ORIGINAL

For CSM Use Only

Filing Date:

RECEIVED
FEB 2 8 2013
COMMISSION ON STATE MANDATES

Test Claim #: 12-TC-01

1. TEST CLAIM TITLE

AGRICULTURAL WATER MEASUREMENT

2. CLAIMANT INFORMATION

RICHVALE IRRIGATION DISTRICT, et al.
Name of Local Agency or School District

Dustin C. Cooper
Claimant Contact

General Counsel
Title

1681 Bird Street, P.O. Box 1679
Street Address

Oroville, CA 95965
City, State, Zip

(530) 533-2885
Telephone Number

(530) 533-0197
Fax Number

dcooper@minasianlaw.com
E-Mail Address

3. CLAIMANT REPRESENTATIVE INFORMATION

Claimant designates the following person to act as its sole representative in this test claim. All correspondence and communications regarding this claim shall be forwarded to this representative. Any change in representation must be authorized by the claimant in writing, and sent to the Commission on State Mandates.

Dustin C. Cooper
Claimant Representative Name

General Counsel
Title

Minasian, Meith, Soares, Sexton & Cooper, LLP
Organization

1681 Bird St., P.O. Box 1679
Street Address

Oroville, CA 95965
City, State, Zip

(530) 533-2885
Telephone Number

(530) 533-0197
Fax Number

dcooper@minasianlaw.com
E-Mail Address

4. TEST CLAIM STATUTES OR EXECUTIVE ORDERS CITED

Please identify all code sections, statutes, bill numbers, regulations, and/or executive orders that impose the alleged mandate (e.g., Penal Code Section 2045, Statutes 2004, Chapter 54 [AB 290]). When alleging regulations or executive orders, please include the effective date of each one.

Agricultural Water Measurement, California Code of Regulations, Title 23 (Water), Division 2 (Department of Water Resources), Chapter 5.1. (Water conservation Act of 2009) Article 2 (Agricultural Water Measurement), commencing with Section 597

☑ *Copies of all statutes and executive orders cited are attached.*

Sections 5, 6, and 7 are attached as follows:

5. Written Narrative: pages 2 to 8.
6. Declarations: pages 9 to 169.
7. Documentation: pages 170 to 179.

Sections 5, 6, and 7 should be answered on separate sheets of plain 8-1/2 x 11 paper. Each sheet should include the test claim name, the claimant, the section number, and heading at the top of each page.

5. WRITTEN NARRATIVE

Under the heading "5. Written Narrative," please identify the specific sections of statutes or executive orders alleged to contain a mandate.

Include a statement that actual and/or estimated costs resulting from the alleged mandate exceeds one thousand dollars ($1,000), and include all of the following elements for each statute or executive order alleged:

(A) A detailed description of the new activities and costs that arise from the mandate.

(B) A detailed description of existing activities and costs that are modified by the mandate.

(C) The actual increased costs incurred by the claimant during the fiscal year for which the claim was filed to implement the alleged mandate.

(D) The actual or estimated annual costs that will be incurred by the claimant to implement the alleged mandate during the fiscal year immediately following the fiscal year for which the claim was filed.

(E) A statewide cost estimate of increased costs that all local agencies or school districts will incur to implement the alleged mandate during the fiscal year immediately following the fiscal year for which the claim was filed.

(F) Identification of all of the following funding sources available for this program:
- (i) Dedicated state funds
- (ii) Dedicated federal funds
- (iii) Other nonlocal agency funds
- (iv) The local agency's general purpose funds
- (v) Fee authority to offset costs

(G) Identification of prior mandate determinations made by the Board of Control or the Commission on State Mandates that may be related to the alleged mandate.

(H) Identification of a legislatively determined mandate pursuant to Government Code section 17573 that is on the same statute or executive order.

6. DECLARATIONS

Under the heading "6. Declarations," support the written narrative with declarations that:

(A) declare actual or estimated increased costs that will be incurred by the claimant to implement the alleged mandate;

(B) identify all local, state, or federal funds, and fee authority that may be used to offset the increased costs that will be incurred by the claimant to implement the alleged mandate, including direct and indirect costs;

(C) describe new activities performed to implement specified provisions of the new statute or executive order alleged to impose a reimbursable state-mandated program (specific references shall be made to chapters, articles, sections, or page numbers alleged to impose a reimbursable state-mandated program);

(D) If applicable, describe the period of reimbursement and payments received for full reimbursement of costs for a legislatively determined mandate pursuant to Section 17573, and the authority to file a test claim pursuant to paragraph (1) of subdivision (c) of Section17574.

(E) are signed under penalty of perjury, based on the declarant's personal knowledge, information or belief, by persons who are authorized and competent to do so.

7. DOCUMENTATION

Under the heading "7. Documention, " support the written narrative with copies of all of the following:

(A) the test claim statute that includes the bill number alleged to impose or impact a mandate; and/or

(B) the executive order, identified by its effective date, alleged to impose or impact a mandate; and

(C) relevant portions of state constitutional provisions, federal statutes, and executive orders that may impact the alleged mandate; and

(D) administrative decisions and court decisions cited in the narrative. Published court decisions arising from a state mandate determination by the Board of Control or the Commission are exempt from this requirement; and

(E) statutes, chapters of original legislatively determined mandate and any amendments.

SECTION 5. WRITTEN NARRATIVE

In Support of Joint Test Claims in Re Agricultural Water Measurement

Claimants:

Richvale Irrigation District
Biggs-West Gridley Water District

Joint Claimants Richvale Irrigation District ("Richvale") and Biggs-West Gridley Water District ("Biggs") (hereinafter collectively "Claimants") represent that the actual costs resulting from the mandate to install, maintain and operate agricultural water measurements under regulations adopted by the California Department of Water Resources (the "Regulations") exceed $1,000. The Regulations at issue in this Test Claim were implemented under authority of the Water Conservation Act of 2009, which is the subject of a pending test claim (10-TC-12) submitted by Claimants jointly with urban retail water suppliers Paradise Irrigation District and South Feather Water & Power Agency.

Claimants respond to each of the separate inquiries on the Test Claim Form as follows:

(A) A detailed description of the new activities and costs that arise from the Mandate

The Regulations impose unfunded state mandates to measure surface water and groundwater (including installation and certification of accuracy of water measurement devices) delivered to customers of local public agencies that are "agricultural water suppliers". An agricultural water supplier "means a water supplier, either publicly or privately owned, providing water to 10,000 or more irrigated acres, excluding acres that receive only recycled water. 'Agricultural water supplier' includes a supplier or contractor for water, regardless of the basis of right, which distributes or sells water for ultimate resale to customers. 'Agricultural water supplier' does not include the Department [of Water Resources]." (Cal. Code Regs., Tit. 23[1], § 597.2, subd. (a)(2)). Agricultural water suppliers that supply water to 25,000 or more irrigated acres are subject to the Regulations. (§ 597.1, subd. (a)).

[1] Unless otherwise noted, all citations are to Title 23 of the California Code of Regulations.

Richvale and Biggs are local public agencies formed and operating under Divisions 11 and 13, respectively, of the Water Code. Richvale and Biggs are "agricultural water suppliers", as defined, and provide water to 25,000 or more irrigated acres. Thus, Claimants must comply with the Regulations' mandates set forth hereafter.

Claimants and other agricultural water suppliers "shall measure water and groundwater that it delivers to its customers pursuant to the accuracy standards in this section." (§ 597.3). Water must be measured at the delivery or farm-gate of each single customer by either (1) using an existing measurement device, certified to be accurate within ±12% by volume or (2) a new or replacement measurement device, certified to be accurate within ± 5% by volume in the laboratory if using a laboratory certification or ± 10% by volume in the field using a non-laboratory certification. (§ 597.3, subd. (a)(1)-(2)).

The Regulations provide for limited exceptions for measurement at each customer's farm-gate including, for example, if the agricultural water supplier does not have legal access to install, maintain and operate the measurement device and the agricultural water supplier's legal counsel certifies that it has sought and been denied access. (§ 597.3, subds. (b)(1)(A), (b)(2)(A)). Another example of when farm-gate measurement is not required is if an engineer determines the accuracy standards cannot be met and certain documentation is provided. (§ 597.3, subds. (b)(1)(B), (b)(2)(B)-(b)(2)(C)).

For existing measurement devices, the Regulations mandate one of two alternatives. First, agricultural water suppliers may select a random and statistically significant sample of measurement devices and field-test them to determine if the devices meet the ± 12% accuracy standard and document the same in a report approved by an engineer. (§ 597.4, subd. (a)(1)(A); see also *id.* at subd. (b)(1)). If the sample of devices field-tested result in more than one quarter of devices failing to meet the ±12% criteria, then an additional round of field-testing an additional 10% of the devices must be completed and corrective actions must be completed within three years of initial testing. (*Id.* at subd. (b)(2)). Alternatively, suppliers may field inspect and analyze every existing measurement device using trained individuals and document the same in a report approved by an engineer. (*Id.* at subd. (a)(1)(B); see also *id.* subd. (b)(3)).

For new or replacement measurement devices, the Regulations mandate one of two alternatives. First, suppliers may obtain a laboratory certification prior to installation of the device with documentation from the manufacturer that it followed industry-established testing protocols such as the National Institute for Standards and Testing traceability standards. (§ 597.4, subd. (a)(2)(A)). Alternatively, suppliers may obtain non-laboratory certifications after installation by either (i) providing an affidavit approved by an engineer documenting design and installation or (ii) providing a report approved by an engineer documenting the field-testing performed on the devices. (*Id.* subd. (a)(2)(B)).

The Regulations require record retention for 10 years demonstrating compliance (§ 597.4, subd. (c)); continued maintenance, operation, inspection and monitoring as required by the manufacturer, the laboratory, or the engineer that signed and stamped the certification of the device (*id.* subd. (d)(1)); and require repair or replacement of measurement devices that no longer satisfy the accuracy requirements of the Regulations (*id.* subd. (d)(2)).

Finally, the regulations require reporting in each supplier's agricultural water management plan: (i) documentation required to demonstrate compliance with the Regulations; (ii) a description of best professional practices including, how water measurement data is collected, frequency of water measurement, method for determining irrigated acres, and quality control and quality assurance procedures; (iii) if devices do not measure total volume of water delivered (e.g., flow rate, velocity or water elevation), a description of how to convert the measure to volume; and (iv) a schedule, budget, and finance plan to bring existing water measurement devices into compliance with the Regulations in 3 years or less. (§ 597.4, subd. (e)(1)-(e)(4)).

All of these requirements are new mandates that did not exist prior to the establishment of the Regulations. A true and correct copy of the Regulations is attached to this test claim at Section 7, pages 170 through 179.

(B) A detailed description of existing activities and costs that are modified by the mandate

The California Constitution requires that all water use be reasonable and beneficial. (Cal Const., Art. 10, § 2; see also Water Code §§ 100, 275, 1050, 1051). At all times Claimants have reasonably applied water under water rights established and recognized under California law and utilized it for beneficial uses, such as irrigation, stockwatering, recreation and environmental enhancement.

The Water Conservation Act mandates agricultural water suppliers to:

> (1) Measure the volume of water delivered to customers with sufficiency accuracy to comply with subdivision (a) of Section 531.10 and to implement paragraph (2).
> (2) Adopt a pricing structure for water customers based at least in part on quantity delivered.

(Water Code § 10608.48, subd. (b)). Water Code section 531.10(a), which predates the Water Conservation Act, provides that

> An agricultural water supplier shall submit an annual report to the department that summarizes aggregated farm-gate delivery data, on a monthly or bi-monthly basis, using best professional practices.

However, subdivision (b) of Water Code section 531.10 provides "Nothing in this article shall be construed to require the implementation of water measurement programs or practices that are not locally cost effective." The Water Conservation Act and Regulations remove this limitation and, instead, mandate measurement devices at each farm-gate regardless local cost effectiveness.

The Regulations expand and amplify the Water Conservation Act by requiring, among other items, that existing measurement devices be certified to be accurate within ±12% by volume and new or replacement devices to be ±5% by volume if laboratory certified or ±10% by volume if using non-laboratory certification. (§ 597.3). Prior to the Regulations, there was no requirement to measure water delivered to the farm-gate of *each* single customer, with limited exception. (See, e.g., *Id.* subds. (a), (b)(1)). Rather, the Water Conservation Act permitted "aggregated farm-gate delivery data" (Water Code § 531.10, subd. (a)) and only required volumetric measurement of water delivered to customers with "sufficient accuracy" (*id.* § 10608.48, subd. (b)(1)). Prior to the Regulations, there was no obligation to certify (using a licensed engineer), test, inspect, analyze and report on water measurement devices in agricultural water management plans. (*Ibid.*; § 597.4). Prior to the Regulations, there was no requirement to include in Claimants' agricultural water management plans the information listed in § 597.4(e)(1) through (e)(4) of the Regulations.

Claimants incorporate by reference the test claim for the Water Conservation Act (10-TC-12) for further details regarding new activities and costs that were modified by the Water Conservation Act.

(C) The actual increased costs incurred by the claimant during the fiscal year for which the claim was filed to implement the alleged mandate.

The fiscal years of Biggs and Richvale run from January 1 through December 31 each year. Claimants current fiscal years are known as Fiscal Year 2013 and its immediate preceding fiscal years are known as Fiscal Year 2012.

Thus far Biggs and Richvale cumulatively incurred approximately $330,000.00 in direct and indirect costs in complying with the Regulation. Claimants estimate a cumulative expenditure of approximately $135,000.00 in Fiscal Year 2013 to comply with the Regulations' mandates. Claimants total costs of complying with the Regulations are expected to be higher in future fiscal years because the Regulations were finalized by the Office of Administrative Law on July 11, 2012, and Claimants have just started to comply with the mandates contained therein.

(D) The actual or estimated annual costs that will be incurred by the claimant to implement the alleged mandate during the fiscal year immediately following the fiscal year for which the claim was filed.

Claimants' next fiscal years are Fiscal Year 2014 (January 1, 2014, through December 31, 2014). It is expected that Claimants costs of complying with the Regulations will be greater than those estimated in Fiscal Year 2012. Richvale estimates that its direct and indirect costs in complying with the Regulations will far exceed the $1000.00 jurisdictional limit in Fiscal Year 2014 and believes costs would be cumulatively in excess of $1,600,000.00 through 2020.

Biggs estimates that its direct and indirect costs in complying with the Regulations will far exceed the $1000.00 jurisdictional limit in Fiscal Year 2014 and believes costs would be cumulatively in excess of $2,000,000.00 through 2020.

(E) A statewide cost estimate of increased costs that all local agencies or school districts will incur to implement the alleged mandate during the fiscal year immediately following the fiscal year for which the claim was filed.

There are a number of variables that make accurate estimation of the statewide costs of the mandate difficult. It is unknown, for example, how many "agricultural water suppliers" there are subject to the Regulations' mandates and are local public agencies eligible for reimbursement for the mandates. Notwithstanding these variables, it appears likely that the costs of the mandate will exceed $10,000,000.00 for agricultural water suppliers per year statewide.

(F) Identification of all the following funding sources available for this program:

(i) Dedicated state funds

Claimants do not receive any dedicated state funds for implementation of the Regulations or for any other purpose. Claimants are unaware of any dedicated state funds currently available for implementing the Regulations' mandates.

(ii) Dedicated federal funds

Claimants do not receive any dedicated federal funds for implementation of the Regulations or for any other purpose. Claimants are unaware of any dedicated federal funds currently available to implement the Regulations' mandates.

(iii) Other nonlocal agency funds

Claimants do not receive any other nonlocal agency funds for implementation of the Regulations or for any other purpose. Claimants are unaware of any other nonlocal agency funds currently available for implementing the Regulations' mandates.

(iv) The local agency's general purpose funds

Because the cost of complying with the Regulations' mandates exceeds the amount of dedicated funds Claimants receive for such services, Claimants must use some of their general purpose funds to make up the difference and comply with the mandates.

(v) Fee authority to offset costs

Claimants are unaware of any authority to assess a fee for complying with the Regulations' mandates to offset the costs agricultural water measurement. Claimants, as local public agencies, are subject to Proposition 218, which divests Claimants of authority to impose assessments or increase service fees without the consent and authorization of Claimants' landowners (which may be withheld despite the Regulations' mandates).

(G) Identification of prior mandate determinations made by the Board of Control or the Commission on State Mandates that may be related to the alleged mandate

As already noted, this test claim is related to the pending test claim challenging the Water Conservation Act of 2009 (10-TC-12). Except as noted, and after diligent inquiry, Claimants have concluded that no prior test claims have been submitted to the Board of Control and/or the Commission on State Mandates on the issue of whether the Regulations' provisions constitute a reimbursable state mandate.

(H) Identification of a legislatively determined mandate pursuant to Government Code section 17573 that is on the same statute of executive order

After diligent inquiry, Claimants have concluded that no prior joint requests have been made to the California Legislature to determine if the Regulations constitutes a reimbursable state mandate.

SECTION 6

DECLARATIONS

In Support of Joint Test Claims In Re Agricultural Water Measurement

Claimants

Biggs-West Gridley Water District

Richvale Irrigation District

Declaration of Sean Earley on Behalf of
Richvale Irrigation District in Support of the Test Claim

I, Sean Earley, declare as follows:

1. I make this declaration based on my personal knowledge, except for matters set forth herein on information and belief, and as to those matters I believe them to be true, and if called upon to testify, I could and would competently testify to the matters set forth herein under oath.
2. I am employed by Richvale Irrigation District (hereinafter "Richvale") as its General Manager
3. I have held my current position since September 10, 2012. My duties include managing the day to day operations of Richvale, including overseeing 6 employees. I report to Richvale's Board of Directors, which holds a regular monthly meeting on the 3rd Thursday of each month.
4. I have reviewed the regulations adopted in the California Code of Regulations, Title 23, Division 2, Chapter 5.1, Article 2 (Agricultural Water Measurement) (hereinafter "Regulations") approved by the Office of Administrative Law on July 11, 2012, and am familiar with the requirements of the Regulations as they apply to Richvale. I have reviewed the narrative accompanying the test claim filing and, as to those matters applicable to Ricvhale, attest to the truth of the statements made therein.
5. Based on my understanding of the requirements of the Regulations, Richvale is an "agricultural water supplier" and subject to the Regulations' mandates applicable to agricultural water suppliers. It is my belief that the Regulations constitute a new program and/or a higher level of service that was not mandated prior to the Regulations and which are almost exclusively unique to local governmental entities like Richvale. I am informed and believe and on that basis declare that the new programs and/or higher levels of service mandated by the Regulations include:
   a. Acquiring and/or retrofitting measuring devices to measuring the volume of water delivered to Richvale's customers using best professional practices to achieve accuracy of ±12% by volume for existing measuring devices, ±5% by volume for new

or replacement if laboratory certified, or ±10% by volume if using non-laboratory certification; and

b. Certifying, inspecting, analyzing and reporting on the water measurement devices in Richvale's agricultural water management plan; and
c. Retaining records of compliance with the Regulations for 10 years; and
d. Maintenance, operation, repair and replacement of the agricultural measurement devices on an annual and as-needed basis.

6. None of the new programs or higher levels of service described above and in the test claim narrative were required prior to the Regulations' enactment.
7. I am informed and believe and on that basis declare that each of the new programs and/or higher levels of service described in paragraph 5 exceed $1,000 to implement.
8. Richvale's current Fiscal Year 2013 runs from January 1, 2013, through December 31, 2013. To date, Richvale has incurred approximately $180,000.00 in direct and indirect costs in beginning to implement the Regulations' mandates. I estimate that Richvale will expend approximately $85,000.00 in Fiscal Year 2013 to comply with the Regulations' mandates.
9. Estimating the exact cost in Fiscal Year 2014 and future fiscal years is difficult to predict at this time. I am informed and believe and on that basis declare that the direct and indirect costs of compliance with the Regulations on Richvale will exceed the $1,000 jurisdictional limit per Fiscal Year and cumulatively through 2020 will exceed $1,600,000.00 and could possibly be much more. Richvale currently does not implement farm-gate measurement and, instead, charges for water on the basis of acreage serviced. Thus, in order to comply with the Regulations, Richvale must install and/or retrofit existing measurement devices at each of its approximately 312 farm-gate turnouts at an estimated cost of $3,500.00 per turnout. Richvale's labor costs will dramatically increase to maintain and operate the farm-gate measurement devices.
10. The Regulations do not generally apply to all residents and entities in the State of California. I am informed and believe and on that basis declare that the predominant majority of "agricultural water suppliers" are local governmental agencies such as Richvale.

Accordingly, it is my belief that the Regulations impose unique requirements primarily on local agencies.

11. The Regulations are mandated by the State of California, Department of Water Resources, not as a result of any federal requirement that requires water measurement or conservation or related measures.
12. Richvale does not receive an annual share of property tax revenue. Accordingly, property tax revenue is neither available nor sufficient to cover the costs of the Regulations' mandates.
13. Richvale does not receive any dedicated funds for implementation of the Regulations or for any other purpose; nor am I aware of any dedicated state funds currently available for implementation of the Regulations. Richvale does not receive any dedicated federal funds for implementation of the Regulations or for any other purpose; nor am I aware of any dedicated federal funds currently available for implementation of the Regulations. Richvale does not receive any other nonlocal agency funds for implementation of the Regulations or for any other purpose; nor am I aware of any nonlocal agency funds currently available for implementation of the Regulations. Accordingly, because the anticipated costs of complying with the Regulations' mandates exceed the amount of dedicated funds Richvale receives for such services, Richvale must use some of its general purpose property tax funds – of which, it receives zero dollars – to make up the shortfall and comply with the Regulations' mandates.
14. I am unaware of any authority available to Richvale to assess a fee for complying with the Regulations' mandates. Richvale is subject to Proposition 218, which divests Richvale of Authority to impose assessments or increase fees without the consent and authorization of its landowners and/or customers. Given this lack of authority, it is noteworthy that Richvale's customers could reject an assessment or fee increase, yet still be subject to the Regulations' mandates.
15. I am informed by Richvale's legal counsel, Dustin C. Cooper, that this test claim is related to the pending test claim challenging the Water Conservation Act of 2009 (10-TC-12). I am also informed by Mr. Cooper that there are no other test claims addressing the issue of whether the Regulations constitute reimbursable state mandates. I am also informed by Mr.

Cooper that there are no previous joint requests made to the California Legislature to determine if the Regulations constitute reimbursable state mandates.

I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct. Executed this the 14 day of FEBRUARY, 2013, at Richvale, California.

SEAN EARLEY

Declaration of Eugene Massa, Jr. on Behalf of
Biggs-West Gridley Water District in Support of the Test Claim

I, Eugene Massa, Jr., declare as follows:

1. I make this declaration based on my personal knowledge, except for matters set forth herein on information and belief, and as to those matters I believe them to be true, and if called upon to testify I could and would competently testify to the matters set forth herein under oath.
2. I am employed by Biggs-West Gridley Water District (hereinafter "Biggs") as its General Manager.
3. I have held my current position since December 1, 2011. My duties include managing the day to day operations of Biggs, including overseeing four fulltime employees and two seasonal employees. I report to Biggs' Board of Directors, which holds monthly meetings on the third Wednesday of every month.
4. I have reviewed the regulations adopted in the California Code of Regulations, Title 23, Division 2, Chapter 5.1, Article 2 (Agricultural Water Measurement) (hereinafter "Regulations") approved by the Office of Administrative Law on July 11, 2012, and am familiar with the requirements of the Regulations as they apply to Biggs. I have reviewed the narrative accompanying the test claim filing and, as to those matters applicable to Biggs, attest to the truth of the statements made therein.
5. Based on my understanding of the requirements of the Regulations, Biggs is an "agricultural water supplier" and subject to the Regulations' mandates applicable to agricultural water suppliers. It is my belief that the Regulations constitute a new program and/or a higher level of service that was not mandated prior to the Regulations and which are almost exclusively unique to local governmental entities like Biggs. I am informed and believe and on that basis declare that the new programs and/or higher levels of service mandated by the Regulations include:
    a. Acquiring and/or retrofitting measuring devices to measuring the volume of water delivered to Biggs's customers using best professional practices to achieve accuracy of ±12% by volume for existing measuring devices, ±5% by volume for new or

replacement if laboratory certified, or ±10% by volume if using non-laboratory certification; and

b. Certifying, inspecting, analyzing and reporting on the water measurement devices in Biggs's agricultural water management plan; and
c. Retaining records of compliance with the Regulations for 10 years; and
d. Maintenance, operation, repair and replacement of the agricultural measurement devices on an annual and as-needed basis.

6. None of the new programs or higher levels of service described above and in the test claim narrative were required prior to the Regulations' enactment.
7. I am informed and believe and on that basis declare that each of the new programs and/or higher levels of service described in paragraph 5 exceed $1,000 to implement.
8. Biggs's current Fiscal Year 2013 runs from January 1, 2013, through December 31, 2013. To date, Biggs has incurred approximately $150,000.00 in direct and indirect costs in beginning to implement the Regulations' mandates. I estimate that Biggs will expend approximately $50,000.00 in Fiscal Year 2013.
9. Estimating the exact cost in Fiscal Year 2014 and future fiscal years is difficult to predict at this time. I am informed and believe and on that basis declare that the direct and indirect costs of compliance with the Regulations on Biggs will exceed the $1,000 jurisdictional limit per Fiscal Year and cumulatively through 2020 will exceed $2,000,000.00 and could possibly be much more. Biggs currently does not implement farm-gate measurement and, instead, charges for water on the basis of crop usage and a not to exceed number of irrigation (rice is charged a flat per acre fee). Thus, in order to comply with the Regulations, Biggs must install and/or retrofit existing measurement devices at each of its approximately 390 farm-gate turnouts at an estimated cost of $3,488.00 per turnout. Biggs's labor costs will dramatically increase to maintain and operate the farm-gate measurement devices.
10. The Regulations do not generally apply to all residents and entities in the State of California. I am informed and believe and on that basis declare that the predominant majority of "agricultural water suppliers" are local governmental agencies such as Biggs. Accordingly, it is my belief that the Regulations impose unique requirements primarily on local agencies.

11. The Regulations are mandated by the State of California, Department of Water Resources, not as a result of any federal requirement that requires water measurement or conservation or related measures.
12. Biggs receives an annual share of property tax revenue. For Fiscal Year 2013 the amount of property tax revenue is expected to be approximately $60,000.00. Along with other demands on these funds, property tax revenue is not sufficient to cover the costs of the Regulations' mandates.
13. Biggs does not receive any dedicated funds for implementation of the Regulations or for any other purpose; nor am I aware of any dedicated state funds currently available for implementation of the Regulations. Biggs does not receive any dedicated federal funds for implementation of the Regulations or for any other purpose; nor am I aware of any dedicated federal funds currently available for implementation of the Regulations. Biggs does not receive any other nonlocal agency funds for implementation of the Regulations or for any other purpose; nor am I aware of any nonlocal agency funds currently available for implementation of the Regulations. Accordingly, because the anticipated costs of complying with the Regulations' mandates exceed the amount of dedicated funds Biggs receives for such services, Biggs must use some of its general purpose property tax funds to make up the shortfall and comply with the Regulations' mandates.
14. I am unaware of any authority available to Biggs to assess a fee for complying with the Regulations' mandates. Biggs is subject to Proposition 218, which divests Biggs of Authority to impose assessments or increase fees without the consent and authorization of its landowners and/or customers. Given this lack of authority, it is noteworthy that Biggs's customers could reject an assessment or fee increase, yet still be subject to the Regulations' mandates.
15. I am informed by Biggs's legal counsel, Dustin C. Cooper, that this test claim is related to the pending test claim challenging the Water Conservation Act of 2009 (10-TC-12). I am also informed by Mr. Cooper that there are no other test claims addressing the issue of whether the Regulations constitute reimbursable state mandates. I am also informed by Mr. Cooper

that there are no previous joint requests made to the California Legislature to determine if the Regulations constitute reimbursable state mandates.

I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct. Executed this 22nd day of February, 2013, at Gridley, California.

EUGENE MASSA, JR.

Declaration of Grant Davids on Behalf of
Biggs-West Gridley Water District and Richvale Irrigation District
in Support of the Test Claim

I, Grant Davids, declare as follows:

1. I am the founder, principal engineer and president of Davids Engineering, Inc. and am a Registered Agricultural Engineer (No. AG00431) and Registered Civil Engineer (No. C47199) in California. I have a Bachelor of Science degree in agricultural engineering from Cal Poly San Luis Obispo and approximately 36 years of professional experience. Most of my experience is related to agricultural water management, focused primarily at the water supplier and on-farm levels. I have personally conducted and supervised several investigations involving measurement of agricultural water suppliers, flow measurement accuracy and development of cost estimates for flow measurement facilities.
2. I was retained by both Richvale Irrigation District and Biggs-West Gridley Water District to assist them in complying with the Water Conservation Act of 2009 and the Agricultural Water Measurement regulations ("Regulations").
3. Attached and incorporated herein as Exhibit A is a true and correct copy of the Evaluation of Customer Delivery Measurement Options ("Biggs Evaluation") my firm prepared on behalf of Biggs-West Gridley Water District. The Biggs Evaluation analyzes various approaches to comply with the Water Conservation Act and accompanying Regulations. It also includes my estimate of installation and ongoing maintenance and operation costs for each compliance approach. The installation costs range from approximately $1.36 million to $2.62 million, depending on approach, while annual maintenance and operation costs range from approximately $71,000 to $153,000 depending on approach.
4. The Board of Directors of Biggs-West Gridley Water District considered the Biggs Evaluation at its board meeting held on January 4, 2013, and adopted Approach 2 (predominately utilizing Remote Tracker measuring devices) as the optimal alternative to comply with the Regulations' mandates.

5. Attached and incorporated herein as Exhibit B is a true and correct copy of the Evaluation of Customer Delivery Measurement Options ("Richvale Evaluation") my firm prepared on behalf of Richvale Irrigation District. The Richvale Evaluation analyzes various approaches to comply with the Water Conservation Act and accompanying Regulations. It also includes my estimate of installation and ongoing maintenance and operation costs for each compliance approach. The installation costs range from approximately $763,000 to $1.95 million, depending on approach, while annual maintenance and operation costs range from approximately $63,000 to $140,000 depending on approach.
6. The Board of Directors of Richvale Irrigation District considered the Richvale Evaluation at its board meeting held on held on January 17, 2013, and adopted Approach 2 (utilizing Remote Tracker measuring devices) as the optimal alternative to comply with the Regulations' mandates.

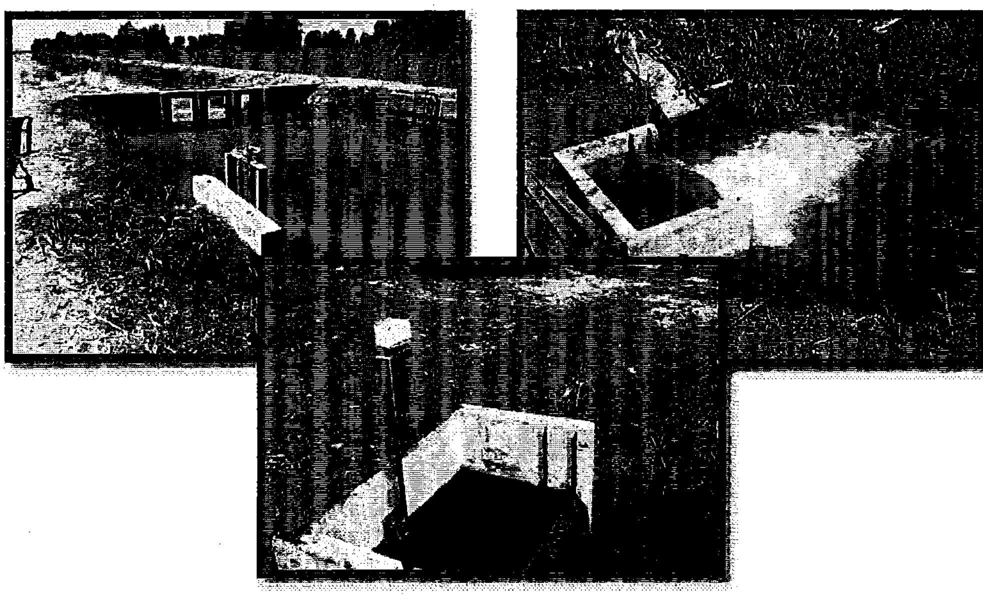
I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct. Executed this the 25th day of February, 2013, at Davis, California.

[signature]
GRANT DAVIDS

Biggs-West Gridley Water District

Evaluation of Customer Delivery Measurement Options

Butte County, California



Prepared by

DAVIDS
ENGINEERING, INC

December 2012

Contents

Abbreviations

ADV	Acoustic Doppler Velocimeter
AF	acre-feet
BWGWD	Biggs-West Gridley Water District
CCR	California Code of Regulations
CDMP	Customer Delivery Measurement Plan
cfs	cubic feet per second
DWR	California Department of Water Resources
ft	feet/foot
ft/s	feet per second
gpm	gallons per minute
RID	Richvale Irrigation District
SNR	Signal-to-Noise Ratio
WCD	Wireless Computing Device
WIS	Water Information System
WMM	U.S. Bureau of Reclamation Water Measurement Manual
WSE	Water Surface Elevation
WWAN	Wireless Wide Area Network
WWVS	Wireless Water Velocity Sensor

List of Figures

List of Tables

List of Appendices

ES-1.0 Executive Summary

ES-1.1 Introduction

Biggs-West Gridley Water District (District or BWGWD) is located in the Sacramento Valley in southern Butte County, Northern California. The District operates and maintains a canal and lateral distribution system that supplies water to roughly 32,000 acres. The primary crop grown within the District is rice. BWGWD's service area also includes portions of the Gray Lodge Wildlife Management Area. The District holds pre-1914 water rights to Feather River water in conjunction with three other districts that make up the Joint Water Districts Board (Richvale Irrigation District, Butte Water District and Sutter Extension Water District).

Due to the unique characteristics and measurement challenges associated with rice water delivery, farm turnout measurement has evolved differently in BWGWD (and in most other rice-dominated water suppliers) as compared to some other suppliers in California. Historically, the District's canal system has been operated based on the management of canal water levels (or pools). With canal water levels held at targeted elevations, certain field-specific gate settings will deliver the necessary rice flood up and maintenance flows. The field-specific gate settings have been determined from years of experience and have been calibrated to deliver sufficient water without causing excessive tailwater. Operating in this manner, appropriate amounts of water are delivered to rice fields without the need to measure delivery rates or volumes. In summary, the operation consists of setting and adjusting turnout gate opening as needed to maintain desired field conditions and adjusting water deliveries into canals as needed to maintain targeted water levels. Flow adjustments are made based on approximations and rules of thumb, and there has been no need to measure water precisely to achieve "good" water management, provided that field tailwater and canal spills are held within reasonable limits.

Senate Bill X7-7 (the "Water Conservation Act") was enacted in November 2009, requiring all water suppliers to increase water use efficiency. Agricultural water suppliers, such as BWGWD, are mandated to prepare and adopt agricultural management plans by December 31, 2012, and update those plans by December 31, 2015, and every 5 years thereafter. The Water Conservation Act included Water Code section 10608.48(i)(1) directing the California Department of Water Resources to adopt regulations providing for a range of options that agricultural water suppliers may use to implement volumetric measurement of farm-gate water deliveries. The resulting regulation, California Code of Regulations Title 23 Division 2 Chapter 5.1 Article 2 Section 597 et seq. (CCR 23 §597), mandates that, on or before July 31, 2012, agricultural water suppliers subject to the law shall measure the volume of water delivered to customers with sufficient accuracy to:

- Enable reporting of aggregated farm-gate delivery data to the State and
- Adopt a pricing structure based at least in part on the quantity of water delivered.

CCR 23 §597 requires that existing farm turnouts like those in the District have a measurement accuracy of ±12 percent by volume, meaning that the measured volume of water delivered at each farm-gate (i.e.

turnout) must be no greater than 12 percent more, or 12 percent less, than the actual volume delivered. Additionally, any new or replacement measurement devices installed must be accurate to within:

- ±5 percent by volume in the laboratory if using a laboratory certification;
- ±10 percent by volume in the field if using a non-laboratory certification

The regulation mandates that an accuracy certification be performed by either: (1) field testing of a random and statistically representative sample of existing farm turnouts, (2) field inspections and analysis of every existing farm turnout, with the testing or inspections documented by a registered engineer, or (3) a laboratory certification.

The purpose of this document is to summarize the activities and analysis performed by Davids Engineering during 2012 in support of the District's evaluation of options for customer delivery measurement that are mandated by CCR 23 §597. The evaluation of options was comprised of the following three tasks:

1. Preparing an inventory of BWGWD delivery gates, including establishing GPS coordinates and critical physical characteristics, including turnout pipe size, gate type and available head.

2. Pilot testing of RemoteTracker operation, and developing and testing measurement data collection and customer billing processes during the 2012 irrigation season.

3. Evaluating alternative measurement devices and compliance approaches, including estimated capital costs.

This report documents the work completed according to the three tasks described above. The report is organized into the following five sections:

- **1.0 Introduction** - Provides information about BWGWD, its existing measurement practices, CCR 23 §597 and the purpose of this report
- **2.0 Farm Turnout Inventory** - Summarizes the findings of the farm turnout inventory
- **3.0 Alternative Measurement Devices** - Presents overviews of four measurement devices, including their respective abilities to meet the accuracy mandates of CCR 23 §597
- **4.0 Alternative Measurement Approaches** – Describes three measurement approaches for District-wide measurement based on the four measurement devices described in Section 3.0
- **5.0 Cost Estimates** - Provides reconnaissance-level capital cost estimates for the three measurement approaches developed in Section 4.0
- **6.0 Corrective Action Plan** - Presents basic overview of BWGWD's selection of a preferred measurement approach

ES-1.2 Farm Turnout Inventory

An inventory was performed during the 2012 irrigation season to identify all existing farm turnouts in the District and to characterize each farm turnout with respect to factors related to application of the four possible measurement devices evaluated.

Figure ES-1 provides a summary of the farm turnout inventory. A total of 359 farm turnouts were identified during the inventory. Of the total of 359 farm turnouts, 329 are served by supply canals and 30 are served by drainage channels (drains). Of the 329 farm turnouts served by supply canals, 321 turnouts operate by gravity and 8 are pumped. All 30 farm turnouts served by drains are pumped. Of the 321 gravity farm turnouts served by supply canals, 279 are controlled by orifice gates (gates) and 42 are controlled by other means (e.g. alfalfa valves, weir structures, or other). Just 29 of the 279 gate-controlled gravity farm turnouts have weir boxes. None of the 42 turnouts from supply canals controlled by other means have weir boxes.

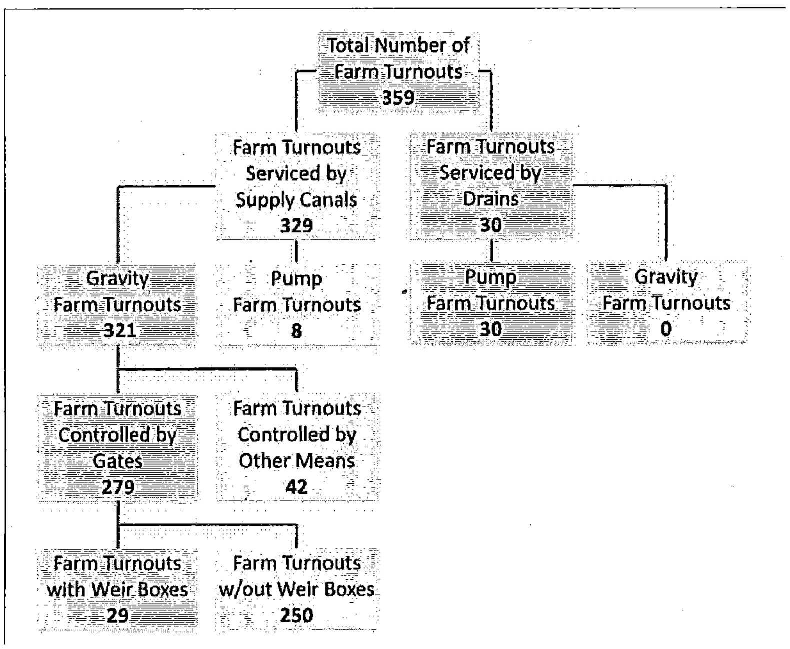


Figure ES-1. Farm Turnout Inventory Summary

ES-1.3 Alternative Measurement Devices

Four measurement devices were evaluated for potential application to achieve compliance with the CCR 23 §597 accuracy mandates. Although presently not used for measurement (see Section 1.2), the existing farm turnout gates could be used for measurement based on the submerged orifice principle. Alternatively, the weir boxes that have been installed at 29 turnout pipe outlets could be used for measurement based on the weir principle. These two existing devices are described further in Sections

3.1 and 3.2. In addition to the existing orifice gates and weir boxes, two new measurement devices were considered for compliance with CCR 23 §597, including the RemoteTracker system and propeller meters. These devices are discussed in Sections 3.3 and 3.4.

