Evaluation of Water Telemetry Equipment

Telemetry Research Unit, Division of Water Rights, State Water Resources Control Board

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Executive Summary

The Drought Planning Unit evaluated water monitoring device information submitted by reporters for compliance with California Code of Regulations 23:931-938 (i.e., SB88) and determined that ten manufacturers accounted for two-thirds of submissions. This staff evaluation required considerable time because the data submissions were inconsistent. Data structures for collecting reporter submissions cannot enforce strict constraints on user-submitted information, leading to inconsistent data that required manual clean-up and review.

The Telemetry Research Unit (TRU) contacted these ten manufacturers regarding their telemetry equipment and data processes for water monitoring. Manufacturers shared information regarding their most popular sensors, data loggers, and transmission devices; the devices' default data reporting content, formats, and processes; and application programming interface (API) availability for data transfer.

Generally, manufacturers had similar capabilities around parameter options; sensor types; and ability to support transmissions, dashboards, and API connections. Nine of the ten manufacturers supported telemetered data transfer from a monitoring site to website dashboard or API. However, considerable variation was reported among data standards for exported data.

Discussions with manufacturer representatives suggested that manufacturers were willing to work with end-users to configure equipment to meet their data export needs, but did not support default exports for common data standards. Furthermore, manufacturer representatives suggested that most end-users did not express a need for data exports in a common data standard. This industry-wide lack of default export standards impairs synthesis and interoperability among monitoring programs.

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1. Manufacturer Research

The Drought Planning Unit of the State Water Resources Control Board analyzed data submitted by reporters in compliance with California Code of Regulations 23:931-938 (i.e., SB 88) for years 2018-2022. Staff evaluated how often manufacturers were reported (Table 1). The ten most reported manufacturers accounted for approximately two-thirds of submissions. The remaining submissions either did not provide a manufacturer, provided information that was unidentifiable, or used a less common manufacturer. Reporters used over 180 unique, less common manufacturers, which averages to about eight measurement devices per less common manufacturer over the four-year period. This situation may represent one reporter with several points of water diversion or a small user community, but demonstrates that those manufacturers are not broadly adopted across California.

This staff evaluation required considerable time because the data submissions were inconsistent. Data structures for collecting reporter submissions at that time could not enforce strict constraints on device information, leading to inconsistent data about equipment manufacturer, equipment model, and use of sensors and/or data loggers that required manual clean-up and review by staff.

Table 1. Most common manufacturers reported in SB88 submissions for years 2018-2022.

Manufacturer	**Reported (%)**
McCrometer	31
Seametrics	13
YSI	4
Badger Meter	4
Netafim	3
In-Situ (formerly Mace)	2
SonTek	2
Sensus	2
Panametrics	2
Rosemount (Emerson)	2
Unspecified[#]	6
Other*	29

[#]Manufacturer could not be determined due to missing or unclear data.
*Includes 181 other manufacturers.

The Telemetry Research Unit of the State Water Resources Control Board contacted the ten most reported manufacturers (Table 1) with questions regarding their telemetry equipment and data features. Specifically:

1) What are your most popular water telemetry device(s)?

2) What parameters do those devices measure?

3) What sensor(s) are used?

4) What is the default data reporting format and process? Please provide an example.

5) Do you support an application programming interface (API) for automatic data transfer?

6) Is the API connection a push process, pull process, or both?

The point of contact for each manufacturer is listed in Appendix A.

2. Equipment Results

Telemetered water monitoring stations typically host sensors, data loggers, transmitters, and power systems. Seven of the ten manufacturers reported only sensors as their most popular products (Appendix B). Of the remaining three companies, two shared their popular data loggers and all three mentioned popular transmission equipment.

2.1. Sensors

Sensors measure a target parameter. Multiple sensors may be bundled in a single sonde for multi-parameter monitoring. Sensors are the most exposed to conditions and most sensitive of the devices and therefore require the most maintenance, including calibration, to ensure proper operation and data reliability.

For water telemetry, common parameters are flow rate, stage height, and temperature which may be collected directly or indirectly depending on parameter and device type. Flow rate can be measured directly by ultrasonic, doppler, and electromagnetic meters, while water depth and volume can be measured indirectly by calculations on pressure transducer readings. Sensor type selection is dependent on installation conditions (e.g., pipe, stream), monitoring goals (e.g., low-flow accuracy, device robustness), and user preferences (e.g., infrequent site visits).

