Maintenance and Monitoring Program Update for Subsurface Gravel Wetland BMP Retrofits on Cape Cod

A TECHNICAL DIRECT ASSISTANCE PROJECT FUNDED BY THE U.S. EPA SOUTHERN NEW ENGLAND PROGRAM (SNEP)

FINAL REPORT
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Prepared for:

U.S. EPA Region 1

Prepared by:

UNH Stormwater Center

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STORMWATER CENTER

SOLICITATION 68HE0119Q0021

To:	Ray Cody, Mark Voorhees (US EPA Region 1)
From:	James Houle, Daniel Macadam (UNH Stormwater Center)
CC:	Project Technical Team
Date:	12/23/2020
Re:	Final Report

I. Executive Summary

UNH Stormwater Center along with EPA Region 1, have developed new and innovative next-generation real-time monitoring approaches for stormwater control measure (SCM) assessment. Previous work has also established the utility and reliability of EPA Region 1's SCM performance curves that have been incorporated into the NH and MA municipal separate storm sewer (MS4) permits. These approaches represent a paradigm shift away from historical approaches in two important ways:

- Empirical monitoring of individual SCMs is difficult and functionally unnecessary if engineered and installed appropriately. The use of EPA performance curves are acceptable and accurate (Houle, Puls, & Ballestero, 2017). More time and attention should thus be spent on proper design and engineering and construction oversight of SCMs; and

- If empirical water quality data is essential, real-time ultraviolet optical spectrometers (UV-Vis), calibrated to Northeast regional stormwater pollutant concentrations, provides a powerful tool for understanding pollutant loading at the individual site scale.

Combined, these approaches can assist stormwater professionals in selecting, sizing and accounting for appropriate structural treatment strategies to protect their water resources.

Over the course of a decade or more, UNHSC has worked with select municipalities throughout the region (e.g., Berry Brook Dover, NH) to select, size, and assess these stormwater innovations (e.g., EPA's Opti-Tool model; Performance Curves[1]).

Most recently, the UNHSC collaborated with the towns of Barnstable and Chatham, MA in a direct system investigation and monitoring project. Some related objectives the Project achieved include:

- Development of an approved quality assurance project protocol (QAPP) for use of UV-Vis probes.

- The Project developed a QAPP to govern monitoring stormwater SCM/GI systems with real-time UV optical sensors;

- Rehabilitation Guidance and Assessment of a hybrid bioretention in Barnstable (Hyannis), MA.

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[1] Performance Curves provide pollutant load reduction estimates for structural controls. A Performance Curve tells a stormwater practitioner how much of a given pollutant (e.g., nitrogen, bacteria) can be controlled simply on the basis of the size of the SCM.

In addition, the Project provides:

- investigation of climate resilience and hydraulic gradient on hybrid bioretention;
- performance monitoring of a subsurface gravel wetland in Chatham, MA;
- a refined approach for characterizing performance for SCM implementation and where necessary monitoring via real-time in-situ UV optical sensors; and
- the Project developed technical information to characterize the hydraulic gradient for a failed coastal SCM and technical documentation for the rehabilitation of same.

NOTE: *Some context for the use of the term "failure" is necessary. Scientific failure provides the greatest potential for scientific advancement. When projects results do not deliver anticipated results, we learn and subsequently advance the science; and conversely, where there is no failure, there is no learning and thus no advancement of the science. What we consider as "success" often produces a lack of innovation and progress. Thus, failure in the context of this report is used in a positive sense and the lessons learned documented for advancement of the practice.*

In addition, several important observations may be summarized:

- **Significance of this Work Beyond Monitoring Requirements.** Increasingly, New England municipalities are recognizing the importance of their environmental resources and the economic services and benefits these resources provide. In addition, these same municipalities are challenged with quantifying and accounting for the benefits of structural SCM installations that municipalities are implementing. Historically many regulatory institutions have required monitoring of implemented systems to quantify the pollutant removal benefits. This project and documentation of efforts develop technical information that supports the estimation of load reductions using EPA's SCM performance curves as opposed to empirically evaluating each installation.
- **Construct SCM to Specification and Maintain.** Because of Performance Curves, municipal practitioners (and others) need not monitor for water quality parameters to determine SCM performance. Rather the emphasis is to be placed on the construction of the SCM to specification and thereafter, maintenance to ensure proper operation into the future.

II. Rehabilitation Maintenance and Assessment of Barnstable (Hyannis) BMP

A. Rehabilitation Maintenance of BMP Aerobic Zone

The Hyannis BMP is under-performing hydraulically due to clogging and excessive vegetative growth of one or more dominant plant species (e.g., Typha, phragmites) in the upper/aerobic zone. A maintenance approach and associated cost was developed for this task (see Appendices). In consideration of pending litigation that arose from a very large storm event and widespread coastal flooding in Falmouth and Barnstable, MA, in 2017, the rehabilitation efforts were unable to be completed.

B. Investigation of Effect of Hydraulic Gradient (Groundwater)

The effects of the hydraulic gradient were studied and shown to have strong diurnal patterns relatively unaffected by the stormwater inflow through the inlet structure. The conductivity monitoring of the water in the inlet structure showed no evidence of seawater intrusion (Figure 1). Typical ocean conductivity is >30,000 µS/cm. Figure 1 shows the inlet specific measurements alongside rainfall depths. Conductivity largely trends with precipitation events and never exceeds 1,100 µS/cm. This monitoring indicates no seawater influence in the inlet structure.

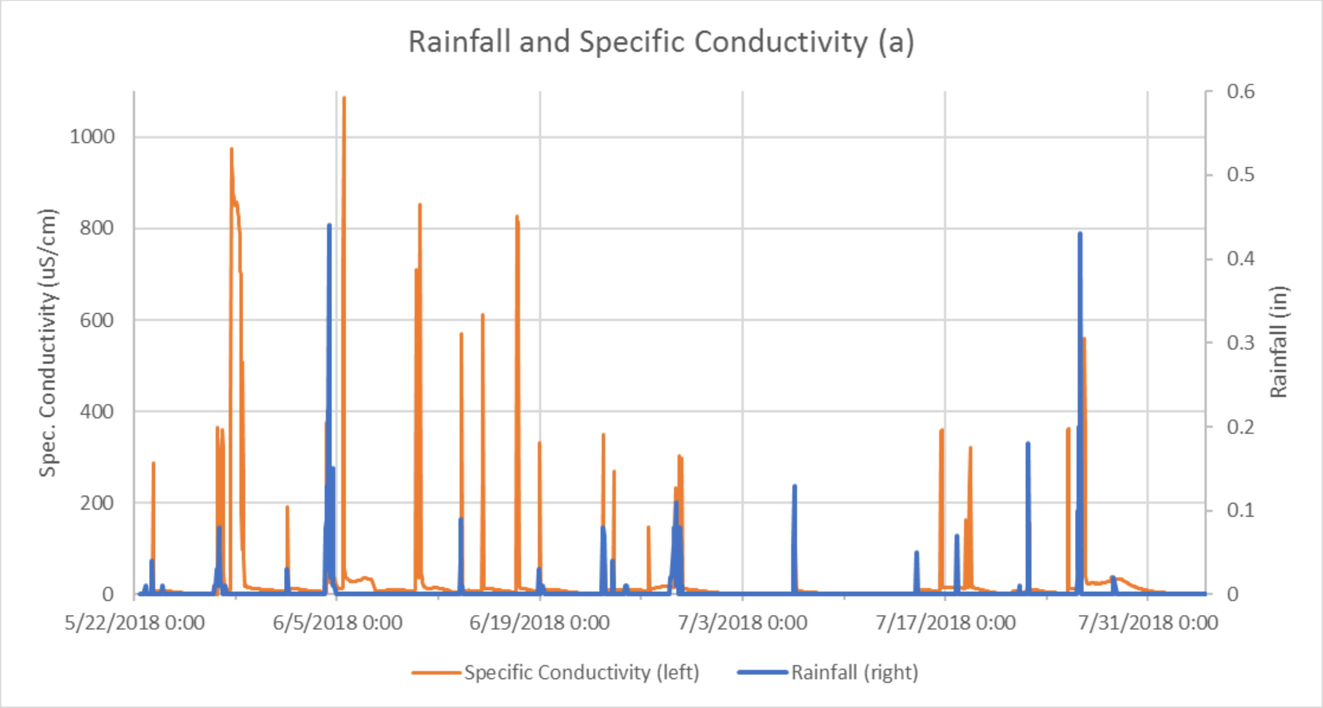

Figure 1: Barnstable: local rainfall and specific conductivity in the inlet structure.

Two groundwater monitoring wells were installed surrounding the BMP. Well 1 was installed on the downgradient side near the outlet structure, and Well 2 was installed on the upgradient side of the BMP.

Elevations were surveyed and related to mean sea level. Figure 2 and Figure 3 show a strong hydraulic gradient across the system. The upgradient well (Well 2) is only influenced by rainfall patterns in the largest event observed over the monitoring period where the downgradient well (Well 1) is more often influenced by rainfall patterns.

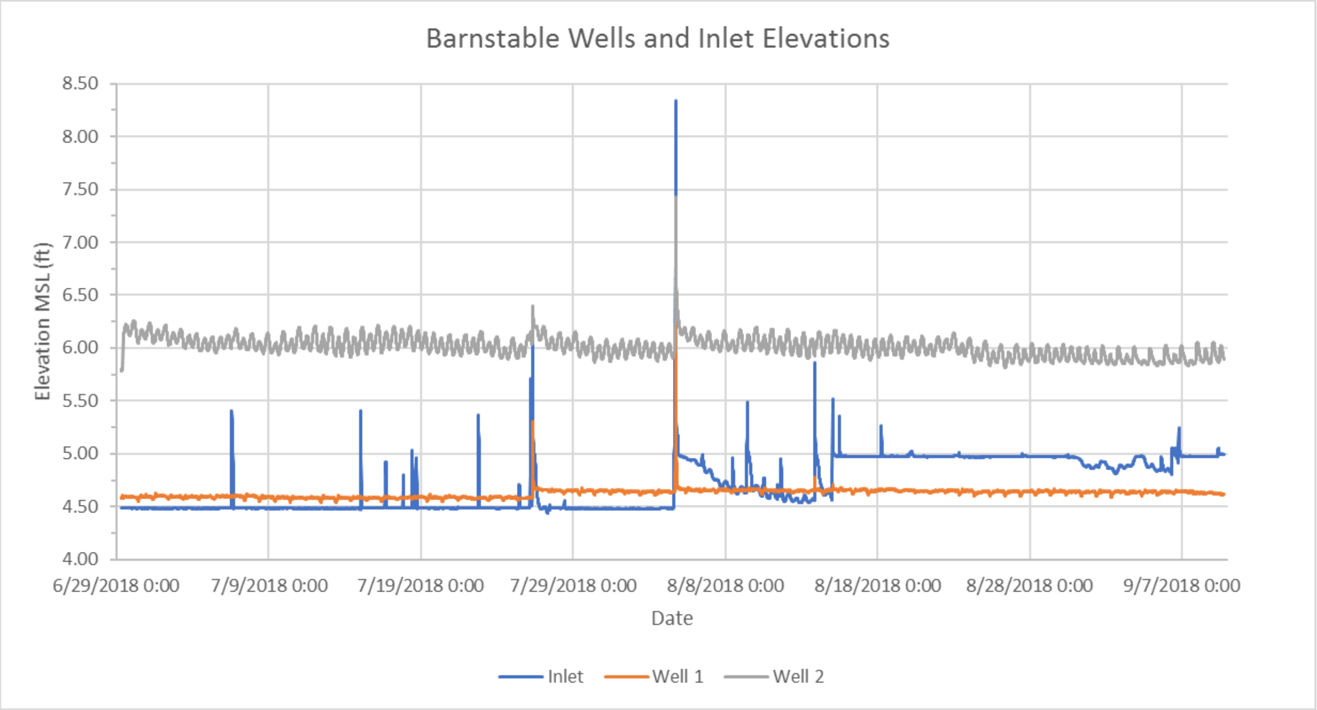

Figure 2: Inlet water elevations and groundwater monitoring wells installed downgradient (well 1) and upgradient (well 2) of the BMP. Elevations are relative to Mean Sea Level.

The groundwater wells showed several important patterns. The system surface was built below the groundwater level and natural groundwater gradient. The above ground ponding area intercepts this hydraulic gradient and results in the permanent ponding conditions and resulting facultative wetland species despite the influent connection being removed. While the elevation of the liner was not verified post-construction, it may be below the upgradient groundwater elevation. In addition, the 1.5 ft drop between the upgradient and downgradient wells may be due to dewatering from the installation of perforated perimeter drains during the time of construction. These perimeter drains run constantly despite the discontinuation of inlet flow further indicating that the system intercepts the natural groundwater gradient by which it is continuously influenced. The diurnal patterns in both wells upgradient and downgradient of the system showed strong evidence of the groundwater being influenced by the tidal cycle. Cycles of low-tide would increase the hydraulic gradient through soil-water suction during the drawdown of low-tide. Figure 3 shows the diurnal groundwater gradient and the small influence of inflow water levels. The main driver of the gradient is the tidal cycle exerting alternating resistance to natural soil transmissivity.

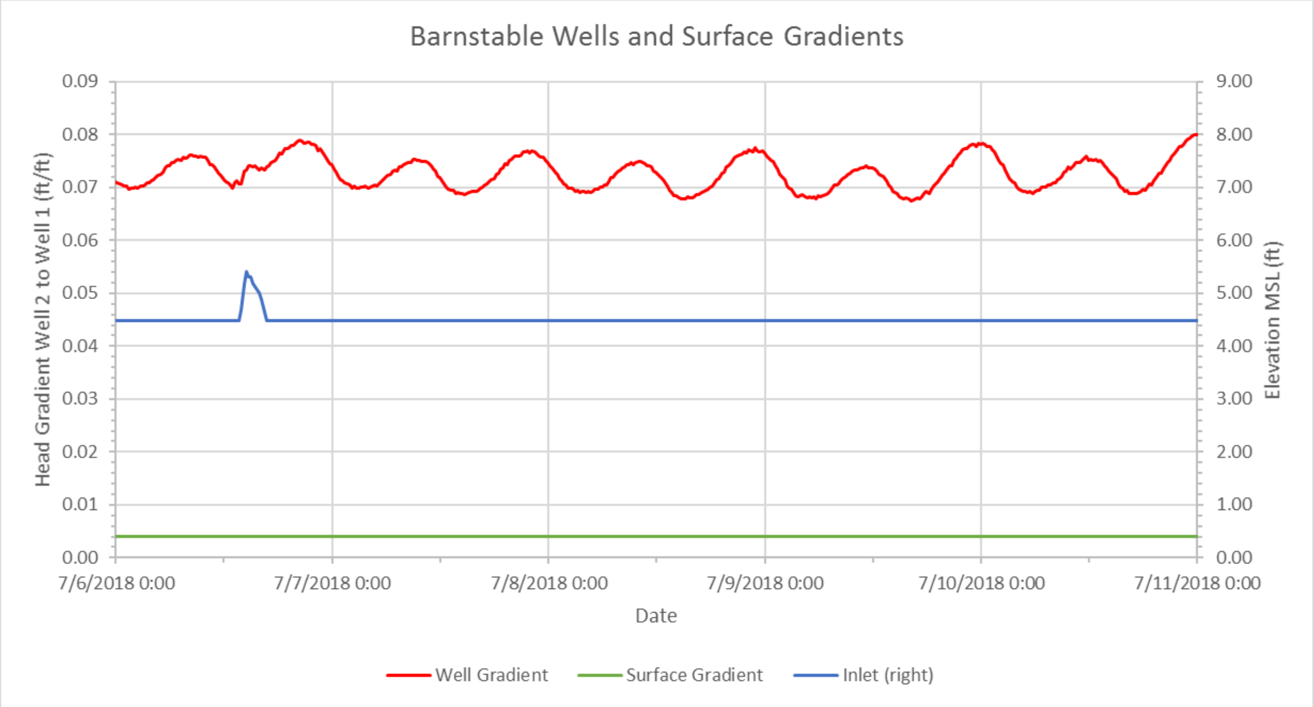

Figure 3: The hydraulic gradient across the system in relation to system surface elevation over four days to show diurnal patterns. The inlet water level is shown on the right axis.

The groundwater gradient is likely artificially lowered on the outlet side by the installation of the 4-inch perforated perimeter drain. As constructed, it is doubtful that the system will generate a sufficient driving head to move stormwater vertically through the system. This could be enhanced by elevating the system surface however it is understood that the surface control is dictated by the invert elevation of the influent pipe that likely cannot be further modified.

In this case, our recommendation is to keep the system offline and elevate the system surface and replant with desired native vegetation if and when access and modification is permitted. The system serves best as a visual educational feature. It was noted throughout our site visits that people frequently stopped and read the signs and learned about the importance of water quality.

More detail may be found in the Final Report from UNHSC in the EPA records submitted regarding the initial monitoring of these BMP’s in 2018.

C. Investigation of Effect of MS4 Baseflow

The effects of the MS4 baseflow on BMP operation and performance were assessed during site visits during dry weather as well as through monitoring of the inlet structure. There was no visible flow in the inlet culvert during site visits during dry weather. Additionally, the longer-term inlet water level monitoring indicates that the inlet water level follows rainfall patterns (see Figure 4). There were a couple of small changes in the inlet water level that did not directly follow rainfall, however, this is not a direct indication of baseflow as the rain data was obtained from the local airport. While the rainfall data is local, there are often very localized microbursts of rainfall that would not appear in the airport rainfall dataset. The specific conductivity is also graphed in orange to compare to possible effects of high-tide seawater intrusion on the system. The conductivity for all storm events matches the pattern for those where no rainfall is recorded.

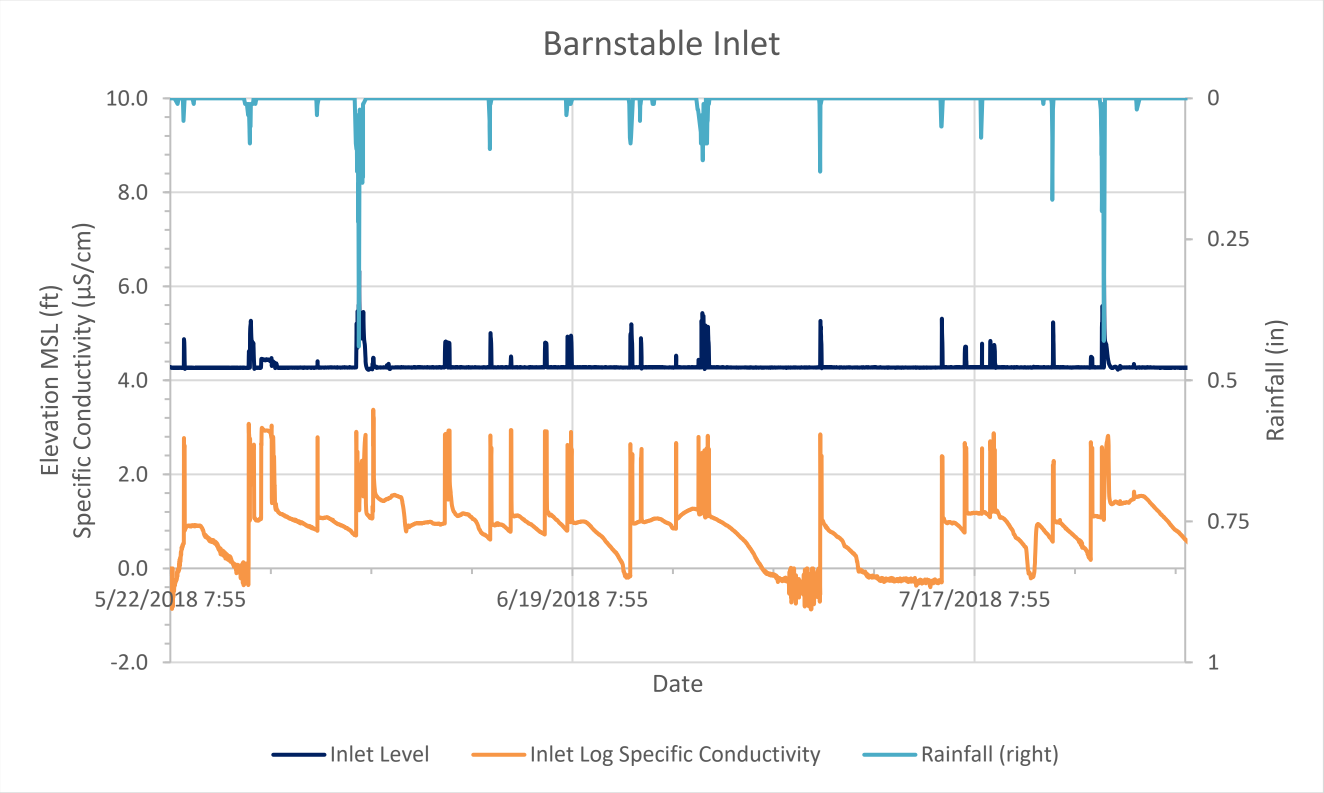

Figure 4: Barnstable rainfall and water elevation at the inlet structure. The dashed lines are reference lines of the system surface and the weir invert in the inlet structure.

Results indicate that baseflow, if an influence at all, is very small and largely insignificant compared with findings of the groundwater hydraulic gradient in Task 3B which would likely drive the performance of the BMP.

D. Climate Resilience

The goal of this task is to be able to operate the BMP in such a way that base flows as low as 10 to 20 gallons per minute may bypass but a tidal surcharge is prevented. A survey of the BMP and outfall indicated the MS4 outfall invert was at about 0.87 ft MSL (Diameter = 2 ft). The outlet invert had an elevation of about 3.7 ft MSL. As the outfall invert is near MSL, a normal high-high tide (without storm surge) may reach 10-15 ft MSL. Without installing pumping capacity, the gravity-fed BMP would not be able to have baseflow outflow during these high tides as there is a lack of driving head to overcome the tidal elevations. During these high tides, the best approach would be to install a one-way valve at the outlet of the BMP to stop tidal water from entering the BMP from the outfall. During lower tides, however, a retrofit option may be a one-way check valve designed for low-flow and tidal scenarios. These valves claim low-head need to open the valve while the curved outlet keeps its shape using the material's memory as well as seawater static pressure to close the outlet during high-tides events. An example of such a valve is the Red Valve Tideflex Series TF-1 or Series 35-1. Outfall modification aside, our recommendations are to keep the system offline, elevate the system surface, and replant with desired native vegetation if and when access and modification is permitted. Modification of the outfall may be unnecessary but may be pursued as a secondary approach.

E. Performance Monitoring Program Update

The BMP was monitored for inlet water level, inlet specific conductivity, groundwater, and real-time water quality using the UV-Vis spectrometer during our final site visit.

The UV-Vis measured parameters are shown in Figure 5 and Figure 6. They show the median values measured over a period of several hours during dry conditions. There was little change over the measurement period, so median values are shown. Note that these measurements were taken during a dry period with no runoff or outflow in the system. These measurements were taken in the inlet structure and outlet structure which is influenced by continuous flow from the perforated perimeter drains. Of note are the readings of DOC, NO3-N, and TN. One of the questions to answer during these measurements was the BMP's performance at denitrifying groundwater during dry weather. These results indicate that the outlet, under the influence of groundwater had elevated values of NO3-N and TN and a lower level of DOC. While the DOC in both the inlet and outlet was in the low range, the cause for the higher nitrogen species in the outlet may be related to the depleted DOC which is a limiting factor of microbially mediated denitrification. Organic carbon is needed as an energy source for the anaerobic bacteria in the saturated zone to denitrify the NO3-N. If the DOC was depleted in this system, the NO3-N (and TN) may be accumulating or otherwise increasing in value due to incoming groundwater with higher levels than at the BMP inlet. Another possibility is higher than expected levels of dissolved oxygen (not measured) in the groundwater due to the high transmissivity of local native soils.

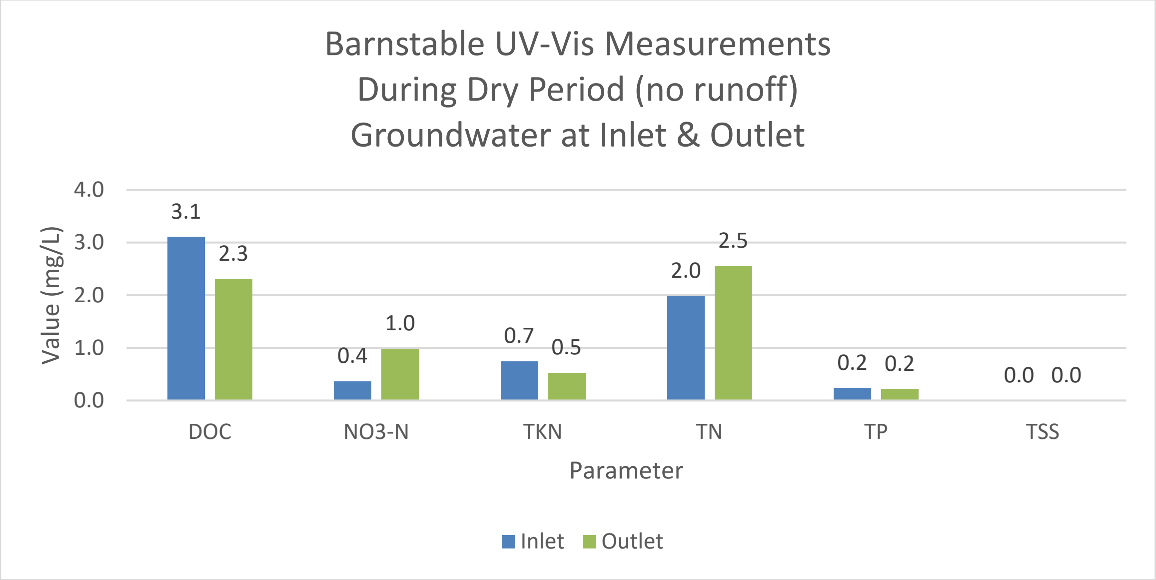

Figure 5: BMP water quality parameters measured with UV-Vis spectrometer.

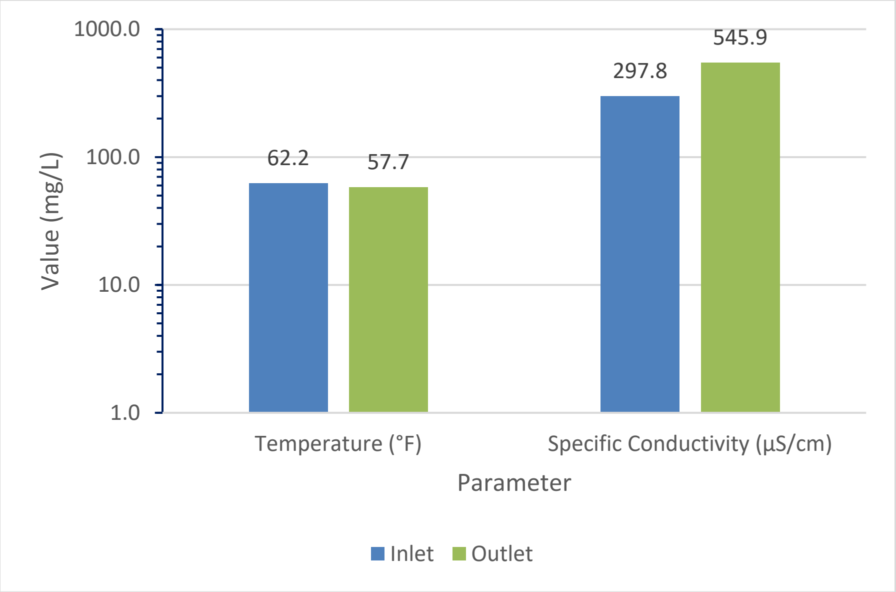

Figure 6: BMP water quality parameters measured with UV-Vis spectrometer.

Regardless of whether high nitrogen loads in the groundwater were due to lack of a carbon source or higher than expected dissolved oxygen levels a simple modification of the subsurface reservoir of any structural system intersecting the natural groundwater gradient would be to add wood chips. UNHSC has done this successfully in other installations and has added 10% wood chips by volume to the reservoir stone course. There is little downside to this simple engineering modification provided that the system is not supporting loading at the surface such as in systems that underlie transportation infrastructure where decomposition of organic material could weaken structural support of anthropomorphic loads.

III. Performance Monitoring Program Update: Chatham

A. Initial Instrumentation Assessment

The first task was to assess the operational status and configurations of the monitoring equipment, emphasizing (initially at least) the status and configurations of equipment for measuring flow. This included the Signature® Flow Meters; and the flow measuring devices, TIENet® Model 350 Area Velocity Sensor (AV sensor) and TRACOM Large 60° V Trapezoidal Flumes (flume) retrofit with the TIENet® 330 Bubbler Module (bubbler). The objective was to attain BMP operational status to obtain hydraulic data over a number of qualifying storm events to ascertain the hydraulic performance of the BMP.

The installed monitoring equipment was not operable after being unused and unattended for 2 years. The equipment remaining at the site was incomplete for operation and/or too fouled for water quality monitoring. Figure 7-8.

Figure 7: Taken 12/20/19. Inlet fiberglass vault and equipment.

The fiberglass vaults were very wet, moldy, and fouled with mouse nests and feces contaminating the instrumentation. Mice were observed directly and/or indirectly during nearly every site visit. See Figure 9 for the mice observed during a visit in September in the outlet vault. They built nests near the door, in the body of the autosampler, and beyond the battery. These were all newly built since they were removed during the previous visit. Besides fouling water quality sampling equipment such as tubing and autosamplers, they chewed through power and data wires several times throughout the monitoring period with the updated UV-sensors. Even with monthly calibration visits the mice and other wildlife challenged the sensitive equipment operations.

Figure 8: Taken 12/20/19. Outlet equipment infested with mice.

Figure 9: Taken 9/1/20. Outlet vault and mice nest. About 10 mice were observed in this vault during the visit. Note the nest in the upper right of the photo.

All exposed wiring was finally enclosed in hard plastic tubing and all entrances filled with rodent-deterrent foam.

Data was attempted to be downloaded from the outlet Signature® Flow Meters to retrieve any data collected prior to our arrival. Once connected to a power source, the Flow Meter was able to pressurize the bubblers but unable to export any data and resulted in exporting errors during every attempt at data retrieval.

The autosamplers and area velocity sensors were very fouled and unusable for this monitoring effort. They had not been used, cleaned, or kept up since the initial installation.

The two TRACOM Large 60° V Trapezoidal Flumes in the inlet and outlet monitoring structures were in good, usable condition and were used after a thorough cleaning to remove the bioaccumulation.

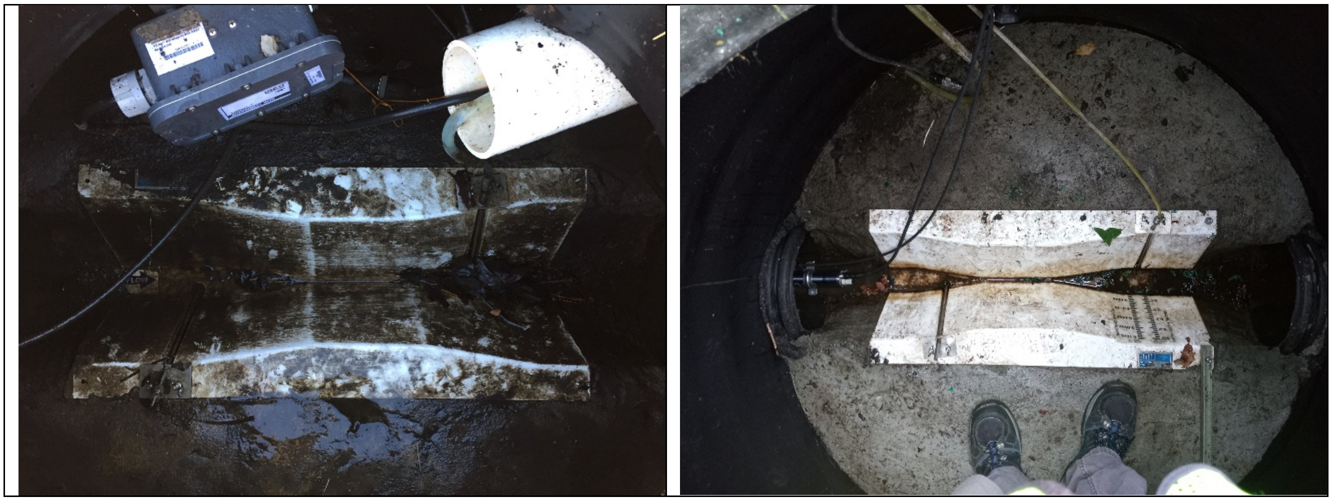

Figure 10 Taken 12/20/19. The inlet and outlet TRACOM Large 60° V Trapezoidal Flumes to show the before and after condition following cleaning.

The two (2) In-Situ Aqua TROLL 600 Multiparameter Sondes installed at both the inlet and outlet structures were very fouled. After inspecting, cleaning, replacing the batteries, and testing the sondes, they were either inoperable and/or unreliable and returned errors upon attempting to download test data. The result of nearly 3 years of inattention was an almost complete loss of all equipment. The exceptions were the flumes, rain gauges, the two ISCOs, and Signature Flow Meters that were housed inside and protected from the elements and wildlife at the Barnstable site.

B. New Monitoring Instrumentation

The objective was to attain BMP operational status to collect hydraulic data over a number of qualifying storm events to ascertain the performance of the BMP. A new monitoring plan and instrumentation installation were implemented to obtain hydraulic performance. The flumes were used as a flow monitoring location at both the inlet and outlet locations as they provide a known geometry and accurate flow estimates.

For the inlet location: a Campbell Scientific CS 451 Pressure Transducer was installed in the TRACOM Large 60° V Trapezoidal Flume along with a UV-Vis spectrometer (s::can spectro::lyser V3). A similar installation was used in the outlet location. Both instruments were connected to a Campbell Scientific CR1000X Datalogger to record data and trigger both instruments during rain events to conserve memory and battery power. The effluent location was also instrumented with a rain gage. The full instrumentation setup is shown in Figure 12.

Figure 11: Taken 7/30/20. Inlet instrumentation in the TRACOM Large 60° V Trapezoidal Flume, Campbell Scientific CS 450

Figure 12: Taken 12/4/20. The effluent monitoring instrumentation included a solar panel, deep cycle marine battery, a tipping bucket rain gage, datalogger, pressure transducer, and UV-Vis spectrometer.

The loggers were programmed to trigger measurements of the pressure transducers and spectrometers once a critical level of rainfall or water level was detected. This was done to conserve battery power, reduce wear and damage to the spectrometer's wiper, increase the spectrometer's measuring lifespan, and not fill the dataloggers with non-useful data during dry periods. Both locations had measurement intervals of 5 minutes once triggered during a wet event. Specific issues in programming and collecting data from the sensors are discussed further in Sections III.C and IV.

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C. Monitoring Results

1. Climate and Rainfall

While much of New England suffered from a significant drought in 2020, Chatham had above average amounts of precipitation throughout the year. However, there were below average rainfall totals during the beginning of the monitoring period when all instrumentation was installed in July. July and August had below-average rainfall amounts. Chatham, MA sees an average of about 47 inches of annual precipitation. This year (with data as of 12/14/20 from Chatham Municipal Airport[2]), there has been a total of about 67 inches of precipitation. See Figure 13 for the 2020 and historic average precipitation depths per month. Note that much of the excess precipitation for 2020 occurred in April with precipitation totals about three times the historic average.

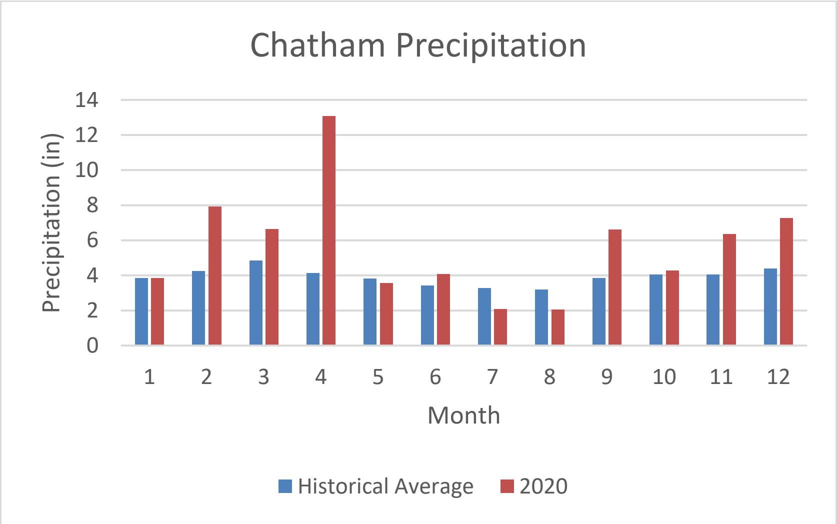

Figure 13: Chatham, MA precipitation by month comparing the historic average and 2020 totals.

One difficulty with the site being remote and without power is that all equipment was battery-operated or needed power from a deep-cycle marine battery recharged by a photovoltaic solar panel. While this gave some freedom to the types and locations of the instruments used, it also provided difficulty. Some instruments were chosen for their portability, accuracy, and onboard power such as the Onset HOBO U20L for measuring water level. There were 8 unique monitoring instruments with different clocks and power needs. While most of the challenges associated with having many instruments with unique power supplies and internal clocks were overcome, some were more problematic.

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[2] Data source: NOAA LCD. https://www.ncdc.noaa.gov/cdo-web/datasets/LCD/stations/WBAN:94624/detail. Downloaded 12/17/20 with data from 1/1/20-12/14/20

One such difficulty was observed in the inlet datalogger at the beginning of July and August when there was a logging error. While the exact cause of the error was unknown, the error was noticed and corrected in early August. The error, which resulted in lost data, fortunately, coincided with the lower-than-average rainfall during July and August, and missed events were minimized. The long-term rainfall, inlet flow, and outlet flow are shown in Figure 14.

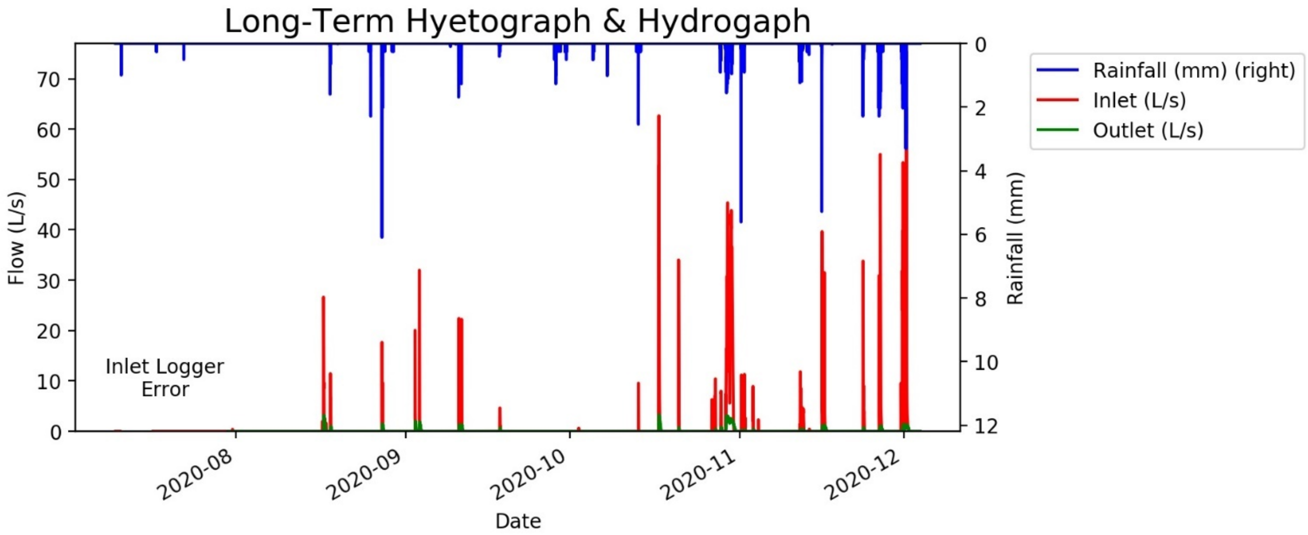

Figure 14: Long-term hyetograph and hydrograph during the monitoring period. Note the period in July-August where the inlet datalogger had a program error and did not record events.

It is also of note that there were six (6) runoff events where rainfall was not logged with the site rain gage or the backup site at the Chatham Municipal Airport. While there was no recorded rainfall, the hydrographs followed a similar pattern to other rainfall/runoff events and are therefore included in the events and summary statistics that follow. The rationale for including these events was that despite not having recorded rainfall, there was measured inflow, outflow, and treatment by the BMP. The BMP treats all incoming runoff despite its source. While the source of the runoff during the events without rainfall record is unknown, there was recorded offline bypass in the bypass structure in all these events.

2. Offline Bypass

Offline bypass of the BMP was measured using a pressure transducer at the downstream side of the diversion weir of the inlet control structure on Oyster Pond Furlong. See Figure 15 for the location of the inlet control structure and the water-level sensor for monitoring offline bypass.

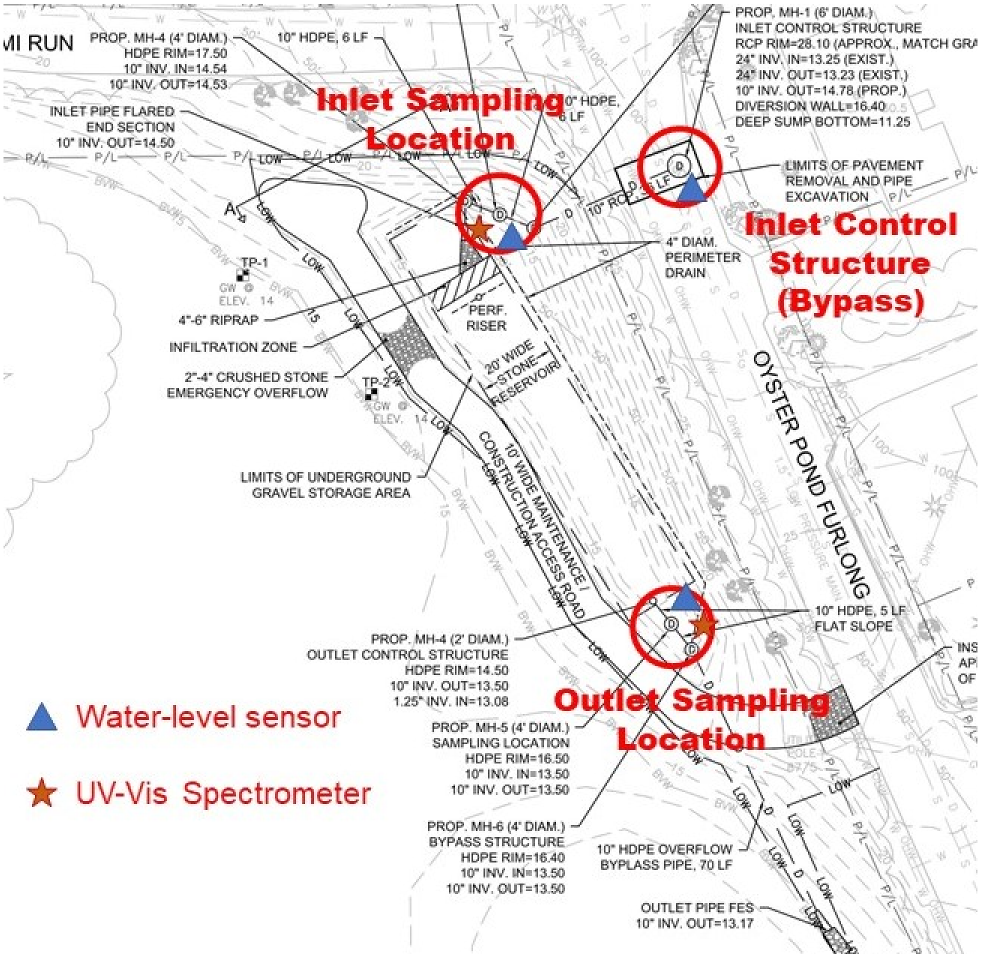

Figure 15: Locations of installed water-level sensors and UV-Vis spectrometers for flow and water-quality monitoring.

Bypass was calculated using the water-level at the entrance of the 24-in RCP outlet that exits and continues down Oyster Pond Furlong where it daylights to Oyster Pond. The inlet control structure has an internal weir wall designed to divert runoff toward the BMP inlet and high flows will overtop the weir and continue to the bypass pipe. All bypass flow is untreated runoff that drains directly to the pond. See Figure 16 and Figure 17 for examples of bypass (in dashed black) for two example events. To see all event bypass hydrographs, see Appendix 1. Note that the bypass during the event of 11/11/20 was negligible while the bypass of event 11/30/20 was very high and exceeded the peak inflow by 1.7 times. This illustrates how increased rainfall and especially higher rainfall intensity rates produce much higher and flashier runoff peaks coinciding with higher peaks and volumes of offline bypass.

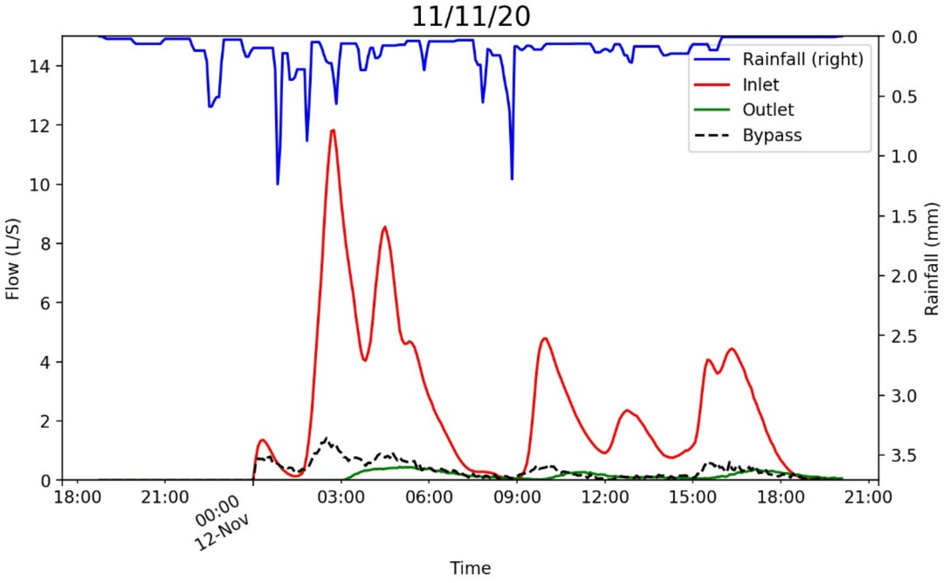

Figure 16: Hyetograph and hydrographs for inflow, outflow, and offline bypass for 11/11/20.

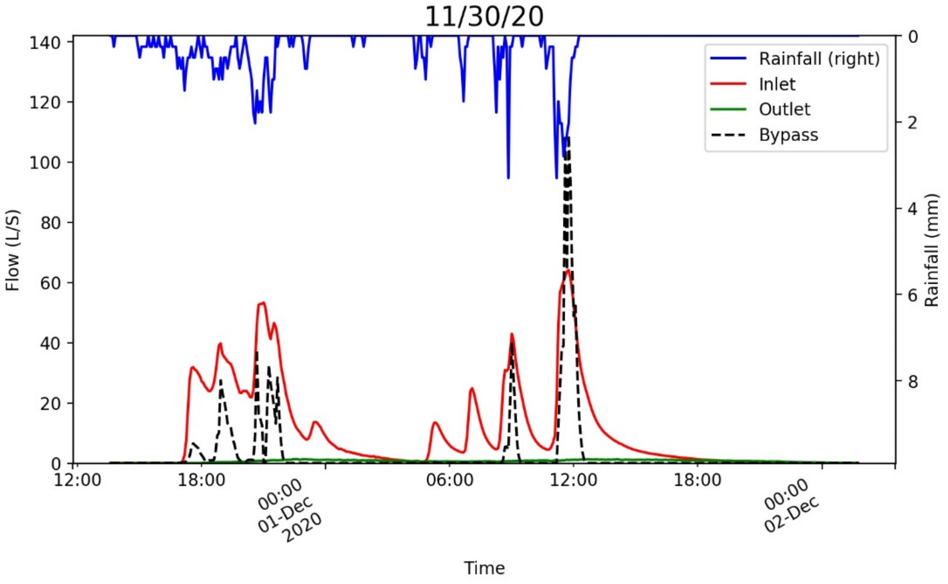

Figure 17: Hyetograph and hydrographs for inflow, outflow, and offline bypass for 11/30/20.

Table 1 shows the rainfall and bypass values and summary statistics. The sixth column shows the ratio of the inlet peak flow to the bypass peak flow. A ratio less than one indicates the bypass peak flow exceeded the inlet peak flow; a ratio greater than 1 exceeded the bypass; a ratio greater than one (1) indicates the opposite scenario that the inlet peak flow exceeded the bypass peak flow. While there wasn't a significant pattern, we would expect to see a ratio greater than 1 for events with low-intensity runoff events. The final column of inlet volume/runoff shows the percent of total runoff that was diverted to the BMP by the inlet control structure. Note that most events conveyed between 56-86% of the total runoff into the BMP. This means that 14-46% of the total runoff bypassed directly to Oyster Pond untreated. This will be revisited when presenting the removal efficiency of runoff volume, but overall the system outperformed the design expectation which would have predicted 75% of the total runoff volume would be bypassed.

Table 1: Rainfall and bypass observations and summary statistics.

Event ID	Event Date	Rainfall (mm) (in)	Mean Intensity (mm/hr) (in/hr)	Peak Intensity (mm/hr) (in/hr)	Inlet Peak Flow / Bypass Peak Flow	Inlet Volume / Runoff Volume
1	8/16/20	-	-	-	0.4	56%
2	8/18/20	14.7 (0.58)	1.4 (0.06)	19.2 (0.75)	28.1	95%
3	8/27/20	24.4 (0.96)	2.2 (0.09)	73.2 (2.88)	0.5	54%
4	9/2/20	33 (1.3)	3 (0.12)	71.9 (2.83)	0.4	55%
5	9/3/20	92.7 (3.65)	7.7 (0.3)	260.6 (10.26)	0.1	28%
6	9/10/20	11.4 (0.45)	1.1 (0.04)	20.2 (0.8)	0.4	55%
7	9/11/20	8.6 (0.34)	0.9 (0.03)	15.2 (0.6)	0.8	74%
8	9/18/20	9.4 (0.37)	0.9 (0.04)	4.9 (0.19)	2.5	56%
9	10/13/20	13 (0.51)	0.7 (0.03)	30.5 (1.2)	5.6	73%
10	10/17/20	4.3 (0.17)	0.3 (0.01)	6.5 (0.26)	0.4	50%
11	10/20/20	-	-	-	2.9	91%
12	10/26/20	-	-	-	3.4	69%
13	10/27/20	-	-	-	8.2	86%
14	10/28/20	9.7 (0.38)	0.6 (0.02)	10.9 (0.43)	6.2	82%
15	10/29/20	93.2 (3.67)	1.9 (0.08)	18.6 (0.73)	1.1	83%
16	11/1/20	13.7 (0.54)	1.8 (0.07)	67.4 (2.65)	130.7	99%
17	11/1/20	5.3 (0.21)	0.4 (0.02)	10.9 (0.43)	31.2	96%
18	11/3/20	-	-	-	7.5	87%
19	11/4/20	-	-	-	5.9	84%
20	11/11/20	34 (1.34)	1.3 (0.05)	14.8 (0.58)	8.3	88%
21	11/13/20	4.8 (0.19)	0.3 (0.01)	4.2 (0.17)	0.8	35%
22	11/15/20	14.5 (0.57)	0.6 (0.02)	63.4 (2.5)	1.6	80%
23	11/23/20	16.3 (0.64)	1.8 (0.07)	27.4 (1.08)	5.4	86%

Event ID	Event Date	Rainfall (mm) (in)	Mean Intensity (mm/hr) (in/hr)	Peak Intensity (mm/hr) (in/hr)	Inlet Peak Flow / Bypass Peak Flow	Inlet Volume / Runoff Volume
24	11/26/20	37.3 (1.47)	1.6 (0.06)	27.4 (1.08)	0.9	76%
25	11/30/20	89.9 (3.54)	2.5 (0.1)	39.6 (1.56)	0.6	77%
	n	19	19	19	25	25
	Minimum	4.3 (0.17)	0.3 (0.01)	4.2 (0.17)	0.1	28%
	First Quartile	9.5 (0.37)	0.6 (0.03)	12.9 (0.51)	0.6	56%
	Median	14.5 (0.57)	1.3 (0.05)	20.2 (0.8)	2.5	77%
	Third Quartile	33.5 (1.32)	1.9 (0.07)	51.5 (2.03)	6.2	86%
	Maximum	93.2 (3.67)	7.7 (0.3)	260.6 (10.26)	130.7	99%
	Total	530.4 (20.88)				

3. BMP Hydraulic Performance

The summary statistics of the inlet and outlet peak flows are shown in Table 2. The inlet had a much larger range and standard deviation of peak flows compared to the outlet. The outlet had very constant peak flows with a small deviation of only 1 L/s. This is also observed in the hydrographs and can be seen in Appendix 1. This is likely a combination of the hydraulic efficiency of routing the runoff volume through the system and the control of the outlet orifice. There was no internal bypass in the system, and the ponding level was never observed more than half full (see the previous report to EPA in 2018).

Table 2: Summary statistics of the inlet and outlet peak flows.

Statistic	Inlet Peak Flow (L/s)	Outlet Peak Flow (L/s)
Minimum	0.4	0.0
First Quartile	9.6	0.4
Median	17.7	0.8
Third Quartile	33.8	1.4
Maximum	64.1	3.3
Standard Deviation	18.6	1.0

4. Pollutant Concentrations

Monitoring for pollutants of interest was performed using real-time, in-situ ultraviolet-visual (UV-vis) spectroscopy and previously developed prediction models (UNHSC, 2019). The UV-vis spectrometers were placed at the inlet and outlet monitoring locations near the calibrated flumes. The locations can be seen in Figure 15.

All events were monitored, and concentrations were calculated for total suspended sediment (TSS), total nitrogen (TN), and total phosphorus (TP). The data recorded is light absorbance per meter for wavelengths in the 220-720 nanometer (nm) range. The concentrations of pollutants were calculated using a prediction model from UNHSC based on Partial Least Squares (PLS) regression comparing to laboratory values. The model is from a previous study by UNHSC submitted in 2018 to and funded by the U.S. EPA titled *Utilizing In-Situ Ultraviolet-Visual Spectroscopy to Measure Nutrients and Sediment Concentrations in Stormwater Runoff*. The PLS prediction model can be used to estimate concentrations of other pollutants, but this study and report focus on TSS, TN, and TP as they are of importance to regulated MS4 communities and current pollution issues related to stormwater runoff.

The process of measuring pollutant concentrations using a spectrometer varies significantly from conventional methods which take physical stormwater samples by grab samples or autosamplers which are refrigerated for preservation, combined or otherwise processed by staff, sent to a laboratory for analysis of the pollutants of interest using wet-chemistry techniques. The spectrometer is a single in-situ instrument with a 5 mm measurement channel where stormwater passes through the channel. The spectrometer measures light absorbance in the UV-vis range according to whatever solids and mixture of dissolved or gross solids mixed with the stormwater within the measurement channel. This measurement process differs from the conventional methods where a strainer of some kind is used at the end of autosampler hoses to exclude gross and non-dissolved solids.

Figure 19 and Figure 20 show the same storms as before. The top subplot shows the rainfall and hydrographs for the inlet and outlet. Subplots 2-4 show the pollutographs for TSS, TN, and TP, respectively. One unique aspect in post-processing the spectrometer data is the need to correct for values before and after the runoff event. Because it records continuously (rather than carefully timed flow-weighted samples during runoff with an autosampler), stagnant water and the accumulation of settling debris is measured and yields unusually high values before and after the hydrograph as well as occasionally during a lull in the runoff. This is compensated during post-processing by eliminating values at the beginning and end of the event where flows are less than 0.063 L/s (1 gpm). The values during a runoff event were left for this report as an example of the unique quirks of working with spectrometers. There are several approaches to adjusting these values: leave them if they seem plausible, remove the high outlier values when the flow is above a certain threshold, or a more sophisticated although possibly unwarranted approach could be to adjust values based on a threshold of the absolute value of the first derivative of the rolling mean pollutograph. The third approach is suggested, although not used here because it would provide a programable solution to processing all events consistently without user judgment needed for individual events and concentrations. At its core, it would take a rolling mean to look smooth out the variance between any two measurements, take the first derivative to look at the slope of the pollutograph, and flag values when the slope is above a certain threshold to remove unusually high spikes which tend to singular values as opposed to several high values in a row. Another similar approach would be to compare the relative percent increase between values of a central rolling mean. These are suggested as possible processing techniques for future studies, but they were ultimately not needed for this study for a simple reason. The high spikes in concentration occurred during very low flow periods, and when converting to mass (concentration times flow volume), the resulting mass delivered is usually very small and almost negligible to the total mass delivered. Figure 18 compares the inlet spectrometer for two separate site visits when the spectrometer was sitting in clean or no water compared to a fouled, highly turbid water. This illustrates why a spike in concentration is sometimes observed as this fouled water and debris settles on the instrument during low flows. However, the lack of flow means the high concentrations of pollutants are not being delivered to the BMP as they are not moving.

Figure 18: The inlet spectrometer during 2 site visits to illustrate the fouling at the receding limb of the hydrograph.

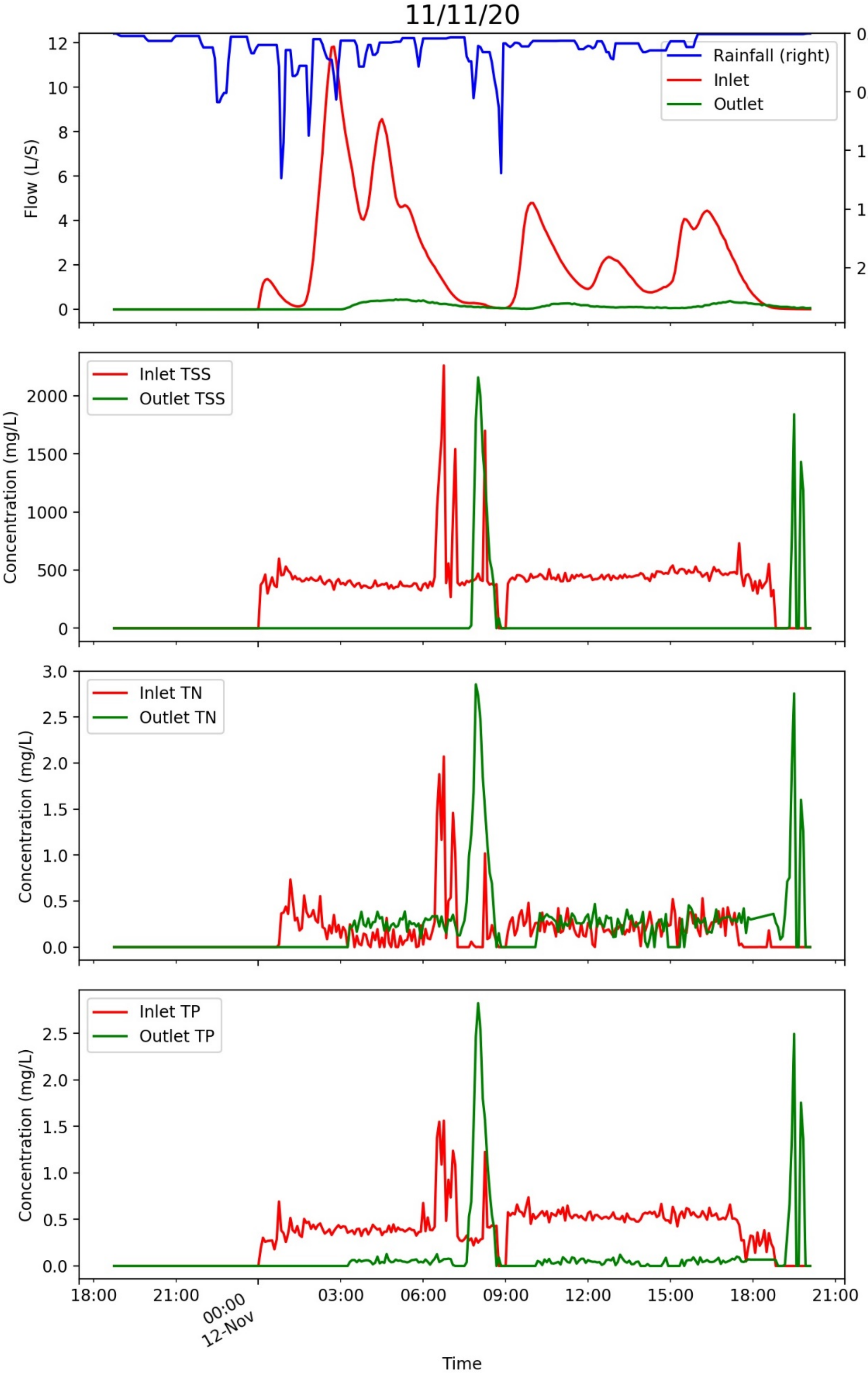

Figure 19: Rainfall, hydrographs, and pollutographs for TSS, TN, and TP for the event of 11/11/20.

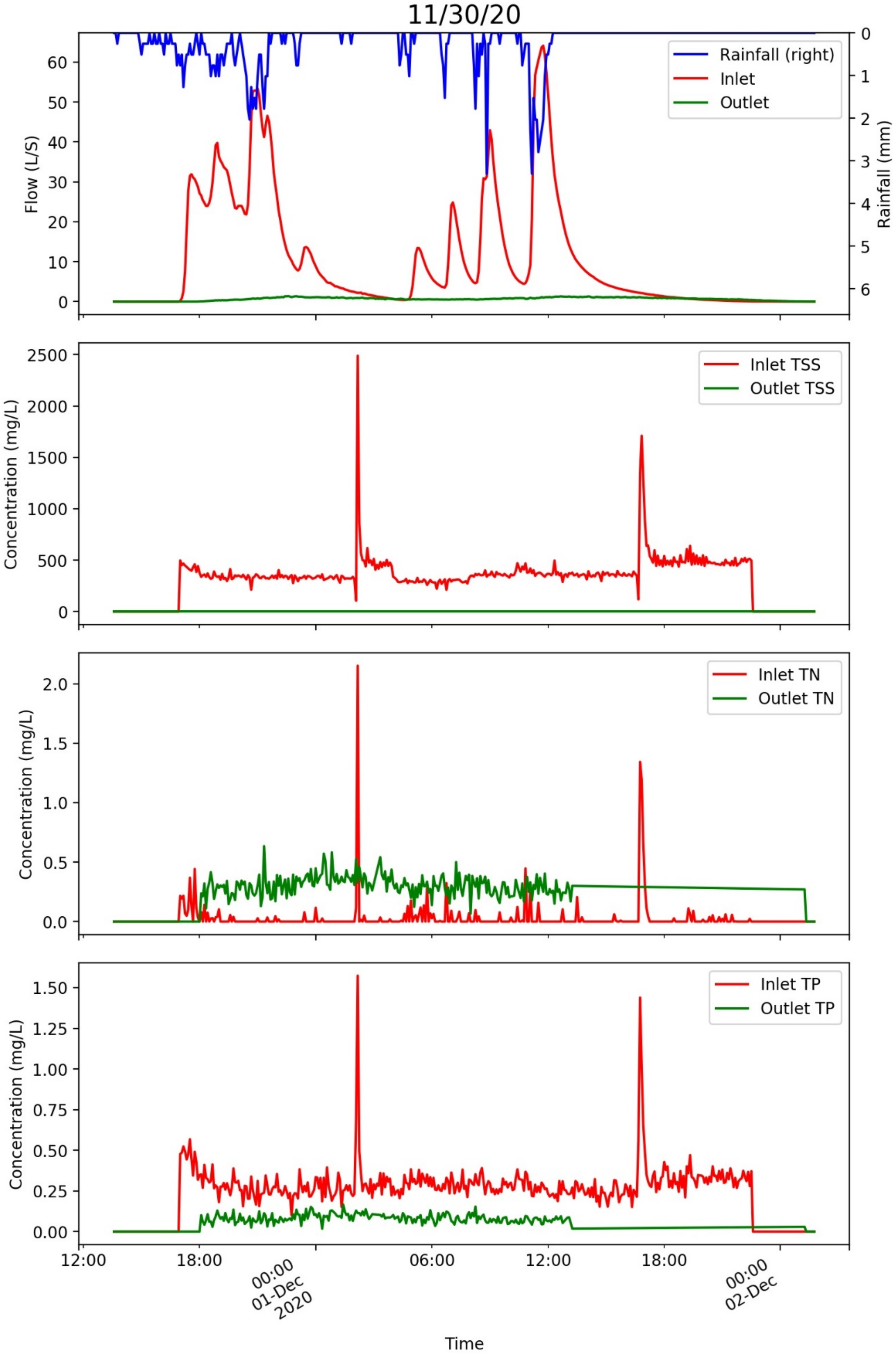

Figure 20: Rainfall, hydrographs, and pollutographs for TSS, TN, and TP for the event of 11/30/20.

Note the spikes in all three pollutographs during the middle of the storms on the receding limbs of the hydrographs in Figure 19 and Figure 20. Another observation for these storms is the delivery of TSS, TN, and TP. While the flow changes significantly, the concentrations of TSS and TP are fairly uniform. TN seems to have a different pattern as it has higher concentrations early on during the event on the rising limb of the hydrograph and occasionally during the rising limb of the second pulse of runoff as seen in Figure 20. These patterns will be explored further in Section III.C.6. See Appendix 3 for the concentration pollutographs of all the monitored events.

5. Pollutant Mass

Once the hydrographs were calculated and the concentrations were calculated for the pollutants using the Partial Least Squares regression prediction model, the mass pollutographs were easily developed multiplying the respective flow (inlet or outlet), the time measurement interval, and each pollutant concentration. The mass pollutographs for the same event of 11/11/30 and 11/30/30 are shown in Figure 21 and Figure 22, respectively. Notice the spikes in the concentration during the low flows previously discussed are now very small relative to the total mass delivered. They were intentionally kept unaltered for the graphs to illustrate the “do nothing” approach as the low flow diminishes their impact on the total mass. However, they could easily be removed if desired.

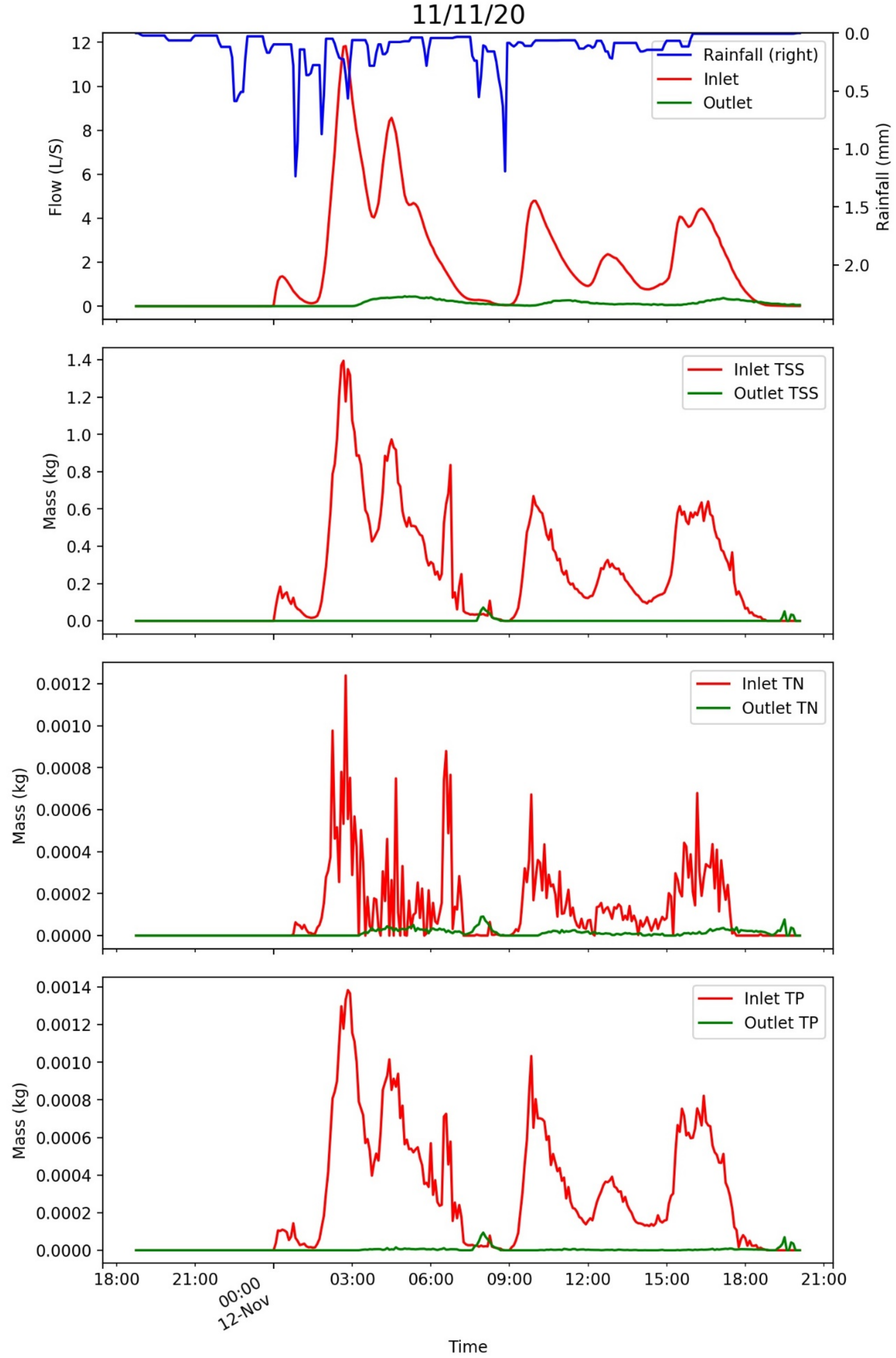

Figure 21: Rainfall, hydrographs, and mass pollutographs for TSS, TN, and TP for the event of 11/11/20.

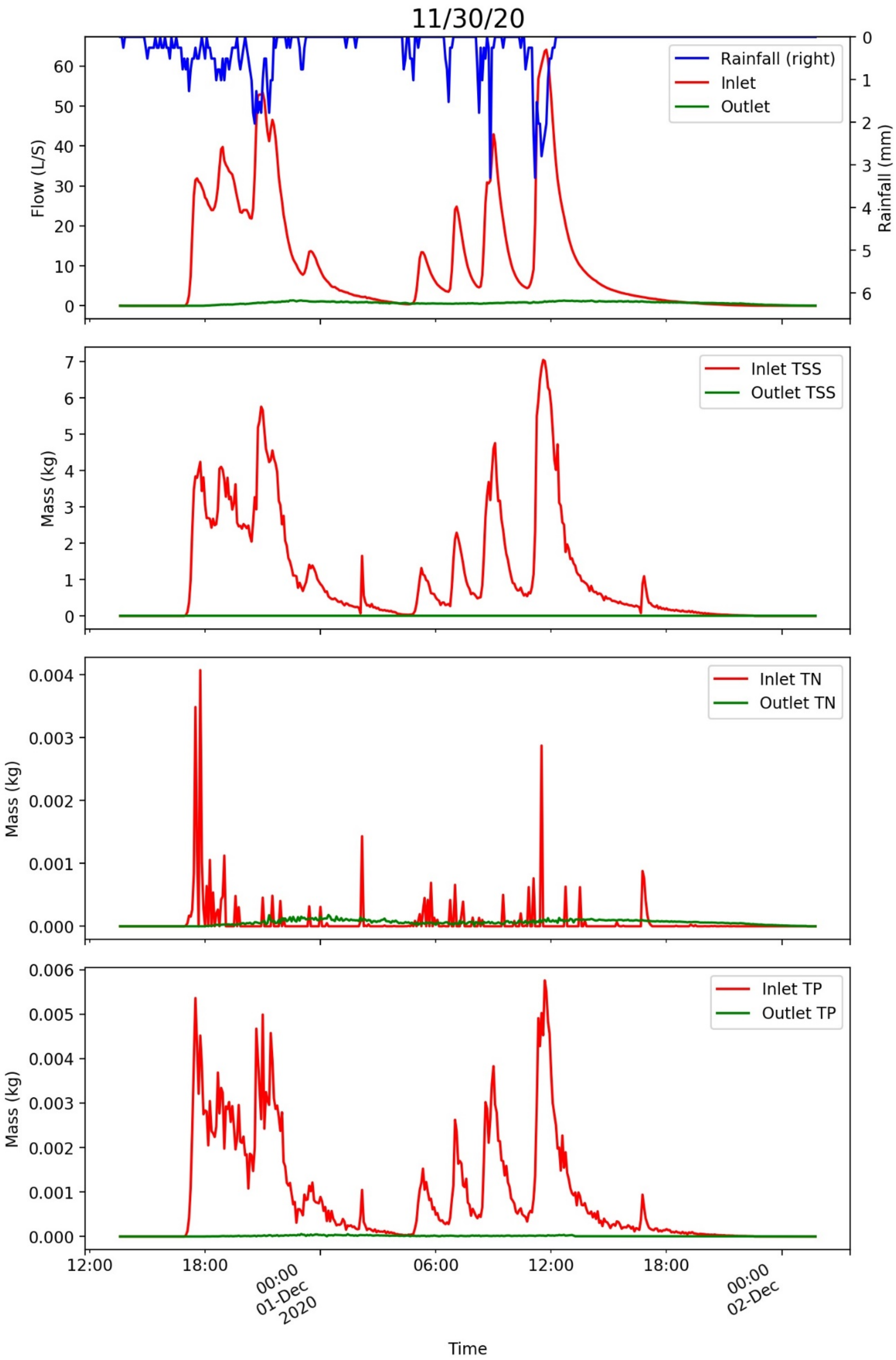

Figure 22: : Rainfall, hydrographs, and mass pollutographs for TSS, TN, and TP for the event of 11/30/20.

Because TSS and TP had consistent concentrations for the duration of runoff as previously discussed, their mass pollutographs closely resemble the hydrographs as a hydrograph multiplied by a constant yields a multiple of itself. The TN, on the other hand, is not generally as consistent. In the first event (11/11/30), the TN concentration is relatively constant and, therefore, the mass curve generally matches the hydrograph. In the second example event (11/30/20), the TN concentration had higher concentrations at the beginning of the rising limb of the first and second pulse of runoff. This translates to a mass curve with a different shape than the hydrograph. This yields a mass curve with high spikes at those times. See Appendix 3 for the mass pollutographs of all the monitored events.

6. Dimensionless Volume and Mass Curves

The runoff hydrographs and mass pollutographs developed in Sections III.C.2 through III.C.5 are helpful to investigate individual events as each is unique. However, to look at all the information at once, it is more helpful to develop dimensionless, cumulative pollutant vs volume curves. This process looks at the cumulative pollutant mass as a function of the cumulative flow (or volume) instead of a function of time. This removes the time component from each event and allows comparison between events of varying runoff duration. The cumulative, dimensionless component changes the scales from 0 to the maximum runoff or pollutant mass to 0-1. This allows the comparison of events with varying volumes and pollutant mass.

For reference, Figure 23 shows the general theoretical dimensionless pollutographs for urban runoff (Lee & Bang, 2000). The graphs are divided into particulate and dissolved pollutants. The curves above the 1:1 reference line depict an early delivery of the load during the event. Curves below the reference line are for late delivery, and the “S” curve that crosses in the middle of the event is middle-flush delivery. An additional curve not shown is one that closely follows the reference line; this kind of delivery would match the flow.

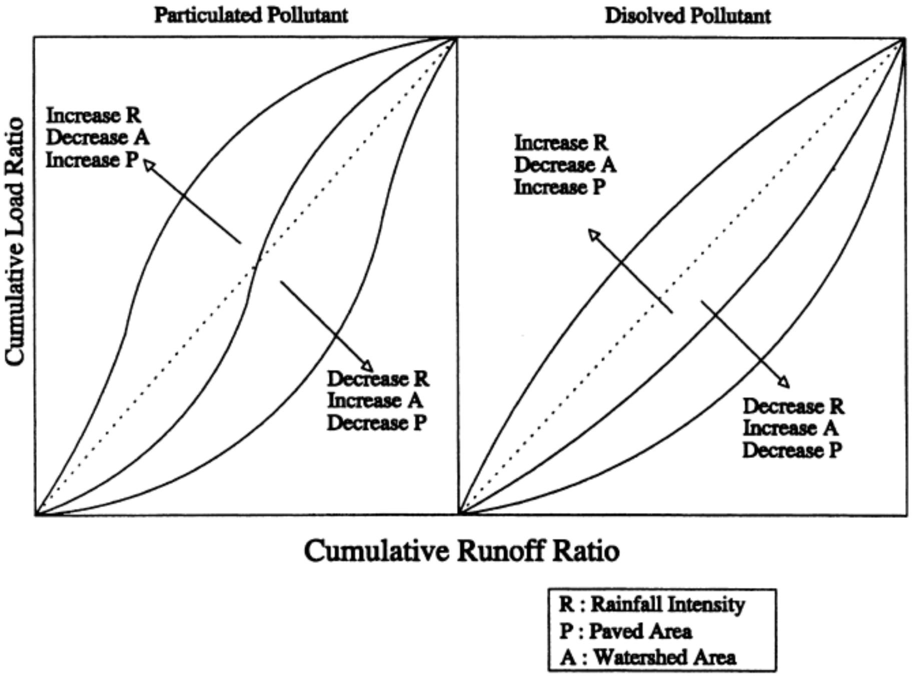

Figure 23: Dimensionless cumulative curves characterized for urban runoff (Lee & Bang, 2000).

Figure 24 shows the dimensionless, cumulative plots for each pollutant vs its respective flow (or volume). Note that flow and volume are used interchangeably in this section as the time step was consistent for all events so the cumulative flow and volumes have the same shape curve but different scales (a factor of the time interval), but the nondimensionalization removes the interval factor.

Note that there are several straight then acute lines that do not fit the smooth theoretical curves. The outlet TSS exemplifies these straight lines. These are largely due to almost no effluent TSS mass, but a single spike in the TSS pollutograph would translate to 100% delivery of the total mass during a single time step.

The inflow TSS generally has more storms that tend toward slightly early delivery. There are all types of delivery events, however. The effluent TSS had the strangest shaped graph as all of the events had one or two measurements of TSS during the event; this produces a very sharply changing line. This is due to almost no TSS mass in the effluent as observed by the mass pollutographs in 3 and Table 5.

The TN and NO_3 curves are the most interesting and variable for the inflow. TN and NO_3 have widely been associated with "first flush" types curves. This would be indicated by a curve to the left of the reference line. The steeper the curve and the greater deviation to the left of the reference line the greater the "first flush" incidence. There is a predominance of first flush event types particularly for NO_3. This supports previous findings. There are also a couple of events that closely follow the reference line. The discrepancy may come from the shape of the hydrographs having multiple peaks and behaving as back-to-back first flush storms where the TN and NO_3 mass spikes on the rising limb of each of the pulses of the variable rainfall intensities. This discrepancy to the straight forward theoretical first flush mass curve seems to come from the widespread use of uniform hydrographs (such as the unit hydrograph) in the common design and modeling approaches compared with the dynamic reality of very non-uniform and more random hydrographs observed in nature. This variability can also be an artifact of the build-up vs wash-off phenomenon. There are mass limited and volume limited storm events coinciding with the depositional mass and antecedent periods between events. Mass limited storms may be due to back-to-back precipitation events that have mobilized all available pollutants. Alternatively, there are instances where large antecedent dry periods or periods of high deposition (such as fall) results in a mass that is not completely mobilized by a storm event thus there is leftover available mass that will be delivered during subsequent runoff events. The effluent curves for all pollutants are more evenly distributed and nearly all fall on or near the reference line indicating a more uniform release of pollutants in the effluent. This is also contrasted by the dramatic reduction of pollutant mass in the effluent across all parameters and subsequent low but continual release of undiminishable or background pollutant concentrations.

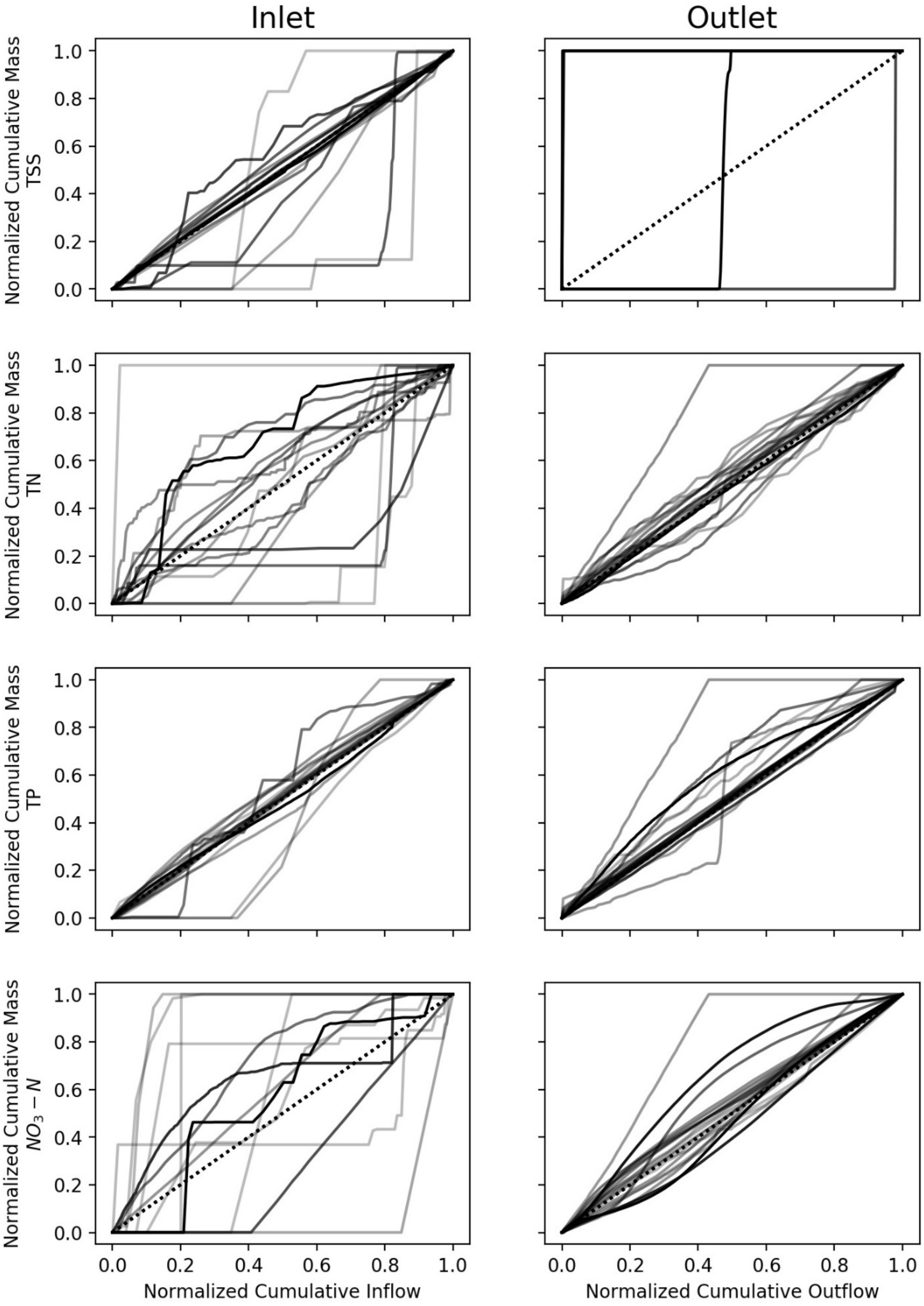

Figure 24: Dimensionless, cumulative mass pollutographs for TSS, TN, and TP and NO_3 vs inflow and outflow volumes. Note the greyscale from lightest to darkest (black) correspond to the respective total pollutant mass per event (least-grey to greatest- black).

7. Pollutant Loading and Removal

One of the benefits of using the UV-Vis spectrometer is that the single instrument can be used to estimate multiple parameters (if there is a previously calibrated curve). Table 3 shows the total estimated mass loading per event at the inlet for the UV-Vis predicted parameters. The summary statistics are shown at the end of the table. Note the different units (mg, g, and kg) to accommodate the varied loading amounts.

Table 3: Estimated total mass loading at the inlet for various pollutants.

Event ID	Event Date	NO3-N (mg)	TKN (g)	DOC (g)	TN (g)	TP (g)	TSS (kg)
1	8/16/20	-	-	-	-	-	-
2	8/18/20	-	-	-	-	-	-
3	8/27/20	-	-	-	-	-	-
4	9/2/20	0	118	16	0	7	15
5	9/3/20	-	-	-	-	-	-
6	9/10/20	-	-	-	-	-	-
7	9/11/20	-	-	-	-	-	-
8	9/18/20	-	-	-	-	-	-
9	10/13/20	56	37	186	9	7	6
10	10/17/20	26233	590	4392	85	235	204
11	10/20/20	0	136	1336	44	70	47
12	10/26/20	88	44	384	10	12	9
13	10/27/20	144435	6359	1051	475	370	196
14	10/28/20	514	104	506	30	41	32
15	10/29/20	85837	309	4	98	2373	121
16	11/1/20	92	0	0	0	19	0
17	11/1/20	31	0	0	0	32	0
18	11/3/20	7372	0	0	2	27	0
19	11/4/20	2670	1726	107	178	36	125
20	11/11/20	0	259	1525	36	83	76
21	11/13/20	0	3	1	0	0	0
22	11/15/20	47764	493	1039	49	133	141
23	11/23/20	120	427	819	84	143	121
24	11/26/20	4	871	1342	10	134	181
25	11/30/20	0	2131	3352	34	380	482
	n	18	18	18	18	18	18
	Minimum	0	0	0	0	0	0
	First Quartile	1	39	7	4	21	7
	Median	90	198	445	32	55	62
	Third Quartile	6196	566	1264	75	141	137
	Maximum	144435	6359	4392	475	2373	482
	Total	315217	13607	16058	1144	4102	1757

An interesting “reality check” can validate the TSS totals. The median total TSS load per storm was about 62 kg. A quick calculation using the bulk density of sand (1680 kg/m^3), yields a volume of about 33 cm cubed (1.3 ft^3). This is a reasonable amount of sediment load.

