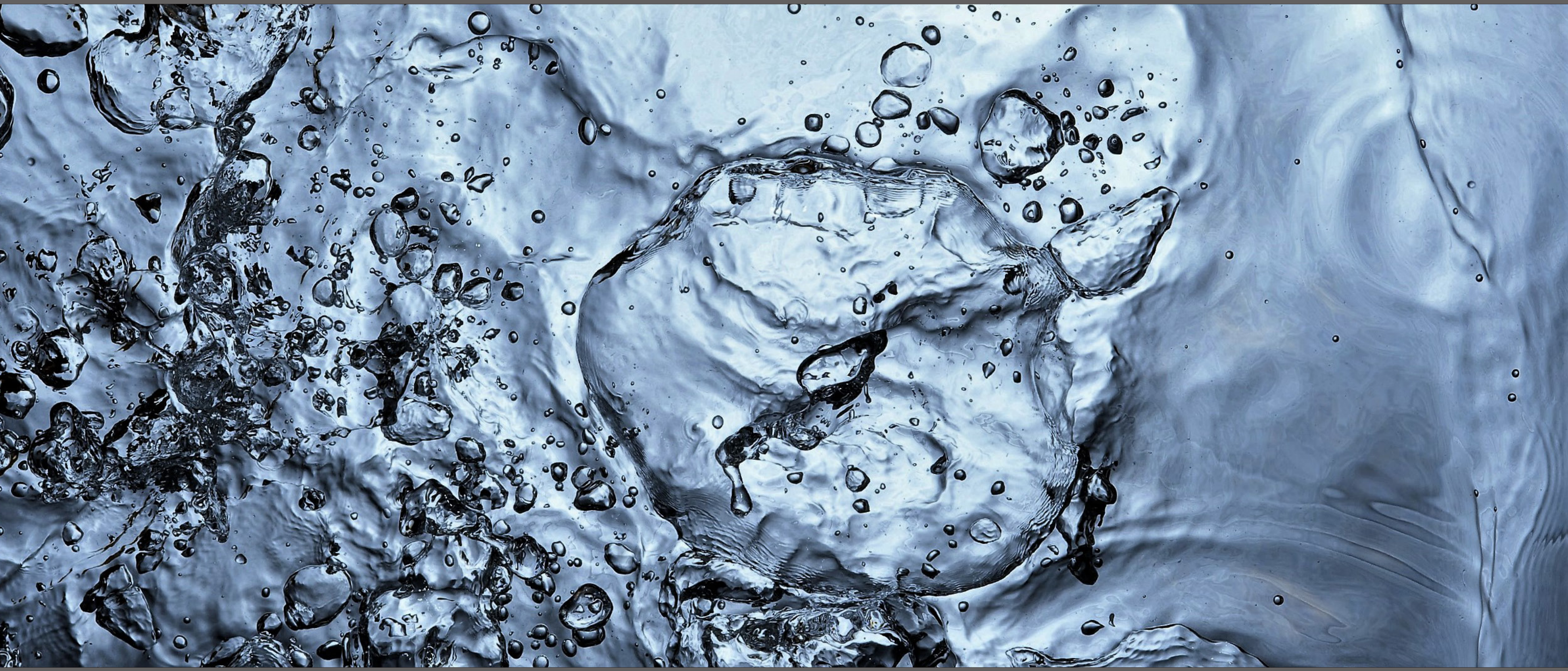
Metering Equipment Alternatives and Analysis



April 2017

DRINKING WATER

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METERING EQUIPMENT ALTERNATIVES AND ANALYSIS

April 2017

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EXECUTIVE SUMMARY

INTRODUCTION

A 2014 legislative audit found that the water system minimum sizing requirements (hereafter "requirements") of R309-510-7 lack supporting data and recommended that the requirements be reevaluated. The Division of Drinking Water considers existing water metering as one limitation to understanding the complex water use occurring in Utah. Through a financial assistance program, the Division would like to encourage water suppliers to adopt enhanced water metering technologies to collect the data needed to update the requirements. The purpose of this report is to identify the data needed to update the requirements and then identify metering equipment capable of generating the required data.

FINDINGS AND RECOMMENDATIONS

Water Use

- Conventional meters with monthly reads do not adequately describe the complex nature of water use needed to inform water system planning, design, and operation. Enhanced metering features are recommended to capture more detailed water use characteristics such as average yearly, peak day, and peak instantaneous demands.
- Water systems must produce more water than the actual demand in order to make up for losses between production and delivery. Thus, a comprehensive metering program must consider both water produced (source meters) as well as water delivered (customer meters). Differences between water produced and water delivered must be considered in planning and design.
- To update Division requirements, it will be necessary to gather metering data for a broad range of water users. This includes collecting data that is distributed geographically to capture the impact of geography, weather, and system size. It also includes collecting a large enough sample set to consider the impact of factors such as type of water user, lot size, availability of secondary water, presence of individual meters, water rates, etc.

Metering Equipment

- Required features of enhanced metering include the ability to accurately measure volumes, flows, and pressures at short time intervals (15 minutes or less recommended) and mechanisms for collecting, recording, and transmitting data.
- Magnetic (mag) meters, being accurate, reliable, and easy to use, are recommended for metering source flows.
- For sensing tank water levels, submerged pressure transducers or ultrasonic level meters are recommended.
- For customer meters, AMI systems with electromagnetic, ultrasonic, nutating disk, or oscillating piston meters are recommended. Numerous models of customer meters can provide the desired features.
- Secondary (irrigation) water meters are recommended to help distinguish indoor and outdoor uses. Secondary meters must be able to pass debris. Meters with no moving

parts, such as ultrasonic and magnetic technologies, are recommended for secondary applications.

- Water systems should plan to replace residential meters about every 20 years (often limited by battery life, but also mechanical wear and tear). Source meters, if properly maintained, have a life expectancy of 20–30 years but should be checked for calibration every few years.

Data Management

- Water metering is an information cycle that requires deliberate data management to gain the most benefit. The proper people, software, and hardware must be in place to handle and analyze data.

Costs

- Total metering costs can vary significantly depending on installation conditions. Costs for proposed metering projects, and the associated financial assistance, should be evaluated on a case-by-case basis.
- Costs for mag meters range from about $2,000 to $5,000 per meter. Adding communication capability to facilitate enhanced metering will add about $450 per meter for the common meter sizes examined as part of this study.
- SCADA improvement costs will vary depending on the status of each water provider's existing SCADA system.
- Costs for customer meters range from about $200 to $1,000 per meter depending on the meter model, communication system, installation conditions, and contractor arrangements. The increased cost of enhanced metering (AMI) above typical base metering can range from $95 to $235 per unit depending on system size and what the Division chooses to consider as a "base meter."

NEXT STEPS

The legislative audit recommended that the Division obtain sufficient data to update the requirements. This report is the first step towards a metering program, and the Division should continue to define the funding, staffing, planning, and public support for such a program. We would recommend that the next steps for the Division be as follows:

- Evaluate the quality and availability of existing data meeting the requirements of enhanced metering as defined in this document. This will include working with Utah's engineering community to look at what water use studies have already been completed. By using quality data where possible, the Division can minimize its data collection costs.
- Identify where additional data are needed to fill in the gaps.
- Design an assistance program that will incentivize enhanced metering in the areas where additional data are needed.
- Administer the assistance program and collect the resulting meter data.
- Analyze all the assembled data to update the Division requirements.

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INTRODUCTION

The Division of Drinking Water (DDW/Division) has long been a trusted voice in developing requirements for the design and evaluation of water systems throughout the State of Utah. Specifically, minimum sizing requirements for public water systems as listed in Utah Administrative Code R309-510 (hereafter "requirements") have served as the basis for master planning and system design efforts for many years. In order to maintain the most accurate requirements possible, the Division is looking to gather and analyze additional water use data for a broad range of users in different locations across the state.

To accomplish this goal, the Division is considering use of an assistance program through their State Revolving Fund (SRF) to provide construction assistance and financial incentives for water system metering projects. Under this approach, the Division would incentivize water purveyors to adopt enhanced metering features that could then be used to provide the State with the water use data it needs to review and update the requirements. This would include collecting peak-day water use data for drinking water systems and distinguishing between indoor and outdoor water use.

Water is one of Utah's most valuable resources and its use should be accurately measured and reported. This document identifies the metering information needed to best define future requirements. The document then identifies equipment capable of generating the required data.

BACKGROUND

Within the Utah Department of Environmental Quality, the Division is responsible to "work with drinking water professionals and the public to ensure a safe and reliable supply of drinking water." To this end, the Division developed requirements for drinking water sources, distribution systems, and storage facilities which are now codified in R309-510.

In recent years, the validity of the indoor and outdoor water source sizing requirements has been questioned. Some claim that the indoor requirements are too conservative and lead to over-designed and more-expensive facilities plus higher impact fees, water right purchases, and other water-related costs. Others claim that the outdoor requirements are insufficient and lead to system deficiencies. A 2014 legislative audit entitled "A Review of the Division of Drinking Water's Minimum Source Sizing Requirements" (No. 2014-13) investigated these claims. The audit found that indoor source sizing requirements appear excessive, that outdoor source sizing requirements appear insufficient, and that both requirements are based on outdated research or assumptions and lack supporting data. The audit recommended reevaluating the requirements.

WATER USE CHARACTERISTICS

Water use is a complex phenomenon that is difficult to project. Understanding the timing, location, magnitude, and purpose of water use is critical to informing water policies and planning the associated infrastructure (Chang and Franczyk 2009). This section describes water use characteristics relevant to the requirements and metering activities. These concepts will be illustrated using figures showing actual data from typical Utah water systems.

Average Yearly, Peak Day, and Peak Instantaneous Demands

Per R309-510-7, water sources must be capable of meeting water demands under two conditions: average yearly demand and peak day demand. The average yearly demand is the total amount of water used in one year and represents the water right capacity needed to supply the system. However, since water use varies throughout the year, individual days must also be considered. The peak day demand is the water demand on the day of highest water use and represents the physical source capacity needed to supply the system. Variation in daily demands throughout the year is shown in Figure 1. As can be seen in the figure, demand on the peak day of the year is more than double the average demand for the year as a whole.

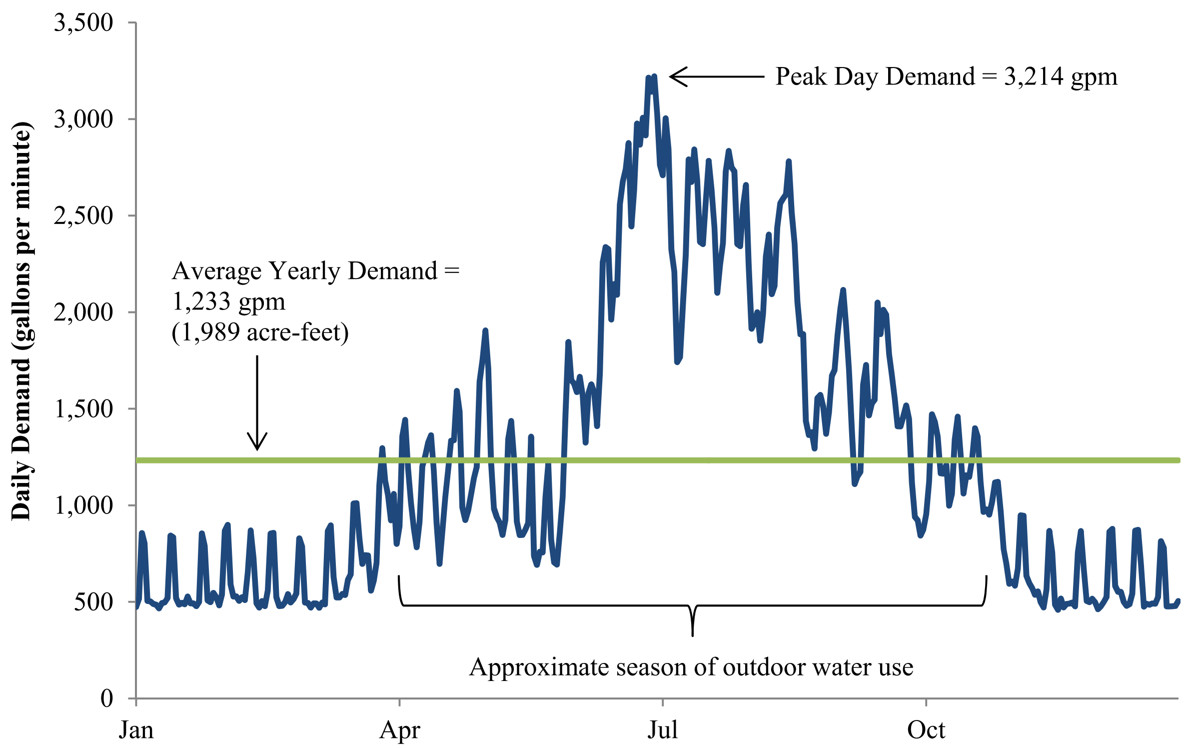

Figure 1: Example of Average Yearly and Peak Day Demand

A third consideration is peak instantaneous demand. This is the moment of highest water demand at any time (i.e., rush hour in the water system). Figure 2 shows instantaneous demand in a water system over a period of 24 hours. Peak instantaneous demand in this example occurs in the early morning hours as residents irrigate their properties. This becomes the design point for water distribution sizing in R309-510-9. Pipes and other distribution facilities must be able to deliver the peak instantaneous demand without impairing system pressures. In an undersized system with distribution deficiencies, the true water use pattern is muted; the system cannot deliver the full demand, which causes pressures to decrease. For this reason it is important to measure pressures as well as flows.

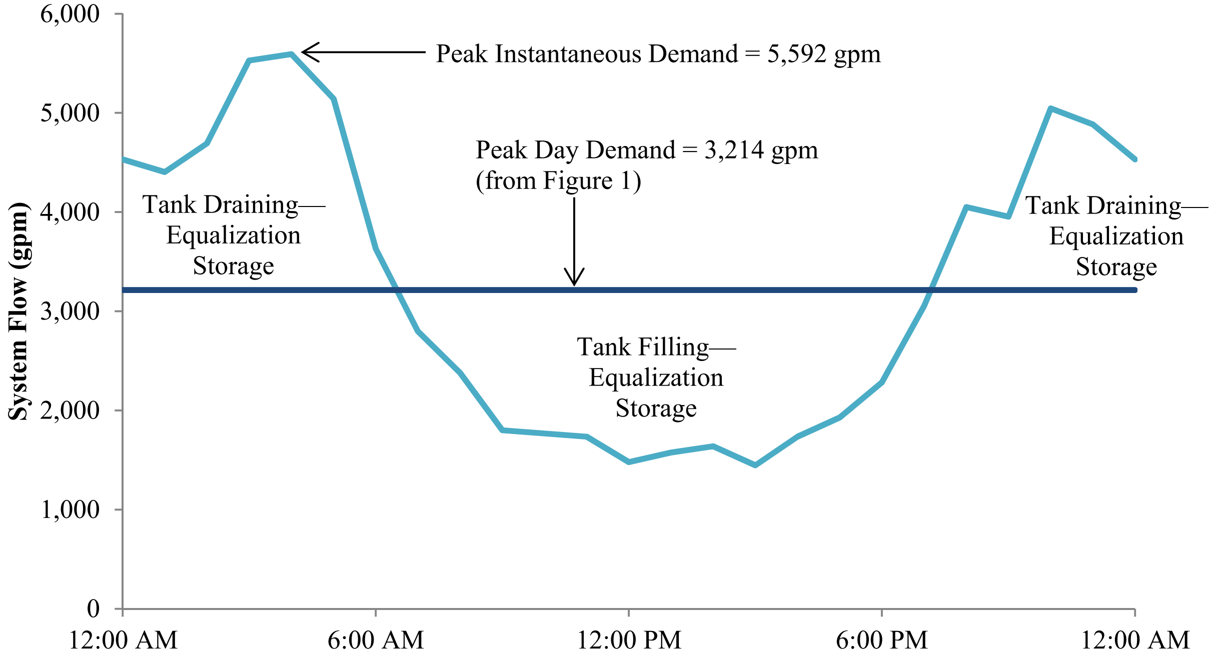

Figure 2: Example of Peak Day and Peak Instantaneous Demand

Also included in Figure 2 is identification of equalization storage. Equalization storage means that storage tank volume which stores water during periods of low demand and releases the water under periods of high demand. As discussed previously, system sources shall be able to meet the anticipated water demand on the day of highest water consumption, which is the peak day demand. With system sources producing water at a relatively steady rate throughout the day, the fluctuation in demand over the course of a day are accommodated using equalization storage. Stored water meets the demand gap when sources cannot keep up. This storage is then replenished later in the day during periods when demand is less than source capacity. Design criteria for equalization storage are found in R309-510-8.

