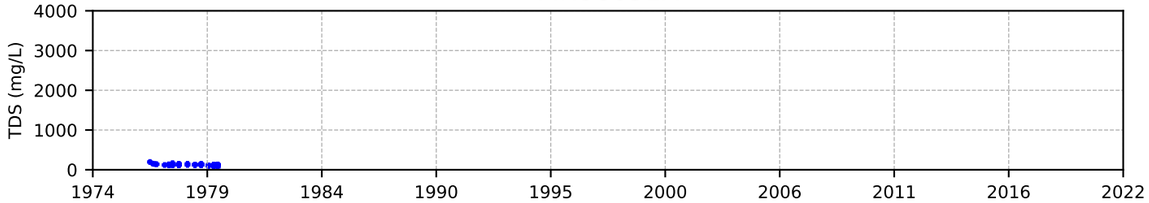

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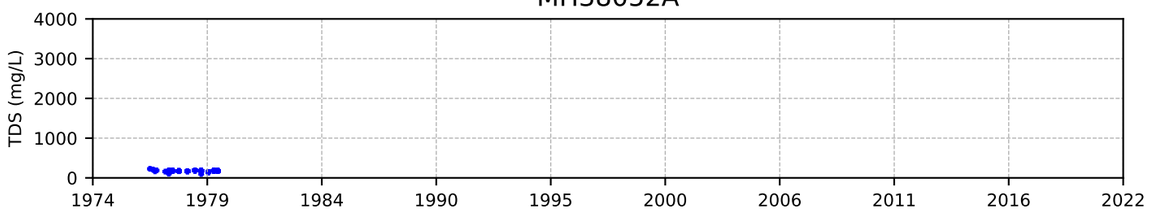

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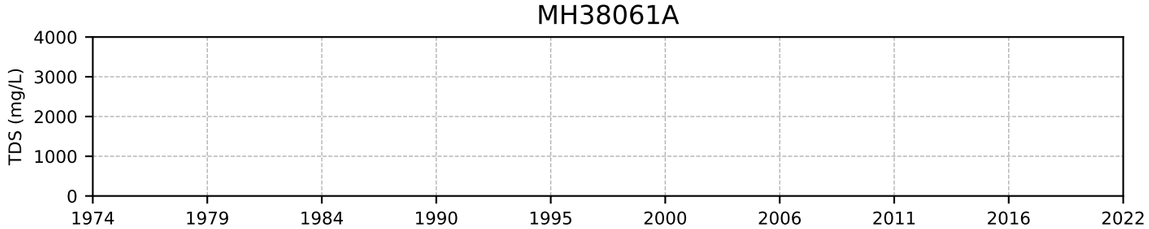

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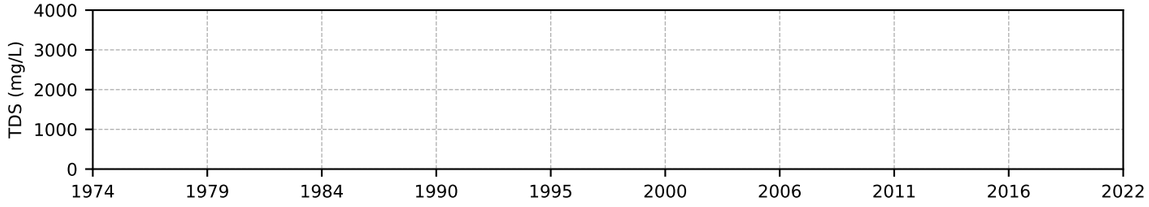

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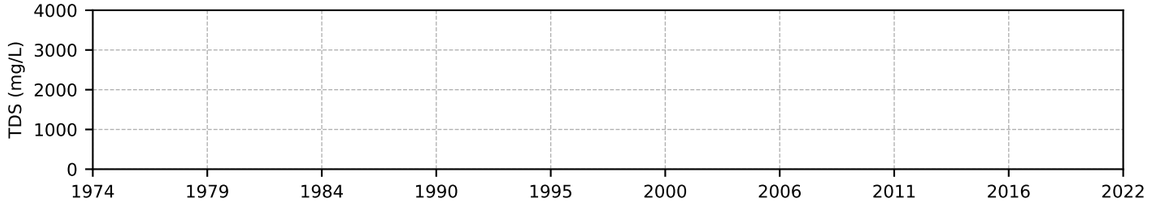

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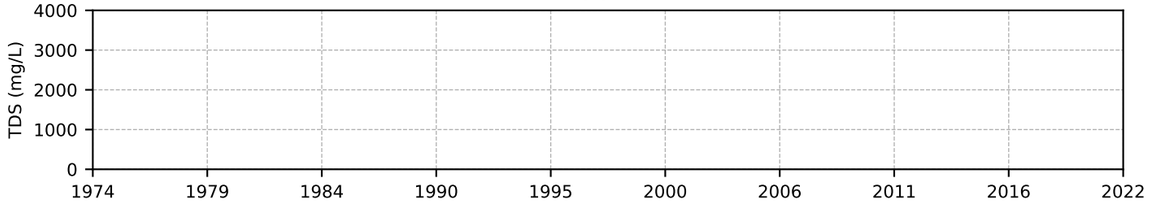

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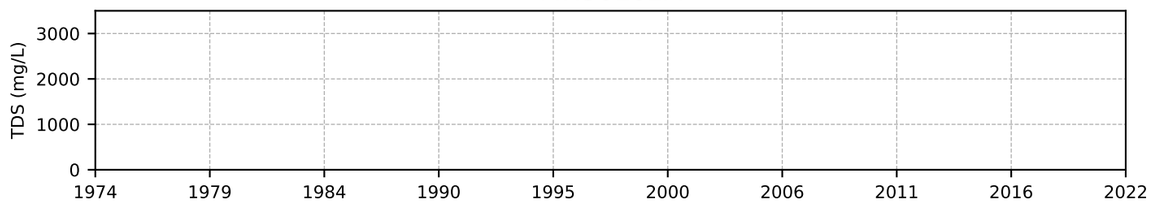

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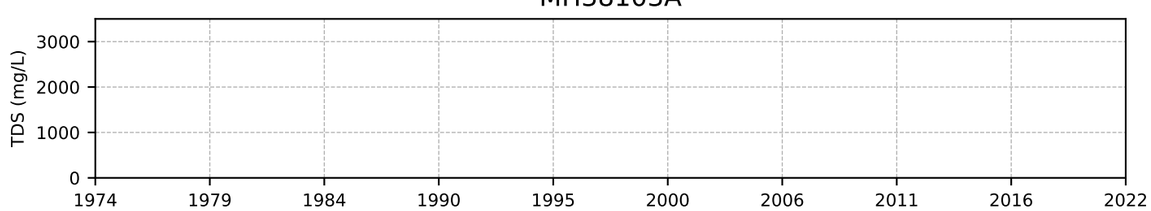

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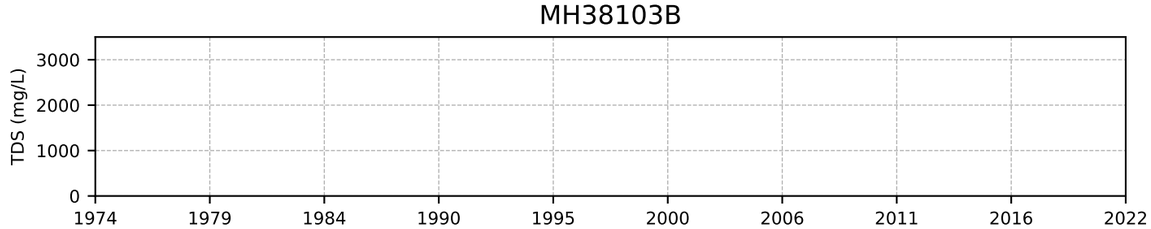

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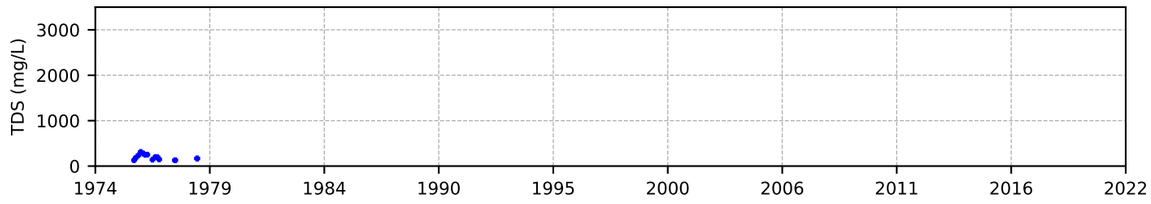

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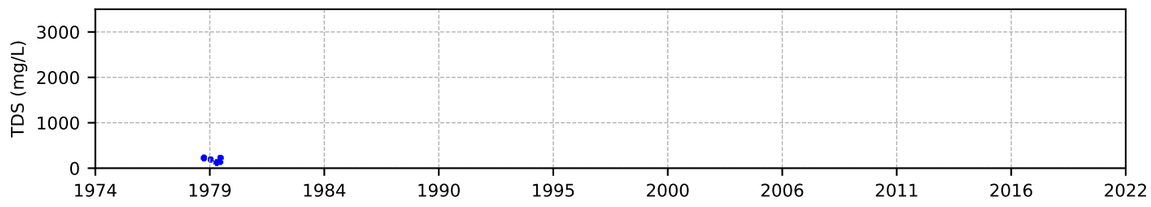

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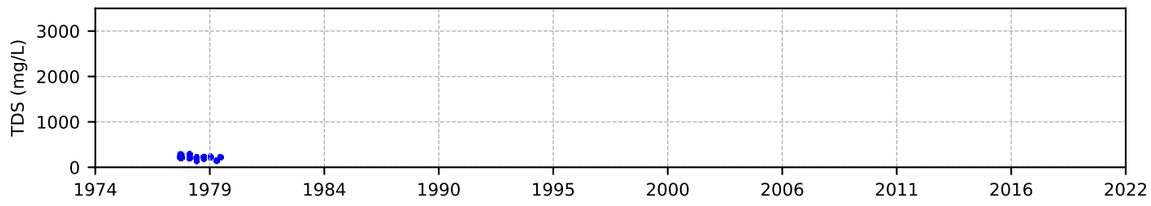

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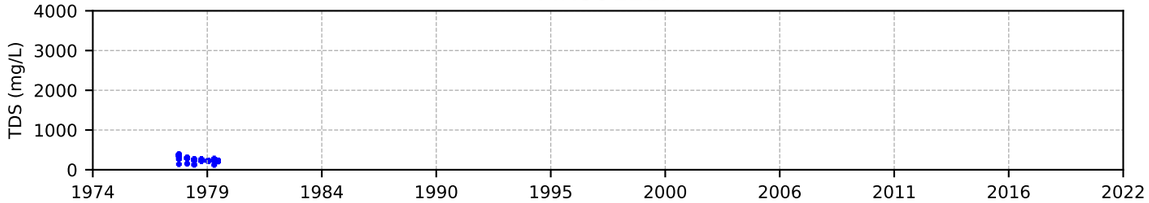

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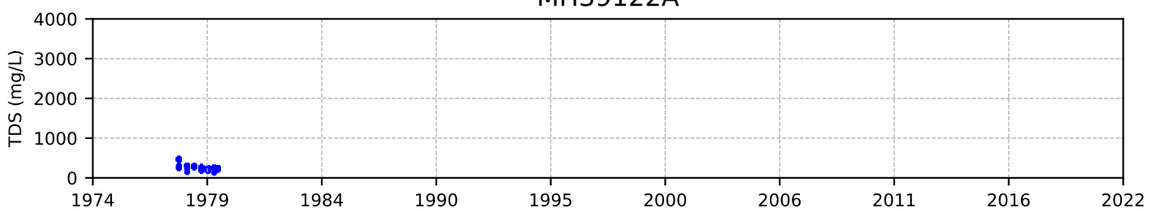

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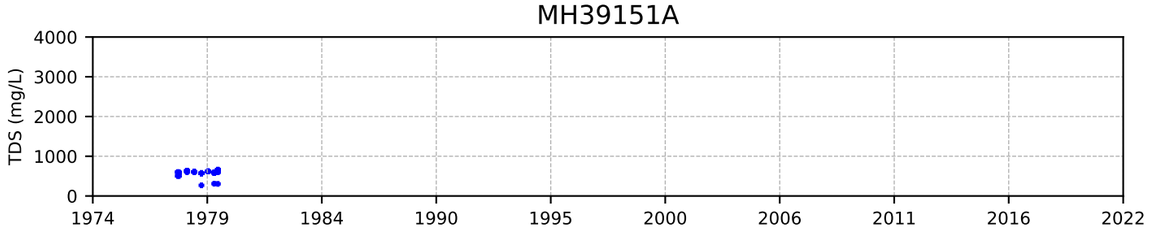

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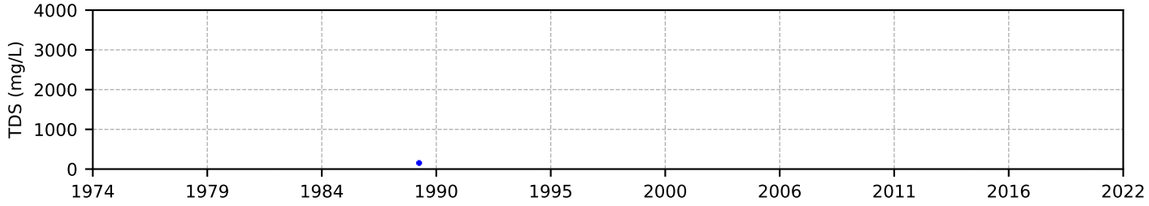

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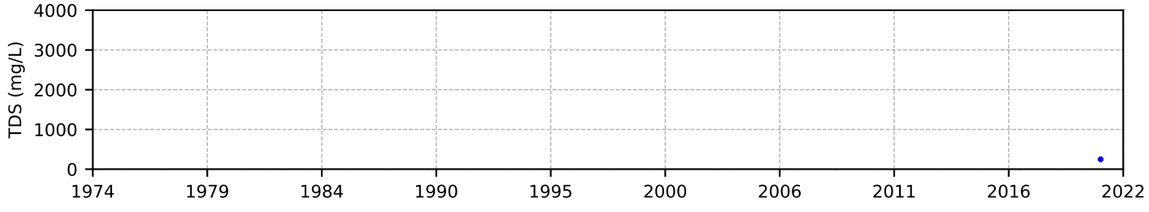

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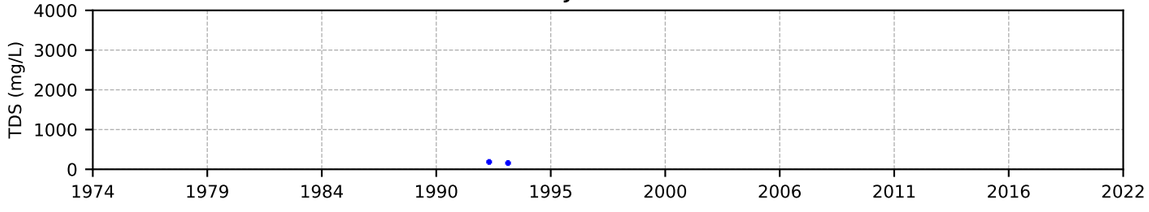

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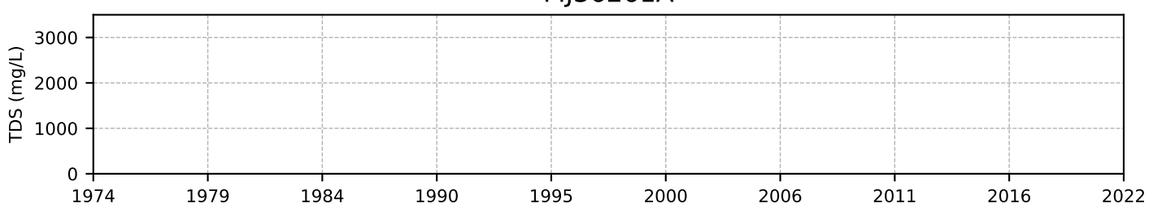

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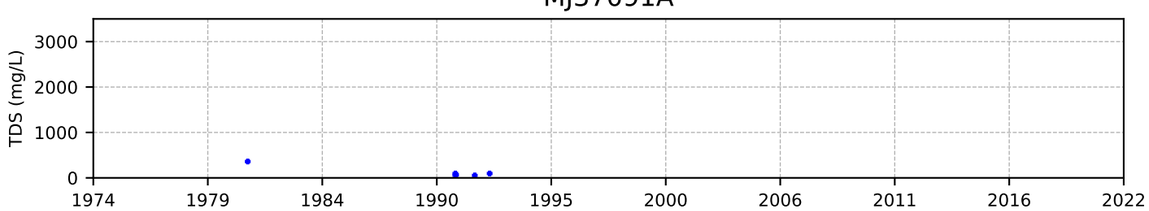

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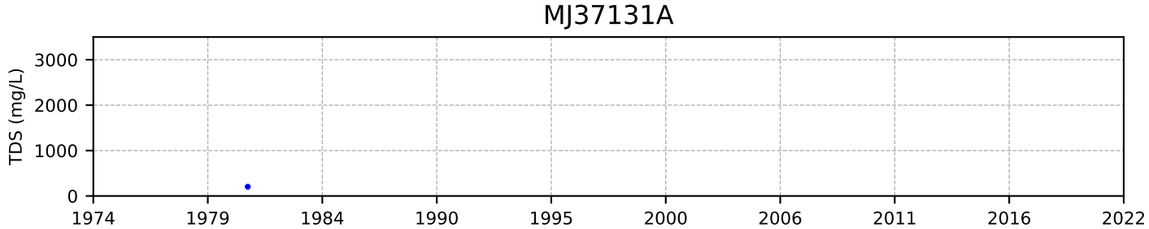

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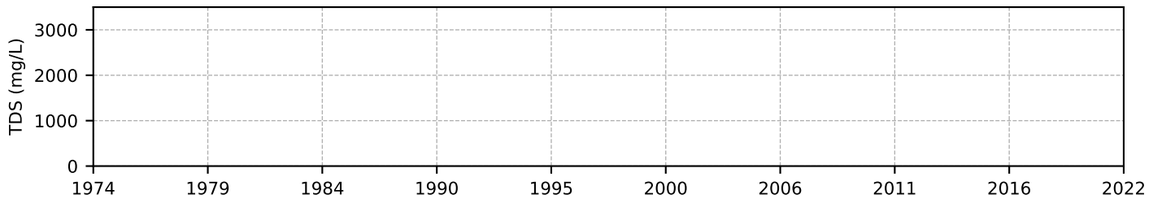

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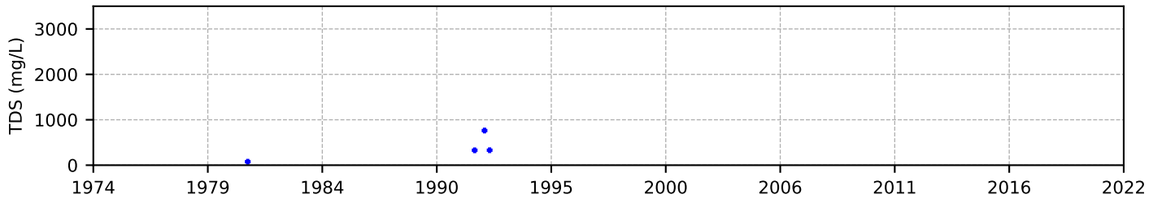

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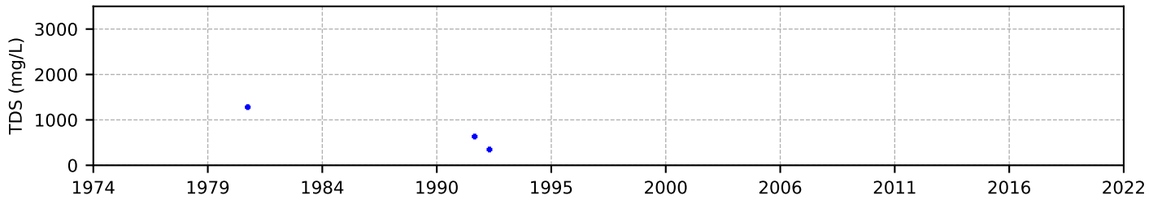

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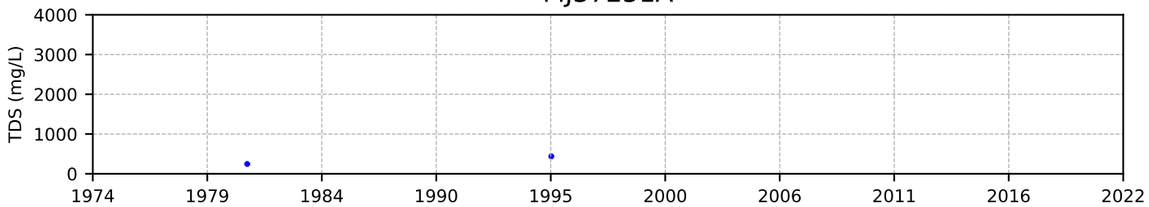

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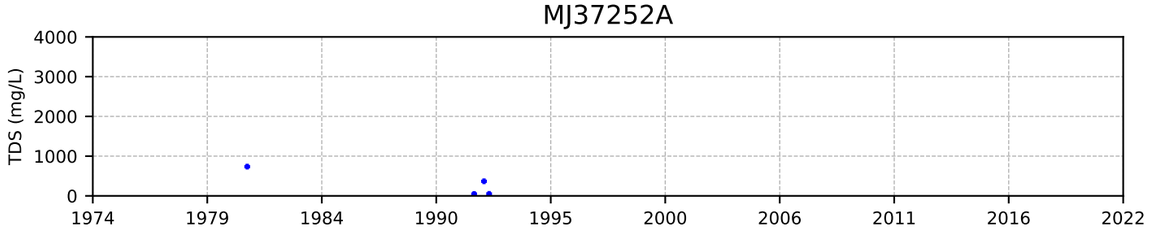

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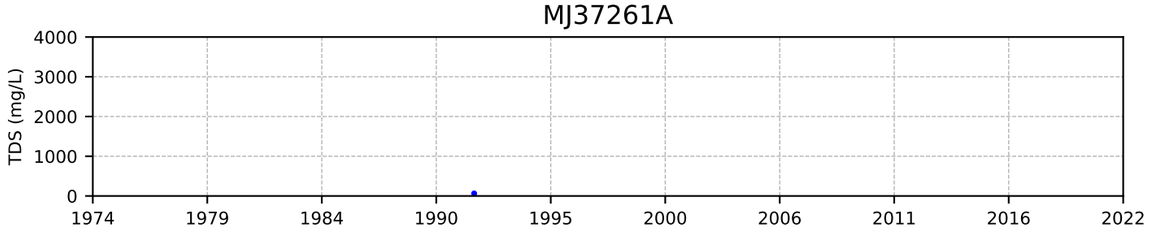

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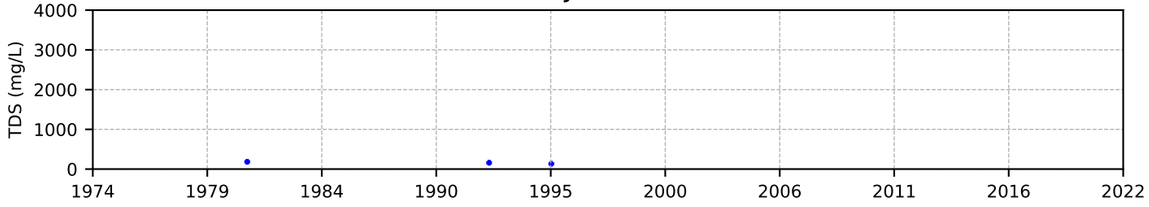

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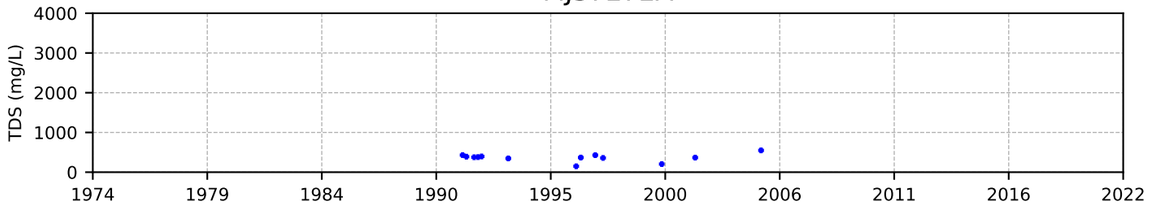

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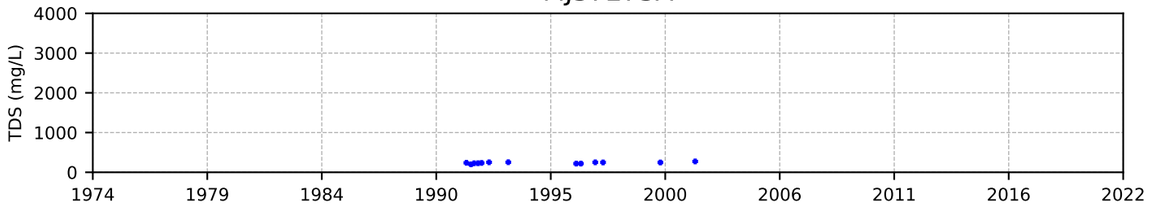

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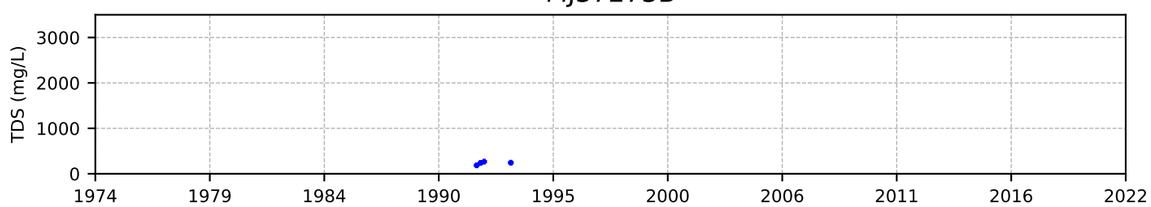

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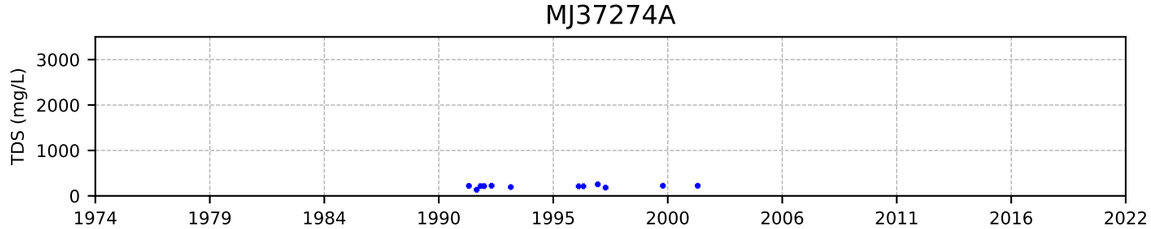

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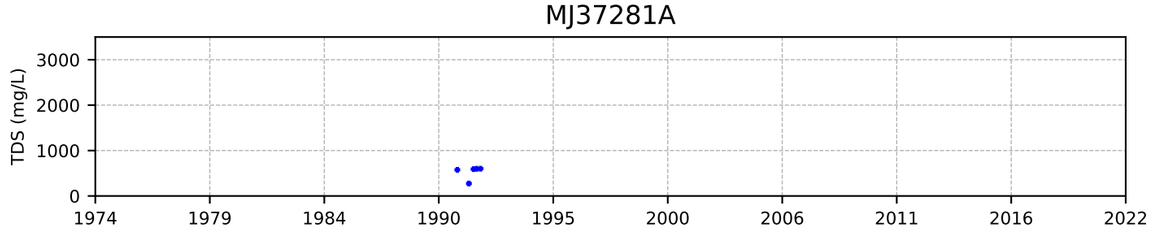

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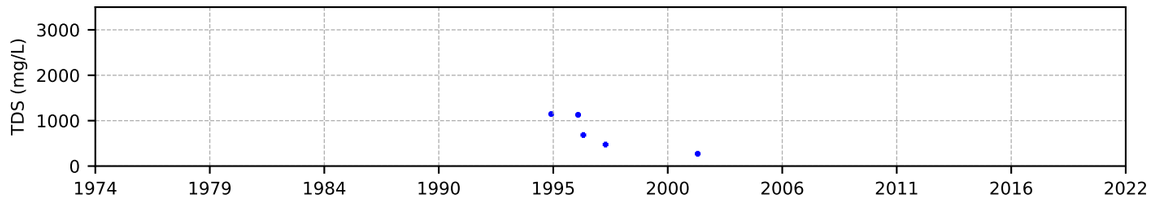

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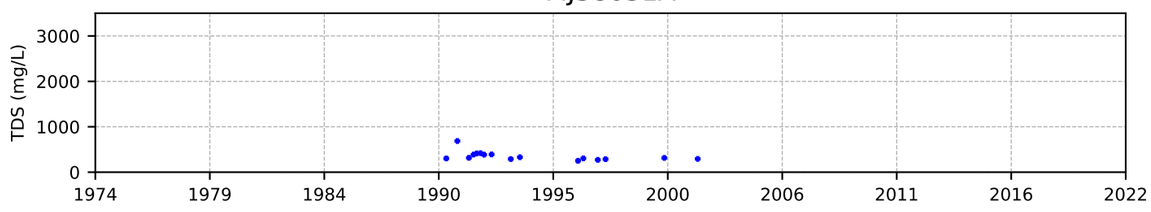

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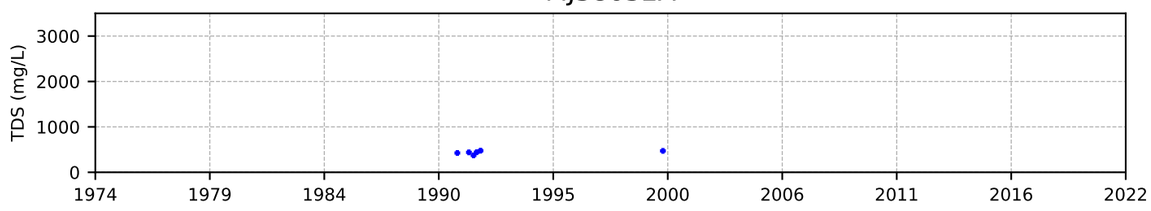

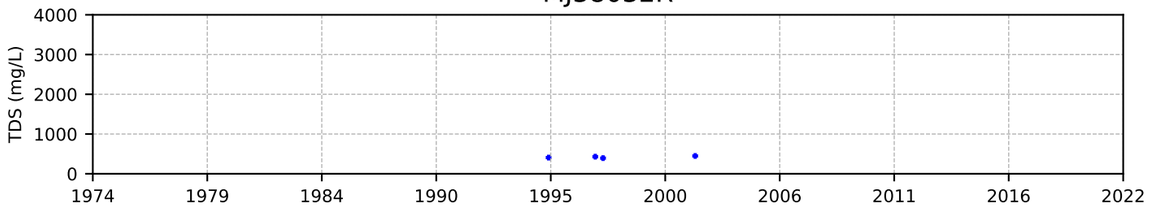
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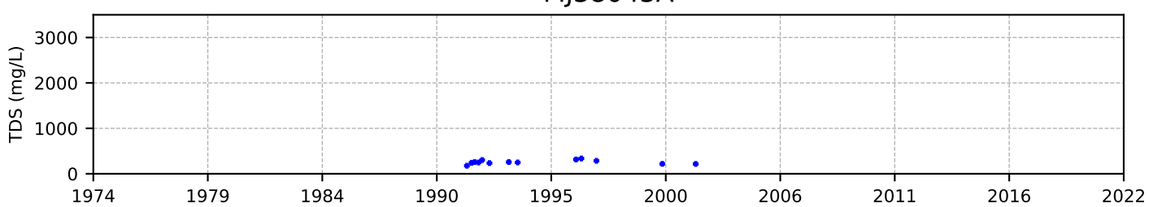
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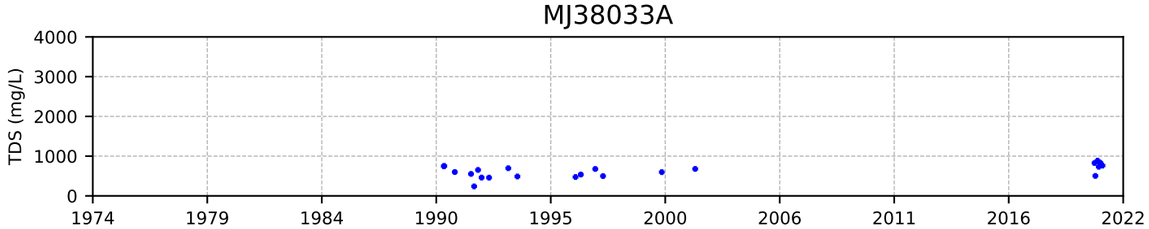
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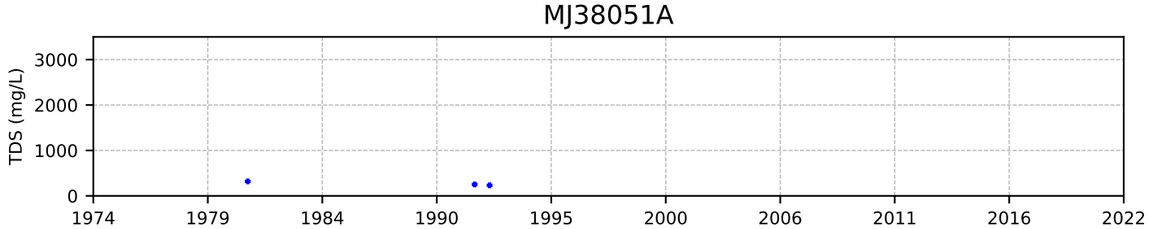
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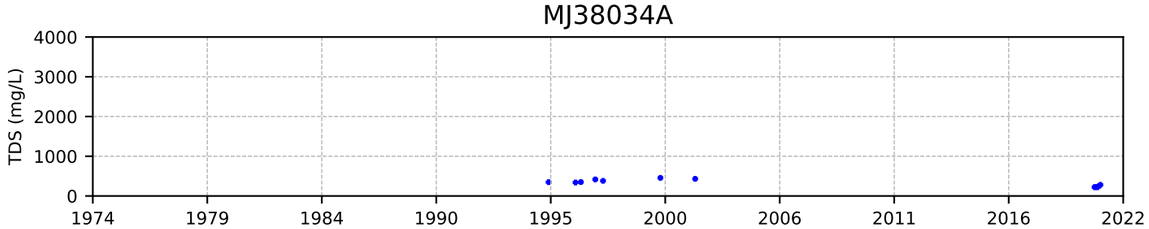
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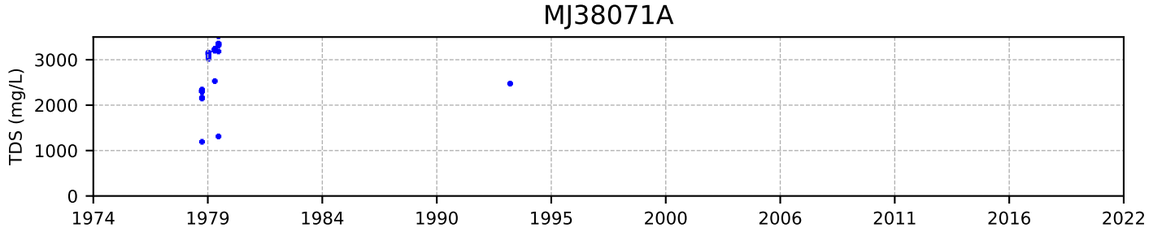
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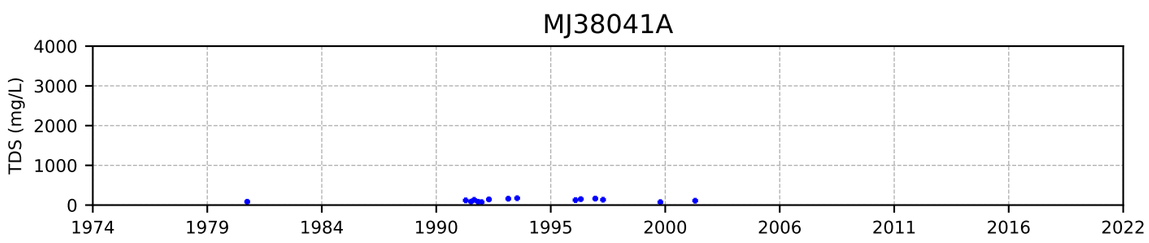
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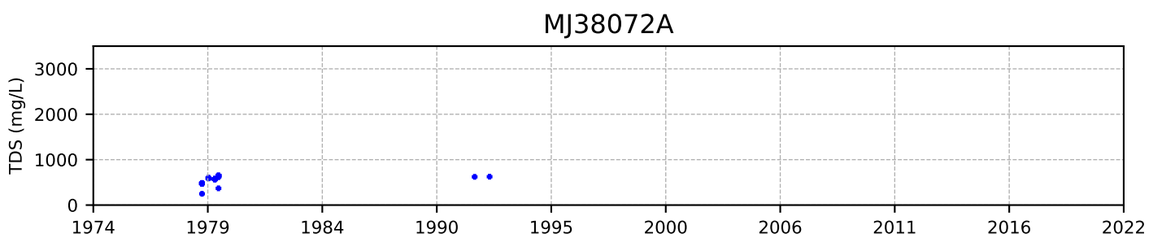
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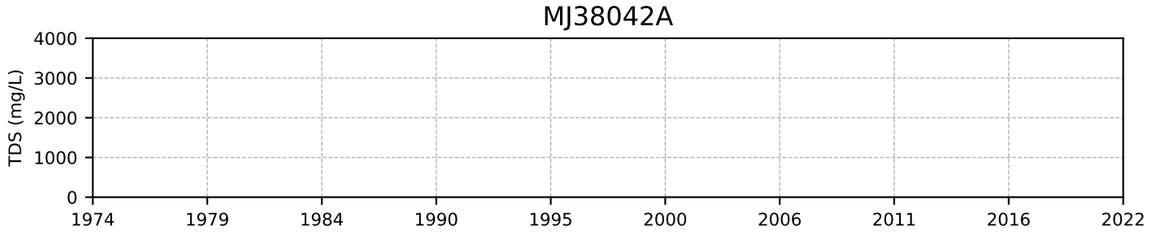
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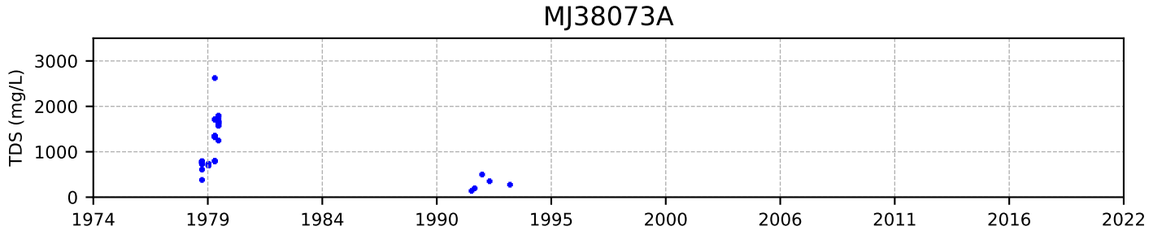
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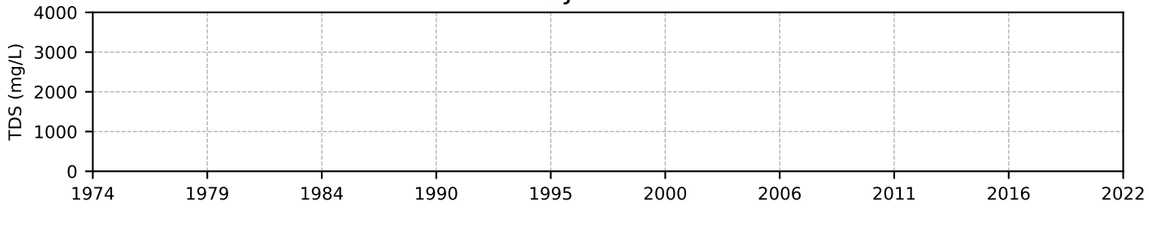
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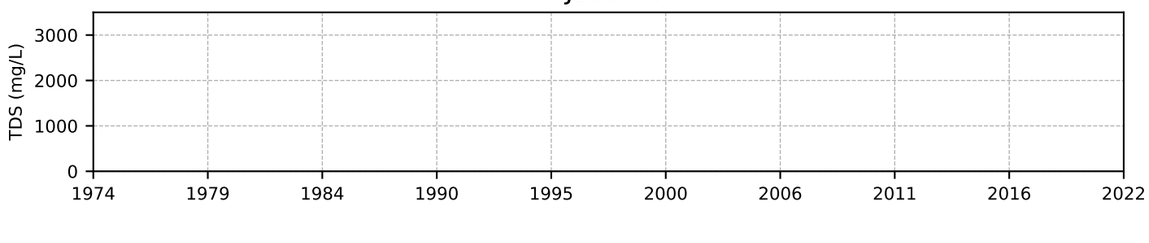
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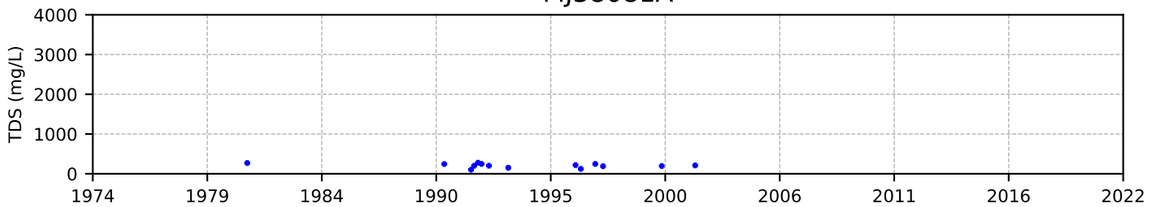

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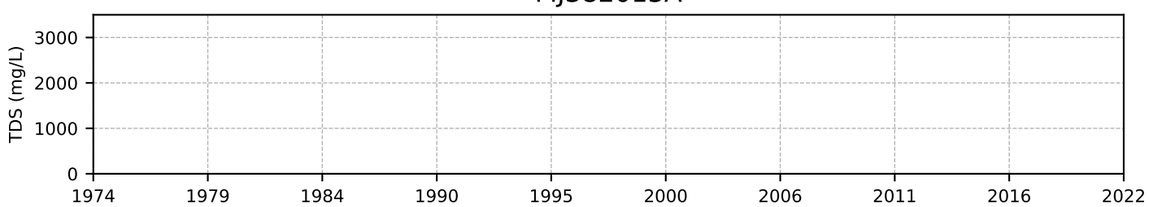

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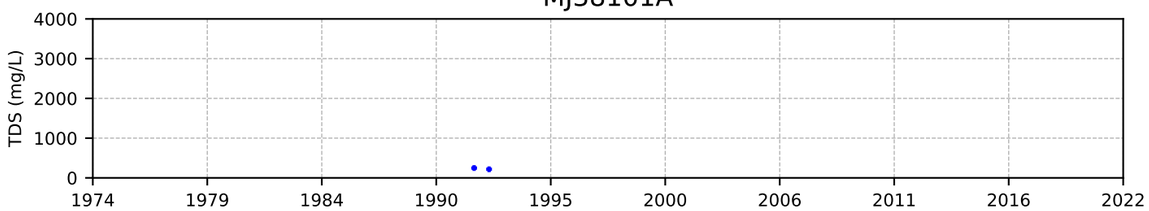

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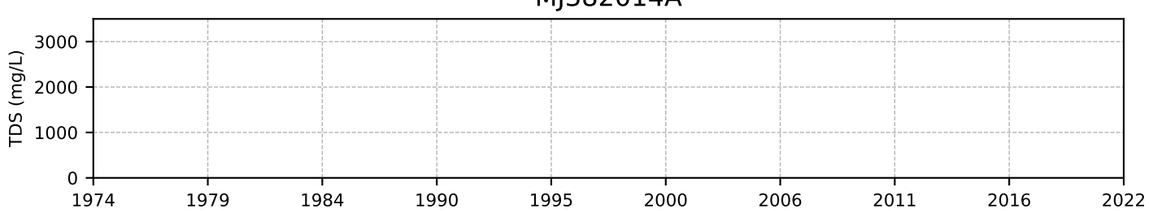

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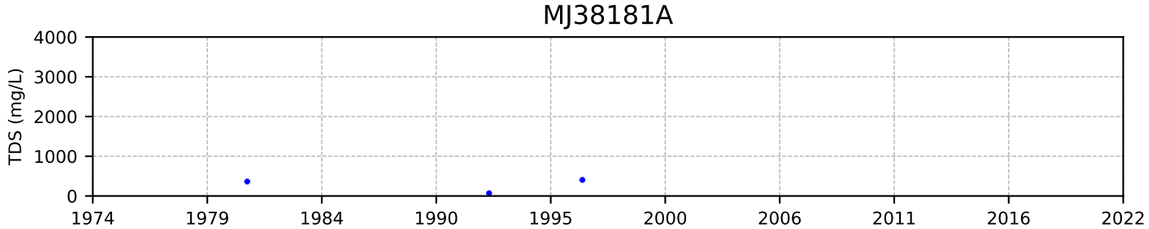

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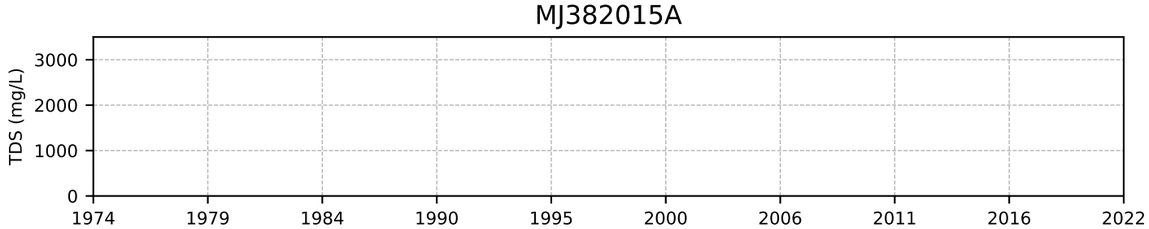

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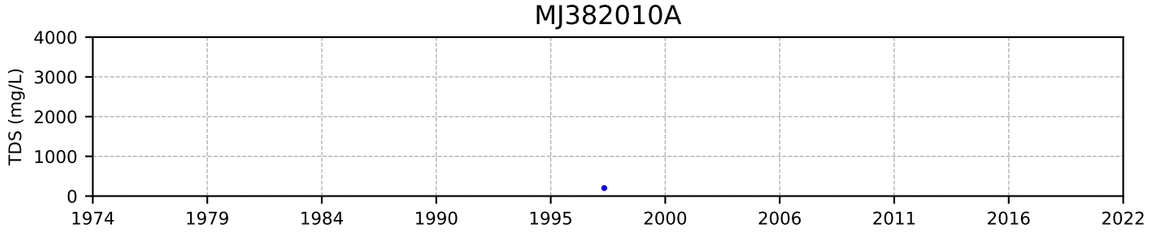

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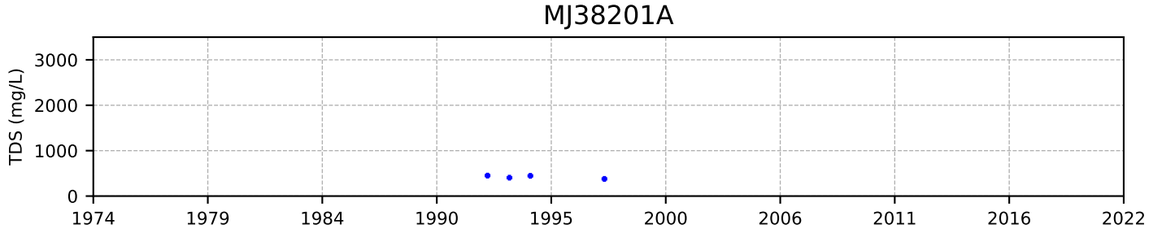

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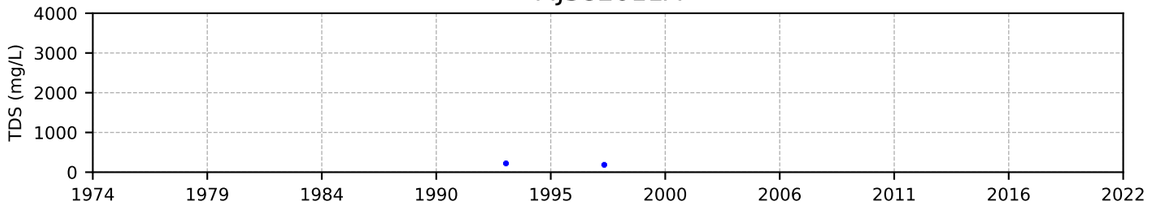

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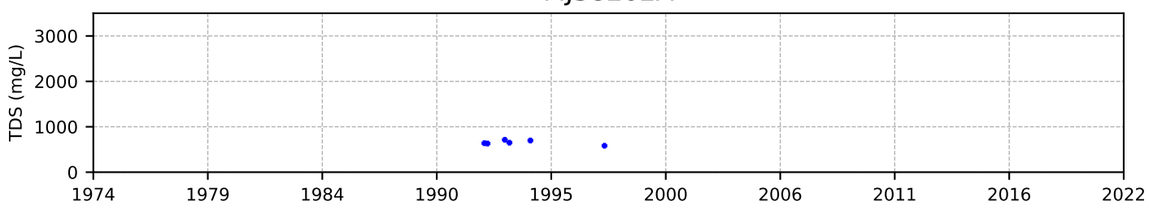

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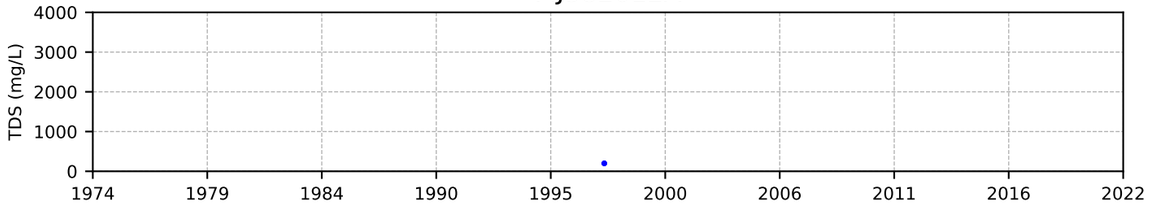

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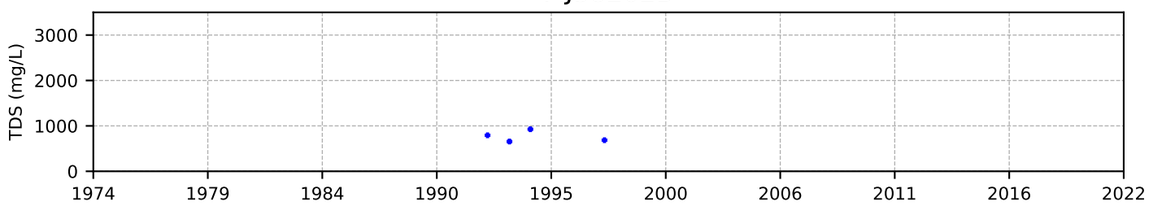

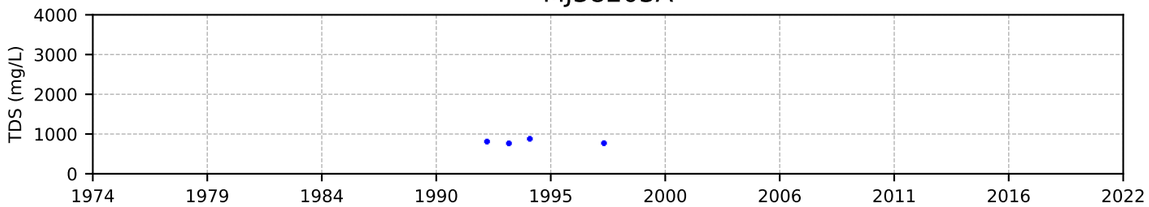
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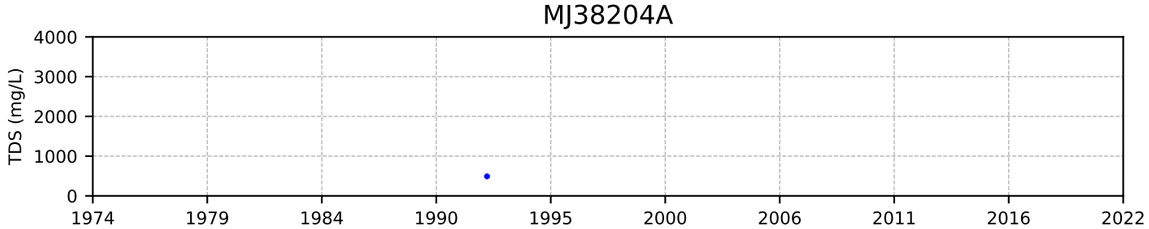
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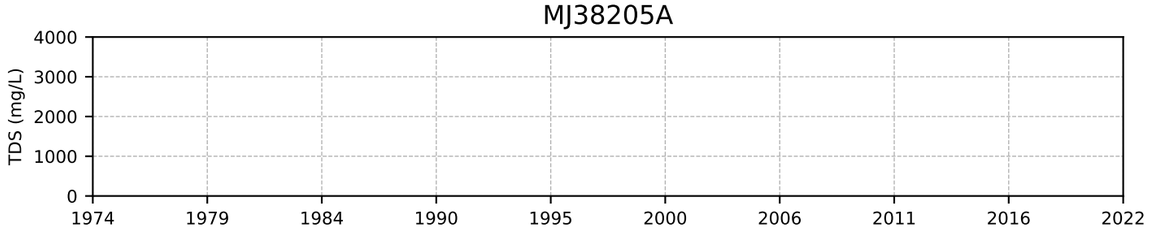
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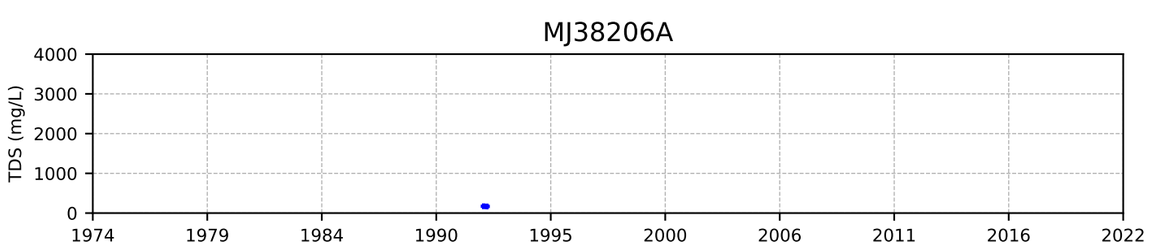
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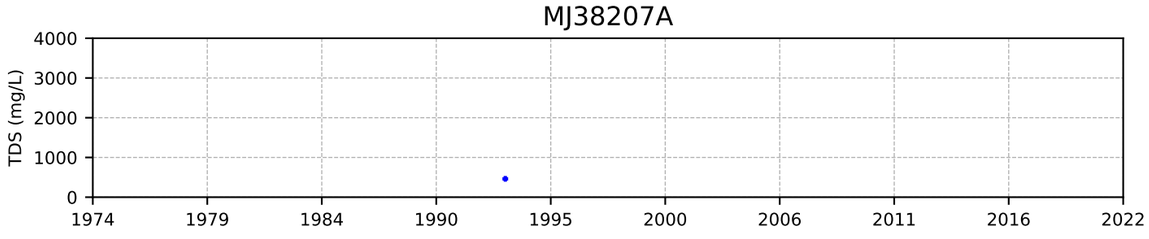
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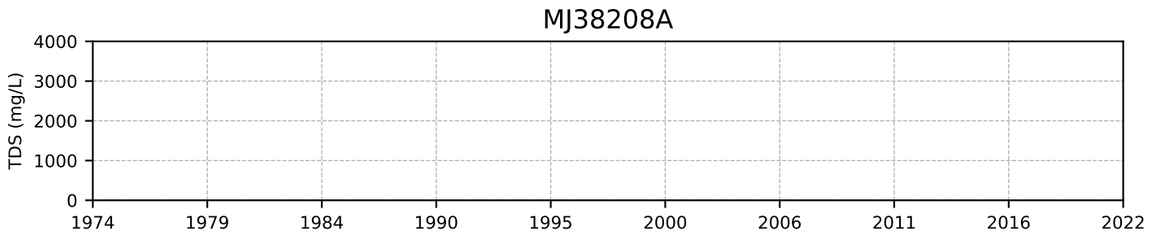
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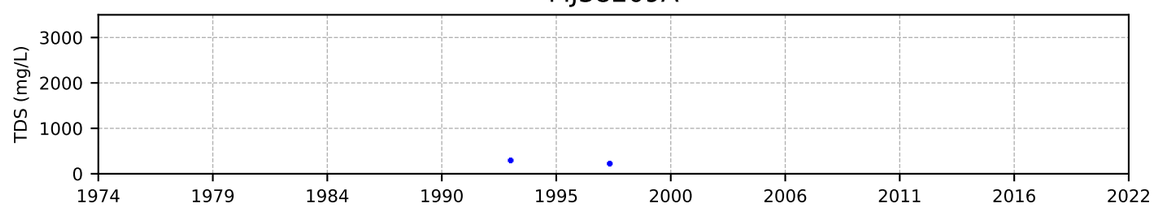
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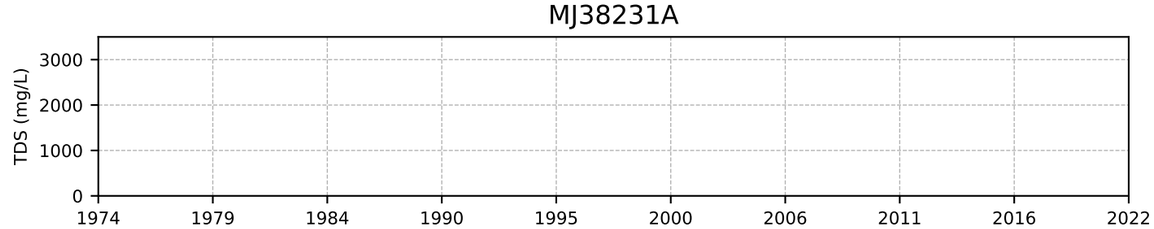
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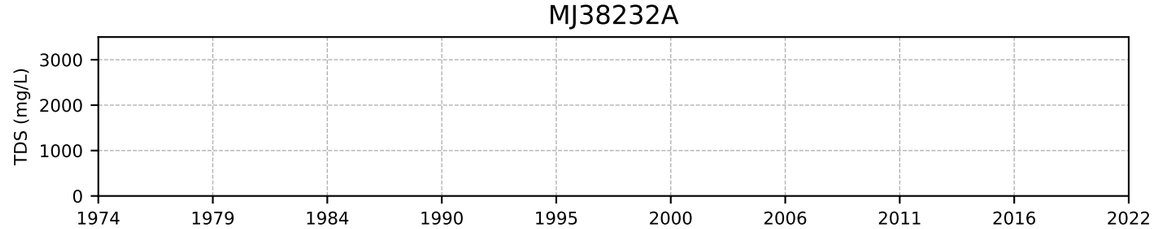
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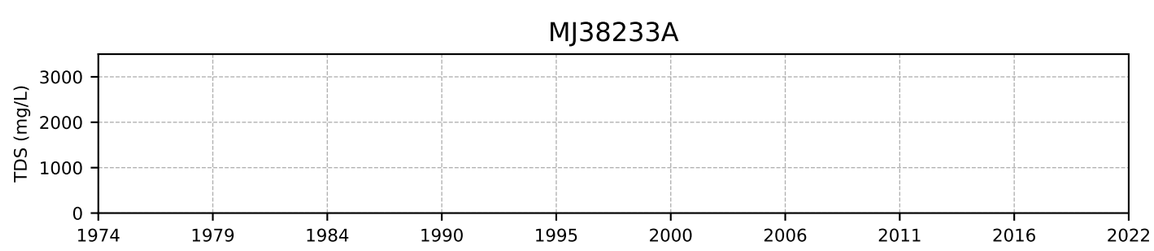
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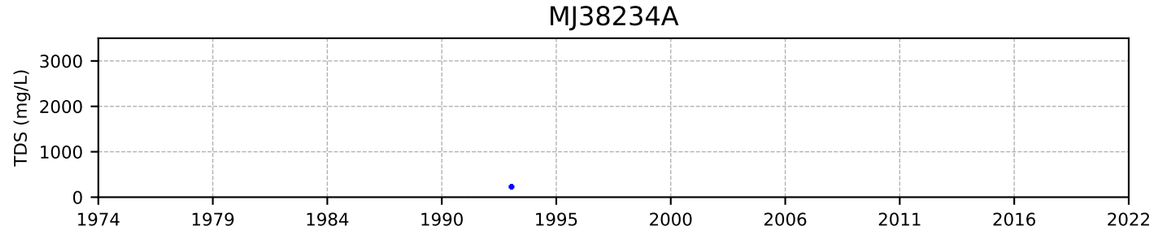
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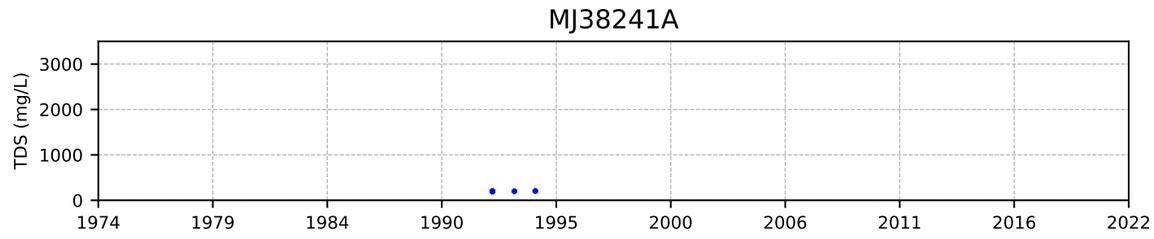
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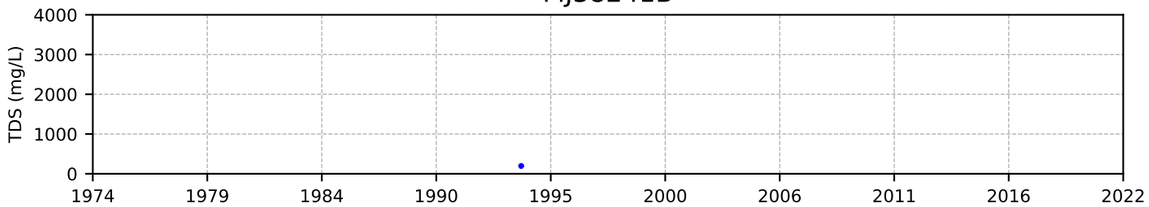

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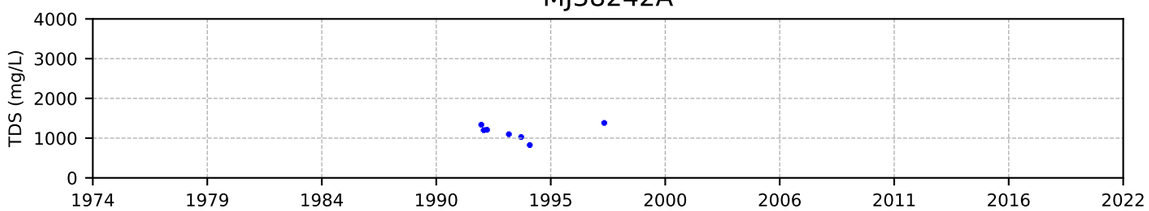

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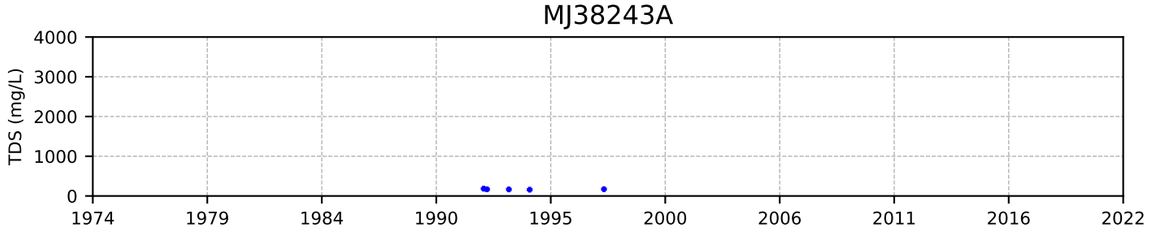

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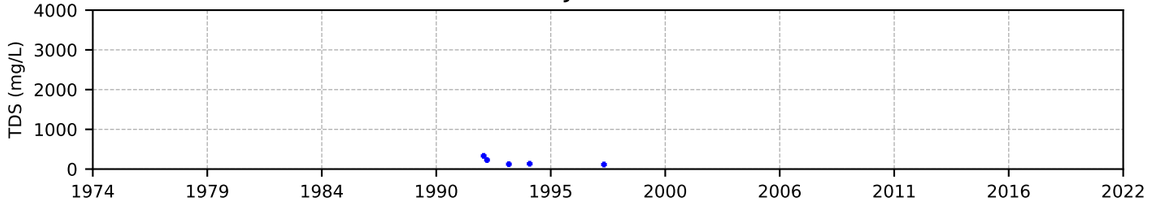

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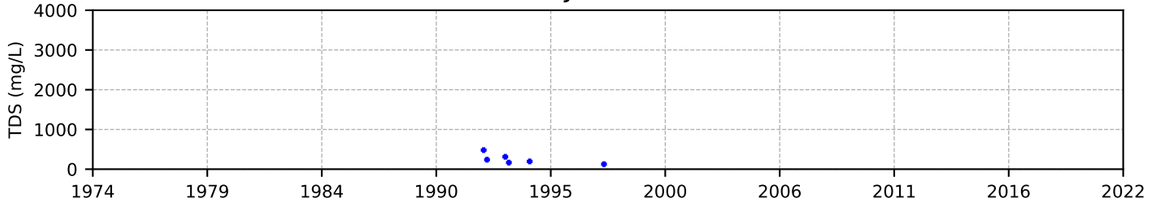

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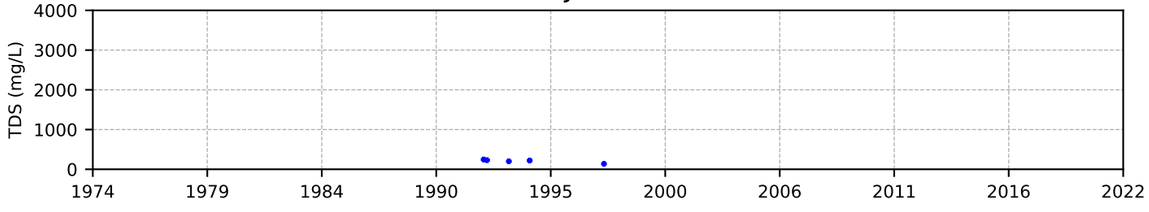

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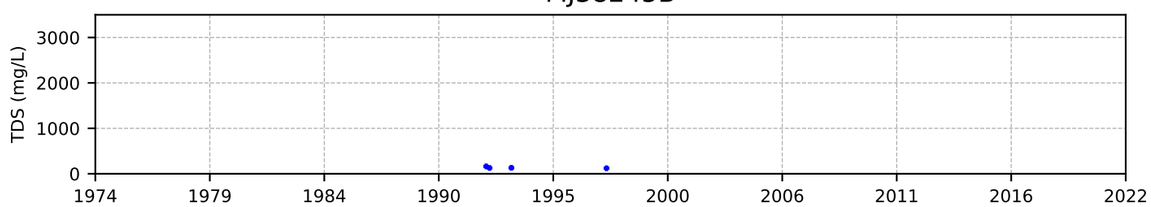

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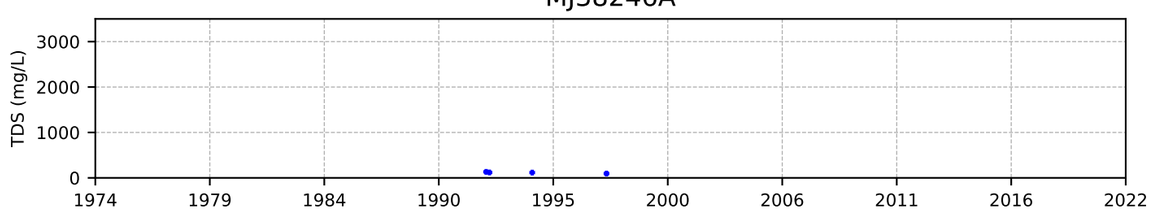

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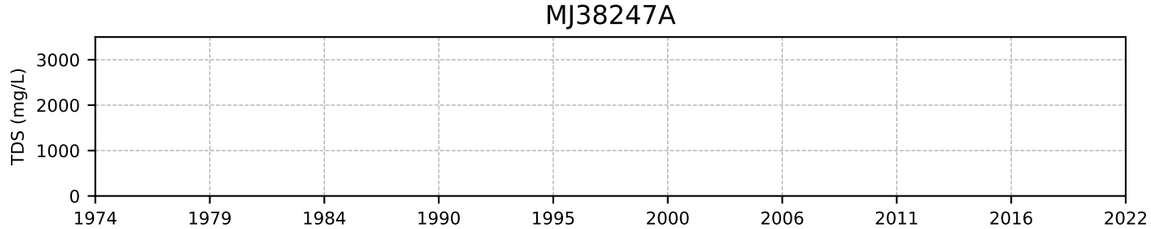

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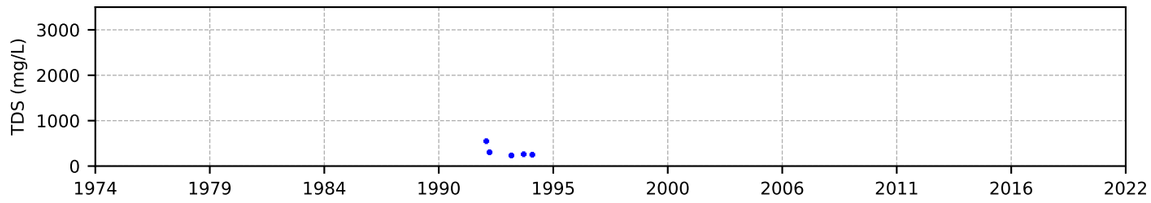

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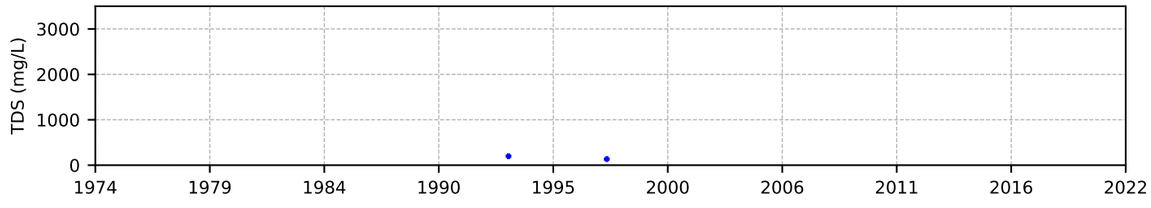

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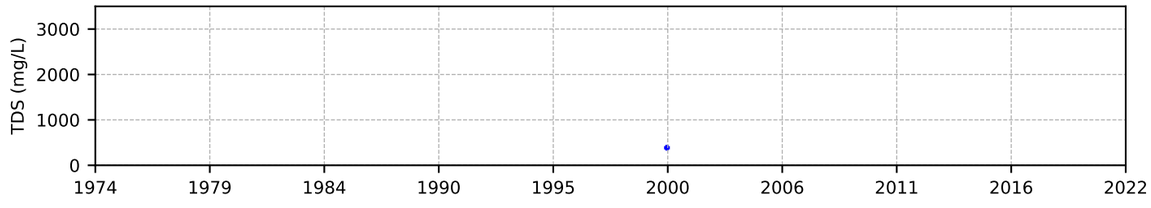

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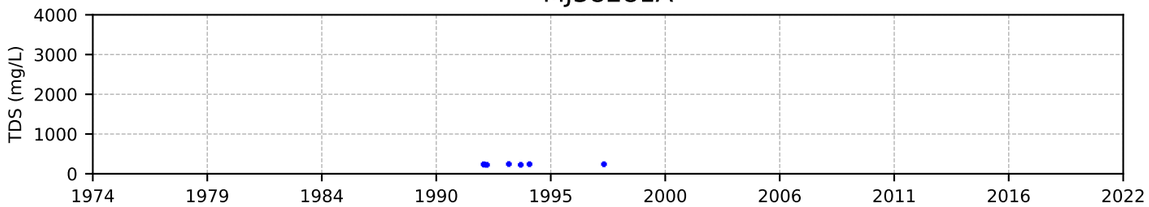

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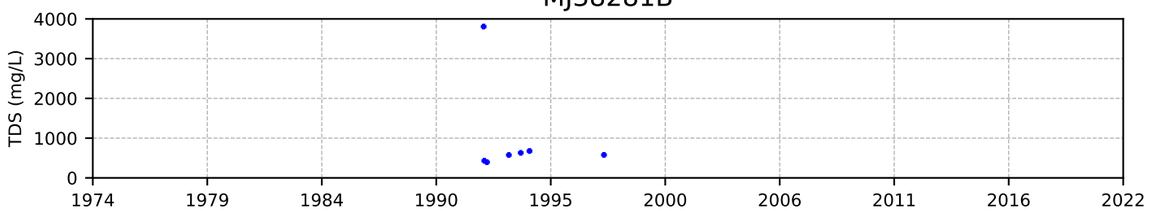

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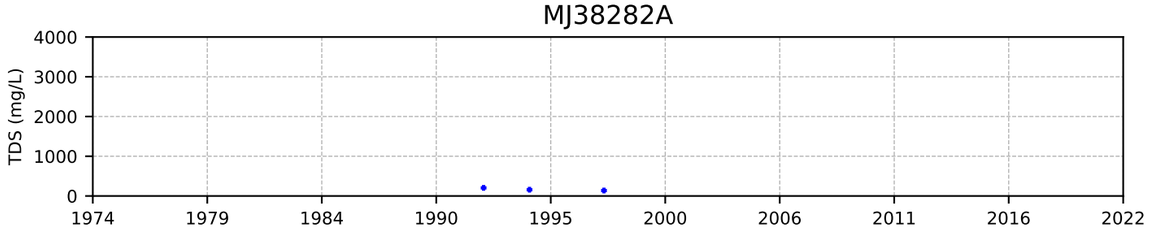

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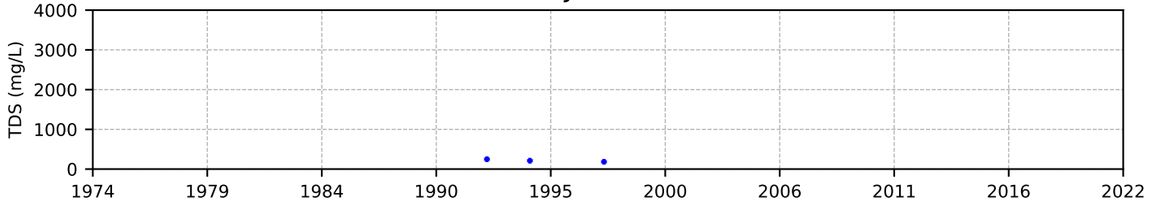

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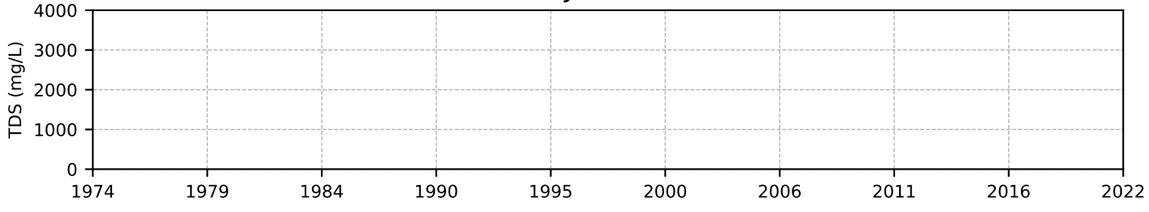

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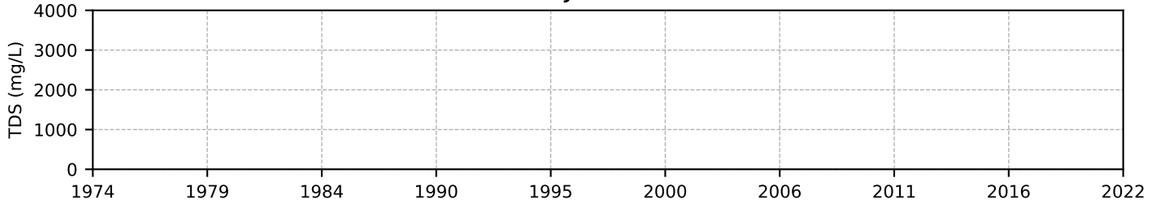

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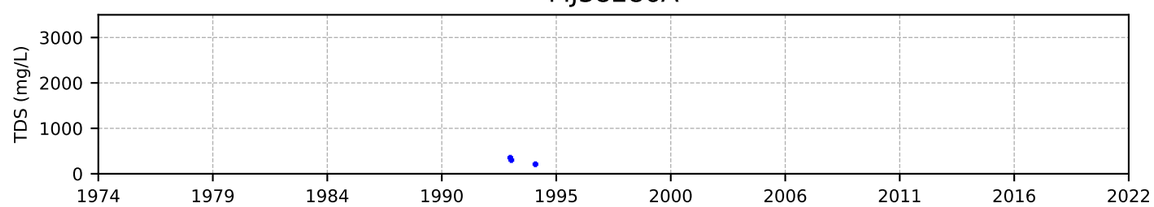

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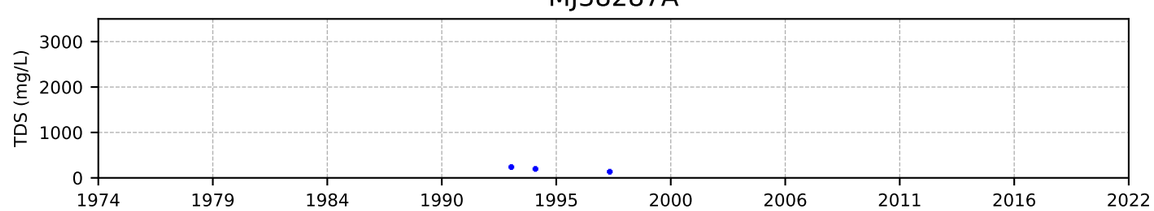

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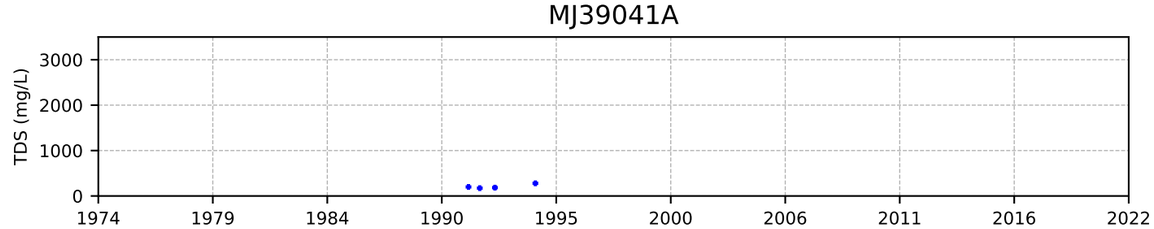

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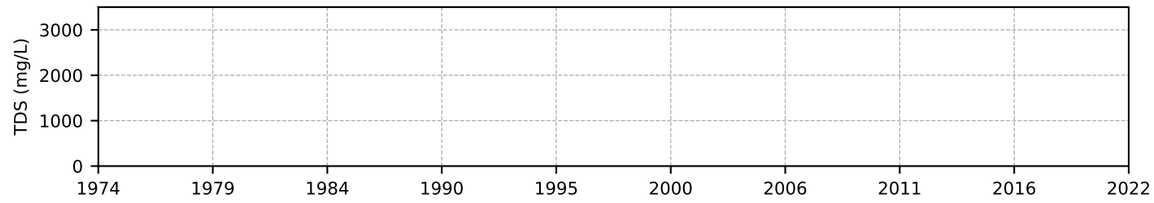

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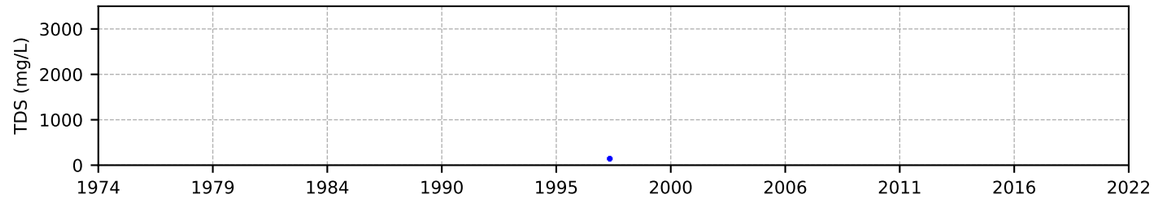

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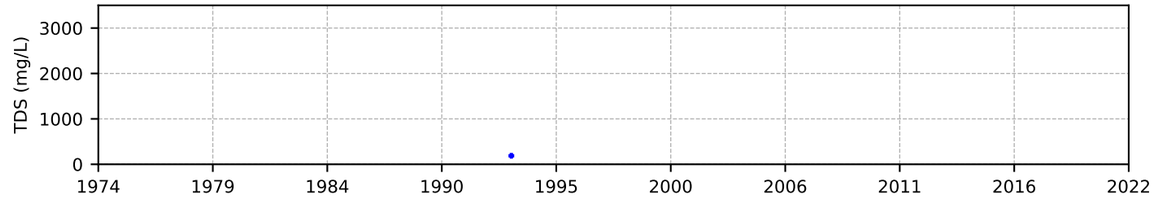

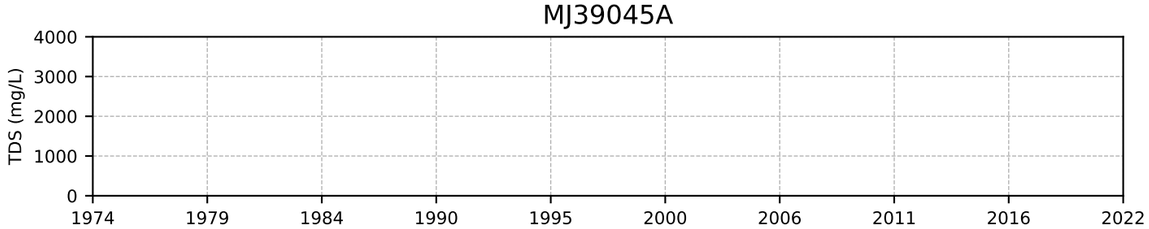
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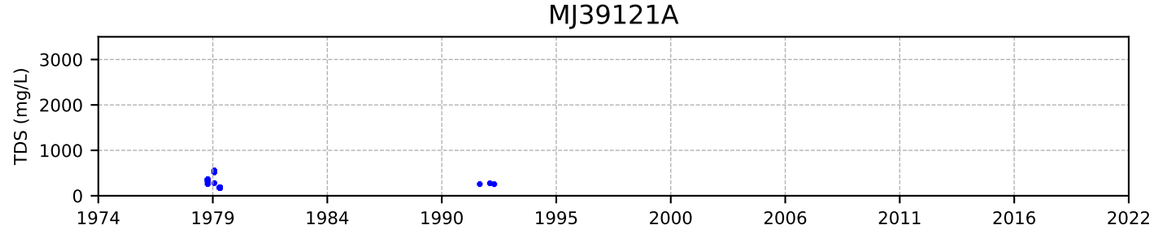
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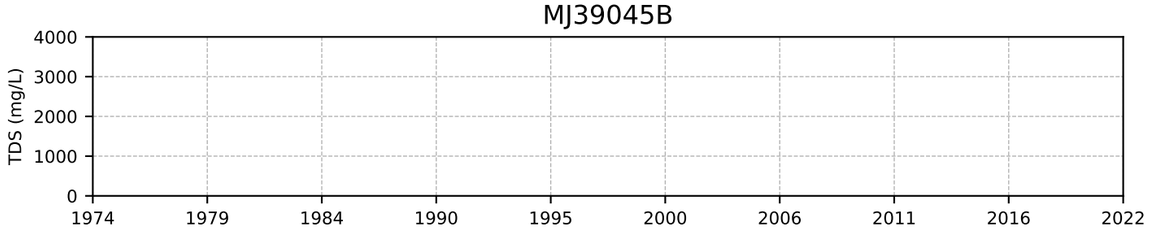
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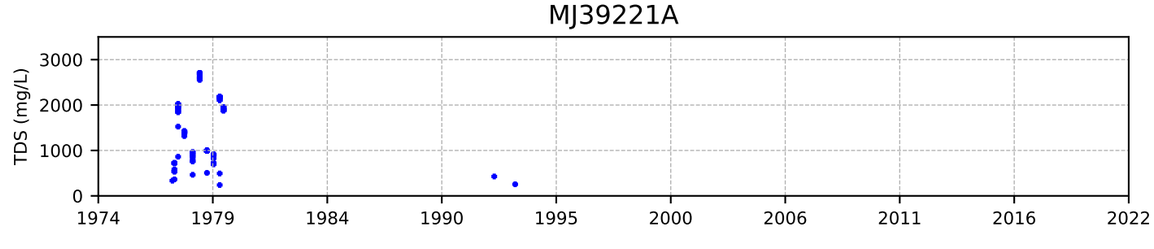
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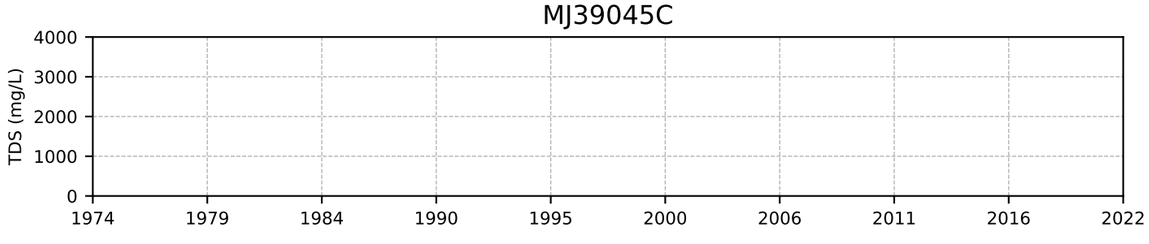
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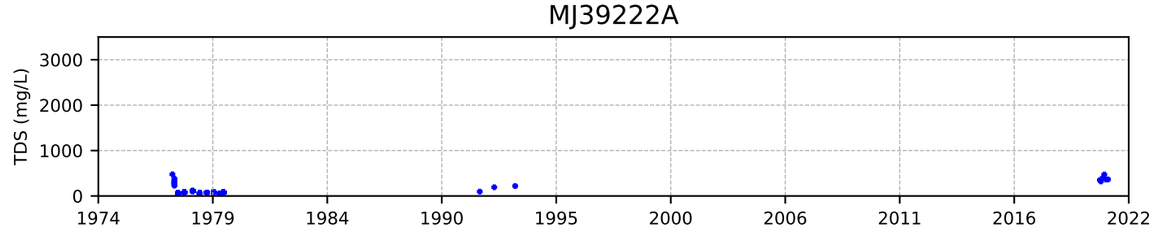
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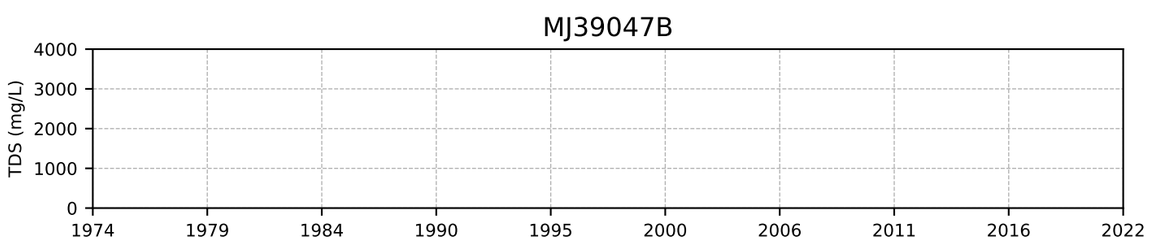
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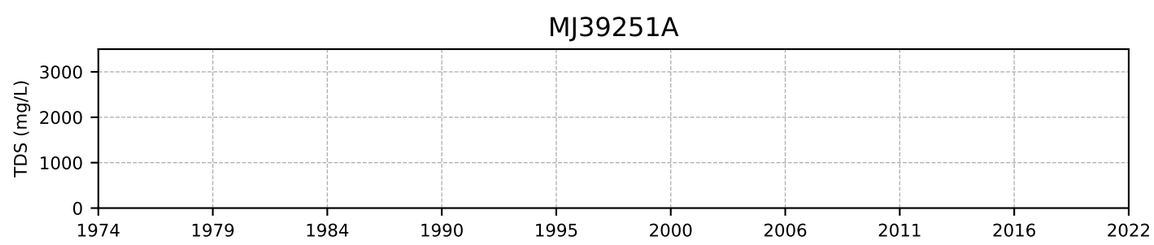
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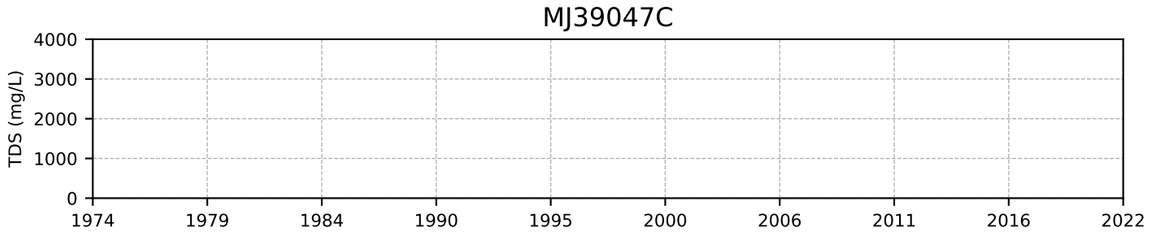
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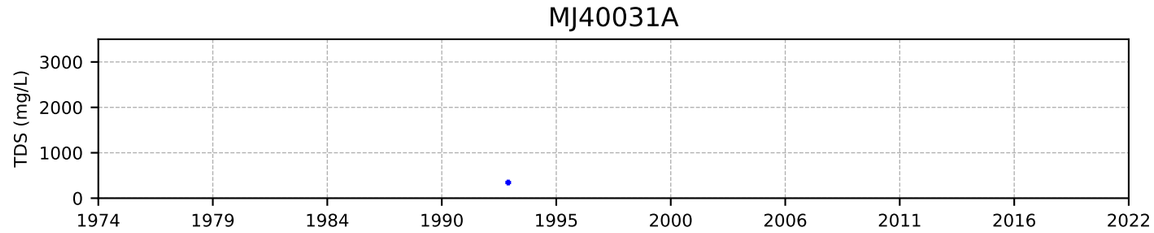
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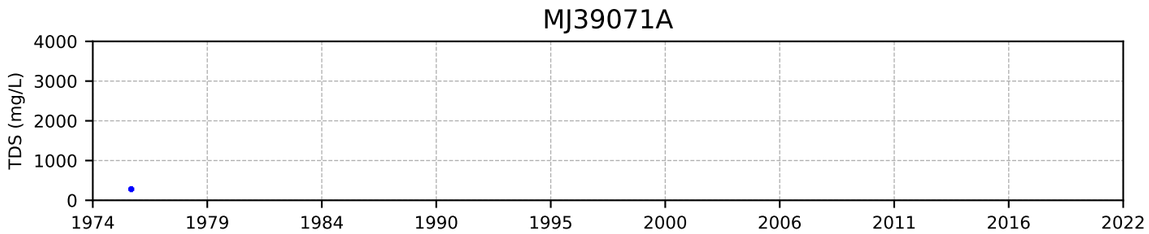
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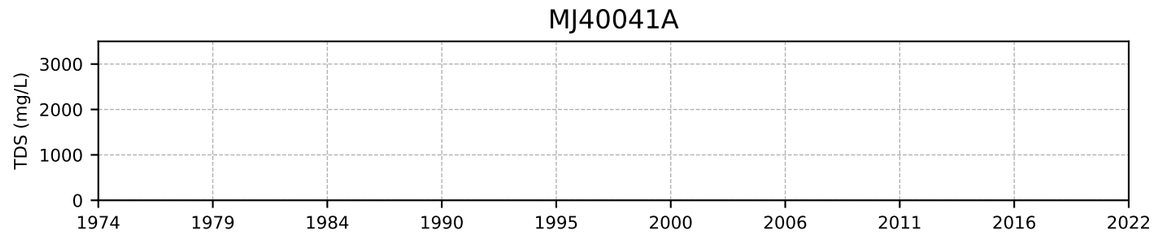
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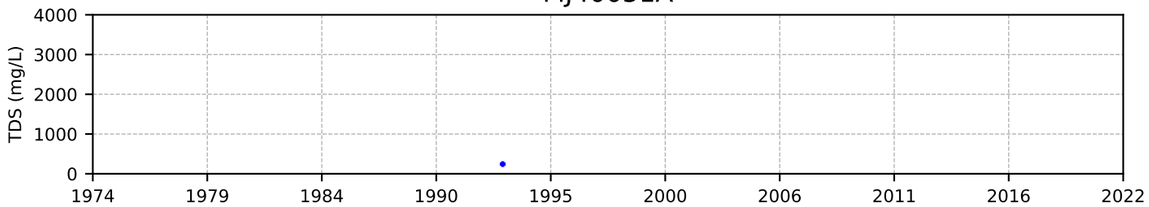

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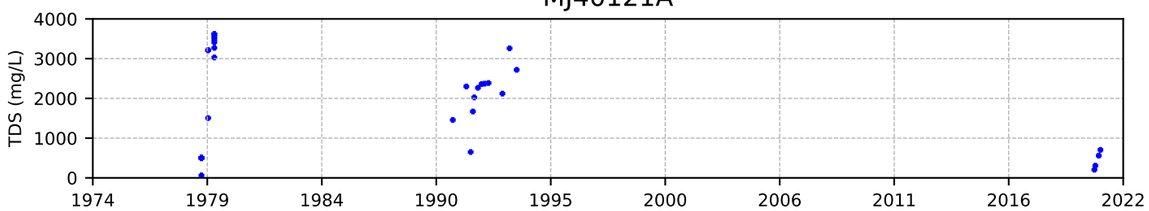

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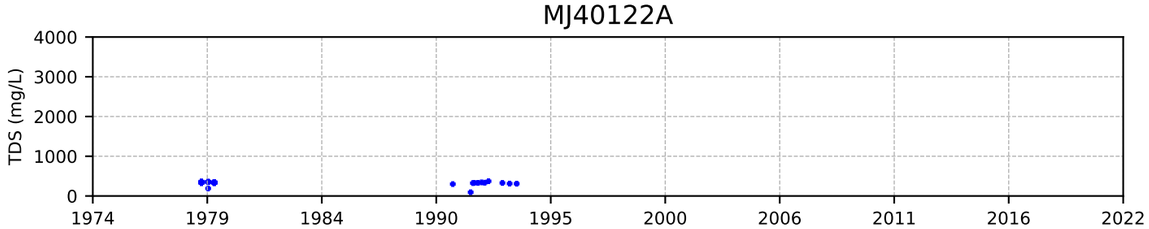

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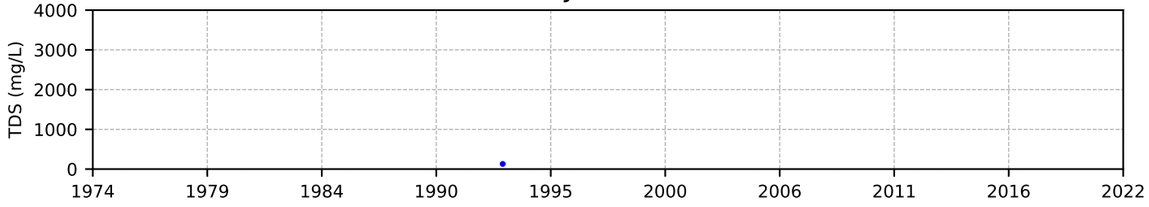

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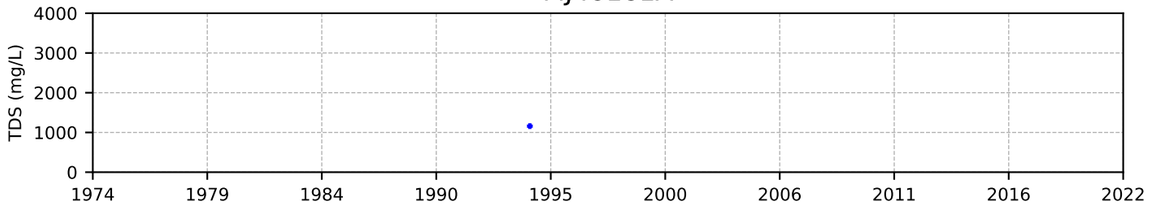

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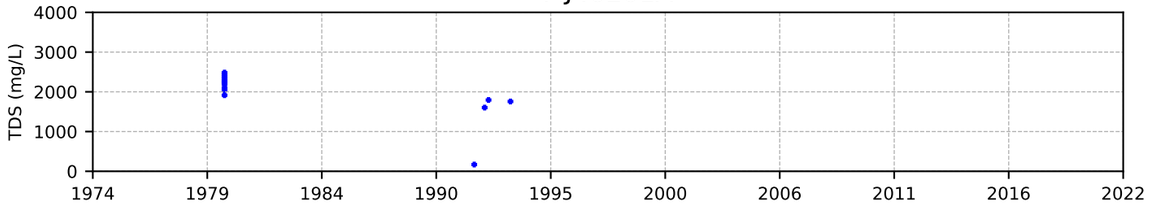

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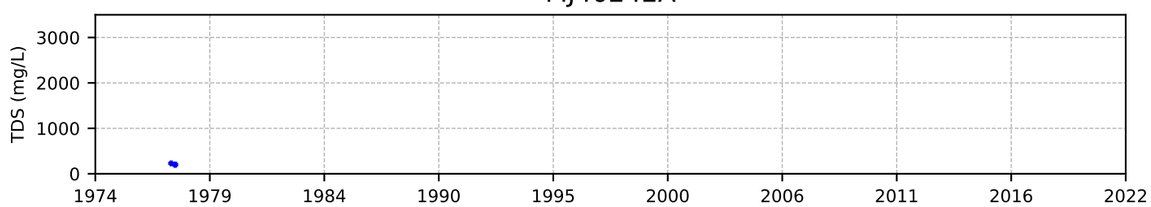

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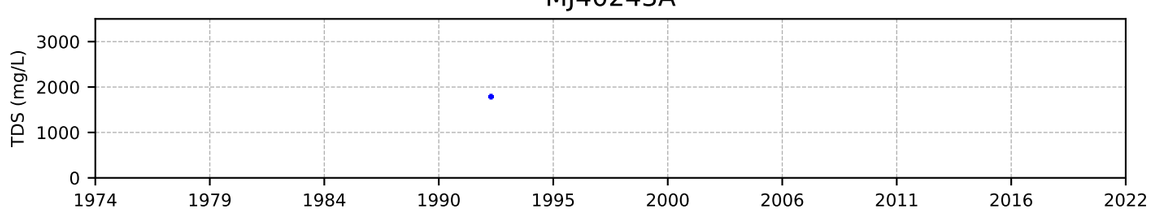

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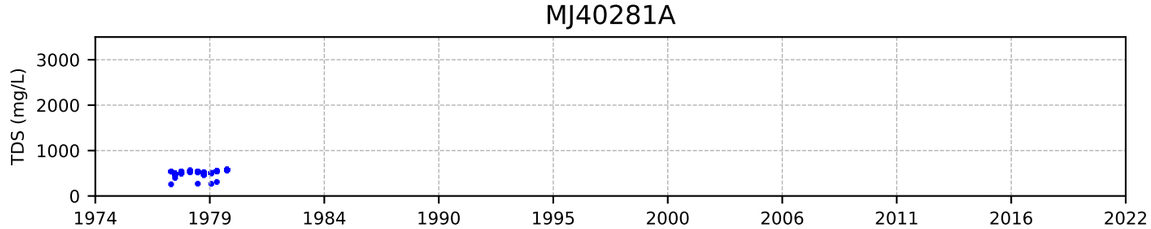

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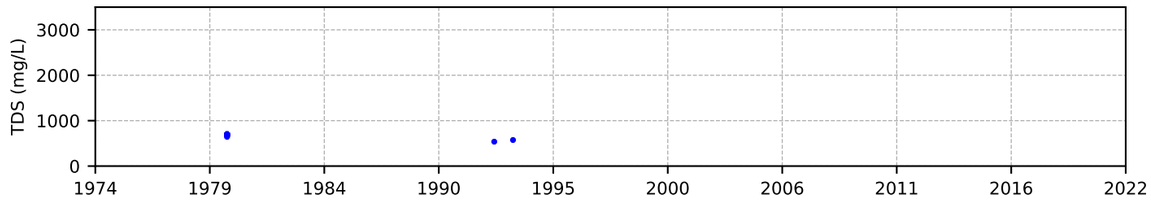

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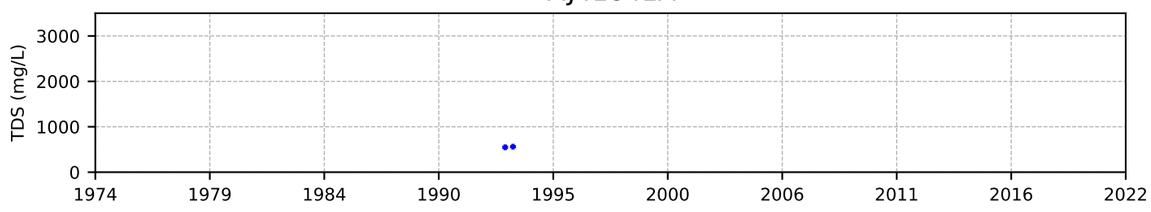

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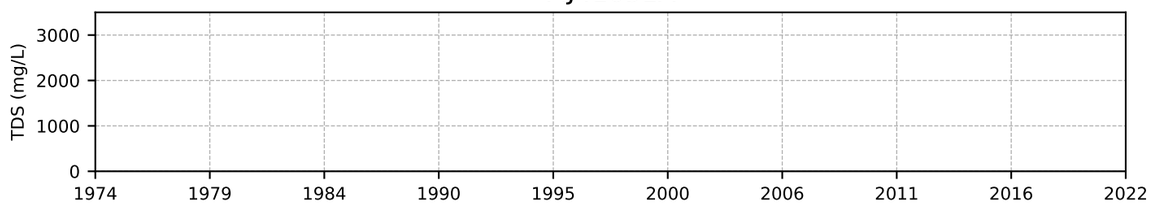

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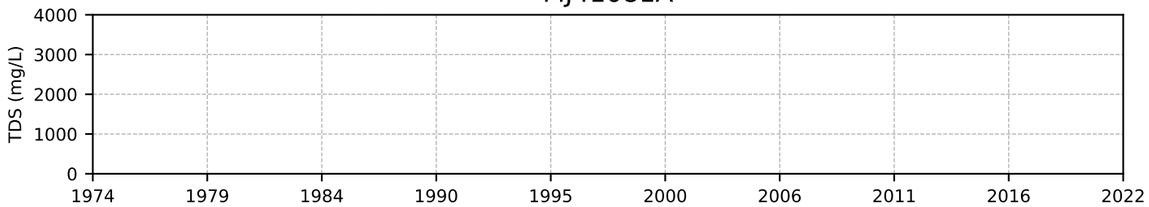

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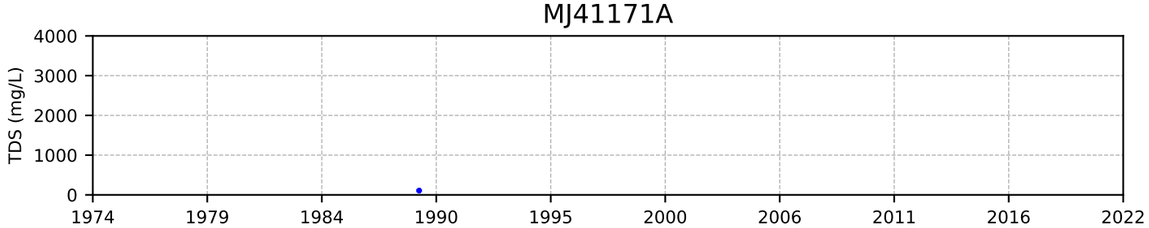

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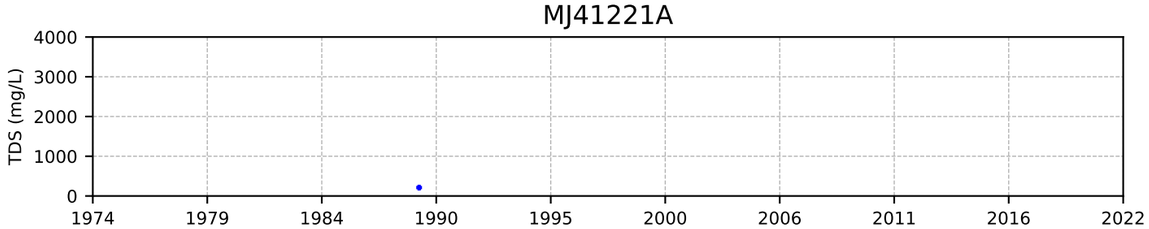

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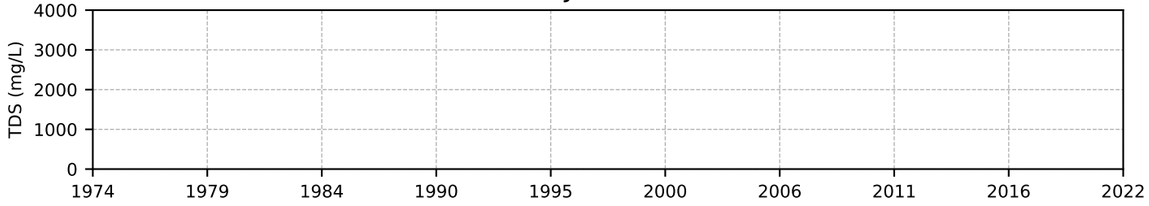

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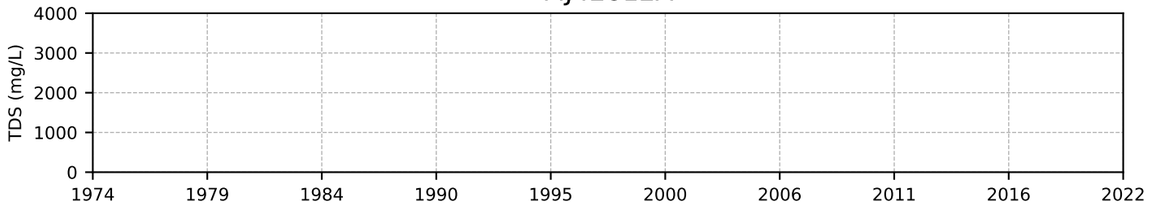

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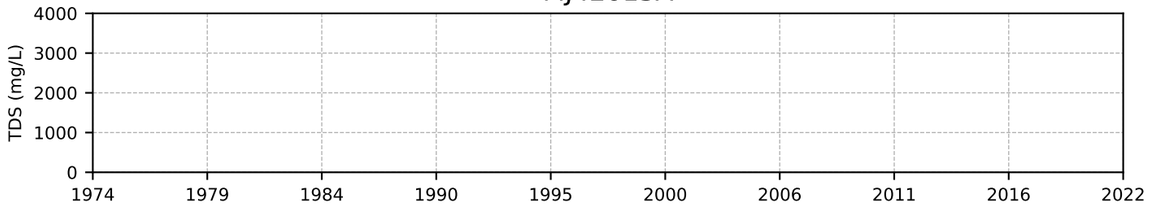

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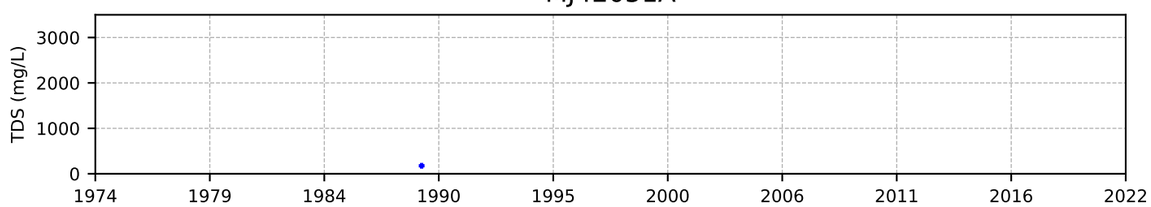

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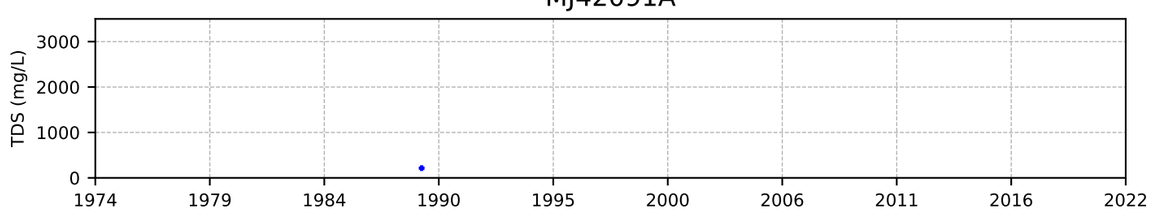

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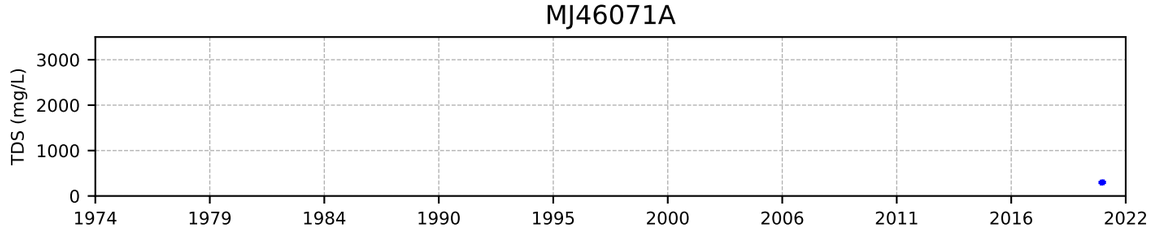

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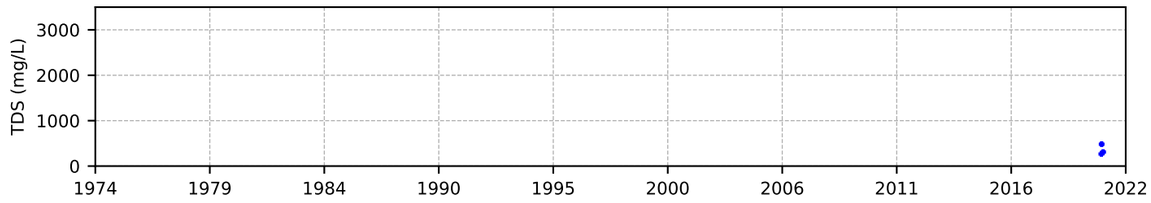

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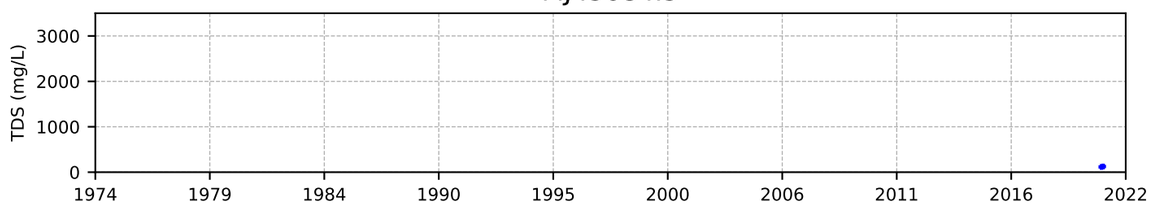

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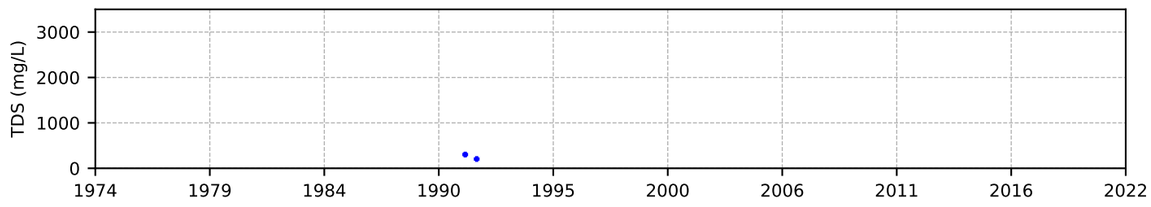

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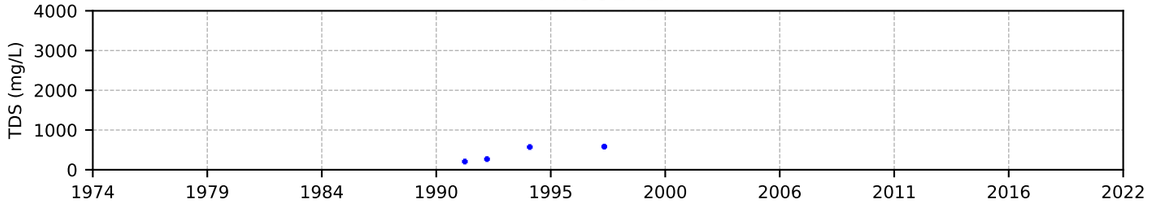

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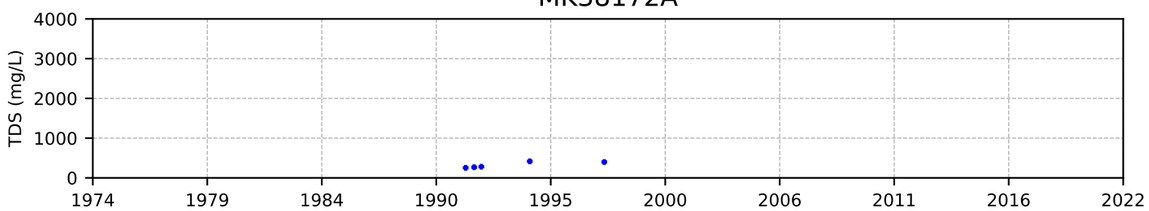

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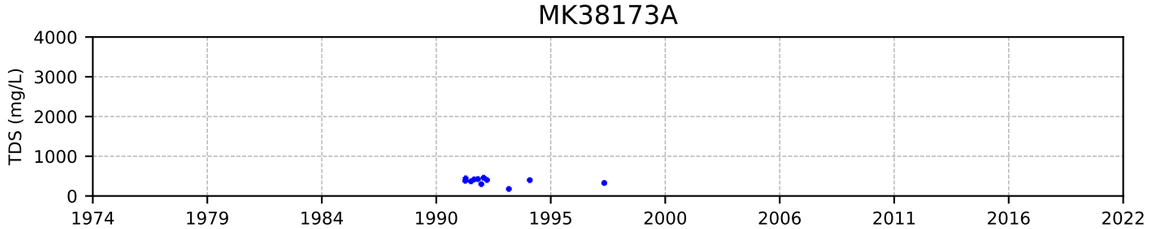

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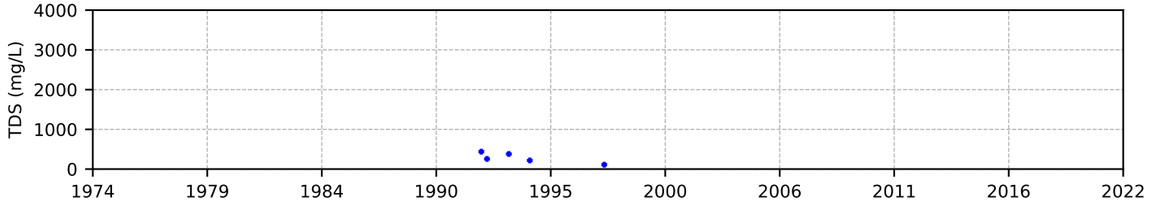

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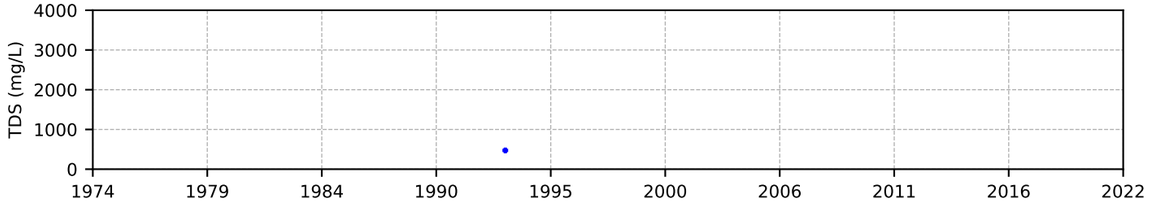

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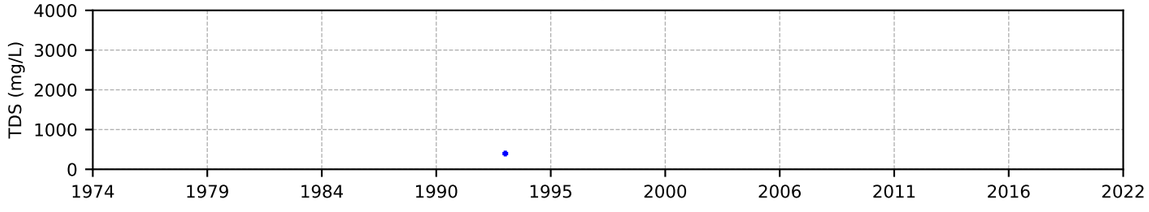

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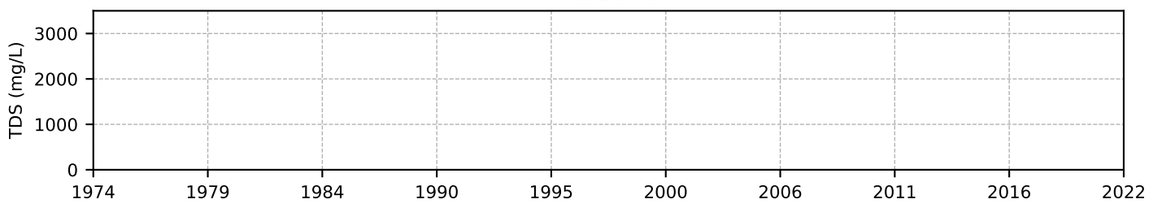

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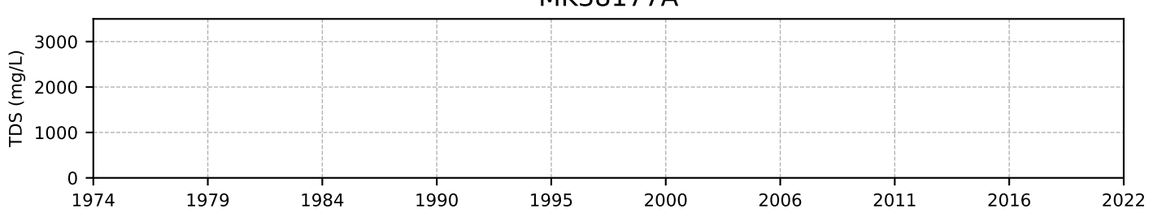

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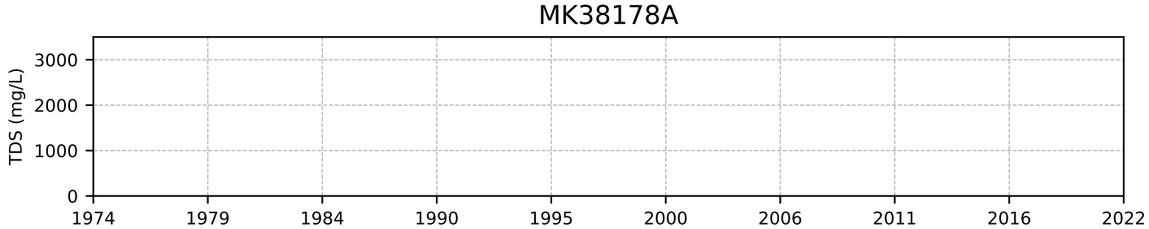

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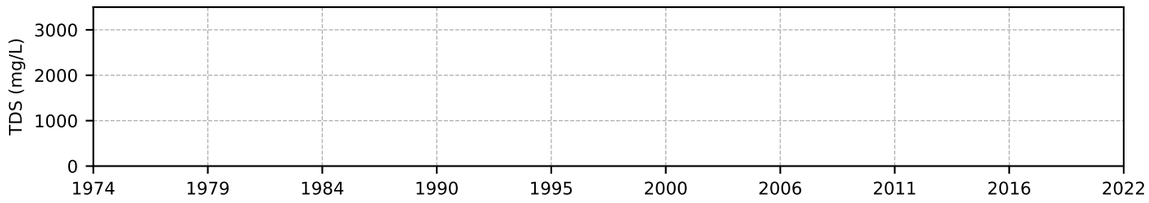

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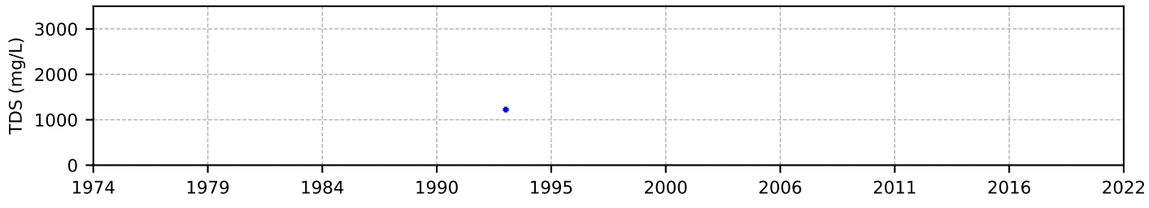

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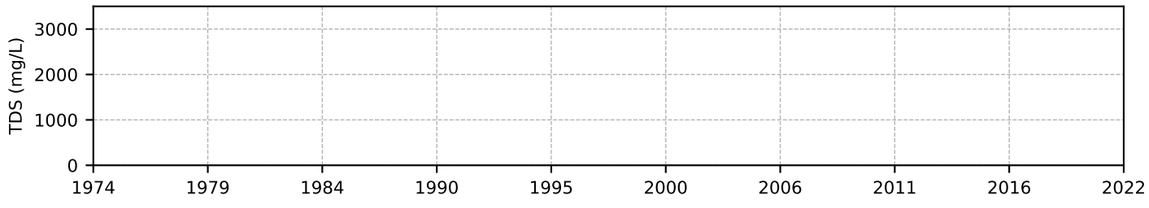

