Irrigation Systems Water/Energy Evaluations
Market and Technology Assessment

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## Abbreviations and Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tr>
<td>AQ</td>
<td>Additional Questions to Management</td>
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<tr>
<td>CE</td>
<td>Combined Evaluation</td>
</tr>
<tr>
<td>CIT</td>
<td>Center for Irrigation Technology at CSU, Fresno</td>
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<tr>
<td>DU</td>
<td>Distribution Uniformity</td>
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<td>IE</td>
<td>Irrigation Efficiency</td>
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<tr>
<td>IrrEval</td>
<td>Irrigation System Evaluation</td>
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<tr>
<td>ITRC</td>
<td>Irrigation Training and Research Center at Cal Poly, San Luis Obispo</td>
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<tr>
<td>NRCS</td>
<td>National Resource Conservation Service</td>
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<tr>
<td>OPE</td>
<td>Overall Pumping Efficiency</td>
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<tr>
<td>PC</td>
<td>Pressure Compensating (emitter)</td>
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<td>PT</td>
<td>Pump Test</td>
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<tr>
<td>RCD</td>
<td>Resource Conservation District</td>
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<tr>
<td>TDH</td>
<td>Total Dynamic Head</td>
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EXECUTIVE SUMMARY

PROJECT GOAL

The project was initiated to test emerging evaluation approaches to identify operational and technical opportunities to optimize energy and water usage of pressurized irrigation systems. The combined evaluation incorporates information derived from a "standard" pump efficiency test and a "standard" irrigation system/management evaluation, augmented by answers to "additional questions to management" and energy usage history. The combination of this data through an integrated audit tool offers new ways to identify additional opportunities for energy use and cost reduction by focusing on system-level operations. By doing so, it is hoped that the customer will be more readily moved to action to conserve water and/or energy.

PROJECT DESCRIPTION

This was a preliminary project that performed forty-five "combined evaluations" of pressurized irrigation systems (micro, sprinkler, spray). The term "combined evaluation" is used instead of audit because the basis of the combined evaluation is a separate evaluation of the irrigation system hardware and a separate pump efficiency test on the pump supplying water and pressure to the system, but performed at the same time. In addition to the two basic audits, a set of additional questions was presented to the customer (the "Additional Questions to Management") and energy usage history was obtained.

The two main objectives were to a) develop the protocols by which the disparate data could be gathered, and b) develop a report format that would convey the results in a comprehensive but understandable manner.

The goal of the combined evaluation is to create an audit tool that addresses the three main opportunities for energy use reductions in irrigated agriculture as well as demand management. The three opportunities for energy use reduction are 1) reduce amount of water applied, 2) reduce total pressure in the system, and 3) improve pumping plant efficiency. Demand management actions can reduce the stress on the grid and may lead to reduced overall energy costs as off-peak operations reduce the average cost per kilowatt-hour used.

PROJECT FINDINGS/RESULTS

1. Forty-five combined evaluations were performed by four different teams in four areas of the PG&E service area from February through September, 2013. The pump efficiency tests and reports, and the additional questions to management were similar for all evaluations. However, even though the irrigation system evaluations were all done using the same basic evaluation protocols, the reports to the customer from the evaluation teams varied.

2. The number and scheduling of evaluations were intended to allow for a progressive development of protocols and report format, while also trying to sample as many different irrigation system scenarios as possible.
3. The project established that there are three functional roles needed to accomplish the combined evaluation, the irrigation system evaluation team, the pump test team, and the "integrator". The integrator is the person who assimilates the disparate data into a coherent report. That function was fulfilled by project management for this effort. The integrator function is the key to the success of the combined evaluation.

4. The data and results from the irrigation system evaluation and the pump efficiency test are not enough to identify opportunities for system pressure reductions or improvements in demand management. Thus, an additional component of the combined evaluation was developed, the Additional Questions to Management. These attempt to identify current water management practices, characteristics of the water supply, aspects regarding on/off-peak operations, and the potential to apply the lessons learned from the evaluation to other fields controlled by management.

5. Three types of report format were developed during the project:

   i. The total report package, which included a cover letter, summary section, the full irrigation system evaluation report, the pump efficiency test report, the answers to the additional questions to management, an optional suggested seasonal irrigation schedule, and copies of technical papers explaining the basis for the audit.

   ii. The summary section as an individual entity of the report package, which summarizes the major findings of the irrigation system evaluation and the pump efficiency test, but also synthesizes findings regarding overall water management, excess pressure issues, and demand management issues from them, the additional questions, and energy usage history. This section also contains the summary table of current and potential performance with subsequent energy use and cost savings.

   iii. A preferred irrigation system evaluation report format, using parts from each of the evaluation team's reports as well as new material. (Appendix 2 contains an example of this report.)

6. The cost of this type of auditing was identified although it is not consistent depending on the evaluation teams and the individual situation. Some efforts involved fields with a straightforward situation- one field, one pump, three-year PG&E billing history, and full answers to the additional questions to management. In these cases the costs were in the $2,000 range. In other cases there were multiple fields supplied by the pump (possibly multiple pumps), no flow meter, and little information forthcoming from the additional questions. In these cases the costs could be in the $2,500 range as it took more effort on the part of the integrator.

7. Thirteen of the forty-five evaluations occurred on fields where the irrigation system had been evaluated before. It was seen that the evaluation protocols could identify improvements in DU. In addition, the experience of APEP over its ten-plus years of existence has shown that pump efficiency tests can identify improvements in OPE as a result of a pump retrofit.

8. The audits cannot identify costs of different actions for improvement without much more effort. For example, a recommendation can be made to replace plugged or worn emission devices. However, it is generally an "eyeball" estimate by the auditor as to the percentage of affected devices and the actual costs will vary with the number of devices replaced, cost of the replacement devices (which could vary area to area for a variety of reasons), and labor.
**PROJECT RECOMMENDATIONS**

1. **Develop integrator function.** Three functional roles were identified that are needed to complete the combined evaluation; 1) irrigation system evaluation team, 2) pump test team, and 3) "integrator". Two, or even all three, functions could be performed by the same entity. But there needs to be an effort to establish how the integrator function will be fulfilled in the future (as well as the cost of integration) as none of the teams used in the project would be considered capable right now.

2. **Coordinate with evaluation teams.** The combined evaluations performed for this project were funded by the project. Total costs for the irrigation system evaluation and pump tests ranged from about $1500 to as much as $2000. The additional cost of report integration varied depending on the field data. However, there are several ways by which future funding could occur. These options need to be identified, both to PG&E and to the evaluation teams in the field. It may be that even if further efforts in this area are not funded, fully or in part, by CPUC/PG&E, individual evaluation teams may work to effect them in their area.

3. **Improve communications between evaluation teams while in progress.** During the irrigation system evaluation, the system layout is identified including spacings of emission devices and unit flow rates. This equates to a required pump flow depending on how many acres are being irrigated during the evaluation. This can be compared to the flow rate found by the pump tester. Each of these measurements has a degree of error involved. The flow rate found during a pump test might be as much as +/- 10% depending on the test section. However, if the pump test flow rate is much difference than indicated by the evaluation then one or the other has an error in the data collection. Thus, these measurements at least need to be reconciled in the field. Also, the pump tester needs to know if the irrigation system is run at different operating conditions on a regular basis. If so, he/she will need to perform a multi-condition test.

4. **Improve communications with customer.** An essential component of the combined evaluation is the additional questions to management. These identify the irrigation scheduling methods in place, whether the customer actually knows how much water is being applied on the field, and will identify issues in demand management (e.g., is there a problem with the primary water supply, either in capacity or flexibility). If it cannot be established that the customer understands what is being attempted and will actively aid in developing the audit then the effort should not be made.

5. **Establish clear eligibility guidelines.** Depending on how the combined evaluation is funded in the future there may need to be a set of guidelines in place to identify which fields are eligible. The key is whether there is a reasonable chance of developing a full and valid report. The eligibility criteria may be flexible depending on the amount of funding. If funding is limited then one criteria may be that the field has only one pump supplying water to it and that pump is dedicated to that field- this will ensure that the amount of currently applied water can be identified.

6. **Estimate aggregate efficiency potential from pressure reduction.** A significant percentage of the evaluated fields had excess pressure; reducing pressure in the system is one of the three main opportunities for reducing energy use. Additionally, new micro-irrigation devices can operate at substantially lower pressures than earlier equipment. There should be some effort to identify how many older systems, or mis-designed systems, are in place so as to evaluate the potential for reducing operating pressures in micro-irrigation systems so as to reduce energy use in California.
7. **Critical need for training and marketing support.** Whether or not PG&E decides to be actively involved with future *field* activities, serious consideration should be given to funding training seminars and a targeted marketing campaign to make sure entities in the business of providing, interpreting, or advising for irrigation system evaluations and pump efficiency tests are aware of this new audit tool.
I. INTRODUCTION

Recent studies of the connection between water use and energy use in California have established that approximately 19% of electricity used in California is for pumping, heating, or purifying water. Agriculture is the largest user of water in the state and thus, it is logical that there be some study of energy used for irrigation and whether it can be reduced.

One way energy used for irrigation of a field can be estimated is with the following three equations:

**Equation 1. Kilowatt-hours used per year for irrigation**

\[ kWh/Year = \text{AcFt/Year} \times \text{kWh/AcFt} \]

Where:
- \( kWh/Year \) = kilowatt-hours used per year
- \( kWh/AF \) = amount of kilowatt-hours required to pump an acre-foot (unit of water)
- \( \text{AcFt/Year} \) = acre-feet of water pumped per year (water units pumped annually)

**Equation 2. Acre-feet pumped per year for irrigation**

\[ \text{AcFt/Year} = \frac{\text{Acres} \times (\text{ETc} - \text{EffRain})}{(1 - \text{LR}) \times \text{IrrEff}} \]

Where:
- \( \text{AcFt/Year} \) = acre-feet of water pumped per year
- \( \text{Acres} \) = irrigated acres
- \( \text{ETc} \) = net crop water use (evapotranspiration)
- \( \text{EffRain} \) = rainfall effective in supplying net crop water needs
- \( \text{LR} \) = leaching ratio required for soil salinity control – a decimal from 0 – 1.0
- \( \text{IrrEff} \) = irrigation efficiency as a decimal from 0 – 1.0

**Equation 3. Kilowatt-hours required to pump an acre-foot for irrigation**

\[ \text{kWh/AcFt} = \frac{1.0241 \times \text{TDH}}{\text{OPE}} \]

Where:
- \( \text{kWh/AcFt} \) = amount of kilowatt-hours required to pump an acre-foot
- \( \text{TDH} \) = total dynamic head (pressure) in the system in feet of water head
- \( \text{OPE} \) = overall pumping plant efficiency as a decimal (0 – 1.0)

The importance of these equations is that they identify the variables that affect the amount of energy used for irrigation and what must be done to reduce it. For example, equation 1 says that to reduce kilowatt-hours used per year (\( kWh/Year \)) you must reduce either the amount of water pumped (\( \text{AcFt/Year} \)) and/or the energy needed to pump an acre-foot of water (\( \text{kWh/AcFt} \)).

Although it is noted that equations 2 and 3 involve a total of seven variables, this project is focused on the three most likely to be modifiable by the customer— the "three opportunities" for energy use reduction.

1. Opportunity 1 - reduce the amount of water pumped by improving irrigation efficiency (IE in equation 2). Equation 2 contains five variables but the one most
under the control of the irrigator is irrigation efficiency. Thus, if IE is improved then the AcFt/Year must necessarily be reduced.

As to the other variables in equation 2, obviously the amount of water pumped can be reduced by reducing Acres (planted) but it is assumed that the farmer wants to utilize his available assets to maximize profits. Net crop water use, ETc, can be changed with the crop (and in many areas of California there has been significant crop-shifting due to water availability issues) but if IE is improved it doesn’t matter which crop is grown, water use is reduced. There may be some techniques to increase the amount of effective rainfall but since most rainfall is outside of the irrigation season in California, it is considered a minor issue. The required leaching ratio (setting the amount of leaching required for long-term salinity control) is affected by the crop and the irrigation water quality but once the crop has been chosen there may be little that can be done.

2. Opportunity 2 - reduce the total dynamic head (TDH), or pressure, in the system. Equation 3 shows that the amount of kiloWatt-hours required to pump an acre-foot of water through the system is directly related to the pressure in the system. Thus, if one reduces TDH, one reduces the kiloWatt-hours required to pump water.

3. Opportunity 3 - improve pumping plant efficiency. Equation 3 also shows that the amount of kiloWatt-hours required to pump an acre-foot of water through the system (kWh/AcFt) is inversely related to the overall pumping efficiency (OPE). Thus, if one increases pumping plant efficiency, one reduces kWh/AcFt.

The fourth opportunity is not associated with reducing energy use but with total energy cost to the customer and peak demand to the system. Thus, there is the need to evaluate "demand management" as well, primarily the pattern of on and off-peak operations. This is more than just identifying if the customer is on or off peak with pumping operations. If there is significant on-peak operation the questions become whether or not there is some operational constraint and if so, can it be overcome? Examples of operational constraints would be:

1. A primary water supply that had to run 24 hours/day, either because it was needed to supply the volume needed to water the crop or because the operations of the primary supply dictated this (a water district that only delivered water in 24-hour blocks).

2. An irrigation system that had to be run 24 hours/day to supply crop water use at peak water use periods.

The question is how to effect these changes - reduce water pumped, reduce pressure in the system, improve pumping efficiency, and improve demand management. The first step, and the goal of this project, is to comprehensively audit the existing hardware and management. Auditing (also referred to as "benchmarking", "evaluating") can identify areas for improvement as well as allowing for an estimation of the benefit/cost ratio for taking action.

Fortunately there are protocols in place for auditing performance of both irrigation systems and pumping plants. There are at least two major sets of protocols for evaluating irrigation system performance, one contained in the Natural Resources Conservation Service (NRCS) National Engineering Handbook and one developed by the Irrigation Training and Research Center at Cal Poly, San Luis Obispo (ITRC) and based on the NRCS concepts. As well there are established procedures for testing pumping plant performance. The Advanced Pumping
However, for the most part these evaluations are done separately and may not be done on the same field. Thus, while the irrigation system evaluation can point out problems with distribution uniformity and overall water management, it does not look "backwards" to the pumping plant to see if it is correctly matched. It will also be seen that most of the time, there is no analysis of system management so as to directly affect the amount of water pumped.

Conversely, the pump efficiency test can identify the current OPE but doesn't look "forward" to the irrigation system to see if it is matched correctly (i.e., no excessive pressure). Thus, while the irrigation system evaluation can identify issues related to IE, and the pump efficiency test can identify a poor OPE, neither alone addresses system operating pressures or demand management issues.

Also, when considered separately it may be that an action taken due to an irrigation system evaluation will worsen the OPE or TDH aspect of equation 3. It should be obvious that the requirements of the irrigation system must be known whenever a retrofit of the pumping plant to improve OPE is being considered.

In summary, the concept of this project is to a) perform the evaluations at the same time and b) combine the results of the different evaluations, with augmenting information, into one report that provides a comprehensive look at all opportunities for energy and water conservation.

II. BACKGROUND

The concept behind this project is to combine two existing, standard audit types with a newly developed third instrument, and PG&E billing history, in order to produce an audit report that is greater than the sum of its parts. The two existing audit types are the Irrigation System Evaluation (IrrEval) and the Pump Efficiency Test (PT). The third audit component is new, the Additional Questions to Management (AQ). Each of the three sub-components will now be discussed.

II.1 THE IRRIGATION SYSTEM EVALUATION

There are two basic measures of irrigation performance, distribution uniformity (DU) and irrigation efficiency (IE). DU is a measure of how evenly water soaks into the ground across a field during the irrigation. If eight inches of water soaks into the ground in one part of the field and only four inches into another part of the field that is poor distribution uniformity.

DU is expressed as a percentage between 0 and 100%. Although 100% DU (the same amount of water soaking in throughout the field) is theoretically possible, it is virtually impossible to attain in actual practice. Good DU is essential for reducing deep percolation, if the entire field is to be watered sufficiently. The actual numeric value for DU is developed by dividing some measure of applied water in the least watered area of a field by the average applied water in the field. Most often the least-watered area is the average of the application in the least-watered 25% of the field and the term "low 1/4 DU" is used to describe this standard (e.g., "the low 1/4 DU for this field is 85"). Other standards would be the "low 1/8 DU" (using the average of the lowest-watered 1/8 of the field) or the "absolute" DU (using the absolute lowest watered part of the field).
Irrigation efficiency (IE) was defined by the American Society of Civil Engineer's On-Farm Irrigation Committee in 1978. It is the ratio of the volume of irrigation water which is beneficially used to the volume of irrigation water applied. Beneficial uses may include 1) crop evapotranspiration, 2) deep percolation needed for leaching for salt control, 3) crop cooling, and 4) as an aid in certain cultural operations. Differences in specific mathematical definitions of IE are due primarily to the physical boundaries of the measurement (a farm, an irrigation district, an irrigation project, or a watershed) and whether it is for an individual irrigation or an entire season.

IEs are also expressed as a percentage between 0 and 100%. 100% IE is not theoretically attainable due to immediate evaporation losses during irrigations. However, there could easily be close to 95% IE if a crop is under-watered. In this case, assuming no deep percolation, all water applied and not immediately evaporated would be used by the crop.

There are two main relationships between DU and IE:

1. There must be good DU before there can be good IE - assuming the entire field is to be irrigated for full yield.

2. Good DU is no guarantee of good IE (for example, I could have 95% DU but if the system is run twice as long as needed the IE is only 50%).

Relationship 1 is the reason that the irrigation system evaluation (IrrEval) is mainly concerned with developing an estimate of DU. For pressurized system types this is a function of 1) the adaptation of the individual system type to site conditions, 2) actual design and construction of the system, and 3) system maintenance. For flood types there is a fourth concern, and probably the most important for that type, management of the system during the irrigation event.

There are two main sets of protocols in use for estimating DU in the field and one is based strongly on the other. The first of are those was developed by the Natural Resources Conservation Service (NRCS) (formally the Soil Conservation Service) as contained in Chapter 15 of the National Engineering Handbook. The other, and most widely used, is the system developed by the Irrigation Training and Research Center at Cal Poly, San Luis Obispo (ITRC). The ITRC system was developed using the NRCS protocols as a base. Differences in the two systems mainly revolve around the sampling procedures and the computer programming that accompanies the ITRC system.

The protocols are based on the physics of each system type that result in the distribution of water. For example, a drip irrigation system delivers water through a system of pipes to an emission device that applies the water at a very slow rate. Pressure is required to move water through the system and the emission device must dissipate this pressure to result in the slow application (in the range of .5 to 2 gallons per hour at the emitter). Thus, to estimate the DU of a drip system, one is interested in the pressure distribution of the system and the condition of the device itself.

Although the resulting effect is dependent on the type of emission device, generally the higher the pressure at an emitter, the greater the flow rate. Thus, one set of measurements involves pressures in the piping system at various locations.

As well, if the emitters are plugged, or worn, or different types of emitters are in the field, the flow rates will be different. Thus, another set of measurements is flow rates of a
random sample of emitters at different pressures, as well as visual observations of plugging, wear, and consistency in device and layout.

Major reasons for the wide use of the ITRC system are the computer programming that was developed for it and a training course provided by ITRC. The programming allows for databasing of the different evaluations, eases the process of mathematical computations, and also automatically creates recommendations for improvement. When first developed it was an early form of an "expert system" - that is, computer programming that emulated a human expert.

**Background: Mobile Irrigation Laboratory Programs**

The term "Mobile Irrigation Laboratory" was first used by the California Department of Water Resources (DWR). In the early 1980's the DWR funded ITRC in the development of their evaluation system and then funded teams of evaluators in the field. These evaluation teams consisted of a pickup truck, required equipment, computer and ITRC software, and evaluators and were referred to as a Mobile Irrigation Laboratory. There may have been 20-25 MILs in operation at one time in California, mostly attached to local Resource Conservation District offices. Their numbers have dwindled to six at present. However, the California effort has inspired many states to implement the same type of program and it is interesting to note that although the actual operations of the different teams are keyed to local conditions and cropping systems, the term "Mobile Irrigation Laboratory" is in widespread use.

