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BEFORE THE DIRECTOR
OF THE DEPARTMENT OF WATER RESOURCES
OF THE STATE OF IDAHO

IN THE MATTER OF DISTRIBUTION FOR WATER TO WATER RIGHT NOS. 36-02551 AND 36-07694 (RANGEN, INC.)	**SPRONK WATER ENGINEERS, INC.** **EXPERT RESPONSE TO IDWR STAFF MEMORANDUM** **DATED APRIL 5, 2013** **PREPARED FOR THE CITY OF POCATELLO**

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Table 2-5 Comparison of USGS and Rangen Hatchery Flow Measurements, 1970 - 2013

Table 2-6 Summary of USGS and Rangen Hatchery Flow Measurements, 1970 - 2013

Table 2-7 Summary of Implicit Weir Coefficients for Rangen Measurements and USGS Measurements

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Appendix A IDWR Minimum Acceptable Standards for Open Channel and Closed Conduit Measuring Devices

Appendix B Updated Tables and Figures, 2013 Expert Rebuttal Report

Response to IDWR Staff Memorandum
Dated April 5, 2013
Prepared for the
City of Pocatello

1.0 Introduction

On December 13, 2011, Rangen, Inc. ("Rangen") filed a Petition for Delivery Call ("Rangen Petition," or "Rangen Call") with the Idaho Department of Water Resources ("IDWR") seeking curtailment of ground water rights in the Eastern Snake Plain Aquifer ("ESPA") with priority dates junior to Rangen's water right nos. 36-02551 (July 13, 1962 priority) and 36-07694 (April 12, 1977 priority).

In December 2012, expert reports were filed on behalf of the following parties to the Rangen Call:

- Rangen
- Idaho Ground Water Appropriators ("IGWA")
- City of Pocatello ("Pocatello")
- Fremont Madison Irrigation District ("Freemont")

In February 2013, expert rebuttal reports were filed on behalf of the following parties:

- Rangen
- IGWA
- Pocatello

On February 27, 2013, a memorandum prepared by the staff of the Idaho Department of Water Resources ("IDWR Memo") was filed to summarize the staff's positions regarding various technical matters related to the Rangen Call. The IDWR Memo was prepared by Jennifer Sukow with assistance from other IDWR staff. IDWR also provided various data, documents, spreadsheets, and other information used in developing the opinions contained in the memorandum.

During March 2013, depositions of the following IDWR staff were taken to obtain additional explanation of the IDWR Memo and other information relevant to the Rangen Call:

- Neal Farmer
- Rick Raymondi
- Jennifer Sukow
- Cindy Yenter
- Tim Luke
- Sean Vincent

Prior to the depositions, IGWA and Pocatello submitted a request for data and information related to the IDWR Memo. IDWR provided electronic documents in response to the request at the depositions.

This report was prepared on behalf of Pocatello to respond to certain elements of the IDWR Staff Memo. The opinions described herein are based on our review of the memo and the various data, information, and deposition testimony described above, our work since the early 1990s in Idaho, our experience in the review and analysis of water use and other data, and our experience in conjunctive management and administration of ground water and surface water supplies and water rights.

This report supplements the December 21, 2012 expert report and February 7, 2013 rebuttal report prepared by Spronk Water Engineers, Inc. ("SWE") for the Rangen Delivery Call ("Rangen Call"). The report is styled to describe or quote the opinion contained in the IDWR Staff Memo (in italics), followed by our response.

2.0 Response to IDWR Opinions

2.1 Inefficiency of Curtailment

IDWR Opinion (p. 6)

ESPAM2.1 predicts that a model-wide curtailment of groundwater irrigation junior to July 13, 1962 would increase discharge at the Rangen spring cell by 17.9 cfs and reach gains in the Buhl

to Lower Salmon Falls reach by 242 cfs at steady state. It would take approximately 13 years to reach 90% of the steady state response. The simulated curtailment would affect approximately 565,000 acres and would increase net aquifer recharge by approximately 1.2 MAF/year (1,705 cfs). The benefit predicted at the Rangen spring cell is only 1% of the curtailed use. The other 99% of the benefit would accrue to other springs and reaches of the Snake River. The predicted benefit to the Buhl to Lower Salmon Falls reach is 14% of the curtailed use. This curtailment simulation includes areas located outside of the current area of common groundwater supply.

Response

The result of the ESPAM 2.1 curtailment run that show that approximately one percent of the curtailed ground water use would accrue to the Rangen spring cell illustrates how inefficient curtailment would be in delivering water to Rangen. To further illustrate this point, the results from the curtailment run described in the IDWR Memo are summarized in Table 2-1. These results are also summarized in Figure 2-1 which illustrates the spatial distribution of the predicted accrual of water to springs and river reaches in the Eastern Snake River basin from curtailment. The steady-state increases in spring flow and river reach gains are shown next to colored arrows that are sized in relative proportion to the gains predicted by the model.

Approximately 416 cubic feet per section ("cfs") of the curtailed ground water use will accrue to springs and spring reaches. A summary of the decreed spring water rights between Kimberly and King Hill is provided in Table 2-2. The combined decreed flow rate for all of the spring water rights totals 3,528 cfs. Of this amount, 2,295 cfs (65%) is junior to Rangen's 1962 priority date. Therefore, if the curtailment that Rangen seeks actually occurs, the paradoxical result will be that substantial portions of the curtailed use of ground water rights with priorities as early as 1962 will accrue to the benefit of spring water rights with priorities junior to 1962 that did not even place a delivery call.

2.2 Variability in Rangen Flow and Effect of Curtailment

IDWR Opinion (p. 9)

Between 2002 and 2011, annual average spring discharge ranged from 12 to 16 cfs, and monthly average spring discharge ranged from 11 to 22 cfs (Sullivan, 2012, Table 2-2). Based on 2002 to 2011 conditions, the predicted total annual average spring discharge would be between 30 and 34 cfs with curtailment.

Response

IDWR took the annual average flows of 12 cfs to 16 cfs that existed from 2002 – 2012 and added the annual average predicted steady-state increase in the flow of the Curren Spring from curtailment of approximately 18 cfs to predict that the annual average flows after curtailment (at steady state) would range from 30 cfs to 34 cfs. These annual average flow rates do not reflect the current seasonal variability of (a) the Curren Spring flows, (b) the predicted increased spring flow from curtailment, and (c) the Curren Spring flows at steady-state after curtailment.

Table 2-3 was prepared to tabulate the seasonal variability of the Curren Spring flows before and after curtailment. The monthly Curren Spring flows are based on reported flows from 2007 – 2011. The predicted monthly spring flow increases from curtailment are near-steady-state results from ESPAM 2.1 from curtailment of pumping of ground water rights junior to July 13, 1962 across the entire model area. These two sets of monthly data were summed to compute the predicted monthly average Rangen flows after curtailment at steady state. The foregoing results represent the total flow at the Curren Spring complex. The results were disaggregated into the amounts at the Curren Tunnel and the amounts at the talus springs below the tunnel using (a) the current measured Curren Spring and Curren Tunnel flows and (b) the portion of the gain from curtailment that would accrue to the Curren Tunnel based on the regression equation shown in Figure 3-9 of the December 21, 2012 expert report prepared for the Idaho Ground Water Appropriators ("IGWA"). The monthly flows shown in Table 2-3 are shown graphically in Figure 2-2. Because Rangen's lower diversion of the talus slope flow is not with the 10-acre tract described as the point of diversion in Rangen's partial decrees (see below), Rangen may not be entitled to the water that would accrue to the talus slope from curtailment.

2.3 Decreed Elements of Rangen Water Rights

IDWR Opinion (p. 11)

Brendecke (2012) concludes that the source for water right 36-2551 is the Martin-Curren Tunnel and that flows from the tunnel have never been high enough to deliver the maximum diversion rate authorized under water right 36-2551. IDWR staff agree that the SRBA partial decree for water right 36-2551 lists the source as Martin-Curren Tunnel and describes the 10-acre tract containing the tunnel. A cursory review of the water right file indicates that the water right was licensed with the source described as "underground springs tributary to Billingsley Creek" and the point of diversion is located in the 40-acre tract containing both Curren Tunnel and Rangen's diversion at the head of the creek. The water right file also contains two survey drawings showing the point of diversion from the creek and the 36-inch pipe to the large raceways. The licensed priority date was July 31, 1962. The files reviewed did not indicate why the source, point of diversion, and priority date were changed in the SRBA.

Response

A map showing the actual and decreed points of diversion and place of use for the 1962 and 1977 Rangen water rights is provided in Figure 2-3. The map shows that Rangen's point of diversion just below the Curren Tunnel that supplies the Hatch House, Greenhouse, and the Small Raceways is within the 10-acre tract described as the location containing the point of diversion in Rangen's partial decrees. However, Rangen's other point of diversion located at the base of the talus slope that supplies the Large Raceways and the CTR Raceways is clearly outside of the 10-acre parcel described in the partial decrees.

2.4 Impact of Pocatello Pumping on Rangen Spring

IDWR Opinion (p.50)

IDWR staff review indicates that ESPAM2.1 steady state response functions for model cells containing groundwater points of diversion for the City of Pocatello range from 0.37% to 0.47% with respect to the Rangen spring cell. Based on the response functions, IDWR staff agrees

with Sullivan (2012) that curtailment of the City of Pocatello's groundwater use will result in a negligible increase in discharge at the Rangen spring complex. ESPAM2.1 predicts that more than 99.5% of the curtailed use would benefit other springs and reaches of the Snake River.

Response

We concur that curtailment of Pocatello's pumping would result in a negligible increase in the discharge of the Rangen spring complex. Based on this conclusion Pocatello's pumping has a de minimus impact on Rangen's water supply.

2.5 Impact of Pumping Within Various Areas on Rangen Spring

IDWR Opinion (p. 50)

Sullivan (2012) provided a copy of the results of an IDWR analysis of the response at the Rangen spring cell to curtailment within various areas defined by steady state response functions. These analyses limited the area of curtailment to areas where the fraction of curtailed use accruing to the Rangen spring cell exceed values ranging from 0.2% to 10%. The results of the analyses performed by IDWR and submitted by Mr. Sullivan were calculated with ESPAM2.0 and were not updated using ESPAM2.1. IDWR staff updated these analyses with ESPAM2.1 in response to Mr. Sullivan's submittal. The results are provided in Table 4 and Figure 18. These results supersede the results presented by Mr. Sullivan in his Figure 8-4.

Response

The updated analyses of the impact of curtailment within various areas developed by IDWR that are summarized in Table 4 and Figure 18 were reviewed, and these results are endorsed and adopted to replace the results that were shown in Figure 8-4 of the December 21, 2012 Pocatello Expert Report.

There has been considerable discussion about the uncertainty of the ESPAM 2.1 model related to the uncertainty of the model itself (e.g., conceptual uncertainty, parameter uncertainty,

calibration uncertainty, etc.). The parameter uncertainty and calibration uncertainty have been evaluated to limited extent by IDWR in their predictive uncertainty analysis.

There is another element of uncertainty associated with the ESPAM 2.1 curtailment runs that has not been evaluated, and this is the uncertainty associated with the change in irrigation consumptive use that would occur as a result of curtailment. In making the curtailment runs, it is necessary to specify the amount of ground water irrigated lands that would go out of irrigation following curtailment. The curtailed acres in the curtailment runs consist of lands irrigated solely with ground water and mixed source lands that may be irrigated from either ground water or surface water.

The ground water only acres junior to July 13, 1962 were determined for ESPAM 2.1 by query of IDWR's water rights database. These are the irrigated acres with water rights junior to July 13, 1962 determined to exist as of 1987 when the Snake River Basin Adjudication commenced. There is some unknown uncertainty about whether the ground water only acres that are currently irrigated are the same as the acres that were reportedly irrigated in 1987.

In addition to the uncertainty of the ground water only acres, there is also uncertainty about the reduction in irrigation of the mixed source lands that would occur following curtailment. According to the ESPAM 2.1 documentation, there are approximately 150,000 mixed source lands within the ESPAM 2.1 boundary. Some of these lands are currently irrigated by only surface water, others by only ground water, and others by both sources.

In developing the input data for ESPAM 2.1, it was necessary for IDWR to disaggregate the mixed source lands into acres irrigated by surface water and acres irrigated by ground water. The procedure for disaggregating the mixed source lands into surface water acres and ground water acres is described in a January 28, 2008 memorandum to the ESHMC from Bryce Contor. The procedure is known as the "Dual 2 Method" and involved estimating the percentage of each mixed source parcel that was irrigated by ground water based on the distance from the parcel to the nearest well. Parcels within 100 meters of a well were assigned a 10% ground water faction,

parcels more than 1,000 meters from a well were assigned a 90% ground water faction, and parcels between 100 meters and 1,000 meters of a well were assigned a 50% ground water fraction. The distances and percentages used in the procedure were arbitrary. Whether the nearest well was actually the source of water for the subject parcel was not considered.

The procedure for disaggregating the mixed source lands into ground water and surface water irrigated areas was discussed with the ESHMC. The focus of that discussion was on the appropriateness of the Dual 2 Method for purposes of model calibration. There was general agreement among the ESHMC members that the model calibration would not be sensitive to selection of the mixed source parcel disaggregation criteria, and as a result, they agreed that it was not necessary that the procedure be accurate for that purpose. However, there was also discussion that specification of the mixed source criteria would need to be revisited in simulating curtailment of ground water use. The 2008 memorandum summarized this discussion as follows:

> *At the ESHMC meeting it was suggested that changing the mixed-source representation may affect curtailment calculations. This is true; Figure 18 shows different indicated ground-water acreage in various regions, by method. While this will not affect calibration, it would affect curtailment estimates. There are a few points to keep in mind regarding curtailment:*
>
> 1. *There is no strong technical indication that any one method is more technically correct than another.*
>
> 2. *Modeling decisions should be based on modeling and calibration considerations.*
>
> 3. *What would actually happen on mixed-source lands under curtailment depends on the ability of users to obtain replacement surface-water supplies and the infrastructure to use them on mixed-source lands. These factors probably introduce far more uncertainty into considerations of curtailment than the differences between these methods.*
>
> 4. *There is no particular reason that IDWR in its curtailment analysis must follow the methods used in model calibration.*

There are approximately 300,000 acres of mixed source lands in the ESPAM 2.1, and a summary of the amount of mixed source acres in selected canal service areas near Rangen is provided in

Table 2-4. The errors in specifying the portion of those lands that are irrigated with ground water will impact the number of ground water irrigated acres in the curtailment run.