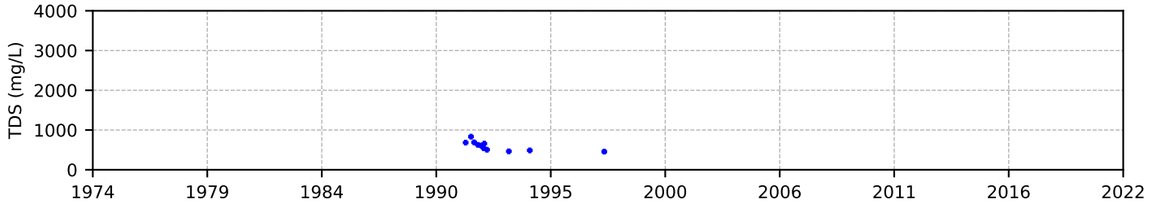
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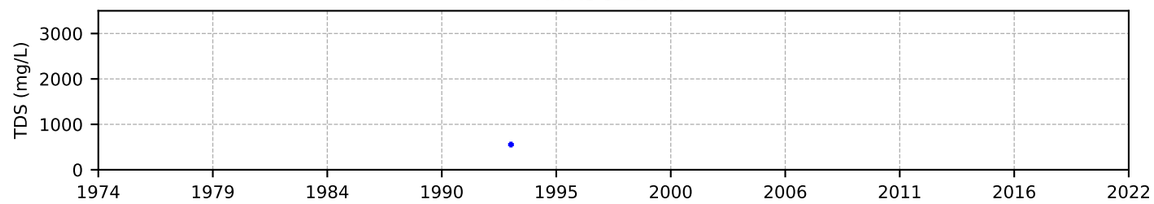
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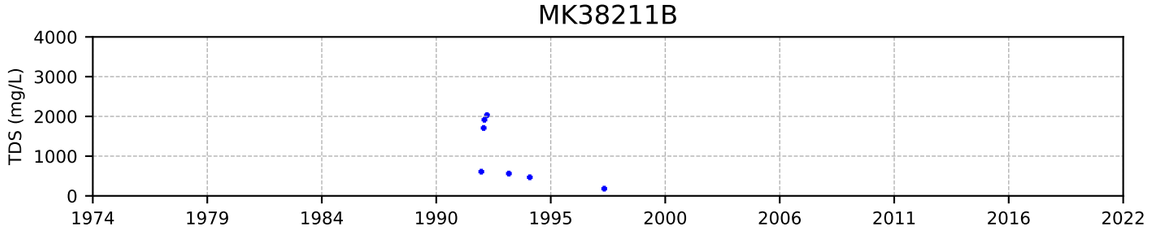
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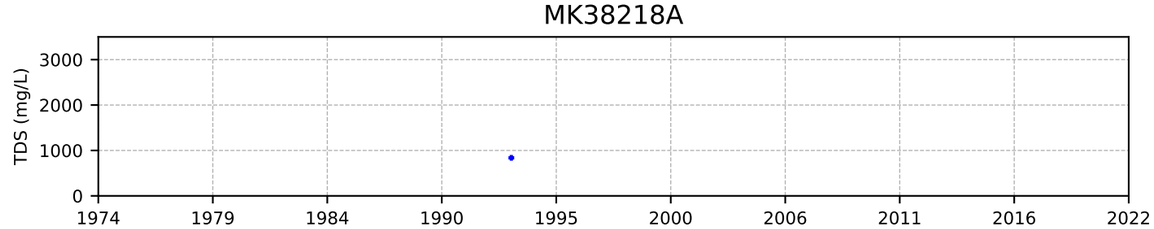
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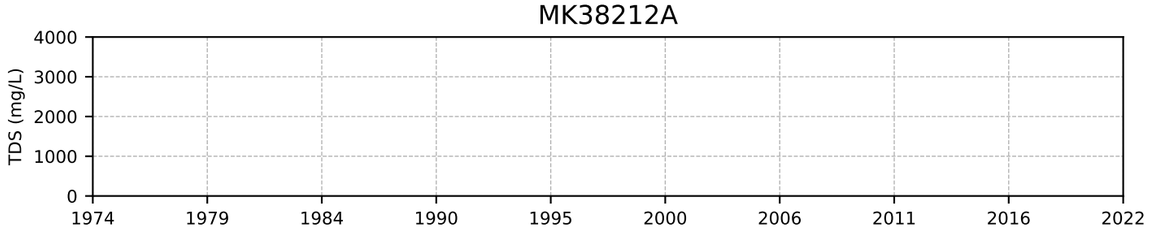
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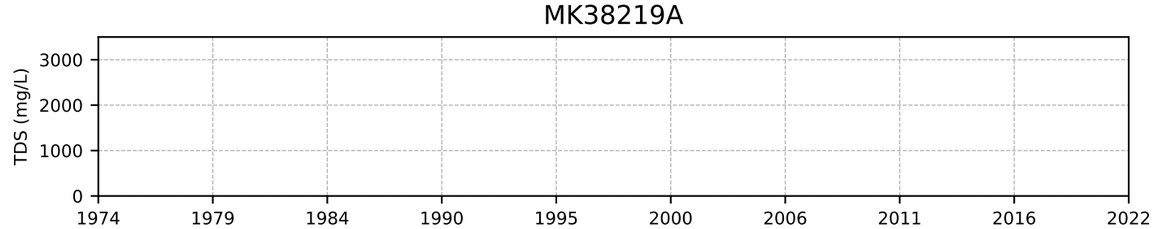
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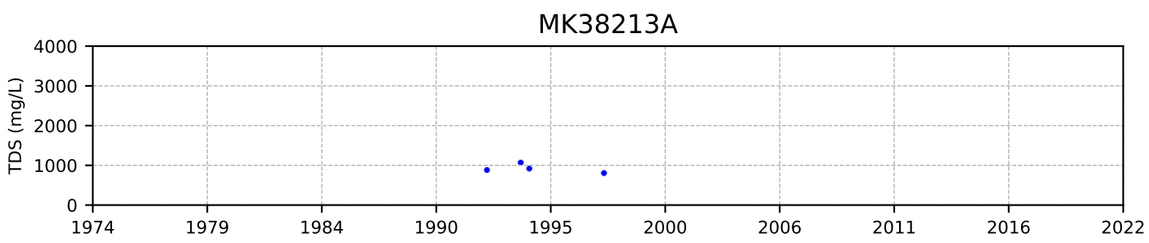
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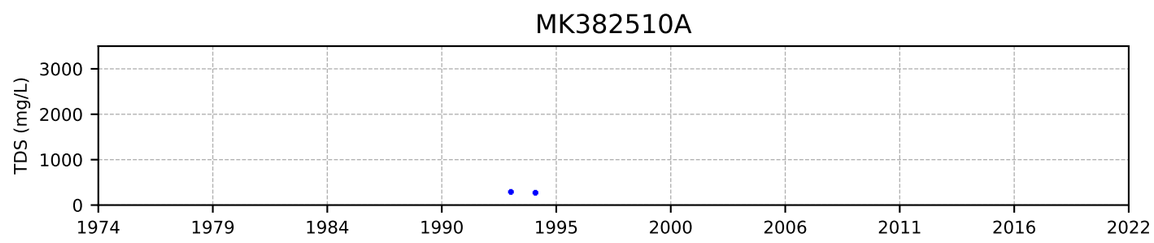
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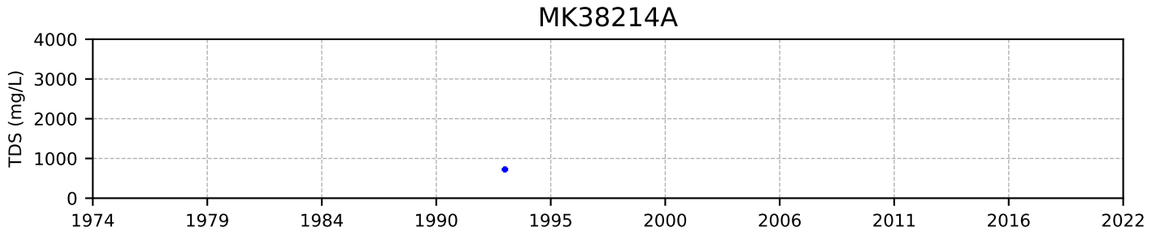
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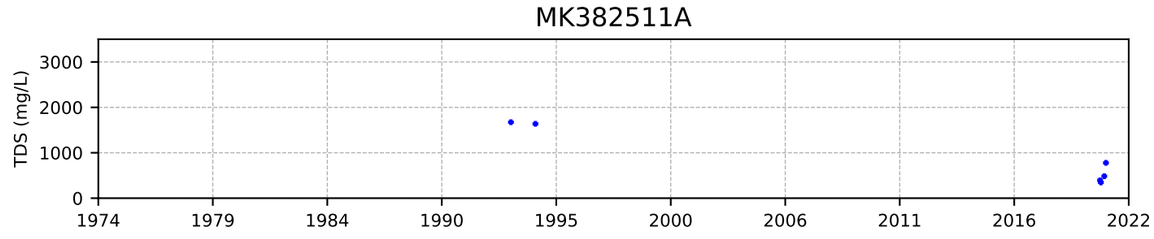
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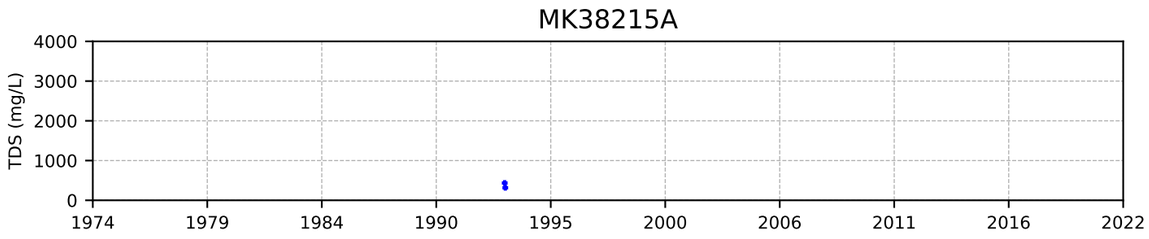
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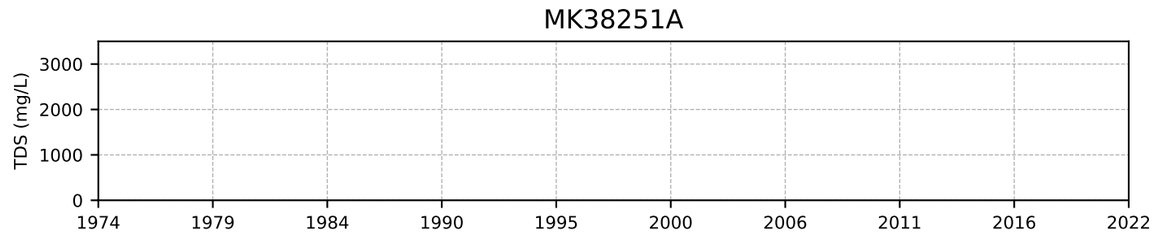
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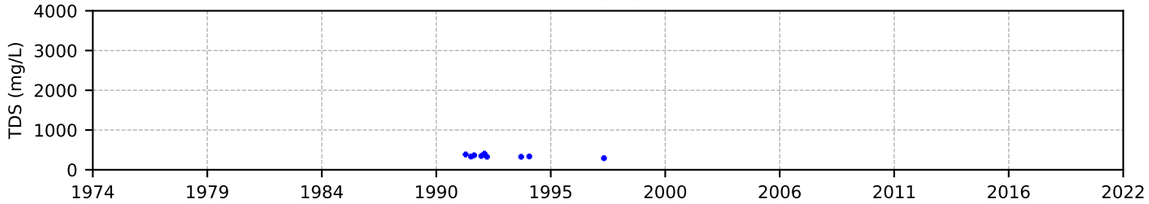

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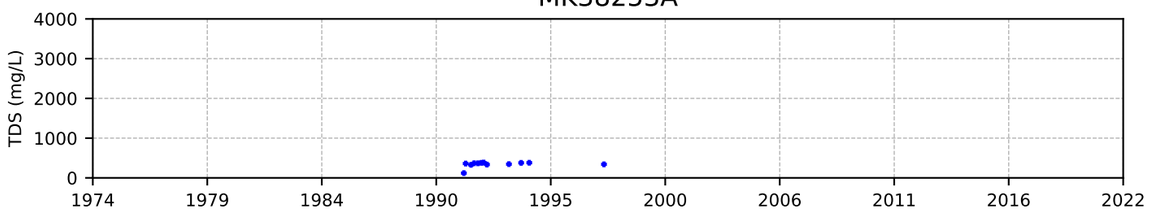

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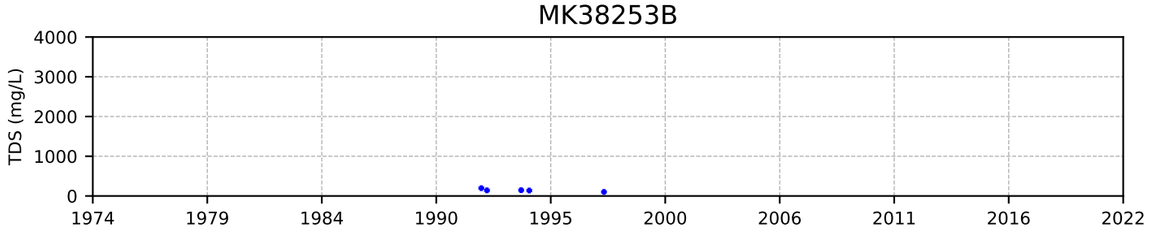

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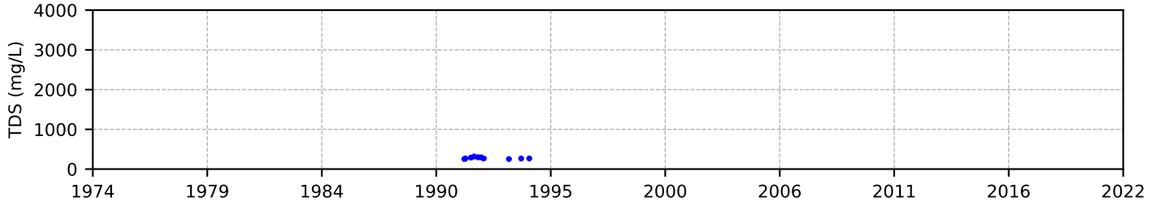

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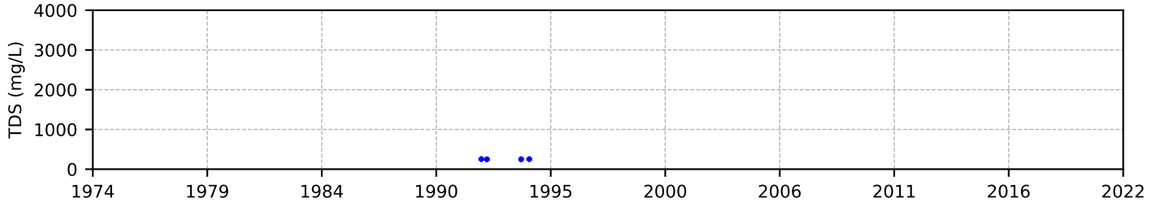

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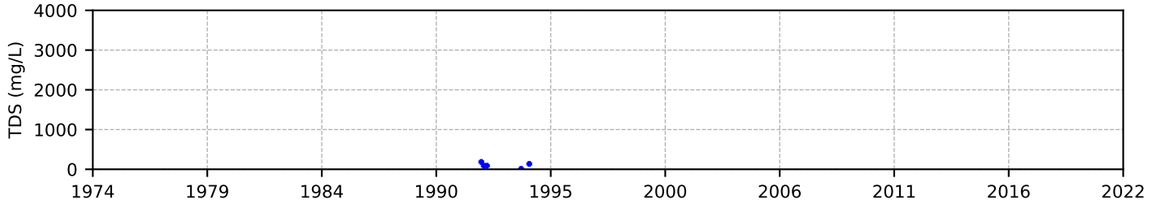

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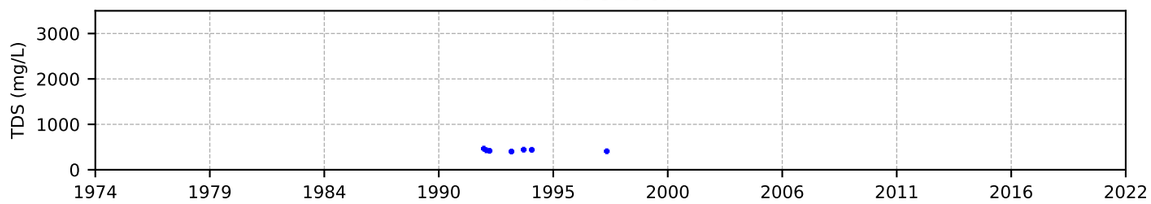

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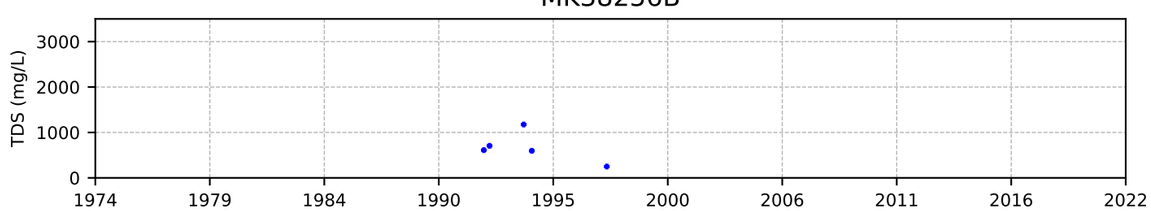

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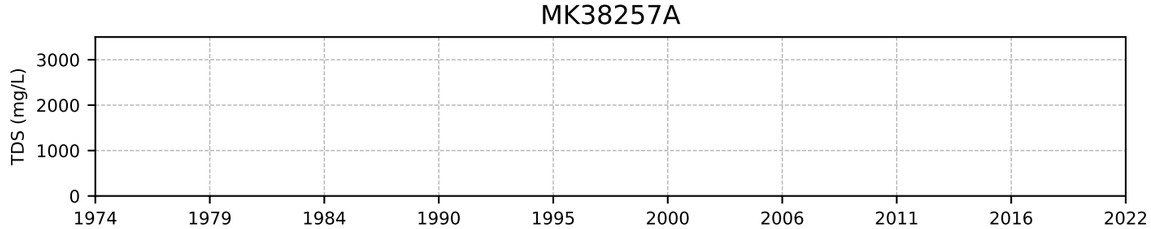

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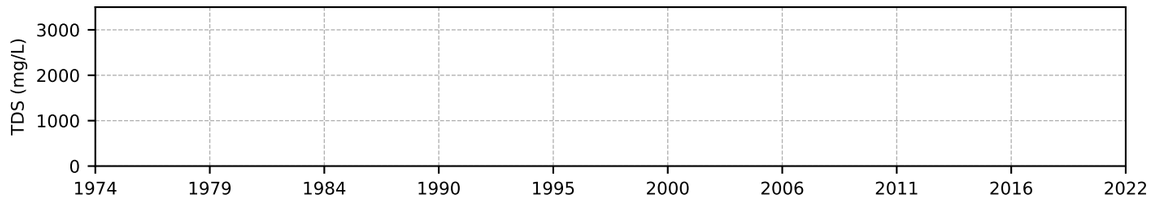

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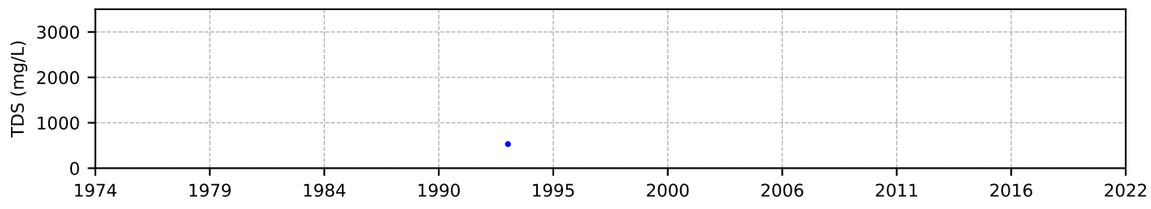

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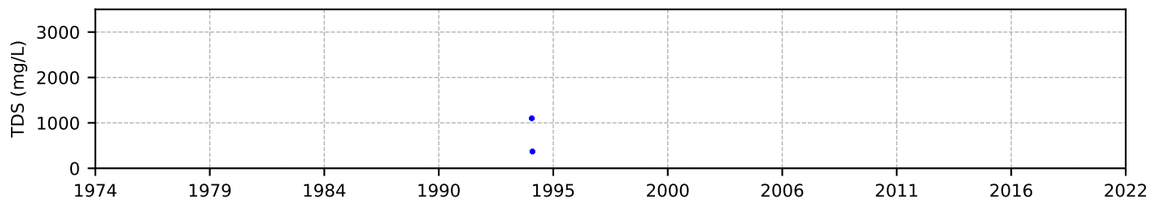

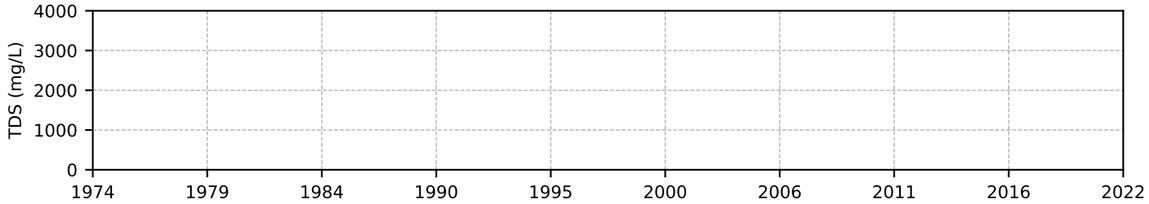
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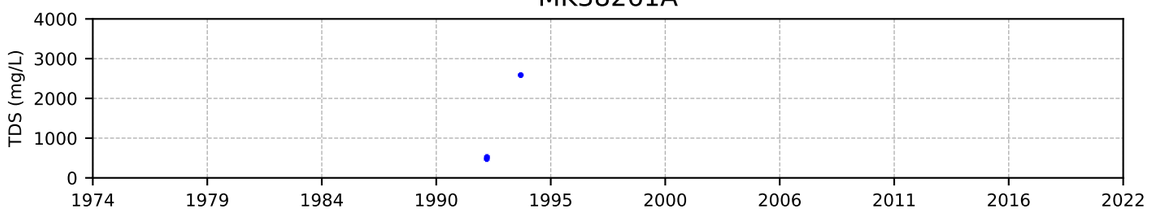
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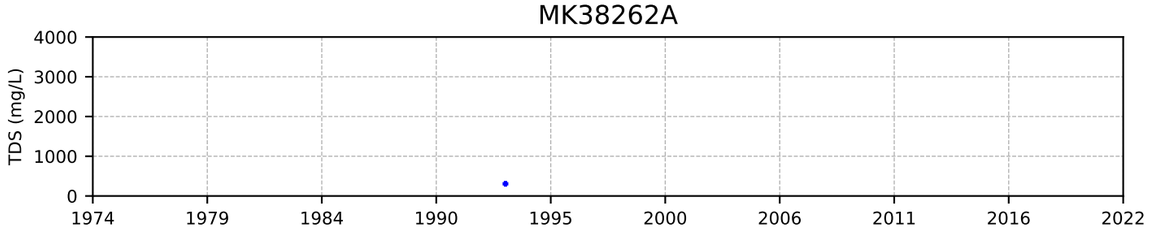
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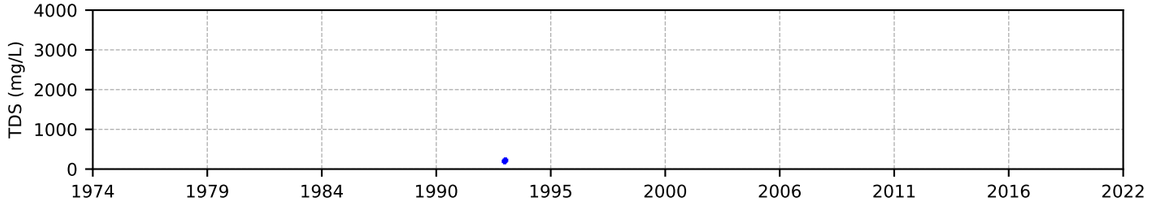
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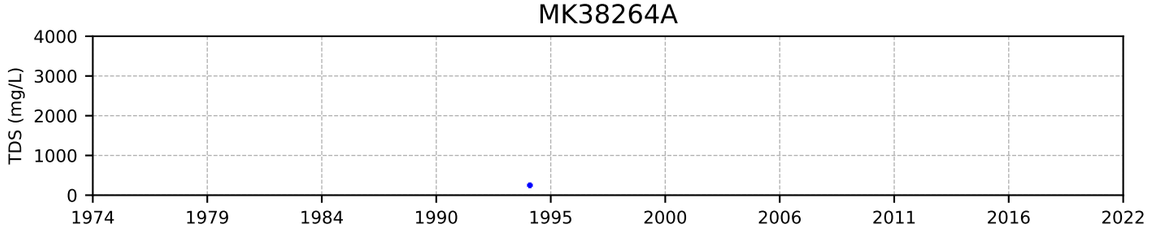
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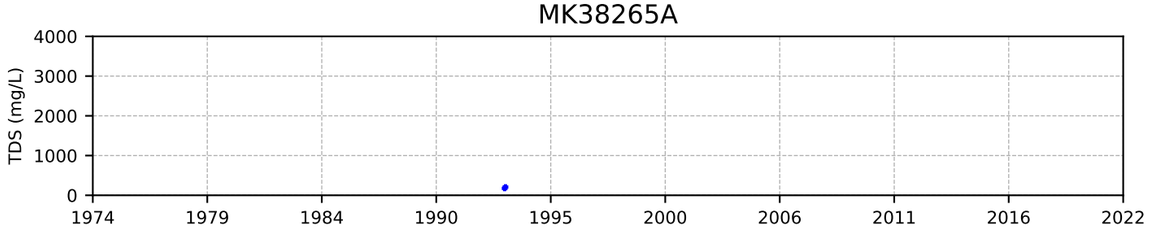
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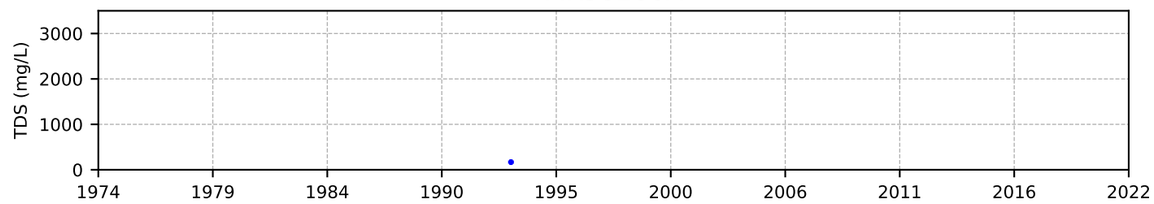
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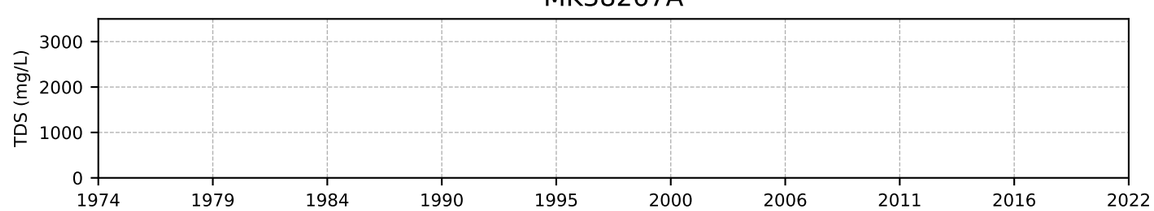
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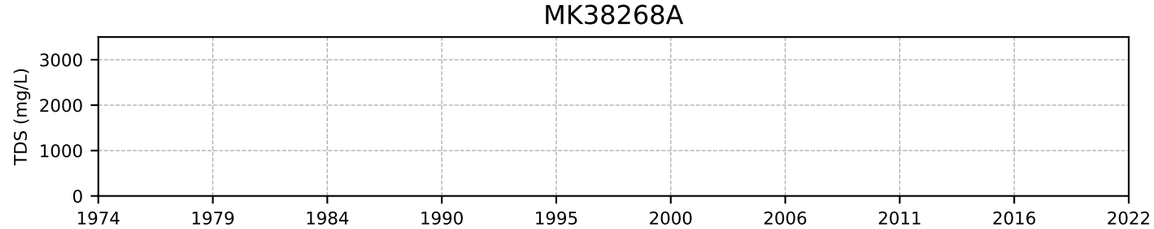
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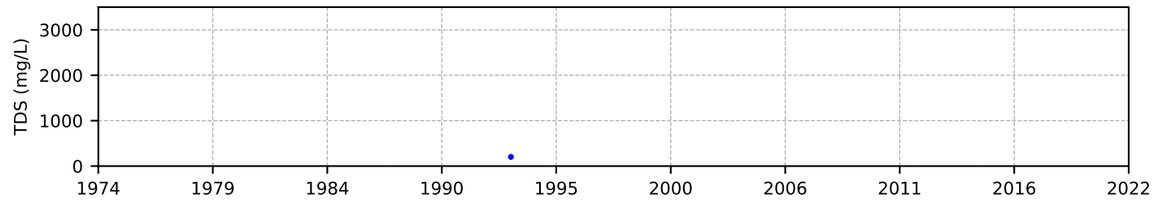
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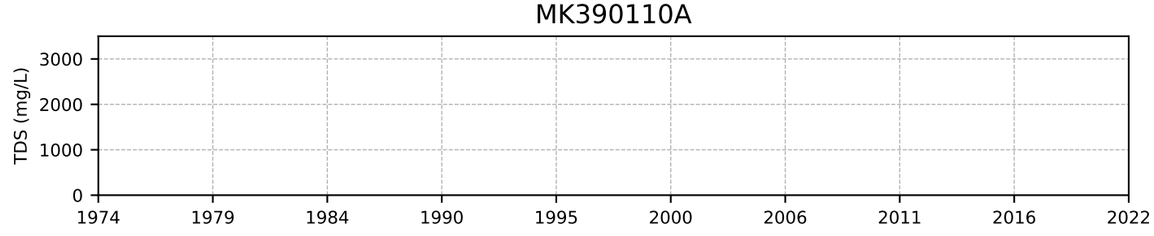
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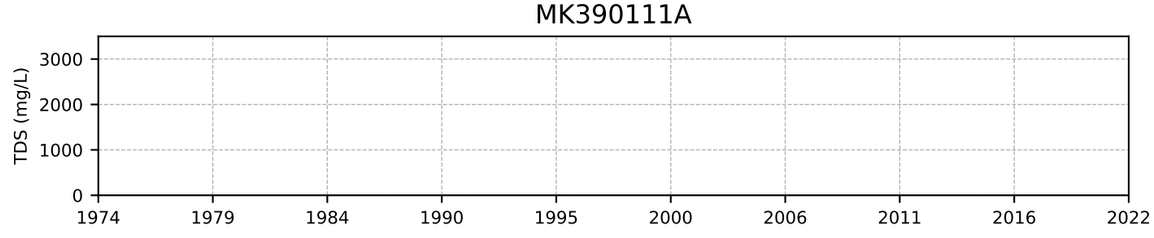
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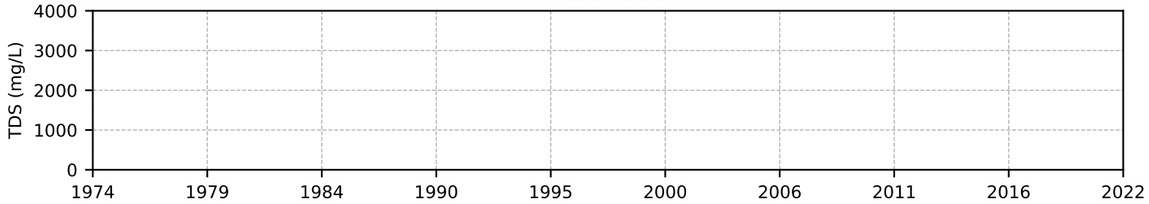

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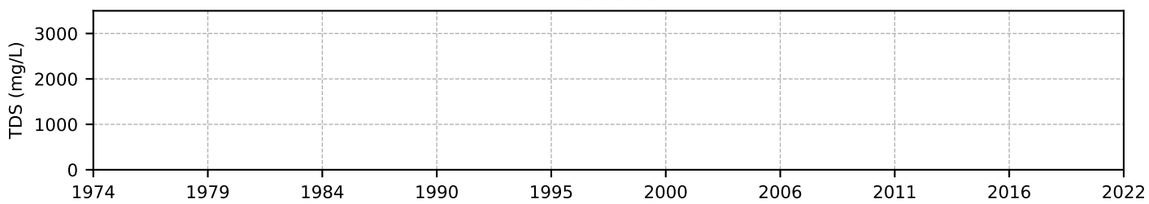

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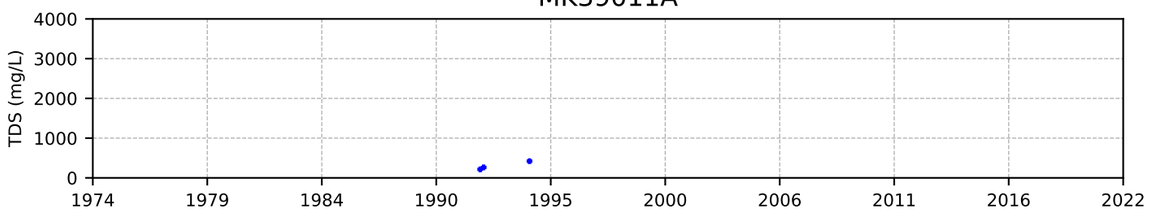

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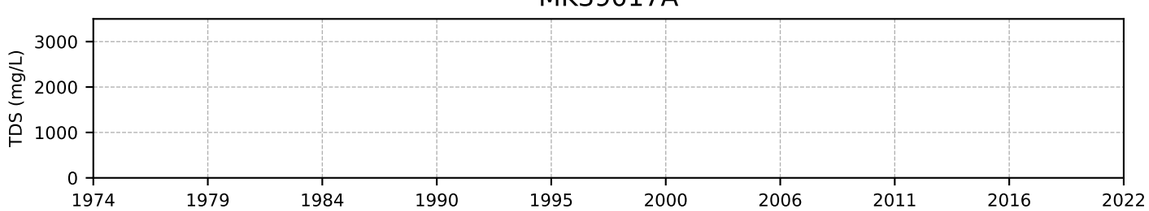

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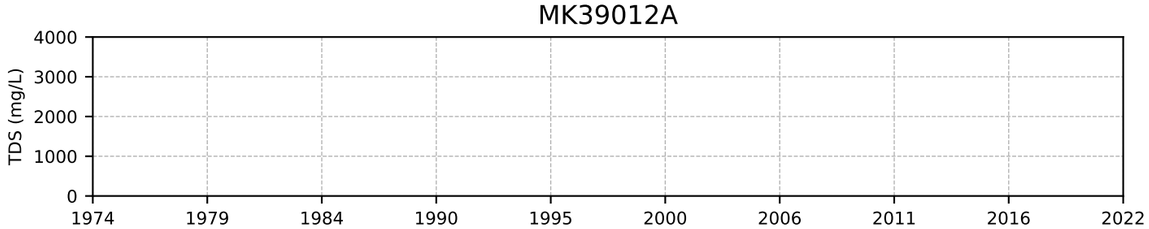

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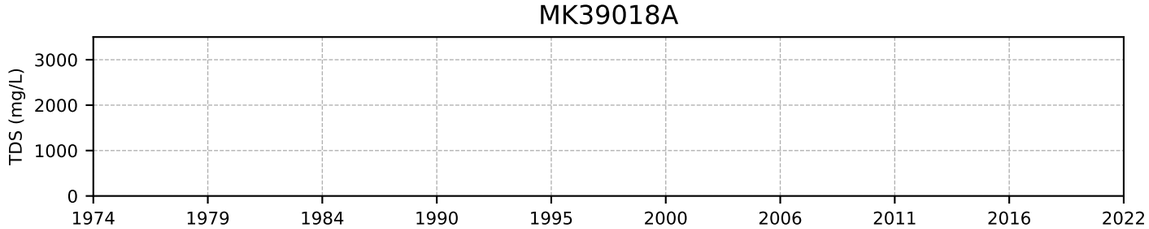

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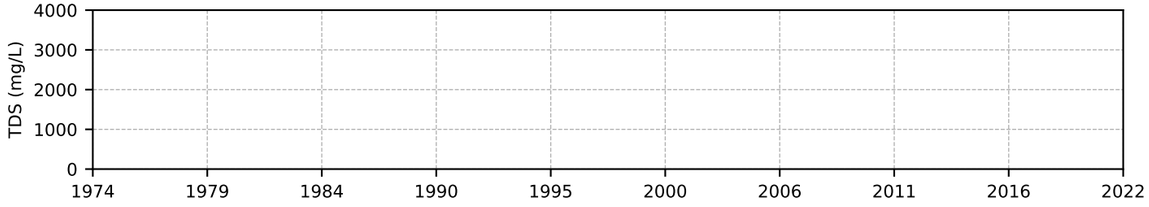

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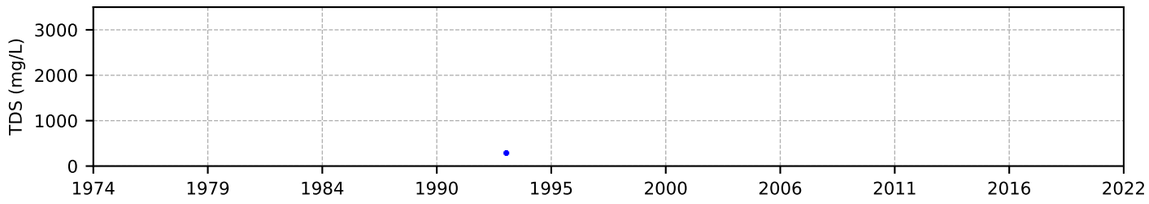

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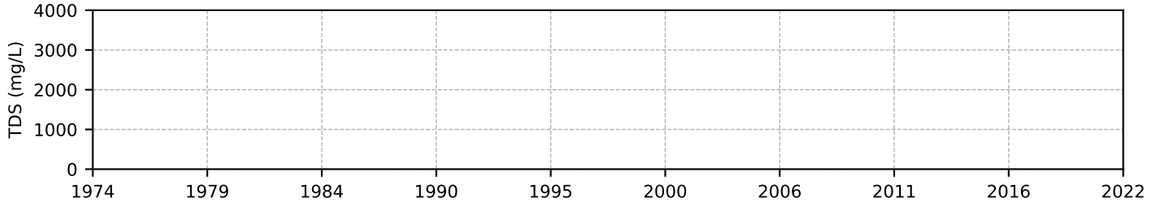

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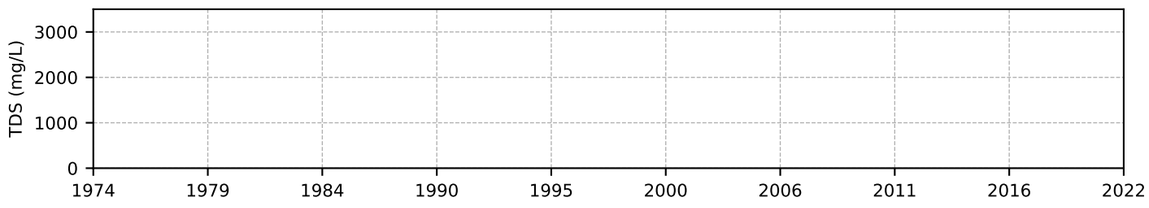

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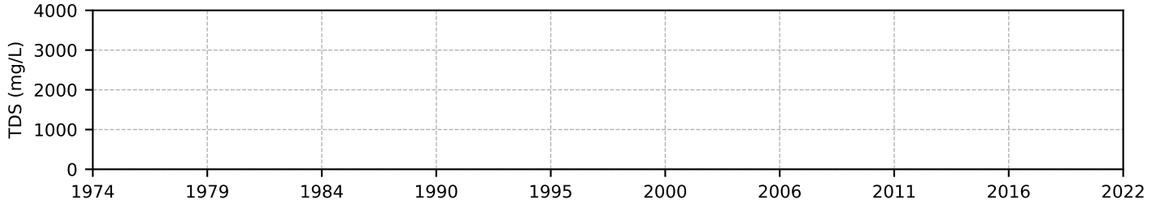

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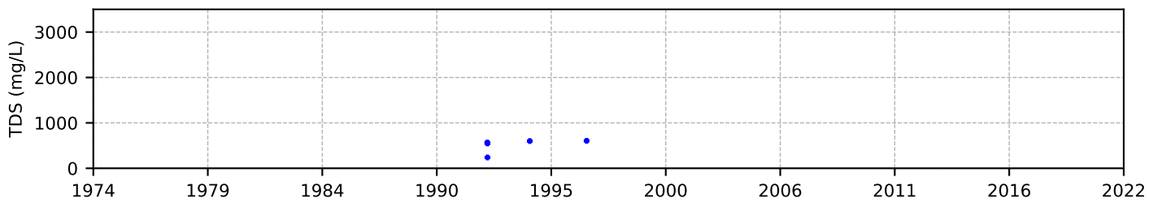

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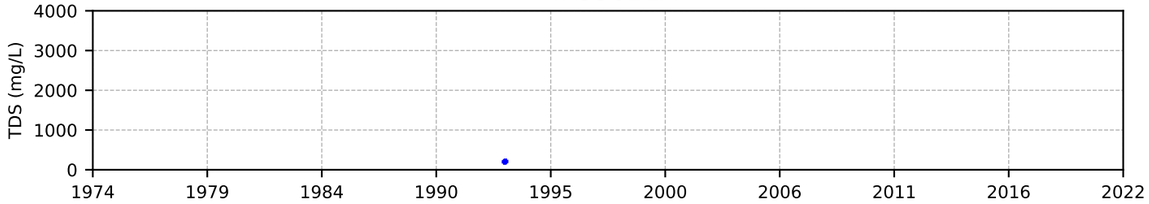

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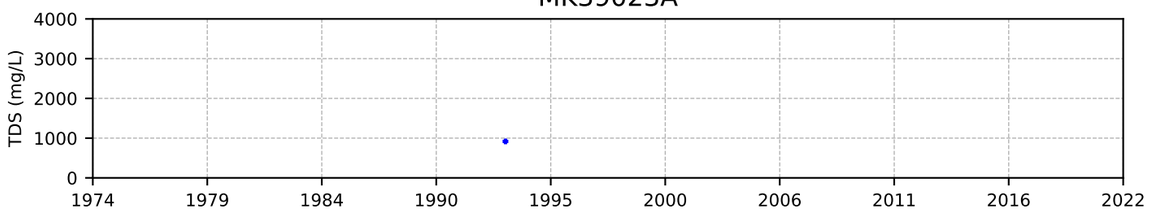

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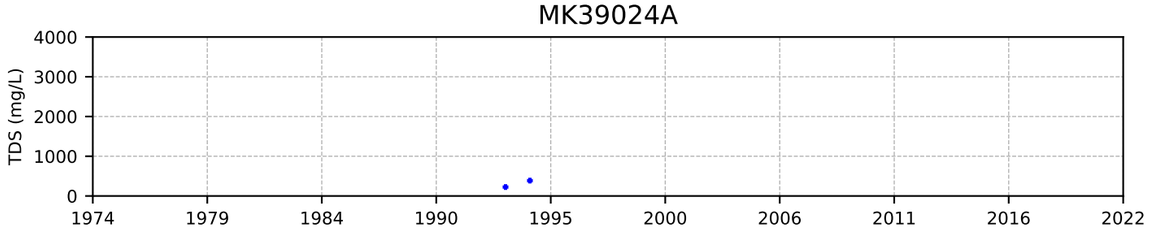

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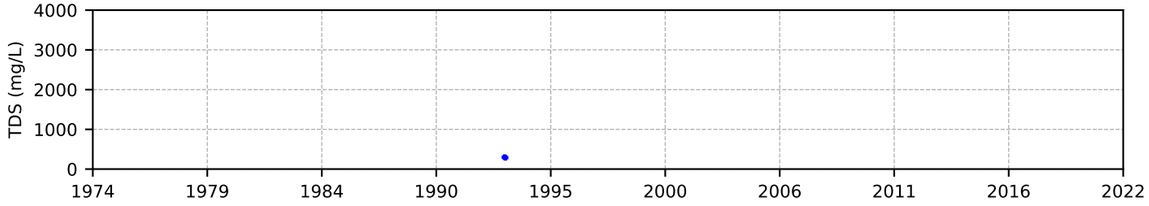

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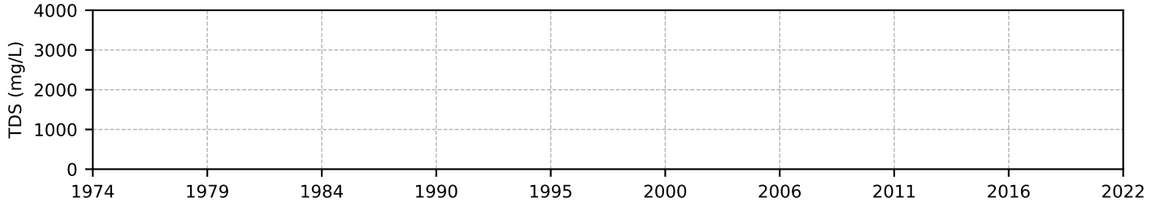

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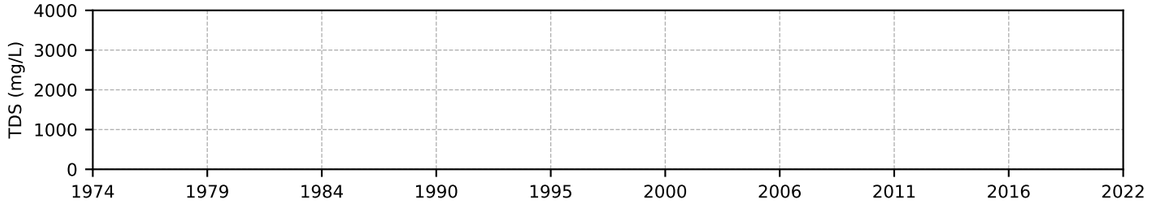

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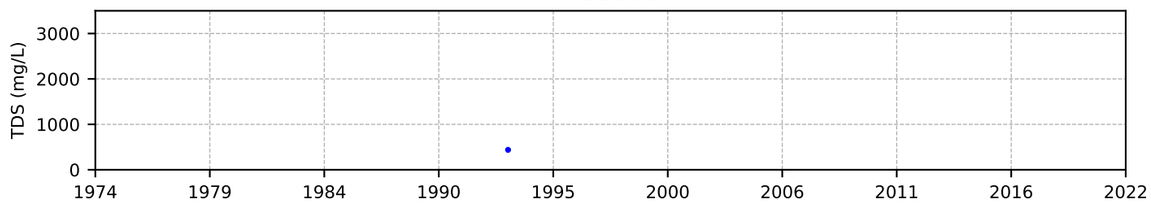

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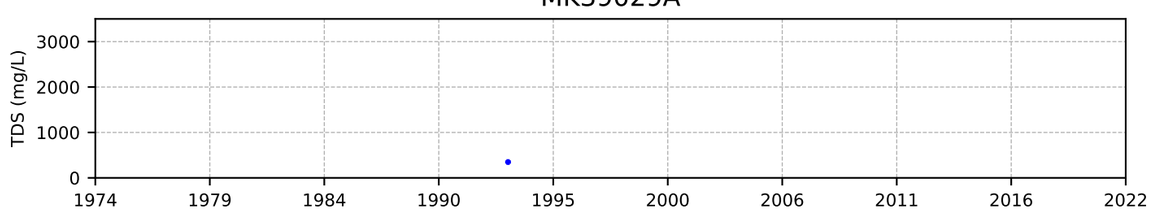

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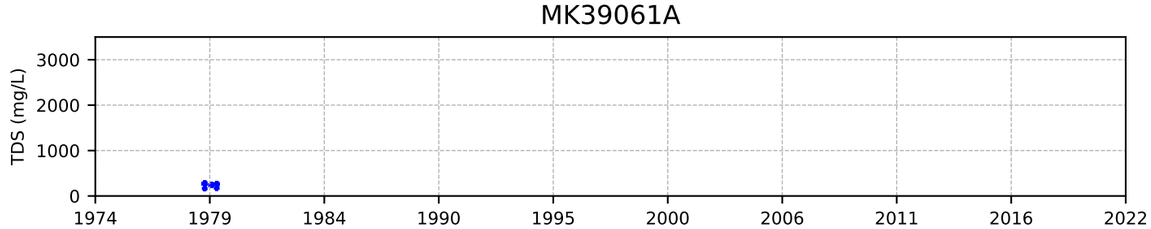

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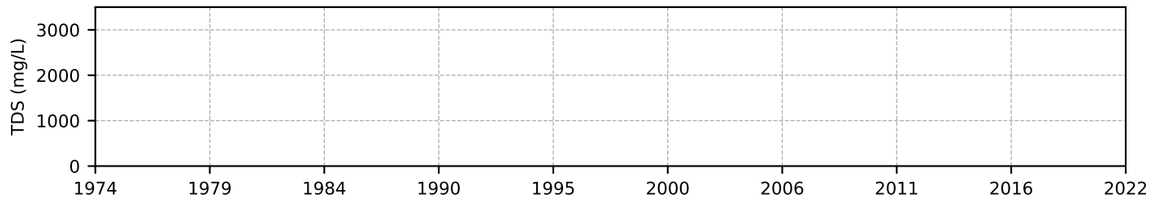

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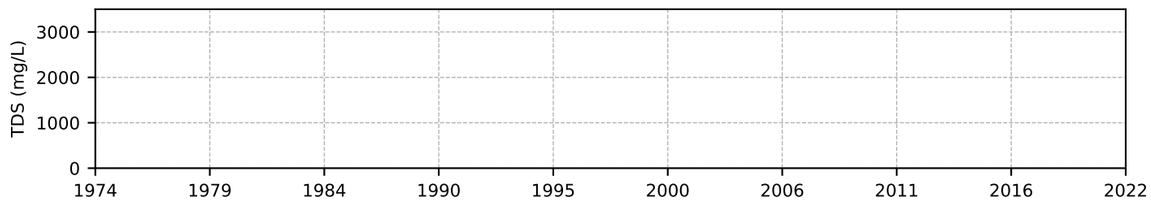

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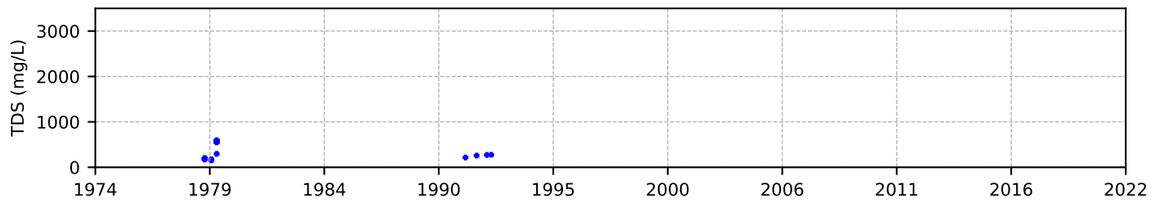

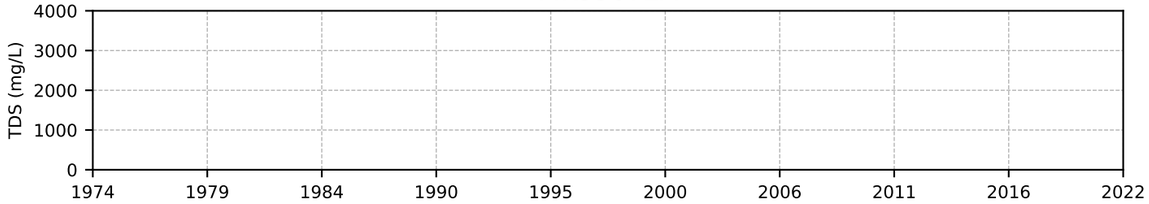
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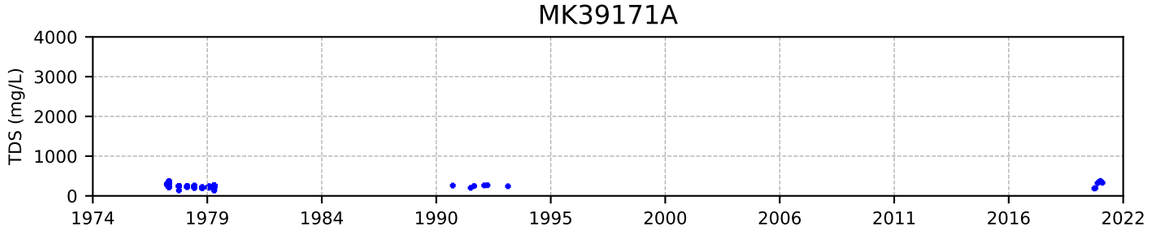
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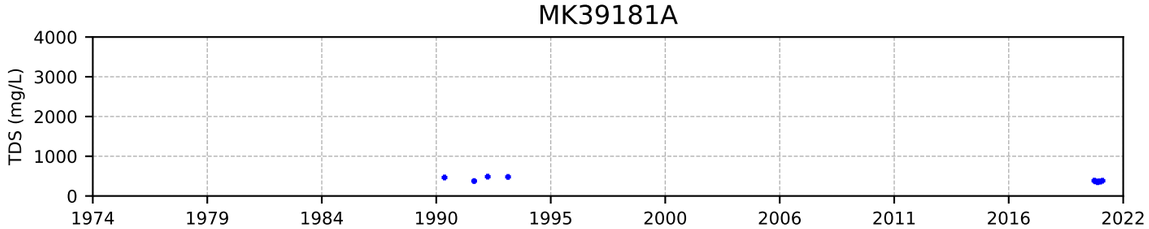
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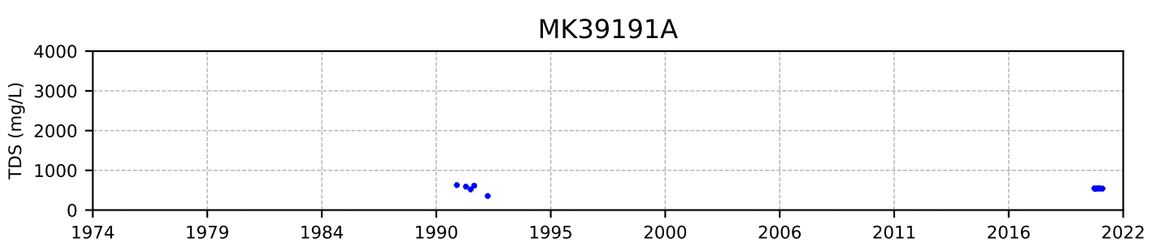
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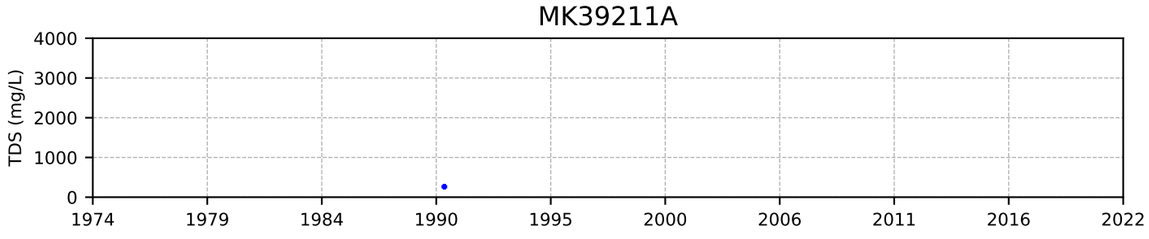
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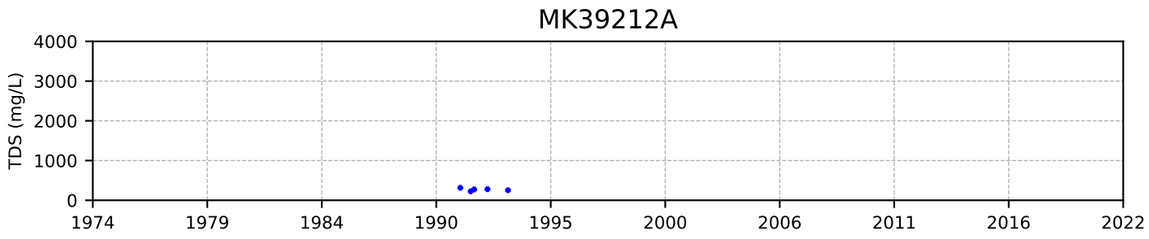
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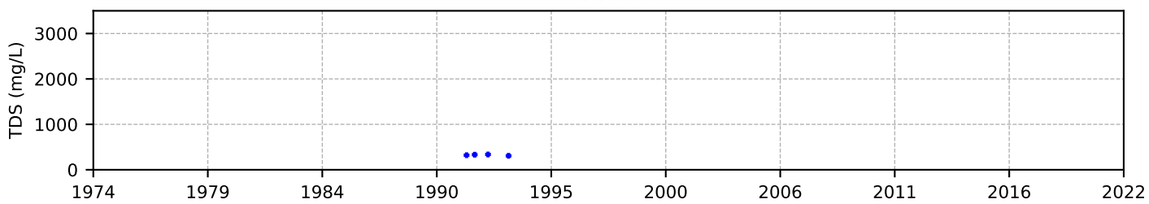
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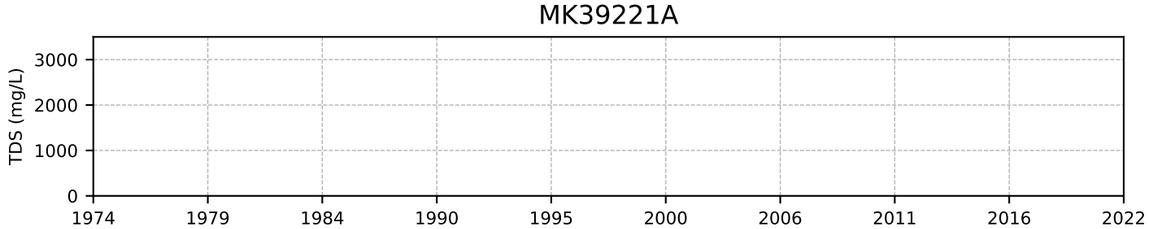
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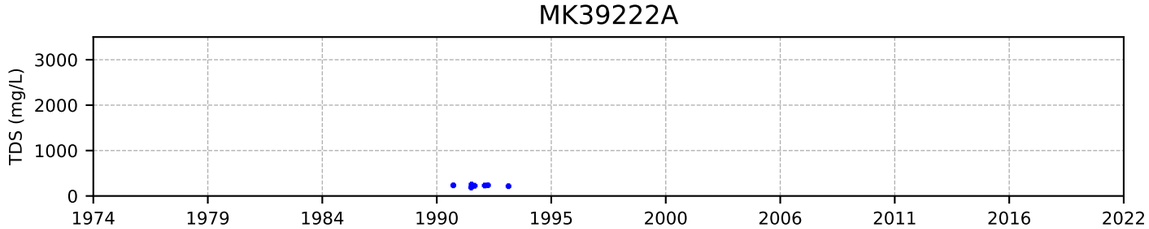
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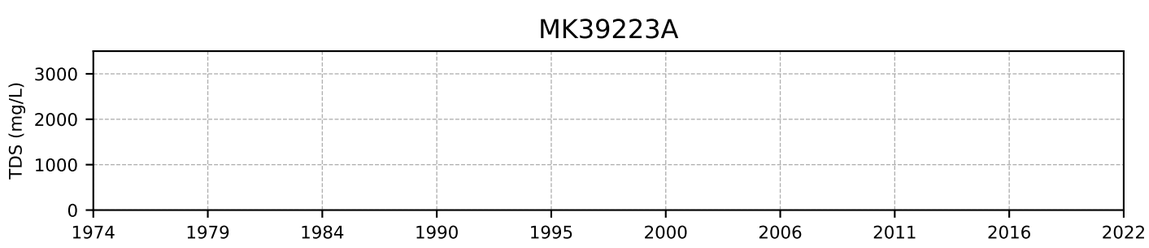
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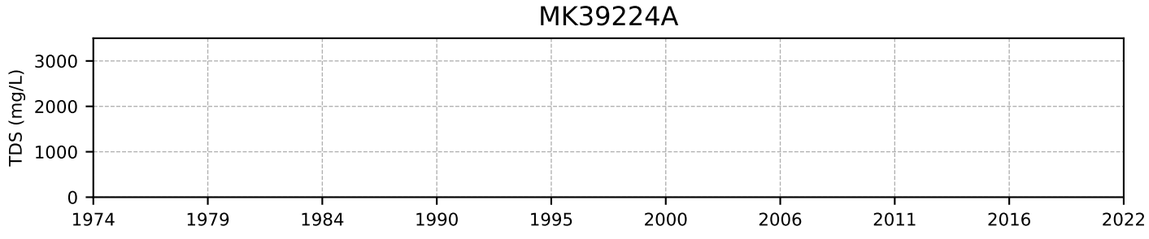
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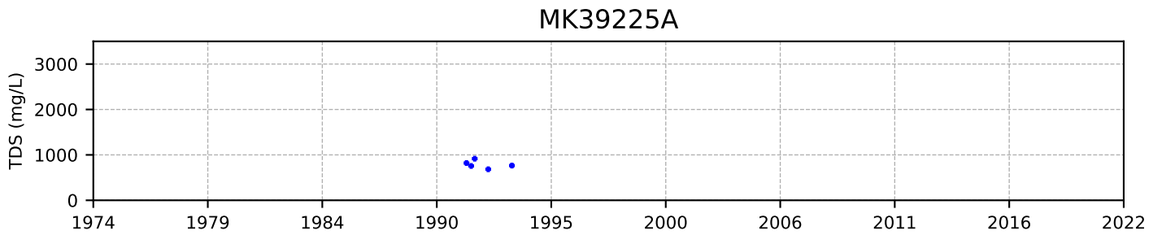
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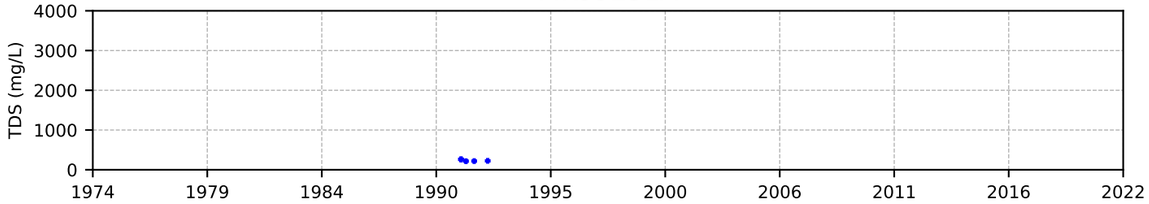

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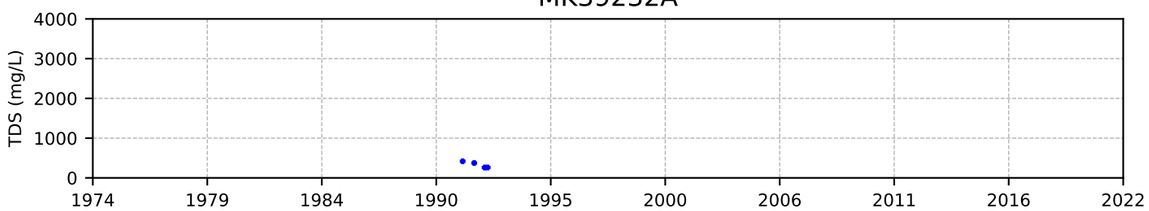

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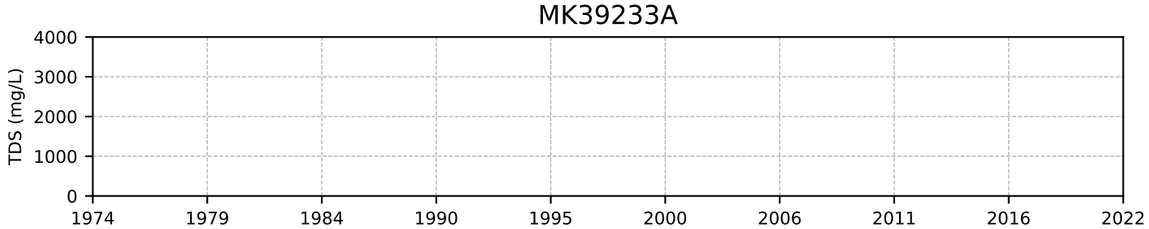

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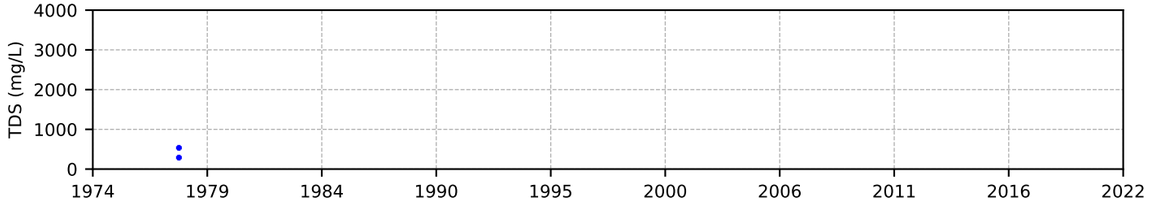

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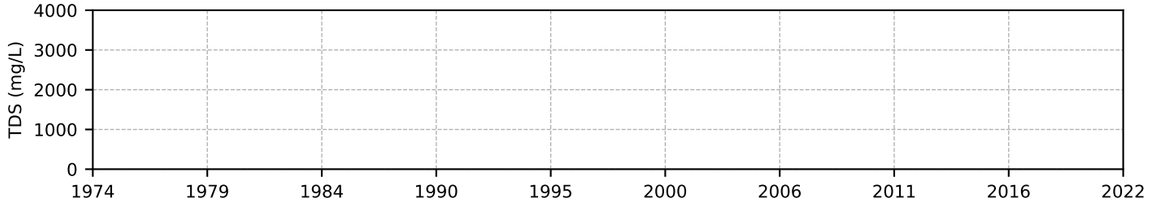

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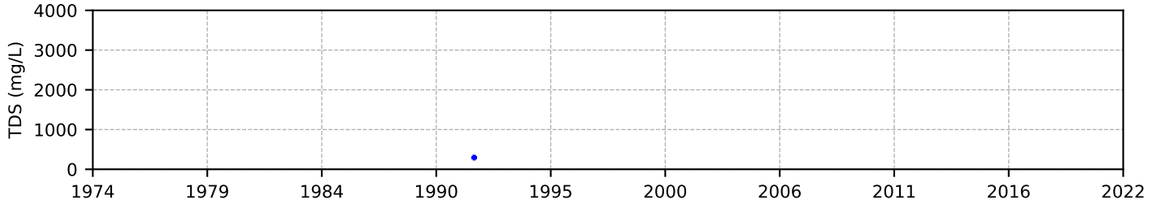

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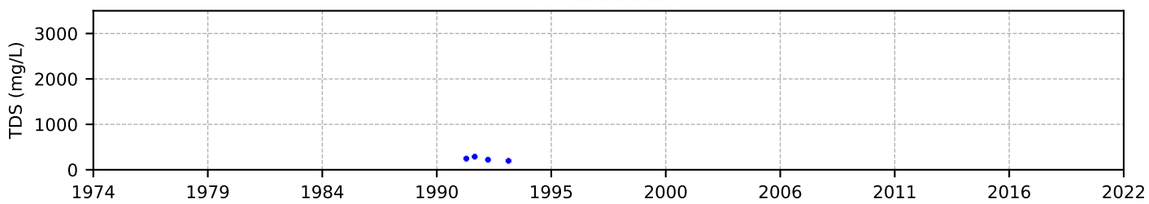

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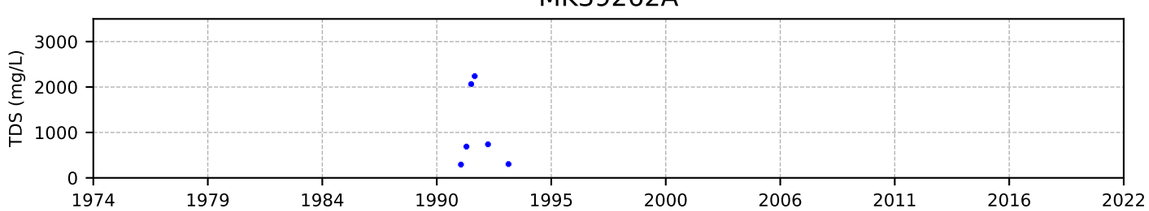

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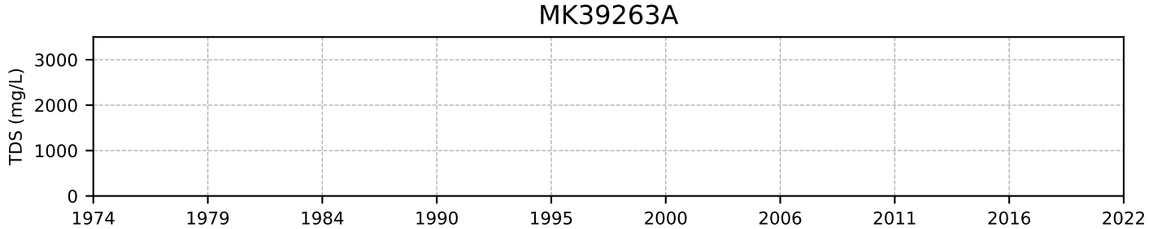

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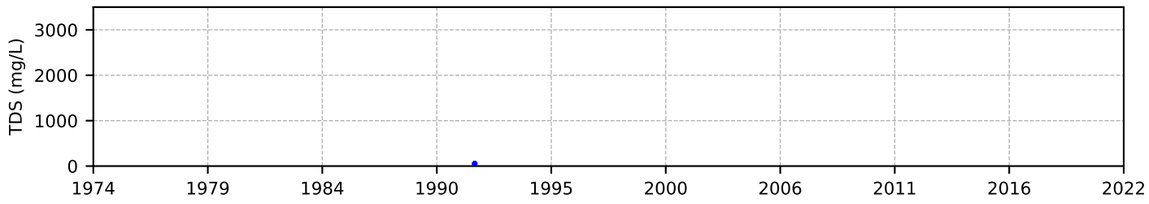

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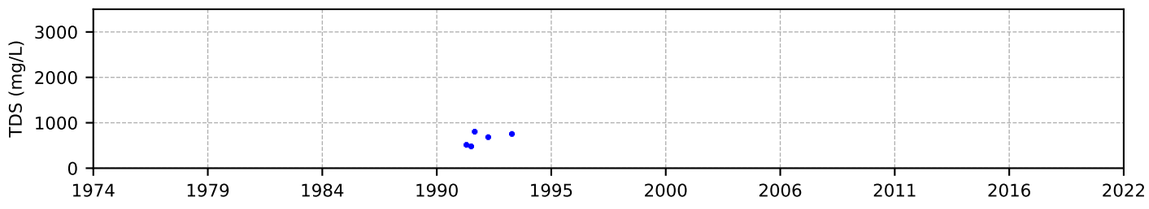

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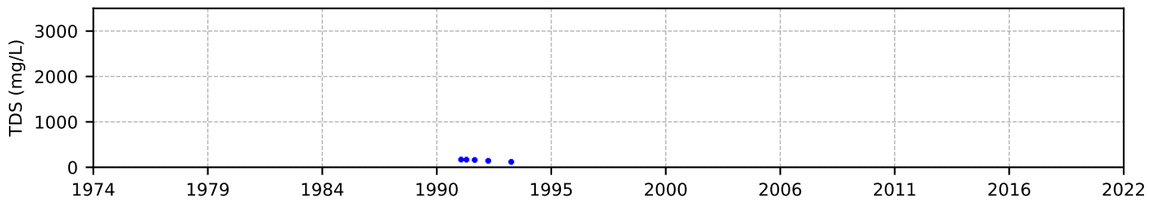

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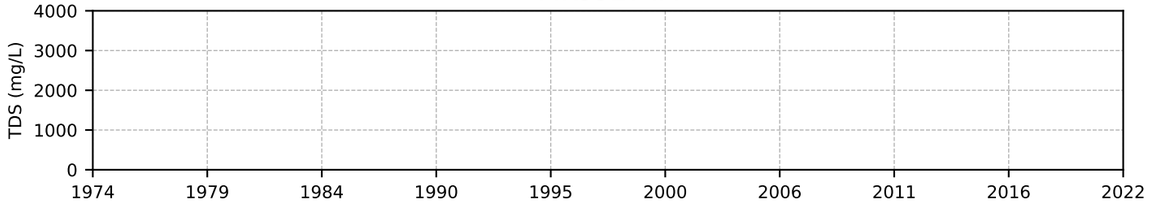

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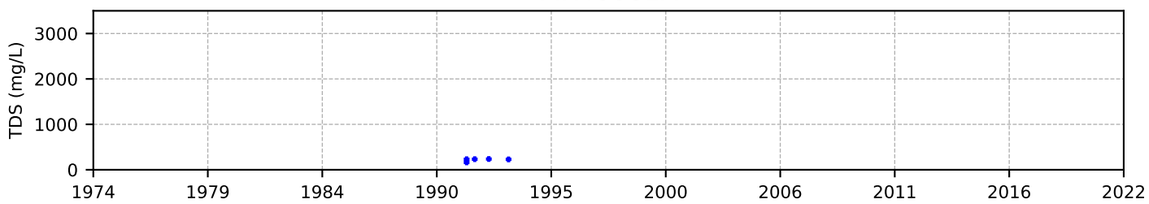

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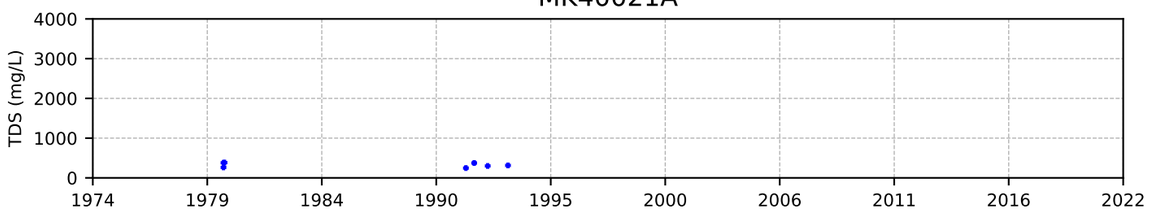

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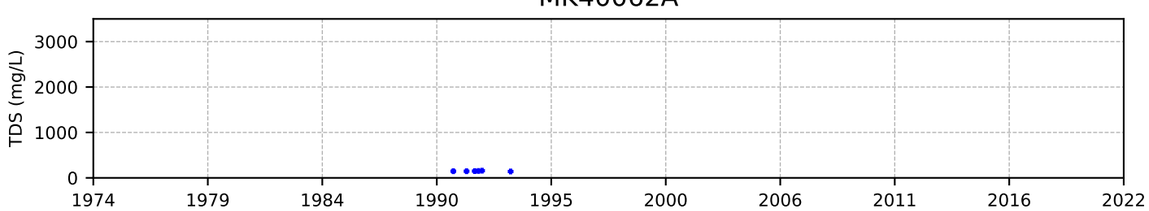

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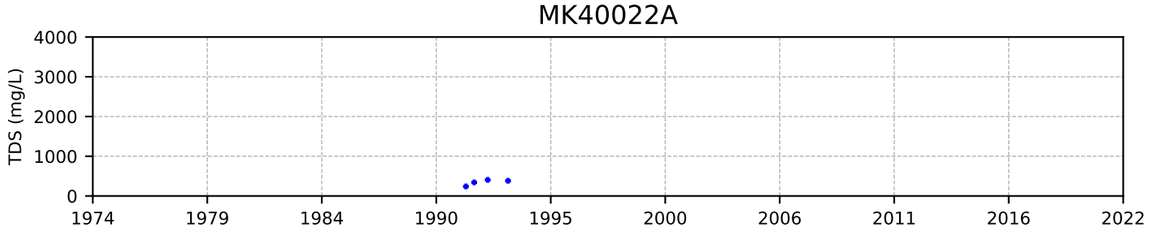

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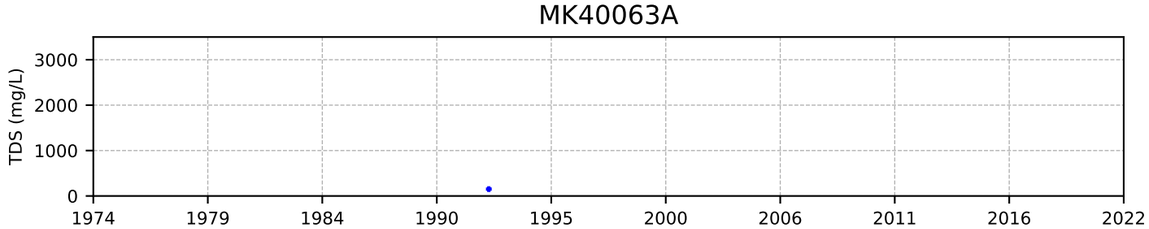

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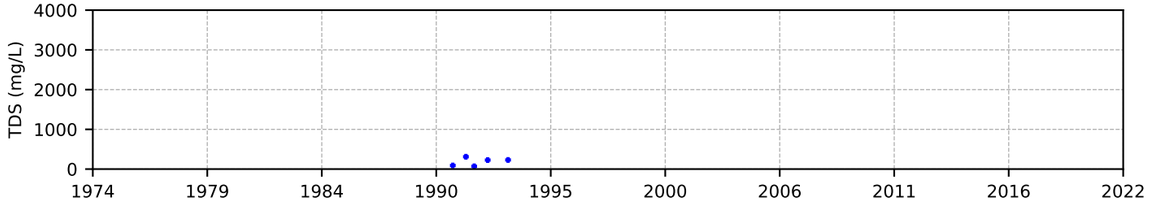

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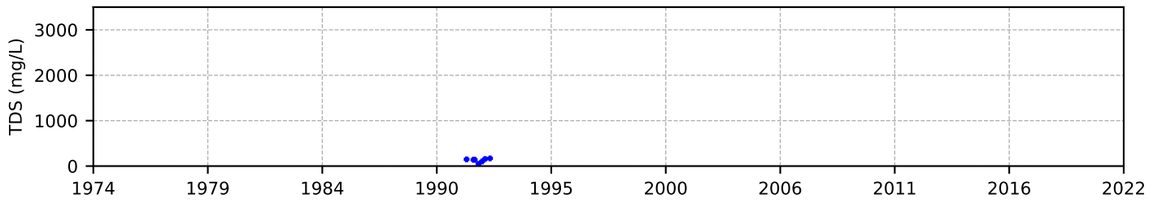

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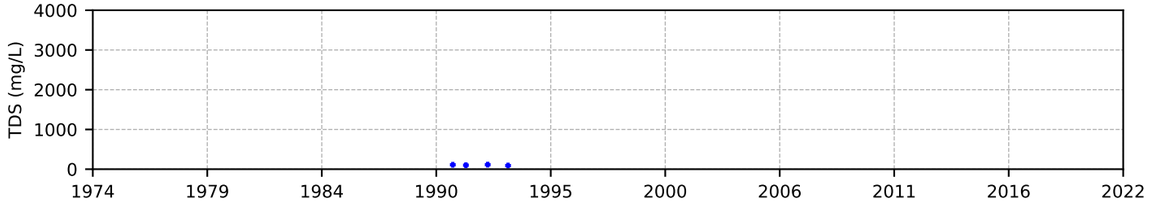

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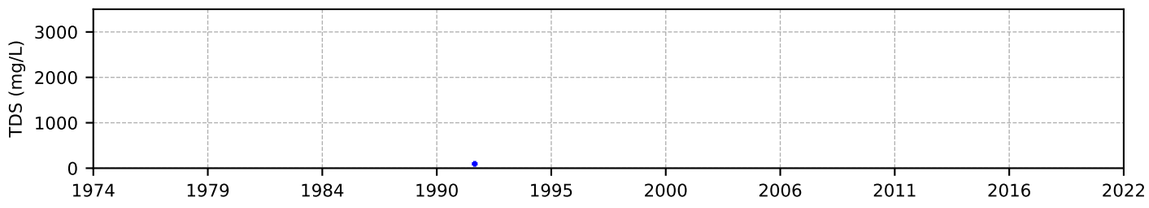

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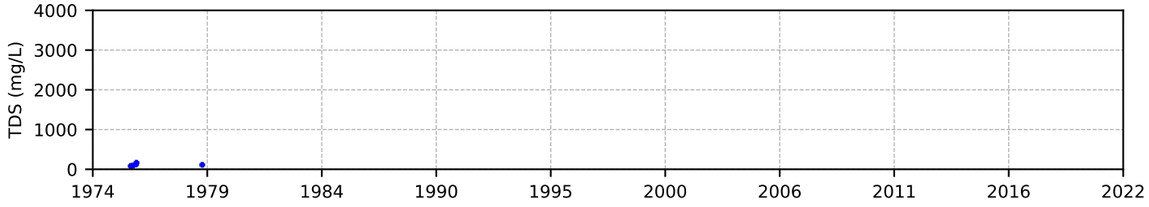

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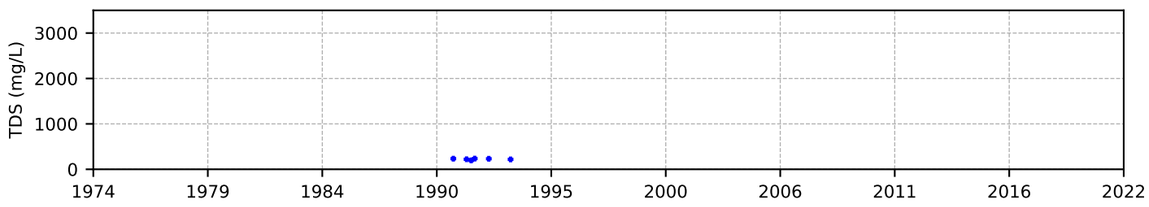

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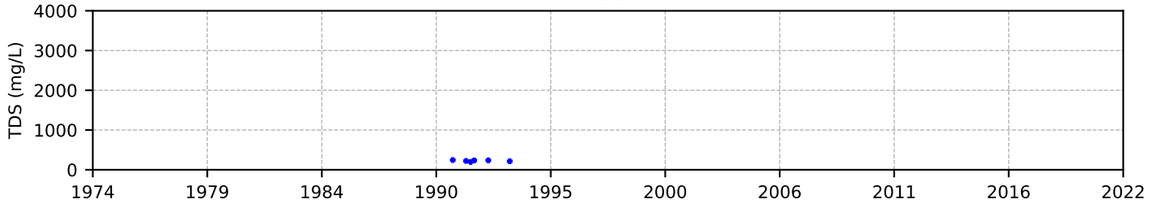

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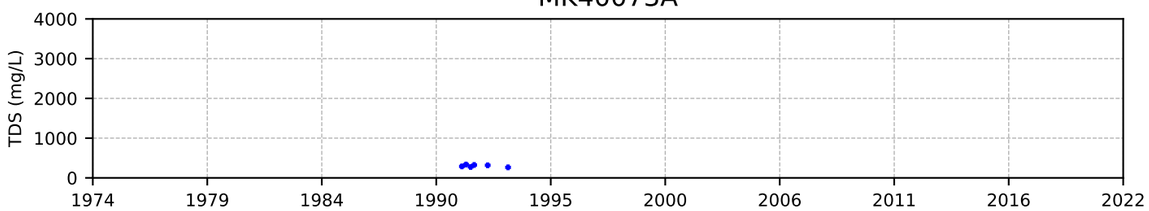

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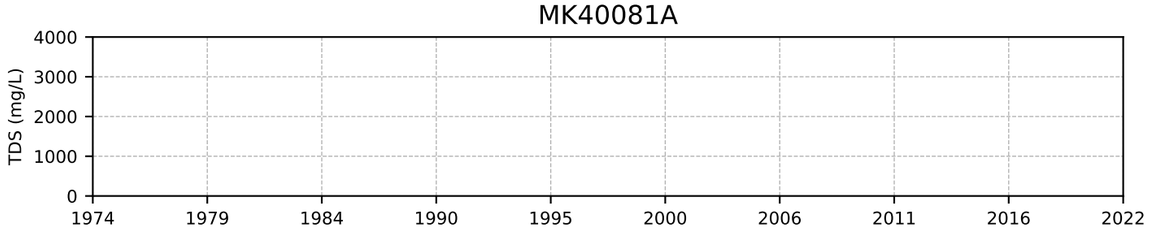

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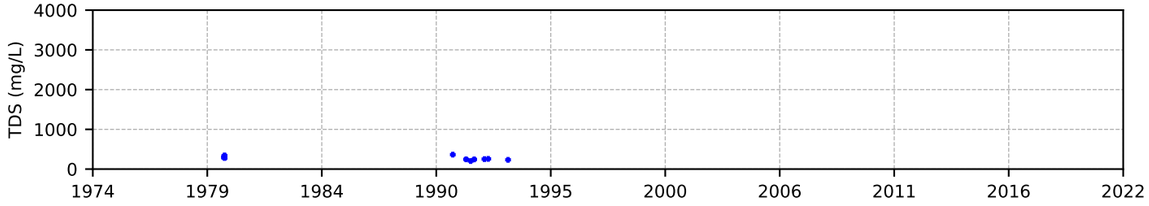

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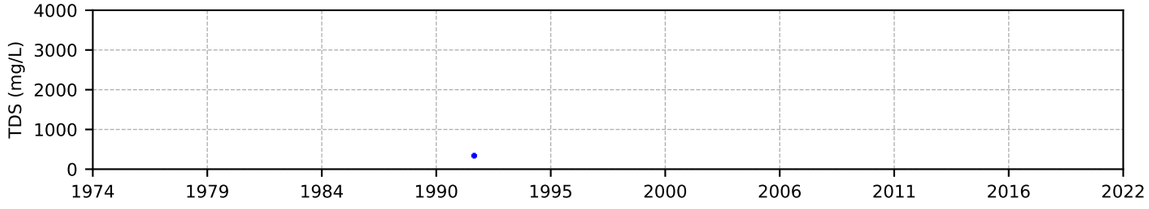

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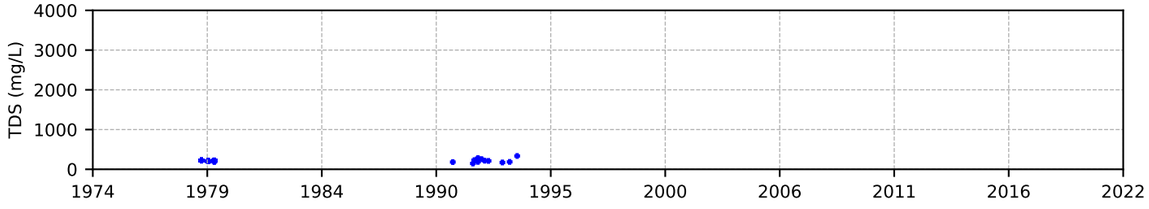

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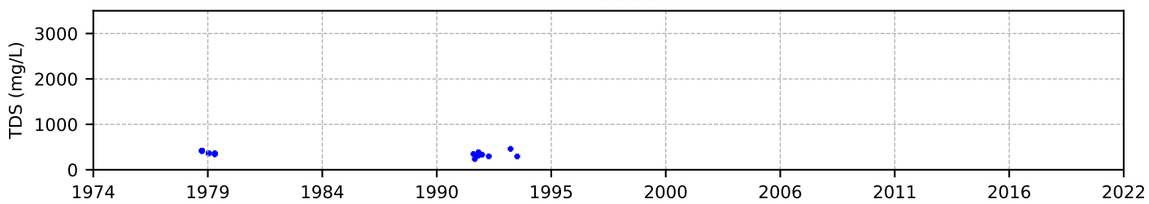

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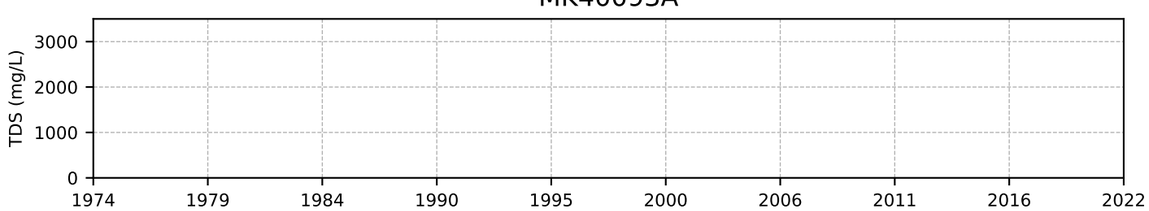

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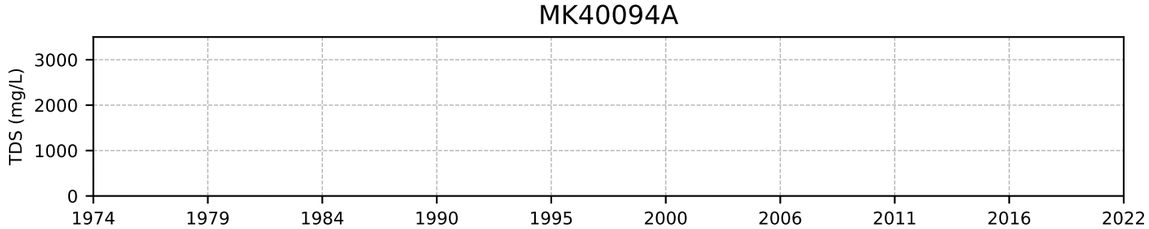

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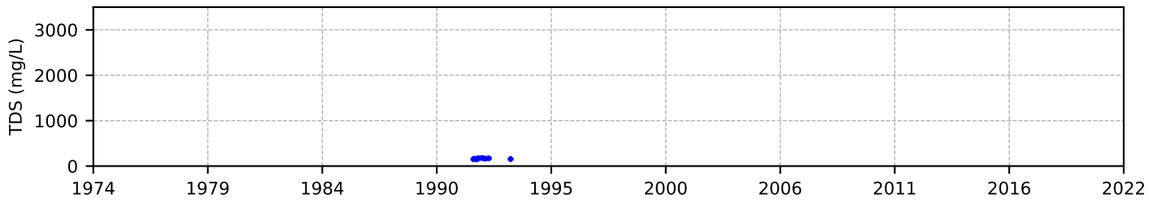

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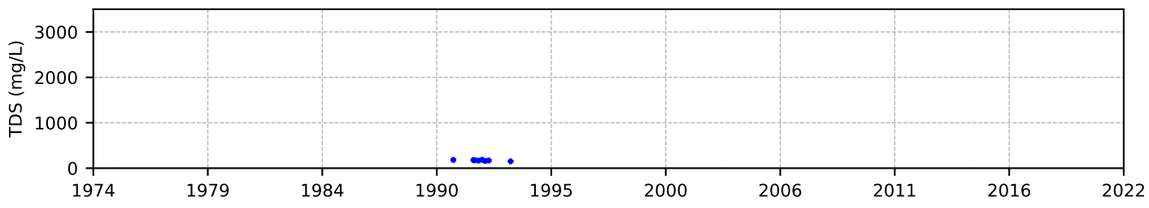

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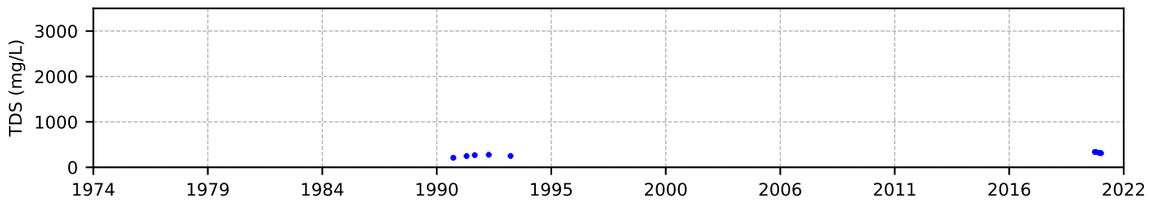

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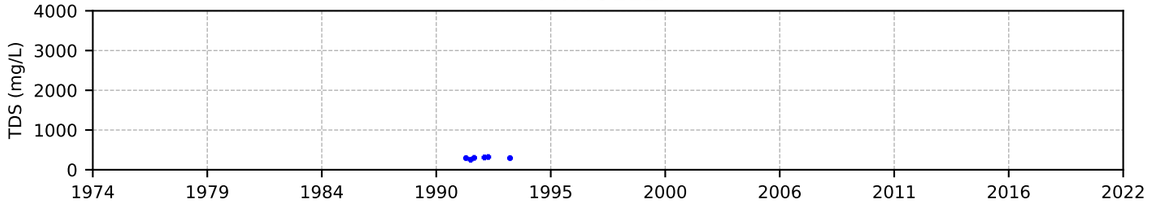

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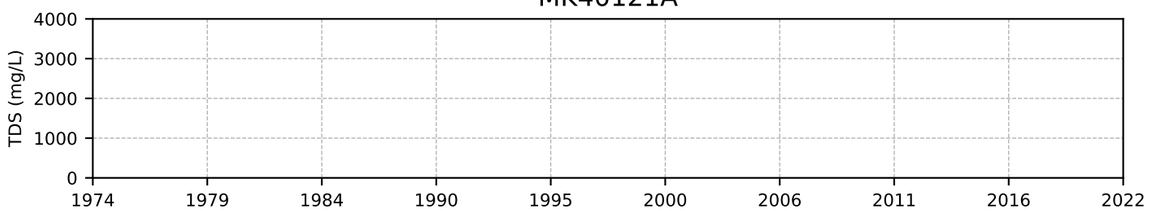

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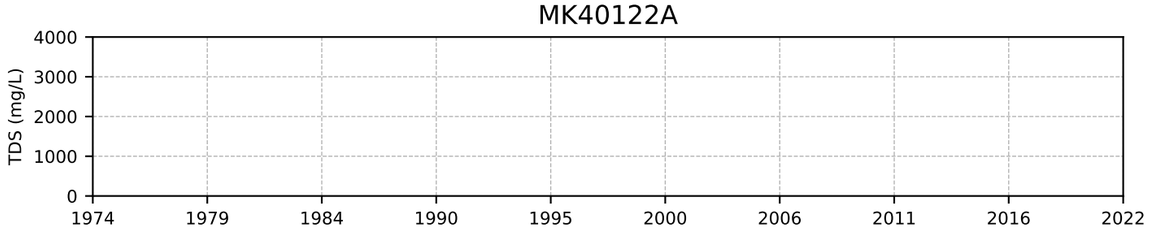

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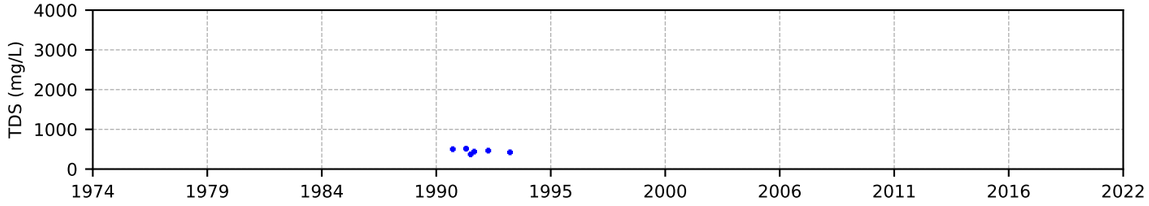

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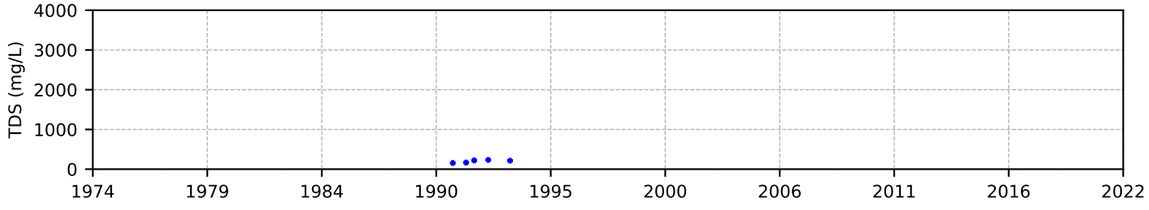

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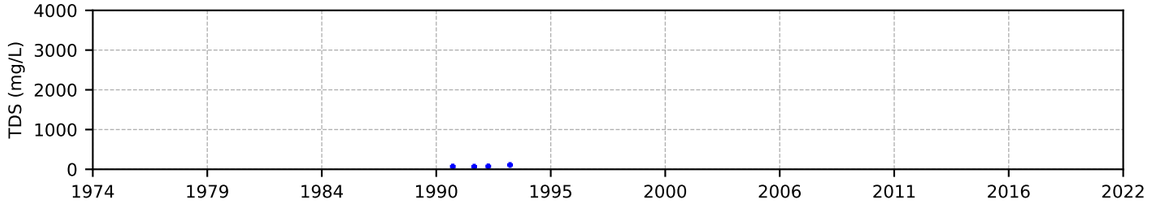

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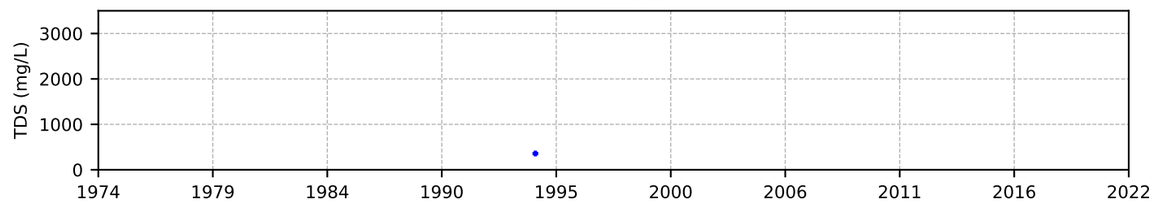

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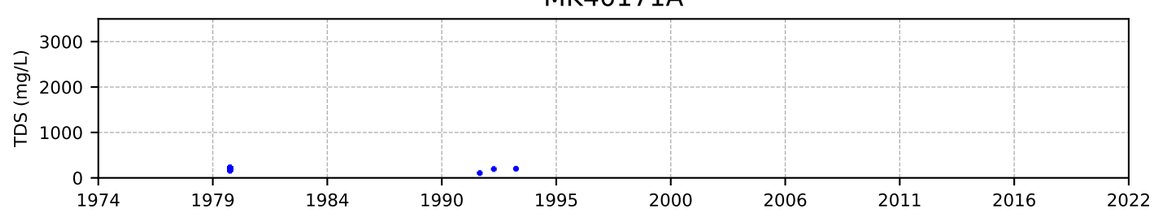

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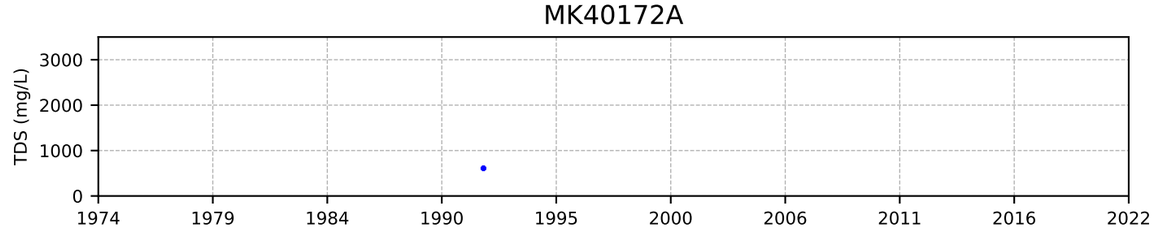

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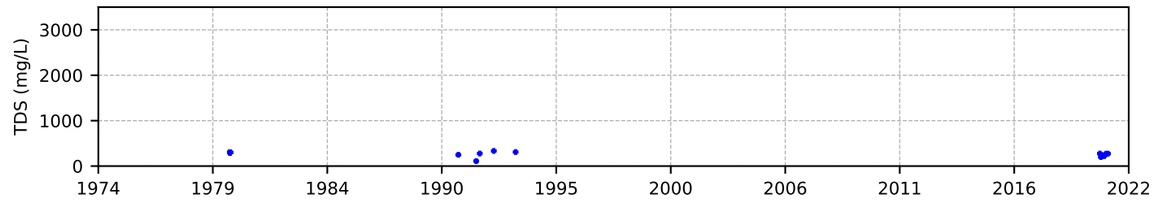

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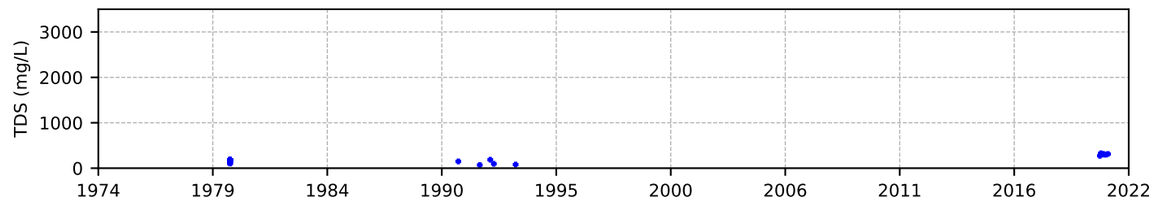

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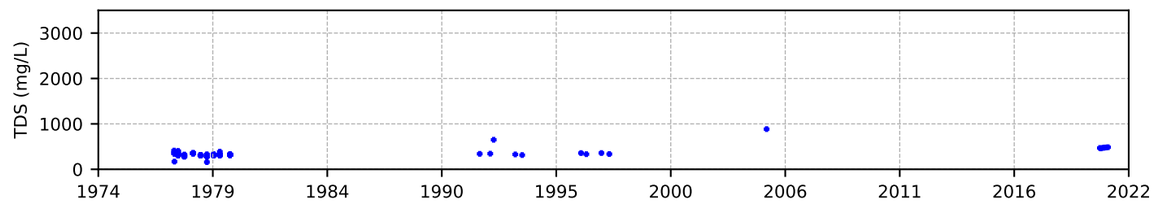

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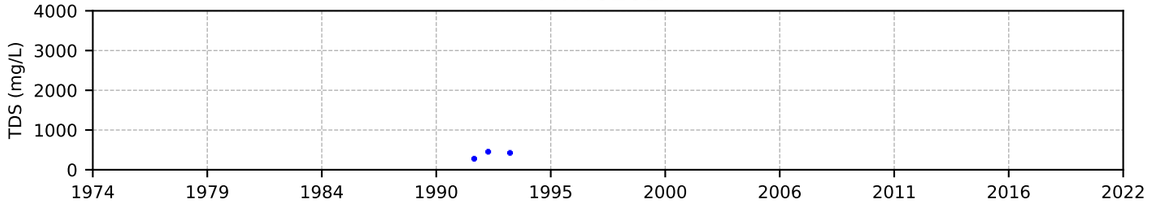

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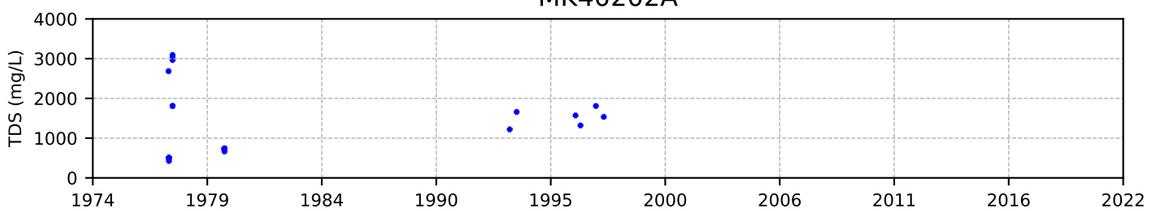

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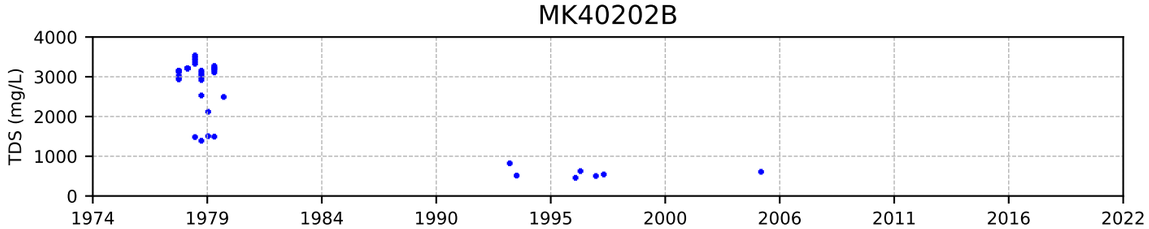

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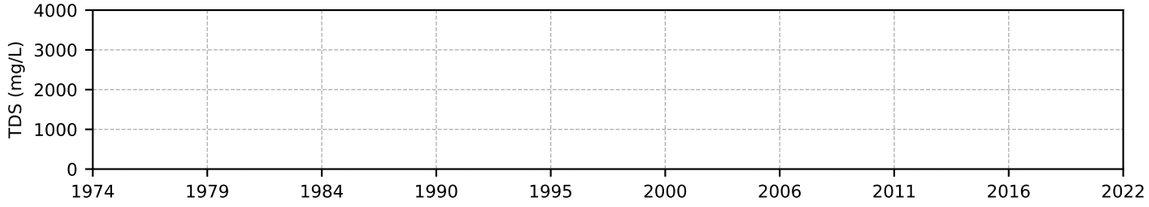

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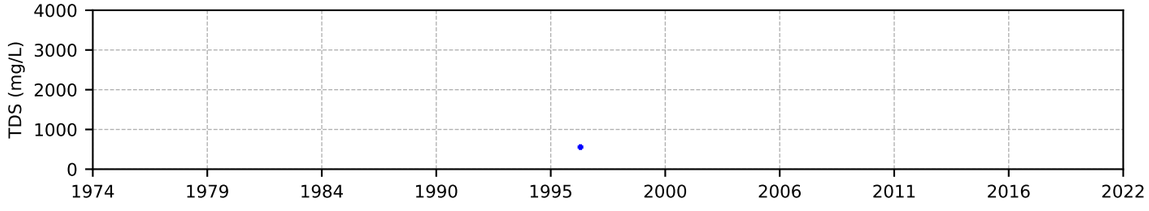

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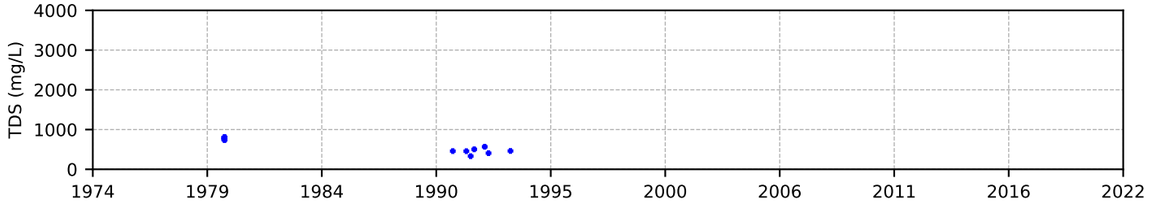

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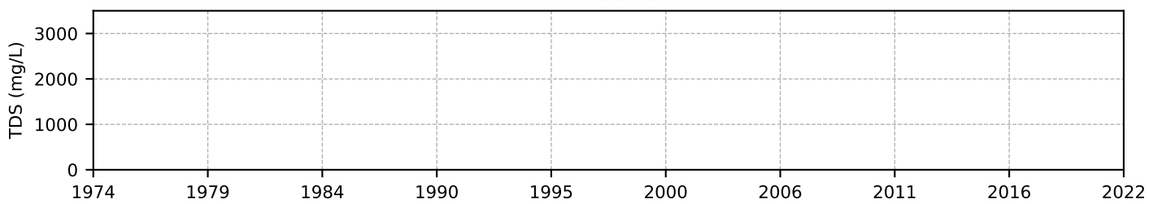

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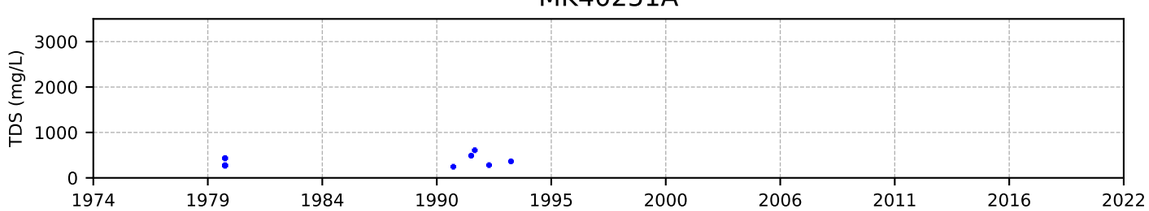

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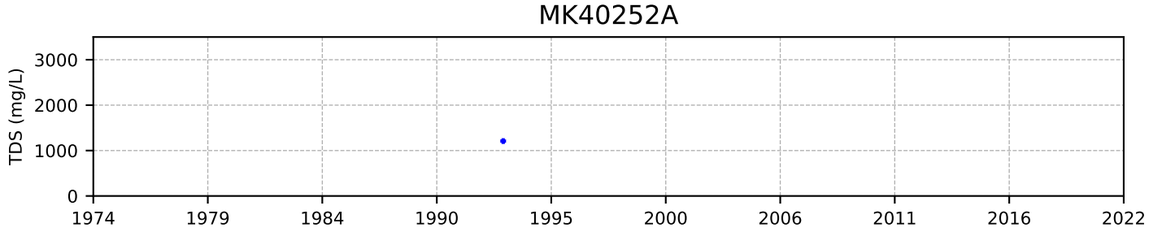

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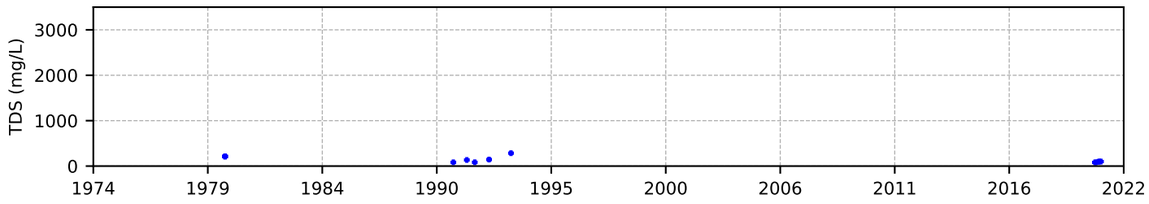

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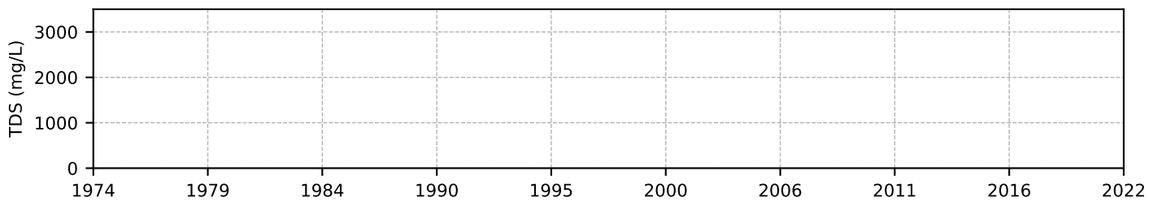

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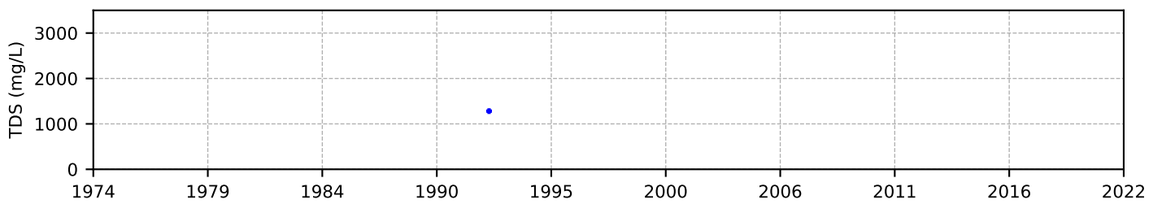

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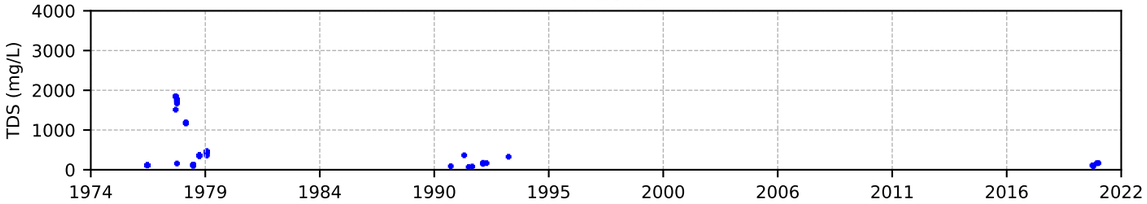

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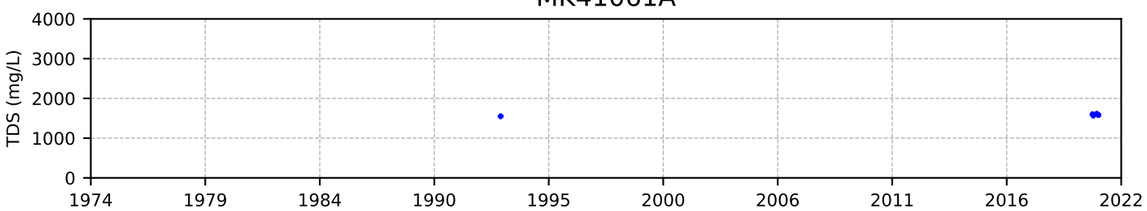

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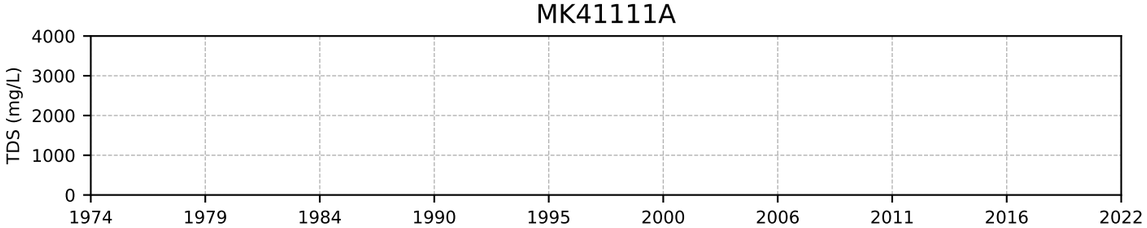

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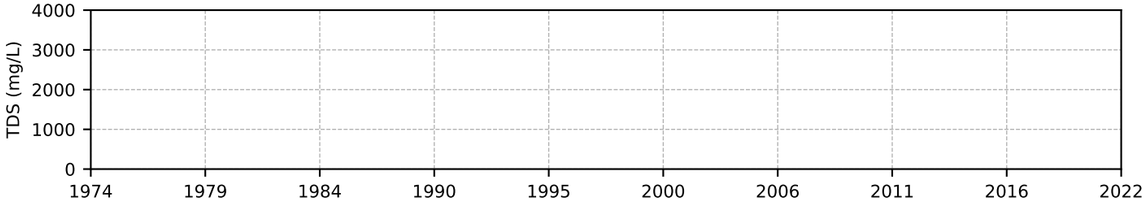

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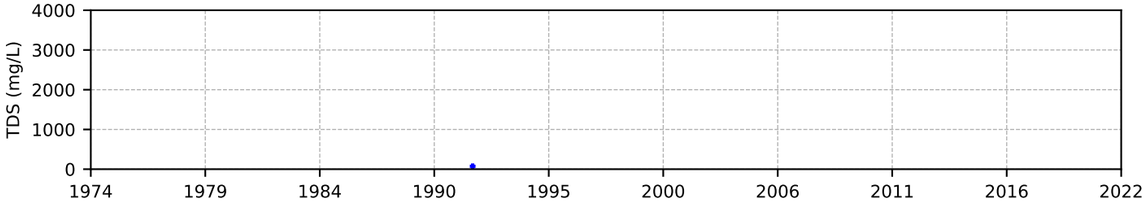

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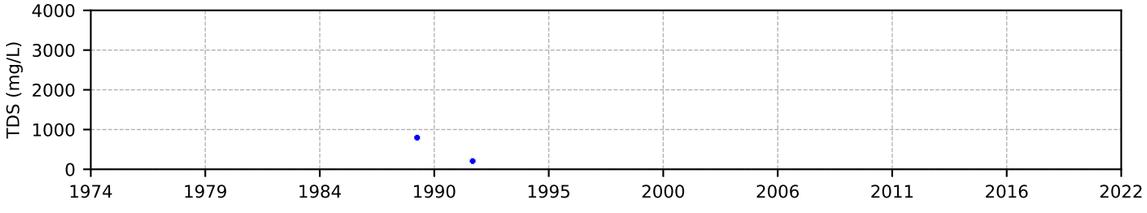

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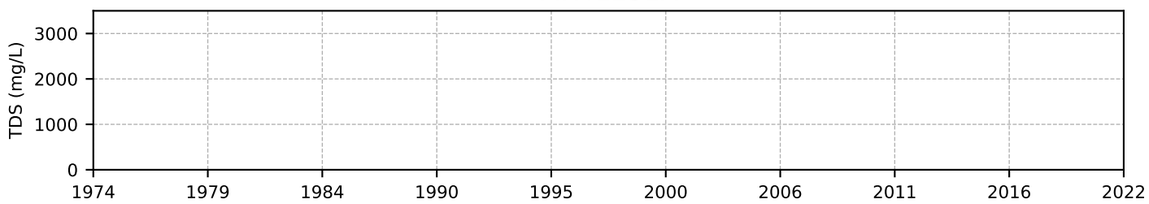

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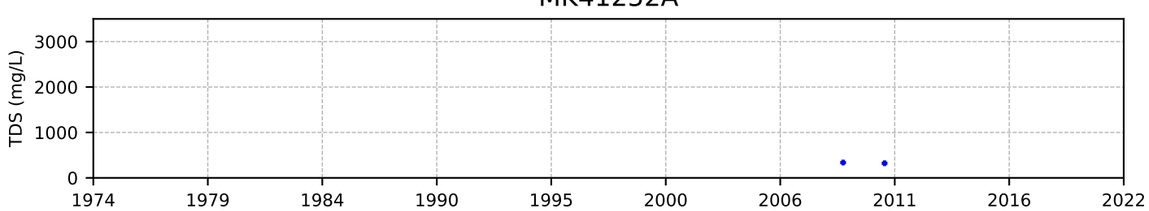

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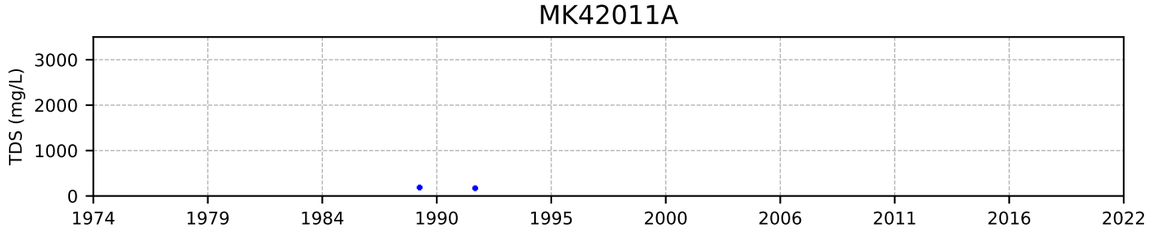

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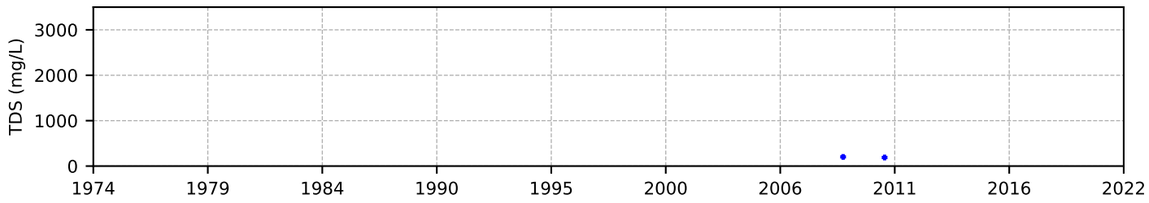

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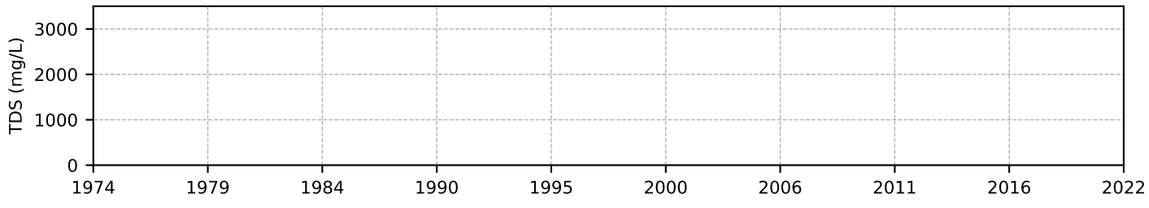

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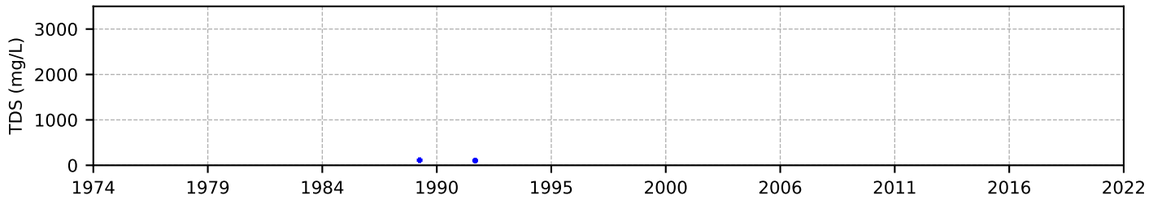

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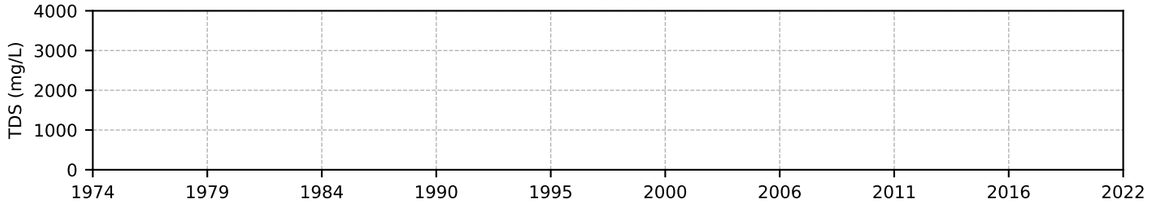

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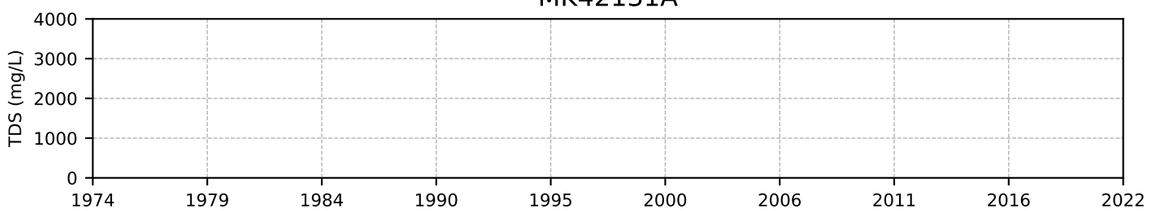

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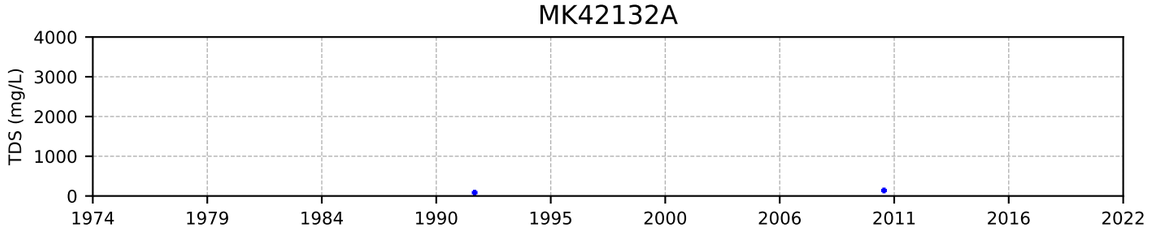

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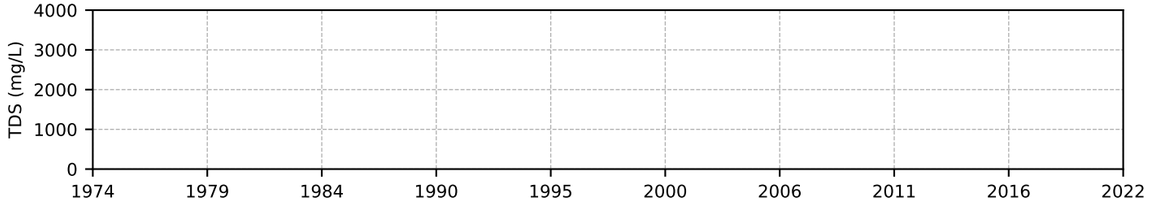

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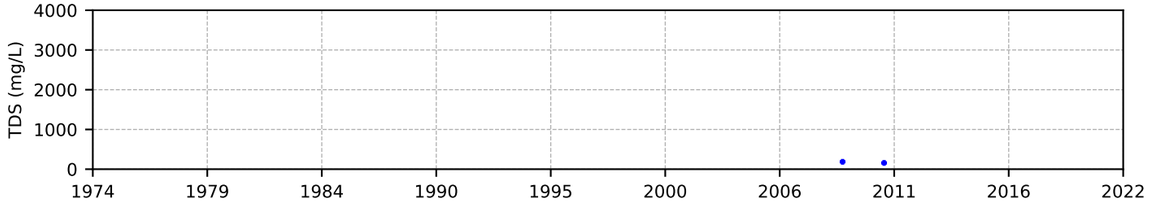

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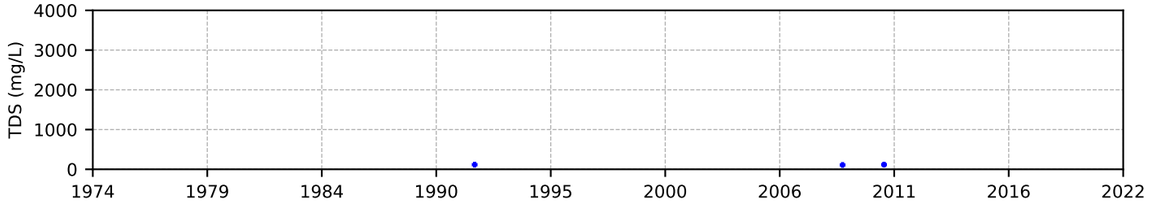

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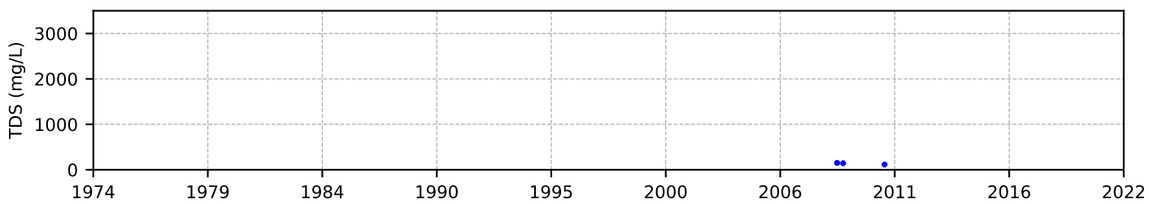

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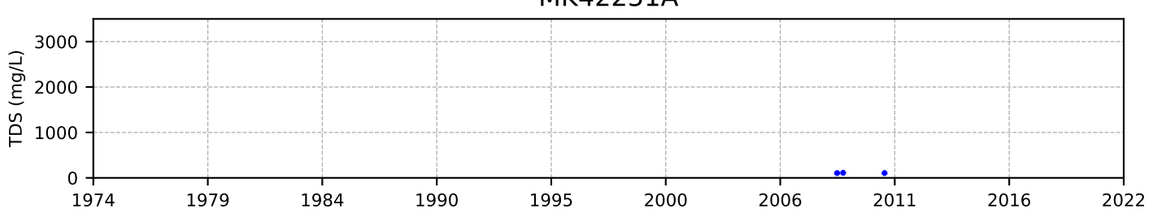

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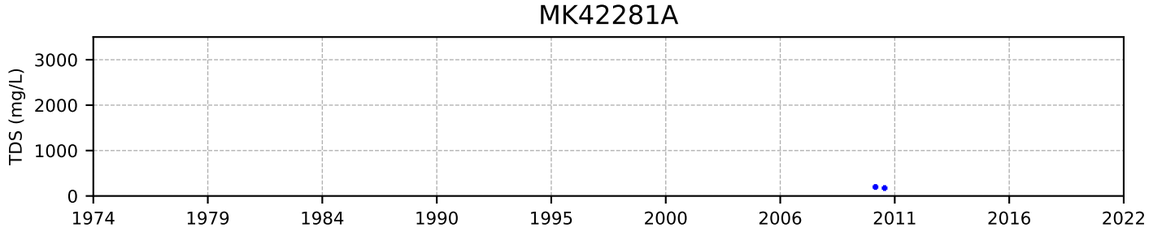

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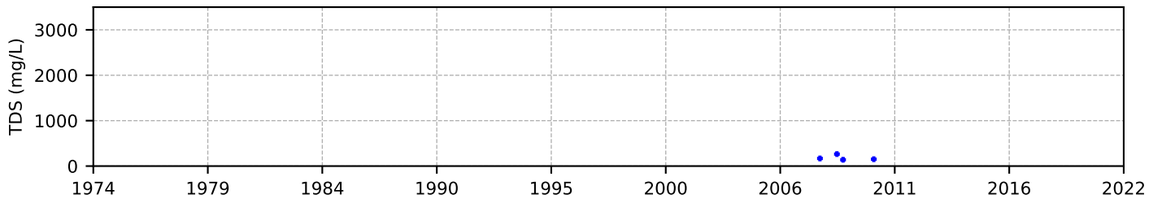

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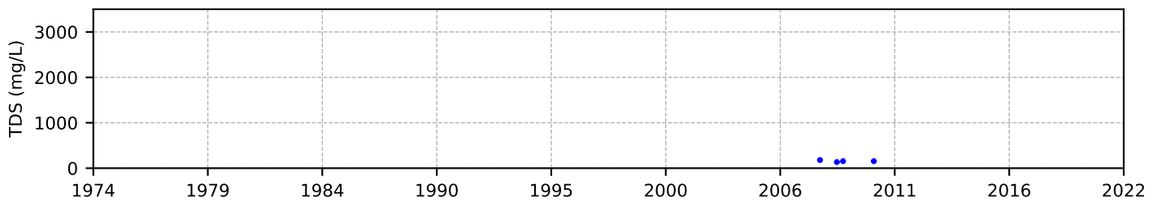

