Water Management Plan - Mine

OP-PLN-00300

Key Environmental Factor: Inland Waters

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Summary

This Water Management Plan (WMP) has been prepared to outline Roy Hill Iron Ore Pty Ltd's (RHIO's) approach to monitoring and managing Inland Waters at the RHIO Mine as outlined in Table 0-1.

Table 0-1 – Summary

Title of proposal	Roy Hill Iron Ore Mine
Proponent	Roy Hill Iron Ore Pty Ltd
Ministerial Statement numbers	To be determined
Purpose of this Condition EMP	Outline RHIO's approach to monitoring and managing groundwater and surface at the Roy Hill Mine.
Key Environmental Factors and Objectives	Inland Waters - To maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected.
Key Provisions of the Plan	Outcome-based and Management-based provisions to: • Minimise potential environmental impacts associated with groundwater abstraction and reinjection including water levels and groundwater quality • Minimise potential impacts to riparian vegetation and groundwater dependent vegetation • Undertake appropriate monitoring and report sufficiently to demonstrate compliance with approval requirements and enable appropriate and informed water management decisions.

1 Context, Scope and Rational

1.1 The Proposal

Roy Hill Iron Ore Pty Ltd (RHIO), a wholly owned subsidiary of Hancock Prospecting Pty Ltd (HPPL), currently operates the RHIO Iron Ore Mine (the Mine). The Mine is located 280km south of Port Hedland and 110km north of Newman in the Pilbara Region of Western Australia (Figure 1-1). The overall RHIO Project involves the open cut mining, processing, transport via heavy haul railway and export of bedded Marra Mamba and detrital iron ore from port facilities in Port Hedland.

The mining activities are undertaken within mining tenements M46/518 and M46/519. RHIO also have miscellaneous licences for the purposes of remote borefields, access roads, dewatering, re-injection and groundwater search activities. Following the granting of the required approvals, construction of the mine commenced in October 2013. Mining began in Delta mine pit in July 2014 and Zulu mine pit in February 2015.

RHIO has submitted a Revised Proposal which incorporates a Life of Mine Water Management strategy (LOM WMS). The LOM WMS identifies the requirement to:

- increase the volume of groundwater abstracted for dewatering from 396GL total to 626GL total for LOM;
- dispose of surplus water via managed aquifer reinjection (MAR) of up to 508GL for life of mine (LOM) utilising re-injection bores;
- dispose of surplus TSF decant water, RO reject water and saline water via dust suppression and/or MAR; and
- dispose of surplus TSF decant water, RO reject water and saline water via evaporation ponds.

The Revised Development Envelope of RHIO Mine and indicative borefields relevant to the LOM WMS, as per the Revised Proposal, are outlined on Figure 1-2. The current existing infrastructure for MAR in the South West Injection Borefield (SWIB) and Stage 1 Borefield are outlined in Figure 1-3.

MAR in the context of Roy Hill's operations is the injection of surplus dewater water Reverse Osmosis (RO) reject water and Tailings Storage Facility (TSF) decant water in the deep confined lower detrital, Marra Mamba and Wittenoom Dolomite aquifers.

Implementation and operation of the Revised Proposal may have impacts to vegetation health, groundwater and surface water quality, groundwater and surface flows, subterranean fauna or the Fortescue Marsh Priority Ecological Community (PEC). This Water Management Plan (WMP) has been prepared to outline RHIO's approach to monitoring and managing water at the Mine.

This WMP has been prepared in accordance with the *Instructions on how to prepare Environmental Protection* Act *1986 Part IV Environmental Management Plans* (2018) developed by the Environmental Protection Authority (EPA).

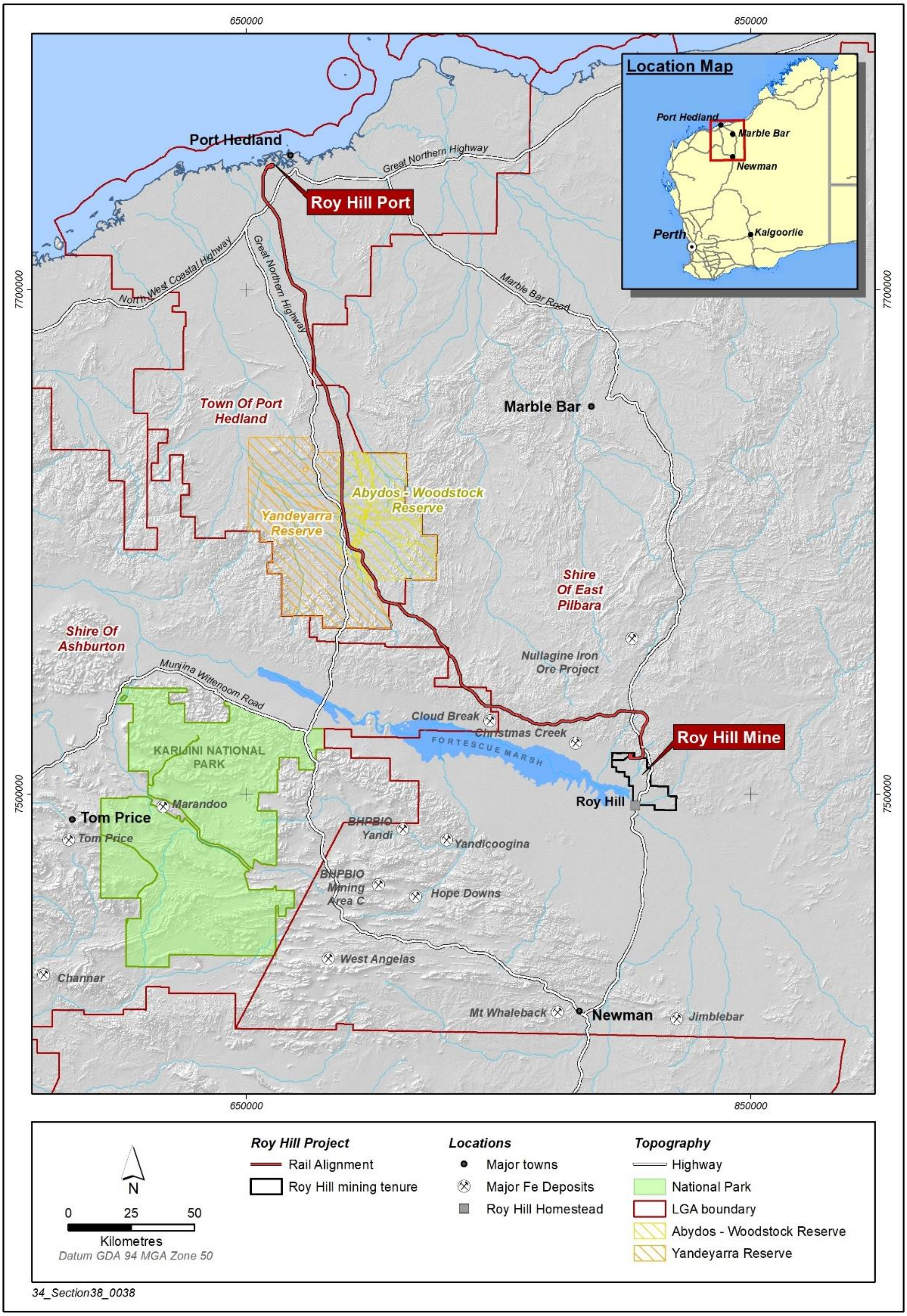


Figure 1-1 – Location of the Roy Hill Iron Ore Mine

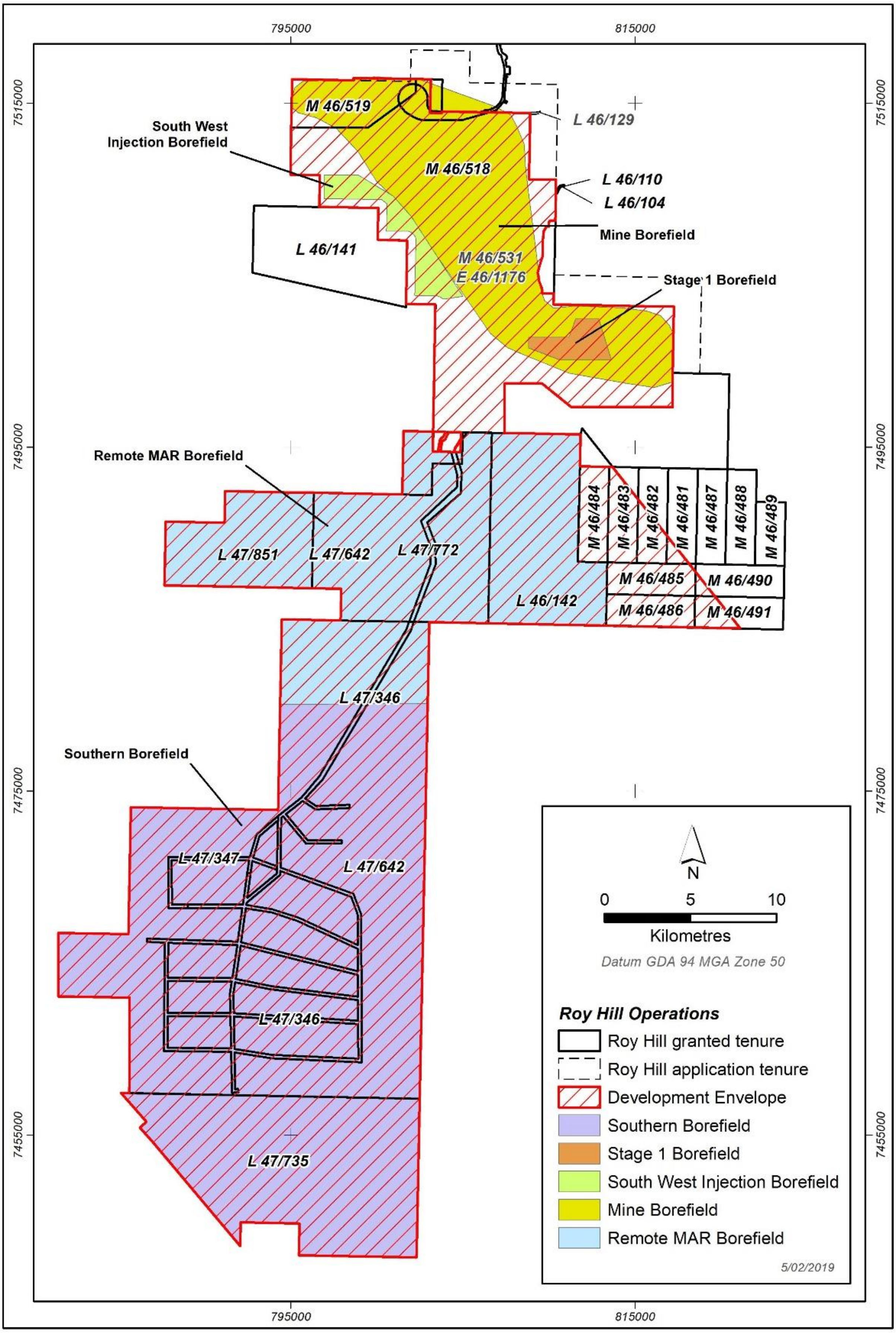


Figure 1-2 – Roy Hill Mine Revised Development Envelope and Borefield Locations

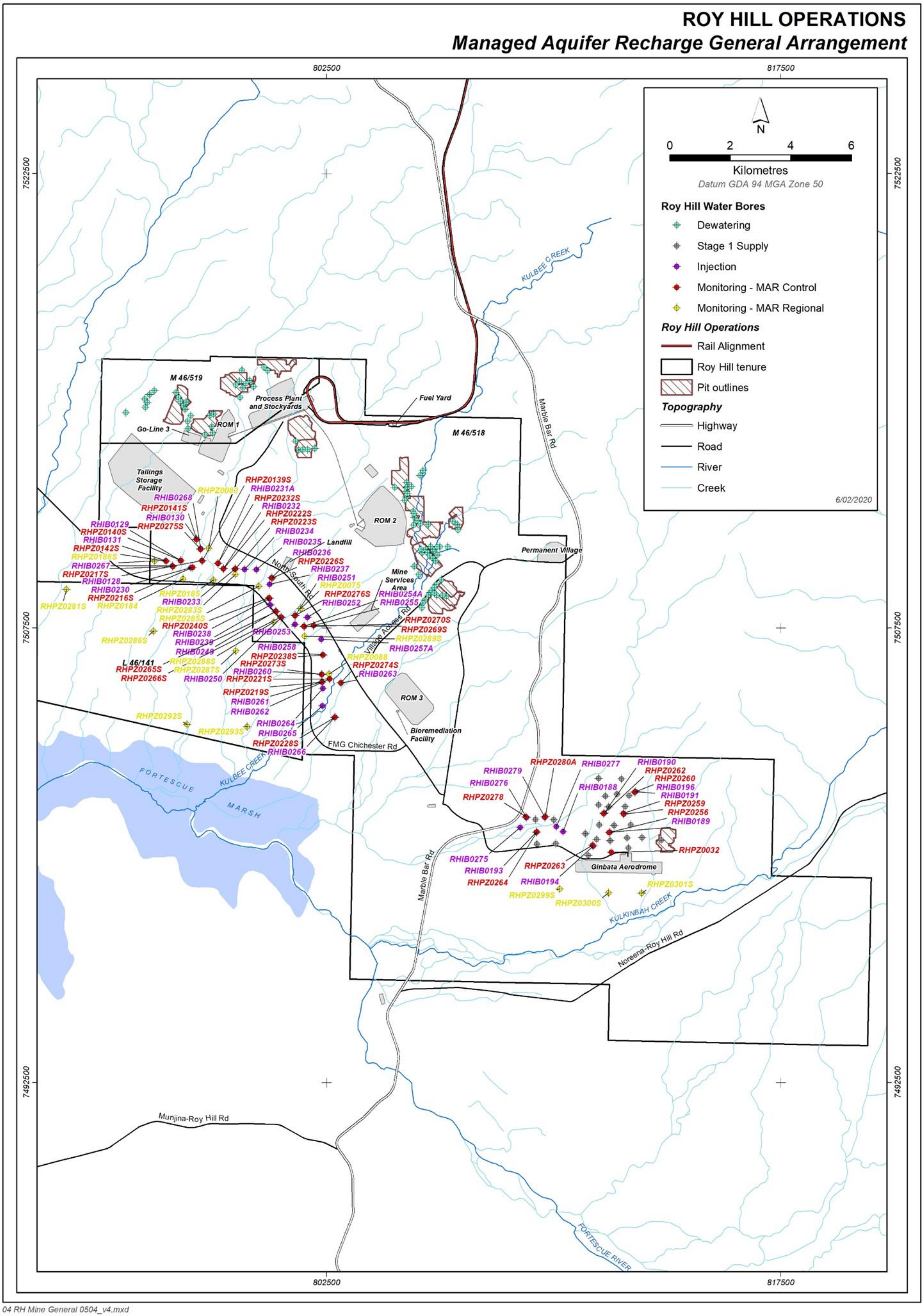


Figure 1-3 – Managed Aquifer Recharge Indicative Bore Types and Locations

1.2 Key Environmental Factors

This WMP has been developed to meet the EPA's key environmental factor objectives as outlined in Table 1-1.

Table 1-1 – Key Environmental Factor

Environmental Factor	Objective
Inland Waters	To maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected.
Flora and Vegetation	To protect flora and vegetation so that biological diversity and ecological integrity are maintained.
Subterranean Fauna	To protect subterranean fauna so that biological diversity and ecological integrity are maintained.
Terrestrial Fauna	To protect terrestrial fauna so that biological diversity and ecological integrity are maintained.

Table 1-2 outlines site specific values, proposal activities and the resulting potential impacts of these activities.

Table 1-2 – Proposal activities and impacts to Environmental Factors

Environmental Factor	Site Specific Value	Potential Impact	Revised Proposal activities
Inland Waters	Fortescue Marsh, Fortescue River and tributaries	Contamination of Surface Water	• Construction of infrastructure including waste rock landforms, roads, borefields and pipelines can alter surface water flows and increase erosion causing increases in sedimentation and turbidity. • Clearing activities and operation of machinery and vehicles can increase erosion causing increases in sedimentation and turbidity • Use of saline water sources for dust suppression has potential to alter the quality of surface water • Inappropriate waste management or leaking chemical and hydrocarbon storage facilities can result in release of hydrocarbons and chemicals to the environment and surface water • Leaching of contaminants from waste rock landforms can alter quality of surface water

		Changes to surface water flows	• Downstream flows and sheet flows can be altered by:
			  • surface water diversions structures
			  • clearing of land; and
			  • development of infrastructure.

		Contamination of groundwater	• Contamination of groundwater from leaching of in-pit TSF • Changes in the quality of the groundwater from MAR • Contamination of groundwater from leaching of WRLs • Inappropriate waste management or leaking chemical and hydrocarbon storage facilities can result in release of hydrocarbons and chemicals to the environment and surface water

Environmental Factor	Site Specific Value	Potential Impact	Revised Proposal activities
		Changes to groundwater flows	• Reduction in groundwater levels from abstraction and dewatering altering water available at root depth • Mounding of groundwater from MAR and in-pit tailings storage altering water available at root depth
Subterranean Fauna	Stygofauna	Changes to groundwater quality outside the range of tolerance of stygofauna	• Changes in groundwater quality from MAR and in-pit tailings storage
		Changes to groundwater flows and levels impacting habitat availability for stygofauna	• Reduction in groundwater levels from abstraction and dewatering
	Troglofauna	Changes to groundwater levels impacting habitat availability for troglofauna	• Mounding of groundwater from MAR and in-pit tailings storage
Flora and Vegetation	Riparian Vegetation and Groundwater Dependant Vegetation (GDV)	Changes to water available at root depth causing waterlogging or reducing available water.	• Mounding of groundwater from MAR and in-pit tailings storage • Reduction in groundwater levels from abstraction and dewatering • Surface water diversion structures altering flow of surface water
Terrestrial Fauna	Habitats	Changes to groundwater and surface water quality and quantity impacting on fauna habitats	• Mounding of groundwater from MAR and in-pit tailings storage altering water available at root depth • Reduction in groundwater levels from abstraction and dewatering altering water available at root depth • Surface water diversion structures altering flow of surface water • Inappropriate waste management or leaking chemical and hydrocarbon storage facilities can result in release of hydrocarbons and chemicals to the environment and surface water • Leaching of contaminants from waste rock landforms can alter quality of surface water

1.3 Condition Requirements

The Mine was originally approved under Part IV of the Environmental Protection Act 1986 (EP Act) through Ministerial Statements 824, 829, 979 and 980 and amended via subsequent s45C and s46 applications (herein after collectively referred to as the "Original Proposal"). These Ministerial Statements require RHIO to monitor and report on potential impacts to groundwater and surface water.

RHIO currently has a Revised Proposal being assessed by the EPA under s38 of the EP Act. This WMP addresses the potential impacts to Inland Waters arising from the Mine as a whole under the Original and Revised Proposal.

1.4 Rationale and approach

This WMP addresses the Inland Waters environmental factor and the EPA's objective to maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected.

A combination of surveys and study findings, risk assessments, monitoring, and the assessment of assumptions and uncertainties have contributed to the establishment of this WMP ensuring that the objective of the EPA is met.

1.4.1 Survey and Study Findings

RHIO have undertaken groundwater monitoring at the Mine since 2007 and surface water monitoring since 2013. Monitoring has consisted of infield measurement and analysis and collection of water samples for analysis at a National Association of Testing Authorities, Australia (NATA) accredited laboratory in line with the requirements of:

- Ministerial Statements;
- Operating Licence and Works Approvals;
- Mining Proposals and Tenement conditions; and
- Groundwater Operating Strategies (GWOS) and 5C licences.

An annual groundwater and surface water monitoring assessment report has been submitted to the EPA since commencement of mining operations in 2015. The assessments have reviewed monitoring data against licence limits, ANZECC/ARMCANZ trigger values and baseline conditions. Conclusions from these reports have indicated that there have been no significant impacts to groundwater or surface water from RHIO mining operations to date.

1.4.1.1 Life of Mine Water Management Strategy

In 2019, GHD completed an assessment of groundwater change for the RHIO Life of Mine Water Management Strategy (LOM WMS) (GHD, 2019) . The assessment includes details of the water balance tasks (including volume estimates) for the Roy Hill mine operations including but not limited to:

- Mine Dewatering Task;
- Raw Water Supply Task;
- Process Water Supply Task;
- Water Treatment Task;
- TSF Water Management Task;
- Dust Suppression Task; and
- Surplus Water Disposal Task.

A schematic of the tasks and components from LOM WMS (GHD, 2019) is illustrated in Figure 1-4.

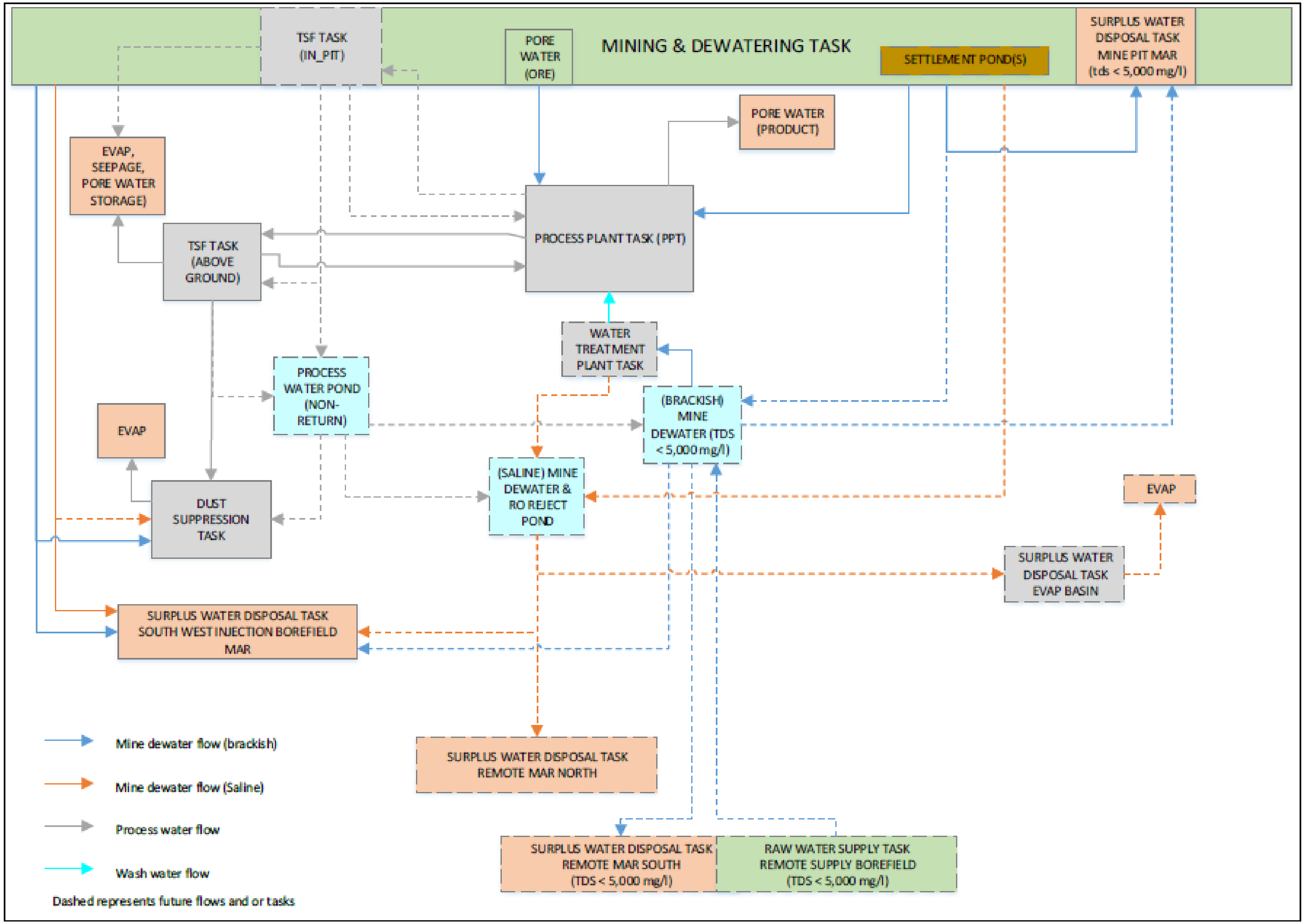


Figure 1-4 LOM WMS Task and components (schematics only, subject to change)

1.4.1.2 LOM WMS Vegetation Risk Assessment

In 2019, Roy hill engaged Astron to undertake a vegetation risk assessment from the changes to groundwater associated with the Roy Hill LOM WMS (discussed in Section 1.4.1.1). Astron considered the following risk scenarios:

- Groundwater drawdown (decoupling of roots from a reliable water source);
- Groundwater mounding to a maximum of 5mbgl at MAR Control Bores causing water logging;
- Unbalanced growth (canopy growth which is not matched by root growth); and
- Groundwater mounding and salinisation from mounding.

The risk was determined based on a likelihood and consequence matrix consistent with Department of Environmental Regulation (DER, 2017) as shown in Table 1-3.

Table 1-3 – Risk Treatment Table

Risk Rating	Acceptability	Treatment
Extreme	Unacceptable	Risk event will not be tolerated
High	May be acceptable. Subject to multiple regulatory controls	Risk event will be tolerated and may be subject to multiple regulatory controls.
Medium	Acceptable, generally subject to regulatory controls.	Risk event is tolerable and is likely to be subject to some regulatory controls.
Low	Acceptable, generally not controlled.	Risk event is acceptable and will generally not be subject to regulatory controls.

The hydrological modelling undertaken in the LOM WMS was utilised for the risk assessment. The LOM WMS considers six dewatering and injection scenarios, with injection occurring in the SWIB, Stage 1 Borefield, Remote MAR and Southern Borefield (either individually or a combination of these). Astron's (2019) risk assessment considers scenario 2B outlined in the LOM WMS (GHD, 2019), in which all four injection fields are used at the same time. This scenario was selected because it represents the largest spatial extent of groundwater mounding, which is considered to pose the greatest threat to vegetation. Temporally, the model output for 2026 was selected to represent a period of high risk of decline or mortality because it represents a phase of the LOM WMS when groundwater drawdown approaches the maximum depth and groundwater mounding has occurred over a sustained period.

The risk assessment identified no areas of vegetation as being at high risk of decline or mortality. Areas at low to medium risk of decline or mortality were predominantly associated with MAR and focussed within the north-west of the Revised Development Envelope, near the current mining area, the proposed clearing footprint and SWIB re-injection fields. The 5mbgl mounding limit significantly reduces the potential impacts to vegetation.

Risk of impacts to vegetation from groundwater drawdown from mine dewatering were from small isolated locations where the risk was predominantly low.

1.4.1.3 TSF Decant Risk Assessment

GHD completed a risk assessment for the re-use of the TSF decant water for dust suppression and disposal via MAR (GHD, 2019a). The assessment was based on TSF decant water quality sampling completed by RHIO on a weekly basis between April and September 2018. The water samples were submitted to a National Association of Testing Authorities (NATA) accredited laboratory for analysis of a broad range of parameters.

Key findings from the decant water analysis are summarised below:

- Total dissolved solids (TDS) concentrations ranged from 2,700 to 5,200 mg/L.
- The values of pH range from 7.6 to 8.0.

Inorganic (including dissolved metals) concentrations were determined for the following:

- As, Ba, Be, B, Cd, Ca, Cl, Cr, Co, Cu, Fe, Pb, Mg, Mn, Mo, Ni, P, K, Se, S, Ag, Na, Sr, S, Tl, Sn, Ti, V, and Zn.

For the purpose of the assessment, maximum concentrations for each metal were compared to ANZECC (2000) fresh water guidelines 95% ecosystem protection, all concentrations were below the guidelines with the exception of metals; boron (average 0.53mg/L), total chromium (average 0.07 mg/L), selenium (average 0.023 mg/L), and zinc (average 0.0006 mg/L).

Dust Suppression

The primary source, pathway, receptor linkage was identified to be metals accumulation in soil directly adjacent to the haul roads, having the potential to cause negative impact of native vegetation health.

Potential contaminants of concern in the TSF decant water used for dust suppression with regard to potential soil contamination included nutrients and metals.

ANZECC (2000b) provides a recommended trigger range for nitrogen concentrations in irrigation waters for agricultural crops of 25 – 125 mg/L for irrigation over 20 years. These values are based on maintaining crop yield and minimising off-site impacts. Concentrations in irrigation water should be less than the recommended trigger values. Applying these values as a screening criteria for comparison, the TSF decant water has mean nitrogen concentration of 42.5 mg/L which is within the acceptable range defined by ANZECC (2000b). As such, nutrients within the TSF decant water are expected to pose a low risk of negative impact to local vegetation.

Estimated concentrations for metals in soil after 13 years of dust suppression using TSF decant water are well below the generic ecological investigation level (EILs) (where available), suggesting a low risk of negative impact to native vegetation, fauna and human health.

Managed Aquifer Reinjection (MAR)

For MAR the predicted maximum concentrations will be in the range of 0.005 mg/L to 0.01 for total Se, 0.02 to 0.05 mg/L of total Cr and 20 to 50 mg/L of nitrate. With exception of Se this would represent a temporary exceedance (up to 40 years post closure for nitrate) of ANZECC trigger values in parts of the plume largely confined to the mining tenement.

There are no indications that the Se, Cr or nitrate plumes would intersect the Fortescue Marsh due to the long-lasting drawdown effect from mining.

1.4.1.4 Groundwater and Surface Water Monitoring Review

In 2020, RHIO commissioned Stantec to undertake an assessment of groundwater and surface water monitoring in the context of RHIO's operations. The assessment reviewed existing Roy Hill water monitoring data, studies and assessments including Waste Rock Leachate testing, the LOM WMS and TSF decant re-use assessment. The review addressed potential impacts from waste rock landforms (WRLs), TSFs and landfill and provided recommendations for a monitoring program including monitoring locations, sampling and an analytics program for the purpose of validating predictions and monitoring for potential environmental harm where identified in the assessment.

Table 1-4 outlines the recommended analysis suite from the Stantec assessment (2020).

Table 1-4 – Analysis suite for water quality monitoring at the Roy Hill mine

Analyte	
Basic	**pH-field**
	TDS
Metals and Metalloids	**Al (pH >6.5)**
	As-total
	B
	Ba
	Cd
	Cr-total *
	Cu
	Hg
	Mn
	Ni
	Pb
	Se-total
	Sr
	Zn
Nutrients	**$N-NH_3$**
	$N-NO_3$
	NO_3
	TN
	TP
Other	**TRH (C6-40)**

* Speciation testing for Trivalent Chromium (Cr+3) and Hexavalent Chromium (Cr+6)

The results of this assessment have contributed to Section 2 and have been incorporated in the Mine monitoring program. It was determined that there is a slight to minor risk from contamination of surface water quality from above ground infrastructure (Stantec, 2020). As such, it is considered that surface water quality sampling is not required, however, RHIO are committing to undertaking opportunistic 'grab sampling' of surface water during flow events in ephemeral creeks in proximity to the mine.

The results of these assessments and RHIO's commitments have contributed to the formulation of management provisions in Section 1.4.4.1 and Section 1.4.4.2 to monitor, mitigate and avoid impacts to inland waters.

1.4.2 Key assumptions and uncertainties

The following key assumptions and uncertainties apply in relation to this WMP:

- As LOM schedule/sequencing/plan changes, the exact location, extent and duration of groundwater abstraction and reinjection may change over time.
- This WMP has been developed based on information incorporated into the LOM WMS (GHD, 2019) and available at the time of preparation. As requirements change and knowledge increases over time this WMP may require update.
- Exact monitoring bores locations will change and adapt over time as mining progresses.
- Trigger levels will be refined over time as additional data is collected and collated.
- The exact area and extent of some surface flow modifications and locations of mining infrastructure are still in the design stage, but the indicative location is known. As the LOM changes, the timing for the installation of these diversion structures may change over time.

1.4.3 Management approach

1.4.3.1 Environmental Management System

The RHIO Environmental Management System (EMS) Framework provides a framework for achieving the key environmental management objectives during the operational phases of the Mine. The framework is illustrated in Figure 1-5. Implementation of the EMS Framework ensures environmental performance is achieved through environmental management practices that are consistent with RHIO's Environmental Policy and objectives. Management measures and controls are specifically detailed in environmental plans, procedures and work instructions which are implemented during the Operation phase of the Mine. RHIO's key environmental management documents have been developed to address environmental risks posed by mining and associated activities.

Figure 1-5 – Environmental Management System Framework

All activities that could impact on Inland Waters are undertaken in accordance with RHIO procedures to minimise environmental impact.

1.4.3.2 Available Information

This WMP has been developed using all available and relevant information. RHIO will continue to utilise and improve on current information to continue to inform best practice management, including:

- Utilisation of results of an annual Groundwater and Surface Water Monitoring Assessment to provide a basis for regular review of monitoring data;
- Consideration and investigation of use of new technologies and techniques that will inform updates to monitoring parameters, monitoring sites, and management measures;
- Regular review and update of the monitoring program based on changes to mine planning, reinjection quantities; diversion designs, timings of construction and operations of these diversion structures, operations, hydrological and surface water flood models, and groundwater monitoring data;
- Review of management measures to be implemented in the event of trigger criteria being exceeded;
- Measurement and review of effectiveness of implemented response actions; and
- Assessment of other effects or impacts not related to mining activities such as rainfall, fire, climate change, grazing and historic degradation from previous land use.

1.4.3.3 Risk Assessment

Risk assessments have been undertaken across the mine site to evaluate risk from water management activities. Risk assessments have been undertaken as components of the following:

- Life of Mine Water Management Strategy – Groundwater Change Assessment (GHD, 2019)
- Management of Saline Water Used for Dust Suppression – Desktop Study and Risk Assessment (Astron, 2015)
- Tailings Storage Facility (TSF) Decant Water Disposal Risk Assessment (GHD, 2019a)
- Life of Mine Water Management Strategy Vegetation Risk Assessment (Astron, 2019)
- Roy Hill Mine Water Monitoring Assessment (Stantec, 2020)

Risk assessments have been utilised to inform the trigger levels for monitoring sites and to identify focus areas for water management to manage, monitor and reduce potential environmental impact.

1.4.3.4 Monitoring

The purpose of monitoring is to inform, through the environmental criteria, if the environmental outcomes are being achieved and if required, when trigger level or threshold levels are exceeded, what contingency management measures need to be implemented. This section describes how RHIO will undertake monitoring to determine performance against the environmental criteria.

The Mine water monitoring program has been developed to specify locations, timing, parameters, triggers and thresholds at monitoring sites for both groundwater and surface water monitoring. The program has considered:

- Existing approvals and compliance requirements (i.e. Operating Licence, Mining Proposal etc)
- Risk Assessments
- Studies and survey findings
- Potential impacts and sensitive receptors
- Background water quality and standing water levels (SWL)
- Specific location of monitoring sites

RHIO have developed monitoring procedures and work instructions to ensure that water monitoring is conducted accurately and in accordance with relevant standards.

RHIO have adopted early response indicators and criteria with multiple performance indicators to track impacts and guide management measures. These include:

- Applying triggers at specific monitoring sites;
- An immediate retest of any monitoring site whereby a monitoring result has exceeded a trigger. This will be undertaken to ensure that the result is not due to an anomaly in testing or error;
- If the retest also exceeds the same trigger level, RHIO will:
  - Commence more frequent monitoring of the affected bore (monthly groundwater levels and quarterly water quality analysis).
  - Investigate the potential cause of the trigger level exceedance, and identify and monitor potential other impacts which may be caused due to the exceedance (i.e. vegetation health).

- Undertake a review of monitoring data and groundwater data from surrounding areas to determine if the changes are localised to the monitoring location.

1.4.3.5 MAR Monitoring for Groundwater Level Change -

As outlined in Section 1.4.1.2, the LOM WMS vegetation risk assessment was undertaken with the major control for preventing impacts to vegetation from mounding being a 5mbgl threshold. This mounding limit was selected as it was achievable under the Roy Hill modelled LOM WMS and it significantly reduce the likelihood of impact to vegetation. A 6mbgl trigger for mounding was selected as an early warning indicator for mounding. These triggers and thresholds have been included in the outcomes-based provisions in Table 2-1.

As outlined in Figure 1-3, all injection bores have an adjacent shallow monitoring bore and deep piezometer. The shallow monitoring bore includes an automatic cut-off mechanism that turns the injection bore off if the water level were to reach 5mbgl.

Roy Hill recognise the ecological value of the Fortescue Marsh which is situated to the west of the Roy Hill project. The LOM WMS groundwater level change modelling indicates that the Fortescue Marsh will not be impacted by changes to groundwater level associated with Roy Hill's MAR program. As an additional monitoring measure Roy Hill have established 3m and 2m trigger and thresholds with response actions for monitoring locations situated distal to the SWIB groundwater operation area and adjacent to the Fortescue Marsh where groundwater levels are naturally shallow and have higher variability.

Monitoring for groundwater level change is outlined in Table 1-5.

Table 1-5 – Trigger and Threshold Criteria for Ground Water Level Change

Groundwater Operations Area	Locality	Forecast change	Baseline water level Characteristics (Alluvium - Water Table) (mbgl)	Trigger	Threshold	Monitoring Bore
SWIB (Injection)	Central Injection Area	Maximum potential groundwater level change predicted	14 -17	6 mbgl	5 mbgl	Control bores and Regional bores as outlined in Figure 1-3.
	Proximal Injection Area	Moderate potential groundwater level change predicted	10 -13	6 mbgl	5 mbgl	RHPZ0287S
						RHPZ0286S
						RHPZ0281S
	Distal Injection Area	No groundwater level change predicted	5 -3	3 mbgl on seasonal basis	2 mbgl minimum	RHPZ0292S
						RHPZ0293S
Stage 1 borefield (Injection)	Central Injection Area	maximum potential groundwater level change predicted	15 - 20	6 mbgl	5 mbgl	Control bores and Regional bores as outlined in Figure 1-3.
	Proximal Injection Area	Moderate potential groundwater level change predicted	15 - 20	6 mbgl	5 mbgl	RHPZ0299
						RHPZ0301
	Distal Injection Area	No groundwater level change predicted	9 - 10 - XX	6 mbgl	5 mbgl	RHPZ0039

Groundwater Operations Area	Locality	Forecast change	Baseline water level Characteristics (Alluvium - Water Table) (mbgl)	Trigger	Threshold	Monitoring Bore
RMARN (Injection)	Central Injection Area	Maximum potential groundwater level change predicted	TBA	TBA	TBA	TBA
	Proximal Injection Area	Moderate potential groundwater level change predicted	TBA	TBA	TBA	TBA
	Distal Injection Area	No groundwater level change predicted	TBA	TBA	TBA	TBA
Southern Borefield (Injection)	Central Injection Area	Maximum potential groundwater level change predicted	TBA	TBA	TBA	TBA
	Proximal Injection Area	Moderate potential groundwater level change predicted	TBA	TBA	TBA	TBA
	Distal Injection Area	No groundwater level change predicted	TBA	TBA	TBA	TBA
In-pit MAR (Injection)	Central Injection Area	Maximum potential groundwater level change predicted	TBA	TBA	TBA	TBA
	Proximal Injection Area	Moderate potential groundwater level change predicted	TBA	TBA	TBA	TBA
	Distal Injection Area	Mo groundwater level change predicted	TBA	TBA	TBA	TBA

1.4.3.6 MAR Change to Groundwater Quality

1.4.3.6.1 Injection Water

MAR injection water source and quality (characterised by salinity) for each of the groundwater operations areas is outlined in Table 1-6.

Table 1-6 – MAR water quality parameters

Groundwater Operations Area	Injection Water Quality*	Injection Water Source
SWIB	Total Dissolved Solids (TDS): Trigger: 45,000mg/L Threshold: 50,000mg/L	Reverse Osmosis Reject Water TSF Decant Water Mine Dewater
Stage 1 Borefield	TDS: Trigger: 4,500mg/L Threshold: 5,000mg/L	Mine Dewater
Mine Borefield	TDS: - TBA Trigger: + 10% of background Threshold: 15% of background	Mine Dewater
RMAR	TDS - TBA Trigger: + 10% of background	Mine Dewater

	Threshold: 15% of background	
Southern Borefield	TDS - TBA Trigger: 4,500mg/L Threshold: 5,000mg/L	Mine Dewater

*Injection water TDS triggers and thresholds are calculated over the monthly flow weighted average of total injected water.

1.4.3.6.2 Monitoring for Groundwater Quality Change

Roy Hill has developed a best practice approach to verify that groundwater quality change is consistent with predicted change in the Alluvium – Water table zone (Appendix 1). The approach is based on appropriate water quality characterisation of the Alluvium – water table zone and potential groundwater quality change. The triggers and thresholds do not represent a level at which environmental harm will occur but rather provide a measure against which to verify the predicted water quality change. If through implementation of this management approach groundwater quality change is predicted to be greater than initially forecast then further environmental impact assessment shall be undertaken to determine any specific potential impact, leading to a revision of triggers and threshold values as appropriate. The trigger and threshold criteria for groundwater quality change is outlined in Table 1-7.

1.4.3.6.3 Baseline Characterisation

The adopted approach will characterise the Alluvium – Water table zone using water quality data for multiple bores, rather than characterise water quality on an individual bore basis. This approach aligns with the spatial scale of the predicted water quality change footprint, avoids bias due to relying on individual bore characteristics, and enables suitable sample population for statistical analysis.

Additionally, the natural salinity gradient that occurs in the Alluvium – water table zone (fresher towards the Chichester Ranges and hyper-saline towards the Fortescue Marsh) has the potential to influence the natural background chemical composition, and therefore the Alluvium – Water Table zone is further zoned based on salinity concentration (Total Dissolved Solids (TDS)) in the following ranges:

- Fresh; 0 – 500 mg/l TDS
- Marginal; 500 – 1,500 mg/l TDS
- Brackish; 1,500 – 5,000 mg/l TDS
- Saline; 5000 – 35,000 mg/l
- Hyper-saline; > 35,000 mg/l TDS

Chemical data for monitoring bores within the Alluvium – Water Table Zone with median TDS values falling within these ranges, have been aggregated to create a suitable sized population for statistical analysis that can be used for control chart construction. The chemical parameters selected for this purpose include TDS, Nitrate (NO_3), Chromium (Cr) and Selenium (Se).

A control chart baseline was established for each chemical parameter within the salinity grouping by assessing all available data from January 2018 to July 2021. The control chart includes the mean (μ) and three standard deviations (σ) from the mean (μ), which defines the baseline confidence intervals for each water type and parameter grouping (See Control Chart Plots in Appendix 2). Three standard deviations is adopted as the range of potential future background variability.

New measurements should be reviewed on a periodic basis for inclusion in defining the baseline characteristics, which will improve the size of the population and resulting characterisation. New measurements shall satisfy criteria to verify that they represent natural variability, and not water quality change due to MAR operations.

1.4.3.6.4 Potential Groundwater Change & Monitoring Zonation

Groundwater quality change in the Alluvium – Water table zone is predicted to manifest as localised plumes surrounding the injection borefields. Water quality change is a function of injection, creating higher pressure in the underlying receiving aquifer leading to diffuse upward migration of groundwater. Three zones are defined as follows:

- Central injection area; area of predicted maximum water quality change
- Proximal injection area; area of predicted lower water quality change; and
- Distal injection area; area of predicted no water quality change

Monitoring bores have been selected to represent each zone and be in the orientation of the principal environmental value, the Fortescue Marsh.

1.4.3.6.5 Establishing Triggers and Thresholds

For the central and proximal injection areas where water quality change is predicted:

- Triggers are set based on the sum of background mean, potential future background variability and ~80% predicted water quality change; and
- Thresholds are set based on sum of background mean, potential future background variability and 100% predicted water quality change

For distal areas, where no impact is expected, the triggers and thresholds are set at three standard deviations from the mean (see method outlined in Section 1.4.3.6.3).

1.4.3.6.6 Tracking Exceedance

Exceedances will be tracked through the:

- Breach of a water quality trigger results from two (2) consecutive measurements exceeding the trigger value
- Breach of a water quality threshold results from three (3) consecutive measurements exceeding the threshold value.

1.4.3.6.7 Response Actions

Breach of a trigger value shall result in investigation to establish causal factors. Breach of trigger values may result from a number of causes including sampling error, lab error, sample population limitations or individual bore characteristics that are anomalous to the method of baseline characterisations defined above and change related to the MAR operations.

Findings of investigations will form the basis of recommendations to correct trigger causes. In the event the breach is deemed to related to MAR operations, the predictive tools will be updated and the change shall be reforecast with any potential related environmental impacts assessed. Where potential environmental impacts are considered low and in consultation with EPA representatives, the triggers and thresholds shall be adjusted to reflect the revised predicted impact.

Table 1-7 – Trigger and Threshold Criteria for Groundwater Quality Change

<table>
<tr><th>Groundwater Operations Area</th><th>Locality</th><th>Forecast change</th><th>Baseline salinity Characteristics (Alluvium - Water Table)</th><th>Trigger</th><th>Threshold</th><th>Monitoring Bore</th></tr>
<tr><td rowspan="3">SWIB (Injection)</td><td>Central Injection Area</td><td>Maximum potential groundwater quality change predicted</td><td>Marginal to brackish</td><td>Two consecutive measurements greater than:
a. 47,000 mg/l TDS; or
b. 104 mg/l NO3; or
c. 0.028 mg/l Cr; or
d. 0.011 mg/l Se</td><td>Three consecutive measurements greater than:
a. 50,000 mg/l TDS; or
b. 113 mg/l NO3; or
c. 0.031 mg/l Cr; or
d. 0.012 mg/l Se</td><td>RHPZ0283S
RHPZ0184
RHPZ0288S
RHPZ0075
RHPZ0088
RHPZ0289S</td></tr>
<tr><td>Proximal Injection Area</td><td>Moderate potential groundwater quality change predicted</td><td>Brackish to saline</td><td>Two consecutive measurements greater than:
a. 35,000 mg/l TDS; or
b. 43 mg/l NO3; or
c. 0.014 mg/l Cr; or
d. 0.016 mg/l Se</td><td>Three consecutive measurements greater than:
a. 38,000 mg/l TDS; or
b. 44 mg/l NO3; or
c. 0.015 mg/l Cr; or
d. 0.017 mg/l Se</td><td>RHPZ0287S
RHPZ0286S</td></tr>
<tr><td>Distal Injection Area</td><td>No groundwater quality change predicted</td><td>Brackish to hypersaline</td><td>Two (2) consecutive measurements > three (3) Standard Deviations:
<table>
<tr><td>Parameter</td><td>RHPZ0292S</td><td>RHPZ0293S</td><td>RHPZ0281S</td></tr>
<tr><td>TDS (mg/l)</td><td>60,574</td><td>24,853</td><td>5,282</td></tr>
<tr><td>NO3 (mg/l)</td><td>27</td><td>32</td><td>40</td></tr>
<tr><td>Cr (mg/l)</td><td>tba</td><td>0.010</td><td>0.013</td></tr>
<tr><td>Se (mg/l)</td><td>0.073</td><td>0.015</td><td>0.008</td></tr>
</table></td><td>Three consecutive measurements > three Standard Deviations:
Note: values as for triggers.</td><td>RHPZ0292S
RHPZ0293S
RHPZ0281S</td></tr>
<tr><td>Stage 1 borefield (Injection)</td><td>Central Injection Area
TDS only. TSF decant not planned to be injected in Stage 1 Borefield</td><td>Maximum potential groundwater quality change predicted</td><td>Marginal to brackish</td><td>Two consecutive measurements greater than:
a. 4,500 mg/l TDS.</td><td>Three consecutive measurements greater than:
a. 5,000 mg/l TDS</td><td>RHPZ0258
RHPZ0259</td></tr>
</table>

	Proximal Injection Area *TDS only. TSF decant not planned to be injected in Stage 1 Borefield*	Moderate potential groundwater quality change predicted	Marginal to brackish	Two consecutive measurements greater than: a. 3,500 mg/l TDS.	Three consecutive measurements greater than: a. > 3,900 mg/l TDS	RHPZ0299 RHPZ0301
	Distal Injection Area	No groundwater quality change predicted	Marginal to brackish	Two (2) consecutive measurements > three (3) Standard Deviations: Parameter: RHPZ0039 TDS (mg/l): 1,704	Three (3) consecutive measurements > three (3) Standard Deviations: Note: values as for triggers.	RHPZ0039
RMARN (Injection)	Central Injection Area	Maximum potential groundwater quality change predicted	Saline to hypersaline	TBA	TBA	TBA
	Proximal Injection Area	Moderate potential groundwater quality change predicted	Saline to hypersaline	TBA	TBA	TBA
	Distal Injection Area	No groundwater quality change predicted	Brackish	TBA	TBA	TBA
Southern Borefield (Injection)	Central Injection Area	Maximum potential groundwater quality change predicted	Marginal to brackish	TBA	TBA	TBA
	Proximal Injection Area	Moderate potential groundwater quality change predicted	Marginal to brackish	TBA	TBA	TBA

	Distal Injection Area	No groundwater quality change predicted	Marginal to brackish	TBA	TBA	TBA
In-pit MAR (Injection)	Central Injection Area	Maximum potential groundwater quality change predicted	Marginal to brackish	TBA	TBA	TBA
	Proximal Injection Area	Moderate potential groundwater quality change predicted	Marginal to brackish	TBA	TBA	TBA
	Distal Injection Area	No groundwater quality change predicted	Marginal to brackish	TBA	TBA	TBA

1.4.4 Rationale for choice of provisions

This WMP has been developed based on the assessment of potential impacts for Inland Waters, and monitoring requirements of relevant approvals such as the RHIO Operating Licence (L8621/2011/1), Groundwater Abstraction Licence (GWL172642) and existing Ministerial Statements.

The potential impacts to Inland Waters are:

- Changes in the quality of groundwater from MAR
- Mounding of groundwater from MAR
- Changes to groundwater flows by abstraction for water supply and mine dewatering
- Changes to surface water flows from creek diversions, additional clearing or development of infrastructure
- Contamination of groundwater or surface water from mining and associated activities i.e. leaching of WRL and Tailings Storage Facilities
- Mounding of groundwater from TSF

The outcomes for this WMP are:

- Minimise potential environmental impacts associated with groundwater abstraction and reinjection including water levels and groundwater quality
- Minimise potential impacts to riparian vegetation and groundwater dependent vegetation
- No significant impact to subterranean fauna such that the biological diversity and ecological integrity are maintained
- No significant impacts to the hydrological regimes and quality of groundwater and surface water such that the environmental values including the Fortescue Marsh are protected
- Undertake appropriate monitoring and report sufficiently to demonstrate compliance with approval requirements and enable appropriate and informed water management decisions.

RHIO propose outcome-based and management-based provisions to ensure the outcomes for the WMP and the EPA's objective for Inland Water are achieved.

1.4.4.1 Outcomes-based Provisions

Outcome-based provisions are performance-based and may be used where the part of the environment is capable of objective measurement and reporting. The outcomes-based provisions for this WMP are outlined in Table 2-1 and have been chosen as they provide a basis for detecting and avoiding or otherwise managing potential impacts, such that the condition environmental outcomes and objectives can be achieved.

Trigger criteria are set at a conservative level to ensure response actions are implemented in advance of the environmental objective being compromised. Exceedance of a trigger criterion will, therefore not be treated as a non-compliance. There is potential for trigger criteria to be exceeded due to natural variability; this must be accounted for in the management response. Exceedance of a threshold criterion will be treated as a potential noncompliance against the environmental outcome.

The selected guidelines for triggers and thresholds (referenced in the provisions tables) are based on project requirements, environmental risk assessments, the findings of annual monitoring assessments and the monitoring requirements of the RHIO Operating Licence.

These have been chosen as they provide a basis for detecting and avoiding or otherwise managing potential impacts, such that the condition environmental outcomes and objectives can be achieved.

1.4.4.2 Management-based Provisions

Management-based provisions relate to management actions and are used where it is not practical, efficient or necessary to implement outcome-based provisions for aspects of the project. Management-based provisions apply where some negative impacts due to mining activities may be unavoidable, but where management actions will be implemented to minimise impacts and meet minimum conservation targets.

The water quality analysis suite in Table 1-4 recommended by Stantec in 2020 has been tailored to identify water quality change of a range of substances and contaminants of concern from Roy Hill mine operations that have the potential to cause harm to environmental receptors. Management provisions where water quality analysis is specified will be undertaken in accordance with this suite.

Through management-based provisions RHIO will monitor for potential impacts to Inland Waters and conduct annual assessments of trends to identify change resulting from RHIO operations that could lead to environmental impact. The results of these assessments will be provided to the EPA in the Annual Compliance Assessment Report.

