Assessment of Continuous Groundwater-Level Monitoring for Long-Term Stewardship

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Purpose

The purpose of this analysis is to evaluate the efficacy of using automated groundwater sensors as part of a long-term groundwater monitoring program to support site stewardship. Long-term stewardship (LTS) activities have associated "mortgage costs", and groundwater monitoring may contribute significantly to such costs. Mortgage reductions may be realized using newer, automated systems to replace at least some of the traditional monitoring performed during active cleanup. The use of sensors is being evaluated as a component of long-term monitoring strategies for sites that are moving from a remedial action phase into an LTS phase. The use of sensors to replace some of the conventional manual measurements of environmental conditions can reduce the cost of long-term monitoring and provide far more frequent measurements of key parameters.

At the Argonne National Laboratory – East (ANL-E) site, continuous water-level recorders have been installed to aid in evaluating the long-term performance of a phytoremediation system designed to provide hydraulic containment as well as soil and groundwater cleanup. This report is a case study investigating the value, both technical and economical, of the use of sensors to determine whether the remedy is meeting objectives, and to evaluate the impact of sensor use on the overall groundwater monitoring strategy for the 317/319 Area. This analysis has been conducted to determine whether data collected by this method would benefit other sites with a significant groundwater monitoring component in their LTS plan.

Use of Sensors in LTS

Sensors are electronic devices used to monitor physical or chemical parameters of interest relevant to the purpose of a study. In environmental applications, sensors can be used to collect such information as contaminant concentrations in water and soils, surface water stage, groundwater levels, general water quality parameters (e.g., temperature, pH, specific conductance), and weather conditions (e.g., wind speed and direction, temperature, precipitation). Sensors can be connected to data loggers, providing the capability to collect and store information at specified or continuous time intervals. Collected data may then be downloaded to provide detailed information on time-varying parameters. The key advantage of the sensor and data logger approach compared with manual measurements is that the continuously recorded data will provide the investigator with a far better understanding of changing site conditions than will occasional spot measurements.

Various types of sensors are available for collecting site monitoring data for LTS. Although this case study focuses on one application of sensor technology relevant to one aspect of groundwater monitoring at ANL-E, it has implications for other sites.

317/319 Area Background and Current Sensor Use

Waste disposal practices of past decades at the 317/319 Area (Figure 1) of ANL-E have resulted in soil and groundwater contamination that persists today. The principal types of contaminants are solvents (i.e., dissolved-phase volatile organic compounds) and tritiated water. Remedial activities at the site have included installation of hydraulic barrier and groundwater extraction wells at the 319 landfill toe in 1996, installation of an interim groundwater extraction system downgradient of the 317 Area in 1997, source area treatment at 317 in 1997, implementation of an 800-tree phytoremediation system in 1999, and capping of the 319 landfill and expansion of its extraction well network in 1999. LTS for this portion of ANL-E has included a proposed long-term groundwater monitoring plan based on a detailed examination of groundwater contaminant distribution, well locations and depths, and the boundaries of a groundwater management zone (Moos 2002). The monitoring program involves sampling (primarily quarterly) of 55 groundwater monitoring wells. The current sampling program relies on manual sample collection and laboratory analyses, as well as manual measurement of groundwater elevations during sampling events, which each last approximately two weeks.

Half of the trees used in the phytoremediation system are patented TreeWells® that have roots directed to a 25-ft deep, confined aquifer downgradient of the contaminant source areas. The trees were installed in 2-ft diameter boreholes that are lined with a plastic sleeve. The trees therefore have the contaminated groundwater as their sole source of water.

To support the deployment of the phytoremediation system, a groundwater flow model was developed. Flow modeling was conducted initially to model the natural, transient changes in the flow field caused by seasonal changes in recharge to a confined, glacial drift aquifer. The model was calibrated to approximately 10 years of water level measurements from site monitoring wells. Anticipated effects of the phytoremediation system were then incorporated. The model, updated to include the as-built configuration of the phytoremediation system, indicates that, when mature, the plantation should provide hydraulic containment even during the winter months when the trees are dormant (Quinn et al. 2001).

A sensor to measure the depth to the water table was installed in each of seven monitoring wells at the 317 and 319 Areas (Figure 1) by the U.S. Environmental Protection Agency (EPA) and its contractor as part of an independent review of phytoremediation technology under the Superfund Innovative Technology Evaluation (SITE) program. These wells are all completed in the same aquifer as that targeted by the TreeWells®. The equipment used is Druck brand, model PDCR 1830 sensors, with vented cable. The vented cable provides measurements in gage pressure; no conversion of measurements relative to barometric pressure is necessary. The data are collected by several battery or solar-powered data loggers made by Campbell Scientific, Inc. (models CR510 and CR10X). Information sheets on the Druck and Campbell equipment are included in the Appendix.

The loggers have been set up to take a reading every hour. Depth-to-water measurements are relative to the surveyed top of the well casing elevation. Water levels (hydraulic heads) are calculated by subtracting the depth-to-water value from the top of casing elevation. A weather station is also connected to one of the loggers; data collected include air temperature, relative humidity, global solar radiation, wind speed, wind direction, soil temperature, and rainfall. Monitoring of the site also includes sensor and data logger equipment for sap flow on the poplars of the phytoremediation plantation and for soil moisture monitoring.

The estimated current (May 2002) cost of the in-place system of seven continuous groundwater-level monitoring sensors and related equipment is as follows:

Item	quantity	unit price	total price
Druck PDCR sensors	7	$505	$3535
Vented cable, approx. 100 ft per sensor	700	$1.50	$1050
Campbell Scientific 510 data logger	2	$775	$1550
Campbell Scientific CR10X data logger	1	$1190	$1190
Batteries, enclosures, misc.			$1000
TOTAL:			$8325

317/319 Area Continuous Water Level Results

Data loggers for the sensors at the seven continuously monitored wells have been programmed to collect hourly water-level readings since November 1999. The data up to December 31, 2001 have been downloaded and processed for analysis (Figure 2). The data for 2002, including the beginning of the 2002 growing season, will be downloaded and processed in June 2002, when the EPA and its contractor relinquish the equipment to ANL-E.

The available data demonstrate some aspects of the site that are relevant to its long-term monitoring. Figure 2 shows the response of the seven monitored wells to precipitation data over the 2+ year period. In Figure 2, a clear response to precipitation is seen, with water levels from six of the seven wells rising within one hour of the onset of precipitation. An obvious conclusion to be drawn is that water-level measurements for the purpose of creating a contour map of hydraulic head should be taken without any intervening rainfall. Ideally, these measurements should be made in a single event (one day) after several days of dry weather, because the water levels rise so quickly during rain. The magnitude of the water level response is roughly correlated with the amount of rainfall, although smaller wintertime precipitation events may create significant head increases because of concurrent snowmelt, such as occurred in February 2000.

The data in Figure 2 also show some obvious problems. Over some time periods, data were not recorded by from one to all seven recorders (e.g. December 2000 to February 2001). The datum of the sensor at each well was adjusted several times over the period of record, and comparison to hand measurements suggests that each datum may have an error (i.e., although the amplitude of the fluctuations is accurate, the actual heads displayed on the graph may be off slightly). An example is in April 2001 for well 317172. The weather station data were also unavailable for time periods. The precipitation data displayed in Figure 2 were therefore taken from the more reliable ANL meteorological station database. This station is 1 km west of the 317 Area, and data are available at http://gonzalo.er.anl.gov/ANLMET/ . For the last three months of 2001, the data for wells 317151, 317181, and 317452 were each logged randomly through each 24-hour period, rather than hourly. The reason for the malfunction has not been determined; however, possible explanations are that an electronic component has burned out or the logger needs to be reprogrammed. Well 319171 has essentially steady water levels for the last five months of 2001; this appears to be another equipment problem.

An evaluation of the available continuous water-level data at a shorter time scale reveals additional details about the effect of the phytoremediation system on the nearby water levels. The 800 trees, including 400 TreeWells® targeting the confined glacial drift aquifer, were planted in summer 1999. The TreeWells® were planted deep ("up to their shoulders") in order to maximize their initial root depth within their lined boreholes, and they were pruned heavily in order to reduce stress during their hot-weather planting. In 2000, the growing season was cool, with 90˚F not reached until September. During that summer, the trees did not exhibit aboveground growth; instead, the cool weather seemed to give them time to establish themselves. An evaluation of the data from this time period showed no obvious impact of the trees on water levels. However, in September 2000, during the warm period, the water levels in the vicinity of the plantation began exhibiting diurnal fluctuations (Figure 3). These fluctuations, which were up to 0.25 ft in monitoring well 317181, were present to a lesser degree at monitoring wells 317172, 317452, and 317151. A time lag is apparent, as water levels at monitoring wells 317181 and 317172 are low during the night and high during the day. Diurnal fluctuations were not present at 317391, which is upgradient of the phytoremediation system, or at the two 319 Area wells, 319261 and 319171. The water levels in the 319 Area wells may not be responding because of different hydrologic conditions or a smaller plantation.

Periods of diurnal fluctuations in May and July of the 2001 growing season are shown in Figures 4 and 5. The diurnal fluctuations vary in amplitude with the amount of daily solar radiation, as determined by inspection of the weather station data. What is noteworthy in the 2001 data is that the water level in well 317181 exhibits a gradual downward trend during sunny periods without rainfall (Figure 6). The daytime decrease of approximately 0.4 ft undergoes partial nighttime recovery, but an overall decline is apparent. For this young tree plantation, this result is an early indication of what can be expected in the upcoming years, namely that the maturing poplars will exert an increasing effect on the site's hydrology and ultimately result in hydraulic containment. This anticipated containment has been evaluated through groundwater modeling that incorporated the best estimate of water use by the TreeWells® through each month (Quinn et al. 2001). Results suggest that despite leaf-off winter periods, the tree plantation will provide full hydraulic containment on the larger western (317 Area) side of the plantation and a strong degree of containment on the eastern (319 Area) side.

Conclusions and Recommendations

The water-level sensor data collected to date have provided ANL-E staff with a valuable understanding of site hydrogeological conditions as shown by the observed water-level responses to precipitation and has demonstrated the effect of the young phytoremediation system on water levels. These relationships could not have been observed without the use of sensors and loggers to record data at a short (i.e., hourly) time interval. This monitoring will continue, providing one form of sensor information relevant to the site's long-term monitoring and performance assessment.

The following activities are recommended for improving the collection and maintenance of the current system of seven water level sensors and supporting equipment:

- Download data more frequently, especially during the growing season; inspect the data for errors; and fix any data-collection problems;
- Determine whether electronic component or logger programming problems interfere with collecting quality hourly readings;
- Move sensors to other wells, as appropriate, to provide improved site coverage;
- Verify the datum of each sensor by measuring the length of cable below the clamp that suspends the cable from the top of the well casing;
- Take hand measurements to verify that the logged water levels are accurate;
- Verify that the time stamping of each of the three loggers is synchronized; and
- Rely on the ANL meteorological station data for weather conditions.

Additional types of sensors may be considered for this site. In particular, sensors monitoring conductivity or chloride concentration at key wells could provide continuous information on the rate of change of natural attenuation processes occurring in the subsurface, as VOCs breakdown through biotic and abiotic means. This type of analysis, when tied to precipitation and water level data, would indicate the degree to which increased water levels, increased hydraulic gradient, and precipitation influence groundwater chemistry. Sensors of this type are available on the market. In-Situ, Inc., for example, has a TROLL 9000 sensor that, when fully equipped, can measure the following parameters: dissolved oxygen (% and mg/L), conductivity, resistivity, total dissolved solids, temperature, pH, oxidation reduction potential, salinity, water level, pressure, barometric pressure, nitrate, chloride, ammonium, ammonia, and turbidity. The cost of such a device, typically $3,000 to $9,000 per probe, depending on the number of sensors and the length of cable (Wardwell 2002), is high compared with the cost of a simple water level probe. However, the benefits of collecting this broad array of data on a continuous basis in terms of improved understanding of the hydrologic setting or performance of a remedial action may justify the cost. Telemetry options are also available, which could reduce time spent in the field, especially for remote sites. The additional cost of a telemetry system that can handle data from up to 32 probes is on the order of $12,000 (Wardwell 2002).