The actual process of evaluating a system, especially a pressurized system (sprinkler, drip, micro) that is the focus of this project is relatively simple. The evaluator takes a series of pressure measurements throughout the field, then measures flow rates through different emission devices, makes some visual observations, and then enters all of this into the computer programming. (With sprinkler systems where the spray patterns from adjacent sprinklers are intended to overlap there will also be some type of "catch-can" test to judge the uniformity of the overlap.) The programming then prints a report. However, as with the pump efficiency test, the real value of the irrigation system evaluation is in the ability of the evaluator to interpret the results.

The interpretation may end with a simple characterization of the measured DU as good, fair, or poor, along with the "canned" recommendations from the programming. The evaluator may be able to relate the DU to differences observed in plant growth or quality throughout the field. The evaluator may be able to make observations as to how well the system type is adapted to site conditions and the crop.

Although there are some questions asked about pressure losses, the evaluation systems were never concerned much with energy efficiency. However, an evaluator may also note excessive pressure losses in the field.

For this project the basic ITRC protocols were used for the IrrEval. However, the reports prepared by the different IrrEval teams varied. There was no attempt in this project to standardize the IrrEval reports. The latest version of the standard ITRC data sheet and report for a drip system is seen in Appendix 4.

**II.2 The Pump Efficiency Test**

The pump efficiency test is an audit of pumping plant performance. Basically it compares the power being input to the pumping plant to the resulting "water horsepower" produced.
**Equation 4. Overall Pumping Plant Efficiency**

\[ \text{OPE} = \frac{\text{WHP}}{\text{InputPower}} \]

Where:

- \( \text{OPE} \): Overall pumping plant efficiency (also termed "wire-to-water efficiency" when talking of electric-powered pumping plants) as a decimal from 0 to 1.0.
- \( \text{WHP} \): Water horsepower output of the pumping plant
- \( \text{InputPower} \): Power input to the pumping plant

**Equation 5. Water Horsepower Output of a Pumping Plant**

\[ \text{WHP} = \frac{Q \times \text{TDH}}{3960} \]

Where:

- \( \text{WHP} \): Water horsepower output of the pumping plant as horsepower
- \( Q \): Water flow from the pump as gallons-per-minute
- \( \text{TDH} \): Total dynamic head in the pumping system as feet of water head
- 3960: Conversion constant

Thus, three basic measurements are taken during the test:

1. Power input through the electric or gas meter
2. Flow rate from the pump
3. Total dynamic head

TDH will have two basic components, pressure on the inlet side (which may be positive if a booster is being fed by an elevated tank or reservoir and negative if a water well) and discharge pressure on the outlet side of the pump. It is noted that in a standard field test there are several other aspects of TDH that are ignored, including strainer losses, shaft losses, column losses, and minor losses.

The tester may take some other measurements, notably standing and/or recovered water levels if a well. Also, the test may be performed at multiple operating conditions - that is, different combinations of flow and TDH.

There are two phases to the pump efficiency test, the test itself and interpretation of the results. It is the second phase where the various level of testers are seen. The lowest level would be someone who does some rough calculations and provides the owner with the basics; flow rate, discharge pressure, pumping lift, possibly amperes if this is a measure of performance, and overall pumping efficiency ("OPE"), etc. The OPE may be characterized as good, fair, poor.

Another level would be if the tester has tested the particular pump many times and can provide a summary history so as to provide a trend of performance.

Another level would be if a pumping cost analysis is provided based on the current efficiency and where the pump tester thinks it should be (refer to Appendix 4 for an example of a pumping cost analysis supplied with an APEP pump test report).

If a water well, a tester, especially if active in a particular area, may be able to relate performance to pumping water level and the local aquifer and aquifer conditions.
A tester may inquire as to operating procedures and rate schedule, resulting in recommendations regarding demand management.

All PT test teams for this project were qualified to perform tests under the Advanced Pumping Efficiency Program ("APEP") (APEP is a customer energy efficiency program offering by PG&E. Part of its mission is to provide subsidized pump efficiency tests using a network of pre-qualified pump testers.) Three of the teams submitted standard APEP pump test reports. The fourth utilized their own format that contained all of the same information. A standard APEP pump test report and cost analysis is seen in Appendix 5.

II.3 THE ADDITIONAL QUESTIONS TO MANAGEMENT

In order to identify opportunities for TDH reduction, issues surrounding demand management, and also to fully identify problems with overall water management, an adjunct tool is needed, termed the Additional Questions to Management (AQ). The AQ has four sections, 1) Overall Water/Field Management, 2) Water Supplies to the Field, 3) Time-of-Use Operations, and 4) Information Leverage.

As previously noted, there are two performance metrics for water management, DU and IE. IE is the actual measure of how much applied water is beneficially used. It would be the metric of interest when trying to reduce water applied. However, all of the individual system evaluation modules in the ITRC system evaluate DU, not IE. Thus, ITRC developed another module, the Seasonal Performance Module ("SPM"), which could be used with any system type. With this module they hoped to provide the irrigator with a sense of his overall IE in light of the crop, climate, and applied water.

No evaluation team currently in operation uses this module, generally because the customer cannot provide an estimate of total water applied. This may be because there is no flow meter in place, or the flow meter (or district outlet) is supplying multiple fields and there is no internal tracking, or possibly because the customer does not want to divulge that information. The statement included with the ITRC User's Instructions for this module is "...it has been clear over the years of use of this program that its inaccuracies are offset by one major benefit: In most cases, it has been impossible to accurately identify the volumes of water applied to individual fields. The Seasonal Performance Estimate has therefore been useful in pointing out to growers the important of developing better records."

However, the goal of the project is to develop an audit tool that would identify all opportunities for energy use reduction, including reduction in water pumped. Thus, the data that might be identified by the Seasonal Performance Module is essential. Thus, the first two sections of the AQ, Overall Field and Water Management and Water Supplies to the Field are in place.

A major difference between the CE report and the results that would be obtained by the ITRC SPM is that with the CE report the actual amount of water applied does not have to be identified for an effective audit report to be prepared. First, estimates of energy use and cost savings can be done on a "per acre-foot currently pumped" basis rather than an absolute "x kWh and y $ will be saved if you do this" basis. Essentially the numerical analysis shifts to percentages, rather than absolute sums. Second, depending on the answers to the AQ, recommendations for improvement in water management can still be made.

Water Supplies to the Field also asks for information that can be used to address demand management. The third section, Time-of-Use Operations, asks explicit questions regarding rate schedules and operations. The answers in the third section are verified (or not as the
PG&E’s Emerging Technologies Program

case may be) by PG&E billing history. However, the answers in the Water Supplies section can inform the Integrator as to why an irrigator is (has to be) operating in on-peak hours.

As will be seen, the CE is rather expensive, especially if considered on a dollars per acre actually evaluated basis. However, in many situations a farmer is operating many fields, orchards, or vineyards with similar irrigations systems, water management strategies, and crops in place. The hope is that the knowledge obtained with the individual CE can be transferred to a much greater acreage. Thus, the final section of the AQ, Information Leverage, was developed.

The current version of the AQ is seen in Appendix 7.

III. EMERGING TECHNOLOGY

Integration of the two existing, standard audits (irrigation system evaluation and pump efficiency test) with a new audit tool, the AQ does not replace existing audit protocols. Instead, it provides a means of combining them so that the sum is greater than the parts. The intent is to provide a comprehensive analysis of how water and energy are being utilized on a particular field as well as recommendations for improvement.

The key to this new technology is in the integration of the results from the three basic audit tools. The term "Integrator" is used for the person (or entity) responsible for this. Functional requirements of an Integrator would include:

1. Knowledge of the system design, maintenance, and operational characteristics of the irrigation systems being evaluated.
2. Knowledge of overall agricultural water management including the basics of soil-water-plant relationships, irrigation scheduling techniques, water quality and non-point source pollution, and salinity and drainage.
3. Knowledge of the science of pumping plants.
4. Knowledge of water and energy issues in California.
5. Knowledge of electricity rate structures and how services are offered and managed.

This is not considered either a common or a low-value skill-set. On the contrary, as discussed in the Recommendations section, new tools and training resources are needed to support this emerging need.

The Combined Evaluation (CE) provides a comprehensive look at energy/water use on the field (amount of water pumped, overall pumping efficiency, total dynamic head in the system, demand management) as well as providing explicit numeric evaluations of potential savings in energy use and costs. The existing IrrEval does not address energy (use or demand) and no IrrEval report seen provided any cost savings estimates. The existing PT report provides a cost savings estimate for improving OPE but on the basis of equal amounts of water pumped before and after the retrofit. The PT does not address any water management or demand management issues.

There are several market barriers to the use of this new audit tool:

1. **Lack of a (low-cost) Integrator** - all available evidence indicates that no existing IrrEval team or PT currently has the ability to act as Integrator. Any competent engineer or technician, versed in both energy and water, should be able to perform as Integrator. However, identifying these individuals and developing a market for their services (via utility program design or other approaches) poses challenges.
2. **Market Unfamiliarity.** The CE is a new audit product and as such, needs to be advertised to both customers and implementation teams. The real problem may lay in understanding the energy/water nexus itself. Customers may not understand the link between energy and water use, and existing IrrEval or PT teams may not either.

3. **Availability and Cost.** Although pump tests are fairly well-understood and reasonably priced, (APEP provides subsidized pump tests to eligible pumpers), the IrrEval is not widely available and is relatively expensive compared to the pump test.

4. **Perception that All Microirrigation Systems are Efficient.** There is the perception that just by installing a drip (or some other "efficient" type) irrigation system, the resulting water management will be efficient. The end result is that many potential audit customers feel that additional field investigations are not needed.

5. **Project Costs to Implement Recommendations.** The current CE protocols will provide recommendations for improvements and estimates of potential cost savings. However, it does not provide the customer with an estimate of costs of implementing these recommendations.

Although any irrigator could arrange for a combined evaluation to be performed, it has not been available as a package from a single source, especially considering the importance of the integration function. However, the different components have been available. Irrigators have had pump tests available for decades. (APEP has been in operation since 2002 promoting improved pumping plant efficiency and in that time has provided over 20,000 subsidized pump efficiency tests.) The irrigation system evaluation protocols have been known for decades also (for example, Keller and Merriam published "Farm Irrigation System Evaluation: A Guide to Management" in 1978, which was partially based on SCS evaluation techniques). The Mobile Irrigation Laboratory system was developed in the mid-1980s but only three are still known to be active in the PG&E service area today.

In certain areas there are also forces at work promoting irrigation scheduling and other Best Management Practices for water conservation. Alleviating some other types of problems, notably non-point source pollution may also lead to improved IE and thus, reduced pumping.

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**Non-Points Source Pollution Programs May Improve Irrigation Efficiency**

The model of non-point source pollution ("NPS") is a three-step process of availability, detachment/transformation, and transport. Using nitrogen fertilizer as an example:

a. The farmer applies fertilizer to a field - it is not a pollutant but is "available" in the environment

b. The fertilizer may transform or detach. A common scenario is for a nitrite form of nitrogen fertilizer to a nitrate form (that will move readily with water). It is still not a pollutant since it is on the field where it is supposed to be.

c. However, excess irrigation may produce deep percolation (water movement below the effective root zone) that will "transport" the fertilizer to an aquifer where it then becomes a pollutant.

Thus, a frequent component of any NPS program is improvement of irrigation efficiency.

PG&E has demand management programs in place and the CPUC has ordered that all customers of a certain size be transitioned to TOU rate schedules.
However, again, the authors are unaware of any coordinated effort to analyze all opportunities for energy and water conservation with an integrated effort. As well, the link between energy and water, while appearing to be obvious, may not be well-understood to all irrigators.

**IV. ASSESSMENT OBJECTIVES**

There were six major objectives identified in the Scope of Work for the project. For each task, an interim report was developed describing the conclusions in detail; results are summarized in the RESULTS section of this report.

1. Identify the most applicable Irrigation System Evaluation Procedure - a literature search was conducted and as previously noted, the only two formal sets of protocols identified were the NRCS National Engineering Handbook and the ITRC system. The ITRC system was judged the most applicable due to all evaluation teams in California currently using it, as well as several other similar efforts across the nation.

2. Develop or identify the data needed to be collected - once the preferred protocol was identified, the data requirements for the irrigation system evaluation were also. The pump efficiency test is a very standard audit and it was decided that all tests would conform to the requirements of the APEP. The AQ were developed over the course of the project.

3. Develop the report format - the report format varied somewhat over the course of the project but basically followed the concept of discussing the three opportunities for energy use reduction plus demand management. The core of the final report package consisted of a Summary section, the full IrrEval report, the PT report, answers to the AQ, a copy of PG&E billing (to back-up conclusions regarding demand management issues).

4. Assess the Field Capacity for Evaluations - over the course of the project, information was gathered on companies offering pump test services, irrigation evaluation capabilities, and integration expertise, and the ability of the industry to support scaling efforts for combined evaluations.

5. Conduct Audits and Investigate Results of System Evaluations on Water and Energy Consumption - forty-five CE were performed. The experiences of the different evaluations led to the refinement of the evaluation protocols, the AQ, and the report format. The actual numeric results should not be viewed as a proxy for agriculture in the PG&E service area. Rather they should be viewed in the context of a) can the CE identify potential savings, b) what indication, if any, can be gleaned as to whether this type of project deserves further funding?

6. Identify Measure Implementation Costs for the various recommendations - a peripheral objective was to determine if there were consistent recommendations being made for improvements. If so, could a benefit/cost ratio be identified that would enable a determination as to whether any one recommendation could be a candidate for a deemed measure?
V. TECHNOLOGY EVALUATION

Forty-Five CE were performed in four different agricultural areas in the PG&E service area, 1) Central Coast, 2) Southern San Joaquin Valley, 3) Northern San Joaquin Valley, and 4) Sacramento Valley. This gave a fair indication of adaptation of the CE to the different soils, climates, water supplies, and marketing pressures in place. The CE occurred from February through August. The time spread was purposeful as that allowed for an on-going evaluation of the efforts and led to changes in the protocols and reporting formats.

For this project the only criteria was that the field have a pressurized irrigation system and that it be a PG&E account. It was desirable, but not required, that the field have had a previous evaluation of the irrigation system since one concern is whether the existing IrrEval is effective in reducing water applications.

The reason that the project was restricted to pressurized irrigation systems is that the evaluation of a pressurized system is very much an evaluation of system DU that will be fairly valid for the entire season. On the other hand, evaluations of flood-type irrigation systems (furrow, border strip, basin) are more an evaluation of the performance by management during a particular irrigation event. This is because water applications using flood irrigation methods are very much governed by soil mechanical and moisture conditions (both at the surface and in the effective rootzone) at the time of irrigation, as well as the amount of water that is trying to be applied (e.g., .5 AcFt/Ac at the start of a season versus 2 AcFt/Ac at the end of a season). Thus, while the DU of a drip irrigation season would be expected to remain relatively constant over a season, the DU of a furrow system could vary greatly.

The project was completed with the aid of outside contractors—four IrrEval teams and pump testers as required. All IrrEval teams have been in place for at least ten years. They are Kevin Peterson of the NRCS office in Santa Maria, Brian Hockett at the Northwest Kern Resource Conservation District, Kevin Greer at the Tehama Resource Conservation District, and Power Hydrodynamics located in Modesto, CA. Pump tests were performed only by APEP-certified pump testers.

Project management and the Integrator function was supplied by the Center for Irrigation Technology at CSU, Fresno. CIT has also designed and implemented the Advanced Pumping Efficiency Program in one form or another since 2001, providing for over 20,000 subsidized pump efficiency tests. In addition, CIT has completed several projects involving assessment of irrigation system performance using the ITRC protocols and participates in many educational seminars regarding various aspects of agricultural water management.

In a sense there is bias inherent in this project as it is a pilot project, not open to the public, and subject to the judgment of the different evaluation teams in deciding which fields would be evaluated. Further, as irrigation system evaluations are not a widespread practice, those asking for them are to a certain extent, self-selecting actors—i.e., those interested in their performance and looking for improvement. However, since a) the actual numeric results of the CE were not the focus (rather whether the CE could do what was anticipated) and b) the new technology (the CE) being tested was actually being developed during the project, the bias is not considered important.

Adaptation of recommendations for an irrigation system may occur over a number of years depending on the resources available to management. There might be a learning curve when implementing irrigation scheduling procedures so that they become more effective over time. Alleviation of plugging or replacement of worn components may occur over time due to financing and/or labor availability constraints.
VI. RESULTS

VI.1 OBJECTIVE 1 - IDENTIFY THE MOST APPLICABLE IRRIGATION SYSTEM EVALUATION PROCEDURE

A literature search was conducted and as previously noted, the only two formal sets of protocols identified were the NRCS National Engineering Handbook and the ITRC system. The ITRC system was judged the most applicable due to all evaluation teams in California currently using it, as well as several other similar efforts across the nation.

VI.2 OBJECTIVE 2 - DEVELOP OR IDENTIFY THE DATA NEEDED TO BE COLLECTED

Once the preferred protocol was identified, the data requirements for the irrigation system evaluation were also. The pump efficiency test is a very standard audit and it was decided that all tests would conform to the requirements of the APEP. The AQ were developed over the course of the project.

VI.3 OBJECTIVE 3 - DEVELOP THE REPORT FORMAT

As a result of earlier efforts to identify irrigation system evaluation protocols in use and the 45 field evaluations performed, a report template and list of data requirements has been developed. The report is a package consisting of a Cover Letter, Table of Contents, and seven sub-sections, some of which are standardized from the two types of evaluations performed and some of which have been developed in the course of this project.

It is noted that this project only evaluated pressurized irrigation system types- micro, mini-sprinkler, and field sprinkler. This is because evaluation of these system types is very straightforward and actually evaluates the irrigation system hardware. In contrast, evaluation of flood type systems (furrow, border checks, level basins) is really an evaluation of management’s ability to control the irrigation- i.e., how management reacts to the rate of water advance, which can change with each irrigation). Thus, the report format developed only addresses pressurized systems.

The seven sub-sections (some of which are optional) of the main report are:

1. Evaluation Summary: The report summary includes a cover letter and several subsections focused on various aspects of the CE: background information, recap of Irrigation System Evaluation, recap of Pump Efficiency Test, system pressure issues, demand management issues, estimated water and energy savings potential. As its name indicates, this section is intended to quickly communicate the key findings and recommendations of the evaluation.


3. Full Report of the Pump Test - including the pumping cost analysis

4. Answers to the Additional Questions for Management

5. Report of PG&E Billing
6. Average Seasonal Irrigation Schedule

7. Technical Papers

In the Table of Contents these are referred to as the "Summary" and Attachments one through six.

A potential criticism is that the package is too large. We note though that in many cases a recommendation is repeated in multiple sections. It is always a question as to what is a priority with any one customer. One may be more interested in the performance of the irrigation system (possibly they just acquired the property), others may be interested in the pumping plant performance and whether there is any excess pressure.

Each of the package components will now be discussed.

**VI.3.i COVER LETTER AND TABLE OF CONTENTS**

The current version of the cover letter and table of contents is seen in Appendix 1. The combined evaluation is greater than the sum of its parts. The purpose of the cover letter is to provide some perspective to the customer as to the "why" of the evaluation process and why the different parts of the report package are included.

The cover letter will obviously be changed as needed in the future as this version was specific to the Program. There are a number of ways that a combined evaluation might be made available- possibly a full-scale program sponsored by the CPUC, possibly a partnership of funding agencies, or possibly funding by the individual customer. However, the cover letter should, at a minimum, include the following information:

- Which agencies are sponsoring the different parts of the evaluation.
- The source of funding.
- The three paragraphs starting with "The key concept... - these provide a summary explanation of why the irrigation system and pump test evaluations are combined.
- How to file a complaint.
- Disclaimers as needed.

**VI.3.ii Summary**

This is the part of the report package that provides a summary of findings and is considered the most important part of the report package. It has six sub-sections:

1. Heading - indicating date of evaluation, field, personnel involved, etc.

2. Recap of irrigation system evaluation - there are two main headings in this sub-section, Hardware, which speaks directly to the distribution uniformity and general condition of the system, and Management, which speaks to irrigation scheduling (i.e., overall water management).
3. Recap of pump efficiency tests.

4. System pressure issues - where opportunities to reduce total system pressure are summarized.

5. Electricity peak demand issues - where opportunities to reduce energy use on-peak are identified.

6. Summary calculation of potential energy and water savings.

An example of the recommended summary section is seen in Appendix 2.