Contamination events identified during the year will be reported to relevant regulatory bodies in accordance with section 72 of the *Environmental Protection Act.*

1.5 Index of Biodiversity Surveys for Assessments

In the event that RHIO is required to undertake any biodiversity surveys to support this WMP, RHIO will submit Index of Biodiversity Surveys for Assessments (IBSA) data packages in accordance with *Preparation of data packages for the Index of Biodiversity Surveys for Assessments (IBSA) guidelines.*

2 Environmental Management Plan Provisions

This WMP outlines outcome-based and management-based provisions and minimum key requirements. All requirements will be undertaken during operations and until the Mine is decommissioned and closed. This Water Management Plan will be undertaken in conjunction with the Vegetation Management Plan (OP-PLN-00344).

The outcome-based provisions are outlined in Table 2-1. Compliance with outcome-based conditions is measured by assessment of monitoring results against trigger and threshold criteria. Where outcome-based conditions are not compliant with trigger or threshold criteria, trigger level management measures and threshold level management measures will be applied.

The management-based provisions are outlined in Table 2-2.

Table 2-1 – Outcome Based Provisions

Environmental Factor and Objectives	Flora and Vegetation – To protect flora and vegetation so that biological diversity and ecological integrity are maintained. Inland Waters – To maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected.		
Objective	No adverse effect on key environmental values (defined below) attributable to water abstraction, reinjection activities or surface water structures beyond the impacts predicted in the Environmental Review Document and associated appendices.		
Key Environmental Values	- Groundwater Dependent and Non-dependant Vegetation - Riparian and Groundwater Dependent Vegetation - Fortescue Marsh Priority Ecological Community - Troglofauna and Stygofauna		
Key Impacts and Risks	**Environmental Criteria**	**Response Actions***	**Monitoring**
Contamination of groundwater resulting from mining and associated activities	**Mine Bulk Fuel Storage Area and Landfill** **Trigger Criteria** Total Recoverable Hydrocarbon (TRH) results above the detectable limit from the Mine Bulk Fuel or landfill groundwater monitoring sites.	**Trigger Response** An immediate retest of the bore will be undertaken to ensure that the result is not due to an anomaly in testing or error. Undertake a review of all Mine Bulk Fuel and Landfill monitoring data and groundwater data from surrounding areas to determine if the changes are localised to the area.	Groundwater quality analysis for parameters required in the Operating Licence L8621/2011/1. Groundwater sampling, infield analysis and NATA accredited analysis. Sampling to be undertaken on a quarterly basis.
	Mine Bulk Fuel Storage Area and Landfill **Threshold Criteria** TRH results above the detectable limit over monitoring event and subsequent retest. AND Subsequent investigations determine that impacts are resulting from leaching of the Mine Bulk Fuel Facility or landfill.	**Threshold Response** If the review determines that the changes in groundwater quality are related to the operation of the Mine Bulk Fuel Storage Area or Landfill, RHIO will undertake an impact assessment and identify appropriate management responses for implementation.	As above for trigger level monitoring. Monitoring of the effectiveness of contingency actions.

Changes in the quality of groundwater from MAR	**MAR Water Quality** **Trigger Criteria** Monthly flow weighted average of total injected water in the borefield with water quality of Total Dissolved Solids (TDS) as outline in Table 1-6.	**Trigger Response** Undertake a review of MAR monitoring data to determine if threshold criteria may be exceeded and enact management measures to ensure reinjection water quality remains under threshold criteria. Modify dewatering and/or water distribution arrangement to reduce flow weighted average EC of injected water below threshold level.	Monitoring is undertaken through EC meters fitted to injection bores. A confirmation sample for TDS will be collected from each injection bore quarterly and sent to a NATA accredited laboratory.
	MAR Water Quality **Threshold Criteria** Monthly flow weighted average of total injected water in the borefield with water quality of TDS in Table 1-6. AND Subsequent investigations determine that the receiving aquifer will be impacted above what the groundwater change assessment has forecast.	**Threshold Response** Impacted bore would be turned off to prevent additional injection of saline water. Once TDS has returned below threshold level the bore can be turned back on. Undertake a review of groundwater quality in control bores and regional MAR monitoring bores. If the review determines that the changes in the groundwater quality are related to the operation of the MAR, RHIO will undertake an impact assessment and identify appropriate management responses for implementation.	As above for trigger level monitoring. Monitoring of the effectiveness of contingency actions.
	Groundwater Quality Change **Trigger Criteria** Refer to trigger criteria outlined in Table 1-7.	**Groundwater Quality Change** **Trigger Response** Review actuals vs forecast and identify any discrepancies. Where discrepancy exists review conceptual model and reforecast groundwater quality change. If projected to exceed threshold value undertake ecological impact assessment	Groundwater quality analysis for parameters required in the Operating Licence L8621/2011/1. Groundwater sampling, infield analysis and NATA accredited analysis. Sampling to be undertaken on a quarterly basis.
	Groundwater Quality Change **Threshold Criteria** Refer to threshold criteria outlined in Table 1-7.	**Groundwater Quality Change** **Threshold Response** Implement actions based on revised impact assessment	Groundwater quality analysis for parameters required in the Operating Licence L8621/2011/1. Groundwater sampling, infield analysis and NATA accredited analysis. Sampling to be undertaken on a quarterly basis.

Mounding of groundwater from MAR	**Depth to Groundwater:** **Trigger Criteria** Depth to groundwater level in MAR injection control bores is less than 6 meters below surface.	**Trigger Response** An immediate retest of the bore will be undertaken to ensure that the result is not due to an anomaly in testing or error. More frequent SWL monitoring will be undertaken (monthly). If the retest also exceeds the same trigger level, RHIO will: Implement management measures to ensure water levels does not rise to threshold level	SWL monitoring in MAR monitor bores (either manual dips or down hole telemetry or a combination of these). Monitoring to be undertaken on a quarterly basis.
	Depth to Groundwater: **Threshold Criteria** Depth to groundwater level in MAR injection control bores is less than 5 meters below surface. AND Subsequent investigations determine that impacts are resulting from MAR.	**Threshold Response** MAR: implement management measures to ensure groundwater mounding is reduced below threshold. This would include reducing flow to the impacted bore to allow a recession of mounding within the impacted areas. RHIO will undertake an impact assessment and identify appropriate management responses for implementation.	As above for trigger level monitoring. Monitoring of the effectiveness of contingency actions.
	Depth to Groundwater: **Trigger Criteria** Depth to groundwater level in MAR regional bores RHPZ0292 and RHPZ0293 is less than 3 meters below surface. AND Subsequent investigations determine that impacts are resulting not from rainfall.	**Trigger Response** An immediate retest of the bore will be undertaken to ensure that the result is not due to an anomaly in testing or error. More frequent SWL monitoring will be undertaken (monthly). If the retest also exceeds the same trigger level, RHIO will: • Conduct an assessment of SWL response relative to rainfall recharge and MAR at the impacted monitoring bore. Confirm breach related to rainfall event. • Monitor SWL over following three months to demonstrate water level is below 3m trigger or declining trend.	SWL monitoring in MAR monitor bores (either manual dips or down hole telemetry or a combination of these). Monitoring to be undertaken on a quarterly basis.

	Depth to Groundwater: **Threshold Criteria** Depth to groundwater level in MAR regional bores RHPZ0292 and RHPZ0293 is less than 2 meters below surface. AND Subsequent investigations determine that impacts are resulting from MAR.	**Threshold Response** MAR: Implement management measures to reduce groundwater mounding below threshold. RHIO will undertake an impact assessment and identify appropriate management responses for implementation.	As above for trigger level monitoring. Monitoring of the effectiveness of contingency actions.
	Groundwater Level Change **Trigger Criteria** Refer to trigger criteria outlined in Table 1-5.	**Trigger Response** An immediate retest of the bore will be undertaken to ensure that the result is not due to an anomaly in testing or error. More frequent SWL monitoring will be undertaken (monthly). If the retest also exceeds the same trigger level, RHIO will: Implement management measures to ensure water levels does not rise to threshold level	Groundwater quality analysis for parameters required in the Operating Licence L8621/2011/1. Groundwater sampling, infield analysis and NATA accredited analysis. Sampling to be undertaken on a quarterly basis.
	Groundwater Level Change **Threshold Criteria** Refer to threshold criteria outlined in Table 1-5.	**Threshold Response** MAR: Implement management measures to reduce groundwater mounding below threshold. RHIO will undertake an impact assessment and identify appropriate management responses for implementation.	Groundwater quality analysis for parameters required in the Operating Licence L8621/2011/1. Groundwater sampling, infield analysis and NATA accredited analysis. Sampling to be undertaken on a quarterly basis.
Changes to groundwater flows by abstraction for	**Trigger Criteria** Refer to the Vegetation Management Plan OP-PLN-00344 for monitoring trigger criteria relating to vegetation impact from groundwater drawdown from water abstraction.		

water supply and mine dewatering.	**Threshold Criteria** Refer to the Vegetation Management Plan OP-PLN-00344 for monitoring threshold criteria relating to impacts to vegetation from groundwater drawdown from water abstraction.		
Changes to surface water flows from creek diversions, additional clearing or development of infrastructure	**Water Diversion Structures** **Trigger Criteria** Geomorphic survey identifies +/-1m of change in permanent surface water diversion structures.	**Trigger Response** Review the extent of erosion/deposition of the diversion structure and assess the risk to environment. Undertake appropriate actions to ensure stability of diversion structure and to mitigate any potential risk to environment.	Annual (post-wet season) geomorphic survey of permanent diversion structures. Water levels are recorded for flood depth for 5 years post construction in all permanent hydraulic structures
	Water Diversion Structures **Threshold Criteria** Geomorphic surveys identify a breach (water is flowing outside of its intended course) of surface water diversion structure that has then led to environmental impacts.	**Threshold Response** Undertake an investigation to assess the impact (if any) to the environment. If impact to environment is determined, report externally. Redesign and reconstruct the surface water diversion with findings from investigation.	As above for trigger level monitoring. Monitoring of the effectiveness of contingency actions.
Changes to groundwater flows by abstraction for water supply and mine dewatering.	**Groundwater Abstraction** **Trigger Criteria** Water abstraction for water supply and mine dewatering exceeds 65GL (only 5GL remaining in Annual Water Entitlement).	**Trigger Response** Review groundwater abstraction requirements and whether an amend to the Groundwater Licence may be required to remain compliant.	Abstraction bore flow meters connected to supervisory control and data acquisition (SCADA) system. Short Term Water Management Plan (monthly) monitoring abstraction against GWL limits
	Groundwater Abstraction **Threshold Criteria** Water abstraction for water supply and mine dewatering exceeds the GWL172642 abstraction limit of 70GL	**Threshold Response** Confirm exceedance by reviewing all water abstraction data. Notify DWER of the exceedance in accordance with DWER regulations	As above for trigger level monitoring. Monitoring of the effectiveness of contingency actions.

*Response Actions are to be implemented as soon as reasonably practical to ensure potential impacts to the environment are minimised.

Table 2-2 – Management-based provisions

Environmental Factor	Flora and Vegetation – To protect flora and vegetation so that biological diversity and ecological integrity are maintained. Inland Waters – To maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected.		
Objective	No adverse effect on key environmental values (defined below) attributable to water abstraction, reinjection activities or surface water structures beyond the impacts predicted in the Environmental Review Document and associated appendices.		
Key Environmental Values	- Groundwater Dependent and Non-dependant Vegetation - Riparian and Groundwater Dependent Vegetation - Fortescue Marsh Priority Ecological Community - Troglofauna and Stygofauna		
Key Impacts and Risks	**Management Actions**	**Management Targets**	**Monitoring**
Contamination of groundwater or surface water resulting from mining and associated activities	1. Undertake water monitoring at locations around the site to identify water quality change resulting from mining and associated activities. 2. Review the water monitoring data to identify trends in water quality outside of seasonal fluctuations.	If the assessment of water quality data identifies abnormal trends (outside of seasonal fluctuations or forecast water quality change) conduct an investigation to identify the source of the contamination. If the source of the contamination is resulting from RHIO operations engage a suitably qualified specialist to determine the risk to the environment and outline mitigation measures to prevent significant impacts.	Groundwater quality sampling for analytes in Table 1-4, infield analysis. Samples to be tested in a NATA accredited facility. Opportunistic surface water monitoring to be undertaken post rain-fall (sufficient to cause a flow event) infield analysis and NATA accredited analysis.
Contamination of groundwater from leaching of WRL and Tailings Storage Facilities	1. Undertake water monitoring at locations around the site with potential to identify water quality change resulting from leaching of WRL and TSF. 2. Review the water monitoring data to identify trends in water quality outside of seasonal fluctuations.	If the assessment of water quality data identifies abnormal trends (outside of seasonal fluctuations or forecast water quality change) conduct an investigation to identify the source of the contamination. If the source of the contamination is resulting from RHIO operations engage a suitably qualified specialist to determine the risk to the environment and outline mitigation measures to prevent significant impacts.	WRL - Six monthly groundwater quality sampling for analytes in Table 1-4, infield analysis. Samples to be tested in a NATA accredited facility. TSF - Quarterly groundwater quality sampling for analytes in Table 1-4, infield analysis. Samples to be tested in a NATA accredited facility. Opportunistic surface water monitoring to be undertaken post rain-fall (sufficient to cause a flow event) infield analysis and NATA accredited analysis.

Mounding of groundwater from TSF	1. Undertake water monitoring in TSF monitor bores with potential to identify mounding resulting from Tailings deposition. 2. Review the water monitoring data to identify trends in water level outside of seasonal fluctuations.	If the assessment of water monitoring data identifies abnormal trends (outside of seasonal fluctuations or forecast water level change) conduct an investigation to identify the source. If the source of the mounding is resulting from RHIO operations engage a suitably qualified specialist to determine the risk to the environment and outline mitigation measures to prevent significant impacts.	SWL monitoring (either manual dips or down hole telemetry or a combination of these). Monitoring to be undertaken on a quarterly basis.
Changes to surface water flows resulting from creek diversions, additional clearing or development of infrastructure	1. Design surface water infrastructure such that where possible diverted water will be returned to the same water catchment. 2. Conduct inspections of surface water diversion structures. 3. Calibrate model with recorded water depth loggers and forecast risk in mine plans.	Surface water diversion structures return diverted water to the same water catchment it originated from. In cases where this is not possible address a design for environmental flows down stream. Integrity of the surface water diversion structures is maintained.	Monitor the construction of surface water diversion structures compliance against design. Water levels are recorded for flood depth 5 years post construction in all permanent hydraulic structures using water depth loggers. Conduct flood risk modelling to predict flood risk areas. Review mine plan design and changes against flood model. Conduct a risk based approach in design including duration of open pit, longevity of Hydraulic Structure and review design principals on the as built information.
	1. Design surface water infrastructure such that upstream containment of flows does not occur. 2. Conduct annual (pre-wet season) inspections of surface water diversion structures.	Surface water diversion structures are designed such that upstream containment of flows does not occur. Integrity of the surface water diversion structures is maintained.	Monitor the construction of surface water diversion structures compliance against design. Conduct flood risk modelling to predict flood risk areas. Review mine plan design and changes against flood model. Conduct a risk based approach in design including duration of open pit, longevity of Hydraulic Structure and review design principals on the as built information.

2.1 Monitoring Trigger and Threshold Levels

The magnitude of change for outcome-based provisions is assessed via the use of trigger and threshold criteria.

The trigger criteria are set at levels to forewarn of the approach of the threshold criteria and trigger response actions are set at a conservative level to ensure trigger level actions can be implemented well in advance of the environmental outcome being compromised.

Threshold criteria represent the limit of acceptable impact on the environment. Exceedance of the threshold criteria signals the environmental outcome has potential to not be met, implies non-compliance and requires threshold contingency management measures to be implemented.

Response actions to trigger and threshold exceedances are to be implemented as soon as reasonably practical to ensure potential impacts to the environment are minimised. Investigation into the trigger and threshold exceedances are to commence immediately upon identification of a potential exceedance.

2.1.1 Trigger Level Actions

In the event that a trigger level is exceeded, Roy Hill will undertake a quality assurance check to confirm the validity of the data collected before a response is enacted. This will include a check of sampling protocols, collection methods, data recording, equipment calibration and documentation to confirm or dismiss the trigger level exceedance.

Any exceedance of a trigger level will also require a review of the Vegetation Management Plan (OP-PLN-00344) outcome and management-based provisions to determine any correlation.

If the trigger level exceedance is confirmed, Roy Hill will undertake an investigation which aims to determine:

- Cause – for example re-injection, abstraction, dewatering, changes in surface water flow or natural fluctuations;
- Cause and effect, particularly with respect to Mine related causes versus external related causes (for example, rainfall or background variation); and
- Rate of change (risk of threshold exceedance).

Responses are then based on the outcome of the investigation and the risk of the threshold exceedance, based on mine related causes in a subsequent 12-month period. If risk of exceedance is low, monitoring of appropriate variables at an increased frequency is to be implemented. If risk of exceedance is moderate or above, appropriate contingency management measures are to be implemented to arrest the decline in conjunction with an increase in monitoring frequency of appropriate variables.

An appropriate management response will be determined to enable exceedances of trigger levels to be reduced back to acceptable levels within a reasonable timeframe. This may include but not be limited to the following:

- Reduce abstraction or reinjection from/to bores;
- Manage aquifer reinjection to re-establish and maintain groundwater levels at the affected site;
- Undertake earthworks/engineering to restore surface flows at site;

The most appropriate management measure will be implemented dependent on the cause and the severity of the impact.

Ongoing monitoring of the effectiveness of the trigger level contingency management measures will be undertaken to ascertain if the adopted measure/s are effective in mitigating impacts to the affected area, and if further investigations and/or management measures are required to arrest the impact.

2.1.2 Threshold Level Actions

In the event of a threshold criteria exceedance RHIO will notify DWER within 7 days of the non-compliance being known and provide a report within 21 days of the non-compliance being known.

If the threshold level is exceeded, then additional management measures will be undertaken which may include but are not limited to:

- Reduce abstraction or reinjection from/to bores, turn off bores;
- Manage aquifer reinjection rates across borefields to re-establish and maintain groundwater levels;
- Conduct earthworks/engineering to restore surface flows at site;
- Undertake rehabilitation to impacted sites

Threshold level contingency management measures may include a combination of actions and this will be dependent on the location of the impact identified through the monitoring program. The most appropriate management measure will be implemented dependent on the cause and the severity of the impact.

2.1.3 Annual Reviews and Compliance Assessment Reporting

The environmental outcome will be reported against each trigger criteria for each calendar year in an Annual Water Review Report and provided to the EPA in the Compliance Assessment Report (CAR). If the trigger criterion was exceeded during the reporting period, the Annual Water Review Report will discuss potential reasons for exceedance of the trigger criterion and include a description of the effectiveness of trigger level actions. If the threshold criterion was exceeded during the reporting period, the Annual Water Review Report will include a description of the effectiveness of threshold contingency action/s that have been implemented to manage the potential impact.

Table 2-3 outlines the format to be used in the Annual Water Review Report to outline the compliance status of RHIO against the Condition EMP requirements.

Table 2-3 – Water Management Plan Reporting Table Template – Outcome-based Condition

Condition environmental outcome and threshold and trigger criteria set in the Water Management Plan	Reporting on the environmental outcome, threshold and trigger criteria for [January 20xx] to [December 20yy]	Status1
Trigger criteria: Geomorphic survey identifies +/-1m of change in permanent surface water diversion structures.	**Trigger criteria**: 1: Example: Trigger not exceeded.	■ YES or ● NO
Threshold criteria: Geomorphic surveys identify a breach of surface water diversion structure that has then led to environmental impacts.	**Threshold criteria:** 1: Example: Threshold not exceeded	■ YES or ● NO
1: The status of achievement of environmental outcome is indicated by the following symbols: ■ Environmental outcome achieved ● Environmental outcome not achieved		

3 Adaptive Management and Review of the EMP

RHIO will employ adaptive management through the LOM to incorporate knowledge from the implementation of mitigation measures, monitoring and evaluation of data against trigger and threshold criteria, to more effectively meet the condition environmental outcomes outlined in this WMP. The following approach will be followed:

- Monitoring data will be systematically evaluated and compared to baseline data and predictions on an annual basis to verify whether groundwater and surface water responses to operational activities are the same or similar to predictions;
- Re-evaluate the risk assessments annually after monitoring is completed;
- Incorporate additional knowledge as it comes to hand to address assumptions and uncertainties to gain increased understanding of vegetation and aquifer response;
- Review mine planning program, Groundwater Operating Strategy, and input changes into risk assessments to refine or modify the monitoring program;
- Undertake revision when Management Plan Provisions are not as effective as predicted, or trigger levels do not have the outcome anticipated or required;
- Incorporate alternative techniques, technologies and methodologies to enhance and improve the program;
- Develop other monitoring programs as required to respond to additional operational activities ; and
- Incorporate and modify the program to include any external changes during the life of the proposal (e.g. changes to the sensitivity of the vegetation, climate change, implementation of other activities in the area, etc.).

4 Stakeholder Consultation

RHIO has actively consulted with stakeholders on a range of environmental matters since the Project commenced. Stakeholder consultation in relation to this WMP is outlined in Table 4-1.

Table 4-1 – Stakeholder Consultation

Stakeholder	Date	Outcome
Nyiyaparli Implementation Committee	14/06/2017	Meeting to discuss ongoing engagement, project updates, amenity, mine closure, vegetation and local food sources, Indigenous cultural heritage, economic opportunities
OEPA	29/06/2017	Meeting to discuss s38 revised proposal and in-pit tailings and s45C for the Long-Term Water Strategy
Nyiyaparli Implementation Committee	10/08/2017	Meeting to discuss ongoing engagement, project updates, amenity, mine closure, vegetation and local food sources, Indigenous cultural heritage, economic opportunities
Nyiyaparli Implementation Committee	02/11/2017	Meeting to discuss ongoing engagement, project updates, amenity, mine closure, vegetation and local food sources, Indigenous cultural heritage, economic opportunities, water management.
OEPA	02/02/2018	MAR Strategy meeting
Nyiyaparli Implementation Committee	22/02/2018	Meeting to discuss water management, project updates, ongoing engagement, amenity, mine closure, vegetation and local food sources, Indigenous cultural heritage, economic opportunities
OEPA	16/04/2018	Section 45C MAR application - additional information response
Nyiyaparli Implementation Committee and Heritage Sub-Committee	24/05/2018	Meeting to discuss ongoing engagement, project updates, amenity, mine closure, vegetation and local food sources, Indigenous cultural heritage, economic opportunities water management.
Nyiyaparli Implementation Committee	22/08/2018	Meeting to discuss ongoing engagement, project updates, amenity, mine closure, vegetation and local food sources, Indigenous cultural heritage, economic opportunities, water management
OEPA	23/10/2018	Site visit to the Mine to view existing reinjection bores in Stage 1 borefield. Overview of SCADA system, View Zulu 5 pit, explanation of SWIB MAR, view of SWIB monitoring bores on L41/141
OEPA	22/11/2018	Meeting to discuss Zulu 5 in-pit tailings detailed design
Nyiyaparli Implementation Committee	22/11/2018	Meeting to discuss ongoing engagement, project updates, amenity, mine closure, vegetation and local food sources, water management, Indigenous cultural heritage, economic opportunities.
OEPA	27/11/2018	Meeting to discuss EPBD referral, s45C in-pit tailings, s38 Revised Propsoal
Nyiyaparli Implementation Committee	14/03/2019	Meeting to discuss ongoing engagement, project updates, amenity, water management, mine closure, vegetation and local food sources, Indigenous cultural heritage, economic opportunities.
Nyiyaparli Implementation Committee and Heritage Sub-Committee	16/05/2019	Meeting to discuss ongoing engagement, project updates, amenity, mine closure, vegetation and local food sources, Indigenous cultural heritage, economic opportunities, water management.
OEPA	22/06/2019	Meeting to discuss S38 revised proposal to cover MAR

Nyiyaparli Implementation Committee	22/08/2019	Meeting to discuss ongoing engagement, project updates, water management, amenity, mine closure, vegetation and local food sources, Indigenous cultural heritage, economic opportunities.
Nyiyaparli Implementation Committee	21/11/2019	Meeting to discuss ongoing engagement, project updates, water management, amenity, mine closure, vegetation and local food sources, Indigenous cultural heritage, economic opportunities.
OEPA	05/02/2020	RHIO Technical Water Presentation with DWER (Water and EPA Services) on 5 February 2020 for Roy Hill Revised Proposal
OEPA	08/02/2020	Pre-referral presentation provided to EPA and update of status for s45C for in-pit tailings disposal
Nyiyaparli Implementation Committee	18/11/2020	Meeting to discuss ongoing engagement, project updates, water management, amenity, mine closure, vegetation and local food sources, Indigenous
Nyiyaparli Implementation Committee	24/03/2021	Meeting to discuss project updates, water management, ongoing engagement, amenity, cumulative impacts, mine closure, vegetation, Indigenous cultural heritage.
KNAC Advisors and Social Surrounds Consultant	06/05/2021	Online Teams meeting to discuss upcoming social surrounds trip and ongoing engagement
Nyiyaparli Implementation Committee	10/05/2021 – 12/05/2021	Social surrounds trip at Roy Hill Mine to discuss water management, project updates, ongoing engagement, amenity, cumulative impacts, mine closure, vegetation, Indigenous cultural heritage.
Nyiyaparli Implementation Committee	02/06/2021	Meeting to discuss economic development and opportunities, ongoing engagement, mine closure, Indigenous cultural heritage, amenity, water management.
Nyiyaparli Implementation Committee	19/07/2021	Meeting to discuss water management, ongoing engagement, amenity, cumulative impacts, mine closure, vegetation, Indigenous cultural heritage.
KNAC Representatives and Advisors	29/07/2021	Nyiyaparli/Roy Hill Social Surroundings meeting to discuss project updates, water management, ongoing engagement, amenity, cumulative impacts, mine closure, vegetation, indigenous cultural heritage.

5 Abbreviations

Table 5-1 – Abbreviations

Abbreviation	Definition
BACI	Before-after-control-impact
DMSI	Digital Multi-Spectral Imagery
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EMS	Environmental Management System
EP Act	*Environmental Protection Act 1986*
EPA	Environmental Protection Authority
GD	Groundwater drawdown
GDV	Groundwater dependent vegetation
IBSA	Index of Biodiversity Surveys for Assessments
KNAC	Karlka Nyiyaparli Aboriginal Corporation RNTBC
LOM	Life of Mine
MS	Ministerial Statement
OEPA	Office of the Environmental Protection Authority
RHIO	Roy Hill Iron Ore Pty Ltd
SFDV	Surface flow dependent vegetation
TDS	Total Dissolved Solids
TSF	Tailings Storage Facility
WMP	Water Management Plan
WMS	Water Management Strategy
WRL	Waste Rock Landform

6 References

Table 6-1 – References

Author	Title
ANZECC/ARMCANZ, 2000	National Water Quality Management Strategy
Astron, 2015	Management of Saline Water Used for Dust Suppression Desktop Study and Risk Assessment
Astron, 2019	Life of Mine Water Management Strategy Vegetation Risk Assessment
Department of Water and Environmental Regulation	GWL172642 – Licence to Take Water
Environmental Protection Authority (EPA) 2018	Instructions on how to prepare *Environmental Protection Act 1986* Part IV Environmental Management Plans. http://epa.wa.gov.au/forms-templates/instructions-part-iv-environmental-management-plans
GHD, 2019	Roy Hill Holdings Pty Ltd Roy Hill Life of Mine Water Management Strategy – Groundwater Impact Assessment
GHD, 2018a	Section 38 Referral, Hydraulic structures, Unpublished report prepared for Roy Hill Iron Ore, August 2018
GHD, 2019	Roy Hill Iron Ore TSF Decant Water Disposal Risk Assessment
GHD, 2020	Addendum to GHD, 2019. Groundwater Model Transport Simulations
GHD, 2020a	Addendum to GHD, 2019, Groundwater Model Sensitivity and Uncertainty Analysis
Stantec, 2020	Roy Hill Mine Water Monitoring Assessment

7 Appendices

Appendix 1 – Predicted Contaminant Distribution Maps

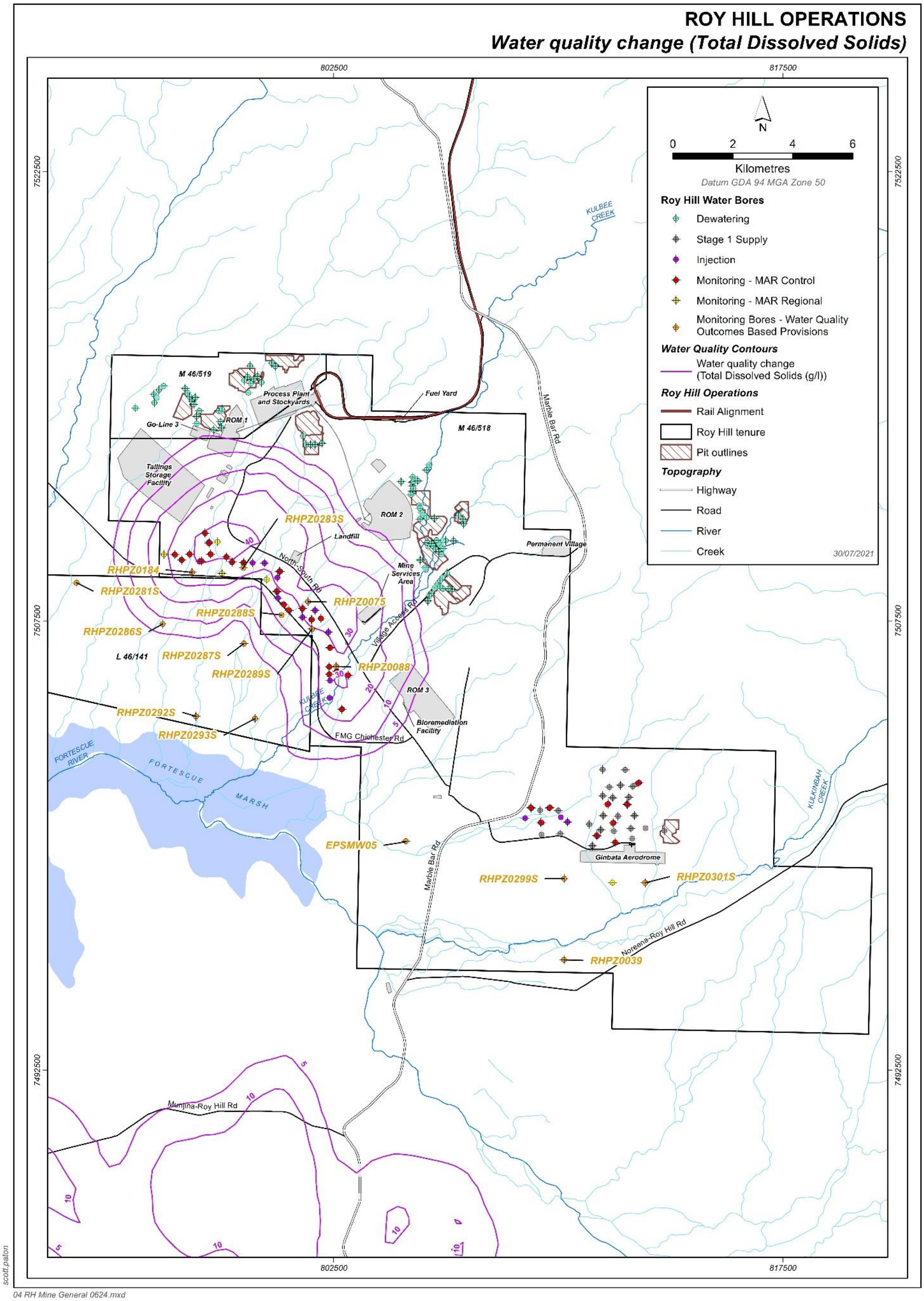


Figure 7-1 – Predicted Distribution of Total Dissolved Solids

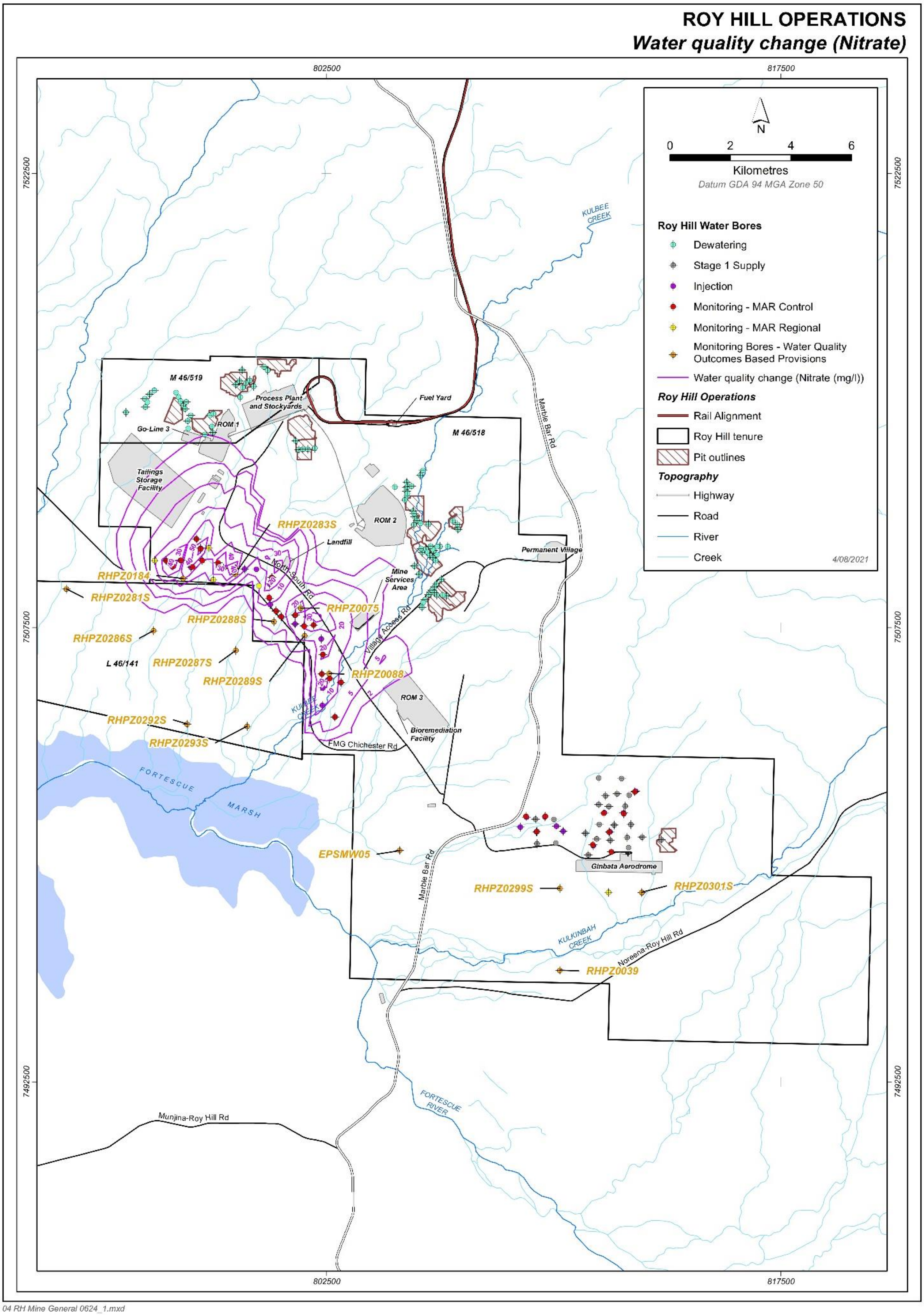


Figure 7-2 – Predicted Distribution of Nitrate

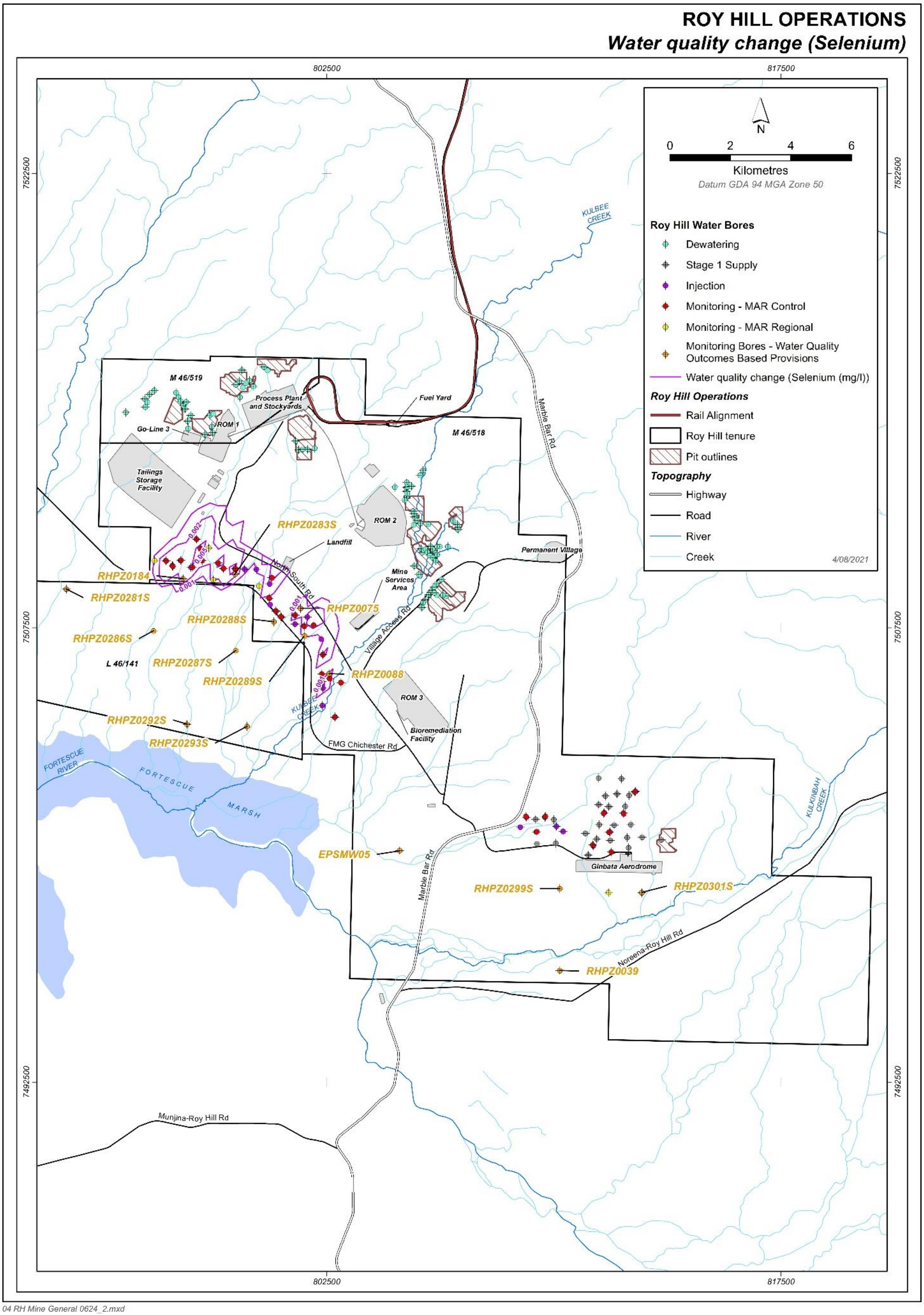


Figure 7-3 – Predicted Distribution of Selenium

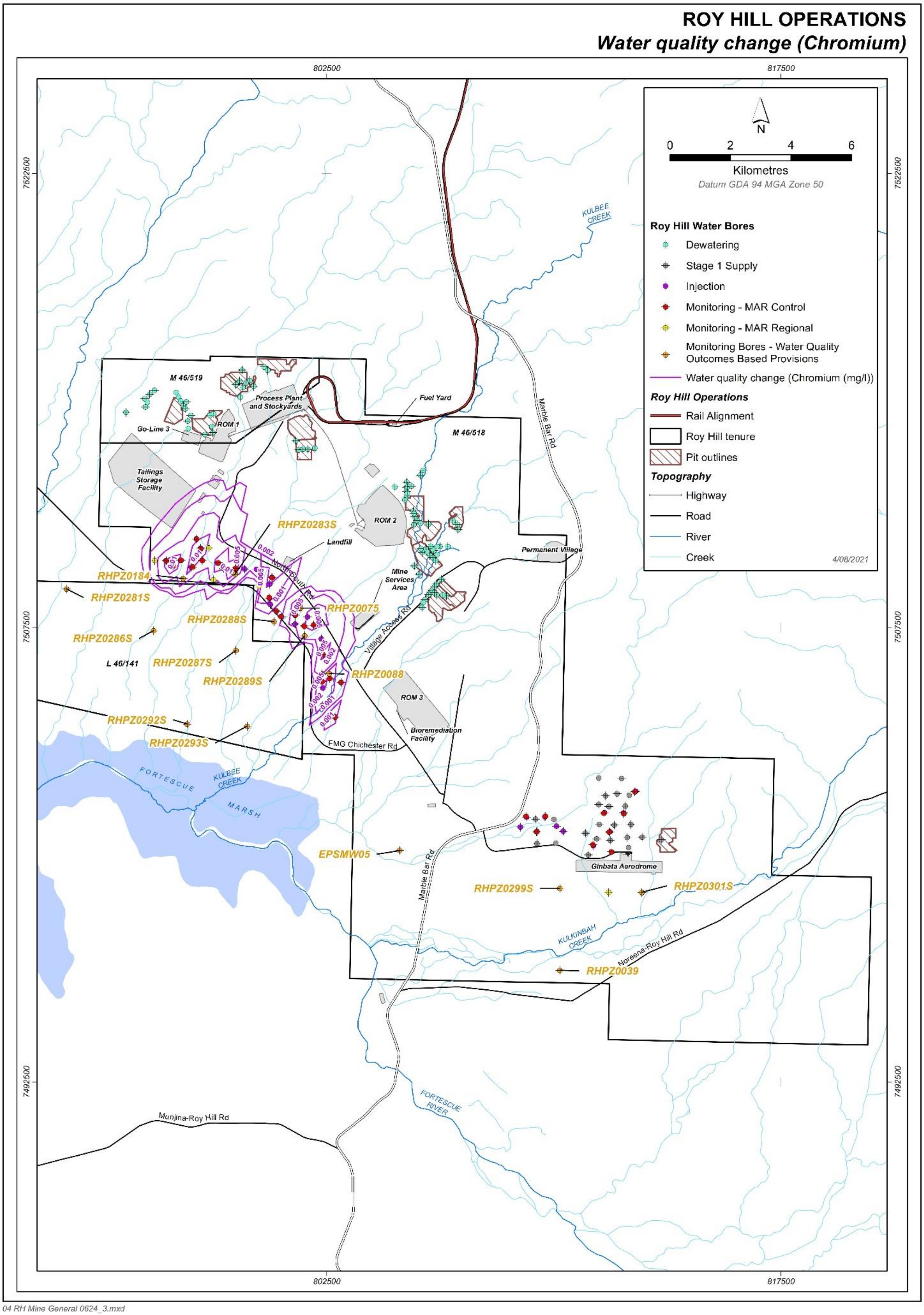
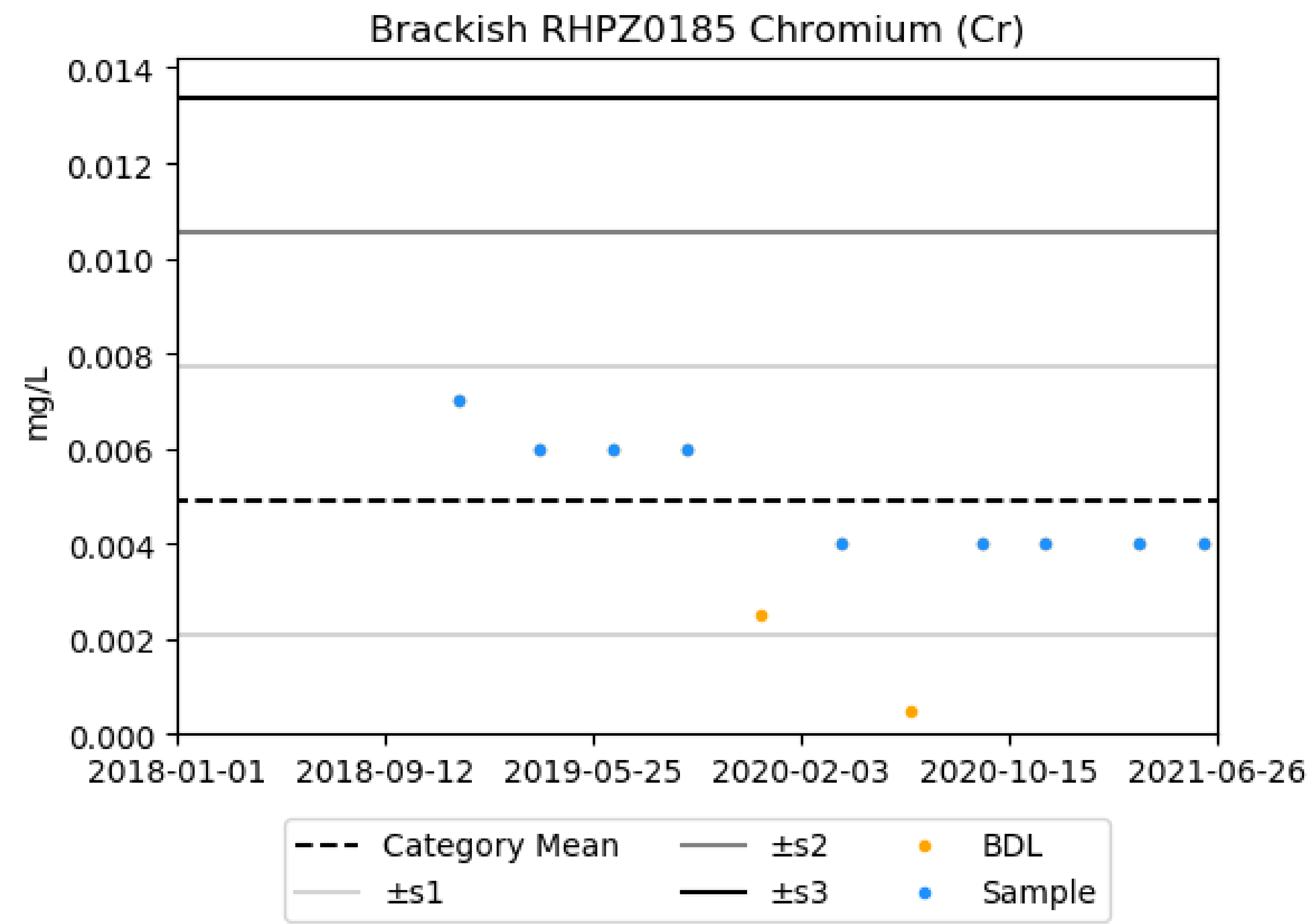
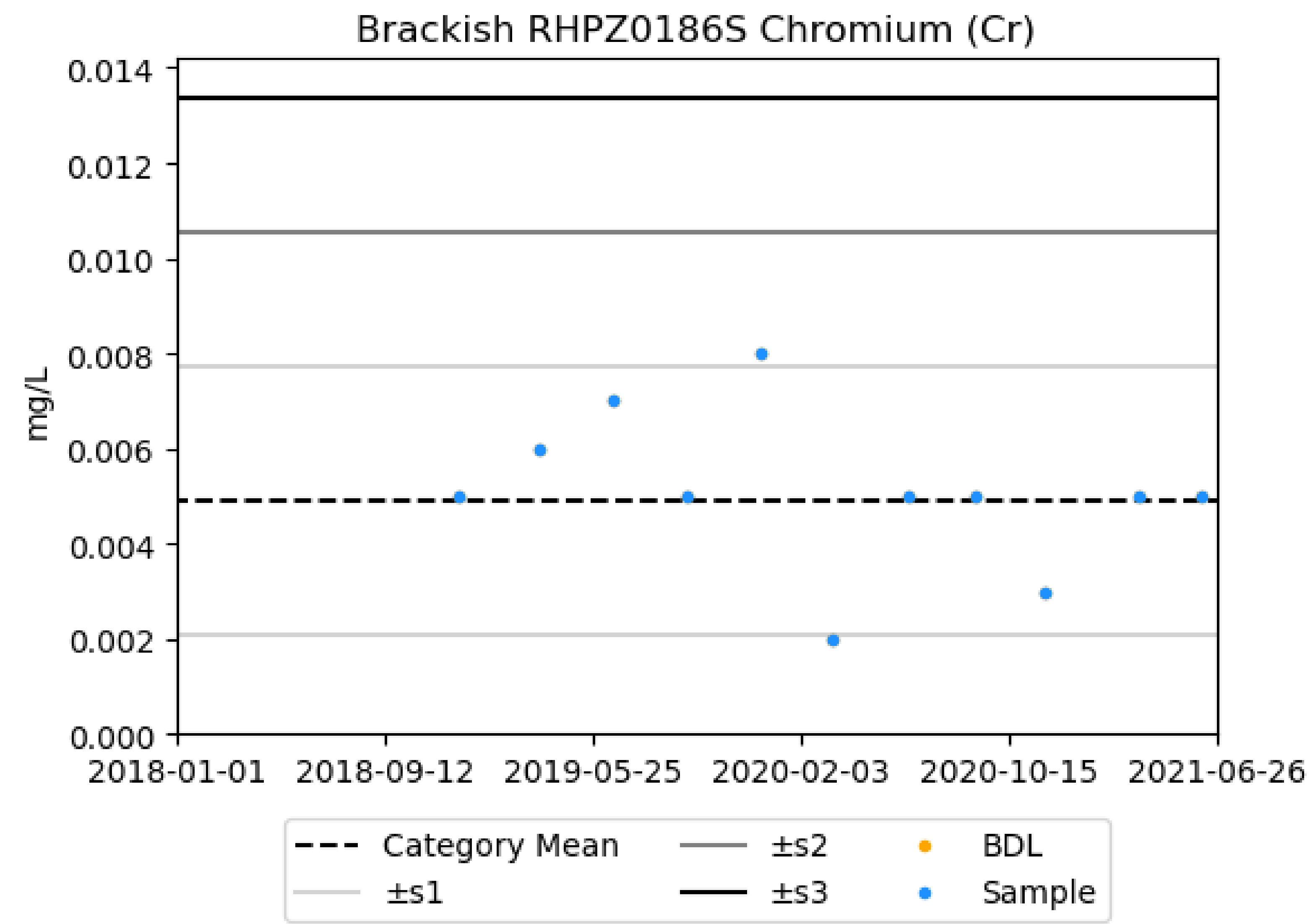


Figure 7-4 – Predicted Distribution of Chromium

Appendix 2 – Control Chart Plots


Brackish RHPZ0185 Chromium (Cr)
mg/L
0.000
0.002
0.004
0.006
0.008
0.010
0.012
0.014
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample