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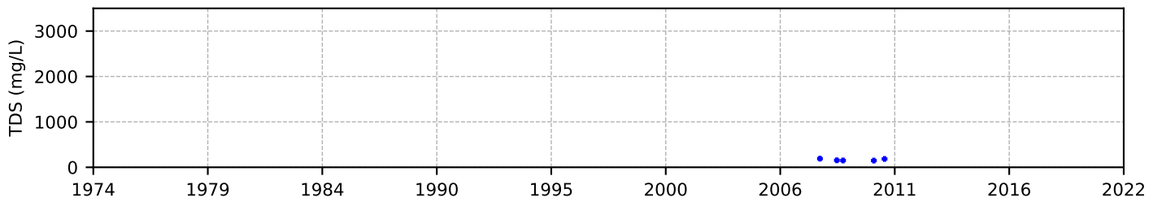

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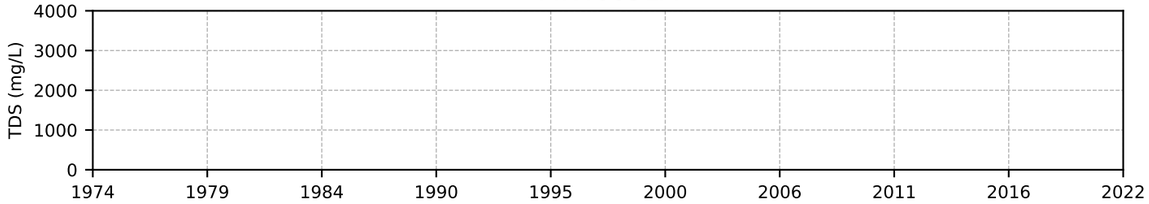

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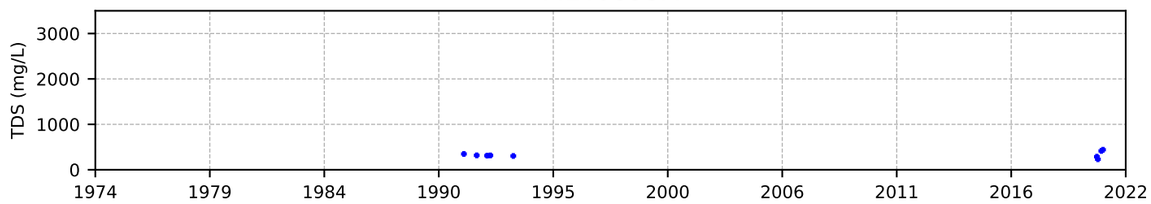

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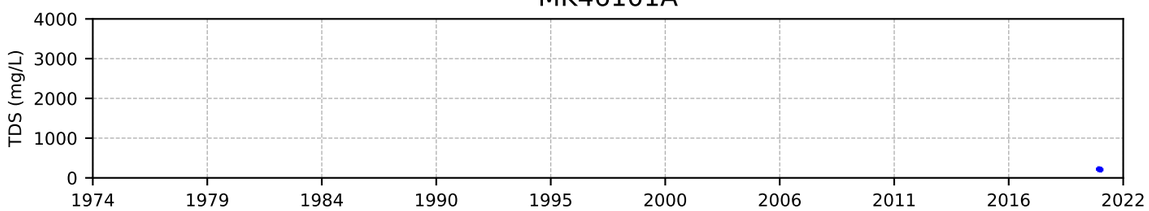

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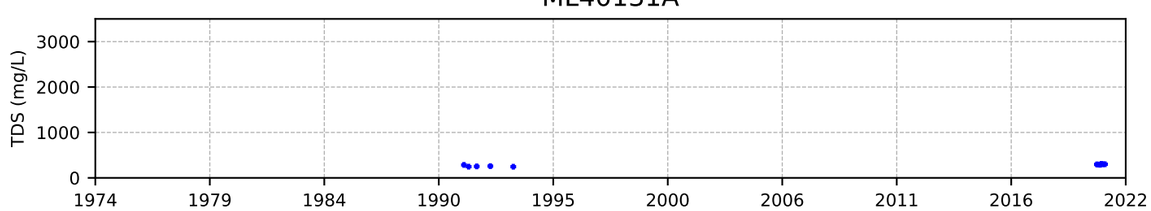

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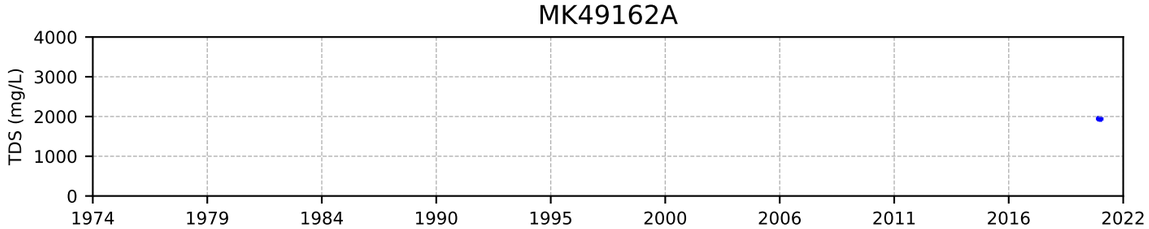

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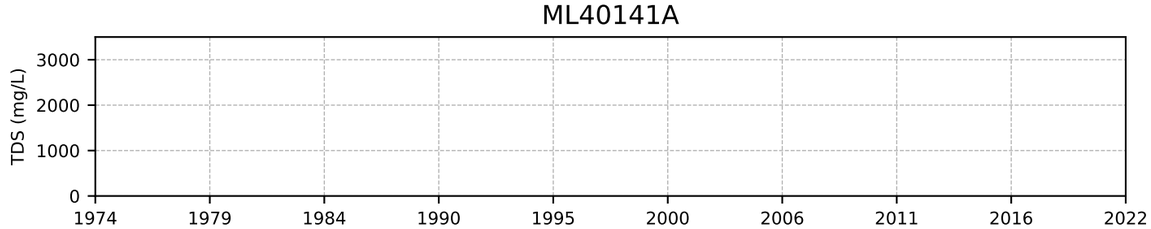

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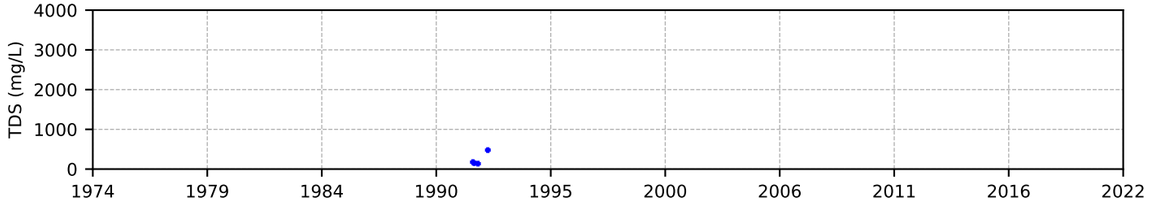

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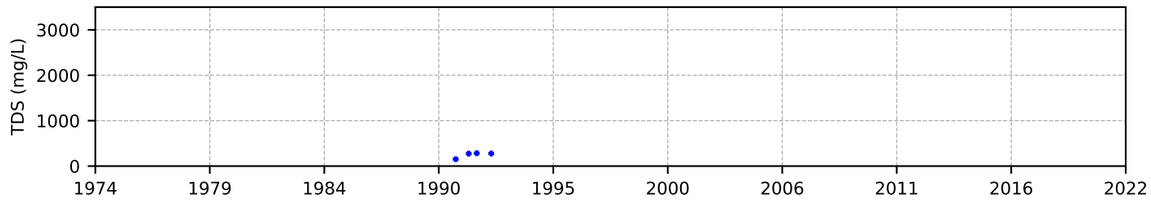

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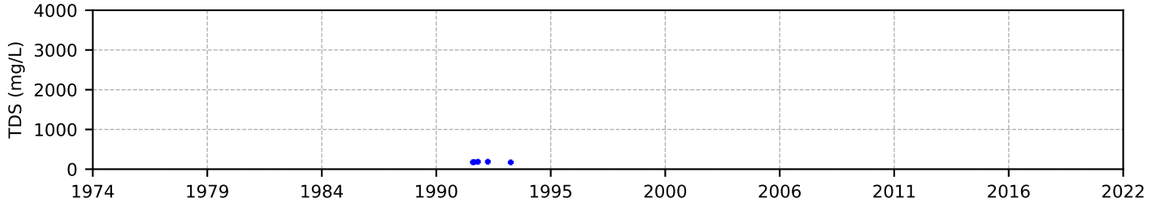

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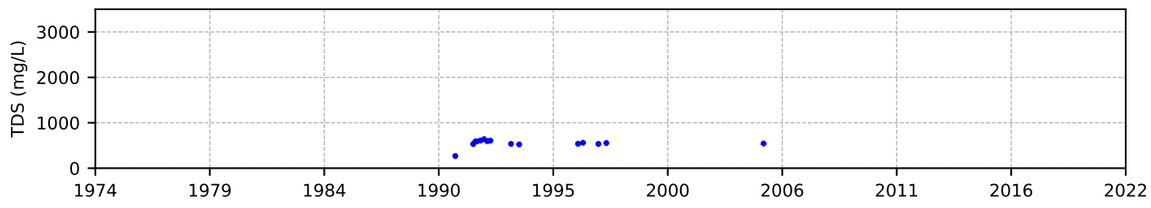

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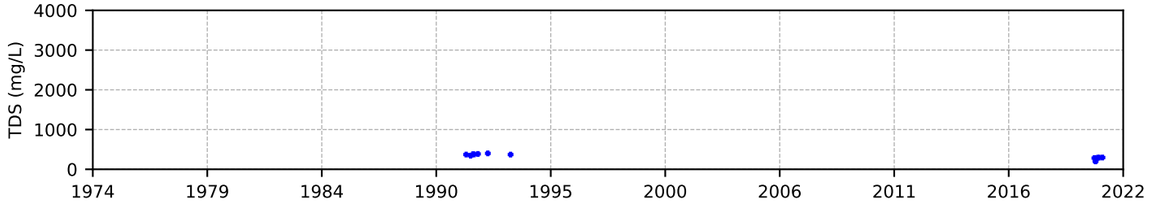

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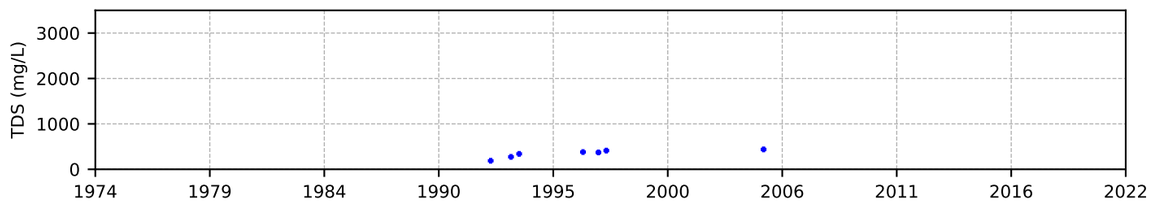

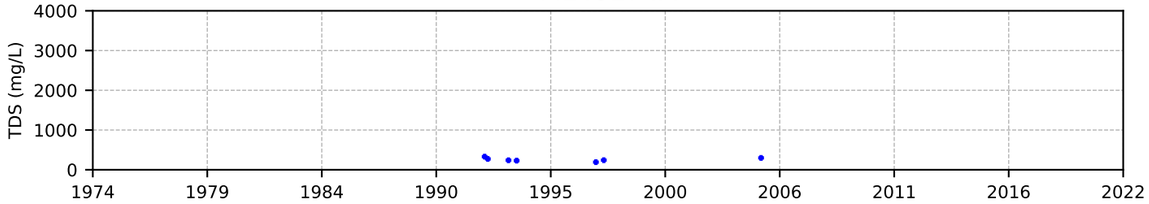
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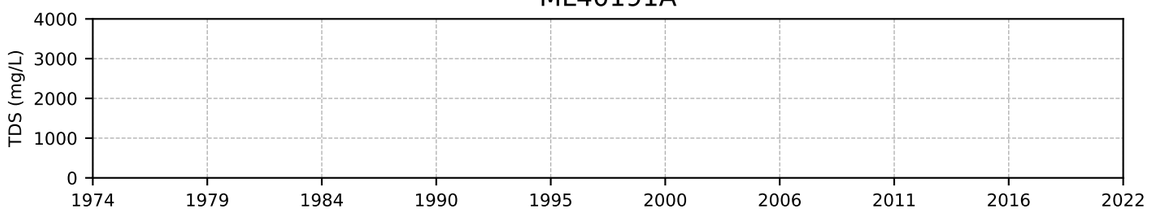
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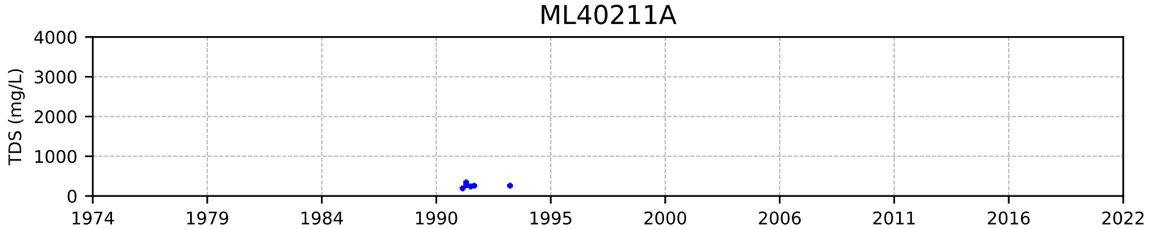
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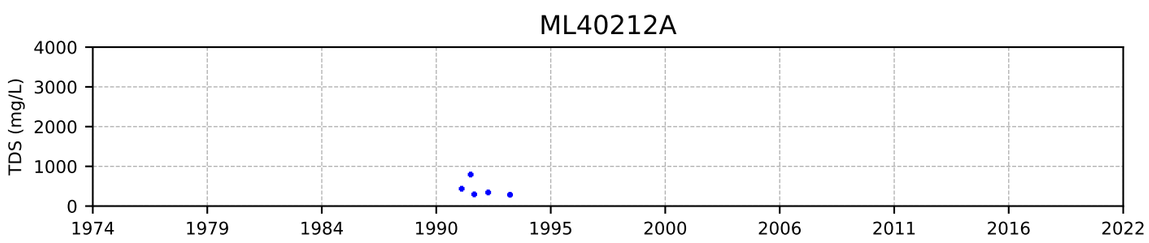
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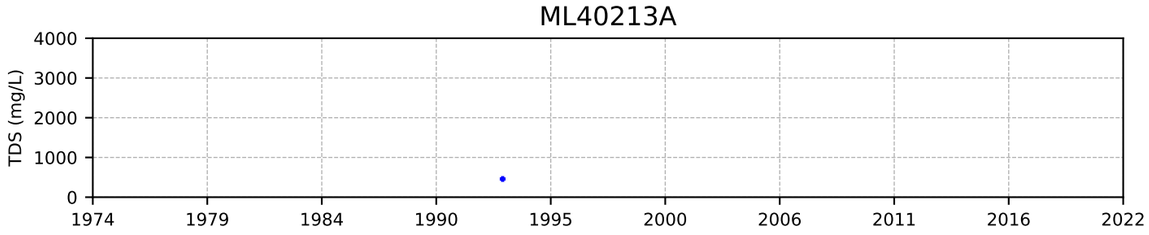
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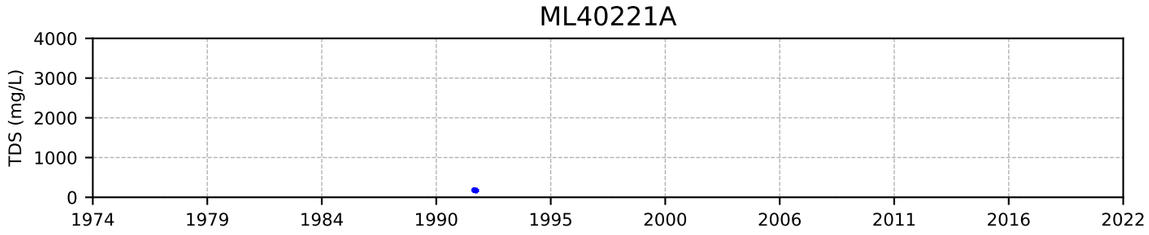
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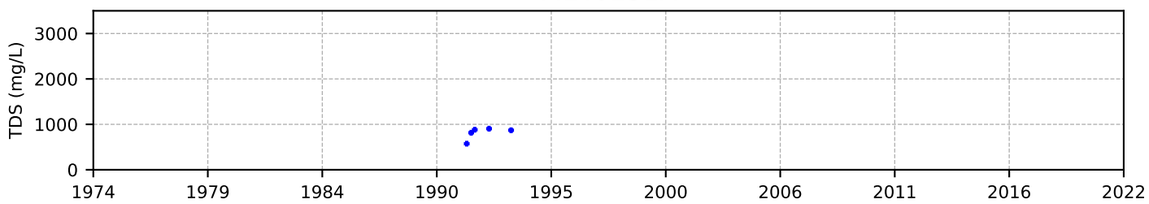
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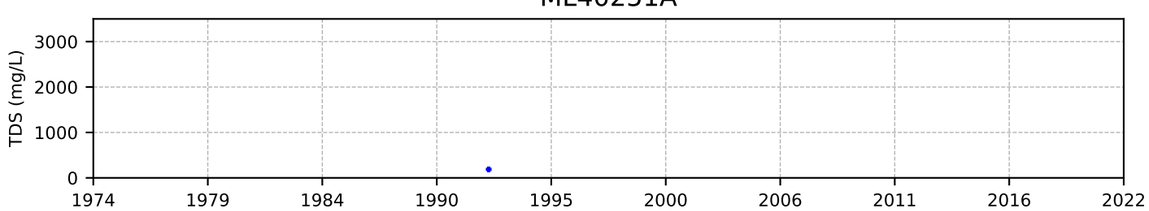
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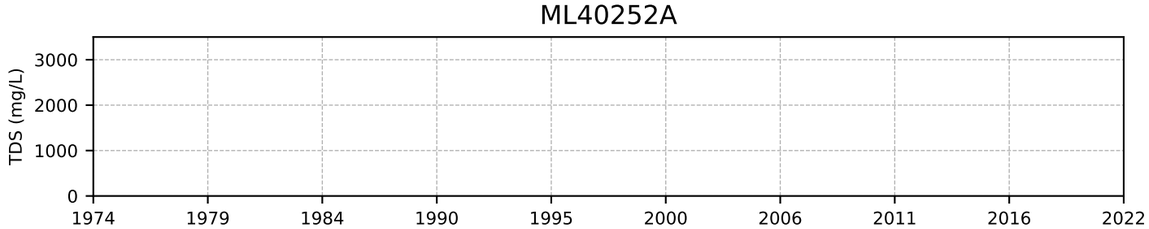
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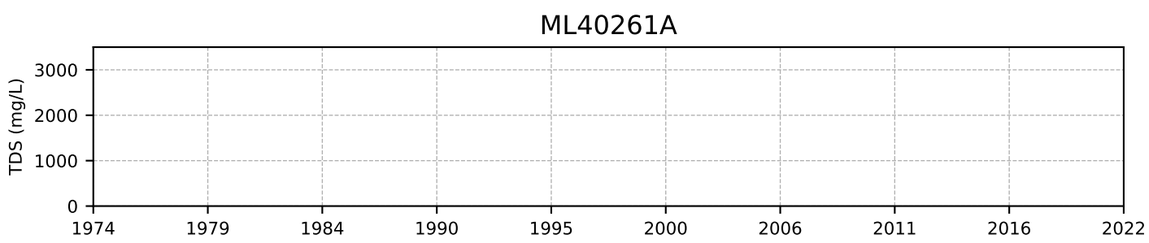
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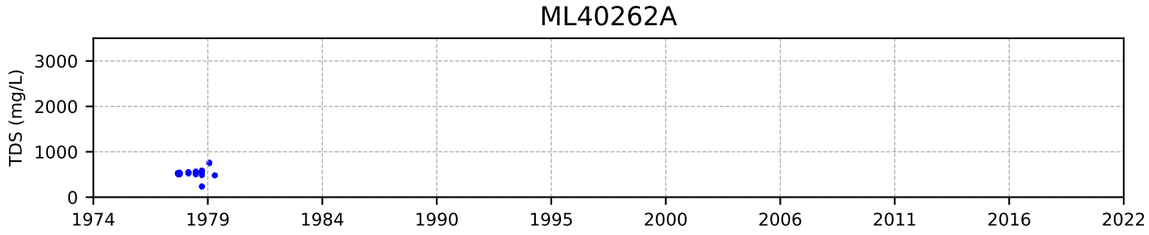
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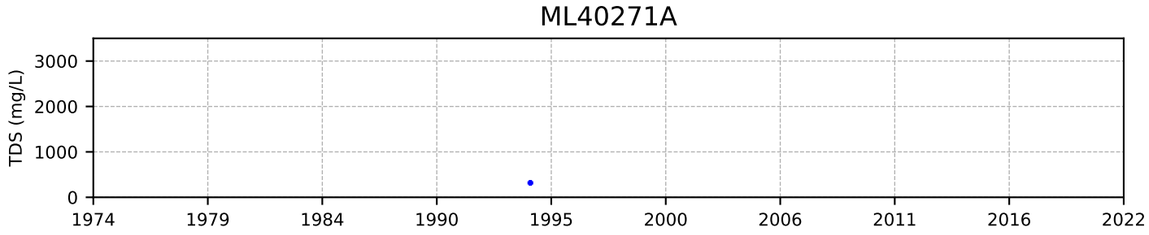
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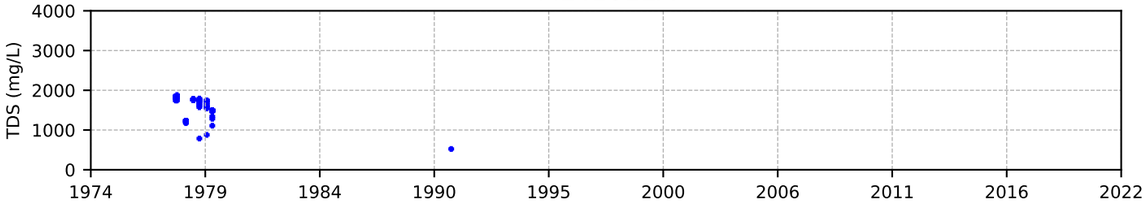
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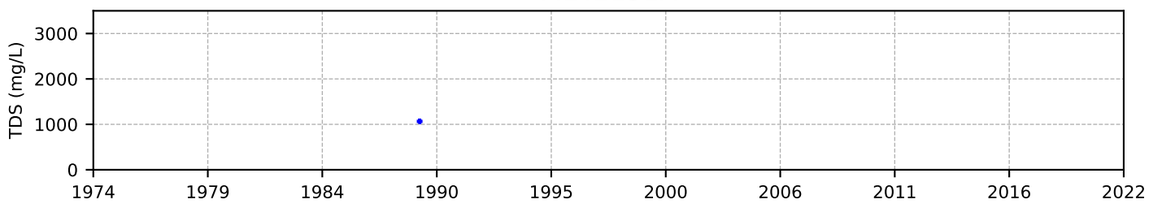
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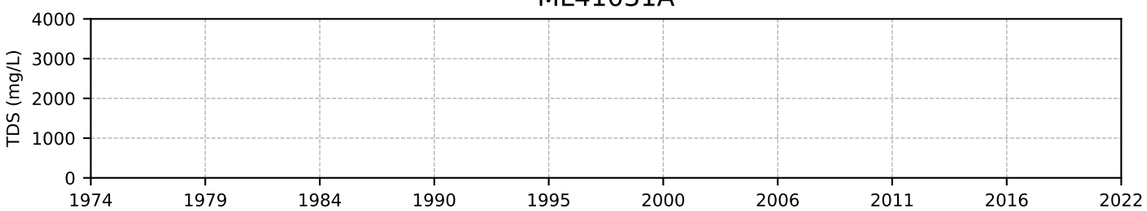
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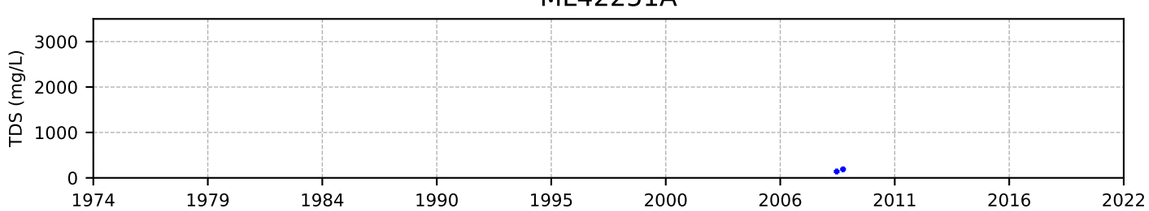
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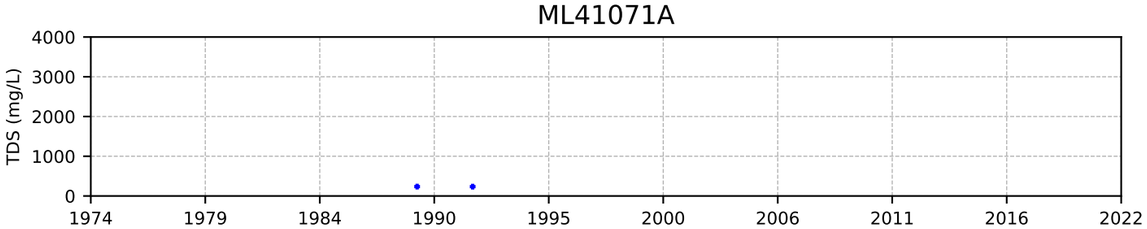
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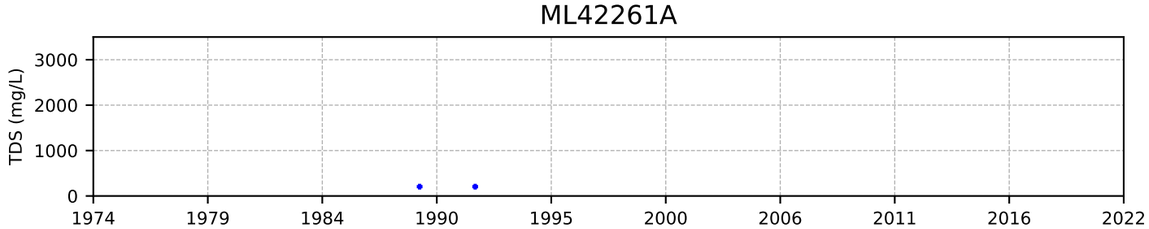
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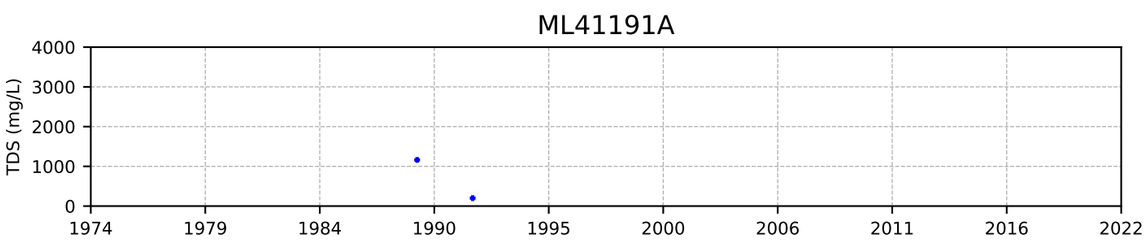
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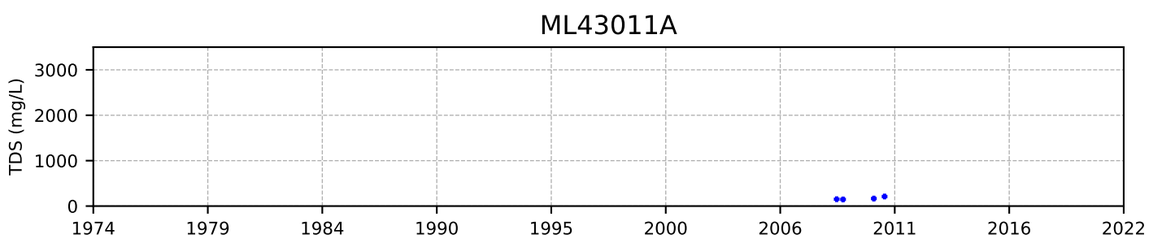
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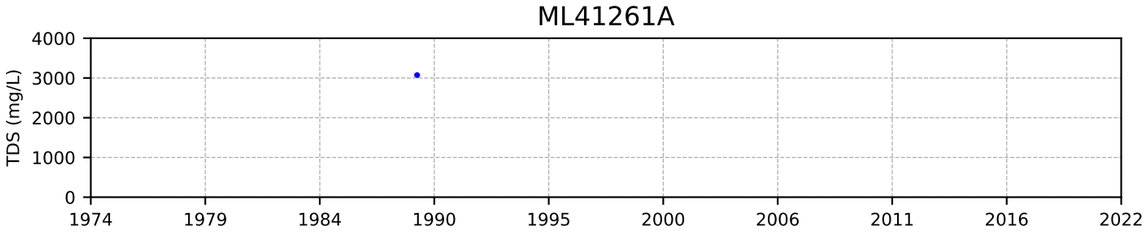
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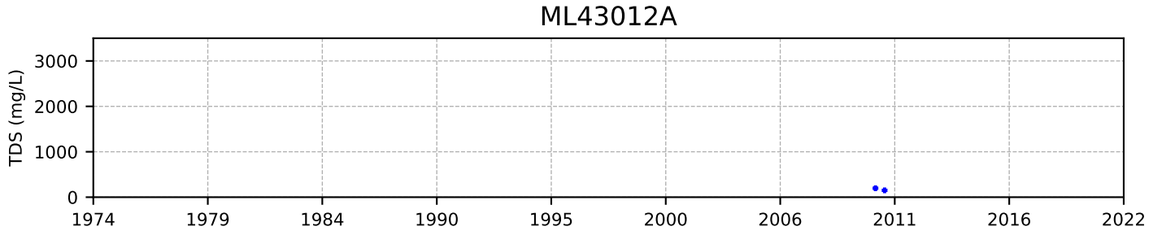
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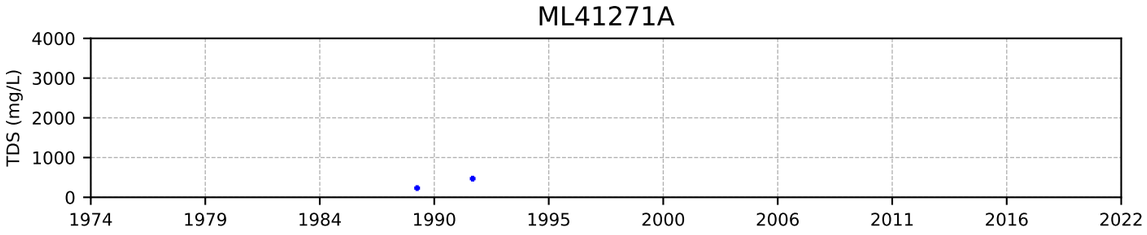
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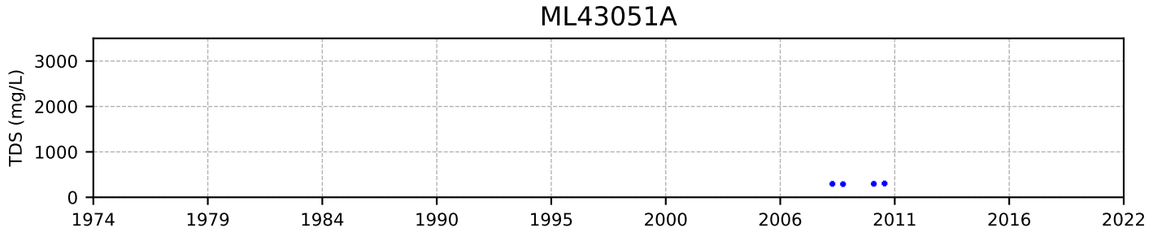
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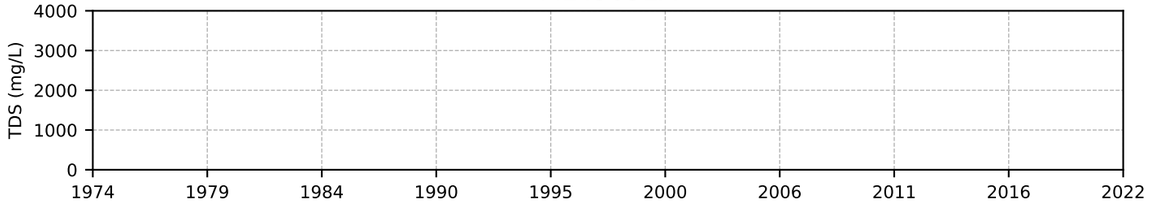

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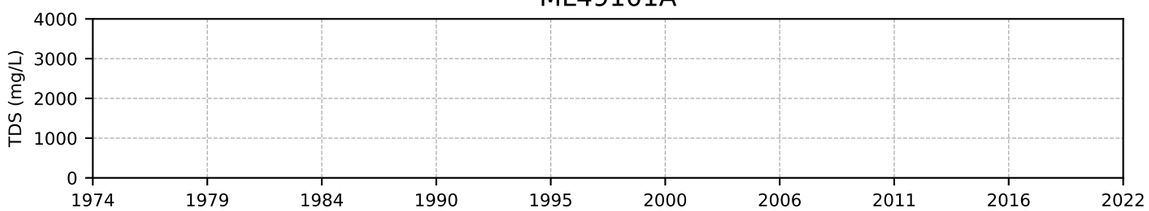

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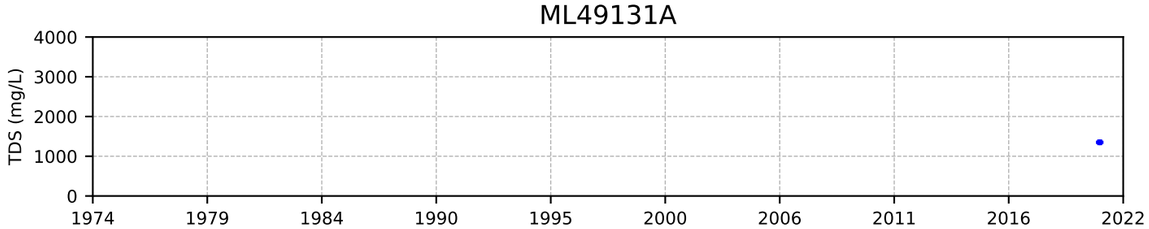

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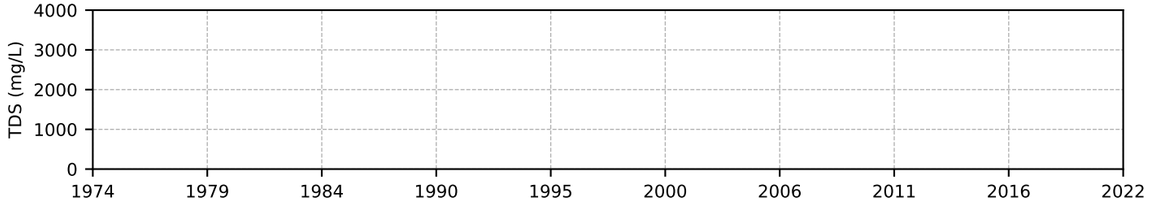

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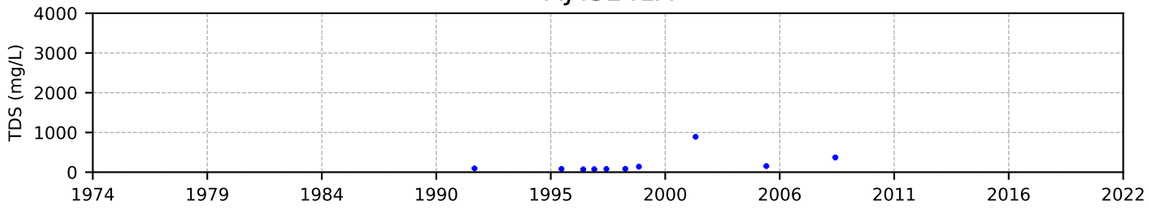

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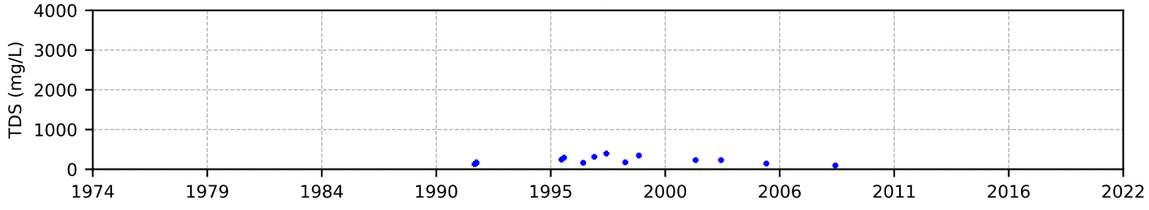

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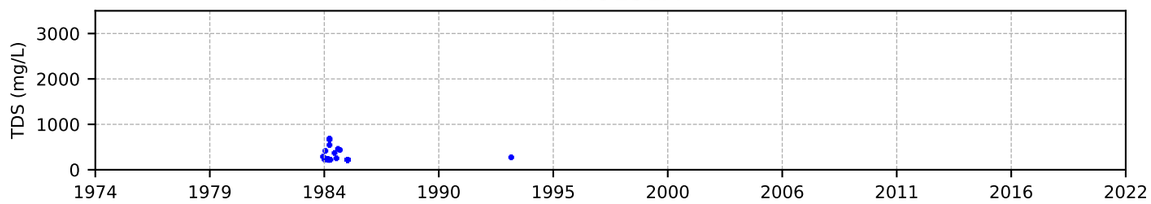

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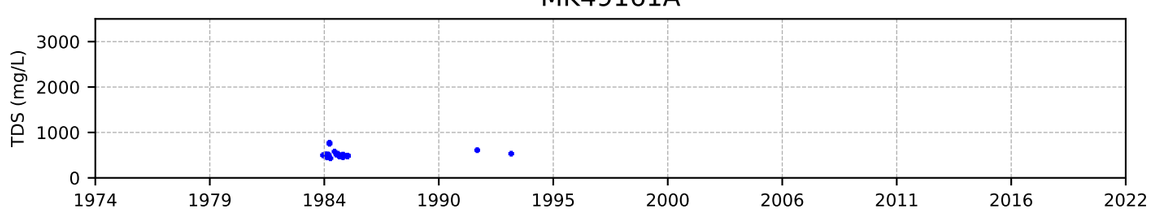

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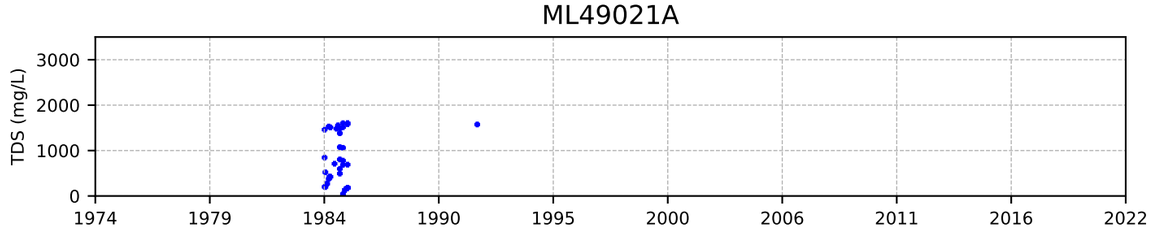

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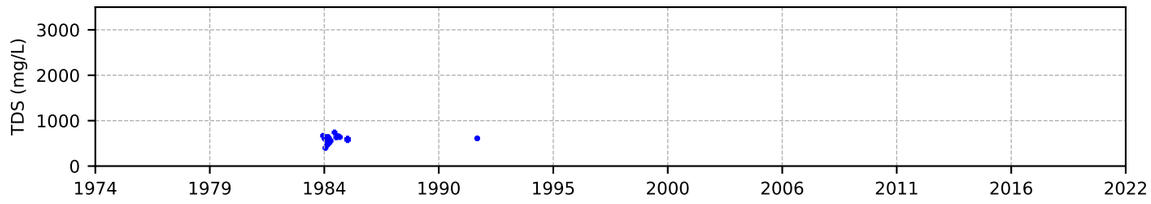

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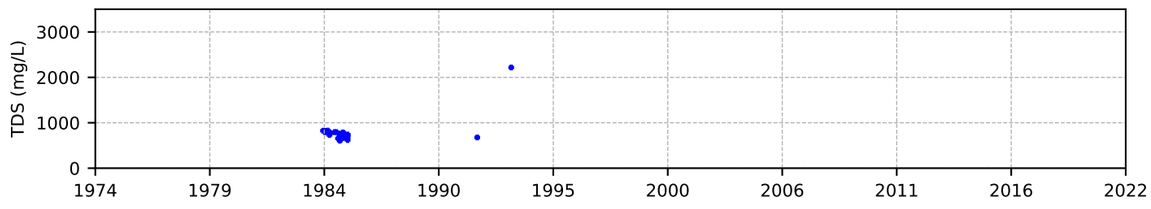

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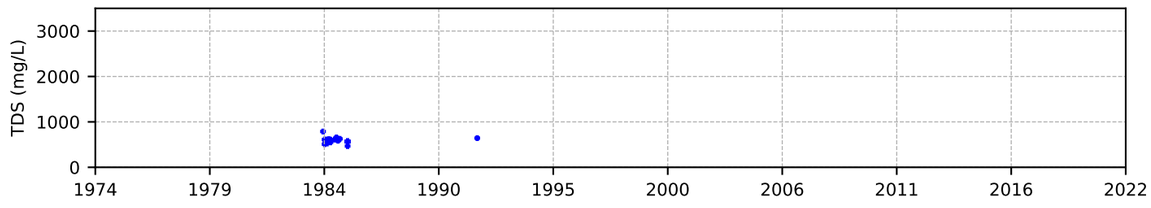

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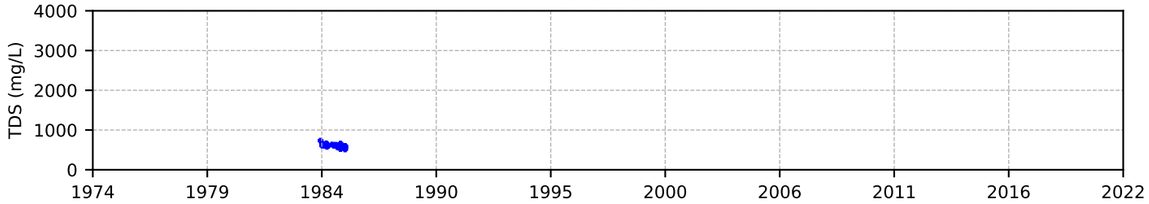

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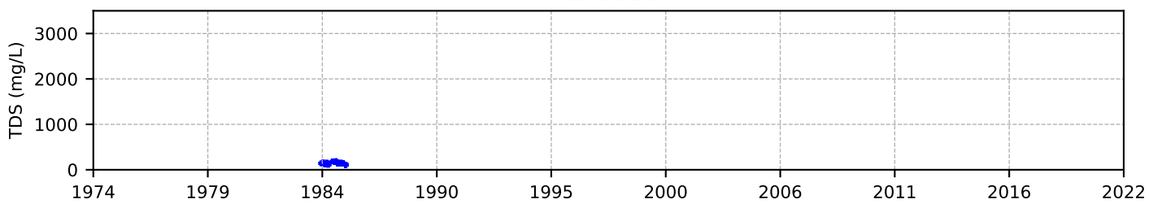

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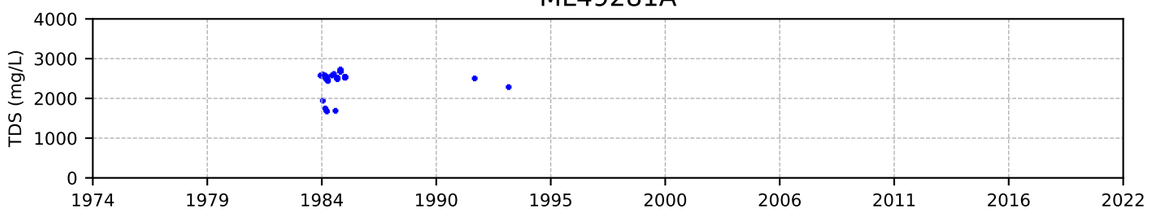

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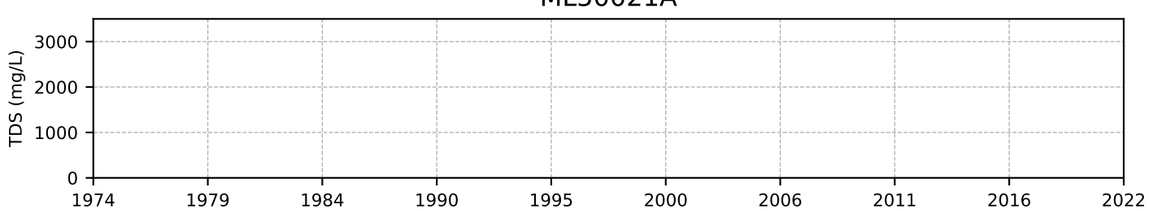

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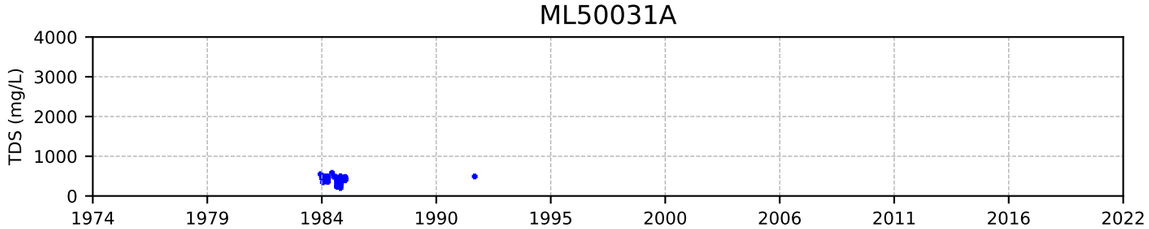

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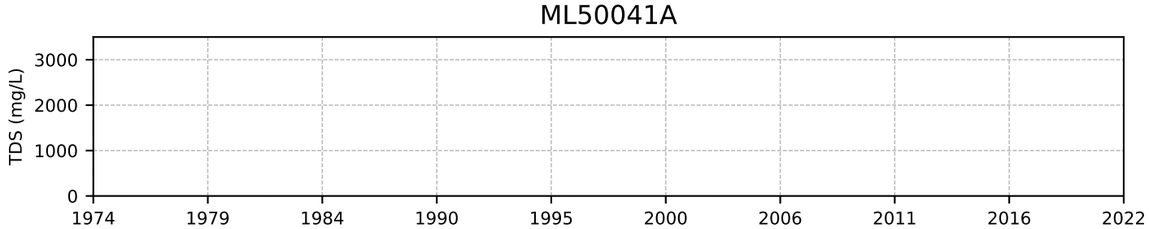

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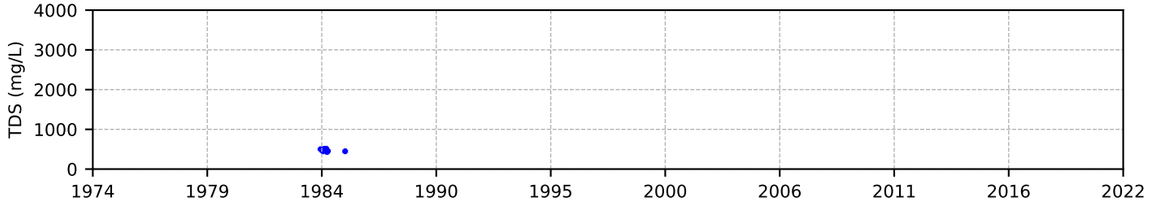

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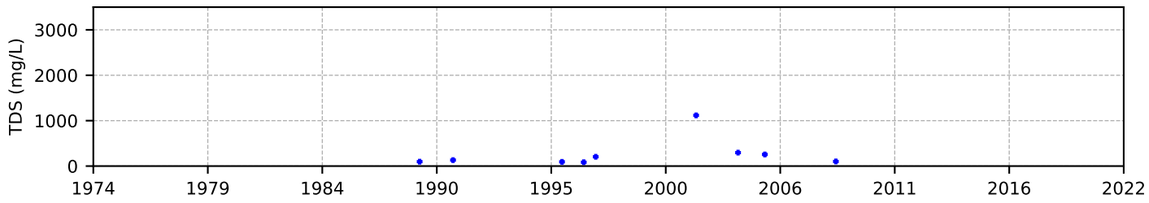

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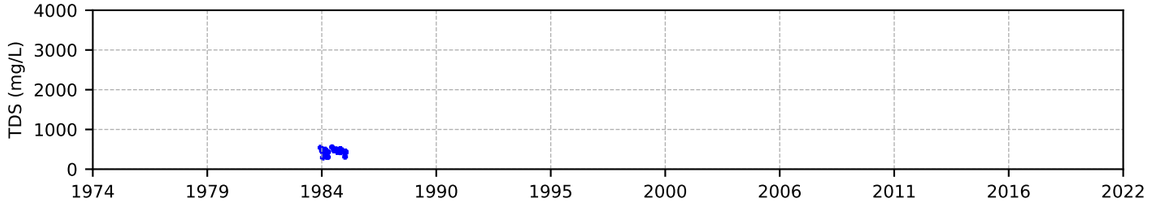

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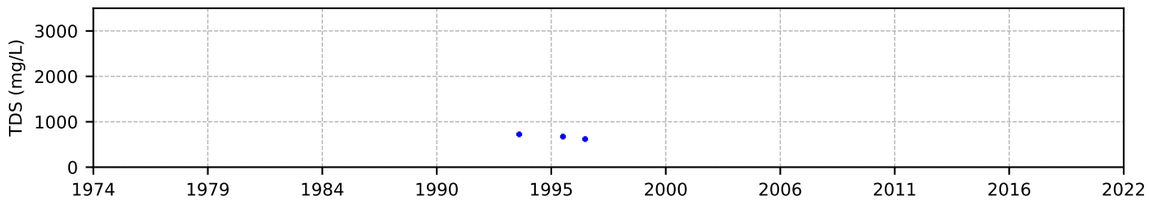

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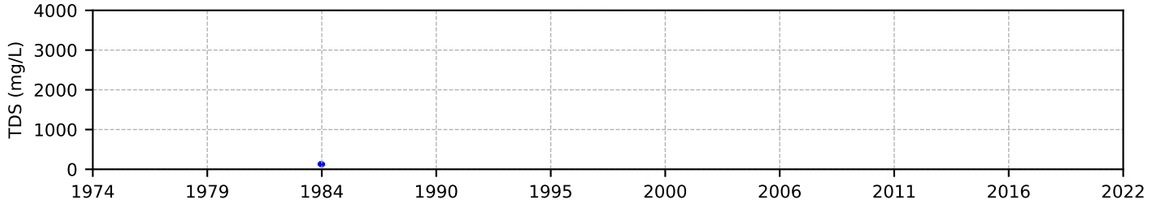

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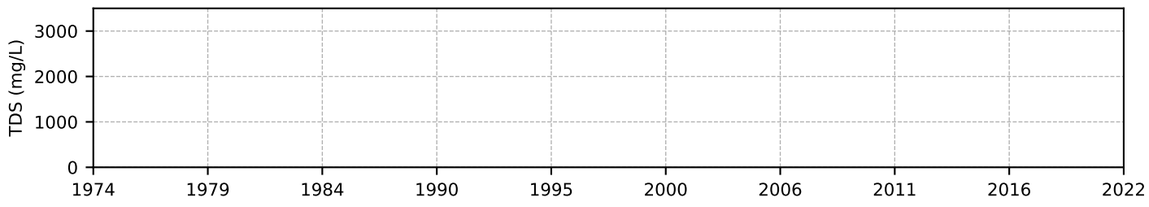

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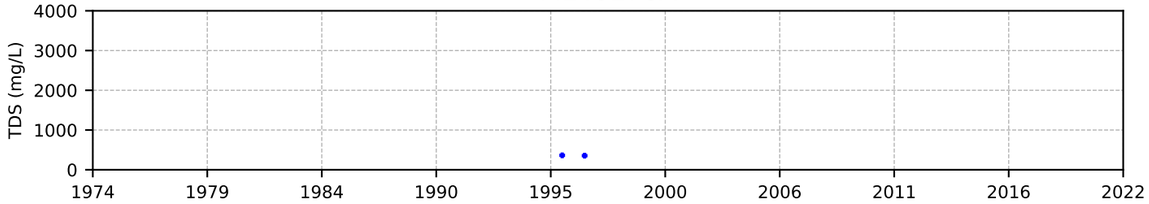

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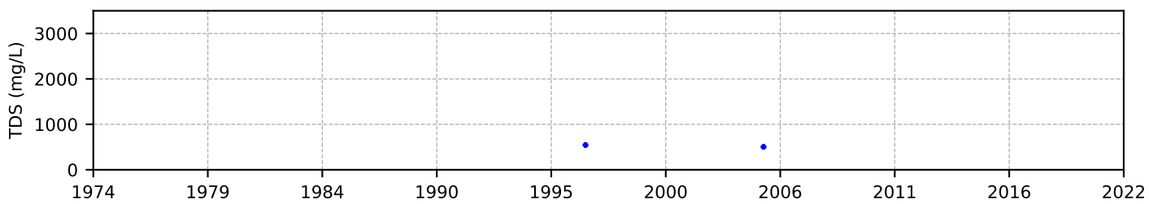

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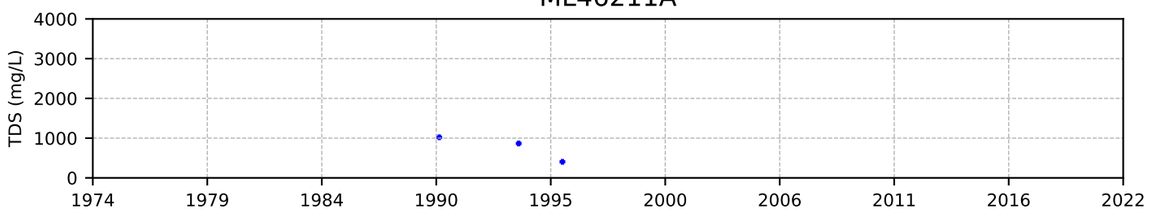

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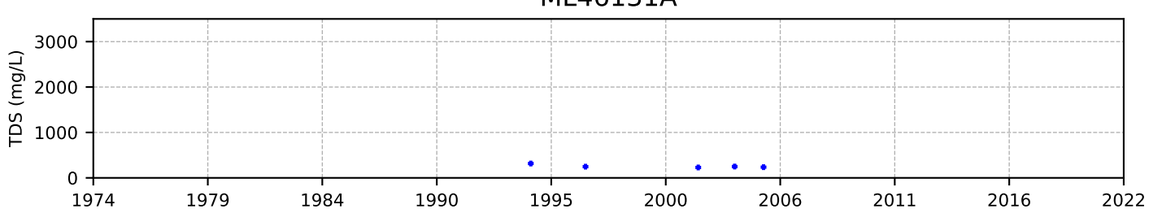

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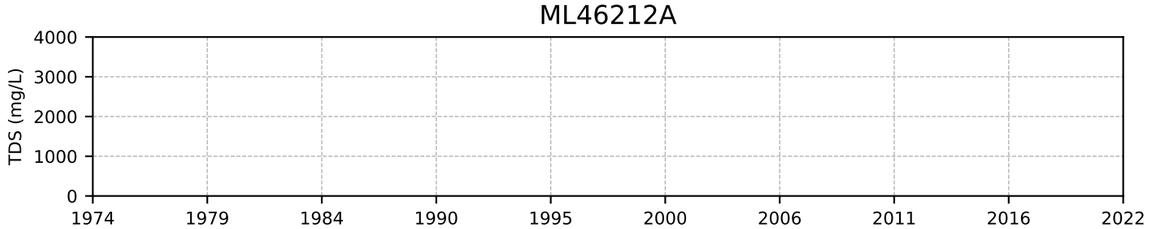

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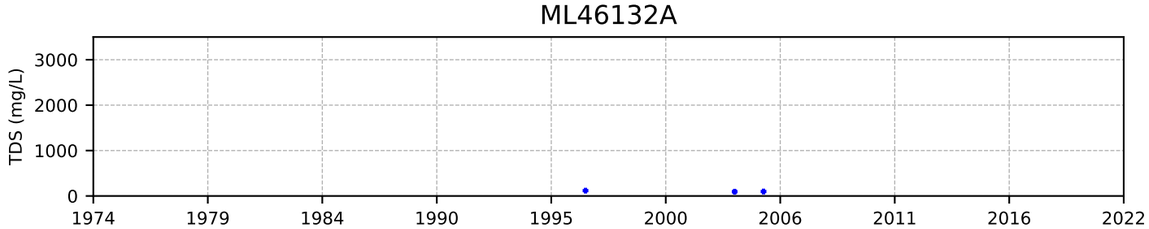

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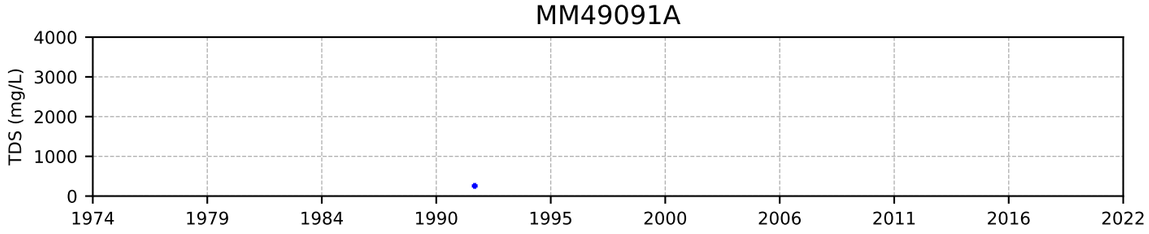

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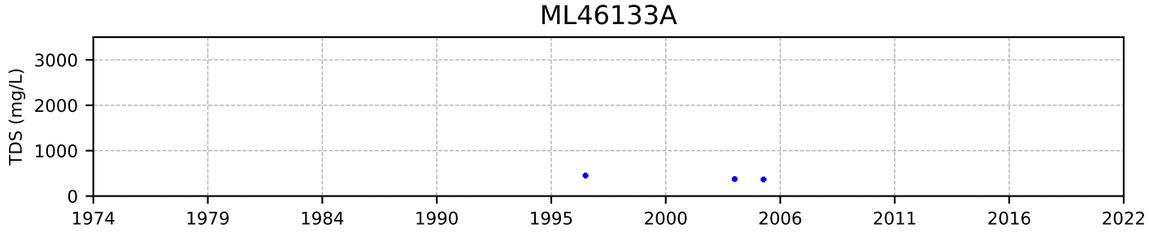

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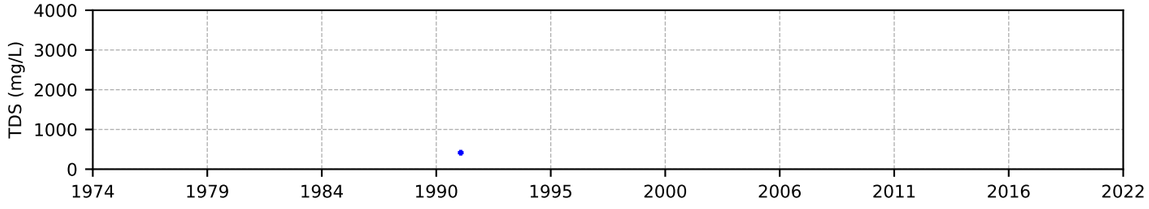

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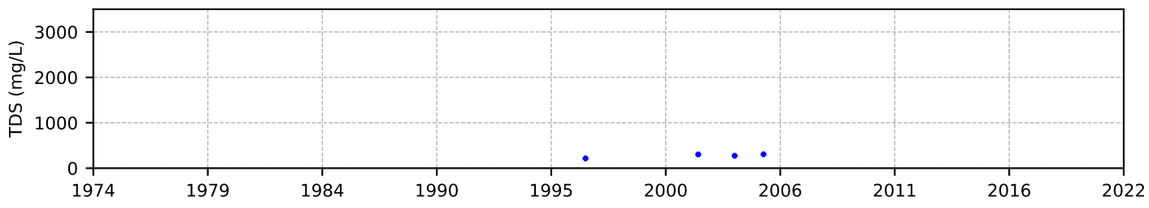

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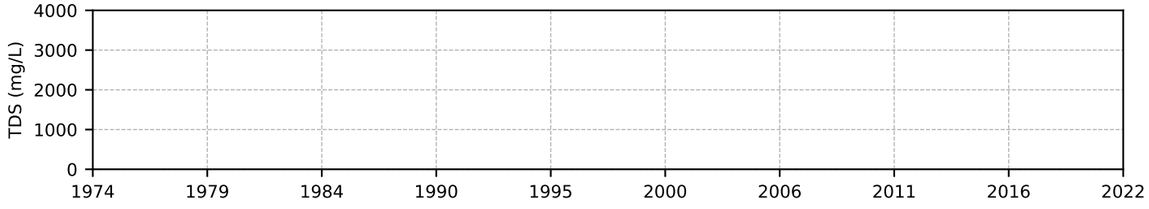

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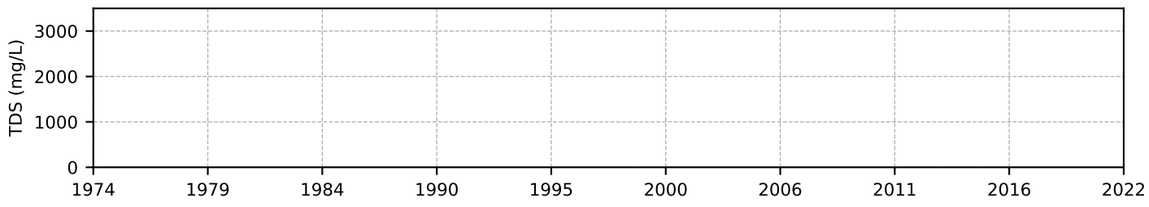

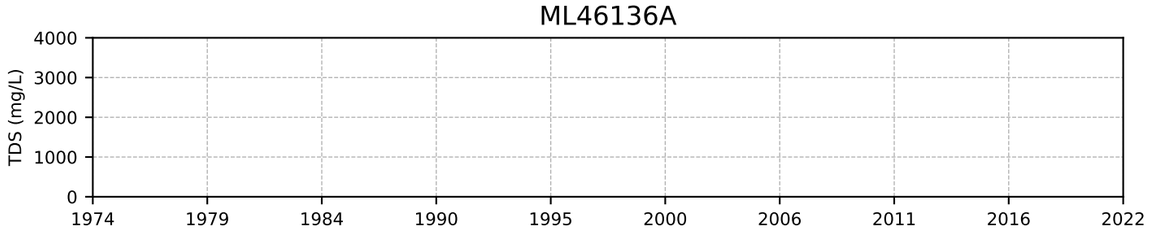
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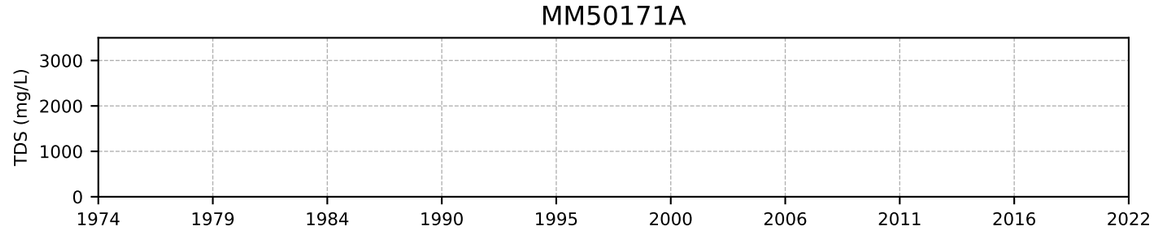
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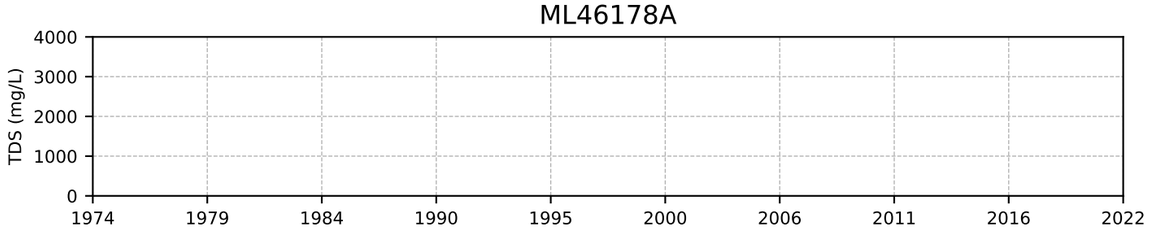
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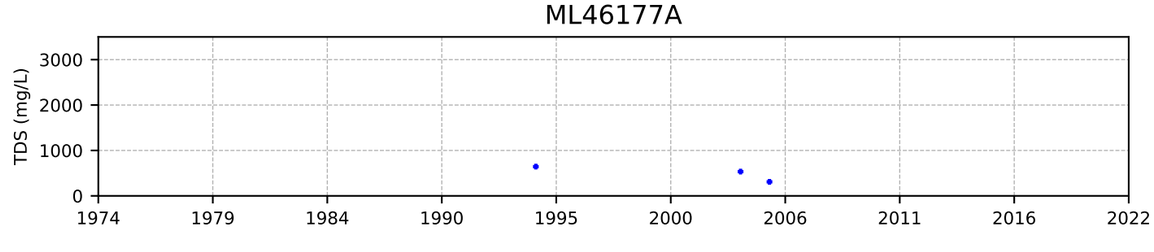
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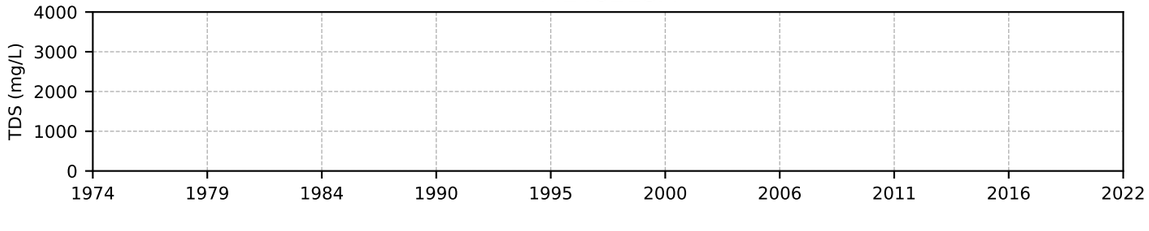
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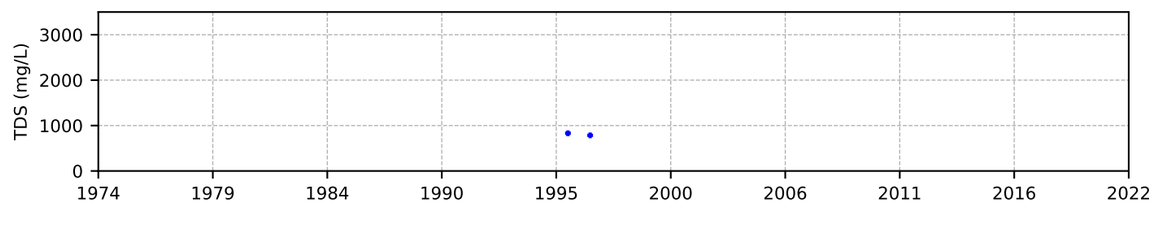
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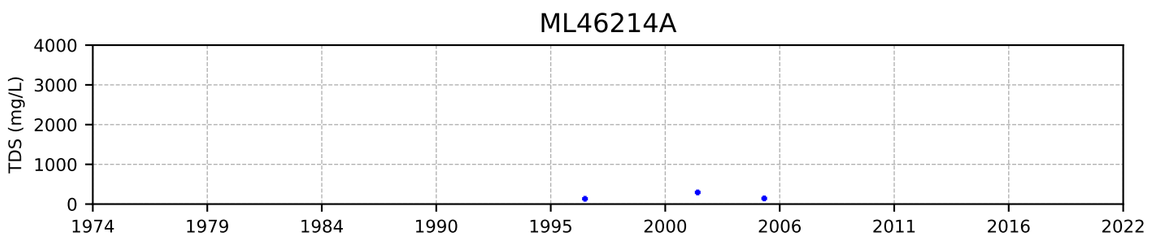
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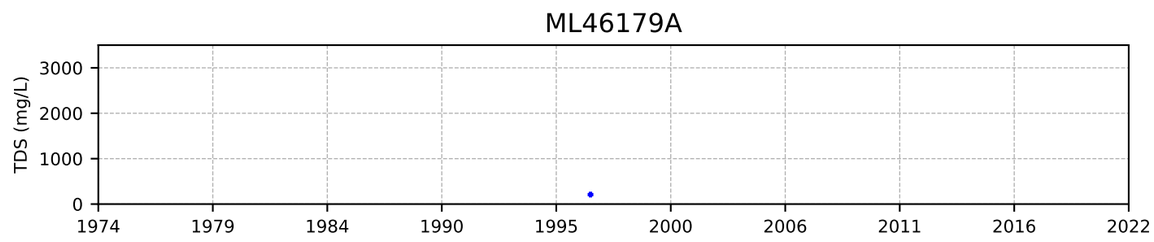
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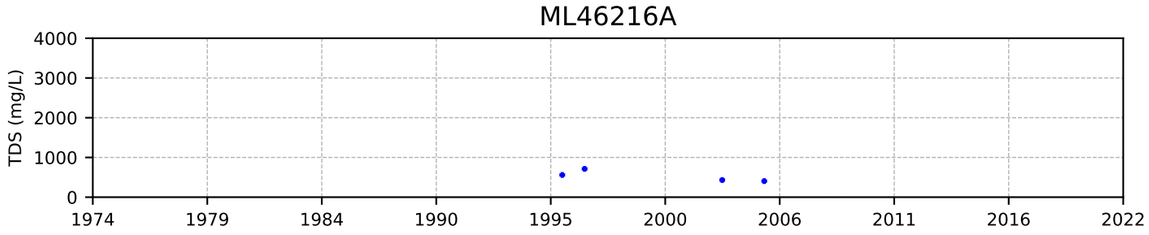
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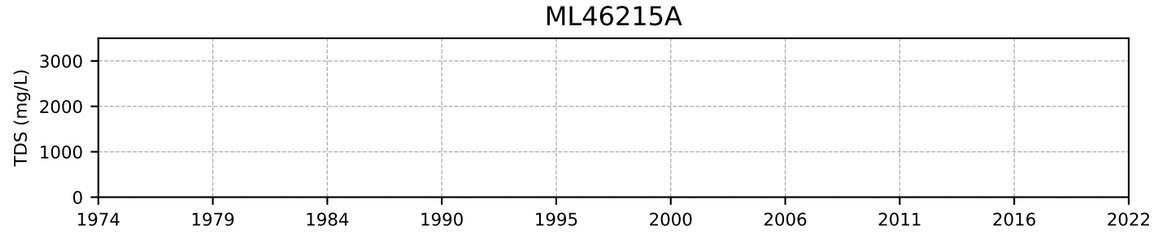
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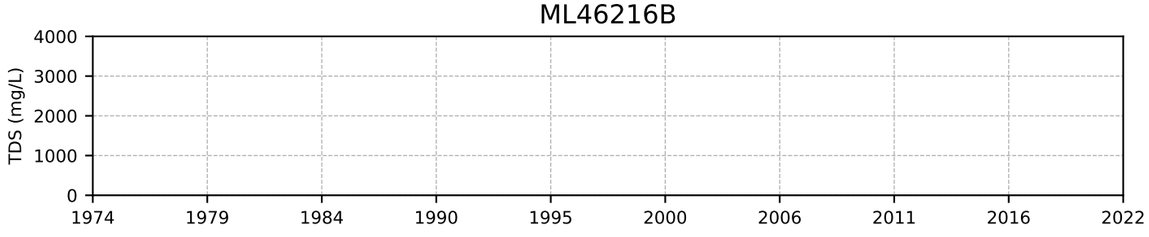
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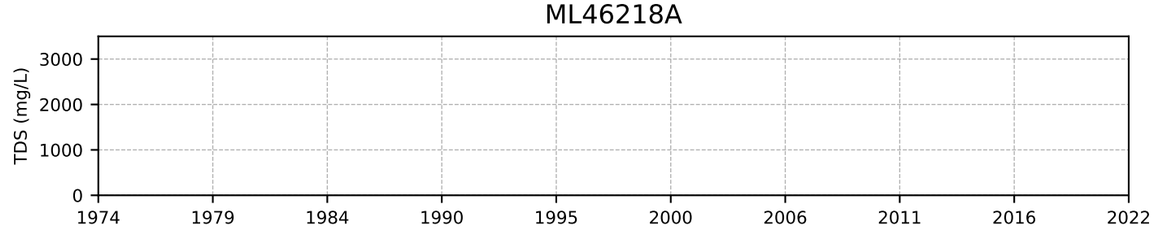
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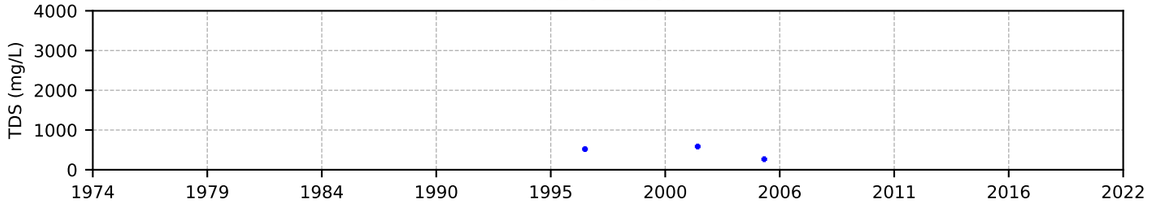

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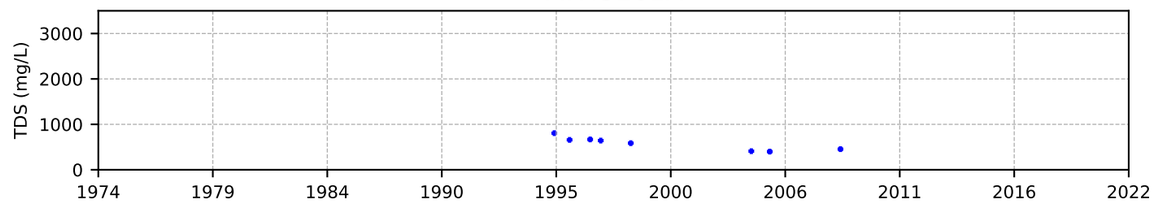

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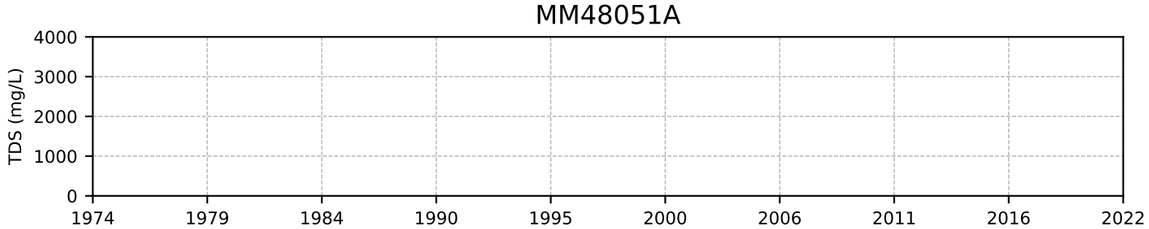

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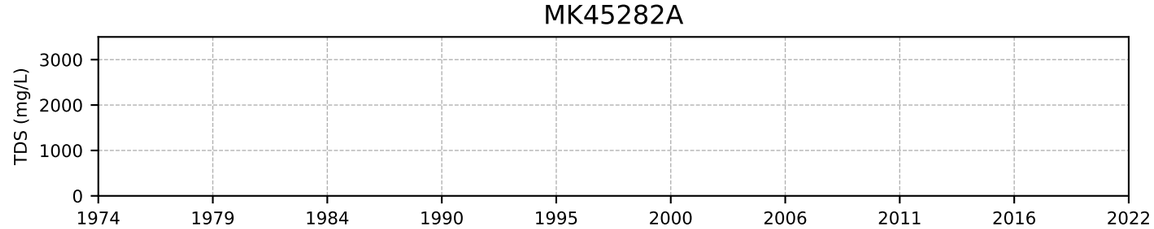

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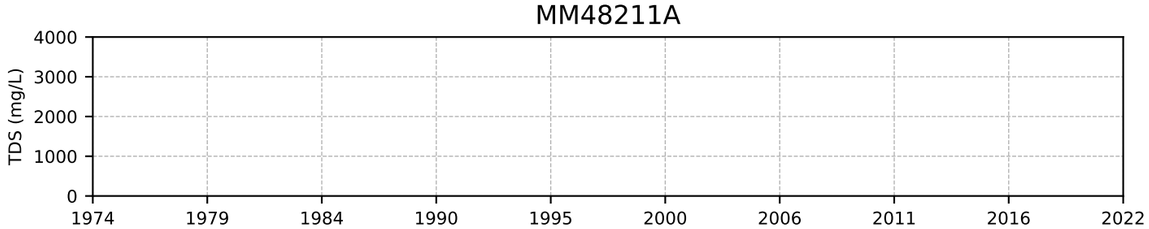

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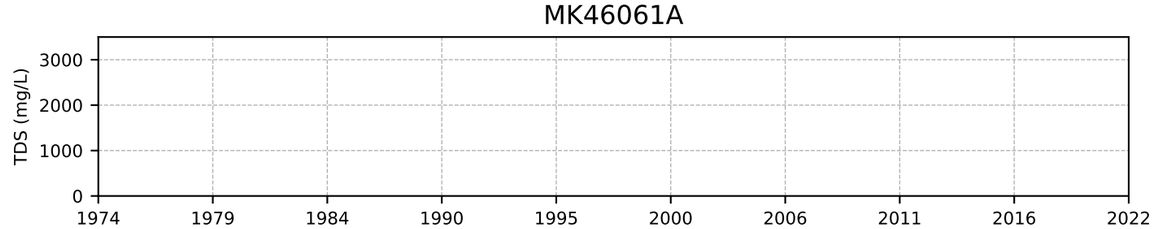

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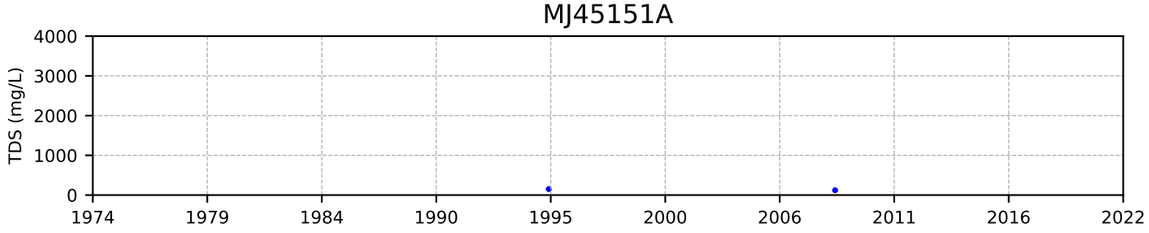

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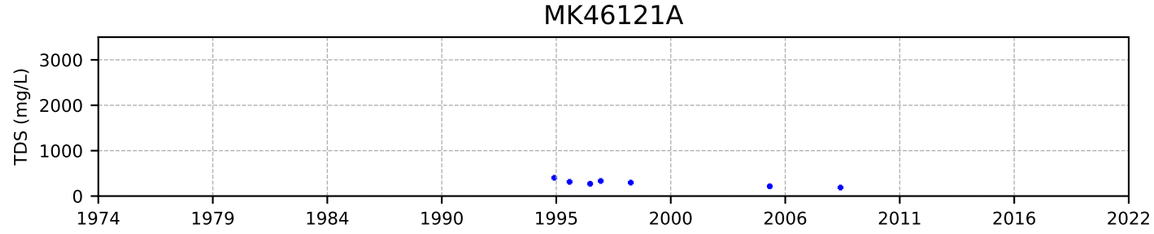

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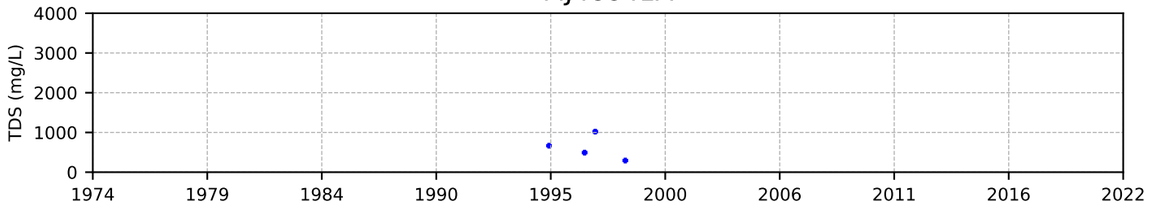

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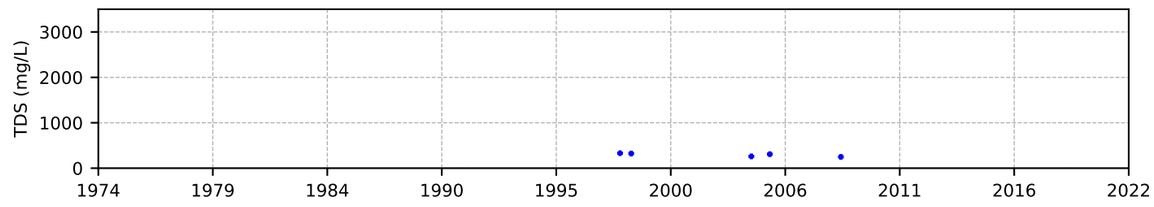

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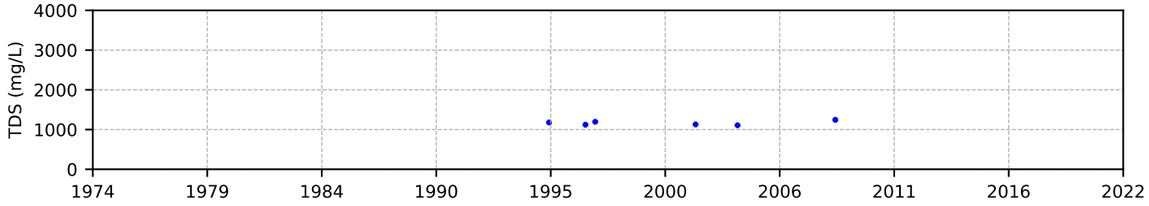

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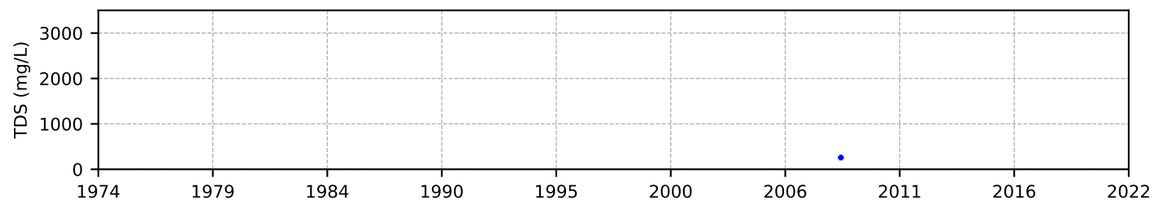