In the more distant future, more complex sensors that measure contaminant concentrations, or surrogate concentrations, in soil and groundwater could be deployed as they become practical and economical.

The results of this study have application to other LTS sites. Continuous water-level data are far more informative than occasional hand measurements for determining the response of a site's subsurface water levels to rainfall or other influences. The data collected on water levels is vital because of the need to understand groundwater flow directions and potential changes in flow directions, with associated influences on contaminant transport. The water-level information would be valuable at one or more time scales. Continuous data would provide the best available information for making comparisons between wet years and dry years, wet seasons and dry seasons, response to individual precipitation events (time to peak levels and character of recession curve), and short time scale events (e.g., effects of phytoremediation or background vegetation, monitoring the effect of extraction wells on containment, monitoring for effect from nearby aquifer testing or recirculation wells). Issues to resolve in the planning of a continuous water-level monitoring program include the selection of water-level sensor locations (quantity, location, depth, target hydrogeologic unit, required length of vented cable), the optimal locations for data loggers (number of sensors that can connect to each, avoiding interference with vehicular traffic, lawnmowers, etc., avoiding tripping hazards), available funding, desired observation frequency, and other sensor types that may be connected to the data loggers.

The information gleaned from a continuous water level monitoring program may lead site managers to more informed decisions about which hydrogeologic units are represented by which monitoring wells, and how the water levels and contaminant concentrations respond to recharge events. If significant responses occur, then accurate site water-level mapping must be done using water level hand measurements taken across the site in a short time frame (e.g., in a day), rather than over the course of a long well sampling program with intervening rain events. Improving the accuracy of data collection will result in a more efficient use of monitoring program resources, which could reduce the cost of long-term monitoring and provide a more accurate performance evaluation. Decisions made on an accurate understanding of the remediation system could eliminate expensive modifications to the system in the future.

Depending on site monitoring needs, other types of automatic sensor and data logging equipment could be used to monitor for surface water stage, contaminant concentrations, soil moisture, weather, and other site-specific monitoring parameters in order for site managers to understand transient aspects of their site on a proper time scale.

Sensor monitoring of any site should be subject to frequent quality checks to determine if the data are accurate. Malfunctions should be analyzed to determine if the problem is a logger programming issue, a bad electronic component, or another sort of problem.

In summary, the key application of sensor and data logger technology is determining whether the remedial system is functioning properly. This knowledge could impact monitoring strategies, resulting in proper scheduling of samples from proper locations. Elimination of extraneous samples would reduce the mortgage of an LTS monitoring program. At ANL-E, the investment of less than $10,000 of equipment has provided site managers with an early indication of the performance of a young phytoremediation system. Continued use of this system will provide the best information for evaluating hydraulic control and remediation progress in future years.

References

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Quinn, J.J., M.C. Negri, R.R. Hinchman, L.P. Moos, J.B. Wozniak, and E.G. Gatliff, 2001, "Predicting the Effect of Deep-Rooted Hybrid Poplars on the Groundwater Flow System at a Phytoremediation Site," *International Journal of Phytoremediation*, 3(1):41-60.

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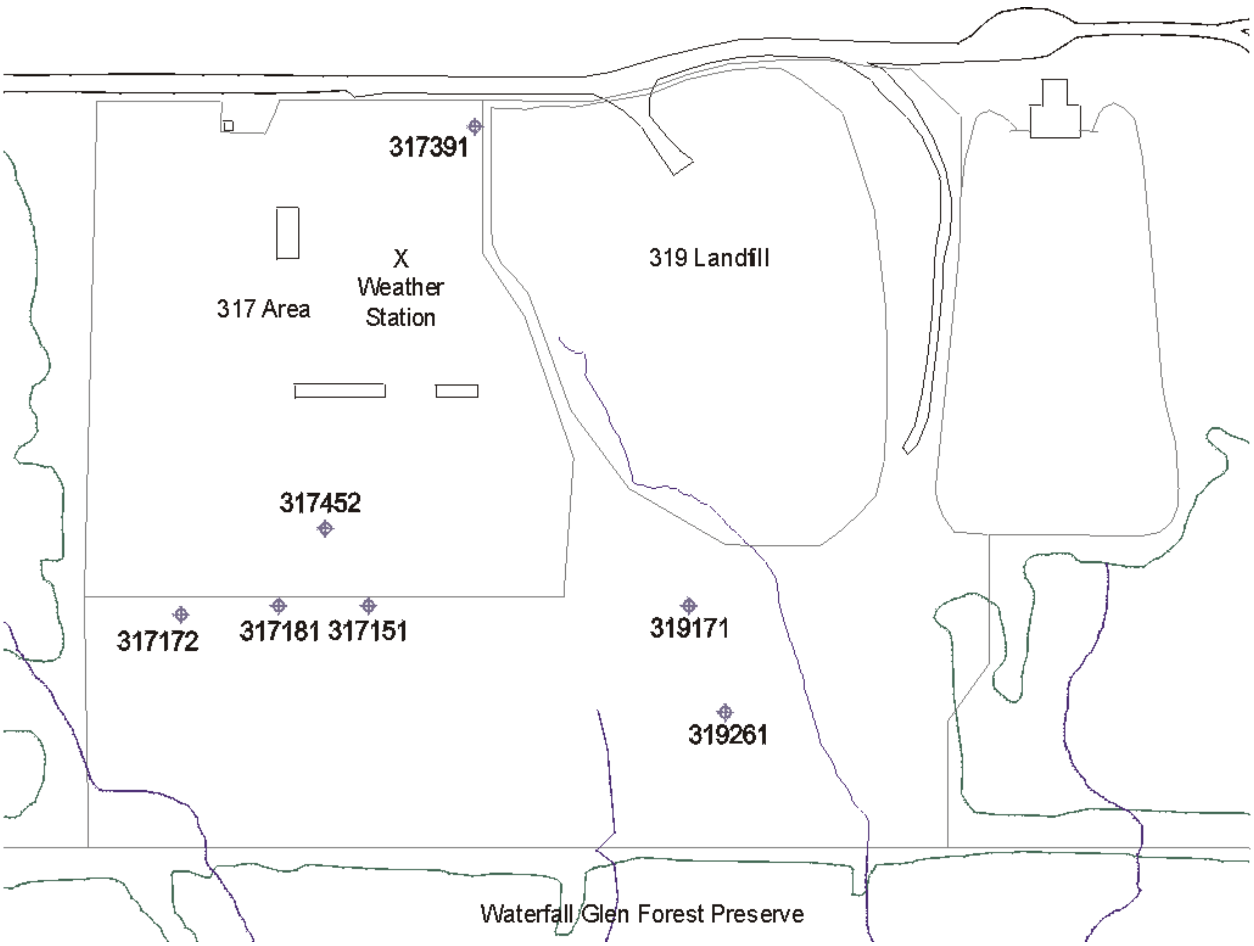


Figure 1. 317/319 Area at Argonne National Laboratory and locations of seven continuous water-level sensors

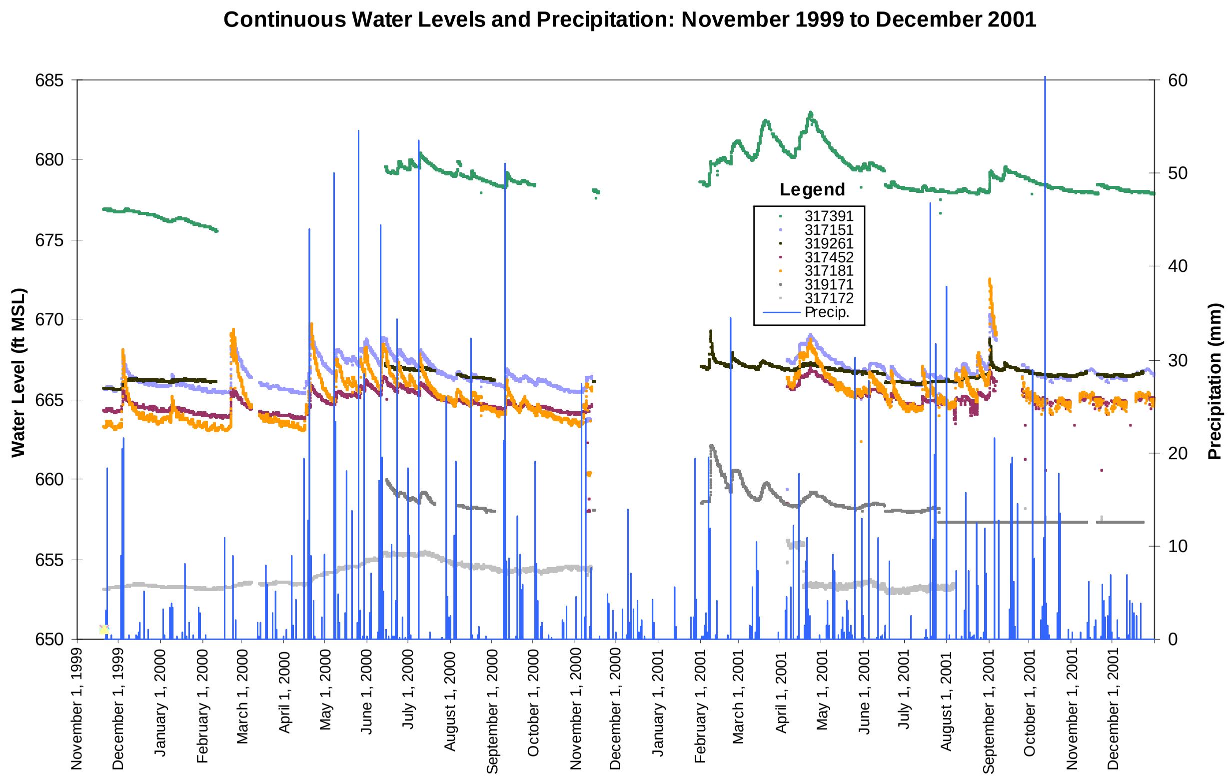


Figure 2. Continuous water level data and precipitation for November 1999 to December 2001