Table 1 summarizes the demand related criteria currently governed by DDW rules.

Table 1: Water Demand Design Points

Design Point	Rule	Definition	Capacity Type
Average yearly demand	R309-510-7	Annual water volume used in one year	Water rights
Peak day demand	R309-510-7	Water volume used on day of highest water use	Source
Peak instantaneous demand	R309-510-9	Momentary highest demand on any day	Distribution
Equalization storage	R309-510-8	Storage of water to compensate for the difference when demand exceeds source capacity. Water is stored during low demand and released during high demand.	Storage

Indoor vs. Outdoor

While all Utah drinking water systems provide water for indoor use, most also provide drinking water for outdoor use (landscaping, irrigation, etc.). Outdoor use is seasonal and peaks in the summer (as shown in Figure 1). It can often be much greater than indoor use. In such systems, most water users have only one meter and it does not distinguish between indoor and outdoor uses, complicating the determination of appropriate source sizing requirements for each.

Production vs. Delivery (Water Loss)

No water system is perfectly tight. There is always some loss between production and delivery, which can include leaks, water theft, inaccurate metering, and other non-revenue water (such as water used for firefighting). The U.S. Environmental Protection Agency reports that water systems lose an average of 16% of their water (EPA 2013). In Utah, some systems lose as much as 30% to 50% of their total water. For this reason, water systems must always produce more than their actual demand and these losses must be considered in planning and design.

Factors Affecting Water Use

Several factors influencing water use are briefly discussed here. These factors are important to understand when planning, designing, and operating public water systems.

> ***Geography.*** Water uses differ geographically at all scales. Residential per-capita water demand is much greater in the western United States than in the eastern United States; Utah's value is the second highest in the country, likely due to a relatively dry climate and water-intensive landscapes (Maupin et al. 2014). Within the state, there is also a large variation in water use, especially relative to outdoor irrigation (DWRe 2010). Required irrigation rates in St. George are much different than required rates in Rich County. Even within a given water system, the water use is not equally distributed as illustrated by water use in Salt Lake City as shown in Figure 3.
>
> ***Time of Day and Time of Year.*** Along with spatial patterns, water use changes over time. Just as traffic ebbs and flows daily, water demands change throughout the day. Indoor water demand, for example, peaks in the morning as residential users shower, flush, and prepare breakfast. Outdoor water demand peaks overnight as shown previously in Figure 2. These peaks often occur around 10:00 PM in systems with manually controlled sprinklers and around 5:00 AM in systems with automated sprinkler timers (this is a common default setting). Over a year, irrigation is confined to the summer, while other uses are more constant throughout the year. In a system with indoor and outdoor uses, the combined effect is complex as shown in Figure 3.

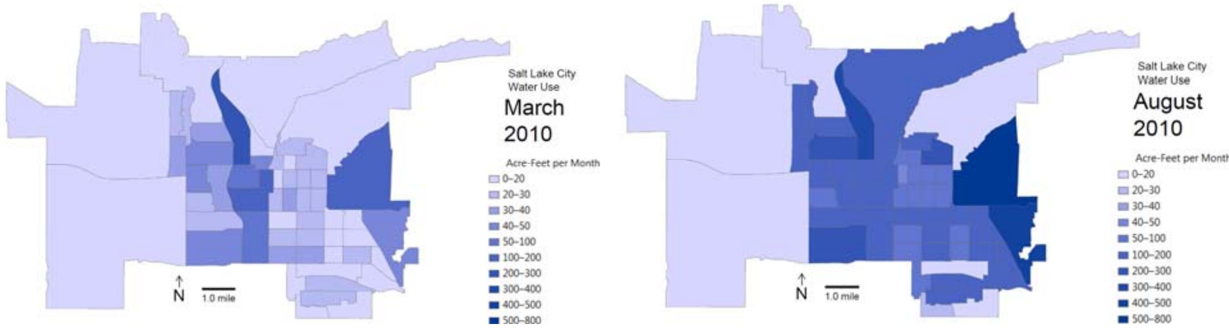

Figure 3: How Water Use Varies by Time and Place in Salt Lake City (Sowby 2016)

Type of Use. The type of use also affects the demand: residential, commercial, industrial, or institutional. Each user type (indeed, each user) has its own demand characteristics. Residential users dominate most water systems, but other user types can be locally significant. Each of the census tracts shown in Figure 3 features a different combination of water use types that contribute to the spatial and temporal variability.

Metering. Metering directly affects water demand, especially when combined with usage-based rate structures. Numerous case studies indicate that metering reduces water use by 15% to 33% (Ornaghi and Tonin 2015; Tanverakul and Lee 2015; Hanke and Flack 1968). This is illustrated in Figure 4. In 2014, the City of Saratoga Springs, Utah, installed secondary water meters and later reported a 20%–36% decrease (Edwards et al. 2016; O'Donoghue 2016).

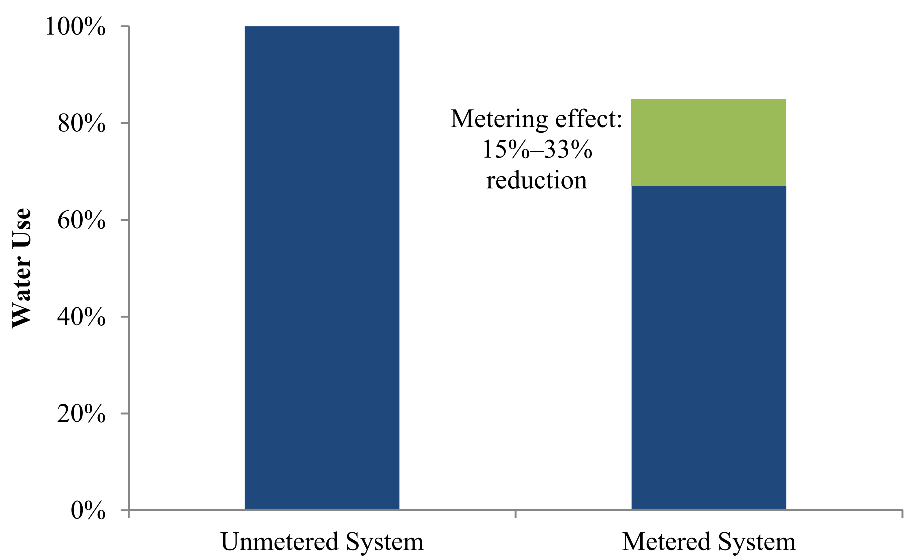

Figure 4: Effect of Metering on Water Use
(Ornaghi and Tonin 2015; Tanverakul and Lee 2015; Hanke and Flack 1968)

Lot Size and Landscaping Patterns. Lot size and landscaping influence outdoor water use. Not surprisingly, larger lots require more water. In Utah, ½-acre lots require 50%

more water than ¼-acre lots, and ¾-acre lots require twice as much water as ¼-acre lots (DWRe 2010). Outdoor water use is directly related to the lot size.

Water Rate Structures. Water rates come in many different structures that affect consumption (EPA 2016). With flat rates, customers are charged the same fee regardless of how much water they use. Flat rates encourage overuse and are discouraged. Uniform rates, or constant block rates, require a metered service and charge according to consumption. Uniform rates provide some stability for utilities and encourage conservation because the consumer bill varies with water usage. However, they do not provide as strong a price incentive for conservation as some other structures. Increasing block rates, or tiered rates, is a rate structure in which the unit price of each succeeding block of usage is charged at a higher unit rate than the previous block. Increasing block rates are designed to promote conservation and are most often found in urban areas and areas with limited water supplies.

System Size and Peaking Factors. Peaking factors differ with every system according to size, timing, and type of water use. The highest peaking factors tend to occur in small systems where most of the users are of a similar type. In these cases, there is a statistically greater chance of the system customers using water at the same time, resulting in a high instantaneous peaking factor. As the system gets larger and includes a more diverse group of water uses, the probability of concurrent use decreases and the overall peaking factor is lower.

Conservation. Per-capita water use tends to decrease over time thanks to efficient appliances and fixtures, water-wise landscapes, and conservation education programs. A North American study found a 13% decrease from 1978 to 2008; the United States observed a 12% decrease from 1990 to 2010 (Coomes et al. 2010; Maupin et al. 2014). In Utah, residential per-capita water use has trended downward since 2000 as shown in Figure 5 (DWRe 2014). In general, water use is becoming more efficient.

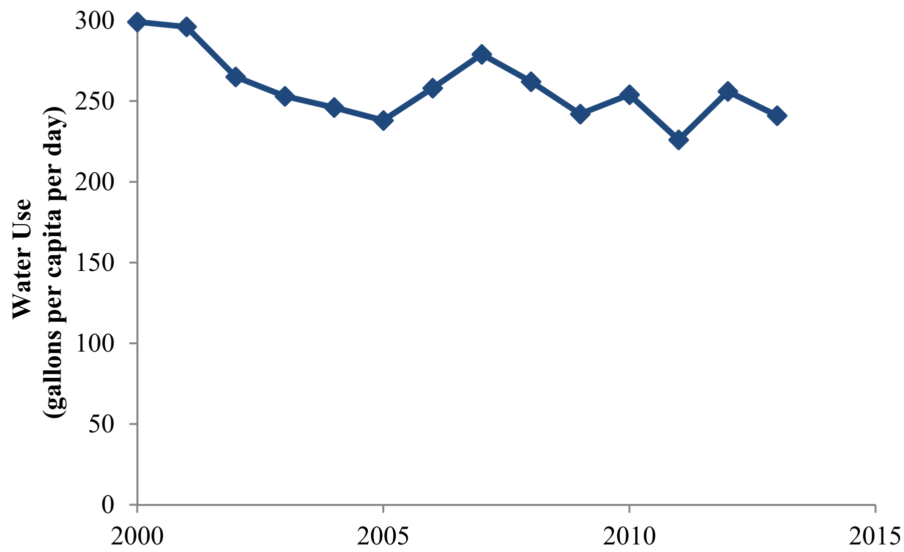

Figure 5: Declining Per-Capita Water Use in Utah (DWRe 2014)

METERING FEATURES NEEDED TO CAPTURE WATER USE CHARACTERISTICS

The foregoing discussion of water use suggests that, in order to accurately update its existing minimum sizing requirements, the Division of Drinking Water will need meter data that can provide the following information:

- Metering data must be capable of defining different demands: average yearly, peak day, and peak instantaneous. In indicating that metering data must be capable of defining peak instantaneous demand, it should be emphasized that metering data is generally collected in discrete moments in time. As a result, there is no guarantee that any recorded measurement will capture the absolute maximum demand experienced through the meter. However, data collection should be at a frequent enough interval to reasonably estimate peak demands in the system during the course of the day.
- Metering data must consider and account for system loss. For example, metering data on both the production side (source meters) as well as the delivery side (customer meters) can be used for estimating water loss.
- Production metering data must account for changes in storage to fully understand water use. Throughout the course of a day, some system demand will be satisfied by water production, and some system demand will be satisfied from stored water. This means it will be necessary to have data on both water source production rates as well as changes in tank levels.
- Metering data must be distributed geographically to capture the impact of geography, weather, and system size on demands.
- Metering data must include a large enough sample set to gather and evaluate information for many different types of water use. This will include consideration of factors such as type of water user, lot size, availability of secondary water, presence of individual meters, water rates, etc.

- Metering data should be tracked over many years to evaluate the effects of conservation on long-term water use trends.

With these basic requirements in mind, the following sections of this report discuss additional details regarding needed metering features.

Source Meters

The primary intent of source meters is to measure instantaneous flow rate and volume. Essentially all source meters have functionality to provide these two measurements. Flow rate is critical in that it allows the source system operator to determine whether the source is operating within expected parameters and whether the source is compliant with water right limitations. Volume is critical because it provides totalized flow over time which helps an entity understand its overall water use.

While the flow rate and volume data are useful, they provide only limited value when they are collected at infrequent intervals. They are of far greater value when time is added as a parameter and when the data are recorded in brief intervals. It is helpful when the data are broadcast in real time to a base station which verifies that data are being collected and makes them available.

The ideal situation is for the source meter to have an electronic output for flow and volume to a local signal relay and local readout. The local relay then sends the data via a Supervisory Control and Data Acquisition (SCADA) system to a remote base that records and processes data for use by system operators.

If timed flow rate and volume data are readily available, average and peak demands can be determined, including peak instantaneous demands from the source. It has been found that good results can be achieved if the flow rate and volume data are recorded on an interval of 15 minutes or less. The maximum 15-minute interval is recommended but may not be possible depending on equipment. Shorter intervals can provide even better data, but the data volumes become increasingly difficult to manage.

As an alternative to automated broadcasting, it is possible to record flow and volume data locally at the source. A system could be set up to record the data and to allow access at each site. In that case, personnel would need to visit the site to obtain data for analysis, which would increase workforce demands and data management efforts.

Other System Flow Meters

In addition to metering each source, it may be useful to consider flow meters at other locations within a larger water system. Flow meters are often installed at booster pump stations and may be installed at tanks or other key locations within the water system. Generally, these meters should follow the same criteria as source meters.

Strategically placed flow meters within a water system may become part of a program of District Metered Areas (DMAs) that can help identify leaks and other causes of non-revenue water by comparing DMA inflows with customer usage in the DMA (Di Nardo et al. 2013). Numerous conference proceedings and articles describe the benefits of district metering.

Storage Tank Level Meters

While meters are useful in identifying source flows, it is often necessary to also determine the fill and drain rates on water storage tanks in order to determine peak instantaneous demands. One option for gathering tank data is to collect, record, and transmit data from a water meter at the inlet and outlet of the tank. The data must be collected at frequent time intervals as previously described for source meters. A simpler solution is to monitor, record, and transmit water tank level data. This provides information on the tank level and how it fluctuates throughout the demand cycle, which allows the determination of inflow and outflow rates.

Customer Meters

The vast majority of drinking water connections in the state are equipped with meters. Unfortunately, most of these conventional customer meters have historically been read only monthly. This means that entities have only one data point of total flow each month from which to estimate demand for individual customers. In these circumstances, there is no daily or hourly data from which to estimate peak day or peak instantaneous demands.

R309-510-9 states that peak instantaneous demands may be determined by hydraulic modeling. The modeling approach requires a peaking factor assumption or data about actual conditions, and these data are impossible to obtain with monthly-read meters. Water meters capable of logging or transmitting finer measurements are necessary to determine peak day and peak instantaneous demands. As with source meters, customer meters should be capable of recording flow reads at an interval of 15 minutes or less. The maximum 15-minute interval is recommended but may not be possible depending on equipment.

AVAILABLE INFRASTRUCTURE, EQUIPMENT, AND TECHNOLOGY

A wide variety of options are available to evaluate flow rate, water volume, and water levels at sources, tanks, and customers. The discussion here is not comprehensive but it does outline basic criteria that should be applied as part of the design process at specific sites.

Source Meters

Sources are highly variable, with a wide range of flows, volumes, locations, water qualities, and other factors. Likewise, the source metering can be met by many types of meters and setups. It is critical that local factors be evaluated during the selection process. At each location, the planning and design process should consider the accuracy and reliability of the meter, proper installation, the need for pre-meter screens or filters, the anticipated flow range, and the ability of the metering equipment to produce a reliable electronic signal.

Common types of source flow meters include magnetic (mag) meters, combination meters, turbine/propeller meters.