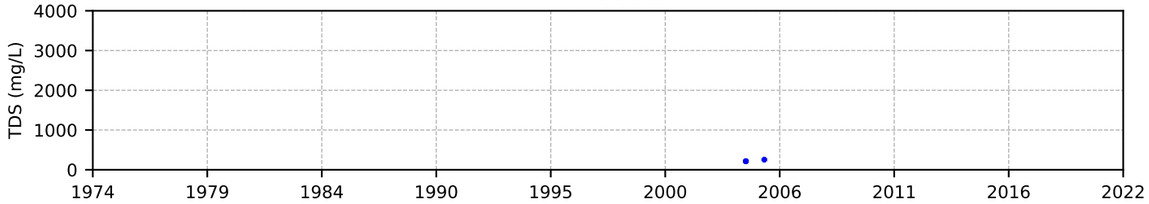
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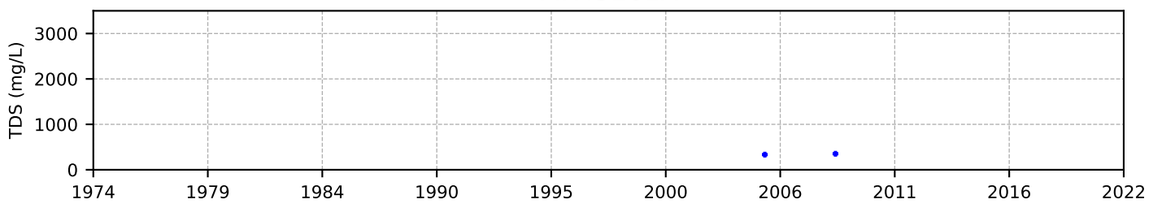
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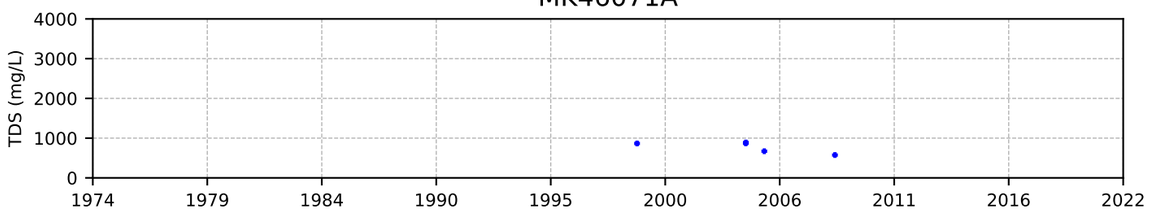
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TDS (mg/L)
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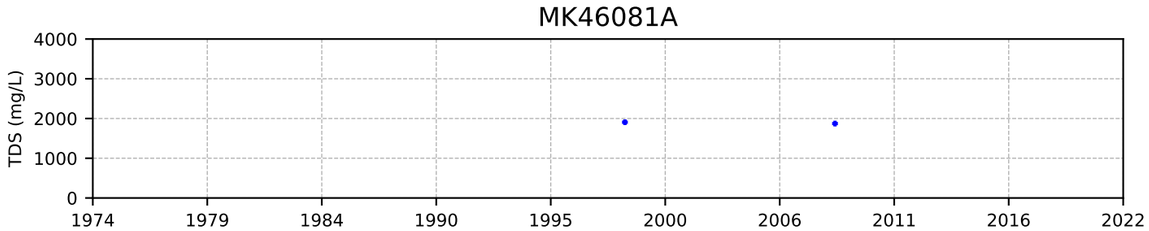
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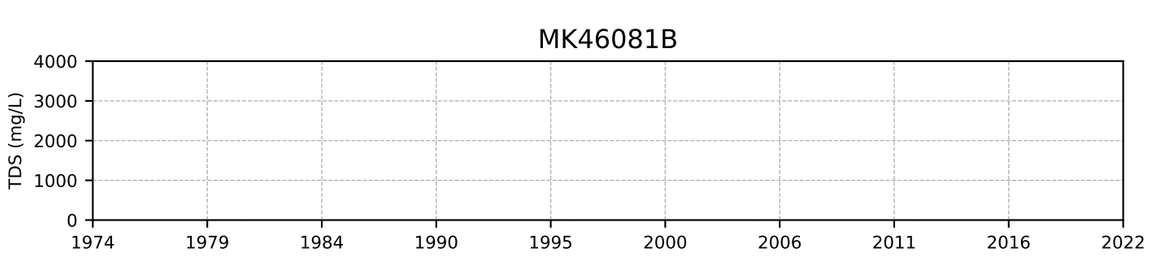
MK46081B
TDS (mg/L)
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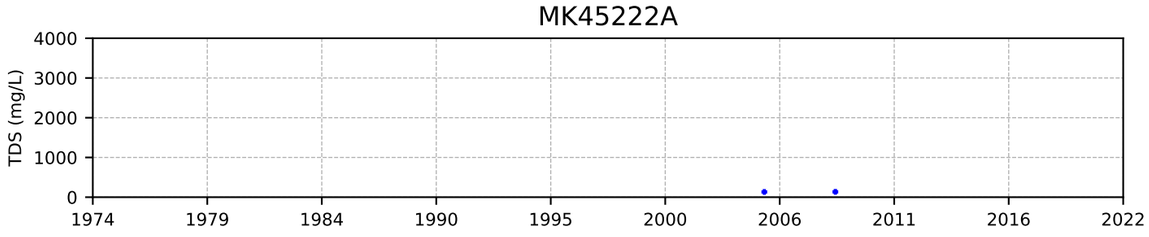
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TDS (mg/L)
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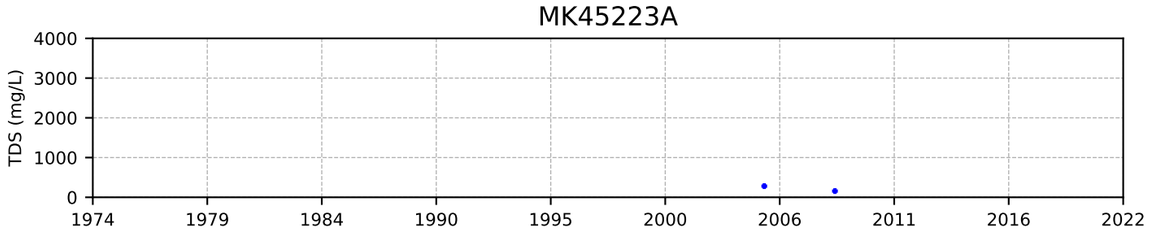
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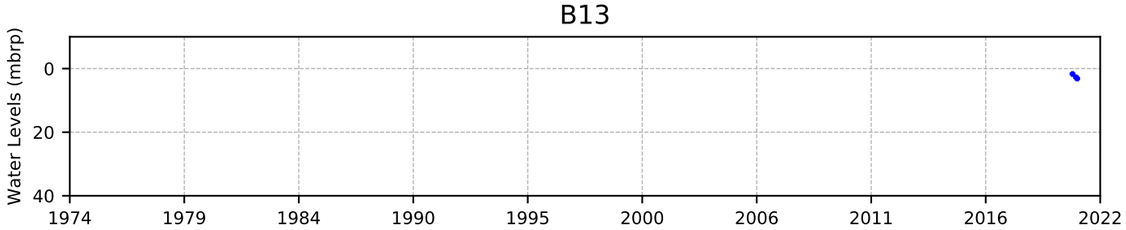
B13
Water Levels (mbrp)
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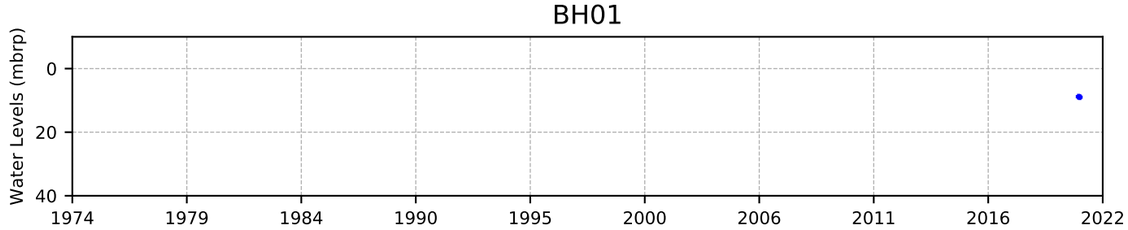
BH01
Water Levels (mbrp)
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2016
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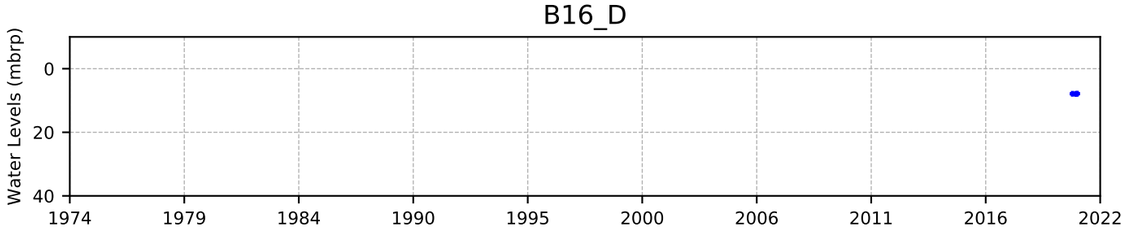
B16_D
Water Levels (mbrp)
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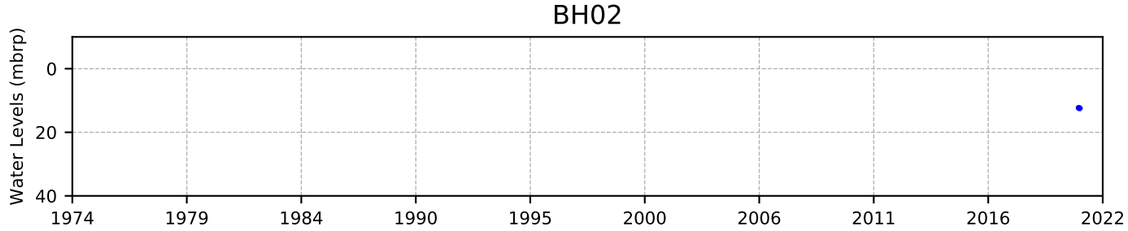
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Water Levels (mbrp)
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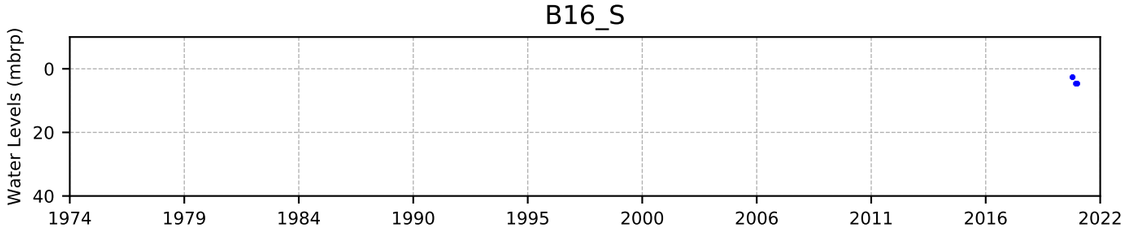
B16_S
Water Levels (mbrp)
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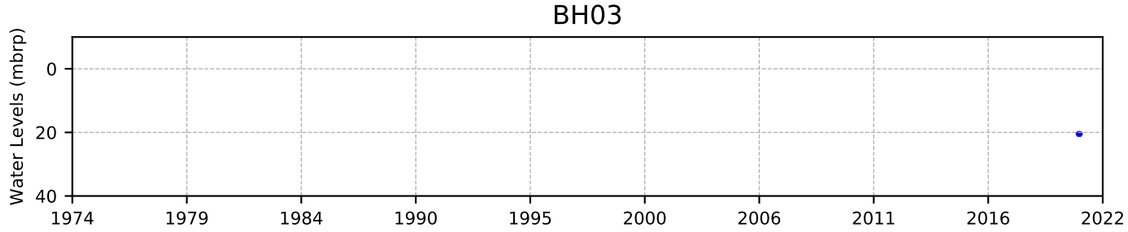
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Water Levels (mbrp)
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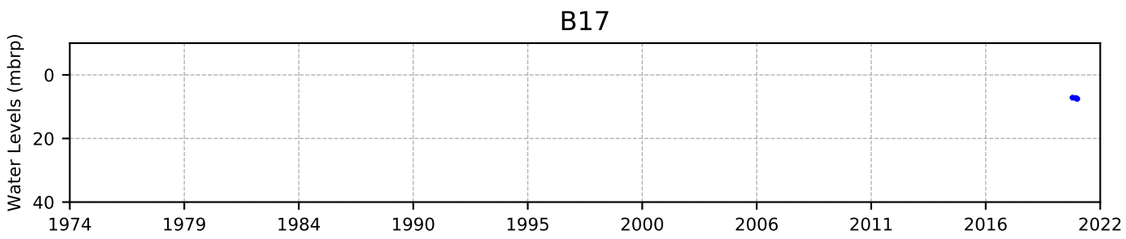
B17
Water Levels (mbrp)
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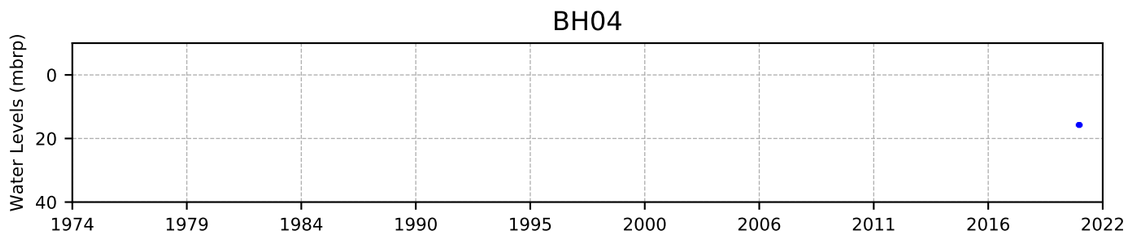
BH04
Water Levels (mbrp)
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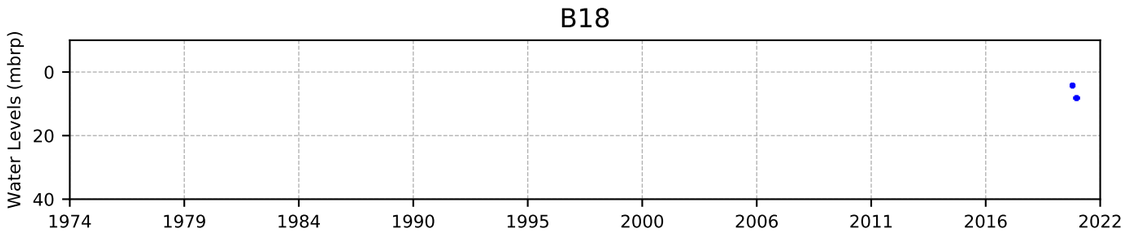
B18
Water Levels (mbrp)
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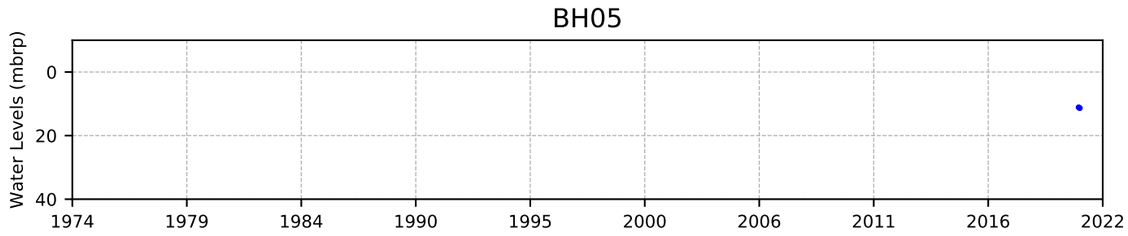
BH05
Water Levels (mbrp)
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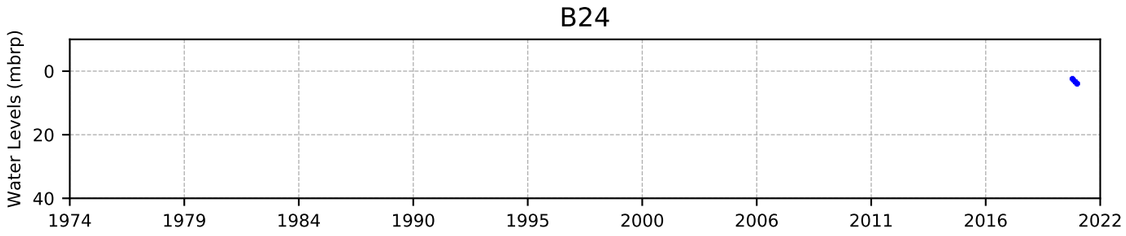
B24
Water Levels (mbrp)
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2016
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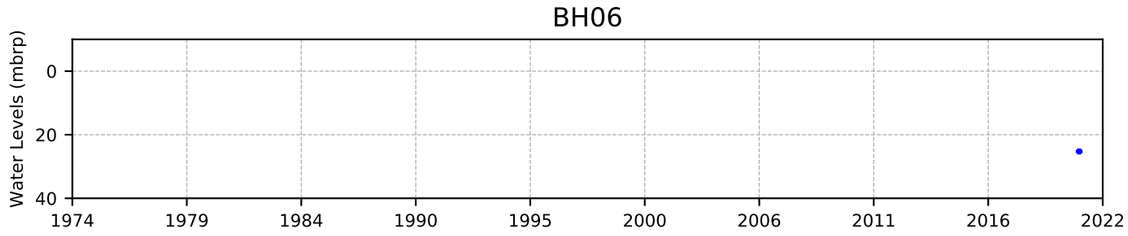
BH06
Water Levels (mbrp)
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2016
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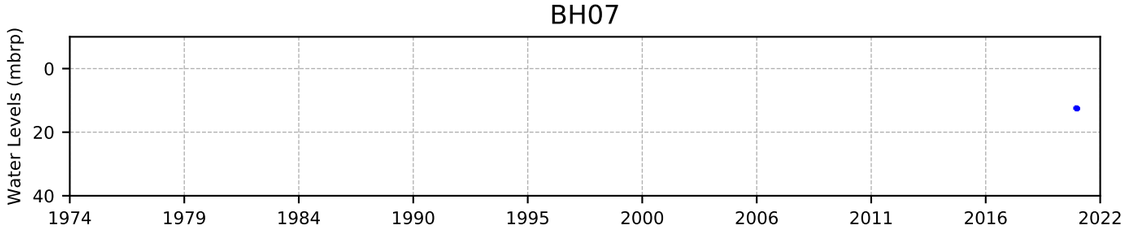
BH07
Water Levels (mbrp)
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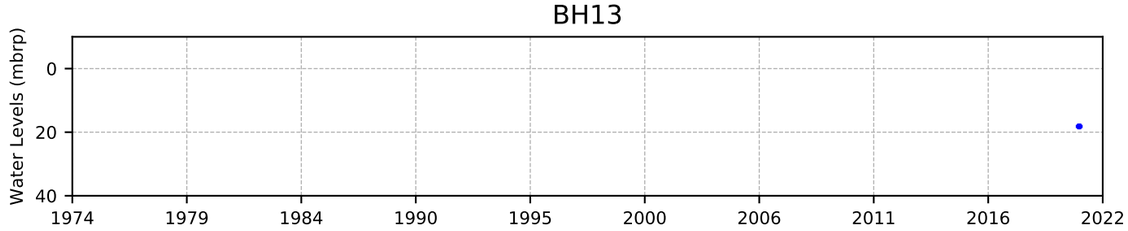
BH13
Water Levels (mbrp)
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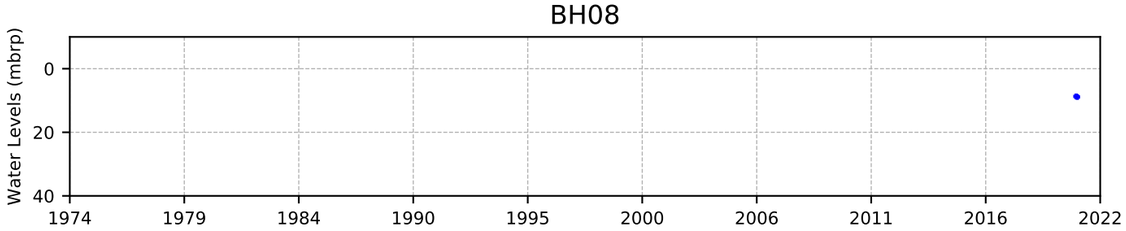
BH08
Water Levels (mbrp)
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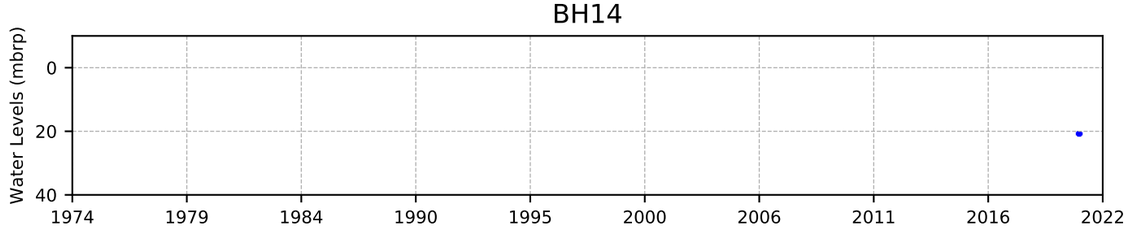
BH14
Water Levels (mbrp)
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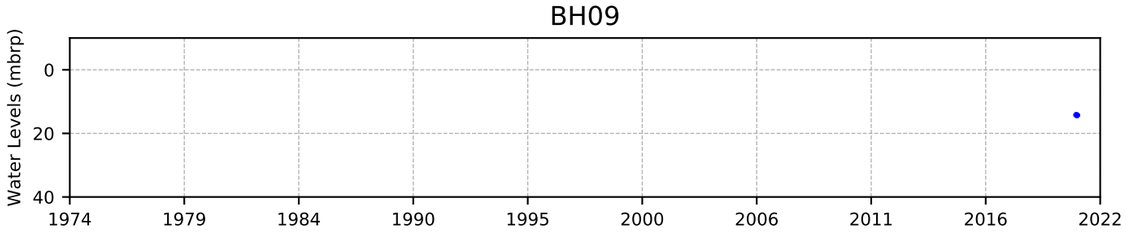
BH09
Water Levels (mbrp)
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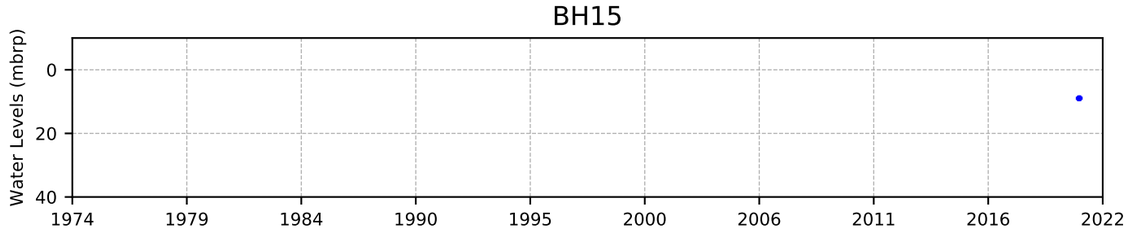
BH15
Water Levels (mbrp)
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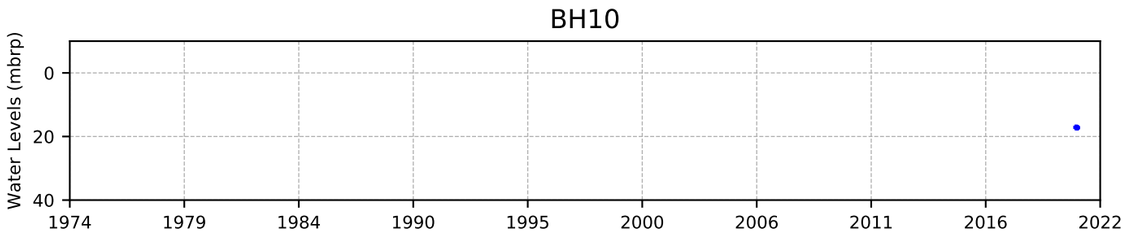
BH10
Water Levels (mbrp)
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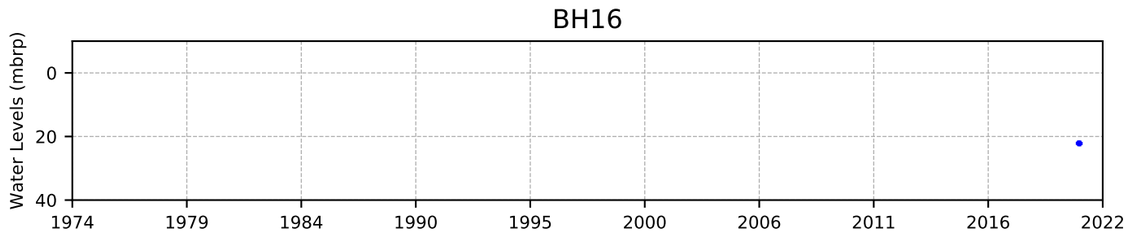
BH16
Water Levels (mbrp)
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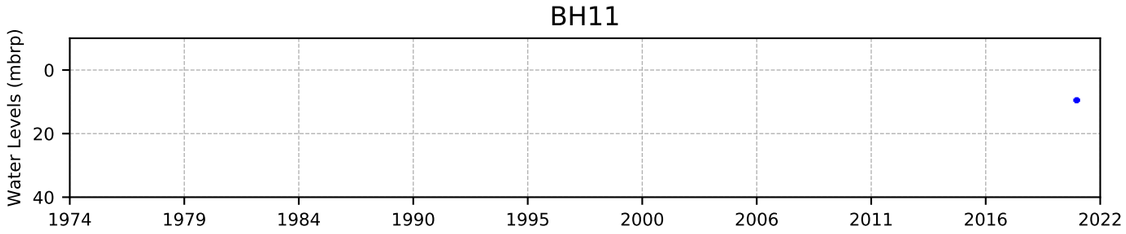
BH11
Water Levels (mbrp)
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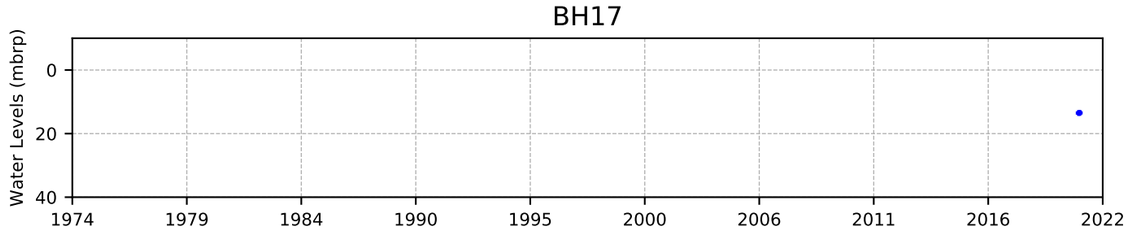
BH17
Water Levels (mbrp)
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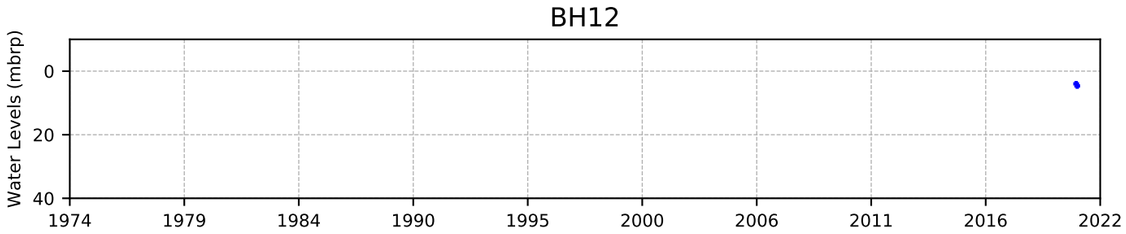
BH12
Water Levels (mbrp)
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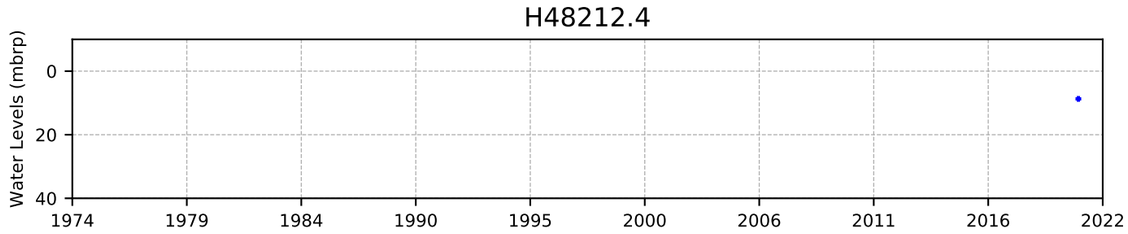
H48212.4
Water Levels (mbrp)
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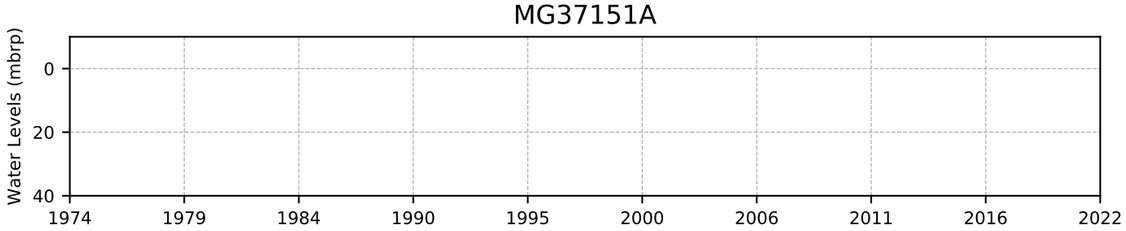
MG37151A
Water Levels (mbrp)
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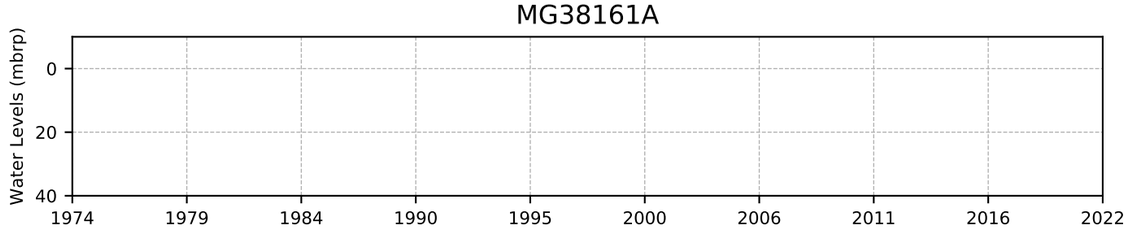
MG38161A
Water Levels (mbrp)
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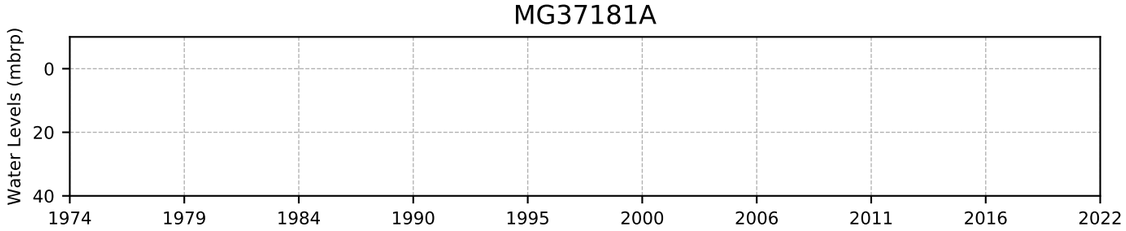
MG37181A
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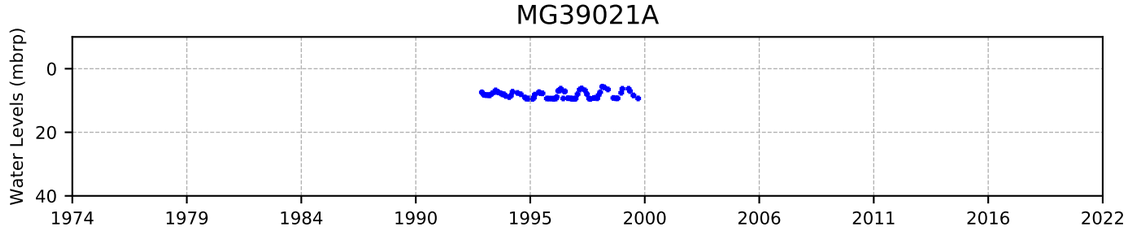
MG39021A
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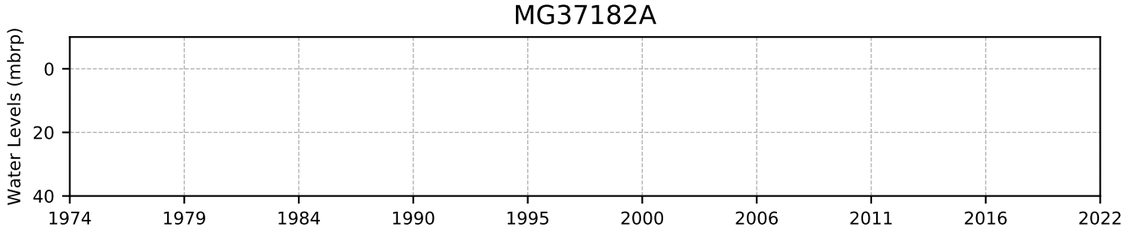
MG37182A
Water Levels (mbrp)
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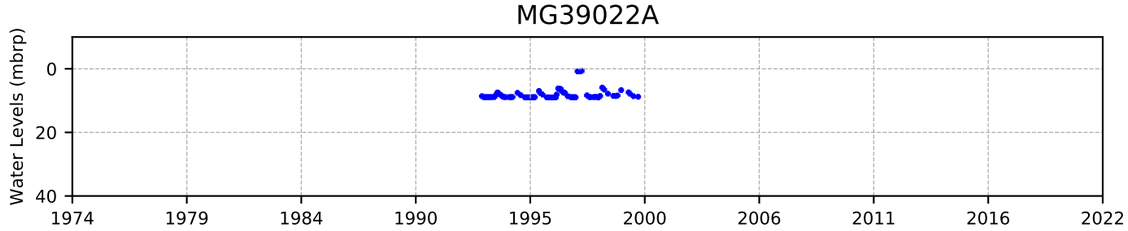
MG39022A
Water Levels (mbrp)
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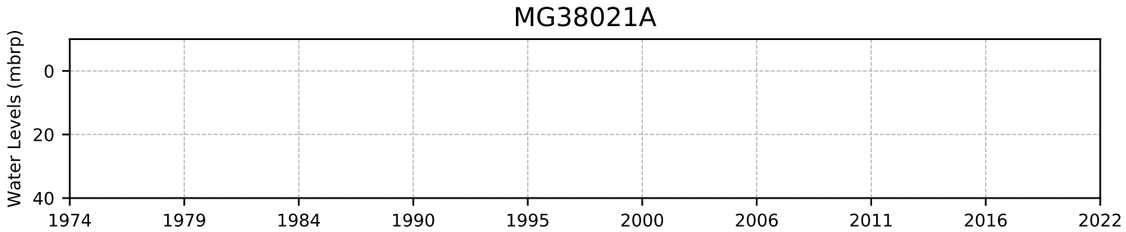
MG38021A
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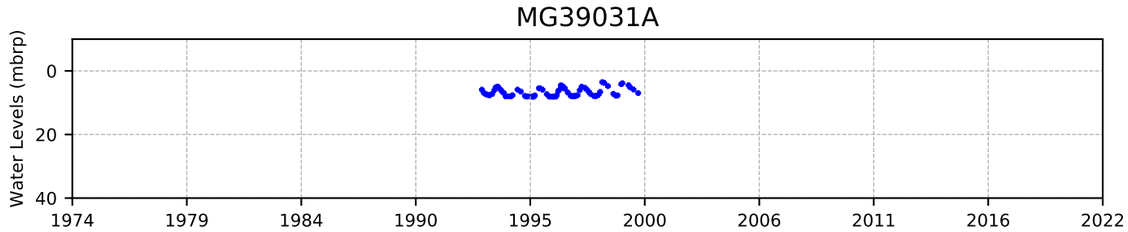
MG39031A
Water Levels (mbrp)
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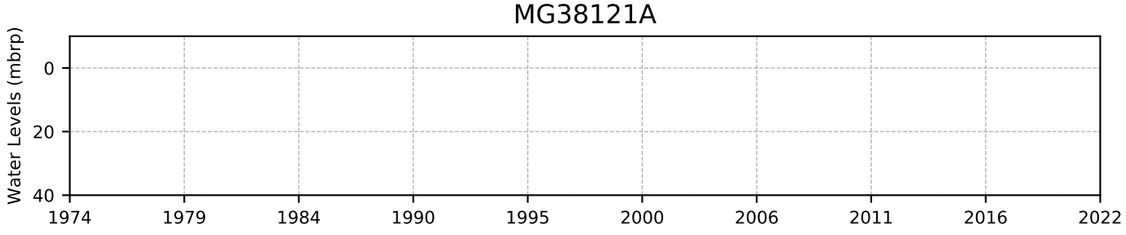
MG38121A
Water Levels (mbrp)
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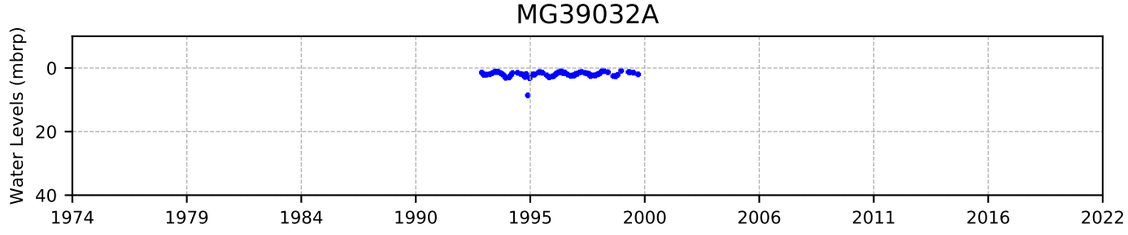
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Water Levels (mbrp)
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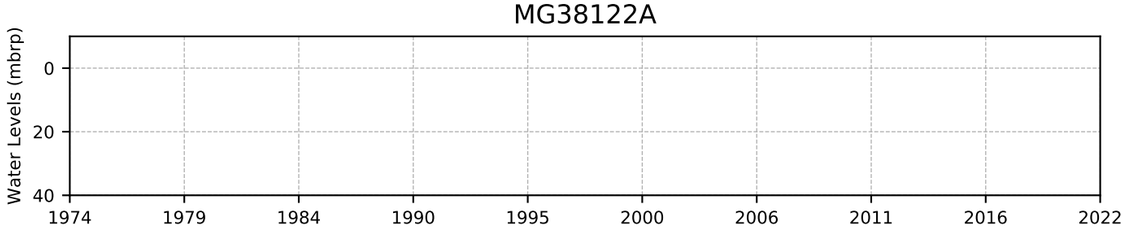
MG38122A
Water Levels (mbrp)
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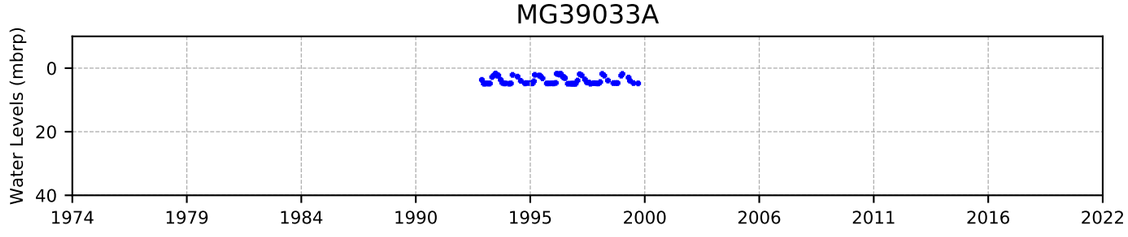
MG39033A
Water Levels (mbrp)
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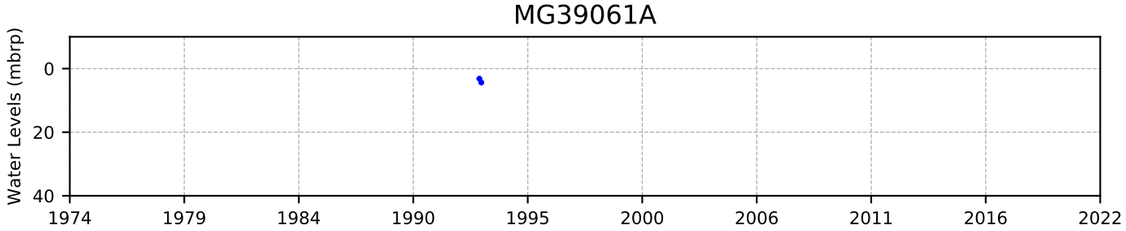
MG39061A
Water Levels (mbrp)
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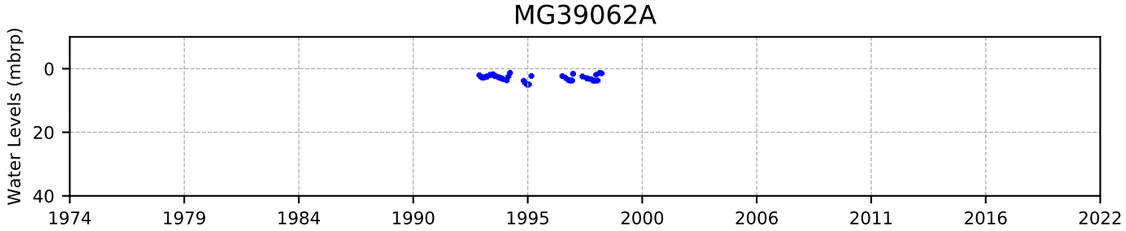
MG39062A
Water Levels (mbrp)
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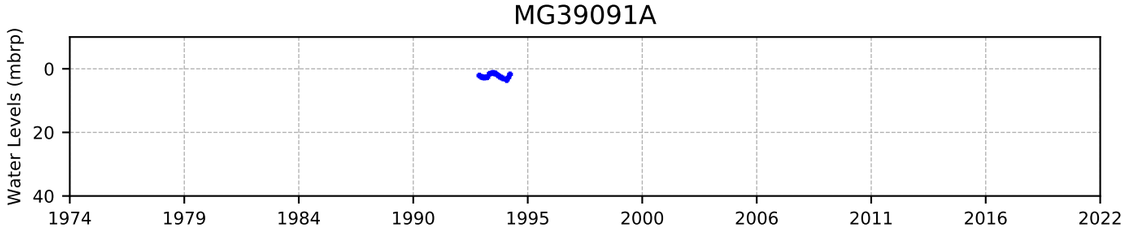
MG39091A
Water Levels (mbrp)
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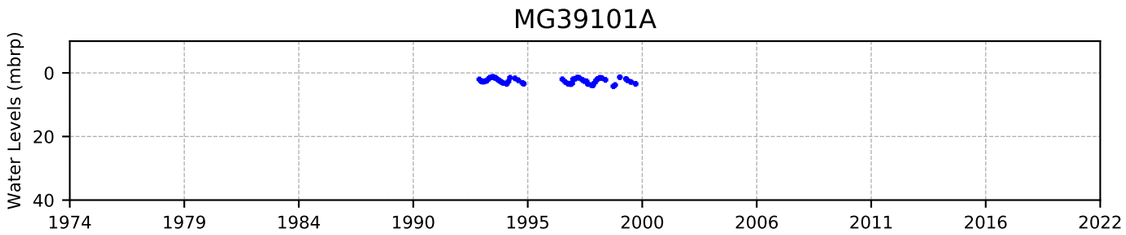
MG39101A
Water Levels (mbrp)
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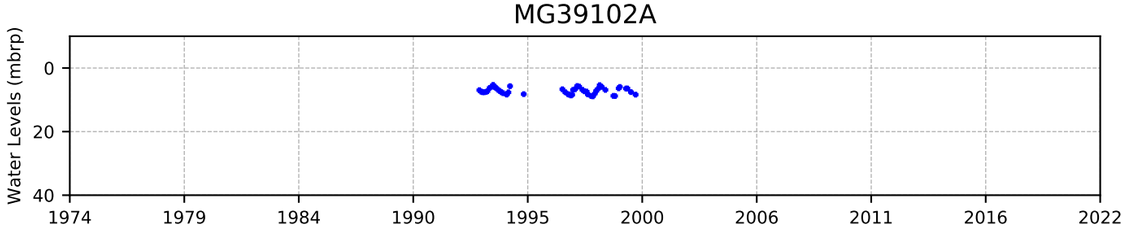
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Water Levels (mbrp)
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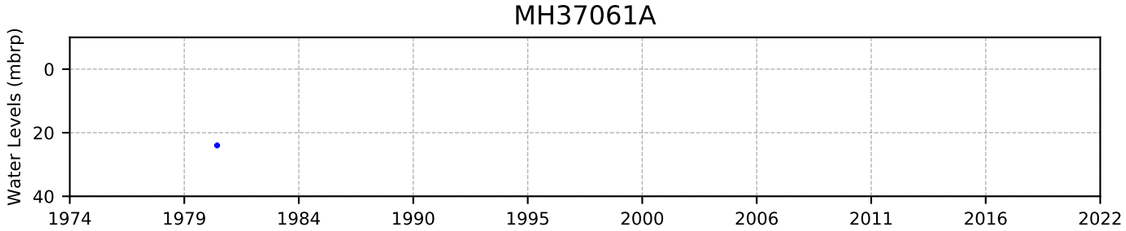
MH37061A
Water Levels (mbrp)
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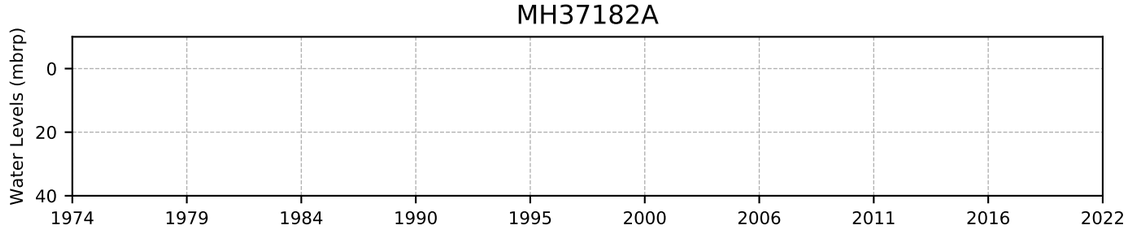
MH37182A
Water Levels (mbrp)
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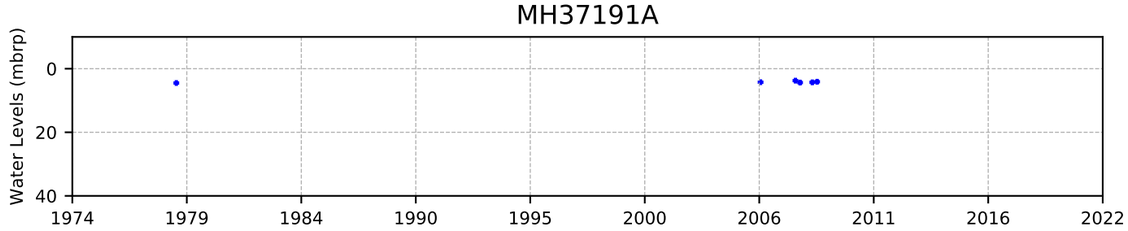
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Water Levels (mbrp)
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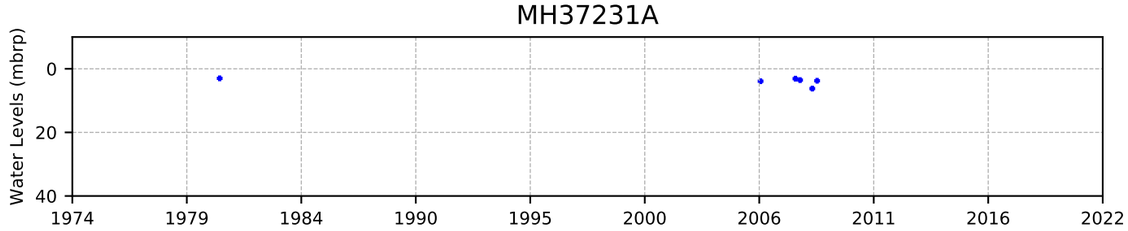
MH37231A
Water Levels (mbrp)
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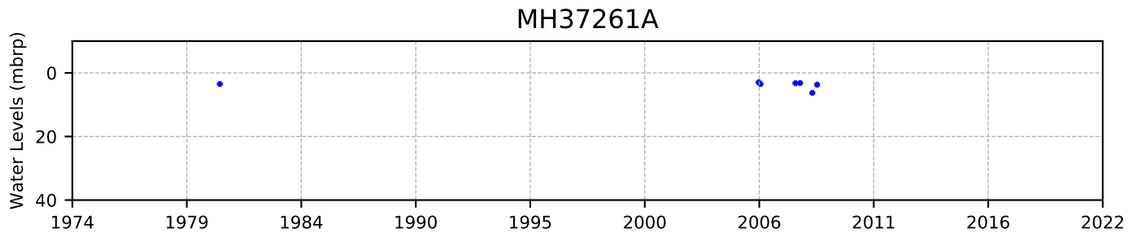
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Water Levels (mbrp)
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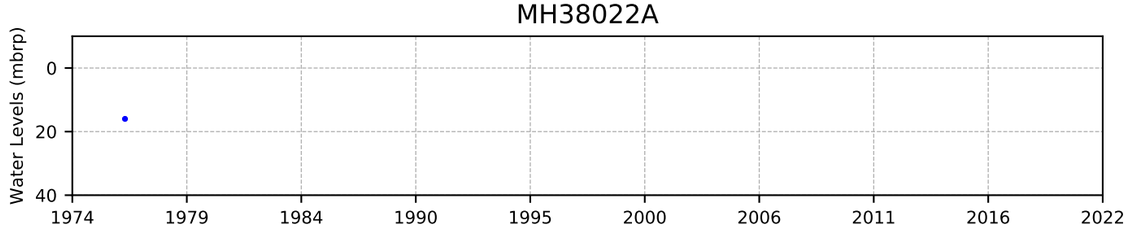
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Water Levels (mbrp)
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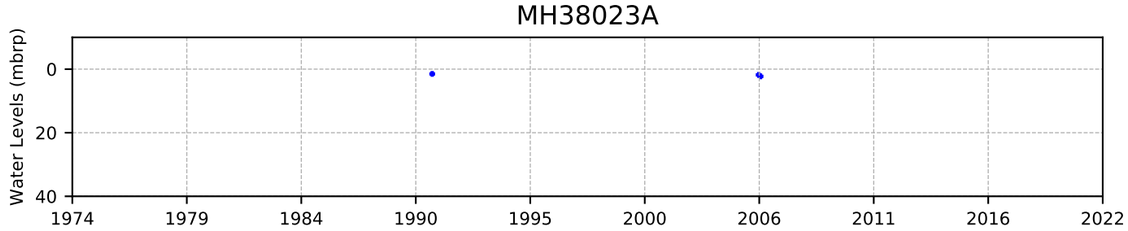
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Water Levels (mbrp)
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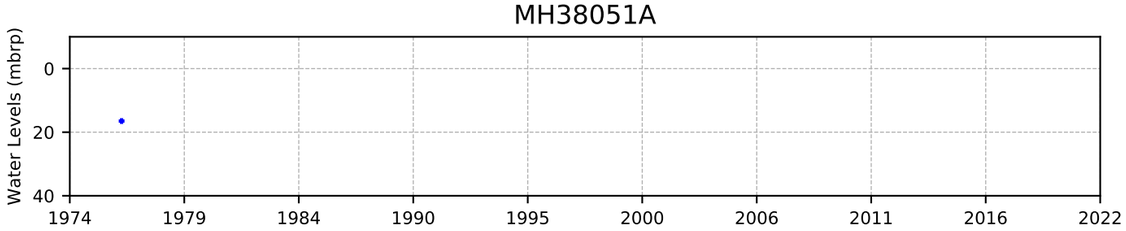
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Water Levels (mbrp)
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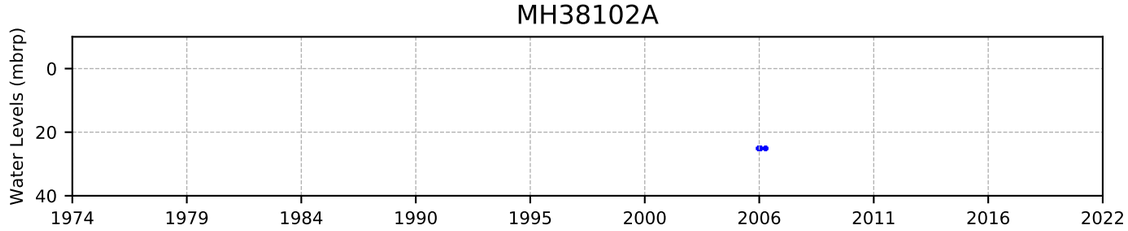
MH38102A
Water Levels (mbrp)
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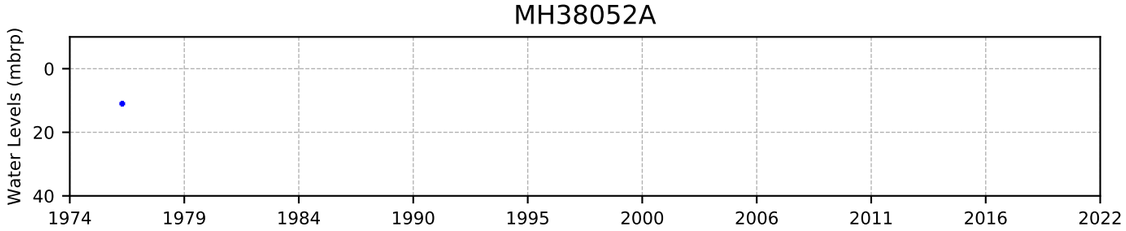
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Water Levels (mbrp)
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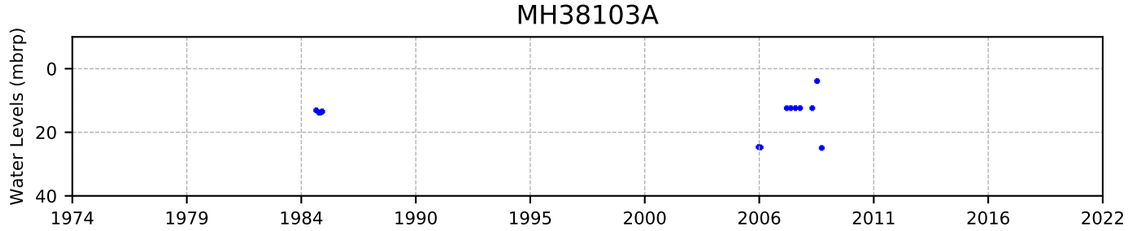
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Water Levels (mbrp)
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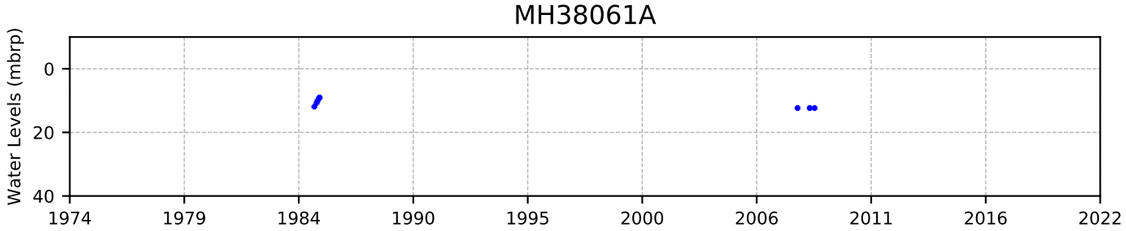
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Water Levels (mbrp)
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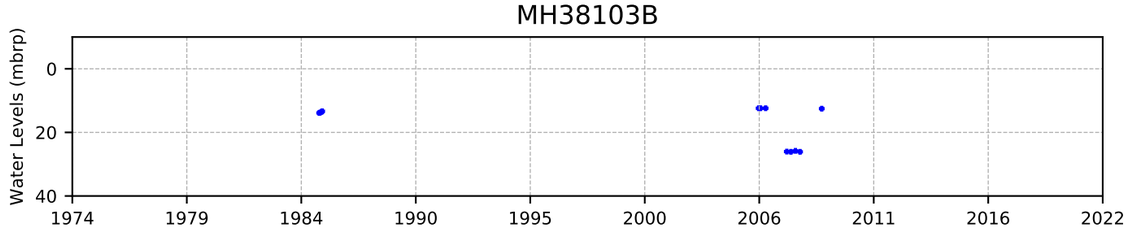
MH38103B
Water Levels (mbrp)
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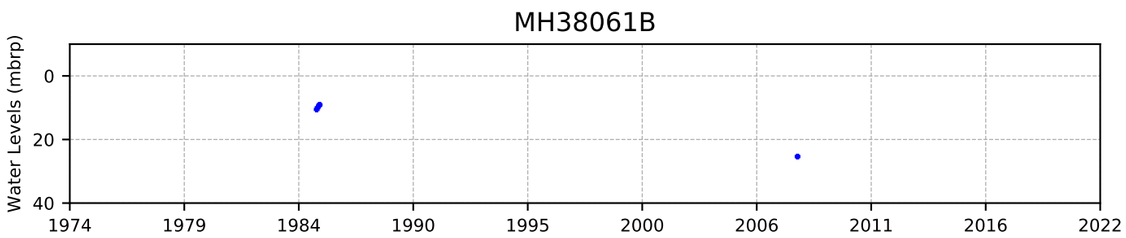
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Water Levels (mbrp)
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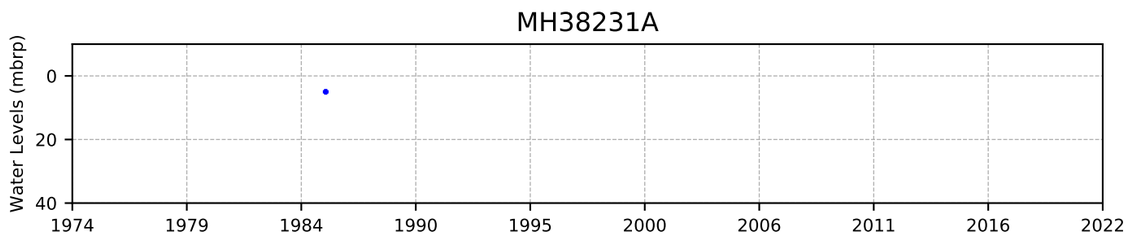
MH38231A
Water Levels (mbrp)
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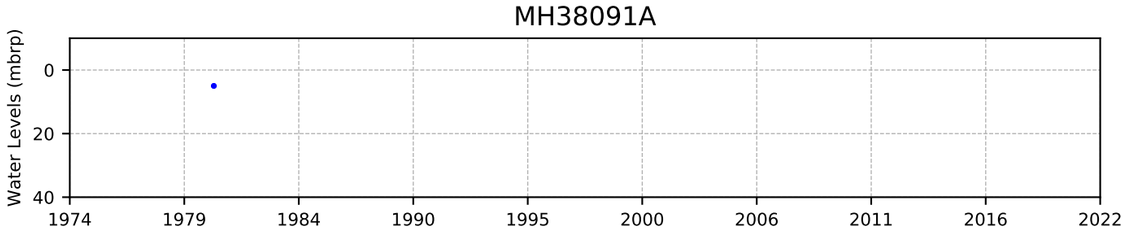
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Water Levels (mbrp)
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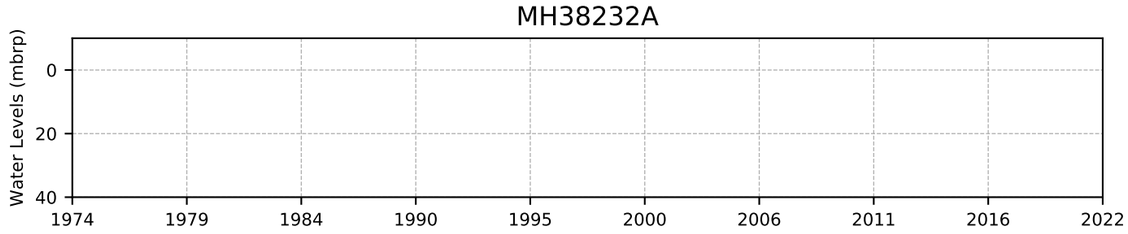
MH38232A
Water Levels (mbrp)
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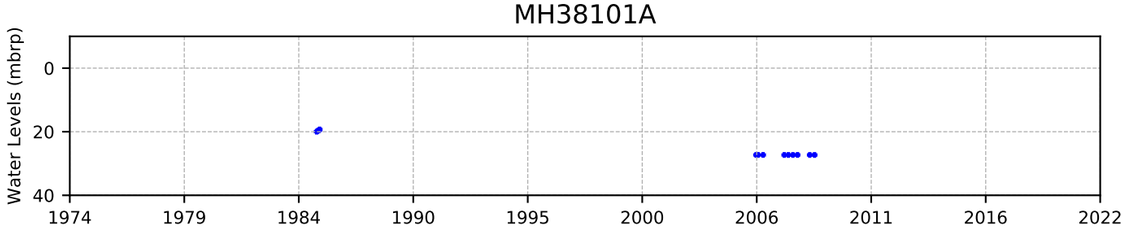
MH38101A
Water Levels (mbrp)
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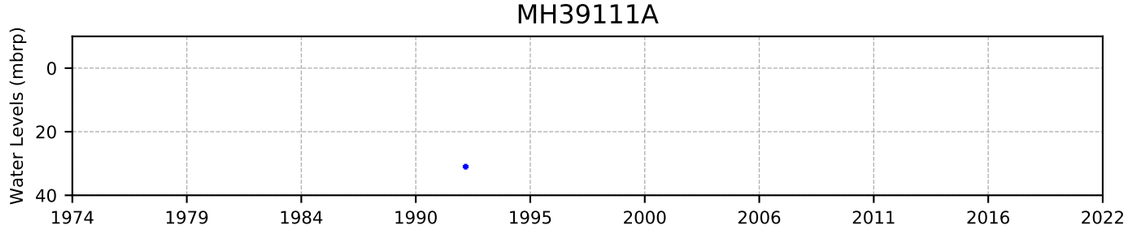
MH39111A
Water Levels (mbrp)
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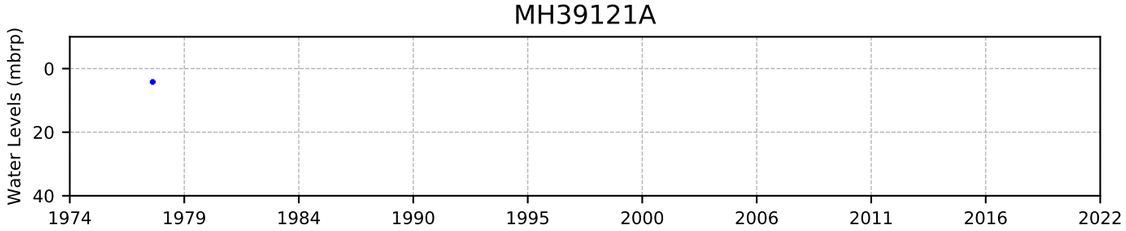
MH39121A
Water Levels (mbrp)
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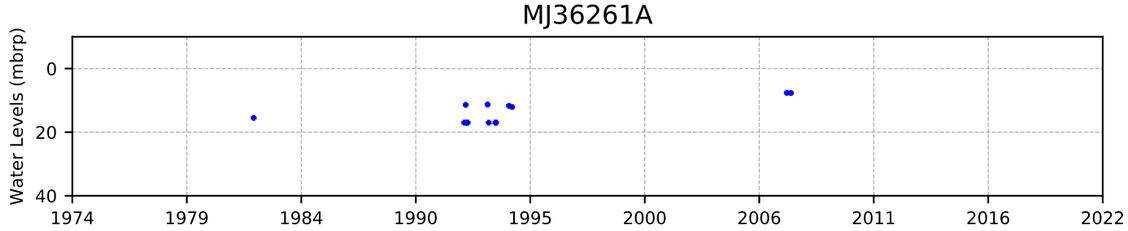
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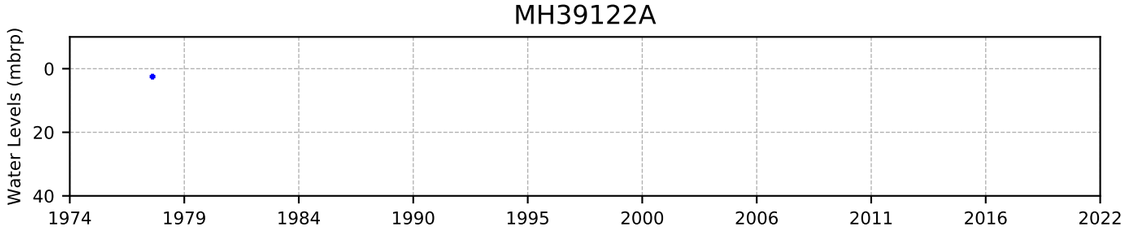
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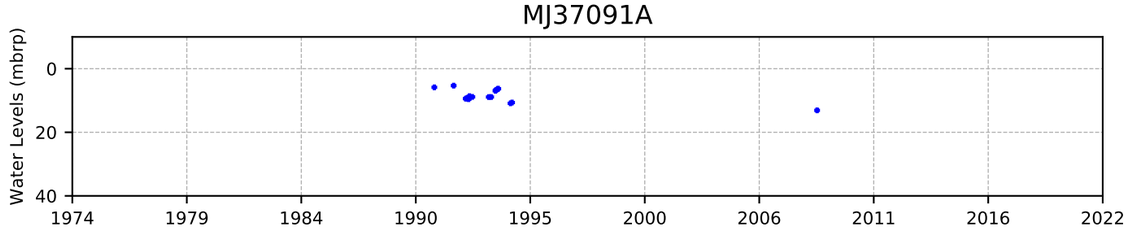
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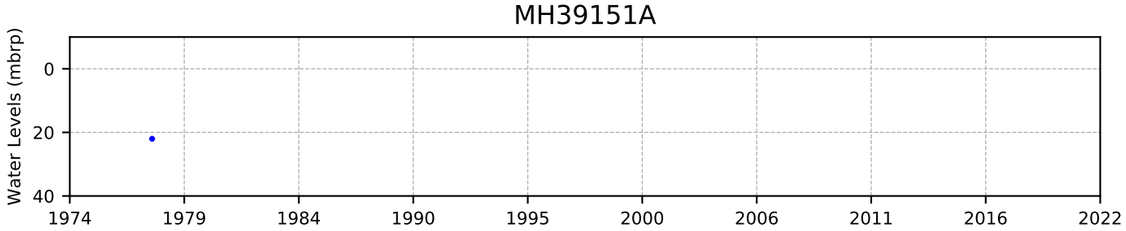
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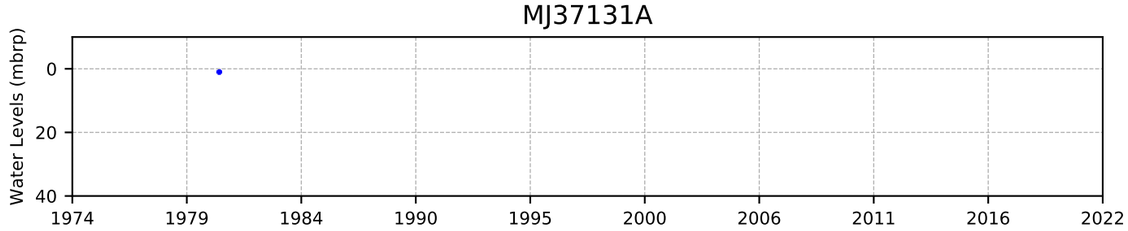
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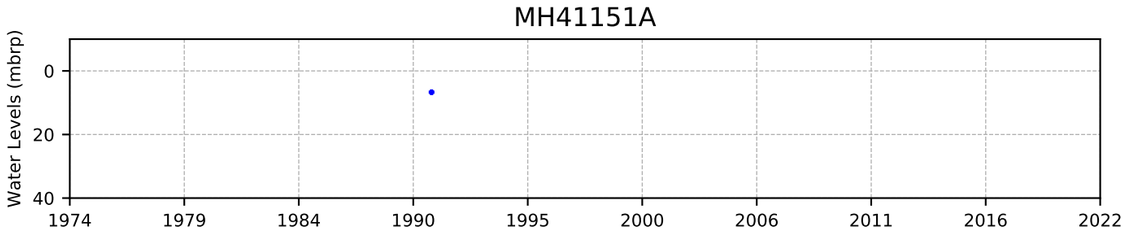
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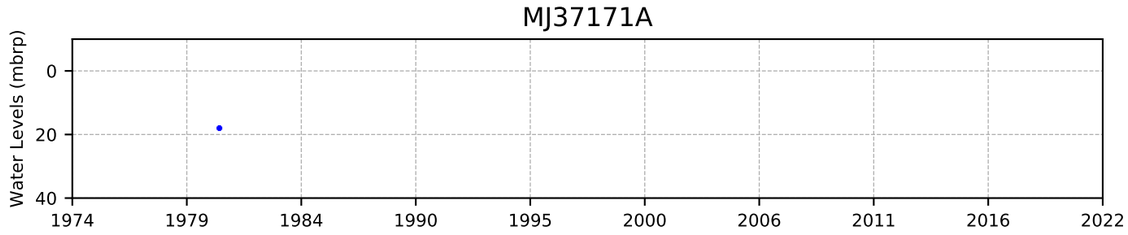
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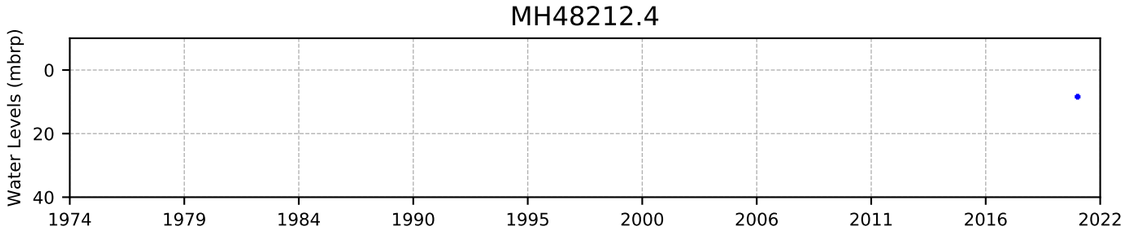
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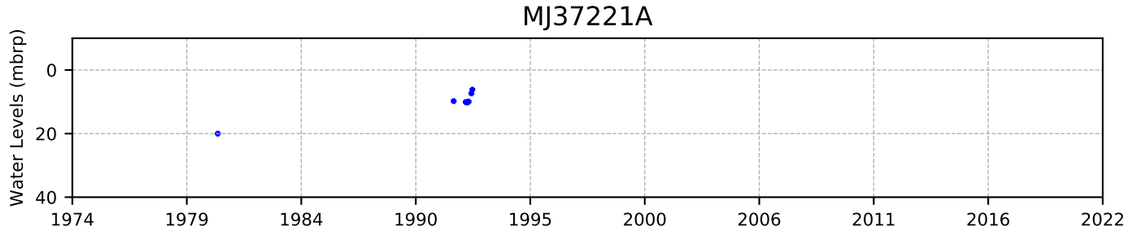
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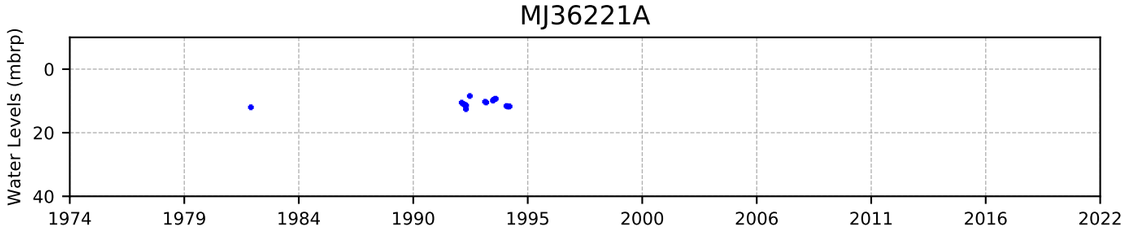
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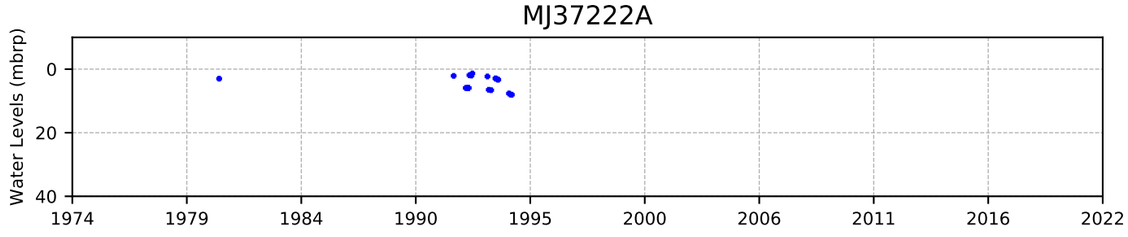
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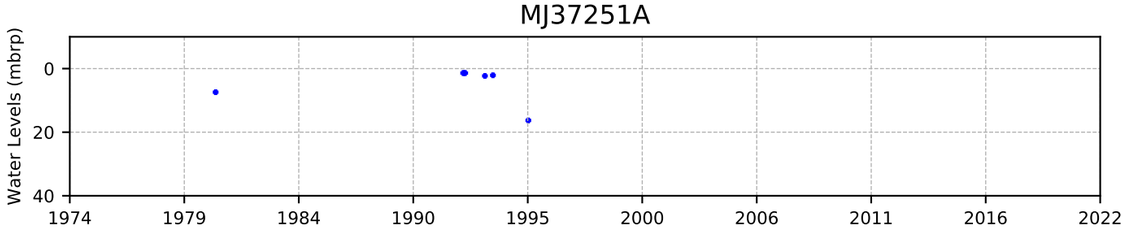
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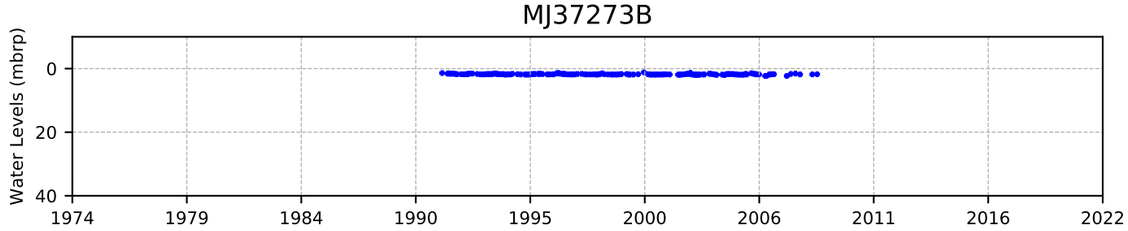
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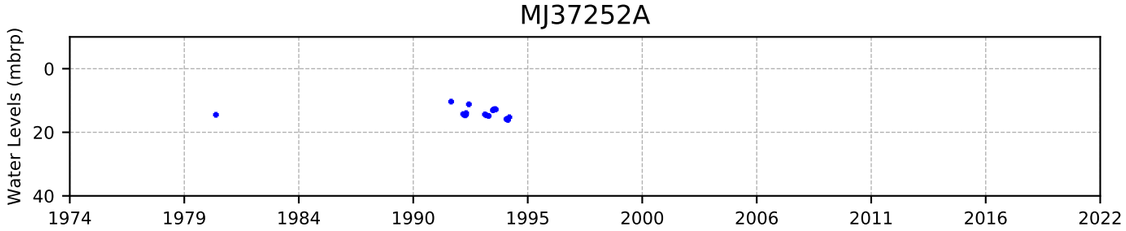
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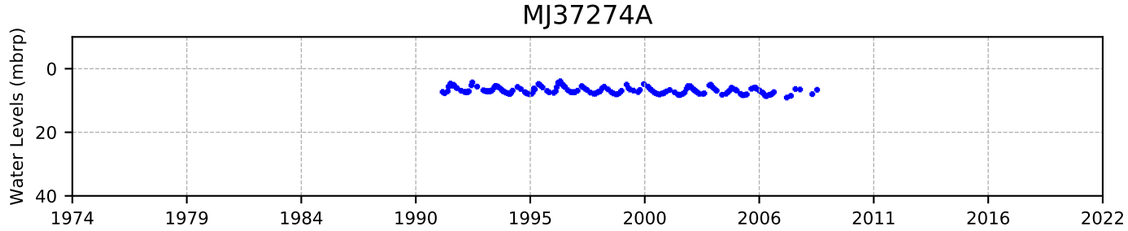
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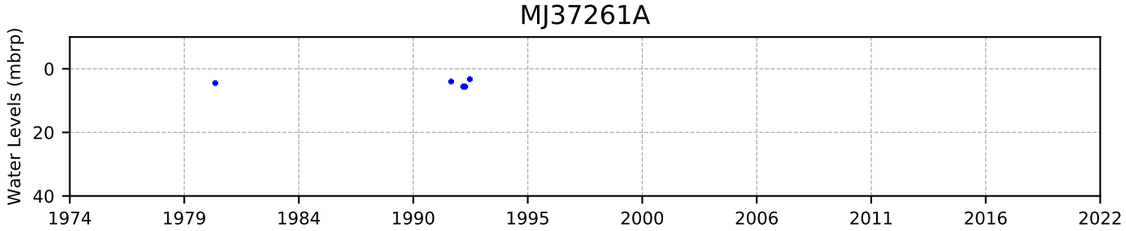
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Water Levels (mbrp)
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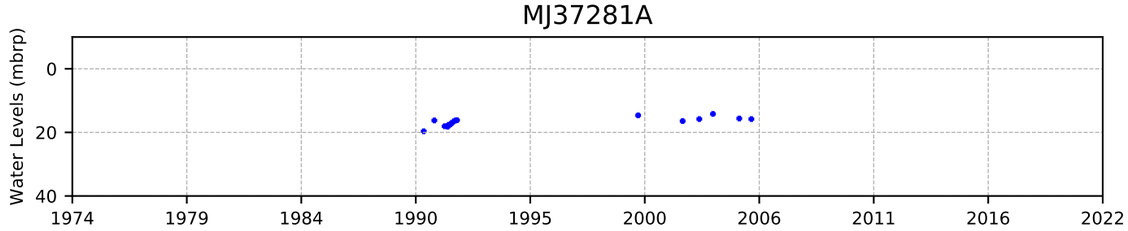
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Water Levels (mbrp)
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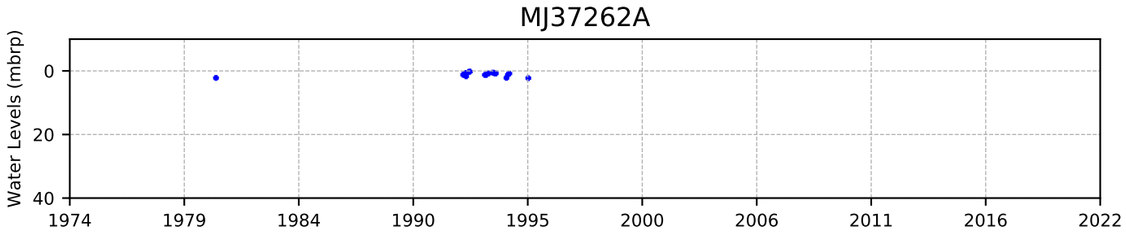
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Water Levels (mbrp)
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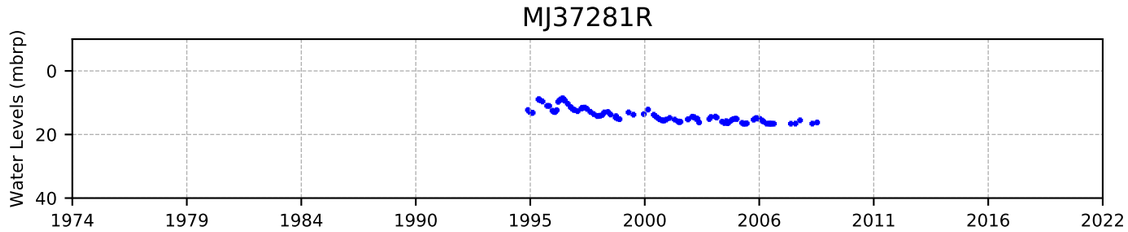
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Water Levels (mbrp)
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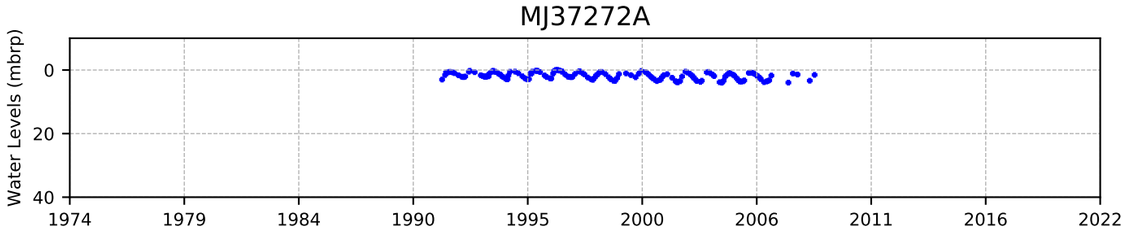
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Water Levels (mbrp)
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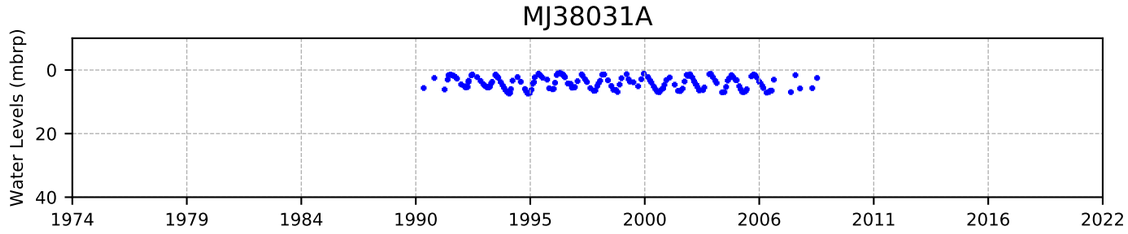
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Water Levels (mbrp)
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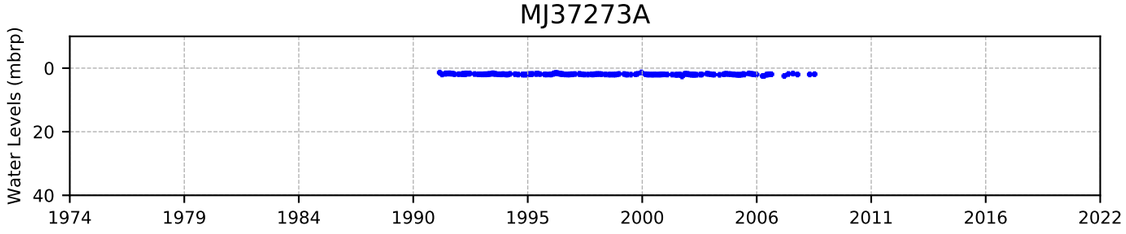
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Water Levels (mbrp)
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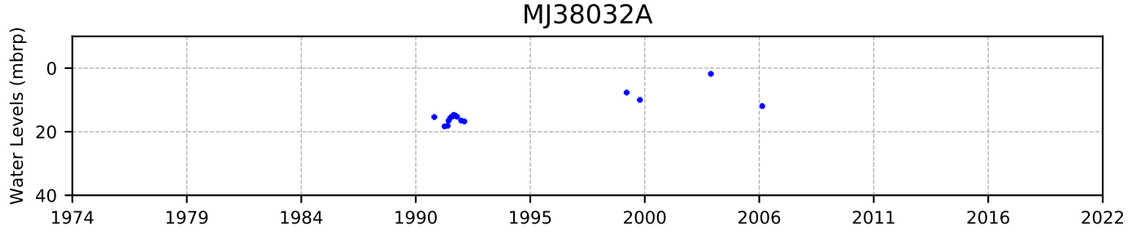
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Water Levels (mbrp)
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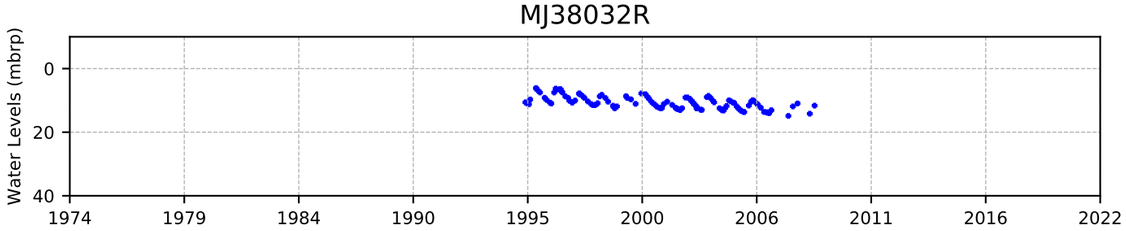
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Water Levels (mbrp)
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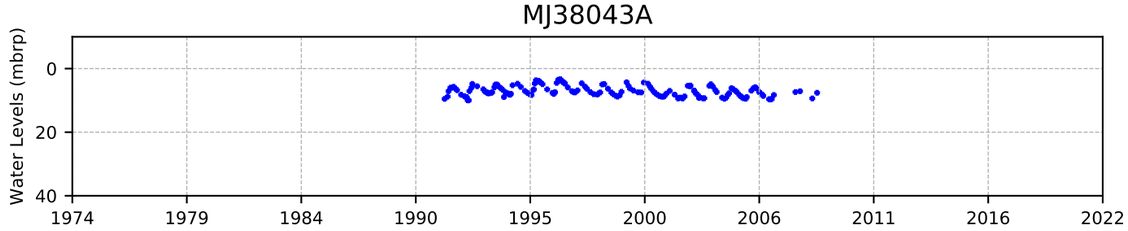
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Water Levels (mbrp)
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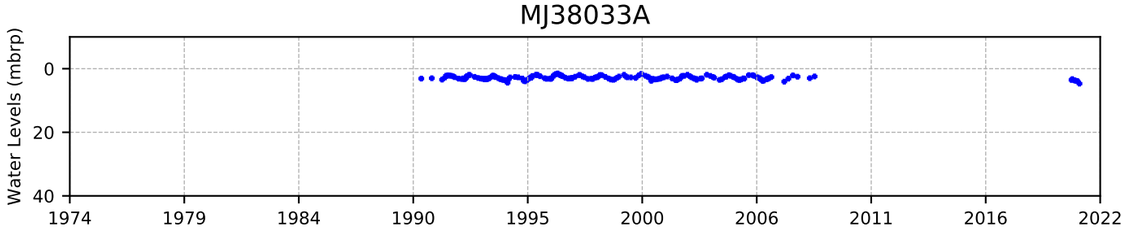
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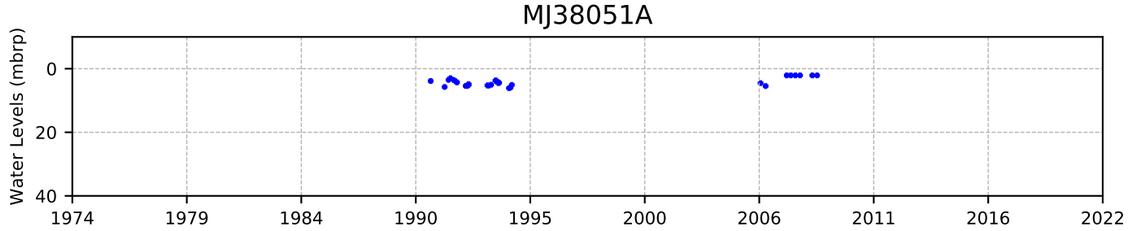
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Water Levels (mbrp)
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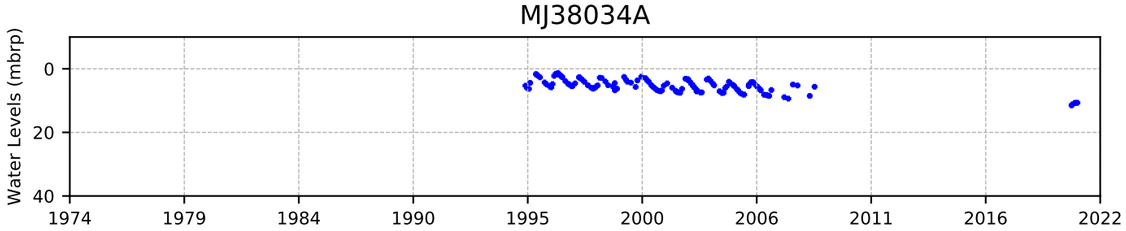
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Water Levels (mbrp)
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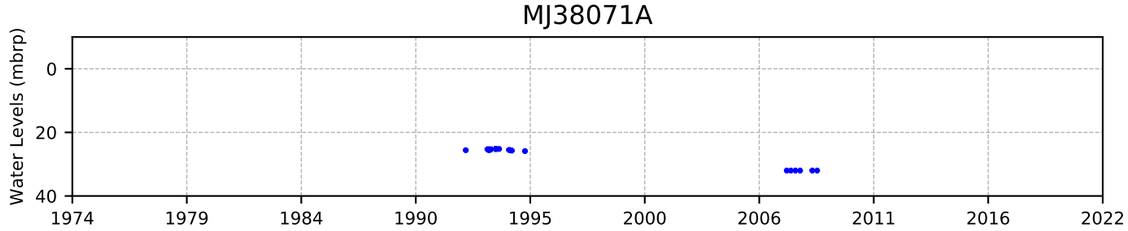
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Water Levels (mbrp)
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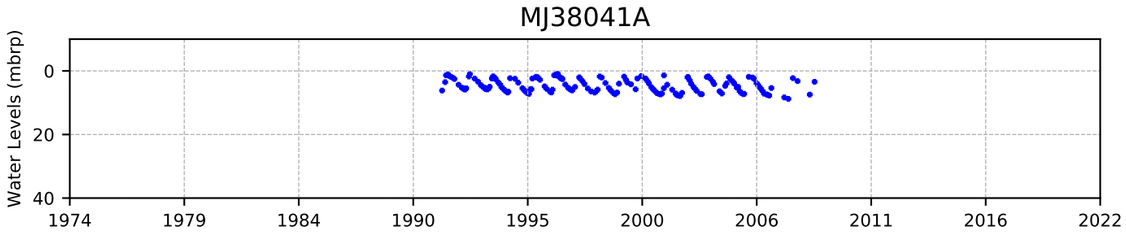
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Water Levels (mbrp)
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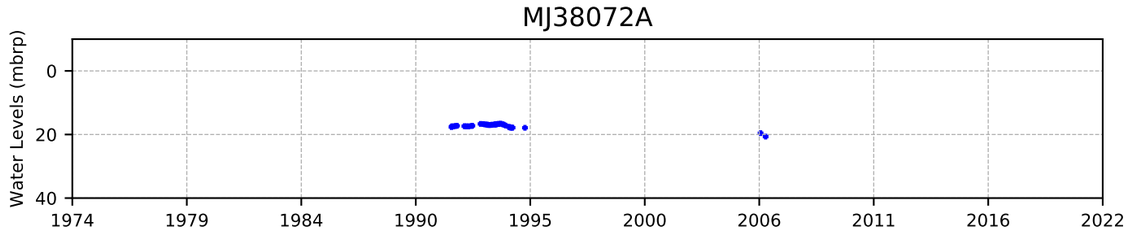
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Water Levels (mbrp)
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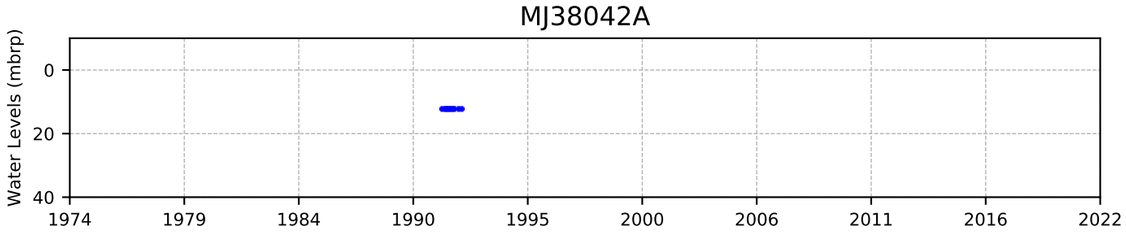
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Water Levels (mbrp)
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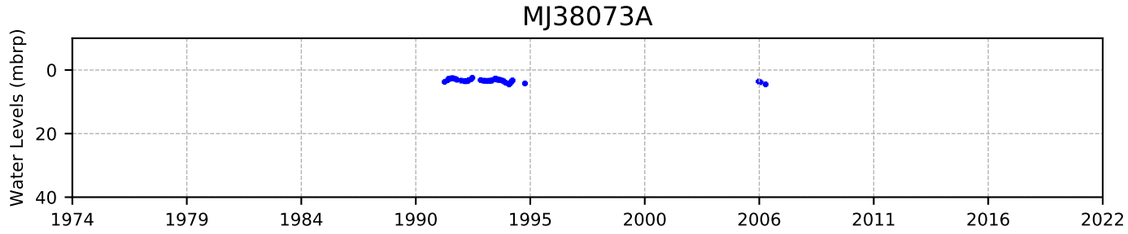
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Water Levels (mbrp)
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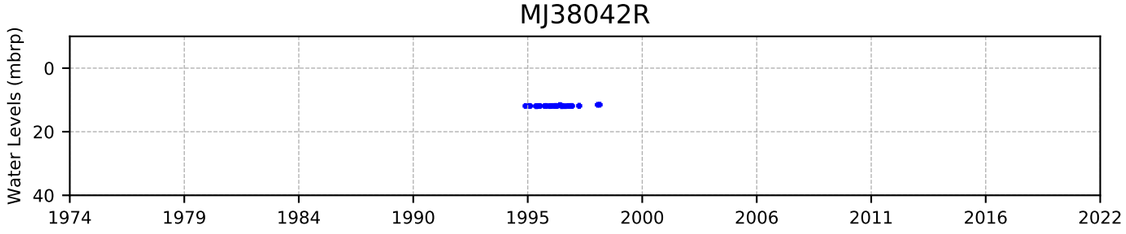
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Water Levels (mbrp)
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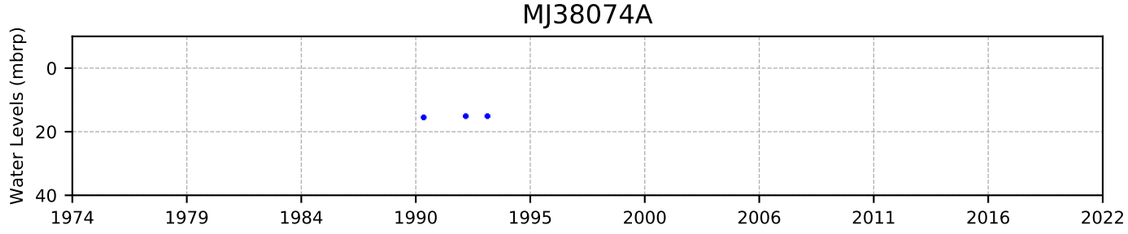
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Water Levels (mbrp)
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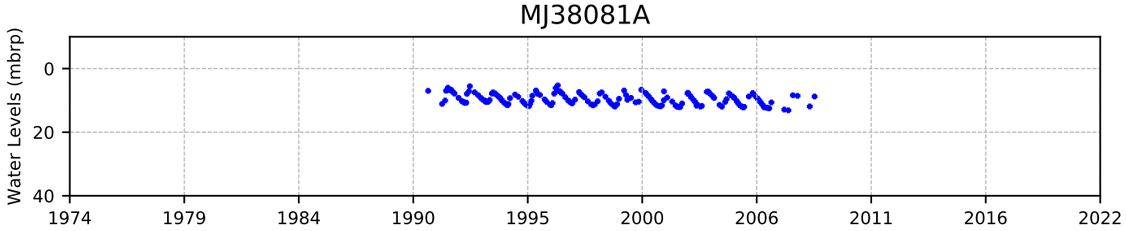
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Water Levels (mbrp)
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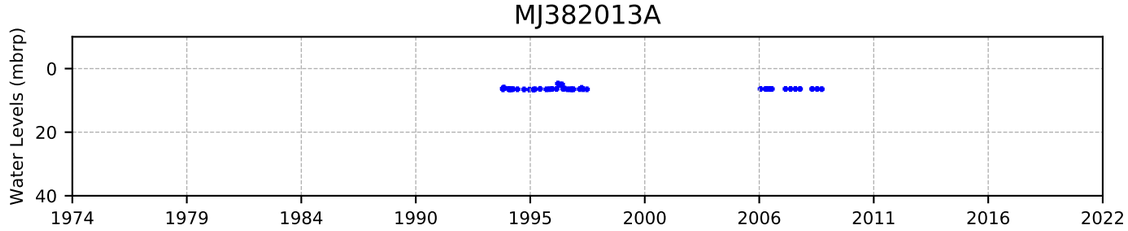
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Water Levels (mbrp)
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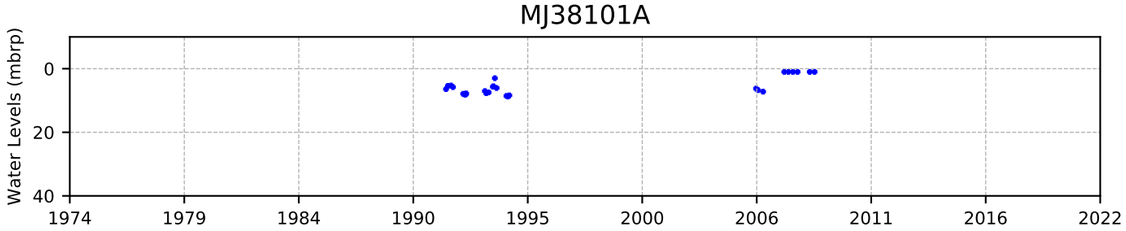
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Water Levels (mbrp)
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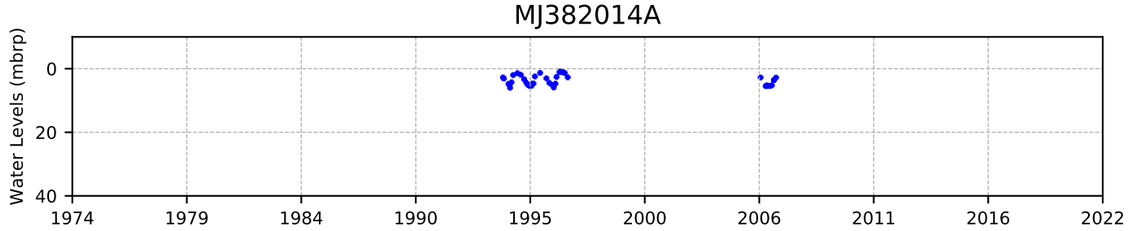
MJ382014A
Water Levels (mbrp)
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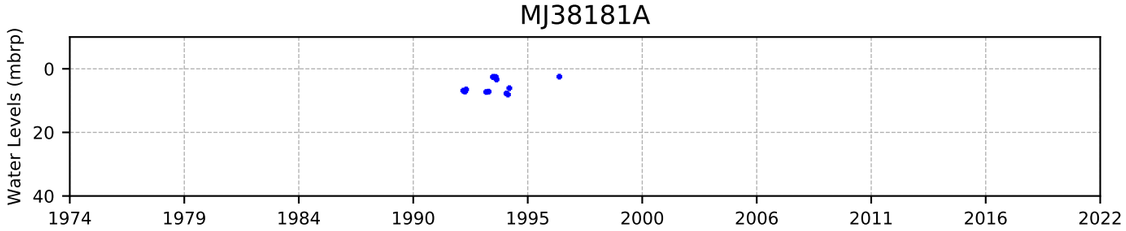
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Water Levels (mbrp)
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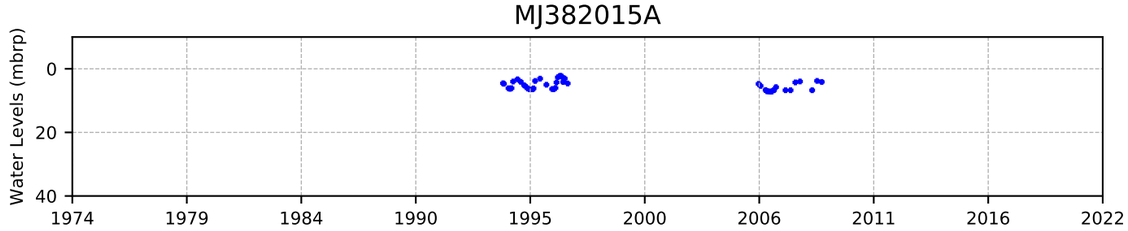
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Water Levels (mbrp)
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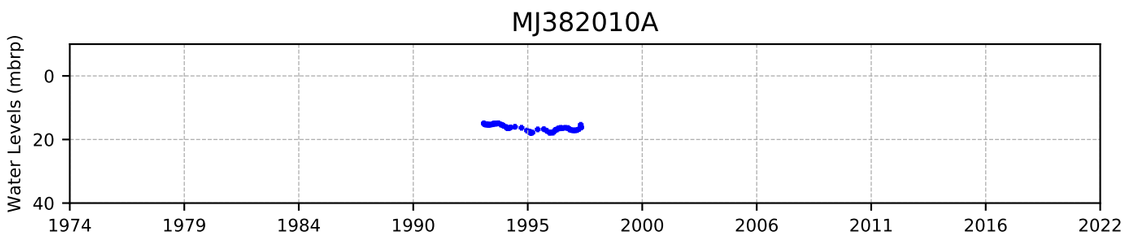
MJ382010A
Water Levels (mbrp)
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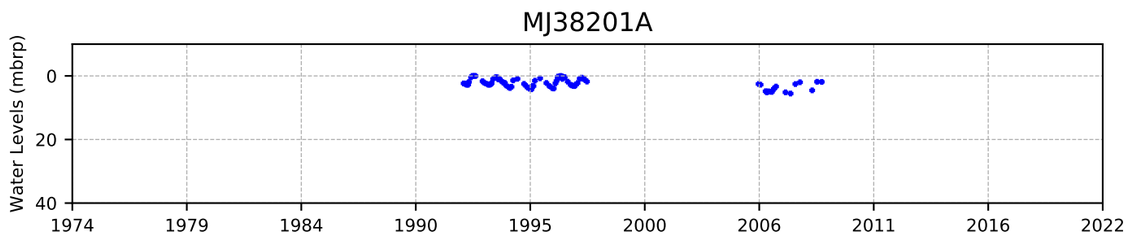
MJ38201A
Water Levels (mbrp)
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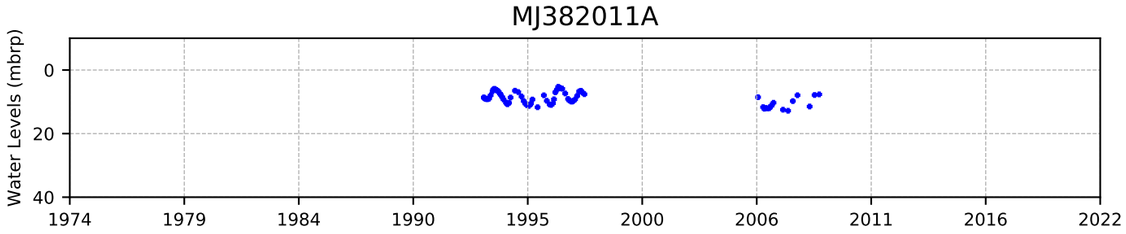
MJ382011A
Water Levels (mbrp)
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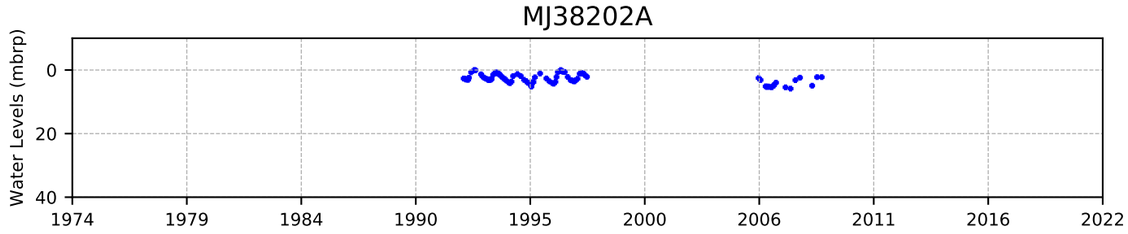
MJ38202A
Water Levels (mbrp)
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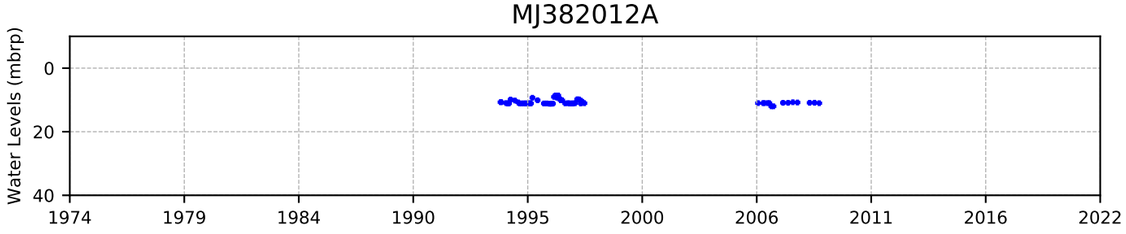
MJ382012A
Water Levels (mbrp)
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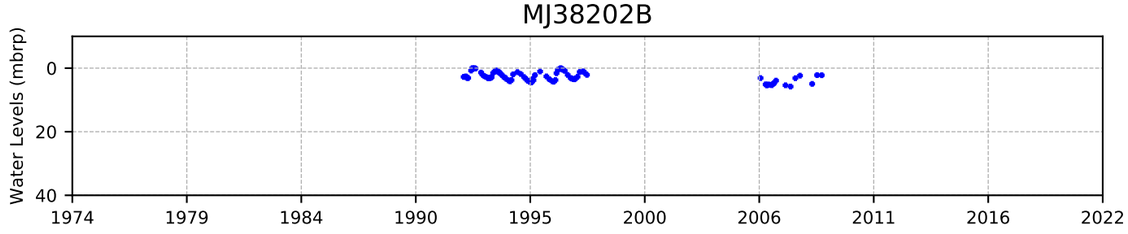
MJ38202B
Water Levels (mbrp)
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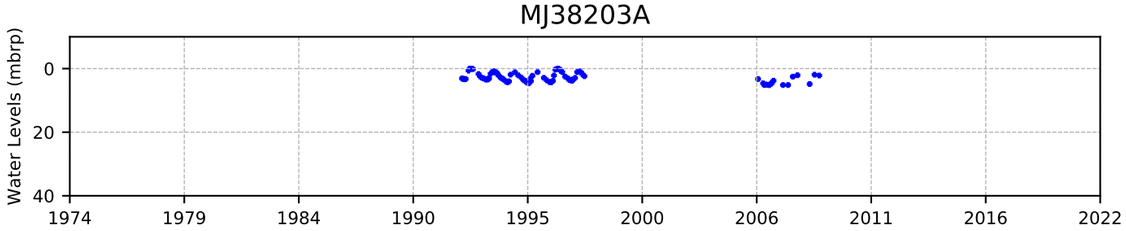
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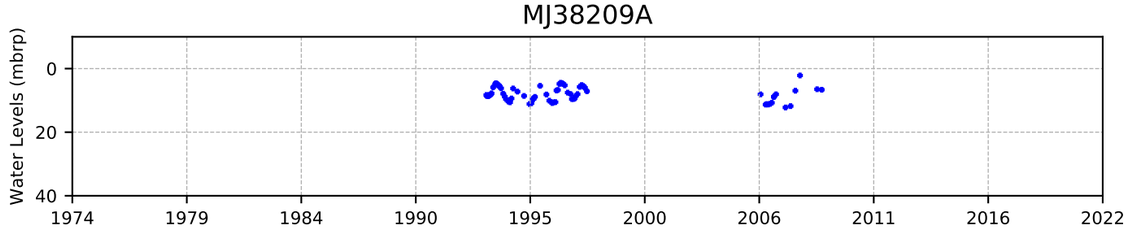
MJ38209A
Water Levels (mbrp)
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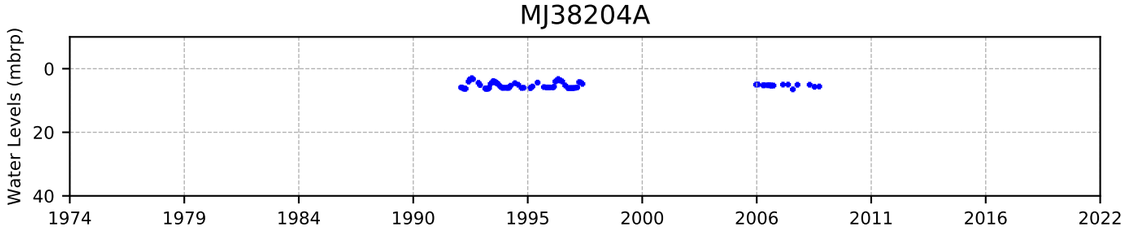
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Water Levels (mbrp)
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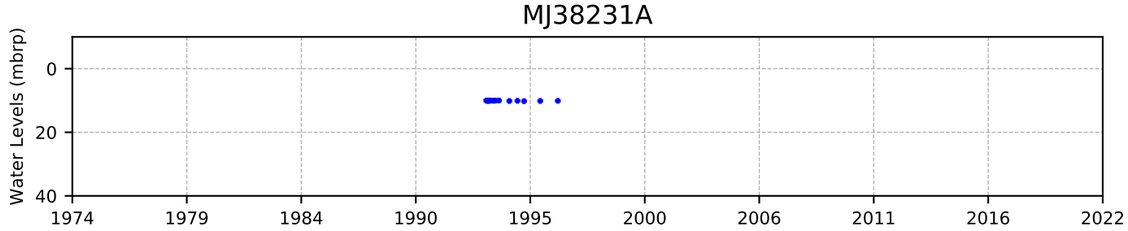
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Water Levels (mbrp)
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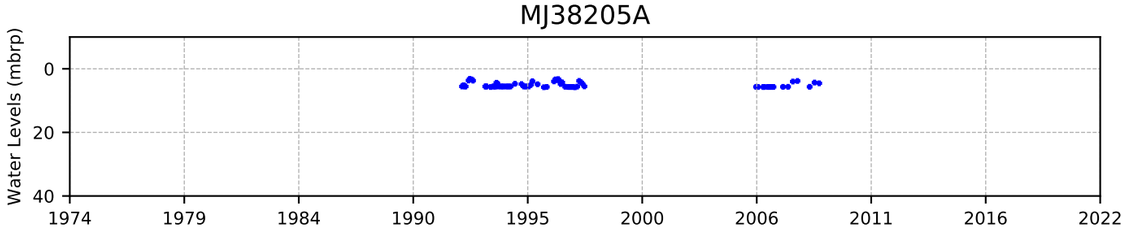
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Water Levels (mbrp)
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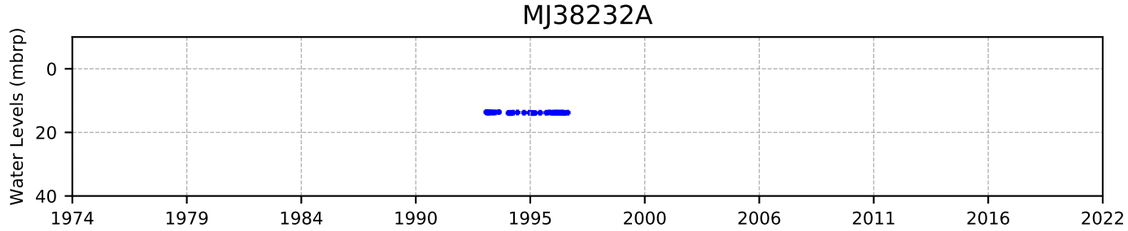
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Water Levels (mbrp)
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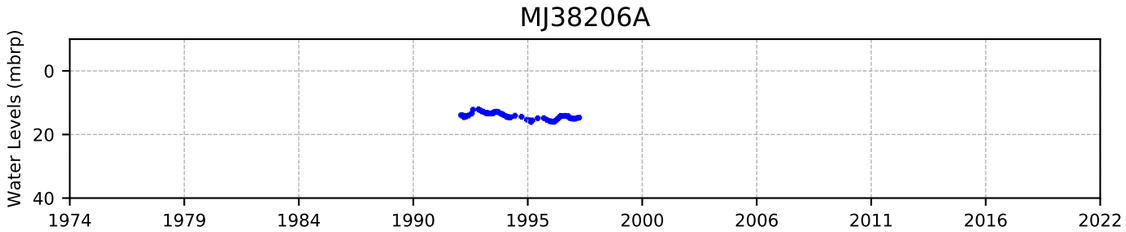
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Water Levels (mbrp)
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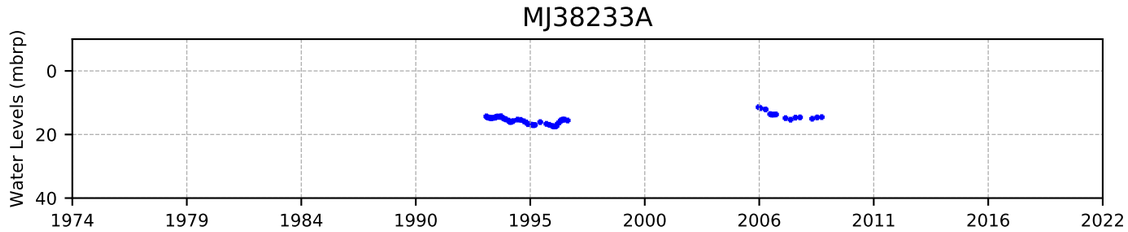
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Water Levels (mbrp)
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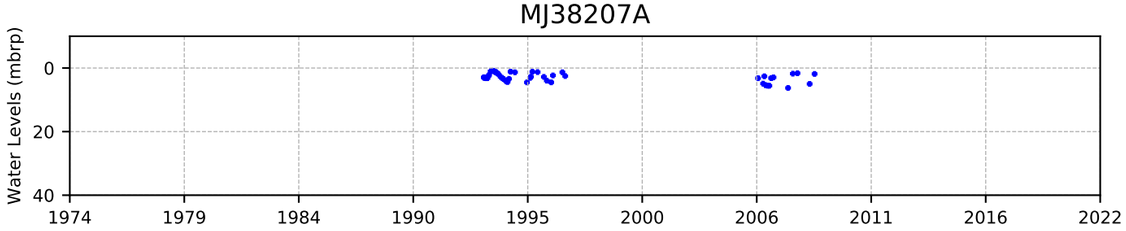
MJ38207A
Water Levels (mbrp)
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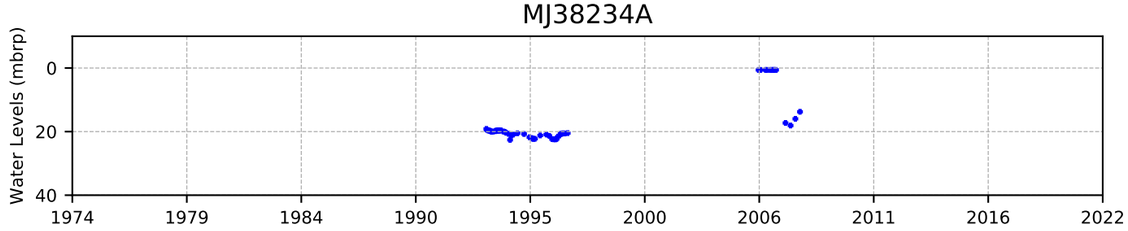
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Water Levels (mbrp)
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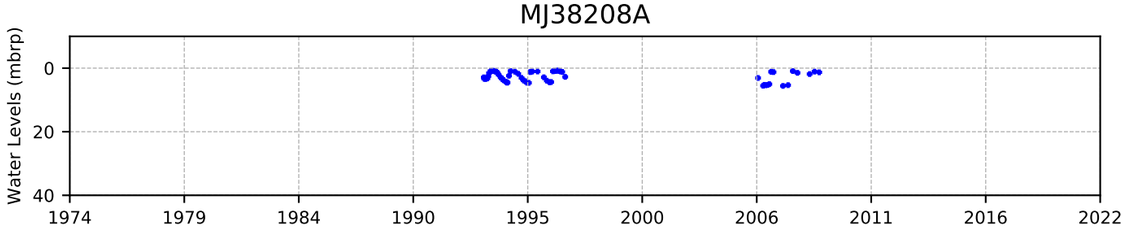
MJ38208A
Water Levels (mbrp)
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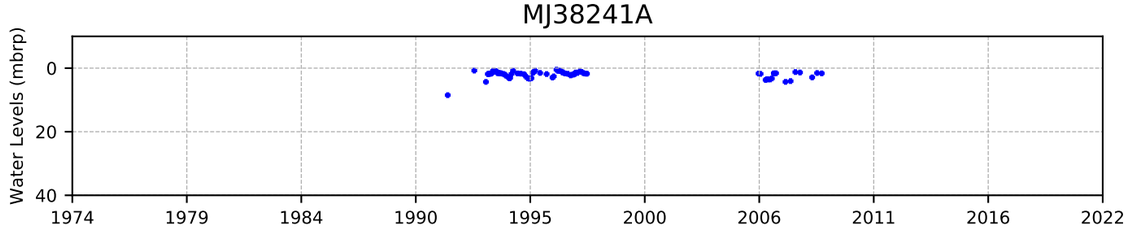
MJ38241A
Water Levels (mbrp)
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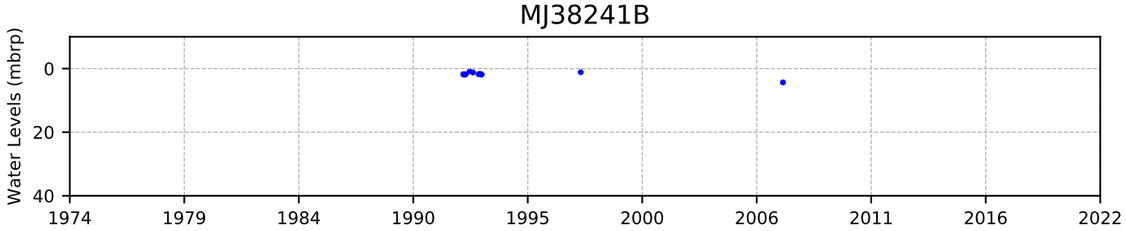
MJ38241B
Water Levels (mbrp)
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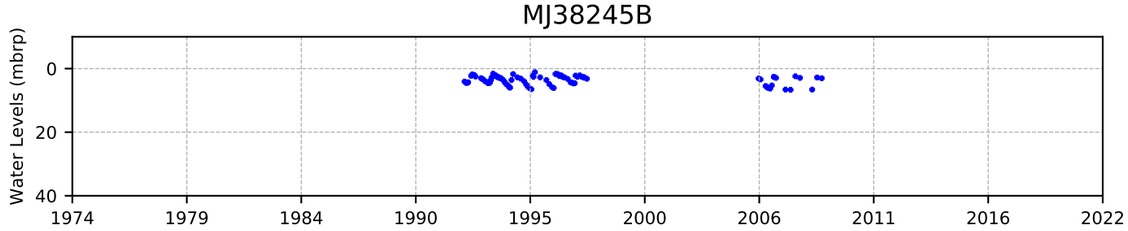
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Water Levels (mbrp)
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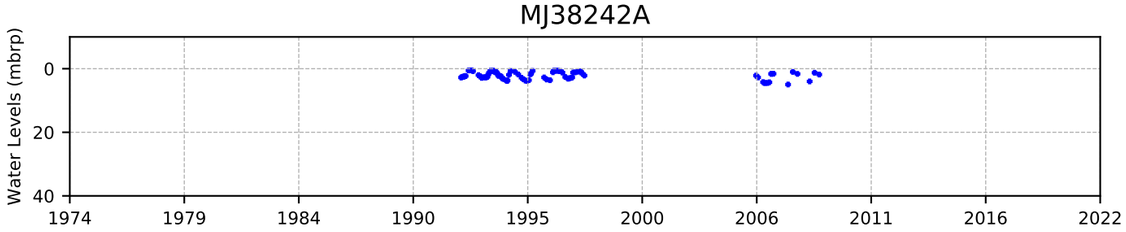
MJ38242A
Water Levels (mbrp)
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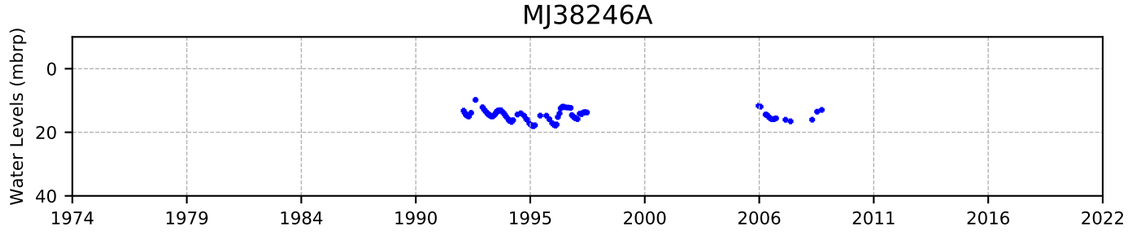
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Water Levels (mbrp)
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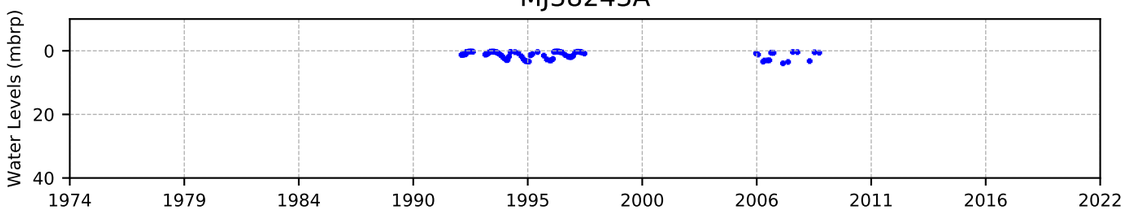
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Water Levels (mbrp)
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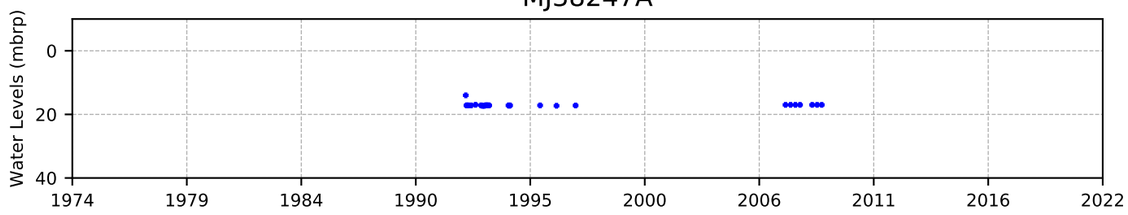
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Water Levels (mbrp)
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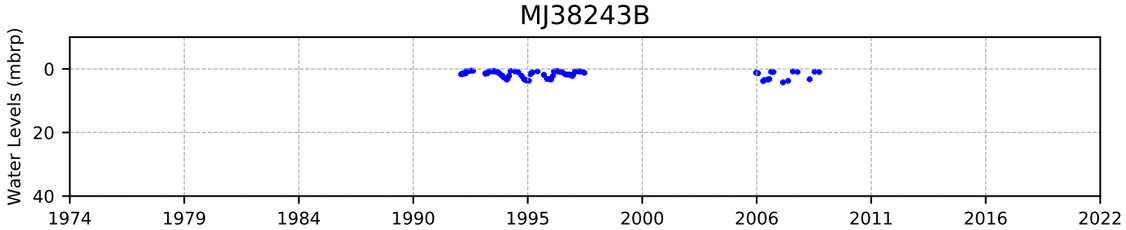
MJ38243B
Water Levels (mbrp)
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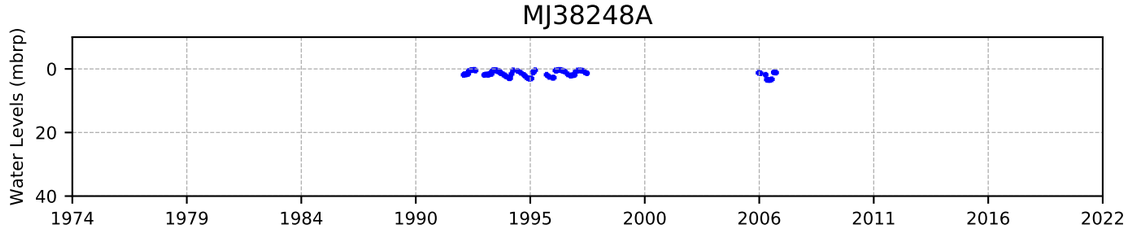
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Water Levels (mbrp)
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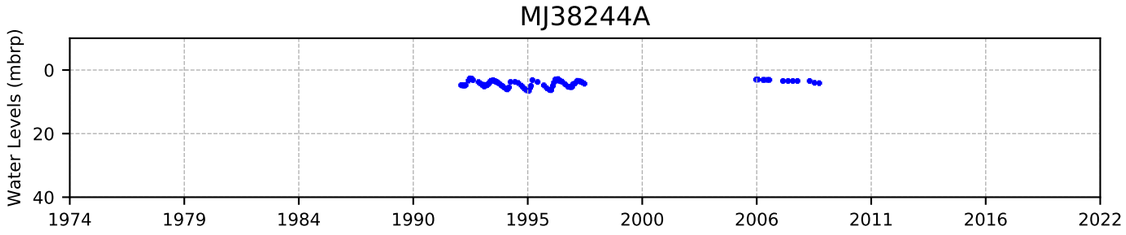
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Water Levels (mbrp)
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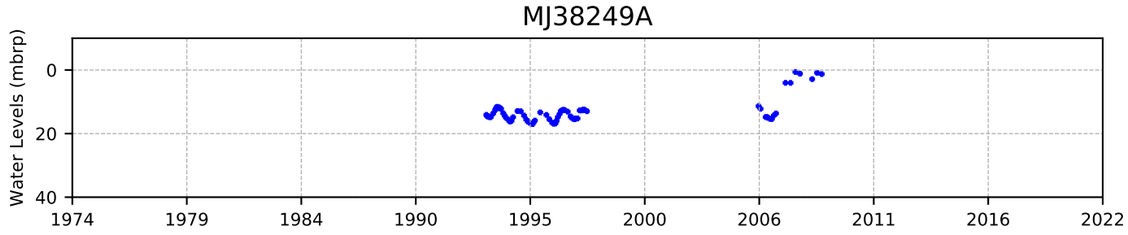
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Water Levels (mbrp)
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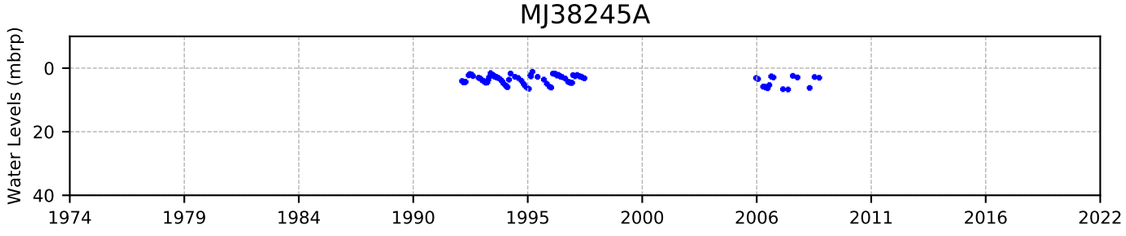
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Water Levels (mbrp)
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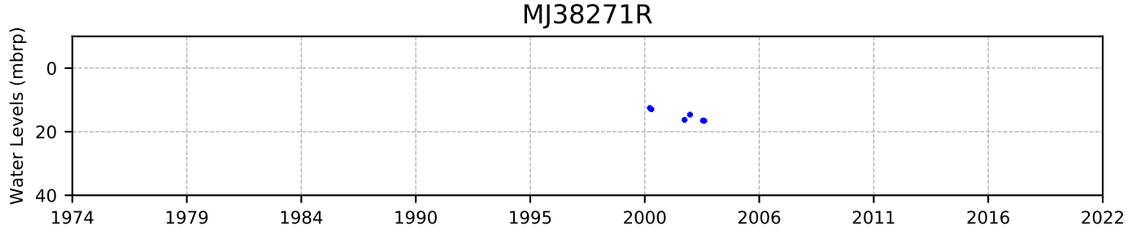
MJ38271R
Water Levels (mbrp)
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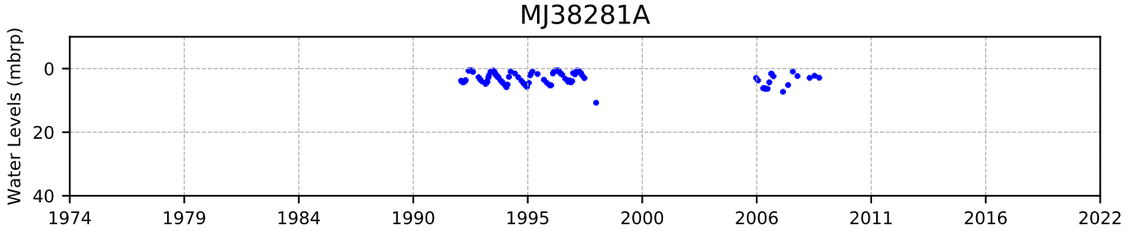
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Water Levels (mbrp)
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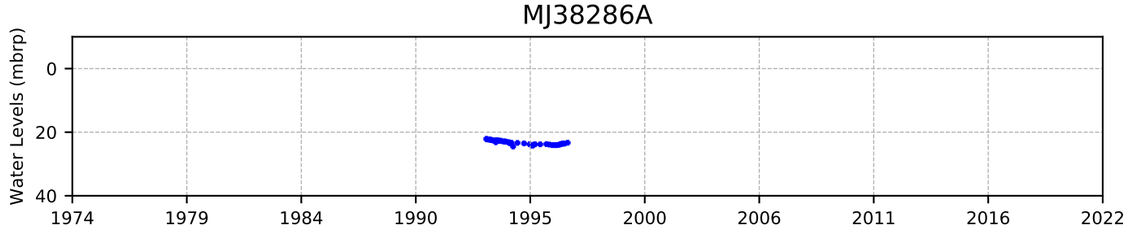
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Water Levels (mbrp)
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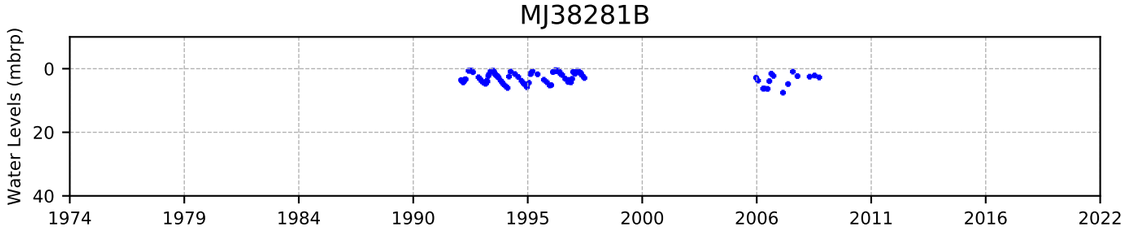
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Water Levels (mbrp)
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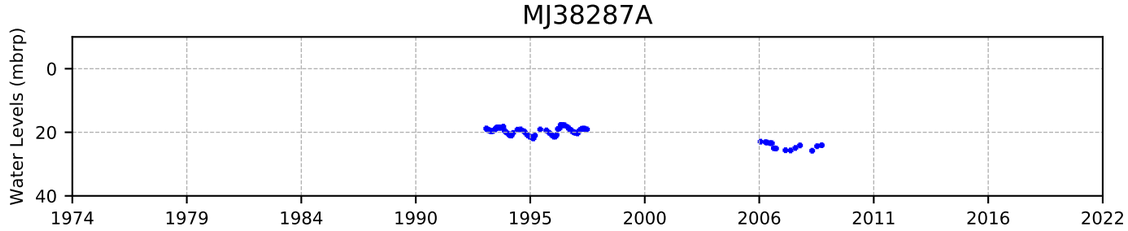
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Water Levels (mbrp)
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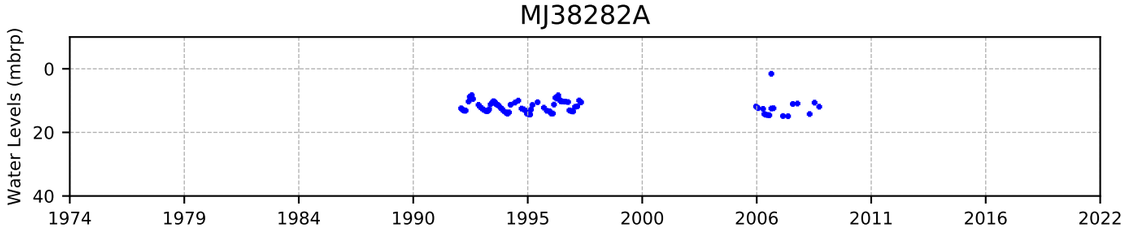
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Water Levels (mbrp)
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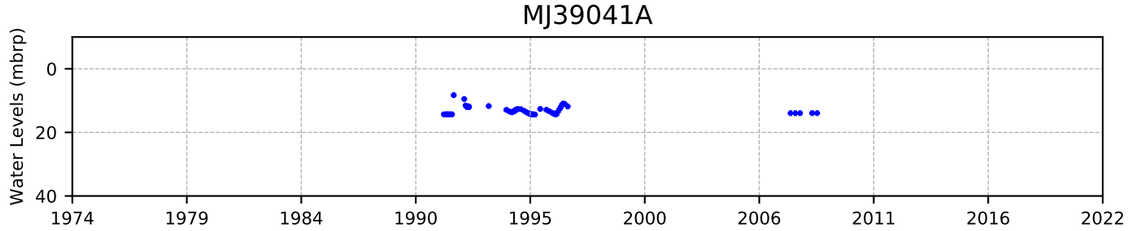
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Water Levels (mbrp)
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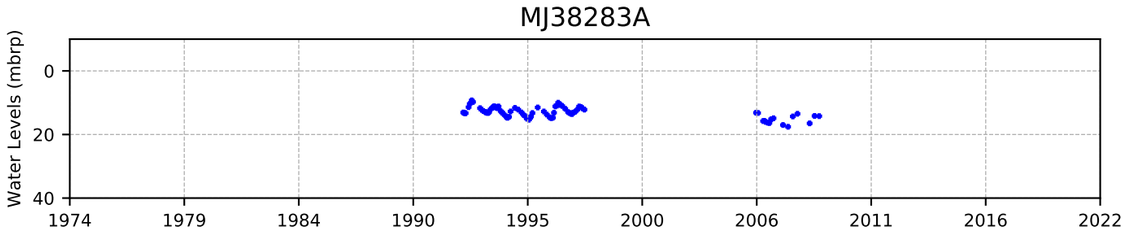
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Water Levels (mbrp)
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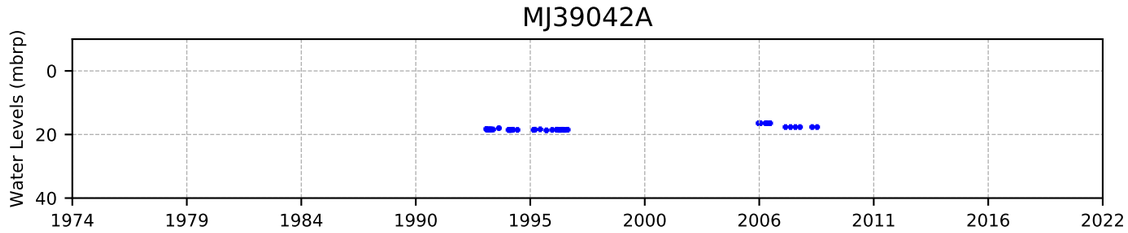
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Water Levels (mbrp)
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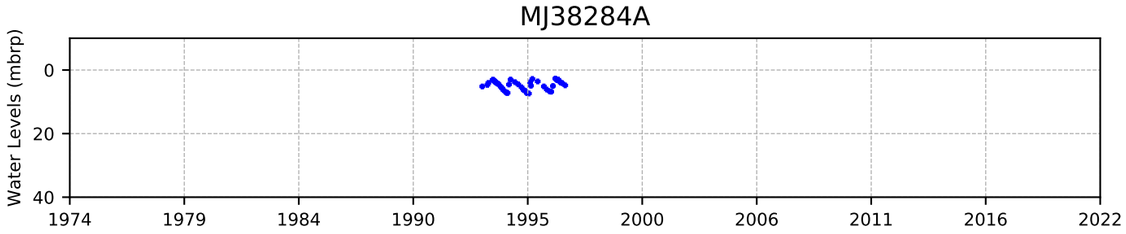
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Water Levels (mbrp)
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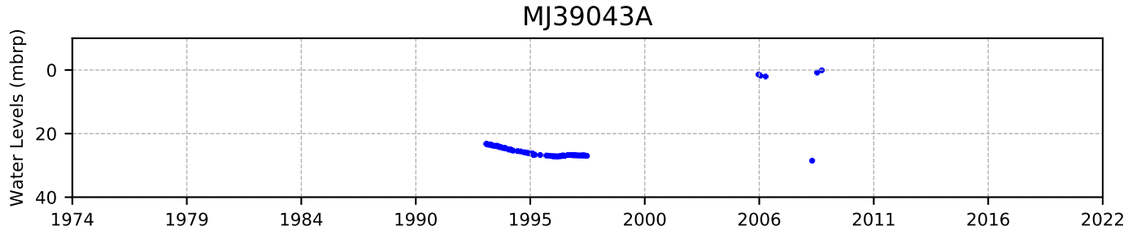
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Water Levels (mbrp)
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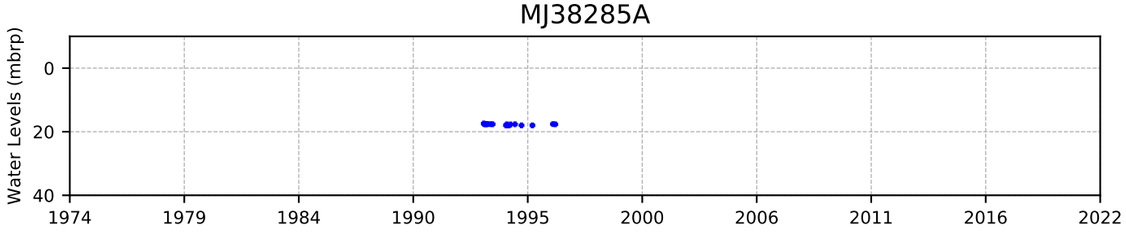
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Water Levels (mbrp)
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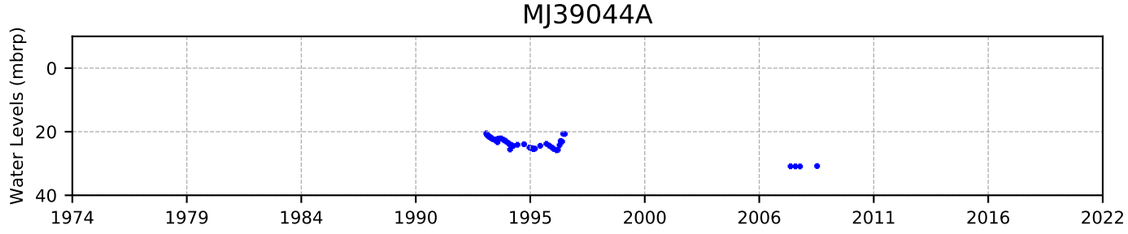
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Water Levels (mbrp)
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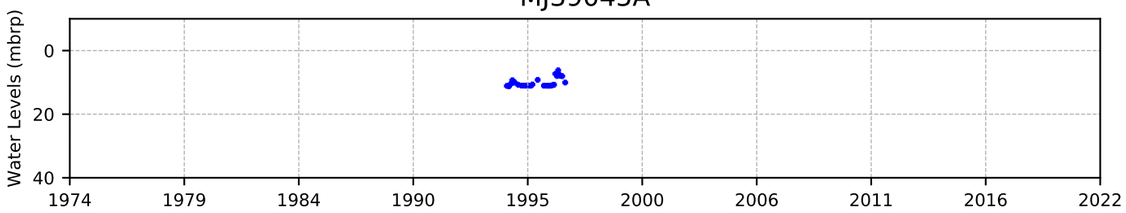
2022

MJ39045A



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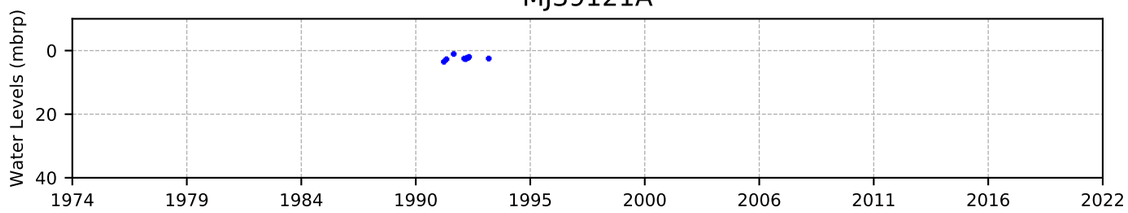

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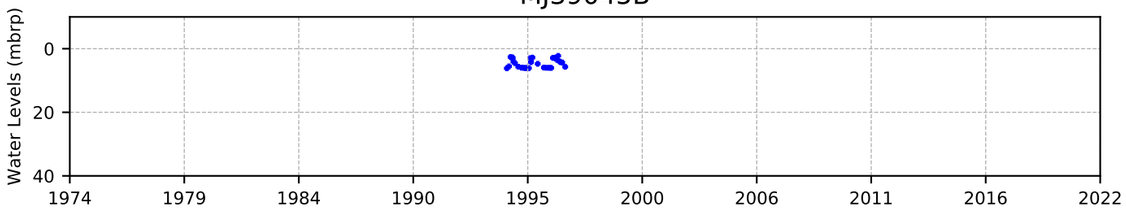

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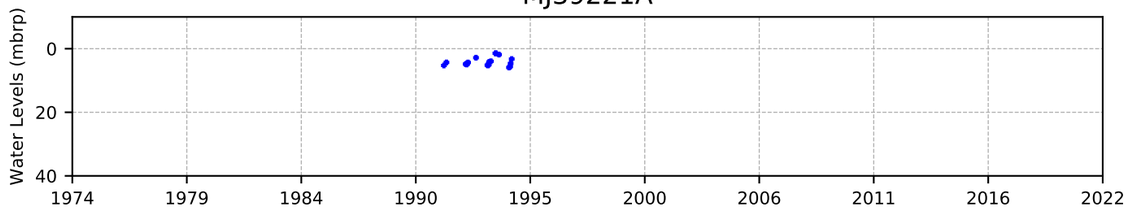

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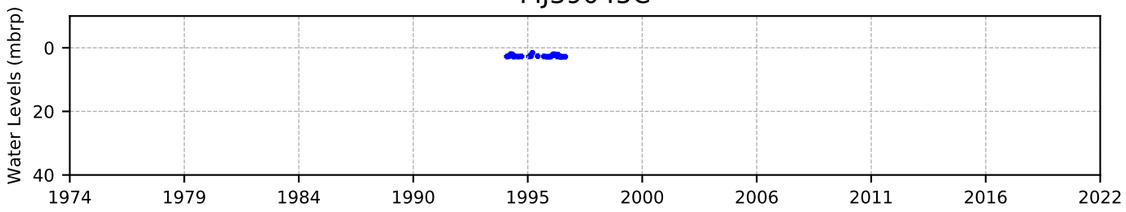

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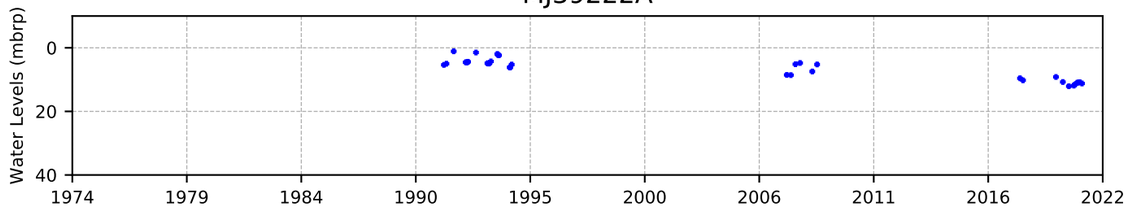
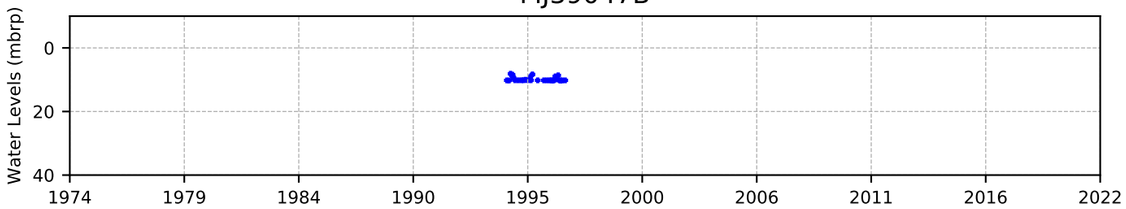


MJ39047B



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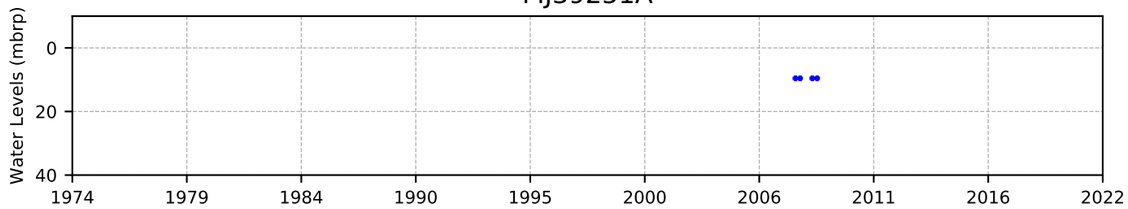

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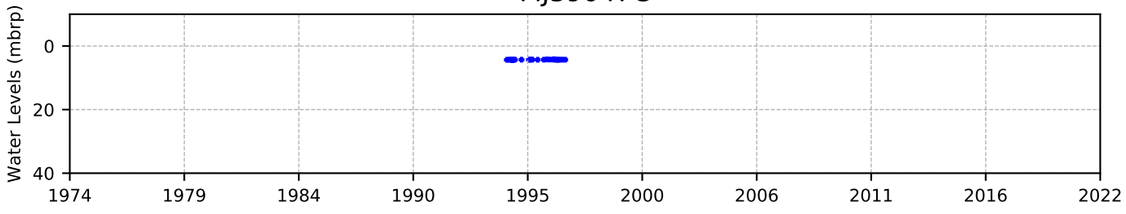

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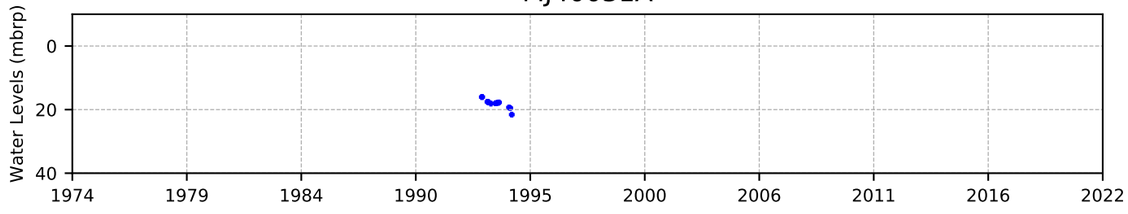

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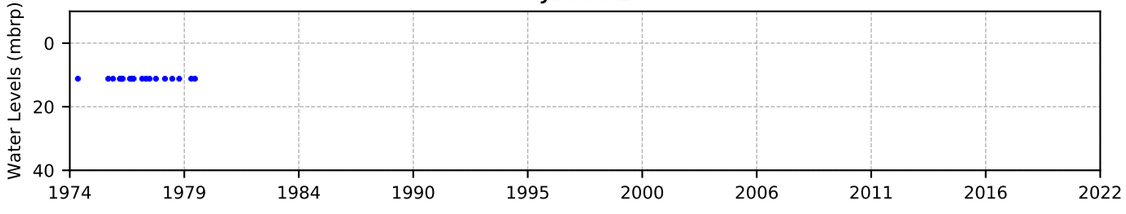

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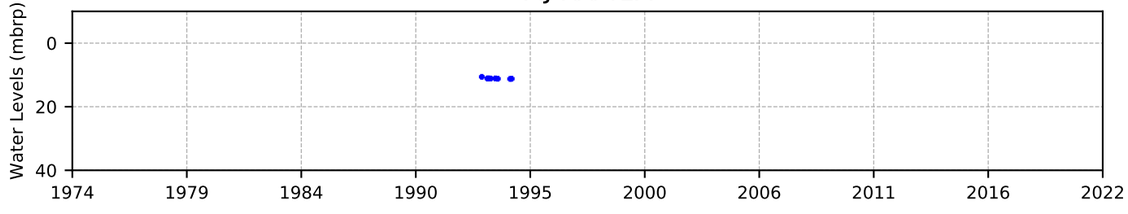

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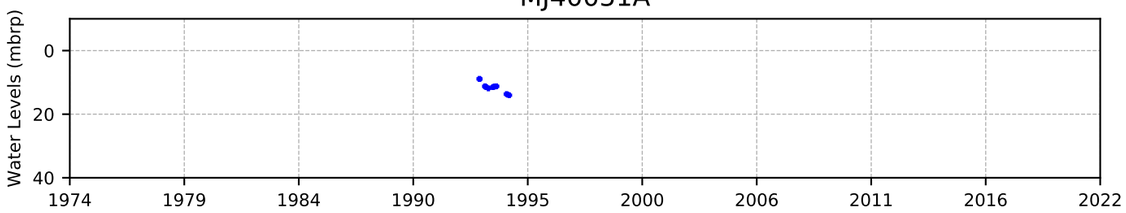

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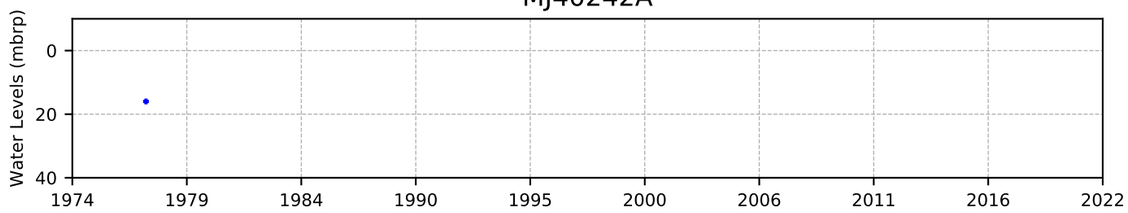

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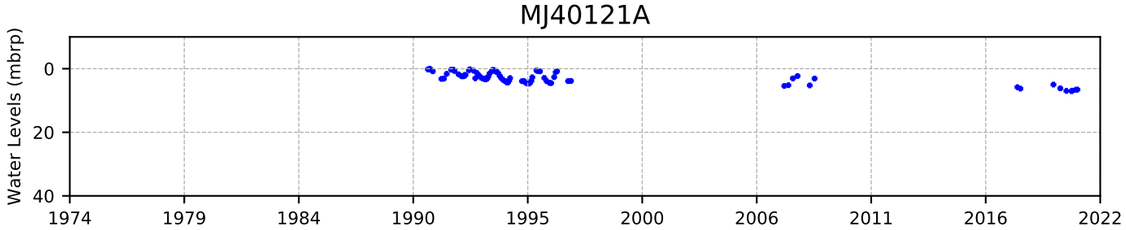

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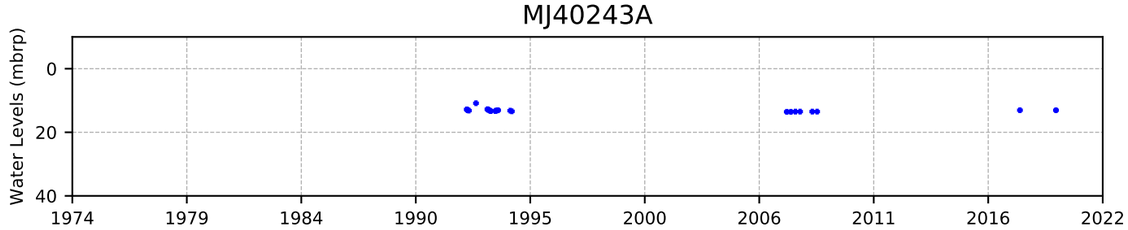

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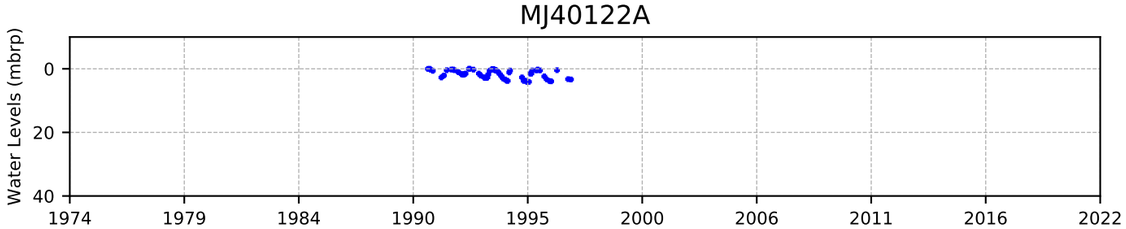

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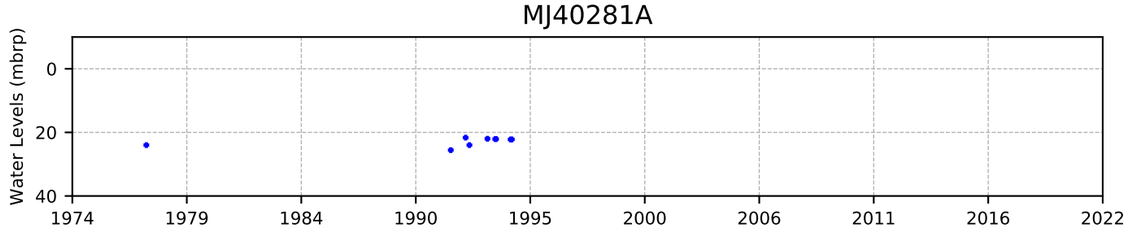

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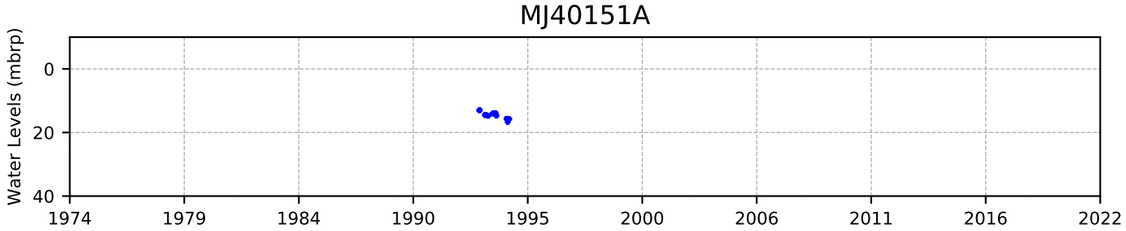

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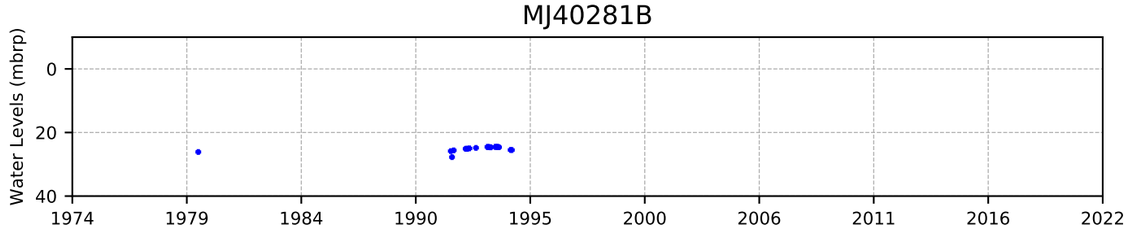

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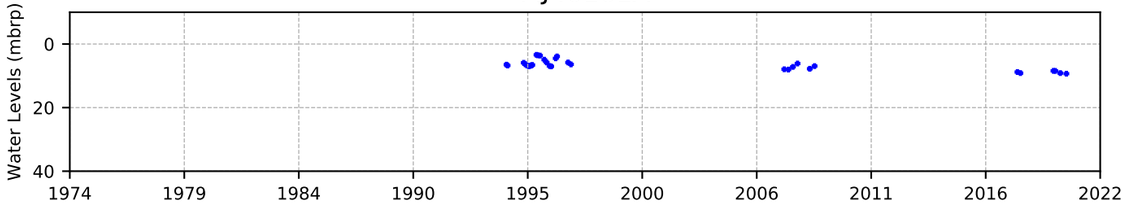

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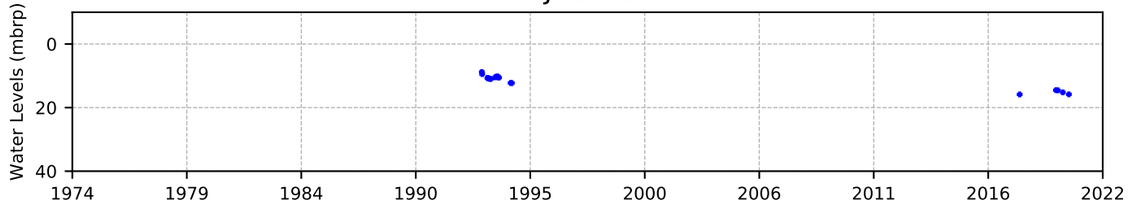

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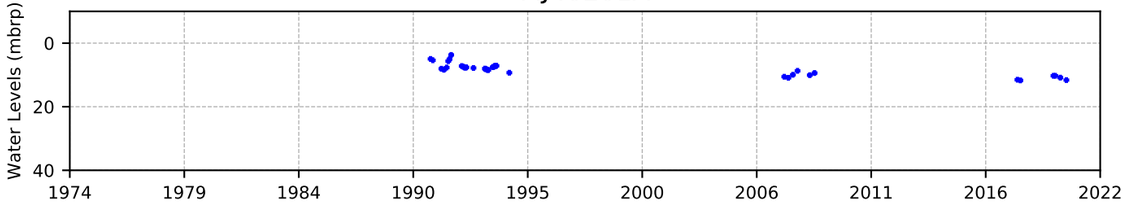

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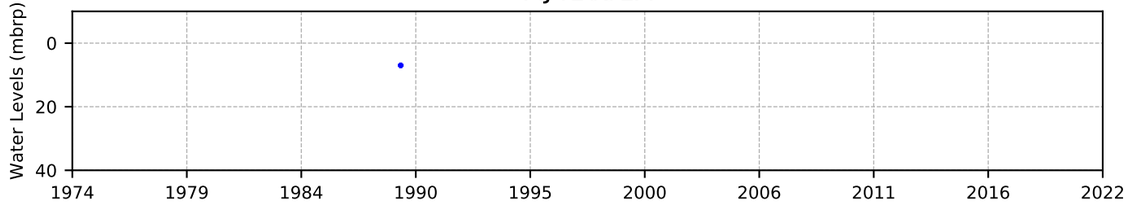

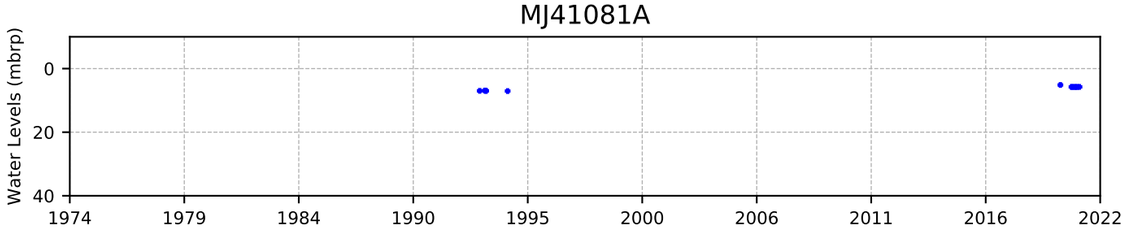
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Water Levels (mbrp)
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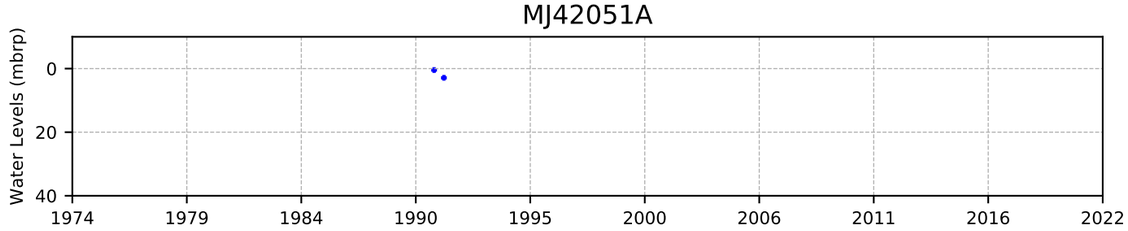
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Water Levels (mbrp)
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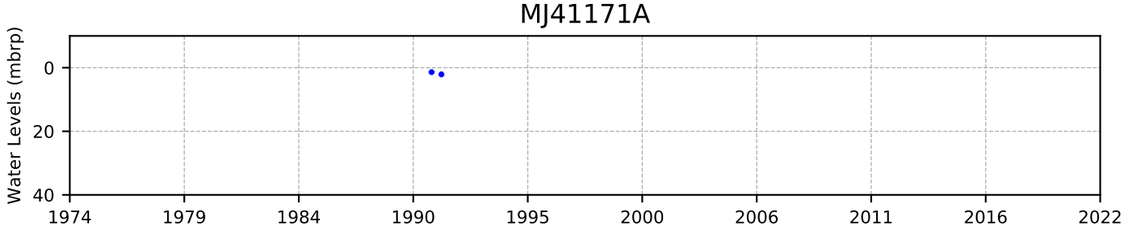
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Water Levels (mbrp)
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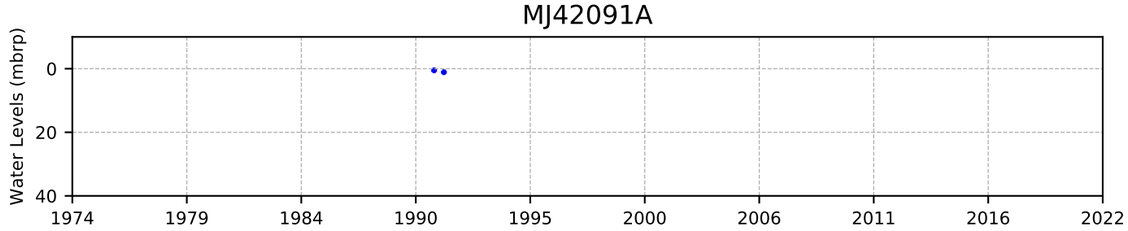
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Water Levels (mbrp)
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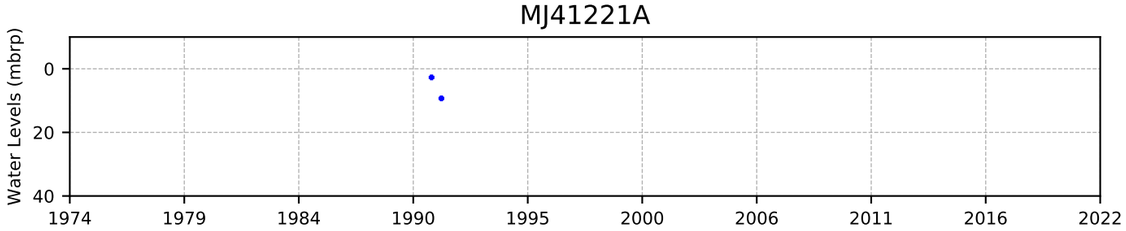
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Water Levels (mbrp)
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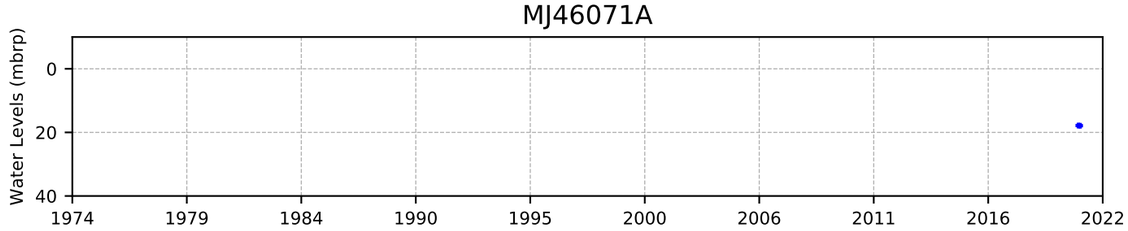
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Water Levels (mbrp)
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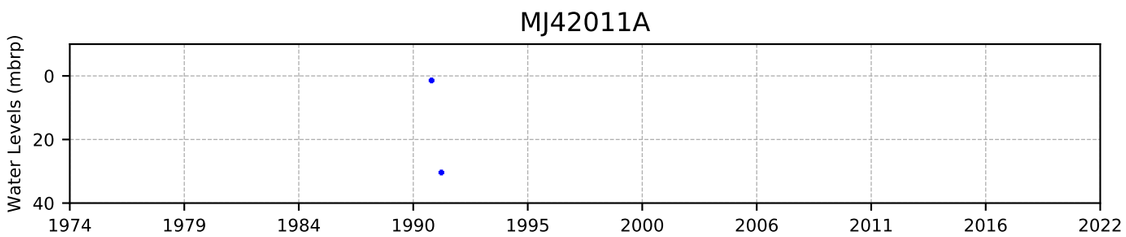
MJ42011A
Water Levels (mbrp)
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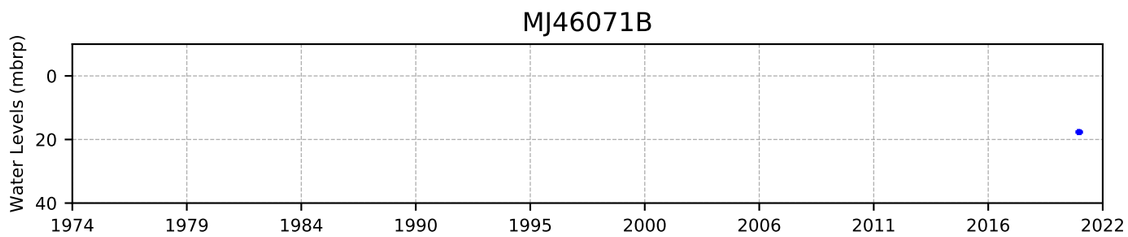
MJ46071B
Water Levels (mbrp)
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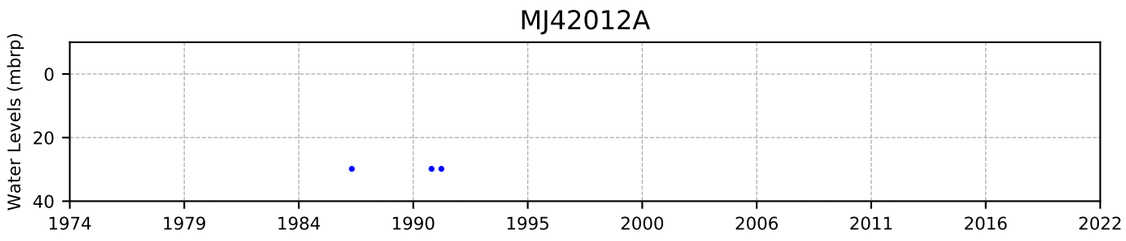
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Water Levels (mbrp)
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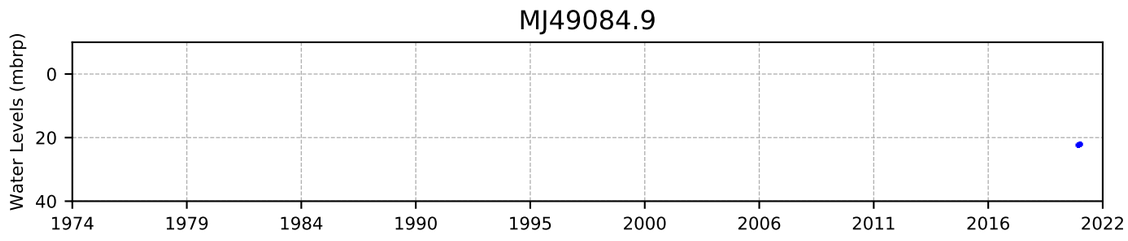
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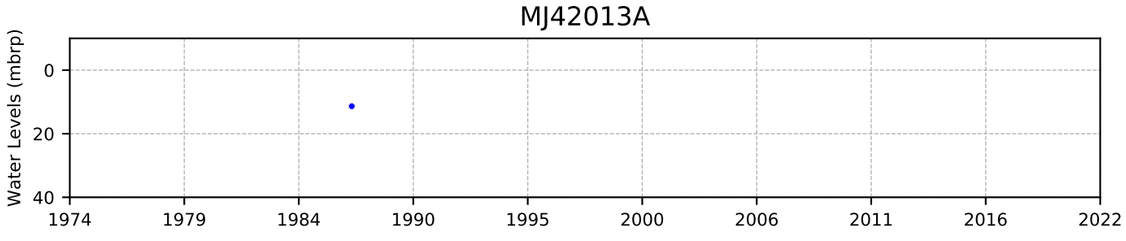
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Water Levels (mbrp)
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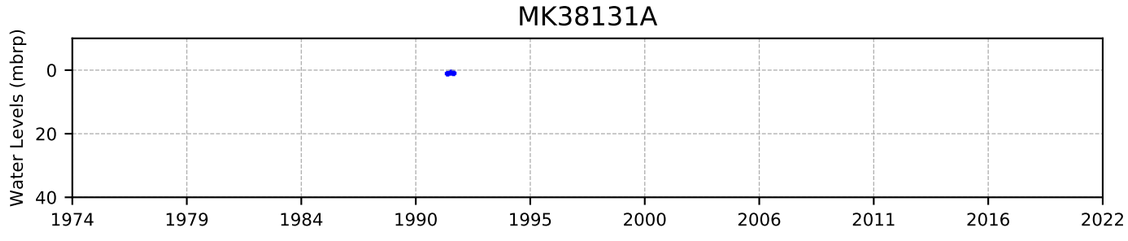
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Water Levels (mbrp)
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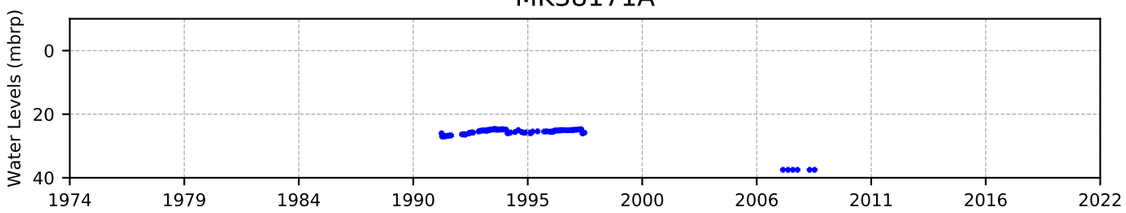
MK38171A