In addition, if there was curtailment, it is likely that the owners of the curtailed wells would seek to irrigate their lands from surface water sources or senior ground water sources, and this would reduce the number of acres that would actually be removed from irrigation under a curtailment order. Curtailing ground water use on a parcel would reduce the consumptive use of ground water and this would ultimately result in greater spring flows and river reach gains. However, if the owner of the curtailed well was able to continue irrigation of all or a portion of the parcel that was previously irrigated by the junior well there would be no net change in the irrigation water budget, no net increase in the ground water supply, and ultimately no increase in spring flows and river reach gains as a result of curtailment of the junior ground water use on that parcel. This could occur either by (a) more efficient use of existing surface water supplies, or (b) increased use of senior ground water supplies.

The foregoing factors add considerable uncertainty to the 17.9 cfs annual average increased flow at the Curren Spring at steady state from curtailment of ground water rights junior to July 13, 1962 that is predicted by ESPAM 2.1.

2.6 Compliance of Rangen Measurements with IDWR Measurement Standards

IDWR Opinion (p. 58-60)

Rangen submitted annual water measurement reports directly to IDWR from 1995 through 2009, and to Water District 36A from 2010 to 2012. IDWR has accepted these annual water measurement reports during this period of record understanding that Rangen estimates hatchery diversions or flows using fish raceway check boards as non-standard weir measuring devices.

Measurement of flow through the hatchery using 2-inch rectangular stop logs or check dam boards (check boards) is not considered a standard methodology of measurement because the check board weirs are not considered standard measurement devices. IDWR's Minimum Acceptable Standards for Open Channel and Closed Conduit Measuring Devices specify that construction, installation and operation of open channel measuring devices, including contracted rectangular weirs and suppressed rectangular weirs, should follow published guidelines such as those published by the United States Bureau of Reclamation (USBR, 1997).

Although the raceway check boards are not considered standard measuring devices, IDWR accepts measurements using these structures at many hatcheries in the area given that IDWR's standards allow an accuracy of +/-10 percent for open channel measuring devices when compared to measurements using standard portable measuring devices. Many of the area hatcheries have long used raceway check board structures for measuring devices out of convenience and lack of any other installed standard type devices. Some hatchery operators have not installed standard measuring devices due to lack of suitable measurement locations and added costs associated with installing standard devices. IDWR has not calibrated or compared the Rangen raceway check board measurements against standard portable measuring device measurements due to the lack of suitable locations within the hatchery where flows can be measured with portable measuring equipment. However, IDWR staff has compared portable discharge measurements against check board structures at other hatchery and irrigation diversions in both the Hagerman area and other locations in Idaho. IDWR has found those check board measurements, when used with the standard suppressed rectangular weir equation11 and acceptable head measurements are typically within +/- 10 percent of standard portable flow meter measurements.

Response

IDWR has published "Minimum Acceptable Standards for Open Channel and Closed Conduit Measuring Devices" ("Measurement Standards"). A copy of the most recent version of the Measurements Standards, dated February 7, 2013, is provided in Appendix A. The Measurement Standards provide that surface water diversions may be measured with either "standard" or "non-standard" open channel measuring devices. Standard devices consist of weirs, flumes, submerged orifices, or acoustic measuring devices that are constructed, installed and operated in accordance with published guidelines. As described above, IDWR does not consider raceway check dam boards, such as are used at Rangen, to be standard measuring devices.

In the absence of standard devices, the Measurement Standards provide that "IDWR may authorize non-standard 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 standard portable open channel measuring device." There has been no evidence presented that the rating tables used by Rangen for determination of the flow in the raceways or at the Lodge Dam in Billingsley Creek were developed through calibration against any flow measurements. No one seems to know the source of Rangen's rating tables.

The discharge coefficients that are implicit in the Rangen rating tables are irregular and contain two unexplainable jumps in values at head of 2-1/4 inches and 4 inches. Graphs illustrating the discharge coefficients for the CTR Raceways and the Lodge Dam are shown in Figures 1-5 and 1-6 of Pocatello's February 7, 2013 Expert Rebuttal Report. Subsequent to preparation of the Expert Rebuttal Report it was discovered that the weir discharge coefficients for the Lodge Dam that were listed in Table 1-5 and plotted in Figure 1-6 were incorrect. Corrected versions of Table 1-5 and Figure 1-6 are provided in Appendix B. The implied coefficients for the Lodge Dam continue to exhibit the irregular shape described above.

Because Rangen's measuring devices are not standard and have not been calibrated, they do not comply with IDWR's Measurement Standards. IDWR's ability to accurately evaluate the Rangen Call is hampered because the water measurements upon which Rangen relies for the proposition that it is short of water are derived from methods and measurements that do not comply with IDWR's Measurement Standards, and, for reasons described below, these measurements are likely incorrect.

2.7 Location of Head Measurement

IDWR Opinion (p. 60)

In her memo dated December 15, 2003, Cindy Yenter, Water District 130 watermaster, states the following:

> *"My experience has been that measurements taken at flat-crested dam boards are generally less accurate than those taken at sharp crested weirs, and that flat crested dam measurements return indications of flow which are typically 5-10% lower than actual flow, when checked against other methods of measurement."*

The Yenter memo further states that the sum of the IDWR staff measurements of the CTR raceways and Lodge dam on November 25, 2003 was 10 percent higher than the measurements taken by the Rangen staff a day earlier12. The memo was the basis for of Finding of Fact No. 76 in the May 19, 2005 Second Amended Order issued by Director Dreher which states in part that "...measurement of flows through hatchery raceways reported by Rangen may be systematically about 10 percent lower than actual flows." The Yenter memo suggests that the difference may be due largely to methods in measuring the head above the weir crest between IDWR and hatchery staff. Yenter notes that the proper location for measurement of head is upstream from the weir crest. Sullivan (2013, p. 11-12) correctly states that the head measurement for a standard weir

should be upstream of the weir crest a distance of at least four times the maximum head on the crest. Yenter (2003) states that if it is not possible to obtain a proper upstream head measurement, "the proper technique for using a hand held staff gage directly on the crest is to turn the surface of the gauge into the flow slightly, to overcome the drawdown (over the crest) and simulate a true head reading." This method of measuring head on a weir is described in more detail in Brockway (2013) on pages 4-5. The description provided by Brockway is consistent with the methodology used by IDWR staff. IDWR rarely finds that staff gages are installed in the proper location for either standard or non-standard weirs. The method described by Yenter and Brockway therefore is used extensively by IDWR staff when measuring head at weirs found in the field where no staff gage is installed or gages are not installed in the proper location.

Response

When Pocatello's Expert Rebuttal Report was prepared, the available evidence suggested that the Rangen staff was measuring the head over the raceway check boards using a metal ruler placed on top of the dam boards with the long edge of the ruler parallel to the direction of flow. This is shown in Figure B-11 of Appendix B of Pocatello's Expert Rebuttal Report. As described in the report, measuring the head in this manner would result in substantial under measurement of the flow by up to 35 percent based on information published by the U.S. Bureau of Reclamation.

Subsequent to preparation of Pocatello's Expert Rebuttal Report, Pocatello obtained additional information and also deposed Rangen and IDWR witnesses. Information from these sources indicates that Rangen measures the head over the raceway check dams with the long edge of the metal ruler placed perpendicular to the direction of flow. When the ruler is placed on the check board in this manner, the flow of water "runs up" the ruler to a level close to the level that would be measured if the measurement took place at the standard location upstream of the dam a distance of at least four times the measured head. This method of measuring the flow has been described as "sticking the weir" by some of the Rangen and IDWR experts. Based on this understanding, the extent of Rangen's under measurement of flow caused by the location of the measurement would be much less than described in Pocatello's Rebuttal Expert Report. However, as described below, Rangen's flow measurements and methodology are still of concern.

Further, while sticking the weir can provide an estimate of the head over a weir, it is not as accurate as a standard staff gage located upstream of the weir. The USBR reports that "the errors involved [in sticking the weir] are always such as to make the measurement low." (USBR, 1970).

2.8 Rangen Rating Table

IDWR Opinion (p. 60-65)

The other source of discrepancy between the IDWR and Rangen staff measurements noted in Yenter (2003) is the use of different weir equations or rating tables. IDWR used the standard suppressed weir equation (Francis equation), Q = 3.33 L H1.5, where Rangen used a rating table based on a modified weir equation. The table used by Rangen is found in Appendix A of the Brockway report dated December 20, 2012. This same table was also found in IDWR's records (attached) and appears to have been faxed to the IDWR Southern Region office on December 18, 2003 by Rangen staff. The table includes a rating for the Large raceways, the CTR raceways and the Lodge dam. The Large and CTR raceway ratings employ a fixed length weir crest even though the crest lengths at individual raceways vary slightly in size.

Page 9 of Brockway (2012) indicates that the Rangen rating table "appears to match most closely with a standard rectangular contracted weir formula with a coefficient of 3.09 rather than the typical 3.33 coefficient." IDWR staff note that use of this formula with the 3.09 coefficient yields values that are slightly different than the values in the Rangen table. Columns 5 and 6 of Tables 1-3 through 1-5 in the SWE rebuttal report show the coefficients derived from both the suppressed weir and contracted weir equations using the Rangen rating table. As seen in Tables 1-3 through 1-5 the coefficients used in the Rangen rating table range from 2.85 to 3.20.

IDWR maintains that without the installation of a standard measuring device, it is more appropriate to use the USBR sharp crested weir formula with a coefficient of 3.33 for estimating flows over the Rangen raceway check boards.

IDWR concurs with Sullivan (2013, p. 8) that the Rangen check boards do not conform to specifications of sharp crested weirs, contracted rectangular weirs, suppressed rectangular weirs or broad crested weirs. IDWR further concurs with Mr. Sullivan that use of the standard weir equation to compute flow does not result in the most accurate measurement of raceway discharges and that "it is appropriate to calibrate the weirs based on flow measurements to establish empirical rating tables that describe the relationship between discharge and measured head." However, IDWR continues to recommend the use of the standard suppressed weir equation at raceway check board dams with a coefficient of 3.33 since neither weir calibrations nor standard measurement devices exist at the Rangen Hatchery. If Mr. Sullivan recommends use of the Hybrid weir equation and coefficients, then IDWR notes that there is no difference in discharges between the Hybrid and standard suppressed weir equations for heads greater than 0.25 ft. Similarly, there is very little difference in discharge between the Hybrid Weir and the

Rangen discharge tables for heads less than 0.25 ft (differences are between +0.8 to -6.8 % for CTR and Large Raceways).

On page 13, Sullivan (2013) argues, "The actual amount of any under-measurement of flow can be determined by conducting discharge measurements in the raceways and in Billingsley Creek using a current meter at various discharges to establish a calibrated rating table for each structure." In the opinion of IDWR staff, it is difficult to obtain good, accurate measurements of discharge at or near the Rangen facility for calibrating the check board measurements, because flow and/or cross-sectional conditions are less than ideal. The USGS periodically measures the discharge in Billingsley Creek just downstream of the Rangen hatchery, but subjectively rates most of the measurements "fair" or "poor" indicating that USGS water measurement experts also found that flow and/or cross-sectional conditions in Billingsley Creek are not ideal and contribute to measurement error.

Response

IDWR recommends use of the standard suppressed weir equation with a coefficient of 3.33 for computing the flow over the raceway check boards at the Rangen facility. Presumably this recommendation also extends to computation of the flow at the Lodge Dam. In their March 22, 2013 Corrections to the Rangen Expert Report submitted by Charles E. Brockway, Dave Colvin, and Jim Brannon on December 20, 2013 'Expert Report in the Matter of Rangen Inc. – Availability of Spring Flow and Injury to Water Rights" ("Corrected Report"), the Rangen experts now recommend use of a suppressed weir equation with a coefficient of 3.33 to compute the Rangen flows.

The IDWR experts also opine that "it is appropriate to calibrate the weirs based on flow measurements to establish empirical rating tables that describe the relationship between discharge and measured head." This opinion is consistent with the requirements of IDWR's Measurement Standards where non-standard measuring devices are used to measure open channel flows.

The IDWR experts recommend use of the standard suppressed weir equation with a coefficient of 3.33 to compute the Rangen flows because neither weir calibrations nor standard measurement devices exist at Rangen. They indicate that it is "difficult to obtain good accurate measurements

of discharge at or near the Rangen facility for calibrating the check board measurements because flow and/or cross-sectional conditions are less than ideal."

Despite less than ideal measuring conditions, the USGS has been periodically measuring the flow in Billingsley Creek immediately downstream of where the outfall from the Rangen facility enters the creek. The USGS staff reported that the measurements are made either upstream or downstream of the culvert that conveys the flow of Billingsley Creek under the entrance road into the Rangen facility. The measurement locations are depicted in Figure 2-3. The flow is measured using standard USGS procedures for current meter measurements. Prior to the measurement, the channel is cleared of vegetation. The flow velocity in the channel is measured at numerous locations across the channel and then the discharge is computed using the velocity-area method.

The USGS measures the Billingsley Creek flow as part of an effort to quantify the flow of the Curren Spring and other springs between Kimberly and King Hill. USGS spot measurements of the Curren Spring were obtained from the USGS for the period from 1970 to the present. Flow measurements were made every year in the spring (typically in March) and sometimes in the fall (typically in November).

When the USGS makes a discharge measurement, the hydrographer typically will assign a "quasi-quantitative" accuracy rating to the measurement based on several factors including cross sectional uniformity, velocity profile uncertainty, and computational procedure uncertainty. The following are the accuracy ratings used by the USGS, and the standard error associated with the rating[1]:

- Excellent (within 2 percent)
- Good (within 5 percent)

[1] Standard error is a statistical term that characterizes the estimated accuracy of a sample mean in representing the true value. The standard error is an amount (plus and minus), around the sample mean that defines a range of values that has a 68% probability of containing the true value. The standard error is computed as plus or minus one standard deviation around the mean value.

- Fair (within 8 percent)
- Poor (greater than 8 percent)

The USGS has performed quantitative studies of the error of discharge measurements and these studies have shown that the quasi-quantitative rating system that has been used by the USGS for many years is reasonable (Sauer and Meyer, 1992). Note that the above system for rating individual flow measurements is slightly different than the rating that the USGS gives to streamflow gage measurement records made at its stream gages[2].

A summary of the USGS measurements of the Billingsley Creek flow immediately downstream of Rangen is provided in Table 2-5, along with the measurement rating assigned by the USGS hydrographer. In some cases a rating was not assigned and this is denoted with a "U" in the table. Also shown in Table 2-5 are the measured flows reported by Rangen based on the sum of the measured flows at the check boards in the CTR Raceways and the Lodge Dam. The Rangen measurements in Table 2-5 are the flows measured closest in time to the USGS measurements. Prior to 1995, the Rangen measurements are reported as monthly average values, so the values in the table are the flows during the months of the USGS measurements. Starting in 1995, the flows were measured weekly with the date of the measurement reported. From 1995 to the present the Rangen values in Table 2-5 represent the measurements on the dates closest to the USGS measurements, generally within a few days. The differences between the USGS measurements and the Rangen measurements are also summarized in Table 2-5, expressed in cfs and percentages of the USGS measured flows.

