FRESNO STATE
California Water Institute

TECHNICAL MEMORANDUM

TASKS 1- 4

East Kaweah Groundwater Sustainability Agency

Groundwater Metering and Well Monitoring Program

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Introduction

The East Kaweah Groundwater Sustainability Agency (EKGSA) on behalf of the Kaweah subasin Groundwater Sustainability Agencies (KSB-GSAs), requested that the California Water Institute (CWI) investigate the functionality of water meter systems to measure, collect, and aggregate pump discharges from groundwater wells. The KSB-GSAs will use the information from the water meters to monitor groundwater use within the GSA and develop groundwater use regulations in the GSA to meet the objectives of the Sustainable Groundwater Management Act (SGMA) of 2014. The State of California passed the act to reduce the impacts of groundwater overdraft within the State.

This report cover the part of the investigation included:

- In collaboration with the KSB-GSA's develop the evaluation criteria (Task 1)
- A questionnaire based upon the agreed criteria sent to each meter, telemetry, and data platform vendor (Task 1)
- A literature search of flow meter technology (Task 2)
- A desktop evaluation of alternative flow meters (Task 3)
- The testing of a series of water meters to determine their accuracy and head loss functions (Task 4)
- The ability of telemetry systems to read, collect, and upload the water meter output to a cloud data platform (Task 4)
- The ability of the cloud data platform to provide metrics critical to the KSB-GSA, primarily water discharge rates from each well within the KSB-GSAs boundary (Task 4)

Water meters are defined as the physical device that uses electronics or a mechanical device to measure the velocity of the water passing through the device. The discharge rate is derived from the velocity using the continuity equation ($Q = VA$, where Q is the discharge rate, V is the velocity, and A is the cross-sectional area of the device). The velocity (discharge) is represented by a pulse of current or a 4 to 20 milliamp output from the water meter. Thus, the faster the velocity, the more pulses per minute or the higher the current output is from the meter. Most water meters have a digital or mechanical display attached to the meter that registers instantaneous and/or accumulated discharge. Most also allow access to a set of system configuration menus accessed through buttons on the device's display. The water meter can be powered using batteries or with line power.

Telemetry is defined as the combination of the technology implemented to collect, store, and transmit the data output from the water meter. Telemetry can be vertically integrated with the water meter or be a system provided by a third-party vendor. The telemetry is typically housed in a box that is connected with cables to the water meter. Storage of the output is typically in random access memory. The transmission of the data can occur using cell phone technology, radio, or Bluetooth. The transmission devices are programmed to connect to only one data cloud platform. Most of the telemetry allows remote access to the water meter's system configuration menus. The telemetry is typically powered with batteries, but some solutions can use line power.

A cloud data platform is defined as the combination of software and hardware that receives the data uploaded from the telemetry unit, stores and aggregates it, and provides a graphical display of the data. Cloud data platforms can be vertically integrated with the telemetry/water meter, the telemetry, or provided by a third-party vendor that is independent of the water meter or the telemetry. The cloud data platform consists of a front end and a back end. The front end consists of the graphical user interface software that allows the user to access and analyze the data and the water meter configuration menus. The back end consists of the hardware that collects, stores, and backs up the data.

The literature search of the various flow meters was used to determine which manufacturers were most suited to this particular use and to invite these vendors to submit their meter for testing. Many of the vendors also provide telemetry and cloud data platform services as well. The telemetry and data cloud platform community is fairly small and word soon got out to local vendors of telemetry and cloud data platform services of the testing program. They then contacted us and offered to provide telemetry and cloud data platform services. All of the telemetry units and cloud data services that were received were tested.

Each participating vendor received a spreadsheet questionnaire that allowed them to uniformly report information regarding their meter, telemetry unit, and/or cloud data platform. The responses were double checked by CWI staff using literature on the unit or service, if that information was available. Flow meters and telemetry units tend to be well documented, making the verification process relatively easy. Cloud data platform services are not as well documented. The testing of these services was used to confirm their assertions regarding the services. The questionnaires were used to rank each vendor's equipment based on a point system assigned to the particular characteristic being evaluated. The point system assigned was determined by both CWI and KSB-GSAs staff. The scores of the questionnaires are proved in the Appendix A to this report.

The testing, conducted by the Center for Irrigation Technology (CIT) Hydraulics Laboratory at Fresno State, was broken down into these three components to provide the KSB-GSAs with a diverse universe of options from which to select their preferred flow meter, telemetry system, and cloud data platform. In most cases, each water meter that was tested also had a vertically integrated telemetry and cloud data platform system. In addition, there are numerous third-party vendors of telemetry systems with cloud data platforms or only cloud data platforms that may be attractive to the KSB-GSAs, which were also proposed for testing.

This Technical Memorandum documents the testing procedures used for the water meters, the telemetry units, and the cloud data platforms and two sets of results. One set consists of a literature review of each water meter, telemetry system, and cloud data platform. The other set consists of the performance results of the laboratory testing of the water meters, telemetry systems, and cloud data platforms. The following sections discuss the water meters results, the telemetry systems results, and finally, the cloud data platforms results.

Water Meters

Twelve meters were evaluated using the vendor's literature and the vendor's responses to questionnaires on their meter. Ten of those meters were evaluated in the CIT Hydraulics Laboratory, an ISO 9000 certified testing facility. The meters were not tested for certification. Instead, they were tested to provide a third-party verification of their accuracy. The information provided in this section includes the evaluation of the meters using the literature, questionnaires and the evaluation from the laboratory testing. The scoring results of the meters using the literature and questionnaires are provided in Appendix A of this report. The results of the CIT Hydraulics Laboratory testing are provided in Appendix B.

Literature Review

Water meters (meters) were requested from all known manufactures of agricultural meters. Six vendors responded to the request by providing one or more of their meters for testing. KSB-GSAs and CWI developed meter review criteria with which to evaluate each meter. Those criteria were narrowed down to:

- Measurement Technology – Meters must be Propeller, Magnetic, or Ultrasonic
- Sizes – Meters must be available in 6, 8, 10, and 12-inch diameters
- Installation Type – Meters can be either flange, saddle/clamp, or insertion
- Accuracy – Meters must have a minimum accuracy of 5-percent
- Life Span – Meters should have a minimum life span of 5 years
- Siting – Meters must have a maximum distance from a downstream disturbance of three pipe diameters or 10 feet (whichever is less), with 5 feet preferred
- Spare Parts – Meters should have spare parts easily availability
- Meter Output – Meters must provide at least pulse or current loop (4 – 20 milliamp) output
- Configuration Options – Meter systems should be configurable
- Power – Meters should have standard sized battery power, rechargeable batteries with solar power, or line power
- Human Interface – Meters must have a human interface with touch screen or button access
- Security – Meters should be tamper-resistant, or password protected and have auditing

A numeric scale was assigned to each criteria by KSB-GSAs and CWI's based on the criterion's importance. Criteria were further scored as listed in *Table 1*.

TABLE 1 - METER REVIEW CRITERIA

Criteria Ranking	Description	Points
Required	A meter must satisfy this criterion	5
Required/Preferred	A meter should satisfy this criterion and it is a preferred criterion	4.5

Preferred	A meter that meets this criterion is preferred	4
Ambivalent	A meter that meets this criterion is acceptable but not preferred or required	2
Disallowed	A meter that meets this criterion is disqualified	-1000

The meters fell into two categories, magnetic meters and propeller meters. The meters were further subdivided into flanged or insertion meters. Installation of a flanged meter requires cutting the discharge pipe to remove a portion of the pipe longer than the meter, welding flanges to the remaining ends of the discharge pipe, and bolting the flanged ends of the meter to the discharge pipe flanges. Usually, a thimble is used with a compression fitting to adjust the meter and the discharge pipe. The insertion meter only requires cutting a hole in the top of the discharge pipe and inserting the meter through the hole. The meter is secured to the discharge pipe using saddle compression bands or using a welded fitting. The list of meters that were provided for testing with their type and installation mode is provided in *Table 2*. The Manufacturer's Suggested Retail Price (MSRP) listed in Table 2 are all for 8-inch diameter meters to provide a relative comparison of cost between the meters.

TABLE 2 – METER TYPES AND INSTALLATION METHOD REVIEWED BY LITERATURE AND QUESTIONNAIRES

Vendors	Model	Meter Type	Meter Diameters Available (inches - nominal)	Installation Method	Manufacturer's Recommended Retail Price
Bermad	EuroMag 2200 EL	Magnetic meter	6-12	Flange	$2,245.10
Bermad	EuroMag 1222	Magnetic meter	6-12	Insertion	$
Bermad	Euromag 2300	Magnetic meter	6-12	Flange	$2,444.20
In-Situ	Signet 2552	Magnetic meter	6-12	Insertion	$
Krohne	Waterflux 3070	Magnetic meter	6-12	Flange	$1,433
Krohne	Enviromag 2050	Magnetic meter	6-12	Flange	$1,988
McCrometer	McMag 2000	Magnetic meter	6-12	Insertion	$1,700
McCrometer	DuraMag	Magnetic meter	6-12	Flange	$2,481
McCrometer	McPropeller	Propeller	6-12	Insertion	$1,258
Seametrics	AG 90	Magnetic meter	6-12	Insertion	$1,377

Vendors	Model	Meter Type	Meter Diameters Available (inches - nominal)	Installation Method	Manufacturer's Recommended Retail Price
Seametrics	AG 3000	Magnetic meter	6-12	Flange	$1,870
TechnoFlo	PS 32	Propeller	6-12	Insertion	$1,148

Questionnaire

The meter vendors were invited to provide their answers to the meter review criteria by completing the form in the spreadsheet questionnaire. Those answers were reviewed and verified by CWI staff and each meter's rating was compiled to select the top ten meters for testing. The final rankings are listed in *Table 3*. The meter review criteria questionnaires and scoring for each category are included in Appendix A of this report.

TABLE 3 - FLOW METERS, SCORING, AND RANKINGS

Meter Manufacturer	Meter Model	Scoring	Ranking
Bermad	Euromag 2300	104	1
Bermad	Euromag 2200 EL	104	1
Bermad	Euromag 1222	98.5	2
McCrometer	DuraMag	92	3
Seametrics	AG3000	90	4
McCrometer	McMag2000	86	5
TechnoFlow	PS32-06	86	6
McCrometer	McPropeller	84	7
Khrone	Waterflux 3070	83	8
Seametrics	AG90	77	9
Khrone	Enviromag 2050	78	10
In-Situ	Signet 2552	-918.5	11

The primary differences between the Bermad meters and the other meters were the number of power supply options and robust electronic interface options provided by the Bermad meters. The Bermad meters provided battery, line power, and solar options. The other meters provided subsets of these options. In all other aspects, the meters scored very much the same. The Bermad meters also provided a full suite of electronic interfaces, including pulse, current loop, a standard protocol cable connection to the meters, and a wireless connection through telemetry. The other meters provided various subsets of these options.

The In-Situ flow meter ranked last due to the requirement to locate the meter more than 10 feet downstream of a disturbance based on a 6-inch diameter meter, which is the smallest diameter that will be installed in the KSB-GSAs. A distance greater than 10 feet was a disqualification threshold for a meter based on the agreed-upon criteria.

CIT Hydraulics Laboratory Testing Results

The CIT Hydraulics Laboratory was contracted to test the top ten meters based on the rankings from the literature and the questionnaire. Of the 12 meters submitted, the CIT Hydraulics Laboratory could not test the Seametrics AG90 due to a bad battery power supply that could not be replaced. The Khrone Enviromag 2050 could not be tested because the vendor did not provide a power supply for the meter. This situation could not be remedied. Bermad did not supply a Euromag 1222 meter for testing. The In-Situ meter required an upstream pipe length that exceeded that criterion. Therefore, it was not tested. The remaining eight meters were tested in the CIT Hydraulic Laboratory in a standard configuration with minimum straight sections of pipe upstream and downstream of the meter. Each meter was tested at 11 different discharge rates for the minimum time required for the meter to stabilize the discharge measurement. The meter results were compared to the discharge rate measured by the Lab's certified venturi meter (BIF Universal Venturi Tube, Model 20181). The meters and their diameters, average errors, range of discharge rates, and range of velocities are presented in *Table 4*.

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Table 4 is on the following page

TABLE 4 - CIT HYDRAULICS LABORATORY METER TEST RESULTS

Meter Name	Diameter inches	Range of Discharge Rates GPM	Range of Test Velocities fps	Average Error percent	Maximum Error percent	Minimum Error percent
Bermad Euromag 2200EL	8	102 - 1138	0.66 – 7.28	-0.95	-3.40	-0.20
Bermad Euromag 2300	6	107 – 1114	1.22 – 12.63	0.78	1.70	0.60
McCrometer DuraMag	8	104 – 1135	0.66 – 7.25	0.34	1.60	-0.10
Seametrics AG 3000	8	81 - 1246	0.52 – 7.96	-0.40	-0.90	-0.10
McCrometer McMag2000	8	114 – 1266	0.72 – 8.08	-0.56	-1.70	-0.10
Technoflo PS23	6	119 - 985	1.38 – 11.15	1.96	1.70	3.00
McCrometer McPropeller	8	97 – 1141	0.63 – 7.28	3.44	4.60	3.00
Krohne WaterFlux	8	105 - 1164	0.66 – 7.42	1.23	2.00	-0.40

All of the meters fell within the accepted maximum allowable 5-percent error. The McCrometer McPropeller exhibited the highest error of 3.44-percent and the McCrometer Duramag exhibited the lowest error of 0.34-percent. The discharge rates produced velocities through the meters that ranged from 1 foot per second to 12 feet per second. The general operating range for velocities in pressure pipe systems is from 3 to 8 feet per second.

Annualized Cost to Own

The amortized or annual cost to own each of the meters was calculated assuming:

- 5-year life for each meter
- no intermediate service of the meter
- no salvage value at the end of 5-years
- and an annual interest rate of 3-percent

A five-year life period was assumed because this was the minimum acceptable life of a meter set by the KSB-GSAs. Five years was used for comparison purposes only and is not meant to imply any particular life for any of the meters.

No service on the meter was assumed because each of the manufactures stated that they expected that their meters would operate within the specifications for at least 5 years.

The meters were assumed to have zero value at the end of the five years. This assumption was used to provide a uniform analysis of the meters. It is also probable that the owner of the meter may perceive that has residual value, but there will probably be few, if any, buyers for a used flow meter.

The annual interest rate of three-percent was assumed to be representative of the long term interest rate.

Figure 1 presents a bar chart of the meters and their amortized values for comparison.

Figure 2 presents a scatter plot with error boxes for each meter. Figure 2 illustrates each meter, its maximum error, minimum error, and average error compared to its annualized cost.