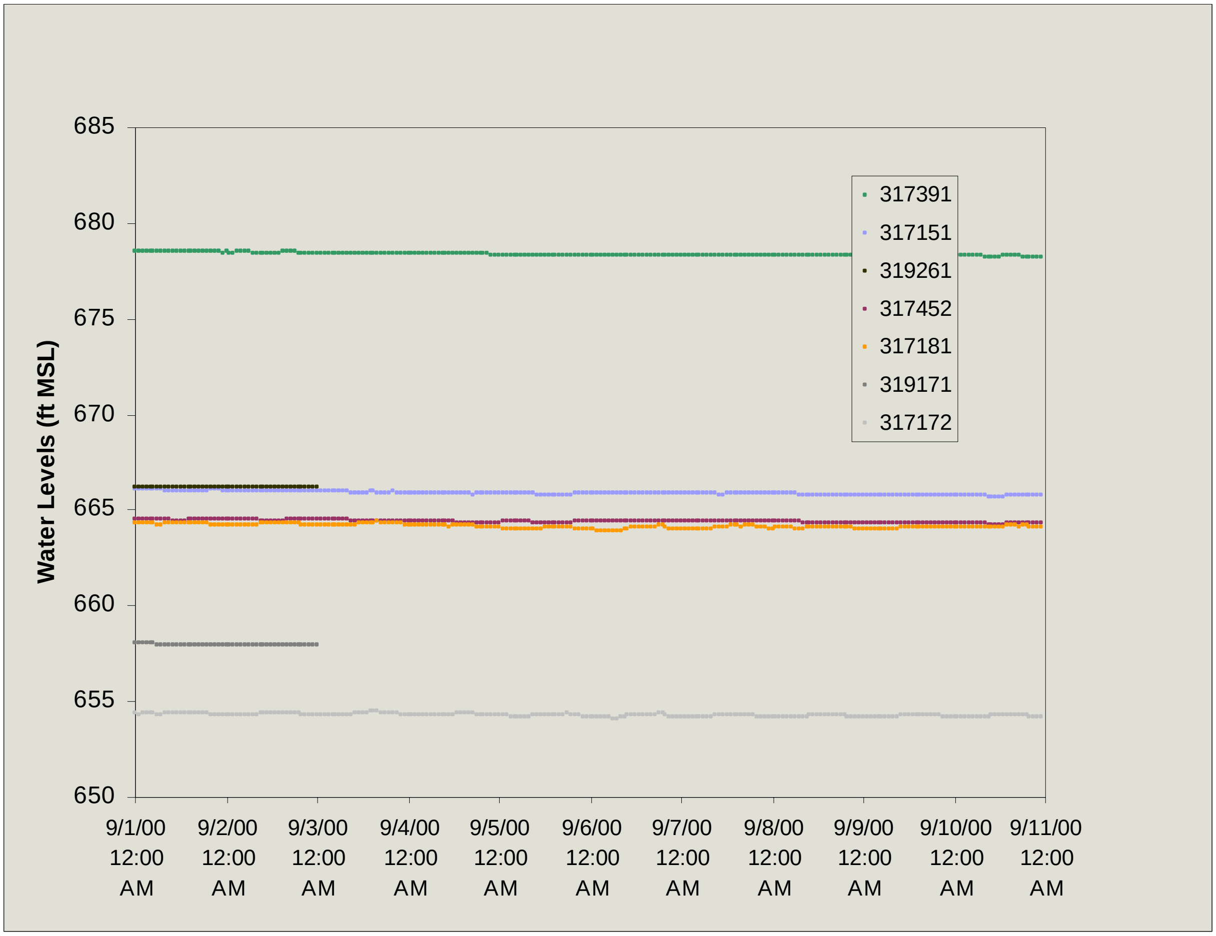


Figure 3. September 1-10, 2000 continuous water levels

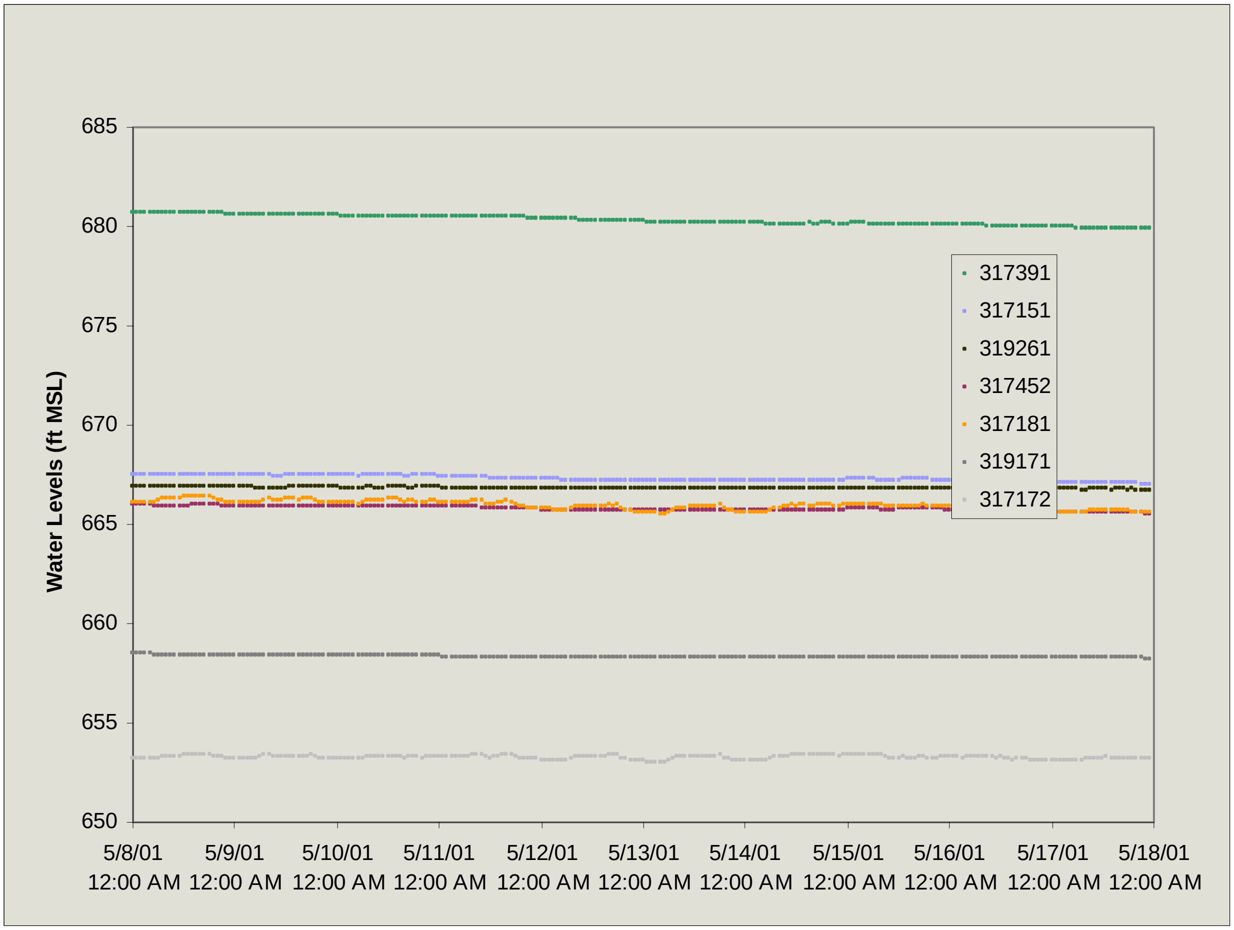


Figure 4. May 8-18, 2001 continuous water levels

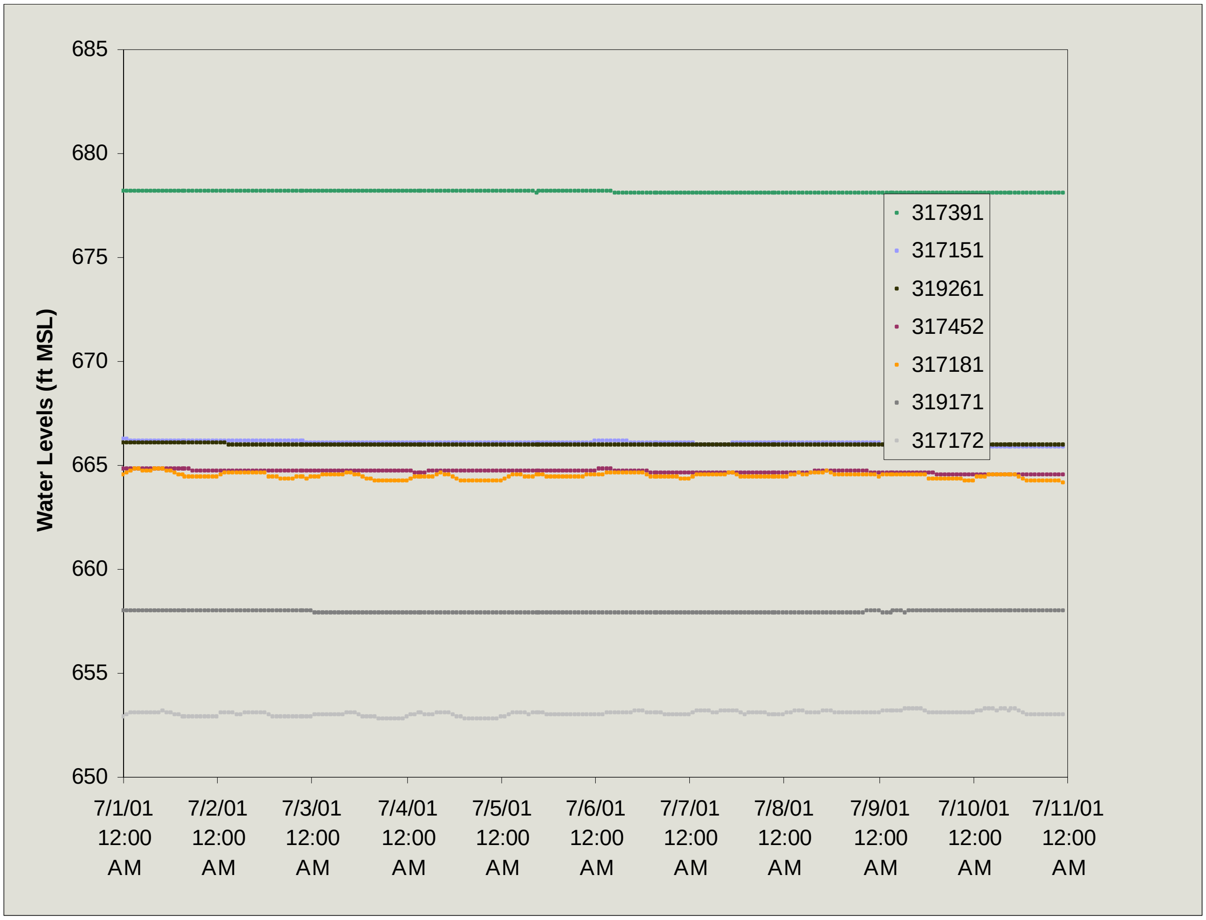


Figure 5. July 1-10, 2001 continuous water levels

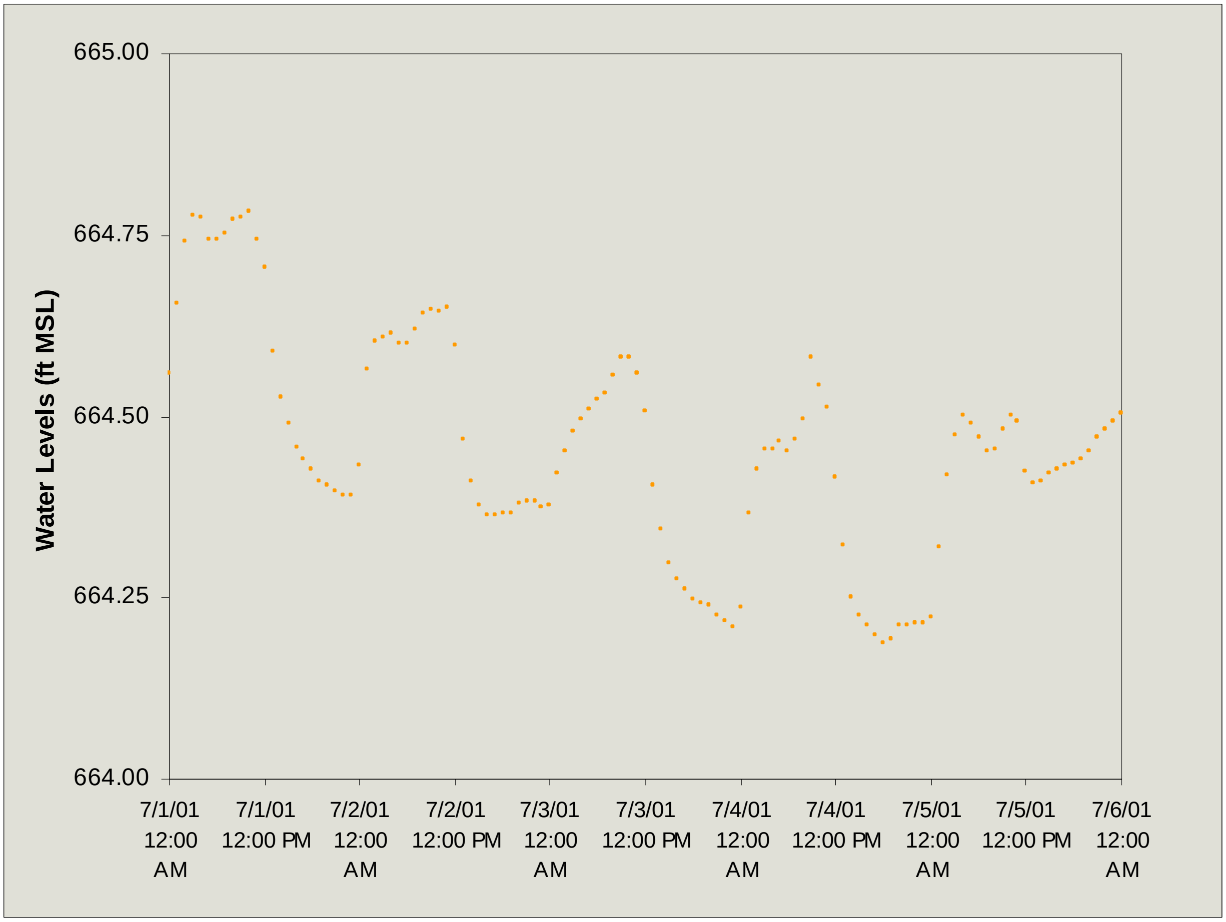


Figure 6. Well 317181 continuous water levels for July 1-5, 2001

Appendix

Information on

Druck PDCR 1830 water level sensor
http://www.druck.com/usa/products/us-1830.pdf

and

Campbell Scientific, Inc. data loggers
ftp://ftp.campbellsci.com/pub/outgoing/lit/cr510.pdf
ftp://ftp.campbellsci.com/pub/outgoing/lit/cr10x.pdf