As will be seen in the following discussion, some issues may be noted in multiple places. For example, having no flow meter installed will flagged in both the Water Management and Pump Test Report sections. The reason for doing this is that possibly the customer may be interested in only a particular section (for example, the pump test report) and not pay much attention to the other sections.

**VI.3.ii.a SUMMARY SUB-SECTION - HEADING**

The heading should contain:

1. Date of evaluation

2. Farm name - this could be the overall holding company or owner’s name, or it could be the individual farm

3. Field identification - this should include
   a. the individual farming operations name (if not seen as the farm name),
   b. the field identity,
   c. overall size of the field serviced by the pump,
   d. size of area evaluated,
   e. crop, crop age, and crop spacing
   f. sense of topography

4. Water Supply - this should include
   a. identification of all water supplies including wells, districts, and rivers.
   b. pressure source (pressurized well, booster pump, gravity).
   c. main filtration.

5. Irrigation system description - this should include:
a. system age.

b. an overall description of the system- examples would be "single line drip with plug-in turbulent flow emitters" or "double line drip with in-line pressure compensating emitters".

c. the emission device manufacturer, model, and size.

d. number of emitters per plant/tree/vine (if applicable).

e. number of sets per irrigation cycle.

6. Contact information to identify

   a. the farming operation contact.
   
   b. irrigation system evaluator.
   
   c. pump tester.
   
   d. integrator (that person responsible for preparing the report package).

VI.3.11.b Summary Sub-Section - Recap of Irrigation System Evaluation

This will have two parts, one addressing the hardware and the other the management of the system. The hardware section will be developed from the report of the irrigation system evaluation, which is a separate section (referred to as Attachment 1 in the Table of Contents) of the total report package. The management section will be developed using that report as well as the responses to the Additional Questions ("AQ") (refer to III.4 Additional Questions to Management later in this report).

Hardware - this area will start with the evaluated distribution uniformity of the system (DU) as well as a characterization (poor, fair, good, excellent). Then, all critical issues identified in the evaluation are noted along with any recommendations. As the full report should contain a narrative with a more detailed discussion of the issues and recommendations this section should only be a summary of the most important issues.

Management - management of a cropped field is a complex process involving multiple trade-offs due to overall crop economics, pest/disease/fertilization issues, water availability, labor availability, as well as the demands of other fields. It is difficult to make definitive assumptions and recommendations as to just one aspect of that management (water) on the basis of possibly just four to six hours of investigation. This section should always start with some type of disclaimer that informs the customer as to our acknowledgement of the difficulties faced. An example, based on micro-irrigation type systems would be:

"Water management of a crop depends on many factors including variety, canopy management, effect of water stress on yields and quality, soil, water quality, pest/disease/weed pressure, scheduling of other farm operations, and overall crop economics. It is difficult to make blanket statements as to correct irrigation scheduling (the frequency and duration of irrigation events). However, irrigation scheduling is generally intended to replace crop evapotranspiration (regardless of
overall crop management) while maintaining root zone soil moisture levels so as to prevent stress—although with some crops stress may be intentional at certain growth stages. Note also that one of the advantages of micro-irrigation systems is the ability to maintain optimum soil moisture levels through high-frequency irrigation, assuming that there is sufficient flexibility in the primary water supply."

IMPORTANT! It is not the intent of this section to assign a number for "irrigation efficiency". Its purpose is to point out if there are any gross defects in the perceived overall water management.

This section should include a discussion of at least four topics:

1. Identification of total, annual water applications (if possible).
2. Identification of irrigation scheduling protocols in place.
3. A judgment as to reasonableness of the reported "main season" irrigation scheduling methods.
4. A judgment as to overall gross over or under irrigation.

This section should start by noting if the total applied water could be identified. Ideally this would be by a direct statement from management (contained in the Additional Questions) and backed up by PG&E billing and the results of a pump test.

Example - Management reports 2.75 acre-feet/acre applied over a mature 40 acre almond orchard. The pump test for a pressurized well shows 235 kilowatt-hours per acre-foot pumped. PG&E billing for 2012 shows 25,400 kilowatt-hours used. This equates to about 2.7 acre-feet/acre. Thus, the applied water is essentially identified.

If the total application cannot be ascertained then the recommendation is to install (or start reading regularly) a flow meter or some other method that will tell management how much is being applied. Note that the economic analysis at the end of the Summary Section can still be presented but only on a "per acre-foot currently pumped" basis.

Also, if using the pump test and PG&E billing as the only estimate (i.e., management did not provide an estimate in the AQ), then this disclaimer should always be present:

"This estimate is based on total energy used in 2012 and the results of the current pump test. For water wells especially it is noted that the kilowatt-hours needed to pump an acre-foot can change seasonally and systemically depending on the aquifer."

Next, this section should identify what, if any, irrigation scheduling protocols are in place. This information should also come from the AQ. Protocols identified in the AQ include:

- Soil and/or plant moisture monitoring
- Estimates of daily/weekly crop ETc in conjunction with system application rate
- Formal water budget or graphical irrigation scheduling system
- Experience only (crop/soil appearance/feel/other factors)
The combination of crop, crop age, and location should then allow an estimate of net annual crop evapotranspiration. This should be corrected for the DU found by the evaluation and two judgments made— one for the daily/weekly irrigation regime in the main part of the season and one for an overall seasonal gross over or under-irrigation. There are a number of sources for the estimate of net annual ETc, one being the WATERIGHT web site at www.wateright.org.

If reported, then management's irrigation regime in the main irrigation season should be compared to crop ETc estimates as well as the annual crop ETc.

Example - Using the WATERIGHT site for mature almonds in the area where the 40 acre almond orchard is located, annual net ETc is seen to be 31.5 acre-inches/acre. Compared to the 33 acre-inches/acre applied reported by management it appears that current irrigation scheduling is very good.

Example - Assume that the orchard was only a third leaf crop with 50% canopy cover at most. Using the WATERIGHT site for almonds in the area where the 40 acre almond orchard is located, annual net ETc might be estimated as only 17 acre-inches/acre. If management is seen as applying 33 acre-inches/acre then gross over-irrigation is indicated.

VI.3.ii.c SUMMARY SUB-SECTION - RECAP OF PUMP EFFICIENCY TEST(S)

This section starts with a disclaimer as to the pump test being a snapshot of the pump performance and a reference to the Pump Test Technical Advisory that should be part of the pump test report. For a well this might be:

"The pump test is a "snapshot" of pumping plant performance at the time of the test. The test should be performed with the pumping plant operating at its most normal condition. If a water well it is especially important to realize that pumping efficiency can change seasonally or systemically according to the reaction of the aquifer to irrigation withdrawals. Refer to the Pump Test Technical Advisory that is part of the pump test report."

If the pump is electric-powered then the following table is included along with the source:

"The table below is from CPUC pump efficiency guidelines and is used to characterize the overall pumping efficiency of the pumps tested."

<table>
<thead>
<tr>
<th>Motor HP</th>
<th>Low</th>
<th>Fair</th>
<th>Good</th>
<th>Excellent</th>
<th>Booster</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 – 5</td>
<td>41.9 or less</td>
<td>42 – 49.9</td>
<td>50 – 54.9</td>
<td>55 or above</td>
<td>55</td>
</tr>
<tr>
<td>7.5 – 10</td>
<td>44.9 or less</td>
<td>45 – 52.9</td>
<td>53 – 57.9</td>
<td>58 or above</td>
<td>58/60</td>
</tr>
<tr>
<td>15 – 30</td>
<td>47.9 or less</td>
<td>48 – 55.9</td>
<td>56 – 60.9</td>
<td>61 or above</td>
<td>60/65</td>
</tr>
<tr>
<td>40 – 60</td>
<td>52.9 or less</td>
<td>53 – 59.9</td>
<td>60 – 64.9</td>
<td>65 or above</td>
<td>65/70</td>
</tr>
<tr>
<td>75 – up</td>
<td>55.9 or less</td>
<td>56 – 62.9</td>
<td>63 – 68.9</td>
<td>69 or above</td>
<td>70/72</td>
</tr>
</tbody>
</table>

*Submersible Well Less an additional 3%
Developing Overall Plant Efficiency Standards for Natural Gas Pumps

A similar table to "Overall Plant Efficiency Ranges Wire to Water" has not been identified for natural gas-powered pumps. However, the following was taken from "Pumping Plant Efficiency - How Much Extra are You Paying?" by Thomas W. Dorn, University of Nebraska Extension Editor:

"The University of Nebraska has conducted hundreds of tests over the years on farmer-owned pumping plants. Based on these field tests and on tests of engine efficiency in the laboratory, the University developed the Nebraska Pumping Plant Performance Criteria, (NPC). The NPC states the brake horsepower output from the engine and drive unit (hp-h) and the amount of useful work output one should expect from a pumping plant (whp-h) per unit of energy consumed.

Table 1. The Nebraska Pumping Plant Performance Criteria (NPC)

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>hp-h/unit of energy</th>
<th>whp-h/unit of energy</th>
<th>Energy Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>16.66</td>
<td>12.5(^d)</td>
<td>Gallon</td>
</tr>
<tr>
<td>Gasoline</td>
<td>11.50</td>
<td>8.6</td>
<td>Gallon</td>
</tr>
<tr>
<td>Propane</td>
<td>9.20</td>
<td>6.89</td>
<td>Gallon</td>
</tr>
<tr>
<td>Natural Gas(^e)</td>
<td>82.20</td>
<td>61.7</td>
<td>Mcf</td>
</tr>
<tr>
<td>Electricity(^f)</td>
<td>1.18</td>
<td>.885</td>
<td>kWh</td>
</tr>
</tbody>
</table>

\(a\) hp-h (horsepower hours) is the work accomplished by the power unit with drive losses considered. This is the horsepower imparted to the lineshaft that drives the pump impellers.

\(b\) whp-h (water horsepower hours) is the work accomplished by the pumping plant (power unit and pump).

\(c\) Based on 75\% pump efficiency.

\(d\) Criteria for diesel formerly 10.94 revised in 1981 to 12.5.

\(e\) Assumes an energy content of 925 BTU/cubic foot.

\(f\) Assumes 88\% electric motor efficiency.

The NPC is apparently considered a threshold value for a reasonably efficient pumping plant. Thus, for natural gas-powered pumps the University of Nebraska expects them to supply at least 82.2 horsepower-hours per therm and 61.7 water horsepower per therm. This implies a pump bowl efficiency of 75\%. Assuming a 92\% efficient motor and a 97\% efficient transmission system this equates to about a 67\% OPE for an electric powered pump. 67\% OPE would be considered excellent in the field and thus, the NPC shown above for natural gas is a very high threshold.

Then for each pump the following a summary of the calculated overall pumping efficiency (OPE) and the important measurements (as an example) should be included, as well as an identification of important issues with recommendations as needed. As an example:

**Pump - Well - Meter 1005833811 - 25 Horsepower**

- Current OPE = 63\% - considered excellent for this horsepower range
- Current Flow = 490 gallons per minute
- Current Total Dynamic Head = 151 feet
- Current Discharge Pressure = 48 psi
ISSUES

1. There is no flow meter installed. RECOMMENDATION - Install a flow meter. In conjunction with a pressure gauge they can serve as an early warning for problems with the pump or the irrigation system. As well, they serve as a back-up to irrigation scheduling.

If the estimated OPE is considered below Fair then the following should be included as an ISSUE (assuming APEP is in operation):

ISSUES

1. The OPE measured is low. RECOMMENDATION - Management should consider the profitability of a pump retrofit in consultation with pump experts. Refer to the Pumping Cost Analysis supplied with the Pump Test Report for an estimate of potential annual savings. The Advanced Pumping Efficiency Program offered by PG&E may be able to provide an incentive. Call the program at 800 845-6038 or go on-line to www.pumpefficiency.org for more information.

Within this section a comparison of pump flow measured versus what the evaluation indicates should be made. That is, the number of operating emission devices and their average flow will provide an estimate of required pump flow. This should be compared to the pump flow observed by the pump tester.

It is important that this calculation be done in the field by the evaluator and any gross differences (more than about 15%) resolved immediately- measuring pump flow accurately can be difficult depending on the test section available. This requires communication between the system tester and the pump tester, as well as accurate field sizes provided by management. Resolving any differences could identify problems with either or both of the system evaluation or pump test data.

Example - 20 acre irrigation set in an orchard with under-tree sprinklers spaced 51 x 24 and flowing .75 gpm on average. This equates to 534 gpm. However, the pump test indicates a pump flow of 750 gpm. This difference needs to be resolved immediately.

Example - 20 acre irrigation set in an orchard with under-tree sprinklers spaced 51 x 24 and flowing .75 gpm on average. This equates to 534 gpm. However, the pump test indicates a pump flow of 570 gpm. This difference should be noted in the report but is not so important that it needs to be resolved immediately.

VI.3.ii.d Summary Sub-Section - System Pressure Issues

Although the main purpose of this section is to identify excess pressure losses there should be some summary of the system pressure uniformity also. Depending on the situation it may be that the excess pressure is causing the poor uniformity.
The analysis of excess pressure can be confounded by a number of factors. It might be that the pump supplies water to other fields that are farther away or possibly at a higher elevation than the field evaluated. It may be that there are multiple planting blocks within the field and management operates these blocks in an inconsistent manner. It may be that a water well is used as a supply and the booster. Thus, as the water table rises and falls overall system pressures will change also. Management's responses to the AQ are then all-important in making any recommendation.

The discussion should identify any apparent excess pressure and then explain whether or not it truly is excess pressure or due to one (or another) operating criteria. True excess pressure arises from either a pump that is not matched to the emission device and piping system or an older (designed when energy prices were lower) or wrongly engineered system. For example if a pressure map of the evaluated field shows consistent 25-28 psi hose pressures and the pump is right next to the field with a 45 psi discharge and supplies no other field, this is an indication of excess pressure. (This situation can come about if the original irrigation system has been updated, without changing the pump - e.g., converting from high pressure, over vine impact sprinklers to drip.)

On the other hand, if there are 20 planting blocks within a vineyard and only 20% of the acreage is operating at the time of the test, apparent excess pressure may be due simply to not enough blocks being operated (possibly because of different age vines, different varieties, or various other vineyard management operations in progress). To repeat though, this is where the responses from management to the AQ are important.

If it is felt that there is actual excess pressure in the field then this should be flagged with a recommendation to management to consult with an irrigation and/or pumping expert to investigate the profitability of changing the pump.

To the extent that the excess pressure is due to the operating criteria of the field (or fields) then it may be that management should investigate the feasibility of installing a variable frequency drive.

**VI.3.II.E SUMMARY SUB-SECTION - DEMAND MANAGEMENT ISSUES**

This section basically reports on on/off-peak operations as currently seen versus potential. The basis would be detailed PG&E billing. Generally the fastest way to obtain this billing is:

1. go to WWW.PGE.COM and click "For my Business" seen at the top of the page
2. click "Analyze my Usage" in the "How Do I" section of the My Business home page
3. click "Business Tools" under the sub-menu "Assess Your Energy Usage" at the left of this page
4. Follow instructions to create an account
5. Access the account billing history and export to an excel file

The billing history is going to provide the rate schedule, annual energy use (used to identify good or bad overall water management), and pattern of on/off-peak operation. If the customer is operating 24 hours/day then this should be pointed out with the recommendation to reassess barriers to off-peak operation (which could be due to the primary water supply or the requirements of the irrigation system). Costs per kWh should
be pointed out for on-peak versus off-peak operation and this should be part of the summary of potential energy use and cost savings.

VI.3. II.F Summary Sub-section - Summary of Potential Water and Energy Savings

This sub-section contains a summary spreadsheet of the observed current operations versus projected, generally at ideal conditions. An example spreadsheet is seen in Figure 1. Note that in this example, the total water application could not be identified and the analysis was done on a "per acre-foot currently pumped" basis.

<table>
<thead>
<tr>
<th></th>
<th>CURRENT</th>
<th>PROJECTED</th>
<th>SAVINGS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Acre-Foot Pumped</td>
<td>1.00</td>
<td>0.88</td>
<td>0.12</td>
<td>Improve DU from 81% to 92%</td>
</tr>
<tr>
<td>OPE (%)</td>
<td>45</td>
<td>62</td>
<td></td>
<td>Improve OPE as per pump test cost analysis</td>
</tr>
<tr>
<td>Total Dynamic Head</td>
<td>166</td>
<td>169</td>
<td></td>
<td>Reduce TDh by removing throttling valve at pump discharge</td>
</tr>
<tr>
<td>kWh/Acre-foot</td>
<td>378</td>
<td>279</td>
<td>99</td>
<td>$/kWh = 102.41 x TDH / OPE</td>
</tr>
<tr>
<td>$/kWh</td>
<td>$0.160</td>
<td>$0.160</td>
<td></td>
<td>Off-peak operations</td>
</tr>
<tr>
<td>TOTAL kWh Usage</td>
<td>378</td>
<td>246</td>
<td>132</td>
<td></td>
</tr>
<tr>
<td>ENERGY COST</td>
<td>$60</td>
<td>$39</td>
<td>$21</td>
<td>35% savings, primarily through improved pumping efficiency</td>
</tr>
</tbody>
</table>

Figure 1 - Example of a Summary of Potential Water and Energy Savings

The calculations are straightforward:

- kWh/Acre-Foot = 102.41 x TDH / OPE
- TOTAL kWh USAGE = Acre-Foot/Year x kWh/Acre-Foot
- ENERGY COST = $/kWh x TOTAL kWh USAGE

The Acre-Feet Pumped will be identified in the water management section. The pump parameter changes will come from the pump test report and the $/kWh will be based on current on/off-peak operating performance.

VI.3. III Report of Irrigation System Evaluation

This will be the full report of the irrigation system evaluation as prepared by the evaluation team. As noted in a previous Interim Report regarding the 45 test evaluations performed, there were four evaluation teams used and, while using the same basic evaluation protocols, each had a different reporting format.
The preferred format for micro systems is seen in Appendix 3. It utilizes the newer ITRC spreadsheet for data entry and calculations. The main components are:

1. Heading section
2. ITRC results section with narrative and recommendations
3. Pressure map
4. Topographic map (optional depending on the extent of elevation changes)
5. Farm map (optional depending on if pump supplies other fields or there are multiple water sources from other areas on the farm)
6. Soils information
7. ITRC data entry sheets

One of the evaluation teams consistently addressed irrigation scheduling issues but since this would be a function of the Summary Section it is not considered a requirement for a combined evaluation. If an evaluation team, operating outside of a combined evaluation process, wanted to include irrigation scheduling issues they would need to have some of the information gleaned from the Additional Questions as well as estimates of net annual crop ETc for the crop, crop age, and location in question. An example of the resulting section might be:

**Overall Water Management - Additional questions for management indicate that irrigation scheduling is based on experience only and there is no estimate of total water applied to the orchard (there is no flow meter in place). PG&E billing through July 29 indicates approximately 73 acre-feet pumped using total kWh usage and the kWh/AF identified with the August 8 pump test. This equates to about 1.16 Ac-Ft/Ac applied over the 63 acres. The orchard is reported to be a mix of 4 - 8 year old trees with a 40% canopy. The average ETc data based on UC crop coefficient curves and the Gerber CIMIS weather station indicates about 2.2 Ac-Ft/Ac required application for a fully mature orchard. Assuming an average 75% of full ETc requirement due to tree ages and canopy cover then approximately 1.7 Ac-Ft/Ac would be required. Assuming some effective rainfall from the gross 23 inches reported, it appears that there is little, if any, over-irrigation occurring presently.**

Additionally, the irrigation regime in the main irrigation season is reported to be 18 hours every five days. At an average application rate of .054 in/hr this equates to .97 inches gross application or .19 inches/day. Given the very good DU found this appears to be reasonable and backs up the thoughts above.

**RECOMMENDATION - Management should implement some form of objective irrigation scheduling and is encouraged to consult with local experts or the UC Cooperative Extension. Personal experience is a critical factor in orchard management but there is always the chance that this experience can be lost suddenly. Thus, some objective form of scheduling should be in place. A viable strategy (as a starting point) would be:**
i. Develop an average seasonal irrigation schedule based on the measured performance of the irrigation system and average crop water use (see Attachment 5 for an example seasonal schedule developed using the WATERIGHT web site, www.wateright.org - uses 62% canopy cover).

ii. Install a soil moisture monitoring system. Factors to consider are placement in representative areas of the orchard and placement so that excessive deep percolation can be identified.

iii. Start irrigation operations as per the schedule. Double-check the applications with the flow meter and read the soil moisture sensors often enough to identify a root zone that is either too wet or too dry. Adjust the irrigation operations as per the feedback from the soil moisture monitoring and management's experience based on other crop monitoring.

iv. Maintain a log of weekly operation time, flow meter readings, and soil moisture sensor readings. These will be helpful in fine-tuning irrigation operations year-to-year.

