

Riparian Monitoring Protocol Implementation Plan for Park Units in the Southern Colorado Plateau Network

Standard Operating Procedure (SOP) # 5

Well Installation and Hydrologic Monitoring

Version SCPN_Riparian_SOP5_20180930

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This SOP is adopted from the Northern Colorado Plateau Network's SOP #10 Well installation and hydrologic monitoring, Version 1.05 (August 2016) in Weissinger, R., D. Witwicki, H. Thomas, A. Wight, K. Lund, and M. Van Grinsven. 2018. Riparian monitoring of wadeable streams protocol for park units in the Northern Colorado Plateau Network: Version 1.05. Natural Resource Report NPS/NCPN/NRR—2018/1636. National Park Service, Fort Collins, Colorado.

This SOP describes installation techniques, instrument set up, and monitoring measurements for surface and groundwater wells. An equipment list is provided in SOP #1. The initial site visit includes infrastructure installation and development, programming and installing dataloggers, and taking initial water level and discharge measurements. Monitoring revisits include water level and discharge measurements, downloading dataloggers, and infrastructure maintenance, if needed. When conducting hydrologic monitoring visits, attempt to access the wells by walking downstream of them to avoid unnecessary trampling along vegetation transects. Installation and ground surface elevations are also recorded during the reach survey (SOP #6).

A three-person team comprised of one installation specialist and two assistants is required to effectively complete the installation tasks described below. All crew members should have good physical endurance and be capable of heavy lifting. Revisits can be completed by one person.

1. Installation type

The most appropriate type of installation depends on the type of data being collected and the stream setting. For groundwater monitoring, including riparian groundwater and instream installations at intermittent or ephemeral streams, below-ground installations such as a well or piezometer are required. For surface water monitoring, including perennial streams and instream installations that focus only on flood flows, above-ground installations may be cheaper and easier to install and maintain over time.

1. Hydrologic monitoring assemblies

The objective of a groundwater monitoring installation is to place the well screen deep enough into the floodplain to penetrate the perennial alluvial water table or deep enough into the channel to maintain contact

with water levels as they decline during the growing season. The deepest placement possible allows for water level measurements to be obtained as groundwater levels decline during long-term drought. Wells can be installed to maximum depths of 3 to 6 meters in finer textured substrates such as sand and gravel by pounding steel pipe into the ground with a post pounder. Deeper wells or wells that must be placed in coarser substrates, such as cobble, may require the use of mechanized equipment, such as a backhoe. Only manual installation will be addressed in this SOP.

Two distinct types of installations are used at hydrologic monitoring sites: riparian wells and stage gages.

Riparian well – This type of well is used to measure groundwater levels in the riparian zone. Riparian wells may be constructed of galvanized steel or PVC pipe; either is typically constructed of one screened section attached to one or more solid pipe sections (risers) reaching to the ground surface (see Fig. 3a). For galvanized steel wells, also known as sand-point wells, an iron drive point at the base of the screened section enables driving the well into the substrate with a post pounder. Sand-point wells are typically used in relatively coarse substrate like sand and gravel. Because the screened section of these wells is relatively short, care should be used where subsurface layers of clay or dense silt are probable. Groundwater can perch on top of these occluding lenses or layers, and driving the screened section too deeply through an occluding layer can result in an apparently dry well or poor connectivity with the perched water table. In coarse, sandy substrate where hydraulic connectivity is high, water levels in a near-channel riparian well can provide a proxy for instream surface water stage.

PVC wells (Fig. 3b), 1.5 or 2 inches in diameter, are typically used in finer-grained (silt) or clayey sediments, and the screened section may be five to 10 ft. in length. They are installed into a 3- to 4-inch diameter hole augered through the substrate to the appropriate depth.

Stage gage – These installations are used to monitor surface water stage and/or groundwater levels in the stream channel. Instrumented stage gages are also known as recording stage gages (RSGs). There are two types of stage gage installations. An *instream well* enables monitoring of both surface flow stage and groundwater level in ephemeral or intermittent systems. It typically consists of one screened drive well point on the bottom attached to a *screened galvanized riser* (see Fig. 3a). The screened riser section must be fabricated prior to the field visit. Cut off the point of a screened well point and thread 1- to 1.25 inches of the base of the remaining screened section to accept a standard heavy-duty drive coupling. A rock saw will easily cut off the tip, and this equipment is often available at maintenance yards in park units. The thread will need to be cut at a local hardware store or plumbing supply.

An *angle iron/pipe gage* consists of a short length of 1.5- or 2-inch diameter galvanized or schedule 80 PVC pipe bolted to a five- to 8-foot length of heavy gauge angle iron.

1.1 Determining locations for hydrologic installations

Hydrologic installations are typically placed on a riparian monitoring transect, (Figure 1), and preferably in a straight section of the reach with smooth flow. Attempt to avoid placing a well downstream of side canyons, culverts, or any other source of disturbance that could increase flood risk or channel change. At some sites, and/or where legacy hydrologic data are available, installations may be sited to take advantage of favorable conditions or to enhance continuity of legacy data. Wells should be co-located with other hydrologic monitoring devices such as gaging stations or existing wells if present anywhere in the reach.

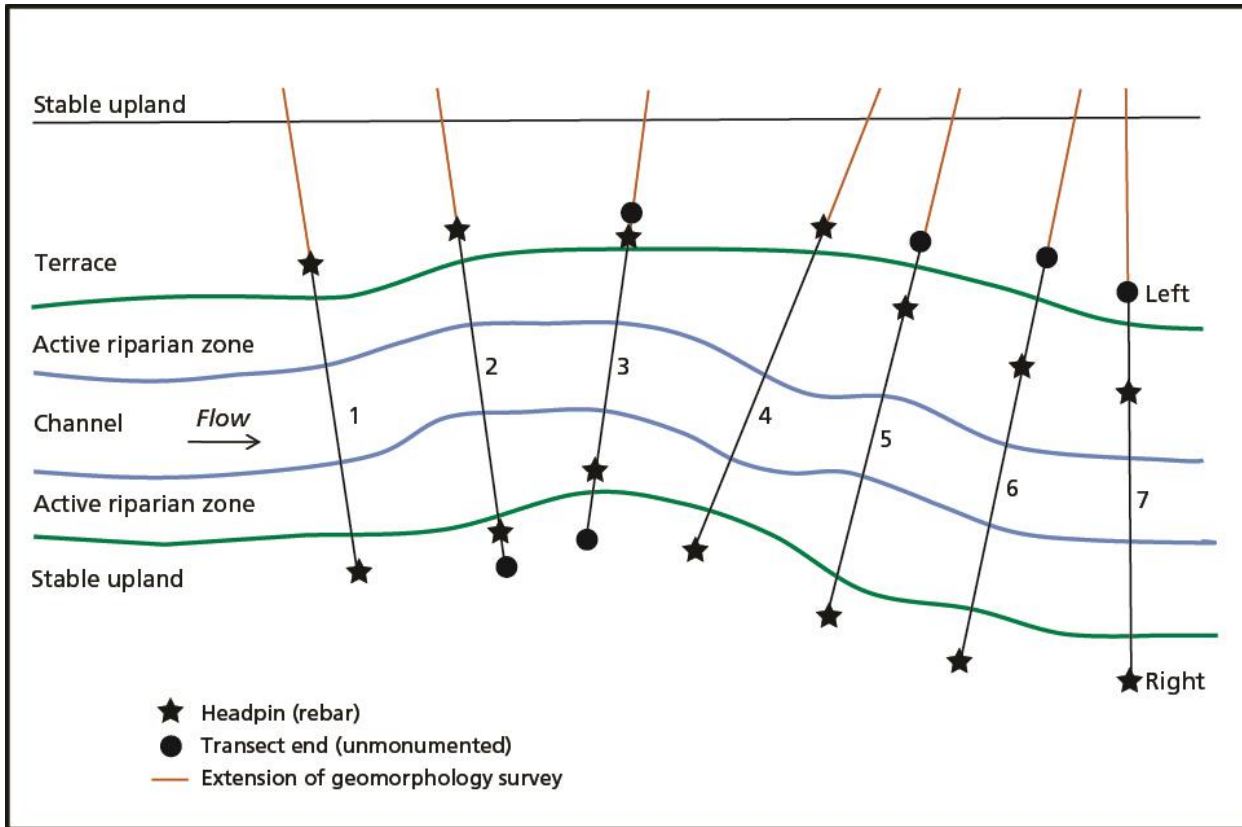


Figure 1. Example of a riparian monitoring reach with seven equidistant cross-section transects. Unmonumented transect ends may occur on bedrock or highly unstable surfaces.

Usually, two riparian wells are installed along the transect in the active riparian zone. They are located three-quarters of the distance from the thalweg to each headpin, one on river left and one on river right (Figure 2). Some constricted reaches may not permit installation of two riparian wells due to the presence of bedrock. In this case, only one riparian well should be installed on the non-constricted side of the riparian corridor.

- A. Locate both headpins within the selected transect. Follow instructions in SOP #2 to run the tagline and 100-m tape between the headpins. Confirm the length of the transect and the location of the headpins along the transect to make sure the entire sampled area is considered, including sections that are not monumented due to bedrock or highly unstable surfaces (Figure 1).
- B. Determine the location of the thalweg within the stream.
- C. Determine the distance between each respective headpin and the thalweg, and calculate location of riparian wells ($\frac{3}{4}$ distance from thalweg to headpin; see Figure 2). Mark riparian well locations using pin flags.

At some sites, three riparian monitoring wells may be installed on a transect. Two wells are installed on the wider floodplain (either river left or river right). One is positioned within 10 m of the active channel margin, and the second within 10 m of the transect headpin. Install the third well on the narrower floodplain (or terrace) on the opposite side of the channel.

If an instream well will be used to monitor both surface flow and groundwater levels, it should be installed in the stream channel near the wetted edge of the stream during base flow conditions or the scoured edge of the channel in intermittent and ephemeral streams; driving a length of heavy-gauge angle iron into the stream bed just upstream of the well can improve flood resilience. If a depositional bank is present, an instream well on this side of the stream may function best. If no obvious depositional bank is present, locate the instream well on the side of the stream that would minimize damage during flood events. Instream wells on perennial streams should be installed at a location that ensures that the pressure transducer is submerged during low-flow periods.

An *angle iron/pipe gage* monitors only surface flow, but can be the most resilient to flood damage in ephemeral or intermittent systems. In ephemeral systems, periodic surface flows typically transport large volumes of fine-grained sediment, and these installations are placed slightly above the stream bed to minimize sedimentation issues within the pipe housing the recording instrumentation. Therefore, these should be installed as near the channel thalweg as possible while maximizing protection from flood damage.

1.2 Riparian and instream wells: drive point assemblies

1.2.1 Drive-point well ground surface preparation

Mark locations for the installations. Dig a hole 1-2 feet deep and no more than 2 feet in diameter with a shovel. This preparation will remove any near-surface cobble that will otherwise make a perfectly plumb installation more difficult, and will also significantly reduce total resistance between the well point assembly and the surrounding sediments during installation.

1.2.2 Drive-point well assembly

The initial height of the well point assembly depends on the depth of the hole in the riparian surface and the height of the crew members relative to the top of the well point assembly.

- A. Connect a screened well point to the appropriate galvanized riser pipe (Figure 3a). Be absolutely sure that you have connected the appropriate type of riser pipe (screened for instream wells or solid for riparian wells—see section 1 for more details). For a 3-foot screen, using a 2- or 3-foot riser length is recommended for the initial installation step. The top of the well point assembly should be approximately shoulder height prior to pounding. Wrap all threads with Teflon tape, and use heavy-duty stainless drive couplings at each pipe junction.
- B. Attach a sacrifice pipe to the top of the well point assembly. Make sure to use Teflon tape and a drive coupling here as well.
- C. Use two large pipe wrenches and a cheater pipe, if available, to tighten all of the threaded junctions as much as possible.

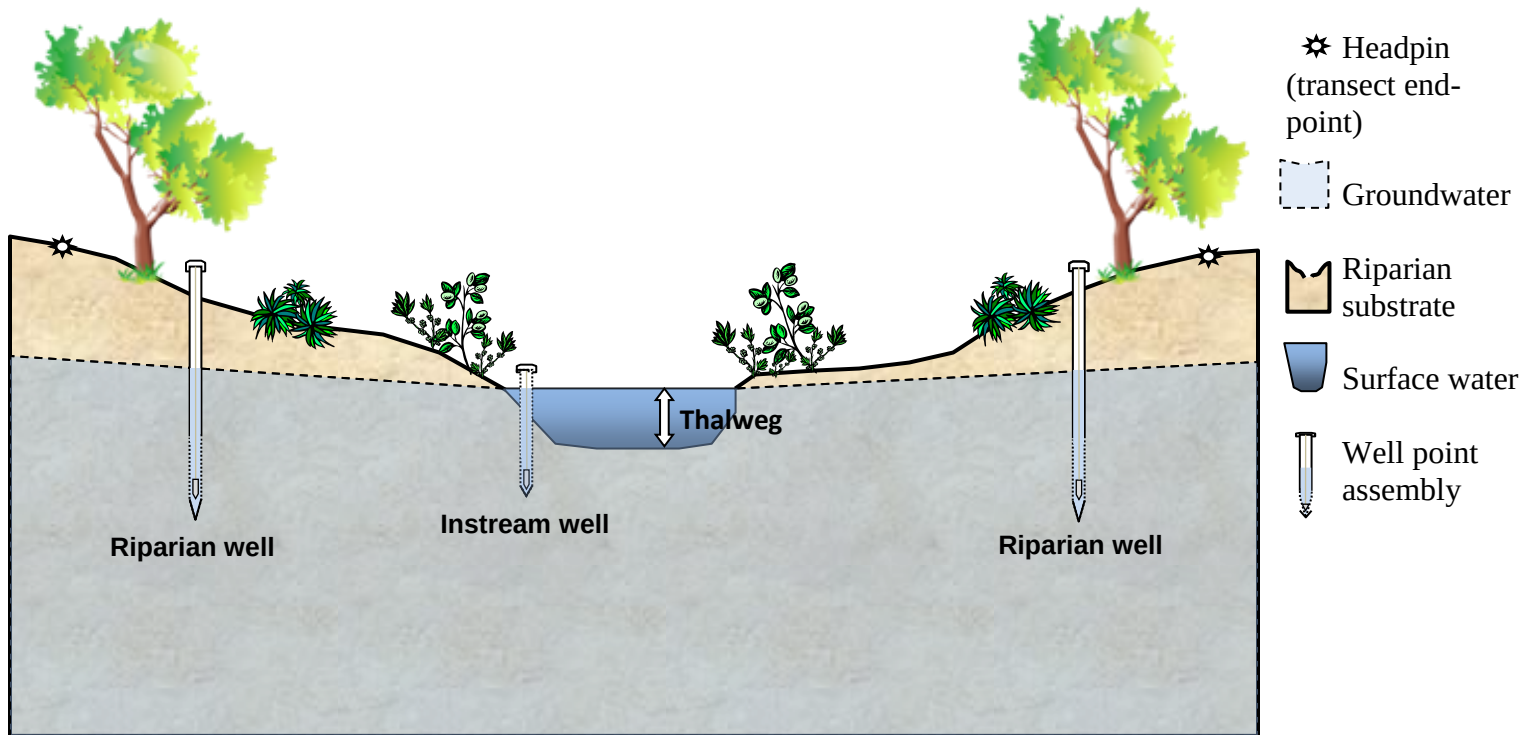


Figure 2. Cross-section of a riparian transect. Notice the riparian wells are spaced three-quarters of the distance from the thalweg to each headpin, and the instream well is placed on the depositional edge of the channel (the gradual sloped edge). The instream well is fully screened (surface and sub-surface), while the riparian wells are screened only at depth.

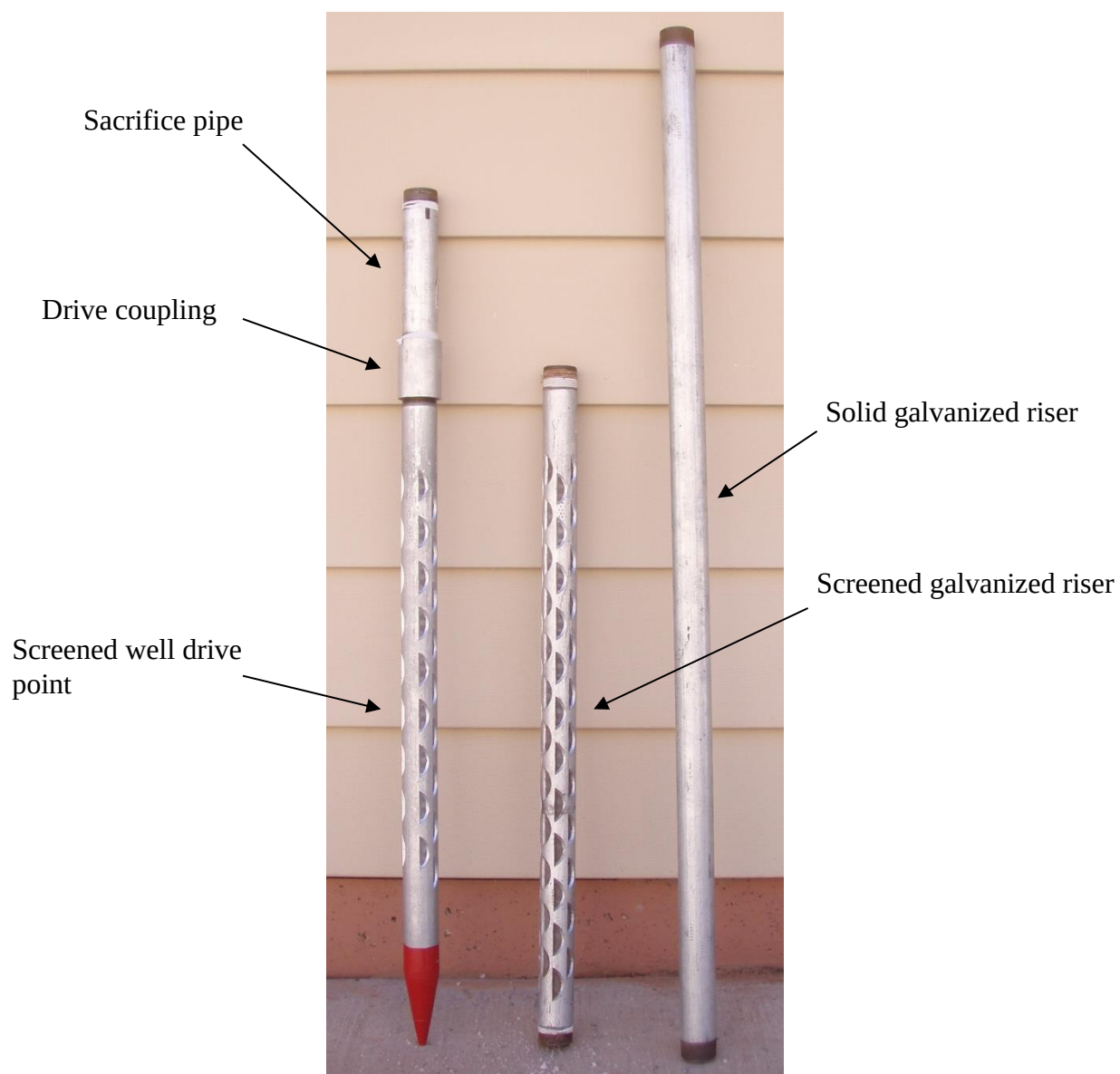


Figure 3a. Components of a steel monitoring well assembly, including screened well drive point, drive coupling, sacrifice pipe, screened galvanized riser, and solid galvanized riser.