Since the site visits last year for the initial monitoring report, the sediment mound at the inlet pipe has been observed to increase at an estimated rate of about 10 cm (about 4 in) in depth by an area of roughly about 2.4 m squared (8 ft squared). The total TSS load over the monitoring period was about 1,757 kg over the monitoring period. Using the same bulk density conversion as above, the total volume of sediment delivered to the BMP inlet over the monitoring period was a little over 1 m^3 (37 ft^3). If the deposit was about 10 cm deep as observed, the area of deposition would be about 3.2 m (10 ft) squared. This is a great, quick “reality check” for the estimated TSS loading compared to visual observation of the deposition mound at the inlet pipe. This validates the prediction model for TSS quite well qualitatively.

Table 4 shows the mass removal efficiency (RE) of each parameter and storm, and summary statistics are shown at the bottom of the table. All storms where the concentration or volume was measured at both the inlet and outlet locations are shown. For events where the inflow mass was zero and the outflow mass was a positive number due to noise, an error is shown (“Err”) due to a divide by zero error. These values indicate that the inflow mass was zero. The pollutants and volume were monitored with different instruments, so some events were the spectrometers did not trigger due to the error in the code, the volume was measured independently and therefore can still be reported here.

Table 4: Mass Removal Efficiency (RE) by event. Note values of "Err" indicate a positive effluent mass and influent of zero.

Event ID	Event Date	NO3-N	TKN	DOC	TN	TP	TSS	Volume
1	8/16/20	-	-	-	-	-	-	72%
2	8/18/20	-	-	-	-	-	-	74%
3	8/27/20	-	-	-	-	-	-	53%
4	9/2/20	Err	72%	Err	Err	28%	99%	49%
5	9/3/20	-	-	-	-	-	-	57%
6	9/10/20	-	-	-	-	-	-	68%
7	9/11/20	-	-	-	-	-	-	58%
8	9/18/20	-	-	-	-	-	-	75%
9	10/13/20	100%	100%	100%	100%	100%	100%	100%
10	10/17/20	31%	87%	82%	86%	95%	100%	89%
11	10/20/20	Err	97%	97%	98%	99%	100%	94%
12	10/26/20	-	-	-	-	-	-	100%
13	10/27/20	-	-	-	-	-	-	95%
14	10/28/20	-24%	97%	89%	98%	98%	100%	85%
15	10/29/20	76%	24%	Err	13%	99%	100%	90%
16	11/1/20	57%	Err	Err	-365%	100%	-	93%
17	11/1/20	-137%	Err	Err	-439%	99%	100%	91%
18	11/3/20	99%	Err	Err	63%	100%	100%	88%
19	11/4/20	-	-	-	-	-	-	100%
20	11/11/20	Err	98%	98%	89%	98%	99%	94%
21	11/13/20	-	-	-	-	-	-	100%
22	11/15/20	98%	99%	91%	88%	99%	100%	88%
23	11/23/20	Err	100%	96%	96%	99%	100%	94%
24	11/26/20	Err	98%	92%	4%	98%	100%	94%
25	11/30/20	Err	98%	89%	25%	99%	100%	94%
	n	8	11	9	13	14	13	25
	Minimum	-137%	24%	82%	-439%	28%	99%	49%
	First Quartile	18%	92%	89%	13%	98%	100%	74%
	Median	66%	98%	92%	86%	99%	100%	90%
	Third Quartile	98%	99%	97%	96%	99%	100%	94%
	Maximum	100%	100%	100%	100%	100%	100%	100%

Table 5: Event Mean Concentrations (EMC) by event.

Event ID	Event Date	Inlet (Outlet) NO3-N (mg/L)	Inlet (Outlet) TKN (mg/L)	Inlet (Outlet) DOC (mg/L)	Inlet (Outlet) TN (mg/L)	Inlet (Outlet) TP (mg/L)	Inlet (Outlet) TSS (mg/L)
1	8/16/20	- (0.45)	- (1.13)	- (12.99)	- (0.24)	- (0.23)	- (4.6)
2	8/18/20	- (0.12)	- (1.31)	- (13.39)	- (0.18)	- (0.25)	- (4)
3	8/27/20	- (0.18)	- (1)	- (11.13)	- (0.14)	- (0.24)	- (0)
4	9/2/20	0 (0.16)	2.58 (1.42)	0.34 (12.25)	0 (0.21)	0.15 (0.22)	339 (3.9)
5	9/3/20	- (0.14)	- (1.48)	- (13.7)	- (0.25)	- (0.19)	- (1.2)
6	9/10/20	- (0.15)	- (1.16)	- (11.17)	- (0.18)	- (0.19)	- (0.1)
7	9/11/20	- (0.17)	- (1.14)	- (12.51)	- (0.14)	- (0.24)	- (0.7)
8	9/18/20	- (0.12)	- (1.4)	- (10.52)	- (0.19)	- (0.29)	- (58.1)
9	10/13/20	0 (0)	2.66 (3.13)	13.2 (0)	0.67 (0.18)	0.52 (0.08)	418 (0)
10	10/17/20	0.04 (0.27)	0.97 (1.18)	7.22 (11.48)	0.14 (0.18)	0.39 (0.18)	335 (0)
11	10/20/20	0 (0.07)	1.29 (0.68)	12.61 (7.09)	0.42 (0.15)	0.66 (0.15)	440 (21.3)
12	10/26/20	0 (-)	2.38 (-)	20.67 (-)	0.54 (-)	0.62 (-)	472 (-)
13	10/27/20	2.08 (-)	91.77 (-)	15.17 (-)	6.85 (-)	5.34 (-)	2833 (-)
14	10/28/20	0.01 (0.08)	1.91 (0.37)	9.32 (6.4)	0.55 (0.08)	0.75 (0.11)	591 (4.8)
15	10/29/20	0.03 (0.07)	0.11 (0.83)	0 (6.05)	0.03 (0.3)	0.82 (0.1)	42 (0)
16	11/1/20	0 (0.02)	0 (0.26)	0 (2.44)	0 (0.24)	0.81 (0.03)	0 (0)
17	11/1/20	0 (0.02)	0 (0.52)	0 (3.36)	0 (0.24)	0.89 (0.05)	11 (0)
18	11/3/20	0.24 (0.01)	0 (0.82)	0 (2.18)	0.06 (0.2)	0.89 (0.04)	3 (0)
19	11/4/20	0.53 (-)	340.46 (-)	21.04 (-)	35.16 (-)	7.05 (-)	24572 (-)
20	11/11/20	0 (0.03)	1.45 (0.51)	8.52 (2.92)	0.2 (0.35)	0.46 (0.13)	427 (55.6)
21	11/13/20	0 (-)	2.29 (-)	0.39 (-)	0.01 (-)	0.26 (-)	364 (-)
22	11/15/20	0.13 (0.02)	1.37 (0.15)	2.89 (2.13)	0.14 (0.13)	0.37 (0.03)	392 (0)
23	11/23/20	0 (0.04)	2.47 (0.16)	4.74 (3.53)	0.49 (0.34)	0.83 (0.09)	701 (0)
24	11/26/20	0 (0.05)	1.82 (0.44)	2.8 (3.74)	0.02 (0.3)	0.28 (0.09)	378 (0)
25	11/30/20	0 (0.07)	1.57 (0.61)	2.47 (4.31)	0.03 (0.3)	0.28 (0.06)	355 (0)
	n	18 (21)	18 (21)	18 (21)	18 (21)	18 (21)	18 (21)
	Minimum	0 (0)	0 (0.15)	0 (0)	0 (0.08)	0.15 (0.03)	0 (0)
	First Quartile	0 (0.03)	1.05 (0.51)	0.35 (3.36)	0.02 (0.18)	0.37 (0.08)	336 (0)
	Median	0 (0.07)	1.69 (0.83)	3.82 (6.4)	0.14 (0.2)	0.64 (0.13)	385 (0)
	Third Quartile	0.04 (0.15)	2.45 (1.18)	11.79 (11.48)	0.53 (0.25)	0.83 (0.22)	464 (4)
	Maximum	2.08 (0.45)	340.46 (3.13)	21.04 (13.7)	35.16 (0.35)	7.05 (0.29)	24572 (58.1)

D. Performance Summary

The Chatham BMP was monitored for water quality and quantity performance for 25 runoff events. The BMP was originally sized to treat about 0.3 in of rainfall over 9.3 ac of IC. The inlet control structure diverted these events to the BMP. As seen from the offline bypass monitoring, the BMP median inlet volume was about 77% of the total runoff volume. This is relatively consistent with the design sizing as about 50% of all rain events are 0.3 inches or less.

The UV-Vis spectrometer was successfully used to monitor and estimate pollutant concentrations at the inlet and outlet locations. The concentration values were estimated using a previously calibrated stormwater regression curve using Partial Least Squares regression to concurrent laboratory samples. The Event Mean Concentrations (EMC) were calculated for these events and had influent median values for TN, TP, and TSS of 0.14, 0.64, and 385 mg/L, respectively. The removal efficiencies (RE) of the total mass per event were calculated. The median event loading, total loading, and median mass RE for the calculated pollutants are summarized in Table 6.

Table 6: Summary of median event loading, total loading, and mass RE median values for the monitoring period.

	NO3-N (g)	TKN (g)	DOC (g)	TN (g)	TP (g)	TSS (kg)	Volume (L)
Median Event Mass Load	0.090	198	445	32	55	62	53,386
Total Mass Load	315	13607	16058	1144	4102	1757	6,930,495
Median RE	66%	98%	92%	86%	99%	100%	90%
Performance Curve Values							
Enhanced Biofiltration with ISR				52%	45%	82%	0%
Gravel Wetland				41%	34%	72%	0%
Infiltration Basin (IR 8.27 in/hr)				96%	90%	98%	87%

Table 6 shows the very high median mass RE of the BMP. At the bottom of Table 6 are also the yearly expected RE using the Performance Curves ((US EPA Region 1, 2017) and (UNHSC, 2019)) for 3 systems: enhanced biofiltration with ISR, gravel wetland, and an infiltration basin (IR 8.27 in/hr). The BMP most closely matches and even outperforms the infiltration basin except for the RE of TN is slightly lower. The system was built with a liner on the bottom of the system to prevent infiltration, but the vertical sidewalls were not lined, and it has been shown that significant infiltration can occur through the BMP sidewalls despite little to no infiltration in the BMP bottom (Macadam, 2018). This is especially relevant on Cape Cod where many soils are very sand with high infiltration rates. The Appendix F performance curve loading rates for TP and TSS as the relative percent differences were 44% and 5%. The TN difference was 192%.

The dimensionless, cumulative pollutographs for TSS, TN, and TP vs inflow and outflow volumes capture an interesting summary of the transport of the nutrients to and out of the system.

E. Conclusions

The Chatham BMP was monitored for water quality and quantity performance for 25 runoff events during the 2020 monitoring season. The flow (and subsequently volumes) of influent and effluent were measuring using water level sensors, and the water quality was measured using an ultraviolet-visual spectrometer using a stormwater calibrated nutrient prediction models. The real-time spectral probes like the s::can spectro::lyser converts UV-Vis spectral absorbance values to parameter concentrations based on the Beer-Lambert Law, which states that light absorption is proportional to both the concentration of a material as well as the thickness of a material within a sample. The stormwater calibration curve employed in this study is calibrated to influent runoff characters in other studies and provided usable results for real-time concentrations of TSS, TP, and TN in addition to other parameters (e.g., DOC). This study supports the potential for developing global calibration curves specific to stormwater runoff for similar real-time ultraviolet sensors. These results are encouraging that real-time ultraviolet sensors are capable of advancing stormwater quality monitoring and hold the potential to deliver more accurate laboratory quality data instantaneously with greater efficiency and at a lower overall cost than conventionally available methodologies. Results also support the use of existing accounting processes (EPA Region 1 Performance Curves (US EPA Region 1, 2017)) as a model for the future to accurately predict SCM performance. The process model represents a paradigm shift away from historical approaches in that they don't require and use intensive empirical monitoring efforts such as auto sampling and composite sampling that generate water samples for chemical analysis, and they introduce performance curves for quantification and accounting of structural SCM load reductions and an in-situ real-time UV optical sensor methodology where monitoring is deemed necessary. The "first flush" relationships are often assumed in stormwater, but with the addition of more and higher resolution monitored data, clear trends are not in the data. For this site and data, the TN pollutograph was the most variable and showed no clear trend generally.

IV. Technical Support Document

The purpose of this technical support document (TSD) is to set forth this next-generation SCM accounting and when necessary innovative monitoring approach as a model for the future.

A. Process Summary

The innovative next-generation SCM monitoring and accounting methods described herein necessitates discussion of the sociological and economic considerations underlying the process that is critical for engendering a meaningful and lasting transfer of technological innovation.

B. Engendering Meaningful and Lasting Transfer of Technology

1. Historical Perspective

Background

For stormwater sampling historically there are two basic techniques: samples may be taken manually or captured using automatic samplers. Obtaining manual samples involves sending personnel to the sampling location before the rain event occurs and physically capturing samples as the stormwater effluent where it is accessible. This process is burdened with resource issues centering on moving personnel to the sampling locations before a rain event and capturing samples in potentially hazardous situations. This method also depends on accurate rainfall forecasts.

The use of automatic samplers provides an alternative solution. These samplers can be triggered remotely or be programmed with a sampling protocol to begin taking samples as soon as the rain event begins (flow trigger or precipitation trigger). The benefit of using automatic samplers is that many samplers may be placed concurrently in different locations to capture a rain event. The location of the sampling intake of the samplers can be secured to the bottom of the invert of a pipe, swale, or another location of interest ensuring the same cross-sectional location of pipe is sampled. This is referred to as a point integrated sample (Lane, Westaway, & Hicks, 2003).

That said automatic sampling is hardly easy. Personnel time and other manual burdens persist, and the incidence of unrepresentative or unusable storms can border on 50% even if you are thorough and knowledgeable about the equipment.

Fundamental sampling methods

Stormwater samples and their analyses yield a description of the fundamental water quality characteristics (median, average, standard deviation, etc.). The data may also be used to assess removal efficiencies for stormwater management systems by synthesizing the water quality and flow data into total mass or event mean concentration. This of course assumes that flow monitoring is reliable and accurate. Grab samples are samples that are taken without interruption and represent the stormwater at that instant of time. Grab samples may be taken manually or by automatic samplers (US EPA, 1992) “Composite samples are samples simply comprised of a series of individual aliquots that when combined, reflect the average pollutant concentration of the storm water discharge during the sampling period (US EPA, 1992).” The spacing between when aliquots are taken is paced using either flow or time. The following two types of composite samples can be developed:

Constant Time-Constant Volume: A single composite average sample created from a set of samples having equal volumes which were taken at equal increments of time during an event. This will result in a sample that averages the individual concentrations but fails to represent pollutant mass.
Constant Time-Volume Proportional to Flow Increment: A single or set of composite samples that were created by varying the volume being placed in them proportionally to the amount of flow that passed by during equal lengths of time. This method results in a sample that represents the event mean concentration.

Most stormwater sampling methods were adopted from the drinking water and wastewater settings. One could question the difficulty of ushering in a set of new sampling standards, but the reality is, there never really were many sampling standards to begin with.

Modern challenges with stormwater sampling.

Much of the data collected in the 1980’s through the national urban runoff program (NURP) was collected using grab samples. Grab samples are exactly that, grabbing a sample sometime during a storm event. These older sampling approaches have largely been supplanted by autosamplers. Still, much of the data, simple as it may be, have been aggregated into simple pollutant load export rates that are largely differentiated by a generic land use category. These pollutant load estimates have remained relevant and applicable largely since collecting trustworthy input data is difficult. The NURP program was a large, well-funded, nationally administered program, not simply a repository for any and all data. Today, many stormwater management systems are designed and installed yet monitoring was never included as an objective. Therefore, monitoring such systems after they are constructed presents significant monitoring issues, including access issues (equipment and personnel), flow pathways, lack of grade (hydraulic head sufficient to allow the monitoring method to be hydraulically invisible) and underdrain/outfall exposure.

Environmental data is variable by nature. For the most part, stormwater sampling equipment was adapted from the wastewater industry. Without strict guidance and protocols, humans are traditionally unreliable, or at least inconsistent, when it comes to methods. With a stormwater sampling, it seems that everyone does things a little bit differently. This is part of the reason why environmental sampling is so hard to standardize. By nature, it is inconsistent and that is just the first part of the story.

Sample programing

At this writing, the most reliable and reproducible sampling method is with automatic samplers. For the most part, autosamplers were an advancement to grab sampling approaches. Autosamplers may be programmed in various ways. Time-based, volume-based, discrete, composite, single bottle, multiple bottle samples may be preserved at the time of sampling as well. Sample splitting may be a challenging step, however, there is no difference with this process between grab and autosamplers.

Unfortunately, there appears to be the perception that anyone can perform sampling and that this will result in defensible research. This seems to be a consequence of more powerful and automated sampling equipment. Using modern equipment instills a belief that defensible data emerges just by turning on the power. The truth however is that these instruments require caretaking and constant program updating. In reality, a few storms are required to "shake down" equipment, personnel, and software. That is assuming that the rainfall intensity, duration, and frequencies do not change much with the season.

Composite sampling

Composite sampling is a much more economical approach to sampling with autosamplers. Storm capture and sample splitting are definite issues. If a single bottle is used for sample collection it often has to be split for different chemical analyses and for quality assurance protocols. Single bottle composites also limit the storm capture rates as anomalies such as short rain bursts may trigger the sampling program and intermingle non-events (rainfall < 0.1 inches).

Flow conversion is a major component of a sampling strategy. There are a number of ways to convert water depth to flow in open channels/pipes, but almost no proven methods to monitor direct flow in open drainage networks smaller with pipes/channels that are 12 inches in diameter or smaller. Manning's equation and volumetrically calibrated weirs are two of the most common methods. The presence of the automatic sampler sampling intakes, pressure transducer/bubbler tube, and sample intake could all be creating an unusual amount of turbulence around the weir. The weir and associated level logger measure the level of water behind the weir and calculates a flow based on the depth vs discharge rating curve developed for the instrument in a laboratory under controlled laminar flow conditions. Turbulent flows however could be introducing different momentum forces at instrument interface not calculated in the lab. These anomalies would most certainly impact sampling programs and the quality of the data collected. Inevitably the manufacturer's rating curve was not calibrated with probes near the point where stage was recorded, this is seldom ever addressed in modern stormwater monitoring QAPPs.

Storm characterization and troubleshooting.

Weather is variable. Rainfall characteristics change with the seasons, it is important that you adjust your sampling approach as well.

Modern Approaches

Most stormwater sampling approaches invite plentiful opportunities for error. From programming to flow depth to flow estimates to extend holding times (since it always seems to rain at 2 am on Sunday). The errors that these methods impart on stormwater sampling data are largely undocumented. Adding sample splitting and issues related to representatives (just where was the sampler intake?) can make even the most seasoned researcher nervous. This is all prior to delivery to the lab. Laboratory analytics carry their own potential bias and often ± 20% is the industry standard. This acceptable deviation is at the very end of a long sampling and chain of custody process that may incur numerous other potential acceptable differences or acceptable protocol error. Table 7 is from a recently accepted QAPP for stormwater control measure verification.

Table 7: Relative percent difference (RPD) for common quality assurance project protocols for stormwater research.

Data Quality Indicators	Measurement Performance Criteria	RPD Value
Precision – Overall	Relative Percent Difference (RPD)	RPD ≤ 20%
Precision – Lab	Relative Percent Difference (RPD)	RPD ≤ 20%
Accuracy / Bias	Relative Percent Difference (RPD)	RPD ≤ 20%

Data Evaluation

Data analyses typically cover a range of approaches including:

- assessment of storm characteristics
- estimation of event mean concentrations
- normalized performance efficiencies

Event mean concentrations (EMC's) are a parameter used to represent the flow-proportional average concentration of a given water quality parameter for a storm event. It is defined as the total constituent mass divided by the total runoff volume. When combined with flow measurement data, the EMC is used to estimate the pollutant mass loading. Most of the EMC data collected in stormwater studies are based on direct measurement from flow-weighted composite samples. Due to the variability of precipitation events and resultant runoff conditions, sample trigger conditions and flow-weighted sample pacing are highly variable and must be adjusted on a storm by storm basis according to the most up-to-date precipitation forecasts.

The range of analyses reveals a range of performance trends. Efficiency Ratio (ER) analysis may be performed with a final dataset. For many performance-related datasets of stormwater treatment systems, the ER is a stable estimation of overall treatment performance as it minimizes the impact of low concentration values or relatively clean storms with low influent EMCs. Whereas Removal Efficiencies (RE) reflect treatment unit performance on a storm by storm basis, ERs weight all storms equally and reflect overall influent and effluent averages across the entire data set. REs are presented as both an average and median of aggregate storm values. In general, aggregate median RE values are more reliable in highly variable, non-normally distributed datasets such as those experienced in stormwater treatment unit performance studies.

When concentration results are below the detection limit (BDL) a value of half the detection limit (DL) is commonly used for statistical purposes.

2. Innovations

Real-time sensing is an innovation to conventional stormwater monitoring efforts that often employs automated samplers, and flow-weighted composite sample splitting for laboratory-produced pollutant export rates and associated stormwater control measure (SCM) removal performance. This groundbreaking approach holds promise to revolutionize field sampling methods and eliminate much of the potential error associated with automated samplers, long holding times, composite sampling approaches, and the time for wet chemistry analyses.

For example, real-time ultra-violet sensors technology is rapidly developing. UV-sensors convert spectral absorbance values to parameter concentrations based on the Beer-Lambert Law which states that light absorption is proportional to both the concentration of a material as well as the thickness of a material within a sample. UV-based measuring approaches have developed a wide range of global calibration curves for monitoring specific parameters in a variety of water compositions applicable to municipal and natural water systems. The global calibration curve employed should be indicative of the closest related water chemistry characteristics. Currently, this is largely limited to the data and calibration curves available. Granted there are still unknowns with these newer instruments. Little is known concerning adequate cleaning and calibration intervals, particularly in closed drainage networks. As sampling techniques evolve, these approaches deserve attention as they have the potential to significantly increase monitoring sensitivity. Regardless of the accepted sampling approach, it is clear that any stormwater sampling is a complex and sensitive activity that it should be assumed can be completed with a vast range of accuracy and precision.

3. Quantify SCM Benefits

A major question remains as to the need for broad data collection approaches. Modeling hydrology with applications such as SWMM will often be far more accurate than data collection efforts. Targeted and defensible field studies can help calibrate superior hydrologic models and develop performance curves that are useful in system accounting.

For purposes of reiteration, a useful summary of the steps leading to benefit quantification was developed in a separate project (US EPA, 2019) and is provided here as it applies to this effort. The full report and project documentation can be found online: https://www.epa.gov/snecwrp/tisbury-ma-impervious-cover-disconnection-icd-project-integrated-stormwater-management

1. Establish baseline condition: Unit-area HRU time series for the period of interest (Jan 1998 – Dec 2018) were used as the boundary condition to the SCM simulation model. The Opti-Tool provides a utility tool that runs the SWMM models, calibrated to Region 1 specific land use average annual loading export rates, and generates the HRU hourly time series in the format needed for the Opti-Tool. The HRU hourly time series was developed using the hourly rainfall and temperature data from a local rain gage located at the Martha Vineyard's airport.
2. Set Management objective: The management objective was to identify the most cost-effective stormwater controls (types and sizes) for achieving a wide range of TN loading, stormwater volume, and storm flow rate reductions at the two outfall locations.
3. Set Optimization target: Cost effectiveness-curves for average annual TN load and average annual stormwater volume reduction were developed.
4. Incorporate Land use information: The area distribution for the major land-use groups within the pilot watershed was estimated. Each land-use group in the model was assigned the corresponding unit-area HRU time series.
5. Incorporate SCM information: Two SCM types, infiltration trench and infiltration basin, were selected for six major land use categories based on the Management Category analysis. SCM specifications were set using the default parameters and SCM cost function available in the Opti-Tool. Impervious drainage areas were assigned to be treated by each SCM type in the model.
6. Run optimization scenario: The simulation period (Jan 1998 – Dec 2018), the stormwater metrics of concern (flow volume and TN loading), the objective function (minimize cost) were defined, and input files were created for the optimization runs. The optimization was performed using the continuous simulation SCM model to reflect actual long-term precipitation conditions that included a wide range of actual storm sizes to find the optimal SCM storage capacities that provided the most cost-effective solution at the watershed scale. Each optimization runs generated a CE-Curve showing the optimal solutions frontier for a wide range of stormwater volume and TN load reduction targets.

C. Conclusions

The purpose of this technical support document (TSD) has been to set forth a next-generation stormwater monitoring and accounting processes as a model for the future. The process model represents a paradigm shift away from historical approaches in that:

- They don't require and use intensive empirical monitoring efforts such as auto sampling and composite sampling that generate water samples for chemical analysis.

and

- Introduces performance curves for quantification and accounting of structural SCM load reductions and an in-situ real-time UV optical sensor methodology where monitoring is deemed necessary.

V. References

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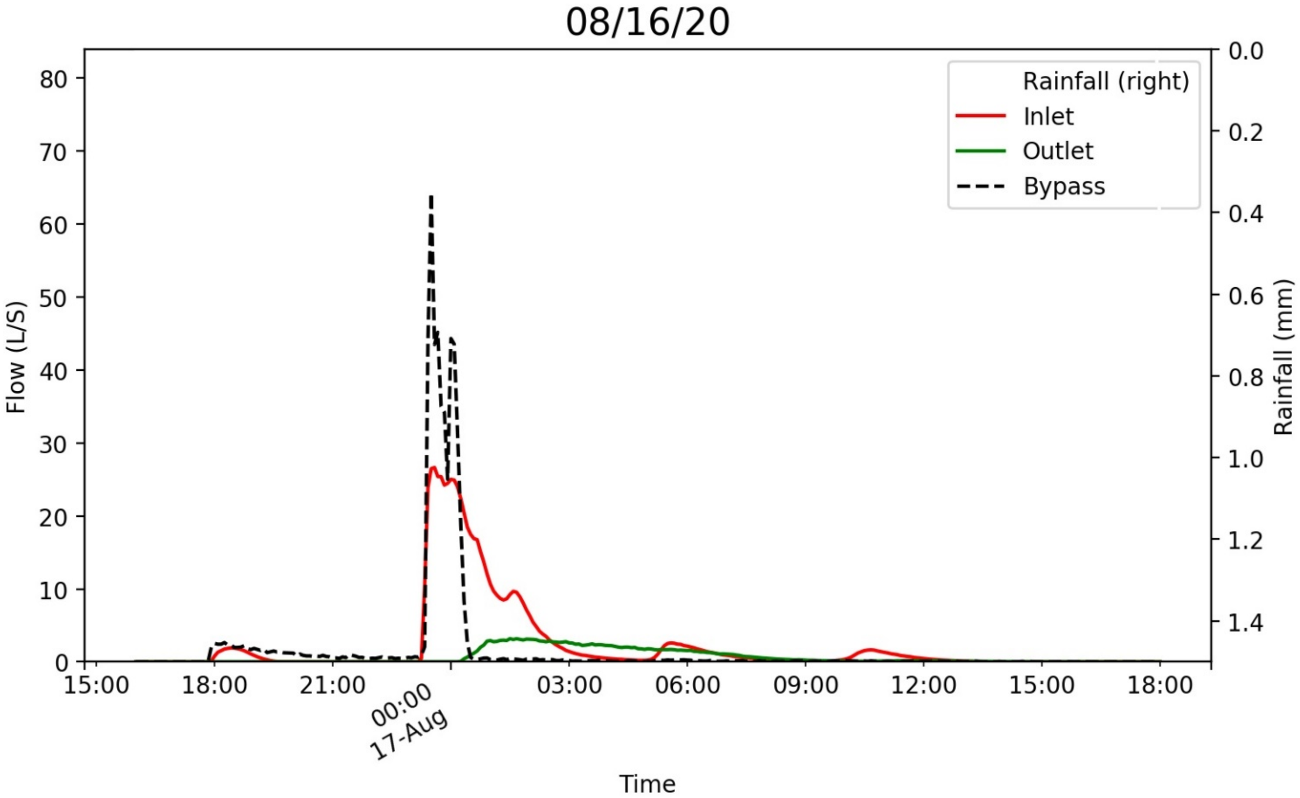
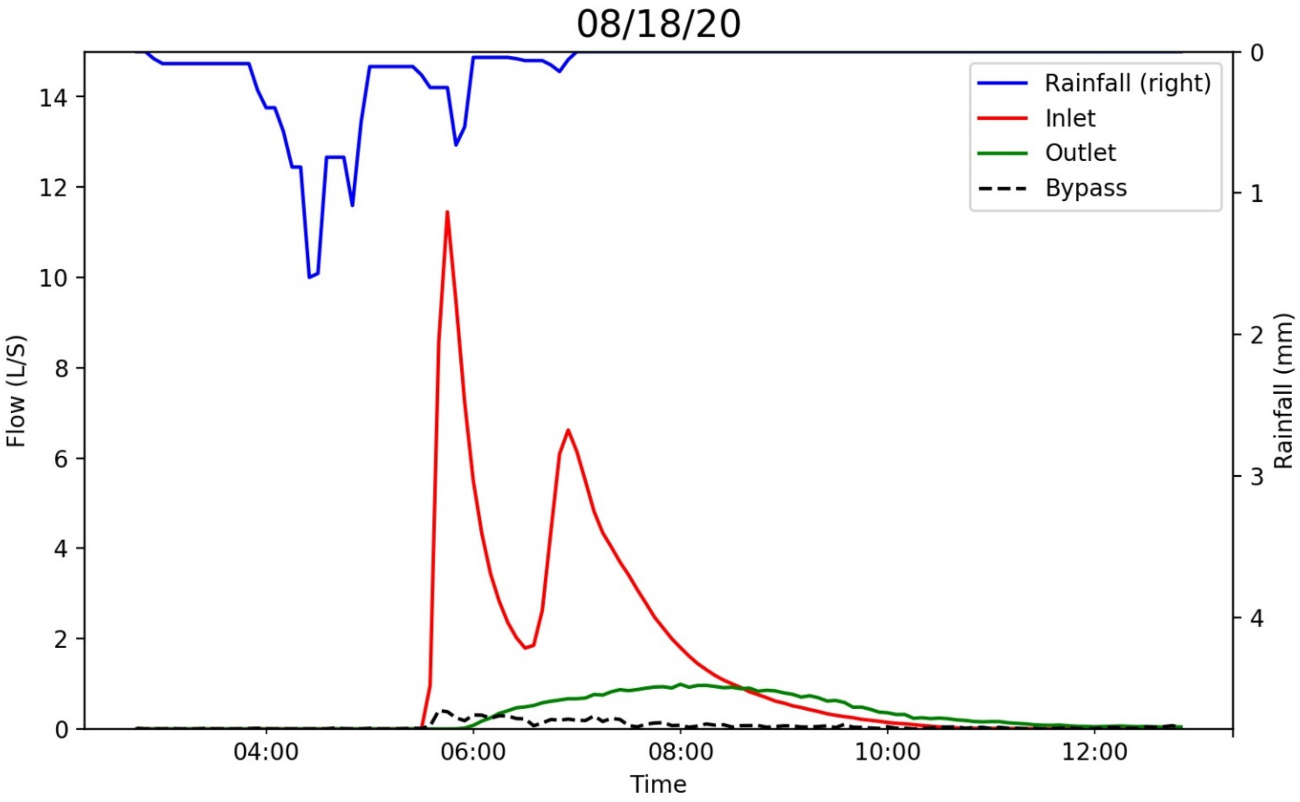
VI. Appendices

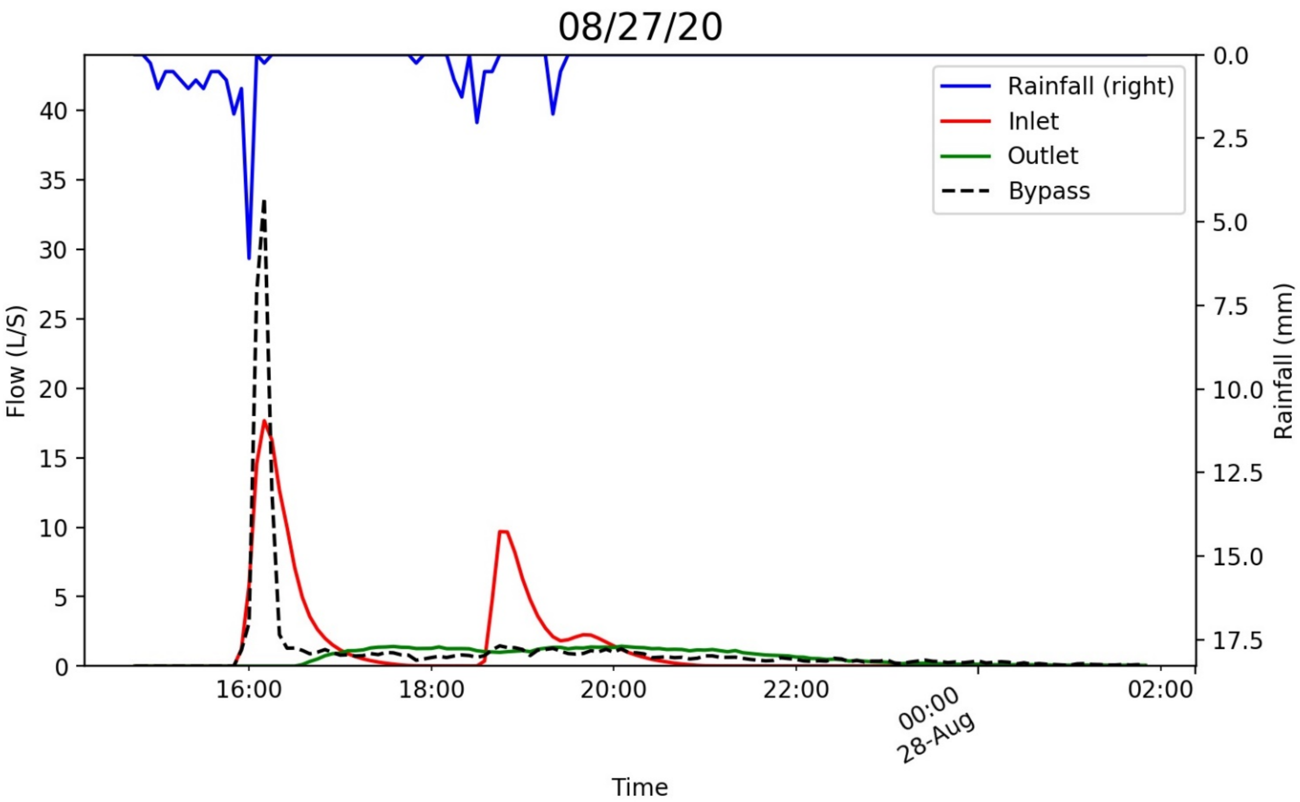
1. Appendix 1: Event Hydrographs and Bypass

This appendix shows all monitored storm events for rainfall, inflow, outflow, and offline bypass in the inlet control structure.

The titles show the date of the start of the event. Flow at the inlet, outlet, and bypass are in liters per second (L/s) and are shown on the left axis. Rainfall in millimeters (mm) is shown on the right, inverted axis.


08/16/20
Rainfall (right)
Inlet
Outlet
Bypass
Flow (L/S)
0
10
20
30
40
50
60
70
80
Rainfall (mm)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
15:00
18:00
21:00
00:00
17-Aug
03:00
06:00
09:00
12:00
15:00
18:00
Time


08/18/20
Rainfall (right)
Inlet
Outlet
Bypass
Flow (L/S)
0
2
4
6
8
10
12
14
Rainfall (mm)
0
1
2
3
4
04:00
06:00
08:00
10:00
12:00
Time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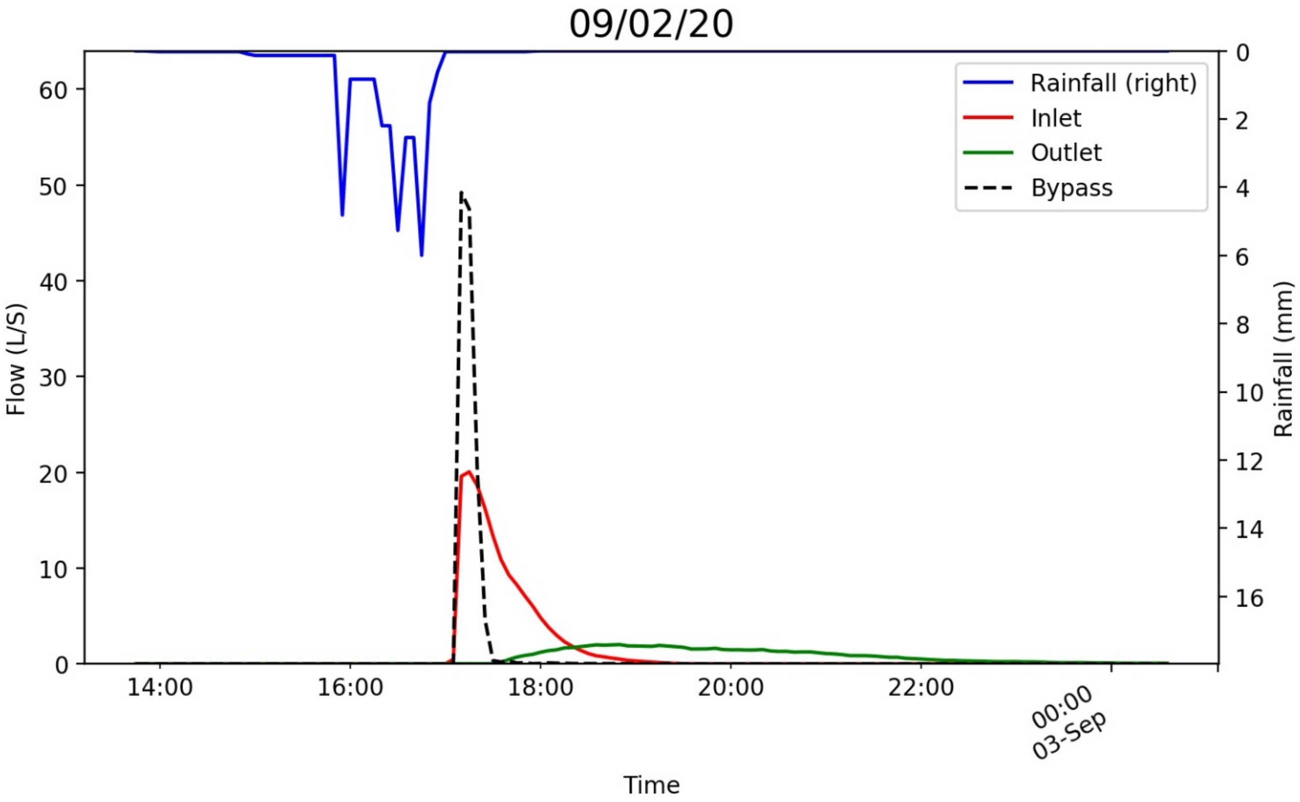
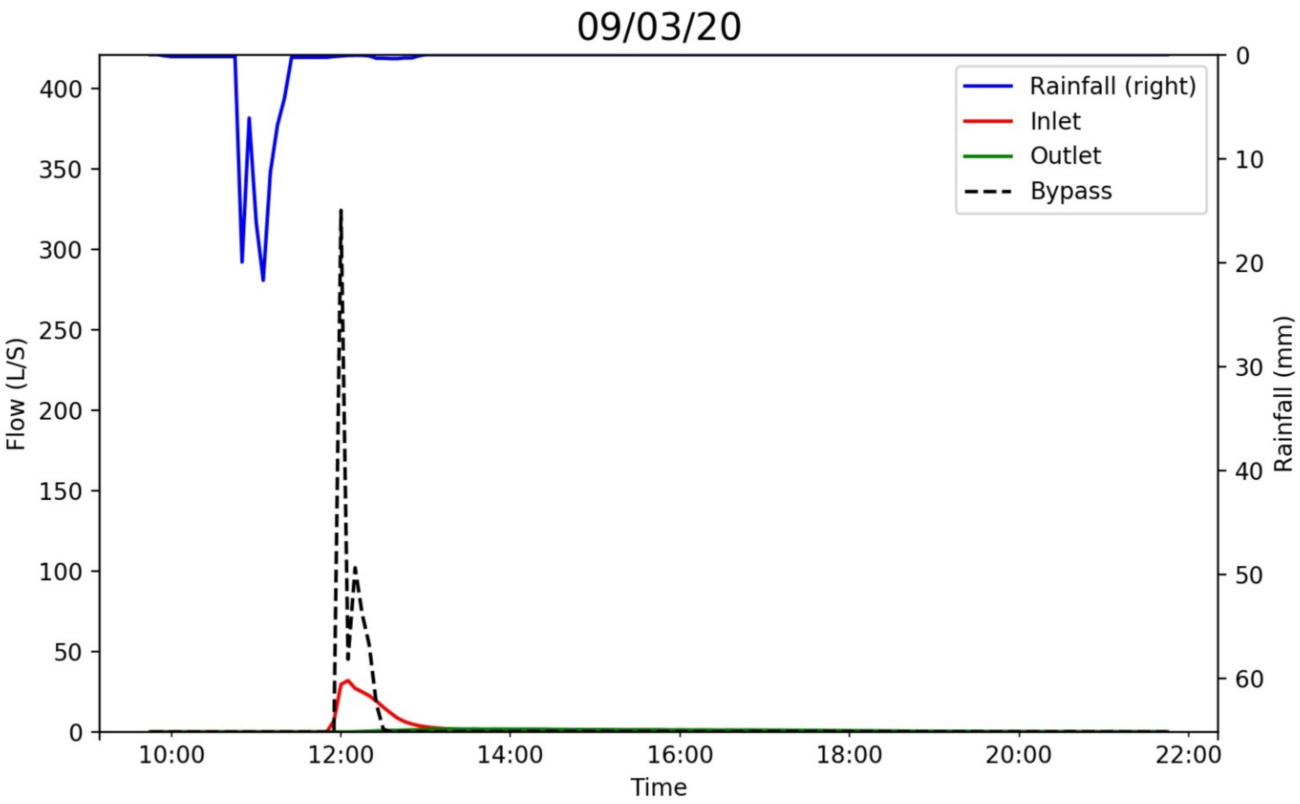
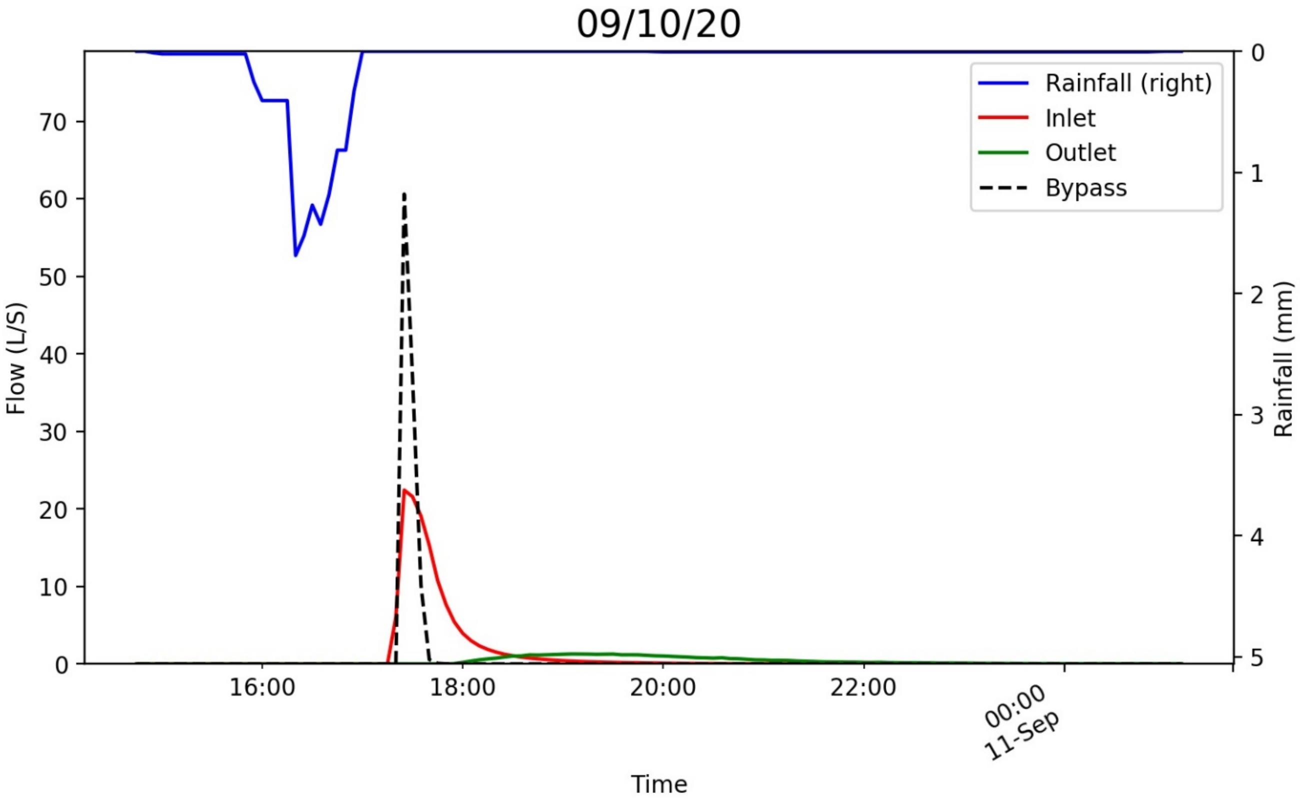
Inlet
Outlet
Bypass
Flow (L/S)
0
5
10
15
20
25
30
35
40
Rainfall (mm)
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
Time
16:00
18:00
20:00
22:00
00:00
28-Aug
02:00


09/02/20
Rainfall (right)
Inlet
Outlet
Bypass
Flow (L/S)
0
10
20
30
40
50
60
Rainfall (mm)
0
2
4
6
8
10
12
14
16
Time
14:00
16:00
18:00
20:00
22:00
00:00
03-Sep


09/03/20
Rainfall (right)
Inlet
Outlet
Bypass
Flow (L/S)
0
50
100
150
200
250
300
350
400
Rainfall (mm)
0
10
20
30
40
50
60
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Time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Inlet
Outlet
Bypass
Flow (L/S)
0
10
20
30
40
50
60
70
Rainfall (mm)
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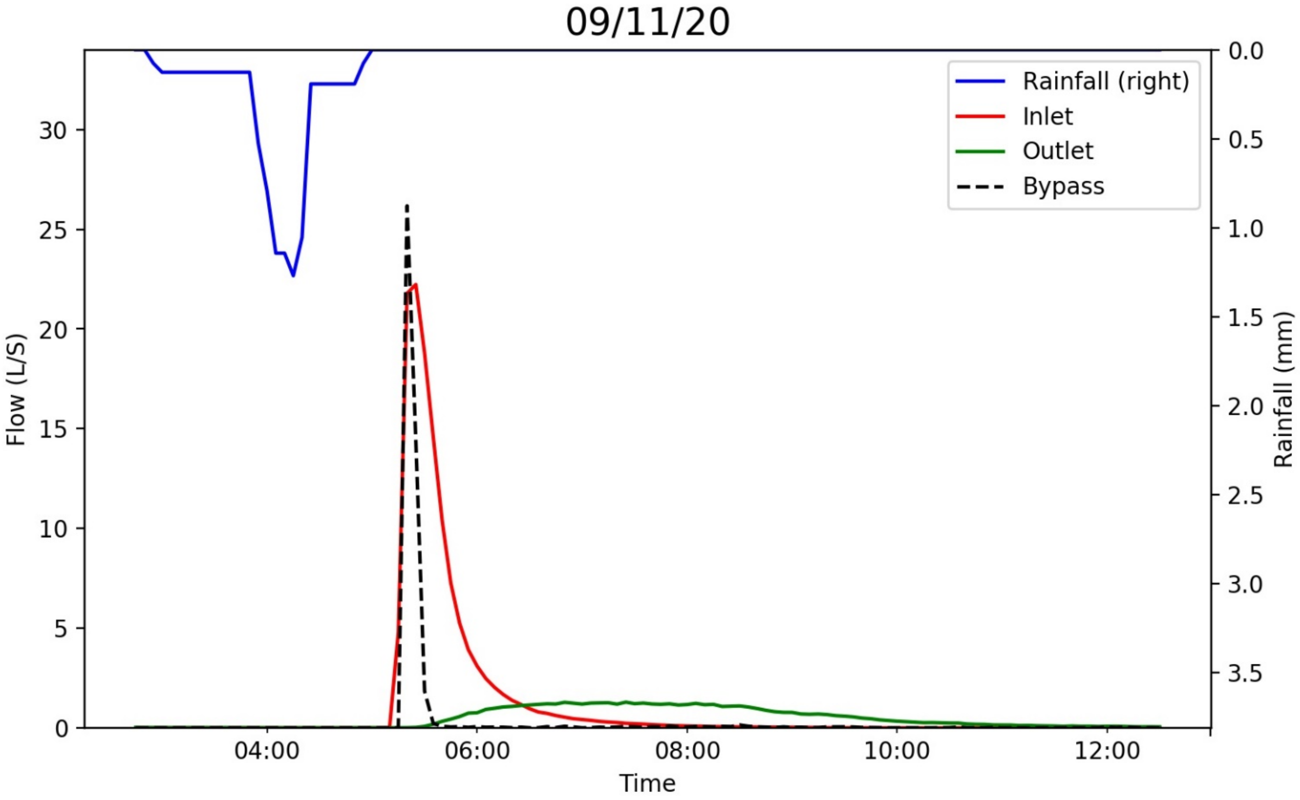
1
2
3
4
5
16:00
18:00
20:00
22:00
00:00
11-Sep
Time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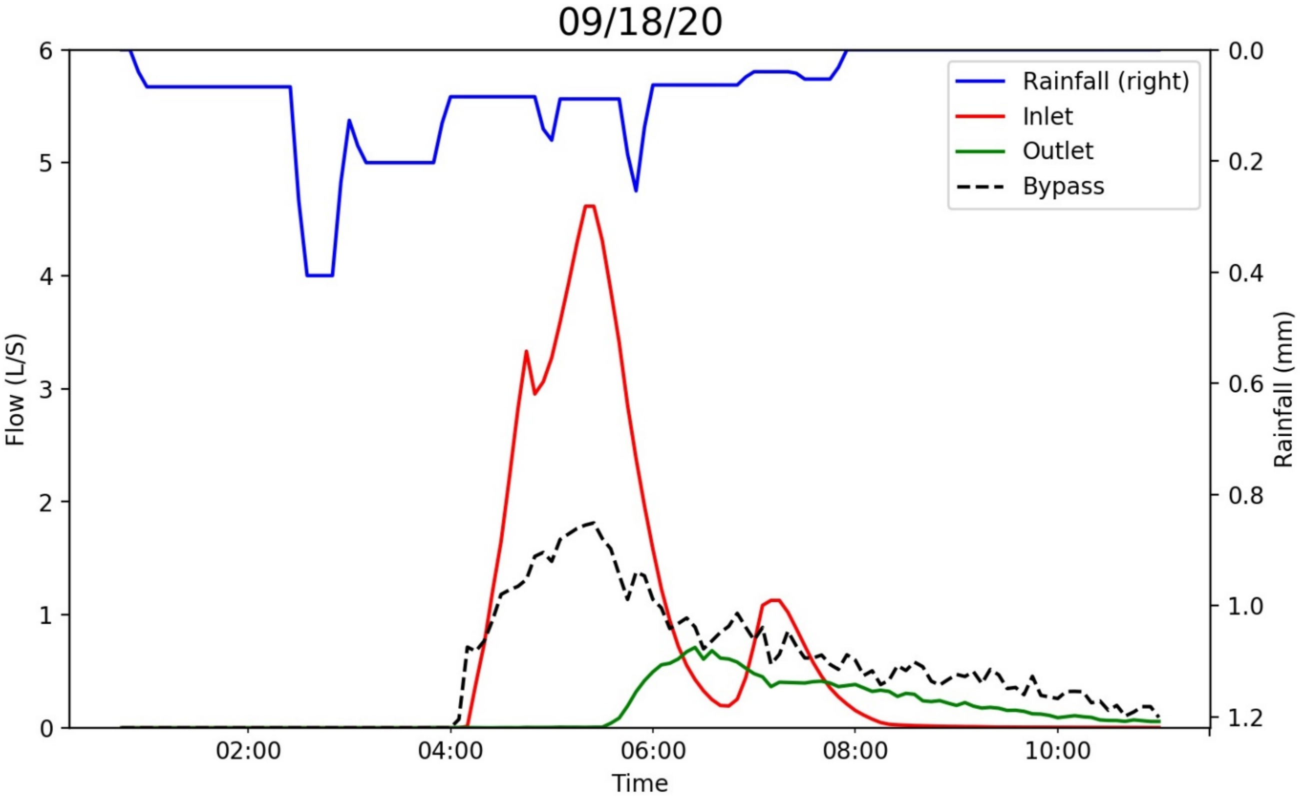
Inlet
Outlet
Bypass
Flow (L/S)
Rainfall (mm)
Time
0
5
10
15
20
25
30
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
04:00
06:00
08:00
10:00
12:00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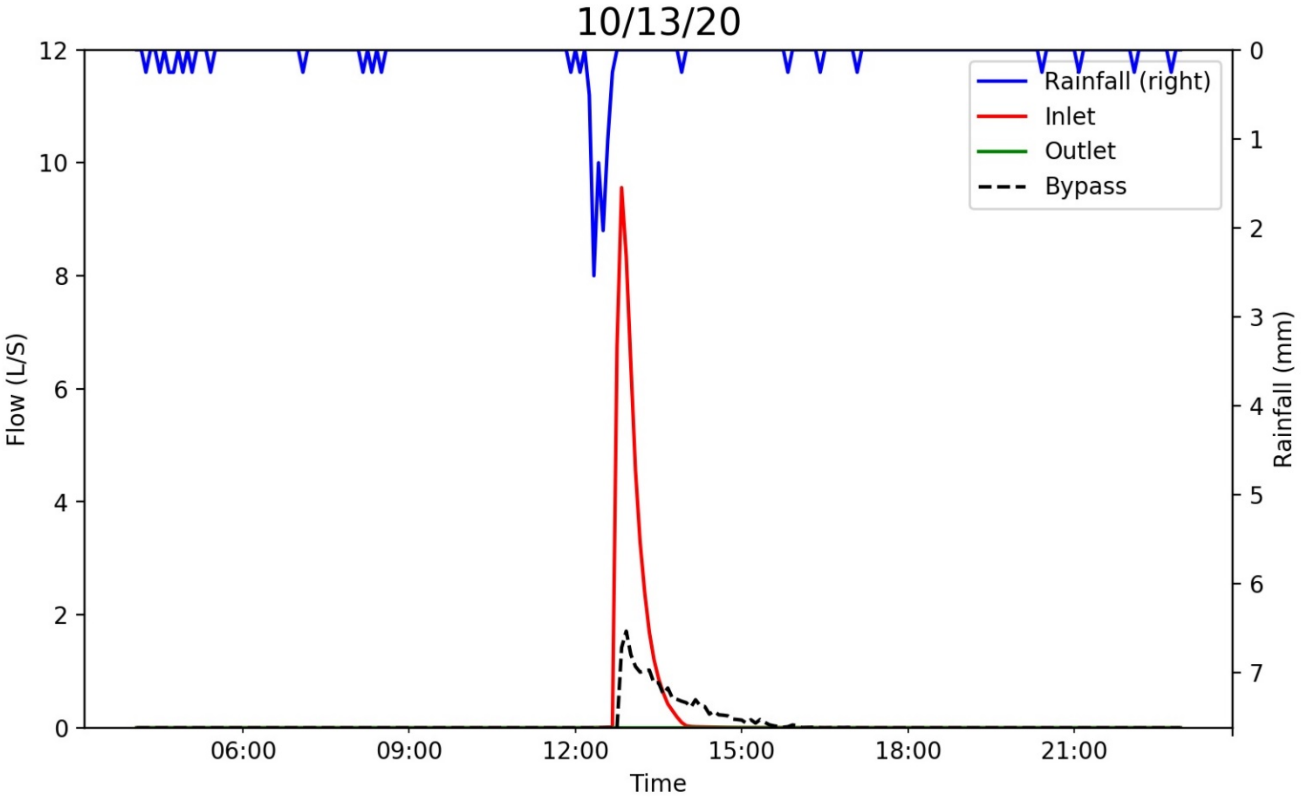
Rainfall (right)
Inlet
Outlet
Bypass
Flow (L/S)
Rainfall (mm)
Time
0
1
2
3
4
5
6
0.0
0.2
0.4
0.6
0.8
1.0
1.2
02:00
04:00
06:00
08:00
10:00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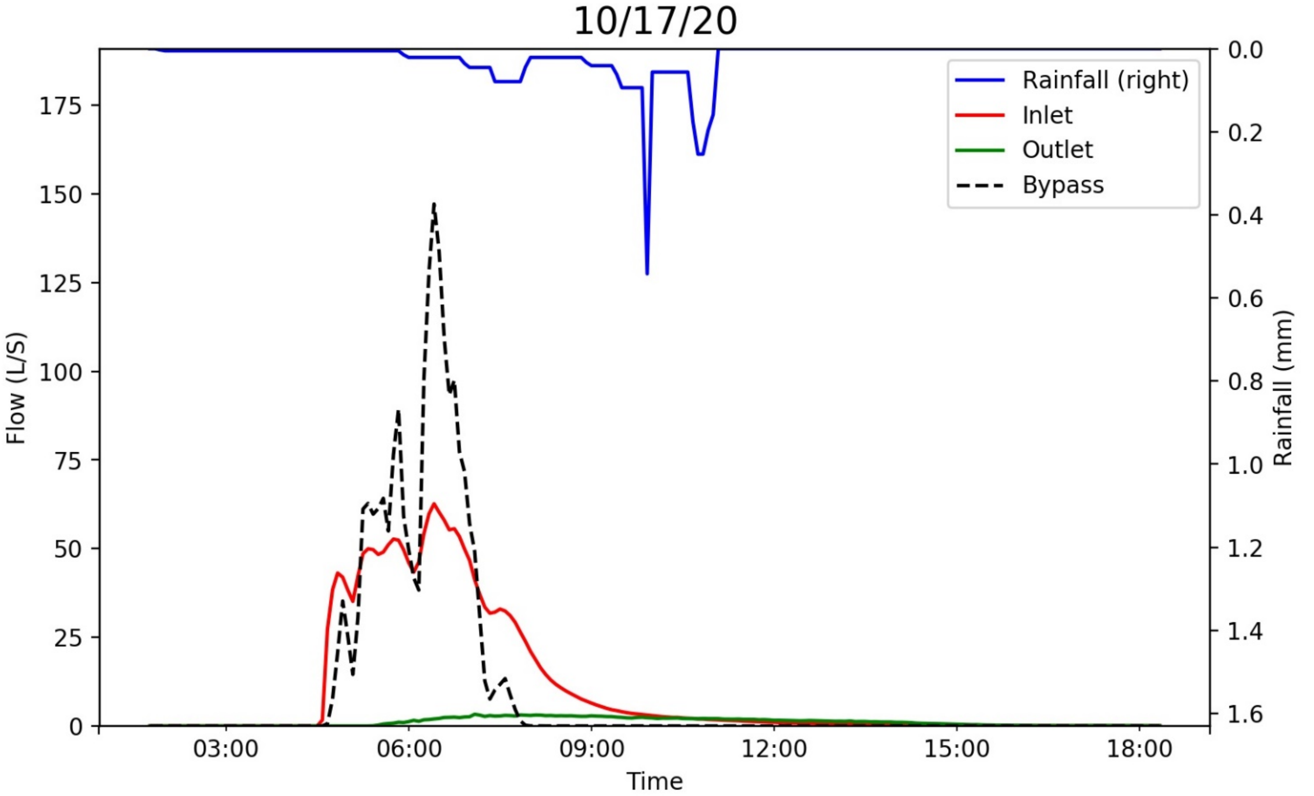
Inlet
Outlet
Bypass
Flow (L/S)
0
2
4
6
8
10
12
Rainfall (mm)
0
1
2
3
4
5
6
7
Time
06:00
09:00
12:00
15:00
18:00
21:00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Outlet
Bypass
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25
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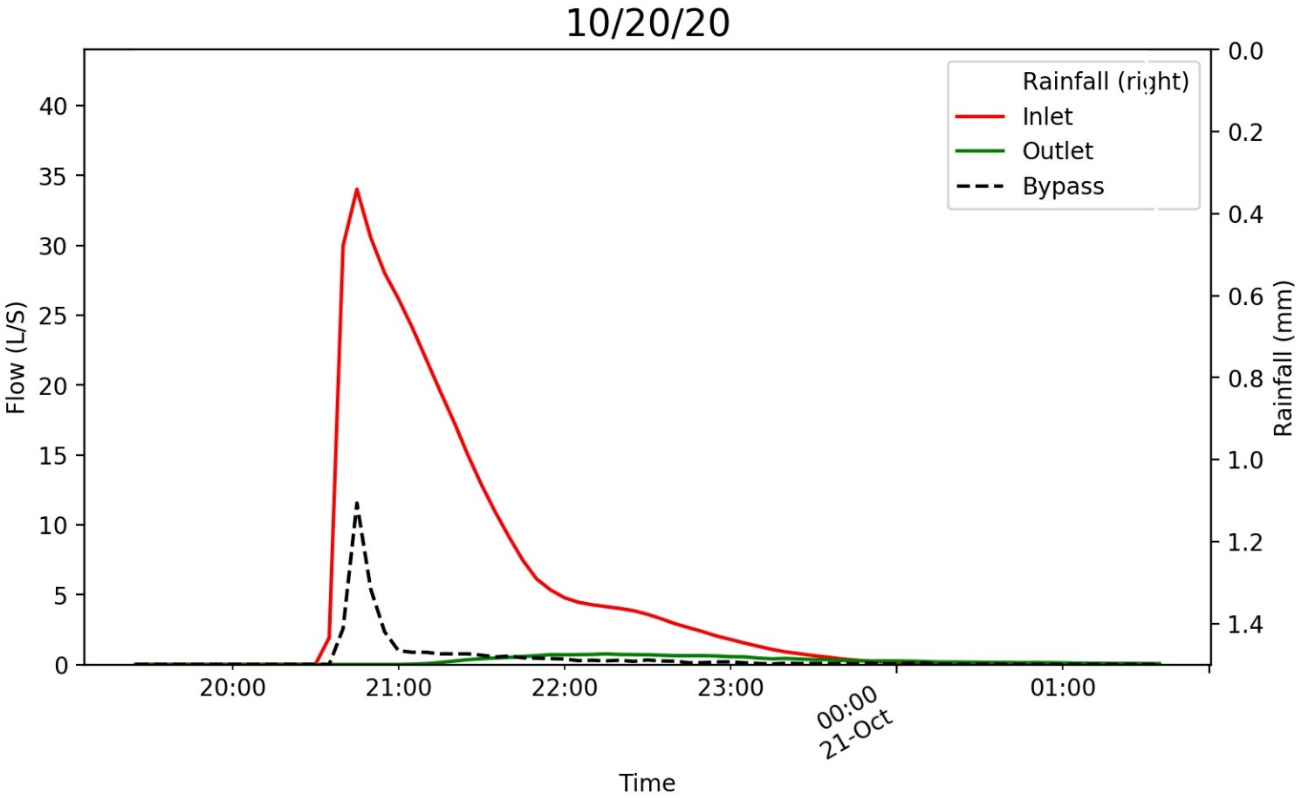
75
100
125
150
175
Rainfall (mm)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
Time
03:00
06:00
09:00
12:00
15:00
18:00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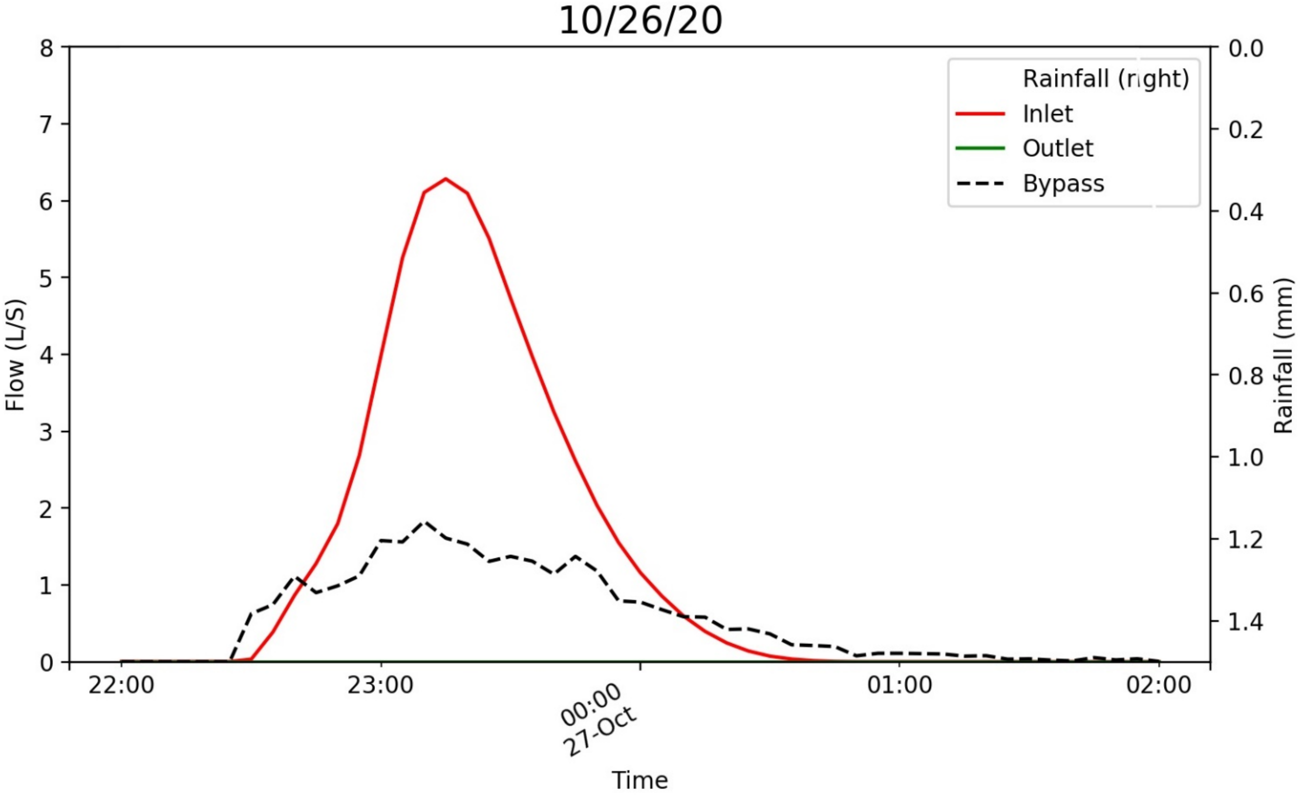
Inlet
Outlet
Bypass
Flow (L/S)
0
5
10
15
20
25
30
35
40
Rainfall (mm)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
20:00
21:00
22:00
23:00
00:00
21-Oct
01:00
Time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Inlet
Outlet
Bypass
Flow (L/S)
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4
5
6
7
8
Rainfall (mm)
0.0
0.2
0.4
0.6
0.8
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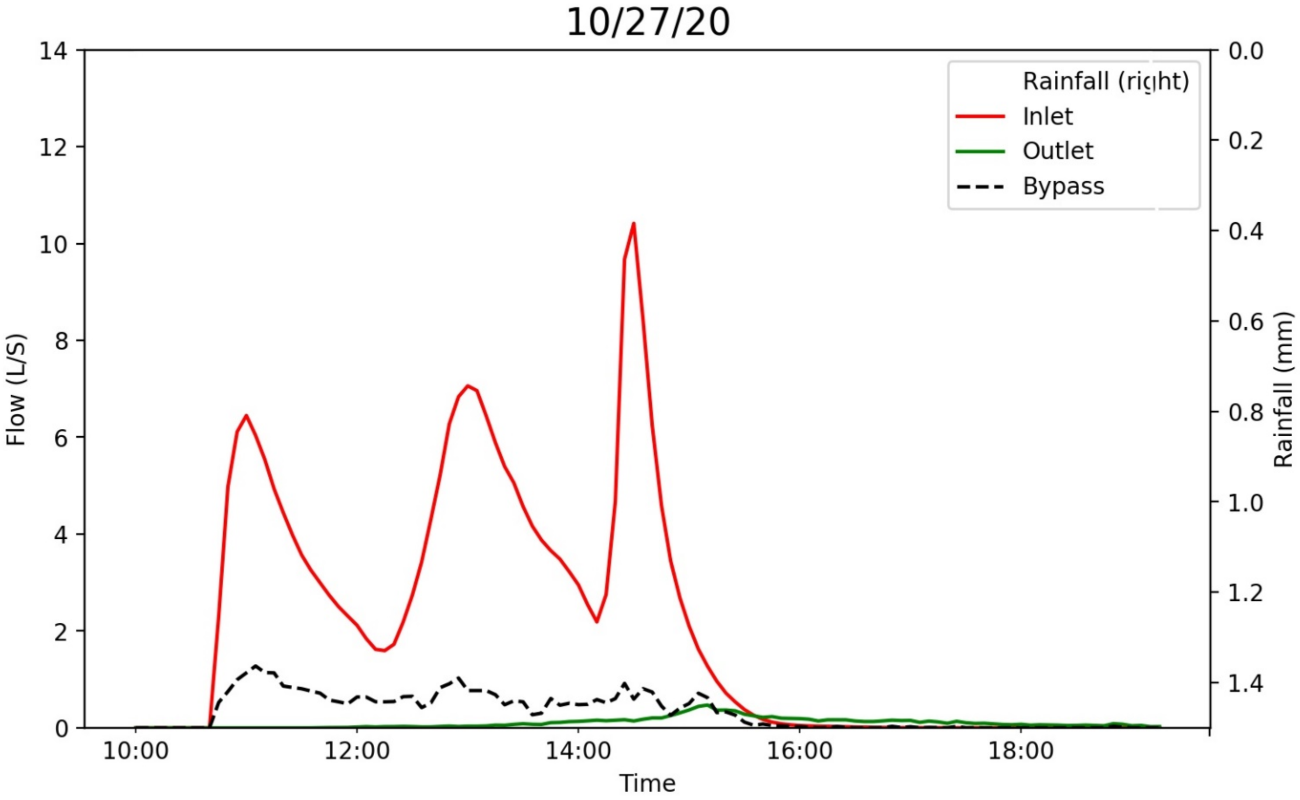
1.2
1.4
22:00
23:00
00:00
27-Oct
01:00
02:00
Time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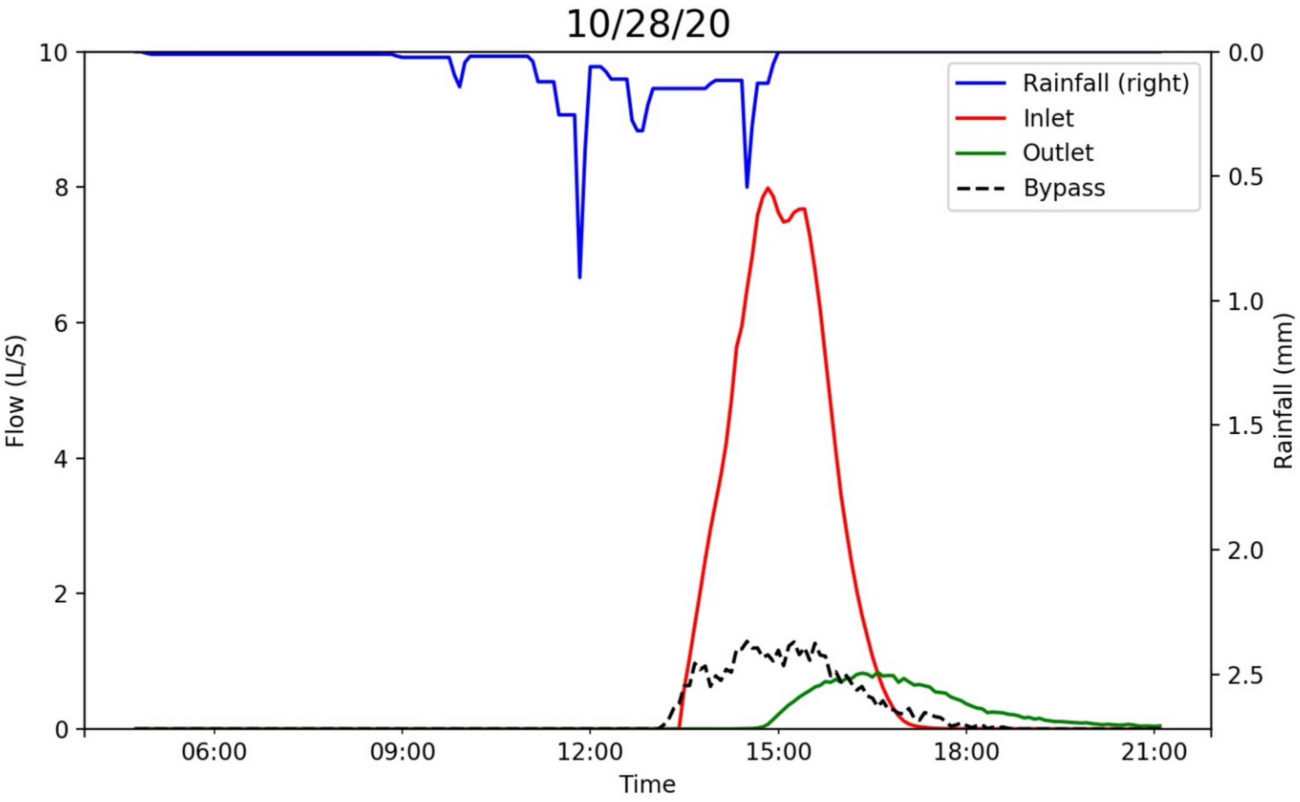
Rainfall (right)
Inlet
Outlet
Bypass
Flow (L/S)
Rainfall (mm)
Time
0
2
4
6
8
10
12
14
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
10:00
12:00
14:00
16:00
18:00


10/28/20
Rainfall (right)
Inlet
Outlet
Bypass
Flow (L/S)
Rainfall (mm)
Time
0
2
4
6
8
10
0.0
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1.5
2.0
2.5
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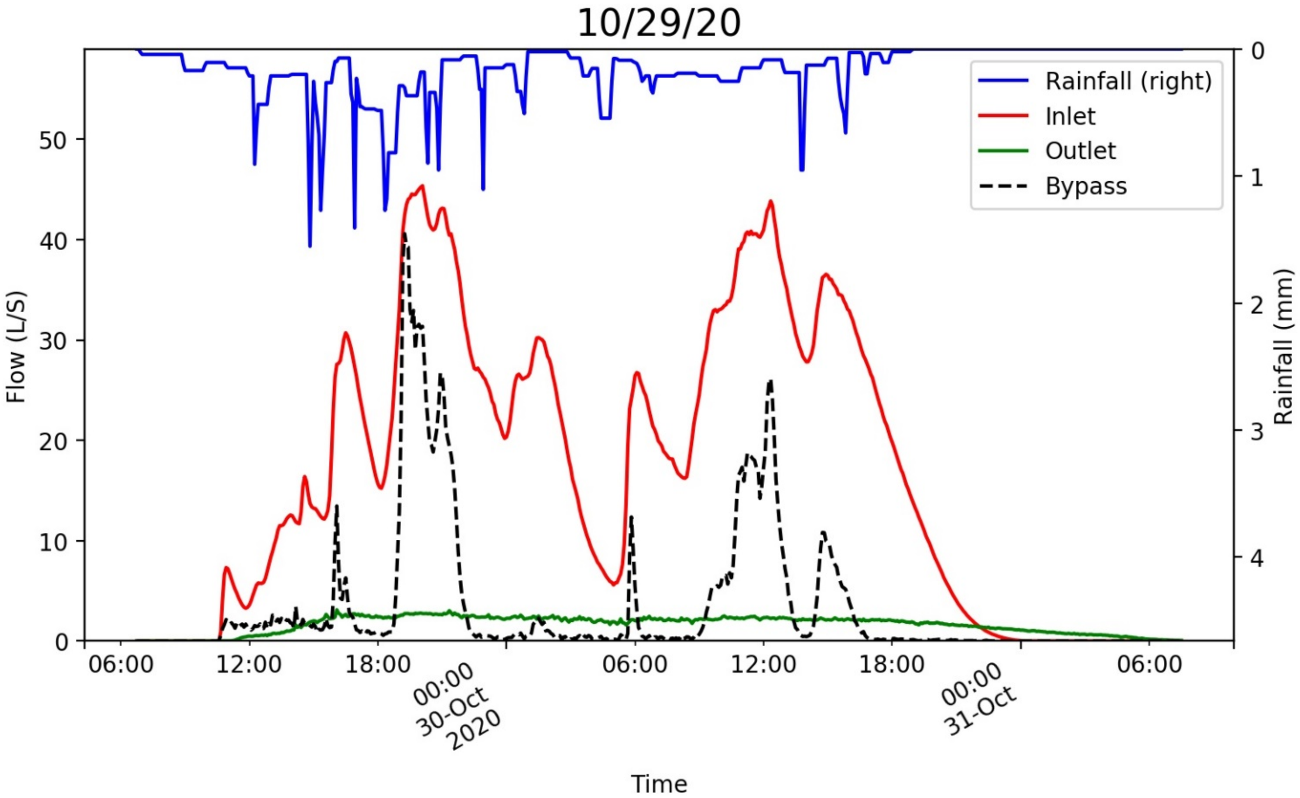
21:00


10/29/20
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Outlet
Bypass
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40
50
Rainfall (mm)
0
1
2
3
4
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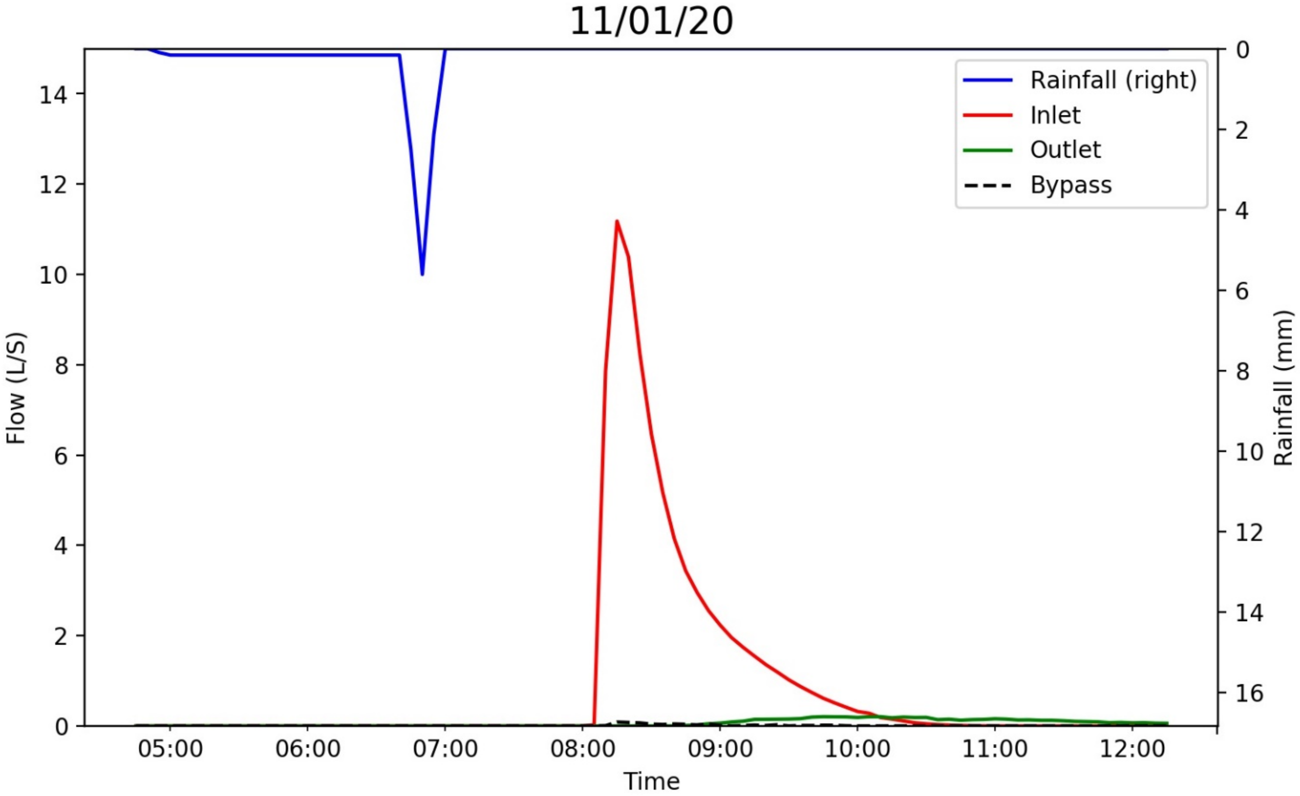
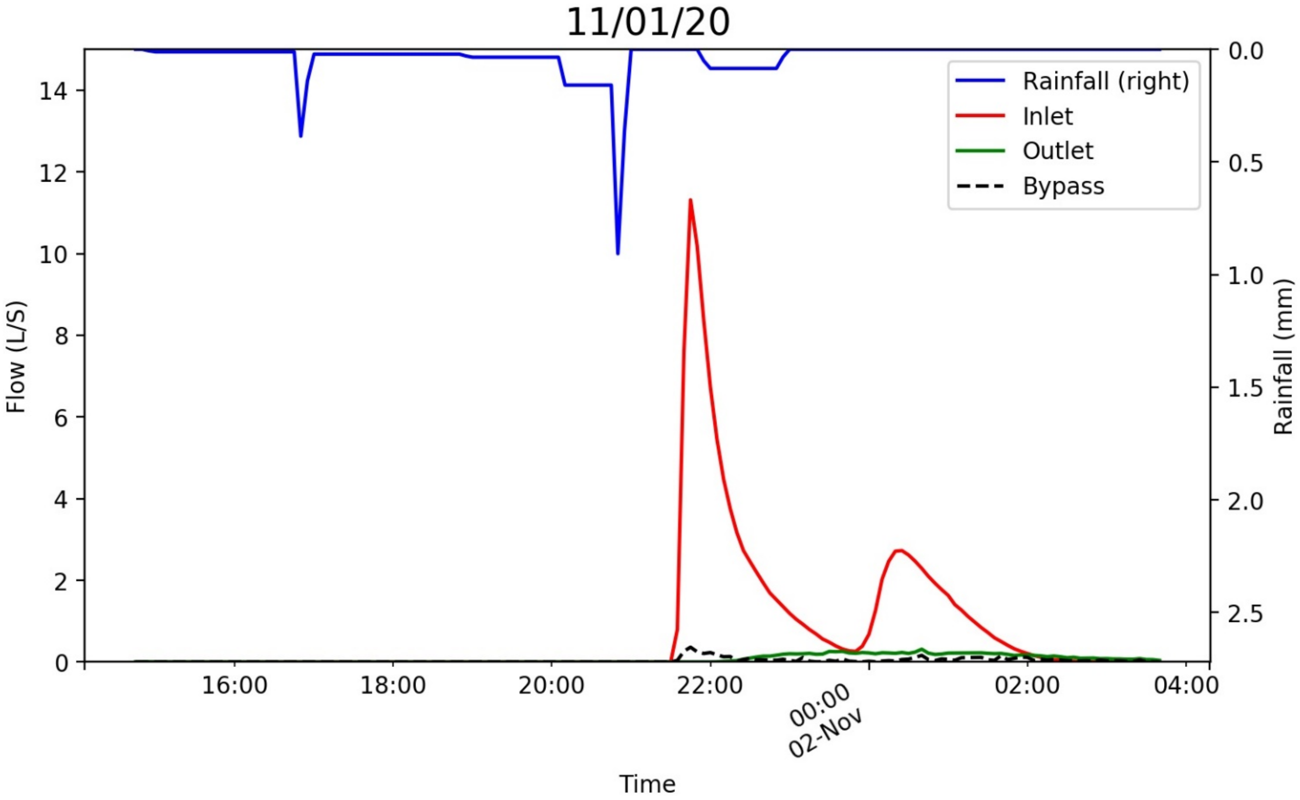
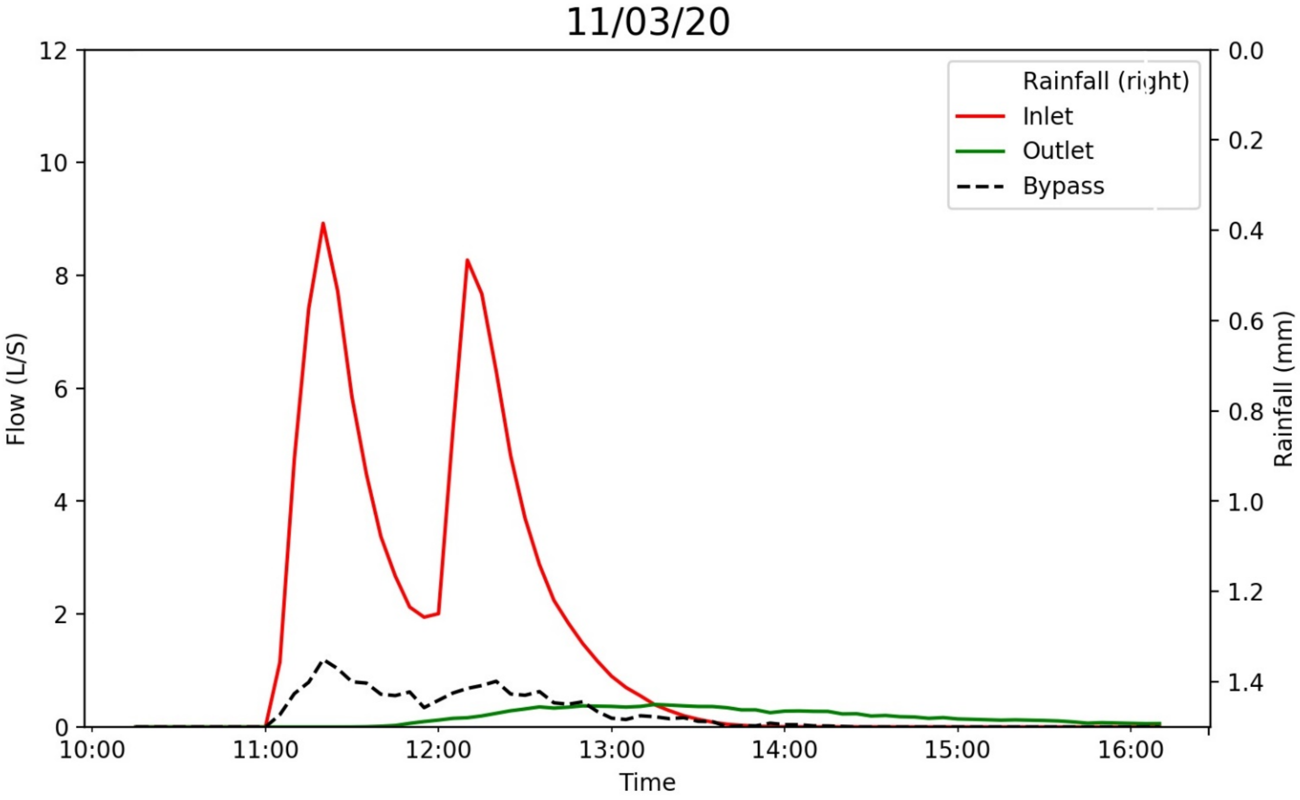
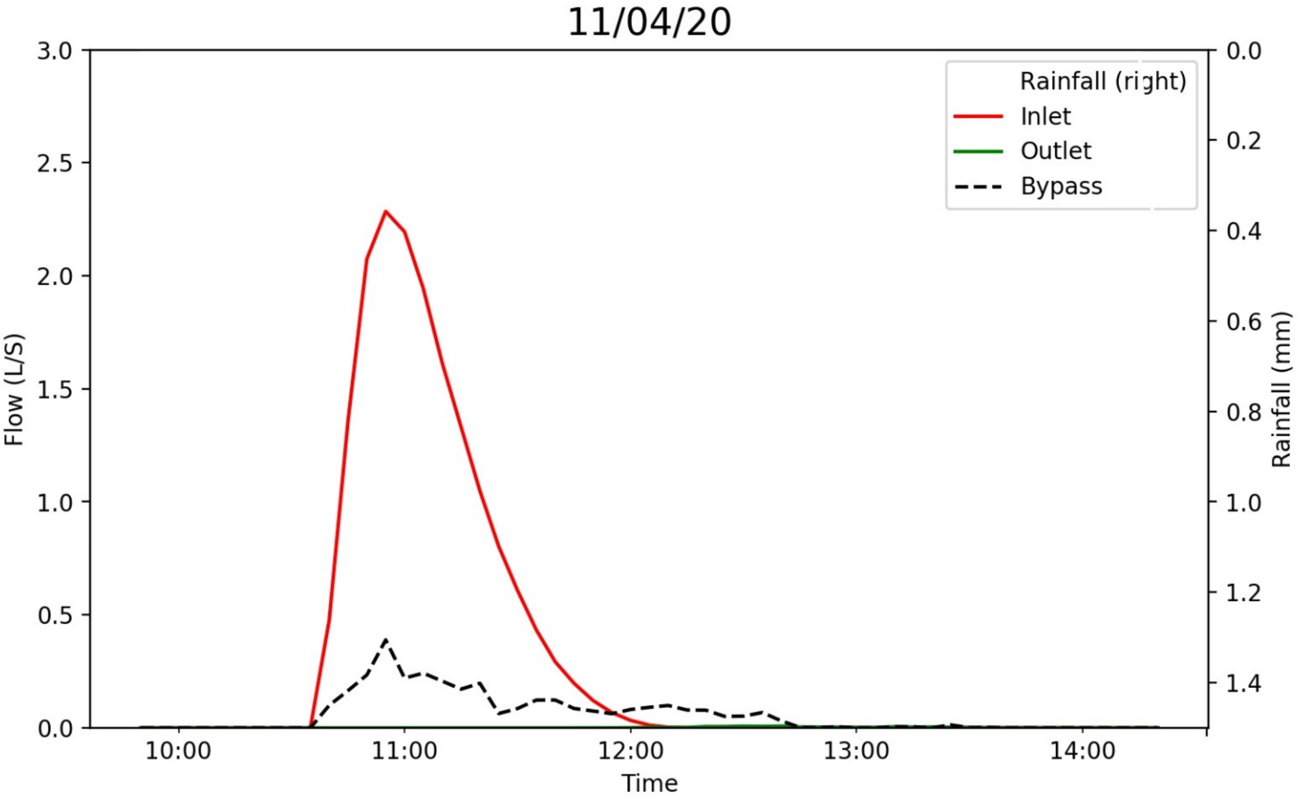
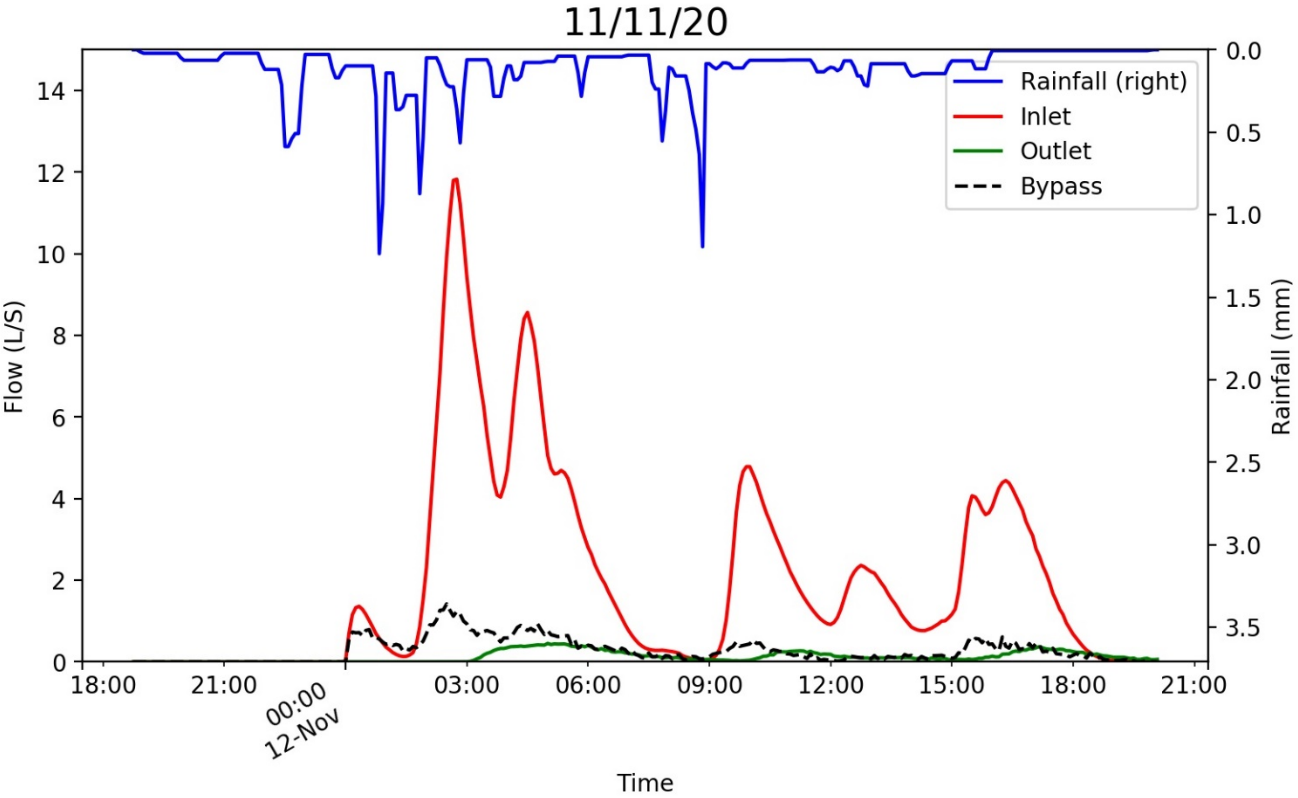
Time

