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Kings River Conservation
District

[CASGEM GROUNDWATER MONITORING PLAN FOR THE KINGS AND TULARE LAKE SUB-BASINS]

An update of the Monitoring Plan for the Kings and Tulare Lake sub-basins addressing data gaps in geospatial, construction, and aquifer coverages.

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Introduction

The Kings River Conservation District (KRCDD) is the reporting agency for the Kings River and Tulare Lake sub-basins under CASGEM. The KRCDD CASGEM program also covers some limited areas that are adjacent to these basins because they are (1) represented by a cooperating agency that reports elevation data to the KRCDD or (2) is located within the KRCDD service area (has water rights to the Kings River and is a member of the Kings River Water Association). The GIS mapping provided by the KRCDD to the Department of Water Resources (DWR) for its initial application to be the Monitoring Entity covers these areas. The coverage area created for this program does extend outside of the defined Bulletin 118 boundaries for both the Kings and Tulare Lake sub-basins, but does so in a manner that eliminates DWR identified gaps in geographic coverage.

Monitoring Network and Cooperating Agencies

The original intent of KRCDDs monitoring effort was to select a subset of the wells currently monitored by the cooperating agencies listed in Table One, such that adequate geographic coverage (number and distribution with minimal clusters) of the monitored area would be created and designate them as CASGEM wells. The wells selected were recommended by the collecting agencies due to their high reliability (consistent reporting of data). Then, in accordance with the requirements of the CASGEM program, we would enhance the available data with well construction records as they were identified. This initially gave the KRCDD a substantial number of reporting wells throughout the basin that were felt to be at a reasonable density level.

Table One: Cooperating Agencies for the KRCDD CASGEM Program

Agency	Sub-Basin
Kings River Conservation District	Kings, Tulare Lake
Orange Cove Irrigation District	Kings (uphill of actual boundary)
Alta Irrigation District	Kings
Consolidated Irrigation District	Kings
Fresno Irrigation District	Kings
James Irrigation District	Kings
Laguna Irrigation District	Kings
Tranquility Irrigation District	Delta-Mendota (per B-118), west of Kings
Kings County Irrigation District	Kings-Tulare Lake boundary area
Tulare Lake Basin Water Storage District	Tulare Lake

Hydrogeologic conditions were also taken into account with the initial well selections, in that the wells represented the dominant aquifer in use within either the Kings or Tulare Lake sub-basins. For the Kings sub-basin, this was much easier as previous work conducted by the KRCDD showed that most of the region is a single, unconfined aquifer, and that the number of wells completed below the Corcoran Clay formation was minimal in comparison to the total present. While restrictive formations are known to exist, they were assumed to be discontinuous in nature and thus not a major factor in much of the sub-basin.

Closer to the Kings River channel, multiple, distinct aquifers are known to exist (above the A-clay formation, between the A and C clay formations, and between the C and E (Corcoran Clay) formations. Each of these layers above the E clay is considered an unconfined aquifer, and care was taken to exclude

composite well constructions (screened in multiple aquifers) due to the anomalies they introduced in KRCDs depth to groundwater analysis.

The Tulare Lake sub-basin presented other issues for the monitoring program in that the landowners within the region constructed their wells in the perimeter areas of the Tulare Lake bed to avoid the periodic flooding of this portion of the sub-basin. Pumped water is then transported through surface canals within the region to its point of use. Also, the majority of the Tulare Lake bed area consists of heavy clay soils, which does not have strong (useful) aquifer formations between the soil surface and the underlying Corcoran Clay formation, meaning that any wells constructed within the Tulare Lake bed proper would need to be completed below the Corcoran Clay formation. This is supported by the e-log findings of the KRCD constructed monitoring wells southwest of Lemoore and southeast of Stratford.

The Corcoran Clay formation is the complicating factor for both sub-basins, as it is present underneath much of the Tulare Lake sub-basin, but only under the western third of the Kings sub-basin. The extent of the utilization of this confined aquifer in this portion of the Kings sub-basin is not currently well understood, and does present one “data-gap” that needs to be addressed.

The program initially contained approximately 115 wells scattered throughout the submitted coverage area. The initial evaluation as to the hydrogeologic uniformity of much of the Kings sub-basin made this well density a reasonable one. The understanding at the time the program was being developed was that regularly reporting wells were more important than obtaining construction information, which at the time, was still confidential. Most of the selected sites were surveyed by KRCD, recording ground surface elevation, location, and reference point data; the balance of the wells had the data provided by the cooperating agency.

The KRCDs intent was to augment this network with additional wells as they became available. An analysis of well data reporting and location showed that some regions did not have adequate coverage (density of wells too low), and grant monies were sought to construct dedicated monitoring wells to close these gaps. The KRCD was successful in constructing nine dedicated monitoring wells in the Kings sub-basin to close most of these gaps. All of these wells were completed above the Corcoran Clay formation (generally above 300 ft. of depth). Full construction details will be uploaded into CASGEM when available.