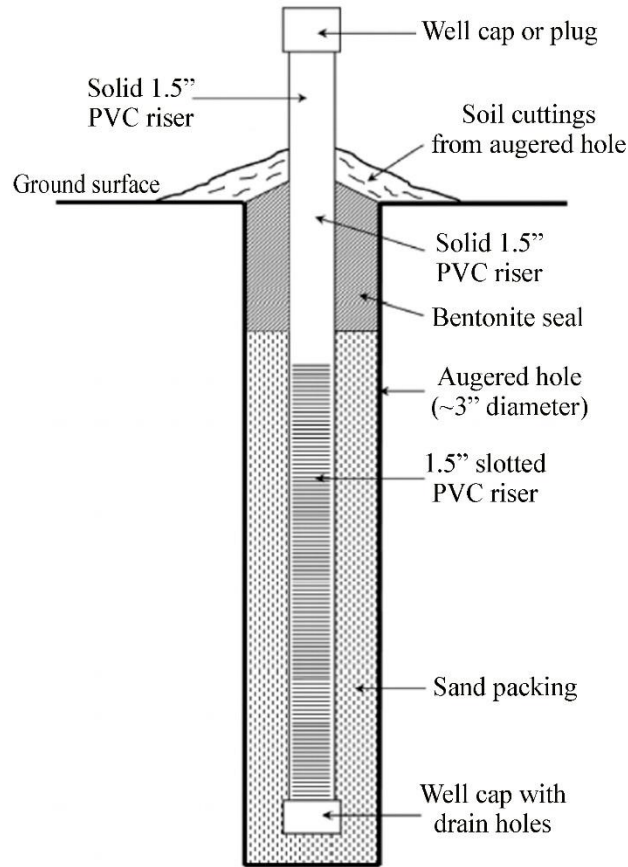


Figure 3b. Diagram of PVC monitoring well installed into augered hole in floodplain, showing screened and solid riser sections, bottom cap, and top plug or cap.

1.2.3 Driving in the well point assembly

Use a large diameter, heavy-weight fence post driver to pound the wells into place (Figure 4). Handlebar grip tape (used on road bikes) attached to the handles of the fence post driver will significantly reduce the vibration on your hands. Use thick padded gloves (or two sets of gloves) to additionally reduce vibration forces. High decibel ear protection must be worn by all crew members at the installation location. Ear muff-type protection is recommended (versus ear-plugs) due to ease of taking them on and off.



Figure 4. Installing a riparian well at the East Fork of the Virgin River, Zion National Park.

- A. Place the well point assembly at the pre-determined instream location or in the hole on the riparian surface. It is easiest to begin installation by sliding the post pounder over the top of the well before it is raised to vertical; one person should then help hold the post pounder while another stabilizes the well point assembly at the point of installation. A third person uses a bubble level to make the well perfectly plumb. Once plumb, two crew members can begin pounding. Determine the number of repetitions (reps) before you begin to pound (typically 7 reps). One person should call out the repetition number (“1, 2, 3.” as pounding proceeds to ensure that both crew members stop pounding at the same time.

Make sure you don't over-drive the well. It needs to be checked and adjusted periodically during installation to ensure it is level upon completion.

Leveling the well point assembly

-Check the alignment of the well at two perpendicular locations along the riser section. Use a bubble level to perform this task between each set of reps of pounding.

-At first it should be easy to level the well point assembly. The well point can be shifted to the level position with little effort in between reps.

-Once the well point assembly attains a sufficient depth, it will no longer be easy to level. Try moving the assembly in a circular motion to loosen the adjacent sediments, and then re-level. Be careful not to torque the assembly while leveling, and always apply pressure toward the base of the well, not the top. Too much torque can bend the well or damage threads, which may necessitate removal and reassembly. It is better to have the well not perfectly vertical than to damage the assembly.

-After 3-5 feet of the well point assembly is beneath sediments, it will become extremely difficult to adjust the alignment of the well. If necessary, one crew member can use a rope or webbing to apply pressure to the well point assembly while the other two crew members initiate pounding. Loop the rope around the well point assembly near the soil surface and apply a constant pulling force.

- B. After one set of reps, remove the fence post driver. Level the well and use the pipe wrenches to tighten all threaded junctions again. Tightening should be performed every time the fence post driver is removed

(between 1 and 3 sets of approximately 7 reps). If threaded junctions are not regularly tightened, the threads will suffer significant and irreparable damage. Thread damage to the well point assembly (not the sacrifice pipe), may necessitate removal and re-assembly.

If the well point assembly is bent or threads are damaged during installation

- The well point assembly should be removed and a new one should be installed. If the screened section, including threads, is undamaged, it can be re-used. It may be necessary to dig deeper to remove the well point assembly. Removal may be difficult or impossible depending on the depth achieved before damaged occurred.

-If the well point assembly has been damaged enough that it will not function properly, and it cannot be removed, the last resort is to detach remaining riser sections and bury the stuck section. ***This should be avoided at all costs.***

- C. Once the well point assembly is level and all pipe junctions are tight, begin pounding again. Continue re-tightening all exposed couplings between 1-2 sets of pounding.
- D. Riparian wells should be installed to a depth of 2-3 feet below the lowest anticipated water level. In most locations, a depth of 11-15 feet is sufficient. Check the depth of water present in the well regularly after the screen and first riser are pounded below ground surface, using the water level meter (see instructions in section 5.1). It will typically be necessary to agitate the water inside the well with an inertial lift pump to clear sediments around the screen and ensure sufficient hydraulic connectivity (see instructions in section 1.2.4). After agitating the sediments, allow time for the water level to equilibrate prior to measuring the water level.
- E. If the depth of the well is not sufficient, continue pounding until the appropriate depth is reached. Depending on the groundwater level, you may choose to use a smaller length of riser pipe for the last section. Six to 18 inches of pipe should be exposed above the surface of the completed well. Shorter exposed sections reduce the likelihood of flood damage and may be desirable for aesthetic reasons (e.g. proximity to a trail or likelihood of visitor interaction). Longer sections help to prevent burial during large flood events. To protect longer exposed sections, a 1-inch diameter galvanized steel pipe five to six feet in length can be driven by post pounder and sledgehammer next to the upstream face of the well. Use a block of wood, if necessary, to carefully drive the last few inches of the protector pipe so that its top is lower than the top threads of the well. Strap the well to the pipe using standard hose clamps.

1.2.4 Developing the well

The sediments surrounding the well screen may become smeared during installation, clogging the well screen and reducing hydraulic conductivity of the sub-surface material. Pump the well with an inertial lift pump to eliminate smearing and to create a sedimentary filter pack surrounding the well screen that maintains proper hydraulic connectivity in the sub-surface environment and responds quickly to changes in water level. The amount of time it takes for water levels to respond to natural variation in the well is a function of the hydraulic conductivity of the sub-surface material and the connectivity between this material and the well screen. The plunging motion of the pump will effectively push the finest sediments (fine sand, silt and clay) further away from the well screen or suck them into the well, allowing coarser materials (coarse sand, gravel, and cobble) to remain closer to the screen. This procedure reduces or eliminates fine sediment buildup in the well over time.

All wells require plunging and pumping for development. This procedure is most effective when performed by two crew members, although the task can be completed by one person if necessary.

- A. Insert the foot valve end of the inertial lift pump into the well until it reaches the bottom (Figure 5). With one person holding the opposite end of the tubing away from the well, the other person should initiate a plunging motion within the well. If there is not enough water to purge the sediment, use a bucket to pour water into the top of the well during purging.
- B. The check valve in the pump allows water in the well to enter the tubing during the downward motion, and prevents water from escaping during the upward motion (see Figure 5). Water will continue to fill the tubing with each plunge and eventually will be expelled from the opposite end. The water will slowly clear as this procedure continues, typically in 5-10 minutes of pumping.
- C. If water quality samples or measurements are to be obtained from the well, remove the inertial hand pump once the water expelled from the well is clear. Insert the tubing attached to the Geopump 2 peristaltic pump (Figure 6). The flexible tubing should reach the bottom of the well. Turn on the peristaltic pump and allow it to continue pumping until the water being removed from the well is visibly clear.

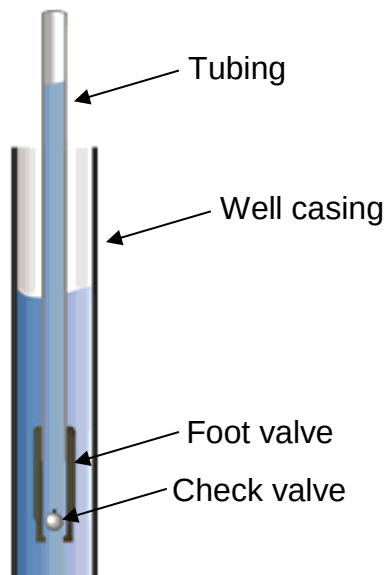


Figure 5. Diagram of inertial lift pump (image from www.waterra.com). On the actual pump, the tubing extends several meters beyond the top of the well casing so that you can direct the expelled water away from the well.



Figure 6. Pumping a well with a peristaltic pump at the East Fork of the Virgin River, Zion National Park.

1.2.5 Completing the well

Once the well is installed to a sufficient depth and pumped, a few remaining tasks are necessary to complete the installation.

Riparian wells

- A. For riparian wells, it will be necessary to back-fill the sediments removed during the installation. Fill in sediments to within 1-2 feet of the ground surface. Compact the soil with your feet.
- B. Place enough dry bentonite pellets in the bottom of the hole surrounding the well to cover the surface (a few shovels worth). Arrange the pellets so that there is a thicker coat around the exposed well riser section.
- C. Using a small bucket or water bottle, slowly pour water on top of the bentonite pellets. Use your hand to ensure that all of the bentonite pellets become saturated and form a smooth impermeable surface. Pay careful attention to the area around the exposed well. Once hydrated, the bentonite pellet layer will effectively seal the annular space surrounding the well and prevent preferential flow paths from forming adjacent to the well.
- D. Back-fill the rest of the hole, and scatter leaves and branches to camouflage the site (Figure 7).



Figure 7. Completed riparian well in Courthouse Wash, Arches National Park.

Instream wells

- A. Pour water into the instream well to ensure proper connectivity with the surface water. If proper connectivity was achieved, the level in the well should quickly equilibrate with the surface water elevation.

1.3 Riparian wells: PVC wells

1.3.1 Augering the well hole

Use an extendable soil auger with ratcheting handle to excavate the hole for the well down to the depth estimated as approximately 2 feet below the low (dry season) water table elevation, probably 11 to 15 ft. below ground surface. A 3- to 4-inch diameter bucket auger works well for installing 1.5-inch or 2-inch PVC wells in most soil conditions. Document the substrate layers found and the depth of saturation on a well log form (sample form in section 7) as augering proceeds (e.g., "dry sand, surface to 2.5 ft., moist clay/loam 2.5 ft. to 4.6 ft., saturated clay/sand 4.6 ft. to 6.0 ft., ..."). Record the total depth to the bottom of the hole from the ground surface when the hole is complete.

1.3.2 Assembling the well

- B. A. "Dry-fit" the well components (bottom cap, screen section, riser section(s) to the desired total length, to exceed the total depth of the well hole by approximately 1-3 feet. A screened section 5 feet in length is generally sufficient, with the remainder of the well composed of solid riser pipe, but a longer screen can be used where large groundwater level fluctuations are anticipated. The length of pipe that should remain exposed above the ground surface partly depends on the well's location relative to the active channel. If possible, approximately 1.5 feet of pipe should remain exposed for wells installed on floodplain surfaces, to minimize the chance of burial during floods; however, the higher the exposed length of pipe, the more susceptible it is to damage during floods (see Completing the well, below). A

hacksaw can be used to cut the top section of riser pipe to the desired length; take care to ensure a uniform cut so that the top of the well is level on completion. To protect an exposed well riser on the floodplain, drive a 5- to 8-foot section of 1-inch galvanized pipe into the ground on the upstream face of the well. Use a post pounder and sledgehammer to drive the pipe. A block of wood can be used to carefully drive the last few inches of the protector pipe so that its top is lower than the top threads of the well. Strap the well and pipe together with two or three standard galvanized hose clamps.) For wells installed on higher surfaces, leave 1 to 1.5 feet of exposed riser pipe above the ground surface.

B. Commercial well screen is pre-threaded to allow the sections to be screwed together; the riser pipe may or may not be threaded. If not, a PVC thread-slip coupling can be used to join a threaded screen section to an unthreaded riser section, and slip couplings used to join the risers to each other. Use Teflon tape on all thread joins.

C. Glued sections and caps: Use PVC primer and the correct PVC cement for glued joins. Resting the PVC parts being glued across a board or flat rock helps to keep the joins clean; it is essential that no grit or dirt adheres to primed or glued surfaces. Glue sections together one at a time. Carefully apply the PVC primer to both surfaces to be glued (e.g., coupling interior/riser exterior). Wear gloves and avoid drips; the primer permanently stains clothing. Apply PVC cement to both surfaces and then immediately and firmly press the two parts together with a ¼ turn to ensure full adhesion. Continue pressing the two parts together for about 30 seconds before moving to the next join.

D. Drill 3-4 small (1/16th inch) holes through the cap for the bottom of the well to allow water to drain from cap and bottom of the screened section. Use a threaded PVC cap, or, if using a slip PVC cap, use a hacksaw to cut off the bottom threads of the screened section. Use Teflon tape on all threads. Screw the drilled bottom cap on tightly, or glue in place.

E. For later measurements, it is easier to remove a threaded top cap than a slip-on cap. If the top of the final riser is not threaded, a slip-male threaded coupling can be glued to the top of the pipe to allow a threaded cap to be used. (Alternatively, a locking well plug can be used inside unthreaded pipe; see Completing the well.) Drill a 1/8" hole through the top plug or cap to allow equalization of atmospheric pressure in the well.

F. Insert the assembled well into the soil hole, making sure that it occupies the full depth of the hole and is seated firmly in the bottom of the hole.

1.3.3 Measuring water depth inside the well

Check the depth of water in the well using a water level meter (see section 5.1). In fine-grained soils, it may take an hour or more for the water level in the well to equilibrate with the surrounding aquifer. Riparian wells should be installed to a depth of 2-3 feet below the lowest anticipated water level. The water level in wells installed during the fall (September-November) should be 4-5 feet above the well bottom; during drier months, depth of water in the well should be a minimum of two feet. If this is not the case, even after the depth to water in the well has stabilized, the pipe may have to be removed and the hole deepened.

1.3.4 Completing the well installation

Use the bubble level to hold the well plumb, and pour coarse sand into the cavity around the well. Tamp the sand down around the screened section with a narrow tool (the shovel handle, auger rods, or a capped length of ½" PVC pipe can be used.) Add enough sand to fill the cavity to at least 2 feet above the top of the well screen. The sand helps filter fine sediments from groundwater entering the well. Fill the remainder of the cavity to within 2 feet of ground surface with bentonite powder or pellets, again tamping the material to avoid leaving large cavities below ground surface. Slowly add water to the bentonite; it will swell and coalesce to seal the

upper cavity so that precipitation or overtopping during floods do not enter along preferential flow paths, resulting in falsely elevated water level readings. Fill the remainder of the cavity with native soil cuttings, packing the soil until it is even with the remaining ground surface. Alternatively, a two-foot diameter hole can be excavated around the top of the well to a depth of approximately one foot. A standard concrete mix can be used to fill the hole; wooden rods or stakes should be used to push the concrete down into the remaining cavity around the top of the well.

1.3.5 Developing the well

Use the inertial hand pump to clear sediment from the well and screen. See section 1.2.4 above.

1.4 Surface water monitoring assemblies

The objective of surface water installations is to capture surface water elevations in perennial streams or to capture flood flows in intermittent and ephemeral streams. Because the installation is above the channel bottom, low flows are vulnerable to missing data.

1.4.1 Assemblies attached to bedrock or large boulders

1.4.1.1 Assemble a casing

Cut 1 ½” inside-diameter schedule 80 slotted PVC well casing into 8 inch or longer lengths. Prime and glue a 1 ½” threaded PVC coupling to the top and bottom of the piece of casing using PVC glue (Fig. 8). Make sure to wear gloves during this process. Allow to dry 15 minutes.

Drill a hole in a threaded PVC plug for a ¼” diameter eyebolt. Thread a nut and washer onto the eyebolt to the top of the threads. Put the eyebolt through the hole in the threaded PVC plug. Put another washer and stopper nut on the eyebolt on the outside of the plug.

Use a small 2” carabiner to attach the data logger to the eyebolt. The bottom of the logger should not be touching or extending past the bottom of the casing.