VI.3.iv REPORT OF PUMP TEST

This should simply be the standard APEP report format with pumping cost analysis. There should be a cover sheet to this section that makes it clear the pumping cost analysis contained here only considers the pumping plant efficiency and total lift - that is, the assumption is that the same amount of water is pumped before and after any pump retrofit. The APEP Pump Test Technical Advisory should also be included.

Pump testers in these situations should be aware of the need for a multi-condition pump test due to the possibility of different required operating conditions depending on which irrigation set was operating.

The current standard APEP test report is seen in Appendix 5.

VI.3.v RESPONSES TO ADDITIONAL QUESTIONS

The current set of Additional Questions is seen in Appendix 7. An explanation of why each section is presented (or the individual question is asked) should be included when presented to management so that the manager, and the evaluation team, is guided to the information needed.

VI.3.vi PG&E BILLING

This is generally a print out from the PG&E web site identifying the rate schedule, total costs, and on/off-peak operations.
VI.3.vii Example Average Seasonal Irrigation Schedule

This is an optional section and is guided by the answers to the Additional Questions. If management indicates little or no formal irrigation scheduling activities then a strategy is suggested during the discussion of Water Management and an example seasonal schedule is supplied here. A cover page should be included here to explain what the WATERIGHT site is and how it can be used. An example scheduling output from WATERIGHT is seen in Appendix 6.

VI.3.viii Technical Papers

There are currently two papers included with the report package. The first is an identification and discussion of the three big ideas for reducing energy use- 1) reduce amount of water pumped, 2) reduce pressure in the system, and 3) improve pumping plant efficiency. This provides back-up for the concept behind performing combined evaluations.

The second is a discussion of the two main performance metrics for an irrigation system, distribution uniformity and irrigation efficiency. The relationships between the two are identified, which leads to why the evaluation of DU is the first priority.

Other papers could be included as applicable. For example, if a field evaluated had very undulating topography it may be helpful to include a discussion paper regarding pressure compensating emitters. Another possibility is a summary discussion of variable frequency drives and their applicability.

VI.4 Data Requirements

Data requirements for a report can be summarized as:

1. The data required to perform the irrigation system evaluation. This is listed in the data input sheets and discussed in the User's Guide to the ITRC evaluation protocols. The current ITRC input sheets are seen in Appendix 4.

2. The data required to perform a standard APEP pump test. Although some of the data entry blocks shown are optional, Figures 2a through 2c indicate the amount of data that might be gathered during a pump test.

3. Responses to the Additional Questions to Management - see Appendix 7.

4. A copy of PG&E billing, preferably for at least the last three years.

5. Preparation of an example average annual irrigation schedule using a system such as that found on the Wateright site, www.wateright.org (see Appendix 6 for an example). This is optional depending on the findings from the Additional Questions to Management.
Figure 2a - First data input screen for an APEP pump test record

Figure 2b - Second data input screen for an APEP pump test record
VI.4 OBJECTIVE 4 - ASSESS THE FIELD CAPACITY FOR EVALUATIONS

Market research indicates that there exists sufficient capacity for both pump tests and irrigation system evaluations. However, the integration function was identified and discussed. The capacity for this function absolutely exists if a professional (certified irrigation system designer, civil or agricultural engineer) is used, but may be costly. A training course can be developed to add the integration ability to system evaluators and pump testers, but it is an open question as to how much experience it will take for any one person to become truly effective.

VI.5 OBJECTIVE 5 - CONDUCT AUDITS AND INVESTIGATE RESULTS OF SYSTEM EVALUATIONS ON WATER AND ENERGY CONSUMPTION

45 CE were performed on 44 different fields (one CE was a re-test of a field evaluated at the on-set of the project). Table 1 contains the identifying features of the different fields, including county, crop, and irrigation system type. Thirty-seven of these fields were used to create various statistics.
The numeric results of the IrrEval and PT are different for each field, as are the estimates for potential savings. These results are not the focus of the project. Rather the focus is on whether a viable set of CE protocols and effective report format could be developed, while identifying costs and issues for deciding whether to take the next step. However, the following statistics, developed using 37 fields of the 45 evaluated, are presented as a matter of interest. The eight fields were discarded for a variety of reasons including incomplete data sets or abnormal situations that could not be reconciled with the other data sets.
VI.5.1 AGGREGATE STATISTICS

IMPORTANT! The reader is cautioned that no claim is made that these statistics reflect the average performance for pressurized irrigation systems in PG&E’s service area.

- **Wide Variance in Distribution Uniformity Observed.**
  - Average DU: **88.5%**;
  - Average of highest five DUs: **98.2%**;
  - Average of lowest five DUs: **69.0%**

The high average DU is to be expected given that the project was restricted to pressurized systems and these were almost all micro-irrigation of some type. It is also not surprising to see the wide spread in low to high DUs. Drip irrigation systems are maintenance intensive and are especially susceptible to plugging by various means (particulates from poor filtration, iron bacteria from wells, algae from reservoirs or service water supplies). Many of the systems evaluated did not have any chemical amendments being added. Thirteen of the thirty-seven fields in the final statistical set were noted to have device problems.

- **Higher Distribution Uniformity for Pressure Compensating Devices**
  - Average DU for Pressure Compensating (PC) devices: **93.4%**
  - Average DU for non-PC devices: **85.5%**

A PC device is one where the flow rate through the device is essentially the same through a range of operating pressures. They generally have some sort of flexible orifice that will deform at different rates under pressure. In the early days of drip irrigation PC devices had high manufacturing variability, operated under fairly small pressure ranges, were significantly more expensive than non-PC devices and their reliability was in question due to the different materials used for the flexible part and unknown interactions with different chemicals in use for control of plugging or fertilization. Modern PC devices are much better, their reliability has been proven, and they operate over very wide pressure ranges (the Netafim Woodpecker has a recommended operating range of from 8 to 45 psi). It is noted that some of the difference in average DUs could be because of system age. That is, it is likely that many of the PC-equipped systems are newer designs (it is noted that the data set did not identify system age in most cases).

- **Higher Distribution Uniformity in Previously Evaluated Sites**
  - Average Improvement in DU from previous evaluation (13 sites): **11.4%**

Of this subset, the average initial DU was 79% and the DU measured during the project was 88%. It is assumed that the previous evaluation provided recommendations that management followed to improve DU. This statistic is important because it is a demonstration that the irrigation evaluation system can identify good and bad systems as well as pick up improvements in the same system.

- **Pump Efficiency in Line with Statewide Average**
  - Average OPE: **56.2%**

This is in line with current total APEP experience where average OPE for all turbine pumps is in the 53% range. An interesting finding during the project was that 30 of the evaluated fields were using "pressurized wells"- that is, wells that were designed
to both produce water and pressurize it. There is always a question as to how OPE changes during a year in a water well as the pumping water level fluctuates.

- **VFDs Could Improve Efficiency at Some Sites**
  Fields with VFDs in Place: **7 evaluations** (out of 37)
  Fields with no VFD in place, where VFD indicates high savings potential: **4 evaluations** (out of 37)

Variable Frequency Drives (VFD) provide the ability to slow the speed of an electric motor. Depending on the circumstances this will allow a single pumping system to be more efficient when there are several different operating conditions it must satisfy. The project findings are not an unexpected result. Pressurized irrigation systems are a way of efficiently irrigating uneven terrain. However, depending on the system layout the pumping system may have to direct water uphill for one set and then downhill for another. Designers can compensate in some cases but for others, either staged pumping systems or VFDs may be warranted.

- **Lower Distribution Uniformity in Sites with Pressure Uniformity Issues**
  Occurrence of Pressure Uniformity Issues (generally more than 20% variation in operating pressures throughout the system) - **24 evaluations** out of 37

Even though pressure uniformity problems can increase pump energy use and decrease distribution uniformity, PC devices may still allow good DU.

On sites with pressure uniformity issues:
- DU without PC device - **82.8%**
- DU with PC device - **91.2%**

Flow through a micro-irrigation device is governed by the equation:

**EQUATION 6. FLOW RATE THROUGH A MICRO-IRRIGATION DEVICE**

\[
Q = K \times H^{exp}
\]

Where:

- \(Q\) = flow rate through emission device (typically expressed as gallons/hour or liters/hour)
- \(K\) = numeric constant that depends on whether a metric or English system is in use
- \(H\) = operating pressure (typically expressed as pounds/square-inch or bars)
- \(exp\) = referred to as the "emitter exponent", this is a value that reflects the physics of the emission device operations - an exp of 1.0 implies a device where there is totally laminar flow through the device and flow is directly proportional to the operating pressure; an exp of 0.5 implies a device where there is turbulent flow through the device and flow is proportional to the square root of the operating pressure; an exp of 0 implies a perfectly pressure compensating device where the flow is constant throughout a given range of operating pressures.

Thus, it is seen that pressure differences within the piping system of a micro-irrigation system are more or less important depending on what type of device is used- laminar, turbulent, or pressure compensating. Currently the only two types of devices being used in the industry are essentially turbulent flow or pressure compensating. Thus, even with systems where there are pressure uniformity problems, the PC emitter is going to provide a good DU.
**Widespread Usage of Water Management Best Practices.**  
Flow meters in Place - 23 evaluations out of 37  
Soil Moisture Monitoring Used - 28 evaluations out of 37  
Water Budget/ETc estimates Used - 28 evaluations out of 37  
Experience Only Used - 8 evaluations out of 37  

These four statistics, which indicate high adoption of modern water management practices, probably mirror two factors at work: 1) the evaluations were performed with a relatively self-selecting group that likely have an above-average interest in water management, which includes irrigation scheduling and 2) the ability of management to utilize a micro-irrigation system to actually implement guidelines supplied by irrigation scheduling methods- thus the methods are seen to be cost-effective.

**DU Improvement May Not Provide Significant Water Savings.**  
Percent average potential AF savings estimated (all 37 fields) - 5.2%  

Note that overall average DU was about 88%. While 92-95% is consistently attainable, no major water savings could reasonably be expected in many cases, given irrigation scheduling methods in place along with a DU over 88%. This result is not surprising, as the evaluated sites were primarily variations of microirrigation systems.

**Average Estimated Energy Savings Potential of 18.4%**  
The three opportunities for kWh reduction are improve OPE, reduce TDH in the system, or reduce water applications. The pump tests showed an average 56% OPE, which is considered a little above average considering the number of wells tested. As noted above, there seem to be only minimal potential reductions in water applications. Thus, the majority of the kWh savings would be in reducing excess pressure in the system.

**Excess Pressue Issues Identified in a Significant Number of Systems**  
Occurrence of Excess Pressure in system - 14 evaluations out of 37  
At sites with excess pressure: percentage potential cost savings: 33.5%  
At sites without excess pressure: percentage potential cost savings: 19.1%  
Average potential energy cost savings across all 37 fields: 23.3% (includes effects of AF/Yr savings, OPE improvement, TDH reduction, and demand management)  

This means that some 38% of evaluated fields had excess pressure in the system. Reducing excess pressure is one of the three major opportunities for reducing energy use and costs. As was previously noted one should be cautious in projecting this number throughout PG&E service area but it is an indication that the subject needs more investigation. It is noted that the farmers in this study were somewhat self-selecting as to conservation awareness. If this group is showing this kind of experience then it may well be expected that the population at large is susceptible. The reader is reminded, even if the DU is good (and possibly even the overall water management), excess pressure will still result in excess energy use.

**Many Sites have Scheduled Operations Around Time of Use Rates**  
TOU Rate Schedule in place: 31 evaluations out of 37  
Average Utilization of TOU (0= 24 hour/day to 2= full off-peak) - .94 (mostly TOU was at the extremes as indicated below)  
24 hour/day operation indicated: 12 evaluations out of 37
Full off-peak operation indicated: 10 evaluations out of 37

Basically, it appears that farmers either utilize off-peak hours totally or disregard TOU altogether. The AQ has a section that attempts to identify why a grower would not use TOU, with the two main reasons being there is not enough capacity in the irrigation system to apply 24 hours of crop ETc in 18 hours or the water supply is such that it has to be delivered 24 hours per day and there is no internal storage capacity (i.e., an on-farm reservoir).

A Customer Satisfaction Survey was distributed (see Appendix 8) as well as an Evaluation Team Survey (see Appendix 9). Three of the Customer surveys and one of the Evaluation Team surveys have been returned as of this report submittal.

VI.5.ii SELECTED SITUATIONS

Several of the individual CEs will now be discussed so as to briefly describe the common situations encountered, with particular focus on the value to both the site management and the statewide energy efficiency programs

VI.5.ii.A WELL-MANAGED OPERATION (PREVIOUSLY EVALUATED)

This example is a 15-acre almond orchard with under-tree sprinklers that had been previously evaluated for DU in June, 2005. At that time, the DU was evaluated at 86%, which is considered barely fair for an under-tree system. The major problems noted were worn nozzles from sand and poor pressure uniformity. Standard bore sprinklers are a turbulent-flow device and thus, pressure uniformity is a primary concern.

The follow-up combined evaluation was conducted July 23, 2013. The DU was now evaluated at 94%, considered very good. It was noted there were some dissimilar devices in the field but the pressure uniformity was much improved with no excess pressure seen. The pump OPE was calculated at 61%, considered excellent.

An analysis of PG&E records along with the pump test results indicated that the orchard may be being under watered. No flow meter was in place and installation of one was a prime recommendation. PG&E billing also indicated almost complete off-peak pumping.

Thus, for the combined evaluation, no savings in energy or energy costs were estimated.

This was an instructive effort in that it showed that the ITRC irrigation system evaluation protocols could pick up improvements and that the evaluation can move management to make changes. While no savings were estimated, several important recommendations were still made including installation of a flow meter and some form of soil or plant moisture measurement to back-up estimates of crop water use.

However, in a real-life situation (as opposed to this pilot project) this would probably not be chosen to receive a subsidized CE. It was known to be previously evaluated. So, either management didn’t change anything, in which case it should not be re-evaluated, or they did and it is a matter of management wanting to establish the value of the improvements. Subsidized CEs should only be provided for fields that have not been previously evaluated, where there is some leveraging of results possible, and where there is some indication that there are improvements available.
VI.5.ii.b Poor Operation (Previously Evaluated)

This example is a 20 acre walnut orchard that had been previously evaluated in June, 2012. The system DU was measured at 77% then, which is considered poor for a micro-irrigation system. Problems noted were poor system pressure uniformity, leaks, mixed emitter types, and worn emitters. However, it is a rectangular field with an even grade and considered a straightforward field for evaluation.

The combined evaluation was conducted May 13, 2013 including pump tests on the well and system booster pumps. The DU was again measured as 77% with the same problems as found in 2012. The pumps were tested at 54% OPE for the well and 70% for the booster. However, the well flow was much higher than would be calculated using the nominal capacity of the installed devices and field area, with the explanation being the excess leakage seen. A major recommendation was to fix the leakage, improve the pressure uniformity and then reevaluate both the irrigation system and pumps.

In addition, an evaluation of PG&E billing, in conjunction with the pump tests indicated overwatering, even though management said they were using soil moisture sensors and water budget irrigation scheduling. It was noted in the report that poor DU could lead to excessive run times in order to ensure all parts of the field were being watered sufficiently.

Excess pressure was noted to be a potential problem but until the leakage was brought under control and pressure uniformity improved a definitive opinion couldn't be made.

Finally, the system was being run 24 hours/day when irrigating with average (total including demand) costs of about $0.30/kWh.

In summary the CE estimated that about 28% of kWh usage could be saved and costs reduced by 52%.

With such significant savings potential, why hasn't management responded to the earlier system evaluation? This field is being operated by a religious order. It may be that their decisions are impacted by factors beyond that of what a normal agriculturalists would face. Another factor may be that although it was estimated that total energy costs could be reduced by 52%, given the small size of the field, this only amounts to $3,180.

The experience with this field indicates:

- Where a field has been previously evaluated management should be asked if the recommended changes have been made. If no changes have been made this is definitely not a candidate for a subsidized CE.

- If management cannot indicate that there is some leverage involved, the small acreage of this field means it is not a candidate for a subsidized CE.

VI.5.ii.c Poor Choice of Site

This example is a 18-acre prune orchard with rotators. It is discussed here as an example of a site that shouldn't receive a subsidized CE. There are several reasons for this but foremost is that the field had been previously evaluated for DU at 92% in July, 2012 and there was no reason to believe anything had seriously deteriorated. Also, it is a rather
small field with farm management controlling minimal total acreage—thus, no information leverage would be expected.

It was stated that this field shouldn't have received a subsidized CE. However, the CE did provide some meaningful data to management:

- There was significant weed growth around the sprinklers, likely affecting some of the spray patterns.
- No provision for chemigation is in place, thus creating the potential for some type of plugging in the future.
- No flow meter in place.
- Significant on-peak energy usage.

Thus, while an organization such as PG&E could choose not to fund an actual CE (as would probably be the case here), there should be some education and demonstration program in place to make sure that farmers know of the CE and what it can tell them. Likewise there should be some effort to ensure that the capability to perform CE is in the field.

VI.5.ii.E Highly Involved Management

One situation involved a large farming organization that had recently taken over significant acreage with older irrigation systems that they recognized to be in disrepair. This was a highly motivated group that had the capability to perform micro-irrigation system evaluations in-house. They also indicated that they would definitely implement any profitable recommendation.

An initial evaluation on 83 acres of a 490 acre lemon orchard was performed March 8, 2013. The DU was estimated at 71%, very poor. Many problems were identified including:

- Plugging and wear of emission devices.
- Different emission devices in the orchard.
- Poor pressure uniformity with pressures in the field varying between 4.5 and 20.5 psi.
- System pressures not high enough to allow installed pressure regulators to work.
- Apparent severe under-watering of crop (analysis of PG&E billing and subjective reports from farm personnel as to fruit size).

There were several pumps supplying the system but the main reservoir pump was tested at 50%, considered just fair. Management was encouraged to investigate the potential of a variable frequency drive due to the very uneven terrain.

The savings analysis indicated that while total energy use would be predicted to increase by 18% due to additional irrigation needed to supply full crop water use, total energy costs could be reduced 32% by improving DU, reducing excess pressure losses, and adding capacity to allow for off-peak operations.
A follow-up meeting to this evaluation took place on April 11 where the results of the CE were discussed with management and various options for improvement identified. A summary of management’s plan was provided by CIT personnel that attended the meeting:

“At the conclusion of the discussion, [the customer] had developed the following plans, phased in over a several year period: all acreage would be irrigated at one time, always during off-peak; 15 psi regulators would be installed at each hose entrance; all acreage would be converted to pressure compensating, double line drip; the required pressure would be determined after the conversion, by checking hose inlet and hose end pressures; a VFD would be installed on the large pump to provide the flexibility; pump efficiency would then be re-evaluated and any potential cost savings from a retrofit would be taken into consideration.

Management acted on this CE and a second evaluation (for DU only) was performed September 6, 2013. DU was now estimated at 99% although there were still some pressure uniformity issues. The reason for the 99% was the installation of the in-line, pressure-compensating emitters in place of the old spray jets.

The savings analysis from the first evaluation indicated potentially in the range of $125/acre could be saved annually. Management invested a total of $61,700 for conversion of the irrigation system on 113 acres ($546/acre). They had not made any changes to the pumping plant at the time of the second evaluation so actual savings are unknown. However, the main reasoning behind the change was the expected improvement in crop yields and quality.

This experience demonstrated that if management is aware of the analysis tools available, have an interest in improving their operations, and have the resources to implement changes, the CE can be very effective. However, in these situations it is always a question as to “free-riders”. That is, if management is very aware and interested, then why should ratepayers subsidize the CE? This is a valid question and one for PG&E to evaluate. However, a key fact is that the CE has been developed and management is aware of its value. Thus, as has been noted previously, regardless of whether subsidized CEs are offered in the future, education and training should be made available to ensure that there is capacity in the field to perform CEs when requested- regardless of who pays for them.