Several graphs illustrating the USGS measurements and the corresponding Rangen measurements are shown in Figure 2-4. The upper graph in Figure 2-4 shows the Rangen measurements as a red squares and the USGS measurements as diamonds colored based on the USGS rating of the estimated accuracy of the measurement. The middle chart shows the difference between the USGS and the Rangen measurements as bars colored based on the

[2] The accuracy of USGS streamflow gaging records is classified based on a 95% confidence interval as follows: Excellent (within 5%), Good (10%), Fair (15%), and Poor (>15%).

accuracy of the measurement. Almost all of the measurement pairs show the Rangen measurement less than the corresponding USGS measurement. The lower chart in Figure 2-4 shows the percentage differences between the measurements. The measurement data illustrated in Figure 2-4 do not include the measurements that were made during the irrigation season in 1980 (5/19, 7/25, and 9/19) when the measurements may be affected by irrigation return flows accruing to Billingsley Creek between the Rangen measurements and the USGS measurement.

The differences between the Rangen and USGS measurements are summarized for various time periods in Table 2-6 in in cfs and percentage of the USGS measurement. Also shown in Table 2-6 is the 95% confidence interval for the percentage differences between the Rangen and USGS measurements.

Examination of the graphs of the measurement differences in Figure 2-4 shows that the pattern of consistent under-measurement of flows by Rangen began in 1980. As summarized in Table 2-6, from 1970 – 1979, the Rangen measurements of flow averaged 2.2% less than the corresponding USGS measurement. From 1980 – 2013, the Rangen measurements averaged 16.6% less than the USGS measurements. The reason for the shift in the magnitude of the differences is unknown.

From 1980 to the present, the magnitude of the differences in cfs between the Rangen and USGS measurements has generally increased and decreased with the fluctuation of the Rangen spring flow. However, the percentage difference between the Rangen and USGS measurements has been relatively steady.

The other statistics in Table 2-6 are for the period from 1980 – 2012 after the shift in the magnitude of the measurement differences. The following is a summary of the measurement comparisons in Table 2-6.

- Spring vs. Fall – The average difference between the USGS and Rangen flow measurements taken in the spring (14.6%) is similar to the average difference between the measurements in the fall (19.3%).

- Measurement Rating – The average differences between the Rangen measurements and the USGS measurements rated as Good (17.1%) and unrated (16.7%) are similar. The difference between the Rangen measurements and the USGS measurements rated as Poor averages 18.5%, but there are only three such measurements. The average differences for the Rangen measurements and the Fair USGS measurements averages 14.8%

- Before and After Weekly Rangen Data – After the weekly Rangen measurement data became available (including the date of the measurement) in 1995 it became possible to more closely match the date of the USGS measurement to the date of the Rangen measurement. Prior to 1995 the Rangen data were only available as monthly averages of the weekly flow measurements. However, there was little difference in the amount of the computed under-measurement before and after the weekly measurement data became available. The average under-measurement of 15.9% from 1980 – 1994 computed with the monthly Rangen data is similar to the average under-measurement of 15.8% from 1995 – 2013 computed with the weekly Rangen data.

- Before and After Change to Rangen Rating Table – As described below, the rating table used by Rangen to convert the head measurements at the check boards at the CTR Raceways and the Lodge Dam changed sometime between December 1998 and July 2003. Until December 1998 the average weir coefficient that was implicit in Rangen's reported measurements was in the range of 3.27 - 3.40. Starting in July 2003 through the present, the available measurement data reflect an implied weir coefficient in the range of 3.05 – 3.09. The current implicit weir coefficient is consistent with the rating table that was disclosed by Rangen and which was provided in Appendix A of the December 2012 Rangen Expert Report. Between December 1998 and July 2003, there are no measured head data available with which to determine the implicit average weir coefficient. Despite the apparent change in the rating table, the average difference between the Rangen and USGS measurements is similar prior to 1998 (15.4%) and after 2003 (13.0%). Note that there are only ten data points for the period that the new rating table has been in use.

The consistent and statistically significant differences between the Rangen and USGS measurements since 1980 is evidence that Rangen has been systematically under-measuring the combined flow in the CTR raceways and in Billingsley Creek at the Lodge Dam for over 30 years.

The availability of a long period of record of USGS spot measurements are a ready source of data that can be used to develop a calibrated weir coefficient that can be used by Rangen to improve its flow measurements and to eliminate the consistent under-measurement of flows that has been occurring for several decades. The process for developing a calibrated weir coefficient involves solving the standard suppressed weir equation for the discharge coefficient using the USGS flow measurements at the Rangen head measurements.

The following is the standard weir equation

$$Q = C \times L \times H^{1.5}$$

where

Q = flow (cfs)
C = weir coefficient
L = weir length (feet)
H = head over weir (feet)

Expanding the weir equation to compute the combined flow through the three flow bays at the bottom of the CTR raceway and the flow at the Lodge Dam yields the following equation,

$$Q = (C_1 \times L_1 \times H_1^{1.5}) + (C_2 \times L_2 \times H_2^{1.5}) + (C_3 \times L_3 \times H_3^{1.5}) + (C_4 \times L_4 \times H_4^{1.5})$$

where, subscripts 1-3 refer to the measurements made over the three sets of check boards in the CTR raceway and subscript 4 refers to the measurement made at the Lodge Dam.

Rearranging the equation to combine the weir coefficients for the individual flow bays into a composite average coefficient results in the following form of the weir equation,

$$Q = C_{avg} \times (L_1 \times H_1^{1.5} + L_2 \times H_2^{1.5} + L_3 \times H_3^{1.5} + L_4 \times H_4^{1.5})$$

Solving for the weir coefficient yields the following equation that can be used to compute an average weir coefficient for each set of measurements.

$$C_{avg} = Q / (L_1 \times H_1^{1.5} + L_2 \times H_2^{1.5} + L_3 \times H_3^{1.5} + L_4 \times H_4^{1.5})$$

The above equation was used to compute a discharge coefficient for the 14 spring and fall USGS measurements since 1989 for which there were Rangen head measurement data available. The results of this analysis are shown in Table 2-7. The average computed weir coefficient for all measurements is 3.62. All but one of these measurements were rated as fair or good by the USGS. The 95% confidence interval for the computed weir coefficient is plus or minus 0.14. This means there is a 95% probability that the true weir coefficient is within the range of 3.48 – 3.75. The weir coefficient of 3.33 proposed by IDWR and Dr. Brockway is outside the 95% confidence interval.

The procedure that is used by Rangen for computing the flows in the CTR Raceways and at the Lodge Dam should be modified to use the standard suppressed weir equation with a weir coefficient of 3.62. This will provide significantly more accurate measurements of the Rangen flow and will eliminate the systematic under-measurement of the Rangen flows that has been occurring for the last 30 years.

The foregoing procedure for computing an average composite discharge coefficient for Rangen is the same procedure that was used by Dr. Brockway to compute the weir coefficient that he developed for use at the Rimview Trout Hatchery. In that case, Dr. Brockway computed a composite weir coefficient of 3.68 using head measurements at 42 raceway flow bays and a single measurement of the combined flow made on March 9, 1979. Documentation of the Rimview analysis was provided by Dr. Brockway at his deposition on March 6, 2013.

The proposed Rangen weir coefficient of 3.62 developed from the USGS flow measurements is similar to the Rimview weir coefficient of 3.68. Given that the procedure for developing a calibrated weir coefficient from a single flow measurement was deemed adequate for Rimview, the proposed weir coefficient for Rangen described above using the same procedure with fourteen flow measurements should also be acceptable.

Use of a calibrated weir coefficient (3.62) rather than the typical coefficient (3.33) for a sharp-crested weir will take into account the differences between the non-standard configuration of the Rangen flow measurements and a standard weir. Use of the calibrated coefficient with the suppressed weir equation will also conform to IDWR's Measurement Standards for non-standard open channel flow measurements.

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Figures

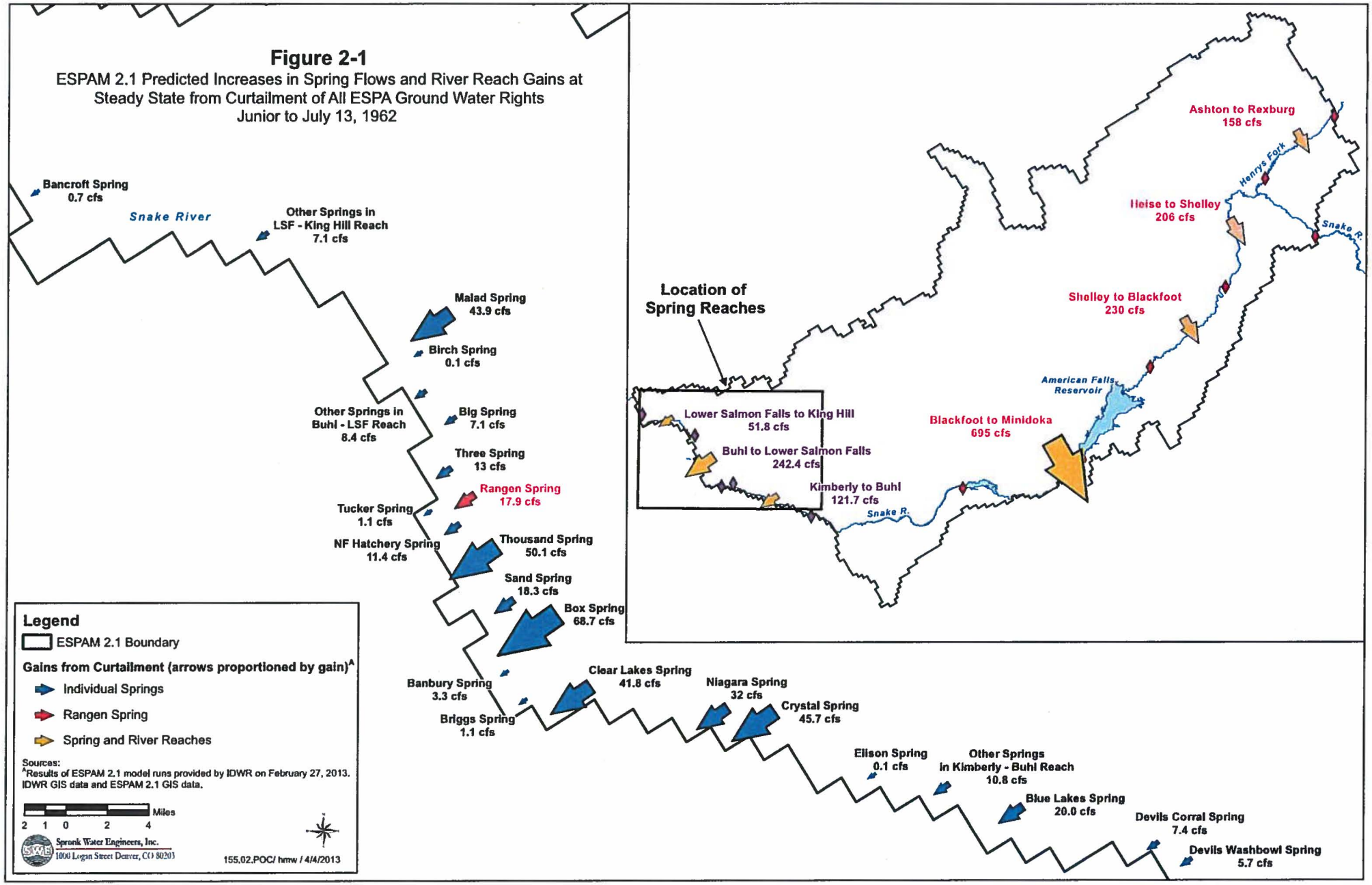
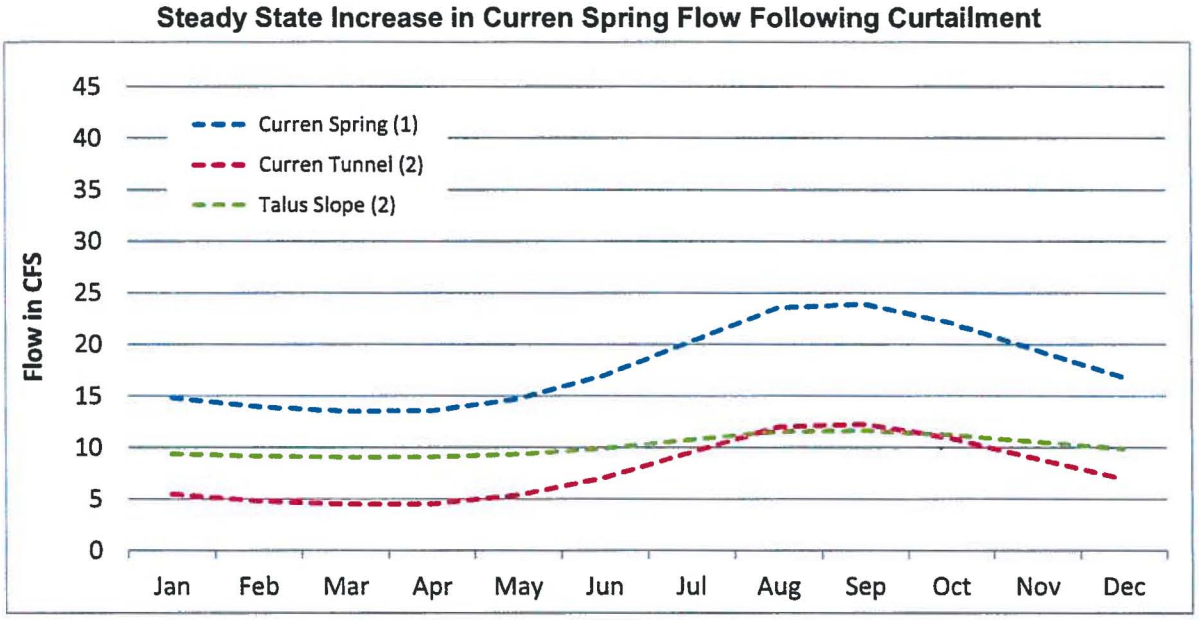