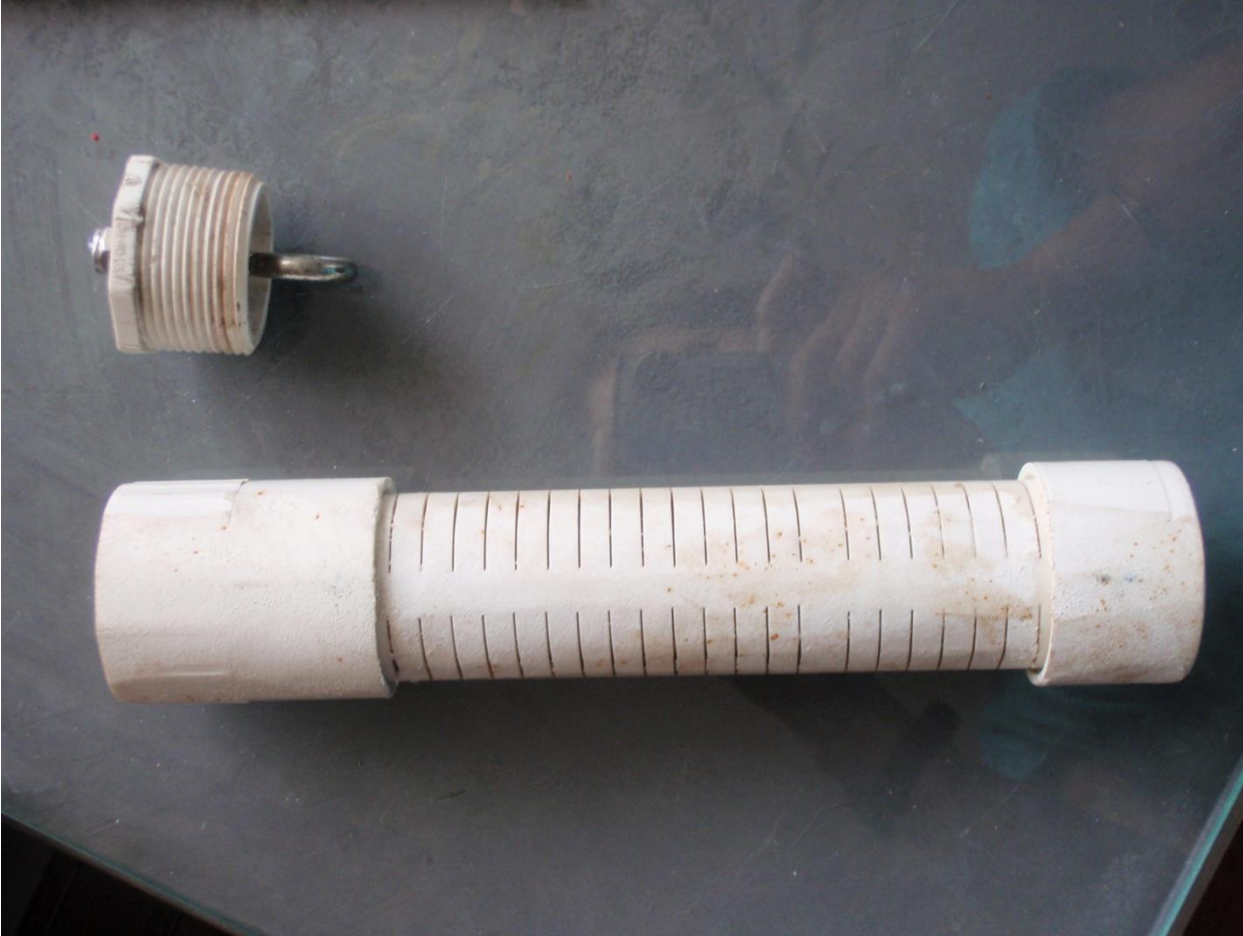


Figure 8. Slotted PVC casing for logger.

1.4.1.2 Mounting the logger

Select a portion of bedrock or large boulder that is relatively vertical and will be inundated by the desired flows (low flows in a perennial stream; flood flows in intermittent and ephemeral streams). Hold the casing up to the rock with metal brackets that will be used to affix the casing to the rock. Make sure the casing is vertical and that you will be able to open and close the threaded cap. Mark the locations of the holes in the metal brackets using a permanent marker.

At a location you have marked, drill a hole big enough for a $\frac{1}{4}$ " expansion bolt using a hammer drill. Level the logger casing against the rock, and put a U-shaped pipe mounting bracket or plumbers hanger tape snug against the lip of the threaded PVC sleeve on the casing. Work the expansion bolt through the hole in the bracket into the drilled hole in the rock, and deploy the expansion bolt by hitting the pin with a hammer. If necessary, before deploying the expansion bolt, use additional washers to make sure that the casing is held snugly to the rock. Drill another hole and mount a bracket near the bottom of the casing in a similar fashion. Add additional holes and bolts if necessary. Paint the casing to match the surrounding rock (Fig. 9).



Figure 9. PVC casing instream installation mounted to boulder at Natural Bridges National Monument.

1.6 Angle iron/pipe stage gages

1.6.1 Components

Stage gages constructed of angle iron and pipe consist of:

- One 5- to 8-foot length of heavy gauge, 1.5 inch or two-inch angle iron
- One eight-inch section of 1.5-inch galvanized pipe or Schedule 80 PVC pipe
- 1.5-inch galvanized coupling or slip-thread coupling (for PVC pipe). A female thread allows installing a well plug on top of the gage.

The pipe is bolted inside the “V”-shaped opening of the angle iron after driving the angle iron into the stream bed, allowing a recording pressure transducer to be installed inside the pipe just above the bottom of the stream channel. The bottom of the pipe is left open to allow water and sediment to drain freely from the pipe.

1.6.2.1 Pre-drilled installation

Attach the couplings to the top and bottom of the pipe. Depending on the site situation, the pipe and angle iron can be pre-drilled before field work, or drilled and assembled at the site. For pre-assembly, drill two holes, near the top and the bottom of the pipe, that will attach to the angle iron. The holes must be accessible from outside the pipe with a combination or small socket wrench, so that later a bolt can be held in position for tightening. Drill a series of holes in the angle iron that can be used to attach the casing. Mark or file a notch in the top coupling to mark the permanent measuring point.

Drill a hole through a threaded plug and attach a ¼” long eyebolt. Thread a nut and washer onto the eyebolt to the top of the threads. Put the eyebolt through the hole in the threaded plug. Put another washer and lock nut on the eyebolt on the outside of the plug.

1.6.2.2 Field-drilled installation

A. Position the pipe with couplings attached inside the “V” of the angle iron (the downstream face) so that its base is approximately 2 cm above the stream bed. The top of the pipe may be lower than the top of the angle iron.

B. Mark a point on the angle iron to drill through the angle iron near the top of the pipe.

C. Drill a ¼-inch diameter hole through the angle iron at the spot marked. After drilling, hold the pipe in the correct position and mark the matching spot to drill on the pipe; the drill bit itself can be used for this. The pipe can then be removed and the hole drilled.

D. Repeat step B for the lower hole through the angle iron, positioning the hole one to two inches above the bottom of the pipe. Place the pipe in the correct position, and check that it is plumb. Temporarily insert a bolt (see step E) through both the pipe and angle iron at the top hole. This will ensure that the pipe is in exactly the correct position before the spot for the bottom hole is marked. Mark the location for the bottom hole on the pipe, remove the pipe, and drill the bottom hole.

E. Insert one bolt through the bottom holes in pipe and angle iron. A #10 diameter (approximately 0.20-inch) stainless steel tap bolt with hexagonal head, 1.5–2 inches long, will fit the ¼-inch hole and provide enough length to securely fasten the pipe. Orient the bolt with the hex head inside the pipe, and use a stainless steel washer and nut on the end protruding from the angle iron. A long combination wrench (hex end and open end) can be used to hold the bolt head in place, while a separate wrench is used to tighten the nut. Insert and fasten the top bolt before fully tightening the bottom bolt, and then fully tighten both bolts.

1.6.3 Preparing the surface

With the shovel, dig a hole one to two feet deep of the smallest diameter possible. Remove any large gravel or cobble in the bottom of the hole.

1.6.4 Driving the gage mount

If possible, select a location in the stream that will be inundated during low flows. Position the angle iron in the hole so that the point of the “V” faces upstream (the “V” opens downstream), and ensure it is plumb. The angle iron can be driven with a post pounder for as long as possible, until the bottom of the pounder reaches ground surface, and then with a 3- to 8-lb. sledge hammer. Check frequently to ensure the angle iron remains plumb. Drive the angle iron into the stream bed until 10 to 12 inches remain exposed above the channel bed. Extra length enables raising the pipe later should the stream bed aggrade. When the angle iron is to the desired depth, use a hacksaw to cut off the top portion if it has been warped during installation. Secure the casing using bolts and nuts (see section 1.6.2.1 or 1.6.2.2). An additional angle iron may be placed upstream to protect the installation from flood debris (Fig. 10).



Figure 10. Angle iron installation in the Fremont River, Capitol Reef National Park.

1.7 Tape-down pipes

A tape-down pipe may be installed at some sites where a perennial pool of surface water is present within a stream channel. Its location and MP elevation are also recorded during the reach survey (SOP #9). Manual measurements obtained at the tape-down pipe provide a QA/QC check of continuous data recorded in any well where pool stage is also monitored. A tape-down pipe is simply a six- to eight-foot length of 1-inch galvanized pipe driven into the streambank at the edge of the low-water surface. Position the pipe to minimize flood damage as much as possible while ensuring accessibility during high-water periods. The length of pipe remaining exposed above low-water surface depends on anticipated changes in stage, but should generally be no more than two feet. Notch or mark the MP on the top of the pipe's streamward edge.

2. Stage gage camera

At ephemeral or intermittent sites, automatic repeat photos of the gage installation can provide valuable quality control data for interpreting apparent surface flow events registered by the datalogger. Sedimentation, ponding, and freezing conditions can affect data reliability; for instance, ports plugged with fine sediments can register as water pressure when no flow is present. A high-quality “trail” camera (e.g., Browning or Moultrie models) with

a programmable repeat photo option is required. Specifications to look for include long battery life, suitable storage card size (to 128 Gb), and durability. The storage card, batteries, and programming screen should be accessible without removing the camera after it is mounted in place. At some sites, the capacity to secure the camera with a locking cable (e.g., “Python” cable) may be useful.



Figure 11. Image from stage gage camera, Chaco Culture National Historical Park. Black arrow points at stage gage.

2.1 Testing the camera

In the office, follow the manufacturer’s instructions to install batteries and storage card. Turn the camera on, and program it to take daily photos at the desired times. Document the steps required for programming. Place the camera where it will not be disturbed, and leave it on for two days. After the second day, download the images acquired to ensure that the camera is correctly programmed. Turn the camera off and remove batteries until its installation at the site.

2.2 Selecting the camera location

Ideally, the camera will take 5–6 photos per day at pre-set times during daylight hours; for instance, at 1.5-hour intervals beginning at 9 a.m. While the programmed times may not coincide with peak flows, the photos will capture any flood evidence, like high-water marks, at the site. Select a sturdy tree or other stable object on a bank above flood danger and within 30–40 m of the stage gage. If possible, avoid a location in which the camera will face directly toward the sun during daylight hours, as direct sunlight on the lens when a photo is taken will make the photo unusable. Deep shadowing across the stage gage can also make it difficult to interpret photos. Try to select a location that will provide a wide image of the banks and channel where the stage gage is positioned.

2.3 Mounting the camera

Install the storage card and batteries and turn on the camera. Use the camera's test mode to take a few photos from the selected position, and then download the images to check that the correct position has been selected. Securely mount the camera using the brackets supplied by manufacturer, or construct a sturdy bracket of steel L-angle braces and screws. Take care that the mounting bracket does not impede opening the camera to access the batteries and programming screen.

2.4 Programming the camera and checking image quality

Follow the documentation created during the in-office camera test to program the camera for repeat photos at the desired intervals. If possible, complete any other field work at the site before returning to the camera to download and check any images acquired during the interval.

3. Installing the pressure transducer

3.1 Program the loggers

For detailed instructions on settings, refer to the instrument's user manual (i.e., Solinst Levellogger User Manual). Depending on accessibility of the reach, you may perform these steps in the office ahead of time or in the field using a laptop loaded with Solinst Levellogger 4.0.3 software. Stage loggers should be programmed for each hydrologic installation, and a barometric logger is needed for each monitoring reach to compensate for atmospheric pressure.

- A. Before employing transducers in the field, it is important to test them to insure they are accurately reading pressure. The easiest way to do this is to put them through an air test. Gather the transducers to be installed at a park on the next monitoring visit. Keep the groups as large as possible to support as many "should be the same" comparisons as possible. The minimum number of transducers should be a set of three transducers that will be used at one site (two water and one air). The transducers to be tested should be placed in a stable environment (office desk). Synchronize the time and program a common start time for all transducers. Let the transducers run for at least a 24 hour period and ideally for up to a week of exposing the transducers to an identical environment. This data will support identification of potential fixed offsets among transducers which will then be used in analysis or may show a transducer is no longer operational.
- B. Stop the test and download the transducers using Solinst or Hobo Software (see Section 2.0 Return Visits below for information on how to download the transducers).
- C. If the transducers air tests are successful (<5 cm deviation, see Figure 12), store the test data on Z and reset the loggers using the elevation of the site where they are to be deployed. NOTE that when comparing data from barologgers (air transducers) to levelloggers (water transducers) the barologgers must be multiplied by 1.01702 for the graphing operations. It is fine to just keep them recording through transport and deployment.

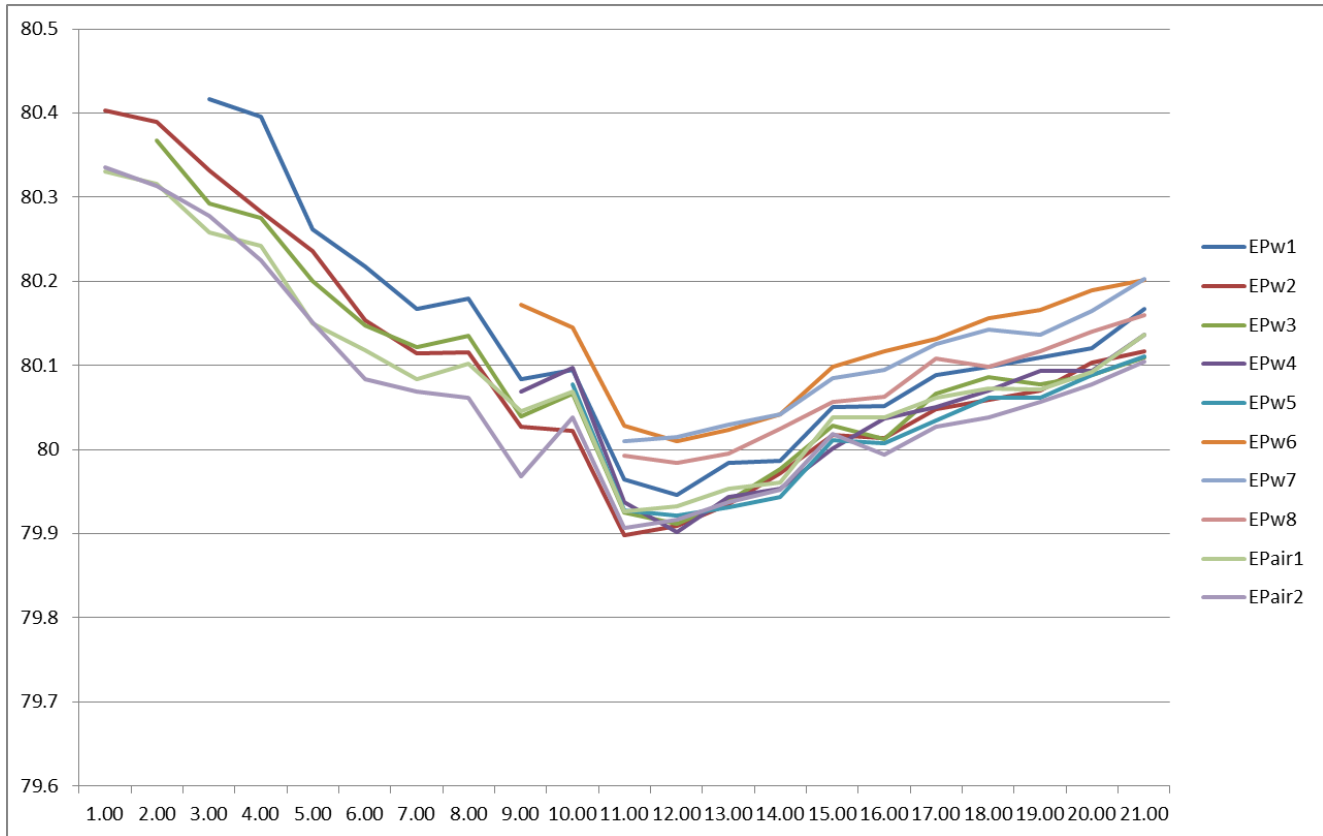


Figure 12. Example of a successful air test.

- D. Electronically label each pressure transducer with the stream and reach location, and any well-specific identification information, e.g. CHA0610a, SAPU01RSG, HUTR_Baro etc.
- E. Set the logging interval to 15 or 30 minutes depending on the data resolution desired.
- F. For stage loggers, change the units to centimeters. For barometric pressure loggers, use the default units. Adjust the site elevation, if programmable. Elevations acquired from online mapping applications such as Google Maps are sufficient for this setting.
- G. Synchronize the logger time to your computer's time. If needed, adjust the computer time to **Mountain Standard Time**. Set a future launch date and time at an even time step interval (e.g., 10:15:00, 13:30:00). It is best to set the start time in the field just prior to logger installation so you can collect a representative water level elevation and flow measurement at the same time. If this step is completed prior to field work, make sure to provide an appropriate buffer between the anticipated time of well completion and the logger start date and time.

3.2 Install the logger

- A. Cut a length of Kevlar cord or line approximately the same length as the depth of casing where the logger will be deployed. Attach one end of the Kevlar line to the hanger on the pressure transducer with a ring terminal. Use the crimping tool to properly connect the ring terminal to the pressure transducer. Alternatively, double the Kevlar line, pull both ends through the cap, and then pull both ends through the loop of the line near the cap.

- B. Stretch the logger and cord out next to a meter tape with casing cap, eyebolt, and a 2" carabiner. Make a mark where the total length is approximately 3 cm shorter than the depth of the casing. Attach the cord to the carabiner using a ring terminal and crimper or a bowline knot. Use electrical tape to secure the end of the line when using a bowline knot. The pressure transducer sensor should be situated at least 3 cm above the bottom of a well to allow for minor sedimentation between visits, and 0.5 to 1 cm above the bottom of the open casing in surface stage installations.
- C. Measure and document the distance to the nearest 0.1 cm from the transducer measuring line (Figure 13) to the point on the cap or plug corresponding with the well or gage measuring point.
- D. Clip the carabiner to the eyebolt attached to the cap, and lower the pressure transducer into the well. For barometric pressure loggers (e.g., Solinst Barologger), suspend the barometric pressure logger in a nearby tree affording the most shade possible but safe from flooding.
- E. Lower the pressure transducer into the well or casing, grease the well threads with plumber's grease, and tighten the well cap or plug with pipe wrenches.

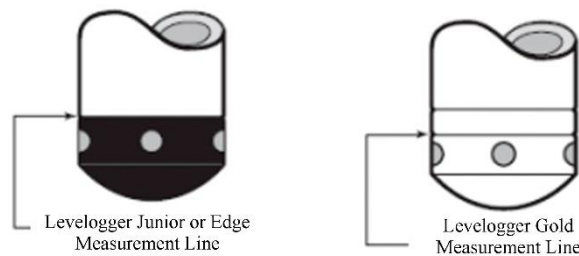


Figure 13. Transducer measurement lines for Solinst Junior, Edge, and Gold models.

4. Recording location and photos

Record a waypoint for each installation and Barometric pressure logger using a mapping grade GPS unit. Make sure the coordinate system of the GPS unit is set to NAD 1983. Also record the northing, easting, and elevation of each well on the Well Installation data sheet.

Photos should be taken throughout the installation process to document conditions that may help interpret results, including photos of each completed installation. To help re-locate installations and the Barometric pressure logger during future site visits, take landscape photos that contain unique features, such as rock outcrops or large trees that serve as reference points. On the Installation data sheet, record the photo number, the installation ID, the photographer, and a brief description of each photo.