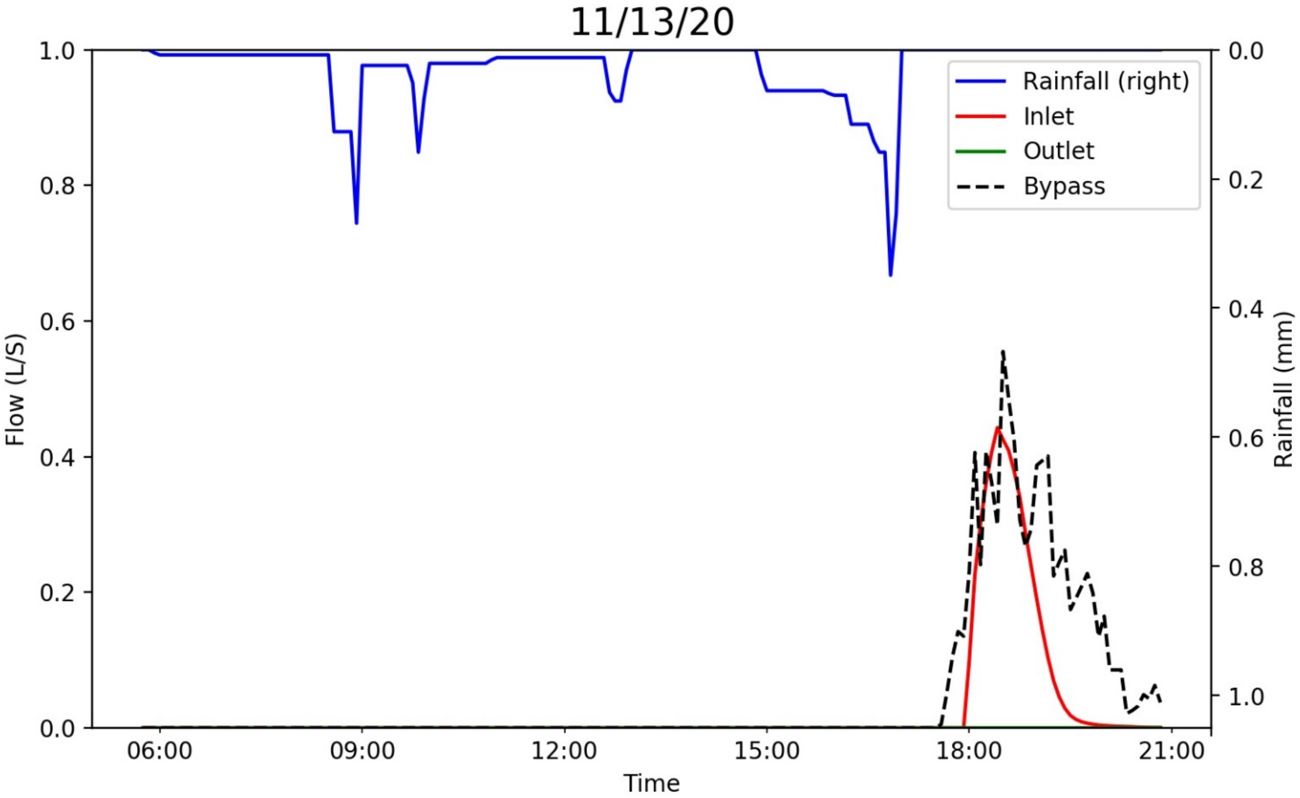

11/01/20
Rainfall (right)
Inlet
Outlet
Bypass
Flow (L/S)
0
2
4
6
8
10
12
14
Rainfall (mm)
0
2
4
6
8
10
12
14
16
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
Time

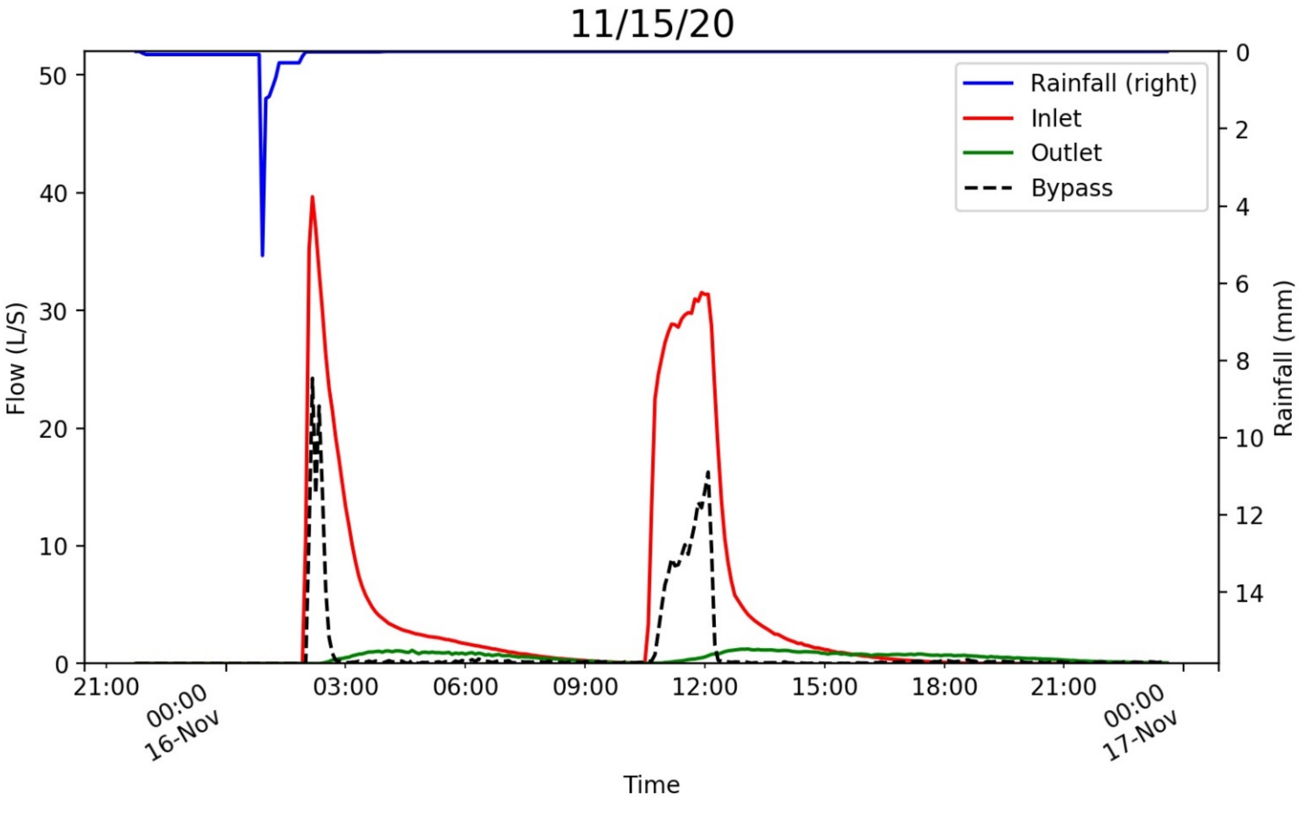

11/01/20
Rainfall (right)
Inlet
Outlet
Bypass
Flow (L/S)
0
2
4
6
8
10
12
14
Rainfall (mm)
0.0
0.5
1.0
1.5
2.0
2.5
16:00
18:00
20:00
22:00
00:00
02-Nov
02:00
04:00
Time

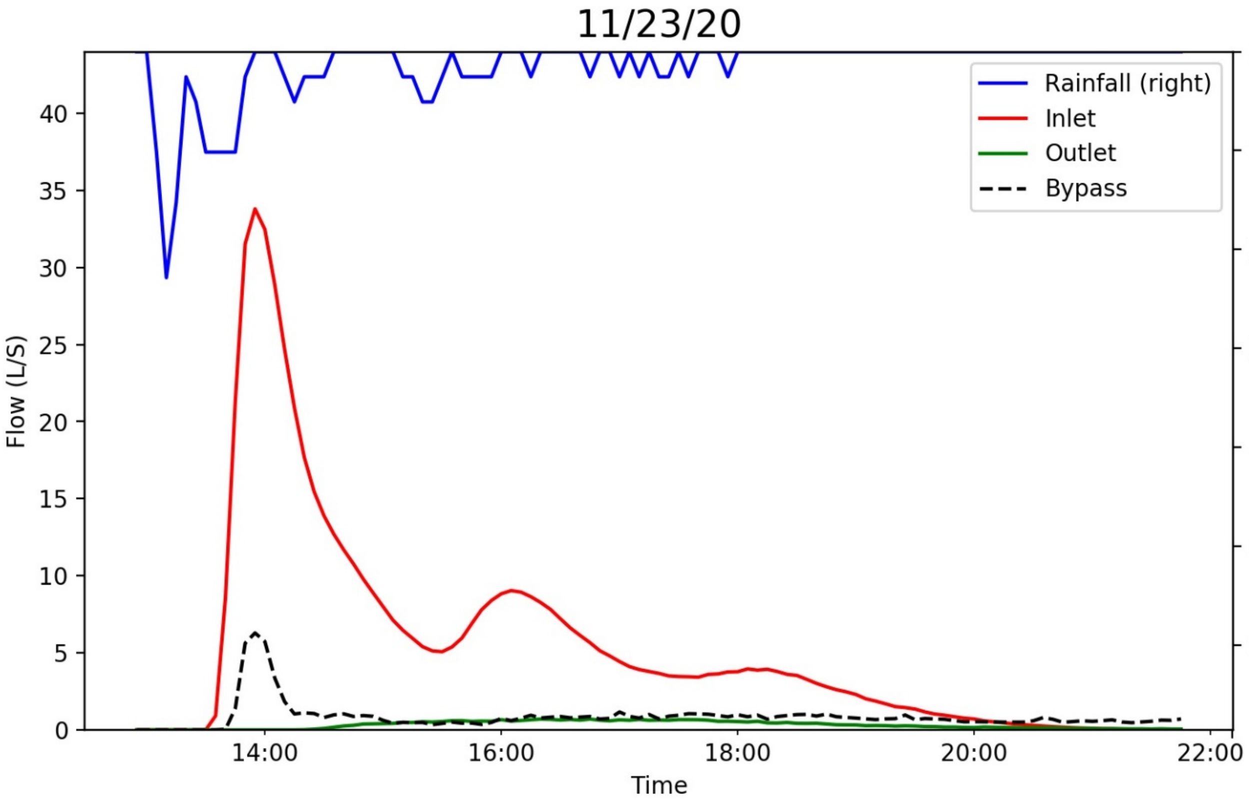

11/03/20
Rainfall (right)
Inlet
Outlet
Bypass
Flow (L/S)
0
2
4
6
8
10
12
Rainfall (mm)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time

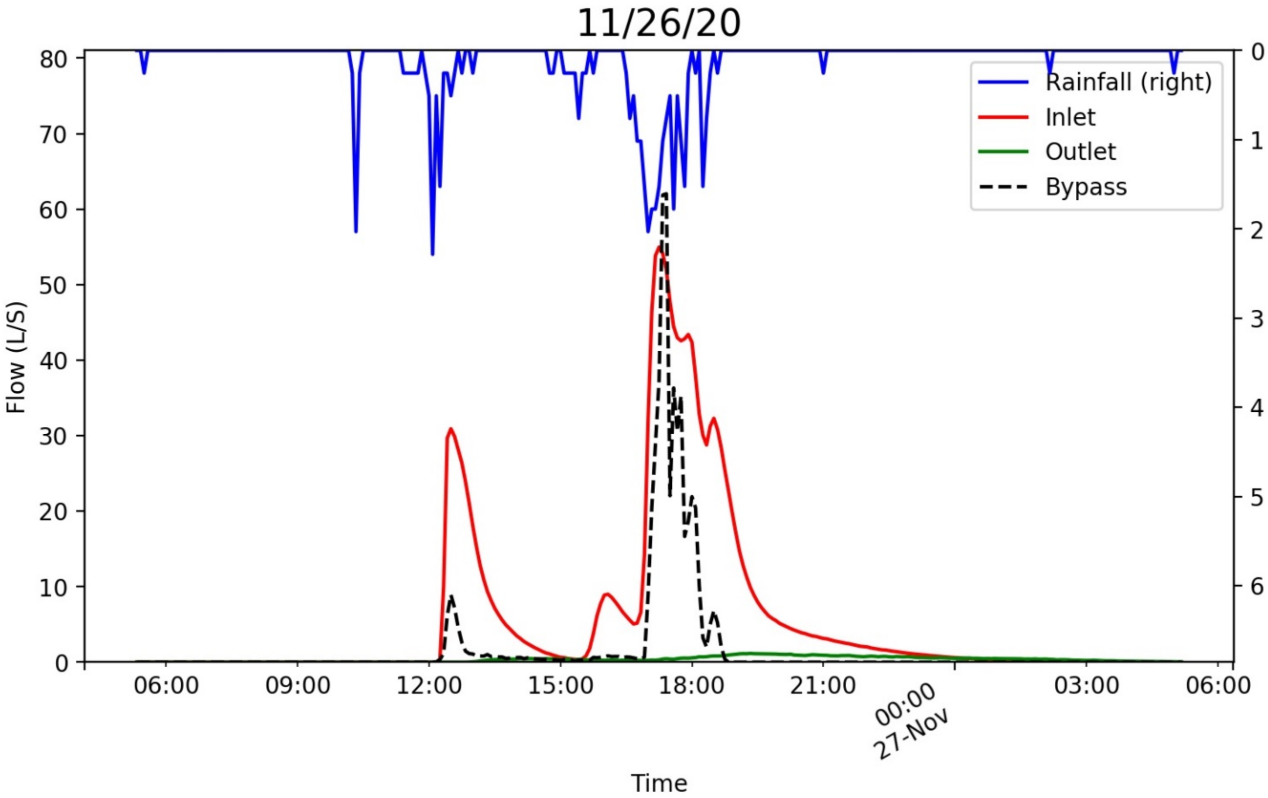

11/04/20
Flow (L/S)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Rainfall (mm)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
10:00
11:00
12:00
13:00
14:00
Time
Rainfall (right)
Inlet
Outlet
Bypass

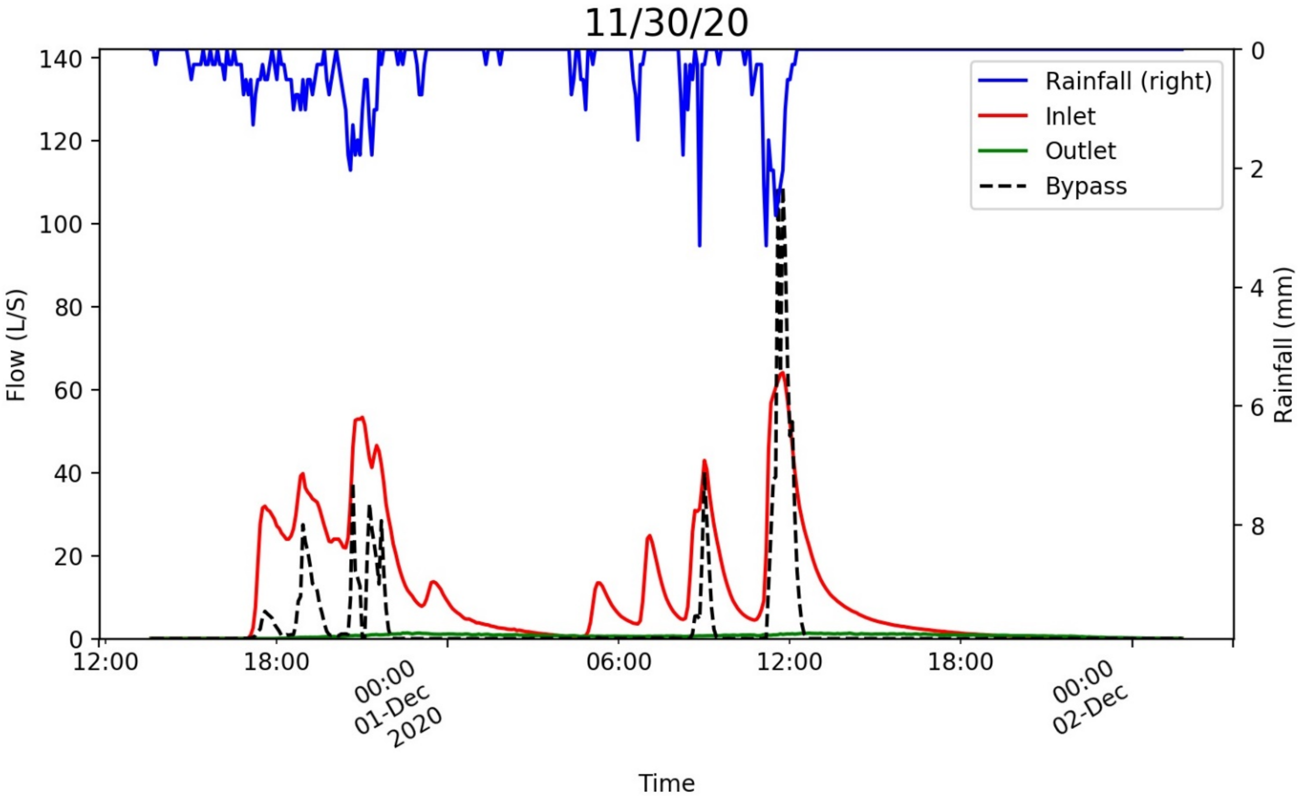

11/11/20
Flow (L/S)
14
12
10
8
6
4
2
0
Rainfall (mm)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
18:00
21:00
00:00
12-Nov
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time
Rainfall (right)
Inlet
Outlet
Bypass


11/13/20
Flow (L/S)
1.0
0.8
0.6
0.4
0.2
0.0
Rainfall (mm)
0.0
0.2
0.4
0.6
0.8
1.0
06:00
09:00
12:00
15:00
18:00
21:00
Time
Rainfall (right)
Inlet
Outlet
Bypass


11/15/20
Flow (L/S)
50
40
30
20
10
0
Rainfall (mm)
0
2
4
6
8
10
12
14
21:00
00:00 16-Nov
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00 17-Nov
Time
Rainfall (right)
Inlet
Outlet
Bypass


11/23/20
Rainfall (right)
Inlet
Outlet
Bypass
Flow (L/S)
0
5
10
15
20
25
30
35
40
Rainfall (mm)
0
1
2
3
4
5
6
Time
14:00
16:00
18:00
20:00
22:00


11/26/20
Rainfall (right)
Inlet
Outlet
Bypass
Flow (L/S)
0
10
20
30
40
50
60
70
80
Rainfall (mm)
0
1
2
3
4
5
6
Time
06:00
09:00
12:00
15:00
18:00
21:00
00:00
27-Nov
03:00
06:00


11/30/20
Rainfall (right)
Inlet
Outlet
Bypass
Flow (L/S)
0
20
40
60
80
100
120
140
Rainfall (mm)
0
2
4
6
8
12:00
18:00
00:00
01-Dec
2020
06:00
12:00
18:00
00:00
02-Dec
Time

2. Appendix 2: Event Hydrographs and Pollutant Concentrations

This appendix shows all monitored storm events for rainfall, inflow, outflow, and concentrations of total suspended sediment (TSS), total nitrogen (TN), and total phosphorus (TP). The TSS, TN, and TP were measured using the UV-Vis spectrometer at the inlet and outlet location. The data recorded is light absorbance per meter for wavelengths in the 220-720 nm range. The concentrations of pollutants were calculated using a prediction model from UNHSC based on Partial Least Squares Regression comparing to laboratory values. The model is from a previous study by UNHSC submitted in 2018 to and funded by the U.S. EPA titled *Utilizing In-Situ Ultraviolet-Visual Spectroscopy to Measure Nutrients and Sediment Concentrations in Stormwater Runoff*.

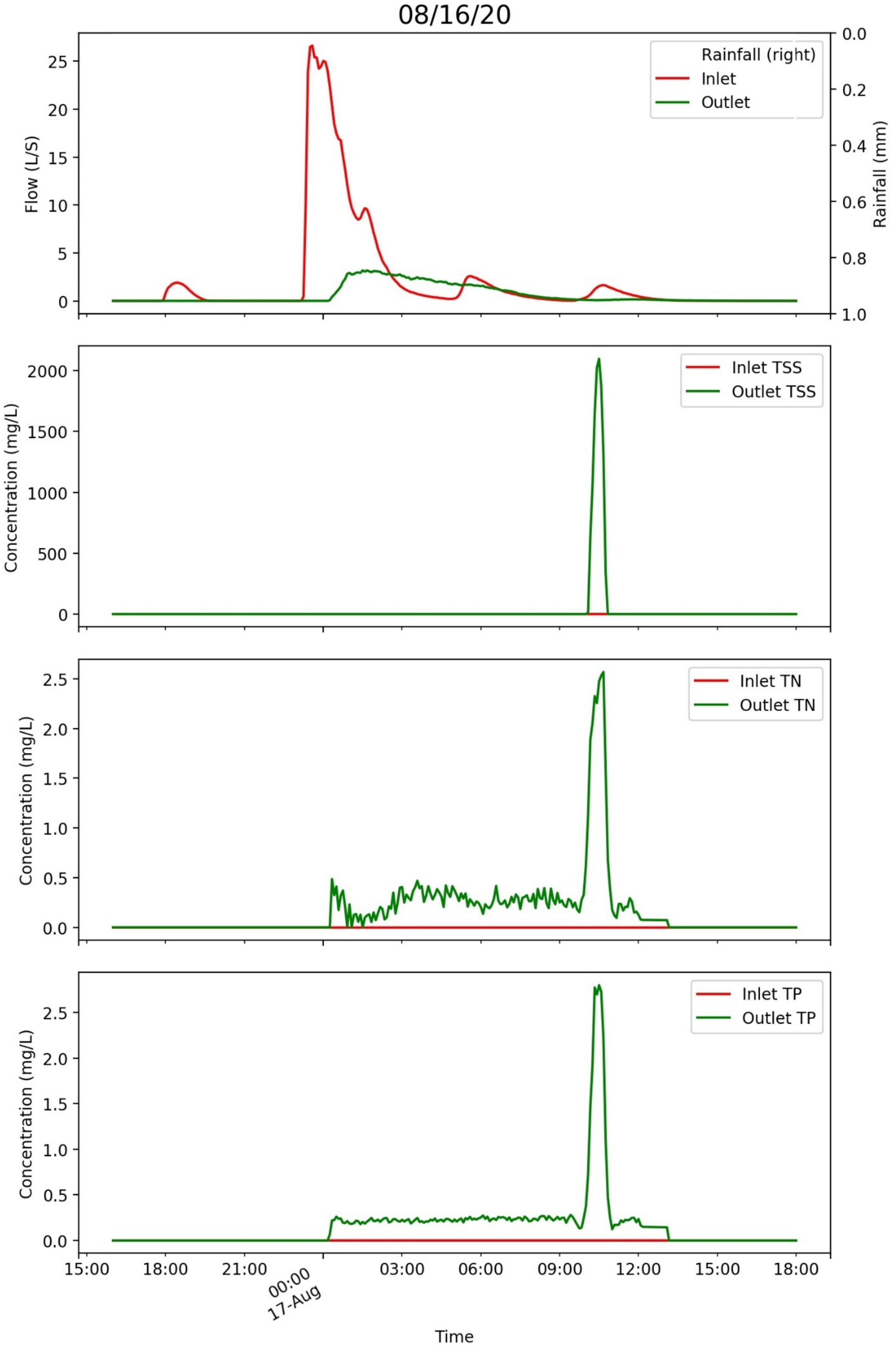
The graphs titles show the date of the start of the event.

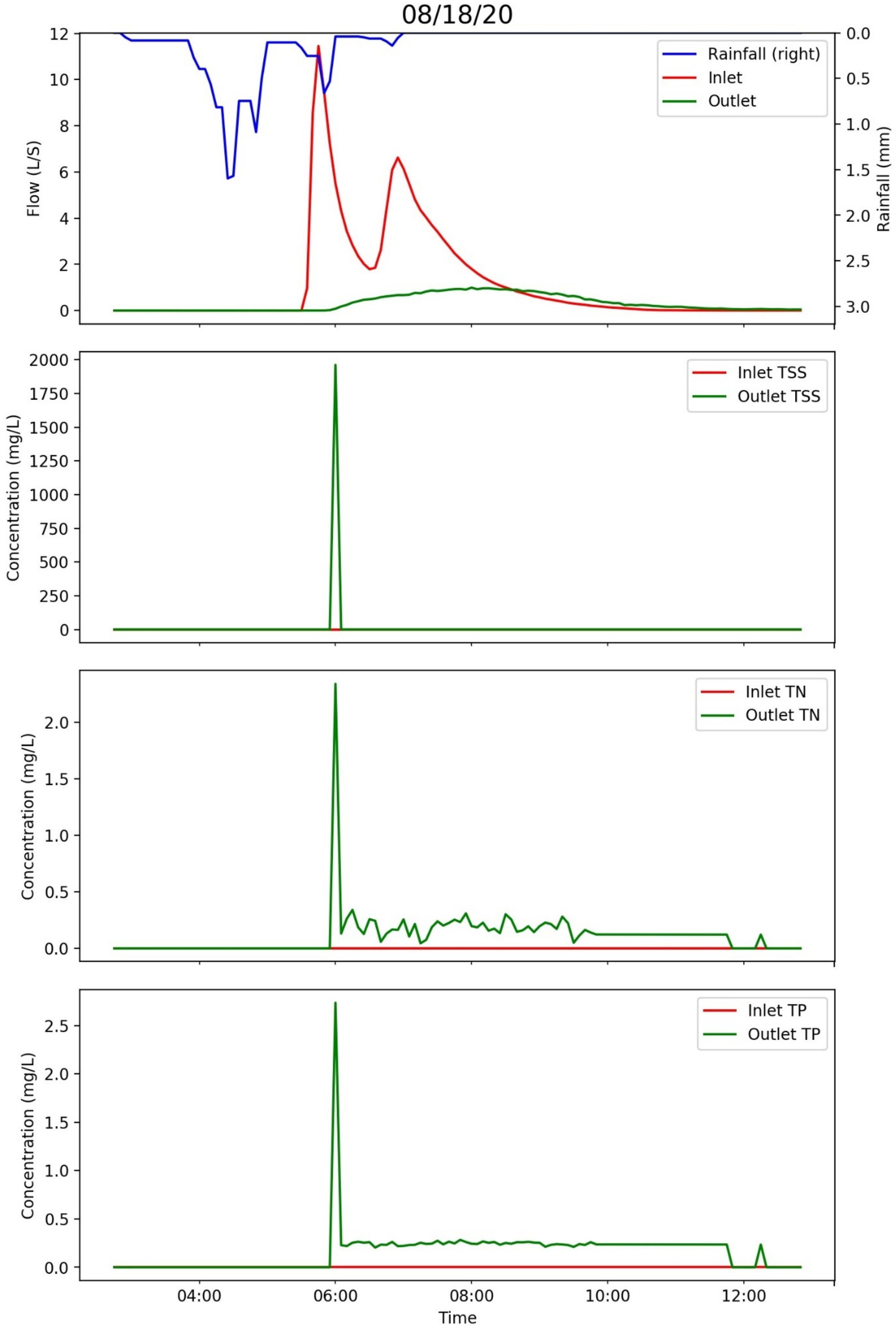
Subplot 1: Flow at the inlet and outlet are in liters per second (L/s) and are shown on the left axis. Rainfall in millimeters (mm) is shown on the inverted right axis.

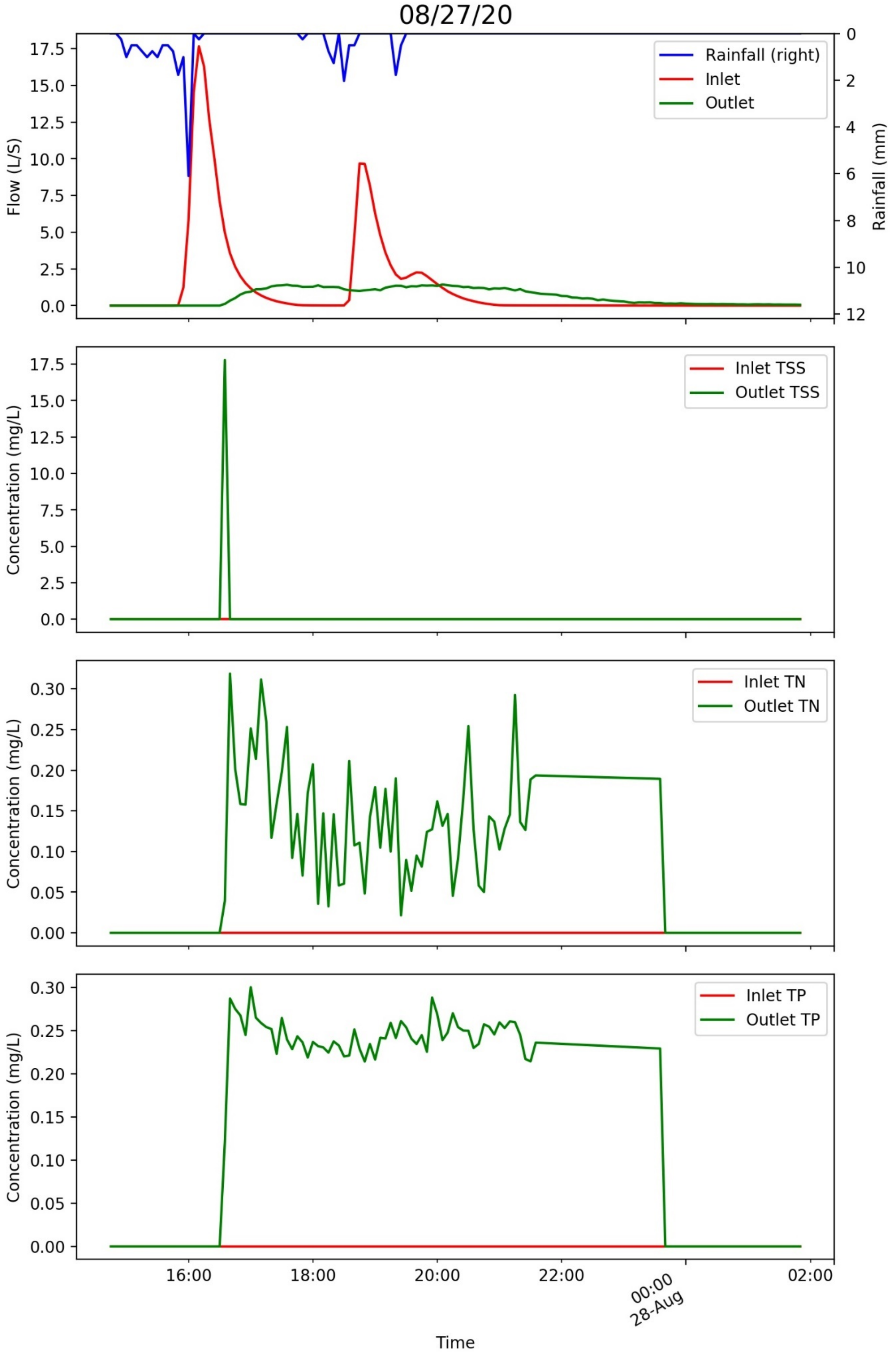
Subplot 2: Concentration of total suspended sediment (TSS) in milligrams per liter (mg/L) at the inlet and outlet locations.

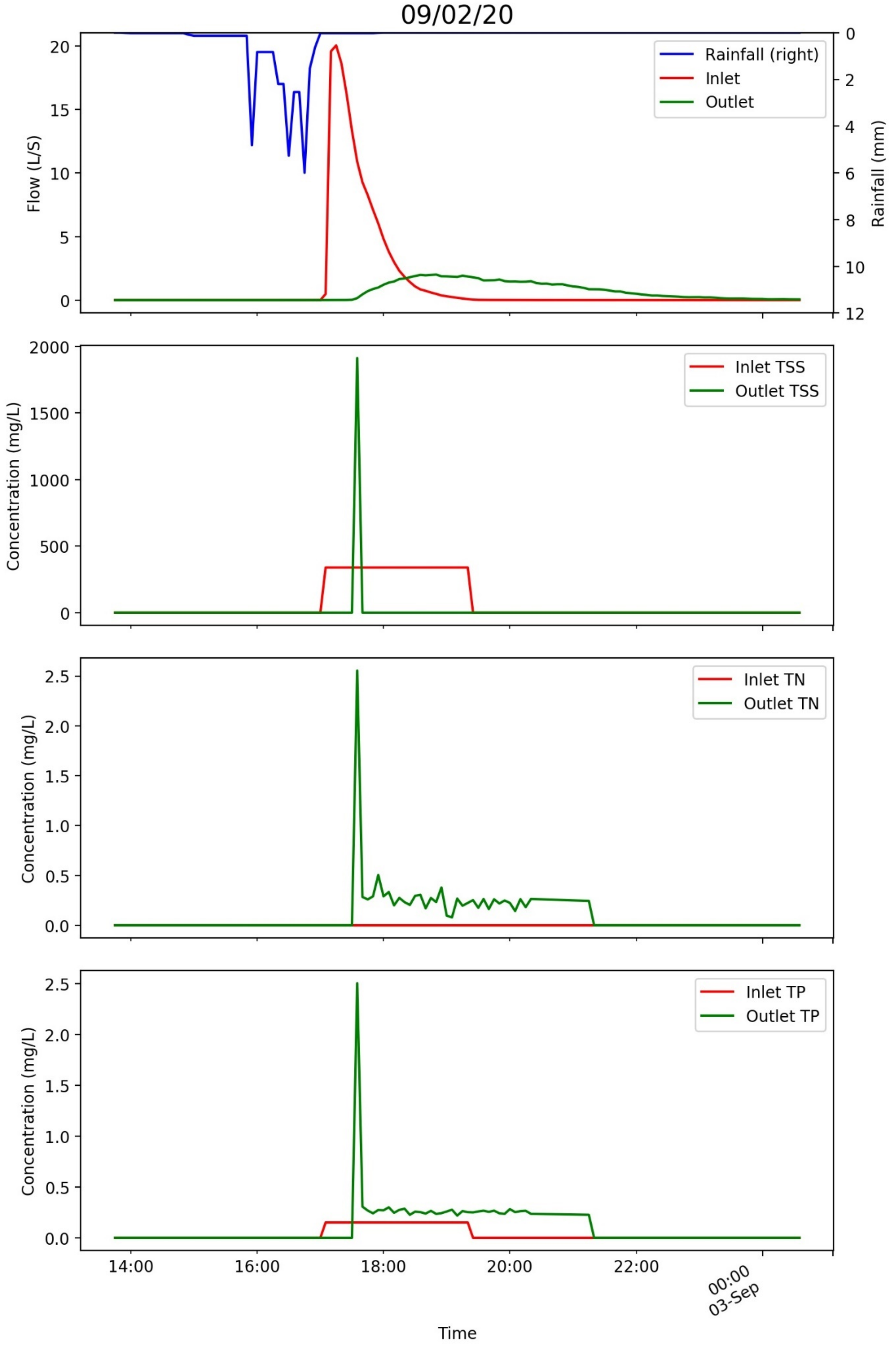
Subplot 3: Concentration of total nitrogen (TN) in milligrams per liter (mg/L) at the inlet and outlet locations.

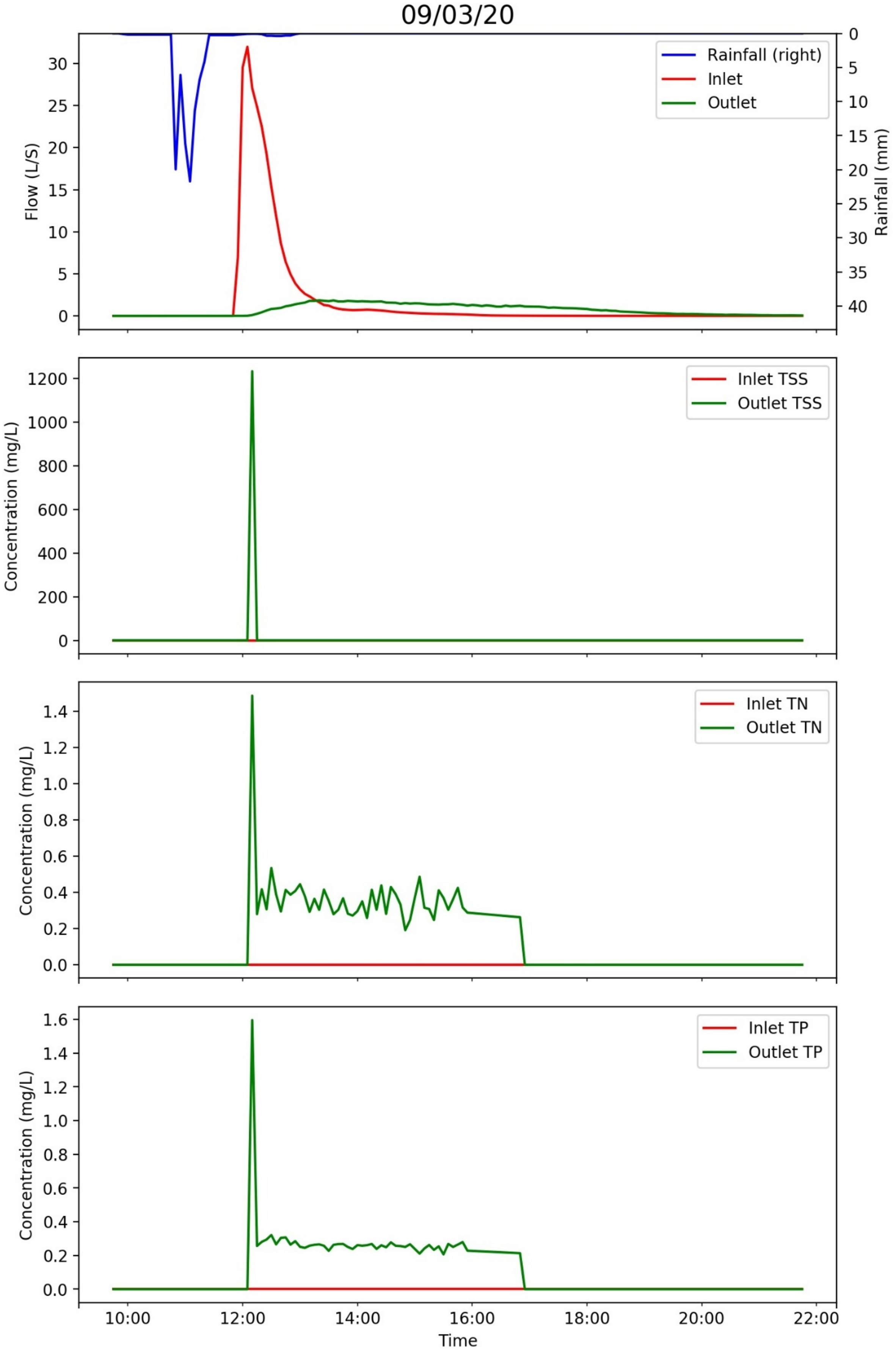
Subplot 4: Concentration of total phosphorus (TP) in milligrams per liter (mg/L) at the inlet and outlet locations.

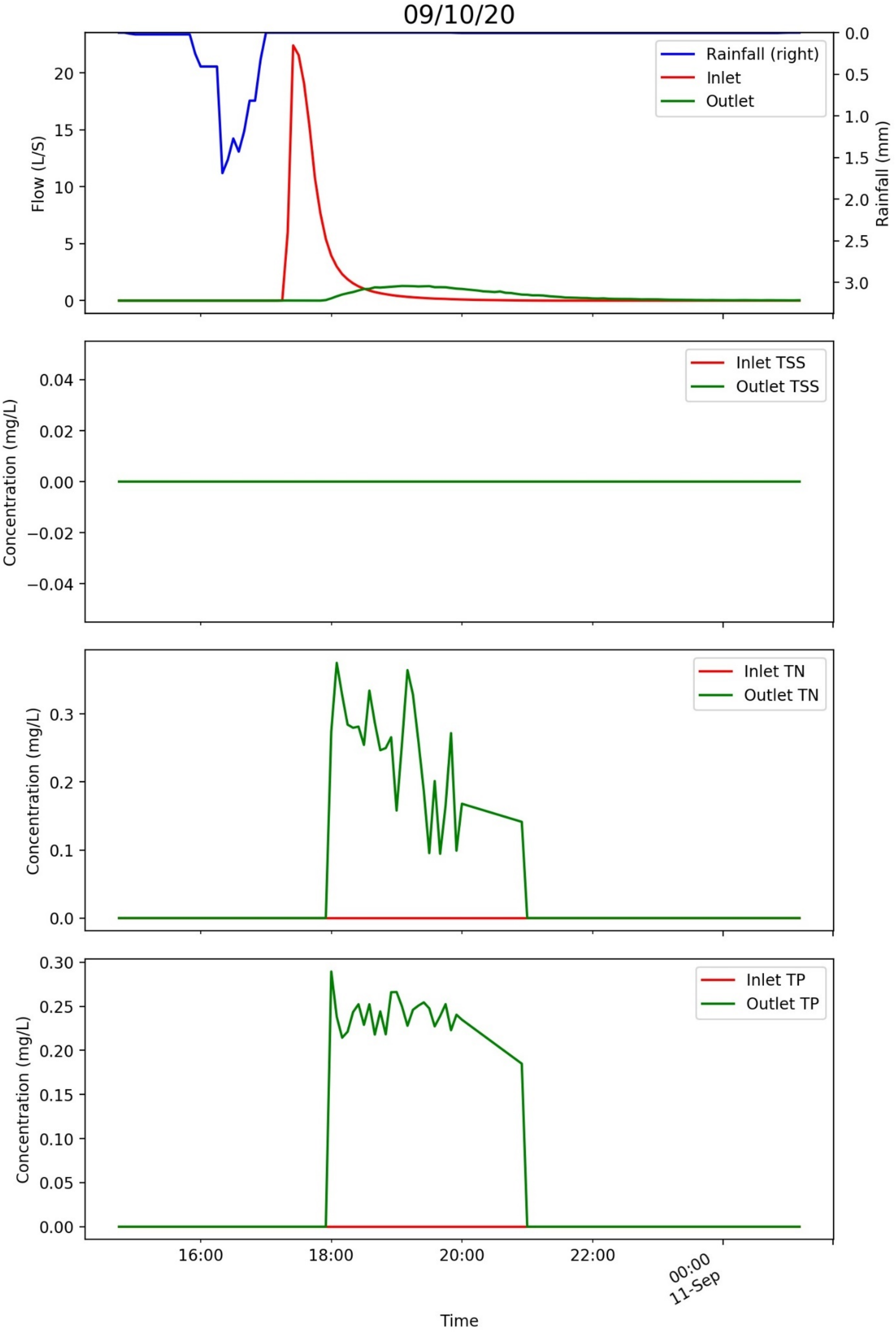

08/16/20
Flow (L/S)
Rainfall (mm)
Rainfall (right)
Inlet
Outlet
0
5
10
15
20
25
0.0
0.2
0.4
0.6
0.8
1.0
Concentration (mg/L)
Inlet TSS
Outlet TSS
0
500
1000
1500
2000
Concentration (mg/L)
Inlet TN
Outlet TN
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (mg/L)
Inlet TP
Outlet TP
0.0
0.5
1.0
1.5
2.0
2.5
15:00
18:00
21:00
00:00
17-Aug
03:00
06:00
09:00
12:00
15:00
18:00
Time

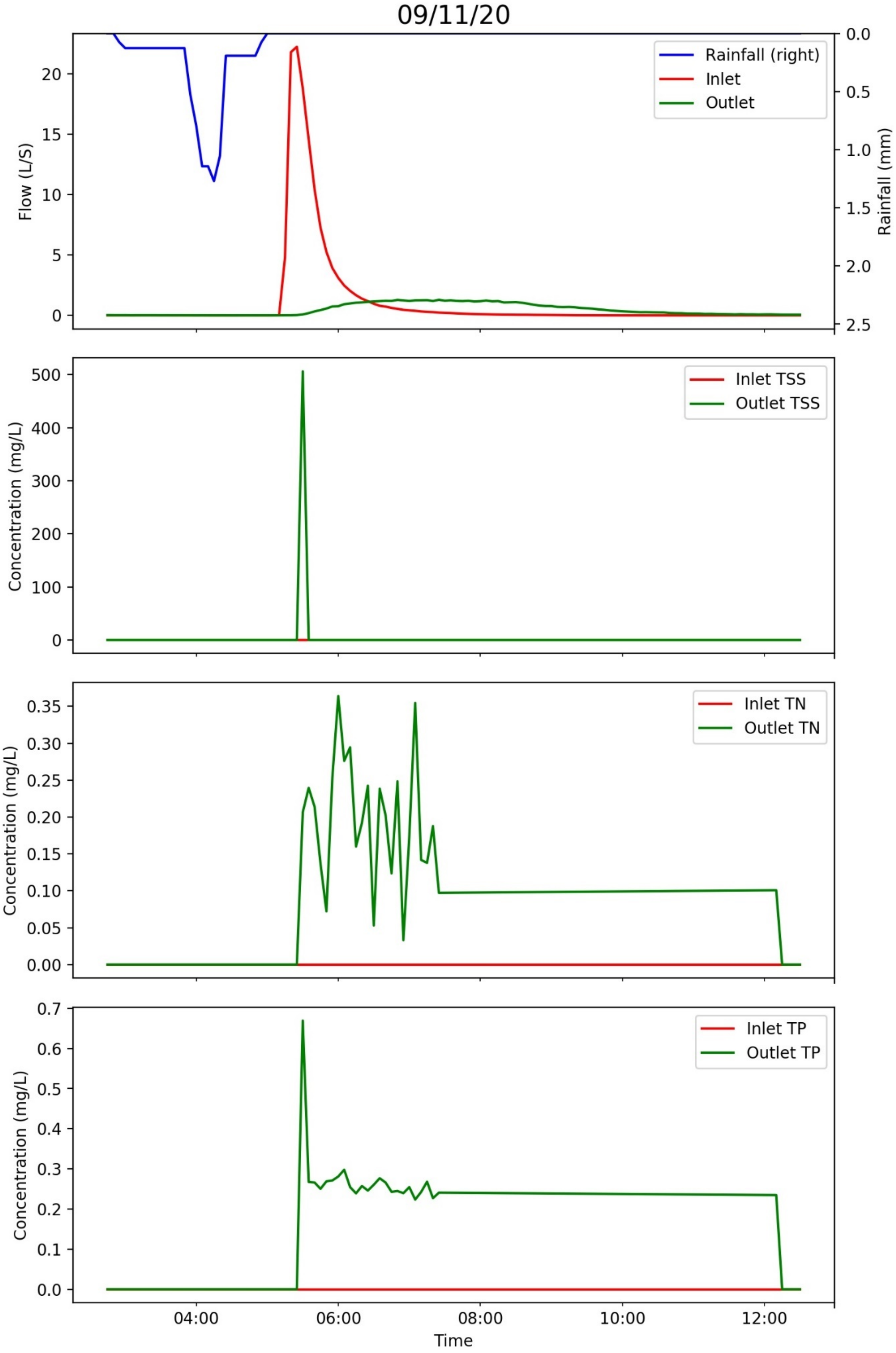

08/18/20
Flow (L/S)
Rainfall (mm)
Rainfall (right)
Inlet
Outlet
12
10
8
6
4
2
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Concentration (mg/L)
Inlet TSS
Outlet TSS
2000
1750
1500
1250
1000
750
500
250
0
Inlet TN
Outlet TN
2.0
1.5
1.0
0.5
0.0
Inlet TP
Outlet TP
2.5
2.0
1.5
1.0
0.5
0.0
04:00
06:00
08:00
10:00
12:00
Time

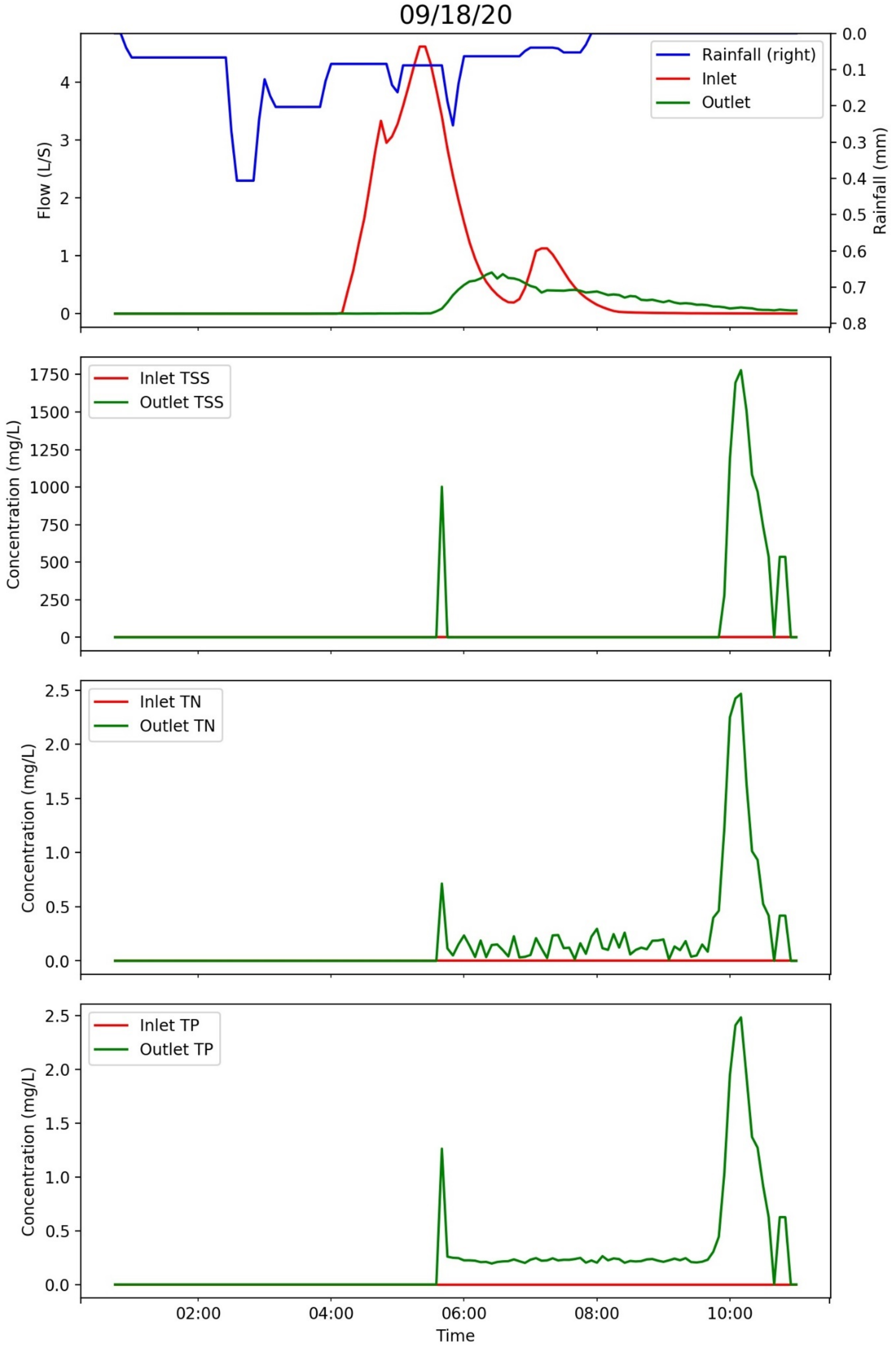

08/27/20
Rainfall (right)
Inlet
Outlet
Flow (L/S)
Rainfall (mm)
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
2
4
6
8
10
12
Inlet TSS
Outlet TSS
Concentration (mg/L)
Inlet TN
Outlet TN
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Inlet TP
Outlet TP
16:00
18:00
20:00
22:00
00:00
28-Aug
02:00
Time

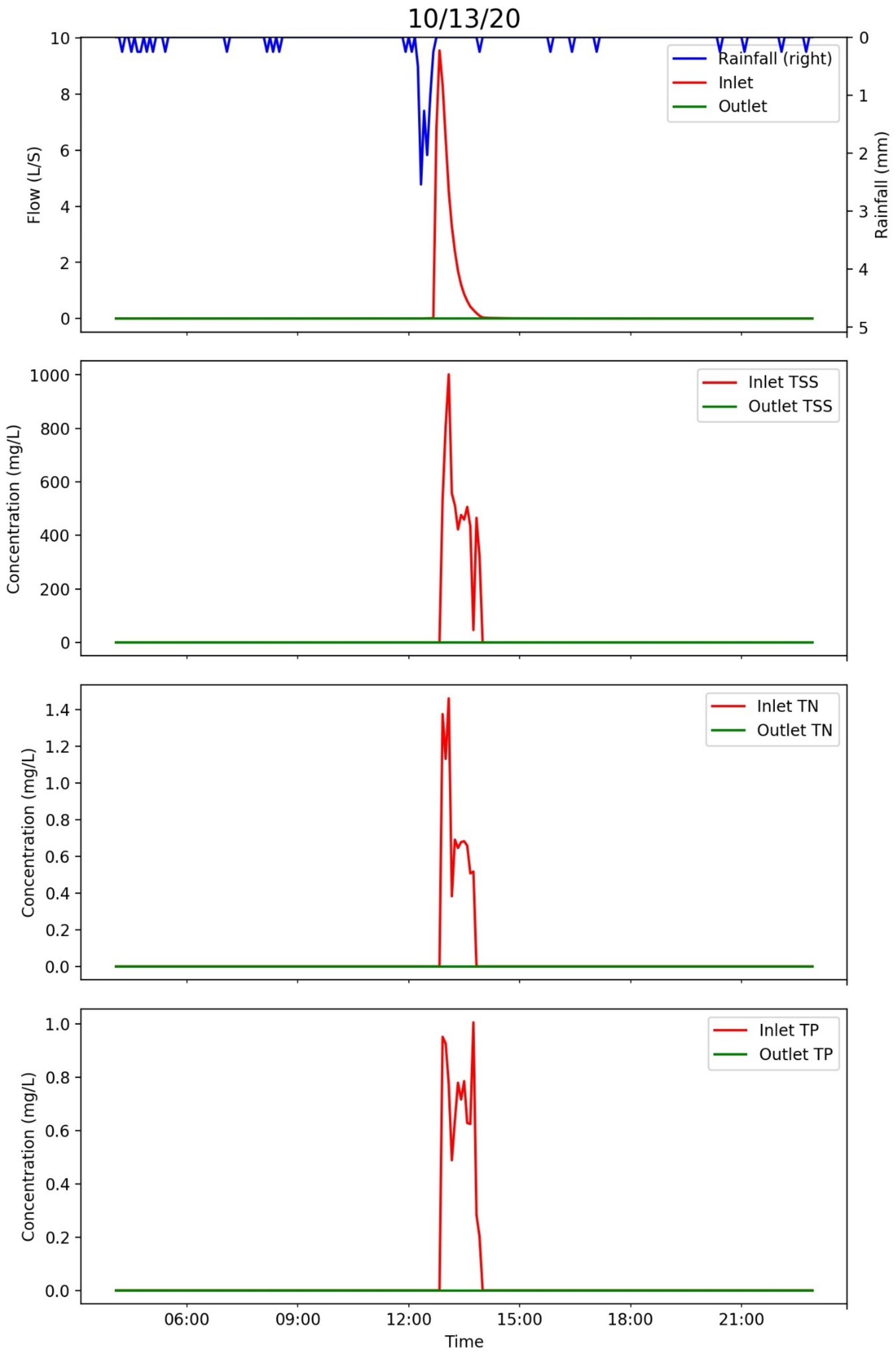

09/02/20
Flow (L/S)
20
15
10
5
0
Rainfall (mm)
0
2
4
6
8
10
12
Rainfall (right)
Inlet
Outlet
Concentration (mg/L)
2000
1500
1000
500
0
Inlet TSS
Outlet TSS
Concentration (mg/L)
2.5
2.0
1.5
1.0
0.5
0.0
Inlet TN
Outlet TN
Concentration (mg/L)
2.5
2.0
1.5
1.0
0.5
0.0
Inlet TP
Outlet TP
14:00
16:00
18:00
20:00
22:00
00:00
03-Sep
Time

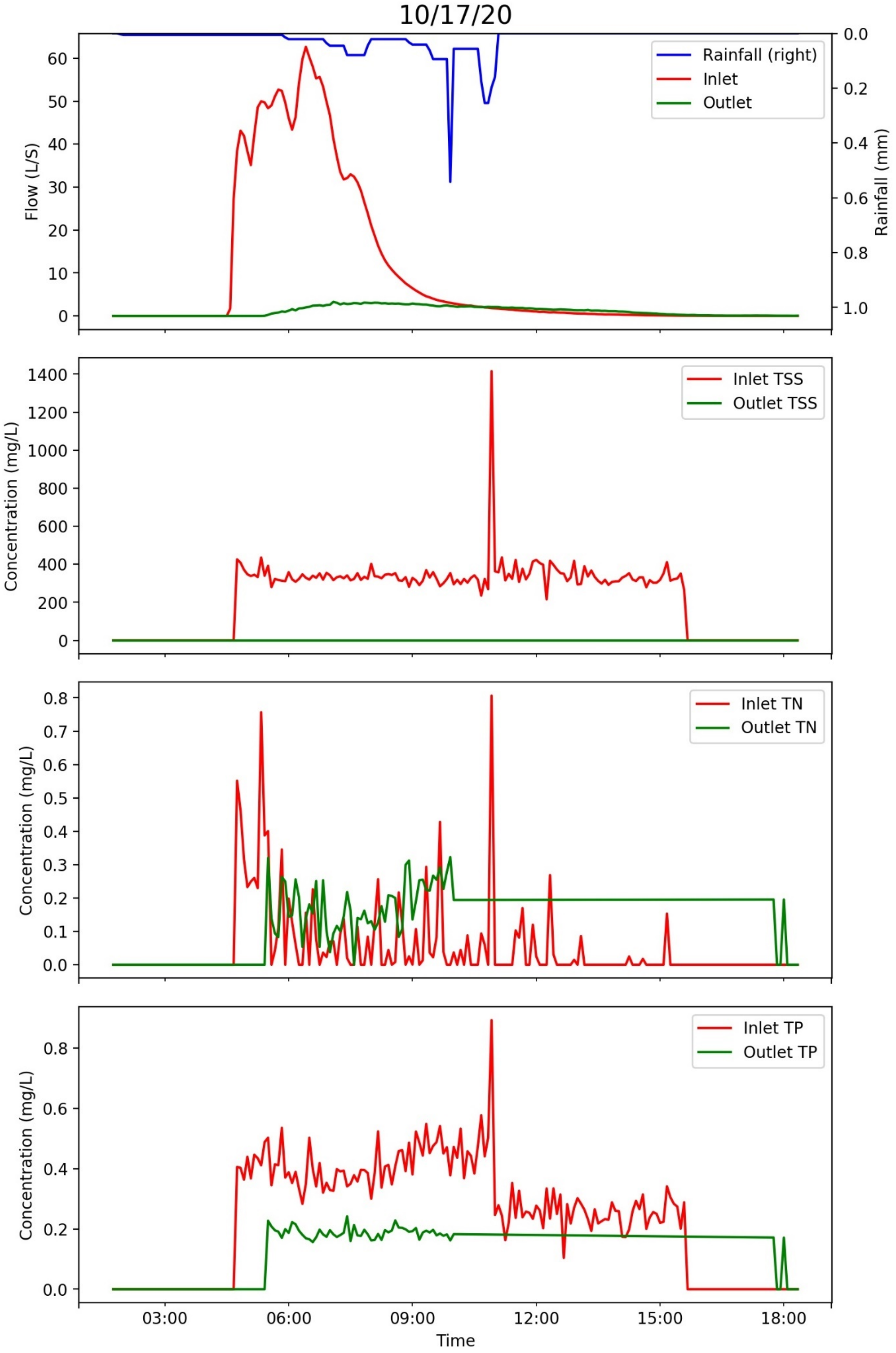

09/03/20
Rainfall (right)
Inlet
Outlet
Flow (L/S)
Rainfall (mm)
0
5
10
15
20
25
30
35
40
Inlet TSS
Outlet TSS
Concentration (mg/L)
0
200
400
600
800
1000
1200
Inlet TN
Outlet TN
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Inlet TP
Outlet TP
1.6
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Time

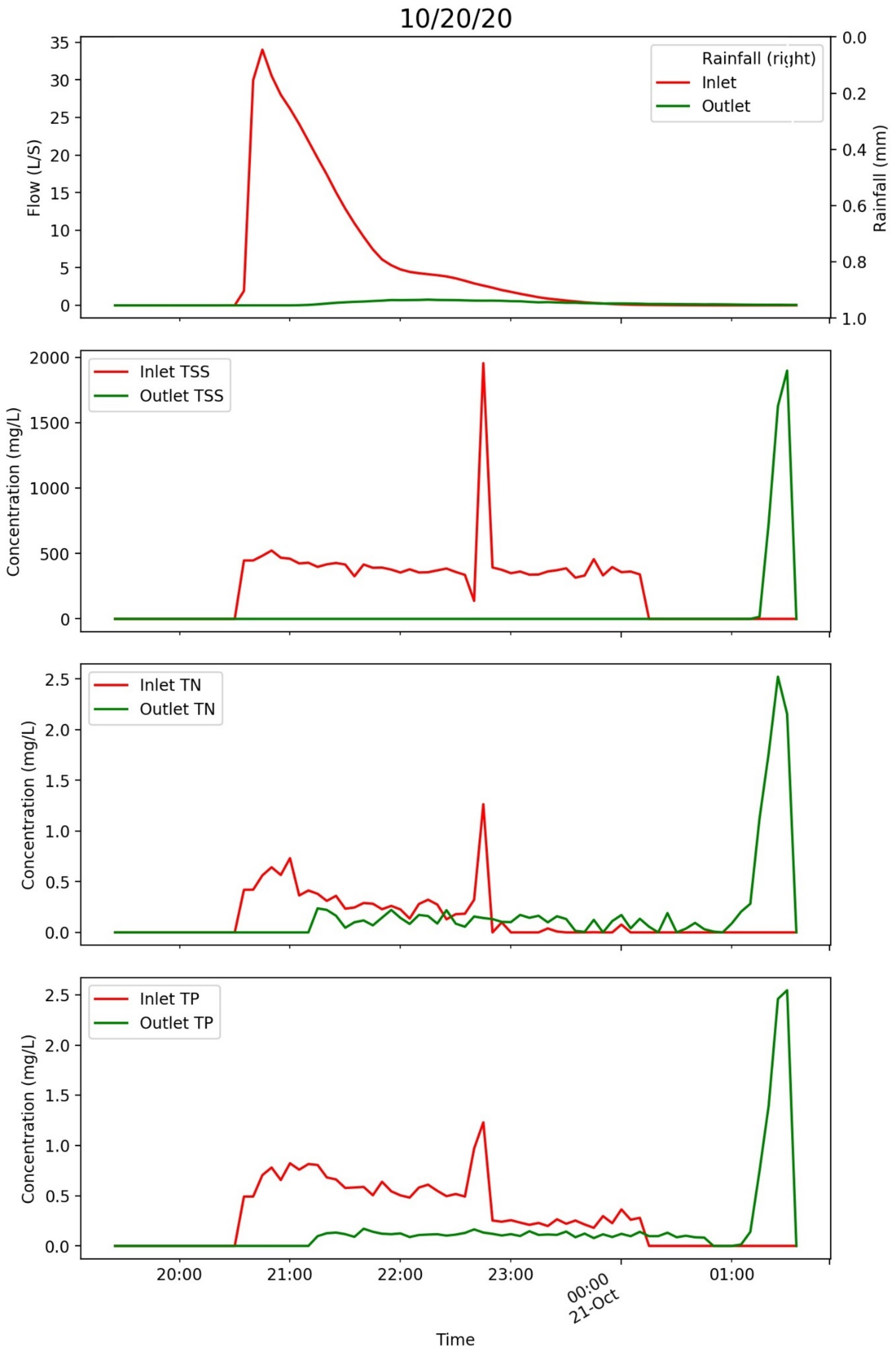

09/10/20
Rainfall (right)
Inlet
Outlet
Flow (L/S)
Rainfall (mm)
0
5
10
15
20
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Inlet TSS
Outlet TSS
Concentration (mg/L)
0.04
0.02
0.00
−0.02
−0.04
Inlet TN
Outlet TN
Concentration (mg/L)
0.0
0.1
0.2
0.3
Inlet TP
Outlet TP
Concentration (mg/L)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
16:00
18:00
20:00
22:00
00:00
11-Sep
Time

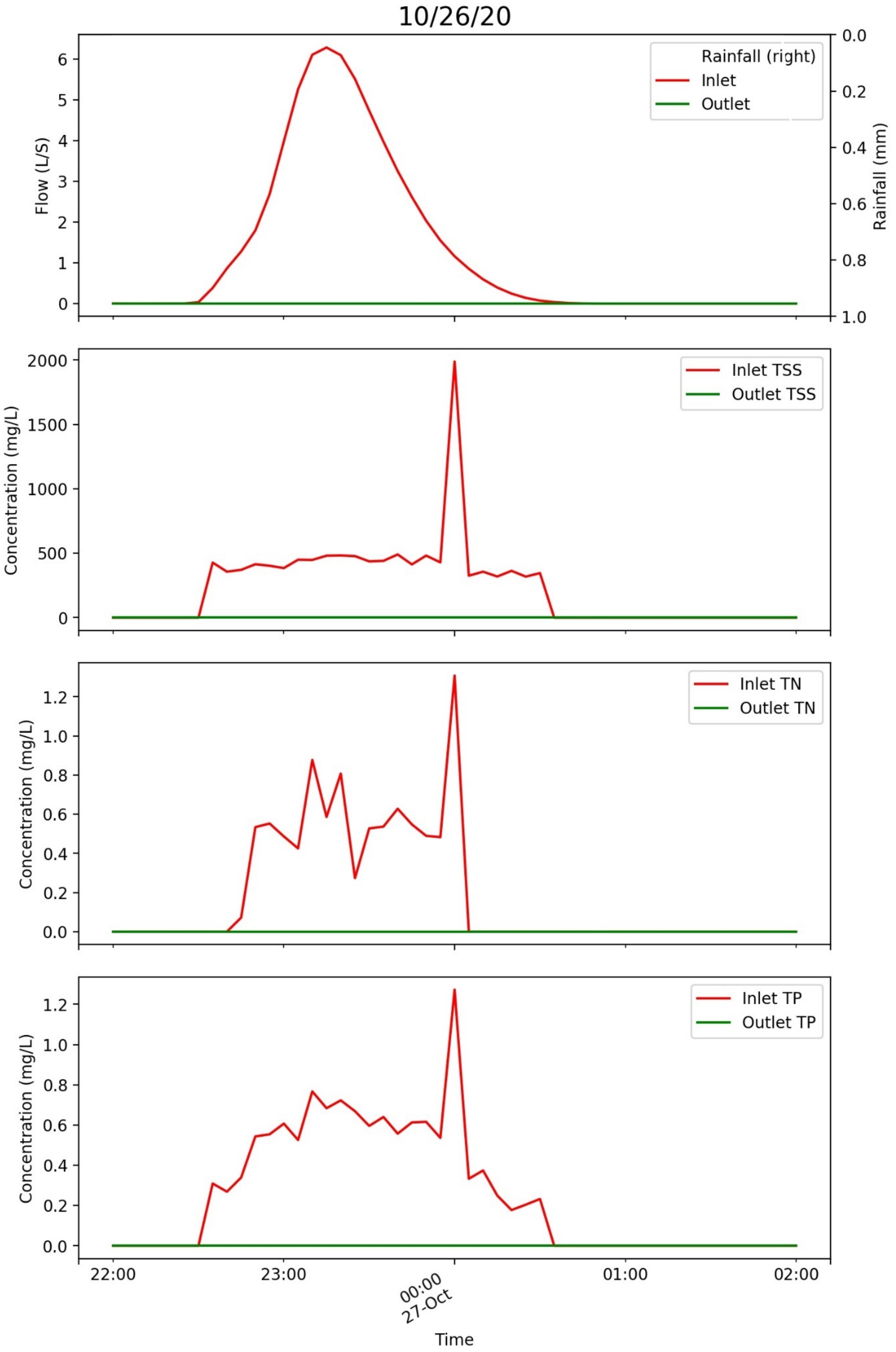

09/11/20
Flow (L/S)
Rainfall (mm)
Rainfall (right)
Inlet
Outlet
0
5
10
15
20
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (mg/L)
Inlet TSS
Outlet TSS
0
100
200
300
400
500
Inlet TN
Outlet TN
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Inlet TP
Outlet TP
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
04:00
06:00
08:00
10:00
12:00
Time

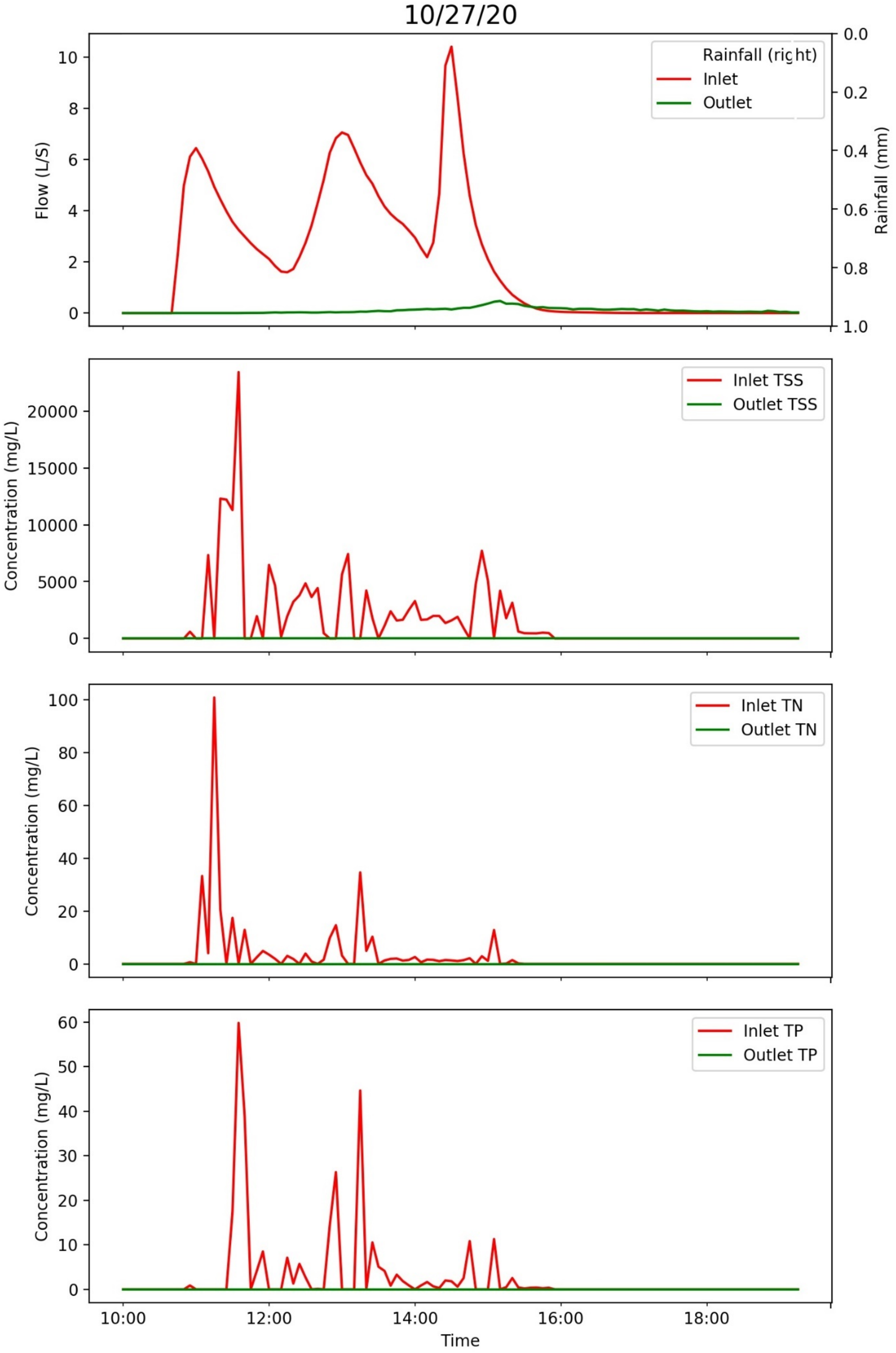

09/18/20
Flow (L/S)
Rainfall (mm)
Rainfall (right)
Inlet
Outlet
0
1
2
3
4
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Concentration (mg/L)
Inlet TSS
Outlet TSS
0
250
500
750
1000
1250
1500
1750
Concentration (mg/L)
Inlet TN
Outlet TN
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (mg/L)
Inlet TP
Outlet TP
0.0
0.5
1.0
1.5
2.0
2.5
02:00
04:00
06:00
08:00
10:00
Time

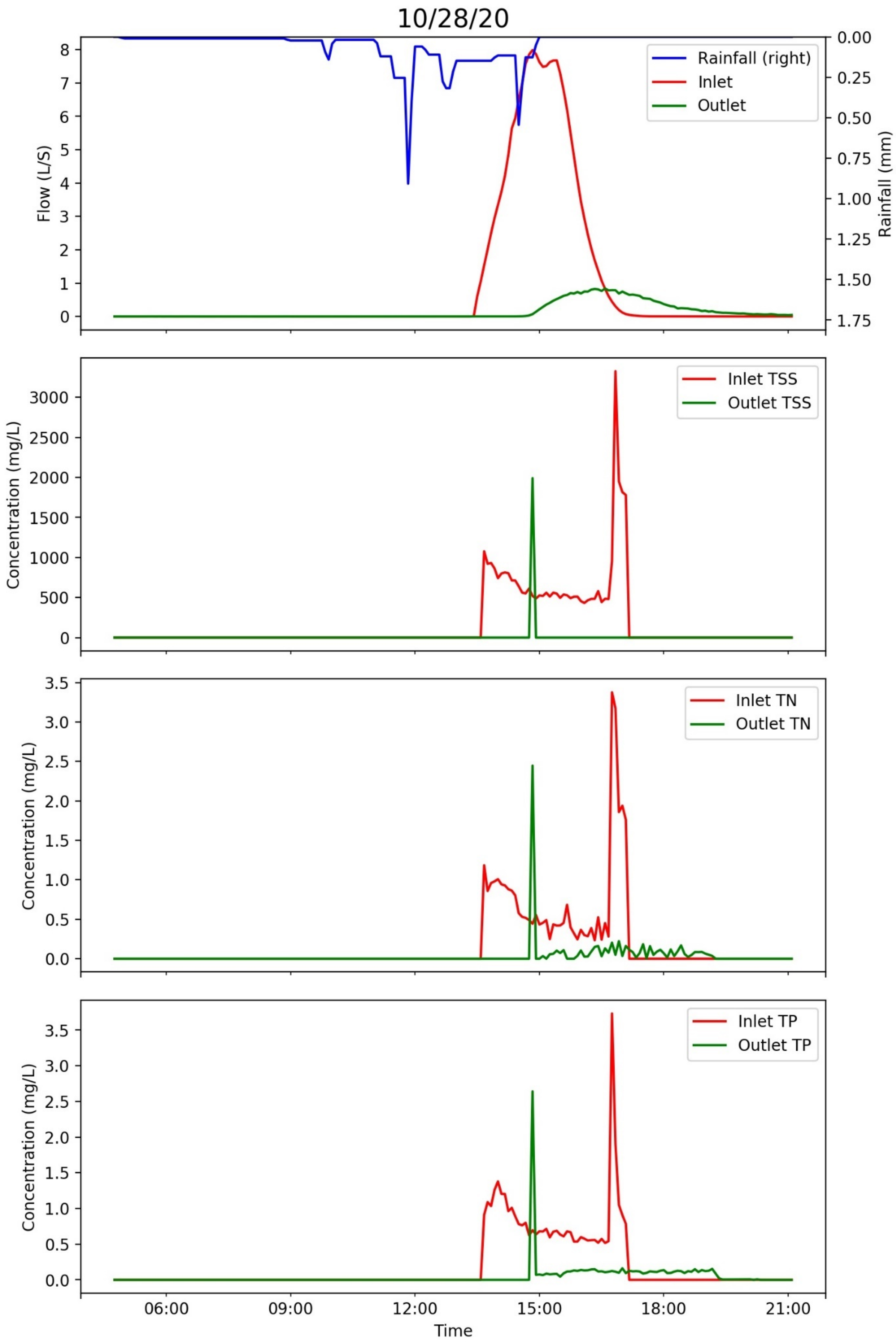

10/13/20
Flow (L/S)
Rainfall (mm)
Rainfall (right)
Inlet
Outlet
10
8
6
4
2
0
0
1
2
3
4
5
Concentration (mg/L)
Inlet TSS
Outlet TSS
1000
800
600
400
200
0
Concentration (mg/L)
Inlet TN
Outlet TN
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Concentration (mg/L)
Inlet TP
Outlet TP
1.0
0.8
0.6
0.4
0.2
0.0
06:00
09:00
12:00
15:00
18:00
21:00
Time