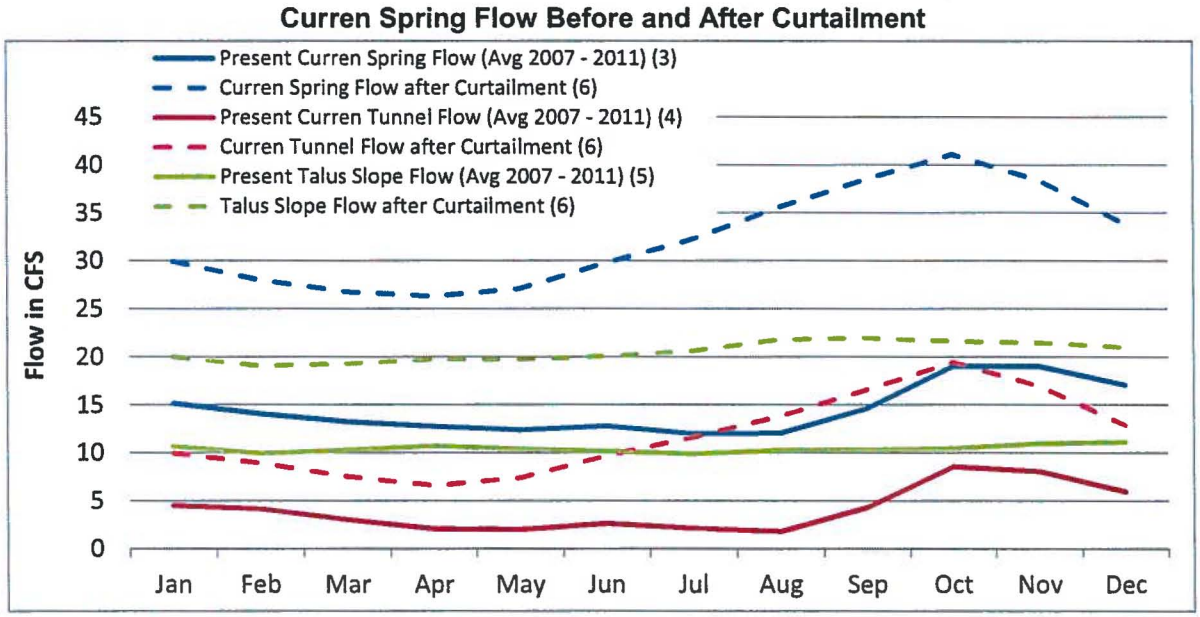
Figure 2-1

ESPAM 2.1 Predicted Increases in Spring Flows and River Reach Gains at Steady State from Curtailment of All ESPA Ground Water Rights Junior to July 13, 1962

Figure 2-2

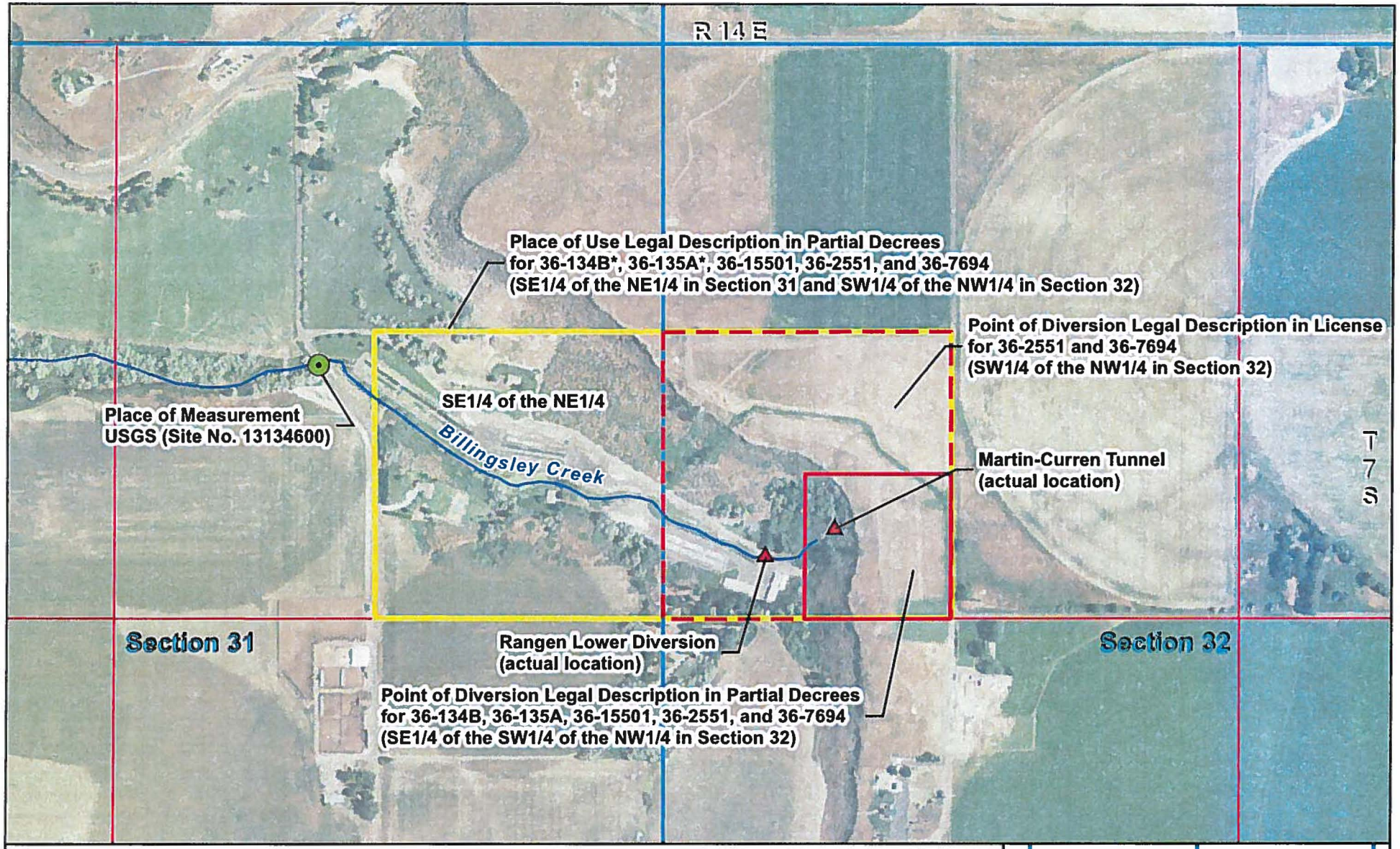
Predicted Increase in Curren Spring Flow at Steady State from Curtailment of Ground Water Rights Junior to July 13, 1962





Notes:

(1) ESPAM 2.1 Model results provided by AMEC for effect of curtailment after 80 years (~ steady state).
(2) Curren Tunnel increase calculated using Total Curren Spring vs. Curren Tunnel regression from Figure 3-9 (Brendecke Expert Report, 12/21/2012) and the predicted increase of the total Curren Spring (1). Talus slope increase is calculated to total Curren Spring increase minus Curren Tunnel increase.
(3) Monthly Rangen flow data provided by Rangen.
(4) Curren Tunnel flow data provided by IDWR.
(5) Calculated as present Curren Spring flow (3) minus present Curren Tunnel flow (4).
(6) Calculated as present flow (3, 4, 5) plus predicted increase in flow (1, 2).



*The place of use for 36-134B and 36-135A in the partial decrees includes the SW/4 of the NE/4 in Section 31.
Source:
IDWR GIS files (wr_pou and idhydro).
Partial Decrees and Licenses for Rangen Inc
PLSS GIS files for Gooding County, ID (BLM)
2011 USDA NAIP aerial photo for Gooding County, ID
USGS personal commications (March 2013).

Spronk Water Engineers, Inc.
1000 Logan Street Denver, CO 80203

Figure 2-3
Points of Diversion and Place of Use
1962 and 1977 Water Rights
Rangen Inc.

400 200 0 400 800 Feet

155.02.POC / hw / 4/4/2013

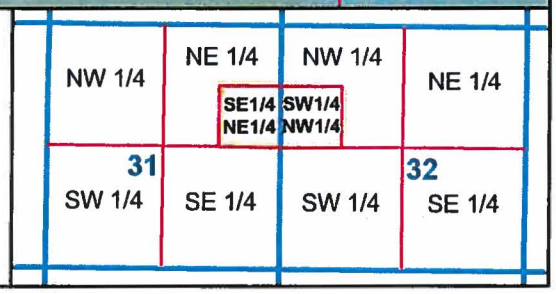
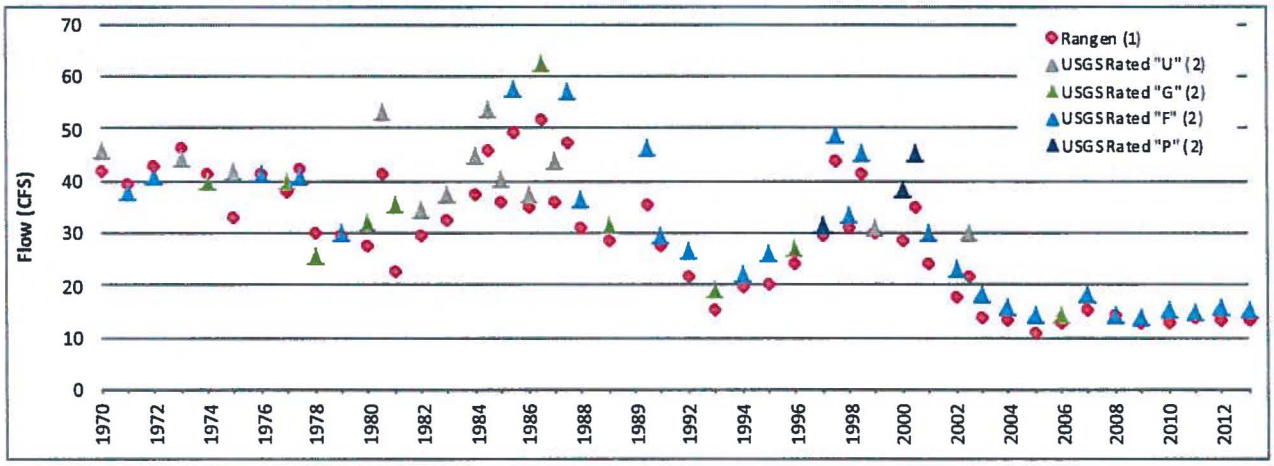
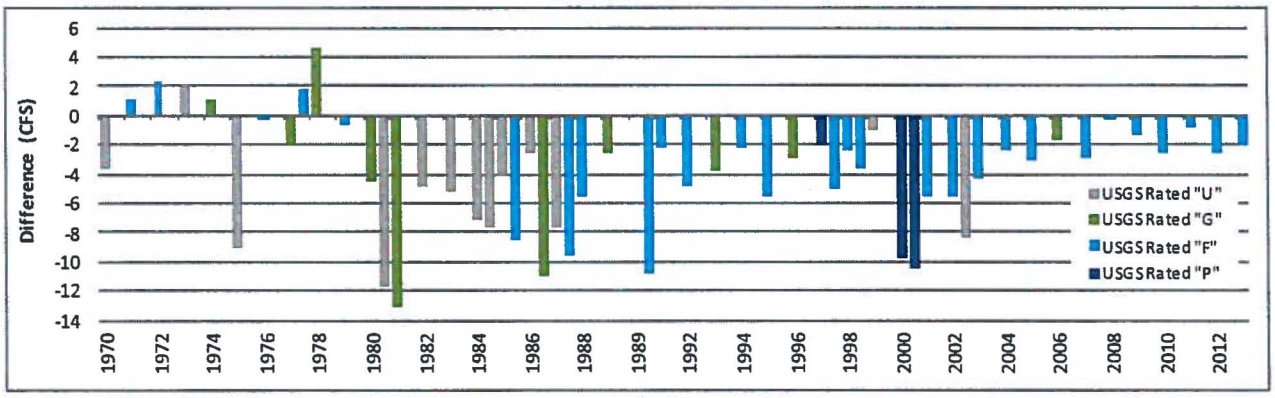


Figure 2-4

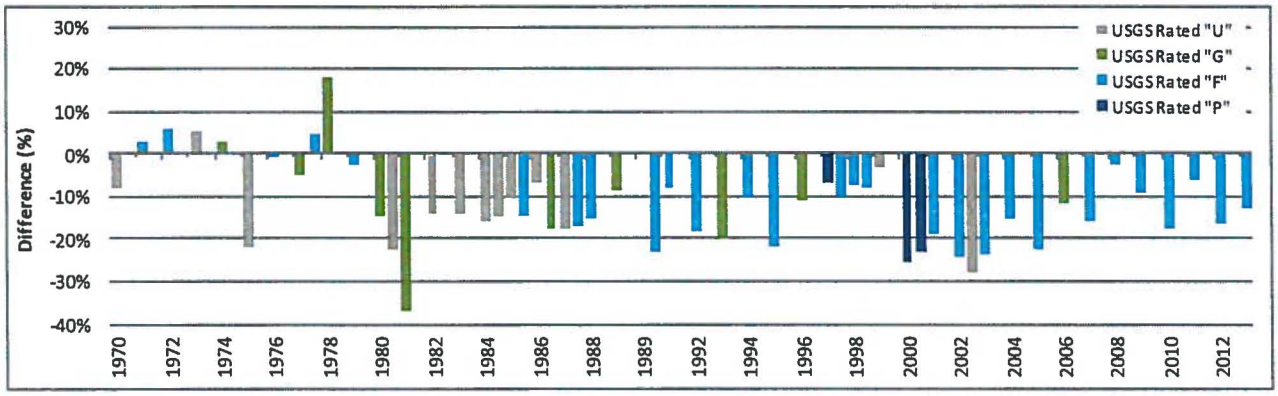
Comparison of Spring and Fall USGS and Rangen Flow Measurements
1970 - 2013



Rangen minus USGS (cfs)



% Difference (3)



Notes:

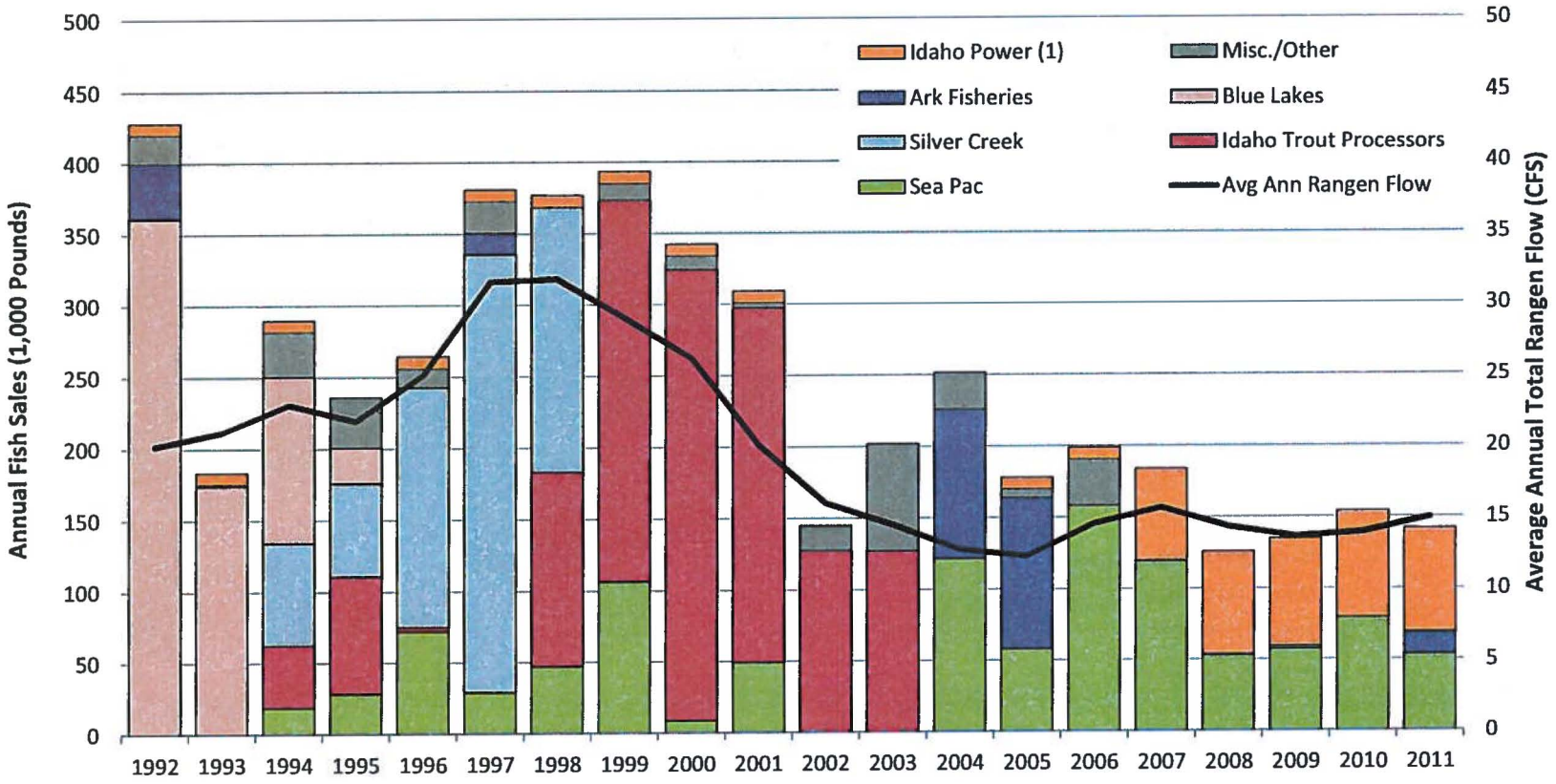
(1) Rangen measurements from 1970 - 1994 are monthly average flows during the month of the USGS measurements. Measurements from 1995 - 201
are spot measurements made during the same week of the USGS measurement.
USGS measurements during the 1980 irrigation season (5/19/1980, 7/25/1980, and 9/19/1980) are not shown.
November 1999 flow was removed as an outlier (Rangen = 38.3 cfs and USGS = 60.5 cfs).

(2) Daily spot measurements by the USGS that were made in the spring and fall (typically March and November through 2002 and in March only there
USGS measurement rating: G = Good (within 5%), F = Fair (8%), P = Poor (>8%), and U = Unrated.

(3) (Rangen - USGS) / USGS

Figure 2-5a

Annual Fish Sales
Rangen Hatchery (excluding Woods)
1992 - 2011



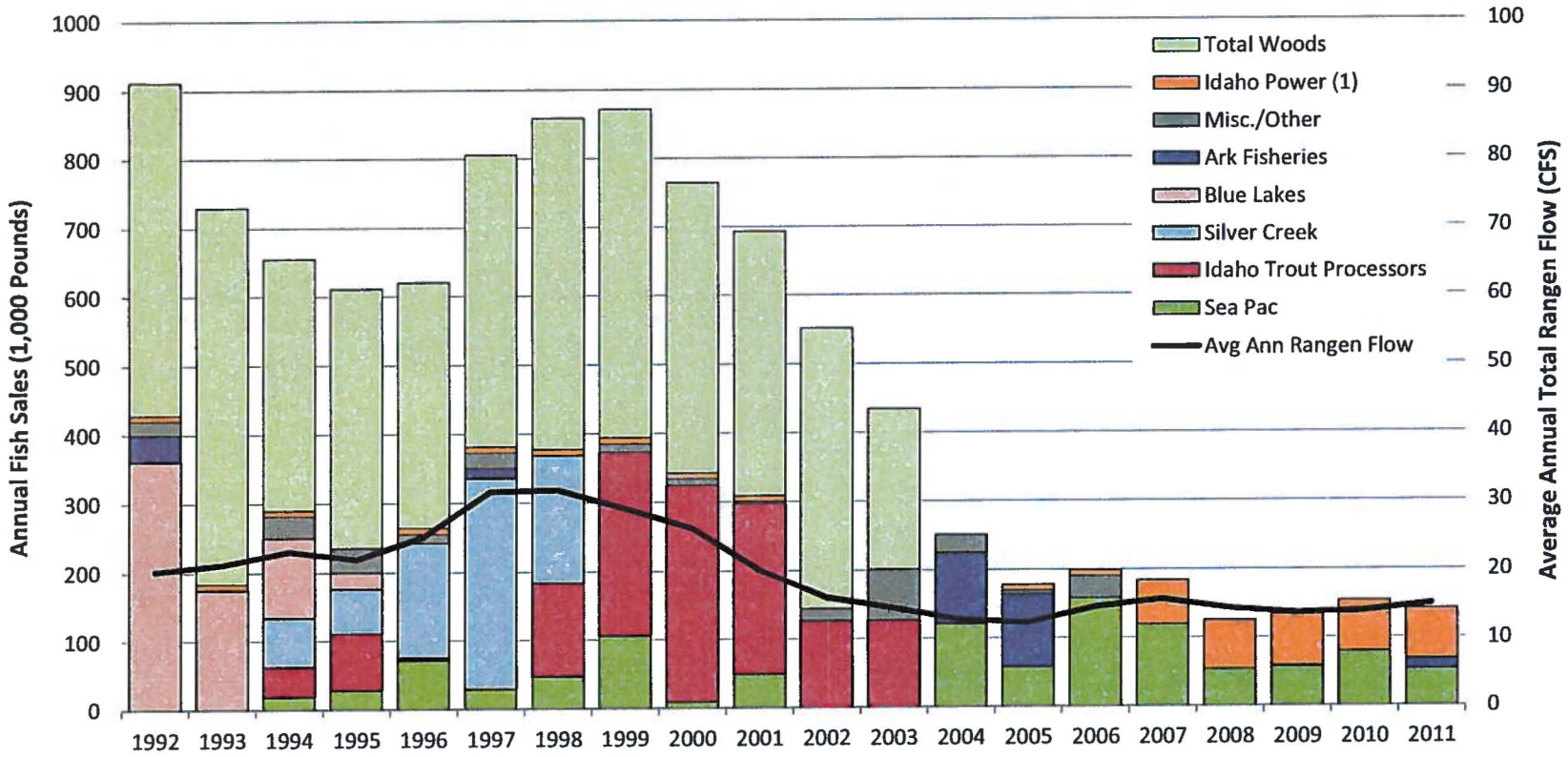
Notes:

(1) Idaho Power fish are conservation fish. All other fish are commercial fish.

(2) Data from Rangen fish sale summaries provided by Rangen.

Figure 2-5b

Annual Fish Sales
Rangen Hatchery (including Woods)
1992 - 2011



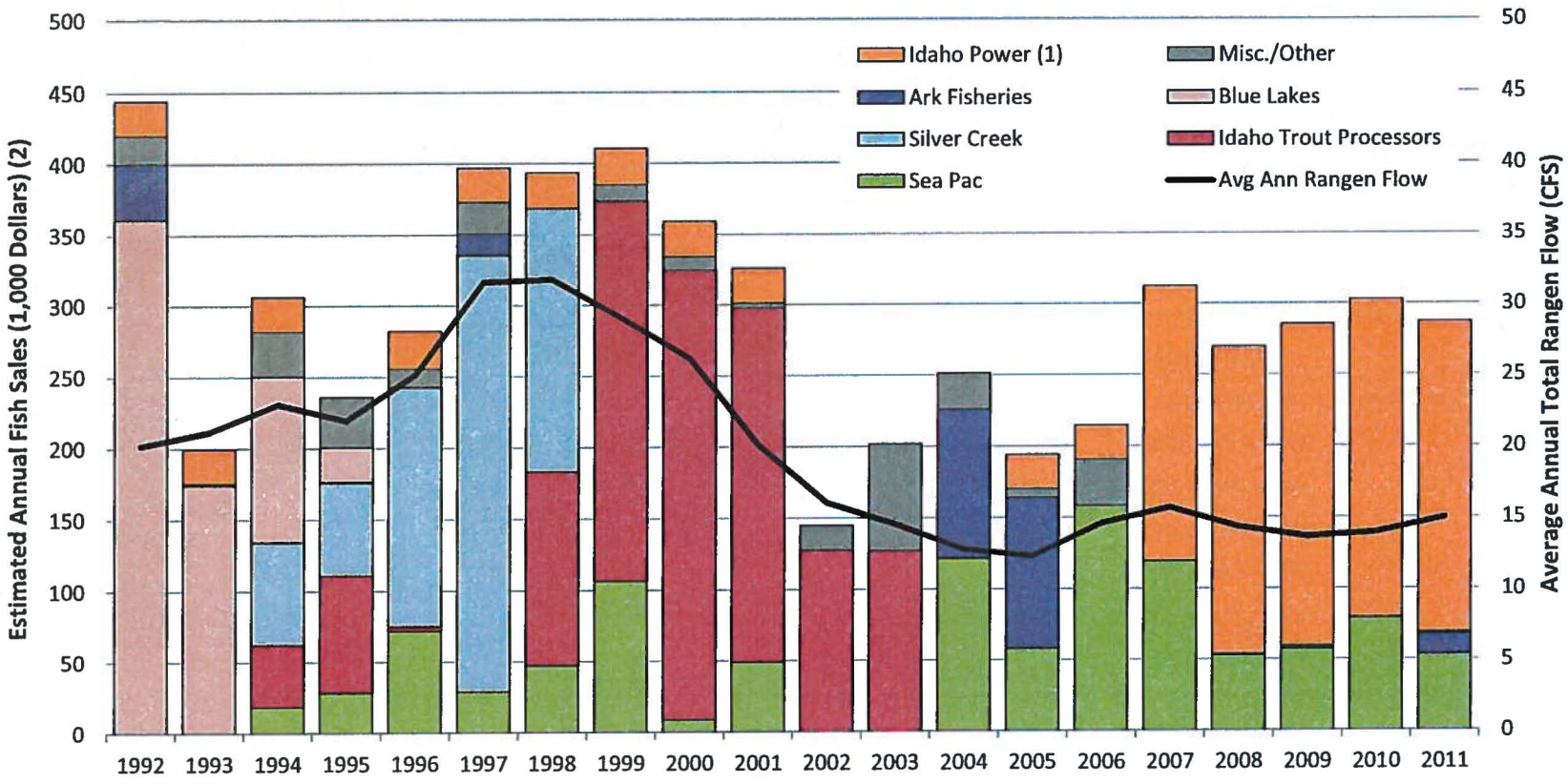
Notes:

(1) Idaho Power fish are conservation fish. All other fish are commercial fish.

(2) Data from Rangen fish sale summaries provided by Rangen.

Figure 2-5c

Annual Fish Sales
Rangen Hatchery (excluding Woods)
1992 - 2011



Notes:

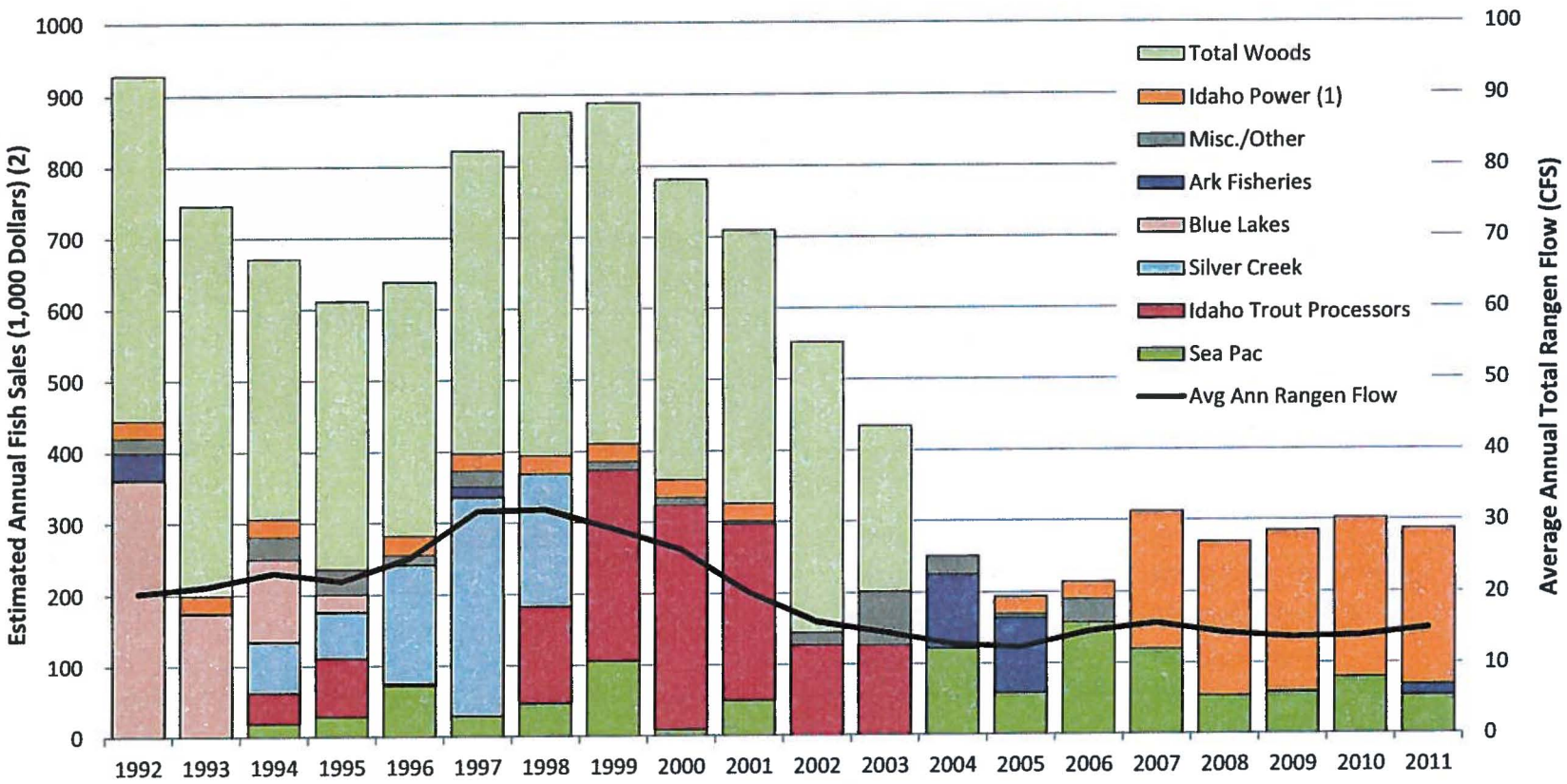
(1) Idaho Power fish are conservation fish. All other fish are commercial fish.