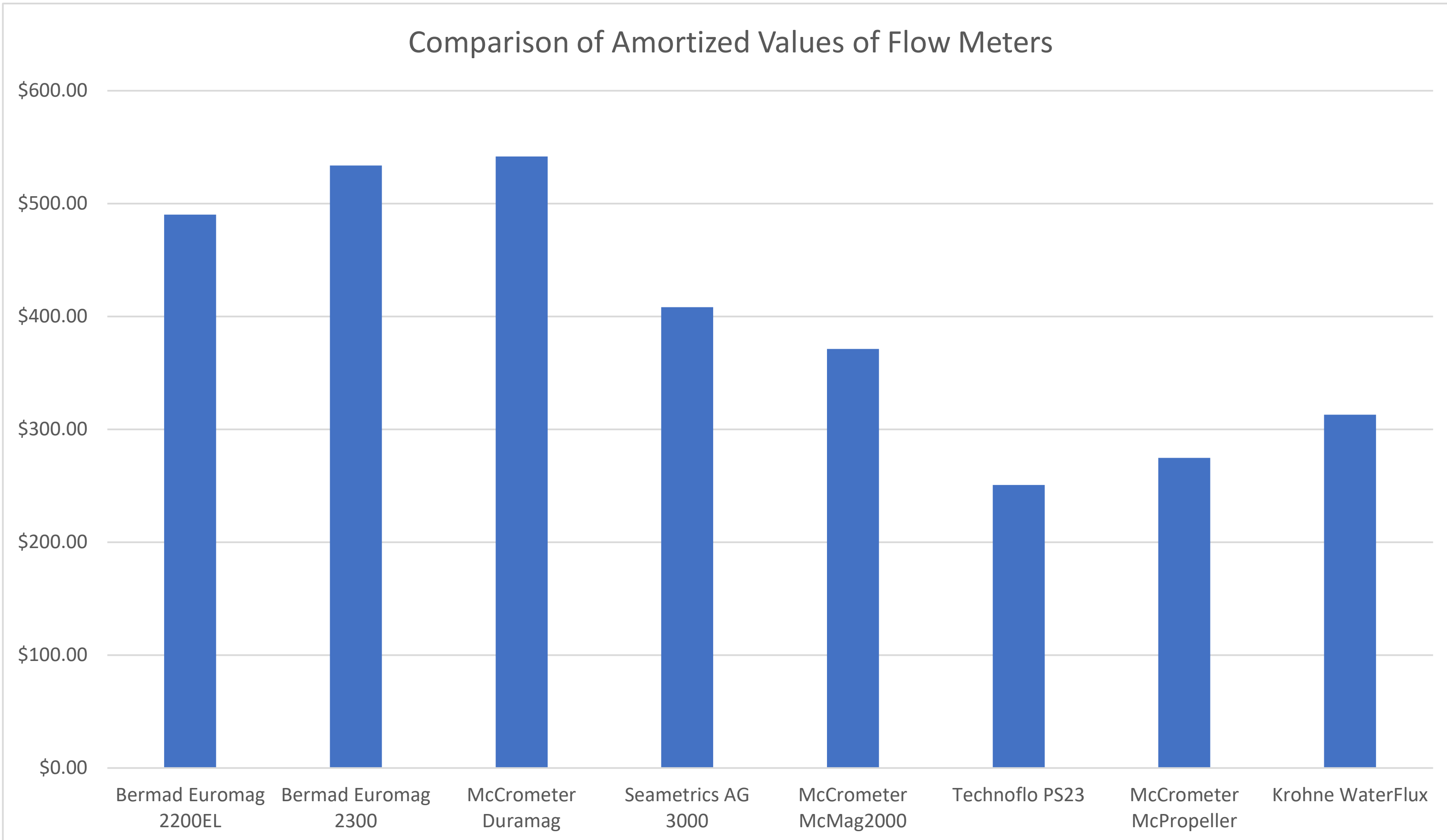

Figure 1 - Amortized Values of Flow Meters

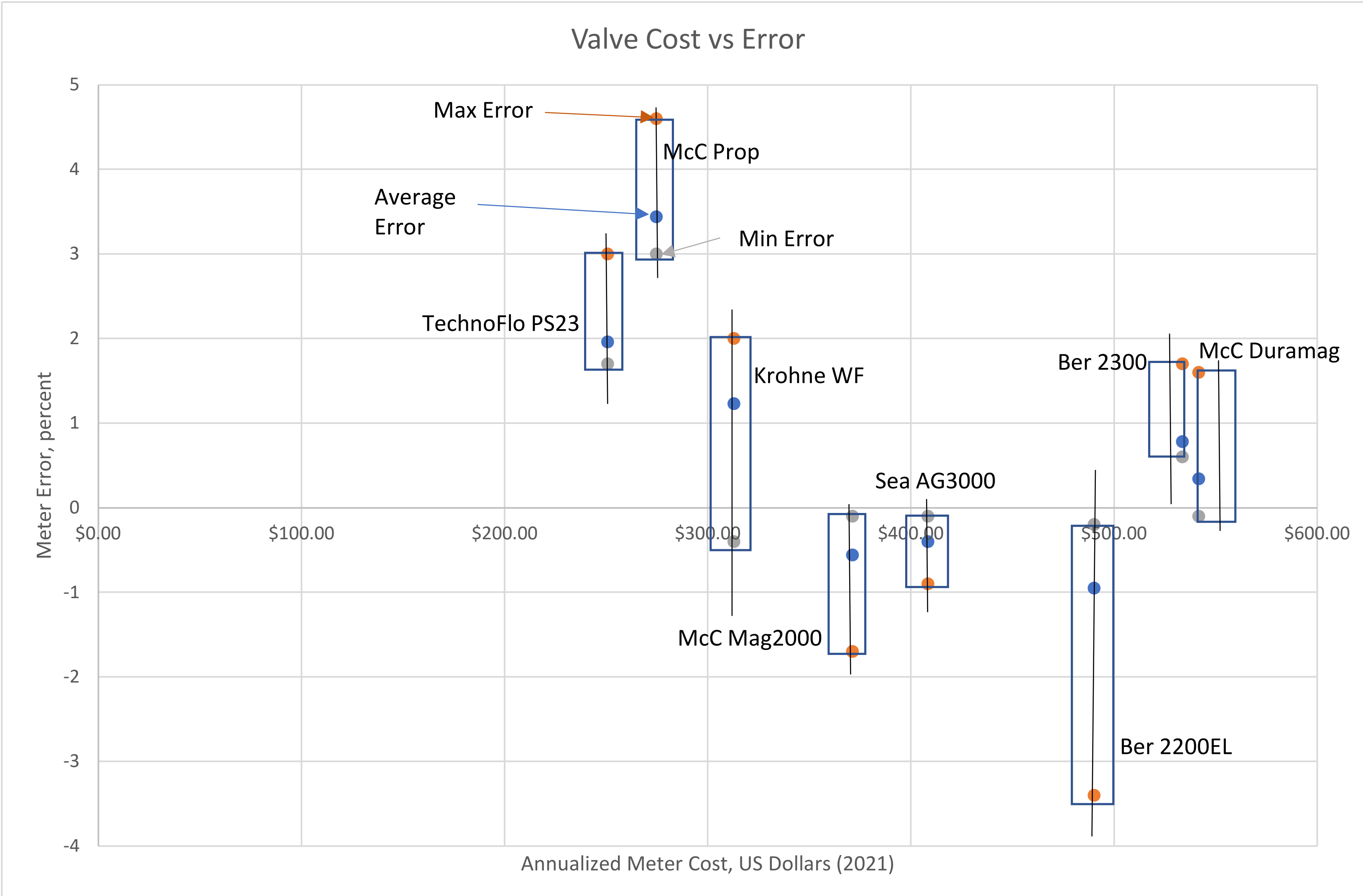

Figure 2 - Annualized Valve Cost vs Error Ellipse

Telemetry

Telemetry systems were requested from all known vendors of telemetry systems used in the agricultural water delivery system. All of the meter vendors provided telemetry systems for testing except Seametrics. Independent telemetry manufacturers are also active in this area. They provided units for testing. The telemetry systems were evaluated and ranked using the literature and answers provided through the questionnaires. The ranking information is presented in the Literature and questionnaire subsection below. The scoring is presented in Appendix C of this report. The CIT Hydraulics Laboratory used the flow meters to develop flow data which was captured by each of the telemetry units and uploaded to a cloud data platform. The testing results are presented in the CIT Hydraulics Laboratory Testing subsection that follows the Literature and Questionnaires subsection. The report prepared by the CIT Hydraulics Laboratory includes both the telemetry and the data platform evaluations. It is included in Appendix E of this report.

Literature Review and

KSB-GSAs and CWI developed telemetry review criteria with which to evaluate each unit. Those criteria were narrowed down to:

- Configuration Options – The telemetry systems should be configurable
- Power – A telemetry system should have standard sized battery power, rechargeable batteries with solar power, or line power
- Human Interface – A telemetry must have some form of human interface, either directly with touch screen or button access on the unit or through a computer interface via cable
- Security – A telemetry should have a tamper-resistant cover or password protected and have auditing
- Connection Protocol – A telemetry system should have an external means of data acquisition and configuration that may be either a hardwire connection to a computer, Bluetooth connection to a device, or through the web-based platform
- Wireless Connection – The telemetry system must have a wireless connection to the web either through a cell modem or radio connection to a gateway

The application of these criteria became slightly subjective because of the wide variety of ways in which the telemetry systems are implemented. Some are integrated into the meter with a digital display of discharge rates and configuring the meter's parameters using the buttons. In other words, the separation between the meter and the telemetry system was not a clear demarcation. Many other telemetry systems were third-party systems that consisted of an external device that accessed the meter and its output through data ports provided by the meter. There is an obvious demarcation between the meter and these telemetry systems. Access to the meter configuration and the data for the third-party telemetry systems was through a computer connected to the telemetry device. The connection was, in some cases, both a hardwire connection and via the web platform, or it was only through the web platform.

Because there are only six criteria for this section, all of the units submitted were tested in the CIT Hydraulics Laboratory to verify that the telemetry systems performed as stated by the manufacturer. The testing setup included connecting each telemetry unit to a flow meter installed in the CIT Hydraulics Laboratory. The meters were installed in series in the CIT Hydraulics Laboratory's pipe loop. Water was circulated through the pipe system for up to 8 hours per day for two weeks. The days were not continuous to simulate an irrigation operation with periods of pump-on and pump-off. The laboratory evaluation of the telemetry units is included in Appendix B of this report, including specific criteria that were evaluated. Those results are incorporated into this report.

Table presents the results of the rubric scoring of the telemetry units from the literature review.

Table 5 - Telemetry Manufacturers and Models Scoring and Ranking from the Literature Review

Telemetry Manufacturer	Model Tested	Scoring	Ranking
Bermad	Integrated Telemetry Unit	59	1
Ctek	Z4550	54.5	2
Wildeye	Not Listed	50.5	3
McCrometer	Integrated Telemetry Unit	49	4
In-Situ	Agriflow XCi	47	5
Ranch Systems	RS 130	47	5
Hotspot AG	Controller	47	5
XiO	Cell Modem Controller	43	6

Questionnaires

The meter with integrated telemetry as well as telemetry only vendors were invited to provide their answers to the meter review criteria by completing the form in the spreadsheet questionnaire. Those answers were reviewed and verified by CWI staff and each meter's rating was compiled to select the top ten meters for testing. The final rankings are listed in 5. The meter review criteria questionnaires and scoring for each category are included in Appendix A of this report.

CIT Hydraulics Laboratory Testing Results

Table and *Table* present the CIT Hydraulics Laboratory evaluation results of the installation of the telemetry systems. All of the systems transmitted data and allowed access to the meter through the telemetry system. In the table, an Easy rating indicates that there were no issues during the installation of the telemetry unit or it was integrated with the meter. Relatively Easy means that there were some cabling or other configuration issues that were overcome with minimal effort. Neutral means that there were cabling of configuration issues that took some effort to overcome. Difficult means that there were cabling or configuration issues that took significant technical support to overcome.

Table 6 - CIT Hydraulics Laboratory Results

Question	Bermad	Ctek	Wildeye	In-Situ	McCrometer
Ease of use of hardware installation	Easy	Relatively Easy	Easy	Difficult	Easy

Table 7 – CIT Hydraulics Laboratory Results (Continued)

Question	Ranch Systems	Hospot AG	XiO
Ease of use of hardware installation	Neutral	Relatively Easy	Relatively Easy

The installation information only affected the ranking of the In-Situ telemetry unit. The suggested ranking due to the Difficult evaluation of the installation is 6.

The number 1 ranking of Bermad is due to the tight integration of the telemetry with the meter and the power options that are available to this unit. However, this strength is also a downside because the telemetry unit will only function with the Bermad flowmeter. This is true of the McCrometer, which was the other integrated telemetry unit.

Of the third-party telemetry units, the primary difference in ranking between the units was the power supply options that each provided. The Ctek ranked the highest due to its numerous power supply options. In-Situ, Ranch Systems, and Hotspot AG all had the next level of power supply options. XiO ranked the lowest due to the lack of power supply options.

All telemetry units acquired the data from the meter and transmitted it to the cloud data platform with no errors.

Cloud Data Platform

Cloud data platforms were provided by all of the manufacturers that provided telemetry units, either integrated with their flow meter or an independent third-party manufacturer of telemetry equipment.

Two of the vendors provided only cloud data platform services. They state that they are telemetry and meter neutral, meaning that their cloud data platform will work with any hardware system that is currently available. Their only requirement is the ability to access the data collected by a meter or third party's telemetry through an Application Programming Interface (API).

The cloud data platform systems were evaluated and ranked using the literature and answers provided through the questionnaires. The ranking information is presented in the Literature and Questionnaire subsection below. The scoring is presented in Appendix D of this report. The CIT Hydraulics Laboratory used the flow meters to develop flow data which was captured by each of the telemetry units and uploaded to a cloud data platform. The testing results are presented in the CIT Hydraulics Laboratory Testing subsection. The report prepared by the CIT Hydraulics Laboratory includes both the telemetry and the data platform evaluations. It is included in Appendix E of this report.

Literature Review

The criteria agreed upon with KSB-GSAs for evaluating the cloud data platforms were:

- Type of data query – Must have push, can have pull, preferred that it have both push and pull
- Type of API integration – API must be provided, Open API is preferred, Additional cost to access the data through the API is disallowed
- Type of data recovery – Data stored for more than a year is preferred, Warning before data deletion is preferred, Daily backups are required, Recover deleted data within one week is required, Redundant servers are required, Server failover 1 second or less is required
- Backend user interface – Available or unavailable are both acceptable
- User interface output – Flow vs. time is required, Cumulative flow for any time interval is required, System status is required, Meter configuration is preferred
- User cost structure – Services billed monthly is preferred, Service billed annually is preferred, A one-time fee is disallowed, Services paid by the users is preferred, Services paid per meter is preferred, Services paid per access is disallowed
- Hosting – Services hosted by the users is disallowed, Services hosted in the cloud is preferred
- Provisioning – User access to the data and platform functions is controlled by permissions is preferred, System is controlled by group permissions is preferred, System is controlled by access to the meter is preferred, System requires each user to authenticate is preferred, System requires organizations to authenticate is ambivalent, System allows some users to read-only access and others to read and write access is preferred
- User authentication – System requires unique user name and password is ambivalent, System is follows published authentication standards is ambivalent
- User Auditing – System logs users access to the system is preferred, System tracks the activities of the users while accessing data is preferred, System tracks changes to the data or the telemetry parameters is preferred

Questionnaires

Each manufacturer was invited to complete the questionnaire containing the criteria. Their answers were collated and entered into a ranking spreadsheet. Each of the responses was scored in accordance with the scoring values presented in *Table* 8. The results of the scoring are presented in *Table* 9.

Table 8 - Cloud Data Platform Review Criteria Scoring

Criteria Ranking	Description	Points
Required	A system must satisfy this criterion	5
Required/Preferred	A system should satisfy this criterion and it is a preferred criterion	4.5
Preferred	A system that meets this criterion is preferred	4
Ambivalent	A system that meets this criterion is acceptable but not preferred or required	2
Disallowed	A system that meets this criterion is disqualified	-1000

Table 9 - Cloud Data Platform Rankings Based on Vendor Answer Scoring

Manufacturer	Scoring	Ranking
Ctek	120	1
REDTrac	118	2
Wildeye	114	3
Bermad	112	4
SweetSense	112	4
Ranch Systems	106	5
HotSpot AG	104	6
XiO	104	6
In-Situ	94	7
Mammoth Water	94	7
Control Design	92	8
Seametrics	-918	9
McCrometer	-1890	10

CIT Hydraulics Laboratory Testing Results

The CIT Hydraulics Laboratory installed and tested each of the telemetry units and the cloud data platforms. Each platform was evaluated using the following questions:

Question 1: Does it have cloud services?

Telemetry devices should be able to record and send data to a cloud/server storage. The evaluation team verified this service existed and data was able to be viewed and downloaded. This question was answered Yes if the platform relied on cloud storage for data transmitted by the telemetry system.

Question 2: Does it have API?

An essential feature for many customers is the ability to access data through an Application Programming Interface (API). The evaluation team confirmed and checked with the manufacturer to ensure this feature was included in the devices.

Question 3: Does it protect stored data?

Most data logging systems have storage capacity. This question ensured that the platform stores data and the user has access to the data. Additionally, is the data retained for a known period. The question was answered Yes, if the platform had secure log-in or other password-protected access. Backup functionality was verified by interviewing the technical representative of the vendor.

Question 4: Is there a Backend User Interface (UI)?

In some instances, the user may have to access the raw data and/or access it using other devices. This was verified by directly asking the manufacturer. The question was answered Yes, if the system had a "backend" interface that enabled more advanced interoperability or automation of the telemetry system.

Question 5: Can data be downloaded?

Many programs or applications allow the user to view and analyze data and download data in a useable format. This is important if the user wants to perform analyses or use the data for other purposes. This question was answered Yes, if the telemetry system provided downloadable files in CSV, XLS, XLSX, TXT, or PDF format.

Question 6: Is there a public cost structure?

This question specifically asked if additional "add-on" or "service extensions" were required to use the telemetry component of the overall metering system and if the cost of the services is available through a publicly available fee structure. The information was verified by directly asking the manufacturer. The question was answered Yes, if the cost information was publicly available.

Question 7: Hosted online?

This question was used to determine if the user accessed the data via a web-based interface (i.e., a website or web application) that included a graphical user interface. It is important to note that some systems use cloud storage but do not always have a cloud-based user interface; hence, both Q1 and Q7 are required to differentiate between the two. This question was answered Yes, if the user accessed the data via a web-based interface that included a graphical user interface.

Question 8: Does it limit user access?

User Provisioning, or other access management features, are essential to any multi-user system. To receive a Yes on this question, the system had to have some features that controlled or managed what the user could access on the site.

Question 9: Does the system maintain an audit trail of user activities?

Knowing who accessed what and when can be essential when analyzing data issues. This question was answered Yes, if the system maintained a log of user changes to system setup or when the user logged in.

Question 10: Ease of use "Software"

Reported on a Likert scale 1 - 5, where 1 is easy and 5 is difficult.

Table and *Table* 11 present the results of the CIT Hydraulics Laboratory review and answers to the questions for each of the tested devices.

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Tables 5 and 6 are on the following pages

Table 10 - Cloud Data Platform *CIT Hydraulics Laboratory* Results

Question	Ctek	REDTrac	Wildeye	Bermad	Ranch Systems
Question 1: Does it have cloud service?	Yes	Yes	Yes	Yes	Yes
Question 2: Does it have API?	Yes	Yes	Yes	Yes	Yes
Question 3: Does it protect stored data?	Yes	Yes	Yes	Yes	Yes
Question 4: Is there a backup UI?	Yes	Yes	Yes	Yes	Yes
Question 5: Can data be downloaded?	Yes	Yes	Yes	Yes	Yes
Question 6: Is there a cost structure?	Yes	Yes	Yes	Yes	Yes
Question 7: Hosted online?	Yes	Yes	Yes	Yes	Yes
Question 8: Does it limit user access?	Yes	Yes	Yes	Yes	Yes
Question 9: Does the system maintain an audit trail of user's activities?	Yes	Yes	Yes	Yes	Yes
Question 10: Ease of Use of the platform	3	2	2	3	3

Table 11 - Cloud Data Platform *CIT Hydraulics Laboratory* Results (continued)

Question	**Hotspot AG**	**XiO**	**In-Situ**	**McCrometer**
Question 1: Does it have cloud service?	Yes	Yes	Yes	Yes
Question 2: Does it have API?	Yes	Yes	Yes	Yes
Question 3: Does it protect stored data?	Yes	Yes	Yes	Yes
Question 4: Is there a backup UI?	Yes	Yes	Yes	Yes
Question 5: Can data be downloaded?	Yes	Yes	Yes	Yes
Question 6: Is there a cost structure?	Yes	Yes	Yes	Yes
Question 7: Hosted online?	Yes	Yes	Yes	Yes
Question 8: Does it limit user access?	Yes	Yes	Yes	Yes
Question 9: Does the system maintain an audit trail of user's activities?	Yes	Yes	Yes	Yes
Question 10: Ease of Use of the platform	2	2	3	2

The user experience as evaluated by the CIT Hydraulics Laboratory investigators did not indicate significant differences between the nine platforms being assessed. The rankings based on the literature review included four units: SweetSense, Mammoth Water, Control Design, and Seametrics, that the CIT Hydraulics Laboratory investigators did not test. The CIT Hydraulics Laboratory investigators were not able to get the SweetSense telemetry unit to collect and transmit data. Therefore, they were not able to evaluate the cloud data platform. The CIT Hydraulics Laboratory investigators contacted SweetSense to correct the issues with the telemetry unit, but the SweetSense staff did not respond to that contact. Mammoth Water was not a telemetry system. It utilizes an upload of a digital image of the meter to their cloud service. Therefore, it was not evaluated by the CIT Hydraulics Laboratory investigators. The Control Design system was not **fully capable** when it was received by the CIT Hydraulics Laboratory investigators. The system could not accept data output from the meters and upload the data to the cloud data platform. Therefore, it was not evaluated. Seametrics did not provide their integrated telemetry system with their meter. Consequently, it was not assessed.

