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WATER LEVEL SENSORS, WHAT WORKS?

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ABSTRACT: Water level sensors come in all shapes, sizes, and types and can range in price from a couple hundred to several thousand US dollars. This project utilizes real world examples from around the western United States to determine what level sensors work well and to document what characteristics may prevent them from providing accurate water level measurements in differing climates. Researchers have developed a calibration procedure that can be used in field or laboratory situations to obtain accurate calibrations of multiple types of water level sensors. Sensors that have been calibrated and installed are being monitored to determine their accuracy and reliability over several irrigation seasons.

Keywords: water level sensors, pressure transducers, ultrasonic, bubbler

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INTRODUCTION

As water delivery entities are incorporating increasing levels of remote monitoring and automated control into their operations, there is increasing need for water level sensors that function reliably. In today's age, a wide variety of sensors are available to measure and monitor water levels. These sensors can range in price from a couple hundred to several thousand US dollars, depending on the type and configuration of sensors selected. This research discusses the need for water level sensors and answers a question that many hydraulic structure operators and managers pose to U.S. Bureau of Reclamation (Reclamation) engineers: What water level sensors provide accurate measurements over a sustained period of time and in a range of field

conditions?

RESEARCH METHODOLOGY

This on-going research is conducted in cooperation with irrigation districts and Area Offices throughout Reclamation. To better represent realistic water level sensor usage, actual projects requiring water level sensors were selected for this study. Researchers installed and monitored the field performance of several water level sensing technologies at Reclamation related field sites. The work done can be summarized with the following objectives:

1. Identify the water level sensors that will be tested. Equipment representing a full range of level sensing technologies commonly employed on canal systems and in conjunction with hydraulic structures will be included in the study.
2. Develop a protocol for periodic water level sensor equipment calibrations and checks. Configure portable calibration equipment that can provide accuracy on par with Reclamation's laboratory calibration equipment. This equipment will be used for regular on-site sensor calibrations.
3. Develop a standardized data collection process. Identify frequency of collection, variables (water level, temperature, elevation, time), and storage.
4. Identify sites within cooperating districts where existing water level monitoring stations can have additional (redundant and different) water level sensors added without extensive costs.
5. Implement calibrations and monitor each water level sensor's field performance over time using the protocols and standards identified in steps 2 & 3.
6. Document each water level sensor's performance and note constraints and/or ancillary capabilities offered by each type of instrument.

TYPES OF WATER LEVEL SENSORS TESTED

Submersible Pressure Transducer

Submersible pressure transducers are installed in the water at the location where the level is to be measured. The transducers convert fluid pressure into a proportional electronic signal over a specified range of water levels. Sensor outputs can vary from 4–20 mA, 0–2.5 or 0–5 volt, SDI12 or Modbus.

Ultrasonic Downlooker

Ultrasonic downlookers are installed suspended above the water at the location where the level is to be measured. Sensors are mounted normal to the water surface such that an acoustic

signal can be sent and the return signal off the surface of the water can be received. Sensor intelligence determines the distance to the reflective surface using the speed of the signal in the surrounding air. Sensor outputs can vary from 4–20 mA, 0–2.5 or 0–5 volt, SDI12 or Modbus.

Float, Pulley, and Potentiometer

These instruments are installed in stilling wells where a float attached to a cable is wrapped around a pulley. As the float raises and lowers, the pulley turns a potentiometer, which outputs an electronic signal based on its position. The float and pulley units that are being used in this study have been custom fabricated by Reclamation using an inexpensive potentiometer with a 0–5 volt output and other parts commonly found in a hardware store.

Bubbler

Submerged air-filled tubes are installed with the free end at the location where the water level measurement is desired. Water level is determined by measuring the required pressure to push a bubble out the end of the tube. Sensor outputs can vary from 4–20 mA, 0–2.5 or 0–5 volt, SDI12 or Modbus.

Table 1 contains a list of the level sensors that have been included in the study so far. Sensors were selected from literature review and from recommendations by end users and other interested parties. Often when sensors are selected for field deployment, price becomes a limiting factor either because of budget constraints or the number of sensors required to accomplish the desired operation. For this reason an approximate price has been included for each of the sensors. Please note that sensor prices can fluctuate, and the authors recommend requesting updated cost information from the manufacturers.

