EASTERN SNAKE PLAIN AQUIFER WATER MEASUREMENT PROGRAM

A SUMMARY OF MEASUREMENT ACTIVITY & RESULTS FROM BASIN 36 PROJECT AREA, 1995-1996 AND A REVIEW OF PROGRAM EXPANSION IN 1997

IDAHO DEPARTMENT OF WATER RESOURCES
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A SUMMARY OF MEASUREMENT ACTIVITY & RESULTS FROM BASIN 36 PROJECT AREA, 1995 - 1996 AND A REVIEW OF PROGRAM EXPANSION IN 1997

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PREFACE

This document describes water measurement results and work accomplished under the Idaho Department of Water Resources (IDWR) Eastern Snake Plain Aquifer (ESPA) water measurement program during 1995, 1996 and 1997. It summarizes the program's background, objectives and implementation methodology. Measurement results and analyses are provided, with emphasis on 1996 data from IDWR administrative basin 36. Expansion of water measurement during 1997 is reviewed along with a brief discussion of proposed future activities.

The 1996 ground water and surface water diversion data, which are reported in Appendices B and C respectively, are printed separate from this document. This latter document is referenced as *Eastern Snake Plain Aquifer Water Measurement Program: Appendices B and C, Water Measurement Report, Ground Water and Surface Water Diversions, Basin 36, 1996.* Copies of this document are available from IDWR upon request.

IDWR acknowledges the cooperation and effort of basin 36 water users in complying with water measurement and reporting requirements, as well as supplying valuable data. The authors also wish to acknowledge Gary Spackman of IDWR for his involvment and leadership of the basin 36 water measurement program between 1994 and 1997, and IDWR staff members Roberta Loveall, Bryce Contor, Jackie Wyatt and Bob Foster for their past assistance.

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INTRODUCTION

BACKGROUND

Interest in the measurement of water diversions within the ESPA has grown in response to several key events and concerns about water availability. The average annual discharge of springs tributary to the Snake River in the Thousand Springs area (Milner to King Hill reach) has experienced a declining trend over the past 40 years. This declining trend as shown in Figure 1 was preceded by a distinct increase in spring discharge during the first half of this century, caused by an increase in recharge resulting from the development of irrigable land within the ESPA. The more recent reduction in spring discharge in the Thousand Springs reach is attributed to rapid growth of ground water irrigation since 1950, conversion of flood irrigation to sprinkler irrigation, cessation of winter diversions by most of the Snake River canals in about 1960, and significant reductions in summer diversions which began in the late 1970's (Idaho Department of Water Resources, 1997). The declining trend over the latter half of the century became more acute during a prolonged drought period in the late 1980's and early 1990's.

In 1993, the holders of a water right from a spring source near Hagerman filed suit against the state in an attempt to have the full amount of their recorded water right delivered from the source. The suit, known as the Musser case, caused considerable concern among junior ground water right holders in the aquifer and served to heighten awareness about the interconnection between ground water and surface water sources. This suit also caused IDWR to develop rules and regulations concerning conjunctive management of ground water and surface water. These rules were adopted as statewide rules in October, 1994. Also in 1994, the Idaho Legislature amended the state's water measurement statute by authorizing the director of IDWR to require annual measurement and reporting of both ground water and surface water diversions. The 1994 amendment provides that users, when ordered by the director, must install and maintain measuring devices, and annually report water diversions. However, if the installation and maintenance of such devices is burdensome, then users may have the opportunity to have their water use estimated by relying on power records and establishing relationships between power usage and water withdrawals. Concurrent legislation was adopted allowing electrical and gas utility companies to supply IDWR with annual energy consumption reports.

In July of 1994, the A&B Irrigation District in Rupert, Idaho filed a petition with IDWR for a priority delivery call for ground water from the ESPA. The petition also sought creation of a ground water management area for the ESPA. A&B holds a ground water right with a 1948 priority date for 1100 cfs, a right that is senior to most ground water rights in the ESPA. The A&B call again caused concern among many junior ground water right holders in the aquifer. A&B, IDWR, and representatives of numerous water users within the aquifer agreed to have the delivery call held in abeyance pending the implementation of certain water management goals, including measurement and reporting of both ground water and surface water diversions. The parties also agreed to work towards establishing and supporting legislation creating water measurement districts and ground water districts.

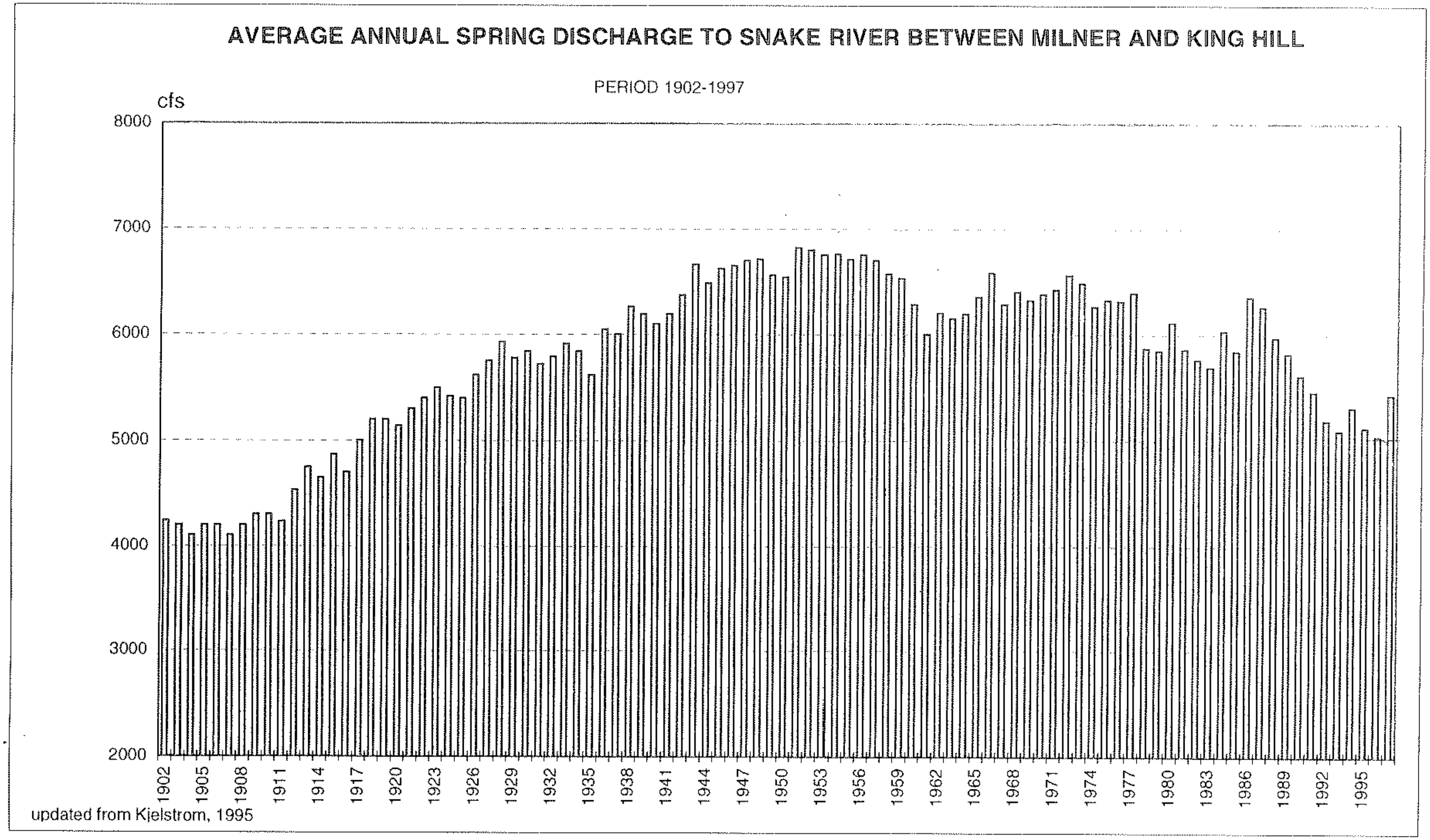

Figure 1. Average Annual Spring Discharge to Snake River: Milner to King Hill

Late in 1994, IDWR began implementation of a water measurement program within the southwestern portion of the ESPA. This program, and measurement results from 1995 and 1996, is addressed in further detail throughout this report. Also in 1995, the Idaho Legislature passed legislation allowing the director of IDWR to create water measurement districts in order to accomplish measurement and reporting of diversions. Specific legislative intent was given to creating measurement districts as expeditiously as possible within the ESPA. The Legislature also adopted the "Ground Water District Act" in 1995 which enables ground water users to organize their own ground water districts. These latter districts have authority to measure and report ground water diversions for district members and petition the director of IDWR to be excluded from a water measurement district once a measurement district is created. Similarly, irrigation districts and holders of water rights for aquaculture, hydropower and in-stream uses may also petition IDWR to be excluded from measurement districts. IDWR may grant exclusions upon a showing that diversions are measured and recorded in an acceptable manner and upon agreement to submit an annual report of diversions to IDWR in accordance with reporting requirements that apply to measurement districts.

Since 1995, four separate ground water districts were organized within the ESPA (see Figure 2, page 5). These districts include the North Snake, Magic Valley, Aberdeen-American Falls, and Bingham ground water districts. In October of 1996, the director of IDWR created three water measurement districts in the ESPA and extended water measurement requirements to the entire aquifer. These districts are the East, North and West ESPA Water Measurement Districts (see Figure 3, page 6). All three measurement districts elected or contracted with hydrographers in 1997 and began implementing water measurement plans. Each of the four ground water districts have petitioned the Department to be excluded from the water measurement districts. Additionally, three irrigation districts with ground water diversions in the ESPA filed petitions with IDWR to be excluded from water measurement districts. Those districts include A&B, Falls and Southwest Irrigation Districts. IDWR approved petitions from ground water and irrigation districts and each of the excluded districts began implementing approved measurement plans during 1997. Table 1 provides a breakdown of the number of ground water diversions that are subject to measurement within the different districts which have assumed responsibility for measurement and reporting.

Table 1. Distribution of Diversions within the ESPA

	Number of Diversions	Percent of Total in ESPA
Ground Water Districts		
Magic Valley	577	11.2%
North Snake	600	11.7%
Aberdeen-American Falls	750	14.6%
Bingham	1000	19.4%
total	2927	56.9%
Irrigation Districts		
A & B	177	3.4%
Southwest	218	4.2%
Falls	26	0.5%
total	421	8.1%
Measurement Districts		
North	729	14.2%
East	688	13.4%
West	383	7.4%
total	1800	35.0%
grand total	5148	

Additional ESPA ground water diversions within INEEL & Ft. Hall reservations, Water Districts 31 & 34, and municipal wells excluded from measurement districts. Estimated additional wells subject to measurement is about 250. There are also an estimated 200 surface water diversions that will be measured through the ESPA program (includes Water District 36A and other basin 36 diversions).

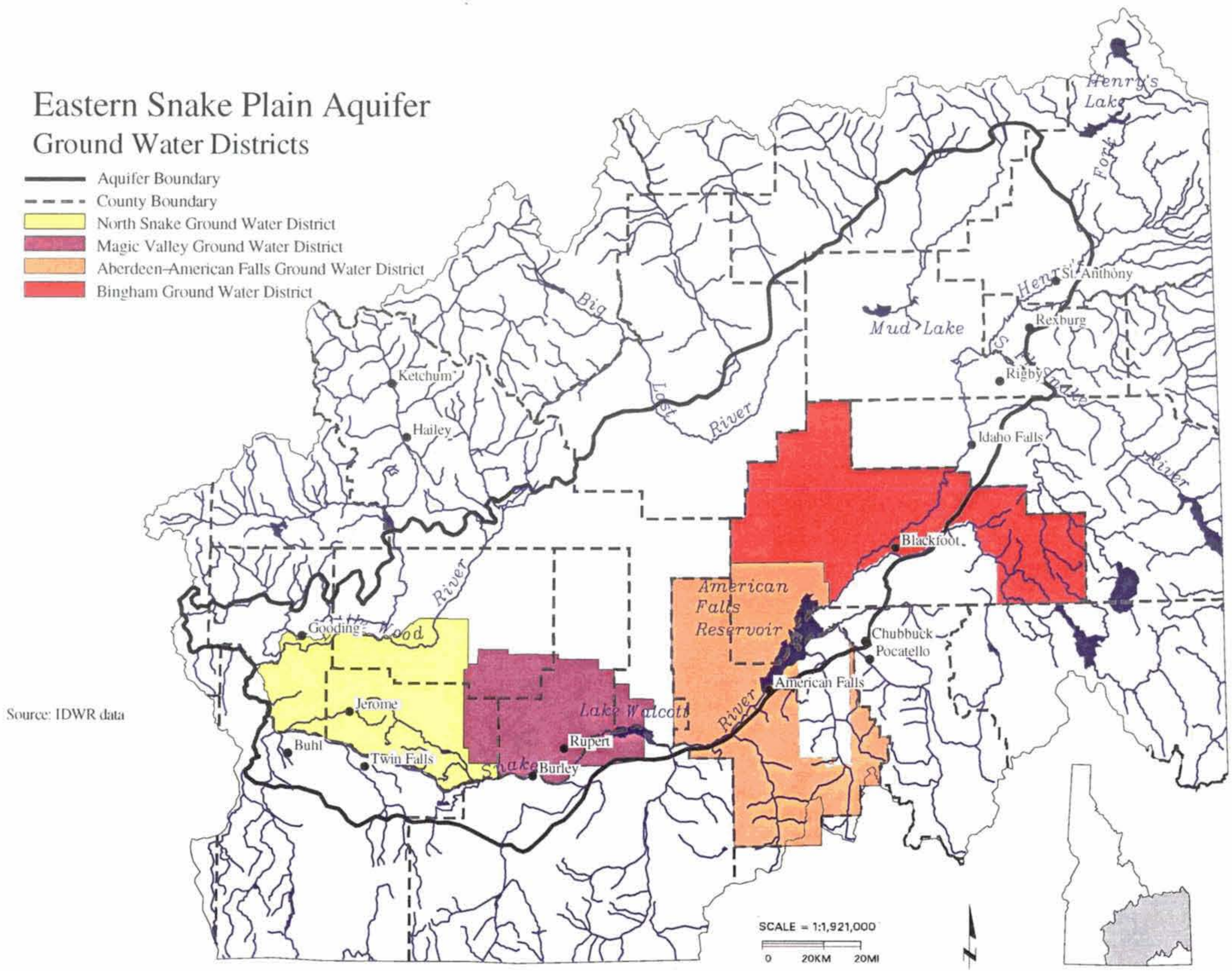

Figure 2. Ground Water Districts in ESPA

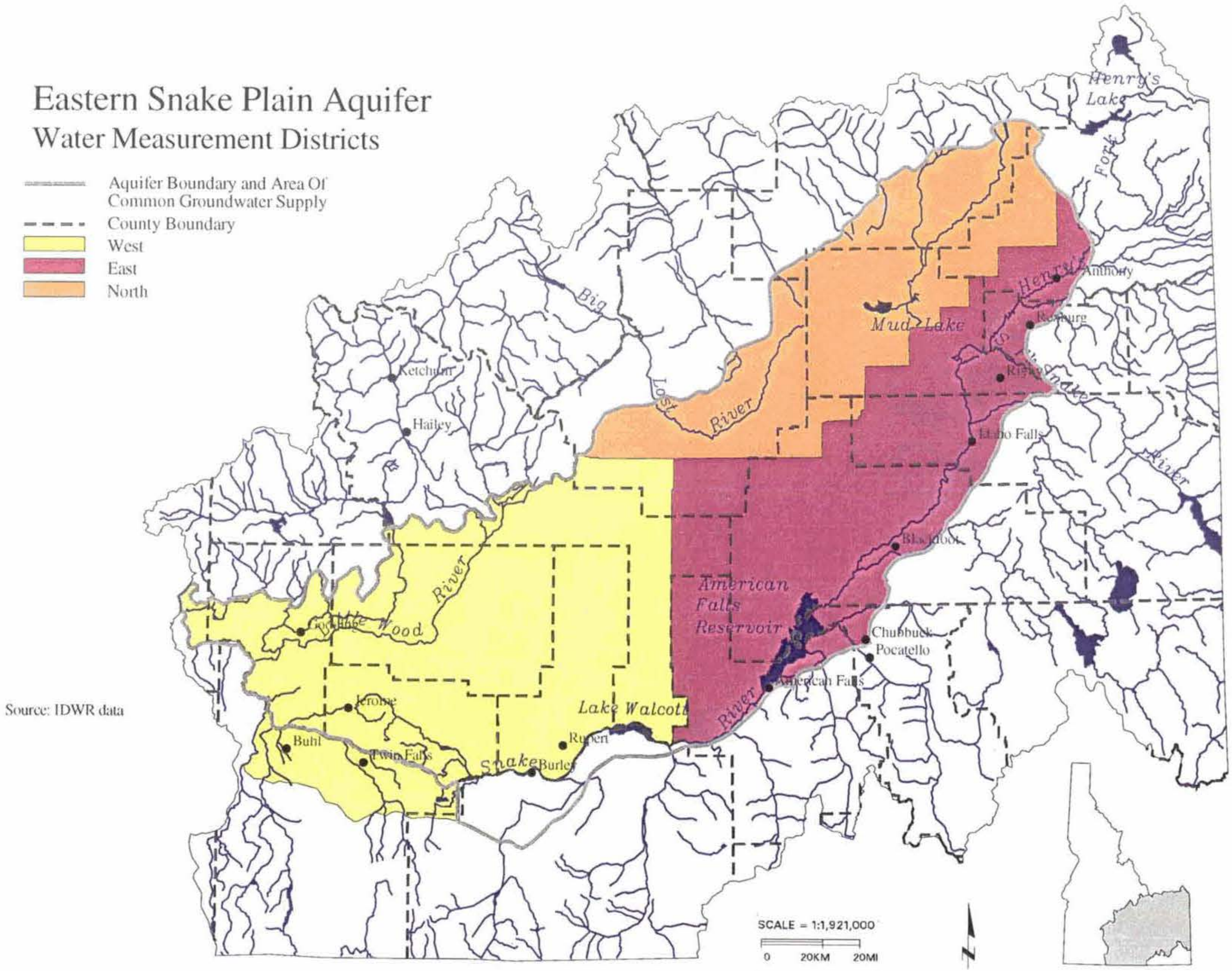

Figure 3. Water Measurement Districts in ESPA

WATER MEASUREMENT OBJECTIVES

In response to the 1994 legislative amendments concerning water measurement, as well as the separate delivery calls in both 1993 and 1994, IDWR considered how to begin implementing water measurement and reporting for thousands of diversions, primarily ground water diversions, in an aquifer as large as the ESPA. The Department held several public meetings in 1994 throughout the aquifer area to solicit comments and input from affected water users. Input was also sought through several smaller meetings involving key representatives from the agricultural and industrial sectors, plus several members of the Idaho Legislature, and some technical and legal experts from within the state. These different meetings focused on program needs and objectives, methodology of measurement and reporting, accuracy and costs. The overwhelming sentiment among water users is that measurement must be accomplished in an accurate, reliable and cost effective manner that is uniformly applied to all water uses.

The objectives of water measurement in the ESPA can be grouped into two general categories as outlined below.

1) Water Management and Planning

a) develop an operational water use data collection and retrieval system that is acceptable to water users and is adequate for water resources management, planning and research

b) determine cumulative water withdrawals in ESPA
- develop a period of historical data for a population of diversions
- use data to evaluate existing modeling and planning efforts
- determine future methods of measurement or sampling needs for estimating annual withdrawals

2) Water Rights Administration

a) determine individual water withdrawals in the ESPA
- compare individual water withdrawals with water rights
- regulate individual diversions and rights if necessary

b) locate and inventory ESPA diversions (GPS and site tagging, exclude small diversions less than 0.241 cfs and/or less than 5.1 acres)

INITIAL PROJECT AREA

Given these broad objectives and size of the aquifer, IDWR felt that it was prudent to first limit measurement to a specific, smaller area of the ESPA and gradually expand a program to the rest of the aquifer over a period of several years. IDWR therefore selected administrative basin 36 as the area in which to begin measurement (see map of basin 36 in Figure 5). The director of IDWR issued orders in December of 1994 to users in this area to begin measuring and reporting their diversions in 1995. This basin was chosen because it is the area where the two separate water right delivery calls were made between 1993 and 1994, and because the basin includes the Thousand Springs area. Also, IDWR had completed a Director's Report of recommended water rights in this basin as part of the Snake River Basin Adjudication (SRBA). This report provided IDWR with an updated reference to water right owners and point of diversion locations which was not available for other areas within the ESPA.

Administrative basin 36 contains over 1300 ground water diversions, and about 100 surface water diversions which are subject to water measurement and reporting requirements. Measurement of water withdrawals from these diversions began in 1995. This program was continued to 1996 and involved IDWR staff working individually with users to measure their diversions using either measuring devices, or using power records and developing relationships between energy consumption and water use.