The top four ranked cloud data platforms were Ctek, REDTrac, Wildeye, and Bermad. Of the four, REDTrac is a **platform-only platform**. They do not have a telemetry system. Their selling point is that their cloud data platform is best used to acquire data uploaded to other systems. The REDTrac platform was evaluated using a third-party telemetry system provided by REDTrac. Ctek, Wildeye, and Bermad all provided their telemetry system and the platform to capture the data from the meters. Ctek and Wildeye are third-party telemetry systems that can connect to various meters. Bermad is an external telemetry unit, but there is no indication that it will work with other than the Bermad meters. It was not tested on any other meters.

Since the top four platforms scored relatively close together, the subjective evaluation of the CIT Hydraulics Laboratory investigators regarding the ease of use of the platform software can be used as an additional criterion with which to evaluate the platforms. The REDTrac and Wildeye platforms scored a 2 in ease of use of the software. The Ctek and Bermad platforms scored a 3. The use of this criteria advances the REDTrac and Wildeye platforms to a higher ranking than the Ctek and Bermad platforms. Other criteria could also be used as tie-breakers. For instance, the significant difference in the literature review between the Bermad, Ctek, RedTrac, and Wildeye systems was in pricing and auditing. Both REDTrac and Wildeye scored higher in Cost Structure. Both of these systems had multiple options for subscribing and paying for their service. Bermad and Ctek had less robust subscription and payment options. Bermad and Ctek scored higher in auditing. They tracked user activities while accessing the data and any changes made by users to the data or the system variables. REDTrac and Wildeye only tracked user login and logout. A final criteria that KSB-GSAs may wish to consider, but the CIT Hydraulics Laboratory investigators did not evaluate, is the platform's ability to acquire data from multiple platforms. All of the systems provided API access to their data. REDTrac was the only platform that specifically structured its system to aggregate data from multiple platforms rather than from their telemetry system. The other systems may be able to do this. They did not specifically mention this capability. The weakness of this capability is the willingness of other platform owners to allow access to their data.

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Appendix A: Meter Scoring Sheets

Item	R/P/D/A	Level of Importance (1 low- 2 medium - 3 high)
Physical Meter		
1. Measurement technology		
1. Propeller	P	
2. Paddle wheel / turbine	A	
3. Mag	P	
4. Doppler	D	
5. Ultrasonic	P	
6. Venturi	D	
2. Nominal Diameter	R	
3. Installation method		
1. Cut/Flange	R/P	
2. Saddle	R/P	
3. Insertion	P	
4. Clamp on	R/P	
5. Cement Pipe	P	3
4. Accuracy threshold	P: 2% - 5%; D: > 7%	
5. Expected lifetime	R: 5 – 10 years, ,more is better	
6. Siting requirements	R: < 10 ft; P: < 5 ft	
7. Required maintenance	A	
8. Material compatibility	A	
9. Cost	?	
10. Availability of spare parts	P	
Electronics		
1. Electronic Interface		
1. Pulse	R	
2. Current Loop	R	
3. Protocol/Standard	A	
4. Wireless	P	
2. Configuration Options	P	
3. Power		
1. Battery (require standard/typical battery size?)	P	
2. Mains/external: voltage, freq. tolerance, isolation	P/A	

3. Solar P 1

4. Human Interface

1. Digital display
2. Configuration via interface P
3. Physical input: buttons, mag switch, cable, wireless A

5. Security

1. Tamper resistant P
2. Password protection A
3. History/auditing P

Appendix B: CIT Hydraulics Laboratory Evaluation of Flow Meters Report

Purpose:

The purpose of this test is to identify differences in flow meters types against a calibrated flow device. There are multiple procedures to measure the flow accuracy of flow measurement devices. However, the most common method is "wet calibration", which entails comparing the measurement of a flow measuring device, in this case flow meters against a calibrated master flowmeter. In this case the master flow meter is are calibrated venturi differential pressure meters accurate to +-0.5%.

In this test flowmeters were installed with ten (10) times the diameter of straight pipe downstream and ten (10) times the diameter of pipe upstream. This is done, to ensure enough straightening of flow and limiting turbulence prior to the water reaching the flowmeter. Upstream of the valve there is a vertical elbow riser to ensure the pipes are completely full of water. After the elbow, there is a valve to control the flow during the test. Upon reaching flow points, the meters were allowed to stabilize for at least 60 seconds prior to a reading be recorded.

Date	2/18/2021
Tech	Kaomine
Test	Flow
Set pressure	30 psi
Model	EUROMAG MUT2200EL/MC 406
Size	8 inch

Venturi (GPM)	Flowmeter (GPM)	Run Time (Sec)	Percent Difference
100.03	102.1	300	-2.0%
203.5	206.7	300	-1.5%
303.7	298.8	300	1.6%
401.4	399.8	300	0.4%
510.6	520.1	300	-1.8%
615.4	622.3	300	-1.1%
712.9	707.5	300	0.8%
820.3	840.4	300	-2.4%
908.4	909.9	300	-0.2%
1041	1078	300	-3.4%
1133	1138	300	-0.4%
NOTES:	Waited 5 minutes for it to stabilize		

Table 1. Bermad EuroMag MUT2200EL Flow and Percent Difference from Venturi Meter

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Date	2/19/2021
Tech	Kaomine
Test	Flow
Set pressure	30 psi
Model	EUROMAG MUT2300
Size	6 inch

Venturi (GPM)	Flowmeter (GPM)	Run Time (Sec)	Percent Difference
104.7	106.56	30	-1.7%
213	209.41	30	1.7%
303.4	299.84	30	1.2%
415.1	408.97	30	1.5%
502.4	499.17	30	0.6%
603.4	598.66	30	0.8%
709.3	702.25	30	1.0%
807.4	801.11	30	0.8%
908.2	900.12	30	0.9%
1010	1001.17	30	0.9%
1125	1113.6	30	1.0%

Table 2. Bermad EuroMag MUT2300 Flow and Percent Difference from Venturi Meter

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Date	2/2/2021
Tech	Kaomine
Test	Flow
Set pressure	30 psi
Model	DuraMag
Size	8 inch

Venturi (GPM)	Flowmeter (GPM)	Run Time (Sec)	Percent Difference
102.5	103.6	60	-1.1%
198.9	199.6	60	-0.4%
303.4	301.7	60	0.6%
405.7	399.6	60	1.5%
507.7	508.3	60	-0.1%
601	598.4	60	0.4%
710.2	702.3	60	1.1%
817.3	805.3	60	1.5%
923.5	909.1	60	1.6%
1026.7	1032.8	60	-0.6%
1126.1	1134.5	60	-0.7%
Notes:	Takes 60 seconds to get stable flow		

Table 3. McCrometer DuraMag Flow and Percent Difference from Venturi Meter

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Date	1/25/2021
Technician:	Kaomine
Test	Flow
Set pressure	30 psi
Model	Seametrics Ag3000
Size	6 inch

Venturi (GPM)	**Flowmeter (GPM)**	**Run Time (sec)**	**Percent Difference (%)**
80.4	81	30	-0.7%
104.1	105	30	-0.9%
200.3	202	30	-0.8%
303.6	304	30	-0.1%
404.6	406	30	-0.3%
502.8	502	30	0.2%
600.5	601	30	-0.1%
705.5	707	30	-0.2%
803.1	805	30	-0.2%
908.3	910	30	-0.2%
1120	1130	30	-0.9%
1236	1246	30	-0.8%
Notes:	takes 30 seconds to get stable flow		

Table 4. Seametrics AG 3000 Flow and Percent Difference from Venturi Meter

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Date	1/27/2021
Tech	Kaomine
Test	Flow
Set pressure	30 psi
Model	McCrometer DuraMag
Size	8 inch

Venturi (GPM)	Flowmeter (GPM)	Run Time (Sec)	Percent Difference
111.6	113.5	120	-1.7%
211.5	214.3	120	-1.3%
303.5	306.2	120	-0.9%
409.7	413.5	120	-0.9%
503.4	505.4	120	-0.4%
603.8	604.7	120	-0.1%
717.5	724.3	120	-0.9%
808.8	811.7	120	-0.4%
910.8	913.2	120	-0.3%
1045	1036	120	0.9%
1177	1188	120	-0.9%
1256	1266	120	-0.8%
Notes:	takes 120 seconds to get to stable flow		

Table 5. McCrometer MCcroPropeller with FS100 Flow and Percent Difference from Venturi Meter

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Date	3/1/2021
Tech	Kaomine
Test	Flow
Set pressure	30 psi
Model	TechnoFlow PS23 (Seametrics – Propeller)
Size	6 inch

Venturi (GPM)	Flowmeter (GPM)	Run Time (Sec)	Percent Difference
116.4	119	120	-2.2%
207.4	204	120	1.7%
301.8	295	120	2.3%
422.7	414	120	2.1%
522.3	508	120	2.8%
615.2	602	120	2.2%
706.9	690	120	2.4%
808.6	785	120	3.0%
905.5	881	120	2.8%
1015	985	120	3.0%
Notes: Propeller meter was installed on 6 inch diameter PVC pipe x 20 ft long			

Table 6. TechnoFlow PS32 (Seametrics Propeller) Flow and Percent Difference from Venturi Meter

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Date	2/24/2021
Tech	Kaomine
Test	Flow
Set pressure	30 psi
Model	Propeller M308
Size	8 inch

Venturi (GPM)	Flowmeter (GPM)	Run Time (Sec)	Percent Difference
101.5	97	120	4.6%
205.6	199	120	3.3%
303.5	292	120	3.9%
403.8	389	120	3.8%
505.7	490	120	3.2%
610.3	588	120	3.8%
715.6	690	120	3.7%
825.9	799	120	3.4%
911.1	884	120	3.1%
1044	1010	120	3.4%
1175	1141	120	3.0%
Notes:	takes 120 seconds to get to stable flow		

Table 7. McCrometer Propeller Meter Flow and Percent Difference from Venturi Meter

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Date	2/3/2021
Tech	Kaomine
Test	Flow
Set pressure	30 psi
Model	KrohneWaterFlux3070
Size	8 inch

Venturi (GPM)	**Flowmeter (GPM)**	**Run Time (Sec)**	**Percent Difference**
103.1	105.2	30	-2.0%
212.1	215.4	30	-1.5%
318.7	321.9	30	-1.0%
412.5	419.7	30	-1.7%
505.9	507.8	30	-0.4%
610.6	619.5	30	-1.4%
713.7	719.9	30	-0.9%
805.3	813.4	30	-1.0%
910.5	921.5	30	-1.2%
1024.9	1036.7	30	-1.1%
1152	1164.4	30	-1.1%
Notes:	takes 30 seconds to get stable flow		

Table 8. Krohne WaterFlux 3070 Flow and Percent Difference from Venturi Meter

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Date	2/4/2021
Tech	Kaomine
Test	Flow
Set pressure	30 psi
Model	EnviroMag 2050
Size	8 inch

NO DATA – Has no power source

Table 9. Krohne EnviroMag 2050 Flow and Percent Difference from Venturi Meter

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Date	2/4/2021
Tech	Kaomine
Test	Flow
Set pressure	30 psi
Model	Seametrics T20200 Propeller Meter
Size	8 inch

NO DATA – Has a bad battery

Table 10. Seametrics T20200 Propeller Meter Flow and Percent Difference from Venturi Meter

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Appendix C: Telemetry and Cloud Storage Scoring Sheets

Communications		
1. Interface w/ Electrical		
2. Sampling Rate	R	
3. Reporting Interval	R	
4. Communication Technology		
1. Cellular	P	
2. LPWAN (LoRa, Sigfox, etc); requires gateway	P	3
3. Other ISM band tech (Wifi, Bluetooth, etc); requires gateway	P	1
4. 900 MHz radio (point to point)	P/A	
5. FM radio (point to point)	D	
6. Satellite modem	P	1
7. Hardwired (no comms, to office or control system)	D	
8. Local storage (no comms, datalogger)		
5. Supported Protocols		
6. Remote Configuration		
7. Power	A	
8. On-bard storage	P	3
1. If communications are lost, are data lost?		
2. How long should the system be able to keep recording?		
9. Push/Pull		
1. Push: the device initiates communication	R	
2. Pull: the server initiates communication		
3. Both	P	

Data/Backend		
1. Data Flow model		
2. API Integration		
1. Do they have an API?	R or P	3
2. Is the API Open?	A/P	1
3. Is NDA required?	A	

4. Will they consider new comms API?			
5. Will they consider new UI API?	A		
6. What APIs are supported now			
7. Is API an added/extra feature (i.e. costs extra)	D/A		
3. Resiliency / Redundancy / Longevity			
1. How long will data remain accessible?	P		1
2. Is data deleted if contract is terminated?	P		
3. Can users request that data be deleted?			
4. What is the maximum storage capacity			
5. Is there a limit to the number of measurements they will store?			
6. How often do they make backups?	R		
7. How long does it take to recover from a backup	R		
8. Do they have redundant servers?	R		
9. How long does failover take?	R		
4. Aggregation & Server Side processing (some examples follow)			
1. Total flow (volume) aggregated over:			
i. Arbitrary time frame (e.g. water year, fiscal year)	P/A		
ii. Arbitrary geography (e.g. white areas)	P/A		
iii. Fixed interval (hourly, daily, monthly, yearly) → R, ,	R		
iv. Arbitrary group of meters (by owner, by area, by crop, QA/QC status)	P		
v. Aggregation of configuration or status	P	medium	
2. Tertiary computations	p		1
i. AI applications			
ii. Inference about well			

health or pump performance

iii. Groundwater/aquifer inference

5. Configuration data

1. Does the system store setup and configuration data about the in-field hardware?	P	1
2. Can you change the reporting interval remotely?	A	
3. Can you change the meter's calibration constants remotely?		
4. Does the platform know when local configuration data is modified in the field?	P	
5. Does the platform include other setup information? (e.g. meter lat/lon, install date, serial number, etc)	P	1
6. Data Auditing		
7. Compatibility List	P	1
8. UI for backend	A	

UI/Frontend

1. What are the required outputs?

1. Flow rate vs time?	R	
2. Cumulative flow?	R	
3. System status?	P	
4. Aggregated outputs (see separate question)?		
5. Configuration info?	P/R	

2. QA/QC Procedures

1. Presence of QA/QC features in the UI?	P	2-3
2. Who does the QC?	P	
3. Eric had being able to revise the data as	P	3
4. Will there be a dispute resolution procedure?	A/P	1
5. Will there be a dispute resolution procedure?	A/P	1

3. Aggregated Outputs

4. Output formats

1. Graphical (for the humans)?	R	
2. File formats (CSV,	R	

XLSX, JSON, XML)?

3. Specific reports (Kaweah will need to specify report contents)? A

4. User defined templates (for arbitrary reports)? A

5. UI Platforms

1. Desktop application (Win, Mac, Linux)? A

2. Web/Desktop browser (Chrome, Safar, Opera, Firefox, Edge, others)? R

3. Web/Mobile? A

4. Mobile native app? P

6. ADA Compliance

7. Software Engineering issues

Frontend and Backend (Questions relevant to both)

1. Cost Structure
    1. Billing cycle
        i. Monthly, Annual? P
        ii. one-time fee? A/D
    2. Cost structure
        i. Per user? P/A
        ii. per meter? P/A
        iii. per use? D
    3. Who pays (grower, GSA, both)?
2. Hosting
    1. User host? D
    2. Vendor host? (their servers) A
    3. Cloud? (AWS, Azure, Google, etc) P
    4. Serverless? (desktop application) D
3. User Access (who uses the system)
    1. GSA staff? R
    2. Grower/Owner? R
    3. State of CA? D
    4. General Public? D
    5. Trusted 3rd Parties (e.g. other GSA, Fresno State, service providers)? R

4. User Provisioning
   1. Are there different groups of users and will they have different levels of access? R
      i. No Provisioning: anyone who logs in can see everything and edit everything (not recommended)? D
      ii. By User / per feature? P
      iii. User groups / per feature? P
      iv. Per meter? A
   2. Do User IDs correspond to individual people or organization? (e.g will all GSA staff use the same ID)
5. User Authentication
   1. OAuth2, OpenID, platform defined?
   2. Does GSA approve/disapprove creation of individual logins?
6. User Auditing
   1. Does the system keep track of P
      i. What did you see?
      ii. When did you log in?
      iii. What did you change?
7. Data Auditing
   1. Does the company perform any auditing of their system (especially security)? P 1
   2. Will they allow 3rd party audits? P 1
8. Security Auditing
   1. Do they do it or do you? P 1
   2. Is the audit done by 3rd party or internally? P 1
   3. Do they use any specific security standards?
   4. If a breach occurs, who is responsible for reporting it?

Appendix E: CIT Telemetry, Cloud and Data Platform Testing Report

Evaluation of Telemetry, Cloud and Data Platform Systems

Contents

Project Purpose

The goal of this project is to test and evaluate different types of (a) irrigation flow metering units, (b) data collection and transmission of flow metering data, and (c) data storage software and hardware systems used to distribute data for analysis and reporting referred to in this report as telemetry systems. This report is one deliverable of an overall contract administered by the California Water Institute (CWI), titled Kaweah Subbasin Groundwater Metering and Well Monitoring Pilot Program, and funded by the Greater Kaweah Groundwater Sustainability Agency (GSA), Mid-Kaweah GSA, and East

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May 7, 2021

Kaweah GSA (collectively referred to as Kaweah in this report). This overall contract included a needs assessment, physical testing of flow meters, evaluation of the telemetry systems, and evaluation of the impacts to meter accuracy resulting from non-standard meter installations.

This Evaluation of Telemetry Devices Report describes the various types of telemetry systems available for irrigation well metering and provides a recommended approach and specification for meter telemetry system implementation.

This report covers the evaluation of telemetry devices and associated software platforms. Water with telemetry units integrated as well as standalone telemetry units were requested from all known vendor. Ten (10) telemetry devices were evaluated at the Center for Irrigation Technology (CIT) Hydraulics Laboratory between February 1, 2021 and April 30, 2021. The vendor and model of each device is listed in Table 5. In one case, REDTrac, the vendor only provides software platform services. In order to be included in the evaluation they provided a third-party telemetry unit.