Installation locations and elevations are also recorded during the reach survey (SOP#9).

5. Data collection

5.1 Manual water level measurements

The water surface level is the depth of the water surface beneath the top of the installation casing. Use a Solinst water level meter and the appropriate data sheet (Well Installation or Well Revisit) to record your measurements.

- A. Remove the cap and pressure transducer, if installed. Wait at least one minute to allow the water level to equilibrate.
- B. Turn on the water level meter and adjust the sensitivity. Setting the sensitivity too high can result in false readings from condensation on the inside of wells; an overly low setting will not register the correct water surface.
- C. Lower the water level sensor into the casing at the marked measuring point (or streamward side of the well if no MP is evident), holding the tape away from the edge of the well until the sensor sounds.
- D. When the sensor encounters water, you will hear a loud constant tone. Raise the water level meter up until the tone stops. Slowly lower the water level meter back into the well, and determine the depth to the water surface (DTW) once the sensor begins making the tone again. It may be necessary to raise and lower several times to obtain an accurate measurement. Keep the tape away from the edge of the well until making the actual measurement.
- E. On the data sheet, record the time the measurement was taken and the DTW in the “Measured” column to the nearest 0.1 cm.
- F. Repeat steps D–E at a one-minute interval. If the readings differ by more than 1 cm, the water level may not have equilibrated sufficiently. Wait five minutes and try again.
- G. Record the true DTW measurement to the nearest 0.1 cm. Make sure all units are the same (cm).
- H. Turn off the sensor.

5.2 Other manual well measurements

- A. Lower water level meter until it reaches the bottom of the well. The tape will go slack when you reach the bottom. It may be necessary to raise and lower the water level meter to obtain an accurate measurement.
- B. Record the depth between the TOC and the bottom of the well (BW) in the “Measured” column on the data sheet to the nearest 1 cm. Make sure the datasheet shows a record of any offset between the tape’s water sensor (the needle near the center of the sensor probe, on some models) and the bottom of the sensor probe. (If the well point assembly has just been installed, this measurement will also be used to estimate the length of Kevlar rope that will suspend the pressure transducer in the well.)
- C. Use a standard hand tape measure to measure (along the outside of the well casing) the distance from the measuring point (TOC) to the ground surface to the nearest 1 cm. Record on the data sheet.

5.3 Surface flow description and measurement

5.3.1 Qualitative descriptions

Record a qualitative description of surface flow based on the description in the following table.

Table 1. Flow Severity

Flow Severity	Description
Dry	No visible water in stream (typical of dry period for an ephemeral/intermittent stream).
No Flow	Discrete pools of water with no apparent connecting flow (at surface).
Low	Base flow for a stream or flow within roughly 10% to 20% of base flow condition.
Normal	When stream flow is considered normal (greatest time that stream is characterized by this in terms of flow quantity, level, or general range of flow during a falling or rising hydroperiod, but above base flow).
Above Normal	Bank full flow or approaching bank full (generally within upper 20% of bank full flow condition).
Flood	Flow extends outside normal bank full condition or spreads across floodplain.

It is also useful to document the hydrographic limb of surface flow, if sufficient evidence is available for an accurate determination. Use the following table.

Table 2. Hydrograph Limb

Code	STORET Description
BASE	Natural groundwater flow unaffected by precipitation events
RISING	Increasing flow associated with precipitation or snowmelt.
PEAK	Highest flow associated with a precipitation event or snowmelt
FALLING	Decreasing flow associated with the return to natural groundwater flow following a precipitation event or snowmelt.

5.3.2 Measurements at stage gages and tape-down pipes

When surface water is present at a gage or tape-down pipe, use a standard metric hand tape to measure from the pipe's MP to the water surface on the outside of the pipe. The end of the tape should lightly break the water meniscus, with the measurement of distance to water surface read at the MP. Record to the nearest 0.1 cm.

5.3.3. Discharge measurement

Discharge is not currently being measured at SCPN hydrologic monitoring sites, but may be measured at some sites in the future.

The current meter procedure - general

- A. Record the water level in the instream installation before and after the discharge measurement to ensure conditions are stable.
- B. Assemble the wading rod and current meter mount. Slide the current meter mount on to the upper sections of the hexagonal wading rod and round setting rod. Screw on the bottom sections of each rod. Place the split washer into the foot of the wading rod, and screw the foot onto the hexagonal rod. Slide the current meter mount to the bottom of the rod.

- C. Ensure the current meter has the correct time in **Mountain Standard Time** (-1 hour from clock time during Daylight Savings).
- D. Choose a cross section in a straight reach that has the following characteristics:
- Streambed is free of large rocks, weeds, and protruding obstructions that create turbulence.
 - Streambed has a flat profile to eliminate vertical components of velocity.
 - All of the flow is directed downstream (i.e., there are no eddies) and lines of flow are as near parallel as possible.
- E. Pull a fiberglass-reel measuring tape taut perpendicular to the channel and secure using chaining pins.
- F. Divide the cross section of the channel into 20 to 30 partial sections.
- A partial section is a rectangle whose depth is equal to the measured depth at the location and whose width is equal to the sum of half the distances of the adjacent sampling locations.
 - The spacing between partial sections is adjusted so that no more than 10% of the flow is in any one partial section. The ideal is to have no more than 5% of the flow in any one partial section. This means that where water is deeper and swifter measurement points are spaced closer together, while in shallow and slow water they are spaced further apart.
- G. Measure the area and mean velocity of each section separately. The person wading the channel should stand downstream of the velocity meter at an arms-length distance from the current meter so as not to disturb the flow path.
- H. At each vertical, the following observations are recorded on the electronic interface:
- The distance to a reference point on the bank along the tag line.
 - The 0.6 tenths of depth value - The velocity should be measured at a depth which is 0.6 of the depth from the surface of water in the channel.
 - The averaged 40-second velocity as indicated by the current meter.

The discharge of each partial section is calculated as the product of mean velocity times depth at the vertical times the sum of half the distances to adjacent sampling locations. The sum of the discharges of each partial section is the total discharge. All of the necessary data and calculations are performed by the electronic interface/datalogger.

The current meter procedure – specific

FlowTracker Procedure

1. Insert the flattened prong into the current meter mount attached to the bottom of the wading rod. Use a screwdriver to tighten the screw and keep the probe in place.
2. Attach the data logger to the top of the wading rod.
3. Turn on the FlowTracker by pressing the On/Off switch for 1 second until the LCD screen turns on.
4. Press Enter to display the Main Menu.
5. Press 1 for the Setup Parameters Menu and verify the following values:
 - a. Units: English
 - b. Avg Time: 40
 - c. Mode: Discharge

6. To set date and time go to Main Menu, press 2 for the System Function Menu, then scroll through screens to select 9: Set System Clock.
7. From the Main Menu, press 3 to Start Data Run
8. Enter a file name
 - a. Naming convention is 2 letter site abbreviation + 2-digit month + 2-digit day + 2-digit year.
 - b. Example: FR110512 for Fremont River November 5, 2012
9. Enter site and operator name (Optional)
10. When prompted to run the automatic QC test, Press 1 to run the test and follow the on-screen instructions. The QC test must be performed at each site to ensure that the FlowTracker is working properly. If all checks say “Pass”, continue with the measurement. If a check fails, readjust the rod, and try again.
11. In the Starting Edge screen, press Set Location and enter the edge of water tag line distance.
12. Press LEW/REW to toggle the starting edge of water (Enter Right or Left *facing downstream*).
13. Press Next Station to continue.
14. Press Set Location and enter the tag line distance.
15. Place the wading rod at the target location. Use the 0.1 ft markings on the hexagonal rod to determine the water depth. Flow dynamics may cause water to rise on the upstream side of the rod and dip on the downstream side of the rod. Do your best to determine the actual depth. Press Set Depth, and enter the stream depth for the location.
16. Adjust the setting rod so that the current meter is located at 0.6 of the total water depth. For the top setting wading rod, move the line with the appropriate number of feet on the round setting rod to match the line with the appropriate tenths of feet depth printed on the wading rod handle. For example, if the water depth is 0.5 feet, slide the setting rod until the setting rod line marked “0” aligns with the handle line marked “5”. This sets the current meter at the correct depth for measuring.
17. Situate the probe so that the current meter mounting pin is perpendicular to the tag line, and the banded probe is on the downstream side. Press Measure.
18. The screen will display a countdown from 40 seconds while velocity is being measured.
19. Once the 40 second measurement is complete, a summary of velocity and quality control data is shown.
 - a. Press 1 to accept the measurement and move on to the next measurement.
 - b. A warning will be issued if any data are outside expected values.
 - i. If the warning is due to operator error, Press 2 to repeat the measurement.
 - ii. If a warning is due to natural elements of the stream, then accept the measurement and move on to the next.
20. Measure the velocity at 20-30 stations following the same procedure outlined above.
21. After recording the final distance at edge of water, press the End Section key.
22. Press Calculate Disch to complete discharge calculations. Press Enter to move between the different display screens.
23. Record discharge (Total Q) and velocity (V Mean) on the field form.
24. Press 0 to return to the main menu. It is important to return to the Main Menu before turning the system off to ensure all data are saved.
25. Power off the FlowTracker by holding the On/Off switch for 4 seconds.

6. Return Site Visits

Each set of monitoring wells is visited at a minimum of 3-month intervals through the year where site conditions make winter visits possible. Visits are timed to capture the greatest variation in groundwater level

and streamflow and will enable computation of a robust stage-discharge relationship over time. At sites where there is a danger of the pressure transducer becoming encased in ice, a freeze-resistant transducer (e.g., some Onset models) should be used, or the transducer should be removed from the installation prior to winter and reinstalled in very early spring. A lens of ice at the surface of the water can affect pressure transducer readings but does not jeopardize the equipment.

On each visit to the installations the following procedures should be performed.

- A. Note on the datasheet whether the visit is in Mountain Standard Time (MST) or Mountain Daylight Time (MDT). Use your watch's time to record times for all field measurements on the datasheet. Adjustments to MST will be made during data entry.
- B. Measure the water level in each well following the instructions in section 5.1.
- C. When possible (staying overnight on sight), take all three transducers out of their casings and place them in a stable environment (i.e. tent) for as long as possible. Then repeat steps 1-9 except naming this as a test. If all water transducers are recording within 3 cm, proceed to step 11. If there is obvious drift, replace the entire set of transducers with a set that has gone through air tests in the office as outlined in section 1.1 above.
- D. If the logger is partially or fully buried in sediment, make a note in the field comments including a qualitative description of the depth and type of sediment or debris. Clean out the sediment and rinse the logger, replace the logger, and take a water level measurement.
- E. Measure the distance between the top of casing (TOC) to the ground surface at the mark on or the notch filed into the well casing.
- F. Measure the distance between the top of casing (TOC) and bottom of the well (BW) following the instructions in section 5.2. If the TOC-BW measurement is smaller than what was recorded during the original installation (due to sediment buildup), then well re-development is necessary. Follow the well development procedures in section 1.2.4 to remove the sediment. If there is more than 6 cm of sediment buildup, you should re-develop the well during this visit. Otherwise, you can plan on developing the well during the next site visit. Always keep well development equipment in your vehicle in case you need it.
- G. Obtain and record measurements to 0.1 cm of distance to any water surface present at angle iron/pipe gages or tape-down pipes (see section 5.3.2) using a standard metric hand tape.
- H. Download data from pressure transducers and barometric loggers. Detailed instructions for downloading data are provided in the manufacturer's user manual for each instrument.

A field laptop loaded with Solinst Software can be used to download data from wells that are close to the vehicle. Make sure to bring the optical interface USB cable that is compatible with the pressure transducers and barometric logger. A field laptop may also be used to re-program instruments when necessary.

For routine visits to wells in remote locations, a smaller Solinst Leveloader PDA is recommended. Make sure to bring the correct interface cable (which is different than the cable used with a field laptop). The Leveloader does not have the ability to re-program the instruments so you will need to bring a laptop if this is necessary.

- I. Record the transducer removal and replacement times, % battery remaining, logger time, and laptop (system) time for each logger. Check the transducer function and battery voltage using the Utilities/Diagnostics in the Solinst download software. For Gold and Edge transducers, if the battery voltage is 3.4 volts or less, replace the logger with a new logger (replace Junior model loggers when battery voltage is 3.3 volts or less). If the logger time and system time are off by more than 5 minutes (accounting for the difference between Standard and Daylight Savings time), the logger should be synchronized with the laptop, set to **Mountain Standard Time**.
- J. It is usually best to stop all loggers at each site to clear memory and avoid “wrapping” the data. Delay-launch loggers to restart simultaneously, again selecting an “even” time step (e.g., 08:15:00, 14:30:00).
- K. If possible, take additional water level measurements after reinstalling a datalogger in a well, using the methods detailed in section 5.1.
- L. Record flow information following the instructions in section 5.3.1.
- M. If a stage gage camera is present, follow the manufacturer’s instructions for removing the data storage card. Download the card and check for image continuity. Clear the card memory before re-installing it in the camera. Replace all batteries and check the camera’s programming. Record the time the card was removed and replaced, the camera re-launch time, and the number of photos taken.
- N. Record detailed notes about any changes to the wells, levelloggers, geomorphic setting (e.g., channel change due to significant flooding), or vegetation noted at the site.

7. Hydrologic Data Processing

Detailed methods for data archiving and processing are provided in Appendix A. Upon returning from a field visit, the datasheet is scanned, and datalogger files are uploaded to the SCPN server. Water level data are barometrically compensated and adjusted to the manual water level measurement taken at the beginning of the test, and all data are visually reviewed for gaps or errors. Logger and manual depth to water data are uploaded to the Aquarius platform as time series datasets. Data are inspected for error or drift, and relevant corrections are applied if manual measurements (true water level) are more than 0.5 cm from the concurrent recorded logger measurement. Derived datasets convert the raw data to data referenced to a permanent datum, referenced to the ground surface, and referenced to a stage-discharge rating curve (when feasible). Finally, daily mean datasets are derived from approved data for data summary and analysis.

Well Installation: Driven Well		Data entered by:		Data verified by:	
SCPN Riparian Monitoring					
Park Code: HUTR		Site Code: HUTRPUE	Date:		
Observers:		Transect number: 2	Start Time:		
Measurements for Levellogger deployment					
WELL ID	Measurement description		Abbrev.	Measured	Units
HUTR02a	Distance between top of casing (TOC) and bottom of well (BW)		TOC- BW		(cm)
(Shoreward left*)	Distance from TOC to pressure transducer sensor (PTS)		TOC-PTS		(cm)
HUTR02b	Distance between top of casing (TOC) and bottom of well (BW)		TOC- BW		(cm)
(Streamward left*)	Distance from TOC to pressure transducer sensor (PTS)		TOC-PTS		(cm)
HUTR02c	Distance between top of casing (TOC) and bottom of well (BW)		TOC- BW		(cm)
(Right*)	Distance from TOC to pressure transducer sensor (PTS)		TOC-PTS		(cm)
*Riparian well on left or right when facing downstream.					
Water Surface Elevation Measurements					
WELL ID	Measurement description		Abbrev.	Time	Measured Units
HUTR02a	Distance between TOC and WS		DWS		(cm)
HUTR02b	Distance between TOC and WS		DWS		(cm)
HUTR02c	Distance between TOC and WS		DWS		(cm)
WS = water surface, Time = time of measurement (24:00)					
GPS Coordinates	UTM NAD 1983				
WELL ID	Northing	Easting		Elevation	Units
HUTR02a					(cm)
HUTR02b					(cm)
HUTR02c					(cm)
Barologger					(cm)
Log at least 30 points on GPS					
Photo Log		Photos taken? yes no		Reference images taken of well and general comments	
<i>Photo #</i>	<i>Photo Type</i>	<i>Well ID</i>	<i>Photographer</i>	<i>Description</i>	
	digital				
	digital				
	digital				
	digital				
	digital				
	digital				

Park Code: HUTR		Site Code: HUTRPUE		Well Subcode: 02a		Date:				
Field Notes Add descriptive notes and general comments below										

Well Installation: PVC Augered Well				Data entered by:				Data verified by:					
SCPN Riparian Monitoring													
Park Code: HUTR		Site Code: HUTRPUE		Date:									
Observers:				Well Subcode: 02a				Start Time:					
Soil textures encountered (well log)													
DEPTH BELOW GROUND SURFACE													
From:	To:	Substrate texture (circle)						Moisture content (circle)					
0		Clay	Clay/Loam	Clay/Sand	Silt	Sand	Coarse Sand/Gravel	Standing water	Saturated	Moist	Dry		
		Clay	Clay/Loam	Clay/Sand	Silt	Sand	Coarse Sand/Gravel	Standing water	Saturated	Moist	Dry		
		Clay	Clay/Loam	Clay/Sand	Silt	Sand	Coarse Sand/Gravel	Standing water	Saturated	Moist	Dry		
		Clay	Clay/Loam	Clay/Sand	Silt	Sand	Coarse Sand/Gravel	Standing water	Saturated	Moist	Dry		
		Clay	Clay/Loam	Clay/Sand	Silt	Sand	Coarse Sand/Gravel	Standing water	Saturated	Moist	Dry		
		Clay	Clay/Loam	Clay/Sand	Silt	Sand	Coarse Sand/Gravel	Standing water	Saturated	Moist	Dry		
		Clay	Clay/Loam	Clay/Sand	Silt	Sand	Coarse Sand/Gravel	Standing water	Saturated	Moist	Dry		
		Clay	Clay/Loam	Clay/Sand	Silt	Sand	Coarse Sand/Gravel	Standing water	Saturated	Moist	Dry		
Measurements for Levelogger deployment													
WELL ID		Measurement description						Abbrev.		Measured		Units	
HUTR02a		Distance between top of casing (TOC) and bottom of well (BW)						TOC- BW				(cm)	
(Shoreward left*)		Distance from TOC to pressure transducer sensor (PTS)						TOC-PTS				(cm)	
*Riparian well on left or right when facing downstream.													
Water Surface Elevation Measurements													
WELL ID		Measurement description						Abbrev.		Measured		Units	
HUTR02a		Distance between TOC and WS						DWS				(cm)	
WS = water surface, Time = time of measurement (24:00)													
GPS Coordinates		UTM NAD 1983											
WELL ID		Northing		Easting				Elevation				Units	
HUTR02a												(m)	
Barologger												(m)	
Log at least 30 points on GPS													
Photo Log				Photos taken? yes no				Reference images taken of well and general comments					
Photo #		Photo Type	Well ID	Photographer				Description					
		digital	02a										
		digital	02a										
		digital	02a										
		digital	02a										

Park Code: HUTR		Site Code: HUTRPUE		Well Subcode: 02a		Date:				
Field Notes	Add descriptive notes and general comments below									

Water Quality Datasheet

Park code: _____ Site name: _____ Date: (yyyymmdd): _____

Site code: _____ Observer(s): _____

Start time: _____ End time: _____ MST or MDT (circle one)

Site access notes, general observations, and other work done:

Precipitation during sampling (circle one): None Rain Freezing rain Hail Sleet Snow

Precipitation 24 hours prior to sampling (circle one): Yes No

Stream channel and flow conditions at the water quality sampling site												
Stream Channel	Channel (check one)	☐ Pool ☐ Riffle ☐ Open channel ☐ Braided ☐ Backwater										
	Substrate	☐ Clay grains not visible, smooth surface	☐ Silt grains not visible, gritty surface	☐ Sand grains visible, gritty, to lab- bag size	☐ Gravel looking to tennis ball size	☐ Cobble tennis ball to basketball size	☐ Boulder basketball to car size	☐ Bedrock larger than a car	☐ Vegetation	☐ Wood	☐ Other	
Flow (check one in each category)	Stream color	Clear	Milky	Foamy	Tan	Muddy	Green	Scum/todor	Other: _____			
	Flow mixing	Excellent	Good	Fair	Poor	% ice cover: _____		Average ice thickness (cm): _____				
	Flow severity	Dry	No flow	Low	Normal	Above normal	Flood	Comments:				
	Hydro-graph limb	Base	Rising	Peak	Falling							
Flood evidence (Check all that apply)	None											
	Fresh debris line: in channel / above active channel (circle one)											
	Grasses/shrubs laid over											
	Recent flood event greater than baseflow, but less than bankfull											
	Recent deposition of sediments on floodplain											
	Riparian vegetation scoured away											
	Other (note in comments)											

Aquatic and air temperature loggers			
Existing logger stop/DL time:	Serial number:	Existing logger stop/DL time:	Serial number:
New logger placement time:	Serial number:	New logger placement time:	Serial number:
Notes on sensor condition, battery %, and actions taken:		Notes on sensor condition, battery %, and actions taken:	
Data file name:		Data file name:	
NIST-Traceable thermometer model and serial number:			
NIST thermometer temp at time of download (°C):		Temperature at time of download (°C):	

Site code: _____ Site name: _____ Date: (yyyymmdd): _____ Observer: _____

Discharge measurement			
Start time:		End time:	
Observer:			
Discharge measurement method (circle one)		Flow meter	Flume
		Volumetric	Visual estimate
Flow meter time zone: MST MDT		File name:	
Flow Meter Make/Model/SNR:		Pygmy meter spin test (45 seconds ok):	
FlowTracker passes quality control test (circle): yes no		Discharge (m ³ /s): R ² :	
Discharge measurement location (e.g. distance upstream from gage):			
Control location, description, and condition:			
Observer's estimate of measurement accuracy (circle one): Excellent (<2%) Good (<5%) Fair (<8%) Poor (>8%)			
Estimate total percent of flow captured by measurement:			
Discharge measurement comments:			

Flow meter						Volumetric measurement	
Point	Velocity measurement depth (circle one)	Location (m)	Depth (m)	Velocity 1 (m/s)	Velocity 2 (m/s)	Container description	Container size
LEW						Try	Time to fill (seconds)
1						1	
2						2	
3						3	
4						4	
5						5	
6						Mean value	
7							
8							
9							
10							
11							
12							
13							
14							
15						Stage height	
16						Time	Height
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							

Field calibration of water quality instrument						
Calibration date:		Water quality instrument make and model:				
Calibration time:		Water quality instrument SCPN name:				
Instrument set to local time (circle one)?		Yes	No	Stream water temperature (°C) at time of calibration:		
Parameter	Standard value	Lot number	Pre-calibration		Post-calibration	
			Reading	Temperature (°C)	Reading	Temperature (°C)
Specific conductance	100 µS/cm					
	1413 µS/cm					
	Other: _____ µS/cm					
pH						
Dissolved oxygen	100% saturation (water saturated w/ air)					
	Barometric pressure (mmHg):					
Calibration notes:						
Water quality field measurements						
Water quality meter (attended)						Multi-parameter sonde (long-term deployment)
Time	Battery (%)	Water temperature (°C)	pH	Specific conductance (µS/cm)	Dissolved oxygen (mg O ₂ /L)	Dissolved oxygen (%Sat)
File name(s):						pH 7 value used: 7.____ temperature:____ reading:____ pH 10 value used: 10.____ temperature:____ reading:____ SpC 100 temperature:____ reading:____ SpC 1413 temperature:____ reading:____
Comments on water quality data collection						
Turbidity						
Turbidimeter Make/Model: Hach 2100P		Serial number: 06110C019647		Observer:		
Be sure to turn on signal average and auto range I				Date of last calibration:		
Calibration check with Secondary Gelox Standards				Sample readings		
Calibration check:	Date:	Time:				
Assigned value	Acceptable range	Reading	Sample #	Readings (NTU)		
$ch = mV_h \cdot 35.31$ $deg F = 1.8 (°C + 32)$		$P_{atm} = 25.4 \cdot P_{altHg}$ $max 3.28 = ft$				
$BP = 750 - 2.50(AH/100)$, where BP = barometric pressure at altitude, AH = altitude in feet						
Acceptable post-calibration ranges for core parameter measurements with Hydrolab MS-5 (Gibbs et al. 2007): Temperature - ±0.2 °C; pH - ±0.2 S.U.; specific conductance - ± 5 µS/cm if <100 µS/cm or ±3% if >100 µS/cm; dissolved oxygen - ± 0.2 mg/L, ± 2% saturation						

Bacteria sample processing			
Processed by:	Tray(s) read by:		
Incubation start time:	Incubation end date:		End time:
Incubator Make/Model:	Item name	Lot number	Expiration date
Temperature logged during incubation: ☐ yes ☐ no	Idea: 120 mL Vessel		
Temperature logger Make/Model:	Idea: Quanti-Tray 2000		
Logger serial number:	Idea: Colilert 18 / 24 (circle)		
Logger data file name:			
Incubator temperature			
Event occurred and/or action taken	Date	Time	Temperature

Bacteria tray readings		
	Positive large wells	Positive small wells
Tray 1: Total Coliform (yellow wells)		
E. coli (yellow & fluorescent wells)		
Tray 2 (circle): ☐ Blank ☐ Duplicate		
Total Coliform		
E. coli		
Comments on bacteria samples:		

Sample collection, processing and shipment			All bottles collected by:	
Sample collection time:			MWQL samples processed by:	
Processing time:				
Filter Make/Model	Quantity used	Lot number	Samples chilled? ☐ yes ☐ no	
			Filtration location: ☐ On-site ☐ At car ☐ Indoors ☐ Chamber	
			Pump Make/serial number: Geopump C08001443	
Bottle or acid type	Quantity used	Lot number / treatment / schedule number	Lab name	
			Shipping method	
			Drop date & time	
			Tracking #	
			Lab name	
			Shipping method	
			Drop date & time	
			Tracking #	
			Lab name	
			Shipping method	
			Drop date & time	
Inorganic blank water			Tracking #	
Comments on sample collection, processing and shipment:				

Appendix A - Hydrologic Data Processing

Hydrologic data collection methods are detailed in SOP #5. Upon returning from a field visit, the datasheet is scanned, and the scanned datasheet, datalogger files, and current meter files are uploaded to the NCPN server. Water stage data are barometrically compensated and adjusted to the manual depth to water measurement from the beginning of the logger test. Logger data are uploaded to the Aquarius platform as time series datasets. Field visit data are entered manually in Aquarius. All data are visually reviewed for gaps or errors. Data are inspected for error or drift, and relevant corrections are applied. Derived datasets convert the raw data to data referenced to the site's permanent datum and referenced to the ground surface for riparian wells. Daily mean datasets are derived from approved data for data summary and analysis.

Acronyms and Naming Conventions

For naming purposes, the following codes should be used:

Park Code	Park
AZRU	Aztec Ruins National Monument
CACH	Canyon de Chelly National Monument
CHCU	Chaco Culture National Historical Park
ELMO	El Morro National Monument
HUTR	Hubbell Trading Post National Historic Site
MEVE	Mesa Verde National Park
NAVA	Navajo National Monument
PEFO	Petrified Forest National Park
PETR	Petroglyph National Monument
SAPU	Salinas Pueblo Missions National Monument
WACA	Walnut Canyon National Monument

Each site and installation is assigned a site sub-code by GIS staff. Site subcodes use the format "PARKXXXXXXXXx." The first 4 characters are the established park code (above); followed by a 3-letter stream identifier code and a 2-digit site number. Where hydrologic installations are sited on a transect, a 2 digit transect number follows, and then an identifier for recording stage gages (RSGs) or a letter identifying each well. Each well on a transect is lettered in left-to-right order facing downstream (e.g., CHCUCHA0206a is the well farthest left at site 02, transect 06 on Chaco Wash at CHCU; CHCUCHA0206b is the center well on the transect; CHCUCHA0206c is the well farthest right).

Site SubCode	Description
CACHCDC0101a	Well on left at Chinle Wash Transect 01
CACHCDC0101b	Well on right at Chinle Wash Transect 01
CACHCDC0104a	Streamward Well on right, Chinle Wash Transect 04
CACHCDC0104b	Shoreward Well on right, Chinle Wash Transect 04
CACHCDC0107a	Well on left, Chinle Wash Transect 07
CACHMDC1402a	Well on left, Chinle Wash near White House Ruin
CACHMDC1402RSG	RSG on right, Chinle Wash near White House Ruin

CACHMDM1402a	Well on right, Tsaile Creek near Ledge Ruin
CACHMDM1402RSG	RSG on left, Tsaile Creek near Ledge Ruin
CHCUCHA0206c	Streamward Well at Chaco Wash Historic Transect 02
CHCUCHA0206a	Shoreward Well at Chaco Wash Historic Transect 02
CHCUCHA0206b	Center Well at Chaco Wash Historic Transect 02
CHCUCHA0206CSG	CSG at Chaco Wash Historic Transect 02
CHCUCHA0610b	Center Well at Chaco Wash Historic Transect 06
CHCUCHA0610a	Shoreward Well at Chaco Wash Historic Transect 06
CHCUCHA0610c	Streamward Well at Chaco Wash Historic Transect 06
CHCUCHA1101c	Shoreward Well at Chaco Wash Historic Transect 11
CHCUCHA1101b	Center Well at Chaco Wash Historic Transect 11
CHCUCHA1101a	Streamward Well at Chaco Wash Historic Transect 11
CHCUCHA14RSG	RSG on Chaco Wash near Visitor Center Bridge
ELMOHPL01a	Tape-down pipe measuring Point in Historic Pool
ELMOHPL01b	North Well near Historic Pool
ELMOHPL01c	Center Well near Historic Pool
ELMOHPL01d	South Well near Historic Pool
ELMOHPL01RSG	RSG in Historic Pool
HUTRPUE0102a	Shoreward Well, Left, Pueblo Colorado Wash Transect 02
HUTRPUE0102b	Streamward Well, Left, Pueblo Colorado Wash Transect 02
HUTRPUE0102c	Well on Right at Pueblo Colorado Wash Transect 02
HUTRPUE0104a	Shoreward Well, Left, Pueblo Colorado Wash Transect 04
HUTRPUE0104b	Streamward Well, Left, Pueblo Colorado Wash Transect 04
HUTRPUE0104c	Well on Right at Pueblo Colorado Wash Transect 04
HUTRPUE0107a	Shoreward Well, Left, Pueblo Colorado Wash Transect 07
HUTRPUE0107b	Streamward Well, Left, Pueblo Colorado Wash Transect 07
HUTRPUE0107c	Well on Right at Pueblo Colorado Wash Transect 07
HUTRPUE0110a	Shoreward Well, Left, Pueblo Colorado Wash Transect 10
HUTRPUE0110b	Streamward Well, Left, Pueblo Colorado Wash Transect 10
HUTRPUE0110c	Well on Right at Pueblo Colorado Wash Transect 10
HUTRPUE01RSG	RSG near Pipeline on Pueblo Colorado Wash
HUTRPUE01Z1	Zeedyk Well 01 on Pueblo Colorado Wash
HUTRPUE01Z2	Zeedyk Well 02 on Pueblo Colorado Wash
MEVEMAN0106a	Streamward Well, Right, near Mancos River at Gage Transect 06
MEVEMAN0106b	Center Well, Right, near Mancos River at Gage Transect 06
MEVEMAN0106c	Shoreward Well, Right, near Mancos River at Gage Transect 06
MEVEMAN0106RSG	RSG at Mancos River at Gage Transect 06

SAPUQUA01a	Measuring Point near Upstream End of Cañon Sapato Spring Pool
SAPUQUA01b	Well at Downstream End of Cañon Sapato Spring Pool
SAPUQUA0201RSG	RSG on Cañon Sapato upstream from pedestrian bridge
SAPUQUA02a	Well in Cañon Sapato downstream from bedrock ledges
WACACHC0102CSG	CSG at Cherry Creek near downstream boundary
WACACHC0102RSG	RSG at Cherry Creek near downstream boundary
WACALLM0102CSG	CSG at Walnut Creek below lower Lake Mary
WACALLM0102RSG	RSG at Walnut Creek below lower Lake Mary
WACANUB0102RSG	RSG at Walnut Creek near upstream boundary

Dates use Year-Month-Day (YYYYMMDD) format, e.g., 20120514

Firmware and Software Deployment History

Data Management	Use started	Use ended
Aquarius 3.x	11/1/2012	
Data sheet v. 1.0	10/2010	11/31/2012
Data sheet v. 1.1	12/12/2012	12/09/2013
Data sheet v. 1.2	12/10/2013	

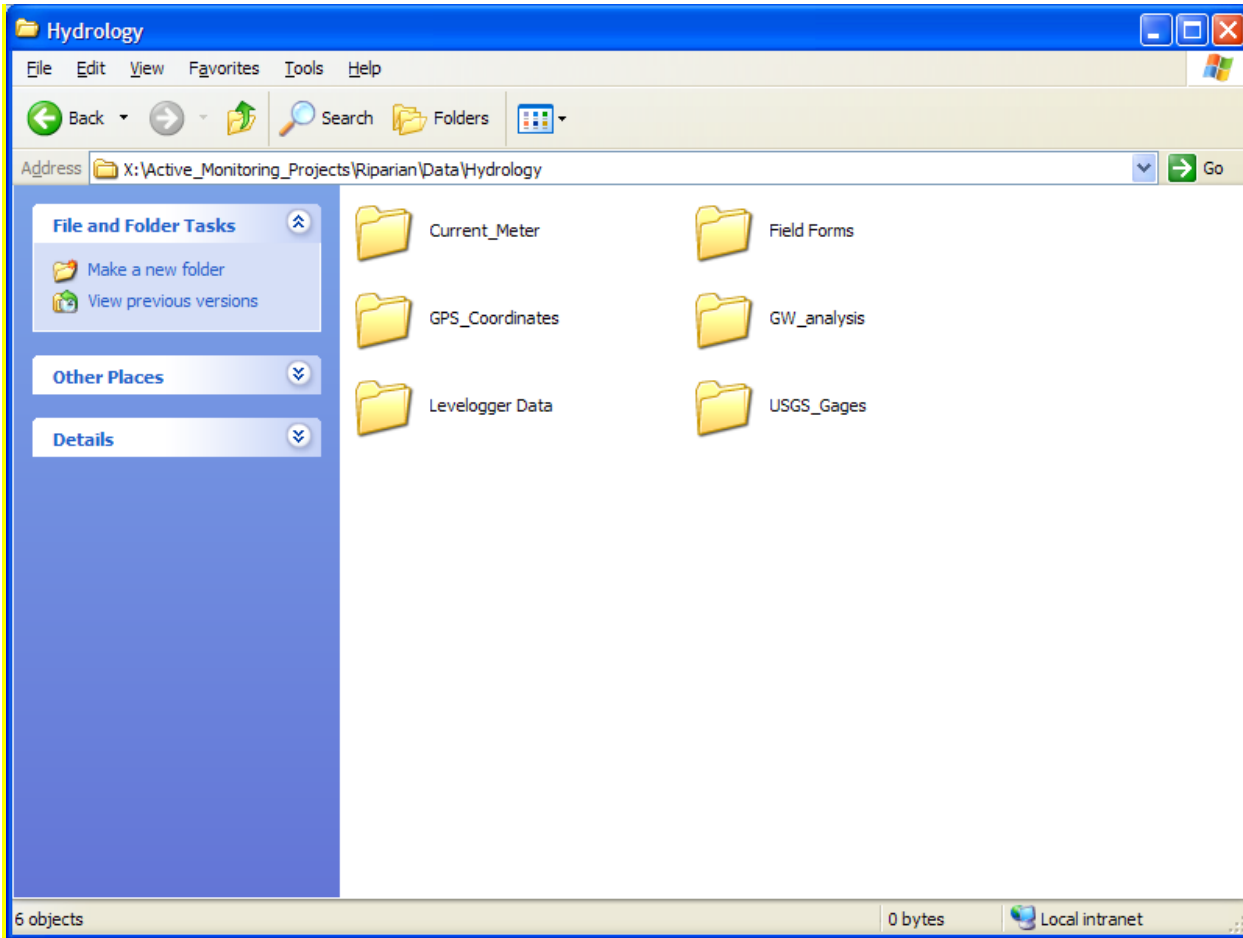


Fig. A-1. File structure for hydrology data on NCPN server.

Upon completing a field visit, upload raw logger files to the SCPN server at X:\Active_Monitoring_Projects\Riparian\Data\Hydrology\Levellogger Data into the appropriate park, reach and date folder (YYYYMMDD of site visit). Make sure the levellogger file uses the following convention:

PARK_Reach_well_date, e.g., ARCH_C1_instrm_20120514.lev, ZION_P3_left_20131008.lev, etc.

Scan the datasheet and upload to X:\Active_Monitoring_Projects\Riparian\Data\Hydrology\Field Forms in the appropriate park, stream reach and date (YYYY) folder. Name the field visit data sheet using the following convention:

PARK_Reach_Date, e.g., ZION_P3_20120514.xls

Update each well log with the site visit date, the period of record that was downloaded, the observer, and any maintenance issues pertaining to the well or notes about geomorphic change at the site. *These logs are essential for interpreting potential jumps or drifts in the logger data.*

When applicable, upload current meter files in their native format and as .csv files to X:\Active_Monitoring_Projects\Riparian\Data\Hydrology\Current_Meter in the appropriate park, stream reach and date (YYYY) folder. Name the current meter file using the following convention:

Reach_date, e.g., F1_20120514.csv

Upload photos to X:\Archive\NCPN Photos\Incoming\Monitoring\Riparian to the appropriate year and project folder. Leave photo names as produced by the camera.