VI.6 OBJECTIVE 6 - IDENTIFY MEASURE IMPLEMENTATION COSTS FOR THE VARIOUS RECOMMENDATIONS

Efforts were made to identify or estimate implementation costs for standard evaluation recommendations by both the evaluators themselves and by CIT staff. However, any standard costs for recommendations, especially on a “per field” or “per acre” basis, are confounded by a number of factors, outlined here:

1. **Scale of the system and change** - examples would be:
   a. Replacement or installation of new main and sub-main pricing will vary with the scale of the system. For example, the cost of switching from 8 inch pipe to 10 inch pipe will be much different than switching from 4 inch to 6 inch.
   b. If replacing emitter and/or hoses, does every emitter and hose have to be replaced or only a certain percentage?
c. Do all regulating valves need to be replaced (or new ones installed everywhere) or only at critical locations?

d. What size regulating valves?

2. **Crop layout** - the number of emission devices and length (and sizes) of hoses may be significantly different in a field depending on the crop. A walnut orchard will have different device and hose counts than an almond or pistachio orchard. Vineyards may be laid out with 5 - 8 foot spacings, both across and down the row, depending on type, cultural system in place, and vineyard age.

3. **Geographic location** - base costs for different components may be different depending on where the component has to be delivered or possibly as a result of more or less competition by suppliers in a certain area. Installation costs can vary depending on the availability of labor.

4. **Implementation strategy.** For some recommendations, multiple methods may be available to achieve the desired end-goal. For example, if implementing an irrigation scheduling system which basic type is used? Will soil or plant-based moisture sensing be used? Is an on-farm weather station required or is a CIMIS station close enough? If replacing all emitters in a field, are pressure compensating (more expensive) versus standard flow emitters to be used?

Further, some recommendations are constrained by either labor, water supply, or crop management issues. For example, a common recommendation to improve overlap uniformity in sprinkler systems is to irrigate only in calm conditions. The recommendations may be complicated by:

a. Irrigation scheduling may dictate that an irrigation proceed, regardless of weather conditions.

b. Irrigating at night is one solution but it may be impossible to find labor willing to work at night.

c. As regards irrigating only at night the water supply may be such that 24-hour per day operating is required.”

For a list of common energy efficiency recommendations, see Appendix 10.

The Work Paper for the Low Pressure Sprinkler Nozzle measure was submitted with the Interim Report as an example of the amount of averaging that would be needed for any one type of recommendation. The basic conclusion was that identification (with sufficient justification) of "standard costs", as understood in the context of CPUC energy efficiency programs, while not impossible depending on the actual measure, was difficult at best.

### VII. CONCLUSIONS

The Combined Evaluation is an audit tool that can evaluate the main opportunities (reduce amount of water pumped, reduce system pressure, improve pumping efficiency, and
address demand management) for reducing energy use and costs for irrigated agriculture. (It is noted though that some evaluations of water management practices could result in more water pumped as improved irrigation scheduling results in supplying full crop water use.) It does this by combining the results from a standard irrigation system evaluation, a standard pump test, and information gleaned from "additional questions to management".

The CE requires three entities, the group performing the irrigation system evaluation, the group performing the pump efficiency test, and the integrator. The integrator is the entity that analyzes the various data and develops the report to the customer. The skill set required of the integrator is diverse and neither common nor low-cost. Fulfilling the integrator's role is a key question for the future of combined evaluations.

Forty-five CE were performed during the project, using four different irrigation system evaluation groups. In terms of coordinating the actual in-field work it was left to the irrigation system team to arrange for the pump test. This was done since the evaluation team had the contacts that were interested in the system evaluation. Both the irrigation evaluation and the pump test reports were forwarded to CIT who acted as integrator. This procedure worked well throughout the project.

The only criteria for site selection was that it be a pressurized irrigation system. It was desirable, but not mandatory that there had been a previous irrigation system evaluation. There may or may not have to be more stringent site selection criteria in place in the future, depending on the funding source for CE. If the CE is to be funded through Public Purpose Program Charges there should be some assurance that:

- There is significant room for improvement.
- There is significant potential for using the results of the CE on additional acreage.
- The customer is willing to be an active participant in the process and is likely to make recommended changes.

It should be self-evident that a field that has been recently evaluated to be well-managed would not be a good candidate. Nor would a field that had been recently evaluated as poorly-managed but no changes had been made.

A main result of the project was development of the report format, including the summary section and a preferred format for the irrigation system evaluation.

The cost of this type of auditing was identified although it is not consistent depending on the evaluation teams and the individual situation. Some efforts involved fields with a straightforward situation- one field, one pump, three-year PG&E billing history, and full answers to the additional questions to management. In these cases the costs were in the $2,000 range. In other cases there were multiple fields supplied by the pump (possibly multiple pumps), no flow meter, and little information forthcoming from the additional questions. In these cases the costs could be in the $2,500 range as it took more effort on the part of the integrator.

There are several important market barriers to adoption of this tool:

- **Cost** - generally the cost of a CE would be considered reasonable when compared to the total cash flow of a modern farming operation. However, unless the customer understands the CE and what it can tell him/her and is truly interested in improving operations, this would be considered truly discretionary.
- **Customer Awareness** - customers may not be fully aware of the connection between energy and water, may not be aware of the irrigation evaluation system, and almost surely do not know anything about a CE.

- **Evaluation Team Awareness** - there are only three active irrigation evaluation teams in the PG&E service area. They, and the one commercial group used in this project, are now aware of the CE and its capabilities. However, other entities, including most pump testers used by APEP, are not aware.

- **Qualified Report Integrators** - as noted, the integrator is the crucial entity for developing a comprehensive CE report. The skill set needed is neither common nor low cost.

The following recommendations are made:

1. **Develop integrator function.** There needs to be an effort to establish how the integrator function will be fulfilled in the future (as well as the cost of integration) as none of the teams used in the project would be considered capable right now.

2. **Coordinate with evaluation teams.** The combined evaluations performed for this project were funded by the project. Total costs for the irrigation system evaluation and pump tests ranged from about $1500 to as much as $2000. The additional cost of report integration varied depending on the field data. However, there are several ways by which future funding could occur. These options need to be identified, both to PG&E and to the evaluation teams in the field. It may be that even if further efforts in this area are not funded, fully or in part, by CPUC/PG&E, individual evaluation teams may work to effect them in their area.

3. **Improve communications between evaluation teams while in progress.** There are checks on data developed separately by the pump tester and irrigation evaluation team that should be compared during the evaluation/test. This can point out potential errors.

4. **Improve communications with customer.** An essential component of the combined evaluation is the additional questions to management. These identify the irrigation scheduling methods in place, whether the customer actually knows how much water is being applied on the field, and will identify issues in demand management (e.g., is there a problem with the primary water supply, either in capacity or flexibility). If it cannot be established that the customer understands what is being attempted and will actively aid in developing the audit then the effort should not be made.

5. **Establish clear eligibility guidelines.** Depending on how the combined evaluation is funded in the future there may need to be a set of guidelines in place to identify which fields are eligible. The key is whether there is a reasonable chance of developing a full and valid report. The eligibility criteria may be flexible depending on the amount of funding. If funding is limited then one criteria may be that the field has only one pump supplying water to it and that pump is dedicated to that field- this will ensure that the amount of currently applied water can be identified.

6. **Estimate aggregate efficiency potential from pressure reduction.** A significant percentage of the evaluated fields had excess pressure and reducing pressure in the system is one of the three main opportunities for reducing energy use. Additionally, new micro-irrigation devices can operate at substantially lower pressures than earlier equipment. There should be some effort to identify how many older systems, or badly
7. **Critical need for training and marketing support.** Whether or not PG&E decides to be actively involved with future field activities, serious consideration should be given to funding training seminars and a targeted marketing campaign to make sure entities in the business of providing, interpreting, or advising for irrigation system evaluations and pump efficiency tests are aware of this new audit tool.

8. **Expand approach to flood irrigated fields.** The current protocols were developed for pressurized systems only. Although the AQ and pump efficiency test would be similar for flood irrigated fields, there needs to be an analysis of actually what the irrigation evaluation of a flood irrigation event does and how representative it may be of seasonal performance.
APPENDICES
APPENDIX 1 - EXAMPLE OF COVER LETTER

Combined Pump Test/Irrigation System Evaluation

FARM: Example Farming
FIELD: Example Field
DATE OF EVALUATION: July 15, 2013
PUMP EVALUATOR: John Doe
IRRIGATION SYSTEM EVALUATOR: John White
FOR CENTER FOR IRRIGATION TECHNOLOGY: Peter Canessa, 805 709-4180 / 800 845-6038

WHY THIS REPORT HAS BEEN PREPARED FOR YOU - This is the report of a combined evaluation of an irrigation system and the pumping system supplying water. The evaluation included pump efficiency tests, measurement of the irrigation system's global distribution uniformity, examination of PG&E billing history, and interviews with farm personnel. It was performed as part of a project funded by the Pacific Gas & Electric Company under the auspices of the California Public Utilities Commission. The intent of the project is to develop new methods of identifying and communicating opportunities for water and energy savings in irrigated agriculture.

The key concept of the project is to perform both pump efficiency tests and the irrigation system evaluation at the same time. There are three opportunities to reduce energy use for irrigation: 1) reduce the amount of water pumped (acre-feet per year applied), 2) improve the overall pumping efficiency of the pumping plants, and 3) reduce total system pressure (also referred to as "total dynamic head"). It is felt that combining the two types of evaluations will allow all three opportunities to be addressed effectively.

In addition, total electrical energy costs may be further reduced by examining opportunities for demand management, mainly by operating pumps in off-peak hours whenever possible. Only by looking at both the pumping capacity, irrigation system capacity, and primary water supply at the same time can this opportunity be fully explored.

Reducing applied water obviously saves the energy that would be needed to pump that water through your irrigation system. However, depending on the situation it may also save the energy needed to deliver that water to your field head- so-called "embedded energy". Improving the water use efficiency will also often result in improved yields, quality, and reduced fertilizer use (and subsequent impacts on groundwater quality).

The project is implemented by the Center for Irrigation Technology on the campus of California State University, Fresno. The Center acts as agent for the California State University Fresno, Foundation. Comments and complaints should be directed to the Center for Irrigation Technology. If any complaints cannot be resolved by the Center they will be forwarded to Pacific Gas & Electric Company.
SUMMARY OF PUMP EFFICIENCY TEST(s) AND IRRIGATION SYSTEM EVALUATION

Evaluations of July 15, 2013

Farm:
Example Farming, Inc.
123 Example Road
Example, CA 93444

Field:
South Forty
40 acres in total, 20 acres evaluated
8 year old Almonds on 20 x 20 spacing
undulating topography, generally downhill from pump

Water Supply:
150 HP pressurized well with sand media filters

Irrigation:
8 year old rotator on single lines, one line per tree row
Nelson R2000 with blue nozzles - nominal .8 gpm at 30 psi
1 rotator per tree
2 sets of 20 acres each per irrigation

Contacts:
Example Farming - John Smith, Foreman, (805) 999-0000
Irrigation System Evaluation - John Doe, Example Resource Conservation District, (805) 999-0001
Pump Tester - John White, White Pump Testing Services, (805) 999-0002
Report Preparation - John Johnson, Example Ag Consulting Services, (805) 999-0003

II. IRRIGATION SYSTEM EVALUATION (see Attachment 1 for full report)

HARDWARE
Distribution Uniformity evaluated as 79%, considered poor.

ISSUES
1. There were some mixed nozzles and sprinkler types observed. RECOMMENDATION - whenever changing out nozzles or sprinklers for wear or plugging ensure that the same type and size are used throughout the orchard.

2. There was no filter type noted on the evaluation data sheet. This might be a mistake in data entry. RECOMMENDATION - all micro systems should have some form of filtration in place.

3. Excessive plugging was noted, reported to be primarily from iron bacteria. RECOMMENDATION - implement chemical injection immediately. Refer to the attached UC Cooperative Extension advisory.

4. No flow meter in place. RECOMMENDATION - Install a flow meter. They can act as objective back-up to irrigation scheduling practices and also serve as an early warning system for system problems.

MANAGEMENT
Water management of a crop depends on many factors including variety, canopy management, effect of water stress on yields and quality, soil, and water quality. It is difficult to make blanket statements as to correct irrigation
scheduling (the frequency and duration of irrigation events). However, irrigation scheduling is generally intended to replace crop evapotranspiration (regardless of overall crop management) while maintaining root zone soil moisture levels so as to prevent stress. Note also that one of the advantages of micro-irrigation systems is the ability to maintain optimum soil moisture levels, assuming that there is sufficient flexibility in the primary water supply.

ISSUES

1. Additional questions for management (see Attachment 3) indicate that irrigation scheduling is based on soil moisture monitoring. However, PG&E billing, in conjunction with the pump test on August 14 indicates in the range of 54.6 Acre-feet pumped through the end of July, about 1.8 Acre-feet/Acre over the reported 30 acre orchard. This is a third leaf orchard with a reported 40% canopy cover. Crop water use statistics supplied with the evaluation report show about 2 AF/AC net ETc for a mature crop through July. Assuming in the range of 60% of mature ETc for this orchard (1.2 AF/Ac) it appears that there is some over-irrigation taking place. RECOMMENDATION - management should ensure that soil moisture monitors are installed in representative areas of the orchard, read regularly, and most importantly, can be used to identify any deep percolation that may be taking place.

2. No flow meter in place. RECOMMENDATION - Install a flow meter. They can act as objective back-up to irrigation scheduling practices and also serve as an early warning system for system problems.

III. PUMPING EFFICIENCY (see Attachment 2 for the full report)
The pump test is a "snapshot" of pumping plant performance at the time of the test. The test should be performed with the pumping plant operating at its most normal condition. If a water well it is especially important to realize that pumping efficiency can change seasonally or systemically according to the reaction of the aquifer to irrigation withdrawals. Refer to the Pump Test Technical Advisory that is part of the Pump Test report.

The table below is from CPUC pump efficiency guidelines and is used to characterize the overall pumping efficiency of the pumps tested. The OPE of water wells can fluctuate depending on the pumping water level, which can change throughout an irrigation season as other pumpers draw on a shared aquifer.

<table>
<thead>
<tr>
<th>Motor HP</th>
<th>Low</th>
<th>Fair</th>
<th>Good</th>
<th>Excellent</th>
<th>Booster</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 – 5</td>
<td>41.9 or less</td>
<td>42 – 49.9</td>
<td>50 – 54.9</td>
<td>55 or above</td>
<td>55</td>
</tr>
<tr>
<td>7.5 – 10</td>
<td>44.9 or less</td>
<td>45 – 52.9</td>
<td>53 – 57.9</td>
<td>58 or above</td>
<td>58/60</td>
</tr>
<tr>
<td>15 – 30</td>
<td>47.9 or less</td>
<td>48 – 55.9</td>
<td>56 – 60.9</td>
<td>61 or above</td>
<td>60/65</td>
</tr>
<tr>
<td>40 – 60</td>
<td>52.9 or less</td>
<td>53 – 59.9</td>
<td>60 – 64.9</td>
<td>65 or above</td>
<td>65/70</td>
</tr>
<tr>
<td>75 – up</td>
<td>55.9 or less</td>
<td>56 – 62.9</td>
<td>63 – 68.9</td>
<td>69 or above</td>
<td>70 /72</td>
</tr>
</tbody>
</table>

*Submersible Well Less an additional 3%

Pump - Well - Meter 1009999990 - 50 Horsepower
Current OPE = 45% - considered low for this horsepower range
Current Flow = 691 gallons per minute
Current Total Dynamic Head = 166 feet
Current Discharge Pressure = 32 psi
Current kWh/AF = 374
Current $/AF = $59.86 @ $.16/kWh

ISSUES
1. The OPE measured is low. RECOMMENDATION - Management should consider the profitability of a pump retrofit in consultation with a pump expert. Refer to the Pumping Cost Analysis in the full Pump Test Report (see Attachment 2) for an estimate of potential savings. The Advanced Pumping Efficiency Program offered by PG&E may be able to provide an incentive. Call the program at 800 845-6038 or go on-line to www.pumpefficiency.org for more information.

2. There is no flow meter installed. RECOMMENDATION - Management should have some objective way to track the actual amount of water being applied to all fields. A flow meter, in conjunction with pressure readings can be an early warning of irrigation system problems also.

3. The meter is on a HAG1A rate schedule. These are to transition to AG4A.

4. There were 30 acres evaluated with 320 square feet per tree and one rotator per tree flowing an average 10.9 gallons-per-hour. This equates to 730 gpm and the pump test shows 691 gpm.

IV. SYSTEM PRESSURE ISSUES
Pressure distribution in the entire orchard is poor with the problem identified as excessive plugging by algae. Pump discharge pressure is seen as 32 psi with 14-24 psi in the hoses (regulator valves are on each hose inlet). However, there must be some provision for pressure loss through the filters and pressurized wells generally have some provision for a drop in water table, either seasonally or systemically. Thus, there is no excess pressure loss seen.

V. ELECTRICITY PEAK DEMAND ISSUES (Indicated by PG&E billing)
Management indicates it attempts to stay off-peak whenever possible and PG&E billing history shows very little on-peak usage since May, 2011.

Note that you can go on-line to WWW.PGE.COM and access this information yourself. Do this by:

1. go to WWW.PGE.COM and click "For my Business" seen at the top of the page

2. click "Analyze my Usage" in the "How Do I" section of the My Business home page

3. click "Business Tools" under the sub-menu "Assess Your Energy Usage" at the left of this page

4. Follow instructions to create an account

There are many other tools for analysis of your energy use on their site.

RECOMMENDATIONS
1. Management should remain aware of any PG&E programs regarding demand management.

VI. SUMMARY OF POTENTIAL ENERGY AND WATER SAVINGS
The table below is an indication of savings with near-ideal conditions. Since this is a third leaf orchard and thus, still growing, it is done on the basis of "per acre-foot pumped". Energy savings are from a improved DU and pump OPE.
<table>
<thead>
<tr>
<th>PG&amp;E’s Emerging Technologies Program</th>
<th>ET 12PGE1401</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Per Acre-Feet Pumped</strong></td>
<td>1.00 0.88 0.12</td>
</tr>
<tr>
<td><strong>OPE (%)</strong></td>
<td>45 62</td>
</tr>
<tr>
<td><strong>Total Dynamic Head (feet)</strong></td>
<td>166 169</td>
</tr>
<tr>
<td><strong>kWh/Acre-foot</strong></td>
<td>378 279 99</td>
</tr>
<tr>
<td><strong>$/kWh</strong></td>
<td>$0.160 $0.160</td>
</tr>
<tr>
<td><strong>TOTAL kWh USAGE</strong></td>
<td>378 246 132</td>
</tr>
<tr>
<td><strong>ENERGY COST</strong></td>
<td>$60 $39 $21</td>
</tr>
</tbody>
</table>
APPENDIX 3 - PREFERRED REPORT FORMAT FOR IRRIGATION EVALUATIONS DEVELOPED BY CIT

REPORT OF IRRIGATION SYSTEM EVALUATION for
Example Farming, Inc.
123 Example Road
Example, CA 93444

South Forty Almonds

Evaluated July 15, 2013
by

John Doe
Example Resource Conservation District
456 Example Road
Example, CA 93444
(805) 999-0001 / j.doe@examplercd.com
PG&E’s Emerging Technologies Program


Farm:
Example Farming, Inc.
123 Example Road
Example, CA 93444
Contact: John Smith, Foreman, (805) 999-0000

Field:
South Forty
40 acres in total, 20 acres evaluated
8 year old Almonds on 20 x 20 spacing
Graded topography, generally downhill from pump

Water Supply:
150 HP pressurized well with sand media filters

Irrigation:
8 year old rotator system - single line down tree row
Nelson R2000 with blue nozzles - nominal .8 gpm at 30 psi
1 rotator per tree
2 sets of 20 acres each per irrigation

This is the report of an evaluation of the irrigation system identified above. It contains a numeric evaluation of the distribution uniformity, a narrative describing issues that are important determinates of that uniformity, various maps that help explain the results, identification of the soils and their important characteristics, and the raw data inputs.

There are two important performance metrics for irrigation systems, distribution uniformity (DU) and irrigation efficiency (IE). DU is a measure of how evenly water is applied throughout a field. IE is a measure of how much of the applied water is beneficially used - with the main beneficial use being crop water use. A full discussion of these parameters is attached but the primary relationship between the two is that there must be good DU before there can be good IE, assuming that the entire field is to be watered. Thus, this evaluation focuses on DU.