Manufacturers reported their most popular sensor type was for measuring multi-parameter water quality, followed by electromagnetic meters, ultrasonic meters, and pressure transducers (Figure 1).

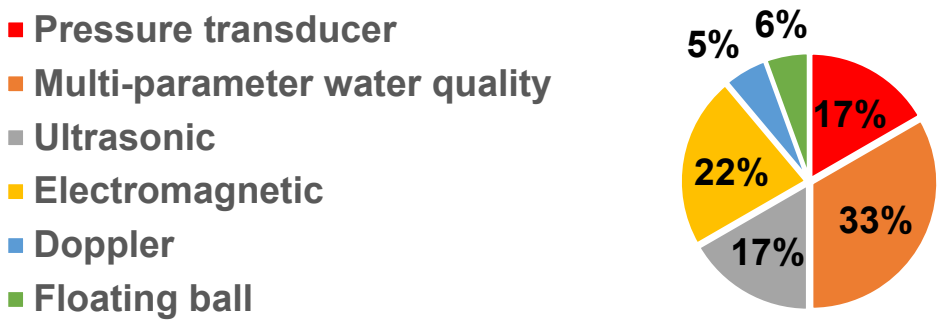

Figure 1. Popular sensor types, as reported by manufacturers.

Manufacturers consistently reported sensors for water flow rate and water quality (Table 3) but varied in offering sensors for other water parameters. Four manufacturers reported sensors for pressure, while four reported sensors for water level.

Table 2. Water parameters measured by popular sensors, as reported by manufacturers.

Manufacturer	Pressure	Water Level	Flow Rate	Water Quality*
McCrometer	x	x		x
Seametrics			x	
YSI		x	x	x
Badger Meter			x	x
Netafim			x	x
In-Situ (formerly Mace)	x	x		x
SonTek		x	x	x
Rosemount	x		x	
Sensus			x	
Panametrics	x		x	x

*For example: temperature, pH, conductivity, etc.

2.2. Data Loggers

Data logger models vary in sensor capacity, data storage capacity, recording interval, interface options, and communication options. Manufacturers reported recording intervals ranging from every second to every 24 hours (Table 5). Loggers can connect to sensors via cable, hardwired integration, or wireless signal, depending on the model. Some loggers contain expansion slots which allow the later installation of additional hardware to

expand capabilities. Data can be retrieved from a data logger remotely (when equipped with a transmitter) or by manual download at site.

Only two manufacturers (YSI and In-Situ) shared information about data loggers (Appendix B). In both cases, the logger was integrated with the sensors. Data loggers can have cross-compatibility with sensors among manufacturers, making data logger choice driven less by manufacturer compatibility issues and more by budget, monitoring goals, and available transmission options. This flexibility has also led some monitoring groups to develop and install self-built data loggers using mini-computers like Raspberry Pi.

Users who purchase from a different manufacturer or build a data logger need to consider the communication standard and protocol that communicates sensor readings to data loggers. Manufacturers reported several standards: ASCII[1] was reported for YSI and SonTek, SDI-12[2] was reported for YSI and SonTek, and Modbus[3] was reported for SonTek and Seametrics. The remaining manufacturers did not specify inter-device communication options.

2.3. Transmitters

Transmission equipment allows data to be sent remotely from the monitoring site to a receiving data system. Transmission typically uses cellular, radio, or satellite technology to send data. Features and costs vary widely among transmission type and equipment. Selection is dependent on budget, site conditions, data timeliness needs, and data management capacity. Most SB88 reporters are not required to report telemetered data currently and do not install transmission equipment at their monitoring site. For example, in 2021 about 18% of registered measurement devices were required to report telemetered data under SB88.

Similar to data loggers, only three manufacturers shared information about transmitters (Appendix B). YSI reported a satellite transmitter integrated with their WaterLOG data logger. Seametrics reported a stand-alone cellular transmitter. In-Situ reported a cellular transmitter integrated with their Vulink data logger, as well as a stand-alone satellite transmitter. Data management capacity is an important selection criterion for transmission equipment since transmitted data must be received by a configured data system.