WATER MEASUREMENT ACTIVITIES: 1995-1996

During the latter half of 1994, IDWR staff evaluated several options for measurement of diversions and presented those methods to water users at several public meetings throughout the aquifer. The methods of measurement adopted by IDWR for basin 36 are outlined below. A more detailed description of these methods and minimum acceptable standards are referenced in IDWR's *"Interim Guidelines for Measuring and Reporting Water Diversions Within Organized Water Measurement Districts, Groundwater Districts and Irrigation Districts, and Non-Irrigation Diversions Excluded From Water Measurement Districts," April 21, 1997.*

METHODS OF MEASUREMENT - GROUND WATER DIVERSIONS

Flow Meters: Installed in-line flow meters used for pressurized pipe systems capable of totalizing volume. A wide variety of meters are available which meet IDWR standards, including various types of differential head and force velocity meters. Meters typically chosen by users include propeller and impeller force velocity meters.

Energy Records: IDWR has chosen to use the Power Consumption Coefficient (PCC) method for estimating diversion withdrawals with energy records. The PCC is the number of kilowatt hours (KWH) required to pump one acre-foot of water. Determining a PCC requires field measurement of pump discharge or flow in gallons per minute (gpm) and kilowatts (KW or energy demand).

The PCC = kw × 5431 ÷ gpm (units are kwh/af; 5431 is a conversion factor)

Using the PCC, the total estimated volume of water pumped can be calculated from the total annual KWH of electrical energy consumed by the pumping plant. Total annual KWH for irrigation diversions is supplied to IDWR by electric utilities upon request and according to rules and regulations adopted by the Public Utilities Commission (PUC).

Total annual volume (acre-feet) = Total annual kwh ÷ PCC

The PCC method may only be used where a single electrical power meter is dedicated to one pumping plant. It is generally intended to be used on pumping plants which are simple in design and operational characteristics, and where water levels do not fluctuate greatly over the season of use. IDWR has allowed use of PCC's on more complex systems by allowing derivation of PCC's on up to three distinct operating conditions, provided that the amount or percentage of time under each condition is adequately tracked or estimated.

Time Clocks: Involves installation of a clock on the electrical panel to track hours of operation of a pump. Used mainly for open discharge pumps where multiple pumps may be on one power meter. Requires field measurement of discharge. Annual withdrawal is determined as the product of discharge and operating hours. Time clocks may also be used to track the number of hours or percentage of time of individual operating conditions for complex systems. In basin 36 however, time clocks were rarely used for this latter purpose.

Total annual volume (acre-feet) = Total annual hours x gpm ÷ 5431

Open Channel Measurement & Operation Records: This method is also used for open discharge pumps or flowing wells. Ground water that discharges to an open channel may be measured by a standard open channel measuring device such as a weir. Weir measurements may be recorded daily by a well owner or ditch rider, or by using some type of continuous recorder. This method is used for a number of wells within the A&B irrigation district, as well as by some other delivery organizations and individuals within the ESPA.

Non-Use of Diversions: Owners of diversions who do not use their wells or withdraw ground water in a given year are required to report non-use. This may include submittal of utility account information to verify non-use.

METHODS OF MEASUREMENT - SURFACE WATER DIVERSIONS

Open Channel Measuring Devices: IDWR accepts use of all standard open channel measuring devices as long as construction and installation follows published guidelines. Examples of open channel devices include contracted and suppressed rectangular weirs, ramped broad crested weir, cipolletti weir, parshall flume, and submerged rectangular orifice. Users with open channel devices are required to record measurements at least once per week, or more frequently if conditions change.

Non-standard Measuring Devices, Rated Structures and Rated Sections: IDWR may authorize the use of non-standard open channel measuring devices and rated sections provided the device or section is rated or calibrated against a set of flow measurements using an acceptable open channel current meter or a standard portable measuring device .

Closed Conduit Measuring Devices: Some surface water is diverted into pressurized systems where water may be measured in a closed conduit. Such systems may be measured using installed flow meters or by power records in the same manner as ground water diversions.

IDWR FIELDWORK

The IDWR notice of measurement and reporting requirements sent to basin 36 ground water users in December of 1994 included water measurement option forms. These forms identified each water user's points of diversion and the different options of measurement, along with some explanation of the measurement options. Each user was asked to choose a measurement option for each well or point of diversion. Users selecting the PCC option were required to execute an agreement with IDWR which outlined the responsibilities between users and IDWR. Under the agreement, users were required to send certain system information to IDWR, including pump curves and schematics of well head and system layouts. Users also agreed to provide IDWR with electrical power account numbers were required to send certain system information to IDWR, including pump curves and schematics of well head and system layouts. Users also agreed to provide IDWR with electrical power account numbers and power meter serial numbers for each diversion. Upon receiving option choices, agreements and system information, staff then worked individually with users to further review systems if necessary and/or schedule appointments to conduct field exams and measurements. Some complex systems were field inspected during the winter or early spring prior to scheduling field exams in order to determine the feasibility of using the power method. Figure 4 is a flow diagram showing the procedures implemented by IDWR to complete measurement and reporting in basin 36. This diagram also shows protocol used for enforcing compliance of measurement requirements.

Field Exams for PCC Method

Field exams for PCC measurements made for individual diversions were generally scheduled ahead of time, and conducted with the owner or operator present. Owners or operators were interviewed about each system's operating conditions. Questions were asked about estimated flow ranges and pressures, number of discharge points, throttling of pumps or valving of mainlines, and estimates of pumping time under different operating conditions. Examiners summarized the operating conditions and system characteristics on field worksheets. Information was obtained from the motor and pump nameplates, and electrical meter nameplates. Photographs were taken at each site and filed with each field worksheet.

Each point of diversion examined was also located using Global Positioning System (GPS) receivers. A GPS site identification tag was affixed to some structure near the well head or point of diversion. The GPS site tag is a 3 inch by 2 inch metal tag that indicates a site has been located with a GPS receiver. Each tag has a number that also serves as a unique identifier for the point of diversion. These site tag numbers have been used extensively by many water users in distinguishing between their multiple owned diversions and in completing annual report forms. The number can also serve as a unique attribute or field in IDWR's water measurement data base.

The GPS field files were later corrected by staff using appropriate software and base station data. Corrected files provide output for correct latitude and longitude coordinates, as well as statistical information which provides a check for the accuracy of the collected GPS data points at each location. GPS receivers used by IDWR are accurate to within 6 meters for latitude and longitude locations after base station correction. Figure 5 on page 14 is a map showing location of diversions in basin 36 which were located with GPS receivers and site tagged from 1995 through 1997.

After obtaining system information and characteristics, and other site information, examiners made discharge and power demand measurements for each operating condition, not to exceed a total of three operating conditions. A PCC was calculated for each condition. For systems with multiple conditions, annual volume is estimated by weighting the total annual KWH with the estimates of time provided by the user. Estimates of time for each condition were determined using tracking forms submitted by the operator, or based on reasonable estimates provided by the operator.

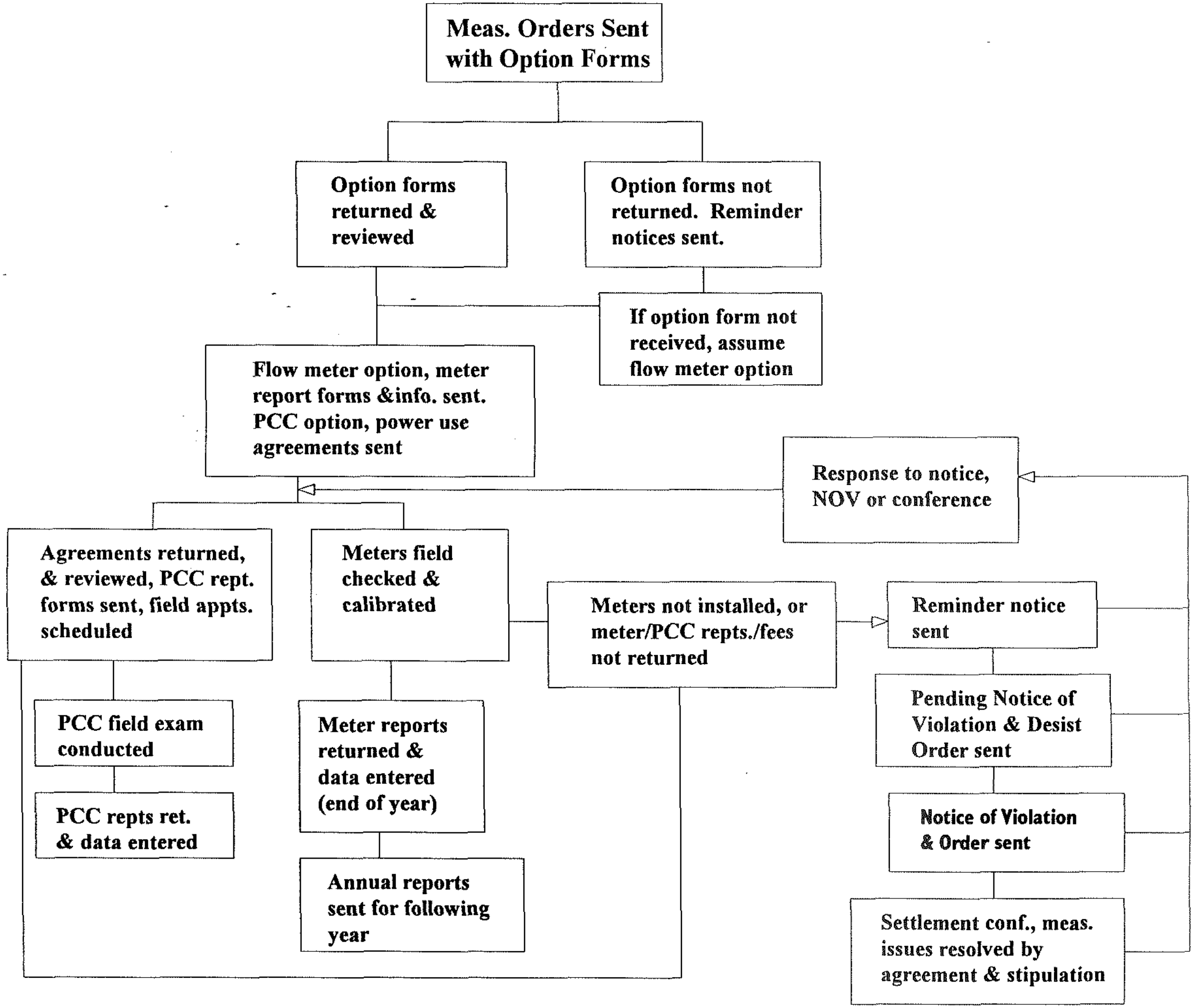

Figure 4. Flow diagram showing IDWR protocol for water meaurement in basin 36, 1995 & 1996

years. For such systems, the annual volume estimate was made using the high flow (low PCC) measurement. Using the low PCC measurement yields a conservative diversion volume estimate that is likely higher than the actual diversion volume.

Flow Meter Inspections & Calibrations

Many users who chose flow meter options for their diversions were contacted during 1995 and 1996 for the purpose of field inspecting and calibrating installed flow meters. IDWR staff made miscellaneous drive-by inspections of other diversions to verify that meters had been installed and were operable. Calibration of meters involved measuring the diversion with a standard portable IDWR flowmeter, and comparing this standard measurement with that of the installed flow meter. The error or difference between the two measurements should be within ± 10 percent. If a meter exceeds ten percent, then the following steps were implemented:

1) if the meter can be physically calibrated or adjusted to the standard meter, then the examiner may adjust the meter to the standard meter following the meter manufacturer's instructions; such adjustment should be made to assure that the installed meter is within ± 10 percent of the standard meter for the full range of anticipated flows;

2) if the meter can not be adjusted, then a calibration factor or multiplier may be applied to the flow rate and volume totalizer readings, providing the inaccuracy is consistent and linear throughout the normal range of flows.

Most flow meter calibrations are one-point calibrations, or calibrations based on one set of flow measurements. IDWR found that the most common type meter installed for irrigation was a force velocity impeller meter from a particular manufacturer where the percent error was fairly consistent throughout the full range of flows.

Field Work for Surface Water Diversions

During the winter and spring of 1995, all surface water diversions in basin 36 subject to measurement requirements were field inventoried. There are about 100 surface water diversions in basin 36 which require measurement and reporting. The source of these diversions are the Snake River tributary springs in Hagerman and Buhl, plus diversions from spring-fed streams such as Billingsley, Riley, and Alpheus Creeks. The inventory involved GPS location and site tagging of diversions, inspection of measurement devices if already existing, or recommendations for measuring devices if not existing. Calibration measurements were made for some non-standard and standard measuring devices during 1995 and 1996. Some non-standard devices required multiple-point calibrations. A number of rated sections had existing and updated ratings. IDWR assisted several users with developing ratings for some sections.

Point of Diversion Distribution in Basin 36

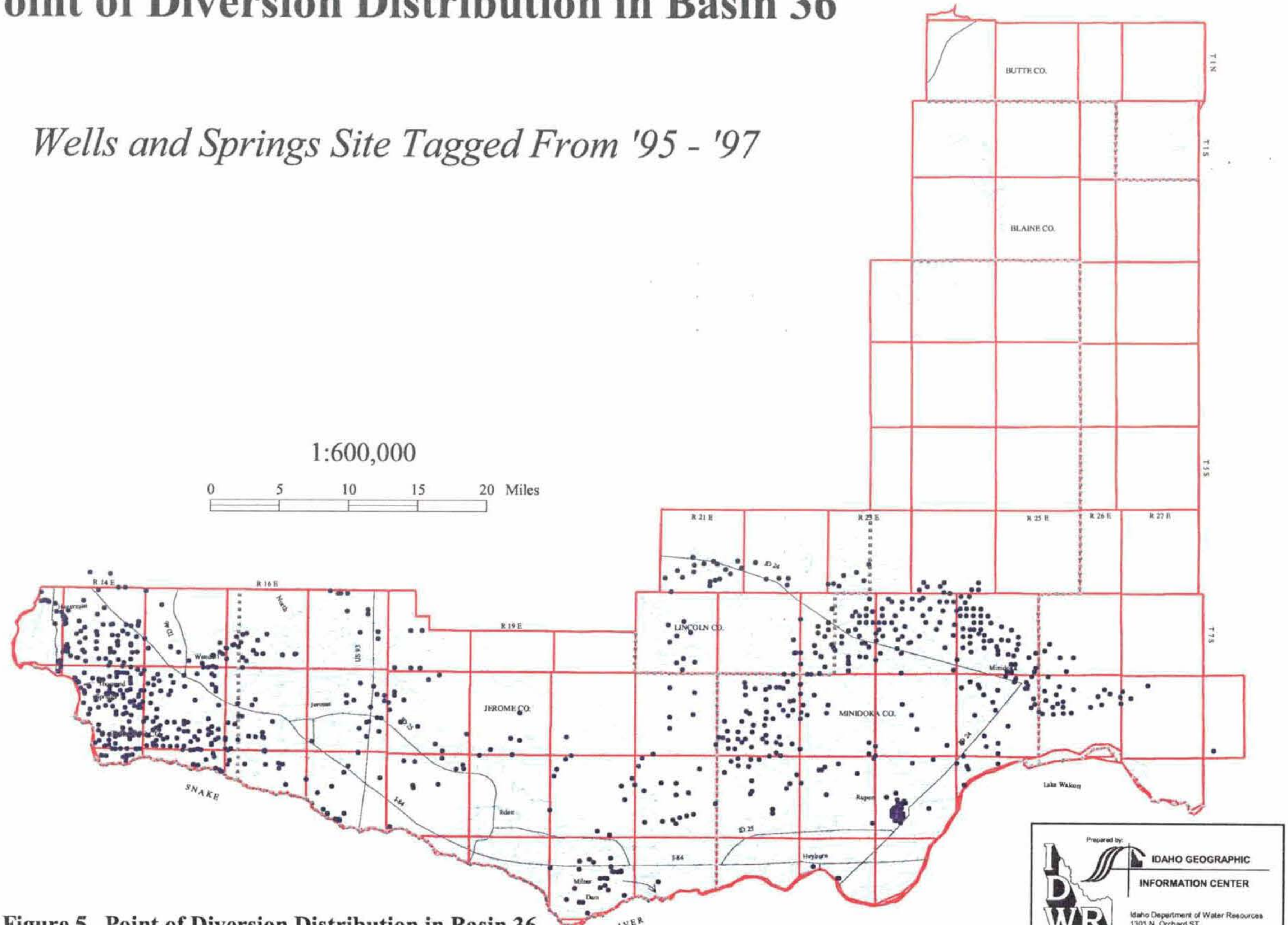

Figure 5. Point of Diversion Distribution in Basin 36

Included on this map are about 65 wells located and tagged by MagicValley Ground Water District during 1997.

REPORTING REQUIREMENTS

IDWR sent annual report forms to water users in basin 36 for 1995 and 1996. Separate report forms were sent depending on the type of measurement method chosen or used. Users were required to complete and return forms to IDWR along with a $25 reporting fee for each diversion reported. Report fees were not required for diversions which were not used in either year. Report forms were distributed early in the year for year round diversions, and in the spring for irrigation diversions. Report reminder notices were sent in November or December of the same year.

All users were asked to submit ownership information including any changes in ownership or address. Depth to water information, both static and pumping water levels, was to be reported for every diversion. Monthly pump discharge pressure was requested on all reporting forms except the 1996 power usage method form. Also, all users were asked to report any changes or modifications made to the diversion system, which could include pump repair or replacement, mainline replacement, conversion from wheel lines to pivot, conversion to low pressure, or any other modification that may change the diversion capacity of the system.

Flow meter users were asked to report the totalizer reading, maximum flow rate, and pumping discharge pressure on a monthly basis. They were also required to report some basic information about the meter used, such as the units of measurement (gallons, acre-feet, gpm, cfs) and multipliers for the rate and volume measurements.

Users with installed time clocks were required to report hours of operation as recorded by the clocks. Surface water users with open channel measuring devices submitted report forms with daily discharge log sheets and information about each measuring device, including all rating tables or charts.

Owners of diversions estimated with power records were to report the Power Consumption Coefficient (if not measured by IDWR staff), utility information, and crop data. Utility information included the name of the electric utility, the customer's account number, the power pole or service number, and the serial number of the utility's power meter that records power used by the pump. Pump owners do not have to keep track of the amount of electricity used, nor report electrical consumption to the department. Instead, utilities provide power consumption reports to the department. The utility information requested from the pump owner is essential in locating an individual's power consumption in the sizeable reports submitted by electric utilities.

Crop data were requested only for diversions estimated with power records, and included the crop type and number of acres of each crop.

Some systems using power records to estimate withdrawals had multiple operating conditions, meaning that operation of the system varied, and therefore flow rate and power consumption also changed. For example, one water user has a pump that delivers water to two pivots, one that goes full circle, and another that only does half a circle. Sometimes both pivots operate together, but usually only one is operated at a time. Power consumption coefficients were measured as follows:

Table 2. Example of Operating Conditions and Measured PCC

Condition	Flow (gpm)	Power (kw)	PCC (kwh/af)	Operating Time during 1996 (%)
Both pivots	1290	99.1	417	10
Full-circle pivot	1070	93.7	476	70
Half-circle pivot	770	78.3	552	20

Since the PCC changed more than 10 percent through the different operating conditions, this operator was asked to track the percent of time operated at each condition and report this tracking with his annual report. With this data an annual average PCC of 480 kwh/af was calculated and used to estimate 1996 withdrawals. For systems where the PCC from various conditions differ by 10 percent or less, tracking is not required, but is accepted if the owner wishes to submit it.

All reports returned to IDWR were reviewed by staff and information entered to a water measurement database. The staff review provided a level of quality assurance prior to data entry. Some post data entry data sorting and analysis provided detection and correction of data entry errors.
Qualification of diversion data is discussed in further detail in the following section of this report.

VIOLATIONS

Users who did not submit reports by the reporting deadline received a second and sometimes third reminder notice. If reports were not submitted within the time designated by the additional notice, then IDWR staff issued the user a notice of pending cease and desist order. Failure to respond to the pending order resulted in the issuance of a notice of violation and cease and desist order which carried certain civil or monetary penalties. Users who receive such orders can request a settlement conference to resolve reporting problems and negotiate any penalties. Notices of pending cease and desist orders and notices of violation were also issued to some users who had failed to install measuring devices.

During 1997, IDWR issued about 35 notice of pending cease and desist orders involving about 68 diversions for which 1996 reports and/or fees had not been submitted, or for failure to install measuring devices. Since the program started in 1995, final notice of violations and cease and desist orders were issued to nine separate users in basin 36, involving 21 points of diversion. Several of these latter orders involved other water rights violations, including diversion of water without water rights or department authorization.

SUMMARY OF DATA COLLECTED

This section of the report summarizes the measurement data gathered in Basin 36 during 1995 and 1996. Measurement and reporting methods are described in greater detail. The adequacy of those methods are also discussed. Estimated or measured diversion volumes and measured rates of diversion are summarized for 1996. These volumes and flow measurements are also compared with water rights records.

MEASUREMENT METHODS CHOSEN

When basin 36 water users were first notified of measurement requirements, they were given the option of installing a measuring device or using power consumption records to estimate water withdrawals. Information was supplied to assist the water user in this decision. Approximately two-thirds of water users replying to the notice initially chose to use power records to estimate withdrawals. Additional information was requested from those choosing power records in order to analyze systems for complexity. Some systems could not use power records, generally due to the complexity of the pumping system and inability to show that power records could be used to reliably estimate withdrawals. Some water users refused to submit additional information or did not execute power use agreements with IDWR. These operators were instructed to install flow meters if they failed to comply with requests for agreements and system information.