Druck

1830 SERIES

Depth & Level Pressure Sensors

- ± 0.1% Accuracy
- Excellent stability
- High Integrity and Reliability
- Fully Welded Titanium Construction
- Backed by 5 Year Corrosion Warranty
- Outputs: 4-20mA, 0-100mV

1830 SERIES: Depth & Level Pressure Sensors

INTRODUCTION

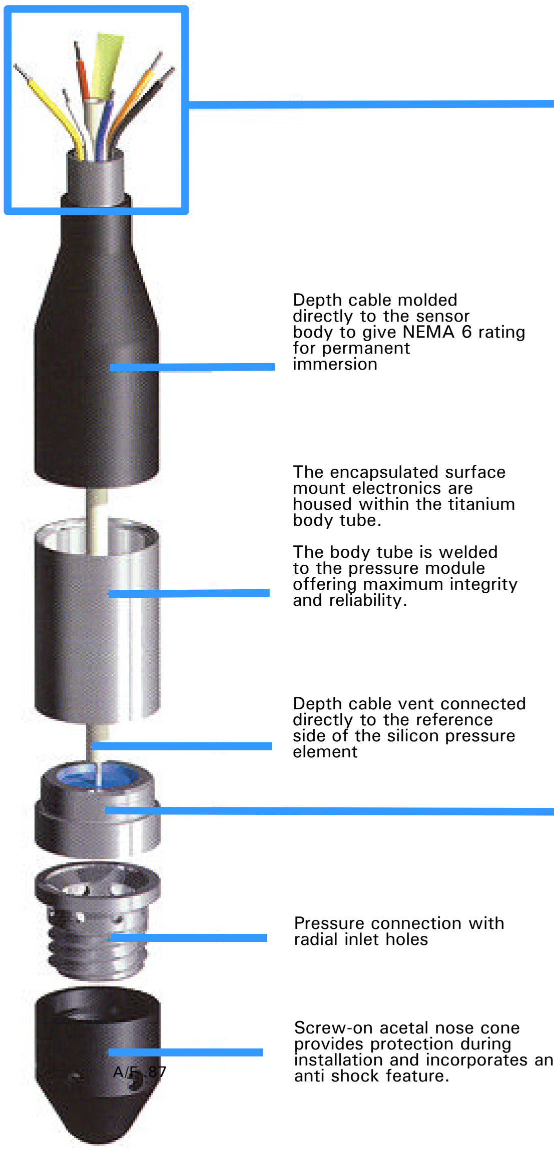
For over 20 years Druck have manufactured pressure sensors specifically for depth & level measurement.

The 1830 Series is the latest generation of fully submersible sensors which incorporate the most recent technical advances in depth & level measurement.

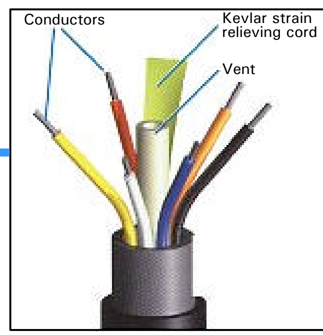
At the heart of the 1830 Series is a high stability pressure sensing element manufactured from micro-machined silicon developed within Druck's own Class 100 processing facility. The silicon sensing element is fully isolated from the media by a titanium isolation diaphragm. The use of titanium enables the sensors to be used in the most hostile of fluids where materials such as stainless steel cannot be considered.

Surface mount electronics within the all-titanium body tube assembly enables minimum sensor size with improved reliability. The purpose-designed vented electrical cable results in a depth and level sensor with the highest integrity and the lowest cost of ownership.

With a choice of millivolt or current outputs, small physical size and wide range of pressures, the 1830 Series can be used in a variety of applications from the smallest diameter bore holes to canals, rivers and reservoirs. They are ideally suited for depth/level application in the oceanographic and remediation industries. The 1830 Series depth-sensing transmitters are backed by Druck's 5-year corrosion warranty.



Depth Cable



Purpose-designed thick walled polyurethane sheathed depth cable with integral large diameter vent tube for fast response. The shielded cable incorporates a Kavlar strain relief cord with a breaking strength of 200 lbs. min.

Pressure Module Assembly

A high stability micro-machined silicon sensing element is contained within the all-titanium pressure module assembly. The sensing element is both electrically and physically isolated from the pressure media.

1830 SERIES: Specification

PDCR 1830

Operating Pressure Range
1, 2.5 psig
5, 10, 15, 20, 30, 50, 75, 100, 150, 200, 300, 500, 900 psia or psig
Other pressure units can be specified.

Overpressure
8x for 1 and 2.5 psig ranges
6x for 5 psig range
4x for ranges of 10psi and above up to a maximum of 2000 psi.

Pressure Containment
10x for 1, 2.5, and 5 psig ranges
6x for ranges of 10 psig and above to a maximum of 2000 psig; 3000 psi for all absolute ranges.

Media Compatibility
Fluids compatible with titanium, acetal and polyurethane.

Excitation Voltage
10 Volts at 5mA maximum.

Output Voltage
25mV for 1 psig range
50mV for 2.5 and 5 psi ranges
100mV for ranges 10 psi and above
Output is ratiometric to supply

Common Mode Voltage
Typically ± 3.5 to ± 9V with respect to the negative supply at 10 V excitation.

Combined Non-linearity, Hysteresis & Repeatability
± 0.1% F.S. BSL for all ranges.

Zero Setting
± 3mV maximum.

Span Setting
± 10mV maximum.

Long Term Stability
Typically ± 0.1mV/annum.

Operating Temperature Range
-4° to +140°F (-20° to + 60°C)

Compensated Temperature Range
+ 28° to + 86°F (-2° to + 30°C)

Temperature Effects
± 0.3% F.S. Total Error Band for ranges of 5 psi and above
± 0.6% F.S. Total error Band for 1 and 2.5 psi ranges.

Pressure Connection
Depth cone with radial inlet holes.

Electrical Connection
Vented Polyurethane depth cable
3 feet supplied as standard
Longer lengths available on request.

Ingress Protection
NEMA 6 (IP68) to 2300 feet of water

Insulation
Greater than 100 MegOhms at 500 Vd.c.

Safety

EMC emissions	EN50081-1
EMC immunity	EN50082-2
Certification	CE Marked

FM and CSA approved, Class 1, Div 1, Groups A, B, C, D Intrinsic Safe.

PTX 1830

Operating Pressure Range
1, 2.5 psig
5, 10, 15, 20, 30, 50, 75, 100, 150, 200, 300, 500, 900 psia or psig
Other pressure units can be specified.

Overpressure
8x for 1 and 2.5 psig ranges
6x for 5 psig range
4x for ranges of 10 psi and above up to a maximum of 2000 psi.

Pressure Containment
10x for 1, 2.5 and 5 psig ranges
6x for ranges of 10 psig and above to a maximum of 2000 psig; 3000 psi for all absolute ranges.

Media Compatibility
Fluids compatible with titanium, acetal and polyurethane.

Excitation Voltage
9 to 30 V d.c.

The minimum supply of voltage (V_{MIN}) that must appear across the transmitter terminals is 9V and is given by:-
V_{MIN} = Vs - (0.02 x R_L)

Where *Vs is excitation voltage in volts*
R_L is total loop resistance in ohms.

Output Current
4 to 20mA, 2 wire.

Combined Non-linearity, Hysteresis & Repeatability
± 0.1% F.S. BSL for all ranges.

Zero Offset & Span Setting
± 0.25% F.S. maximum.

Long Term Stability
Typically ± 0.1% F.S./annum

Operating Temperature Range
-4° to +140°F (-20° to + 60°C)

Compensated Temperature Range
+ 28° to + 86°F (-2° to + 30°C)

Temperature Effects
± 0.3% F.S. Total Error Band for ranges of 5 psi and above
± 0.6% F.S. Total Error Band for 1 and 2.5 psi ranges

Pressure Connection
Depth cone with radial inlet holes.

Electrical Connection
Vented polyurethane depth cable
3 feet supplied as standard
Longer lengths available on request.

Ingress Protection
NEMA 6 (IP68) to 2300 feet of water

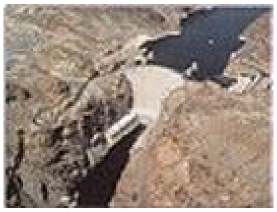
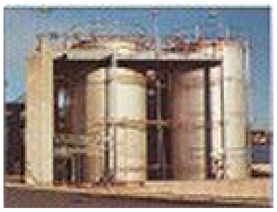
Insulation
Greater than 100 MegOhms at 500 Vd.c.

Voltage Spike Protection
Units will withstand a 600 V voltage spike in accordance with ENV 50142 without damage when applied between all excitation lines and case.

Safety

EMC emissions	EN50081-1
EMC immunity	EN50082-2
Certification	CE Marked

FM, UL and CSA approved, Class 1, Div 1, Groups A, B, C, D Intrinsic Safe; Cenelec Intrinsic Safe Approved.

1830 SERIES: Depth & Level Pressure Sensors

ORDERING INFORMATION

Please state the following:-
(1) Type number
(2) Pressure range
(3) Gauge or absolute
(4) Vented electrical cable length
3 ft. supplied as standard.

For non-standard requirements please refer to Druck.