Table 5. List of evaluated telemetry devices

NUMBER	MANUFACTURER	MODEL
1	Ctek	Z4550
2	HotSpotAG	Controller
3	McCrometer	Telemetry Device
4	Ranch Systems	RS130
5	REDTrac	Software
6	Wildeye	Telemetry Unit
7	XiO	Cell Modem Controller
8	Bermad	Bermad Telemetry Unit
d9	In-Situ	AgriFlo XCI
10	Control Design	Control Design

Evaluation Criteria

The purpose of this evaluation was to verify that the participating telemetry systems would meet the requirements needed for working with different GSAs in their compliance with the Sustainable Groundwater Water Management Act (SGMA) and achievement of groundwater sustainability. Prior to performing these evaluations, CWI and CIT conducted a survey of 10 systems. This survey was based on a needs assessment conducted in collaboration with Kaweah regarding their telemetry system requirements. The resulting survey questions are provided in Appendix Y of this report. Evaluation units were requested from third party telemetry system vendors and from meter manufacturers who have integrated telemetry systems. The telemetry system vendors were sent the surveys prior to the CIT Hydraulics Laboratory receiving the devices and CWI followed up with the manufacturers via telephone interviews focused on the surveys. The survey was used to produce the ranking of the telemetry systems. Details of this survey and its results are in a separate report. Physical components (telemetry devices) and platform credentials (login info) were provided by both third-party telemetry system vendors and flow meter manufacturers whose meters include integrated telemetry systems.

To expedite the project, physical testing of flow meters was conducted prior to evaluation of the telemetry systems. Results of the physical testing is provided in a separate report. Evaluation of the telemetry systems was conducted only by CIT staff. A series of flow meters were installed in a loop pipeline in the CIT Hydraulics laboratory and water was pumped through the meters at flow rates approximating field conditions. Each telemetry system was connected to one of the meters. This arrangement enabled a data stream that should approximate normal operating conditions. For those telemetry systems that were fully integrated with the meter, the entire meter (and telemetry system) was installed in the pipeline loop.

For each system, CIT staff:

a) went through the process of setting up the system (i.e., physically attaching it to the meter) according to the vendor’s instructions,
b) went through the process of account setup and login,
c) pumped water through the series of flow meters for not less than 24 hours,
d) directly verified presence or absence features on the website or data access platform.

Verified Features

CIT staff verified the presence or absence of key features identified during the needs evaluation phase. These features are listed in Q1 through Q11 explained in the following paragraphs. These questions were also included in the survey described previously. The evaluation of each telemetry system based on the verification of these features using the Q1 through Q11 follows the explanation of the features. Wherever possible, screen shots were collected to document the verification process.

Q1 : Does it have cloud services?

Telemetry devices should be able to record and send data to a cloud/server storage. The evaluation team verified this service existed and data was able to be viewed and downloaded. This question was answered Yes if the platform relied on cloud storage for data transmitted by the telemetry system.

Q2 : Does it have API?

An important feature for many customers including the Kaweah is the ability to access data through an Application Programming Interface (API). The evaluation team confirmed and checked with manufacturers to ensure this feature was included in the devices.

Q3 : Does it protect stored data?

Most data logging systems have storage capacity. This question ensured that data is stored by the platform and the user has access to the data. Additionally, is the data maintained and backed up for a period. The question was answered Yes if the platform had secure login, or other password protected access. Backup functionality was verified by interviewing the technical representative of the manufacturer.

Q4 : Is there a backend UI?

In some instances, the user may have to access the raw data and/or have access to it using other devices. This was verified by directly asking the vendor. The question was answered Yes if the system had any type of "backend" interface that enabled more advanced interoperability or automation of the telemetry system.

Q5 : Can data be downloaded?

Many programs or applications allow the user to not only view and analyze data, but to also download data in useable format. This is important if the user wants to perform analysis or use the data for other purposes. This question was answered Yes if the telemetry system provided downloadable files in CSV, XLS, XLSX, TXT, or PDF format.

Q6 : Is there a public cost structure?

This question specifically asked if additional "add on" or "service extensions" were required to use the telemetry component of the overall metering system and if the cost of the services is publicly available describing the fee structure. The information was verified by directly asking the vendor. The question was answered Yes if the cost information was publicly available.

Q7 : Hosted online?

This question was used to determine if the user accessed the data via a web-based interface (i.e., a website or web application) that included a graphical user interface. It is important to note that some systems use cloud storage but do not always have a user interface that is cloud based; hence the need for both Q1 and Q7 to differentiate. This question was answered Yes if the user accessed the data via a web-based interface that included a graphical user interface.

Q8 : Does it limit user access?

User Provisioning, or other access management features, are essential to any multi-user system. To receive a Yes on this question, the system had to have some features that controlled or managed what the user could access on the site.

Q9 : Does the system maintain an audit trail of user activities?

Knowing who accessed what and when can be essential when reporting. This question was answered Yes if it was verified that the system had a log of user changes to system setup or logs of when the user logged in.

Qualitative Assessment

While all the information in questions 1-9 are important to users, it is also important to users that the device can be easily accessed, understood, and installed. CIT has over a decade of experience working with telemetry, data logging, and wireless technology. The technologies provided by the device manufacturers should be straightforward for the team to install. However, the purpose of this evaluation is to view each device objectively and from a new user's perspective. Therefore, a scale of 1 to 5 was utilized to accurately discern the ease-of-use and installation by the evaluators. The questions are rated on a scale of 1 to 5 with 1 being "easy" and 5 being "difficult."

Q10 Ease of use "Software"

Reported on a Likert scale of 1 - 5, where 1 is easy and 5 is difficult.

Q11 Ease of Installation "Hardware"

Reported on a Likert scale 1 - 5, where 1 is easy and 5 is difficult.

Terminology and Acronyms

Acronyms and terminology used in the evaluation of each telemetry system is explained in Table 2.

Table 6. Terminology and acronyms used in this report

TERM/ACRONYM	MEANING
API	Application Programming Interface, an interface which allows two different programs to talk to each other
application	A program or software utilized to view, retrieve and access collected data
cellular	The signals received by cell phone infrastructure to transmit data
cloud	Storage and applications accessed over the internet
CSV	Comma Separated Values, a text file delimited by comma to separate values (can usually be downloaded into a spreadsheet)
dashboard	A display of information and data. Usually the home page of a software program which displays basic information.

TERM/ACRONYM	MEANING
PDF	Portable Document Format
telemetry	The ability of a device to wirelessly transmit data across an electronic platform
UI	User Interface, an interface that allows a user and a computer system to interact, in particular the use of input devices and software
VPN	Virtual Private Network, a technology that allows users to create private connections over less private networks

Summary of Telemetry Device Evaluation

1. Ctek – Z4550 and SkyCloud Application

Hardware: The Ctek telemetry unit is roughly a 10-inch by 10-inch metal box (Figure 3). Installation was easy and required no modification or additional add-ons. The connection utilized small wires readily found at the local hardware store. The instructions were provided. The team had to calibrate the K Factor for the device to operate with the Seametrics flowmeter to which it was connected. Upon calibrating the K Factor, the device recorded correctly.

Software: The software is an online application called Ctek SkyCloud and was accessed via the web. The application consists of several menu options. The software was simple and allowed easy viewing of the data. Figure 4 is a screen shot of the web application. The application also displays a list of devices (Figure 6). The application provides periodic updates (every 15 minutes) and shows flow data live. The site allows the user to specify the data range in which the graph will display. The display shows total water use and flow rates. The dashboard data can be adjusted to display information in different cycles.

A VPN is required to access data stored by the telemetry device. Once the VPN is activated, the user can access the data. According to Ctek, there is an API that can be utilized by users. However, this feature requires additional security clearance and must be obtained from Ctek . Under the settings tab, additional assets can be added to the site location **(**Figure 7**)**. Device settings can be configured by the user and the naming conventions can be changed based on user preferences. The application allows for comma separated values (CSV) files to be downloaded.

Additional features such as geospatial location of the device can be programmed into the application. This feature gives the user a map view that can be zoomed in to view where the device is located. However, this feature does not provide a live view. If the location is entered incorrectly, it will show up incorrectly (Figure 5). Figure 5 is not the actual location of the device and is actually in the wrong location.

Pros: Access to the data can be done locally as well as through a web application. Installation did not require any additional cables or equipment. Has good customer service response.

Cons: Web application does not have many menu options. Requires a VPN to access data locally which is uncommon, most devices can be plugged in with USB to download the data

Table 7. Ctek evaluation scores

Criteria	Feature	Answer
Q1	Does it have cloud services?	Yes
Q2	Does it have API?	Yes
Q3	Does it protect stored data?	Yes
Q4	Is there a backend UI?	Yes
Q5	Can data be downloaded?	Yes
Q6	Is there a cost structure?	Yes
Q7	Hosted online?	Yes
Q8	Does it limit user access?	Yes
Q9	Does the system maintain an audit trail of user activities?	Yes
Q10	Ease of use "Software" (scale 1 - 5, where 1 is easy and 5 is difficult)	3
Q11	Ease of Installation “Hardware” (scale 1 - 5, where 1 is easy and 5 is difficult)	2

Figure 3. Photo of the Ctek tested device

Center for Irrigation Technology
California State University, Fresno
5370 N. Chestnut Ave. M/S OF 18 · Fresno, California 93740-8021
Phone: 559.278.2066 **Website:** www.fresnostate.edu/jcast/cit/

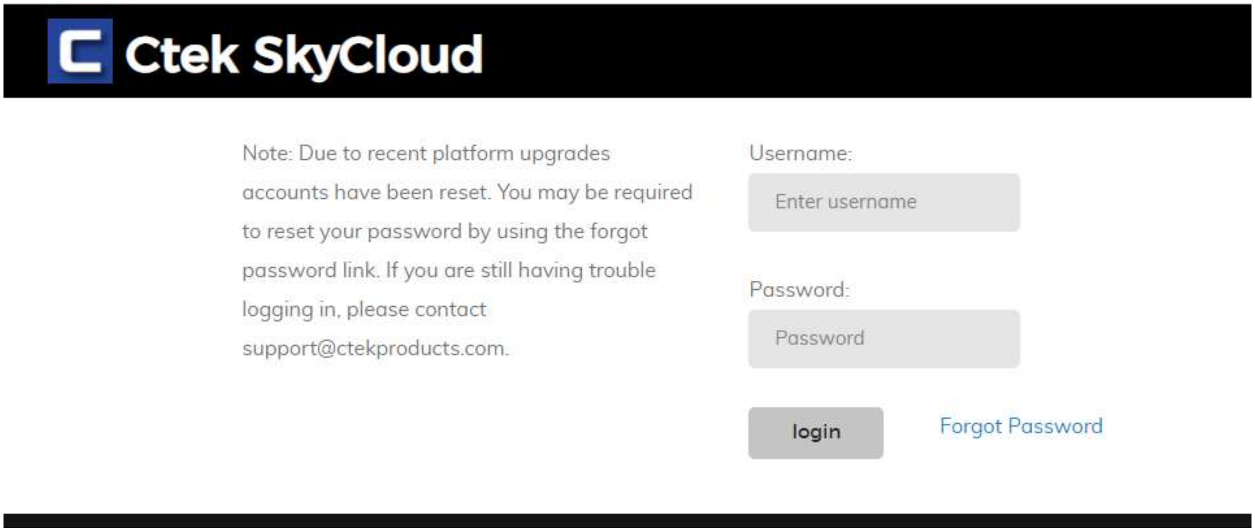

Figure 4. Image of Ctek SkyCloud login page (online application)

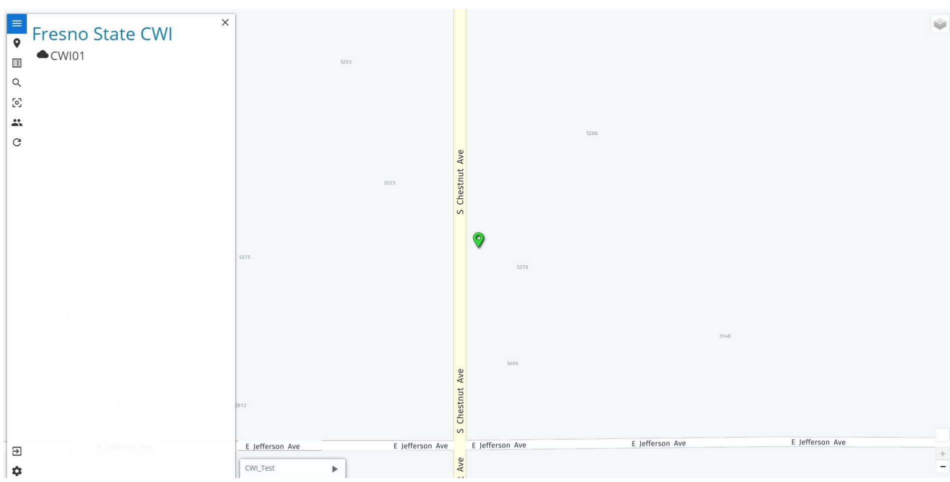

Figure 5. Ctek GPS location of device

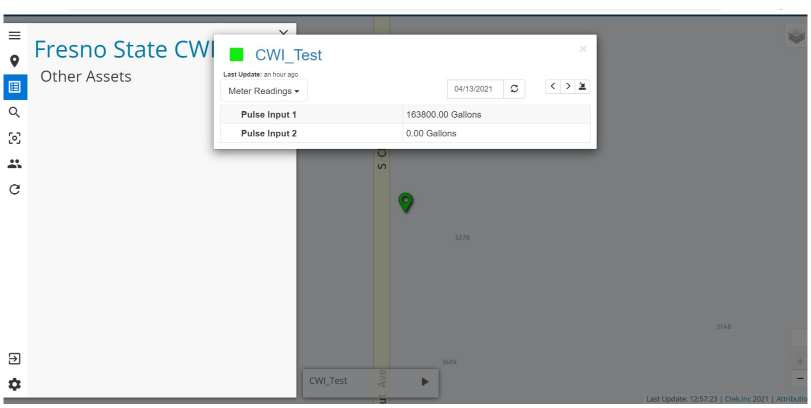

Figure 6. Ctek list of devices

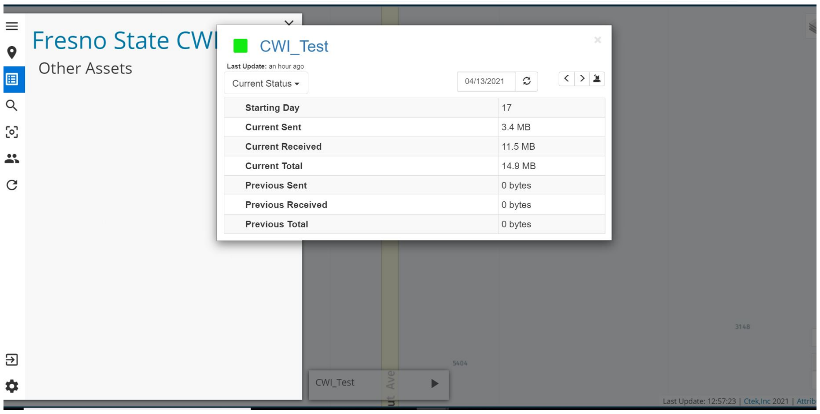

Figure 7. Ctek list of data size

2. Hotspot Ag

Hardware: The unit comes in two different configurations: 1) a solar panel and battery system unit and 2) hardwired to an electrical source. The unit hard wired to an electrical source was utilized in this evaluation (Figure 8). The unit has multiple ports to allow for different sensors and devices to be attached.

Software: Upon login, the dashboard displays the physical location of the device based on the address that is entered (in this demo the address was entered incorrectly) so the office location displays the incorrect building. The dashboard can be programmed to display output from different sensors such as salinity level, pH, nitrates to mention a few (Figure 9). The device utilizes a cellular signal. The application allows the user to identify its location via cellular signal, this takes you to the correct location of the device (Figure 10). This is a bit confusing as it shows two different locations.

The menu options allow the user to add and adjust the existing units of measurement. The units can be programmed by the user based on personal preferences. Additional sensors or devices can be added to the list on the dashboard. Each location can be assigned a specific grouping. The data is displayed via line graph (Figure 11). The dashboard allows the user to select different elements to display such as power, discharge rate, pressure, total volume, etc. The dashboard also displays different elements of the pump and other devices and can be programmed for other features. In this case, the dashboard displayed the discharge rate line graph **(Figure 12?)**. Users can download the graphs in different formats (Figure 13). The data is collected every 15 minutes and sent to the web application. The application allows users to determine the data range for viewing. The data can also be downloaded via a comma separated values (CSV) file and saved. An API exists and is available to the user. The API documentation is made available to the users upon request.

Pros: Device has many menu options. The device can handle multiple sensors and other data collection devices. Customer service is quick to respond.

Cons: Hardware may need be installed by manufacturer as it has multiple settings that need to be changed. Need better installation instructions. Customer service was very responsive.