Magnetic Flow Meters. For source flows, mag meters are a favorite choice with a high accuracy (generally within 0.5%), low maintenance requirements, easy installation, low head loss, no obstruction within the flow, and production of a signal that is readily transferred to SCADA systems. Mag meters are available for almost any flow rate.

Combination Meters. Combination, or compound, meters are another choice. These meters have relatively high accuracy (generally within 1.5% or better). Often used for flows less than 200 gpm, models are available up to about 10 inches and flow rates of 4,000 gpm. With the correct appurtenances, the register can provide an electronic output. This output can then be transmitted to SCADA. Strainers are recommended to protect the internal parts when there is the possibility of sand or grit in the water.

Turbine Meters. Another option is the turbine (turbo) meter. These meters are usually accurate within 3% and can be a cost-effective choice with sustained medium to high flows. The measuring mechanism is not intended to detect small flows; however, source meters generally are not as concerned with low flows since sources are usually on or off and, when on, have adequate flow to register. Thus, turbo meters may be a suitable choice. The turbo meter may not be the best choice for a spring or other source that varies widely throughout the year. It may also not be the best choice for non-source flow meters within a water system. This is especially true for non-pumped inline flows where velocities are expected to be very low.

Storage Tank Level Meters

Accurate measurement of the water level in tanks is critical. The water level sensor should generally be able to detect changes as small as 1 inch or 0.1 feet. Level floats or sensors that just show overflows and low levels are not adequate. Sensors should be located so that they are readily visible and accessible for maintenance, but also located so that splashing and wave action does not interfere with the readings. Common types of level meters include pressure transducers and ultrasonic sensors.

Pressure Transducers. Level measurement in drinking water tanks is often achieved by using submersible pressure transducers located at or near the bottom of the tank. The pressure transducer should be designed for low-head operations and should be vented to atmosphere so that the level is not distorted by changes in atmospheric pressure. The pressure recorded by the pressure transducer is converted to a signal that can be recorded and transmitted via a SCADA system to a base station with data-logging capability.

Pressure transducers can be installed within the tank as a submersible unit connected to the surface via a vented wire, or they can be installed as a differential pressure (DP) cell attached to piping at the bottom of the tank. The DP cell is vented to atmosphere. Pressure transducers can have an accuracy of better than 1 inch.

Ultrasonic Sensors. Ultrasonic sensors are another option for measuring water level. These devices sense the water depth by projecting a sonic signal to the water surface and timing the reflected return signal. These sensors can provide accuracy better than 1 inch and are readily connected to a SCADA system.

System Communication and Data Storage

While it is important that accurate meters and level sensors be used in the measurement of flow rate, volumes, and water level, accurate data transmittal and recording are just as important. The measuring devices will measure the indicated parameter and provide a signal that can be matched to the desired specific value. The signals produced by the measurement devices are often continuous. However, a transmitting and data-logging system must be set up to receive the data and record at the desired intervals. The data must then be readily available for operators to obtain and evaluate.

Customer Meters

As noted previously, data for the vast majority of existing customer meters in the state provide water use information on a once-a-month basis only. This occurs through either reading the meters manually or via an automatic meter reading (AMR) system. AMR allows meters to be read remotely (most often by driving through the system with a vehicle mounted radio), but still only collect one data point at a time. To capture water use characteristics associated with peak day and peak instantaneous demands, the Division will need to consider Advanced Metering Infrastructure (AMI). AMI refers to a system that communicates remotely with metering devices (in this case water meters) to collect and analyze data. For a water system, an AMI system typically has these components available:

- Water meters to meter flow at each connection
- A two-way communication system between the meters and a data storage location
- Data storage
- Software for organizing, analyzing, and displaying water use data
- (Optional) A portal for communication with the customer and customer access to the data

There are a large number of AMI capable meters available in the market. Additional technical details about several different AMI technologies are found in Appendix A.

ADDITIONAL METERING CONSIDERATIONS

Water Quality

The main consideration for secondary metering is water quality. Moss, leaves, insects, sand, and other debris carried from natural water sources can clog conventional meters, causing pressure loss, flow reduction, and inaccurate measurements (Richards 2009). Meters with no moving parts (such as ultrasonic and magnetic technologies) overcome these problems, but with additional expense and power requirements.

Design Life

Most residential water meters must be replaced every 15–20 years. This is the service life that numerous water utilities and meter manufacturers acknowledge. Battery life is usually the limitation. Meters may be replaced in a single project (as described in Table 2) or in an ongoing replacement program as described by AWWA (2012) in which a portion of the meters are replaced every year.

Source meters, if properly maintained, have a life expectancy of 20–30 years. The calibration may be checked in the field on most meters, but actual calibration must occur in the factory. Many manufacturers offer this service for the lifetime of the meter or for a certain warranty period.

Data Management

To be most effective, water metering requires deliberate data management. It is not enough to just "install a meter." Rather, water metering is a data gathering and management project with a cycle that not only provides a mechanism for billing but can also offer insights into water use and its implications for water system planning, design, operation, and management. Components of an effective data management cycle are shown in Figure 6.

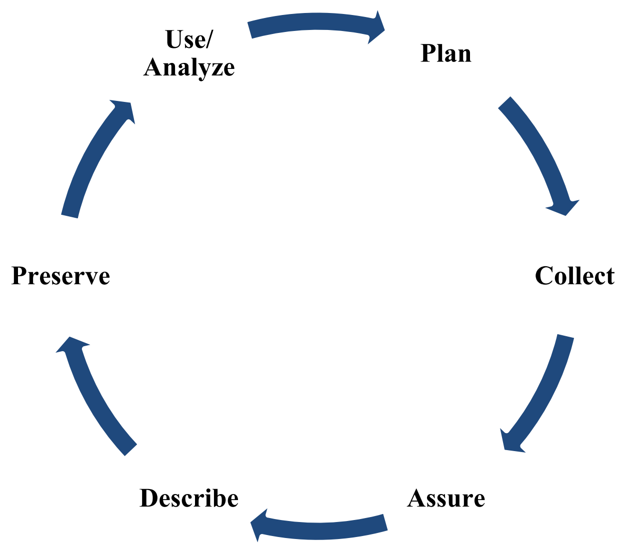

Figure 6: Data Management Cycle

Components of the data management cycle include the following:

- First, the metering program must be planned, with considerations for scientific or business objectives and the equipment, schedule, staff, and funding needed to achieve those objectives.
- After planning (and initial deployment), meters begin collecting data at whatever interval the equipment dictates.
- The data are then transmitted and collected, whether by fixed networks, drive-by radio, or manual readings. For enhanced meters, the data stream is almost continuous.

- After collection, the data should be quality assured and described with metadata (data about the data) such as date, time, time interval, location, user, units, etc. These metadata are critical for understanding the context of the water use measurement.
- The data should then be preserved in a relational database, whether in-house or in the cloud, to enable discovery and analysis. Many AMI systems handle data collection, assurance, description, and preservation automatically.
- Finally, the data are used to assess customer charges and/or evaluate the timing, location, and magnitude of water uses that can help improve the water system, and the cycle begins anew.

The data storage requirements of AMI are often overlooked. In conventional metering, only one data point per connection per month is recorded, and relatively little storage capacity is needed. In enhanced metering with hourly reads, the number of data points increases to 720, and, with 15-minute reads, approaches 3,000 data points per connection per month. Even with a moderate number of connections, a water system may be accumulating millions of data points every month from its metering infrastructure. If the data are to be stored in-house, back-office computer hardware and software must be able to handle this load. Most AMI providers offer data storage, analytics, and related services as a subscription.

Some AMI systems have proprietary data storage technologies that prohibit or limit the ability to share and analyze data. The data are only useful to water utilities, their consultants, and regulators if they can be readily accessed, so this consideration is of some importance when selecting metering systems. Above all, the data should be *used*. Operators, engineers, regulators, and others should examine the data regularly and use the insights for the benefit of the water system and its users.

COSTS

In assembling a potential grant program to encourage and incentivize enhanced metering, the Division will need to have an understanding of potential costs. The challenge with estimating costs at this phase is that the cost of metering can vary greatly depending on water system conditions. Thus, it is impossible to get a full understanding of costs until the details of the individual systems to be metered are understood. With this in mind, the following sections provide general cost information and guidelines only. More detailed cost estimates can be constructed as more is learned about how metering will actually occur. Because customer meters have a little less cost variability and are easier to understand than source meters, they will be examined first.

Customer Meter Costs

In considering customer meters, it is useful to first consider overall metering costs. The difference between basic and enhanced metering will then be considered.

Total Customer Meter Costs. Total meter costs will vary from system to system depending on issues such as system size and installation conditions. Table 2 summarizes costs from 16 past customer metering projects using actual costs or bid amounts (rather than manufacturers' estimates). These numbers reflect the total project cost for acquiring and installing the meters. Data originate from personal communications, water utility websites, and references listed at the end of this report. Costs range from about $200 to $1,000 per meter depending on the meter model, communication system, installation conditions, and contractor arrangements. Unit costs are generally less for larger projects as shown in Figure 7.

Table 2: Past Customer Metering Projects and Costs

Location	Years	Meter/System Type	Total Project Cost	Number of Meters Installed	Unit Cost
Weber Basin WCD, UT (secondary)	2016–2017	Sensus iPERL (AMI)	$1,250,000	1,200	$1,042
Manheim, PA	2010–2011	Severn Trent SmartMeter	$1,041,000	3,000	$347
Saratoga Springs, UT (secondary)	2014	Badger E Series	$3,600,000	4,000	$900
Golden, CO	2016	Sensus iPERL & OMNI (AMI)	$1,775,000	4,200	$423
Highland Park, IL	2015–2016	Neptune T-10	$5,000,000	6,500	$769
Benicia, CA	2016–2017	Neptune MACH 10 (AMI)	$7,992,000	9,580	$834
Riverbank, CA	2016–2017	Unknown (AMI)	$4,100,000	7,000	$586
Tewksbury, MA	2008–2010	Badger Recordall (AMI)	$3,600,000	9,800	$367
Euless, TX	2016–2017	Sensus iPERL & OMNI (AMI)	$3,970,000	13,384	$297
St. Louis Park, MN	2016–2017	Neptune (AMI)	$3,500,000	14,000	$250
Auburn, WA	2015–2017	Sensus iPERL & OMNI (AMI)	$6,000,000	14,860	$404
Lakewood Water District, WA	2014–2015	Sensus iPERL (AMI)	$6,900,000	15,500	$445
Glenview, IL	2012–2015	Sensus iPERL (AMI)	$8,372,000	16,000	$523
Dubuque, IA	2011	Neptune T-10	$9,000,000	22,619	$398
Lawton, OK	2009–2010	Unknown (AMI)	$10,600,000	29,046	$365
Clermont County, OH	2016–2018	Sensus accuSTREAM & OMNI (AMI)	$8,311,000	41,640	$200

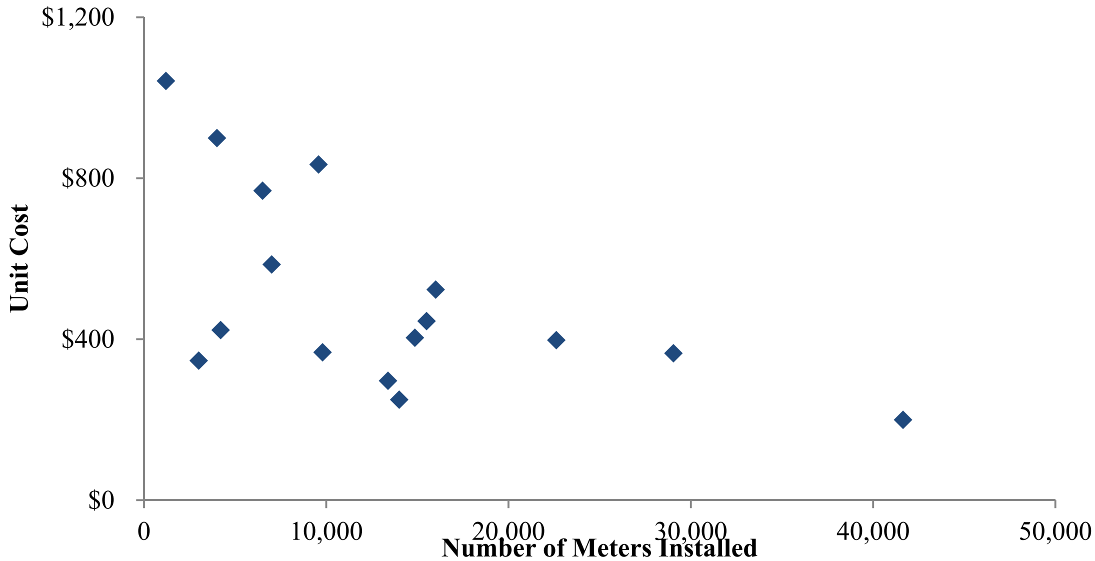

Figure 7: Unit Costs for Installed Water Meters

In looking at the projects contained in Table 2, it should be noted that many of the most expensive projects involved significant installation costs. For example, both the Weber Basin and Saratoga Springs projects (the two most expensive projects contained in the table) involved systems that did not have existing meters. In addition to installing the meters themselves, these projects involved significant cost associated with installing new meter boxes and meter setters.

Cost of Enhanced Customer Metering. Because installation conditions can have such a large effect on total project costs, it may be more useful to consider equipment costs only when comparing basic metering to the enhanced metering needed to update the Division's requirements. While this will not represent total project costs, it should be a relatively accurate estimate of the difference in cost between basic and enhanced metering since installation costs would essentially be the same for either option.

With this goal in mind, Table 3 provides a summary of estimated equipment costs for several different meter options as provided by manufacturers contacted as part of this study. While each manufacturer emphasized that actual costs will vary depending on the final project, this provides a general estimate of the difference between basic and enhanced metering. For enhanced meters, the costs reported in the table include all required equipment costs including the meter, radio or cellular transmitter, and tower costs.

Table 3: Approximate Customer Metering Costs
(Equipment Only – ¾-Inch Residential Meters)

	Base Unit (Manual Read)	Base Unit (AMR)	Cellular	Radio Frequency (Mesh or Point-to-Point)	
			Enhanced Hosted Unit (AMI)	Enhanced Hosted Unit (AMI)	Enhanced Non-Hosted Unit (AMI)
Small System (0–500 Units)	$140	$270	$375	$1,465	$665
Medium System (500–5000 Units)	$130	$190	$365	$380	$300
Large System (5,000+ Units)	$130	$180	$355	$345	$275

Several items should be noted regarding this table. First, the difference in cost between base meters and enhanced meters will depend on what is selected as the standard for the base meter. We would recommend that the base unit under consideration include AMR capability. This is the current standard for the majority of customers within the State of Utah. Although less common, it is possible that the Division could consider a manual read meter as the base unit for comparison.

A second item to note is that radio frequency options for AMI include options both with and without data hosting. Data hosting services mean that the meter manufacturer will organize and store the data coming from the meters. Without this service, the water provider must take care of this on their own. This decision can have a significant impact on cost, especially for smaller systems.

The final difference in cost between a base meter and a meter with enhanced metering functions will depend on the two factors highlighted above. Table 4 summarizes the difference in cost for each potential scenario. The table includes both the total cost difference for each scenario and also identification of the lowest cost enhanced metering option for that scenario.

Table 4: Difference in Per Unit Metering Costs
(Equipment Only – ¾-Inch Residential Meters)

	Manual Read Base Meters		AMR Base Meters	
	With Data	Without Data Hosting	With Data	Without Data Hosting
Small System (0–500 Units)	$235 (Cellular)	--*	$105 (Cellular)	--*
Medium System (500–5000 Units)	$235 (Cellular)	$170 (RF)	$165 (Cellular)	$110 (RF)
Large System (5,000+ Units)	$215 (RF)	$145 (RF)	$165 (RF)	$95 (RF)

*For small systems, radio frequency is not cost competitive with cellular. Since data hosting is a required component of the cellular system, no logical option exists without data hosting.