Research and cooperative work between the department staff and some users identified a third method of estimating withdrawals from some well pumps which is referred to as the "time clock method." The flow rate of the pump is measured with a portable device and a time clock or hour meter is installed, which records the number of hours the pump operates. Volume is calculated by multiplying the flow rate times the yearly operation hours. Time clocks are relatively inexpensive; some owners have reported installing their own for around $30 each, others have had them installed by electricians for less than $100. The method is generally restricted to situations where a pump open-discharges flow, usually to a tank, pond or ditch. Also, flow is not throttled or controlled by the operator and does not normally fluctuate, water level fluctuations are minimal, and the power meter is not isolated to the well pump (often supplying power to other ditch or pond pumps).

Some ground water pumpers measure their water, but not with totalizing devices. For example, many of the A & B Irrigation District pumps discharge into a ditch where flow is measured with a weir or flume. The District's ditch riders adjust the flows, read the weirs, and track operation times on a daily basis in order to calculate total annual diversion volume. In basin 36, this method of measurement is rare outside of the A & B District for several reasons. Many ground water diversions enter directly into pressurized systems and cannot be measured with an open channel device. Although those that open discharge could often be measured this way, power records or time clocks are frequently used instead. Since this method is largely an honor system method of measuring, good documentation of operating hours and flow rate measurements are required, and power records are sometimes used to confirm hours of operation.

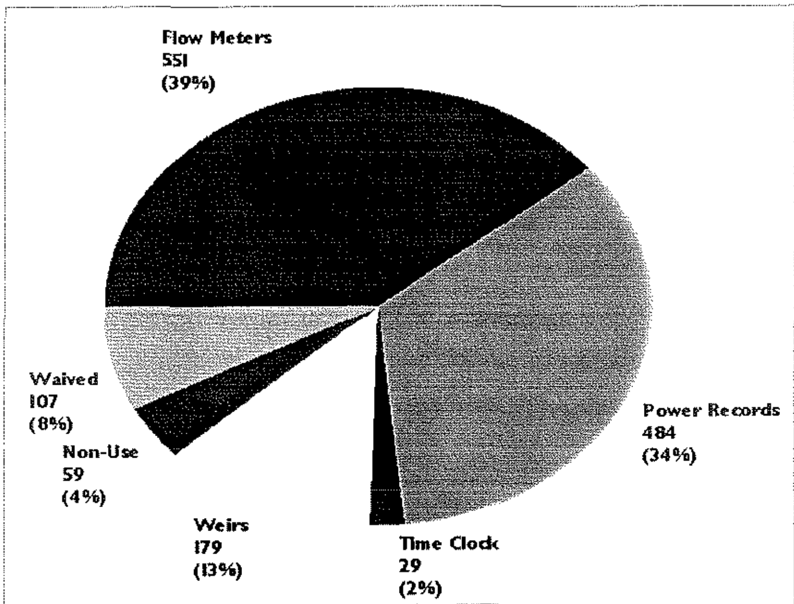

Figure 6: Distribution of Measurement Choices, Basin 36 Ground Water Diversions

Figure 6. shows the breakdown between these various methods of measuring diversions. The figure also shows the number of diversions that have been "waived" from the measuring requirement, as well as the number of wells that are not being used, sometimes due to federal crop set-aside programs. As a matter of convenience, IDWR placed all of the A&B Irrigation District diversions (178) under the 'weirs' choice even though some of the A&B wells are measured with flow meters. A&B uses a combination of weirs and flow meters. IDWR did not track the type of device at each A&B well.

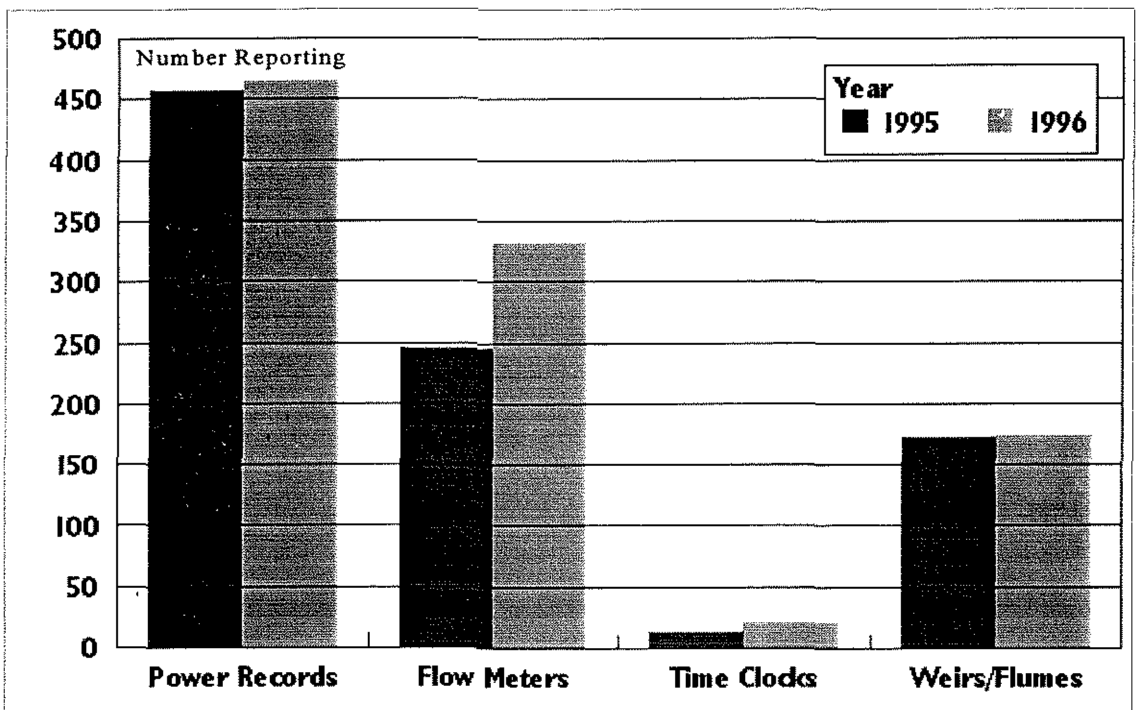

Figure 7. Methods of Reporting Ground Water Diversions in Basin 36. Graph shows number reporting by measurement method. Weirs/Flumes includes A&B wells which are measured by combination of weirs, flumes and flow meters.

SELF REPORTING

Report Returns and Adequacy

Figure 7 graphically represents the number of ground water diversions measured using power records, flow meters, time clocks, and weirs or flumes. The graph includes only those wells which have been measured and for which volumes were reported. This is different from Figure 6, which shows the method chosen for measuring withdrawals. Note that not all of the wells were measured in 1995 or 1996. Again, the number of reports under weirs/flumes is almost exclusively associated with the A&B Irrigation District wells and does include a combination of open channel devices and flow meters.

Department staff and others (utilities, consultants, etc.) measured about 447 Power Consumption Coefficients (PCCs) prior to or during 1995. IDWR measured an additional 95 PCCs during 1996. Many of the PCCs measured during 1996 were used to calculate 1995 withdrawals based on the 1996 measurements and 1995 energy consumption records. Therefore, there was not a large increase in number of volumes reported using power records from 1995 to 1996.

On the other hand, many flow meters were installed after the 1995 irrigation season. These users did not have a volume to report for 1995, but did report 1996 diversions, indicated by the significant increase in flow meter reports from 1995 to 1996. Volumes measured using the time clock method are similar, with a comparatively significant increase in numbers reporting volume from 1995 to 1996.

Water users measuring with weirs or flumes generally had the devices in place before water measurement requirements were imposed, and users reporting with this method in 1996 also reported in 1995.

In 1995, 75 percent of 1187 diversions expected to report diversion volumes included volume in the report. Flow rate was reported for only 52 percent of diversions, most coming from diversions using power records to estimate withdrawals since flow rate is measured during the PCC determination. Only 12 percent of flow meter users who reported diversion volume also included flow rate in their report.

In 1996, the number of diversions expected to report volumes increased to 1226, and about 81 percent of these included volume in the 1996 report. Of those reporting volume, 47 percent are using power records, 51 percent are using permanent measuring devices, and the remainder are using time clocks. The largest deficiency is with flow meter users. Approximately 150 diversions must either have flow meters installed and/or the flow meters must be read and readings reported. Systems lacking flow meters include both irrigation systems and dairy facilities. Some of the irrigation systems may actually be able to use power records. Others cannot, but owners have been hesitant to install meters. About 20 power consumption coefficients need to be determined, and flow rate measurements are needed on about 8 wells using time clocks.

Self-reporting of volumes and rates of diversion by flow meter users continued to be a problem in 1996. Volumes were either not included on reports or were classified as unacceptable for nearly one-third of the flow meter reports submitted while only about 20 percent of the reports included acceptable rates of diversion. Although this is an increase over 1995, more work needs to be done to get water users to read their measuring devices. Although some flow meters indicate rate of flow as part of the display, others require the operator to use a stopwatch and measure the time required to divert a given volume of water, then calculate flow rate.

Water Level Measurement Reporting

The 1995 and 1996 ground water report forms requested water level data be submitted by the well owner or operator. Static and pumping water levels taken during the respective reporting years were requested to be included on the report. The goals of this request were to meet statutory requirements, to track general ground water trends in localized areas, and to form a source of data which would be available or useful for ground water studies or planning. Unfortunately, response to the request for water level data was low in this reporting area in both years, with a good deal of the responding wells clustered in one area and owned by a single water user. As a result, IDWR has modified its expectation of individual water level monitoring and is instead concentrating efforts to gather water level data by developing a network of monitoring wells spread across the ESPA.

For purposes of this section, reported water level measurement data are either an acceptable static water level or pumping water level, or both, from a single well in a single year. A measurement was considered "acceptable" for 1995 if it was dated during or prior to the 1995 reporting year and appeared to reflect a reasonable water level for the area. An "acceptable" measurement for 1996 was dated during 1996 and did not appear to be a duplicate of the 1995 measurement. None of the owner-reported measurements were verified. Reported measurements which were not acceptable are not included in the following counts. Acceptable data were further sorted as to date of collection for purposes of water level change analysis.

There are presently over 1300 wells and more than 600 well owners subject to the water measurement program in Basin 36. In 1995, 158 water users reported water level measurement data for 480 wells. This represents approximately 25% of the program water users and 33% of the Basin 36 wells. In 1996, 117 users returned acceptable water level data for 390 wells, depicting 18% of the water users and nearly 27% of the wells. An undetermined number of users returned suspect or repeat measurements for both years. Many annual reports were returned with water level data not completed.

Forty-one percent of the 1995 acceptable water level measurements and one-half of the 1996 acceptable water level measurements were submitted by only two water users. City of Rupert reported water level measurements for 35 diversions in 1995 and 33 diversions in 1996, and A & B Irrigation reported for 161 wells in both years. Other than these two entities, independent basin-wide water level measurements are available for only 284 wells in 1995 and 196 wells in 1996.

Water levels reported for 1996 were for the most part very near those reported for 1995. Average change in static water levels over 251 wells indicated a 0.5 feet water level increase. This comparison was limited to those wells reporting acceptable static water levels in both 1995 and 1996 with measurements taken January through May. Average change in pumping water levels indicates a 0.7 feet water level decrease. This comparison involves 186 wells with pumping measurements taken during the active irrigation season June through September. Since both static and pumping water level measurements were taken each year with a four month period of time, then the water level changes described here are probably insignificant.

Most reported water levels came from municipal or irrigation wells. Few were from smaller commercial or dairy wells. Those not reporting water level measurements listed several reasons, the most common being that wells did not have access ports. Although not specifically mentioned, lack of water level measuring equipment was likely a significant factor in the number of owners who did not report this information.

Based on the above returns, reliance on individual water users for the establishment of a ground water level monitoring network may not provide enough certifiable information. Verification of the accuracy of the submitted measurements and the suitability of the collection method is also a problem.

VOLUME QUALIFIERS

Data qualifiers have been developed for reported diversion volume information. These qualifiers are used to identify the status of the reported volume quantity. They are specific to measuring method (power records, flow meter, weirs and flumes) rather than to water source. Qualifiers may give data users an idea of the general degree of accuracy of calculated volumes. Qualifiers are assigned to each measured diversion in the water measurement database. The qualifier codes are identified and described in Appendix A along with the number of diversions assigned under each qualifier from the 1996 water measurement database and reports. Qualifier codes are also listed with individual diversions in Appendices B and C.

FLOW METERS

The water measurement database includes information on flow meter type, manufacturer, model and serial numbers, and other data. The information was either supplied by water users with their annual reports or gathered by IDWR staff working in the field. Table 3 lists the manufacturers and types of flow meters used in basin 36.

Table 3. Flowmeter Types and Manufacturers, Basin 36 Water Measurement Data Base

Flow Meter Type	Meter Manufacturer	Number
Impeller	Grainland / Aquamaster	147
Impeller	Data Industrial	2
Impeller	Seaflow	3
Impeller	Signet	2
Propeller	McCrometer	56
Propeller	Water Specialties	53
Propeller	Sparling	1
Shunt Venturi	Miller SLV	66
Shunt Venturi	Trimmer Engineering	4
Short-shaft Turbine	Badger	11
Mitered-bend	ID Tech	4
Magnetic	Sparling	4
Turbine	Rockwell	2
Turbine	Sensus	2

The vast majority (92 percent) of flow meters encountered were impeller, propeller, or shunt-venturi types. The remaining meters were turbine, magnetic and mitered-bend types. About 42 percent of all meters were impeller types.

During 1995 and 1996, IDWR staff were able to check the accuracy of about 138 in-line totalizing flow meters. Most all of these were in Basin 36 and were installed on a variety of systems, such as ground water diversions to irrigation, commercial, dairy, or municipal uses and surface water diversions to irrigation and aquaculture uses. IDWR staff generally used portable, ultrasonic flow measuring equipment to measure flow and check the measurement against the owner's permanent flow meter. Some of the permanent flow meters were working very well, some were inaccurate beyond acceptable limits, and some meters had failed after being used for only a few months time. Unfortunately, the results were not strongly encouraging, but they did provide insight to which flow meters tend to perform better and problems that are often encountered. Table 4 shows the number of flow meters that were checked for accuracy during 1995 and 1996, the number of meters considered "new" (installed after December 1994), the range of accuracy observed from the flow meters, and the confidence level of the new meters. The confidence level is the percent of meters expected to have an in-field operating accuracy within +/- 10 percent.

Table 4. Flow Meter Accuracy

	IMPELLER	PROPELLER	SHUNT VENTURI	SHORT-SHAFT TURBINE
Number of meters checked	45	33	25	4
Number of new meters	44	26	25	1
Accuracy range of new and old	-75 to +44	-20 to +19	-8 to +100	-13 to -2
Confidence level of **new** meters (+/-10%)	57%	85%	44%	n/a

The propeller-type meters performed the best of the types encountered. Most were within the +/- 10 percent accuracy limit, and those outside of this limit were either old meters, were installed in very bad locations, or were not matched to the pipe size. IDWR found seven "old" propeller meters which had been installed prior to 1994 and were generally more than 10 years old. These older propeller meters had little to no maintenance, and were still operating reliably, although some were not quite accurate. It was also discovered that the "new" propeller meters that did not meet the ten percent accuracy standard were generally not the correct meter for the pipe size. For example, several propeller meters designed for a pipe with an inside diameter of 10 inches were installed in pipes with an inside diameter of 10.75 inches. This observation stresses the importance of measuring pipe size before ordering this type of meter.

Impeller meters were the most widely encountered type, largely due to their inexpensive purchase price and strong sales representation. Although several types are on the market, one particular brand was more frequently used. The impeller type meters did not perform as well as the propeller meters, with accuracies ranging from 75 percent lower to 44 percent higher than the standard flowmeter. After checking 20 meters in 1995, it appeared only 40 percent of the impeller meters were within the +/- 10 percent confidence limit; 60 percent of the meters did not provide measurements within 10 percent of the actual flow. The number meeting +/- 10 percent accuracy threshold increased to about 60 percent after checking an additional 24 flow meters in 1996. It is likely that a good portion of this accuracy increase was due to increased education and experience of the flowmeter dealers and installers. The manufacturer of one meter visited Idaho in late August 1995 to hold a training session for meter dealers and installers. Two IDWR staff attended the training session. This session included classroom type instruction on proper meter setup and installation as well as an in-field visit where the meter manufacturer and IDWR staff demonstrated the importance of proper setup and installation. Attendees also learned how to troubleshoot and make some repairs and adjustments.

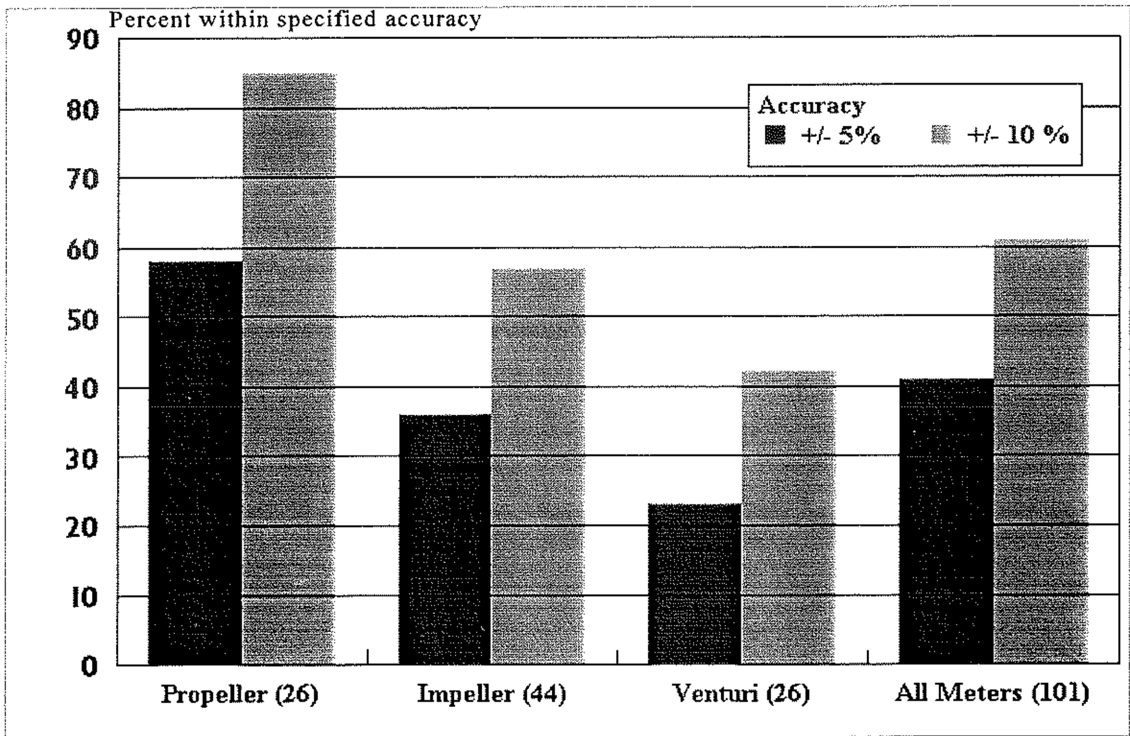

Figure 8. Flow Meter Accuracy, showing percentage of meters within specified accuracy limits for new flow meters only (installed after December 1,1994). Numbers in parentheses are number of total meters tested.

Many of the worst accuracy problems with impeller meters can at least partly be attributed to improper meter settings and/or poor locations. Because this meter senses only a portion of the flow, it is much more likely to be affected by turbulence and flow disturbances. However, IDWR staff has observed that even when the impeller meter is properly installed in a good location, accuracies are occasionally outside of the +/- 10 percent limit. It is suggested that this meter be installed only where at least 10 diameters of straight pipe is upstream of the meter (and more if turbulence is extreme), and that installers are careful to set the switches correctly and insert the meter at the proper depth and orientation to the flow. Even with proper installation, the meter must be checked with a secondary device of known accuracy and adjusted if necessary to insure accurate measurements.

During 1996, IDWR staff encountered many impeller meters that had failed and were no longer measuring flow. Some of these failures were attributed to improper maintenance such as a break or disconnection of the wire connecting the sensor to the display unit. Others had display units that were destroyed due to condensation which could have been prevented if the display unit was covered or placed in an enclosure. Several display units were found lying in the weeds or even in a mud puddle. Others had failed because the impeller had either stopped or had become dislodged from the axle assembly. These problems underscore the importance of proper meter maintenance and of frequent reading to timely discover and fix meter failures.

The third most installed type of meter were shunt venturi meters. As with impeller meters, one manufacturer largely dominated the market with nearly 95 percent of the shunt venturi meters encountered. Table 4 shows that these meters were found to read from 8 percent lower to 100 percent higher than the standard flow meter, and that only 44 percent of the meters installed were within +/- 10 percent accuracy. The inaccuracy problem was largely attributable to one size of meter. Of the ten-inch meters checked, only 3 of 15 had accuracies within +/- 10 percent. Conversely, of the eight-inch meters, 9 of 10 were within 10 percent accuracy. Furthermore, inaccuracies were not consistent for a given meter; the meter may be off 30 percent at low flow and 50 percent off at high flow.

IDWR staff were able to adjust some of the shunt venturi flow meters to read within acceptable limits. The process involved dismantling the assembly and replacing an orifice plate with a smaller orifice. Unfortunately, the size needed was not consistent from one meter to the next, and it was frequently necessary to try multiple sizes of orifices. This process was very time consuming because the pumping plant usually needed to be shut down and restarted with each change of orifice. Even after adjustment, accuracies of the ten-inch meters were not always consistent, and therefore staff attempted to make adjustments that would yield the best results.