The current selection of wells is highly biased towards agricultural production wells, as these were the most readily available at the time of initial program development. Public water source wells were not available at the start of the program, and domestic water wells were not considered good sources of data due to their constant state of usage. Certain areas within the coverage area have a greater percentage of dedicated monitoring wells (Consolidated IDs wells are almost exclusively monitoring wells of various construction types) than others, and it is recognized that dedicated monitoring wells is the preferred option.

Monitoring Sites and Timing

Monitoring is conducted in the Spring and Fall of each year by the KRCD and its cooperating entities. The Spring survey is ideally conducted in April, but staffing concerns at the cooperating agencies can impact timing (usually in March). The DWR has determined that the ideal Spring measurements should occur in March of each year. This survey is designed to capture the recovery of the groundwater basin

after an extended period of minimal agricultural demand, assuming a normal rainfall season. Groundwater levels would begin to be impacted until the onset of surface water deliveries in May, and ideally, these deliveries would reduce the demand upon the aquifer until late summer.

The Fall survey would take place in October (again, subject to staffing availability for some cooperators), capturing a period after the peak irrigation demands have ceased, showing the cumulative impact of the irrigation season on the groundwater basin before any natural recovery has taken place. Notices of upcoming monitoring periods are sent out to all cooperating agencies so as to attempt to sample in as tight a time window as possible. Where possible, the KRCD does attempt to reschedule the monitoring effort to match that of the DWR request.

The KRCD would then collect the data from the cooperating agencies and upload it into the CASGEM system.

Monitoring History

The cooperating agencies for this effort have a long record of monitoring groundwater levels and submitting the data to the DWR for record keeping and analysis. The KRCD has independently monitored groundwater levels in the western region of the Kings sub-basin that was annexed into the KRCD service area (outside of the Kings River Water Association member boundaries within the Kings sub-basin) in the mid-1990s. This data was used to further refine the depth to groundwater maps developed by the KRCD.

Field Methods

Standardized sampling methods are used by the various cooperating agencies to sample the wells within their service areas. Typical sampling methods are (1) Steel Tape, (2) Electric Sounder, and (3) Acoustic Sounder.

Prior to collecting groundwater levels and before going to the field, sampling personnel shall clean, maintain, and test/calibrate the water level sounding equipment.

The sampling personnel will assemble the following equipment and supplies:

- a. Copies of Groundwater Data Level Form (Table 1) on waterproof paper
- b. Copies of well cards for wells being monitored
- c. Copy Monitoring Network Location map
- d. Water level sounding equipment (one or more)
 - a. Acoustic Well Sounder
 - b. Steel Tape
 - c. Electrical Wire Sounder
 - d. Air Pressure Source and Pressure Gauges
- e. Measuring Tape with gradations in tenths and hundredths of feet.
- f. Ballpoint pen (waterproof) and clipboard
- g. Paper towels
- h. Bleach
- i. Spray bottles

j. Distilled water

During use of a steel tape or electrical wire sounder, it is possible for the tape/cable to become stretched or shortened because of tangles and obstructions in wells. Before each monitoring event, the equipment shall be calibrated by laying it out and comparing it with a steel tape and the results documented. When calibration measurements show that the difference between the two is greater than 0.1 ft., replacement of the steel tape/electrical cable is recommended. Replacement of the electrical cable is recommended if more than 10 ft. of cable has been lost within a well, as the cable is likely stretched from the failed extraction process.

For electric wire sounders or acoustic sounders, fresh batteries should be installed yearly.

The KRCD uses an Acoustic sounder on the majority of the wells it samples within the Kings Basin. Readings using the acoustic sounder are corrected to ground level at the time of recording. An electric wire sounder is also available for those wells that prove difficult to sound. The readings between the two methods are very consistent. The Acoustic sounder has a minimum distance of 25 ft., so it is not useful in those regions with exceptionally shallow groundwater. It is best suited to the western portions of the basin where depths of 100 ft. or greater are encountered. The unit reads to the nearest foot. The majority of the cooperating agencies also use electric wire sounders to measure their wells, although steel tape is used by a few.

Reference Point Verification

The reference point at each monitored is to be established once the well is selected for inclusion in the program. It is the tester's responsibility to verify that the correct reference point is used at each well. Any changes due to access or physical changes in the well should be documented. Significant changes may require a new survey to establish proper surface levels and reference point measurements.

Recording Measurements

Each well has been assigned a unique identification number and a common name. The Groundwater Level Data Form (Table 1 DWR Form) will be used to record all groundwater level measurements and other information regarding well while in the field.

