PAJARO RIVER WATERSHED
FLOOD PREVENTION AUTHORITY
Phase 4b: Implementation Plan for Soap Lake Floodplain Preservation Project and Watershed Flood Protection Actions

Technical Memorandum No. 4.4.4

Task:	**Evaluation of Gage Rehabilitation Options**
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Introduction

This technical memorandum presents information pertaining to installation of real time data transmission equipment at two proposed streamflow gage sites in the upper Pajaro River watershed. Data gathered from these two sites will be very valuable for flood forecasting and water resource management. All photographs shown in this report were taken at the two sites of interest with the exception of the current meter used for the measurement of water velocity (Figure 2) and the sonic downlooker (Figure 7).

The two sites are identified by the United States Geological Survey (UGGS) as Pacheco Creek near Dunneville, CA (Site #11153000) and San Benito River near Willow Creek School, CA (Site #11156500). For simplicity in this report, these two gage sites and the streams they measure shall be referred to as “Pacheco” and “SB WC”, respectively.

The Pacheco site is approximately 9 miles north of Hollister along Pacheco Creek in southern Santa Clara County. The existing streamflow equipment no longer functions and will need to be repaired or replaced. Installation of data transmission equipment will also be required.

The SB WC site is located along the San Benito River in southern San Benito County approximately 20 miles south of Hollister. This site has a fully functioning and routinely calibrated streamflow gage run by the USGS. Installation of data transmission equipment in addition to that operated by the USGS is the only requirement for local agencies to remotely monitor channel flow at this location.

Further information about these sites is presented in Table 1 below. Figure 1 shows where the sites are located in the upper Pajaro River watershed.

Table 1: Streamflow gage sites.

USGS I.D. No.	Streamflow Gage Site Name	Abbreviated Gage Name	Drainage Area (sq. mi.)	Period of Record
11153000	Pacheco Creek near Dunneville, CA	Pacheco	146	Oct 1982 to Sept 2003 (discontinued)
11156500	San Benito River near Willow Creek School	SB WC	249	Oct 1988 to present (continuous)