As with the impeller meter, staff found several shunt venturi meters that had failed during 1995 after just a few months of operation. More failures were discovered in 1996. An advantage of this type of meter is that it is comparatively easy and inexpensive to repair or replace the totalizing unit. Flow is measured with a small municipal type flow meter, similar or identical to those used to measure water used by individual homeowners. The meter can be replaced for around $100, and with some models it is possible to replace the internal portion of the meter without changing the housing for less than $100.

Shunt venturi meters are particularly susceptible to sand, cinders, or other debris in the water which plugs the workings in the small totalizing turbine device. At least one was found to be plugged with the turbine oil frequently used for bearing lubrication on well pumps. After flushing, the meter worked for a short period, then slowed to a stop again due to the oil. These problems did not appear to be widespread and will likely be site specific depending on oil and debris contamination of the water. Because of the small pieces and difficulty in draining, it is likely that winter freeze and thaw will also damage these meters. Users of these meters are advised to keep in inventory repair kits or replacement meters, and to regularly inspect the meter during the irrigation season to ensure operation.

Manufacturers of the shunt venturi meter have told IDWR they are making improvements to the meter. Until such improvements are made and acceptable operation is demonstrated, use of the ten-inch shunt venturi meter will require in-field calibration at the time of installation is absolutely necessary. However, it appears that the smaller sizes generally attain acceptable accuracies and should not be avoided for accuracy reasons.

For additional information regarding closed conduit flow meters, see *"Selecting and Installing Flow meters for Pressurized Pipes" University of Idaho, College of Agriculture Bulletin 791.*

COMPARISONS WITH WATER RIGHTS

Ground Water Diversions

Results of water measurement activities can be compared with two components of a water right: (1) the total volume of water diverted over a given period of time, and (2) the rate of water diversion. Volume units are usually measured in acre-feet (af) with one acre-foot being the amount of water that covers one acre with one foot of depth, equivalent to about 326,000 gallons. The period of time allowed to divert a given volume of water is usually the "irrigation season" for irrigators and the calendar year for non-irrigators.

Diversion rate is measured in cubic feet per second (cfs), sometimes called a "second-foot." One cfs is equivalent to about 450 gallons per minute (gpm).

Comparisons of water measurements to water rights show that the majority of ground water pumpers divert at flow rates at or below those authorized by water rights, and nearly all pumped less volume than the maximum allowed. Figure 9, *Diversion rate comparison histogram*, shows the distribution of comparisons between measured flow rates and authorized diversion rates. A total of 410 ground water diversions were investigated and compared with water rights. The x-axis is a "percent of water right diverted" so that if a water user was diverting exactly the authorized rate, he would be diverting 100 percent of his water right, and would be placed in the ">80 to 100" range. A water user having a water right pumping rate of 2.0 cfs with a measured rate of 2.5 cfs would be considered pumping 125 percent of their right ($2.5 \div 2.0 \times 100 = 125$, which is 25 percent above the authorized amount), and would be placed in the ">120 to 140" range. The y-axis is percent of diversions. The figure shows about 19.5 percent of comparisons lie in the ">60 to 80" range, which would be a total of 80 pumps ($410 \times 0.195 = 80$).

Figure 9 shows that although the majority of water users pump at or below their authorized flow rate (100 percent or less), about 2 of every 5 pump at rates exceeding authorized limits (above 100 percent on the histogram). About 1 in 5 pumpers divert in excess of 120 percent of their right, and about 1 in 10 divert in excess of 140 percent of their right.

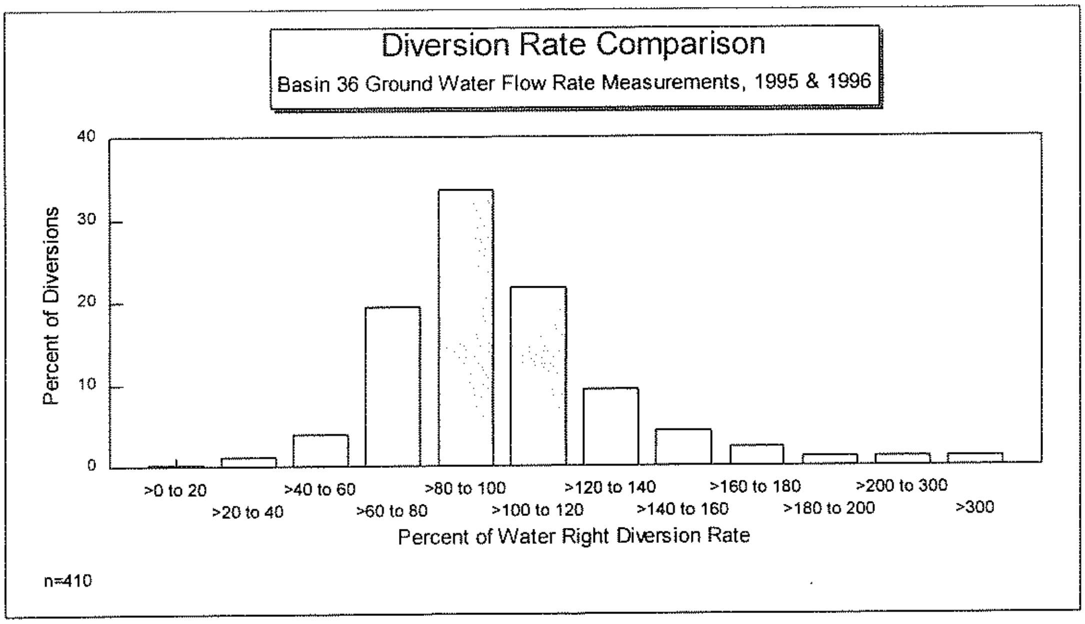

Figure 9. Diversion Rate Comparison Histogram

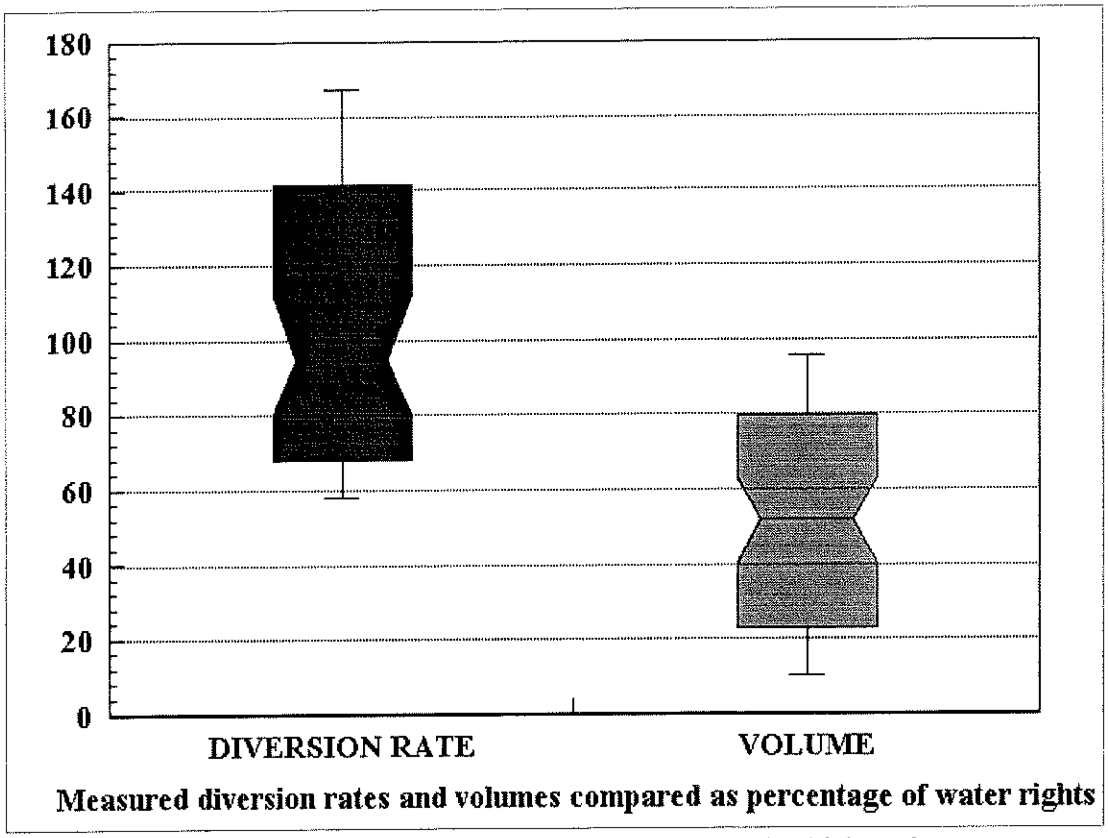

Figure 10. Diversion rate and volume comparison box-and-whisker plots.

Figure 10, *Diversion rate and volume comparison box-and-whisker plots*, shows the same data as in Figures 9 and 11, but in box-and-whisker plot form. The vertical axis in the figure is the percentage of the authorized water right. The "box" portion of each plot includes diversions between the 10th and 90th percentiles. The center of the notch in each box with the horizontal line represents the median or 50th percentile. The lower and upper notch edges of each box represent the 25th and 75th percentiles respectively. The lower and upper "whiskers" on each plot are the 5th and 95th percentiles. These box plots do not show outlier values either below or above the 5th and 95th percentiles.

In the diversion rate box plot, the median diversion rate is 95 percent of the water right. The notch edges, or the 25th and 75th percentiles, include the middle 50 percent of diversions which are between 80 and 112 percent of the water right. The 5th and 95th percentiles are respectively 58 and 167 percent of the water right. Although not shown in Figure 10, there were nine outlier values between 200 and 500 percent of the water right, which is about two percent of the diversions sampled. This box plot indicates that the typical ground water pumper diverts at or near the water right, and although some pump at flow rates significantly less than the right authorizes, some also pump at higher rates, up to two, three, and even five times the authorized rate of diversion.

On the high end of the diversion rate plot, some of the high diversion rates are due to water right transfers. Part of the original water right was transferred out of the original well for diversion from another well. Often, the original pump is kept in the original well, so that now the same flow rate is diverted as before the transfer, but only a portion of the water right flow rate remains.

The original well may be expected to divert the same volume per acre after a transfer as it had originally diverted, but fewer acres are irrigated from the original well. Therefore, it is expected that higher diversion rates should not necessarily lead to higher diversion volumes. However, of the top two percent of diverters (nine outlier values between 200 and 500 percent of the water right), three also diverted more volume than authorized by water rights. Two of these appear to be affected by the transfer process described above.

Volume of diverted water compared to water rights is displayed in Figure 11, *Diversion volume comparison histogram*. This comparison is similar to the flow rate comparison above, except that instead of comparing the speed at which water is diverted, the total amount of water pumped during 1996 is compared to water rights. A total of 578 ground water diversions were investigated and compared with water rights volumes. The highest percent of pumpers lie in the ">50 to 60" range; this group includes those pumping 50 to 60 percent of the authorized water right quantity. For example, if the water right authorized 100 acre-feet per year, this group pumped between 50.01 and 60 acre-feet.

This figure shows that very few water users diverted more volume in 1996 than their water rights authorize. About 96 percent of pumpers are within their volume limits, leaving 4 percent, or about 1 in 25 pumpers, diverting more volume than authorized. Limited investigation has indicated some of these may be irrigating more acres than authorized. Others may be within their acreage limit, but are less efficient with their water, using ground water to flood irrigate when most pumpers use more efficient sprinkler application methods. Some may also be erroneous measurements or an incomplete determination of water rights associated with the diversion.

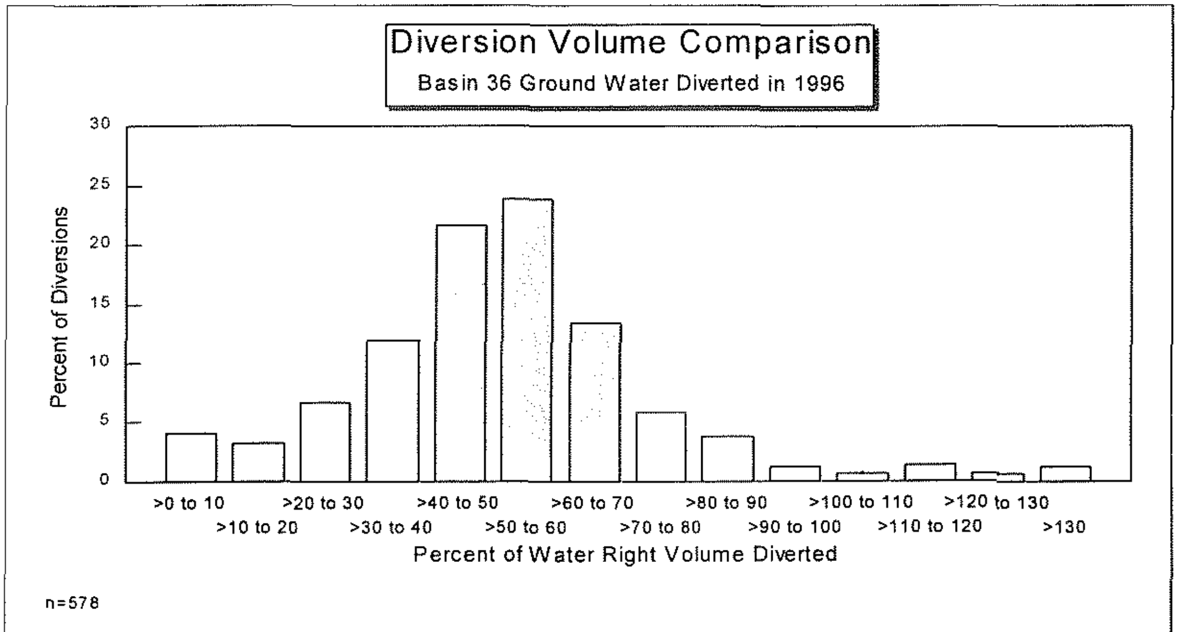

Figure 11. Diversion volume comparison histogram

Results indicate that of the 23 diversions identified to have diverted more volume than authorized by water rights, the amount in excess ranged from 0.5 to 303 acre feet per diversion. A total of 1388 acre feet was over-diverted by these 23 pumpers. Measurements and records of these pumpers appearing to divert in excess of water right limits are being reviewed to determine the cause of excessive diversion.

On the low end, a number of pumpers divert significantly less than the water right authorizes. Many of these use both surface and ground water for irrigation. The figure represents measurements of only ground water, which is just a portion of the total amount used for certain pumpers.

The volume box-and-whisker plot displayed in Figure 10 shows that the middle 50 percent of diversion volumes are between 39 and 62 percent of the water right volume. The median diversion volume is 51 percent of the water right. Although not shown on this plot, there are outlier values above the 95th percentile whisker, representing about 3 percent of the sampled diversions. Six diversions (1 percent of total sampled diversions) were found to be within about 150 and 200 percent of the water right volume.

Surface Water Diversions

Surface water sources in Basin 36 with diversions subject to measurement requirements are tributary to the Snake River and include the Thousand Springs complex. Total water uses in this area are a mix of seasonal irrigation use and year-round, non-consumptive diversions for domestic, stock water, power or fish propagation purposes. Because of the largely non-consumptive nature of these uses, comparison of annual water diversions to recorded water rights for surface water diversions requires a different approach than for ground water diversions.

A non-consumptive use is defined as one in which discharges from the system are equal or nearly equal to the total diversion. Usually, discharges are made back to the original source at a point downstream from the diversion, where they are then available to the next user. Sometimes, overflow from one facility contributes all or in part to the diversion of the next user, without the flow returning to the stream. Each new use, however, is considered a separate diversion requiring a separate water right. This is important when considering the actual impact of total diversion volumes. Cumulative volumes will indicate an inflated appropriation of water due to re-use of flows.

As with a ground water right, diversion of a surface water right is gauged as an instantaneous rate of delivery (cubic feet per second or gallons per minute), and annual volume is the product of rate of flow and time, usually expressed in acre-feet. For purposes of this report, the primary comparison parameter is rate of flow. Allowable surface water diversion rates included in this report are those which IDWR has recommended to the SRBA court in the 1992 Basin 36 Director's Report, and/or those which are represented by a water right permit or license issued after November 19, 1987 and which are not a part of the SRBA. At this time some water right limits may be in question due to ongoing procedures in the SRBA. The allowable diversion rate may be modified as final decrees are issued.

Annual diverted volumes for surface water diversions are included in this report but are not compared to water right limits. Rights partly or entirely for non-consumptive purposes such as power or fish propagation do not have an annual volume contained in the water right record. Also, consumptive volumes cannot be differentiated from total reported volumes for most diversions which supply both a consumptive and a non-consumptive use. At this time, the diversion rate component is the best indicator of compliance with the diversion allowed by the recorded right. In future years, season of use restrictions and seasonal diversion rate limits may also be monitored to further refine the level of adherence to allowable uses.

Maximum rates of diversion, or highest reported flows, are noted along with annual reported volume in Appendix B, *Basin 36 Surface Water Diversion Summary, 1996.* The highest reported flow is sometimes in excess of the water right limit, but may have been diverted for only a few days or longer.

Comparison of high diversion rates to recommended water rights for 79 diversions showed that the largest proportion of water users (73%) were diverting at rates of flow which were less than 110%

of their total recommended right(s). Considering that the department's allowable error for measuring devices under the ESPA measurement program is ±10%, this group falls within an acceptable rate of diversion range. The remainder of the diversions were diverting at rates of flow in excess of 110% of their rights for one or more days during the reporting period.

Figure 12 shows the distribution of maximum diversion rate as a percentage of the recommended water right rate. The largest group of water users is diverting in the range of 60% to 100% of the water right limit. Again, the maximum diversion rate does not necessarily represent the average diversion rate and therefore does not relate directly to diverted volume.

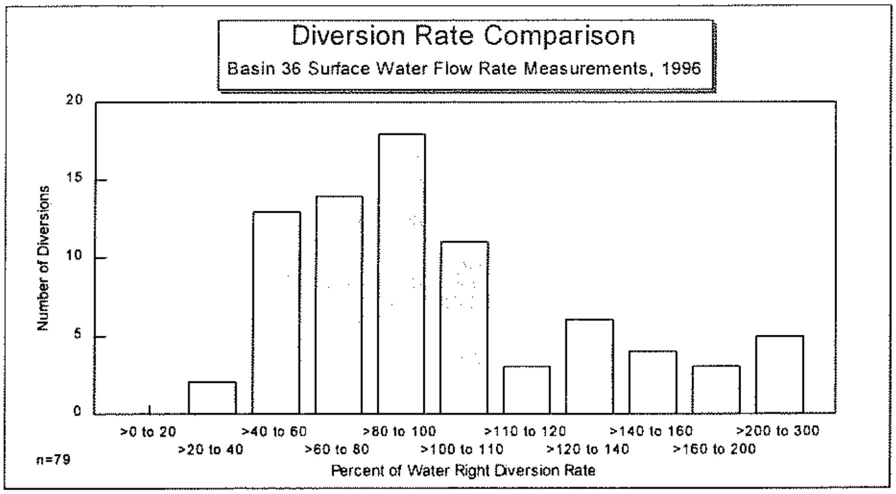

Figure 12. Maximum diversion rate comparison of surface water rights

Figure 13, *Frequency of Excess Diversions,* shows the proportion of days at an excess diversion rate for those diversions over 110% of a water right limit. These figures are presented as a percent of total days diverted, since the season of use varies for each diversion. Excess flows were diverted for only a few days at one-third of these sites, usually during high flow periods. Another 1 in 3 diversions maintain an excess flow for virtually their entire season of use.

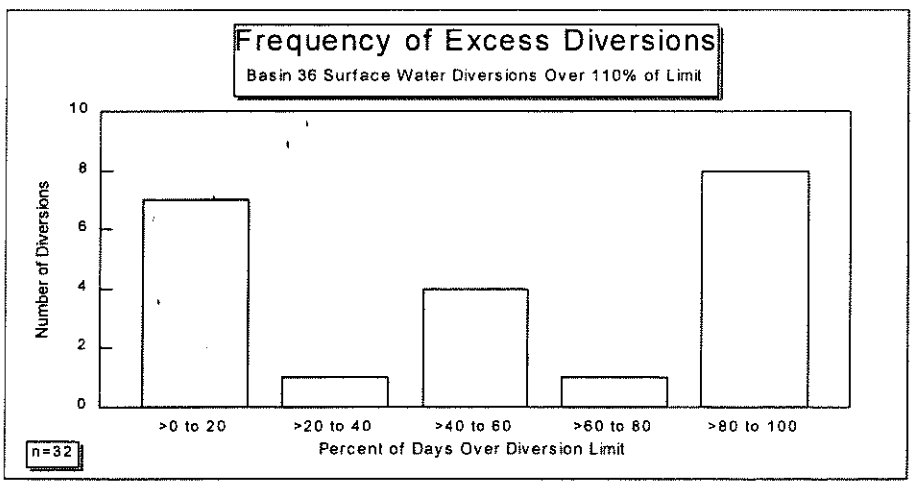

Figure 13. Frequency of excess diversions, surface water rights

ANALYSIS OF GROUNDWATER MEASUREMENT METHODS

As the measurement program was being implemented, IDWR recognized a need to understand if the flow meter and PCC methods of ground water measurement were reasonably accurate and would correlate well with one another. This section looks at comparisons between these two methods. There has also been some interest among the water user community for consideration of alternative or more indirect measuring methods. Comparisons between PCC and several alternative methods are also summarized here.