Table 8. Hotspot Ag evaluation scores

Criteria	Feature	Answer
Q1	Does it have cloud services?	Yes
Q2	Does it have API?	Yes
Q3	Does it protect stored data?	Yes
Q4	Is there a backend UI?	Yes
Q5	Can data be downloaded?	Yes
Q6	Is there a cost structure?	Yes
Q7	Hosted online?	Yes
Q8	Does it limit user access?	Yes
Q9	Does the system maintain an audit trail of user activities?	Yes
Q10	Ease of use "Software" (scale 1 - 5, where 1 is easy and 5 is difficult)	2
Q11	Ease of Installation “Hardware” (scale 1 - 5, where 1 is easy and 5 is difficult)	2

Figure 8. Hotspot Ag unit

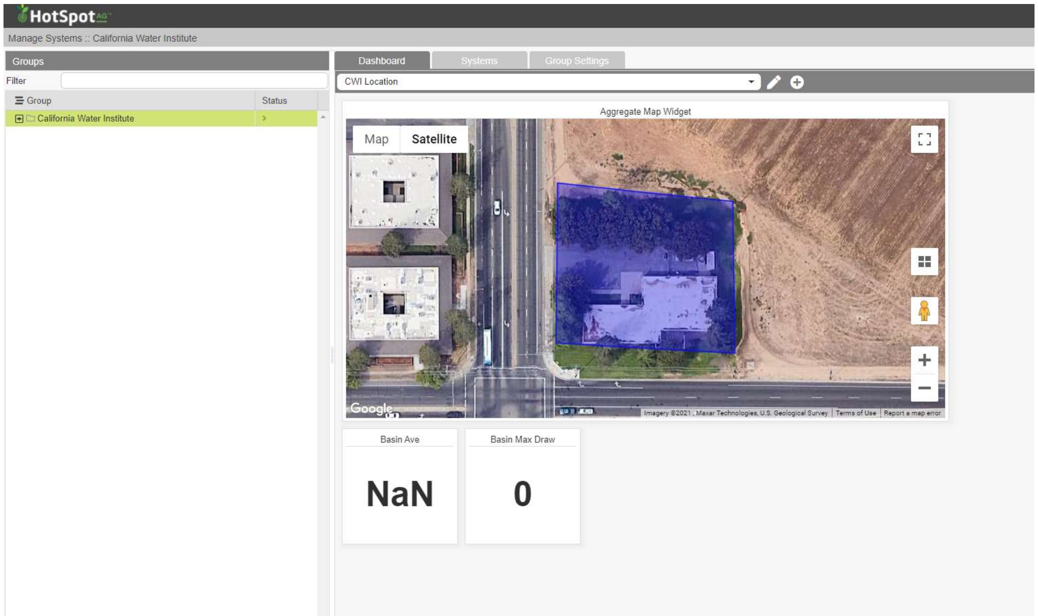

Figure 9. Dashboard for Hotspot Ag device

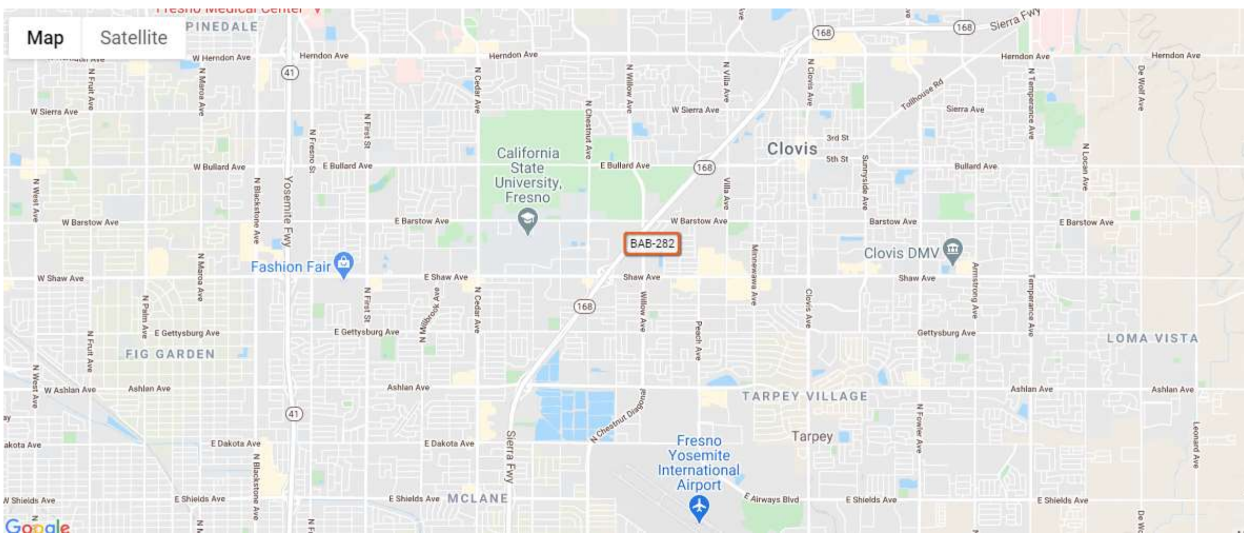

Figure 10. Real location of device based on cellular signal

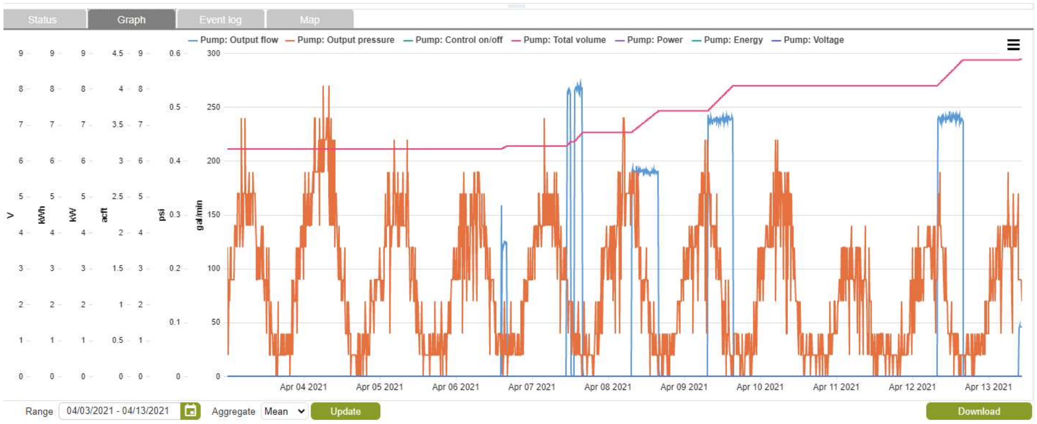

Figure 11. Graphs of different pump conditions

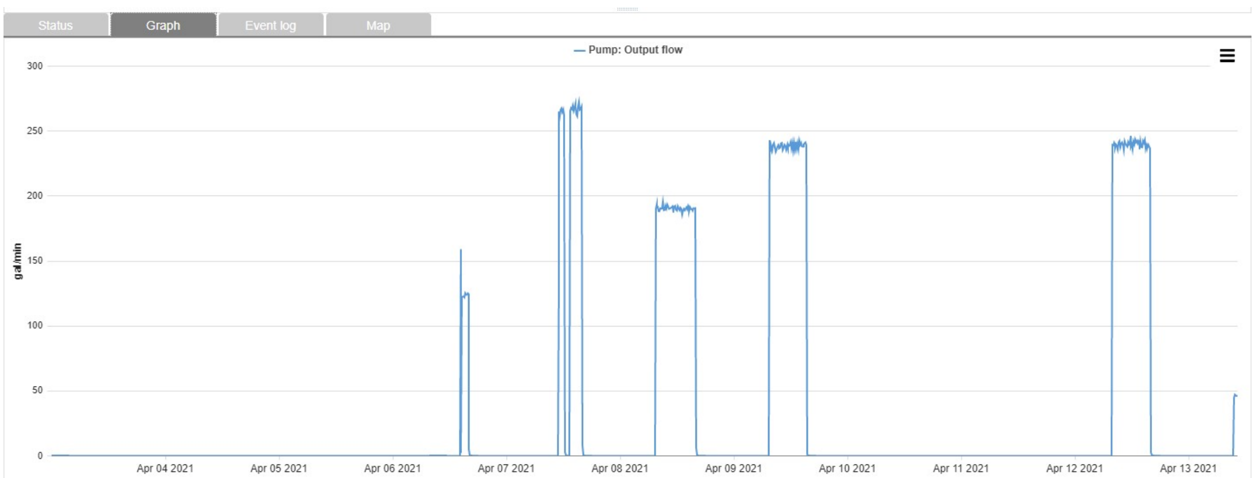

Figure 12. Flow output from the device

Figure 13. Graphs download feature

Status | Graph | Event log | Map

		Name	View	Value	Unit
☑	☐	Pump: Output flow	45.69	45.69	gal/min
☐	☐	Pump: Output pressure	0	0	psi
☐	☐	Pump: Control on/off		0	
☐	☐	Pump: Total volume	4.42	4.42	acft
☐	☐	Pump: Remaining runtime	0s	0	
☐	☐	Pump: Next run	-	0	
☐	☐	Pump: Next run duration	0s	0	
☐	☐	Pump: Power	0.0	0.0	kW
☐	☐	Pump: Energy	0.0	0.0	kWh
☐	☐	Pump: Voltage	0	0	V
☐	☐	Pump: Current	0	0	A
☐	☐	Pump: Energy MonthToDate	0	0	kWh
☐	☐	Pump: Efficiency MonthToDate	0.0	0.0	kWh/AcFt
☐	☐	Pump: Well depth	0.0	0.0	ft
☐	☐	Pump: Volt phase A	0.0	0.0	V
☐	☐	Pump: Volt phase B	0.0	0.0	V
☐	☐	Pump: Volt phase C	0.0	0.0	V

Figure 14. Status of the devices connected to telemetry

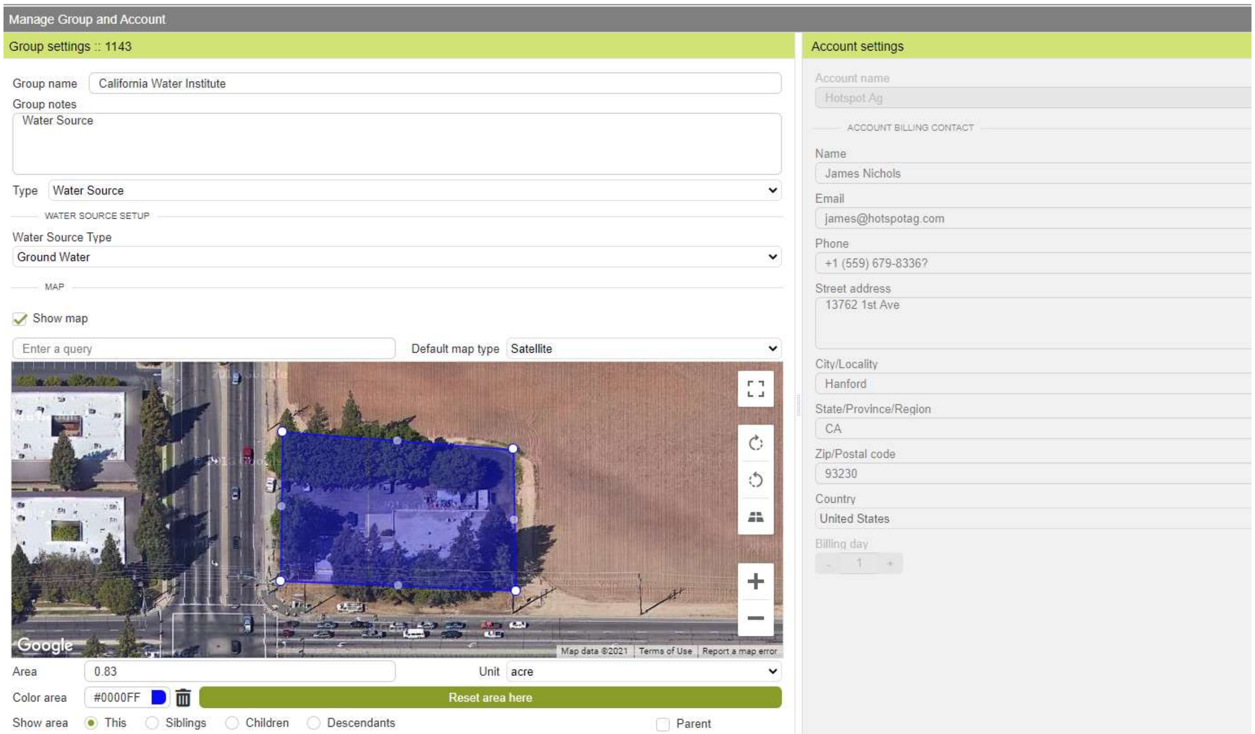

Figure 15. Address location of the device

3. McCrometer - FlowConnect

Hardware: The McCrometer M0308 FlowConnect telemetry device is a compact unit integrated with a McCrometer flowmeter (Figure 16). It comes fully wired and ready to use. Installation did not required any modification or additional add on. The instructions provided by the manufacture were easy to follow and only needed the battery to be activated. The cellular mechanism is fully enclosed and encapsulated in the readout unit of the flowmeter.

Software: The software is an online application called AdCon and was accessed via the web. The application consists of several menu options. The software allowed users to navigate the website and view the data. Figure 17 is a screen shot of the web application. The application provides updates every 15 minutes. The site allows the user to specify the data range for the graph display (Figure 18). The dashboard data can be adjusted to display information in different cycles (monthly, weekly, annually, daily).

The manufacturer states that there is an API available to users, however, this feature requires additional security clearance. Device settings can be configured by the user and the naming conventions can be changed based on user preferences. The application allows for comma separated values (CSV) files to be downloaded, emailed, or converted to pdf. Graphs can be saved as pdf, jpeg, or png files. The application creates a log of user activities and allows the administrative user tochange the settings as needed. The settings can allow different levels of user access.

Pros: The device is preinstalled and can be operated easily. Once devices are found on the website, access to the data was simple and the data could be downloaded.

Cons: Website has different menu options for the same device in the device library. Finding the correct device to view is hidden under different icons. For instance, FC-flow is located in multiple locations. This would take some training for users to get use to.

Table 9. McCrometer FlowConnect evaluation scores

Criteria	Feature	Answer
Q1	Does it have cloud services?	Yes
Q2	Does it have API?	Yes
Q3	Does it protect stored data?	Yes
Q4	Is there a backend UI?	Yes
Q5	Can data be downloaded?	Yes
Q6	Is there a cost structure?	Yes
Q7	Hosted online?	Yes
Q8	Does it limit user access?	Yes
Q9	Does the system maintain an audit trail of user activities?	Yes
Q10	Ease of use "Software" (scale 1 - 5, where 1 is easy and 5 is difficult)	2
Q11	Ease of Installation “Hardware” (scale 1 - 5, where 1 is easy and 5 is difficult)	1

Figure 16. McCrometer FlowConnect telemetry unit and flow meter

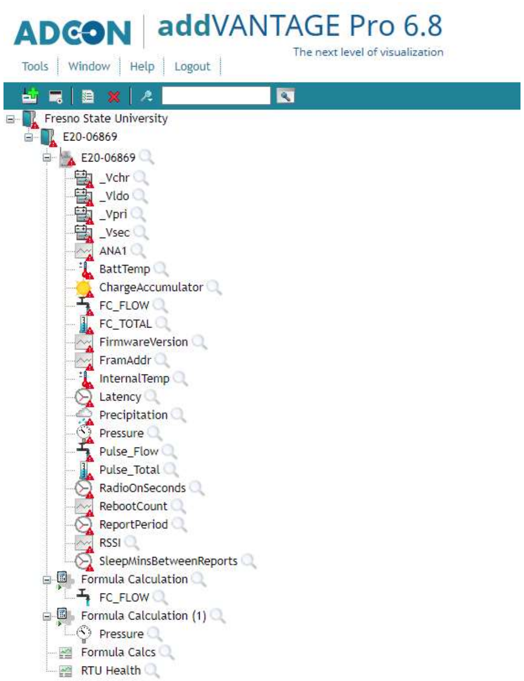

Figure 17. McCrometer AdCon software dashboard

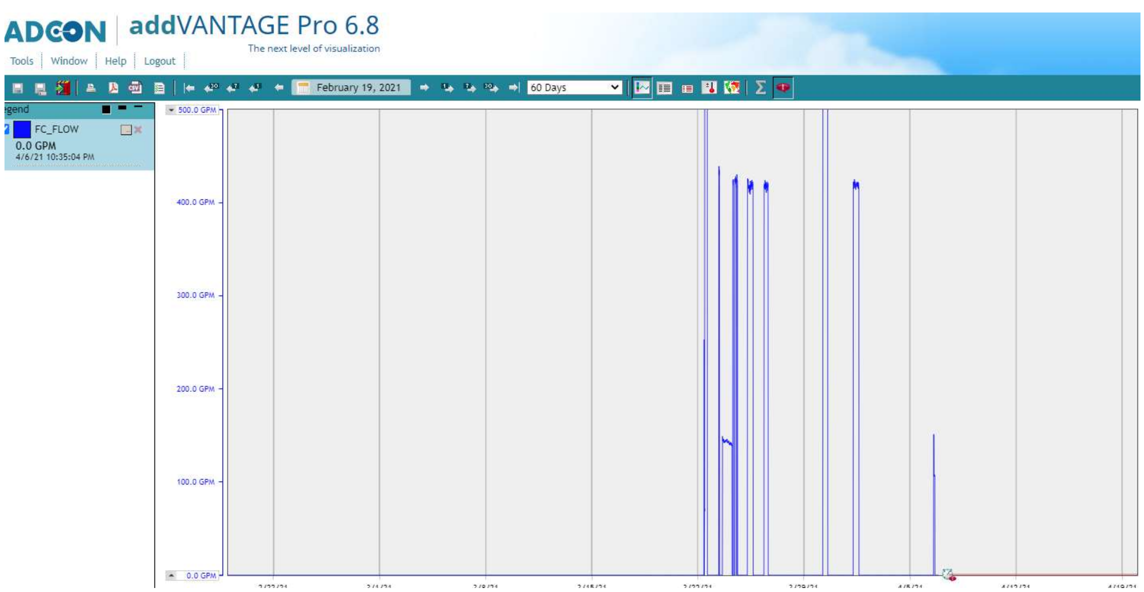

Figure 18. McCrometer AdCon graphing feature of the data

4. Ranch Systems RS130

Hardware: The Ranch System RS130 telemetry device is a compact cylindrical unit. It comes with solar power installed and utilizes a cellular signal to deliver the data to the cloud. Installation required the installation of a resistor to allow connection to the flowmeter. Once that issue was resolved, the installation instructions were easy to follow and only needed the battery to be activated. The cellular mechanism is fully enclosed and encapsulated in the unit of the device and the device has an LED readout (Figure 19). The system needs to be calibrated in order for the readings to be correct. The K Factor has to be calculated after the resistor is installed. The team worked with the Ranch System technician to change the K Factor. Once the K Factor is calibrated based on the settings on the flow meter the readings were correct.

Software: The software is an online application that was accessed via the web. The application consists of several menu options. Figure 20 is a screen shot of the web application. The application provides updates every 15 minutes. The site allows the user to specify the data range in which the graph will display. The dashboard data can be adjusted to display information in different cycles (monthly, weekly, daily).

The manufacturer states that there is an API and backdoor entrance that can be utilized by users, however, this feature requires additional security clearance. A side menu gives the user the ability to set properties, rules, and alerts. The user can define different zones. Device settings can be configured by the user and the naming conventions can be changed based on user preferences. The application allows for comma separated values (CSV) files to be downloaded. Graphs can be saved as pdf, jpeg or png files. The application has a log of user activities. The GPS location is live and identifies the location based on the cellular signal (Figure 21).

Pros: Customer service was good. Displays live data. Interactive graph display. Has ability to add cameras. Has a live geolocation of the device. Displays battery health **(Figure ?)**.