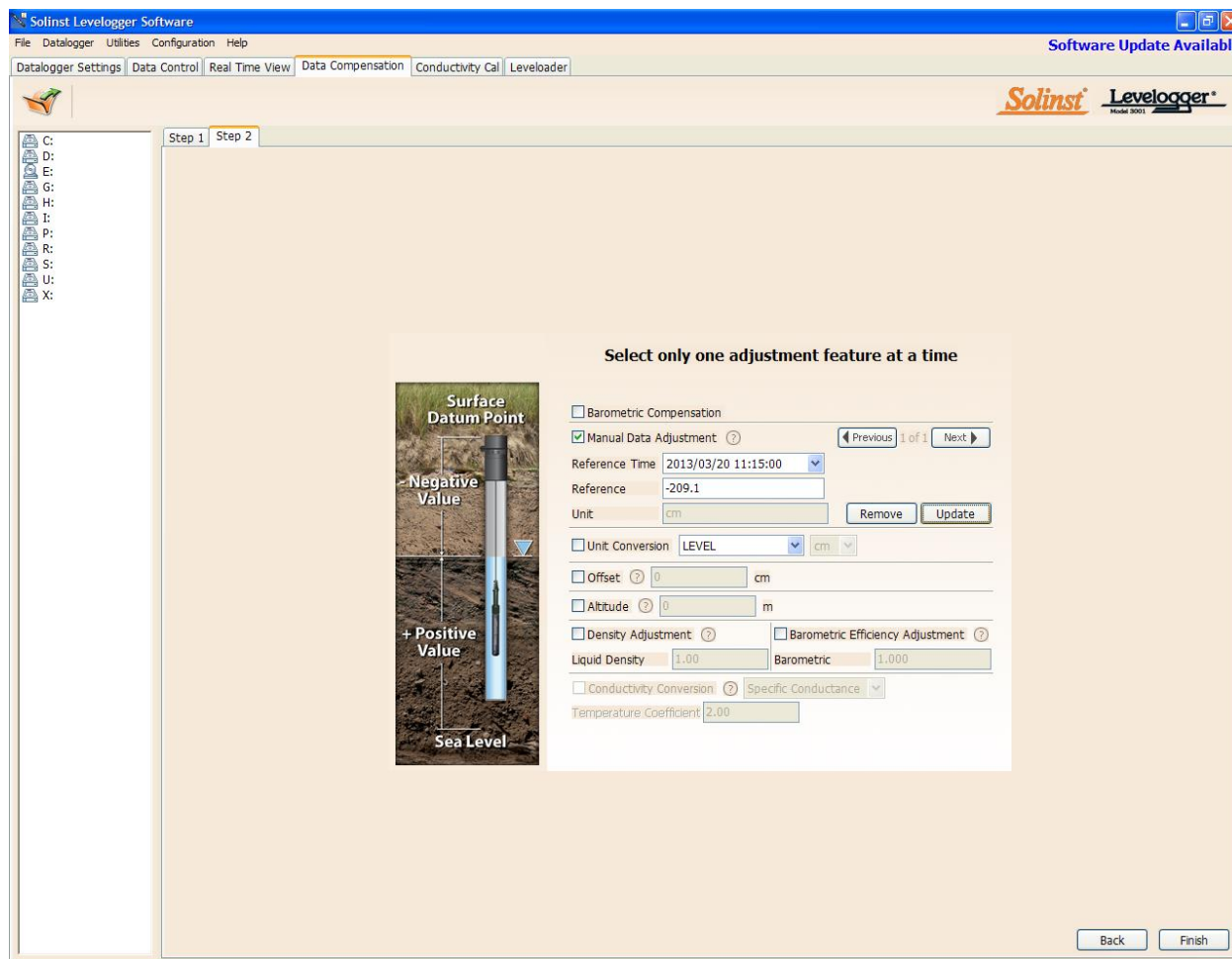
Barometric Pressure Compensation of Water Level Logger Data

All water stage data must be barometrically compensated by subtracting the barometric pressure recorded by the barometric pressure logger from the water stage recorded by each well's pressure transducer. Barometric pressure compensation can be completed using Solinst Levellogger software. Compensated data are then adjusted to the manual water level measurement taken during the field visit at the beginning of the logger record using Aquarius software.

Software compensation

These instructions are written for Solinst Levellogger Software v. 4.3.0 for use with the Levellogger Gold and Edge series.

1. Open Solinst Levellogger Software.
2. Open groundwater or surface water data file. Multiple files from a single site visit can be opened simultaneously.
3. Open the corresponding Barologger data file.
4. Select Data Wizard tab.
 - a. Make sure Barologger file is active (highlighted) under "Select a Barologger file."
 - b. Make sure submerged levellogger file(s) is/are active (highlighted) under "Select Levellogger file(s) to compensate," then click next. Barometric compensation will be performed on each file selected, and a list of compensated files appears on the screen.
5. If a "Warning" message is displayed next to the file name, data collected by the Barologger file do not overlap completely enough with the transducer data. Open the compensated file and compare the beginning and end time and date with those from the Barologger file. Compensation may need to be repeated (steps 2–4 above) using a Barologger file downloaded at an earlier or later date. In this case, the second compensated file generated will probably include only a few hours of data (from the missing period of overlap). Save the second compensated file as "xxx_Compensated-2" to avoid overwriting the first file.
6. Once a complete compensated data set is generated, open each file or set of files and export it (File/Export) as a .csv file with the same name as the compensated .xle file.



7. Open the adjusted levellogger file you just created (filename_compensated_compensated.lev). Export the adjusted and compensated levellogger file as a comma separated value (filename.csv) file. All files should be saved in the same folder on X (original, compensated, and exported .csv files).
8. Open the .csv file and delete any measurements taken prior to the equilibrated measurement. Round the level measurement column to the nearest 0.1 cm and the temperature measurement column to the nearest 0.01°C.
9. Repeat steps 2-6 for each levellogger file (riparian groundwater and instream levelloggers).

Aquarius Database

The following instructions are written for Aquarius 3.x developed by Aquatic Informatics.

The Aquarius database is currently accessed through five concurrent licenses held by the Water Resources Division (WRD). Permission to use a license is arranged by contacting the data manager for WRD, Dean Tucker (Dean_Tucker@nps.gov). Each unique user must have an account created by Dean.

Once an account has been created, to access the Aquarius database, double click the Aquarius Remote Assistant icon on your desktop. Use your PIV card or NPS username and password to log in to the Ft. Collins server ('localhost' or 'inp2300fcvgett1.nps.doi.net'). Once you have logged in to the server, right click the Aquarius Assistant (Remote) icon in the notification area of the Windows Task Bar (you might have to click the double-carets to show hidden icons), and select "Launch Springboard." Log in to the Aquarius database using your NPS username and password.

When you are finished using Aquarius, close the interface (Workstation/Whiteboard or Springboard). Right click the Aquarius Assistant (Remote) icon in the notification area of the Windows Task Bar, and select “Exit” to free up the license for another person’s use.

Data in the Aquarius database are organized by Organization, Project, and Location. Use the Northern Colorado Plateau Network Organization folder and Wadeable Streams Project folder. Each installation is a Location, and each parameter (i.e., levellogger depth to water, manual depth to water measurement, manual discharge measurement) is stored in a separate time series within the Location. Tutorials for getting started in Aquarius are available from WRD at:

<http://nrdata.nps.gov/programs/water/aquarius/AquariusVideos.htm>

and at the Aquatic Informatics support portal: http://aquaticinformatics.com/main/%3FSupport_Login.

Data in Aquarius

After all steps have been completed, you should have the following time series in Aquarius for each well:

Filename	Type	Description	Use
DepthtoWaterFromCasingTop.compensated logger@Location	Basic	15-minute barometrically compensated water stage data adjusted to manual depth to water measurement (cm)	Convert to Stage or Discharge; apply data corrections
Water Temp. logger@Location	Basic	15-minute water temperature (°C) from datalogger	Summarize and analyze approved data (optional)
DepthtoWaterFromCasingTop.Field Visits@Location	Basic	Manual depth to water (cm)	Compare to logger time series to determine drift corrections

Filename	Type	Description	Use
Stage.Datum@Location	Derived – calculated	Depth to water data converted to water elevation referenced to site's permanent Datum (m)	Summarize and analyze approved data (SOP 14; stage metrics); apply well elevation corrections; archive; compare groundwater well elevations to interpolate groundwater elevations between wells; compare to geomorphology data
Stage.Dailies@Location	Derived – statistical	Calculated daily mean stage in site datum (m)	Summarize and analyze approved data (SOP 14)
Riparian shallow groundwater wells			
DepthtoGroundFromCasingTop.Field Visits@Location	Basic	Manual depth to ground (cm)	Look for changes in ground surface elevation
DepthtoWaterFromGroundSurface.Calculated@Location	Derived – calculated	Calculated 15-minute depth to water from ground surface (m)	Convert to daily mean time series; apply ground surface elevation corrections
DepthtoWaterFromGroundSurface.Dailies@Location	Derived – statistical	Calculated daily mean depth to water from ground surface (m)	Summarize and analyze approved data (SOP 14)
Instream wells (CARE and ZION only)			
Discharge.Field Visits@Location	Basic	Manual discharge measurements (m ³ /s)	Create and maintain rating curve
Stage-Discharge.rating curve@Location	Rating curve	Stage-discharge relationship based on field visit measurements	Convert 15-minute stage to 15-minute discharge time series

Filename	Type	Description	Use
Discharge.Calculated@Location	Derived – rating curve	Derived discharge (m ³ /s) based on rating curve	Convert to daily mean time series
Discharge.Dailies@Location	Derived – statistical	Calculated daily mean discharge (m ³ /s)	Summarize and analyze approved data (SOP 14)
Discharge.gagenumber.Discharge_(cfs)_Daily_Mean@Location	External – USGS	Daily mean discharge (cfs) at USGS gaging station	Data quality checking and interpretation; summarize and analyze data (SOP 14; optional)

The screenshot displays the AQUARIUS Springboard web application in a Windows Internet Explorer browser. The interface includes a left sidebar with 'Location Folders' listing various national park and network locations. The main area is titled 'Data Sets' and shows a table of data sets for 'NCPN riparian monitoring Fremont River reach 1 instream well'. The table has columns for Dataset Id, Description, and Last Measurement. Below the data sets table, there is a 'Visits' section with a table showing dates, parties, and comments for the same location. The bottom of the screen shows the total data sets count and the user login information.

Dataset Id	Description	Last Measurement
Discharge.09330000.Discharge_(cfs)_Daily_Mean@CARE_F1_instream		
Stage.barometrically compensated water level above sensor@CARE_F1_instream		11/9/2012 12:45 PM
Stage.Elevation above sensor@CARE_F1_instream		
Stage.Field Visits@CARE_F1_instream		11/9/2012 12:00 PM
Discharge.Field Visits@CARE_F1_instream		11/9/2012 2:29 PM
River X Area.Field Visits@CARE_F1_instream		11/9/2012 2:29 PM
River X Width.Field Visits@CARE_F1_instream		11/9/2012 2:17 PM
Water Temp.Field Visits@CARE_F1_instream		11/9/2012 2:29 PM
Water Velocity.Field Visits@CARE_F1_instream		11/9/2012 2:29 PM
Water Temp.water temperature@CARE_F1_instream		11/9/2012 12:45 PM
Stage-Discharge.rating curve@CARE_F1_instream		

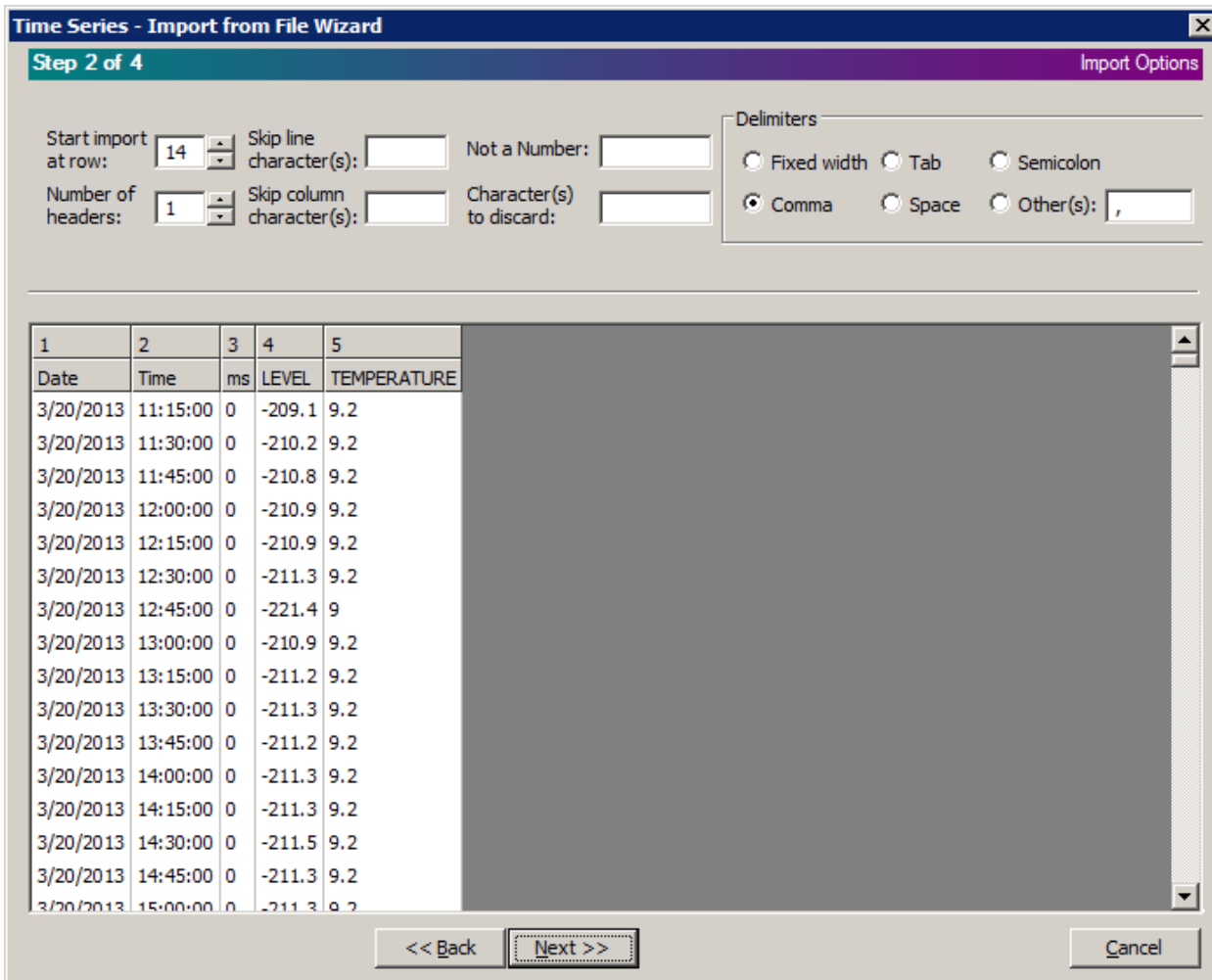
Date	Party	Comments
11/9/2012 12:00 PM	CH	water above top of casing at instream well, no
7/25/2012 11:00 AM	C. Hackbarth	pygmy meter with Aquacalc Pro
6/14/2012 7:40 AM	C. Hackbarth	instream levellogger line shortened to 122 cm
4/21/2012 12:22 PM	M. Van Grinsven	Well installation. No data collected.
9/15/2011 2:54 PM	K. Crawford, R. Weissinger	
1/20/2011 2:40 PM		88.75 cfs
10/26/2010 12:20 PM	M. Van Grinsven	No data collected. Check for erroneous logger

Total data sets: 11
Logged in: rweissinger

Fig. A-2. Example data set file structure for an instream well in Aquarius.

Upload Logger Data to Aquarius

1. Open the Northern Colorado Plateau Network organization folder.
2. Select the appropriate well location, e.g., CARE_F1_instrm.
3. Click on the Append Logger File icon.
4. Browse to the appropriate park and reach folder on X, and select the.csv file for upload. *Make sure you upload the compensated and adjusted data!* Use the appropriate configuration file or set up a configuration using the following steps.
5. Click on Config Settings.
 - a. Select Time Series, Text File (CSV, etc), and click Next.
 - b. Adjust the “Start import at row” so that the first row of data in your .csv file is shown in white in the import box in Aquarius (Solinst v.4.0.3 row 14). Adjust the “Number of headers” so only the column names are shown in gray in the import box (Solinst v.4.0.3 = 1). The “Delimiter” should default to “Comma.” Click Next.



Time Series - Import from File Wizard

Step 2 of 4 Import Options

Start import at row: Skip line character(s): Not a Number:

Number of headers: Skip column character(s): Character(s) to discard:

Delimiters

☐ Fixed width ☐ Tab ☐ Semicolon

☒ Comma ☐ Space ☐ Other(s):

1	2	3	4	5
Date	Time	ms	LEVEL	TEMPERATURE
3/20/2013	11:15:00	0	-209.1	9.2
3/20/2013	11:30:00	0	-210.2	9.2
3/20/2013	11:45:00	0	-210.8	9.2
3/20/2013	12:00:00	0	-210.9	9.2
3/20/2013	12:15:00	0	-210.9	9.2
3/20/2013	12:30:00	0	-211.3	9.2
3/20/2013	12:45:00	0	-221.4	9
3/20/2013	13:00:00	0	-210.9	9.2
3/20/2013	13:15:00	0	-211.2	9.2
3/20/2013	13:30:00	0	-211.3	9.2
3/20/2013	13:45:00	0	-211.2	9.2
3/20/2013	14:00:00	0	-211.3	9.2
3/20/2013	14:15:00	0	-211.3	9.2
3/20/2013	14:30:00	0	-211.5	9.2
3/20/2013	14:45:00	0	-211.3	9.2
3/20/2013	15:00:00	0	-211.3	9.2

<< Back **Next >>** Cancel

Fig. A-3.

Importing logger data into Aquarius.

- c. Define upload information for each column. For Solinst v.4.0.3 logger files:
 - i. For Column 1 (Date), select “Date/Time” and choose mm/yy/dddd in the ‘Date/Time Format’ drop down list. Select time zone UTC-07:00 (Mountain Standard Time). If for some reason the logger used a different time zone (such as daylight savings) during the period of upload, select

the time zone used by the datalogger, and Aquarius will adjust to the correct Standard time when appending the data to the existing time series.

Time Series - Import from File Wizard
Step 3 of 4 Column Parameters

Column 1

☒ Date/Time:
☐ Data
☐ Do not import column (skip)

Date/Time Format: mm/dd/yyyy
Time Zone: UTC-07:00

1:mm/dd/yyyy	2:HH:MM:SS	3:Skip	4:Raw'compensated logger'	5:Raw'logger'
Date	Time	ms	LEVEL	TEMPERATURE
3/20/2013	11:15:00	0	-209.1	9.2
3/20/2013	11:30:00	0	-210.2	9.2
3/20/2013	11:45:00	0	-210.8	9.2
3/20/2013	12:00:00	0	-210.9	9.2
3/20/2013	12:15:00	0	-210.9	9.2
3/20/2013	12:30:00	0	-211.3	9.2
3/20/2013	12:45:00	0	-221.4	9
3/20/2013	13:00:00	0	-210.9	9.2
3/20/2013	13:15:00	0	-211.2	9.2
3/20/2013	13:30:00	0	-211.3	9.2
3/20/2013	13:45:00	0	-211.2	9.2
3/20/2013	14:00:00	0	-211.3	9.2
3/20/2013	14:15:00	0	-211.3	9.2
3/20/2013	14:30:00	0	-211.5	9.2
3/20/2013	14:45:00	0	-211.3	9.2
3/20/2013	15:00:00	0	-211.3	9.2

<< Back Next >> Cancel

Fig. A-4.