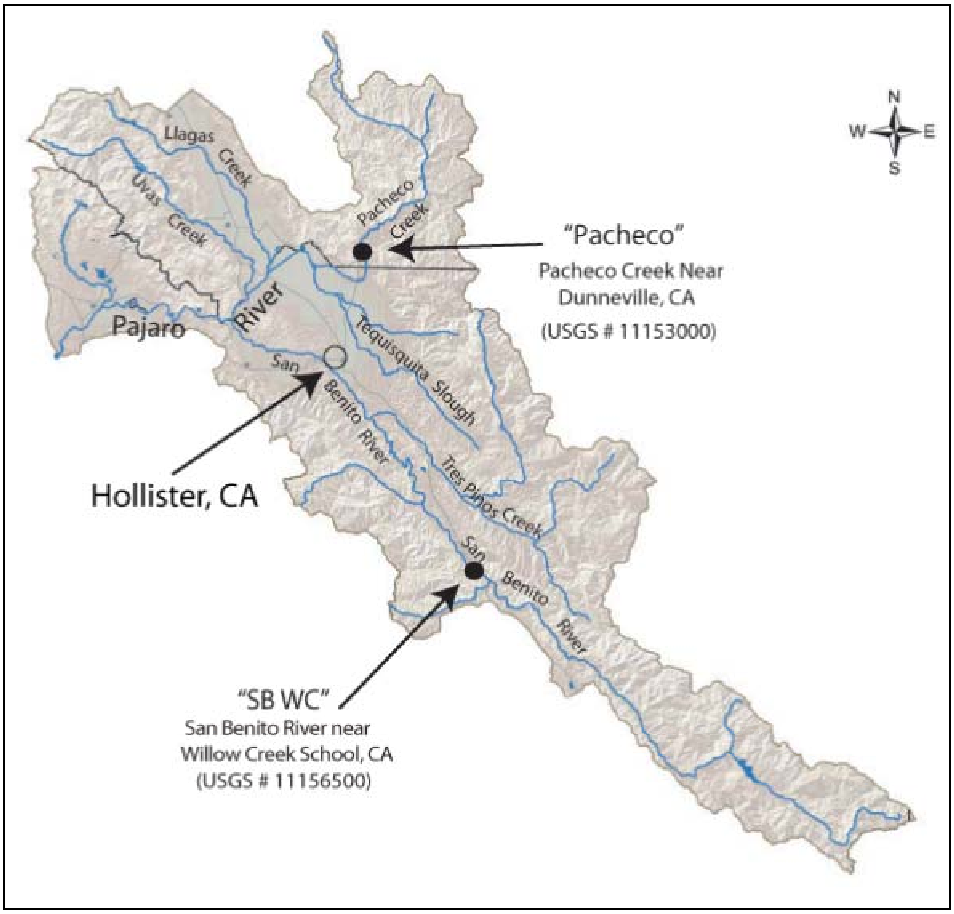

Figure 1: Pajaro River watershed map with gage locations.

Background

Streamflow Measurement Principles

With the exception of very small creeks that can be completely diverted to fill a measurable container such as a hand-held bucket, direct measurement of discharge in open channels is costly and time consuming. However, channel stage (water height above the channel bottom) is relatively inexpensive to monitor. Because it varies in direct proportion to the discharge of a channel, it acts as a practical surrogate measurement parameter.

Streamflow measurement based on stage is therefore a two step process. First, stage is measured either directly at surface or by the water pressure at the bottom of the channel. The stage is then translated into its corresponding streamflow by using a predetermined mathematical relationship. This relationship is commonly known as a rating curve. An example rating curve is presented in Figure 2.

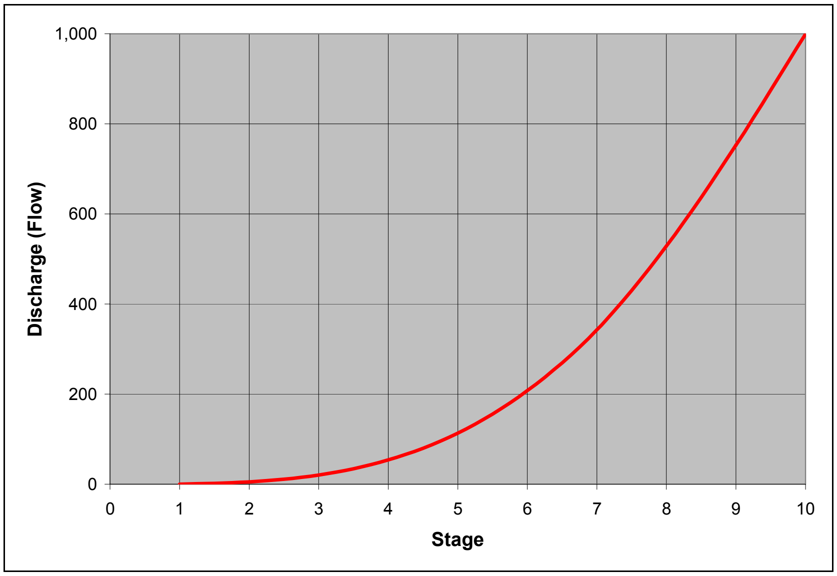

Figure 2: Example rating curve.

Development of a rating curve at a particular location along a channel can be accomplished by measuring the velocity of the water at several different depths and positions along the width of the channel at that location. A commonly used device for measuring local water velocities in this manner is a current meter. An example current meter is shown in Figure 3.

Figure 3: Example current meter used to measure water velocity.

The average of all measured velocities multiplied by the cross sectional area of the channel results in the total discharge or streamflow at that particular stage per the following equation:

Q (flow) = A (cross sectional area) x V (average velocity).