Brackish RHPZ0186S Chromium (Cr)
mg/L
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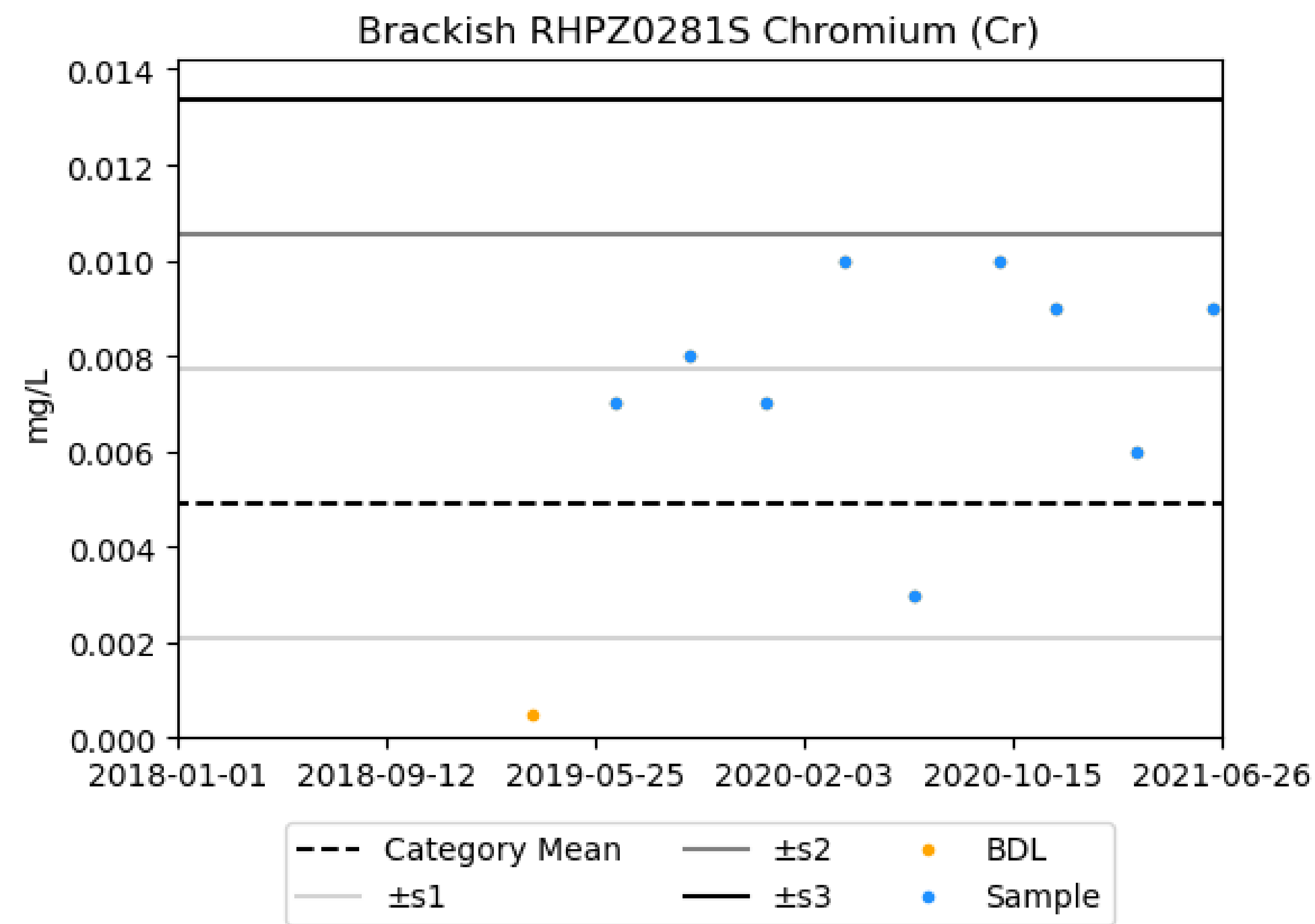
0.002
0.004
0.006
0.008
0.010
0.012
0.014
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample


Brackish RHPZ0281S Chromium (Cr)
mg/L
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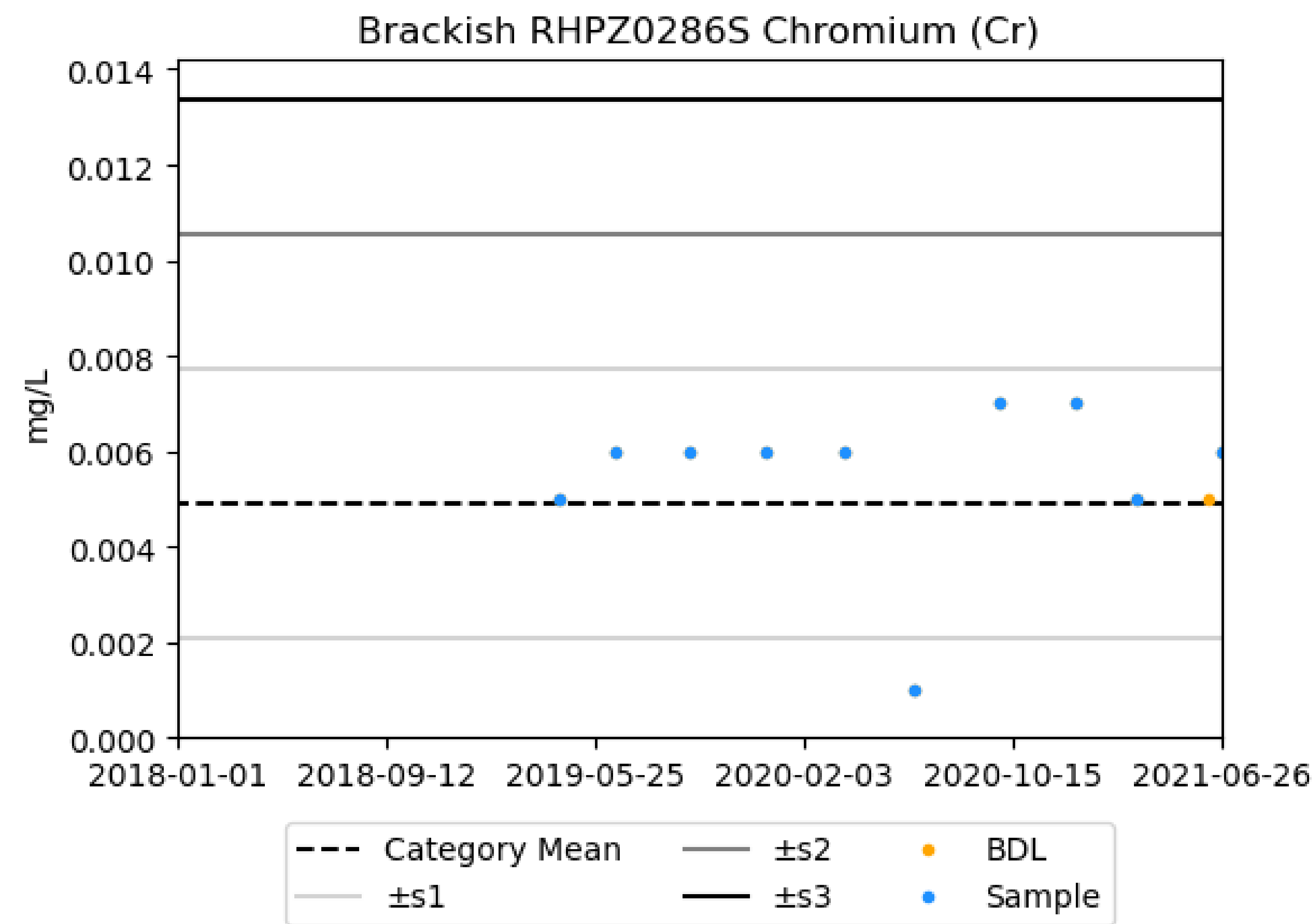
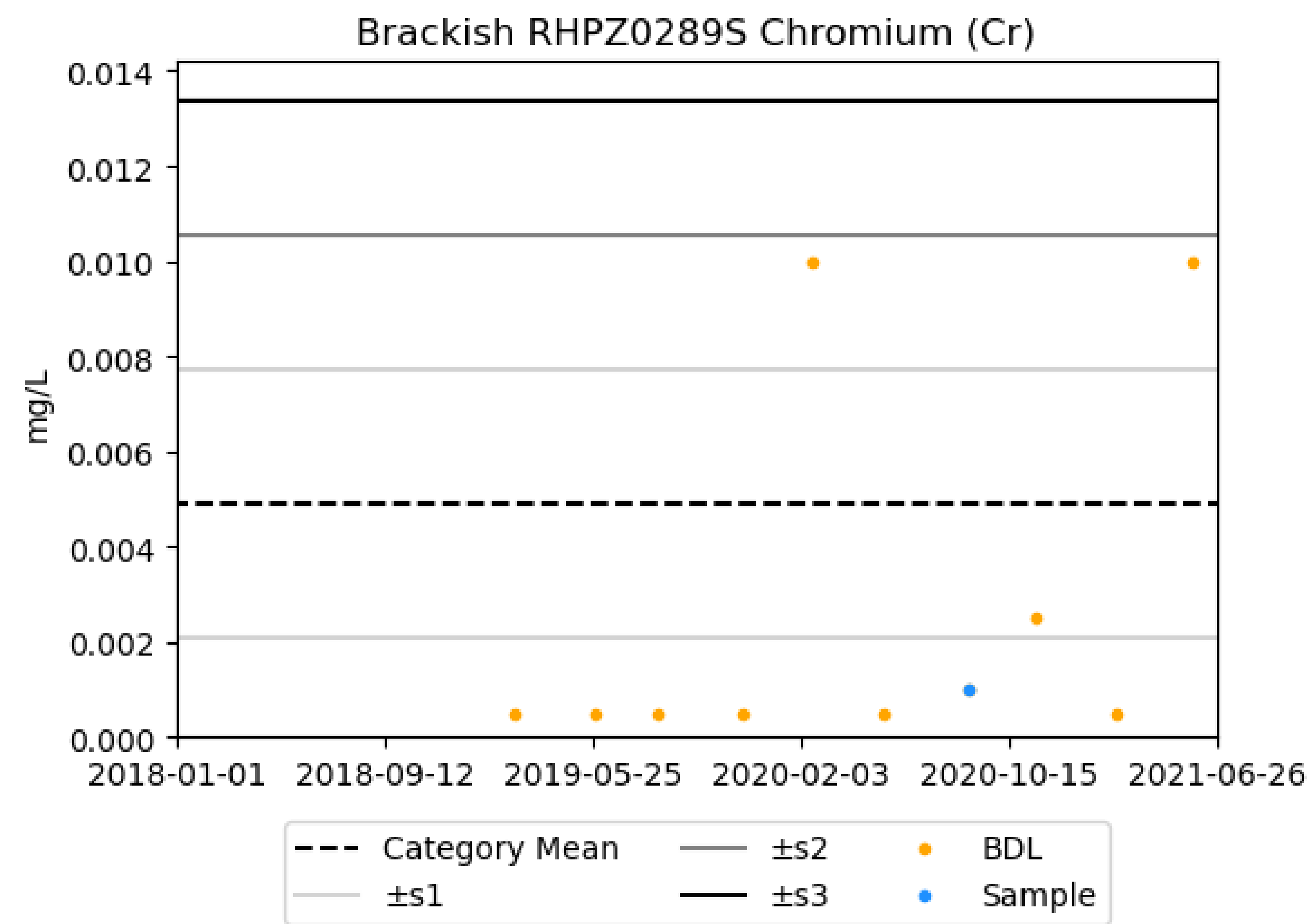
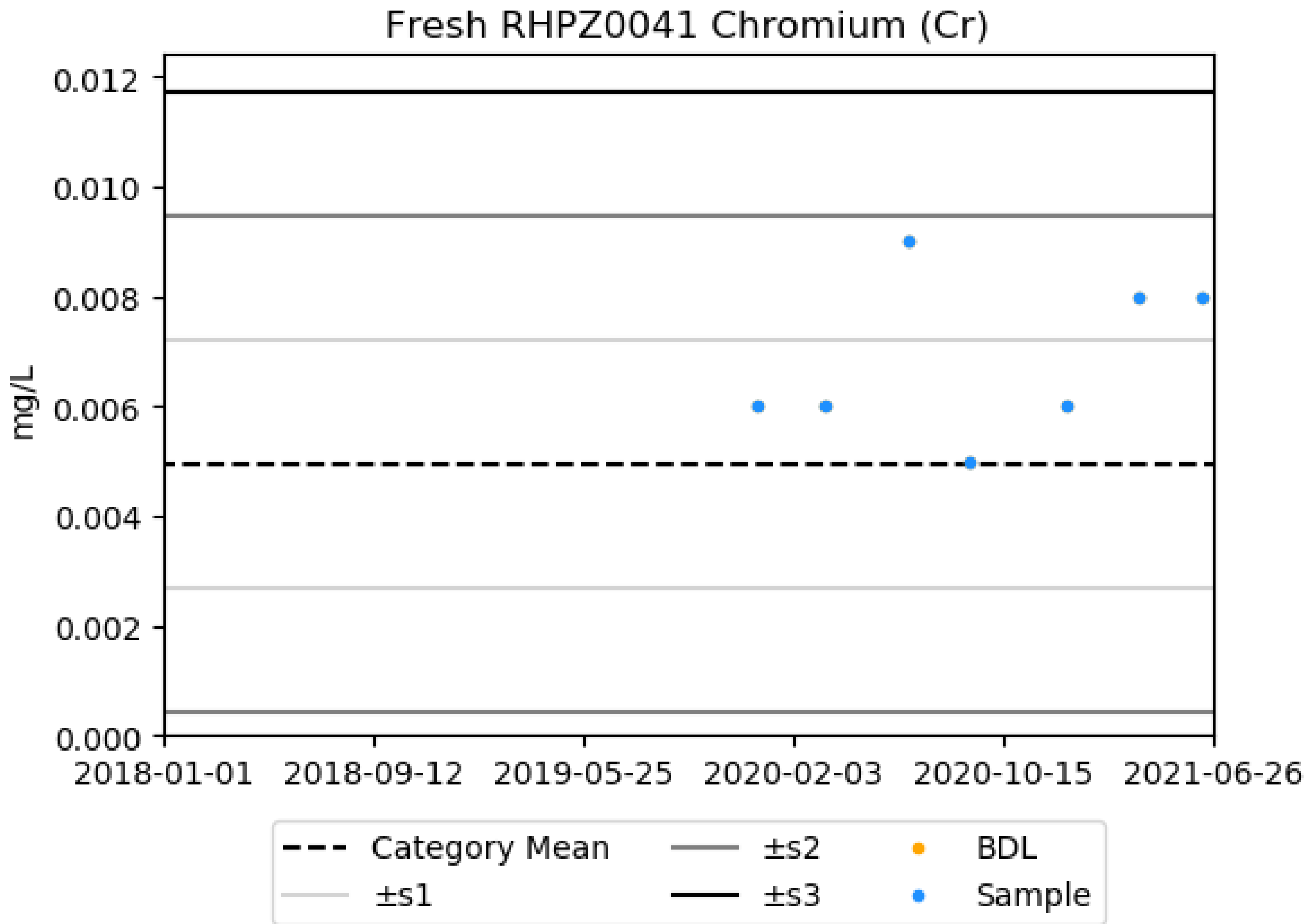
0.002
0.004
0.006
0.008
0.010
0.012
0.014
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample


Brackish RHPZ0286S Chromium (Cr)
mg/L
0.000
0.002
0.004
0.006
0.008
0.010
0.012
0.014
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample


Brackish RHPZ0289S Chromium (Cr)
mg/L
0.000
0.002
0.004
0.006
0.008
0.010
0.012
0.014
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample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mg/L
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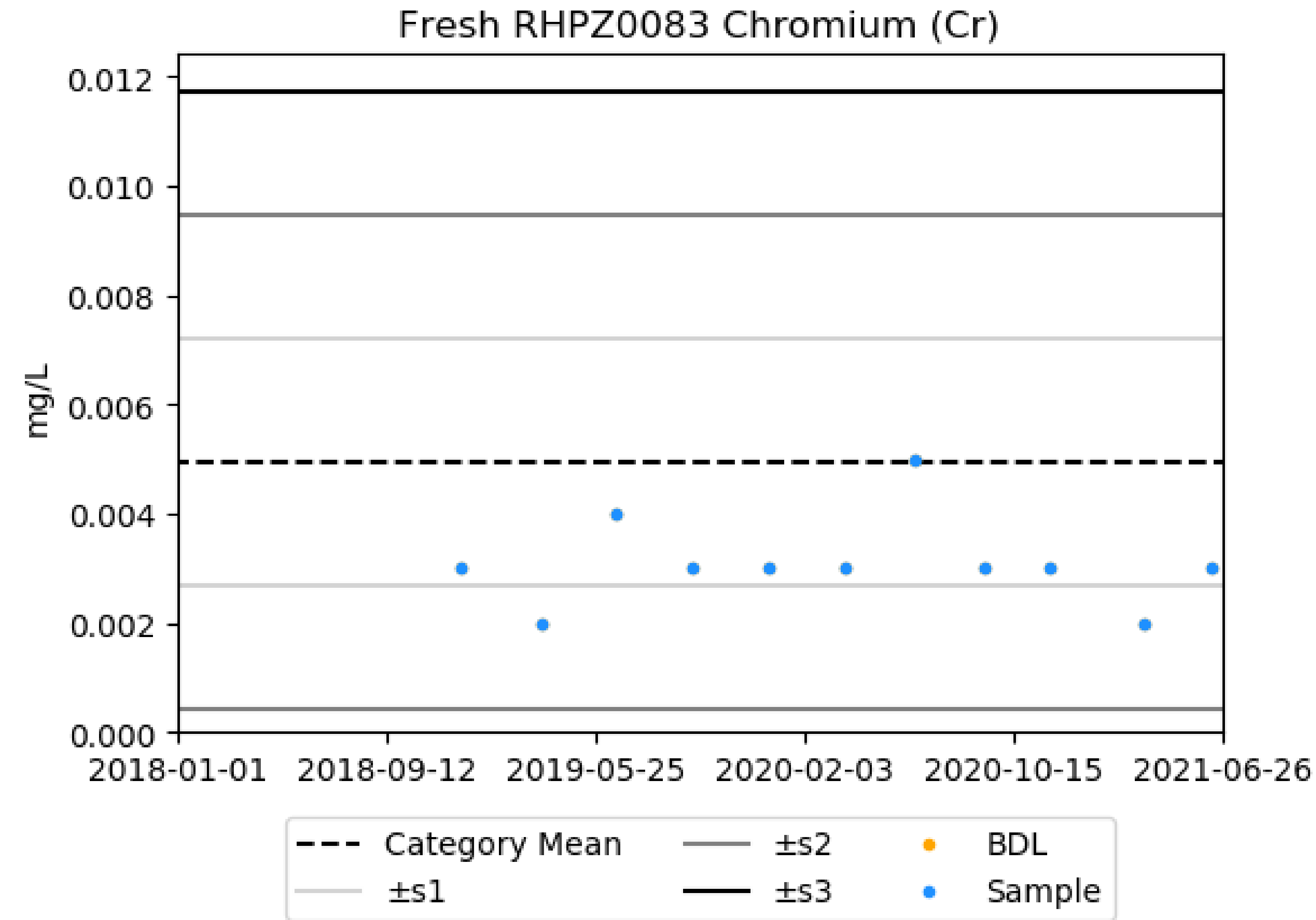
0.002
0.004
0.006
0.008
0.010
0.012
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample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mg/L
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0.002
0.004
0.006
0.008
0.010
0.012
2018-01-01
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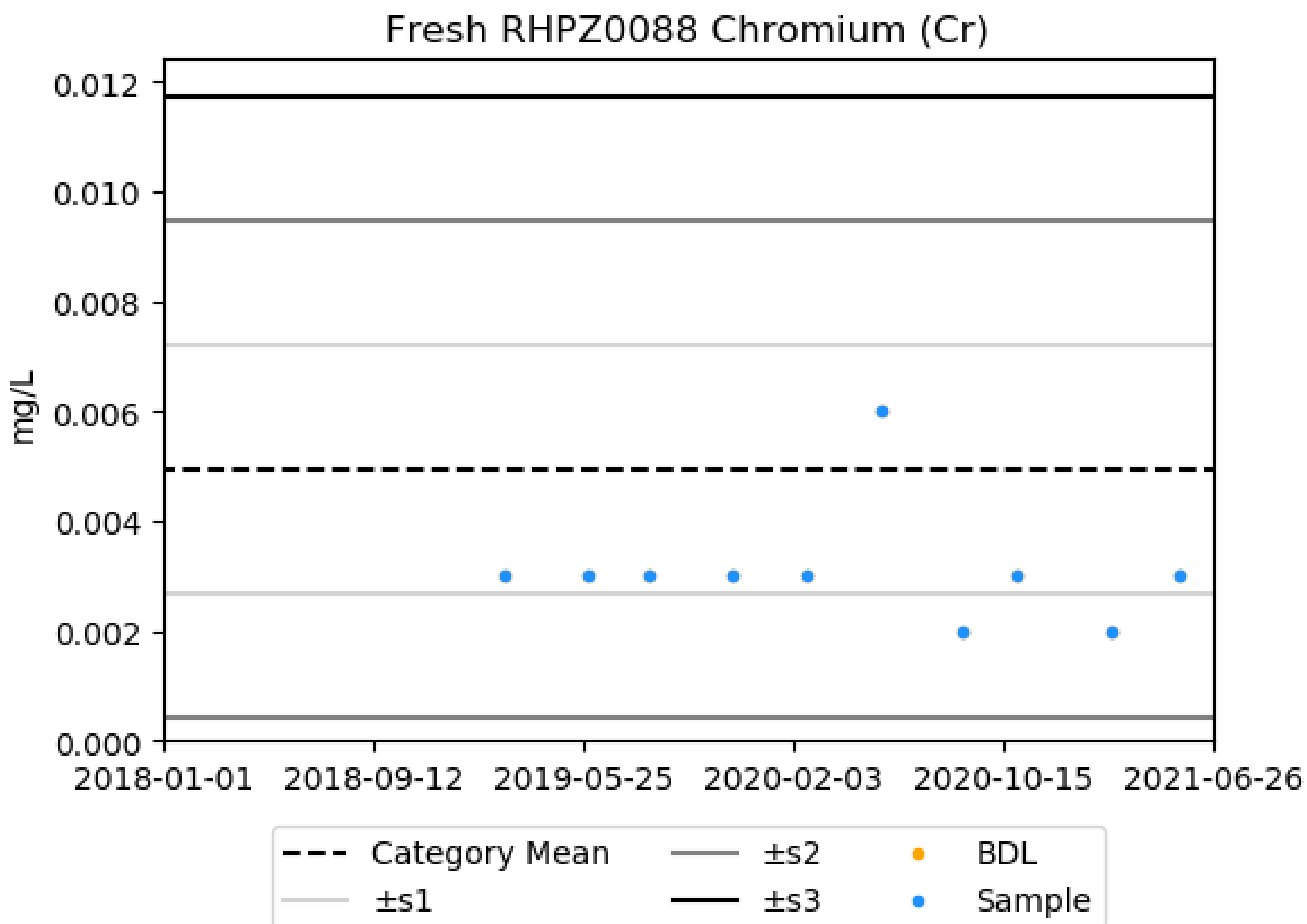
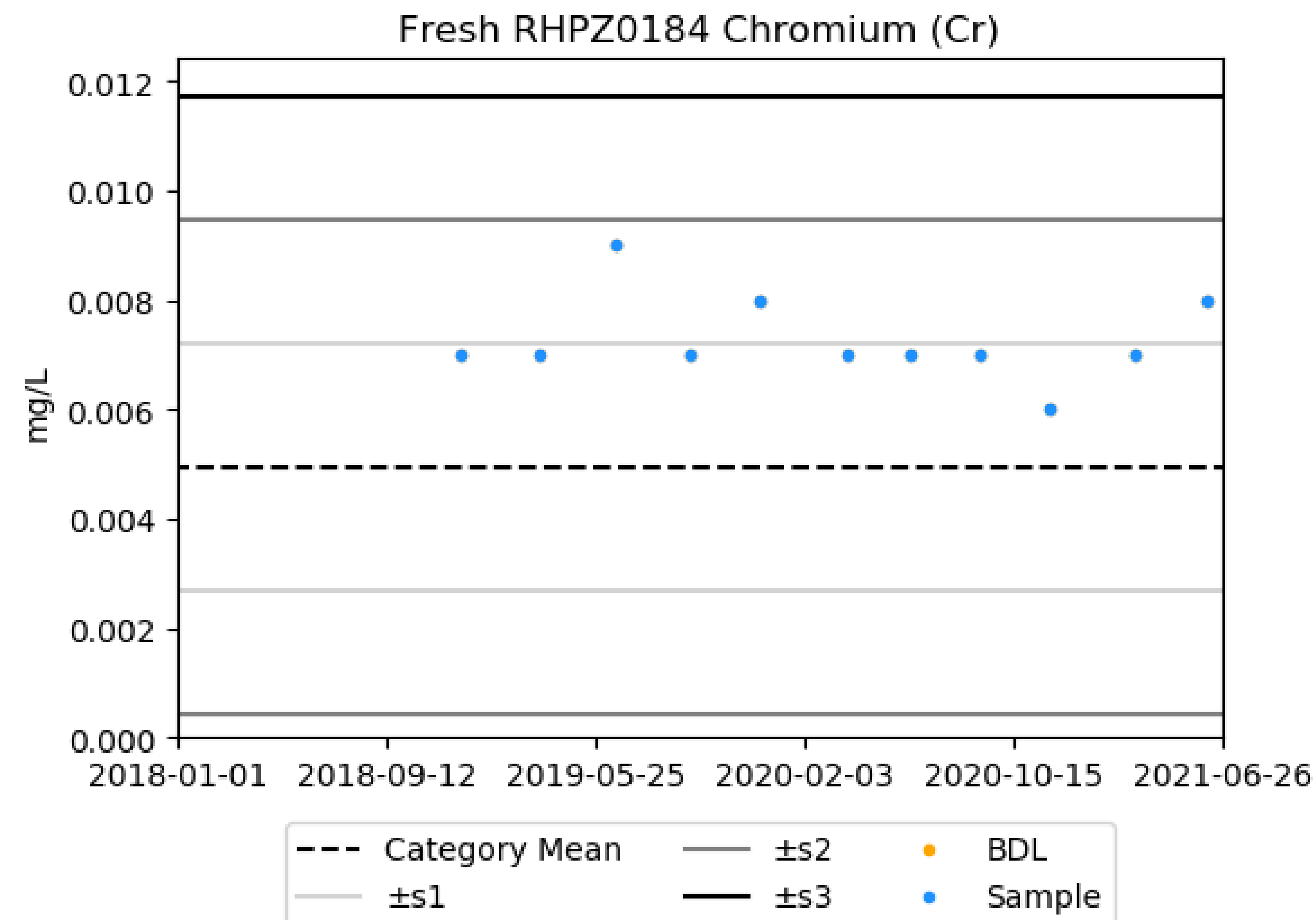
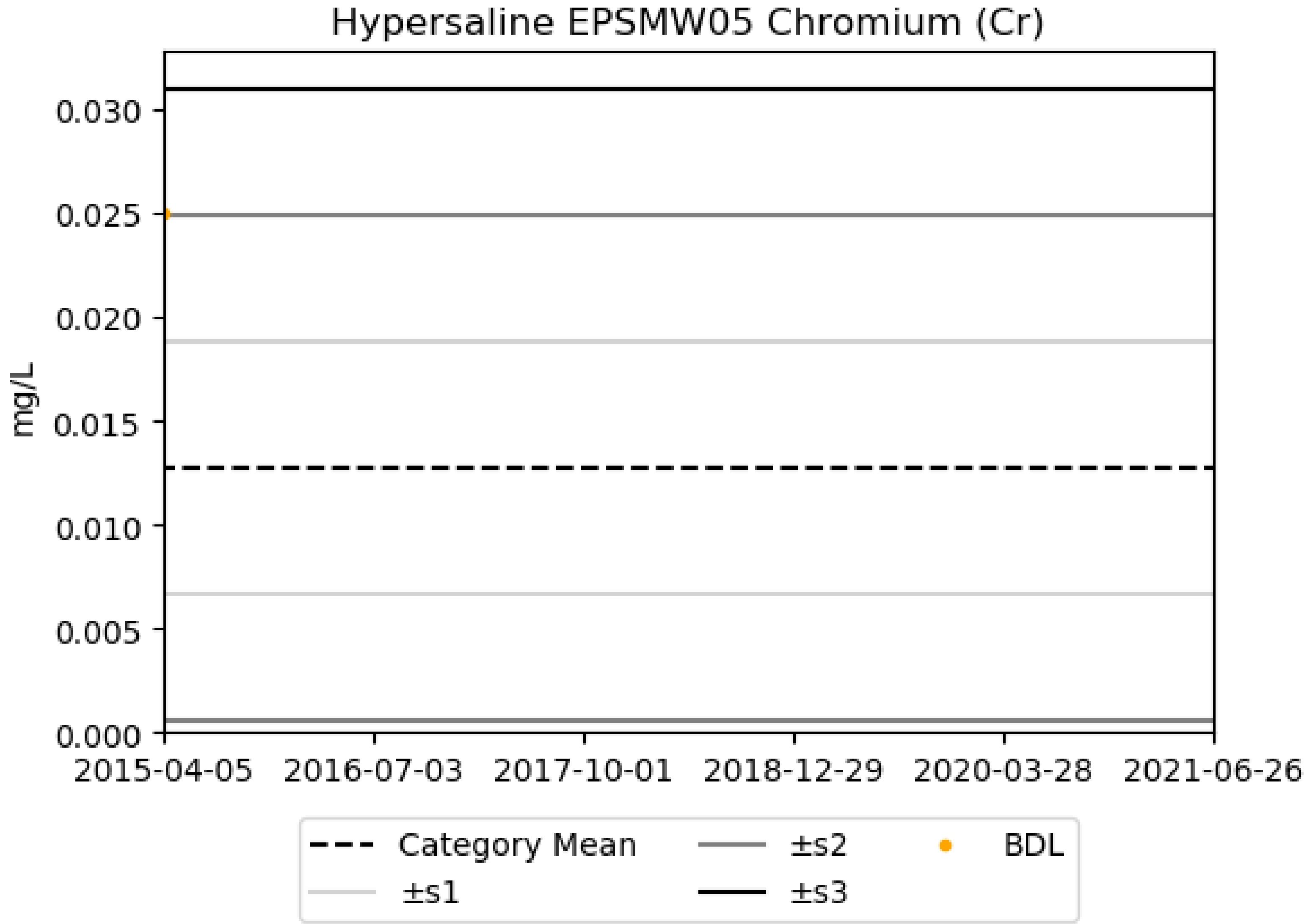
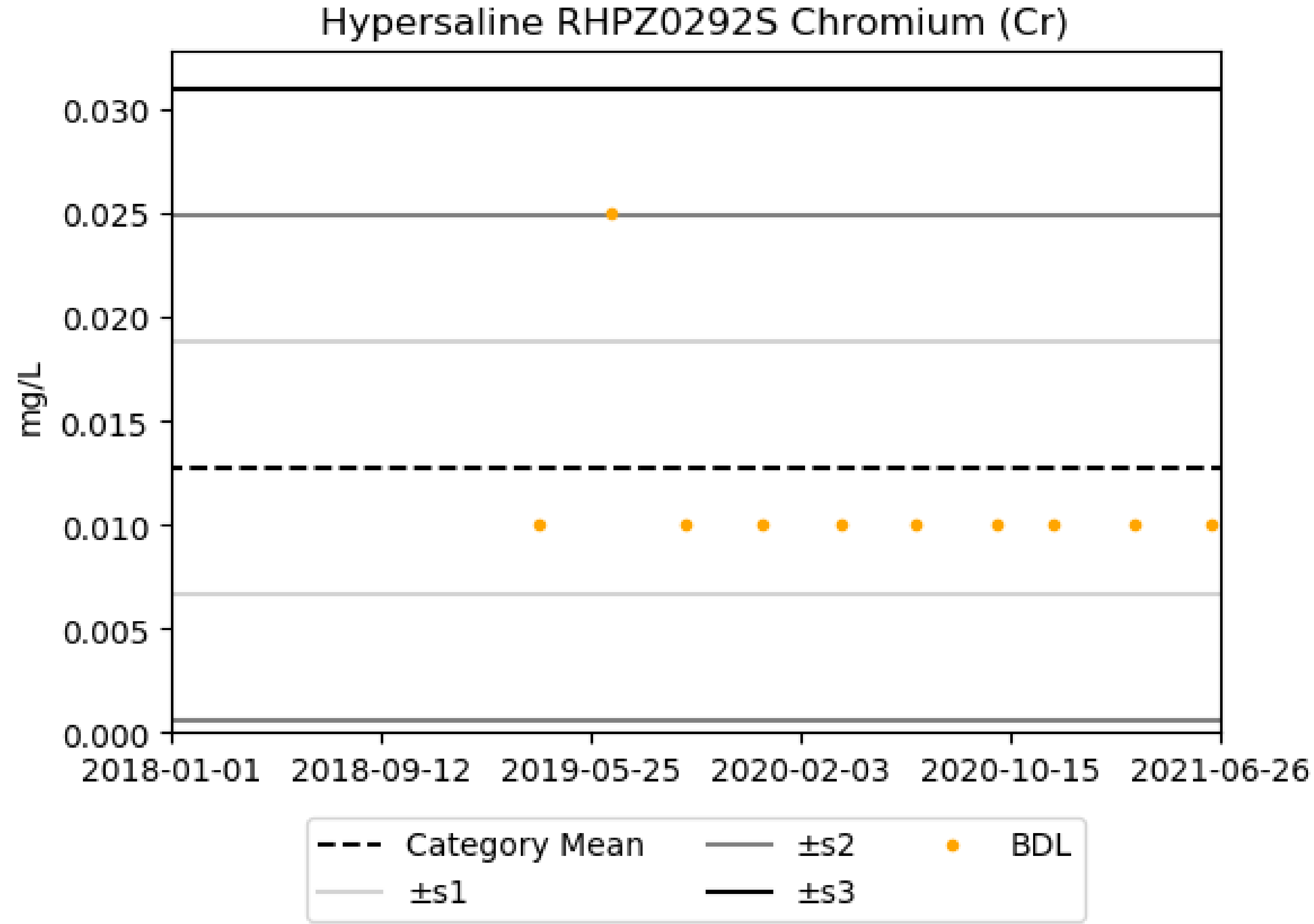
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample

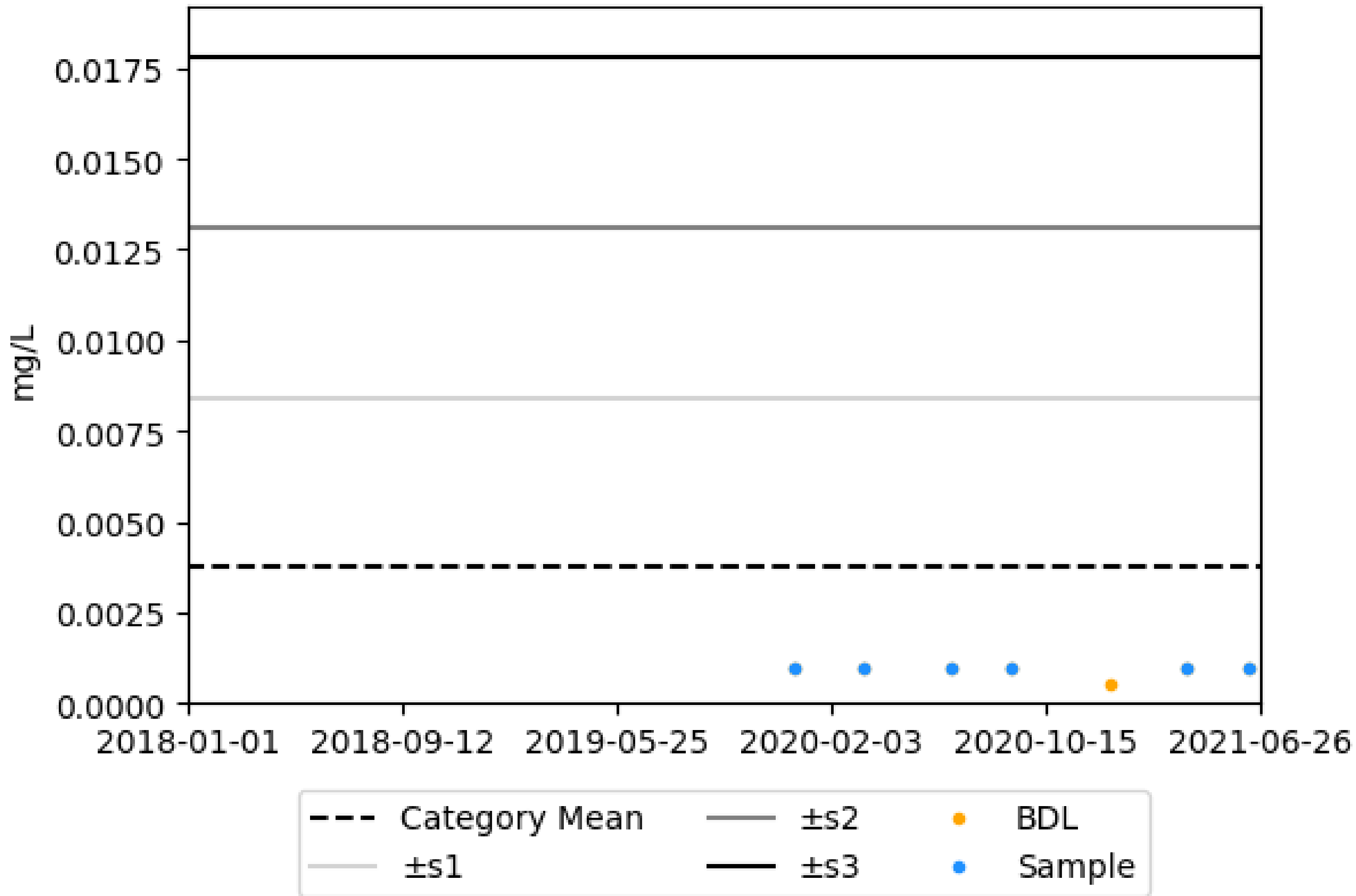

Fresh RHPZ0088 Chromium (Cr)
mg/L
0.000
0.002
0.004
0.006
0.008
0.010
0.012
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample


Fresh RHPZ0184 Chromium (Cr)
mg/L
0.000
0.002
0.004
0.006
0.008
0.010
0.012
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample

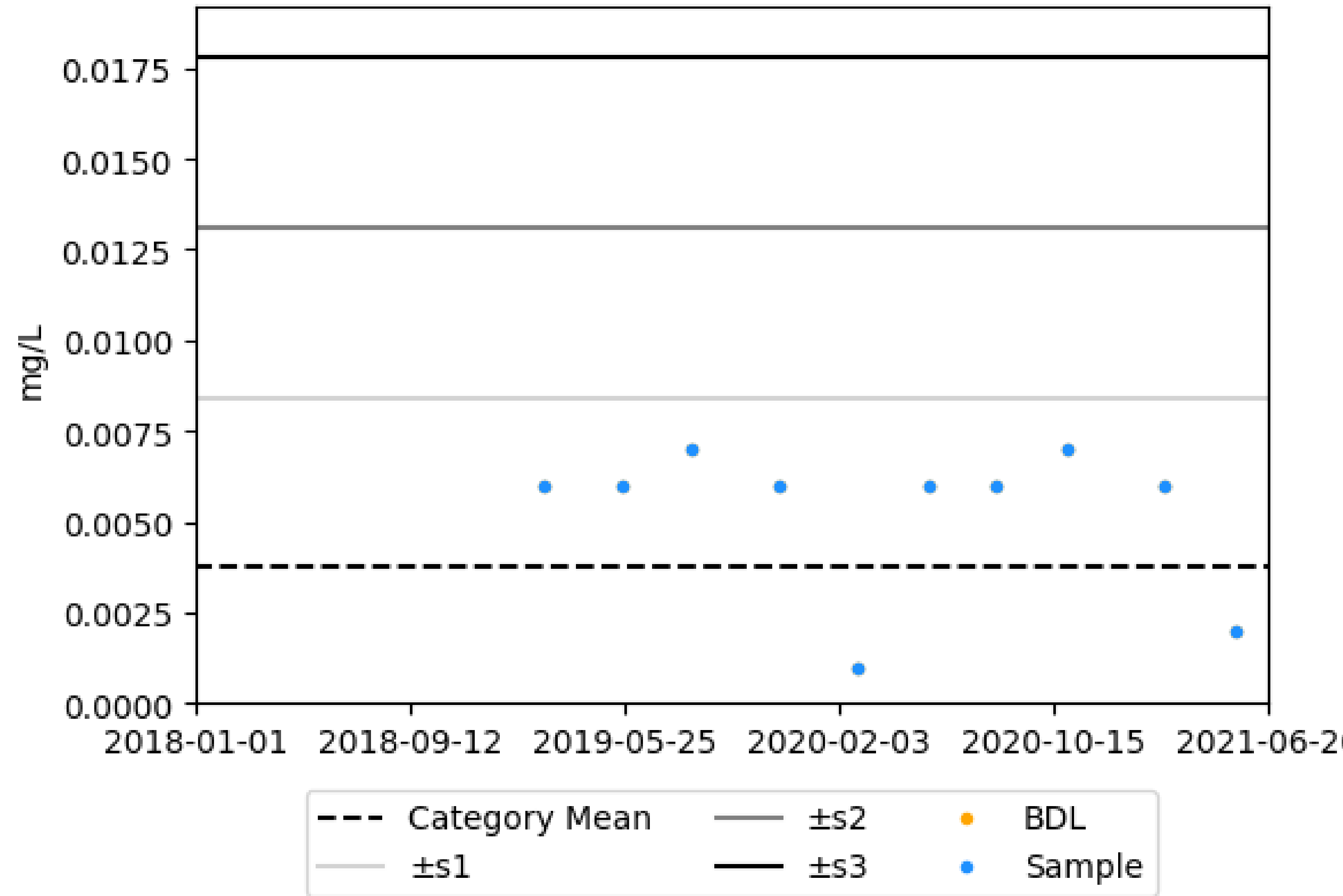

Hypersaline EPSMW05 Chromium (Cr)
mg/L
0.030
0.025
0.020
0.015
0.010
0.005
0.000
2015-04-05
2016-07-03
2017-10-01
2018-12-29
2020-03-28
2021-06-26
Category Mean
±s1
±s2
±s3
BDL


Hypersaline RHPZ0292S Chromium (Cr)
mg/L
0.030
0.025
0.020
0.015
0.010
0.005
0.000
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL

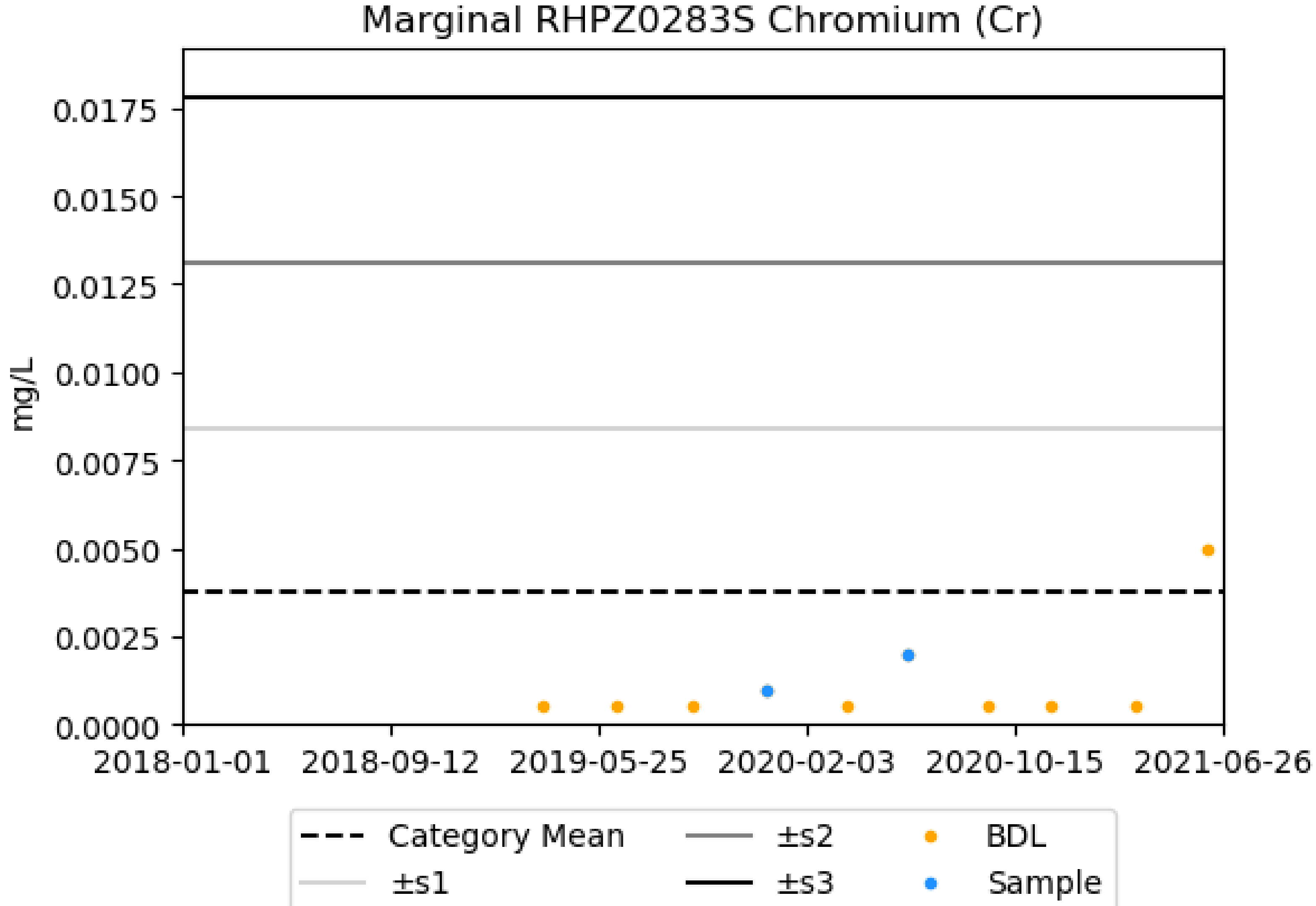
Marginal RHPZ0039 Chromium (Cr)



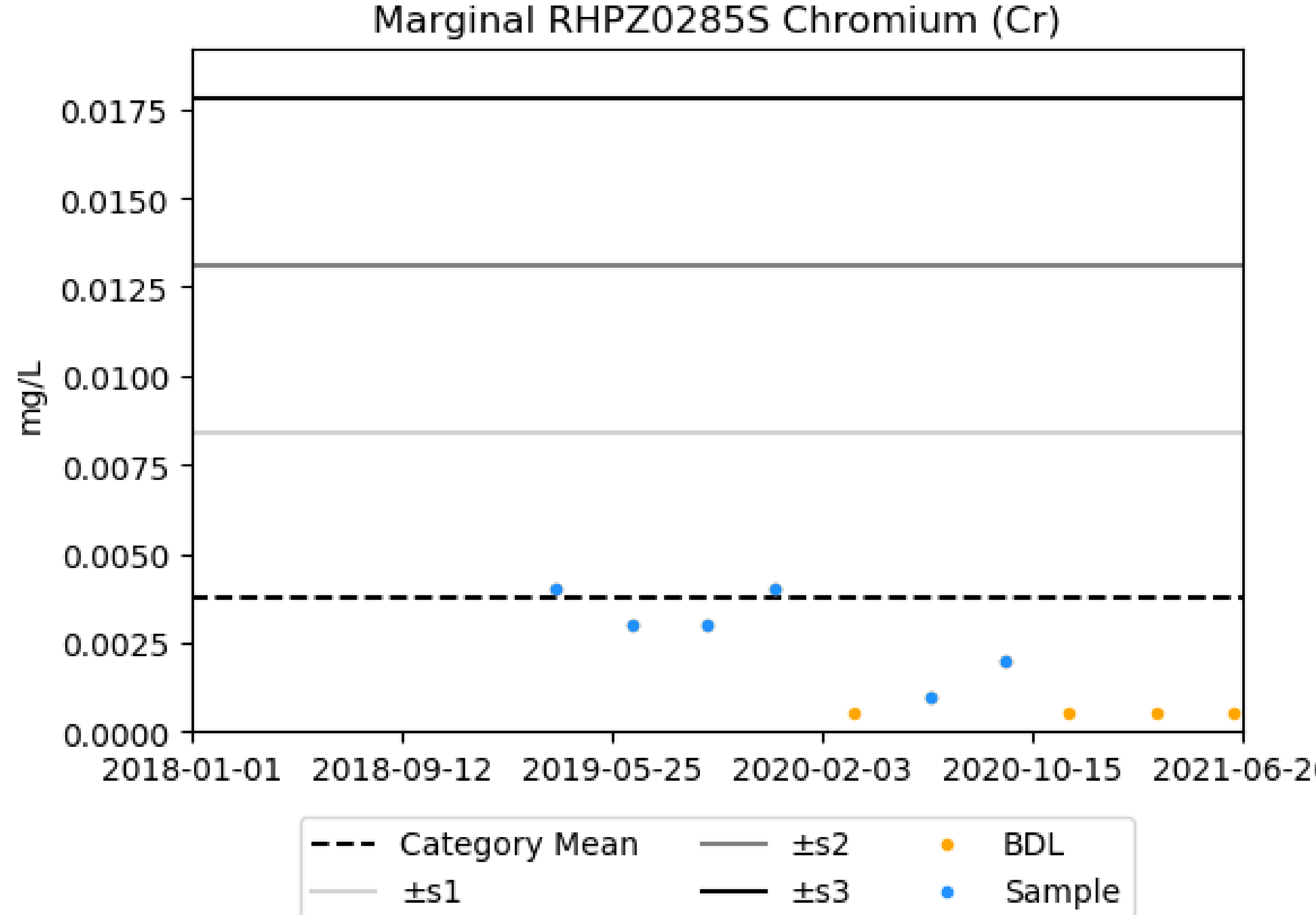
Marginal RHPZ0075 Chromium (Cr)



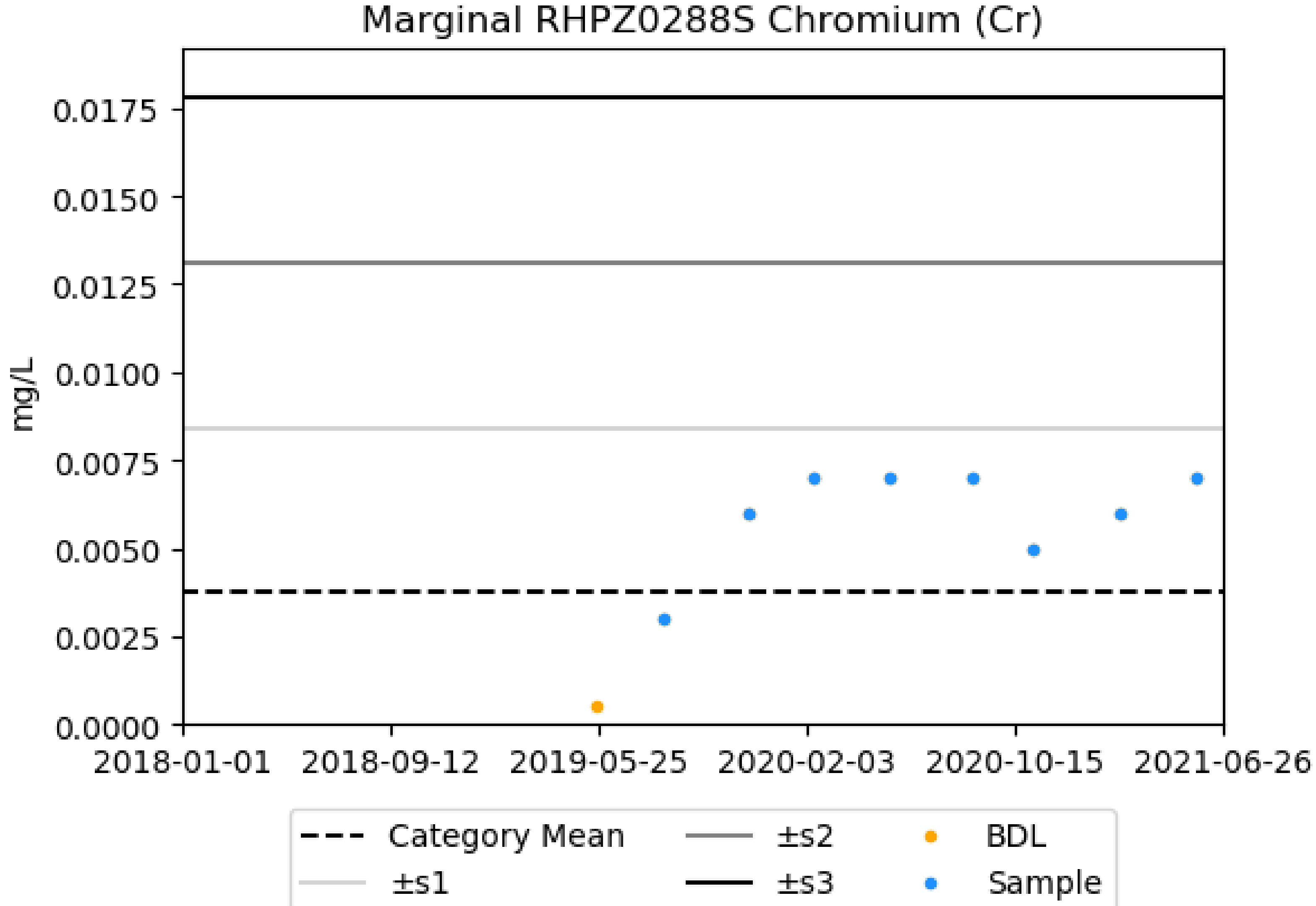
Marginal RHPZ0283S Chromium (Cr)