100% DU is theoretically possible but is impossible in practice, even with micro-irrigation (manufacturing variances in the different devices used, in themselves, will reduce DU to come extent). However, DU’s over 90% are entirely possible with well-designed and maintained systems.

The DU reported herein was evaluated using a set of protocols and computer programming developed by the Irrigation Training and Research Center at California Polytechnic State University. These protocols have been in use in California since the mid-1980's and are largely based on methods developed over decades by the USDA Natural Resources Conservation Service (formally the Soil Conservation Service) and universities.

Contents of this report:
I. Results of evaluation - numeric evaluation of DU along with a narrative as to important issues
2. Pressure map of evaluated field
3. Overall map of farm showing proximity of field and water source(s)
4. Topographic map (optional)
5. Soils map and discussion of soil characteristics important to irrigation
6. Raw data inputs

Section 1 - Summary of DU Evaluation Results
- Overall Distribution Uniformity - 88%, considered fair
- Maximum, average, and minimum pressures measured - 39 psi, 35 psi, 32 psi
- Maximum, average, and minimum device flows found - .8 gpm, .74 gpm, .7 gpm
ISSUES
1. Pressure and Pressure Uniformity - The Nelson R2000 is rated from 30-60 psi. The system is being run at approximately 35 psi but pressure uniformity is only fair, even with pressure regulators in place at sub-main inlets. However, a device with flow-control nozzles is being used and thus, pressure uniformity is not as critical as it normally would be.

2. Wear or Plugging - the main problem was plugging within the system from algae. Hose inlets are equipped with screens and most examined had some level of algae present. When flushing hoses, large amounts of algae were seen. It is possible that some of the pressure uniformity problem will be alleviated when this is fixed.

3. Filtration, chemigation, flushing - filtration is by sand media filters but management reports infrequent chemical injections with no field checks as to sufficient dispersal of the chemicals throughout the system. The injection apparatus is downstream of the filters, which is not recommended. Hose flushing is reported to be only monthly.

4. Flow meter or other measurement of applied water - there is no flow meter in place.

5. Wetted rootzone - this emission device wets approximately 60% of the available surface and is felt reasonable for this crop and design.

RECOMMENDATIONS & TIPS
[Here would standard recommendations from ITRC system or developed over time by the evaluation teams, possibly standard Tips that are included in the ITRC system]

Section 2 - Following is a pressure map of the field as evaluated [ideally this is a Google Maps-type picture with main piping and measured pressures overlaid as per example]
Pressure and Flow Test Locations

- Flow #1
- Flow #2
- Flow #3
- Flow #4

Legend:
- Pump
- Main Line
- Sprinkler lines
- Flow Test
- Pressure Test
Section 3 - Following is a schematic map of the adjacent farming operations showing proximity of field and water supplies. It is noted that the supply for this field is adjacent to the field and this pump supplies water only to this field.

Legend:
- ▲ H2O_filtration_Station_21
- ⬤ Reservoir_21
- ✤ Section Gate Valves
- □ Reducators
- ⬤ SubMain
- ⬤ MainLine

Test Set Blocks:
1-10, PN 7.68 ac
1-11, PN 7.67 ac
2-9, CH 11.27 ac
2-10, PN 11.23 ac
2-11, PN 9.61 ac

Total Set Acres: 47.46 ac
Section 4 - this field is graded smooth with minimal fall. No topographic map is included in this report.

Section 5 - Figure __ is a soils map of the orchard showing two major complexes, XXX and YYY.

AcA/AvA -

KoA/KpA -

The important characteristics for these soils as regards irrigation are:
1) composition - [identify sand/silt/clay %]
2) rootzone restrictions - [identify rootzone depth, presence of hard pans, etc.]
3) intake rates - [potential for runoff problems - note also if irrigation system design is mismatched to intake rates]
4) available water holding capacity - [not normally an issue with high frequency irrigation systems]
5) drainage - [identify restricted internal drainage, high runoff potential]
6) salinity, sodic, or sodic-saline problems -
   i) native (unbalanced salts)
   ii) potential due to irrigation water applications (high salt or sodium contents)
7) erosion hazard - [highly sloped fields, silty soils with no cover crop, high wind areas, etc.]
APPENDIX 4 - CURRENT ITRC DATA INPUT/REPORTING SPREADSHEET FOR Drip Irrigation

Following are the different pages of the current ITRC data input section for the micro-irrigation evaluation section. You will note that they become mis-labeled as to Page number at Page 5.

| FIELD IDENTIFICATION |  |  |  |
|----------------------|------------------|------------------|
| 1                    | Farm Name        | Hobson Vineyard  |
| 2                    | Field identification | 3C & 3D         |
| 3                    | Field Location   | King City        |
| 4                    | Contact Name     | Doug Bank        |
| 5                    | Address Line 1   | 40410 Amaya South Rd. |
| 6                    | Address Line 2   |                   |
| 7                    | Phone            | (831) 678-4845   |

| JOB IDENTIFICATION |  |  |
|--------------------|------------------|
| 8                  | Evaluator        | Kevin Peterson   |
| 9                  | Date             | 4/28/2013        |

| SYSTEM DESCRIPTION |  |  |
|--------------------|------------------|
| 10                 | Age of system    | 10 years         |
| 11                 | Is there a water penetration problem? | No |
| 12                 | Is there undulating (rolling, up-and-down)topography? | No |
| 13                 | Percentage of applied water that runs off the field | 0 % |
| 14                 | Number of modeled emitter designs used in the system | 1 |
| 15                 | Type of water source | Multi |

| Emitter INFORMATION |  |  |
|---------------------|------------------|
| 16                  | Manufacturer     |               |
| 17                  | Model            |               |
| 18                  | Nominal flow rate (gph) | 0.5 |
| 19                  | Units of nominal flow rate | gpm |
| 20                  | Emitter pack type |               |

| Filtration |  |  |
|------------|------------------|
| 21         | Automatic backwash on the primary filter? | Yes |
| 22         | Type of filter (select all that apply):  |
| 23         | Tubular screen? | Yes |
| 24         | Downflow screen? | No |
| 25         | Media filter? | No |
| 26         | Sand (centrifugal) separation? | No |
| 27         | Desludger? | No |
|            | "Vacuum cleaned" tubular screens? | No |

| CHEMICAL INJECTION SYSTEM |  |  |
|---------------------------|------------------|
| 28                       | Location of fertigation injector with respect to filter |               |
| 29                       | Location of pepticide injector with respect to filter |               |
| 30                       | Location of acid injector with respect to filter |               |
| 31                       | Location of gypsum injector with respect to filter |               |
| 32                       | Frequency of fertilizer or polymer injection |               |
| 33                       | Frequency of acid injection |               |
## PUMP STATION MEASUREMENTS

<table>
<thead>
<tr>
<th>Question</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do any of the injection system pressure throttling valves on the mainline to create a pressure differential?</td>
<td>No</td>
</tr>
<tr>
<td>Frequency of hose-tape flushing</td>
<td>Manual</td>
</tr>
<tr>
<td>Pump discharge pressure</td>
<td>92 psi</td>
</tr>
<tr>
<td>Pressure downstream of filters and control valves</td>
<td>68 psi</td>
</tr>
<tr>
<td>Total lift loss</td>
<td>6 psi</td>
</tr>
<tr>
<td>Total pump control valve loss</td>
<td>0 psi</td>
</tr>
<tr>
<td>Loss from throttled manual valves</td>
<td>20 psi</td>
</tr>
</tbody>
</table>

## VALVING

<table>
<thead>
<tr>
<th>Question</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of automatic pressure control valves near the filter and pump</td>
<td>1</td>
</tr>
<tr>
<td>Is there a partially closed (i.e., &quot;choked&quot;) manually operated valve</td>
<td>No</td>
</tr>
<tr>
<td>Does the head of each manifolds have an automatic pressure regulator?</td>
<td>No</td>
</tr>
<tr>
<td>Does the head of each hose have an automatic pressure regulator?</td>
<td>Yes</td>
</tr>
<tr>
<td>Is there a flow meter?</td>
<td>No</td>
</tr>
</tbody>
</table>

## FIELD PRESSURE MEASUREMENTS

**Location #1:** Submain or regulated manifold just upstream the pump

<table>
<thead>
<tr>
<th>Closest hose to the inlet of the submain (or regulated manifold)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downstream end of &quot;uplift&quot; side pressure</td>
<td>13 psi</td>
</tr>
<tr>
<td>Middle of &quot;uplift&quot; side pressure</td>
<td>14 psi</td>
</tr>
<tr>
<td>Hose inlet pressure</td>
<td>16 psi</td>
</tr>
<tr>
<td>Middle of &quot;downlift&quot; side pressure</td>
<td>17 psi</td>
</tr>
<tr>
<td>Downstream end of &quot;downlift&quot; side pressure</td>
<td>13 psi</td>
</tr>
<tr>
<td>Most distant hose from the inlet of the submain (or regulated manifold)</td>
<td>12 psi</td>
</tr>
<tr>
<td>Downstream end of &quot;uplift&quot; side pressure</td>
<td>13 psi</td>
</tr>
<tr>
<td>Middle of &quot;uplift&quot; side pressure</td>
<td>14 psi</td>
</tr>
<tr>
<td>Hose inlet pressure</td>
<td>15 psi</td>
</tr>
<tr>
<td>Middle of &quot;downlift&quot; side pressure</td>
<td>15 psi</td>
</tr>
<tr>
<td>Downstream end of &quot;downlift&quot; side pressure</td>
<td>10 psi</td>
</tr>
</tbody>
</table>

**Location #2:** Submain or regulated manifold most distant from the pump (or where the pressure is lowest)

<table>
<thead>
<tr>
<th>Closest hose to the inlet of the submain (or regulated manifold)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downstream end of &quot;uplift&quot; side pressure</td>
<td>7 psi</td>
</tr>
<tr>
<td>Middle of &quot;uplift&quot; side pressure</td>
<td>8 psi</td>
</tr>
<tr>
<td>Hose inlet pressure</td>
<td>11 psi</td>
</tr>
<tr>
<td>Middle of &quot;downlift&quot; side pressure</td>
<td>12 psi</td>
</tr>
<tr>
<td>Downstream end of &quot;downlift&quot; side pressure</td>
<td>13 psi</td>
</tr>
<tr>
<td>Location #3: Subman or regulated manifold at an intermediate distance from the pump.</td>
<td></td>
</tr>
<tr>
<td>-------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Closest gauge to the inlet of the subman (or regulated manifold):</td>
<td></td>
</tr>
<tr>
<td>Closest gauge to the inlet of the subman (or regulated manifold):</td>
<td></td>
</tr>
<tr>
<td>Downstream end of &quot;Uphill&quot; side pressure: 12 psi</td>
<td></td>
</tr>
<tr>
<td>Middle of &quot;Uphill&quot; side pressure: 13 psi</td>
<td></td>
</tr>
<tr>
<td>Hose inlet pressure: 14 psi</td>
<td></td>
</tr>
<tr>
<td>Middle of &quot;Downhill&quot; side pressure: 15 psi</td>
<td></td>
</tr>
<tr>
<td>Downstream end of &quot;Downhill&quot; side pressure: 16 psi</td>
<td></td>
</tr>
<tr>
<td>Most distant gauge from the inlet of the subman (or regulated manifold):</td>
<td></td>
</tr>
<tr>
<td>Downstream end of &quot;Uphill&quot; side pressure: 11 psi</td>
<td></td>
</tr>
<tr>
<td>Middle of &quot;Uphill&quot; side pressure: 12 psi</td>
<td></td>
</tr>
<tr>
<td>Hose inlet pressure: 13 psi</td>
<td></td>
</tr>
<tr>
<td>Middle of &quot;Downhill&quot; side pressure: 13 psi</td>
<td></td>
</tr>
<tr>
<td>Downstream end of &quot;Downhill&quot; side pressure: 14 psi</td>
<td></td>
</tr>
<tr>
<td>Location #4: Intermediate subman or regulated manifold close to the pump.</td>
<td></td>
</tr>
<tr>
<td>Closest gauge to the inlet of the subman (or regulated manifold):</td>
<td></td>
</tr>
<tr>
<td>Closest gauge to the inlet of the subman (or regulated manifold):</td>
<td></td>
</tr>
<tr>
<td>Downstream end of &quot;Uphill&quot; side pressure: 12 psi</td>
<td></td>
</tr>
<tr>
<td>Middle of &quot;Uphill&quot; side pressure: 13 psi</td>
<td></td>
</tr>
<tr>
<td>Hose inlet pressure: 13 psi</td>
<td></td>
</tr>
<tr>
<td>Middle of &quot;Downhill&quot; side pressure: 13 psi</td>
<td></td>
</tr>
<tr>
<td>Downstream end of &quot;Downhill&quot; side pressure: 14 psi</td>
<td></td>
</tr>
<tr>
<td>Most distant gauge from the inlet of the subman (or regulated manifold):</td>
<td></td>
</tr>
<tr>
<td>Downstream end of &quot;Uphill&quot; side pressure: 13 psi</td>
<td></td>
</tr>
<tr>
<td>Middle of &quot;Uphill&quot; side pressure: 14 psi</td>
<td></td>
</tr>
<tr>
<td>Hose inlet pressure: 14 psi</td>
<td></td>
</tr>
<tr>
<td>Middle of &quot;Downhill&quot; side pressure: 15 psi</td>
<td></td>
</tr>
<tr>
<td>Downstream end of &quot;Downhill&quot; side pressure: 16 psi</td>
<td></td>
</tr>
<tr>
<td>Location #5: Intermediate subman or regulated manifold distant from the pump.</td>
<td></td>
</tr>
<tr>
<td>Closest gauge to the inlet of the subman (or regulated manifold):</td>
<td></td>
</tr>
<tr>
<td>Closest gauge to the inlet of the subman (or regulated manifold):</td>
<td></td>
</tr>
<tr>
<td>Downstream end of &quot;Uphill&quot; side pressure: 10 psi</td>
<td></td>
</tr>
<tr>
<td>Middle of &quot;Uphill&quot; side pressure: 11 psi</td>
<td></td>
</tr>
<tr>
<td>Hose inlet pressure: 12 psi</td>
<td></td>
</tr>
<tr>
<td>Middle of &quot;Downhill&quot; side pressure: 13 psi</td>
<td></td>
</tr>
<tr>
<td>Downstream end of &quot;Downhill&quot; side pressure: 13 psi</td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>Measurement Description</td>
</tr>
<tr>
<td>----------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>#5</td>
<td>Most distant from the inlet of the submain (or regulated manifold)</td>
</tr>
<tr>
<td>#1</td>
<td>Downstream end of &quot;uphill&quot; side pressure</td>
</tr>
<tr>
<td>#2</td>
<td>Middle of &quot;uphill&quot; side pressure</td>
</tr>
<tr>
<td>#3</td>
<td>Horse inlet pressure</td>
</tr>
<tr>
<td>#4</td>
<td>Middle of &quot;downhill&quot; side pressure</td>
</tr>
<tr>
<td>#5</td>
<td>Downstream end of &quot;downhill&quot; side pressure</td>
</tr>
</tbody>
</table>

Location #6: Immediate to submain or regulated manifold:

<table>
<thead>
<tr>
<th>Location</th>
<th>Measurement Description</th>
<th>Pressure (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#6</td>
<td>Most distant from the inlet of the submain (or regulated manifold)</td>
<td>12</td>
</tr>
<tr>
<td>#7</td>
<td>Downstream end of &quot;uphill&quot; side pressure</td>
<td>12</td>
</tr>
<tr>
<td>#8</td>
<td>Middle of &quot;uphill&quot; side pressure</td>
<td>13</td>
</tr>
<tr>
<td>#9</td>
<td>Horse inlet pressure</td>
<td>13</td>
</tr>
<tr>
<td>#10</td>
<td>Middle of &quot;downhill&quot; side pressure</td>
<td>13</td>
</tr>
<tr>
<td>#11</td>
<td>Downstream end of &quot;downhill&quot; side pressure</td>
<td>14</td>
</tr>
</tbody>
</table>

Pressure loss across hose entrance covers all heads of hoses:

<table>
<thead>
<tr>
<th>Hose</th>
<th>Pressure (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
</tr>
</tbody>
</table>

EMITTER FLOW MEASUREMENTS

All pressure measurements are in MSL3/PG&E.

| Number of emitters that supply water to each plant | 2 |

For all emitter types, flow must be measured at locations A through H throughout the field.

Location A - The middle of a hose midway between the inlet and the downstream end that is a "clean" area of the field. Typically this is hydraulically close to the pump. Flow measurements must be taken at 15 emitters, all at the same pressure.

Location B - The middle of a hose midway between the inlet and the downstream end that is near the middle of the field. Flow measurements must be taken at 10 emitters, all at the same pressure.

Location C - The tail end of a hose that is at the tail end of the field. Flow measurements must be taken at 20 emitters, all at the same pressure.
Location A

There are differences in how many tests of emitter flow are to be measured in Location A.
Answer the following questions to determine which tests are performed at Location A.

You must answer ONE of the following questions with a "YES". There can only be one "YES" answer.

**Question 1:** Do you know that the discharge coefficient of the emitter is about 0.5 in a non-pressure compensating microspray, non-pressure compensating microsprinkler, clean cushion path emitter, and mist tape?

**Question 2:** Since you answered "no" to Question 1, please go on to the next question. Is the discharge coefficient known to equal 0.5?

**Question 3:** Since you answered "no" to Question 2, please go on to the next question. Does the emitter or microspray or microsprinkler have a pressure compensating (PC) feature?

*Since you answered "yes" to Question 3, for Location A do Tests 1-5.

YOU MAY CONTINUE

Location A: The middle of a hose between the inlet and the downstream end) that is a "clean area of the hose"?

**Notes:**
- All emitters must be disconnected before testing.
- Select hose with the relative highest pressure, or nearest pressure to the electric meter base.

**Location A, Test 1:**

Test is required for emitter types.

<table>
<thead>
<tr>
<th>Collection time:</th>
<th>2 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hose pressure:</td>
<td>19 psi</td>
</tr>
</tbody>
</table>

**Collected volume:**

<table>
<thead>
<tr>
<th>Emitter</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>60 mL</td>
</tr>
<tr>
<td>#2</td>
<td>75 mL</td>
</tr>
<tr>
<td>#3</td>
<td>72 mL</td>
</tr>
<tr>
<td>#4</td>
<td>70 mL</td>
</tr>
<tr>
<td>#5</td>
<td>74 mL</td>
</tr>
<tr>
<td>#6</td>
<td>75 mL</td>
</tr>
<tr>
<td>#7</td>
<td>69 mL</td>
</tr>
<tr>
<td>#8</td>
<td>77 mL</td>
</tr>
<tr>
<td>#9</td>
<td>74 mL</td>
</tr>
<tr>
<td>#10</td>
<td>65 mL</td>
</tr>
<tr>
<td>#11</td>
<td>75 mL</td>
</tr>
<tr>
<td>#12</td>
<td>62 mL</td>
</tr>
<tr>
<td>#13</td>
<td>69 mL</td>
</tr>
<tr>
<td>#14</td>
<td>75 mL</td>
</tr>
<tr>
<td>#15</td>
<td>74 mL</td>
</tr>
<tr>
<td>#16</td>
<td>75 mL</td>
</tr>
</tbody>
</table>
### Location A, Test 2:

Test 2 is required for all emitter types. **Sample** those for which you know the best fit at a pressure 1.5 times the lowest measured in the field.

<table>
<thead>
<tr>
<th>Collection time</th>
<th>psi</th>
<th>mL</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>6</td>
<td>1138</td>
</tr>
<tr>
<td>Number of emitters</td>
<td>16</td>
<td></td>
</tr>
</tbody>
</table>

### Location A, Test 3:

PC emitters only Low intermediate pressure. Same emitters as Test 1.

<table>
<thead>
<tr>
<th>Collection time</th>
<th>psi</th>
<th>mL</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>7.5</td>
<td>1076</td>
</tr>
<tr>
<td>Number of emitters</td>
<td>16</td>
<td></td>
</tr>
</tbody>
</table>

### Location A, Test 4:

PC emitters only Intermediate pressure. Same emitters as Test 1.