ASSOCIATED PRODUCTS

Special Depth/Level Transmitter
PDCR/PTX 1880
- Suitable for aggressive environment
- Tefzel/Titanium construction
- Compact 0.69″
- Accuracy: ± 0.1%
- 4-20mA or mV output
- Seawater compatible

Cable Termination w/ Remote Electronics
SCU-220
- 2-wire 4-20mA
- Desiccant Indicator
- Din-Rail for lightning suppressor
- NEMA 4X

Cable Termination
STE 110
- Low maintenance
- Desiccant indicator
- Suitable for all sensors
- Rated NEMA 4X
- Din-Rail for lightning suppressor or IS barriers

Pressure Level Handbook
- Full range of products
- Installation details
- Application information
- Lightning protection

Lightning Arresters

MDK-24	2-wire
MDK-LC	4-wire
MDK-LV	3-wire

- DIN rail mountable
- Fits in STE 110 & SCU 220

Signal Conditioners/Controllers
DPI 280 Series
- Dual Scaling
- Suitable for all sensors
- Programmable features
- Level control/measurement
- RS 232 and RS 485 interface
- Up to 4 flexible alarms

DPI 280 Series Digital Process Indicators

Portable Barometric Standards
DPI 740
- Battery powered
- Pocket-sized
- Barometric range
- Accuracy: ± 0.015% value
- Stability: 100 ppm/year

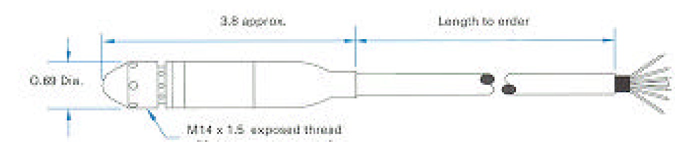
Field Pressure Calibrator
DPI 600 Series
- Accuracy: ± 0.025% F.S.
- Integral ranges to 300 psi
- Voltage/current power source
- Higher ranges to 10,000 psi available
- Integral pressure/vacuum generation

Continuing development sometimes necessitates specification changes without notice.

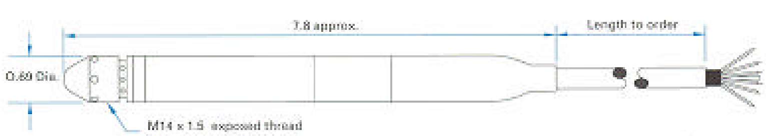
Druck Inc. is an ISO 9001 registered company

DPI 600 Series Field Pressure Calibrators

INSTALLTION DRAWINGS Dimensions: inches (NOT TO SCALE)



PDCR 1830



PTX 1830

PDCR 1830
Electrical Connection
Vented polyurethane cable

Red	Positive supply
White	Negative supply
Yellow	Positive output
Blue	Negative output
Shield	connected to case

Any other conductors not connected

PTX 1830
Electrical Connection
Vented polyurethane cable

Red	Positive supply
Black	Negative supply
Shield	connected to case

Any other conductors not connected

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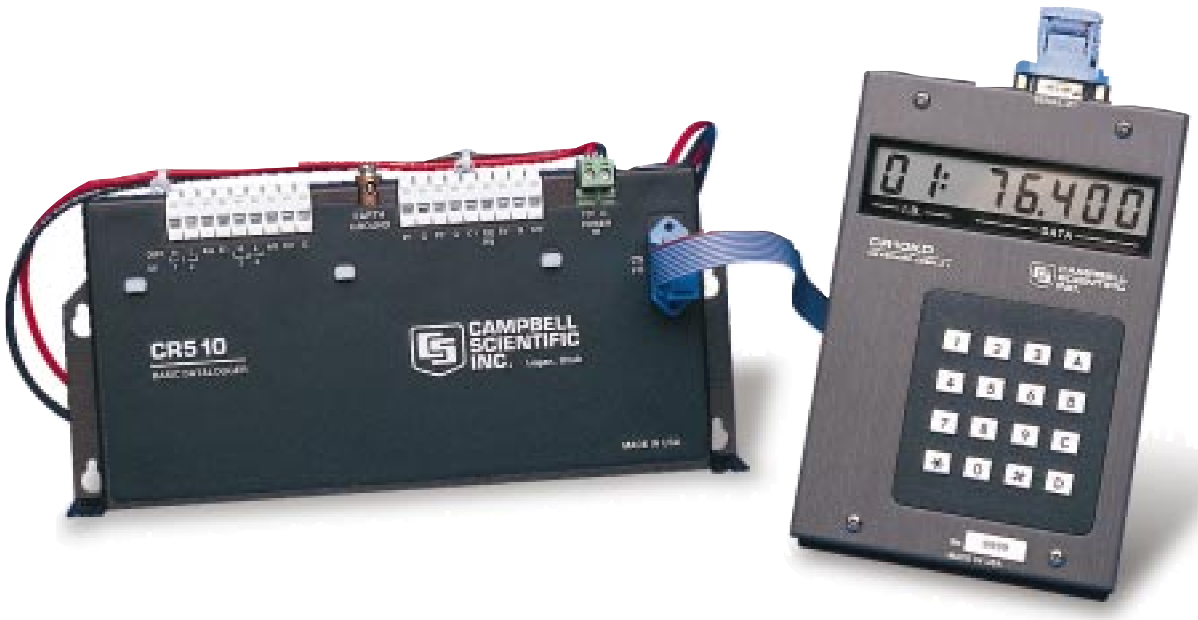
Representative

CR510 Basic Datalogger

Research-grade performance in a small package



System Description

Input/Output Connections

The CR510 provides precision channels that allow you to accurately measure a variety of sensors:

- Two differential (four single-ended) analog channels
- Two pulse counting channels (an additional channel [C2/P3] can also be configured to count switch closures)
- Two switched excitation channels
- Two digital I/O ports (both ports support SDI-12 sensors; control port C1 also supports output control of external devices)
- 5 and 12 V power terminals
- 9-pin CS I/O port

12-Volt Powered

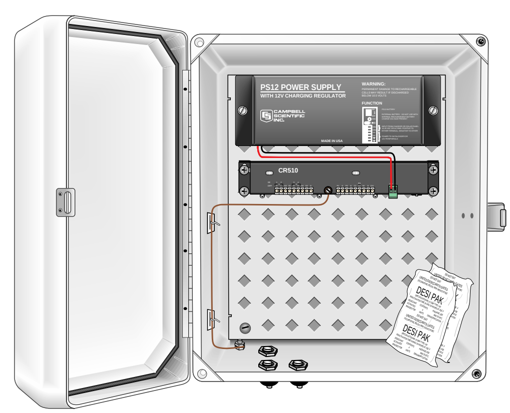
Any 12 VDC source can power the CR510; it typically uses our BPALK or PS12LA power supply. The BPALK consists of eight D-cell batteries and the PS12LA includes a sealed rechargeable battery that can be float-charged with a solar panel or AC power.

Storage Capacity

Data and programs are stored either in non-volatile Flash memory or battery-backed SRAM. The CR510 has two Final Storage areas that store up to 62,000 data points. Optional versions store up to 2 million data points.

Operation in Harsh Environments

The standard operating temperature range is -25° to +50°C; an extended range of -55° to +85°C is available. A CR510 housed in an enclosure with desiccant is protected from humidity and most contaminants.



Our weather-resistant enclosures (model 6447 10” x 12” shown), rechargeable power supplies, and the CR510’s minimal power requirements allow extended field use.

Cover photos: At left: CR510. At right: A shaft encoder measures water level; the data is transmitted to a base station via radio telemetry.

Telecommunications

Telecommunication options include multidrop (coaxial cable) and short-haul modems, radios (UHF, VHF, spread spectrum), telephones (including cellular and voice-synthesized), and satellite transmitters.

Up to 254 sites can be interrogated over a UHF or VHF frequency.

On-site Communications

Data and program transfer and storage capabilities are provided by our storage modules. Direct communication to the serial port of a computer, printer, or display is supported via RS-232 interfaces. For simple on-site data review and program changes, the CR10KD is recommended.

Battery-Backed SRAM and Clock

When the CR510 is disconnected from its 12 V power source, a user-replaceable internal battery retains programming and data, and powers the clock.

Ease of Use

Free software, shipped with the CR510 and also available from our Web site, allows you to choose compatible sensors, select scan and data output intervals, and output a wiring diagram to connect your sensors.

Support Software

Our computer software simplifies the exchange of data, programs, and commands between the CR510 and a PC. Software that is compatible with the CR510 includes Short Cut Program Builder, PC200W Starter Software, PC208W Datalogger Support Software, and Real-Time Data Monitor (RTDM). For more information, see our software literature.

Transient Protected

Encased in metal with gas discharge tubes on the panel, the CR510 has EMI filtering and ESD protection on all input and output connections.

Small Package

Built with surface-mount technology, the CR510 is a small (8.4” x 1.5” x 3.9”), lightweight (15 oz.) datalogger.

Sensors and Applications

The measurement precision, long-term reliability, and economical price of the CR510 make it ideal for a variety of applications that require a small number of sensors. Compatible sensors include:

- SDI-12 sensors
- Pressure transducers
- Shaft encoders
- Ultrasonic level sensors
- Flow meters
- Conductivity sensors
- pH sensors
- Thermistors
- Tipping bucket and weighing rain gages
- Wind vanes
- Anemometers
- Relative humidity sensors
- Pyranometers
- Leaf wetness sensors
- Fuel moisture / temperature sensors

The CR510 supports many water resources, agricultural, and meteorological applications including:

- Water level / stage
- Well draw-down test
- Water quality
- Alarm and pump actuation
- SCADA / Modbus
- Flood warning / ALERT
- Disease forecasting
- Wind studies

The CR510 supports many applications including the monitoring of fire conditions.

Note: The CR510 does not support multiplexers, SDM devices, or thermocouples. If you need additional channels for future use, consider a CR10X.

CR510 Specifications

Electrical specifications are valid over a -25° to +50°C range unless otherwise specified; non-condensing environment required. To maintain electrical specifications, yearly calibrations are recommended.

PROGRAM EXECUTION RATE

System tasks initiated in sync with real-time up to 64 Hz. One measurement with data transfer is possible at this rate without interruption.

ANALOG INPUTS

NUMBER OF CHANNELS: 2 differential or 4 single-ended, individually configured.

RANGE AND RESOLUTION:

Full Scale Input Range (mV)	*Resolution (µV) Differential*	*Single-Ended*
±2500	333	666
±250	33.3	66.6
±25	3.33	6.66
±7.5	1.00	2.00
±2.5	0.33	0.66

INPUT SAMPLE RATES: Includes the measurement time and conversion to engineering units. The fast and slow measurements integrate the signal for 0.25 and 2.72 ms, respectively. Differential measurements incorporate two integrations with reversed input polarities to reduce thermal offset and common mode errors.

Fast differential voltage:	4.2 ms
Slow differential voltage:	9.2 ms
Differential with 60 Hz rejection:	25.9 ms

ACCURACY: ±0.1% of FSR (-25° to 50°C);
±0.05% of FSR (0° to 40°C);
e.g., ±0.1% FSR = ±5.0 mV for ±2500 mV range

INPUT NOISE VOLTAGE (for ±2.5 mV range):
Fast differential: 0.82 µV rms
Slow differential: 0.25 µV rms
Differential with
60 Hz rejection: 0.18 µV rms

COMMON MODE RANGE: ±2.5 V

DC COMMON MODE REJECTION: > 140 dB

NORMAL MODE REJECTION: 70 dB (60 Hz with slow differential measurement)

INPUT CURRENT: ±9 nA maximum

INPUT RESISTANCE: 20 Gohms typical

ANALOG OUTPUTS

DESCRIPTION: 2 switched excitations, active only during measurement, one at a time.

RANGE: ±2.5 V

RESOLUTION: 0.67 mV

ACCURACY: ±2.5 mV (0° to 40°C);
±5 mV (-25° to 50°C)

CURRENT SOURCING: 25 mA

CURRENT SINKING: 25 mA

FREQUENCY SWEEP FUNCTION: The switched outputs provide a programmable swept frequency, 0 to 2.5 V square wave for exciting vibrating wire transducers.

RESISTANCE MEASUREMENTS

MEASUREMENT TYPES: The CR510 provides ratiometric bridge measurements of 4- and 6-wire full bridge, and 2-, 3-, and 4-wire half bridges. Precise dual polarity excitation using any of the switched outputs eliminates dc errors. Conductivity measurements use a dual polarity 0.75 ms excitation to minimize polarization errors.

ACCURACY: ±0.02% of FSR plus bridge errors.

PERIOD AVERAGING MEASUREMENTS

DEFINITION: The average period for a single cycle is determined by measuring the duration of a specified number of cycles. Any of the 4 single-ended analog input channels can be used. Signal attenuation and ac coupling is typically required.