As can be seen in the table, the difference in cost per unit can range from $95 to $235 depending on the system size and comparison scenario. If the Division wanted to stretch its available funding as far as possible, it could structure its assistance program to establish AMR as the standard for base meters and require that water entities either provide for their own data storage or pay the costs of data hosting. Under this approach, the difference in cost per unit is expected to be $95 to $110.

Source Meter Costs

Assembling cost information for source metering is much more difficult than customer metering. This is because costs will vary based on number of sources, size of sources, number of tanks, type of meter selected, installation conditions, available communications system, etc. With this in mind, this analysis is limited to consideration of two items where enhanced metering considerations may be most applicable – actual source meters and SCADA communications.

Source Meters. As with customer meters, much of the variability in the cost of source meters will be associated with installation conditions. Therefore, to consider just the potential cost of enhanced metering, this section will consider just a few examples of equipment costs only for a few of the most common potential source meters.

Table 5 summarizes costs for two types of mag meters for water sources. Costs have been provided in sizes ranging from 6 to 10 inches, relatively common sizes for system sources. The data come from an equipment supplier. The costs are for equipment only and do not include installation. Included in the table is a column with costs for a base meter that provides measurements of instantaneous flow and total volume, but does not record or transmit this data over time. A second column provides costs for an enhanced meter that provides the measurements, but has capability to communicate this data over time remotely.

Table 5: Source Meter Costs (Equipment Only)

Model	Size (inches)	Base Meter Cost (Integral Configuration)	Enhanced Meter Cost (Remote Configuration with Cable)
Toshiba GF Series (electromagnetic flow meter, polyurethane liner, HART 4-20 mA communication)	6	$ 2,163	$ 2,613
	8	$ 2,418	$ 2,868
	10	$ 3,339	$ 3,789
Toshiba LF Series (electromagnetic flow meter, polyurethane liner, HART 4-20 mA communication)	6	$ 2,899	$ 3,349
	8	$ 3,181	$ 3,631
	10	$ 4,505	$ 4,960

As can be seen in the table, the cost of enhanced metering in this type of source meter is approximately $450 per meter. This is an increase of between 10 and 20 percent of the total meter cost (equipment only) depending on meter size. This value may vary significantly depending on meter type.

SCADA Communications. Once the data has been collected and communicated by the source meter, it must be stored on site or transmitted to a central data storage location. In most cases, water providers will use a SCADA system to transmit the data from the location of the water source to the data storage location. While many water providers already have functioning SCADA systems, some would likely require adding these capabilities to achieve the Division's enhanced metering goals. This report recommends that the Division consider these upgrades as being eligible for funding because SCADA improvements assist in the collection of detailed data collection.

SCADA costs will vary significantly depending on the status of the water provider's existing system. Some approximate costs for budgeting purposes are as follows:

- Installation of a central SCADA system (small to medium service area): $95,000
- Programming modifications to an existing SCADA system to add additional metering locations: $20,000
- Remote Terminal Unit at new metering locations: $14,000 per site

CONCLUSIONS AND RECOMMENDATIONS

Measuring water use (and the associated flows, volumes, and pressures) is important for managing the state's water resources. This report describes water use characteristics necessary for the planning, design, and operation of public water systems and recommends the following aspects for water metering:

Water Use

- Conventional meters with monthly reads do not adequately describe the complex nature of water use needed to inform water system planning, design, and operation. Enhanced metering features are recommended to capture more detailed water use characteristics such as average yearly, peak day, and peak instantaneous demands.
- Water systems must produce more water than the actual demand in order to make up for losses between production and delivery. Thus, a comprehensive metering program must consider both water produced (source meters) as well as water delivered (customer meters). Differences between water produced and water delivered must be considered in planning and design.
- To update the Division's minimum sizing requirements, it will be necessary to gather metering data for a broad range of water users. This includes collecting data that is distributed geographically to capture the impact of geography, weather, and system size. It also includes collecting a large enough sample set to consider the impact of factors such as type of water user, lot size, availability of secondary water, presence of individual meters, water rates, etc.

Metering Equipment

- Required features of enhanced metering include the ability to accurately measure volumes, flows, and pressures at short time intervals (15 minutes or less recommended) and mechanisms for collecting, recording, and transmitting data.
- Magnetic (mag) meters, being accurate, reliable, and easy to use, are recommended for metering source flows. Combination and turbine meters may also be acceptable in some circumstances.
- For sensing tank water levels, submerged pressure transducers or ultrasonic level meters are recommended. Data from level sensors are needed to help define the peak instantaneous demand.
- For customer meters, AMI systems with electromagnetic, ultrasonic, nutating disk, or oscillating piston meters are recommended. Turbine, fluidic-oscillator, and single-jet meters are not recommended due to poor accuracy at lower flows.
- Secondary (irrigation) water meters are recommended to help distinguish indoor and outdoor uses. Secondary meters must be able to pass debris. Meters with no moving parts, such as ultrasonic and magnetic technologies, are recommended for secondary applications.
- Residential water meters should be replaced every 15–20 years or when they no longer function as intended. Source meters, if properly maintained, have a life expectancy of 20–30 years but should be checked for calibration every few years.

- Recommended technical specifications for enhanced metering equipment meeting the requirements described above are included in Appendix B of this report.

Data Management

- Water metering is an information cycle that requires deliberate data management to gain the most benefit. The proper people, software, and hardware must be in place to handle and analyze data.

Costs

- Total metering costs can vary significantly depending on installation conditions. Cost estimating will be limited in its accuracy until actual installation conditions are identified.
- Costs for mag meters range from about $2,000 to $5,000 per meter (equipment only) depending on model, size, and configuration. Adding communication capability to facilitate enhanced metering will add about $450 per meter for the common meter sizes examined as part of this study.
- SCADA improvement costs will vary depending on the status of each water provider's existing SCADA system. Costs for adding a basic remote terminal unit at a source site is approximately $14,000.
- Costs for customer meters range from about $200 to $1,000 per meter depending on the meter model, communication system, installation conditions, and contractor arrangements. The increased cost of enhanced metering (AMI) above typical base metering can range from $95 to $235 per unit depending on system size and what the Division chooses to consider as a "base meter."

NEXT STEPS

The legislative audit recommended that the Division obtain sufficient data to update the requirements. This report is the first step towards a metering program, and the Division should continue to define the funding, staffing, planning, and public support for such a program. We would recommend that the next steps for the Division be as follows:

- Evaluate the quality and availability of existing data meeting the requirements of enhanced metering as defined in this document. This will include working with Utah's engineering community to look at what water use studies have already been completed. By using quality data where it already exists, the Division can minimize its data collection costs.
- Identify where additional data are needed to fill in the gaps.
- Design an assistance program that will incentivize enhanced metering in the areas where additional data are needed.
- Administer the assistance program and collect the resulting meter data.
- Analyze all the assembled data to update the Division requirements.

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APPENDIX A

AMI METERING TECHNOLOGIES

Available AMI Technologies and Providers

There are a number of vendors providing AMI solutions for municipal water use. As part of this study, several of these providers were contacted to discuss their products. We also researched provider information available online and contacted water systems that have recently been through the process of selecting an AMI system. While not a comprehensive list of all potential providers, a list of those researched for this study is provided as Table A1. Included in the table is a summary of each provider's approach to meters and communications. These are the two areas of greatest difference between the various approaches to AMI.

Table A1: Partial Listing of Potential AMI Providers

Provider	AMI System Name	Communication Type	Manufacturer's Residential Meter
Metron-Farnier	Innov8	Cellular – Verizon Network	Spectrum (Single Jet)[2]
Badger	Galaxy	Point-to-Point RF[1]	Recordall (Nutating Disk) E Series (Ultrasonic)
Itron	Water Savesource	Point-to-Point RF	None[2]
Sensus	FlexNet	Point-to-Point RF	accuSTREAM or SR II (Oscillating Piston) iPERL (Electromagnetic)
Neptune	R450	Point-to-Point RF[1]	Neptune T-10 (Nutating Disk)
Mueller	Mi.Net	RF Mesh	Hersey (Nutating Disk)

[1] Also offers cellular option, but point-to-point RF is primary product.
[2] AMI meter register compatible with many meters from other manufacturers.

The following sections discuss metering and communication approaches in general and then discuss each of the providers individually.

Meter Technology

There are two main types of water meters available for residential metering applications:

1. **Volumetric** – Volumetric meters directly measure the volume of water that passes through the meter in discrete volumes as it passes through the metering chamber. The water fills and rotates the measuring device as it travels through. Each rotation is correlated to a specific volume of water passing through the meter. These types of meters are also sometimes referred to as positive displacement meters.
2. **Velocity-Based** – Velocity-based meters use a relationship between the velocity of the water flowing through the meter and the flow rate through the meter to calibrate the meter register, which measures the total flow going through the meter over time.

The following sections summarize the characteristics of each of these meter technologies and specific types of meters for each. Included is a list of typical advantages and disadvantages. It should be noted, however, that these lists are subjective and may not apply universally. Ultimately, there are many factors such as wear, deterioration, buildup of deposits, water quality, water velocities, throughput volumes, installation and handling, and environmental causes that can all impact the overall effectiveness of a particular meter type or technology in a residential water metering application.

Volumetric (Positive Displacement)

Volumetric or positive displacement meters are the most common type of residential water meter used in utilities throughout the United States. These meters use a volumetric method for measuring flow. Two volumetric meter types are commonly used in residential water metering applications: the nutating disc and the oscillating piston.

Nutating Disk:

The nutating disk meter consists of a circular disk which is attached to a central ball and mounted in a metering chamber with spherical walls and conical top and bottom surfaces. The water enters the metering chamber through an opening in the wall on one side and leaves through a similar opening in the opposite side. As the water flows through the meter, it creates a "wobbling" or nutating motion of the disc. Since the volume of water required to make the disc complete a single revolution is known, the total flow can be calculated by multiplying the number of disc rotations by the known volume of water.

Primary Advantages:

- **Direct Volumetric Measurement** – Because this type of meter measures volume directly and does not rely on any velocity-flow rate relationships to determine the volume of throughput, the flow profile does not have to be fully developed and symmetrical at the metering location in order to maintain accuracy.
- **Proven Reliability –** While various other metering technologies have cropped up over the last several decades, positive displacement meters remain by far the most common type of residential water meter used in utilities throughout the United States.

Primary Disadvantages:

- **Potential Low-Flow Inaccuracy –** As flow rates become smaller and smaller, the bearing, friction, and drag forces within the mechanical metering mechanism become proportionally larger, creating potential for accuracy degradation at lower flows. That being said, low-flow accuracy of nutating disc meters has been shown to exceed that of other mechanical meters over a full life cycle of throughput (Barfuss et al. 2011).

Oscillating Piston:

Similar to the nutating disc meter, water passing through the oscillating piston's metering chamber causes a moving part to rotate, which then rotates a magnet coupled to the meter's register. The difference between the nutating disc type and oscillating piston type is that the nutating disc is fixed horizontally and rotates about the center as the edge of the disc moves vertically allowing the water to pass. The oscillating piston meter's moving part is a piston, which is fixed vertically and can move horizontally. As the water fills the piston, it forces the piston to rotate as the water exits the meter. Since the volume of water required to make the piston complete a single revolution is known, the total flow can be calculated by multiplying the number of rotations by the known volume of water.

Primary Advantages:

- **Direct Volumetric Measurement** – Because this type of meter measures volume directly and does not rely on any velocity-flow rate relationships to determine the volume of throughput, the flow profile does not have to be fully developed and symmetrical at the metering location in order to maintain accuracy.
- **Proven Reliability –** While various other metering technologies have cropped up over the last several decades, positive displacement meters remain by far the most common type of residential water meter used in utilities throughout the United States.

Primary Disadvantages:

- **Potential Low-Flow Inaccuracy –** As flow rates become smaller and smaller, the bearing, friction, and drag forces within the mechanical metering mechanism become proportionally larger, creating potential for accuracy degradation at lower flows.
- **Sensitive to Poor Water Quality –** Because of moving parts, viscous effects and water quality issues over time have been shown to have a significant effect on meter accuracy, both off the shelf and after a life cycle of throughput at both high and low flows.

Velocity-Based

Velocity-based meters are also used in residential water metering applications. As the name implies, these meters use the velocity of the water passing through the meter chamber and velocity-flow rate relationships to determine the total metered throughput. Three velocity-based meter types discussed in this report are: single-jet, electromagnetic, and the ultrasonic.

Single-Jet:

For single-jet meters, the moving element is a rotor that is pushed as water flows through the metering chamber. The velocity of the water that goes through the meter has a linear relationship with the rotational speed of the rotor. The register is calibrated to match the flow going through the meter.

Primary Advantages:

- **Installation Considerations –** The single-jet meter, because of the Venturi-style inlet which conditions the flow stream, allows the meter to be installed with less straight piping upstream and downstream of the metering location than is required for other velocity-based meter types.
- **Longevity –** Single-jet water meters were designed for high accuracy and longevity. High-quality meter design and manufacturing can help this type of meter to remain accurate over an extended period of time. Features of certain single-jet meters can allow

debris to pass through the impeller without causing significant damage that is often observed in other mechanical meters.

Primary Disadvantages:

- **Potential Low-Flow Inaccuracy** – As flow rates become smaller and smaller, the bearing, friction, and drag forces within the mechanical metering mechanism become proportionally larger, creating potential for accuracy degradation at lower flows. Some of these effects can be mitigated through high-quality meter design and implementation of several design features (optical encoders, floating impellers, etc.)

Electromagnetic:

While previously impractical for small water meters because of a need for a constant power supply, improvements in battery technology have made electromagnetic meters (e.g. Sensus iPERL) practical for residential water metering applications. This type of flow meter does not have any moving parts and works by establishing a magnetic field throughout the cross-section of the flow tube. Faraday's Law states that the voltage induced across any conductor as it moves at right angles through a magnetic field is proportional to the velocity of that conductor. The velocity can then be used to determine the flow going through the meter.

Primary Advantages:

- **Longevity –** Because this type of meter has no moving mechanical parts, it should theoretically be capable of maintaining its accuracy over a longer period of time. Meters like the Sensus iPERL typically come with 20-year warranties.
- **Reduced Sensitivity to Poor Water Quality –** Due to the lack of moving parts, viscous effects and water quality issues over time do not affect meter accuracy as much as they do with positive displacement meters.
- **Extended Low-Flow Accuracy –** Meters like the Sensus iPERL claim higher accuracies at flows well below the AWWA Standard Low Flow of ¼ gpm.

Primary Disadvantages:

- **Installation Considerations –** For this type of flow meter to register flow accurately, the flow profile must be fully developed and not affected by any disturbances. While this is typically of more concern in non-residential metering applications, it should not be ignored. The internal software used by an electromagnetic flow meter assumes that the velocity profile of the fluid at the location of measurement is fully developed and symmetrical about the centerline of the pipe. Minimum requirements for straight piping upstream and downstream of the metering location allow adequate distance and time for the flow to stabilize and approach uniformity.
- **New Technology –** While several US manufacturers have introduced small solid-state water meters in recent years, it is still a relatively young technology for residential metering applications.

Ultrasonic:

Similar to electromagnetic meters in that they have no moving parts and are now more practical due to improvements in battery technology, transit-time ultrasonic flow meters (e.g. Badger) are another velocity-based solid state metering option. While the actual ultrasonic metering technology is different than that used in electromagnetic meters, the primary advantages and disadvantages of each are nearly identical. Transit-time ultrasonic flow meters emit two ultrasonic signals across the cross-section of the pipe. One signal travels with the direction of the flow and the other travels against the flow. The difference in signal travel time is then used along with the known geometry of the pipe to calculate the average flow velocity of the fluid. The velocity can then be used to determine the flow going through the meter.

Primary Advantages:

- **Longevity –** Because this type of meter has no moving mechanical parts, it should theoretically be capable of maintaining its accuracy over a longer period of time. Meters like the Badger E-Series typically come with 20-year warranties.
- **Not Sensitive to Poor Water Quality –** Due to the lack of moving parts, viscous effects and water quality issues over time do not affect meter accuracy as much as they do with positive displacement meters.
- **Extended Low-Flow Accuracy –** Meters like the Badger E-Series claim higher accuracies at flows well below the AWWA Standard Low Flow of ¼ gpm.