<table>
<thead>
<tr>
<th>Collection time</th>
<th>psi</th>
<th>mL</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>13</td>
<td>1136</td>
</tr>
<tr>
<td>Number of emitters</td>
<td>16</td>
<td></td>
</tr>
</tbody>
</table>

### Location A, Test 5:

PC emitters only High intermediate pressure. Same emitters as Test 1.

<table>
<thead>
<tr>
<th>Collection time</th>
<th>psi</th>
<th>mL</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>19</td>
<td>1136</td>
</tr>
<tr>
<td>Number of emitters</td>
<td>16</td>
<td></td>
</tr>
</tbody>
</table>

### Location B:

The middle of an "average hose" in the field.

For all emitter types. All 8 emitters must be at the same pressure.

<table>
<thead>
<tr>
<th>Collection time</th>
<th>psi</th>
<th>mL</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>15</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Emitter</th>
<th>Volume</th>
<th>psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>74</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>71</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>74</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>55</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>72</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>36</td>
<td></td>
</tr>
</tbody>
</table>
**Location E:** At the downstream end of a hose at the most downstream end of the system. All emissions must be at the same pressure.

<table>
<thead>
<tr>
<th>Location</th>
<th>Collection time</th>
<th>Hose pressure at emitter</th>
<th>Collected volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 minutes</td>
<td>7 psi</td>
<td></td>
</tr>
</tbody>
</table>

| #1       | 65 mL           |                          | 72 mL             |
| #2       | 71 mL           |                          |                   |
| #3       | 74 mL           |                          |                   |
| #4       | 70 mL           |                          |                   |
| #5       | 68 mL           |                          |                   |
| #6       | 65 mL           |                          |                   |
| #7       | 72 mL           |                          |                   |
| #8       | 70 mL           |                          |                   |
| #9       | 70 mL           |                          |                   |
| #10      | 66 mL           |                          |                   |
| #11      | 65 mL           |                          |                   |
| #12      | 72 mL           |                          |                   |
| #13      | 75 mL           |                          |                   |
| #14      | 66 mL           |                          |                   |
| #15      | 66 mL           |                          |                   |
| #16      | 66 mL           |                          |                   |
| #17      | 74 mL           |                          |                   |
| #18      | 67 mL           |                          |                   |
| #19      | 65 mL           |                          |                   |
| #20      | 66 mL           |                          |                   |
| #21      | 65 mL           |                          |                   |
| #22      | 65 mL           |                          |                   |
| #23      | 66 mL           |                          |                   |
| #24      | 66 mL           |                          |                   |
| #25      | 66 mL           |                          |                   |
| #26      | 68 mL           |                          |                   |
| #27      | 67 mL           |                          |                   |
| #28      | 65 mL           |                          |                   |
### Emitter Spacing

<table>
<thead>
<tr>
<th>Area Number 1</th>
<th>Area Number 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Emitter Spacing</strong></td>
<td><strong>Emitter Spacing</strong></td>
</tr>
<tr>
<td><strong>Area with this combination</strong></td>
<td><strong>Area with this combination</strong></td>
</tr>
<tr>
<td>27 acres</td>
<td>100% Root zone available area holding capacity: 3.5 inches</td>
</tr>
<tr>
<td>40 ft²</td>
<td><strong>Number of emitters per plant (emitter/plan ratio)</strong></td>
</tr>
<tr>
<td>2</td>
<td><strong>The computed flow rate per emitter was found to be:</strong></td>
</tr>
<tr>
<td>0.3 gpm</td>
<td><strong>Do you want to override the computed flow per emitter?</strong></td>
</tr>
<tr>
<td>Yes</td>
<td><strong>Over-ride flow rate (gph, gal, or ml/min)</strong></td>
</tr>
<tr>
<td><strong>Units of over-ride flow rate</strong></td>
<td><strong>Units of flow rate (gph, gal, or ml/min)</strong></td>
</tr>
<tr>
<td><strong>Watered soil area per emitter</strong></td>
<td><strong>Watered soil area per emitter</strong></td>
</tr>
<tr>
<td>4 ft²</td>
<td><strong>Crop ET during peak ET period</strong></td>
</tr>
<tr>
<td><strong>100% Root zone available area holding capacity: 3.5 inches</strong></td>
<td>0.12 inches/day</td>
</tr>
<tr>
<td><strong>Watered soil area per emitter</strong></td>
<td><strong>Number of emitters per plant (emitter/plan ratio)</strong></td>
</tr>
<tr>
<td>2</td>
<td>0.30 gpm</td>
</tr>
<tr>
<td><strong>Do you want to override the computed flow per emitter?</strong></td>
<td><strong>Units of flow rate (gph, gal, or ml/min)</strong></td>
</tr>
<tr>
<td>Yes</td>
<td><strong>Over-ride flow rate (gph, gal, or ml/min)</strong></td>
</tr>
<tr>
<td><strong>Units of over-ride flow rate</strong></td>
<td><strong>Units of flow rate (gph, gal, or ml/min)</strong></td>
</tr>
</tbody>
</table>

*Note that adding plant spacing, emitter spacing, emitter flow rate, irrigation duration or frequency plant types, canopy covers, or ET rates in different blocks will affect equally as multiple spacings.*
### PGA's Emerging Technologies Program

#### AREA NUMBER: 3

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area with this combination</td>
<td>acres</td>
</tr>
<tr>
<td>Area per plant (low spacing = plant spacing)</td>
<td>ft²</td>
</tr>
<tr>
<td>Number of emitters per plant (emitter/plant ratio)</td>
<td>2.0</td>
</tr>
<tr>
<td>Do you want to over-ride the computed flow per emitter?</td>
<td>Yes</td>
</tr>
<tr>
<td>Units of over-ride flow rate</td>
<td>ft³</td>
</tr>
<tr>
<td>Wetted soil area per emitter</td>
<td>ft²</td>
</tr>
<tr>
<td>Root zone available water holding capacity</td>
<td>inches</td>
</tr>
<tr>
<td>Set duration during peak ET:</td>
<td>hours</td>
</tr>
<tr>
<td>Irrigation frequency during peak ET:</td>
<td>days</td>
</tr>
<tr>
<td>Crop ET during peak ET period</td>
<td>inches/day</td>
</tr>
</tbody>
</table>

#### CONTAMINANTS AND PLUGGING LEAKS

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flushing time to get clear water from the end of the lowest non-adjacent home</td>
<td>2 seconds</td>
</tr>
<tr>
<td>Rate the amount of material caught in the flush bag when flushing the hoses:</td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>None</td>
</tr>
<tr>
<td>Clay</td>
<td>None</td>
</tr>
<tr>
<td>Beetle/gnats</td>
<td>None</td>
</tr>
<tr>
<td>Rate the following causes of emitter plugging:</td>
<td></td>
</tr>
<tr>
<td>For this question, review the section on apparent low flows. Take them under to inspect for the cause of plugging.</td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>None</td>
</tr>
<tr>
<td>Pores (bubbles with a tight drop)</td>
<td>None</td>
</tr>
<tr>
<td>Bacteria</td>
<td>None</td>
</tr>
<tr>
<td>Chlorides</td>
<td>None</td>
</tr>
<tr>
<td>Insects</td>
<td>None</td>
</tr>
<tr>
<td>Plastic parts</td>
<td>None</td>
</tr>
<tr>
<td>Rate the visible signs of abnormal emitter flow due to cracked hoses, babble leaks, etc.:</td>
<td></td>
</tr>
<tr>
<td>Unequal Drainage</td>
<td></td>
</tr>
<tr>
<td>Time some emitters run after most emitters stop:</td>
<td>5 minutes</td>
</tr>
<tr>
<td>Percentage of emitters that do this:</td>
<td>5 %</td>
</tr>
</tbody>
</table>
APPENDIX 5 - EXAMPLE APEP PUMP TEST REPORT AND PUMPING COST ANALYSIS

Following are examples of the four pages that make up the standard APEP pump test report. They include a cover letter with a Record of Test, to be signed by the customer, the Pumping Cost Analysis, the measurements and calculations of the test itself, and an information page indicating how to participate in all aspects of APEP.
CONFIDENTIAL AND PROPRIETARY INFORMATION PUMPING COST ANALYSIS FROM Adv Pumping Efficiency Program

DAVID ZOLDOSEKKE
CSU PRISNO
5370 NORTH CHESTNUT AVE.
FRESNO, CA 93749
Test Date: 6/6/2012
Pump 09370729
Nameplate H.P. 150.0
Our Pump Test 300334
This is water well used for Irrigation - Agriculture and assumed to be operated 1000 hours/year.

The following Pumping Cost Analysis is presented as an estimate prepared from data acquired from the pump test performed 6/6/2012 and information provided by you. Please pay careful attention to the assumptions. The estimated savings are only valid for the assumptions made and conditions measured during the pumping test. Note that only numbers are rounded during calculations.

NOTE: * denotes a value that was assumed or provided by Customer

<table>
<thead>
<tr>
<th>Measure</th>
<th>Measured Pump Condition</th>
<th>Assumed Condition After Retrofit</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Overall pumping efficiency:</td>
<td>35 %</td>
<td>69 %</td>
<td></td>
</tr>
<tr>
<td>2. Nameplate Horsepower:</td>
<td>150.0 hp</td>
<td>150.0 hp</td>
<td></td>
</tr>
<tr>
<td>3. Motor Efficiency:</td>
<td>92 %</td>
<td>92 %</td>
<td></td>
</tr>
<tr>
<td>4. Actual Motor Input Horsepower:</td>
<td>147.5 hp</td>
<td>158.0 hp</td>
<td></td>
</tr>
<tr>
<td>5. Motor loaded at:</td>
<td>90 %</td>
<td>97 %</td>
<td></td>
</tr>
<tr>
<td>6. Flow rate (gpm):</td>
<td>800 gpm</td>
<td>1,481 gpm</td>
<td></td>
</tr>
<tr>
<td>7. Pumping Level (ft):</td>
<td>250 ft</td>
<td>280 ft</td>
<td></td>
</tr>
<tr>
<td>8. Discharge Pressure (psi):</td>
<td>1 psi</td>
<td>5 psi</td>
<td></td>
</tr>
<tr>
<td>9. Total Dynamic Head (feet):</td>
<td>292 ft</td>
<td>291 ft</td>
<td>Rounded TSH = line 7 + (2.5 ft x line 8)</td>
</tr>
<tr>
<td>10. Acme-est. Pumped/yr:</td>
<td>147.30 afyw*</td>
<td>147.30 afyw*</td>
<td>Same afyw AFTER</td>
</tr>
<tr>
<td>11. Average Cost per kWh:</td>
<td>$0.114 /KWh*</td>
<td>$0.140 /KWh*</td>
<td>Same $/KWh AFTER</td>
</tr>
</tbody>
</table>

Estimated Savings from Retrofit

12. Estimated Total kWh per Year: 110,000 kWhyr | 33,018 kWhyr | 46,362 kWhyr |
13. Hours of Operation: 1,000 hr/yr | 540 hr/yr | 460 hr/yr |
14. Kilowatt-hours per acre-ft: 747 kWh/af | 412 kWh/af | 319 kWh/af |
15. Average Cost Per acre-ft: $104.55 /af | $90.49 /af | $44.06/af = 42.18% |

- Estimated savings = $44.06/af = 42.18% of energy costs
- If pumping 147.30 af/yr this equals about $5,491 annual savings

Analysis Remarks:

It is sincerely hoped that this information will prove helpful to you, and that your concern over maintaining optimum pumping efficiency will continue. If you have any questions, please contact Peter Carese at 909-0456039.

Regards,
Peter Carese
### Test Report

**Pump Location:** 1000 B Street

**GPS Coord.**
- **Long:** 34
- **Lat:** -120

**Motor Make:** NONE

**Type of Turbine:** None

**Customer Address:**
- **Street:** 5370 North Chestnut Ave.
- **City:** Fresno, CA 93740

**Contact:**
- **Name:** David Zoladz
- **Phone:** (559) 278-2066
- **Fax:** Cell:

**Test Date:** 6/6/2012

**Tester:** Peter Caines

---

<table>
<thead>
<tr>
<th>Test Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run Number (ft)</td>
<td>55</td>
</tr>
<tr>
<td>Pumping Water Level (ft)</td>
<td>250</td>
</tr>
<tr>
<td>Standing Water Level (ft)</td>
<td>415</td>
</tr>
<tr>
<td>Draw Down (ft)</td>
<td>25</td>
</tr>
<tr>
<td>Recovered Water Level (ft)</td>
<td>215</td>
</tr>
<tr>
<td>Discharge Pressure at Gauge (psig)</td>
<td>1</td>
</tr>
<tr>
<td>Total Lift (ft)</td>
<td>252</td>
</tr>
<tr>
<td>Flow Velocity (ft/sec)</td>
<td>3.3</td>
</tr>
<tr>
<td>Measured Flow Rate (gpm)</td>
<td>500</td>
</tr>
<tr>
<td>Customer Flow Rate (gpm)</td>
<td>0</td>
</tr>
<tr>
<td>Specific Capacity (gpm/ft-draw)</td>
<td>22.9</td>
</tr>
<tr>
<td>Acre Feet per 24 Hr.</td>
<td>3.8</td>
</tr>
</tbody>
</table>

**Million Gallons per 24 Hr.**
- 1,152

**Cubic Feet per Second (cu ft/s):**
- 1.8

**Horsepower Input to Motor:**
- 147

**Percent of Rated Motor Load (%):**
- 50

**Kilowatt Input to Motor:**
- 110

**Kilowatt Hours per acre-foot:**
- 747

**Cost to Pump an acre-foot:**
- $1.04

**Energy Cost ($/hour):**
- $1.25

**Base Cost per kWh:**
- $0.140

**Nameplate rpm:**
- 0

**rpm at Nohead:**
- 0

**Overall Pumping Efficiency (%):**
- 25

---

All results are based on conditions during the time of the test. If these conditions vary from the normal operation of your pump, the results shown may not describe the pump's normal performance.

---

Estimated savings of 35% WWF and $6,903/2 annual energy costs from retrofit Current OPE of 35% and estimated potential OPE of 69%
How to Participate in the
Advanced Pumping Efficiency Program:

EDUCATIONAL SEMINARS
Seminars are free of charge. Our seminar schedule is on the Events Calendar on our website (www.pumpedefficiency.org) or you can call the main office. Also, all of our educational materials are on the website and can be downloaded free of charge. We are always looking for partners for our seminars and if your organization has an event that we might be able to help with, please give us a call - 1-800-846-6038.

TECHNICAL ASSISTANCE
We are here to help you in your pump test, fill out an incentive application, discuss other PG&E energy efficiency programs, or answer general questions regarding design and management of pumping systems. Please note that we cannot supply site-specific engineering services.

SUBSIDIZED PUMP EFFICIENCY TESTS
If you are reading this and you already know how to obtain a subsidized test from AEP. Please tell your friends and neighbors about our Program. The pump efficiency test is the first step in maintaining an efficient pumping plant. Please note that subsidies depend on available funding and are on a first-come, first-served basis.

CASH INCENTIVES FOR PUMP RETROFITS
If you are thinking of retrofitting a pumping plant to improve efficiency we may be able to provide a cash incentive (again depending on available funding). The actual incentive depends on your annual energy use and the maximum incentive allowed is 60% of the total project cost. Some important eligibility factors include:
- We need a copy of a pump test performed both before and after the project. They cannot be more than 3 years apart. An application must be complete and approved within 2 years after the post-project test. This test does not have to be done by AEP testers but we must feel they are accurate.
- The only eligible project is a retrofit or replacement of either or both of the pump(s) or
- We can accept an incentive application for a project after the fact (i.e. the project has already been completed before you fill out the application). Again, though, the application has to be complete and approved within 2 years after the post-project pump test.

Ineligible projects include:
- Replacement of the motor only.
- Installation of a variable frequency drive (although check with your PG&E rep for other energy efficiency programs that may allow for this).
- A simple pump impeller adjustment.
- Construction, rehabilitation, or finishing of a water well (although check with your PG&E rep for other applicable energy efficiency programs).
- Retrofit intended to change the operational purpose of the pump (e.g., changing a well pump from low pressure flood irrigation to high pressure drip irrigation).
- Retrofit projects, unless the system is a booster pump series with a water well.
- Projects intended to reduce the total dynamic head at the system (e.g., remove a throttling valve).

The AEP Policies and Procedures manual that contains all eligibility factors and incentive application forms for other electric or natural gas-powered pumping plants are on the website.

Please call one of the AEP offices to discuss any project you think might be eligible for the incentive program. PG&E and other utilities and agencies have many energy efficiency programs available. Call your local utility or check out the PG&E web site at www.pge.com or go to www.caliiforniaenergyefficiency.com for more information.

Again, we appreciate your participation in the Program.
APPENDIX 6 - EXAMPLE SEASONAL IRRIGATION SCHEDULING REPORT FROM THE WATERIGHT WEB SITE - WWW.WATERIGHT.ORG

This is a series of 3 "screen shots". Please note the scheduling parameters at the top. This schedule was developed using the Gerber CIMIS station.

Agricultural Irrigation Scheduling
- Agricultural Irrigation Scheduling
Seasonal Irrigation Schedule

IMPORTANT!
- Please refer to the notes at the bottom of this page for information on how the schedule was calculated.
- Users ABSOLUTELY need to verify the plant health and soil moisture in their fields.
- This is an AVERAGE SEASONAL schedule and should be used as INITIAL GUIDANCE ONLY.

The Irrigation Schedule starts just below the Field Data Summary.

Field Data Summary

<table>
<thead>
<tr>
<th>CIMIS SN</th>
<th>Gerber #8</th>
</tr>
</thead>
<tbody>
<tr>
<td>City of Gerber in Tehama County</td>
<td></td>
</tr>
</tbody>
</table>

Field Number 1
Description Brandt
Crop Walnuts
Crop Season 4/1 - 9/15
Stop Irrigating 9/15
Soil Loams/Silt Loams
Maximum Root Zone (ft) 4
Irrigation System Microsprinkler
Irrigation Efficiency 99%
Gross Application Rate (in/hr) 0.026
Scheduling Basis Max. Allowed Depletion
Management Allowed Depletion 50%
Allowed Depletion at Max. RlZn (in) 2.00
Runtime at Maximum RlZn (hh:mm) 21:57