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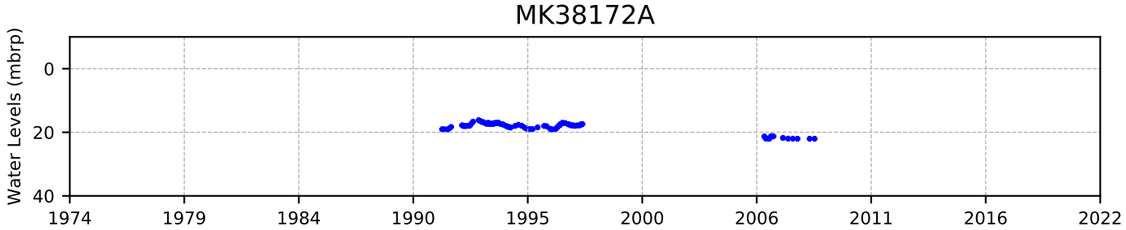

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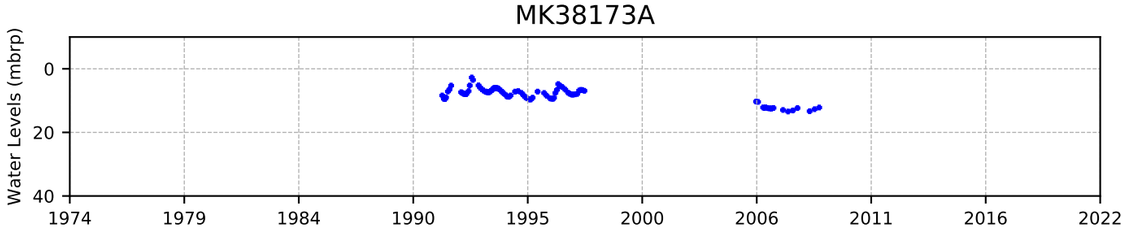

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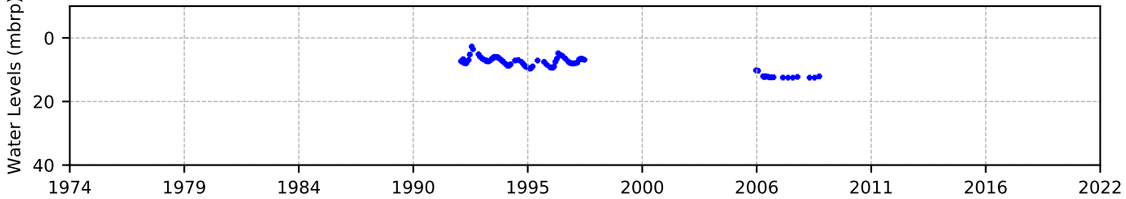

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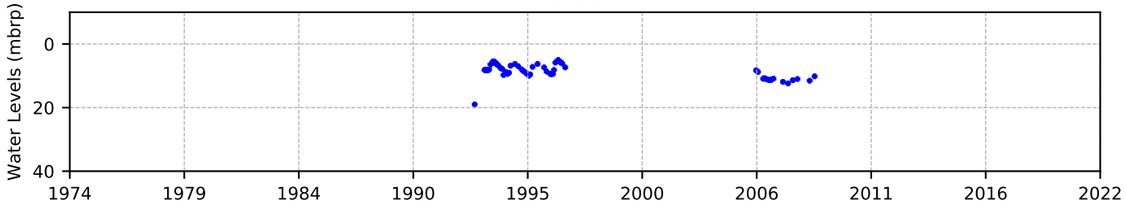

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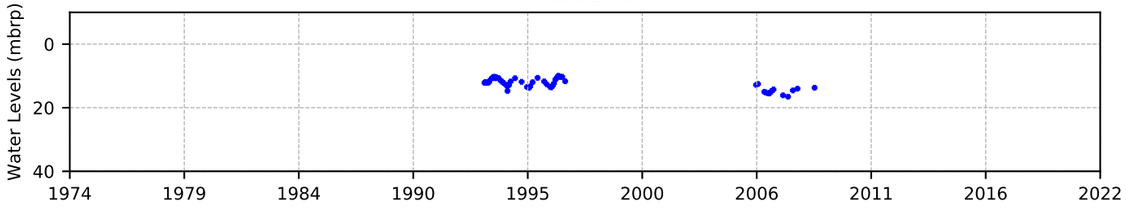

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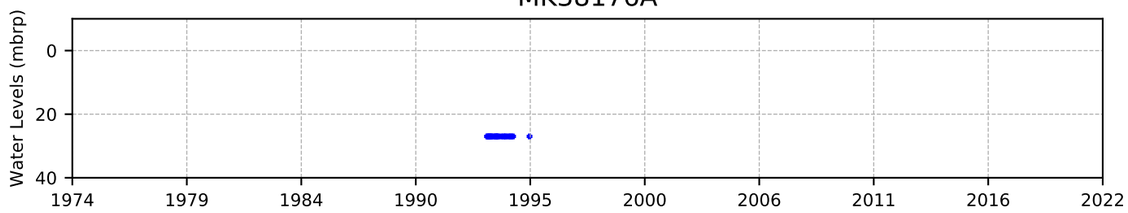

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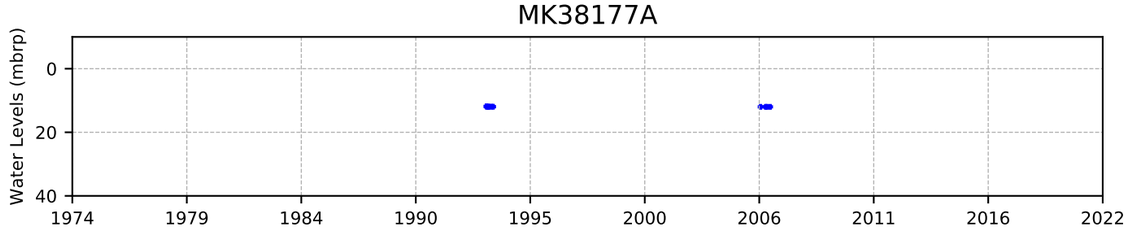

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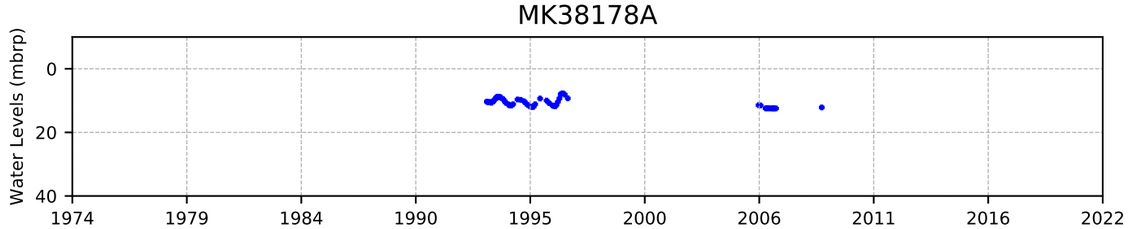

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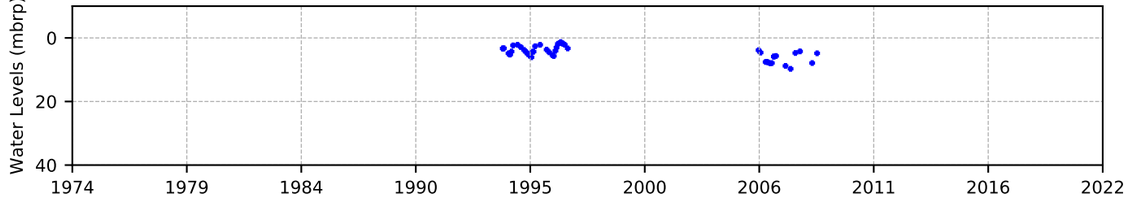

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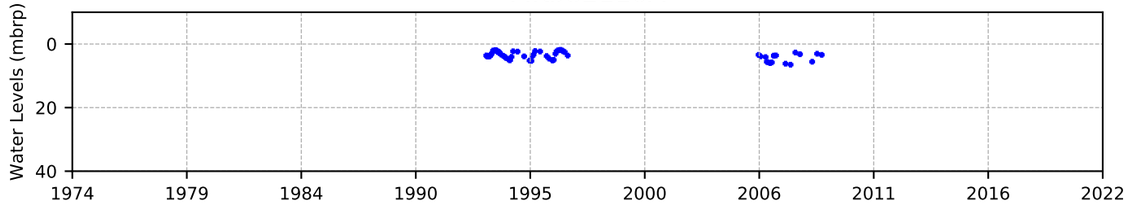

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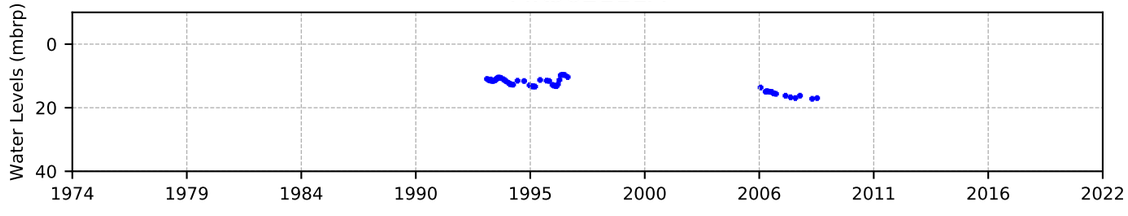

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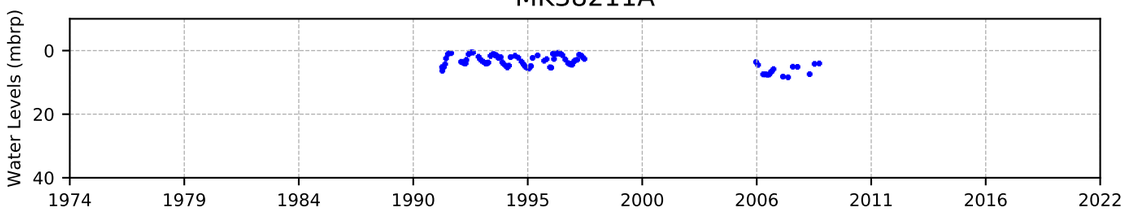

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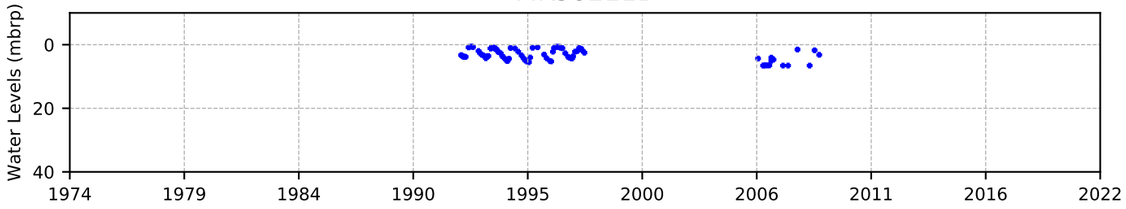

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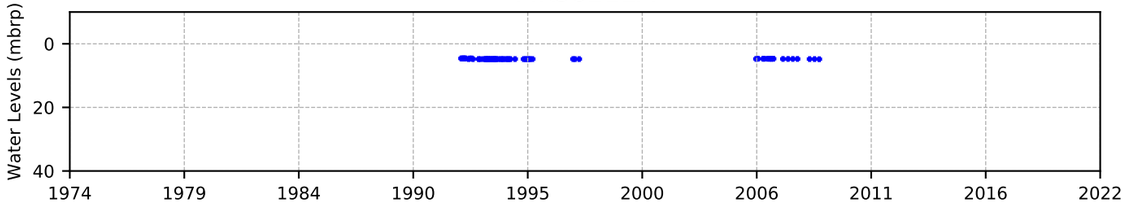

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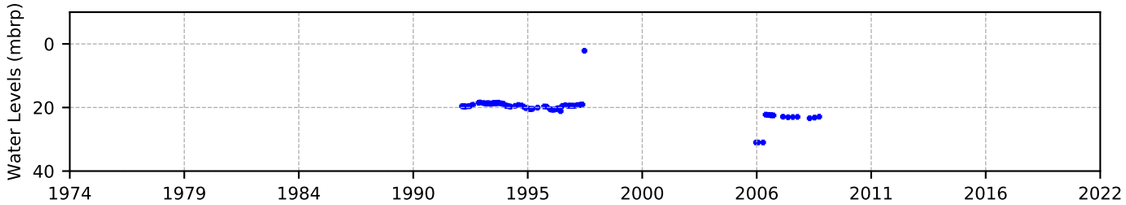

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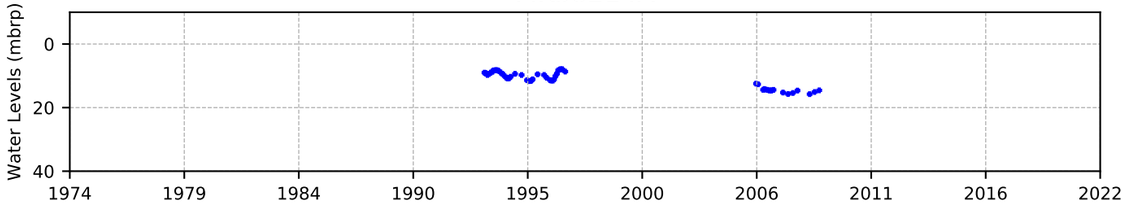

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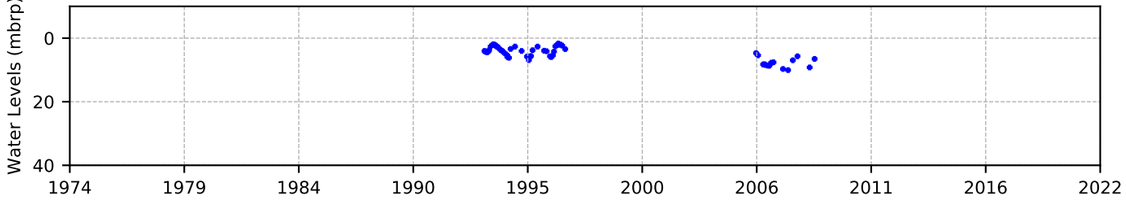

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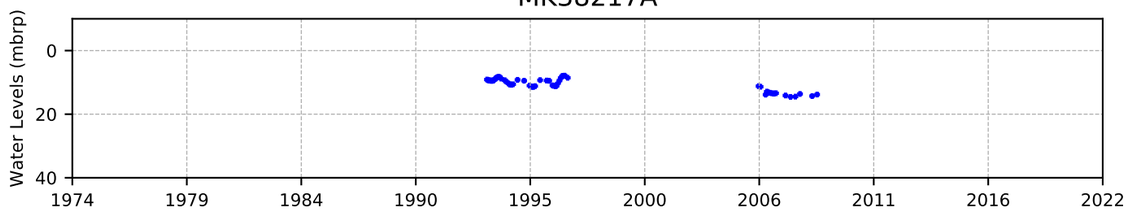

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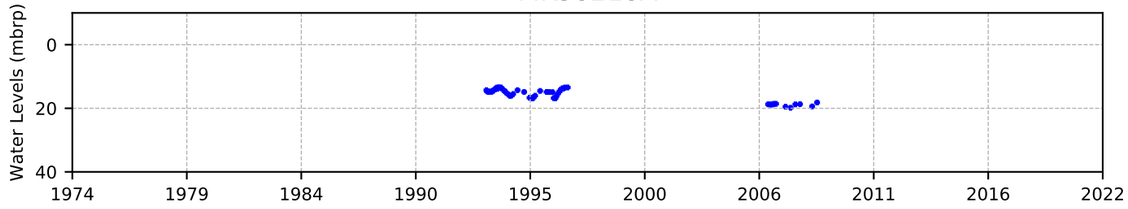

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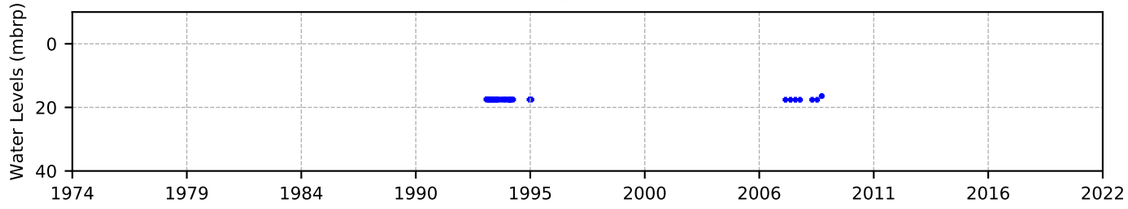

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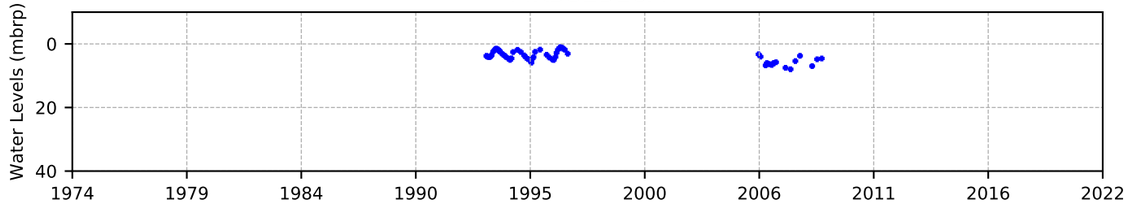

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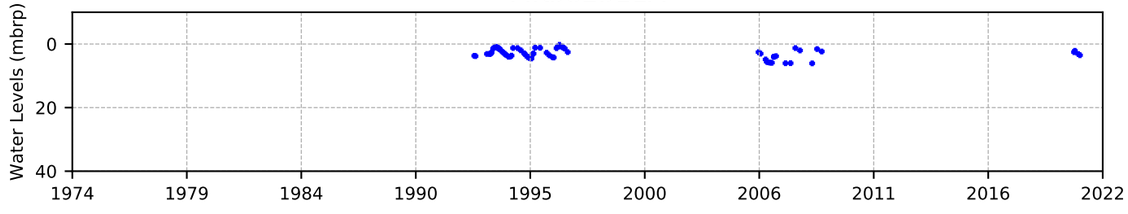

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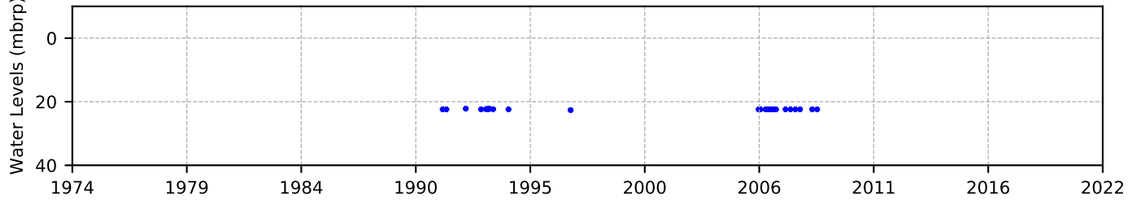

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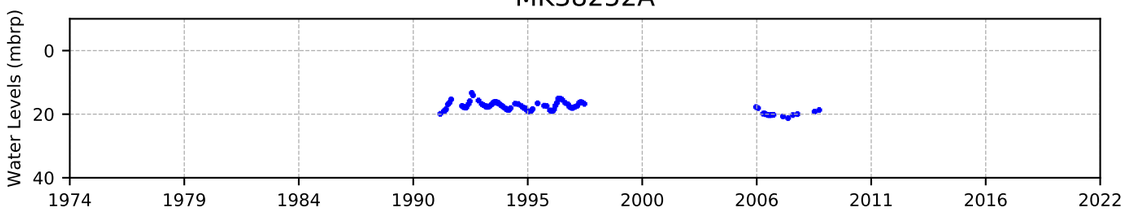

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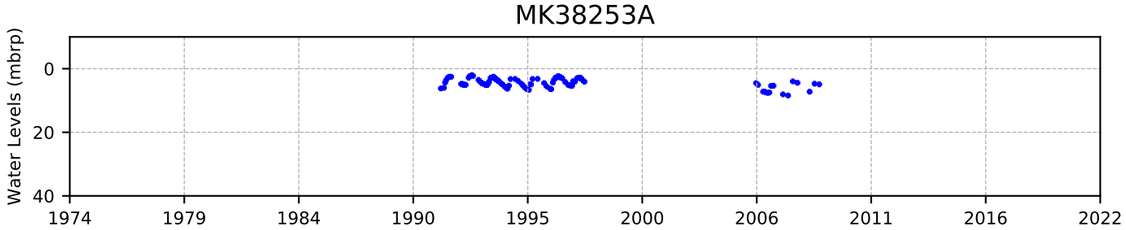

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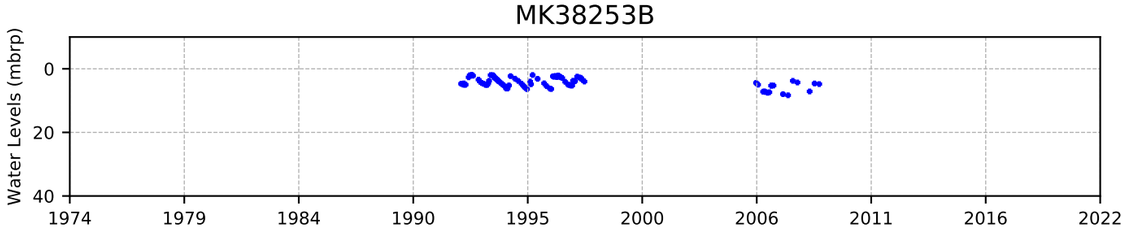

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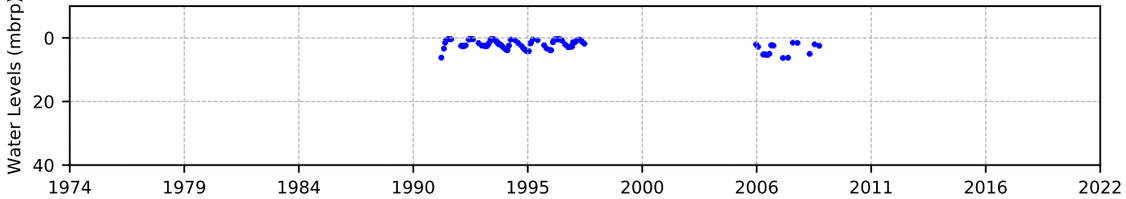

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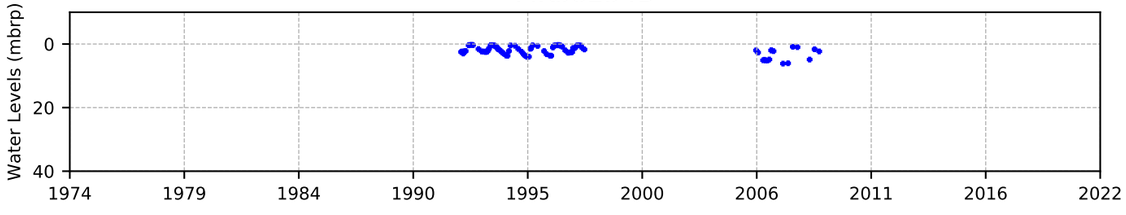

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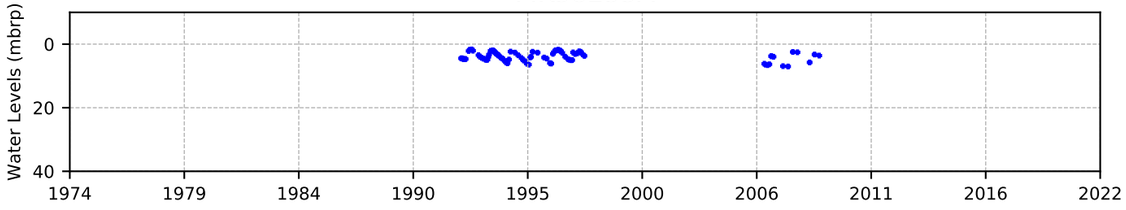

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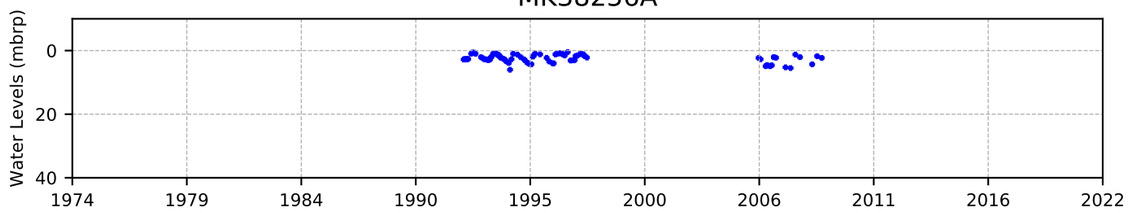

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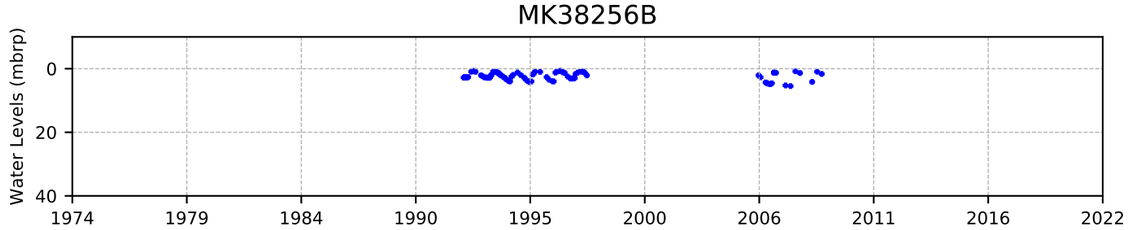

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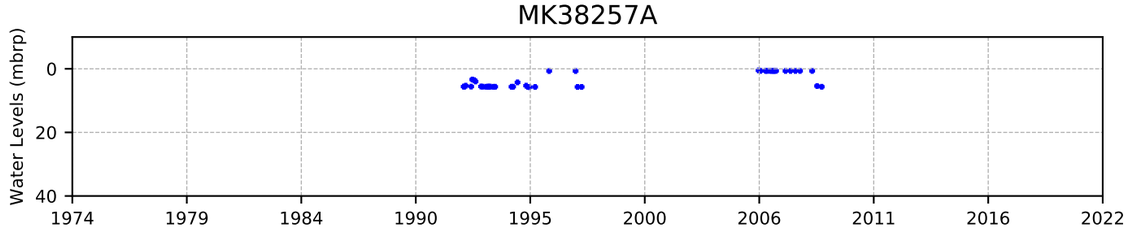

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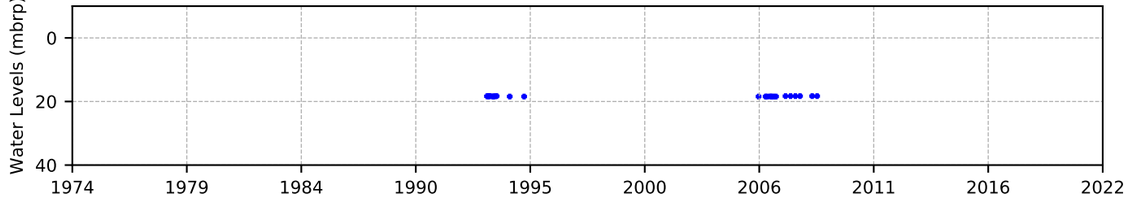

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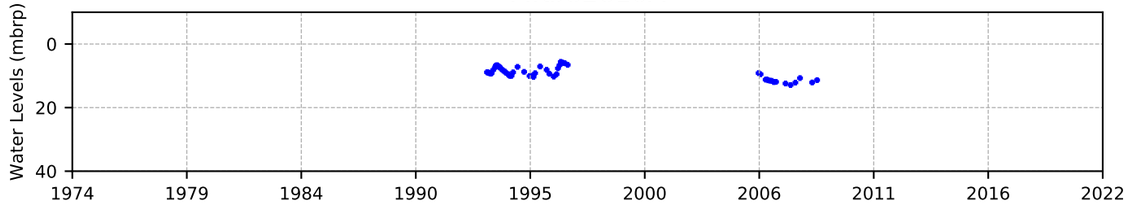

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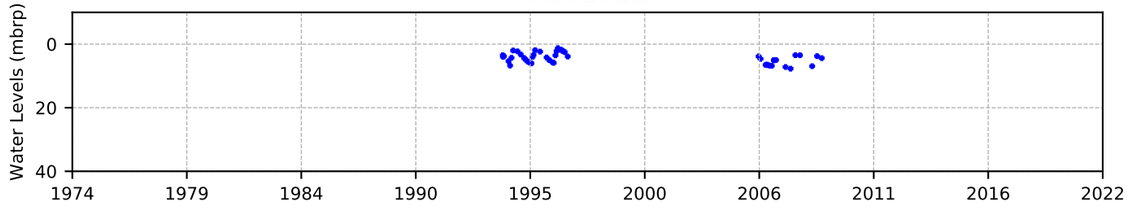

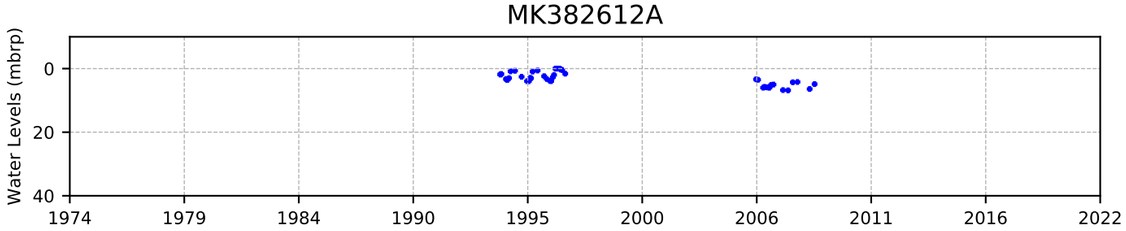
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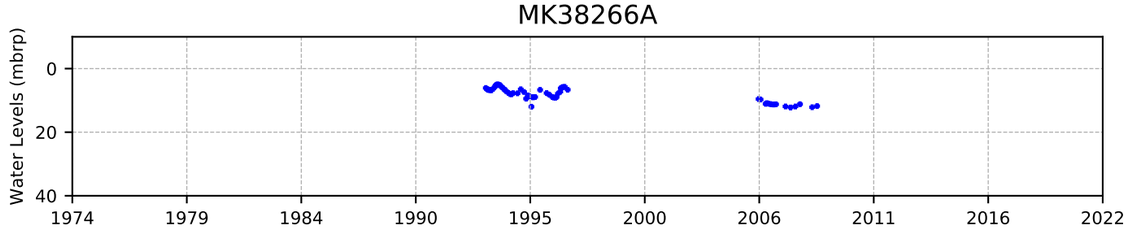
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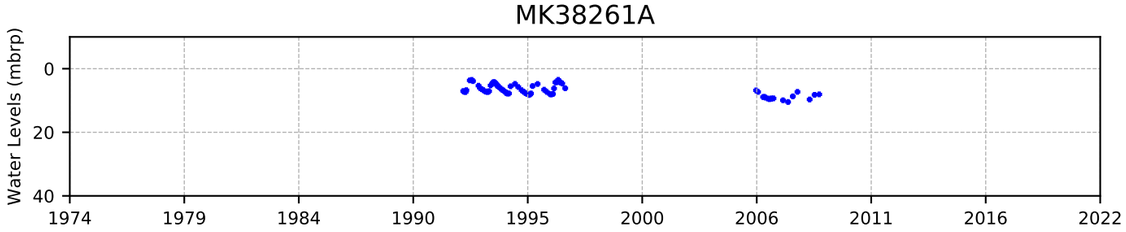
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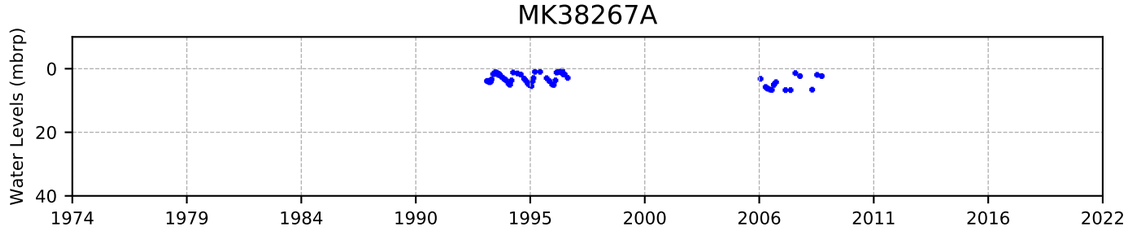
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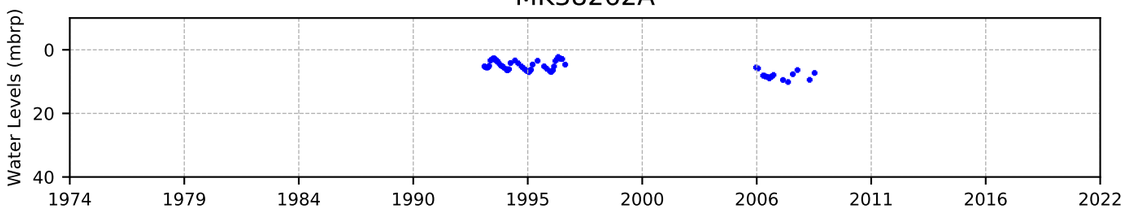
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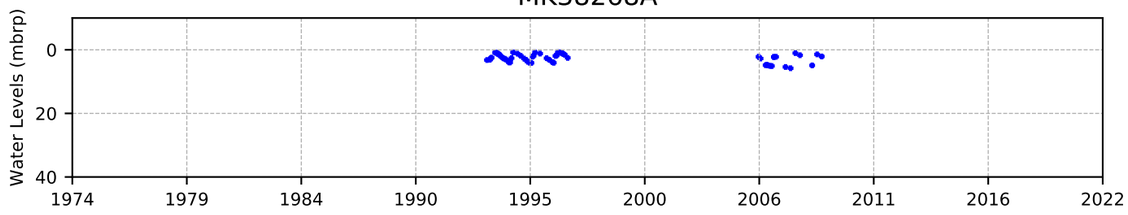
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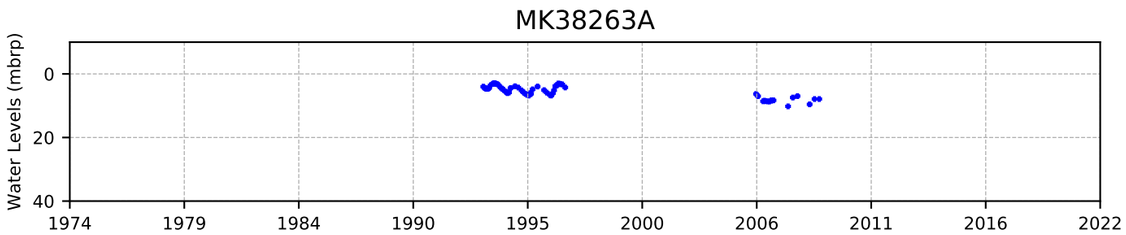
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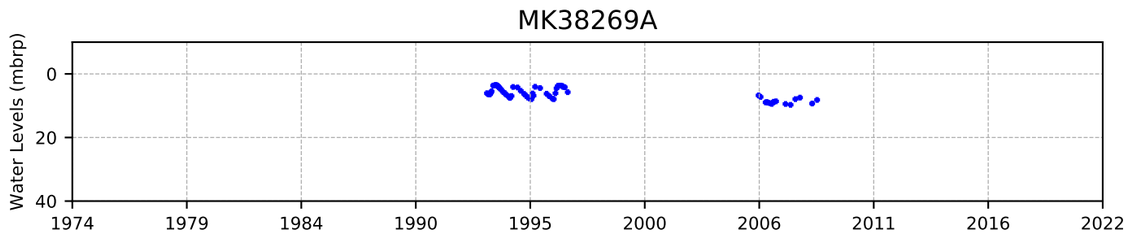
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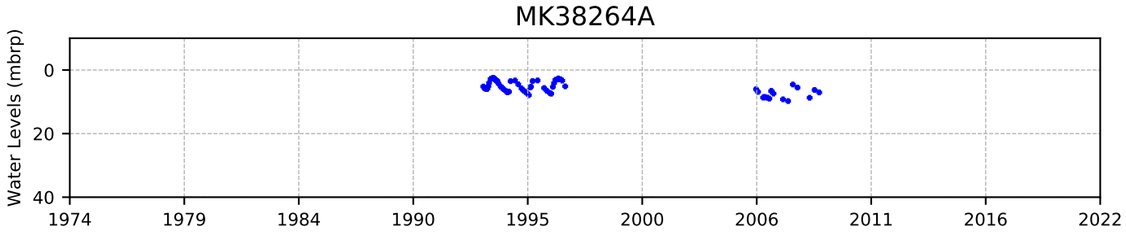
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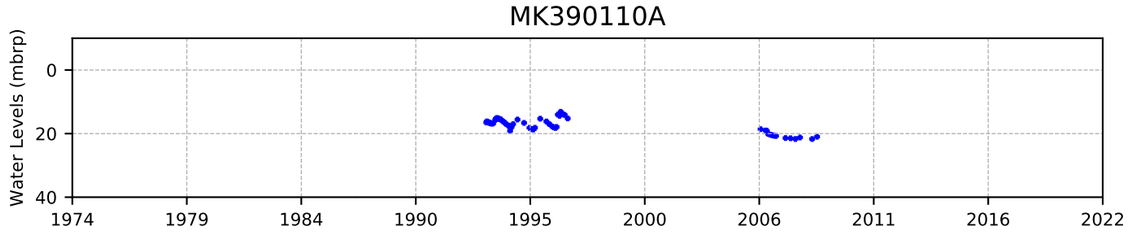
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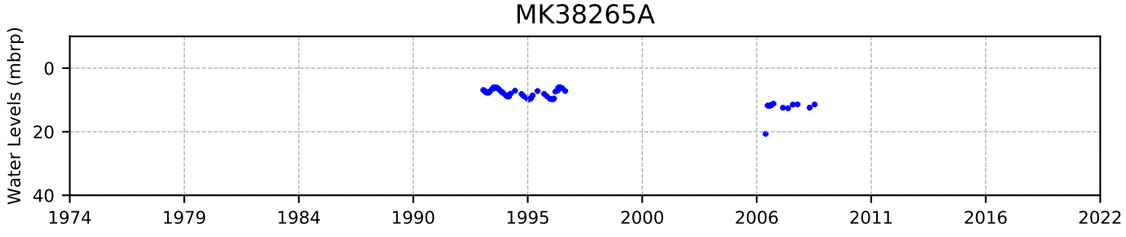
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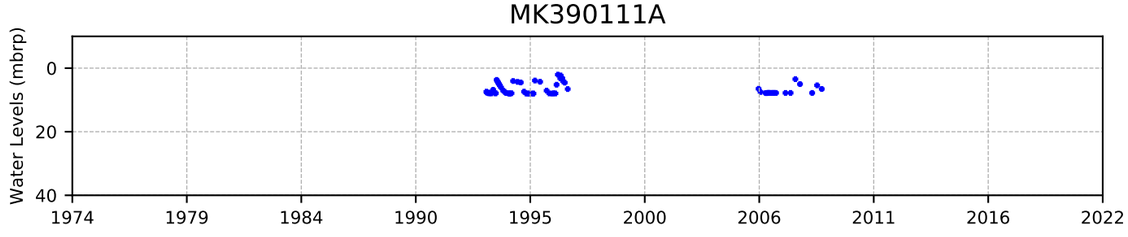
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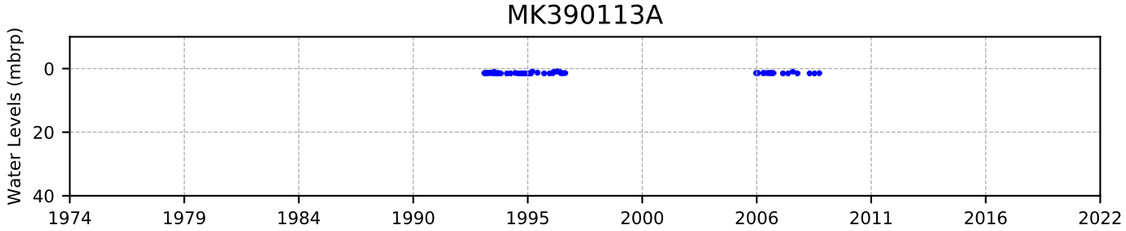
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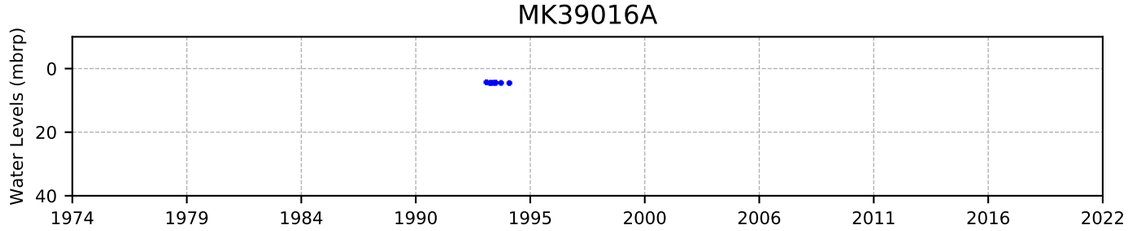
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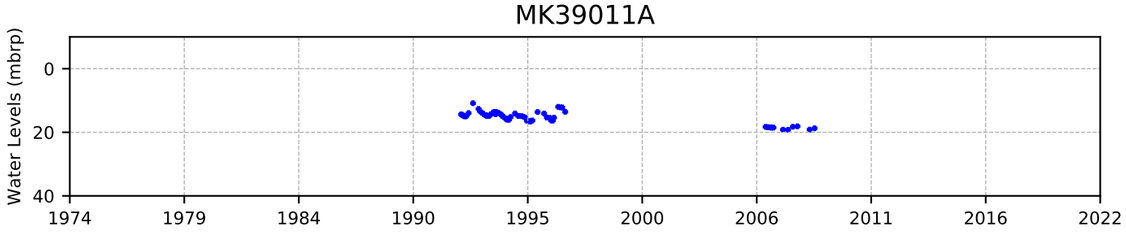
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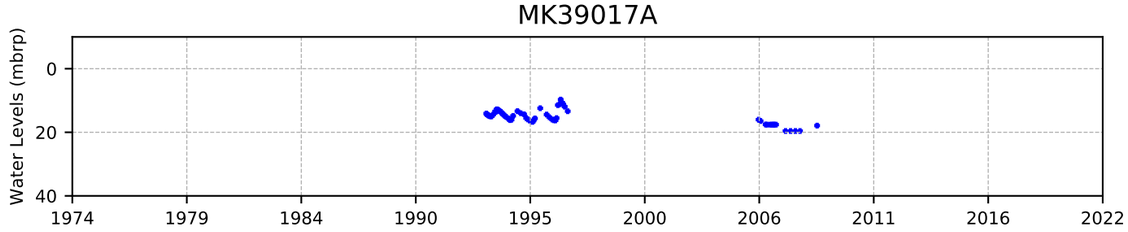
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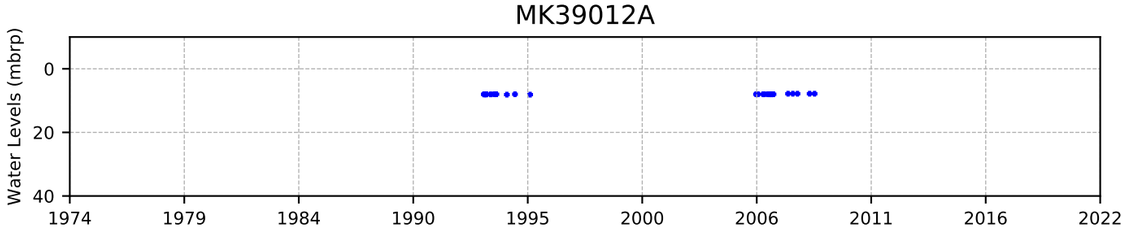
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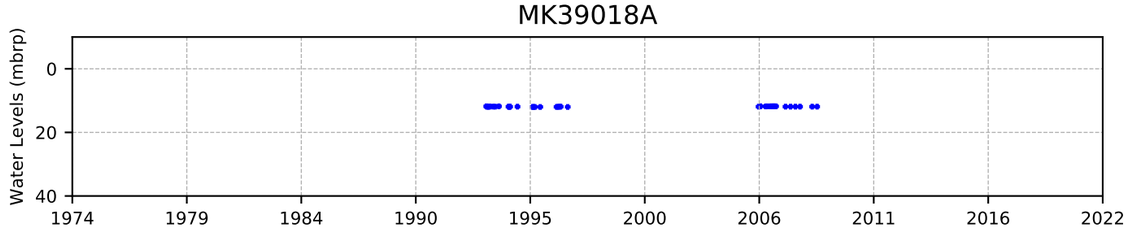
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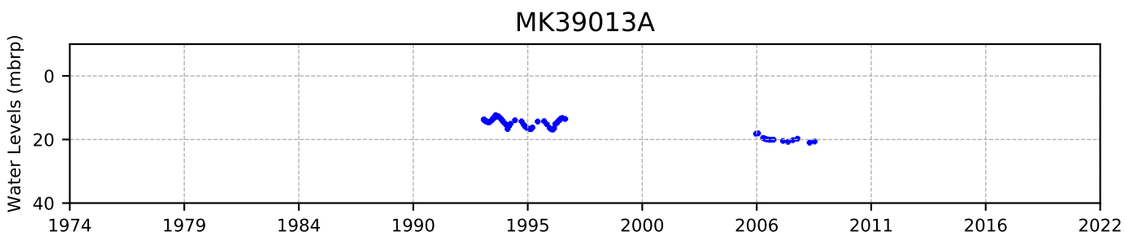
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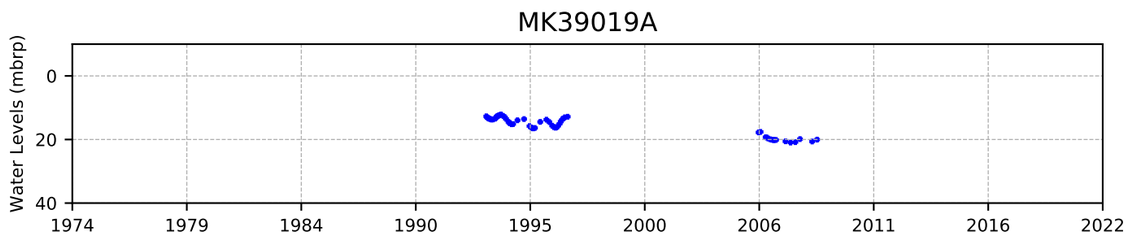
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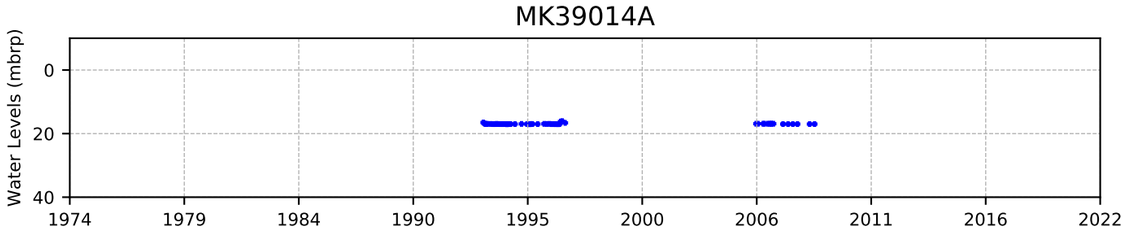
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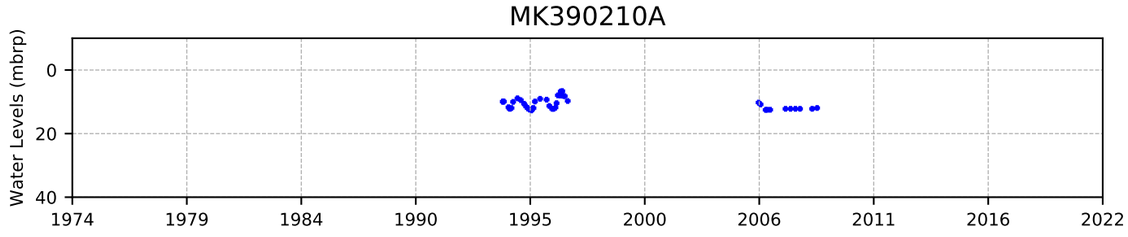
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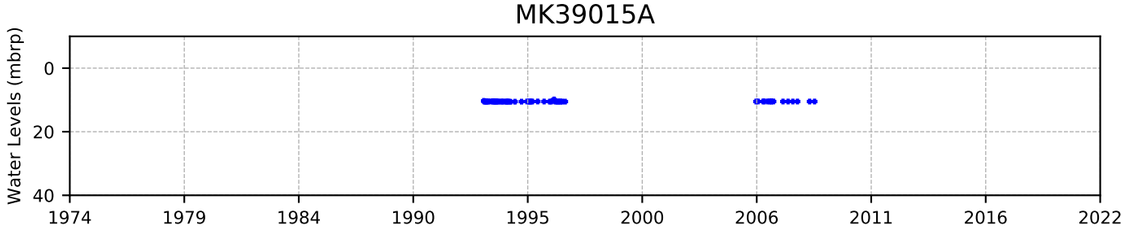
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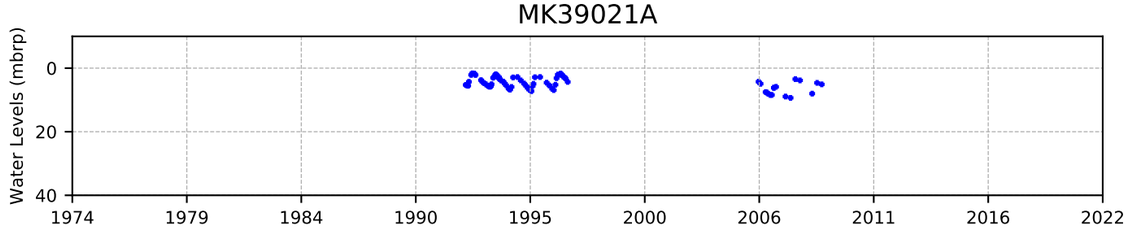
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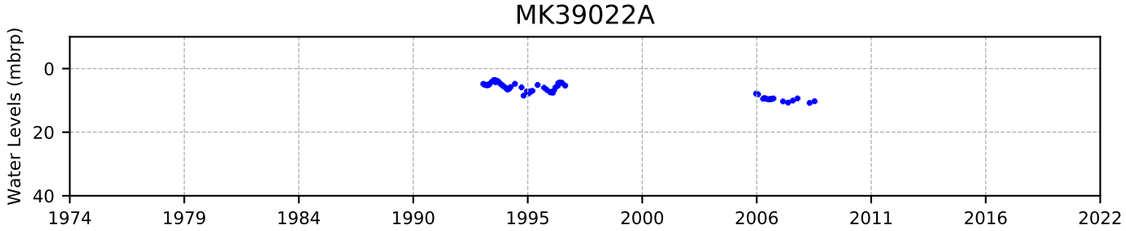
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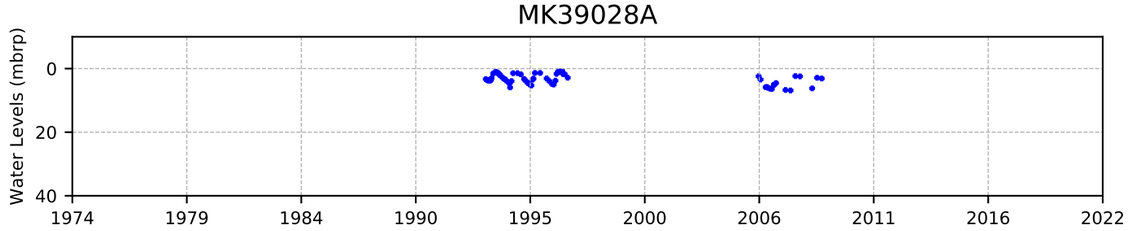
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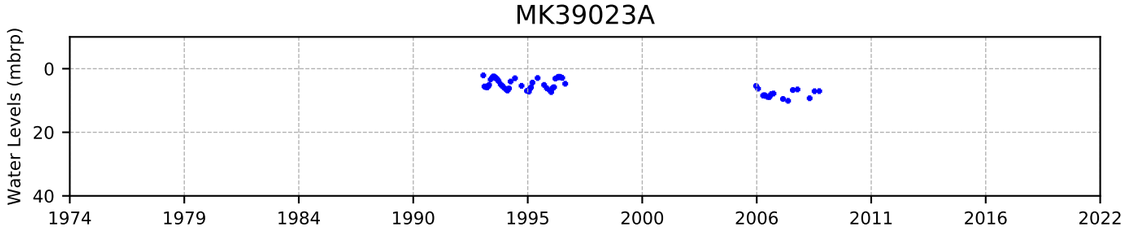
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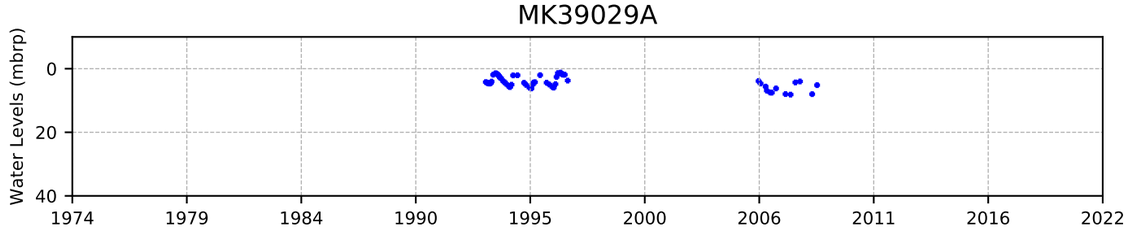
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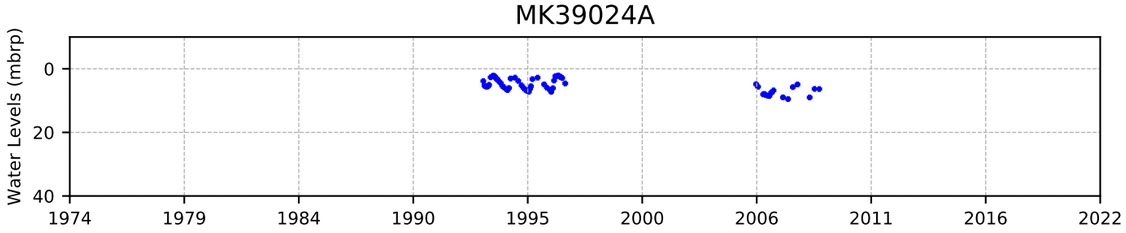
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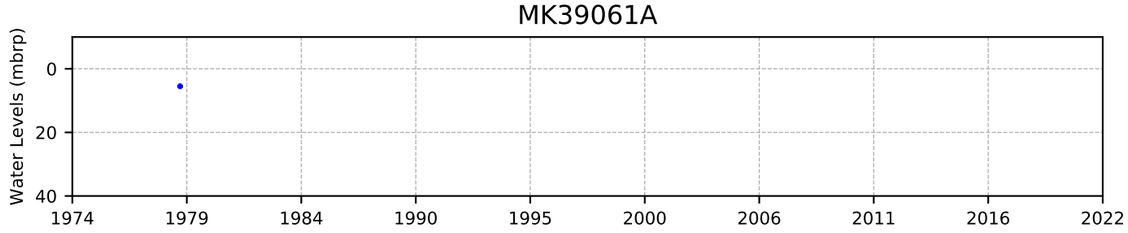
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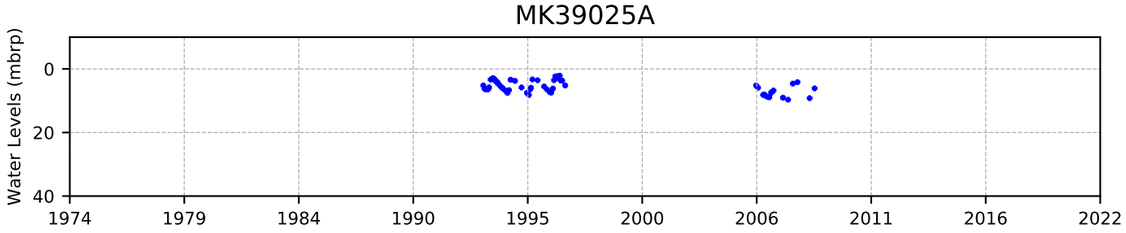
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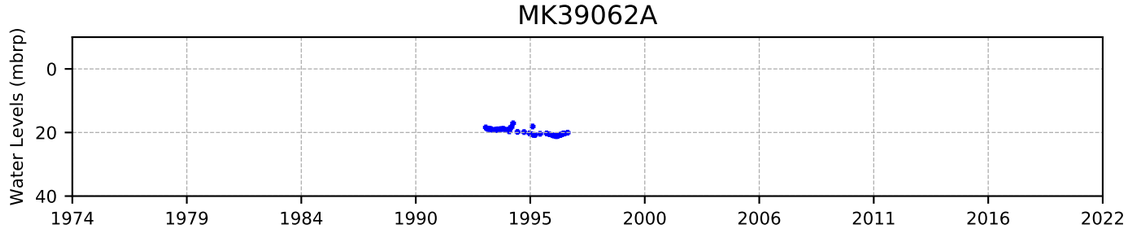
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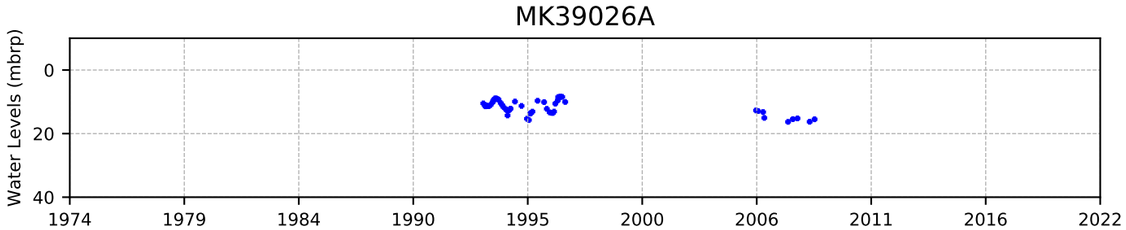
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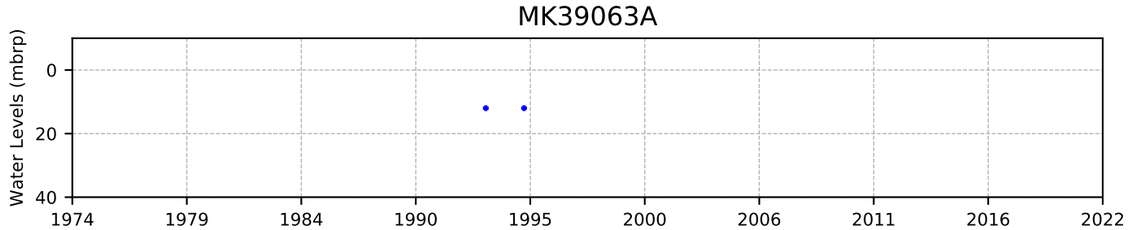
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Water Levels (mbrp)
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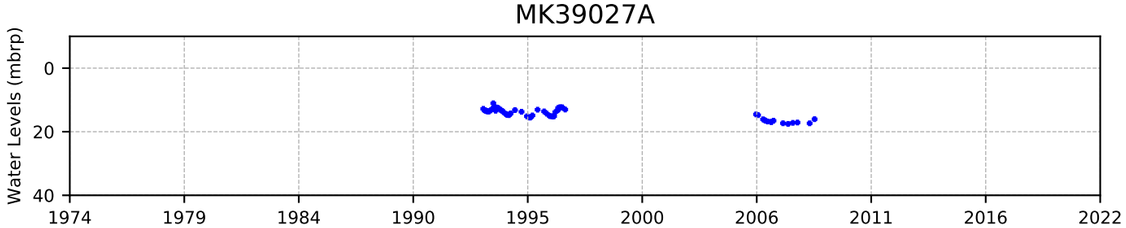
MK39027A
Water Levels (mbrp)
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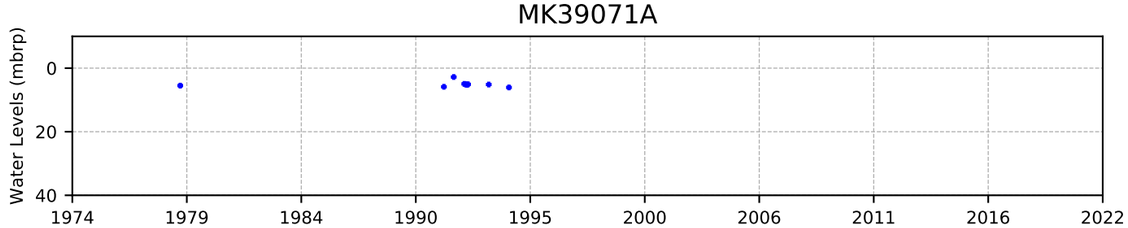
MK39071A
Water Levels (mbrp)
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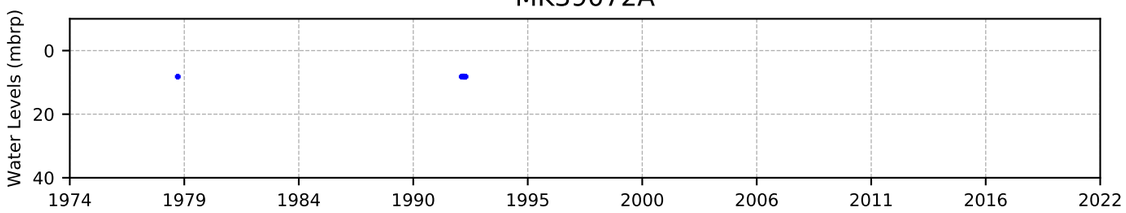
MK39072A



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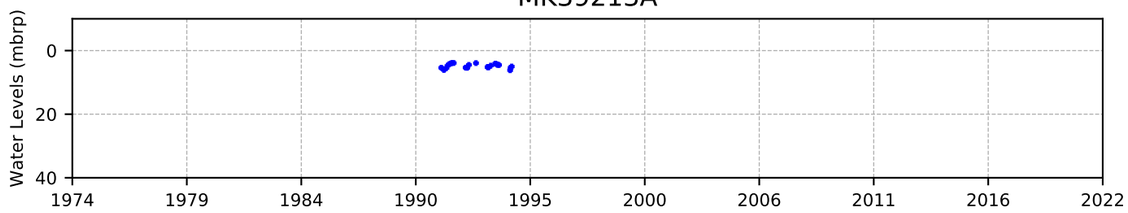

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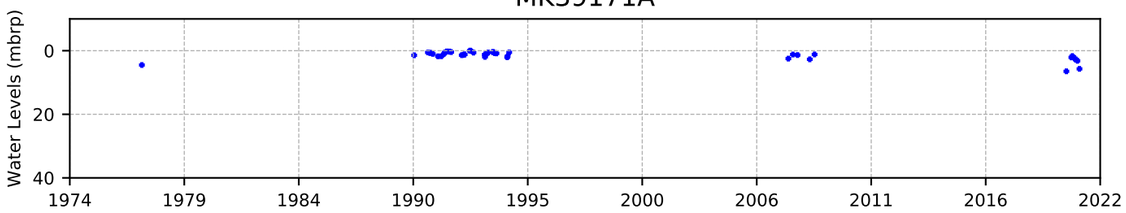
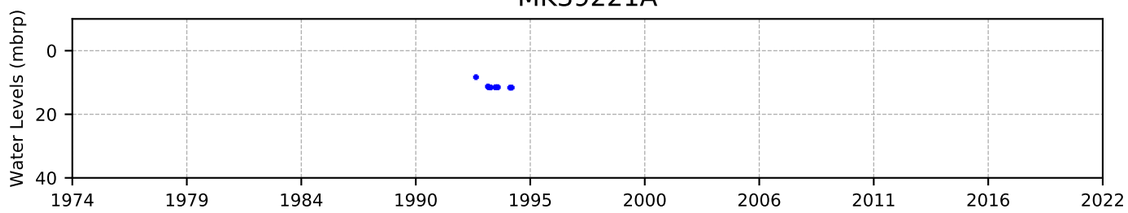


MK39221A



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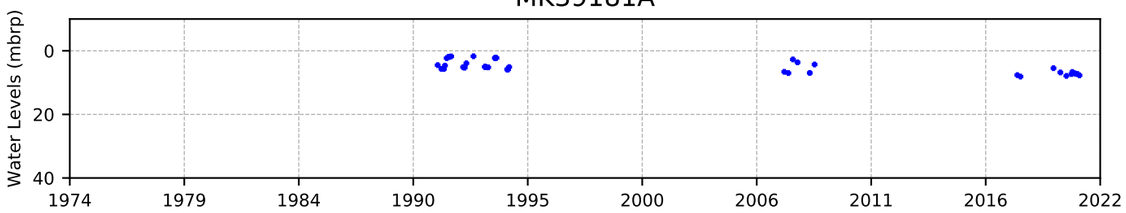

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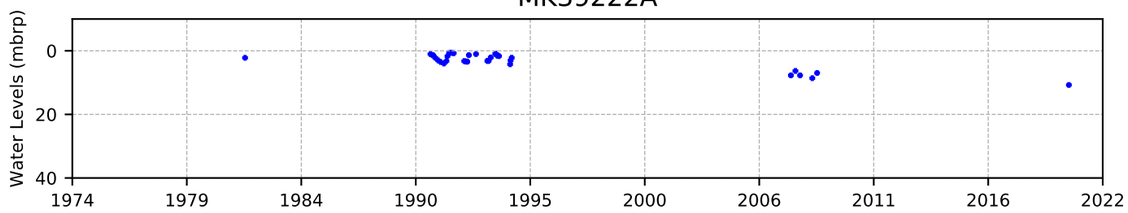

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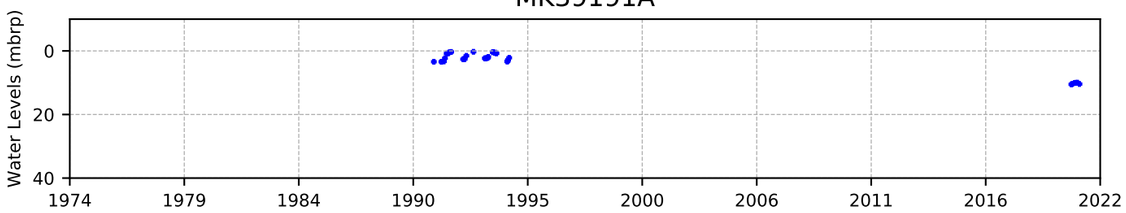

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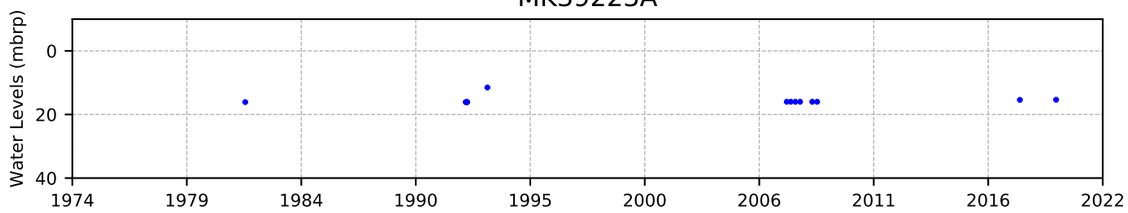

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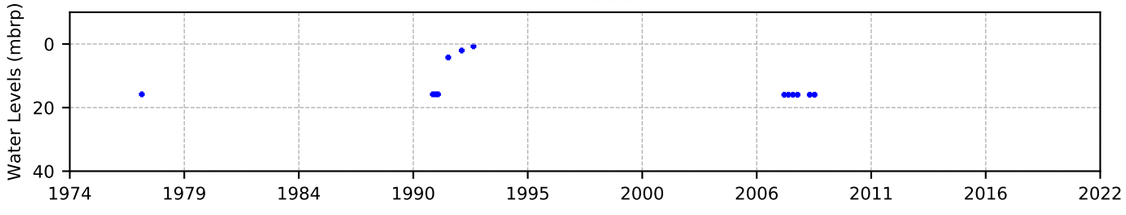

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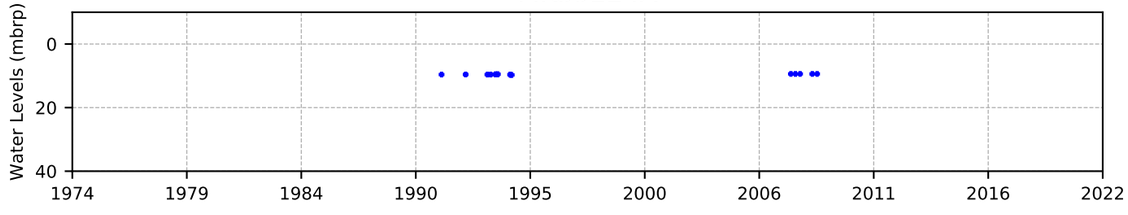

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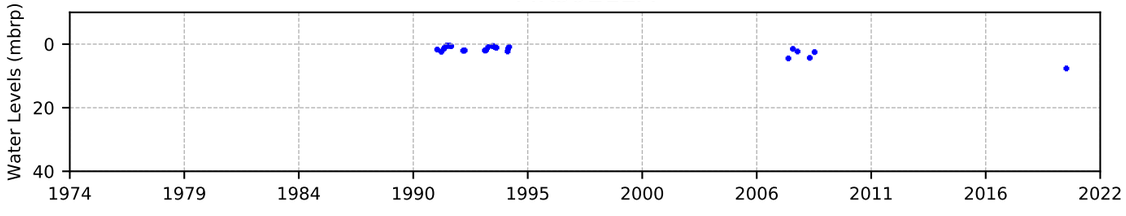

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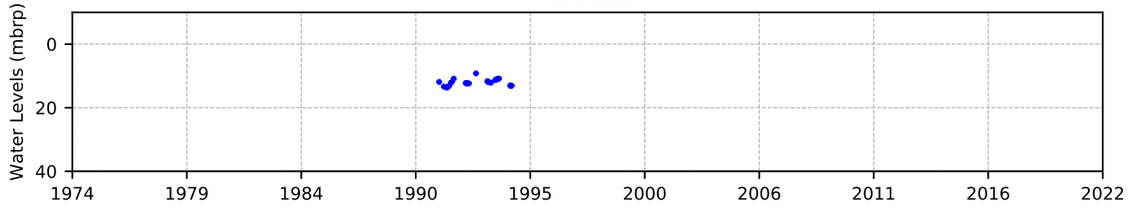

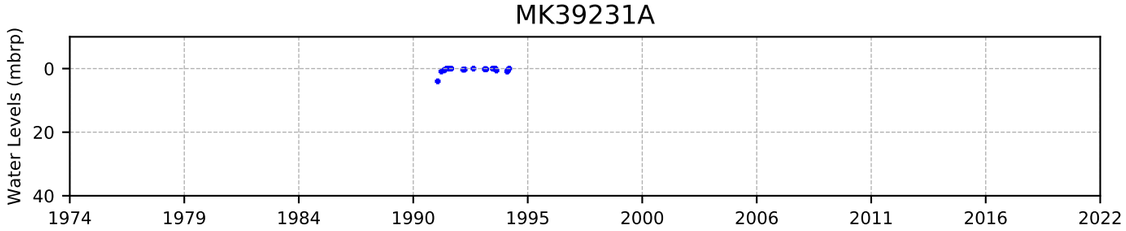
MK39231A
Water Levels (mbrp)
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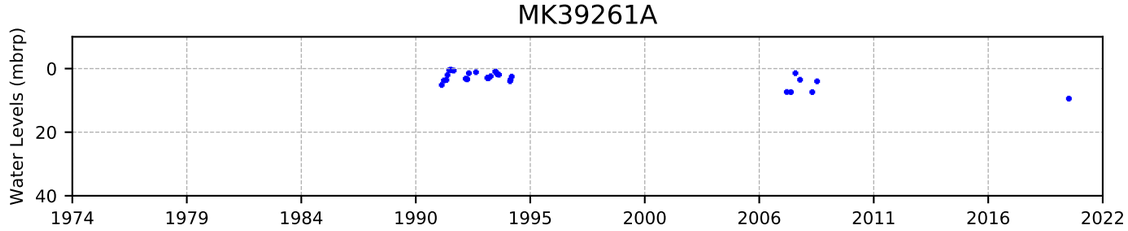
MK39261A
Water Levels (mbrp)
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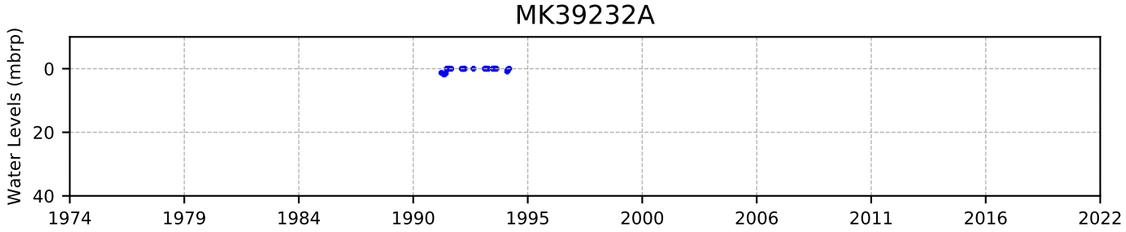
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Water Levels (mbrp)
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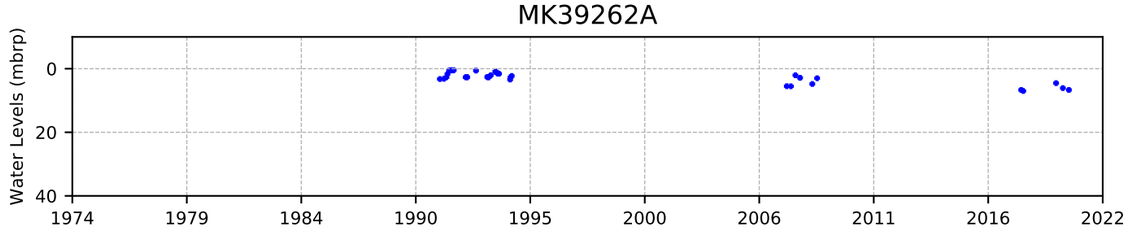
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Water Levels (mbrp)
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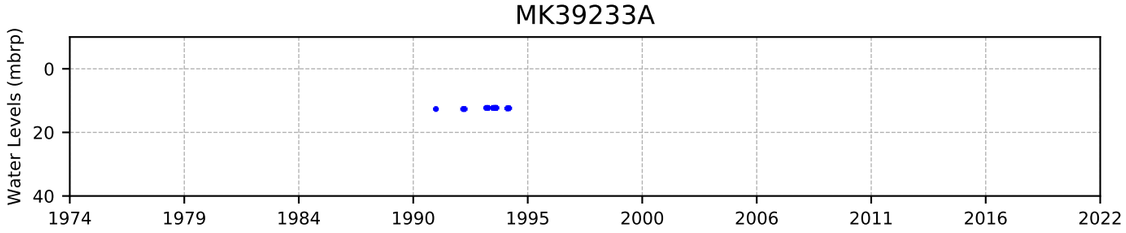
MK39233A
Water Levels (mbrp)
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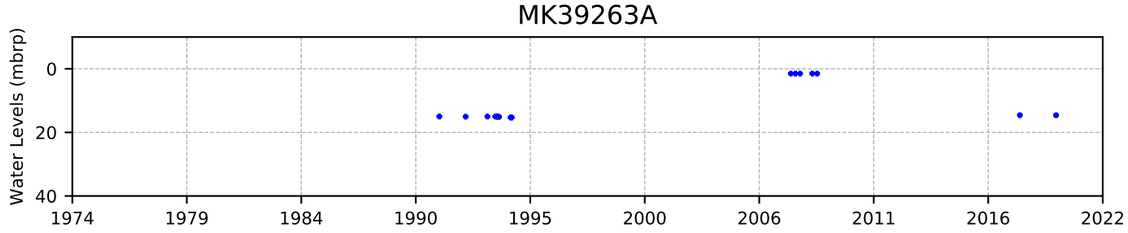
MK39263A
Water Levels (mbrp)
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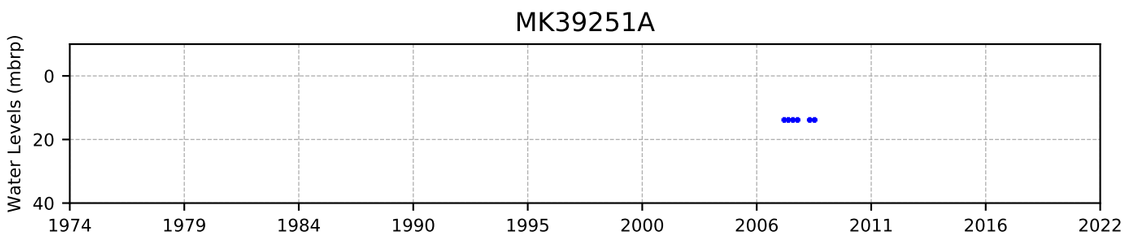
MK39251A
Water Levels (mbrp)
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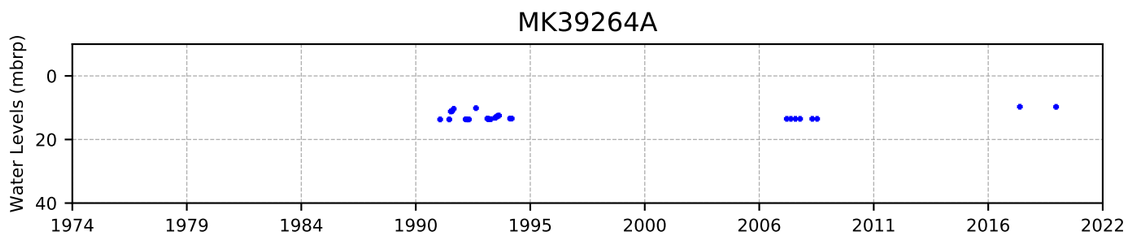
MK39264A
Water Levels (mbrp)
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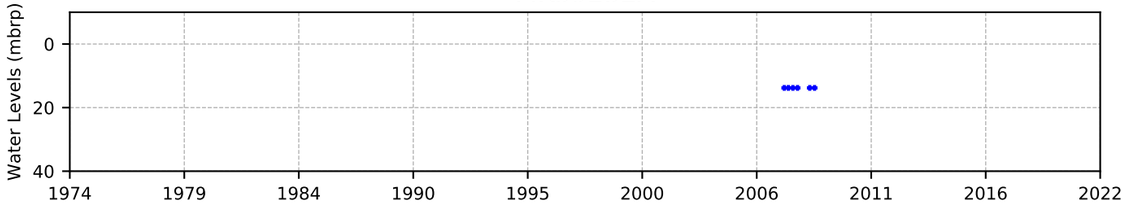
MK39252A
Water Levels (mbrp)
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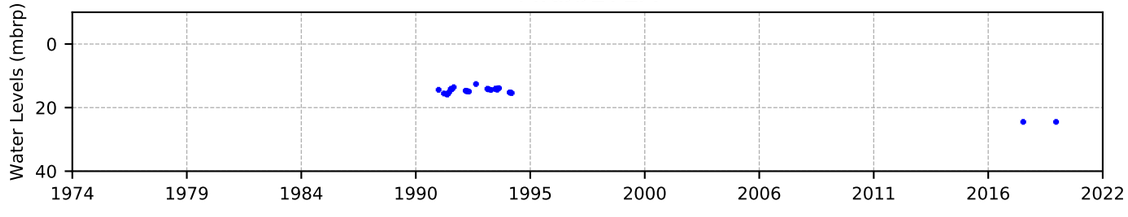
MK39272A
Water Levels (mbrp)
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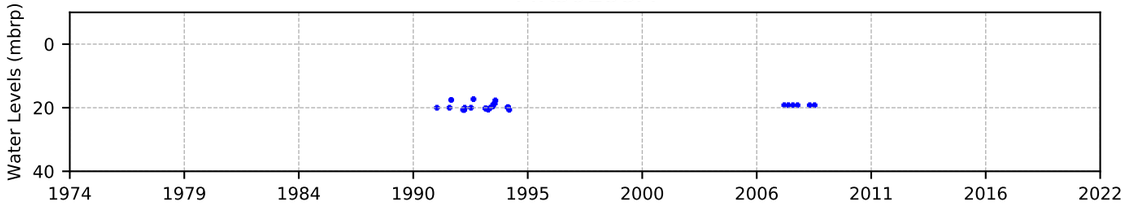
MK39253A
Water Levels (mbrp)
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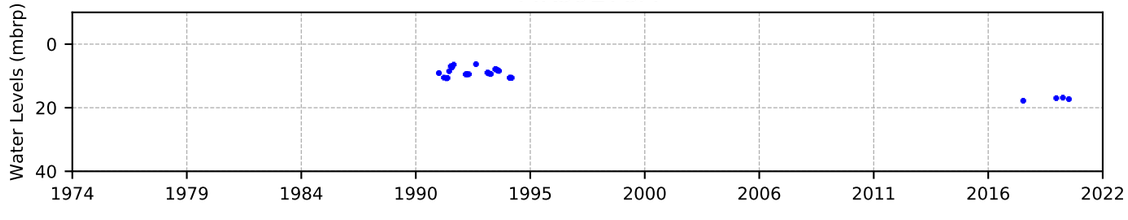
MK39273A
Water Levels (mbrp)
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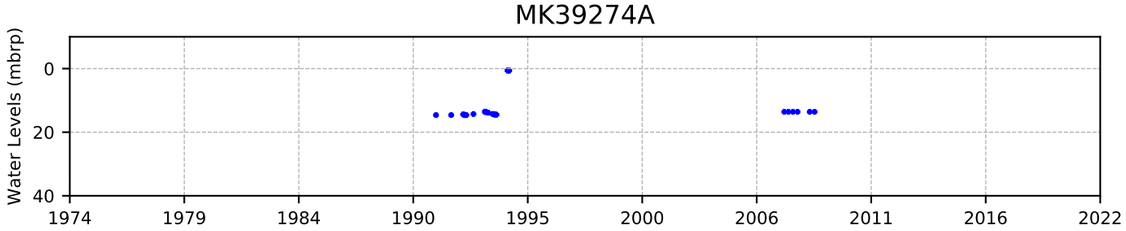
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Water Levels (mbrp)
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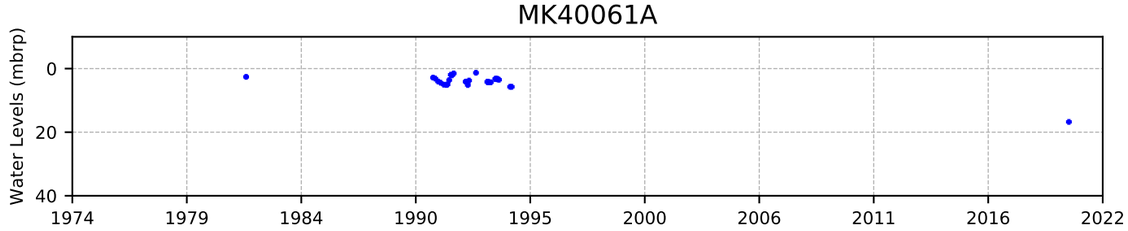
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Water Levels (mbrp)
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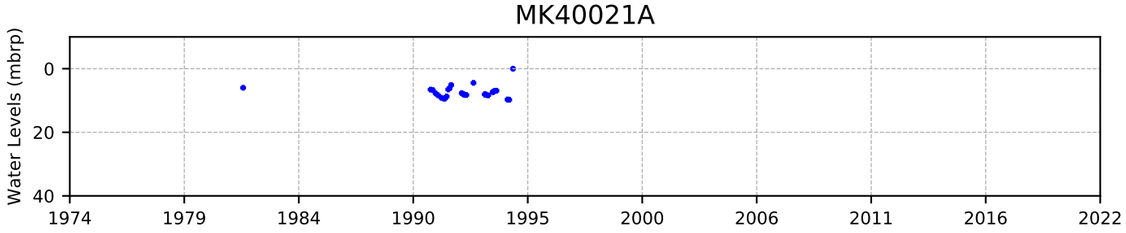
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Water Levels (mbrp)
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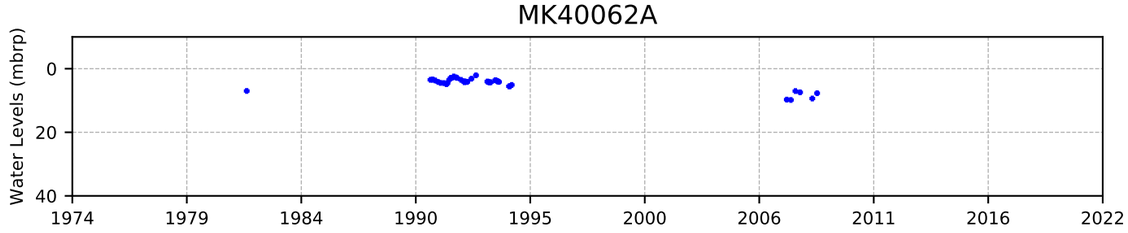
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Water Levels (mbrp)
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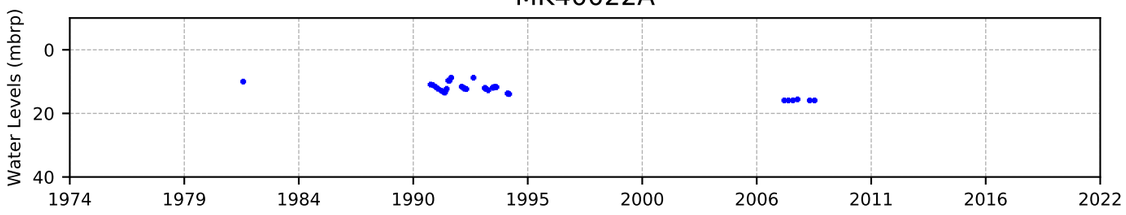
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Water Levels (mbrp)
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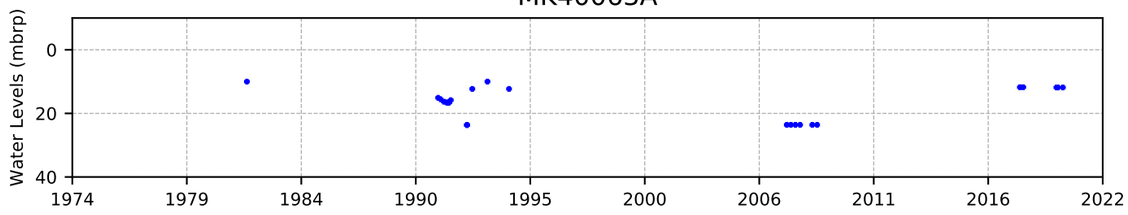
MK40063A
Water Levels (mbrp)
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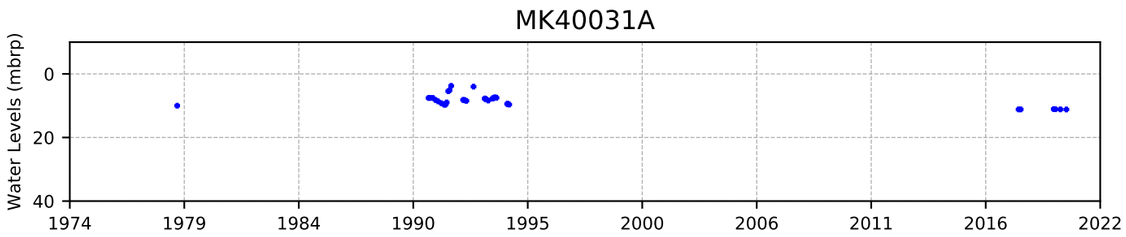
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Water Levels (mbrp)
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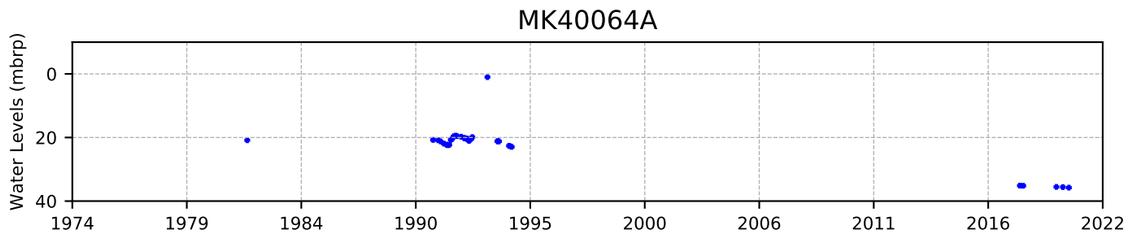
MK40064A
Water Levels (mbrp)
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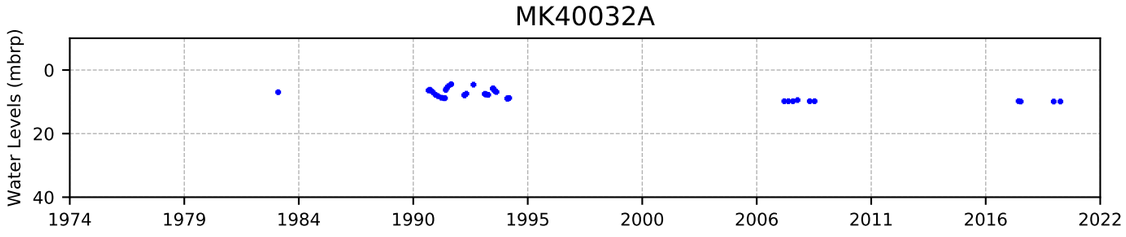
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Water Levels (mbrp)
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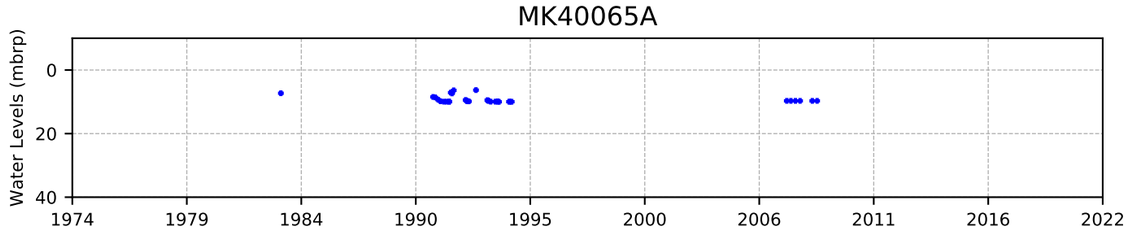
MK40065A
Water Levels (mbrp)
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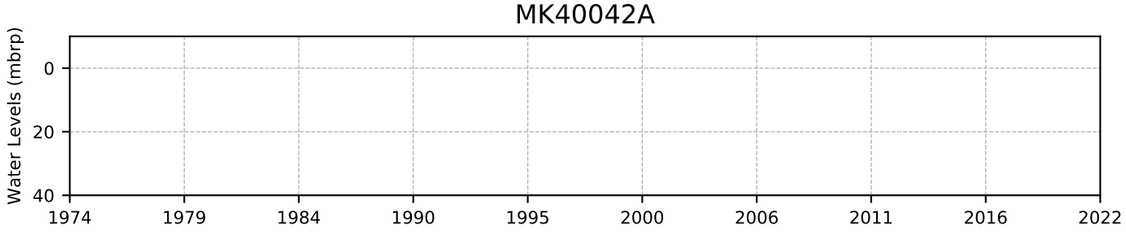
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Water Levels (mbrp)
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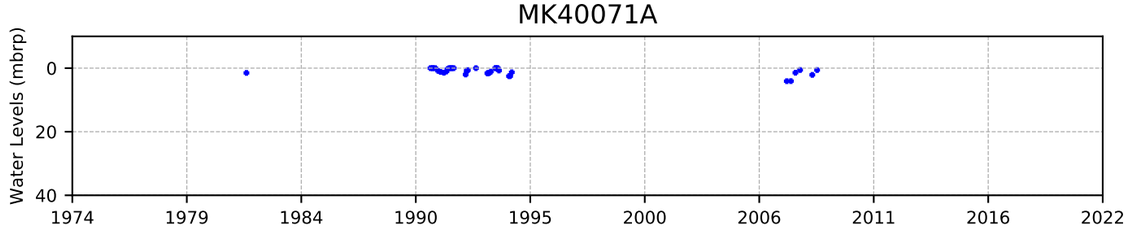
MK40071A
Water Levels (mbrp)
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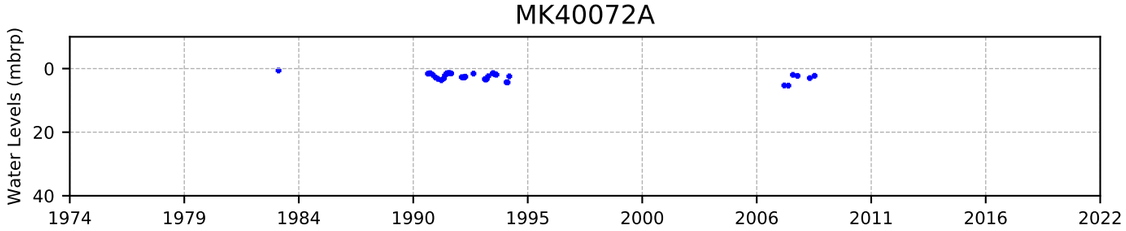
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Water Levels (mbrp)
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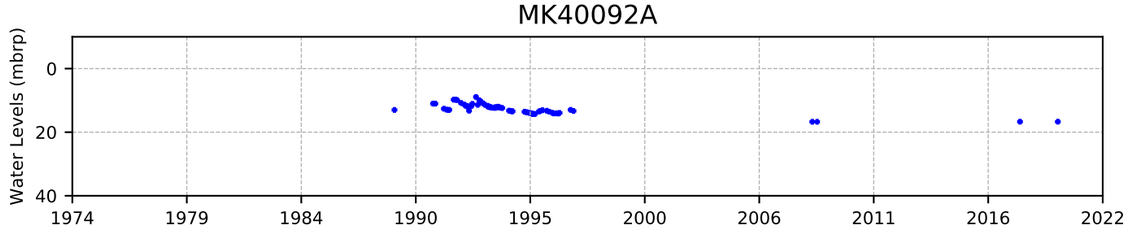
MK40092A
Water Levels (mbrp)
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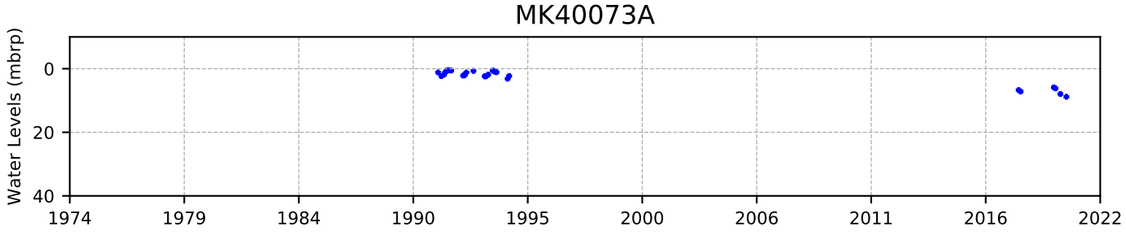
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Water Levels (mbrp)
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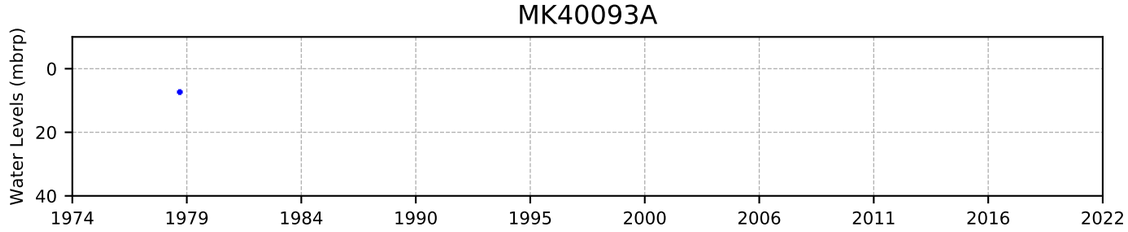
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Water Levels (mbrp)
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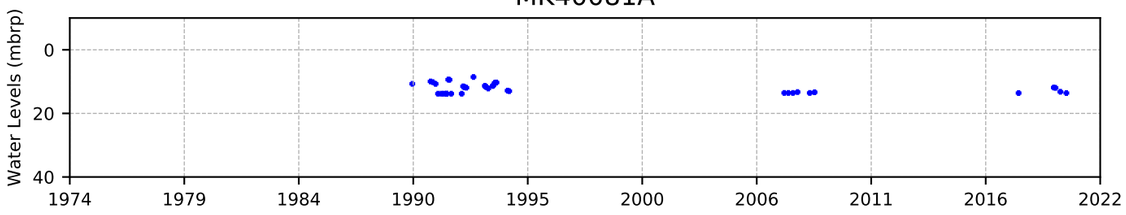
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Water Levels (mbrp)
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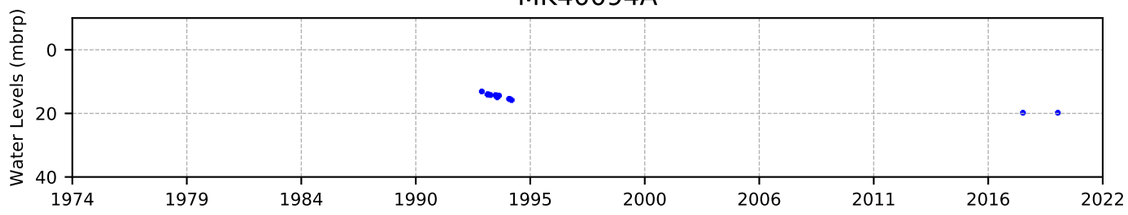
MK40094A
Water Levels (mbrp)
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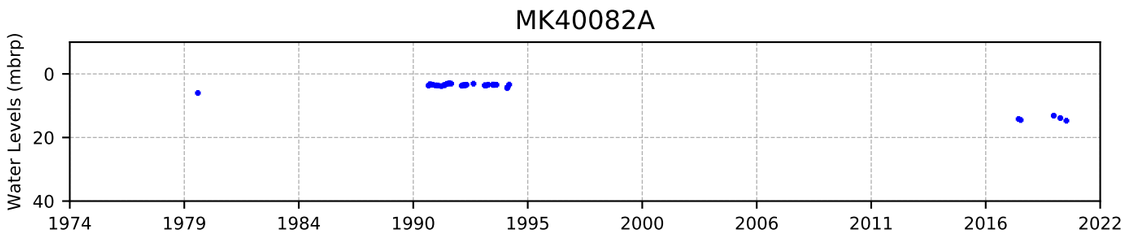
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Water Levels (mbrp)
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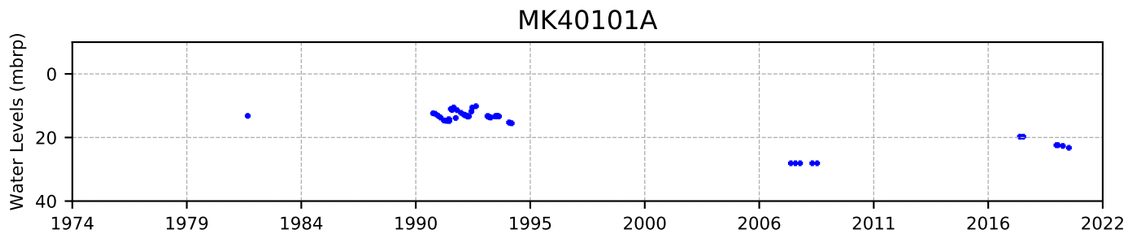
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Water Levels (mbrp)
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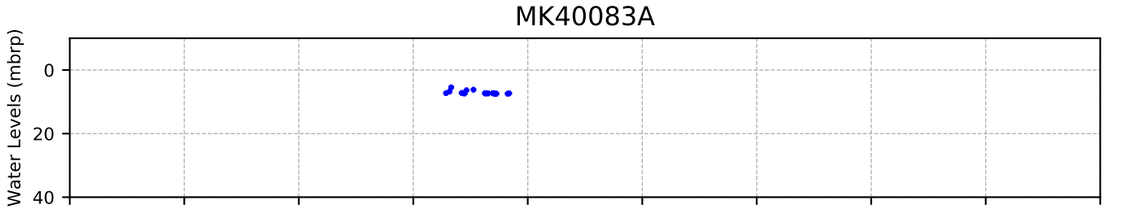
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Water Levels (mbrp)
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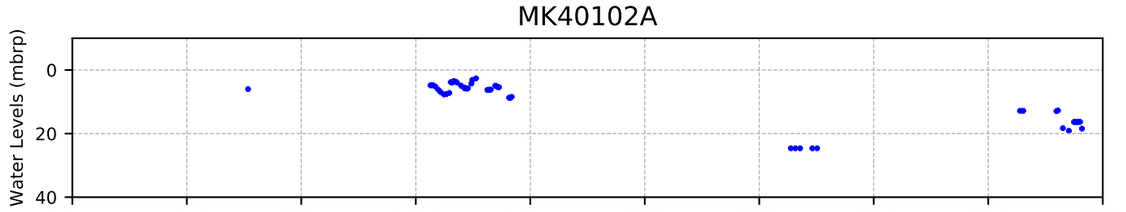
MK40102A
Water Levels (mbrp)
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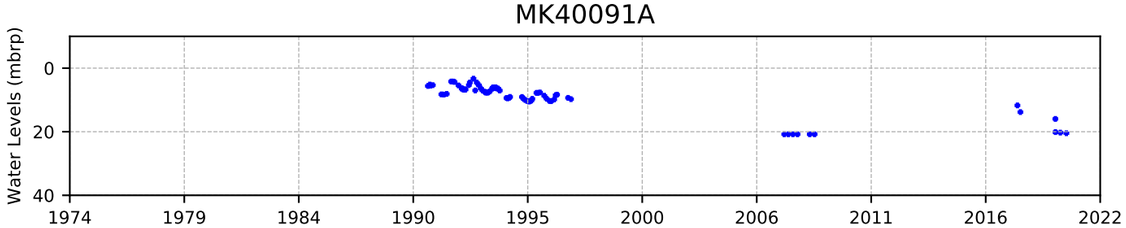
MK40091A
Water Levels (mbrp)
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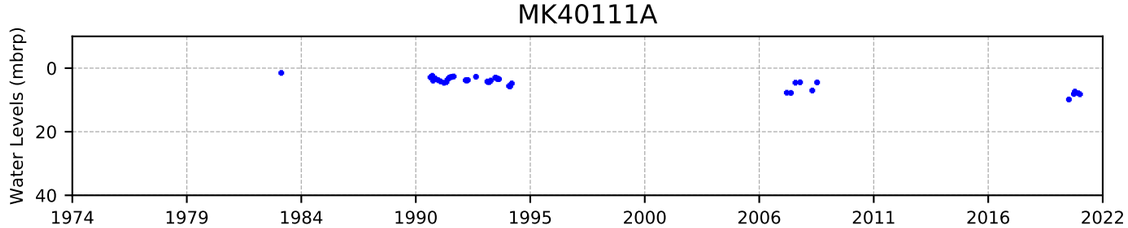
MK40111A
Water Levels (mbrp)
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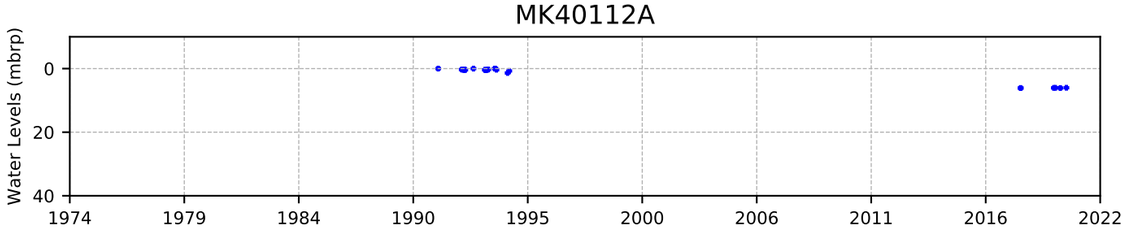
MK40112A



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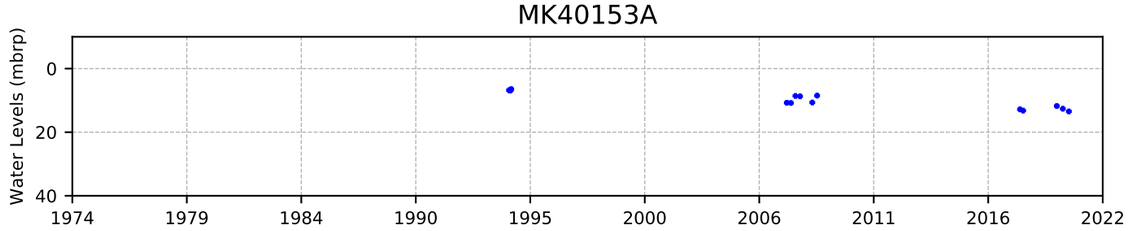

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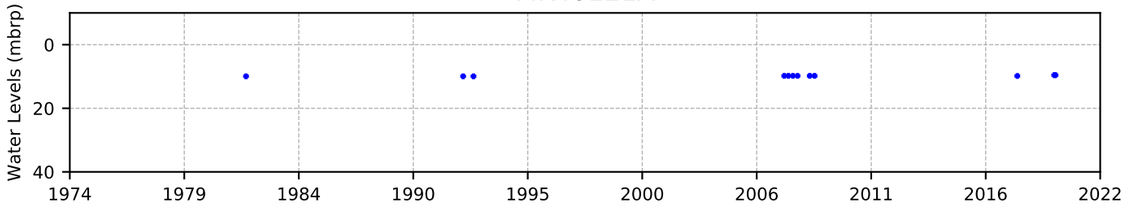
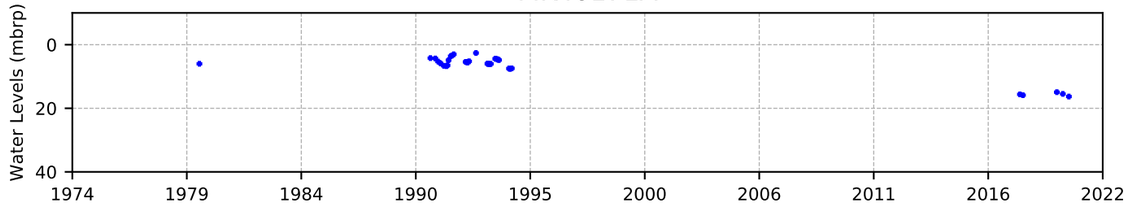


MK40171A



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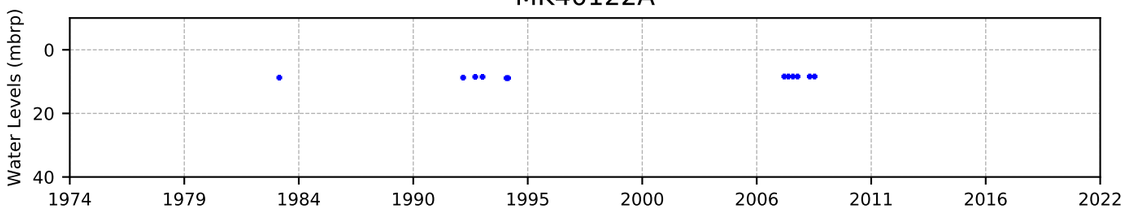

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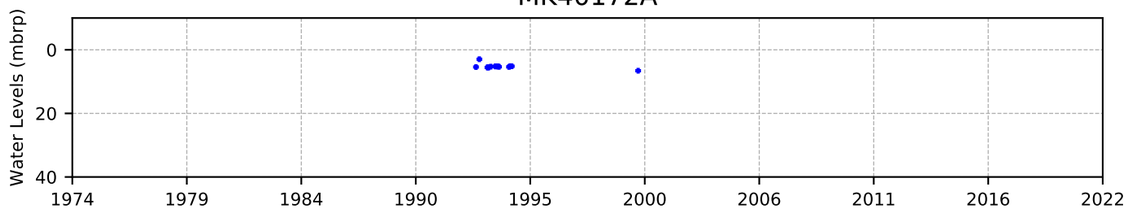

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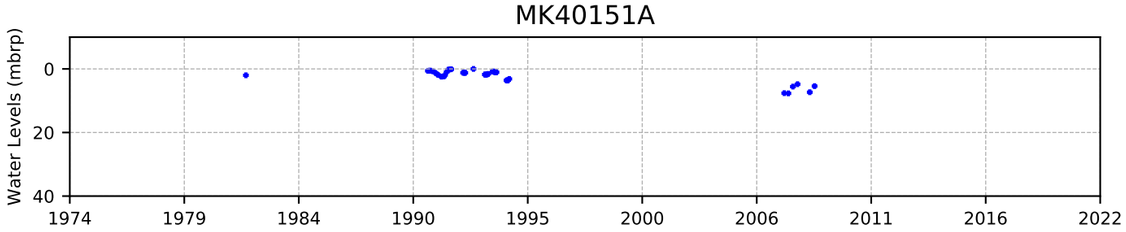

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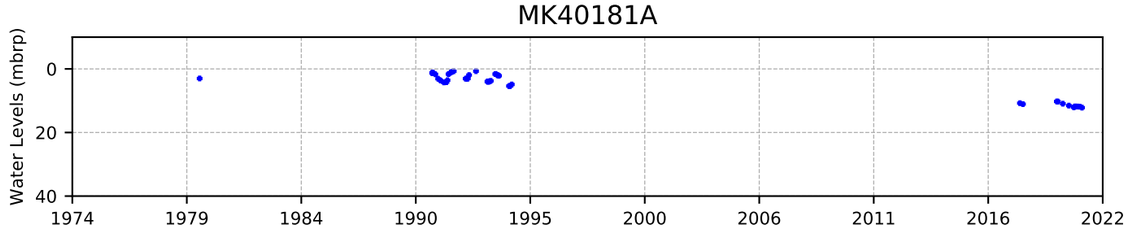

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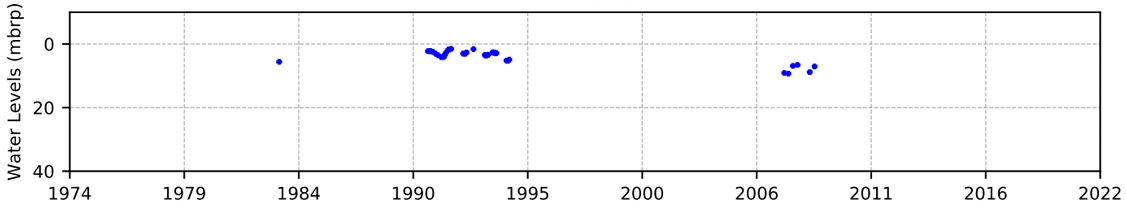

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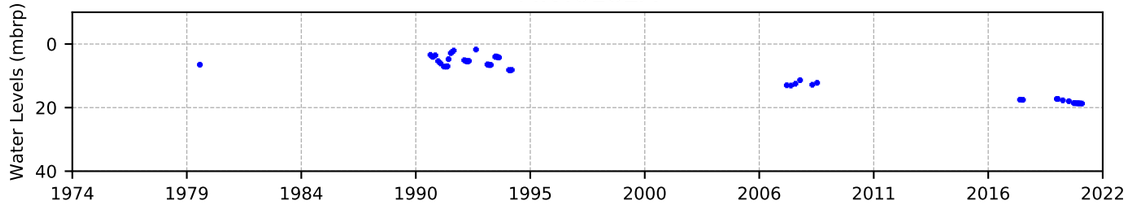

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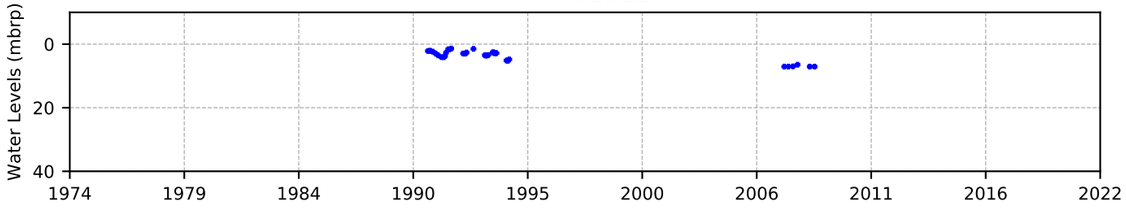

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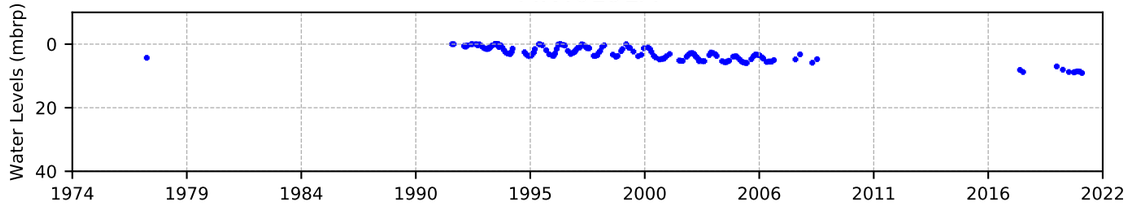