Groundwater level measurements will be measured to the nearest 0.01 foot (0.2 ft. for production wells). To obtain a depth to water measurement, the electric sounder cable will be lowered slowly into the well through the access port until the sounder indicates submergence by a beeping sound and/or light, depending on the type of sounder being used. At this point, the sampling personnel will note the depth to water from the reference point. The depth shall be confirmed by lifting the sounder above the water surface by about 2 to 3 feet and then re-measuring the depth to water. If the depth remains constant, the depth-to-water shall be recorded on the Groundwater Level Data Form, along with the time and date of the measurement. If the depth changes, the sampling personnel shall indicate that on the form, as well as the variable nature of the measurement and its possible cause (e.g., bouncing, recovering water levels, oil on water surface). The following measurements will be recorded:

1. Depth from Reference Point: Total distance from the reference point to the top of the water.

2. Reference Point Distance: Total distance from ground to reference point. If the reference point is above the ground surface, the reference point distance is a positive value. If the reference point is below the ground surface, the reference point distance is a negative value.
3. Depth to Water: Total distance from the ground surface to the top of the water. It is calculated as the "Depth from Reference Point less the Reference Point Distance".
4. Obs. Initials.: Initials of sampling personnel
5. Remarks: Any special remarks will go in this area.

The use of an acoustic sounder will yield a distance measurement to the nearest foot. A distance correction, based on where the measuring point is located shall be taken into account and noted on the data form.

Measurement Guidelines

Steel Tape

The graduated steel-tape (wetted-tape) procedure is considered to be the most accurate method for measuring water levels in non-flowing (non-artesian) wells. A graduated steel tape is commonly marked to 0.01 foot. When measuring deep water levels (>500 ft), thermal expansion and stretch of the steel tape starts to become significant (Garber and Koopman, 1968). The method is most accurate for water levels less than 200 feet below land surface. The equipment and supplies needed for this method are shown in Table 4.

The following issues should be considered with this method:

1. It may be difficult or impossible to get reliable results if water is dripping into the well or condensing on the well casing.
2. If the well casing is angled, instead of vertical, the depth to water should be corrected, if possible. This correction should be recorded in the field folder.
3. Check that the tape is not hung up on obstructions.

Before making a measurement:

1. Maintain the tape in good working condition by periodically checking the tape for rust, breaks, kinks, and possible stretch. Record all calibration and maintenance data associated with the steel tape in a calibration and maintenance log book.
2. If the steel tape is new, be sure that the black sheen on the tape has been dulled so that the tape will retain the chalk.
3. Prepare the field forms (Table 1). Place any previous measured water-level data for the well into the field folder.

4. Check that the RP is clearly marked on the well and accurately described in the well file or field folder. If a new RP needs to be established, follow the procedures above.
5. In the field, wipe off the lower 5 to 10 feet of the tape with a disinfectant wipe, rinse with de-ionized or tap water, and dry the tape.
6. If possible, attach a weight to the tape that is constructed of stainless steel or other non-contaminating material to protect groundwater quality in the event that the weight is lost in the well. Do not attach a weight for production wells.

Making a measurement

1. If the water level was measured previously at the well, use the previous measurement(s) to estimate the length of tape that should be lowered into the well. Preferably, use measurements that were obtained during the same season of the year.
2. Chalk the lower few feet of the tape by pulling the tape across a piece of blue carpenter's chalk or sidewalk chalk (the wetted chalk mark identifies that part of the tape that was submerged).
3. Slowly lower the weight (for monitoring wells only) and tape into the well to avoid splashing when the bottom end of the tape reaches the water. Develop a feel for the weight of the tape as it is being lowered into the well. A change in this weight will indicate that either the tape is sticking to the side of the casing or has reached the water surface. Continue to lower the end of the tape into the well until the next graduation (a whole foot mark) is at the RP and record this number on DWR Form 1213 (Table 5) next to "Tape at RP" as illustrated on Figure 4.
4. Rapidly bring the tape to the surface before the wetted chalk mark dries and becomes difficult to read. Record the number to the nearest 0.01 foot in the column labeled as "Tape at WS."
5. If an oil layer is present, read the tape at the top of the oil mark to the nearest 0.01 foot (0.2 ft. in production wells) and use this value for the "Tape at WS" instead of the wetted chalk mark. Mark an "8" in the QM column of DWR Form 1213 (see Table 5) to indicate a questionable measurement due to oil in the well casing. There are methods to correct for oil, such as the use of a relatively inexpensive water-finding paste. The paste is applied to the lower end of the steel tape and the top of the oil shows as a wet line and the top of the water shows as a distinct color change. Since oil density is about three-quarters that of water, the water level can be estimated by adding three-quarters of the thickness of the oil layer to the oil-water interface elevation (U.S. Geological Survey, 2006).
6. Subtract the "Tape at WS" number from the "Tape at RP" number and record the difference (to the nearest 0.01 ft., 0.2 ft. in production wells) as "RP to WS". This reading is the depth to water below the RP.
7. Wipe and dry off the tape and re-chalk based on the first measurement.
8. Make a second measurement by repeating steps 3 through 5, recording the time of the second measurement on the line below the first measurement (Table 5). The second measurement

should be made using a different “Tape at RP” than that used for the first measurement. If the second measurement does not agree with the original within 0.02 of a foot (**0.2 of a foot for production wells**), make a third measurement, recording this measurement and time on the row below the second measurement with a new time. If more than two readings are taken, record the average of all reasonable readings.