Primary Disadvantages:

- **Installation Considerations –** For this type of flow meter to register flow accurately, the flow profile must be fully developed and not affected by any disturbances. While this is typically of more concern in non-residential metering applications, it should not be ignored. The internal software used by a transit-time ultrasonic flow meter assumes that the velocity profile of the fluid at the location of measurement is fully developed and symmetrical about the centerline of the pipe. Minimum requirements for straight piping upstream and downstream of the metering location allow adequate distance and time for the flow to stabilize and approach uniformity.
- **New Technology –** While several US manufacturers have introduced small solid-state water meters in recent years, it is still a relatively young technology for residential metering applications.

Overall Meter Accuracy

Between the several types of meters, accuracy varies with flow rate and with age. Figures A1 and A2 summarize testing results for a meter accuracy study (based on ¾-inch meters) conducted by the Utah Water Research Laboratory (Barfuss et al. 2011). Major conclusions from the study are as follows:

- **Accuracy Relative to Flow Rate –** In their new condition, all meter types are reasonably accurate at flows above 2 gpm. Turbine (TU) and fluidic-oscillator (FO) meters are the most sensitive to flow rate and do not accurately measure flows below 2 gpm. Nutating-disk (ND) meters are the most accurate at low flows. Displacement-piston (DP) meters (also called or oscillating-piston meters) are most accurate between 1 and 3 gpm, with about 95% accuracy down to 0.5 gpm and up to 25 gpm.

- **Accuracy Over Time –** Single-jet (SJ) meters degrade the most over their lifetime, registering only about 65% of the flow by the end. Turbine and fluidic-oscillator meters maintain accuracy at high flow rates even after their full life, and nutating-disk meters maintain accuracy across all flow rates even after their full life. For displacement-piston meters, accuracy is affected most at low flows. (In the study, "full life" was considered to be 2 million gallons, approximating indoor use for four persons over 15 years.)

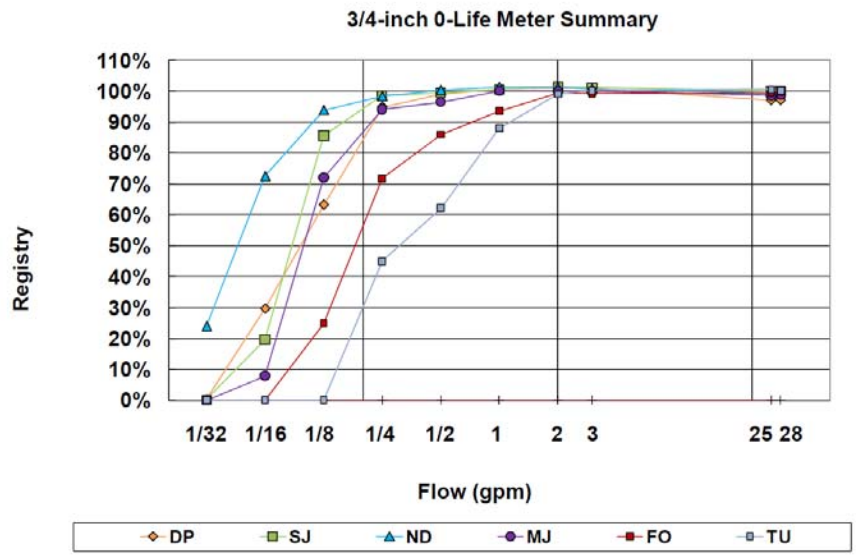

Figure A1: Meter Accuracy in New Condition (Barfuss et al. 2011)

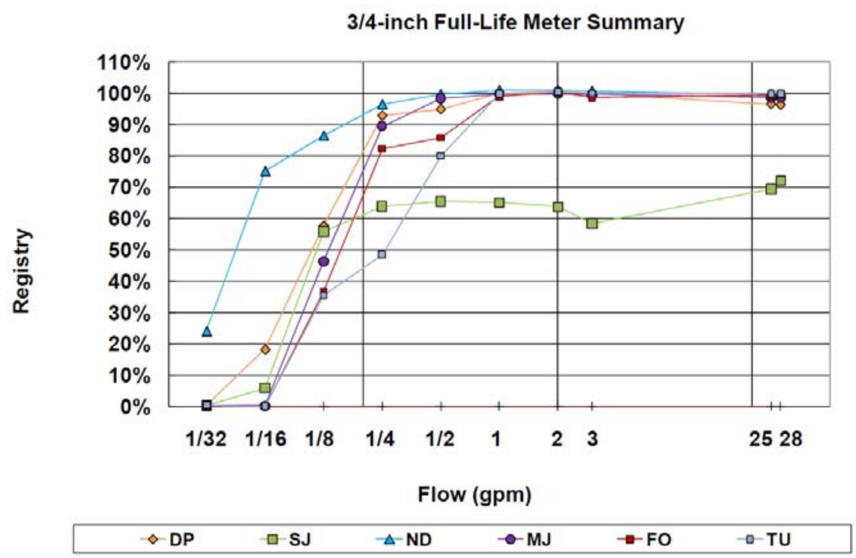

Figure A2: Meter Accuracy after Full Life (Barfuss et al. 2011)

Communications Technology

Two types of wireless communication are commonly used for AMI, cellular and radio frequency (RF). Within radio frequency, technologies can further be grouped into three categories:

1. Point-to-Point Licensed RF
2. Point-to-Point Unlicensed RF
3. RF Mesh

The following sections summarize the characteristics of each of the communication technologies. Included is a list of typical advantages and disadvantages. It should be noted, however, that these lists are subjective and may not apply universally. In many cases, providers have developed solutions to mitigate or eliminate certain disadvantages.

Cellular

Cellular AMI systems use existing cellular data communication devices and a public network such as Verizon or AT&T to communicate with each meter. In essence, each meter is equipped with its own "cell phone" that allows it to call in and report its data on a fixed schedule.

Primary Advantages:

- **Minimal Infrastructure –** One of the primary advantages of cellular communication is that it uses a network that has already been set up for other purposes. This means the City does not need to construct and maintain new infrastructure for communication purposes. This is particularly beneficial on small systems by reducing costs (compared to RF systems) due to avoiding special equipment such as RF towers.
- **Reliability –** Because the network is used for other purposes, it is closely monitored and maintained by the cellular provider, resulting in extremely reliable coverage of the system.
- **Coverage –** The coverage is equal to cell phone coverage. Thus this AMI system will match the coverage of the public cellular network it is connected into.
- **Phasing –** Because it does not require large infrastructure investments, cellular communication can be implemented with any number of meters. This may facilitate implementation of a system with budget limitations.
- **Compatibility with Other Systems –** Radio frequency networks often struggle to reach 100 percent of the meters in the system. Because it can be deployed for just a small number of meters, cellular communication could be used for those areas without coverage in a radio frequency network.

Primary Disadvantages:

- **Experience –** Cellular communication is relatively new to AMI systems. While several providers are now developing cellular products, cellular still represents only a small portion of the overall AMI market. However, because of some of the advantages above, it is expected that cellular will expand in markets where radio frequency technologies are not appropriate.

- **Higher Costs for Larger System** – While cellular can be significantly less expensive for small deployments (as a result of minimal infrastructure costs), preliminary cost estimates for large citywide systems are higher than RF networks. For medium sized systems, cellular is more expensive than non-hosted RF but less expensive than hosted RF.
- **Data Delay** – To minimize costs, current cellular technology "calls in" its information only once per day. While this will probably be adequate for nearly all of the Division's data needs, it may mean a delay in identifying leaks or other items that may be time sensitive.

Point-to-Point Licensed Radio Frequency

Radio frequencies can be licensed or unlicensed. A licensed frequency gives the license holder exclusive use of the frequency. In an AMI system that uses Point-to-Point licensed RF, a direct connection is established between radio collector towers and each meter. Because the spectrum is licensed radio noise is minimized and higher transmit power can be used (> 1 watt). This allows coverage to be obtained using a relatively small number of towers.

<u>Primary Advantages:</u>

- **Experience** – Point-to-point licensed RF has been the standard for AMI systems to date. Most of the largest AMI providers use point-to-point licensed RF as their primary communications technology, including the majority of the individual providers considered here.
- **Costs** – While there are some significant infrastructure costs associated with the initial phases of this technology, costs for citywide systems have traditionally been lower for point-to-point systems than other approaches.
- **Real-time Data** – With a licensed frequency and its own collector towers, point-to-point systems can quickly and cost effectively collect data anytime desired. This means reads can be continuously updated, resulting in near-real time access to data.

<u>Primary Disadvantages:</u>

- **Initial Infrastructure** – Before data from a single meter can be collected, at least one collector tower must be constructed. This means higher up-front costs which may complicate phasing depending on the City's available budget.
- **Coverage** – While having a licensed frequency with increased signal power improves coverage, point-to-point RF systems often struggle to reach 100 percent coverage. If the City selects a point-to-point RF system, it may need to augment the system with cellular technology in areas that struggle to communicate through RF.
- **Licensing** – Licensing through the FCC will be required for this type of system.

Point-to-Point Unlicensed Radio Frequency

This approach is identical to the previous except that it uses an unlicensed frequency. Because the frequency is unlicensed, increased collectors are needed to catch the signal, adding to infrastructure costs. As a result, none of the identified providers uses this approach and it has been dropped from further discussion.

Radio Frequency Mesh

A final approach to radio frequency systems is the mesh network. Mesh networks overcome the challenges associated with unlicensed frequencies by essentially turning each meter into a mini collector. Each meter is able to communicate with its neighbors, sending data from meter to meter through a defined path back to central collectors. This approach is designed to work in "noisy" environments and improve communication performance without having to install numerous collectors. While mesh networks generally utilize unlicensed frequencies, licensed frequencies can also be used.

Primary Advantages:

- **Costs –** Costs for RF mesh systems have been competitive with point-to-point systems. Variations between the two will primarily be a function of the individual needs of each system.
- **Real-time Data –** RF mesh systems provide the same ability as point-to-point systems to provide reads on demand.
- **Initial Infrastructure –** Initial infrastructure costs are generally less than point-to-point systems, but are more than cellular systems.
- **Coverage –** The mesh approach is able to eliminate most coverage issues as long as meters are not in locations isolated from other meters.

Primary Disadvantages:

- **Experience –** While there is one well established provider using RF mesh technology identified in this memorandum, RF mesh does not have the same volume of installations as licensed point-to-point RF.
- **Infrastructure Maintenance –** The RF mesh approach normally relies on a large number of small data collectors to receive and transmit data within the network. Although these are only a fraction of the size and cost of collectors in a point-to-point system, this results in a far greater number of sites to maintain and secure to keep communications working.

AMI Providers

A short description of each of the providers researched for this memorandum is contained below:

- **Metron-Farnier –** Metron-Farnier is a manufacturer of single-jet meters. It has teamed up with Transparent Technologies to develop an electronic register called Inov8. This register is capable of reading existing Metron meters or meters from a large number of other common manufacturers. The register includes a Verizon LTE network chip that allows the register to use the Verizon network for data transmission. Transmission occurs during early morning hours when traffic is low and data prices are extremely cheap. As one of the newest companies considered, Metron-Farnier has a small install base and limited track record.

- **Badger –** Badger is a well-established meter manufacturer. Badger's primary AMI system is based on point-to-point licensed RF, but it also has a cellular option for areas lacking RF coverage. While extremely experienced in the area of water meters, Badger has a much smaller share of the AMI market than some other providers listed here.
- **Itron –** Itron is unique in that it does not manufacture residential water meters. It provides AMI registers that are compatible with most other common meters. In the local market, Itron has commonly teamed with Badger meters. Itron registers have a 1-watt radio designed to have a wide coverage area, reaching collectors more than 1 mile away. Itron has been focused on utility metering for decades and has the largest AMI market share, although largely within the electric industry.
- **Sensus –** Sensus is another one of the biggest players in the AMI market and has an especially strong presence with water utilities in the local market. Sensus SmartPoint M2 transceivers have 2 watts of output power resulting in a large coverage area and relatively few collectors to support data collection. Sensus is also the manufacturer of the iPERL residential meter. This unique electromagnetic meter has no moving parts and claims to hold its accuracy through its full 20 year life span.
- **Neptune –** Neptune is another point-to-point RF provider with a high-power, two-way radio network. Although smaller than Itron and Sensus, Neptune provides a similar system. Neptune's primary AMI system is based on point-to-point licensed RF, but it also has a cellular option that could compliment an RF system.
- **Mueller –** Mueller Systems Mi.Net system is the only RF mesh system considered as part of the evaluation. The meter register provides full two-way communications between the network and the smart meter. Periodic or on demand reads are sent to collectors through the network via an unlicensed radio frequency and then relayed to the host server for analysis and storage. The mesh approach allows the system to successfully overcome obstacles encountered in varied and difficult network topographies. Although they use a different type of communication technology, Mueller is similar to Badger in that it has extensive experience in water metering (Hersey meters), but currently holds a smaller share of the AMI market than some other providers.

APPENDIX B

METERING EQUIPMENT TECHNICAL SPECIFICATIONS

SECTION 40 63 01
NETWORKED DATA COLLECTOR UNIT

PART 1 - GENERAL

1.1 SUMMARY

A. General: This technical specification provides guidance to water system managers in selecting source data collection units consistent with the goals of the Utah Division Drinking Water.

B. Application: This data collector unit is intended to be used as part of an advanced metering network of multiple meters and sensors. The data collector unit is intended to be centrally located and capable of directly communicating with central data storage unit. (See specification 40 63 03)

1.2 REFERENCE SPECIFICATIONS, CODES AND STANDARDS

A. FCC Part 90, UL, CMA

1.3 SUBMITTALS

A. Product Data:
1. Complete manufacturer's brochures identify instrument construction, accuracy, ranges, materials, and options.
2. Completed instrument data sheets including catalog number and source for determining catalog number.
3. Manufacturer's installation instructions.

B. Shop Drawings:
1. Mechanical connection diagrams.
2. Data collector mounting requirements with dimensions and elevations.
3. Electrical connection diagrams.

C. Test Reports:
1. Certified factory and field accuracy and consistency in collecting data from metering units.

D. Operating Manuals:
1. Certified factory operations manual(s). Include operation of all functions, troubleshooting guide, and technical support contact information.

E. Record Drawings:
1. Complete drawings showing installation location and wiring diagram(s) showing connections to other equipment.

F. Spare Parts: The SUPPLIER shall provide all spare parts as recommended by the MANUFACTURER suitably packaged and labeled for each data collector device.

G. Special Tools: The SUPPLIER shall supply special tools recommended by the MANUFACTURER suitably wrapped and identified for application.

H. Software: The SUPPLIER shall provide a copy of the software application(s) and drivers required to access and download stored data from the data collector device.

1.4 WARRANTY

A. The supplier shall provide a 2-year unconditional warranty for the data collector unit operating continuously under the specified environmental conditions.

1.5 SITE CONDITIONS

A. Units shall operate in the following site conditions:
   1. Periodic submersion in water with a static head pressure of up to 3 feet.
   2. Wind speeds up to 90 MPH
   3. Snow load of up to 6 feet.
   4. Altitude, Temperature and Humidity:
      a. Altitude: 10,000 feet above msl.
      b. Temperature Range: -40°F to 120°F.
      c. Relative Humidity: 20% - 80 % (non-condensing).
      d. Provide all equipment and instrumentation fully rated for continuous operation at this altitude, temperature and humidity conditions with no additional derating factors applied.
      e. Provide additional temperature conditioning equipment to maintain all equipment and instrumentation in non-conditioned spaces or outdoors subject to these ambient temperatures 10°F above the minimum operating temperature and 10°F below maximum operating temperature as determined by the equipment manufacturer's guidelines:

PART 2 - PRODUCTS

2.1 DATA COLLECTOR UNITS

A. At a minimum, units shall wirelessly receive data from residential and commercial water service flow meters. Other possible devices include source water flow meters, storage tank level indicators, and open channel flow meters.