COMPARISON OF FLOW METER AND PCC METHODS

During 1995 and 1996 department staff was able to obtain both PCC and flow meter measurement data for 56 wells. At these sites, staff verified flow meter accuracy and derived at least one PCC measurement. Several analyses were conducted on these data and are summarized in this section.

The above sample size represents about 42 percent of the ground water diversion flow meter installations that were checked for accuracy by IDWR during 1995 and 1996. The sample size was not higher because a number of the total systems checked were non-irrigation wells, or were systems where the PCC method could not be used (i.e.; multiple pumps connected to one power meter). Additionally, annual reports submitted for some systems which had both PCC and flow meter accuracy tests were incomplete due to reporting errors or various meter failure and installation problems. Some irrigation wells were rejected because meters were adjusted late in the 1996 irrigation season, and meter readings could not be adjusted for a full season.

The type of flow meters found within the sample study include:
- Propeller meters manufactured by McCrometer and Water Specialties
- Impeller meters manufactured by Aquamaster, Signet and Data Industrial.
- Venturi Shunt Line meters manufactured by Miller SLV and Trimmer Engineering.
- Short Shaft Turbine meters manufactured by Badger.
- Mitered Bend Differential Head meters manufactured by ID Tech.

The flow meter diversion volume data were obtained from annual reports submitted by the water user. The water user was requested to read the meter totalizer each month and record the volume on the reporting form in the appropriate place. As stated in the previous section, only a small percentage of users reported monthly readings. Typically, users reported readings at the start and end of the season. Estimated PCC diversion volumes were calculated by dividing the total seasonal KWH supplied by the electrical utility by each PCC. Figure 18 shows the location of the 56 wells.

Several simple linear regression analyses were made for the 56 wells which have both flow meter and PCC volumes. Regression analyses were also completed for PCC qualifier groups. Group one was with all 56 wells in the data set. Group two was for PCC qualifiers one through three. Group three was for qualifiers five through eight. See the Volume Qualifier section of this report for a detailed explanation of the qualifiers. Table 6 is a listing showing the PCC qualifiers, reported PCC and flow meter volumes, and percent differences between the two reported volumes for each of the 56 wells in the study. Figures 14 through 16 are plots of the PCC-flow meter distribution and linear regression for each of the three groups. Table 5 summarizes the regression statistics for each group.

Group One: Using linear regression for all 56 wells and qualifier groups yielded a coefficient of determination, or r^2 value of 0.834, and a correlation coefficient (r) of 0.914. This represents a rather strong linear correlation between flow meter volumes and estimated PCC volume. This indicates that using PCC under all conditions may be an acceptable method of estimating ground water withdrawals. However, PCC volumes for specific wells may or may not be within an acceptable accuracy range. For example, Figure 14 below includes an outlier where the flow meter volume is 1180 acre-feet and the PCC volume is only 520 acre-feet.

Group Two: A very strong linear correlation exists for qualifiers one through three (simple well systems with few operating conditions or variations during the season). The resulting r^2 value of 0.972 and correlation coefficient (r) of 0.986 confirms IDWR's expectations that the PCC method is acceptable for estimating volumes for diversion systems that are relatively simple. It is noted however that flow meter and PCC volumes varied by more than ±10 percent for six of the 26 wells in this group. There is no clear explanation as to why there was a higher variation between the two methods for those six wells.

Group Three: As compared to Group Two, the PCC and flow meter volumes exhibited a weaker correlation for those diversions with qualifiers five through eight (these are considered complex systems with variable operating conditions). The r^2 value of 0.737 and a correlation coefficient (r) of 0.859 indicates a lesser degree of accuracy when using the PCC method for estimating water withdrawals from more complex systems. It should be expected that the correlation in group three would not be as strong as group two since the group three qualifiers are representative of systems that usually lack additional PCC measurements for individual operating conditions.

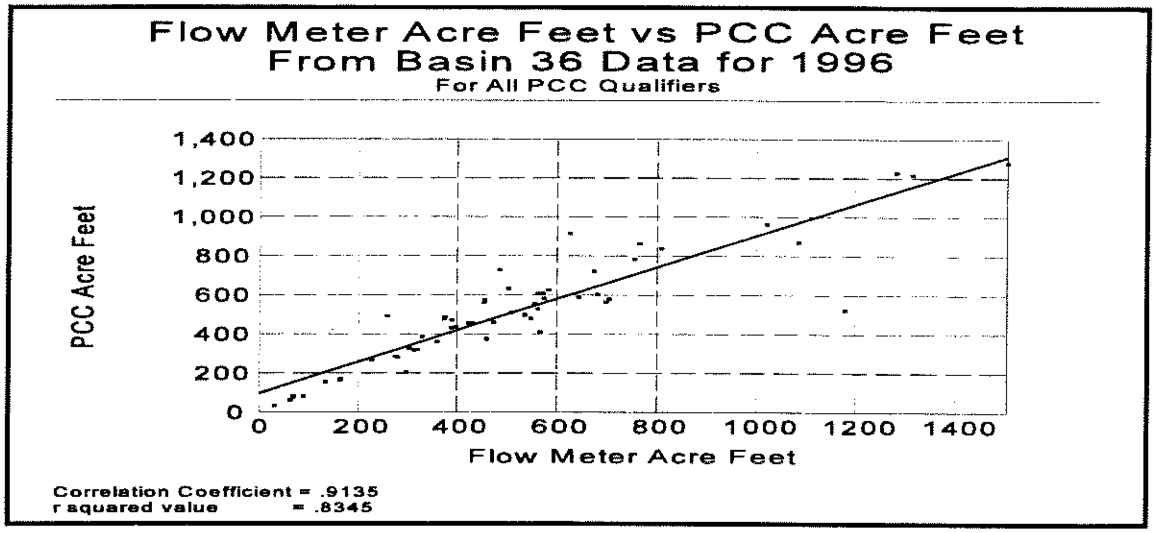

Figure 14. Linear regression of flow meter volumes vs. PCC volumes for 56 well data set, including all volume qualifier groups.

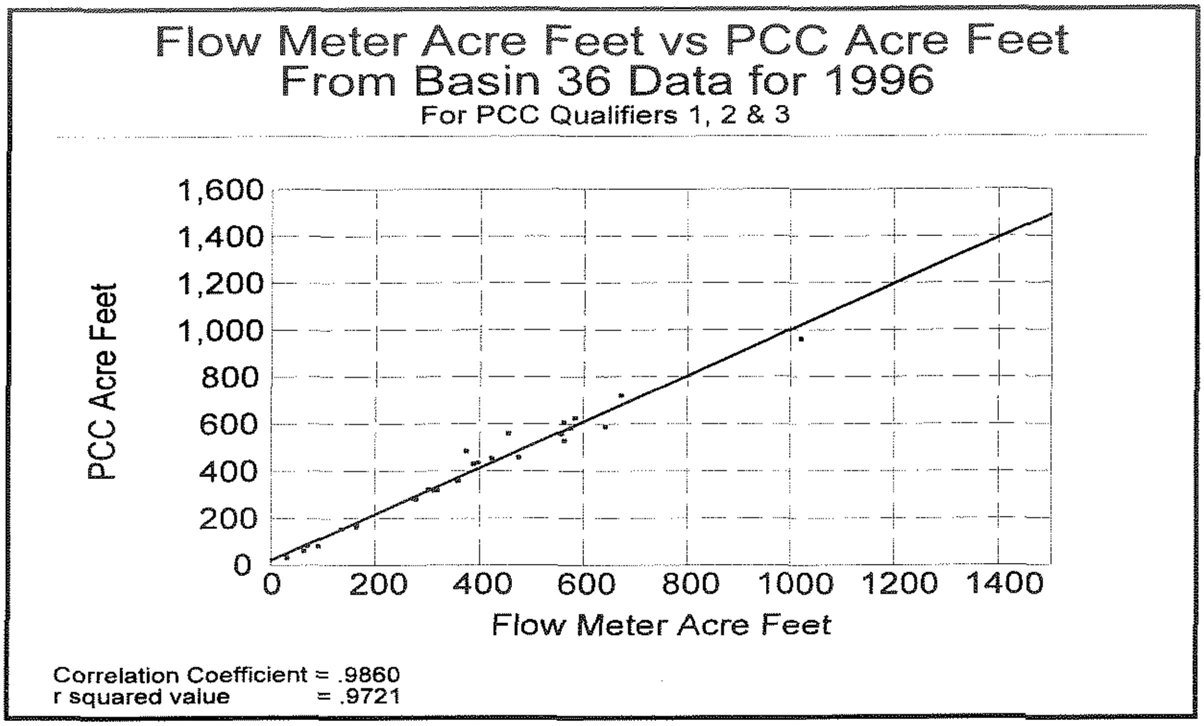

Figure 15. Linear regression of flow meter vs. PCC volumes for 27 wells, volume qualifiers 1 through 3

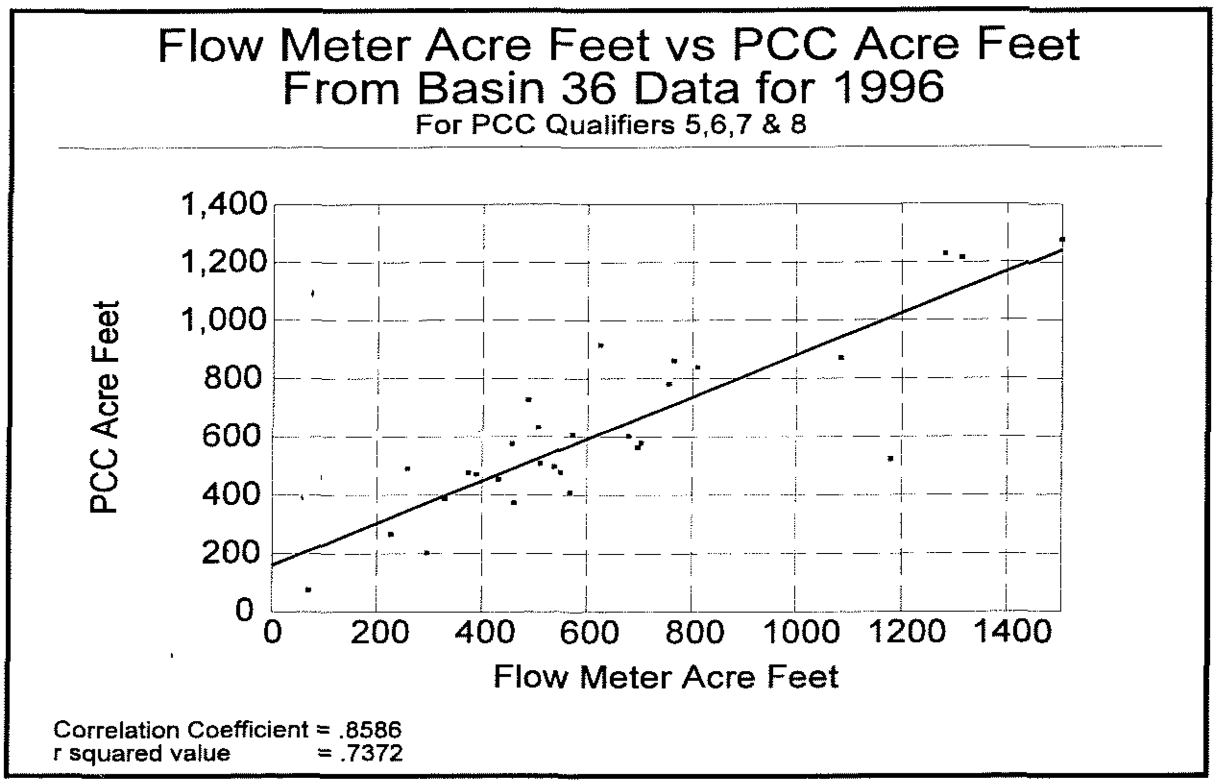

Figure 16. Linear regression of flow meter vs. PCC volumes for 29 wells, volume qualifiers 5 through 8

Table 5. Regression Data "Flow Meter vs PCC Volume

PCC Qual. ALL

Constant		−13.65963
Std Err of Y Est		131.19078
R Squared		0.834438
No. of Observations		56
Degrees of Freedom		54
Correl.Coeff.	0.9134758	
X Coefficient(s)	1.0330538	
Std Err of Coef.	0.0626195	

PCC Qual 1,2&3

Constant		−10.15661
Std Err of Y Est		38.806666
R Squared		0.9721207
No. of Observations		27
Degrees of Freedom		25
Correl.Coeff.	0.9859618	
X Coefficient(s)	0.9920421	
Std Err of Coef.	0.0336001	

PCC Qual 5−8

Constant		3.7346565
Std Err of Y Est		180.63438
R Squared		0.7372717
No. of Observations		29
Degrees of Freedom		27
Correl.Coeff.	0.8586453	
X Coefficient(s)	1.0239337	
Std Err of Coef.	0.1176331	

Table 6. FLOW METER VS POWER CONSUMPTION COEFFICIENT VOLUME
Basin 36 Data for 1996

SITE IDENTIFICATION AND OTHER INFO.			FLOW METER vs PCC		
POD	Site Tag No.	PCC Qual	Flow Mtr AF	PCC AF	% Difference
06S 22E 27 SWSWSW	A0004030	1	643.4	587.1	8.75
06S 22E 27 SWSWSW	A0003672	1	1020.6	962.6	5.68
07S 14E 26 SESENE	A0003668	1	164.9	170.0	-3.09
07S 21E 15 SWNWNE	A0004144	1	673.9	721.4	-7.05
07S 23E 27 NESESE	A0004135	1	475.4	457.9	3.68
07S 23E 33 SENW	A0002554	1	575.3	582.7	-1.29
07S 23E 34 NESESE	A0004134	1	359.5	358.8	0.19
07S 24E 32 SESESE	A0004026	1	31.3	32.1	-2.56
07S 25E 30 NENENW	A0003691	1	303.5	324.1	-6.79
08S 22E 16 NWSWSW	A0004040	1	397.7	437.5	-10.01
08S 22E 20 NWNESE	A0003345	1	562.4	606.9	-7.91
08S 22E 21 SWNWSE	A0003354	1	584.3	624.5	-6.88
08S 22E 34 NWNWNE	A0003397	1	275.1	284.3	-3.34
08S 22E 35 NENWNW	A0004023	1	279.9	280.8	-0.32
08S 23E 7 SWNE 2	A0003374	1	164.0	163.8	0.12
08S 23E 16 NESENW	A0002540	1	563.2	528.8	6.11
08S 23E 16 NESESW	A0002541	1	455.1	559.4	-22.92
08S 24E 27 NWNWNW	A0003687	1	69.9	83.0	-18.74
09S 14E 1 NENENW 3	A0003643	1	135.6	155.3	-14.53
09S 17E 10 NWNW	A0003751	1	90.9	79.9	12.10
10S 20E 33 NWNWSE 2	A0003706	1	63.6	60.3	5.19
07S 23E 32 SWSESE	A0004136	2	423.5	454.2	-7.25
08S 22E 19 NWNWSE	A0003348	2	314.3	317.3	-0.95
08S 22E 30 NESWNE	A0003359	2	388.6	430.8	-10.86
08S 23E 6 NENENE 1	A0002555	2	374.9	485.1	-29.39
10S 21E 18 NESENW	A0001600	2	320.8	320.1	0.22
07S 23E 21 SESE	A0001247	3	557.0	558.7	-0.31
07S 14E 17 NESWSW	A0001631	5	704.6	578.6	17.88
07S 22E 12 SESE	A0003368	5	431.1	453.7	-5.24
07S 23E 31 NWSWNE	A0002556	5	697.9	562.5	19.40
07S 23E 34 SENENE	A0001618	5	505.2	632.2	-25.14
07S 25E 14 SWNWSW	A0003702	5	680.8	602.5	11.50
08S 14E 23 NWNWSE	A0001679	5	460.3	373.5	18.86
09S 23E 11 NESWNE	A0003701	5	567.5	409.4	27.86
10S 20E 23 NWNWNW	A0003661	5	573.5	608.2	-6.05
07S 25E 7 SWNESW	A0004148	6	389.8	471.8	-21.04
07S 15E 8 NWNWSW	A0001246	7	227.7	266.2	-16.91
07S 21E 21 SENE	A0004090	7	456.8	576.1	-26.12
07S 21E 33 NESENE	A0004091	7	764.4	862.0	-12.77
07S 21E 34 SENESW	A0004092	7	486.3	727.9	-49.68
07S 21E 35 SWNENW	A0004095	7	258.8	491.6	-89.95
07S 23E 25 NENENW	A0004010	7	1179.5	522.1	55.74
07S 23E 25 SENWSW	A0004009	7	1314.6	1215.9	7.51
08S 14E 13 NWNWSW	A0003645	7	69.3	75.6	-9.09
08S 22E 11 NENWNW	A0003476	7	549.6	477.9	13.05
06S 21E 21 SWSENW	A0004005	8	1085.2	869.9	19.84
07S 22E 24 NWNWSE	A0003364	8	510.7	508.0	0.53
07S 22E 25 SESWNE	A0003362	8	755.0	782.7	-3.67
07S 22E 25 SWSWNE	A0003363	8	329.9	386.5	-17.16
07S 22E 36 SWSWSE	A0003383	8	374.3	477.2	-27.49
07S 23E 30 SWSWNW 2	A0003361	8	1282.3	1228.1	4.23
08S 22E 2 NWNENE 1	A0003360	8	1503.4	1278.1	14.99
08S 22E 28 NESENW	A0003351	8	624.7	914.5	-46.39
08S 22E 29 NESESW	A0003353	8	538.0	497.0	7.62
09S 22E 4 SENENW	A0003387	8	296.6	202.8	31.63
10S 20E 9 NESESE	A0003665	8	809.6	838.4	-3.56

Wells With Flow Meter & PCC Volumes in Basin 36

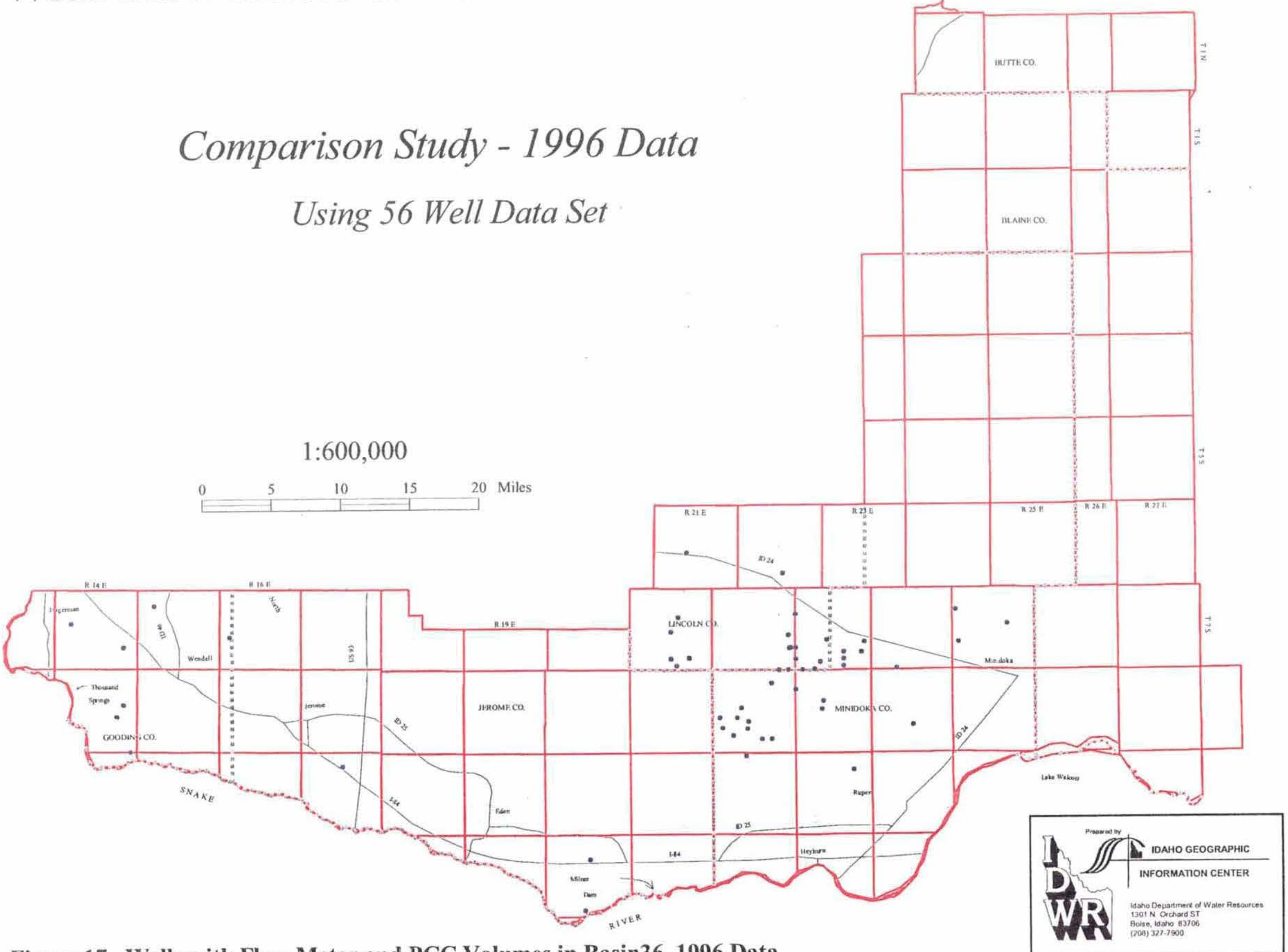

Figure 17. Wells with Flow Meter and PCC Volumes in Basin36, 1996 Data.