2.4. Power Systems

Sensors, data loggers, and transmitters all rely on power sources to operate. Specific power demands vary by equipment and monitoring set-up, with more frequent sample intervals requiring more power. Power may be supplied by connection to an electrical

[1] American Standard Code for Information Interchange (ASCII) is a data standard that represents text characters with unique computer bit sequences.
[2] Serial Digital Interface at 1200 baud (SDI-12) is a communications protocol developed in 1988 by United States Geological Survey and partners to transfer monitoring data from sensors to data loggers.
[3] Modbus is a communication protocol developed in 1979 and common among electronic devices due to being free and highly-configurable.

grid, such as when monitoring occurs in large diversion tunnels, but more commonly is supplied by internal or external batteries. Batteries may be replaced or recharged when staff visit the site, but more self-sufficient sites may use solar panels to recharge the batteries. Solar panels require maintenance to remove debris that reduces energy efficiency. With recent improvements in battery technology, solar panels are not needed for some monitoring stations. For example, In-Situ's VuLink equipment can sample at 15-minute intervals for up to 2 years before the internal batteries need recharge. Generally, sourcing power systems is the simplest step of equipment procurement, since electrical power is fairly standardized and cross-compatibility between equipment is typical.

2.5. Equipment Integration

Several manufacturers reported integrated monitoring equipment. In-Situ reported a single device with integrated sensor, data logger, and cellular transmitter. YSI reported a data logger with an integrated satellite transmitter. Integrated devices offer a simpler monitoring set-up that reduces selection effort and installation effort. However, when one component of an integrated device needs repair then the whole device must be sent to the manufacturer for repairs, potentially resulting in station downtime and data gaps. In contrast, stand-alone equipment can be replaced and repaired in a modular fashion by knowledgeable staff.

3. Data Results

3.1. Dashboards and APIs

Manufacturers who sell transmission equipment typically offer subscription services to end-users to receive and store their transmitted data. Data access is frequently through a user-friendly dashboard on the manufacturer website, but two manufacturers reported supporting data connection to dashboards by other manufacturers (Table 3). Nine manufacturers reported supporting APIs so that end-users could direct data to their own data systems. Only Rosemount reported a lack of transmission equipment and support for telemetered data. Users of this equipment need to source their own transmitter and receiving data system or manually download data at a monitoring site.

Table 3. Dashboard services and API connections as reported by manufacturers.

Manufacturer	**Dashboard**	**API Process[#]**
McCrometer	SmartTrax, 3rd party	Both
Seametrics	SignalFire Cloud	Pull
YSI	HydroSphere	Push
Badger Meter	AquaCUE	Pull
Netafim	Netafim dashboard	Both
In-Situ (formerly	HydroVu	Push
SonTek	SonTek dashboard	Both

Manufacturer	Dashboard	API Process[#]
Rosemount	N/A*	N/A*
Sensus	3rd party compatible[$]	Pull
Panametrics	Panametrics dashboard	Pull

#Data transfer may be initiated by source system (i.e., “push”), by receiving system (i.e., “pull”), or may support both processes (i.e., “both”).
$Offers compatibility with data dashboards by other manufacturers.
*No data support.

3.2. Data Standards

Monitoring equipment varies in the content, format, and file type of the exported data. Nine manufacturers provided examples of their data standards and export files (Tables 4 and 5). Files are available from TRU upon request. Overall, manufacturers demonstrated broad variability in their data standards, both between manufacturers and even among their own equipment.

Discussions with representatives suggested that manufacturers were willing to work with end-users to configure equipment to meet their data export needs, but did not support default exports for common data standards (e.g., California Data Exchange Center (CDEC) or National Water Information System (NWIS)). Furthermore, manufacturer representatives suggested that most end-users did not express a need for data exports in common data standards.

3.2.1. Data Content and Format

Manufacturers reported consistent formatting for dates and times (Table 5). For example, dates were usually in month/day/year format with two digits for month and day and 4 digits for year separated by forward slashes (i.e., MM/DD/YYYY). Netafim also supported year-month-day format with 4 digits for the year and 2 digits for the month and day separated by dashes (i.e., YYYY-MM-DD). However, the format of all other parameters and units varied greatly (Tables 4 and 5). For example, flow was named Flow Rate, SL(Flow), Flow Actual, Total FLOW, Flow, and Pulse_Flow among the manufacturers. Likewise, gallons per minute was variously named GPM, G/M, and gal/m. Parameter and unit names even varied among a manufacturer depending on the device and configuration.