This process must be done during at least three different flows in order to define the nonlinear curve shown in Figure 2. Measurement of more than three flows will improve the accuracy of the curve.

Rating curves of natural channels must be periodically updated to account for changes in channel shape caused by geomorpohologic processes. Updating of rating curves of relatively stable channels can be very infrequent and therefore less costly.

Additional information about developing, maintaining, and using rating curves can be found in TM 4.4.1.

Channel Stage Measurement Equipment

Examples of equipment used to measure creek or river stage include staff gages, stilling wells, pressure transducers, bubble gages, and sonic downlookers. In all cases, stage data obtained from this equipment can be easily converted into streamflow or discharge by using an accurate rating curve.

The data are collected with graphic recorders, digital punch-tape recorders, or electronic data loggers which function either continuously or at preset time intervals, usually 15 minutes. At both the Pacheco and SB WC sites, solar panels can provide sufficient energy for the operation of any gage and Automated Local Evaluation in Real Time (ALERT) transmission equipment that may be installed.

In addition to ALERT transmission equipment at a given streamflow measuring site, a radio repeater may need to be installed on a nearby hilltop in order to relay the ALERT transmissions to a distant receiving station. This additional cost has not been factored into the estimates provided in this report.

Staff Gages

Approximate equipment cost: *$100 - $200*

Staff gages are a graduated measuring stick or panel that can be hand held, driven into a channel bottom, or mounted to a bridge or other sturdy in-channel feature. Low tech and inexpensive, they can provide very accurate stage measurement. However, they can only be read by an onsite observer or remotely operated camera.

Staff gages are almost always located near a more sophisticated measuring device in order to verify the device's accuracy. An example staff gage is shown in Figure 4. This staff gage is located at the San Benito River near Willow Creek School (SB WC) in conjunction with a bubble gage and satellite transmission equipment. The river at low flow is visible in the background. Conduit running from the instrument shelter to the low flow channel is visible to the right.

Figure 4: Staff Gage on the San Benito River (SB WC).

Stilling Wells

Approximate equipment cost: *Unknown though relatively expensive. May be greater than $10,000 in some locations.*

A stilling well consists of a well casing that extends vertically upward from a channel bottom or the bottom of a channel bank. The height of the well is almost always at least as high as the depth of the channel. Stilling wells are designed such that the level of water inside them goes up and down with the stage of the channel to be measured.

The water surface in the well is sheltered and remains calm and free of waves, wind, and debris. A float suspended by a pulley moves up and down with the water surface. In early versions, movement of the pulley in response to changes in water surface elevation causes an ink needle to draw a line on a disk or reel of paper, much like a seismograph that measures earthquakes. The paper was periodically retrieved for analysis and archiving. Newer equipment can track movement of the pulley more accurately and reliably. Stilling wells are an older technology widely considered to be obsolete due to their installation and maintenance costs.

A view looking down into a stilling well at Pacheco Creek near Dunneville, CA (Pacheco) is shown in Figure 5. An access ladder and internal staff gage are visible. The bucket acts as a funnel to receive water for flushing sediment out of the pipe that hydraulically connects the well to the bottom of the creek.

Figure 5: View inside of stilling well (Pacheco Creek).

Pressure Transducers

Approximate equipment cost: *$1,000 – $2,000.*

A pressure transducer consists of a submersible electronic probe attached by wires and tubing to support and data collection equipment stored in a nearby instrument shelter. The submersible transducer probe is placed securely near the channel bottom. When accurately calibrated, electrical resistance in the probe varies with water pressure and can therefore be measured to determine channel stage to within one hundredth of a foot. The tube that carries electrical wiring to the probe is also open to the atmosphere in order to compare channel bottom pressure to ambient air pressure.