INPUT FREQUENCY RANGE:

Signal peak-to-peak[1] Min.	*Max.*	*Min. Pulse w.*	*Max Freq.[2]*
500 mV	5.0 V	2.5 µs	200 kHz
10 mV	2.0 V	10 µs	50 kHz
5 mV	2.0 V	62 µs	8 kHz
2 mV	2.0 V	100 µs	5 kHz

RESOLUTION: 35 ns divided by the number of cycles measured

ACCURACY: ±0.03% of reading

TIME REQUIRED FOR MEASUREMENT: Signal period multiplied by the number of cycles measured plus 1.5 cycles + 2 ms.

PULSE COUNTERS

NUMBER OF CHANNELS: 2 eight-bit or 1 sixteen-bit; software selectable as switch closure, high frequency pulse, or low-level ac modes. An additional channel (C2/P3) can be software configured to read switch closures at rates up to 40 Hz.

MAXIMUM COUNT RATE: 16 kHz, eight-bit counter; 400 kHz, sixteen-bit counter. Channels are scanned at 8 or 64 Hz (software selectable).

SWITCH CLOSURE MODE:
Minimum Switch Closed Time: 5 ms
Minimum Switch Open Time: 6 ms
Maximum Bounce Time: 1 ms open without being counted

HIGH FREQUENCY PULSE MODE:
Minimum Pulse Width: 1.2 µs
Maximum Input Frequency: 400 kHz
Maximum Input Voltage: ±20 V
Voltage Thresholds: Count upon transition from below 1.5 V to above 3.5 V at low frequencies. Larger input transitions are required at high frequencies because of input filter with 1.2 µs time constant. Signals up to 400 kHz will be counted if centered around +2.5 V with deviations ≥ ± 2.5 V for ≥ 1.2 µs.

LOW LEVEL AC MODE:
(Typical of magnetic pulse flow transducers or other low voltage, sine wave outputs.)

Input Hysteresis: 14 mV
Maximum ac Input Voltage: ±20 V
Minimum ac Input Voltage:

*(Sine wave mV rms)**	*Range (Hz)*
20	1 to 1000
200	0.5 to 10,000
1000	0.3 to 16,000

*16-bit config. or 64 Hz scan req'd for freq. > 2048 Hz

DIGITAL I/O PORTS

DESCRIPTION: Port C1 is software selectable as a binary input, control output, or as an SDI-12 port. Port C2/P3 is input only and can be software configured as an SDI-12 port, a binary input, or as a switch closure counter (40 Hz max).

OUTPUT VOLTAGES (no load): high 5.0 V ±0.1 V; low < 0.1 V

OUTPUT RESISTANCE: 500 ohms

INPUT STATE: high 3.0 to 5.5 V; low -0.5 to 0.8 V

INPUT RESISTANCE: 100 kohms

SDI-12 INTERFACE STANDARD

DESCRIPTION: Digital I/O Ports C1-C2 support SDI-12 asynchronous communication; up to ten SDI-12 sensors can be connected to each port. Meets SDI-12 standard Version 1.2 for datalogger and sensor modes.

EMI and ESD PROTECTION

The CR510 is encased in metal and incorporates EMI filtering on all inputs and outputs. Gas discharge tubes provide robust ESD protection on all terminal block inputs and outputs. The following European CE standards apply.

EMC tested and conforms to BS EN61326:1998.

Details of performance criteria applied are available upon request.

CPU AND INTERFACE

PROCESSOR: Hitachi 6303.

PROGRAM STORAGE: Up to 16 kbytes for active program; additional 16 kbytes for alternate programs. Operating system stored in 128 kbytes Flash memory.

DATA STORAGE: 128 kbytes SRAM standard (approximately 62,000 values). Additional 2 Mbytes Flash available as an option.

OPTIONAL KEYBOARD DISPLAY: 8 digit LCD (0.5" digits).

PERIPHERAL INTERFACE: 9 pin D-type connector for keyboard display, storage module, modem, printer, card storage module, and RS-232 adapter.

BAUD RATES: Selectable at 300, 1200, and 9600, 76,800 for certain synchronous devices. ASCII communication protocol is one start bit, one stop bit, eight data bits (no parity).

CLOCK ACCURACY: ±1 minute per month

SYSTEM POWER REQUIREMENTS

VOLTAGE: 9.6 to 16 Vdc

TYPICAL CURRENT DRAIN: 1.3 mA quiescent, 13 mA during processing, and 46 mA during analog measurement.

BATTERIES: Any 12 V battery can be connected as a primary power source. Several power supply options are available from Campbell Scientific. The model CR2430 lithium battery for clock and SRAM backup has a capacity of 270 mAhr.

PHYSICAL SPECIFICATIONS

SIZE: 8.4" x 1.5" x 3.9" (21.3 cm x 3.8 cm x 9.9 cm). Additional clearance required for serial cable and sensor leads.

WEIGHT: 15 oz. (425 g)

WARRANTY

Three years against defects in materials and workmanship.

We recommend that you confirm system configuration and critical specifications with Campbell Scientific before purchase.

CAMPBELL SCIENTIFIC, INC.
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CR10X Measurement and Control System

A Rugged Instrument with Research-Grade Performance

The CR10X is a rugged measurement and control system that delivers accurate, reliable measurements in a variety of applications. Designed for both research and day-to-day monitoring operations, the CR10X combines the ability to measure virtually any sensor with the control capability to respond to specific site conditions (e.g., open flood gates, turn fans off/on). From simple to complex, Campbell Scientific data acquisition systems are at work on every continent, at sea, and in space.

Measurement Example - Weather Station

Measurements: The CR10X measures wind speed and direction, air temperature, relative humidity, precipitation, barometric pressure, soil moisture and temperature, and solar radiation. Scan rates are programmable from 1/64 second to 2.5 hours.

Data Processing: Output intervals for raw or processed data are user-specified. Typically, hourly and daily summaries (e.g., maxima, minima, averages, histograms) are stored. Conditional outputs, such as rainfall intensity, can also be processed and stored.

Data Storage: The non-volatile Flash memory and lithium-backed SRAM store up to 62,000 data points—equating to more than three months of data when typical hourly and daily outputs are stored from typical meteorological application. An optional memory expansion allows the CR10X to store more than one million data points—or about 12 years' worth of meteorological data.

Data Retrieval: Data can be transferred to a computer using telephones (including cellular or voice-synthesized), radio telemetry, short-haul modems, satellite transmitters, multidrop modems, Ethernet, or storage modules.

12-Volt Power: The low-power design allows the CR10X to operate up to one year on a 7 Ahr, unregulated 12 Vdc source, depending on scan rate, number of sensors, data retrieval method, and external temperature.

Measurement and Control Example - Head Gates

Measurements: The CR10X measures water level upstream, downstream, and in a diversion ditch.

Data Storage/Processing/Retrieval: Data are recorded over time, showing trends. The CR10X calculates flow and summarizes the data as averages, maxima, or totals. A PC, Palm handheld, or keyboard display can show both real-time and summarized data.

Equipment Control: The CR10X controls multiple headgates based on measured conditions, flow, or time. The control capabilities of the CR10X allow levels to be maintained, even in the absence of a manager. The gates can also be controlled remotely by the water master if conditions change.

Alarms: If high or low water levels are detected, the CR10X can initiate on-site alarms, data or voice-synthesized warning calls, or activate pagers.

Cover Photos At left: CR10X. From top right: *Water Resources* Reservoir gate control via radio telemetry, Emery County, Utah; *Industrial/Automotive* Super Comp dragster performance testing, (photo courtesy of RPM photography); *Meteorology* Weather station installation, St. Mary's Lake, Glacier National Park, Montana; *Geotechnical/Historical Preservation* CR10X monitors cracks in the southwest bastion of fort, Castillo de San Marcos National Monument, St. Augustine, Florida.

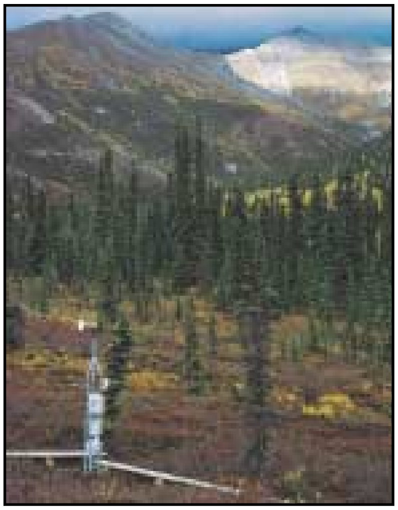
Applications

The measurement precision, flexibility, long-term reliability, and economical price of the CR10X make it ideal for scientific, commercial, and industrial applications.

Meteorology

The CR10X is used in long-term climatological monitoring, meteorological research, and routine weather measurement applications. Sensors the CR10X can measure include:

- cup, propeller, and sonic anemometers
- tipping bucket and weighing rain gages
- wind vanes
- evaporation pans and lysimeters
- pyranometers
- ultrasonic distance sensors
- thermistors, thermocouples, and RTDs
- capacitance and strain gage barometric pressure sensors
- RH sensors
- cooled mirror hygrometers



Weather station at Denali National Park, Alaska, monitors meteorological and soil conditions.

The CR10X can output data in your choice of units (e.g., wind speed in miles per hour, meters per second, or knots). Standard CR10X outputs include wind vector averaging, sigma, theta, histograms, saturation vapor pressure, and vapor pressure from wet / dry bulb temperatures.

Air Quality

The CR10X can monitor and control gas analyzers, particle samplers, and visibility sensors. The CR10X can also automatically control calibration sequences and compute conditional averages that exclude invalid data (e.g., data recorded during power failures or calibration intervals).

Network of approximately 20 stations continuously monitors air quality, northern Oquirrh Mountains, Utah.

Agriculture and Agricultural Research

The versatility of the CR10X allows measurement of agricultural processes and equipment in applications such as:

- plant water research
- canopy energy balance
- machinery performance
- plant pathology
- crop management decisions
- food processing / storage
- frost prediction
- irrigation scheduling
- integrated pest management

Typical agricultural research sites integrate meteorological, soil, and crop measurements.

Soil Moisture

The CR10X is compatible with the following soil moisture measurement technologies:

- **Soil moisture blocks** are inexpensive sensors that estimate soil water potential.
- **Matric water potential sensors** also estimate soil water potential but are more durable than soil moisture blocks.
- **Time-Domain Reflectometry Systems (TDR)** use a reflectometer controlled by a CR10X to accurately measure soil water content. Multiplexers allow sequential measurement of a large number of probes by one reflectometer, reducing cost per measurement.
- **Self-contained water content reflectometers** are sensors that emit and measure a TDR pulse.
- **Tensiometers** measure the soil pore pressure of irrigated soils and calculate soil moisture.

Industry

Vehicle Testing

The CR10X performs well in cold / hot temperature, high altitude, off-highway, and cross-country tests. It can measure temperature, fuel flow, velocity, acceleration, engine RPM, force, displacement, and electrical system load. The CR10X is often interfaced to a dashboard-mounted heads up display for luminescent data display in real time.

HVAC Systems

The CR10X optimizes HVAC performance by monitoring and controlling pumps, fans, and starter motors.

Process Control

Both product and assembly line status can be monitored simultaneously, providing on-line quality control while minimizing production down-time.

Water Resources

The CR10X is well-suited to remote, unattended monitoring of hydrologic conditions. Many hydrologic sensors, including SDI-12 sensors, interface directly to the CR10X.

Typical hydrologic measurements:

- **Water level** is monitored with incremental shaft encoders, double bubblers, ultrasonic level transducers, resistance tapes, or strain gage or vibrating wire pressure transducers. Some shaft encoders require a QD1 Interface. Vibrating wire transducers require an AVW1, AVW4, or AVW100 Interface.
- **Well draw-down tests** use a pressure transducer measured at logarithmic intervals or at a rate based on incremental changes in water level.
- **Ionic conductivity** measurements use one of the switched excitation ports from the CR10X.
- **Samplers** are controlled by the CR10X as a function of time, water quality, or water level.
- **Alarm and pump actuation** are controlled through digital I/O ports that operate external relay drivers.