ES-1.3.1 Gates

Discharge through a submerged orifice gate can be computed with the Bernoulli equation. Data from previous investigations (Davids Engineering 2012) indicates that orifice gates can measure within the CCR 23 §597 accuracy mandate for existing measurement devices (±12 percent) provided that:

- Gate-specific variable coefficients based on multiple measurements at each gate are developed and
- Sufficient headloss occurs through the orifice gate to facilitate differential head measurements with low relative uncertainty (i.e. gates not operating near fully open position leading to minimal headloss through the gate and high relative uncertainties in water level measurements)

Hydraulic analysis of a 24 inch orifice gate indicates that, if a 12 cubic foot per second (cfs) flood flow is desired, a minimum of 0.5 feet of head is required. Based on this criterion, and the survey information discussed in Section 2.6, 172 of the 321 gravity farm turnouts (54 percent) have enough head to measure with an orifice gate.

ES-1.3.2 Weirs

Weirs installed in boxes placed at the turnout pipe outlets operate as standard suppressed rectangular weirs because the weir crest occupies the full box width (i.e., there is no flow contraction). Data from previous field investigations (Davids Engineering 2012) indicates that weirs can measure within the CCR 23 §597 accuracy mandate for existing measurement devices (±12 percent) provided that:

- Sufficient head (drop) is available between the canal water level and field water level
- Leakage through weir boards is stopped (or accounted for)

Hydraulic analysis of a four foot wide weir box indicates that, if a 12 cubic foot per second (cfs) flood flow is desired, a minimum of 1.5 feet of head is required. Based on this criterion, and the survey information discussed in Section 2.6, 123 of the 321 gravity farm turnouts (38 percent) have enough head to measure with a weir.

ES-1.3.3 RemoteTracker System

The RemoteTracker is an integrated turnout flow measurement, data management and volumetric accounting system developed by H2oTech specifically for agricultural water suppliers. The RemoteTracker system is comprised of (1) a wireless water velocity sensor, (2) a ruggedized tablet PC carried in the operator's vehicle and (3) a database residing on a file server connected to the tablet PC via a cellular internet connection. The RemoteTracker system is compliant with the volumetric accuracy mandates of CCR 23 §597. See Appendix A for a laboratory based volumetric accuracy certification of the RemoteTracker system. The RemoteTracker system can provide accurate flow data over all farm turnout head ranges.

ES-1.3.4 Propeller Meters

Using propellers meters for farm turnout measurement involves permanently installing a propeller meter device at each farm turnout. Propeller meters have a propeller that is placed in the outfall of the farm turnout pipe. Laboratory certifications of flow measurement accuracy are available for most commercially available propeller meters. Since propeller meters are permanently installed devices, volumetric accuracy is the same as flow rate accuracy. Therefore, propeller meters are compliant with the volumetric accuracy mandates of CCR 23 §597. Propeller meters can provide accurate flow data over all farm turnout head ranges.

ES-1.4 Alternative Measurement Approaches

To facilitate the development of measurement approaches, all farm turnouts within the District were classified into one of four farm turnout categories:

1. Low Head Gravity (i.e. head less than 0.5 feet),
2. Medium Head Gravity (i.e. head between 0.5 and 1.5 feet),
3. High Head Gravity (i.e. head greater than 1.5 feet) and
4. Pump (i.e. water supplied to fields via pumps).

Table ES-1 presents a summary of three measurement approaches considered to be potentially viable for the District to comply with CCR 23 §597. Table 5 indicates the number of turnouts falling in each category and, for each approach, the measurement device that would be used for each category. The three approaches are discussed in greater detail in Sections 4.1 through 4.3. None of the measurement devices discussed in Section 3 can be utilized to measure pump deliveries. Therefore, all three approaches include the use of totalizing flow meters at the 38 pump deliveries within the District.

Table ES-2 summarizes the different levels of turnout improvement needed for each of the farm turnout categories, and the number of turnouts in each improvement level. All measurement approaches require gravity farm turnouts to have an orifice gate and a weir box. All pump farm turnouts require a totalizing flow meter. The classifications have been developed to be mutually exclusive so that each farm turnout only corresponds with one improvement classification within the table, which facilitates the ability to sum the number of farm turnouts in each row to develop the total number or farm turnouts in each farm turnout category. The Gray Lodge project will be replacing or retrofitting a number of gravity farm turnouts in each classification; therefore, a 'Gray Lodge' classification is necessary to avoid double counting.

Table ES-1. Measurement Approach Summary

Farm Turnout Category	Count of Farm Turnout Categories	Measurement Devices		
		Approach 1 - Maximum Use of Existing Devices	Approach 2 - RemoteTracker System	Approach 3 - Propeller Metering Program
Low Head Gravity (H < 0.5 feet)	26	Propeller Meters	RemoteTracker System	Propeller Meters
Medium Head Gravity (0.5' < H < 1.5')	172	Orifice Gates		
High Head Gravity (H > 1.5'	123	Weir Boxes		
Pump	38	Totalizing Flow Meters	Totalizing Flow Meters	Totalizing Flow Meters

Table ES-2. Farm Turnout Improvement Classification Count Summary

Farm Turnout Category	Farm Turnout Improvement Classification Counts						Sum
	Requires Orifice Gate and Weir Box	Requires Orifice Gate Only	Requires Weir Box Only	Requires No Improvements	Improvements by Gray Lodge Project	Requires Totalizing Flow Meter	
Low Head Gravity (H < 0.5 feet)	10	0	11	4	1	n/a	26
Medium Head Gravity (0.5' < H < 1.5')	22	0	95	12	43	n/a	172
High Head Gravity (H > 1.5'	7	0	60	5	51	n/a	123
Pump	n/a	n/a	n/a	0	0	38	38
Totals	39	0	166	21	95	38	359

ES-1.4.1 Approach 1 - Maximum Use of Existing Devices

Approach 1 is based on maximizing the use of existing measurement devices; however, neither of the two existing measurement devices (i.e. orifice gates and weir boxes) alone unconditionally meets the volumetric accuracy mandates of CCR 23 §597 across all gravity farm turnouts. Therefore, to achieve maximum use of existing devices, a hybrid approach involving multiple measurement devices is necessary. Approach 1 utilizes weir boxes for high head gravity farm turnouts and orifice gates for medium head gravity farm turnouts. Propeller meters, a new device, would be used for low head gravity farm turnouts because neither gates nor weirs work under low head conditions. Measurement of the 38 pump deliveries in the District requires the installation of totalizing flow meters.

ES-1.4.2 Approach 2 - RemoteTracker System

Approach 2 involves the use of the RemoteTracker system at all gravity farm turnout categories (i.e. high head, medium head and low head gravity farm turnouts). Measurement of the 38 pump deliveries in the District requires the installation of totalizing flow meters.

ES-1.4.3 Approach 3 - Propeller Metering Program

Approach 3 involves the use of propeller meters at all gravity farm turnout categories (i.e. high head, medium head and low head gravity farm turnouts). Measurement of the 38 pump deliveries in the District requires the installation of totalizing flow meters.

ES-1.5 Reconnaissance-Level Cost Estimates

BWGWD, along with other agricultural and urban water suppliers, filed a Test Claim with the Commission on State Mandates alleging that the Water Conservation Act constitutes a reimbursable state mandate. That Test Claim is pending before the Commission and it is anticipated that a hearing will be held in September, 2013, and a decision will be made shortly thereafter. BWGWD, along with other agricultural water suppliers, are in the process of filing a supplemental Test Claim challenging CCR 23 § 597. If the Test Claims are successful, BWGWD will be entitled to reimbursement of all direct and indirect costs of compliance with the Water Conservation Act and 23 CCR § 597, including initial and annualized capital and maintenance and operation costs of farm-gate measurement devices.

Table ES-3 provides reconnaissance-level (1) initial capital, (2) annualized capital and (3) annual maintenance cost estimates for full scale implementation of the three measurement approaches discussed in Section 4. Each approach lists two possible scenarios regarding the farm turnouts within the Gray Lodge project. The left column reflects the annualized capital and maintenance cost under the conditions that certain improvement requirements for farm turnouts within the Gray Lodge project will be covered by an entity other than the District. The right column reflects the annualized capital and maintenance cost for all improvements including the farm turnouts within the Gray Lodge project. The annualized maintenance cost, which is unchanging in either scenario, will be the sole responsibility of the District. The last row provides the annualized capital and maintenance cost estimates. Differences among the three approaches with respect to operation costs (primarily labor and transportation) are not considered significant; therefore they are not included. A five percent interest rate was used for all calculations.

Table ES-3. Reconnaissance-Level Capital Cost Estimates for Three Measurement Approaches

Cost Category	Measurement Program Cost Estimate					
	Approach 1 - Maximum Use of Existing Devices		Approach 2 - RemoteTracker System		Approach 3 - Propeller Metering Program	
	With Gray Lodge Project	Without Gray Lodge Project	With Gray Lodge Project	Without Gray Lodge Project	With Gray Lodge Project	Without Gray Lodge Project
Initial Capital	$1,501,146	$1,713,538	$1,147,810	$1,360,202	$2,403,455	$2,615,848
Annualized Capital	$103,320	$116,016	$91,777	$104,473	$179,751	$192,447
Annualized Maintenance	$71,207		$70,999		$153,075	
Annualized Capital and Maintenance	**$174,527**	**$187,223**	**$162,776**	**$175,472**	**$332,826**	**$345,522**

ES-1.6 Corrective Action Plan

At a special, scheduled meeting on January 4, 2013, the BWGWD Board considered this report and the customer delivery measurement options presented herein. By unanimous vote, the Board accepted the report and adopted measurement Approach 2 - RemoteTracker System as the District's preferred approach for implementing a customer delivery measurement program. The program is intended to comply with the measurement accuracy standards specified in CCR 23 §597 and to be capable of supporting implementation of a water rate structure based at least in part on the volume of water delivered. Such a rate structure remains to be designed and adopted by the Board in the future.

Approach 2 has an estimated capital cost of $1,147,810 assuming that the Gray Lodge water conveyance project is implemented, or a cost of $1,360,202, if the Gray Lodge project does not proceed. Recognizing that these capital improvement costs are relatively large in comparison to the District's current revenue and operating budgets, the Board also unanimously agreed that the program will be implemented on a "pay-as-you-go" basis as discretionary revenues above operating and maintenance costs become available.

1.0 Introduction

1.1 Biggs-West Gridley Water District

Biggs-West Gridley Water District (District or BWGWD) is located in the Sacramento Valley in southern Butte County, Northern California. The District operates and maintains a canal and lateral distribution system that supplies water to roughly 32,000 acres. The primary crop grown within the District is rice. BWGWD's service area also includes portions of the Gray Lodge Wildlife Management Area. The District holds pre-1914 water rights to Feather River water in conjunction with three other districts that make up the Joint Water Districts Board (Richvale Irrigation District, Butte Water District and Sutter Extension Water District). Figure 1 shows the District's boundary, laterals, drains and turnouts.

1.2 Existing Measurement Practices

The large majority of the District's service area is planted to rice. There are essentially two different water delivery flow rates associated with irrigating a rice field: flood-up and maintenance. During flood-up, the goal is to quickly establish ponded water on the field. Flood-up deliveries typically range from 10 to 25 cubic feet per second (cfs), and can last from hours to days depending on field size and other factors. Once a rice field is flooded to the desired depth, the flow is decreased to a maintenance flow rate. Depending on field size, maintenance deliveries typically range from 1 to 6 cfs, and last for several weeks. During the maintenance period, fields may be drained and re-flooded one or more times for purposes of applying herbicides. The same delivery infrastructure is used to deliver both flood-up and maintenance flows.

Rice cultivation primarily occurs in river basin flood plains with very flat topography, resulting in small (or "low") "heads" (water surface elevation differences) between supply canals and the fields receiving water deliveries. Low heads make certain measurement devices unusable and can cause high measurement error. Measurement devices that are affected by low head include weirs, flumes, and orifices. Additionally, large ranges in delivery flow rates (e.g., 1 cfs during maintenance to 25 cfs during flood-up; see discussion above) pose challenges to certain measurement devices.

Due to these unique characteristics and measurement challenges associated with rice water delivery, farm turnout measurement has evolved differently in BWGWD (and in most other rice-dominated water suppliers) as compared to some other suppliers in California. Historically, the District's canal system has been operated based on the management of canal water levels (or pools). With canal water levels held at targeted elevations, certain field-specific gate settings will deliver the necessary rice flood up and maintenance flows. The field-specific gate settings have been determined from years of experience and have been calibrated to deliver sufficient water without causing excessive tailwater. Operating in this manner, appropriate amounts of water are delivered to rice fields without the need to measure delivery rates or volumes. In summary, the operation consists of setting and adjusting turnout gate opening as needed to maintain desired field conditions and adjusting water deliveries into canals as needed to

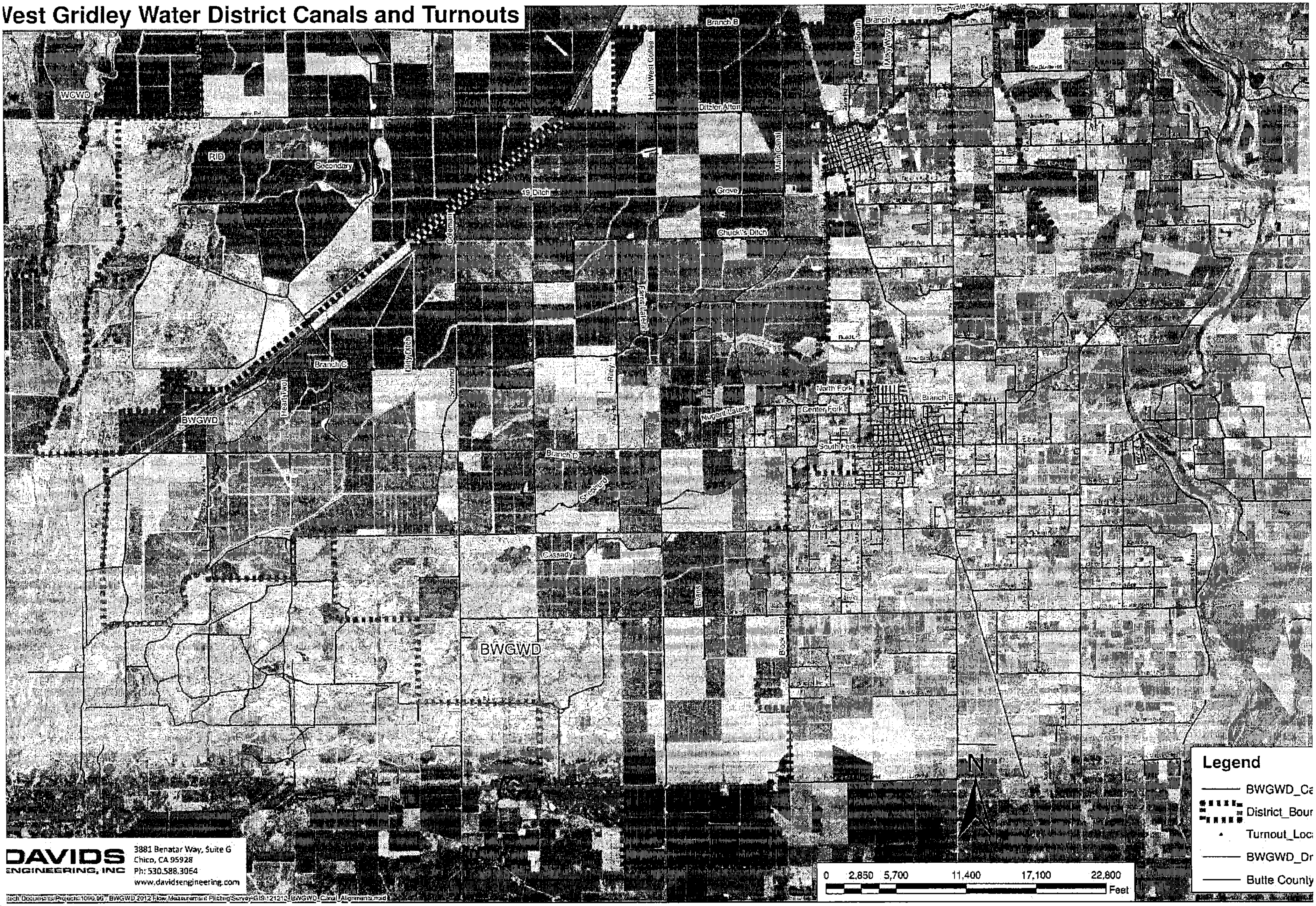


Figure 1. Biggs-West Gridley Water District Map Overview

maintain targeted water levels. Flow adjustments are made based on approximations and rules of thumb, and there has been no need to measure water precisely to achieve "good" water management, provided that field tailwater and canal spills are held within reasonable limits.

1.3 SBx7-7 (CCR 23 §597) Overview

The Comprehensive Water Package passed by the California State legislature in November 2009 consists of four policy bills and an $11.14 billion water bond. One of the policy bills (Senate Bill x7-7 or SBx7-7) addresses both urban and agricultural water conservation and, with respect to agriculture, includes new mandates regarding the accuracy of customer delivery measurement, applicable to agricultural water suppliers serving more than 25,000 acres. BWGWD serves more than 25,000 acres and therefore is an agricultural water supplier subject to the new regulation.

The California Department of Water Resources (DWR) was responsible for developing and adopting regulations pursuant to SBx7-7. The rule making process was formally launched during the latter half of 2010 and first half of 2011. DWR developed the draft regulation with the input and involvement of an Agricultural Stakeholder Committee comprised primarily of staff members from agricultural water suppliers and environmental advocacy organizations, plus some academics and consultants. On October 19, 2011, the Office of Administrative Law (OAL) disapproved the proposed regulations because they failed to comply with the clarity, consistency and necessity standards contained in Government Code section 11349.1, and DWR failed to adequately summarize and respond to each comment made regarding the proposed action, including comments of BWGWD. Ultimately, after a number of revisions, OAL approved DWR's agricultural water measurement regulations as California Code of Regulations Title 23 Division 2 Chapter 5.1 Article 2 Section 597 et seq. (CCR 23 §597) on July 11, 2012.

CCR 23 §597 requires that, on or before July 31, 2012, agricultural water suppliers subject to the law shall measure the volume of water delivered to customers with sufficient accuracy to:

- Enable reporting of aggregated farm-gate delivery data to the State and
- Adopt a pricing structure based at least in part on the quantity of water delivered.

CCR 23 §597 requires that existing farm turnouts[1] like those in the District have a measurement accuracy of ±12 percent by volume, meaning that the measured volume of water delivered at each farm-gate (i.e. turnout) must be no greater than 12 percent more, or 12 percent less, than the actual volume delivered. Additionally, any new or replacement measurement devices installed must be accurate to within:

- ±5 percent by volume in the laboratory if using a laboratory certification;
- ±10 percent by volume in the field if using a non-laboratory certification

[1] The use of "farm turnout" in this document is synonymous with "farm-gate" and "customer delivery point" utilized in CCR 23 §597.

The regulation requires that an accuracy certification be performed by either: (1) field testing of a random and statistically representative sample of existing farm turnouts, (2) field inspections and analysis of every existing farm turnout, with the testing or inspections documented by a registered engineer, or (3) a laboratory certification.

1.4 Purpose and Structure of Report

The purpose of this document is to summarize the activities and analysis performed by Davids Engineering during 2012 in support of the District's evaluation of options for customer delivery measurement that are compliant with CCR 23 §597. The evaluation of options was comprised of the following three tasks:

1. Preparing an inventory of BWGWD delivery gates, including establishing GPS coordinates and critical physical characteristics, including turnout pipe size, gate type and available head.
2. Pilot testing of RemoteTracker operation, and developing and testing measurement data collection and customer billing processes during the 2012 irrigation season.
3. Evaluating alternative measurement devices and compliance approaches, including estimated capital costs.

This report documents the work completed according to the three tasks described above. The report is organized into the following five sections:

- **1.0 Introduction** - Provides information about BWGWD, its existing measurement practices, CCR 23 §597 and the purpose of this report
- **2.0 Farm Turnout Inventory** - Summarizes the findings of the farm turnout inventory
- **3.0 Alternative Measurement Devices** - Presents overviews of four measurement devices, including their respective abilities to meet the accuracy mandates of CCR 23 §597
- **4.0 Alternative Measurement Approaches** - Describes three measurement approaches for District-wide measurement based on the four measurement devices described in Section 3.0
- **5.0 Cost Estimates** - Provides reconnaissance-level capital cost estimates for the three measurement approaches developed in Section 4.0
- **6.0 Corrective Action Plan** - Presents basic overview of BWGWD's selection of a preferred measurement approach

2.0 Farm Turnout Inventory

2.1 Inventory Data Collection

An inventory was performed during the 2012 irrigation season to identify all existing farm turnouts in the District and to characterize each farm turnout with respect to factors related to application of the four possible measurement devices evaluated. The following conditions/attributes were determined for each farm turnout:

- Turnout operation status (active/inactive)
- Crop currently being served (rice or other)
- Turnout type defined by unique combinations of certain conditions on the District side and farm side of the turnout
- Turnout gate manufacturer, configuration (square or round) and dimensions
- Structure/culvert/pipeline dimensions (lengths and diameters of critical hydraulic dimensions)
- Critical elevations (canal high water, field, field high water, top of structure)

Additionally, photographs were recorded of each farm turnout, focused on the key attributes noted above.

Figure 2 shows the form used to record inventory measurements and observations at each farm turnout.

Field Served by Turnout:		Gate Brand:		Bench Mark:	
Date:		Gate Type:		U/S WSE:	
Time In/Out:	/	Gate Size:		U/S HWM:	
District:		Closed/Dead Stem:	/	D/S WSE:	
Canal:		Weir Length:		D/S HWM:	
Barcode SKU:		Meter Type:		D/S Top Of Box:	
Pipe Inner Diameter:		Photos:	U/S D/S	Crown:	
Pipe Length/Type:	/	Flow Rate:			
Site Type:	Gate / Pump	Totalizer:			
Notes:					

Figure 2. Standard Farm Turnout Inventory Form

A database was developed to contain and enable convenient access to and analysis of the inventory data (e.g. photographs, critical elevations, crop type, etc.). The database was used to develop a Google Earth user interface that retrieves a tabular summary of a site's attributes and photographs to be viewed on-screen when the site is selected. Figure 3 shows a screen shot of several turnouts on the Ashley and Ditzler Afton Canals near Afton Road and Figure 4 shows a sample of the site detail accessed via the Google Earth user interface.

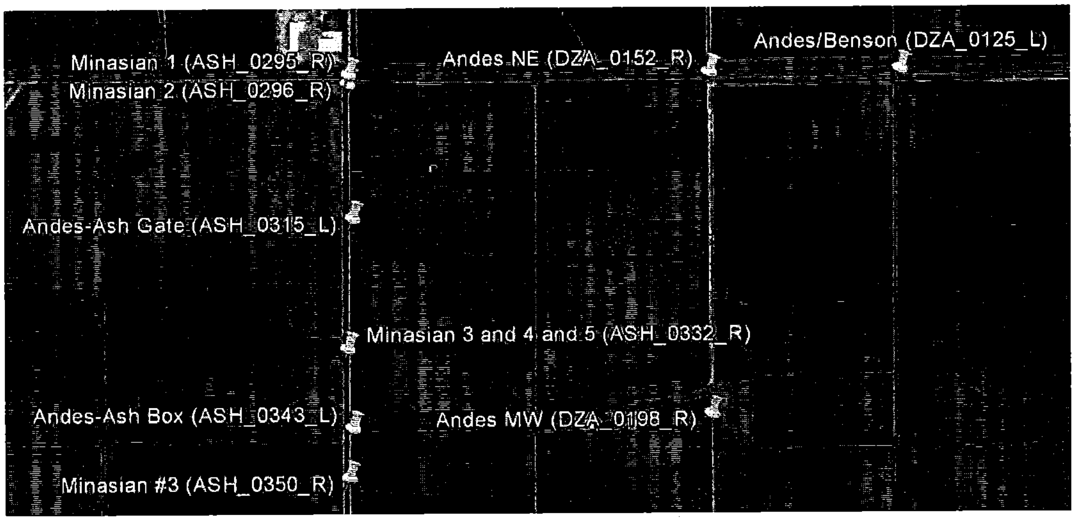
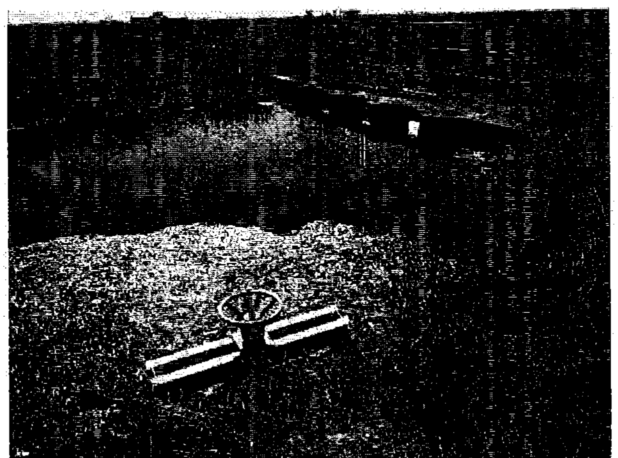


Figure 3. Google Earth Turnout Inventory Overview of the Ashley Canal near Afton Road

Minasian 3 and 4 and 5 (ASH_0332_R)



Common Name:	Minasian 3 and 4 and 5
Site ID:	ASH_0332_R
Canal:	Ashley (ASH)
Ride:	Chuck
Crop:	Rice
Site Type:	Gate
Measurement Method:	Manual
Gate Brand:	Gator Gates
Gate Type:	Rectangular
Gate Size (in):	30
Pipe Type:	Concrete
Pipe Inner Diameter (ft):	
Pipe Length (ft):	24
Weir Length (ft):	
Available Head (ft):	1.61

C:\Turnout_Inventory_BWGWD\Photos\Ashley (ASH)\ASH_0332_R

Figure 4. Sample of Inventory Detail Accessed via the Google Earth User Interface

2.2 Farm Turnout Inventory Summary

Figure 5 provides a summary of the farm turnout inventory. A total of 359 farm turnouts were identified during the inventory. Of the total of 359 farm turnouts, 329 are served by supply canals and 30 are served by drainage channels (drains). Of the 329 farm turnouts served by supply canals, 321 turnouts operate by gravity and 8 are pumped. All 30 farm turnouts served by drains are pumped. Of the 321 gravity farm turnouts served by supply canals, 279 are controlled by orifice gates (gates) and 42 are controlled by other means (e.g. alfalfa valves, weir structures, or other). Just 29 of the 279 gate-controlled gravity farm turnouts have weir boxes. None of the 42 turnouts from supply canals controlled by other means have weir boxes.

As part of the Gray Lodge Wildlife Area Water Supply Project[2] (Gray Lodge Project), the District will be replacing, or retrofitting in some cases, a total of 95 gravity farm turnouts along the Upper Belding, Traynor, Rising River, Lower Belding, Schwind and Cassady laterals. This represents about 30 percent of the District's 321 canal-fed gravity turnouts. The farm turnout (and other) modifications have been designed, but not yet constructed; thus, the information summarized below does not account for the improvements that will eventually be made to the 95 affected farm turnouts.

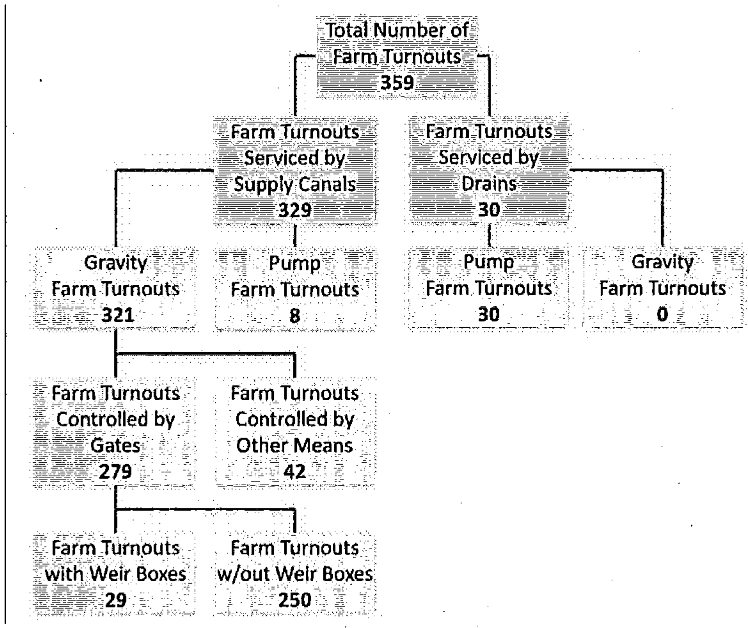


Figure 5. Farm Turnout Inventory Summary

2.3 Crop Types

Table 1 summarizes the District's farm turnouts according to the type of crop served during the 2012 irrigation season. Of the total 359 turnouts, 290 (or 81 percent) serve rice fields. The next most common crop types are orchards and pasture, which each account for 5 percent of the total turnout count. Additional crops include row crops, alfalfa and unknown crops.

[2] The District is presently implementing this project under a cooperative agreement with the U.S. Bureau of Reclamation (Reclamation). The project generally consists of canal widening and structure replacement along certain reaches of the District's water distribution that supply water to the wildlife area. The purpose of the project is to provide additional water to the wildlife area, made available by Reclamation, above the supplies received from the District and other sources.

Table 1. Turnout Distribution by Type of Crop Served during 2012

Crop Type							
	Rice	Orchard	Pasture	Row Crop	alfalfa	Unknown[3]	Total
Count	290	19	17	2	1	30	359

2.4 Farm Turnout Pipe Lengths

Farm turnout pipe lengths vary from less than 10 feet to over 70 feet. Table 2 provides a summary of the pipe lengths in the District.

Table 2. Summary of Pipe Lengths

Pipe Length								
	<10'	10'-20'	20'-30'	30'-50'	50'-70'	>70'	Unknown	Total
Count	8	77	113	53	21	16	71	359

2.5 Orifice Gate Characteristics

Table 3 summarizes the characteristics of the 279 existing orifice gates inventoried during the 2012 irrigation season. The dominant gate brand is Waterman Industries, accounting for 166 gates (59%). 122 farm turnouts have circular orifice gates, while 157 have rectangular orifice gates. The most common gate size (based on gate frame widths) is 24 inches (110 in total), followed by 14 to 16 inch and 18 inch (69 and 40 gates, respectively).

Table 3. Orifice Gate Inventory Summary

Gate Brand								
	Water-man	Armco	Mech. Assc.	Gator Gates	Fresno Valves	Generic[4]		Total
Count	166	25	13	15	2	58		279
Gate Type								
	Circular	Rectang-ular						Total
Count	122	157						279
Gate Dimensions								
	<14"	14"-16"	18"	20"	24"	26"-30"	26"-48"	Total
Count	19	69	40	6	110	18	17	279

[3] The 30 pump farm turnouts serviced by drains were inventoried via satellite imagery with District personnel. The crop types for these 30 farm turnouts are unknown because the sites were not being field inspected.
[4] 'Generic' gate brand indicates that there were no specific markings on the orifice gate that identified the gate manufacturer.

2.6 Turnout Head

Where possible, the farm turnout head (difference in typical upstream and downstream water surface elevations) was surveyed. The typical canal operating water level was used for the upstream level and the high water mark on the field side was used for the downstream level. If no downstream high water mark was evident, the downstream water level for rice fields was estimated to be six inches higher than the field elevation. Figure 6 displays a histogram of heads for the 321 gravity farm turnouts served by supply canals.

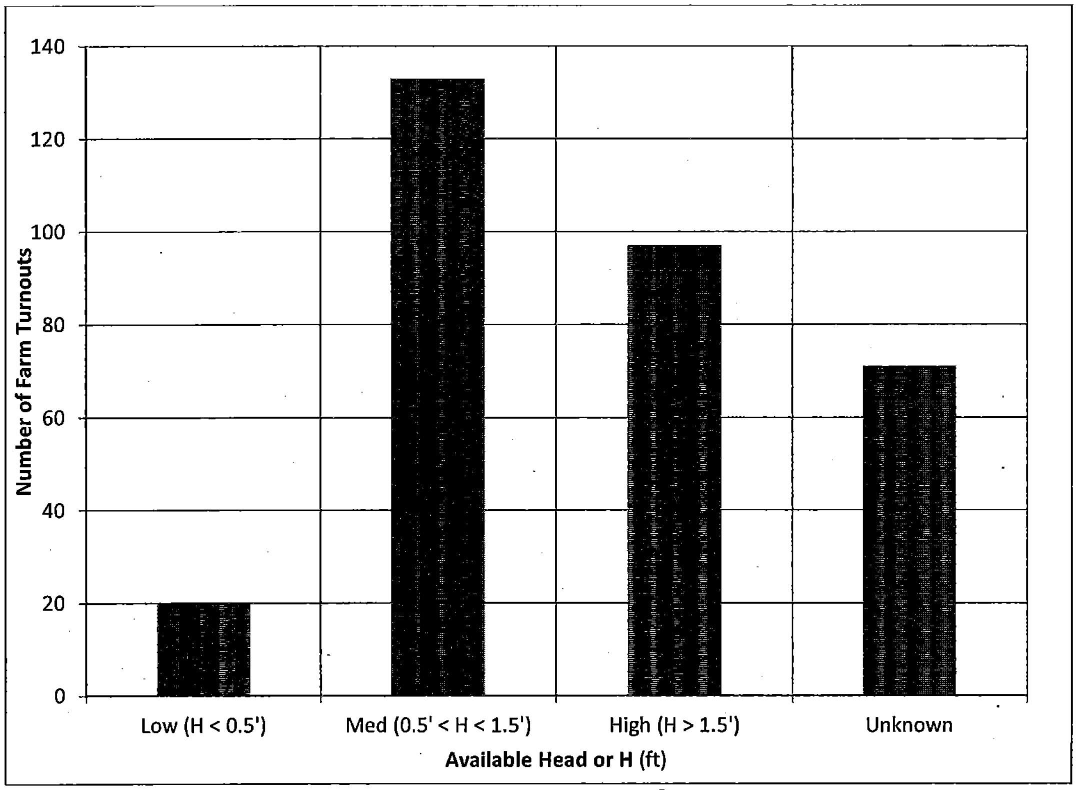


Figure 6. Turnout Head[5]

The gravity farm turnouts are classified into basic categories: low head (less than 0.5 feet), medium head (between 0.5 and 1.5 feet) and high head (greater than 1.5 feet). There are 20 low head gravity farm turnouts, 133 medium head gravity farm turnouts and 97 high head gravity farm turnouts. 71 gravity farm turnouts have an unknown amount head[6].

[5] Includes heads for only the 321 gravity farm turnouts served by supply canals.
[6] Farm turnout head was categorized as "unknown" category if the upstream or downstream water level could not be quantified with sufficient accuracy due to lack of physical access or lack of physical evidence (e.g. water stains) of typical operating water levels.

3.0 Alternative Measurement Devices

Four measurement devices were evaluated for potential application to achieve compliance with the CCR 23 §597 accuracy mandates. Although presently not used for measurement (see Section 1.2), the existing farm turnout gates could be used for measurement based on the submerged orifice principle. Alternatively, the weir boxes that have been installed at 29 turnout pipe outlets could be used for measurement based on the weir principle. These two existing devices are described further in Sections 3.1 and 3.2 below. In addition to the existing orifice gates and weir boxes, two new measurement devices were considered for compliance with CCR 23 §597, including the RemoteTracker system and propeller meters. These devices are discussed in Sections 3.3 and 3.4 below.

The discussion of each device concludes with an assessment of the device's ability to comply with the volumetric accuracy mandates of CCR 23 §597. With the exception of propeller meters, which would be permanently installed at each farm turnout, orifice gates, weir boxes and the RemoteTracker do not provide continuous records of flow rate over time; rather they provide "spot" measurements of flow rate at specific points in time. Accurate determinations of delivery volumes can be made with spot flow rate measurements if (1) the spot flow rate measurement and the actual average flow rate during the delivery event are similar and (2) accurate determinations of delivery durations are made. In Biggs-West Gridley Water District, canal water levels are controlled by a variety of structures, including standard check structures and orifice gates. However, farm-gate deliveries (i.e. the "delivery points" as defined by CCR 23 §597.2(a)(6)) are predominantly made through orifice gates. Delivery flow rates through orifice gates will vary if fluctuations occur in canal water levels[7] (i.e. upstream) or on-farm water levels (i.e. downstream). Therefore, an understanding of water level fluctuations is required to characterize the relationship between spot flow rate measurements and the actual average flow rates over time.

Analysis of continuous water level data recorded between 2004 and 2006 from eight sites on BWGWD canals indicates that the effects of fluctuating water levels on the accuracy of volumetric measurements developed from "spot" flow measurements are negligible. A similar analysis performed by the California Polytechnic State University San Luis Obispo Irrigation Training and Research Center reached a similar conclusion (Burt and Geer 2012).

Therefore, the discussion of compliance with CCR 23 §597 focuses on each device's ability to accurately measurement flow rate, even though the regulation is for volumetric accuracy.

[7] Canal water levels fluctuate because it is not possible to set control gates perfectly as agricultural water demands change during an irrigation season.

3.1 Orifice Gates

3.1.1 Overview

Discharge through a submerged orifice gate (example shown in Figure 7) can be computed with the Bernoulli Equation (Equation 1), where C is an empirical coefficient used to account for energy loss (i.e. entrance/exit losses through the orifice), flow contraction (i.e. vena contracta), and velocity of approach

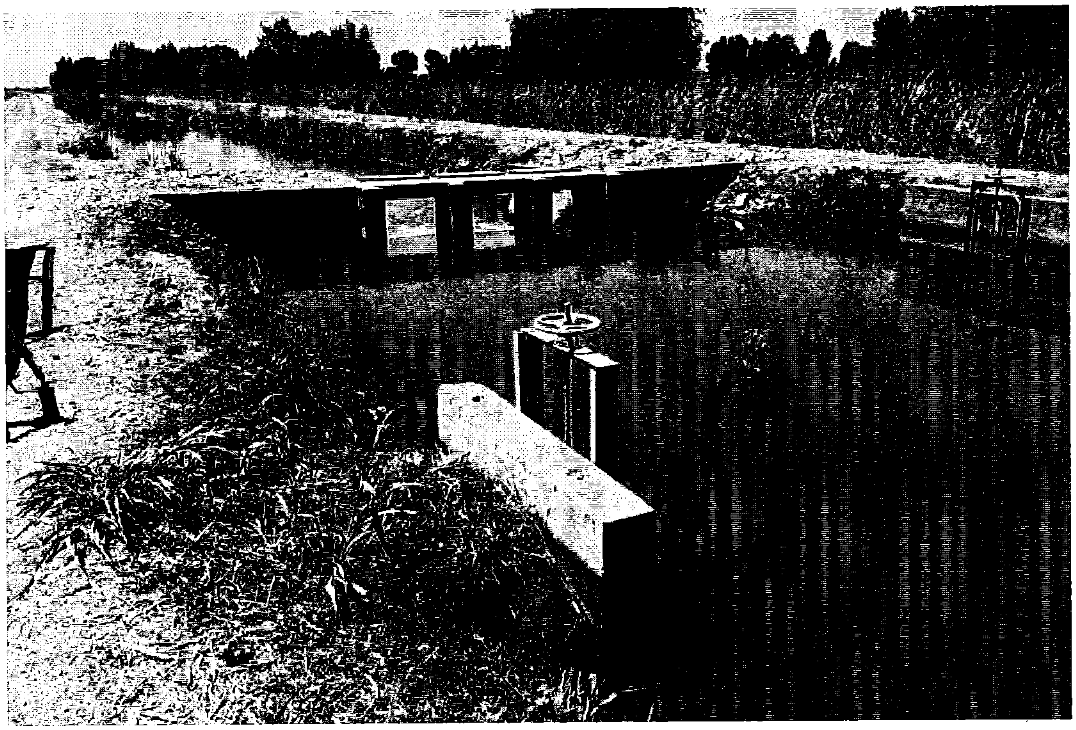


Figure 7. Typical Orifice Gate Farm Turnout on the Green Lateral (GRN_0620_L)

(Water Measurement Manual (WMM) 2001; King 1963), A is the cross section flow area through the gate (dependent on gate opening), h is the head loss through the orifice and g is the gravitational constant.

$$Q = C * A * \sqrt{2 * g * h}$$ ***(Equation 1 – Lindeburg 2008)***

The difference between water surface elevations (WSE) upstream and downstream of the orifice gate indicate the head loss, and the flow area is determined from the gate size and the gate opening, which is indicated by the gate stem position. The stem position is the measured distance between the highest part of the gate 'lift nut' and the top of the gate stem. Dead-stem is defined as the stem position at the onset of flow when moving the gate from a closed to open position. Full-stem is defined as the stem position when the gate is opened for operation. A term representing the actual gate opening called "good-stem" was then defined as the difference between full-stem and dead-stem (Equation 2).

$$Goodstem = (Fullstem) - (Deadstem) \qquad \textbf{(Equation 2)}$$

"Good-stem" is used to calculate the actual area of the opening with the gate size and gate type (circular or rectangular) known.