Cons: Website can be difficult to understand. Help documents require a separate login to access. Requires a resistor to make the unit connect. This would be difficult for growers; however, the device is meant to be installed by the vendor. Also required additional programming. K Factor needs to be calculated for accurate values.

Table 10. Ranch Systems RS130 evaluation scores

Criteria	Feature	Answer
Q1	Does it have cloud services?	Yes
Q2	Does it have API?	Yes
Q3	Does it protect stored data?	Yes
Q4	Is there a backend UI?	Yes
Q5	Can data be downloaded?	Yes
Q6	Is there a cost structure?	Yes

Q7	Hosted online?	Yes
Q8	Does it limit user access?	Yes
Q9	Does the system maintain an audit trail of user activities?	Yes
Q10	Ease of use "Software" (scale 1 - 5, where 1 is easy and 5 is difficult)	3
Q11	Ease of Installation "Hardware" (scale 1 - 5, where 1 is easy and 5 is difficult)	3

Figure 19. Ranch Systems unit with encapsulated solar and LED screen

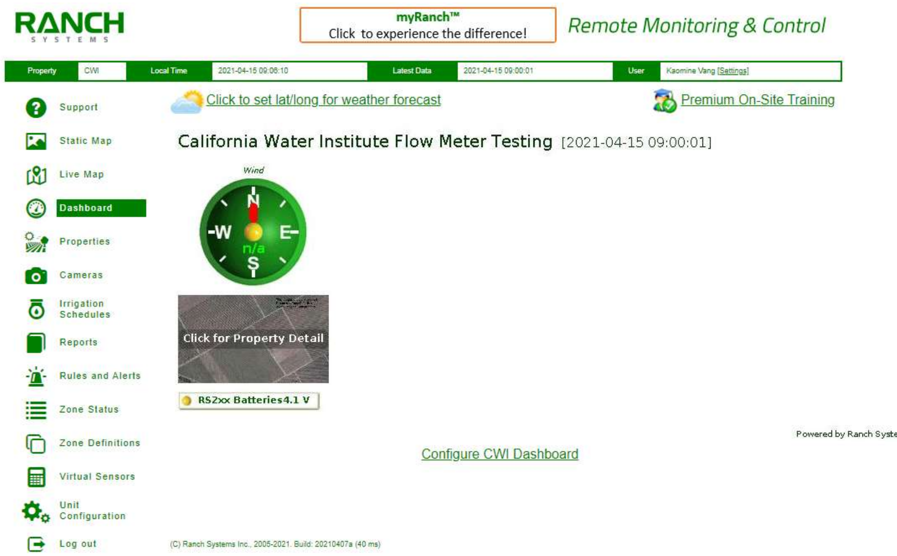

Figure 20. Dashboard of Ranch Systems

Figure 21. Ranch Systems live GPS location using cellular signal

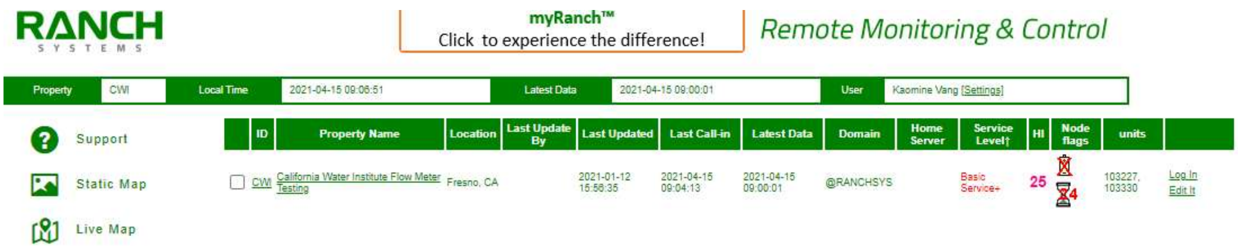

Figure 22. Ranch Systems List of devices

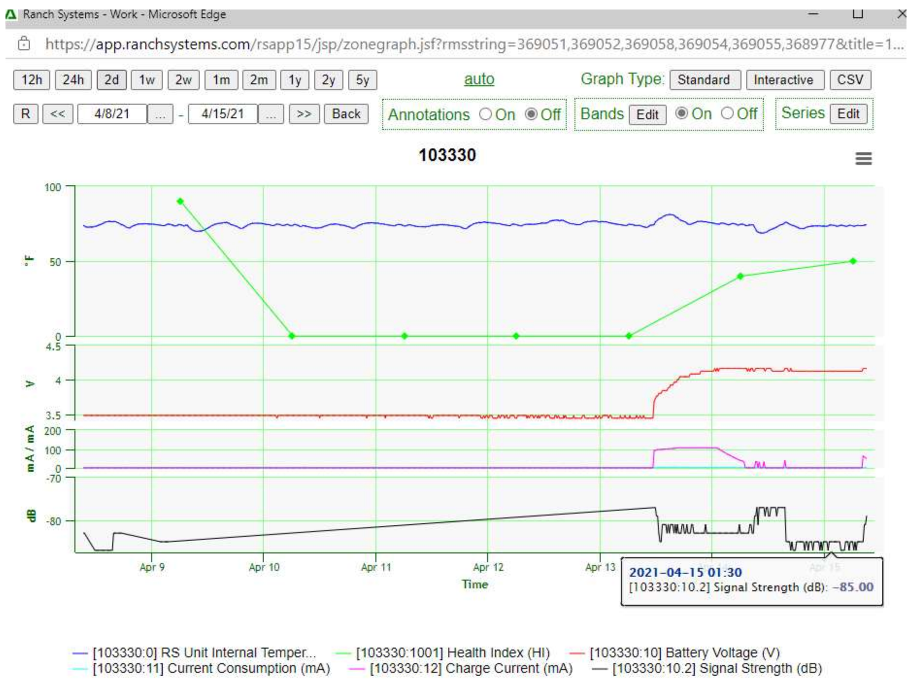

Figure 23. Ranch Systems readout of power and flow

5. REDTrac

Hardware: REDTrac is a vendor that only provides a third-party web-based application to monitor devices and sensors. They supplied a telemetry unit that they sell, but do not manufacture. The unit was battery powered and was contained in a small weatherproof plastic box (Figure 24), roughly 8 inches by 3 inches. This telemetry unit was connected to a flowmeter with pulse output utilizing two wires in this case the device was setup to take a pulse reading. Once device was correctly connected to the flowmeter the device read correctly. If device was not able to produce pulse readings a different cable may have been needed.

Software: The application is located online and consists of several menu options. Figure 25 is a screen shot of the web application. The application provides hourly updates and displays the data in speedometer format. Below the speedometer, the user can click on a data graphing display. The graph can be adjusted to demonstrate daily, weekly, and monthly values. The site allows the user to specify the data range in which the graph will display. The display shows monthly water use and flow rates. The dashboard data can be adjusted to display information in different cycles.

According to the vendor, an API is available to the users. This feature requires additional security clearance and must be negotiated with the vendor. Device settings can be configured by the user and the naming conventions can be changed based on user preferences. The application allows for comma separated values (CSV) files to be downloaded. The software has several other special options. It allows the user to view the location (Figure 26) of the device and irrigation scheduling, and predicted upcoming weather (Figure 27 and Figure 28).

Pros: Access to the data was simple and the application was easy to navigate. Installation was easy with only two cables. The REDTrac platform can add multiple devices to one cellular output. GPS location of the devices was accurate.

Cons: To add multiple devices, more than one box would be required. More instantaneous readings would be helpful.

Table 11. REDTrac evaluation scores

Criteria	Feature	Answer
Q1	Does it have cloud services?	Yes
Q2	Does it have API?	Yes
Q3	Does it protect stored data?	Yes
Q4	Is there a backend UI?	Yes
Q5	Can data be downloaded?	Yes
Q6	Is there a cost structure?	Yes
Q7	Hosted online?	Yes
Q8	Does it limit user access?	Yes
Q9	Does the system maintain an audit trail of user activities?	Yes
Q10	Ease of use "Software" (scale 1 - 5, where 1 is easy and 5 is difficult)	2
Q11	Ease of Installation “Hardware” (scale 1 - 5, where 1 is easy and 5 is difficult)	2

Figure 24. REDTrac telemetry device

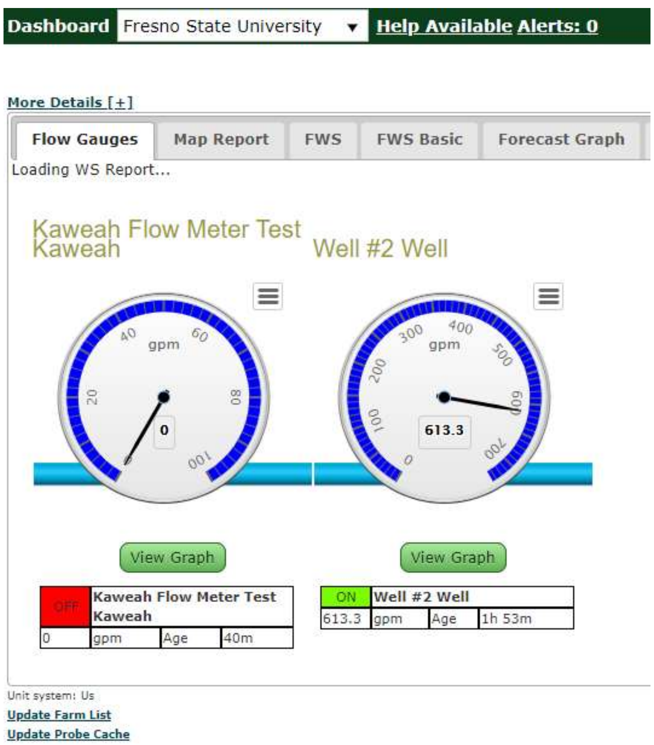

Figure 25. REDTrac dashboard – displays two sites located on the Fresno State property

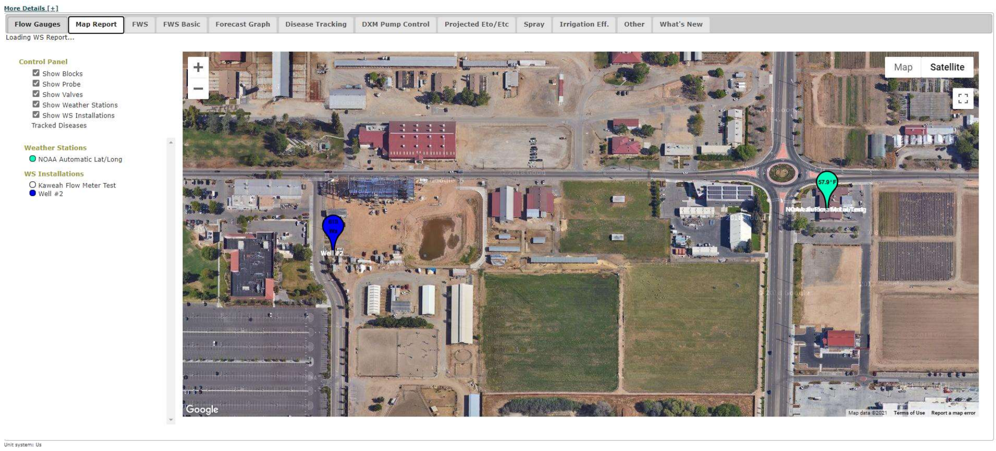

Figure 26. REDTrac GPS locations of the two sites on the Fresno State campus

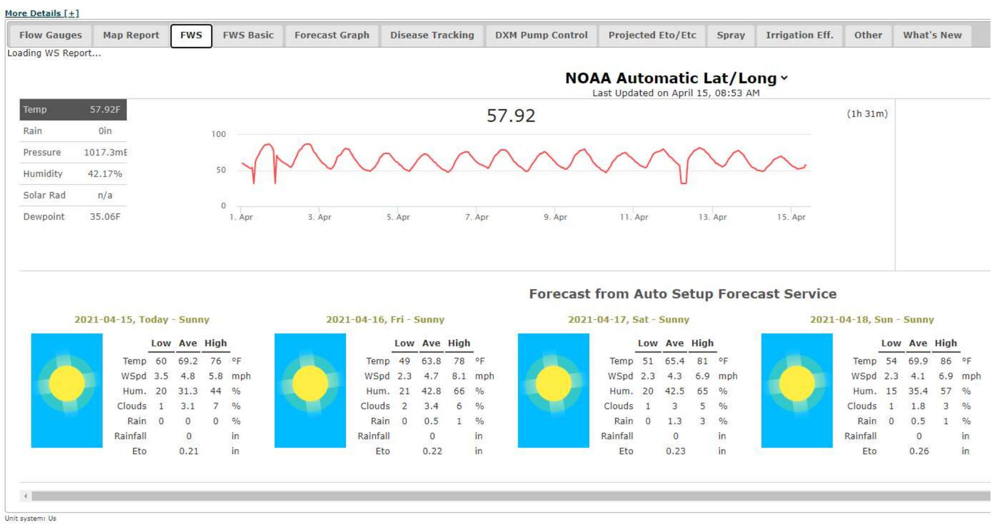

Figure 27. REDTrac Local weather data from the dashboard

Flow Gauges | Map Report | FWS | FWS Basic | Forecast Graph | Disease Tracking | DXM Pump Control | Projected Eto/Etc | Spray | Irrigation Eff. | Other | What's New

Loading WS Report...

Farm's Irrigation Efficiency

	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Thursday 2021-04-15											74	72	72	68	68	68	68	66	66	68	70	72	72	74
Friday 2021-04-16	76	78	78	78	78	78	78	78	78	78	74	72	70	68	68	66	66	66	66	66	70	72	72	74
Saturday 2021-04-17	74	78	78	78	78	78	78	78	78	78	74	72	70	68	68	66	66	64	66	68	68	70	72	74
Sunday 2021-04-18	74	74	78	78	78	78	78	78	76	74	72	68	68	66	64	64	64	64	64	64	68	68	70	72
Monday 2021-04-19	72	74	74	76	76	78	76	76	74	72	70	68	66	64	64	64	64	62	62	62	68	68	70	72
Tuesday 2021-04-20	74	74	76	78	78	78	78	78	76	76	74	70	68	66	66	66	64	62	64	66	70	70	74	74
Wednesday 2021-04-21	76	76	78	78	78	78	78	78	78	78	76	74	70	70	68	68	66	68	68	68	70	72	72	74
Thursday 2021-04-22	74	76	78	78	78	78	78	78	78	76	74	72	70	68	66	66	66	66	66	66	66	66	66	66
Friday 2021-04-23	66	66	66	66	66	66																		

Unit system: Us

Figure 28. REDTrac Irrigation efficiency based on calculations

6. Wildeye

Hardware: The Wildeye telemetry device is a compact unit roughly the size of an average touch screen cell phone (Figure 29). Installation was easy and required no modification or add on. The device was plug-and-play. The instructions were easy to follow and a video link on how to start up the device was included. The device came calibrated to operate with the Seametrics AG3000 flowmeter. The device came with a five-pin female plug with threading coupling which plugged directly to the flowmeter. If devices had different wiring, the device can be ordered with different wiring. The telemetry wiring would have to match the device.

Software: The software is an online application accessible via the web. The application consists of several menu options. The software was simple and allowed easy viewing of the data. Figure 30 is a screen shot of the web application. The application provides daily updates and shows the data in bar graph format. The graph can be adjusted to demonstrate daily, weekly, and monthly values (Figure 31 **32?**). The site allows the user to specify the data range in which the graph will display. In this case, the display shows monthly water use and flow rates (Figure 32 and Figure 33). Figure 34 shows graph download options and Figure 35 shows the ability to add additional nodes. The dashboard data can be adjusted to display information in different cycles. For this demonstration, the cycle was every 24 hours.

According to the vendor, there is an API that can be accessed by users. This feature requires additional security clearance that must be negotiated with the vendor. Device settings can be configured by the user and the naming conventions can be changed based on user preferences. The application allows for comma separated values (CSV) files to be downloaded, emailed or converted to pdf. Graphs can be saved as pdf, jpeg or png files.

Pros: The device is a plug-and-play device and can be operated easily. Access to the data was simple and the application was easy to navigate.

Cons: The website can be difficult to understand as bar graphs expand over several days and only display totals. Limited to one device per unit. If installation does not use five (5) pin cable, the user would have to rewire the unit.