(2) Present value of fish sales estimated as $1 per pound for commercial fish and $3 per pound for conservation fish.

(3) Data from Rangen fish sale summaries provided by Rangen.

Figure 2-5d

Annual Fish Sales
Rangen Hatchery (including Woods)
1992 - 2011



Notes:

(1) Idaho Power fish are conservation fish. All other fish are commercial fish.

(2) Present value of fish sales estimated as $1 per pound for commercial fish and $3 per pound for conservation fish.

(3) Data from Rangen fish sale summaries provided by Rangen.

Tables

Table 2-1

Predicted Increase in Flow at Steady State from Curtailment of All ESPA Ground Water Rights Junior to July 13, 1962

	Increased Flow (cfs)	Increased Flow (% Total)
Spring Reach: Kimberly to Buhl		
Niagara	32.0	1.9%
Crystal	45.7	2.7%
Blue Lakes	20.0	1.2%
Elison	0.1	0.0%
Devils Corral	7.4	0.4%
Devils Washbowl	5.7	0.3%
Other Springs	10.8	0.6%
Total Kimberly to Buhl	**121.7**	**7.1%**
Spring Reach: Buhl to Lower Salmon Falls		
Clear Lakes	41.8	2.5%
Briggs	1.1	0.1%
Banbury	3.3	0.2%
Box	68.7	4.0%
Sand	18.3	1.1%
Thousand	50.1	2.9%
NF Hatchery	11.4	0.7%
Rangen	17.9	1.0%
Tucker	1.1	0.1%
Three	13.0	0.8%
Big	7.1	0.4%
Birch	0.1	0.0%
Other Springs	8.4	0.5%
Total Buhl to Lower Salmon Falls	**242.4**	**14.2%**
Spring Reach: Lower Salmon Falls to King Hill		
Bancroft	0.7	0.0%
Malad	43.9	2.6%
Other Springs	7.1	0.4%
Total Lower Salmon Falls to King Hill	**51.8**	**3.0%**
River Reaches		
Ashton to Rexburg	158	9.3%
Heise to Shelley	206	12.1%
Shelley to Near Blackfoot	230	13.5%
Near Blackfoot to Minidoka	695	40.8%
Total (All Reaches)	**1,705**	**100.0%**

Source:
Results of ESPAM 2.1 model runs provided by IDWR on February 27, 2013.

Table 2-2
Summary of Decreed Spring Diversions
in ESPAM 2.1 Spring Cells

		(1) No. of Water Rights	Kimberly to Buhl (cfs)	Buhl to Lower Salmon Falls (cfs)	Lower Salmon Falls to King Hill (cfs)	Total (cfs)
(2)	All Springs	279	1,002	2,501	26	3,528
(3)	Springs Junior to Rangen	84	976	1,302	17	2,295
(4)	Springs Senior to Rangen	195	26	1,199	8	1,233
(5)	**Increased Flow from Curtailment (steady state)**		**122**	**242**	**52**	**416**

Source:

IDWR points of diversions GIS file overlaid onto IDWR ESPAM 2.1 Spring Cells GIS coverage and limited to water sources that are springs (i.e., contains "spring" in the name).

Notes:

(1) Number of individual water right ID's with springs as the water source.
(2) Sum of water rights for all springs (decreed).
(3) Total junior to Rangen (July 13, 1962).
(4) Total senior to Rangen (July 13, 1962).
(5) Results of ESPAM 2.1 model runs provided by IDWR on February 27, 2013.

Table 2-3

Predicted Increase in Curren Spring Flow at Steady State from Curtailment of Ground Water Rights Junior to July 13, 1962

Values in CFS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Steady State Increase in Curren Spring Flow after Curtailment			Curren Spring Flow Before and After Curtailment					
				Curren Spring		Curren Tunnel		Talus Slope	
Month	Curren Spring	Curren Tunnel	Talus Slope	Present Flow (2007 - 2011)	After Curtailment (Steady State)	Present Flow (2007 - 2011)	After Curtailment (Steady State)	Present Flow (2007 - 2011)	After Curtailment (Steady State)
Jan	14.8	5.5	9.3	15.1	29.9	4.5	10.0	10.6	20.0
Feb	13.9	4.8	9.1	14.1	28.0	4.1	8.9	9.9	19.1
Mar	13.5	4.5	9.0	13.2	26.8	3.0	7.5	10.2	19.3
Apr	13.6	4.5	9.0	12.7	26.3	2.1	6.6	10.7	19.7
May	14.7	5.4	9.3	12.4	27.1	2.0	7.4	10.4	19.7
Jun	17.0	7.1	9.9	12.8	29.8	2.6	9.7	10.2	20.0
Jul	20.2	9.5	10.7	12.0	32.2	2.1	11.6	9.9	20.6
Aug	23.5	12.0	11.5	12.0	35.6	1.8	13.8	10.2	21.8
Sep	23.9	12.3	11.6	14.6	38.5	4.3	16.6	10.3	21.9
Oct	22.1	10.9	11.2	19.0	41.1	8.6	19.4	10.4	21.6
Nov	19.4	8.9	10.5	19.0	38.4	8.1	17.0	10.9	21.4
Dec	16.8	7.0	9.9	17.0	33.8	5.9	12.9	11.1	21.0
Avg	17.8	7.7	10.1	14.5	32.3	4.1	11.8	10.4	20.5
Min	13.5	4.5	9.0	12.0	26.3	1.8	6.6	9.9	19.1
Max	23.9	12.3	11.6	19.0	41.1	8.6	19.4	11.1	21.9

Notes:

(1) ESPAM 2.1 Model results provided by AMEC for effect of curtailment after 80 years (~ steady state).
(2) Curren Tunnel Flow calculated using Total Curren Spring vs. Curren Tunnel regression from Figure 3-9 (Brendecke Expert Report, 12/21/2012).
(3) Total Curren Spring flow (1) minus Curren Tunnel flow (2).
(4) Monthly Rangen flow data provided by Rangen.
(5) Increase in Curren Spring flow (1) plus present Curren Spring flow (4).
(6) Curren Tunnel flow data provided by IDWR.
(7) Increase in Curren Tunnel flow (2) plus present Curren Tunnel flow (6).
(8) Average total Curren Spring flow (4) minus average Current Tunnel flow (6).
(9) Increase in Talus Slope Flow (3) plus present Talus slope (8).

Table 2-4

Summary of Irrigated Acres in ESPAM 2.1 for Selected Canal Companies and Irrigation Districts

Values in Acres (1)

Irrigation District	Ground Water	Surface Water	Mixed	Total
North Side Canal Company	70,780	136,820	8,770	216,370
American Falls Reservoir District # 2	7,250	82,340	13,610	103,200
Minidoka Irrigation District	5,160	61,670	1,300	68,130
Burley Irrigation District	16,500	39,390	3,540	59,430
Milner Irrigation District	610	330	10,760	11,700
A&B Irrigation District	86,070	11,360	9,170	106,600
Aberdeen-Springfield Irrigation District	10,000	1,280	52,420	63,700
Total	196,370	333,190	99,570	629,130

Notes:

(1) ESPAM 2.1 irrigated lands in 2006 within the Irrigation District boundary.

Table 2-5

Comparison of USGS and Rangen Hatchery Flow Measurements 1970 - 2013

	(1) USGS Measurement Date	Flow (cfs)	(2) Rating	(3) Rangen Measurement (cfs)	(4) Rangen Head Measurement Available	(5) Measurement Difference (cfs)	(6) Measurement Difference (%)
	3/29/1970	45.7	U	42.0		-3.7	-8.1%
	3/30/1971	38.0	F	39.1		1.1	2.9%
	3/31/1972	40.7	F	43.0		2.3	5.7%
	4/5/1973	44.0	U	37.6		-6.4	-14.5%
	3/25/1974	40.0	G	41.1		1.1	2.8%
	3/10/1975	41.9	U	32.8		-9.1	-21.7%
	3/9/1976	41.5	F	41.1		-0.4	-1.0%
	2/28/1977	39.7	G	39.5		-0.2	-0.5%
	11/3/1977	40.6	F	42.4		1.8	4.4%
	3/28/1978	25.5	G	30.1		4.6	18.0%
	3/27/1979	30.0	F	29.3		-0.7	-2.3%
	3/25/1980	32.1	G	27.5		-4.6	-14.3%
(7)	5/19/1980	14.9	G	22.7		7.8	52.3%
(7)	7/25/1980	20.7	F	32.7		12.0	58.0%
(7)	9/19/1980	37.9	G	37.8		-0.1	-0.3%
	11/4/1980	52.9	U	41.1		-11.8	-22.3%
	3/9/1981	35.5	G	22.4		-13.1	-36.9%
	3/25/1982	34.5	U	29.7		-4.8	-13.9%
	3/14/1983	37.6	U	32.3		-5.3	-14.1%
	3/12/1984	44.5	U	37.4		-7.1	-16.0%
	11/12/1984	53.5	U	45.8		-7.7	-14.4%
	12/3/1984	52.4	F	44.1		-8.3	-15.8%
	3/21/1985	40.3	U	36.1		-4.2	-10.4%
	11/12/1985	57.6	F	49.1		-8.5	-14.8%
	3/19/1986	37.4	U	34.8		-2.6	-7.0%
	11/4/1986	62.5	G	51.5		-11.0	-17.6%
	3/16/1987	43.7	U	36.1		-7.6	-17.4%
	11/2/1987	57.0	F	47.4		-9.6	-16.8%
	3/21/1988	36.3	F	30.8		-5.5	-15.2%
	3/20/1989	31.3	G	28.7	Yes	-2.6	-8.3%
	11/6/1990	46.4	F	35.6		-10.8	-23.3%
	3/18/1991	29.6	F	27.3	Yes	-2.3	-7.8%
	3/3/1992	26.6	F	21.8		-4.8	-18.0%
	3/10/1993	19.2	G	15.4		-3.8	-19.8%
	3/7/1994	22.1	F	19.8		-2.3	-10.4%
	3/27/1995	25.9	F	20.3		-5.6	-21.6%
	3/11/1996	27.2	G	24.3	Yes	-2.9	-10.8%
	3/18/1997	31.6	P	29.5	Yes	-2.2	-6.8%
	11/17/1997	48.6	F	43.5	Yes	-5.1	-10.5%
	3/9/1998	33.6	F	31.2		-2.4	-7.2%

Table 2-5

Comparison of USGS and Rangen Hatchery Flow Measurements 1970 - 2013

	(1)	(2)	(3)	(4)	(5)	(6)
	USGS Measurement		Rangen	Rangen Head	Measurement	Measurement
	Flow		Measurement	Measurement	Difference	Difference
Date	(cfs)	Rating	(cfs)	Available	(cfs)	(%)
11/16/1998	45.1	F	41.4		-3.7	-8.2%
3/17/1999	31.1	U	30.1		-1.1	-3.4%
11/15/1999	60.5	U	38.2		-22.3	-36.9%
3/13/2000	38.2	P	28.5		-9.7	-25.5%
11/14/2000	45.2	P	34.7		-10.5	-23.1%
3/6/2001	29.8	F	24.2		-5.6	-18.7%
3/11/2002	23.1	F	17.6		-5.6	-24.0%
11/5/2002	29.9	U	21.5		-8.4	-28.2%
3/13/2003	18.1	F	13.8		-4.3	-23.7%
3/15/2004	15.8	F	13.4	Yes	-2.4	-15.2%
3/15/2005	14.2	F	11.0	Yes	-3.2	-22.5%
3/14/2006	14.3	G	12.6	Yes	-1.7	-11.9%
3/9/2007	18.0	F	15.1	Yes	-2.9	-16.1%
3/18/2008	14.4	F	14.0	Yes	-0.4	-2.8%
3/18/2009	13.9	F	12.6	Yes	-1.3	-9.4%
3/9/2010	15.3	F	12.6	Yes	-2.7	-17.4%
3/7/2011	14.7	F	13.8	Yes	-0.9	-6.1%
3/6/2012	15.7	F	13.2	Yes	-2.6	-16.2%
3/11/2013	15.2	F	13.2		-2.0	-13.0%
Avg 1970-2013	34.3		29.7		-4.6	-13.0%
Avg 1980-2013	33.2		27.7		-5.5	-15.9%
Avg 1995-2013	26.6		22.1		-4.6	-15.8%

Notes:

(1) USGS measurements below Rangen Hatchery (provided by the USGS).
November 1999 flow was removed as an outlier (Rangen = 38.3 cfs and USGS = 60.5 cfs).

(2) USGS measurement rating: G = Good (within 5%), F = Fair (8%), P =Poor (>8%), and U = Unrated.

(3) Rangen measurements from 1970 - 1994 are monthly average flows during the month of the USGS measurements.
Measurements from 1995 - 2012 are spot measurements made during the same week of the USGS measurement.

(4) Available head measurement data available for CTR Raceways and Lodge Dam.

(5) Rangen Hatchery measurement (3) minus USGS measurement (1).

(6) Difference (5) divided by USGS measurement (1).

(7) Irrigation season measurements made on 5/19/80, 7/25/80, and 9/19/80 were not included in the averages.