3.1.2 Compliance with CCR 23 §597

Data from previous investigations (Davids Engineering 2012) indicates that orifice gates can measure within the CCR 23 §597 accuracy mandate for existing measurement devices (±12 percent) provided that:

- Gate-specific variable coefficients based on multiple measurements at each gate are developed and
- Sufficient headloss occurs through the orifice gate to facilitate differential head measurements with low relative uncertainty (i.e. gates not operating near fully open position leading to minimal headloss through the gate and high relative uncertainties in water level measurements)

Results of an evaluation of orifice coefficients are summarized below in Table 4, including indication of whether the coefficient is adequate for meeting the ±12 percent accuracy mandate for existing devices. Using the standard "rating table" coefficients, 27 percent of the orifice measurements fall within ±12 percent of the verification measurements. Using a "District-wide constant" coefficient, just 11 percent of the orifice measurements fall within ±12 percent of the verification measurements. Using a "gate-specific constant" coefficient, 25 percent of the orifice measurements fall within ±12 percent of the verification measurements. Finally, using a "gate-specific variable" coefficient, 96 percent of the orifice measurements fall within ±12 percent of the verification measurements. Only "gate-specific variable" coefficients ensure that at least 75 percent of the sample falls within ±12 percent of the verification measurements. If orifice gates were used for measurement, every gate would need to have a customized variable coefficient developed for it using field testing procedures.

Hydraulic analysis of a 24 inch orifice gate indicates that, if a 12 cubic foot per second[8] (cfs) flood flow is desired, a minimum of 0.5 feet of head is required[9]. Based on this criterion, and the survey information discussed in Section 2.6, 172 of the 321 gravity farm turnouts (54 percent) have enough head to measure with an orifice gate.

[8] 12 cfs is used throughout the remainder of this document as the minimum acceptable delivery flow rate for complaint devices.

[9] This analysis assumes that a 0.3 foot headloss through the orifice gate is required to facilitate differential head measurements with low relative uncertainty. The additional 0.2 feet of head is required for major and minor head losses between the orifice gate and the field.

Table 4. Overview of Orifice Gate Measurements with Different Methods of Calculating Orifice Coefficient

Basis for Coefficient	Meets SBx7-7 ±12 Percent Accuracy?	% of Farm Turnouts Within ±12 Percent
Standard "rating table" coefficients	No	27%
District-wide constant coefficient derived from measurements at a sample of gates	No	11%
Gate-specific constant coefficients based on multiple measurements at each gate	No	25%
Gate-specific variable coefficients based on multiple measurements at each gate	Yes	96%

3.2 Weirs

3.2.1 Overview

Weirs installed in boxes placed at the turnout pipe outlets operate as standard suppressed rectangular weirs because the weir crest occupies the full box width (i.e., there is no flow contraction) (Figure 8). The Francis equation, which was empirically derived in 1883 to calculate flow over a standard suppressed rectangular weir is shown in Equation 3, where (L) is the length of the weir in feet (ft), and (h) is the height of the fluid over the crest in feet.

$$Q = 3.33\, L\, h^{3/2} \qquad \textit{(Equation 3 – WMM 2001)}$$

The coefficient of discharge (3.33) was obtained by a set of experiments to correlate the head above the crest with the amount of flow passing over the weir (WMM 2001). For this equation to be most accurate, certain conditions must be met. The weir crest elevation should be at least 0.2 ft above the field WSE so that a free fall occurs (WMM 2001). If the elevation difference is less than 0.2 ft, the free fall of the water may be affected by "backwater" effects and the accuracy of the measurement may be decreased. Additionally, when h is less than 0.2 ft or greater than one-third the crest length, acquiring a precise head measurement becomes challenging and measurement accuracy may be compromised (WMM 2001).

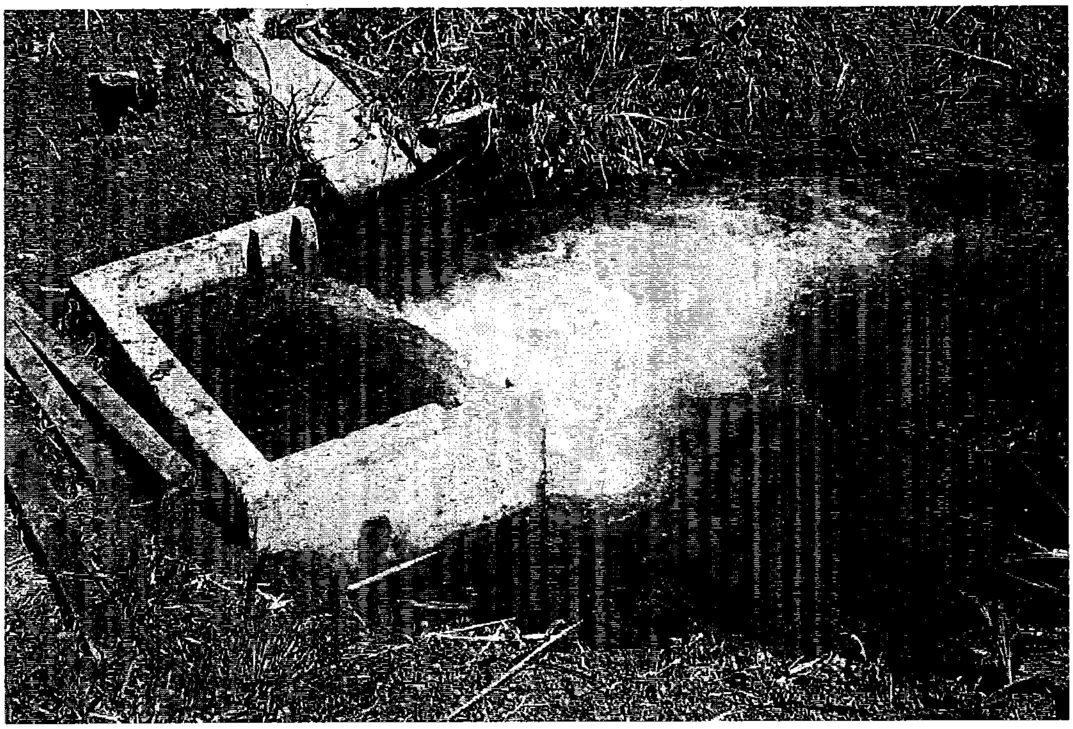


Figure 8. Typical Weir Box on the Ashley Canal near Afton Road

3.2.2 Compliance with CCR 23 §597

Data from previous field investigations (Davids Engineering 2012) indicates that weirs can measure within the CCR 23 §597 accuracy mandate for existing measurement devices (±12 percent) provided that:

- Sufficient head (drop) is available between the canal water level and field water level
- Leakage through weir boards is stopped (or accounted for)

Hydraulic analysis of a four foot wide weir box indicates that, if a 12 cubic foot per second (cfs) flood flow is desired, a minimum of 1.5 feet of head is required[10]. Based on this criterion, and the survey information discussed in Section 2.6, 123 of the 321 gravity farm turnouts (38 percent) have enough head to measure with a weir.

[10] Roughly 1.0 foot of head over a four foot weir produces 12 cfs. Additionally, the analysis assumes a 0.3 foot headloss through the orifice gate is required for the delivery to remain in 'orifice control', plus 0.2 feet of headloss for major and minor losses between the orifice gate and the weir box.

3.3 RemoteTracker System

3.3.1 Overview

The RemoteTracker is an integrated turnout flow measurement, data management and volumetric accounting system developed by H2oTech[11] specifically for agricultural water suppliers. The RemoteTracker system is comprised of (1) a wireless water velocity sensor, (2) a ruggedized tablet PC carried in the operator's vehicle and (3) a database residing on a file server connected to the tablet PC via a cellular internet connection. The user interface on the tablet PC enables operators to view real time flow data from the wirelessly controlled water velocity sensor via a Bluetooth radio connection while adjusting flows at the turnout gate. The RemoteTracker calculates flow rate with Equation 4.

$$Q = C_{RT} * V_D * A \qquad \textit{(Equation 4)}$$

Where:

- C_{RT}: RemoteTracker velocity coefficient
- V_D: Velocity measured by the wireless water velocity sensor
- A: Cross-section flow area

The key to pipe flow measurement using the RemoteTracker is the consistent relationship between a single velocity measurement at the center of the pipe and the average pipe flow velocity shown derived from 146 measurements of center and mean pipe velocity (Figure 9). Based on this relationship, and with the pipe diameter and cross sectional flow area known, the single point velocity can be accurately and reliably correlated with flow rate.

[11] H2oTech is a company based in Chico, California that focuses on the development of innovative technologies to solve water management challenges.

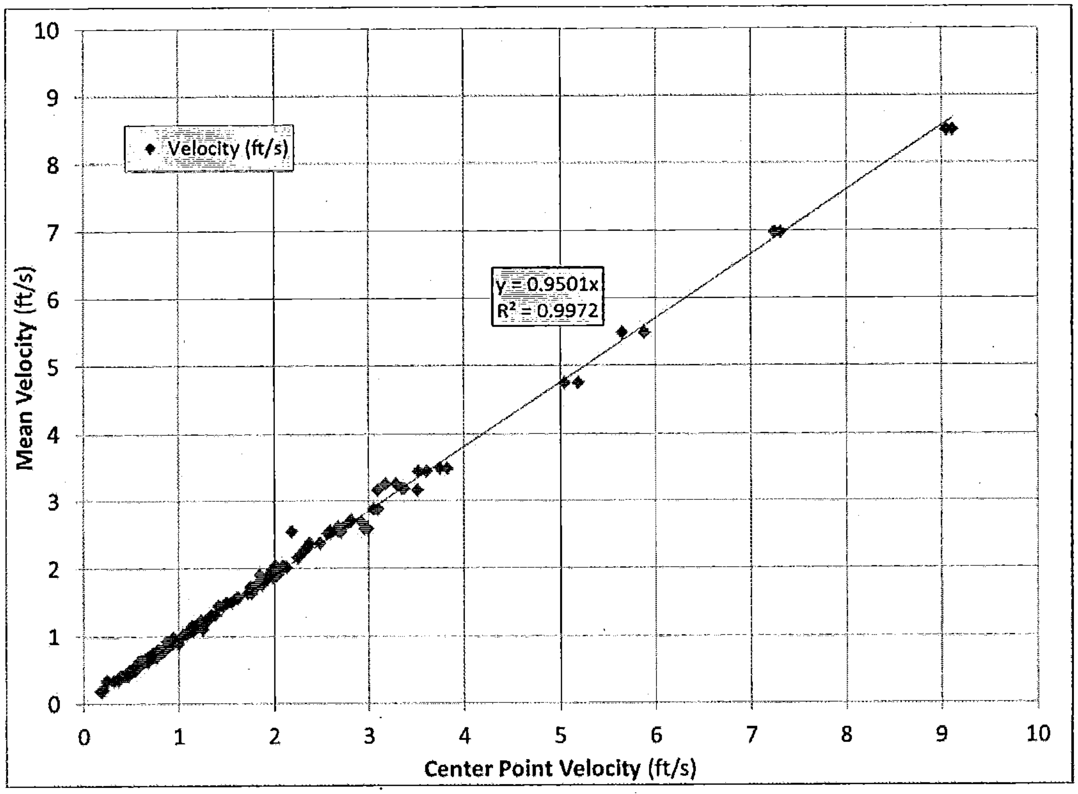


Figure 9. Relationship between Average and Center Point Pipe Flow Velocity

As for weirs and orifice gates, full pipe flow is required for the RemoteTracker to measure correctly. Therefore, a weir box is needed at each turnout to ensure full pipe flow as well as to accommodate the mounting bracket to hold the wireless water velocity sensor, during deployment, so that the sample volume is near the center of the pipe. Figure 10 shows the RemoteTracker wireless water velocity sensor deployed in a weir box.

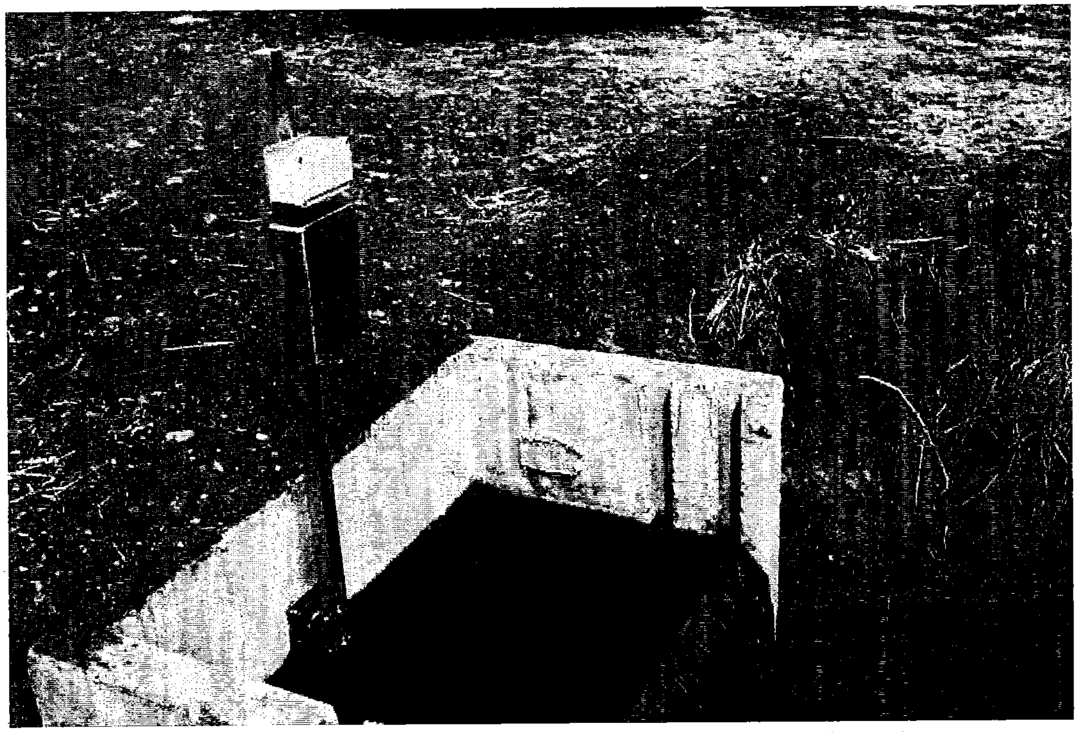


Figure 10. RemoteTracker Wireless Water Velocity Sensor Deployed in Weir Box

A more detailed explanation of the RemoteTracker system, including results of laboratory and field testing, is included in Sections A-2.0 and A-3.0 of Appendix A.

3.3.2 Compliance with CCR 23 §597

The RemoteTracker system is compliant with the volumetric accuracy mandates of CCR 23 §597. See Appendix A for a laboratory based volumetric accuracy certification of the RemoteTracker system. The RemoteTracker system can provide accurate flow data over all farm turnout head ranges.

3.4 Propeller Meters

3.4.1 Overview

Using propellers meters for farm turnout measurement involves permanently installing a propeller meter device at each farm turnout[12]. Propeller meters have a propeller that is placed in the outfall of the farm turnout pipe. The propeller is rotated by water flowing in the pipe and is mechanically or

[12] Because of the heaviness of propeller meters and the need to match meter size to the different turnout pipe sizes, it is considered impractical to deploy propeller meters temporarily for spot flow checks in the same manner that the RemoteTracker is deployed. Instead propeller meters would be permanently deployed at each turnout for the duration of each irrigation season.

electronically coupled with a display and recording device. The rate of rotation is directly proportional to velocity of the water in the pipe. With the pipe diameter and cross-sectional area known, flow rate can be calculated as the product of velocity and area. Propeller meters typically measure flow rate continuously and totalize the delivery volume. The display typically indicates instantaneous flow rate and cumulative volume delivered. For deployment in BWGWD, propeller meters would require the same farm turnout infrastructure as the RemoteTracker. An orifice gate would be required at the farm turnout inlet to control flow and a weir box would be required at the turnout pipe outlet to (1) keep the pipe full and (2) provide a place to mount the propeller meter.

3.4.2 Compliance with CCR 23 §597

Laboratory certifications of flow measurement accuracy are available for most commercially available propeller meters. Since propeller meters are permanently installed devices, volumetric accuracy is the same as flow rate accuracy. Therefore, propeller meters are compliant with the volumetric accuracy mandates of CCR 23 §597. Propeller meters can provide accurate flow data over all farm turnout head ranges.

4.0 Alternative Measurement Approaches

As discussed in Sections 3.1.2 and 3.2.2, orifice gates and weir boxes require a minimum of 0.5 feet and 1.5 feet of head respectively to measure a minimum of 12 cfs. To facilitate the development of measurement approaches, all farm turnouts within the District were classified into one of four farm turnout categories[13]:

1. Low Head Gravity (i.e. head less than 0.5 feet),
2. Medium Head Gravity (i.e. head between 0.5 and 1.5 feet),
3. High Head Gravity (i.e. head greater than 1.5 feet) and
4. Pump (i.e. water supplied to fields via pumps).

Table 5 presents a summary of three measurement approaches considered to be potentially viable for the District to comply with CCR 23 §597. Table 5 indicates the number of turnouts falling in each category and, for each approach, the measurement device that would be used for each category. The three approaches are discussed in greater detail in Sections 4.1 through 4.3. None of the measurement devices discussed in Section 3 can be utilized to measure pump deliveries. Therefore, all three approaches include the use of totalizing flow meters at the 38 pump deliveries within the District.

Table 5. Measurement Approach Summary

Farm Turnout Category	Count of Farm Turnout Categories	Measurement Devices		
		Approach 1 - Maximum Use of Existing Devices	Approach 2 - RemoteTracker System	Approach 3 - Propeller Metering Program
Low Head Gravity (H < 0.5 feet)	**26**	Propeller Meters		
Medium Head Gravity (0.5' < H < 1.5')	**172**	Orifice Gates	RemoteTracker System	Propeller Meters
High Head Gravity (H > 1.5')	**123**	Weir Boxes		
Pump	**38**	Totalizing Flow Meters	Totalizing Flow Meters	Totalizing Flow Meters
Total	**359**			

[13] Farm turnouts with unknown heads were distributed between the three gravity farm turnout categories in the same proportion as the known farm turnouts. In other words, of the turnouts with known heads, 8 percent were low head, 53 percent were medium head and 39 percent were high head. These percentages were then used to distribute the 71 unknown gravity farm turnouts among the three gravity farm turnout categories.

Table 6 summarizes the different levels of turnout improvement needed for each of the farm turnout categories, and the number of turnouts in each improvement level. These farm turnout counts are utilized in Section 5.0 to develop capital cost estimates for each measurement approach. All measurement approaches require gravity farm turnouts to have an orifice gate and a weir box. All pump farm turnouts require a totalizing flow meter. The classifications have been developed to be mutually exclusive so that each farm turnout only corresponds with one improvement classification within the table, which facilitates the ability to sum the number of farm turnouts in each row to develop the total number or farm turnouts in each farm turnout category. The Gray Lodge project will be replacing or retrofitting a number of gravity farm turnouts in each classification; therefore, a 'Gray Lodge' classification is necessary to avoid double counting. The farm turnout improvement classifications include:

- **Requires Orifice Gate and Weir Box** - existing gravity farm turnout has neither an orifice gate or a weir box
- **Requires Orifice Gate Only** - existing gravity farm turnout has a weir box, but no orifice gate
- **Requires Weir Box Only** - existing gravity farm turnout has a orifice gate, but no weir box
- **Requires No Improvements** - existing gravity farm turnout has an orifice gate and a weir box
- **Improvements by Gray Lodge Project** - improvements to existing farm turnout to be made by others
- **Requires Totalizing Flow Meter** - existing pump farm turnout has no measurement device

Table 6. Farm Turnout Improvement Classification Count Summary

	Farm Turnout Improvement Classification Counts						
Farm Turnout Category	**Requires Orifice Gate and Weir Box**	**Requires Orifice Gate Only**	**Requires Weir Box Only**	**Requires No Improvements**	**Improvements by Gray Lodge Project**	**Requires Totalizing Flow Meter**	**Sum**
Low Head Gravity (H < 0.5 feet)	10	0	11	4	1	n/a	26
Medium Head Gravity (0.5' < H < 1.5')	22	0	95	12	43	n/a	172
High Head Gravity (H > 1.5'	7	0	60	5	51	n/a	123
Pump	n/a	n/a	n/a	0	0	38	38
Totals	39	0	166	21	95	38	**359**

4.1 Approach 1 - Maximum Use of Existing Devices

Approach 1 is based on maximizing the use of existing measurement devices; however, neither of the two existing measurement devices (i.e. orifice gates and weir boxes) alone unconditionally meets the volumetric accuracy mandates of CCR 23 §597 across all gravity farm turnouts. Therefore, to achieve maximum use of existing devices, a hybrid approach involving multiple measurement devices is necessary. Approach 1 utilizes weir boxes for high head gravity farm turnouts and orifice gates for medium head gravity farm turnouts. Propeller meters, a new device, would be used for low head gravity farm turnouts because neither gates nor weirs work under low head conditions. Measurement of the 38 pump deliveries in the District requires the installation of totalizing flow meters.

4.2 Approach 2 - RemoteTracker System

Approach 2 involves the use of the RemoteTracker system at all gravity farm turnout categories (i.e. high head gravity, medium head and low head gravity farm turnouts). Measurement of the 38 pump deliveries in the District requires the installation of totalizing flow meters.

4.3 Approach 3 - Propeller Metering Program

Approach 3 involves the use of propeller meters at all gravity farm turnout categories (i.e. high head gravity, medium head and low head gravity farm turnouts). Measurement of the 38 pump deliveries in the District requires the installation of totalizing flow meters.

5.0 Reconnaissance Cost Estimates

BWGWD, along with other agricultural and urban water suppliers, filed a Test Claim with the Commission on State Mandates alleging that the Water Conservation Act constitutes a reimbursable state mandate. That Test Claim is pending before the Commission and it is anticipated that a hearing will be held in September, 2013, and a decision will be made shortly thereafter. BWGWD, along with other agricultural water suppliers, are in the process of filing a supplemental Test Claim challenging CCR 23 § 597. If the Test Claims are successful, BWGWD will be entitled to reimbursement of all direct and indirect costs of compliance with the Water Conservation Act and 23 CCR § 597, including initial and annualized capital and maintenance and operation costs of farm-gate measurement devices.

As part of the Gray Lodge Wildlife Area Water Supply Project (Gray Lodge Project), the District will be replacing, or retrofitting, a total of 95 gravity farm turnouts[14] along the Upper Belding, Traynor, Rising River, Lower Belding, Schwind and Cassady laterals. This represents about 30 percent of the District's 321 canal-fed gravity turnouts. The farm turnout (and other) modifications to be implemented under the project have not yet been constructed but have been designed to facilitate measurement with any of the four measurement devices evaluated (i.e. orifice gates, weirs, the RemoteTracker and propeller meters). Therefore, the cost estimates included herein do not include the capital costs for weir box and orifice gate installation at these 95 gravity farm turnouts because those costs will be borne by the Gray Lodge Project. The farm turnout inventory discussed in Section 2, however, does not account for the improvements that will eventually be made to the affected farm turnouts.

Table 7 provides reconnaissance-level (1) initial capital, (2) annualized capital and (3) annual maintenance cost estimates for full scale implementation of the three measurement approaches discussed in Section 4. Each approach lists two possible scenarios regarding the farm turnouts within the Gray Lodge project. The left column reflects the annualized capital and maintenance cost under the conditions that certain improvement requirements for farm turnouts within the Gray Lodge project will be covered by an entity other than the District. The right column reflects the annualized capital and maintenance cost for all improvements including the farm turnouts within the Gray Lodge project. The annualized maintenance costs are the same for both scenarios. The last row provides the annualized capital and maintenance cost estimates. Differences among the three approaches with respect to operation costs (primarily labor and transportation) are not considered significant; therefore they are not included. A five percent interest rate was used for all calculations.

Sections 5.1 through 5.3 below contain additional details regarding the capital cost estimates for the three alternative measurement programs evaluated. Each of the three alternative measurement approaches requires (1) a Water Information System (WIS) to store and process farm turnout delivery data and (2) the installation of totalizing flow meters on all pump deliveries. The measurement devices

[14] As summarized in Table 6, the Gray Lodge Project will be replacing or retrofitting one low head, 43 medium head and 51 high head gravity farm turnouts, for a total of 95 farm turnouts.

Table 7. Reconnaissance-Level Cost Estimates for Three Measurement Approaches

Cost Category	Measurement Program Cost Estimate					
	Approach 1 - Maximum Use of Existing Devices		Approach 2 - RemoteTracker System		Approach 3 - Propeller Metering Program	
	With Gray Lodge Project	Without Gray Lodge Project	With Gray Lodge Project	Without Gray Lodge Project	With Gray Lodge Project	Without Gray Lodge Project
Initial Capital	$1,501,146	$1,713,538	$1,147,810	$1,360,202	$2,403,455	$2,615,848
Annualized Capital	$103,320	$116,016	$91,777	$104,473	$179,751	$192,447
Annualized Maintenance	$71,207		$70,999		$153,075	
Annualized Capital and Maintenance	$174,527	$187,223	$162,776	$175,472	$332,826	$345,522

evaluated (i.e. gates, weirs, RemoteTracker and Propeller Meters) are designed for measurement of gravity deliveries, and are therefore unable to measure pump deliveries. Note that all cost estimates located in section 5.1 through 5.3 assume that improvements made to all turnouts within the Gray Lodge project will be covered by an entity other than the District. Appendix B provides additional information about the estimates for all unit costs, including the WIS and totalizing flow meters.

5.1 Approach 1 - Maximum Use of Existing Devices

Table 8 provides a cost summary for Approach 1, listing the necessary improvements, the number of farm turnouts that require the improvement and the expected life of the improvement.

Table 8. Approach 1 Cost Summary

#	Improvements	# of Sites Required	Unit cost	Initial Capital Sub-Total	Expected Life (years)	Annualized Sub-Total
1	Propeller Meter	26	$4,528	$117,733	20	$9,447
2	Orifice Gate	39	$5,017	$195,681	25	$13,884
3	Differential Head Measurement	172	$1,198	$206,038	25	$14,619
4	Gate Coefficient	172	$1,323	$227,470	25	$16,140
5	Weir Box	211	$2,230	$470,492	40	$27,419
6	Water information System (WIS)	1	$132,911	$132,911	50	$7,280
7	Totalizing Flow Meter	38	$3,969	$150,820	15	$14,530
			Totals	$1,501,146		$103,320

Improvements 1 through 5 are required on a farm turnout level. Improvement 6 is required on the system wide level to facilitate data storage and management. Improvement 7 is required to measure pump deliveries (from either supply canals or drains) within the District.

Summaries of the specific improvements required for each gravity farm turnout classification (i.e. low head, medium head and high head), and the associated initial capital costs, are provided in Sections 5.1.1 through 5.1.3 below.

5.1.1 Low Head Device (Propeller Meters)

Table 9 presents the estimated capital costs to measure at 26 low head farm turnouts with propeller meters. The normalized per farm turnout improvement cost is $8,259.

Table 9. Low Head Farm Turnout (Propeller Meter) Cost Estimate

#	Improvements	# of Sites Required	Unit Cost	Sub-Total
1	Orifice Gate	10	$5,017	$50,175
2	Weir Box	21	$2,230	$46,826
3	Propeller Meter	26	$4,528	$117,733
			Total	**$214,734**
		Number of Farm Turnouts Utilizing Propeller Meters		**26**
		Normalized Per Farm Turnout Initial Capital Cost		**$8,259**

Table 9 lists the infrastructure required at each low head gravity farm turnout to use propeller meters (improvements 1 through 3) and the number of gravity farm turnouts that do not currently have the required infrastructure (i.e. the number of sites requiring the specific improvement). The following summarizes the three improvements in Table 9:

1. **Orifice Gate** - for flow control. Includes gate procurement and installation. 10 low head gravity farm turnouts do not currently have orifice gates.
2. **Weir Box** - to maintain full pipe flow and prevent field fluctuation from affecting flow. Includes weir box procurement and installation. 21 low head gravity farm turnouts do not currently have weir boxes.
3. **Propeller Meter** - totalizing propeller meter with mounting brackets. Includes propeller meter procurement and all installation processes. 26 low head gravity turnouts do not currently have propeller meters.

5.1.2 Medium Head Device (Orifice Gates)

Table 10 presents the estimated capital costs to measure at 172 medium head gravity farm turnouts with orifice gates. The normalized per farm turnout improvement cost is $4,718.

Table 10. Medium Head Farm Turnout (Orifice Gate) Cost Estimate

#	Improvements	# of Sites Required	Unit Cost	Sub-Total
1	Orifice Gate	22	$5,017	$110,384
2	Differential Head Measurement	172	$1,198	$206,038
3	Gate Coefficient	172	$1,323	$227,470
4	Weir Box	120	$2,230	$267,579
			Total	**$811,471**
			Number of Farm Turnouts Utilizing Propeller Meters	**172**
			Normalized Per Farm Turnout Initial Capital Cost	**$4,718**

Table 10 lists the infrastructure required at each medium head gravity farm turnout to use orifice gates (improvements 1 through 4) and the number of gravity farm turnouts that do not currently have the required infrastructure (i.e. the number of sites requiring the specific improvement). The following summarizes the three improvements in Table 10:

1. **Orifice Gate** - for flow control. Includes gate procurement and installation. 22 medium head gravity farm turnouts do not currently have orifice gates.
2. **Differential Head Measurement** - infrastructure alterations to allow for the head difference to be read upstream of the orifice gate and approximately 1 foot downstream of the orifice gate. 172 medium head gravity farm turnouts do not currently have the ability to measure differential heads.
3. **Gate Coefficient** - five flow measurements performed at various stages of flow and development of a farm turnout specific rating curve. 172 medium head gravity farm turnouts do not currently have custom farm turnout specific ratings.
4. **Weir Box** - to maintain full pipe flow and prevent field fluctuation from affecting flow. Includes weir box procurement and installation. 120 medium head gravity farm turnouts do not currently have weir boxes.

5.1.3 High Head Device (Weir Boxes)

Table 11 presents the estimated capital costs to measure at 123 high head gravity farm turnouts with weir boxes. The normalized per farm turnout improvement cost is $1,555.

Table 11 lists the infrastructure required at each high head farm turnout to use weir boxes (improvements 1 and 2) and the number of sites that do not currently have the required infrastructure

Table 11. High Head Farm Turnout (Weir Box) Cost Estimate

#	Improvements	# of Sites Required	Unit Cost	Sub-Total
1	Orifice Gate	7	$5,017	$35,122
2	Weir Box	70	$2,230	$156,087
			Total	**$191,210**
	Number of Farm Turnouts Utilizing Propeller Meters			**123**
	Normalized Per Farm Turnout Initial Capital Cost			**$1,555**

(i.e. the number of sites requiring the specific improvement). The following summarizes the two improvements in Table 11:

1. **Orifice Gate** - for flow control. Includes gate procurement and installation. 7 high head gravity farm turnouts do not currently have orifice gates.
2. **Weir Box** - to maintain full pipe flow and prevent field fluctuation from affecting flow. Includes weir box procurement and installation. 70 high head gravity farm turnouts do not currently have weir boxes.

5.2 Approach 2 - RemoteTracker System

Table 12 provides a cost summary for Approach 2, listing the necessary improvements, the number of farm turnouts that require the improvement and the expected life of the improvement.

Table 12. Approach 2 Cost Summary

#	Improvements	# of Sites Required	Unit cost	Initial Capital Sub-Total	Expected Life (years)	Annualized Sub-Total
1	Orifice Gate	39	$5,017	$195,681	25	$13,884
2	Weir Box	211	$2,230	$470,492	40	$27,419
3	RemoteTracker Mounting Plate	304	$325	$98,718	40	$5,753
4	RemoteTracker System	3	$33,063	$99,188	5	$22,910
5	Water Information System (WIS)	1	$132,911	$132,911	50	$7,280
6	Totalizing Flow Meter	38	$3,969	$150,820	15	$14,530
			Totals	**$1,147,810**		**$91,777**

Improvements 1 through 3 are required on a farm turnout level. Improvements 4 and 5 are improvements on the operator or system wide level to facilitate use of the RemoteTracker system. Improvement 6 is required to measure pump deliveries within the District.

1. **Orifice Gate** - for flow control. Includes gate procurement and installation. 39 gravity farm turnouts do not currently have orifice gates.
2. **Weir Box** - to maintain full pipe flow and prevent field fluctuation from affecting flow. Includes weir box procurement and installation. 211 gravity farm turnouts do not currently have weir boxes.
3. **RemoteTracker Mounting Plate** - for mounting wireless water velocity sensor onto turnout. Includes plate fabrication and all installation processes. 304 turnouts do not currently have RemoteTracker plates.
4. **RemoteTracker System** - consists of the wireless water velocity sensor and computing device on a per operator basis. Includes all procurement and assembly costs. Three additional RemoteTracker systems are required.
5. **Water Information System** - water information system to collect and process measurement data. Includes customized database for volumetric accounting. Only one database per District is required.
6. **Totalizing Flow Meter** - for measurement of pump diversions from either supply canals or drains. Includes the meter and installation. 38 known pump farm turnouts within the District will require the installation of totalizing flow meters.

5.3 Approach 3 - Propeller Metering Program

Table 13 provides a cost summary for Approach 3, listing the necessary improvements, and the number of farm turnouts that still require the improvement, and the expected life of each improvement.

Table 13. Approach 3 Cost Summary

#	Improvements	# of Sites Required	Unit Cost	Initial Capital Sub-Total	Expected Life (years)	Annualized Sub-Total
1	Orifice Gate	39	$5,017	$195,681	25	$13,884
2	Weir Box	211	$2,230	$470,492	40	$27,419
3	Propeller Meter	321	$4,528	$1,453,551	20	$116,637
4	Water Information System (WIS)	1	$132,911	$132,911	50	$7,280
5	Totalizing Flow Meter	38	$3,969	$150,820	15	$14,530
			Totals	**$2,403,455**		**$179,751**

Improvements 1 through 3 are required on a farm turnout level. Improvement 4 is required on the system wide level to facilitate data storage and management. Improvement 5 is required to measure pump deliveries within the District.

1. **Orifice Gate** - for flow control. Includes gate procurement and installation. 39 gravity farm turnouts do not currently have orifice gates.

2. **Weir Box** - to maintain full pipe flow and prevent field fluctuation from affecting flow. Includes weir box procurement and installation. 211 gravity farm turnouts do not currently have weir boxes.
3. **Propeller Meter** - totalizing propeller meter with mounting brackets. 321 turnouts do not currently have propeller meters.
4. **Water Information System** - water information system to collect and process measurement data. Includes customized database for volumetric accounting. Only one database per District is required.
5. **Totalizing Flow Meter** - for measurement of pump diversions from either supply canals or drains. Includes the meter and installation. 38 known pump deliveries within the District will require the installation of a totalizing flow meter.

5.4 Maintenance Cost Estimates

Table 14 provides additional details pertaining to the development of annual maintenance costs. Annual maintenance costs are estimated as a percentage of the initial capital costs. Each approach contains a column for the counts of each maintenance item and the annual maintenance cost. The annual maintenance costs are estimated to be $71,207, $70,999 and $153,075 for Approaches 1 through 3, respectively.

Table 14. Operation and Maintenance Cost Summary

Maintenance Item	Annual Maintenance - Percentage of Capital	Annual Maintenance Unit Cost Estimate	Approach 1 - Maximum Use of Existing Devices		Approach 2 - RemoteTracker System		Approach 3 - Propeller Metering Program	
			Number of O&M Items	Annual Maintenance Cost	Number of O&M Items	Annual Maintenance Cost	Number of O&M Items	Annual Maintenance Cost
Propeller Meter	8%	$289	26	$7,505	0	$0	321	$92,657
Weir Box	2%	$36	321	$11,407	321	$11,407	321	$11,407
Orifice Gate	2%	$80	321	$25,667	321	$25,667	321	$25,667
Differential Head Measurement	2%	$19	172	$3,283	0	$0	0	$0
Totalizing Pump Flow Meter	5%	$158	38	$6,009	38	$6,009	38	$6,009
Water Information System	15%	$17,336	1	$17,336	1	$17,336	1	$17,336
RemoteTracker System	8%	$2,645	0	$0	4	$10,580	0	$0
Totals			-	$71,207	-	$70,999	-	$153,075

6.0 Corrective Action Plan

At a special, scheduled meeting on January 4, 2013, the BWGWD Board considered this report and the customer delivery measurement options presented herein. By unanimous vote, the Board accepted the report and adopted measurement Approach 2 - RemoteTracker System as the District's preferred approach for implementing a customer delivery measurement program. The program is intended to comply with the measurement accuracy standards specified in CCR 23 §597 and to be capable of supporting implementation of a water rate structure based at least in part on the volume of water delivered. Such a rate structure remains to be designed and adopted by the Board in the future.

Approach 2 has an estimated capital cost of $1,147,810 assuming that the Gray Lodge water conveyance project is implemented, or a cost of $1,360,202, if the Gray Lodge project does not proceed. Recognizing that these capital improvement costs are relatively large in comparison to the District's current revenue and operating budgets, the Board also unanimously agreed that the program will be implemented on a "pay-as-you-go" basis as discretionary revenues above operating and maintenance costs become available.

References Cited

Burt, C.M. and E. Geer 2012. *SBx7 Flow Rate Measurement Compliance for Agricultural Irrigation Districts*. Irrigation Training & Research Center, California Polytechnic State University, San Luis Obispo, California, USA.

Davids Engineering, *Field Turnout Measurement Accuracy Study,* Davids Engineering, Davis, CA, 2012

King, Horace Williams. *Handbook of Hydraulics.* Fourth ed. York: McGraw-Hill Book, 1963. Print.

Lindeburg, M.R. *Civil Engineering Reference Manual for the PE Exam*, Eleventh Edition, Professional Publications, Inc., Belmont, CA, 2008.

Water Measurement Manual, Bureau of Reclamation, United States. 2001. *Water Measurement Manual* – 3rd Edition, A Water Resources Technical Publication.

CCR 23 §597, California Code of Regulations Title 23 Division 2 Chapter 5.1 Article 2 Section 597, Sacramento, CA, 2012

Appendix A. RemoteTracker System Overview and Volumetric Accuracy Certification

A-1.0 Introduction and Summary

This document (1) provides an overview of the RemoteTracker system (Section A-2.0), (2) presents results of initial laboratory and field testing (Section A-3.0) and (3) develops a volumetric accuracy analysis to support compliance of RemoteTracker system with California Code of Regulations Title 23 Division 2 Chapter 5.1 Article 2 Section 597 (CCR 23 §597) (Section A-4.0). Based on the analysis in Section A.3, the expected accuracy in volumetric measurements performed with the RemoteTracker system is ±4.6 percent. Because the RemoteTracker system utilizes a laboratory certified acoustic doppler velocimeter manufactured by SonTek to measure water velocity, the ±5 percent by volume laboratory certification option presented in CCR 23 §597.3(a)(2)(B) applies. Thus, the demonstrated accuracy of the RemoteTracker complies with the ±5 percent by laboratory certification standard. Documentation of the protocols associated with the measurement of the cross-section flow area and duration of delivery, as required by §597.4(e)(3)(B), is presented in Section A-4.0.

A-2.0 RemoteTracker System Overview

The RemoteTracker is an integrated turnout flow measurement, data management and volumetric accounting system developed by H2oTech[15] specifically for agricultural water suppliers in response to CCR 23 §597. The RemoteTracker system is comprised of (1) a wirelessly controlled water velocity sensor, (2) a ruggedized tablet PC in the operator's vehicle and (3) a database running on a file server connected to the internet. The user interface on the tablet PC enables operators to view real time flow data from the wirelessly controlled water velocity sensor via a Bluetooth radio connection while adjusting flows at the turnout gate. Data is automatically transferred over a wireless wide area network (WWAN) to a centralized file server at the District headquarters where it is automatically loaded into a custom database application. The database performs quality control and quality assurance procedures on the data and then develops daily volumes for each customer delivery point (turnout or delivery) within the District.