The main drawback of pressure transducers is the required maintenance. The pressure transducer probe must be checked and cleaned of silt at least once a year. Several cleanings each year must be done if the channel has high turbidity. The probe is relatively delicate and can be damaged by vandalism or rocks and debris moving along the bottom of a channel. Also, the electrical resistance of the probe changes or “drifts” over time and must be periodically recalibrated.

In the instrument shelter, the "desiccant box" contains wiring that supplies voltage to the probe and also acts as the atmospheric pressure reference for the probe. The inside of the box must remain dry by regular replacement of its internal "dry can" which contains silica gel to absorb moisture in the air. Build up of moisture in the desiccant box and probe conduit can cause faulty readings.

An advantage of pressure transducer systems is that they can be easily installed into an existing stilling well system. The stilling well provides sturdy pipe conduit for positioning the probe at the channel bottom. The instrument shelter built into the top of a stilling well can house supporting electronic equipment such as the blue metallic desiccant box shown in the center of the photo in Figure 6. The transducer and appurtenant equipment shown in the picture have been abandoned in place since 2003. The site never had radio transmission equipment, and its solar panel had been removed.

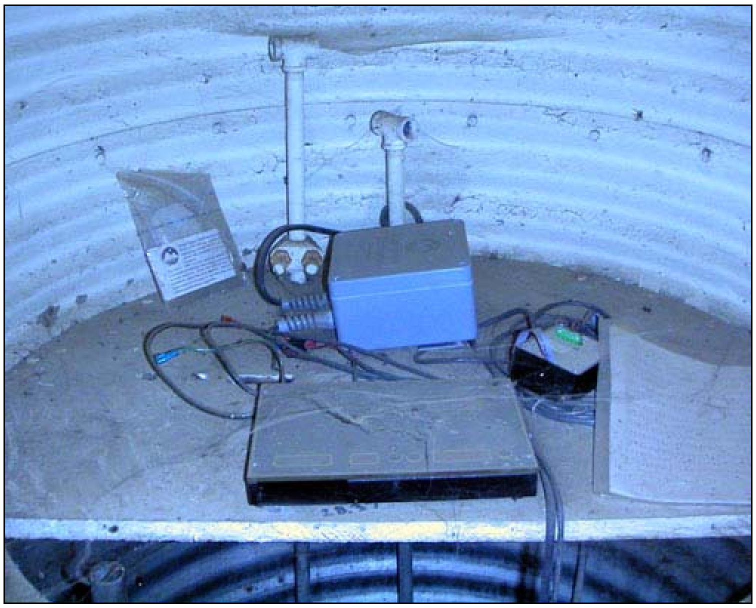

Figure 6: Pressure transducer equipment in a stilling well (Pacheco).

Bubbler Gages

Approximate equipment cost: *$2,000 to $4,000*

Bubbler gages are similar to pressure transducers in that they measure the water pressure at the bottom of a channel. In a bubbler system, an orifice is attached securely below the water surface and connected to a pressure-sensing device by a length of plastic tubing. Pressurized gas (usually nitrogen or air) is forced through the tubing and out the orifice. The gas pressure needed to produce bubbles varies linearly with the stage of the channel and can be measured to within one hundredth of a foot. Bubbler gages can be installed at a stilling well site using the same basic installation method for that of a pressure transducer. They may occupy more space than the dessicant box of a pressure transducer.

Bubbler gages have several advantages over pressure transducers. One is that all sensitive components of the system can remain in the protection of the instrument shelter. The portion of the system at the bottom of the channel has no probe and is simply the end of a rugged, flexible tube that must remain free of sediment. Bubbler gages can automatically clear some sediment blockages by brief blasts of high pressure gas.

Some modern bubbler gage systems containing compressors can provide continuous, accurate data for years with zero maintenance. Periodic replacement of components with moving parts such as the compressor can be postponed until failure when used in conjunction with a backup compressor and/or gas bottle and radio transmission equipment capable of reporting the failure. Some compressor systems have a backup compressor and backup gas bottle.