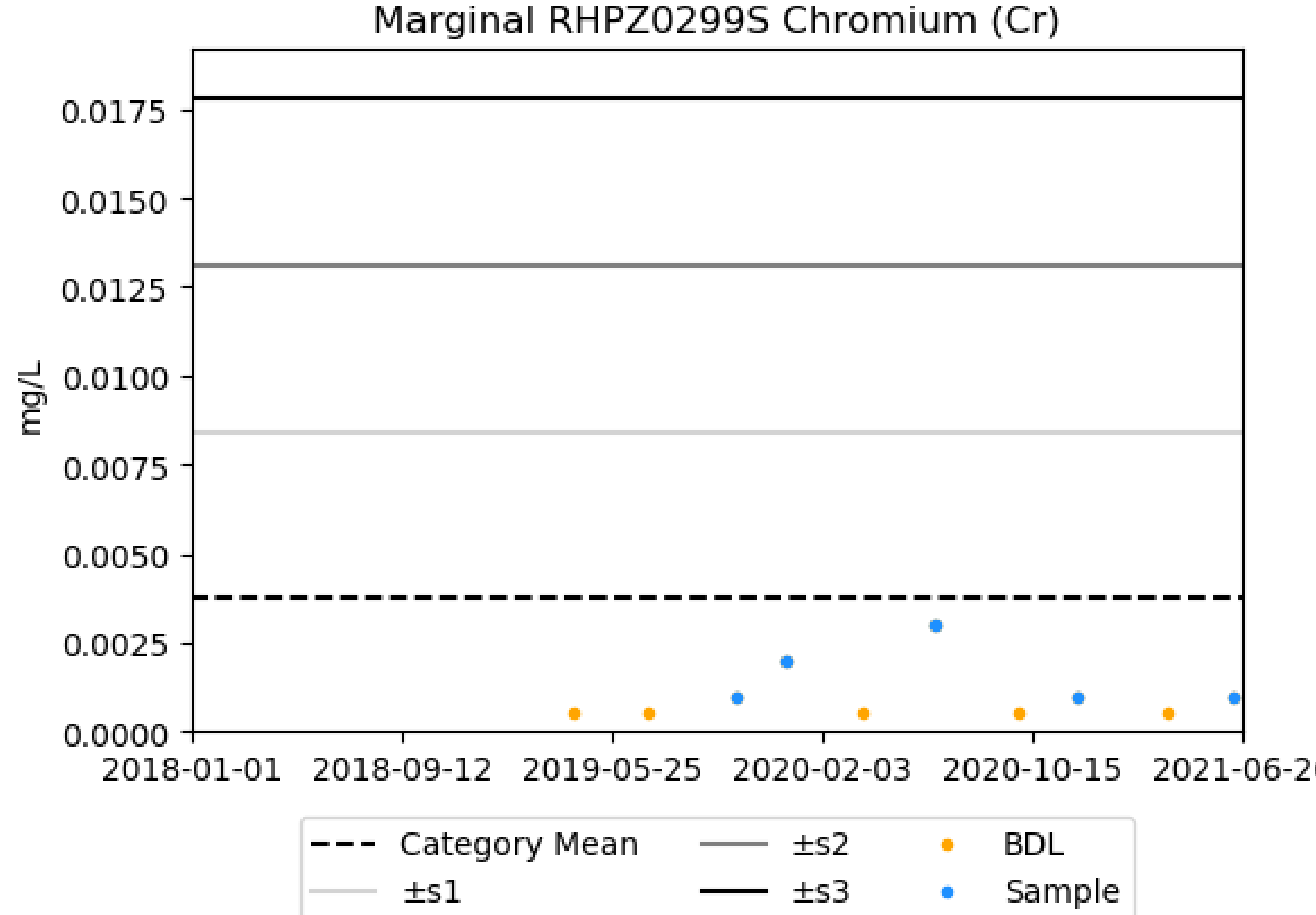
Marginal RHPZ0285S Chromium (Cr)

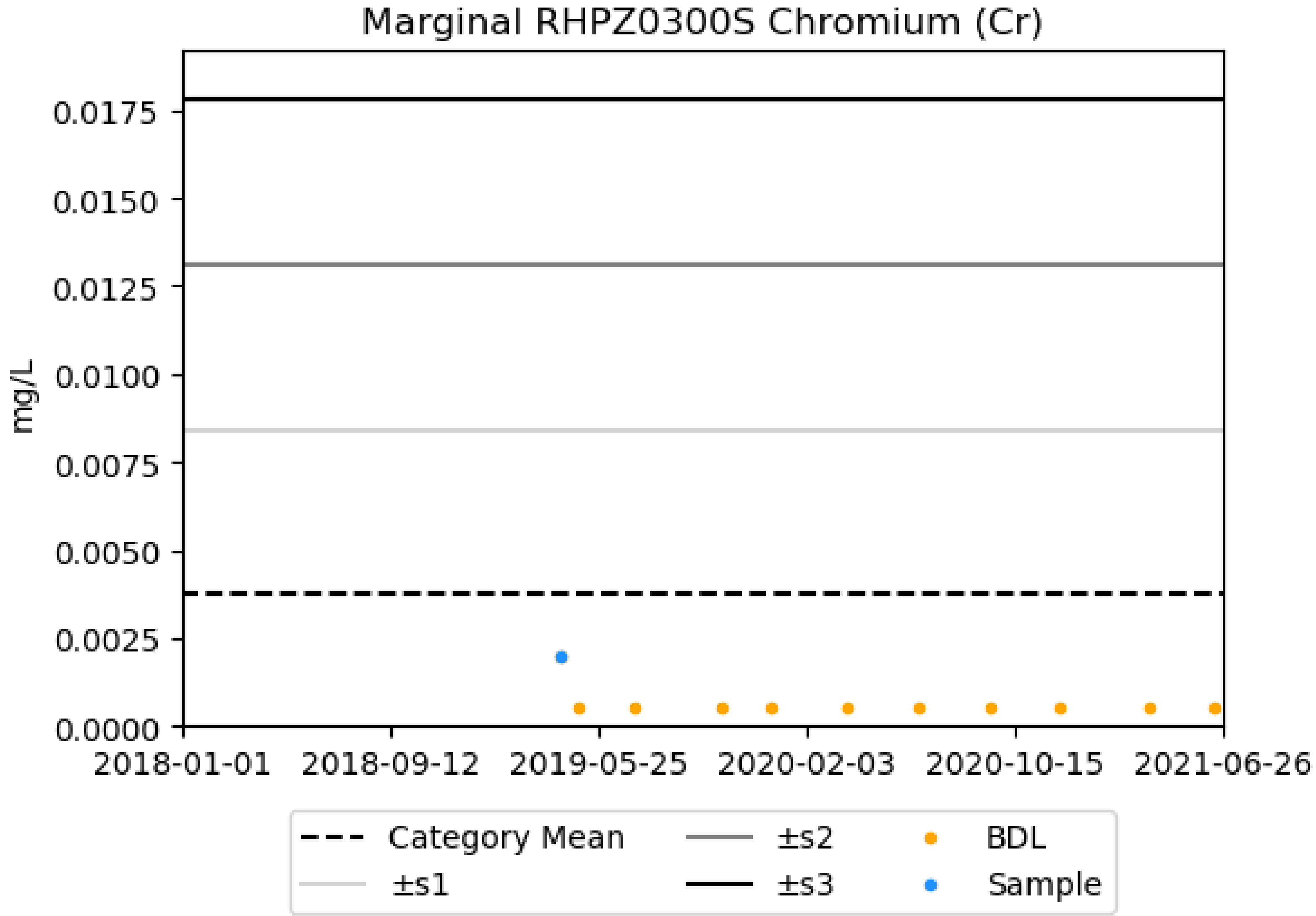


Marginal RHPZ0288S Chromium (Cr)



Marginal RHPZ0299S Chromium (Cr)




Marginal RHPZ0300S Chromium (Cr)
mg/L
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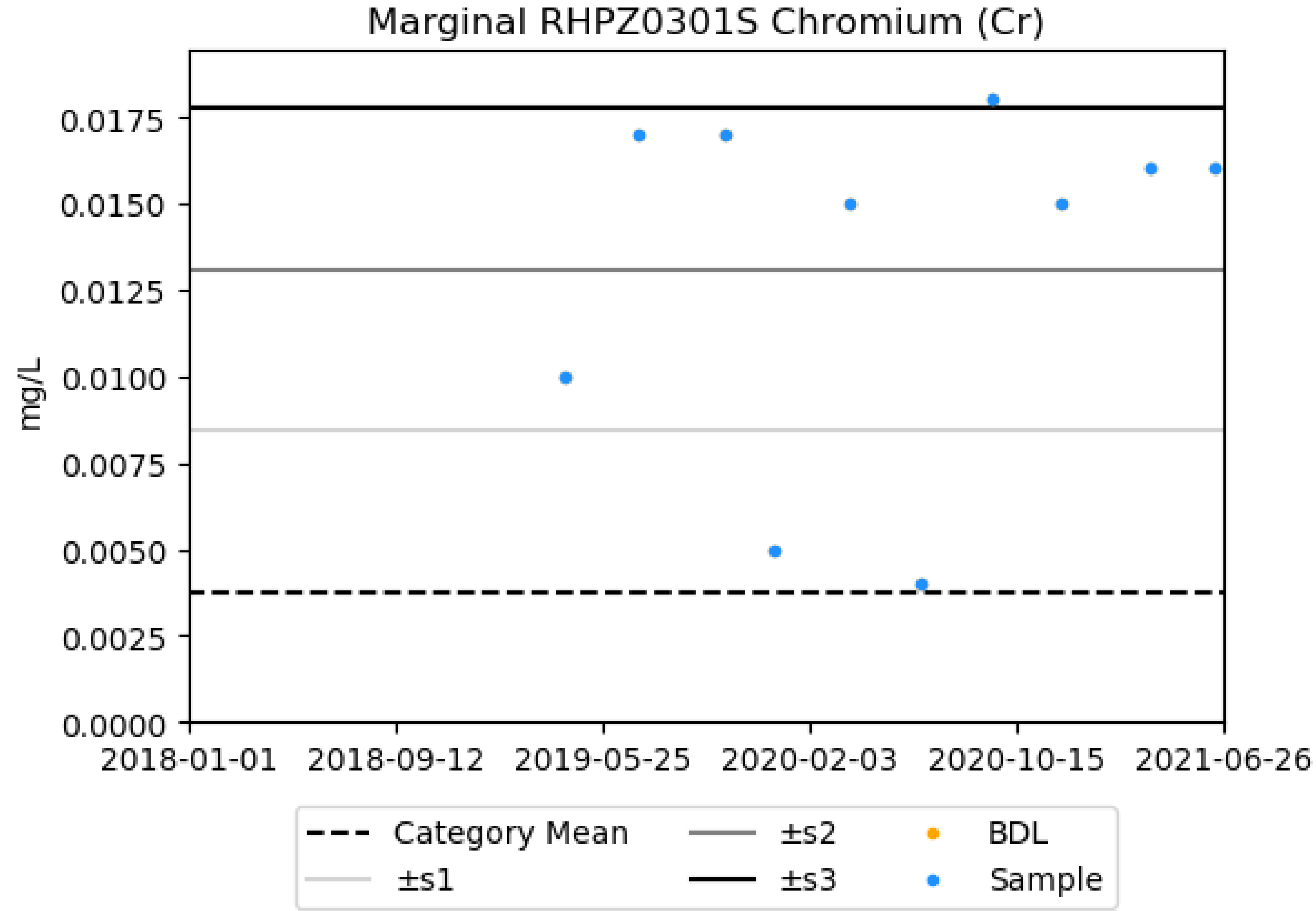
0.0025
0.0050
0.0075
0.0100
0.0125
0.0150
0.0175
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample


Marginal RHPZ0301S Chromium (Cr)
mg/L
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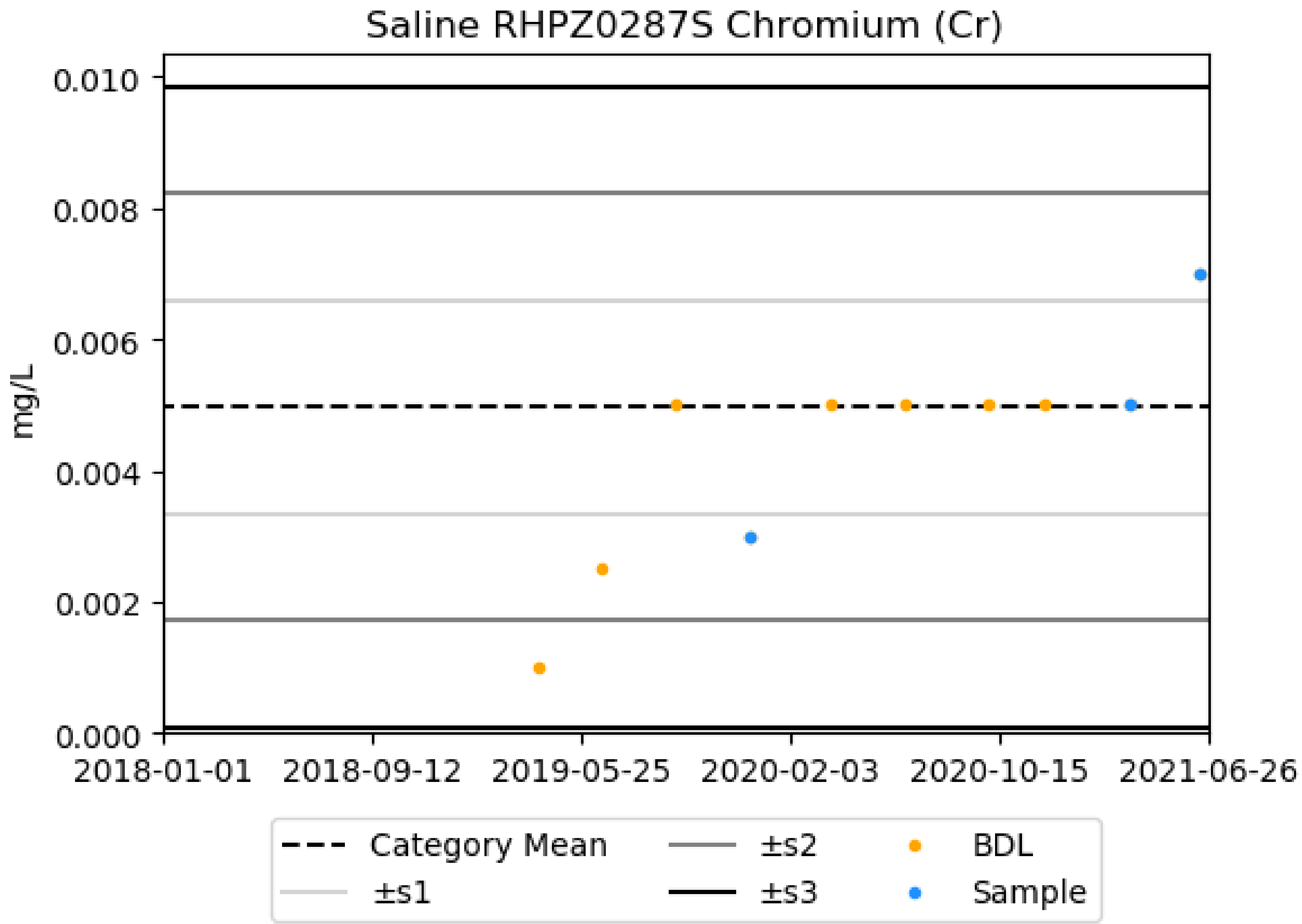
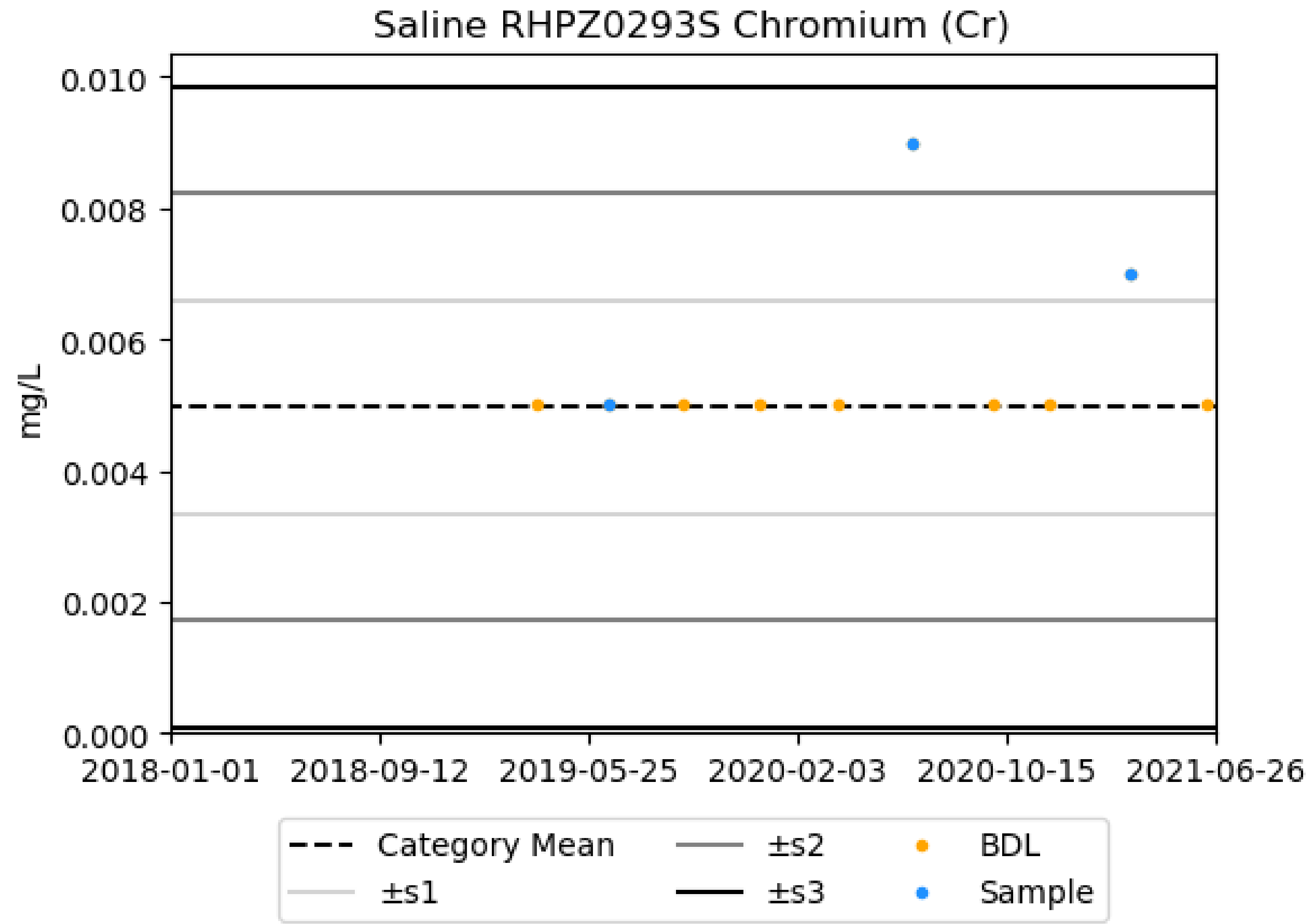
0.0025
0.0050
0.0075
0.0100
0.0125
0.0150
0.0175
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample


Saline RHPZ0287S Chromium (Cr)
mg/L
0.010
0.008
0.006
0.004
0.002
0.000
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample


Saline RHPZ0293S Chromium (Cr)
mg/L
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0.008
0.006
0.004
0.002
0.000
2018-01-01
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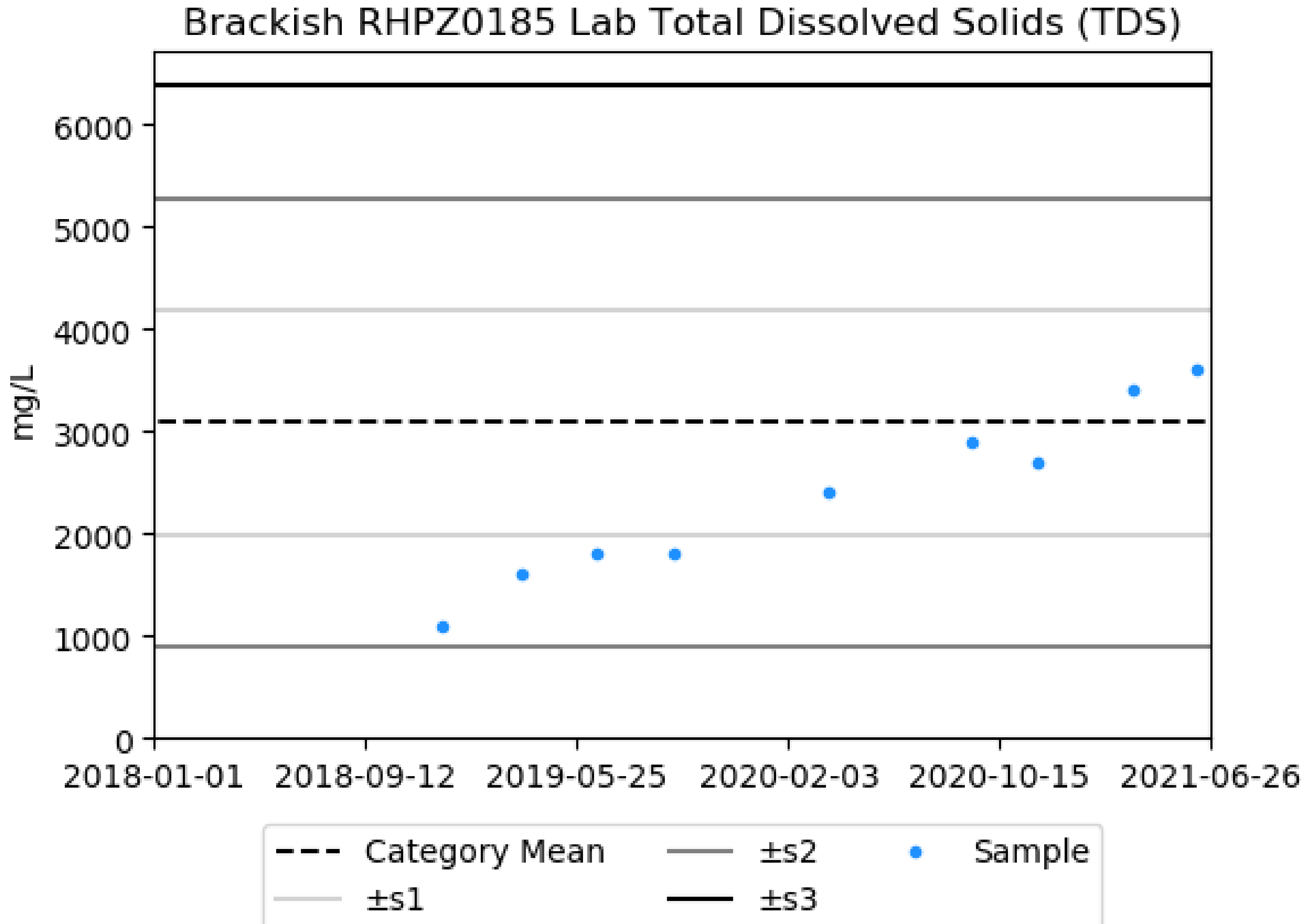
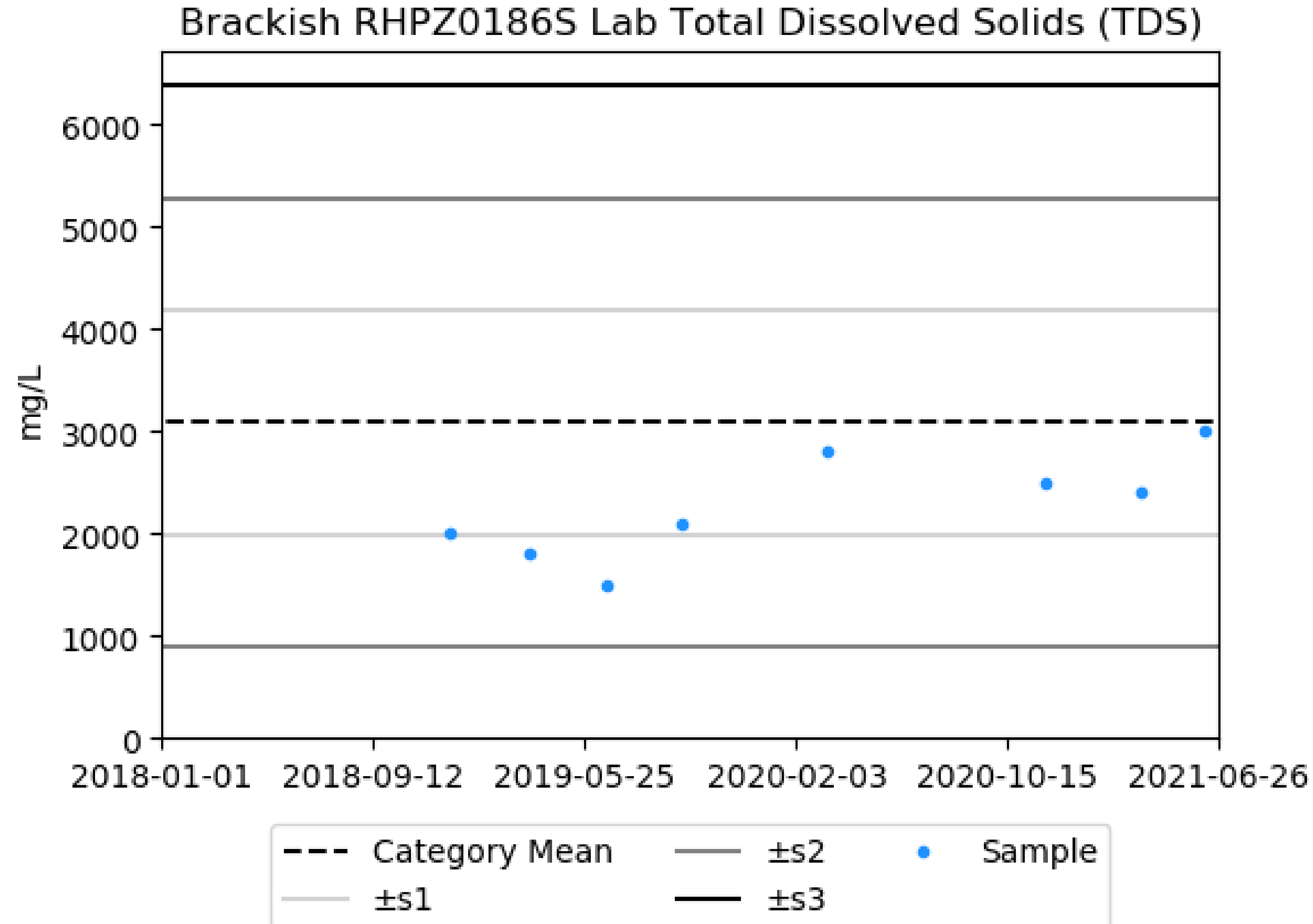
Category Mean
±s1
±s2
±s3
BDL
Sample


Brackish RHPZ0185 Lab Total Dissolved Solids (TDS)
mg/L
0
1000
2000
3000
4000
5000
6000
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample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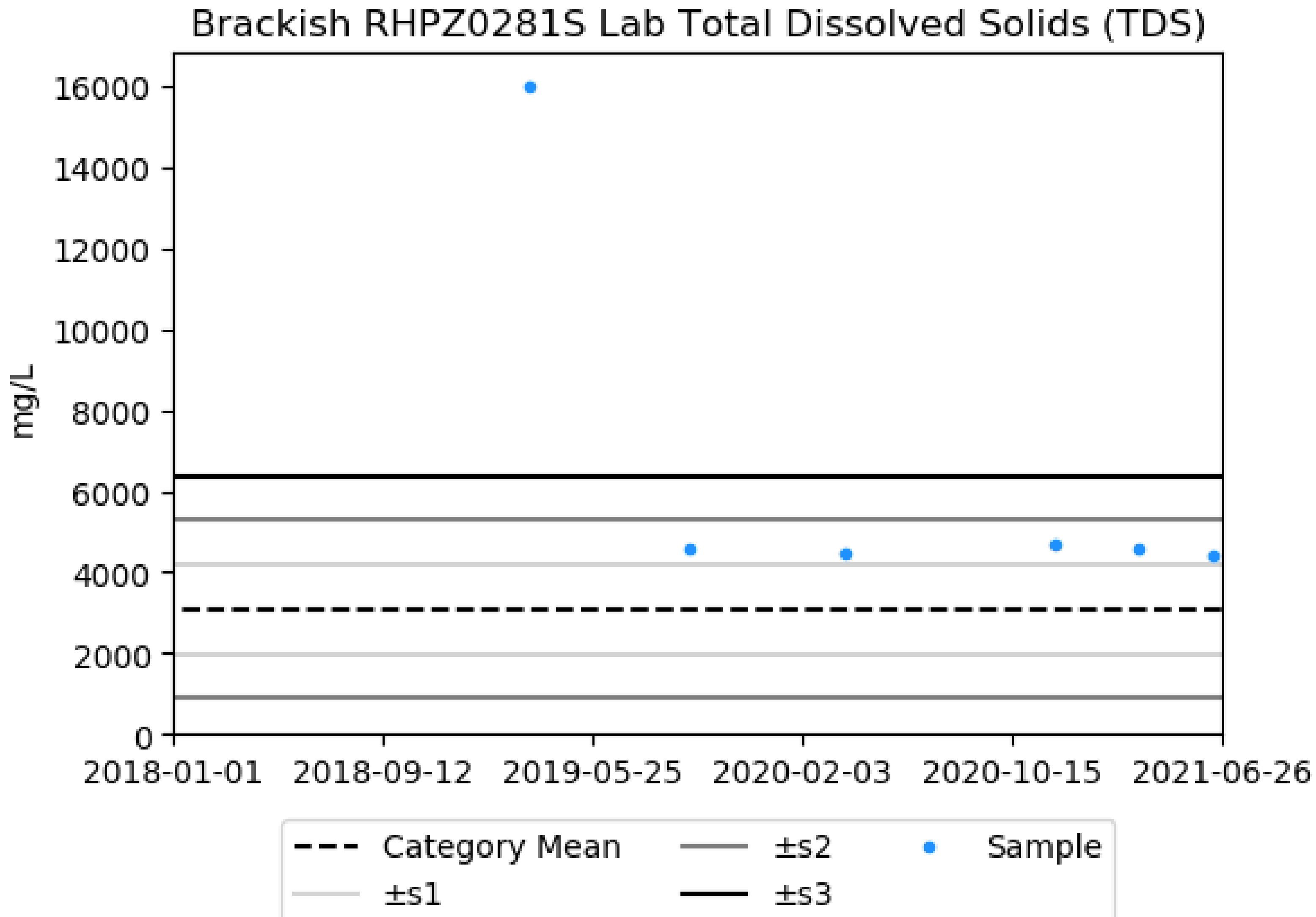
mg/L
0
1000
2000
3000
4000
5000
6000
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample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mg/L
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2000
4000
6000
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12000
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2018-01-01
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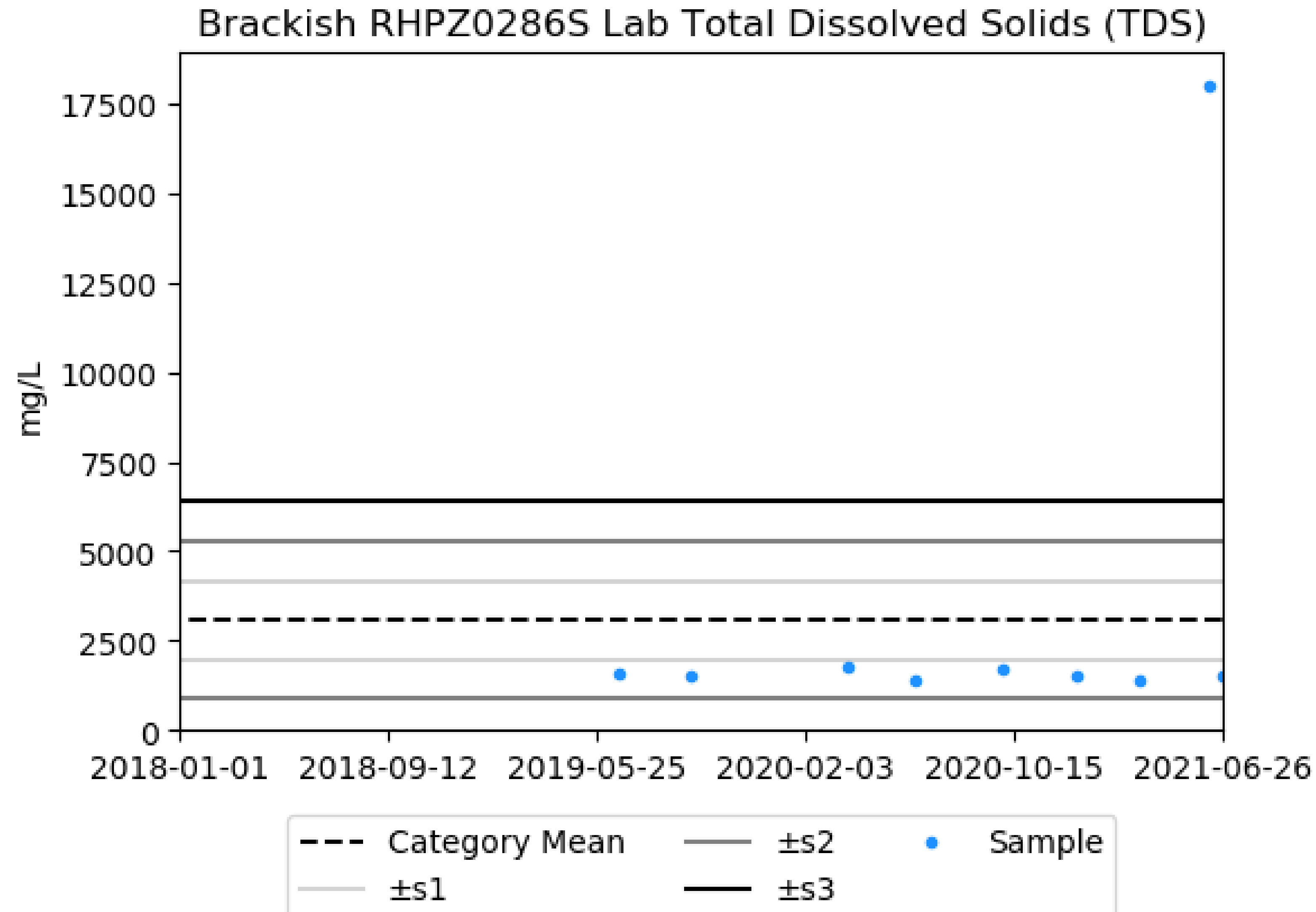
2021-06-26
Category Mean
±s1
±s2
±s3
Sample


Brackish RHPZ0286S Lab Total Dissolved Solids (TDS)
mg/L
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2500
5000
7500
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2018-01-01
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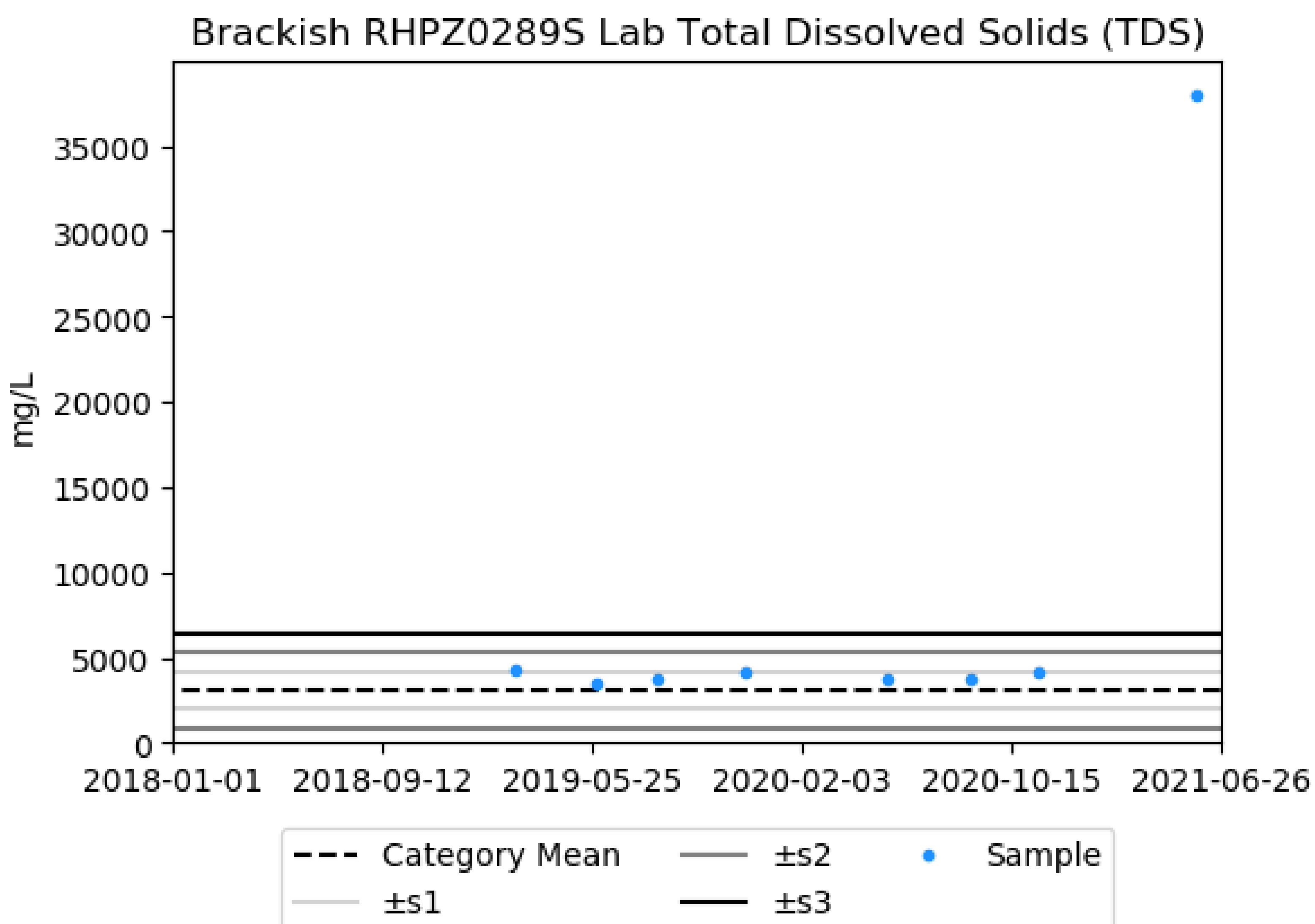
2021-06-26
Category Mean
±s1
±s2
±s3
Sample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mg/L
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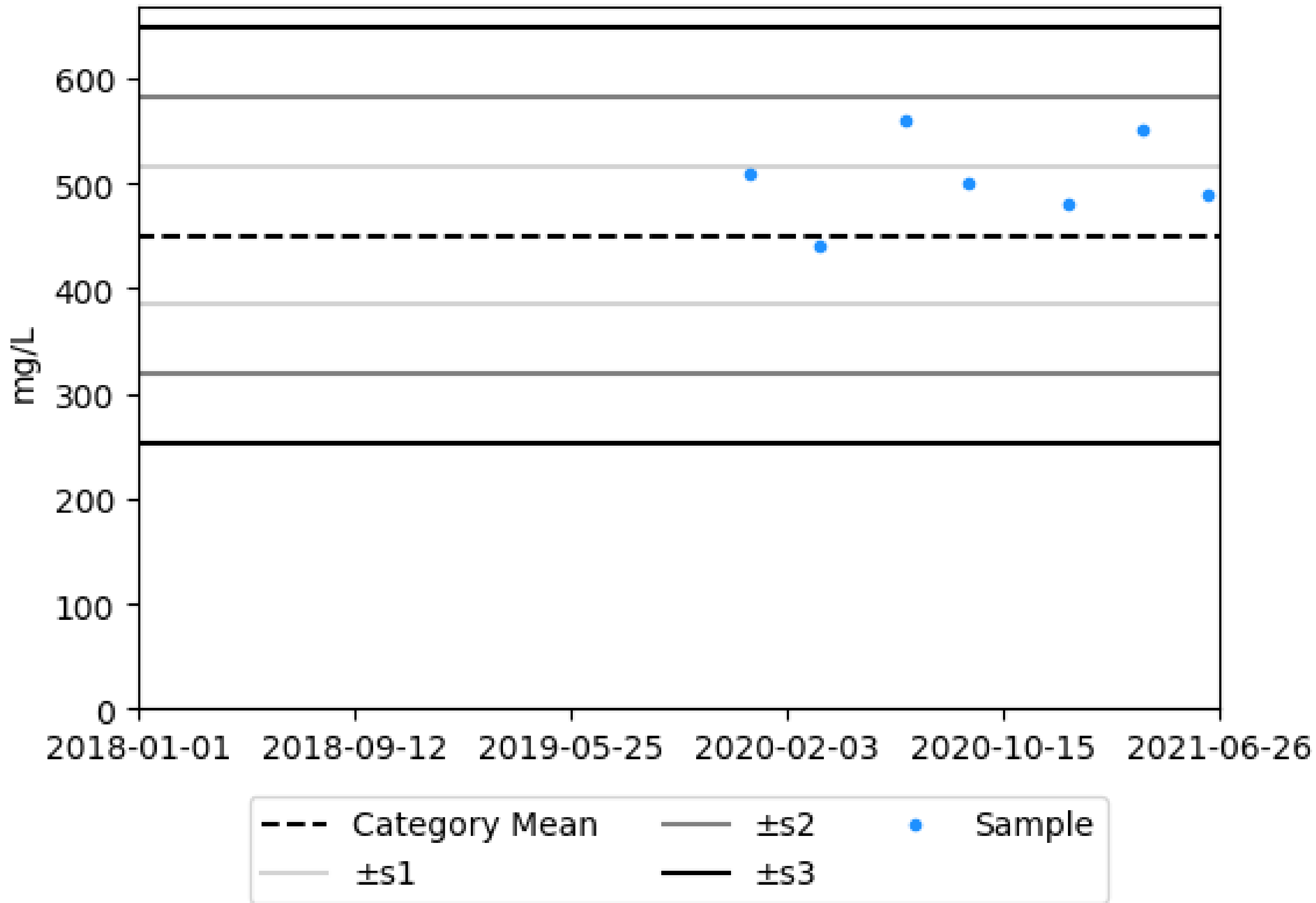
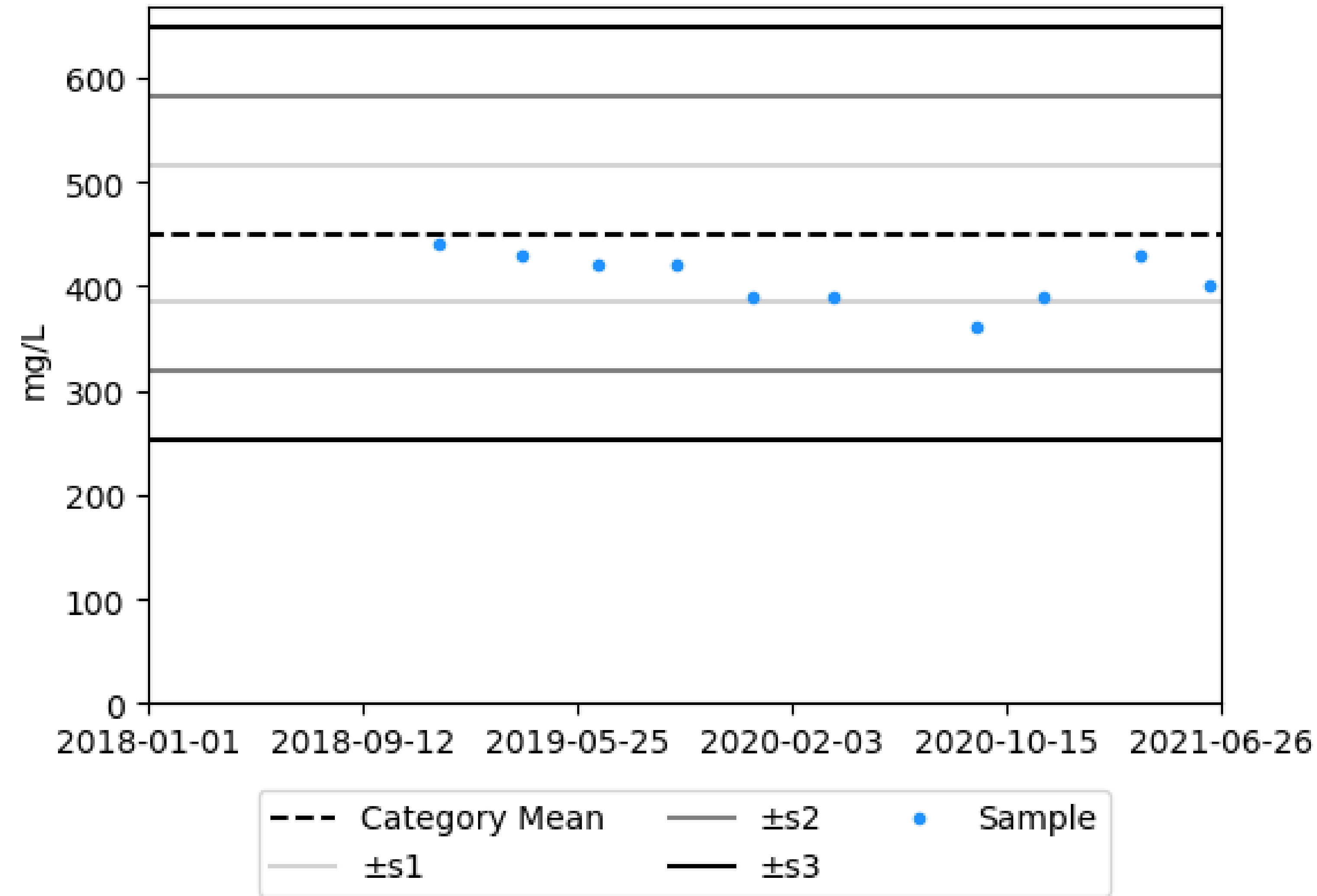
10000
15000
20000
25000
30000
35000
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

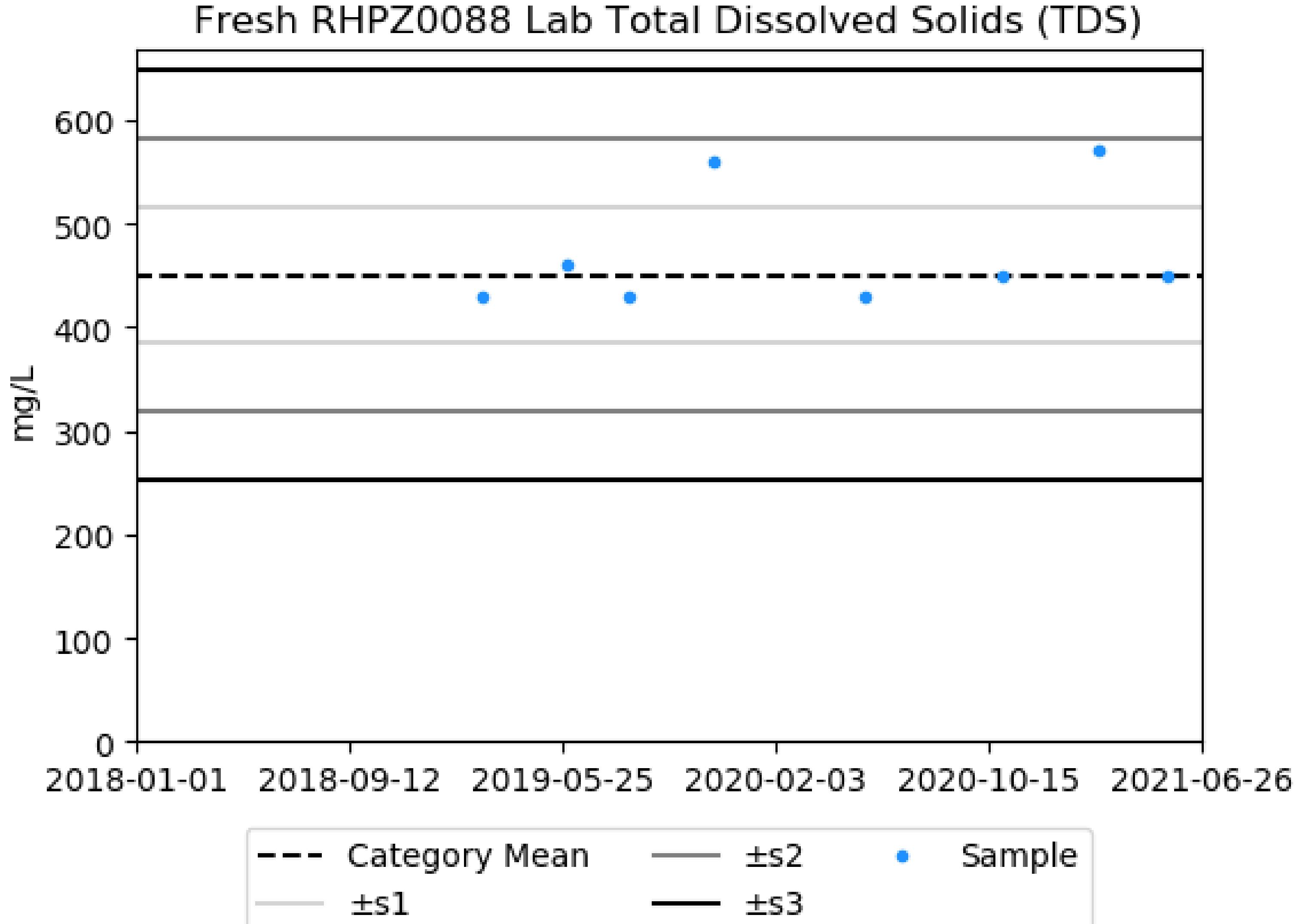
Fresh RHPZ0041 Lab Total Dissolved Solids (TDS)



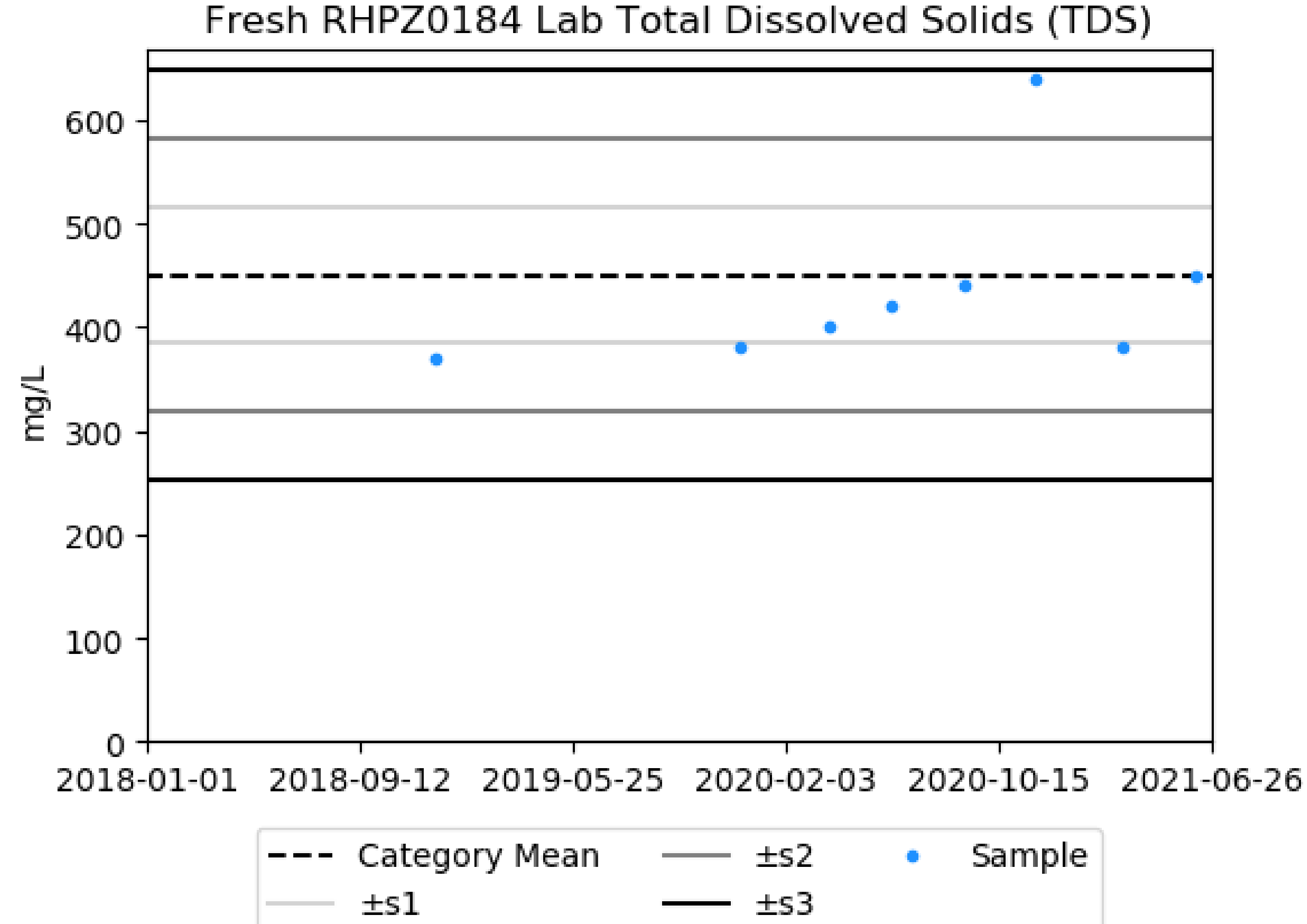
Fresh RHPZ0083 Lab Total Dissolved Solids (TDS)