B. At a minimum, units shall be capable of wirelessly receiving data from 1,000 measuring devices.

Units shall be capable of reporting the following data and metadata with each reading logged:
   1. Water System Number (static value)
   2. Meter/Sensor Identifier (static value)
   3. Geographic Coordinates of attached meter/sensor location (static value)
   4. Water type – potable or secondary (static value)
   5. Time stamp of reading accurate to the nearest second
   6. Flow rate at time of reading in gallons per minute or level in feet and tenths of feet.
   7. Cumulative volume passed through the meter at time of reading.

8. Unit shall be capable of synchronizing with local network time and automatically adjust for daylight savings time and leap year.

C. Units shall log readings from each meter/sensor every 15 minutes continually

D. Units shall transmit readings to a central data storage unit at least once daily via:
1. FCC licensed radio frequency
2. Cellular signal
3. Wireless internet signal

E. Units shall be capable of storing data for a minimum of three days in the event of communication failure between the unit and the central data storage unit.

F. In the event of communication failure, stored readings on the unit shall be accessible and downloadable by at least one of the following methods:
1. Wireless communication (NFC, Bluetooth)
2. Serial cable connection to a portable computer
3. USB cable connection to a portable computer
4. USB flash drive direct download
5. Ethernet
6. Fiber optic

G. Power input for the units shall be one or more of the following options:
1. Units shall be capable of operating on replaceable or rechargeable batteries taking readings every 15 minutes for a minimum of 30 days.

2. Solar with 3-day battery backup.

3. Units shall be capable of operating on 100 to 240 VAC 50/60 Hz. With this power option, units shall have Units powered via utility power, line voltage or external power supply, shall be provided with an uninterruptable power supply (UPS) capable of providing a minimum of (8) hours of battery backup. See Section 2.2 Accessories for additional UPS specifications

H. Units shall come with all necessary software to communicate with, access, and download stored memory at no additional charge and no ongoing subscription service required.

I. Units shall come with all necessary hardware, adapters, or cables necessary to communicate with, access, and download stored memory.

J. Where there is more than one item of similar equipment being furnished under this Contract, all such similar equipment shall be the product of a singular manufacturer.

K. Manufacturers
a. Badger
b. Metron-Farnier
c. Neptune
d. Sensus
e. Itron
f. Mueller

2.2 ACCESSORIES

A. Uninterruptable Power Supply (UPS):

1. General:
   a. Completely static uninterruptible AC power supplier system shall be provided to power to CSS.
   b. Each UPS system shall consist of a static inverter, rectifier charger, static transfer switch and storage battery.
   c. The UPS battery shall be capable of supplying the rated load of the UPS equipment for a minimum of 30 minutes.
2. Operation: The system shall be a single-conversion/ferroresonance or double-conversion type and shall operate as follows:
   a. Normal AC Power: Critical load shall be supplied from the AC power line through the static invertor and the rectifier charger which also shall maintain the battery in fully charge "float" condition.
   b. Abnormal AC Power: Critical load shall be continuously supplied from the battery through the static invertor whenever the AC line voltage dips or fails.
   c. Return of Normal AC Power: Rectifier charger shall supply power from AC line to critical loads without disturbance and at the same time shall recharge the battery in preparation for future AC power line failure.
   d. Loss of Rectifier/Charger, Battery or Invertor: Static switch shall bypass critical load to normal AC power upon deviation of invertor output power from preset voltage and frequency parameters.
      1) Sensing shall be accomplished at input terminals of static bypass to prevent disturbance in excess of ¼ cycle for any failures up to these terminals.
      2) Upon restoration of normal invertor operation after a preset timing interval and automatic re-synchronization to AC power line, static switch shall return critical load back to invertor without disturbance.
      3) A synchronizing check shall present return if the invertor and line voltage are not within 5 electrical degrees.
3. Voltage tolerances:
   a. Input shall be 120 VAC (±10%), 60 Hertz ± 1 Hertz.
   b. Output shall be 115 VAC (±2%), 60 Hertz (±0.5%) when not synchronized to line (i.e. – during AC line failure).
   c. Frequency shall be synchronized to AC line during normal operation.
4. Frequency Stability:
   a. Rate of frequency change (Hz/SEC) of the UPS system during switch over shall be held to a limit which will not cause malfunction of the data collection unit.
5. UPS Manufacturer:
   a. Eaton 5S Series
   b. Toshiba 1000/1000+ Series
   c. APC SmartUPS Series
   d. Tripplite SmartPro Series
   e. Or, Approved Equal.

END OF SECTION

SECTION 40 63 03
CENTRAL DATA STORAGE UNIT

PART 1 - GENERAL

1.1 SUMMARY

A. General: This technical specification provides guidance to water system managers in selecting a central data storage unit. The intent of the unit is store water measurement readings collected on the water system prior to transmitting them to the Utah Division of Drinking Water.

1.2 SYSTEM DESCRIPTION

A. General:
   1. The Contractor shall furnish, supervise installation, assemble, configure, and place into service the central storage unit.

1.3 WARRANTY

A. Provide a warranty on all components for a three-year period from the date of commission.

B. Provide a minimum of 4 onsite service visits per year for the duration of the warranty.

C. Provide unlimited phone support for the duration of the warranty.

1.4 MAINTENANCE

A. Before substantial completion, perform all maintenance activities required by any sections of the specifications including any calibrations, final adjustments, component replacements or other routine service required before placing equipment or systems in service.

PART 2 - PRODUCTS

2.1 DESKTOP PERSONAL COMPUTER (PC)

A. All materials and all central storage unit equipment furnished under this Contract shall be new, free from defects, of first quality, off-the-shelf and produced by manufacturers regularly engaged in the manufacture of these products.

B. Where there is more than one item of similar equipment being furnished under this Contract, all such similar equipment shall be the product of a singular manufacturer.

C. Manufacturers for desktop PCs.
   1. Dell.
   2. Hewlett Packard.

D. The PC shall include but not be limited to a computer configuration with color monitor displays, keyboard and mouse input, an uninterruptible power supply and remote portable terminal.

E. The PC shall be furnished with all necessary power supplies, processors, main memory, auxiliary and bulk memories and their corresponding drives, peripheral interface cards, network cards, auxiliary function cards, modems, etc. to meet the functional requirements.

F. Central Processing Unit (CPU):
   1. The CPU shall be 64-bit
   2. Intel Core i5 minimum
   3. 3.2GHz minimum.

G. Random Access Memory (RAM):
   1. Minimum of 8GB.
   2. Field expandable.

H. Drives:
   1. Hard disc memory of the non-removable rigid disk type shall be provided.
      a. Shall be a solid state
      b. 1 TB capacity minimum
   2. CD-RW/DVD-RW Combination Drive.

I. Color Graphic Display:
   1. 512 GB Video card shall be furnished for monitor.
   2. Size 24” Flat panel monitor.
      a. Minimum resolution 1280 x 1024 @ 60Hz, 75Hz.
   3. The display system shall be capable of performing all of the specified display functions and formats.

J. Keyboard:
   1. A full 101-key ASCII keyboard shall be furnished:
      a. Including a standard typewriter group.
      b. Cursor control keys.
      c. Numeric keypad.
      d. At least 12 special function keys.

K. Network card:
   1. 10/100/1000Base TX connection.

L. Modem (where applicable):
   1. V.90/56k TCI Telephony Modem – Sound Option

M. Operating System
   1. Microsoft Windows 10 Professional

N. Motherboard
   1. Minimum of 3 spare PCI slots.

2.2 PORTABLE COMPUTER:

A. All materials and all central storage unit equipment furnished under this Contract shall be new, free from defects, of first quality, off-the-shelf and produced by manufacturers regularly engaged in the manufacture of these products.

B. Where there is more than one item of similar equipment being furnished under this Contract, all such similar equipment shall be the product of a singular manufacturer.

C. Manufacturers for desktop PCs.
1. Dell.
2. Hewlett Packard.
3. Lenovo

D. The portable computer shall be furnished with all necessary power supplies, processors, main memory, auxiliary and bulk memories and their corresponding drives, peripheral interface cards, network cards, auxiliary function cards, modems, etc. to meet the functional requirements.

E. Central Processing Unit (CPU):
1. The CPU shall be 64-bit
2. Intel Core i5 minimum
3. 2.6 GHz minimum.

F. Random Access Memory (RAM):
1. Minimum of 8GB.

G. Drives:
1. Hard disc memory of the non-removable rigid disk type shall be provided.
   a. Shall be a solid state
   b. 1 TB capacity minimum
2. CD-RW/DVD-RW Combination Drive.

H. Color Graphic Display:
1. 512 GB Video card shall be furnished for monitor.
2. Size 13-inch display.
3. The display system shall be capable of performing all of the specified display functions and formats.

I. Keyboard:
1. A full 101-key ASCII keyboard shall be furnished:
   a. Including a standard typewriter group.
   b. Cursor control keys.
   c. Numeric keypad.
   d. At least 12 special function keys.

J. Wireless:
1. 802.11ac+ Bluetooth 4.1, Dual Band 2.4&5GHz, 1x1.

K. Battery:

1. Minimum 40Whr

L. Operating System

1. Microsoft Windows 10 Professional

M. Communication Ports and Modems:

1. The computer shall be furnished with sufficient serial communication ports necessary to communicate with peripheral equipment to meet the functional requirements of the system.
2. The computer shall be capable of wirelessly connecting to the internet.

2.3 DATA STORAGE AND MANAGEMENT

1. The computer shall be provided with a database management platform capable of creating and managing relational databases.
   a. Software must provide the ability to export data in non-proprietary formats (plain-text, tab-delimited, coma-separated, etc.).
   b. Database Management Software:
      1) Microsoft SQL Server
      2) Or Equal
2. The computer shall be provided with database reporting software.
   a. Database Reporting Software:
      1) Crystal Reports
      2) Or Equal
3. The computer must store metering data for a minimum of (1) year.

2.4 ACCESSORIES

A. Uninterruptable Power Supply (UPS) for Desktop PC:

1. General:
   a. Completely static uninterruptible AC power supplier system shall be provided to power to CSS.
   b. Each UPS system shall consist of a static inverter, rectifier charger, static transfer switch and storage battery.
   c. The UPS battery shall can supply the rated load of the UPS equipment for a minimum of 30 minutes.
2. Operation: The system shall be a single-conversion/ferro-resonance or double-conversion type and shall operate as follows:
   a. Normal AC Power: Critical load shall be supplied from the AC power line through the static invertor and the rectifier charger which also shall maintain the battery in fully charge “float” condition.
   b. Abnormal AC Power: Critical load shall be continuously supplied from the battery through the static invertor whenever the AC line voltage dips or fails.
   c. Return of Normal AC Power: Rectifier charger shall supply power from AC line to critical loads without disturbance and at the same time shall recharge the battery in preparation for future AC power line failure.
   d. Loss of Rectifier/Charger, Battery or Invertor: Static switch shall bypass critical load to normal AC power upon deviation of invertor output power from preset voltage and frequency parameters.

1) Sensing shall be accomplished at input terminals of static bypass to prevent disturbance in excess of ¼ cycle for any failures up to these terminals.
2) Upon restoration of normal invertor operation after a preset timing interval and automatic re-synchronization to AC power line, static switch shall return critical load back to invertor without disturbance.
3) A synchronizing check shall present return if the invertor and line voltage are not within 5 electrical degrees.

3. Voltage tolerances:
   a. Input shall be 120 VAC (±10%), 60 Hertz ± 1 Hertz.
   b. Output shall be 115 VAC (±2%), 60 Hertz (±0.5%) when not synchronized to line (i.e. – during AC line failure).
   c. Frequency shall be synchronized to AC line during normal operation.
4. Frequency Stability:
   a. Rate of frequency change (Hz/SEC) of the UPS system during switch over shall be held to a limit which will not cause malfunction of the computer system including disk and peripherals.
5. UPS Manufacturer:
   a. Eaton 5S Series
   b. Toshiba 1000/1000+ Series
   c. APC SmartUPS Series
   d. Tripplite SmartPro Series
   e. Or Approved Equal.

END OF SECTION

SECTION 40 63 43
REMOTE DATA COLLECTOR UNIT

PART 1 - GENERAL

1.1 SUMMARY

A. General: This technical specification provides guidance to water system managers in selecting remote data collection units consistent with the goals of the Utah Division of Drinking Water.

B. Application: This remote data collector unit is intended for use in non-networked or remote locations where power or other supporting infrastructure may not be available. The data collector unit would be located onsite and manually accessed by system operators. The data would be downloaded by the operator from the unit and manually transferred to a central data storage unit (See specification 40 63 03)

1.2 REFERENCE SPECIFICATIONS, CODES AND STANDARDS

A. FCC Part 90, UL, CMA

1.3 SUBMITTALS

A. Product Data:
  1. Complete manufacturer's brochures identify instrument construction, accuracy, ranges, materials, and options.
  2. Completed instrument data sheets including catalog number and source for determining catalog number.
  3. Manufacturer's installation instructions.

B. Shop Drawings:
  1. Mechanical connection diagrams.
  2. Data collector mounting requirements with dimensions and elevations.
  3. Electrical connection diagrams.

C. Test Reports:
  1. Certified factory and field accuracy and consistency in collecting data from metering units.

D. Operating Manuals:
  1. Certified factory operations manual(s). Include operation of all functions, troubleshooting guide, and technical support contact information.

E. Record Drawings:
  1. Complete drawings showing installation location and wiring diagram(s) showing connections to other equipment.

F. Spare Parts: The SUPPLIER shall provide all spare parts as recommended by the MANUFACTURER suitably packaged and labeled for each data collector device.

G. Special Tools: The SUPPLIER shall supply special tools recommended by the MANUFACTURER suitably wrapped and identified for application.

1.4 WARRANTY

A. The supplier shall provide a 2-year unconditional warranty for the data collector unit operating continuously under the specified environmental conditions.

1.5 SITE CONDITIONS

A. Units shall operate in the following site conditions:
   1. Periodic submersion in water with a static head pressure of up to 3 feet.
   2. Wind speeds up to 90 MPH
   3. Snow load of up to 6 feet.
   4. Altitude, Temperature and Humidity:
      a. Altitude: 10,000 feet above msl.
      b. Temperature Range: -40°F to 120°F.
      c. Relative Humidity: 20% - 80 % (non-condensing).
      d. Provide all equipment and instrumentation fully rated for continuous operation at this altitude, temperature and humidity conditions with no additional derating factors applied.
      e. Provide additional temperature conditioning equipment to maintain all equipment and instrumentation in non-conditioned spaces or outdoors subject to these ambient temperatures 10°F above the minimum operating temperature and 10°F below maximum operating temperature as determined by the equipment manufacturer's guidelines:

PART 2 - PRODUCTS

2.1 REMOTE DATA COLLECTOR UNITS

A. General: Data collector units shall be furnished with all necessary power supplies, processors, main memory, auxiliary memory, peripheral interface cards, network cards, auxiliary function cards, to meet the functional requirements as specified herein.

B. Units shall connect to a variety of flow and level measurement devices. At a minimum, these devices include:
   1. Magnetic flow meters
   2. Pressure Transducers
   3. Area Velocity Probes
   4. Ultrasonic level sensors
   5. Radar based level sensors
   6. Laser based level sensors
   7. SDI-12 devices
   8. Bubbler level sensors

C. Units shall store readings from a single input device for a minimum of 30 days in non-volatile memory.

D. Power input for the units shall be one or more of the following options:

1. Units shall be capable of operating on replaceable or rechargeable batteries taking readings every 15 minutes for a minimum of 30 days.
2. Solar with 3-day battery backup.
3. Units shall be capable of operating on 100 to 240 VAC 50/60 Hz. With this power option, units shall have Units powered via utility power, line voltage or external power supply, shall be provided with an uninterruptable power supply (UPS) capable of providing a minimum of (8) hours of battery backup. See Section 2.2 Accessories for additional UPS specifications.