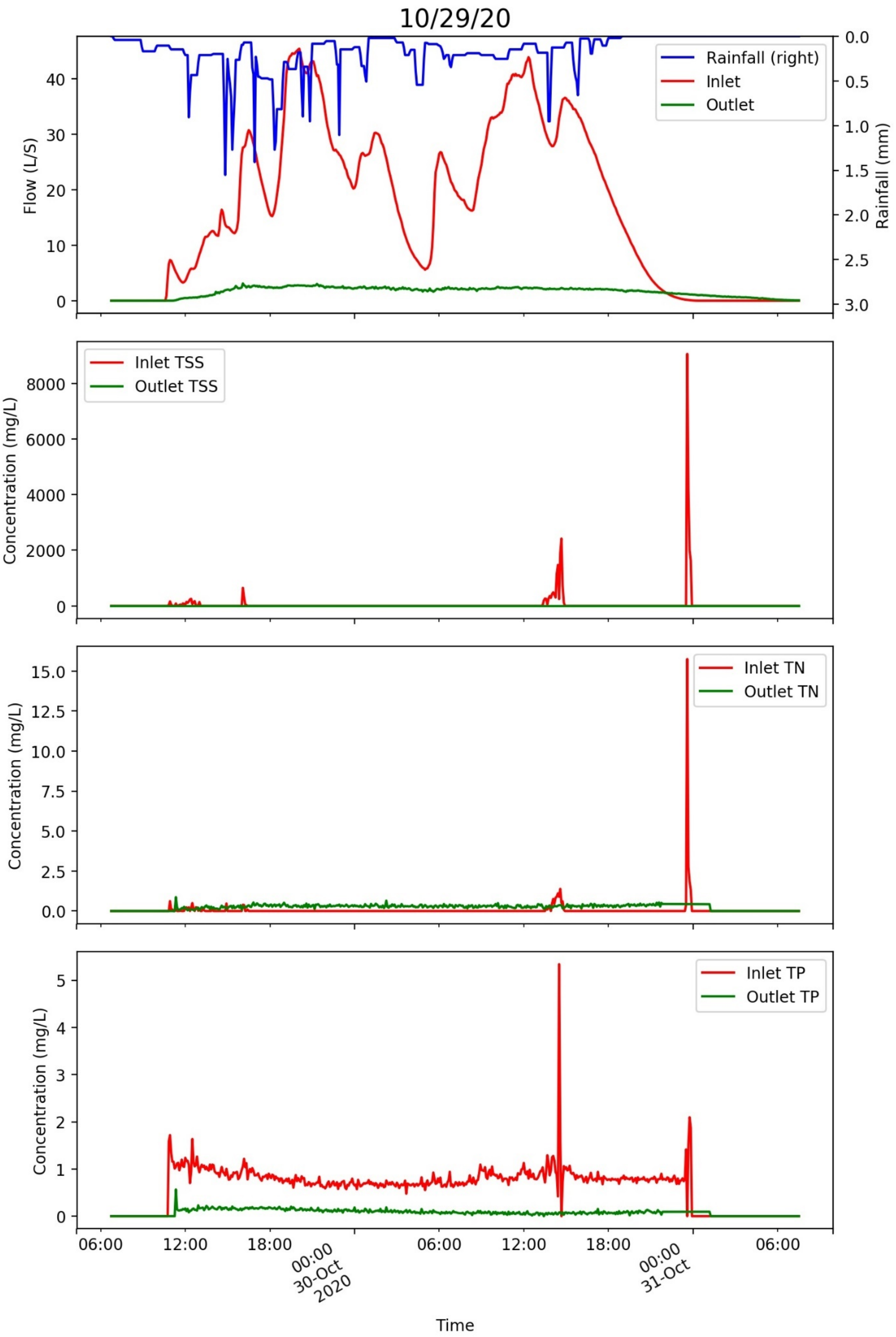

10/17/20
Rainfall (right)
Inlet
Outlet
Flow (L/S)
Rainfall (mm)
0
10
20
30
40
50
60
0.0
0.2
0.4
0.6
0.8
1.0
Inlet TSS
Outlet TSS
Concentration (mg/L)
0
200
400
600
800
1000
1200
1400
Inlet TN
Outlet TN
Concentration (mg/L)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Inlet TP
Outlet TP
Concentration (mg/L)
0.0
0.2
0.4
0.6
0.8
03:00
06:00
09:00
12:00
15:00
18:00
Time

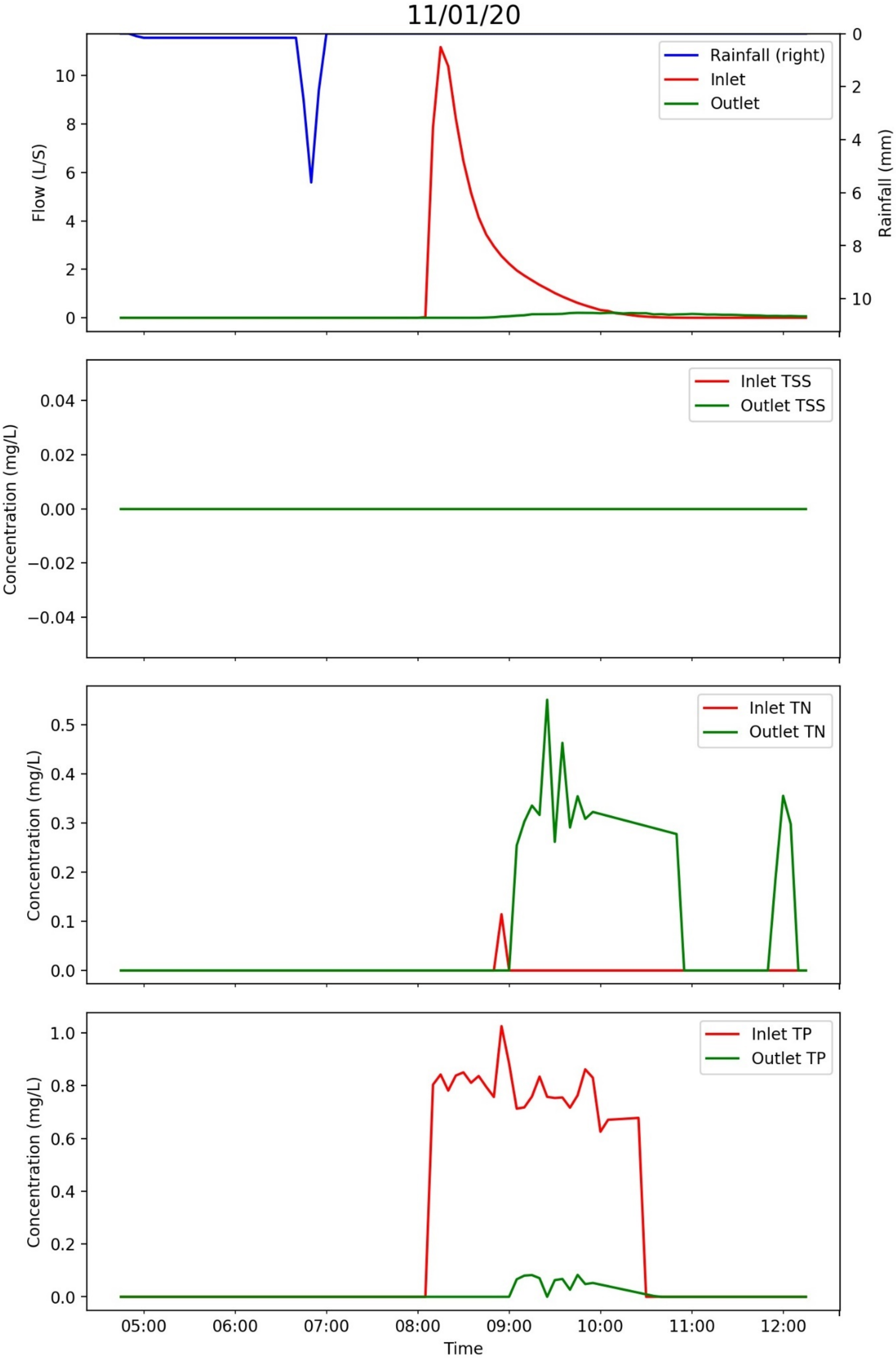

10/20/20
Flow (L/S)
0
5
10
15
20
25
30
35
Rainfall (mm)
0.0
0.2
0.4
0.6
0.8
1.0
Rainfall (right)
Inlet
Outlet
Concentration (mg/L)
0
500
1000
1500
2000
Inlet TSS
Outlet TSS
Concentration (mg/L)
0.0
0.5
1.0
1.5
2.0
2.5
Inlet TN
Outlet TN
Concentration (mg/L)
0.0
0.5
1.0
1.5
2.0
2.5
Inlet TP
Outlet TP
20:00
21:00
22:00
23:00
00:00
21-Oct
01:00
Time

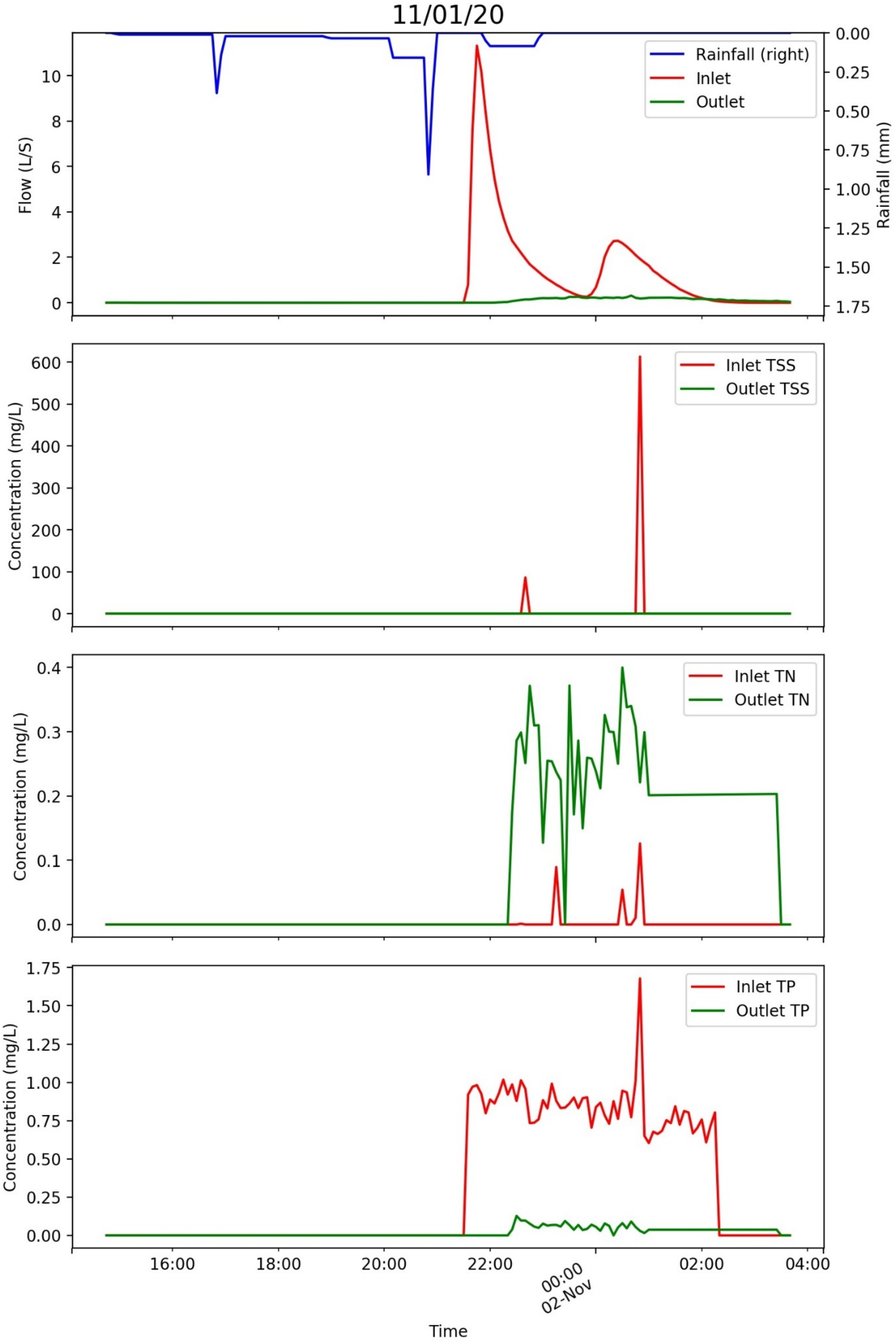

10/26/20
Flow (L/S)
Rainfall (mm)
Rainfall (right)
Inlet
Outlet
0
1
2
3
4
5
6
0.0
0.2
0.4
0.6
0.8
1.0
Concentration (mg/L)
Inlet TSS
Outlet TSS
0
500
1000
1500
2000
Concentration (mg/L)
Inlet TN
Outlet TN
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Concentration (mg/L)
Inlet TP
Outlet TP
0.0
0.2
0.4
0.6
0.8
1.0
1.2
22:00
23:00
00:00
27-Oct
01:00
02:00
Time

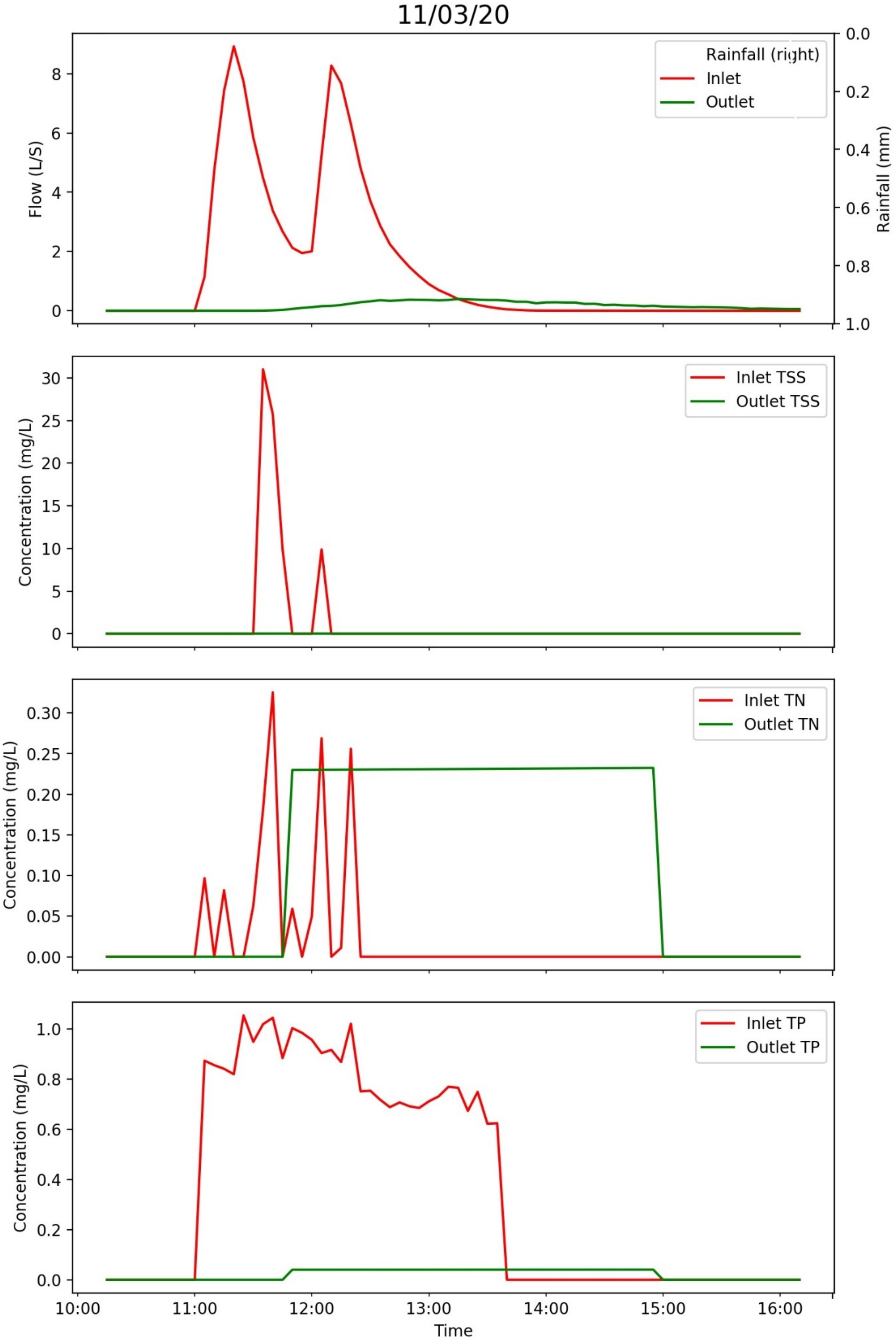

10/27/20
Flow (L/S)
0
2
4
6
8
10
Rainfall (mm)
0.0
0.2
0.4
0.6
0.8
1.0
Rainfall (right)
Inlet
Outlet
Concentration (mg/L)
0
5000
10000
15000
20000
Inlet TSS
Outlet TSS
Concentration (mg/L)
0
20
40
60
80
100
Inlet TN
Outlet TN
Concentration (mg/L)
0
10
20
30
40
50
60
Inlet TP
Outlet TP
10:00
12:00
14:00
16:00
18:00
Time

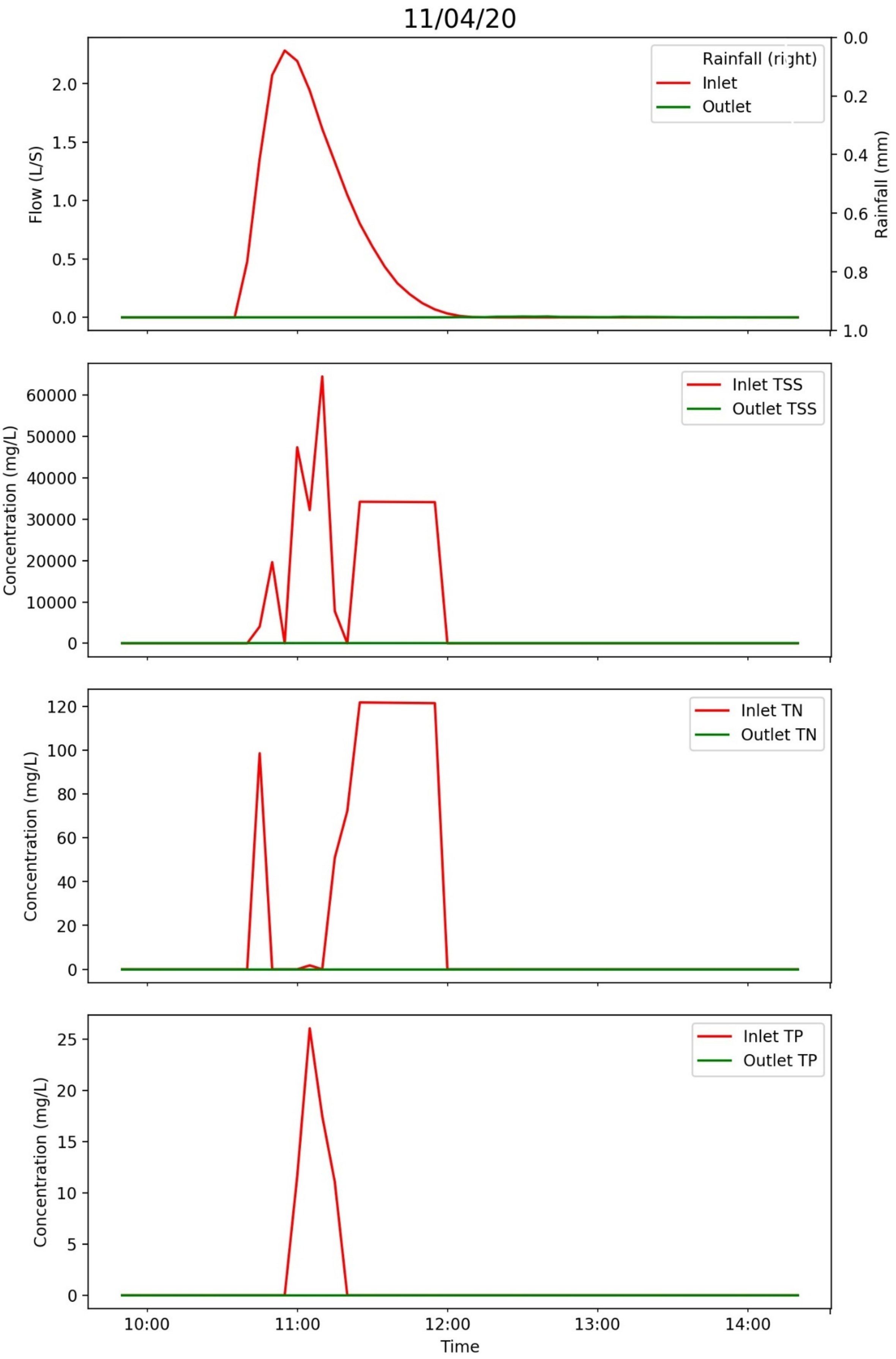

10/28/20
Flow (L/S)
Rainfall (mm)
Rainfall (right)
Inlet
Outlet
0
1
2
3
4
5
6
7
8
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
Concentration (mg/L)
Inlet TSS
Outlet TSS
0
500
1000
1500
2000
2500
3000
Inlet TN
Outlet TN
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Inlet TP
Outlet TP
06:00
09:00
12:00
15:00
18:00
21:00
Time

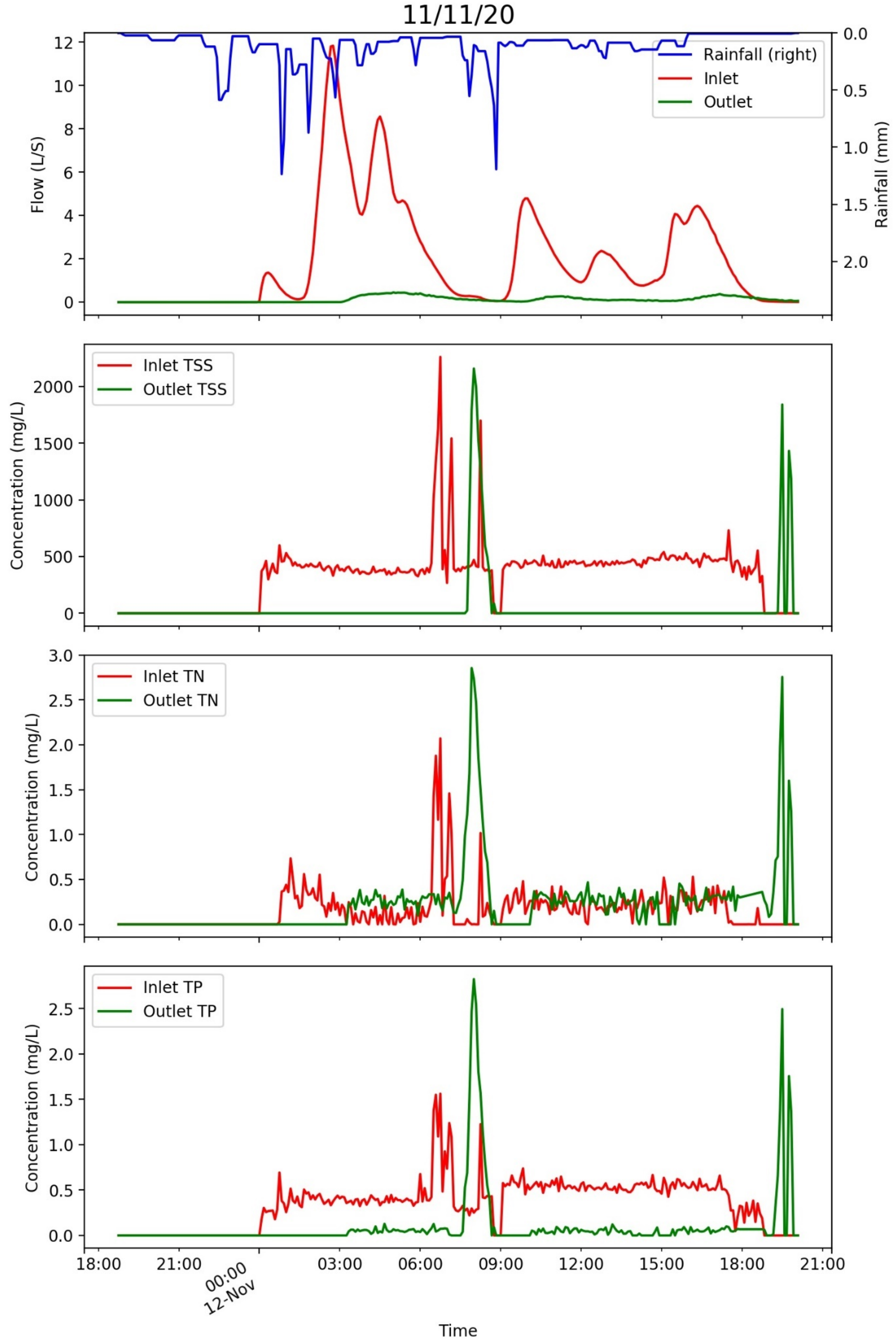

10/29/20
Rainfall (right)
Inlet
Outlet
Flow (L/S)
Rainfall (mm)
0
10
20
30
40
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Inlet TSS
Outlet TSS
Concentration (mg/L)
0
2000
4000
6000
8000
Inlet TN
Outlet TN
Concentration (mg/L)
0.0
2.5
5.0
7.5
10.0
12.5
15.0
Inlet TP
Outlet TP
Concentration (mg/L)
0
1
2
3
4
5
06:00
12:00
18:00
00:00 30-Oct 2020
06:00
12:00
18:00
00:00 31-Oct
06:00
Time

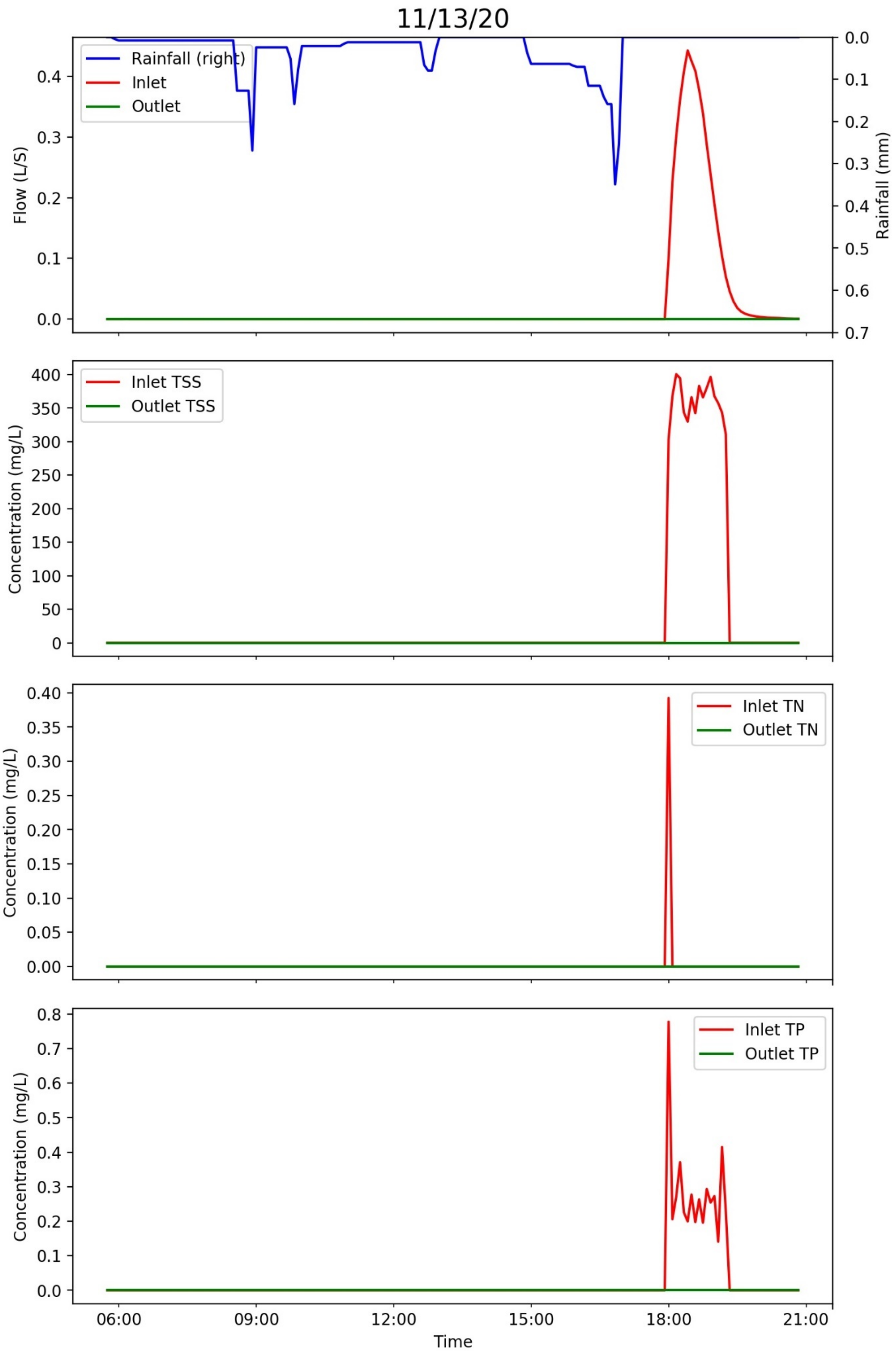

11/01/20
Flow (L/S)
Rainfall (mm)
Rainfall (right)
Inlet
Outlet
0
2
4
6
8
10
Inlet TSS
Outlet TSS
Concentration (mg/L)
0.04
0.02
0.00
−0.02
−0.04
Inlet TN
Outlet TN
0.0
0.1
0.2
0.3
0.4
0.5
Inlet TP
Outlet TP
0.2
0.4
0.6
0.8
1.0
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
Time

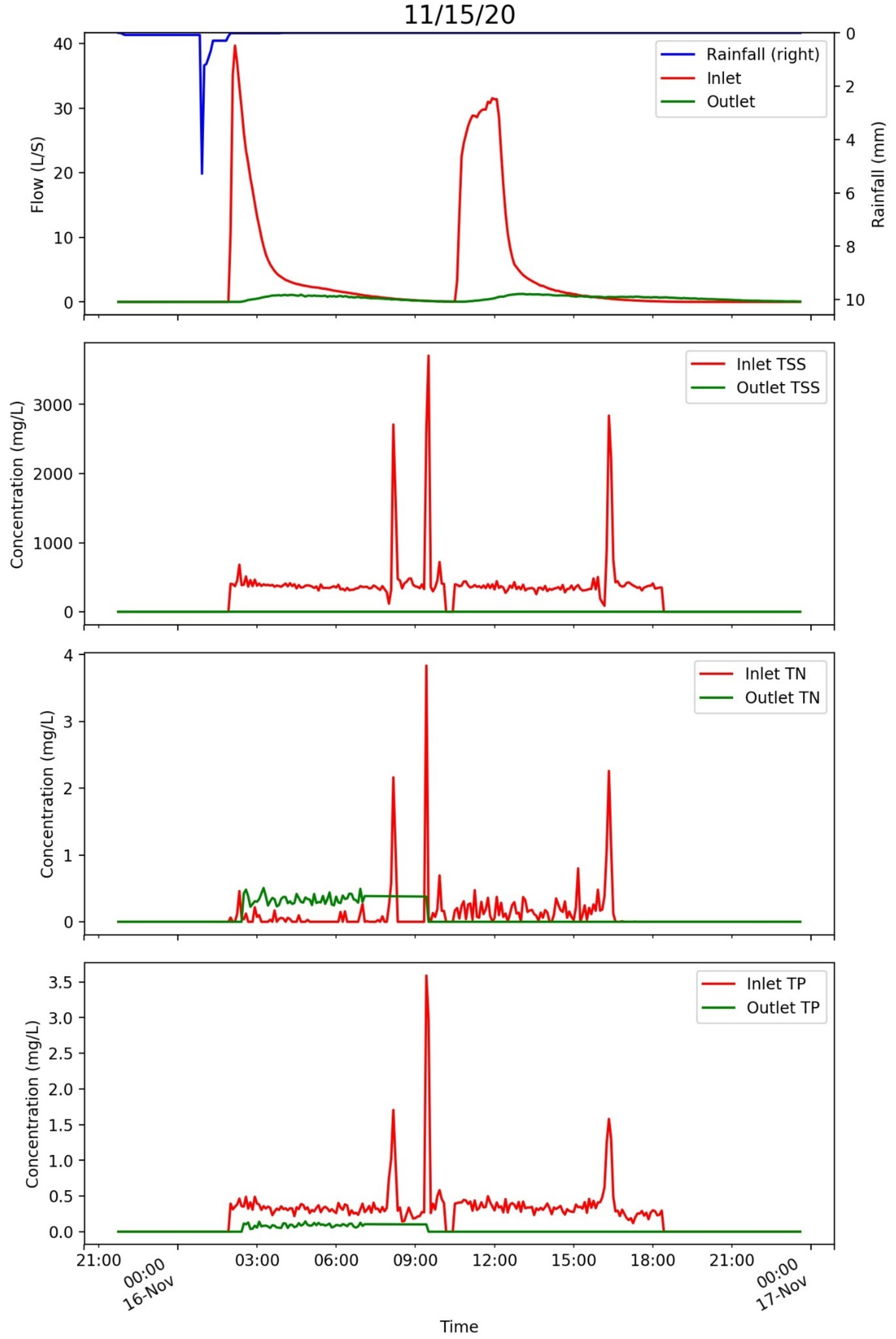

11/01/20
Flow (L/S)
0
2
4
6
8
10
Rainfall (mm)
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
Rainfall (right)
Inlet
Outlet
Concentration (mg/L)
0
100
200
300
400
500
600
Inlet TSS
Outlet TSS
Concentration (mg/L)
0.0
0.1
0.2
0.3
0.4
Inlet TN
Outlet TN
Concentration (mg/L)
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
Inlet TP
Outlet TP
16:00
18:00
20:00
22:00
00:00
02-Nov
02:00
04:00
Time

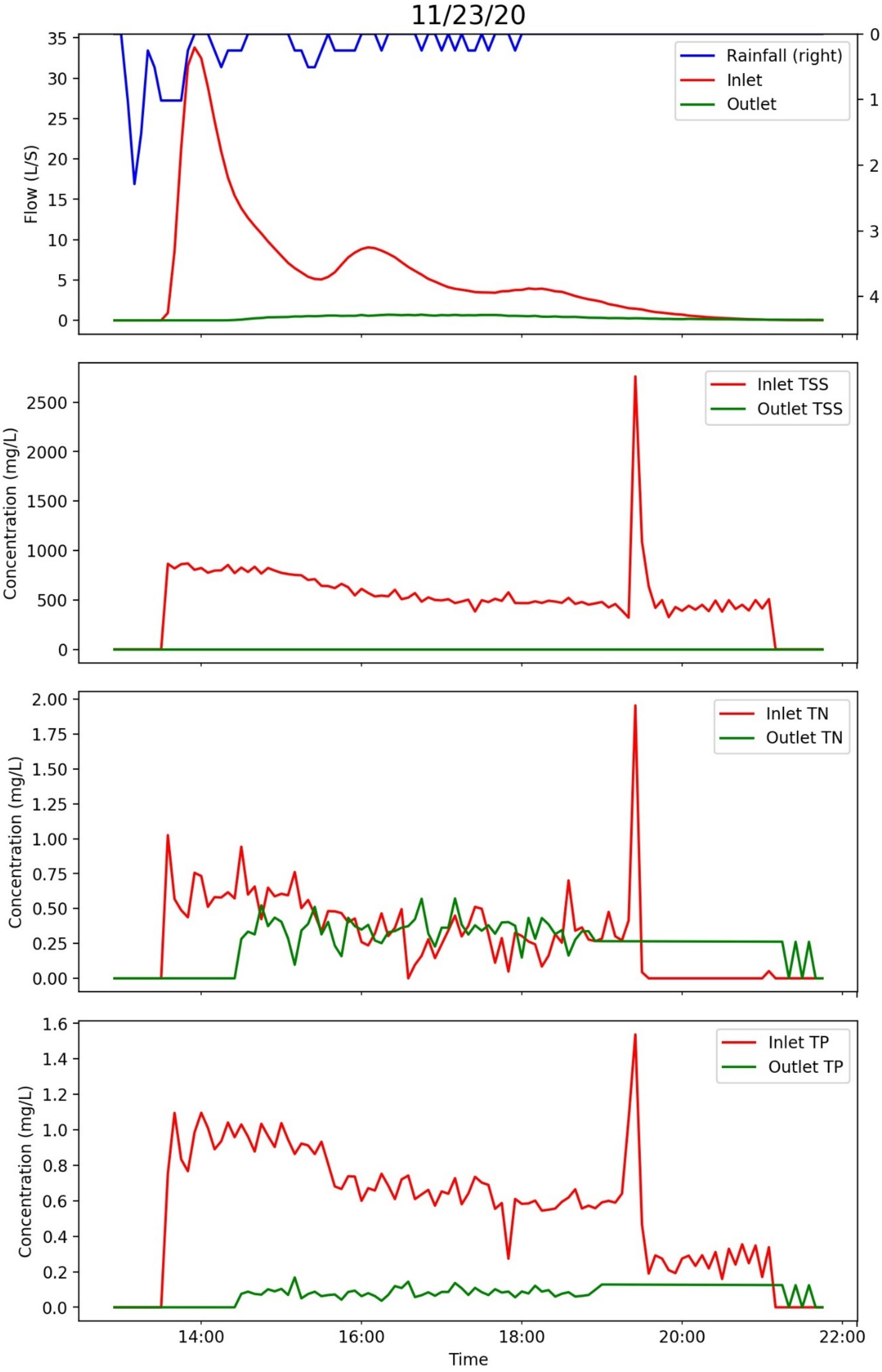

11/03/20
Rainfall (right)
Inlet
Outlet
Flow (L/S)
Rainfall (mm)
0
2
4
6
8
0.0
0.2
0.4
0.6
0.8
1.0
Inlet TSS
Outlet TSS
Concentration (mg/L)
0
5
10
15
20
25
30
Inlet TN
Outlet TN
Concentration (mg/L)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Inlet TP
Outlet TP
Concentration (mg/L)
0.0
0.2
0.4
0.6
0.8
1.0
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time

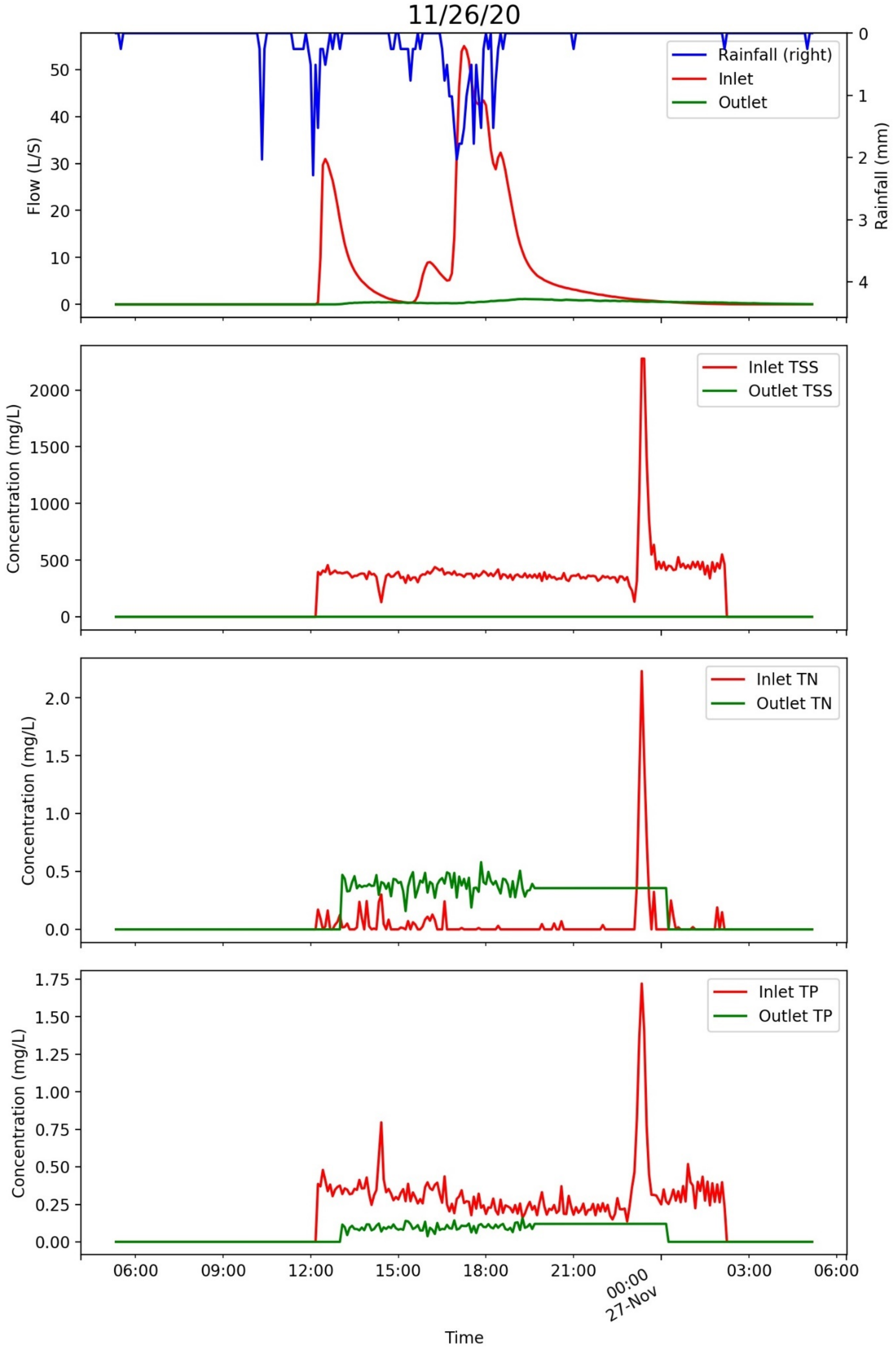

11/04/20
Flow (L/S)
0.0
0.5
1.0
1.5
2.0
Rainfall (mm)
0.0
0.2
0.4
0.6
0.8
1.0
Rainfall (right)
Inlet
Outlet
Concentration (mg/L)
0
10000
20000
30000
40000
50000
60000
Inlet TSS
Outlet TSS
Concentration (mg/L)
0
20
40
60
80
100
120
Inlet TN
Outlet TN
Concentration (mg/L)
0
5
10
15
20
25
Inlet TP
Outlet TP
10:00
11:00
12:00
13:00
14:00
Time

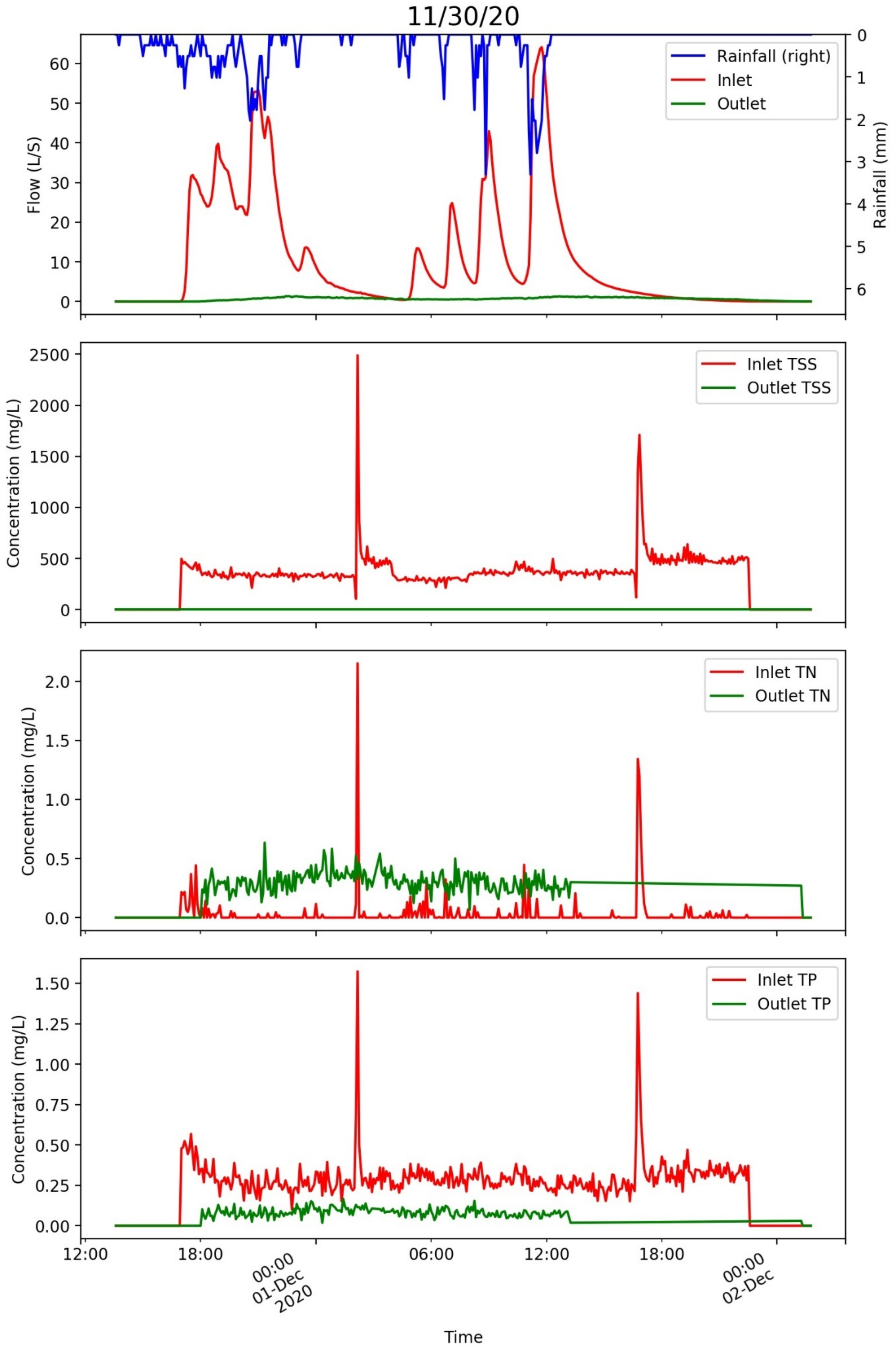

11/11/20
Flow (L/S)
Rainfall (mm)
Rainfall (right)
Inlet
Outlet
0
2
4
6
8
10
12
0.0
0.5
1.0
1.5
2.0
Concentration (mg/L)
Inlet TSS
Outlet TSS
0
500
1000
1500
2000
Inlet TN
Outlet TN
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Inlet TP
Outlet TP
0.0
0.5
1.0
1.5
2.0
2.5
18:00
21:00
00:00
12-Nov
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time


11/13/20
Rainfall (right)
Inlet
Outlet
Flow (L/S)
0.0
0.1
0.2
0.3
0.4
Rainfall (mm)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Inlet TSS
Outlet TSS
Concentration (mg/L)
0
50
100
150
200
250
300
350
400
Inlet TN
Outlet TN
Concentration (mg/L)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Inlet TP
Outlet TP
Concentration (mg/L)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
06:00
09:00
12:00
15:00
18:00
21:00
Time


11/15/20
Flow (L/S)
Rainfall (mm)
Rainfall (right)
Inlet
Outlet
0
10
20
30
40
0
2
4
6
8
10
Inlet TSS
Outlet TSS
Concentration (mg/L)
0
1000
2000
3000
Inlet TN
Outlet TN
Concentration (mg/L)
0
1
2
3
4
Inlet TP
Outlet TP
Concentration (mg/L)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
21:00
00:00
16-Nov
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
17-Nov
Time


11/23/20
Rainfall (right)
Inlet
Outlet
Flow (L/S)
Rainfall (mm)
35
30
25
20
15
10
5
0
0
1
2
3
4
Inlet TSS
Outlet TSS
Concentration (mg/L)
2500
2000
1500
1000
500
0
Inlet TN
Outlet TN
Concentration (mg/L)
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Inlet TP
Outlet TP
Concentration (mg/L)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
14:00
16:00
18:00
20:00
22:00
Time


11/26/20
Flow (L/S)
0
10
20
30
40
50
Rainfall (mm)
0
1
2
3
4
Rainfall (right)
Inlet
Outlet
Concentration (mg/L)
0
500
1000
1500
2000
Inlet TSS
Outlet TSS
Concentration (mg/L)
0.0
0.5
1.0
1.5
2.0
Inlet TN
Outlet TN
Concentration (mg/L)
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
Inlet TP
Outlet TP
06:00
09:00
12:00
15:00
18:00
21:00
00:00
27-Nov
03:00
06:00
Time


11/30/20
Flow (L/S)
Rainfall (mm)
Rainfall (right)
Inlet
Outlet
0
10
20
30
40
50
60
0
1
2
3
4
5
6
Concentration (mg/L)
Inlet TSS
Outlet TSS
0
500
1000
1500
2000
2500
Concentration (mg/L)
Inlet TN
Outlet TN
0.0
0.5
1.0
1.5
2.0
Concentration (mg/L)
Inlet TP
Outlet TP
0.00
0.25
0.50
0.75
1.00
1.25
1.50
12:00
18:00
00:00
01-Dec
2020
06:00
12:00
18:00
00:00
02-Dec
Time

3. Appendix 3: Event Hydrographs and Pollutant Masses

This appendix shows all monitored storm events for rainfall, inflow, outflow, and masses of total suspended sediment (TSS), total nitrogen (TN), and total phosphorus (TP). The TSS, TN, and TP were measured using the UV-Vis spectrometer at the inlet and outlet location. The data recorded is light absorbance per meter for wavelengths in the 220-720 nm range. The concentrations of pollutants were calculated using a prediction model from UNHSC based on Partial Least Squares Regression comparing to laboratory values. The model is from a previous study by UNHSC submitted in 2018 to and funded by the U.S. EPA titled *Utilizing In-Situ Ultraviolet-Visual Spectroscopy to Measure Nutrients and Sediment Concentrations in Stormwater Runoff*.

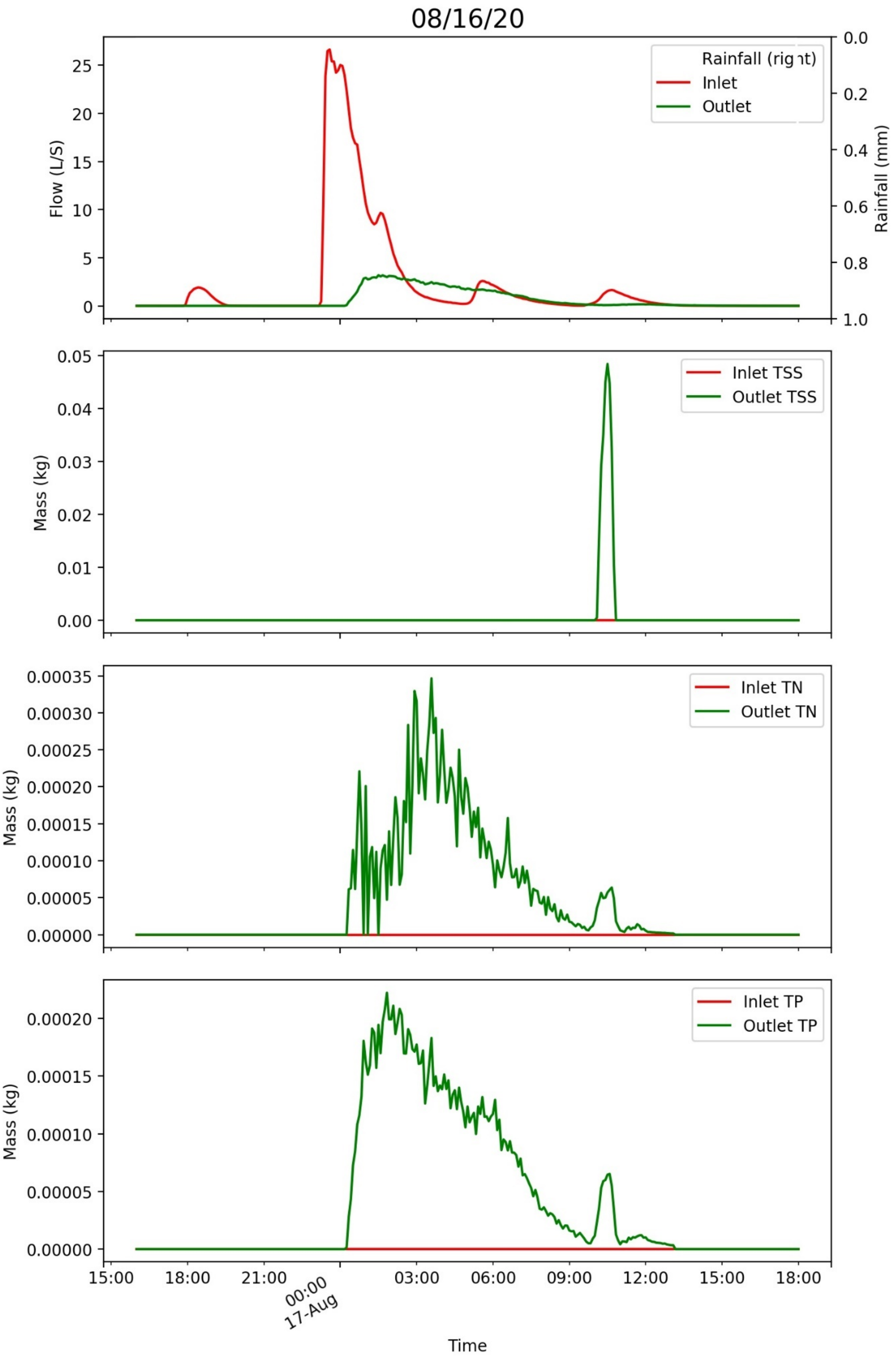
The graphs titles show the date of the start of the event.

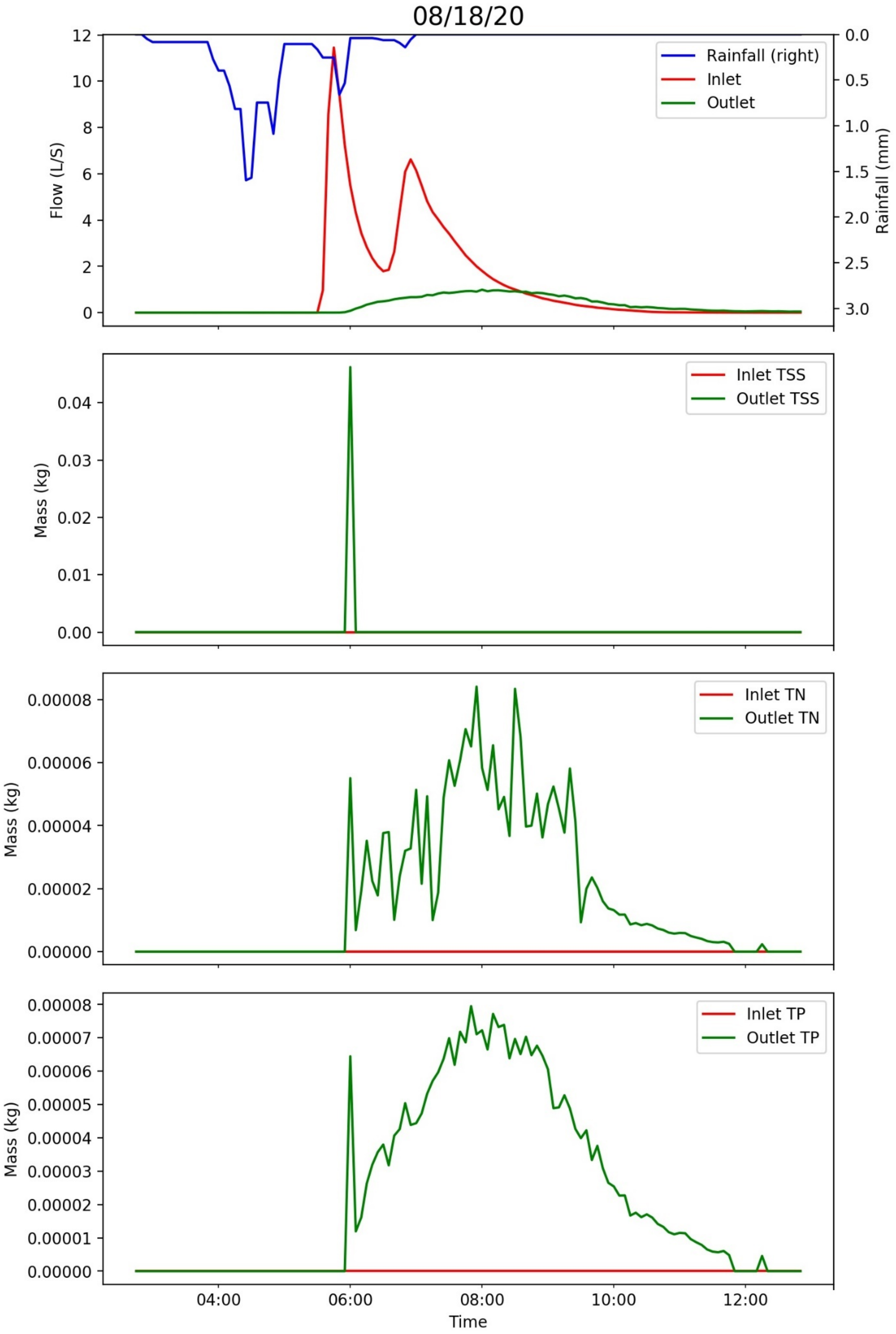
Subplot 1: Flow at the inlet and outlet are in liters per second (L/s) and are shown on the left axis. Rainfall in millimeters (mm) is shown on the inverted right axis.

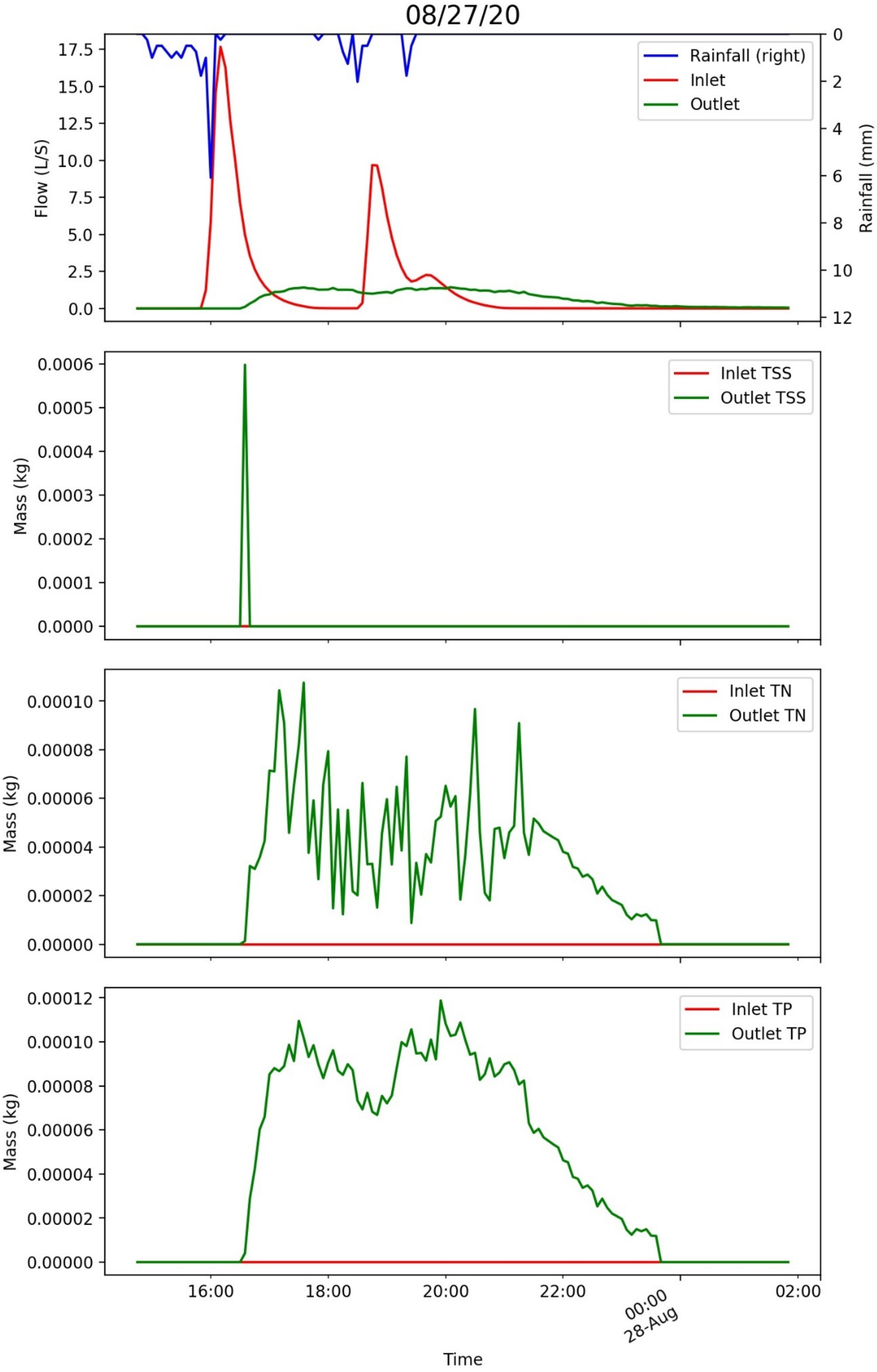
Subplot 2: Mass of total suspended sediment (TSS) in kilograms (kg) at the inlet and outlet locations.

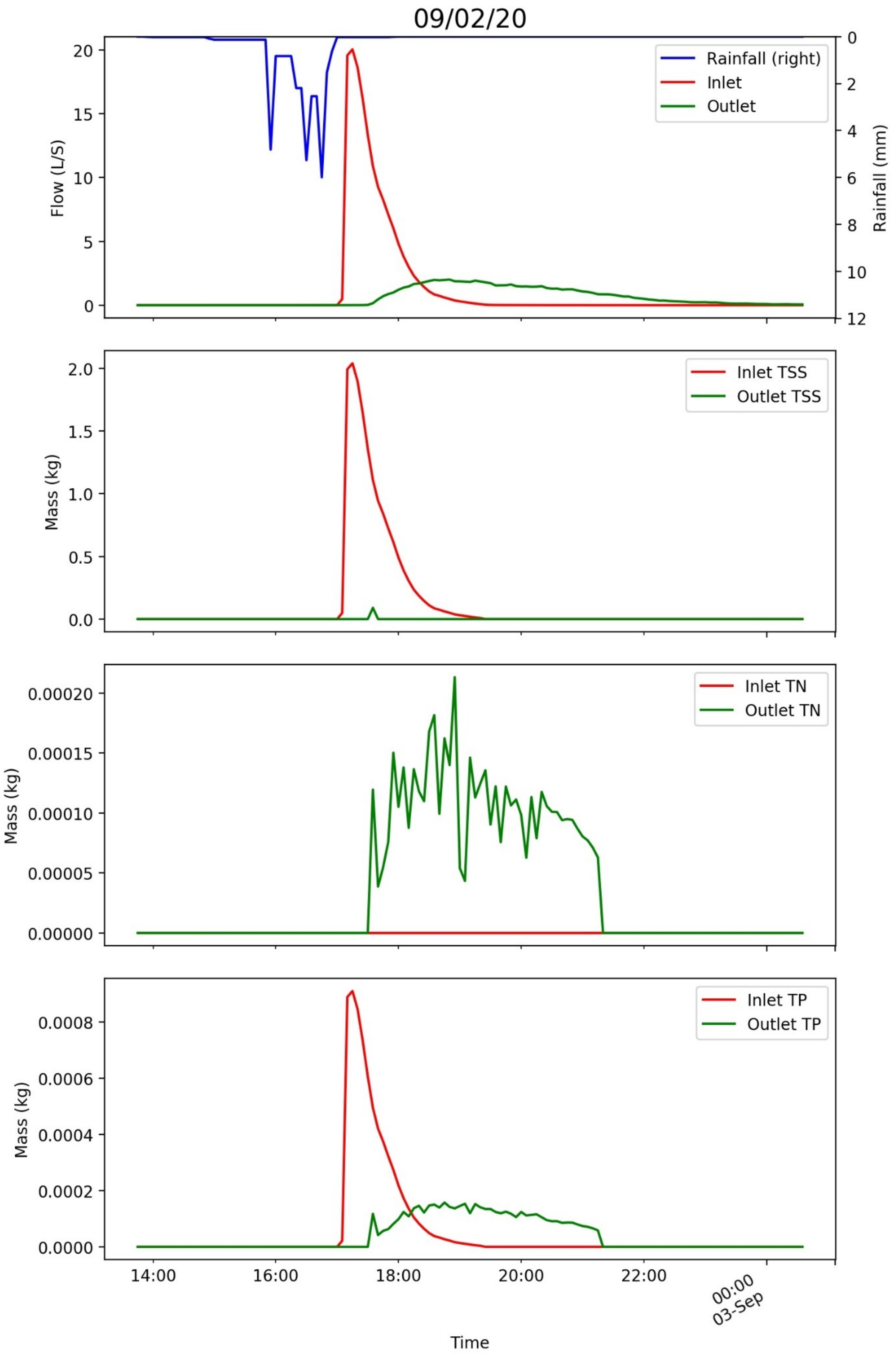
Subplot 3: Mass of total nitrogen (TN) in kilograms (kg) at the inlet and outlet locations.

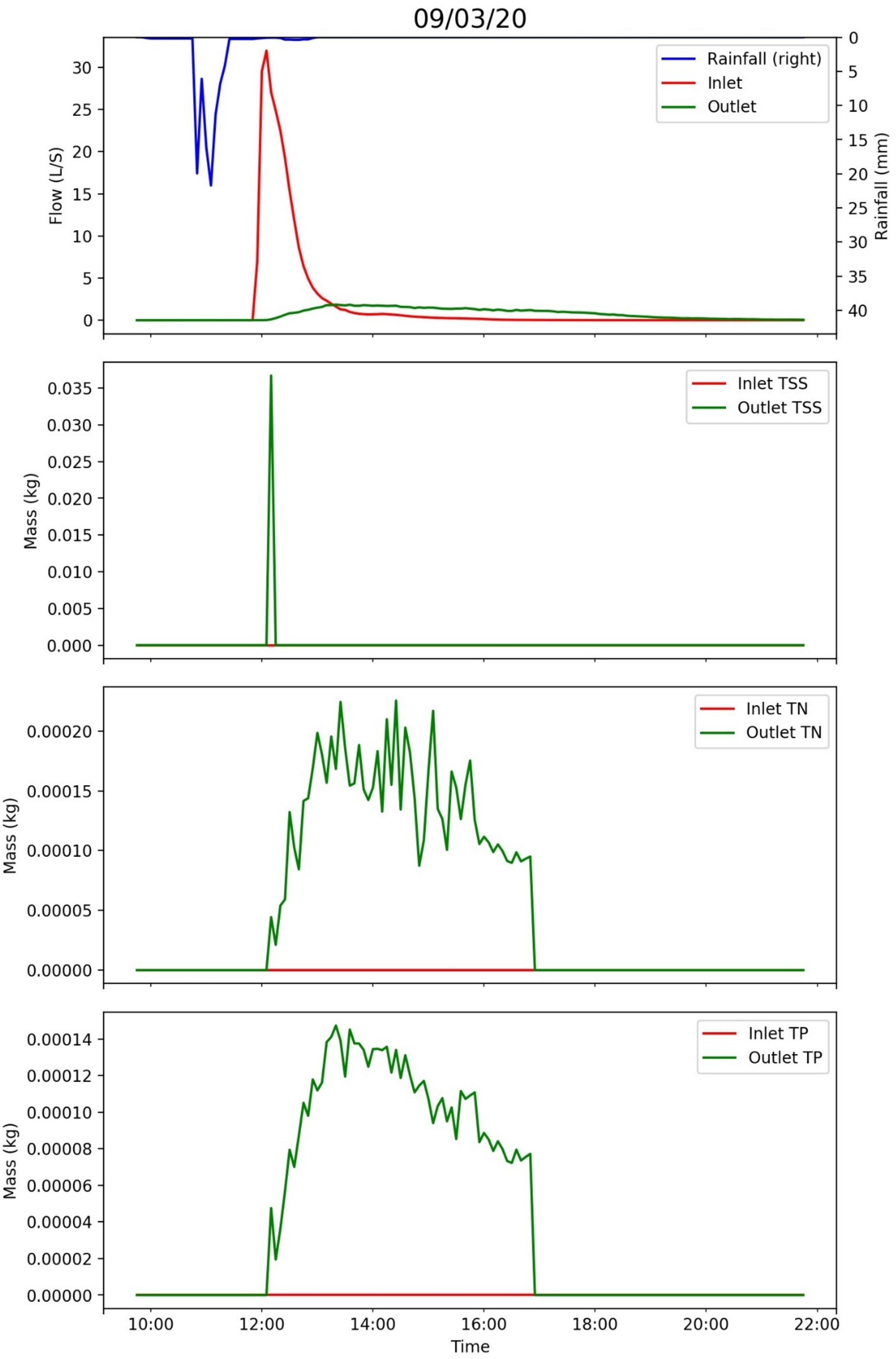
Subplot 4: Mass of total phosphorus (TP) in kilograms (kg) at the inlet and outlet locations.

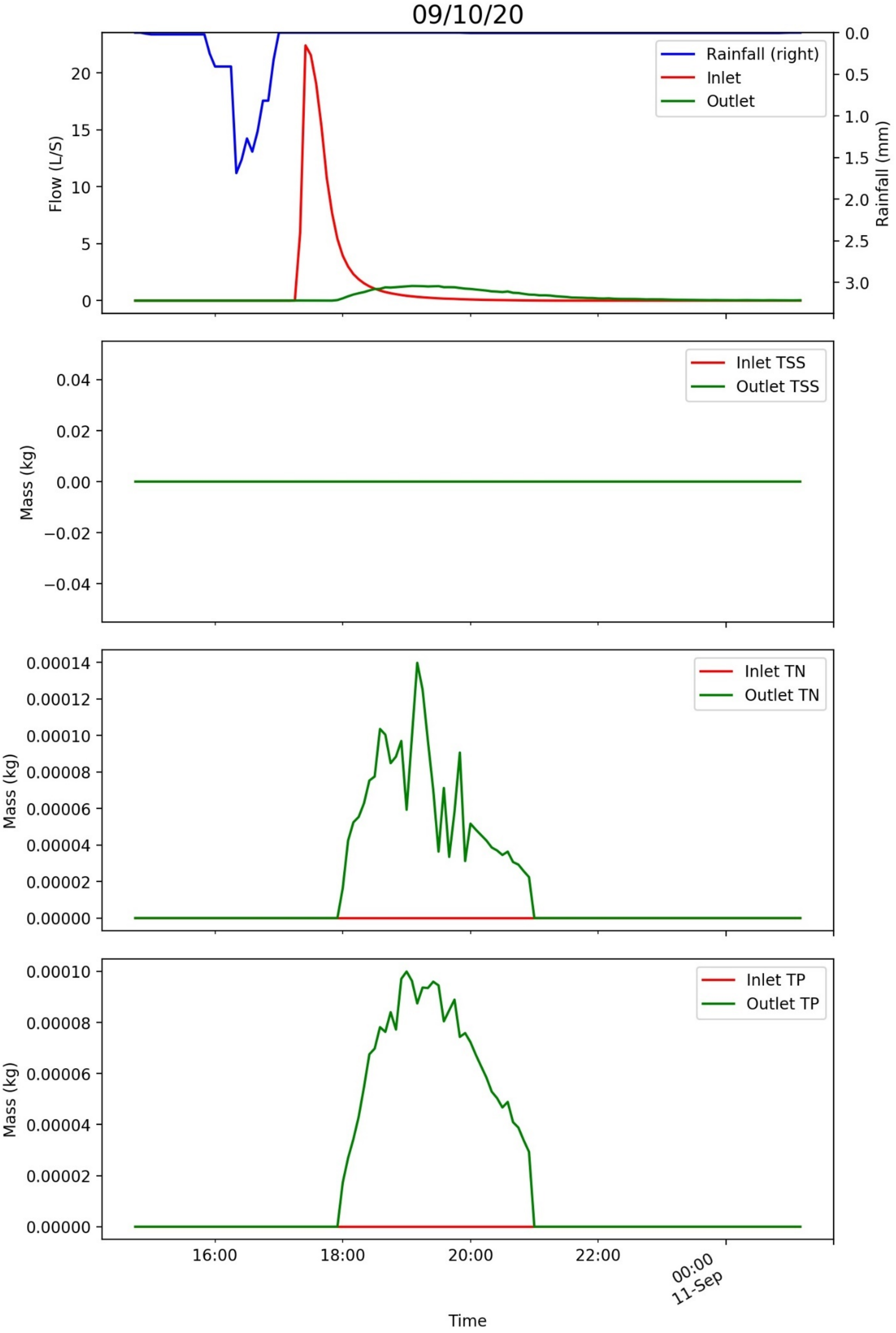

08/16/20
Rainfall (right)
Inlet
Outlet
Flow (L/S)
Rainfall (mm)
0
5
10
15
20
25
0.0
0.2
0.4
0.6
0.8
1.0
Inlet TSS
Outlet TSS
Mass (kg)
0.00
0.01
0.02
0.03
0.04
0.05
Inlet TN
Outlet TN
Mass (kg)
0.00000
0.00005
0.00010
0.00015
0.00020
0.00025
0.00030
0.00035
Inlet TP
Outlet TP
Mass (kg)
0.00000
0.00005
0.00010
0.00015
0.00020
15:00
18:00
21:00
00:00
17-Aug
03:00
06:00
09:00
12:00
15:00
18:00
Time

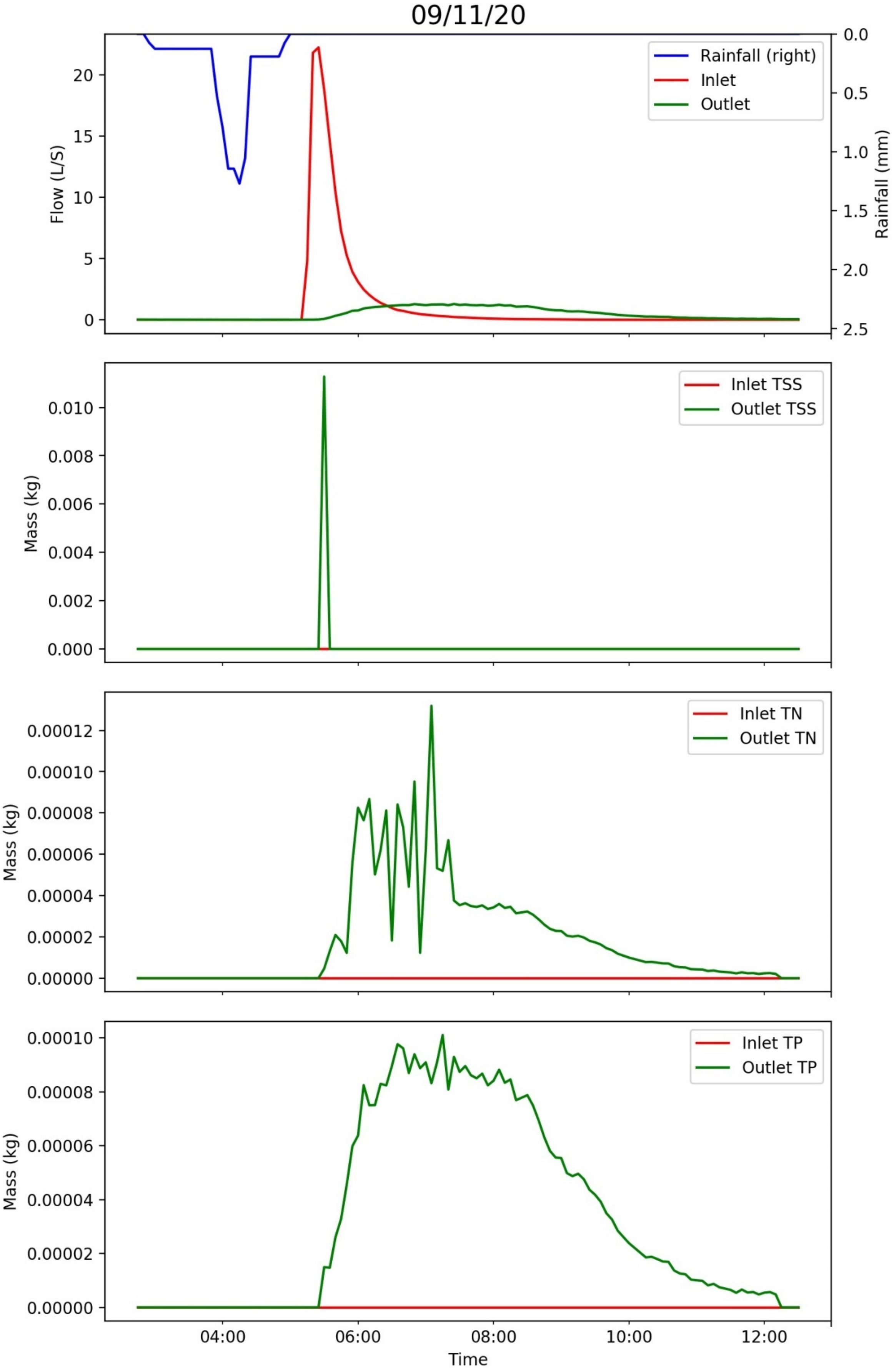

08/18/20
Flow (L/S)
0
2
4
6
8
10
12
Rainfall (mm)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Rainfall (right)
Inlet
Outlet
Mass (kg)
0.00
0.01
0.02
0.03
0.04
Inlet TSS
Outlet TSS
Mass (kg)
0.00000
0.00002
0.00004
0.00006
0.00008
Inlet TN
Outlet TN
Mass (kg)
0.00000
0.00001
0.00002
0.00003
0.00004
0.00005
0.00006
0.00007
0.00008
Inlet TP
Outlet TP
04:00
06:00
08:00
10:00
12:00
Time

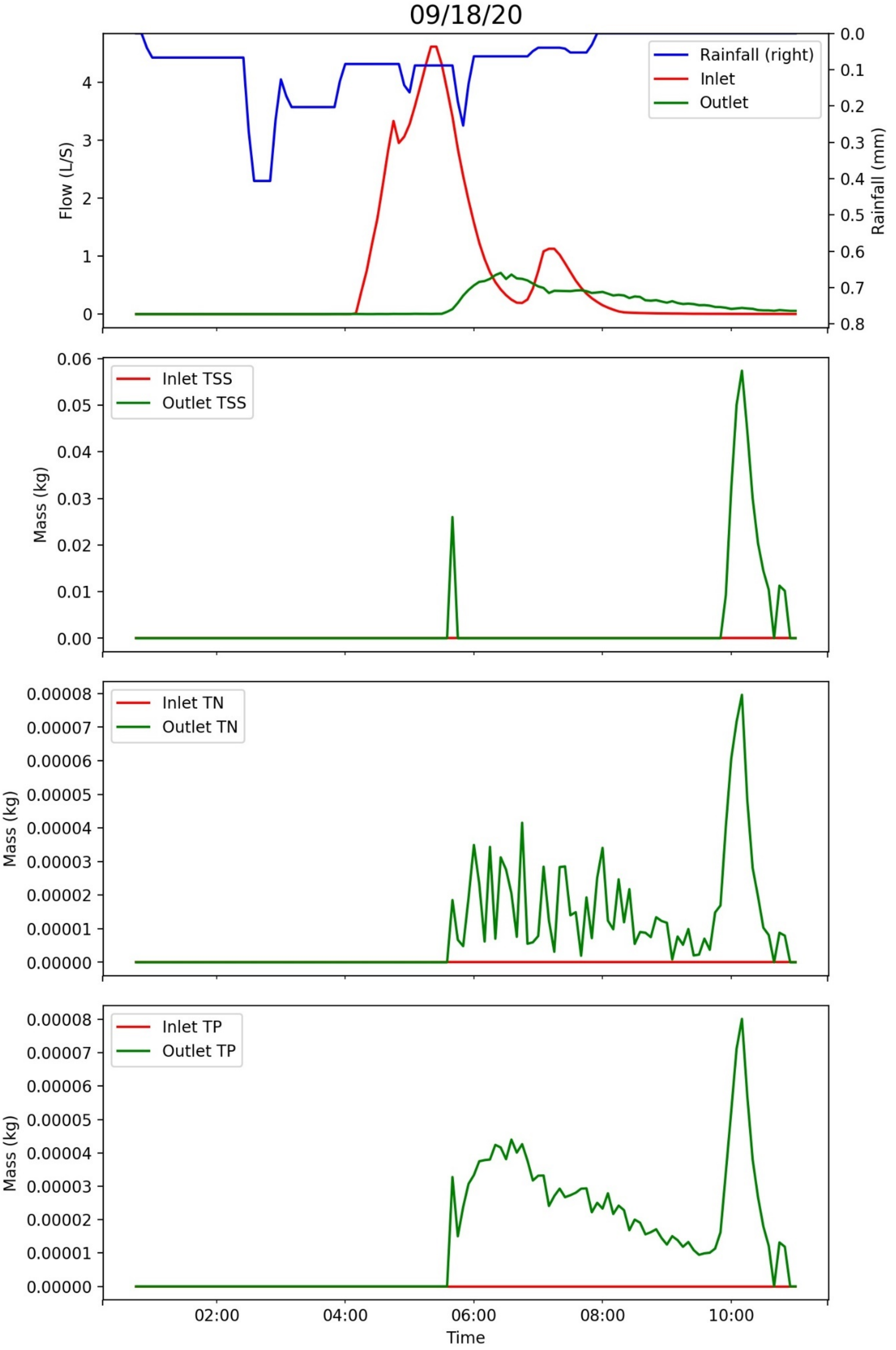

08/27/20
Flow (L/S)
Rainfall (mm)
Rainfall (right)
Inlet
Outlet
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
2
4
6
8
10
12
Mass (kg)
Inlet TSS
Outlet TSS
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0.0000
Inlet TN
Outlet TN
0.00010
0.00008
0.00006
0.00004
0.00002
0.00000
Inlet TP
Outlet TP
0.00012
0.00010
0.00008
0.00006
0.00004
0.00002
0.00000
16:00
18:00
20:00
22:00
00:00
28-Aug
02:00
Time

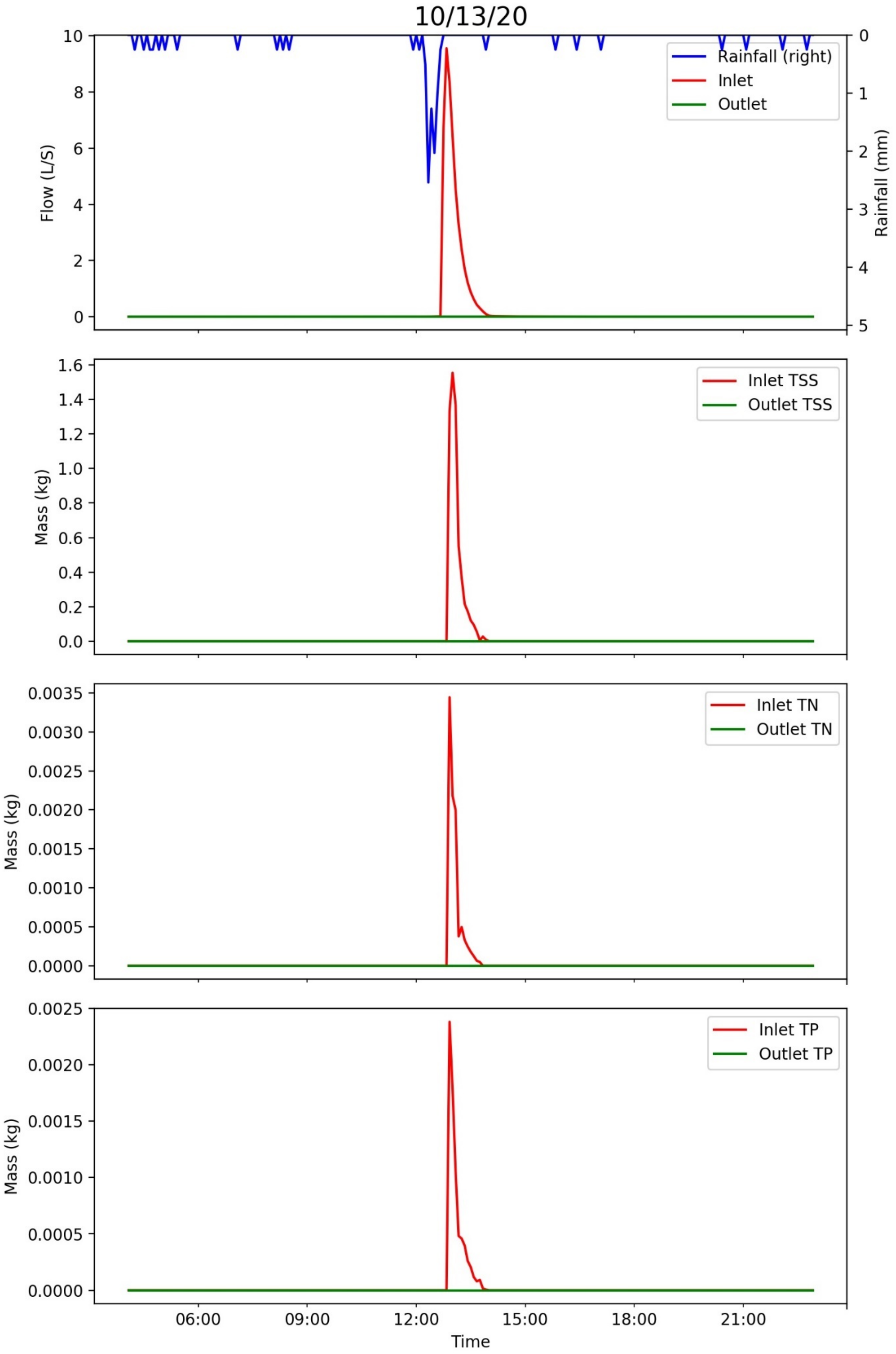

09/02/20
Flow (L/S)
Rainfall (mm)
Rainfall (right)
Inlet
Outlet
20
15
10
5
0
0
2
4
6
8
10
12
Mass (kg)
Inlet TSS
Outlet TSS
2.0
1.5
1.0
0.5
0.0
Mass (kg)
Inlet TN
Outlet TN
0.00020
0.00015
0.00010
0.00005
0.00000
Mass (kg)
Inlet TP
Outlet TP
0.0008
0.0006
0.0004
0.0002
0.0000
14:00
16:00
18:00
20:00
22:00
00:00
03-Sep
Time