Example Date Format for logger data import in Aquarius

- ii. For Column 2 (Time), select “Date/Time” and choose HH:MM:SS in the ‘Date/Time Format’ drop down list. Leave the default Time Zone value selected for Column 1.
- iii. For Column 3 (ms), select “Do not import column (skip).”
- iv. For Column 4 (LEVEL), select Data (Raw). For “Parameter” select DepthtoWaterFromCasingTop. For “Units”, select cm. If for some reason the logger file is not in cm, select the appropriate unit (such as m), and Aquarius will adjust to the correct unit when appending to the existing time series. For Gap Tolerance, write in the sampling interval plus one (e.g., “16” for a 15-minute sampling interval). For “Label” write “compensated logger.” The remaining selections can remain at their defaults (Int. Type = 1, Grade = unspecified, Approval = unspecified).

Time Series - Import from File Wizard

Step 3 of 4 Column Parameters

Column 4

☐ Date/Time:
 ☐ Data: Raw
☐ Do not import column (skip)

Parameter: DepthToWaterFr
 Int. Type: 1 - Inst. Values

Units: cm
 Grade: <unspecified>

Gap Tolerance: 16 Minutes
 Approval: <unspecified>

Label: compensated_logger

1:mm/dd/yyyy	2:HH:MM:SS	3:Skip	4:Raw'compensated_logger'	5:Raw'lqquer'
Date	Time	ms	LEVEL	TEMPERATURE
3/20/2013	11:15:00	0	-209.1	9.2
3/20/2013	11:30:00	0	-210.2	9.2
3/20/2013	11:45:00	0	-210.8	9.2
3/20/2013	12:00:00	0	-210.9	9.2
3/20/2013	12:15:00	0	-210.9	9.2
3/20/2013	12:30:00	0	-211.3	9.2
3/20/2013	12:45:00	0	-221.4	9
3/20/2013	13:00:00	0	-210.9	9.2
3/20/2013	13:15:00	0	-211.2	9.2
3/20/2013	13:30:00	0	-211.3	9.2
3/20/2013	13:45:00	0	-211.2	9.2
3/20/2013	14:00:00	0	-211.3	9.2
3/20/2013	14:15:00	0	-211.3	9.2
3/20/2013	14:30:00	0	-211.5	9.2
3/20/2013	14:45:00	0	-211.3	9.2
3/20/2013	15:00:00	0	-211.3	9.2

<< Back
 Next >>
 Cancel

Fig. A-5. Example depth to water data format for logger data import.

- v. For Column 5 (TEMPERATURE), select Data (Raw). For “Parameter” select Water Temp. For “Units”, select °C. If for some reason the logger file is not in °C, select the appropriate unit (such as °F), and Aquarius will adjust to the correct unit when appending to the existing time series. For Gap Tolerance, write in the sampling interval plus one (e.g., “16” for a 15-minute sampling interval). For “Label” write “logger.” The remaining selections can remain at their defaults (Int. Type = 1, Grade = unspecified, Approval = unspecified).
 - vi. Once all columns are defined, click Next.
 - d. On “Time Series Import Options” accept the default of “Apply Gap Processing Tolerance.” If you have not used a pre-made configuration file, you can choose to save the configuration you just created. Click Finish.
 6. Select the target datasets and, in the “Append to” dropdown boxes, select the appropriate existing time series. Click Append.

- vi. Once all columns are defined, click Next.

- d. On “Time Series Import Options” accept the default of “Apply Gap Processing Tolerance.” If you have not used a pre-made configuration file, you can choose to save the configuration you just created. Click Finish.

6. Select the target datasets and, in the “Append to” dropdown boxes, select the appropriate existing time series. Click Append.

Append Logger File - Fremont River Reach 1 river right riparian groundwater well | CARE_F1_right

Step 1: Select a logger file and load it:

Logger File: ...

Config File: (Optional) ...

Step 2: Choose the target data sets and append:

Label	Paramet	Units	# Points	From	To	Append to	Status
compensa	DepthToW	cm	1170	3/20/2013 11:15:00 AM	4/1/2013 3:30:00 PM	DepthToWaterFrc	
logger	Water Terr	°C	1170	3/20/2013 11:15:00 AM	4/1/2013 3:30:00 PM	Water Temp.logg	

History:

Time	Data Set	File	Message
12/19/2013 10:21:54	DepthToWaterFrom	CARE_F1_right_20130320_20130401_impo	Data points appended:1170.
12/19/2013 10:13:53	DepthToWaterFrom	CARE_F1_right_20121109_20130320_impo	Data points appended:12569.
12/19/2013 10:08:23	DepthToWaterFrom	CARE1_right_20120725_20121109_import.	Data points appended:10267.
12/19/2013 10:01:05	DepthToWaterFrom	CARE_F1_right_201206_import.csv	Data points appended:32000.
12/19/2013 9:59:52	DepthToWaterFrom	CARE_R1T1_right_Down_1_20_11_import.c	Data points appended:39502.
8/19/2013 12:24:13	Water Temp.logger	CARE_F1_right_20130524_20130811.csv	Data points appended:7566.

Fig. A-6. Appending data to existing datasets. Note the import history at the bottom of the screen and the ability to undo imports.

- You can then choose to upload additional files, or exit out of the Append Logger tool by closing the window via the 'X' in the upper right corner of the window to return to the Location folder.
- To ensure that the data have uploaded correctly, click on the large, right-pointing blue arrow to move to the location's data sets. Select a data set and then click on the Quick View icon to visually inspect the period of data just uploaded.
- If incorrect data are uploaded (i.e., the wrong well, data that have not been barometrically compensated, etc.), select the appropriate location, and launch the Append Logger File toolbox. In the History section at the bottom

of the window, select the date/time and data set(s) that were incorrectly uploaded and click “Undo.” The incorrect data will be removed from the time series.

Enter Field Visit Data in Aquarius

1. Select the appropriate well location.
2. Click on the Field Visit icon, and select New Field Visit in the field visit toolbox.
 - a. Enter the date, start time (**adjusted to Mountain Standard Time**), observer (party), and relevant logger, well, or geomorphic notes in the Remarks section. Record top of casing to bottom of well (TOC-BOW) in the Remarks section.
 - b. For instream wells, under Hydrometric Field Notes, upload copies of the data sheet and current meter file. Under Maintenance Notes, upload the updated well log.
 - c. For all wells, under Hydrometric Field Notes, upload copies of relevant site visit photographs.
 - d. If applicable, under Survey Notes, upload final copies of the survey data for the well transect (see geomorphology SOP).
 - e. Click Save.

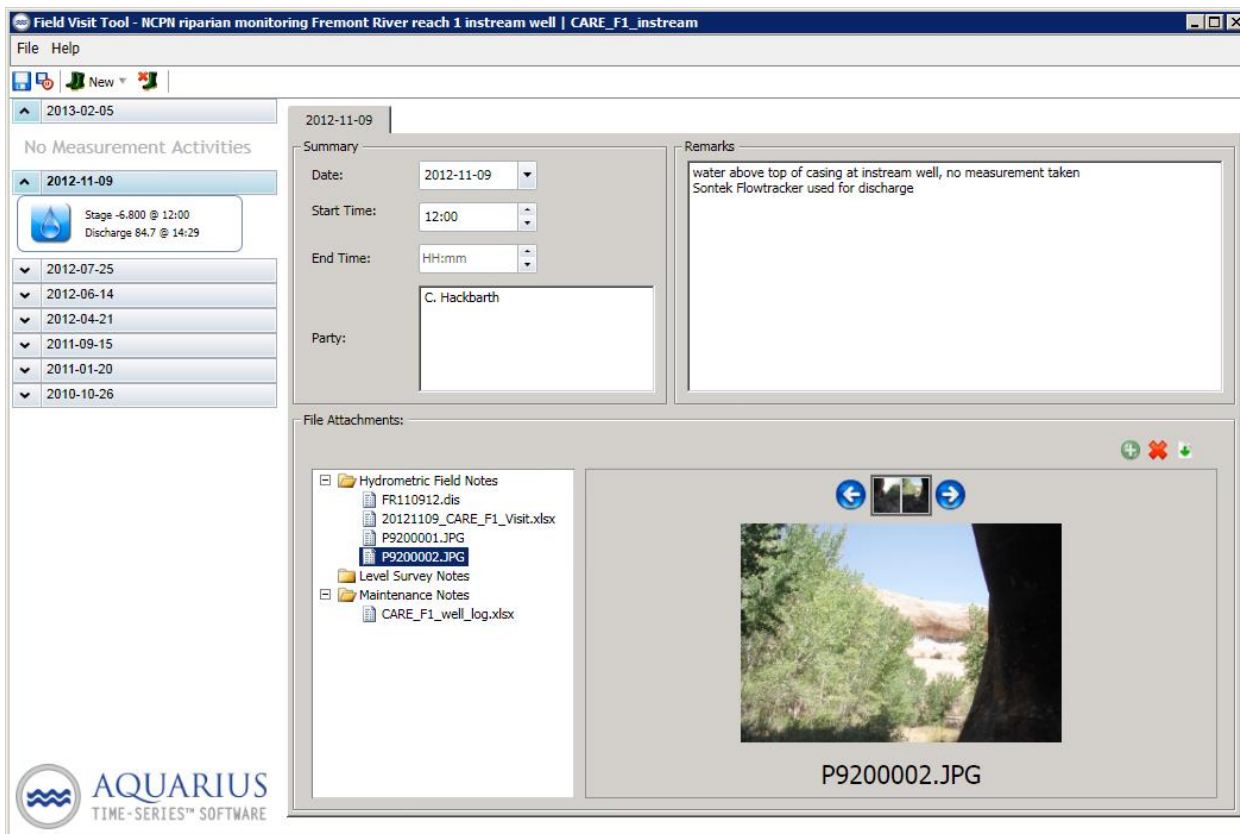


Fig. A-7. Example Field Visit in Aquarius.

3. For instream wells, select “New Measurement Activity from File” in the field visit toolbox, and select Flowtracker DIS.
 - a. Navigate to the appropriate current meter file on X and import the discharge data. Aquarius will create five parameters with default units: Discharge, River x Area, Water Velocity, River x Width, and Water Temp.

- b. Click Save.
- c. After the data have imported, click on the Discharge Measurement Details icon. Look at the Summary Result tab. Evaluate the Uncertainty (Stats) to determine the data quality as follows:

Uncertainty (Stats)	Grade
<2%	Excellent
2-5	Good
5-8	Fair
8-10	Poor
>10	Unusable

- d. Click Save.
4. For “Conditions” include the hydrograph stage (base, rising, falling) and weather conditions during the site visit.
5. For instream wells, click the green plus icon to add observations. For riparian wells, select New Measurement Activity. Manually enter the Depth to Water measurements from the data sheet to the nearest -0.01 cm (e.g., if the depth to water was 213.1, enter -213.1). If the tape guide was used, enter 6 in the Correction cell, and the true depth to water will automatically be calculated. **Adjust the time of the measurement to Mountain Standard Time if necessary.** Grade the measurements as follows:

Range of 3 measurements	Grade
0 cm	Excellent
0.1-0.3	Very Good
0.4-0.5	Good
0.5-0.8	Fair
0.8-1.0	Poor
>1.0	Unusable

6. Enter the Depth to Ground from Top of Casing measurement to the nearest -0.01 cm (e.g., if the depth to ground was 14.5 cm, enter -14.5)
7. For instream wells, click the green plus icon to add observations. Manually enter the stages recorded before and after the discharge measurement.
8. Click Save and close. The new site visit will show up in the Visit Log on the location page, and the data will be appended to the relevant field visit data set automatically.

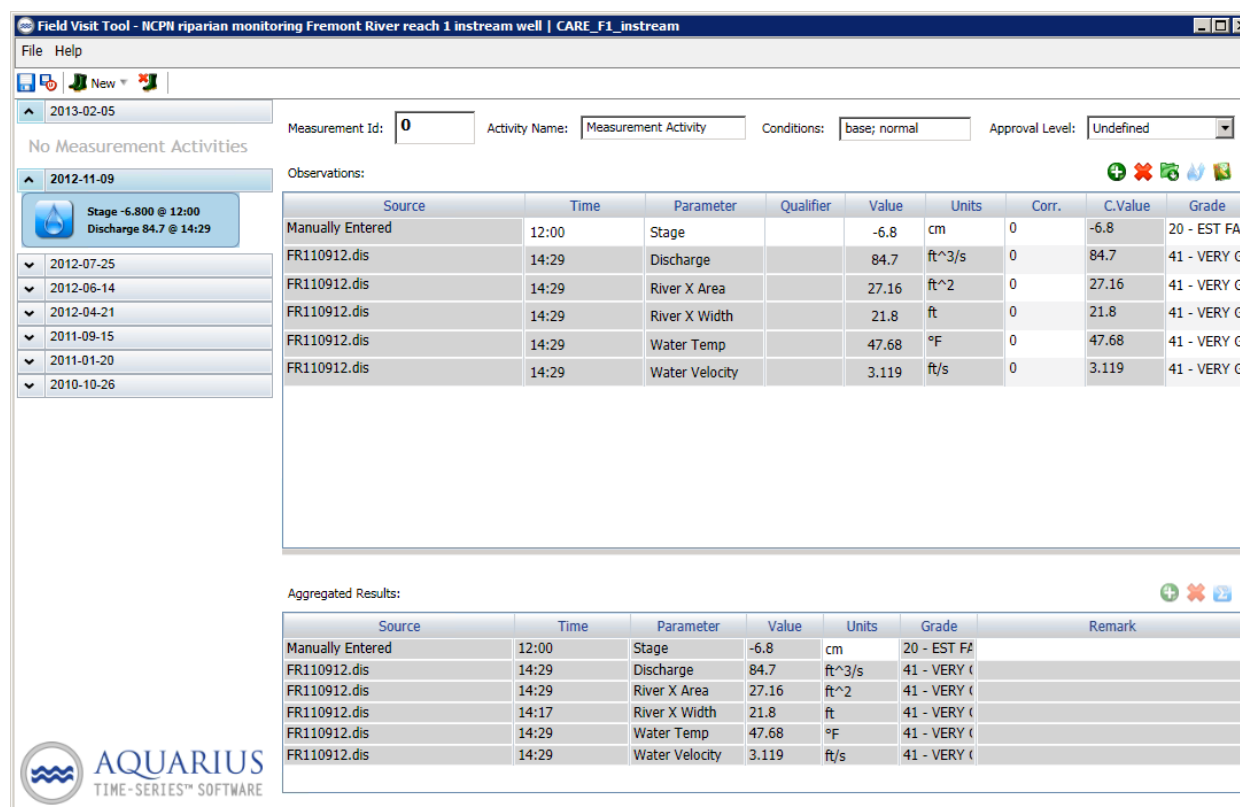


Fig. A-8. Example Measurement Activity for an instream well showing imported discharge data and manually entered stage data.

Acquire USGS gage data in Aquarius

The East Fork Virgin River and Fremont River have USGS gages with 15-minute discharge data relevant to our monitoring locations.

Gage number	Gage name	Location relative to monitoring site
09330000	Fremont River near Bicknell, UT	About 21 miles upstream of CARE-F01
09404900	East Fork Virgin River near Springdale, UT	Co-located with ZION-P03

The East Fork Virgin gage is co-located with the monitoring wells at Zion, and gage data may be used to quality check NCPN data and fill gaps in the NCPN data record for discharge. The Fremont gage is too far upstream from the monitoring wells at CARE to be used in the same way, but it can still provide a useful comparison to NCPN data for identifying some flood events, the opening and closure of irrigation diversions, etc.

1. Select the appropriate instream location, and click on the Location Manager icon. Select the Data Sets tab, and click on the New Time Series icon.
2. Under Type, select 'External'. Click on the '...' and set the Data Provider to 'USGS Water Services'.
3. Enter the gage number in the Location field or Browse to find a gage and then click 'Load'.

4. Once a gage has been selected, select the time series of interest (generally Discharge (cfs) Daily Mean).
 - a. The Start date and End date will show the period of record available. You may select the entire period of record or specify an interval to extract. Click OK.
5. Specify Parameter (Discharge), Units (ft³/s), and Gap Tolerance (1440 minutes per day).
6. Save and close. Launch the time series in Quick View to visually inspect the data.

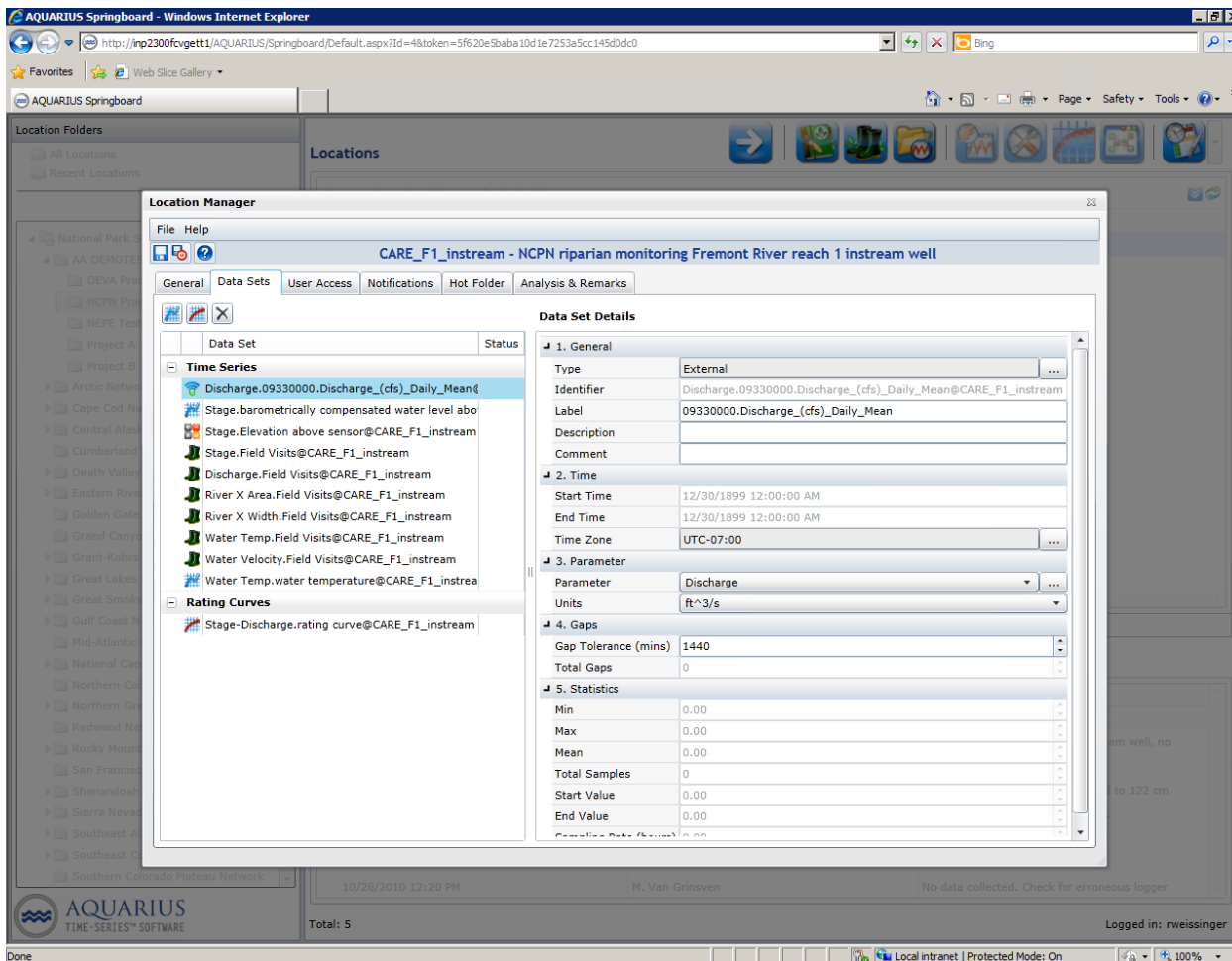


Fig. A-9. Creating an external dataset to acquire USGS gage data.