E. Units shall log input device readings every 15 minutes continually

F. Stored readings on the unit shall be accessible and downloadable by at least one of the following methods:

1. Wireless communication (e.g. NFC, Bluetooth)
2. Remote Cellular communication
3. Serial cable connection to a portable computer
4. USB cable connection to a portable computer
5. USB flash drive direct download
6. Ethernet
7. Removable memory storage cards

G. Units shall be capable of built-in weir and flume hydraulic tables relating level to flow rate.

H. Units shall be capable of logging permanently cumulative data.

I. Units shall be capable of reporting the following data and metadata with each reading logged:

1. Water System Number (static value)
2. Attached Meter/Sensor Identifier (static value)
3. Geographic Coordinates of attached meter/sensor location (static value)
4. Water type – potable or secondary (static value)
5. Time stamp of reading accurate to the nearest second
6. Flow rate at time of reading in gallons per minute or level in feet and tenths of feet.
7. Cumulative volume passed through the meter at time of reading.
8. Unit shall be capable of synchronizing with local network time and automatically adjust for daylight savings time and leap year.

J. Units shall allow for memory download without interrupting ongoing data logging.

K. Units shall come with all necessary software to communicate with, access, and download stored memory at no additional charge and no ongoing subscription service required.

L. Units shall come with all necessary hardware, adapters, or cables necessary to communicate with, access, and download stored memory.

M. Where there is more than one item of similar equipment being furnished under this Contract, all such similar equipment shall be the product of a singular manufacturer.

N. Manufacturers
   a. Teledyne Isco
   b. Hach
   c. Campbell Scientific
   d. Sutron
   e. Mace

2.2 ACCESSORIES

A. Uninterruptable Power Supply (UPS):
   1. General:
      a. Completely static uninterruptible AC power supplier system shall be provided to power to CSS.
      b. Each UPS system shall consist of a static inverter, rectifier charger, static transfer switch and storage battery.
      c. The UPS battery shall be capable of supplying the rated load of the UPS equipment for a minimum of 30 minutes.
   2. Operation: The system shall be a single-conversion/ferroresonance or double-conversion type and shall operate as follows:
      a. Normal AC Power: Critical load shall be supplied from the AC power line through the static invertor and the rectifier charger which also shall maintain the battery in fully charge “float” condition.
      b. Abnormal AC Power: Critical load shall be continuously supplied from the battery through the static invertor whenever the AC line voltage dips or fails.
      c. Return of Normal AC Power: Rectifier charger shall supply power from AC line to critical loads without disturbance and at the same time shall recharge the battery in preparation for future AC power line failure.
      d. Loss of Rectifier/Charger, Battery or Invertor: Static switch shall bypass critical load to normal AC power upon deviation of invertor output power from preset voltage and frequency parameters.
         1) Sensing shall be accomplished at input terminals of static bypass to prevent disturbance in excess of ¼ cycle for any failures up to these terminals.
         2) Upon restoration of normal invertor operation after a preset timing interval and automatic re-synchronization to AC power line, static switch shall return critical load back to invertor without disturbance.
         3) A synchronizing check shall present return if the invertor and line voltage are not within 5 electrical degrees.
   3. Voltage tolerances:
      a. Input shall be 120 VAC (±10%), 60 Hertz ± 1 Hertz.
      b. Output shall be 115 VAC (±2%), 60 Hertz (±0.5%) when not synchronized to line (i.e. – during AC line failure).
      c. Frequency shall be synchronized to AC line during normal operation.
   4. Frequency Stability:
      a. Rate of frequency change (Hz/SEC) of the UPS system during switch over shall be held to a limit which will not cause malfunction of the data collection unit.

5. UPS Manufacturer:
    a. Eaton 5S Series
    b. Toshiba 1000/1000+ Series
    c. APC SmartUPS Series
    d. Tripplite SmartPro Series
    e. Or, Approved Equal.

END OF SECTION

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SECTION 40 71 01
SERVICE FLOW METERS

PART 1 - GENERAL

1.1 SUMMARY

A. General: This technical specification provides guidance to water system managers in selecting service flow meters as part of an advanced metering infrastructure consistent with the goals of the Utah Division of Drinking Water.

1.2 REFERENCE SPECIFICATIONS, CODES, AND STANDARDS

A. Commercial Standards:

ASME REPORT	Fluid Meters, Sixth Edition, 1971
ISA – S 5.1	Instrumentation Symbols and Identification
AWWA C700	Cold-water Meter specifications

1.3 SUBMITTALS

A. Shop Drawings: The SUPPLIER shall submit complete Shop Drawings of all meters for review, in accordance with the OWNER's requirements. Each meter shall be identified with a unique identification number.

B. Manufacturer's Data: With the shop drawings, SUPPLIER shall furnish certified curves indicating flow versus differential pressure and any other information called for in the individual meter Specifications.

C. Technical Manuals: The SUPPLIER shall furnish to the OWNER complete operation and maintenance instructions of all the metering systems, including instrumentation and controls, manufacturer's written guarantees and warranties.

D. Spare Parts: The SUPPLIER shall provide all spare parts as recommended by the MANUFACTURER suitably packaged and labeled for each meter device.

E. Special Tools: The SUPPLIER shall supply special tools recommended by the MANUFACTURURER suitably wrapped and identified for application.

1.4 QUALITY ASSURANCE

A. Meters, encoders, and meter interface units shall be constructed to withstand field environmental conditions such as dirt, dust, and insects. Pit-installed equipment shall be waterproof and withstand complete submersion in a flooded pit.

B. Meters, encoders, and meter interface units shall operate as designed in temperatures ranging from -10°C to 60°C and in humidity ranging from 0-100%.

C. Meters, encoders, and meter interface units shall be protected against static discharge in accordance with IEC 801-2, edition 2.

PART 2 - PRODUCTS

2.1 SERVICE FLOW METER

A. General: The service flow meter may employ any physical metering methodology consistent with the OWNER's existing standards and experience with various source waters.

B. The service meter shall be covered by a 20-year service life and accuracy warranty. At a minimum, the service flow meter shall conform to accuracy and pressure loss requirements of the AWWA C700 series of standards for various meter sizes and types.

C. The lead content of the service meters shall be compliant with NSF/ANSI Standard 61 Annex F and G.

D. The service flow meter shall be capable of field calibration.

E. The service flow meter shall communicate with an absolute encoder register unit meeting the requirements specified in subsection 2.2

2.2 ABSOLUTE ENCODER REGISTER UNIT

A. Shall be designed to obtain water meter readings matching exactly with the mechanical register odometer of the water meter.

B. Shall provide leak, tamper, and reverse flow data.

C. Shall collect and store data at 15-minute intervals over a 24-hour period.

D. Shall digitally transmit stored data to a data collection system.

E. Shall transmit data at least once daily at a time selected by system operator.

F. Shall provide eight-digit visual registration at the meter.

G. Shall be accessible for service while allowing continued meter operation.

H. Shall store and report the following attributes at the specified time interval and over the specified temporal period:

1. Water System Number (static value)
2. Meter Identifier (static value)
3. Geographic Coordinates of meter location (static value)
4. Water type – potable or secondary (static value)
5. Time stamp of reading accurate to the nearest second
6. Flow rate at time of reading in gallons per minute
7. Cumulative volume passed through the meter at time of reading.

8. Unit shall be capable of synchronizing with local network time and automatically adjust for daylight savings time and leap year.

I. Encoder data shall be in an open source non-proprietary format.

2.3 METER INTERACE UNIT

A. Shall provide two-way communication with an absolute encoder register of a water meter.

B. Shall transmit meter reading data through radio or cellular means to a central data collector.

C. Shall be compatible with absolute encoder registers.

D. Shall have capacity to read two separate networked encoders.

E. Pit installed units shall have a lid-top antenna and shall have no degradation of transmission range despite local conditions such as piled snow.

F. Pit installed unit lid-top antennas shall not protrude more than 0.25-inches from the lid top.

G. Lid-top antennae shall be traffic rated and have a dual-seal connection the meter interface unit.

H. Shall be capable of transmitting alarms for leaks, reverse flows, or other user-selected conditions such as extended no flow/ high flow.

I. The unit battery minimum design life shall be 20 years, if applicable.

J. The unit battery shall be field replaceable without interrupting meter operation.

K. Manufacturers
   1. Badger
   2. Metron-Farnier
   3. Neptune
   4. Sensus
   5. Itron
   6. Mueller

2.4 DATA COLLECTOR

A. The data collector to which the flow meter assembly transmits data shall be a remotely located central data collection and storage system. See Specification 40 63 43.

END OF SECTION

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SECTION 40 71 14
SOURCE FLOW METER IN AMI NETWORK

PART 1 - GENERAL

1.1 SUMMARY

A. General: This technical specification provides guidance to water system managers in selecting source flow meters as part of an advanced metering infrastructure consistent with the goals of the Utah Division of Drinking Water.

1.2 REFERENCES SPECIFICATIONS, CODES, AND STANDARDS

A. All instruments shall comply with the latest edition and standards of the Instrumentation Systems and Automation Society.

B. IP67, IP68/NEMA 4, NEMA 6P Enclosure ratings

C. MIL-STD-45662A Calibration Standard

D. ISO Standard 9001 Manufacturing Quality

1.3 SUBMITTALS

A. Product Data:
1. Complete manufacturer's brochures identify instrument construction, accuracy, ranges, materials, and options.
2. Completed instrument data sheets including catalog number and source for determining catalog number.
3. Manufacturer's installation instructions.

B. Shop Drawings:
1. Mechanical connection diagrams.
2. Sensor transducer mounting requirements with dimensions and elevations.
3. Electrical connection diagrams.

C. Test Reports:
1. Certified factory and field calibration data sheets for instruments and devices that require set-up and calibration.
   a. Including factory calibration for each instrument with stated accuracy.

D. Operating Manuals:
1. Certified factory and field calibration data sheets for instruments and devices that require set-up and calibration.
   a. Including factory calibration for each instrument with stated accuracy.
2. Complete installation, calibration, and testing manuals.

E. Record Drawings:

1. Complete field calibration sheets, including range, span, PLC/PAC I/O address, register, and scaling coefficients where applicable.

F. Spare Parts: The SUPPLIER shall provide all spare parts as recommended by the MANUFACTURER suitably packaged and labeled for each meter device.

G. Special Tools: The SUPPLIER shall supply special tools recommended by the MANUFACTURURER suitably wrapped and identified for application.

1.4 QUALITY ASSURANCE

A. Source flow meters shall be constructed to operate as designed in temperatures ranging from -10°C to 60°C and in humidity ranging from 0-100%.

B. Manufacturer's representative shall be responsible for proving all 4-20mA output loops.

1.5 WARRANTY

A. Manufacture shall warranty the meter against defects for 20-years of continuous operation under specified environmental conditions.

PART 2 - PRODUCTS

2.1 SOURCE FLOW METERS

A. Source meters shall be magnetic flow meters:
1. Magnetic Flow Meters.
    a. General:
        1) Magnetic flowmeter systems shall be of the low frequency electromagnetic induction type and produce a DC-pulsed linear signal which is directly proportional to the liquid flow rate.
        2) Complete zero stability shall be an inherent characteristic of the flowmeter system.
        3) Each magnetic flow metering system shall include:
            a) A metering tube.
            b) Signal cable.
            c) Transmitter.
            d) Flow meter grounding rings.
    b. Source quality control.
        1) Shall be manufactured at facilities certified to the quality standards of ISO Standard 9001 - Quality Systems - Model for Quality Assurance in Design/Development, Production, Installation, and Servicing.
    c. Metering tube:
        1) Constructed of 316 stainless steel
        2) Utilize a minimum of 2 bullet-nosed, self-cleaning electrodes.
        3) Liner in conformance with:
            a) As identified on the instrument data sheet.
            b) Manufacturer's recommendations for the intended service.

c) Whichever is the more stringent.

4) Electrodes in conformance with:
   a) As identified on the instrument data sheet.
   b) Manufacturer's recommendations for the intended service.
   c) Whichever is the more stringent.

5) Meter housing NEMA 4X corrosive conditions.

6) Meter coating consisting of epoxy painted finish.

7) Two grounding rings:
   a) Which are in conformance with the Manufacturer's bore and material recommendation for the meter's intended service.
   b) Designed to protect and shield from abrasion the liner's edge interface at the meter's end.

d. Transmitter.

1) Microprocessor-based signal converter/transmitter.

2) Utilize DC-pulse technique to drive flux-producing coils.

3) Contain a 6-digit display for flow rate, percent of span, and totalizer.

4) Operator interface consisting of keypads which respond to English text entry.

5) Integral zero return to provide a consistent zero output signal in response to an external dry contact closure.

6) Integral low flow cut-off zero return.

7) Automatic range change.

8) Programmable parameters including:
   a) Meter size.
   b) Full scale flow rate.
   c) Magnetic field frequency.
   d) Time constant.

9) The transmitter shall log the following data on 15-minute increments and transmit logged data to a data collector at least once per 24-hour period.
   a) Water System Number (static value)
   b) Meter Identifier (static value)
   c) Geographic Coordinates of meter location (static value)
   d) Water type – potable or secondary (static value)
   e) Time stamp of reading accurate to the nearest second
   f) Flow rate at time of reading in gallons per minute
   g) Cumulative volume passed through the meter at time of reading.
   h) Unit shall be capable of synchronizing with local network time and automatically adjust for daylight savings time.

10) Data retention for a minimum of 30 days without auxiliary main or battery power.

11) Self-diagnostics and automatic data checking.

12) Protected terminals and fuses in a separate compartment which isolates field connection from electronics.

13) Ambient operating temperature limits of -10 to 60 °C (14 to 140 °F).

e. Performance requirements:

1) Time constant:

a) 0.5 to 1,000 seconds.

2) Accuracy:

a) 0.25 percent of flow rate from 10 to 100 percent of full scale for velocities over 3 ft per second.

3) Repeatability:

a) 0.25 percent of full scale.

4) Isolation:

a) Galvanic or.

b) Optical.

5) Power supply:

a) 120 VAC ± 10%.

b) 60 Hz.

c) 30 Watts Max.

6) Output/Input signal:

a) Output signal: Measured range – Current 4 to 20 mA;

f. Factory testing:

1) Each flow metering system shall be hydraulically calibrated at a facility which is traceable to the Nation Institute of Testing Standards.

2) The calibration procedure shall conform to the requirements of MIL-STD-45662A.

3) A real-time computer generated printout of the actual calibration data indicating apparent and actual flows at 20%, 40%, 60%, 80% and 100% of the calibrated range shall be submitted to the OWNER.

g. Manufacturers:

1) Endress+Hauser

2) Rosemount

3) Foxboro

4) Siemens

5) Krohne

6) Azbil Magnew

7) Xylem

2.2 DATA COLLECTOR

A. The data collector to which the flow meter assembly transmits data shall be one of the following types.

1. Remote data collector unit. See Specification 40 63 02
2. Networked Data Collector Unit. See Specification 40 63 01.

END OF SECTION

SECTION 40 71 15
STORAGE TANK MEASUREMENT

PART 1 - GENERAL

1.1 SUMMARY

A. General: Water entering and exiting a storage tank is an important element in measuring a system's total water usage. This technical specification provides guidance to water system managers in selecting measurement devices for water storage tanks consistent with the goals of the Utah Division of Drinking Water for measuring water use throughout the state.

1.2 REFERENCES

A. All instruments shall comply with the latest edition and standards of the Instrumentation Systems and Automation Society.

1.3 SUBMITTALS

A. Furnish complete submittals to the OWNER.

B. Product Data:
   1. Complete manufacturer's brochures identify instrument construction, accuracy, ranges, materials, and options.
   2. Completed instrument data sheets including catalog number and source for determining catalog number.
   3. Manufacturer's installation instructions. Follow all installation and material recommendation based on the manufacturers recommendations. Verify with engineer any discrepancies found.

C. Shop Drawings
   1. Mechanical connection diagrams.
   2. Sensor transducer mounting requirements with dimensions and elevations.
   3. Electrical connection diagrams.

D. Test Reports
   1. Certified factory and field calibration data sheets for instruments and devices that require set-up and calibration.
      a. Including factory calibration for each instrument with stated accuracy.

E. Operating Manuals
   1. Certified factory and field calibration data sheets for instruments and devices that require set-up and calibration.
      a. Including factory calibration for each instrument with stated accuracy.
   2. Complete installation, calibration, and testing manuals.