Table 7 below shows the total volume as measured by flow meters and estimated by PCC for the 56 wells. Note that the total volume difference between the two methods is negligible. The mean and standard deviation between the two methods is also very similar.

Table 7. Volume and Statistics Comparison for 56 Wells in Basin 36, 1996 Data
PCC and Demand KW vs Flow Meter

	FLOW METER	PCC	DEMAND KW
TOTAL VOLUME (ACRE FEET)	28696	28518.3	32068.5
% DIFF. FROM FLOW METER	-	0.62%	10.5%
MINIMUM (AF)	31.300	32.100	20.100
MAXIMUM (AF)	1503.400	1278.100	1664.100
MEAN (AF)	512.429	509.255	572.646
STANDARD DEV	319.476	282.496	328.900

Figure 18 is a box-and-whiskers plot of the flow meter and PCC volumes for the 56 well data set. Note that the medians and quartiles are very similar for the two variables, but that there is some variance between the 90th and 95th percentiles. The plot also shows that the PCC volumes are symmetrical around the median, whereas the flow meter volumes are skewed slightly to the right as a result of having several additional outliers.

Several statistical tests may be used to further compare the differences between flow meter and PCC volumes for the 56 wells. Two tests were made and are discussed below. These particular tests were chosen because the Colorado Department of Water Resources and the US Geological Survey (USGS) are currently involved in selecting sites to compare ground water withdrawal estimates between flow meter and PCC methods in the Arkansas River basin. The USGS has proposed using the paired t-test and the Wilcoxon signed-rank test to compare differences in ground water pumpage between the two methods (Dash, 1997).

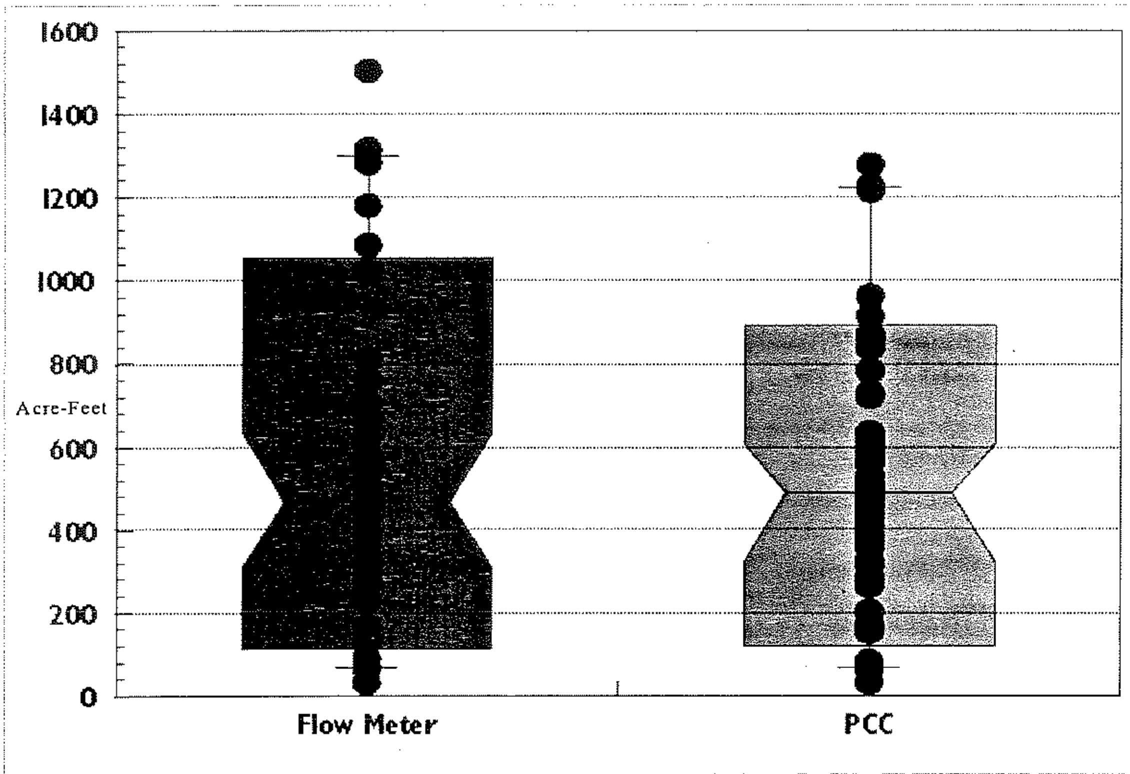

Figure 18. Box-Whisker Plot diagram, flow meter & PCC volumes for 56 well data set, showing 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles, plus outliers.

The paired t-test is the most commonly used test for evaluating matched pairs of data. The test assumes that the paired differences are normally distributed around their mean, and that the two groups of data have the same variance and shape (Helsel and Hirsch, 1992). The null hypothesis for the test is Ho: $\mu_{FM} = \mu_{PCC}$ (i.e.; the means are identical, or stated differently, there is no significant difference in the mean volume withdrawal between the flow meter and PCC methods for the 56 wells selected). For a t-test at the 95 percent confidence level, the null hypothesis is rejected if the computed t-value is greater than the critical value $t_{\propto,.05, df}$, where df, or degrees of freedom is n-1, or 55. For the 56 well data set, the computed t-value is 0.182 and the critical t-value is 1.67. Since the computed value is less than the critical, the null hypothesis can not be rejected. The test indicates that there is no significant difference between the means of the flow meter and PCC volumes at the 95 percent confidence level.

An additional test, the Wilcoxon signed-rank test, provides an alternative to the paired t-test. It is used to determine if the distribution shapes of two groups are different or if the data is non-normal (Ott, 1984). Stated in more precise terms, it is a test to determine if the median difference between paired observations equals zero. The test's only assumption is that the differences between the two groups are symmetrical (Helsel and Hirsch, 1992). The null hypothesis is Ho: median difference (D) = 0, whereas the alternative hypothesis for a two-sided test is that the differences tend to be either larger or smaller than zero, Ha: D > 0, or D<0 (Ott, 1984). The null is rejected if the computed test statistic, z, is greater than the critical value z at the selected confidence level, or if the computed probability (p) value of z is less than the selected level of confidence (95 percent or 0.05 in this case).

To conduct the test, the absolute values of the differences in flowmeter and PCC volume at each site are ranked from lowest to highest. The appropriate sign is then attached to each rank (+ or -), and then the positive and negative ranks are summed. The smaller of the two summed ranks, T, is then used as a value in the test statistic, z. For this group of 56 wells, the computed test statistic is 0.783. The probability (p) of the test statistic z, is 0.434. Since the probability is greater than 0.05, then the null hypothesis can not be rejected at the 95 percent confidence level. Therefore, the test indicates that the medians and distributions are not significantly different at the 95 percent confidence level. In other words, the flow meter and PCC volumes for the 56 paired observations are very similar.

The two statistical tests discussed above are presented to show that ground water pumpage determined by flow meter and PCC methods for the given sample provide very similar distributions. This provides support for using the PCC method as a method for estimating ground water withdrawals. This does not necessarily mean that the PCC method will always yield results at a desired level of accuracy. As evidenced by the raw data, the volume difference between PCC and flow meters for more complicated systems is not entirely satisfactory in terms of accuracy.

FLOW METERS VS DEMAND KW

Using data from the same 56 wells described above, IDWR staff conducted a preliminary analysis for an additional method using power kilowatt demand data and pumping water levels to calculate withdrawal volumes. Each method and analysis is described below. The Demand KW method of measurement is not a method currently recognized under IDWR guidelines, but could perhaps be considered as an alternative method and was compared in the analysis.

This method has four separate equations to derive the volume of water pumped. The known input values are demand KW and total seasonal KWH obtained from the electric utilities' power usage data submitted to the department, and pumping water levels. The assumed input values are discharge pressure and pumping plant efficiency. Pumping water levels were reported by owners or water users for most of the 56 wells. Where levels were not reported, they were estimated by using reported pumping and/or adjusted static water levels from nearby wells, including some active or discontinued USGS observation wells, or by contacting the owners directly. The lack of accurate pumping levels for some of the wells and assumed discharge pressure are definitely limitations with this simple study.

Explanation of equation components:

KW = average annual peak demand KILOWATT power requirement as reported by the electrical utility.
KWH = seasonal KILOWATT HOURS consumed as reported by the electrical utility.
TDH = TOTAL DYNAMIC HEAD is pumping water level lift and an assumed 60 psi discharge pressure.
GPM = GALLONS PER MINUTE - a theoretical flow rate derived, based on IHP, EFF &TDH
IHP = INPUT HORSEPOWER
PCC = POWER CONSUMPTION COEFFICIENT

AF = ACRE FEET

EFF = PUMPING PLANT EFFICIENCY = pump efficiency × motor efficiency (62 %)
Pump efficiency assumed at 68% (mid point of turbine pump efficiency new and used)
Pump motor efficiency = 91%(typical)
pump efficiency (68%) × motor efficiency (91%) = 62 %
Efficiency of 62% represents average state-wide efficiency of pumps tested in Idaho based on efficiency tests completed by IDWR Energy Division

Equations used for volume computation

EQUATION	1.	IHP	=	KW × 1.34
" "	2.	GPM	=	IHP × EFF × 3960 ÷ TDH
" "	3.	PCC	=	KW × 5431 ÷ GPM
" "	4.	AF	=	KWH ÷ PCC

The regression analysis compared the estimated Demand KW volumes to flow meter volumes. Each PCC qualifier group was again considered in the analysis.

Group One: Regression on volumes for 56 sample data set which includes all PCC volume qualifiers. The regression shows a fairly strong correlation, with a correlation coefficient (r) of 0.909 and a r^2 value of 0.826. These values indicate this method of estimating water withdrawal may have some potential as an alternative measurement method.

Group Two: This group is a subset of group one above and includes the 26 wells with PCC qualifiers one through three. The regression yields a stronger correlation. The r^2 value for this group is 0.892 while the correlation coefficient (r) is 0.945.

Group Three: Regression for PCC qualifiers five through eight did not correlate as well as the other groups. The r^2 value was only 0.756 with a correlation coefficient (r) of 0.870.

Table 9 lists the individual 56 wells and their measured flow meter volumes, estimated Demand KW volumes and percent difference between the two volume methods. Note that the individual percent differences between the methods generally vary more than the PCC-flow meter percent differences. The differences exceeded ± 10 percent for 16 of the 27 wells in group two, or those wells with qualifiers one through three. Note further in Table 7 that the total estimated volume of the Demand KW for the 56 wells is significantly higher than the PCC and flow meter total volumes.

Overall, this investigation of the Demand KW shows that this method of measurement may have some potential for estimating total withdrawals for groups of wells. However, the method does not appear to be as accurate as the PCC method, nor does it seem to be as accurate for estimating individual diversions. Consideration for using this method in estimating aggregate ground water withdrawals would require additional field studies to obtain more accurate pumping water levels and discharge pressures. The pump efficiency estimate should also be refined.

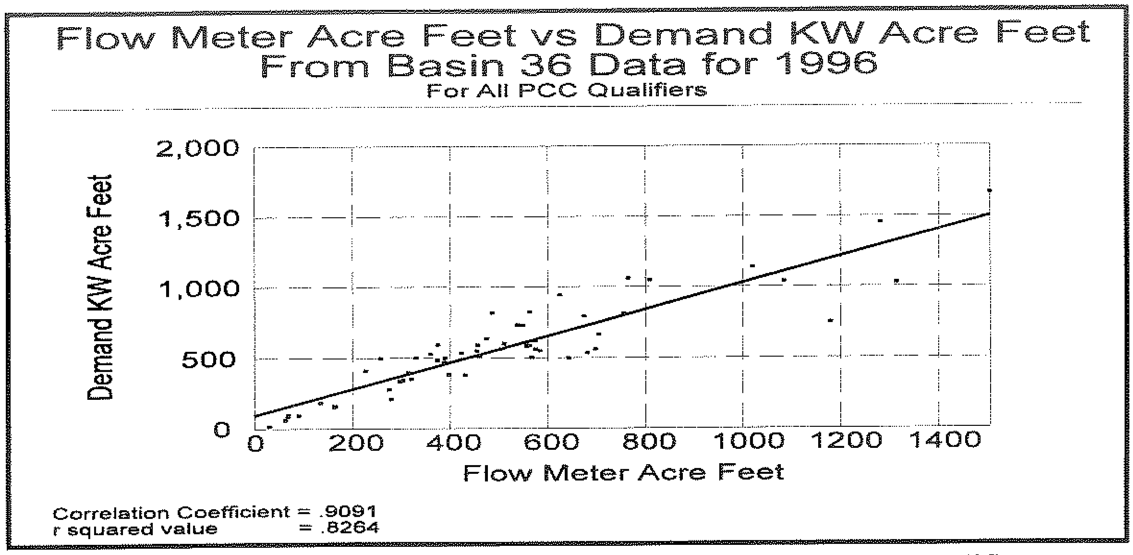

Figure 19. Linear regression, flow meter vs. demand KW volumes, all qualifiers

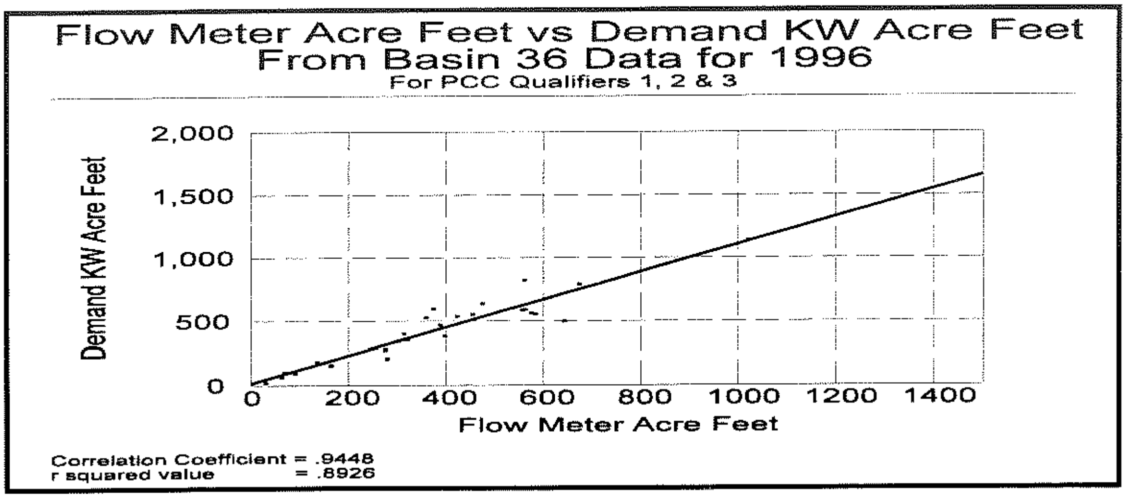

Figure 20. Linear regression, flow meter vs. demand KW volumes, qual. 1 through 3

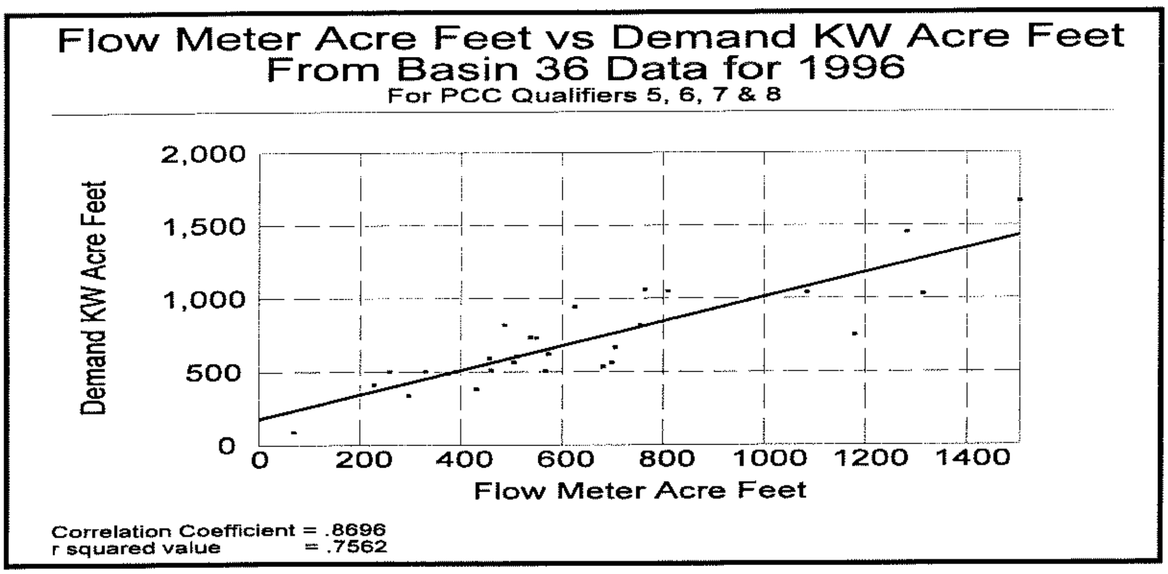

Figure 21. Linear regression, flow meter vs. demand KW volumes, qual. 5 through 8

Table 8. Regression Data: Flow Meter vs Demand KW Volume

PCC Qual ALL		
Constant		6.7646387
Std Err of Y Est		134.32107
R Squared		0.826443
No. of Observations		56
Degrees of Freedom		54
Correl.Coeff.	0.9090891	
X Coefficient(s)	0.883022	
Std Err of Coef.	0.0550667	

PCC Qual 1,2&3		
Constant		28.98263
Std Err of Y Est		76.164412
R Squared		0.8926076
No. of Observations		27
Degrees of Freedom		25
Correl.Coeff.	0.9447791	
X Coefficient(s)	0.8167094	
Std Err of Coef.	0.0566571	

PCC Qual 5–8		
Constant		−4.048391
Std Err of Y Est		174.00535
R Squared		0.7562014
No. of Observations		29
Degrees of Freedom		27
Correl Coeff.	0.8695984	
X Coefficient(s)	0.9066812	
Std Err of Coef.	0.0990763	

Table 9. FLOW METER VS POWER DEMAND KW CALCULATED VOLUME
Basin 36 Data for 1996

SITE IDENTIFICATION AND OTHER INFO.			FLOW METER vs DEMAND KW CALCULATED VOLUME		
POD	Site Tag No.	PCC Qual	Flow Mtr AF	Demand AF	% Difference
06S 22E 27 SWSWSW	A0004030	1	643.4	499.5	22.36
06S 22E 27 SWSWSW	A0003672	1	1020.6	1138.6	−11.56
07S 14E 26 SESENE	A0003668	1	164.9	160.1	2.94
07S 21E 15 SWNWNE	A0004144	1	673.9	793.3	−17.72
07S 23E 27 NESESE	A0004135	1	475.4	638.7	−34.35
07S 23E 33 SENW	A0002554	1	575.3	562.4	2.24
07S 23E 34 NESESE	A0004134	1	359.5	529.4	−47.26
07S 24E 32 SESESE	A0004026	1	31.3	20.1	35.63
07S 25E 30 NENENW	A0003691	1	303.5	343.9	−13.30
08S 22E 16 NWSWSW	A0004040	1	397.7	383.6	3.55
08S 22E 20 NWNESE	A0003345	1	562.4	825.8	−46.83
08S 22E 21 SWNWSE	A0003354	1	584.3	552.0	5.53
08S 22E 34 NWNWNE	A0003397	1	275.1	277.3	−0.79
08S 22E 35 NENWNW	A0004023	1	279.9	208.3	25.57
08S 23E 7 SWNE 2	A0003374	1	164.0	155.7	5.09
08S 23E 16 NESENW	A0002540	1	563.2	590.1	−4.77
08S 23E 16 NESESW	A0002541	1	455.1	552.7	−21.46
08S 24E 27 NWNWNW	A0003687	1	69.9	100.4	−43.60
09S 14E 1 NENENW 3	A0003643	1	135.6	184.5	−36.03
09S 17E 10 NWNW	A0003751	1	90.9	94.4	−3.86
10S 20E 33 NWNWSE 2	A0003706	1	63.6	63.6	0.00
07S 23E 32 SWSESE	A0004136	2	423.5	536.3	−26.63
08S 22E 19 NWNWSE	A0003348	2	314.3	399.9	−27.24
08S 22E 30 NESWNE	A0003359	2	388.6	470.8	−21.15
08S 23E 6 NENENE 1	A0002555	2	374.9	595.0	−58.72
10S 21E 18 NESENW	A0001600	2	320.8	353.4	−10.17
07S 23E 21 SESE	A0001247	3	557.0	585.2	−5.06
07S 14E 17 NESWSW	A0001631	5	704.6	665.0	5.62
07S 22E 12 SESE	A0003368	5	431.1	380.6	11.72
07S 23E 31 NWSWNE	A0002556	5	697.9	562.6	19.38
07S 23E 34 SENENE	A0001618	5	505.2	564.7	−11.78
07S 25E 14 SWNWSW	A0003702	5	680.8	535.5	21.34
08S 14E 23 NWNWSE	A0001679	5	460.3	511.0	−11.01
09S 23E 11 NESWNE	A0003701	5	567.5	505.5	10.93
10S 20E 23 NWNWNW	A0003661	5	573.5	620.9	−8.27
07S 25E 7 SWNESW	A0004148	6	389.8	500.3	−28.35
07S 15E 8 NWNWSW	A0001246	7	227.7	412.6	−81.22
07S 21E 21 SENE	A0004090	7	456.8	592.9	−29.79
07S 21E 33 NESENE	A0004091	7	764.4	1061.7	−38.89
07S 21E 34 SENESW	A0004092	7	486.3	818.1	−68.24
07S 21E 35 SWNENW	A0004095	7	258.8	500.6	−93.42
07S 23E 25 NENENW	A0004010	7	1179.5	750.5	36.37
07S 23E 25 SENWSW	A0004009	7	1314.6	1028.2	21.78
08S 14E 13 NWNWSW	A0003645	7	69.3	89.1	−28.62
08S 22E 11 NENWNW	A0003476	7	549.6	729.8	−32.79
06S,21E 21 SWSENW	A0004005	8	1085.2	1039.3	4.23
07S 22E 24 NWNWSE	A0003364	8	510.7	603.2	−18.11
07S 22E 25 SESWNE	A0003362	8	755.0	815.0	−7.95
07S 22E 25 SWSWNE	A0003363	8	329.9	502.8	−52.42
07S 22E 36 SWSWSE	A0003383	8	374.3	484.9	−29.55
07S 23E 30 SWSWNW 2	A0003361	8	1282.3	1454.6	−13.44
08S 22E 2 NWNENE 1	A0003360	8	1503.4	1664.1	−10.69
08S 22E 28 NESENW	A0003351	8	624.7	942.4	−50.86
08S 22E 29 NESESW	A0003353	8	538.0	733.8	−36.39
09S 22E 4 SENENW	A0003387	8	296.6	335.9	−13.25
10S 20E 9 NESESE	A0003665	8	809.6	1047.6	−29.40

PCC VS EVAPOTRANSPIRATION (ET)

Some additional analyses were made using 1996 PCC report data to compare PCC derived volumes with estimated volumes calculated from evapotranspiration (ET) and precipitation data. The IDWR basin 36 water measurement database contained 227 ground water diversions with adequate 1996 report information on irrigated acreage and crop types. As mentioned earlier in this report, water users reported the irrigated acres and crop type by point of diversion. As shown under Table 10, there were 38,792 total reported crop acres for the 227 diversions in 1996. Total volume estimates for each of the 227 diversions were derived using the following methods for estimating ET.