Table 2-6

Summary of USGS and Rangen Hatchery Spring and Fall Flow Measurements 1970 - 2013

		No. of Meas.	Avg USGS (cfs)	Avg Rangen (cfs)	Avg Difference (cfs)	Avg Difference (%)	Standard Deviation (%)	95% Confidence Level (%)	Confidence Range at 95% Lower End (%)	Confidence Range at 95% Upper End (%)
(1)	**All Data (before and after shift in magnitude of differences)**									
	1970 - 2013	56	34.3	29.7	-4.6	-13.0%	10.0%	± 2.6%	-15.6%	-10.4%
	1970 - 1979	11	38.9	38.0	-0.9	-1.3%	10.6%	± 6.3%	-7.6%	5.0%
	1980 - 2013	45	33.2	27.7	-5.5	-15.9%	7.6%	± 2.2%	-18.1%	-13.6%
(2)	**Spring vs. Fall (1980 - 2013)**									
	1980 - 2013	45	33.2	27.7	-5.5	-15.9%	7.6%	± 2.2%	-18.1%	-13.6%
	Spring	33	26.7	22.8	-3.9	-14.6%	7.3%	± 2.5%	-17.1%	-12.1%
	Fall	12	51.0	41.2	-9.8	-19.3%	7.9%	± 4.5%	-23.8%	-14.8%
(3)	**Measurement Rating (1980 - 2013)**									
	1980 - 2013	45	33.2	27.7	-5.5	-15.9%	7.6%	± 2.2%	-18.1%	-13.6%
	"G" Rating	10	31.7	26.1	-5.7	-17.1%	9.6%	± 5.9%	-23.0%	-11.1%
	"F" Rating	29	28.7	24.5	-4.3	-14.8%	6.1%	± 2.2%	-17.0%	-12.5%
	"P" Rating	3	38.3	30.9	-7.4	-18.5%	10.2%	± 11.5%	-30.0%	-7.0%
	"U" Rating	14	42.4	34.8	-7.5	-16.7%	9.5%	± 5%	-21.7%	-11.7%
(4)	**Before and After Weekly Rangen Data (1980 - 2013)**									
	1980 - 2013	45	33.2	27.7	-5.5	-15.9%	7.6%	± 2.2%	-18.1%	-13.6%
	1980 - 1994	21	40.6	34.0	-6.6	-15.9%	6.5%	± 2.8%	-18.7%	-13.2%
	1995 - 2013	24	26.6	22.1	-4.5	-15.8%	8.6%	± 3.5%	-19.2%	-12.3%
(5)	**Before and After Change in Rangen Rating Table (1980 - 2013)**									
	1980 - 2013	45	33.2	27.7	-5.5	-15.9%	7.6%	± 2.2%	-18.1%	-13.6%
	1980 - 1997	25	39.5	33.3	-6.2	-15.4%	6.5%	± 2.5%	-17.9%	-12.8%
	2004 - 2013	10	15.2	13.2	-2.0	-13.0%	5.8%	± 3.6%	-16.6%	-9.4%

Notes:

(1) From 1970 - 1979 differences between the USGS and Rangen measurements are positive or negative. After 1980, Rangen measurements are consistently less than USGS measurements.

(2) Spring vs. Fall measurements from 1980 - 2013.

(3) USGS measurement rating: G = Good (within 5%), F = Fair (8%), P = Poor (>8%), and U = unrated.

(4) Daily data available from Rangen after March 1995.

Table 2-7

Summary of Implicit Weir Coefficients for Rangen Measurements and USGS Measurements

	(1)	(2, 3) Measurement Details					(4, 5) Total Flow (cfs)		(6) Calculated C	
Entity	Date	BD	H_1 (in)	H_2 (in)	H_3 (in)	L (in)	Rangen	USGS	Rangen	USGS
Rangen	3/23/1989	BB	3 1/2	3 7/8	3 3/8	58.5				
		BD	4 1/4	4 1/2	4 3/4	58.5	28.70	31.30	3.64	3.97
		Dam	7 7/8			48				
USGS	3/20/1989	Billingsley Creek			Rating =	GOOD				
Rangen	3/5/1991	CA	4 1/8	4 1/8	3 7/8	58.5				
		CB	4	4	4	58.5				
		CD	3 1/2	3 3/4	3 7/8	58.5	29.97	29.60	3.40	3.36
		Dam	3 1/2			48				
USGS	3/18/1991	Billingsley Creek			Rating =	FAIR				
Rangen	3/11/1996	TA	3 3/8	4 1/8	4 1/2	58.5				
		TB	4 3/4	4 5/8	4 1/2	58.5	24.27	27.20	3.28	3.67
		Dam	5			48				
USGS	3/11/1996	Billingsley Creek			Rating =	GOOD				
Rangen	3/18/1997	TA	4 1/3	5 1/4	5 5/8	58.5				
		TB	4 1/4	4 1/2	4 1/2	58.5	29.45	31.60	3.28	3.52
		Dam	6 3/4			48				
USGS	3/18/1997	Billingsley Creek			Rating =	POOR				
Rangen	11/17/1997	TA	3 4/7	4 1/2	4 3/4	58.5				
		TB	5 1/8	5 1/8	5	58.5				
		TD	5 1/2	5 1/4	5 1/5	58.5	43.51	48.60	3.30	3.68
		Dam	7			48				
USGS	11/17/1997	Billingsley Creek			Rating =	FAIR				
Rangen	3/15/2004	TA	2 1/4	3	3 1/4	58.5				
		TB	3 3/8	3 7/8	3 1/8	58.5	13.44	15.80	3.05	3.59
		Dam	2 3/4			48				
USGS	3/15/2004	Billingsley Creek			Rating =	FAIR				
Rangen	3/14/2005	TA	3 1/2	4 1/8	4 1/2	58.5				
		Dam	3 3/4			48	10.94	14.20	3.07	3.98
USGS	3/15/2005	Billingsley Creek			Rating =	FAIR				
Rangen	3/13/2006	TD	4 7/8	4 3/4	4 1/2	58.5				
		Dam	3			48	12.61	14.30	3.08	3.49
USGS	3/14/2006	Billingsley Creek			Rating =	GOOD				
Rangen	3/12/2007	TB	4 3/4	4 3/4	4 1/2	58.5				
		Dam	4 3/8			48	13.69	18.00	3.09	4.06
USGS	3/9/2007	Billingsley Creek			Rating =	FAIR				
Rangen	3/17/2008	TD	4 3/4	4 1/2	4 1/4	58.5				
		Dam	5 1/4			48	13.96	14.40	3.09	3.19
USGS	3/18/2008	Billingsley Creek			Rating =	FAIR				
Rangen	3/16/2009	TA	3 3/4	4 1/2	4 7/8	58.5				
		Dam	4 1/4			48	12.53	13.90	3.07	3.41
USGS	3/18/2009	Billingsley Creek			Rating =	FAIR				
Rangen	3/8/2010	TB	4 3/4	4 3/4	4 1/2	58.5				
		Dam	3 1/4			48	12.66	15.30	3.08	3.72
USGS	3/9/2010	Billingsley Creek			Rating =	FAIR				
Rangen	3/7/2011	TB	4 7/8	4 7/8	4 5/8	58.5				
		Dam	4			48	13.79	14.70	3.09	3.30
USGS	3/7/2011	Billingsley Creek			Rating =	FAIR				
Rangen	3/5/2012	TA	4 1/4	4 3/4	5 1/4	58.5				
		Dam	3 1/2			48	13.15	15.70	3.07	3.67
USGS	3/6/2012	Billingsley Creek			Rating =	FAIR				
						Average =	19.48	21.76	3.19	3.62

Notes:

(1) Date of Rangen measurement and date of corresponding USGS measurement.

(2) Head measurements provided by Rangen and USGS rating provided by USGS.

(3) USGS rating of measurement error: G = Good (within 5%), F = Fair (8%), and P = Poor (>8%).

(4) Rangen flow determined by Rangen staff using measured heads in the CTR Raceway and Lodge Dam and corresponding rating table of unknown source.

(5) USGS flow measured by USGS personnel in Billingsley Cr. downstream of the confluence with the Rangen outfalls (Site No. 13134600).

(6) Weir coefficient derived using supressed weir equation: $Q\ (CFS) = C*L(ft)*H(ft)^{1.5}$

$$Q = C*(L_1*H_1^{1.5} + L_2*H_2^{1.5} + \ldots + L_n*H_n^{1.5})$$

Equation solved for weir coefficient: $C = Q / (L_1*H_1^{1.5} + L_2*H_2^{1.5} + \ldots + L_n*H_n^{1.5})$

Appendix A
IDWR Minimum Acceptable Standards for Open Channel and Closed Conduit Measuring Devices

STATE OF IDAHO
DEPARTMENT OF WATER RESOURCES (IDWR)

MINIMUM ACCEPTABLE STANDARDS FOR OPEN CHANNEL AND CLOSED CONDUIT MEASURING DEVICES

The source and means of diversion of water, whether surface or ground water, generally affects the selection of a measuring device. Surface water sources such as streams, springs and waste channels are normally diverted into open channels (ditches or canals), but closed conduits (pipes or culverts) are also used. Ground water is usually diverted into pipes (which may also discharge into open channels).

Measuring devices when required by IDWR are to be installed at or near the point of diversion from the public water source.

I. MEASUREMENTS IN OPEN CHANNELS

The following discussion is applicable only to diversions from surface water sources. Measurement of a ground water diversion with an open channel measuring device must be pre-approved by the IDWR.

A. Standard Open Channel Measuring Devices

All open channel surface water diversions should be measured using one of the following standard open channel flow measuring devices commonly used in Idaho:

- **Weirs:** contracted or suppressed rectangular weirs, Cipolletti weir, 90 degree V-notch weir
- **Submerged Orfices:** submerged rectangular orifice, constant head orifice
- **Flumes:** Parshall flume, trapezoidal flume, ramped flume (ramped, broad-crested weir)
- **Acoustic:** acoustic Doppler flow meter (ADFM), acoustic Doppler current profiler

The installed flow rate accuracy of open channel measurement devices must be +/- 10.0% as compared to an acceptable open channel current meter or other standard portable measuring devices such as an acoustic Doppler flow meter or acoustic Doppler current profiler.

Construction, installation and operation of these devices should follow published guidelines, such as those published by the United States Bureau of Reclamation[1]

B. Non-standard open channel devices: Rated Structures or Rated Sections

Any weir, flume, or other measuring device that has not been constructed, installed, or maintained correctly and therefore does not measure flow in the standard manner consistent with standard rating tables or curves is considered to be a non-standard device. IDWR may authorize the use of non-standard 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 standard portable open channel measuring device. Examples of standard portable open channel measuring devices include the acoustic Doppler flow meter, the acoustic Doppler current profiler, or a portable flume. These devices are acceptable provided they are installed and operated according to all relevant manufacturer recommendations.

Further information and requirements are available from IDWR upon request.

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[1] The Bureau of Reclamation measurement guidelines can be found at;
http://www.idwr.idaho.gov/WaterManagement/WaterMeasurement/PDFs/BoR_WMM_%202001revision.pdf

II. CLOSED CONDUIT MEASURING DEVICES

The following discussion is applicable to measurement of diversions from any water source that diverts via a full-flowing, closed conduit.

A. Standard Closed Conduit Measuring Devices

A certified meter is required on new installations of measuring devices for closed conduit or pipe line diversions. A certified meter is a model of flow meter that has participated in independent third party testing and has been approved by IDWR for use. IDWR has published a list of meters that have participated in independent third party testing[2] and have been certified for use where the installation configuration and application meet manufacturer's requirements. Tests were conducted for both accuracy and repeatability on all submitted models, and a pass/fail rating awarded. A list of these meters may be found at:

http://www.idwr.idaho.gov/WaterManagement/WaterMeasurement/PDFs/Approved_flow_meter_list.pdf.

Owners or operators who install a certified meter without the minimum manufacturer spacing requirements, or otherwise inconsistent with manufacturer's specifications, may need to provide an adequate testing section of straight pipe located somewhere on the diversion system either upstream or downstream of the installed flow meter. This testing section can be excavated pipeline as long as the section of pipe carries all water being measured through the installed flow meter. Water users choosing to expose pipe will be required to excavate the pipe at their expense at the request of the district hydrographer, watermaster and/or IDWR staff.

B. Non-standard Closed Conduit Measuring Devices: Requests for Variance

In some cases, site conditions preclude use of a certified meter, and another meter or method of measurement will produce similarly accurate results. In cases where the user can show that a proposed alternative meter or method would be as accurate as, or otherwise is better suited to an application than any of the meters on the approved list, a user can propose using an alternative meter or method by submitting a Request for Variance Form, available from IDWR. If a request is submitted and granted, the water user bears the risk that the alternative meter or method will perform as expected.

The following alternate measurement methods may be considered:

- Development of a Power Consumption Coefficient (PCC), which is a ratio of power usage to water withdrawal. Acceptance of the PCC method may be provided *for qualifying irrigation diversions only*;
- Use of an hour meter (time clock) *for qualifying diversions only*;
- Use of an acceptable flow meter that was installed *prior to the date of the measurement order*;
- *For irrigation diversions only,* use of an acceptable non-certified flow meter where it can be shown that installation of a certified flow meter would be burdensome or ineffective.

If a meter is already installed, that meter may be used if the meter is field-tested by IDWR staff, the water district watermaster, or a district hydrographer using a portable standard flow meter and upon a determination that the meter is installed properly and accurate to within ±10% of actual rate of flow and volume. If a non-certified meter is approved and installed but does not pass a field check, IDWR may require the water user to replace the meter with a certified meter at the water user's expense.

If an alternative method is approved and that method is later found to be insufficient, the variance will be withdrawn and a certified meter will be required to be installed. The suitability of any pumping station for an hour meter or the PCC method of measurement will be based on criteria found in this document and in the document entitled *IDWR ESPA Water Measurement and Reporting Guidelines*[3].

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[2] Testing was conducted at the Utah Water Research Laboratory (UWRL), a National Institute of Standards and Technology (NIST) traceable lab in Logan, Utah.

[3] This document can be found at:
http://www.idwr.idaho.gov/WaterManagement/WaterMeasurement/PDFs/IDWRESPA_WaterMeasurement_ReportingGuidlines.pdf