The wireless water velocity sensor (WWVS) is held in place at a precise location at the pipe outlet by an aluminum or stainless steel mounting bracket. The user interface, shown in Figure A-1, was designed with simplicity and ease of use in mind. If 'Auto Locate' is selected, the program automatically populates the three site identification pull-downs at the top of the screen. If the operator needs to select a different site, the pull-downs can be manually changed. The site selection hierarchy is a three digit abbreviation of 'Operator Route' (i.e. ride, beat or division) on the left, a three digit abbreviation of 'Canal' in the middle and site name on the right. The most recently measured flow, and any pending orders are shown on the 'Home' tab. Many useful reports, including (1) Delivery History, (2) Pending Orders, (3) Fulfilled Orders and (4) Canal Management are available on the 'Reports' tab. These reports can be sorted at any spatial or temporal scale. The data sharing and management framework allows

[15]H2oTech is a company based in Chico, California that focuses on the development of innovative technologies to solve water management challenges.

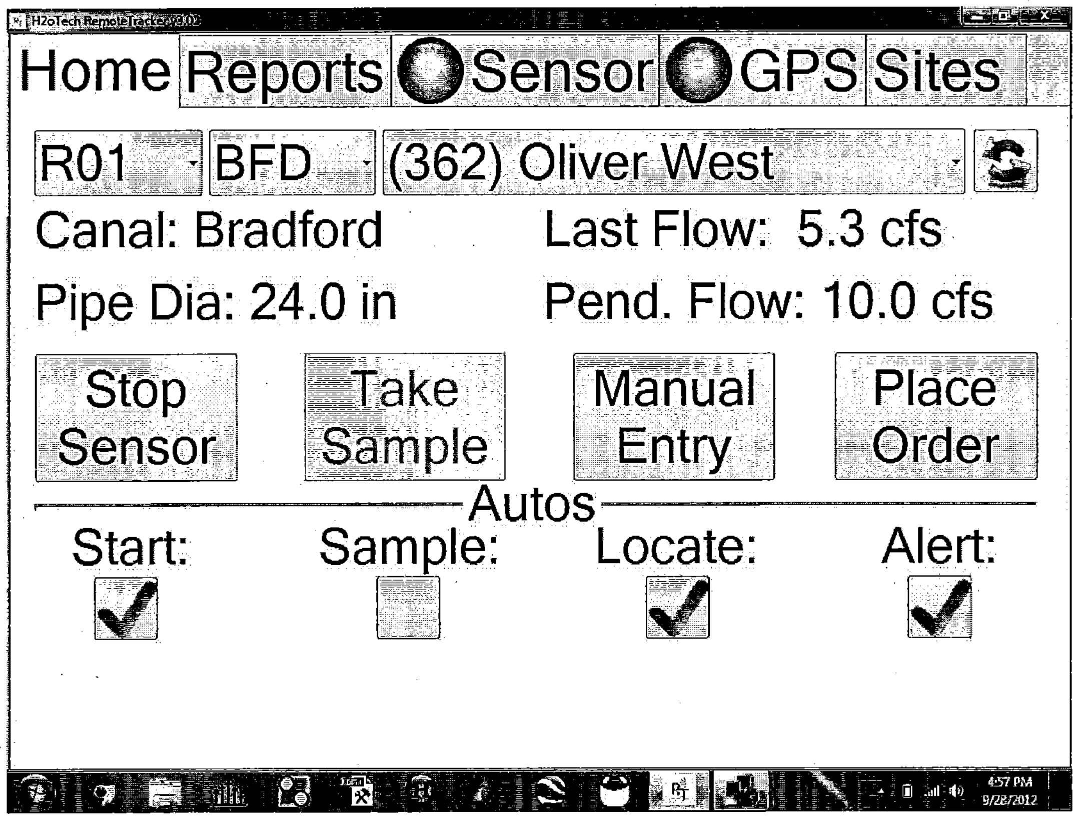


Figure A-1. RemoteTracker User Interface - Home Tab Shown

water order and delivery data collected by any operator to be automatically available for viewing by other operators or management staff in a matter of minutes.

The basic components of the RemoteTracker system are illustrated in Figure A-2. Water velocity is collected by a portable acoustic Doppler velocimeter deployed during measurement by hanging it on brackets permanently installed at each turnout. The brackets are precisely positioned such that the sample volume is at the center of the pipe. Data is transmitted via a class 1 Bluetooth radio to a ruggedized tablet PC where it is processed, displayed and stored. Data is then transferred via a WWAN to a file server at the District headquarters. Data from each operator is aggregated with an automated database procedure and then returned to each operator via WWAN, thereby ensuring that delivery and order data is shared and accessible throughout the entire District.

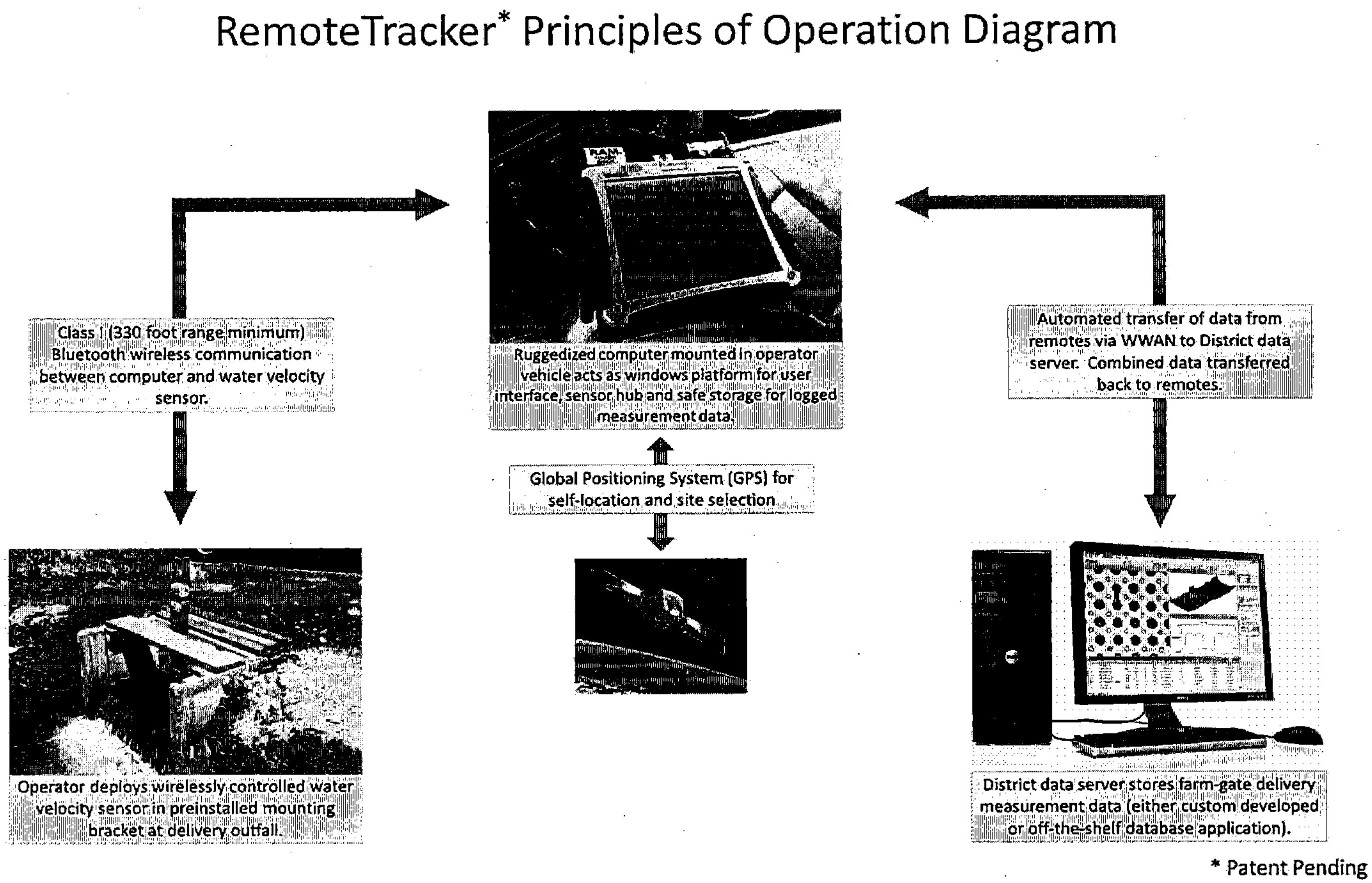


Figure A-2. RemoteTracker Principles of Operation Overview

The key to pipe flow measurement using the RemoteTracker is the consistent relationship between a single velocity measurement at the center of the pipe and the average pipe flow velocity shown in Figure A-3 derived from 146 measurements of center and mean pipe velocity. Based on this relationship, with the pipe diameter and cross sectional area known, the single point velocity can be accurately and reliably correlated with mean pipe velocity (flow rate).

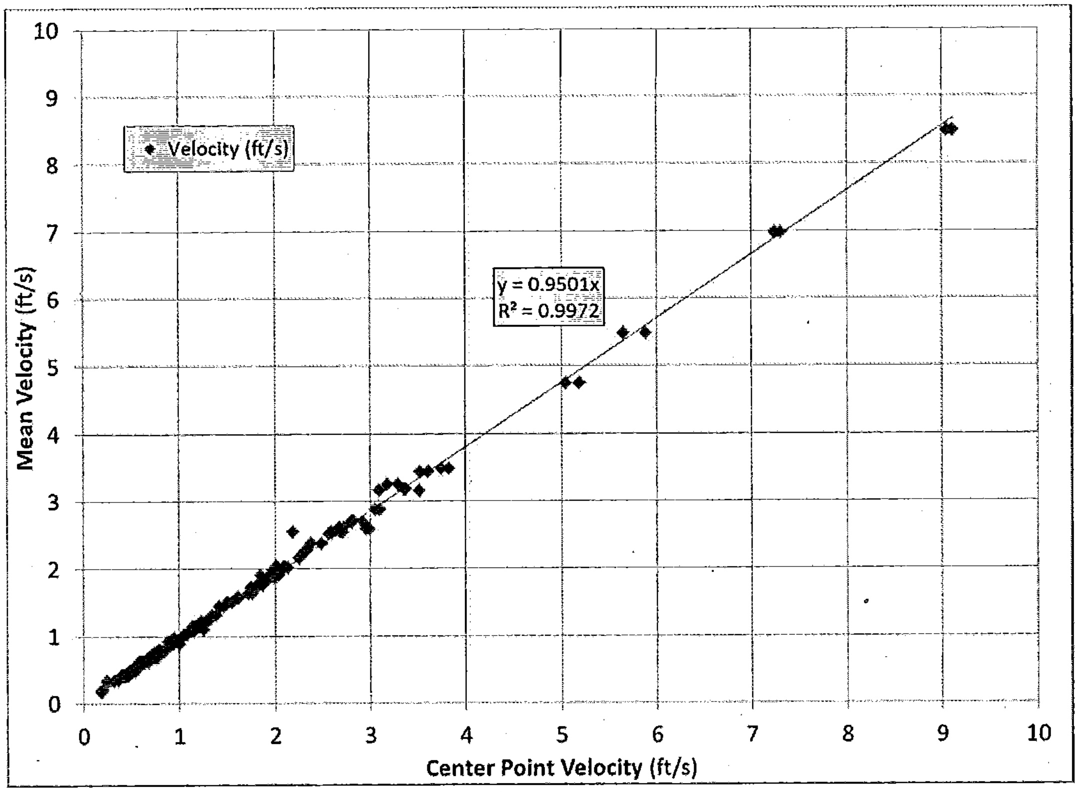


Figure A-3. Relationship between Average and Center Point Pipe Flow Velocity

As with weir and orifice gate measurement, full pipe flow is required for the RemoteTracker to measure correctly. Therefore, a weir box is needed at each turnout to ensure full pipe flow as well as to accommodate the mounting bracket to hold the wireless water velocity sensor so that the sample volume is at the center of the pipe.

The RemoteTracker system can also be integrated with existing or new data management systems at the District office for report generation, accounting and billing. This capability can be added later to provide additional efficiencies in water billing and accounting procedures.

A-3.0 Initial Testing Results

A-3.1 Laboratory Testing

Additional testing was performed at the California State University Chico Agricultural Teaching and Research Center (CSUC ATRC) in July of 2012. Flow data obtained from the RemoteTracker was compared to measurements taken with a 10-inch diameter magnetic flow meter manufactured by Water Specialties. Figure A-4 shows the Water Specialties Magnetic meter with an Endress & Hauser Transit-Time Meter installed just upstream as an additional check. The 3 foot wide by 3 foot deep concrete flume was modified to simulate a typical delivery configuration by forcing all the flow through a 20 foot length of 18 inch HDPE smooth interior wall pipe submerged in the concrete flume. The RemoteTracker wireless water velocity sensor was installed at the pipe outfall using a temporarily constructed headwall with a mounting bracket as shown in Figure A-5.

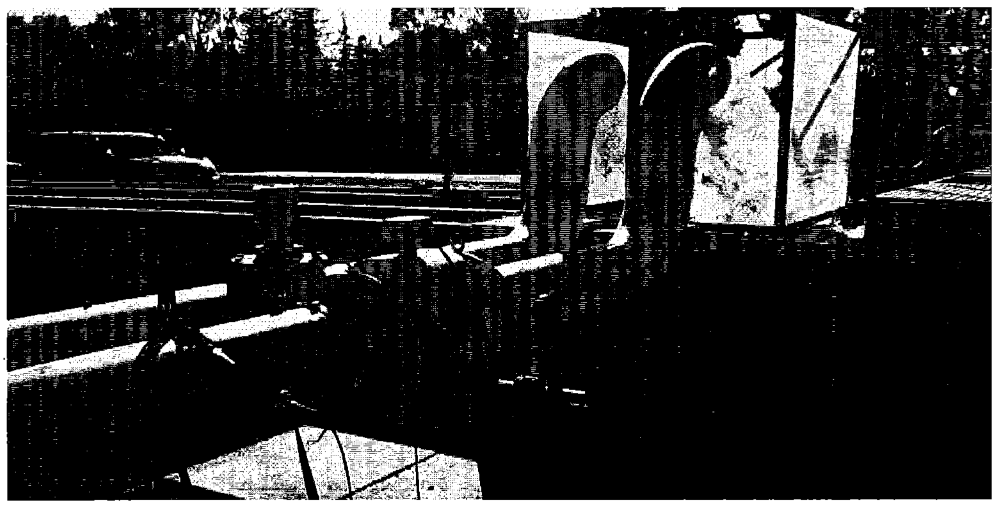


Figure A-4. Water Specialties Magnetic Flow Meter at CSUC ATRC

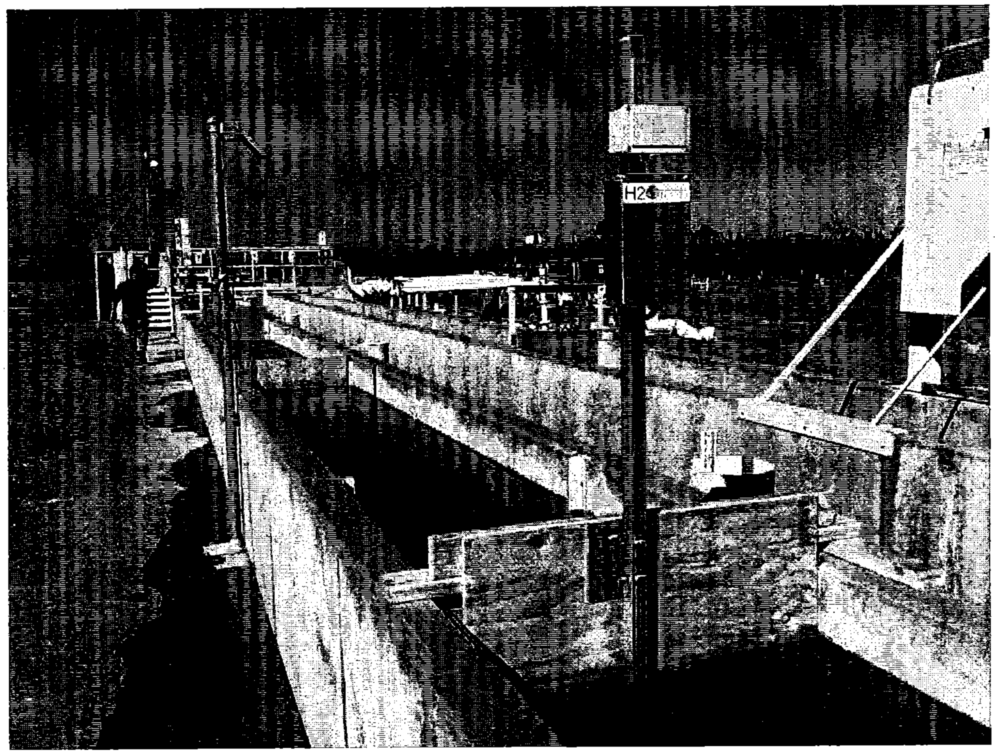


Figure A-5. RemoteTracker Wireless Water Velocity Sensor Installed at CSUC ATRC

Seven comparison measurements were made between the RemoteTracker and magnetic meter ranging from 0.5 cfs to just over 3.0 cfs (the maximum pump capacity). The percent difference between the two measurements averaged roughly -2.6 percent with a range of -10.2 to 2.8 percent indicating that the RemoteTracker measurement methodology compares very well with the magnetic meter. Note that the -10.2 percent difference occurred at the lowest flow rate of approximately 0.5 cfs and represents an absolute flow rate difference of just 0.05 cfs between the two measurement methods. The results of the comparison measurements are presented in Figure A-6 where the blue bars represent flow rates obtained with a magnetic meter, the red bars represent flow rates obtained with the RemoteTracker and the green triangles represent the percent difference between the two (secondary vertical axis).

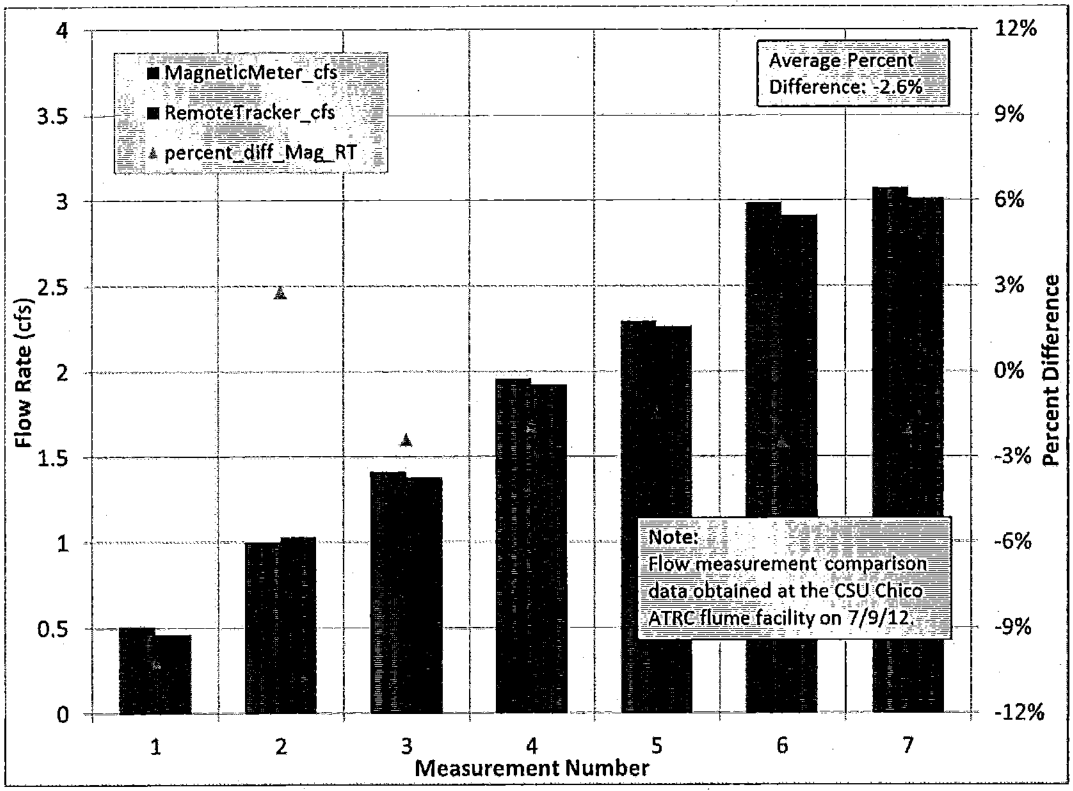


Figure A-6. RemoteTracker and CSUC ATRC Magmeter Comparisons

A-3.2 Field Testing

Five comparison measurements between the RemoteTracker and USGS mid-section method measurements with a SonTek ADV were performed at two turnouts in two irrigation districts (one turnout in each District) in Northern California during the 2011 irrigation season. The turnouts were selected because the delivery spilled into a field ditch (or head ditch) rather than a field, so both a RemoteTracker and a USGS mid-section method measurement (Rantz 1982) could be taken and compared. Figure A-7 shows the cross section report for one of the measurements in a typical earthen head ditch, in this case with a maximum depth of 2.5 feet, top width of 14 feet and bottom width of 5 feet. Typically, velocity measurements were performed at 0.5 foot intervals with velocities averaged over a 40 second period.

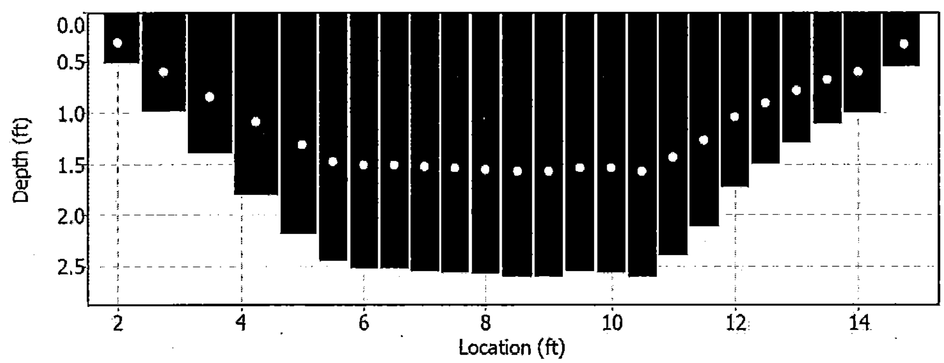


Figure A-7. SonTek ADV Cross Section for Canal Verification Measurement

The percent difference between the RemoteTracker and the USGS mid-section method averaged roughly 0.9 percent with a range of -0.8 to 3.4 percent, indicating that the RemoteTracker measurement methodology compares very well with the standard mid-section open channel methodology. The results of the comparison measurements are presented below in Figure A-8 where the blue bars represent flow rates obtained with a SonTek ADV in an open channel downstream of the turnout, the red bars represent flow rates obtained with the RemoteTracker and the green triangles represent the percent difference between the two (secondary vertical axis).

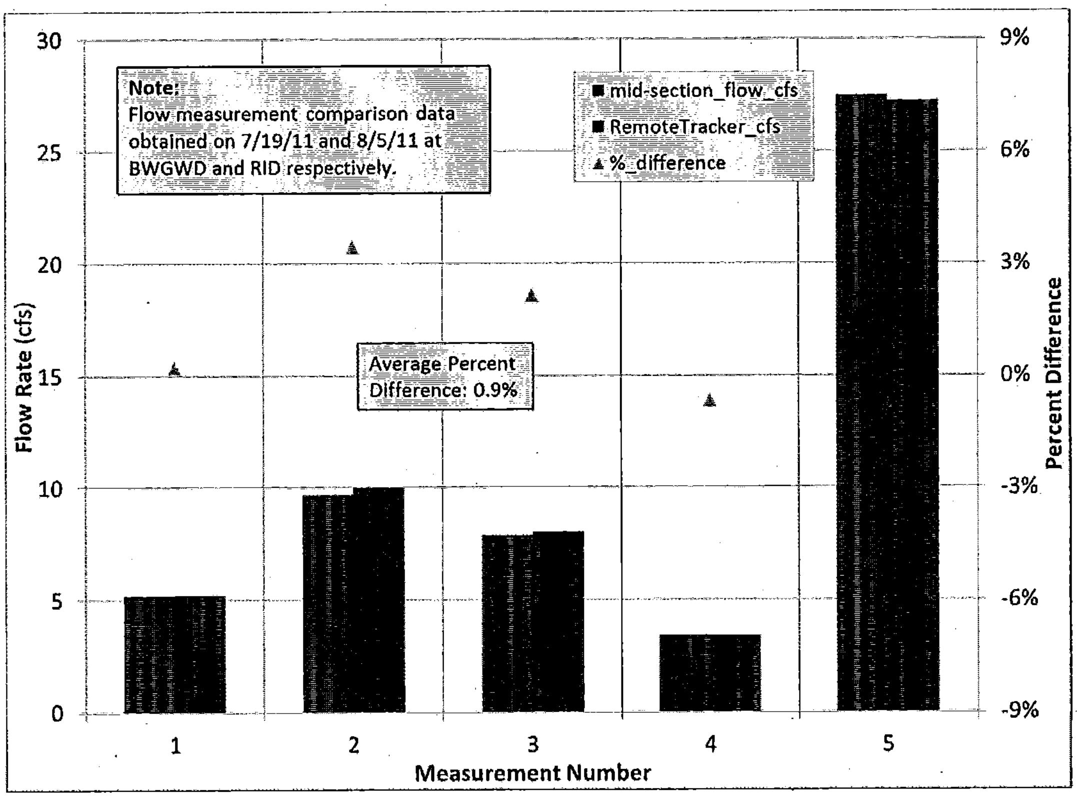


Figure A-8. RemoteTracker and Mid-Section method Comparisons

A-4.0 Volumetric Conversion (CCR 23 §597.4(e)(3))

Accuracy mandates established by CCR 23 §597 apply to delivery volume and not instantaneous flow rate or velocity. CCR 23 §597.4(e)(3)(B) states, "For devices that measure velocity only, the documentation shall describe protocols associated with the measurement of the cross-sectional area of flow and duration of water delivery...". This document provides descriptions of the protocols associated with the measurement of (1) average velocity, (2) cross-sectional area of flow and (3) duration of delivery, in addition to the corresponding accuracies associated with each measurement.

Because the RemoteTracker WWVS measures water velocity only, Equation A-1 suggested in CCR 23 597.4(e)(3)(B) is used to calculate volume.

$$\forall = V * A * \Delta t$$ **(Equation A-1)**

Where the variables are defined as:

- $\forall$: Volume
- V: Average Velocity
- A: Cross-Section Flow Area
- Δt: Duration of Delivery

This relative accuracy analysis assumes:

- 3 cubic foot per second (cfs) maintenance delivery
- A 24 inch inner diameter delivery pipe
- Normal distribution of measurement errors

A 3 cfs delivery was selected because it represents the lower range of agricultural water delivery rates and accuracy is harder to achieve at low flows. A 24 inch pipe is the average turnout pipe size within most agricultural districts. These assumptions lead to the listed variables having the values presented below.

- V_{RT} = RemoteTracker Velocity Measurement = 1.00 ft/s
- $V_{Avg}*$ = Average Velocity of the pipe at the time of the RemoteTracker spot measurement = 0.95 ft/s (determined by correlation with measured velocity; see Figure A-3)
- D = Pipe Diameter = 2.00 ft
- A = Cross-Section Flow Area = 3.14 ft^2

Based on the following analysis, the expected accuracy in volumetric measurements performed with the RemoteTracker system is ±4.6 percent.

A-4.1 Volumetric Accuracy Analysis Overview

Volumetric accuracy of water deliveries consists of the accuracies in each of the following three components:

- Average Velocity (V_{Avg})
- Cross-Section Flow Area (A)
- Duration of Delivery (Δt)

The total absolute accuracy is found using the following equation;

$$\sigma_{\forall} = \pm\sqrt{\left(\frac{\partial\forall}{\partial V_{Avg}}\sigma_{V_{Avg}}\right)^2 + \left(\frac{\partial\forall}{\partial A}\sigma_A\right)^2 + \left(\frac{\partial\forall}{\partial\Delta t}\sigma_{\Delta t}\right)^2} \quad \textbf{(Equation A-2)}$$

Where the variables are defined as:

- $\forall$: Volume
- V_{Avg}: Average Velocity
- Δt: Duration of Delivery
- σ: Absolute Accuracy (expressed in the units of the term in question)
- U: Relative Accuracy (expressed as a percentage)

The total relative accuracy is:

$$U_{\forall} = \frac{\sigma_{\forall}}{\forall} = \pm\frac{1}{\forall}\sqrt{\left(\frac{\partial\forall}{\partial V_{Avg}}\sigma_{V_{Avg}}\right)^2 + \left(\frac{\partial\forall}{\partial A}\sigma_A\right)^2 + \left(\frac{\partial\forall}{\partial\Delta t}\sigma_{\Delta t}\right)^2} \quad \textbf{(Equation A-3)}$$

$$U_{\forall} = \pm\sqrt{\frac{1}{\forall^2}\left(\left(\frac{\partial\forall}{\partial V_{Avg}}\sigma_{V_{Avg}}\right)^2 + \left(\frac{\partial\forall}{\partial A}\sigma_A\right)^2 + \left(\frac{\partial\forall}{\partial\Delta t}\sigma_{\Delta t}\right)^2\right)}$$

Where the partial derivatives are:

$$\frac{\partial\forall}{\partial V_{Avg}} = A\Delta t \;,\; \frac{\partial\forall}{\partial A} = V_{Avg}\Delta t \,,\; \frac{\partial\forall}{\Delta t} = V_{Avg}A$$

Substituting in the solutions to the partial derivatives:

$$U_{\forall} = \pm\sqrt{\frac{1}{\forall^2}\left(\left(A\Delta t\sigma_{V_{Avg}}\right)^2 + \left(V_{Avg}\Delta t\sigma_A\right)^2 + \left(V_{Avg}A\sigma_{\Delta t}\right)^2\right)}$$

$$U_{\forall} = \pm\sqrt{\left(\frac{A\Delta t\sigma_{V_{Avg}}}{\forall}\right)^2 + \left(\frac{V_{Avg}\Delta t\sigma_A}{\forall}\right)^2 + \left(\frac{V_{Avg}A\sigma_{\Delta t}}{\forall}\right)^2}$$

$$U_{\forall} = \pm\sqrt{\left(\frac{\sigma_{V_{Avg}}}{V_{Avg}}\right)^2 + \left(\frac{\sigma_A}{A}\right)^2 + \left(\frac{\sigma_{\Delta t}}{\Delta t}\right)^2}$$

This becomes:

$$U_{\forall} = \pm\sqrt{\left(U_{V_{Avg}}\right)^2 + (U_A)^2 + (U_{\Delta t})^2}$$ **(Equation A-4)**

Based on Equation A-4, the relative accuracies of Average Velocity, Cross-Section Flow Area, and Duration of Delivery are required. The following sections detail their determination.

A-4.2 Relative Accuracy in Velocity

The following bullet points provide protocols for the collection of water velocity data.

- The RemoteTracker WWVS will be deployed in the delivery pipe outfall so that the sample volume is located in the center of the delivery pipe
- Water velocities will be collected with the RemoteTracker WWVS at:
  - The start of all delivery events
  - After any changes in delivery events
- Shutoffs will be recorded on the RemoteTracker user interface with the "Record Shutoff" button at the time the gate is closed

The accuracies in average velocity consist of three parts:

1. $\sigma_{V_{RT}}$: Accuracy of RemoteTracker velocity measurements
2. $\sigma_{V_{Avg}*}$: Accuracy due to the process of correlating RemoteTracker velocity measured at the pipe center and the average velocity of the pipe at the time of the RemoteTracker spot measurement[16]
3. $\sigma_{\Delta V_T}$: Accuracy due to the difference between the average velocity at the time of the RemoteTracker spot measurement and the actual average velocity for the duration of the delivery (i.e. change in velocity over time)

The average velocity relative accuracy is:

[16] Average velocity at the time of the RemoteTracker spot measurement represents a snapshot of the average water velocity in a delivery pipe at the time of the RemoteTracker measurement.

$$U_{V_{Avg}} = \pm \frac{\sigma_{V_{Avg}}}{V_{Avg}}$$ **(Equation A-5)**

Where the variables are defined as:

- V_{Avg}: Average Velocity
- $U_{V_{Avg}}$: Relative Velocity Accuracy
- $\sigma_{V_{Avg}}$: Absolute Velocity Accuracy

The average velocity of the entire irrigation event is the summation of the average velocity at the time of observation and the average change in velocity throughout the remainder of the event due to water level fluctuations.

$$V_{Avg} = V_{Avg} * + \Delta V_T$$ **(Equation A-6)**

Where the variables are defined as:

- V_{Avg}: Average Velocity
- V_{Avg} $*$: Average Velocity at the time of the RemoteTracker spot measurement
- ΔV_T: Average Change in Velocity over time

Therefore:

$$\sigma_{V_{Avg}} = \pm \sqrt{\left(\frac{\partial V_{Avg}}{\partial V_{AvgO}} \sigma_{V_{AvgO}}\right)^2 + \left(\frac{\partial V_{Avg}}{\partial \Delta V_T} \sigma_{\Delta V_T}\right)^2}$$ **(Equation A-7)**

Where the partial derivatives are:

$$\frac{\partial V_{Avg}}{\partial V_{Avg*}} = 1, \ \frac{\partial V_{Avg}}{\partial \Delta V_T} = 1$$

Substituting in the solutions to the partial derivatives:

$$\sigma_{V_{Avg}} = \pm \sqrt{\left(\sigma_{V_{Avg*}}\right)^2 + \left(\sigma_{\Delta V_T}\right)^2}$$ **(Equation A-8)**

The following subsections present (1) the accuracy of the RemoteTracker velocity measurements, (2) the accuracy of the average velocity at the time of the RemoteTracker spot measurements ($\sigma_{V_{Avg}*}$) and (3) the accuracy in the change in average velocity over time ($\sigma_{\Delta V_T}$).

A-4.2.1 Accuracy of RemoteTracker Velocity Measurement

The RemoteTracker system uses a SonTek ADV for water velocity measurements. The SonTek ADV technical specifications sheet lists a velocity measurement error of 0.01 or 1.0 percent (SonTek 2006). Therefore, $\sigma_{V_{RT}}$ is equal to 0.010 ft/s, or 1.0 percent of 1.00 ft/s (V_D).

A-4.2.2 Accuracy of the Average Velocity at the Time of the RemoteTracker Spot Measurement

The average velocity is computed as the product of the velocity measured by the RemoteTracker and the coefficient correlating the RemoteTracker velocity measurement to the average velocity at the time of the RemoteTracker spot measurement.

$$V_{Avg} *= CV_{RT} \qquad \textbf{(Equation A-9)}$$

Where the variables are defined as:

- V_{Avg} *: Average velocity at the time of the RemoteTracker spot measurement
- C: Coefficient correlating the RemoteTracker velocity measurement to the average velocity at the time of the RemoteTracker spot measurement, which is equal to 0.95 (see Figure A-3)
- V_{RT}: RemoteTracker velocity measurement

Therefore:

$$\sigma_{V_{Avg}*} = \pm\sqrt{\left(\frac{\partial V_{Avg}*}{\partial C}\sigma_C\right)^2 + \left(\frac{\partial V_{Avg}*}{\partial V_{RT}}\sigma_{V_{RT}}\right)^2} \qquad \textbf{(Equation A-10)}$$

Where the partial derivatives are:

$$\frac{\partial V_{Avg}*}{\partial C} = V_{RT}, \frac{\partial V_{Avg}*}{\partial V_{RT}} = C$$

Substituting in the solutions to the partial derivatives:

$$\sigma_{V_{Avg}*} = \pm\sqrt{(V_{RT}\sigma_C)^2 + \left(C\sigma_{V_{RT}}\right)^2} \qquad \textbf{(Equation A-11)}$$

Based on water velocity data collected, the average error introduced by converting the RemoteTracker velocity measurement to the average velocity at the time of the RemoteTracker spot measurement (σ_C) is 0.014 or 1.4 percent.

Inserting the determined values into Equation A-11:

$$\sigma_{V_{Avg^*}} = \pm\sqrt{(1.0 * 0.014)^2 + (0.95 * 0.010)^2} = \pm\, 0.017\, ft/s$$

A-4.2.3 Accuracy of the Change in Velocity over Time

A Microsoft Access database was developed to assess the accuracy in the change in velocity over time. Based on the orifice equation, the change in velocity through an orifice is solely a function of changes in head (or difference between upstream and downstream water level). Only water level data from the typical irrigation season (i.e. May through August) was used. It was assumed that measurements of velocity were performed every three days.

The difference between the head observed every three days and the actual average of the 15 minute data during the three day period was computed for each 15 minute record and then averaged over the observation period. Equation A-14 was then used to calculate the change in velocity over time (ΔV_T) for each three day period. The initial head (h_i) was assumed to be 0.5 feet to simulate a low head delivery. A low head was chosen because water level fluctuations impact the velocity of low head deliveries more significantly than high head deliveries.

Rearranging Equation A-6:

$$\Delta V_T = V_{Avg} - V_{Avg} *$$

From the orifice equation:

$$V = C(2gh)^{0.5}$$ **(Equation A-12)**

Where the variables are defined as:

- V: Velocity
- C: Discharge Coefficient
- g: gravitational constant
- h: Head

Orifice gates in most agricultural water districts operate under submerged conditions (i.e. not free flow conditions). As upstream canal water levels fluctuate, the flow through the orifice would theoretically vary as a function of the changes in canal water level to the one-half power. However, since the orifice gates are submerged, the hydraulically connected downstream water level also varies together with the upstream canal water level. This provides a damping effect on the overall change in velocity due to upstream water level fluctuations. The California Polytechnic State University at San Luis Obispo Irrigation Training and Research Center (ITRC) suggest using a power of 0.38 in the orifice equation to simulate the damping effect of submergence for a range of downstream channel conditions (Burt and Geer 2012).

$$V = C(2gh)^{0.38} \quad \textbf{(Equation A-13)}$$

Substituting values:

$$\Delta V_T = C(2gh_{avg})^{0.38} - C(2gh_O)^{0.38}$$

Where the variables are defined as:

- h_{avg}: Average Head
- h_O: Observed Head

Factoring:

$$\Delta V_T = C(2g)^{0.38}\left((h_{avg})^{0.38} - (h_O)^{0.38}\right)$$

Substituting values:

$$\Delta V_T = C(2g)^{0.38}\left((h_i + \Delta h_{avg})^{0.38} - (h_i)^{0.38}\right) \quad \textbf{(Equation A-14)}$$

Where the variables are defined as:

- h_i= Initial head at time of observation
- Δh_{avg}= average change in head

Since the volumetric reporting mandates apply to a monthly or bi-monthly basis (California Water Code §531.10(a)), the change in velocity over time was then averaged on a monthly time step. The average of the absolute values of each of the average monthly changes in velocity over time was taken across all nine sites. Largely due to the fact that water level fluctuations are normally distributed, the results of the hydraulic database model suggest that the average change in velocity over time due to water level fluctuation is:

$$\sigma_{\Delta V_T} = \pm\, 0.033\, ft/s$$

Based on the evaluation of continuous upstream and downstream water level data from 14 irrigation events in RD 108 with an average duration of five days, the average change in velocity over time was determined to be ±1.0 percent. In the context of this analysis, the accuracy in the change in velocity over time would be:

$$\sigma_{\Delta V_T} = \pm 1.0\% \; or \pm 0.010 \; ft/s$$

Therefore, utilizing the value of ±0.033 ft/s for the volumetric accuracy analysis is a conservative assumption.

Inserting the calculated values into Equation A-8, the average velocity accuracy is:

$$\sigma_{V_{Avg}} = \pm\sqrt{(0.017)^2 + (0.033)^2} = 0.037 \; ft/s$$

The relative accuracy of the average velocity is:

$$\boxed{U_{V_{Avg}} = \pm\frac{\sigma_{V_{Avg}}}{V_{Avg}} = \pm\frac{0.037 \; ft/s}{0.95 \; ft/s} = \pm 0.039 \; or \; 3.9\%}$$

A-4.3 Relative Accuracy in Cross-Section Flow Area

The following bullet points provide protocols for the collection of cross-section flow area data.