1) Modified Blaney-Criddle

The Modified Blaney-Criddle historical ET data for individual crop type is available from the Natural Resources Conservation Service's Idaho Irrigation Guide Table 683-2 for Climatic Area II (some literature may refer to NRCS reported Modifed-Blaney Criddle rates as SCS Blaney-Criddle). The ET rates provided in these tables are based on historical weather data from 1941 through 1970. The NRCS publication lists both gross and net ET rates. Gross ET values for each crop type may be multiplied by the number of acres for each crop to estimate total crop consumptive use (CU) or ET. Net ET or consumptive irrigation requirement (CIR) is the amount of water required for consumptive use that is artificially applied to the soil. The CIR is determined by subtracting effective precipitation from consumptive use (Sutter, 1970). A farm or project irrigation requirement is determined by applying an irrigation efficiency to the CIR. For purposes of this report, the terms CIR and net ET are used interchangeably.

Total volume estimates for the 227 wells using both the Modified Blaney-Criddle gross ET and CIR rates is given under columns 2 and 3 of Table 10. Volumes were computed for each diversion by multiplying the reported irrigated crop acres by the appropriate gross and net ET rates. Several wells in the group were used on the same acreage, so care was taken to avoid potential duplication of irrigated acreage and crops.

An irrigation application efficiency of 75% was applied to the CIR to obtain the gross application or farm requirement. Column 4 of Table 10, labeled Blaney-Criddle Historical CIR @ 75%, lists the total farm requirement volume associated with the 227 diversions. A 75 percent efficiency was selected since IDWR applies a 70 to 75 percent efficiency to CIR statewide in determining authorized water right diversion volumes (IDWR, 1992). Note that the farm requirement and PCC total volumes are nearly identical. The PCC volume should represent the total pumpage or farm requirement.

Table 10. PCC vs ET Comparisons of Estimated Volumes

	1 1996 PCC Measured	2 Blaney-Criddle Historical ET (Gross)	3 Blaney-Criddle Historical CIR (Net)	4 Blaney-Criddle Historical CIR @ 75% eff.	5 AgriMet 1996 ET (Gross)	6 AgriMet 1996 County WTD_ET (Gross)	7 AgriMet 1996 Est. CIR @ 75% eff.	8 1996 Reported Crop Acres
Total AF	87608	73582	66426	88568	89333	88450	109,451	38794
AF/AC	2.26	1.90	1.71	2.28	2.30	2.28	2.86	

Note: There are 227 individual wells in this data set.

Explanation of Columns:

1. Total acre-feet measured using the PCC method on 227 wells in 1996.
2. Total acre-feet estimated using Blaney-Criddle gross ET values (not adjusted for effective rainfall). ET multiplied by reported crops and acres from 227 wells.
3. Total acre-feet estimated using the Blaney -Criddle method adjusted for effective rainfall resulting in a consumptive irrigation requirement (CIR), or net ET.
4. Column 3 adjusted for an application efficiency of 75% to reflect a gross amount required, or gross farm requirement.
5. Total or gross acre-feet estimated using 1996 AgriMet ET data from individual farm crops and irrigated acres.
6. Total acre-feet estimated using the 1996 AgriMet ET data weighted for all harvested crops in Jerome and Minidoka County.
7. Column 5 reduced by 7% as estimate for effective precipitation or CIR, then adjusted for an application efficiency of 75% for estimate of gross farm requirement.
8. Total 1996 irrigated crop acres as reported by water users for 227 wells.

   Note: Acre-feet per acre (AF/AC) is obtained by dividing the total acre-feet by the total crop acres in column 8.

2) AgriMet ET (Modified Kimberly-Penman)

AgriMet is an agricultural weather station network maintained by the US Bureau of Reclamation (BOR), Pacific Northwest Region. The 1996 AgriMet ET information for the Rupert and Twin Falls weather stations is reported by the BOR for individual crop types grown in the vicinity of each station (BOR, 1995). AgriMet ET values are not adjusted for effective rainfall, so only gross ET rates are reported by the BOR. The AgriMet ET values are calculated using the 1982 Kimberly-Penman equation.

As a comparison with the Modified Blaney-Criddle method, actual 1996 AgriMet ET data from the above weather stations were used. ET values from the two stations were averaged and then multiplied by the reported irrigated crop acres to obtain a gross ET or consumptive use volume. Net AgriMet ET or CIR volumes were not determined since net AgriMet ET rates are not reported. Therefore, the total gross AgriMet ET volume shown under column 5 of Table 10 represents a consumptive use volume that includes both effective rainfall and artificial irrigation.

Linear regression analyses were made using the reported PCC volumes compared to the volume estimates computed by the Blaney-Criddle farm requirement and 1996 AgriMet gross ET methods. As shown in Table 11, the correlation coefficients (r) for both regression models are about 0.88 while the coefficients of determination (r^2) are about 0.78. These values represent fairly strong linear relationships.

3) AgriMet Weighted ET: Jerome and Minidoka Counties

Column 6 of table 10 shows a total volume estimate using 1996 AgriMet ET data weighted for all harvested crops in Jerome and Minidoka Counties. The US Department of Agriculture (USDA) Agriculture Statistic Service annually reports harvested acres by crop type for each county (USDA, 1996). The harvested crop acres are multiplied by the AgriMet ET values for each crop to obtain total ET crop volumes for each county. The total crop volumes are divided by the total harvested acres to obtain a weighted average ET value, given in acre-feet per acre. The mean of the weighted average ET values from the two counties is then applied to the total reported acreage for a total estimated volume. Similar to the total gross AgriMet ET volume under column 5 of Table 10, the AgriMet county weighted ET volume shown in column 6 represents a gross consumptive use volume that includes both effective rainfall and artificial irrigation. Note that this resulting volume is almost identical to the PCC, AgriMet gross ET, and Blaney-Criddle farm requirement volumes.
It is important to note that the most common approach to estimating water withdrawals for individual farms or diversions with ET data is to account for effective precipitation and derive a farm or project irrigation requirement by applying an irrigation efficiency. This of course was the approach taken using the Blaney-Criddle estimate reported under column 4 of Table 10.

Examination of Table 10 shows that the 1996 gross AgriMet ET volume given in column 5 is about 18 percent higher than the Blaney-Criddle historical gross ET volume. However, it is only about one percent higher than the volume estimate from the Blaney-Criddle farm requirement at 75 percent efficiency, and about two percent higher than the PCC volume.

A direct comparison of a farm requirement volume using AgriMet data was not done for this report because AgriMet ET data are reported as gross values only. In other words, the AgriMet data are not adjusted for effective precipitation. In order to compare a farm requirement volume using AgriMet, the gross AgriMet volume in Column 5 was reduced by eight percent to account for effective precipitation and estimate a CIR volume. The eight percent figure was based on averaging the cumulative rainfall events greater than 0.20 inches between April 1 and October 10, 1996, at the Twin Falls and Rupert AgriMet stations. This estimated AgriMet CIR was then adjusted for a 75 percent application efficiency to derive the AgriMet farm requirement volume given in column 7. This adjusted volume is about 24% higher than both the PCC withdrawal volume and the Blaney-Criddle farm requirement volume.

The fact that the gross Blaney-Criddle consumptive use estimate is considerably less than the gross AgriMet estimate is consistent with published reports that the modified NRCS Blaney-Criddle method underestimates monthly consumptive use when compared with other ET methods, particularly in arid regions (Allen and Brockway, 1983). A question raised here however is whether AgriMet ET rates were particularly high for 1996 or if AgriMet rates generally tend to over-estimate actual consumptive use rates.

The average 1996 AgriMet ET for all crops at Rupert and Twin Falls is only about one percent higher then the average period of record AgriMet rates at these stations (reported averages for period 1984 through 1994, Bureau of Reclamation, 1995). In contrast, the 1996 average AgriMet consumptive use rate for all crops is about ten percent higher than the average gross or consumptive use Blaney-Criddle rates reported by the NRCS. Again, the discrepancies may suggest that the respective methods may tend to over or under-estimate actual consumptive use.

The data summarized in Table 10 and the regression analyses indicate that some ET based methods are very useful for estimating total water withdrawals for large areas of irrigated acreage within the ESPA. However, PCC and ET comparisons for individual wells can vary significantly. The bar chart histogram in Figure 22 shows percent differences between the PCC and Blaney-Criddle farm requirement volumes for individual wells. About 48% of the wells have differences greater than +/- 20%. This indicates that estimated ET withdrawals for many individual wells may not be reliable within an acceptable range of accuracy.

Comparison of direct measurement methods and the PCC method with ET estimates should be further investigated using sampled data throughout the ESPA. Other ET methods should be investigated and compared with the ET methods described in this report. In particular, crop consumptive use estimates modified specifically for Idaho and reported by Allen and Brockway should be considered for use in any further investigations.

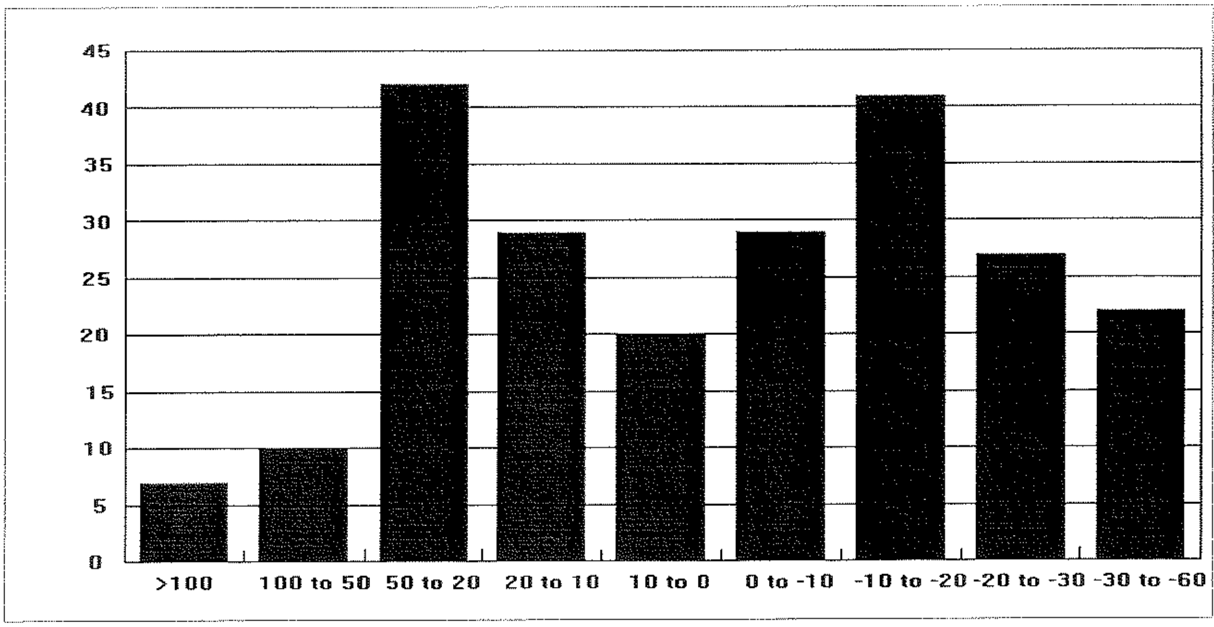

Figure 22. Histogram of percent differences between estimated volumes, PCC vs. NRCS modified Blaney-Criddle farm requirement at 75 percent efficiency.

Table 11. Regression Statistics

PCC AF vs B-C ET @ 75% Application Efficiency

Constant		58.3823199
Std Err of Y Est		109.980567
R Squared		0.78149509
No. Of Observations		227
Degrees of Freedom		225
Correlation Coeff.	0.8840221	
X Coefficient(s)	0.8395183	
Std Err of Coef.	0.0295942	

PCC AF vs AgriMet ET (Gross)

Constant		54.8491651
Std Err of Y Est		111.569965
R Squared		0.77513395
No. Of Observations		227
Degrees of Freedom		225
Correlation Coeff.	0.8804169	
X Coefficient(s)	0.8413095	
Std Err of Coef.	0.0302091	

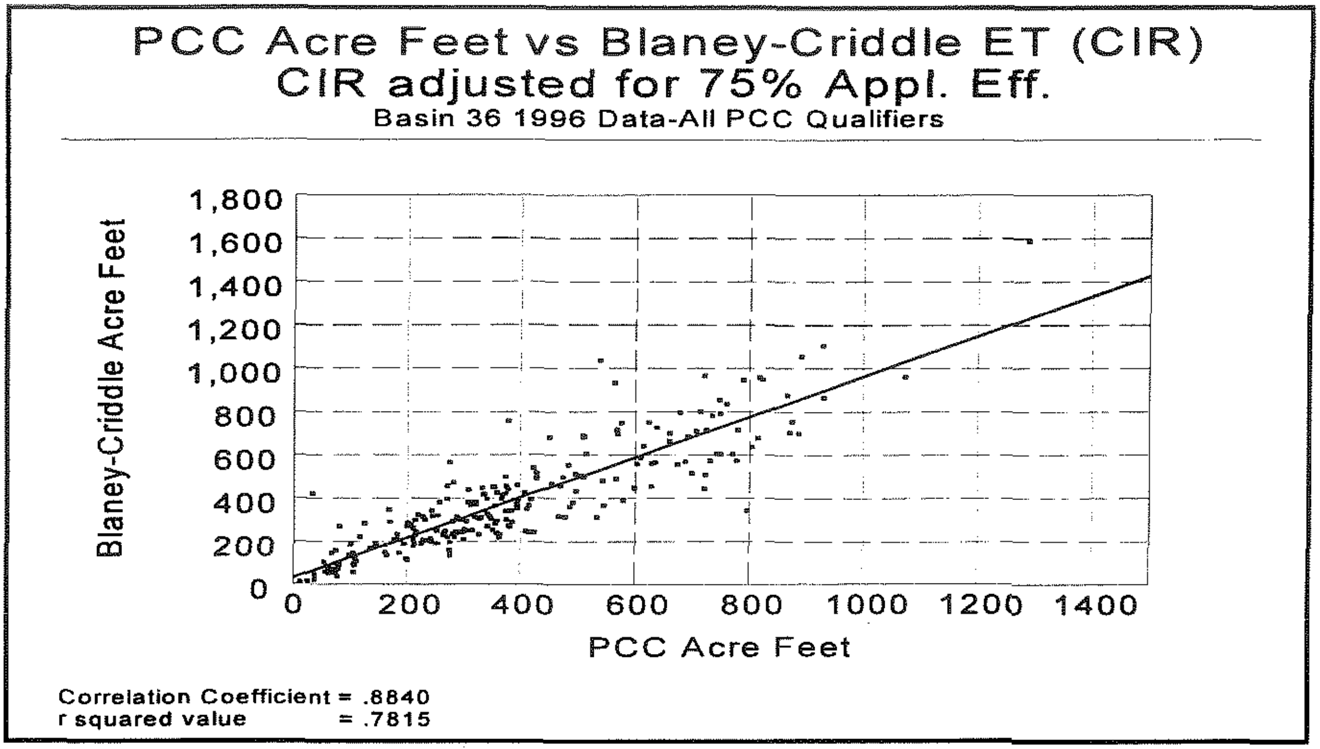

Figure 23. Linear regression, PCC vs. Blaney-Criddle ET CIR with 75 percent efficiency applied