CALIBRATION PROCEDURE

Researchers developed a portable calibration stand and procedure that provides the ability to accurately calibrate sensors in the laboratory or field. The calibration stand consists of a 10-ft-long piece of heavy-duty structural steel (Unistrut) attached to a 5-ft piece of light-duty structural steel (Unistrut). The light-duty Unistrut attaches to a standard surveying tripod (Figures 1 and 2) and is staked to the ground at the base. Pressure transducers and bubblers are tested in a 2-inch clear PVC pipe that is oriented vertically and attached to the heavy duty Unistrut with hose clamps. The pipe is filled using a 12 volt pump and 5 gallon storage reservoir filled with water. Ultrasonic downlookers are tested using a control arm that attaches to the heavy duty Unistrut and can be adjusted up and down the calibration stand using a thumb nob set screw (Figure 3). Acoustic signals are reflected off a level surface mounted at the bottom of the test stand (Figure 4). Depth and distance measurements used to calibrate each sensor are taken using a tape

measure that is attached to the outside of the calibration stand and can be read in 0.005-ft or 0.0625-inch increments depending on the user's preference.

Table 1 – List of sensors and their approximate cost

	Manufacturer	Model	Approx. Cost (\$/Unit)	Quantity
Pressure Transducer	AGP	PT-500	460	3
	AutoMata	Level-Watch	280	3
	Endress Hauser	FMX21	955	2
	Endress Hauser	FMX167	1045	1
	GE Druck	PTX 1730	525	2
	Global Water	WL400	590	2
	Instrumentation Northwest	98i	540	4
	Keller	Acculevel	480	2
	Keller	Levelgage	315	4
	Stevens	SDX	355	4
Ultrasonic Downlooker	Judd Communications	-	655	4
	AGP	IRU-2005	495	3
	AutoMata	Ultra-Ultra	720	2
	EMS	SR6	250	5
	Flowline	EchoPod DL10-00	255	2
	Flowline	EchoPod DX10-00	235	2
	Global Water (EMS)	WL700	665	2
	Nova Lynx (APG)	IRU 9423	475	2
	Siemens "The Probe"	7ML12011EF00	860	3
Other	Float, Pulley and Potentiometer	USBR Design	150	3
	Bubbler - Control Design	CD 103-1	595	4
	Bubbler - OTT	CBS – Std.	1690	1
	Dwyer Temperature & Humidity	RHP-2R11	200	3

To remain consistent throughout the research, calibrations are conducted the same for all level sensors and can be summarized in the following steps:

1. Setup and level the calibration stand.
2. Determine the range of the sensor/s that will be calibrated.
3. Setup the sensors with the same equipment that will be used to obtain the level measurements when installed in the field.
4. Collect 10 data points with the water surface or distance increasing.
5. Collect 10 different data points with the water surface or distance decreasing.
6. Determine the linear regression lines for each:

- a. The rising water surface or distance calibration
- b. The decreasing water surface or distance calibration
7. Compare the slopes and coefficient of determinations for both linear regressions.
8. Determine the average slope, print a tag with the sensors serial number, slope, and date of calibration, and attach it to the sensor cable.



Figure 1 – Calibration stand



Figure 2 – Calibration stand mount on tripod



Figure 3 – Ultrasonic mount

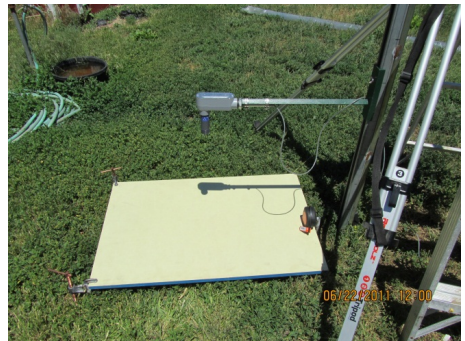


Figure 4 – Reflective surface for ultrasonics

SITE SELECTION

Geographic

Funding for this project was provided by Reclamation Science and Technology Research Program, with additional funds from Reclamation Area Offices and support from irrigation districts. To keep costs at a reasonable level and to ensure that the project would be useful to contributing partners, sites were selected where water level measurements were needed and existing infrastructure could support multiple measurement devices at one location.

Sites located near Yuma Arizona (extreme high temperature), Grand Junction Colorado (moderate temperatures), and Sterling Colorado (moderate temperatures) have already been identified and have instrumentation either installed and operational or in the process of being installed. Sites in Montana and North Dakota are both being investigated to represent a much colder environment.