A disadvantage of bubbler gages is that their capital cost is typically higher than that of a pressure transducer, often by as much as two or three times. However, compared to pressure transducers, their infrequent maintenance requirements can make them more cost effective in the long run.

Sonic Downlookers

Approximate Equipment Cost: *$1,000 - $2,000*

Sonic downlookers measure the stage of a channel by using high frequency sound waves similar to the sonar system of bats. A stand alone unit containing a solar panel and transmitter can be mounted to the side of a bridge where its sonar transmitter and receiver can "look" downward to measure the water surface elevation (see Figure 7).

Figure 7: Sonic downlooker.

A disadvantage of this configuration is that on most bridges it would be vulnerable to vandalism. This can be avoided by mounting only the sonar sensor portion of the system underneath the bridge or out of reach on the side of a bridge. The supporting equipment can be protected in an instrument shelter several hundred feet away. Like bubbler gages, sonic downlookers typically provide continuous and accurate data for years with zero maintenance.

The sonic downlooker emits an 8 degree cone-shaped projection of sound waves at the water. Proper operation depends upon a relatively smooth water surface (subcritical flow) free of waves and significant debris. The area of water surface to be measured must be clear of any other features such as bridge abutments to avoid false echoes. The accuracy of sonic downlookers is generally to the nearest tenth of a foot which is well within the range of uncertainty of most rating curves.

Sonic downlooker systems cost approximately the same as pressure transducers.

ALERT systems

Approximate equipment cost: $2,000 to $4,000.

Data provided by a streamflow gage can be logged at the gage site for periodic retrieval or can be transmitted in real time via radio waves to a distant monitoring station. A widely used system for remote monitoring of hydrologic data is known as ALERT, an acronym for Automated Local Evaluation in Real Time. ALERT equipment installed at a streamflow gaging site can be used to easily monitor the activity of a stream for water resource management and flood forecasting purposes.

Evaluation of Pacheco Creek Gage

Gage Site

The Pacheco site has a stilling well structure and is located along Highway 152 in southern Santa Clara County just north of the border with San Benito County (see Figure 1). It can be visited by taking the Walnut Avenue exit from Highway 152 and parking near the Walnut Avenue bridge which crosses over Pacheco Creek a few hundred yards from the highway exit. The gage is located approximately 450 feet downstream from the bridge on the right side of the creek as one faces downstream. Photos of the Walnut Avenue bridge and the gage's instrument shelter are shown in Figures 8 and 9.

Figure 8: Walnut Avenue Bridge (facing downstream)

Figure 9: Pacheco Creek Gage Site

Gage History

A history of the Pacheco site is as follows:

- **1939:** Staff gage on Walnut Avenue bridge pier established by the USGS and Army Corps of Engineers (Corps)
- **1950:** New staff gage installed. Readings taken two times daily.
- **1960:** Recording station installed in August. Velocity measurements made at Walnut Ave bridge.
- **1982:** Gage no longer operated by the USGS and Corps. Taken over by the Santa Clara Valley Water District (SCVWD).
- **2003:** Gage gives obviously inaccurate data and then ceases to function. Abandoned in place due to lack of budget.
- **2004:** The Pajaro River Watershed Flood Prevention Authority pursues rehabilitation of the Pacheco gage and installation of ALERT equipment at the site.

The first streamflow recording system at this location was a stilling well formed by a 36-inch corrugated metal pipe installed vertically in the streambank. The top part of the pipe serves as the instrument shelter for the recording equipment and is accessible by a catwalk and locking hatch. Another view of the stilling well is shown in Figure 10. Note the access steps to the bottom of the channel and heavy growth of poison oak. Photo was taken in November 2004 when water was not flowing in the channel.

Figure 10: View of Pacheco Creek stilling well structure.

Pacheco Creek: Status of Gage Site

In the year 2000, the SCVWD installed a pressure transducer system at the Pacheco stilling well. A few years later in 2003, the equipment began to malfunction and soon stopped working altogether.