- The cross-section flow area will be calculated by measuring the inner diameter of the delivery pipe at the location of the water velocity measurement and using Equation A-16 to calculated area from inner diameter
- Inner pipe diameters will be measured with best professional practices when the pipe is dry

The accuracy in the inner pipe diameter measurement is assumed to be 0.02 feet (or 1/4 inch). The relative accuracy due to area is:

$$U_A = \pm\frac{\sigma_A}{A} \qquad \textbf{(Equation A-15)}$$

The correlation between diameter and area is:

$$A = \frac{\pi D^2}{4} \qquad \textbf{(Equation A-16)}$$

Where the variables are defined as:

- A: Cross-Section Flow Area
- π: Pi
- D: Inner Diameter

The accuracy is:

$$\sigma_A = \pm\sqrt{\left(\frac{\partial A}{\partial D}\sigma_D\right)^2}$$ **(Equation A-17)**

Where the partial derivative is equal to:

$$\frac{\partial A}{\partial D} = \frac{2\pi D}{4} = \frac{\pi D}{2}$$

The assumed pipe is 2.00 feet (24 inch) in diameter, giving an area of 3.142 ft^2

$$\sigma_A = \pm\sqrt{\left(\frac{\partial A}{\partial D}\sigma_D\right)^2} = \sqrt{\left(\frac{\pi D}{2}0.02\right)^2} = \sqrt{\left(\frac{\pi 2}{2}0.02\right)^2} = \pm\, 0.063\, ft$$

The relative accuracy in the cross-section flow area is:

$$U_A = \pm\frac{\sigma_A}{A} = \pm\frac{0.063\, ft}{3.142\, ft} = \pm\, 0.020\ or\ 2.0\%$$

A-4.4 Relative Accuracy in Duration of Delivery

The following bullet points provide protocols for the collection of duration of delivery data.

- The start time for delivery will be the date and time recorded in the RemoteTracker system when a velocity measurement is taken at the start of a delivery
- The stop time for delivery will be the date and time recorded in the RemoteTracker system when either:
  - "Record Shutoff" is pressed after a gate is closed at the end of a delivery or
  - A new velocity measurement is taken after a change in delivery flow rate is made

A conservative value for the duration of an irrigation event is assumed to be a period of 24 hours. The possible accuracy in duration measurement is considered to be 15 minutes for the startup and 15 minutes for the shutoff (or 0.25 hours for both). Realistically, the actual accuracy in duration is much smaller when using the RemoteTracker system since the operator is recording water velocity data on site when gate position changes are made. The relative accuracy due to duration of delivery is:

$$U_{\Delta t} = \pm\frac{\sigma_{\Delta t}}{\Delta t}$$ **(Equation A-18)**

Where:

$$\Delta t = Et - St$$ **(Equation A-19)**

Where the variables are defined as:

- Δt: Duration of Delivery
- St: Start Time
- Et: End Time

The accuracy of the Duration of Delivery is:

$$\sigma_{\Delta t} = \pm\sqrt{\left(\frac{\partial \Delta t}{\partial St}\sigma_{St}\right)^2 + \left(\frac{\partial \Delta t}{\partial Et}\sigma_{Et}\right)^2}$$ **(Equation A-20)**

Where the partial derivatives are equal to:

$$\frac{\partial \Delta t}{\partial St} = 1, \frac{\partial \Delta t}{\partial Et} = 1$$

$$\sigma_{\Delta t} = \pm\sqrt{(\sigma_{St})^2 + (\sigma_{Et})^2} = \sqrt{(.25)^2 + (0.25)^2} = 0.35\ hrs$$

The relative accuracy in the duration of delivery is:

$$U_{\Delta t} = \pm\frac{\sigma_{\Delta t}}{\Delta t} = \pm\frac{0.35}{24} = \pm\ 0.015\ or\ 1.5\%$$

A-4.5 Relative Accuracy in Volume

As previously stated this relative accuracy assumes a 3 cfs maintenance delivery in a 24" pipe. Inserting the calculated accuracy value for each component, the relative accuracy is as follows:

$$U_{\forall} = \pm\sqrt{\left(U_{V_{Avg}}\right)^2 + (U_A)^2 + (U_{\Delta t})^2}$$ **(Equation A-21)**

Inserting all calculated accuracy values the relative accuracy in volumetric measurements is:

$$U_{\forall} = \pm\sqrt{(.039)^2 + (.020)^2 + (.015)^2}$$

$$U_{\forall} = \pm\ 0.046\ or\ \pm 4.6\%$$

Based on the foregoing analysis and the resulting ±4.6% accuracy in delivery volume determined for the RemoteTracker, the RemoteTracker complies with the ±5.0% accuracy mandate in CCR 23 §597 for laboratory testing.

Appendix B. Detailed Cost Estimates

Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$400	0%	$400	
							$400	$400
Preparation								
2	Mobilization	ls	1	5%	$200	0%	$200	
							$200	$200
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	18" Orifice Gate	ea	25%	$1,890	$473	15%	$543	
7	24" Orifice Gate	ea	50%	$2,110	$1,055	15%	$1,213	
8	30" Orifice Gate	ea	25%	$2,736	$684	15%	$787	
9	Concrete Headwall	ea	1	$1,265	$1,265	15%	$1,455	
10								
11								
12								
13								
14								
							$3,998	$3,998
PROJECT SUBTOTAL								$4,598
Project Administration								
15	Construction Management and Overhead	ls	1	10%	$420	0%	$420	$420
TOTAL								$5,017

Figure B-1. Orifice Gate Unit Cost Breakdown

Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$115	0%	$115	
							$115	$115
Preparation								
2	Mobilization	ls	1	5%	$58	0%	$58	
							$58	$58
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	Calibration and Rating - Orifice Gate	ls	1	$1,000	$1,000	15%	$1,150	
7								
8								
9								
10								
11								
12								
13								
14								
							$1,150	$1,150
PROJECT SUBTOTAL								$1,323
Project Administration								
15	Planning/mobilization contingency	ls	1	0%	$0	0%	$0	$0
TOTAL								$1,323

Figure B-2. Orifice Gate Calibration Unit Cost Breakdown

Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$95	0%	$95	
							$95	$95
Preparation								
2	Mobilization	ls	1	5%	$48	0%	$48	
							$48	$48
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	Stilling Well 1' Downstream of Gate	ea	1	$530	$530	15%	$610	
7	Staff Gages	ea	1	$300	$300	15%	$345	
8								
9								
10								
11								
12								
13								
14								
							$955	$955
PROJECT SUBTOTAL								$1,098
Project Administration								
15	Construction Management and Overhead	ls	1	10%	$100	0%	$100	$100
TOTAL								$1,198

Figure B-3. Orifice Gate Differential Head Unit Cost Breakdown

Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$178	0%	$178	
							$178	$178
Preparation								
2	Mobilization	ls	1	5%	$89	0%	$89	
							$89	$89
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	4-ft concrete weir box	ea	1	$1,265	$1,265	15%	$1,455	
7	Aggregate Base	cy	3	$60	$180	15%	$207	
8	Weir boards and stand plate	ea	1	$100	$100	15%	$115	
9								
10								
11								
12								
13								
14								
							$1,777	$1,777
PROJECT SUBTOTAL								$2,043
Project Administration								
15	Construction Management and Overhead	ls	1	10%	$187	0%	$187	$187
TOTAL								$2,230

Figure B-4. Weir Box Cost Breakdown

Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$316	0%	$316	
							$316	$316
Preparation								
2	Mobilization	ls	1	5%	$158	0%	$158	
							$158	$158
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	Mag Meter	ea	1	$2,750	$2,750	15%	$3,163	
7								
8								
9								
10								
11								
12								
13								
14								
							$3,163	$3,163
PROJECT SUBTOTAL								$3,637
Project Administration								
15	Construction Management and Overhead	ls	1	10%	$332	0%	$332	$332
TOTAL								$3,969

Figure B-5. Totalizing Flow Meter Unit Cost Breakdown

Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$11,558	0%	$11,558	
							$11,558	$11,558
Preparation								
2	Mobilization	ls	1	5%	$5,779	0%	$5,779	
							$5,779	$5,779
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	MS Office Suite	ea	1	$500	$500	15%	$575	
7	Database Customization for Volumetric Tracking	ls	1	$30,000	$30,000	15%	$34,500	
8	Development of Automated Quality Control Proc	ls	1	$25,000	$25,000	15%	$28,750	
9	Creating Invoicing and Accounting Process	ls	1	$45,000	$45,000	15%	$51,750	
10								
11								
12								
13								
14								
							$115,575	$115,575
PROJECT SUBTOTAL								$132,911
Project Administration								
15	Planning/mobilization contingency	ls	1	0%	$0	0%	$0	$0
TOTAL								$132,911

Figure B-6. Water Information System Unit Cost Breakdown

Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$2,875	0%	$2,875	
							$2,875	$2,875
Preparation								
2	Mobilization	ls	1	5%	$1,438	0%	$1,438	
							$1,438	$1,438
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	RemoteTracker System	ea	1	$25,000	$25,000	15%	$28,750	
7								
8								
9								
10								
11								
12								
13								
14								
							$28,750	$28,750
PROJECT SUBTOTAL								$33,063
Project Administration								
15	Planning/mobilization contingency	ls	1	0%	$0	0%	$0	$0
TOTAL								$33,063

Figure B-7. RemoteTracker System Unit Cost Breakdown

Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$26	0%	$26	
							$26	$26
Preparation								
2	Mobilization	ls	1	5%	$13	0%	$13	
							$13	$13
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	RemoteTracker Plate	ea	1	$200	$200	15%	$230	
7	Pipe Diameter measurements	ea	1	$25	$25	15%	$29	
8								
9								
10								
11								
12								
13								
14								
							$259	$259
PROJECT SUBTOTAL								$298
Project Administration								
15	Construction Management and Overhead	ls	1	10%	$27	0%	$27	$27
TOTAL								$325

Figure B-8. RemoteTracker Plate Unit Cost Breakdown

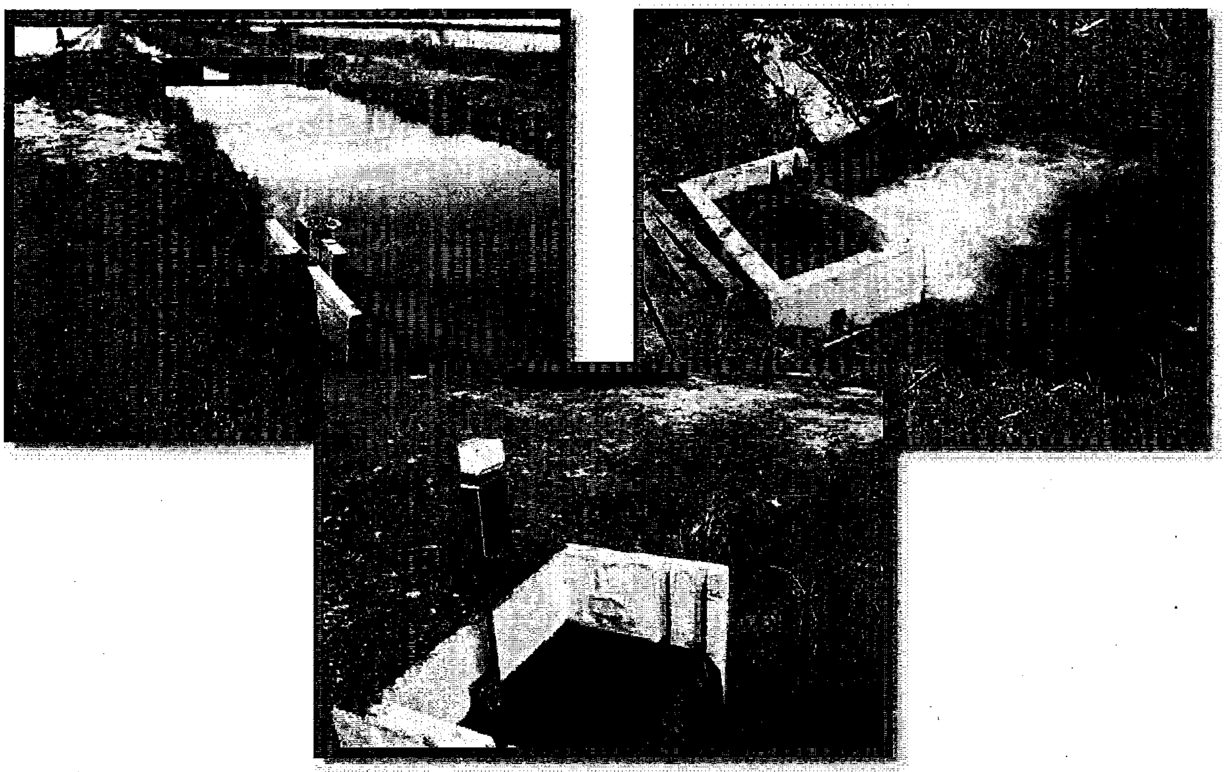
Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$361	0%	$361	
							$361	$361
Preparation								
2	Mobilization	ls	1	5%	$180	0%	$180	
							$180	$180
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	18" Propeller Meter	ea	25.0%	$2,920	$730	15%	$840	
7	24" Propeller Meter	ea	50.0%	$3,210	$1,605	15%	$1,846	
8	30" Propeller Meter	ea	25.0%	$3,210	$803	15%	$923	
9	Propeller Meter Plate	ea	1	$0	$0	15%	$0	
10								
11								
12								
13								
14								
							$3,608	$3,608
PROJECT SUBTOTAL								$4,149
Project Administration								
15	Construction Management and Overhead	ls	1	10%	$379	0%	$379	$379
TOTAL								$4,528

Figure B-9. Propeller Meter Unit Cost Breakdown

Richvale Irrigation District

Evaluation of Customer Delivery Measurement Options

Butte County, California



Prepared by

DAVIDS ENGINEERING, INC

December 2012

Contents

Abbreviations

ADV	Acoustic Doppler Velocimeter
AF	acre-feet
BWGWD	Biggs-West Gridley Water District
CCR	California Code of Regulations
CDMP	Customer Delivery Measurement Plan
cfs	cubic feet per second
DWR	California Department of Water Resources
ft	feet/foot
ft/s	feet per second
gpm	gallons per minute
RID	Richvale Irrigation District
SNR	Signal-to-Noise Ratio
WCD	Wireless Computing Device
WIS	Water Information System
WMM	U.S. Bureau of Reclamation Water Measurement Manual
WSE	Water Surface Elevation
WWAN	Wireless Wide Area Network
WWVS	Wireless Water Velocity Sensor

List of Figures

List of Tables

List of Appendices

ES-1.0 Executive Summary

ES-1.1 Introduction

Formed on July 7, 1930, Richvale Irrigation District (RID or District) is located in the Sacramento Valley in southern Butte County, northern California. The District holds pre-1914 water rights to Feather River water in conjunction with three other districts that make up the Joint Water Districts Board (Biggs-West Gridley Water District, Butte Water District and Sutter Extension Water District). The District operates and maintains a canal and lateral distribution system that supplies water to roughly 34,000 acres. The primary crop grown in the District is rice. RID's service area also includes the Upper Butte Basin Wildlife Area. RID has a water service contract with the Department of Water Resources (DWR) for an annual allocation of 149,850 acre feet.

Due to the unique characteristics and measurement challenges associated with rice water delivery, farm turnout measurement has evolved differently in RID (and in most other rice-dominated water suppliers) as compared to some other suppliers in California. Historically, the District's canal system has been operated based on the management of canal water levels (or pools). With canal water levels held at targeted elevations, certain field-specific gate settings will deliver the necessary rice flood up and maintenance flows. The field-specific gate settings have been determined from years of experience and have been calibrated to deliver sufficient water without causing excessive tailwater. Operating in this manner, appropriate amounts of water are delivered to rice fields without the need to measure delivery rates or volumes. In summary, the operation consists of setting and adjusting turnout gate opening as needed to maintain desired field conditions and adjusting water deliveries into canals as needed to maintain targeted water levels. Flow adjustments are made based on approximations and rules of thumb, and there has been no need to measure water precisely to achieve "good" water management, provided that field tailwater and canal spills are held within reasonable limits.

Senate Bill X7-7 (the "Water Conservation Act") was enacted in November 2009, requiring all water suppliers to increase water use efficiency. Agricultural water suppliers, such as RID, are mandated to prepare and adopt agricultural management plans by December 31, 2012, and update those plans by December 31, 2015, and every 5 years thereafter. The Water Conservation Act included Water Code section 10608.48(i)(1) directing the California Department of Water Resources to adopt regulations providing for a range of options that agricultural water suppliers may use to implement volumetric measurement of farm-gate water deliveries. The resulting regulation, California Code of Regulations Title 23 Division 2 Chapter 5.1 Article 2 Section 597 et seq. (CCR 23 §597), mandates that, on or before July 31, 2012, agricultural water suppliers subject to the law shall measure the volume of water delivered to customers with sufficient accuracy to:

- Enable reporting of aggregated farm-gate delivery data to the State and
- Adopt a pricing structure based at least in part on the quantity of water delivered.

CCR 23 §597 requires that existing farm turnouts like those in the District have a measurement accuracy of ±12 percent by volume, meaning that the measured volume of water delivered at each farm-gate (i.e. turnout) must be no greater than 12 percent more, or 12 percent less, than the actual volume delivered. Additionally, any new or replacement measurement devices installed must be accurate to within:

- ±5 percent by volume in the laboratory if using a laboratory certification;
- ±10 percent by volume in the field if using a non-laboratory certification

The regulation mandates that an accuracy certification be performed by either: (1) field testing of a random and statistically representative sample of existing farm turnouts, (2) field inspections and analysis of every existing farm turnout, with the testing or inspections documented by a registered engineer, or (3) a laboratory certification.

The purpose of this document is to summarize the activities and analysis performed by Davids Engineering during 2012 in support of the District's evaluation of options for customer delivery measurement that are mandated by CCR 23 §597. The evaluation of options was comprised of the following three tasks:

1. Preparing an inventory of RID delivery gates, including establishing GPS coordinates and critical physical characteristics, including turnout pipe size, gate type and available head.
2. Pilot testing of RemoteTracker operation, and developing and testing measurement data collection and customer billing processes during the 2012 irrigation season.
3. Evaluating alternative measurement devices and compliance approaches, including estimated capital costs.

This report documents the work completed according to the three tasks described above. The report is organized into the following five sections:

- **1.0 Introduction** - Provides information about RID, its existing measurement practices, CCR 23 §597 and the purpose of this report
- **2.0 Farm Turnout Inventory** - Summarizes the findings of the farm turnout inventory
- **3.0 Alternative Measurement Devices** - Presents overviews of four measurement devices, including their respective abilities to meet the accuracy mandates of CCR 23 §597
- **4.0 Alternative Measurement Approaches** - Describes three measurement approaches for District-wide measurement based on the four measurement devices described in Section 3.0
- **5.0 Cost Estimates** - Provides reconnaissance-level capital cost estimates for the three measurement approaches developed in Section 4.0
- **6.0 Corrective Action Plan** - Presents basic overview of RID's selection of a preferred measurement approach

ES-1.2 Farm Turnout Inventory

An inventory was performed during the 2012 irrigation season to identify all existing farm turnouts in the District and to characterize each farm turnout with respect to factors related to application of the four possible measurement devices evaluated.

Figure ES-1 provides a summary of the farm turnout inventory. A total of 302 farm turnouts were identified during the inventory. Of the total of 302 farm turnouts, 302 are served by supply canals and none are served by drainage channels (drains). Of the 302 gravity farm turnouts served by supply canals, 233 are controlled by orifice gates (gates) and 69 are controlled by other means (e.g. alfalfa valves, weir structures, or other). 210 of the 233 gate-controlled gravity farm turnouts have weir boxes. None of the 69 turnouts from supply canals controlled by other means have weir boxes.

In the late fall of 2012, subsequent to the farm turnout inventory, the District replaced, or retrofitting in some cases, a total of 24 gravity farm turnouts. The information summarized below does not account for these improvements.

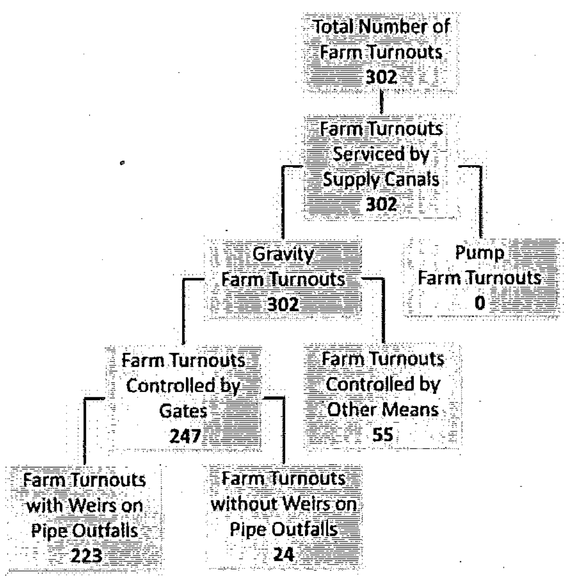


Figure ES-1. Farm Turnout Inventory Summary

ES-1.3 Alternative Measurement Devices

Four measurement devices were evaluated for potential application to achieve compliance with the CCR 23 §597 accuracy mandates. Although presently not used for measurement (see Section 1.2), the existing farm turnout gates could be used for measurement based on the submerged orifice principle. Alternatively, the weir boxes that have been installed at 223 turnout pipe outlets could be used for measurement based on the weir principle. These two existing devices are described further in Sections 3.1 and 3.2. In addition to the existing orifice gates and weir boxes, two new measurement devices were considered for compliance with CCR 23 §597, including the RemoteTracker system and propeller meters. These devices are discussed in Sections 3.3 and 3.4.

ES-1.3.1 Gates

Discharge through a submerged orifice gate can be computed with the Bernoulli equation. Data from previous investigations (Davids Engineering 2012) indicates that orifice gates can measure within the CCR 23 §597 accuracy mandate for existing measurement devices (±12 %) provided that:

- Gate-specific variable coefficients based on multiple measurements at each gate are developed and
- Sufficient headloss occurs through the orifice gate to facilitate differential head measurements with low relative uncertainty (i.e. gates not operating near fully open position leading to minimal headloss through the gate and high relative uncertainties in water level measurements)

Hydraulic analysis of a 24 inch orifice gate indicates that, if a 12 cubic foot per second (cfs) flood flow is desired, a minimum of 0.5 feet of head is required. Based on this criterion, and the survey information discussed in Section 2.6, 198 of the 302 gravity farm turnouts (66 %) have enough head to measure with an orifice gate.

ES-1.3.2 Weirs

Weirs installed in boxes placed at the turnout pipe outlets operate as standard suppressed rectangular weirs because the weir crest occupies the full box width (i.e., there is no flow contraction). Data from previous field investigations (Davids Engineering 2012) indicates that weirs can measure within the CCR 23 §597 accuracy mandate for existing measurement devices (±12 %) provided that:

- Sufficient head (drop) is available between the canal water level and field water level
- Leakage through weir boards is stopped (or accounted for)

Hydraulic analysis of a four foot wide weir box indicates that, if a 12 cubic foot per second (cfs) flood flow is desired, a minimum of 1.5 feet of head is required. Based on this criterion, and the survey information discussed in Section 2.6, 69 of the 302 gravity farm turnouts (23 %) have enough head to measure with a weir.

ES-1.3.3 RemoteTracker System

The RemoteTracker is an integrated turnout flow measurement, data management and volumetric accounting system developed by H2oTech specifically for agricultural water suppliers. The RemoteTracker system is comprised of (1) a wireless water velocity sensor, (2) a ruggedized tablet PC carried in the operator's vehicle and (3) a database residing on a file server connected to the tablet PC via a cellular internet connection. The RemoteTracker system is compliant with the volumetric accuracy mandates of CCR 23 §597. See Appendix A for a laboratory based volumetric accuracy certification of the RemoteTracker system. The RemoteTracker system can provide accurate flow data over all farm turnout head ranges.

ES-1.3.4 Propeller Meters

Using propellers meters for farm turnout measurement involves permanently installing a propeller meter device at each farm turnout. Propeller meters have a propeller that is placed in the outfall of the farm turnout pipe. Laboratory certifications of flow measurement accuracy are available for most commercially available propeller meters. Since propeller meters are permanently installed devices, volumetric accuracy is the same as flow rate accuracy. Therefore, propeller meters are compliant with the volumetric accuracy mandates of CCR 23 §597. Propeller meters can provide accurate flow data over all farm turnout head ranges.

ES-1.4 Alternative Measurement Approaches

To facilitate the development of measurement approaches, all farm turnouts within the District were classified into one of four farm turnout categories:

1. Low Head Gravity (i.e. head less than 0.5 feet),
2. Medium Head Gravity (i.e. head between 0.5 and 1.5 feet),
3. High Head Gravity (i.e. head greater than 1.5 feet) and
4. Pump (i.e. water supplied to fields via pumps).

Table ES-1 presents a summary of three measurement approaches considered to be potentially viable for the District to comply with CCR 23 §597. Table ES-1 indicates the number of turnouts falling in each category and, for each approach, the measurement device that would be used for each category. The three approaches are discussed in greater detail in Sections 4.1 through 4.3. None of the measurement devices discussed in Section 3 can be utilized to measure pump deliveries.

Table ES-2 summarizes the different levels of turnout improvement needed for each of the farm turnout categories, and the number of turnouts in each improvement level. All measurement approaches require gravity farm turnouts to have an orifice gate and a weir box. All pump farm turnouts require a totalizing flow meter. The classifications have been developed to be mutually exclusive so that each farm turnout only corresponds with one improvement classification within the table, which facilitates the ability to sum the number of farm turnouts in each row to develop the total number or farm turnouts in each farm turnout category. The District has replaced or retrofitted farm turnouts subsequent to the inventory; therefore, an 'Improvements after Inventory' classification is necessary to avoid double counting.

Table ES-1. Measurement Approach Summary

Farm Turnout Category	Count of Farm Turnout Categories	Measurement Program Devices		
		Approach 1 - Maximum Use of Existing Devices	Approach 2 - RemoteTracker System	Approach 3 - Propeller Metering Program
Low Head Gravity (H < 0.5 feet)	35	Propeller Meters	RemoteTracker System	Propeller Meters
Medium Head Gravity (0.5' < H < 1.5')	198	Orifice Gates		
High Head Gravity (H > 1.5'	69	Weir Boxes		
Total	302			

Table ES-2. Farm Turnout Improvement Classification Count Summary

Farm Turnout Category	Farm Turnout Improvement Requirement Counts						Sum
	Requires Orifice Gate and Weir Box	Requires Orifice Gate Only	Requires Weir Box Only	Requires Totalizing Flow Meter	Requires No Improvements	Improvements by District after Inventory	
Low Head Gravity (H < 0.5 feet)	8	0	0	n/a	25	2	35
Medium Head Gravity (0.5' < H < 1.5')	41	0	18	n/a	130	9	198
High Head Gravity (H > 1.5'	6	0	6	n/a	55	2	69
Total	55	0	24	n/a	210	13	302

ES-1.4.1 Approach 1 - Maximum Use of Existing Devices

Approach 1 is based on maximizing the use of existing measurement devices; however, neither of the two existing measurement devices (i.e. orifice gates and weir boxes) alone unconditionally meets the volumetric accuracy mandates of CCR 23 §597 across all gravity farm turnouts. Therefore, to achieve maximum use of existing devices, a hybrid approach involving multiple measurement devices is necessary. Approach 1 utilizes weir boxes for high head gravity farm turnouts and orifice gates for medium head gravity farm turnouts. Propeller meters, a new device, would be used for low head gravity farm turnouts because neither gates nor weirs work under low head conditions.

ES-1.4.2 Approach 2 - RemoteTracker System

Approach 2 involves the use of the RemoteTracker system at all gravity farm turnout categories (i.e. high head, medium head and low head gravity farm turnouts).

ES-1.4.3 Approach 3 - Propeller Metering Program

Approach 3 involves the use of propeller meters at all gravity farm turnout categories (i.e. high head, medium head and low head gravity farm turnouts).

ES-1.5 Reconnaissance-Level Cost Estimates

RID, along with other agricultural and urban water suppliers, filed a Test Claim with the Commission on State Mandates alleging that the Water Conservation Act constitutes a reimbursable state mandate. That Test Claim is pending before the Commission and it is anticipated that a hearing will be held in September, 2013, and a decision will be made shortly thereafter. RID, along with other agricultural water suppliers, are in the process of filing a supplemental Test Claim challenging CCR 23 § 597. If the Test Claims are successful, RID will be entitled to reimbursement of all direct and indirect costs of compliance with the Water Conservation Act and 23 CCR § 597, including initial and annualized capital and maintenance and operation costs of farm-gate measurement devices.

Table ES-3 provides reconnaissance-level (1) initial capital, (2) annualized capital and (3) annual maintenance cost estimates for full scale implementation of the three measurement approaches discussed in Section 4. The last row provides the annualized capital and maintenance cost estimates. Differences among the three approaches with respect to operation costs (primarily labor and transportation) are not considered significant; therefore they are not included. A five percent interest rate was used for all calculations.

Table ES-3. Reconnaissance-Level Capital Cost Estimates for Three Measurement Approaches

Cost Category	Measurement Program Cost Estimate		
	Approach 1 - Maximum Use of Existing Devices	Approach 2 - RemoteTracker System	Approach 3 - Propeller Metering Program
Initial Capital	$1,242,553	$762,800	$1,952,543
Annualized Capital	$85,252	$64,616	$146,860
Annualized Maintenance	$66,098	$62,796	$139,388
Annualized Capital and Maintenance	$151,350	$127,412	$286,247

ES-1.6 Corrective Action Plan

At a regularly scheduled meeting on January 17, 2013, the RID Board considered this report and the customer delivery measurement options presented herein. By unanimous vote, the Board accepted the report and adopted measurement Approach 2 - RemoteTracker System as the District's preferred approach for implementing a customer delivery measurement program. The program is intended to comply with the measurement accuracy standards specified in CCR 23 §597 and to be capable of supporting implementation of a water rate structure based at least in part on the volume of water delivered. Such a rate structure remains to be designed and adopted by the Board in the future.

Approach 2 has an estimated capital cost of $762,800. Recognizing that this capital improvement cost is relatively large in comparison to the District's current revenue and operating budgets, the Board also unanimously agreed that the program will be implemented on a "pay-as-you-go" basis as discretionary revenues above operating and maintenance funds become available.

1.0 Introduction

1.1 Richvale Irrigation District

Formed on July 7, 1930, Richvale Irrigation District (RID or District) is located in the Sacramento Valley in southern Butte County, northern California. The District holds pre-1914 water rights to Feather River water in conjunction with three other districts that make up the Joint Water Districts Board (Biggs-West Gridley Water District, Butte Water District and Sutter Extension Water District). The District operates and maintains a canal and lateral distribution system that supplies water to roughly 34,000 acres. The primary crop grown in the District is rice. RID's service area also includes the Upper Butte Basin Wildlife Area. RID has a water service contract with the Department of Water Resources (DWR) for an annual allocation of 149,850 acre feet. Figure 1 shows the District's boundary, laterals, drains and turnouts. The District is divided into primary and secondary service areas.

1.2 Existing Measurement Practices

The large majority of the District's service area is planted to rice. There are essentially two different water delivery flow rates associated with irrigating a rice field: flood-up and maintenance. During flood-up, the goal is to quickly establish ponded water on the field. Flood-up deliveries typically range from 10 to 25 cubic feet per second (cfs), and can last from hours to days depending on field size and other factors. Once a rice field is flooded to the desired depth, the flow is decreased to a maintenance flow rate. Depending on field size, maintenance deliveries typically range from 1 to 6 cfs, and last for several weeks. During the maintenance period, fields may be drained and re-flooded one or more times for purposes of applying herbicides. The same delivery infrastructure is used to deliver both flood-up and maintenance flows.

Rice cultivation primarily occurs in river basin flood plains with very flat topography, resulting in small (or "low") "heads" (water surface elevation differences) between supply canals and the fields receiving water deliveries. Low heads make certain measurement devices unusable and can cause high measurement error. Measurement devices that are affected by low head include weirs, flumes, and orifices. Additionally, large ranges in delivery flow rates (e.g., 1 cfs during maintenance to 25 cfs during flood-up; see discussion above) pose challenges to certain measurement devices.

Due to these unique characteristics and measurement challenges associated with rice water delivery, farm turnout measurement has evolved differently in RID (and in most other rice-dominated water suppliers) as compared to some other suppliers in California. Historically, the District's canal system has been operated based on the management of canal water levels (or pools). With canal water levels held at targeted elevations, certain field-specific gate settings will deliver the necessary rice flood up and maintenance flows. The field-specific gate settings have been determined from years of experience and have been calibrated to deliver sufficient water without causing excessive tailwater. Operating in this manner, appropriate amounts of water are delivered to rice fields without the need to measure delivery rates or volumes. In summary, the operation consists of setting and adjusting turnout gate opening as

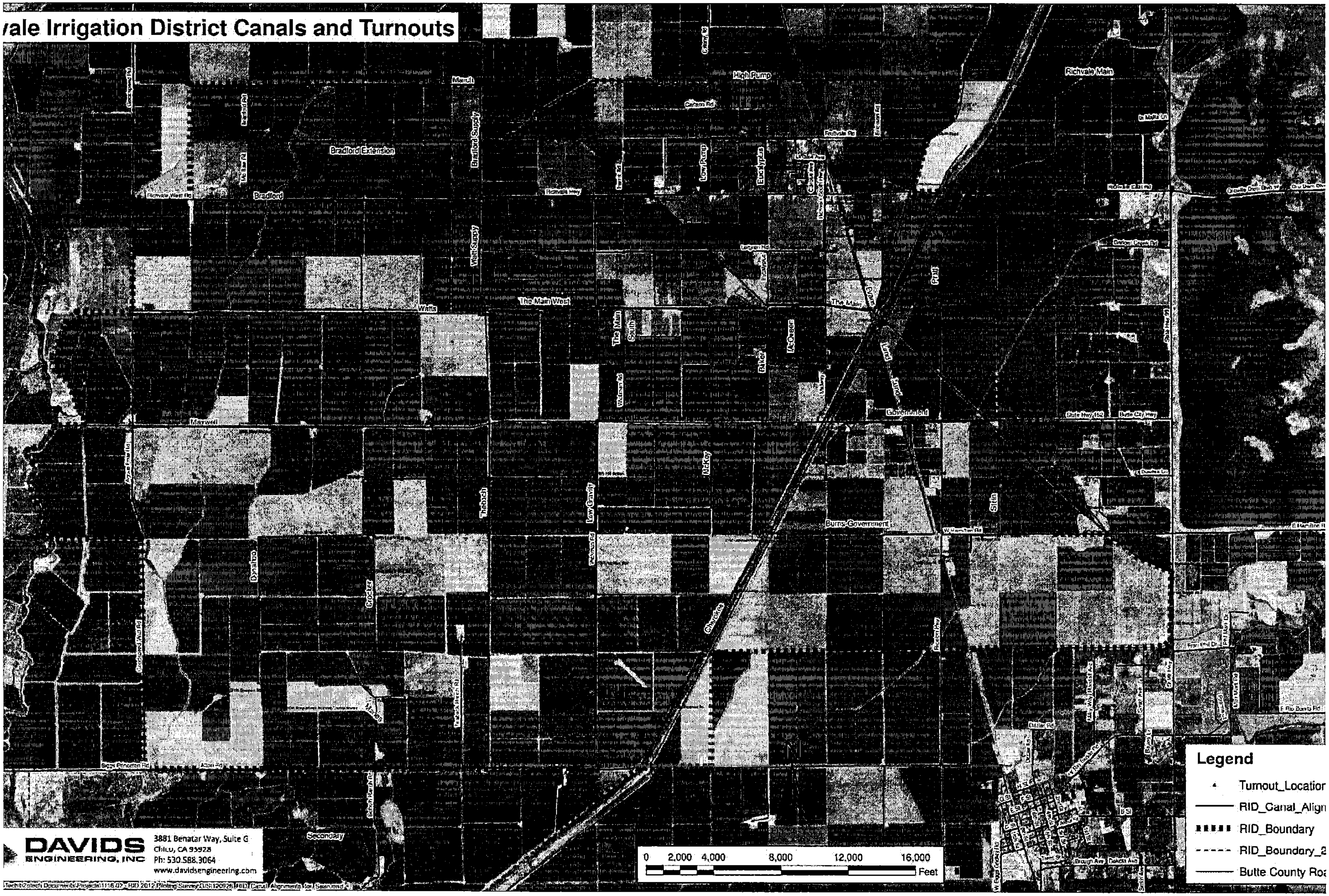


Figure 1. Richvale Irrigation District Map Overview

needed to maintain desired field conditions and adjusting water deliveries into canals as needed to maintain targeted water levels. Flow adjustments are made based on approximations and rules of thumb, and there has been no need to measure water precisely to achieve "good" water management, provided that field tailwater and canal spills are held within reasonable limits.

1.3 SBx7-7 (CCR 23 §597) Overview

The Comprehensive Water Package passed by the California State legislature in November 2009 consists of four policy bills and an $11.14 billion water bond. One of the policy bills (Senate Bill x7-7 or SBx7-7) addresses both urban and agricultural water conservation and, with respect to agriculture, includes new mandates regarding the accuracy of customer delivery measurement, applicable to agricultural water suppliers serving more than 25,000 acres. RID serves more than 25,000 acres and therefore is an agricultural water supplier subject to the new regulation.

The California Department of Water Resources (DWR) was responsible for developing and adopting regulations pursuant to SBx7-7. The rule making process was formally launched during the latter half of 2010 and first half of 2011. DWR developed the draft regulation with the input and involvement of an Agricultural Stakeholder Committee comprised primarily of staff members from agricultural water suppliers and environmental advocacy organizations, plus some academics and consultants. On October 19, 2011, the Office of Administrative Law (OAL) disapproved the proposed regulations because they failed to comply with the clarity, consistency and necessity standards contained in Government Code section 11349.1, and DWR failed to adequately summarize and respond to each comment made regarding the proposed action, including comments of RID. Ultimately, after a number of revisions, OAL approved DWR's agricultural water measurement regulation as California Code of Regulations Title 23 Division 2 Chapter 5.1 Article 2 Section 597 et seq. (CCR 23 §597) on July 11, 2012.

CCR 23 §597 requires that, on or before July 31, 2012, agricultural water suppliers subject to the law shall measure the volume of water delivered to customers with sufficient accuracy to:

- Enable reporting of aggregated farm-gate delivery data to the State and
- Adopt a pricing structure based at least in part on the quantity of water delivered.

CCR 23 §597 requires that existing farm turnouts[1] like those in the District have a measurement accuracy of ±12 percent by volume, meaning that the measured volume of water delivered at each farm-gate (i.e. turnout) must be no greater than 12 percent more, or 12 percent less, than the actual volume delivered. Additionally, any new or replacement measurement devices installed must be accurate to within:

[1] The use of "farm turnout" in this document is synonymous with "farm-gate" and "customer delivery point" utilized in CCR 23 §597.

- ±5 percent by volume in the laboratory if using a laboratory certification;
- ±10 percent by volume in the field if using a non-laboratory certification

The regulation requires that an accuracy certification be performed by either: (1) field testing of a random and statistically representative sample of existing farm turnouts, (2) field inspections and analysis of every existing farm turnout, with the testing or inspections documented by a registered engineer, or (3) a laboratory certification.

1.4 Purpose and Structure of Report

The purpose of this document is to summarize the activities and analysis performed by Davids Engineering during 2012 in support of the District's evaluation of options for customer delivery measurement that are compliant with CCR 23 §597. The evaluation of options was comprised of the following three tasks:

1. Preparing an inventory of RID delivery gates, including establishing GPS coordinates and critical physical characteristics, including turnout pipe size, gate type and available head.
2. Pilot testing of RemoteTracker operation, and developing and testing measurement data collection and customer billing processes during the 2012 irrigation season.
3. Evaluating alternative measurement devices and compliance approaches, including estimated capital costs.

This report documents the work completed according to the three tasks described above. The report is organized into the following five sections:

- **1.0 Introduction** - Provides information about RID, its existing measurement practices, CCR 23 §597 and the purpose of this report
- **2.0 Farm Turnout Inventory** - Summarizes the findings of the farm turnout inventory
- **3.0 Alternative Measurement Devices** - Presents overviews of four measurement devices, including their respective abilities to meet the accuracy mandates of CCR 23 §597
- **4.0 Alternative Measurement Approaches** - Describes three measurement approaches for District-wide measurement based on the four measurement devices described in Section 3.0
- **5.0 Cost Estimates** - Provides reconnaissance-level capital cost estimates for the three measurement approaches developed in Section 4.0
- **6.0 Corrective Action Plan** - Presents basic overview of RID's selection of a preferred measurement approach

2.0 Farm Turnout Inventory

2.1 Inventory Data Collection

An inventory was performed during the 2012 irrigation season to identify all existing farm turnouts in the District and to characterize each farm turnout with respect to factors related to application of the four possible measurement devices evaluated. The following conditions/attributes were determined for each farm turnout:

- Turnout operation status (active/inactive)
- Crop currently being served (rice or other)
- Turnout type defined by unique combinations of certain conditions on the District side and farm side of the turnout
- Turnout gate manufacturer, configuration (square or round) and dimensions
- Structure/culvert/pipeline dimensions (lengths and diameters of critical hydraulic dimensions)
- Critical elevations (canal high water, field, field high water, top of structure)

Additionally, photographs were recorded of each farm turnout, focused on the key attributes noted above.