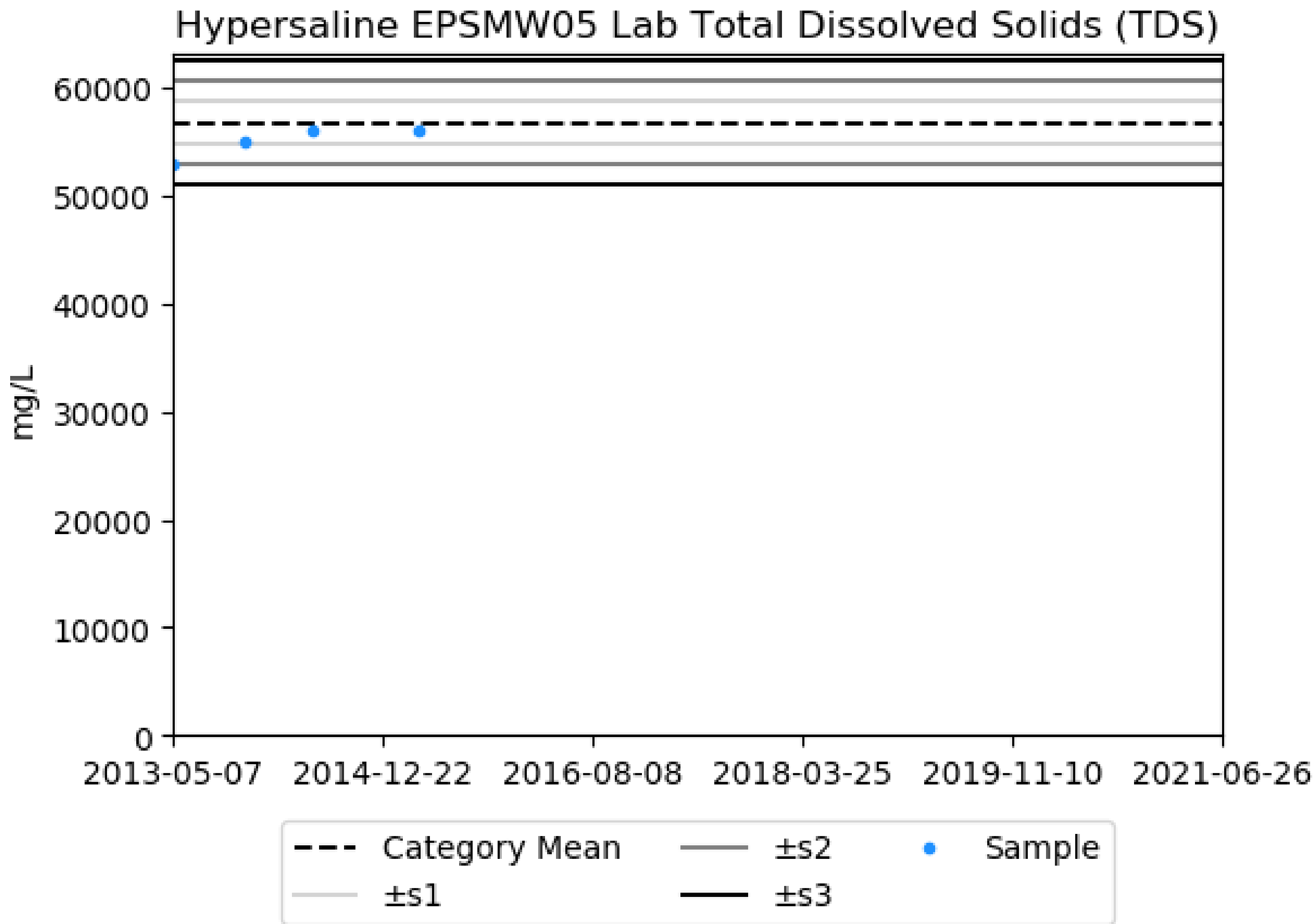


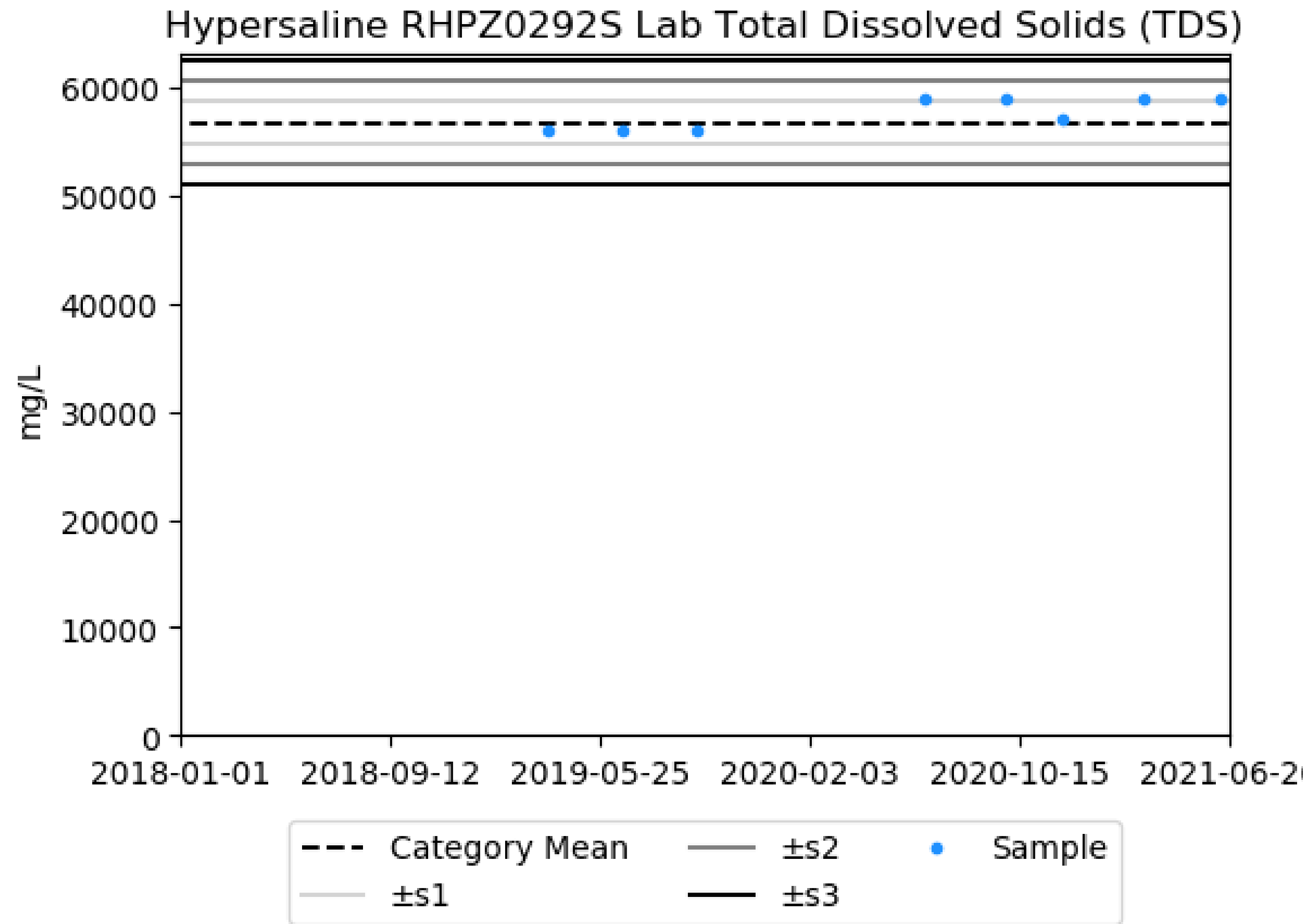
Fresh RHPZ0088 Lab Total Dissolved Solids (TDS)

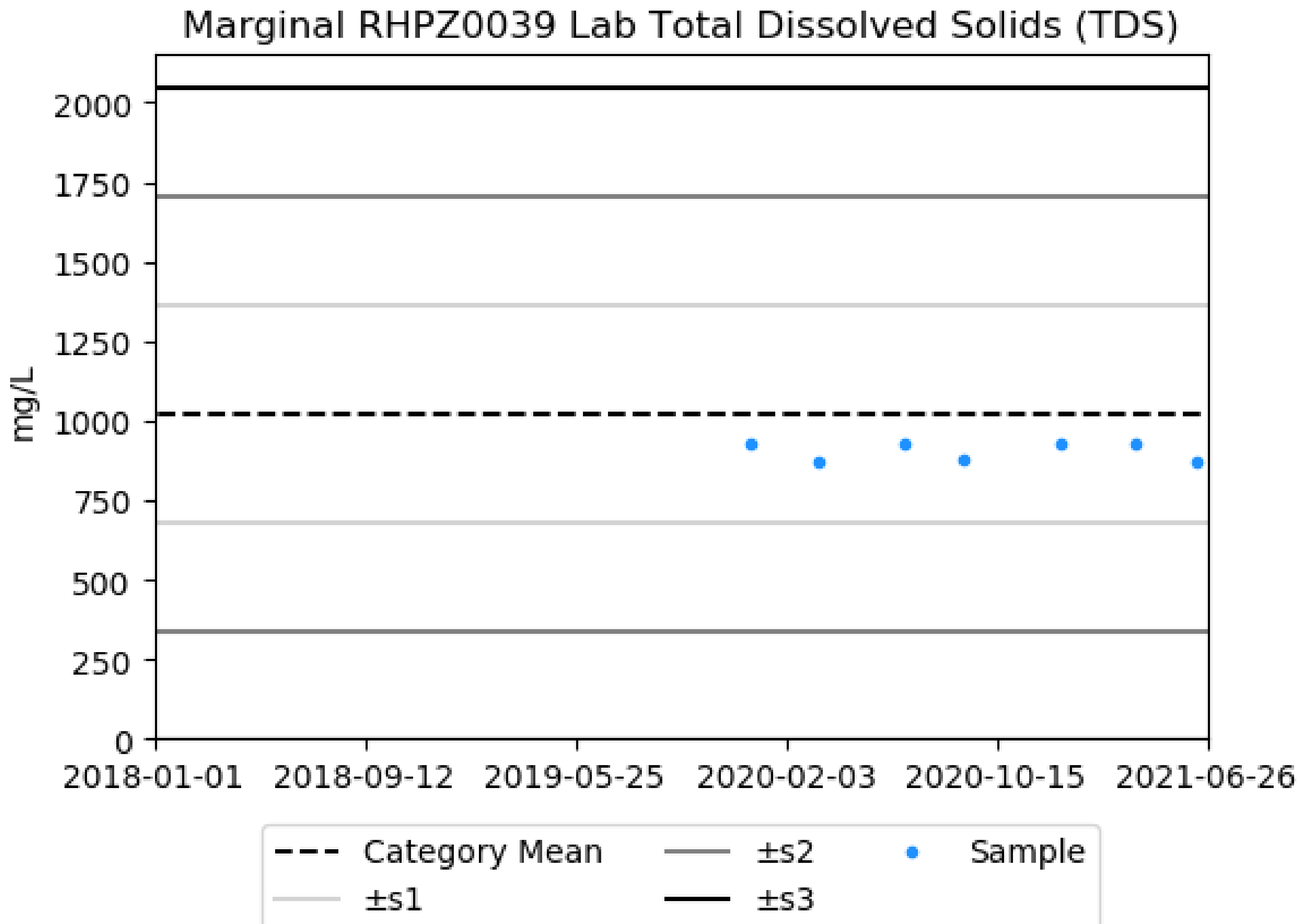


Fresh RHPZ0184 Lab Total Dissolved Solids (TDS)




Hypersaline EPSMW05 Lab Total Dissolved Solids (TDS)
mg/L
60000
50000
40000
30000
20000
10000
0
2013-05-07
2014-12-22
2016-08-08
2018-03-25
2019-11-10
2021-06-26
Category Mean
±s1
±s2
±s3
Sample


Hypersaline RHPZ0292S Lab Total Dissolved Solids (TDS)
mg/L
60000
50000
40000
30000
20000
10000
0
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample


Marginal RHPZ0039 Lab Total Dissolved Solids (TDS)
mg/L
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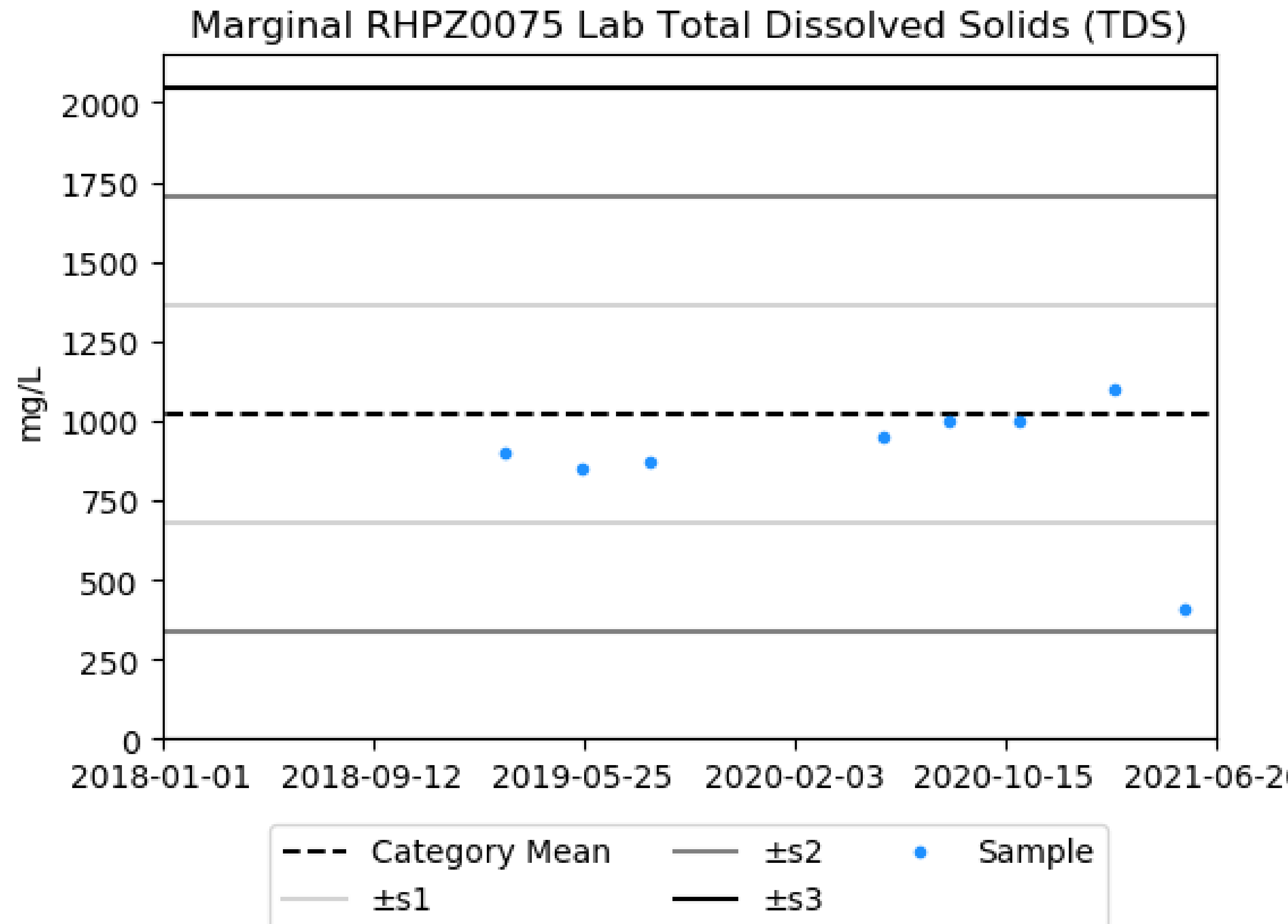
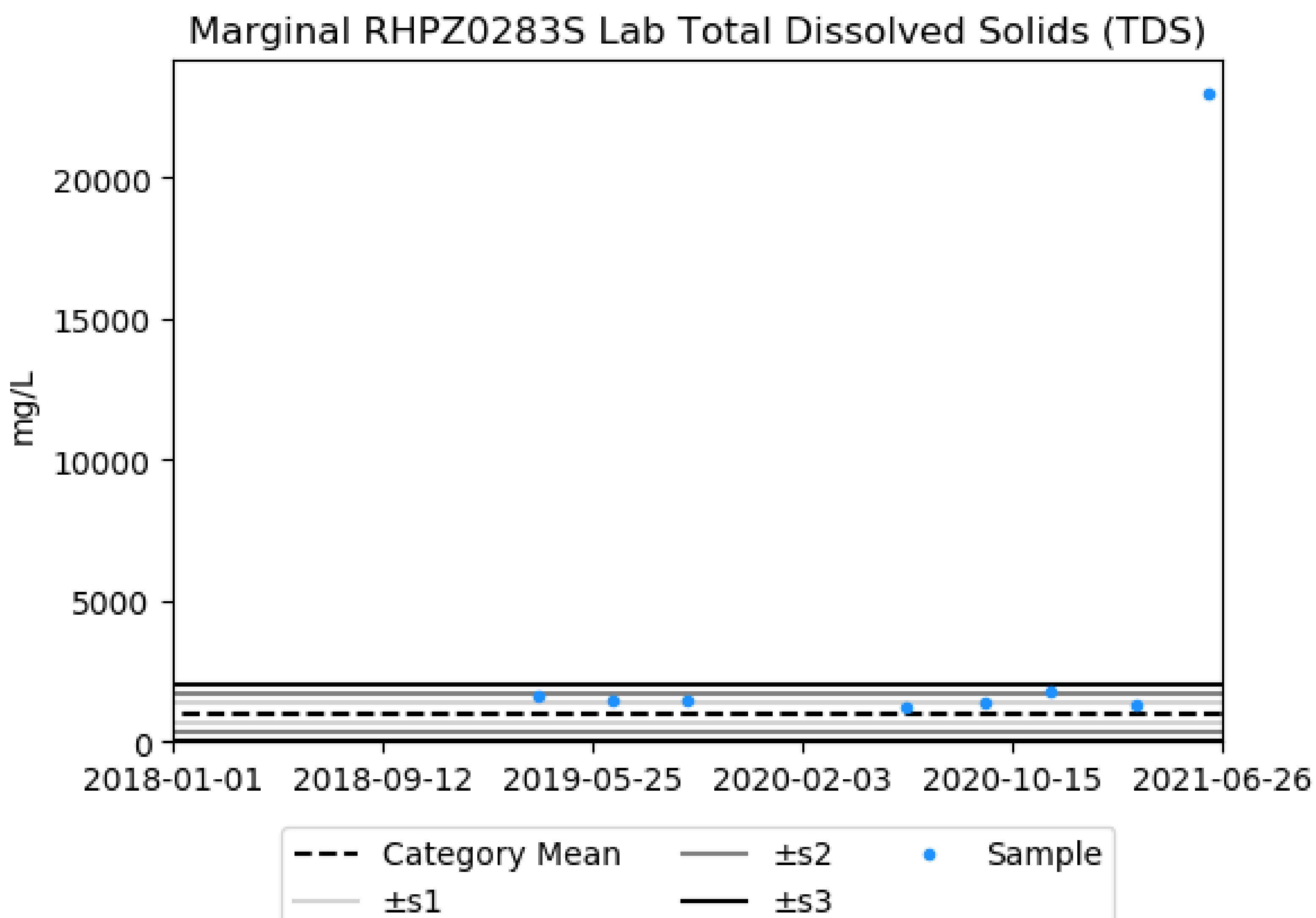
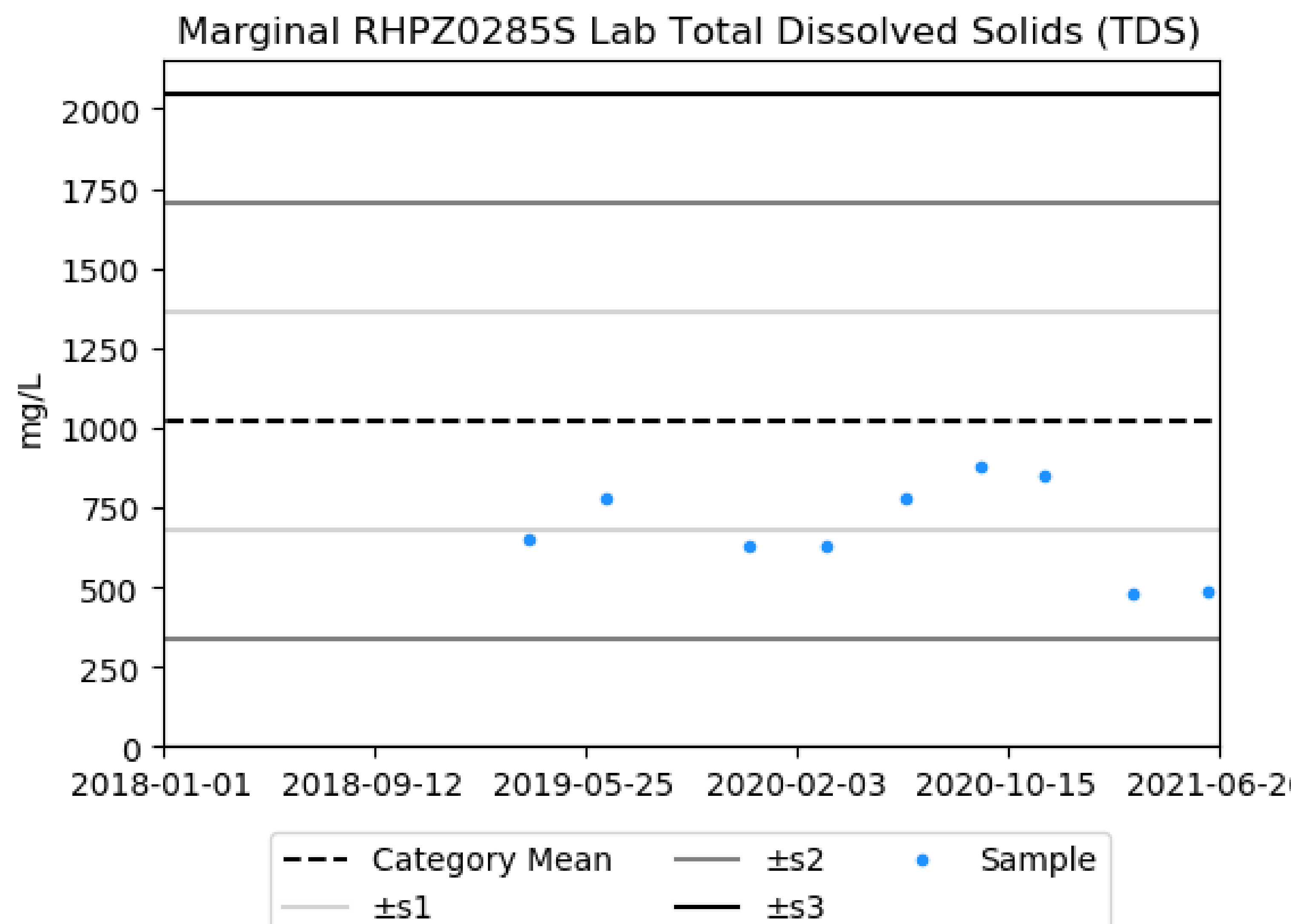
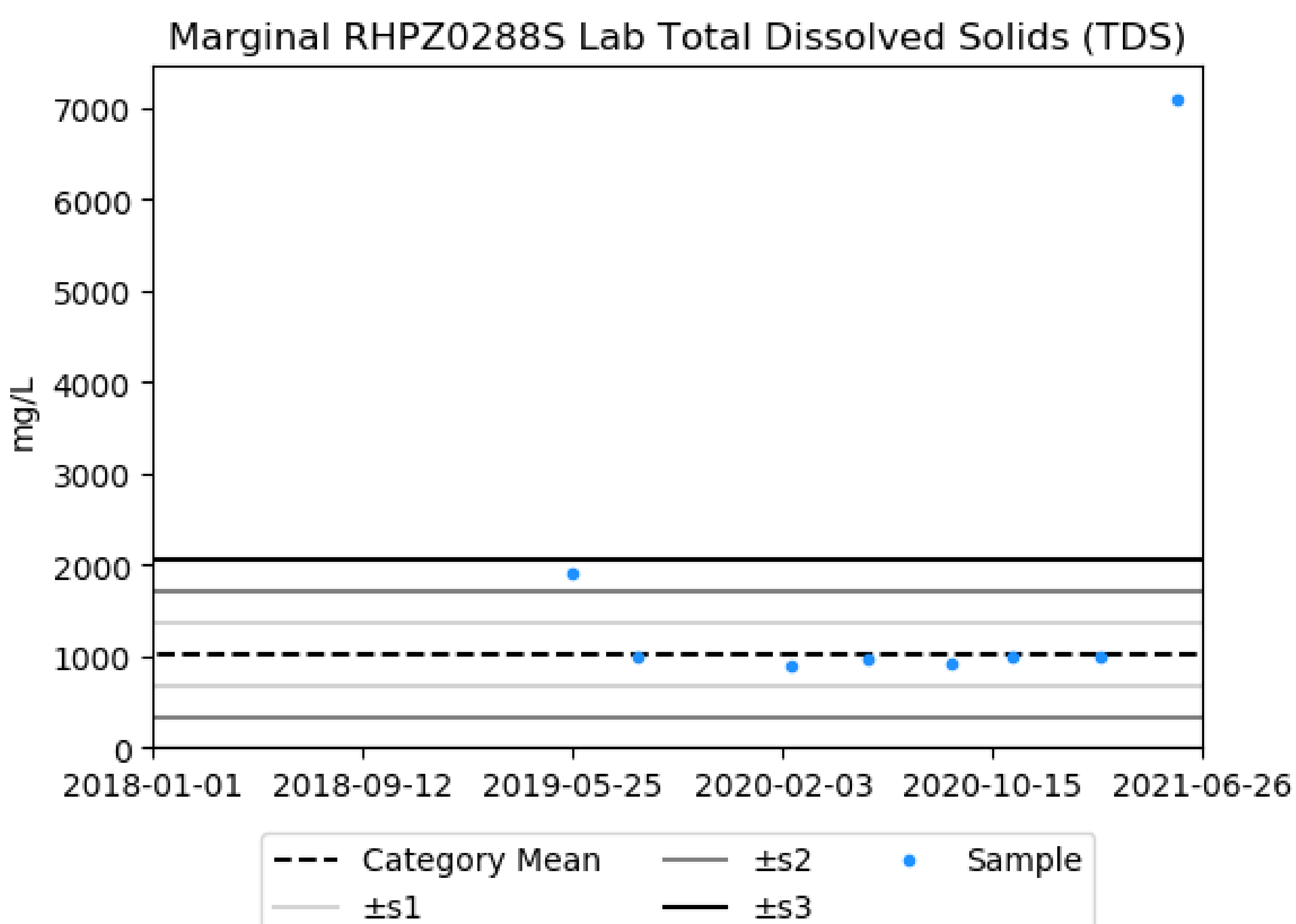
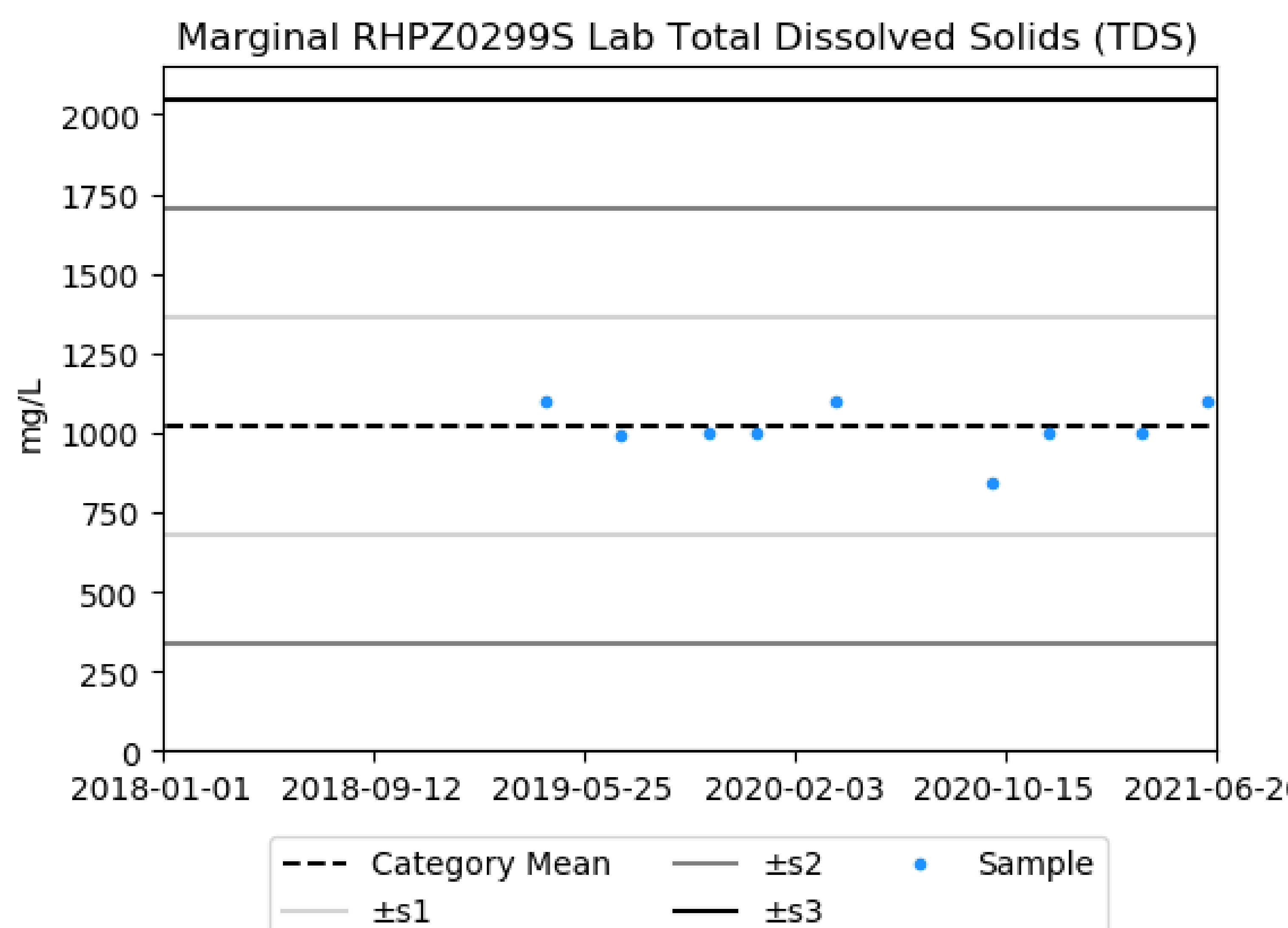
250
500
750
1000
1250
1500
1750
2000
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

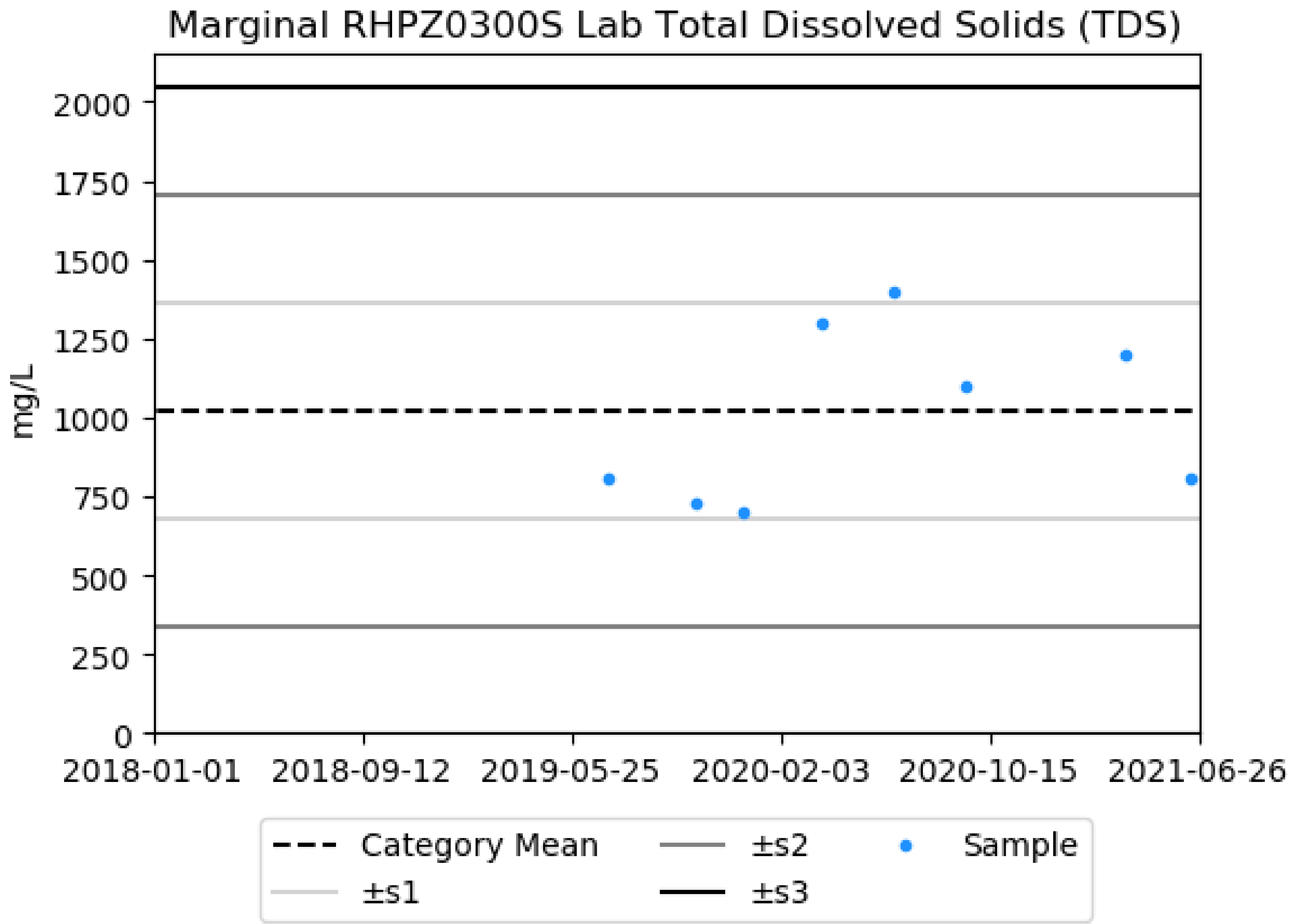

Marginal RHPZ0075 Lab Total Dissolved Solids (TDS)
mg/L
0
250
500
750
1000
1250
1500
1750
2000
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

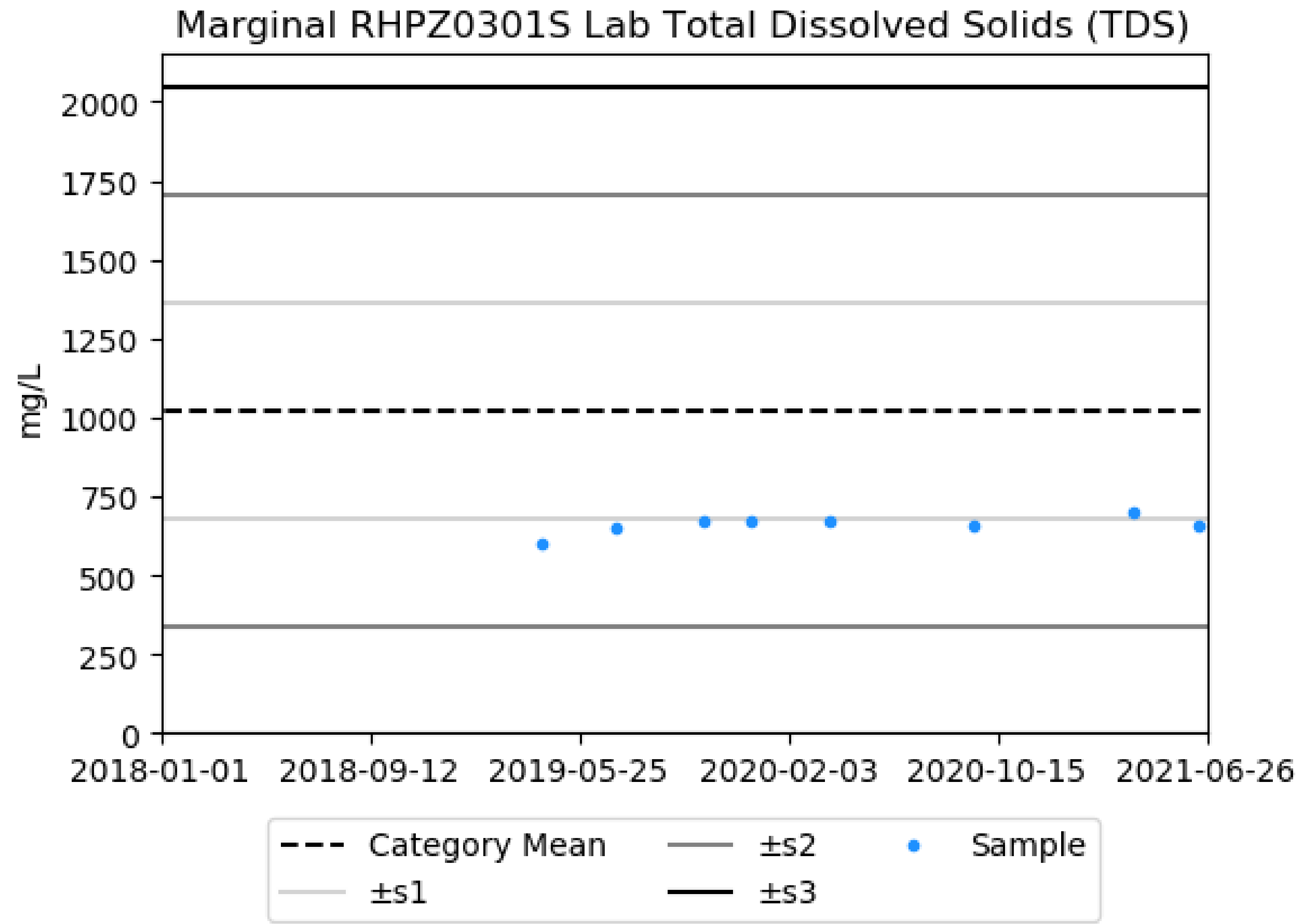

Marginal RHPZ0283S Lab Total Dissolved Solids (TDS)
mg/L
0
5000
10000
15000
20000
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

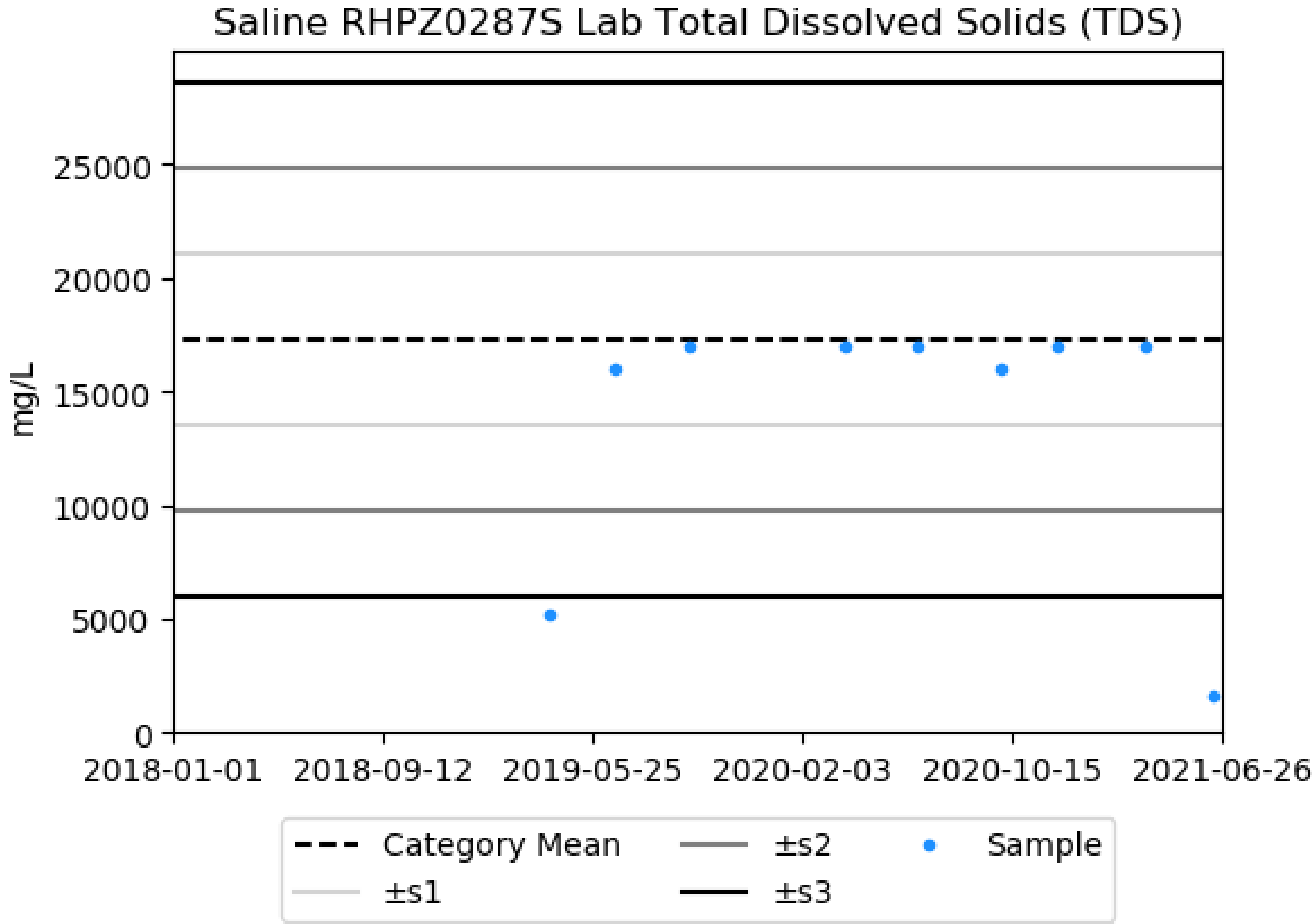

Marginal RHPZ0285S Lab Total Dissolved Solids (TDS)
mg/L
0
250
500
750
1000
1250
1500
1750
2000
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

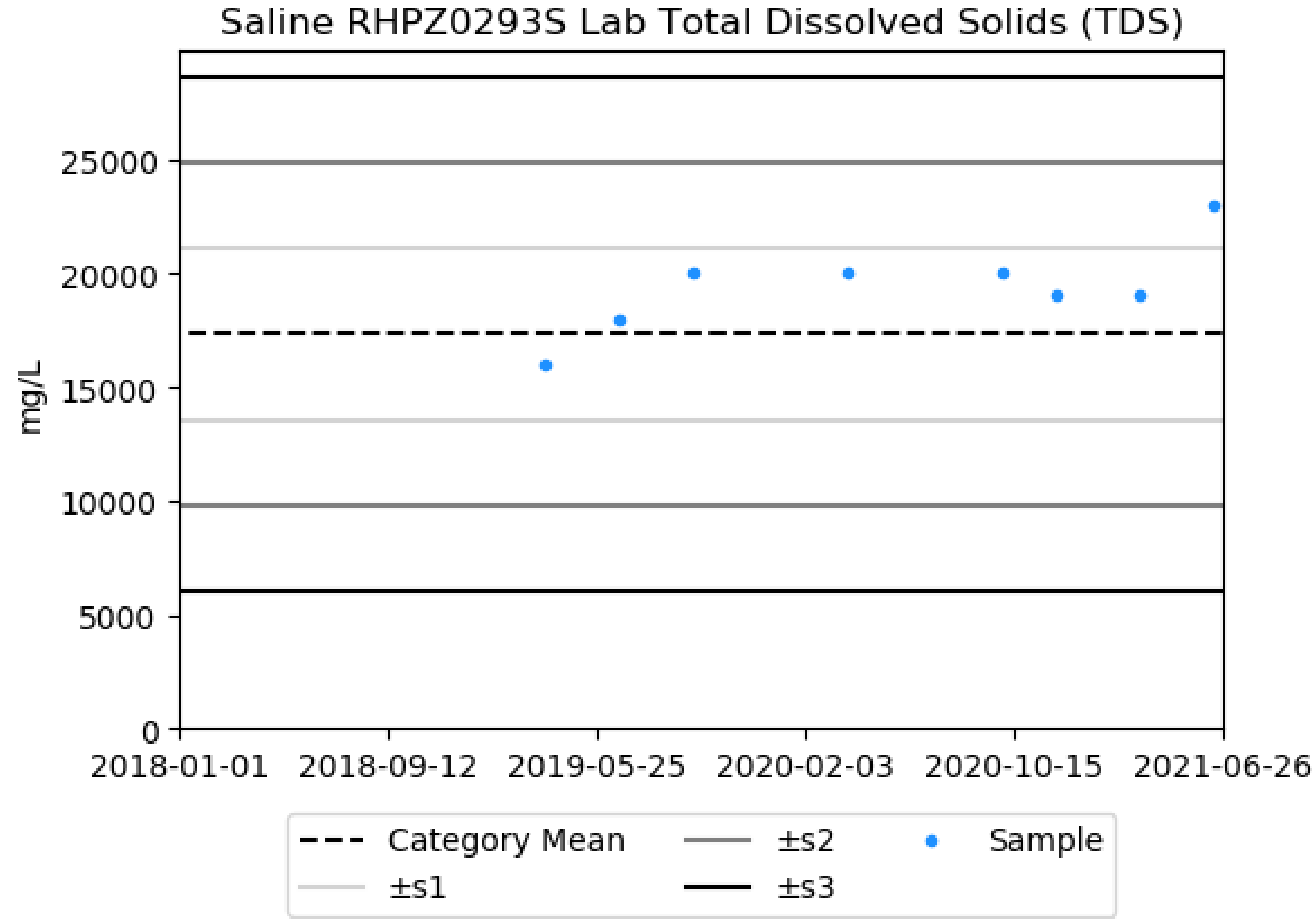

Marginal RHPZ0288S Lab Total Dissolved Solids (TDS)
mg/L
0
1000
2000
3000
4000
5000
6000
7000
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

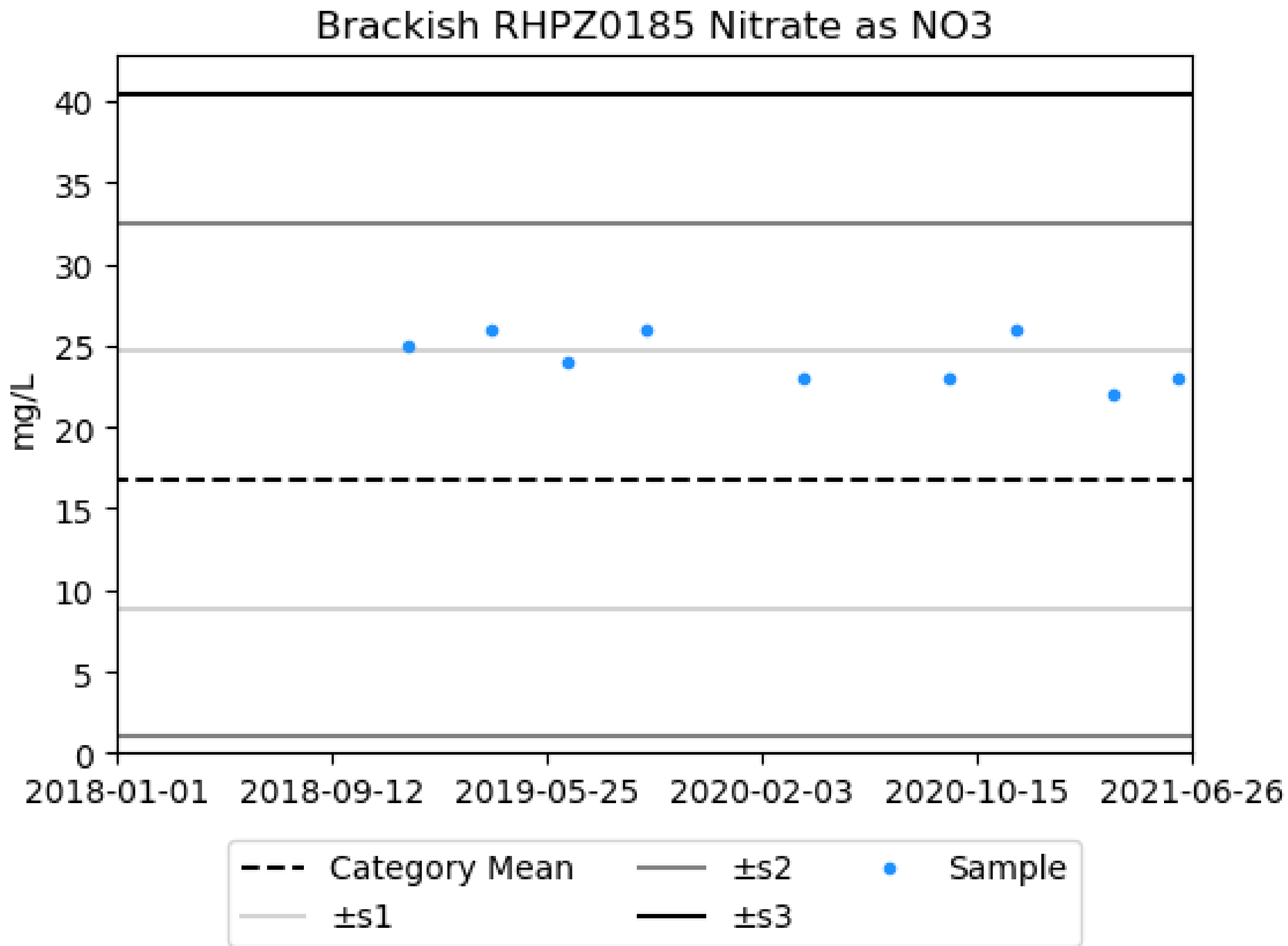

Marginal RHPZ0299S Lab Total Dissolved Solids (TDS)
mg/L
0
250
500
750
1000
1250
1500
1750
2000
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