Datalogger measures water level using a shaft encoder, then calculates flow. The data are telemetered, via radio, to the water master for further processing, review, and archive. Stilling well at diversionary dam, Emery County, Utah.

Mining, Earth Science, and Geotechnical

The small size, low power requirements, and wide operating temperature range of the CR10X make it a good choice for these remote, typically harsh applications. Multiple CR10Xs can be accessed via telemetry allowing monitoring and review of measurements across an entire study area. Vibrating wire sensors, strain gages, load cells, pressure transducers, linear and string potentiometers, GPS receivers, and frequency output devices are regularly used in these systems.

Historical Preservation

Weather measurements on the Sphinx provided input for its preservation, Cairo, Egypt.

The CR10X's small size, versatility, and expandability allow it to simultaneously monitor environmental variables that could be detrimental to works of art (e.g., relative humidity, solar radiation, air temperature, water table level, gas concentrations). By using multiplexers or SDMs, these parameters (and others) can be monitored at a number of locations in a building or across a structure. This enables comprehensive monitoring, management, remediation efforts, and documentation.

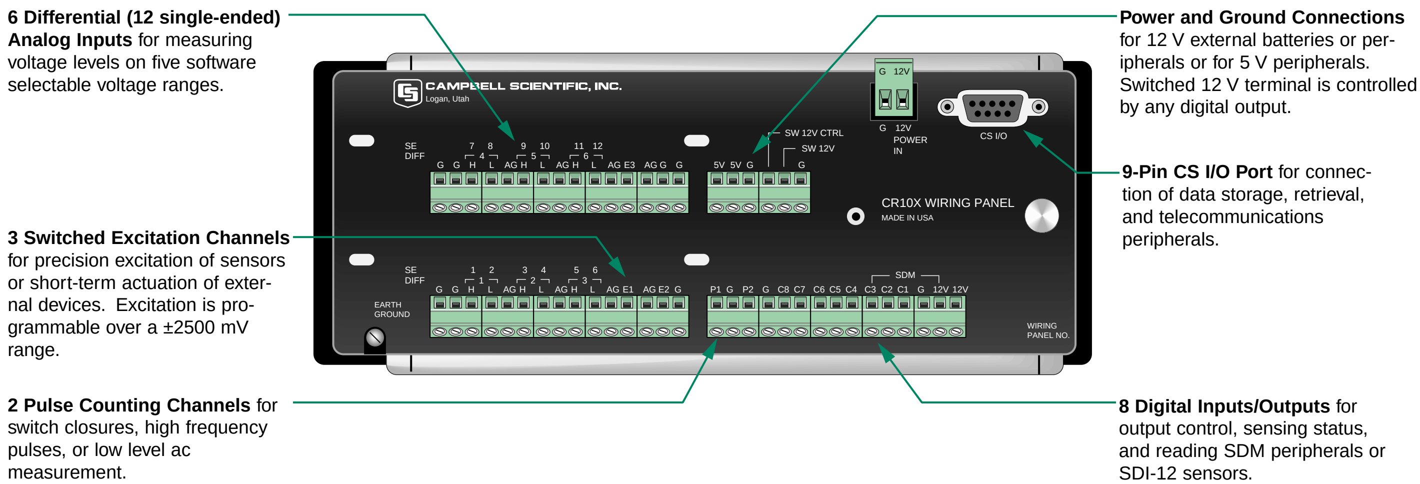
Other Applications

- Avalanche control, snow science, and Arctic research
- Highway and pavement studies
- Sporting events
- Space research

Our dataloggers measured the effects of gravity on a test structure aboard a NASA low-gravity flight.

System Description

The CR10X consists of a Measurement and Control Module and a detachable Wiring Panel. The Mean Time Between Failures (MTBF) for the CR10X is over 180 years.



Measurement and Control Module

The module measures sensors, drives direct communications and telecommunications, reduces data, controls external devices, and stores data and programs in on-board, non-volatile storage. The electronics are RF shielded and glitch protected by the sealed, stainless steel canister. A battery-backed clock assures accurate timekeeping. The multi-tasking operating system allows simultaneous measurement and communication.

The CR10X contains a comprehensive set of processing, math, and program control instructions to build a datalogger program. The maximum rate the CR10X can execute its program is 64 times per second. (The maximum rate a single input can be measured is 750 samples per second.) Data and programs are stored either in non-volatile Flash memory or battery-backed SRAM. The standard memory stores 62,000 data points in two Final Storage areas. Optional versions store up to one million data points.

Several operating system options are available. The standard operating system stores data in an array-based format. This format stores arrays of data at specified intervals or when some other set condition has been met. An operating system that stores data in a table-based format is available. The table-based format allows you to group and store like-data in seperate tables. Other optional operating systems support Modbus and ALERT protocols. Modbus protocol enables the CR10X to interface with SCADA and MMI software packages. ALERT protocol allows the CR10X to be used in an ALERT system. CSOS Downloading Software allows you to change or upgrade the operating system without opening the CR10X and changing hardware.

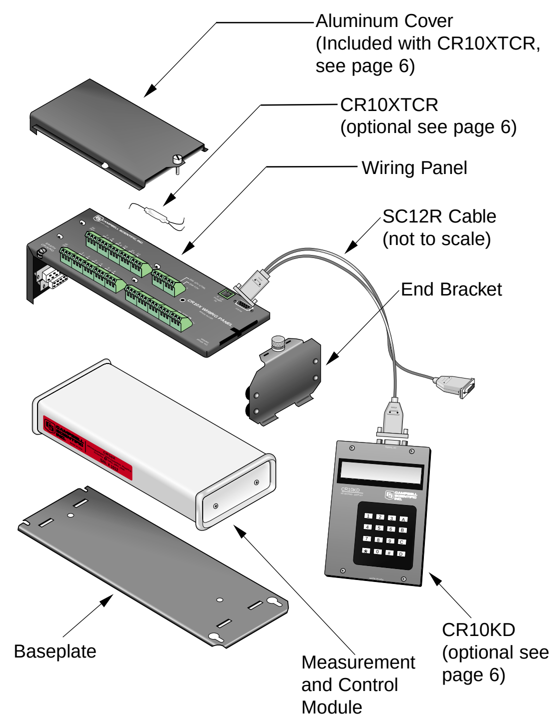
Standard operating range is -25° to +50°C. With the extended range option, the CR10X's electronics are tested and guaranteed over a -55° to +85°C range.

SC12 and SC12R Cables

The SC12 is a ribbon cable connects communication devices to the CR10X's 9-pin port. The SC12 is shipped with most of our communication devices, including our phone modems, satellite transmitters, and keyboard display. The SC12R cable is a rugged, temperature resistant alternative (purchased separately).

Wiring Panel

The Wiring Panel consists of a top and side panel, end bracket, and baseplate. The top panel includes screw terminals for sensor connections and a 9-pin CS I/O port; the end bracket attaches the Wiring Panel to the Control Module and to an enclosure-mounted or free-standing baseplate. The Control Module easily disconnects from the Wiring Panel allowing field replacement without rewiring the sensors. Gas tubes on the wiring panel provide rugged electrostatic discharge protection.



Peripherals

Typical field-based CR10X systems include a data retrieval option, power supply, and environmental enclosure. Peripherals that expand the CR10X's measurement and control capabilities are also available.

Data Storage and Retrieval Options

To determine the best option for your application, consider the accessibility of your site, availability of services (e.g., cellular phone or satellite coverage), quantity of data to collect, and desired time between data-collection sessions.

Telephone Networks use landlines or cellular transceivers for communications between the datalogger and PC. Our voice-synthesized modem allows a CR10X "speak" to you or transmit data to a computer.

Radio Frequency (RF) Communications are supported via UHF, VHF, spread spectrum, or meteor burst radios.

Direct Links use the SC32A RS-232 Interface to provide an optically isolated connection between the CR10X and a laptop or desktop computer.

Palm™ Handhelds can communicate with the CR10X via a serial cable and PConnect Software (purchased separately). On-site communications supported include setting the datalogger's clock, monitoring real-time data, retrieving stored data, and transferring datalogger programs. Contact Campbell Scientific about compatibility with Handspring Inc.'s Visor™.

Short Haul Modems provide local communications between the CR10X and a PC with an RS-232 serial port.

Multidrop Interface links a central computer to as many as 200 dataloggers on a single coaxial cable.

Satellite Transmitters transmit data via the GOES, Argos, or INMARSAT-C satellite systems. Campbell Scientific's SAT HDR GOES transmitter has been certified by NESDIS for High Data Rates (HDR).

Ethernet Communications Peripherals allow the CR10X to communicate over a local network or the Internet.

Storage Modules reliably store data and datalogger programs. This allows you to transport programs between the datalogger and PC or use the storage modules to serve as an independent backup of the datalogger data.

CR10KD Keyboard Display programs the CR10X, manually initiates data transfer, and displays data. One CR10KD can be carried from station to station in a CR10X network.

Thermocouple Reference Thermistor

Campbell Scientific offers the CR10XTCR which provides a temperature reference for thermocouple measurements. It requires one single-ended analog input channel. A cover that reduces temperature gradients along the input terminals is included.

Channel Expandability

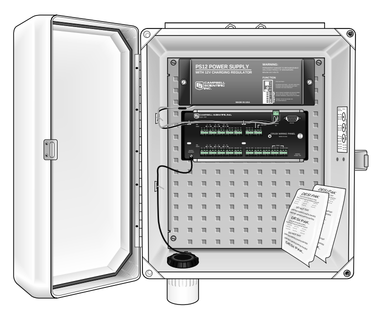
The already formidable measurement and control capabilities can be expanded using CSI multiplexers and Synchronous Devices for Measurement (SDMs). SDMs are addressable peripherals that expand digital I/O ports, plus interval channels analog output ports, and datalogger measurement capabilities. Up to 16 SDMs can be connected to three CR10X control ports.

The INMARSAT-C satellite system provides telecommunications for remote Argentine stations where phone lines are impractical.

Multiplexers increase the number of sensors that can be measured by a CR10X by sequentially connecting each sensor to the datalogger. Several multiplexers can be connected to, and controlled by, a single CR10X.

Enclosures

A CR10X housed in a weather-resistant enclosure can collect data under extremely harsh conditions. The enclosure protects the CR10X from dust, water, sunlight, or pollutants. Typically a 12" x 14" or 16" x 18" enclosure is used. They are NEMA 4X enclosures modified for cable entry. The enclosures attach to a flat surface, 1.00" to 1.25" IPS pipe, or vertical mast or leg of a tripod or tower. These white fiberglass-reinforced polyester enclosures are UV-stabilized and reflect solar radiation, reducing temperature gradients inside the housing. An internal mounting plate is prepunched for easy system configuration and exchange of equipment in the field. A lockable hasp adds security.

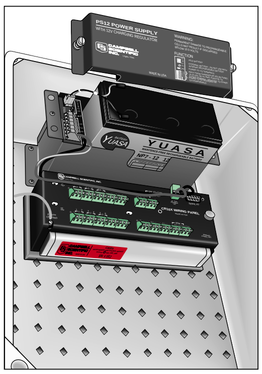


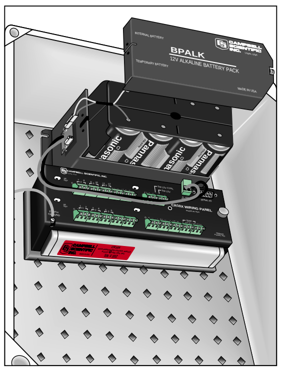
A CR10X housed in an enclosure with desiccant is protected from humidity and most contaminants.