After making a measurement

Clean the exposed portion of the tape using a disinfectant wipe, rinse with de-ionized or tap water, and dry the tape. Do not store a steel tape while dirty or wet.

Electric Sounding Method

The electric sounding procedure for measuring depth to the water surface is especially useful in wells with dripping water or condensation, although there are still precautions needed as noted in the beginning of this section. Other benefits of this method include:

1. Easier and quicker than steel tapes, especially with consecutive measurements in deeper wells.
2. Better than steel tapes for making measurements in the rain.
3. Less chance for cross-contamination of well water than with steel tapes, as there is less tape submerged. The accuracy of electric sounder measurements depends on the type of tape used and whether or not the tape has been stretched out of calibration after use. Tapes that are marked the entire length with feet, tenths, and hundredths of a foot should be read to 0.01 ft. (0.2 ft. in production wells). Electric sounders are harder to keep calibrated than are steel tapes. As with steel tapes, electric sounders are most accurate for water levels less than 200 ft. below land surface, and thermal expansion and stretch start to become significant factors when measuring deep water levels (>500 ft.) (see Garber and Koopman, 1968).

The following issues should be considered with this method:

1. If the well casing is angled, instead of vertical, the depth to water will have to be corrected, if possible. This correction should be recorded in the field folder.
2. Check that the electric sounding wire/weights are not hung up on an obstruction in the well.
3. The electric sounder should be calibrated annually against a steel tape in the field (using monitoring wells only) as follows: Compare water-level measurements made with the electric sounding tape to those made with a steel tape in several wells that span the range of depths to water encountered in the field. The measurements should agree to within ± 0.02 ft. If this accuracy is not met, a correction factor should be applied. All calibration and maintenance data should be recorded in a calibration and maintenance log book for the electric sounding tape.
4. Oil on the surface of the water may interfere with obtaining consistent readings and could damage the electrode probe. If oil is present, multiple readings should be attempted to insure that the probe is free of oil at the water surface.

5. If using a repaired/spliced tape: see section A4-B-3(b) (page B16) of the NFM (U.S. Geological Survey, 2006).

Before making a measurement

1. Inspect the electric sounder wire and electrode probe before using it in the field. Check the wire for wear, kinks, frayed electrical connections and possible stretch; the cable jacket tends to be subject to wear and tear. Test that the battery and replacement batteries are fully charged.
2. Check the distance from the electrode probe's sensor to the nearest foot marker on the tape, to ensure that this distance puts the sensor at the zero foot point for the tape. If it does not, a correction must be applied to all depth-to-water measurements. Record this in an equipment log book and on the field form.
3. Prepare the field forms (DWR Form 1213; see Table 5) and place any previous measured water-level data for the well into the field folder.
4. After reaching the field site, check that the RP is clearly marked on the well and is accurately described in the well file or field folder. If a new RP needs to be established, follow the procedures above.
5. Check the circuitry of the electric sounding tape before lowering the electrode probe into the well. To determine proper functioning of the tape mechanism, dip the electrode probe into tap water and observe whether the indicator needle, light, and/or beeper (collectively termed the "indicator" in this document) indicate a closed circuit. For an electric sounding tape with multiple indicators (sound and light, for instance), confirm that the indicators operate simultaneously. If they do not operate simultaneously, determine which is the most accurate and use that one.
6. Wipe off the electrode probe and the lower 5 to 10 feet of the tape with a disinfectant wipe, rinse with de-ionized or tap water, and dry.

Making a measurement

1. If the water level was measured previously at the well, use the previous measurement(s) to estimate the length of tape that should be lowered into the well. Preferably, use measurements that were obtained during the same season of the year.
2. Lower the electrode probe slowly into the well until the indicator shows that the circuit is closed and contact with the water surface is made. Avoid letting the tape rub across the top of the well casing. Place the tip or nail of the index finger on the insulated wire at the RP and read the depth to water to the nearest 0.01 foot (0.2 ft. for production wells). Record this value in the column labeled "Tape at RP", with the appropriate measurement method code and the date and time of the measurement (see Table 5).

3. Lift the electrode probe slowly up a few feet and make a second measurement by repeating step 2 and record the second measurement with the time in the row below the first measurement in Table 5. Make all readings using the same deflection point on the indicator scale, light intensity, or sound so that water levels will be consistent between measurements. If the second measurement does not agree with the first measurement within 0.02 of a foot (**0.2 of a foot for production wells**), make a third measurement, recording this measurement with the time in the row below the second measurement. If more than two readings are taken, record the average of all reasonable readings.