Appendix B
Updated Tables and Figures
2013 Expert Rebuttal Report

Table 1-5, Updated April 2013

Analysis of Rangen Rating Table

Lodge Dam

Width of Dam Openings (in) 48

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Coefficient (C) =			3.33	3.33	3.09	Calculated Discharge Coefficient (C) for		Weir Breadth (in)		2.00		
			Discharge (Q) for Standard Weirs					Discharge (Q) for Hybrid Weir			Rangen vs. Hybrid	
Water Level / Head (H) (inches)	Water Level / Head (H) (feet)	Rangen Discharge Table (cfs)	Suppressed Weir (cfs)	Contracted Weir (cfs)	Broad-Crested Weir (cfs)	Suppressed Weir Equation	Contracted Weir Equation	Head / Breadth (H/B)	Discharge Coefficient (C)	Hybrid Weir Discharge (cfs)	Rangen minus Hybrid (cfs)	Difference %
1	0.083	0.28	0.32	0.32	0.30	2.91	2.92	0.50	2.83	0.27	0.01	2.8%
1 1/8	0.094	0.33	0.38	0.38	0.35	2.87	2.89	0.56	2.85	0.33	0.00	0.9%
1 1/4	0.104	0.39	0.45	0.45	0.42	2.90	2.92	0.63	2.87	0.39	0.00	1.2%
1 3/8	0.115	0.45	0.52	0.51	0.48	2.90	2.92	0.69	2.88	0.45	0.00	0.6%
1 1/2	0.125	0.51	0.59	0.58	0.55	2.88	2.90	0.75	2.90	0.51	0.00	-0.6%
1 5/8	0.135	0.57	0.66	0.66	0.62	2.86	2.88	0.81	2.92	0.58	-0.01	-2.3%
1 3/4	0.146	0.64	0.74	0.74	0.69	2.87	2.89	0.88	2.95	0.66	-0.02	-2.6%
1 7/8	0.156	0.71	0.82	0.82	0.76	2.87	2.90	0.94	2.97	0.73	-0.02	-3.4%
2	0.167	0.78	0.91	0.90	0.84	2.87	2.89	1.00	3.00	0.82	-0.04	-4.5%
2 1/8	0.177	0.88	0.99	0.98	0.92	2.95	2.98	1.06	3.02	0.90	-0.02	-2.4%
2 1/4	0.188	1.01	1.08	1.07	1.00	3.11	3.14	1.13	3.05	0.99	0.02	2.0%
2 3/8	0.198	1.09	1.17	1.16	1.09	3.09	3.13	1.19	3.07	1.08	0.01	0.7%
2 1/2	0.208	1.18	1.27	1.25	1.18	3.10	3.13	1.25	3.11	1.18	0.00	-0.2%
2 5/8	0.219	1.26	1.36	1.35	1.26	3.08	3.11	1.31	3.14	1.29	-0.03	-2.0%
2 3/4	0.229	1.35	1.46	1.44	1.36	3.08	3.11	1.38	3.17	1.39	-0.04	-3.2%
2 7/8	0.240	1.44	1.56	1.54	1.45	3.07	3.11	1.44	3.21	1.50	-0.06	-4.5%
3	0.250	1.53	1.67	1.64	1.55	3.06	3.10	1.50	3.24	1.62	-0.09	-5.9%
3 1/8	0.260	1.62	1.77	1.75	1.64	3.05	3.09	1.56	3.28	1.74	-0.12	-7.6%
3 1/4	0.271	1.72	1.88	1.85	1.74	3.05	3.09	1.63	3.31	1.87	-0.15	-8.5%
3 3/8	0.281	1.81	1.99	1.96	1.84	3.03	3.08	1.69	3.32	1.98	-0.17	-9.4%
3 1/2	0.292	1.91	2.10	2.07	1.95	3.03	3.08	1.75	3.32	2.09	-0.18	-9.5%
3 5/8	0.302	2.01	2.21	2.18	2.05	3.03	3.07	1.81	3.32	2.20	-0.19	-9.7%
3 3/4	0.313	2.11	2.33	2.29	2.16	3.02	3.07	1.88	3.32	2.32	-0.21	-9.9%
3 7/8	0.323	2.32	2.44	2.40	2.27	3.16	3.21	1.94	3.32	2.44	-0.12	-5.0%
4	0.333	2.43	2.56	2.52	2.38	3.16	3.21	2.00	3.32	2.56	-0.13	-5.2%
4 1/8	0.344	2.53	2.68	2.64	2.49	3.14	3.19	2.06	3.32	2.68	-0.15	-5.8%
4 1/4	0.354	2.64	2.81	2.76	2.61	3.13	3.19	2.13	3.32	2.80	-0.16	-6.0%
4 3/8	0.365	2.75	2.93	2.88	2.72	3.12	3.18	2.19	3.32	2.92	-0.17	-6.3%
4 1/2	0.375	2.87	3.06	3.00	2.84	3.12	3.18	2.25	3.32	3.05	-0.18	-6.3%
4 5/8	0.385	2.98	3.19	3.13	2.96	3.11	3.17	2.31	3.32	3.18	-0.20	-6.6%
4 3/4	0.396	3.10	3.32	3.25	3.08	3.11	3.17	2.38	3.32	3.31	-0.21	-6.7%
4 7/8	0.406	3.21	3.45	3.38	3.20	3.10	3.16	2.44	3.32	3.44	-0.23	-7.1%
5	0.417	3.33	3.58	3.51	3.32	3.10	3.16	2.50	3.32	3.57	-0.24	-7.3%
5 1/8	0.427	3.45	3.72	3.64	3.45	3.09	3.16	2.56	3.32	3.71	-0.26	-7.4%
5 1/4	0.438	3.57	3.85	3.77	3.58	3.08	3.15	2.63	3.32	3.84	-0.27	-7.6%
5 3/8	0.448	3.69	3.99	3.90	3.71	3.08	3.15	2.69	3.32	3.98	-0.29	-7.9%
5 1/2	0.458	3.82	4.13	4.04	3.84	3.08	3.15	2.75	3.32	4.12	-0.30	-7.9%
5 5/8	0.469	3.94	4.27	4.17	3.97	3.07	3.14	2.81	3.32	4.26	-0.32	-8.2%
5 3/4	0.479	4.07	4.42	4.31	4.10	3.07	3.14	2.88	3.32	4.40	-0.33	-8.2%
5 7/8	0.490	4.20	4.56	4.45	4.23	3.07	3.14	2.94	3.32	4.55	-0.35	-8.3%
6	0.500	4.33	4.71	4.59	4.37	3.06	3.14	3.00	3.32	4.70	-0.37	-8.4%
6 1/8	0.510	4.46	4.86	4.73	4.51	3.06	3.14	3.06	3.32	4.84	-0.38	-8.6%
6 1/4	0.521	4.59	5.01	4.88	4.65	3.05	3.13	3.13	3.32	4.99	-0.40	-8.8%
6 3/8	0.531	4.72	5.16	5.02	4.79	3.05	3.13	3.19	3.32	5.14	-0.42	-8.9%
6 1/2	0.542	4.86	5.31	5.17	4.93	3.05	3.13	3.25	3.32	5.29	-0.43	-8.9%
6 5/8	0.552	4.99	5.46	5.31	5.07	3.04	3.13	3.31	3.32	5.45	-0.46	-9.2%
6 3/4	0.563	5.13	5.62	5.46	5.21	3.04	3.13	3.38	3.32	5.60	-0.47	-9.2%
6 7/8	0.573	5.27	5.78	5.61	5.36	3.04	3.13	3.44	3.32	5.76	-0.49	-9.3%

(1) Stage vs. Discharge by raceway or dam from Appendix A (Rangen Expert Report, Brockway et al., 12/20/12).

(2) Suppressed Weir Eq. $Q = C*L*H^{1.5}$ where: Q = discharge (cfs); C = discharge coefficient;

(3) Contracted Weir Eq. $Q = C*(L - .2*H)*H^{1.5}$ H = head (ft); L = length of dam board(s).

(4) Broad Crested Weir Eq. $Q = C*L*H^{1.5}$

(5,6) Discharge coefficient derived from Suppressed Weir Equation and Contracted Weir Equation using Rangen Discharge Table.

(7) Measured Head (H) divided by Breadth (B) of weir.

(8) Discharge coefficient for H/B for 6-inch weir computed relationship derived from Table 5-3 of King Handbook of Hydraulics (1976).

(9) Computed discharge using Suppressed Weir Eq. (above).

(10) Col. (1) minus col. (9)

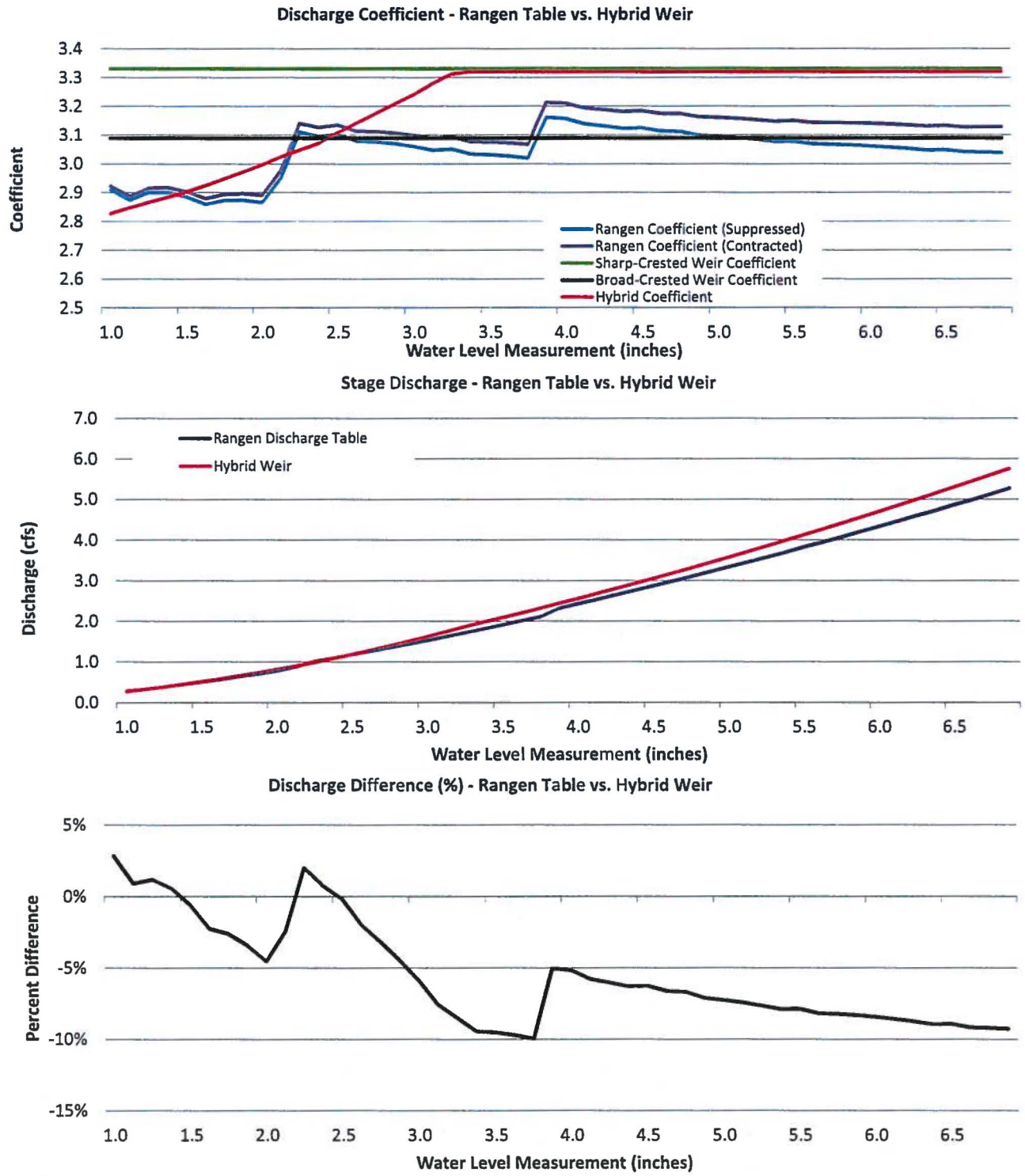
(11) Col. (10) / col. (1).

Average weir water level in measurements taken from 6/13/11 to 4/23/2012 "RANGEN000032_WATER MEASUREMENTS 6-13-11 - 4-23-12".

Figure 1-6, Updated April 2013

Analysis of Rangen Rating Table

Lodge Dam

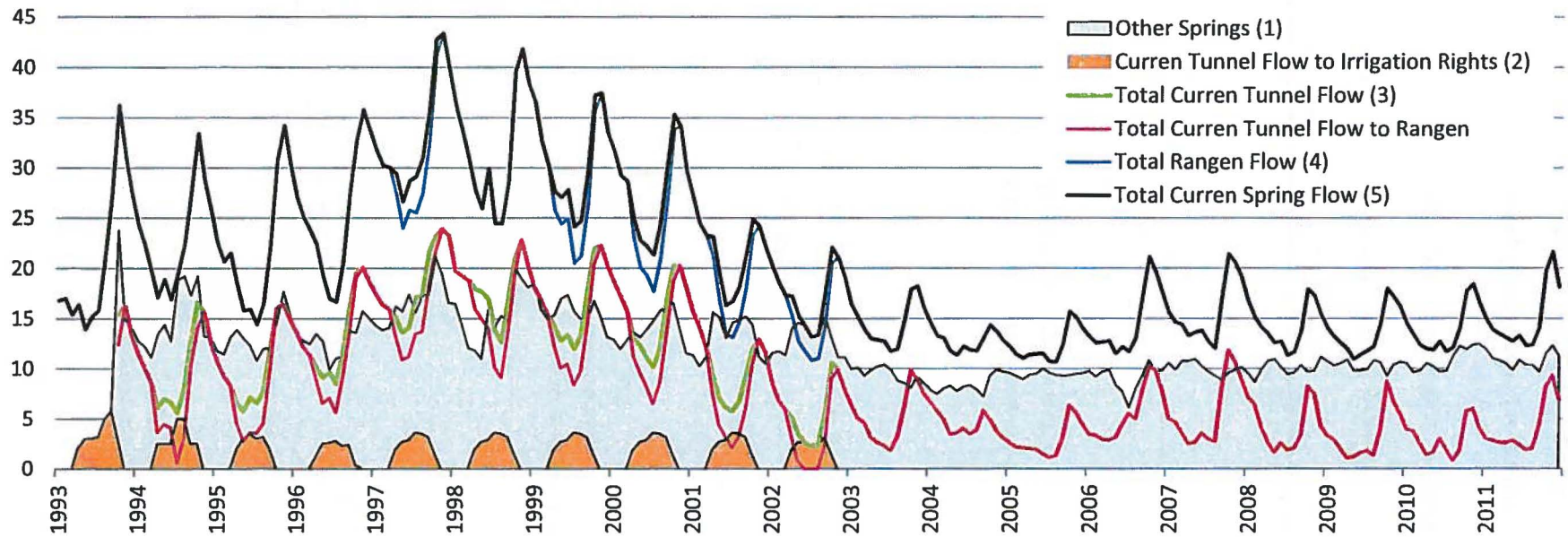


Information from Table 1-5.

Figure 2-7, Updated April 2013

Monthly Average Rangen Hatchery Flow vs. Curren Tunnel and Other Springs 1993 - 2011

Values in CFS



Source: Rangen monthly flow data reported by Rangen (1993 - Feb 1995) and IDWR reported flow data (March 1995 - 2011).
Curren Tunnel flow data provided by IDWR.

Notes: The 2008 data and 2011 Curren Tunnel data have been graded by the IDWR as poor due to equipment problems. IDWR generated the 2011 data by replicating Box Canyon Spring data with a reduced amplitude and fitting the data to the flow measurements made on site.

(1) Computed as Total Curren Spring Flow minus Total Curren Tunnel Flow.

(2) Curren Tunnel to irrigation rights from 1993 - 1996 provided by George Lemmon. The 1997 - 2002 irrigation diversions were estimated based on the 1993 - 1996 average monthly diversions. Diversions of the irrigation rights from the Curren Tunnel ceased after 2002 with the construction of the Sandy Pipeline to supply the irrigation water rights from the North Side Canal.

(3) Total Curren Tunnel Flow includes total flow to Rangen plus flow to irrigation pipelines, but does not include flow in Rangen's domestic pipeline.

(4) Total Rangen Flow provided by Rangen.

(5) Total Curren Spring Flow is equal to the total flow through raceways plus Dam flow plus flow to irrigation pipelines. Total Rangen Flow contained diversions by "estimated farmers" in 1993-1996 and 1998. Total Rangen Flow in 1997 and 1999 - 2002 only includes CTR plus Dam Flow; therefore, irrigation diversions were added into Total Rangen Flow in those years to estimate Total Curren Spring Flow.