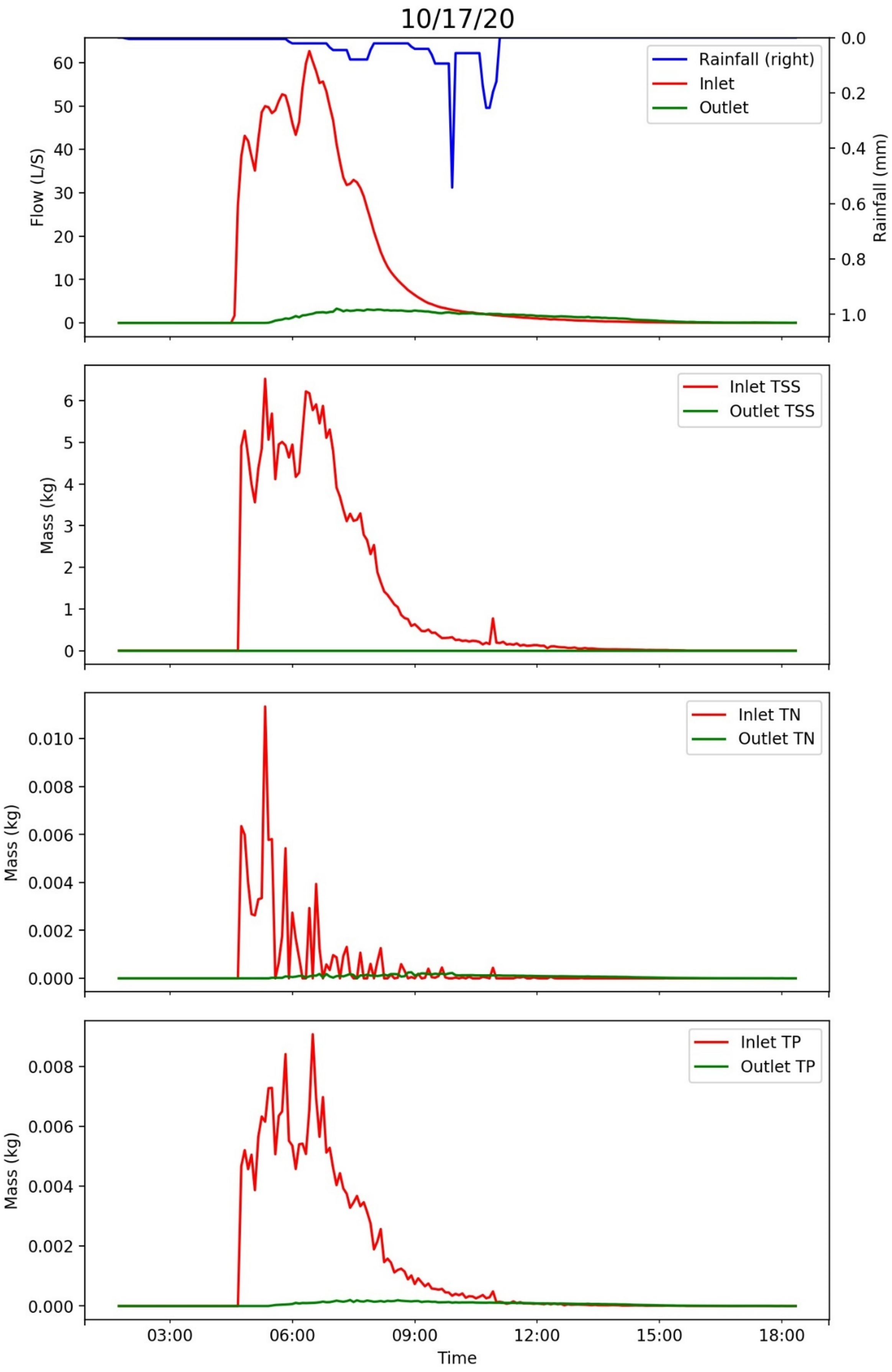

09/03/20
Rainfall (right)
Inlet
Outlet
Flow (L/S)
Rainfall (mm)
0
5
10
15
20
25
30
35
40
Inlet TSS
Outlet TSS
Mass (kg)
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
Inlet TN
Outlet TN
0.00000
0.00005
0.00010
0.00015
0.00020
Inlet TP
Outlet TP
0.00002
0.00004
0.00006
0.00008
0.00010
0.00012
0.00014
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Time

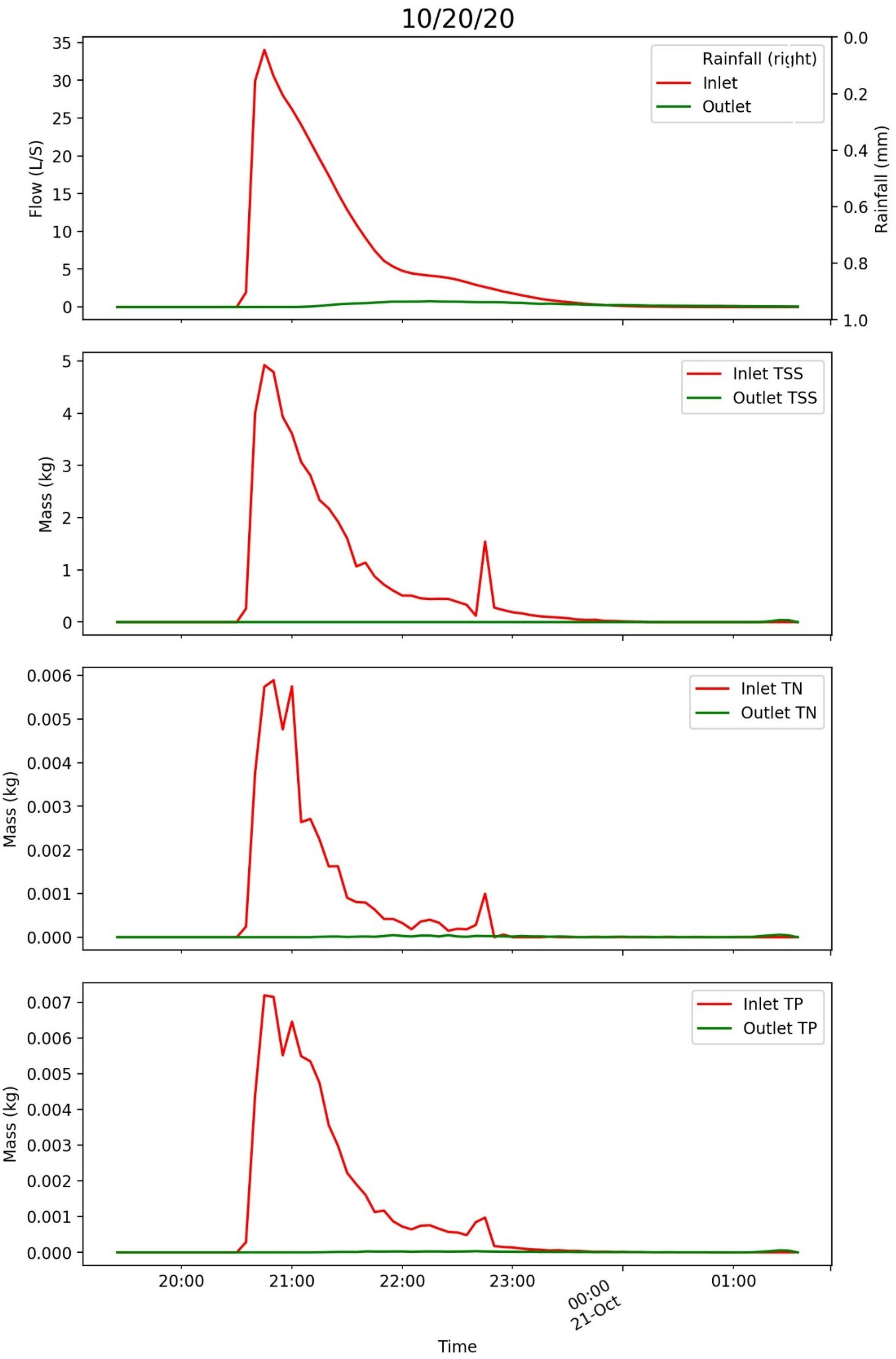

09/10/20
Rainfall (right)
Inlet
Outlet
Flow (L/S)
0
5
10
15
20
Rainfall (mm)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Inlet TSS
Outlet TSS
Mass (kg)
0.04
0.02
0.00
−0.02
−0.04
Inlet TN
Outlet TN
Mass (kg)
0.00014
0.00012
0.00010
0.00008
0.00006
0.00004
0.00002
0.00000
Inlet TP
Outlet TP
Mass (kg)
0.00010
0.00008
0.00006
0.00004
0.00002
0.00000
16:00
18:00
20:00
22:00
00:00
11-Sep
Time

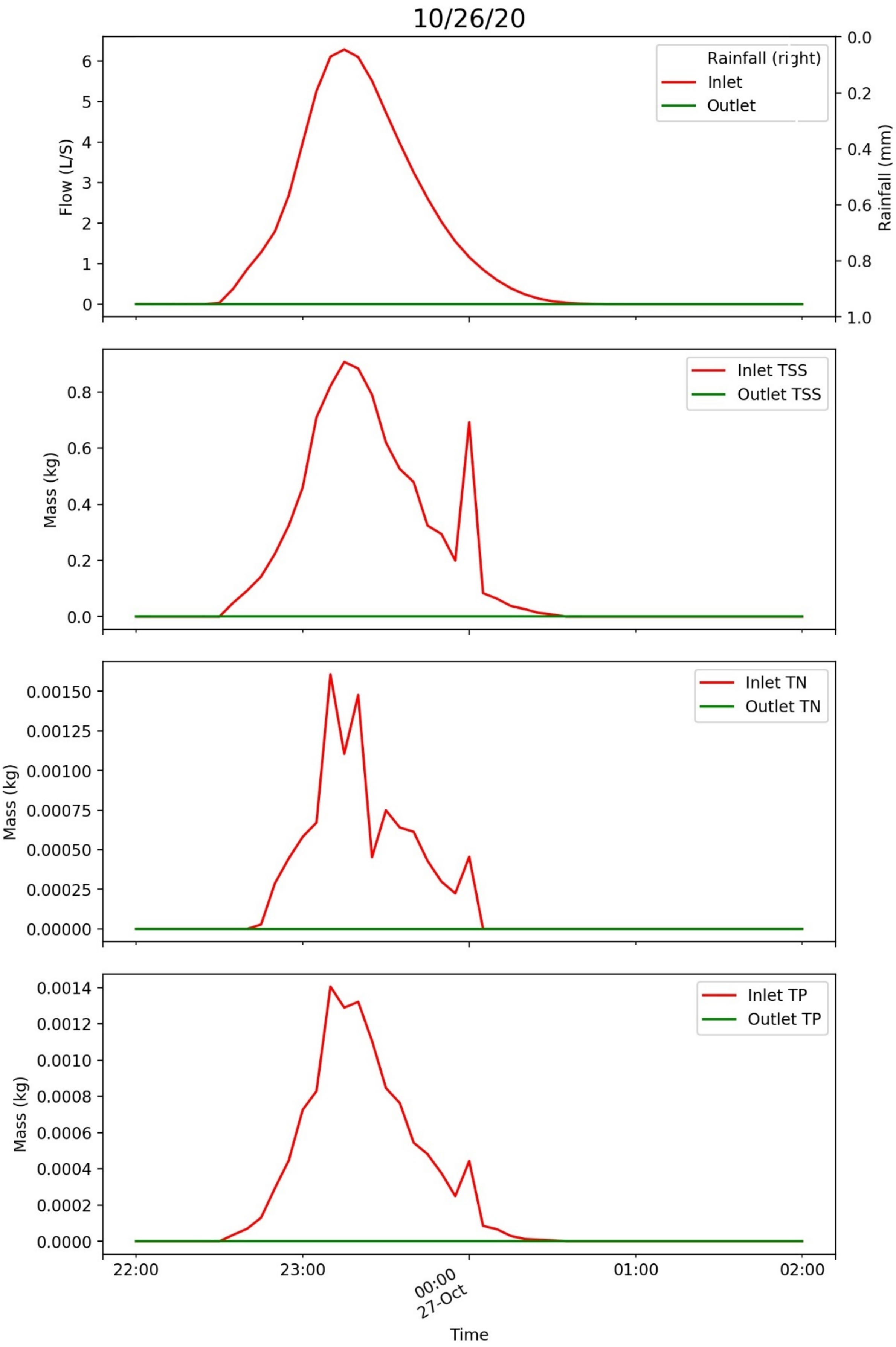

09/11/20
Flow (L/S)
Rainfall (mm)
0
5
10
15
20
0.0
0.5
1.0
1.5
2.0
2.5
Rainfall (right)
Inlet
Outlet
Mass (kg)
0.000
0.002
0.004
0.006
0.008
0.010
Inlet TSS
Outlet TSS
Mass (kg)
0.00000
0.00002
0.00004
0.00006
0.00008
0.00010
0.00012
Inlet TN
Outlet TN
Mass (kg)
0.00000
0.00002
0.00004
0.00006
0.00008
0.00010
Inlet TP
Outlet TP
04:00
06:00
08:00
10:00
12:00
Time


09/18/20
Rainfall (right)
Inlet
Outlet
Flow (L/S)
Rainfall (mm)
0
1
2
3
4
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Inlet TSS
Outlet TSS
Mass (kg)
0.00
0.01
0.02
0.03
0.04
0.05
0.06
Inlet TN
Outlet TN
Mass (kg)
0.00000
0.00001
0.00002
0.00003
0.00004
0.00005
0.00006
0.00007
0.00008
Inlet TP
Outlet TP
Mass (kg)
0.00000
0.00001
0.00002
0.00003
0.00004
0.00005
0.00006
0.00007
0.00008
02:00
04:00
06:00
08:00
10:00
Time


10/13/20
Flow (L/S)
Rainfall (mm)
Rainfall (right)
Inlet
Outlet
10
8
6
4
2
0
0
1
2
3
4
5
Mass (kg)
Inlet TSS
Outlet TSS
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Mass (kg)
Inlet TN
Outlet TN
0.0035
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
Mass (kg)
Inlet TP
Outlet TP
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
06:00
09:00
12:00
15:00
18:00
21:00
Time


10/17/20
Rainfall (right)
Inlet
Outlet
Flow (L/S)
Rainfall (mm)
0
10
20
30
40
50
60
0.0
0.2
0.4
0.6
0.8
1.0
Inlet TSS
Outlet TSS
Mass (kg)
0
1
2
3
4
5
6
Inlet TN
Outlet TN
Mass (kg)
0.000
0.002
0.004
0.006
0.008
0.010
Inlet TP
Outlet TP
Mass (kg)
0.000
0.002
0.004
0.006
0.008
03:00
06:00
09:00
12:00
15:00
18:00
Time


10/20/20
Flow (L/S)
Rainfall (mm)
Rainfall (right)
Inlet
Outlet
35
30
25
20
15
10
5
0
0.0
0.2
0.4
0.6
0.8
1.0
Mass (kg)
Inlet TSS
Outlet TSS
5
4
3
2
1
0
Mass (kg)
Inlet TN
Outlet TN
0.006
0.005
0.004
0.003
0.002
0.001
0.000
Mass (kg)
Inlet TP
Outlet TP
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
20:00
21:00
22:00
23:00
00:00
21-Oct
01:00
Time


10/26/20
Rainfall (right)
Inlet
Outlet
Flow (L/S)
Rainfall (mm)
0
1
2
3
4
5
6
0.0
0.2
0.4
0.6
0.8
1.0
Inlet TSS
Outlet TSS
Mass (kg)
0.0
0.2
0.4
0.6
0.8
Inlet TN
Outlet TN
Mass (kg)
0.00000
0.00025
0.00050
0.00075
0.00100
0.00125
0.00150
Inlet TP
Outlet TP
Mass (kg)
0.0000
0.0002
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0.0006
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0.0014
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23:00
00:00
27-Oct
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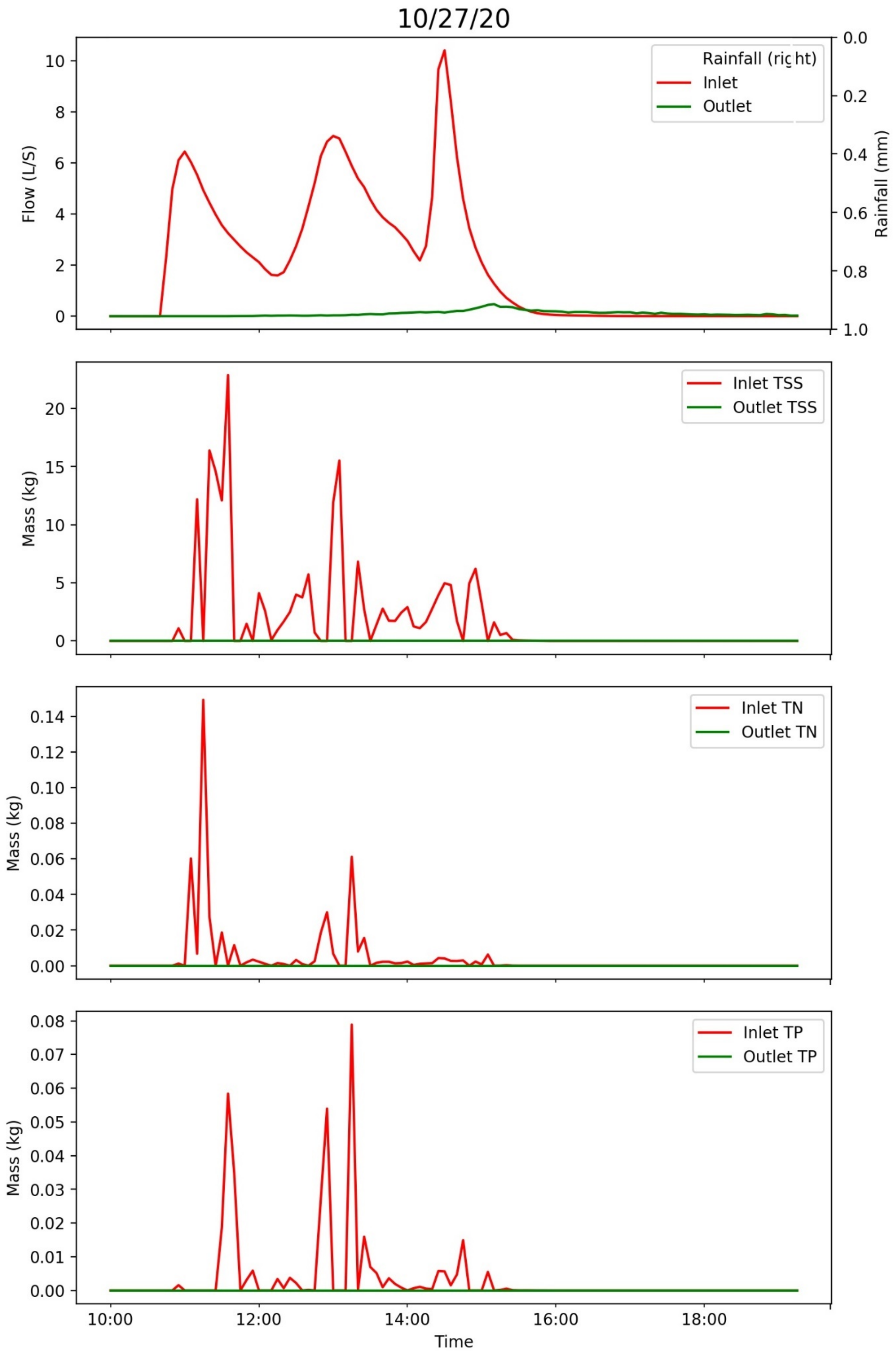
02:00
Time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Inlet
Outlet
Flow (L/S)
Rainfall (mm)
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8
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0.2
0.4
0.6
0.8
1.0
Inlet TSS
Outlet TSS
Mass (kg)
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10
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20
Inlet TN
Outlet TN
Mass (kg)
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0.04
0.06
0.08
0.10
0.12
0.14
Inlet TP
Outlet TP
Mass (kg)
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0.01
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12:00
14:00
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18:00
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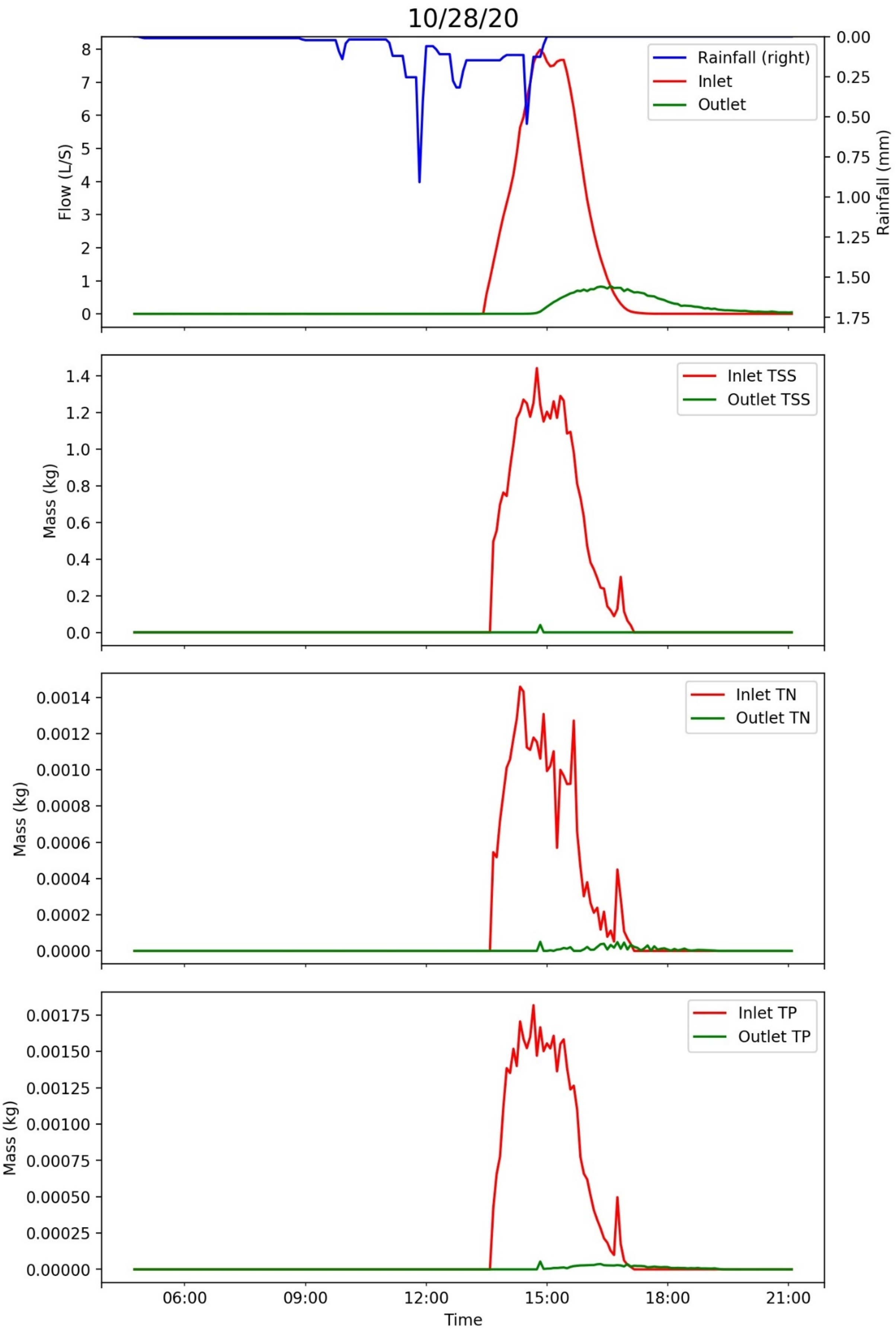
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1
2
3
4
5
6
7
8
Rainfall (mm)
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0.25
0.50
0.75
1.00
1.25
1.50
1.75
Rainfall (right)
Inlet
Outlet
Mass (kg)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Inlet TSS
Outlet TSS
Mass (kg)
0.0000
0.0002
0.0004
0.0006
0.0008
0.0010
0.0012
0.0014
Inlet TN
Outlet TN
Mass (kg)
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0.00025
0.00050
0.00075
0.00100
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0.00175
Inlet TP
Outlet TP
06:00
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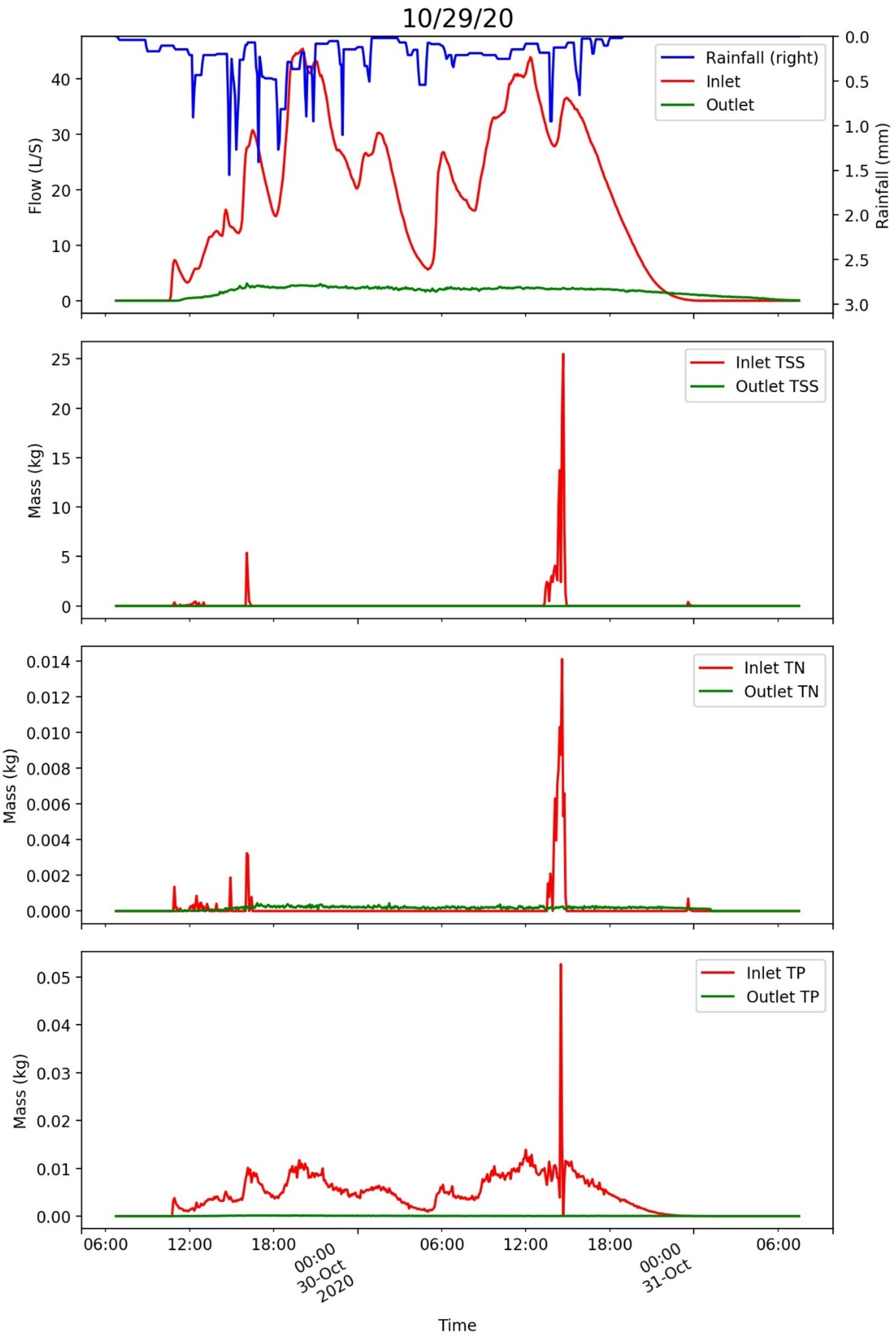
12:00
15:00
18:00
21:00
Time


10/29/20
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Rainfall (mm)
Rainfall (right)
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Outlet
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1.5
2.0
2.5
3.0
Mass (kg)
Inlet TSS
Outlet TSS
0
5
10
15
20
25
Mass (kg)
Inlet TN
Outlet TN
0.000
0.002
0.004
0.006
0.008
0.010
0.012
0.014
Mass (kg)
Inlet TP
Outlet TP
0.00
0.01
0.02
0.03
0.04
0.05
06:00
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30-Oct
2020
06:00
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18:00
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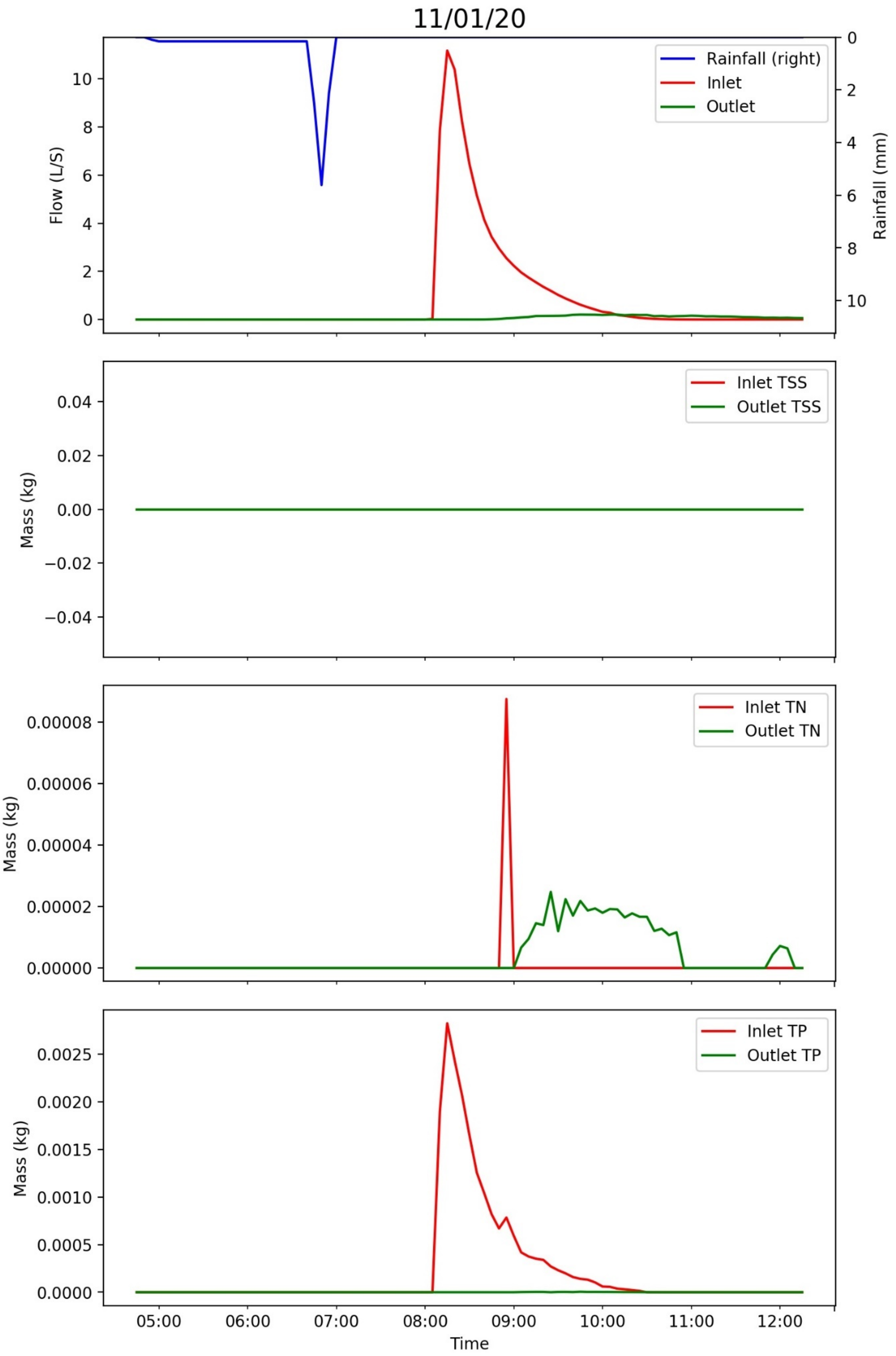
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Inlet
Outlet
Flow (L/S)
Rainfall (mm)
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4
6
8
10
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Outlet TSS
Mass (kg)
0.04
0.02
0.00
−0.02
−0.04
Inlet TN
Outlet TN
0.00008
0.00006
0.00004
0.00002
0.00000
Inlet TP
Outlet TP
0.0025
0.0020
0.0015
0.0010
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09:00
10:00
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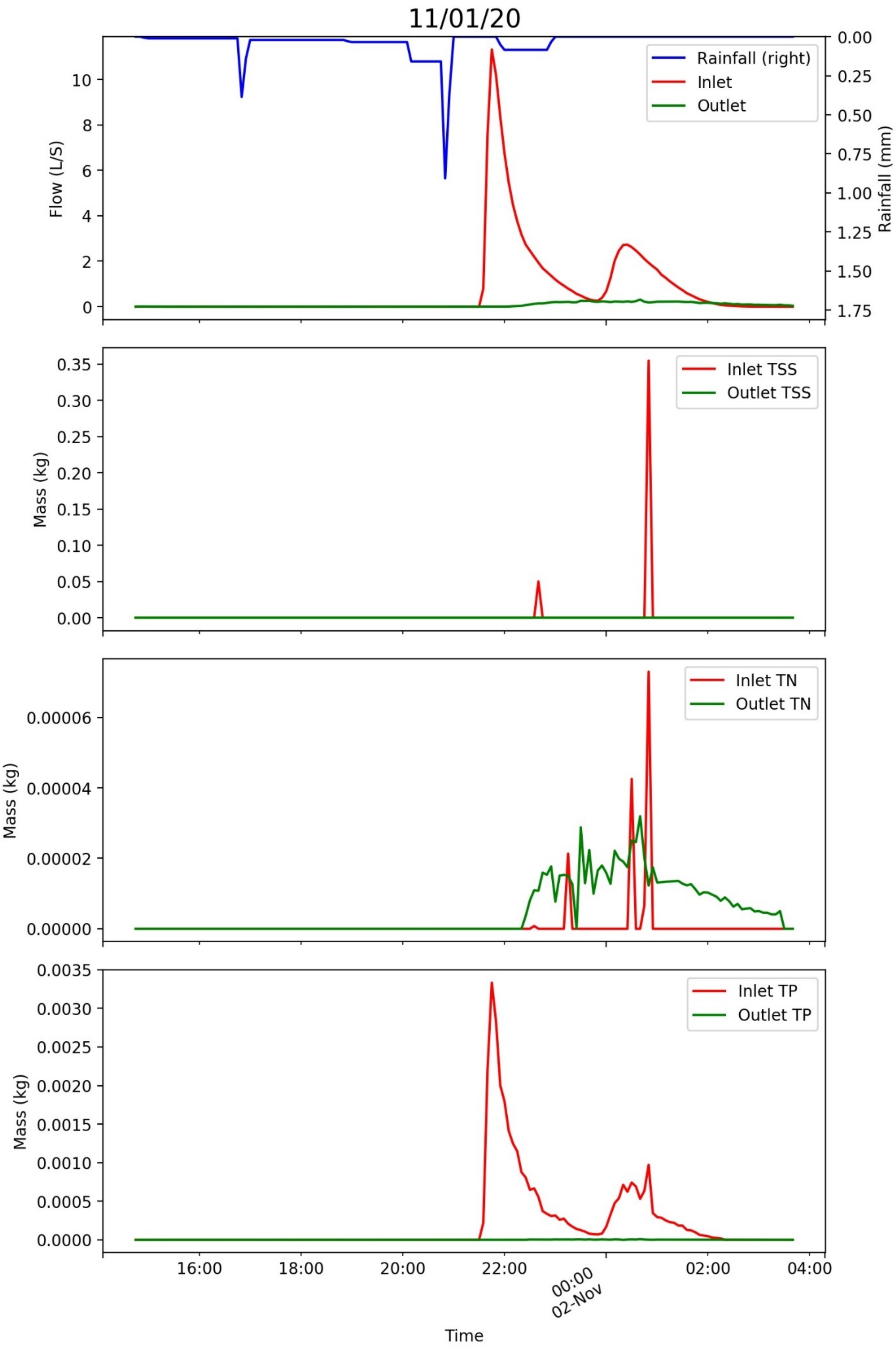
Time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Rainfall (mm)
Rainfall (right)
Inlet
Outlet
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4
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0.25
0.50
0.75
1.00
1.25
1.50
1.75
Mass (kg)
Inlet TSS
Outlet TSS
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Mass (kg)
Inlet TN
Outlet TN
0.00000
0.00002
0.00004
0.00006
Mass (kg)
Inlet TP
Outlet TP
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0.0005
0.0010
0.0015
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0.0030
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02-Nov
02:00
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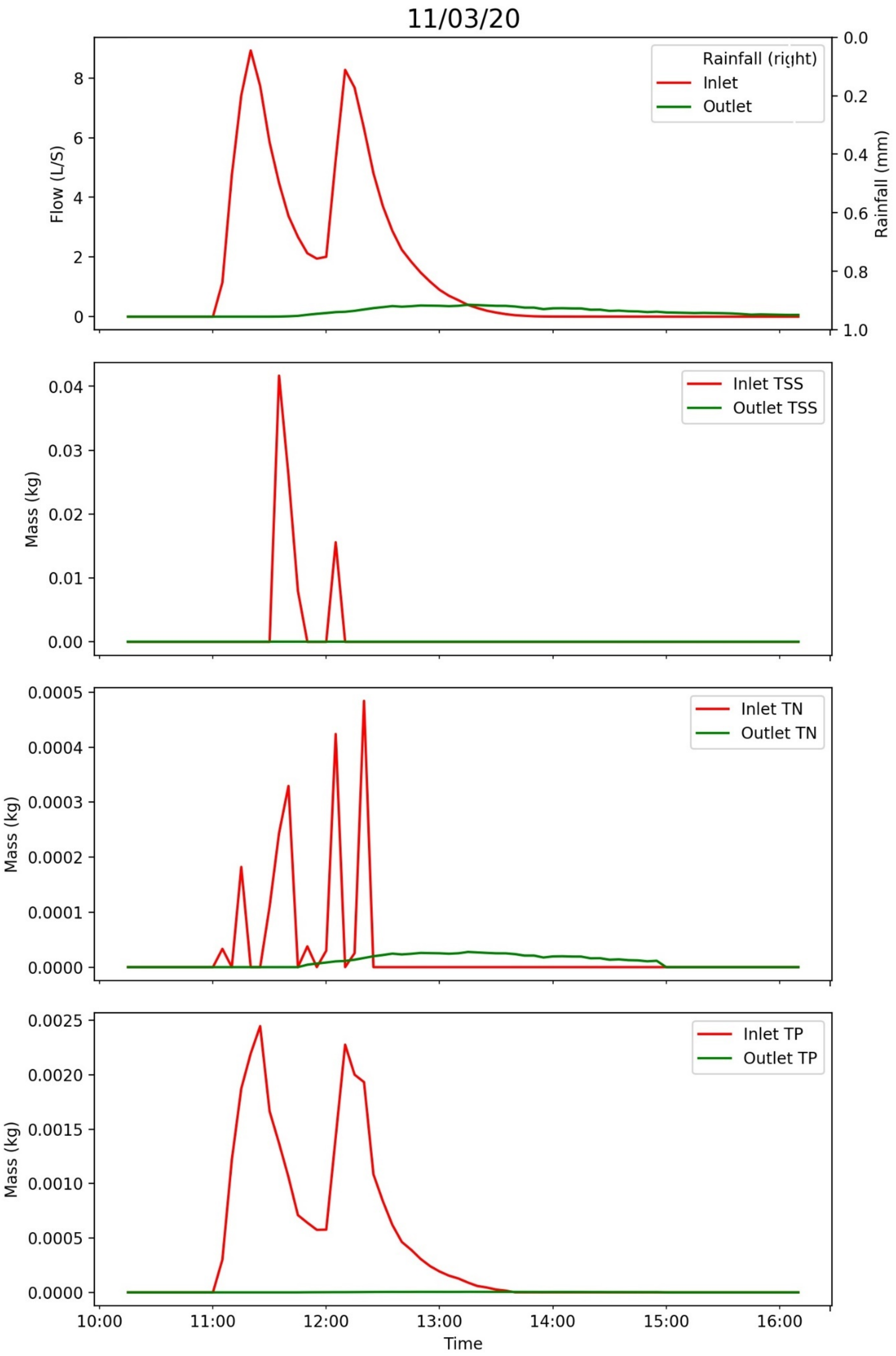
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Outlet
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Rainfall (mm)
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0.4
0.6
0.8
1.0
Inlet TSS
Outlet TSS
Mass (kg)
0.00
0.01
0.02
0.03
0.04
Inlet TN
Outlet TN
Mass (kg)
0.0000
0.0001
0.0002
0.0003
0.0004
0.0005
Inlet TP
Outlet TP
Mass (kg)
0.0000
0.0005
0.0010
0.0015
0.0020
0.0025
10:00
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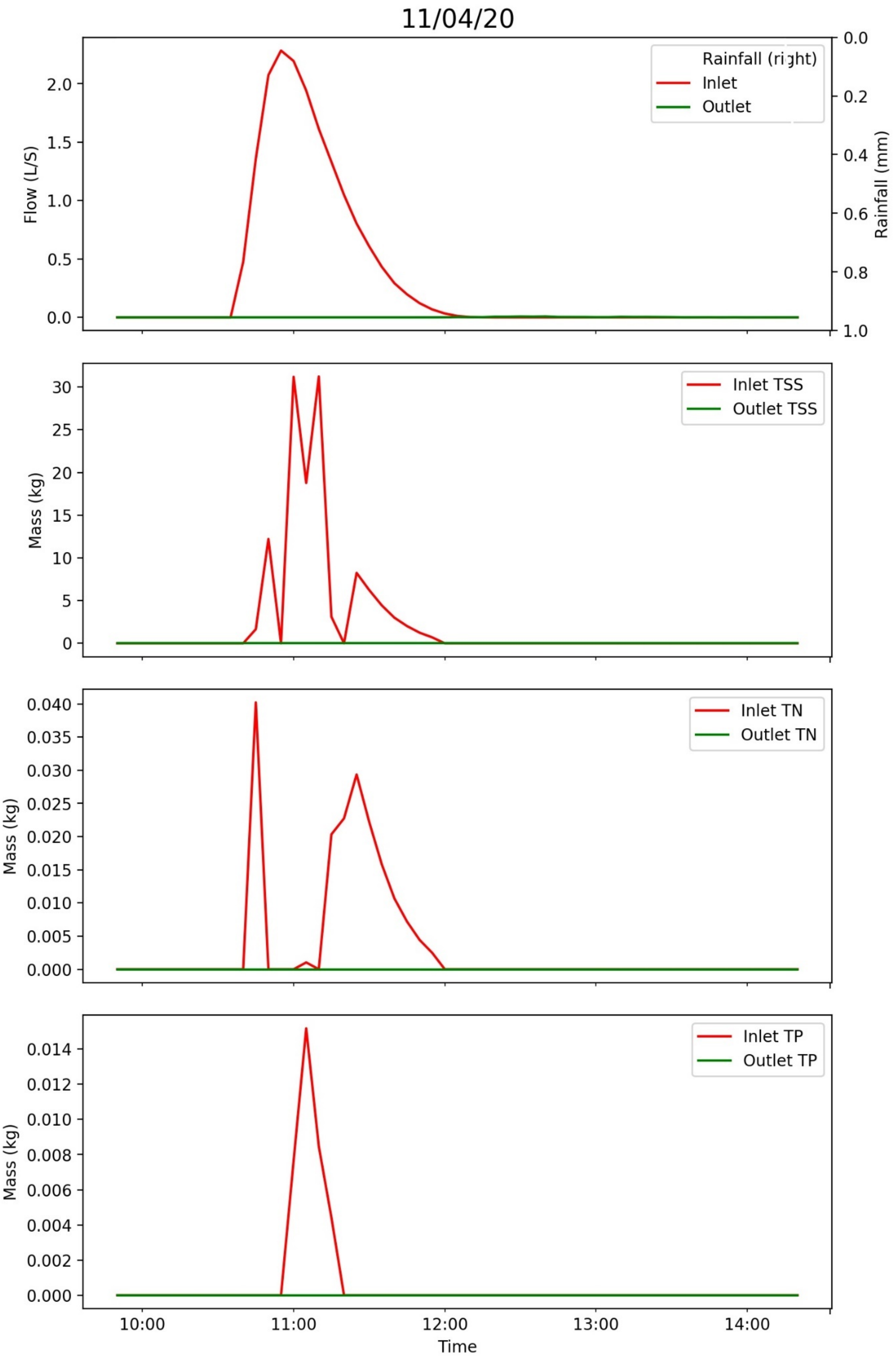
12:00
13:00
14:00
15:00
16:00
Time


11/04/20
Flow (L/S)
Rainfall (mm)
Rainfall (right)
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Outlet
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0.5
1.0
1.5
2.0
0.0
0.2
0.4
0.6
0.8
1.0
Mass (kg)
Inlet TSS
Outlet TSS
0
5
10
15
20
25
30
Mass (kg)
Inlet TN
Outlet TN
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
0.040
Mass (kg)
Inlet TP
Outlet TP
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11:00
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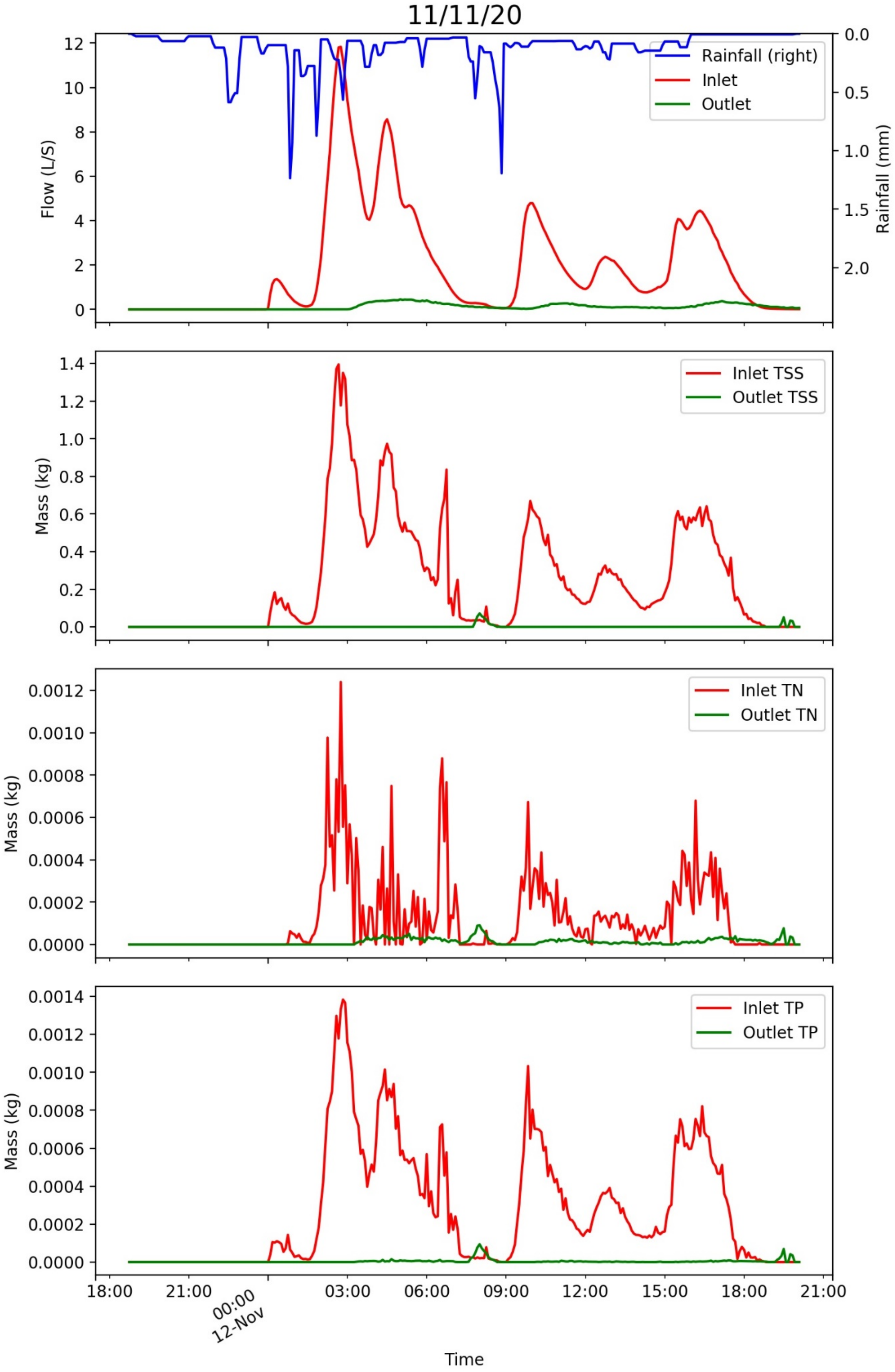
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Rainfall (mm)
Rainfall (right)
Inlet
Outlet
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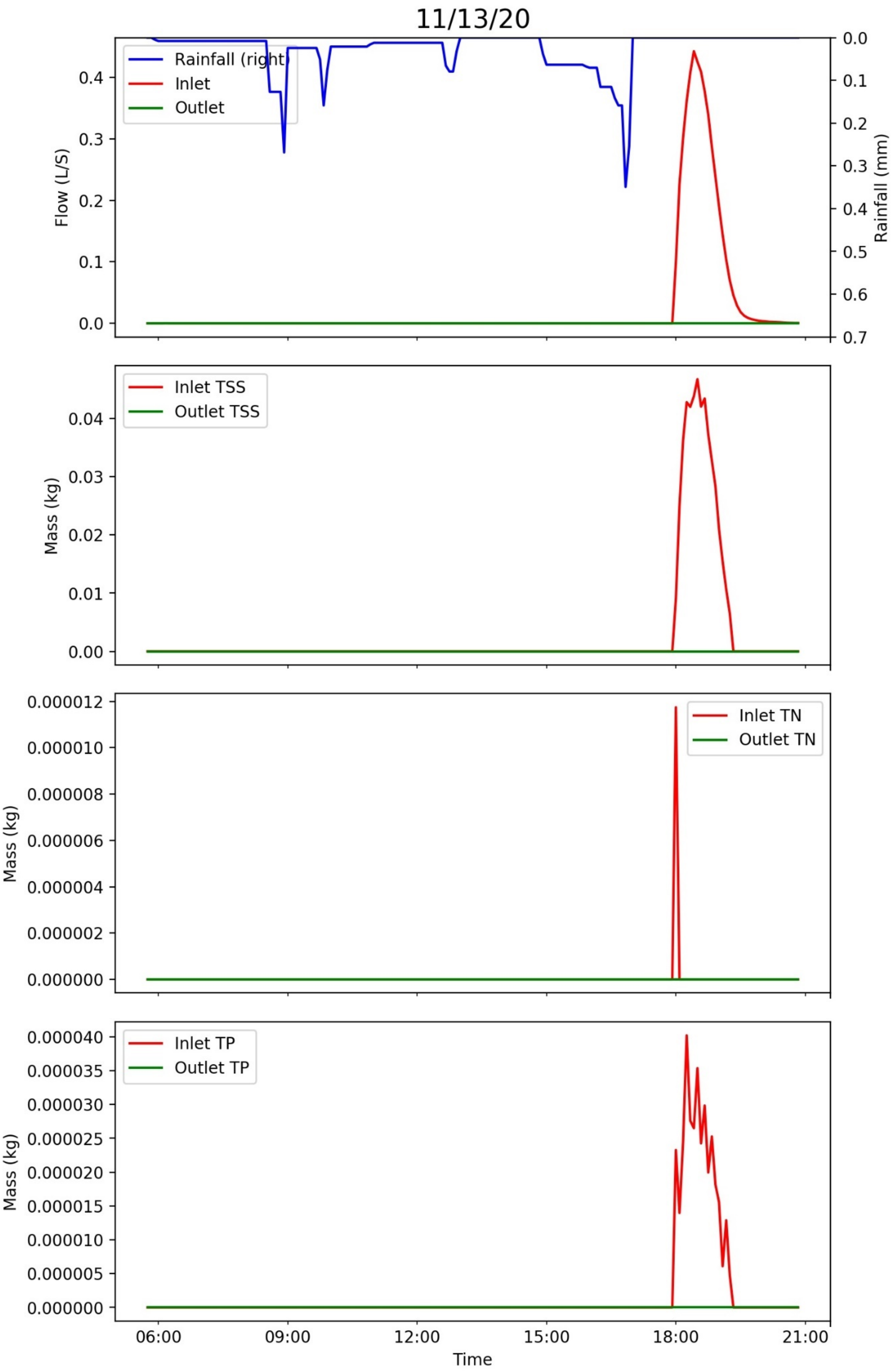
2
4
6
8
10
12
0.0
0.5
1.0
1.5
2.0
Mass (kg)
Inlet TSS
Outlet TSS
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Inlet TN
Outlet TN
0.0000
0.0002
0.0004
0.0006
0.0008
0.0010
0.0012
Inlet TP
Outlet TP
0.0014
18:00
21:00
00:00
12-Nov
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time


11/13/20
Rainfall (right)
Inlet
Outlet
Flow (L/S)
Rainfall (mm)
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0.1
0.2
0.3
0.4
0.5
0.6
0.7
Inlet TSS
Outlet TSS
Mass (kg)
0.00
0.01
0.02
0.03
0.04
Inlet TN
Outlet TN
0.000000
0.000002
0.000004
0.000006
0.000008
0.000010
0.000012
Inlet TP
Outlet TP
0.000005
0.000015
0.000020
0.000025
0.000030
0.000035
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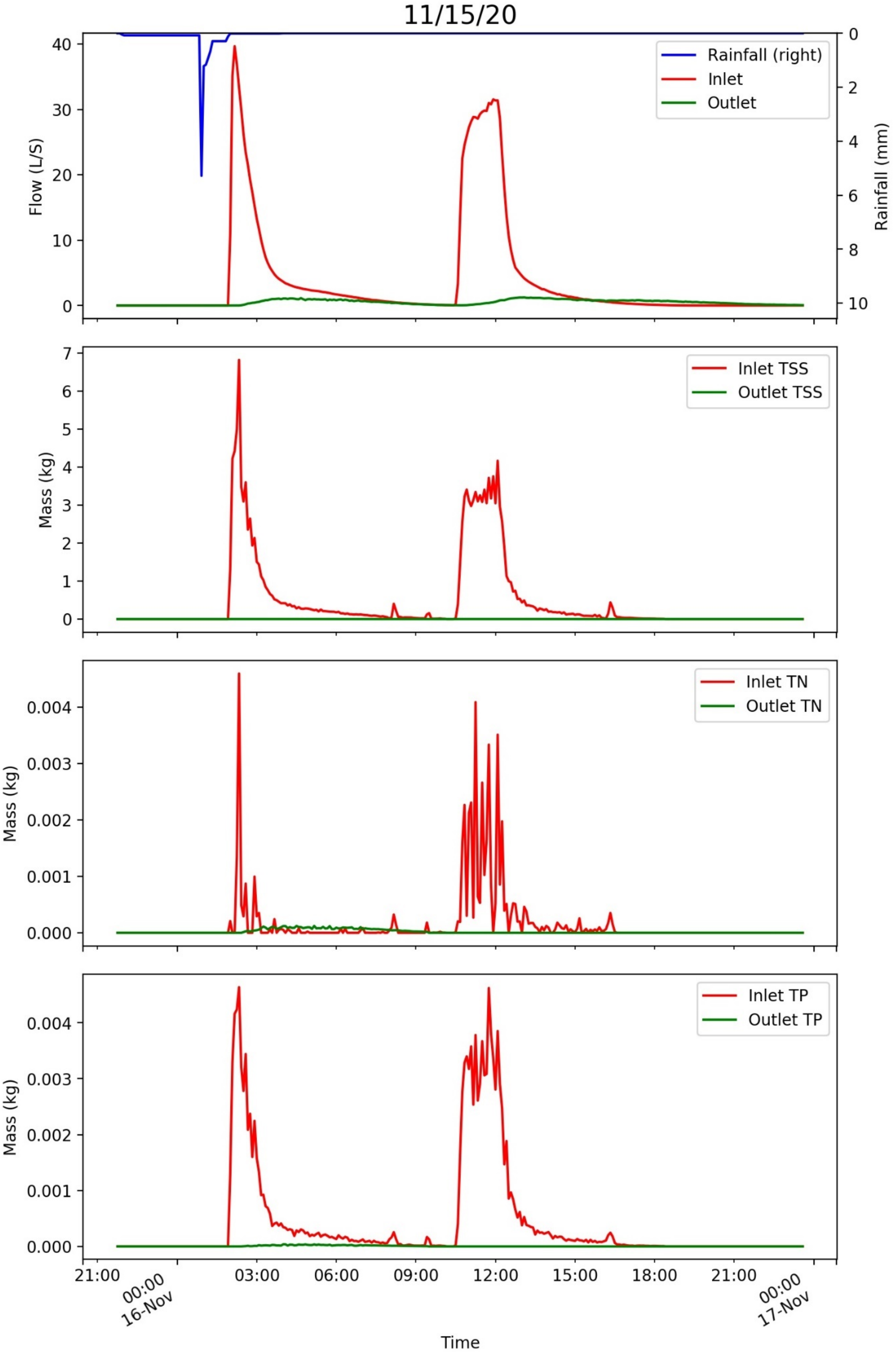
06:00
09:00
12:00
15:00
18:00
21:00
Time


11/15/20
Rainfall (right)
Inlet
Outlet
Flow (L/S)
Rainfall (mm)
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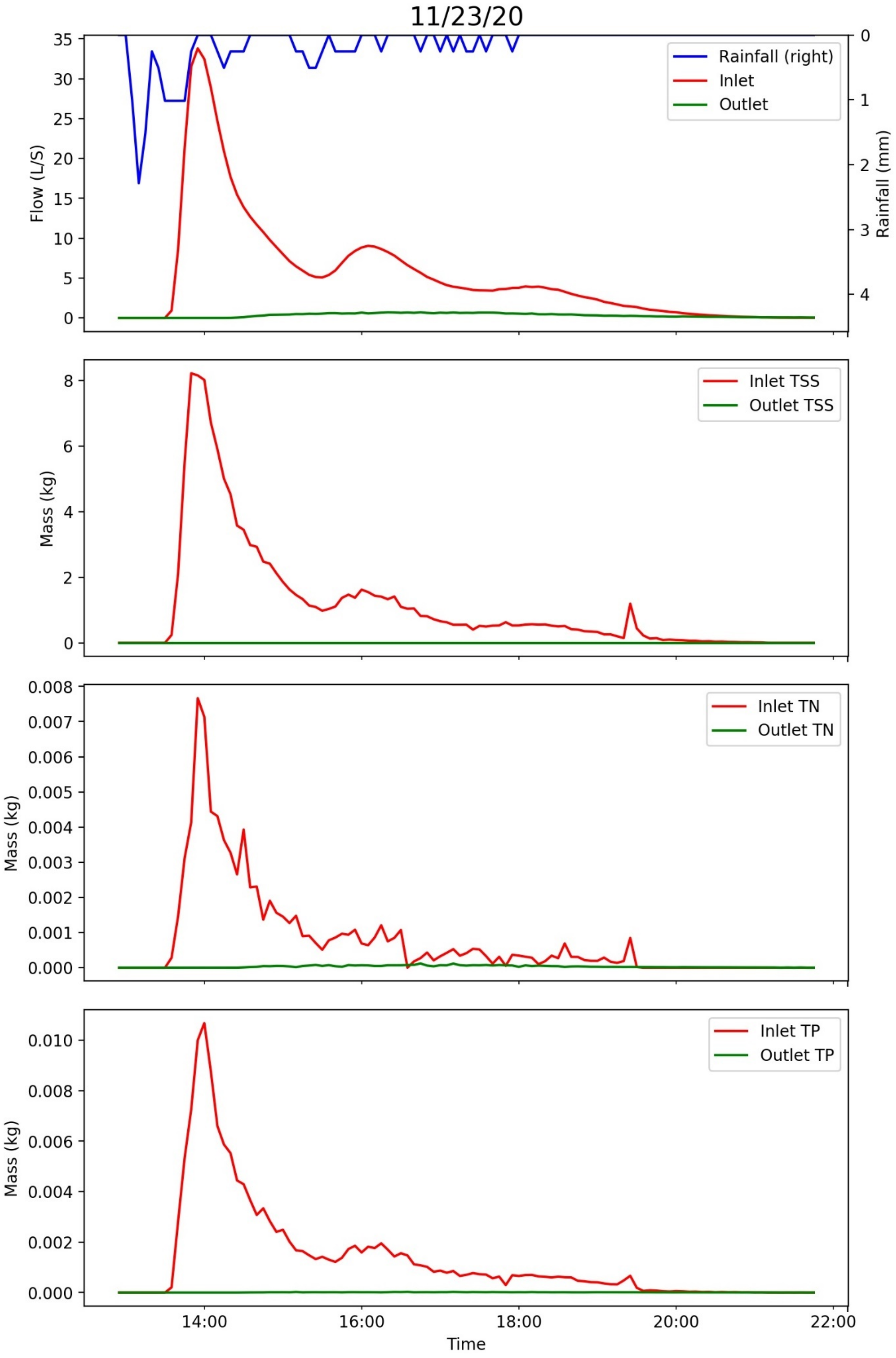
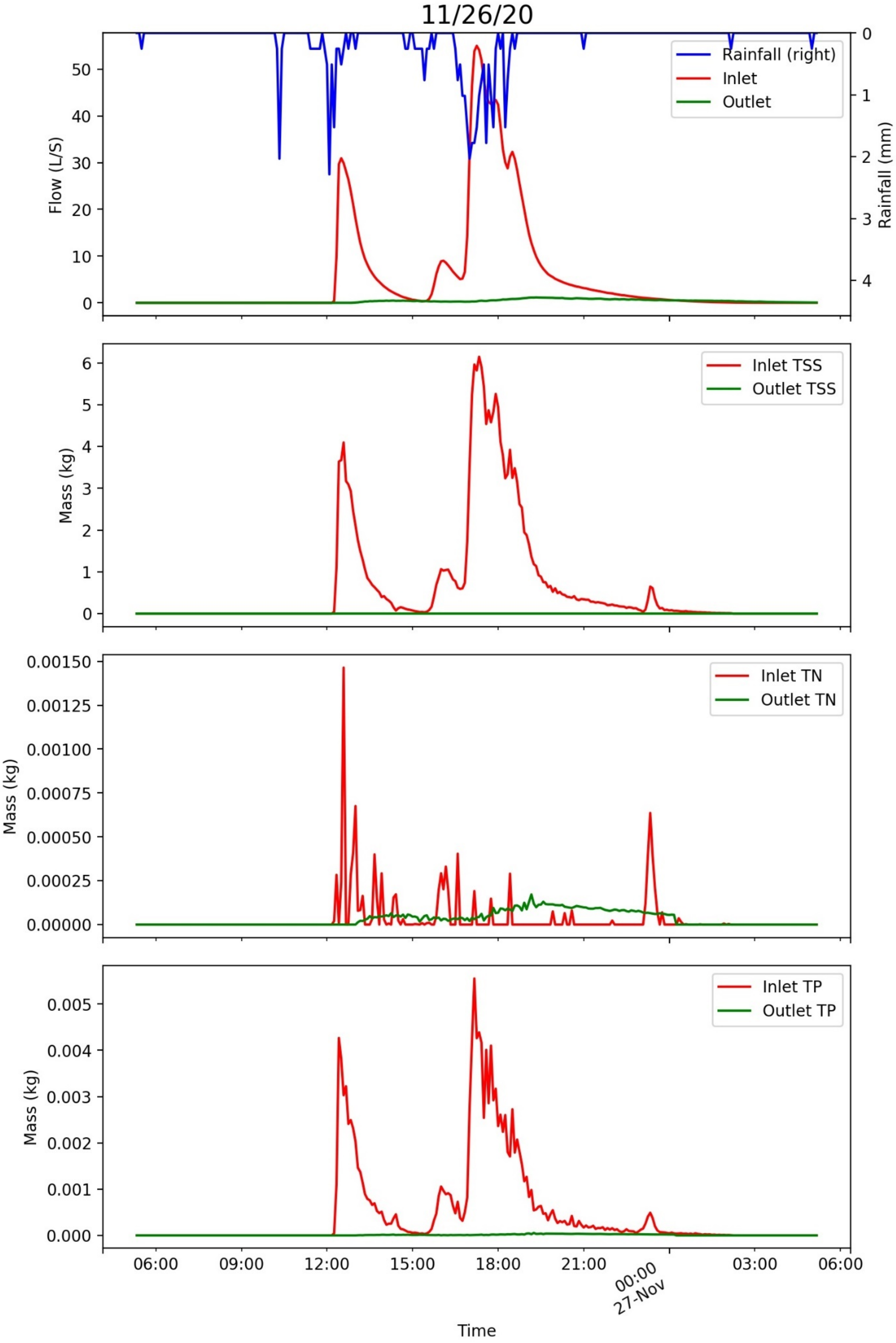
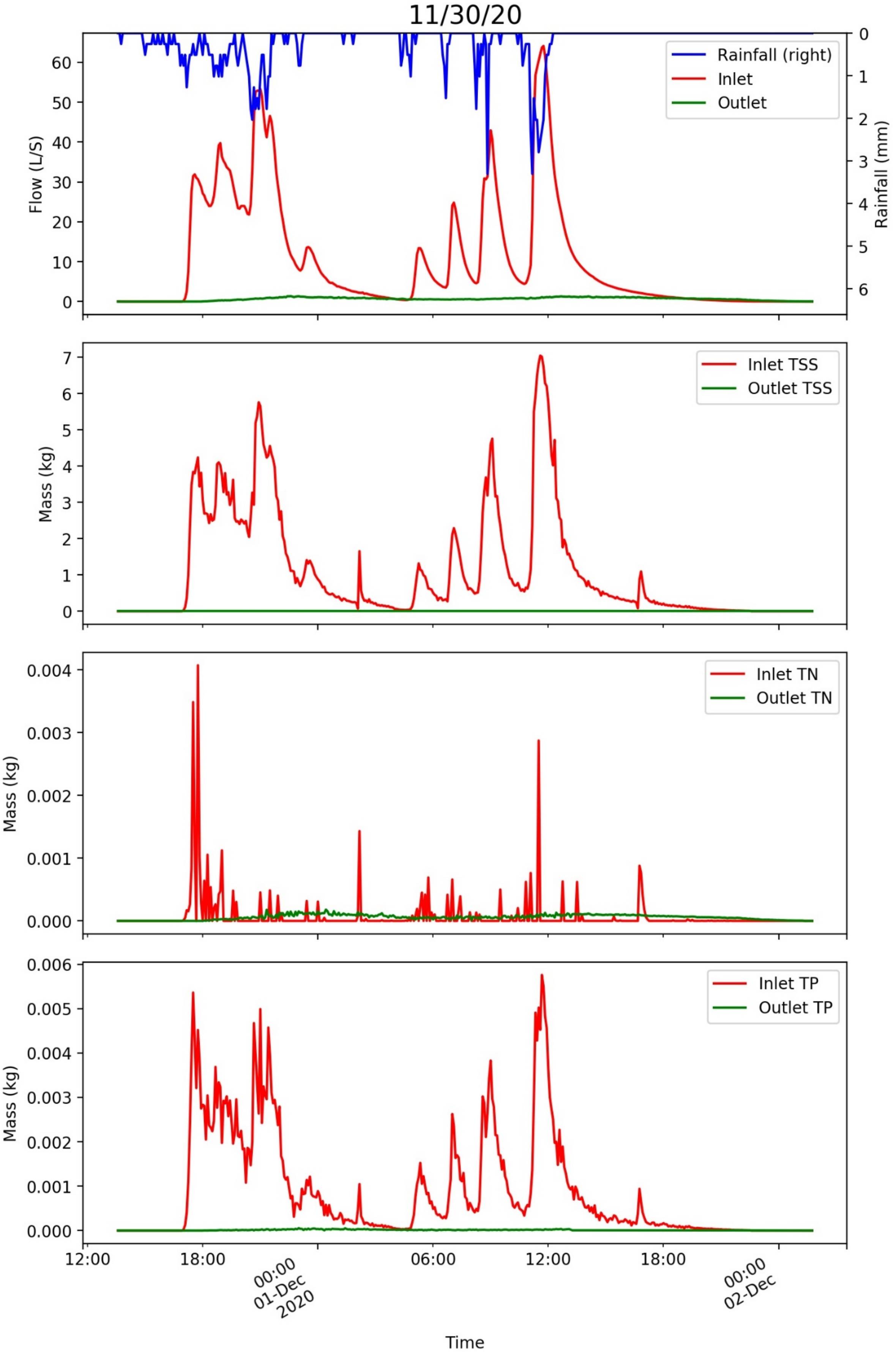
10
20
30
40
0
2
4
6
8
10
Inlet TSS
Outlet TSS
Mass (kg)
0
1
2
3
4
5
6
7
Inlet TN
Outlet TN
Mass (kg)
0.000
0.001
0.002
0.003
0.004
Inlet TP
Outlet TP
Mass (kg)
0.000
0.001
0.002
0.003
0.004
21:00
00:00
16-Nov
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
17-Nov
Time


11/23/20
Flow (L/S)
35
30
25
20
15
10
5
0
Rainfall (mm)
0
1
2
3
4
Rainfall (right)
Inlet
Outlet
Mass (kg)
8
6
4
2
0
Inlet TSS
Outlet TSS
Mass (kg)
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
Inlet TN
Outlet TN
Mass (kg)
0.010
0.008
0.006
0.004
0.002
0.000
Inlet TP
Outlet TP
14:00
16:00
18:00
20:00
22:00
Time


11/26/20
Flow (L/S)
Rainfall (mm)
Rainfall (right)
Inlet
Outlet
0
10
20
30
40
50
0
1
2
3
4
Mass (kg)
Inlet TSS
Outlet TSS
0
1
2
3
4
5
6
Mass (kg)
Inlet TN
Outlet TN
0.00000
0.00025
0.00050
0.00075
0.00100
0.00125
0.00150
Mass (kg)
Inlet TP
Outlet TP
0.000
0.001
0.002
0.003
0.004
0.005
06:00
09:00
12:00
15:00
18:00
21:00
00:00
27-Nov
03:00
06:00
Time


11/30/20
Flow (L/S)
Rainfall (mm)
Rainfall (right)
Inlet
Outlet
0
10
20
30
40
50
60
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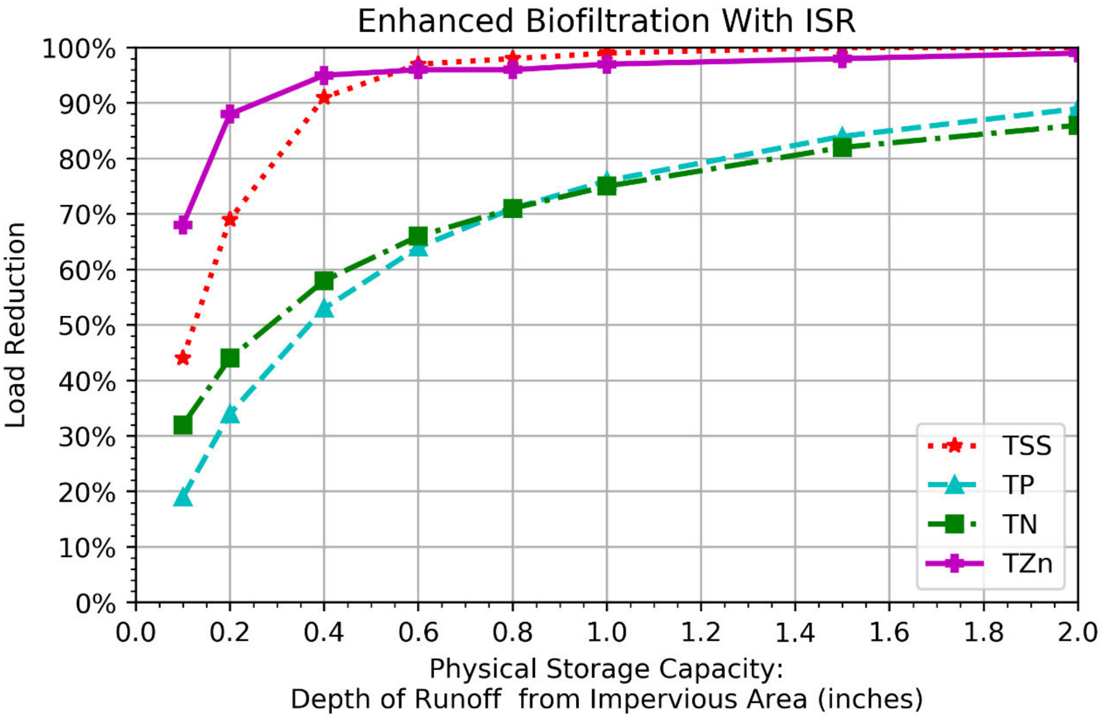
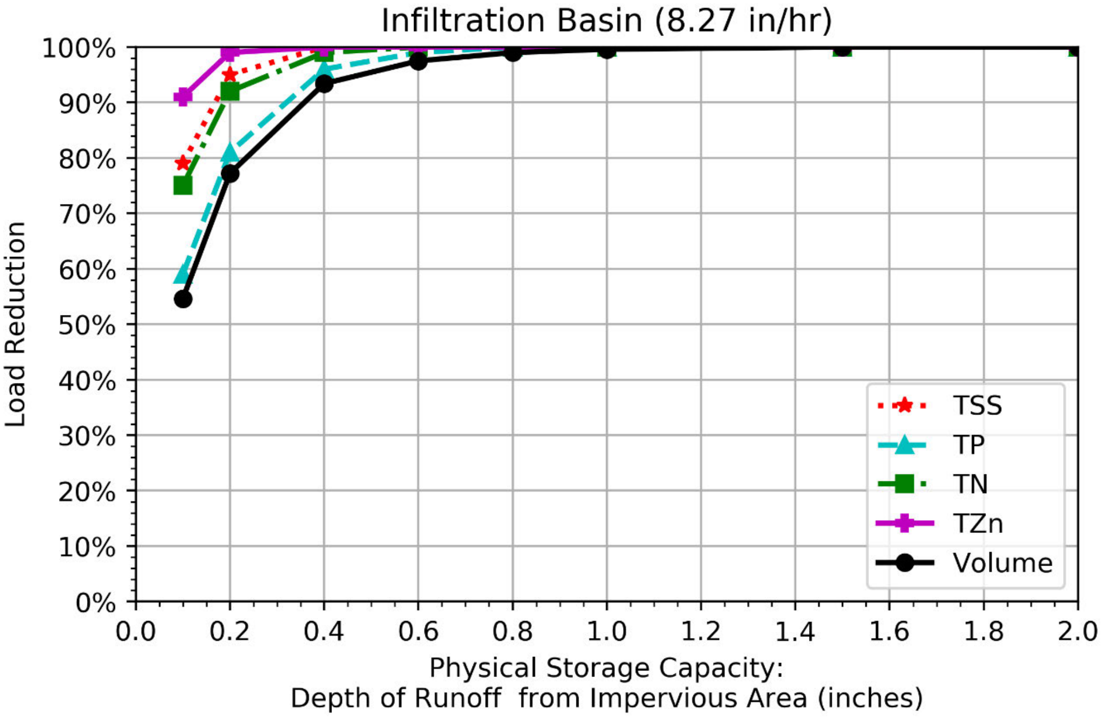
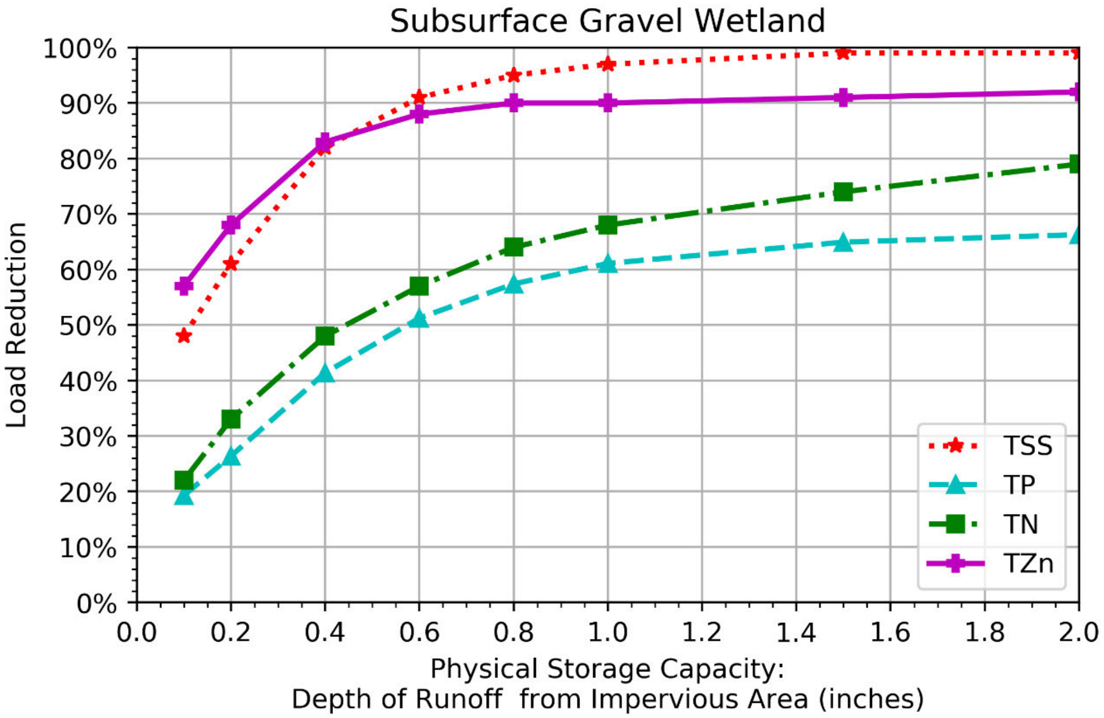
1
2
3
4
5
6
Mass (kg)
Inlet TSS
Outlet TSS
0
1
2
3
4
5
6
7
Mass (kg)
Inlet TN
Outlet TN
0.000
0.001
0.002
0.003
0.004
Mass (kg)
Inlet TP
Outlet TP
0.000
0.001
0.002
0.003
0.004
0.005
0.006
12:00
18:00
00:00
01-Dec
2020
06:00
12:00
18:00
00:00
02-Dec
Time

4. Appendix 4: Performance Curves

The BMP Performance Curves used to estimate the performance of the BMP are shown below. These can be found in Appendix F of the NH Small MS4 General Permit (US EPA Region 1, 2017) and the BMP Performance Fact Sheets by UNHSC (UNHSC, 2019).


Enhanced Biofiltration With ISR
Load Reduction
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
Physical Storage Capacity:
Depth of Runoff from Impervious Area (inches)
TSS
TP
TN
TZn


Infiltration Basin (8.27 in/hr)
Load Reduction
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
Physical Storage Capacity:
Depth of Runoff from Impervious Area (inches)
TSS
TP
TN
TZn
Volume


Subsurface Gravel Wetland
Load Reduction
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
Physical Storage Capacity:
Depth of Runoff from Impervious Area (inches)
TSS
TP
TN
TZn

Appendices

Appendix: Estimate for Optional Period 1

Appendix: Optional Budget Estimate for repairs of the Hyannis BMP

SCOPE OF WORK

Barnstable Innovative Bioretention Project

The coastal embayments of Cape Cod have historically received excess nitrogen loadings, with a portion of nitrogen coming from stormwater runoff. Consequently, the Massachusetts Estuaries Project (MEP) developed total maximum daily load allocations (TMDLs) for many southern Massachusetts embayments including those in Cape Cod. To begin the process of reaching the TMDL goals, the City of Barnstable partnered with the United States Environmental Protection Agency (EPA), WaterVision, LLC, and Comprehensive Environmental Inc. (CEI) to initiate a pilot project in Cape Cod in 2014 and demonstrate the effectiveness of nitrogen load-reducing stormwater BMPs. This project was designed to monitor and quantify the BMP performance for nitrogen removal. Since the BMPs installation there has been significant surface clogging of the system such as to necessitate maintenance and system repair. There are numerous confounding issues that the University of New Hampshire Stormwater Center (UNHSC) has been contracted to investigate. This project has three tasks:

Task 1: Contractor Selection and system maintenance and repair
Task 2: Preliminary Monitoring
Task 3: Initial System Monitoring

Task 1: Contractor Selection and system maintenance and repair

This part of the project includes the labor and materials necessary for the maintenance of the Barnstable Bioretention system. Work will include but may not be limited to: excavation of the first 4-6 inches of the existing bioretention area or until original engineered soils are exposed. This scope also includes the purchase and placement of all additional system materials necessary to rehabilitate and reestablish the originally designed hydraulic routing, hauling of cut soils, and seeding as necessary. UNHSC will be available to oversee maintenance and coordinate operations with the contractor such that site stabilization and safety considerations will be managed appropriately.

Construction will follow the previously developed scope of work (see attachment). Particular attention will be spent to ensure system resiliency across several variable climate conditions such as seasonally high water table elevations, sea level rise and storm surge.

Task 1 Deliverables:
- An online working innovative bioretention system
- Built in resiliency to variable climate conditions

Estimated expenses

Contractor subcontract and supplies: [redacted]

Project Management and Engineering Oversite: [redacted]

Task 2: Preliminary Monitoring

UNHSC will conduct field investigations to ensure proper system function. These will include depth to water measurements to understand ground water elevation, reinstrumentation of the facility to measure influent and effluent flows, investigation of tidal surge and other hydraulic factors that may influence system operation.

Task 2 Deliverables:

- Verification of functional system hydrology and hydraulics.
- Documentation of variable climate conditions

Estimated Expenses

Project Management and data collection: [redacted]

Task 3: Initial System Monitoring

On successful reconstruction and reestablishment of the BMP a limited number of storms will be monitored. Depending on the acquisition of real-time probes the monitoring will either be conducted with existing equipment or with real time UV-sensors (see attached quote).

The purpose of the monitoring program for the Barnstable BMP is to quantify the nitrogen load-reduction performance of the innovative bioretention system. A confounding issue that has been historically raised for coastal systems is how they would operate under changing water elevations either due to rising sea levels or other natural phenomena. Until now there has been little other than speculation as to system performance under these variable conditions. This data will help answer in part the effect of these fluxuations on system performance. To quantify the effectiveness of the Barnstable BMP, parameters including flow, total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS) will monitored at the inlet and outlet of the BMP. These measurements will be analyzed to compare the percentage of nutrients and sediment entering and leaving the treatment system.

Task 3a: Monitoring Program Overview
UNHSC will develop a sampling approach consistent with equipment availability and update or develop a Quality Assurance Project Protocol (QAPP) as necessary.

Task 3b: Monitoring Program Management:
Note: this requirement necessitates the contractor is able to travel on short notice to the BMPs in order to oversee execution of the MP during storm events.
UNHSC will collect data and assist with the administration of three to five (3-5) storm events. There is limited availability of local volunteers to assist with the project but UNHSC staff will provide guidance and direction as necessary to help enhance the amount of monitoring results collected.

Monitoring program protocols will be specifically outlined and detailed in the approved QAPP.

Task 3 Deliverables:

- An updated and approved QAPP
- Capture and collection of 3-5 storm events
- Analysis of all associated data
- Final report

Estimated Expenses:

Project Management and reporting: [redacted]

Appendix: Performance Work Statement

Performance Work Statement (PWS)

for

Maintenance and Monitoring Program Update for Subsurface Gravel Wetland BMP Retrofits on Cape Cod

December 23, 2020

I. Background

In 2015, EPA constructed two GI SGW BMP retrofits in Hyannis and Chatham MA to control and treat discharges of nitrogen (**N**) in stormwater.[1] The Cape N BMP retrofits had been constructed to accommodate monitoring of physical and chemical parameters; namely, influent and effluent flow, and water quality (**WQ**) data. The complexity associated with monitoring of stormwater BMPs, and in particular BMP retrofits discharging within confined areas, has highlighted the difficulty of BMP monitoring. Performance monitoring of stormwater BMP retrofits like these SGW retrofits requires the expertise of a dedicated and experienced stormwater technician. Many practitioners do not have or cannot afford such expertise. Consequently, the Project has demonstrated the importance of using EPA's 'Performance Curves' to assess BMP performance[2] causing EPA R1 to reprioritize expectations for performance assessment of these Cape Cod BMPs. Specifically, priority emphasis will shift to the Chatham BMP where site conditions are less constrained. In addition, the multifaceted complexities associated with using ISCO samplers for collection of water quality samples has led EPA R1 to reconsider the practicability of using ISCOs for water quality sampling. The Project goal was to acquire and employ state-of-the-art sensors for water quality measurements and divest from ISCO-based WQ sample collection and wet chemical analysis. The data collected through this project can be used to assess the reliability and verification of performance curves for the BMP(s) (as appropriate).

II. Performance Work Statement

Prior to initiation of activities, EPA coordinated with UNHSC and each municipality to obtain **access agreements** for UNHSC to access and perform work at each site. All work described herein is presumed to be within the scope of EPA's existing Memorandum of Understandings (MOU) with each municipality (whether in draft or final form; signed or unsigned) and complies to the extent possible with the EPA Performance Work Statement.

Task 0. Work Plan and Budget Development

UNHSC prepared a detailed work plan and budget response to the requested work scope describing its proposed approach to completing all the tasks in this PWS. Its response included a description of all assumptions and contingencies made by the Contractor (UNHSC), a budget, proposed schedule (including a list of deliverables with due dates), and a description of proposed staff.

Task 0 deliverables included:

---

[1] Information on these BMPs, including Construction As-Built Plans, may be found at https://www.epa.gov/snecwrp/cape-cod-stormwater-best-management-practice-bmp-retrofits-control-nitrogen.

[2] Refer generally to Attachment III of Appendix F of EPA's 2017 New Hampshire Small MS4 General Permit, located at https://www3.epa.gov/region1/npdes/stormwater/nh/2017-appendix-f-sms4-nh.pdf.

- This plan and budget is part of the official record with EPA.

Task 1. Project Management and Administration

UNHSC initiated a Project Kick-off Teleconference with the project team.

Following the Kickoff Teleconference, UNHSC provided for monthly conference calls or as necessary to keep the project team updated as to the status of the project.