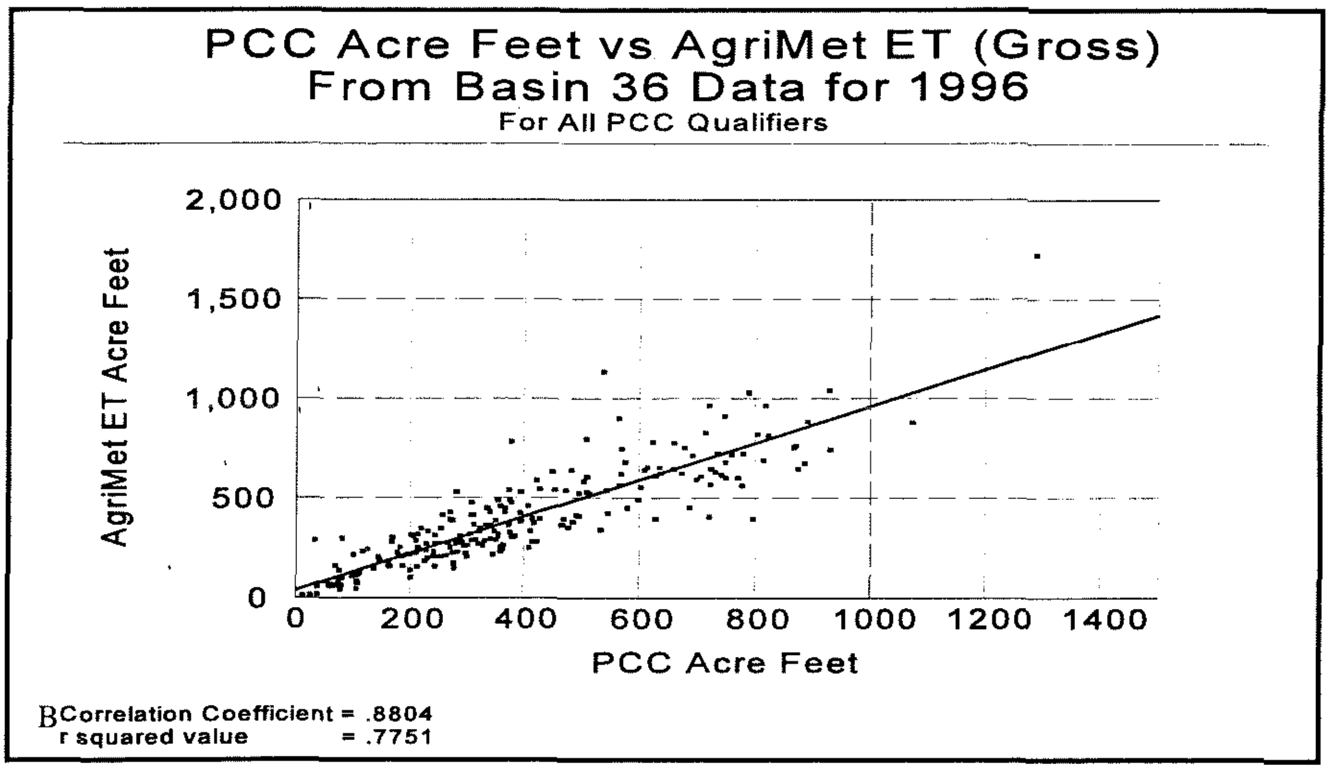

Figure 24. Linear regression, PCC vs. gross AgriMet ET

Wells With PCC and Estimated ET Volumes in Basin 36

Comparison Study Using 1996 Data

Using 227 Well Data Set

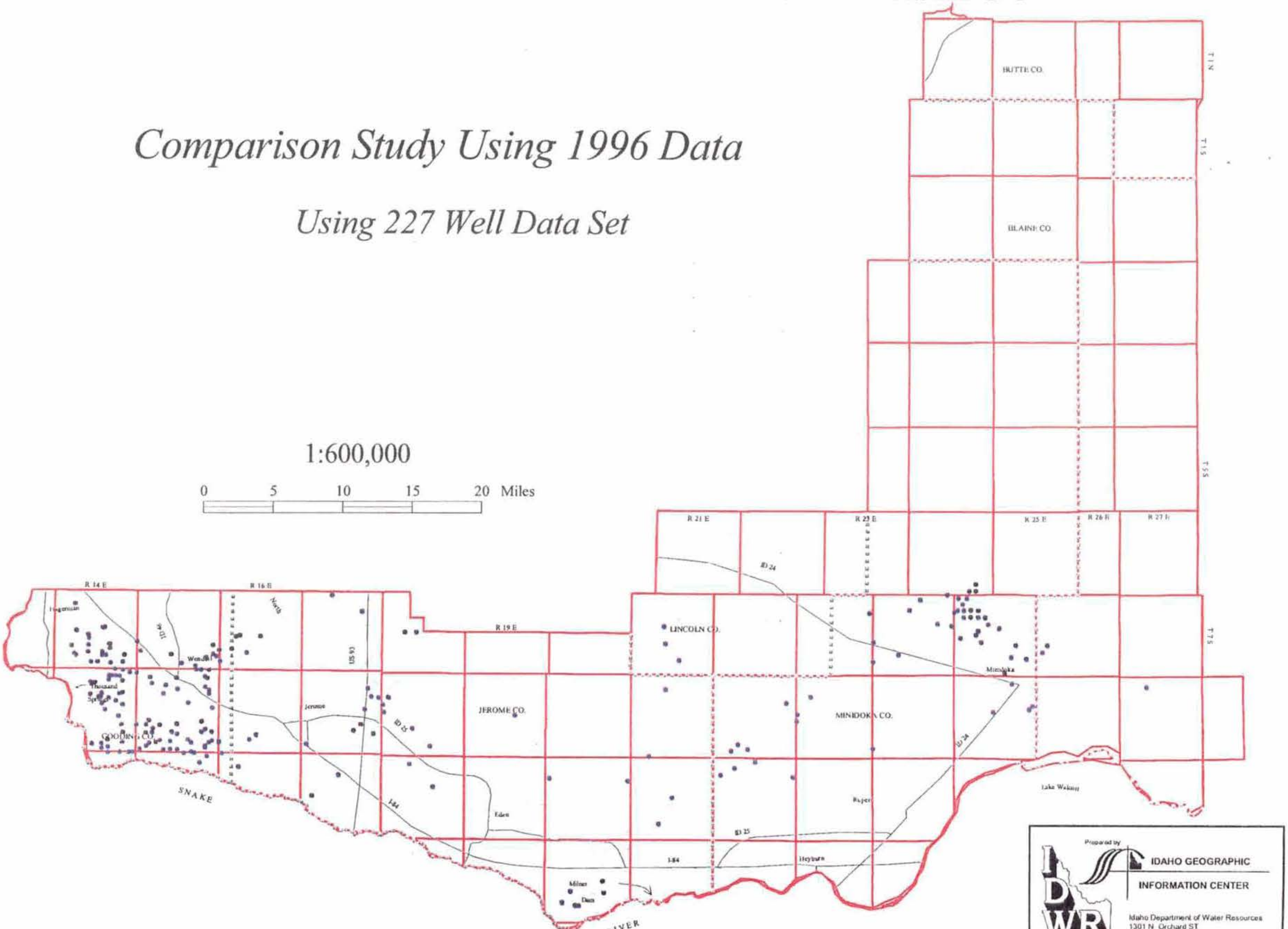

Figure 25. Wells with PCC and Estimated ET Volumes in Basin 36, 1996.

BASIN 36 TOTAL ESTIMATED GROUND WATER WITHDRAWALS AND COMPARISONS

Results from 1996 water measurement activities indicate total withdrawals from basin 36 during 1996 were approximately 600,000 acre-feet. This value includes all ground water diversions with irrigated acreage of 5 acres or more, or diversions with water right flow rates exceeding 0.24 cfs. Therefore, smaller diversions are not included, but are expected to be insignificant compared to total withdrawals.

Because not every ground water diversion scheduled for measurement was actually measured during 1996, it's necessary to use data from the measured diversions to extrapolate for the unmeasured diversions. Diversion volumes are available for more than 80 percent of wells scheduled for measurement. A total of 502,090 acre-feet was diverted from 950 measured wells. About 239 wells did not have measurement data, and 309 were known to have zero diversion volume. Three extrapolation methods were used to develop total diversion volume for the 239 wells.

First, measurements show that the mean diversion was 52 percent of the water right volume, so that the unmeasured diversions can be estimated by taking 52 percent of the water right amount. Secondly, the average diversion per well is 528.5 acre-feet (502,090 acre-feet ÷ 950 wells = 528.5 acre-feet per well), which can be applied to the 239 unmeasured wells. However, many of the unmeasured non-irrigation wells supply water to dairies which typically divert significantly less than 528 acre-feet per year so that this method may tend to over estimate diversions.

The third method utilizes the average diversion of 2.26 acre-feet per acre (see Table 10) applied to 38,097 acres irrigated with unmeasured diversions, and then assumes 52 percent of the water right volume for 62 unmeasured non-irrigation diversions with a sum total water right volume of 1645 acre-feet. Table 12 shows total volumes for these three extrapolation methods.

Table 12. Total Estimated Volumes of Unmeasured Wells in Basin 36, 1996

Method to Estimate Unmeasured Wells	Volume of Measured Wells (acre-feet)	Estimated Volume of Unmeasured Wells (acre-feet)	Total Diversion Volume (acre-feet)
52% of water right acre-feet	502,090	91,542	593,632
528.5 acre-feet per well	502,090	126,315	628,405
2.26 acre-feet per acre; 52% of water right acre-feet for non-irrigation wells	502,090	86,955	589,045

These values compare favorably with other published and unpublished estimates of water use. The Eastern Snake Plain Aquifer ground water flow model supported by IDWR and co-developed with the University of Idaho (UI) employs a ground water consumptive irrigation requirements of 450,950 acre-feet within the basin 36 boundaries (Internal Communication with John Lindgren, May 1998). This value is based on 242,668 ground water irrigated acres from 1992 data. The model uses an average consumptive irrigation requirement value of 1.86 acre-feet per acre for this region based on consumptive irrigation requirements reported by Allen and Brockway (Allen and Brockway, 1983). Assuming an average irrigation application efficiency of 75 percent yields total ground water withdrawals of 601,300 acre-feet.

The United States Geological Survey (USGS) estimates nearly 776,000 acre-feet of groundwater was withdrawn for irrigation in Gooding, Jerome, Lincoln, and Minidoka counties during 1992 (Maupin, 1997). Sampling methods were used to determine the percent of total irrigation with a source of ground water. Ground water irrigation was assumed to have an application efficiency of 70 percent. Given estimates of total consumptive use and percent of land irrigated with ground water, Maupin computed total ground water irrigation withdrawals by county, as shown in Table 13.

Based upon the USGS report, approximately 222,257 acres are irrigated with ground water in these four counties. Although Jerome and Minidoka counties are wholly included within Basin 36, Lincoln and Gooding counties are not. Using acreage figures from the USGS report and data from IDWR's water rights database, it is estimated that 85 percent of Gooding County and 86 percent of Lincoln County ground water irrigated lands are within basin 36 boundaries. Therefore, about 213,400 acres of land are irrigated with ground water within basin 36.

Table 13 is a combination of data from USGS investigations and IDWR adjustments for percent of land within basin 36 boundaries. Utilizing USGS data, about 741,300 acre-feet of ground water was withdrawn from basin 36 for irrigation during 1992.

Table 13. 1992 USGS Estimates of Irrigated Acreage and Ground Water Withdrawals, Adjusted for Basin 36, by County

County	1992 Land Irrigated with Ground Water (acres)	Ground Water Irrig. Withdrawals (acre-feet)	Percent of Withdrawals in Basin 36	Total Basin 36 Withdrawals (acre-feet)	Basin 36 Ground Water Irrig. Land (acres)
Gooding	32,340	125,310	85%	106,514	27,489
Jerome	47,175	158,180	100%	158,180	47,175
Lincoln	28,424	112,370	86%	96,638	24,445
Minidoka	114,318	379,930	100%	379,930	114,318
Total	222,257	775,790		741,262	213,427

The USGS report relies on AgriMet stations to estimate total consumptive use for each county. Effective precipitation was neglected and all crop ET was assumed to be supplied by irrigation. Average county-wide consumptive use (CU) varied from 2.33 to 2.77 acre-feet per acre with a weighted average of 2.44 acre-feet per acre for all four counties. Ground water irrigation application efficiency was assumed to be 70 percent. Therefore, the average ground water withdrawal for each acre is 3.49 acre-feet (2.44 ÷ 0.70).

This value of total withdrawals per acre is significantly higher than the IDWR measured withdrawals of 2.26 acre-feet per acre for 1996 (see Table 10). AgriMet weighted ET of 2.44 acre-feet per acre for 1992 was higher than the 1996 value of 2.28. It is possible that actual irrigation application efficiency is greater than 70 percent. It is also possible that some crops are under-irrigated and therefore measured withdrawals are less than theoretical estimates which assume maximum yields and adequate irrigation.

The IDWR ground water model utilizes about 14 percent more ground water irrigated acres than the USGS report for the basin 36 area (242,668 and 213,427 respectively). Although USGS acreage was lower, their estimated CU value is higher, resulting in a total CU for ground water irrigation of about 518,900 acre-feet compared to 450,950 acre-feet for the IDWR ground water model.

Assuming 2.26 acre-feet per acre and a total withdrawal of 600,000 acre-feet, this study indicates an irrigated acreage of about 265,500 acres. This acreage value is within 10 percent of the 242,668 acres used in the IDWR ground water model. Note that not all 600,000 acre-feet of measured withdrawal was used for irrigation, but that irrigation uses are expected to comprise at least 95% of total withdrawals. Also, some ground water irrigation is supplemental to available surface water supplies.

1997 ACTIVITY AND BEYOND

The water measurement program in the ESPA expanded in 1997 from basin 36 to the rest of the aquifer. Responsibilities for measurement and reporting of most diversions was assumed in 1997 by water measurement districts, ground water districts and irrigation districts.

As stated earlier in this report, IDWR approved water measurement and implementation plans in 1997 for each of the districts involved in measurement of ESPA diversions. These plans follow the general direction of phased implementation that was provided by the director's order of October 24, 1996 creating water measurement districts. Specifically, the order allowed districts to implement a measurement program over a three year period beginning in 1997. All diversions within the district will be measured by the end of the third year using either power consumption coefficients or measuring devices.

During the first quarter of 1997, IDWR drafted guidelines for measurement and reporting standards (Idaho Department of Water Resources, April 21, 1997). These guidelines assisted districts with developing implementation plans. IDWR also held a two day workshop for all districts or entities involved with water measurement and reporting within the ESPA. Additionally, IDWR staff conducted some in-field training and review with staff or contractors from individual districts.

Also during the first quarter of 1997, IDWR staff developed point of diversion lists and data base files using the IDWR water rights data base and prepared assessment notices for each of the three water measurement districts. Point of diversion data base files were also developed for the ground water districts and irrigation districts who are participating in ESPA measurement.

District hydrographers or contractors have been in the field during 1997 conducting inventories of diversions and measuring some individual ground water wells or systems. The inventory will be used to determine the best methods of measurement during the three year implementation period, as well as to verify point of diversion locations. Although data have not yet been submitted to IDWR for 1997, IDWR estimates that nearly 60 percent of the diversions in the ESPA requiring measurement have been physically inventoried. Additional diversions were reviewed by district staff or contractors by interview of diversion owners and operators or review of information submitted by the owners. It is further estimated that over 20 percent of the ESPA diversions have been physically measured through 1997, including the basin 36 pilot program during 1995 & 1996, which accounts for about 12 percent of those measured diversions.

IDWR initiated steps in 1997 toward developing a ground water level monitoring network within the ESPA. This network will serve to supplement the existing IDWR-USGS cooperative network. IDWR staff selected nearly 100 potential observation wells within the ESPA using the USGS site inventory data base. Various criteria were used in selecting these wells, including spatial considerations, but all wells chosen had one or more past measurements, generally between 1980 and 1988. This period was chosen because a large number of wells within the ESPA were measured in 1980, and because it preceded an extended period of drought in southern Idaho. Most of the wells chosen were investigated during 1997 while at least one or more measurements were obtained for about 50 of the sites. The sites were investigated or measured by staff from IDWR and the three water measurement districts. Another dozen wells were measured by the North Water Measurement district to substitute for some of the former USGS wells which could no longer be measured. Most of the replacement wells in this area however were not part of the USGS data base.

Additional miscellaneous ground water level measurements were made in 1997 by the irrigation districts and ground water districts. A number of wells within the irrigation districts are measured annually and have considerable amounts of historical data. IDWR will work with the different districts in identifying sites which may be added to the ESPA network. Other entities which regularly measure water levels and will participate in sharing data with IDWR through the water measurement program include the Ft. Hall Indian Reservation, INEEL and various municipalities.

With the expansion of measurement in 1997, IDWR has initiated development of a new water measurement data base. This data base, called Water Measurement Information System (WMIS), is an SQL compliant data base that will be maintained by IDWR. It will include the diversion discharge and volume data that are collected and submitted annually by the different measuring districts or entities within the ESPA. Ground water level measurement data collected as part of the ESPA measurement effort will also be submitted and stored in WMIS. Other areas outside of the ESPA where ground water measurement data are collected may be submitted to WMIS beginning in 1998. These other areas include the Big Lost River basin (Water District 34), and several ground water management areas.

IDWR also initiated development of a water measurement data entry application program that will be available to the districts, at no charge, later in 1998. The application is a stand-alone program which will simplify data entry and minimize errors.

Finally in 1997, IDWR administrative staff began a process for development of statewide rules and regulations governing water use, water measurement and reporting, and enforcement. These rules may replace the interim ESPA measurement guidelines drafted by IDWR earlier in 1997. The process in 1997 was limited to several scoping meetings with water users and representatives within the ESPA. Draft rules have not been released to the public but IDWR expects to hold hearings and adopt rules in 1998.

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APPENDIX A

VOLUME QUALIFIERS USED IN

WATER MEASUREMENT REPORTS AND DATABASE

WATER MEASUREMENT VOLUME QUALIFIERS

Data qualifiers have been developed for reported diversion volume information. These qualifiers are used to identify the status of the reported volume quantity. They are specific to measuring method rather than to water source. Qualifiers may give data users an idea of the general degree of accuracy of calculated volumes. This appendix identifies the different volume qualifiers that are used by IDWR in the ESPA measurement program. A description of each qualifier is given along with the number of diversions for each qualifier from the 1996 reports. The 1996 water measurement report for basin 36 listing withdrawals for individual diversions is printed separately (see *Eastern Snake Plain Aquifer Water Measurement Program: Basin 36 Ground Water and Surface Water Diversions, 1996).*

PCC Qualifiers

The following qualifiers apply to diversion volumes estimated with power.

Note: Qualifiers (1) through (6) should only be used on systems with minimal seasonal water level fluctuations. If water level fluctuations cause more than 10 percent change in the PCC, qualifiers (1) though (6) should not be used, and qualifier number (8) is generally suggested. However, if the fluctuations can be treated as operating "conditions" and the PCC at these conditions measured, then qualifiers (2) through (5) can be assigned as appropriate.

Volume Qualifier	No. of Diversions with Qualifier	Qualifier Description
Z	21	Zero pumpage based on zero energy consumption.
1	325	Simple systems with only one operating condition and minimal water level fluctuations where power records should work well. Examples include a well to 6 wheel lines where all 6 lines are operated together, or a well to one pivot without corner systems or end guns unless the gun is on all the time, or a well that is never throttled or valved back open discharging to a pond or ditch, or any system where the flow rate and power consumption do not fluctuate significantly.
2	40	Systems with multiple operating conditions, all of which were measured and PCC varied ten percent or less, or varied more than ten percent but tracking is not required due to consistent changes (pivots with corner systems and/or end guns); estimate accuracy should be close to qualifier (1). Examples include some well and booster systems where the PCC changes little when the booster is operated. Many pivots with end guns have less than a 10 percent difference in PCC when the end gun is turned off. However, most pivots with corner systems have more than a 10 percent

		change in PCC between the full open condition and the fully retracted condition, and these systems should be measured at both full open (high flow) and full retraction (low flow) and these two conditions can usually be assigned 50/50 percent of the time operation.
3	17	Systems with multiple operating conditions, all measured, PCC varied more than ten percent, tracking is required and owner reported percent of time at each condition; volume estimate accuracy may be similar to or slightly less than qualifiers (1) & (2) above. An example is a well to two pivots, one larger than the other, where either can operate alone or both together. The owner reports both operated together 1230 hours, the big pivot ran alone 630 hours, and the little one ran alone 460 hours. Another example is a well that supplies water to either a pivot or solid set hand lines and the operator reports that the pivot operated 65 percent of the time and the solid sets operated 35 percent of the time.
4	23	Systems with multiple operating conditions, all measured, PCC varied more than ten percent, tracking is required but was not reported by the owner or considered inaccurate and unreliable. Use the low PCC to calculate volume. Volume estimate may therefore be higher than actual diversions.
5	41	Systems with multiple operating conditions that were not all measured but can be measured so that a (2), (3), or (4) qualifier could be assigned in the future; or a system that needs re-measured (possibly due to system changes or incorrect initial measurements). Estimate accuracy less than qualifiers (1) & (2).
6	2	Known problem with reported kwh data (e.g. transformers were out on power meter for part of year). Estimate is likely low because not all kwh consumed were reported.
7	33	Measured PCC during flowmeter check. Calculated PCC volume may not be as accurate, especially if system operation changes significantly. However, if the system is simple or has multiple measured conditions and one of the above qualifiers applies, than it was used.
8	65	PCC measured on a complex system where flow meters or time clocks should probably be used. The PCC measurement used for calculating volume should be at high flow (low PCC) condition. Calculated volume estimates will usually be high since these

		systems are usually measured at capacity or additional loads were on the power meter.
9	11	PCC not measured, but may have been estimated based on system characteristics, location, results from other near by measurements, etc.
N	55	PCC not measured or estimated. Energy consumption data unavailable
Q	2	The above qualifiers are not applicable, see comments or memo field for additional explanation.

Flow Meter Qualifiers

Diversion volumes measured with flow meters or time clocks are assigned the following set of data qualifiers.

Volume Qualifier	No. of Diversions with Qualifier	Qualifier Description
PM	17	Partial year measurement. Flowmeter not installed or not working properly for the complete season and the actual diversion is greater than reported amount.
FE	48	Full year estimate. An estimate for the full year based upon partial data when flowmeter data is not available for the full season. Examples may include dairy facilities where the month to month usage is fairly consistent and enough months of data exist to extrapolate usage for months where data was not reported.
MR	145	Owner has reported flowmeter measurements and readings are recorded on at least a monthly basis.
NM	110	Owner has reported flowmeter measurements but readings are NOT recorded on at least a monthly basis. Readings are less frequent than monthly.
EM	12	Owner has reported flowmeter measurements are obviously incorrect or erroneous, usually because the flowmeter is not accurate or not operating properly. Actual diversion amount could be higher or lower.
ND	231	Flowmeters or time clocks have not been installed or the annual report did not include any meter readings. Diversions have likely occurred and the reported volume of zero is erroneous.

Z	51	Non-use of a diversion per flowmeter and/or confirmation from the operator.
OW	53	Water diverted from this well is co-mingled with flow from another well and measured with one flowmeter.

Open Channel Measurement Qualifiers

The following are qualifiers for acre-feet volumes computed from open-channel device flow rate measurements (weirs, flumes, rated structures) or from non-totalizing flow meters. These qualifiers also appear with the surface water diversions listed in Appendix C.

Volume Qualifier	No. of Diversions with Qualifier	Qualifier Description
PM	2	Partial year Measurement: Owner reports that device was not installed or was not operating properly for complete season of use and full-year estimate is not possible due to fluctuating flows; actual diversions are greater than computed amount. *If records are incomplete and device malfunctions are not indicated,* ***IR*** *is used.*
FE	4	Full year Estimate: Owner reports that device was not installed or was not operating properly for complete season of use; an estimated diversion for the full year or season has been calculated based on partial data because flow rates are expected to be more or less consistent. *If records are incomplete and device malfunctions are not indicated,* ***IR*** *is used.*
WR	56	Weekly Recording: Device readings taken daily or weekly during reporting period (required minimum frequency is weekly unless otherwise approved).
BE	4	Monthly or Bi-monthly Recording: IDWR has approved that device readings may be taken monthly or twice-monthly during reporting period. *If monthly or bi-monthly recording has not been approved,* ***IR*** *is used.*
IR	6	Insufficient Recording: Owner has not reported for a full year or season and no explanation is provided, or, owner has reported for a full year or season but has not supplied a sufficient number or quality of device readings to adequately represent changes in flows; actual diverted volume may be higher or lower than

		computed. *Use of this qualifier requires that RPT_ACPT field is N.*
EM	0	Erroneous Measurement: Owner reported measurements are obviously incorrect due to staff gage errors, use of incorrect discharge tables, etc. Actual diverted volume may be higher or lower than computed. *RPT_ACPT field may be **N** or **Y** depending on circumstances.*
Z	1	Zero diversion: non-use or no diversion per report or owner/operator confirmation.