After making a measurement

Wipe down the electrode probe and the section of the tape that was submerged in the well water, using a disinfectant wipe and rinse thoroughly with de-ionized or tap water. Dry the tape and probe and rewind the tape onto the tape reel. Do not rewind or otherwise store a dirty or wet tape.

Acoustic Sounder

This meter uses sound waves to measure water levels. It requires an access port that is 5/8 – inch or greater in diameter and measurement of the average air temperature in the well casing. The meter can be used to quickly measure water levels in both monitoring wells and production wells. Also, since this method does not involve contact of a probe with the water, there is no concern over cross contamination between wells. However, the method is not as accurate as the other methods, with a typical accuracy of 0.2 ft. for water levels less than 100 ft. or 0.2% for water levels greater than 100 ft. This unit returns measurements to the nearest foot.

Some of the instructions here do not apply to all Acoustic Sounder units.

The following issues should be considered with this method:

1. The accuracy of the meter decreases with well diameter and should not be used with well diameters greater than 10 inches.
2. An accurate air temperature inside the well casing is necessary so that the variation of sound velocity with air temperature can be accounted for.
3. Obstructions in the well casing can cause erroneous readings, especially if the obstruction is close to half the well diameter or more.

Before making a measurement

1. Check the condition of the meter, especially the batteries. Take extra batteries to the field.
2. Take a temperature probe with a readout and 50-ft cable.
3. If open wellheads with diameter greater than the factory cover plate and less than 10 inches will be monitored, fabricate appropriately-sized cover plates using plastic or sheet metal.

4. Prepare the field forms (Table 1). Place any previous measured water-level data for the well into the field folder.
5. Check that the RP is clearly marked on the well and accurately described in the well file or field folder. If a new RP needs to be established, follow the procedures above.

Making a measurement

1. If the water level was measured previously at the well, lower the temperature probe to about half that distance in the well casing. Preferably, use measurements that were obtained during the same season of the year.
2. Record this temperature in the comments column of Ground Water Level Data Form (Table 1). Use this temperature reading to adjust the temperature toggle switch on the sonic meter.
3. Select the appropriate depth range on the sonic meter.
4. For a covered wellhead, insert the meter duct into the access port and push the power-on switch. Record the depth from the readout.
5. For an open wellhead, slip the provided cover plate onto the wellhead to provide a seal. If the cover plate is not large enough, use a fabricated cover plate for diameters up to 10 inches. Record the depth from the readout.

After making a measurement

Make sure the temperature probe and the sonic meter are turned off and put away in their cases.

Pressure Transducer Method

Automated water-level measurements can be made with a pressure transducer attached to a data logger. Care should be taken to choose a pressure transducer that accurately measures the expected range of groundwater levels in a well. Pressure-transducer accuracy decreases linearly with increases in the depth range (also known as pressure rating). A pressure transducer with a depth range of 0 to 10 ft (0 to 4.3 psi) has an accuracy of 0.01 ft while a pressure transducer with a depth range of 0 to 100 ft (0 to 43 psi) has an accuracy of 0.1 ft. But if the measurement range exceeds the depth range of a pressure transducer, it can be damaged. So it is important to have a good idea of the expected range of groundwater levels in a well, and then refer to the manufacturer's specification when selecting a pressure transducer for that well.

Calibration checks on the transducer should be done yearly.

Some of the advantages of automated monitoring include:

1. No correction is required for angled wells, as pressure transducers only measure vertical water levels.

2. A data logger can be left unattended for prolonged periods until data can be downloaded in the field.
3. Downloaded data can be imported directly into a spreadsheet or database.

Some of the disadvantages of automated monitoring include:

1. It may be necessary to correct the data for instrument drift, hysteresis, temperature effects, and offsets. Most pressure transducers have temperature compensation built-in. Others may require barometric pressure compensation.
2. Pressure transducers operate only in a limited depth range. The unit must be installed in a well in which the water level will not fluctuate outside the operable depth range for the specific pressure transducer selected. Wells with widely fluctuating water levels may be monitored with reduced resolution or may require frequent resetting of the depth of the pressure transducer.
3. With some data loggers, previous water-level measurements may be lost if the power fails.

There are two types of pressure transducers available for measuring groundwater levels; non-vented (absolute) and vented (gauged). A non-vented pressure transducer measures absolute pressure, is relative to zero pressure, and responds to atmospheric pressure plus pressure head in a well (see Figure 5). A vented pressure transducer measures gauge pressure, is relative to atmospheric pressure, and only responds to pressure head in a well.