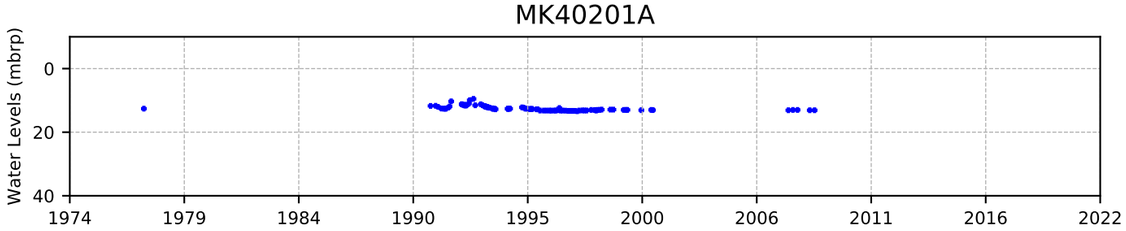
MK40201A
Water Levels (mbrp)
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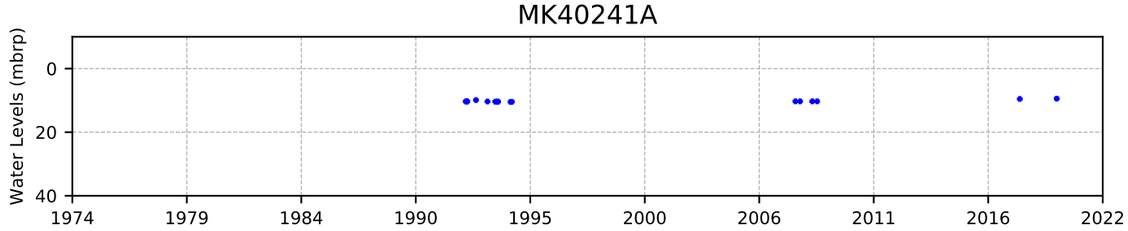
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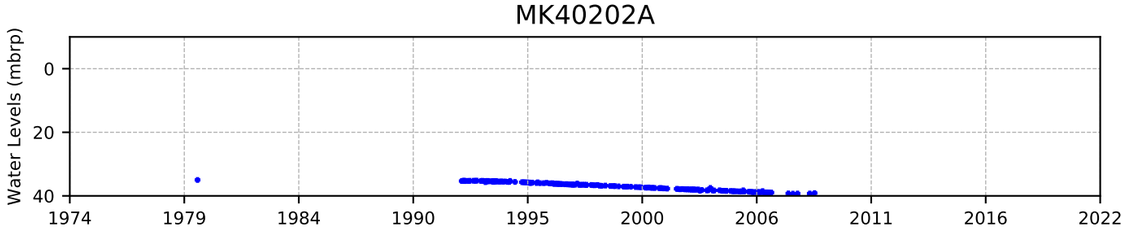
MK40202A
Water Levels (mbrp)
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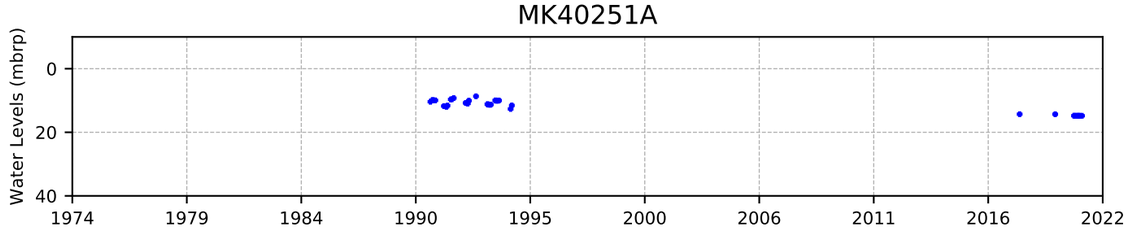
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Water Levels (mbrp)
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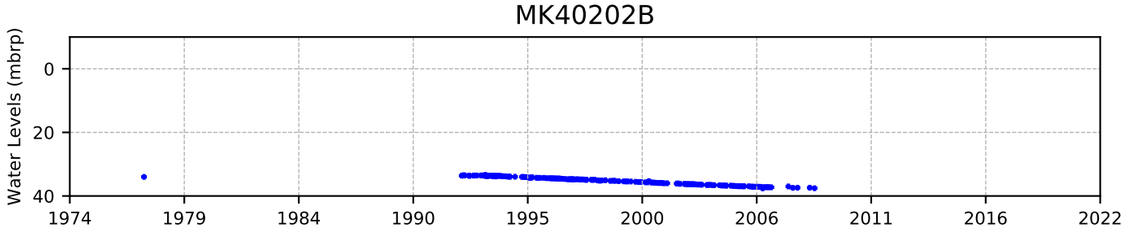
MK40202B
Water Levels (mbrp)
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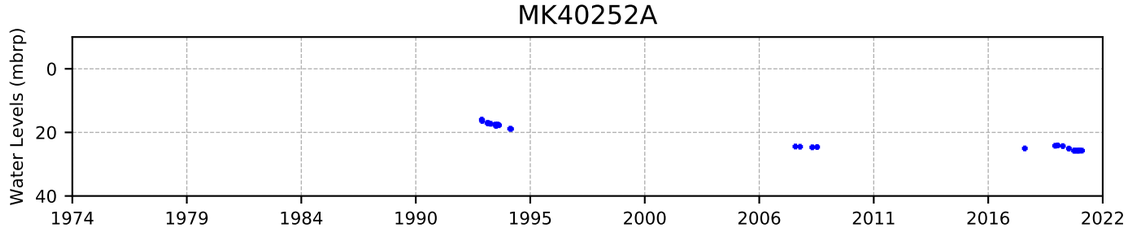
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Water Levels (mbrp)
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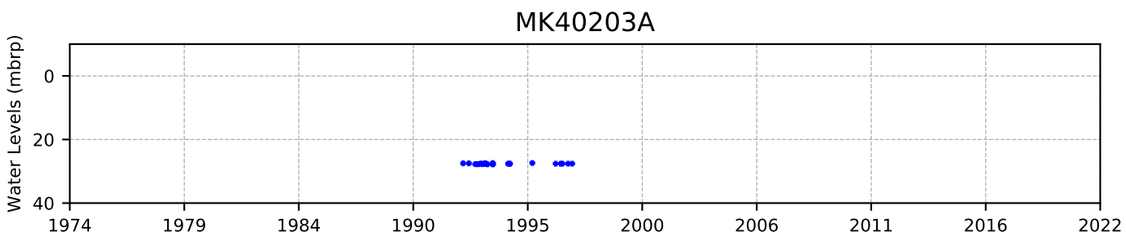
MK40203A
Water Levels (mbrp)
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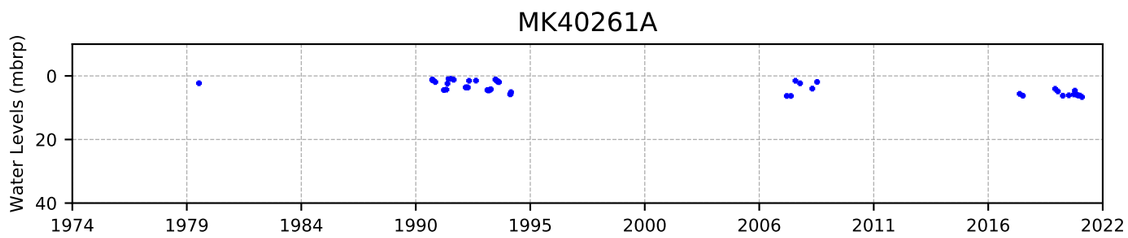
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Water Levels (mbrp)
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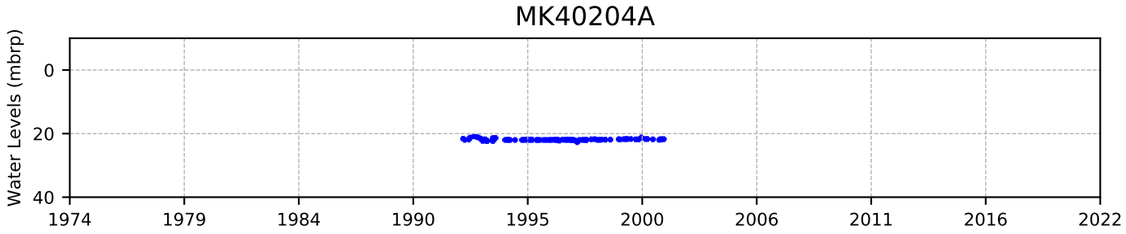
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Water Levels (mbrp)
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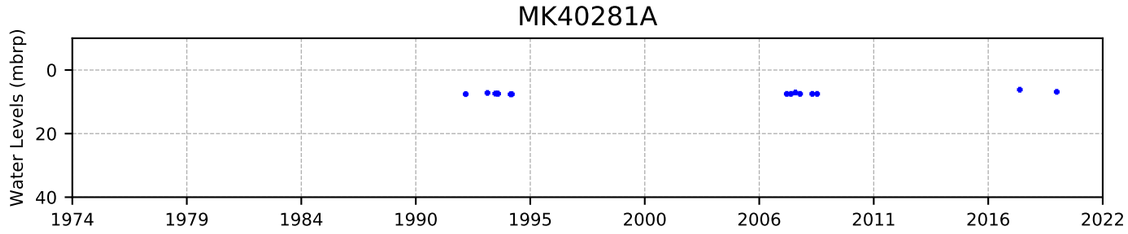
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Water Levels (mbrp)
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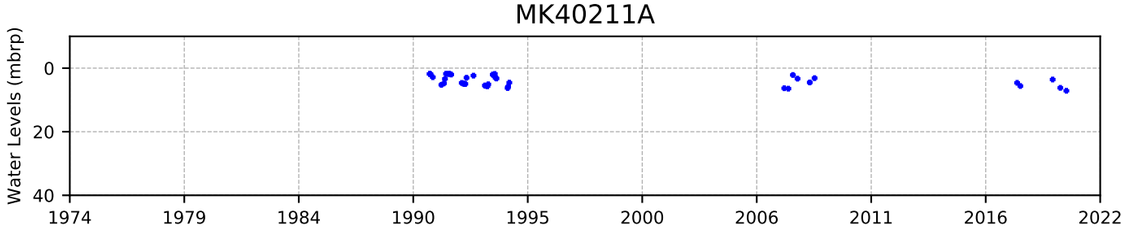
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Water Levels (mbrp)
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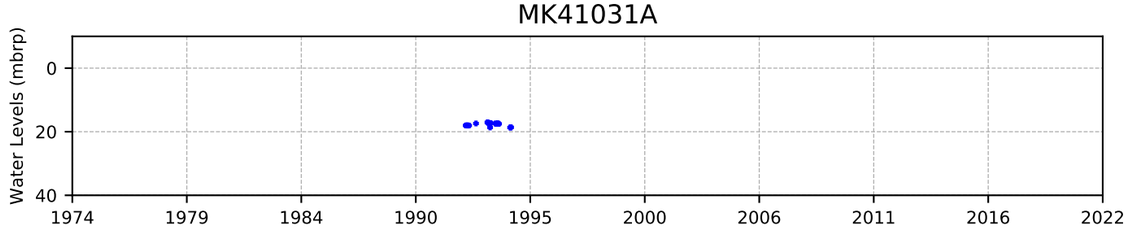
MK41031A
Water Levels (mbrp)
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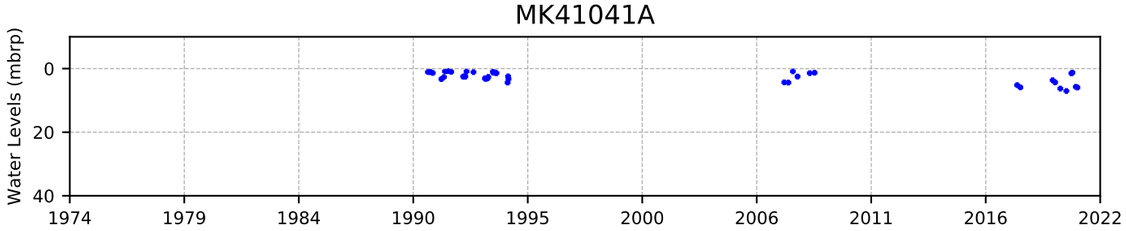
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Water Levels (mbrp)
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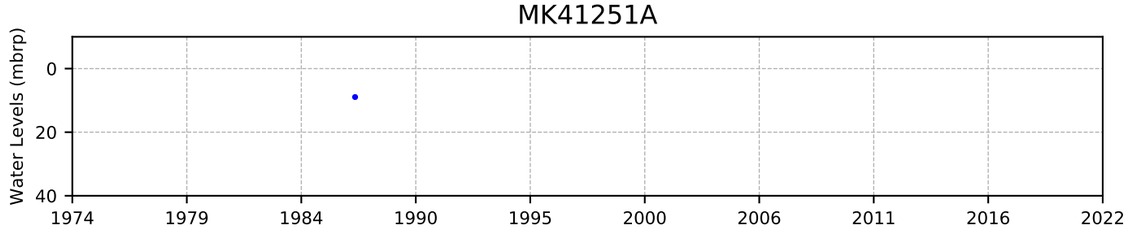
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Water Levels (mbrp)
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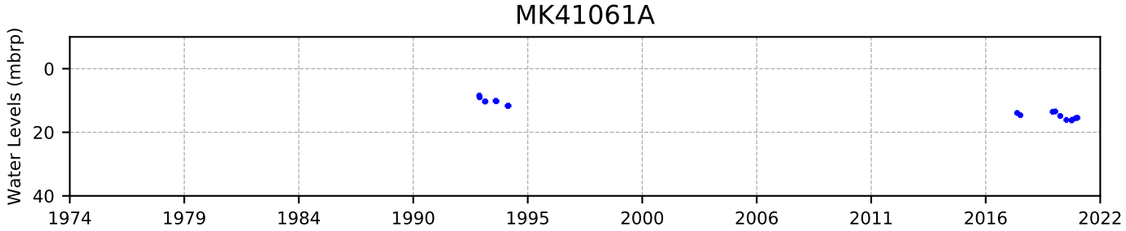
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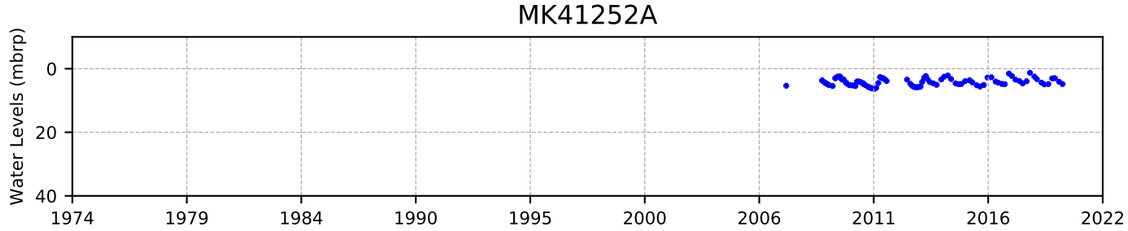
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Water Levels (mbrp)
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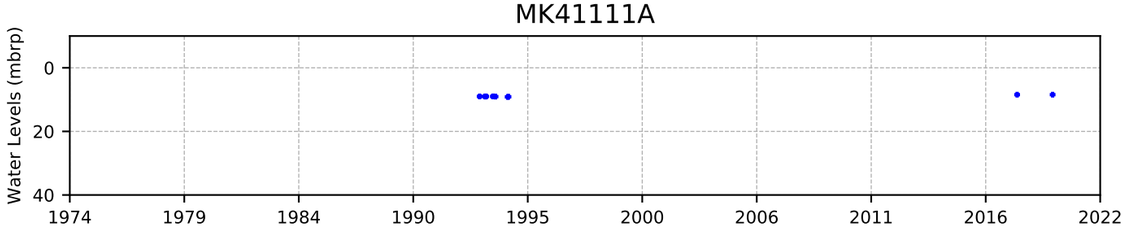
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Water Levels (mbrp)
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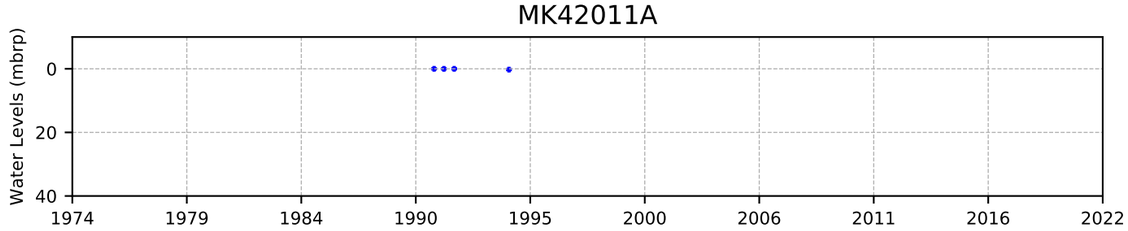
MK42011A
Water Levels (mbrp)
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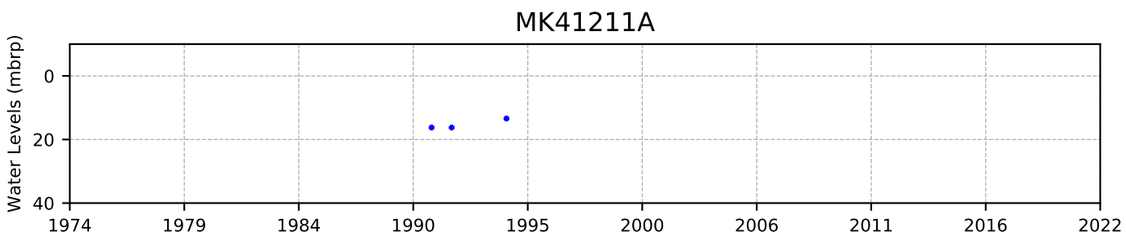
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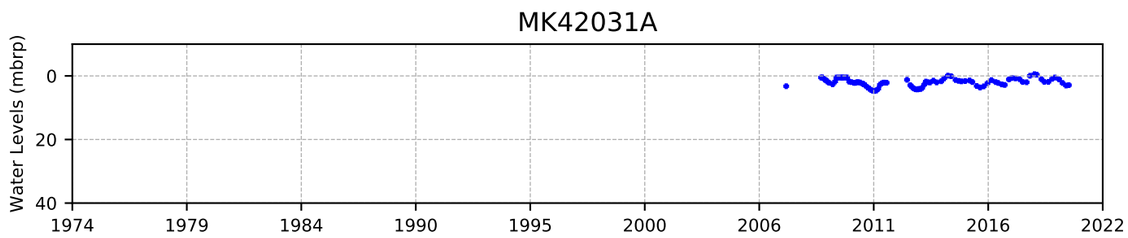
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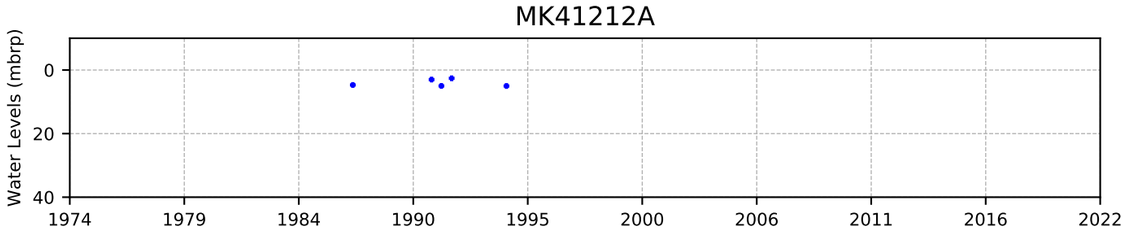
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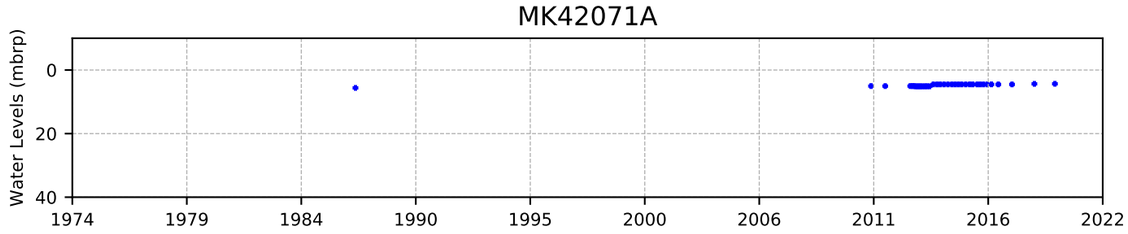
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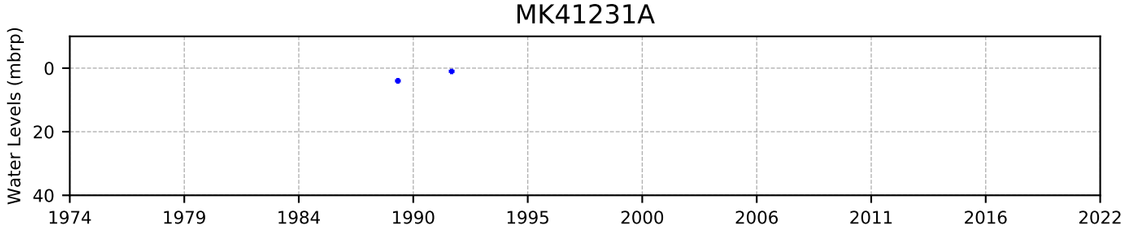
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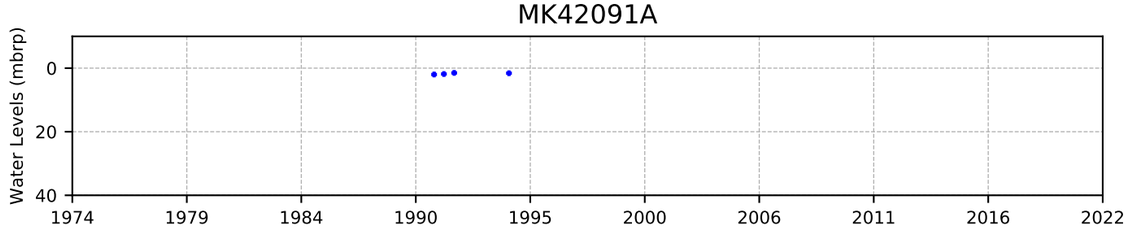
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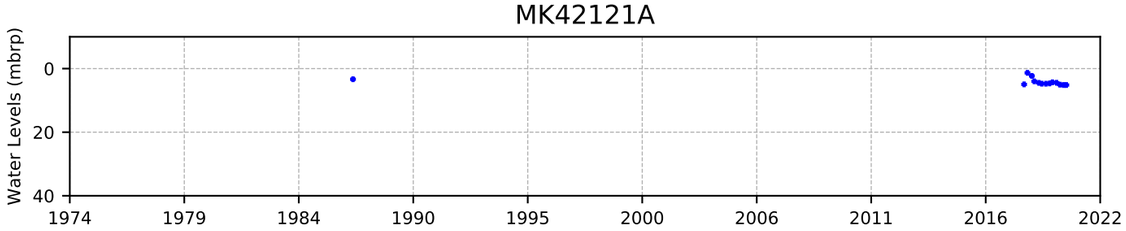
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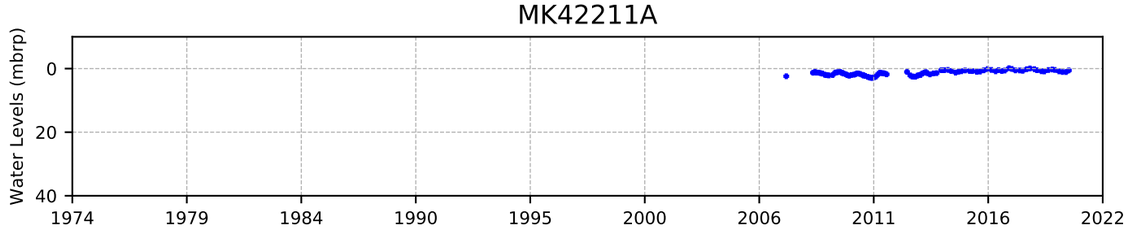
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Water Levels (mbrp)
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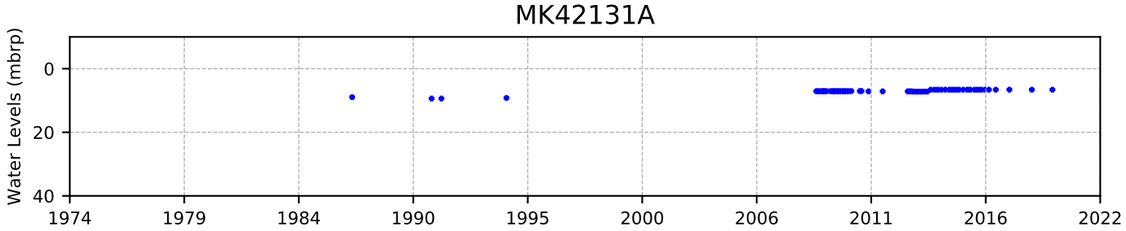
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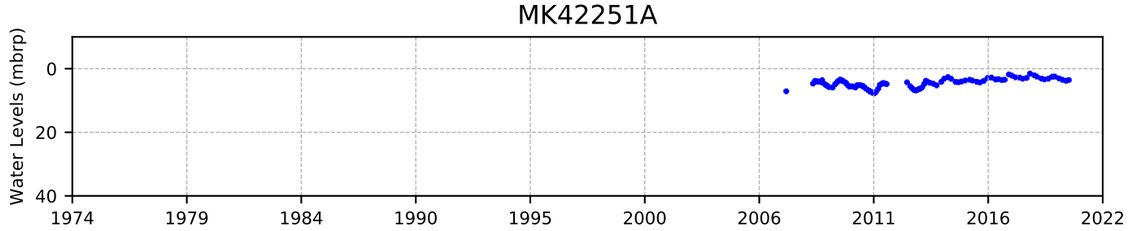
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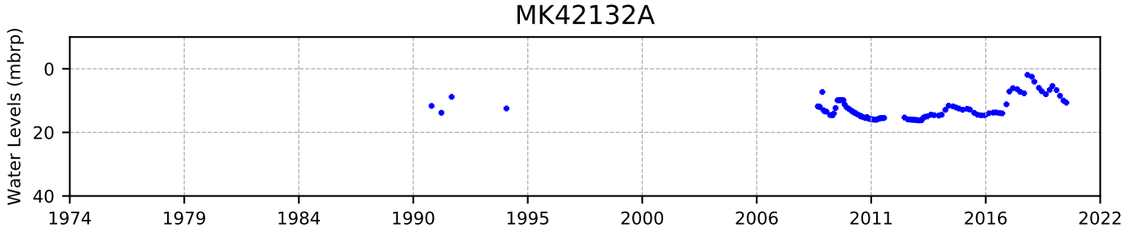
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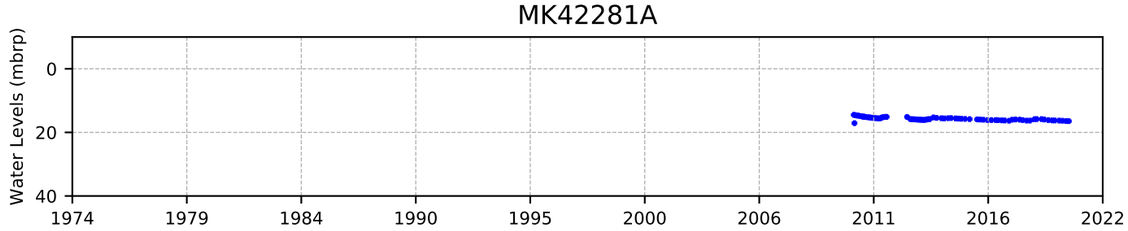
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Water Levels (mbrp)
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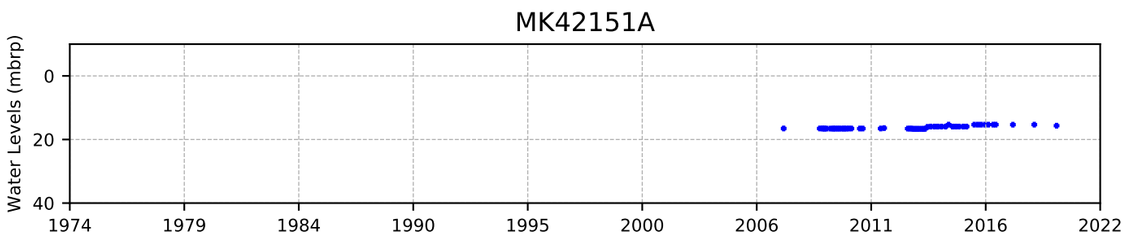
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Water Levels (mbrp)
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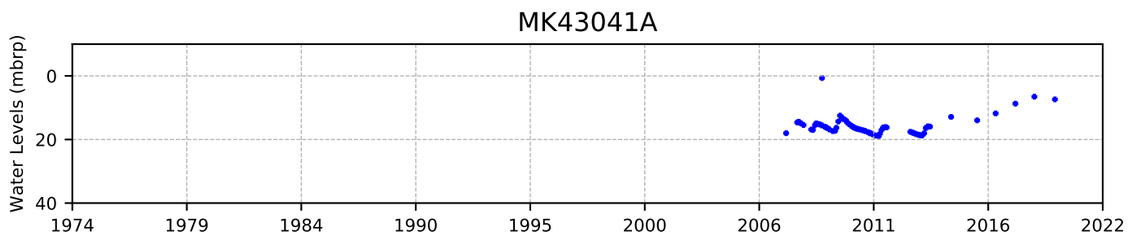
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Water Levels (mbrp)
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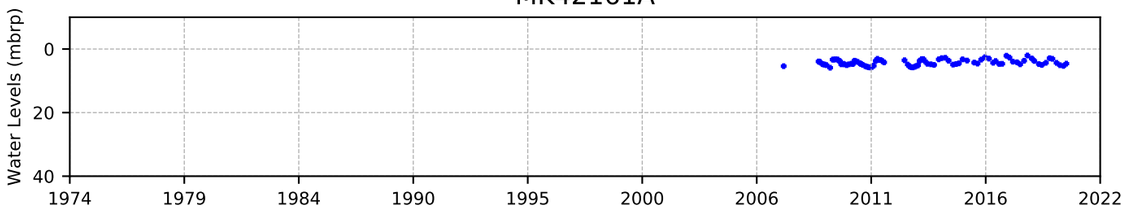
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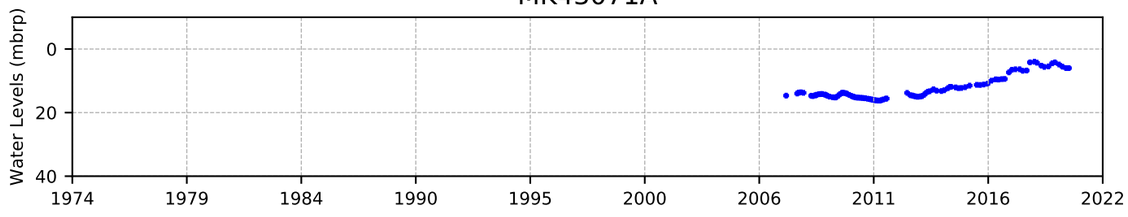
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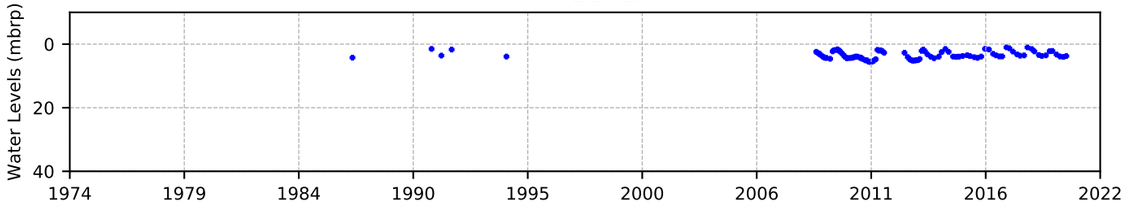
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Water Levels (mbrp)
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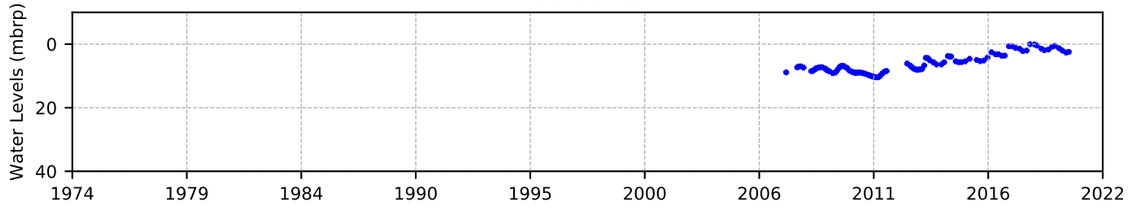
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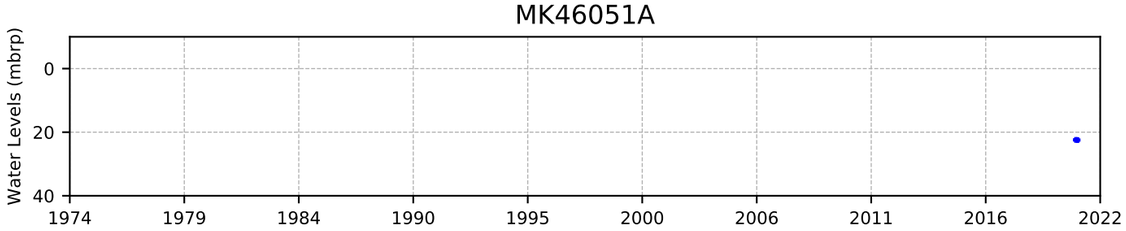
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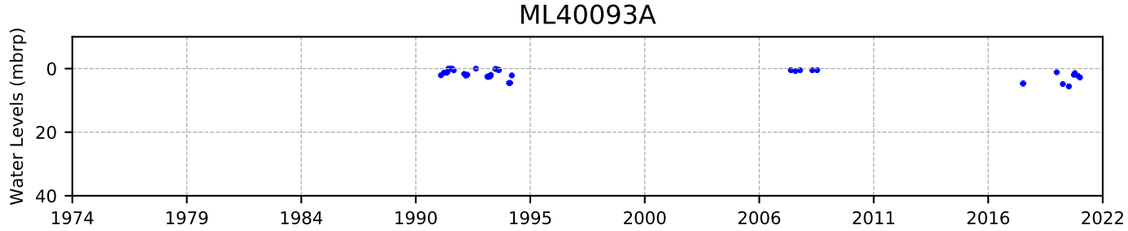
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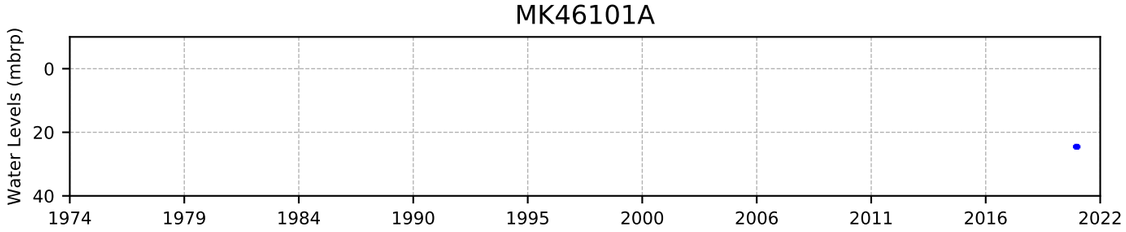
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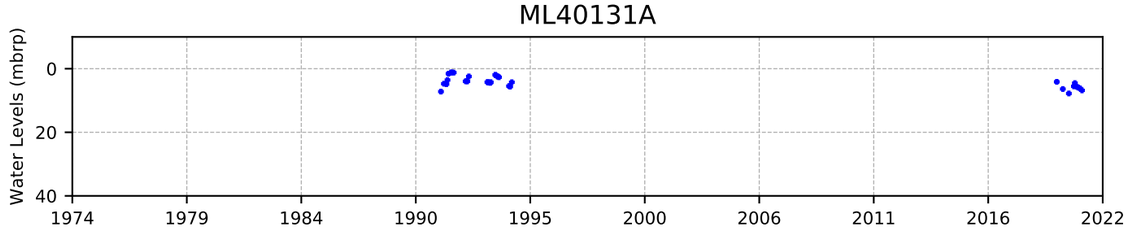
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Water Levels (mbrp)
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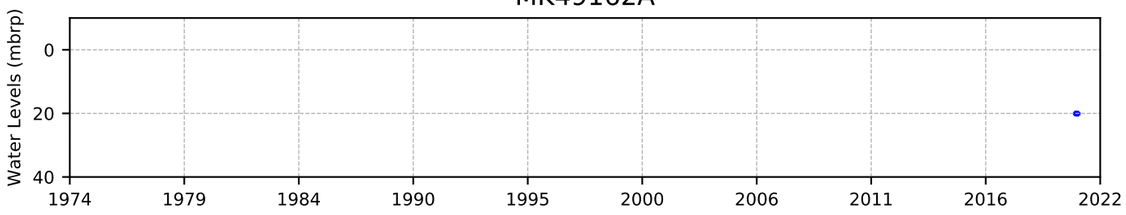
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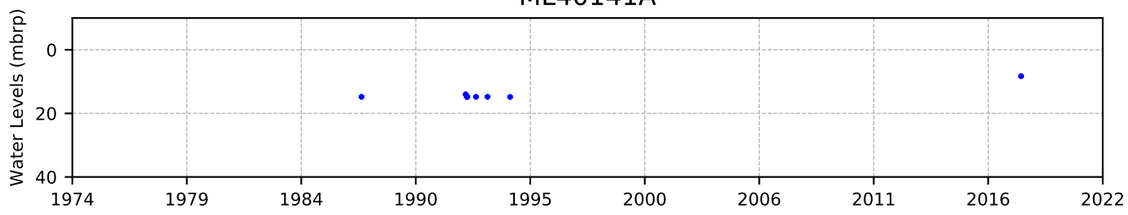
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Water Levels (mbrp)
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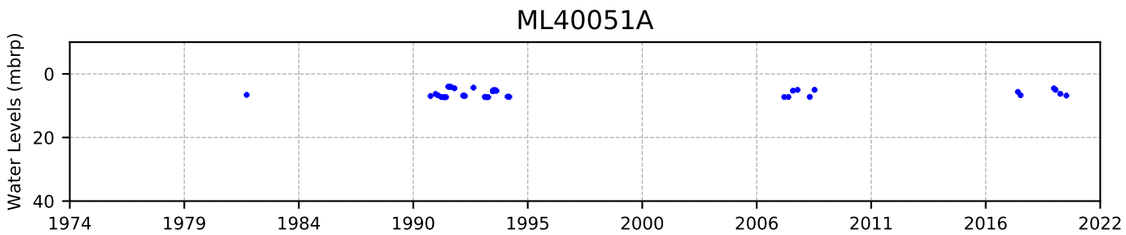
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Water Levels (mbrp)
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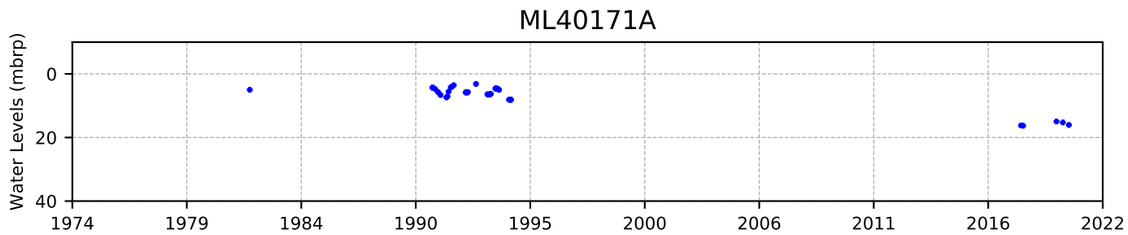
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Water Levels (mbrp)
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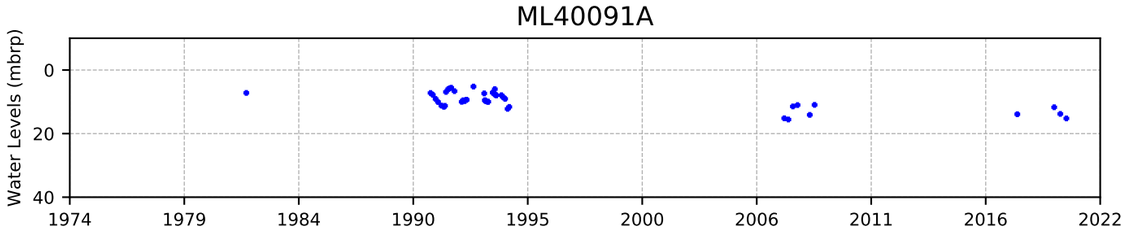
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Water Levels (mbrp)
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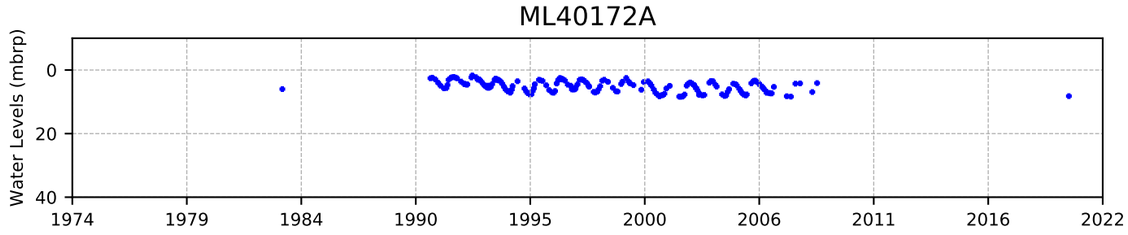
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Water Levels (mbrp)
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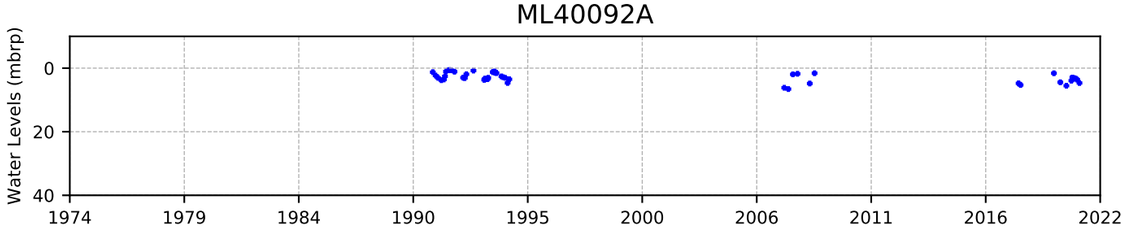
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Water Levels (mbrp)
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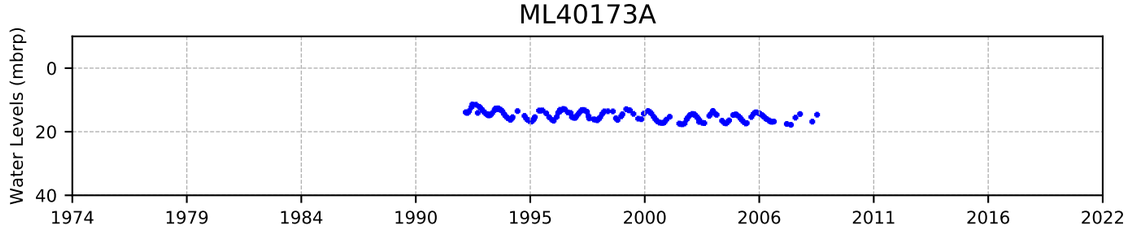
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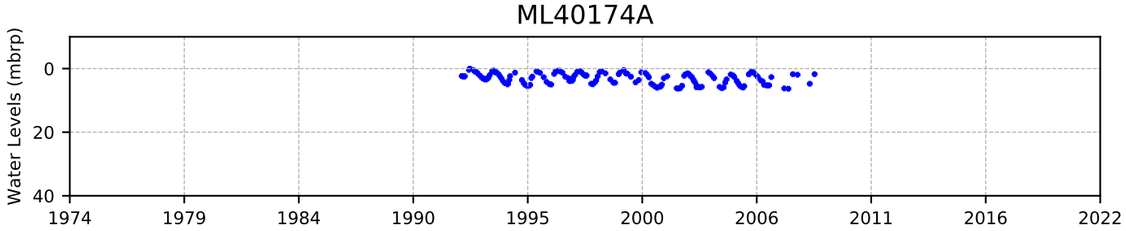
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Water Levels (mbrp)
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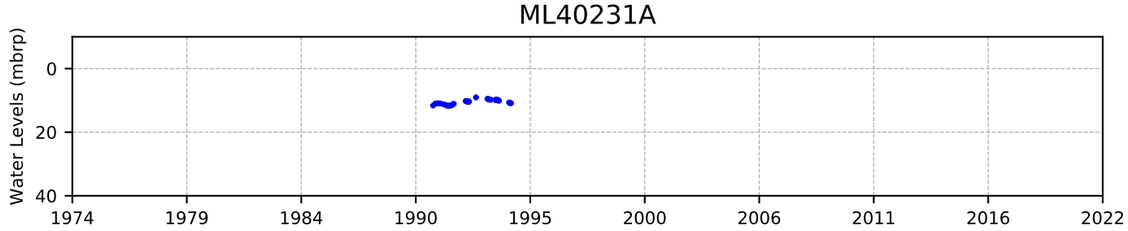
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Water Levels (mbrp)
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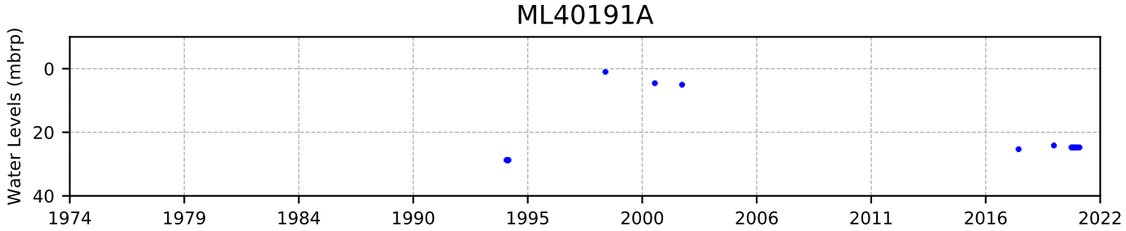
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Water Levels (mbrp)
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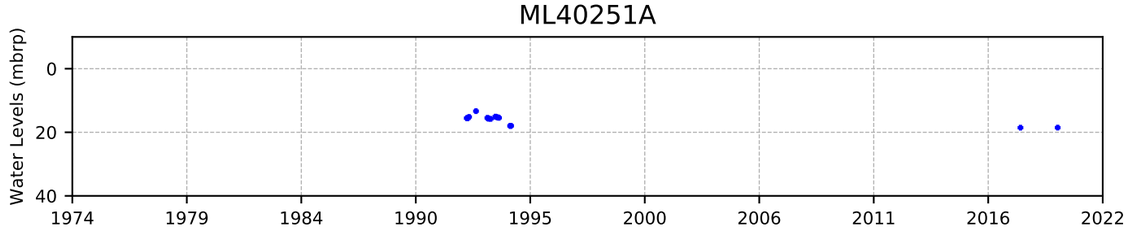
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Water Levels (mbrp)
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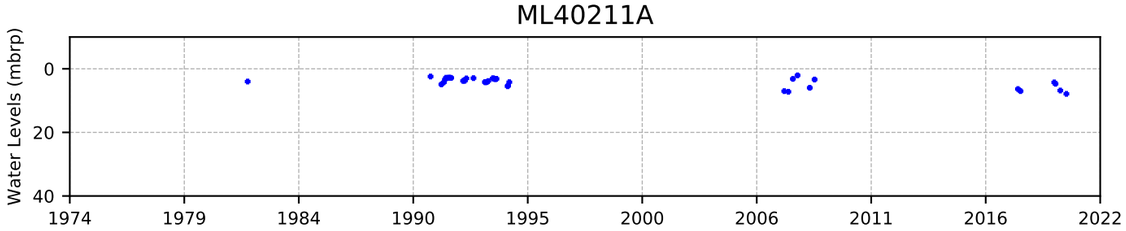
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Water Levels (mbrp)
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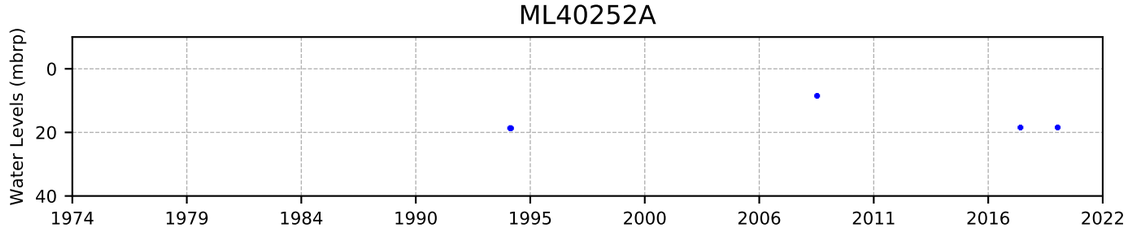
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Water Levels (mbrp)
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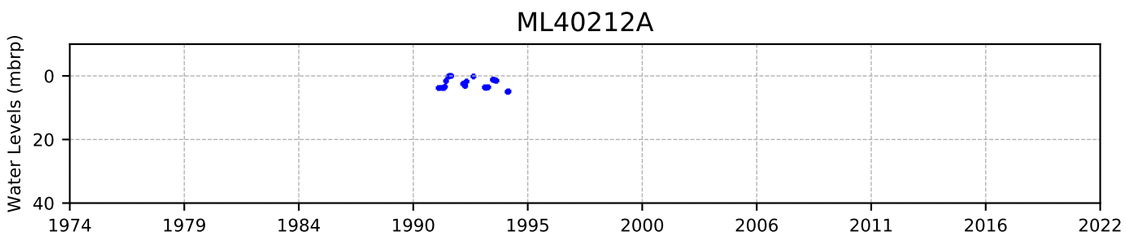
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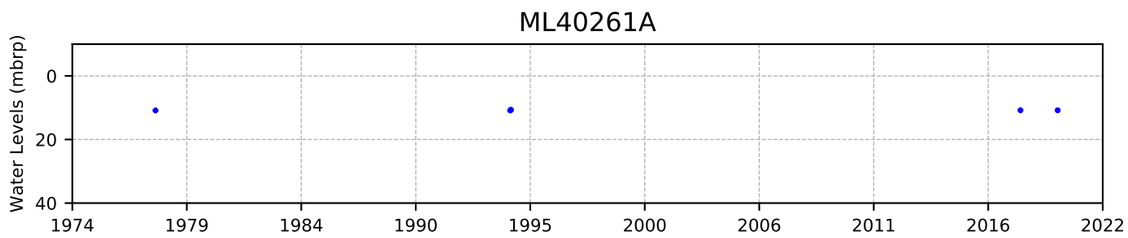
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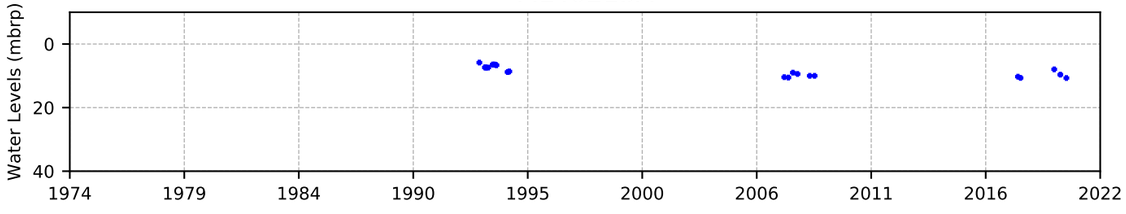
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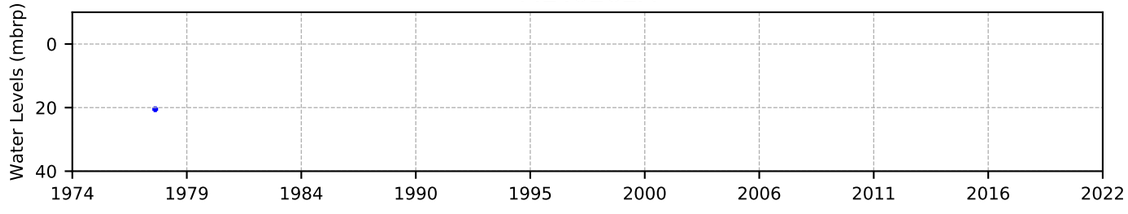
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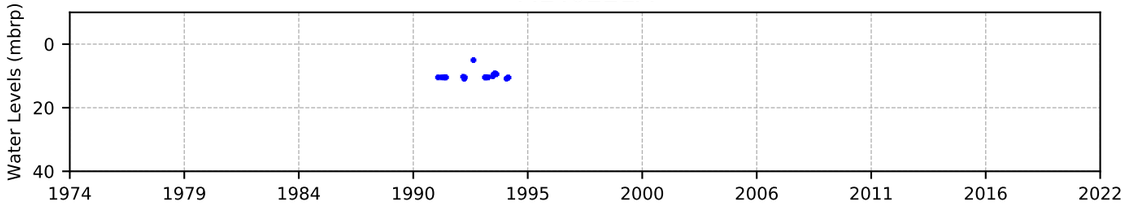
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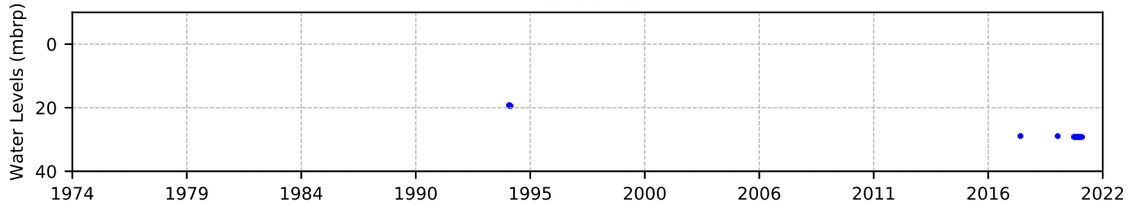
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Water Levels (mbrp)
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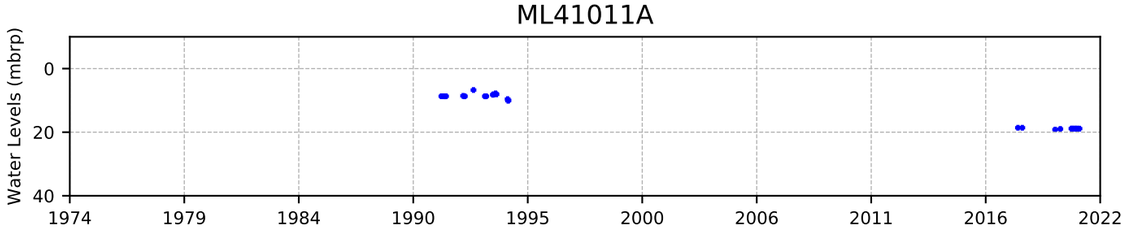
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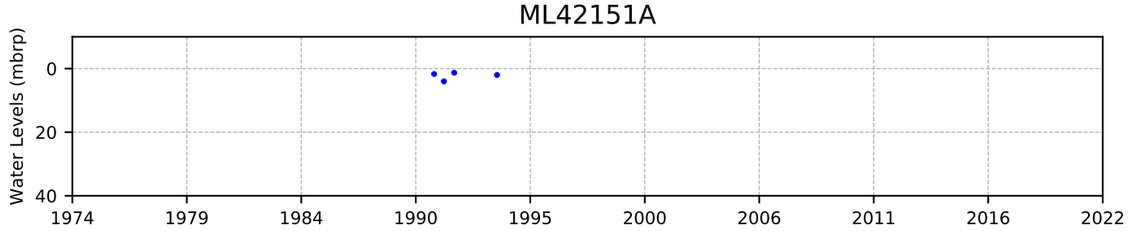
ML42151A
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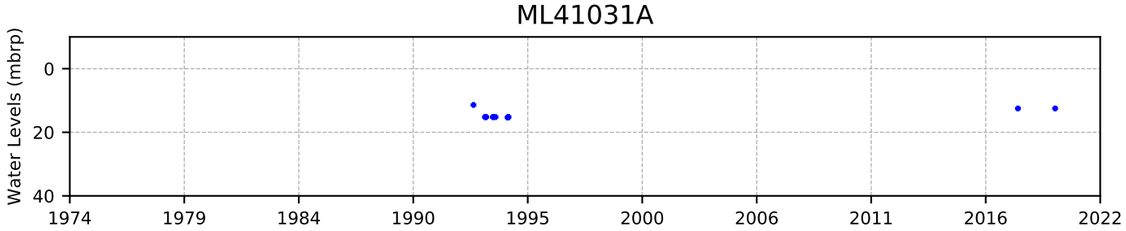
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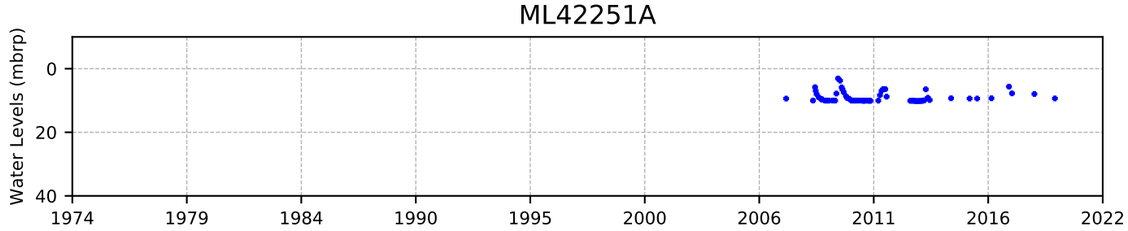
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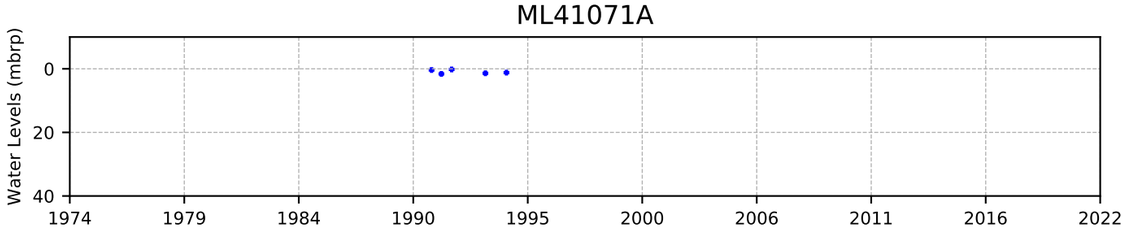
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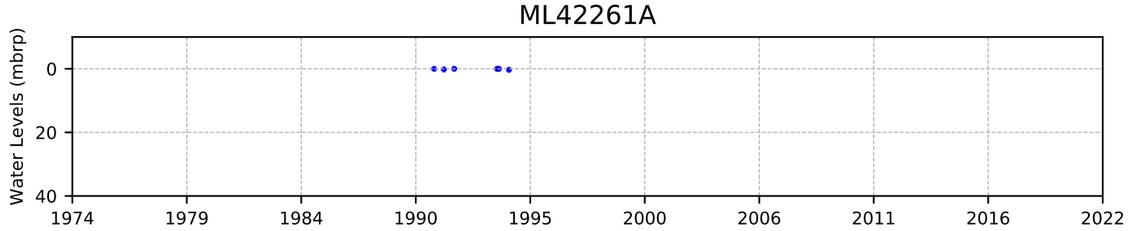
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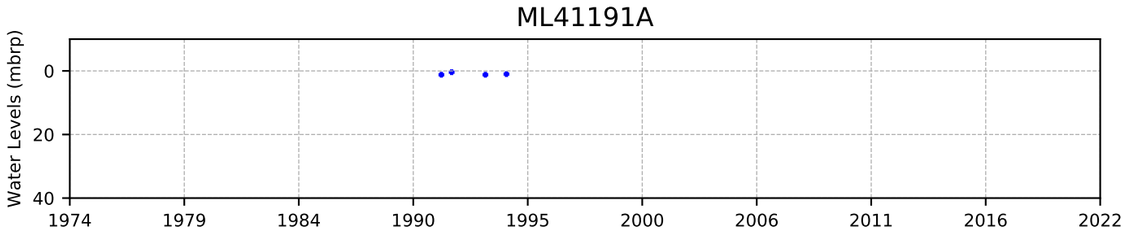
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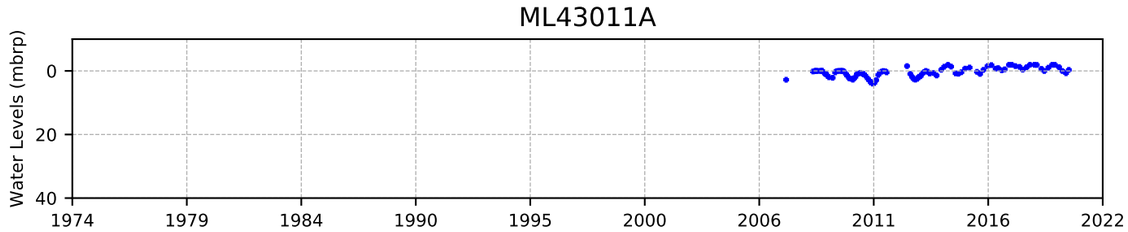
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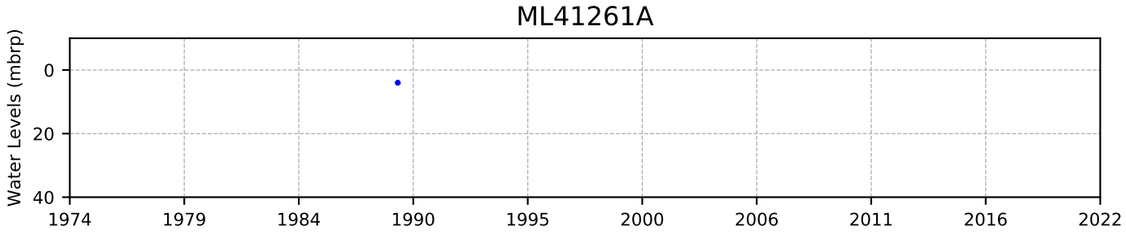
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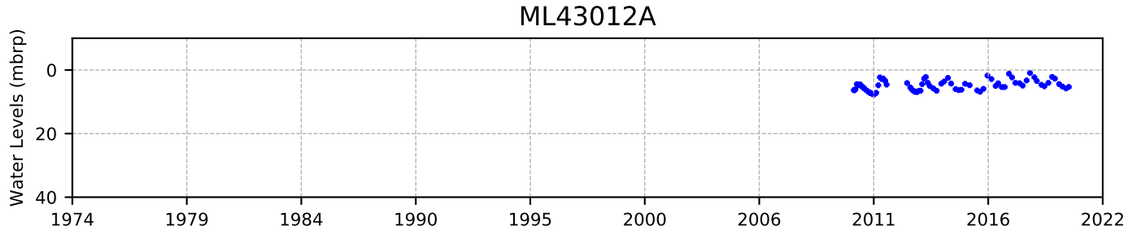
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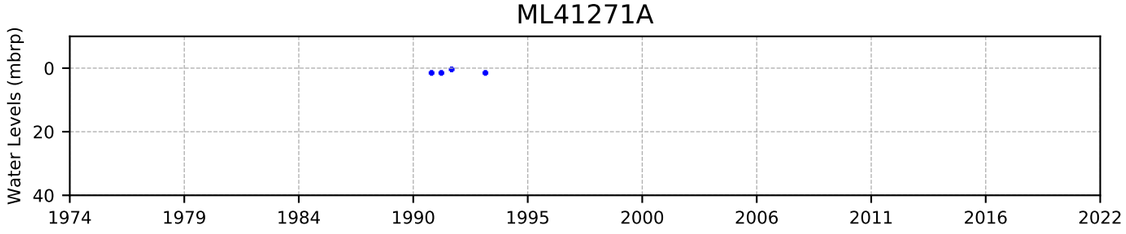
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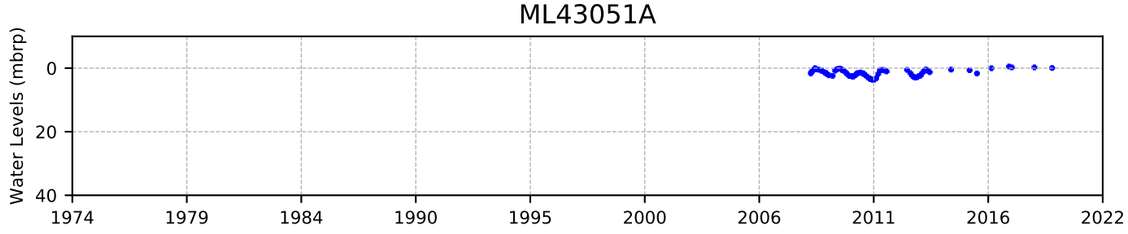
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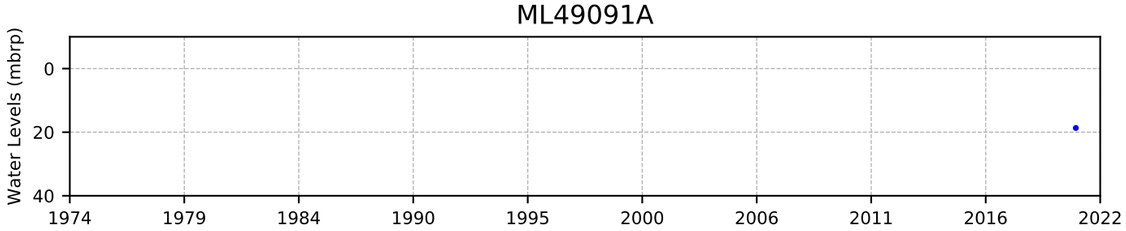
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Water Levels (mbrp)
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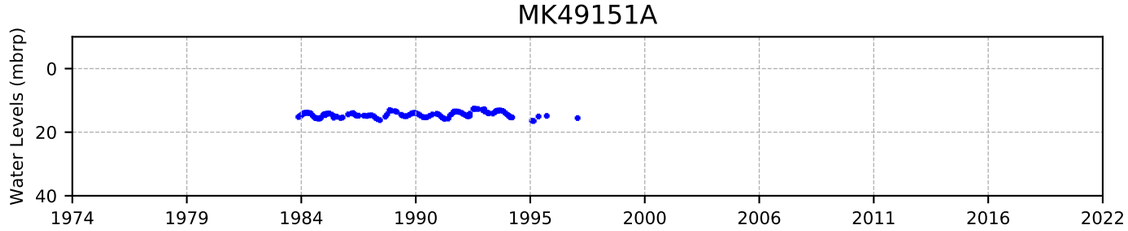
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Water Levels (mbrp)
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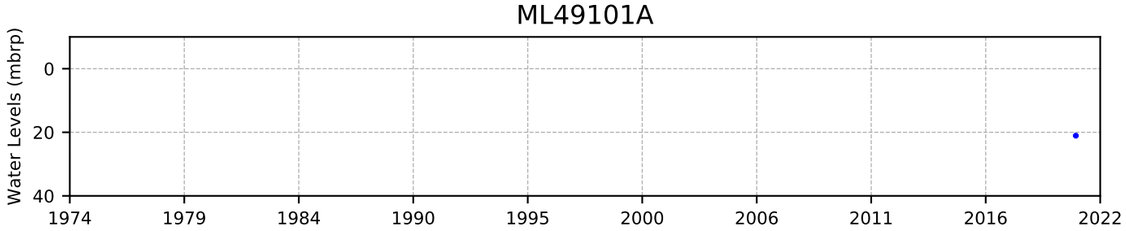
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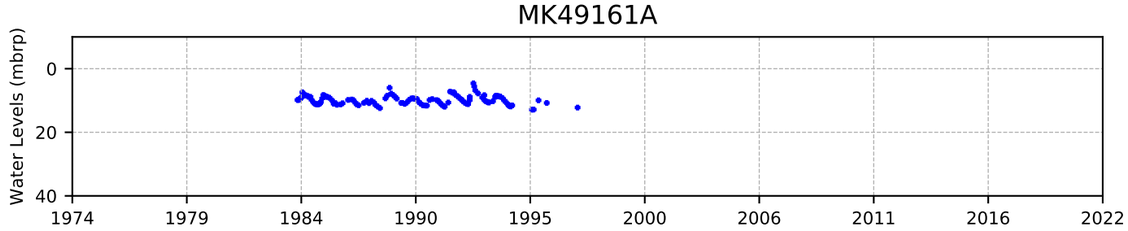
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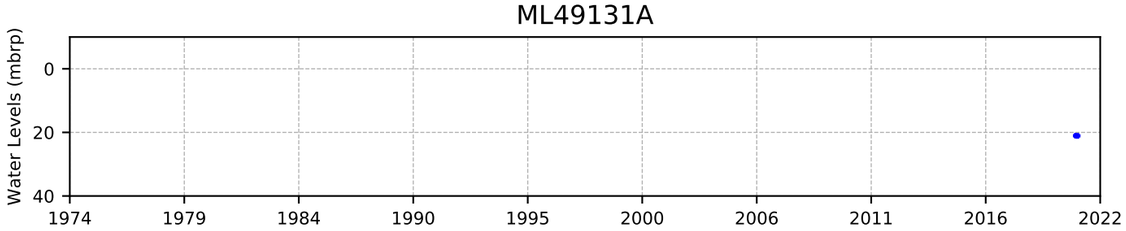
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Water Levels (mbrp)
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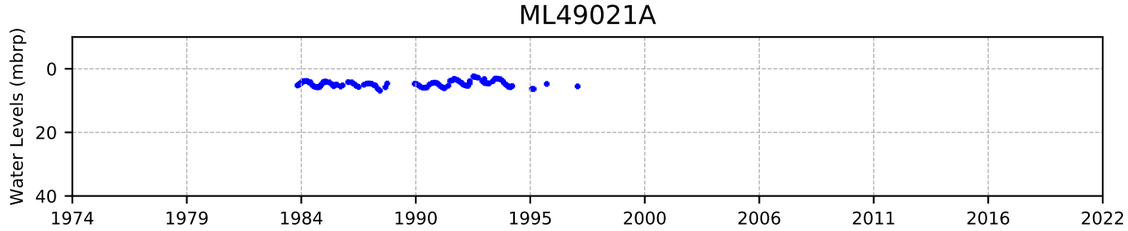
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Water Levels (mbrp)
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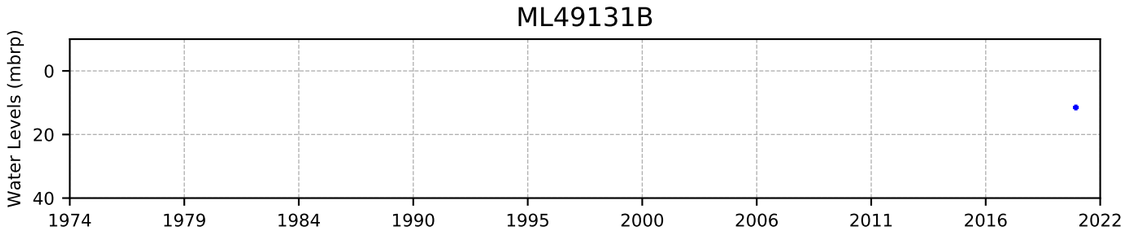
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Water Levels (mbrp)
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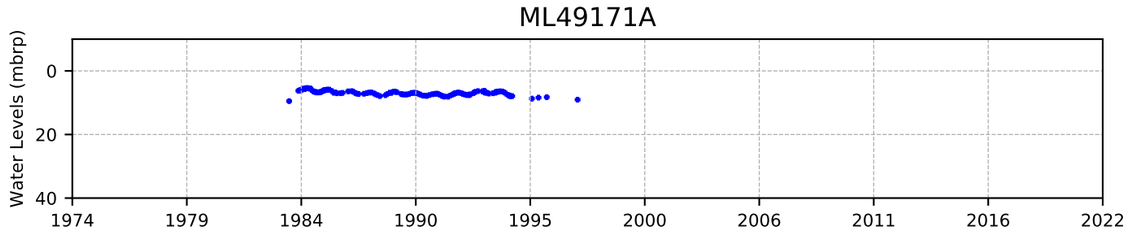
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Water Levels (mbrp)
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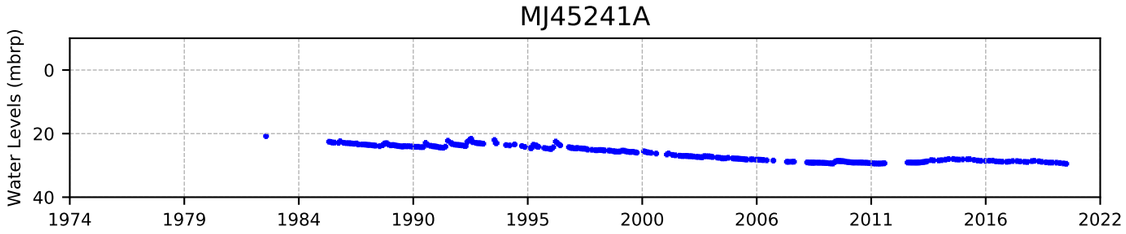
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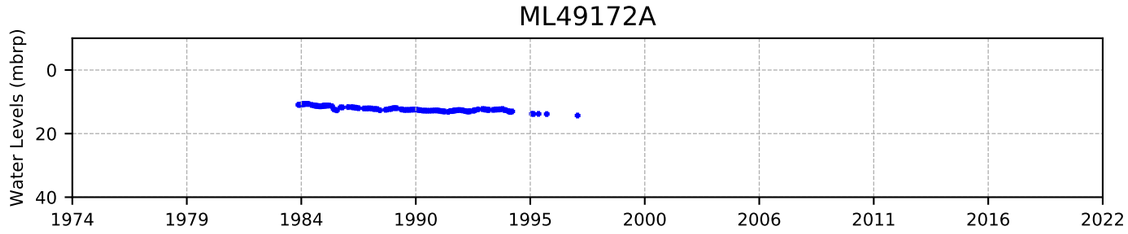
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Water Levels (mbrp)
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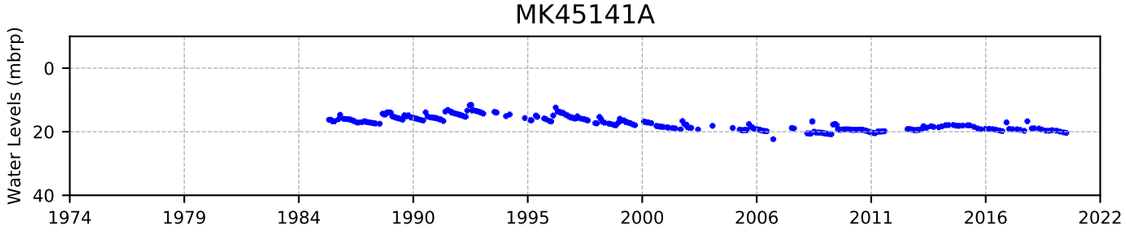
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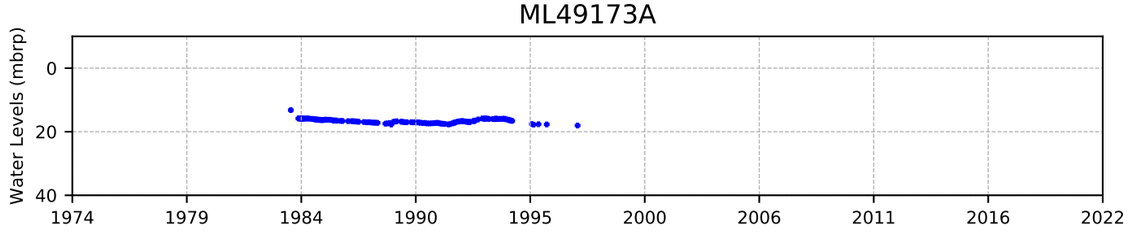
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Water Levels (mbrp)
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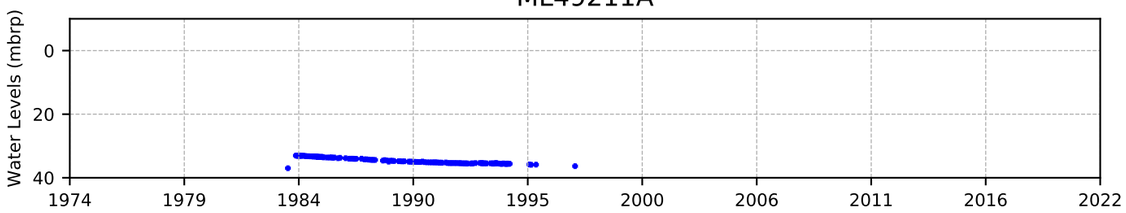
ML49211A



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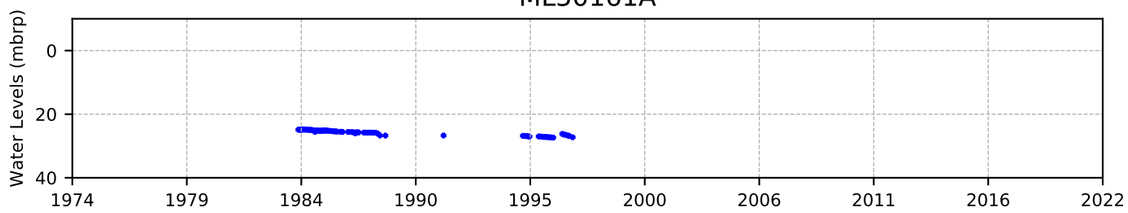

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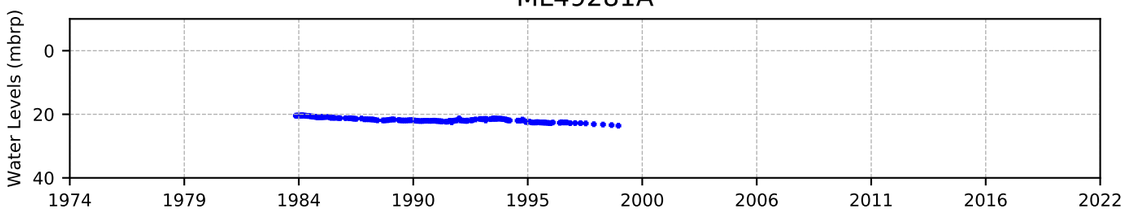

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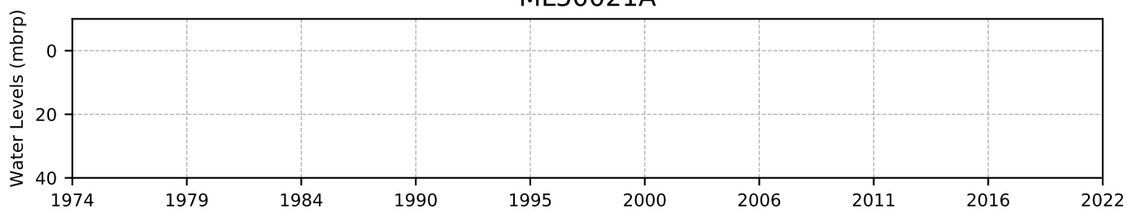

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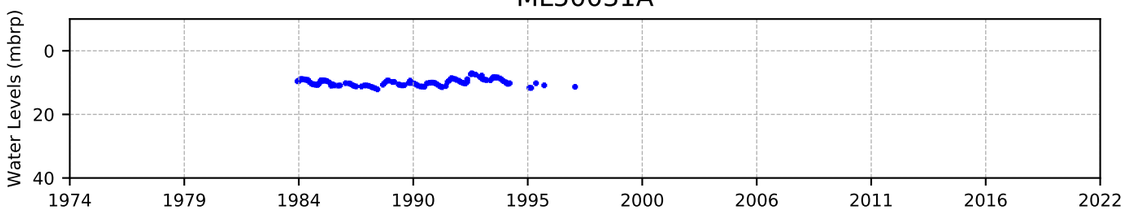

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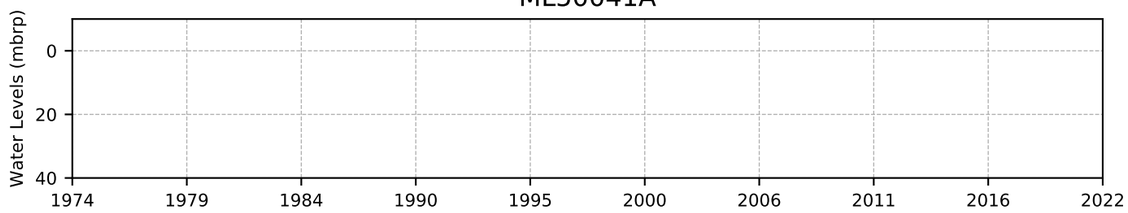

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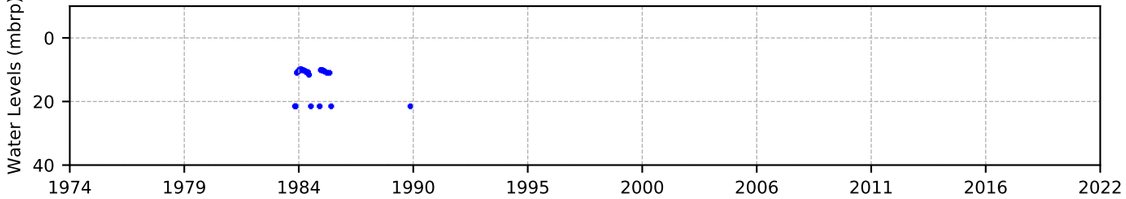

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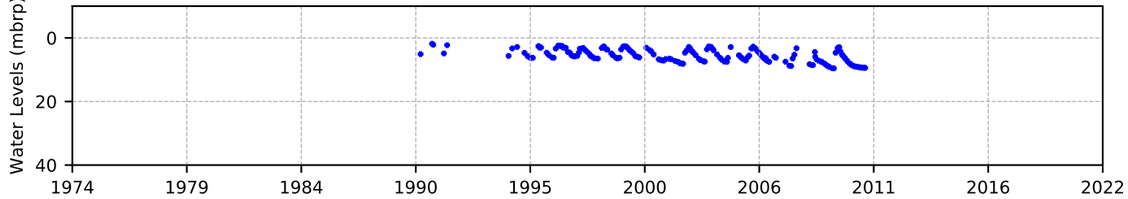

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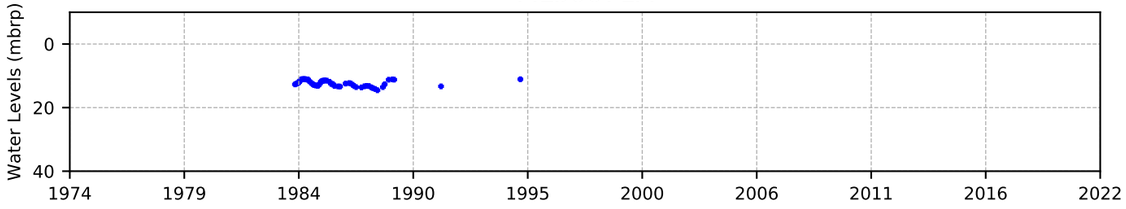

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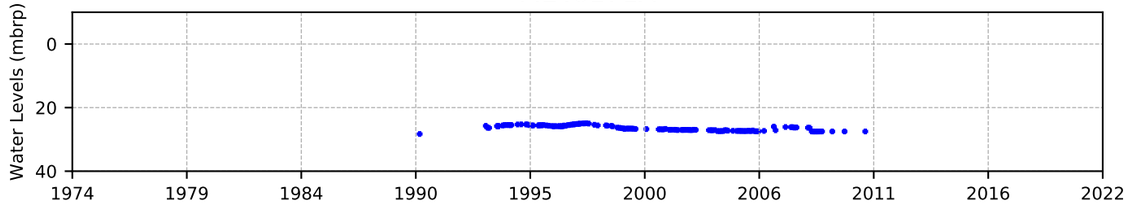

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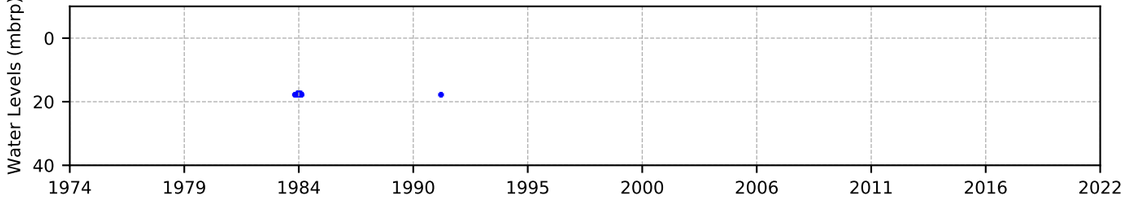

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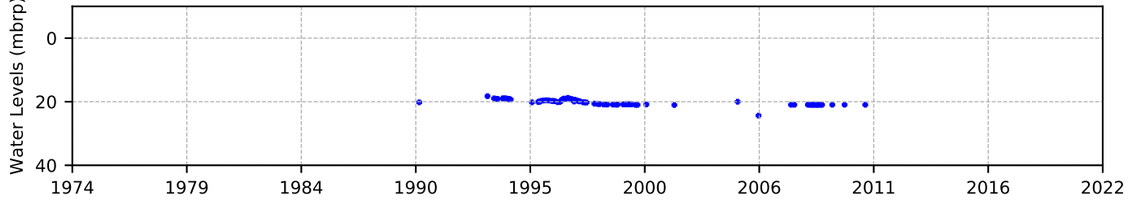

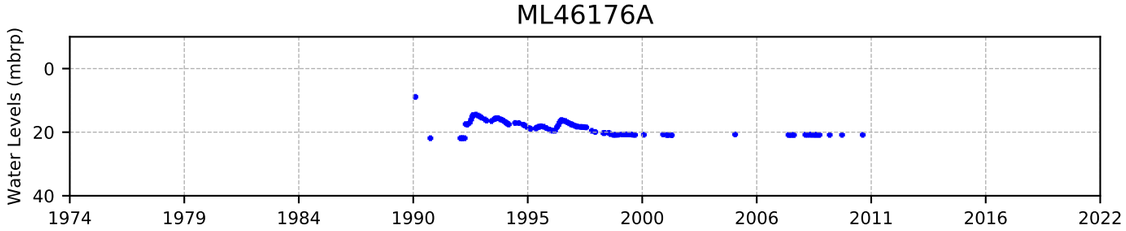
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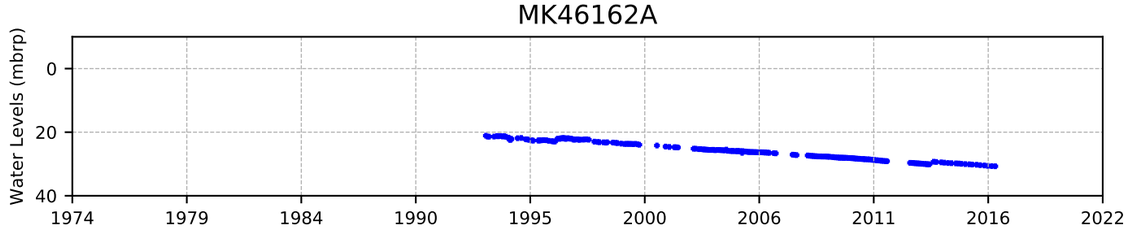
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Water Levels (mbrp)
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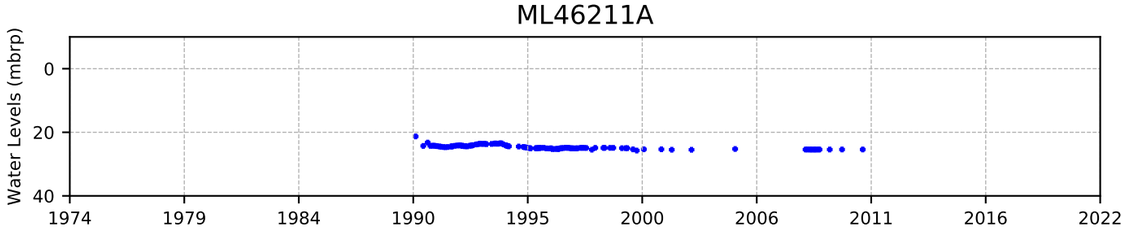
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Water Levels (mbrp)
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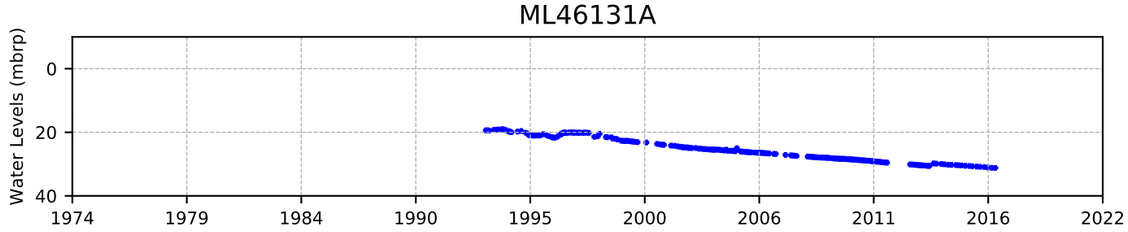
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Water Levels (mbrp)
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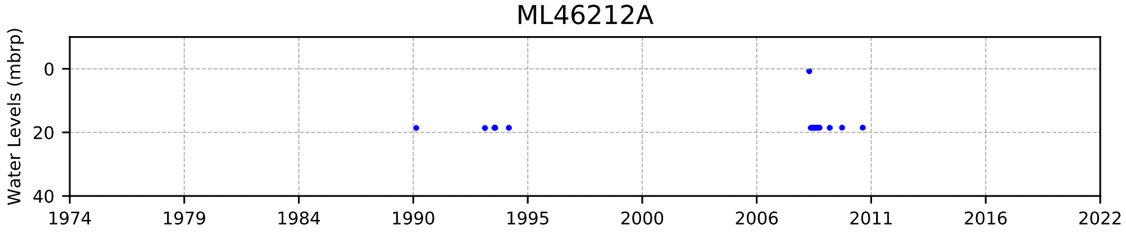
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Water Levels (mbrp)
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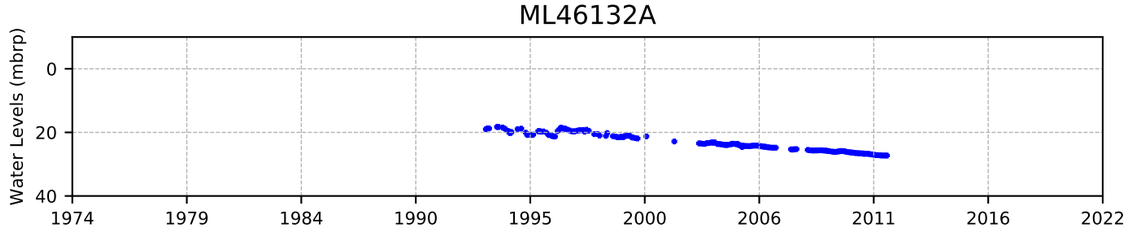
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Water Levels (mbrp)
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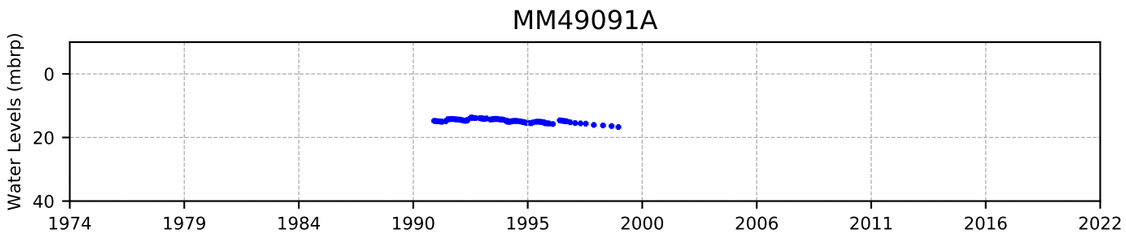
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Water Levels (mbrp)
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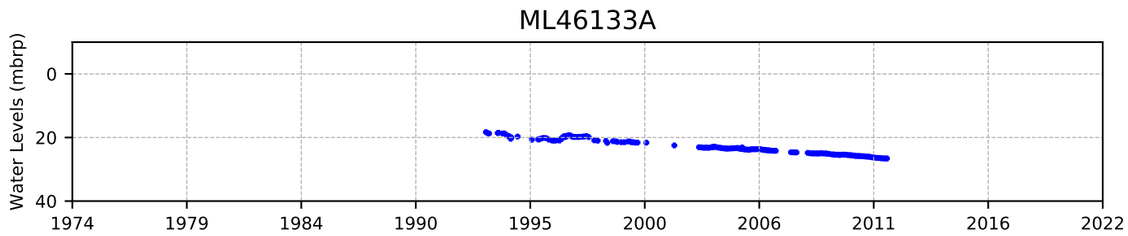
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Water Levels (mbrp)
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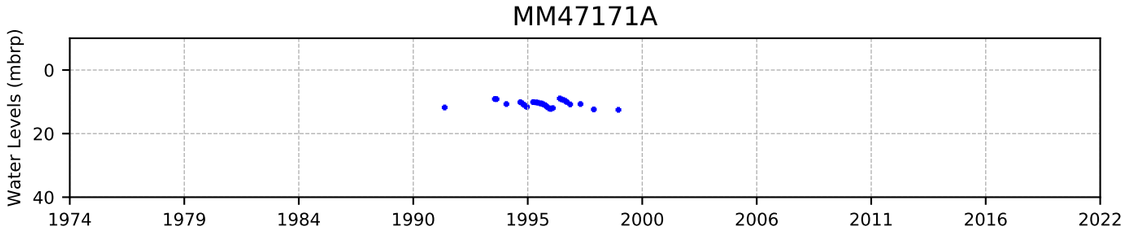
MM47171A
Water Levels (mbrp)
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2011
2016
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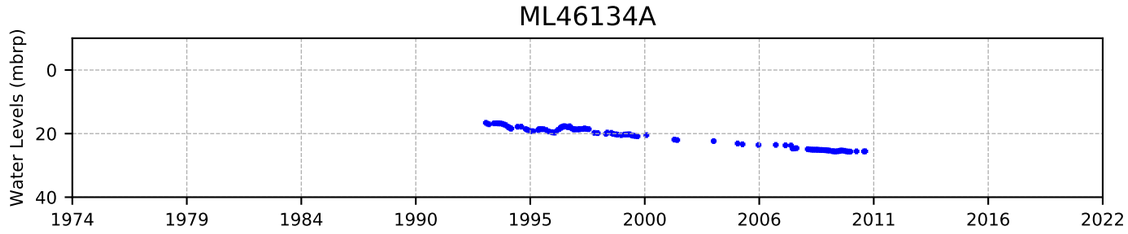
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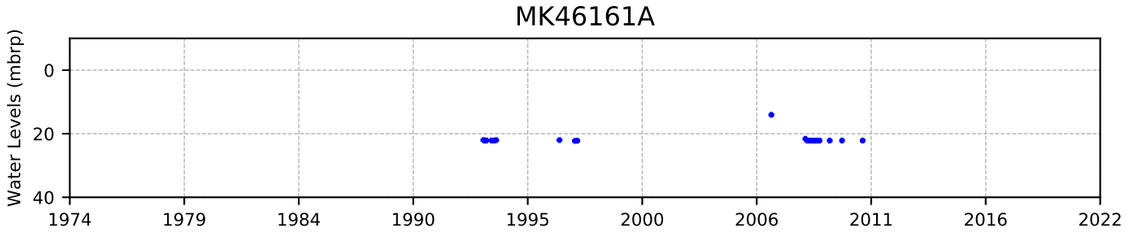
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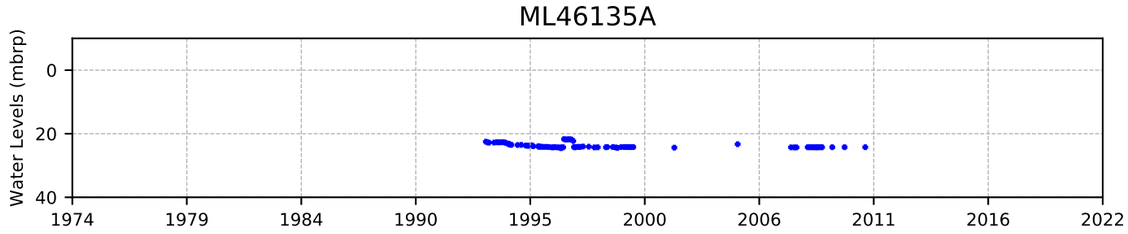
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2016
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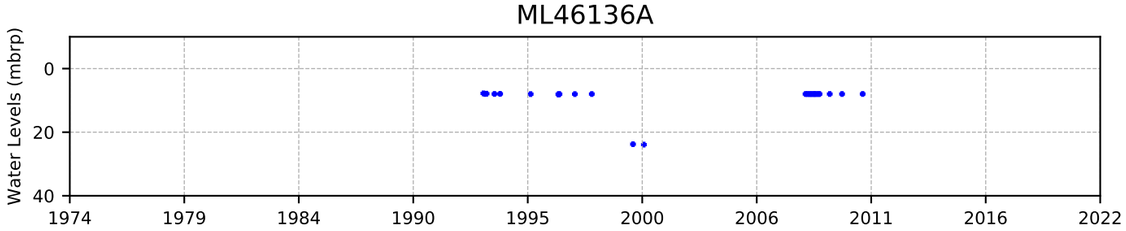
ML46136A
Water Levels (mbrp)
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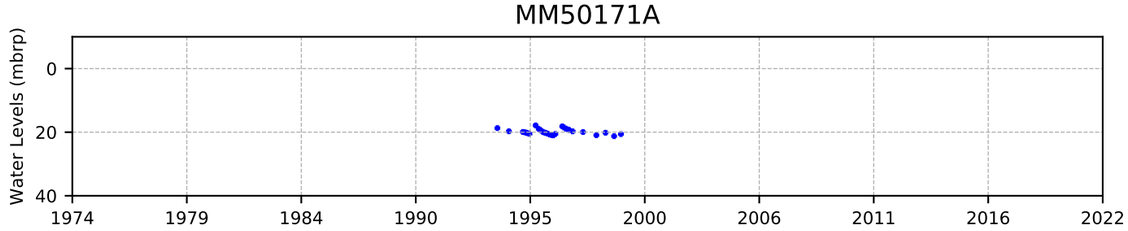
MM50171A
Water Levels (mbrp)
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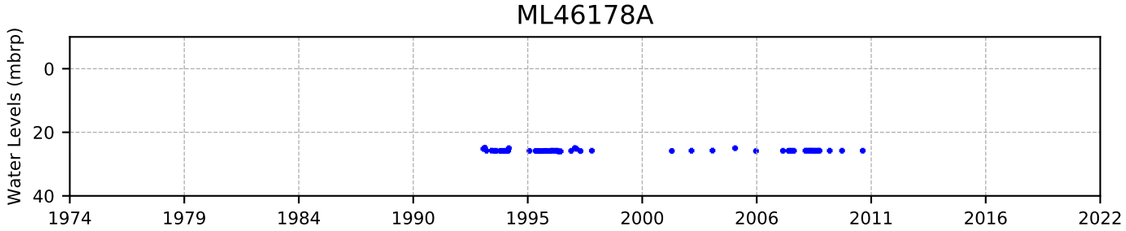
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Water Levels (mbrp)
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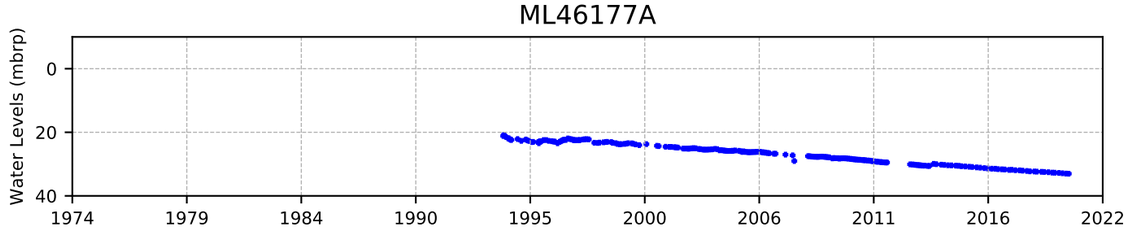
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Water Levels (mbrp)
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2006
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2016
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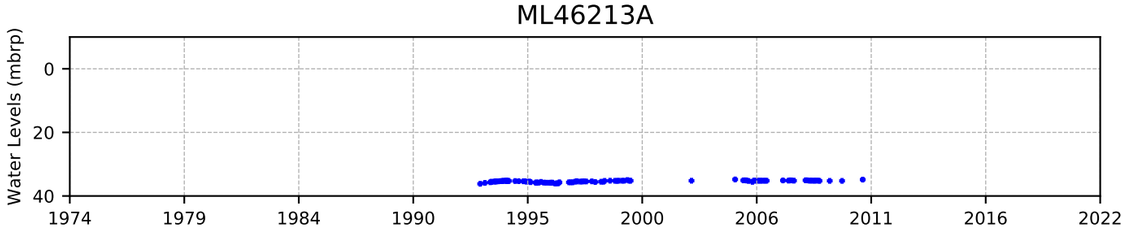
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Water Levels (mbrp)
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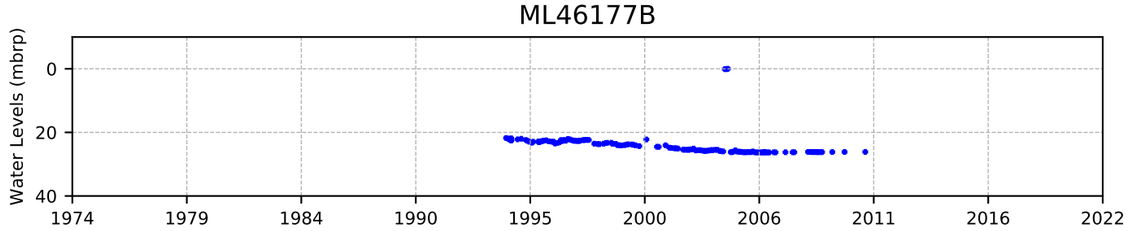
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Water Levels (mbrp)
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2016
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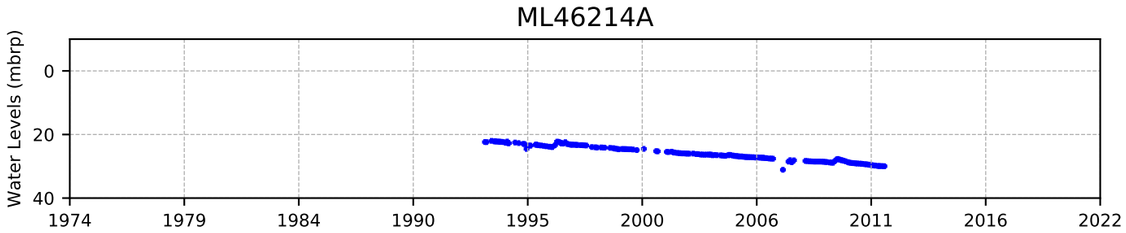
ML46214A
Water Levels (mbrp)
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2016
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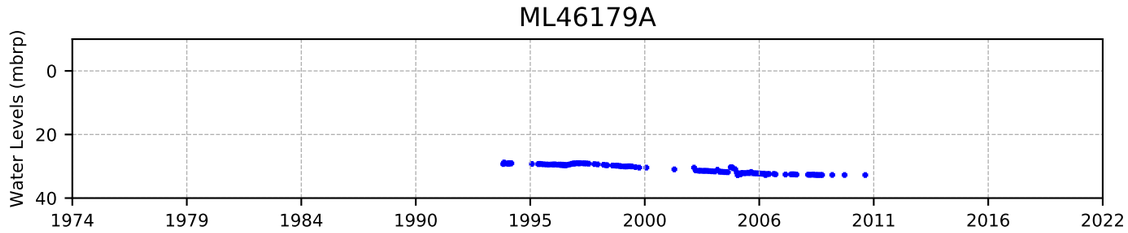
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Water Levels (mbrp)
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2006
2011
2016
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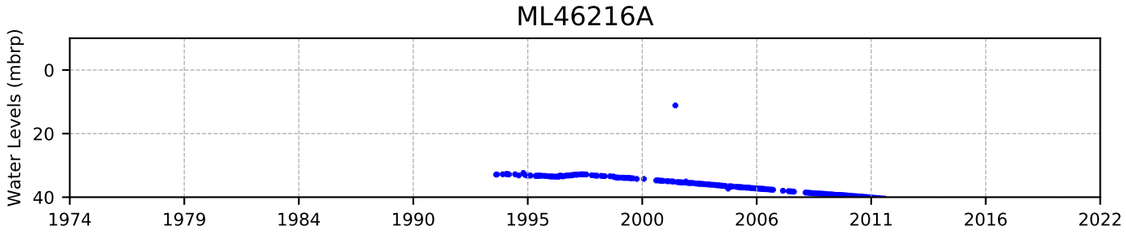
ML46216A
Water Levels (mbrp)
0
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1984
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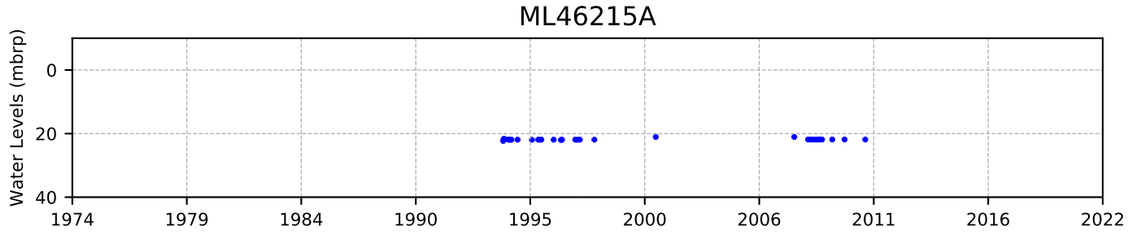
1995
2000
2006
2011
2016
2022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Water Levels (mbrp)
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1984
1990
1995
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2011
2016
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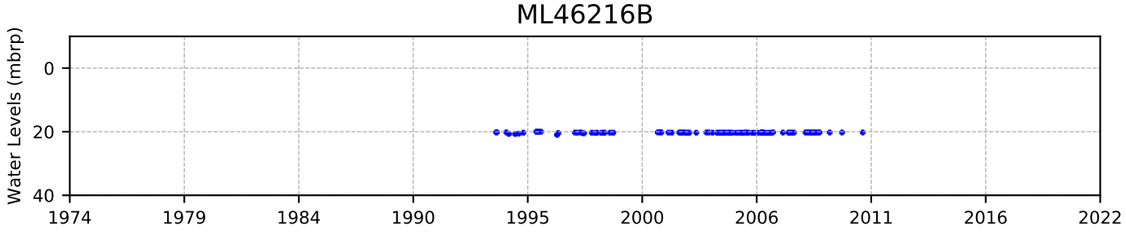
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Water Levels (mbrp)
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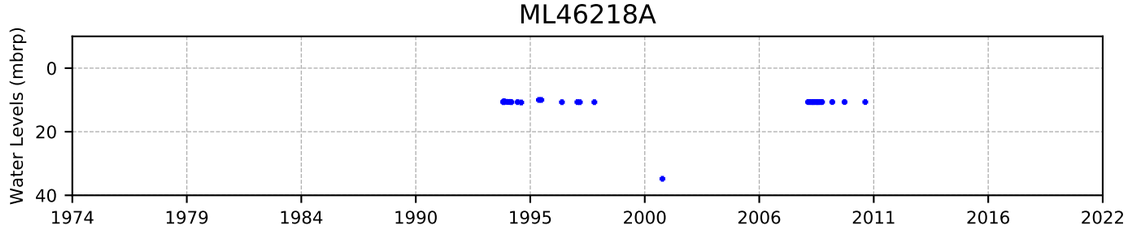
1990
1995
2000
2006
2011
2016
2022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Water Levels (mbrp)
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2016
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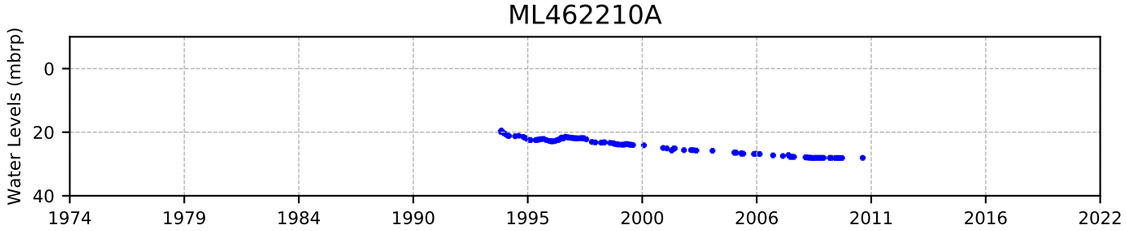
ML462210A
Water Levels (mbrp)
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2016
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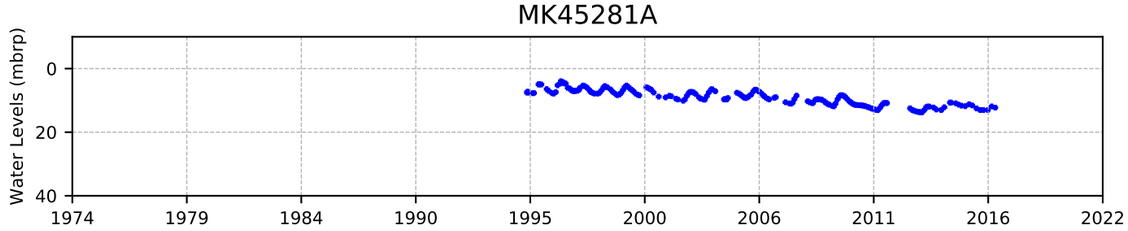
MK45281A
Water Levels (mbrp)
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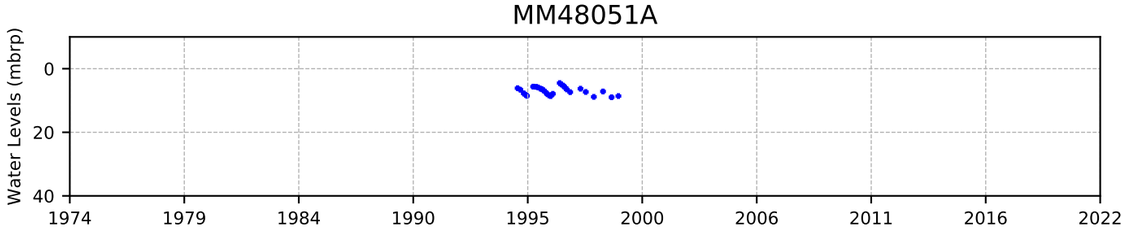
MM48051A
Water Levels (mbrp)
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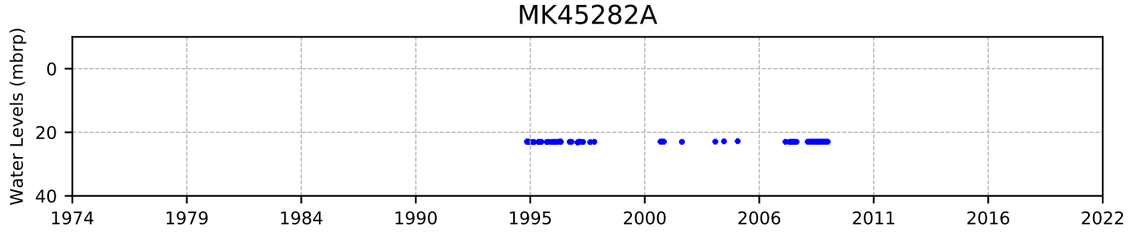
2000
2006
2011
2016
2022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Water Levels (mbrp)
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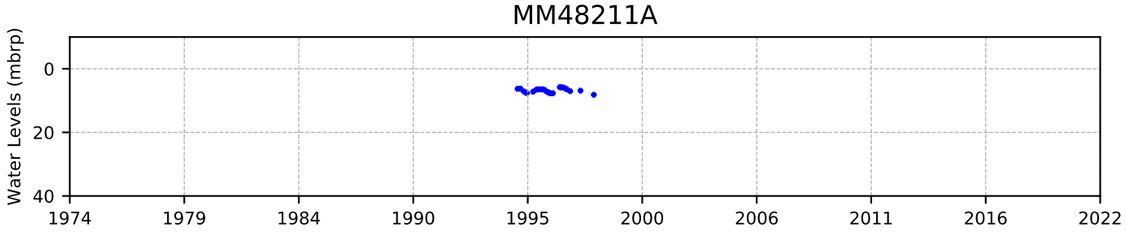
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Water Levels (mbrp)
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2011
2016
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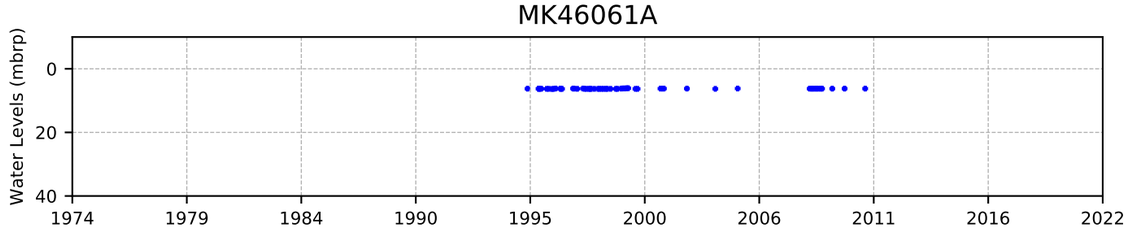
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Water Levels (mbrp)
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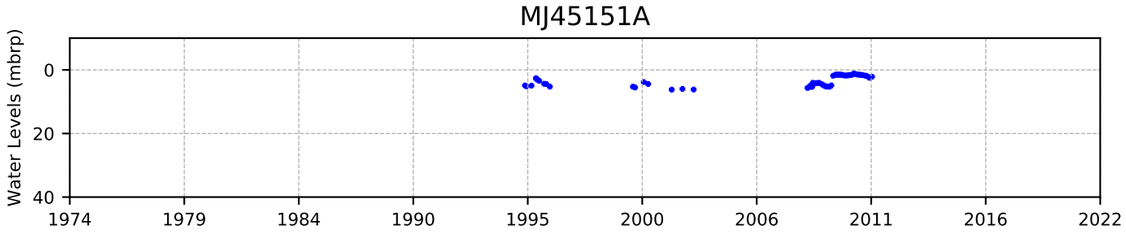
MJ45151A
Water Levels (mbrp)
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2016
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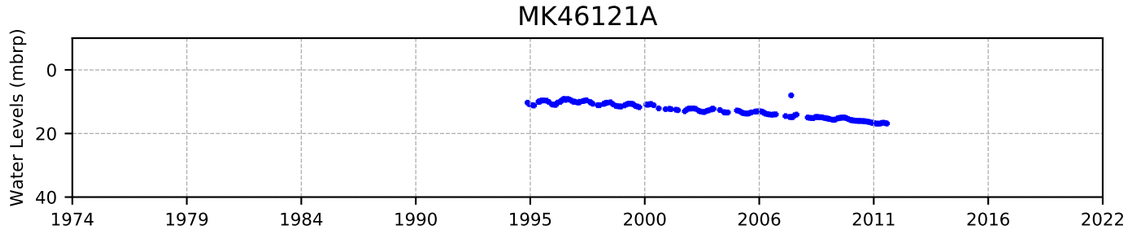
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Water Levels (mbrp)
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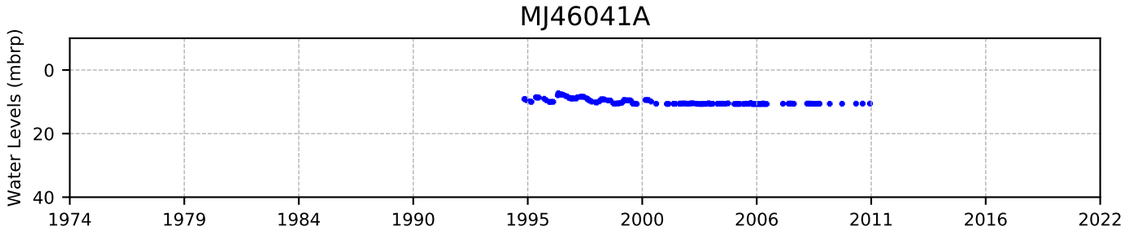
MJ46041A
Water Levels (mbrp)
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2016
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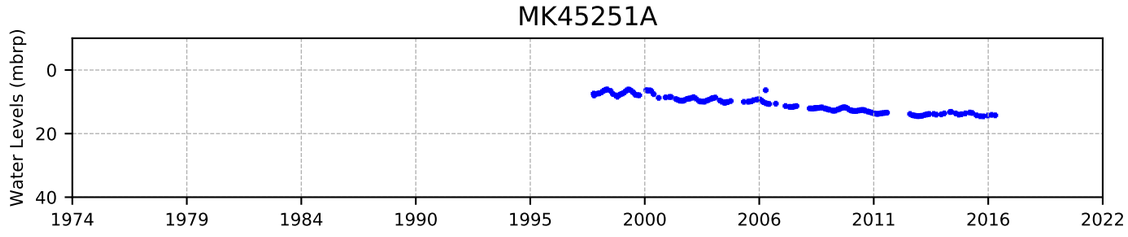
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Water Levels (mbrp)
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2016
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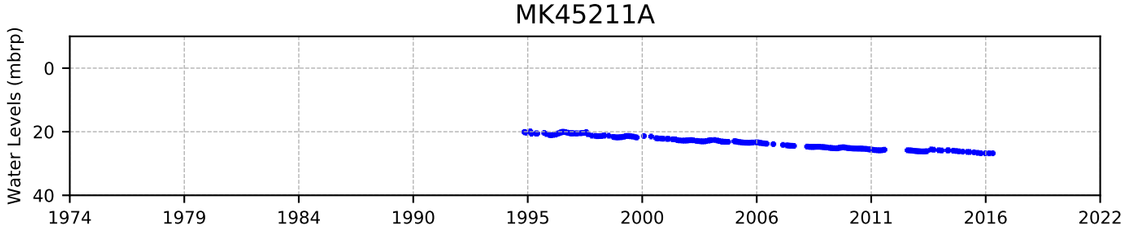
MK45211A
Water Levels (mbrp)
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1974
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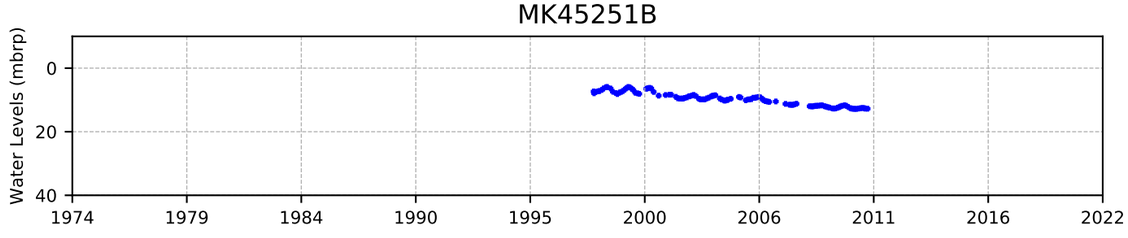
2006
2011
2016
2022


MK45251B
Water Levels (mbrp)
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1990
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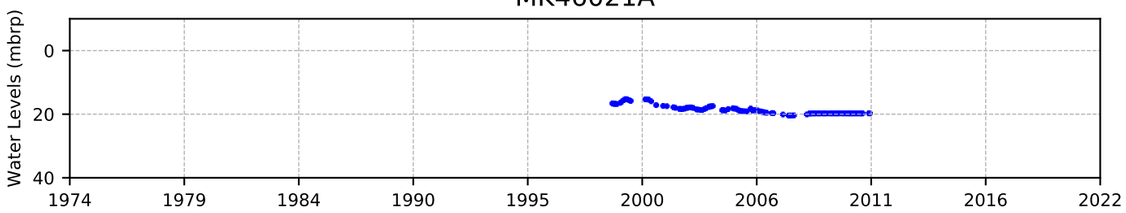
2006
2011
2016
2022


MK46021A
Water Levels (mbrp)
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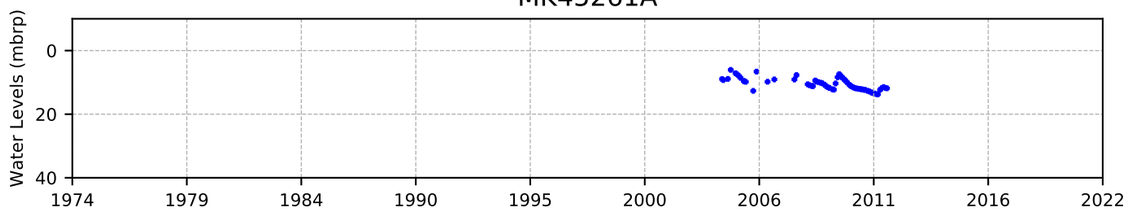
2006
2011
2016
2022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Water Levels (mbrp)
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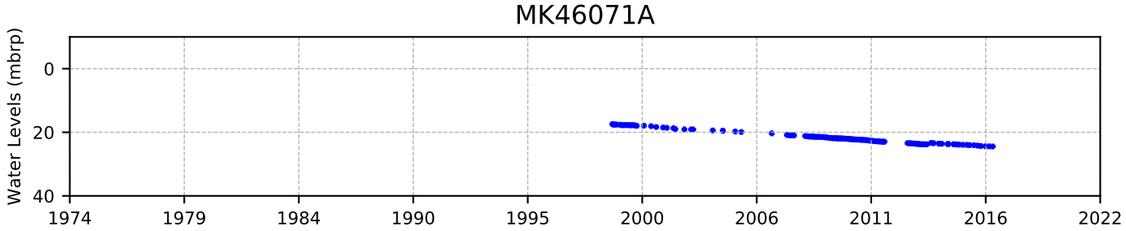
1984
1990
1995
2000
2006
2011
2016
2022


MK46071A
Water Levels (mbrp)
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20
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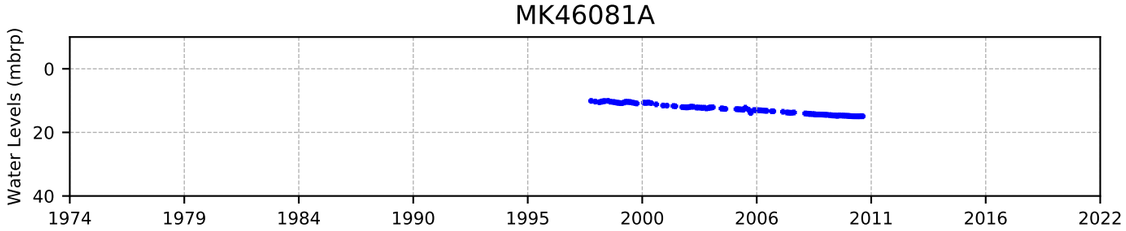
1974
1979
1984
1990
1995
2000
2006
2011
2016
2022


MK46081A
Water Levels (mbrp)
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1979
1984
1990
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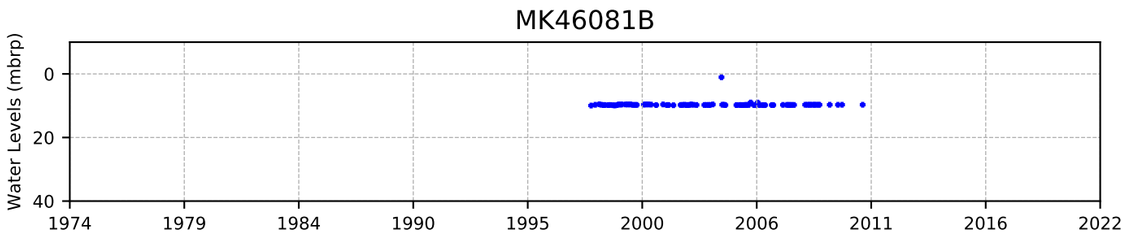
2011
2016
2022


MK46081B
Water Levels (mbrp)
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1974
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1984
1990
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2006
2011
2016
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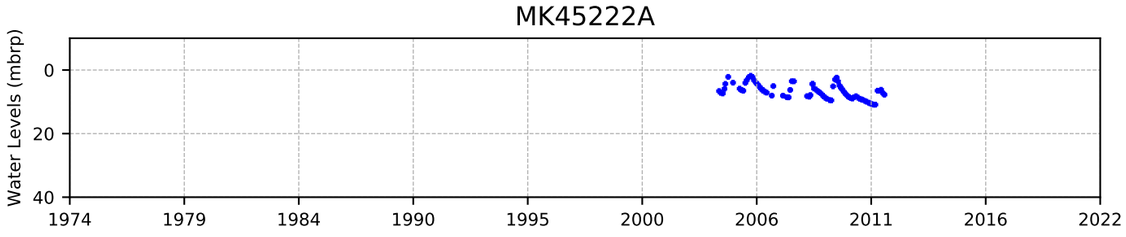
MK45222A
Water Levels (mbrp)
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1990
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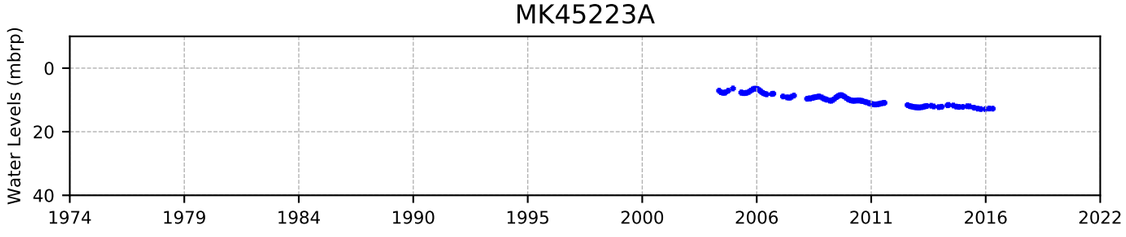
2006
2011
2016
2022


MK45223A
Water Levels (mbrp)
0
20
40
1974
1979
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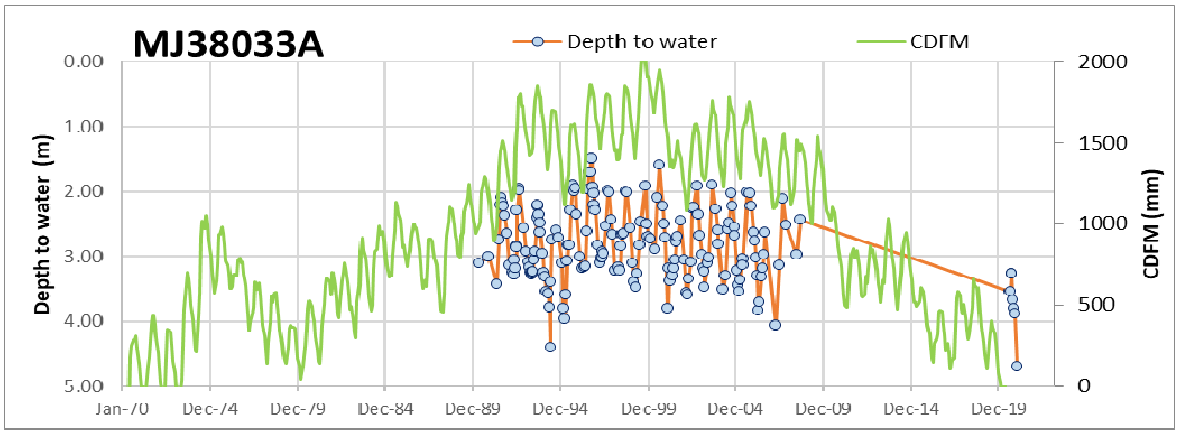
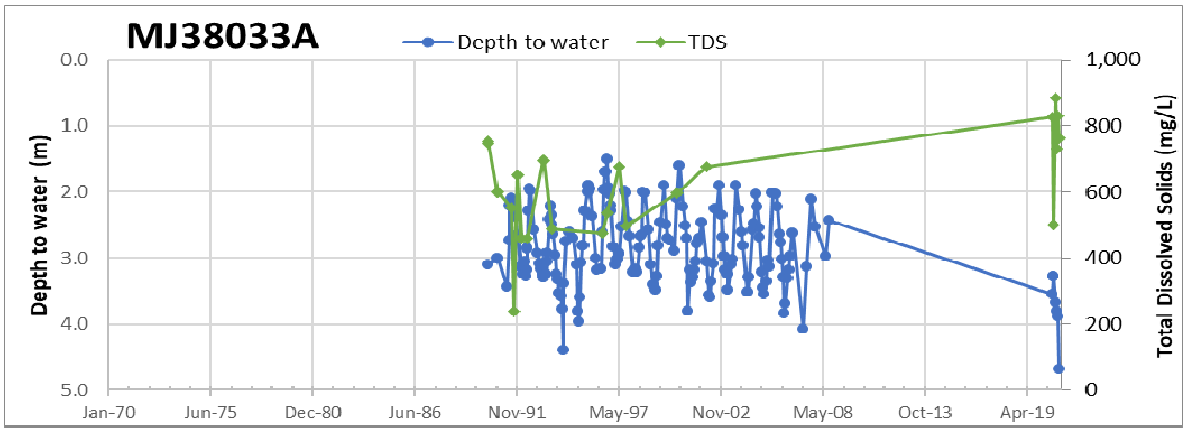
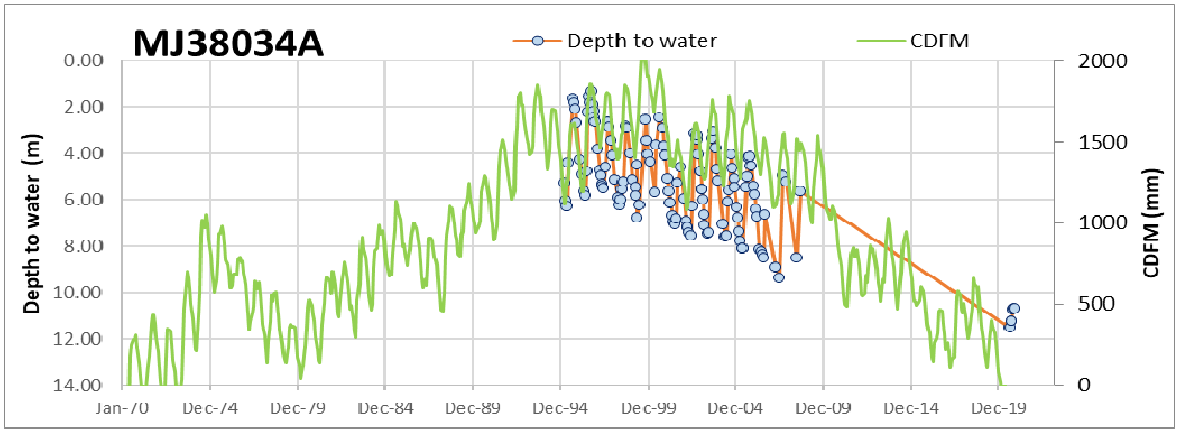
1990
1995
2000
2006
2011
2016
2022

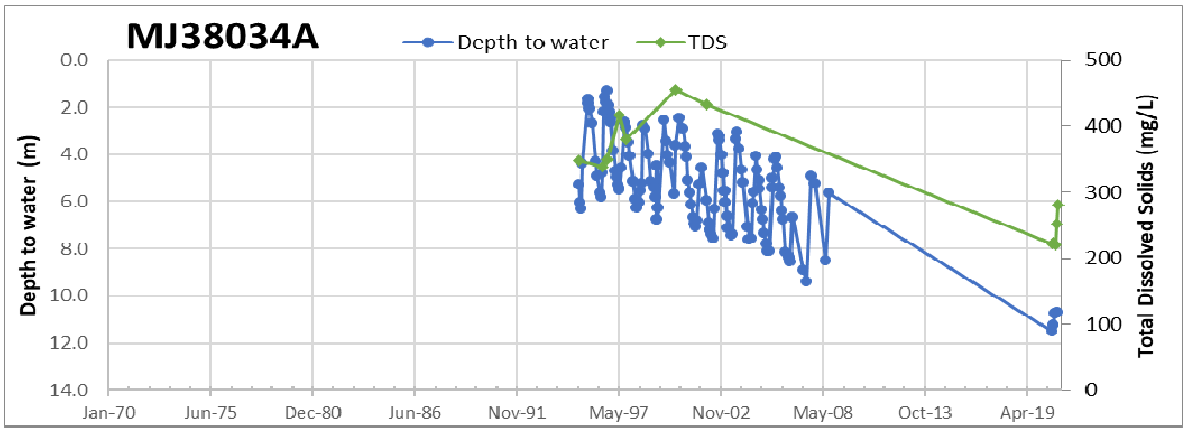
Appendix C

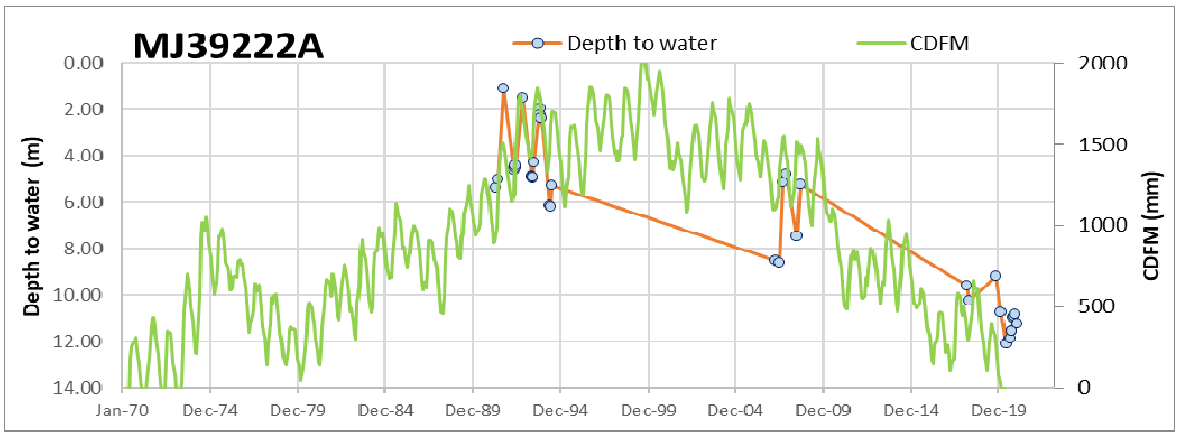
Selected Myara North monitoring bore hydrographs and salinity graphs

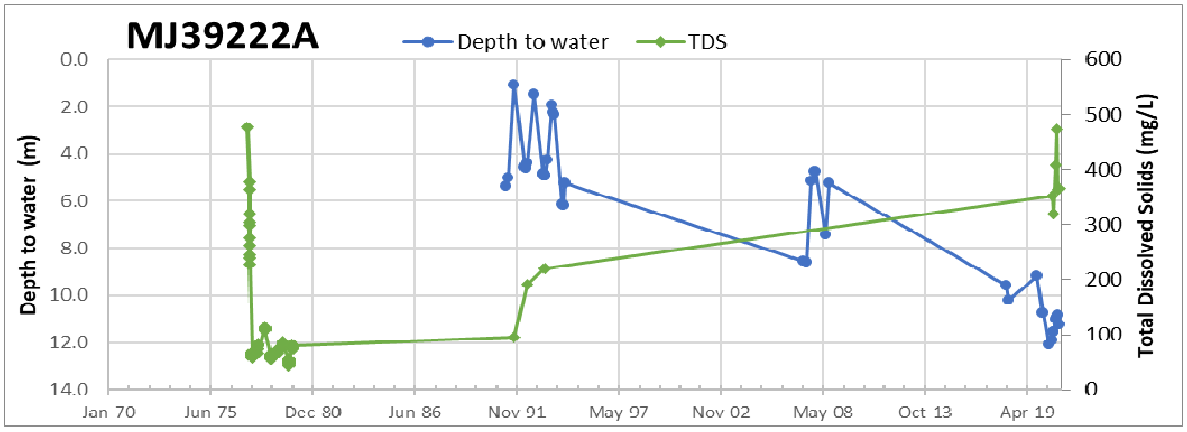

MJ38033A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
1.00
2.00
3.00
4.00
5.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19

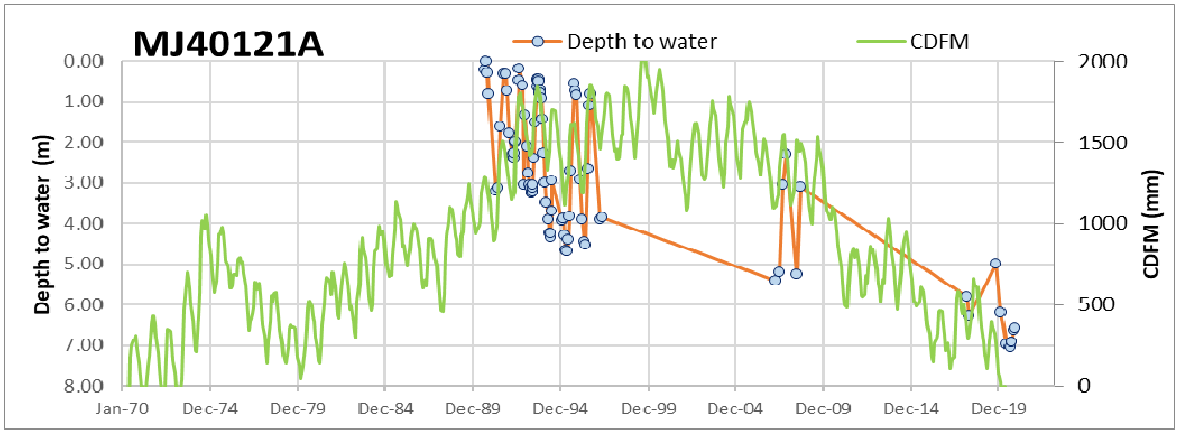

MJ38033A
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
1.0
2.0
3.0
4.0
5.0
1,000
800
600
400
200
0
Jan-70
Jun-75
Dec-80
Jun-86
Nov-91
May-97
Nov-02
May-08
Oct-13
Apr-19

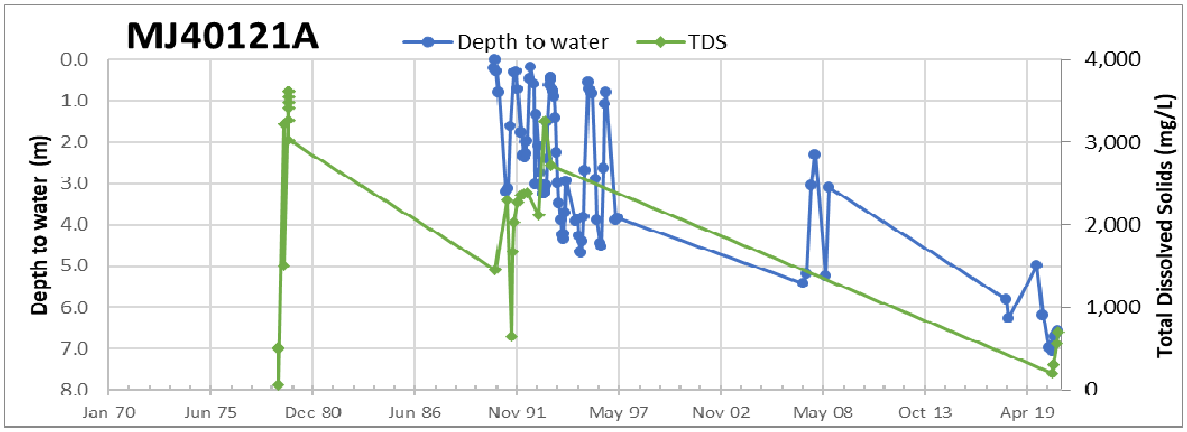

MJ38034A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19

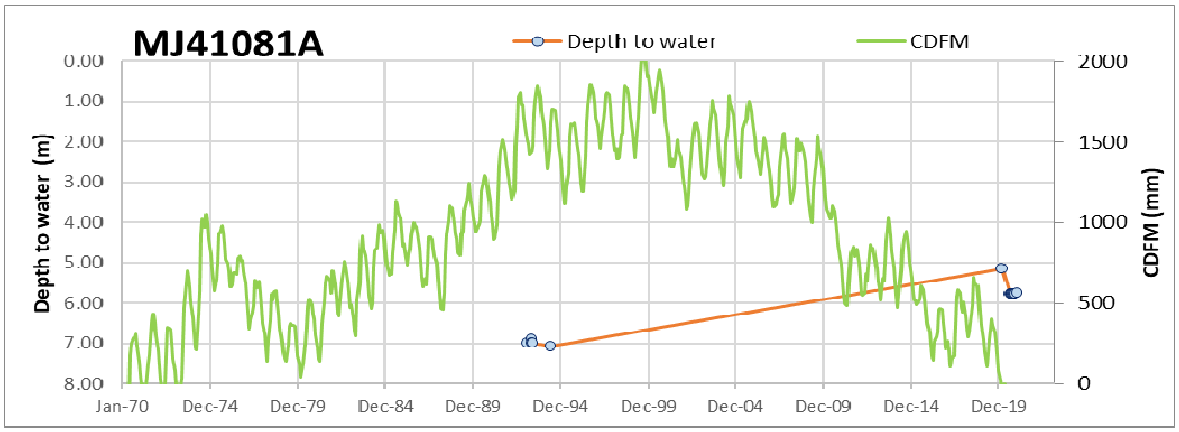

MJ38034A
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
500
400
300
200
100
0
Jan-70
Jun-75
Dec-80
Jun-86
Nov-91
May-97
Nov-02
May-08
Oct-13
Apr-19