Task 1 deliverables included:

- Kickoff teleconference with project projects
- Monthly Conference Calls or as necessary

Task 2. Modification of QAPP

For this Task, UNHSC modified the original Quality Assurance Project Plan (**QAPP**) EPA had developed for the Project to reflect and outline the state-of -the-art monitoring approach. The QAPP is provided as a separate attachment to this Final Report. QAPP modification required submittal to the Contracting Officer Representative (COR) for the project who coordinate with UNHSC and ultimately was approved by the EPA Region 1 Quality Assurance Unit (QAU), Office of Environmental Measurement and Evaluation (OEME). No data or results were collected prior to the QAPPs approval in June of 2020.

Task 2 deliverables included:

- A new approved QAPP for UV-Vis *in-situ* monitoring was developed and submitted named "2020 06 22 - EPA Chatham UV-Vis QAPP - FINAL.pdf"
- Approved QAPP is included as an appendix.

Task 3. Rehabilitation Maintenance and Assessment of Barnstable (Hyannis) BMP

Task 3 entailed rehabilitation maintenance of the Hyannis BMP aerobic zone (Task 3A) and investigations of changing water elevations due either to rising sea levels or potential groundwater infiltration into the BMP (Task 3B), assessment of the BMP for climate resilience (Task 3C) and a performance monitoring update for the program (Task 3D).

Task 3 deliverables included:

- Monitoring, analysis, and findings are reported in the Final Report for Tasks 3-5
- Final Report for Tasks 3-5 is included as the primary deliverable.

Task 3A. Rehabilitation Maintenance of BMP Aerobic Zone

The Hyannis BMP is under-performing hydraulically due to clogging and excessive vegetative growth of one or more dominant plant species (e.g., Typha, phragmites) in the upper / aerobic zone. This zone requires rehabilitation maintenance to remove the vegetation and modify the zone with appropriate soil and a drought-tolerant low-maintenance grass (similar if not identical to the grass used for the Chatham BMP).

Results are included in the final report for tasks 3-5.

Task 3B. Investigation of Effect of Hydraulic Gradient (Groundwater)

The BMP is likely exhibiting short-circuit infiltration of groundwater, most likely occurring (a) because of groundwater elevations in exceedance of the BMP liners and/or (b) at the 'interface' of the liners with the inlet and outlet structures. For this Subtask, UNHSC investigated whether and to what extent changing water elevations (e.g., tidal, groundwater) may be affecting BMP performance.

Results are included in the final report for tasks 3-5.

Task 3C. Investigation of Effect of MS4 Baseflow

The presence of base flow in the municipal separate storm sewer system (**MS4**) has made application of the SGW technology more complex. For this task, UNHSC assessed and estimated the effects of the MS4 baseflow on BMP operation and performance and recommend operational and/or management approaches for the baseflow.

Results are included in the final report for tasks 3-5.

Task 3D. Climate Resilience

New England and the lower Cape have experienced some very large storm events. UNHSC reviewed the As-Builts and Operation and Maintenance (O&M) Plans (which already contemplates management approaches for larger storms) and developed a best approach for operating the BMP during large storm events.

Results are included in the final report for tasks 3-5.

Task 3E. Performance Monitoring Program Update

Once Subtasks 3A thru 3D were completed, UNHSC modified the monitoring program for the Hyannis BMP.

Results are included in the final report for tasks 3-5.

Task 4. Performance Monitoring Program Update: Chatham

The original work scope for construction of the BMPs incorporated provisions for monitoring of the BMPs under an assumption that performance data would be useful to EPA and its stakeholders, and for providing data for improving EPA's BMP Performance Curves. Accordingly, EPA provisioned each BMP with inlet and outlet monitoring structures and related flow and water quality monitoring equipment.

For this Task and in general conformance with the updated and approved QAPP UNHSC assumed primary responsibility for performance assessment monitoring using realtime optical UV sensors.

Results are included in the final report for tasks 3-5.

Task 4 deliverables included:

- Monitoring, analysis, and findings were reported in the Final Report for Tasks 3-5
- Results are included in the final report for tasks 3-5.

Task 5. Technical Support Document

An underlying assumption for EPA's role in a project to demonstrate and showcase innovative stormwater controls for nitrogen is the transfer of 'lessons learned' to document and facilitate practitioner understanding and appreciation for the controls. To this end UNHSC developed a Technical Support Document (**TSD**) to summarize the salient aspects of the Project for technical transfer, including BMP design, construction and performance with an emphasis on those elements that should be essential to the transfer of the technology to other practitioners. The TSD has been formatted to existing TSDs that have already been developed for EPA's webpages.

The TSD is included in the final report for tasks 3-5.

Task 5 deliverables included:

- TSD included in the Final Report for Tasks 3-5

IV. Deliverables

Deliverables are included in this final report and its associated appendices

IV. OPTION PERIODS

Because monitoring of the Chatham and Hyannis best management practices will require time to establish a baseline of performance data, the project schedule is based on completing the specified work by one year from **task order issuance (the base year**) with four (4) additional one-year **option periods** (OP) for continuance of monitoring activities. UNHSC is prepared and ready to continue additional option periods at the discretion of EPA Region 1 guidance.

Option Period 1 thru 4

UNHSC provided a reasonable budget estimate for continuation of monitoring activities for the Chatham BMP over the course of four (4) OPs, each one year in duration. For this effort, UNHSC assumed for the provision for a minimum of seven (7) qualifying storm events over the course of a given OP. UNHSC has also provided a fixed cost line item potential modifications for the Hyannis BMP in the event work can continue.

The budget estimate of for continued monitoring for the Chatham BMP is included as an appendix.

The budget estimate for repairs of the Hyannis BMP is included in appendix F.

Appendix: Approved QAPP

Quality Assurance Project Plan (QAPP)
for
Performance Assessment Monitoring of Green Infrastructure Stormwater Best Management Practice Retrofit Constructed on Cape Cod for the Control and Treatment of Nitrogen Utilizing In-Situ Ultraviolet-Visual Spectroscopy

Prepared by:
UNH Stormwater Center
35 Colovos Drive
Durham, NH 03824

68HE0119P0031
Date: January 28, 2020

Project Co-Manager: UNH Stormwater Center	(Dr. Thomas P. Ballestero)	(Date)
Project Co-Manager: UNH Stormwater Center	(Dr. James Houle)	(Date)
Quality Assurance Officer: UNH Stormwater Center	(Daniel Macadam)	(Date)
Lead PI and COR: EPA Region 1	(Ray Cody)	(Date)
Quality Assurance Officer: EPA Region I	(Bryan Hogan)	(Date)

2.0 TABLE OF CONTENTS AND DOCUMENT FORMAT

2.1 Document Control Format

The document control format is shown in the upper left-hand corner of each page of this document.

2.2 Document Control Numbering System

A document control numbering system for all copies of this QAPP was not used because this project is of a small scale. The people who will receive copies of the QAPP are listed in Table 1 in Section 3.0.

3.0 DISTRIBUTION LIST

Table 1 presents a list of people who will receive the approved Quality Assurance Project Plan (QAPP), the QAPP revisions, and any amendments. A project-personnel sign-off sheet is included as the Title and Approval page in this draft. All people related to the project will indicate they have read the QAPP before completing any analysis work on this project.

Table 1: QAPP Distribution List

QAPP Recipient Name	Project Role	Organization	Contact Information: Telephone Numbers and email Addresses
Thomas P. Ballestero	Project Co-Manager	UNH Stormwater Center	(603) 826-1405 tom.ballestero@unh.edu
James Houle	Project Co-Manager	UNH Stormwater Center	(603) 862-1445 james.houle@unh.edu
Daniel Macadam	Project Quality Assurance Officer	UNH Stormwater Center	(603) 862-4024 daniel.macadam@unh.edu
Ray Cody	Project Manager	EPA Region 1	617) 918-1366 cody.ray@epa.gov
Bryan Hogan	EPA Region I Quality Assurance Officer	EPA Region 1	(617) 918-8634 hogan.bryan@epa.gov
Robert Reinhart	Chief, EPA Quality Assurance Unit	EPA Region 1	(617) 918-8633

FOREWORD

This Quality Assurance Project Plan (QAPP) has been prepared for use during the University of New Hampshire Stormwater Center (UNHSC) and the United States Environmental Protection Agency Office of Research and Development's research activities for the project "Performance Assessment Monitoring of Green Infrastructure Stormwater Best Management Practice Retrofit Constructed on Cape Cod for the Control and Treatment of Nitrogen Utilizing In-Situ Ultraviolet-Visual Spectroscopy". This QAPP has been prepared in accordance with EPA Guidance for Quality Assurance Project Plans (EPA, 2002).

4.0 PROJECT ORGANIZATION

4.1 Project Responsibilities and Communication Pathways

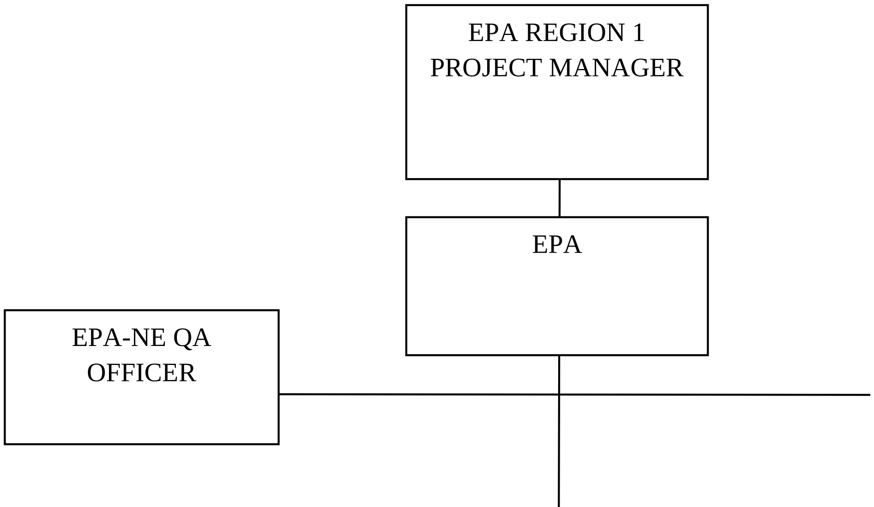
Dr. Thomas P. Ballestero is the UNHSC Director and will act as the Project Co-Manager for the project. Dr. Ballestero is responsible for coordinating specific details of the project and ensuring that the work completed by the UNHSC meets the scope and objectives of the project. Dr. Ballestero will coordinate all aspects of the project including the sampling surveys, data analysis, report preparation, and budget oversight. He will also work closely with all interested parties to formulate an effective sampling plan and solicit feedback regarding sampling efforts.

Dr. James Houle is the UNHSC Program Manager and will act as the Project Co-Manager for this project. Dr. Houle will assist Dr. Ballestero in all responsibilities listed above as well as work closely with the UNHSC Project Quality Assurance Officer in all data generation, data quality, and data analysis efforts.

Daniel Macadam is the UNHSC Quality Assurance (QA) Officer. His primary responsibility will be to ensure that data collected throughout this investigation meet the quality objectives set forth in this QAPP. During the study he will be responsible for conducting analyses according to the procedures in this QA Project Plan, identifying any non-conformities or analytical problems, and reporting any problems to the Project Co-manager. At the end of this study, the QA Officer will check, analyze, and compile all QA/QC records and documentation. The QA Officer will be responsible for a memorandum summarizing any deviations from the procedures in the QA Project Plan and updating this QA Project Plan as necessary to reflect any changes. The UNHSC Quality Assurance Officer will also be responsible for summarizing the results of the QA/QC tests and whether the reported data meet the data quality objectives of the project. The UNHSC Quality Assurance Officer, in conjunction with the UNHSC Project Co-manager, will also be responsible for training any UNH staff participating in the assessment, in the applicable sample collection and water quality monitoring techniques required as outlined in this proposal. Field collections, field measurements, and data analysis as described in the work plan will be performed by the UNHSC.

The principal users of the data from this project will be the UNHSC and EPA New England. Project results may also be of interest to co-occurring projects not covered by this QAPP, including the study of water quality impacts due to the implementation of low-impact development best management practices in highly urbanized settings.

Figure 1: Organizational Chart outlining the parties involved in this investigation and the communication pathways.



EPA-QA

UNHSC
PROJECT CO-MANAGERS
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UNHSC QA OFFICER/
LAB MANAGER
Daniel Macadam
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UNHSC FIELD SAMPLING TEAM
UNHSC Staff

4.2 Modification to Approved QAPP

The QAPP will be reviewed annually. If the sampling design, sample collection procedures, or data assessment and reporting change significantly, the UNHSC Project Co-manager will consult with QA Coordinators to submit modifications to EPA New England for approval.

4.3 Personnel Qualifications and Experience

Table 2 displays the personnel credentials of the project team. Responsibilities have been discussed in more detail above.

Table 2: Personnel Qualifications and Experience

Name and Affiliation	Responsibilities	Qualifications
Dr. Thomas P. Ballestero, PE UNH Stormwater Center	Project Co-Manager/ UNHSC	Director UNH Stormwater Center
Dr. James Houle UNH Stormwater Center	Project Co-Manager/ UNHSC	Program Manager UNH Stormwater Center
Daniel Macadam, EIT UNH Stormwater Center	UNHSC QA Officer	Site Facility Manager Research Engineer UNH Stormwater Center
UNHSC Student Technicians	Lab and Field Support	Trained by Project Co-manager and Facility Manager

(Based on Worksheet #7 (EPA, 2012))

4.4 Training Requirements/Certification

Table 3 displays the project activities that require some level of training and the location where the training records will be compiled. UNHSC field team members are well trained in stormwater sampling, sample analysis, instrument deployment, data collection, and record-keeping.

Table 3: Special Personnel Training Requirements Table

Project Function	Description of Training	Training Provided by	Training Provided to	Location of Training Records
Stormwater Control Data Collection	Measuring influent & effluent flows	James Houle & Daniel Macadam	UNHSC Field Team Members	UNHSC Laboratory

(Based on Worksheet #8 (EPA, 2012))

5.0 PROBLEM DEFINITION & BACKGROUND

This section documents the project planning, identifies the environmental problem, defines the environmental questions that need to be answered, and provides background information.

5.1 Introduction

EPA has retrofitted existing stormwater discharges in the Towns of Barnstable and Chatham, MA, by constructing innovative green infrastructure (GI) subsurface gravel wetland BMP retrofits as a demonstration for control of nitrogen pollution in stormwater discharges. EPA is coordinating with the Towns of Barnstable and Chatham to conduct monitoring of the BMPs to assess their overall performance for treating nitrogen. The work conducted as part of this project may have broad applicability throughout New England.

A project for design and construction of a stormwater BMP to control and treat nitrogen aligns with EPA priorities. These include selecting sites that are consistent with TMDLs and the Section 208 Water Quality Plan Update, promoting the appropriate application of GI, using technologies that improve stormwater infiltration, lead to reductions in runoff volume and peak volume discharge, improving water quality, and potentially reducing combined sewer overflow (CSO) events (if locations are in a CSO area). Other important objectives include engaging local departments of public works personnel in GI installation techniques, operation and maintenance practices, and for assistance in monitoring the physical and water quality parameters that help determine BMP performance.

This plan describes the field and QA program for assessing the overall performance of the BMPs for treating nitrogen, including the objectives, responsibilities, and the field and laboratory tasks for this phase of the Project.

This project will focus on the use of technologies and methods from previous freshwater and marine applications of UV-Vis spectrophotometry sensors to monitor stormwater pollutant concentrations.

5.2 Background and Objective

The specific objective of this GI implementation demonstration and education and outreach project was to design and construct two GI stormwater BMP retrofits for the control and treatment of nitrogen on Cape Cod, Massachusetts. An additional objective is to assess and determine the performance of the BMPs, in part to help develop and/or refine performance curves for the BMPs.

Construction of the BMPs occurred in spring, summer, and fall of 2015. The retrofits have been provisioned for monitoring the BMP inflow and outflow. Discharge of stormwater to the BMPs did not begin until early spring of 2016, in part to allow BMP plantings to establish. Moreover, once discharge to the BMPs occurs, additional time is required to establish a robust anaerobic microbe population within the BMP. Consequently, BMP monitoring is expected to occur in the fall of 2016 at the earliest.

The goal is to monitor the BMPs for approximately 8 or more rain events of various intensities and depths over the course of a sampling season. Core monitoring for performance sampling will consist of flow and in-situ, real-time UV-Vis monitoring for regression outputs of nitrate (NO_3-N), total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS).

6.0 PROJECT / TASK DESCRIPTION AND SCHEDULE

6.1 Task Description

The contractor shall achieve two (2) primary goals:

1) The successful demonstration of the site's real-time pollutographs using the UV-Vis sensor and previously developed UNHSC prediction models.
2) Evaluation of the employed monitoring methodology for stormwater controls for regional and national applicability.

The contractor shall complete the following tasks:

Task 1 – Quality Assurance Project Plan (QAPP) / Work plan:
Develop QAPP and work plan documenting all tasks of the project in detail. The QAPP and work plan must be submitted and approved by EPA prior to the start of sampling activities. Documentation shall also include methods for sampling and analytical work with a projected schedule of activities. Selected sampling sites shall be identified in the work plan both in the description and geographic location for EPA review of land use composition.

Task 2 – Site Monitoring:
Sampling of selected sites shall be conducted through the collection of real-time (in-situ) monitoring via instrumentation. Monitoring shall be conducted so as to create a sample database containing a minimum of 8 storm events (runoff), preferably spread across spring, summer and fall seasons. Monitoring shall include the following sub-tasks:

Task 2a: Real-Time UV-Vis sensor monitoring of stormwater runoff. Provide raw real-time UV absorbance and processed spectral data (absorbance from 220.0 nm to 720 nm at 2.5 nm intervals). The UV-Vis sensor shall be procured (see Task 5) and sensor specifications and model will require EPA approval. The selected sensor package shall include all software and accessories required for operation. It will be capable of the following measurements: NO3-N, TN, TP, TSS, as well as raw UV absorbance data. The sensor system shall be programmed to collect recorded measurements at five (5) minute intervals (maximum) during storm events.

Task 2b: Stormwater flow will be measured using Teledyne ISCO Signature® Flowmeters (or equivalent) in combination with Thel-mar volumetric weirs (or equivalents), installed TRACOM Large 60° V Trapezoidal Flumes, and/or HOBO U20L water level loggers as appropriate.

Task 2c: Rainfall depth shall be monitored throughout the study period using rain gauges (e.g. ISCO 674 rain gauge or equivalent). Rain gauges shall be provided by the contractor. As a backup, the Chatham Municipal Airport records precipitation and barometric pressure; the airport is located 1.28 miles from the site.

Task 3 – Data processing and analysis:

Task 3: NO3-N, TN, TP, and TSS, and continuous data for storm events shall be generated using globally-calibrated regressions available from the in-situ spectrometer manufacturer and UNHSC calibration.

Task 4 - Reporting:

Distribution of all reporting products shall be communicated to EPA via the COR.

Task 4a: Interim Progress Reporting:

Interim reporting shall include the following: (1) data report indicating accomplishments in-detail), discussion, and data reporting to date including applicable QA samples as available. (2) Presentation to workgroup (at Region 1 office – or pre-arranged meeting location) including accomplishments to date. These reporting products will occur on a schedule every 6 months.

Task 4b: Final Reporting & Data Delivery:

Two versions of a final report shall be provided at the conclusion of the period of performance (EPA Grey/Internal report and manuscript).

1) A draft of the grey final report shall be submitted (12) weeks prior to the contract period of performance conclusion date for review by EPA. The grey report shall consist of the following; Overview, details of system / monitoring design and analysis/results (with applicable QA control reporting), problems encountered, detailed financials / full accounting (including all expenditures throughout the period of performance). This grey report shall be submitted in Microsoft Office format(s) (i.e. Word, Excel, etc.). All data, field notes, lab notes, analytic reports in both raw and summarized formats shall be submitted as part of the grey report

package as Appendices (ORD is now required to compile raw and analyzed data for reporting as part of its Scientific Data Management Policy – as mandated by Open Government Initiative). The grey final report shall be submitted (3) weeks after receipt of EPA comments on the grey draft report (report comments will be returned in written format and may also require conference call with the contractor – as needed).

2) Draft manuscript, ready for peer review for a journal publication (Journal to be selected at a later date – TBD) 12 weeks prior to the conclusion of the contract period of performance with the final peer review ready copy due within (3) weeks post receipt of EPA comments on draft copy.

Task 5 – Equipment Purchases and Management:

Task 5a: Purchase of UV-VIS spectrophotometry instrumentation. The contractor shall purchase two (2) UV-VIS instrument packages with the following specifications:

- Measurement parameters: TSS, Turbidity, NO3-N, COD, BOD, TOC, DOC, UV254, NO2-N, fingerprinting, temperature
- Spectral range: 220-720 nm with variable optical path length options (0.5 mm – 15mm)
- Adjustable open path length
- Designed to operate in surface water, groundwater, drinking water and or wastewater
- Stable readings in long term
- Automatic lens cleaning
- Flow cell capable
- Width < 2 inches
- Must be able to provide raw spectral data
- Flow velocity 3 m/s (maximum)
- Accuracies: NO3-N ± 2%, COD-KHP ± 2%

The contractor shall seek EPA review and approval of UV-Vis instrument procurement. The contractor shall be responsible for the calibration and maintenance of UV-Vis instrument packages and shall provide calibration and documentation notes regarding calibrations, maintenance, and quality control checks.

Task 5b: The contractor shall be responsible for the operation, maintenance, and documentation of all EPA equipment made available for use under this contract. The contractor shall document and provide for review by EPA all: calibration records, maintenance records, and any other documentable incidents relative to the equipment made available for use under this contract. The contractor shall notify EPA of any instrumentation problems (via regularly scheduled reports) and any incidents involving loss, theft, or damage (in writing) immediately. In the event of loss, theft, or damage (including vandalism) the contractor shall provide EPA with a documented record of the event(s) in writing.

6.2 Project Schedule

Delivery dates are based on a one (1) year Period of Performance, more years of monitoring can be added as necessary as an extension of the contract. It is the contractor's responsibility to notify the COR of any scheduling changes/conflicts, technical difficulties, or any other project condition which may affect the delivery dates of products within five (5) business days of realization of change in working condition or project status. Table 4 summarizes the tasks listed above and includes the projected schedule to complete them.

Table 4: Anticipated Project Schedule.

Task	Anticipated Dates of Initiation and Completion	Responsible Persons / Group	Products
QAPP Development	March 1, 2020	UNHSC Project Manager and UNHSC QA Officer	Draft QAPP
QAPP Revisions and Approval	Within one week of EPA comments	UNHSC and EPA QA Officers	QAPP
1st 6-month progress report (written / teleconference or on-site)	March 30, 2020	UNHSC Project Manager and UNHSC QA Officer	Progress Report
Monitoring	July 1, 2020 - October 9, 2020	UNHSC Project Manager and UNHSC QA Officer	
Calibration, Cleaning, and Downloading data	Quarterly or as needed	UNHSC QA Officer	
Annual Report	October 15, 2020	UNHSC Project Manager and UNHSC QA Officer	Year 1 Annual Report
Periodic meetings/conference calls	As needed; technical workgroup requests through the EPA	UNHSC and EPA QA Officers	

(Based on Worksheet #16 (EPA, 2012))

** Products will be delivered in both electronic and hardcopy formats with the exception of raw data which can be provided in electronic format only.

** Progress reports should be brief and contain budget detail. A presentation to the technical group may accompany this product.

6.3 Summary of Analysis Tasks

Table 5 presents a breakdown of who will be responsible for sample analysis and fieldwork.

Table 5: Analytical services table

Real-time Parameters	
UV Absorbance, processed Spectral data to water quality parameters	s::can spectro::lyser, detector UV-Vis 220-720mm, 5mm QUARTZ window UNHSC QA Officer
Flow	ISCO Signature® Flowmeter with Parshall flume UNHSC QA Officer

Precipitation	ISCO 674 Rain Gauge or equivalent UNHSC QA Officer

7.0 DATA QUALITY OBJECTIVES FOR MEASUREMENT DATA

7.1 Project Data Quality Objectives (DQOs)

The data quality objective is to produce precise and accurate data, which is representative of true field conditions. These DQOs were developed for *Performance Assessment Monitoring of Green Infrastructure Stormwater Best Management Practice Retrofit Constructed on Cape Cod for the Control and Treatment of Nitrogen Utilizing In-Situ Ultraviolet-Visual Spectroscopy*. And are based on statistical confidence and numeric thresholds generated through previous EPA funded efforts (UNHSC, 2019). The QA Officer reviews all data for conformance with expected parameters. The criteria for performance measures are described below.

Precision

The UV-Vis instrument will be tested and calibrated quarterly or sooner. Known concentrations of analytes, as well as pure water obtained through reverse osmosis (RO), will be measured under field conditions before cleaning and calibration. For data to be precise and credible, measurements should return at or below the desired relative percent difference (RPD).

Precision goals vary according to specific pollutants but should remain within a threshold of 20% RPD. The RPD will be calculated as follows:

$$RPD = \left[\frac{|x_1 - x_2|}{\frac{x_1 - x_2}{2}}\right] \times 100\%$$

Where the numerator is the absolute value of the difference between duplicates, and the denominator is the average value.

Representativeness

Representativeness is a measure of the degree to which data accurately and precisely represent a characteristic of a population at a sampling point or for a process condition or environmental condition. Representativeness is achieved through the consistent use of documented procedures for field monitoring.

Comparability

The UNHSC assessment methodology is based on those developed in a previous study titled *Utilizing In-Situ Ultraviolet-Visual Spectroscopy to Measure Nutrients and Sediment Concentrations in Stormwater Runoff* (UNHSC, 2019). The final report released in 2019 details the assessment and analysis of the UV-Vis in-situ data to conventional auto-sampler water samples analyzed using standard laboratory methods.

Completeness

Completeness is a measure of the amount of valid data obtained from a measurement system, expressed as a percentage of the number of valid measurements expected to be obtained under normal conditions. For analytical methods, completeness is based on the number of valid results generated over a specific period compared to the number of results expected. This project takes measurements at an interval of five (5) minutes. Completeness of the real-time data is judged by the data covering a minimum of 75% of the storm event.

7.2 Experimental Design and Rationale for Design

The primary research objectives are to characterize the control performance using global calibration equations and UNHSC calibrations for NO3-N, TN, TP, and TSS using data reported by the UV-Vis spectrometer probe. Monitoring locations will be selected based on the previous control instrumentation and desire to observe control performance and loading data. UV-Vis data will be evaluated for completeness after each storm event or several events as judged by the QA Officer.

7.3 Field Sampling Rationale

The performance evaluation shall be based on data from a minimum of 8 storm events. Storm event criteria have been adopted from, and are in compliance with, the NPDES Storm Water Sampling Guidance Document (EPA, 1992) and dictate the following:

- The depth of the storm must be greater than 0.1-inch accumulation.
- The storm must be preceded by at least 72 hours of dry weather.
- If possible, the total precipitation and duration should be within 50 percent of the average or median storm event for the area.

Precipitation and flow measurement records are maintained for all events that occur during the study period. If an event fails to meet the criteria for a qualified sampling event, the samples collected will not be analyzed. Only data from qualified sampling events shall be used in the calculation of pollutant loads and pollutant removal efficiencies.

Additionally, for an event to be considered a qualified sampling event, the following conditions will also be met:

- Flow shall be successfully measured and recorded over the duration of the runoff period.

7.4 Rationales for Parameters Measured and Samples Taken

Table 6 summarizes the various rationales for including the different measurements.

Table 6: Sampling Parameters and Rationale

Sampling Parameters	Rationale
Total Suspended Solids (TSS)	TSS reflects the amount of undissolved solids that persist in the water column. TSS is a general water quality parameter and will provide a good overall indication of stormwater pollution.
Total Nitrogen (TN)	Total Nitrogen is the sum of inorganic nitrogen (NH3, NO3, NO2) and TKN (total Kjeldahl nitrogen).

Nitrate (NO3)	Nitrate (NO_3) is one species of Dissolved Inorganic Nitrogen (DIN). DIN is the limiting nutrient in coastal water. DIN is the sum of nitrate, nitrite, and ammonia and can be used to determine a saltwater body's trophic state. In a previous study using UV-Vis (UNHSC, 2019), nitrite and ammonia were rarely measured at a level above the detection limit in stormwater runoff.
Total Phosphorus (TP)	TP is the limiting nutrient in freshwater systems. Total phosphorus is the sum of phosphorus in all its forms and can be used to determine a freshwater body's trophic state.
Precipitation	Precipitation will influence the amount of overland runoff and groundwater recharge and can be correlated to nutrient and sediment loading episodes.

8.0 MONITORING METHOD PROCEDURE REQUIREMENTS

8.1 Sampling Procedure

All monitoring units are weatherproof or sheltered to maintain manufacture operation specifications. All instruments are secured with locks to maintain instruments and data integrity.

Monitoring Locations
The two (2) monitoring locations at the BMP will be at the influent and effluent locations. The flow and in-situ real-time UV-Vis will be monitored at both influent and effluent locations. The UNHSC staff will install the instrumentation in locations with the highest chance of remaining submerged during an event, the wiping blade may move unconstructively, and flow backup and fowling are judged to be unlikely. The installation locations must also be easily accessible and safe for access to be removed, tested, and calibrated by staff. Possible locations for the UV-Vis instrument include in the pipes connecting structures near the flume or in the inlet and/or outlet pipes.

Data Evaluation
Data analyses include a range of approaches. Analyses include:

- Characterization of storm events
- UV-Vis spectral data and flow
- Pollutant loading graphs based on global calibration equations and UNHSC regressions

Real-time recording with the UV-Vis spectrometer at 5-min intervals will characterize the absorbance of visible ultra-violet wavelengths over the duration of the storm event. Through the use of the global calibration equations provided by the manufacturer, the changes in concentrations of NO3-N, TN, TP, and TSS can be observed over the course of the event. The UNHSC regression models will also be used as with the Partial Least Squares (PLS) models for the mentioned parameters as published through previous EPA funded efforts (UNHSC, 2019). The PLS regression models were developed with statistical analysis of ultraviolet visual absorbance from multiple spectra from the UV-Vis probe and concurrent runoff grab samples analyzed using current laboratory methods. See UNHSC, 2019 for more details.

8.2 Monitoring SOP Modifications

It is not expected that any modification of monitoring will occur. However, corrective action in the field may be needed if the strategy needs to be modified (i.e., monitoring additional locations other than those specified in the QAPP, not enough water sample to meet original requirements, etc.), or when sampling procedures and/or field analytical procedures require modification, due to equipment failure or unexpected conditions. In general, the field team may identify the need for corrective action on-site. The field staff, in consultation with the UNHSC Project Manager, will evaluate and suggest corrective action. The field team will implement corrective action. Any modifications/corrective actions will be noted on the field data forms. The UNHSC QA Officer will be notified as soon as possible and will provide the field team with any additional actions required to maintain quality assurance and control with respect to corrective actions. It will be the responsibility of the UNHSC Project Manager to ensure the corrective action has been implemented correctly and reported to the EPA New England QA Officer. If any of the aforementioned QA Officers have additional actions recommended to maintain quality assurance and control they will be implemented retroactively, if possible, and for any sampling events after the event that triggered the corrective action.

8.3 Cleaning and Decontamination of Equipment / Sample Containers

Prior to use, all instrumentation and tools will be vigorously cleaned with a phosphorus-free detergent (i.e., Alconox) and rinsed generously with distilled water. The UV-Vis has a wiper blade to prevent growth or debris buildup inside the measurement channel, but the instrument may be removed and thoroughly cleaned as described at the discretion of the QA Officer to prevent fouling of the instrument and subsequent data. Cleaning and calibration will be performed as described in the s::can spectro::lyser V3 Owners' Manual.

8.4 Field Equipment Calibration

Field equipment will be calibrated in accordance with the manufacturer calibration directions as listed below and as summarized in Table 7:

Table 7: Field Equipment Calibration Table

Equipment Name	Procedure and SOP Reference	Frequency of Calibration	Acceptance criteria	Correction action	Person Responsible
ISCO Signature® Flowmeter	Manufacturers recommendations	Quarterly or at each site visit	±0.005 ft	Clear bubbler line with compressed air. Recalibrate. If problem persists change filter and desiccant.	UNHSC QA Officer
s::can spectro::lyser	Manufacturers recommendations	Quarterly or at each site visit	±20% RPD	Clean instrument per manufacturer	UNHSC QA Officer

				instructions and re-calibrate.	

8.5 Field Equipment Maintenance, Testing, and Inspection Requirements

Field equipment will be maintained, tested, and inspected in accordance with the manufacturer directions as listed and summarized in Table 8. Procedures other than those specifically described in the QAPP for field monitoring and sample collection are outlined in the manufacturers' operation and maintenance manuals (ISCO and s::can). These include procedures for field instrument calibration, field equipment cleaning, operation and maintenance.

Table 8: Equipment maintenance schedule and instrument calibration schedule

Equipment Name	Operation	Frequency
ISCO 6712		
s::can spectro::lyser	Check/calibrate water levels	Bi-weekly
	Desiccant Air Filter replacement	Replace as needed
	Instrument Inspection (look for kinks in line, clogs, etc)	Replace if damaged
ISCO Signature® Flowmeter	Inspect pump tube, replace if worn	When necessary
	Check humidity indicator	When necessary
	Check controller's internal battery status and replace	Every 5 years

(Based on Worksheet #19 (EPA, 2012))

9.0 SAMPLE HANDLING AND CUSTODY

9.1 Sample Collection Documentation

A combination of field logbooks, field data sheets, and a consistent labeling protocol will help ensure sample authenticity, data integrity, and project completion goals.

9.2 Field Notes

The sampling team will complete field data logbooks and forms on-site at the time when measurements are made and the team is on site. Field logbooks will provide the means of recording the data collecting activities performed during the investigation. As such, entries will be described in as much detail as possible so that persons going to the site could reconstruct a particular situation without reliance on memory.

The logbooks will contain some, but not all, of the following information as is pertinent to each site visit:

- Date / Time Arrived and Time Left
- Sampling Site ID (w/ Location and Coordinates)
- Full Names of Field Team Members
- Additional Persons Present
- Weather Conditions Throughout Visit
- General Observations
- Transportation Details

- Equipment Employed and Calibrations
- Measurements Made
- Photos Taken

10.0 QUALITY CONTROL

Additional field QA/QC measurements will be provided to ensure the accuracy and precision of analytical results. For conventional parameters such as nutrients, a synthetic blind reference standard is prepared from known reagent grade standard solutions for measurement by the UV-Vis instrument during calibration and cleaning. These measurements will be taken before and after cleaning and calibration to observe and avoid future drift in the measurements. Known concentrations of analytes listed in Table 6, as well as pure water obtained through reverse osmosis (RO), will be measured under field conditions before cleaning and calibration as appropriate. These measurements will occur at the frequency listed in Table 4.

11.0 DATA ACQUISITION REQUIREMENTS

There are no non-direct measurements incorporated into this study.

12.0 DOCUMENTATION, RECORDS, AND DATA MANAGEMENT

12.1 Project Documentation and Records

UNH researchers keep daily field notes depicting the conditions at the field location where each sample is taken and other relevant information including, but not limited to the following:

- Date of event
- Time and duration of the storm event
- Size of the storm event
- Inches of rain and intensity
- Number of days since preceding storm event
- Total volume of runoff
- Condition of the drainage area prior to and during the event
- Chemicals, materials, equipment, or vehicles stored or handled in the drainage area
- Good housekeeping measures implemented prior to the event
- Upset, spills, or leaks in the drainage area, including the material or chemical
- Construction or maintenance activities in the drainage area

Hard copies and electronic copies of field notes and sample events are kept on file at UNH. Backups of electronic copies of our database and sampling event records are made weekly stored in two separate locations, backed up using cloud computing services, and backed up monthly on external hard drives. Laboratory data packages are delivered electronically and in hard copy to the UNH project manager. The data are reviewed by the QC manager, then filed and saved for at least five years after project completion and transferred to EPA.

12.2 Field Analysis Data Package Deliverables

Field analytical measurements will be generated on-site. Measurements will be recorded on field data sheets or in the case of multi-parameter Sonde data, digitally onto the computer data logger and these data will be transferred to an electronic spreadsheet (MS Excel) that is a part of the project-specific electronic database system. Entries into the spreadsheet will be compared against the field sheets by a second person as a quality check before it is appended to the project database. UNHSC QA officer will be responsible for cross-referencing data and ensuring accuracy.

12.3 Data Handling and Management

All data recorded for each sample is downloaded from the data logger quarterly or sooner. The project manager enters all data into Excel Spreadsheets (or equivalent) where all relevant graphs and calculations are made for each treatment unit per storm event. All results are checked for quality control prior to data analysis and/or reporting. A copy of the original records are archived at the UNHSC site by the QA Officer and backup copies of all electronic files are made weekly and stored on a cloud server (Box) in separate locations.

All rainfall data is downloaded from the data logger quarterly or sooner. Rainfall hyetographs are developed for each rain event. The hyetographs show rainfall amounts for the minimum increment of time (5 minutes) recorded by the gauge and a cumulative rainfall curve.

All flow data is downloaded from the data logger quarterly or sooner. A runoff hydrograph is developed showing flow rates during the monitoring period. Hydrographs show the start and end times for the rainfall event. In addition, the real-time water quality parameters are plotted under the storm event hydrograph.

Databases are maintained on the dedicated site computer by the UNHSC QA Officer. Retrieval of data can be accomplished by opening files on this computer and either printing hard copies, or by sending electronic files via e-mail. Copies of standard operating procedures (SOP’s), instrument manuals, and other protocols are maintained digitally on said computer and/or in 3-ring binders located at the UNHSC. SOP’s are reviewed annually or more frequently as changes are required. Multiple database backup procedures are initiated weekly and stored in two distinct locations in addition to storage in an external hard drive. Hardcopies of all reports are retained by UNHSC.

13.0 ASSESSMENTS AND RESPONSE ACTIONS

The QA Officer is responsible for evaluating the field assessment, stormwater run-off sampling, and water quality analysis throughout the project. Specifically, this includes during the initial training of field and monitoring protocols for the project. QA Officer is responsible for observing procedures to determine proper sampling and analysis is undertaken. Unanticipated problems with the procedures are addressed to avoid difficulties during subsequent sampling efforts.

EPA may implement, at their discretion, various audits or reviews of this project to assess conformance and compliance with the quality assurance project plan.

14.0 MANAGEMENT REPORTS

Biannual progress reports, as well as a final report, will be prepared by the UNHSC and submitted to EPA Contracts Officer Representative for distribution and review.

15.0 VERIFICATION AND VALIDATION REQUIREMENTS

A review of all data generated by this project is conducted by the UNHSC Project Manager. The completeness, transcription errors, and compliance with procedures are evaluated by comparison of tabulated results to what has been proposed in the original project proposal and this QAPP. The specific activities include the generation of data namely, flow measurements, precipitation amount, storm event duration, and water quality analytes. After each storm data download, hyetographs and hydrographs are reviewed to verify that specific storm and monitoring criteria have been met. Omissions of data in spreadsheets will trigger a search of raw datasheets, equipment maintenance, or re-sampling and re-analysis. If re-analysis is not possible or if data remain missing, invalid or otherwise affected entries will not be incorporated into the useable data sets. When results appear to be abnormal, all appropriate project participants will review the available data and discuss the problem in periodic meetings to attempt to identify potential problems in sampling or analysis.

16.0 VERIFICATION AND VALIDATION METHODS

The process by which data is verified involves one or more of the following:

1. The project QA officer will verify proper sample preservation and handling for completeness and consistency.
2. At the end of each field session, the QA officer will evaluate whether the data quality objectives of this plan are being met.
3. If discrepancies cannot be resolved, appropriate measures will be taken. These measures could include but are not limited to:
    a. Rejection and exclusion of data from reports with an explanation.

17.0 DATA USABILITY / RECONCILIATION WITH PROJECT QUALITY OBJECTIVES

Data is generated based on the quality objectives defined in this plan and verified according to Section 16. Limitations in the data will be clearly defined for potential end-users in all reports produced.

18.0 REFERENCES

EPA. (1992). *NPDES Storm Water Sampling Guidance Document, EPA 833-B-92-001*. Washington, DC: United States Environmental Protection Agency.

EPA. (2002). *Guidance for Quality Assurance Project Plans, EPA QA/G-5*. Washington, DC: United States Environmental Protection Agency.

EPA. (2006). *Guidance for the Data Quality Objectives Process, EPA QA-G4*. Washington, DC: United States Environmental Protection Agency.

EPA. (2012). *Uniform Federal Policy for Quality Assurance Project Plans*. Washington, DC: United States Environmental Protection Agency.

UNHSC. (2019). *Utilizing In-Situ Ultraviolet-Visual Spectroscopy to Measure Nutrients and Sediment Concentrations in Stormwater Runoff*. Durham, NH: University of New Hampshire Stormwater Center.

19.0 APPENDICES

19.1 Field Protocols for Installation and Operation of Flow Monitoring Equipment

Reference: 730 Bubbler Flow Module Installation and Operation Guide
Sample requirement: Collected instream connected to Thelmar Weir or fastened to base of pipe. The meter (Teledyne Isco Model 730 Bubbler Module) is linked to a Teledyne ISCO 6700 series data logger.

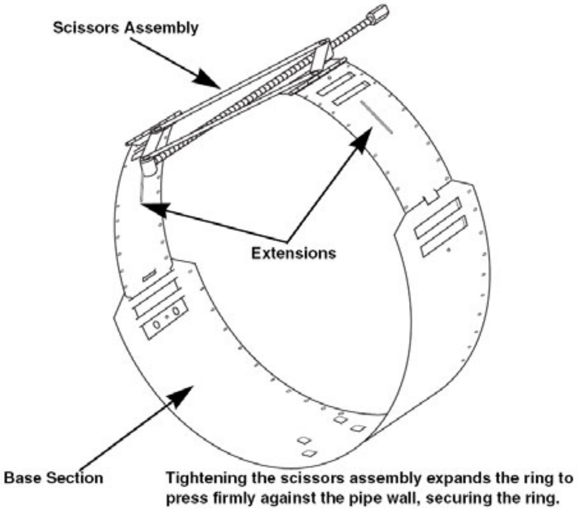
C.1 Installation
For pipes up to 15" (38.1 cm) in diameter, stainless steel self-expanding mounting rings (Spring Rings) are used. For pipes larger than 15" in diameter, Scissors Rings (Universal Mounting Rings) are used for probe installation.

C.1.1 Spring Rings: To install a spring ring, you compress the ring, slip it inside the pipe, and then allow it to spring out to contact the inside diameter of the pipe. The inherent outward spring force of the ring firmly secures it in place. A typical self-expanding mounting ring (with a probe mounted on it) is shown in Figure C-1.

Figure C-1: Spring ring installation

C.1.2 Scissor Rings: For pipes larger than 15" in diameter, Scissors Rings (also known as the Universal Mounting Rings) are used. This device consists of two or more metal strips that lock together with tabs to form a single assembly. There is a base section where the sensors are mounted, one or more extension sections (usually), and a scissors section at the top that expands the entire assembly and tightens it inside the pipe. The scissors mechanism includes a long screw that increases the width as it is tightened. The assembled rings fit pipe diameters from 16" to 80". Secure the unit in place by tightening the scissors mechanism with a 5/8" socket wrench or other suitable tool. Ring sections are .040" thick half-hard 301 stainless steel sheet see figure C-2 for a typical scissor ring installation.

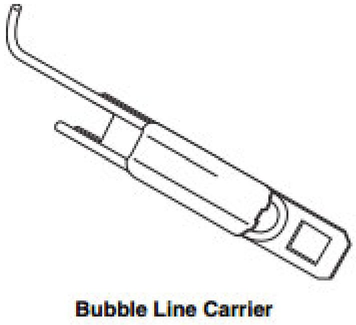
Figure C-2: typical scissor ring installation.



C.1.3 Installation Finalization

First attach the bubble line to the bubbler carrier assembly (Figure C-3). Then fit the carrier onto the mounting tables of the ring, making sure the tabs completely engage the slots in the carrier. This method of attaching the bubble line to the ring allows for easy removal in case service is needed later. Route the vinyl bubble line away from the carrier and along the spring ring's edge with holes. Secure the line in position by placing plastic ties through the holes and then locking them around the line. To prevent debris from collecting, attach the line so that it offers as little resistance to the flow as possible. Avoid loops or slack sections. Attach it neatly and closely to the spring ring.

Figure C-3: Bubble Line Carrier



C.2 Operation and Maintenance

The 730 Bubbler Flow Module have no user-serviceable parts. They are completely sealed to protect the internal components. The module will provide reliable readings over a long service life with a minimum of maintenance. Maintaining the module requires regular cleaning and keeping the desiccant active.

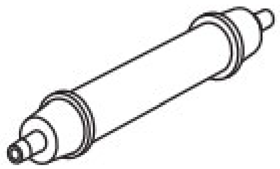
C.2.1 Changing the Desiccant

A cartridge on the side of the module dries the air inside the module and probe reference line (Figure C-4). It contains a silica gel desiccant with a color indicator that changes from blue to pink, or yellow to green, when saturated. Pink or green desiccant cannot remove moisture and must be replaced or reactivated. A saturated desiccator will let moisture into the bubbler system, which can cause several undesirable effects, including:

- The moisture may block internal tubing and cause reading errors.
- The air in many installations contains fumes that will form acids in the presence of moisture. These acids may corrode internal components.
- At temperatures near or below freezing, there could be permanent damage if ice forms inside the air pump.

To reactivate the desiccant, pour the desiccant out of the cartridge into a heat-resistant container. Never heat the plastic cartridge; it will melt. Heat the silica gel in a vented convection oven at 212° to 350° F (100° to 175° C) for two to three hours, or until the blue or yellow color returns. Allow the desiccant to cool and then refill the cartridge.

Figure C-4: Desiccant Cartridge



C.2.2 Bubble Line Maintenance

Periodically inspect the bubble line to make sure that it has not become kinked or damaged in any way. If you find damage to the bubble line, replace it. A leaking or obstructed line will cause inaccurate level readings and lower battery life. (The pump must run more frequently.) If you need to replace the bubble line, install a new line the same way you installed the original. Generally, the new line should be the same length as the old. If you replace the bubble line or if you change the outlet either by cutting off the tip or by installing a bubble line extension, you must recalibrate the level. Inspect the outlet of the bubble line regularly for any signs of clogging. Sediment or debris from the flow stream and algae can all clog the line.

If the line is blocked, you can either clean it out, or simply cut off the tip. If algae growth is a problem, consider using a copper bubble line extension. The copper salts formed on a copper line will prevent algae growth.

19.2 Operating Manual for s::can Spectrometer Probe

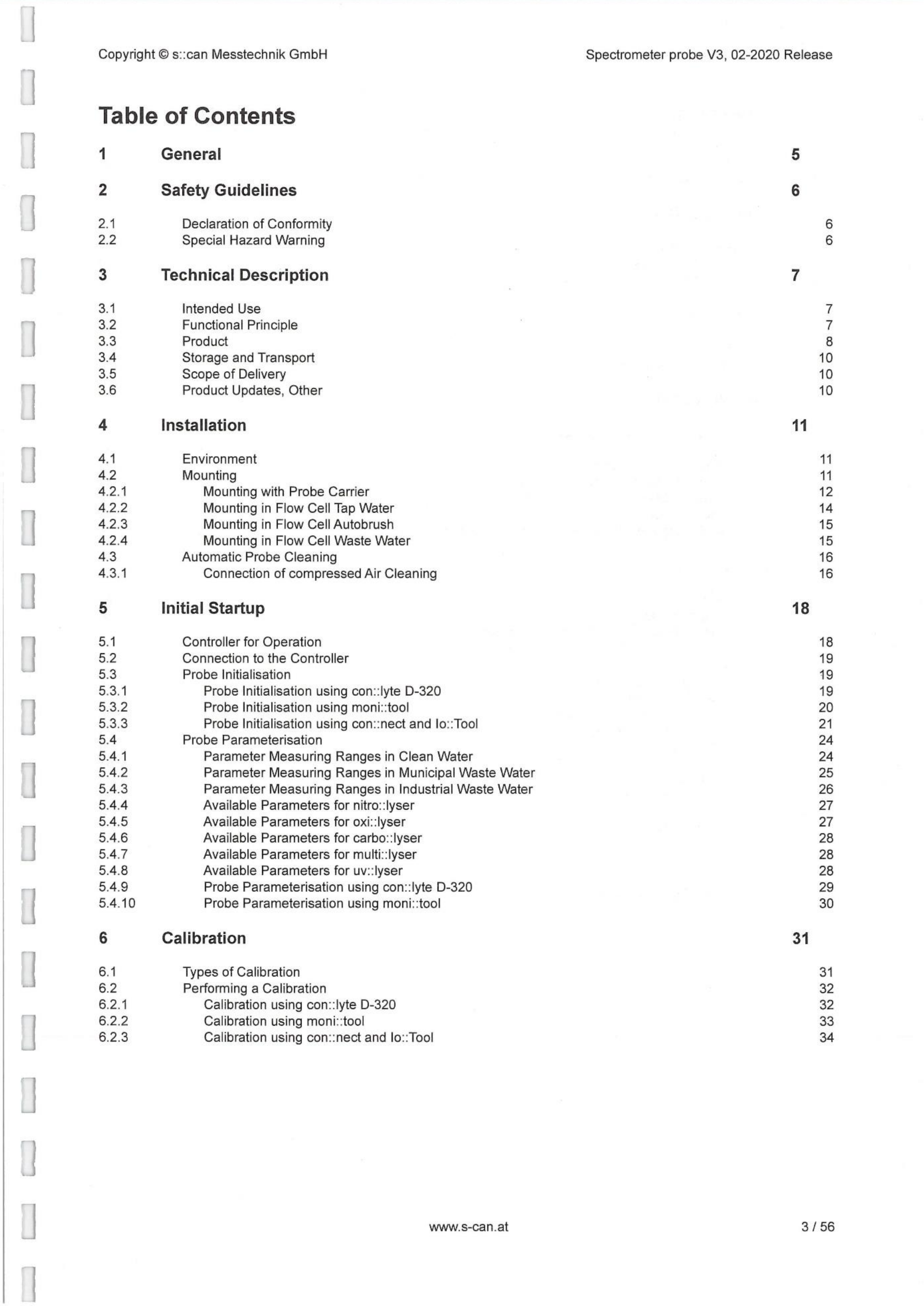
s::can
Intelligent. Optical. Online.

Manual

Spectrometer Probe V3

February 2020 Release

S-30-M



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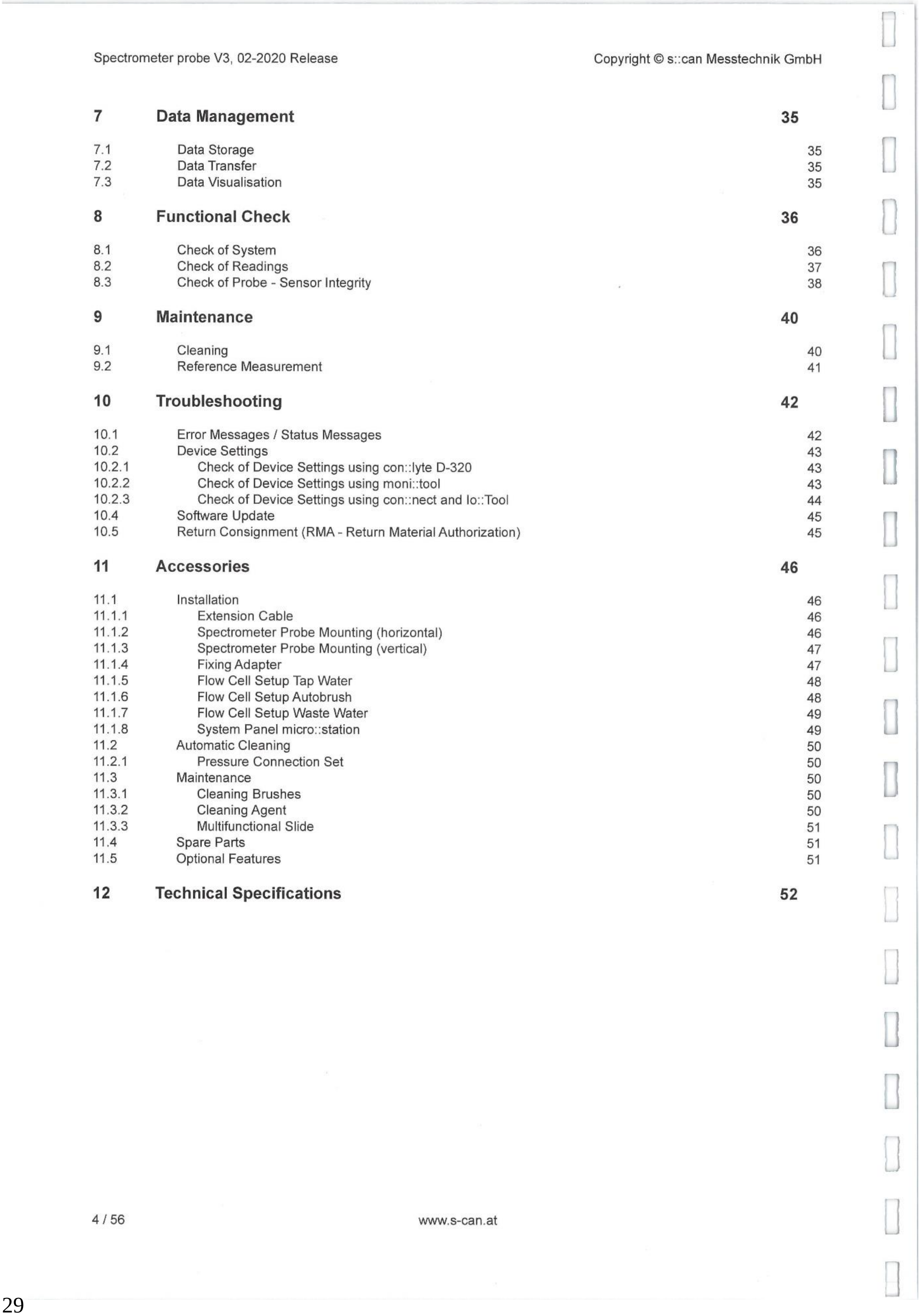


1 General

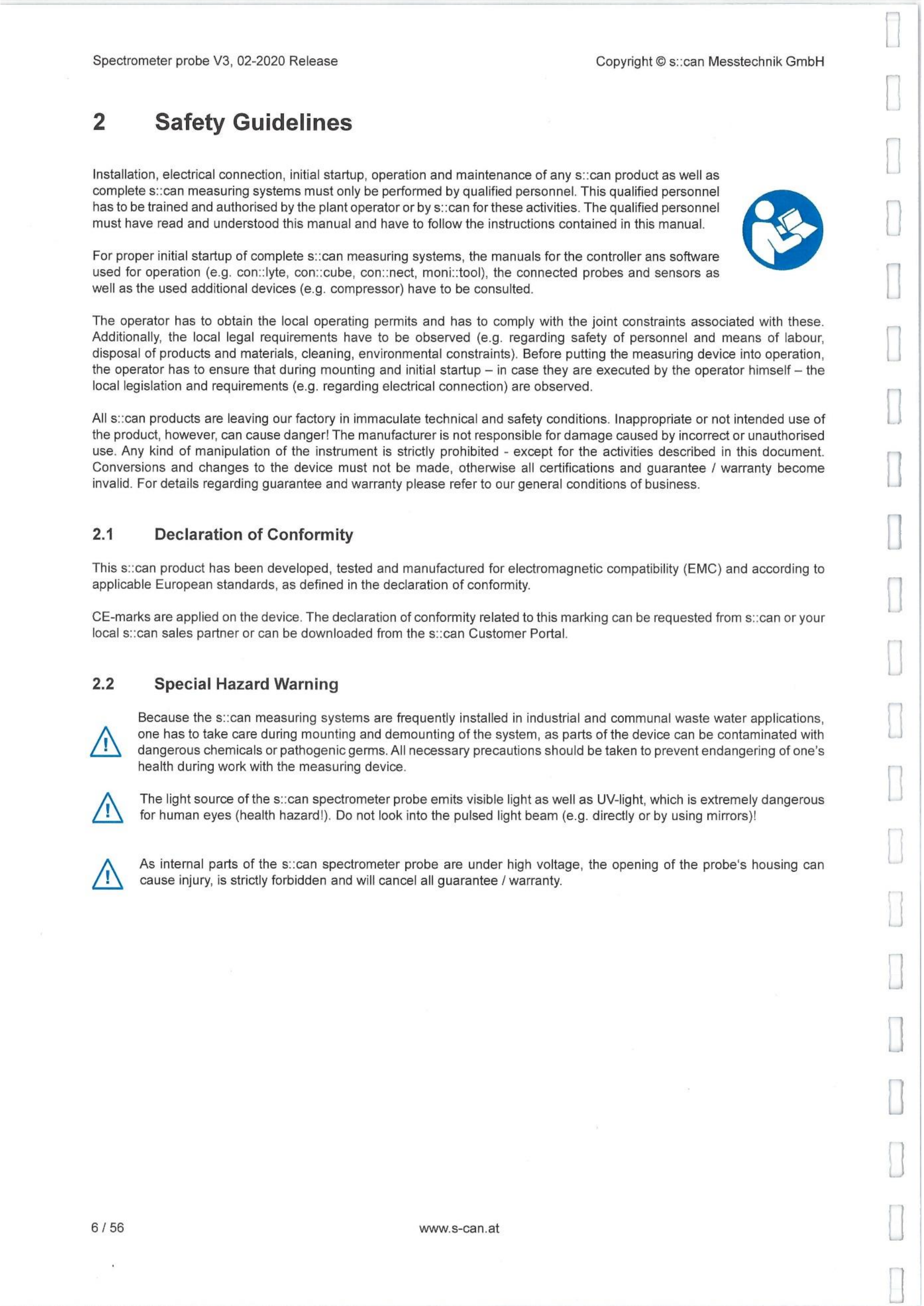
This manual contains, firstly, general information (chapter 1) and safety guidelines (chapter 2). The next chapter (chapter 3) provides a technical description of the s::can product itself as well as information regarding transport and storage of the product. In further chapters the installation (chapter 4) and the initial startup (chapter 5) are explained. Furthermore information regarding calibration of the device (chapter 6), data management (chapter 7), how to perform a functional check (chapter 8) and maintenance (chapter 9) can be found in this manual. Information regarding troubleshooting (chapter 10), the available accessories (chapter 11) and the technical specifications (chapter 12) complete the document.

Each term in this document that is marked *italic and underlined*, can be found on the display of your controller for operation or as lettering on your s::can product.

In spite of careful elaboration this manual may contain errors or incompletion. s::can does not assume liability for errors or loss of data due to such faults in the manual. The original manual is published in English and German by s::can. This original manual serves as the reference in case discrepancies occur in versions of the manual after translation into third languages.

This manual, at the time of its publication (see release date printed on the top of this document), concerns the s::can products listed in chapter 3. Information and technical specifications regarding these items in s::can manuals from earlier release dates are herewith replaced by this manual.

The electronic version (pdf-document) of this manual is available on the s::can Customer Portal (Services for Customer) of the s::can Homepage (www.s-can.at).



2 Safety Guidelines

Installation, electrical connection, initial startup, operation and maintenance of any s::can product as well as complete s::can measuring systems must only be performed by qualified personnel. This qualified personnel has to be trained and authorised by the plant operator or by s::can for these activities. The qualified personnel must have read and understood this manual and have to follow the instructions contained in this manual.

For proper initial startup of complete s::can measuring systems, the manuals for the controller ans software used for operation (e.g. con::lyte, con::cube, con::nect, moni::tool), the connected probes and sensors as well as the used additional devices (e.g. compressor) have to be consulted.

The operator has to obtain the local operating permits and has to comply with the joint constraints associated with these. Additionally, the local legal requirements have to be observed (e.g. regarding safety of personnel and means of labour, disposal of products and materials, cleaning, environmental constraints). Before putting the measuring device into operation, the operator has to ensure that during mounting and initial startup – in case they are executed by the operator himself – the local legislation and requirements (e.g. regarding electrical connection) are observed.

All s::can products are leaving our factory in immaculate technical and safety conditions. Inappropriate or not intended use of the product, however, can cause danger! The manufacturer is not responsible for damage caused by incorrect or unauthorised use. Any kind of manipulation of the instrument is strictly prohibited - except for the activities described in this document. Conversions and changes to the device must not be made, otherwise all certifications and guarantee / warranty become invalid. For details regarding guarantee and warranty please refer to our general conditions of business.

2.1 Declaration of Conformity

This s::can product has been developed, tested and manufactured for electromagnetic compatibility (EMC) and according to applicable European standards, as defined in the declaration of conformity.

CE-marks are applied on the device. The declaration of conformity related to this marking can be requested from s::can or your local s::can sales partner or can be downloaded from the s::can Customer Portal.

2.2 Special Hazard Warning

⚠ Because the s::can measuring systems are frequently installed in industrial and communal waste water applications, one has to take care during mounting and demounting of the system, as parts of the device can be contaminated with dangerous chemicals or pathogenic germs. All necessary precautions should be taken to prevent endangering of one's health during work with the measuring device.

⚠ The light source of the s::can spectrometer probe emits visible light as well as UV-light, which is extremely dangerous for human eyes (health hazard!). Do not look into the pulsed light beam (e.g. directly or by using mirrors)!

⚠ As internal parts of the s::can spectrometer probe are under high voltage, the opening of the probe's housing can cause injury, is strictly forbidden and will cancel all guarantee / warranty.

3 Technical Description

3.1 Intended Use

All s::can spectrometer probes are compact spectrometer probes, designed for continuous online measurements of absorption spectra (UV-Vis and derived parameters) with high quality. The spectrometer probes are available with three different optical path lengths (OPL).

These probes can be operated either directly submersed in liquid media (in-situ) or in by-pass via flow cell setup but also outside of the medium using a multifunctional slide. Applications range from ultra pure water (DOC > 0,01 mg/l) up to industrial waste water with COD concentrations of several 1000 mg/l, and from single substance detection in sub-ppm concentrations up to surrogate and sum parameters in highest concentrations. The possibility to use the measured absorption spectrum (fingerprint) for spectral alarms complete the application field.

In all types of applications, the respective acceptable limits, which are provided in the technical specifications in the respective s::can manuals, have to be observed. All applications falling outside of these limits, and which are not authorised by s::can Messtechnik GmbH in written form, do not fall under the manufacturer's liability.

The device must only be used for the purpose described in this manual. Use in applications not described in this manual, or modification of the device without written agreement from s::can, is not allowed. s::can is not liable for claims following from such unauthorised use. In such a case, the risks are the sole responsibility of the operator.

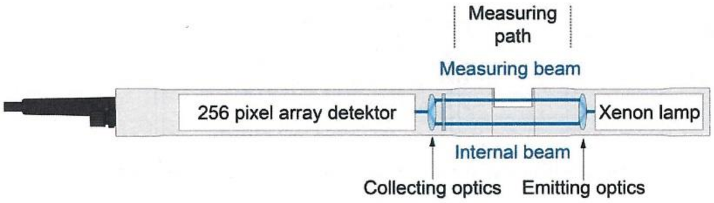
3.2 Functional Principle

Spectrometer probes work according to the principle of UV-Vis spectrometry. Substances contained in the medium to be measured weaken a light beam that moves through this medium. The light beam is emitted by a lamp, and after contact with the medium its intensity is measured by a detector over a range of wavelengths. Each molecule of a dissolved substance absorbs radiation at a certain and known wavelength. The concentration of substances contained determines the size of the absorption of the sample – the higher the concentration of a certain substance, the more it will weaken the light beam.

Extinction or absorbance stands for a ratio of two light intensities: The intensity of light after the beam passed through the medium to be measured and the intensity of light determined after the beam passed through a so-called reference medium (distilled water). There is a linear increase in absorption with higher concentrations.

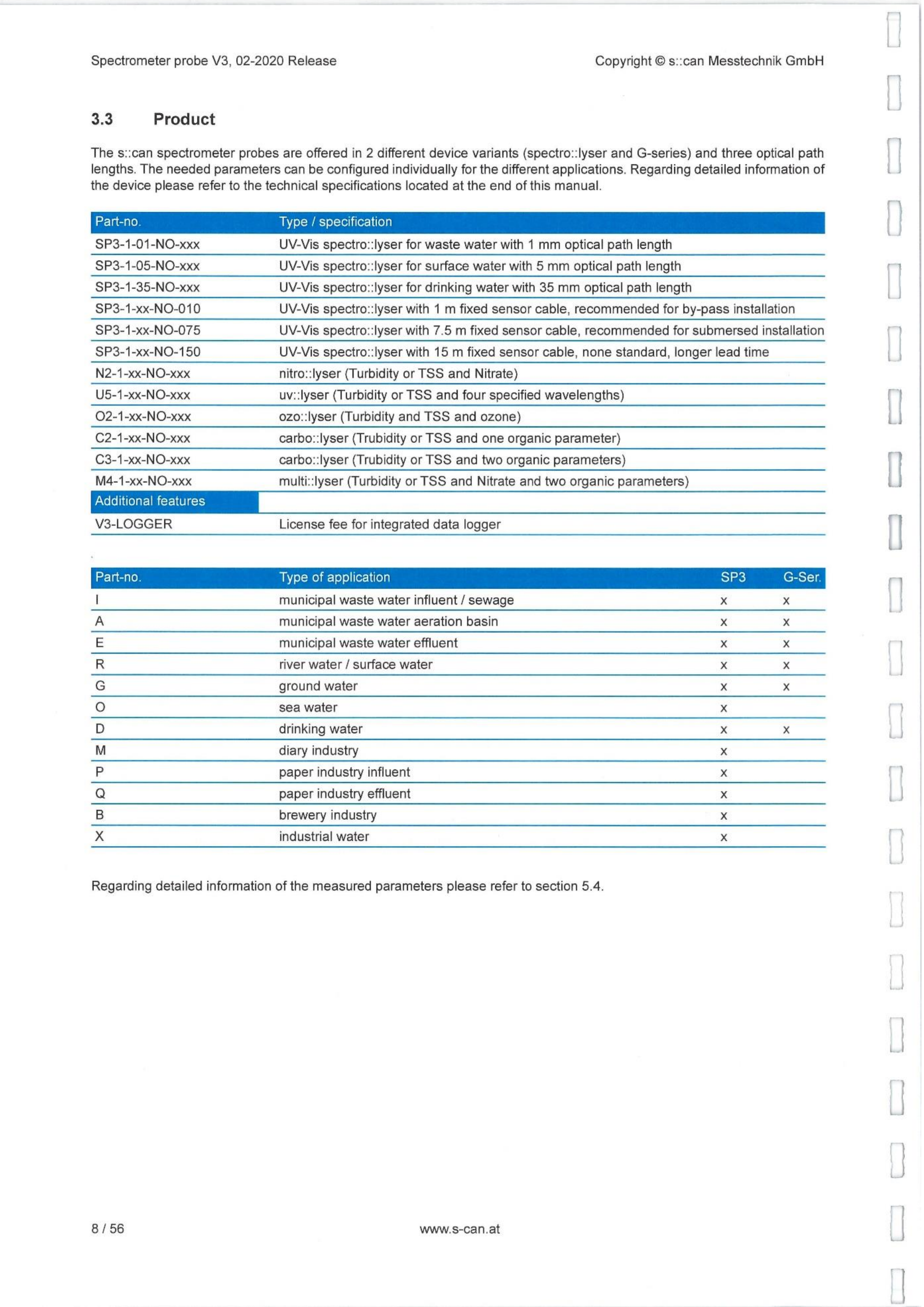
Every s::can spectrometer probe consists of three main components: the emitter unit, the measuring section and the receiving unit.

The central element of the emitter is a light source – a xenon flash lamp. This is complemented by an optical system to guide the light beam and an electronic control system to operate the lamp.



In the measuring section the light passes through the space between the two measuring windows which is filled with the measuring medium and interacts with it. A second light beam within the probe – called compensation beam - is guided across an internal comparison section. Every s::can spectrometer probe is a dual-beam measuring instrument, allowing the automatic compensation of disturbances in the measuring process (e.g. ageing of the flash lamp).

The receiving unit is located on the side of the spectrometer probe where the probe cable is attached, and it consists of two major components: the detector and the operating electronics. An optical system focuses the measuring and compensation beams on the entrance port of the detector. The light received by the detector is split up into its wavelengths and guided to the 256 fixed photodiodes, making the use of sensitive moving components unnecessary. The operating electronics contained in this part of the probe are responsible for controlling the entire measuring process and all the various processing steps required to edit and check the measuring signal and to calculate fingerprints and parameters values.



3.3 Product

The s::can spectrometer probes are offered in 2 different device variants (spectro::lyser and G-series) and three optical path lengths. The needed parameters can be configured individually for the different applications. Regarding detailed information of the device please refer to the technical specifications located at the end of this manual.

Part-no.	Type / specification
SP3-1-01-NO-xxx	UV-Vis spectro::lyser for waste water with 1 mm optical path length
SP3-1-05-NO-xxx	UV-Vis spectro::lyser for surface water with 5 mm optical path length
SP3-1-35-NO-xxx	UV-Vis spectro::lyser for drinking water with 35 mm optical path length
SP3-1-xx-NO-010	UV-Vis spectro::lyser with 1 m fixed sensor cable, recommended for by-pass installation
SP3-1-xx-NO-075	UV-Vis spectro::lyser with 7.5 m fixed sensor cable, recommended for submersed installation
SP3-1-xx-NO-150	UV-Vis spectro::lyser with 15 m fixed sensor cable, none standard, longer lead time
N2-1-xx-NO-xxx	nitro::lyser (Turbidity or TSS and Nitrate)
U5-1-xx-NO-xxx	uv::lyser (Turbidity or TSS and four specified wavelengths)
O2-1-xx-NO-xxx	ozo::lyser (Turbidity and TSS and ozone)
C2-1-xx-NO-xxx	carbo::lyser (Trubidity or TSS and one organic parameter)
C3-1-xx-NO-xxx	carbo::lyser (Trubidity or TSS and two organic parameters)
M4-1-xx-NO-xxx	multi::lyser (Turbidity or TSS and Nitrate and two organic parameters)
Additional features	
V3-LOGGER	License fee for integrated data logger

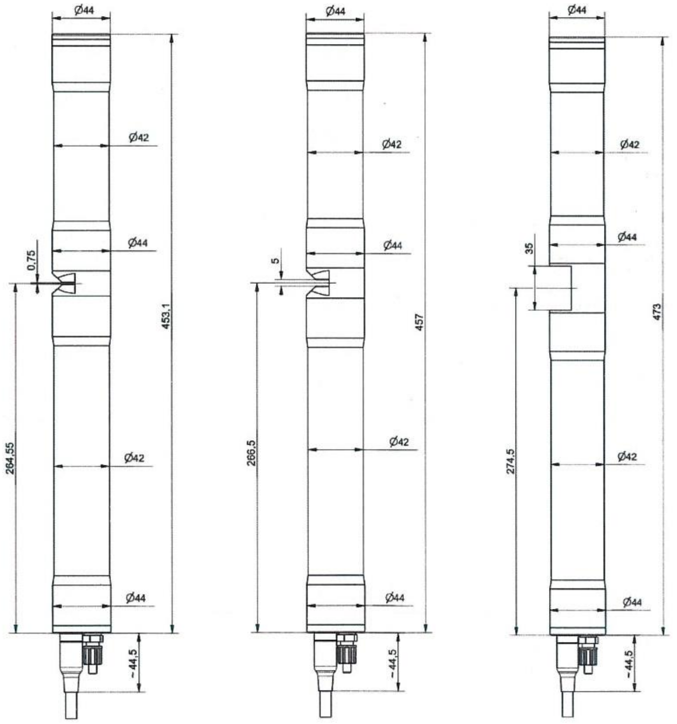
Part-no.	Type of application	SP3	G-Ser.
I	municipal waste water influent / sewage	x	x
A	municipal waste water aeration basin	x	x
E	municipal waste water effluent	x	x
R	river water / surface water	x	x
G	ground water	x	x
O	sea water	x	
D	drinking water	x	x
M	diary industry	x	
P	paper industry influent	x	
Q	paper industry effluent	x	
B	brewery industry	x	
X	industrial water	x	

Regarding detailed information of the measured parameters please refer to section 5.4.

The device is typified by a type label, as shown on the right, that contains the following information:

- Manufacturer's name and country of origin
- Several certification marks
- Device name
- QR code to s::can Support
- Part number (Type)
- Bar code
- Device serial number (S/N)
- Information on power supply
- Acceptable temperature limits
- Environment rating (IP)
- Maximal power consumption

1	Probe housing (lamp side)
2	Measuring section (optical measuring path)
3	Probe housing (detector side)
4	Connection for automatic cleaning
5	Cable gland
6	Probe cable



Dimension of probe in mm (OPL 1 mm left side, OPL 5 mm middle side and OPL 35 mm right side)

3.4 Storage and Transport

The temperature limits for device storage and transport, which are described in the section technical specifications, have to be observed at all times. The device shall not be exposed to strong impacts, mechanical loads or vibrations. The device should be kept free of corrosive or organic solvent vapours, nuclear radiation as well as electromagnetic radiation.

Damage to the device caused by wrong storage will not be covered by warranty.

Transport should be done in a packaging that protects the device (original packaging or protective covering if possible).

This product is marked with the WEEE symbol to comply with the European Union's Waste Electrical & Electronic Equipment (WEEE) Directive 2012/19/EC. The symbol indicates that this product should not be treated as household waste. It must be disposed and recycled as electronic waste. Please assist to keep our environment clean.

3.5 Scope of Delivery

Immediately upon receipt, please check the received consignment for completeness on the basis of the delivery note and check for any possible damage incurred during shipping. Please inform the delivering dispatcher and s::can immediately in case of any damages in transit.

The following parts should be included in the delivery:

- s::can spectrometer probe (part-no. according to section 3.3)
- Connection set for automatic cleaning (part-no. B-41-sensor)
- Cleaning brushes - 2 pieces (part-no. B-60-1 for OPL < 5 mm or B-60-2 for OPL > 2 mm)
- Multifunctional slide (part-no. E-421-V3 for all OPL)
- s::can manual spectrometer probe (part-no. S-30-M)

The following parts could be included in the delivery if ordered as an option:

- Adapter cable (part-no. C-32-V3, C-32-MIL)
- Extension cable (part-no. C-210-V3 or C-220-V3)
- con::ncet box (part-no. B-33-012)
- Probe carrier (part-no. F-110-V3 for 45 degree installation or F-120-V3 for vertical installation)
- Fixing adapter - stainless steel (part-no. F-15)
- Flow cell waste water (part-no. F-48-V3 for all OPL)
- Flow cell clean water (part-no. F-445-V3 for all OPL)
- Flow cell - autobrush (part-no. F-446-V3 for OPL 35 mm or F-446-V3-TI for OPL 35 mm titanium)
- Cleaning valve (part-no. B-44 or B-44-2)
- s::can compressor (item-no. B-32-230, B-32-110 or B-32-012)

In case of incompleteness please contact your s::can sales partner immediately!

3.6 Product Updates, Other

The manufacturer reserves the rights to implement, without prior notice, technical developments and modifications in the light of continuous product care.

4 Installation

4.1 Environment

The correct installation of measuring instruments is an important prerequisite for satisfactory operation. Therefore the following checklist for the installation can be used to ensure that all sources for potential operational problems can be ruled out to the greatest possible extent during the installation, allowing the monitoring system to operate properly.

- Favourable flow conditions (little turbulence, acceptable flow rate, pressure, etc.)
- Unadulterated, representative measuring medium
- Measuring medium is in equilibrium state (no gas release, no precipitation, etc.)
- No external interferences (no electric and electro-magnetic interferences by leakage current, earth fault of pumps, electric motors, electric power lines, etc.)
- Easy accessibility (mounting, sampling, functional check, demounting)
- Availability of sufficient space (probe / sensor, installation fitting, controller, etc.)
- Adherence to limit values (see technical specifications located at the end of this manual)

- Power supply for controller (operational reliability, voltage, power, peak free)
- Oil- and particle free compressed-air supply (optional for automatic probe / sensor cleaning)
- Best possible weather and splash water proof conditions
- Shortest possible distances between system components (probe / sensor – controller – compressed-air supply – energy supply)
- Correct dimensioning, mounting and protection of all cables and lines (non-buckling, no risk of stumbling, no damage etc.)

4.2 Mounting

When mounting the s::can spectrometer probe, please ensure that it is not possible that the measuring section (optical path) becomes blocked accidentally or by build-up of large particles present in the medium.

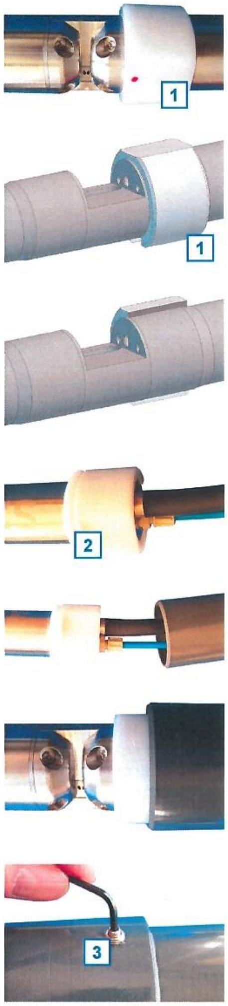
- Horizontal orientation (i.e. with measuring windows in vertical position) with plane face of the measuring section in vertical position. This will ensure no sedimentation of particles in the measuring section will take place and no gas bubbles will adhere to the measuring windows. The proper usage of an s::can probe carrier or s::can flow cell setup will ensure the correct position.
- Vertical orientation (i.e. with measuring windows in horizontal position) is only possible in applications with sufficient medium flow or automatic cleaning to ensure that no particles can sediment on the lower measuring window and no gas bubble might be captured within the measuring section. The proper usage of an s::can probe carrier will ensure the correct position.
- Flow velocity: < 3 m/s to avoid cavitations and therefore deterioration of measuring quality
  > 1 m/s when vertically mounted
- Abrasive solids (sand): < 1 g/l
- Recommended water level: > 10 cm at horizontal installation
- The housing must not be in direct contact with other metals, to prevent the possibility of contact corrosion.
- The probe cable has to be protected appropriately against cuts or damage induced by foreign objects in the water.
- In case of shallow water and / or low flow velocities the compressed-air cleaning system may swirl up sediments surrounding the measuring site (e.g. at the sewerage bottom). As a result the state of the measuring medium will not be representative of the normal water quality directly after cleaning. To avoid this from happening, the probe should be installed in such a way that the openings of the cleaning nozzles point towards the surface. This orientation is ensured when the cable gland is oriented above the connection for the automatic cleaning.

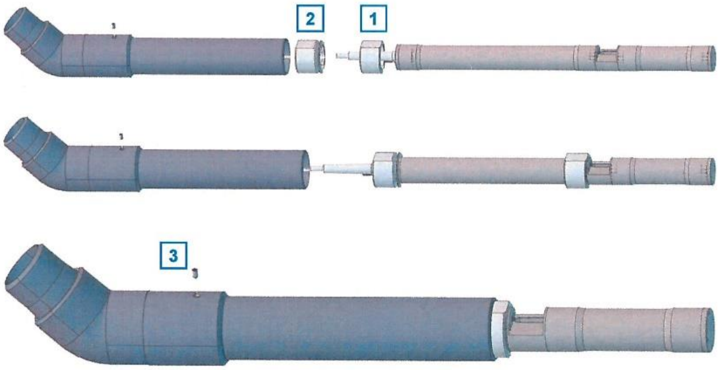
⚠ Even though the cable entry of the spectrometer probes is equipped with a protective mechanism against forces along the axis of the probe, the probe cable must never bear the weight of the spectrometer probe!

4.2.1 Mounting with Probe Carrier

The submersed installation of a spectrometer probe using the specific probe carrier (part-no. F-110-V3 or F-120-V3) is performed by the following steps (see figures on the right hand side and below also):

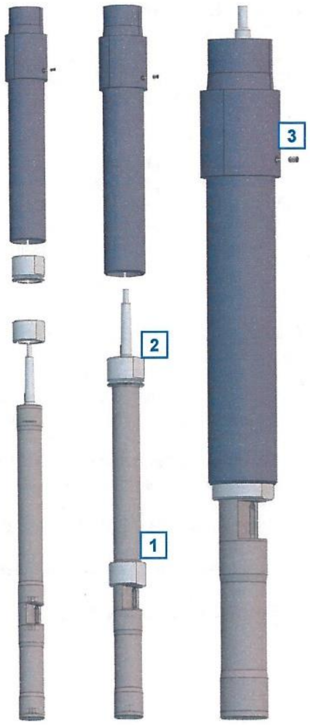
- The shorter spacer ring [1] has to be placed on the cable side of the probe housing close to the measuring section with the red marking towards the optical path (please note the first 3 figures on the right hand side for correct positioning of the spacer ring).
- The longer spacer ring [2] has to be placed on the cable side of the probe housing close to the probe cable with the groove towards the optical path.
- After mounting the spacer rings, the compressed-air cleaning must be connection to the probe (see section 4.3).
- Subsequently, the probe cable and the compressed-air hose are inserted into the probe carrier (e.g. with the help of a cable pulling device); when doing so, the cable plug and cleaning hose end must be protected from becoming dirty. The delivered M5 hexagon socket screw [3] has to be placed in the provided tap hole, but should not be tightened yet.
- Now slide the spectrometer probe into the probe carrier, so that the spacer ring close to the measuring section juts out 1.5 cm of the edge of the carrier (see marking on the spacer). When using probe carrier for horizontal installation the probe has to be placed in such a way that the plane face of the measuring section has a perpendicular orientation so that there can be no sedimentation in the measuring section and so that air bubbles can escape upwards.
- The probe can now be fixed in this position by means of the hexagon socket screw [3], which will fall into the V-shaped groove of the spacer ring sitting on the end of the probe where the cable is located.



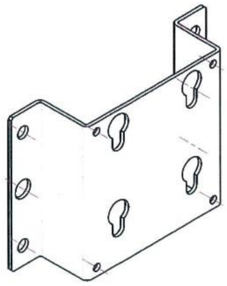


When necessary the probe carrier can be supplied with a tube extension that can simply be fixed to a railing by means of the fixing adapter (part-no. F-15). Appropriate measures must be taken to protect the probe cable and the compressed-air hose from damage due to buckling, abrasion etc. at the point where they exit the extension pipe.

For cleaning or checking the reference measurement (functional check) using the multifunctional slide, the spectrometer probe can be slid out of the probe carrier slightly after loosening of the hexagon socket [3].

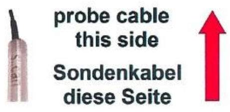


4.2.2 Mounting in Flow Cell Tap Water



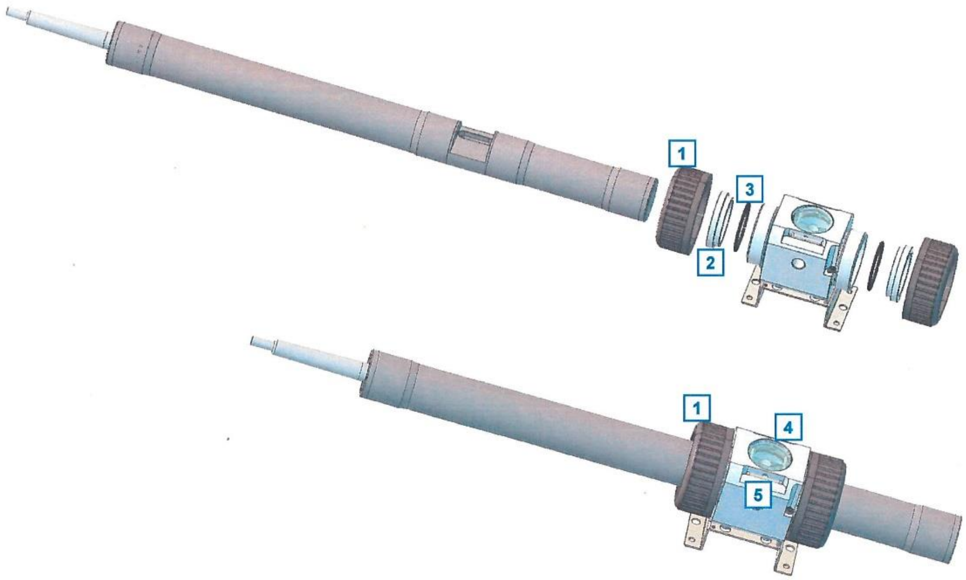
The flow cell can be mounted directly on a solid and flat surface (wall, mounting panel, etc.) using the mounting bracket (included in delivery). Once the mounting bracket is fixed the complete flow cell can easily be removed by unscrewing the safety screw (M4x45).

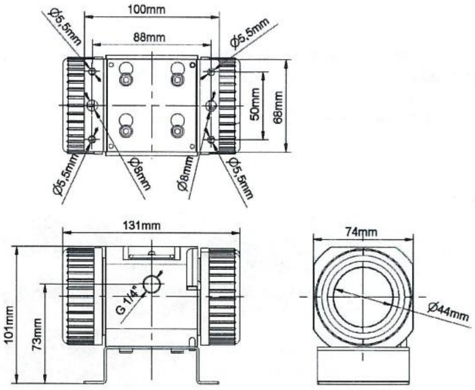
Please note, that the spectrometer probe can only be mounted in one way, because the measurement cell as well as the inside of the flow cell are not symmetrical. A red marking dot and a label on the flow cell indicate the position of the spectrometer probe in respect of the probe cable.



The installation of a spectrometer probe using the flow cell setup (part-no. F-445-V3) is performed by the following steps (see figures below also):

- Loosen both nuts [1], which compress the O-rings of the flow cell. Do not unscrew completely – the compression inserts [2] and O-rings [3] must stay in place.
- Insert the spectrometer probe so that the cable points to the marked side (red marking dot and label) and align, so that the optical path appears level and centred in the flow cell.
- Fasten both nuts [1] while holding the spectrometer probe firmly in place.
- Check the correct assembly by peering into the glass window [4] on top of the flow cell.
- For cleaning purposes the glass window [4] can be opened by removing the metal bracket [5] with a flat screw driver.





Dimension of flow cell (F-445-V3)

For connection of the water supply use any fittings with $^1/_4$ inch outside thread. To ensure that flow cell is always completely filled with water the medium supply has to be done vertically from bottom to top.