Figure 2 shows the form used to record inventory measurements and observations at each farm turnout.

Field Served by Turnout:		Gate Brand:		Bench Mark:	
Date:		Gate Type:		U/S WSE:	
Time In/Out:	/	Gate Size:		U/S HWM:	
District:		Closed/Dead Stem	/	D/S WSE:	
Canal:		Weir Length:		D/S HWM:	
Barcode SKU:		Meter Type:		D/S Top Of Box:	
Pipe Inner Diameter:		Photos:	U/S D/S	Crown:	
Pipe Length/Type:	/	Flow Rate:			
Site Type:	Gate / Pump	Totalizer:			

Notes:

Figure 2. Standard Farm Turnout Inventory Form

A database was developed to contain and enable convenient access to and analysis of the inventory data (e.g. photographs, critical elevations, crop type, etc.). The database was used to develop a Google Earth user interface that retrieves a tabular summary of a site's attributes and photographs to be viewed on-screen when the site is selected. Figure 3 shows a screen shot of several farm turnouts on the Low Gravity canal near Wickman Road and Figure 4 shows a sample of the site detail accessed via the Google Earth user interface.

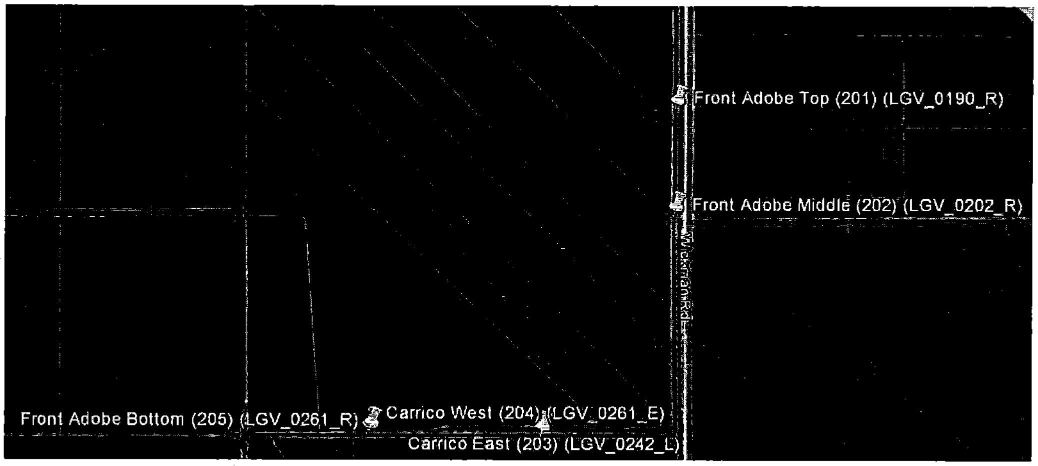
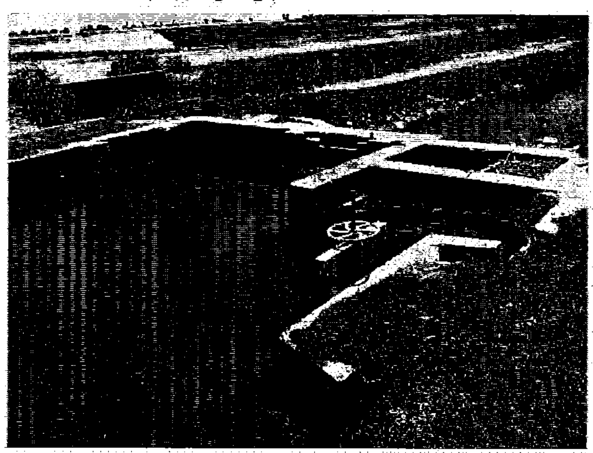


Figure 3. Google Earth Turnout Inventory Overview of the Low Gravity Canal near Wickman Road

Front Adobe Middle (202) (LGV_0202_R)



Common Name:	Front Adobe Middle
Site ID:	LGV_0202_R
SKU:	202
Canal:	Low Gravity (LGV)
Ride:	Left
Crop:	Rice
Site Type:	Gate
Measurement Method:	Manual
Gate Brand:	Fresno Valves
Gate Type:	Circular
Gate Size (in):	24
Pipe Type:	Concrete
Pipe Inner Diameter (ft):	2
Pipe Length (ft):	18
Weir Length (ft):	4
Available Head (ft):	1.17

C:\Turnout_Inventory_RID\Photos\Low Gravity (LGV)\LGV_0202_R

Figure 4. Sample of Inventory Detail Accessed via the Google Earth User Interface

2.2 Farm Turnout Inventory Summary

Figure 5 provides a summary of the farm turnout inventory[2]. A total of 302 farm turnouts were identified during the inventory. Of the total of 302 farm turnouts, 302 are served by supply canals and none are served by drainage channels (drains). Of the 302 gravity farm turnouts served by supply canals, 233 are controlled by orifice gates (gates) and 55 are controlled by other means (e.g. alfalfa valves, weir structures, or other). 223 of the 247 gate-controlled gravity farm turnouts have weir boxes. None of the 55 turnouts from supply canals controlled by other means have weir boxes.

[2] The farm turnout inventory only includes farm turnouts in the primary service area of the District.

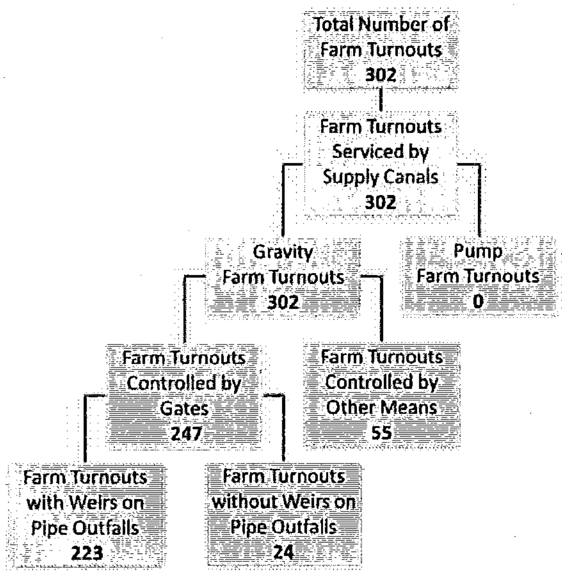


Figure 5. Farm Turnout Inventory Summary

2.3 Crop Types

Table 1 summarizes the District's farm turnouts according to the type of crop served during the 2012 irrigation season. Of the total 302 turnouts, 298 (99 %) serve rice fields and four (1 %) serve pastures.

Table 1. Turnout Distribution by Type of Crop Served during 2012

	Crop Type		
	Rice	**Pasture**	**Total**
Count	298	4	302

2.4 Farm Turnout Pipe Lengths

Farm turnout pipe lengths vary from less than 10 feet to over 70 feet. Table 2 provides a summary of the pipe lengths in the District.

Table 2. Summary of Pipe Lengths

	Pipe Length							
	<10'	**10'-20'**	**20'-30'**	**30'-50'**	**50'-70'**	**>70'**	**Unknown**	**Total**
Count	3	106	71	43	15	16	48	302

2.5 Orifice Gate Characteristics

Table 3 summarizes the characteristics of the 247 existing orifice gates inventoried during the 2012 irrigation season. The dominant gate brand is Waterman Industries, accounting for 137 gates (55%). 138 farm turnouts have circular orifice gates, while 109 have rectangular orifice gates. The most common gate size (based on gate frame widths) is 24 inches (128 in total), followed by 18 inch and 26 to 30 inch (72 and 22 gates, respectively).

Table 3. Orifice Gate Inventory Summary

Gate Brand								
	Water-man	Armco	Mech. Assc.	Gator Gates	Fresno Valves	Generic[3]		Total
Count	137	4	3	1	80	22		247
Gate Type								
	Circular	Rect-angular						Total
Count	138	109						247
Gate Dimensions								
	<14"	14"-16"	18"	20"	24"	26"-30"	26"-48"	Total
Count	8	5	72	2	128	22	10	247

2.6 Turnout Head

Where possible, the farm turnout head (difference in typical upstream and downstream water surface elevations) was surveyed. The typical canal operating water level was used for the upstream level and the high water mark on the field side was used for the downstream level. If no downstream high water mark was evident, the downstream water level for rice fields was estimated to be six inches higher than the field elevation. Figure 6 displays a histogram of heads for the 302 gravity farm turnouts served by supply canals.

[3] Generic gate brand indicates that there were no specific markings on the orifice gate that identified the gate manufacturer.

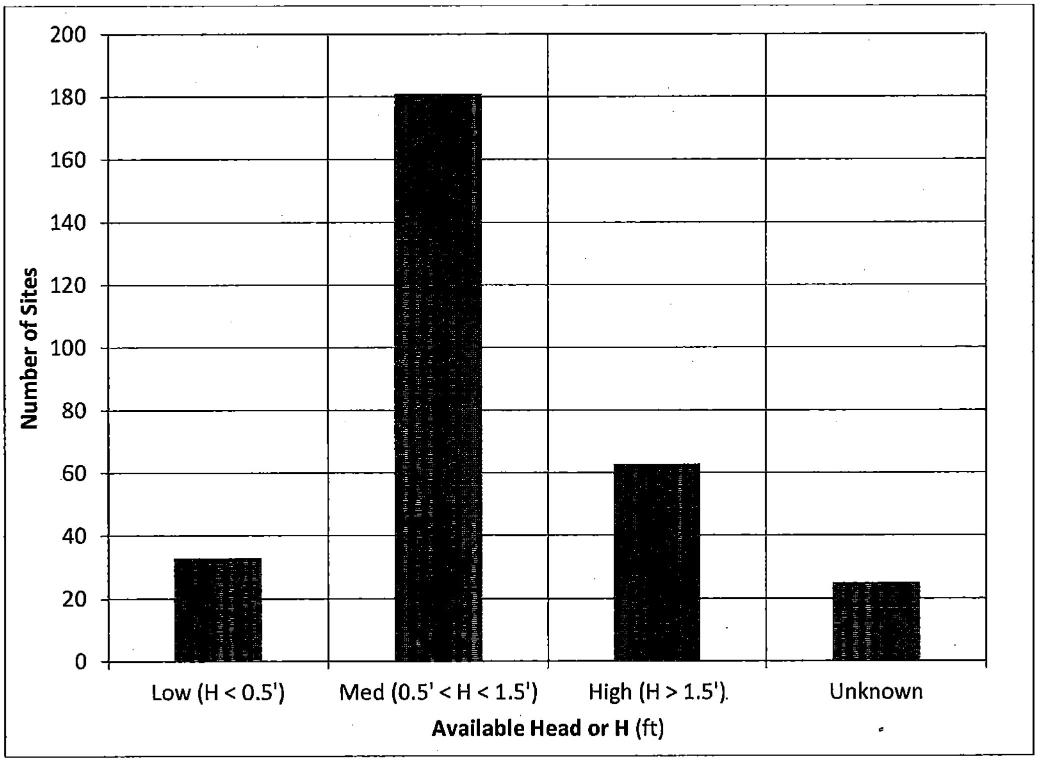


Figure 6. Turnout Head

The gravity farm turnouts are classified into basic categories: low head (less than 0.5 feet), medium head (between 0.5 and 1.5 feet) and high head (greater than 1.5 feet). There are 33 low head gravity farm turnouts, 181 medium head gravity farm turnouts and 63 high head gravity farm turnouts. 25 gravity farm turnouts have an unknown amount head[4].

[4] Farm turnout head was categorized as "unknown" category if the upstream or downstream water level could not be quantified with sufficient accuracy due to lack of physical access or lack of physical evidence (e.g. water stains) of typical operating water levels.

3.0 Alternative Measurement Devices

Four measurement devices were evaluated for potential application to achieve compliance with the CCR 23 §597 accuracy mandates. Although presently not used for measurement (see Section 1.2), the existing farm turnout gates could be used for measurement based on the submerged orifice principle. Alternatively, the weir boxes that have been installed at 210 turnout pipe outlets could be used for measurement based on the weir principle. These two existing devices are described further in Sections 3.1 and 3.2 below. In addition to the existing orifice gates and weir boxes, two new measurement devices were considered for compliance with CCR 23 §597, including the RemoteTracker system and propeller meters. These devices are discussed in Sections 3.3 and 3.4 below.

The discussion of each device concludes with an assessment of the device's ability to comply with the volumetric accuracy mandates of CCR 23 §597. With the exception of propeller meters, which would be permanently installed at each farm turnout, orifice gates, weir boxes and the RemoteTracker do not provide continuous records of flow rate over time; rather they provide "spot" measurements of flow rate at specific points in time. Accurate determinations of delivery volumes can be made with spot flow rate measurements if (1) the spot flow rate measurement and the actual average flow rate during the delivery event are similar and (2) accurate determinations of delivery durations are made. In RID, canal water levels are controlled by a variety of structures, including standard check structures and orifice gates. However, farm-gate deliveries (i.e. the "delivery points" as defined by CCR 23 §597.2(a)(6)) are predominantly made through orifice gates. Delivery flow rates through orifice gates will vary if fluctuations occur in canal water levels[5] (i.e. upstream) or on-farm water levels (i.e. downstream). Therefore, an understanding of water level fluctuations is required to characterize the relationship between spot flow rate measurements and the actual average flow rates over time.

Analysis of continuous water level data recorded between 2004 and 2006 from eight sites on neighboring Biggs-West Gridley Water District (BWGWD) canals indicates that the effects of fluctuating water levels on the accuracy of volumetric measurements developed from "spot" flow measurements are negligible. A similar analysis performed by the California Polytechnic State University San Luis Obispo Irrigation Training and Research Center reached a similar conclusion (Burt and Geer 2012). Therefore, the discussion of compliance with CCR 23 §597 focuses on each device's ability to accurately measure flow rate, even though the regulation is for volumetric accuracy.

3.1 Orifice Gates

3.1.1 Overview

Discharge through a submerged orifice gate (example shown in Figure 7) can be computed with the Bernoulli Equation (Equation 1), where C is an empirical coefficient used to account for energy loss (i.e. entrance/exit losses through the orifice), flow contraction (i.e. vena contracta), and velocity of approach

[5] Canal water levels fluctuate because it is not possible to set control gates perfectly as agricultural water demands change during an irrigation season.

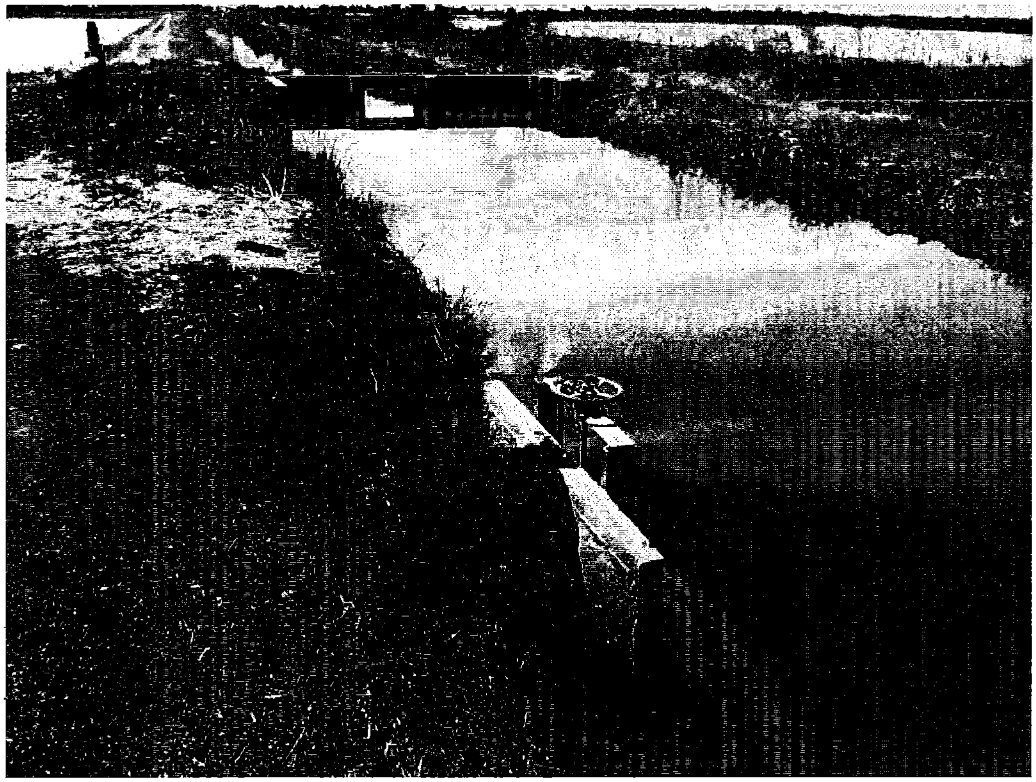


Figure 7. Typical Orifice Gate Farm Turnout on the Watt Lateral (WTT_0251_L)

(Water Measurement Manual (WMM) 2001; King 1963), A is the cross section flow area through the gate (dependent on gate opening), h is the head loss through the orifice and g is the gravitational constant.

$$Q = C * A * \sqrt{2 * g * h}$$ ***(Equation 1 – Lindeburg 2008)***

The difference between water surface elevations (WSE) upstream and downstream of the orifice gate indicate the head loss, and the flow area is determined from the gate size and the gate opening, which is indicated by the gate stem position. The stem position is the measured distance between the highest part of the gate 'lift nut' to the top of the gate stem. Dead-stem is defined as the stem position at the onset of flow when moving the gate from a closed to open position. Full-stem is defined as the stem position when the gate is opened for operation. A term representing the actual gate opening called "good-stem" was then defined as the difference between full-stem and dead-stem (Equation 2).

$$Goodstem = (Fullstem) - (Deadstem)$$ ***(Equation 2)***

"Good-stem" is used to calculate the actual area of the opening with the gate size and gate type (circular or rectangular) known.

3.1.2 Compliance with CCR 23 §597

Data from previous investigations (Davids Engineering 2012) indicates that orifice gates can measure within the CCR 23 §597 accuracy mandate for existing measurement devices (±12 %) provided that:

- Gate-specific variable coefficients based on multiple measurements at each gate are developed and
- Sufficient headloss occurs through the orifice gate to facilitate differential head measurements with low relative uncertainty (i.e. gates not operating near fully open position leading to minimal headloss through the gate and high relative uncertainties in water level measurements)

Results of an evaluation of orifice coefficients are summarized below in Table 4, including indication of whether the coefficient is adequate for meeting the ±12 percent accuracy mandate for existing devices. Using the standard "rating table" coefficients, 42 percent of the orifice measurements fall within ±12 percent of the verification measurements. Using a "District-wide constant" coefficient, just 31 percent of the orifice measurements fall within ±12 percent of the verification measurements. Using a "gate-specific constant" coefficient, 67 percent of the orifice measurements fall within ±12 percent of the verification measurements. Finally, using a "gate-specific variable" coefficient, 88 percent of the orifice measurements fall within ±12 percent of the verification measurements. Only "gate-specific variable" coefficients ensure that at least 75 percent of the sample falls within ±12 percent of the verification measurements. If orifice gates were used for measurement, every gate would need to have a customized variable coefficient developed for it using field testing procedures.

Hydraulic analysis of a 24 inch orifice gate indicates that, if a 12 cubic foot per second[6] (cfs) flood flow is desired, a minimum of 0.5 feet of head is required[7]. Based on this criterion, and the survey information discussed in Section 2.6, 199 of the 302 gravity farm turnouts (66 %) have enough head to measure with an orifice gate.

[6] 12 cfs is used throughout the remainder of this document as the minimum acceptable delivery flow rate for complaint devices.

[7] This analysis assumes that a 0.3 foot headloss through the orifice gate is required to facilitate differential head measurements with low relative uncertainty. The additional 0.2 feet of head is required for major and minor head losses between the orifice gate and the field.

Table 4. Overview of Orifice Gate Measurements with Different Methods of Calculating Orifice Coefficient

Basis for Coefficient	Meets SBx7-7 ±12 Percent Accuracy?	% of Farm Turnouts Within ±12 Percent Accuracy
Standard "textbook" coefficients	No	42%
District-wide constant coefficient derived from measurements at a sample of gates	No	31%
Gate-specific constant coefficients based on multiple measurements at each gate	No	67%
Gate-specific variable coefficients based on multiple measurements at each gate	Yes	88%

3.2 Weirs

3.2.1 Overview

Weirs installed in boxes placed at the turnout pipe outlets operate as standard suppressed rectangular weirs because the weir crest occupies the full box width (i.e., there is no flow contraction) (Figure 8). The Francis equation, which was empirically derived in 1883 to calculate flow over a standard suppressed rectangular weir is shown in Equation 3, where (L) is the length of the weir in feet (ft), and (h) is the height of the fluid over the crest in feet.

$$Q = 3.33\, L\, h^{3/2}$$ ***(Equation 3 – WMM 2001)***

The coefficient of discharge (3.33) was obtained by a set of experiments to correlate the head above the crest with the amount of flow passing over the weir (WMM 2001). For this equation to be most accurate, certain conditions must be met. The weir crest elevation should be at least 0.2 ft above the field WSE so that a free fall occurs (WMM 2001). If the elevation difference is less than 0.2 ft, the free fall of the water may be affected by "backwater" effects and the accuracy of the measurement may be decreased. Additionally, when h is less than 0.2 ft or greater than one-third the crest length, acquiring a precise head measurement becomes challenging and measurement accuracy may be compromised (WMM 2001).

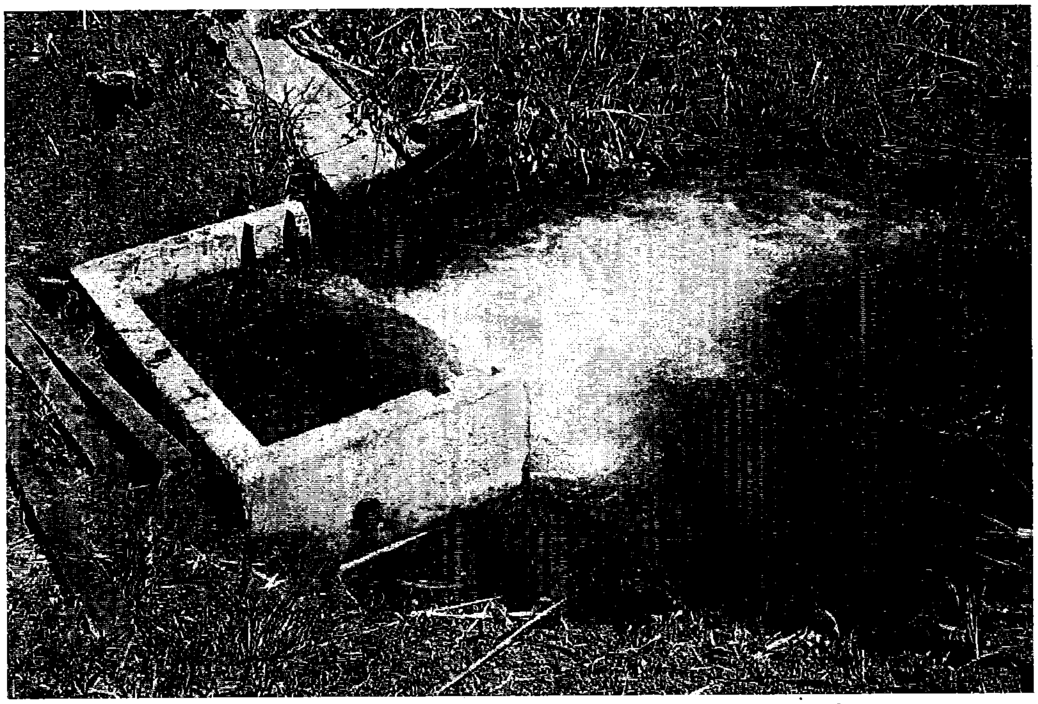


Figure 8. Typical Weir Box on the Ashley Canal near Afton Road

3.2.2 Compliance with CCR 23 §597

Data from previous field investigations (Davids Engineering 2012) indicates that weirs can measure within the CCR 23 §597 accuracy mandate for existing measurement devices (±12 %) provided that:

- Sufficient head (drop) is available between the canal water level and field water level
- Leakage through weir boards is stopped (or accounted for)

Hydraulic analysis of a four foot wide weir box indicates that, if a 12 cubic foot per second (cfs) flood flow is desired, a minimum of 1.5 feet of head is required[8]. Based on this criterion, and the survey information discussed in Section 2.6, 68 of the 302 gravity farm turnouts (23 %) have enough head to measure with a weir.

[8] Roughly 1.0 foot of head over a four foot weir produces 12 cfs. Additionally, the analysis assumes a 0.3 foot headloss through the orifice gate is required for the delivery to remain in 'orifice control', plus 0.2 feet of headloss for major and minor losses between the orifice gate and the weir box.

3.3 RemoteTracker System

3.3.1 Overview

The RemoteTracker is an integrated turnout flow measurement, data management and volumetric accounting system developed by H2oTech[9] specifically for agricultural water suppliers. The RemoteTracker system is comprised of (1) a wireless water velocity sensor, (2) a ruggedized tablet PC carried in the operator's vehicle and (3) a database residing on a file server connected to the tablet PC via a cellular internet connection. The user interface on the tablet PC enables operators to view real time flow data from the wirelessly controlled water velocity sensor via a Bluetooth radio connection while adjusting flows at the turnout gate. The RemoteTracker calculates flow rate with Equation 4.

$$Q = C_{RT} * V_D * A \qquad \textit{(Equation 4)}$$

Where:

- C_{RT}: RemoteTracker velocity coefficient
- V_D: Velocity measured by the wireless water velocity sensor
- A: Cross-section flow area

The key to pipe flow measurement using the RemoteTracker is the consistent relationship between a single velocity measurement at the center of the pipe and the average pipe flow velocity shown derived from 146 measurements of center and mean pipe velocity (Figure 9). Based on this relationship, and with the pipe diameter and cross sectional flow area known, the single point velocity can be accurately and reliably correlated with flow rate.

[9] H2oTech is a company based in Chico, California that focuses on the development of innovative technologies to solve water management challenges.

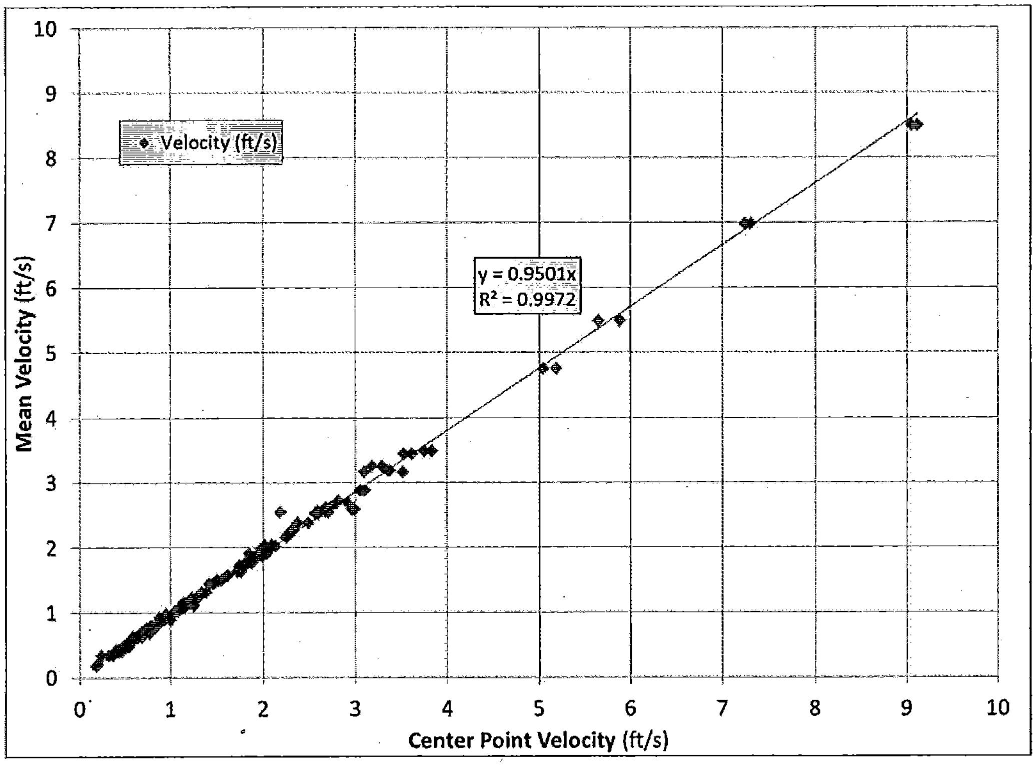


Figure 9. Relationship between Average and Center Point Pipe Flow Velocity

As for weirs and orifice gates, full pipe flow is required for the RemoteTracker to measure correctly. Therefore, a weir box is needed at each turnout to ensure full pipe flow as well as to accommodate the mounting bracket to hold the wireless water velocity sensor, during deployment, so that the sample volume is near the center of the pipe. Figure 10 shows the RemoteTracker wireless water velocity sensor deployed in a weir box.

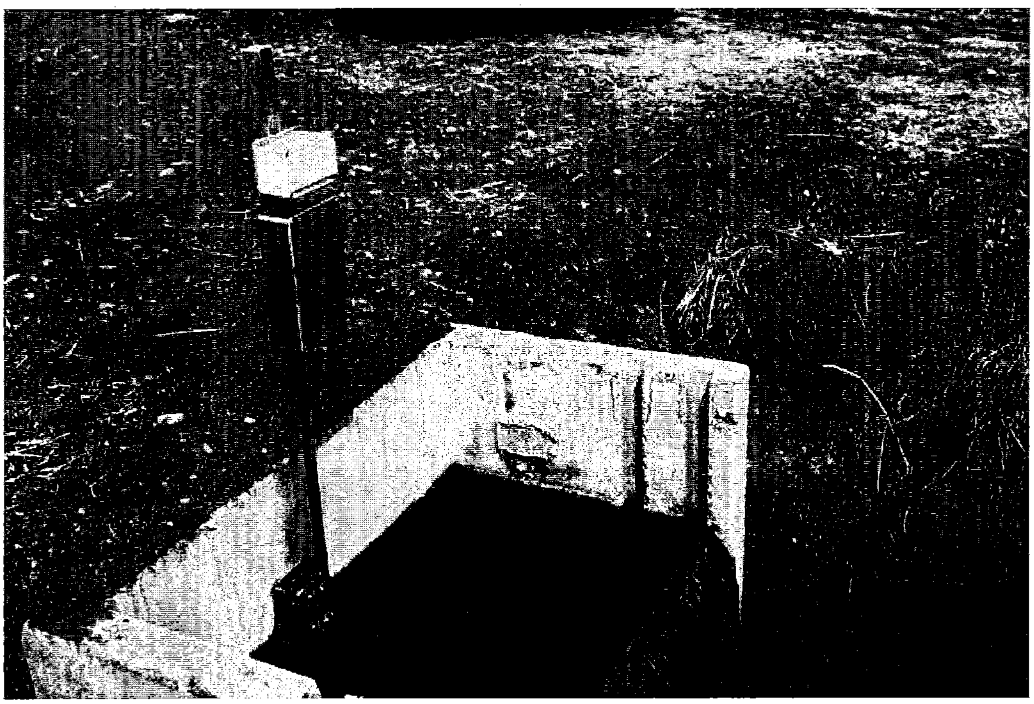


Figure 10. RemoteTracker Wireless Water Velocity Sensor Deployed in Weir Box

A more detailed explanation of the RemoteTracker system, including results of laboratory and field testing, is included in Sections A-2.0 and A-3.0 of Appendix A.

3.3.2 Compliance with CCR 23 §597

The RemoteTracker system is compliant with the volumetric accuracy mandates of CCR 23 §597. See Appendix A for a laboratory based volumetric accuracy certification of the RemoteTracker system. The RemoteTracker system can provide accurate flow data over all farm turnout head ranges.

3.4 Propeller Meters

3.4.1 Overview

Using propellers meters for farm turnout measurement involves permanently installing a propeller meter device at each farm turnout[10]. Propeller meters have a propeller that is placed in the outfall of the farm turnout pipe. The propeller is rotated by water flowing in the pipe and is mechanically or

[10] Because of the heaviness of propeller meters and the need to match meter size to the different turnout pipe sizes, it is considered impractical to deploy propeller meters temporarily for spot flow checks in the same manner that the RemoteTracker is deployed. Instead propeller meters would be permanently deployed at each turnout for the duration of each irrigation season.

electronically coupled with a display and recording device. The rate of rotation is directly proportional to velocity of the water in the pipe. With the pipe diameter and cross-sectional area known, flow rate can be calculated as the product of velocity and area. Propeller meters typically measure flow rate continuously and totalize the delivery volume. The display typically indicates instantaneous flow rate and cumulative volume delivered. For deployment in RID, propeller meters would require the same farm turnout infrastructure as the RemoteTracker. An orifice gate would be required at the farm turnout inlet to control flow and a weir box would be required at the turnout pipe outlet to (1) keep the pipe full and (2) provide a place to mount the propeller meter.

3.4.2 Compliance with CCR 23 §597

Laboratory certifications of flow measurement accuracy are available for most commercially available propeller meters. Since propeller meters are permanently installed devices, volumetric accuracy is the same as flow rate accuracy. Therefore, propeller meters are compliant with the volumetric accuracy mandates of CCR 23 §597. Propeller meters can provide accurate flow data over all farm turnout head ranges.

4.0 Alternative Measurement Approaches

As discussed in Sections 3.1.2 and 3.2.2, orifice gates and weir boxes require a minimum of 0.5 feet and 1.5 feet of head respectively to measure a minimum of 12 cfs. To facilitate the development of measurement approaches, all farm turnouts within the District were classified into one of four farm turnout categories[11]:

1. Low Head Gravity (i.e. head less than 0.5 feet),
2. Medium Head Gravity (i.e. head between 0.5 and 1.5 feet),
3. High Head Gravity (i.e. head greater than 1.5 feet) and
4. Pump (i.e. water supplied to fields via pumps).

Table 5 presents a summary of three measurement approaches considered to be potentially viable for the District to comply with CCR 23 §597. Table 5 indicates the number of turnouts falling in each category and, for each approach, the measurement device that would be used for each category. The three approaches are discussed in greater detail in Sections 4.1 through 4.3. None of the measurement devices discussed in Section 3 can be utilized to measure pump deliveries. However, none of the farm turnouts in the District's primary service area are served by pumps. Note that the 25 turnouts with unknown head were distributed into each category by ratio.

Table 5. Measurement Approach Summary

Farm Turnout Category	Count of Farm Turnout Categories	Measurement Program Devices		
		Approach 1 - Maximum Use of Existing Devices	Approach 2 - RemoteTracker System	Approach 3 - Propeller Metering Program
Low Head Gravity (H < 0.5 feet)	**35**	Propeller Meters	RemoteTracker System	Propeller Meters
Medium Head Gravity (0.5' < H < 1.5')	**198**	Orifice Gates		
High Head Gravity (H > 1.5'	**69**	Weir Boxes		
Total	**302**			

[11] Farm turnouts with unknown heads were distributed between the three gravity farm turnout categories in the same proportion as the known farm turnouts. In other words, of the turnouts with known heads, 8 percent were low head, 53 percent were medium head and 39 percent were high head. These percentages were then used to distribute the 71 unknown gravity farm turnouts among the three gravity farm turnout categories.

Table 6 summarizes the different levels of turnout improvement needed for each of the farm turnout categories, and the number of turnouts in each improvement level. These farm turnout counts are utilized in Section 5.0 to develop capital cost estimates for each measurement approach. All measurement approaches require gravity farm turnouts to have an orifice gate and a weir box. All pump farm turnouts require a totalizing flow meter. The classifications have been developed to be mutually exclusive so that each farm turnout only corresponds with one improvement classification within the table, which facilitates the ability to sum the number of farm turnouts in each row to develop the total number or farm turnouts in each farm turnout category. The District has replaced or retrofitted farm turnouts subsequent to the inventory; therefore, an 'Improvements after Inventory' classification is necessary to avoid double counting. The farm turnout improvement classifications include:

- **Requires Orifice Gate and Weir Box** - existing gravity farm turnout has neither an orifice gate or a weir box
- **Requires Orifice Gate Only** - existing gravity farm turnout has a weir box, but no orifice gate
- **Requires Weir Box Only** - existing gravity farm turnout has a orifice gate, but no weir box
- **Requires Totalizing Flow Meter** - existing pump farm turnout has no measurement device
- **Requires No Improvements** - existing gravity farm turnout has an orifice gate and a weir box
- **Improvements by District After Inventory** - improvements to existing farm turnouts made after the 2012 inventory was complete

4.1 Approach 1 - Maximum Use of Existing Devices

Approach 1 is based on maximizing the use of existing measurement devices; however, neither of the two existing measurement devices (i.e. orifice gates and weir boxes) alone unconditionally meets the volumetric accuracy mandates of CCR 23 §597 across all gravity farm turnouts. Therefore, to achieve maximum use of existing devices, a hybrid approach involving multiple measurement devices is necessary. Approach 1 utilizes weir boxes for high head gravity farm turnouts and orifice gates for medium head gravity farm turnouts. Propeller meters, a new device, would be used for low head gravity farm turnouts because neither gates nor weirs work under low head conditions.

4.2 Approach 2 - RemoteTracker System

Approach 2 involves the use of the RemoteTracker system at all gravity farm turnout categories (i.e. high head gravity, medium head and low head gravity farm turnouts).

4.3 Approach 3 - Propeller Metering Program

Approach 3 involves the use of propeller meters at all gravity farm turnout categories (i.e. high head gravity, medium head and low head gravity farm turnouts).

Table 6. Farm Turnout Improvement Classification Count Summary

Farm Turnout Category	Farm Turnout Improvement Requirement Counts						Sum
	Requires Orifice Gate and Weir Box	Requires Orifice Gate Only	Requires Weir Box Only	Requires Totalizing Flow Meter	Requires No Improvements	Improvements by District after Inventory	
Low Head Gravity (H < 0.5 feet)	8	0	0	n/a	25	2	35
Medium Head Gravity (0.5' < H < 1.5')	41	0	18	n/a	130	9	198
High Head Gravity (H > 1.5'	6	0	6	n/a	55	2	69
Total	55	0	24	n/a	210	13	302

5.0 Reconnaissance Cost Estimates

RID, along with other agricultural and urban water suppliers, filed a Test Claim with the Commission on State Mandates alleging that the Water Conservation Act constitutes a reimbursable state mandate. That Test Claim is pending before the Commission and it is anticipated that a hearing will be held in September, 2013, and a decision will be made shortly thereafter. RID, along with other agricultural water suppliers, are in the process of filing a supplemental Test Claim challenging CCR 23 § 597. If the Test Claims are successful, RID will be entitled to reimbursement of all direct and indirect costs of compliance with the Water Conservation Act and 23 CCR § 597, including initial and annualized capital and maintenance and operation costs of farm-gate measurement devices.

In the late fall of 2012, subsequent to the farm turnout inventory, the District replaced, or retrofitting in some cases, a total of 13 gravity farm turnouts. Therefore, the cost estimates included herein do not include the capital costs for weir box and orifice gate installation at these 13 gravity farm turnouts because they have already been performed by the District.

Table 7 provides reconnaissance-level (1) initial capital, (2) annualized capital and (3) annual maintenance cost estimates for full scale implementation of the three measurement approaches discussed in Section 4. The last row provides the annualized capital and maintenance cost estimates. Differences among the three approaches with respect to operation costs (primarily labor and transportation) are not considered significant; therefore they are not included. A five percent interest rate was used for all calculations.

Table 7. Reconnaissance-Level Capital Cost Estimates for Three Measurement Approaches

Cost Category	Measurement Program Cost Estimate		
	Approach 1 - Maximum Use of Existing Devices	Approach 2 - RemoteTracker System	Approach 3 - Propeller Metering Program
Initial Capital	$1,242,553	$762,800	$1,952,543
Annualized Capital	$85,252	$64,616	$146,860
Annualized Maintenance	$66,098	$62,796	$139,388
Annualized Capital and Maintenance	**$151,350**	**$127,412**	**$286,247**

Sections 5.1 through 5.3 below contain additional details regarding the capital cost estimates for the three alternative measurement programs evaluated. Note that each of the three alternative measurement approaches requires (1) a Water Information System (WIS) to store and process farm

turnout delivery data and (2) the installation of totalizing flow meters on all pump deliveries. The measurement devices evaluated (i.e. gates, weirs, RemoteTracker and Propeller Meters) are designed for measurement of gravity deliveries, and are therefore unable to measurement pump deliveries. Appendix B provides additional information about the estimates for all unit costs, including the WIS and totalizing flow meters.

5.1 Approach 1 - Maximum Use of Existing Devices

Table 8 provides a cost summary for Approach 1, listing the necessary improvements, the number of farm turnouts that require the improvement and the expected life of the improvement.