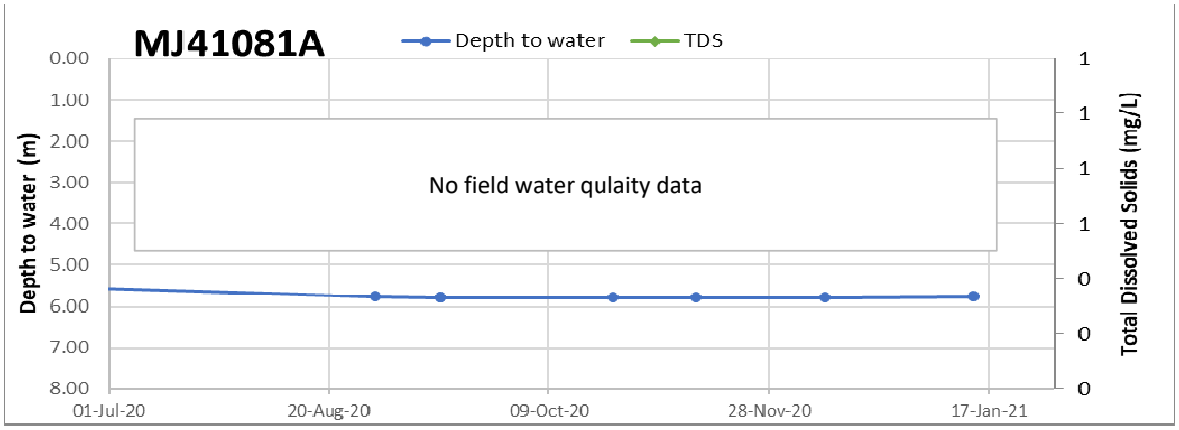

MJ39222A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19

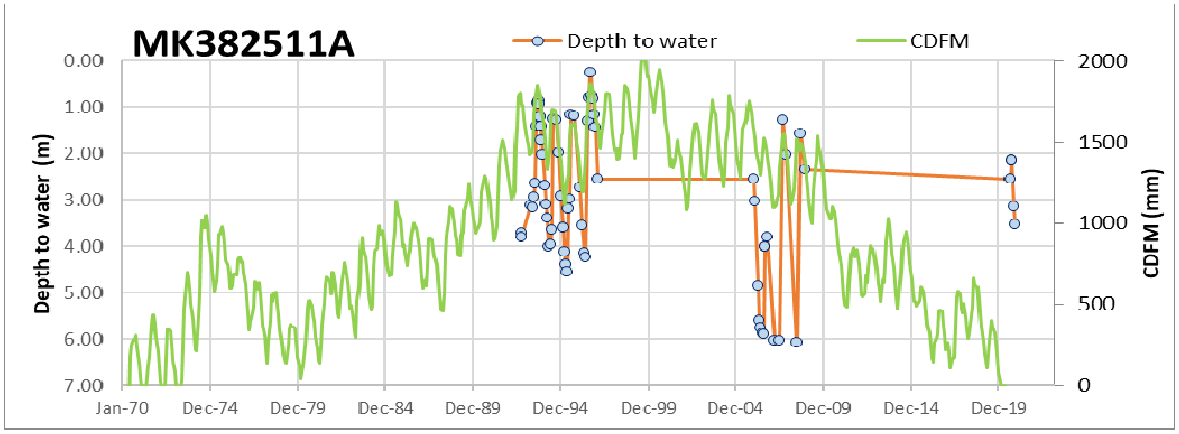

MJ39222A
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
600
500
400
300
200
100
0
Jan 70
Jun 75
Dec 80
Jun 86
Nov 91
May 97
Nov 02
May 08
Oct 13
Apr 19

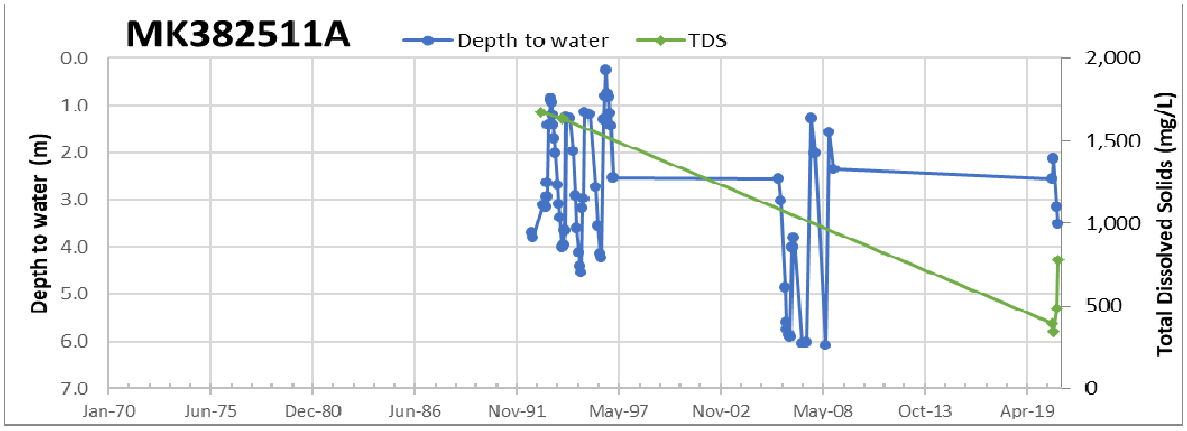

MJ40121A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19

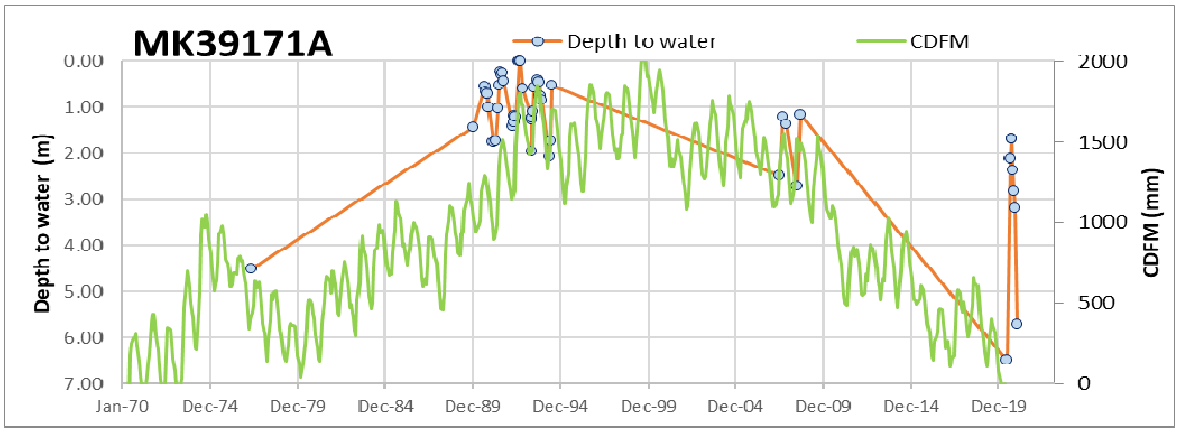

MJ40121A
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
4,000
3,000
2,000
1,000
0
Jan 70
Jun 75
Dec 80
Jun 86
Nov 91
May 97
Nov 02
May 08
Oct 13
Apr 19

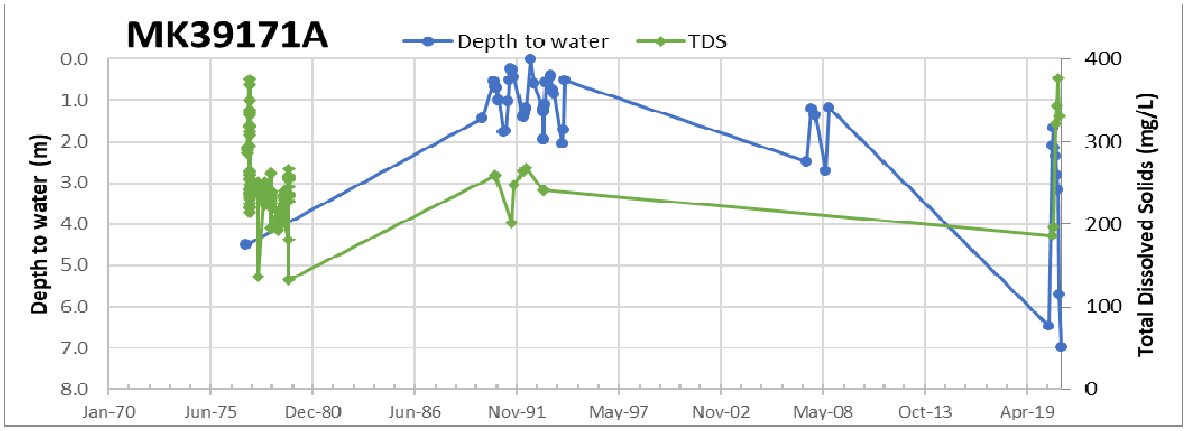

MJ41081A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19

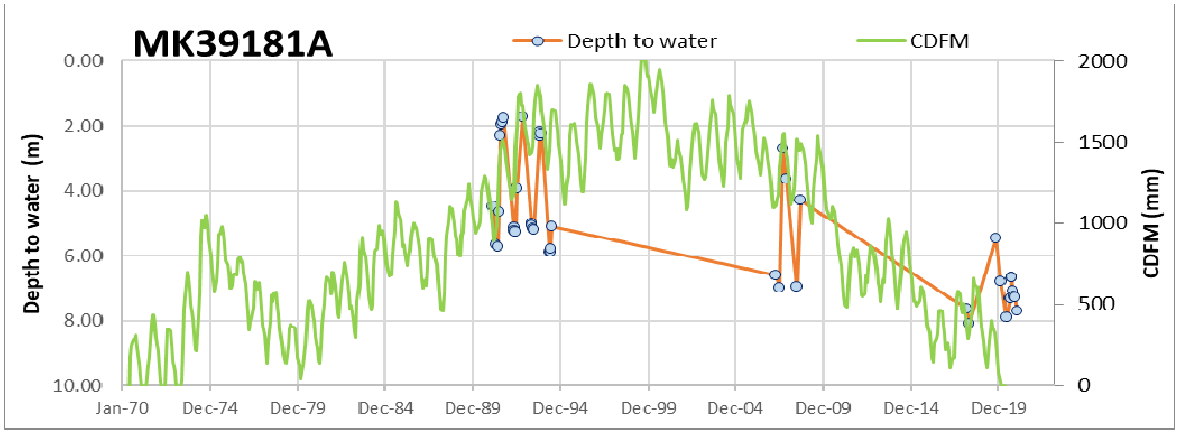

MJ41081A
Depth to water
TDS
No field water qulaity data
Depth to water (m)
Total Dissolved Solids (mg/L)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
1
1
1
1
0
0
0
01-Jul-20
20-Aug-20
09-Oct-20
28-Nov-20
17-Jan-21

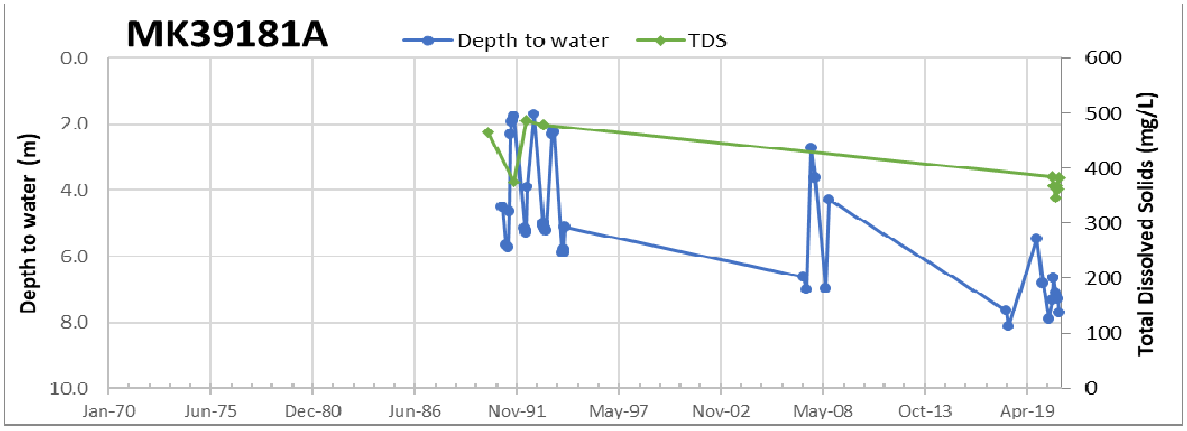

MK382511A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19

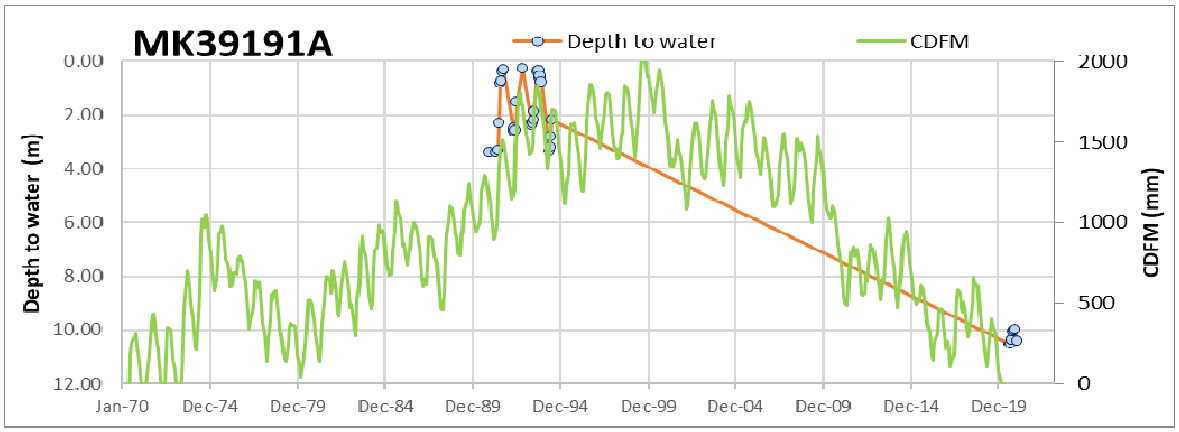

MK382511A
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
2,000
1,500
1,000
500
0
Jan-70
Jun-75
Dec-80
Jun-86
Nov-91
May-97
Nov-02
May-08
Oct-13
Apr-19

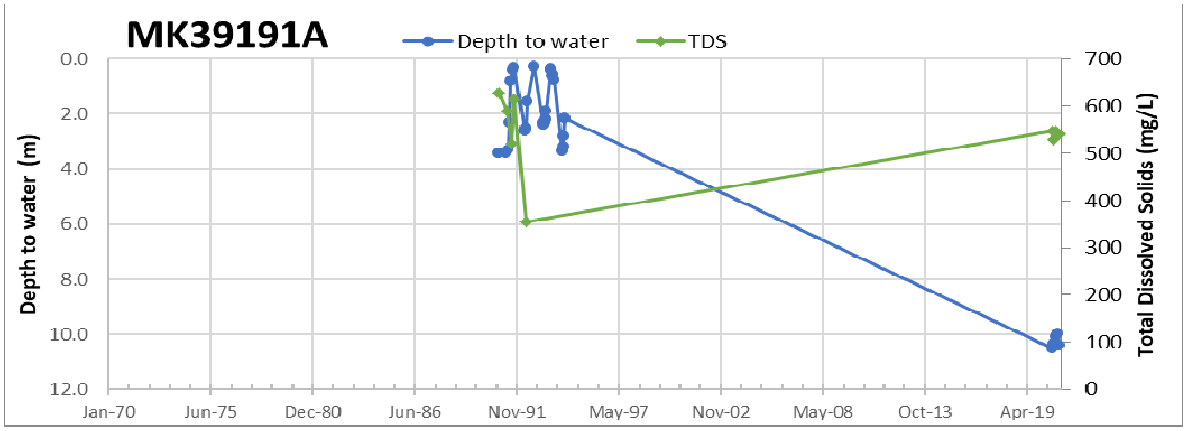

MK39171A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19

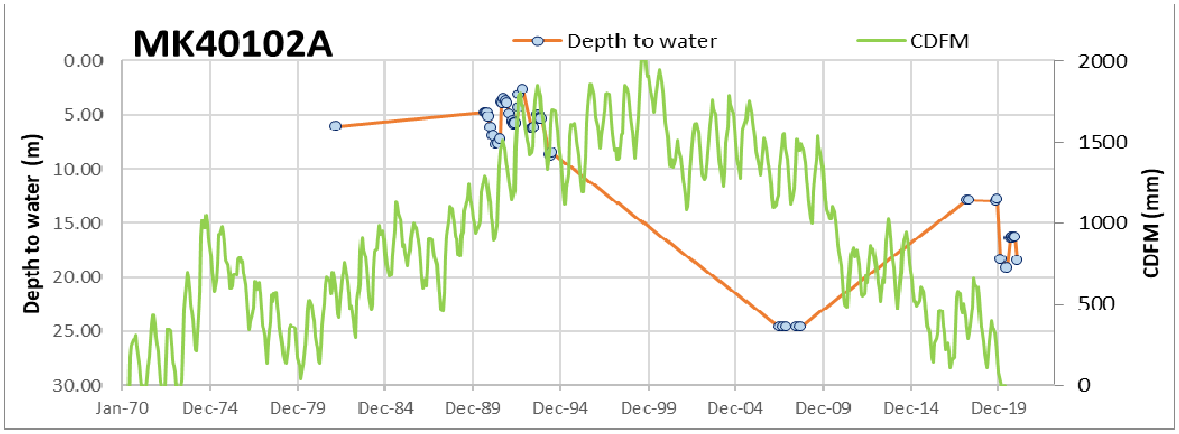

MK39171A
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
400
300
200
100
0
Jan-70
Jun-75
Dec-80
Jun-86
Nov-91
May-97
Nov-02
May-08
Oct-13
Apr-19

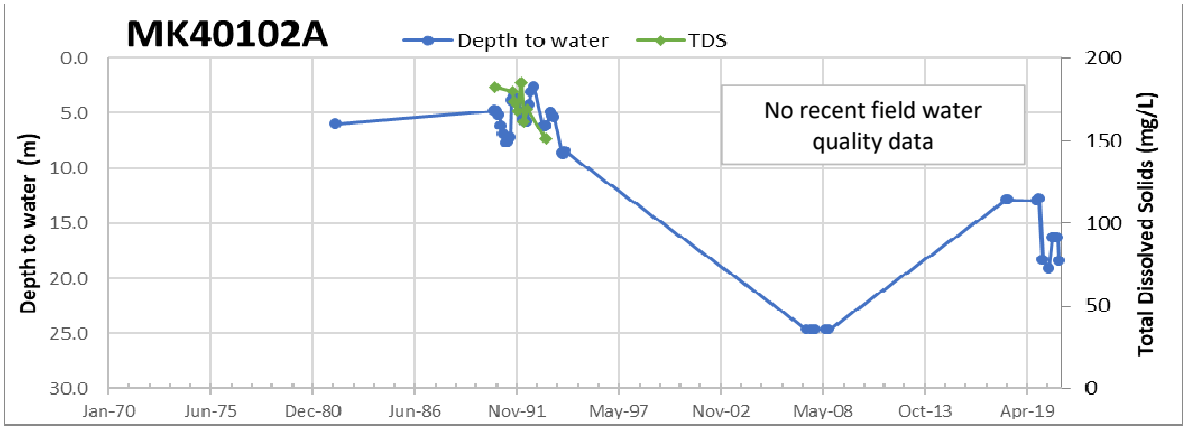

MK39181A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
2.00
4.00
6.00
8.00
10.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19

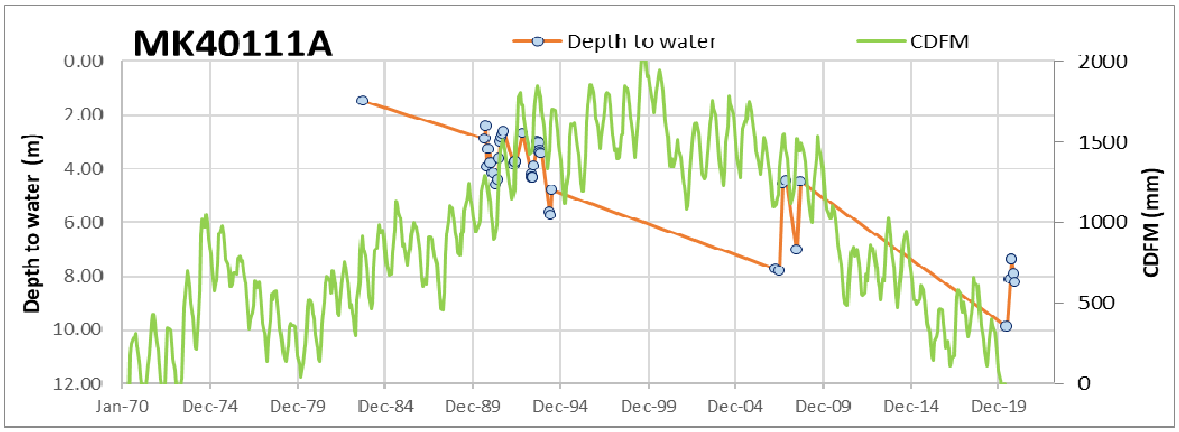

MK39181A
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
2.0
4.0
6.0
8.0
10.0
600
500
400
300
200
100
0
Jan-70
Jun-75
Dec-80
Jun-86
Nov-91
May-97
Nov-02
May-08
Oct-13
Apr-19

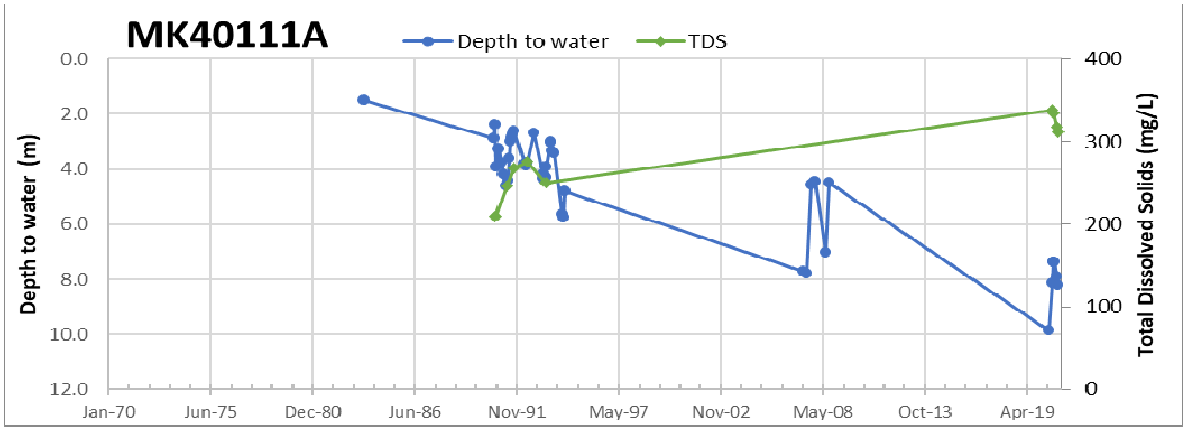

MK39191A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19

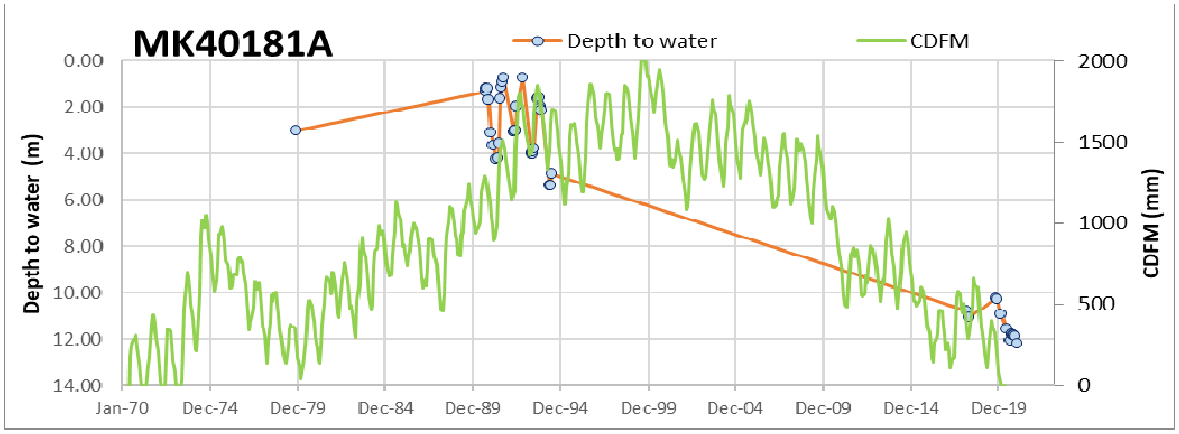

MK39191A
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
700
600
500
400
300
200
100
0
Jan-70
Jun-75
Dec-80
Jun-86
Nov-91
May-97
Nov-02
May-08
Oct-13
Apr-19

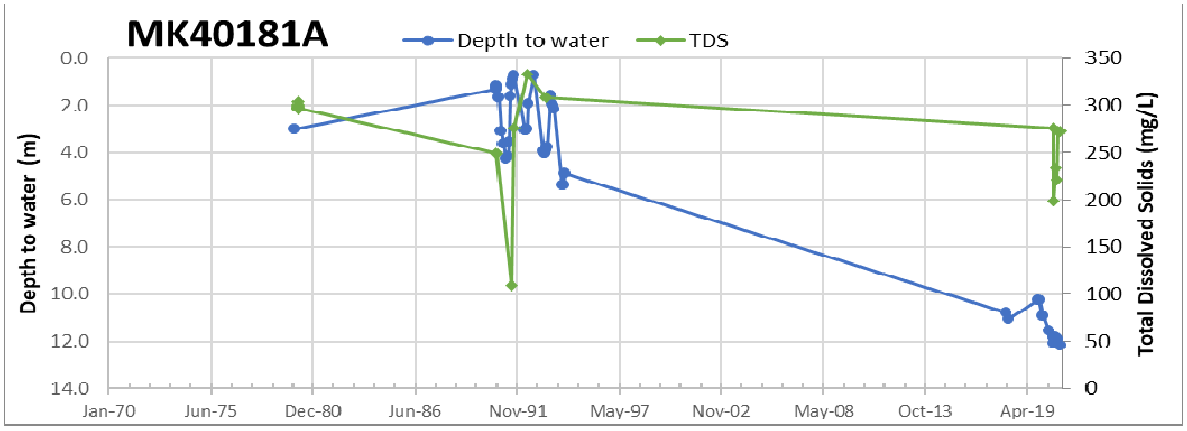

MK40102A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19

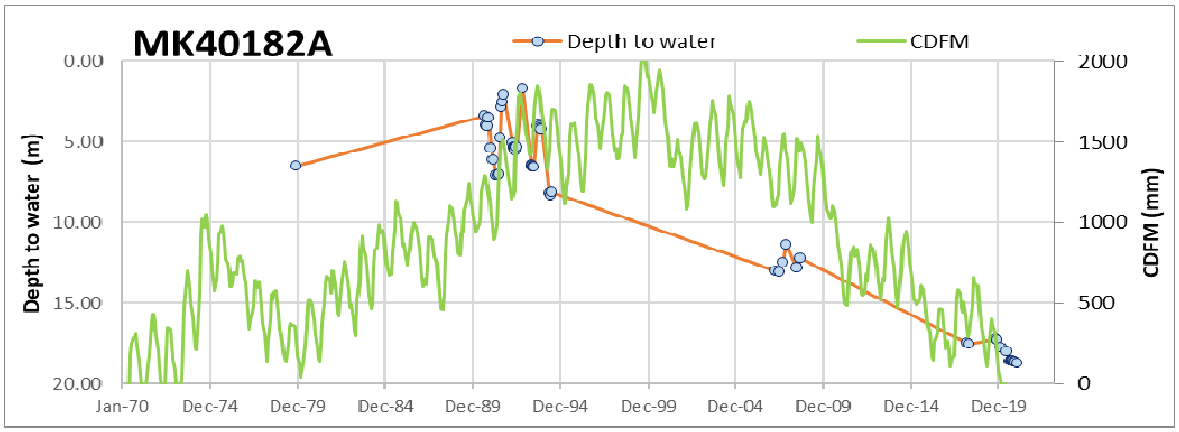

MK40102A
Depth to water
TDS
No recent field water quality data
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
200
150
100
50
0
Jan-70
Jun-75
Dec-80
Jun-86
Nov-91
May-97
Nov-02
May-08
Oct-13
Apr-19

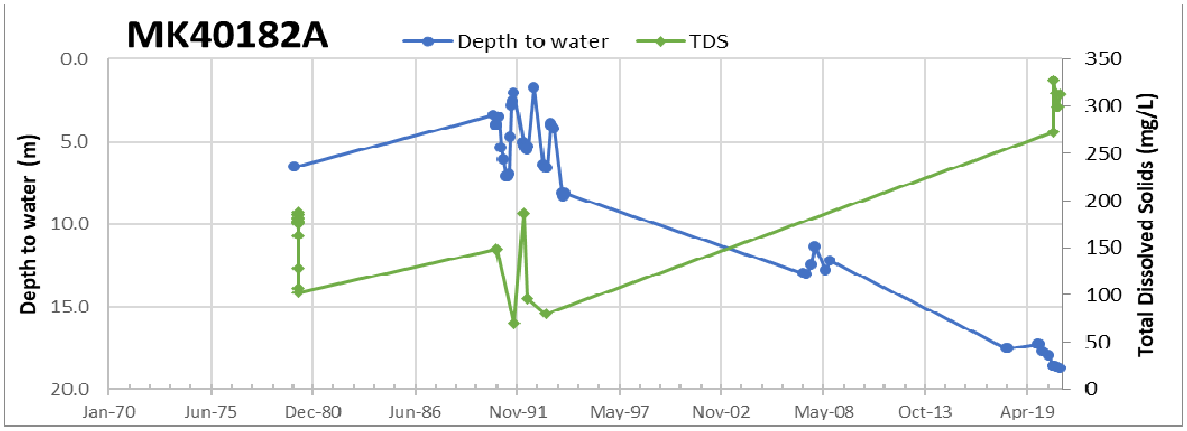

MK40111A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19

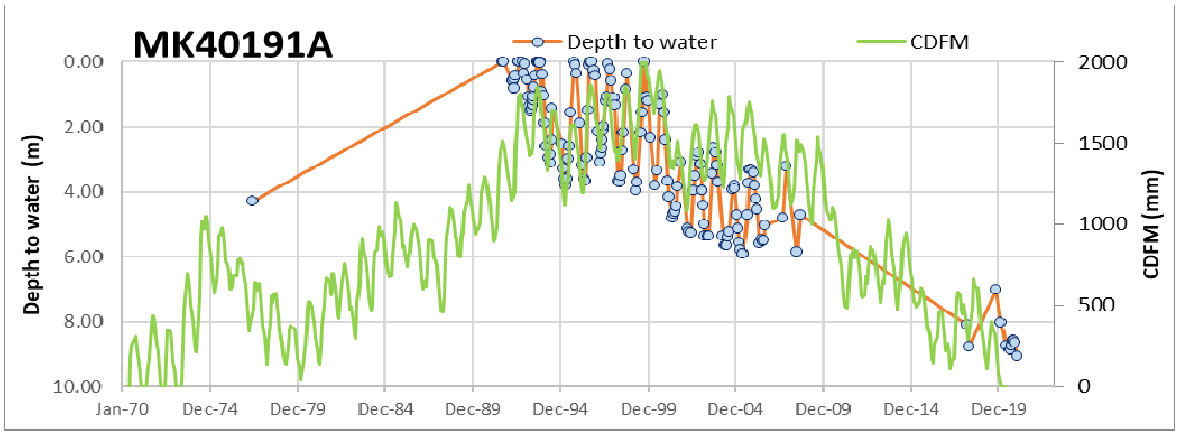

MK40111A
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
400
300
200
100
0
Jan-70
Jun-75
Dec-80
Jun-86
Nov-91
May-97
Nov-02
May-08
Oct-13
Apr-19

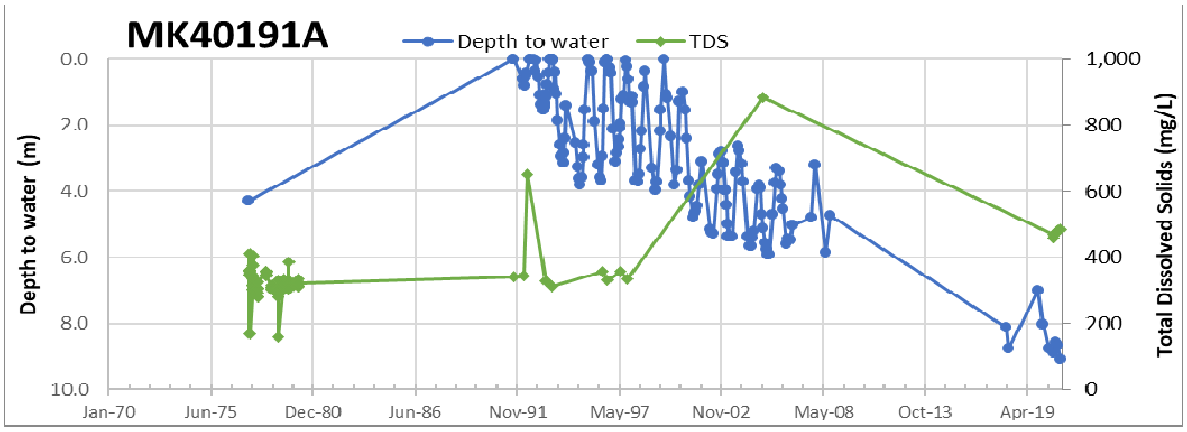

MK40181A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19

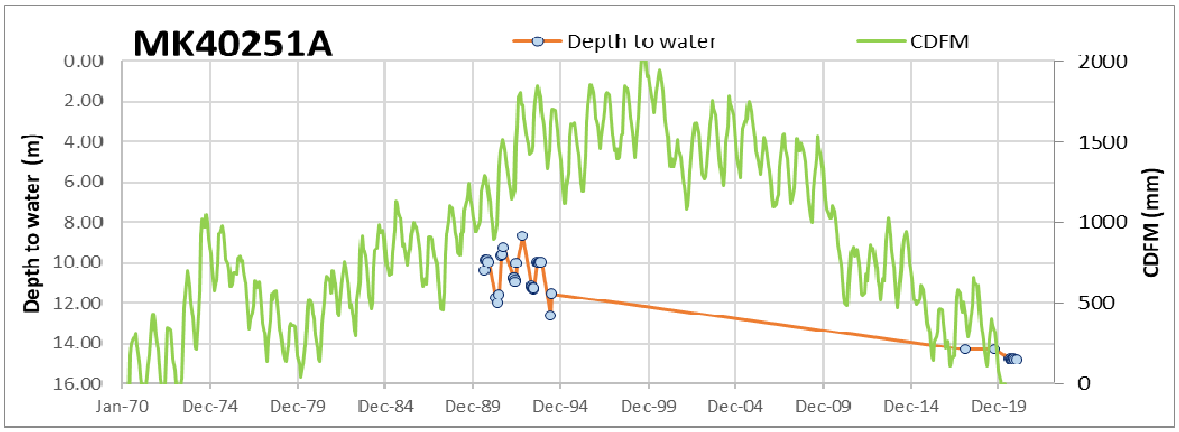

MK40181A
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
350
300
250
200
150
100
50
0
Jan-70
Jun-75
Dec-80
Jun-86
Nov-91
May-97
Nov-02
May-08
Oct-13
Apr-19

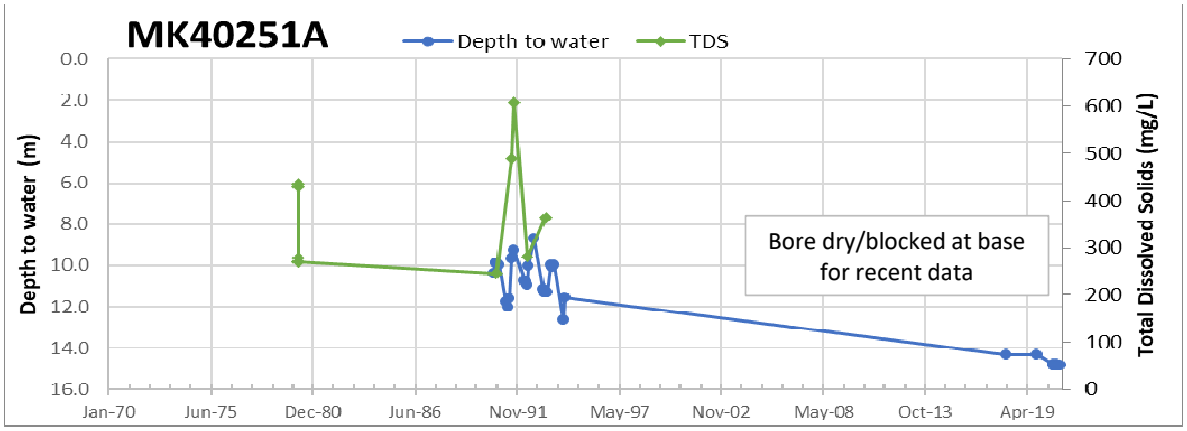

MK40182A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
5.00
10.00
15.00
20.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19

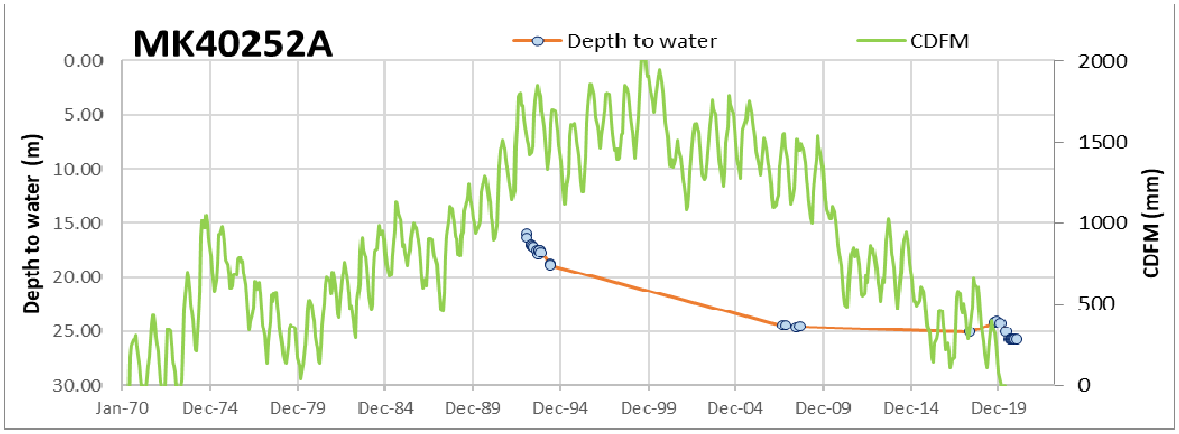

MK40182A
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
5.0
10.0
15.0
20.0
350
300
250
200
150
100
50
0
Jan-70
Jun-75
Dec-80
Jun-86
Nov-91
May-97
Nov-02
May-08
Oct-13
Apr-19

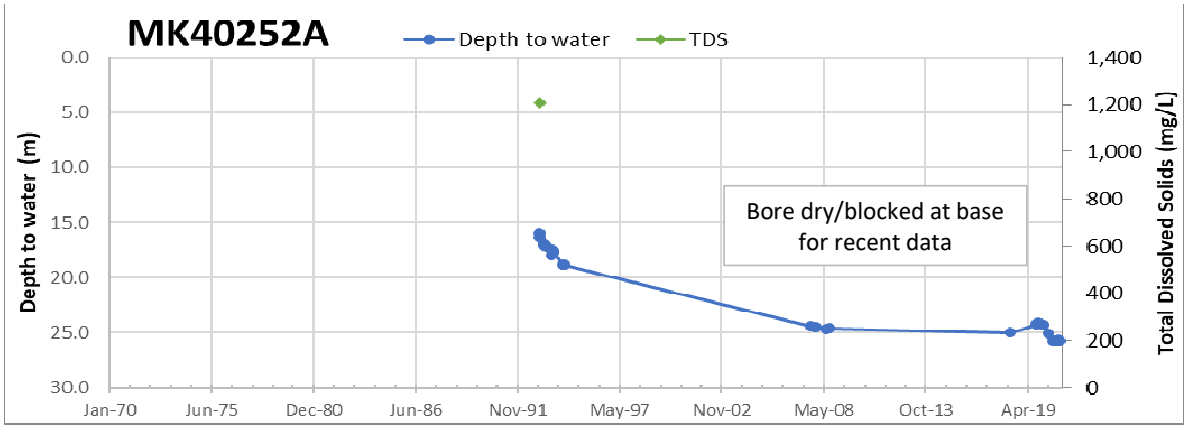

MK40191A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
2.00
4.00
6.00
8.00
10.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19

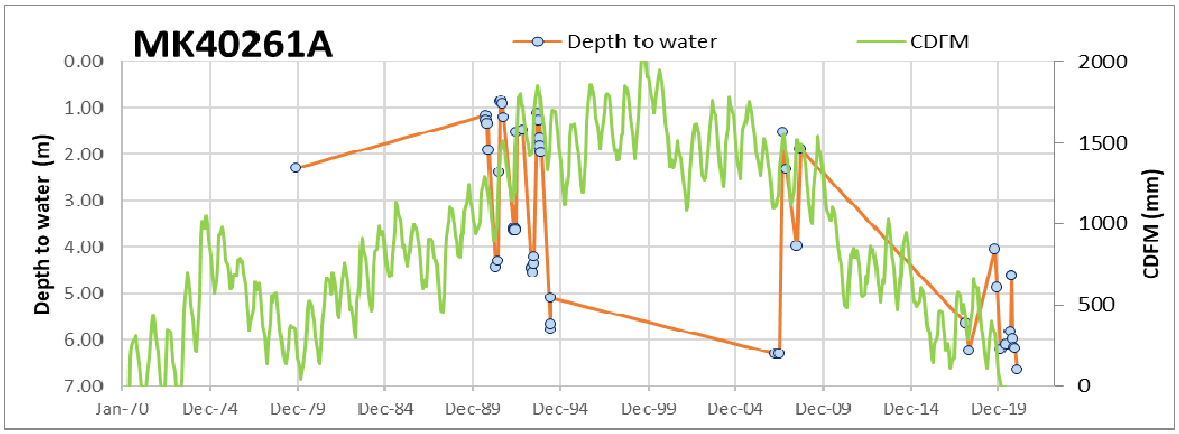

MK40191A
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
2.0
4.0
6.0
8.0
10.0
1,000
800
600
400
200
0
Jan-70
Jun-75
Dec-80
Jun-86
Nov-91
May-97
Nov-02
May-08
Oct-13
Apr-19

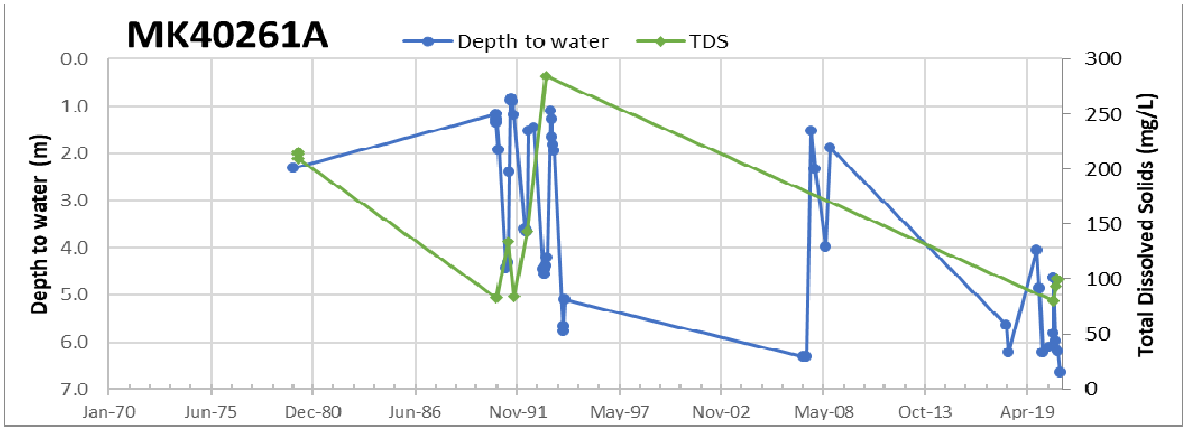

MK40251A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19

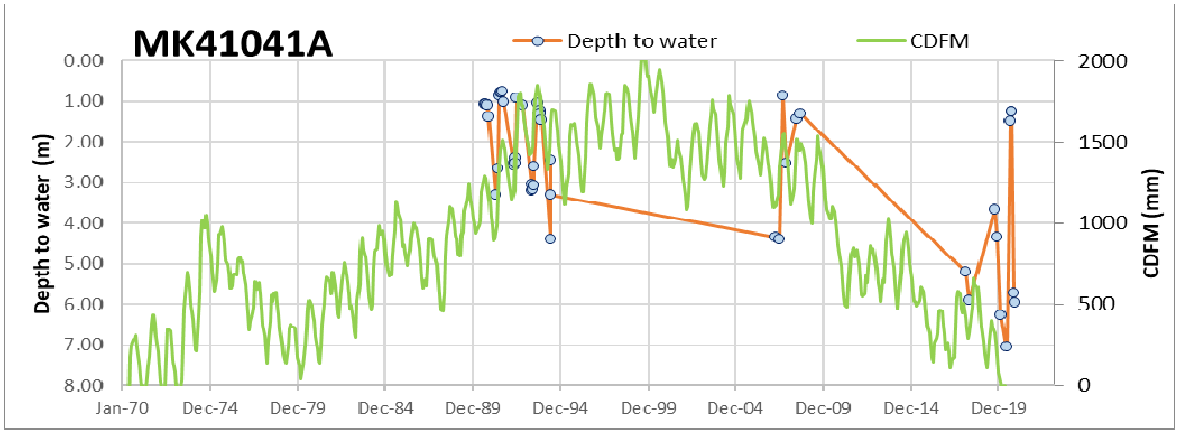

MK40251A
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
Bore dry/blocked at base for recent data
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
700
600
500
400
300
200
100
0
Jan-70
Jun-75
Dec-80
Jun-86
Nov-91
May-97
Nov-02
May-08
Oct-13
Apr-19

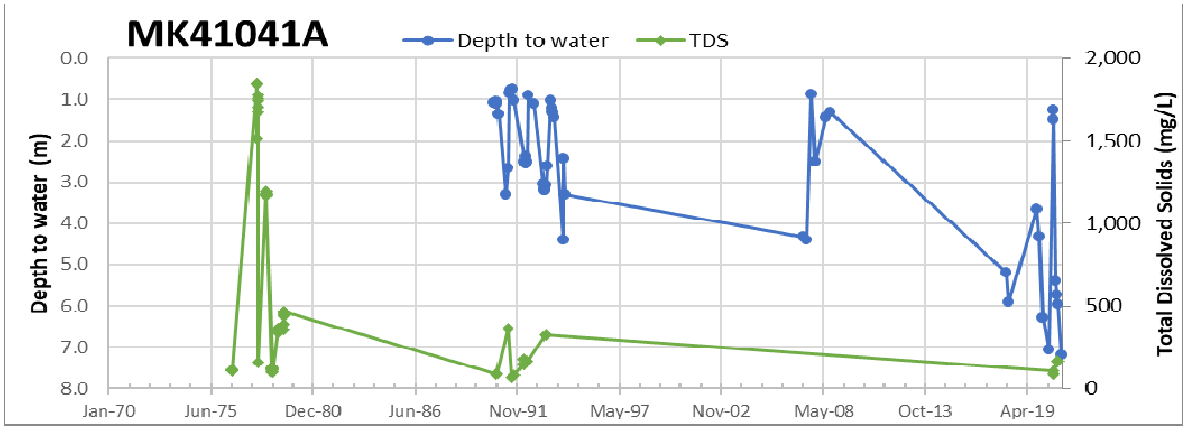

MK40252A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19

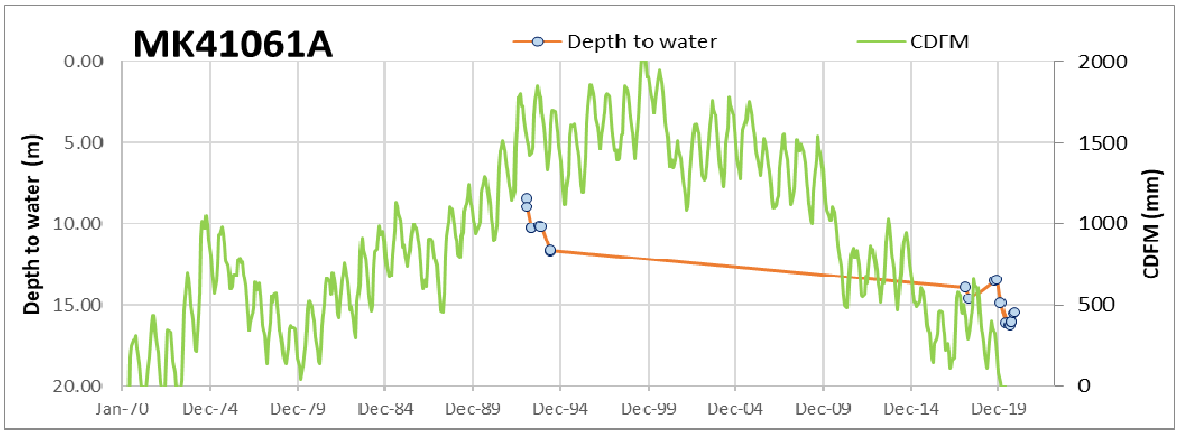

MK40252A
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
Bore dry/blocked at base for recent data
0.0
5.0
10.0
15.0
20.0
25.0
30.0
1,400
1,200
1,000
800
600
400
200
0
Jan-70
Jun-75
Dec-80
Jun-86
Nov-91
May-97
Nov-02
May-08
Oct-13
Apr-19

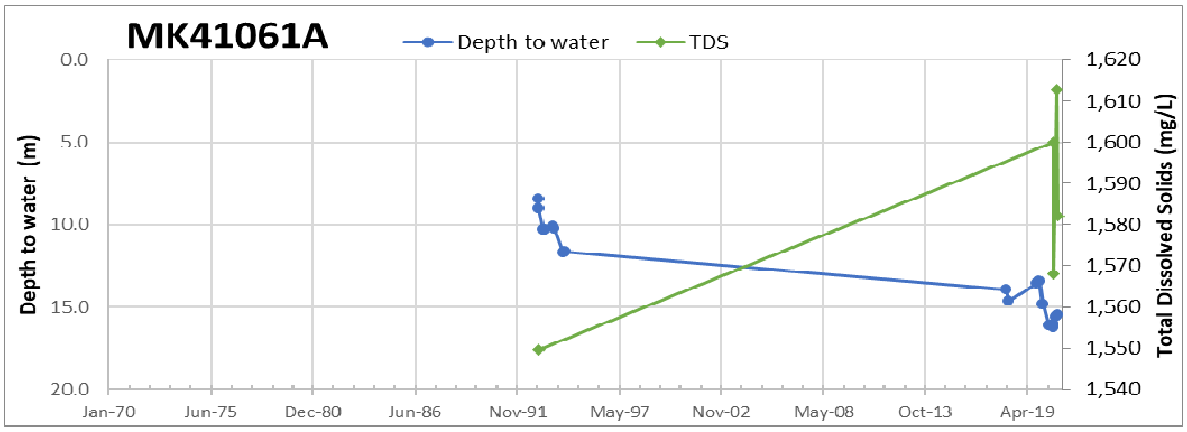

MK40261A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19

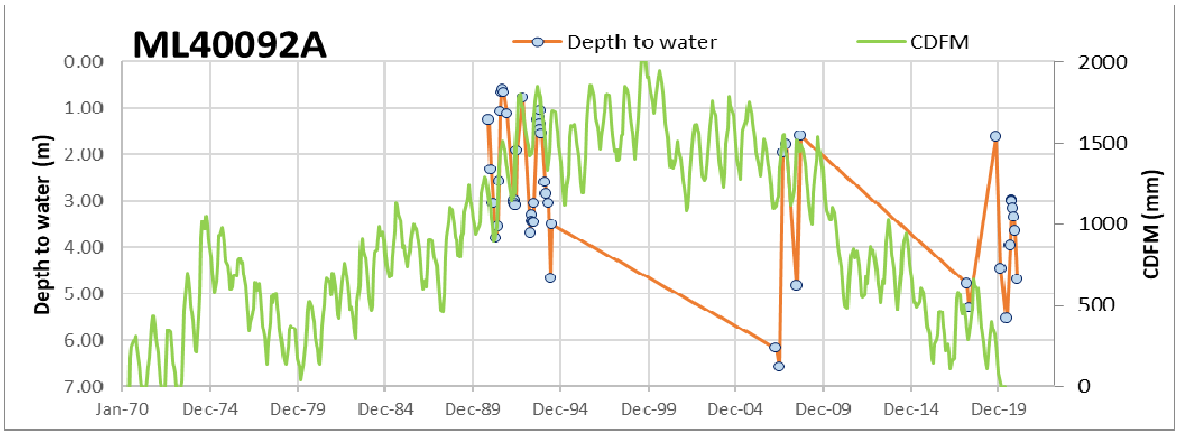

MK40261A
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
300
250
200
150
100
50
0
Jan-70
Jun-75
Dec-80
Jun-86
Nov-91
May-97
Nov-02
May-08
Oct-13
Apr-19

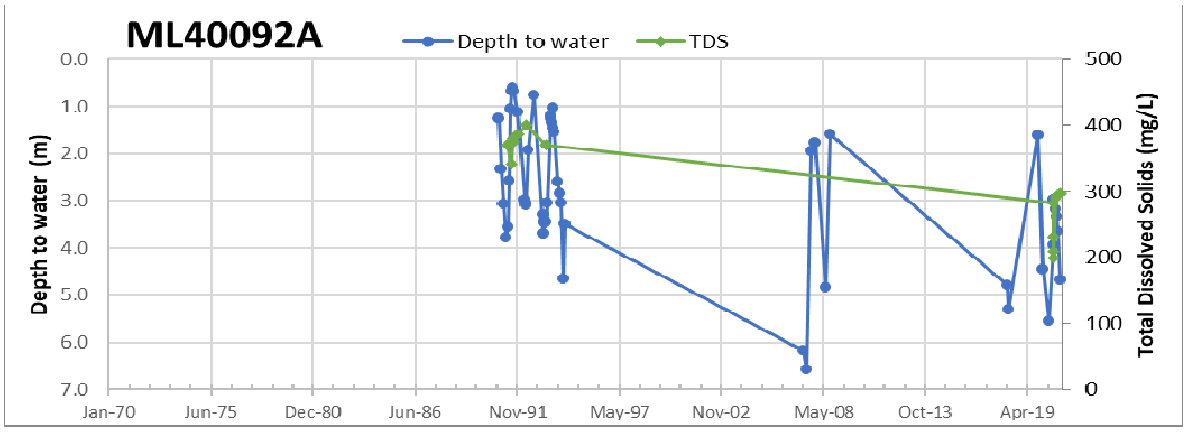

MK41041A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19

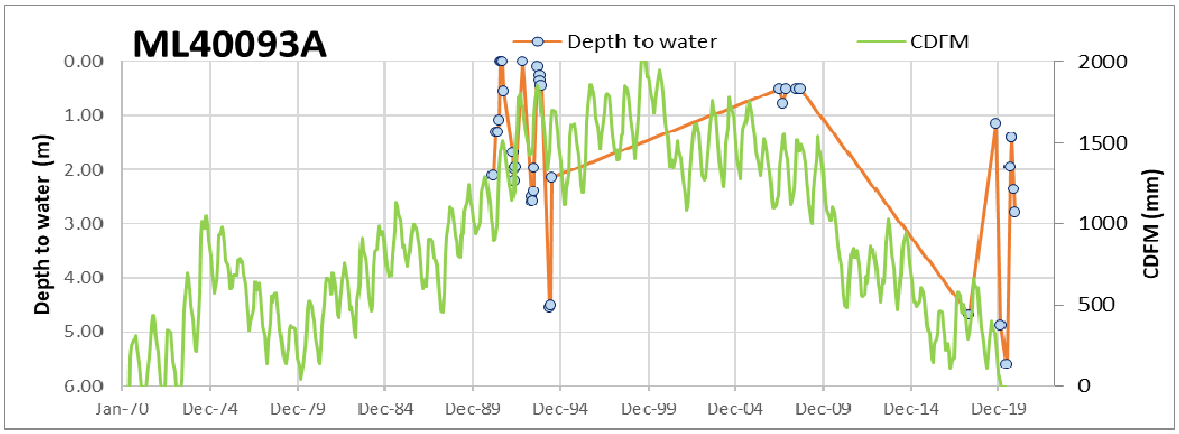

MK41041A
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
2,000
1,500
1,000
500
0
Jan-70
Jun-75
Dec-80
Jun-86
Nov-91
May-97
Nov-02
May-08
Oct-13
Apr-19

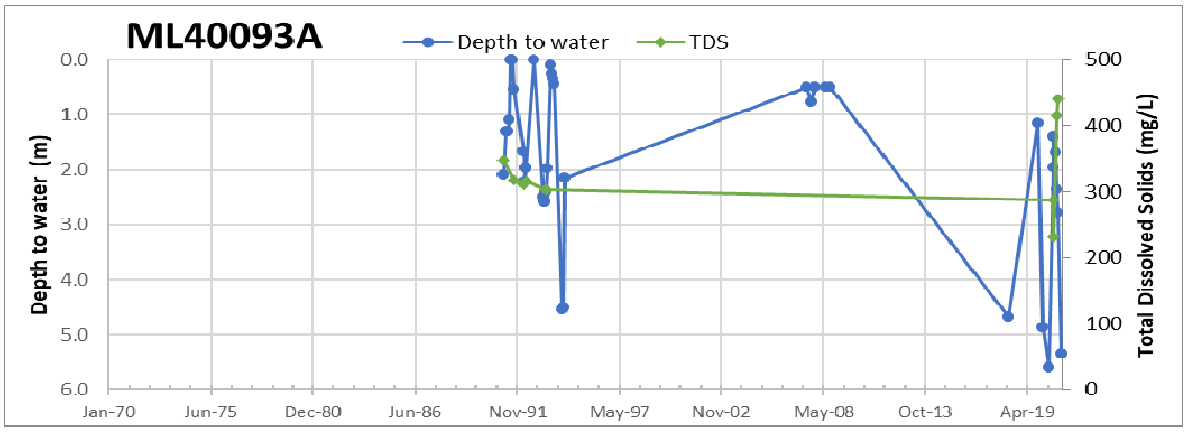

MK41061A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
5.00
10.00
15.00
20.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19

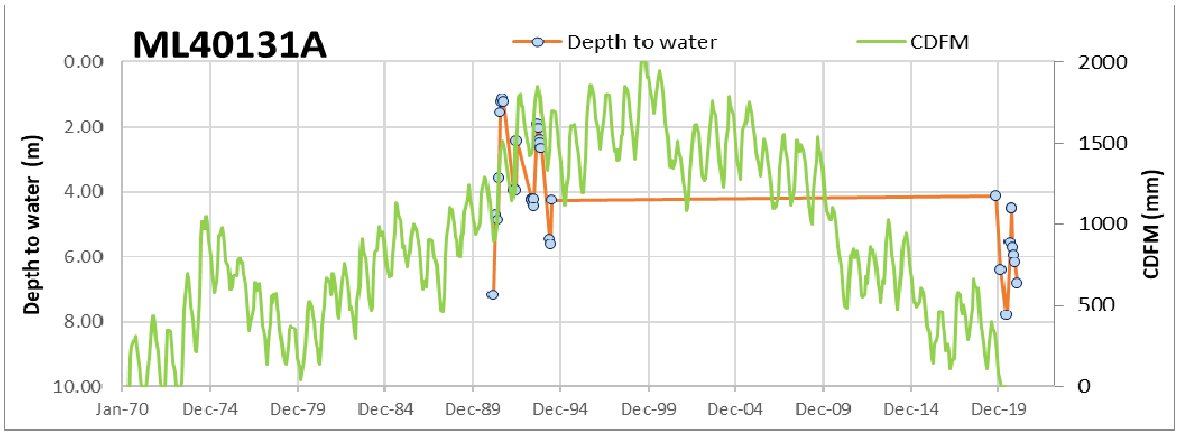

MK41061A
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
5.0
10.0
15.0
20.0
1,620
1,610
1,600
1,590
1,580
1,570
1,560
1,550
1,540
Jan-70
Jun-75
Dec-80
Jun-86
Nov-91
May-97
Nov-02
May-08
Oct-13
Apr-19

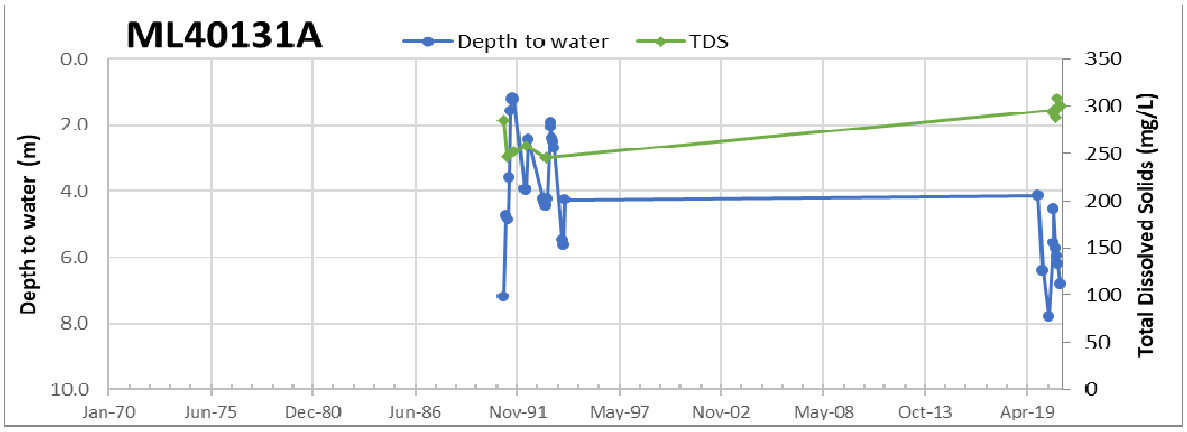

ML40092A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19

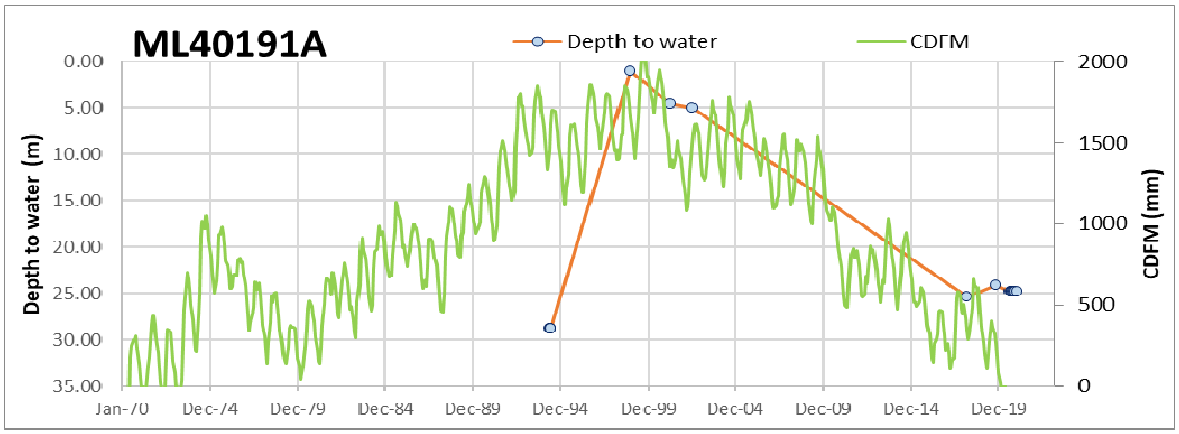

ML40092A
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
500
400
300
200
100
0
Jan-70
Jun-75
Dec-80
Jun-86
Nov-91
May-97
Nov-02
May-08
Oct-13
Apr-19

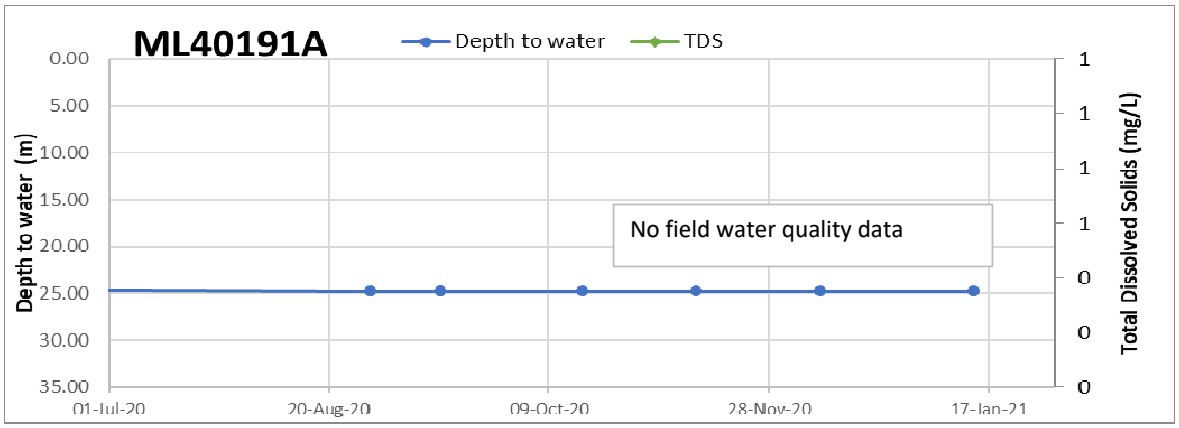

ML40093A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19

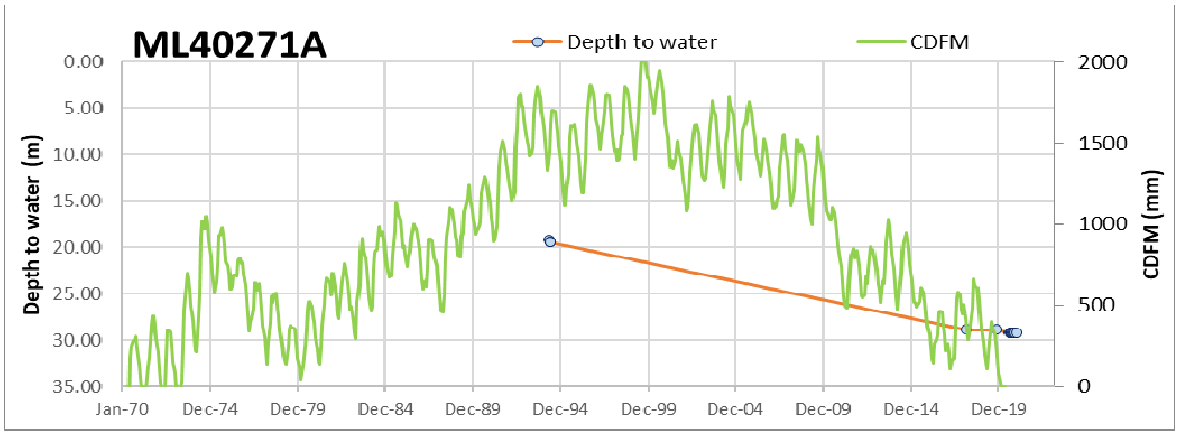

ML40093A
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
500
400
300
200
100
0
Jan-70
Jun-75
Dec-80
Jun-86
Nov-91
May-97
Nov-02
May-08
Oct-13
Apr-19

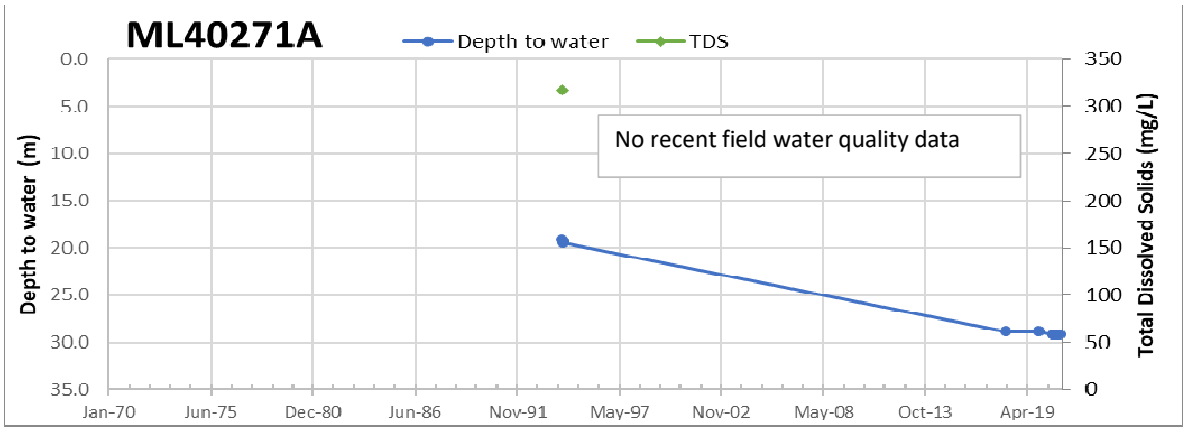

ML40131A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
2.00
4.00
6.00
8.00
10.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19

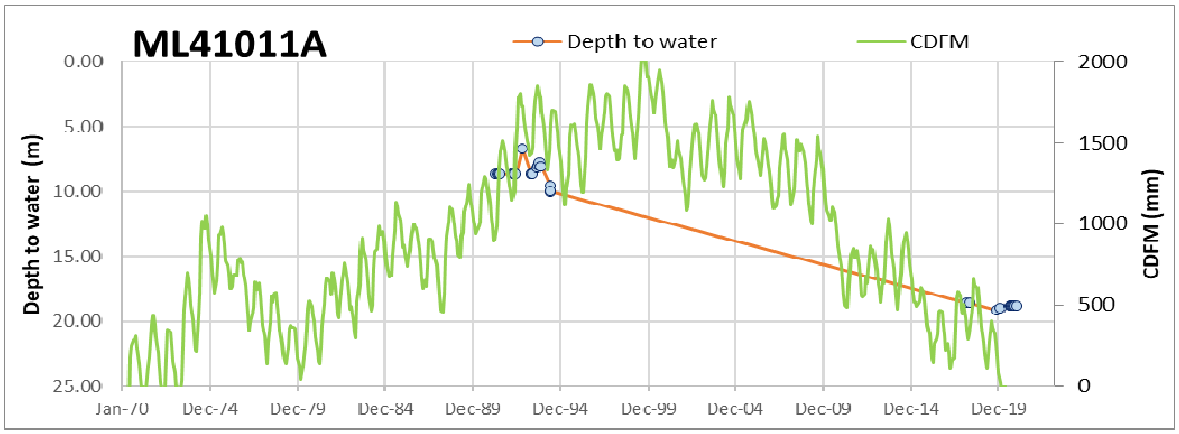

ML40131A
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
2.0
4.0
6.0
8.0
10.0
350
300
250
200
150
100
50
0
Jan-70
Jun-75
Dec-80
Jun-86
Nov-91
May-97
Nov-02
May-08
Oct-13
Apr-19

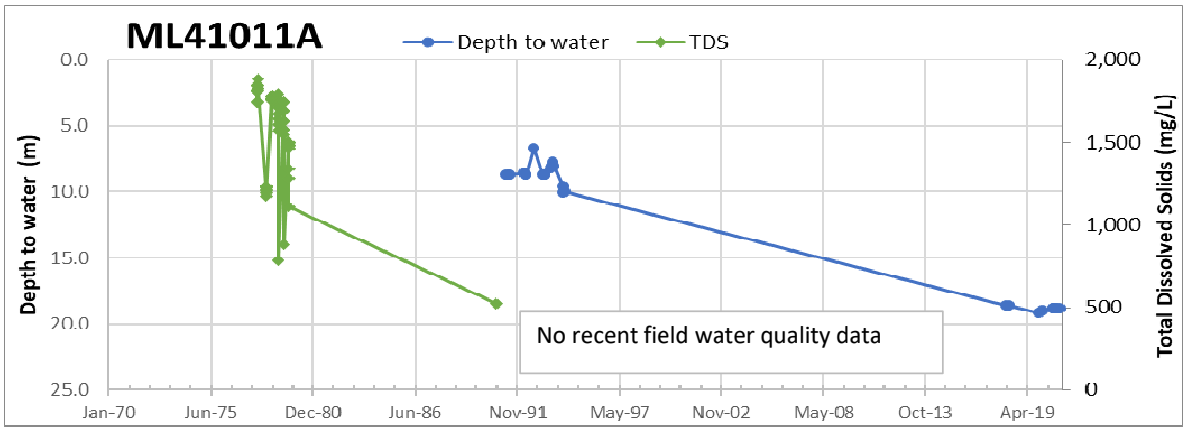

ML40191A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19


ML40191A
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
No field water quality data
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
1
1
1
1
0
0
0
01-Jul-20
20-Aug-20
09-Oct-20
28-Nov-20
17-Jan-21


ML40271A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19


ML40271A
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
No recent field water quality data
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
350
300
250
200
150
100
50
0
Jan-70
Jun-75
Dec-80
Jun-86
Nov-91
May-97
Nov-02
May-08
Oct-13
Apr-19

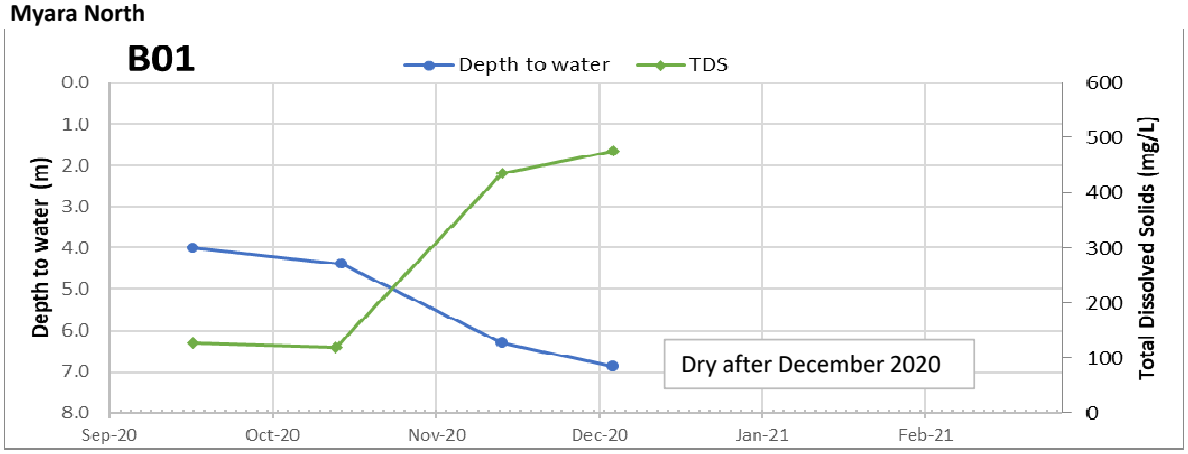

ML41011A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
5.00
10.00
15.00
20.00
25.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19

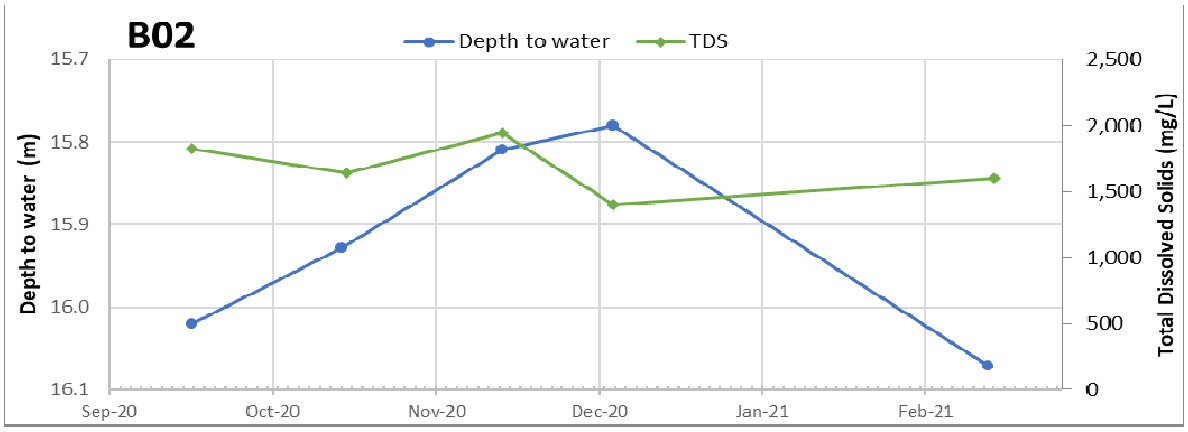

ML41011A
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
5.0
10.0
15.0
20.0
25.0
2,000
1,500
1,000
500
0
Jan-70
Jun-75
Dec-80
Jun-86
Nov-91
May-97
Nov-02
May-08
Oct-13
Apr-19
No recent field water quality data

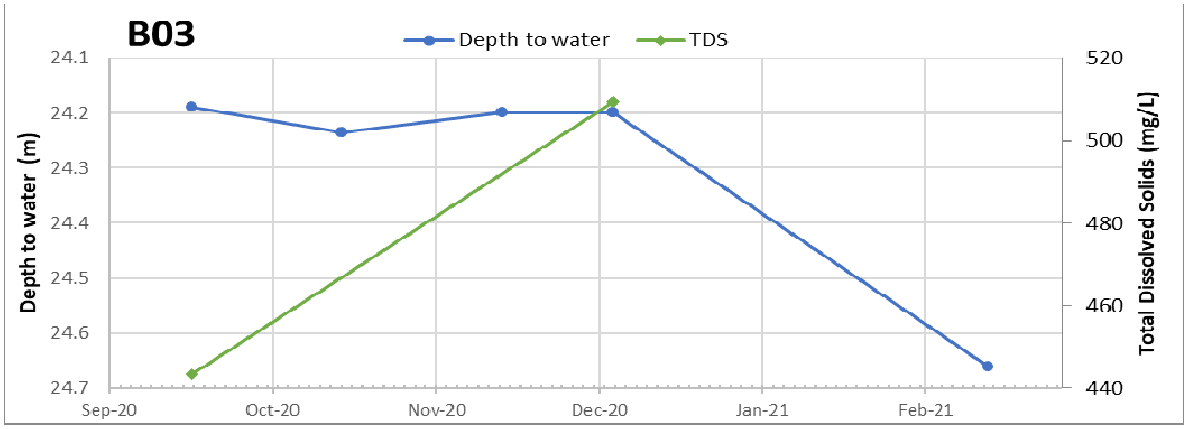
Appendix D

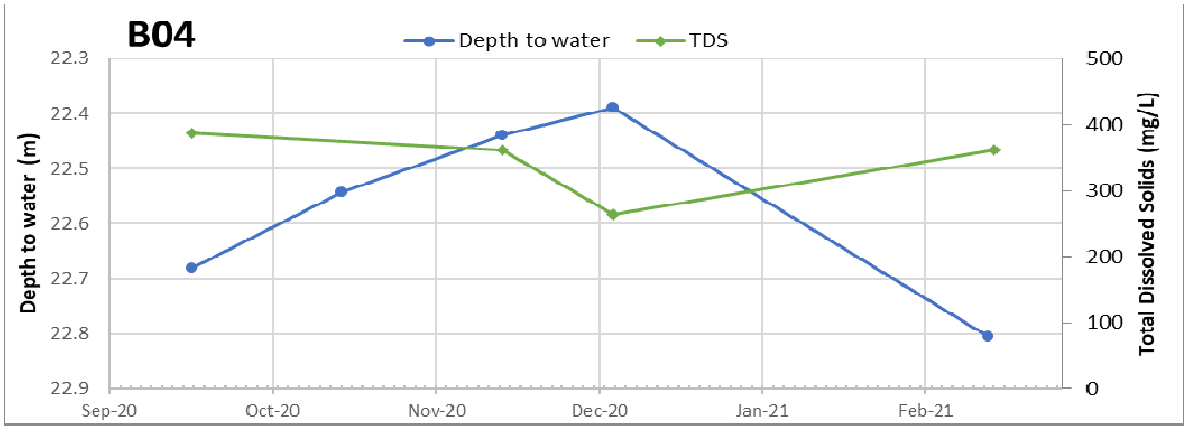
New monitoring bore hydrographs and salinity graphs Myara North and Holyoake

Myara North

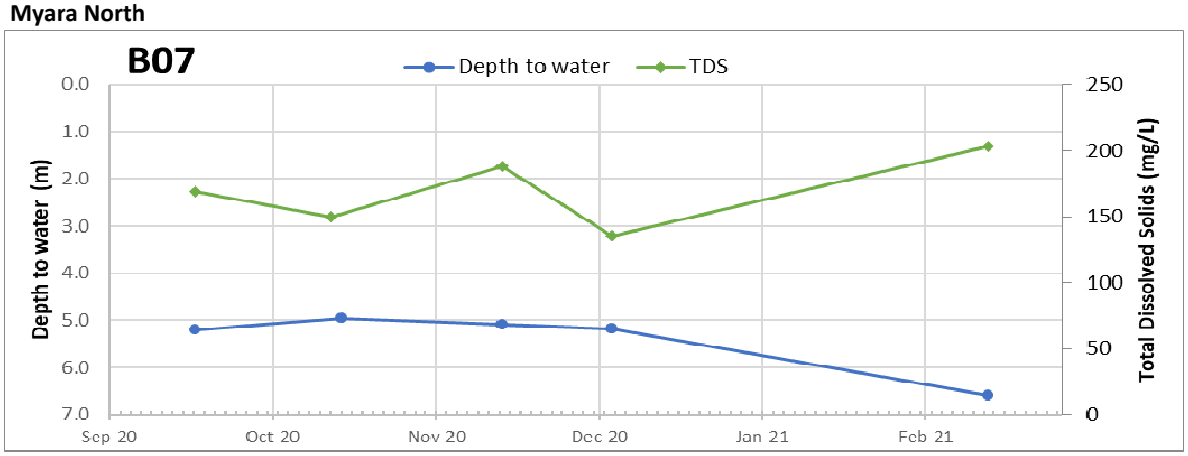

B01
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
600
500
400
300
200
100
0
Dry after December 2020
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

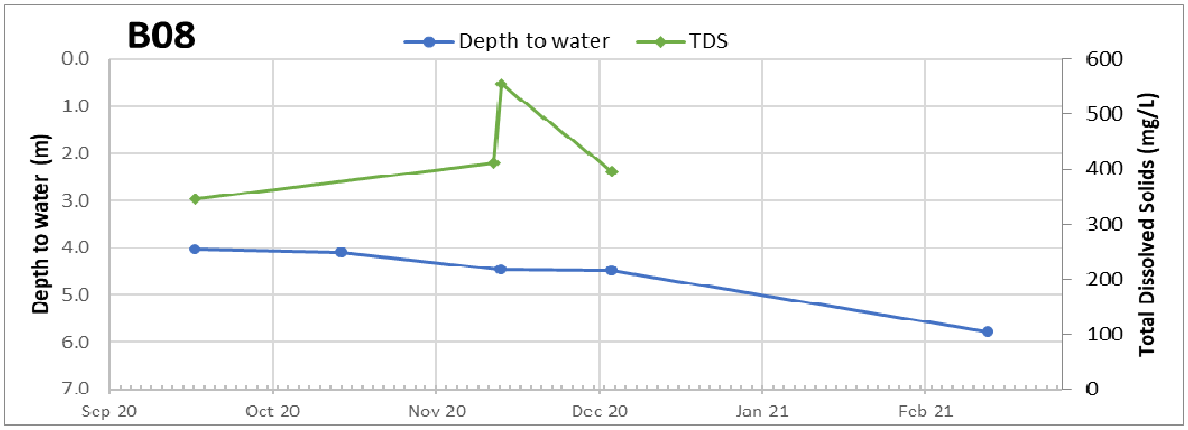

B02
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
15.7
15.8
15.9
16.0
16.1
2,500
2,000
1,500
1,000
500
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

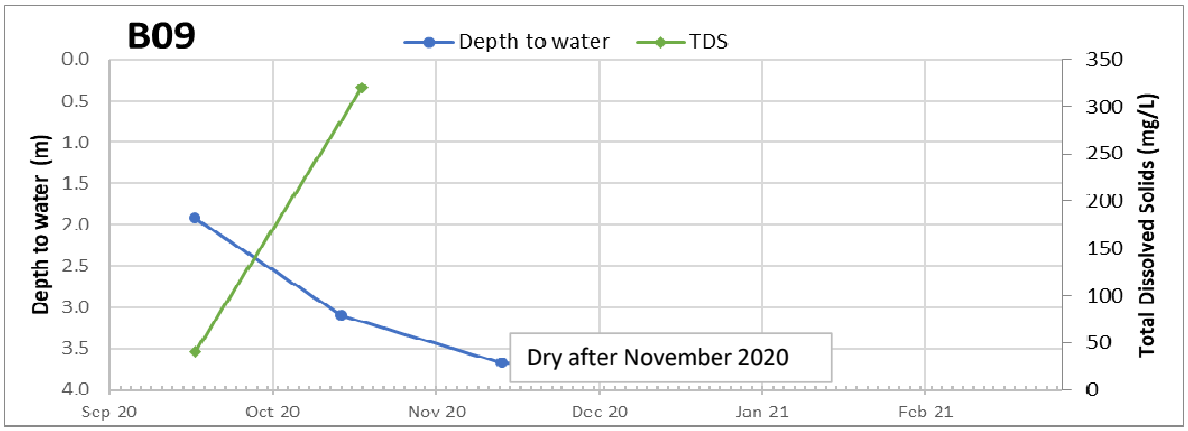

B03
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
24.1
24.2
24.3
24.4
24.5
24.6
24.7
520
500
480
460
440
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

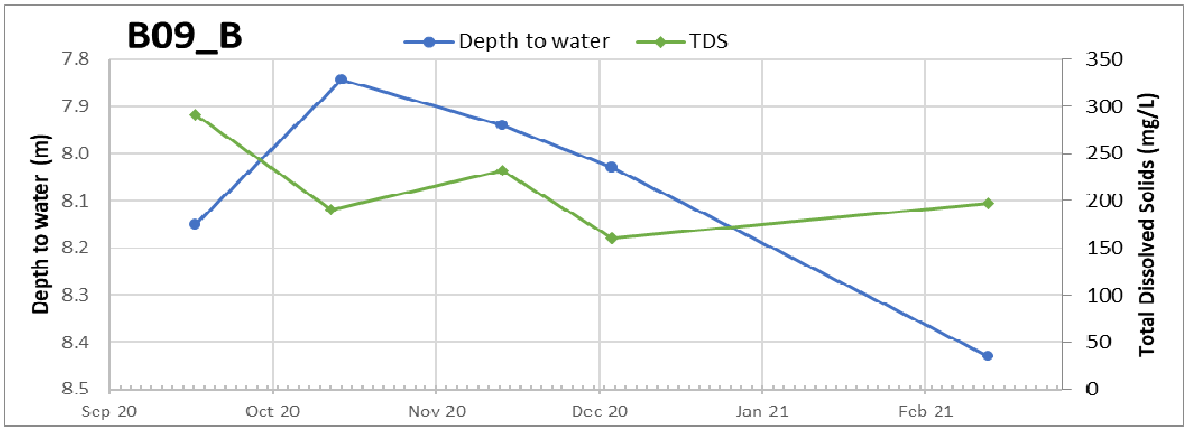

B04
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
22.3
22.4
22.5
22.6
22.7
22.8
22.9
500
400
300
200
100
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

Myara North

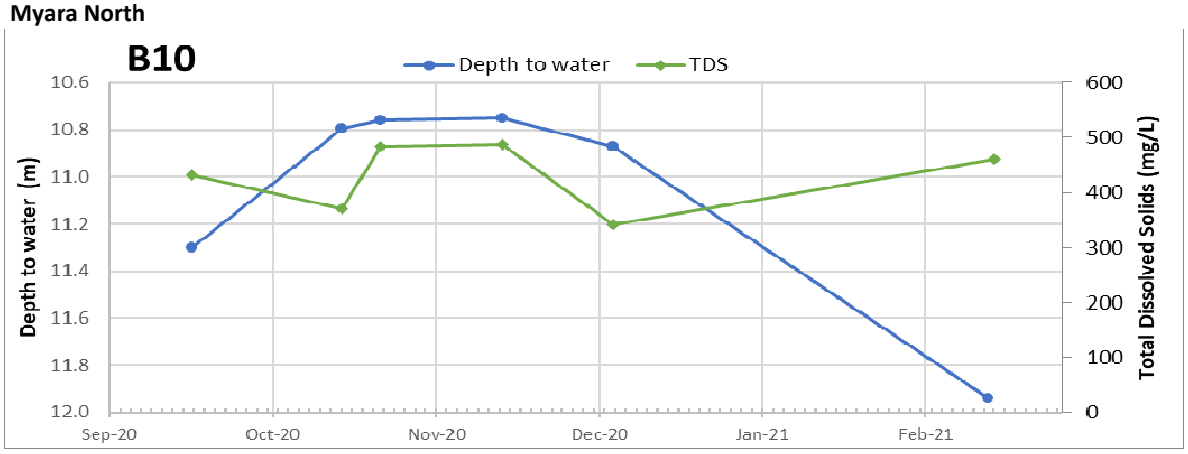

B07
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
250
200
150
100
50
0
Sep 20
Oct 20
Nov 20
Dec 20
Jan 21
Feb 21

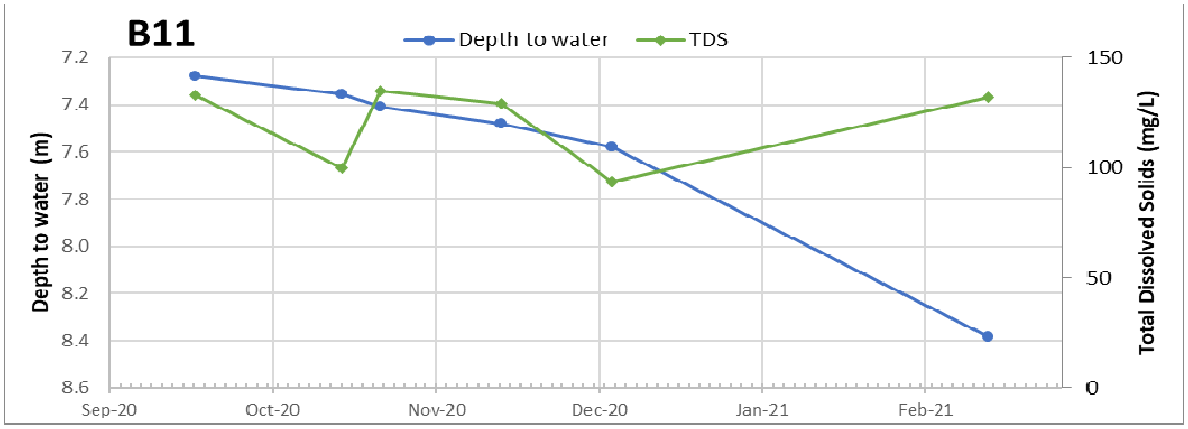

B08
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
600
500
400
300
200
100
0
Sep 20
Oct 20
Nov 20
Dec 20
Jan 21
Feb 21

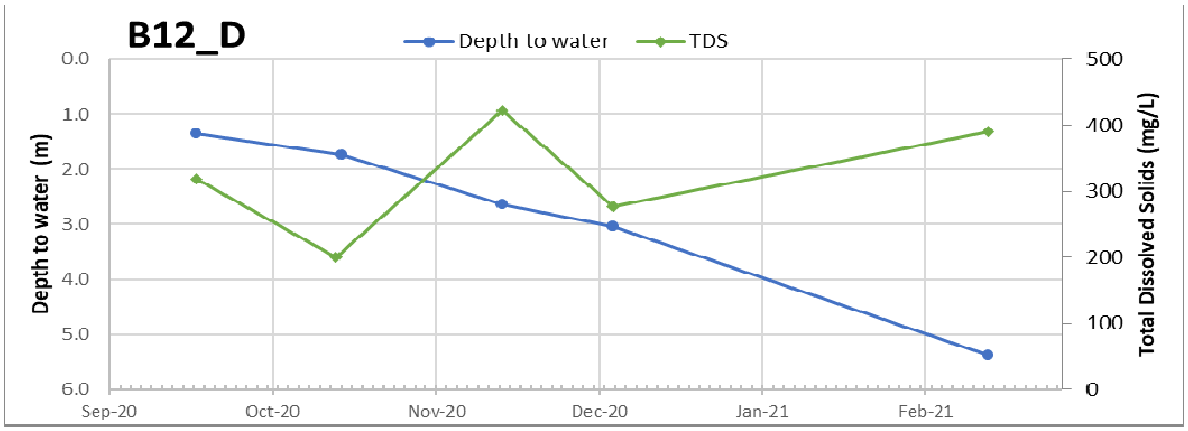

B09
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
350
300
250
200
150
100
50
0
Dry after November 2020
Sep 20
Oct 20
Nov 20
Dec 20
Jan 21
Feb 21

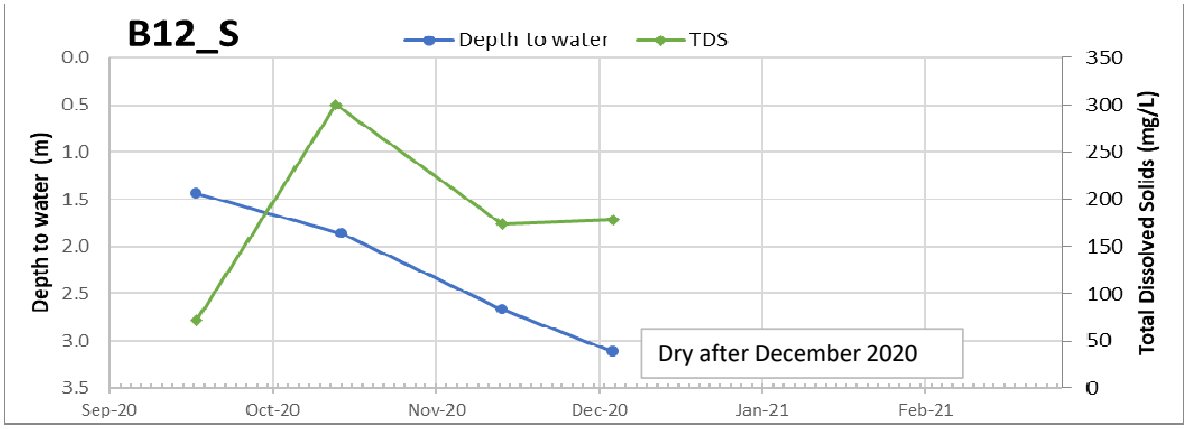

B09_B
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
7.8
7.9
8.0
8.1
8.2
8.3
8.4
8.5
350
300
250
200
150
100
50
0
Sep 20
Oct 20
Nov 20
Dec 20
Jan 21
Feb 21

Myara North

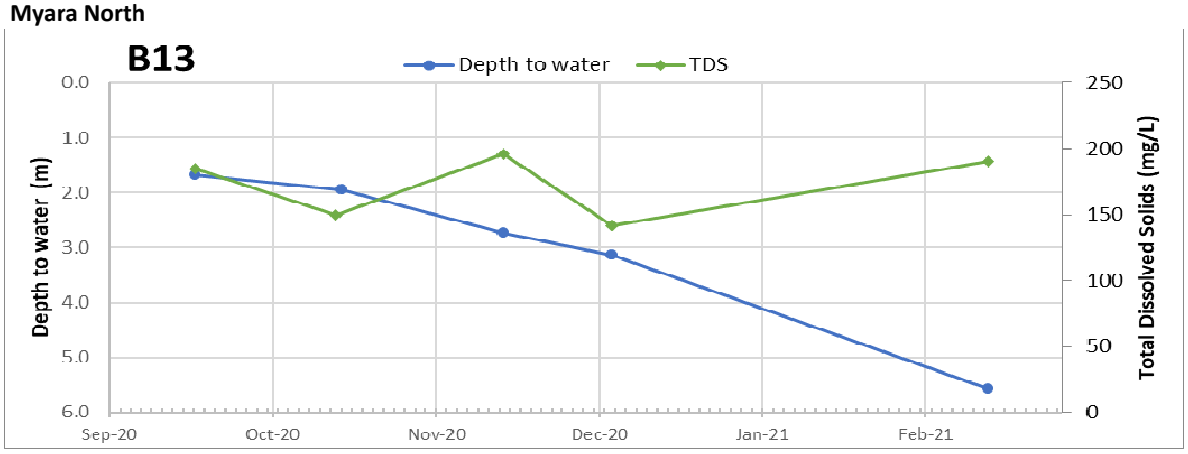

B10
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
10.6
10.8
11.0
11.2
11.4
11.6
11.8
12.0
600
500
400
300
200
100
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

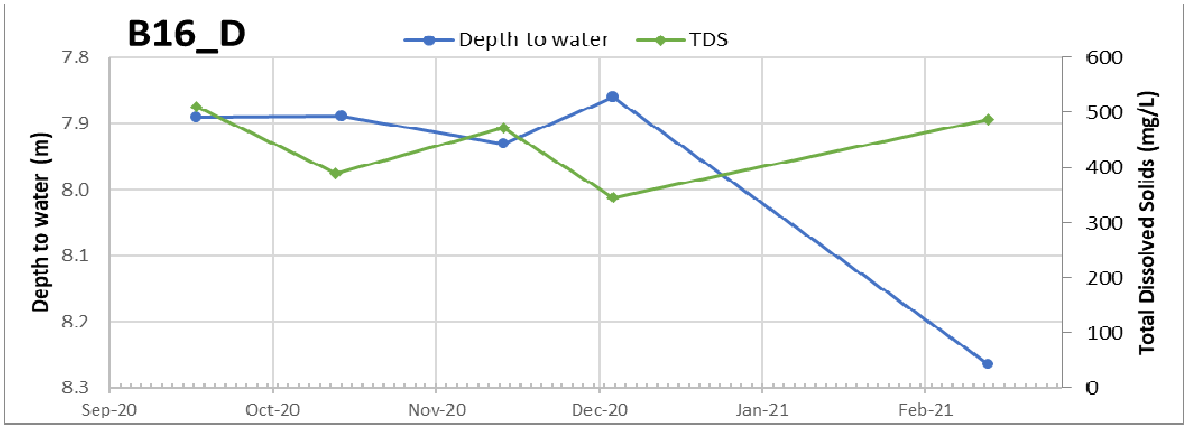

B11
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
7.2
7.4
7.6
7.8
8.0
8.2
8.4
8.6
150
100
50
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

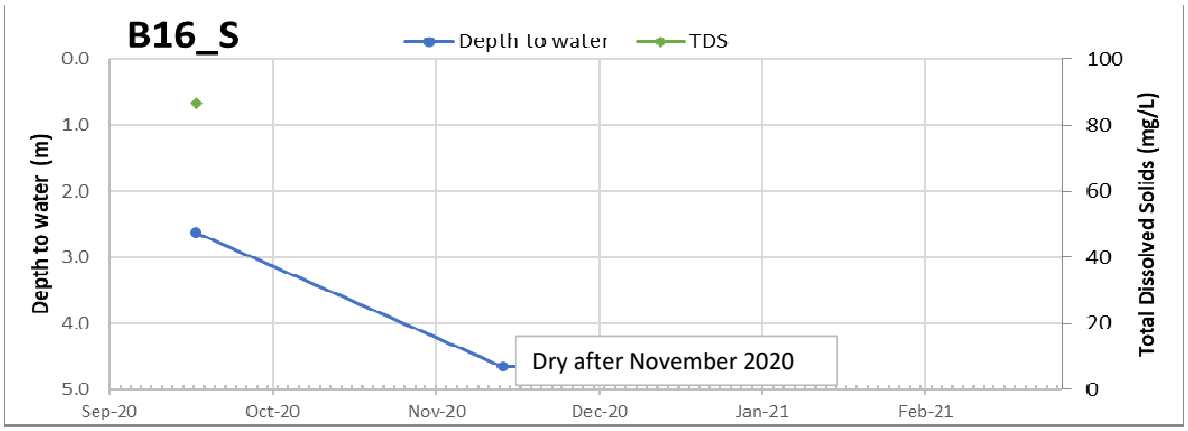

B12_D
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
500
400
300
200
100
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

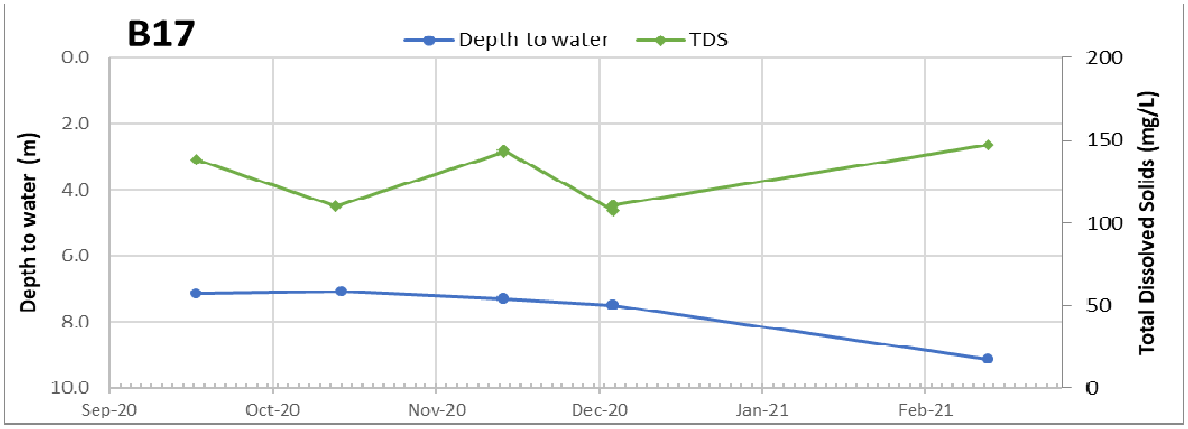

B12_S
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
350
300
250
200
150
100
50
0
Dry after December 2020
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

Myara North

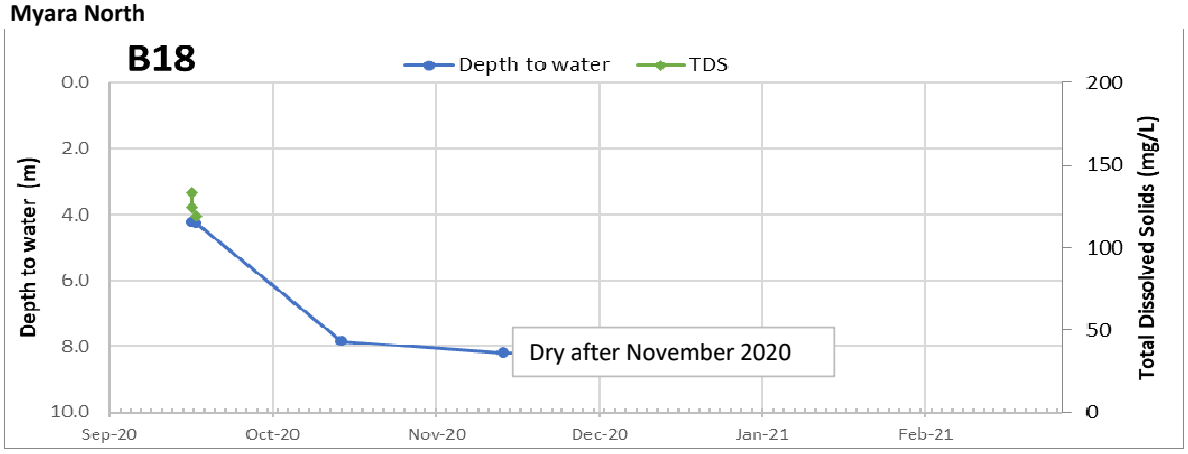

B13
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
250
200
150
100
50
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

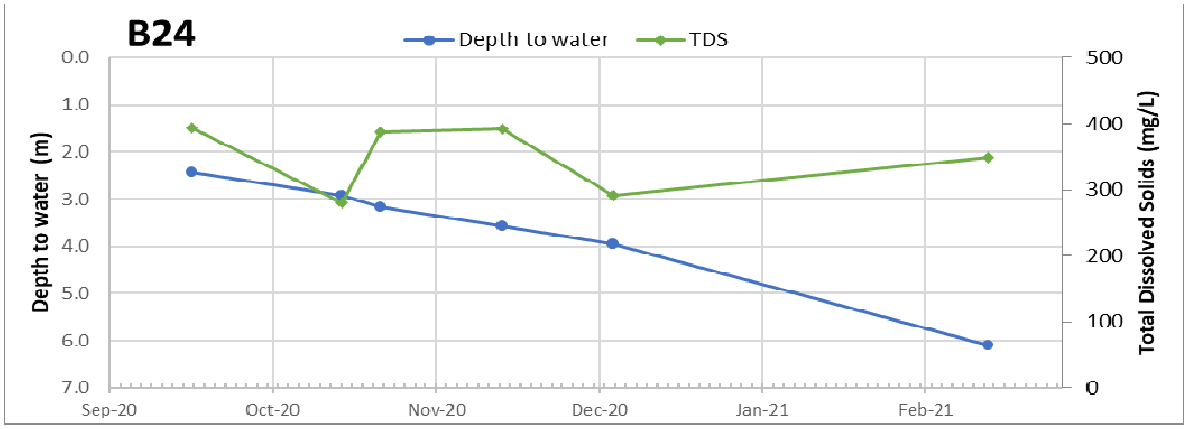

B16_D
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
7.8
7.9
8.0
8.1
8.2
8.3
600
500
400
300
200
100
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21


B16_S
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
1.0
2.0
3.0
4.0
5.0
100
80
60
40
20
0
Dry after November 2020
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

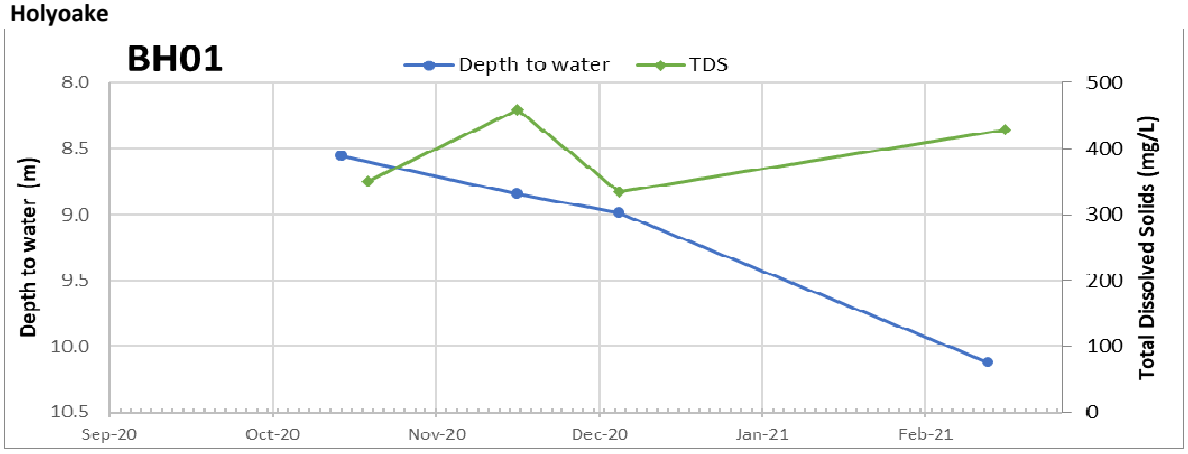

B17
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
2.0
4.0
6.0
8.0
10.0
200
150
100
50
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

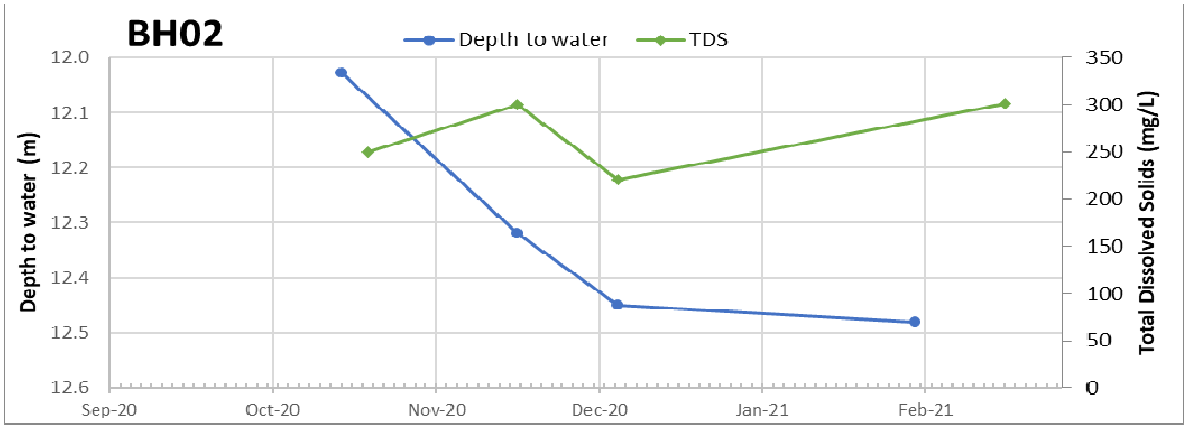
Myara North

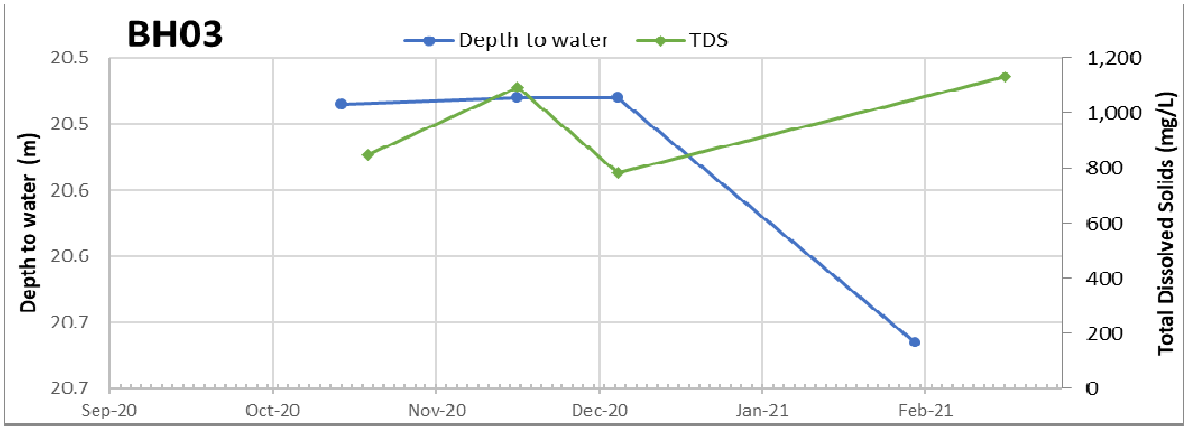

B18
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
2.0
4.0
6.0
8.0
10.0
200
150
100
50
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21
Dry after November 2020

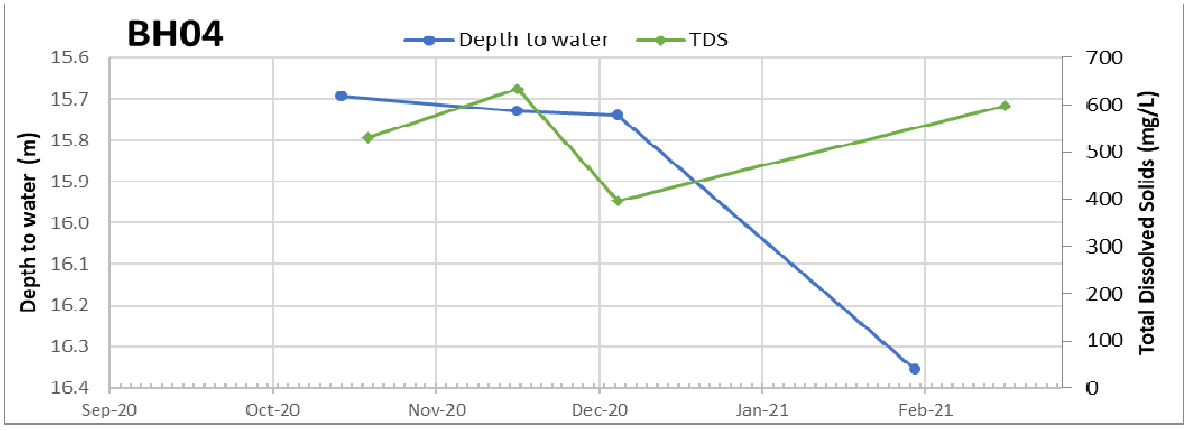

B24
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
500
400
300
200
100
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

Holyoake

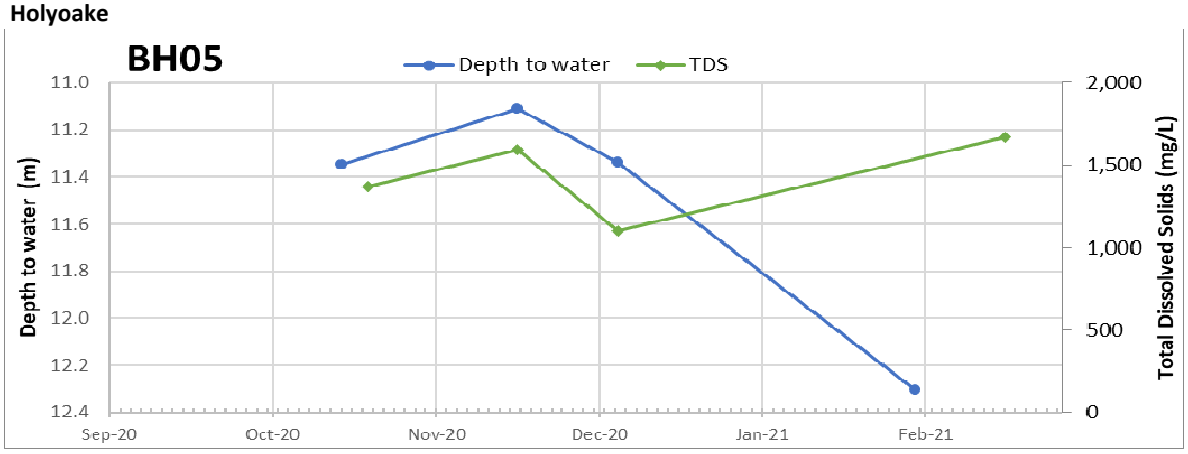

BH01
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
8.0
8.5
9.0
9.5
10.0
10.5
500
400
300
200
100
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

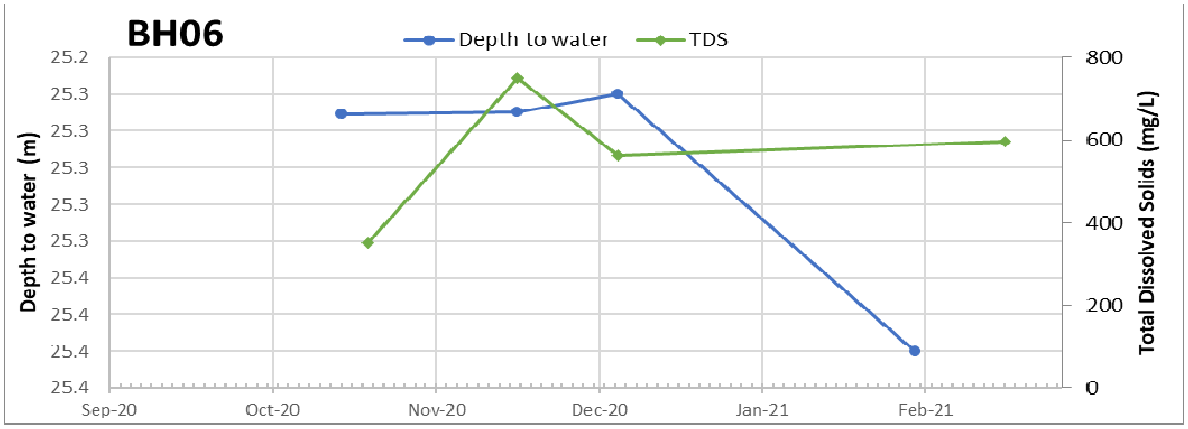

BH02
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
12.0
12.1
12.2
12.3
12.4
12.5
12.6
350
300
250
200
150
100
50
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

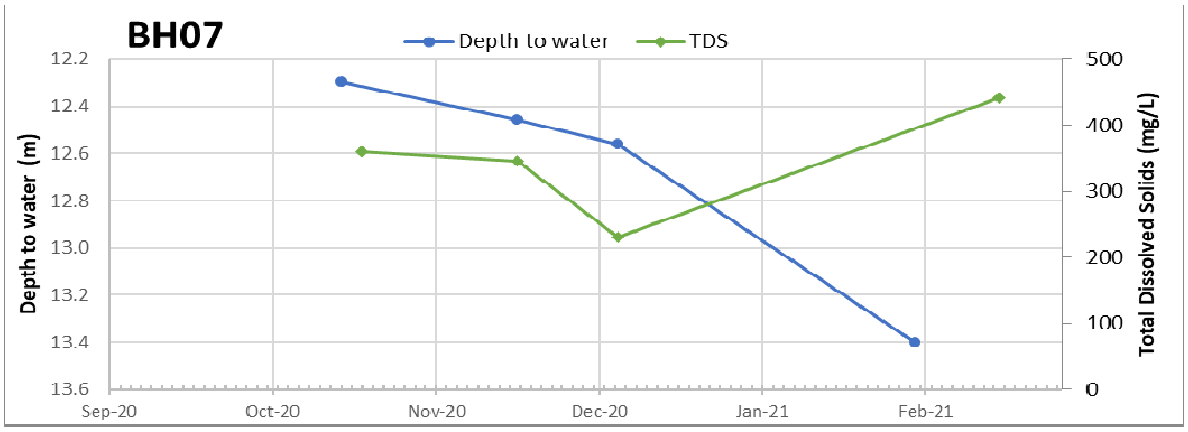

BH03
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
20.5
20.5
20.6
20.6
20.7
20.7
1,200
1,000
800
600
400
200
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

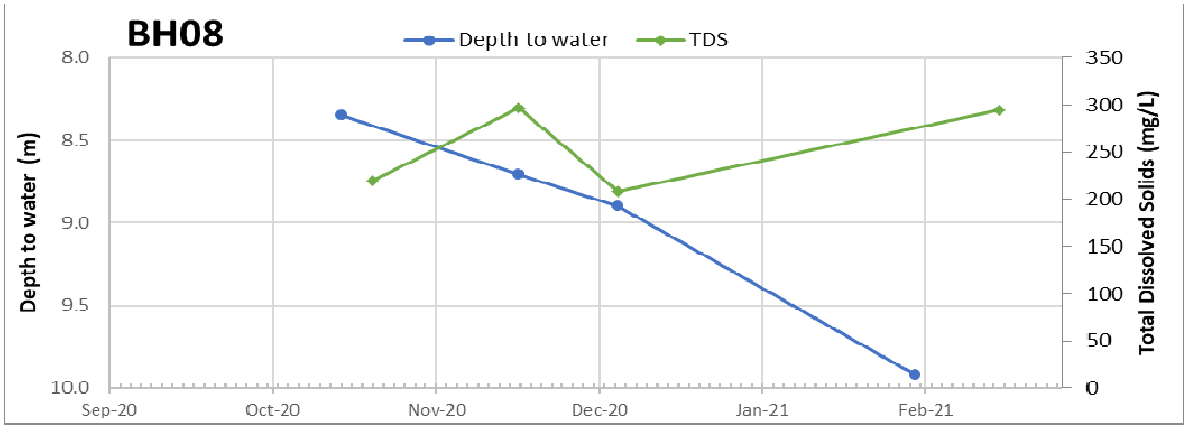

BH04
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
15.6
15.7
15.8
15.9
16.0
16.1
16.2
16.3
16.4
700
600
500
400
300
200
100
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

Holyoake

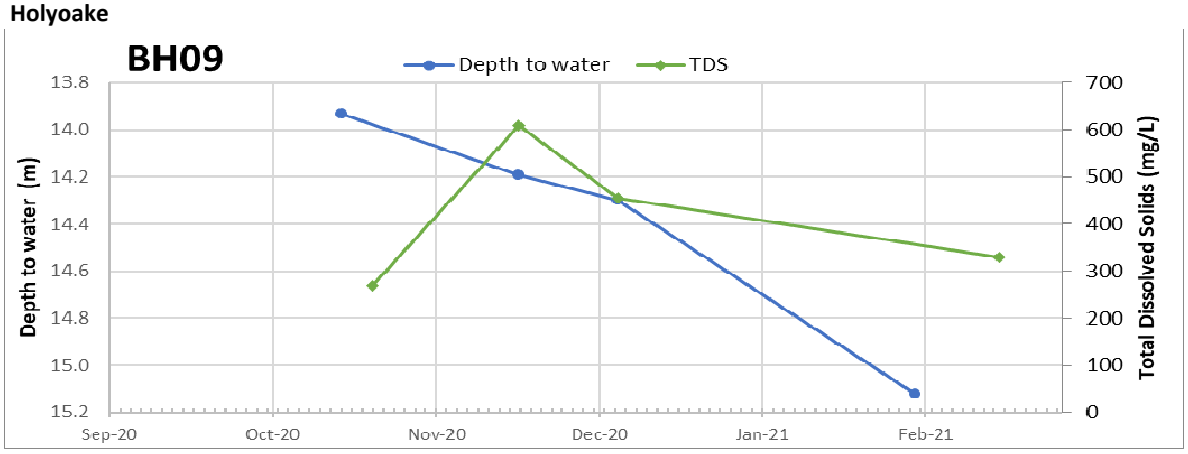

BH05
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
11.0
11.2
11.4
11.6
11.8
12.0
12.2
12.4
2,000
1,500
1,000
500
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

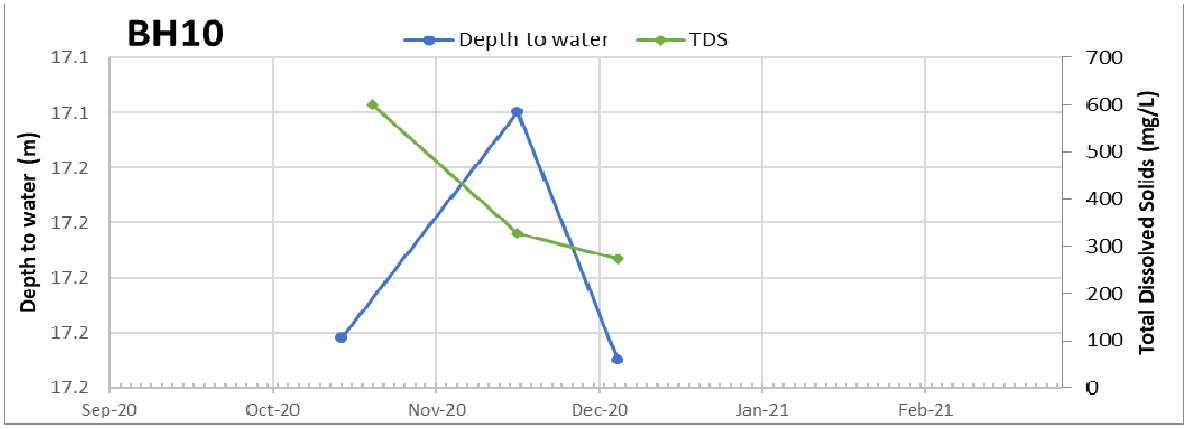

BH06
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
25.2
25.3
25.3
25.3
25.3
25.3
25.4
25.4
25.4
25.4
800
600
400
200
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

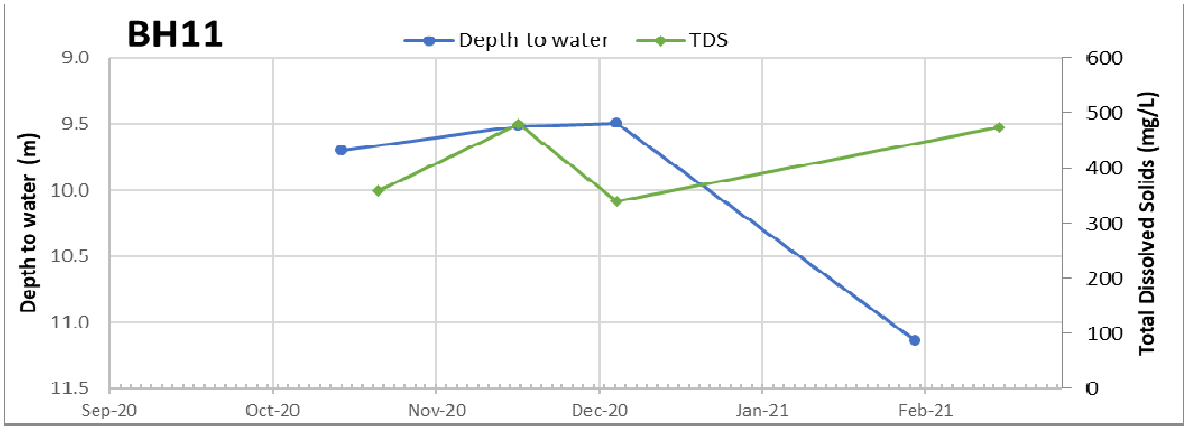

BH07
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
12.2
12.4
12.6
12.8
13.0
13.2
13.4
13.6
500
400
300
200
100
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