Pressure transducers of this nature require regular maintenance to be sure that the probe remains free of sediment and that the desiccant within the desiccant box (located in the instrument gage) is relatively fresh. Furthermore, the probe must be periodically recalibrated.

Deficiencies in the installation and/or maintenance of the equipment may have resulted in the failure of the Pacheco gage in 2003. The perforated ends of the original stilling well intake and discharge pipes, where the pressure transducer probe is most likely located, did not appear to be buried in sediment (see Figure 11). The good condition of the wooden access steps and position of the pipes relative to the bottom of the channel are indications of good channel stability.

Figure 11: Intake and discharge pipes at Pacheco.

Pacheco Creek Gage – Rehabilitation and ALERT Options

Repair Existing Pressure Transducer, install ALERT equipment:

Approximate cost of labor and materials**:** $4,000 to $8,000

Troubleshooting and testing of the existing pressure transducer can be done to determine what is necessary for repair. This work can be done in the field or the gage can be sent to the supplier, High Sierra Electronics in Grass Valley, CA. If repair of this equipment is cheaper than its replacement cost, reactivation of the gage and installation of ALERT equipment may be the least costly alternative in terms of capital cost. However, as described above, the pressure transducer is more prone to failure and has the highest maintenance cost.

Replace Pressure Transducer, install ALERT equipment:

Approximate cost of labor and materials: $6,000 to $10,000

If the existing pressure transducer is more expensive to repair than to replace, a new pressure transducer can be installed.

Install new bubbler gage, install ALERT equipment:

Approximate cost of labor and materials: $7,000 to $11,000

A bubbler gage has a higher startup cost but is more cost effective than pressure transducers in the long run. There is sufficient room in the Pacheco stilling well instrument shelter to install bubbler gage equipment.

Install sonic downlooker, install ALERT equipment:

Approximate cost of labor and materials: $6,000 to $10,000

This option assumes that the sonar sensor would be mounted on the Walnut Avenue bridge and all other equipment housed in the existing stilling well. This option would cost approximately the same as installation of a pressure transducer. Applicability to the Walnut Avenue bridge must first be determined.

Recommended Option:

Installation of ALERT equipment and a sonic downlooker or bubbler gage.

<u>Pacheco Creek Gage – Additional Considerations</u>

Right of Way

Although easily accessible from a public road, the stilling well structure of the Pacheco Creek gage is located on private property. The current land use appears to be row crops. Owner information obtained from the Santa Clara County Assessor's Office in December 2004 is as follows:

Assessor's Parcel Number (APN):	898-22-025
Parcel Size:	36.78 Acres
Owner names:	Emily A. Mamone and Luis A. Scaglione, Jr.
Mailing address:	8430 Pacheco Pass Highway, Hollister, CA 95023

The Santa Clara Valley Water District (SCVWD) does not have any records of real estate agreements with the owner for operation of the gage. The SCVWD's jurisdiction over the gage may have been officially or unofficially grandfathered into the existing property deed. Coordination with the owners may be appropriate or necessary if equipment is to be installed and maintained at the site.

Rating Curve

Rating curves from 1978 and 1989 are shown in Figure 12.