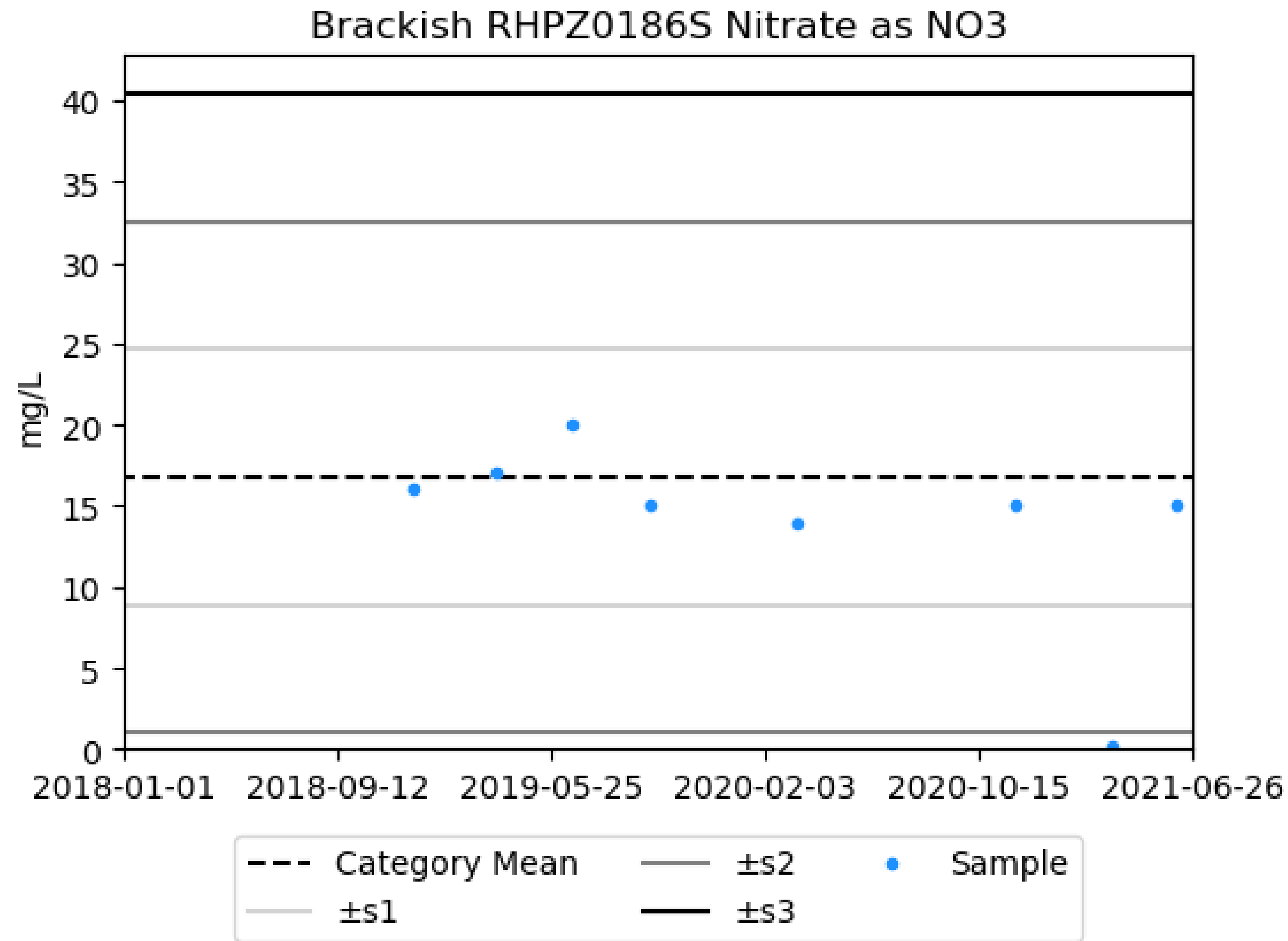

Marginal RHPZ0300S Lab Total Dissolved Solids (TDS)
mg/L
2000
1750
1500
1250
1000
750
500
250
0
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

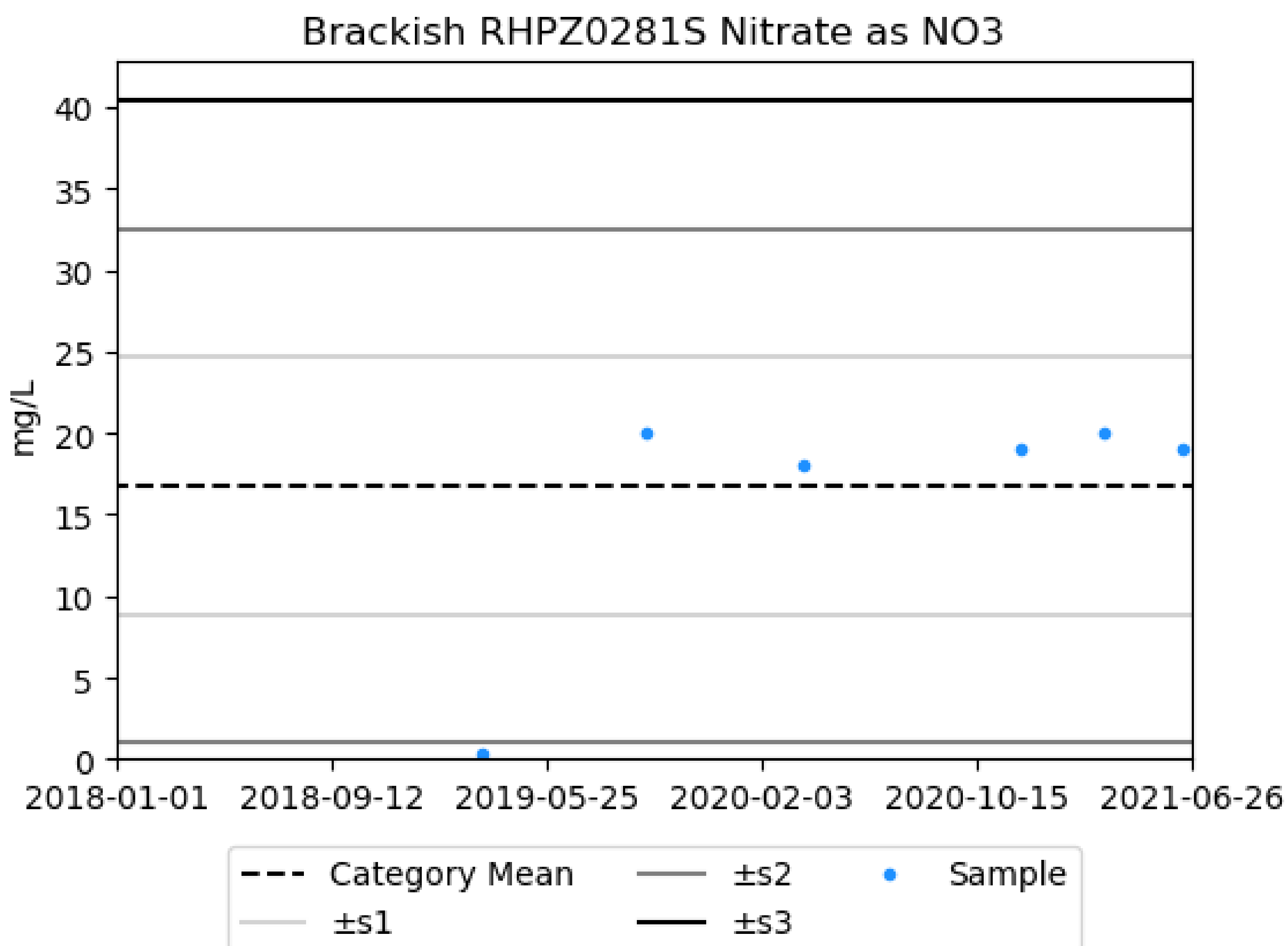

Marginal RHPZ0301S Lab Total Dissolved Solids (TDS)
mg/L
2000
1750
1500
1250
1000
750
500
250
0
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

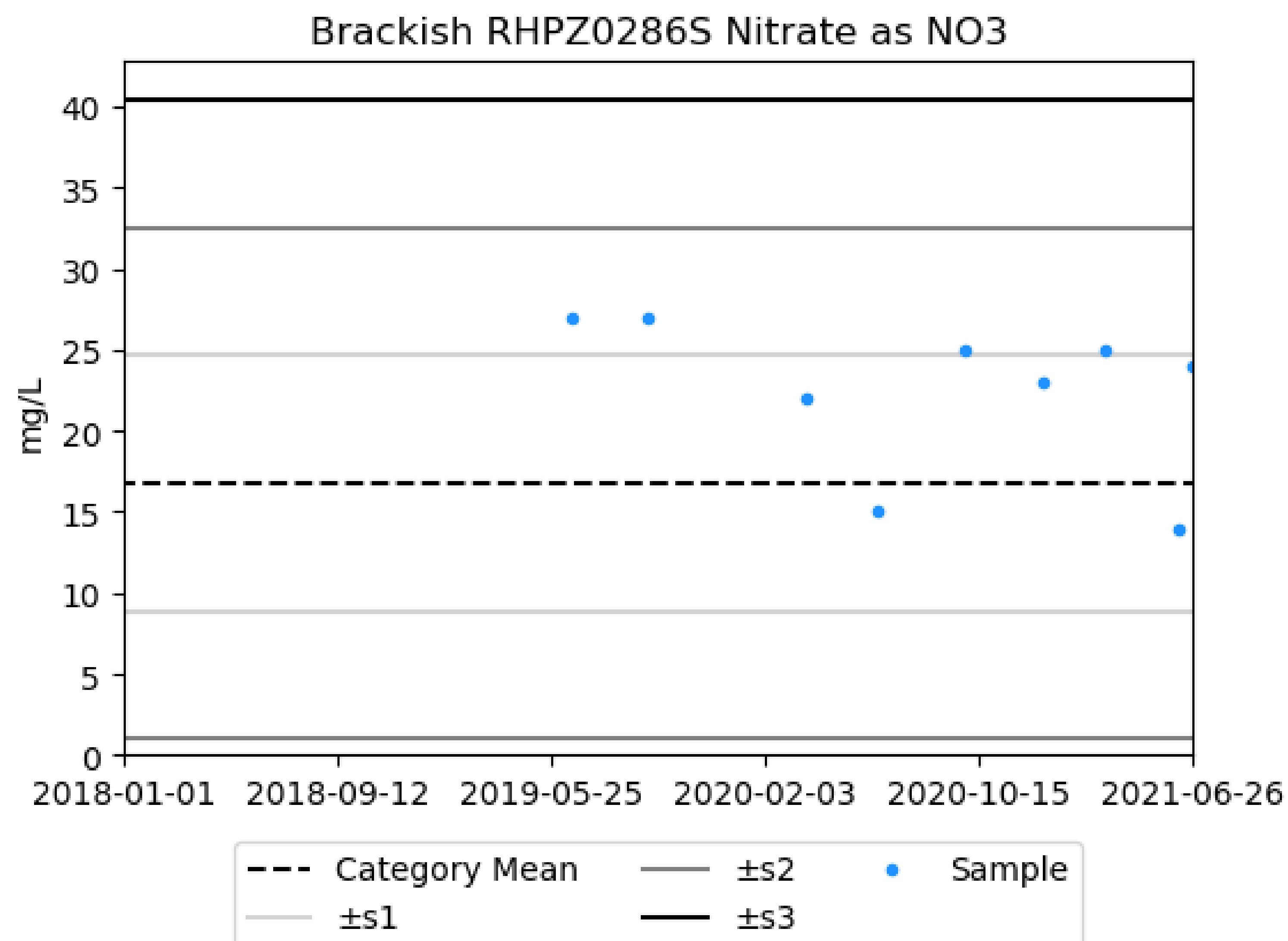

Saline RHPZ0287S Lab Total Dissolved Solids (TDS)
mg/L
25000
20000
15000
10000
5000
0
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

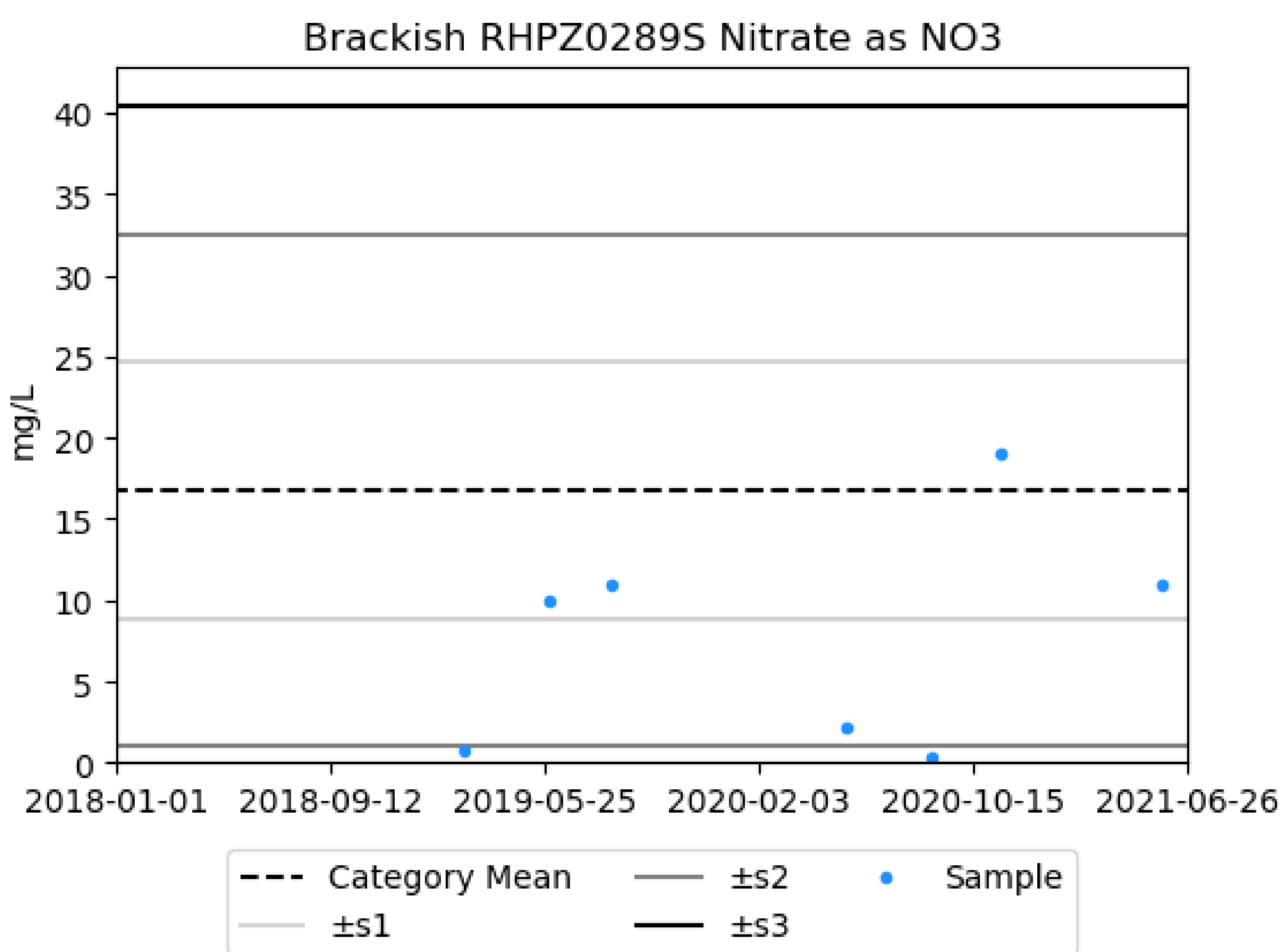

Saline RHPZ0293S Lab Total Dissolved Solids (TDS)
mg/L
25000
20000
15000
10000
5000
0
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

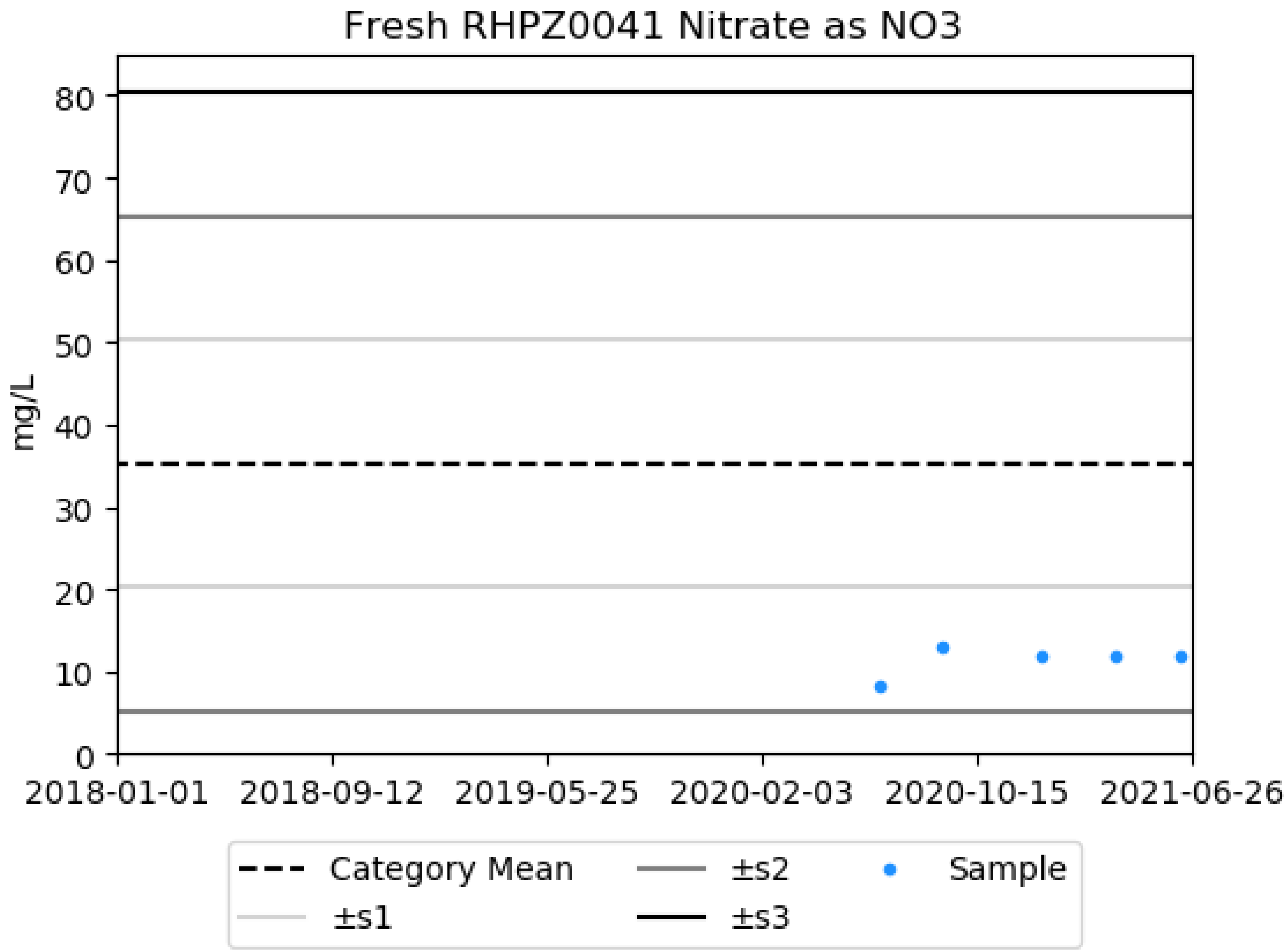

Brackish RHPZ0185 Nitrate as NO3
mg/L
0
5
10
15
20
25
30
35
40
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

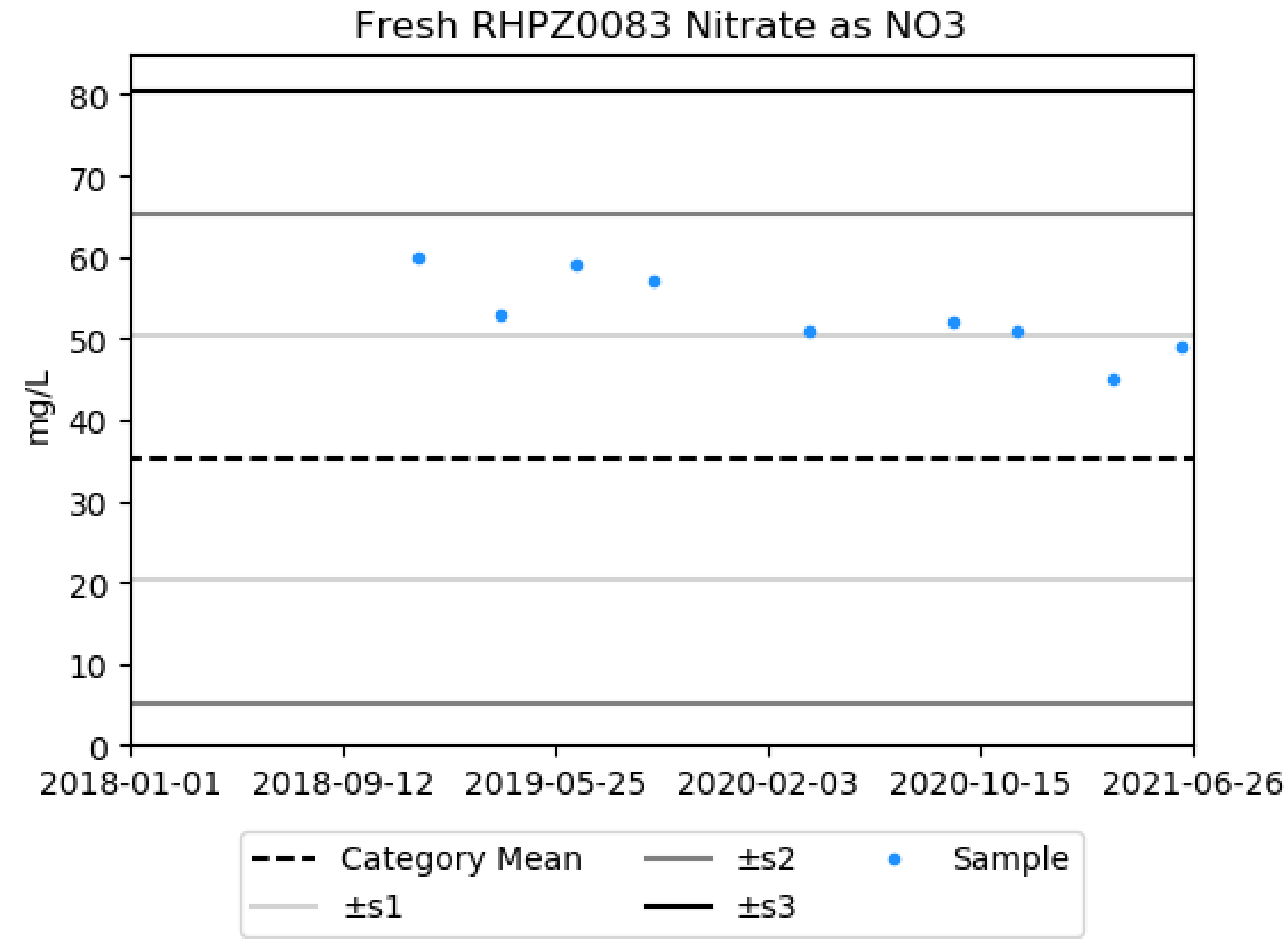

Brackish RHPZ0186S Nitrate as NO3
mg/L
0
5
10
15
20
25
30
35
40
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

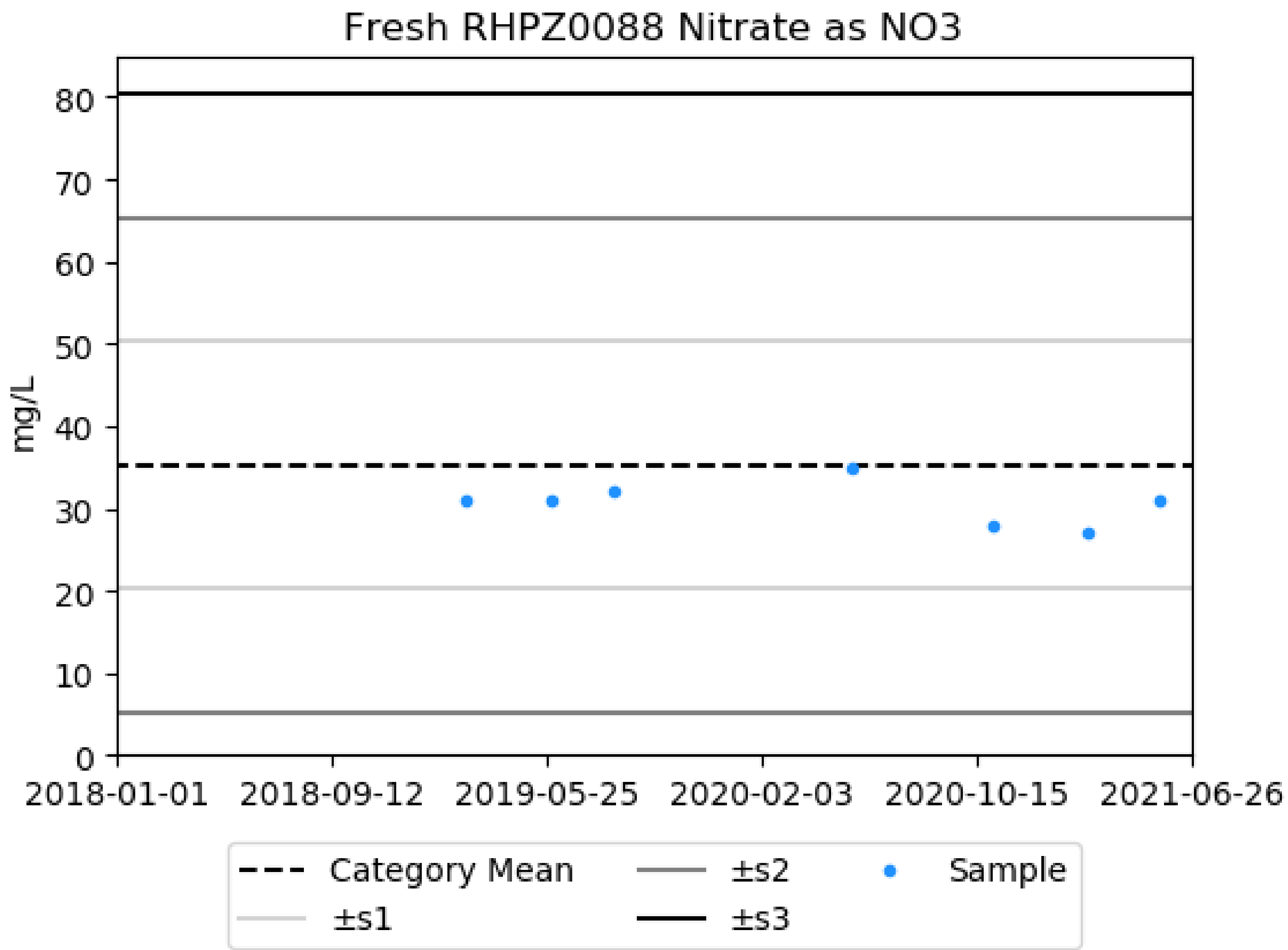

Brackish RHPZ0281S Nitrate as NO3
mg/L
0
5
10
15
20
25
30
35
40
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

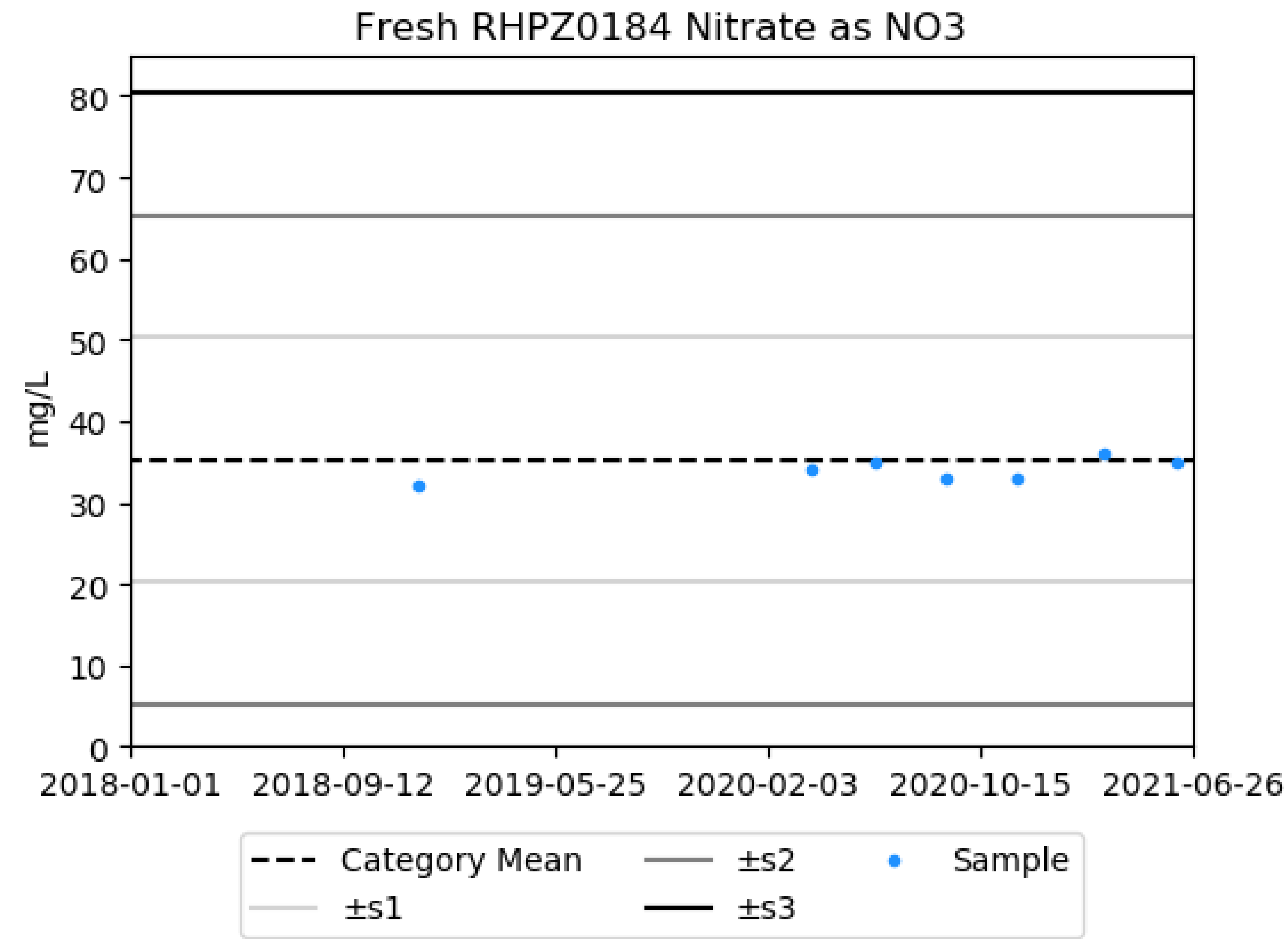

Brackish RHPZ0286S Nitrate as NO3
mg/L
0
5
10
15
20
25
30
35
40
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

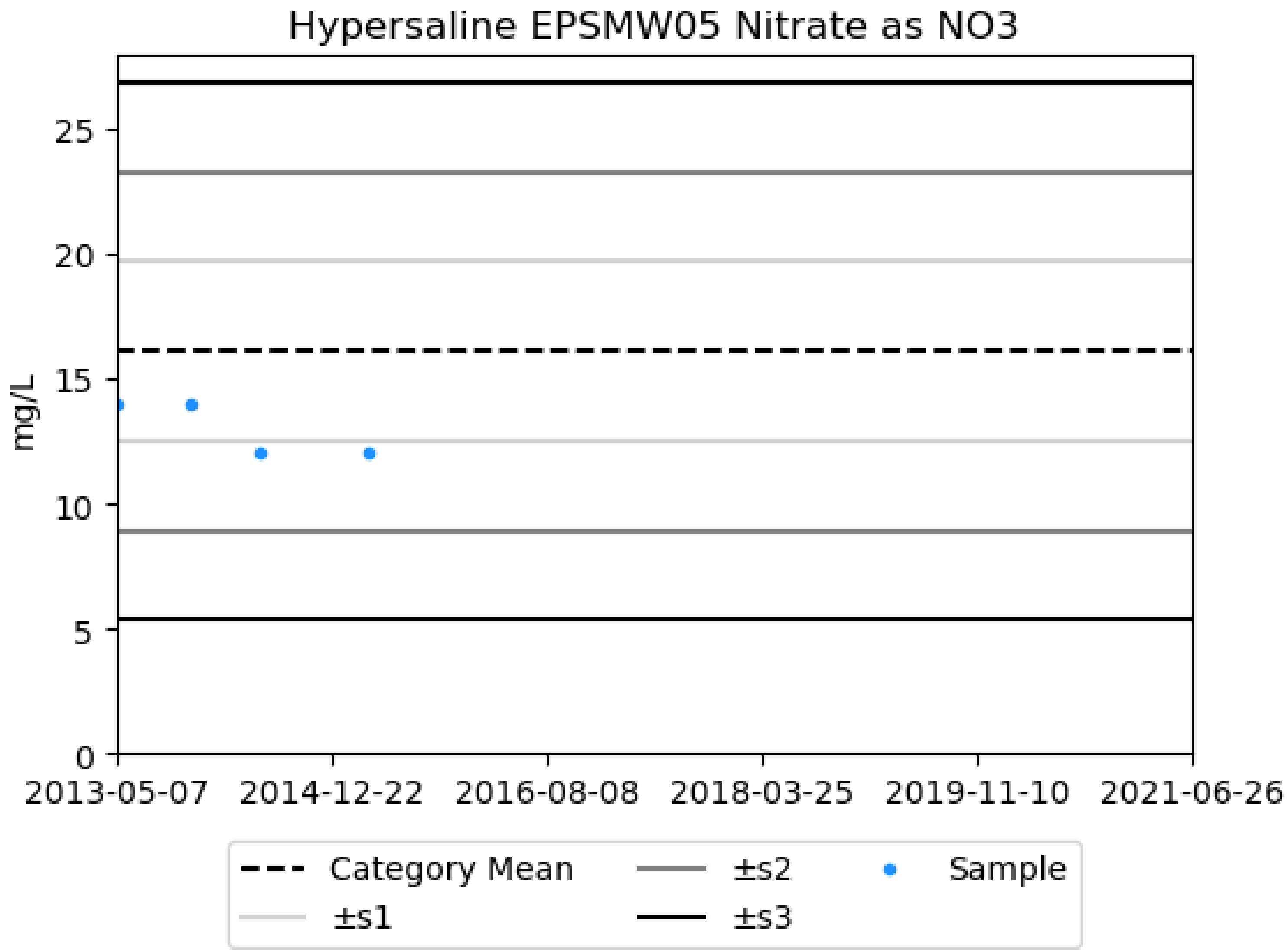

Brackish RHPZ0289S Nitrate as NO3
mg/L
0
5
10
15
20
25
30
35
40
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

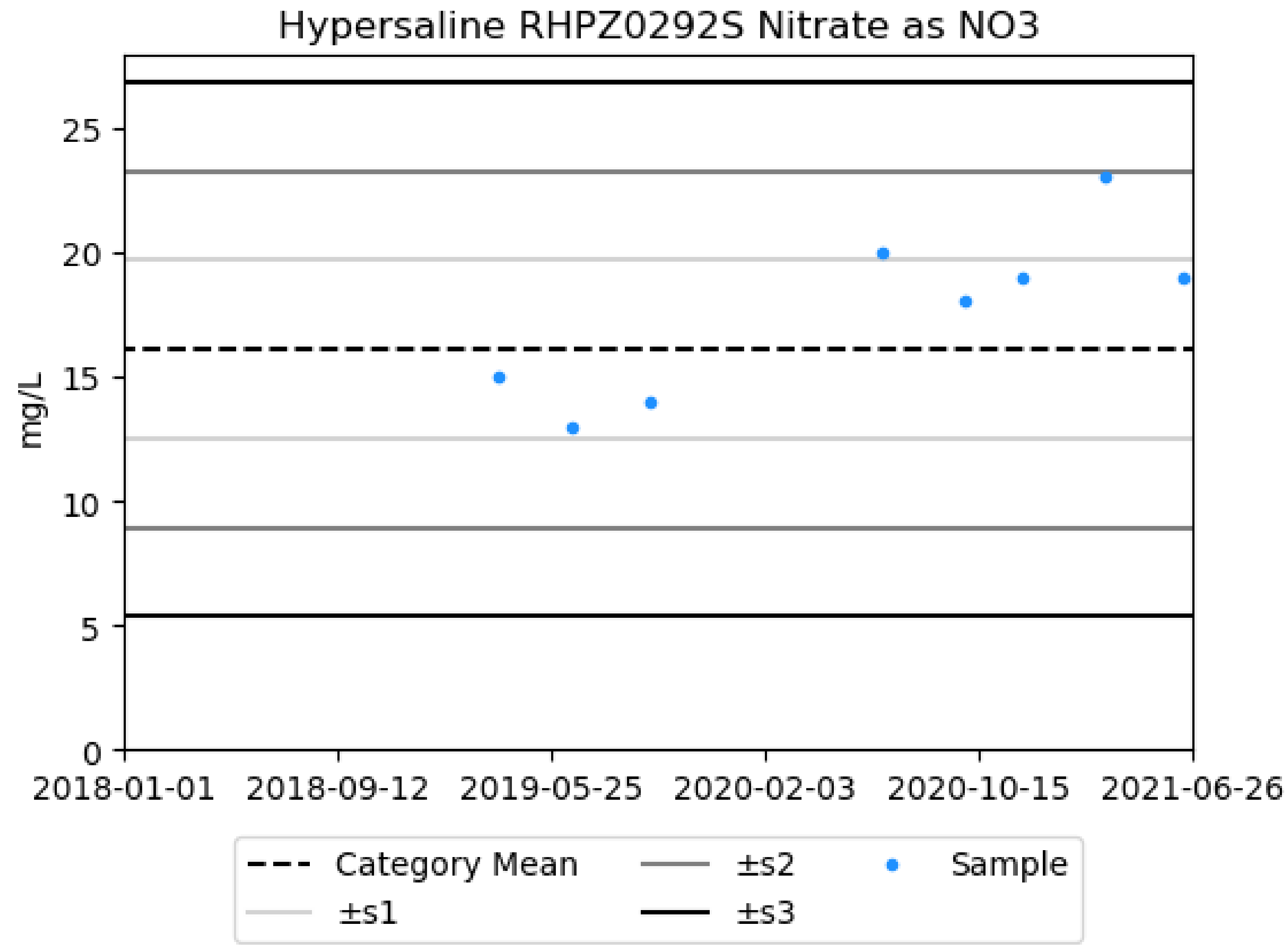

Fresh RHPZ0041 Nitrate as NO3
mg/L
0
10
20
30
40
50
60
70
80
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

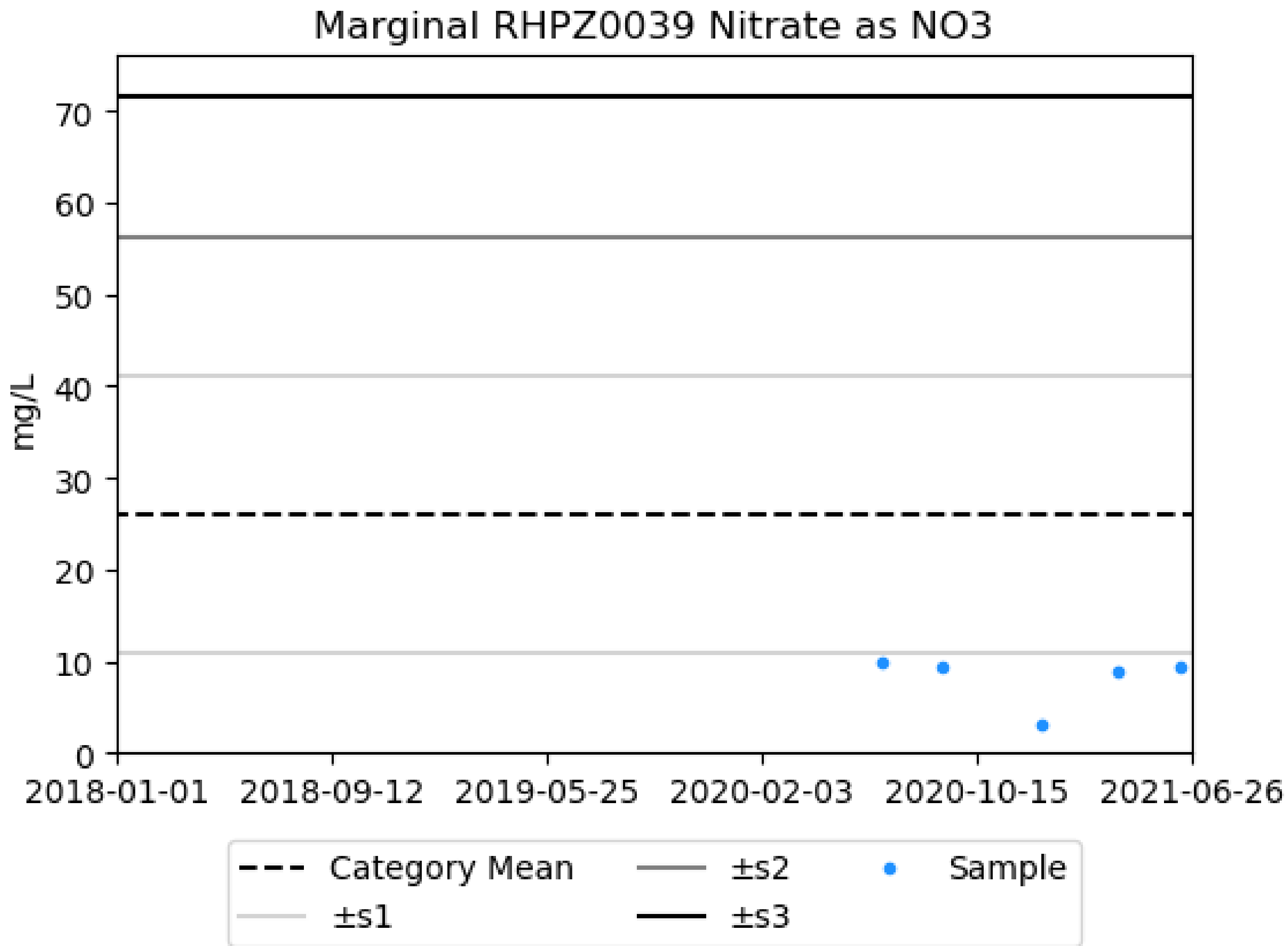

Fresh RHPZ0083 Nitrate as NO3
mg/L
0
10
20
30
40
50
60
70
80
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

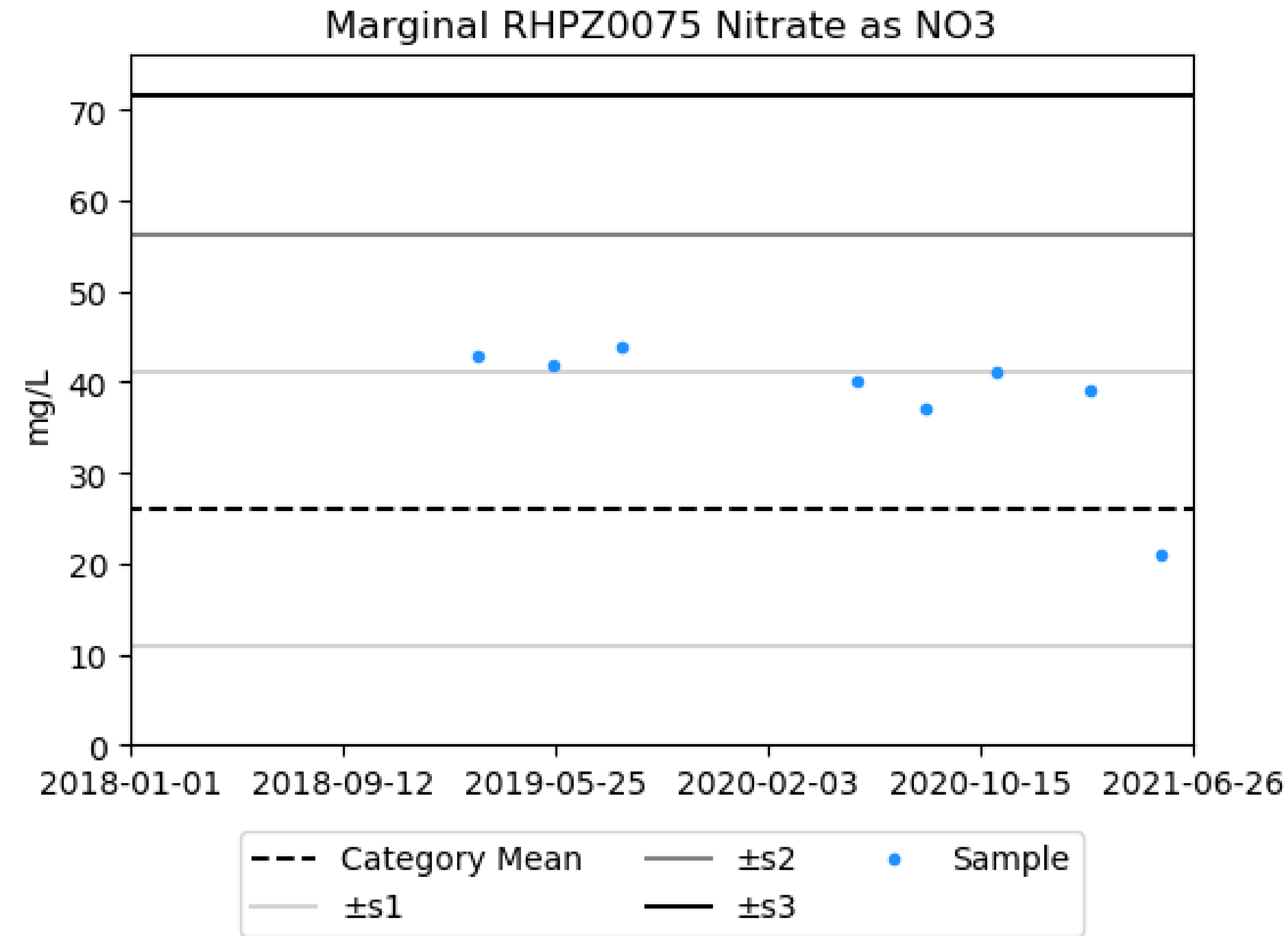

Fresh RHPZ0088 Nitrate as NO3
mg/L
0
10
20
30
40
50
60
70
80
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

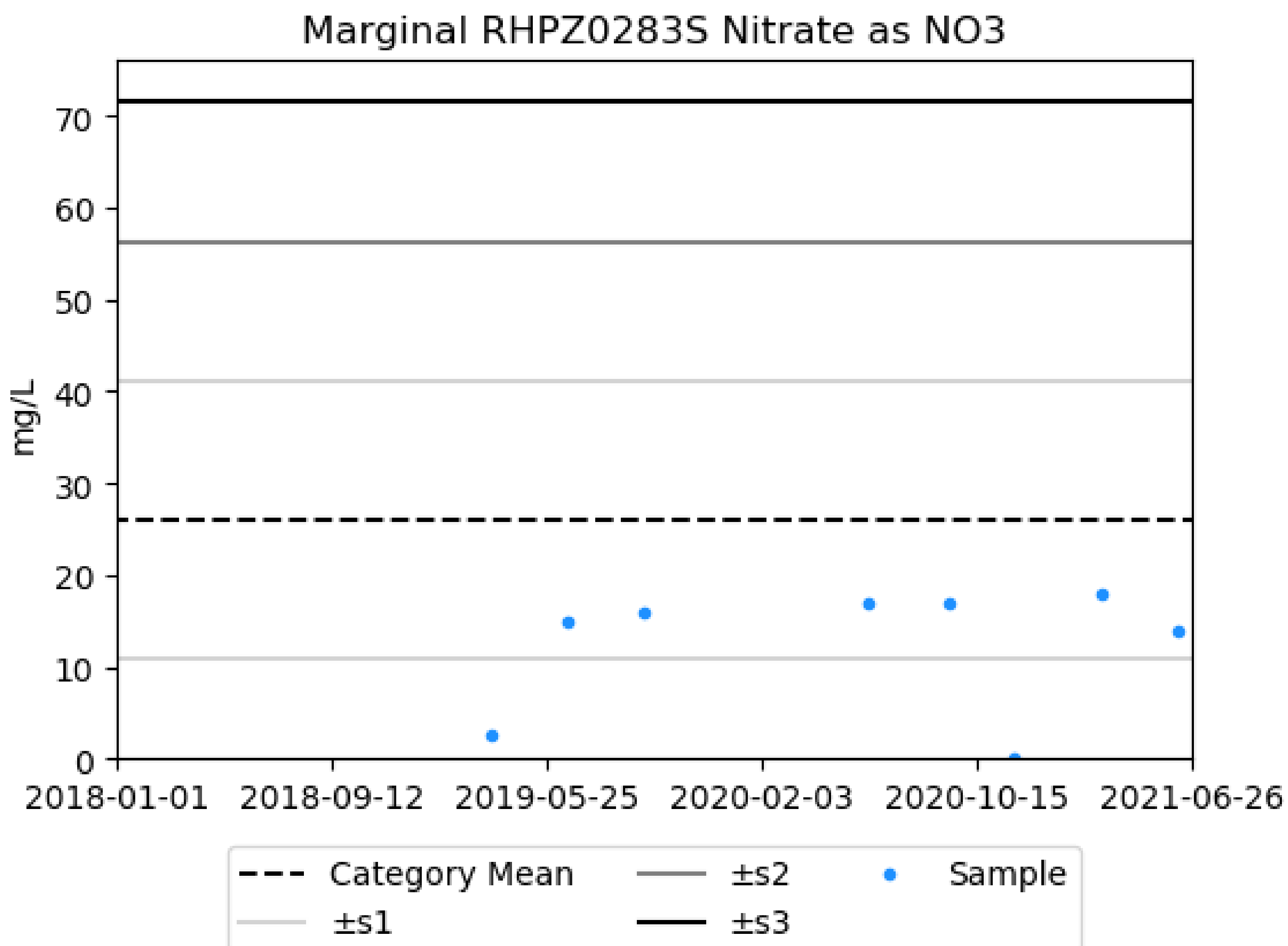

Fresh RHPZ0184 Nitrate as NO3
mg/L
0
10
20
30
40
50
60
70
80
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

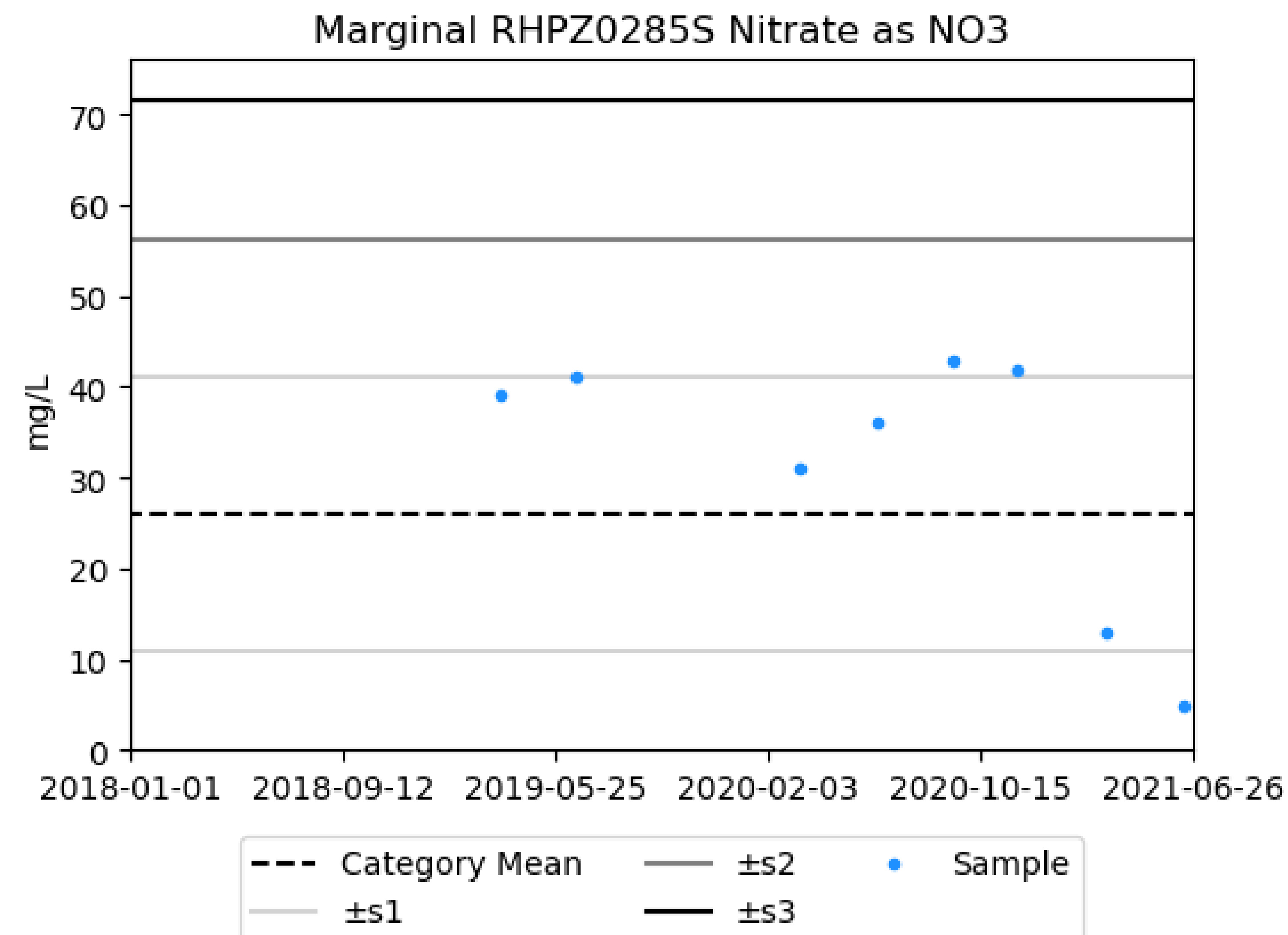

Hypersaline EPSMW05 Nitrate as NO3
mg/L
0
5
10
15
20
25
2013-05-07
2014-12-22
2016-08-08
2018-03-25
2019-11-10
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