Table 12. Wildeye evaluation scores

Criteria	Feature	Answer
Q1	Does it have cloud services?	Yes
Q2	Does it have API?	Yes
Q3	Does it protect stored data?	Yes
Q4	Is there a backend UI?	Yes
Q5	Can data be downloaded?	Yes
Q6	Is there a cost structure?	Yes
Q7	Hosted online?	Yes
Q8	Does it limit user access?	Yes

Criteria	Feature	Answer
Q9	Does the system maintain an audit trail of user activities?	Yes
Q10	Ease of use "Software" (scale 1 - 5, where 1 is easy and 5 is difficult)	2
Q11	Ease of Installation “Hardware” (scale 1 - 5, where 1 is easy and 5 is difficult)	1

Figure 29. Wildeye telemetry unit

Figure 30. Wildeye dashboard sites list

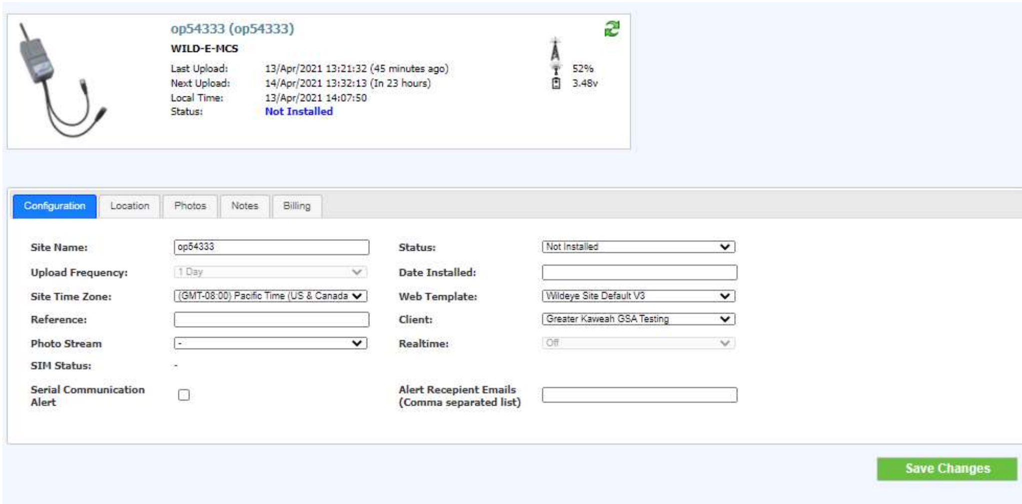

Figure 31. Wildeye dashboard configuration page

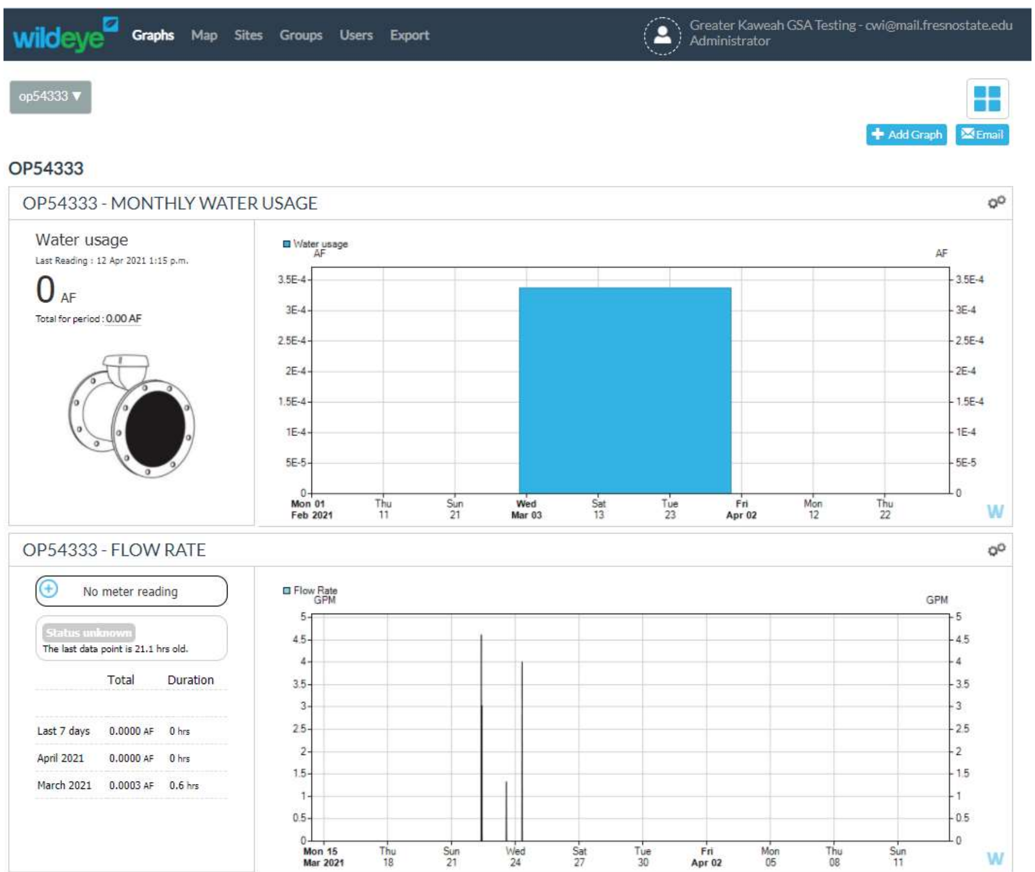

Figure 32. Wildeye dashboard flow and water usage totals

Figure 33. Wildeye monthly water use totals

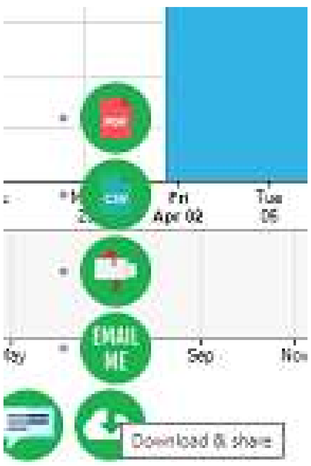

Figure 34. Wildeye graph download options

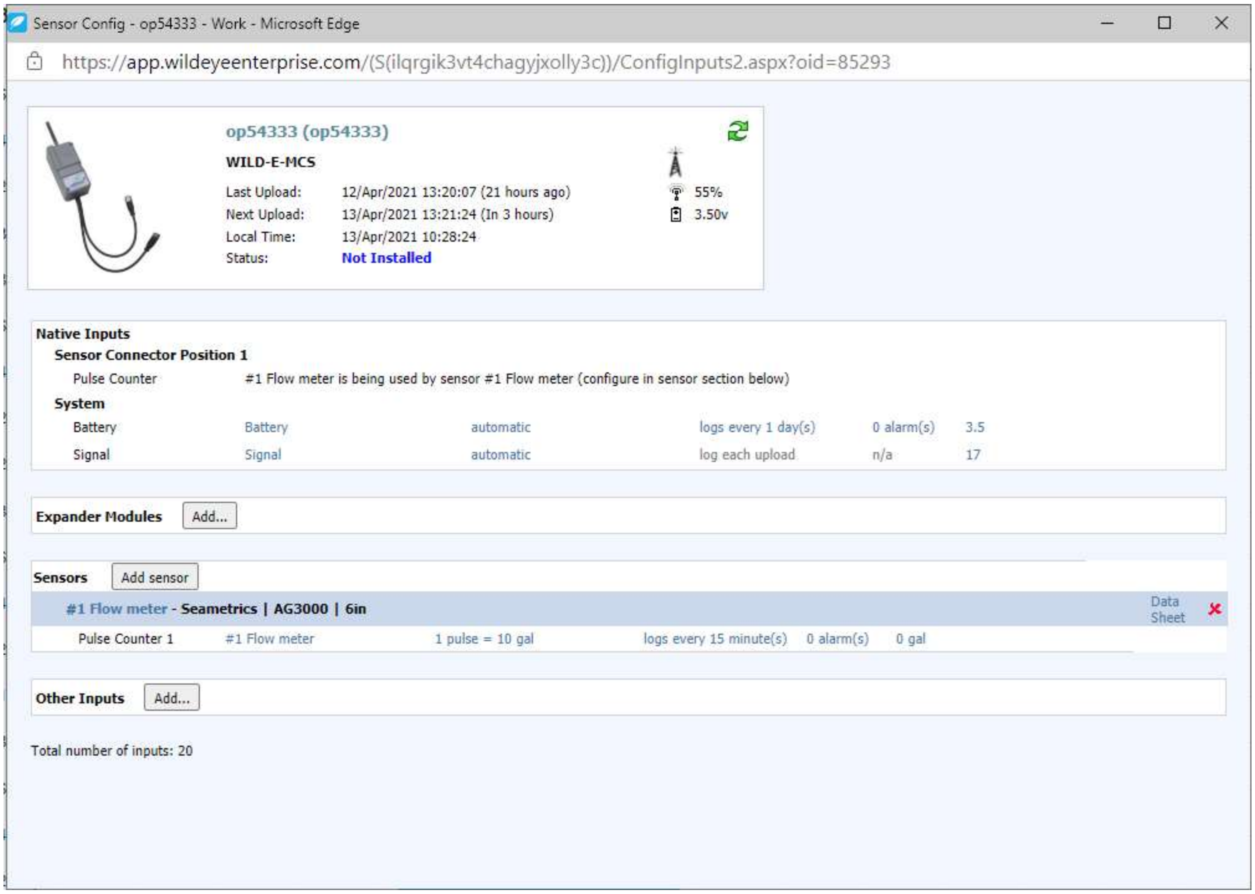

Figure 35. Wildeye configuration page allows for adding more nodes

7. XiO

Hardware: The XiO is a self-contained battery powered unit with the telemetry unit installed into a small box (Figure 36) that is connected to a data logger box (Figure 37). Both units are hard wired to an electrical outlet.

Software: The application is located online and is accessed through the web. The application consists of several menu options. Figure 38 is a screen shot of the web application home page. The application provides hourly updates. The site allows the user to specify the data range in which the graph will display. The first menu gives the user a summary of the device or sensor status (Figure 39). Several display options allow the user to view data for monthly water use and flow rates (Figure 40, Figure 41, and Figure 42). The dashboard data can be adjusted to display information in different monthly cycles.

According to the manufacturer, there is an API that is available to the users. The application allows for comma separated values (CSV) files to be downloaded.

Pros: Access to the data was simple and the application was easy to navigate. Installation was easy with only two cables. Can add multiple devices to the units.

Cons: Has multiple boxes for the device to work. Wiring the box can be complicated as the instructions are not clear. Wiring setup is specific to different loggers and the data logger box is setup for specific flowmeter devices.

Table 13. XiO evaluation scores

Criteria	Feature	Answer
Q1	Does it have cloud services?	Yes
Q2	Does it have API?	Yes
Q3	Does it protect stored data?	Yes
Q4	Is there a backend UI?	Yes
Q5	Can data be downloaded?	Yes
Q6	Is there a cost structure?	Yes
Q7	Hosted online?	Yes
Q8	Does it limit user access?	Yes
Q9	Does the system maintain an audit trail of user activities?	Yes
Q10	Ease of use "Software" (scale 1 - 5, where 1 is easy and 5 is difficult)	2
Q11	Ease of Installation “Hardware” (scale 1 - 5, where 1 is easy and 5 is difficult)	2

Figure 36. XiO self-contained battery-powered unit with telemetry unit installed

Figure 37. XiO secondary box containing cellular unit

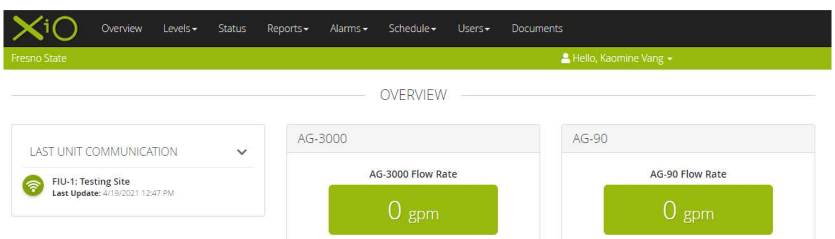

Figure 38. XiO live view of the flow

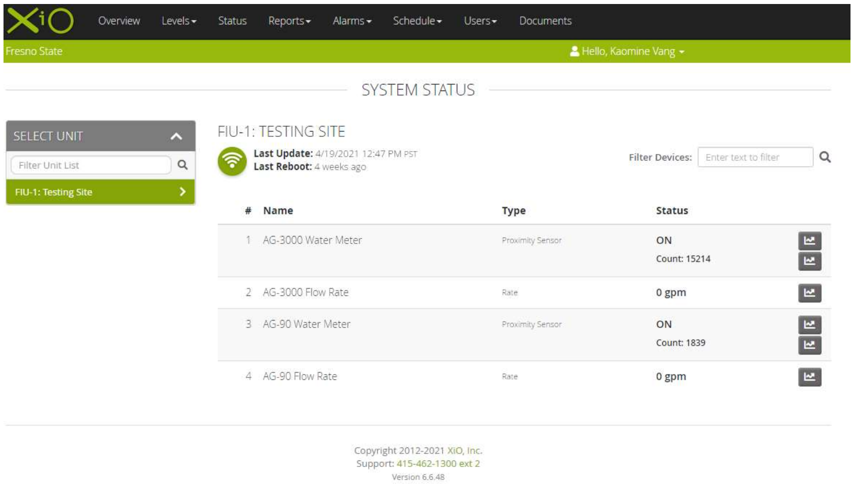

Figure 39. XiO system overview

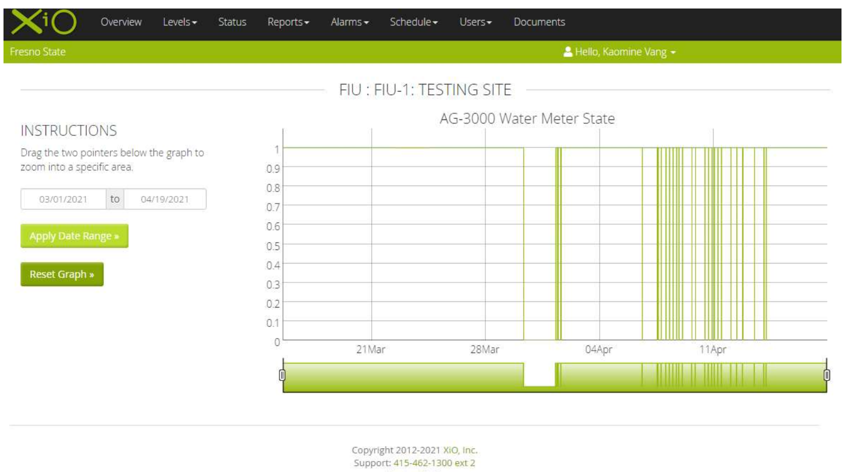

Figure 40. XiO graph of water use at site

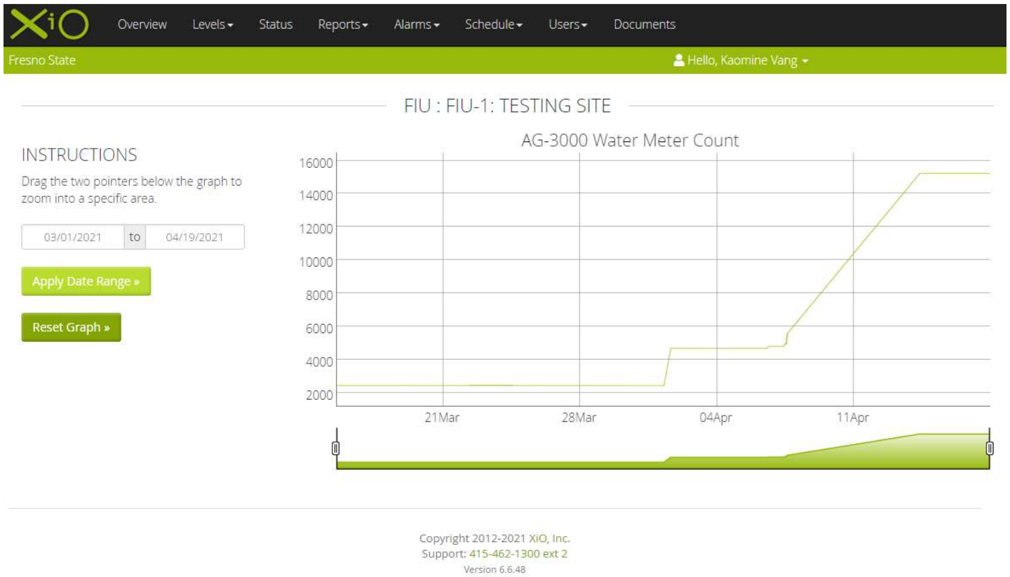

Figure 41. XiO water meter count

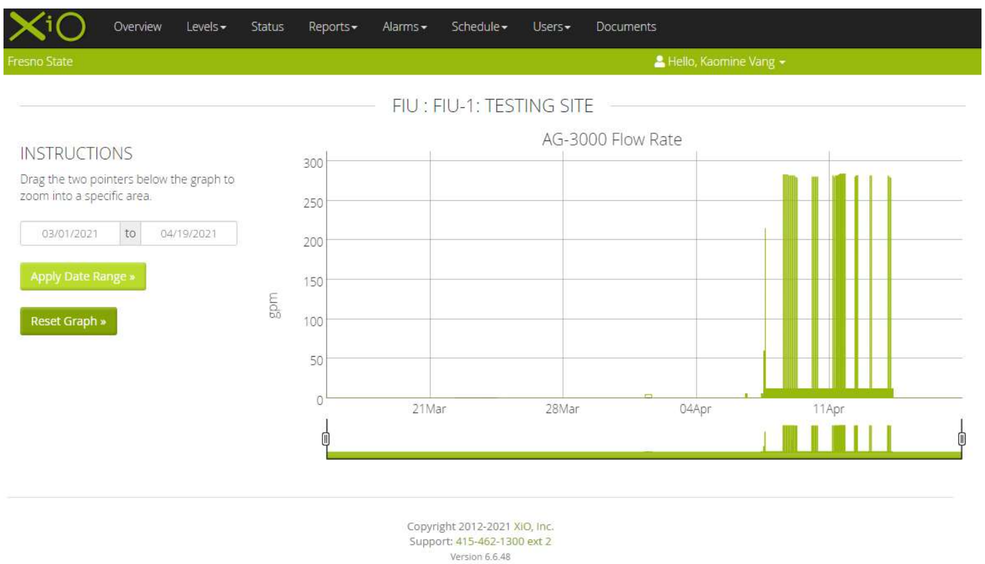

Figure 42. XiO daily flow rate

8. Bermad – Model MUT2200EL

Hardware: The Bermad telemetry unit consists of three separate units. The flow sensor is integrated with the Bermad flowmeter as depicted in Figure 43. The telemetry system was requires two external units, one unit contains the data logging electronics and the second contains the cellular transmission electronics (Figure 44). The unit as tested was battery powered. Bermad offers the option for a solar power add on. Installation was easy and required no modifications or add-ons. The installation instructions were clear and easy to follow.

Software: The application is downloaded and installed on a local device. It consists of several menu options. Figure 46 is a screen shot of the application. The data can also be accessed via the web, however, the web site was not used in this test. Figure 45, shows the desktop icon to the application. The desktop application provides daily updates and shows the data in bar graph format The graph can be adjusted to demonstrate daily, weekly, and monthly values. The site allows the user to specify the data range in which the graph will display. The display shows monthly, daily or weekly water use totals in acre feet or total gallons. The dashboard data can be adjusted to display information in different cycles (Figure 46). For this demonstration, the cycle was every 24 hours. Additional features of the application include queries and analysis feature, display of the total water volume as measured by the flowmeter (Figure 48), list of devices (Figure 49), data download (Figure 50), and adding new systems under the configuration menu (Figure 51).

According to the manufacturer, there is an API available to users. This feature requires additional security clearance and permissions provided by the manufacturer. Device settings can be configured by the user and the naming conventions can be changed based on user preferences. The application allows for the download of comma separated values (CSV) data files.

Pros: Access to the data was simple and the application was easy to navigate. Installation was easy as the telemetry unit was prewired into the Bermad flowmeter. Multiple devices can be added to one cellular output.

Cons: Website can be difficult to understand. Many terms used by the web application do not correspond to terminology generally utilized in agriculture. Data does not appear to be real-time and only displays acre feet or total volume pumped.