Non-vented pressure transducer data require post processing. Barometric pressure data must be collected at the same time as the absolute pressure data at the well, and subtracted from each absolute pressure data record before the data can be used to calculate groundwater levels. Thus, if a non-vented pressure transducer is used, a barometric pressure transducer will also be needed near the well. This subject is usually covered in more detail by the manufacturer of the pressure transducer. In an area with little topographic relief, a barometer at one site should be sufficient for use by other sites within a certain radius (9 miles reported by Schlumberger <http://www.swstechnology.com/groundwater-monitoring/groundwater-dataloggers/baro-diver> and 100 miles reported by Global Water <http://www.globalw.com/support/barocomp.html>). In an area of significant topographic relief, it would be advisable to have a barometer at each site.

Vented pressure transducers can be programmed so no post processing of the data is necessary. The vent is usually a small tube in the communication cable that runs from the back of the pressure transducer to the top of the well. This vent enables the pressure transducer to cancel the effect of atmospheric pressure and record groundwater level as the distance from the RP to the WS (see figure 1). However, if the vent is exposed to excessive moisture or submerged in water it can cause failure and damage to the pressure transducer.

The existing well conditions should be considered when deciding which type of pressure transducer to use. Non-vented pressure transducers should be used when the top of a well or its enclosure may at any time be submerged in water. This can happen when artesian conditions have been observed or are likely, the well is completed at or below the LSD, or the well or its enclosure are susceptible to periods of high water. Otherwise, it is advisable to use a vented pressure transducer.

The following guidelines are USGS guidelines from Drost (2005) and Freeman and others (2004) for the use of pressure transducers. These USGS guidelines have not been incorporated as yet in the NFM.

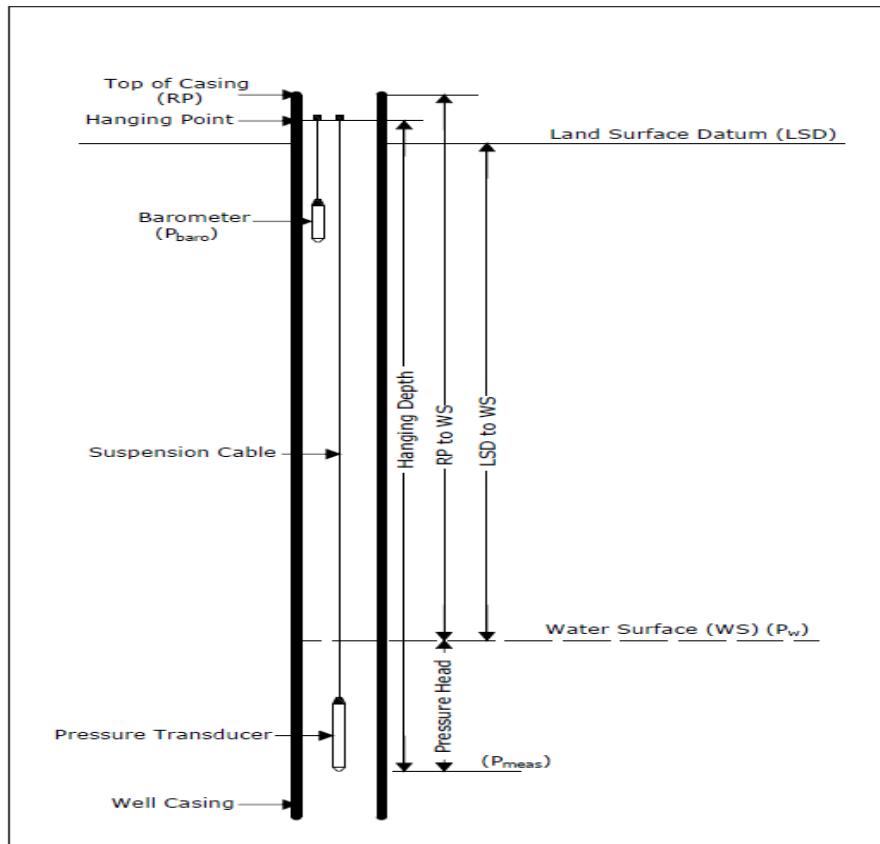


Figure 1. Groundwater-level measurements using a pressure transducer (vented or non-vented) (modified from Drost, 2005)

Before making a measurement

1. Keep the pressure transducer packaged in its original shipping container until it is installed.
2. Fill out the DWR field form (Table 2), including the type, serial number, and range of measurement device; and what units are being measured (ft., psi).
3. Take a reading from the pressure transducer before placing into the well. For a vented pressure transducer the reading should be zero. For a non-vented pressure transducer the reading should be a positive number equivalent to atmospheric pressure. Configure the units (ft., psi) on a barometric pressure transducer the same as the non-vented pressure transducer. A reading from the barometric pressure transducer should be the same as the non-vented pressure transducer reading.
4. Lower the pressure transducer into the well slowly. Conduct a field calibration of the pressure transducer by raising and lowering it over the anticipated range of water-level fluctuations. Take two readings at each of five intervals, once during the raising and once during the lowering of the pressure transducer. Record the data on the DWR field form (Table 2). If using a non-vented

pressure transducer, take a reading from the barometric pressure transducer at the same time as the other readings.