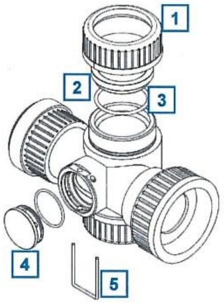
4.2.3 Mounting in Flow Cell Autobrush

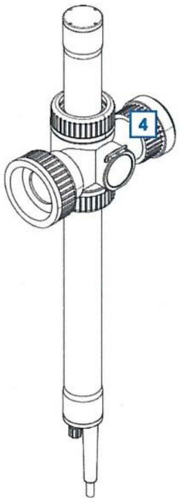
Please refer to the seperate s::can manual flow cell autobrush regarding correct installation of the spectrometer probe using this accessory.

4.2.4 Mounting in Flow Cell Waste Water

The installation of a spectrometer probe using the flow cell setup waste water (part-no. F-48-V3) is performed by the following steps (see figures on the right side also):

- Loosen both nuts [1], which compress the O-rings of the flow cell. Do not unscrew completely – the compression inserts [2] and O-rings [3] must stay in place.
- Insert the spectrometer probe so that the optical path appears level and centred in the flow cell.
- Fasten both nuts [1] while holding the spectrometer probe firmly in place.
- Check the correct assembly by peering into the glass window [4].
- For cleaning purposes the glass window [4] can be opened by removing the metal bracket [5] with a flat screw driver.





4.3 Automatic Probe Cleaning

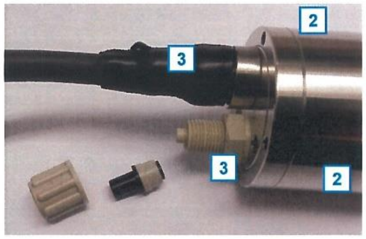
The automatic cleaning of optical windows is needed to ensure a correct and stable measurement. For automatic probe cleaning either cleaning devices with a rotating brush (ruck::sack or auto::brush) or compressed air is needed.

For mounting of the cleaning devices please see the manuals and installation notes of the specific devices. The connection of the pressurized air cleaning is explained in the following section.

4.3.1 Connection of compressed Air Cleaning

The pressure connection set (B-41) supplied with the system contains components necessary to connect the spectrometer probe to the cleaning valve. The connection to the probe is performed by the following steps (see pictures on the right hand side also):

- Remove black dummy insert [1] from pressure connection on top of probe be unscrewing the connecting nut [2] and removing the conical part [3].
- Put the connecting nut [2] and the conical part [3] over the blue cleaning hose.
- Push the cleaning hose over the pressure connection on top of the probe (warm up cleaning hose in hot water if necessary).
- Fasten connecting nut [2] by hand.

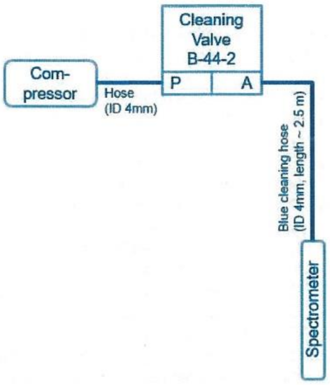


The connection to the cleaning valve depends on the used type of cleaning valve.

- Cleaning valve B-44

A compressed air hose (to be provided by customer, ID 8 mm to 9 mm, UV- / ozone resistant) must be used to connect the adapter fitting of the pressure connection set to the output side of the cleaning valve (marked with A). Fasten the air hose with hose clamps.

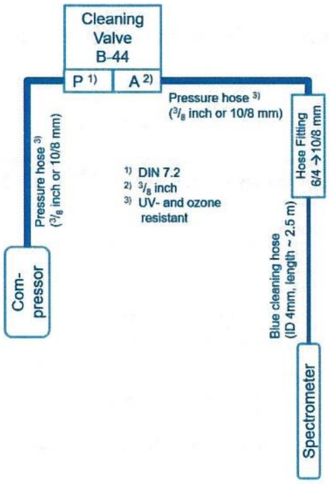
Another air hose and DIN 7.2 compressed air coupling are required to hook up the compressed air supply to the input side of the cleaning valve (marked with P).



- Cleaning valve B-44-2

The adapter fitting of the pressure connection set can be removed to connect the blue tube directly to the push-pull fitting of the cleaning valve. The same type of tube can be used to connect the cleaning valve to the s::can compressor.

The cleaning valve should never be connected to the compressed air coupling of your compressor directly, i.e. without a pressure hose in between. The total length of hoses should be as short as possible to avoid unnecessary pressure loss. In special occasions, drinking water may be used to operate the hydraulic-pneumatic cleaning appliance instead or compressed air – for more information please contact your local s::can sales partner.

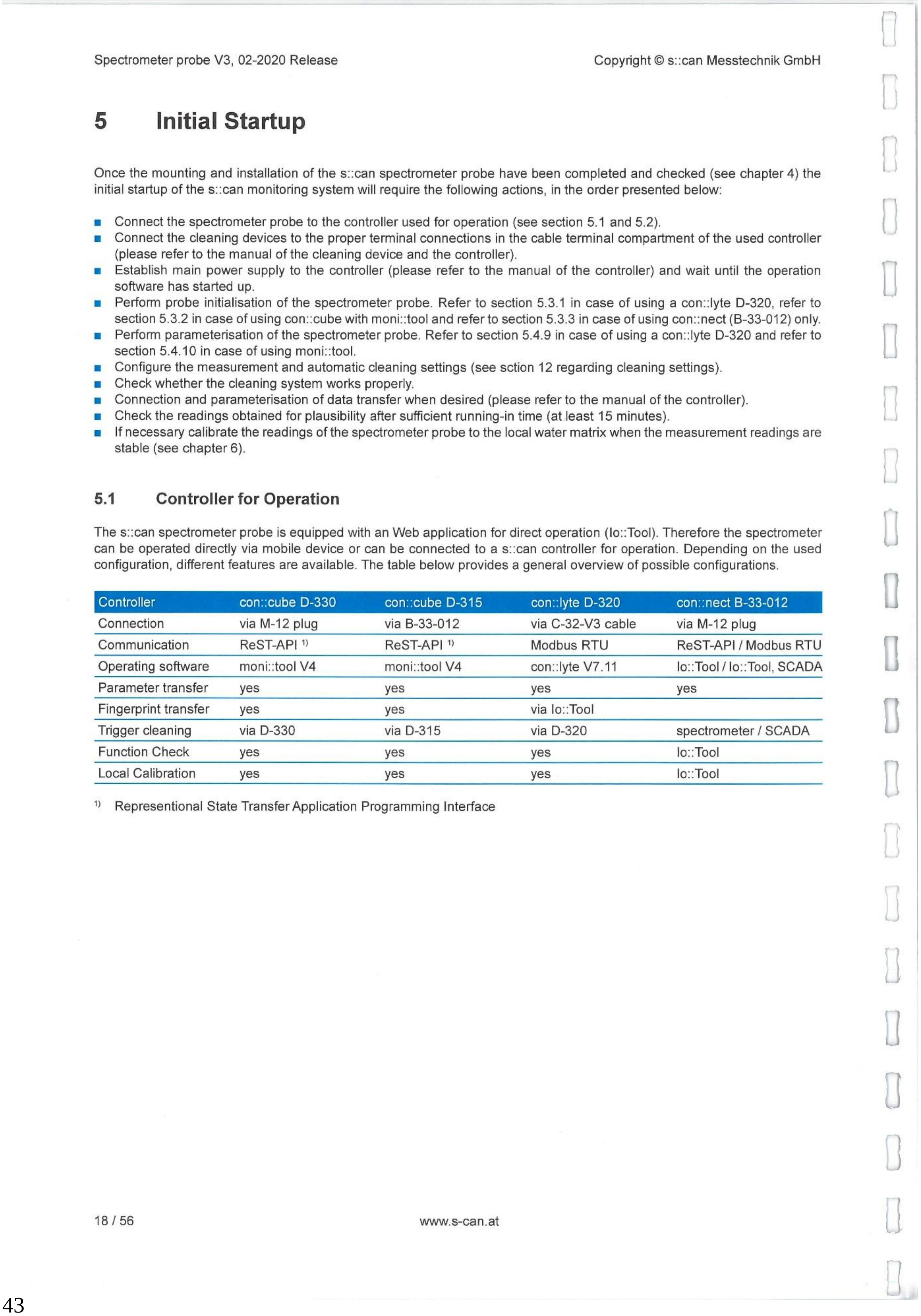


Any foreign matter in the compressed air supply may impair the hydraulic-pneumatic cleaning process. If you have any doubts about the purity of the air used (contamination by particles, oil, etc.), please install an appropriate filter upstream from the solenoid valve.

In areas with extremely low outside air temperature, s::can recommends laying the compressed air hoses such that they remain frost-free to prevent freezing of condensed water in the compressed air hose.

Please note that depending on the s::can probe and sensor type you are using, different maximum allowed pressures may be specified. In case a central pressurised air supply is used in such a case the lowest maximum allowed pressure amongst those specified for the individual instruments is to be used to supply all instruments or the use of pressure reducing valves to supply each instrument with the correct pressure is necessary.

In order to ensure proper operation of automatic cleaning s::can highly recommends to use s::can compressor optimized for compressed air supply of all probes and sensors.



5 Initial Startup

Once the mounting and installation of the s::can spectrometer probe have been completed and checked (see chapter 4) the initial startup of the s::can monitoring system will require the following actions, in the order presented below:

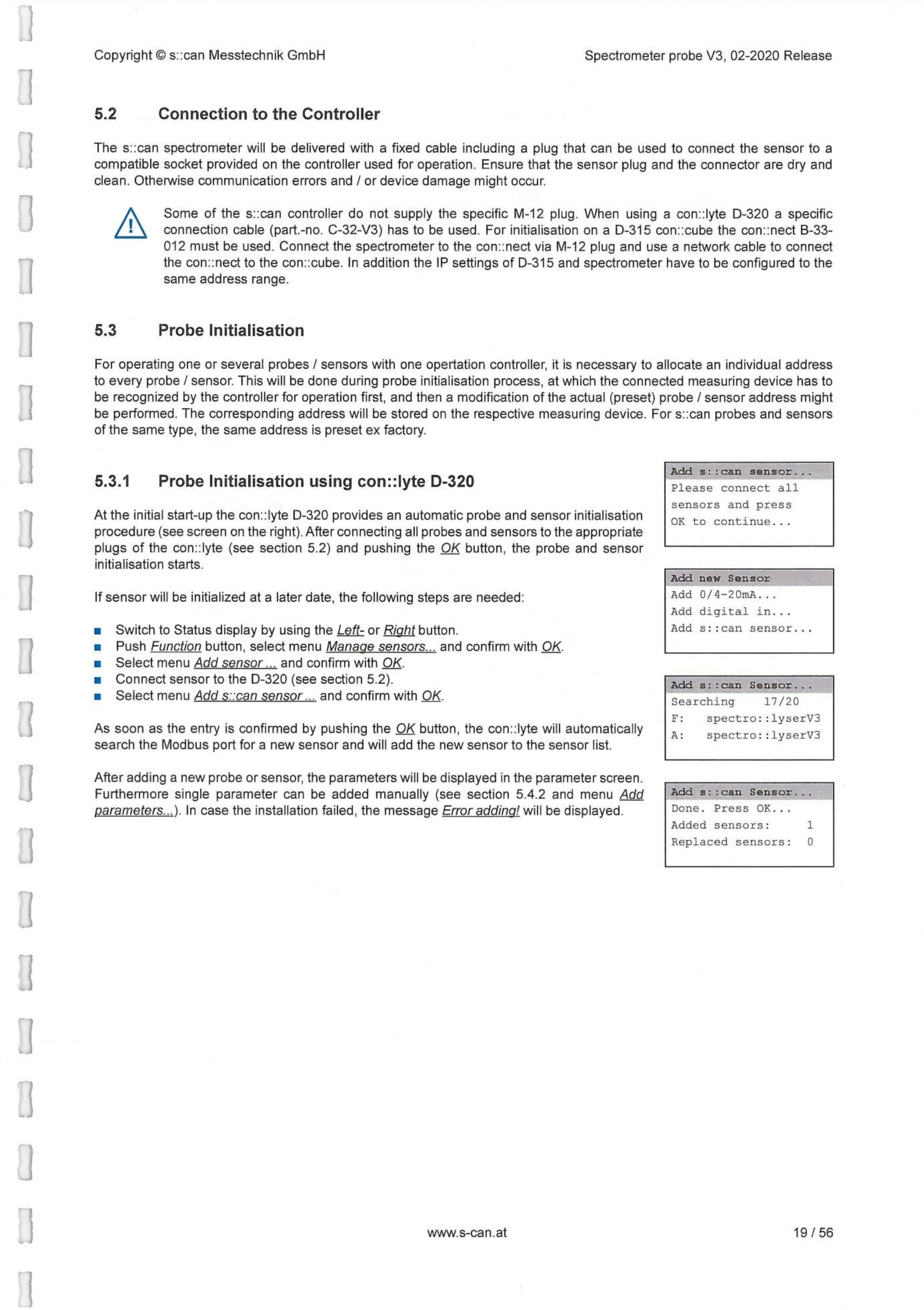
- Connect the spectrometer probe to the controller used for operation (see section 5.1 and 5.2).
- Connect the cleaning devices to the proper terminal connections in the cable terminal compartment of the used controller (please refer to the manual of the cleaning device and the controller).
- Establish main power supply to the controller (please refer to the manual of the controller) and wait until the operation software has started up.
- Perform probe initialisation of the spectrometer probe. Refer to section 5.3.1 in case of using a con::lyte D-320, refer to section 5.3.2 in case of using con::cube with moni::tool and refer to section 5.3.3 in case of using con::nect (B-33-012) only.
- Perform parameterisation of the spectrometer probe. Refer to section 5.4.9 in case of using a con::lyte D-320 and refer to section 5.4.10 in case of using moni::tool.
- Configure the measurement and automatic cleaning settings (see sction 12 regarding cleaning settings).
- Check whether the cleaning system works properly.
- Connection and parameterisation of data transfer when desired (please refer to the manual of the controller).
- Check the readings obtained for plausibility after sufficient running-in time (at least 15 minutes).
- If necessary calibrate the readings of the spectrometer probe to the local water matrix when the measurement readings are stable (see chapter 6).

5.1 Controller for Operation

The s::can spectrometer probe is equipped with an Web application for direct operation (Io::Tool). Therefore the spectrometer can be operated directly via mobile device or can be connected to a s::can controller for operation. Depending on the used configuration, different features are available. The table below provides a general overview of possible configurations.

Controller	con::cube D-330	con::cube D-315	con::lyte D-320	con::nect B-33-012
Connection	via M-12 plug	via B-33-012	via C-32-V3 cable	via M-12 plug
Communication	ReST-API [1]	ReST-API [1]	Modbus RTU	ReST-API / Modbus RTU
Operating software	moni::tool V4	moni::tool V4	con::lyte V7.11	Io::Tool / Io::Tool, SCADA
Parameter transfer	yes	yes	yes	yes
Fingerprint transfer	yes	yes	via Io::Tool	
Trigger cleaning	via D-330	via D-315	via D-320	spectrometer / SCADA
Function Check	yes	yes	yes	Io::Tool
Local Calibration	yes	yes	yes	Io::Tool

[1] Representional State Transfer Application Programming Interface



5.2 Connection to the Controller

The s::can spectrometer will be delivered with a fixed cable including a plug that can be used to connect the sensor to a compatible socket provided on the controller used for operation. Ensure that the sensor plug and the connector are dry and clean. Otherwise communication errors and / or device damage might occur.

Some of the s::can controller do not supply the specific M-12 plug. When using a con::lyte D-320 a specific connection cable (part.-no. C-32-V3) has to be used. For initialisation on a D-315 con::cube the con::nect B-33-012 must be used. Connect the spectrometer to the con::nect via M-12 plug and use a network cable to connect the con::nect to the con::cube. In addition the IP settings of D-315 and spectrometer have to be configured to the same address range.

5.3 Probe Initialisation

For operating one or several probes / sensors with one opertation controller, it is necessary to allocate an individual address to every probe / sensor. This will be done during probe initialisation process, at which the connected measuring device has to be recognized by the controller for operation first, and then a modification of the actual (preset) probe / sensor address might be performed. The corresponding address will be stored on the respective measuring device. For s::can probes and sensors of the same type, the same address is preset ex factory.

5.3.1 Probe Initialisation using con::lyte D-320

At the initial start-up the con::lyte D-320 provides an automatic probe and sensor initialisation procedure (see screen on the right). After connecting all probes and sensors to the appropriate plugs of the con::lyte (see section 5.2) and pushing the _OK_ button, the probe and sensor initialisation starts.

If sensor will be initialized at a later date, the following steps are needed:

- Switch to Status display by using the _Left-_ or _Right_ button.
- Push _Function_ button, select menu _Manage sensors..._ and confirm with _OK_.
- Select menu _Add sensor ..._ and confirm with _OK_.
- Connect sensor to the D-320 (see section 5.2).
- Select menu _Add s::can sensor ..._ and confirm with _OK_.

As soon as the entry is confirmed by pushing the _OK_ button, the con::lyte will automatically search the Modbus port for a new sensor and will add the new sensor to the sensor list.

After adding a new probe or sensor, the parameters will be displayed in the parameter screen. Furthermore single parameter can be added manually (see section 5.4.2 and menu _Add parameters..._). In case the installation failed, the message _Error adding!_ will be displayed.

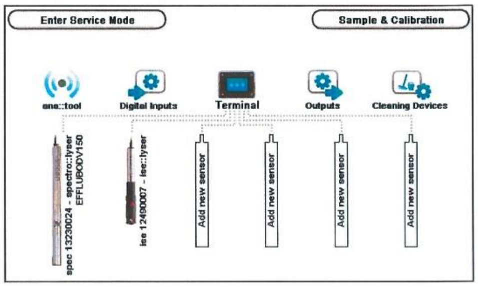
```
Add s::can sensor...
Please connect all
sensors and press
OK to continue...
```

```
Add new Sensor
Add 0/4-20mA...
Add digital in...
Add s::can sensor...
```

```
Add s::can Sensor...
Searching    17/20
F:   spectro::lyserV3
A:   spectro::lyserV3
```

```
Add s::can Sensor...
Done. Press OK...
Added sensors:     1
Replaced sensors:  0
```

5.3.2 Probe Initialisation using moni::tool



- Click the *Service* tab of the moni::tool screen and logon as *Administrator*.
- Click on an empty sensor icon (*Add new Sensor*) to initiate the initialisation process.

Searching for sensor at: **rest_tcp://https/sp3-00000026**, please wait...

- An automatic search procedure will start, searching for the connected sensor.

Found sensor devices	Status	Retry
rest_tcp://https/sp3-00000026	✓ Found new sensor.	

spectro::lyser
Address: **rest_tcp://https/sp3-00000026**
Sensor name: spec 00000026
Previous names:
Status:

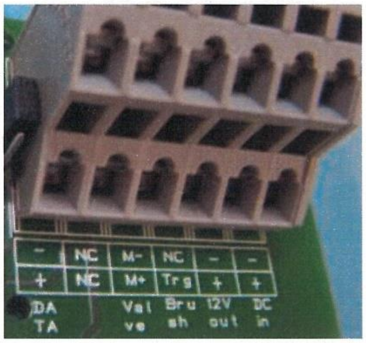
If a connected new sensor is not listed here, please detach all other sensors and try again.

- When the automatic search prodedure is finished, moni::tool will display all connected probes and sensors. Those sensors that are connected for the first time will have the Status *Found new sensor* (also listed as *New Sensors* below).
- If needed *Sensor name* can be modified now, which can be any descriptive name you desire or select one of the previous names listed below this entry field.
- To install the new sensor click on the blue + sign on the right side of the sensor or push the button *Install All*.
- moni::tool will install the sensor and switch to the *Service* tab showing the new sensor in the system overview. Now pushing the button *Leave Service Mode* located on the upper left side to start the measuring process.

5.3.3 Probe Initialisation using con::nect and Io::Tool

In case the s::can spectrometer probe will be operated as stand alone measuring device without an s::can terminal, the probe initialisation and the start-up of Io::Tool is performed by the following steps:

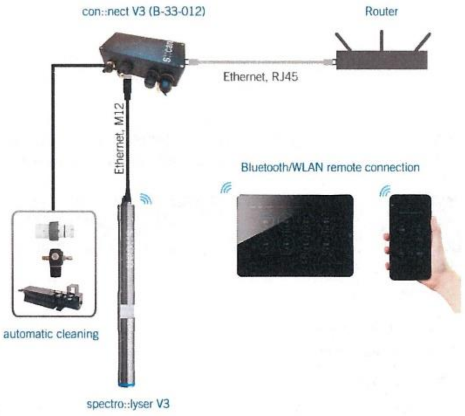
- Connect the spectrometer probe to the compatible socket of the con::nect. Ensure that the sensor plug and the connector are dry and clean. Otherwise communication errors and / or device damage might occur.
- Wire the cleaning device for automatic cleaning of the spectrometer probe to the con::nect directly. The table below displays the different possibilities for connection.



Cleaning Device	Colour of wire	Labelling
Cleaning valve	Blue	M+ Valve
	Brown	M- Valve
Autobrush	Purple (yellow [1])	Trg Brush
	Black (brown [1])	- 12V out
	Red (white [1])	+ 12V out
ruck::sack	Purple	Trg Brush
	Black	- 12V out
	Red	+ 12V out

[1] previous used cable version

Once the cleaning device has been electrically connected, the device needs to be parameterised within the operating software (please refer to according manual).



- Connect the con::nect to the main power supply (DC in). This work must be performed by authorised persons only!
- Several seconds after the con::nect box was connected to power supply, the LED ring will flash blue.
- Within one minute the LED ring will change from flashing to continuous color. The spectro::lyser is online now and measurements will start automatically according to user settings.
- Enter the IP address of the spectro::lyser into your Web-Browser to start Io::Tool. The table below displays the different possibilities to get the correct IP address:

Connection methode	IP address of spectrometer	Remark
via WLAN	192.168.43.1	default address; password = *spectrolyser*
via Bluetooth	192.168.44.1	default address
via LAN	to be checked on DHCP Server	DHCP active on spectrometer probe per default
via LAN	192.168.42.10	fall back (static) if network without DHCP Server (e.g. when connecting directly with notebook)

As soon as the connection is established, Io::Tool will pop up in the Web-Browser showing the actual readings of the spectrometer probe (see figure on the right).

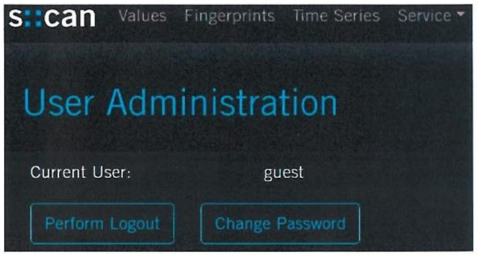
1 Main tabs to change the displyed information.

2 User logged in actually. For operation of Io::Tool there are three users available. Per default the user is logged in as *guest* automatically (no password required). For the normal operator the level *user* (with password *scan*) and for service personal the user *expert* (with password *scan*) is available.

3 Actual parameter readings.

4 Actual system date and time.

5 Activity (e.g. *Idle*, *Measuring*, *Offline*). In case the probe is operated with an s::can terminal (e.g. con::lyte) the displayed activity is *con::lyte Operation*.



Current User: guest

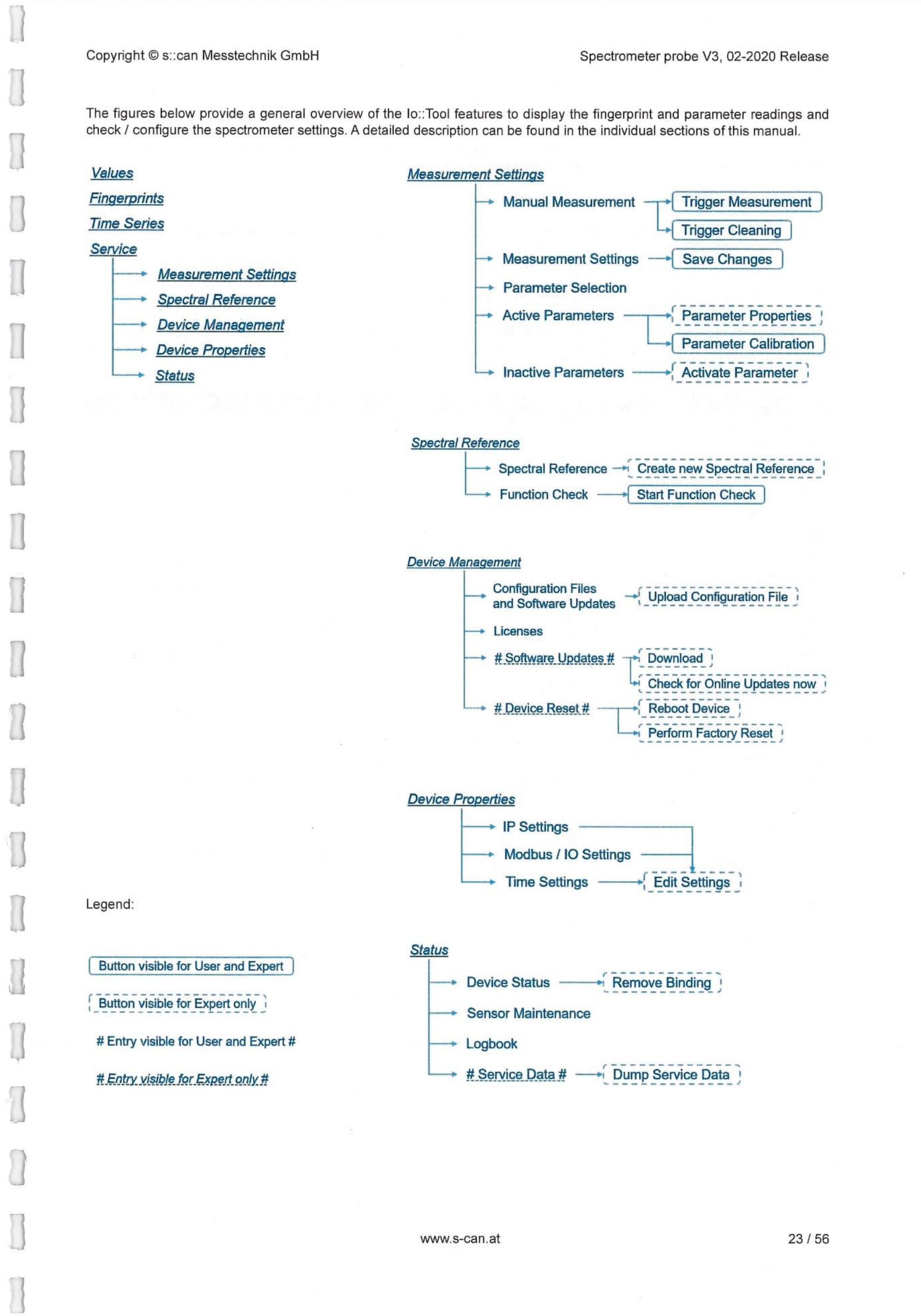
A change of the user is performed by the following steps:

- Click on the user icon in the upper right corner of Io::Tool.
- Click on button *Perform Logout* to logout the actual user.
- Enter the new *Username* (e.g. user).
- Enter the *Password* (e.g. scan).
- Click on button *Perform Login* to login as new user.

Username: user
Password: ••••

The table below displays which operator functions are allocated to the different user types and which information are visible on the different user displays of Io::Tool.

Fuctionality	Guest		User		Expert		
	View	Edit	View	Edit	View	Edit	Remark
Service mode	X		X	X	X	X	
Reboot probe			X	X	X	X	
Trigger measurement				X		X	
Measurement settings	X		X	X	X	X	
Local calibration	X		X	X	X	X	
Activate and modify parameters	X		X		X	X	
Create or edit zero reference	X		X	X	X	X	
Upload config file						X	License, updates, GCs
Probe name	X		X		X	X	
GPIO mode	X		X		X	X	Modbus, air, bush
System time	X		X		X	X	
IP configuration			X		X	X	
Modbus configuration	X		X		X	X	
Sensor maintenance	X		X	X	X	X	



Spectrometer probe V3, 02-2020 Release

The figures below provide a general overview of the Io::Tool features to display the fingerprint and parameter readings and check / configure the spectrometer settings. A detailed description can be found in the individual sections of this manual.

Legend:

Button visible for User and Expert

Button visible for Expert only

Entry visible for User and Expert

Entry visible for Expert only

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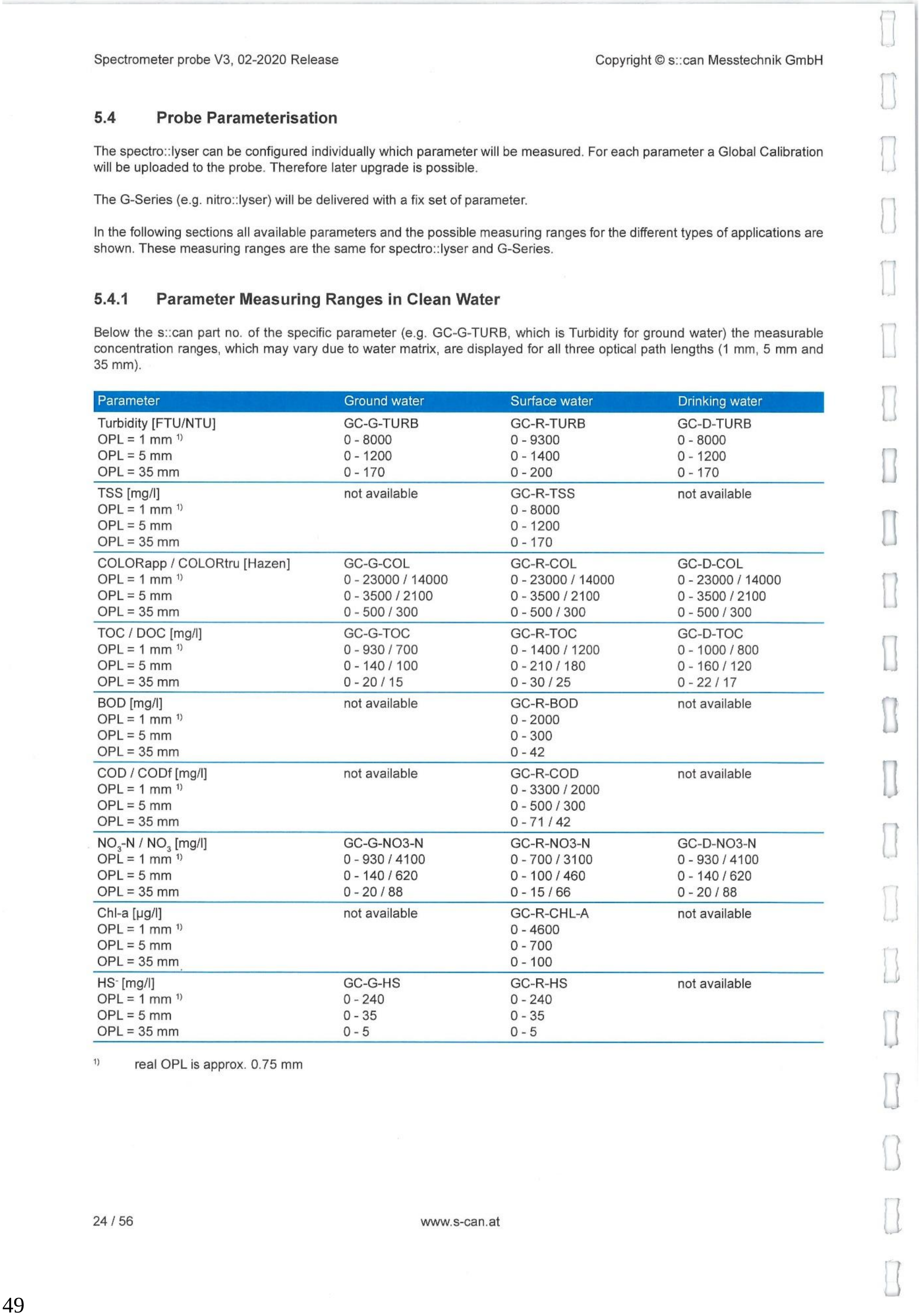


5.4 Probe Parameterisation

The spectro::lyser can be configured individually which parameter will be measured. For each parameter a Global Calibration will be uploaded to the probe. Therefore later upgrade is possible.

The G-Series (e.g. nitro::lyser) will be delivered with a fix set of parameter.

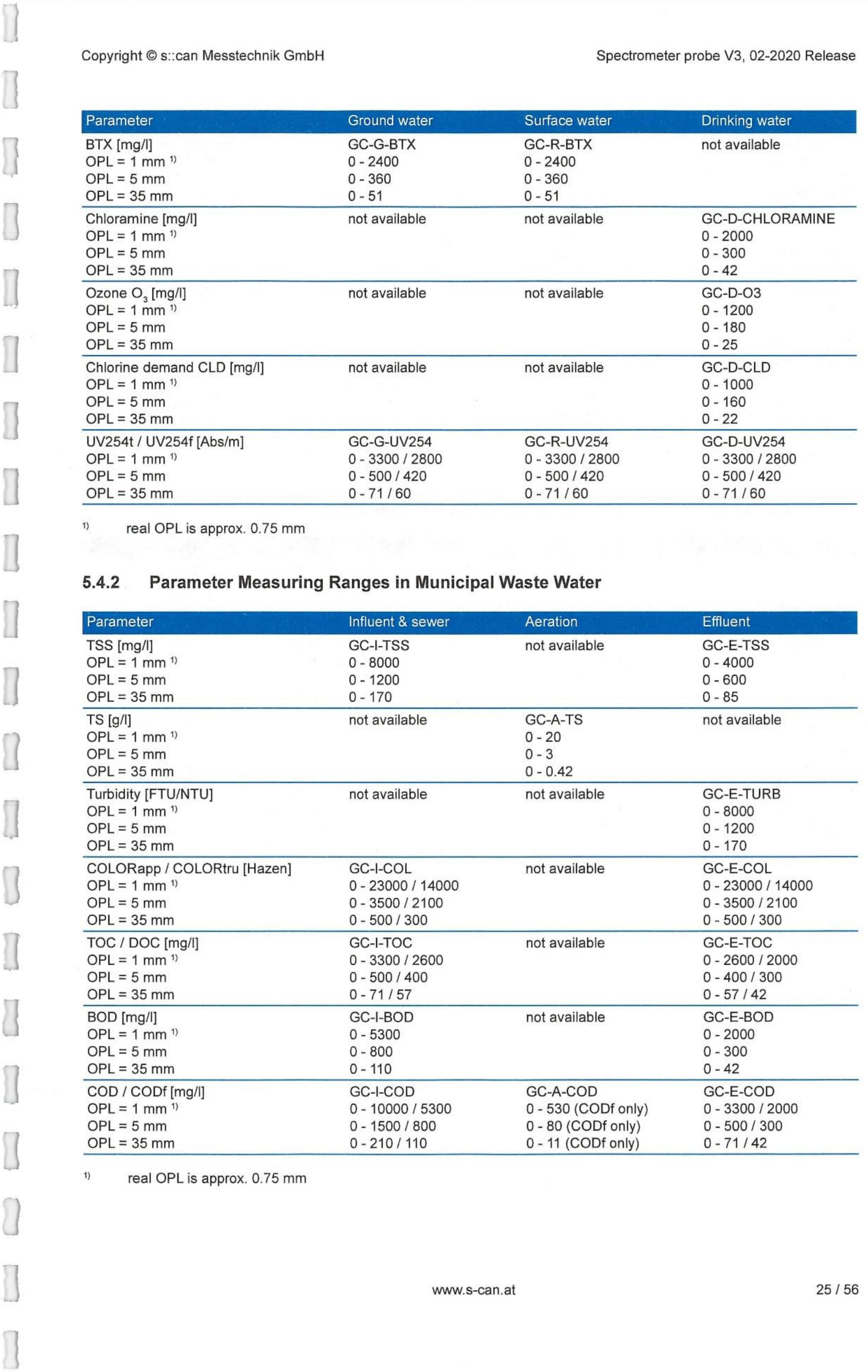
In the following sections all available parameters and the possible measuring ranges for the different types of applications are shown. These measuring ranges are the same for spectro::lyser and G-Series.

5.4.1 Parameter Measuring Ranges in Clean Water

Below the s::can part no. of the specific parameter (e.g. GC-G-TURB, which is Turbidity for ground water) the measurable concentration ranges, which may vary due to water matrix, are displayed for all three optical path lengths (1 mm, 5 mm and 35 mm).

Parameter	Ground water	Surface water	Drinking water
Turbidity [FTU/NTU]	GC-G-TURB	GC-R-TURB	GC-D-TURB
OPL = 1 mm 1)	0 - 8000	0 - 9300	0 - 8000
OPL = 5 mm	0 - 1200	0 - 1400	0 - 1200
OPL = 35 mm	0 - 170	0 - 200	0 - 170
TSS [mg/l]	not available	GC-R-TSS	not available
OPL = 1 mm 1)		0 - 8000	
OPL = 5 mm		0 - 1200	
OPL = 35 mm		0 - 170	
COLORapp / COLORtru [Hazen]	GC-G-COL	GC-R-COL	GC-D-COL
OPL = 1 mm 1)	0 - 23000 / 14000	0 - 23000 / 14000	0 - 23000 / 14000
OPL = 5 mm	0 - 3500 / 2100	0 - 3500 / 2100	0 - 3500 / 2100
OPL = 35 mm	0 - 500 / 300	0 - 500 / 300	0 - 500 / 300
TOC / DOC [mg/l]	GC-G-TOC	GC-R-TOC	GC-D-TOC
OPL = 1 mm 1)	0 - 930 / 700	0 - 1400 / 1200	0 - 1000 / 800
OPL = 5 mm	0 - 140 / 100	0 - 210 / 180	0 - 160 / 120
OPL = 35 mm	0 - 20 / 15	0 - 30 / 25	0 - 22 / 17
BOD [mg/l]	not available	GC-R-BOD	not available
OPL = 1 mm 1)		0 - 2000	
OPL = 5 mm		0 - 300	
OPL = 35 mm		0 - 42	
COD / CODf [mg/l]	not available	GC-R-COD	not available
OPL = 1 mm 1)		0 - 3300 / 2000	
OPL = 5 mm		0 - 500 / 300	
OPL = 35 mm		0 - 71 / 42	
NO_3-N / NO_3 [mg/l]	GC-G-NO3-N	GC-R-NO3-N	GC-D-NO3-N
OPL = 1 mm 1)	0 - 930 / 4100	0 - 700 / 3100	0 - 930 / 4100
OPL = 5 mm	0 - 140 / 620	0 - 100 / 460	0 - 140 / 620
OPL = 35 mm	0 - 20 / 88	0 - 15 / 66	0 - 20 / 88
Chl-a [µg/l]	not available	GC-R-CHL-A	not available
OPL = 1 mm 1)		0 - 4600	
OPL = 5 mm		0 - 700	
OPL = 35 mm		0 - 100	
HS^- [mg/l]	GC-G-HS	GC-R-HS	not available
OPL = 1 mm 1)	0 - 240	0 - 240	
OPL = 5 mm	0 - 35	0 - 35	
OPL = 35 mm	0 - 5	0 - 5	

1) real OPL is approx. 0.75 mm



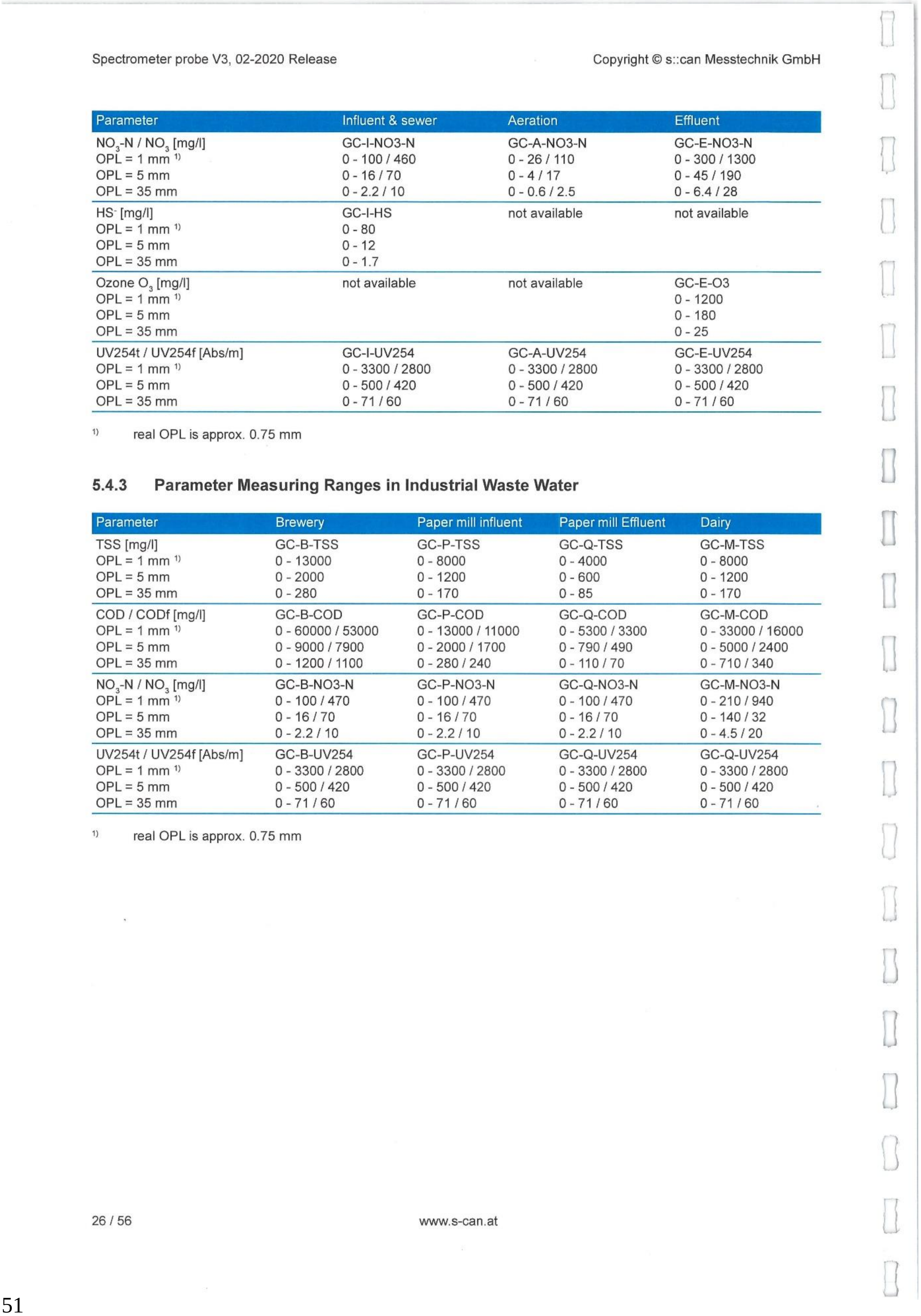
Parameter	Ground water	Surface water	Drinking water
BTX [mg/l] OPL = 1 mm [1] OPL = 5 mm OPL = 35 mm	GC-G-BTX 0 - 2400 0 - 360 0 - 51	GC-R-BTX 0 - 2400 0 - 360 0 - 51	not available
Chloramine [mg/l] OPL = 1 mm [1] OPL = 5 mm OPL = 35 mm	not available	not available	GC-D-CHLORAMINE 0 - 2000 0 - 300 0 - 42
Ozone O_3 [mg/l] OPL = 1 mm [1] OPL = 5 mm OPL = 35 mm	not available	not available	GC-D-O3 0 - 1200 0 - 180 0 - 25
Chlorine demand CLD [mg/l] OPL = 1 mm [1] OPL = 5 mm OPL = 35 mm	not available	not available	GC-D-CLD 0 - 1000 0 - 160 0 - 22
UV254t / UV254f [Abs/m] OPL = 1 mm [1] OPL = 5 mm OPL = 35 mm	GC-G-UV254 0 - 3300 / 2800 0 - 500 / 420 0 - 71 / 60	GC-R-UV254 0 - 3300 / 2800 0 - 500 / 420 0 - 71 / 60	GC-D-UV254 0 - 3300 / 2800 0 - 500 / 420 0 - 71 / 60

[1] real OPL is approx. 0.75 mm

5.4.2 Parameter Measuring Ranges in Municipal Waste Water

Parameter	Influent & sewer	Aeration	Effluent
TSS [mg/l] OPL = 1 mm [1] OPL = 5 mm OPL = 35 mm	GC-I-TSS 0 - 8000 0 - 1200 0 - 170	not available	GC-E-TSS 0 - 4000 0 - 600 0 - 85
TS [g/l] OPL = 1 mm [1] OPL = 5 mm OPL = 35 mm	not available	GC-A-TS 0 - 20 0 - 3 0 - 0.42	not available
Turbidity [FTU/NTU] OPL = 1 mm [1] OPL = 5 mm OPL = 35 mm	not available	not available	GC-E-TURB 0 - 8000 0 - 1200 0 - 170
COLORapp / COLORtru [Hazen] OPL = 1 mm [1] OPL = 5 mm OPL = 35 mm	GC-I-COL 0 - 23000 / 14000 0 - 3500 / 2100 0 - 500 / 300	not available	GC-E-COL 0 - 23000 / 14000 0 - 3500 / 2100 0 - 500 / 300
TOC / DOC [mg/l] OPL = 1 mm [1] OPL = 5 mm OPL = 35 mm	GC-I-TOC 0 - 3300 / 2600 0 - 500 / 400 0 - 71 / 57	not available	GC-E-TOC 0 - 2600 / 2000 0 - 400 / 300 0 - 57 / 42
BOD [mg/l] OPL = 1 mm [1] OPL = 5 mm OPL = 35 mm	GC-I-BOD 0 - 5300 0 - 800 0 - 110	not available	GC-E-BOD 0 - 2000 0 - 300 0 - 42
COD / CODf [mg/l] OPL = 1 mm [1] OPL = 5 mm OPL = 35 mm	GC-I-COD 0 - 10000 / 5300 0 - 1500 / 800 0 - 210 / 110	GC-A-COD 0 - 530 (CODf only) 0 - 80 (CODf only) 0 - 11 (CODf only)	GC-E-COD 0 - 3300 / 2000 0 - 500 / 300 0 - 71 / 42

[1] real OPL is approx. 0.75 mm



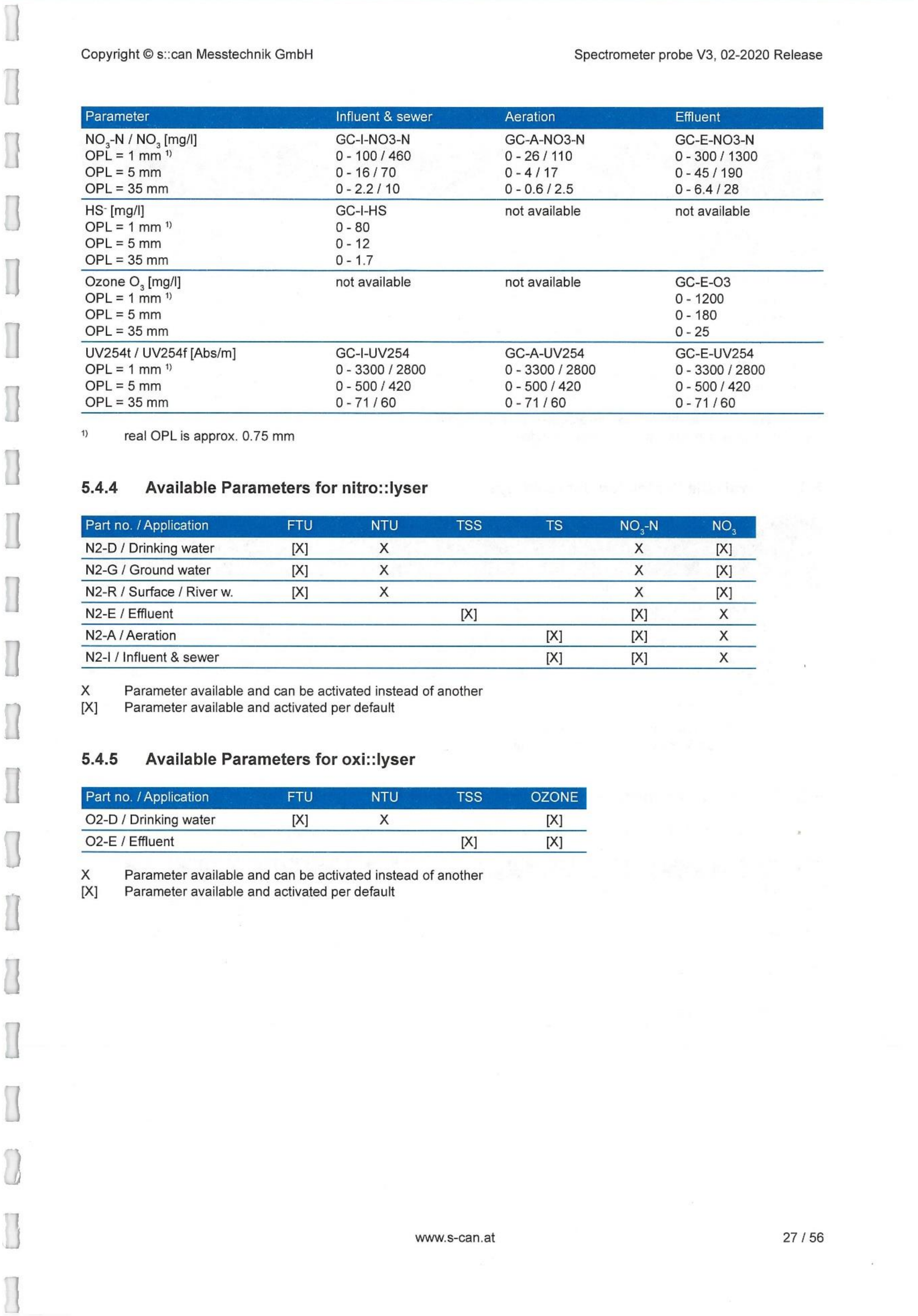
Parameter	Influent & sewer	Aeration	Effluent
NO$_3$-N / NO$_3$ [mg/l]	GC-I-NO3-N	GC-A-NO3-N	GC-E-NO3-N
OPL = 1 mm 1)	0 - 100 / 460	0 - 26 / 110	0 - 300 / 1300
OPL = 5 mm	0 - 16 / 70	0 - 4 / 17	0 - 45 / 190
OPL = 35 mm	0 - 2.2 / 10	0 - 0.6 / 2.5	0 - 6.4 / 28
HS$^-$ [mg/l]	GC-I-HS	not available	not available
OPL = 1 mm 1)	0 - 80		
OPL = 5 mm	0 - 12		
OPL = 35 mm	0 - 1.7		
Ozone O$_3$ [mg/l]	not available	not available	GC-E-O3
OPL = 1 mm 1)			0 - 1200
OPL = 5 mm			0 - 180
OPL = 35 mm			0 - 25
UV254t / UV254f [Abs/m]	GC-I-UV254	GC-A-UV254	GC-E-UV254
OPL = 1 mm 1)	0 - 3300 / 2800	0 - 3300 / 2800	0 - 3300 / 2800
OPL = 5 mm	0 - 500 / 420	0 - 500 / 420	0 - 500 / 420
OPL = 35 mm	0 - 71 / 60	0 - 71 / 60	0 - 71 / 60

1) real OPL is approx. 0.75 mm

5.4.3 Parameter Measuring Ranges in Industrial Waste Water

Parameter	Brewery	Paper mill influent	Paper mill Effluent	Dairy
TSS [mg/l]	GC-B-TSS	GC-P-TSS	GC-Q-TSS	GC-M-TSS
OPL = 1 mm 1)	0 - 13000	0 - 8000	0 - 4000	0 - 8000
OPL = 5 mm	0 - 2000	0 - 1200	0 - 600	0 - 1200
OPL = 35 mm	0 - 280	0 - 170	0 - 85	0 - 170
COD / CODf [mg/l]	GC-B-COD	GC-P-COD	GC-Q-COD	GC-M-COD
OPL = 1 mm 1)	0 - 60000 / 53000	0 - 13000 / 11000	0 - 5300 / 3300	0 - 33000 / 16000
OPL = 5 mm	0 - 9000 / 7900	0 - 2000 / 1700	0 - 790 / 490	0 - 5000 / 2400
OPL = 35 mm	0 - 1200 / 1100	0 - 280 / 240	0 - 110 / 70	0 - 710 / 340
NO$_3$-N / NO$_3$ [mg/l]	GC-B-NO3-N	GC-P-NO3-N	GC-Q-NO3-N	GC-M-NO3-N
OPL = 1 mm 1)	0 - 100 / 470	0 - 100 / 470	0 - 100 / 470	0 - 210 / 940
OPL = 5 mm	0 - 16 / 70	0 - 16 / 70	0 - 16 / 70	0 - 140 / 32
OPL = 35 mm	0 - 2.2 / 10	0 - 2.2 / 10	0 - 2.2 / 10	0 - 4.5 / 20
UV254t / UV254f [Abs/m]	GC-B-UV254	GC-P-UV254	GC-Q-UV254	GC-Q-UV254
OPL = 1 mm 1)	0 - 3300 / 2800	0 - 3300 / 2800	0 - 3300 / 2800	0 - 3300 / 2800
OPL = 5 mm	0 - 500 / 420	0 - 500 / 420	0 - 500 / 420	0 - 500 / 420
OPL = 35 mm	0 - 71 / 60	0 - 71 / 60	0 - 71 / 60	0 - 71 / 60

1) real OPL is approx. 0.75 mm



Parameter	Influent & sewer	Aeration	Effluent
NO_3-N / NO_3 [mg/l] OPL = 1 mm [1] OPL = 5 mm OPL = 35 mm	GC-I-NO3-N 0 - 100 / 460 0 - 16 / 70 0 - 2.2 / 10	GC-A-NO3-N 0 - 26 / 110 0 - 4 / 17 0 - 0.6 / 2.5	GC-E-NO3-N 0 - 300 / 1300 0 - 45 / 190 0 - 6.4 / 28
HS^- [mg/l] OPL = 1 mm [1] OPL = 5 mm OPL = 35 mm	GC-I-HS 0 - 80 0 - 12 0 - 1.7	not available	not available
Ozone O_3 [mg/l] OPL = 1 mm [1] OPL = 5 mm OPL = 35 mm	not available	not available	GC-E-O3 0 - 1200 0 - 180 0 - 25
UV254t / UV254f [Abs/m] OPL = 1 mm [1] OPL = 5 mm OPL = 35 mm	GC-I-UV254 0 - 3300 / 2800 0 - 500 / 420 0 - 71 / 60	GC-A-UV254 0 - 3300 / 2800 0 - 500 / 420 0 - 71 / 60	GC-E-UV254 0 - 3300 / 2800 0 - 500 / 420 0 - 71 / 60

[1] real OPL is approx. 0.75 mm

5.4.4 Available Parameters for nitro::lyser

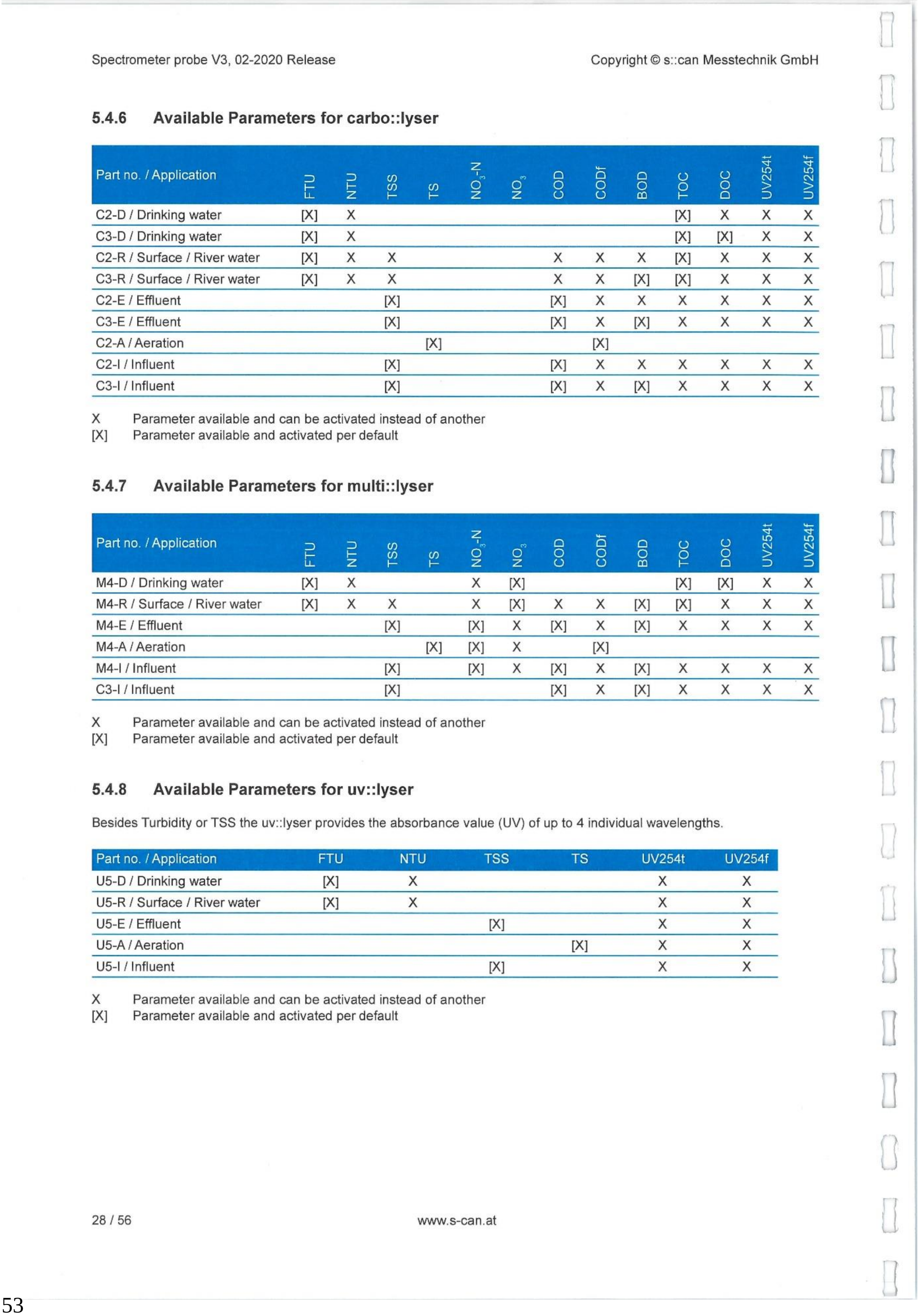
Part no. / Application	FTU	NTU	TSS	TS	NO_3-N	NO_3
N2-D / Drinking water	[X]	X			X	[X]
N2-G / Ground water	[X]	X			X	[X]
N2-R / Surface / River w.	[X]	X			X	[X]
N2-E / Effluent			[X]		[X]	X
N2-A / Aeration				[X]	[X]	X
N2-I / Influent & sewer				[X]	[X]	X

X Parameter available and can be activated instead of another
[X] Parameter available and activated per default

5.4.5 Available Parameters for oxi::lyser

Part no. / Application	FTU	NTU	TSS	OZONE
O2-D / Drinking water	[X]	X		[X]
O2-E / Effluent			[X]	[X]

X Parameter available and can be activated instead of another
[X] Parameter available and activated per default



5.4.6 Available Parameters for carbo::lyser

Part no. / Application	FTU	NTU	TSS	TS	NO_3-N	NO_3	COD	CODf	BOD	TOC	DOC	UV254t	UV254f
C2-D / Drinking water	[X]	X								[X]	X	X	X
C3-D / Drinking water	[X]	X								[X]	[X]	X	X
C2-R / Surface / River water	[X]	X	X				X	X	X	[X]	X	X	X
C3-R / Surface / River water	[X]	X	X				X	X	[X]	[X]	X	X	X
C2-E / Effluent			[X]				[X]	X	X	X	X	X	X
C3-E / Effluent			[X]				[X]	X	[X]	X	X	X	X
C2-A / Aeration				[X]				[X]					
C2-I / Influent			[X]				[X]	X	X	X	X	X	X
C3-I / Influent			[X]				[X]	X	[X]	X	X	X	X

X	Parameter available and can be activated instead of another
[X]	Parameter available and activated per default

5.4.7 Available Parameters for multi::lyser

Part no. / Application	FTU	NTU	TSS	TS	NO_3-N	NO_3	COD	CODf	BOD	TOC	DOC	UV254t	UV254f
M4-D / Drinking water	[X]	X			X	[X]				[X]	[X]	X	X
M4-R / Surface / River water	[X]	X	X		X	[X]	X	X	[X]	[X]	X	X	X
M4-E / Effluent			[X]		[X]	X	[X]	X	[X]	X	X	X	X
M4-A / Aeration				[X]	[X]	X		[X]					
M4-I / Influent			[X]		[X]	X	[X]	X	[X]	X	X	X	X
C3-I / Influent			[X]				[X]	X	[X]	X	X	X	X

X	Parameter available and can be activated instead of another
[X]	Parameter available and activated per default

5.4.8 Available Parameters for uv::lyser

Besides Turbidity or TSS the uv::lyser provides the absorbance value (UV) of up to 4 individual wavelengths.

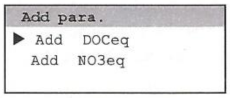
Part no. / Application	FTU	NTU	TSS	TS	UV254t	UV254f
U5-D / Drinking water	[X]	X			X	X
U5-R / Surface / River water	[X]	X			X	X
U5-E / Effluent			[X]		X	X
U5-A / Aeration				[X]	X	X
U5-I / Influent			[X]		X	X

X	Parameter available and can be activated instead of another
[X]	Parameter available and activated per default

5.4.9 Probe Parameterisation using con::lyte D-320

After successful probe initialisation (see section 5.3.1) the needed measuring parameters of the spectrometer probe have to be added to the parameter display. This is performed by the following steps:

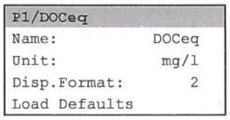
- Switch to status display with *Left-* or *Right* button.
- Push *Function* button, select menu *Manage sensors...* and confirm with *OK*.
- Select *spectro::lyserV3/0/x* and confirm with *OK*.
- Select menu *Add parameters...* and confirm with *OK*.
- Select needed parameter and confirm with *OK*.


Add para.
▶ Add DOCeq
Add NO3eq

The selected parameter will be displayed now on the next free position of the parameter display. The default display configuration is used. Changing the display format is performed by the following steps:

- Select the parameter in the parameter display using *Up-* or *Down* button.
- Push *Function* button, select menu *Display settings...* and confirm with *OK*.
- Select *spectro::lyserV3/0/x* and confirm with *OK*.
- Select menu *Add parameters...* and confirm with *OK*.
- Select needed parameter and confirm with *OK*.

In the displayed parameter configuration the following settings can be modified.


P1/DOCeq
Name: DOCeq
Unit: mg/l
Disp.Format: 2
Load Defaults

- *Name* Displays the actual name of the paramter.
- *Unit* Displays the actual unit of the paramter.

To change the name or unit of the parameter, select the entry with *Up-* and *Down* buttons and by pushing the *OK* button the name can be changed with *Up-*, *Down-*, *Left-* and *Right* buttons. Pushing the *OK* button confirms the new name.

Please note that change of parameter name or unit will not change the parameter configuration itself (e.g. if you change the parameter name NO$_3$-N to NO$_3$ the reading will still be NO$_3$-N).

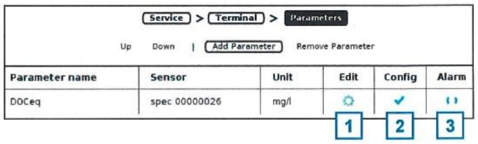
- *Disp.Format* Within this line the number of displayed decimal places (between 0 and 5) can be set. Please note that in case of too many digits high values can not be displayed and the parameter reading will switch to plus signs (++.+++++).

- *Load Defaults* Confirming this entry by pushing the *Ok* button will restore the default display settings from the sensor.

All modifications performed by the operator within these settings menu will be documented in the config file of the con::lyte (see manual con::lyte D-320).

5.4.10 Probe Parameterisation using moni::tool

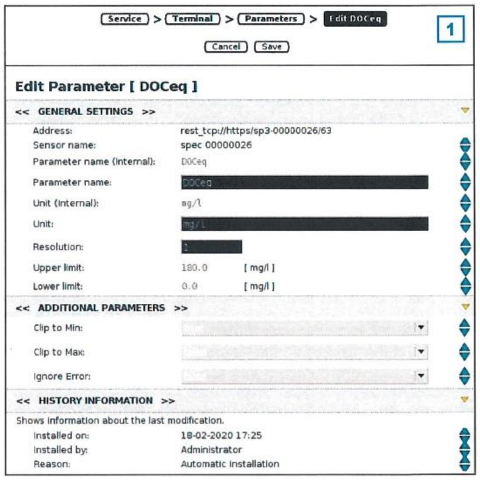
After successful probe initialisation (see section 5.3.2) all parameters of the spectrometer probe will be installed and the active parameters will be displayed on the *Values* screen of moni::tool. If you want to configure the measuring parameters individually, this can be done using the menu item *Menu / Settings / Parameter*.



Parameter name	Sensor	Unit	Edit	Config	Alarm
DOCeq	spec 00000026	mg/l	⚙	✓	( )

After selecting that menu item a list of all installed parameters is displayed. After selecting one or several parameters by clicking on them the following activities can be performed:

- Moving the selected parameter to a higher position in the *Values* display by pushing the entry *Up*.
- Moving the selected parameter to a lower position in the *Values* display by pushing the entry *Down*.
- Deleting the selected parameter from *Values* display by pushing the entry *Remove Parameter*. This action has to be confirmed in a new screen by pushing the button *Delete all*.
- A new parameter can be added to the *Value* display by pushing the entry *Add Parameter*. A table of all parameters that are available will be displayed.
- Click on the blue plus sign (+) on the right hand side of the parameter you want to add to the *Values* display.
- A new screen showing the configuration of the selected parameter will pop up. The *Parameter name* and the *Unit* can be modified in the entry field. Confirm this screen by pushing the entry *Save*.
- Click on the blue wheel (*Edit*) on the right hand side of the parameter will display the actual parameter settings. Depending on the actual *Service Level* different settings are displayed and can be edited. *Parametername*, *Unit* and *Resolution* can be modified in the *Basic* level.
- On a higher *Service Level* (*Advanced*, *Expert*) the *Additional Parameters* can be configured.
- Click on the blue check mark (*Config*) on the right hand side of the parameter to check or modify the settings for vali::tool of this parameter. The *Basic* screen is displayed on the right. Please refer to the manual moni::tool for further information.
- Click on the next blue sign (*Alarm*) on the right hand side of the parameter to check or modify the alarm settings for this parameter. The basic screen is displayed on the right. Please refer to the manual moni::tool for further information.



Edit Parameter [DOCeq]

<< GENERAL SETTINGS >>

Address: rest_tcp://https/sp3-00000026/63
Sensor name: spec 00000026
Parameter name (internal): DOCeq
Parameter name: DOCeq
Unit (internal): mg/l
Unit: mg/l
Resolution: 1
Upper limit: 180.0 [mg/l]
Lower limit: 0.0 [mg/l]

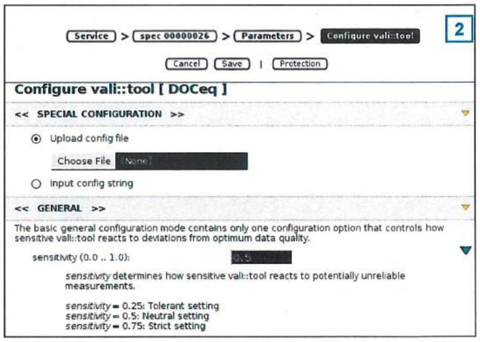
<< ADDITIONAL PARAMETERS >>

Clip to Min:
Clip to Max:
Ignore Error:

<< HISTORY INFORMATION >>

Shows information about the last modification.

Installed on: 18-02-2020 17:25
Installed by: Administrator
Reason: Automatic installation



Configure vali::tool [DOCeq]

<< SPECIAL CONFIGURATION >>

● Upload config file
Choose File (None)
○ Input config string

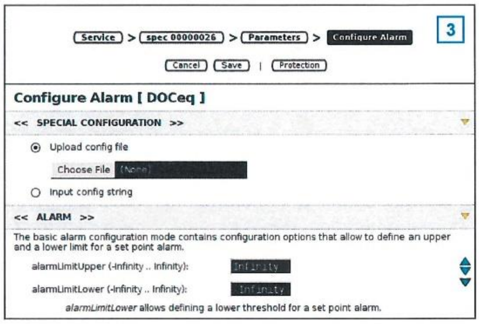
<< GENERAL >>

The basic general configuration mode contains only one configuration option that controls how sensitive vali::tool reacts to deviations from optimum data quality.

sensitivity (0.0 .. 1.0): 0.5

sensitivity determines how sensitive vali::tool reacts to potentially unreliable measurements.

sensitivity = 0.25: Tolerant setting
sensitivity = 0.5: Neutral setting
sensitivity = 0.75: Strict setting



Configure Alarm [DOCeq]

<< SPECIAL CONFIGURATION >>

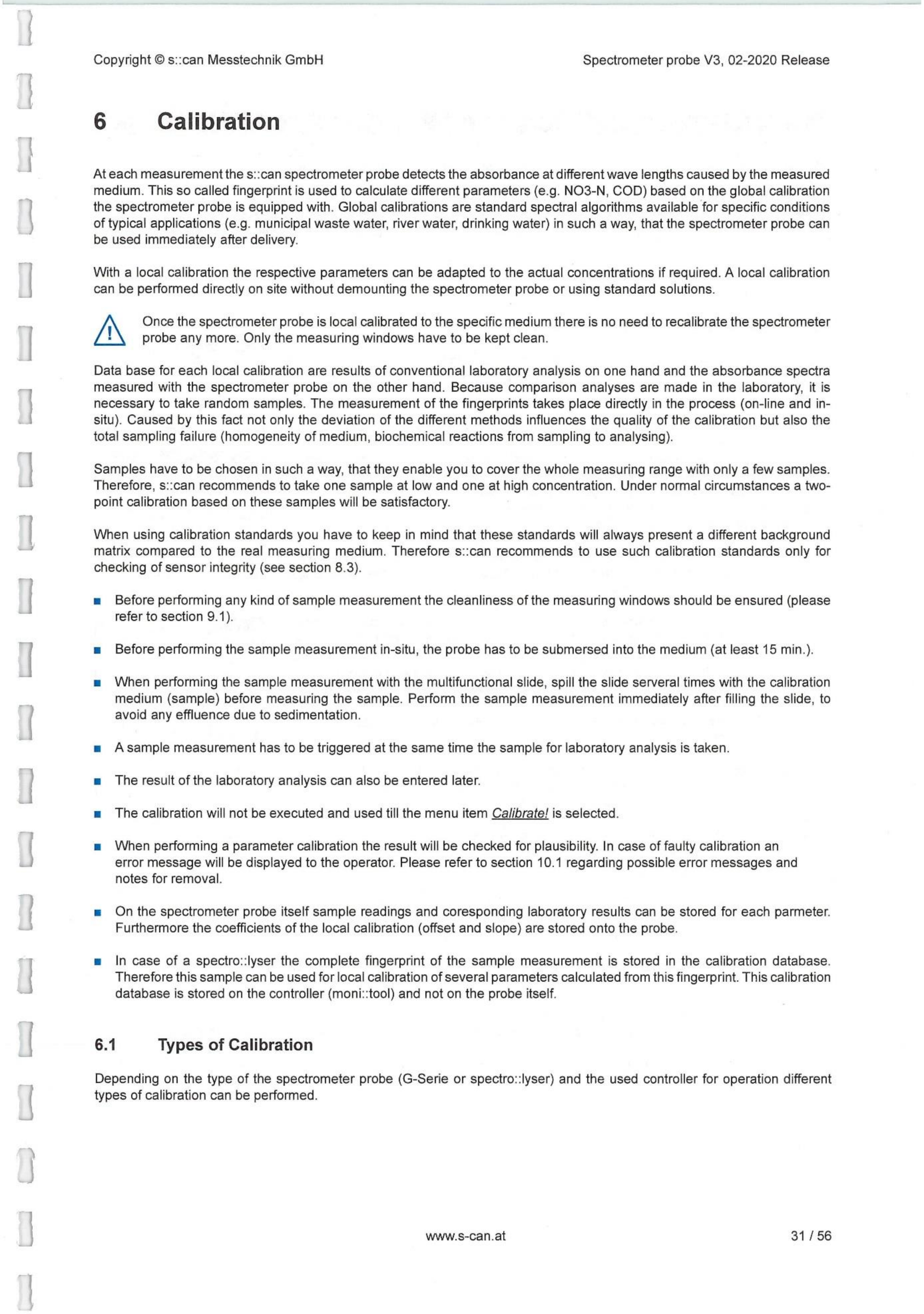
● Upload config file
Choose File (None)
○ Input config string

<< ALARM >>

The basic alarm configuration mode contains configuration options that allow to define an upper and a lower limit for a set point alarm.

alarmLimitUpper (-Infinity .. Infinity): Infinity
alarmLimitLower (-Infinity .. Infinity): Infinity

alarmLimitLower allows defining a lower threshold for a set point alarm.



6 Calibration

At each measurement the s::can spectrometer probe detects the absorbance at different wave lengths caused by the measured medium. This so called fingerprint is used to calculate different parameters (e.g. NO3-N, COD) based on the global calibration the spectrometer probe is equipped with. Global calibrations are standard spectral algorithms available for specific conditions of typical applications (e.g. municipal waste water, river water, drinking water) in such a way, that the spectrometer probe can be used immediately after delivery.

With a local calibration the respective parameters can be adapted to the actual concentrations if required. A local calibration can be performed directly on site without demounting the spectrometer probe or using standard solutions.

⚠ Once the spectrometer probe is local calibrated to the specific medium there is no need to recalibrate the spectrometer probe any more. Only the measuring windows have to be kept clean.

Data base for each local calibration are results of conventional laboratory analysis on one hand and the absorbance spectra measured with the spectrometer probe on the other hand. Because comparison analyses are made in the laboratory, it is necessary to take random samples. The measurement of the fingerprints takes place directly in the process (on-line and in-situ). Caused by this fact not only the deviation of the different methods influences the quality of the calibration but also the total sampling failure (homogeneity of medium, biochemical reactions from sampling to analysing).

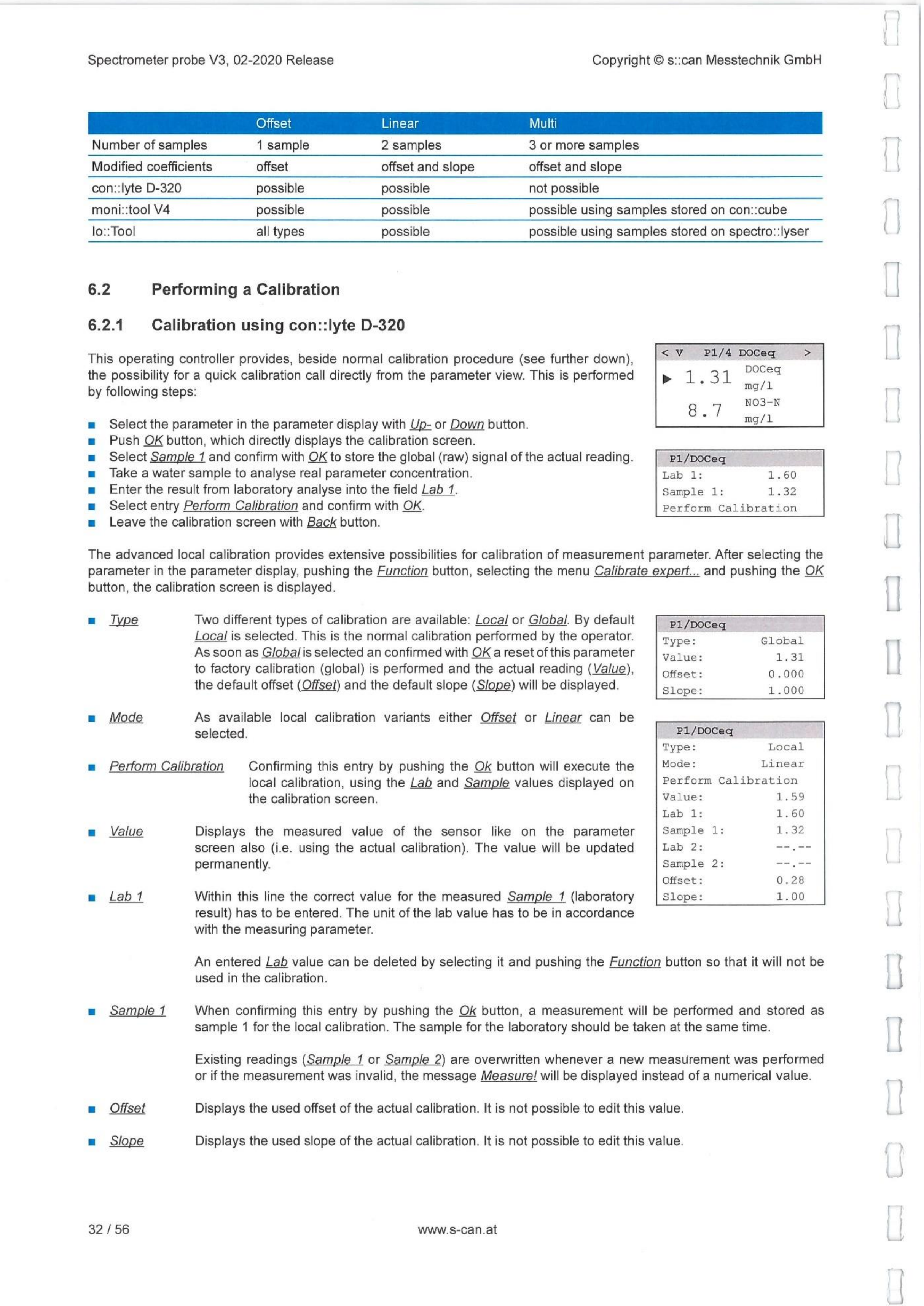
Samples have to be chosen in such a way, that they enable you to cover the whole measuring range with only a few samples. Therefore, s::can recommends to take one sample at low and one at high concentration. Under normal circumstances a two-point calibration based on these samples will be satisfactory.

When using calibration standards you have to keep in mind that these standards will always present a different background matrix compared to the real measuring medium. Therefore s::can recommends to use such calibration standards only for checking of sensor integrity (see section 8.3).

- Before performing any kind of sample measurement the cleanliness of the measuring windows should be ensured (please refer to section 9.1).
- Before performing the sample measurement in-situ, the probe has to be submersed into the medium (at least 15 min.).
- When performing the sample measurement with the multifunctional slide, spill the slide serveral times with the calibration medium (sample) before measuring the sample. Perform the sample measurement immediately after filling the slide, to avoid any effluence due to sedimentation.
- A sample measurement has to be triggered at the same time the sample for laboratory analysis is taken.
- The result of the laboratory analysis can also be entered later.
- The calibration will not be executed and used till the menu item *Calibrate!* is selected.
- When performing a parameter calibration the result will be checked for plausibility. In case of faulty calibration an error message will be displayed to the operator. Please refer to section 10.1 regarding possible error messages and notes for removal.
- On the spectrometer probe itself sample readings and coresponding laboratory results can be stored for each parmeter. Furthermore the coefficients of the local calibration (offset and slope) are stored onto the probe.
- In case of a spectro::lyser the complete fingerprint of the sample measurement is stored in the calibration database. Therefore this sample can be used for local calibration of several parameters calculated from this fingerprint. This calibration database is stored on the controller (moni::tool) and not on the probe itself.

6.1 Types of Calibration

Depending on the type of the spectrometer probe (G-Serie or spectro::lyser) and the used controller for operation different types of calibration can be performed.



	Offset	Linear	Multi
Number of samples	1 sample	2 samples	3 or more samples
Modified coefficients	offset	offset and slope	offset and slope
con::lyte D-320	possible	possible	not possible
moni::tool V4	possible	possible	possible using samples stored on con::cube
lo::Tool	all types	possible	possible using samples stored on spectro::lyser

6.2 Performing a Calibration

6.2.1 Calibration using con::lyte D-320

This operating controller provides, beside normal calibration procedure (see further down), the possibility for a quick calibration call directly from the parameter view. This is performed by following steps:

```
< V   P1/4 DOCeq     >
▶ 1.31    DOCeq
          mg/l
  8.7     NO3-N
          mg/l
```

- Select the parameter in the parameter display with *Up-* or *Down* button.
- Push *OK* button, which directly displays the calibration screen.
- Select *Sample 1* and confirm with *OK* to store the global (raw) signal of the actual reading.
- Take a water sample to analyse real parameter concentration.
- Enter the result from laboratory analyse into the field *Lab 1*.
- Select entry *Perform Calibration* and confirm with *OK*.
- Leave the calibration screen with *Back* button.

```
 P1/DOCeq
Lab 1:          1.60
Sample 1:       1.32
Perform Calibration
```

The advanced local calibration provides extensive possibilities for calibration of measurement parameter. After selecting the parameter in the parameter display, pushing the *Function* button, selecting the menu *Calibrate expert...* and pushing the *OK* button, the calibration screen is displayed.

- *Type* Two different types of calibration are available: *Local* or *Global*. By default *Local* is selected. This is the normal calibration performed by the operator. As soon as *Global* is selected an confirmed with *OK* a reset of this parameter to factory calibration (global) is performed and the actual reading (*Value*), the default offset (*Offset*) and the default slope (*Slope*) will be displayed.

```
 P1/DOCeq
Type:         Global
Value:          1.31
Offset:        0.000
Slope:         1.000
```

- *Mode* As available local calibration variants either *Offset* or *Linear* can be selected.
- *Perform Calibration* Confirming this entry by pushing the *Ok* button will execute the local calibration, using the *Lab* and *Sample* values displayed on the calibration screen.
- *Value* Displays the measured value of the sensor like on the parameter screen also (i.e. using the actual calibration). The value will be updated permanently.
- *Lab 1* Within this line the correct value for the measured *Sample 1* (laboratory result) has to be entered. The unit of the lab value has to be in accordance with the measuring parameter.

  An entered *Lab* value can be deleted by selecting it and pushing the *Function* button so that it will not be used in the calibration.

```
 P1/DOCeq
Type:          Local
Mode:         Linear
Perform Calibration
Value:          1.59
Lab 1:          1.60
Sample 1:       1.32
Lab 2:          --.--
Sample 2:       --.--
Offset:         0.28
Slope:          1.00
```

- *Sample 1* When confirming this entry by pushing the *Ok* button, a measurement will be performed and stored as sample 1 for the local calibration. The sample for the laboratory should be taken at the same time.

  Existing readings (*Sample 1* or *Sample 2*) are overwritten whenever a new measurement was performed or if the measurement was invalid, the message *Measure!* will be displayed instead of a numerical value.
- *Offset* Displays the used offset of the actual calibration. It is not possible to edit this value.
- *Slope* Displays the used slope of the actual calibration. It is not possible to edit this value.

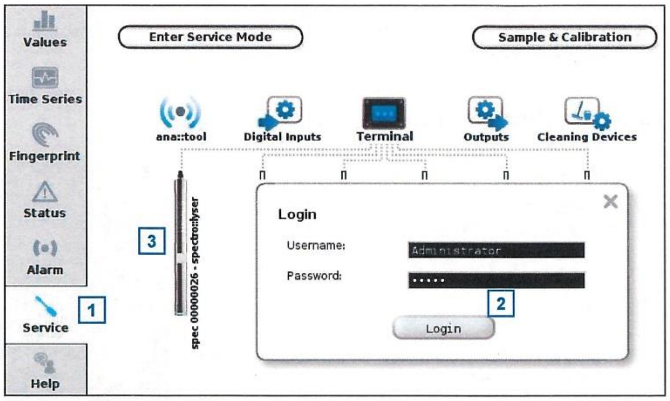
6.2.2 Calibration using moni::tool

1 Click the *Service* tab of the moni::tool screen.

2 Logon as *Administrator* with password *admin1* or your individual username.

3 Click the icon of the sensor you want to calibrate in the displayed system overview.

4 Click the icon *Calibrate sensor* in the next screen.



Login

Username: Administrator

Password: •••••

Now the screen shows a list of all parameters being measured by this sensor (*Parameter name*).

5 Clicking on the blue triangles will open more information about actual used calibration for this parameter.

6 Furthermore a click on the *History* icon rightmost opens a logbook showing all up to now with this con::cube performed calibration procedures.

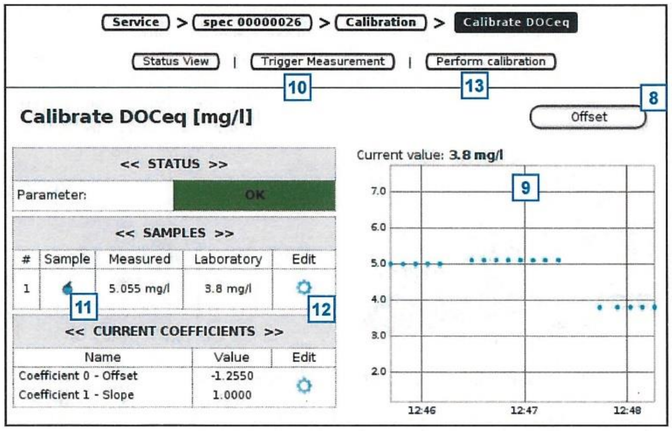
7 Open the calibration screen by clicking on the *Calibrate* icon on the right side of the paramter you want to calibrate.

8 This button displays the actual used calibration (*Global*, *Offset*, *Linear* or *Multi*). Push this button to select the type of calibration you want to perform.

9 The current readings of the parameter will be displayed numerically and graphically.

10 A new measurement of the spectrometer probe will be performed whenever you push the button *Trigger measurement*.

Parameter name	Last calibration	Calibrate	History
DOCeq	[Global]		
	Name [Linear]		
TOCeq	Coefficient 0 - Offset: **1.1947** Coefficient 1 - Slope: **0.8467**		



Calibrate DOCeq [mg/l]

Current value: **3.8 mg/l**

<< STATUS >>

Parameter: OK

<< SAMPLES >>

#	Sample	Measured	Laboratory	Edit
1		5.055 mg/l	3.8 mg/l	

<< CURRENT COEFFICIENTS >>

Name	Value	Edit
Coefficient 0 - Offset	-1.2550	
Coefficient 1 - Slope	1.0000	

11 Push the *Sample* icon to perform a new measurement and store the reading on the probe. Please note that the displayed value is the *Raw* value, based on the global calibration.