Seasonal Irrigation Schedule

<table>
<thead>
<tr>
<th>For Week Ending</th>
<th>Average Year ETo</th>
<th>Rain</th>
<th>This Year ETo</th>
<th>Rain</th>
<th>Averages for Week Kc</th>
<th>ETo</th>
<th>Root Zone</th>
<th>Runtime Zone</th>
<th>Change This Yr Avg Yr</th>
<th>Total ETo to Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In/Dy</td>
<td>In/Wk</td>
<td>In/Dy</td>
<td>In/Wk</td>
<td>In/Dy</td>
<td>Pt</td>
<td>HH:MM</td>
<td>%</td>
<td>In</td>
<td></td>
</tr>
<tr>
<td>4/6/2013</td>
<td>0.14</td>
<td>0.31</td>
<td>0.12</td>
<td>0.32</td>
<td>0.57</td>
<td>0.08</td>
<td>4.00</td>
<td>6:16</td>
<td>-17</td>
<td>0.57</td>
</tr>
<tr>
<td>4/13/2013</td>
<td>0.16</td>
<td>0.64</td>
<td>0.21</td>
<td>0.00</td>
<td>0.61</td>
<td>0.09</td>
<td>4.00</td>
<td>6:58</td>
<td>35</td>
<td>1.21</td>
</tr>
<tr>
<td>Date</td>
<td>Rainfall</td>
<td>Temperature</td>
<td>Wind Speed</td>
<td>Wind Direction</td>
<td>Start Time</td>
<td>End Time</td>
<td>Run Time</td>
<td>Rainfall Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>----------</td>
<td>-------------</td>
<td>------------</td>
<td>----------------</td>
<td>------------</td>
<td>----------</td>
<td>----------</td>
<td>----------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4/22/2013</td>
<td>0.17</td>
<td>0.10</td>
<td>0.24</td>
<td>0.00</td>
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<td>0.10</td>
<td>4.00</td>
<td>7:50</td>
<td>0.84</td>
<td>1.92</td>
</tr>
<tr>
<td>4/29/2013</td>
<td>0.18</td>
<td>0.03</td>
<td>0.27</td>
<td>0.00</td>
<td>0.70</td>
<td>0.11</td>
<td>4.00</td>
<td>0:41</td>
<td>0.51</td>
<td>2.72</td>
</tr>
<tr>
<td>5/6/2013</td>
<td>0.19</td>
<td>0.01</td>
<td>0.29</td>
<td>0.00</td>
<td>0.74</td>
<td>0.13</td>
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<td>10:07</td>
<td>0.22</td>
<td>3.64</td>
</tr>
<tr>
<td>5/13/2013</td>
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<td>0.09</td>
<td>0.21</td>
<td>0.00</td>
<td>0.78</td>
<td>0.15</td>
<td>4.00</td>
<td>11:12</td>
<td>0.33</td>
<td>4.66</td>
</tr>
<tr>
<td>5/20/2013</td>
<td>0.22</td>
<td>0.45</td>
<td>0.23</td>
<td>0.56</td>
<td>0.82</td>
<td>0.16</td>
<td>4.00</td>
<td>12:27</td>
<td>0.60</td>
<td>5.00</td>
</tr>
<tr>
<td>5/27/2013</td>
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<td>0.24</td>
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<td>0.86</td>
<td>0.19</td>
<td>4.00</td>
<td>14:18</td>
<td>0.41</td>
<td>7.11</td>
</tr>
<tr>
<td>6/3/2013</td>
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<td>0.15</td>
<td>0.30</td>
<td>0.00</td>
<td>0.90</td>
<td>0.21</td>
<td>4.00</td>
<td>15:46</td>
<td>0.22</td>
<td>8.55</td>
</tr>
<tr>
<td>6/10/2013</td>
<td>0.26</td>
<td>0.20</td>
<td>0.29</td>
<td>0.01</td>
<td>0.94</td>
<td>0.23</td>
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<td>17:24</td>
<td>0.41</td>
<td>10.14</td>
</tr>
<tr>
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<td>0.01</td>
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<td>0.04</td>
<td>1.02</td>
<td>0.26</td>
<td>4.00</td>
<td>20:14</td>
<td>-0.7</td>
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<td>0.25</td>
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<td>1.03</td>
<td>0.27</td>
<td>4.00</td>
<td>20:46</td>
<td>-0.11</td>
<td>15.52</td>
</tr>
<tr>
<td>7/8/2013</td>
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<td>0.33</td>
<td>0.00</td>
<td>1.03</td>
<td>0.27</td>
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<td>0.17</td>
<td>17.50</td>
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<td>0.30</td>
<td>0.00</td>
<td>1.03</td>
<td>0.27</td>
<td>4.00</td>
<td>20:26</td>
<td>0.19</td>
<td>19.37</td>
</tr>
<tr>
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<td>0.28</td>
<td>0.00</td>
<td>1.03</td>
<td>0.27</td>
<td>4.00</td>
<td>20:32</td>
<td>0.20</td>
<td>21.24</td>
</tr>
<tr>
<td>7/29/2013</td>
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<td>0.00</td>
<td>0.27</td>
<td>0.00</td>
<td>1.03</td>
<td>0.26</td>
<td>4.00</td>
<td>19:42</td>
<td>0.23</td>
<td>23.04</td>
</tr>
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<td>0.25</td>
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<td>1.03</td>
<td>0.25</td>
<td>4.00</td>
<td>19:17</td>
<td>-0.1</td>
<td>24.90</td>
</tr>
<tr>
<td>8/12/2013</td>
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<td>0.00</td>
<td>0.23</td>
<td>0.00</td>
<td>1.01</td>
<td>0.24</td>
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<td>0.97</td>
<td>0.22</td>
<td>4.00</td>
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<td>0.28</td>
<td>28.02</td>
</tr>
<tr>
<td>8/26/2013</td>
<td>0.24</td>
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<td>0.93</td>
<td>0.21</td>
<td>4.00</td>
<td>16:07</td>
<td>N/A</td>
<td>29.49</td>
</tr>
<tr>
<td>9/2/2013</td>
<td>0.23</td>
<td>0.00</td>
<td>N/A</td>
<td>N/A</td>
<td>0.89</td>
<td>0.19</td>
<td>4.00</td>
<td>14:53</td>
<td>N/A</td>
<td>30.05</td>
</tr>
<tr>
<td>9/9/2013</td>
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<td>0.01</td>
<td>N/A</td>
<td>N/A</td>
<td>0.85</td>
<td>0.18</td>
<td>4.00</td>
<td>13:32</td>
<td>N/A</td>
<td>32.08</td>
</tr>
<tr>
<td>9/16/2013</td>
<td>0.21</td>
<td>0.02</td>
<td>N/A</td>
<td>N/A</td>
<td>0.70</td>
<td>0.13</td>
<td>4.00</td>
<td>10:17</td>
<td>N/A</td>
<td>33.02</td>
</tr>
</tbody>
</table>

Total Run Time = 361:43 h

Rainfall = 34.76 inches Gross Applied
The column titled "Change, This Year vs. Average Year" is the percentage difference between the actual ET0 for this year versus an average year. A positive number means that this year has higher ET0 and thus, higher crop water use than normal.

NOTES ON THE CALCULATION OF THIS SCHEDULE:

- Suggested irrigations are based on AVERAGE CROP COEFFICIENT CURVES and HISTORICAL AVERAGES FOR ET0 and RAINFALL.

- Average daily rainfalls are summed for the week and disregarded if less than 0.5 inch.

- Wet soil evaporation is accounted for after irrigations at the scheduling criteria (Management Allowed Depletion, Time per Set, or Rotation Days) or if the summed rainfall for a week is greater than 0.5 inch.

- For annual crops, the root zone is estimated to achieve full root depth at 80% of time to maturity. The minimum root zone is 1 foot.

- There is no allowance for excess irrigation being used for crop ET0 while it moves down through the root zone.

- IMPORTANT! Users ABSOLUTELY need to verify plant health and/or soil moisture level.

The WATERIGHT site is a joint project of the Center for Irrigation Technology and Advanced Technology Information Network which are part of the California Agricultural Technology Institute at California State University, Fresno. The WATERIGHT site is funded by the Bureau of Reclamation, US Department of Interior.
APPENDIX 7 - ADDITIONAL QUESTIONS TO MANAGEMENT

Following are the current set of "Additional Questions to Management". The reason for a question or the type of data needed from the question, if the question is not straightforward, will appear bracketed in italics in red type. Suggested new questions, or changes to existing questions, will be in blue type.

Additional Information Needed for System Evaluation

[Section 1) leads to an idea as to whether gross over or under-irrigation is taking place and whether management needs to improve their irrigation scheduling]

1) Overall Water/Field Management

Crop: ________________
Variety: ________________
Age(s): ________________

[This is an important question and leads to an estimate of annual crop ETc, which can then be compared to the actual annual water application. However, the question that should be asked in conjunction is "Is there a cover crop present?"]

Estimated canopy percentage (shading when sun directly overhead): ______%
If a vineyard or orchard, Is there a cover crop present?  YES  NO

Length of irrigation season (months) - average start/stop dates: __________  __________

[This is the seasonal crop evapotranspiration, not the reference ET. If management cannot answer this it is an indication of poor scheduling practices.]

Seasonal net crop evapotranspiration: __________ inches/year

Other beneficial water used (leaching, soil prep, etc.): __________ inches/year

Gross annual rainfall: __________ inches/year

Estimate of effective annual rainfall: __________ inches/year (effective implies useful for beneficial crop uses)

[YES answers here will underscore the need for good water management]

Water Quality/Drainage Issues:
- SAR high enough to require amendments?  YES  NO
- Salinity high enough to require explicit leaching applications?  YES  NO
- Need to file nutrient management plan?  YES  NO
- High water table - no outlet?  YES  NO
- High water table - artificial/tile drainage system in place?  YES  NO

[This set of questions helps to identify excess pressure or the potential feasibility for a variable frequency drive. They need to be moved to Section 2]

Field Variability:
- Does the booster (or well if a pressurized well) pump supply different flow rates to different planting blocks or combinations of planting blocks?  YES  NO
- Does the booster (or well if a pressurized well) pump supply different pressures to different blocks or combinations of planting blocks?  YES  NO

If uneven flow rates/pressure to different blocks or block combinations - why (circle all that apply)?
Different block sizes
Different combinations of blocks have different total acreages
Different crops in different blocks
Different crop ages in different blocks
Different irrigation system designs in different blocks
Blocks are situated uphill/downhill from booster

Is booster pump (or well if a pressurized well) VFD-controlled?  YES  NO
Multiple pumps supplying field?  YES  NO
If YES: same sizes different sizes

[The next three sets of questions are trying to identify the extent/sophistication of irrigation scheduling methodology.]

Irrigation Scheduling Activities (circle all that apply):
- On-farm weather stations
- Soil and/or plant moisture monitoring
- Soil and/or plant moisture monitoring with record-keeping (written or graphical)
- Use daily/weekly ETc to set run-time
- Formal water budget
- My experience only
- I use a consultant

If daily or weekly crop ETc is used to set run-time, how is this estimate derived?
- On-farm weather station and Univ. California crop coefficient curve
- CIMIS weather station and Univ. California crop coefficient curve
- Provided by my consultant - his method is ________________________________
- Using an average weather year and Univ. California crop coefficient curve
- Other (please describe) _______________________________________________________

If a flow meter is installed do you check your desired water applications by it?  YES  NO

[This speaks to the irrigation system specifications, not what was found with the pump test. That is, if the system specification is 1,000 gpm at 40 psi downstream of the filters then that is what is entered here, regardless of pump test results. This speaks to if management can spot a developing problem with the irrigation system, most commonly plugging of the emitters. This probably belongs in Section 2) also]
Do you know the designed irrigation system specifications for input pressure/flow?  YES  NO
 If YES pressure _____ psi    flow _____ gpm

[This is another clue as to the effectiveness of current irrigation scheduling methodology. This can be used with the evaluated average application rate to judge whether in-season scheduling is effective.]
In the main irrigation season, what would be your normal watering pattern (if any)?
_____ days on  _____ days off  Is this variable?  YES  NO
_____ hours per day  Is this variable?  YES  NO
_____ hours per week  Is this variable?  YES  NO

Is the variable timing due to…
- any type of estimate of crop ETc?
- appearance of crop (experience)?
- soil moisture measurements?
- crop moisture measurements?
[This section is primarily aimed at identifying what restrictions there might be for effective irrigation scheduling as well as off-peak operations. The more restrictive the primary water supplies are, either in terms of flow rates, timing, or duration, the less flexibility the irrigator has in irrigation scheduling and on/off-peak operations.]

2) Water Supplies to Field

Supply is (circle all that apply): WELL DISTRICT DIRECT FROM RIVER

[This identifies whether there is a buffer between the primary water supply and the irrigation system.]

Do you have an on-farm reservoir or other water storage? YES NO
Is it large enough to allow you to shut down your pumps for the 4-6 hours of electrical on-peak hours?

If in an irrigation or water district:
What is the typical delivery season? Start __________ Stop __________
Strict Rotation or Arranged (ARRANGED means able to call deliveries on and off in advance) - STRICT ARRANGED
If Rotation - Days between __________ Days on __________ Flow rate flexibility? YES NO
If Arranged - lead time for ordering water on and off? On __________ Off __________
Flow rate flexibility? YES NO

[This question, as with Wells and Rivers is important. Does management know how much water is being applied to an individual field? Note that management may not want to answer this question.]

What is the total volume delivered to field per year from the district? __________ ac-feet
Flow/volume measuring device installed at outlet? YES NO

[These questions may not be needed but could, if populated, provide some sort of relationship between level of water management versus cost of water.]

Priced how: Per Acre-Foot Delivered Per Acre per Year
Price: $_________ per acre-foot / per acre-year
Tiered-rate in place? YES NO
Price: $_________ per acre-foot for ________ acre-feet
Price: $_________ per acre-foot for next ________ acre-feet
Price: $_________ per acre-foot for next ________ acre-feet

If a well, is it shared or used solely by you? SHARED SOLE USE:
Power source DIESEL NATURAL GAS ELECTRIC
Flow meter installed? YES NO
VFD controlled? YES NO
Water table fluctuation summer to winter (when operating): __________ ft
If shared:
Formal contract between owners as to use? YES NO
Any arrangement as to off-peak operation? YES NO
If the well is solely used by you:
Do you mind turning it on and off every day? YES NO
Don't want to, but if there was a reason…
Is it supplying multiple fields? YES NO
Total Volume delivered from well to field per year? __________ ac-feet

If Direct from River, are you using a shared pump or one only used by you? SHARED SOLE USE
Flow meter on pump? YES NO
VFD controlled? YES NO
If shared:
Formal contract between owners as to use? YES NO
Any arrangement as to off-peak operation? YES NO
If the pump is used solely by you:

Do you mind turning it on and off every day?   YES   No   Don't want to, but if there was a reason…

Is it supplying multiple fields?   YES   NO

Total Volume delivered from pump to field per year? __________ ac-feet

[This question has been re-phrased for this report.]

If the water supply (or supplies) to this field are shared can you estimate the acreage and crops also being irrigated by the pump (or pumps)?

<table>
<thead>
<tr>
<th>Crop</th>
<th>Crop Age</th>
<th>Acreage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop</td>
<td>Crop Age</td>
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<td>Crop</td>
<td>Crop Age</td>
<td>Acreage</td>
</tr>
</tbody>
</table>

[Trying to identify issues surrounding on/off-peak operation.]

3) Time-Of-Use Operations

TOU schedule(s) in place?

- Well pumps          YES   NO   ON SOME PUMPS
- Booster pumps       YES   NO   ON SOME PUMPS
- River/Canal Lift pumps YES   NO   ON SOME PUMPS

Current Rate Schedule (s)________________________

Last time rate analysis performed? __________________

[Note the options for why they are not off-peak - trying to identify restrictions.]

Off-peak now? - choose best answer

For Wells

- Aggressive/Always
  - Try to be off-peak whenever possible
  - Can't be off-peak - need all the water it can pump
  - Can't be off-peak - don't like to turn on and off
  - Don't worry about it

For Boosters

- Aggressive/Always
  - Try to be off-peak whenever possible
  - Can't be off-peak - constraints from supply (e.g., 24 hour delivery)
  - Can't be off-peak - constraints from irrigation system (e.g., need 24 hour day operation at peak ETc)
  - Don't worry about it

For River/Canal Lifts

- Aggressive/Always
  - Try to be off-peak whenever possible
  - Can't be off-peak - constraints from supply
  - Can't be off-peak - constraints from irrigation system
  - Can't be off-peak - need all the water it can pump
  - Don't worry about it

[In place primarily because of this project. Trying to ascertain whether the combined evaluation can be used for other fields. Provides an idea as to dollar benefit from an evaluation.]

4) Information Leverage

[In some cases the irrigation system evaluation report will only report the acres evaluated, not the entire field.]
Is the block/field evaluated part of a larger field/orchard/vineyard?  YES  NO
   If YES, what is the size of the entire field? _________ acres

Do you have other fields/orchards/vineyards that use similar irrigation systems and management?  YES  NO
   If YES, what is the total acreage that is similar to the block/field evaluated? _________ acres
   Does the total acres include double-cropping as well? YES  NO

Do you think the information gained from this evaluation will be useful on these other similar fields/orchards/vineyards?  YES  NO
   If YES, which types of information (circle all that apply)?
      problems to look for in improving DU
      problems to look for in decreasing leakage
      problems to look for in decreasing excess pressure losses
      issues for improving overall water management (scheduling, moisture monitoring)
      issues for moving operations to off-peak hours
APPENDIX 8 - CUSTOMER SATISFACTION SURVEY

CUSTOMER FEEDBACK SURVEY - COMBINED EVALUATIONS PILOT PROJECT

Thank you for participating in our Combined Evaluations pilot project. As noted in the report(s) sent to you the purpose of this project is to perform a pump efficiency test, an irrigation system evaluation, and present a set of questions to you regarding overall water and energy management - all at the same time. The goal is to provide you with a comprehensive look at how energy and water are being utilized on your farm.

Your feedback as to the experience is extremely valuable to us in deciding on what changes need to be made and/or whether to fund a similar program in the future. We hope you can find the time to answer the ten questions below.

A stamped, pre-addressed envelope is enclosed for your convenience.

Any other comments or suggestions would be welcome. Again, thank you for your participation.

1. We understand that the complete report package is long. However, did the Summary Section in particular convey the critical information completely and clearly? YES NO

2. Combining the pump efficiency test and the irrigation system evaluation is intended to provide a more complete picture of energy and water use in your field. Did the report improve your understanding of energy and water use in your field? YES NO

3. Were you able, or will you be able to, use the information developed during the Combined Evaluation on fields other than the particular field evaluated? YES NO
   If YES, any comments as to what information and why you can use it?

4. Assuming the cost of a Combined Evaluation is in the range of $1,750 would you be willing to pay for some portion of that cost? YES NO
   If YES, what percentage? ___________

5. What was the hardest part of the report package to understand? (circle one)
   Summary
   Irrigation System Evaluation (Hardware)
   Pump test report
   Additional Questions to Management

6. What was the easiest part of the report to understand? (circle one)
   Summary
   Irrigation System Evaluation (Hardware)
   Pump test report
   Additional Questions to Management

7. Would you like to have more of your fields evaluated like this? YES NO

8. Any further comments as to other factors that should have been evaluated? Increased emphasis on one aspect or another? Missing information?

9. Do you plan on making any of the recommended improvements and if so, which ones and why?

10. May we contact you for a 10-15 minute personal phone conversation? YES NO
    If YES -
    a) Best Time to contact ________________
    b) Phone number ____________________
APPENDIX 9 - QUESTIONS TO EVALUATION TEAMS

Did you understand what it was we were trying to produce?

Do you understand the concept of the three big ideas for reducing energy use?

Do you think that combining the two types of evaluations is advantageous?

If you have been strictly doing system evaluations do you now plan to incorporate, or try to incorporate, simultaneous pump testing?

How do you see the combination evaluation occurring? That is, what steps lead to the evaluation and pump test being done at the same time?

How do you envision funding for the CE to happen?

Attached is a description of the three entities identified as required to make a CE happen.

1. Do you think you are qualified to be the Integrator?
2. What training do you think would be needed?
3. How much would you like to be paid to serve as the Integrator?

Attached is the current version of the Summary Section of the integrated report. What would you change or add?
APPENDIX 10 - COMMONLY RECOMMENDED IRRIGATION EFFICIENCY MEASURES

Common recommendations for improving pressure uniformity include:
1. Replace hose and/or emitters - switch to larger diameter hose for less friction loss and/or to an emitter with a lower exponent.
2. Replace pressure regulator at hose entrance.
3. Install a pressure regulator at hose entrance (there are wide pressure differences in the manifold feeding the individual hoses).
4. Install a pressure regulator at the manifold entrance (there are wide pressure differences in the sub-main piping supplying the manifolds).
5. Install a pressure regulator at the block entrance (there are wide pressure differences in the mainline piping supplying the blocks).
6. Increase pressure in system to offset elevation differences.
7. Increase main, sub-main, and/or manifold pipe diameters.
8. Replace screens at hose entrances because of plugging.
9. Install automatic filter backwash controllers - this will prevent excessive losses through the filter system and maintain correct operating pressures in the field.

Common recommendations for improving device uniformity include:
1. Replace hose and/or emitters because of plugging and/or wear.
2. Replace hose and/or emitters because of variances in emitter devices or layout in the field.
3. Replace drip hose or drip tape because of emitter failure (generally clogging of some sort but may also be due to mechanical damage or failure).
4. Replace sprinkler nozzles due to wear.
5. Replace sprinkler nozzles so as to have only one nozzle size in the field.
6. Replace sprinkler heads due to rotational or other mechanical failure.

Common recommendations to improve overlap uniformity include:
1. Fix problems of device uniformity so design flow from adjacent devices is achieved.
2. Decrease spacing of adjacent devices or change devices at the current spacing.
3. Change head angle to prevent crop interference (generally with under-tree systems).
4. Use longer sprinkler risers to prevent crop interference (generally with field crops).
5. Irrigate during calm conditions (wind is a major factor in reduced overlap uniformity).
6. Offset laterals by 1/2 spacing every irrigation (only applicable to portable systems).

Recommendations related to improving overall water management include:
1. Install flowmeters so as to be able to measure individual irrigation and seasonal applications of irrigation water.
2. Implement some form of irrigation scheduling to provide repeatable and objective information to guide both timing and amount of irrigations.
3. Line distribution canals and/or storage reservoirs to prevent seepage losses.
4. Install a runoff return system to capture and reuse surface runoff.