Table 8. Approach 1 Cost Summary

#	Improvements	# of Sites Required	Unit cost	Initial Capital Sub-Total	Expected Life (years)	Annualized Sub-Total
1	Propeller Meter	35	$4,528	$158,487	20	$12,717
2	Orifice Gate	55	$5,017	$275,960	25	$19,580
3	Differential Head Measurement	198	$1,198	$237,184	25	$16,829
4	Gate Coefficient	198	$1,323	$261,855	25	$18,579
5	Weir Box	79	$2,230	$176,156	40	$10,266
6	Water Information System (WIS)	1	$132,911	$132,911	50	$7,280
7	Totalizing Flow Meter	0	$3,969	$0	15	$0
			Totals	$1,242,553		$85,252

Improvements 1 through 5 are required on a farm turnout level. Improvement 6 is required on the system wide level to facilitate data storage and management. Improvement 7 is required to measure pump deliveries (from either supply canals or drains) within the District.

Summaries of the specific improvements required for each gravity farm turnout classification (i.e. low head, medium head and high head), and the associated initial capital costs, are provided in Sections 5.1.1 through 5.1.3 below.

5.1.1 Low Head Device (Propeller Meters)

Table 9 presents the estimated capital costs to measure at 35 low head farm turnouts with propeller meters. The normalized per farm turnout improvement cost is $6,185.

Table 9. Low Head Farm Turnout (Propeller Meter) Cost Estimate

#	Improvements	# of Sites Required	Unit Cost	Sub-Total
1	Orifice Gate	8	$5,017	$40,140
2	Weir Box	8	$2,230	$17,839
3	Propeller Meter	35	$4,528	$158,487
			Total	**$216,465**
			Number of Farm Turnouts Utilizing Propeller Meters	**35**
			Normalized Per Farm Turnout Cost	**$6,185**

Table 9 lists the infrastructure required at each low head gravity farm turnout to use propeller meters (improvements 1 through 3) and the number of gravity farm turnouts that do not currently have the required infrastructure (i.e. the number of sites requiring the specific improvement). The following summarizes the three improvements in Table 9:

1. **Orifice Gate** - for flow control. Includes gate procurement and installation. 8 low head gravity farm turnouts do not currently have orifice gates.
2. **Weir Box** - to maintain full pipe flow and prevent field fluctuation from affecting flow. Includes weir box procurement and installation. 8 low head gravity farm turnouts do not currently have weir boxes.
3. **Propeller Meter** - totalizing propeller meter with mounting brackets. Includes propeller meter procurement and all installation processes. 35 low head gravity turnouts do not currently have propeller meters.

5.1.2 Medium Head Device (Orifice Gates)

Table 10 presents the estimated capital costs to measure at 198 medium head gravity farm turnouts with orifice gates. The normalized per farm turnout improvement cost is $4,224.

Table 10. Medium Head Farm Turnout (Orifice Gate) Cost Estimate

#	Improvements	# of Sites Required	Unit Cost	Sub-Total
1	Orifice Gate	41	$5,017	$205,716
2	Differential Head Measurement	198	$1,198	$237,184
3	Gate Coefficient	198	$1,323	$261,855
4	Weir Box	59	$2,230	$131,559
			Total	**$836,314**
			Number of Farm Turnouts Utilizing Propeller Meters	**198**
			Normalized Per Farm Turnout Cost	**$4,224**

Table 10 lists the infrastructure required at each medium head gravity farm turnout to use orifice gates (improvements 1 through 4) and the number of gravity farm turnouts that do not currently have the required infrastructure (i.e. the number of sites requiring the specific improvement). The following summarizes the three improvements in Table 10:

1. **Orifice Gate** - for flow control. Includes gate procurement and installation. 41 medium head gravity farm turnouts do not currently have orifice gates.
2. **Differential Head Measurement** - infrastructure alterations to allow for the head difference to be read upstream of the orifice gate and approximately 1 foot downstream of the orifice gate. 198 medium head gravity farm turnouts do not currently have the ability to measure differential heads.
3. **Gate Coefficient** - five flow measurements performed at various stages of flow and development of a farm turnout specific rating curve. 198 medium head gravity farm turnouts do not currently have custom farm turnout specific ratings.
4. **Weir Box** - to maintain full pipe flow and prevent field fluctuation from affecting flow. Includes weir box procurement and installation. 59 medium head gravity farm turnouts do not currently have weir boxes.

5.1.3 High Head Device (Weir Boxes)

Table 11 presents the estimated capital costs to measure at 69 high head gravity farm turnouts with weir boxes. The normalized per farm turnout improvement cost is $824.

Table 11. High Head Farm Turnout (Weir Box) Cost Estimate

#	Improvements	# of Sites Required	Unit Cost	Sub-Total
1	Orifice Gate	6	$5,017	$30,105
2	Weir Box	12	$2,230	$26,758
			Total	**$56,863**
			Number of Farm Turnouts Utilizing Propeller Meters	**69**
			Normalized Per Farm Turnout Cost	**$824**

Table 11 lists the infrastructure required at each high head farm turnout to use weir boxes (improvements 1 and 2) and the number of sites that do not currently have the required infrastructure (i.e. the number of sites requiring the specific improvement). The following summarizes the two improvements in Table 11:

1. **Orifice Gate** - for flow control. Includes gate procurement and installation. 6 high head gravity farm turnouts do not currently have orifice gates.

2. **Weir Box** - to maintain full pipe flow and prevent field fluctuation from affecting flow. Includes weir box procurement and installation. 12 high head gravity farm turnouts do not currently have weir boxes.

5.2 Approach 2 - RemoteTracker System

Table 12 provides a cost summary for Approach 2, listing the necessary improvements, and the number of farm turnouts that require the improvement.

Table 12. Approach 2 Cost Summary

#	Improvements	# of Sites Required	Unit cost	Initial Capital Sub-Total	Expected Life (years)	Annualized Sub-Total
1	Orifice Gate	55	$5,017	$275,960	25	$19,580
2	Weir Box	79	$2,230	$176,156	40	$10,266
3	RemoteTracker Mounting Plate	242	$325	$78,585	40	$4,580
4	RemoteTracker System	3	$33,063	$99,188	5	$22,910
5	Water Information System (WIS)	1	$132,911	$132,911	50	$7,280
6	Totalizing Flow Meter	0	$3,969	$0	15	$0
			Totals	$762,800		$64,616

Improvements 1 through 3 are required on a farm turnout level. Improvements 4 and 5 are improvements on the operator or system wide level to facilitate use of the RemoteTracker system. Improvement 6 is required to measure pump deliveries within the District.

1. **Orifice Gate** - for flow control. Includes gate procurement and installation. 55 gravity farm turnouts do not currently have orifice gates.
2. **Weir Box** - to maintain full pipe flow and prevent field fluctuation from affecting flow. Includes weir box procurement and installation. 79 gravity farm turnouts do not currently have weir boxes.
3. **RemoteTracker Mounting Plate** - for mounting wireless water velocity sensor onto turnout. Includes plate fabrication and all installation processes. 242 turnouts do not currently have RemoteTracker plates.
4. **RemoteTracker System** - consists of the wireless water velocity sensor and computing device on a per operator basis. Includes all procurement and assembly costs. Three (3) additional RemoteTracker wireless water velocity sensors are required.
5. **Water Information System** - water information system to collect and process measurement data. Includes customized database for volumetric accounting. Only one (1) database per District is required.

6. **Totalizing Flow Meter** - for measurement of pump diversions from either supply canals or drains. Includes the meter and installation. No known pump farm turnouts within the District exist.

5.3 Approach 3 - Propeller Metering Program

Table 13 provides a cost summary for Approach 3, listing the necessary improvements, and the number of farm turnouts that still require the improvement.

Table 13. Approach 3 Cost Summary

#	Improvements	# of Sites Required	Unit Cost	Initial Capital Sub-Total	Expected Life (years)	Annualized Sub-Total
1	Orifice Gate	55	$5,017	$275,960	25	$19,580
2	Weir Box	79	$2,230	$176,156	40	$10,266
3	Propeller Meter	302	$4,528	$1,367,515	20	$109,733
4	Water Information System (WIS)	1	$132,911	$132,911	50	$7,280
5	Totalizing Flow Meter	0	$3,969	$0	15	$0
			Totals	**$1,952,543**		**$146,860**

Improvements 1 through 3 are required on a farm turnout level. Improvement 4 is required on the system wide level to facilitate data storage and management. Improvement 5 is required to measure pump deliveries within the District.

1. **Orifice Gate** - for flow control. Includes gate procurement and installation. 55 gravity farm turnouts do not currently have orifice gates.
2. **Weir Box** - to maintain full pipe flow and prevent field fluctuation from affecting flow. Includes weir box procurement and installation. 79 gravity farm turnouts do not currently have weir boxes.
3. **Propeller Meter** - totalizing propeller meter with mounting brackets. 302 turnouts do not currently have propeller meters.
4. **Water Information System** - water information system to collect and process measurement data. Includes customized database for volumetric accounting. Only one (1) database per District is required.
5. **Totalizing Flow Meter** - for measurement of pump diversions from either supply canals or drains. Includes the meter and installation. There are no known pump deliveries within the District.

5.4 Maintenance Cost Estimates

Table 14 provides additional details pertaining to the development of annual maintenance costs. Annual maintenance costs are estimated as a percentage of the initial capital costs. Each approach contains a column for the counts of each maintenance item and the annual maintenance cost. The annual maintenance costs are estimated to be $38,424, $32,476 and $111,714 for Approaches 1 through 3, respectively.

Table 14. Operation and Maintenance Cost Summary

Maintenance Item	Annual Maintenance - Percentage of Capital	Annual Maintenance Unit Cost Estimate	Approach 1 - Maximum Use of Existing Devices		Approach 2 - RemoteTracker System		Approach 3 - Propeller Metering Program	
			Number of O&M Items	Annual Maintenance Cost	Number of O&M Items	Annual Maintenance Cost	Number of O&M Items	Annual Maintenance Cost
Propeller Meter	8%	$289	35	$10,103	0	$0	302	$87,172
Weir Box	2%	$36	302	$10,732	302	$10,732	302	$10,732
Orifice Gate	2%	$80	302	$24,148	302	$24,148	302	$24,148
Differential Head Measurement	2%	$19	198	$3,780	0	$0	0	$0
Totalizing Pump Flow Meter	5%	$158	0	$0	0	$0	0	$0
Water Information System	15%	$17,336	1	$17,336	1	$17,336	1	$17,336
RemoteTracker System	8%	$2,645	0	$0	4	$10,580	0	$0
		Totals	-	$66,098	-	$62,796	-	$139,388

6.0 Corrective Action Plan

At a regularly scheduled meeting on January 17, 2013, the RID Board considered this report and the customer delivery measurement options presented herein. By unanimous vote, the Board accepted the report and adopted measurement Approach 2 - RemoteTracker System as the District's preferred approach for implementing a customer delivery measurement program. The program is intended to comply with the measurement accuracy standards specified in CCR 23 §597 and to be capable of supporting implementation of a water rate structure based at least in part on the volume of water delivered. Such a rate structure remains to be designed and adopted by the Board in the future.

Approach 2 has an estimated capital cost of $762,800. Recognizing that this capital improvement cost is relatively large in comparison to the District's current revenue and operating budgets, the Board also unanimously agreed that the program will be implemented on a "pay-as-you-go" basis as discretionary revenues above operating and maintenance funds become available.

References Cited

Burt, C.M. and E. Geer, *SBx7 Flow Rate Measurement Compliance for Agricultural Irrigation Districts*, Irrigation Training & Research Center, California Polytechnic State University, San Luis Obispo, California, 2012.

Davids Engineering, *Field Turnout Measurement Accuracy Study,* Davids Engineering, Davis, CA, 2012.

King, Horace Williams, *Handbook of Hydraulics,* Fourth ed. York, McGraw-Hill Book, 1963.

Lindeburg, M.R., *Civil Engineering Reference Manual for the PE Exam*, Eleventh Edition, Professional Publications, Inc., Belmont, CA, 2008.

Water Measurement Manual, Bureau of Reclamation, United States, *Water Measurement Manual – 3rd Edition*, A Water Resources Technical Publication, 2001.

CCR 23 §597, California Code of Regulations Title 23 Division 2 Chapter 5.1 Article 2 Section 597, Sacramento, CA, 2012.

Appendix A. RemoteTracker System Overview and Volumetric Accuracy Certification

A-1.0 Introduction and Summary

This document (1) provides an overview of the RemoteTracker system (Section A-2.0), (2) presents results of initial laboratory and field testing (Section A-3.0) and (3) develops a volumetric accuracy analysis to support compliance of RemoteTracker system with California Code of Regulations Title 23 Division 2 Chapter 5.1 Article 2 Section 597 (CCR 23 §597) (Section A-4.0). Based on the analysis in Section A.3, the expected accuracy in volumetric measurements performed with the RemoteTracker system is ±4.6 percent. Because the RemoteTracker system utilizes a laboratory certified acoustic doppler velocimeter manufactured by SonTek to measure water velocity, the ±5 percent by volume laboratory certification option presented in CCR 23 §597.3(a)(2)(B) applies. Thus, the demonstrated accuracy of the RemoteTracker complies with the ±5 percent by laboratory certification standard. Documentation of the protocols associated with the measurement of the cross-section flow area and duration of delivery, as required by §597.4(e)(3)(B), is presented in Section A-4.0.

A-2.0 RemoteTracker System Overview

The RemoteTracker is an integrated turnout flow measurement, data management and volumetric accounting system developed by H2oTech[12] specifically for agricultural water suppliers in response to CCR 23 §597. The RemoteTracker system is comprised of (1) a wirelessly controlled water velocity sensor, (2) a ruggedized tablet PC in the operator's vehicle and (3) a database running on a file server connected to the internet. The user interface on the tablet PC enables operators to view real time flow data from the wirelessly controlled water velocity sensor via a Bluetooth radio connection while adjusting flows at the turnout gate. Data is automatically transferred over a wireless wide area network (WWAN) to a centralized file server at the District headquarters where it is automatically loaded into a custom database application. The database performs quality control and quality assurance procedures on the data and then develops daily volumes for each customer delivery point (turnout or delivery) within the District.

The wireless water velocity sensor (WWVS) is held in place at a precise location at the pipe outlet by an aluminum or stainless steel mounting bracket. The user interface, shown in Figure A-1, was designed with simplicity and ease of use in mind. If 'Auto Locate' is selected, the program automatically populates the three site identification pull-downs at the top of the screen. If the operator needs to select a different site, the pull-downs can be manually changed. The site selection hierarchy is a three digit abbreviation of 'Operator Route' (i.e. ride, beat or division) on the left, a three digit abbreviation of 'Canal' in the middle and site name on the right. The most recently measured flow, and any pending orders are shown on the 'Home' tab. Many useful reports, including (1) Delivery History, (2) Pending Orders, (3) Fulfilled Orders and (4) Canal Management are available on the 'Reports' tab. These reports can be sorted at any spatial or temporal scale. The data sharing and management framework allows

[12] H2oTech is a company based in Chico, California that focuses on the development of innovative technologies to solve water management challenges.

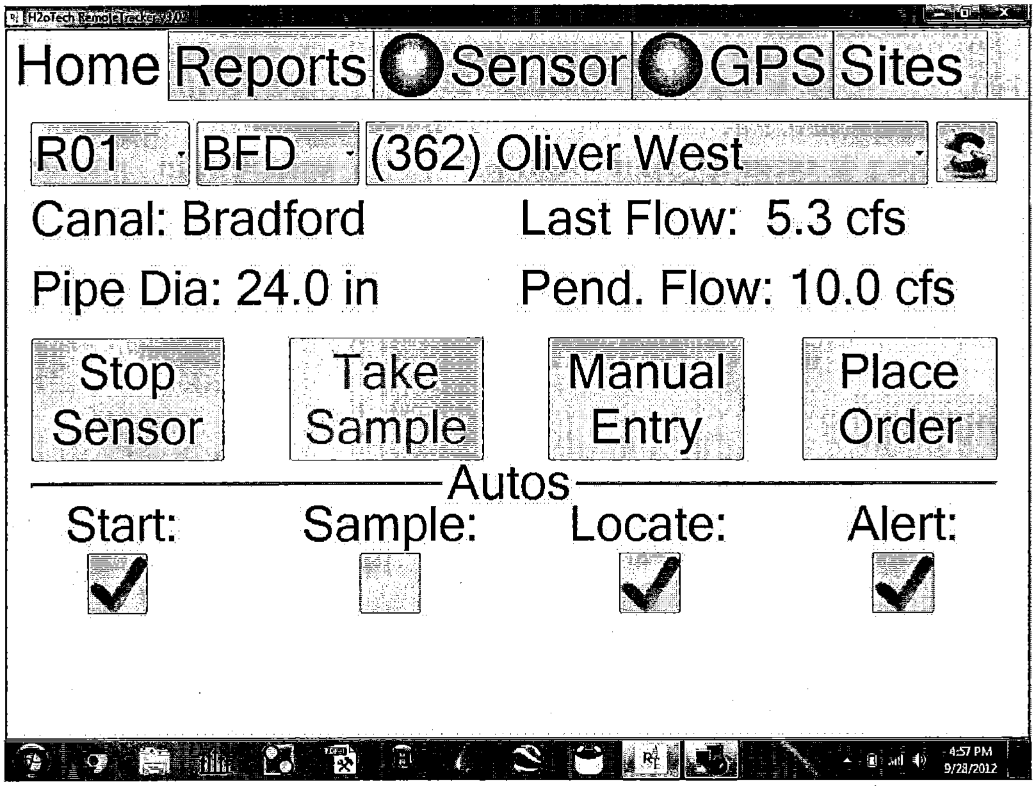


Figure A-1. RemoteTracker User Interface - Home Tab Shown

water order and delivery data collected by any operator to be automatically available for viewing by other operators or management staff in a matter of minutes.

The basic components of the RemoteTracker system are illustrated in Figure A-2. Water velocity is collected by a portable acoustic Doppler velocimeter deployed during measurement by hanging it on brackets permanently installed at each turnout. The brackets are precisely positioned such that the sample volume is at the center of the pipe. Data is transmitted via a class 1 Bluetooth radio to a ruggedized tablet PC where it is processed, displayed and stored. Data is then transferred via a WWAN to a file server at the District headquarters. Data from each operator is aggregated with an automated database procedure and then returned to each operator via WWAN, thereby ensuring that delivery and order data is shared and accessible throughout the entire District.

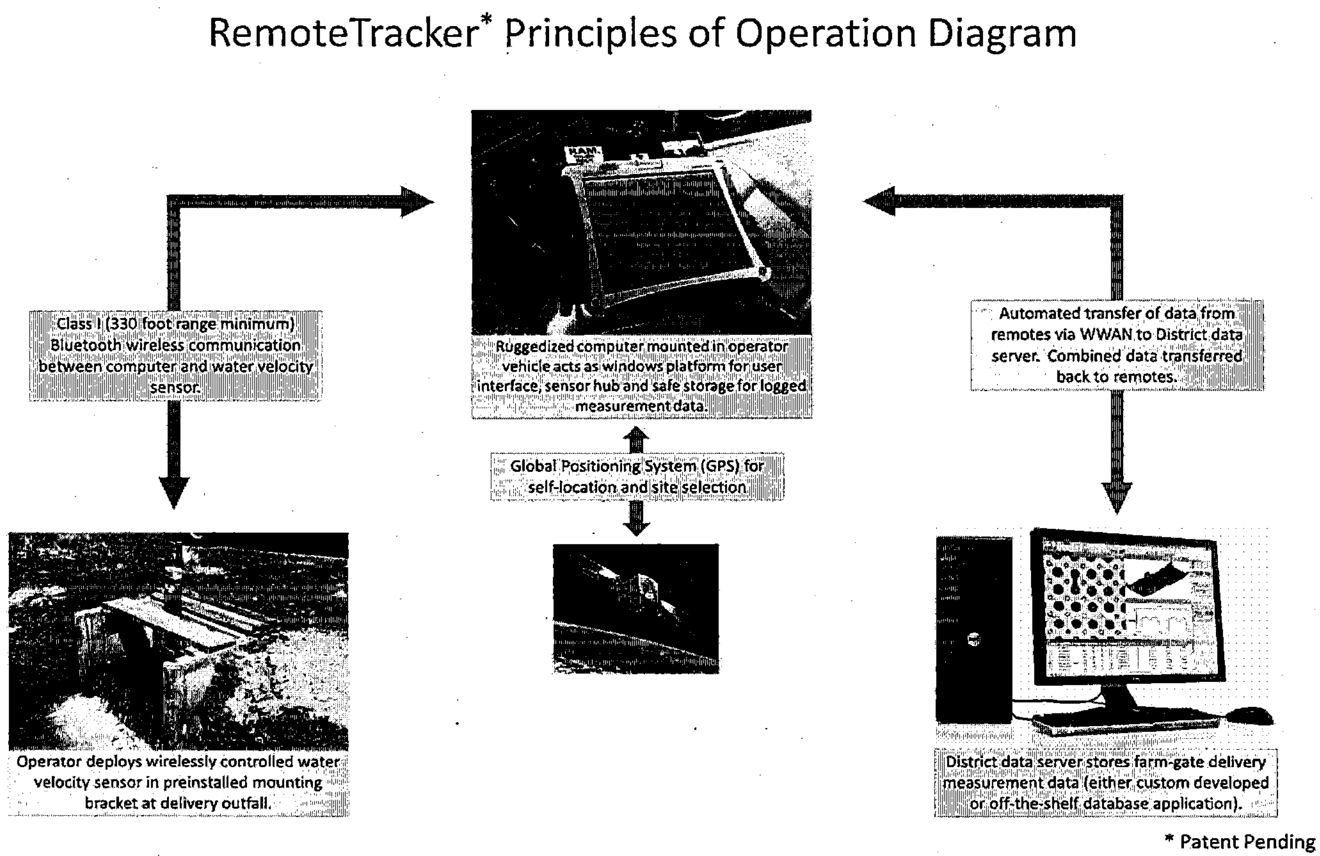


Figure A-2. RemoteTracker Principles of Operation Overview

The key to pipe flow measurement using the RemoteTracker is the consistent relationship between a single velocity measurement at the center of the pipe and the average pipe flow velocity shown in Figure A-3 derived from 146 measurements of center and mean pipe velocity. Based on this relationship, with the pipe diameter and cross sectional area known, the single point velocity can be accurately and reliably correlated with mean pipe velocity (flow rate).

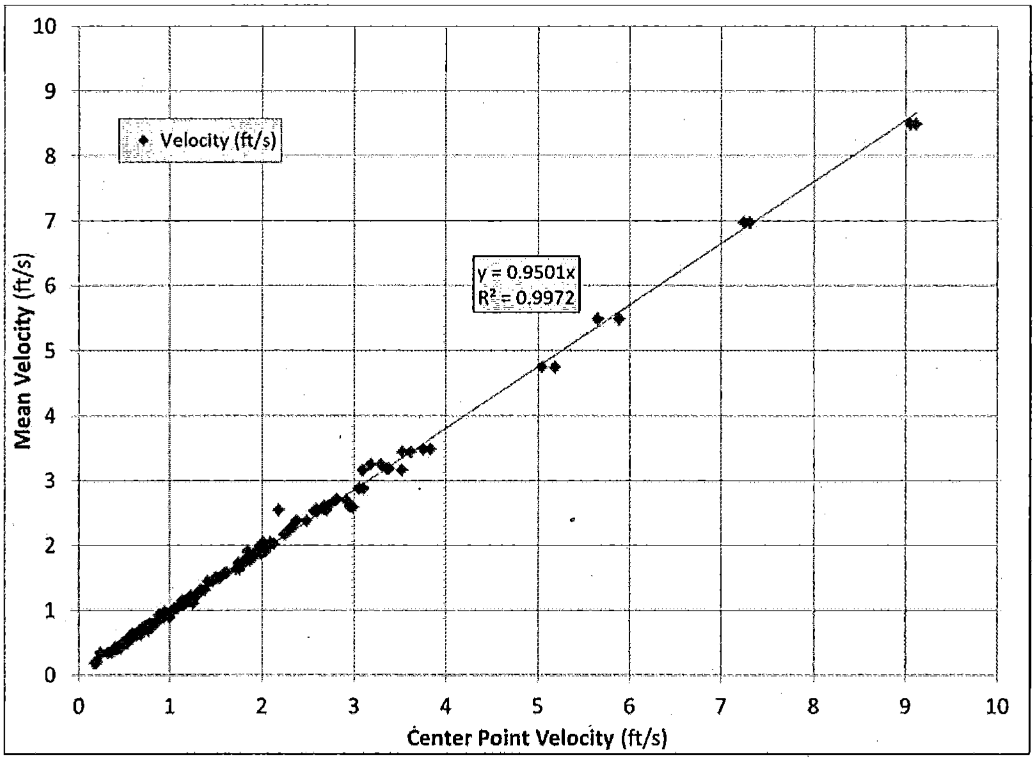


Figure A-3. Relationship between Average and Center Point Pipe Flow Velocity

As with weir and orifice gate measurement, full pipe flow is required for the RemoteTracker to measure correctly. Therefore, a weir box is needed at each turnout to ensure full pipe flow as well as to accommodate the mounting bracket to hold the wireless water velocity sensor so that the sample volume is at the center of the pipe.

The RemoteTracker system can also be integrated with existing or new data management systems at the District office for report generation, accounting and billing. This capability can be added later to provide additional efficiencies in water billing and accounting procedures.

A-3.0 Initial Testing Results

A-3.1 Laboratory Testing

Additional testing was performed at the California State University Chico Agricultural Teaching and Research Center (CSUC ATRC) in July of 2012. Flow data obtained from the RemoteTracker was compared to measurements taken with a 10-inch diameter magnetic flow meter manufactured by Water Specialties. Figure A-4 shows the Water Specialties Magnetic meter with an Endress & Hauser Transit-Time Meter installed just upstream as an additional check. The 3 foot wide by 3 foot deep concrete flume was modified to simulate a typical delivery configuration by forcing all the flow through a 20 foot length of 18 inch HDPE smooth interior wall pipe submerged in the concrete flume. The RemoteTracker wireless water velocity sensor was installed at the pipe outfall using a temporarily constructed headwall with a mounting bracket as shown in Figure A-5.

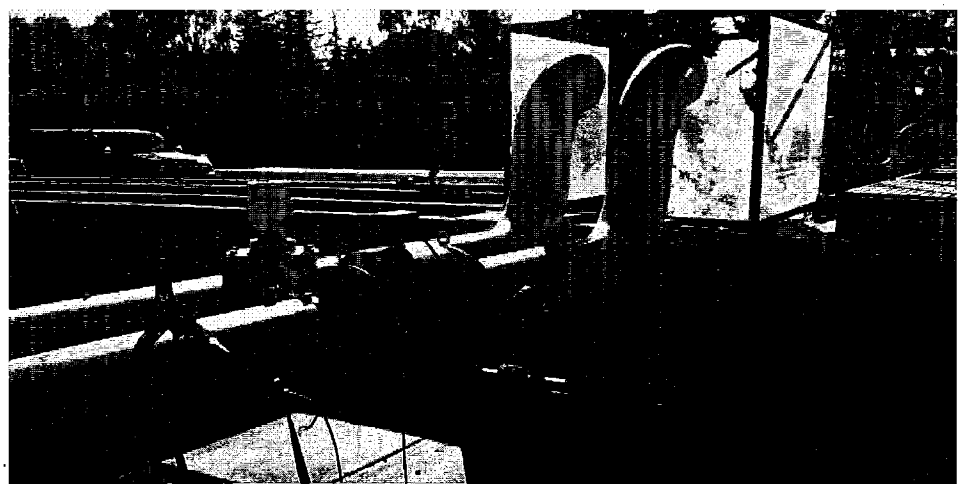


Figure A-4. Water Specialties Magnetic Flow Meter at CSUC ATRC

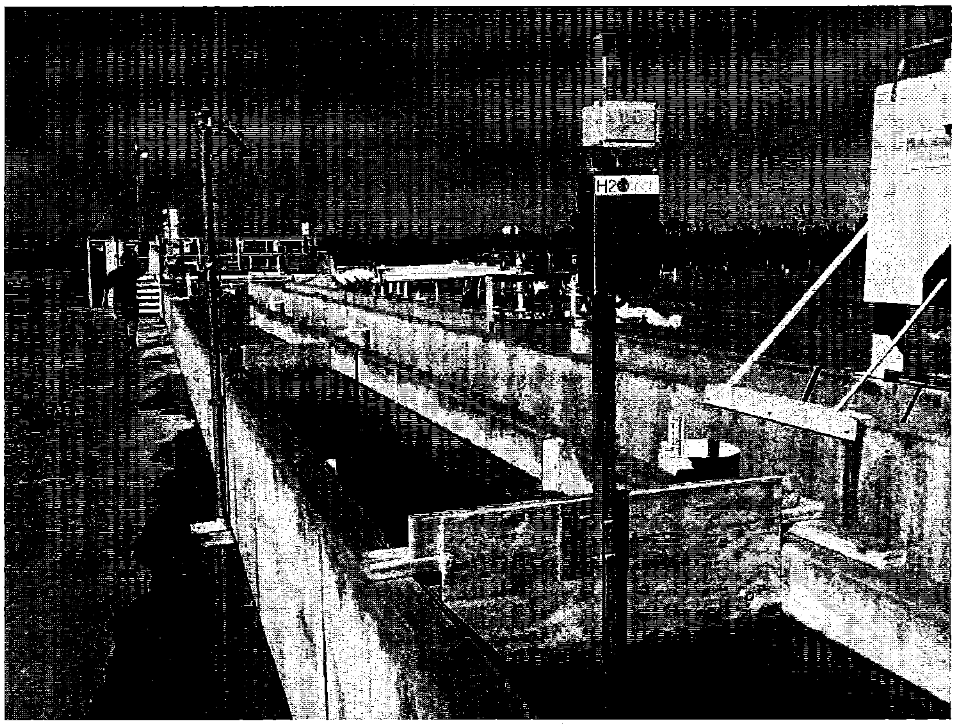


Figure A-5. RemoteTracker Wireless Water Velocity Sensor Installed at CSUC ATRC

Seven comparison measurements were made between the RemoteTracker and magnetic meter ranging from 0.5 cfs to just over 3.0 cfs (the maximum pump capacity). The percent difference between the two measurements averaged roughly -2.6 percent with a range of -10.2 to 2.8 percent indicating that the RemoteTracker measurement methodology compares very well with the magnetic meter. Note that the -10.2 percent difference occurred at the lowest flow rate of approximately 0.5 cfs and represents an absolute flow rate difference of just 0.05 cfs between the two measurement methods. The results of the comparison measurements are presented in Figure A-6 where the blue bars represent flow rates obtained with a magnetic meter, the red bars represent flow rates obtained with the RemoteTracker and the green triangles represent the percent difference between the two (secondary vertical axis).

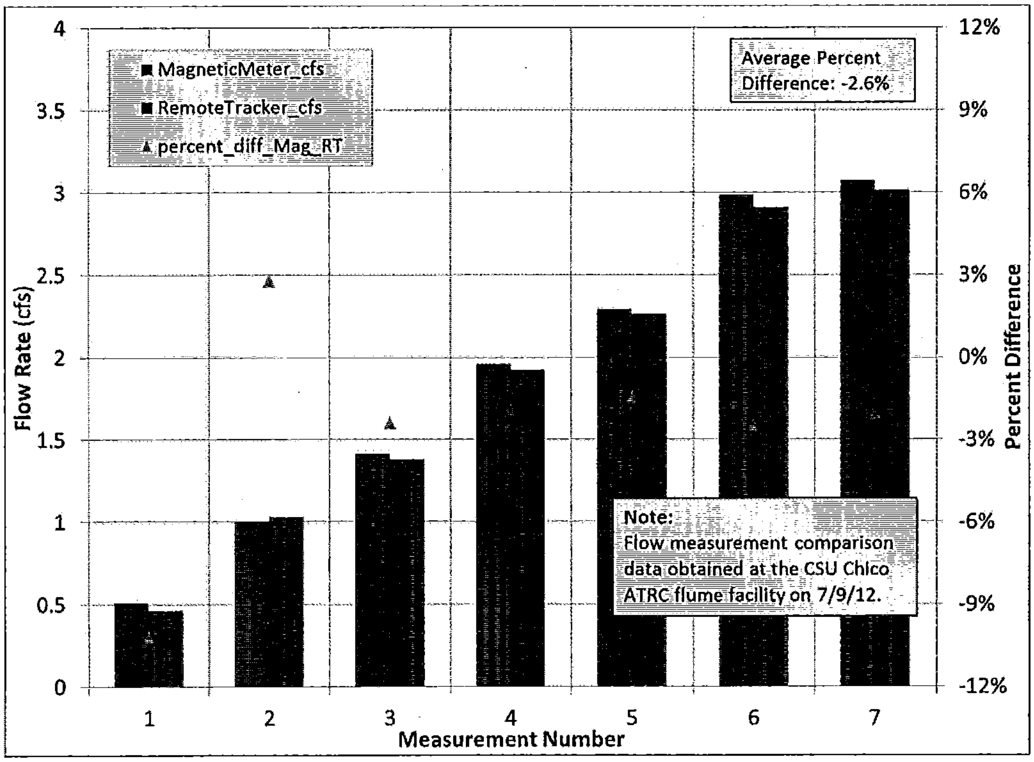


Figure A-6. RemoteTracker and CSUC ATRC Magmeter Comparisons

A-3.2 Field Testing

Five comparison measurements between the RemoteTracker and USGS mid-section method measurements with a SonTek ADV were performed at two turnouts in two irrigation districts (one turnout in each District) in Northern California during the 2011 irrigation season. The turnouts were selected because the delivery spilled into a field ditch (or head ditch) rather than a field, so both a RemoteTracker and a USGS mid-section method measurement (Rantz 1982) could be taken and compared. Figure A-7 shows the cross section report for one of the measurements in a typical earthen head ditch, in this case with a maximum depth of 2.5 feet, top width of 14 feet and bottom width of 5 feet. Typically, velocity measurements were performed at 0.5 foot intervals with velocities averaged over a 40 second period.

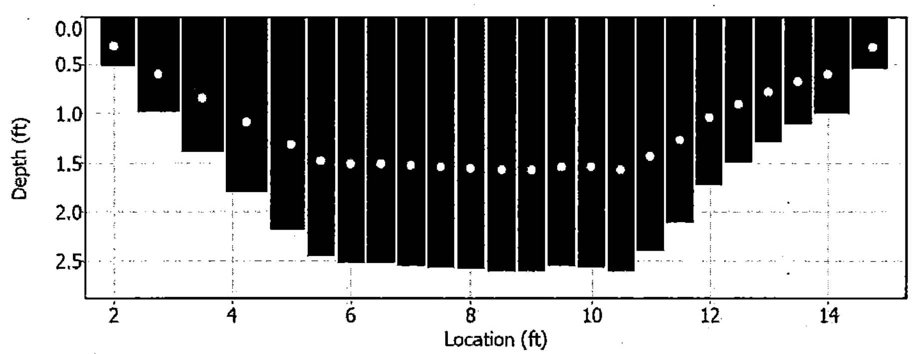


Figure A-7. SonTek ADV Cross Section for Canal Verification Measurement

The percent difference between the RemoteTracker and the USGS mid-section method averaged roughly 0.9 percent with a range of -0.8 to 3.4 percent, indicating that the RemoteTracker measurement methodology compares very well with the standard mid-section open channel methodology. The results of the comparison measurements are presented below in Figure A-8 where the blue bars represent flow rates obtained with a SonTek ADV in an open channel downstream of the turnout, the red bars represent flow rates obtained with the RemoteTracker and the green triangles represent the percent difference between the two (secondary vertical axis).

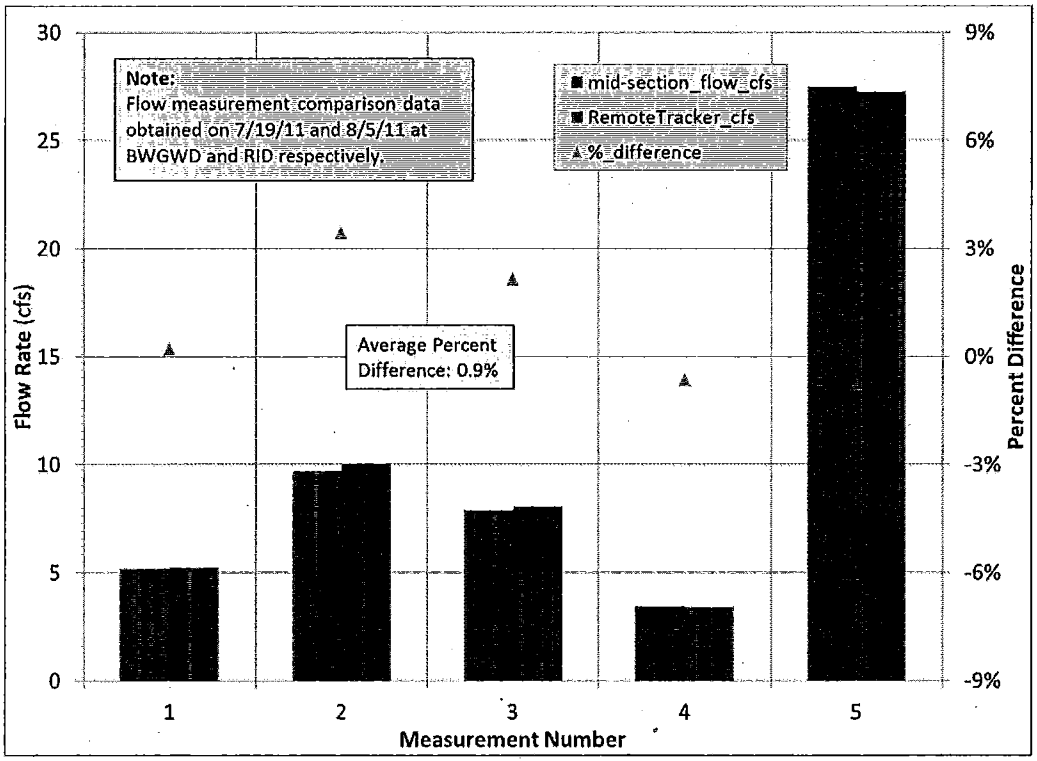


Figure A-8. RemoteTracker and Mid-Section method Comparisons

A-4.0 Volumetric Conversion (CCR 23 §597.4(e)(3))

Accuracy mandates established by CCR 23 §597 apply to delivery volume and not instantaneous flow rate or velocity. CCR 23 §597.4(e)(3)(B) states, "For devices that measure velocity only, the documentation shall describe protocols associated with the measurement of the cross-sectional area of flow and duration of water delivery...". This document provides descriptions of the protocols associated with the measurement of (1) average velocity, (2) cross-sectional area of flow and (3) duration of delivery, in addition to the corresponding accuracies associated with each measurement.

Because the RemoteTracker WWVS measures water velocity only, Equation A-1 suggested in CCR 23 597.4(e)(3)(B) is used to calculate volume.

$$\forall = V * A * \Delta t \quad \textbf{(Equation A-1)}$$

Where the variables are defined as:

- $\forall$: Volume
- V: Average Velocity
- A: Cross-Section Flow Area
- Δt: Duration of Delivery

This relative accuracy analysis assumes:

- 3 cubic foot per second (cfs) maintenance delivery
- A 24 inch inner diameter delivery pipe
- Normal distribution of measurement errors

A 3 cfs delivery was selected because it represents the lower range of agricultural water delivery rates and accuracy is harder to achieve at low flows. A 24 inch pipe is the average turnout pipe size within most agricultural districts. These assumptions lead to the listed variables having the values presented below.

- V_{RT} = RemoteTracker Velocity Measurement = 1.00 ft/s
- $V_{Avg}*$ = Average Velocity of the pipe at the time of the RemoteTracker spot measurement = 0.95 ft/s (determined by correlation with measured velocity; see Figure A-3)
- D = Pipe Diameter = 2.00 ft
- A = Cross-Section Flow Area = 3.14 ft^2

Based on the following analysis, the expected accuracy in volumetric measurements performed with the RemoteTracker system is ±4.6 percent.