F. Record Drawings
   1. Complete field calibration sheets, including range, span, PLC/PAC I/O address, registers, and scaling coefficients.

1.4 QUALITY ASSURANCE

A. All instruments of similar nature must be furnished by the same manufacturer.

B. Manufacturer's representative shall be responsible for proving all 4-20mA output loops.

C. Calibration of instruments will be performed by the Instrumentation and Control Systems Contractor (ICSC).

D. Instruments shall be manufactured at facilities certified to the quality standards of ISO Standard 9001 - Quality Systems - Model for Quality Assurance in Design/Development, Production, Installation, and Servicing.

E. All instruments and/or representative instruments shall be calibrated in facilities and with instruments traceable to the National Bureau of Standards.
   1. Provide complete documentation covering the traceability of all calibration instruments.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Store all instruments in a dedicated storage structure with space conditioning to meet the recommended storage requirements provided by the manufacturer.
   1. Any instruments that are not stored in strict conformance with the manufacturer's recommendation shall be replaced at no additional costs to the Owner.

1.6 PROJECT/SITE CONDITIONS

A. All instruments must be compatible for the installed site conditions including but not limited to material compatibility, site altitude, installed temperature and humidity conditions.

1.7 WARRANTY

A. Manufacturer shall warranty the level measuring equipment against defects for 2-years of continuous operation.

1.8 MAINTENANCE

A. Provide all necessary materials and equipment required for proper calibration, maintenance, and repair purposes.

PART 2 - PRODUCTS

2.1 EQUIPMENT

A. General: Measurement of storage levels may be accomplished by Liquid level transmitters, ultrasonic level sensors, radar level sensors, or pressure transducers as specified herein.

B. Alternative equipment: Volumes and flow rates into and out of storage tanks may more accurately be measured by magnetic flow meters (see Specification 40 71 14 Source Flow Meter) or in some cases service flow meters (see Specification 40 71 01 Service Flow Meter).

2.2 ULTRASONIC LEVEL TRANSMITTER

A. Shall be of the non-contact microprocessor-based type for the continuous measurement of liquid levels.

B. Components.
  1. A transducer with sufficient cable attached to the transducer for a complete, non-spliced, cable run from the transducer to the transmitter.
  2. A control transmitter unit which can be located up to 1200 feet away from the sensor.
  3. A removable programming unit.

C. Transmitter
  1. The transmitter shall store the ultrasonic profile in the processor memory and moment by moment, analyze the profile to determine the actual liquid level.
  2. Unit shall alter the ultrasound profile to enhance the echo with every momentary variation in the various level measuring conditions.
  3. All program data shall be safeguarded internally in non-volatile EEPROM memory.
  4. Enclosure NEMA 4X enclosure with an integral front panel mounted meter indicating in scaled engineering units.
  5. 4-20 mA output directly proportional to level.
  6. The unit shall be capable of displaying by software selection either:
     a. Distance to liquid surface from transmitter.
     b. Distance from bottom of tank to liquid surface.
     c. Remaining volume in tank.
  7. Shall contain a minimum of two relays for use as programmable alarm points.
  8. Power requirements shall be specific to site conditions; either 120 VAC, 24 V DC or loop powered.
  9. Shall be short circuit proof with respect to transducer connections.

D. Transducer
  1. Shall be encapsulated.
  2. Operating temperature range -20°C - 60°C with an accuracy of ± 0.25% of range.
  3. Measuring range 45 feet.
  4. Provided for flange mounting.
  5. Integral temperature compensation.
  6. Manufacturer to furnish sufficient cable attached to the transducer for a complete, non-spliced, cable run from the transducer to the transmitter.

E. Performance requirements:
  1. Accuracy: 0.25% or range or 0.24 inches; whichever is greater.
  2. Resolution: 0.1% or range or 0.08 inches; whichever is greater.
  3. Electronics Ambient Temperature: -5°F to 122 °F (-20°C to 50 °C).
  4. Transducer Process Temperature: -40°F to 300 °F (-40°C to 150 °C).

F. As manufactured by:

1. Siemens HydroRanger 200 w/ Echomax Sensor
2. Siemens SITRANS LU Series w/ Echomax Sensor
3. Endress+Hauser Prosonic FMU Series w/ FDU Sensor

2.3 RADAR LEVEL SENSORS

A. Shall be of the non-contact microprocessor-based type for the continuous measurement of liquid levels.

B. Components.
   1. A transducer with sufficient cable attached to the transducer for a complete, non-spliced, cable run from the transducer to the transmitter.

C. Transmitter
   1. The transmitter shall store the radar profile in the processor memory and moment by moment, analyze the profile to determine the actual liquid level.
   2. Unit shall alter the profile to enhance the echo with every momentary variation in the various level measuring conditions.
   3. All program data shall be safeguarded internally in non-volatile EEPROM memory.
   4. Enclosure NEMA 4X enclosure with an integral front panel mounted meter indicating in scaled engineering units.
   5. The transmitter shall provide a 4-20mA signal proportional to liquid level.
   6. The unit shall display by software selection either:
      a. Distance to liquid surface from transmitter.
      b. Distance from bottom of tank to liquid surface.
      c. Remaining volume in tank.
   7. Shall contain a minimum of two relays for use as programmable alarm points.
   8. Power requirements shall be specific to site conditions; either 120 VAC, 24 VDC or loop powered.
   9. Shall be short-circuit proof with respect to transducer connections.

D. Transducer
   1. Shall be encapsulated.
   2. Operating temperature range -20°C to 60°C with an accuracy of ± 0.25% of range.
   3. Measuring range 45 feet.
   4. Provided for flange mounting.
   5. Integral temperature compensation.
   6. Manufacturer to furnish sufficient cable attached to the transducer for a complete, non-spliced, cable run from the transducer to the transmitter.

E. Performance requirements:
   1. Accuracy: 0.25% or range or 0.24 inches whichever is greater.
   2. Resolution: 0.1% or range or 0.08 inches whichever is greater.
   3. Electronics Ambient Temperature: -5°F to 122 °F (-20°C to 50 °C).
   4. Transducer Process Temperature: -40°F to 300 °F (-40°C to 150 °C).

F. As manufactured by:
   1. Endress+Hauser Micropilot FMR Series w/ Micropilot FMR Sensor.

2. Siemens SITRANS LR250 Series.

2.4 LIQUID LEVEL TRANSMITTER (FLANGE INSTALLATION).

A. Transmitter.
1. Shall be a 2-wire device.
2. With continuously adjustable span, zero and damping adjustments.
3. With integral indicator scaled in engineering units.
4. Solid state circuitry.
5. 4-20 mA output directly proportional to level.

B. Transducer.
1. Shall be a differential pressure sensing unit.
2. The low-pressure connection shall be 1/2 NPT.
3. The flanged process connection shall be ANSI 4-inch, 150 lbs.

C. Performance requirements.
1. Accuracy shall be ± 0.025 percent of span.

D. As manufactured by:
1. Rosemont 3051S.
2. Endress + Hauser Cerabar S.
3. Azbil AT9000 Series.

2.5 LIQUID LEVEL TRANSMITTER (SUBMERSIBLE INSTALLATION).

A. Transmitter.
1. Shall be a 2-wire device.
2. With continuously adjustable span, zero and damping adjustments.
3. With integral indicator scaled in engineering units.
4. Solid state circuitry.
5. 4-20 mA output directly proportional to level.

B. Transducer.
1. Shall measure the height of liquid above the transducer position in the vessel referenced to atmospheric pressure.
2. Shall have a wired pigtail electrical connection.
3. Shall include an integrated ventilation tube manufactured into the cable, with appropriate bellows, to allow for automatic compensation for changes in atmospheric pressure above the vessel.
4. Shall provide a durable cage for the transducer that is designed to prevent clogging of the diaphragm seal and resistance to floating solids in harsh environments.

C. Performance requirements.
1. Accuracy shall be ± 0.025 percent of span.

D. As manufactured by:
1. Dwyer Series PBLT2 or PBLTX.
2. Drexelbrook–Ametek Model 750P.
3. Measurement Specialties MEAS KPSI 750.

4. Ametek Model 675 Series.
5. NoShok 612/613 Series.

2.6 REPORTING REQUIREMENTS

A. Regardless of the level measurement technology applied, the following data shall be collected every 15-minutes and reported at least once per 24 hours to a data collector. The static metadata values may be either reported by the sensor or the data collector unit (see Specification 40 63 01 Networked Data Collector Unit or Specification 40 63 02 Remote Data Collector Unit).
   1. Water System Number (static value)
   2. Level Measuring Device Identifier (static value)
   3. Geographic Coordinates of device (static value)
   4. Water type – potable or secondary (static value)
   5. Time stamp of reading accurate to the nearest second
   6. Level of effective depth measured from bottom up to free water surface
   7. Unit shall be capable of synchronizing with local network time and automatically adjust for daylight savings time.

2.7 DATA COLLECTOR

A. The data collector to which the flow meter assembly transmits data shall be one of the three following types.
   1. Local Battery Powered data collector and storage unit. Specification 40 63 02
   2. Local electrically powered data collector and storage unit. Specification 40 62 02
   3. Centrally located networked data collector and storage unit. Specification 40 62 01

2.8 ADJUSTING

A. All instruments shall be field calibrated to match the installed conditions.

2.9 CLEANING

A. All instrument enclosures shall be vacuumed clean after calibration and before commissioning.

2.10 DEMONSTRATION

A. Performance of all instruments shall be demonstrated to the Engineer prior to commissioning.

B. All instrument calibration shall be witnessed by the Owner's Representative.

C. Each and every instrument shall be tested during the Loop Validation Tests and the Owner's Representative shall witness the response in the PLC/PAC control system and associated registers.

2.11 PROTECTION

A. All instruments shall be fully protected after installation and before commissioning. The Contractor shall replace any instruments damaged prior to commissioning.
   1. The Engineer shall be the sole party responsible for determining the corrective measures.

END OF SECTION

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SECTION 40 71 18
OPEN CHANNEL FLOW MEASUREMENT

PART 1 - GENERAL

1.1 SUMMARY

A. General: This technical specification provides guidance to water system managers in selecting open channel flow measurement consistent with the goals of the Utah Division of Drinking Water.

1.2 REFERENCE SPECIFICATIONS, CODES, AND STANDARDS

A. Commercial Standards:

ASTM A193	Stainless Steel Anchor Bolts
ASTM D256	Izod Impact Strength
ASTM D570	Water Absorption Rate
ASTM D638	Tensile Strength
ASTM D695	Compressive Properties of Rigid Plastic
ASTM D696	Coefficient of Linear Expansion
ASTM D790	Flexural Properties
ASTM D792	Density and Specific Gravity at 23° C
ASTM D1056	Polymer Grade
ASTM D2583	Indentation Hardness
ASTM D2584	Resin, Glass & Filler Content
ASTM D 2563	Classifying Visual Defects in Glass-Reinforced Plastic Laminate Parts
ISO1438/1-1980	Open Channel Flow Measurement

1.3 SUBMITTALS

A. Shop Drawings: The SUPPLIER shall submit complete Shop Drawings of all flow measurement equipment for review, in accordance with the OWNER's requirements. Each meter shall be identified with a unique identification number.

B. Manufacturer's Data: With the shop drawings, SUPPLIER shall furnish certified curves indicating flowrate versus level, head loss through flume, required head, and other hydraulic testing and calibration data.

C. Technical Manuals: The SUPPLIER shall furnish to the OWNER complete operation and maintenance instructions of all the metering systems, including instrumentation and controls, manufacturer's written guarantees and warranties.

D. Spare Parts: The SUPPLIER shall provide all spare parts as recommended by the MANUFACTURER suitably packaged and labeled for each flume.

E. Special Tools: The SUPPLIER shall supply special tools recommended by the MANUFACTURURER suitably wrapped and identified for application.

1.4 QUALITY ASSURANCE

A. Flow measurement units shall be constructed to withstand field environmental conditions such as ultraviolent exposure, high flows, low flows, submersion, debris, snow loads, and wind loads. Pit-installed equipment shall be waterproof and withstand complete submersion in a flooded pit.

B. Flow measurement units shall operate as designed in temperatures ranging from -30°C to 65°C and in humidity ranging from 0-100%.

PART 2 - PRODUCTS

2.1 FLUMES

A. General: Flumes are a widely-accepted standard for measuring open channel flow. A licensed and competent professional engineer shall select and size the flume for each application.

B. Unit Responsibility: A single supplier shall be responsible for post installation support, delivery, and warranty of all flume components and shall represent the flume and its components as a single unit to the OWNER.

C. Types of generally accepted industry standard flumes include. The most appropriate type will depend on the specific hydraulic conditions of the proposed installation location:

1. Parshall
2. Trapezoidal
3. Cutthroat
4. H-type
5. Montana
6. Palmer Bowlus
7. RBC

D. Typical flume construction materials:

1. Fiberglass Reinforced Polyester (FRP):
   a. Shall be modeled in one seamless piece.
   b. Flume wall and floor thickness shall not be less than ¼ inch.
   c. Reinforcing shall be designed to provide structural support throughout the width and length of the flume floor.
   d. Visual inspection for defects shall be made without the aid of magnification and defects shall be classified as to type and level as shown in Table 1 of ANSI/ASTM D2563-0, approved 1977, (or subsequent revision). Allowable surface tolerances are as follows:

DEFECTS	ALLOWABLE TOLERANCE
Cracks Crazing Blisters Chips Pits Dry Spots Fish Eyes Burned Areas Entrapped Air	None
Wrinkles and solid blisters, not to exceed 1/8”	Maximum Deviation: 10% of thickness
Surface porosity (pinholes or pores in the laminate surface)	None
Exposed Glass Exposure of cut edges	None
Scratches	None more than 0.002 inches deep
Foreign Matter	None

e. Structural characteristics for a 1/8-inch glass mat laminate shall meet the following minimum physical properties:

Tensile strength	15,000 psi
Flexural modulus	1,000,000 psi
Flexural strength	20,000 psi
Compressive strength	22,000 psi
Impact strength	9.0 ft-lbs/in.
Water absorption	0.13% (in 24 hours)

2. Alternative Materials: Stainless Steel, Aluminum, Galvanized Steel, and Cast in Place Concrete. Refer to the design engineer’s specifications for these alternative materials.
3. Manufacturers:
   a. Plastifab
   b. Open Channel Flow

2.2 WEIRS

A. General: Weirs are a widely-accepted standard for measuring open channel flow. A licensed and competent professional engineer shall select and size the weir for each application.

B. Unit Responsibility: A single supplier shall be responsible for post installation support, delivery, and warranty of all flume components and shall represent the flume and its components as a single unit to the OWNER.

C. Types of generally accepted industry standard flumes include. The most appropriate type will depend on the specific hydraulic conditions of the proposed installation location:

1. Rectangular
2. V-Notch
3. Trapezoidal
4. Compound
5. Crump
6. Needle dam

D. Typical weir construction materials:

1. Fiberglass reinforced polyester
2. Aluminum
3. Galvanized Steel
4. Stainless Steel
5. Cast in Place Concrete

E. Manufacturers:

1. Plastifab
2. Open Channel Flow

2.3 LEVEL SENSORS

A. General: Level sensors are used in combination with weirs and flumes to measure flow rate in open channels. This section summarizes industry standard level sensing methods.

1. Bubbler Level Sensors
2. Ultrasonic Level Sensors
3. Pressure Transducer Level Sensors
4. Doppler Radar Level Sensors
5. Shaft Encoder Level Sensors

B. A competent and licensed professional engineer shall evaluate the installation location and hydraulic conditions to identify an appropriate level sensor.

C. Accuracy of the level sensor shall be within 1/8 inch for normal operating conditions.

D. Sensor shall communicate readings to a data collector (See Specification 40 63 01 Networked Data Collector Unit and 40 63 02 Remote Data Collector Unit)

E. Manufacturers:

1. Campbell Scientific
2. Sutron
3. Mace
4. YSI/WaterLog
5. Hach
6. Teledyne Isco

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