Sensor location

Once a geographical location has been established, locating a site to install sensors that will provide stable water surface measurements is essential. This can be done by locating the instrument in a stilling well with a port of around 1/20–1/30 the size of the stilling well diameter connecting the well to the hydraulic structure (RECLAMATION 2001). Another method is to select a location free from drawdown influences, waves, or other disturbances that could influence water level readings. When installing a submerged sensor, it is important to make sure the sensor will not be damaged by debris or sediment in the flowing water.

SENSOR INSTALLATION PROCEDURE

The following procedure is followed when installing a new sensor at a site:

1. Determine the min and max water levels to be measured.
2. Determine the type of controller or base unit that will be used to record/transmit the data and what type of inputs it will accept.
3. Select multiple sensors that will accommodate the range and controller inputs.
4. Install a staff gauge and determine a reference to a readily identifiable datum or bench mark.
5. Install infrastructure that will allow multiple sensors to be installed in acceptable conditions (away from drawdown, waves, damage from debris, disturbances)
6. Install controller (base unit) in a secure location (preferably a lockable enclosure)
7. If applicable, install solar panel, ground-rod, antenna, and battery box.
8. Install sensors with the correct calibration slopes.
9. Trouble shoot sensors and base unit to ensure everything is working.
 - a. Simulate different level measurements if possible to make sure sensor is working.
 - b. Determine if the correct sign is used on the calibration slope by raising and lowering sensor ensuring that the output corresponds appropriately.
 - c. Simulate radio communications (if necessary).
 - d. Use controller menus to adjust offsets and shifts to check functionality.
10. Determine the sensor offset using a known datum, and program it into controller.

11. Record necessary information in the project book. Include: Installation date, sensor types and serial numbers, slopes, offsets, datum reference used and where it came from, controller ID and any other important information.

DATA COLLECTION

Data collected for each site becomes a unique challenge because each site will have unique sensors and datum. To help manage the data, water levels are recorded at least fifteen minutes apart. All data are arranged with a date and time stamp. In addition, all sites should log battery and charge voltage and internal base unit temperature, and one site in each geographical location should log the ambient air temperature. Where possible, manual data collection of the installed staff gauge will be taken periodically to compare to the logged data and determine what sensors, if any, are drifting or having any other issues. Data collection is in the beginning stages; any suggestions on how to improve the data management portion of the research are welcome.

KNOWN ISSUES

To date, there are several known issues that have arisen when it comes to installing and using water level sensors that may prevent accurate level measurements. Ultrasonic downlookers are sensitive to spider webs; most often the webs will concentrate near the sensor face and prevent accurate measurements. Although many of the manufacturers claim to be compensating for fluctuations in the temperature, the authors noticed that during rapid changes in temperature, some of the sensors that “compensate” for temperature fluctuations would not provide repeatable calibrations. Pressure transducers seem to be sensitive to calibration shifts if they are mishandled, dropped, or banged. To date, we have had one sensor stop working; we have not determined why, but we hope the manufacturer will replace the sensor as it malfunctioned after 2 months of use. Although many of the sensors claim to work with as little as 12 volts power, the authors have found that in most cases using a 12 to 24 volt converter to increase the supply voltage has provided more consistent measurements and calibrations. As more issues arise the authors will be documenting the problems and any solutions that are found.

CONCLUSIONS

To better understand water level sensors and to evaluate performance in a range of operating environments, the U.S. Bureau of Reclamation has been installing level sensors in varying climates and documenting any issues and successes that are observed. Sensors from multiple manufacturers and of multiple types have been purchased and installed in both hot and mild

climates including Yuma Arizona, Grand Junction Colorado, and near Sterling Colorado. Additional sites located in a colder environment are being investigated in Montana and North Dakota.

Once geographic locations are determined, sensor sites can be identified and equipment can be deployed in the field. Researchers developed a portable calibration procedure that allows all sensors to be calibrated before they are deployed. Sensors are calibrated in both a rising and decreasing water surface or distance, with 10 points in each direction. Calibrations are performed periodically when needed but at least once per year. Data is collected and compared against periodic manually recorded data to determine if sensors are drifting or calibrations have shifted. Data collection is just beginning and will be on-going for multiple years.

Several issues have already been documented that prevent accurate water level measurement, including by not limited to:

- Spider webs preventing ultrasonic downlookers from working
- Lagging temperature compensation in response to rapid temperature changes
- Sensors failing for no apparent reason
- 12-volt supply power inadequate for consistent measurements

As more issues and successes are found, the list will continue to grow.

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