A-4.1 Volumetric Accuracy Analysis Overview

Volumetric accuracy of water deliveries consists of the accuracies in each of the following three components:

- Average Velocity (V_{Avg})
- Cross-Section Flow Area (A)
- Duration of Delivery (Δt)

The total absolute accuracy is found using the following equation;

$$\sigma_{\forall} = \pm\sqrt{\left(\frac{\partial\forall}{\partial V_{Avg}}\sigma_{V_{Avg}}\right)^2 + \left(\frac{\partial\forall}{\partial A}\sigma_A\right)^2 + \left(\frac{\partial\forall}{\partial\Delta t}\sigma_{\Delta t}\right)^2} \quad \textbf{(Equation A-2)}$$

Where the variables are defined as:

- $\forall$: Volume
- V_{Avg}: Average Velocity
- Δt: Duration of Delivery
- σ: Absolute Accuracy (expressed in the units of the term in question)
- U: Relative Accuracy (expressed as a percentage)

The total relative accuracy is:

$$U_{\forall} = \frac{\sigma_{\forall}}{\forall} = \pm\frac{1}{\forall}\sqrt{\left(\frac{\partial\forall}{\partial V_{Avg}}\sigma_{V_{Avg}}\right)^2 + \left(\frac{\partial\forall}{\partial A}\sigma_A\right)^2 + \left(\frac{\partial\forall}{\partial\Delta t}\sigma_{\Delta t}\right)^2} \quad \textbf{(Equation A-3)}$$

$$U_{\forall} = \pm\sqrt{\frac{1}{\forall^2}\left(\left(\frac{\partial\forall}{\partial V_{Avg}}\sigma_{V_{Avg}}\right)^2 + \left(\frac{\partial\forall}{\partial A}\sigma_A\right)^2 + \left(\frac{\partial\forall}{\partial\Delta t}\sigma_{\Delta t}\right)^2\right)}$$

Where the partial derivatives are:

$$\frac{\partial\forall}{\partial V_{Avg}} = A\Delta t\ ,\ \frac{\partial\forall}{\partial A} = V_{Avg}\Delta t\ ,\ \frac{\partial\forall}{\Delta t} = V_{Avg}A$$

Substituting in the solutions to the partial derivatives:

$$U_{\forall} = \pm\sqrt{\frac{1}{\forall^2}\left(\left(A\Delta t\sigma_{V_{Avg}}\right)^2 + \left(V_{Avg}\Delta t\sigma_A\right)^2 + \left(V_{Avg}A\sigma_{\Delta t}\right)^2\right)}$$

$$U_{\forall} = \pm\sqrt{\left(\frac{A\Delta t\sigma_{V_{Avg}}}{\forall}\right)^2 + \left(\frac{V_{Avg}\Delta t\sigma_A}{\forall}\right)^2 + \left(\frac{V_{Avg}A\sigma_{\Delta t}}{\forall}\right)^2}$$

$$U_{\forall} = \pm\sqrt{\left(\frac{\sigma_{V_{Avg}}}{V_{Avg}}\right)^2 + \left(\frac{\sigma_A}{A}\right)^2 + \left(\frac{\sigma_{\Delta t}}{\Delta t}\right)^2}$$

This becomes:

$$U_{\forall} = \pm\sqrt{\left(U_{V_{Avg}}\right)^2 + (U_A)^2 + (U_{\Delta t})^2} \quad \textbf{(Equation A-4)}$$

Based on Equation A-4, the relative accuracies of Average Velocity, Cross-Section Flow Area, and Duration of Delivery are required. The following sections detail their determination.

A-4.2 Relative Accuracy in Velocity

The following bullet points provide protocols for the collection of water velocity data.

- The RemoteTracker WWVS will be deployed in the delivery pipe outfall so that the sample volume is located in the center of the delivery pipe
- Water velocities will be collected with the RemoteTracker WWVS at:
  - The start of all delivery events
  - After any changes in delivery events
- Shutoffs will be recorded on the RemoteTracker user interface with the "Record Shutoff" button at the time the gate is closed

The accuracies in average velocity consist of three parts:

1. $\sigma_{V_{RT}}$: Accuracy of RemoteTracker velocity measurements
2. $\sigma_{V_{Avg*}}$: Accuracy due to the process of correlating RemoteTracker velocity measured at the pipe center and the average velocity of the pipe at the time of the RemoteTracker spot measurement[13]
3. $\sigma_{\Delta V_T}$: Accuracy due to the difference between the average velocity at the time of the RemoteTracker spot measurement and the actual average velocity for the duration of the delivery (i.e. change in velocity over time)

The average velocity relative accuracy is:

[13] Average velocity at the time of the RemoteTracker spot measurement represents a snapshot of the average water velocity in a delivery pipe at the time of the RemoteTracker measurement.

$$U_{V_{Avg}} = \pm \frac{\sigma_{V_{Avg}}}{V_{Avg}}$$ **(Equation A-5)**

Where the variables are defined as:

- V_{Avg}: Average Velocity
- $U_{V_{Avg}}$: Relative Velocity Accuracy
- $\sigma_{V_{Avg}}$: Absolute Velocity Accuracy

The average velocity of the entire irrigation event is the summation of the average velocity at the time of observation and the average change in velocity throughout the remainder of the event due to water level fluctuations.

$$V_{Avg} = V_{Avg} * + \Delta V_T$$ **(Equation A-6)**

Where the variables are defined as:

- V_{Avg}: Average Velocity
- V_{Avg} $*$: Average Velocity at the time of the RemoteTracker spot measurement
- ΔV_T: Average Change in Velocity over time

Therefore:

$$\sigma_{V_{Avg}} = \pm \sqrt{\left(\frac{\partial V_{Avg}}{\partial V_{AvgO}} \sigma_{V_{AvgO}}\right)^2 + \left(\frac{\partial V_{Avg}}{\partial \Delta V_T} \sigma_{\Delta V_T}\right)^2}$$ **(Equation A-7)**

Where the partial derivatives are:

$$\frac{\partial V_{Avg}}{\partial V_{Avg*}} = 1, \ \frac{\partial V_{Avg}}{\partial \Delta V_T} = 1$$

Substituting in the solutions to the partial derivatives:

$$\sigma_{V_{Avg}} = \pm \sqrt{\left(\sigma_{V_{Avg*}}\right)^2 + \left(\sigma_{\Delta V_T}\right)^2}$$ **(Equation A-8)**

The following subsections present (1) the accuracy of the RemoteTracker velocity measurements, (2) the accuracy of the average velocity at the time of the RemoteTracker spot measurements ($\sigma_{V_{Avg}*}$) and (3) the accuracy in the change in average velocity over time ($\sigma_{\Delta V_T}$).

A-4.2.1 Accuracy of RemoteTracker Velocity Measurement

The RemoteTracker system uses a SonTek ADV for water velocity measurements. The SonTek ADV technical specifications sheet lists a velocity measurement error of 0.01 or 1.0 percent (SonTek 2006). Therefore, $\sigma_{V_{RT}}$ is equal to 0.010 ft/s, or 1.0 percent of 1.00 ft/s (V_D).

A-4.2.2 Accuracy of the Average Velocity at the Time of the RemoteTracker Spot Measurement

The average velocity is computed as the product of the velocity measured by the RemoteTracker and the coefficient correlating the RemoteTracker velocity measurement to the average velocity at the time of the RemoteTracker spot measurement.

$$V_{Avg}* = CV_{RT}$$ **(Equation A-9)**

Where the variables are defined as:

- $V_{Avg}*$: Average velocity at the time of the RemoteTracker spot measurement
- C: Coefficient correlating the RemoteTracker velocity measurement to the average velocity at the time of the RemoteTracker spot measurement, which is equal to 0.95 (see Figure A-3)
- V_{RT}: RemoteTracker velocity measurement

Therefore:

$$\sigma_{V_{Avg^*}} = \pm\sqrt{\left(\frac{\partial V_{Avg^*}}{\partial C}\sigma_C\right)^2 + \left(\frac{\partial V_{Avg^*}}{\partial V_{RT}}\sigma_{V_{RT}}\right)^2}$$ **(Equation A-10)**

Where the partial derivatives are:

$$\frac{\partial V_{Avg}*}{\partial C} = V_{RT}, \frac{\partial V_{Avg}*}{\partial V_{RT}} = C$$

Substituting in the solutions to the partial derivatives:

$$\sigma_{V_{Avg^*}} = \pm\sqrt{(V_{RT}\sigma_C)^2 + \left(C\sigma_{V_{RT}}\right)^2}$$ **(Equation A-11)**

Based on water velocity data collected, the average error introduced by converting the RemoteTracker velocity measurement to the average velocity at the time of the RemoteTracker spot measurement (σ_C) is 0.014 or 1.4 percent.

Inserting the determined values into Equation A-11:

$$\sigma_{V_{Avg^*}} = \pm\sqrt{(1.0 * 0.014)^2 + (0.95 * 0.010)^2} = \pm\, 0.017\, ft/s$$

A-4.2.3 Accuracy of the Change in Velocity over Time

A Microsoft Access database was developed to assess the accuracy in the change in velocity over time. Based on the orifice equation, the change in velocity through an orifice is solely a function of changes in head (or difference between upstream and downstream water level). Only water level data from the typical irrigation season (i.e. May through August) was used. It was assumed that measurements of velocity were performed every three days.

The difference between the head observed every three days and the actual average of the 15 minute data during the three day period was computed for each 15 minute record and then averaged over the observation period. Equation A-14 was then used to calculate the change in velocity over time (ΔV_T) for each three day period. The initial head (h_i) was assumed to be 0.5 feet to simulate a low head delivery. A low head was chosen because water level fluctuations impact the velocity of low head deliveries more significantly than high head deliveries.

Rearranging Equation A-6:

$$\Delta V_T = V_{Avg} - V_{Avg}\, *$$

From the orifice equation:

$$V = C(2gh)^{0.5}$$ **(Equation A-12)**

Where the variables are defined as:

- V: Velocity
- C: Discharge Coefficient
- g: gravitational constant
- h: Head

Orifice gates in most agricultural water districts operate under submerged conditions (i.e. not free flow conditions). As upstream canal water levels fluctuate, the flow through the orifice would theoretically vary as a function of the changes in canal water level to the one-half power. However, since the orifice gates are submerged, the hydraulically connected downstream water level also varies together with the upstream canal water level. This provides a damping effect on the overall change in velocity due to upstream water level fluctuations. The California Polytechnic State University at San Luis Obispo Irrigation Training and Research Center (ITRC) suggest using a power of 0.38 in the orifice equation to simulate the damping effect of submergence for a range of downstream channel conditions (Burt and Geer 2012).

$$V = C(2gh)^{0.38}$$ **(Equation A-13)**

Substituting values:

$$\Delta V_T = C(2gh_{avg})^{0.38} - C(2gh_O)^{0.38}$$

Where the variables are defined as:

- h_{avg}: Average Head
- h_O: Observed Head

Factoring:

$$\Delta V_T = C(2g)^{0.38}\left((h_{avg})^{0.38} - (h_O)^{0.38}\right)$$

Substituting values:

$$\Delta V_T = C(2g)^{0.38}\left((h_i + \Delta h_{avg})^{0.38} - (h_i)^{0.38}\right)$$ **(Equation A-14)**

Where the variables are defined as:

- h_i= Initial head at time of observation
- Δh_{avg}= average change in head

Since the volumetric reporting mandates apply to a monthly or bi-monthly basis (California Water Code §531.10(a)), the change in velocity over time was then averaged on a monthly time step. The average of the absolute values of each of the average monthly changes in velocity over time was taken across all nine sites. Largely due to the fact that water level fluctuations are normally distributed, the results of the hydraulic database model suggest that the average change in velocity over time due to water level fluctuation is:

$$\sigma_{\Delta V_T} = \pm\, 0.033\, ft/s$$

Based on the evaluation of continuous upstream and downstream water level data from 14 irrigation events in RD 108 with an average duration of five days, the average change in velocity over time was determined to be ±1.0 percent. In the context of this analysis, the accuracy in the change in velocity over time would be:

$$\sigma_{\Delta V_T} = \pm 1.0\% \; or \pm 0.010 \; ft/s$$

Therefore, utilizing the value of ±0.033 ft/s for the volumetric accuracy analysis is a conservative assumption.

Inserting the calculated values into Equation A-8, the average velocity accuracy is:

$$\sigma_{V_{Avg}} = \pm\sqrt{(0.017)^2 + (0.033)^2} = 0.037 \; ft/s$$

The relative accuracy of the average velocity is:

$$U_{V_{Avg}} = \pm\frac{\sigma_{V_{Avg}}}{V_{Avg}} = \pm\frac{0.037 \; ft/s}{0.95 \; ft/s} = \pm 0.039 \; or \; 3.9\%$$

A-4.3 Relative Accuracy in Cross-Section Flow Area

The following bullet points provide protocols for the collection of cross-section flow area data.

- The cross-section flow area will be calculated by measuring the inner diameter of the delivery pipe at the location of the water velocity measurement and using Equation A-16 to calculated area from inner diameter
- Inner pipe diameters will be measured with best professional practices when the pipe is dry

The accuracy in the inner pipe diameter measurement is assumed to be 0.02 feet (or 1/4 inch). The relative accuracy due to area is:

$$U_A = \pm\frac{\sigma_A}{A}$$ **(Equation A-15)**

The correlation between diameter and area is:

$$A = \frac{\pi D^2}{4}$$ **(Equation A-16)**

Where the variables are defined as:

- A: Cross-Section Flow Area
- π: Pi
- D: Inner Diameter

The accuracy is:

$$\sigma_A = \pm\sqrt{\left(\frac{\partial A}{\partial D}\sigma_D\right)^2}$$ **(Equation A-17)**

Where the partial derivative is equal to:

$$\frac{\partial A}{\partial D} = \frac{2\pi D}{4} = \frac{\pi D}{2}$$

The assumed pipe is 2.00 feet (24 inch) in diameter, giving an area of 3.142 ft^2

$$\sigma_A = \pm\sqrt{\left(\frac{\partial A}{\partial D}\sigma_D\right)^2} = \sqrt{\left(\frac{\pi D}{2}0.02\right)^2} = \sqrt{\left(\frac{\pi 2}{2}0.02\right)^2} = \pm\, 0.063\, ft$$

The relative accuracy in the cross-section flow area is:

$$U_A = \pm\frac{\sigma_A}{A} = \pm\frac{0.063\, ft}{3.142\, ft} = \pm\, 0.020\ or\ 2.0\%$$

A-4.4 Relative Accuracy in Duration of Delivery

The following bullet points provide protocols for the collection of duration of delivery data.

- The start time for delivery will be the date and time recorded in the RemoteTracker system when a velocity measurement is taken at the start of a delivery
- The stop time for delivery will be the date and time recorded in the RemoteTracker system when either:
    - "Record Shutoff" is pressed after a gate is closed at the end of a delivery or
    - A new velocity measurement is taken after a change in delivery flow rate is made

A conservative value for the duration of an irrigation event is assumed to be a period of 24 hours. The possible accuracy in duration measurement is considered to be 15 minutes for the startup and 15 minutes for the shutoff (or 0.25 hours for both). Realistically, the actual accuracy in duration is much smaller when using the RemoteTracker system since the operator is recording water velocity data on site when gate position changes are made. The relative accuracy due to duration of delivery is:

$$U_{\Delta t} = \pm\frac{\sigma_{\Delta t}}{\Delta t}$$ **(Equation A-18)**

Where:

$$\Delta t = Et - St$$ **(Equation A-19)**

Where the variables are defined as:

- Δt: Duration of Delivery
- St: Start Time
- Et: End Time

The accuracy of the Duration of Delivery is:

$$\sigma_{\Delta t} = \pm\sqrt{\left(\frac{\partial \Delta t}{\partial St}\sigma_{St}\right)^2 + \left(\frac{\partial \Delta t}{\partial Et}\sigma_{Et}\right)^2}$$ **(Equation A-20)**

Where the partial derivatives are equal to:

$$\frac{\partial \Delta t}{\partial St} = 1, \ \frac{\partial \Delta t}{\partial Et} = 1$$

$$\sigma_{\Delta t} = \pm\sqrt{(\sigma_{St})^2 + (\sigma_{Et})^2} = \sqrt{(.25)^2 + (0.25)^2} = 0.35\ hrs$$

The relative accuracy in the duration of delivery is:

$$U_{\Delta t} = \pm\frac{\sigma_{\Delta t}}{\Delta t} = \pm\frac{0.35}{24} = \pm\, 0.015\ or\ 1.5\%$$

A-4.5 Relative Accuracy in Volume

As previously stated this relative accuracy assumes a 3 cfs maintenance delivery in a 24" pipe. Inserting the calculated accuracy value for each component, the relative accuracy is as follows:

$$U_V = \pm\sqrt{\left(U_{V_{Avg}}\right)^2 + (U_A)^2 + (U_{\Delta t})^2}$$ **(Equation A-21)**

Inserting all calculated accuracy values the relative accuracy in volumetric measurements is:

$$U_V = \pm\sqrt{(.039)^2 + (.020)^2 + (.015)^2}$$

$$U_V = \pm\, 0.046\ or\ \pm 4.6\%$$

Based on the foregoing analysis and the resulting ±4.6% accuracy in delivery volume determined for the RemoteTracker, the RemoteTracker complies with the ±5.0% accuracy mandate in CCR 23 §597 for laboratory testing.

Appendix B. Detailed Cost Estimates

Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$400	0%	$400	
							$400	$400
Preparation								
2	Mobilization	ls	1	5%	$200	0%	$200	
							$200	$200
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	18" Orifice Gate	ea	25%	$1,890	$473	15%	$543	
7	24" Orifice Gate	ea	50%	$2,110	$1,055	15%	$1,213	
8	30" Orifice Gate	ea	25%	$2,736	$684	15%	$787	
9	Concrete Headwall	ea	1	$1,265	$1,265	15%	$1,455	
10								
11								
12								
13								
14								
							$3,998	$3,998
PROJECT SUBTOTAL								$4,598
Project Administration								
15	Construction Management and Overhead	ls	1	10%	$420	0%	$420	$420
TOTAL								$5,017

Figure B-1. Orifice Gate Unit Cost Breakdown

Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$115	0%	$115	
							$115	$115
Preparation								
2	Mobilization	ls	1	5%	$58	0%	$58	
							$58	$58
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	Calibration and Rating - Orifice Gate	ls	1	$1,000	$1,000	15%	$1,150	
7								
8								
9								
10								
11								
12								
13								
14								
							$1,150	$1,150
PROJECT SUBTOTAL								$1,323
Project Administration								
15	Planning/mobilization contingency	ls	1	0%	$0	0%	$0	$0
TOTAL								$1,323

Figure B-2. Orifice Gate Calibration Unit Cost Breakdown

Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$95	0%	$95	
							$95	$95
Preparation								
2	Mobilization	ls	1	5%	$48	0%	$48	
							$48	$48
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	Stilling Well 1' Downstream of Gate	ea	1	$530	$530	15%	$610	
7	Staff Gages	ea	1	$300	$300	15%	$345	
8								
9								
10								
11								
12								
13								
14								
							$955	$955
PROJECT SUBTOTAL								$1,098
Project Administration								
15	Construction Management and Overhead	ls	1	10%	$100	0%	$100	$100
TOTAL								$1,198

Figure B-3. Orifice Gate Differential Head Unit Cost Breakdown

Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$178	0%	$178	
							$178	$178
Preparation								
2	Mobilization	ls	1	5%	$89	0%	$89	
							$89	$89
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	4-ft concrete weir box	ea	1	$1,265	$1,265	15%	$1,455	
7	Aggregate Base	cy	3	$60	$180	15%	$207	
8	Weir boards and stand plate	ea	1	$100	$100	15%	$115	
9								
10								
11								
12								
13								
14								
							$1,777	$1,777
PROJECT SUBTOTAL								$2,043
Project Administration								
15	Construction Management and Overhead	ls	1	10%	$187	0%	$187	$187
TOTAL								$2,230

Figure B-4. Weir Box Cost Breakdown

Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$316	0%	$316	
							$316	$316
Preparation								
2	Mobilization	ls	1	5%	$158	0%	$158	
							$158	$158
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	Mag Meter	ea	1	$2,750	$2,750	15%	$3,163	
7								
8								
9								
10								
11								
12								
13								
14								
							$3,163	$3,163
PROJECT SUBTOTAL								$3,637
Project Administration								
15	Construction Management and Overhead	ls	1	10%	$332	0%	$332	$332
TOTAL								$3,969

Figure B-5. Totalizing Flow Meter Unit Cost Breakdown

Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$11,558	0%	$11,558	
							$11,558	$11,558
Preparation								
2	Mobilization	ls	1	5%	$5,779	0%	$5,779	
							$5,779	$5,779
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	MS Office Suite	ea	1	$500	$500	15%	$575	
7	Database Customization for Volumetric Tracking	ls	1	$30,000	$30,000	15%	$34,500	
8	Development of Automated Quality Control Proc	ls	1	$25,000	$25,000	15%	$28,750	
9	Creating Invoicing and Accounting Process	ls	1	$45,000	$45,000	15%	$51,750	
10								
11								
12								
13								
14								
							$115,575	$115,575
PROJECT SUBTOTAL								$132,911
Project Administration								
15	Planning/mobilization contingency	ls	1	0%	$0	0%	$0	$0
TOTAL								$132,911

Figure B-6. Water Information System Unit Cost Breakdown

Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$2,875	0%	$2,875	
							$2,875	$2,875
Preparation								
2	Mobilization	ls	1	5%	$1,438	0%	$1,438	
							$1,438	$1,438
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	RemoteTracker System	ea	1	$25,000	$25,000	15%	$28,750	
7								
8								
9								
10								
11								
12								
13								
14								
							$28,750	$28,750
PROJECT SUBTOTAL								$33,063
Project Administration								
15	Planning/mobilization contingency	ls	1	0%	$0	0%	$0	$0
TOTAL								$33,063

Figure B-7. RemoteTracker System Unit Cost Breakdown

Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$26	0%	$26	
							$26	$26
Preparation								
2	Mobilization	ls	1	5%	$13	0%	$13	
							$13	$13
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	RemoteTracker Plate	ea	1	$200	$200	15%	$230	
7	Pipe Diameter measurements	ea	1	$25	$25	15%	$29	
8								
9								
10								
11								
12								
13								
14								
							$259	$259
PROJECT SUBTOTAL								$298
Project Administration								
15	Construction Management and Overhead	ls	1	10%	$27	0%	$27	$27
TOTAL								$325

Figure B-8. RemoteTracker Plate Unit Cost Breakdown

Item #	Description	Units	Quantity	Unit Price ($)	Cost ($)	Contingency	Cost + Contingency ($)	Subtotal ($)
Planning								
1	Design and Engineering	ls	1	10%	$361	0%	$361	
							$361	$361
Preparation								
2	Mobilization	ls	1	5%	$180	0%	$180	
							$180	$180
Structure Improvements								
3								
4								
5								
							$0	$0
Measurement Equipment and Materials								
6	18" Propeller Meter	ea	25.0%	$2,920	$730	15%	$840	
7	24" Propeller Meter	ea	50.0%	$3,210	$1,605	15%	$1,846	
8	30" Propeller Meter	ea	25.0%	$3,210	$803	15%	$923	
9	Propeller Meter Plate	ea	1	$0	$0	15%	$0	
10								
11								
12								
13								
14								
							$3,608	$3,608
PROJECT SUBTOTAL								$4,149
Project Administration								
15	Construction Management and Overhead	ls	1	10%	$379	0%	$379	$379
TOTAL								$4,528

Figure B-9. Propeller Meter Unit Cost Breakdown

California Code of Regulations
Title 23. Waters
Division 2. Department of Water Resources
Chapter 5.1. Water Conservation Act of 2009
Article 2. Agricultural Water Measurement

§597. Agricultural Water Measurement

Under the authority included under California Water Code §10608.48(i)(1), the Department of Water Resources (Department) is required to adopt regulations that provide for a range of options that agricultural water suppliers may use or implement to comply with the measurement requirements in paragraph (1) of subdivision (b) of §10608.48.

For reference, §10608.48(b) of the California Water Code states that:

> *Agricultural water suppliers shall implement all of the following critical efficient management practices:*
>
> *(1) Measure the volume of water delivered to customers with sufficient accuracy to comply with subdivision (a) of Section 531.10 and to implement paragraph (2).*
>
> *(2) Adopt a pricing structure for water customers based at least in part on quantity delivered.*

For further reference, §531.10(a) of the California Water Code requires that:

> *(a) An agricultural water supplier shall submit an annual report to the department that summarizes aggregated farm-gate delivery data, on a monthly or bi-monthly basis, using best professional practices.*

Notes:

(1) Paragraphs (1) and (2) of §10608.48(b) specify agricultural water suppliers' reporting of aggregated farm-gate water delivery and adopting a volumetric water pricing structure as the purposes of water measurement. However, this article only addresses developing a range of options for water measurement.

(2) Agricultural water suppliers reporting agricultural water deliveries measured under this article shall use the “Agricultural Aggregated Farm – Gate Delivery Reporting Format for Article 2” (Rev. 6-20-12), developed for this article and hereby incorporated by reference.

(3) The Department shall report on the availability of new commercially available water measurement technologies and impediments to implementation of this article when reporting to the Legislature the status of adopted Agricultural Water Management Plans in plan submittal years 2012, 2015 and every five years thereafter as required by California Water Code §10845. The Department shall also report the findings to the California Water Commission.

Note: Authority cited: Section 10608.48, Water Code. Reference: Sections 531.10, 10608.48 (b), 10608.48 (i), 10608.52 (b) and 10845 Water Code.

§597.1. Applicability

(a) An agricultural water supplier providing water to 25,000 irrigated acres or more, excluding acres that receive only recycled water, is subject to this article.

(b) A wholesale agricultural water supplier providing water to another agricultural water supplier (the receiving water supplier) for ultimate resale to customers is subject to this article at the location at which control of the water is transferred to the receiving water supplier. However, the wholesale agricultural water supplier is not required to measure the receiving agricultural water supplier's deliveries to its customers.

(c) A water supplier providing water to wildlife refuges or habitat lands where (1) the refuges or habitat lands are under a contractual relationship with the water supplier, and (2) the water supplier meets the irrigated acreage criteria of Water Code §10608.12(a), is subject to this article.

(d) An agricultural water supplier providing water to less than 10,000 irrigated acres, excluding acres that receive only recycled water, is not subject to this article.

(e) An agricultural water supplier providing water to 10,000 or more irrigated acres but less than 25,000 irrigated acres, excluding acres that receive only recycled water, is not subject to this article unless sufficient funding is provided specifically for that purpose, as stated under Water Code §10853.

(f) A canal authority or other entity that conveys or delivers water through facilities owned by a federal agency is not subject to this article.

(g) Pursuant to Water Code §10608.8(d), an agricultural water supplier "that is a party to the Quantification Settlement Agreement, as defined in subdivision (a) of Section 1 of Chapter 617 of the Statutes of 2002, during the period within which the Quantification Settlement Agreement remains in effect," is not subject to this article.

(h) Pursuant to Water Code §10608.12(a), the Department is not subject to this article.

Note: Authority cited: Section 10608.48, Water Code. Reference: Sections 10608.12 (a), 10608.48 (d), 10608.48 (f), 10828, and 10853 Water Code.

§597.2. Definitions

(a) For purposes of this article, the terms used are defined in this section.

(1) "Accuracy" means the measured volume relative to the actual volume, expressed as a percent. The percent shall be calculated as 100 x (measured value – actual value) / actual value, where "measured value" is the value indicated by the device or determined through calculations using a measured value by the device, such as flow rate, combined with a duration of flow, and "actual value" is the value as determined through laboratory, design or field testing protocols using best professional practices.

(2) "Agricultural water supplier," as defined in Water Code §10608.12(a), means a water supplier, either publicly or privately owned, providing water to 10,000 or more irrigated acres, excluding acres that receive only recycled water. "Agricultural water supplier" includes a supplier or contractor for water, regardless of the basis of right, which distributes or sells water for ultimate resale to customers. "Agricultural water supplier" does not include the Department.

(3) "Approved by an engineer" means a California-registered Professional Engineer has reviewed, signed and stamped the plans, design, testing, inspection, and/or documentation report for a measurement device as described in this article.

(4) "Best professional practices" means practices attaining to and maintaining accuracy of measurement and reporting devices and methods described in this article, such as operation and maintenance procedures and practices recommended by measurement device manufacturers, designers, and industry professionals.

(5) "Customer" means the purchaser of water from an agricultural water supplier who has a contractual arrangement with the agricultural water supplier for the service of conveying water to the customer delivery point.

(6) "Delivery point" means the location at which the agricultural water supplier transfers control of delivered water to a customer or group of customers. In most instances, the transfer of control occurs at the farm-gate, which is therefore, a delivery point.

(7) "Existing measurement device," means a measurement device that was installed in the field prior to the effective date of this article.

(8) "Farm-gate," as defined in Water Code §531(f), means the point at which water is delivered from the agricultural water supplier's distribution system to each of its customers.

(9) "Irrigated acres," for purposes of applicability of this article, is calculated as the average of the previous five-year acreage within the agricultural water supplier's service area that has received irrigation water from the agricultural water supplier.

(10) "Manufactured device" means a device that is manufactured by a commercial enterprise, often under exclusive legal rights of the manufacturer, for direct off-the-shelf purchase and installation. Such devices are capable of directly measuring flow rate, velocity, or accumulating the volume of water delivered, without the need for additional components that are built on-site or in-house.

(11) "Measurement device" means a device by which an agricultural water supplier determines the numeric value of flow rate, velocity or volume of the water passing a designated delivery point. A measurement device may be a manufactured device, on-site built device or in-house built device.

(12) "New or replacement measurement device" means a measurement device installed after the effective date of this article.

(13) "Recycled water" is defined in subdivision (n) of §13050 of the Water Code as water that, as a result of treatment of waste, is suitable for a direct beneficial use or a controlled use that would not otherwise occur, and is therefore considered a valuable resource.

(14) "Type of device" means a measurement device that is manufactured or built to perform similar functions. For example, rectangular, v-notch, and broad crested weirs are one type of device. Similarly, all submerged orifice gates are considered one type of device.

Note: Authority cited: Section 10608.48, Water Code. Reference: Sections 10608.12 (a), 10608.12 (m), 10608.48, and 10813 Water Code.

§597.3 Range of Options for Agricultural Water Measurement

An agricultural water supplier subject to this article shall measure surface water and groundwater that it delivers to its customers pursuant to the accuracy standards in this section. The supplier may choose any applicable single measurement option or combination of options listed in paragraphs (a) or (b) of this section. Measurement device accuracy and operation shall be certified, tested, inspected and/or analyzed as described in §597.4 of this article.

(a) Measurement Options at the Delivery Point or Farm-gate of a Single Customer

An agricultural water supplier shall measure water delivered at the delivery point or farm-gate of a single customer using one of the following measurement options. The stated numerical accuracy for each measurement option is for the volume delivered. If a device measures a value other than volume, for example, flow rate, velocity or water elevation, the accuracy certification must incorporate the measurements or calculations required to convert the measured value to volume as described in §597.4(e).

(1) An existing measurement device shall be certified to be accurate to within ±12% by volume.

and,

(2) A new or replacement measurement device shall be certified to be accurate to within:

(A) ±5% by volume in the laboratory if using a laboratory certification;

(B) ±10% by volume in the field if using a non-laboratory certification.

(b) Measurement Options at a Location Upstream of the Delivery Points or Farm-gates of Multiple Customers

(1) An agricultural water supplier may measure water delivered at a location upstream of the delivery points or farm-gates of multiple customers using one of the measurement options described in §597.3(a) if the downstream individual customer's delivery points meet either of the following conditions:

(A) The agricultural water supplier does not have legal access to the delivery points of individual customers or group of customers needed to install, measure, maintain, operate, and monitor a measurement device.

Or,

(B) An engineer determines that, due to small differentials in water level or large fluctuations in flow rate or velocity that occur during the delivery season at a single farm-gate, accuracy standards of measurement options in §597.3(a) cannot be met by installing a measurement device or devices (manufactured or on-site built or in-house built devices with or without additional components such as gauging rod, water level control structure at the farm-gate, etc.). If conditions change such that the accuracy standards of measurement options in §597.3(a) at the farm-gate can be met, an agricultural water supplier shall include in its Agricultural Water Management Plan, a schedule, budget and finance plan to demonstrate progress to measure water at the farm-gate in compliance with §597.3(a) of this article.

(2) An agricultural water supplier choosing an option under paragraph (b)(1) of this section shall provide the following current documentation in its Agricultural Water Management Plan(s) submitted pursuant to Water Code §10826:

(A) When applicable, to demonstrate lack of legal access at delivery points of individual customers or group of customers downstream of the point of measurement, the agricultural water supplier's legal counsel shall certify to the Department that it does not have legal access to measure water at customers delivery points and that it has sought and been denied access from its customers to measure water at those points.

(B) When applicable, the agricultural water supplier shall document the water measurement device unavailability and that the water level or flow conditions described in §597.3(b)(1)(B) exist at individual customer's delivery points downstream of the point of measurement as approved by an engineer.

(C) The agricultural water supplier shall document all of the following criteria about the methodology it uses to apportion the volume of water delivered to the individual downstream customers:

(i) How it accounts for differences in water use among the individual customers based on but not limited to the duration of water delivery to the individual customers, annual customer water use patterns, irrigated acreage, crops planted, and on-farm irrigation system,

and;

(ii) That it is sufficient for establishing a pricing structure based at least in part on the volume delivered,

and;

(iii) That it was approved by the agricultural water supplier's governing board or body.

Note: Authority cited: Section 10608.48, Water Code. Reference: Sections 531.10, 10608.48 *(i)* (1), and 10826 Water Code.

§597.4 Accuracy Certification, Records Retention, Device Performance, and Reporting

(a) Initial Certification of Device Accuracy

The accuracy of an existing, new or replacement measurement device or type of device, as required in §597.3, shall be initially certified and documented as follows:

(1) For existing measurement devices, the device accuracy required in section 597.3(a) shall be initially certified and documented by either:

(A) Field-testing that is completed on a random and statistically representative sample of the existing measurement devices as described in §597.4(b)(1) and §597.4(b)(2). Field-testing shall be performed by individuals trained in the use of field-testing equipment, and documented in a report approved by an engineer.

Or,

(B) Field-inspections and analysis completed for every existing measurement device as described in §597.4(b)(3). Field-inspections and analysis shall be performed by trained individuals in the use of field inspection and analysis, and documented in a report approved by an engineer.

(2) For new or replacement measurement devices, the device accuracy required in sections 597.3 (a)(2) shall be initially certified and documented by either:

(A) Laboratory Certification prior to installation of a measurement device as documented by the manufacturer or an entity, institution or individual that tested the device following industry-established protocols such as the National Institute for Standards and Testing (NIST) traceability standards. Documentation shall include the manufacturer's literature or the results of laboratory testing of an individual device or type of device.

Or,

(B) Non-Laboratory Certification after the installation of a measurement device in the field, as documented by either:

(i) An affidavit approved by an engineer submitted to the agricultural water supplier of either (1) the design and installation of an individual device at a specified location, or (2) the standardized design and installation for a group of measurement devices for each type of device installed at specified locations.

Or,

(ii) A report submitted to the agricultural water supplier and approved by an engineer documenting the field-testing performed on the installed measurement device or type of device, by individuals trained in the use of field testing equipment.

(b) Protocols for Field-Testing and Field-Inspection and Analysis of Existing Devices

(1) Field-testing shall be performed for a sample of existing measurement devices according to manufacturer's recommendations or design specifications and following best professional practices. It is recommended that the sample size be no less than 10% of existing devices, with a minimum of 5, and not to exceed 100 individual devices for any particular device type. Alternatively, the supplier may develop its own sampling plan using an accepted statistical methodology.

(2) If during the field-testing of existing measurement devices, more than one quarter of the samples for any particular device type do not meet the criteria pursuant to §597.3(a), the agricultural water supplier shall provide in its Agricultural Water

Management Plan, a plan to test an additional 10% of its existing devices, with a minimum of 5, but not to exceed an additional 100 individual devices for the particular device type. This second round of field-testing and corrective actions shall be completed within three years of the initial field-testing.

(3) Field-inspections and analysis protocols shall be performed and the results shall be approved by an engineer for every existing measurement device to demonstrate that the design and installation standards used for the installation of existing measurement devices meet the accuracy standards of §597.3(a) and operation and maintenance protocols meet best professional practices.

(c) **Records Retention**

Records documenting compliance with the requirements in §597.3 and §597.4 shall be maintained by the agricultural water supplier for ten years or two Agricultural Water Management Plan cycles.

(d) **Performance Requirements**

(1) All measurement devices shall be correctly installed, maintained, operated, inspected, and monitored as described by the manufacturer, the laboratory or the registered Professional Engineer that has signed and stamped certification of the device, and pursuant to best professional practices.

(2) If an installed measurement device no longer meets the accuracy requirements of §597.3(a) based on either field-testing or field-inspections and analysis as defined in sections 597.4 (a) and (b) for either the initial accuracy certification or during operations and maintenance, then the agricultural water supplier shall take appropriate corrective action, including but not limited to, repair or replacement to achieve the requirements of this article.

(e) **Reporting in Agricultural Water Management Plans**

Agricultural water suppliers shall report the following information in their Agricultural Water Management Plan(s):

(1) Documentation as required to demonstrate compliance with §597.3 (b), as outlined in section §597.3(b)(2), and §597.4(b)(2).

(2) A description of best professional practices about, but not limited to, the (1) collection of water measurement data, (2) frequency of measurements, (3) method for determining irrigated acres, and (4) quality control and quality assurance procedures.

(3) If a water measurement device measures flow rate, velocity or water elevation, and does not report the total volume of water delivered, the agricultural water supplier must document in its Agricultural Water Management Plan how it converted the

measured value to volume. The protocols must follow best professional practices and include the following methods for determining volumetric deliveries:

(A) For devices that measure flow-rate, documentation shall describe protocols used to measure the duration of water delivery where volume is derived by the following formula: Volume = flow rate x duration of delivery.

(B) For devices that measure velocity only, the documentation shall describe protocols associated with the measurement of the cross-sectional area of flow and duration of water delivery, where volume is derived by the following formula: Volume = velocity x cross-section flow area x duration of delivery.

(C) For devices that measure water elevation at the device (e.g. flow over a weir or differential elevation on either side of a device), the documentation shall describe protocols associated with the measurement of elevation that was used to derive flow rate at the device. The documentation will also describe the method or formula used to derive volume from the measured elevation value(s).

(4) If an existing water measurement device is determined to be out of compliance with §597.3, and the agricultural water supplier is unable to bring it into compliance before submitting its Agricultural Water Management Plan in December 2012, the agricultural water supplier shall provide in its 2012 plan, a schedule, budget and finance plan for taking corrective action in three years or less.

Note: Authority cited: Section 10608.48, Water Code. Reference: Sections 531.10, 10608.48 *(i)* (1), and 10826 Water Code.

Agricultural Aggregated Farm-Gate[1] Delivery Reporting Format for Article 2

Due annually beginning no later than July 31, 2013 from agricultural water suppliers subject to Title 23, Division 2, Chapter 5.1, Article 2 of the CCR - Agricultural Water Measurement

1. Water Supplier Information

Name:

Address:

Phone Number:

Fax:

Total Number of Farm-Gates:

Number of Measured Farm-Gates:

Service Area Acreage:

2. Contact information

Name:

Title:

Address:

Phone Number:

Fax:

E-mail:

Submittal date:

3. Aggregated Farm-Gate Delivery Data[2]: (*provide monthly or bimonthly data, acre-feet*)

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
Monthly Deliveries													

	Jul-Aug	Sep-Oct	Nov-Dec	Jan-Feb	Mar-Apr	May-Jun	Total
Bimonthly Deliveries							

4. Explanations, Comments and Best Professional Practices[3]:

Note: An agricultural water supplier's total water use may be different from Aggregated Farm-Gate deliveries because measurement at these points may not account for other practices (such as groundwater recharge/conjunctive use, water transfers, wheeling to other agencies, urban use, etc).

1. "Farm-gate" means the point at which water is delivered from the agricultural water supplier's distribution system to each of its individual customers as specified in the Agricultural Water Measurement Regulation (Title 23, Division 2, Chapter 5.1, Article 2 of the CCR).
2. "Aggregated farm-gate delivery data" means information reflecting the total volume of water an agricultural water supplier provides to its customers and is calculated by totaling its deliveries to customers.
3. "Best Professional Practices" is defined in Title 23, Division 2, Chapter 5.1, Article 2 of the CCR, Section 597.2.

8. CLAIM CERTIFICATION

*Read, sign, and date this section and insert at the end of the test claim submission.**

This test claim alleges the existence of a reimbursable state-mandated program within the meaning of article XIII B, section 6 of the California Constitution and Government Code section 17514. I hereby declare, under penalty of perjury under the laws of the State of California, that the information in this test claim submission is true and complete to the best of my own knowledge or information or belief.

DUSTIN C. COOPER

Print or Type Name of Authorized Local Agency or School District Official

GENERAL COUNSEL

Print or Type Title

Signature of Authorized Local Agency or School District Official

February ~~26~~ 27, 2013

Date

** If the declarant for this Claim Certification is different from the Claimant contact identified in section 2 of the test claim form, please provide the declarant's address, telephone number, fax number, and e-mail address below.*