5. Lower the pressure transducer to the desired depth below the water level (caution: do not exceed the depth range of the pressure transducer).
6. Fasten the cable or suspension system to the well head using tie wraps or a weatherproof strain-relief system. If the vent tube is incorporated in the cable, make sure not to pinch the cable too tightly or the vent tube may be obstructed.
7. Make a permanent mark on the cable at the hanging point, so future slippage, if any, can be determined.
8. Measure the static water level in the well with a steel tape or electric sounding tape. Repeat if measurements are not consistent within 0.02 ft. **(0.2 ft. for production wells).**
9. Record the well and RP configuration, with a sketch. Include the RP height above the LSD, the hanging point, and the hanging depth (Drawing 1).
10. Connect the data logger, power supply, and ancillary equipment. Configure the data logger to ensure the channel, scan intervals, units, etc., selected are correct. Activate the data logger. Most data loggers will require a negative slope in order to invert water levels for ground-water applications (i.e., distance from the RP to the WS). If using a non-vented pressure transducer the data logger will not require a negative slope, but atmospheric pressure data will need to be collected by a barometric pressure transducer.

Making a measurement

1. Retrieve water-level data (to 0.01 ft) using instrument or data logger software. If using a non-vented pressure transducer, retrieve barometric pressure data.
2. Measure the water level with a steel tape or electric sounding tape (to 0.01 ft) and compare the reading with the value recorded by the pressure transducer and data logger. Record the reading and time in the file folder. If using a non-vented pressure transducer, subtract the barometric pressure value from the transducer pressure value to obtain the water level pressure value. The water level pressure can then be multiplied by 2.3067 to convert from psi of pressure to feet of water (Freeman and others, 2004). Report the calculated water level to the nearest 0.01 ft.
3. If the tape and pressure transducer readings differ by more than (the greater of 0.2 ft or) two times the accuracy of the specific pressure transducer, raise the pressure transducer out of the water and take a reading to determine if the cable has slipped, or whether the difference is due to drift. The accuracy of a pressure transducer is typically defined as 0.001 times the full scale of the pressure transducer (e.g., a 0 to 100 ft pressure transducer has a full scale of 100 ft). The accuracy of a specific pressure transducer should be specified by the manufacturer's specifications.

4. If drift is significant, recalibrate the pressure transducer as described using a steel tape. If using a non-vented pressure transducer, keep the pressure transducer out of the water and calibrate to the barometric pressure transducer value. If field calibration is not successful, retrieve the transducer and send back to the manufacturer for re-calibration.
5. Use the multimeter (see Table 4) to check the charge on the battery, and the charging current supply to the battery. Check connections to the data logger, and tighten as necessary. Burnish contacts if corrosion is occurring.
6. Replace the desiccant, battery (if necessary), and data module. Verify the data logger channel and scan intervals, document any changes to the data logger program and activate the data logger.
7. If possible, wait until data logger has logged a value, and then check for reasonableness of data.

Data Reporting

The KRCD emails its cooperating agencies the requested timeline for the Spring and Fall well surveys (including any timing requests from DWR) at least four weeks in advance. Included in this email is a populated field sheet with CASGEM well names for each agency to use. The agencies then return an electronic copy of this field sheet to the KRCD for consolidation into the upload template.

The KRCD is expanding its data requests to the cooperating agencies to include all well elevation data that was previously reported to the Water Data Library system. This will assist the KRCD in preparing a more complete assessment of the groundwater conditions within the Kings and Tulare Lake sub-basins by increasing the number of data points included within the analysis. These wells would be reported to the CASGEM system as Voluntary wells.

Data Gaps

Current Coverage

The initial assessment and selection of wells to include within the CASGEM program was based upon the reliability of the well to produce data and the distribution of such wells within the confines of the coverage area. This created what KRCD considered a viable network within the Kings sub-basin, but other issues related to the Tulare Lake sub-basin created a significant region of the coverage area that would not have any data. This was expected by both the KRCD and DWR at the outset of the program.

The monitoring network had as a goal of having a well at nearly two-mile separation intervals, with potentially higher densities in those areas most impacted by groundwater overdraft. Prior to the reclassification of wells from CASGEM to Voluntary due to lack of construction information, the initial selection of monitored wells provided a solid distribution of wells that represented the unconfined aquifer within the coverage areas.

Well availability is rapidly becoming an issue within the basin as more growers seek to provide security to their pumping plants (namely to prevent wire theft). These locked enclosures increasingly block our access to wells that we have monitored in the past, and unless the measuring point is located outside of

the enclosure, we generally are at the mercy of the landowner as to whether the enclosure is open or not on the day of the survey. System changes (conversion from flood to drip irrigation) can complicate matters through the changes in discharge piping. Both of these issues primarily affect wells that are acoustically sounded, since direct access to the well casing is not required.