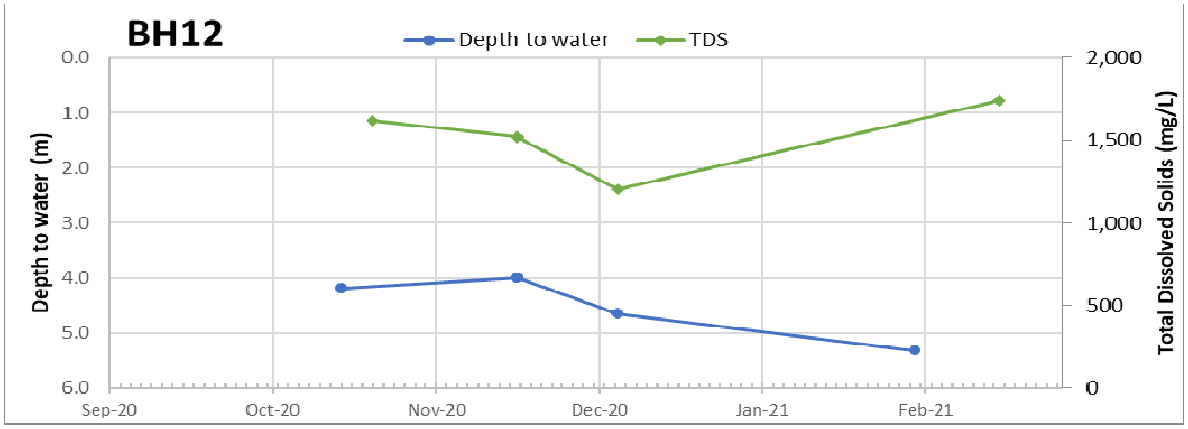

BH08
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
8.0
8.5
9.0
9.5
10.0
350
300
250
200
150
100
50
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

Holyoake

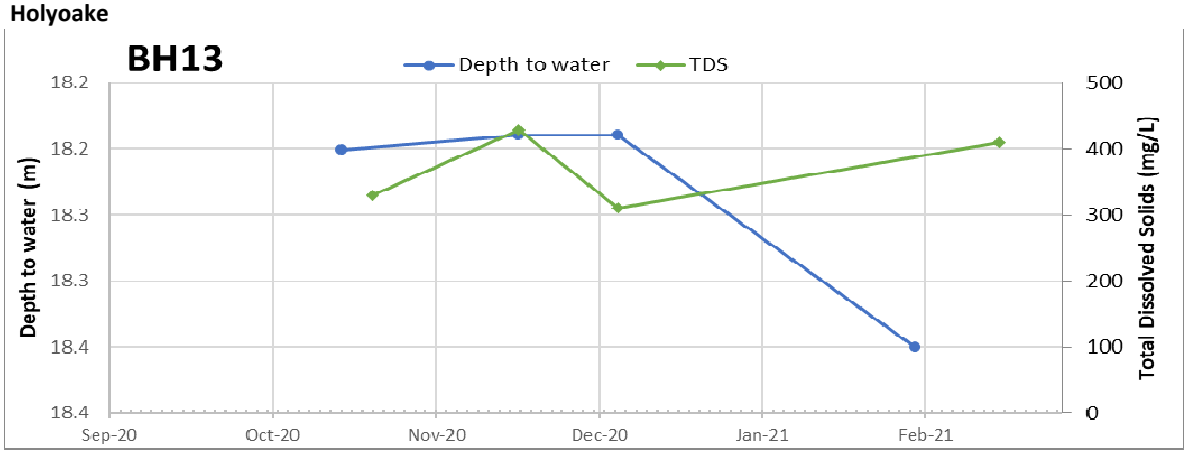

BH09
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
13.8
14.0
14.2
14.4
14.6
14.8
15.0
15.2
700
600
500
400
300
200
100
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

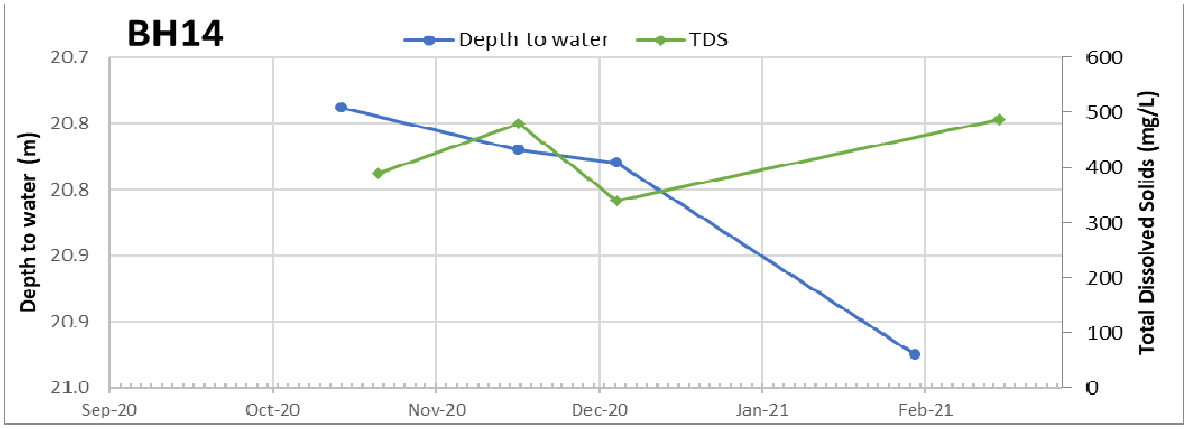

BH10
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
17.1
17.1
17.2
17.2
17.2
17.2
17.2
700
600
500
400
300
200
100
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

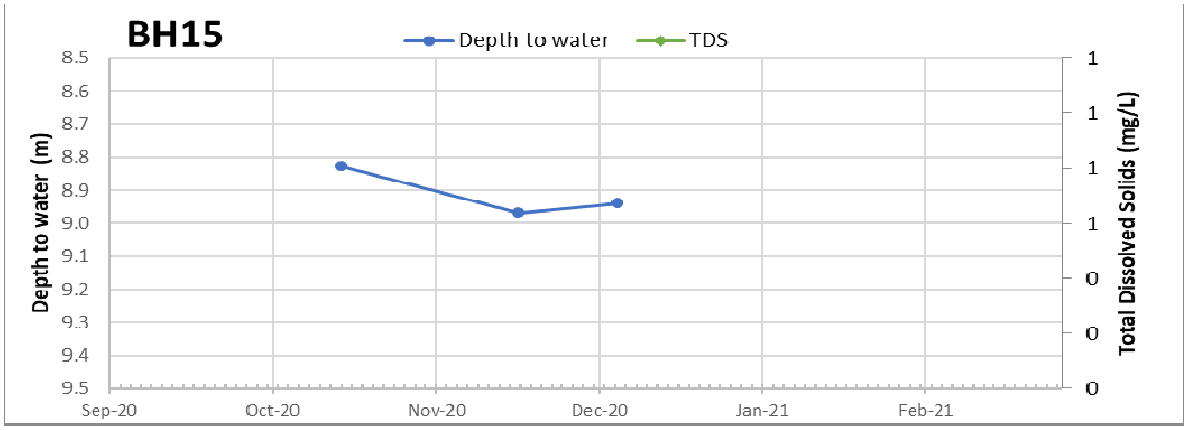

BH11
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
9.0
9.5
10.0
10.5
11.0
11.5
600
500
400
300
200
100
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

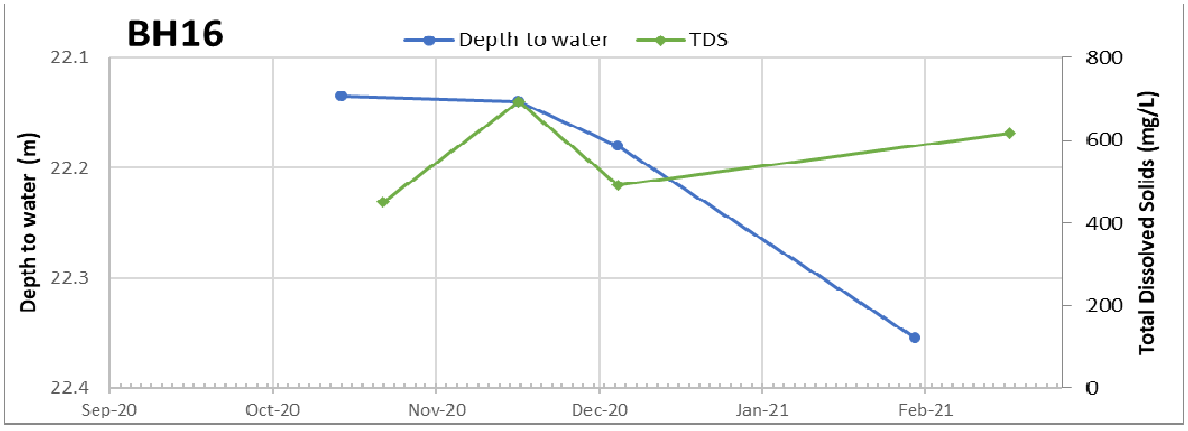

BH12
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
2,000
1,500
1,000
500
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

Holyoake

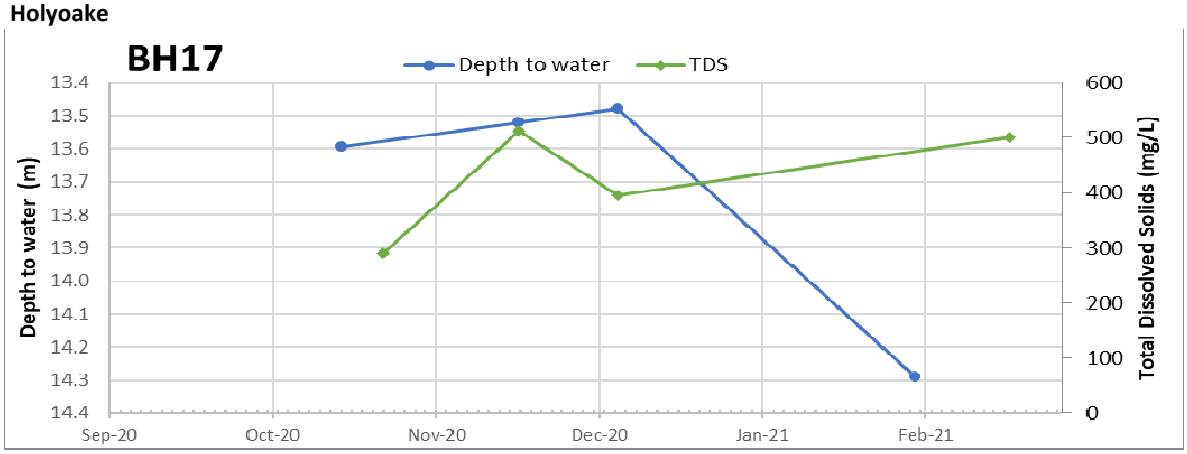

BH13
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
18.2
18.2
18.3
18.3
18.4
18.4
500
400
300
200
100
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21


BH14
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
20.7
20.8
20.8
20.9
20.9
21.0
600
500
400
300
200
100
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21


BH15
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
8.5
8.6
8.7
8.8
8.9
9.0
9.1
9.2
9.3
9.4
9.5
1
1
1
1
0
0
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

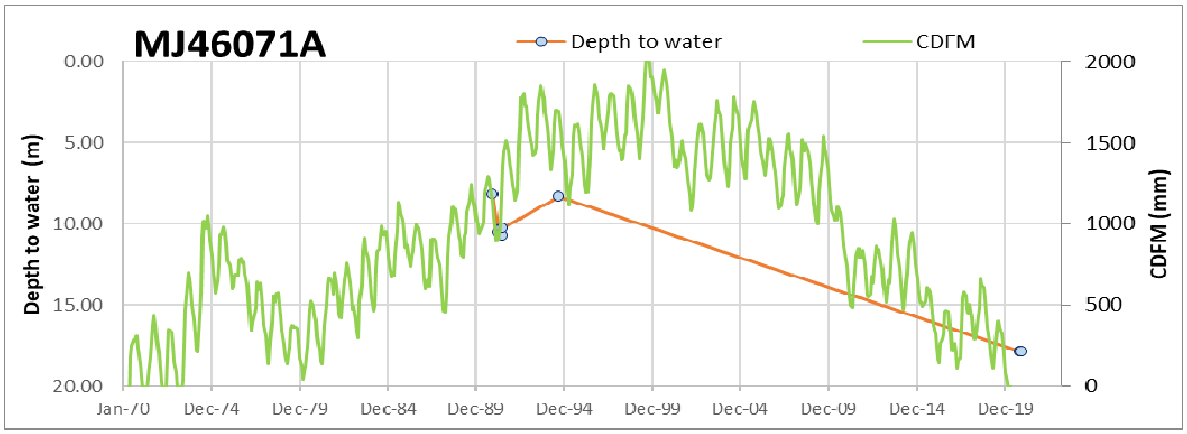

BH16
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
22.1
22.2
22.3
22.4
800
600
400
200
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

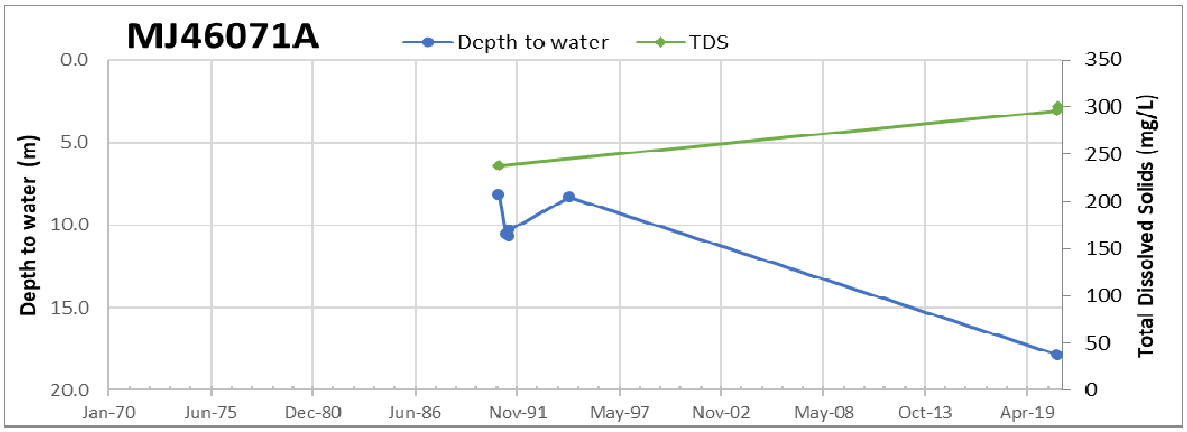
Holyoake

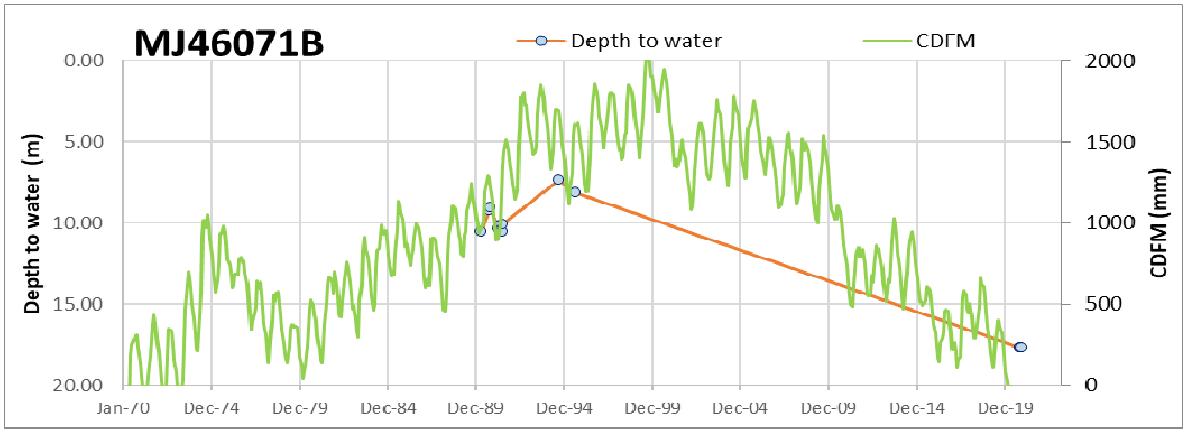

BH17
Depth to water
TDS
Depth to water (m)
13.4
13.5
13.6
13.7
13.8
13.9
14.0
14.1
14.2
14.3
14.4
Total Dissolved Solids (mg/L)
600
500
400
300
200
100
0
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21

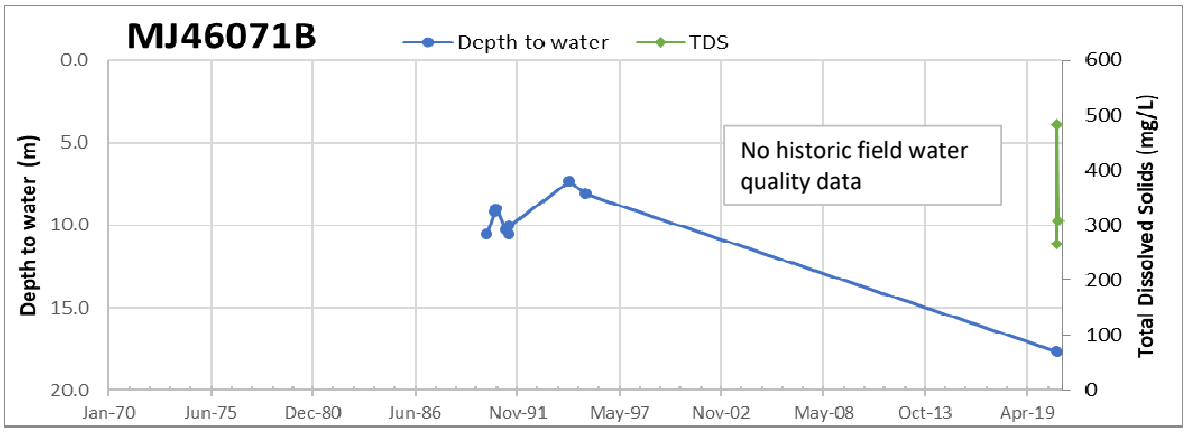
Appendix E

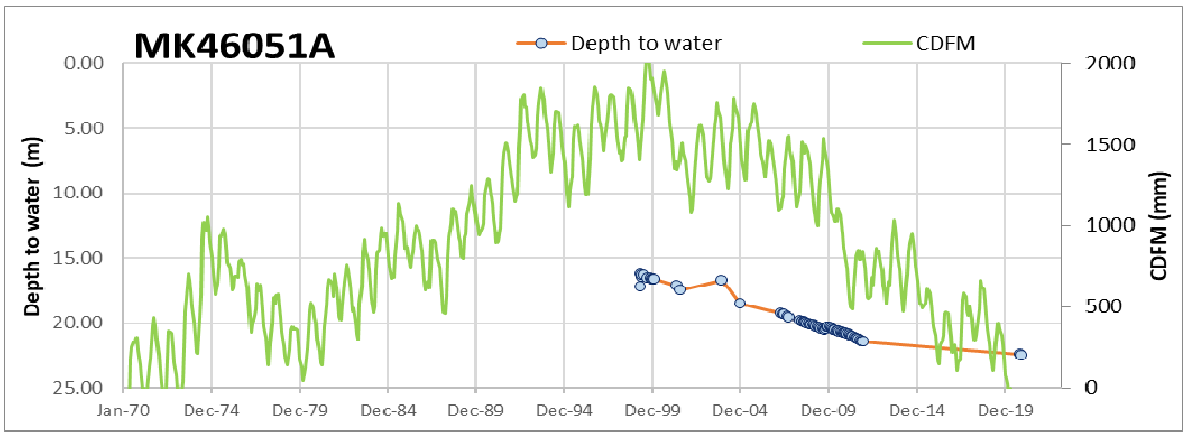
Selected Holyoake monitoring bore hydrographs and salinity graphs

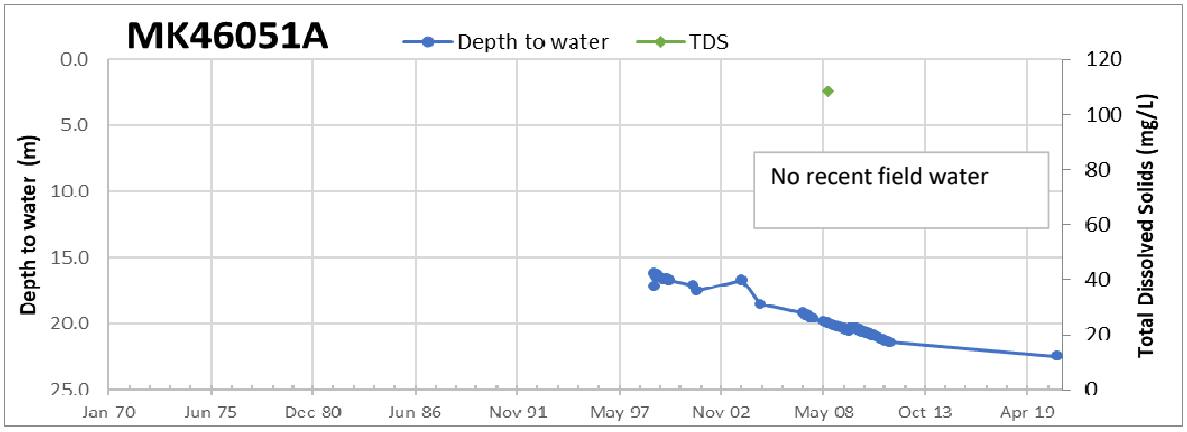

MJ46071A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
5.00
10.00
15.00
20.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19

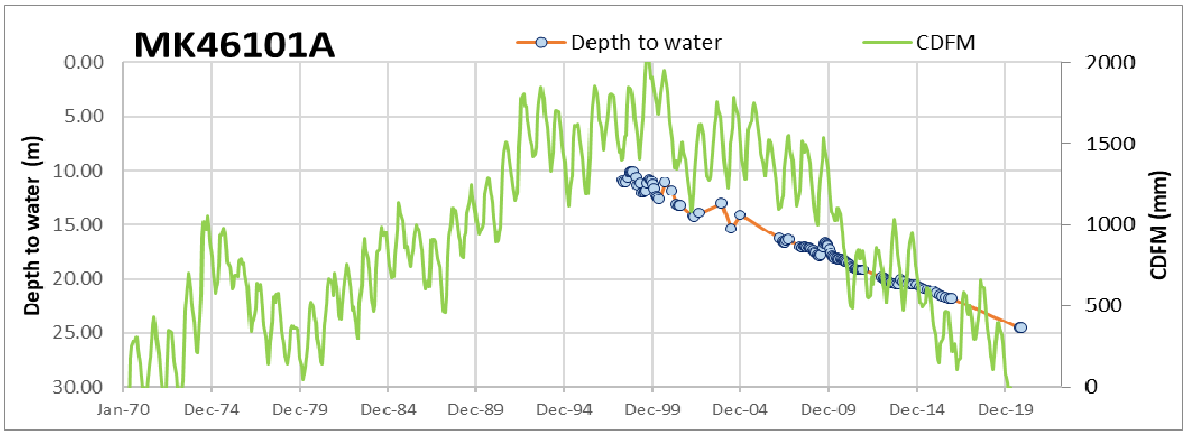

MJ46071A
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
5.0
10.0
15.0
20.0
350
300
250
200
150
100
50
0
Jan-70
Jun-75
Dec-80
Jun-86
Nov-91
May-97
Nov-02
May-08
Oct-13
Apr-19

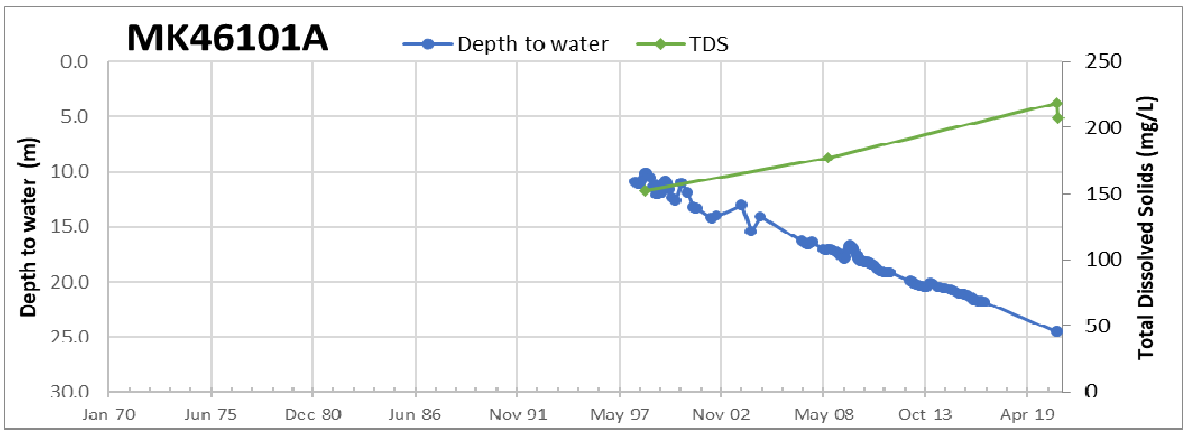

MJ46071B
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
5.00
10.00
15.00
20.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19

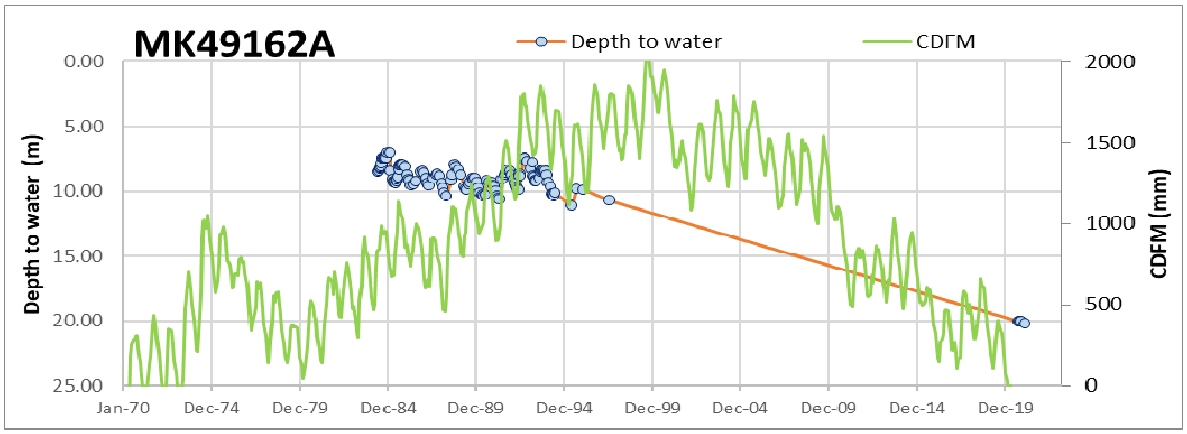

MJ46071B
Depth to water
TDS
No historic field water quality data
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
5.0
10.0
15.0
20.0
600
500
400
300
200
100
0
Jan-70
Jun-75
Dec-80
Jun-86
Nov-91
May-97
Nov-02
May-08
Oct-13
Apr-19

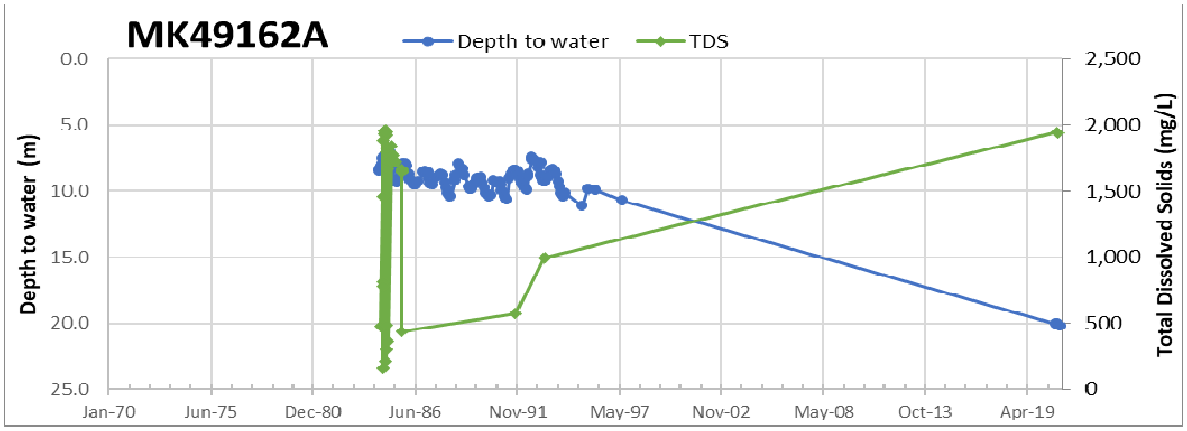

MK46051A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
5.00
10.00
15.00
20.00
25.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19


MK46051A
Depth to water
TDS
No recent field water
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
5.0
10.0
15.0
20.0
25.0
120
100
80
60
40
20
0
Jan 70
Jun 75
Dec 80
Jun 86
Nov 91
May 97
Nov 02
May 08
Oct 13
Apr 19


MK46101A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19


MK46101A
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
250
200
150
100
50
0
Jan 70
Jun 75
Dec 80
Jun 86
Nov 91
May 97
Nov 02
May 08
Oct 13
Apr 19


MK49162A
Depth to water
CDFM
Depth to water (m)
CDFM (mm)
0.00
5.00
10.00
15.00
20.00
25.00
2000
1500
1000
500
0
Jan-70
Dec-74
Dec-79
Dec-84
Dec-89
Dec-94
Dec-99
Dec-04
Dec-09
Dec-14
Dec-19


MK49162A
Depth to water
TDS
Depth to water (m)
Total Dissolved Solids (mg/L)
0.0
5.0
10.0
15.0
20.0
25.0
2,500
2,000
1,500
1,000
500
0
Jan-70
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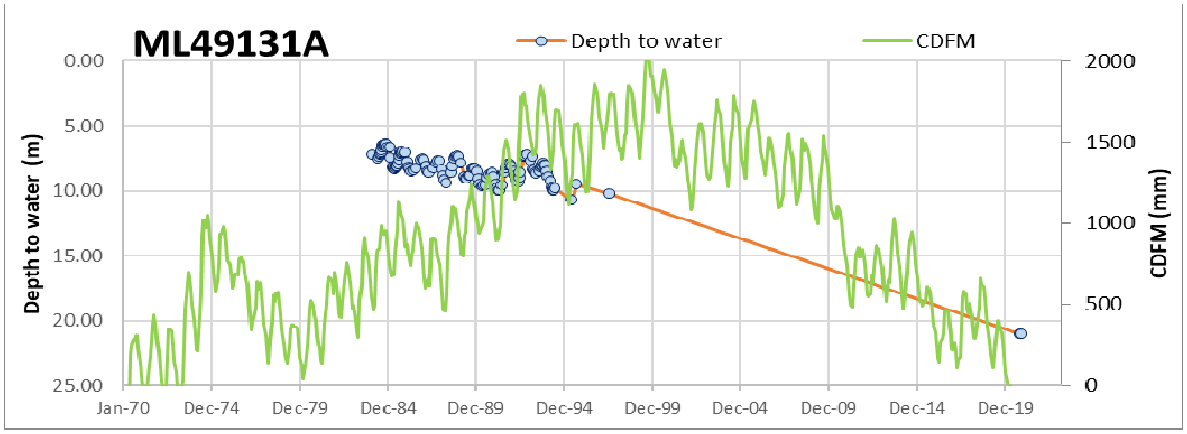
Jun-86
Nov-91
May-97
Nov-02
May-08
Oct-13
Apr-19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CDFM (mm)
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1500
1000
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Dec-99
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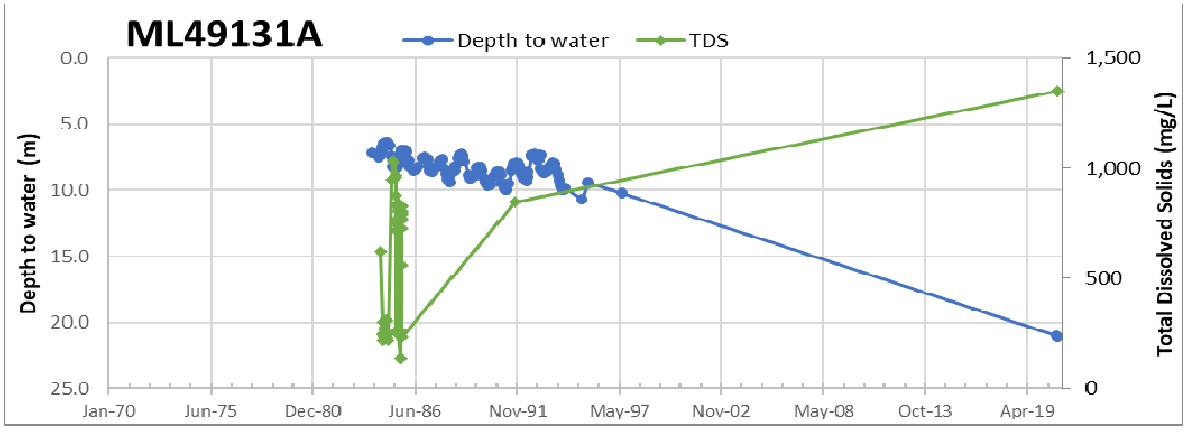
Dec-14
Dec-19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Depth to water (m)
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1,000
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Jun-75
Dec-80
Jun-86
Nov-91
May-97
Nov-02
May-08
Oct-13
Apr-19

Appendix F

Surface water quality summary statistics, Tables F-1 to F-12

Myara North

Table F-7-1 Surface water TDS (mg/L) – Alcoa sites

Tributary	Site ID	Count	Min	Average	Median	Max	Start record	End record
Wungong Brook	WG72	26	113	147	142	191	1/09/1991	18/11/1997
	WG67	9	115	154	130	230	1/01/1991	21/08/1996
	WG20	36	112	158	149	230	22/12/1975	20/10/1997
	WG16	8	131	217	218	285	22/12/1975	12/12/1978
	WG17	12	184	312	334	398	22/12/1975	12/12/1978
	WG19	20	148	276	294	334	24/08/1977	24/07/1991
	WG63	22	103	206	211	282	1/07/1991	18/08/2000
	WG61	27	96	183	189	275	1/01/1991	2/08/1999
	WG68	13	80	103	95	205	1/07/1991	18/08/2000
	WG14	33	141	232	243	305	27/07/1977	20/10/1993
	WG13	12	155	226	228	280	22/12/1975	12/12/1978
	WG54	14	157	237	239	296	25/01/1979	23/06/1994
	WG15	9	134	209	206	293	22/12/1975	12/12/1978
Gooralong Brook	GG08	14	103	176	178	243	19/01/1976	11/12/1978
	GG07	14	121	171	165	231	19/01/1976	11/12/1978
	GG06	9	108	132	128	162	19/12/1975	11/12/1978
	GG05	13	117	129	131	138	19/12/1975	11/12/1978
	GG03	52	89	151	153	247	19/12/1975	20/10/1993
39 Mile Brook	TN11	28	103	177	178	265	4/11/1975	21/06/1994
	TN30	13	131	183	190	231	4/11/1975	26/10/1993
	TN34	6	157	179	173	225	1/09/1991	18/10/1993
	TN33	17	178	255	267	306	22/11/1990	21/06/1994
	TN10	24	118	188	187	284	22/11/1990	21/06/1994
	TN09	20	123	250	250	357	18/10/1977	21/06/1994
	TN31	16	133	226	197	343	19/11/1975	12/10/1992
	TN01	60	116	255	261	419	30/10/1975	19/11/1993
	TN02	52	114	216	219	330	4/11/1975	19/11/1993
	TN13	9	113	212	217	280	18/10/1977	11/12/1978
	TN14	126	101	232	229	486	25/01/1979	13/02/1990
East of 1100mm isohyet								
Banksia Gully	SN01	86	82	229	210	583	22/06/1981	8/09/1998
Goldmine Gully	SN05	10	184	278	242	574	1/09/1991	2/06/1994
	SN02	96	110	283	248	2078	22/06/1981	8/09/1998
Eastern Trib 1	SN06	7	168	209	205	265	1/09/1991	18/10/1995
	SN03	86	77	205	192	653	22/06/1981	8/09/1998
Eastern Trib 2	SN04	45	59	173	109	728	1/07/1991	14/01/2020

Table F-7-2 Surface water EC (uS/cm) – Alcoa sites

Tributary	Site ID	Count	Min	Average	Median	Max	Start record	End record
Wungong Brook	WG72	26	204	269	261	356	1/09/1991	18/11/1997
	WG67	9	206	284	237	434	1/01/1991	21/08/1996
	WG20	36	201	292	275	434	22/12/1975	20/10/1997
	WG16	8	239	409	409	542	22/12/1975	12/12/1978
	WG17	12	343	595	639	764	22/12/1975	12/12/1978
	WG19	20	272	524	559	638	24/08/1977	24/07/1991
	WG63	22	182	387	396	537	1/07/1991	18/08/2000
	WG61	27	170	341	352	522	1/01/1991	2/08/1999
	WG68	13	137	184	167	385	1/07/1991	18/08/2000
	WG14	33	258	437	460	582	27/07/1977	20/10/1993
	WG13	12	286	426	431	533	22/12/1975	12/12/1978
	WG54	14	290	448	451	564	25/01/1979	23/06/1994
	WG15	9	245	392	387	557	22/12/1975	12/12/1978
Gooralong Brook	GG08	14	182	327	331	459	19/01/1976	11/12/1978
	GG07	14	219	318	305	435	19/01/1976	11/12/1978
	GG06	9	194	241	233	300	19/12/1975	11/12/1978
	GG05	13	211	235	239	251	19/12/1975	11/12/1978
	GG03	52	155	278	281	468	19/12/1975	20/10/1993
39 Mile Brook	TN11	28	184	328	332	503	4/11/1975	21/06/1994
	TN30	13	239	342	355	435	4/11/1975	26/10/1993
	TN34	6	290	334	320	423	1/09/1991	18/10/1993
	TN33	17	330	483	506	583	22/11/1990	21/06/1994
	TN10	24	213	351	349	540	22/11/1990	21/06/1994
	TN09	20	223	474	472	684	18/10/1977	21/06/1994
	TN31	16	243	427	368	657	19/11/1975	12/10/1992
	TN01	60	209	484	495	806	30/10/1975	19/11/1993
	TN02	52	206	407	411	630	4/11/1975	19/11/1993
	TN13	9	203	398	407	533	18/10/1977	11/12/1978
	TN14	126	180	437	432	938	25/01/1979	13/02/1990
East of 1100mm isohyet								
Banksia Gully	SN01	86	142	432	394	1129	22/06/1981	8/09/1998
Goldmine Gully	SN05	10	342	528	457	1113	1/09/1991	2/06/1994
	SN02	96	197	537	469	3874	22/06/1981	8/09/1998
Eastern Trib 1	SN06	7	311	391	385	503	1/09/1991	18/10/1993
	SN03	86	133	384	359	1268	22/06/1981	8/09/1998
Eastern Trib 2	SN04	45	98	322	195	1415	1/07/1991	14/01/2020

Table F-7-3 Surface water EC (uS/cm) – DWER sites

Tributary	Site ID	Count	Min	Average	Median	Max	Start record	End record
Wungong	6161352	24	307	596	607	714	4/05/1976	9/07/1980
	616058[2]	4138	0	124	22	479	3/04/1992	8/07/2013
	616058[3]	525	210	554	536	1180	25/06/1992	22/10/1997
	6161353	18	238	454	470	649	6/07/1976	4/10/1979
	6161351	21	298	513	510	682	21/10/1975	4/10/1979
	6161338	25	286	409	386	588	3/11/1975	4/10/1979
	6161339	23	298	489	481	867	3/11/1975	4/10/1979
	6161340	23	298	497	500	691	4/05/1976	4/10/1979
	6161337	23	286	424	423	540	3/11/1975	1/06/1983
	6161341	106	161	358	365	531	4/05/1976	13/12/1984
	6161343	108	286	344	326	598	4/05/1976	13/12/1984
	6161342	107	105	408	403	761	3/11/1975	13/12/1984
	6161349	103	122	255	253	488	3/11/1975	13/12/1984
	6161348	90	111	215	219	313	3/11/1975	13/12/1984
	6161347	113	106	214	215	314	3/08/1976	13/12/1984
Gooralong Brook	6141622	119	175	270	274	390	21/10/1975	15/12/1986
Minor tributary	6141104	207	120	306	318	547	28/10/1975	7/09/1995
39 Mile Brook	6141118	110	173	410	403	762	22/01/1976	19/12/1984
	6141117	105	176	360	330	806	27/05/1976	14/11/1984
	6141116	16	398	529	527	667	21/10/1975	22/11/1977
	6141114	16	218	328	343	378	27/05/1976	25/07/1978
	6141115	17	341	429	417	561	21/10/1975	12/09/1977
	614031[4]	290	0	513	505	928	30/05/1985	23/09/1998
	6141113	24	242	397	371	800	17/10/1979	17/09/1980
East of 1100mm isohyet								
Banksia Gully	6141120	84	23	365	352	833	10/08/1976	14/11/1984
	6141121	150	18	535	537	1216	28/10/1975	10/10/1994
Goldmine Gully	6141126	83	16	340	330	761	10/08/1976	7/09/1995
	6141125	114	28	468	437	1857	2/12/1975	10/10/1994
Eastern Trib 1	6141128	83	16	340	330	761	10/08/1976	10/10/1994
	6141127	22	171	387	384	689	17/10/1979	5/11/1980
Serpentine River	6141138	112	103	438	425	889	9/07/1980	7/09/1995
	614035[5]	269	152	579	557	1388	26/07/1982	14/10/1998
	6141142	84	130	441	390	1009	4/06/1981	11/11/1985
	6141141	86	130	431	441	840	4/06/1981	18/11/1985
	6141140	140	390.85	360	724	94	28/05/1981	18/11/1985
	6141147	120	511.09	447	1889	104	22/06/1976	1/10/1985

[2] Wungong Cobiac gauging station continuous EC logging – summary of maximum EC values with 0 value representing no flow.
[3] Wungong Cobiac gauging station discrete monitoring. Single sample recorded 24/01/2000.
[4] 39 Mile Brook Jack Rocks gauging station location discrete monitoring.
[5] Serpentine River River Road gauging station location discrete monitoring.

Tributary	Site ID	Count	Min	Average	Median	Max	Start record	End record
	6141148	41	401.48	370	833	117	9/10/1975	11/11/1985

Table F-7-4 Surface water turbidity (NTU) – Alcoa sites

Tributary	Site ID	Count	Min	Average	Median	Max	Start record	End record
Wungong Brook	WG16	8	0.2	0.5	0.5	0.6	22/12/1975	12/12/1978
	WG17	12	0.1	0.4	0.3	1	22/12/1975	12/12/1978
	WG19	19	0.1	0.4	0.2	3.8	24/08/1977	24/07/1991
	WG14	20	0.1	0.3	0.2	0.9	27/07/1977	20/10/1993
	WG13	12	0.2	0.5	0.3	1.9	22/12/1975	12/12/1978
	WG54	5	0.2	0.2	0.2	0.3	25/01/1979	23/06/1994
	WG15	9	0.1	0.3	0.3	0.6	22/12/1975	12/12/1978
Gooralong Brook	GG08	7	0.4	1.0	0.9	1.8	19/01/1976	11/12/1978
	GG07	9	0.3	0.5	0.3	0.9	19/01/1976	11/12/1978
	GG06	5	0.2	0.3	0.3	0.5	19/12/1975	11/12/1978
	GG05	6	0.1	0.3	0.2	0.6	19/12/1975	11/12/1978
	GG03	32	0.2	0.7	0.5	5.4	19/12/1975	20/10/1993
39 Mile Brook	TN11	8	0.2	0.4	0.3	1	4/11/1975	21/06/1994
	TN09	9	0.1	1.9	0.9	10	18/10/1977	21/06/1994
	TN01	19	0.2	0.7	0.5	1.9	30/10/1975	19/11/1993
	TN02	12	0.2	0.9	0.3	3.2	4/11/1975	19/11/1993
	TN13	9	0.2	0.6	0.3	2.5	18/10/1977	11/12/1978
	TN14	126	0.2	1.8	0.9	45	25/01/1979	13/02/1990
Banksia Gully	SN01	47	0.3	1.7	1.2	8.8	22/06/1981	8/09/1998
Goldmine Gully	SN02	51	0.3	1.1	0.9	3.2	22/06/1981	8/09/1998
Eastern Trib 1	SN03	49	0.3	1.3	1.1	4.8	22/06/1981	8/09/1998

Table F-7-5 Surface water turbidity (NTU) – DWER sites

Tributary	Site ID	Count	Min	Average	Median	Max	Start record	End record
Wungong	6161352	17	0.2	1.1	0.5	10.0	4/05/1976	9/07/1980
	616058[6]	432	0.1	1.0	0.5	31.0	25/06/1992	22/10/1997
	6161353	14	0.2	0.6	0.5	1.4	6/07/1976	4/10/1979
	6161351	12	0.3	0.8	0.6	4.0	21/10/1975	4/10/1979
	6161338	16	0.3	0.9	0.7	5.0	3/11/1975	4/10/1979
	6161339	17	0.2	0.7	0.6	1.4	3/11/1975	4/10/1979
	6161340	17	0.2	0.6	0.5	2.4	4/05/1976	4/10/1979
	6161337	16	0.3	0.7	0.5	2.5	3/11/1975	1/06/1983
	6161341	99	0.1	0.8	0.6	8.8	4/05/1976	13/12/1984
	6161343	101	0.2	0.9	0.7	5.5	4/05/1976	13/12/1984
	6161342	101	0.2	1.3	1.0	21.0	3/11/1975	13/12/1984
	6161349	101	0.2	0.8	0.7	1.9	3/11/1975	13/12/1984
	6161348	84	0.2	1.1	0.9	7.2	3/11/1975	13/12/1984
	6161347	112	0.2	0.8	0.7	2.4	3/08/1976	13/12/1984
Gooralong Brook	6141621	139	0.2	2.1	1.1	35.0	21/10/1975	13/12/1984
	6141622	124	0.3	1.1	0.7	13.0	21/10/1975	15/12/1986
Minor tributary	6141104	206	0.3	1.4	1.2	6.2	7/06/1977	7/09/1995
39 Mile Brook	6141118	103	0.3	0.9	0.7	3.2	22/01/1976	19/12/1984
	6141117	99	0.3	0.9	0.7	8.0	27/05/1976	14/11/1984
	6141116	5	0.3	0.7	0.5	1.8	21/10/1975	22/11/1977
	6141114	7	0.3	0.5	0.6	0.8	27/05/1976	25/07/1978
	614031[7]	243	0.2	0.8	0.5	4.3	30/05/1985	23/09/1998
	6141113	23	0.4	2.1	0.8	23.0	17/10/1979	17/09/1980
Banksia Gully	6141120	83	0.5	3.0	1.3	55.0	10/08/1976	14/11/1984
	6141121	175	0.2	2.3	1.2	54.0	28/10/1975	10/10/1994
Goldmine Gully	6141126	134	0.4	1.7	1.4	10.0	10/08/1976	7/09/1995
	6141125	274	0.4	1.6	1.3	14.0	2/12/1975	10/10/1994
Eastern Trib 1	6141128	110	0.3	1.4	1.1	10.0	10/08/1976	10/10/1994
	6141127	21	0.5	1.6	1.4	4.0	17/10/1979	5/11/1980
Serpentine River	6141138	148	0.3	2.4	2.0	7.9	9/07/1980	7/09/1995
	614035[8]	220	0.5	2.3	1.7	18.0	26/07/1982	14/10/1998
	6141142	84	0.6	2.4	2.0	8.6	4/06/1981	11/11/1985
	6141141	86	0.8	2.3	2.1	7.1	4/06/1981	18/11/1985
	6141140	94	0.6	2.0	1.7	7.0	28/05/1981	18/11/1985
	6141147	102	0.1	3.3	2.6	14.0	22/06/1976	1/10/1985
	6141148	113	0.4	2.0	1.6	7.0	9/10/1975	11/11/1985

[6] Wungong Cobiac gauging station discrete monitoring. Single sample recorded 24/01/2000.
[7] 39 Mile Brook Jack Rocks gauging station location discrete monitoring.

Table F-7-6 Surface water pH – Alcoa sites

Tributary	Site ID	Count	Min	Average	Median	Max	Start record	End record
Wungong Brook	WG17	5	6.2	6.4	6.4	6.7	22/12/1975	12/12/1978
	WG19	7	6.1	6.3	6.2	6.7	24/08/1977	24/07/1991
	WG14	7	6.1	6.4	6.3	6.8	27/07/1977	20/10/1993
	WG13	5	6.3	6.5	6.4	6.9	22/12/1975	12/12/1978
	WG15	5	6.2	6.5	6.4	6.8	22/12/1975	12/12/1978
Gooralong Brook	GG08	11	5.9	6.4	6.5	6.8	19/01/1976	11/12/1978
	GG07	10	5	6.2	6.05	6.8	19/01/1976	11/12/1978
	GG06	6	6.2	6.6	6.6	6.9	19/12/1975	11/12/1978
	GG05	9	5.6	6.2	6.2	6.9	19/12/1975	11/12/1978
	GG03	20	5.8	6.4	6.4	7.4	19/12/1975	20/10/1993
39 Mile Brook	TN01	30	5.4	6.3	6.4	7.3	30/10/1975	19/11/1993
	TN02	25	5.1	6.2	6.2	7.2	4/11/1975	19/11/1993
	TN14	19	6.2	7.1	7.1	8.5	25/01/1979	13/02/1990
Banksia Gully	SN01	6.0	5.2	6.1	6.2	6.6	22/06/1981	8/09/1998
Goldmine Gully	SN02	6.0	5.6	6.1	6.1	6.5	22/06/1981	8/09/1998
Eastern Trib 1	SN03	6.0	5.9	6.2	6.2	6.7	22/06/1981	8/09/1998
Eastern Trib 2	SN04	29	5.6	6.2	6.2	6.8	1/07/1991	14/01/2020

Table F-7-7 Surface water pH – DWER sites

Tributary	Site ID	Count	Min	Average	Median	Max	Start record	End record
Wungong Brook	616058[9]	62	6.30	6.82	6.90	7.00	30/06/1992	22/10/1997
	614031[10]	237	5.40	6.58	6.60	8.50	30/05/1985	23/09/1998
	614035[11]	240	5.60	6.49	6.40	8.60	26/07/1982	14/10/1998

[9] Wungong Cobiac gauging station discrete monitoring. Single sample recorded 24/01/2000.
[10] 39 Mile Brook Jack Rocks gauging station location discrete monitoring.
[11] Serpentine River River Road gauging station discrete monitoring.

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Table F-7-8 Surface water EC (uS/cm) – Alcoa sites

Tributary	Site ID	Count	Min	Average	Median	Max	Start record	End record
Davis Brook	DV04	22	352	672	646	914	4/02/1976	29/11/1979

Table F-7-9 Surface water EC (uS/cm) – DWER sites

Tributary	Site ID	Count	Min	Average	Median	Max	Start record	End record
South Dandalup	614060[12]	226	122	205	169	6880	21/06/1988	15/08/2000
	6141360	47	150	310	240	978	11/08/1976	27/09/1984
	6141352	67	151	307	265	1100	22/10/1975	20/09/1984
	6141349	10	278	489	308	2000	3/11/1975	14/10/1980
	6141350	65	142	309	263	950	22/10/1975	20/09/1984
	6141345	31	17	259	240	1064	6/10/1976	20/09/1984
	6141344	51	22	331	322	870	15/09/1976	20/09/1984
	6141342	55	19	209	216	479	11/08/1976	20/09/1984
	6141005	7	296	641	699	923	13/07/1972	25/09/1975
	6141333	7	150	342	316	682	22/10/1975	4/10/1984
	6141337	76	124	199	189	426	11/08/1976	4/10/1984
	6141336	56	17	210	216	272	25/06/1980	30/08/1984
	614043[13]	12648	0	77	16	605	13/05/1991	14/01/1997
	614043[14]	930	61	346	351	547	5/06/1984	26/09/1994
	6141340	86	26	350	335	681	22/10/1975	4/10/1984
Swamp Oak Brook	6141021	23	511	751	763	941	20/06/1972	22/11/1976

Table F-7-10 Surface water turbidity (NTU) – Alcoa sites

Tributary	Site ID	Count	Min	Average	Median	Max	Start record	End record
Davis Brook	DV04	16	0.7	1.8	1.8	3.5	4/04/1977	24/10/1979

[12] South Dandalup Gordon Catchment gauging station discrete monitoring.
[13] South Dandalup Pindalup gauging station continuous EC logging – summary of maximum EC values with 0 value representing no flow.
[14] South Dandalup Pindalup gauging station discrete monitoring.

Table F-7-11 Surface water turbidity (NTU) – DWER sites

Tributary	Site ID	Count	Min	Average	Median	Max	Start record	End record
South Dandalup	614060[12]	112	0.3	1.4	1.0	6.7	21/06/1988	15/08/2000
	6141360	44	0.8	4.5	2.6	23.0	24/08/1977	27/09/1984
	6141352	65	0.7	2.8	2.0	12.0	19/07/1978	20/09/1984
	6141349	37	0.5	3.4	2.2	9.8	11/08/1980	7/08/1995
	6141350	79	1.0	2.7	2.3	6.4	24/08/1977	13/09/1994
	6141345	31	17	259	240	1064	6/10/1976	20/09/1984
	6141344	51	0.7	7.8	7.3	18.0	24/08/1977	20/09/1984
	6141342	55	1.1	3.7	2.5	41.0	19/07/1978	20/09/1984
	6141333	101	0.8	3.1	2.6	12.0	27/07/1977	4/10/1984
	6141337	74	0.6	1.9	1.5	6.6	19/07/1978	4/10/1984
	6141336	56	0.7	1.9	1.6	8.2	25/06/1980	30/08/1984
	614043[14]	176	0.1	1.6	1.0	65.0	5/06/1984	26/09/1994
	6141340	106	0.3	1.1	0.9	12	24/08/1977	12/10/1994
Davis Brook	6141465	5	1.6	5.8	5.0	12.0	18/07/1978	17/07/1979

Table F-7-12 Surface water pH – DWER sites

Tributary	Site ID	Count	Min	Average	Median	Max	Start record	End record
South Dandalup	614060[15]	115	6.0	6.9	6.9	8.3	21/06/1988	26/09/2014
	614043[16]	223	6.1	7.1	7.1	8.2	6/06/1984	26/09/1994

[15] South Dandalup Gordon Catchment gauging station discrete monitoring.
[16] South Dandalup Pindalup gauging station discrete monitoring.

Appendix G

Surface water quality plots

Myara North historic salinity

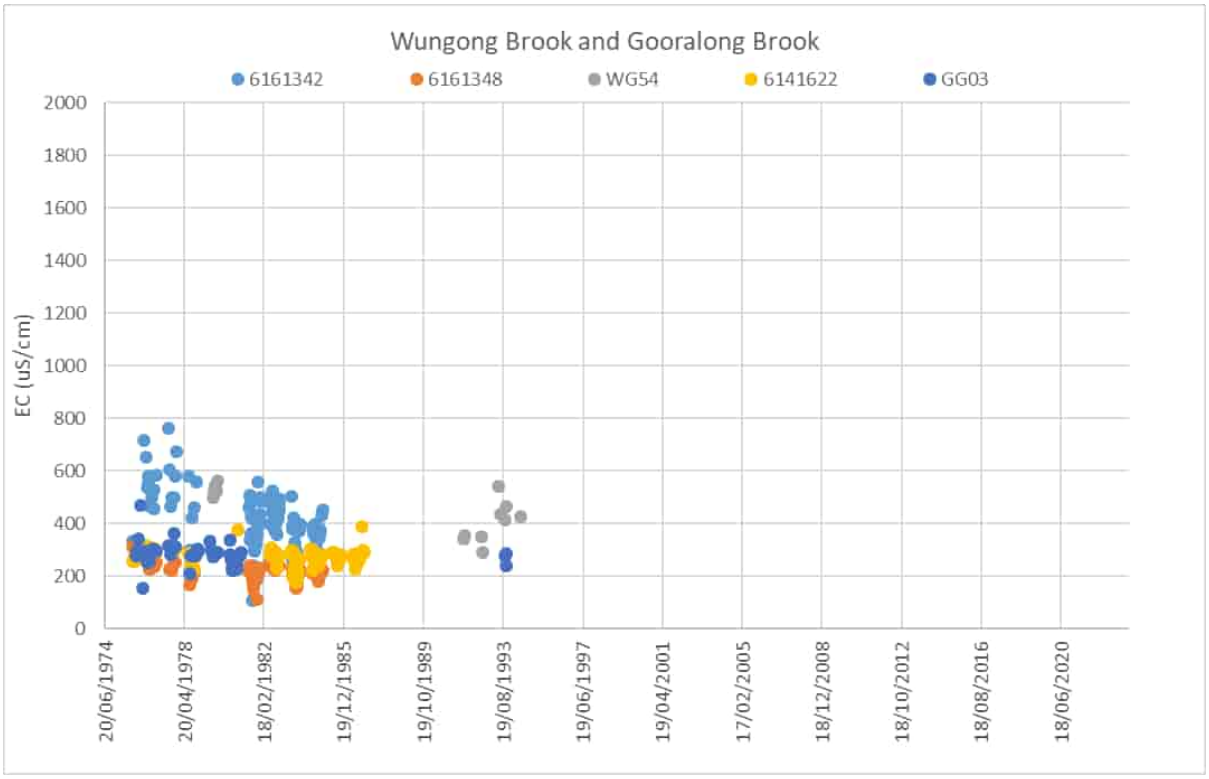


Figure G-1 Surface water EC (uS/cm) – Wungong and Gooralong Brook

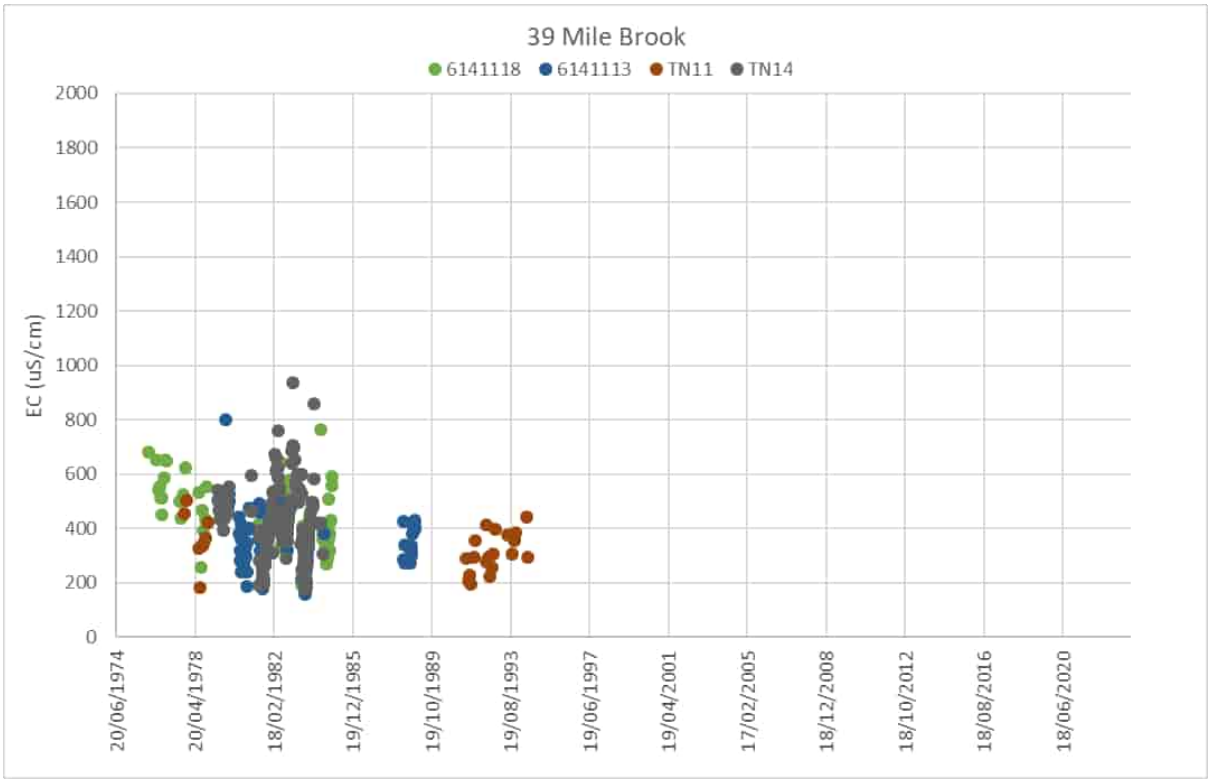


Figure G-2 Surface water EC (uS/cm) – 39 Mile Brook

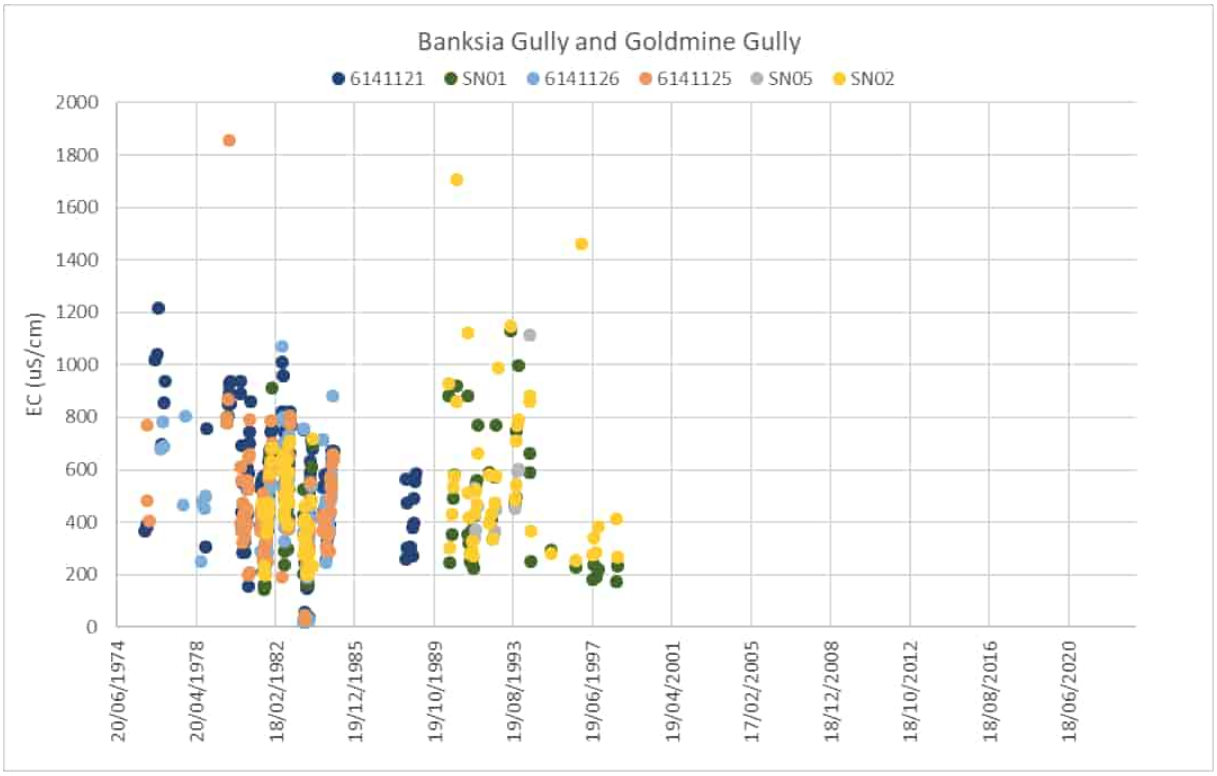


Figure G-3 *Surface water EC (uS/cm) – Banksia Gully and Goldmine Gully*

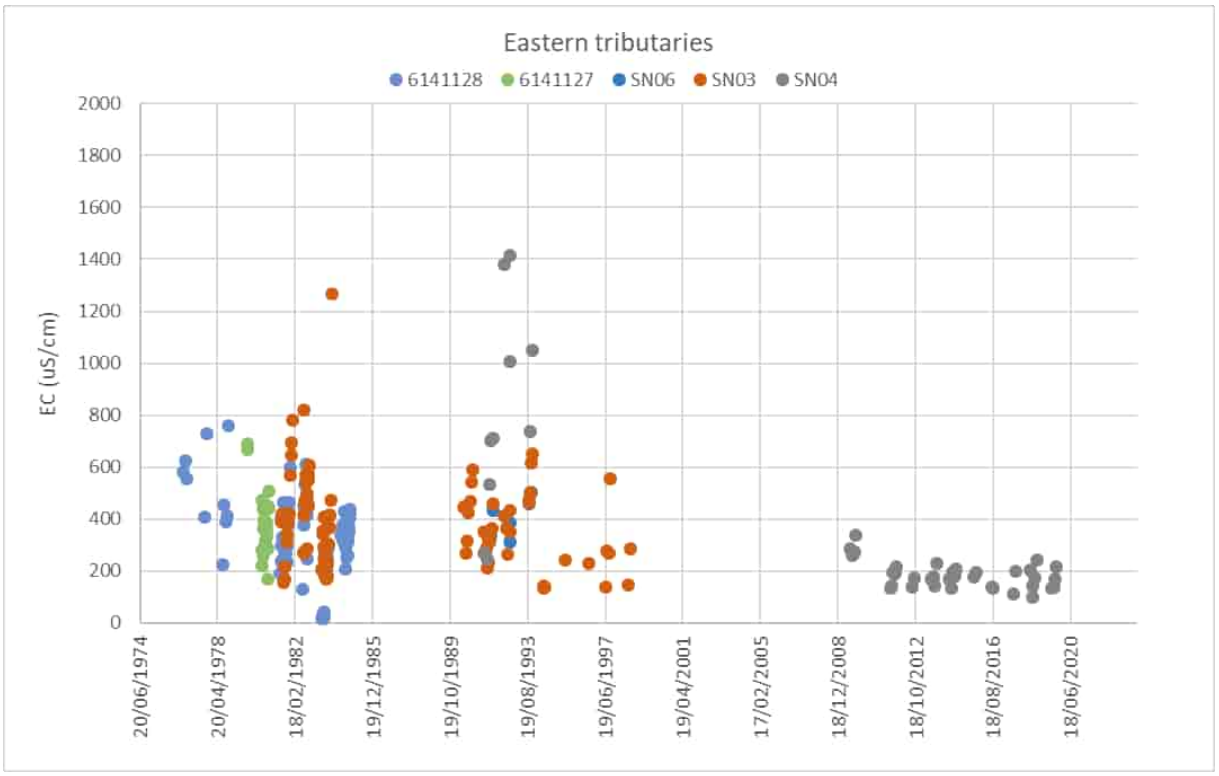


Figure G-4 *Surface water EC (uS/cm) – Eastern tributaries*

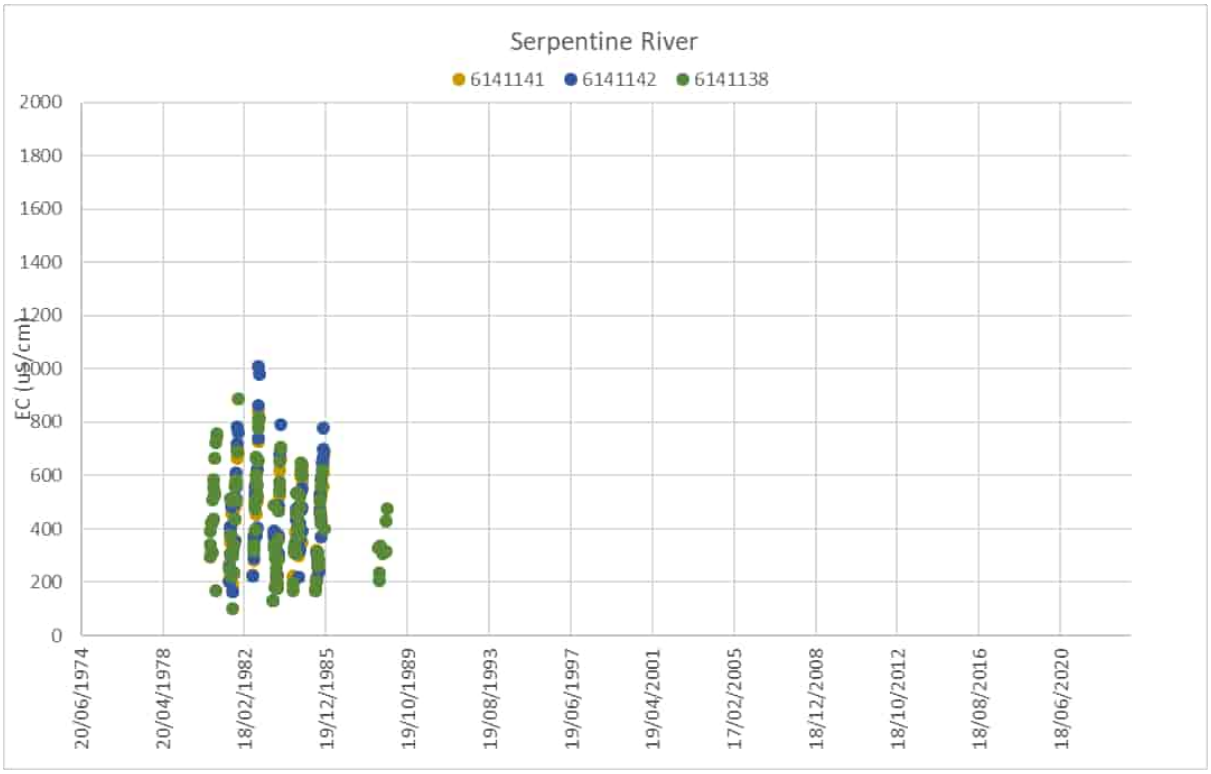


Figure G-5 Surface water EC (uS/cm) – Serpentine River

Appendix H

Technical documents reviewed

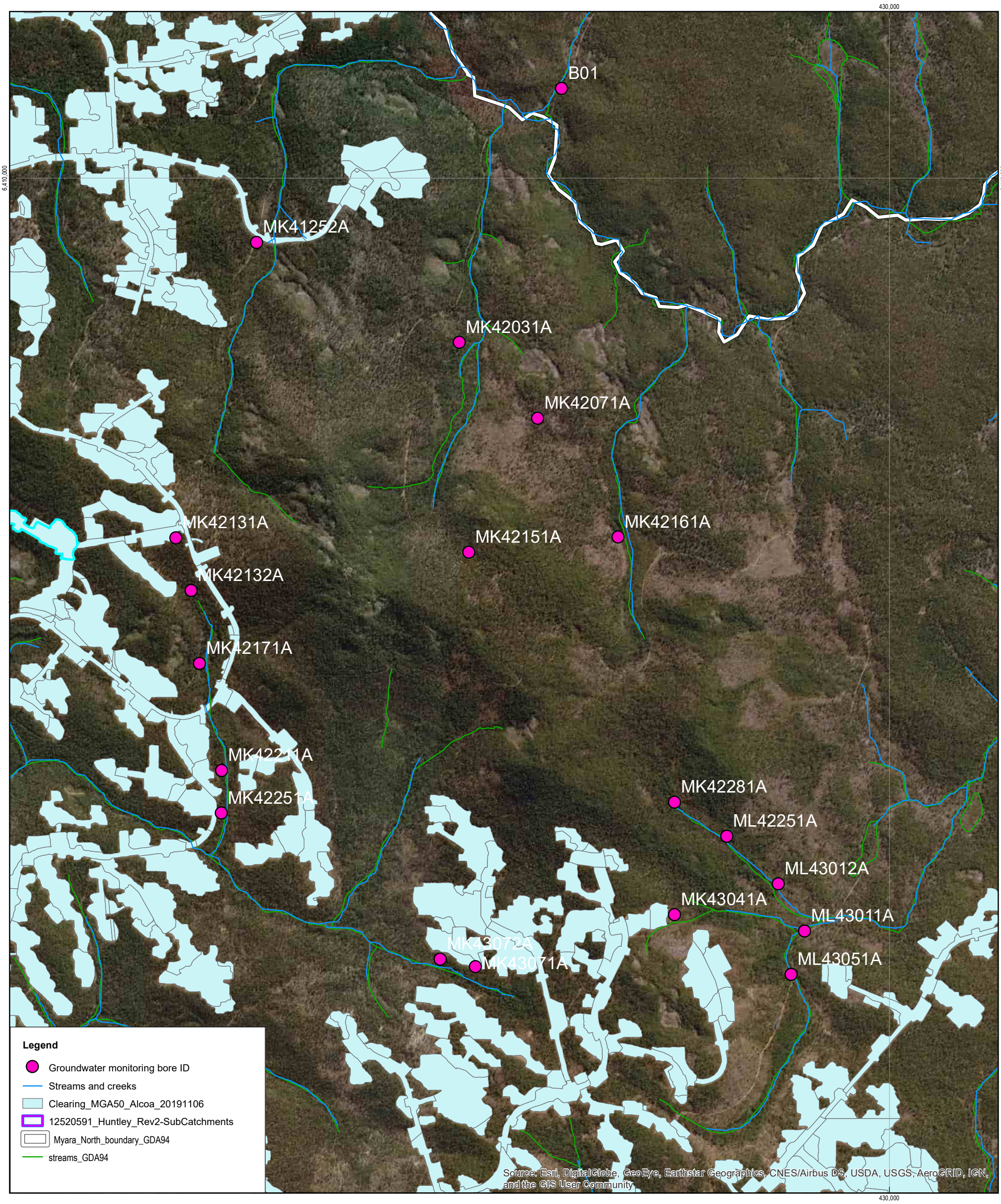
Title	Key Features	Findings	Gaps/limitations
Documents relevant to Hydrology and Hydrogeology:			
(Ruprecht and Stoneman, Water yield issues in the jarrah forest of south-western Australia 1993) (Bari and Ruprecht, Water yield response to land use change in south-west Western Australia 2003) (Croton and Reed 2007)	Mining in public drinking water catchments	Mining initially caused increases in streamflow, followed by a return to pre-mining levels or below after rehabilitation.	
Hydrological Response of the O'Neil to McCoy Mining Area (Water & Environmental Consultants 2013)	Six year GW/SW/salinity monitoring Mining in public drinking water catchment and control catchment Some mining areas within IRZ	Mining-related stream-salinity response observed, albeit much less than had previously been modelled.	Given mining-related stream-salinity response observed, there may be cumulative impacts from other areas in Myara yet to be mined or rehabilitated within Serpentine catchment.
Review of the Trial Mining Project (Water & Environmental Consultants 2011) (Water & Environmental Consultants 2013)	20+ year GW/SW/salinity monitoring in IRZ Mined catchments compared to control catchments	Experimental catchments in IRZ dominated by below-average rainfall conditions since 1974, with groundwater recharge processes essentially considered at zero or negative. No streamflow and stream-salinity response from mining. Little to no potential for significant streamflow or stream-salinity response in experimental catchments to mining as long as below-average rainfalls continue.	Cumulative effect of concurrent or quasi-concurrent mining in a number of areas could not be assessed due to limited size of the experimental catchments.
Hydrological response to bauxite mining and rehabilitation in the jarrah forest in south west Australia (A. H. Grigg, Hydrological response to bauxite mining and rehabilitation in the 2017)	36-year monitoring period Mined, thinned, control catchments compared	Mining caused peak streamflow response of 225 mm or 18% rainfall, returned to pre-disturbance levels 11 years after mining commenced. Changes in groundwater level related to rainfall and LAI, indistinguishable between rehabilitated and unmined areas. Mining could not be distinguished from thinning, clearing or clear-felling. No shallow-subsurface flow processes beyond valley floor and immediately adjacent slopes. Catchment disconnection observed such that paired catchment approach may be ineffective for future forecasts.	Localised impacts of short-term events (significant storm events) immediately after clearing.

Title	Key Features	Findings	Gaps/limitations
A standardised Landsat time series (1973–2016) of forest leaf area index using pseudoinvariant features and spectral vegetation index isolines and a catchment hydrology application (McFarlane, Grigg and Daws 2017)	Remotely sensed imagery from Landsat dating back to 1972	Standardised time series of LAI was developed that could inform future hydrological modelling in the area, as previous modelling has typically been based on rainfall only. For long-term annual average rainfall of 1,200 mm their model predicts zero streamflow when catchment average LAI reaches 2.	Potential for application of LAI time series in new models in the area.
Nonstationarity driven by multidecadal change in catchment groundwater storage: A test of modifications to a common rainfall–run-off model (Grigg and Hughes, Nonstationarity driven by multidecadal change in catchment groundwater storage: A test of modifications to a common rainfall-run-off model 2018)	GR8J Model 21,000 individual groundwater records 40 year dataset Model incorporates “catchment memory”	Improved rainfall-runoff model match to observed data (streamflows)	Not applied to proposed mining areas
Documents relevant to surface water and groundwater salinity			
Environmental Research Bulletin No. 16. Salt Storage in the Bauxitic Laterite Region of the Darling Range, Western Australia (Slessar, Murray and Passchier 1983)	327 bores drilled in Darling Range	Darling Range exhibits low soil salt storage west of 1100 mm isohyet (0.16±0.15 kg/m^3) Near-exponential increase in soil salt content with distance inland (0.79 ± 0.84 kg/m^3)	Limited resolution within proposed mining areas, and in close proximity east of 1100 mm isohyet
Environmental Research Bulletin No. 22. Estimation of Soil Salinities East of the Huntly Mine, Darling Range, WA	70 bores drilled east of Huntly mine (south-east of Myara North), predominantly in IRZ Soil salt content estimated in grid-cells based on rainfall, terrain type, vegetation “greenness” and position in landscape.	High rainfall areas had low soil salt contents (<0.4 kg/m^3), lower rainfall areas had high salt contents.	Limited resolution within proposed mining areas
Hydrology and Bauxite Mining on the Darling Plateau (Croton and Reed 2007)	Literature review	Under current rainfall regimes, it is unlikely that there will be a significant salinity response due to Alcoa’s mining, but it is inadvisable to discount the salinity issue in the lower rainfall zone, and research will need to consider the possibility of further climate change.	Water quality issues only discuss salinity. Myara North has specific setting in a drinking water catchment and would require assessment beyond salinity.

Title	Key Features	Findings	Gaps/limitations
Salinity Risk Assessment for the O'Neil to McCoy Mining Area (Water & Environmental Consultants 2010)	Mining in public drinking water catchment Application of (unknown) groundwater flow model (data from 1970 – 2007) Application of salinity risk methodology	Stream salinities below average for the period of low rainfall post 1999, likely driven by falling groundwater levels. Modelling concluded that there will be streamflow, stream salt-load and stream salinity increases due to the mining of O'Neil to McCoy.	Unspecified groundwater model with simplistic parameterisation. Limited information on the model and its spatial domain.
Modelling long-term flow and salinity response to bauxite mining in the upper Serpentine catchment (DWER 2019)	Mining/rehab in dam catchment LUCICAT SW/salinity modelling	Regardless of mining case or future climate, change in inflows due to mining was assessed to be on average less 2 GL/year, or five percent of flow on an annual average basis. Effects on reservoir salinity of mining within Upper Serpentine were within 3% of no-mining case.	Dynamics of simulated groundwater levels in context of strong drought years not well understood in model (flows in these instances are overestimated). Model is suited to large catchment areas, however, the proposal area includes one large catchment (Upper Serpentine), and two smaller separate catchment areas (Lower Serpentine, and Wungong Brook). Model data is 10 years old. Landsat LAI data from 1963 to 1972 is linearly extrapolated. Short-term impacts are either not captured by the model, or not described in the report.

Appendix I

Myara North assessment of previously mined area (figures and hydrographs)



Paper Size A3

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Metres

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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

GHD

Client Logo

Alcoa of Australia Limited Huntly Mine Extension

Previous mining area groundwater monitoring bore and mining location plan

Job Number	12520591
Revision	A
Date	23 Feb 2021

Figure I1

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© 2021. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

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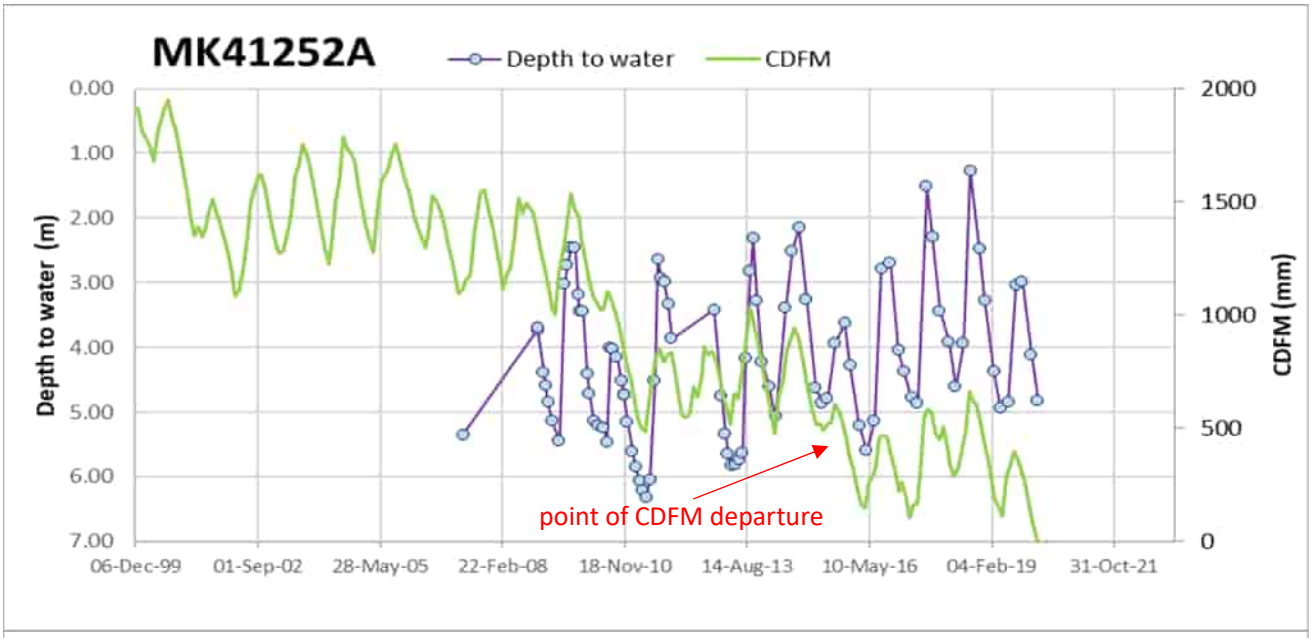
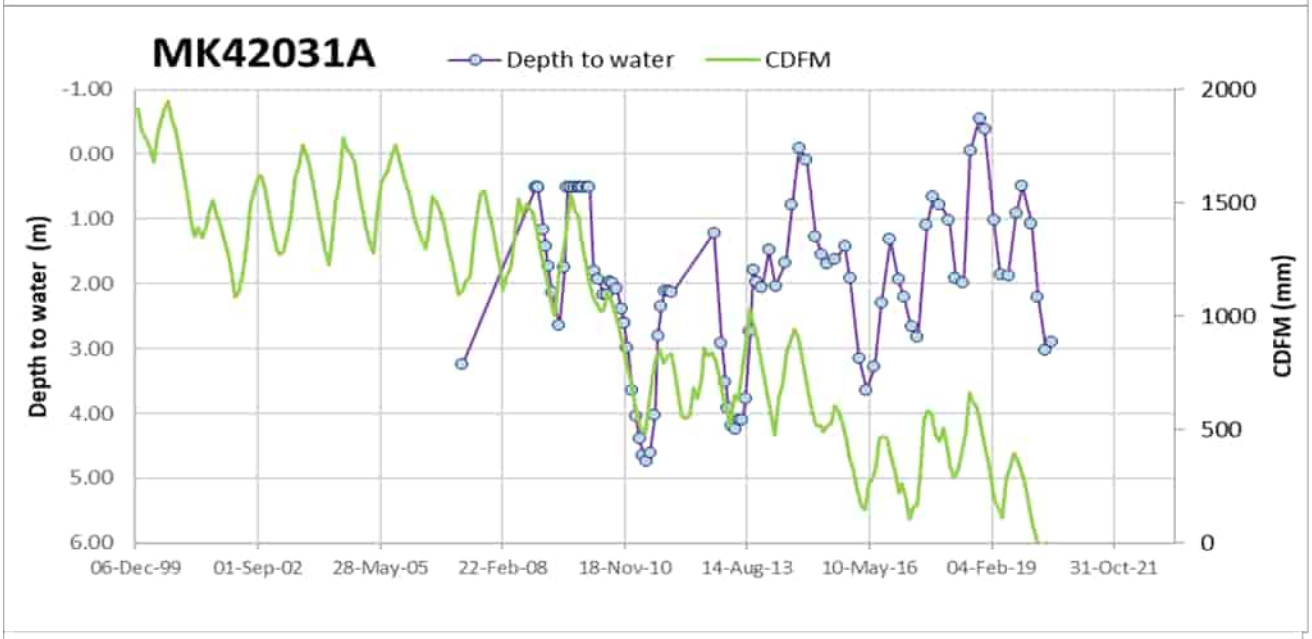
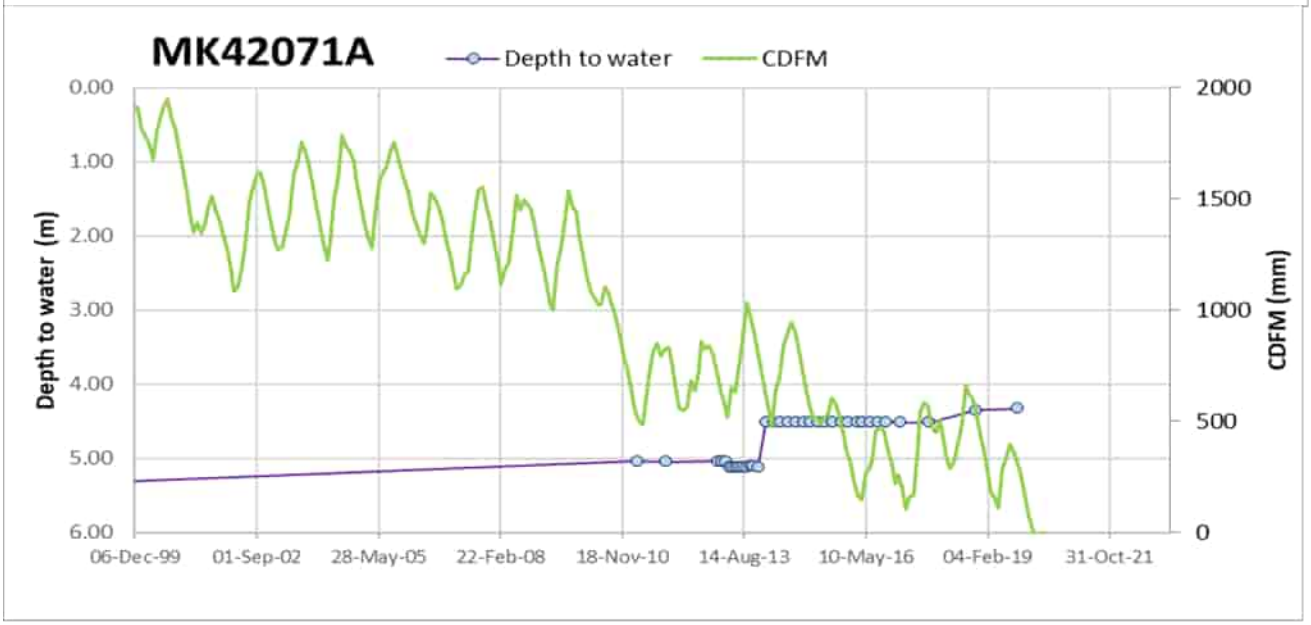
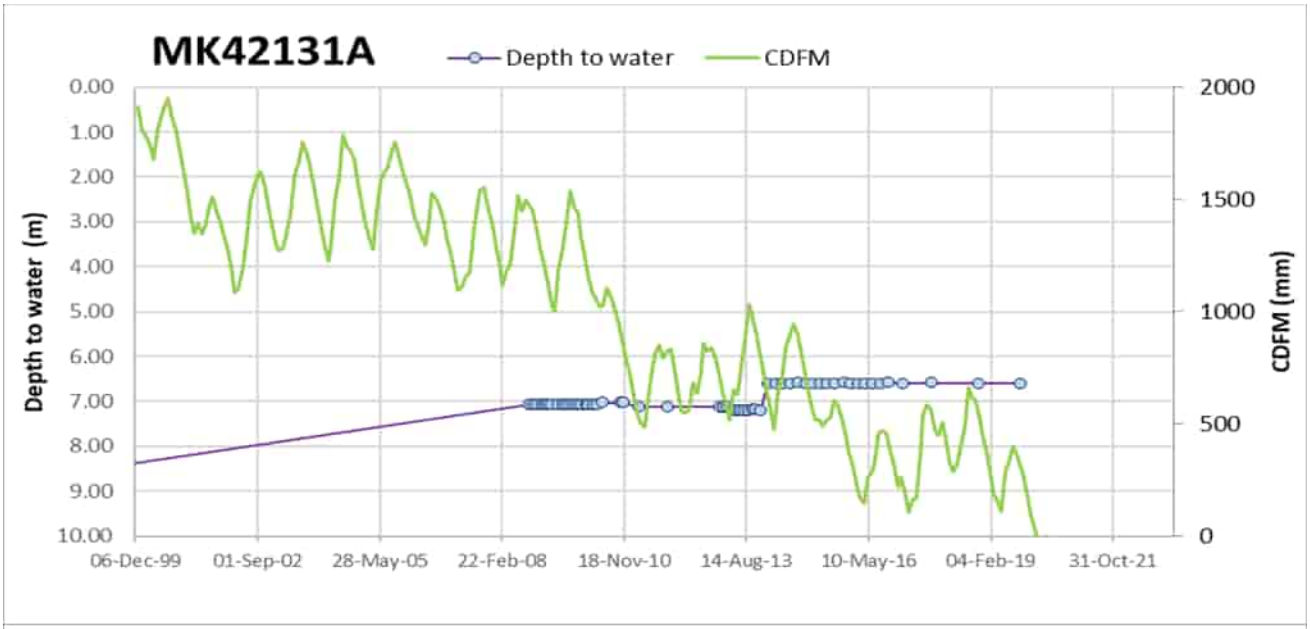
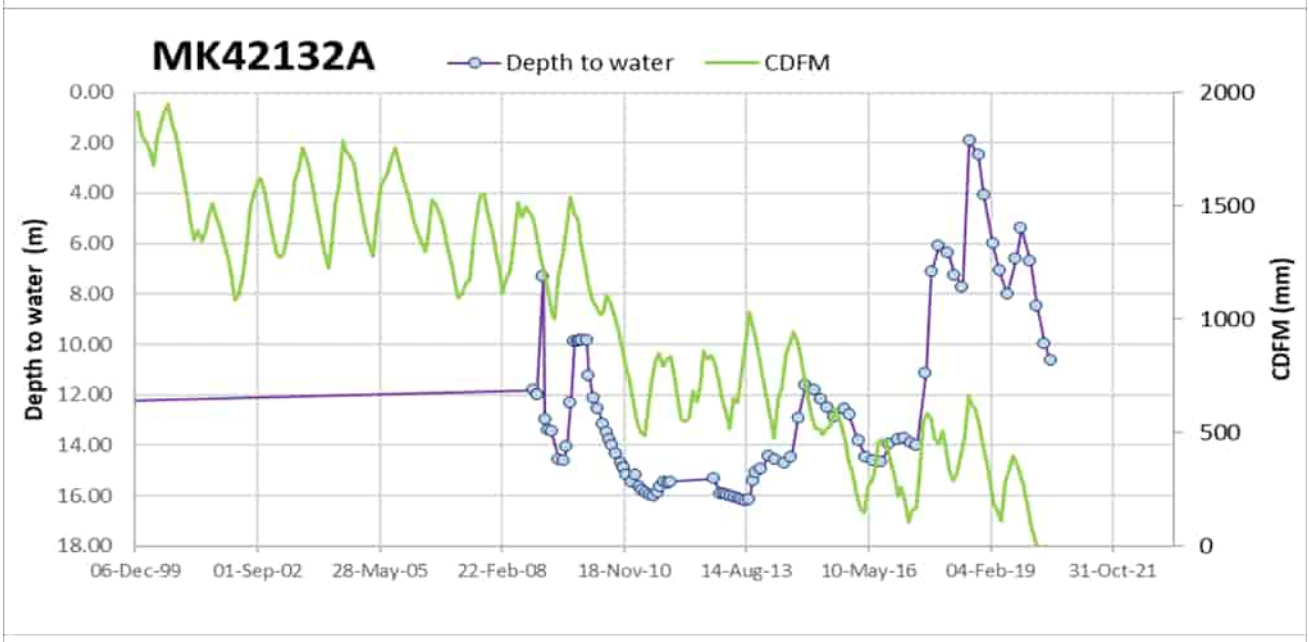


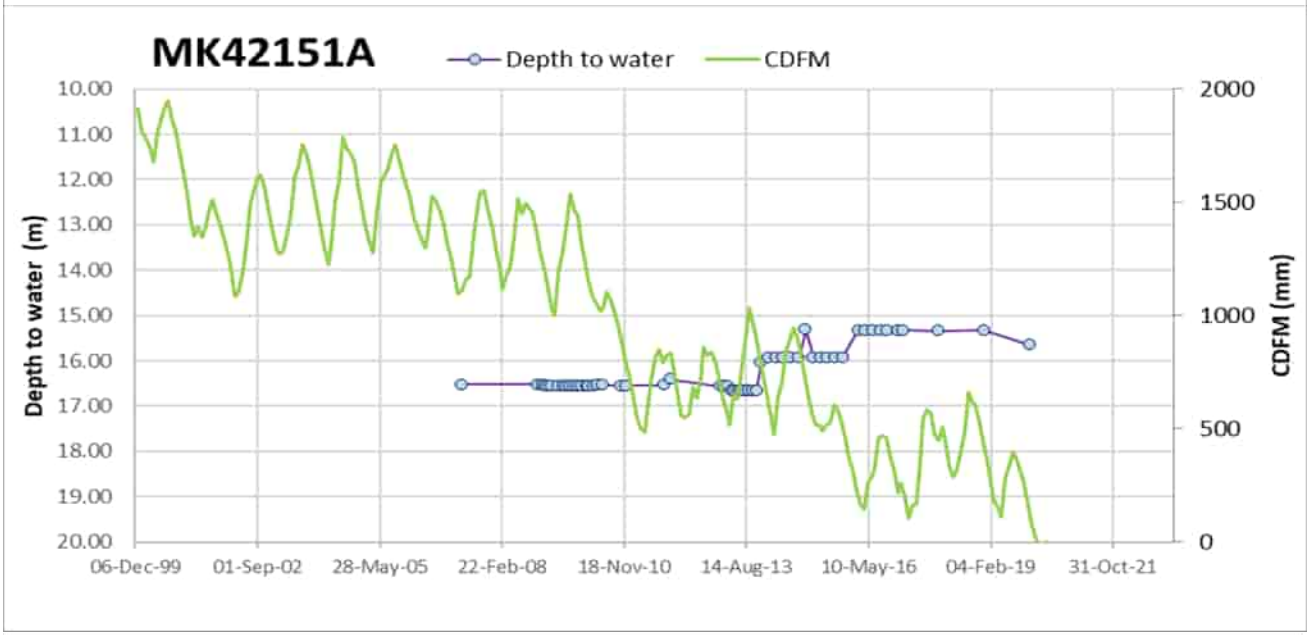




Appendix I
Myara previous mining area
Groundwater bore levels and CDFM







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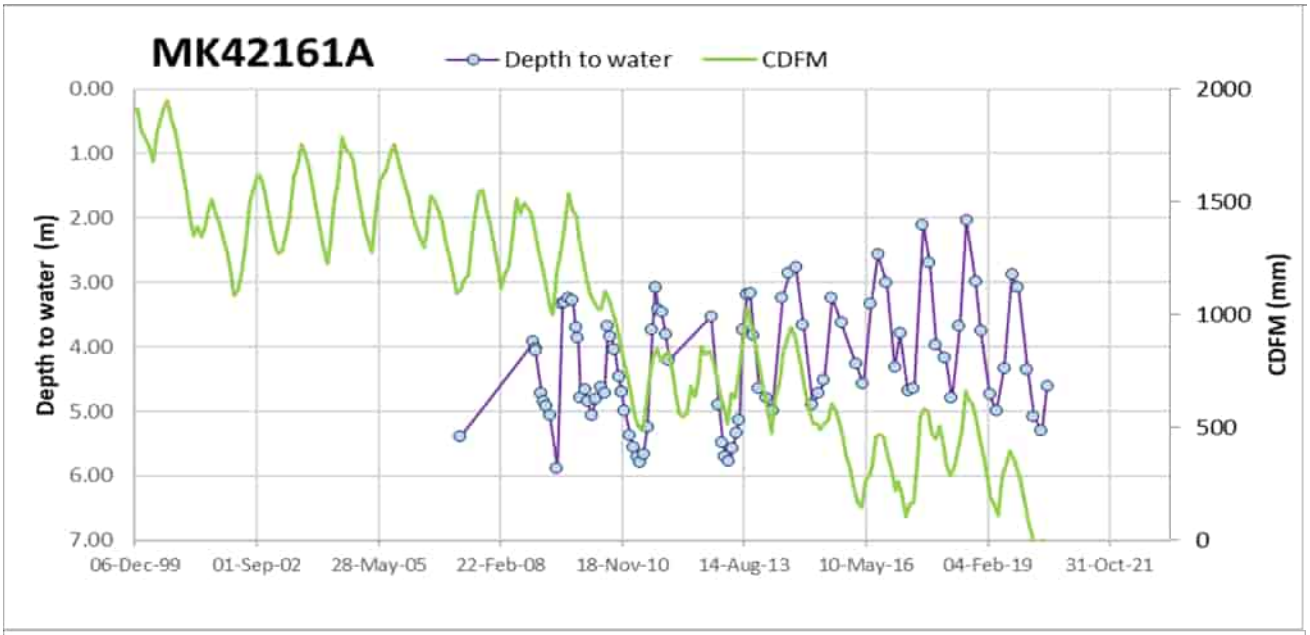

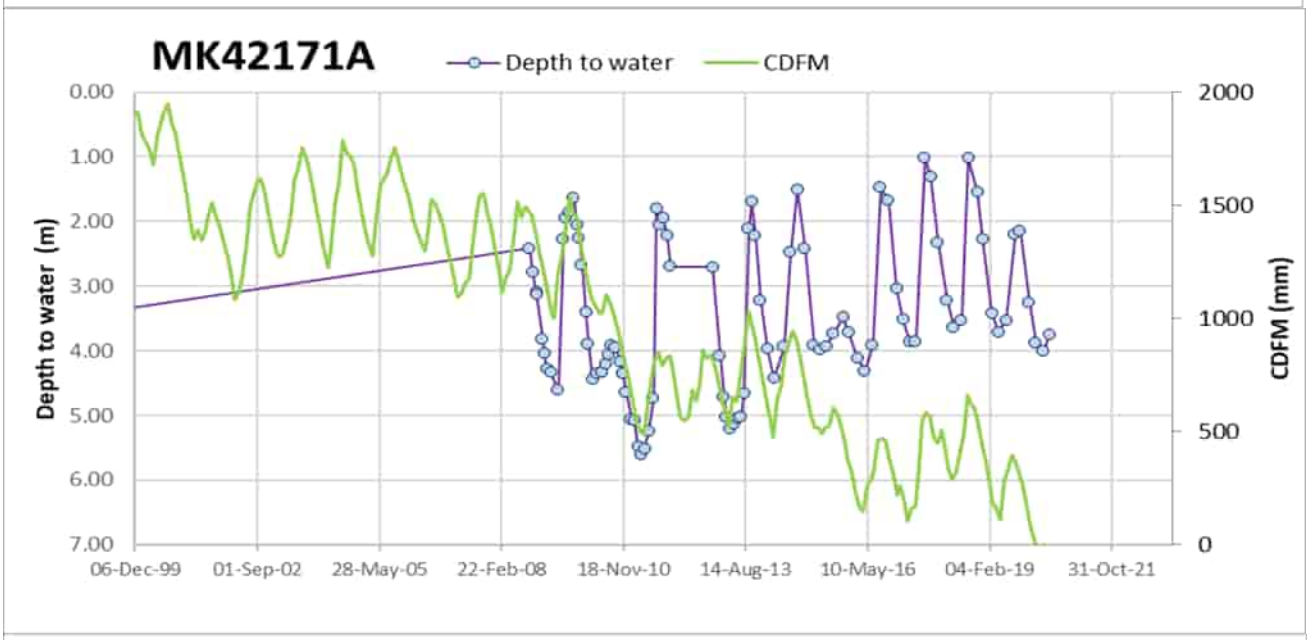

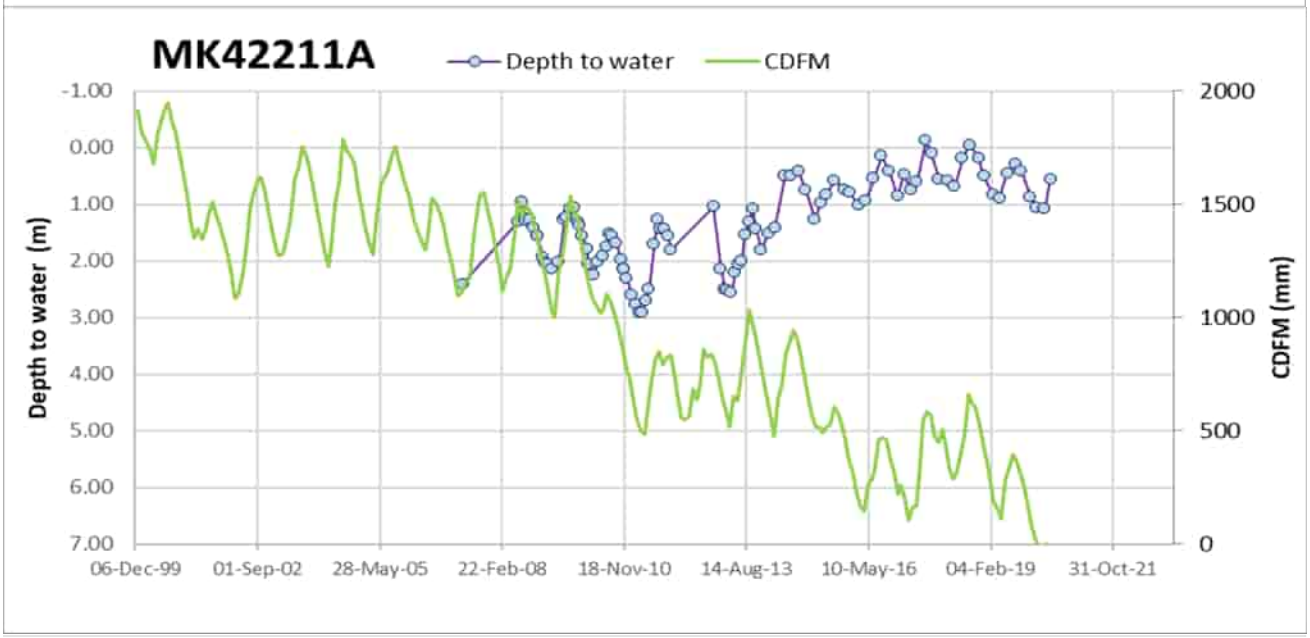

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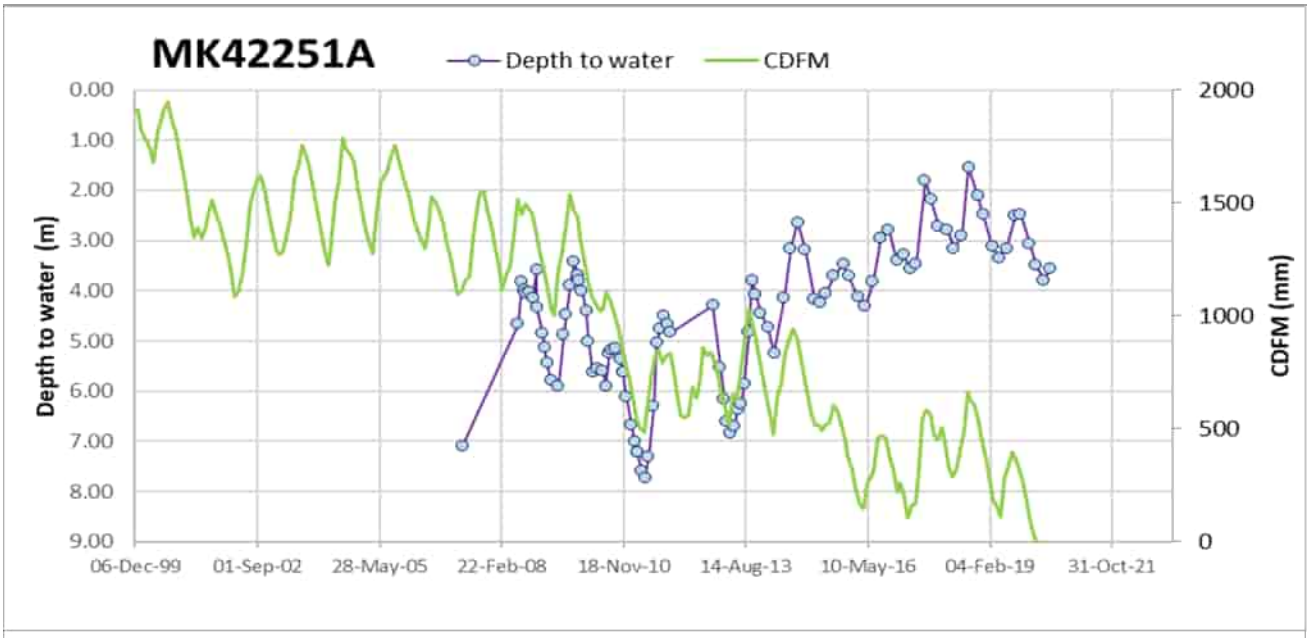

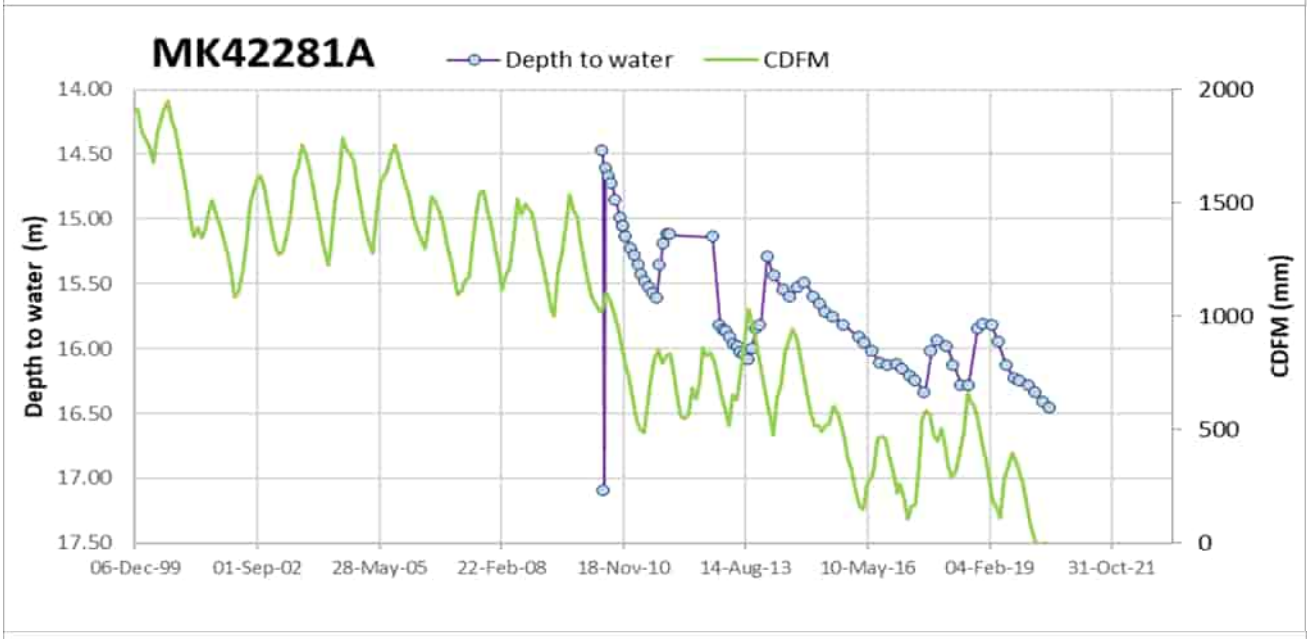

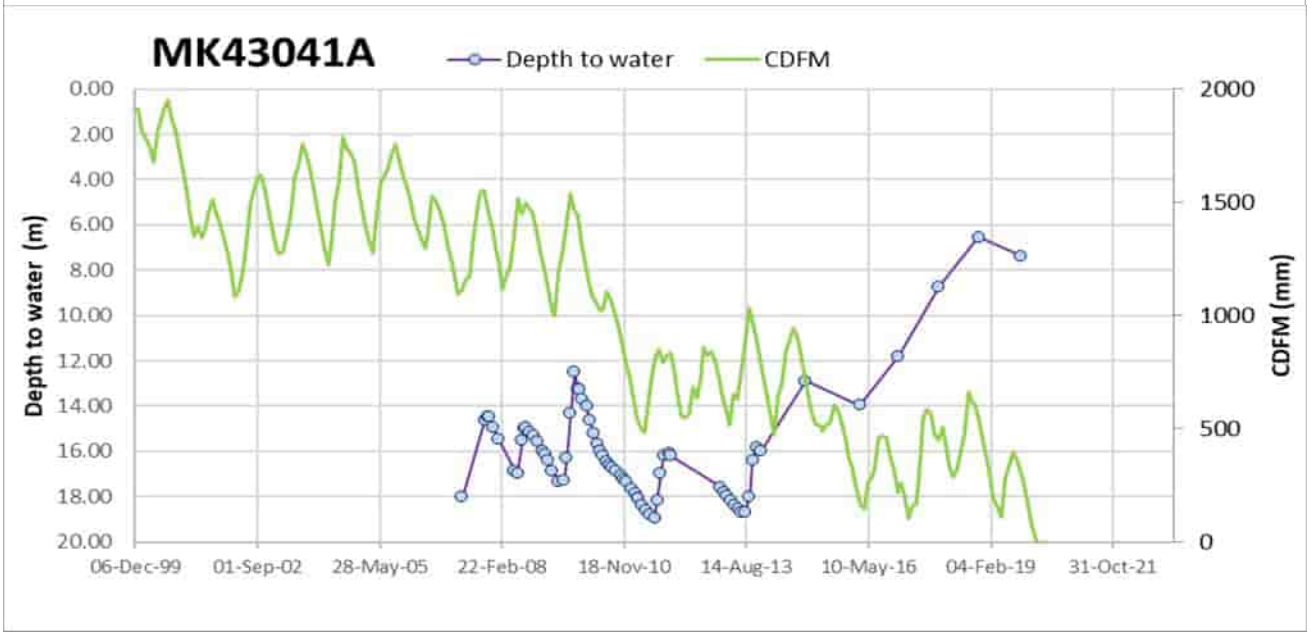

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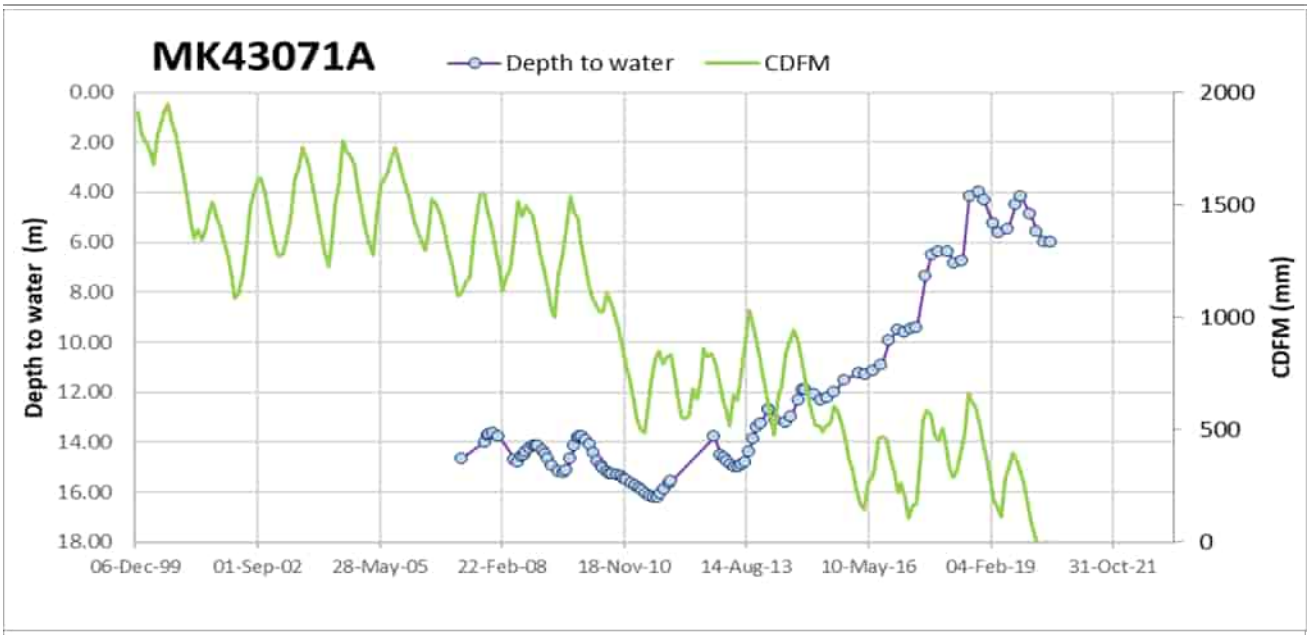

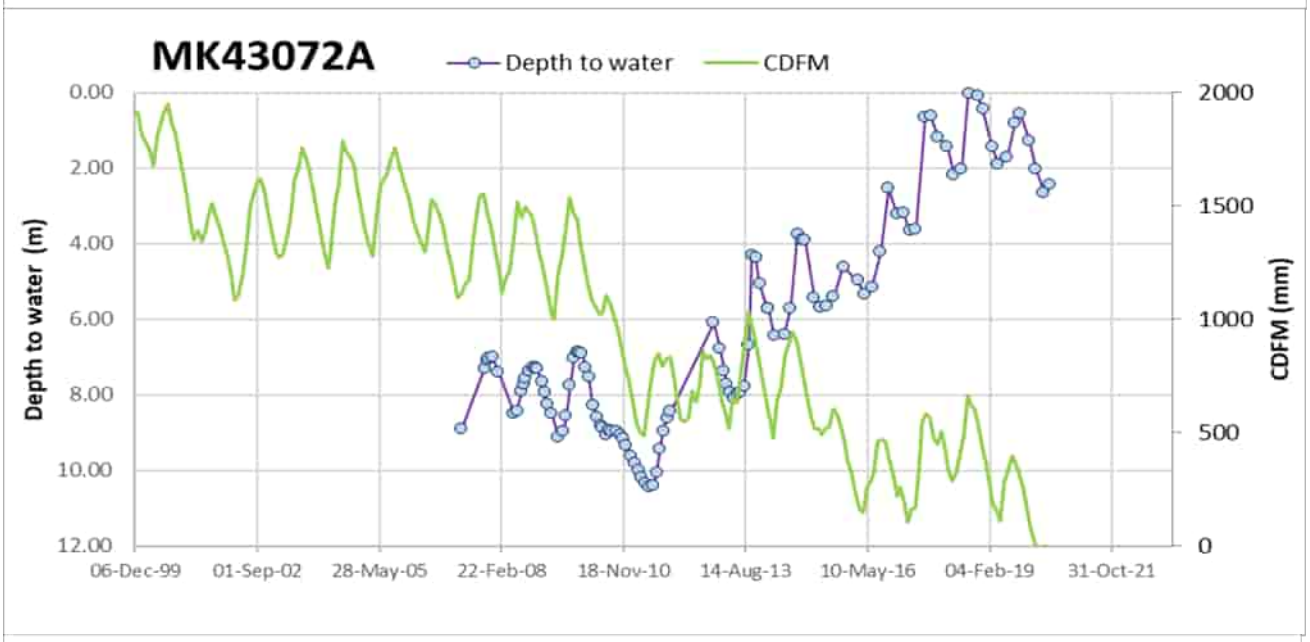

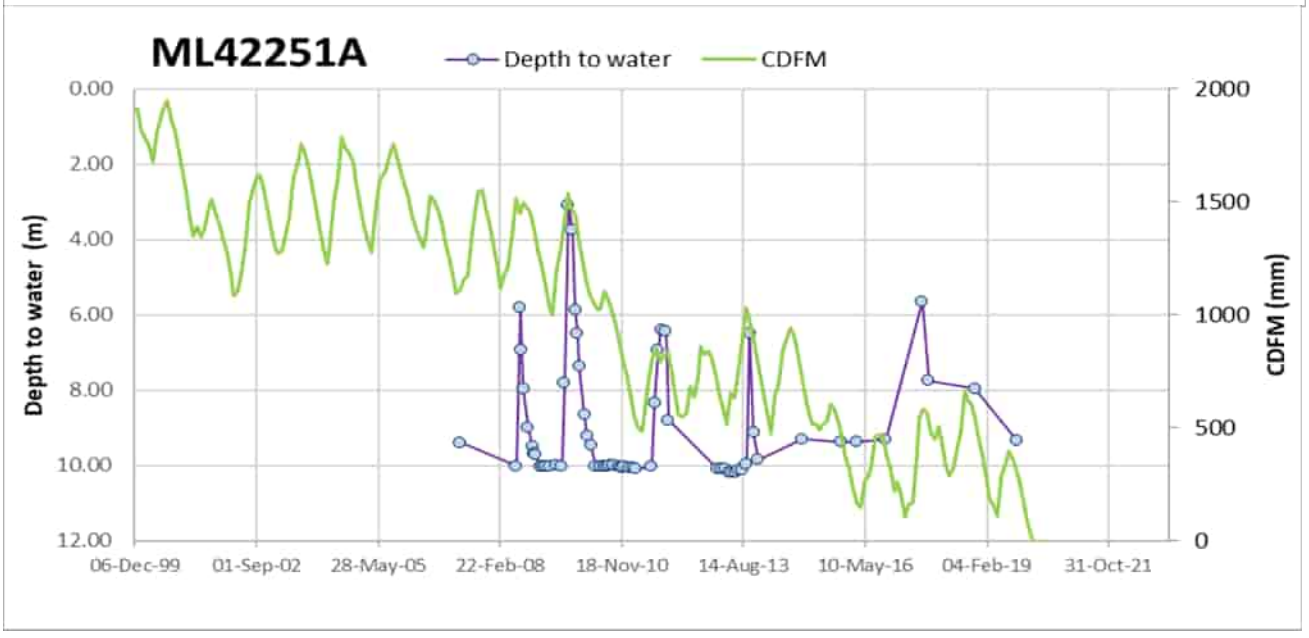

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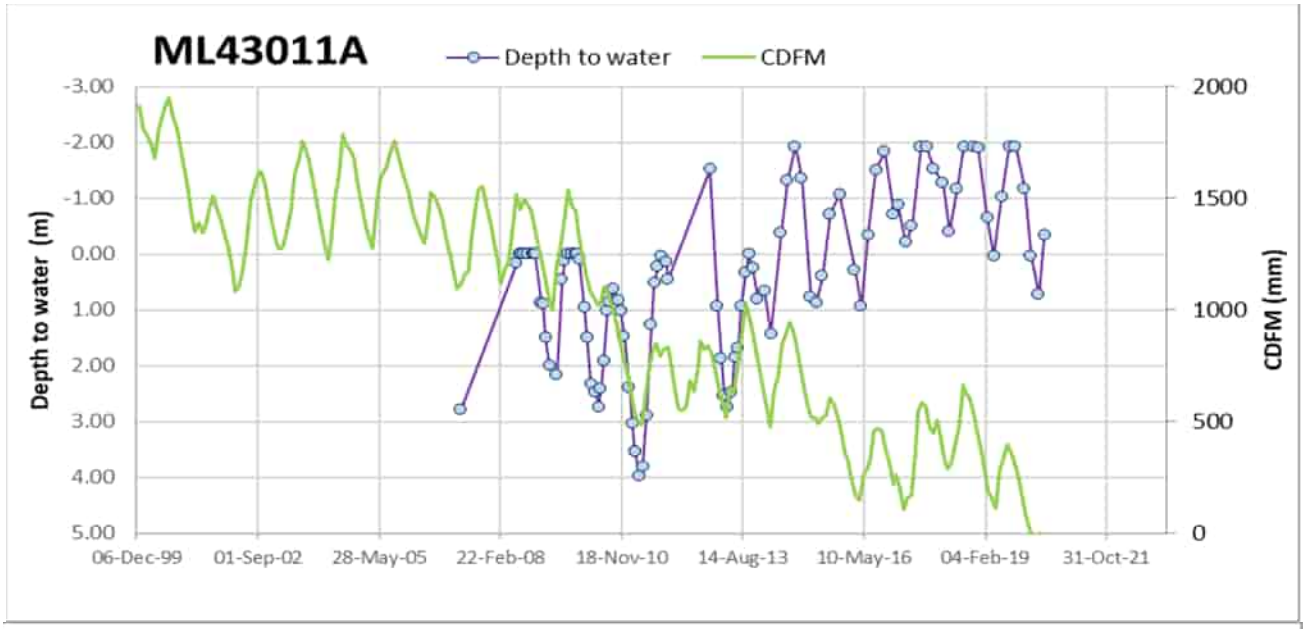

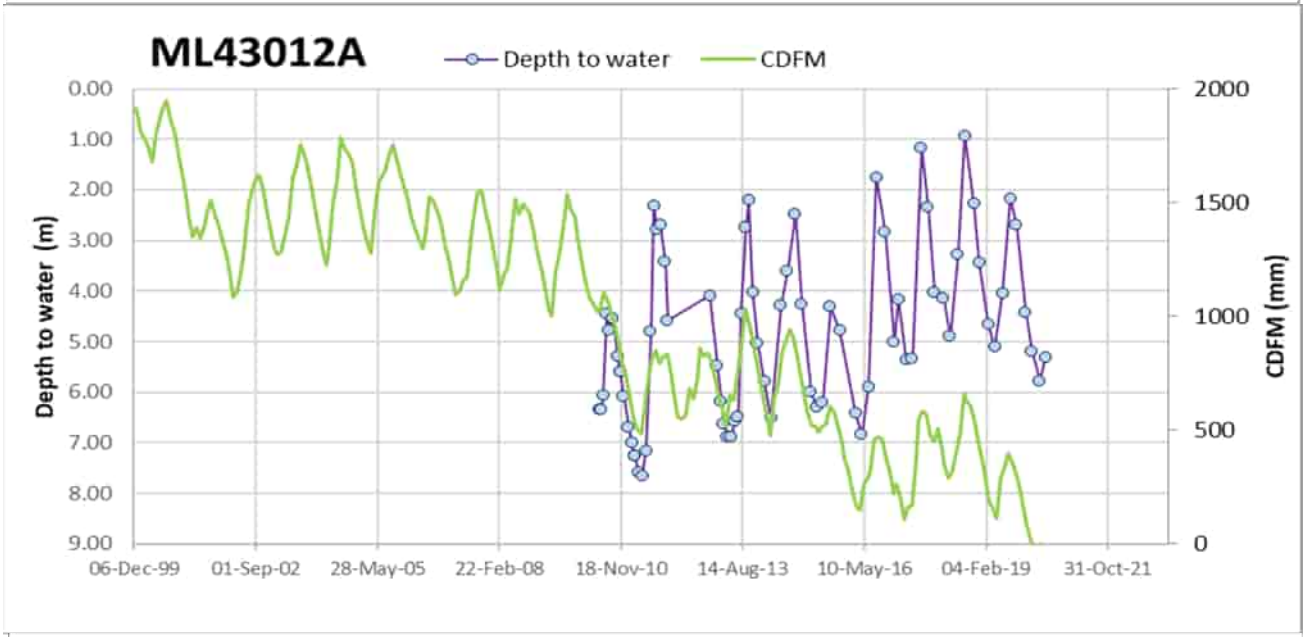

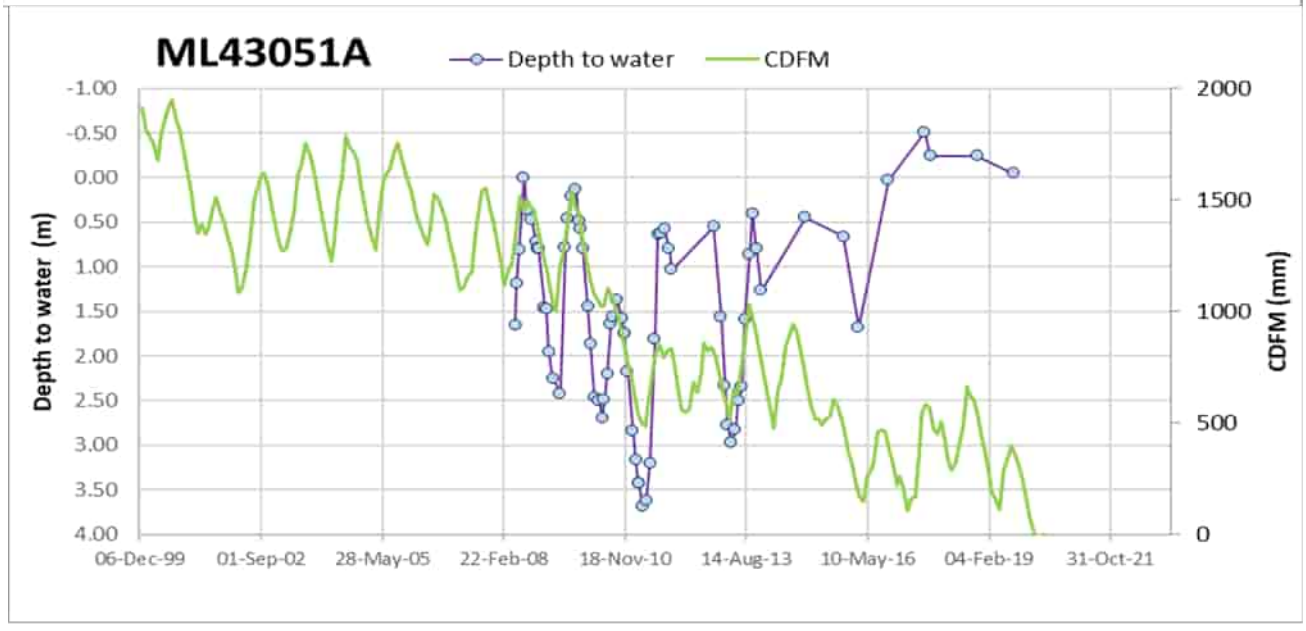

Appendix I
Myara previous mining area
Groundwater bore levels and CDFM

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The Power of Commitment