Power Supplies

Any 12 Vdc source can power the CR10X; a PS12LA or BPALK is typically used. The PS12LA includes one 7 Ahr rechargeable battery, charged with ac power (requires the optional wall charger) or a solar panel. The BPALK consists of eight non-rechargeable D-cell alkaline batteries with a 7.5 Ahr rating at 20°C. An external AA-cell pack that supplies power while the D-cells are replaced is included.

The BP12 and BP24 battery packs are also available. The BP12 and BP24 have nominal ratings of 12 and 24 Ahrs, respectively. The batteries should be connected to a charging regulator, typically our CH12R, and a charging source. For information about analyzing your system's power requirements, see our Power Supply brochure or Application Note 5-F. Both can be obtained from www. campbellsci.com





Minimal power requirements allow extended field use while powered by the PS12LA (left) or the BPALK (right).

Systems that include high current drain peripherals such as satellite transmitters or are located where it's inconvenient to replace batteries might require batteries with larger Ahr capacities than our PS12LAs or BPALKs. Campbell Scientific offers the BP12 and BP24 battery packs for these systems.

Software Packages

Campbell Scientific software supports datalogger programming, communications between the datalogger and PC, and data display. Brief descriptions follow; for more information, see our literature or Web site.

Getting Started

PCTour for Windows provides a quick tutorial that introduces you to the CR10X and our PC208W software.

SCWin program builder creates datalogger programs requiring only sensor measurement and data output. It supports most of the sensors on our U.S. price lists.

PC200W starter software allows you to transfer a program to, or retrieve data from, a CR10X via a direct communications link (i.e., an optically isolated RS-232 interface or a similar device).

SCWin, PCTour for Windows, and PC200W are available at no charge from http://www.campbellsci.com/resource.html

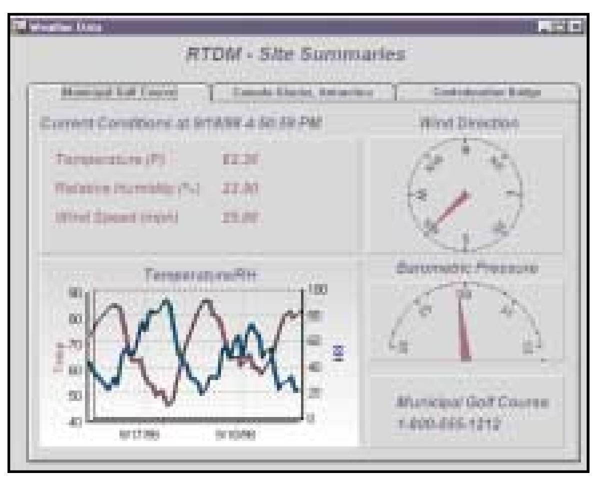
Datalogger Support Software

LoggerNet 2.0 and PC208W are our full-featured software. They support:

- direct connection and telecommunications links
- scheduled data collection
- programming for most commercially available sensors as well as devices such as SDMs, multiplexers, and relays
- storage module communication
- report generation

Real-Time Data Monitor (RTDM)

RTDM allows experienced users to create custom graphic screens. RTDM supports automatic generation of JPEG output for Internet display. Developer and display-only versions are also available.



RTDM is powerful, versatile software that can display real-time or archived data in bar, lines, area, or point charts. Automatic generation of JPEG outputs facilitates displaying information on Internet pages.

CR10X Specifications

Electrical specifications are valid over a -25° to +50°C range unless otherwise specified; non-condensing environment required. To maintain electrical specifications, yearly calibrations are recommended.

PROGRAM EXECUTION RATE

Program is synchronized with real-time up to 64 Hz. One channel can be measured at this rate with uninterrupted data transfer. Burst measurements up to 750 Hz are possible over short intervals.

ANALOG INPUTS

NUMBER OF CHANNELS: 6 differential or 12 single-ended, individually configured. Channel expansion provided by AM16/32 or AM416 Relay Multiplexers and AM25T Thermocouple Multiplexers.

ACCURACY: ±0.1% of FSR (-25° to 50°C);
±0.05% of FSR (0° to 40°C);
e.g., ±0.1% FSR = ±5.0 mV for ±2500 mV range

RANGE AND RESOLUTION:

Full Scale Input Range (mV)	*Resolution (µV) Differential*	*Single-Ended*
±2500	333	666
±250	33.3	66.6
±25	3.33	6.66
±7.5	1.00	2.00
±2.5	0.33	0.66

INPUT SAMPLE RATES: Includes the measurement time and conversion to engineering units. The fast and slow measurements integrate the signal for 0.25 and 2.72 ms, respectively. Differential measurements incorporate two integrations with reversed input polarities to reduce thermal offset and common mode errors.

Fast single-ended voltage:	2.6 ms
Fast differential voltage:	4.2 ms
Slow single-ended voltage:	5.1 ms
Slow differential voltage:	9.2 ms
Differential with 60 Hz rejection:	25.9 ms
Fast differential thermocouple:	8.6 ms

INPUT NOISE VOLTAGE (for ±2.5 mV range):
Fast differential: 0.82 µV rms
Slow differential: 0.25 µV rms
Differential with 60 Hz rejection: 0.18 µV rms

COMMON MODE RANGE: ±2.5 V

DC COMMON MODE REJECTION: >140 dB

NORMAL MODE REJECTION: 70 dB (60 Hz with slow differential measurement)

INPUT CURRENT: ±9 nA maximum

INPUT RESISTANCE: 20 Gohms typical

ANALOG OUTPUTS

DESCRIPTION: 3 switched, active only during measurement, one at a time.

RANGE: ±2.5 V

RESOLUTION: 0.67 mV

ACCURACY: ±5 mV; ±2.5 mV (0° to 40°C)

CURRENT SOURCING: 25 mA

CURRENT SINKING: 25 mA

FREQUENCY SWEEP FUNCTION: The switched outputs provide a programmable swept frequency, 0 to 2.5 V square wave for exciting vibrating wire transducers.

RESISTANCE MEASUREMENTS

MEASUREMENT TYPES: The CR10X provides ratiometric bridge measurements of 4- and 6-wire full bridge, and 2-, 3-, and 4-wire half bridges. Precise dual polarity excitation using any of the switched outputs eliminates dc errors. Conductivity measurements use a dual polarity 0.75 ms excitation to minimize polarization errors.

ACCURACY: ±0.02% of FSR plus bridge resistor error.

PERIOD AVERAGING MEASUREMENTS

The average period for a single cycle is determined by measuring the duration of a specified number of cycles. Any of the 12 single-ended analog input channels can be used. Signal attentuation and ac coupling are typically required.

INPUT FREQUENCY RANGE:

Signal peak-to-peak[1] Min.	*Max.*	*Min. Pulse w.*	*Max Freq.[2]*
500 mV	5.0 V	2.5 µs	200 kHz
10 mV	2.0 V	10 µs	50 kHz
5 mV	2.0 V	62 µs	8 kHz
2 mV	2.0 V	100 µs	5 kHz

[1]Signals centered around datalogger ground
[2]Assuming 50% duty cycle

RESOLUTION: 35 ns divided by the number of cycles measured

ACCURACY: ±0.03% of reading

TIME REQUIRED FOR MEASUREMENT: Signal period times the number of cycles measured plus 1.5 cycles + 2 ms

PULSE COUNTERS

NUMBER OF PULSE COUNTER CHANNELS: 2 eight-bit or 1 sixteen-bit; software selectable as switch closure, high frequency pulse, and low level ac.

MAXIMUM COUNT RATE: 16 kHz, eight-bit counter; 400 kHz, sixteen-bit counter. Channels are scanned at 8 or 64 Hz (software selectable).

SWITCH CLOSURE MODE
Minimum Switch Closed Time: 5 ms
Minimum Switch Open Time: 6 ms
Maximum Bounce Time: 1 ms open without being counted

HIGH FREQUENCY PULSE MODE
Minimum Pulse Width: 1.2 µs
Maximum Input Frequency: 400 kHz
Voltage Thresholds: Count upon transition from below 1.5 V to above 3.5 V at low frequencies. Larger input transitions are required at high frequencies because of input filter with 1.2 µs time constant. Signals up to 400 kHz will be counted if centered around +2.5 V with deviations ≥ ±2.5 V for ≥ 1.2 µs.
Maximum Input Voltage: ±20 V

LOW LEVEL AC MODE
(Typical of magnetic pulse flow transducers or other low voltage, sine wave outputs.)

Input Hysteresis: 14 mV

Maximum ac Input Voltage: ±20 V

Minimum ac Input Voltage:

(Sine wave mV RMS)	Range (Hz)
20	1.0 to 1000
200	0.5 to 10,000
1000	0.3 to 16,000

DIGITAL I/O PORTS

8 ports, software selectable as binary inputs or control outputs. 3 ports can be configured to count switch closures up to 40 Hz.

OUTPUT VOLTAGES (no load): high 5.0 V ±0.1 V; low < 0.1 V

OUTPUT RESISTANCE: 500 ohms

INPUT STATE: high 3.0 to 5.5 V; low -0.5 to 0.8 V

INPUT RESISTANCE: 100 kohms

SDI-12 INTERFACE STANDARD

Digital I/O Ports C1-C8 support SDI-12 asynchronous communication; up to ten SDI-12 sensors can be connected to each port. Meets SDI-12 Standard version 1.2 for datalogger and sensor modes.

CR10XTCR THERMOCOUPLE REFERENCE

POLYNOMIAL LINEARIZATION ERROR: Typically <±0.5°C (-35° to +50°C), <±0.1°C (-24° to +45°C).

INTERCHANGEABILITY ERROR: Typically <±0.2°C (0° to +60°C) increasing to ±0.4°C (at -35°C).

CE COMPLIANCE (as of 09/01)

STANDARD(S) TO WHICH CONFORMITY IS DECLARED:
EN55022: 1995 and EN61326: 1998

EMI and ESD PROTECTION

IMMUNITY: Meets or exceeds following standards:
ESD: per IEC 1000-4-2; ±8 kV air, ±4 kV contact discharge
RF: per IEC 1000-4-3; 3 V/m, 80-1000 MHz
EFT: per IEC 1000-4-4; 1 kV power, 500 V I/O
Surge: per IEC 1000-4-5; 1 kV power and I/O
Conducted: per IEC 1000-4-6; 3 V 150 kHz-80 MHz

Emissions and immunity performance criteria available on request.

CPU AND INTERFACE

PROCESSOR: Hitachi 6303

PROGRAM STORAGE: Up to 16 kbytes for active program; additional 16 kbytes for alternate programs. Operating system stored in 128 kbytes Flash memory.

DATA STORAGE: 128 kbytes SRAM standard (approximately 60,000 data values). Additional 2 Mbytes Flash available as an option.

OPTIONAL KEYBOARD DISPLAY: 8-digit LCD (0.5" digits)

PERIPHERAL INTERFACE: 9 pin D-type connector for keyboard display, storage module, modem, printer, card storage module, and RS-232 adapter.

BAUD RATES: Selectable at 300, 1200, 9600 and 76,800 bps for synchronous devices. ASCII communication protocol is one start bit, one stop bit, eight data bits (no parity).

CLOCK ACCURACY: ±1 minute per month

SYSTEM POWER REQUIREMENTS

VOLTAGE: 9.6 to 16 Vdc

TYPICAL CURRENT DRAIN: 1.3 mA quiescent, 13 mA during processing, and 46 mA during analog measurement.

BATTERIES: Any 12 V battery can be connected as a primary power source. Several power supply options are available from Campbell Scientific. The Model CR2430 lithium battery for clock and SRAM backup has a capacity of 270 mAhr.

PHYSICAL SPECIFICATIONS

SIZE: 7.8" x 3.5" x 1.5" - Measurement & Control Module; 9" x 3.5" x 2.9" - with CR10WP Wiring Panel. Additional clearance required for serial cable and sensor leads.

WEIGHT: 2 lbs

WARRANTY

Three years against defects in materials and workmanship.

We recommend that you confirm system configuration and critical specifications with Campbell Scientific before purchase.

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