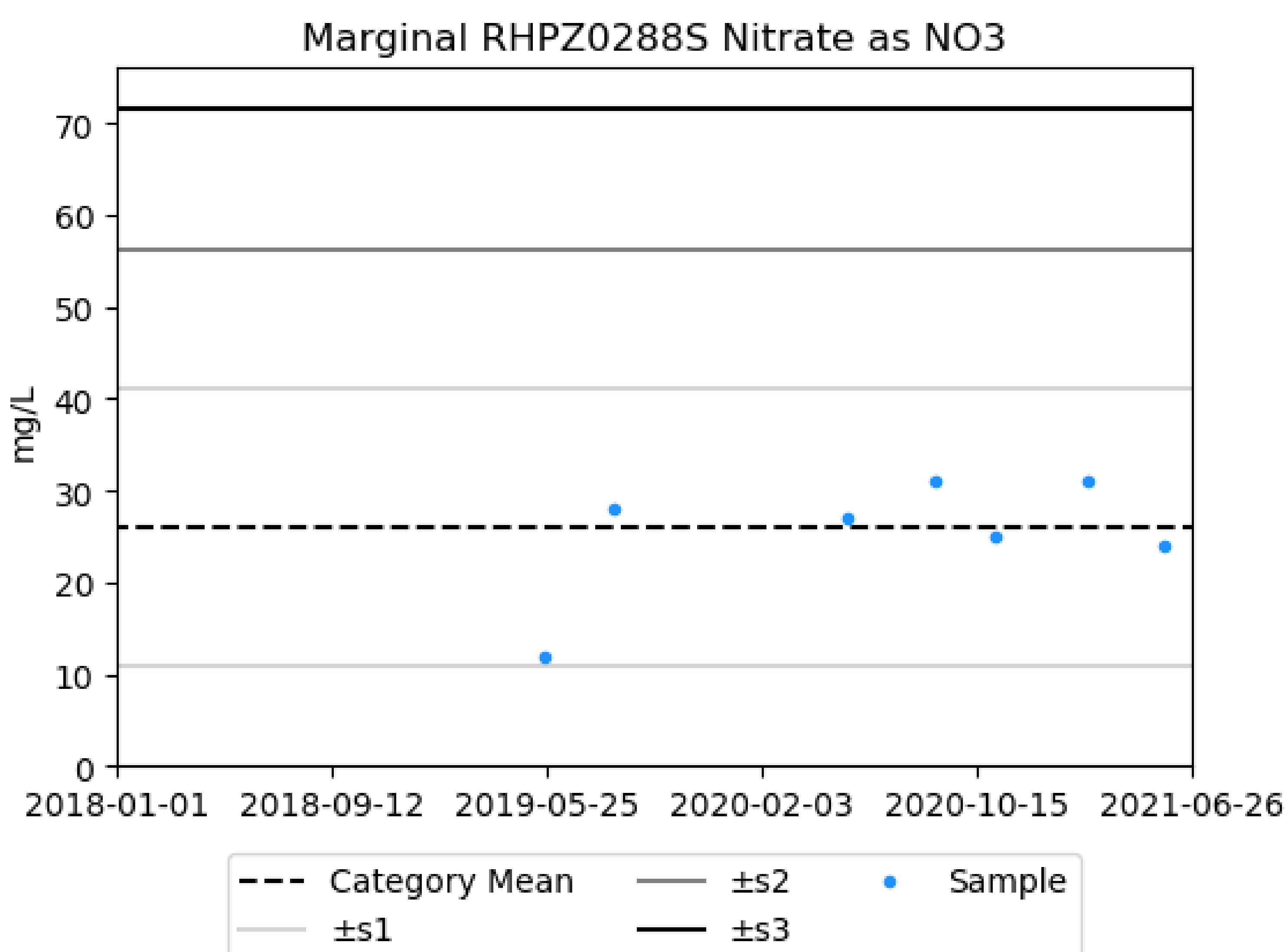

Hypersaline RHPZ0292S Nitrate as NO3
mg/L
0
5
10
15
20
25
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

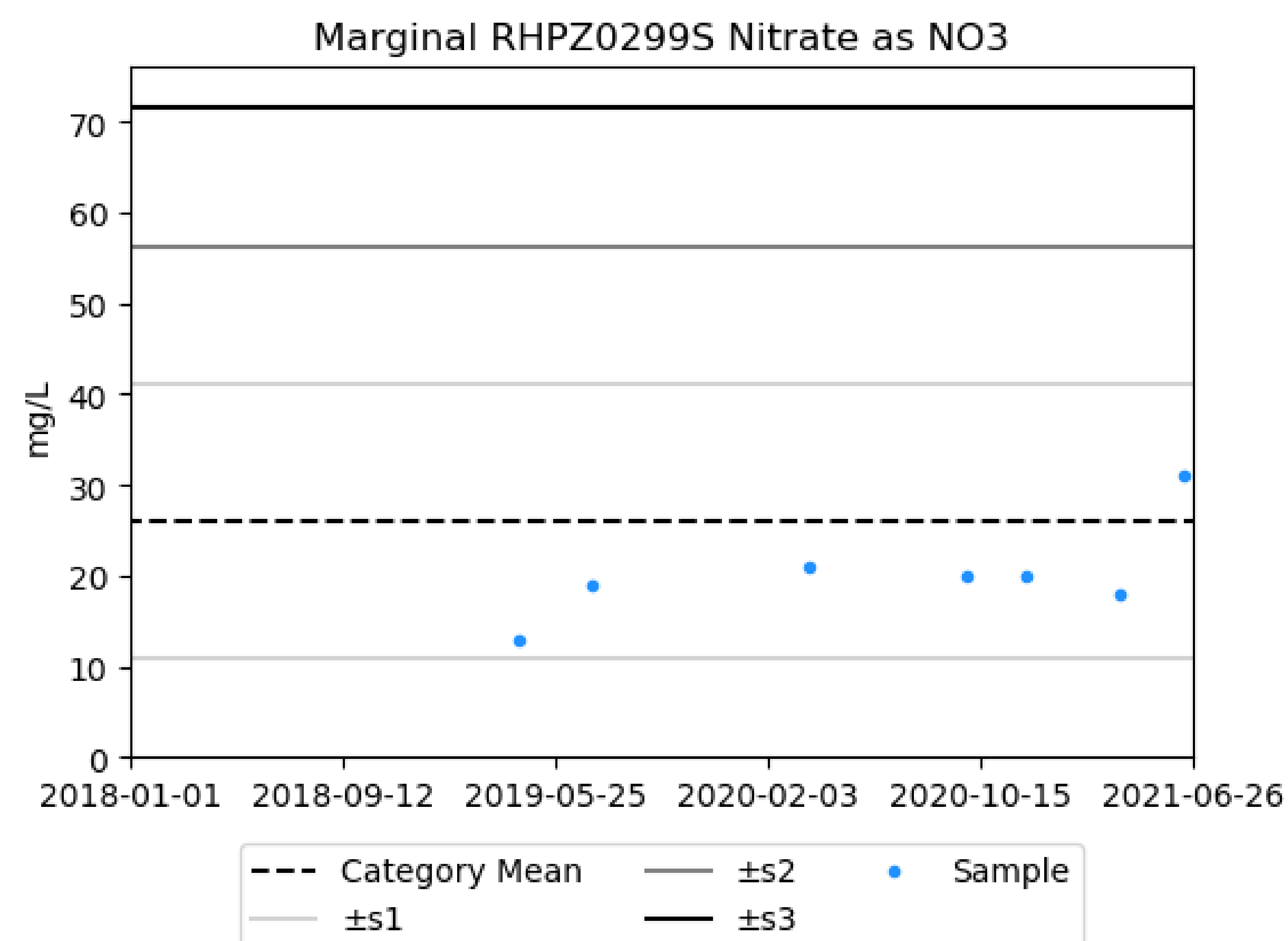

Marginal RHPZ0039 Nitrate as NO3
mg/L
0
10
20
30
40
50
60
70
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

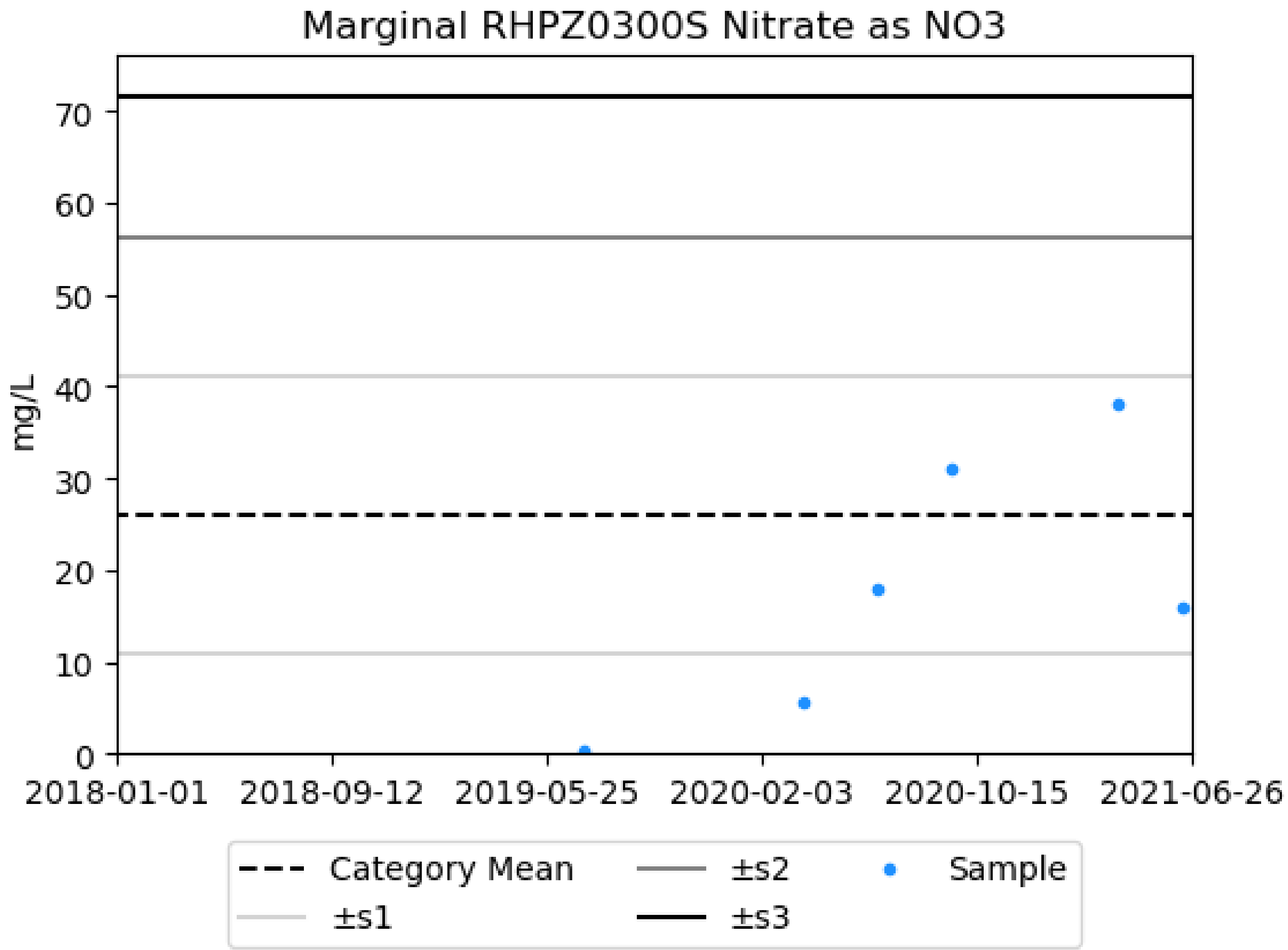

Marginal RHPZ0075 Nitrate as NO3
mg/L
0
10
20
30
40
50
60
70
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample


Marginal RHPZ0283S Nitrate as NO3
mg/L
0
10
20
30
40
50
60
70
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

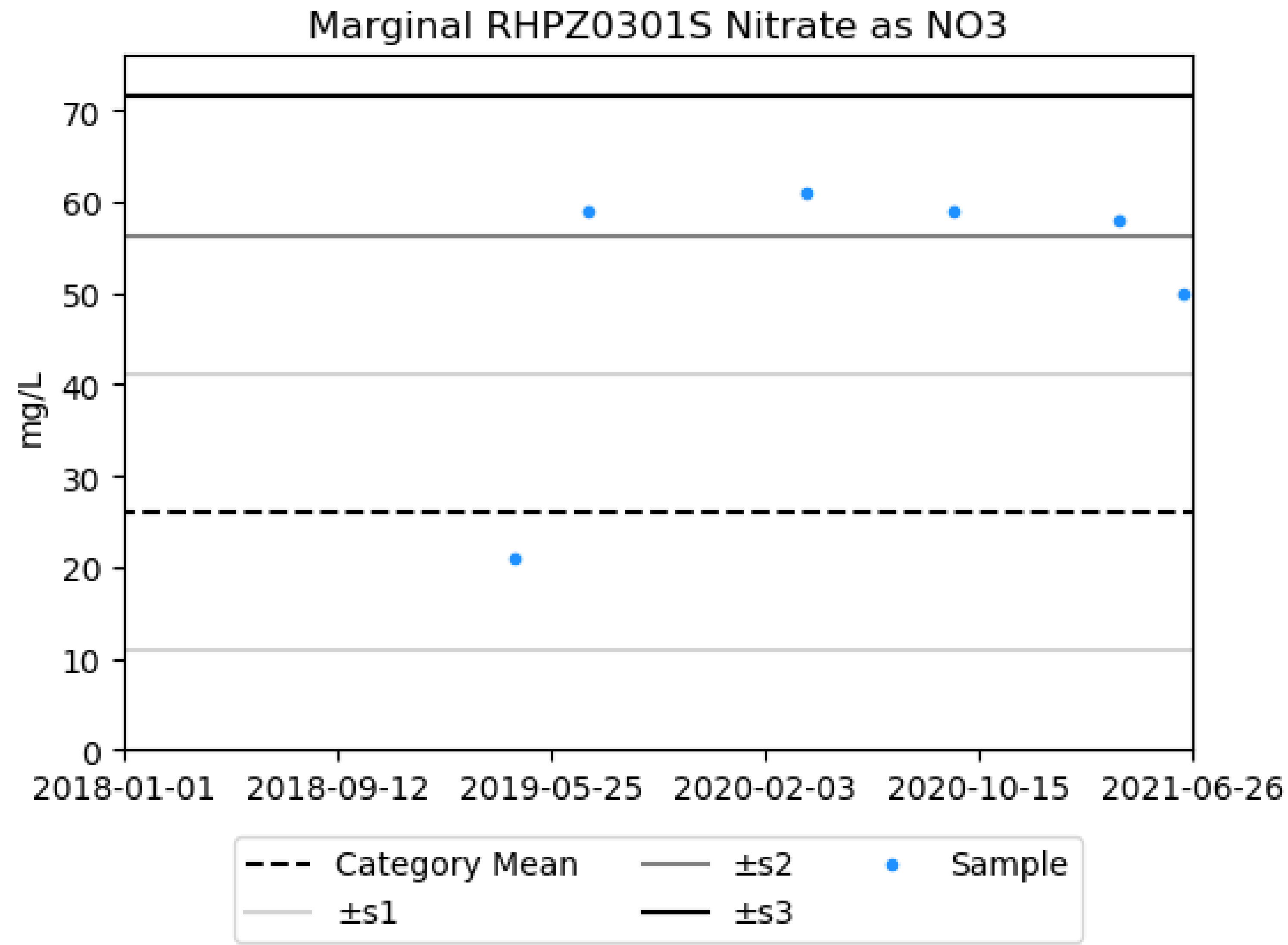

Marginal RHPZ0285S Nitrate as NO3
mg/L
0
10
20
30
40
50
60
70
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample


Marginal RHPZ0288S Nitrate as NO3
mg/L
0
10
20
30
40
50
60
70
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

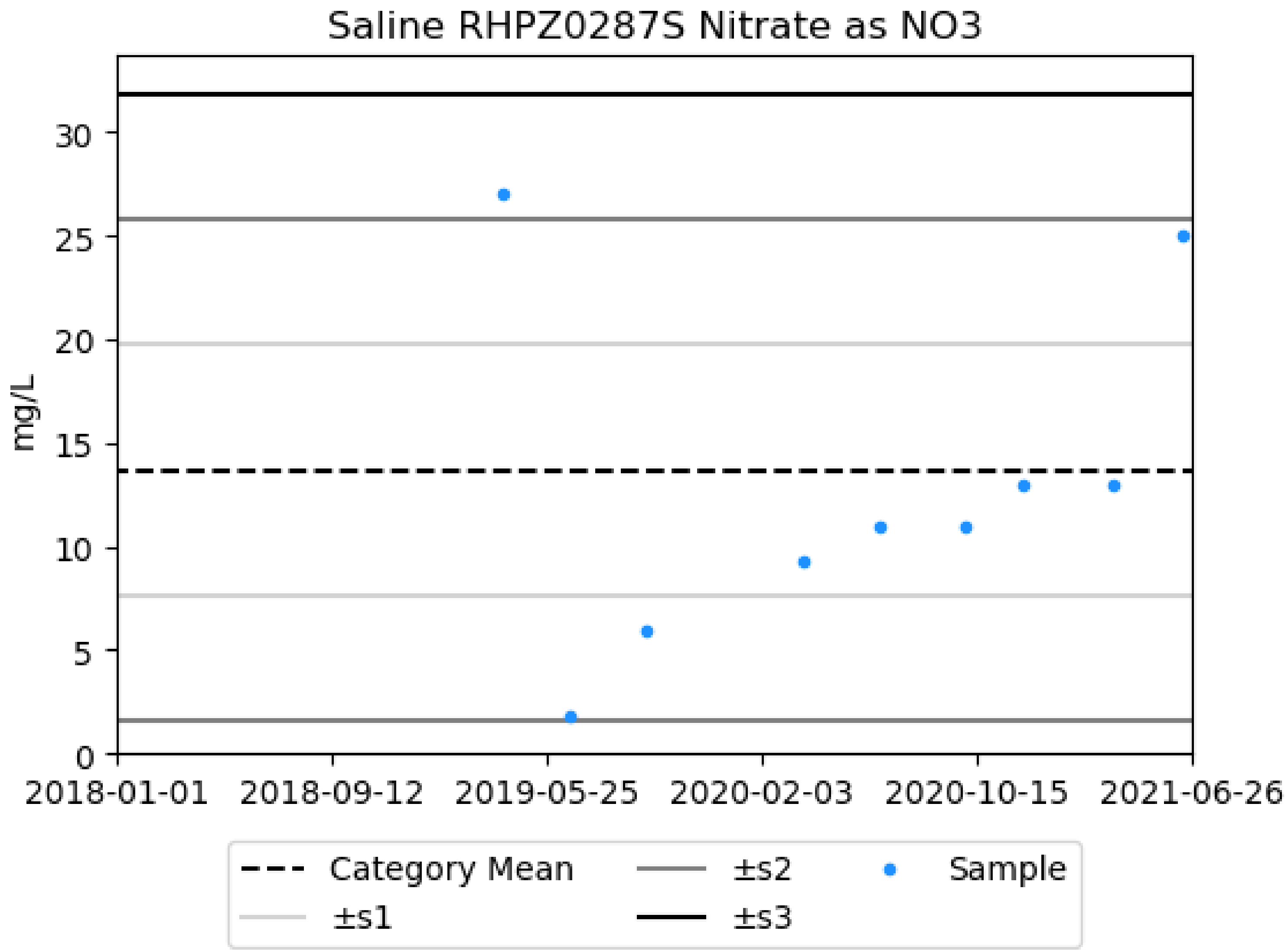

Marginal RHPZ0299S Nitrate as NO3
mg/L
0
10
20
30
40
50
60
70
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

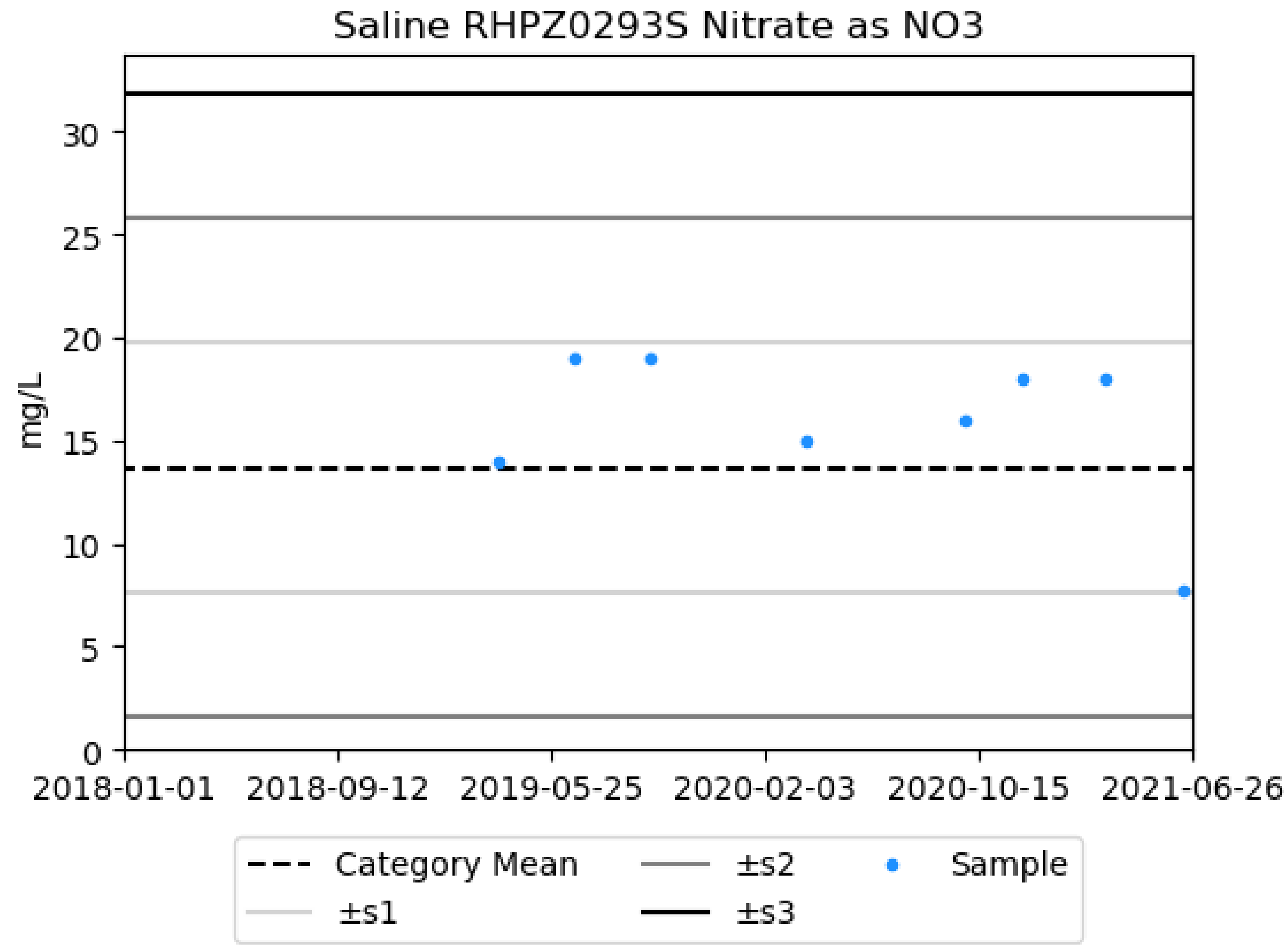


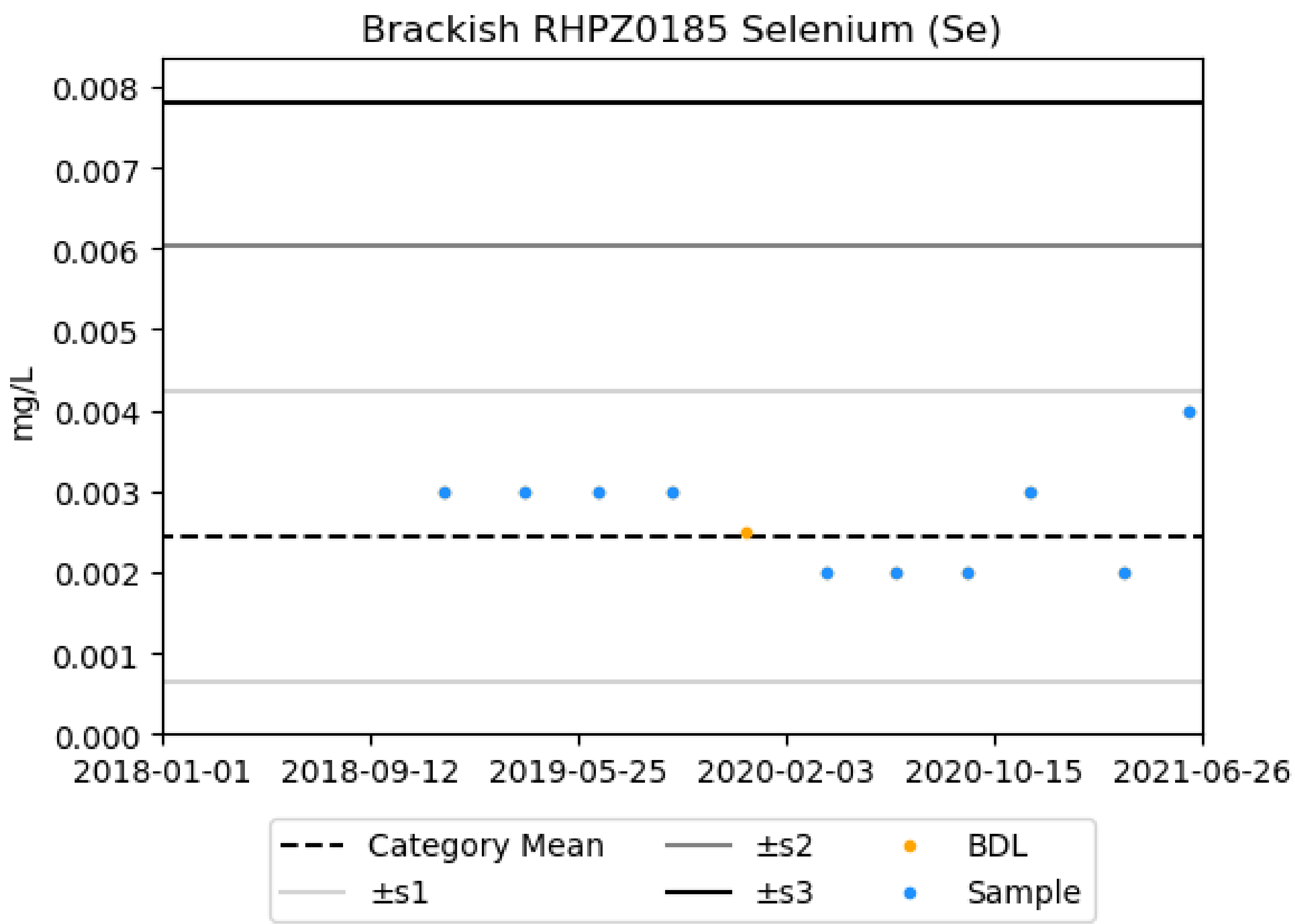
Marginal RHPZ0300S Nitrate as NO3
mg/L
0
10
20
30
40
50
60
70
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

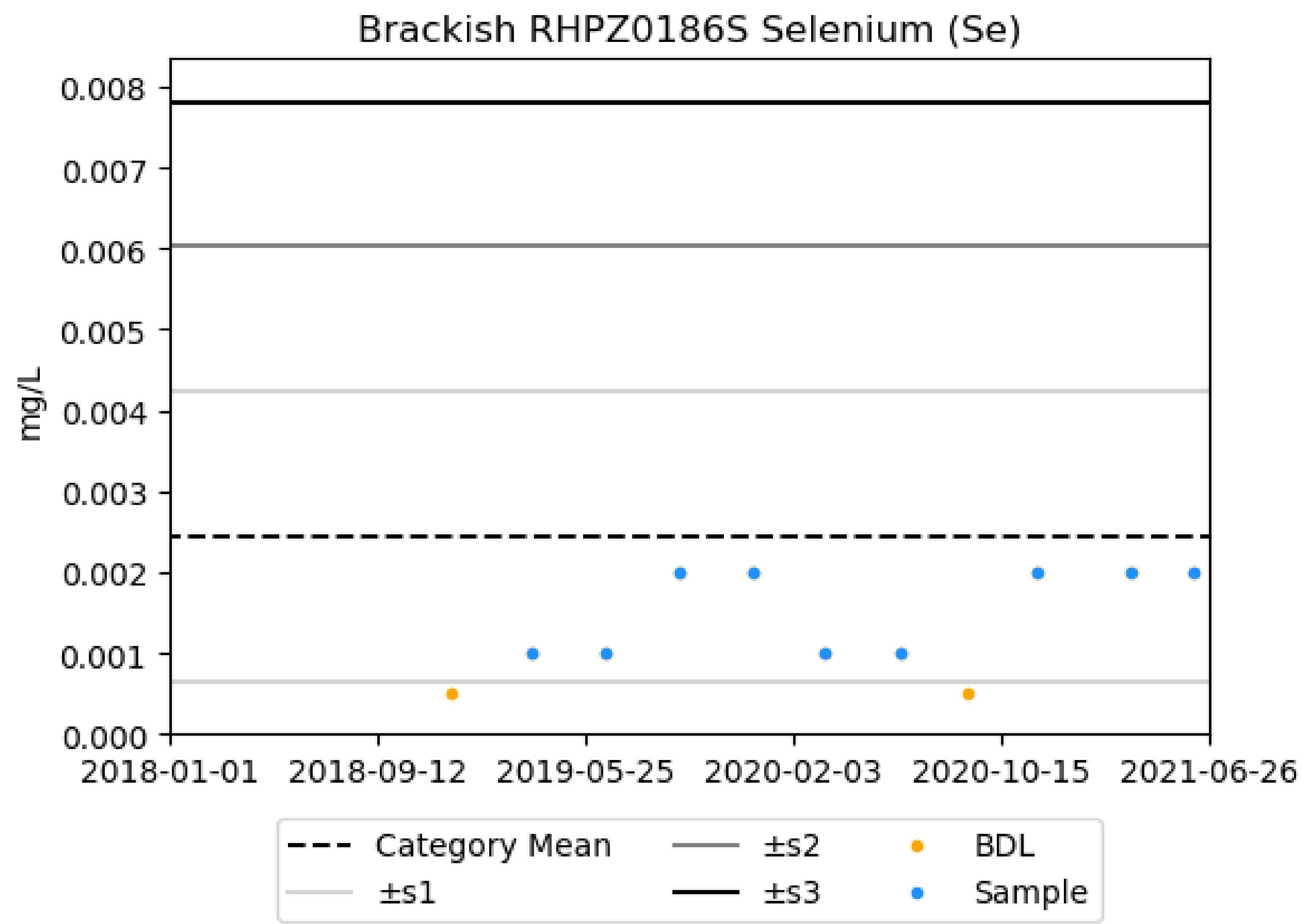


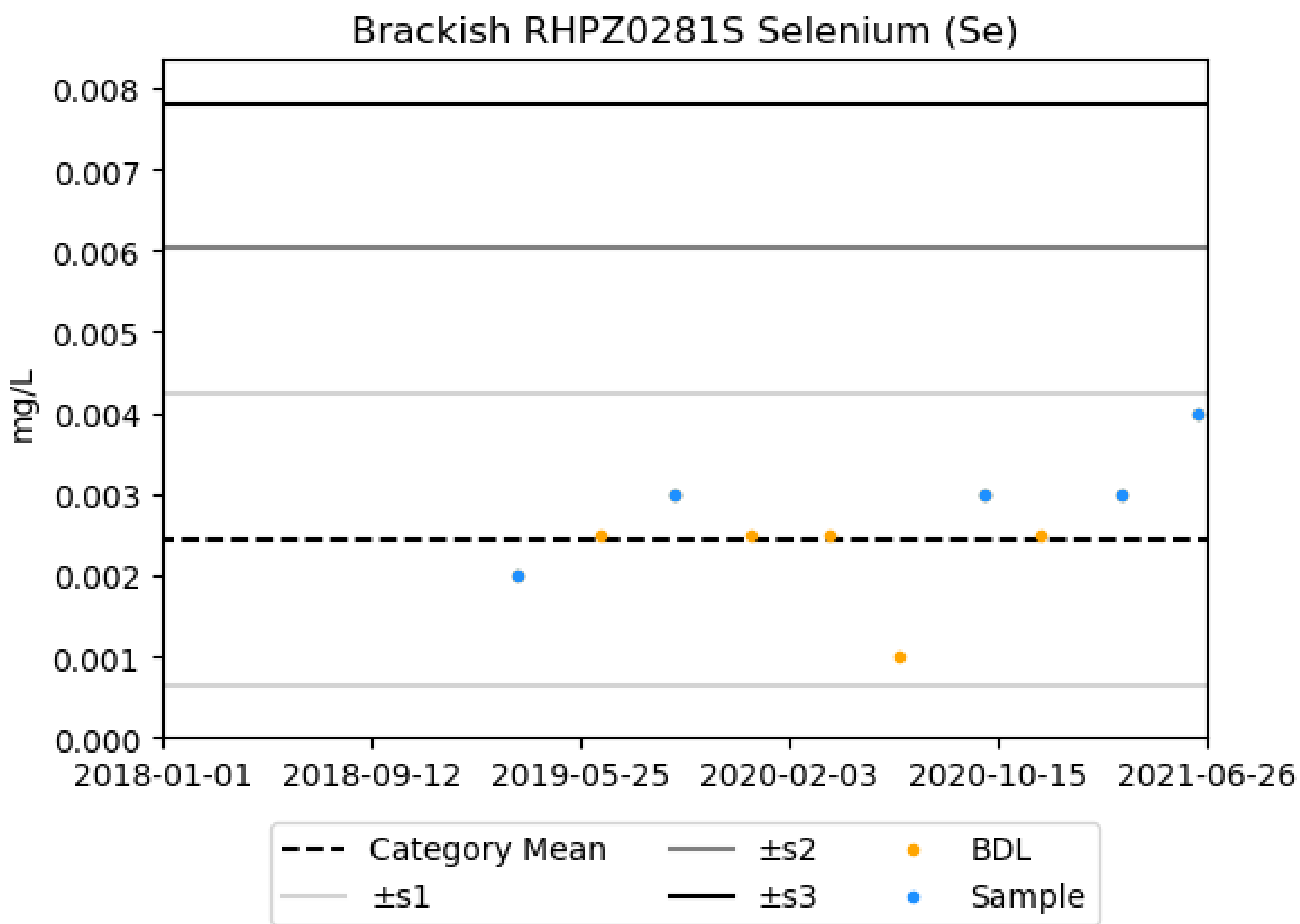
Marginal RHPZ0301S Nitrate as NO3
mg/L
0
10
20
30
40
50
60
70
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

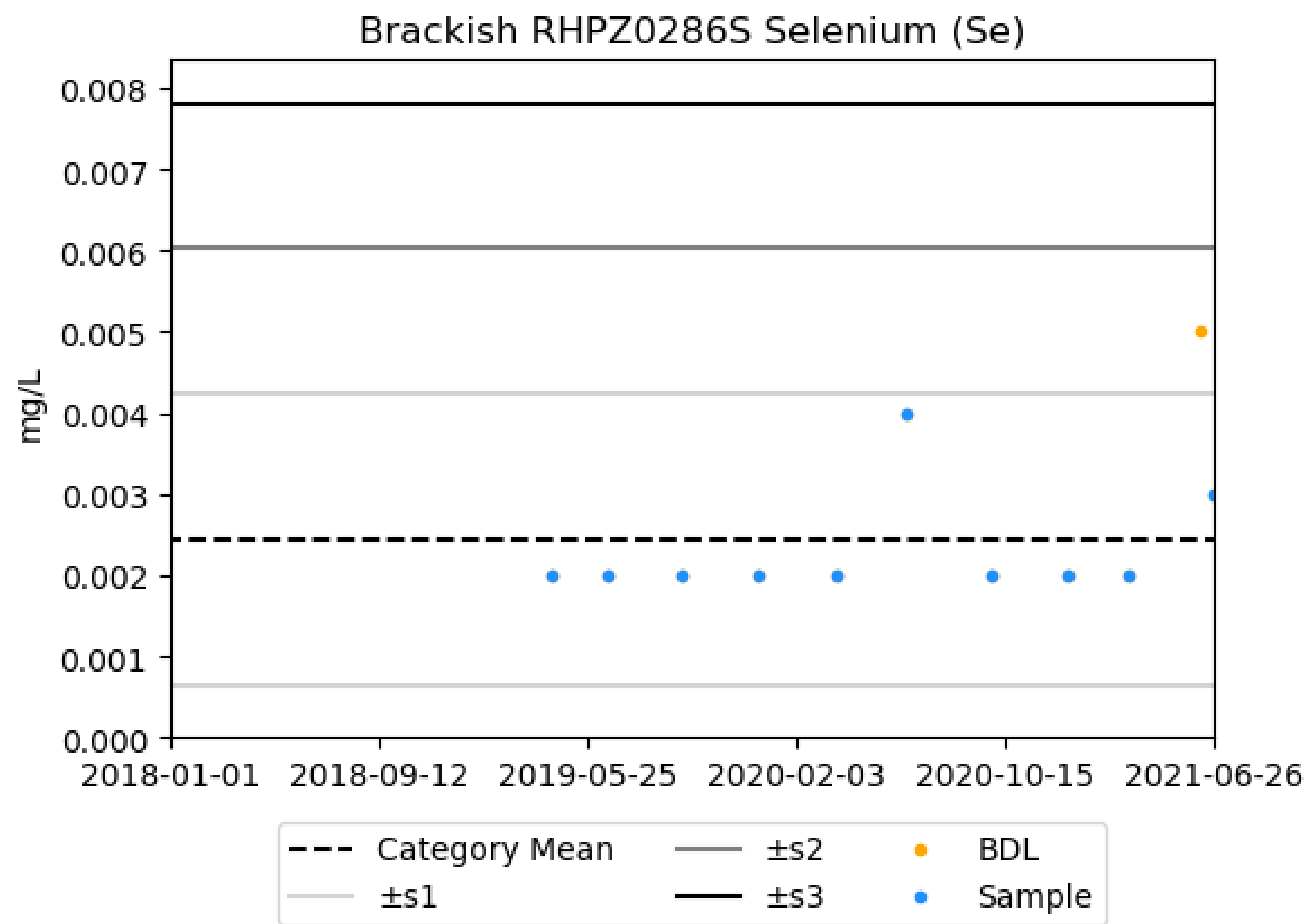

Saline RHPZ0287S Nitrate as NO3
mg/L
0
5
10
15
20
25
30
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

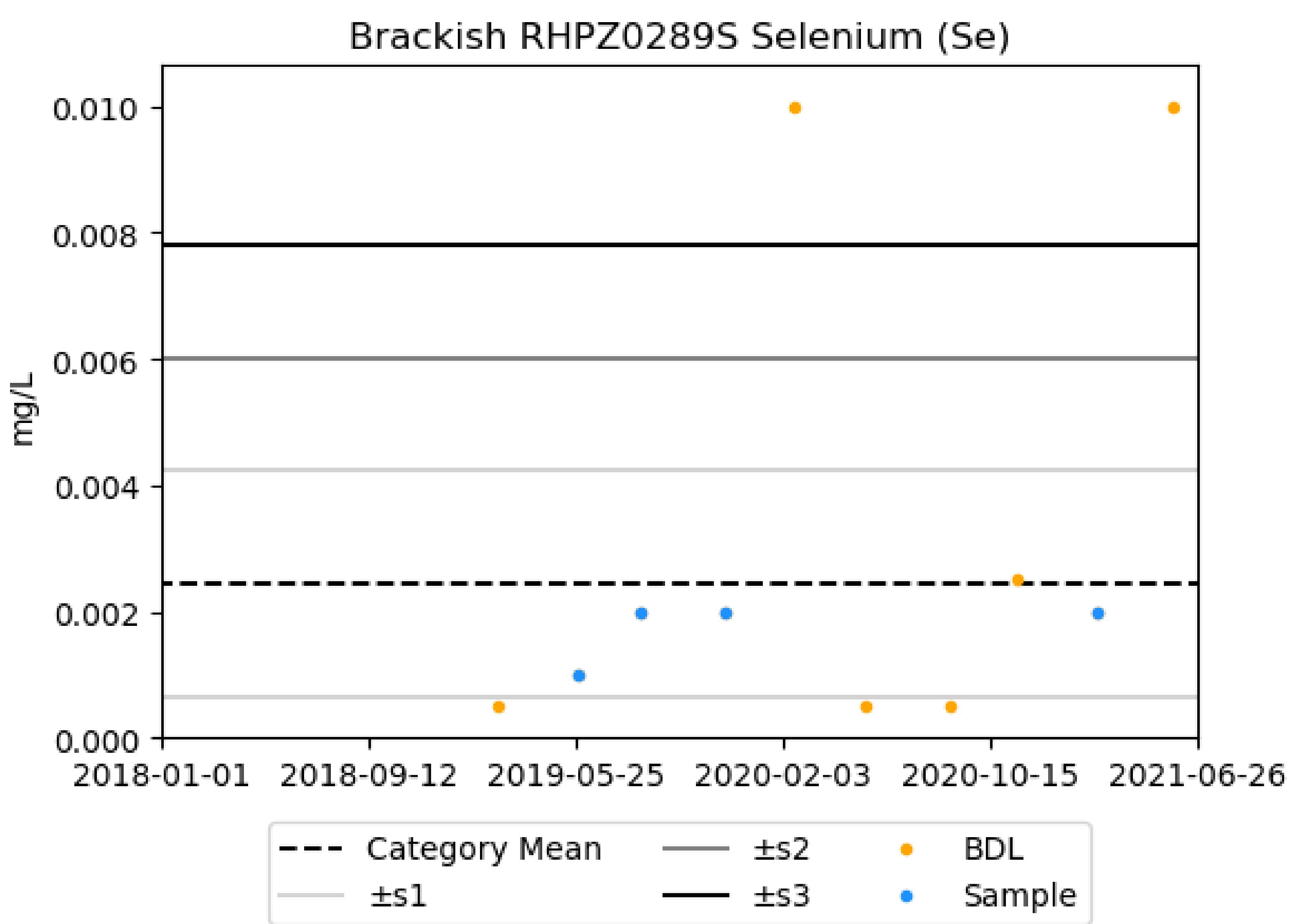

Saline RHPZ0293S Nitrate as NO3
mg/L
0
5
10
15
20
25
30
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
Sample

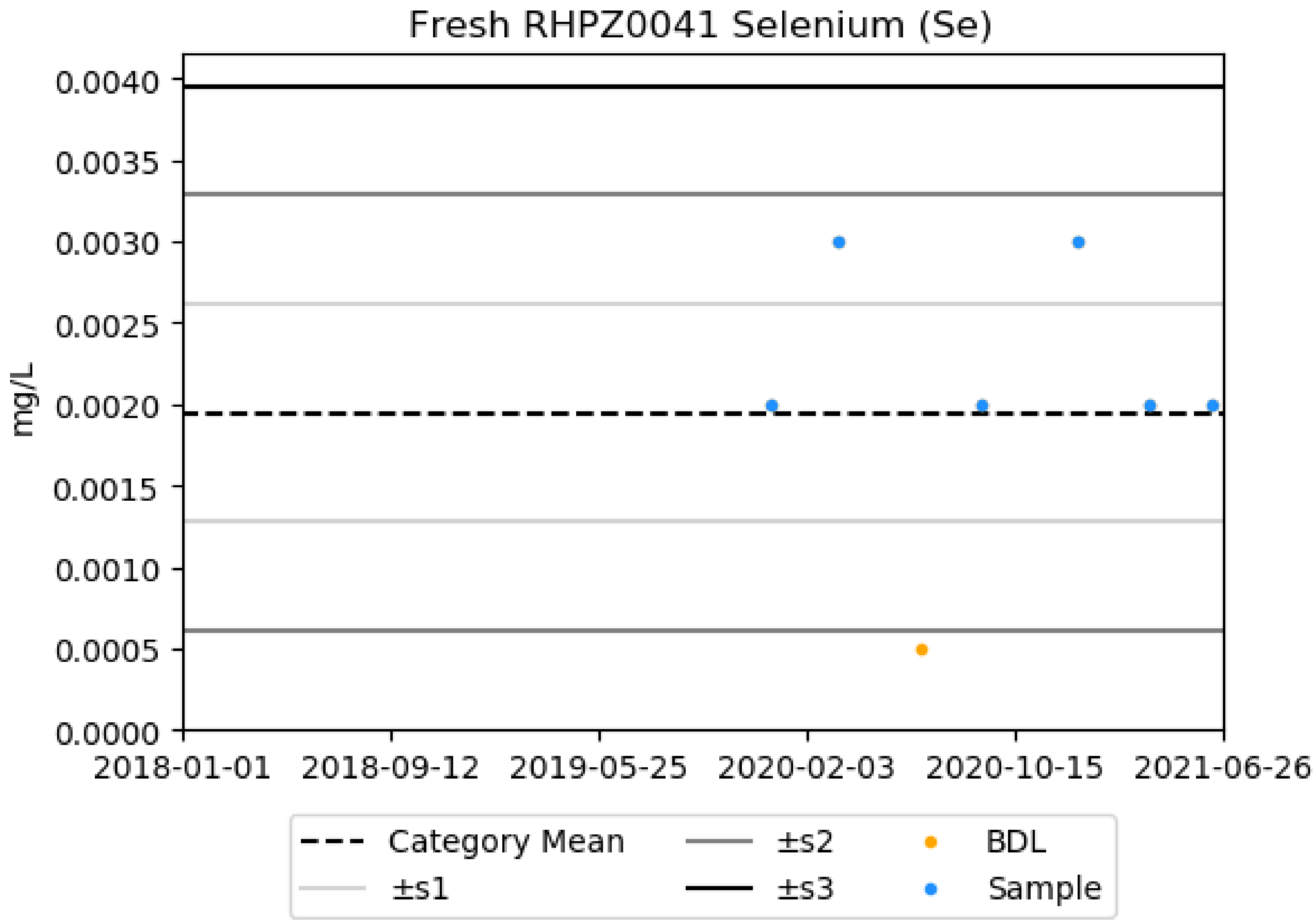

Brackish RHPZ0185 Selenium (Se)
mg/L
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample

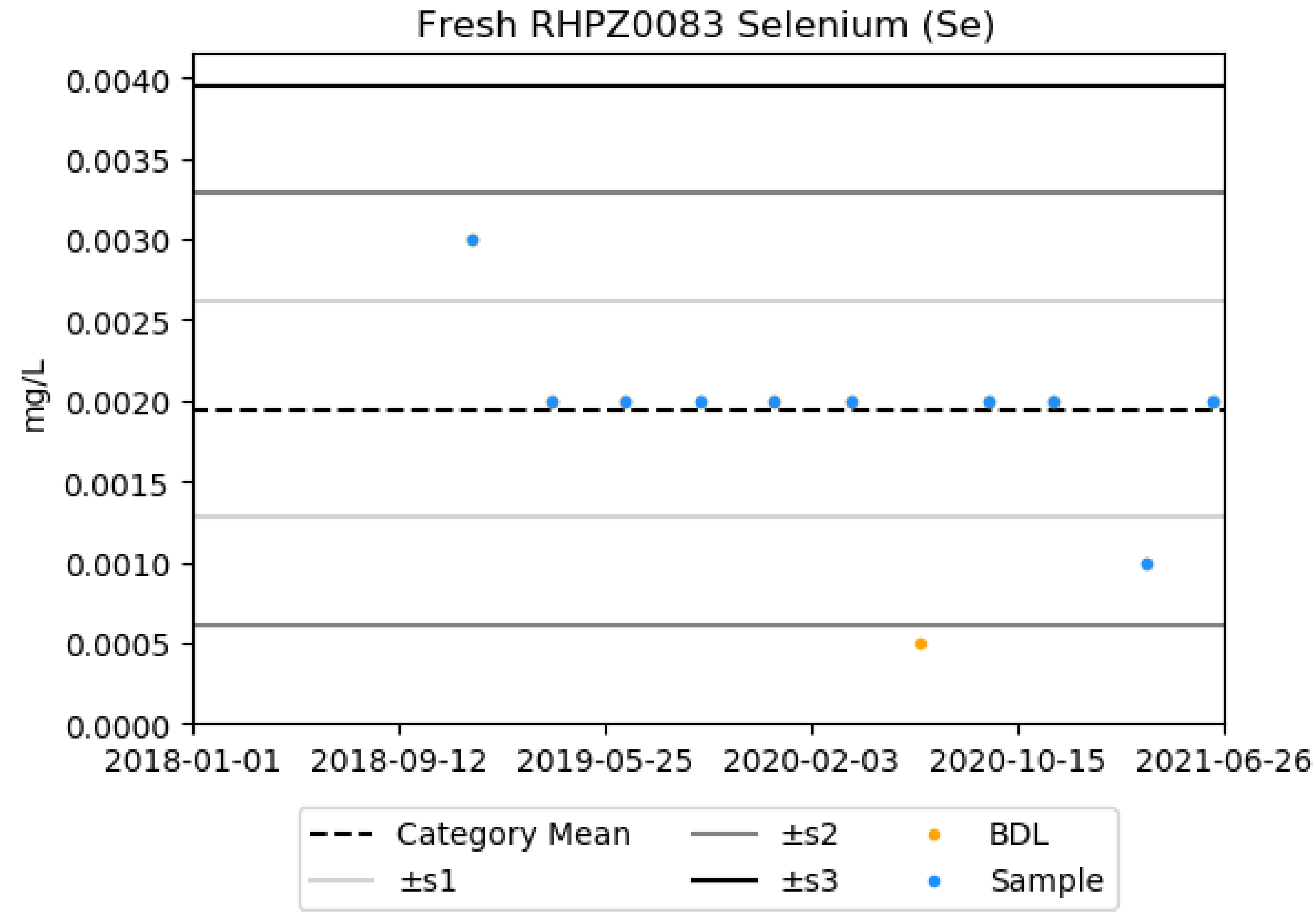

Brackish RHPZ0186S Selenium (Se)
mg/L
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample

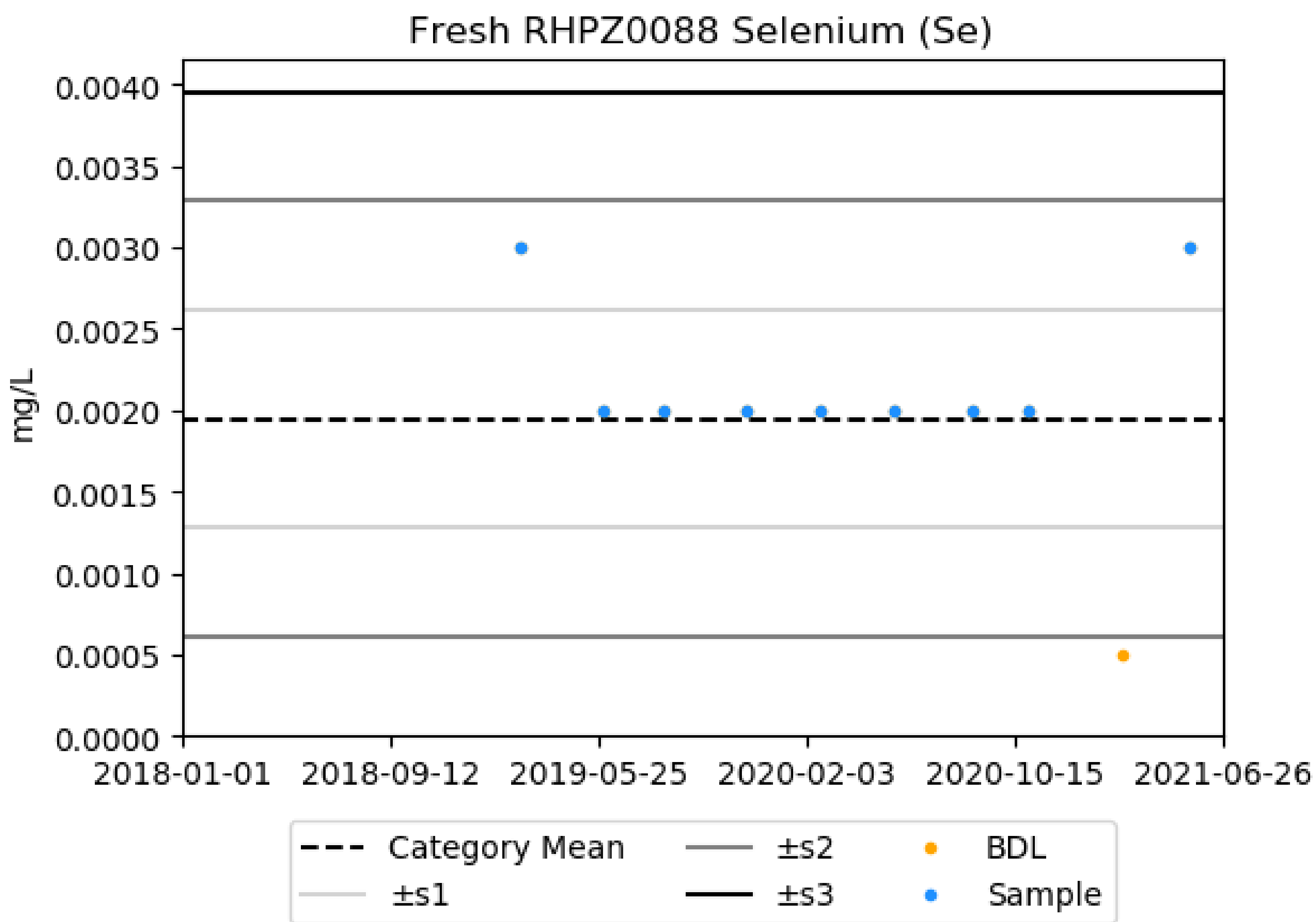

Brackish RHPZ0281S Selenium (Se)
mg/L
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample

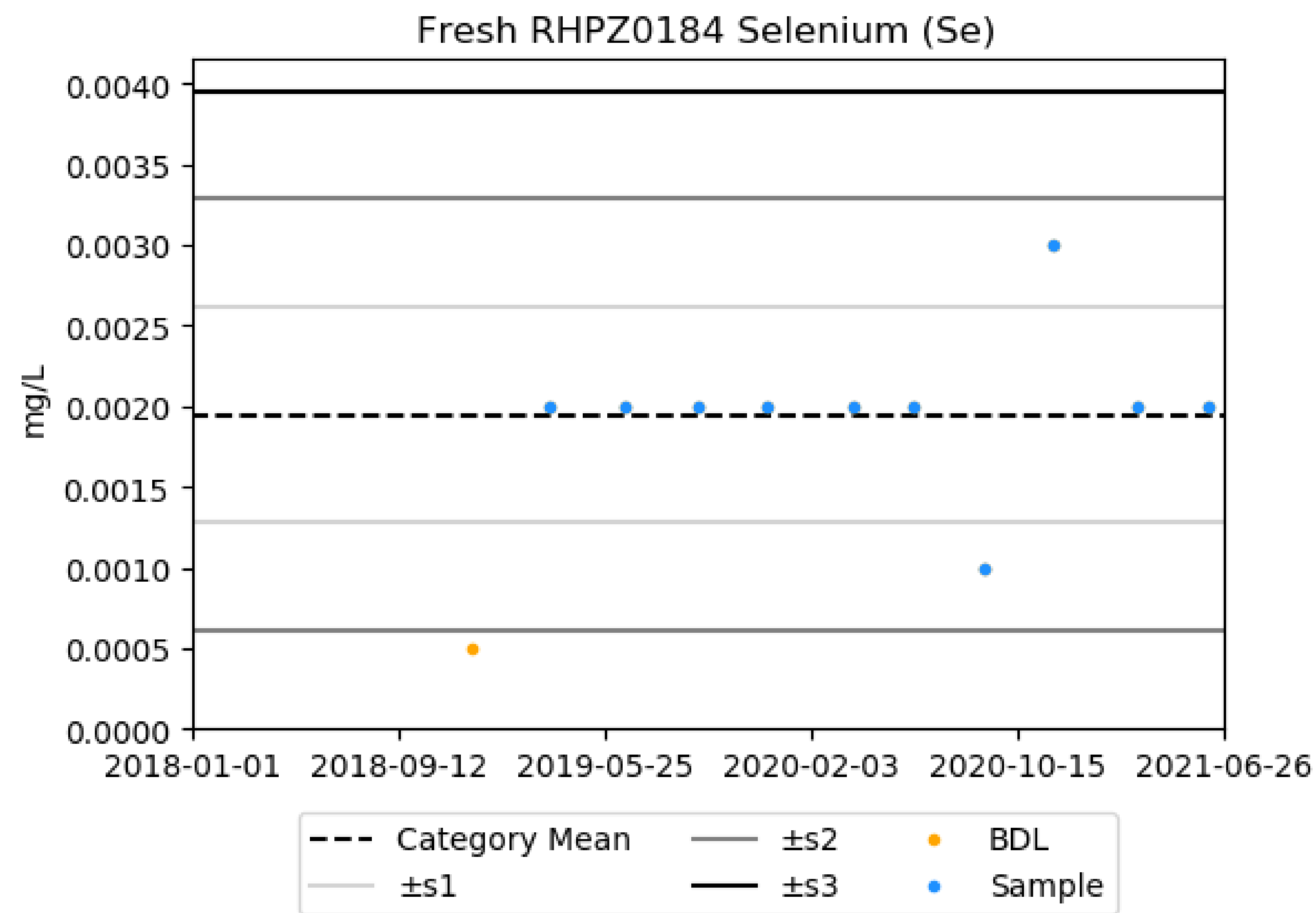

Brackish RHPZ0286S Selenium (Se)
mg/L
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample

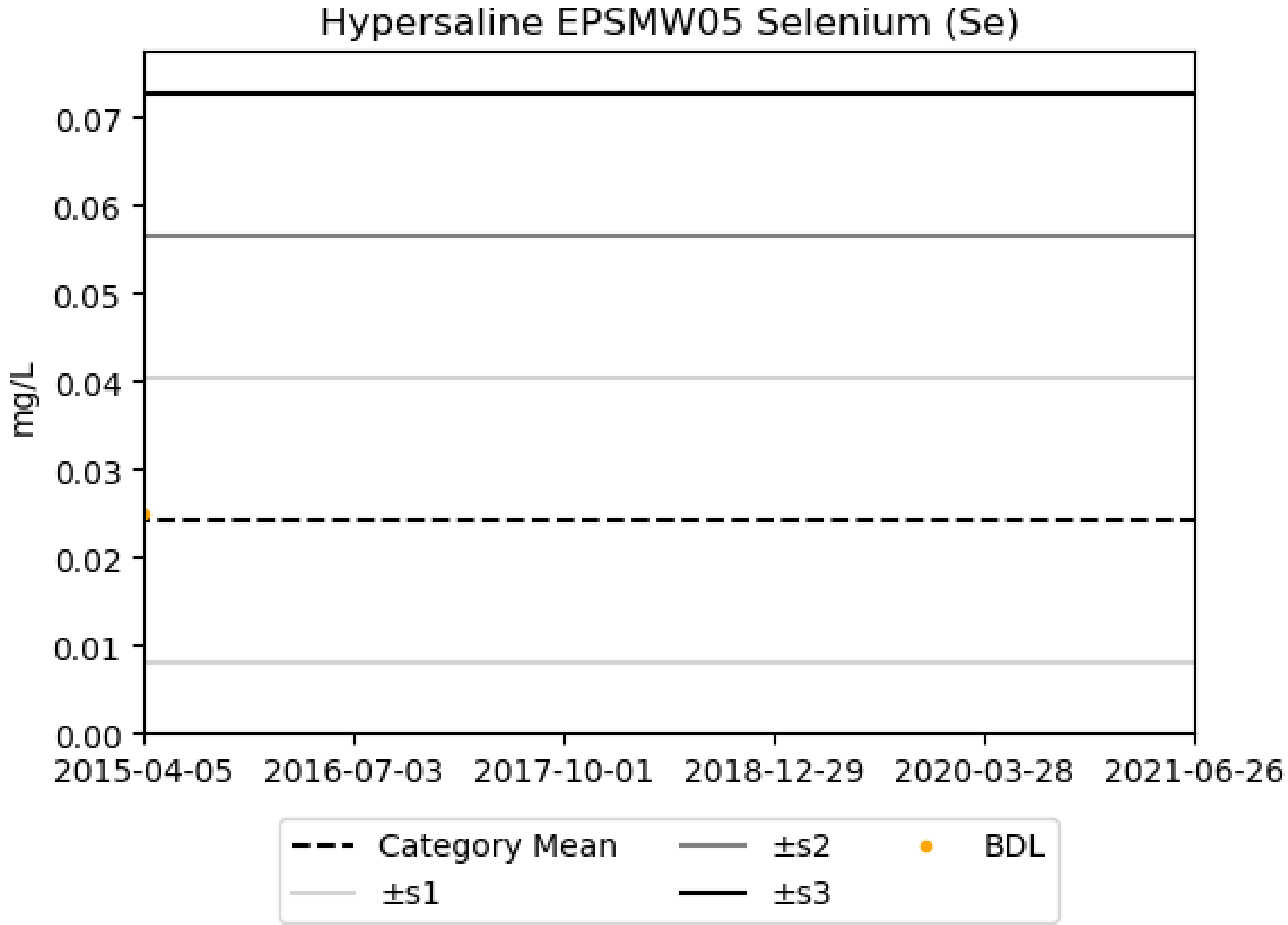

Brackish RHPZ0289S Selenium (Se)
mg/L
0.010
0.008
0.006
0.004
0.002
0.000
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample


Fresh RHPZ0041 Selenium (Se)
mg/L
0.0040
0.0035
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample

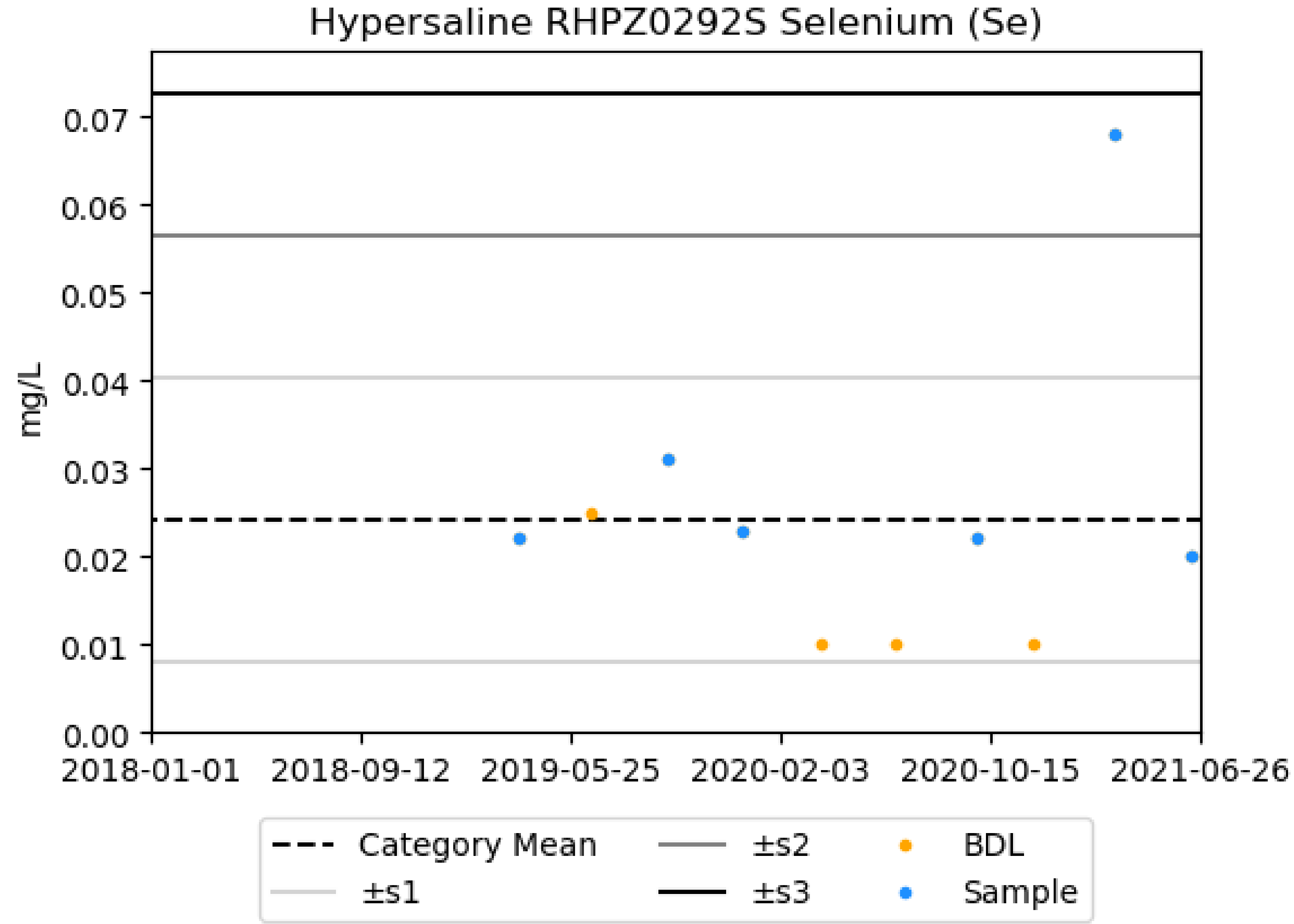

Fresh RHPZ0083 Selenium (Se)
mg/L
0.0040
0.0035
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample


Fresh RHPZ0088 Selenium (Se)
mg/L
0.0040
0.0035
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample

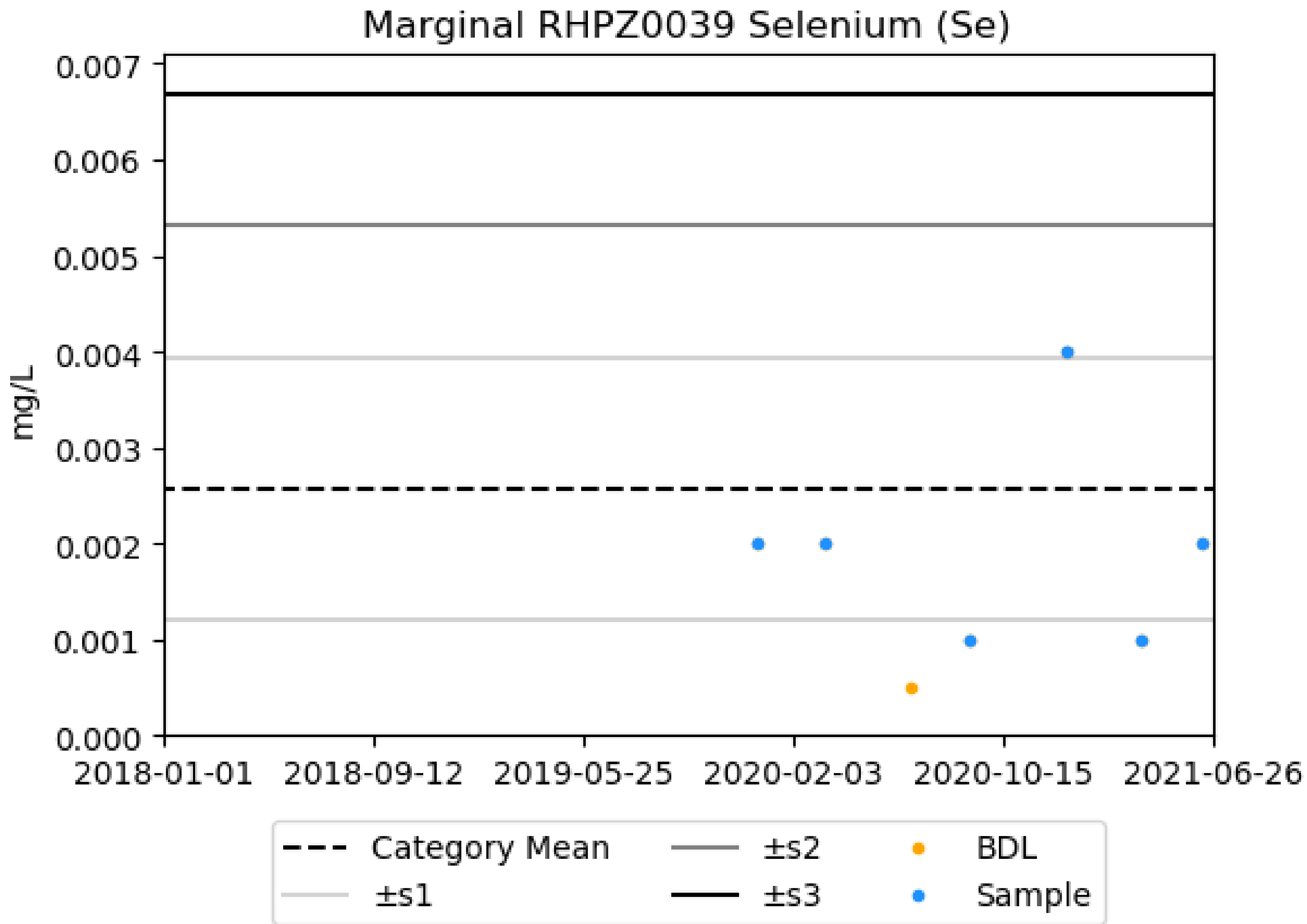

Fresh RHPZ0184 Selenium (Se)
mg/L
0.0040
0.0035
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample

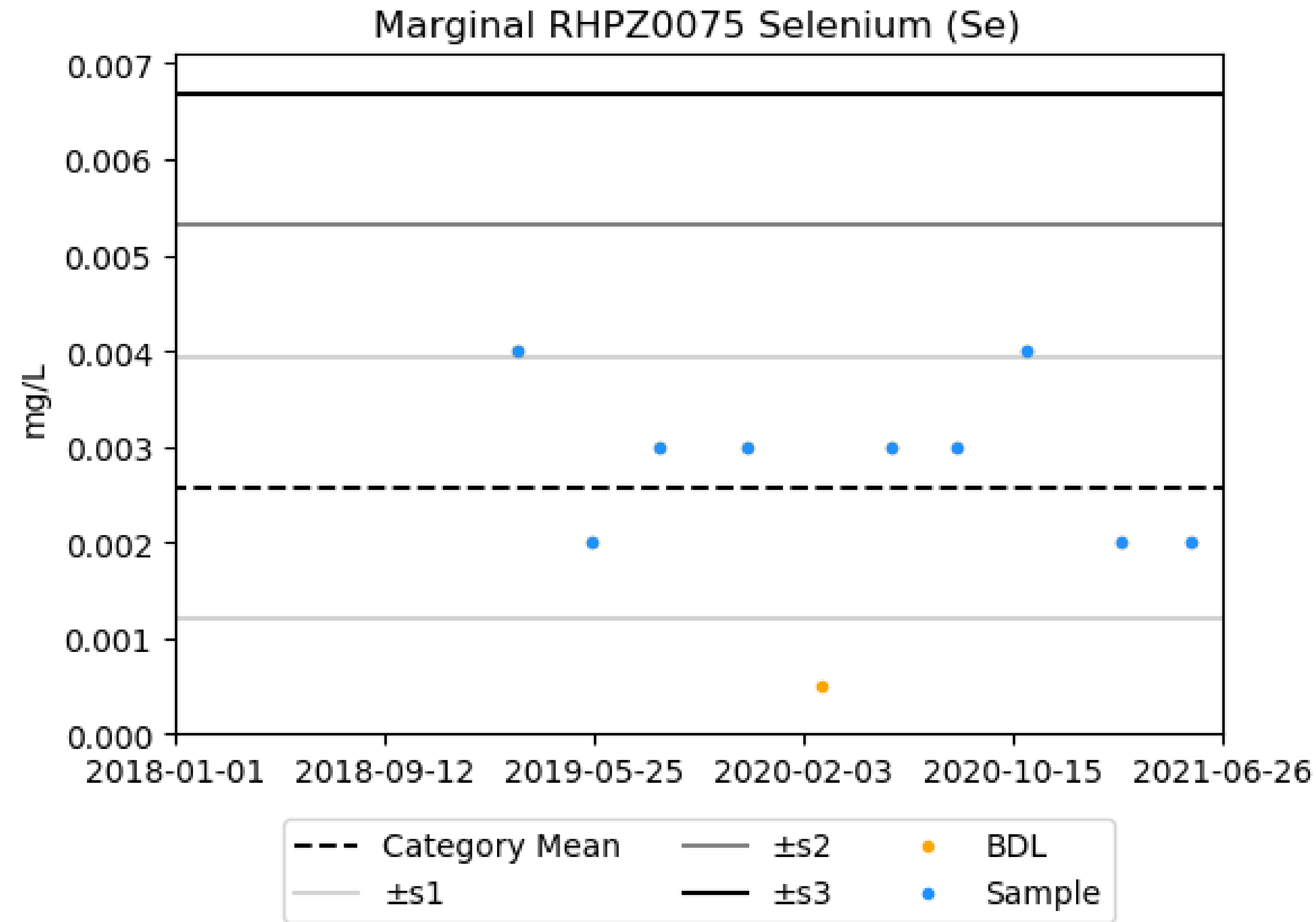


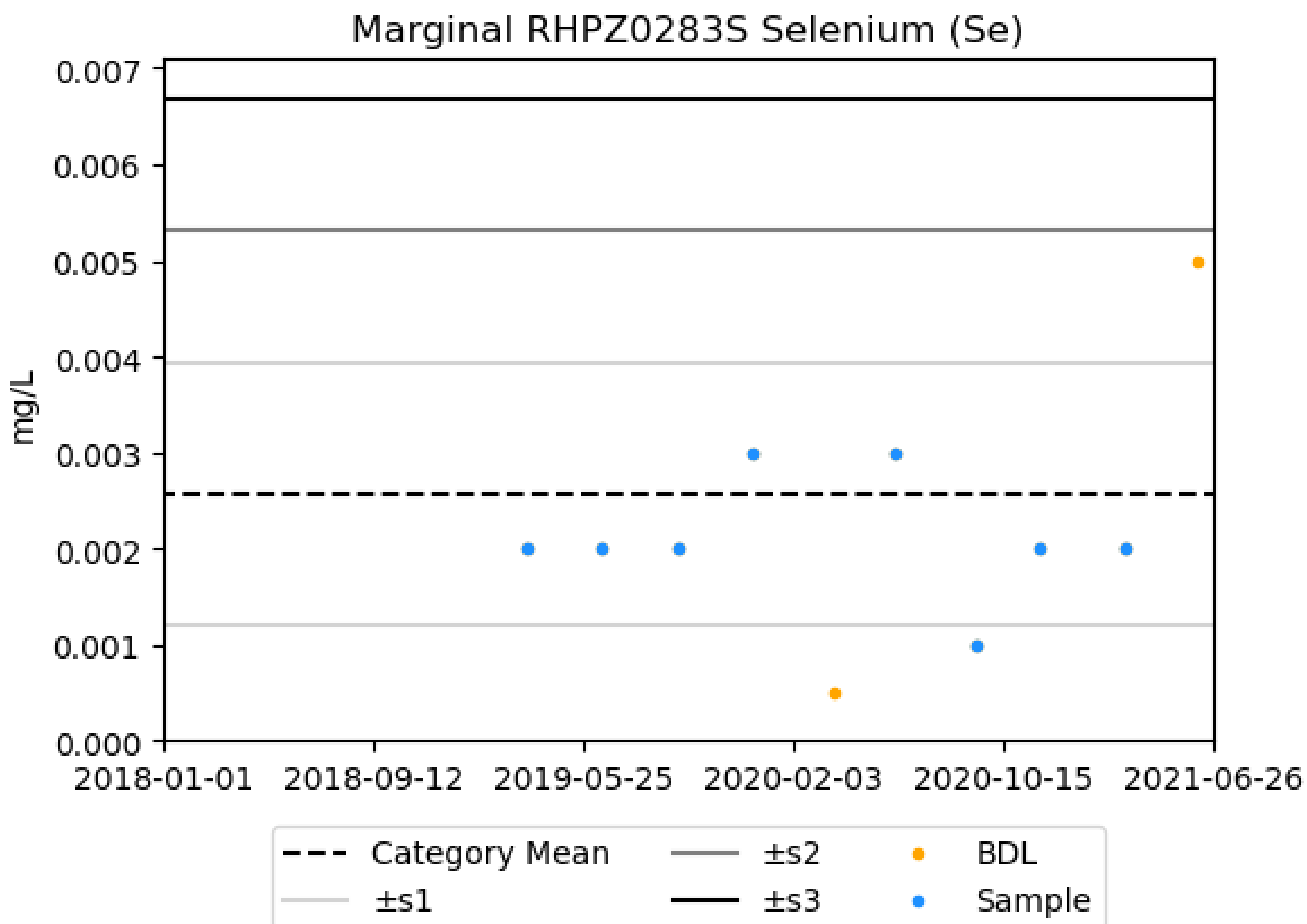
Hypersaline EPSMW05 Selenium (Se)
mg/L
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
2015-04-05
2016-07-03
2017-10-01
2018-12-29
2020-03-28
2021-06-26
Category Mean
±s1
±s2
±s3
BDL

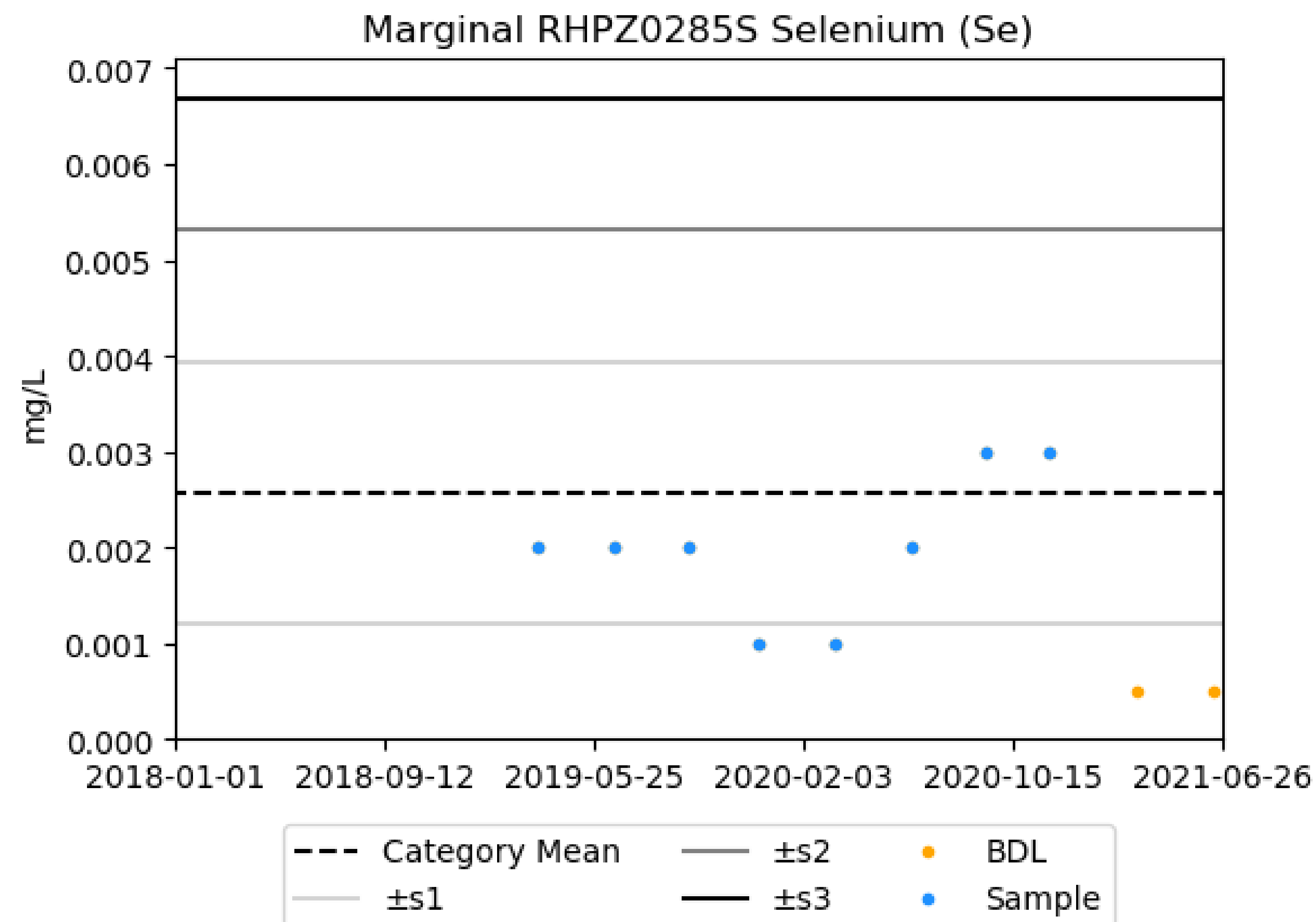


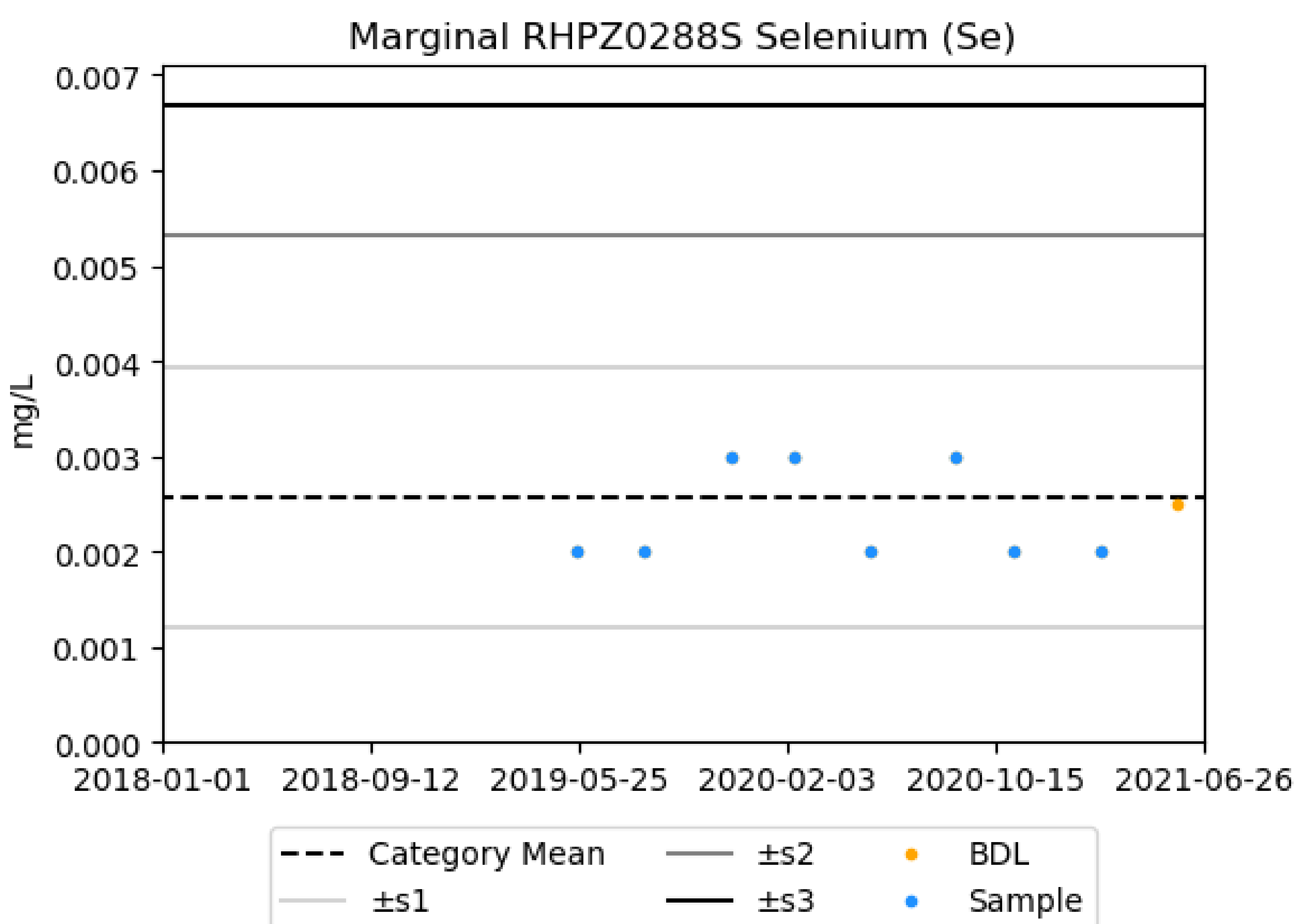
Hypersaline RHPZ0292S Selenium (Se)
mg/L
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample

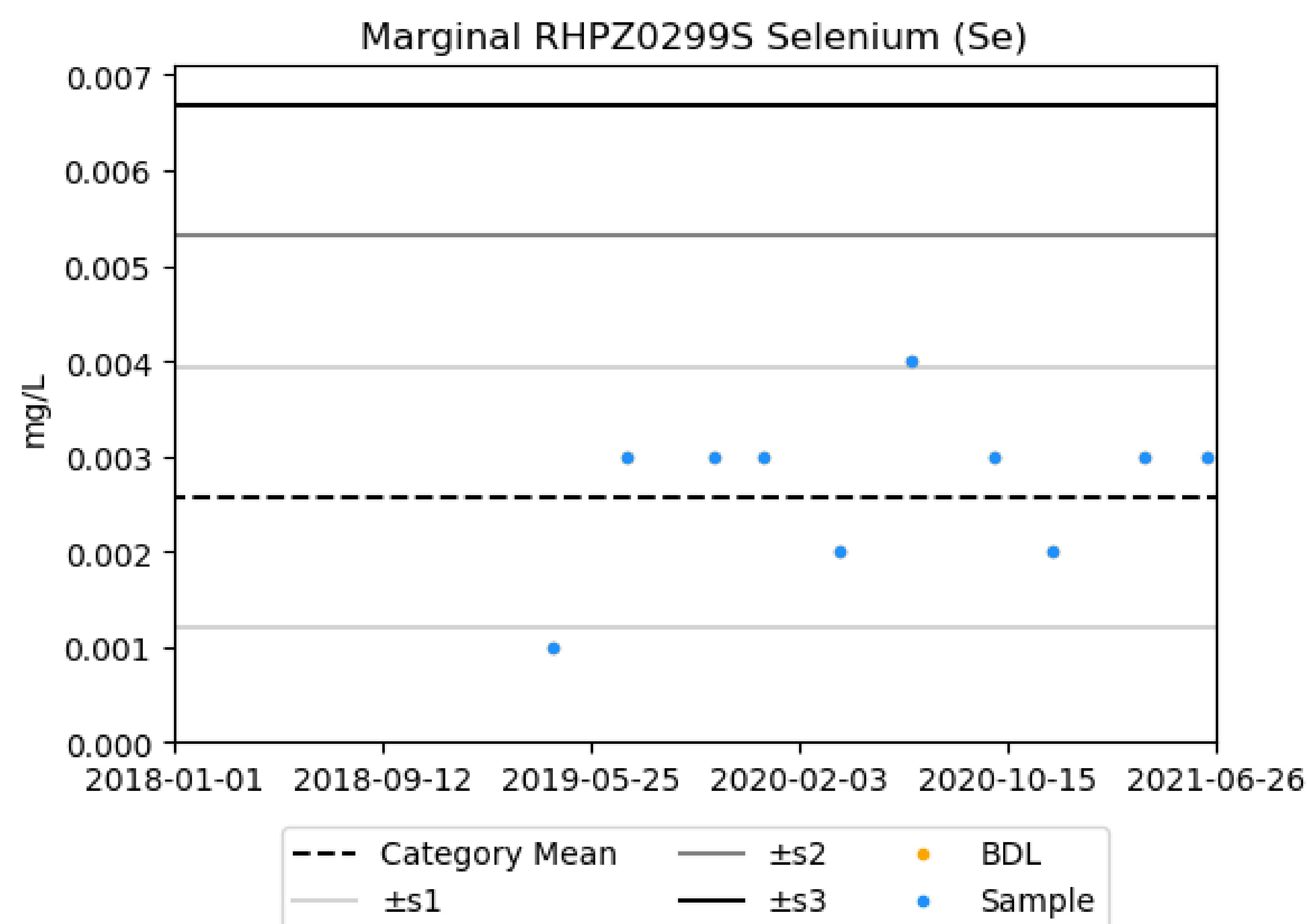

Marginal RHPZ0039 Selenium (Se)
mg/L
0.000
0.001
0.002
0.003
0.004
0.005
0.006
0.007
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample

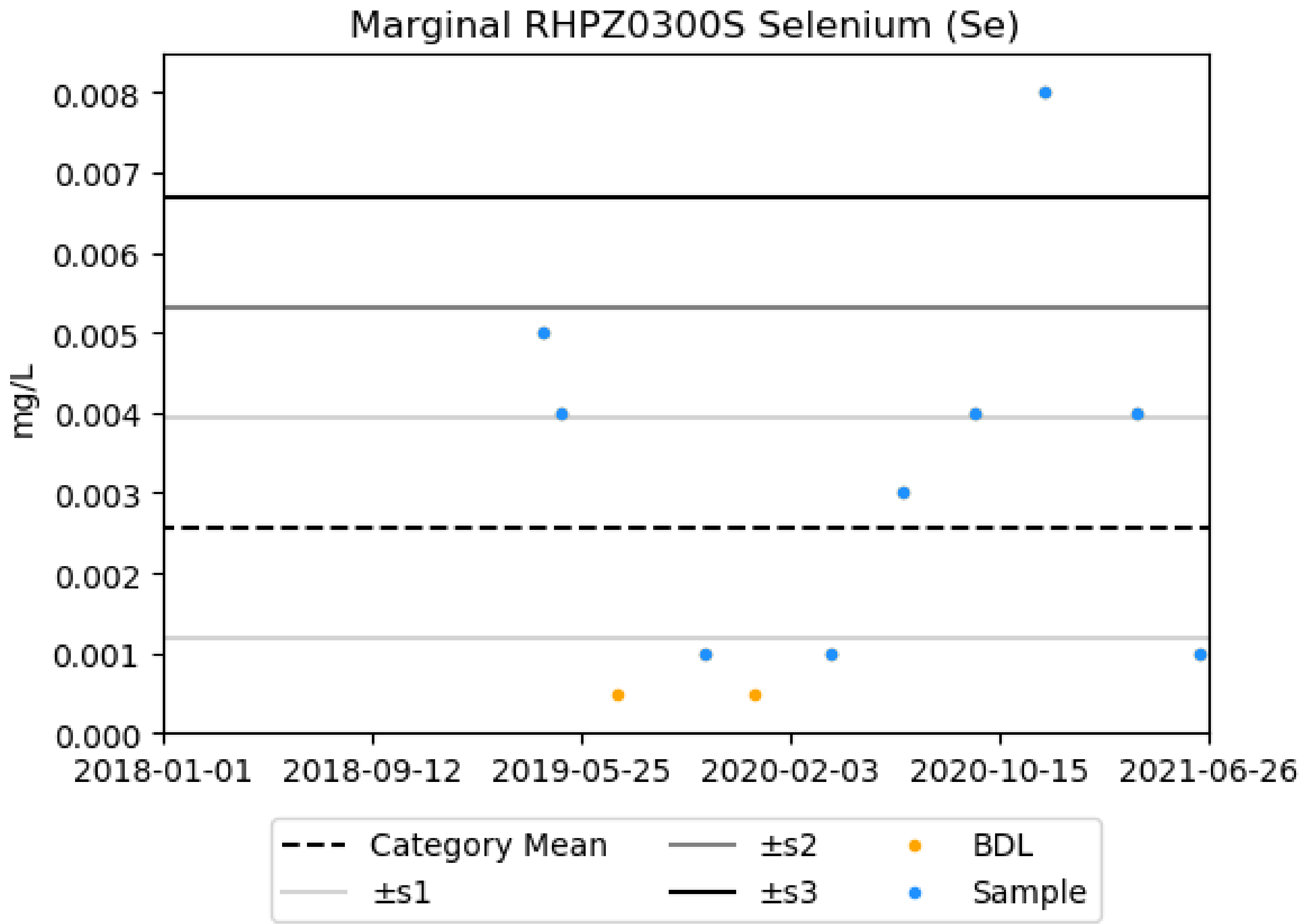

Marginal RHPZ0075 Selenium (Se)
mg/L
0.000
0.001
0.002
0.003
0.004
0.005
0.006
0.007
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample

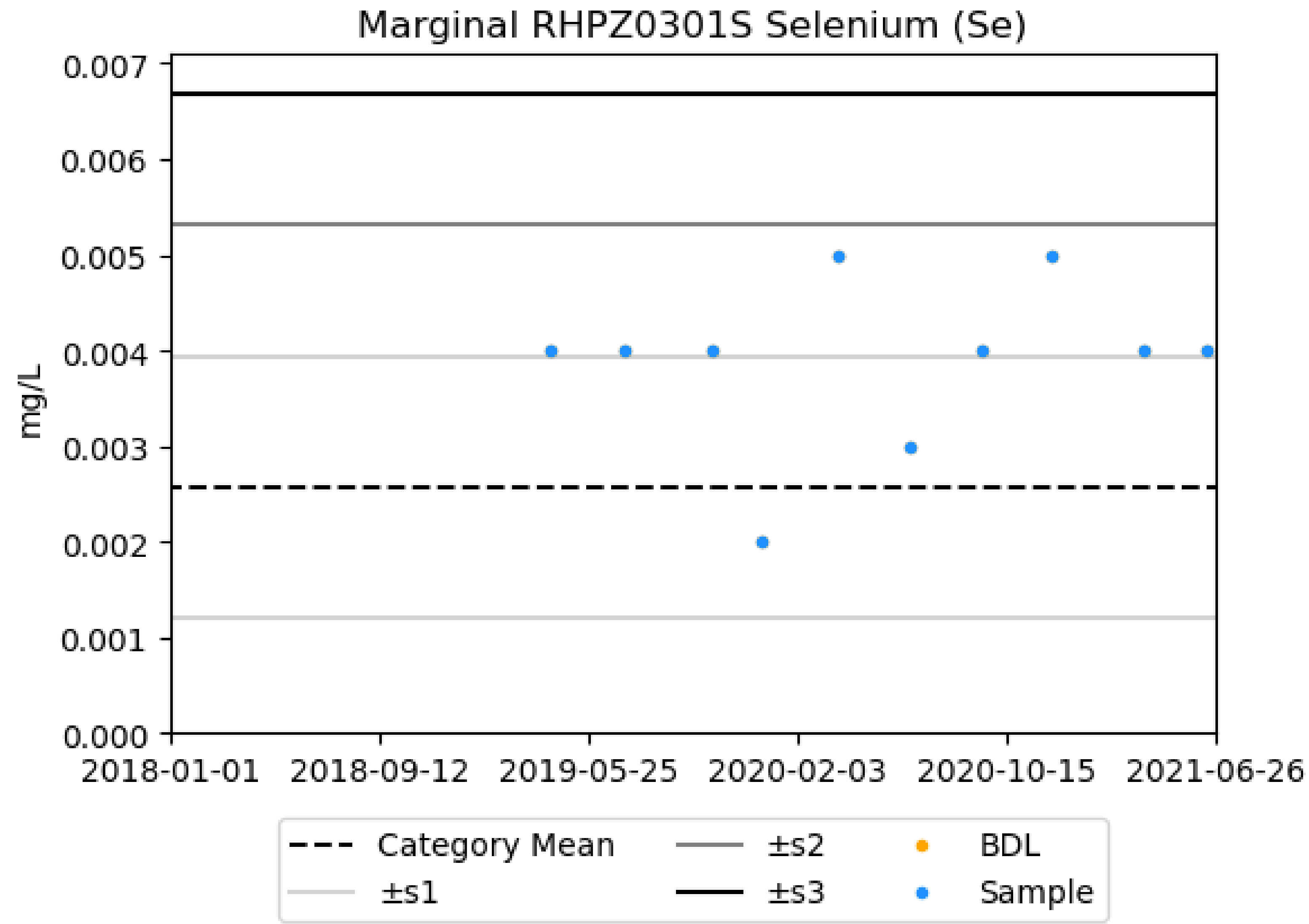

Marginal RHPZ0283S Selenium (Se)
mg/L
0.000
0.001
0.002
0.003
0.004
0.005
0.006
0.007
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample

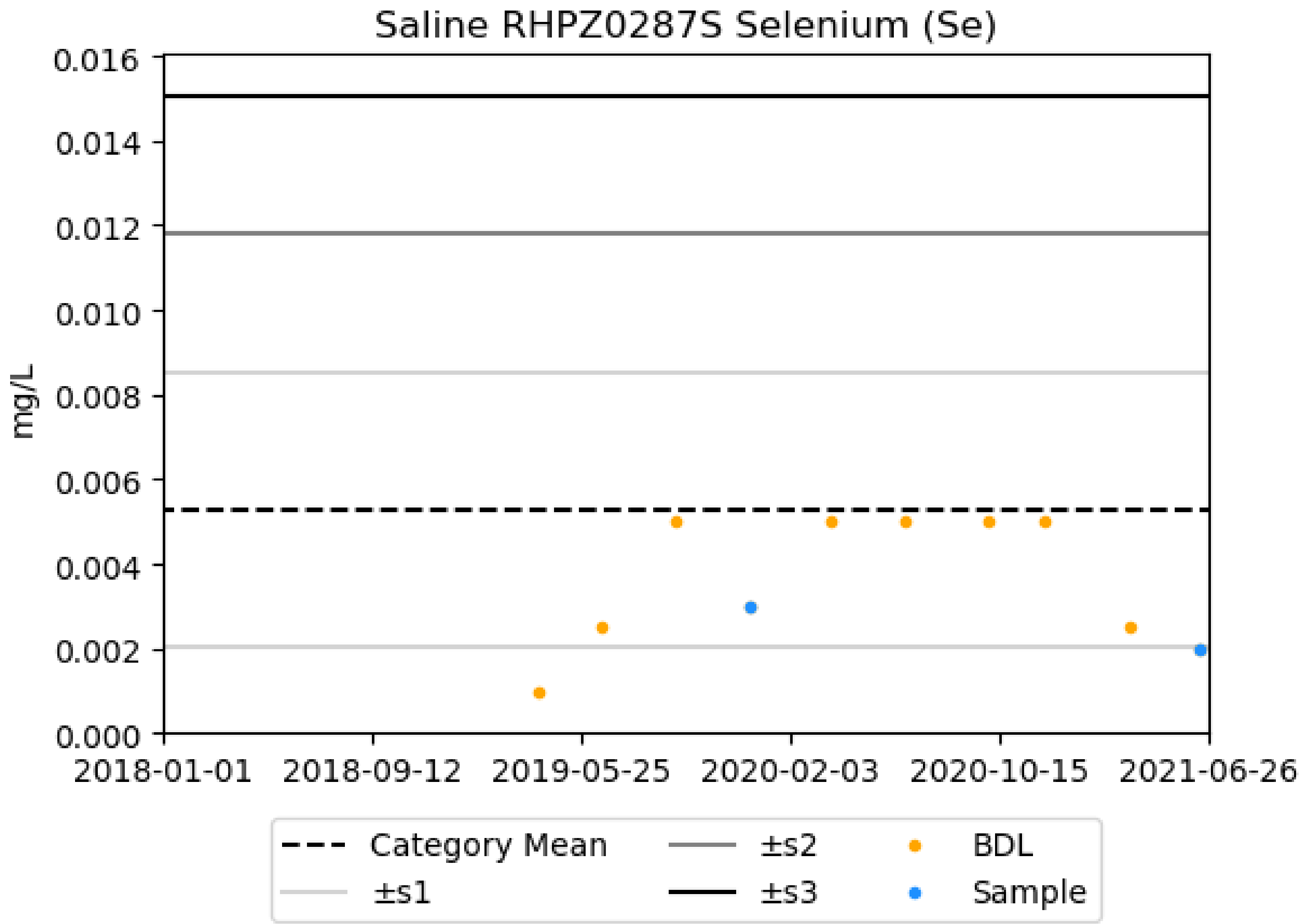

Marginal RHPZ0285S Selenium (Se)
mg/L
0.000
0.001
0.002
0.003
0.004
0.005
0.006
0.007
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample

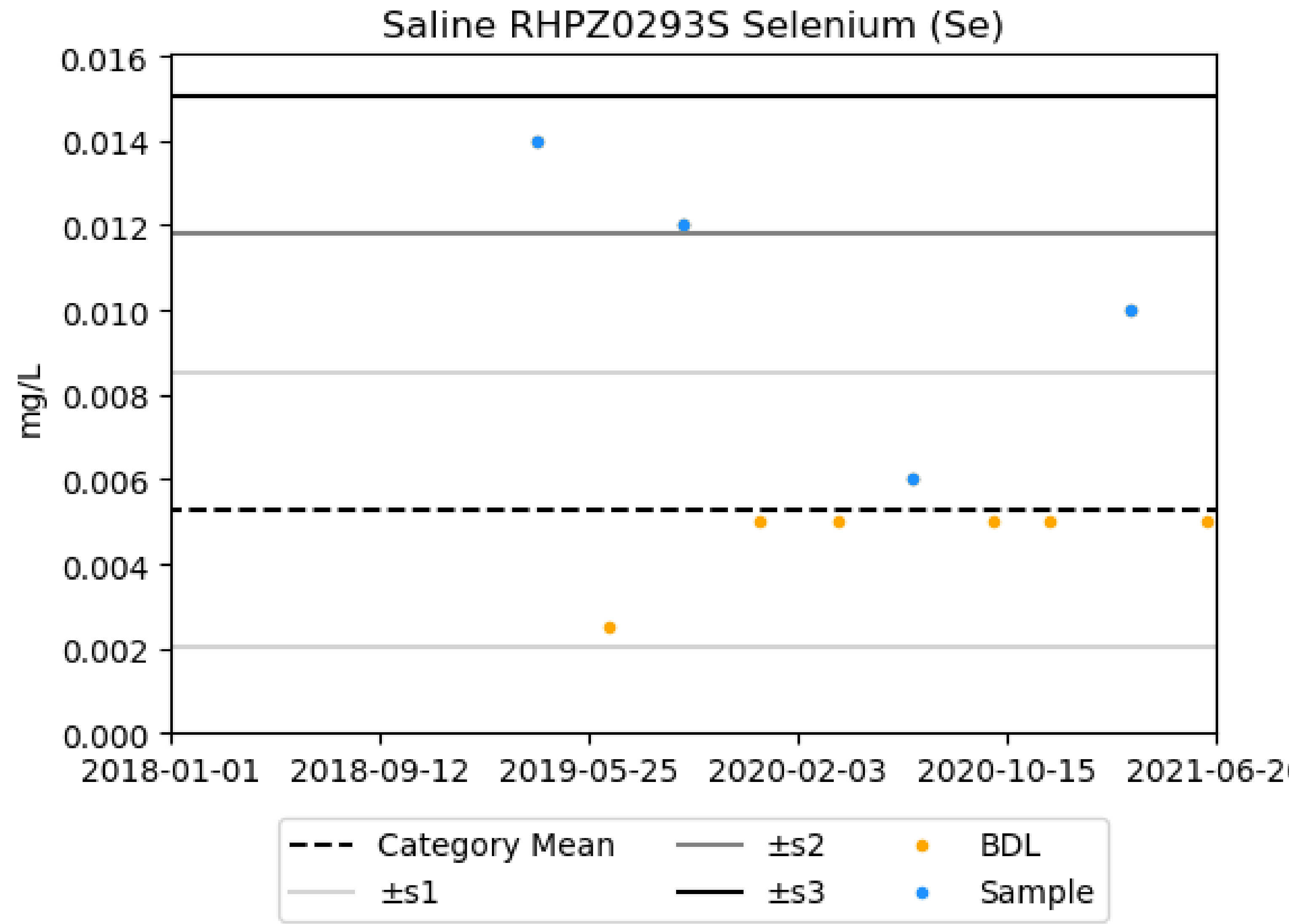

Marginal RHPZ0288S Selenium (Se)
mg/L
0.000
0.001
0.002
0.003
0.004
0.005
0.006
0.007
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample


Marginal RHPZ0299S Selenium (Se)
mg/L
0.000
0.001
0.002
0.003
0.004
0.005
0.006
0.007
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample


Marginal RHPZ0300S Selenium (Se)
mg/L
0.000
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample


Marginal RHPZ0301S Selenium (Se)
mg/L
0.000
0.001
0.002
0.003
0.004
0.005
0.006
0.007
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample


Saline RHPZ0287S Selenium (Se)
mg/L
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample


Saline RHPZ0293S Selenium (Se)
mg/L
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
2018-01-01
2018-09-12
2019-05-25
2020-02-03
2020-10-15
2021-06-26
Category Mean
±s1
±s2
±s3
BDL
Sample