Potential Shortfalls

Four data gaps have been identified within the KRCDs coverage area. They are: (1) insufficient number of CASGEM wells within the coverage area; (2) limited construction details for wells currently being monitored, (3) a lack of monitored wells in the confined aquifer area (below the Corcoran Clay formation) of the coverage area, and (4) the bulk of the Tulare Lake bed due to a lack of wells.

The first three data gaps can be corrected through the selection of additional monitored wells (with construction details, plus the necessary research into finding wells completed below the Corcoran Clay only. The lack of wells in the Tulare Lake bed will continue to prevent coverage in this region, as landowners are unlikely to drill wells in an area prone to periodic flooding. Should this condition change and well data be developed, the KRCD will attempt to include it into the CASGEM program.

Corrective Actions

The first data gap is easily corrected through the selection of additional wells within the KRCD service area. The KRCD has held discussions with its cooperating agencies to obtain all the monitored well data from each agency for reporting into the CASGEM system, either as future CASGEM wells or as Voluntary wells. These are the wells that were previously reported to the Water Data Library. The selection of additional wells will depend upon the success of the efforts to correct the second identified data gap.

The second data gap is the limited number of wells that are currently monitored that have construction details associated with them. The recent changes to the law regarding well log confidentiality should assist in this effort, and as more wells are identified for inclusion into the program, their construction details can be added as they are included in the monitoring plan. The difficulty in this effort is the imprecise location information on the well completion reports currently available to the KRCD and matching these locations to the wells we wish to monitor.

Another facet in this process is the need by the Kings River Water Quality Coalition (KRWQC) to develop a groundwater *quality* monitoring network within the same geographic area. The exact requirements and design of this network has not been developed, but it is anticipated that well construction information and depth to groundwater data would be collected in the process. These wells would likely only be surveyed once per year, probably in May.

The third data gap will have more impact on the Tulare Lake sub-basin than on the Kings sub-basin, even though the conditions that created the data gap exist in both. For reasons stated earlier, the unconfined aquifer in the Tulare Lake sub-basin (especially in the Tulare Lake bed proper) is fairly weak except on the eastern periphery. Wells do exist that draw water from the confined aquifer in this region, and they will need to be included in future monitoring efforts. The density of such wells is likely to remain under the ideal levels requested by DWR.

Wells completed under the Corcoran Clay formation represent withdrawals from the confined aquifer that underlies most of the coverage area, but outside of the Tulare Lake sub-basin, is rarely used. Uses of this aquifer may well be limited to the extreme western portions of the Kings sub-basin, where the shallower, unconfined aquifer may be of lower quality and production than the confined aquifer below. Care will need to be exercised to avoid any composite wells that draw from both aquifer systems.

The last data gap concerns the Tulare Lake bed proper, and will depend upon the KRCD getting access to any wells that have been constructed within a region prone to periodic flooding.

Schedule

Research into construction details for existing monitored wells and the selection of additional wells is a time consuming process and staffing time for such work is limited. It is possible that 20 or more wells could be researched per year, thus providing full basin coverage in approximately five years.

It should be recognized that wells completed below the Corcoran Clay formation may have limited availability and potentially not have sufficient density to satisfy the CASGEM program goals.

It is understood by the KRCD that efforts to include and monitor groundwater wells for the CASGEM program within the Kings and Tulare Lake sub-basins (above and below the Corcoran Clay) at an acceptable level of density and quality is an ongoing process. Continual evaluation of the Monitoring Program is required, and changes will be reflected in updated versions of this Monitoring Plan.

Quality Control/Quality Assurance

The cornerstone to any data collection effort is the reliability of the data collected. To insure that such data is of high quality, every effort must be made to collect the data in a proper, consistent manner and to insure that the tools used return accurate results.

To this end, the measurement devices used are cross-checked with each other to verify their accuracy. The acoustic sounder is cross-checked with a wire sounder, which itself is checked against a measuring tape to be sure that the wire is not stretched. Similar checks are performed for steel tapes.

One variable that needs periodic checking is the ground surface elevations and the reference points used at each well site. Reference points are re-verified at each sampling event, giving a twice per year look at the well. Ground surface elevations are reevaluated once every 5 years or so, as part of other efforts to evaluate surface subsidence within the Kings and Tulare Lake sub-basins. This insures that water surface elevations (WSEs) are accurate.

Readings collected at the time of each survey should be compared to the previously recorded reading to insure that what is being seen is close to the expected value. By this it is meant that if the previous history of a particular site is a depth to groundwater of a value x, and it has shown a history of increasing by y-z feet per year, then a value in excess of this expected range would be flagged. Such wells would need to be rescheduled for sampling to verify the original observation, or to obtain a value closer to the expected.

Currently Monitored Wells (Table)