After the time series is created, Aquarius creates an active link to the USGS gage data. The data are not stored in Aquarius, but are pulled in each time the time series is needed.

Data Corrections and Edits to the compensated logger time series in Aquarius

Data corrections and edits are accomplished using the Data Corrections toolbox. The Data Corrections toolbox creates a log of each edit applied to the dataset. The underlying raw data are maintained in Aquarius as well as the corrected dataset, and each edit can be toggled on or off by selecting it in the correction log.

The goal for each well's hydrograph is to have the logger data match up with manual water level measurements taken during each field visit. Manual depth to water measurements are assumed to be the true water level, and logger data should be corrected to match the manual water level measurements. The beginning datapoint of each imported logger file is adjusted to match the manual water level measurement using Solinst Levellogger software (see Software Compensation section above).

Several types of data corrections may be needed. Faulty data are collected any time the sensor is out of water, such as during data download or sensor programming. Drift corrections occur due to the gradual degradation of the pressure transducer sensor and components and can be seen as a mismatch between the last recorded logger value and the manual water measurement taken during the field visit at the end of the logger record. Offset corrections may be needed to correct unusual jumps in the data, perhaps from sedimentation, ice, or differing sensor elevations. All of these corrections should be applied to the `DepthtoWaterFromCasingTop.compensated logger@Location` time series.

When evaluating a data record, look for smooth curves and reasonable agreement between wells. Investigate and attempt to explain any jagged (noisy), spike (non-event related jumps), or flat (instrument malfunction) data. Do instream peaks match known precipitation events or rises in discharge or stage at relevant gaging stations? Do Stage.Datum curves match for all wells? Detailed instructions for removing faulty data and adjusting for sensor drift are included below.

Removing faulty readings corresponding to field visits

Incorrect depth to water data that correspond to when Leveloggers are removed from wells for data downloads should be flagged in the raw dataset and removed for data summary and analysis. In Aquarius, open the logger time series for the well of interest in the Data Correction toolbox. Select the values that correspond to when the logger was out of the water, and select Delete Region. When prompted, add a note, e.g. "logger out of water." Save.

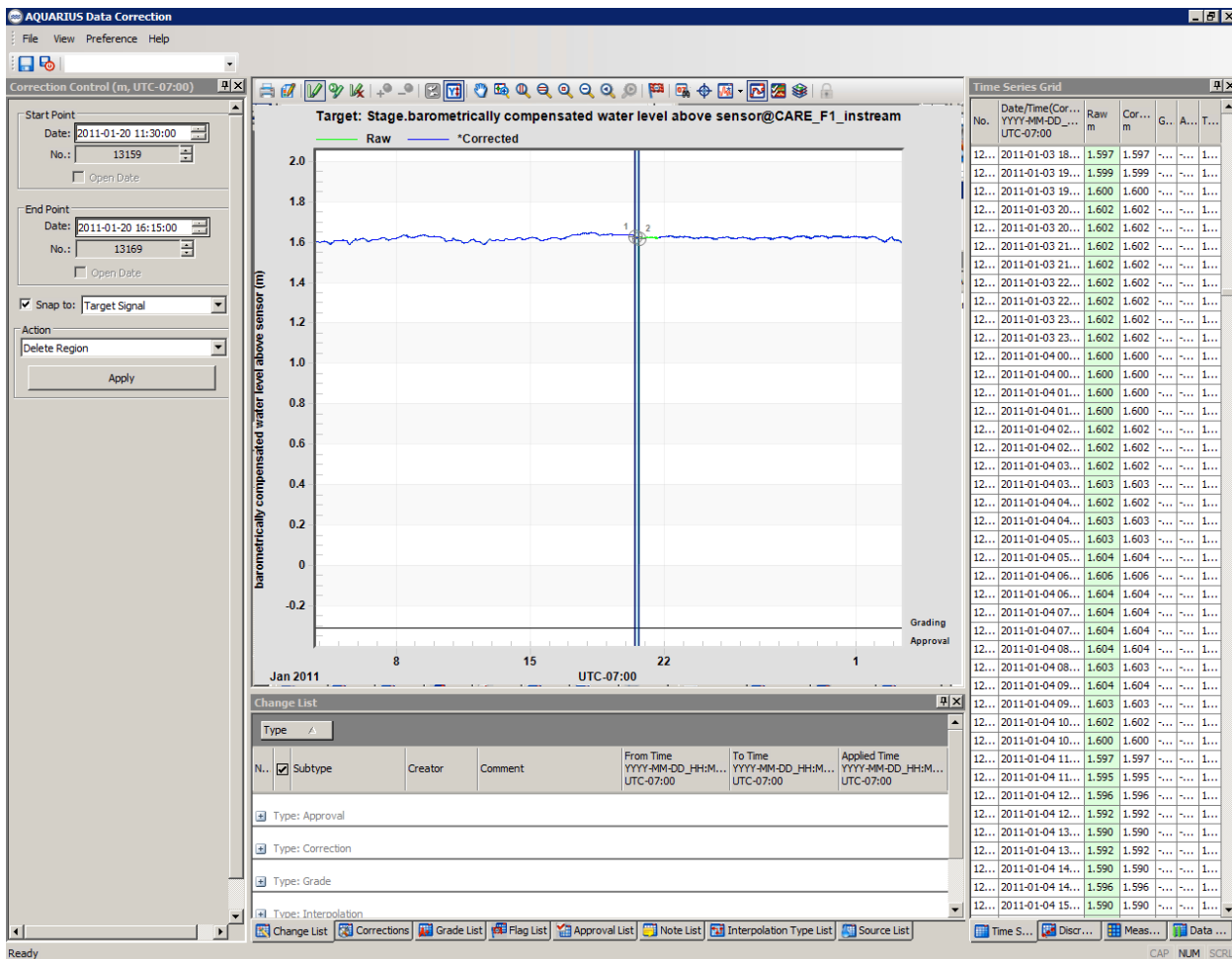


Fig. A-10. Deleting erroneous data in the Data Correction toolbox.

Adjusting for sensor drift or offsets

Compare the levellogger reading at the end of the period with the manually measured depth to water reading from the corresponding field visit. If the difference is 0.5 cm or less, no corrections are applied.

If there is more than 0.5 cm difference between the two measurements, a data correction should be applied. The quality goal for NCPN is to have less than 1.5 cm drift between site visits spaced two months apart. If there is more than 1.5 cm difference between the two measurements on a recurring basis, the logger should be serviced or replaced.

In the Data Correction toolbox, open the logger (DepthtoWaterFromCasingTop.compensated logger) time series as the Target and the field visit time series (DepthtoWaterFromCasingTop. FieldVisit) as the Surrogate. If field visit values are offset from the logger time series, check for possible user errors such as: an offset of one hour due to differences between Daylight Savings and Standard time, an offset of 6 cm due to incorrectly accounting for whether or not the tape guide was used, etc. Other specific corrections include corrections for sediment and ice effects.

Adjusting for sedimentation

If a logger sensor becomes partially or completely covered in sediment, the pressure of the sediment is added to the water pressure, and stage records can be artificially high. If the logger record is higher than the manual measurement, check the field visit information to see if sediment may have affected the record. If so, apply the relevant offset correction back to the peak flood flow since the previous field visit and record "sedimented logger" as a note on the data correction.

Adjusting for ice effects

During particularly cold periods, surface ice may accumulate on streams. When the stream warms, an ice blockage may suddenly break, causing a surge of water down the stream that is unrelated to a precipitation event. Remove the false spike using the Delete Region function, and interpolate a linear line between the stable water depth measurements using the instructions below.

Interpolating missing data

Missing data can occur due to equipment failure, staff turnover, ice, flooding, siltation or other causes. Gaps of less than two hours may be filled using linear interpolation, although caution should be used during flood events. Open the time series of interest in the Data Correction toolbox. Select the gap of interest, and choose "Fill Data Gaps" and "Linear Interpolation." Apply and save.

Corrections when the cause is unclear

If no user errors are apparent and the data record is smooth with no apparent problematic areas, select the appropriate period of record, and select "Drift Correction". A drift correction applies a correction incrementally over the selected time period.

Click on the hand icon and select the crosshairs at the end of the selected region. Drag the crosshairs to the manual water level reading data point. Note the calibration drift, and click Apply. When prompted, add a note indicating the

series was adjusted to the manual water level reading and the level of drift, e.g., “adjusted to manual water level reading, drift =- 1.2 cm.” Save.

Other data corrections

For corrections based on changes in well elevations or ground surface elevations, see the section on correcting derived datasets below. No other routine data corrections are anticipated at this time. However, should the need for additional data corrections arise, make sure each correction is documented using an explanatory note in Aquarius.

Approving and grading the time series for data summary and analysis

Once the data have been corrected and edited and are ready for use in derived datasets, data summary and analysis, select the appropriate period of record, and select “Set Approval.” Select “Approved,” and apply it to the time series. For any period of data that has a beginning and ending field visit, a minimal drift correction, and no unexplained noise or jumps, set the Grade to “Good”. For any period of data that has a beginning and ending field visit, but has an unusually large offset, unexplained spikes, or some other problem that can be rectified with corrections, set the Grade to “Fair.” For any period of data that 1) is missing either a beginning field visit, an ending field visit, or both; or 2) has unexplained spikes or noise that cannot be reasonably corrected, set the Grade to “Poor” or “Unusable”. Save and close. Only “Fair” or better graded data should be summarized and used for analyses.

Create Derived Datasets in Aquarius

Derived datasets include calculating water elevation tied to the site’s permanent datum and depth from ground surface for riparian well logger data. Statistically derived datasets include daily mean depth to water, stage and discharge.

Calculate derived datasets

1. Select the appropriate location and click on the Location Manager icon. Select the Data Sets tab, and click on the New Time Series icon.
2. For type, select Derived – calculated.
3. Click on the ellipsis to select the time series from which you will derive the calculated time series.
 - a. For Stage.Datum, select the DepthtoWaterFromCasingTop.compensated logger time series.
 - b. For DepthtoWaterFromGroundSurface.calculated, select the Stage.Datum time series.
4. Create a formula to calculate the new time series:
 - a. For Stage.Datum: calculated $y = \text{initial datum elevation of top of casing from geomorphic surveys} + \text{data } x1$

Reach	Right well elev (m) – Date	Instream well elev (m) – Date	Left well elev (m) - Date
ARCH C-01	N/A	993.350 – 3/1/2014	995.749 – 3/1/2014
CARE F-01	1580.555 – 3/20/2013	1578.501 – 3/20/2013	1580.603 – 3/20/2013
NABR A-05	N/A	1976.717 – 3/25/2015	N/A
ZION P-03	998.347 – 2/28/2013	996.075 – 2/28/2013	997.962 – 2/28/2013

- b. For DepthtoWaterFromGroundSurface.calculated: calculated $y = -(\text{initial datum elevation of ground surface from geomorphic surveys} - \text{data } x1)$

Reach	GS at right well (m) - Date	GS at left well (m) - Date
ARCH C-01	N/A	995.592 – 3/1/2014

CARE F-01	1580.244 – 11/14/2009	1580.471 – 11/14/2009
ZION P-03	997.450 – 10/27/2011	997.606 – 10/27/2011

- c. Make sure all units in the formula are the same. To convert from an input in centimeters to an output of meters, write the formula so that all units are in cm. Set the dataset units to m.
- d. Add a label: “Datum” for elevation referenced to the datum or “calculated” for depth to water. Select the appropriate Time Zone (UTC-07:00), Parameter (Stage or Depth to water from ground) and units (cm). Choose a Gap Tolerance of the sampling interval plus one (e.g., “16” for a 15-minute sampling interval).
5. Click Save and Exit. A new derived time series will appear in the dataset list. Visually inspect the dataset using the Quick View toolbox. After a derived time series is created, the derived dataset is updated each time data are appended to the original time series or the original time series is edited or corrected.

Daily means

1. Select the appropriate location and click on the Location Manager icon. Select the Data Sets tab, and click on click on the New Time Series icon.
2. For type, select Derived – Statistical.
3. Choose the parameter (Stage, Depth to water from ground or Discharge) and the appropriate units.
4. Click on the ellipsis to select the time series from which you will derive the daily mean time series, the 15-minute depth to water or discharge data.
5. Select Aggregate and Daily, and click OK.
6. Add a label “Dailies.” Choose a Gap Tolerance of 1440 (number of minutes per day).
7. Click Save and Exit. A new derived time series will appear in the dataset list. Visually inspect the dataset using the Quick View toolbox. After a derived time series is created, the derived dataset is updated each time data are appended to the original time series or the original time series is edited or corrected.

Derived dataset corrections

Changes in well elevations

Occasionally, the top of well casing elevations may change due to flood damage, the need to deepen a well to capture extreme drought, or for other reasons. If the well casing elevation changes by more than 0.01m, an offset should be applied. In the Data Correction toolbox, open the Stage.Datum time series. Select the period affected by the change and select “Offset Correction”. An offset correction applies the correction immediately and for the entire period selected, rather than incrementally. Enter the offset needed, and click Apply. When prompted, add a note indicating the well elevation changed and the level of offset, e.g., “well deepened, offset = 58 cm.” Save.

Offsets to the DepthtoWaterFromGroundSurface time series should be applied if the ground surface elevation has changed more than .05 m (5 cm) based on field measurements of top of casing to the ground surface and/or geomorphic survey data. If a flood event has caused significant change, apply the new ground surface elevation as an offset correction at the flood peak. If there is no associated flood event, a drift correction can be applied between field visits.

1. Open the derived dataset using the Data Correction toolbox. Select the region to which the correction needs to be applied.
 - a. If you want to apply an open-ended correction (i.e., a change that should be applied to data added to the time series in the future), check the Open box under End Date.
2. Select Offset Correction, and enter the correction that needs to be applied. You will see a preview of a corrected time series shifted to your offset. If you are satisfied with the correction, click Apply.
3. Add a note indicating the reason for and magnitude of the offset correction, e.g., “Flood reshaped groundsurface; resurvey indicates surface is +0.22m higher than earlier survey.” Click save.

Create a Rating Curve in Aquarius

Once the instantaneous (15-minute) water stage data have been corrected, additional steps are needed to convert water stage data to discharge. These steps include the establishment or maintenance of the stage-discharge relationship (rating curve), and finally, computation of 15-minute and mean daily discharges. The development of the rating is one of the principal tasks in computing discharge records. Due to predominate low flows, no stable section control, and a very dynamic channel geometry it would be extremely difficult to create an accurate stage-discharge relationship at ARCH C-01. Stage-discharge relationships may be created for CARE and ZION.

A rating curve or stage-discharge relationship is developed from numerous stage and discharge measurement computations made at the site over a range in flows by plotting stage versus discharge in the Rating Development toolbox. The more points, the more precise the rating curve is likely to be. A minimum of 10 sampling events over a range of flow levels is recommended initially. However, the rating curve will shift over time, and periodic measurements are necessary throughout operation to either confirm the permanence of the rating or to apply changes/shifts in the rating. In order to be most accurate, it is important that the rating curve include measurements made at flow extremes, under both high flow and extreme low flow conditions. Because of the flashy nature of NCPN streams, it is unlikely NCPN will be able to sample high flow events for safety and access reasons. Extrapolating values for discharge outside of the range of actual stage/discharge measurements can introduce error. Because of the log relationship between stage and discharge, small errors in the rating curve can result in large errors in discharge calculations. NCPN may require expert assistance when first developing rating curves for each site.

Open the Location Manager toolbox for the appropriate instream well, select the Data Sets tab, and click on the New Rating Curve icon. Label “rating curve”. Specify the Input Parameter as Stage (cm) and the Output Parameter as discharge (m^3s). Click Save and Exit. Aquarius automatically populates the rating curve with the manual stage and discharge measurements taken during field visits.

Go to Data Sets. Select the rating curve and stage time series, then open the Rating Development toolbox.

Select the points to use to develop the rating curve; for example, measurements taken during the period of record, measurements at stages that fall into the same type of control, etc.

In log-log space (Rating Zoom 1 view), use the Offset Manager tool to create Offset 1, single plotting offset. Enter offsets until the selected points begin to create a straight line in log-log space. To better visualize departures from linearity, add rating points between the lowest and highest selected points. Consult the Shift Diagram. For a good offset, the rating curve line will cross the error bars of all points. Look at the Rating Table, and check that the slope is between about 1.3 and 2.8.

Create additional offsets for stages with different control, geomorphic breaks, etc. When adding additional offsets, one of the rating points must be defined as the breakpoint.

It is highly unlikely that NCPN will have measured stage and discharge values for high flow events. Extrapolation of the rating curve is acceptable up to 2x the highest measured discharge value OR up to a stage that corresponds to a different channel geometry (e.g., when flow overtops the channel and moves onto the floodplain). To extrapolate the rating curve, use the Extend Rating in a Straight Line icon.

Open the Rating Period Measure and choose the period of record for which the rating curve applies.

Temporary shifts to the rating curve

Temporary shifts to the rating curve often apply during periods of scour (rising hydrograph) and deposition (falling hydrograph). Stage/discharge measurements from these periods may not align well with an established rating curve. In such cases, the Shift Manager can be used to shift the curve away from the underlying curve temporarily. Select the applicable points, and in Shift Diagram select Move Shift Point. In Shift Diagram, drag the rating curve to the applicable points. Set the start date and end date to which to apply the shift in the Shift Manager toolbox, and fine tune dates using Adjust Date in the Time Series View.