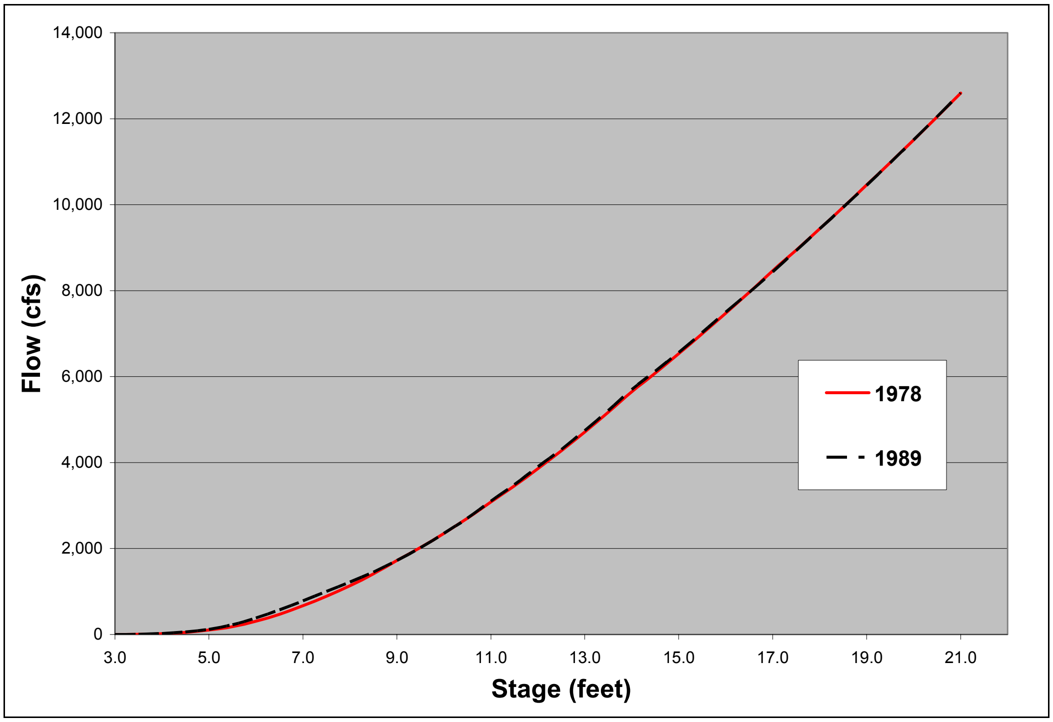

Figure 12: Historical Rating Curves at Pacheco from 1978 and 1989.

Observed channel stability at the gage site and the nearly identical rating curves from 1978 and 1989 indicate the stable nature of the channel. The current accuracy of the curves should be verified and, if necessary, a new curve should be developed.

Evaluation of San Benito River near Willow Creek School Gage

Unlike Pacheco, the San Benito River near Willow Creek School gage (SB WC) is a fully functioning gaging station operated by the USGS and is shown in Figure 13. It consists of a bubbler gage, solar panel, and satellite antenna.

Figure 13: San Benito River near Willow Creek School

Streamflow data from this station are provided approximately every four hours on the internet at:

http://waterdata.usgs.gov/ca/nwis/uv?11156500

The San Benito County Water District is a cooperator with the USGS and shares the operation cost of this gage. The USGS maintains the measurement equipment and rating curve. Installation of ALERT equipment at the site, along with an additional solar panel, is all that is needed and will not result in any additional charges from the USGS.

Install ALERT equipment to work with existing USGS gage:

Approximate cost of labor and materials: $4,000 to $6,000

Pacheco and SB WC: Additional Information

Equipment cost information was provided by High Sierra Electronics of Grass Valley, CA. Additional equipment vendors include HydroLynx Systems of West Sacramento, and Design Analysis of Logan, Utah.

The USGS normally does not allow non-USGS staff to have access to their gage sites. Larry Freeman, the USGS Field Office Chief responsible for the SB WC gage, will allow either of two specific independent technicians to install ALERT equipment at the site. Their names are Scott Siegel of the SCVWD and John Stremmel of Pacific Coast Forecasting.

Both are experienced with gaging and ALERT equipment installation and normally work on an individual basis. As of early 2005, both are available for consultation about performing the necessary installation and/or maintenance at the Pacheco and/or SB WC site. Because the Pacheco site is no longer run by the USGS, additional technicians can be considered.

Labor costs are approximate and account for a wide range of potential installation scenarios. More refined installation and maintenance costs can be obtained upon the final selection of alternatives and a detailed site inspection by the chosen contractor.