3.2.2. File Type

Three manufacturers reported downloads as comma-separated values (CSV) files, two reported Excel files, and two reported both CSV and Excel formats. Seametrics also reported downloads of graphs directly from the data logger.

Table 4. File output types, date formats, time formats, and units of water parameters reported by manufacturers. Unit abbreviations for date and time are defined in the column header; remaining abbreviations are defined in table footnote. Rosemount is excluded from this table as they only support manual data logging.

Manufacturer	File Output Type	Date (Month, Day, Year)	Time (Hour, minute, second)	Sampling Interval	Flow	Volume	Temperature	Depth	Pressure	Turbidity	Velocity
McCrometer	CSV	MM/DD/YYYY	HH:mm:ss	12 hour	GPM	ac-ft	°F	-	-	-	-
Seametrics	CSV, Excel, Graphs	MM/DD/YYYY	HH:mm:ss	2 minute	-	L	-	-	-	-	-
Seametrics	CSV, Excel, Graphs	MM/DD/YYYY	HH:mm:ss	15 second	G/M	G	-	-	-	-	-
YSI	CSV	MM/DD/YYYY	HH:mm:ss	1 hour	-	AcFt	°C	ft	-	FNU	-
Badger Meter	CSV	MM/DD/YYYY	HH:mm	1 day	KGAL/day	KGAL	-	-	-	-	-
Netafim	Excel	YYYY-MM-DD	HH:mm:ss	2 hour	gal/m	Gallon	-	-	-	-	-
Netafim	Excel	MM/DD/YYYY	HH:mm	3 hour	gal/m	Gallon	-	-	-	-	-
In-Situ (formerly Mace)	Excel	MM/DD/YYYY	HH:mm	1 hour	Ml/day	Ml	C	m	psi	NTU	m/s
SonTek	ASCII	MM/DD/YYYY	HH:mm	-	-	-	°C	mm, m	counts, dBar	-	m/s
SonTek	ASCII	MM/DD/YYYY	HH:mm	-	-	-	°F	ft	PSI		ft/s
Sensus	CSV, Excel	MM/DD/YYYY	HH:mm:ss	1 hour	cft/m, GPM, m^3/hr	cft, Gal, ac-ft, m^3	-	-	-	-	-
Panametrics	Not Stated	MM/DD/YYYY	HH:mm:ss	1 second	gal/m	gal	-	-	-	-	ft/s

Acre-feet (AcFt, ac-ft); Celsius (°C, C); cubic feet (cft); cubic feet per minute (cft/m); cubic meter (m^3) ; cubic meter per hour (m^3/hr); decibar (dBar); Fahrenheit (°F); feet (ft); feet per second (ft/s); Formazin Nephelometric Unit (FNU); gallons (G, Gal, gal); gallons per minute (GPM, G/M, gal/m); kilogallons (KGAL); kilogallons per day (KGAL/day); liter (L); megaliter (Ml); megaliter per day (Ml/day); meter (m); meter per second (m/s); millimeter (mm); Nephelometric Turbidity Unit (NFU); pounds per square inch (psi, PSI).

Table 5. Column headers for the first 10 columns in 13 data files submitted by manufacturers. The bottom row documents the most common data element in that specific column among submitted manufacturer files, with fraction of files in parentheses. Rosemount is excluded from this table as they only support manual data logging.