Table 14. Bermad evaluation scores

Criteria	**Feature**	**Answer**
Q1	Does it have cloud services?	Yes
Q2	Does it have API?	Yes
Q3	Does it protect stored data?	Yes
Q4	Is there a backend UI?	Yes
Q5	Can data be downloaded?	Yes
Q6	Is there a cost structure?	Yes
Q7	Hosted online?	Yes
Q8	Does it limit user access?	Yes
Q9	Does the system maintain an audit trail of user activities?	Yes
Q10	Ease of use "Software" (scale 1 - 5, where 1 is easy and 5 is difficult)	3
Q11	Ease of Installation “Hardware” (scale 1 - 5, where 1 is easy and 5 is difficult)	2

Figure 43. Bermad Model MUT2200EL flowmeter with telemetry

Figure 44. Bermad telemetry datalogger and cellular unit

Figure 45. Bermad desktop application

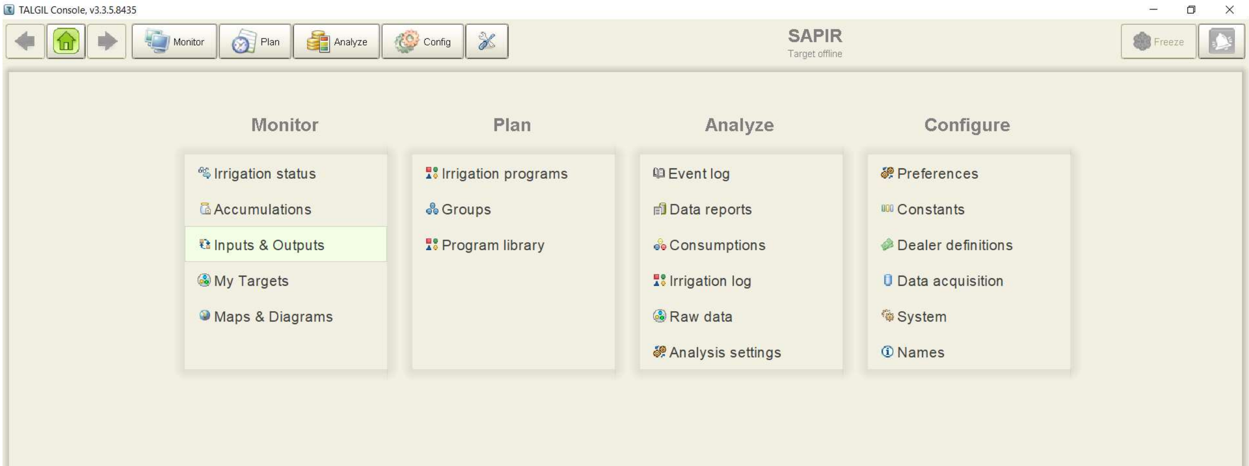

Figure 46. Bermad dashboard

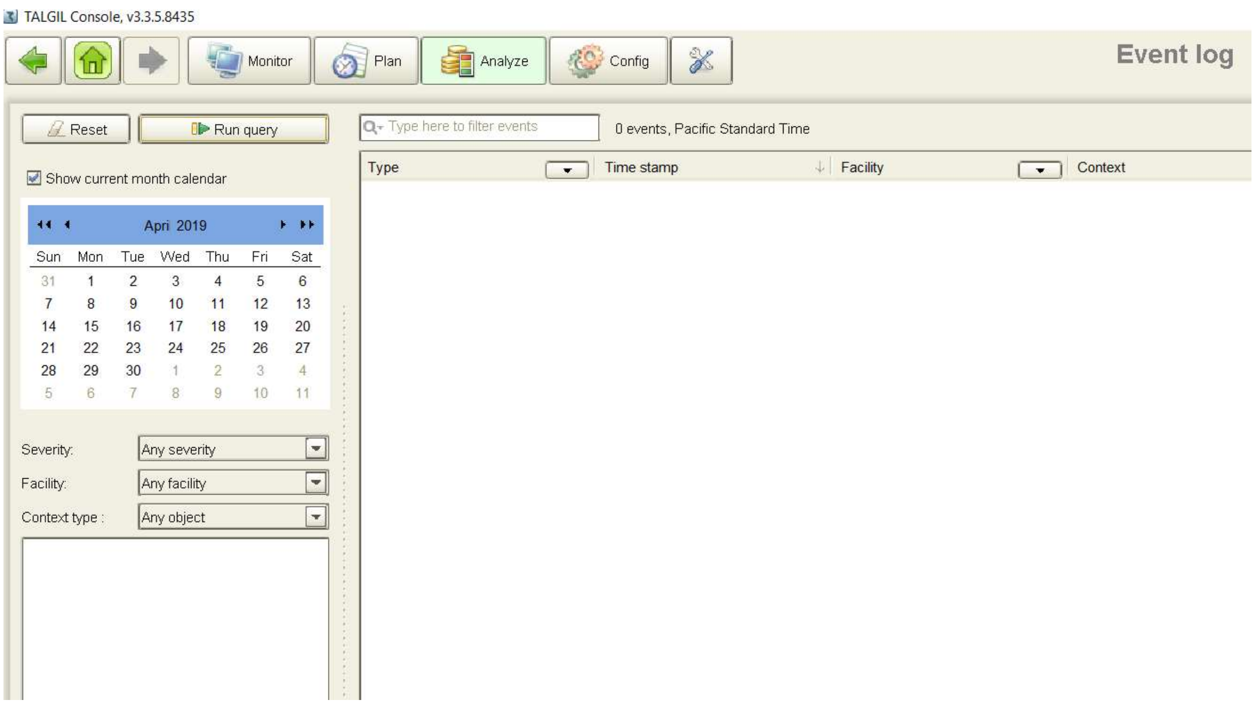

Figure 47. Bermad can run queries and analyze data

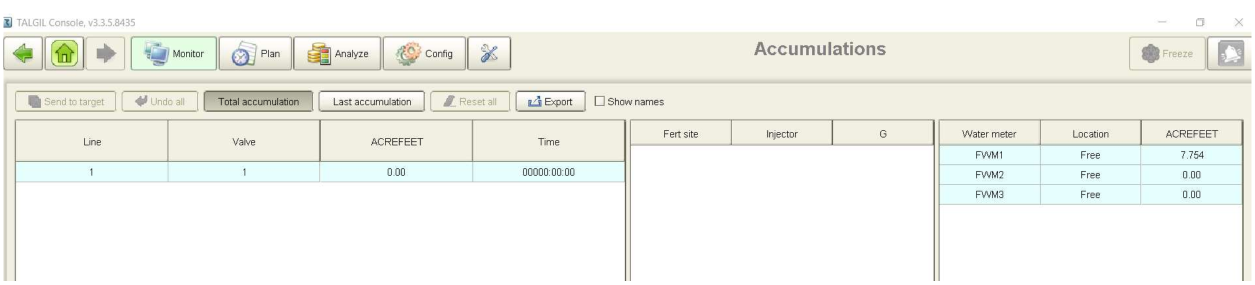

Figure 48. Bermad displays total water from the flowmeter

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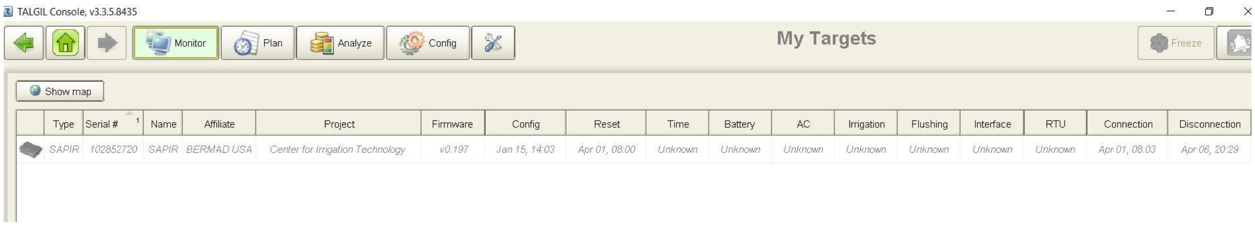

Figure 49. Bermad list of devices

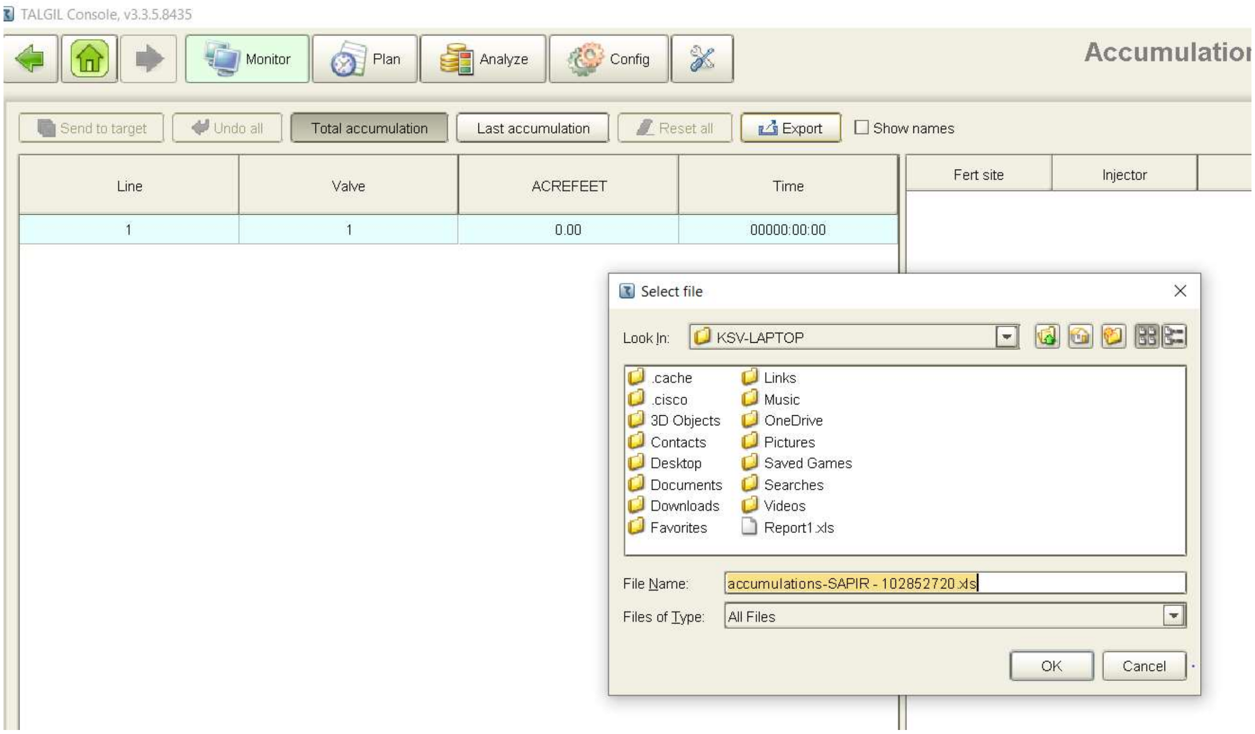

Figure 50. Bermad can download data

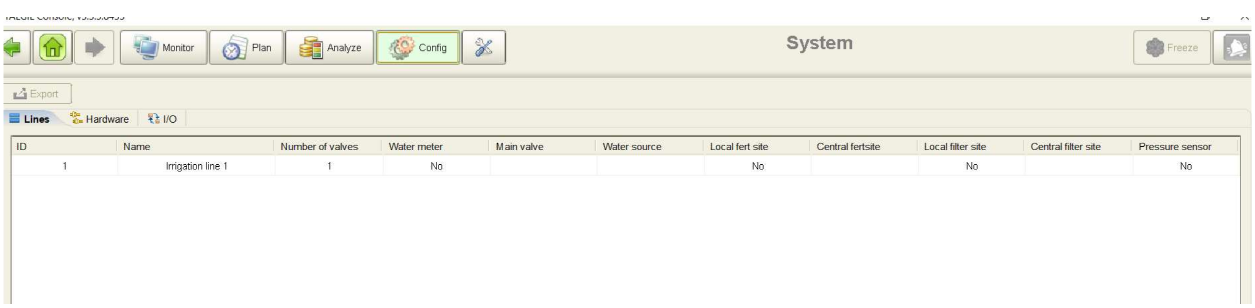

Figure 51. Bermad new systems can be added under the configuration menu

9. In Situ – AgriFlo XCi

Hardware: The telemetry device is an external unit that is paired with the In Situ insertion meter. The device came in a custom container (Figure 52. In Situ device). The device has a display which allows the user to view the status of the device (Figure 53). Figure 54 depicts the In Situ flow meter to which the AgriFlow XCi telemetry unit was paired.

Software: The application was downloaded and installed on a local device. The application accessed the data over the web. It provides the user with several menu options. Figure 55 is a screen shot of the application. The desktop application provides daily updates and shows the data only in a csv file (**Figure 54?**). The software allows users to view any sensor installed with the unit. The application allows the user to configure the device and download the data.

According to the vendor, there is an API available to users. However, this feature requires additional security clearance. Device settings can be configured by the user and the naming conventions can be changed based on user preferences. The application allows the download of the data using comma separated values (CSV) files.

Pros: Access to the data was simple and the application was easy to navigate. Multiple devices can be added to one unit.

Cons: Wiring the device can be difficult as instructions were not clear. The team was provided with an insertion meter, however, the insertion meter did not provide accurate data based on the wiring schematic provided. The team was asked to contact the meter manufacturer of the insertion meter. There is no graphing feature on the application. Data was in CSV form.

Table 15. In Situ evaluation scores

Criteria	Feature	Answer
Q1	Does it have cloud services?	Yes
Q2	Does it have API?	Yes
Q3	Does it protect stored data?	Yes
Q4	Is there a backend UI?	Yes
Q5	Can data be downloaded?	Yes
Q6	Is there a cost structure?	Yes
Q7	Hosted online?	Yes
Q8	Does it limit user access?	Yes
Q9	Does the system maintain an audit trail of user activities?	Yes
Q10	Ease of use "Software" (scale 1 - 5, where 1 is easy and 5 is difficult)	3
Q11	Ease of Installation “Hardware” (scale 1 - 5, where 1 is easy and 5 is difficult)	4

Figure 52. In Situ device

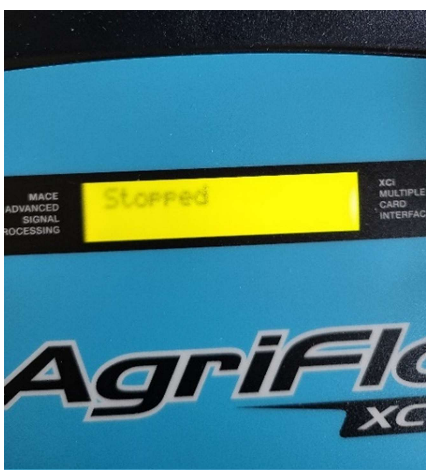

Figure 53. In Situ display on the In Situ telemetry unit

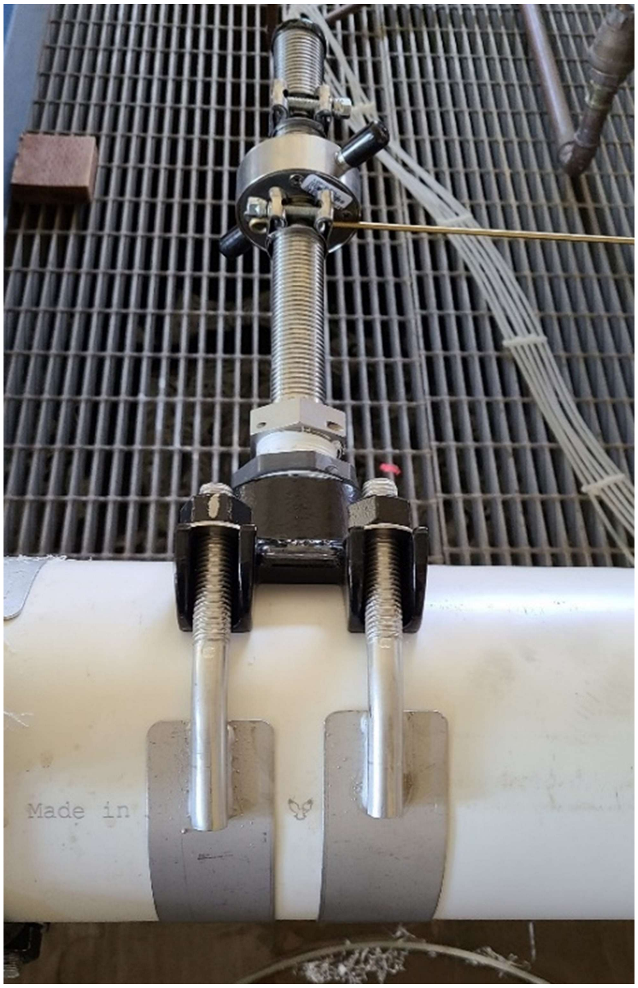

Figure 54. In Situ insertion meter provided by manufacturer

Figure 55. Screen shot of In Situ application

10. Control Design Telemetry Unit

Will be evaluated later and reported in an addendum.

Summary:

A total of ten (10) different manufactured units were evaluated. The tests and evaluations were all performed in the CIT Hydraulics Laboratory to provide a controlled environment. An outdoor installation may inhibit, or in some cases, assist the devices. For example, some of the devices utilize solar-powered accessories to charge their batteries. For these devices, an outdoor location would allow the batteries to maintain a consistent charge. However, other variables would affect them, such as dust, animals, and vandalism.

The telemetry devices and data platforms tested and evaluated in this process produced reasonable results in that they collected pulse or analog output from the meters, stored that data, and transmitted it to the cloud where it was accessed by a vendor provided application that displayed the data for the user. We observed that each manufacturer put a great deal of thought and work into their telemetry device and data platform. In all cases, the installation of the application and connection to the web data portal was not difficult. In some cases, the applications were less intuitive, and therefore took more time to become familiar with the features. In all cases, the vendors provided API access to the data after establishing permissions to access the data and security protocols. The ease with which the security protocols could be established with the vendors was not evaluated. Each vendor provided the ability to download the data using the CSV format. The two things that differentiated the telemetry devices was the ease with which they were installed. The integrated units were the easiest to install. Some of the third-party telemetry devices required special cables or specific resister to pair with a particular meter. This would make it difficult for the average user to install and implement the telemetry device. The second was the compact nature of the telemetry devices. One set of devices were very compact, requiring little space and only one "box". Others required multiple boxes and required a large footprint for their installation, in some cases a board or post on which to hang them.

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