12 Push the *Edit* icon to enter the result of the laboratory analysis and store it on the probe.

13 Push the button *Perform Calibration* to start the calibration procedure.

After the calibration procedure is finished a user message will inform you, if the local *calibration of parameter* was *successful*. In case of an error the reason will be displayed to the user in red letters (e.g. *Please enter at least lab values for 2 samples*).

The coefficients of the new local calibration will be displayed in the column *Value*. It is also possible to write coefficients directly onto the probe by pushing the button *Edit*.

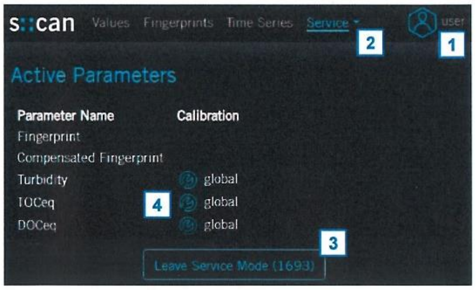
6.2.3 Calibration using con::nect and lo::Tool

1 Enter the IP of the spectrometer probe into your webbrowser (see section 5.3.3) to start lo::Tool. Logout user *guest* and logon as *user* or *expert*.

2 Select menu *Service \ Measurement Settings*.

3 Push the button *Enter Service Mode*.

4 Push the blue calibration icon on the left side of the parameter you want to calibrate.



Active Parameters

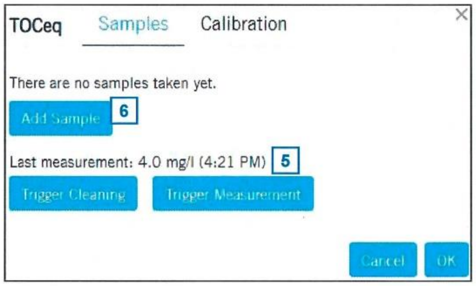
Parameter Name	Calibration
Fingerprint	
Compensated Fingerprint	
Turbidity	global
TOCeq	global
DOCeq	global

5 Within the calibration screen the last measurement reading is displayed.

6 Push the button *Add Sample* to store the last measurement as sample

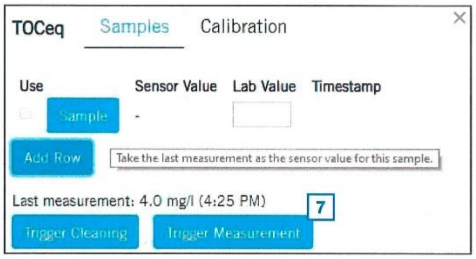
7 New measurements can be performed by pushing *Trigger Measurement*.

8 Select the samples that shall be used for local calibration.



There are no samples taken yet.

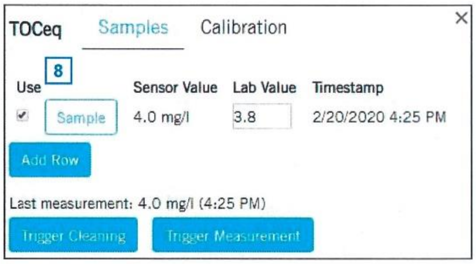
Last measurement: 4.0 mg/l (4:21 PM)



Use		Sensor Value	Lab Value	Timestamp
☐	Sample	-		

Take the last measurement as the sensor value for this sample.

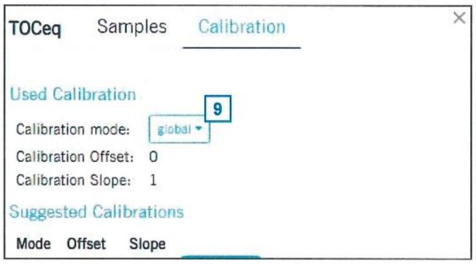
Last measurement: 4.0 mg/l (4:25 PM)



Use		Sensor Value	Lab Value	Timestamp
☑	Sample	4.0 mg/l	3.8	2/20/2020 4:25 PM

Last measurement: 4.0 mg/l (4:25 PM)

9 Within the *Calibration* tab the *Calibration mode* can be selected.

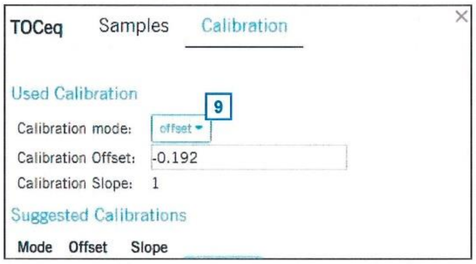


Used Calibration

Calibration mode: global

Calibration Offset: 0

Calibration Slope: 1



Used Calibration

Calibration mode: offset

Calibration Offset: -0.192

Calibration Slope: 1

7 Data Management

7.1 Data Storage

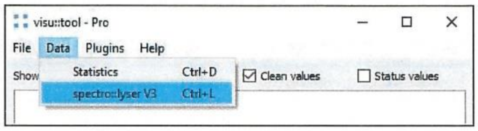
The following information are stored directly on the spectrometer probe:

- Global calibration for all uploaded parameters
- Actual used local calibration for each parameter
- Readings of sample measurements for each spectral parameter
- Laboratory results of samples for each spectral parameter
- Reference measurement
- Device information (e.g. type, serialnumber, address, please refer to section 10.2)
- Service information in the internal probe logfile

Furthermore the spectro::lyser enables logging of fingerprint and parameter results. Please refer to the technical specifications located at the end of this manual regarding amount of data being stored.

7.2 Data Transfer

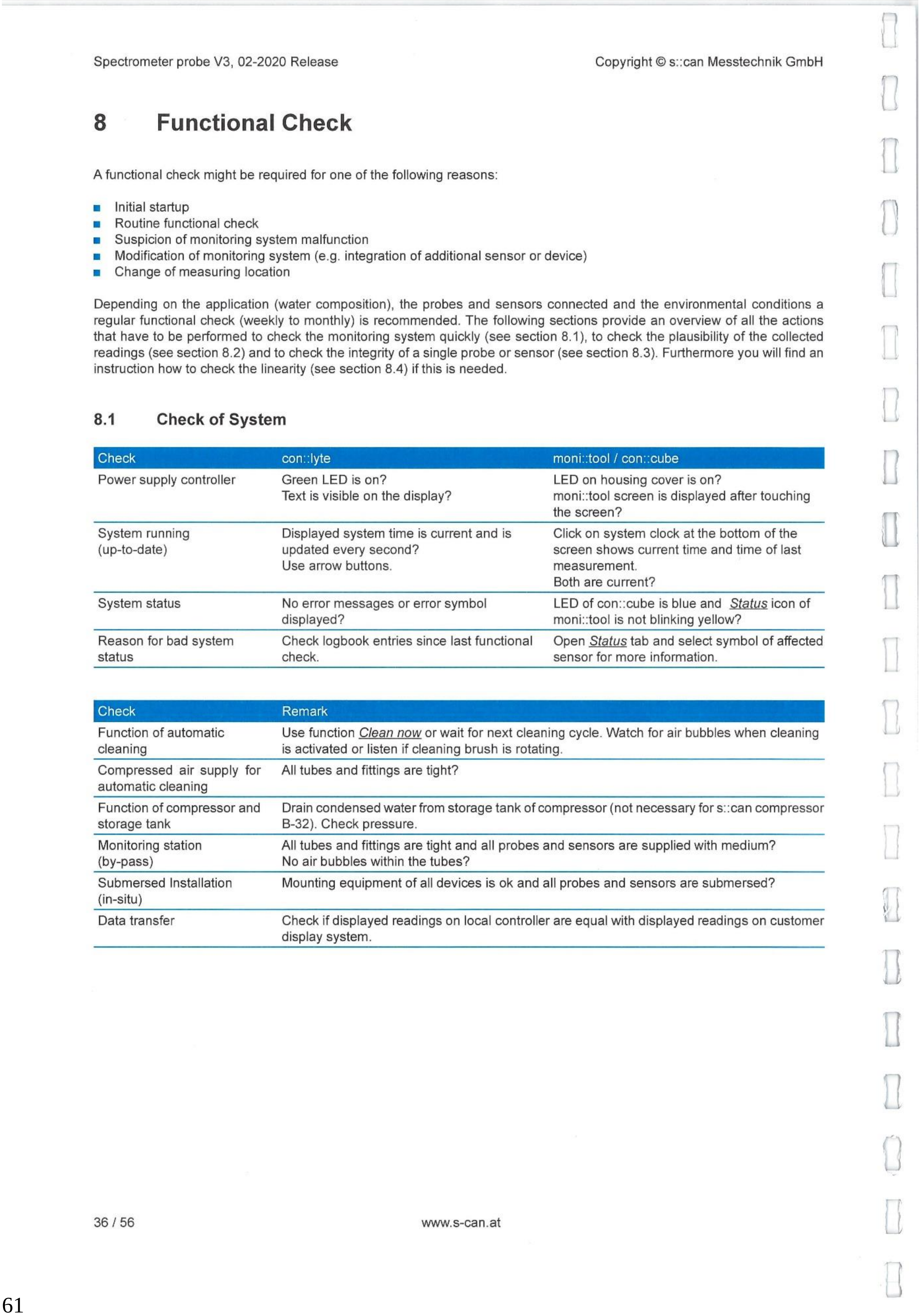
Stored fingerprint and parameter results can be downloaded from the probe with visu::tool. Please refer to manual visu::tool for further details.



7.3 Data Visualisation

For visualisation of the spectrometer probe readings one of the following s::can controller can be used:

- con::lyte (parameter readings)
- con::cube (parameter readings, time series and fingerprints in case of spectro::lyser)
- con::nect with PC using Io::Tool (parameter readings, time series and fingerprints in case of spectro::lyser)



8 Functional Check

A functional check might be required for one of the following reasons:

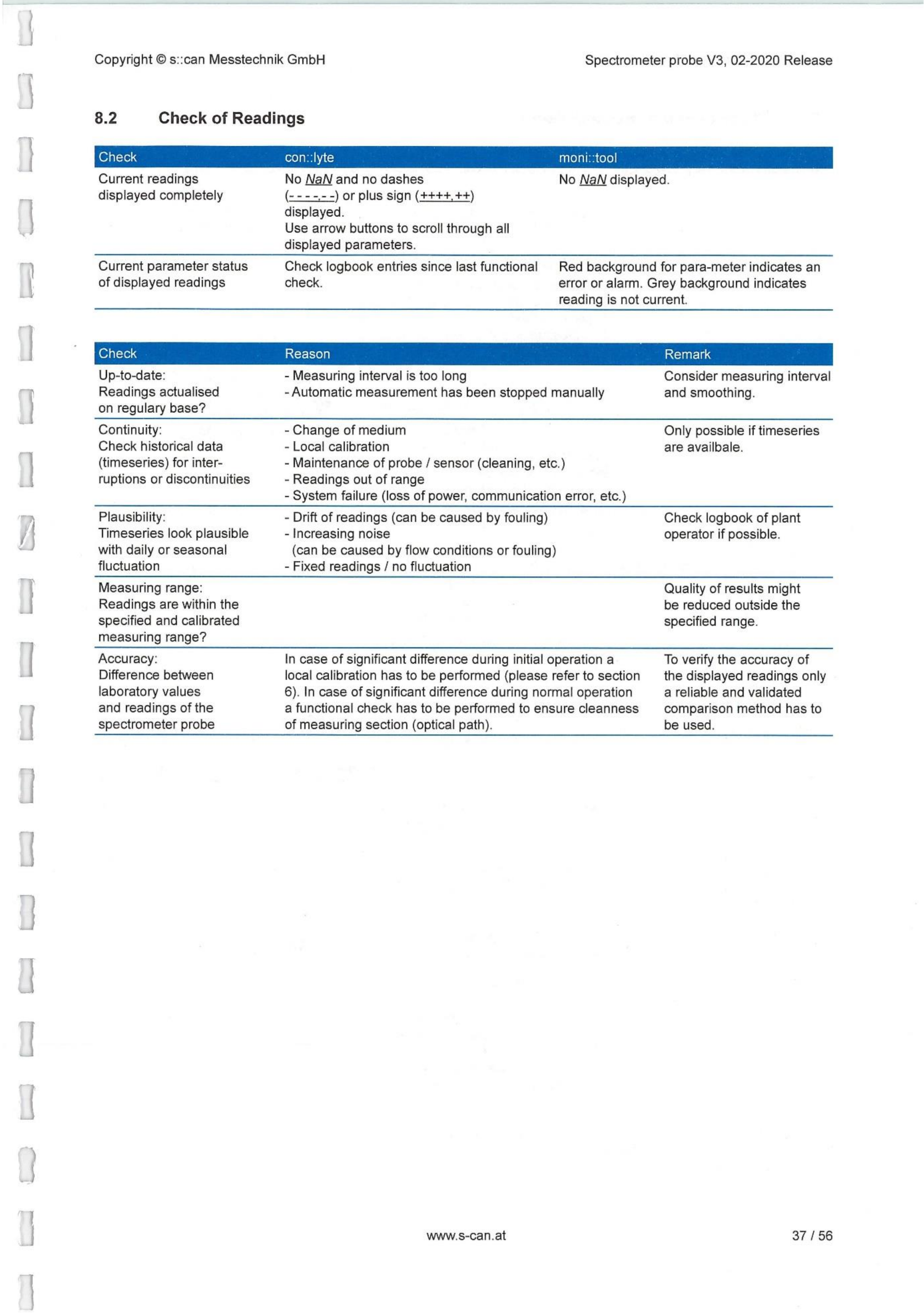
- Initial startup
- Routine functional check
- Suspicion of monitoring system malfunction
- Modification of monitoring system (e.g. integration of additional sensor or device)
- Change of measuring location

Depending on the application (water composition), the probes and sensors connected and the environmental conditions a regular functional check (weekly to monthly) is recommended. The following sections provide an overview of all the actions that have to be performed to check the monitoring system quickly (see section 8.1), to check the plausibility of the collected readings (see section 8.2) and to check the integrity of a single probe or sensor (see section 8.3). Furthermore you will find an instruction how to check the linearity (see section 8.4) if this is needed.

8.1 Check of System

Check	con::lyte	moni::tool / con::cube
Power supply controller	Green LED is on? Text is visible on the display?	LED on housing cover is on? moni::tool screen is displayed after touching the screen?
System running (up-to-date)	Displayed system time is current and is updated every second? Use arrow buttons.	Click on system clock at the bottom of the screen shows current time and time of last measurement. Both are current?
System status	No error messages or error symbol displayed?	LED of con::cube is blue and *Status* icon of moni::tool is not blinking yellow?
Reason for bad system status	Check logbook entries since last functional check.	Open *Status* tab and select symbol of affected sensor for more information.

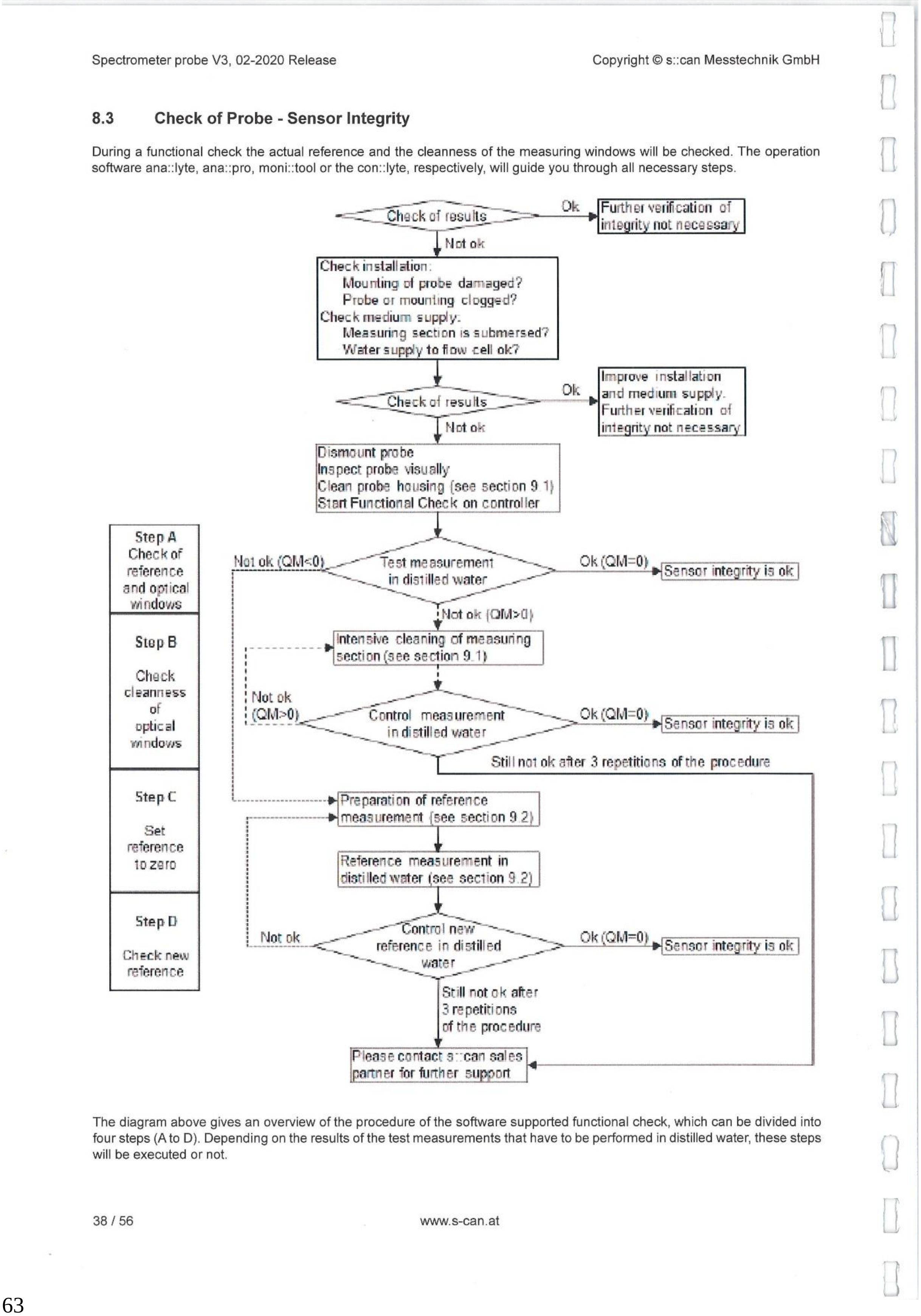
Check	Remark
Function of automatic cleaning	Use function *Clean now* or wait for next cleaning cycle. Watch for air bubbles when cleaning is activated or listen if cleaning brush is rotating.
Compressed air supply for automatic cleaning	All tubes and fittings are tight?
Function of compressor and storage tank	Drain condensed water from storage tank of compressor (not necessary for s::can compressor B-32). Check pressure.
Monitoring station (by-pass)	All tubes and fittings are tight and all probes and sensors are supplied with medium? No air bubbles within the tubes?
Submersed Installation (in-situ)	Mounting equipment of all devices is ok and all probes and sensors are submersed?
Data transfer	Check if displayed readings on local controller are equal with displayed readings on customer display system.



8.2 Check of Readings

Check	con::lyte	moni::tool
Current readings displayed completely	No *NaN* and no dashes (- - - -,- -) or plus sign (++++,++) displayed. Use arrow buttons to scroll through all displayed parameters.	No *NaN* displayed.
Current parameter status of displayed readings	Check logbook entries since last functional check.	Red background for para-meter indicates an error or alarm. Grey background indicates reading is not current.

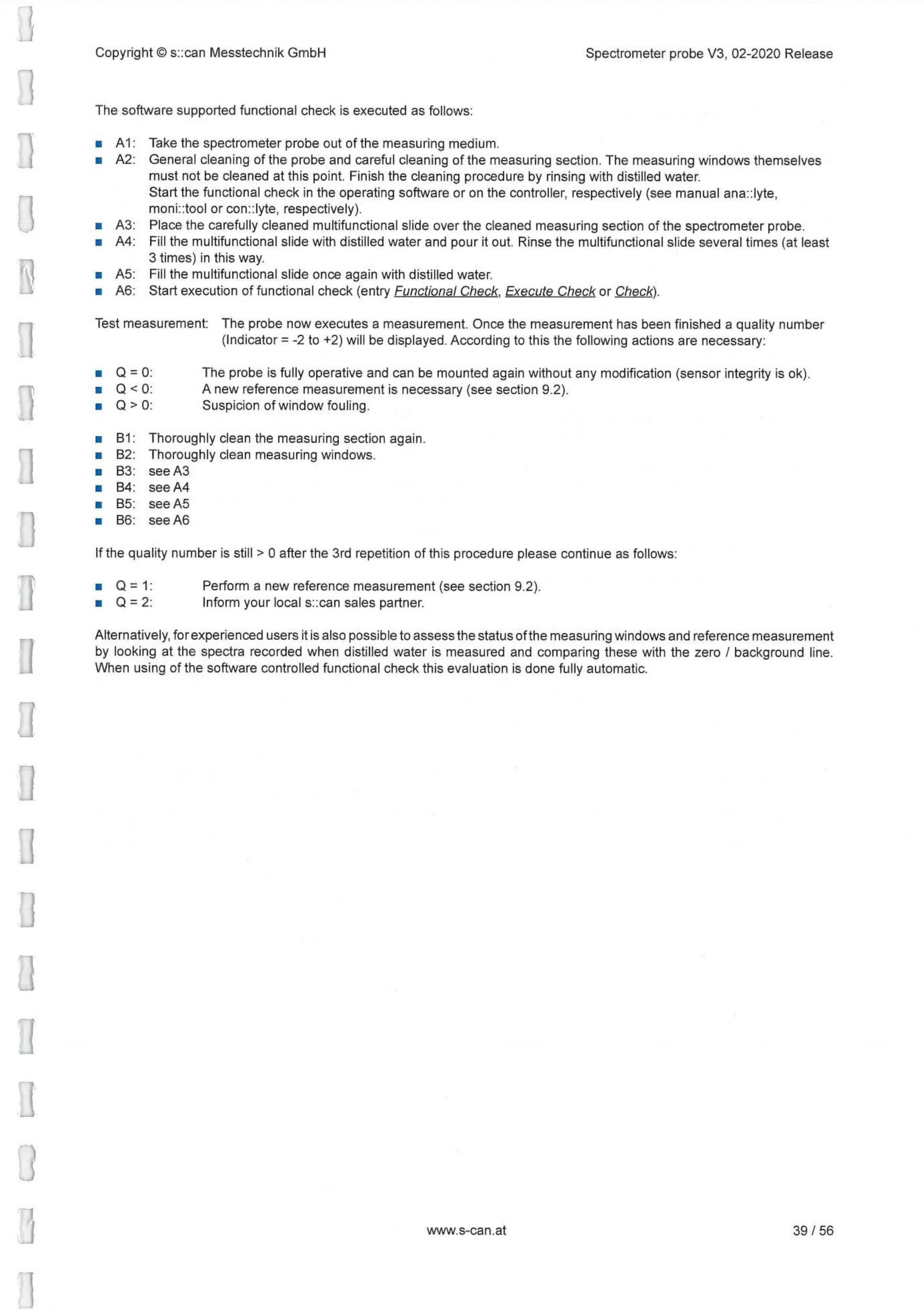
Check	Reason	Remark
Up-to-date: Readings actualised on regulary base?	- Measuring interval is too long - Automatic measurement has been stopped manually	Consider measuring interval and smoothing.
Continuity: Check historical data (timeseries) for interruptions or discontinuities	- Change of medium - Local calibration - Maintenance of probe / sensor (cleaning, etc.) - Readings out of range - System failure (loss of power, communication error, etc.)	Only possible if timeseries are availbale.
Plausibility: Timeseries look plausible with daily or seasonal fluctuation	- Drift of readings (can be caused by fouling) - Increasing noise (can be caused by flow conditions or fouling) - Fixed readings / no fluctuation	Check logbook of plant operator if possible.
Measuring range: Readings are within the specified and calibrated measuring range?		Quality of results might be reduced outside the specified range.
Accuracy: Difference between laboratory values and readings of the spectrometer probe	In case of significant difference during initial operation a local calibration has to be performed (please refer to section 6). In case of significant difference during normal operation a functional check has to be performed to ensure cleanness of measuring section (optical path).	To verify the accuracy of the displayed readings only a reliable and validated comparison method has to be used.



8.3 Check of Probe - Sensor Integrity

During a functional check the actual reference and the cleanness of the measuring windows will be checked. The operation software ana::lyte, ana::pro, moni::tool or the con::lyte, respectively, will guide you through all necessary steps.

The diagram above gives an overview of the procedure of the software supported functional check, which can be divided into four steps (A to D). Depending on the results of the test measurements that have to be performed in distilled water, these steps will be executed or not.



The software supported functional check is executed as follows:

- A1: Take the spectrometer probe out of the measuring medium.
- A2: General cleaning of the probe and careful cleaning of the measuring section. The measuring windows themselves must not be cleaned at this point. Finish the cleaning procedure by rinsing with distilled water.
  Start the functional check in the operating software or on the controller, respectively (see manual ana::lyte, moni::tool or con::lyte, respectively).
- A3: Place the carefully cleaned multifunctional slide over the cleaned measuring section of the spectrometer probe.
- A4: Fill the multifunctional slide with distilled water and pour it out. Rinse the multifunctional slide several times (at least 3 times) in this way.
- A5: Fill the multifunctional slide once again with distilled water.
- A6: Start execution of functional check (entry *Functional Check*, *Execute Check* or *Check*).

Test measurement: The probe now executes a measurement. Once the measurement has been finished a quality number (Indicator = -2 to +2) will be displayed. According to this the following actions are necessary:

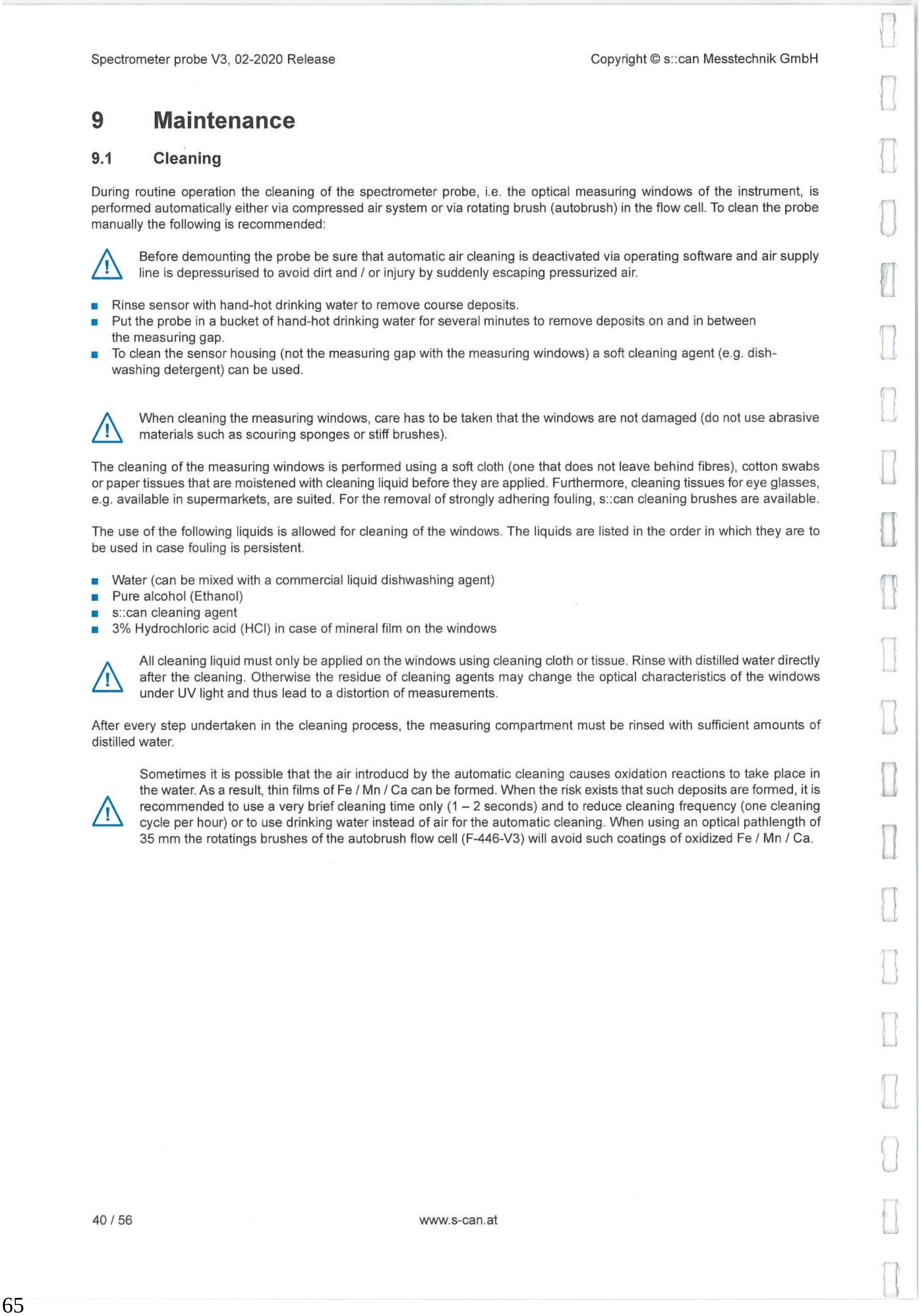
- Q = 0: The probe is fully operative and can be mounted again without any modification (sensor integrity is ok).
- Q < 0: A new reference measurement is necessary (see section 9.2).
- Q > 0: Suspicion of window fouling.

- B1: Thoroughly clean the measuring section again.
- B2: Thoroughly clean measuring windows.
- B3: see A3
- B4: see A4
- B5: see A5
- B6: see A6

If the quality number is still > 0 after the 3rd repetition of this procedure please continue as follows:

- Q = 1: Perform a new reference measurement (see section 9.2).
- Q = 2: Inform your local s::can sales partner.

Alternatively, for experienced users it is also possible to assess the status of the measuring windows and reference measurement by looking at the spectra recorded when distilled water is measured and comparing these with the zero / background line. When using of the software controlled functional check this evaluation is done fully automatic.



9 Maintenance

9.1 Cleaning

During routine operation the cleaning of the spectrometer probe, i.e. the optical measuring windows of the instrument, is performed automatically either via compressed air system or via rotating brush (autobrush) in the flow cell. To clean the probe manually the following is recommended:

⚠ Before demounting the probe be sure that automatic air cleaning is deactivated via operating software and air supply line is depressurised to avoid dirt and / or injury by suddenly escaping pressurized air.

- Rinse sensor with hand-hot drinking water to remove course deposits.
- Put the probe in a bucket of hand-hot drinking water for several minutes to remove deposits on and in between the measuring gap.
- To clean the sensor housing (not the measuring gap with the measuring windows) a soft cleaning agent (e.g. dish-washing detergent) can be used.

⚠ When cleaning the measuring windows, care has to be taken that the windows are not damaged (do not use abrasive materials such as scouring sponges or stiff brushes).

The cleaning of the measuring windows is performed using a soft cloth (one that does not leave behind fibres), cotton swabs or paper tissues that are moistened with cleaning liquid before they are applied. Furthermore, cleaning tissues for eye glasses, e.g. available in supermarkets, are suited. For the removal of strongly adhering fouling, s::can cleaning brushes are available.

The use of the following liquids is allowed for cleaning of the windows. The liquids are listed in the order in which they are to be used in case fouling is persistent.

- Water (can be mixed with a commercial liquid dishwashing agent)
- Pure alcohol (Ethanol)
- s::can cleaning agent
- 3% Hydrochloric acid (HCl) in case of mineral film on the windows

⚠ All cleaning liquid must only be applied on the windows using cleaning cloth or tissue. Rinse with distilled water directly after the cleaning. Otherwise the residue of cleaning agents may change the optical characteristics of the windows under UV light and thus lead to a distortion of measurements.

After every step undertaken in the cleaning process, the measuring compartment must be rinsed with sufficient amounts of distilled water.

⚠ Sometimes it is possible that the air introducd by the automatic cleaning causes oxidation reactions to take place in the water. As a result, thin films of Fe / Mn / Ca can be formed. When the risk exists that such deposits are formed, it is recommended to use a very brief cleaning time only (1 – 2 seconds) and to reduce cleaning frequency (one cleaning cycle per hour) or to use drinking water instead of air for the automatic cleaning. When using an optical pathlength of 35 mm the rotatings brushes of the autobrush flow cell (F-446-V3) will avoid such coatings of oxidized Fe / Mn / Ca.

9.2 Reference Measurement

All s::can spectrometer probes will be delivered with a high quality reference measurement and therefore can be used at once. The reference measurement serves to define the zero point of all wavelengths that are measured by the spectrometer probe.

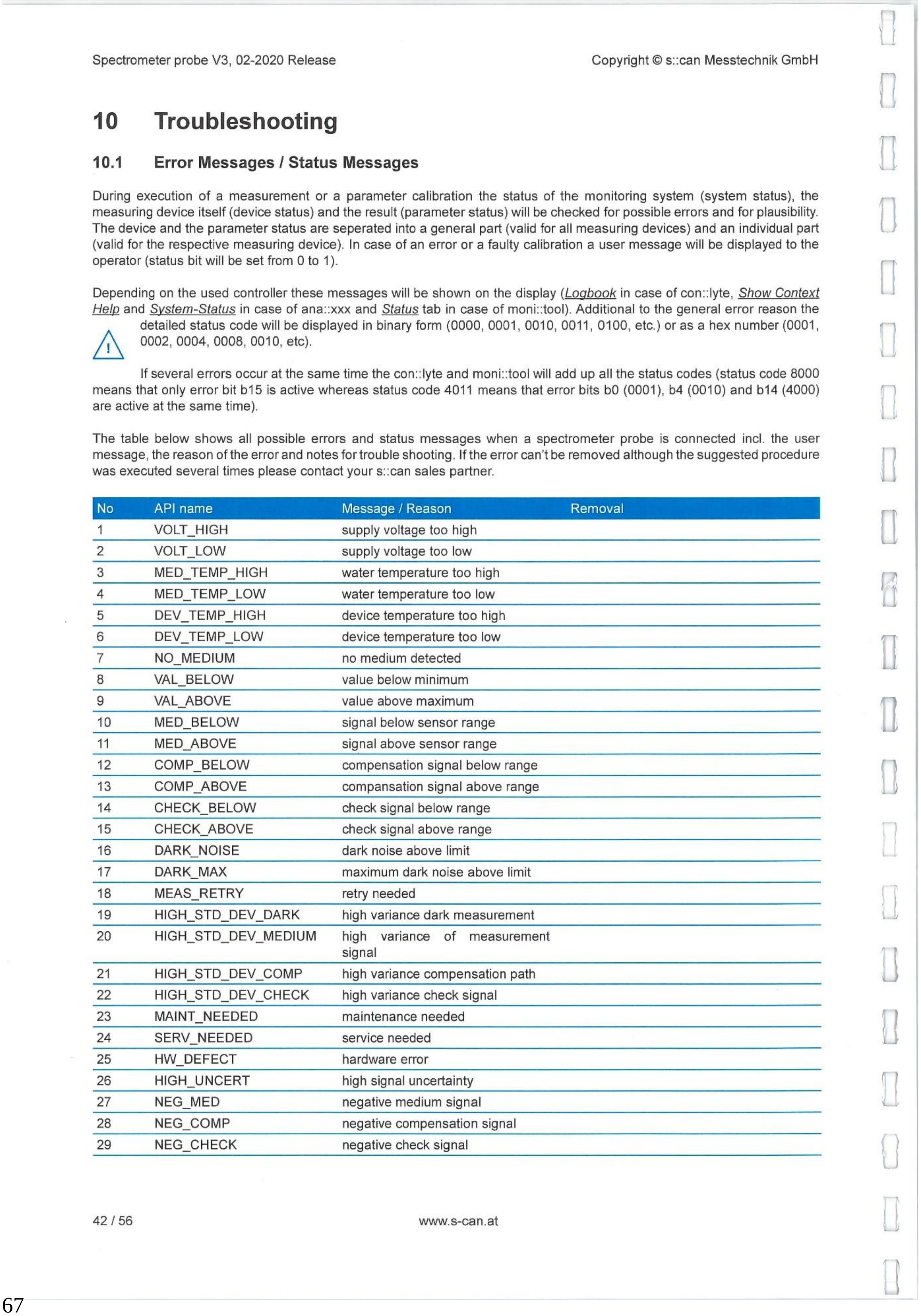
⚠ A new reference measurement shall only be performed due to result of a performed functional check (see section 8.3) or if recommended from your s::can sales partner. As faulty reference measurement will lead to falsification of all subsequent readings, replacing a reference measurement has to be done with great care.

- Thoroughly clean the measuring section, the measuring windows (see section 9.1) as well as the multifunctional slide.
- Place the carefully cleaned multifunctional slide over the cleaned measuring section of the spectrometer probe.
- Fill the multifunctional slide with distilled water and pour it out. Rinse the multifunctional slide several times (at least 3 times) in that way.
- Fill the multifunctional slide once again with controlled distilled water.
- Start the reference measurement (see manual ana::lyte, moni::tool or con::lyte). The measurement ends automatically and replaces the last reference measurement.
- Check the new reference measurement by means of the functional check (quality number Q = 0) or manual measurement in the reference medium (Fingerprint = zero).

⚠ High quality distilled water must be used for the reference measurement. In this context, please ensure that it contains no foreign matter (e.g. air bubbles, contamination) whatsoever! There is no way to check the quality of the distilled water used automatically.

For the highest possible accuracy of measurements, it is recommended to perform the reference measurement at the temperature and with the probe in the same orientation as it will be used when the probe is installed.

⚠ Poor referencing (e.g. when the measuring windows have not been properly cleaned or there are traces of cleaning agents on the measuring windows) may reduce the quality of the readings provided by your spectrometer probe.



10 Troubleshooting

10.1 Error Messages / Status Messages

During execution of a measurement or a parameter calibration the status of the monitoring system (system status), the measuring device itself (device status) and the result (parameter status) will be checked for possible errors and for plausibility. The device and the parameter status are seperated into a general part (valid for all measuring devices) and an individual part (valid for the respective measuring device). In case of an error or a faulty calibration a user message will be displayed to the operator (status bit will be set from 0 to 1).

Depending on the used controller these messages will be shown on the display (*Logbook* in case of con::lyte, *Show Context Help* and *System-Status* in case of ana::xxx and *Status* tab in case of moni::tool). Additional to the general error reason the detailed status code will be displayed in binary form (0000, 0001, 0010, 0011, 0100, etc.) or as a hex number (0001, 0002, 0004, 0008, 0010, etc).

If several errors occur at the same time the con::lyte and moni::tool will add up all the status codes (status code 8000 means that only error bit b15 is active whereas status code 4011 means that error bits b0 (0001), b4 (0010) and b14 (4000) are active at the same time).

The table below shows all possible errors and status messages when a spectrometer probe is connected incl. the user message, the reason of the error and notes for trouble shooting. If the error can't be removed although the suggested procedure was executed several times please contact your s::can sales partner.

No	API name	Message / Reason	Removal
1	VOLT_HIGH	supply voltage too high	
2	VOLT_LOW	supply voltage too low	
3	MED_TEMP_HIGH	water temperature too high	
4	MED_TEMP_LOW	water temperature too low	
5	DEV_TEMP_HIGH	device temperature too high	
6	DEV_TEMP_LOW	device temperature too low	
7	NO_MEDIUM	no medium detected	
8	VAL_BELOW	value below minimum	
9	VAL_ABOVE	value above maximum	
10	MED_BELOW	signal below sensor range	
11	MED_ABOVE	signal above sensor range	
12	COMP_BELOW	compensation signal below range	
13	COMP_ABOVE	compansation signal above range	
14	CHECK_BELOW	check signal below range	
15	CHECK_ABOVE	check signal above range	
16	DARK_NOISE	dark noise above limit	
17	DARK_MAX	maximum dark noise above limit	
18	MEAS_RETRY	retry needed	
19	HIGH_STD_DEV_DARK	high variance dark measurement	
20	HIGH_STD_DEV_MEDIUM	high variance of measurement signal	
21	HIGH_STD_DEV_COMP	high variance compensation path	
22	HIGH_STD_DEV_CHECK	high variance check signal	
23	MAINT_NEEDED	maintenance needed	
24	SERV_NEEDED	service needed	
25	HW_DEFECT	hardware error	
26	HIGH_UNCERT	high signal uncertainty	
27	NEG_MED	negative medium signal	
28	NEG_COMP	negative compensation signal	
29	NEG_CHECK	negative check signal	

No	API name	Message / Reason	Removal
30	NEG_FP	negative fingerprint	
31	NEG_LIMIT_EXT	extinction limit reached	
32	COMP_ABOVE_REF	compensation above reference	
33	COMP_BELOW_REF	compensation below reference	
34	CHECK_ABOVE_REF	check signal above reference	
35	CHECK_BELOW_REF	check signal below reference	
36	INV_REF_ENER	invalid spectral reference	
37	MATH_UNCERT	high mathematical uncertainty	
38	MATH_ERR	calculation error	

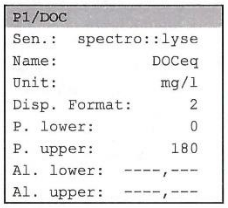
10.2 Device Settings

10.2.1 Check of Device Settings using con::lyte D-320

Select the entry *Manage sensors...* in the main menu of the status screen. Select the name *spectro::lyserV3/0/4* in the list of installed sensors, in which the second number (*4*) indicates the address assigned to the sensor. After confirming the entry *Configure...* as well as the entry *Probesettings* in the next view, the following information of the sensor will be displayed:

- Internal sensor identifier (*M-Version* and *Model*)
- Sensor name (*ammo::lyser*)
- Serialnumber of the sensor (*S/N*)
- Hardware version of the sensor (*H/W-Version*)
- Software version of the sensor (*S/W-Version*)
- Information about probe type (*UV-VIS*)
- Information about optical pathlength (*Path length*)
- Information about actual used reference (*Name*, *Date*)
- Information about maintenance (*xx %*)

Information of the single measuring parameter can be retrieved via the entry *Parameter info...* from the main menu of the parameter display. In addition to the parameter name (*Name*), the unit of measurement (*Unit*) the number of decimal places (*Disp. Format*), also the lower and upper limit of the parameter range (*P. lower* / *P. upper*) and the adjusted alarm range (*Al. lower* / *Al. upper*) are displayed.

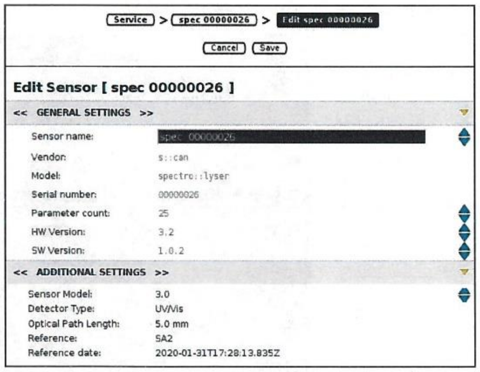


```
P1/DOC
Sen.:  spectro::lyse
Name:          DOCeq
Unit:           mg/l
Disp. Format:      2
P. lower:          0
P. upper:        180
Al. lower:  ----,---
Al. upper:  ----,---
```

10.2.2 Check of Device Settings using moni::tool

For checking the sensor settings click on the spectrometer icon within the system overview of the *Service* tab and select *Sensor Settings*. Depending on the *Service Level* (figure below is *Service Level* *Advanced*) some or all of the following information will be displayed:

- Interface of the sensor (*Address*)
- Sensor name used internal (*internal*)
- *Sensor Name* allocated to the device by the operator
- Manufacturer name of the sensor (*Vendor*)
- Type of the sensor (*Model*)
- Serial number of the sensor (*Serial Number*)
- Number of available parameters (*Parameter count*)
- Information regarding the purchase (*Purchase date*, *Warranty expiry date*)
- Actual hardware version of the sensor (*HW Version*)
- Actual software version of the sensor (*SW Version*)
- Cleaning device allocated to the sensor (*Cleaning device*)



Edit Sensor [spec 00000026]

<< GENERAL SETTINGS >>

Sensor name: spec 00000026
Vendor: s::can
Model: spectro::lyser
Serial number: 00000026
Parameter count: 25
HW Version: 3.2
SW Version: 1.0.2

<< ADDITIONAL SETTINGS >>

Sensor Model: 3.0
Detector Type: UV/Vis
Optical Path Length: 5.0 mm
Reference: SA2
Reference date: 2020-01-31T17:28:13.835Z

- *Sensor Model* of the spectrometer probe
- Type of the spectrometer probe (*Detector Type*)
- *Optical Path Length* of the spectrometer probe in mm
- Name of the actual used zero reference (*Reference*)
- Internal number of the actual used zero reference (*Reference index*)
- Name of the actual used zero reference (*Reference*)
- Actual used operation mode of the spectrometer probe (*Measurement mode*)
- Actual used measuring interval of the spectrometer probe (*Measurement interval*)
- *Logging interval* for Datalogger of the spectrometer probe
- Actual used mode of allocated *cleaning* device (e.g. automatic, manual off)
- Actual used cleaning interval (*Time between cleaning*) in sec.
- Actual used cleaning duration (*Cleaning duration*) in sec.
- Actual used waiting time (*Delay after cleaning*) in sec.
- History information about installation (*Installed on*, *Installed by*)

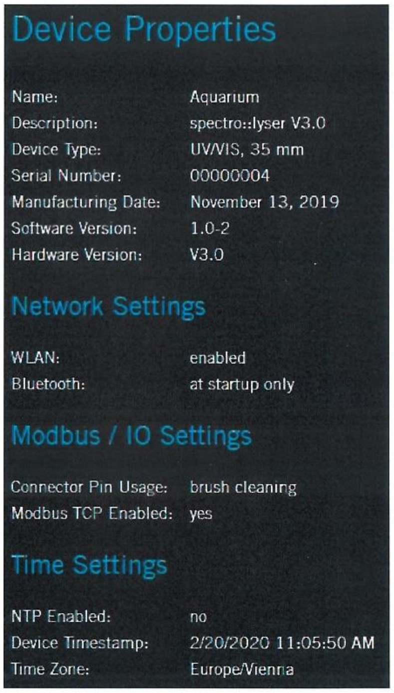
10.2.3 Check of Device Settings using con::nect and Io::Tool

Enter the IP of the spectrometer probe into your webbrowser (see section 5.3.3) and select *Service \ Device Properties*. The following information will be displayed:

- User specific Name of the location
- Description of the measuring device
- Detector type (e.g. UV/Vis) and optical path length of the spectrometer probe (*Device Type*)
- Serial number of the sensor (*Serial Number*)
- Production date of the sensor (*Manufacturing Date*)
- Actual software version of the sensor (*Software Version*)
- Actual hardware version of the sensor (*Hardware Version*)
- Actual network settings of *WLAN*. The following options are possible: *enabled*, *disabled* or *at startup only* (i.e. WLAN is enabled for approx. 10 minutes after a power reset of the spectrometer probe).
- Actual network settings of *Bluetooth*. The following options are possible: *enabled*, *disabled* or *at startup only* (i.e. Bluetooth is enabled for approx. 10 minutes after a power reset of the spectrometer probe).
- Actual *usage* of the *connector pin*. The following options are possible: *Modbus*, *air cleaning* or *brush cleaning*.
- Actual status of *Modbus TCP* (enabled or disabled)
- Actual status of *NTP* server (enabled or disabled)
- Actual date and time of the internal clock (*Device Timestamp*)
- Actual used time zone (*Time Zone*)

When logging on as *user* additional information will be displayed (e.g. IP addresses within the network settings.

To modify the device properties logon as *expert* is needed. Then push the button *Edit Settings* which is visible below the *Time Settings*. Now properties can be modified as displayed in the figures on the right hand side. After all changes are finished push the button *Save Changes* to change the configuration permanently.



Device Properties

Name:	Aquarium
Description:	spectro::lyser V3.0
Device Type:	UV/VIS, 35 mm
Serial Number:	00000004
Manufacturing Date:	November 13, 2019
Software Version:	1.0-2
Hardware Version:	V3.0

Network Settings

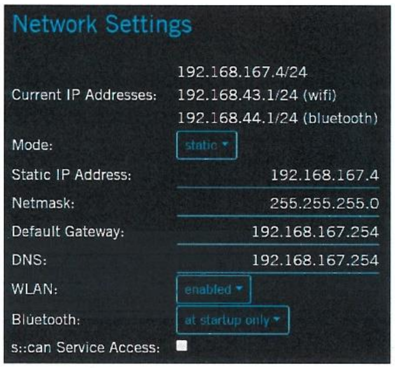
WLAN:	enabled
Bluetooth:	at startup only

Modbus / IO Settings

Connector Pin Usage:	brush cleaning
Modbus TCP Enabled:	yes

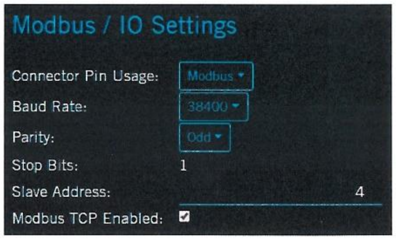
Time Settings

NTP Enabled:	no
Device Timestamp:	2/20/2020 11:05:50 AM
Time Zone:	Europe/Vienna



Network Settings

Current IP Addresses:	192.168.167.4/24 192.168.43.1/24 (wifi) 192.168.44.1/24 (bluetooth)
Mode:	static
Static IP Address:	192.168.167.4
Netmask:	255.255.255.0
Default Gateway:	192.168.167.254
DNS:	192.168.167.254
WLAN:	enabled
Bluetooth:	at startup only
s::can Service Access:	☐

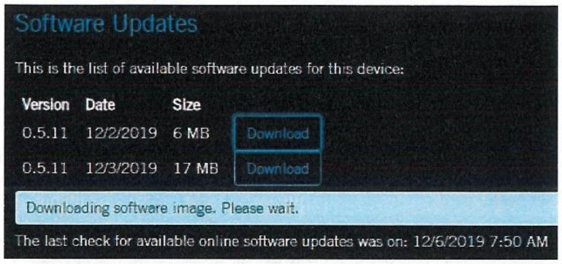


Modbus / IO Settings

Connector Pin Usage:	Modbus
Baud Rate:	38400
Parity:	Odd
Stop Bits:	1
Slave Address:	4
Modbus TCP Enabled:	☑

10.4 Software Update

- Enter the IP of the spectrometer probe into your webbrowser (see section 5.3.3) to start Io::Tool
- Logout user *guest* and logon as *expert*.
- Select menu *Service \ Device Management*.



Software Updates

This is the list of available software updates for this device:

Version	Date	Size	
0.5.11	12/2/2019	6 MB	Download
0.5.11	12/3/2019	17 MB	Download

Downloading software image. Please wait.

The last check for available online software updates was on: 12/6/2019 7:50 AM

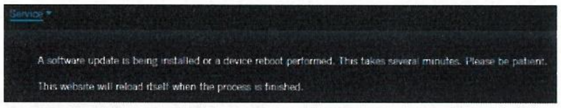
- Below the header line *Software Updates* all available download files are displayed. You can also push the button *Check for Online Updates now* to search for actual updates.
- Select the most actual version and push the button *Download*.
- After the download is finished push the button *Install* to start the update procedure.

Software Updates

This is the list of available software updates for this device:

Version	Date	Size	
0.5.11	12/2/2019	6 MB	Install
0.5.11	12/3/2019	17 MB	Download

The last check for available online software updates was on: 12/6/2019 7:50 AM



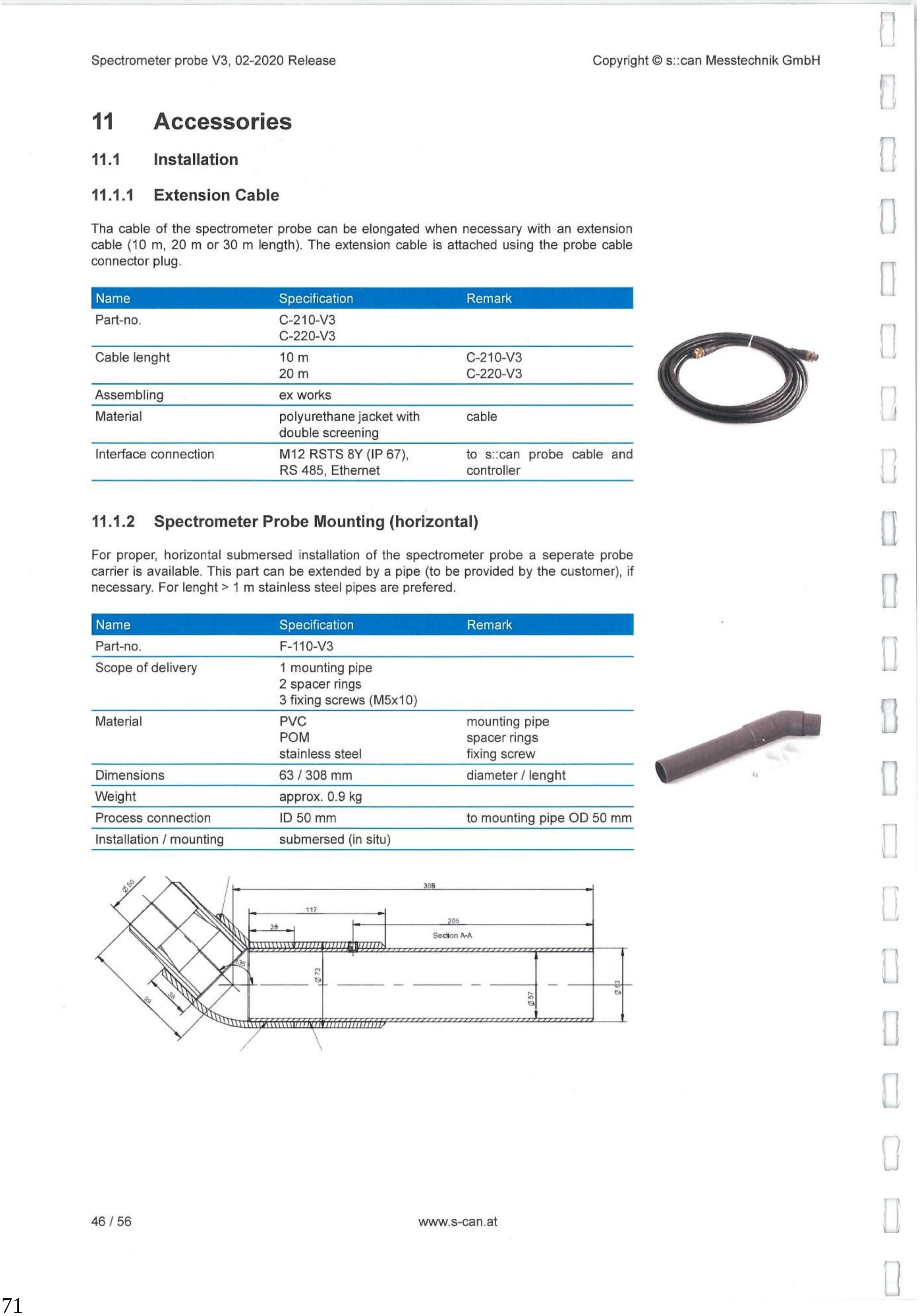
A software update is being installed or a device reboot performed. This takes several minutes. Please be patient.

This website will reload itself when the process is finished.

10.5 Return Consignment (RMA - Return Material Authorization)

Return consignments of the s::can monitoring system, or parts of the system, shall be done in a packaging that protects the device (original packaging or protective covering if possible). Before returning a consignment, you have to contact your s::can sales partner or s::can customer support (support@s-can.at). A RMA number will be assigned for each device, independent if the reason of the return consignment is service, repair or demo equipment.

RMA numbers can be requested from the s::can Costomer Portal available on the s::can webpage directly. Return consignments without an RMA number will not be accepted. The customer always has to bear the costs for return consignment.



11 Accessories

11.1 Installation

11.1.1 Extension Cable

Tha cable of the spectrometer probe can be elongated when necessary with an extension cable (10 m, 20 m or 30 m length). The extension cable is attached using the probe cable connector plug.

Name	Specification	Remark
Part-no.	C-210-V3 C-220-V3	
Cable lenght	10 m 20 m	C-210-V3 C-220-V3
Assembling	ex works	
Material	polyurethane jacket with double screening	cable
Interface connection	M12 RSTS 8Y (IP 67), RS 485, Ethernet	to s::can probe cable and controller

11.1.2 Spectrometer Probe Mounting (horizontal)

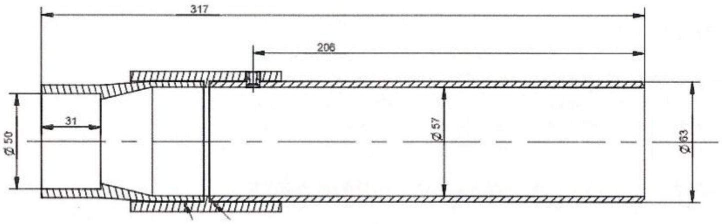
For proper, horizontal submersed installation of the spectrometer probe a seperate probe carrier is available. This part can be extended by a pipe (to be provided by the customer), if necessary. For lenght > 1 m stainless steel pipes are prefered.

Name	Specification	Remark
Part-no.	F-110-V3	
Scope of delivery	1 mounting pipe 2 spacer rings 3 fixing screws (M5x10)	
Material	PVC POM stainless steel	mounting pipe spacer rings fixing screw
Dimensions	63 / 308 mm	diameter / lenght
Weight	approx. 0.9 kg	
Process connection	ID 50 mm	to mounting pipe OD 50 mm
Installation / mounting	submersed (in situ)	

11.1.3 Spectrometer Probe Mounting (vertical)

For proper, vertical submersed installation of the spectrometer probe a seperate probe carrier is available. This part can be extended by a pipe (to be provided by the customer), if necessary. For lenght > 1 m stainless steel pipes are prefered.

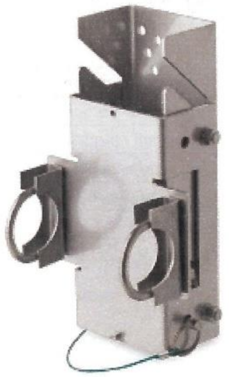
Name	Specification	Remark
Part-no.	F-120-V3	
Scope of delivery	1 mounting pipe 2 spacer rings 3 fixing screws (M5x10)	
Material	PVC POM stainless steel	mounting pipe spacer rings fixing screw
Dimensions	63 / 317 mm	diameter / length
Weight	approx. 0.6 kg	
Process connection	ID 50 mm	to mounting pipe OD 50 mm
Installation / mounting	submersed (in situ)	



11.1.4 Fixing Adapter

For proper and easy mounting of installation pipes onto the railing a seperate fixing adapter carries is available.

Name	Specification	Remark
Part-no.	F-15	
Material	Stainless steel	
Dimensions	158 / 267 / 73 mm	W / H / D
Weight	approx. 2.6 kg	
Process connection	ID 50 mm	OD installation pipe
Installation / mounting	OD up to 64 mm	on rail

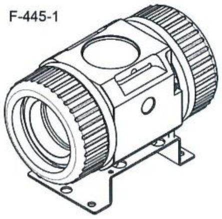


11.1.5 Flow Cell Setup Tap Water

For measurement of sample stream outside the medium with a spectrometer probe a separate flow-through installation is available.

Name	Specification	Remark
Item-no.	F-445-V3	
Material	POM-C stainless steel	flow cell mounting
Dimensions	132 / 101 / 74 mm	W / H / D
Weight	approx. 0.45 kg	
Process connection	$^{1}/_{4}$ inch inside	
Installation / mounting	flow-through (by pass)	
Operating temperature	0 to 60 °C (32 to 140 °F)	
Operating pressure	0 to 6 bar (0 to 87 psi)	
Accessories	Hose nozzle $^{1}/_{4}$ inch (ID 6 mm)	F-45-PROCESS

F-445-1



11.1.6 Flow Cell Setup Autobrush

For measurement of sample stream outside the medium with a spectrometer probe in such applications, where fouling of the measuring windows may occur and automatic cleaning is not sufficient or not applicable, a separate flow-through installation with an automatic brush is available.

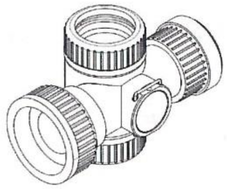
Name	Specification	Remark
Part-no.	F-446-V3	for 35 mm OPL
Material	POM-C stainless steel	flow cell mounting
Dimensions	132 / 155 / 74 mm	W / H / D
Weight	approx . 0.9 kg	
Power supply	10.5 to 13.5 VDC	
Power consumption	1.2 W (typ.)	
Process connection	$^{1}/_{4}$ inch inside	
Installation / mounting	flow-through (by pass)	
Operating temperature	0 to 40 °C (32 to 104 °F)	
Operating pressure	0 to 6 bar (0 to 87 psi)	
Accessories	Hose nozzle $^{1}/_{4}$ inch (ID 6 mm)	F-45-PROCESS

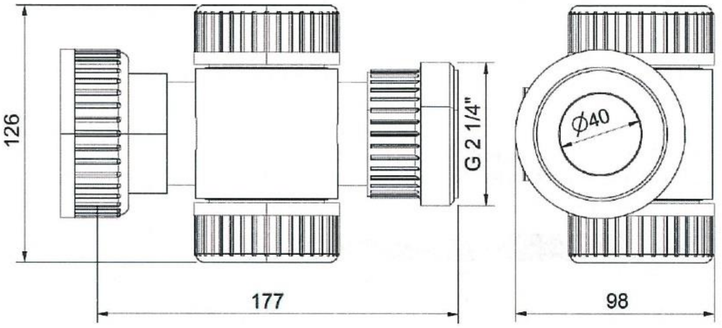
For this s::can product a seperate manual is available.

11.1.7 Flow Cell Setup Waste Water

For measurement of waste water sample stream outside the medium with a spectrometer probe a separate flow-through installation is available.

Name	Specification	Remark
Item-no.	F-48-V3	
Material	PVC	
Dimensions	126 / 98 / 177	W / H / D
Weight	approx. 0.65 kg	
Process connection	ID 40 mm	
Installation / mounting	flow-through (by pass)	
Operating pressure	0 to 3 bar (0 to 43.5 psi)	

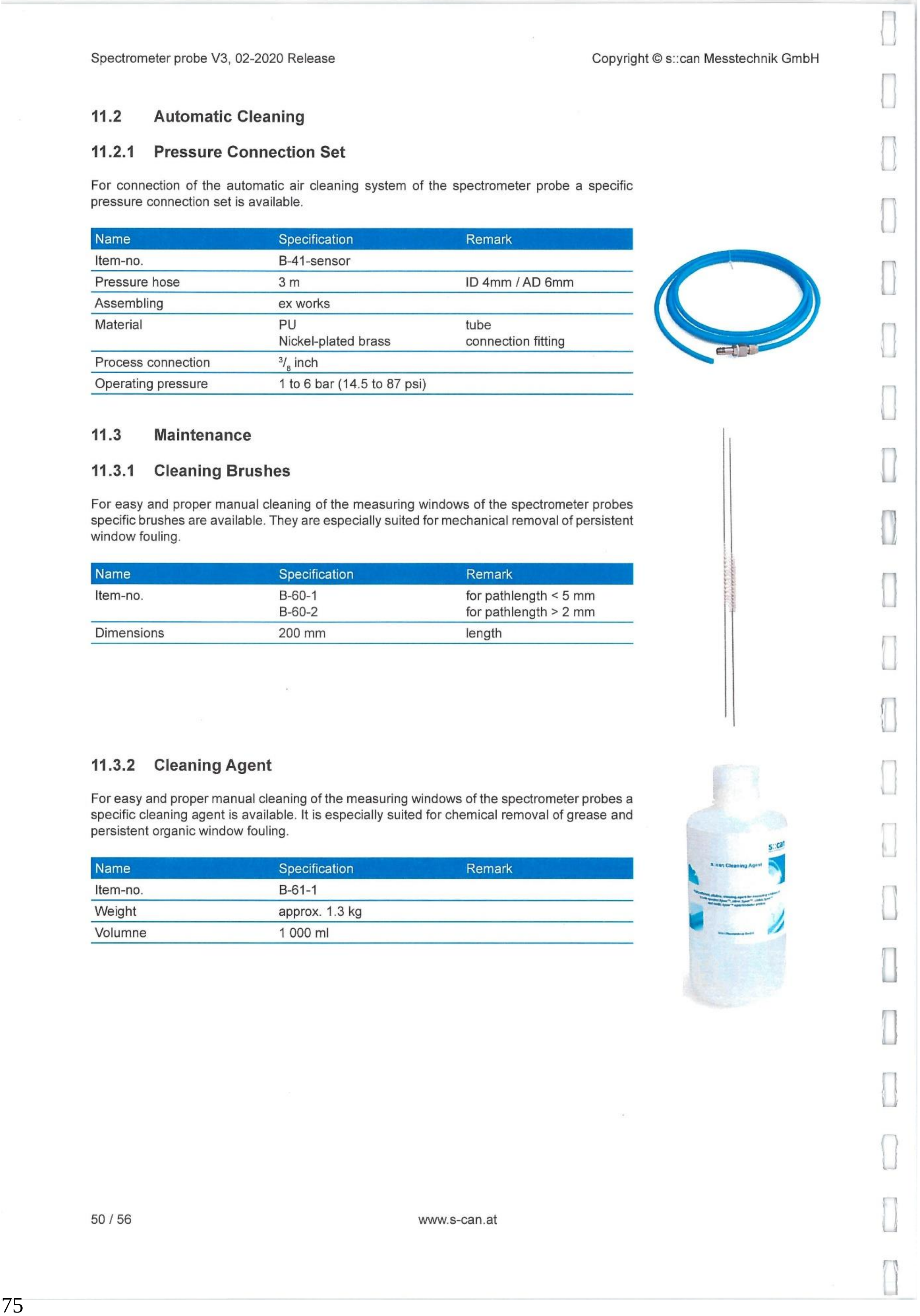




11.1.8 System Panel micro::station

For easy attachment of a complete s::can monitoring system (s::can controller, flow cell autobrush and two other flow cells) a separate system panel with holes for mounting of different devices is available.

Name	Specification	Remark
Part-no.	F-501-eco-eu F-501-eco-us	
Material	PP	
Dimensions	450 / 750 / 10 mm 450 / 750 / 190 mm	W / H / D (panel itself) W / H / D (required depth)
Process connection	G $^{1}/_{4}$ inch $^{1}/_{4}$ inch NPT	F-501-eco-eu F-501-eco-us



11.2 Automatic Cleaning

11.2.1 Pressure Connection Set

For connection of the automatic air cleaning system of the spectrometer probe a specific pressure connection set is available.

Name	Specification	Remark
Item-no.	B-41-sensor	
Pressure hose	3 m	ID 4mm / AD 6mm
Assembling	ex works	
Material	PU Nickel-plated brass	tube connection fitting
Process connection	$^3/_8$ inch	
Operating pressure	1 to 6 bar (14.5 to 87 psi)	

11.3 Maintenance

11.3.1 Cleaning Brushes

For easy and proper manual cleaning of the measuring windows of the spectrometer probes specific brushes are available. They are especially suited for mechanical removal of persistent window fouling.

Name	Specification	Remark
Item-no.	B-60-1 B-60-2	for pathlength < 5 mm for pathlength > 2 mm
Dimensions	200 mm	length

11.3.2 Cleaning Agent

For easy and proper manual cleaning of the measuring windows of the spectrometer probes a specific cleaning agent is available. It is especially suited for chemical removal of grease and persistent organic window fouling.

Name	Specification	Remark
Item-no.	B-61-1	
Weight	approx. 1.3 kg	
Volumne	1 000 ml	

11.3.3 Multifunctional Slide

For easy and proper functional check and reference measurements of the spectrometer probe a multifunctional slide is available.

This slide can also be used for measuring individual samples outside the process flow (e.g. spot samples in a laboratory). To place the multifunctional slide without requiring excessive force and risk of damaging the O-rings, the contacting surfaces on the probe, as well as the O-rings of the multifunctional slide can be moistened with water.

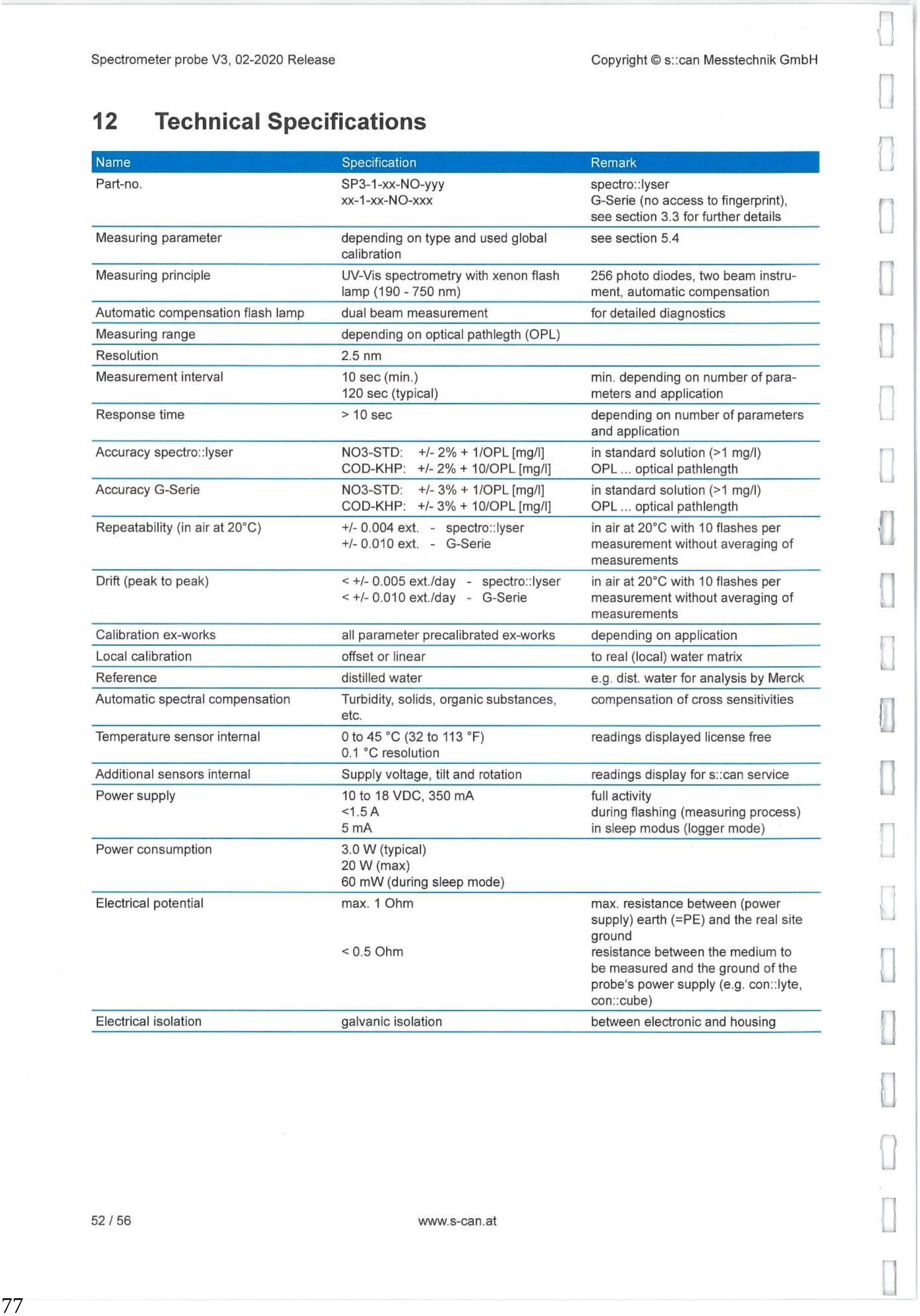
After fitting, the multifunctional slide must always be rinsed first using distilled water. This is done to avoid influence of subsequent measurements by traces of O-ring material left on the probe during fitting.

Name	Specification	Remark
Item-no.	B-421-V3	
Material	POM-H FPM	housing sealing
Dimensions	100 / 44 / 60 mm 26 mm	B-421-V3: W / H / D circular opening
Volumne	30 ml 40 ml	B-421-V3: for 5 mm OPL for 35 mm OPL
Weight	approx. 0.17 kg	B-421-V3

11.4 Spare Parts

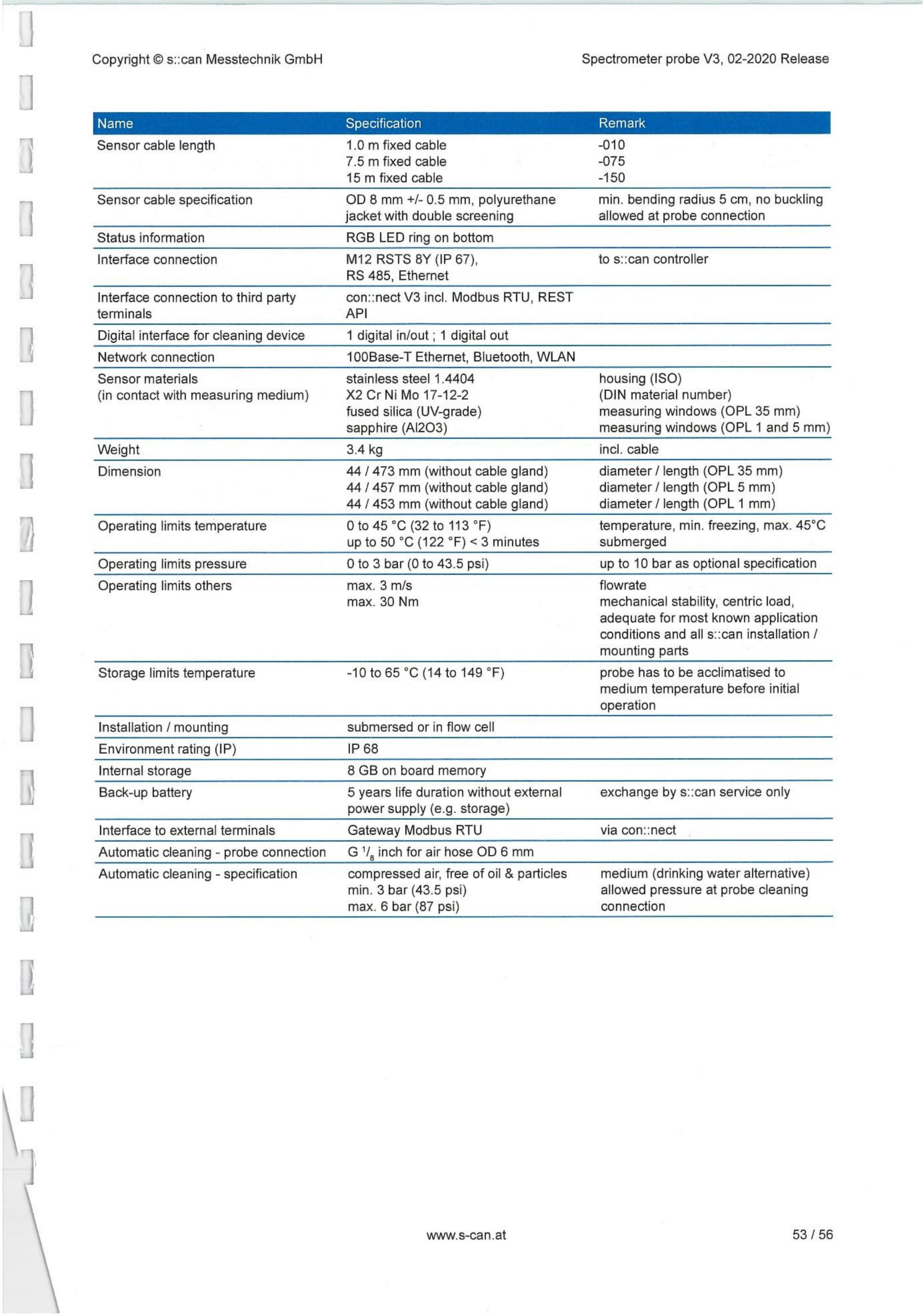
The spectrometer probe is not equipped with any consumables that need to be replaced periodically. Therefore there is no need to store any spare parts.

11.5 Optional Features

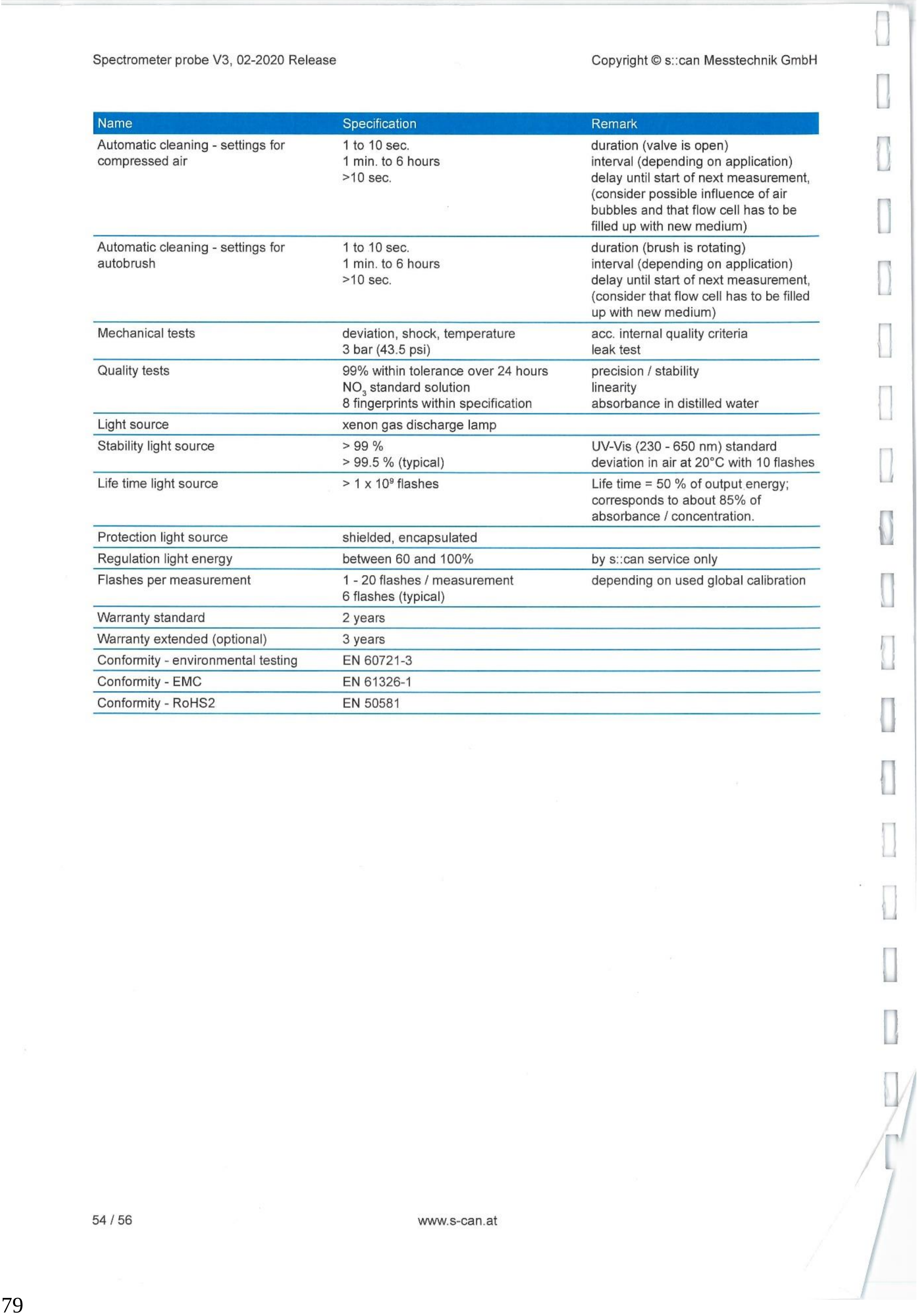


12 Technical Specifications

Name	Specification	Remark
Part-no.	SP3-1-xx-NO-yyy xx-1-xx-NO-xxx	spectro::lyser G-Serie (no access to fingerprint), see section 3.3 for further details
Measuring parameter	depending on type and used global calibration	see section 5.4
Measuring principle	UV-Vis spectrometry with xenon flash lamp (190 - 750 nm)	256 photo diodes, two beam instrument, automatic compensation
Automatic compensation flash lamp	dual beam measurement	for detailed diagnostics
Measuring range	depending on optical pathlegth (OPL)	
Resolution	2.5 nm	
Measurement interval	10 sec (min.) 120 sec (typical)	min. depending on number of parameters and application
Response time	> 10 sec	depending on number of parameters and application
Accuracy spectro::lyser	NO3-STD: +/- 2% + 1/OPL [mg/l] COD-KHP: +/- 2% + 10/OPL [mg/l]	in standard solution (>1 mg/l) OPL ... optical pathlength
Accuracy G-Serie	NO3-STD: +/- 3% + 1/OPL [mg/l] COD-KHP: +/- 3% + 10/OPL [mg/l]	in standard solution (>1 mg/l) OPL ... optical pathlength
Repeatability (in air at 20°C)	+/- 0.004 ext. - spectro::lyser +/- 0.010 ext. - G-Serie	in air at 20°C with 10 flashes per measurement without averaging of measurements
Drift (peak to peak)	< +/- 0.005 ext./day - spectro::lyser < +/- 0.010 ext./day - G-Serie	in air at 20°C with 10 flashes per measurement without averaging of measurements
Calibration ex-works	all parameter precalibrated ex-works	depending on application
Local calibration	offset or linear	to real (local) water matrix
Reference	distilled water	e.g. dist. water for analysis by Merck
Automatic spectral compensation	Turbidity, solids, organic substances, etc.	compensation of cross sensitivities
Temperature sensor internal	0 to 45 °C (32 to 113 °F) 0.1 °C resolution	readings displayed license free
Additional sensors internal	Supply voltage, tilt and rotation	readings display for s::can service
Power supply	10 to 18 VDC, 350 mA <1.5 A 5 mA	full activity during flashing (measuring process) in sleep modus (logger mode)
Power consumption	3.0 W (typical) 20 W (max) 60 mW (during sleep mode)	
Electrical potential	max. 1 Ohm < 0.5 Ohm	max. resistance between (power supply) earth (=PE) and the real site ground resistance between the medium to be measured and the ground of the probe's power supply (e.g. con::lyte, con::cube)
Electrical isolation	galvanic isolation	between electronic and housing



Name	Specification	Remark
Sensor cable length	1.0 m fixed cable 7.5 m fixed cable 15 m fixed cable	-010 -075 -150
Sensor cable specification	OD 8 mm +/- 0.5 mm, polyurethane jacket with double screening	min. bending radius 5 cm, no buckling allowed at probe connection
Status information	RGB LED ring on bottom	
Interface connection	M12 RSTS 8Y (IP 67), RS 485, Ethernet	to s::can controller
Interface connection to third party terminals	con::nect V3 incl. Modbus RTU, REST API	
Digital interface for cleaning device	1 digital in/out ; 1 digital out	
Network connection	100Base-T Ethernet, Bluetooth, WLAN	
Sensor materials (in contact with measuring medium)	stainless steel 1.4404 X2 Cr Ni Mo 17-12-2 fused silica (UV-grade) sapphire (Al2O3)	housing (ISO) (DIN material number) measuring windows (OPL 35 mm) measuring windows (OPL 1 and 5 mm)
Weight	3.4 kg	incl. cable
Dimension	44 / 473 mm (without cable gland) 44 / 457 mm (without cable gland) 44 / 453 mm (without cable gland)	diameter / length (OPL 35 mm) diameter / length (OPL 5 mm) diameter / length (OPL 1 mm)
Operating limits temperature	0 to 45 °C (32 to 113 °F) up to 50 °C (122 °F) < 3 minutes	temperature, min. freezing, max. 45°C submerged
Operating limits pressure	0 to 3 bar (0 to 43.5 psi)	up to 10 bar as optional specification
Operating limits others	max. 3 m/s max. 30 Nm	flowrate mechanical stability, centric load, adequate for most known application conditions and all s::can installation / mounting parts
Storage limits temperature	-10 to 65 °C (14 to 149 °F)	probe has to be acclimatised to medium temperature before initial operation
Installation / mounting	submersed or in flow cell	
Environment rating (IP)	IP 68	
Internal storage	8 GB on board memory	
Back-up battery	5 years life duration without external power supply (e.g. storage)	exchange by s::can service only
Interface to external terminals	Gateway Modbus RTU	via con::nect
Automatic cleaning - probe connection	G $^{1}/_{8}$ inch for air hose OD 6 mm	
Automatic cleaning - specification	compressed air, free of oil & particles min. 3 bar (43.5 psi) max. 6 bar (87 psi)	medium (drinking water alternative) allowed pressure at probe cleaning connection



Name	Specification	Remark
Automatic cleaning - settings for compressed air	1 to 10 sec. 1 min. to 6 hours >10 sec.	duration (valve is open) interval (depending on application) delay until start of next measurement, (consider possible influence of air bubbles and that flow cell has to be filled up with new medium)
Automatic cleaning - settings for autobrush	1 to 10 sec. 1 min. to 6 hours >10 sec.	duration (brush is rotating) interval (depending on application) delay until start of next measurement, (consider that flow cell has to be filled up with new medium)
Mechanical tests	deviation, shock, temperature 3 bar (43.5 psi)	acc. internal quality criteria leak test
Quality tests	99% within tolerance over 24 hours NO_3 standard solution 8 fingerprints within specification	precision / stability linearity absorbance in distilled water
Light source	xenon gas discharge lamp	
Stability light source	> 99 % > 99.5 % (typical)	UV-Vis (230 - 650 nm) standard deviation in air at 20°C with 10 flashes
Life time light source	> 1 x 10^9 flashes	Life time = 50 % of output energy; corresponds to about 85% of absorbance / concentration.
Protection light source	shielded, encapsulated	
Regulation light energy	between 60 and 100%	by s::can service only
Flashes per measurement	1 - 20 flashes / measurement 6 flashes (typical)	depending on used global calibration
Warranty standard	2 years	
Warranty extended (optional)	3 years	
Conformity - environmental testing	EN 60721-3	
Conformity - EMC	EN 61326-1	
Conformity - RoHS2	EN 50581	

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