Manufacturer	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9	Column 10
McCrometer	FirmwareVersion	RSSI	FC_FLOW (GPM)	Pulse_Flow (GPM)	Precipitation (inch)	BattTemperature(F)	RadioOn seconds (s)	Reported Period (min)	FC_TOTAL (ac-ft)	-
Seametrics	Index	Date	Time	Flow Rate(L/S)	Incremental Volume(L)	Totalized Volume(L)	-	-	-	-
Seametrics	Index	Date	Time	Flow Rate(G/M)	Incremental Volume(G)	Totalized Volume(G)	-	-	-	-
YSI	Date	Time	Time (Fract. Sec)	Site Name	Depth ft	SpCond µS/cm	Turbidity FNU	Temperature° C	Battery V	-
YSI	Date	Time	System Battery	SL(Flow)	SL(MeanSNR)	SL(Speed)	SL (Integrated VelY)	SL (Integrated VelX)	SL(Multi CellEnd)	SL(Mean Temp)
Badger Meter	Meter_SN	Read_Time	Service_Point _Timezone	Read	Read_Unit	Read_ Method	Encoder _ Read	Flow_Time	Flow_Unit	Flow
Netafim	Date	Time	Program	Shift	Valves	Flow Actual gal/m	Flow Expected gal/m	Water Actual Gallon	Water Expected Gallon	Duration Actual
Netafim	Date	Valve	Reason	Total Time	Total Water	Flow	Chan1	Chan2	Chan3	Chan4
Mace	Velocity m/s	Depth	FlowRate	Total FLOW	Battery Voltage	Solar Panel	-	-	-	-
Mace	Date Time	Actual Conductivity (µS/cm)	Specific Conductivity (µS/cm)	Salinity (psu)	Resistivity (Ω×cm)	Density (g/cm³)	Total Dissolved Solids (mg/L)	FDOM Fluorescence (RFU)	Chl-a Fluorescence (RFU)	Turbidity (NTU)
SonTek	Date	Time	Velocity comp	Water level	Standard error of velocity	Signal strength	-	-	-	-
Sensus	Date	Time	Min Flow	Max Flow	Volume	-	-	-	-	-
Panametrics	Date	Time	Velocity	Volumetric	Standard Volumetric	Mass	Batch Forward Totalizer	Batch Reverse Totalizer	Batch Net Totalizer	Batch Totalizer Time
Most Common	date (8/13)	time (7/13)	flow (3/13)	flow (6/13)	N/A*	flow (2/13)	- (5/13)	- (5/13)	- (5/13)	- (7/13)

*N/A – no data element was repeated for that column among submitted files

Appendix A

Table A. Manufacturer contact information.

Manufacturer	Contact	Email	Phone	Website
McCrometer	Pamela Fuller	pamf@mccrometer.com	951-757-6416	www.mccrometer.com
Seametrics	Paul Carlson	pcarlson@seametrics.com	253-872-0284	www.seametrics.com
YSI	Michael Sundman	michael.sundman@xylem.com	937-688-4255 877-726-0975	www.ysi.com
Badger Meter	Rob Fehl Beth Thomas	rfehl@badgermeter.com Bthomas@badgermeter.com	Municipal: 800-616-3837 Commercial & Industrial: 877-243-1010	www.badgermeter.com
Netafim	Roy Levinson	roy.levinson@netafim.com	559-396-6812	www.netafimusa.com
In-Situ (formerly Mace)	Chris Howard	choward@in-situ.com	970-232-4321	www.in-situ.com
SonTek	Brittany Jenner	brittany.jenner@xylem.com	858-688-4371	www.xylemanalytics.co.uk/sontek
Rosemount	Wendy Hathaway	wendy.hathaway@emerson.com	800-406-5252	www.emerson.com/en-us/automation/rosemount
Sensus	James "June" Green Alek Cloyd	james.green.jr@xylem.com alek.cloyd@aqua-metric.com	951-637-1400	www.sensus.com
Panametrics	MaryKate Hanchett	mhanchett@instrumart.com	800-235-8367	www.bakerhughes.com/panametrics

Appendix B

Table B. Most popular equipment models as reported by manufacturers.

Manufacturer	Sensors	Data Loggers	Transmission
McCrometer	FlowConnect propellor meters		
Seametrics	Seametrics AG90 magmeter series; AG3000p magmeter		SignalFire EX90 Ranger (stand-alone cellular)
YSI	Storm3 data logger Campbell private label	Storm3; DL Series; WaterLOG H-522+	WaterLOG H-522+ (integrated satellite)
Badger Meter	ORION product family		
Netafim	M; WMR; WST; IRT series water meters; Hydrometer water meters; Octave ultrasonic meters		
In-Situ (formerly Mace)	Vulink	Vulink (integrated data logger)	TROLL Link 201 (stand-alone satellite); Vulink (integrated cellular)
SonTek	SonTek-IQ series: IQ-Standard; IQ-Plus; IQ-Pipe acoustic doppler flow meters; SonTek-SL series: SL1500-3G; Argonaut-SL500 side-looking doppler current meters		
Rosemount	Rosemount 3051CF flow meter; Pressure differential sensors		
Sensus	OMNI R2; T2; C2 series floating ball water meters		
Panametrics	PT900 ultrasonic flow meter		