*Project No. 1159-01-2011 and 1179MSB01*

# Expert Report in the Matter of Rangen Inc. - Availability of Spring Flow and Injury to Water Rights

*Prepared for:*

*Rangen, Inc.*

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# A. Background

Rangen Inc. (Rangen) submitted a new Petition for Delivery Call to the Idaho Department of Water Resources (IDWR) on December 13, 2011 requesting relief from material injury to spring flow water rights held by Rangen. This Petition addressed the injury to Rangen's water rights 36-02551 and 36-07694 for the Rangen Aquaculture Research Center (Research Hatchery).

This report addresses the procedures and analytical approaches documenting the injury to the Rangen water rights and the procedures which the Department utilized in evaluating the trends in historical discharge and the seasonal and pumping-impacted variability in discharge of the Rangen water supply at the time of appropriation. The report outlines alternative procedures to evaluate spring responses and injury resulting from changes in water use on the ESPA, particularly the pumping of ground water by junior water right holders. The report also addresses the particulars of the recently completed ground water model, ESPAM 2.1, and the methods of utilizing the model to determine impacts or injury to existing spring water rights and appropriate uses for the model. Figure 1 shows the location of the Rangen facility.

The previous determination (Second Amended Order of May 19, 2005) of the estimated increase at Rangan Spring at steady state with the effective response constrained to wells providing more than 10% of pumped volumes was 0.4 CFS. The best available science for predicting beneficial impacts of curtailing ground water pumpers junior to July 13, 1962 is ESPAM 2.1. ESPAM 2.1 predicts a steady state impact of 17.9 CFS from curtailment of ground water pumping within the area of the model, under water rights junior to July 13, 1962. The measured average flow available to Rangen over the last 10 years is 14.1 cfs. Restoration of the depletion of flow caused by junior priority ground water pumping would more than double the available flow to Rangen spring.

## A.1. Eastern Snake Plain Aquifer Geology and Hydrogeology

The Snake River Plain is a 15,600 square mile regional aquifer system in the southern portion of Idaho. The plain exists in a graben-like feature, likely created by Middle Miocene crustal extension forces. The graben is primarily filled by Tertiary and Quaternary basalts intercalated with less extensive sedimentary rocks. Basalt deposits are made up of many thinner basalt flows (tens of feet thick) that combine to create cumulative thicknesses in excess of 1,000 feet. The eastern plain aquifer system is dominated by the Snake River Group basalt layers. Snake River Group basalt deposits are known to be up to 5,000 feet thick in some locations. (Whitehead, 1992)

The Eastern Snake Plain Aquifer (ESPA) is primarily an aquifer consisting of relatively shallow (a few hundred feet deep) and highly transmissive rubble and pillow basalts. Deeper aquifer conditions exist and are likely confined, but little data is available to evaluate them.

Sources of recharge into the aquifer include infiltration of precipitation, natural surface water losses, irrigation canal losses, deep percolation of irrigation water, recharge projects, and ground water inflow from tributary basins. Discharge out of the aquifer includes well pumping, spring discharge, ground water flow into surface water features (including the Snake River), and evapotranspiration.

Most ESPA ground water pumping occurs in the Quaternary basalts of the Snake River Group. Most wells are shallow and many can produce sustained flow rates in excess of 1,000 gallons per minute (GPM), or 2.28 cubic feet per second (CFS).

Another source of aquifer discharge is through springs in and near the canyon walls between Milner and King Hill. These springs also exhibit high flow rates and can exceed total flows of 6,000 CFS. (Whitehead, 1992)

## A.2. Historical Response of Aquifer to Changing Water Use

The Eastern Snake Plain Aquifer, as outlined in Section A.1., has been described geologically as a graben filled primarily with basalt from volcanic activity throughout geologic history. The North Fork (Henry's Fork) of the Snake River enters onto the Eastern Snake Plain near the city of Ashton and the South Fork flows from Wyoming onto the ESPA at the town of Heise. Early irrigation, beginning around 1871 consisted of a myriad of canals diverting from the Snake River and tributaries and flood irrigating lands near the river (Carter, Kate, 1955 Pioneer Irrigation, Upper Snake River Valley). Early development of irrigation is documented by Stearns (1938) and later by the U.S. Geological Survey (Garrabedian, 1992). Deep percolation of irrigation water from the Snake River and tributaries began to raise water tables within the aquifer and increase discharge from the various springs issuing from the aquifer and increase the ground water reach-gain in the Snake River in hydraulically connected reaches.

Data provided by Stearns (1938) indicate that many springs issuing from the ESPA doubled in discharge between 1902 and 1917. USGS records for Curren Tunnel indicate 50 cfs in 1902 and 96 cfs in 1917 (USGS, 1958), which corresponds with the development of large irrigation projects on the ESPA. Mundorf (1964) compared early measured ground water levels in selected wells from the early 1900s to 1959 and showed that some water levels had increased between 35 and 45 feet during that period. Garrabedian (1992) estimated irrigation development for various dates during the period 1899 to 1980 indicating that major irrigation from surface sources began about 1880 and major ground water pumping for irrigation increased rapidly after 1945. The ESPA water levels rose rapidly after 1900 with some wells showing increases of 60 to 70 feet from 1902 to 1917. Spring flows, particularly on the western boundary of the aquifer (Thousand Springs area) responded to the increased aquifer water levels and began to peak about 1950. Data on continuous measured spring flows prior to 1950 are sparse; however, Kjelstrom (1986) developed an empirical procedure for estimating the total spring flow from Northside Springs which shows the general response of ESPA outflow from

1902 through 1980. This graph, Figure 2, has been updated annually by the USGS and shows that the total spring flow peaked in about 1950 and has been declining since then.

Garrabedian (1992) reported that pumping for ground water for irrigation increased rapidly after 1945 and by 1959 had reached about 400,000 acres; by 1966, 640,000 acres of Eastern Snake Plain (ESP) land were irrigated with ground water and by 1979, 930,000 acres or 40 percent of the irrigated lands on the ESP were irrigated with ground water.

Figure 3 is a graph of the cumulative discharge authorized by water rights issued by IDWR for ground water in the Eastern Snake River Plain from 1867 through 2005. A plot of the number of ground water rights issued versus the estimated Northside Spring flow (Kjelstrom) shows the relationship between estimated ground water extraction and spring response over the ESPA. The magnitude of the decline in Northside Spring flow is caused by decreases in net recharge to the ESPA caused by changes in water use, including conversion from surface irrigation to sprinkler irrigation, ground water pumping for irrigation, and, to a lesser extent, changes in climate or drought.

## A.3. Rangen History of Development

Historic anecdotal evidence indicates that the Curren Tunnel was advanced into the Malad Basalt above the Rangen Research Hatchery in order to facilitate delivery of high quality spring water. Curren tunnel water was utilized for irrigation around the turn of the 20th century. Several irrigation water rights exist at the Curren Tunnel and are described in section A.4.

Rangen is one of the largest suppliers of high yield, low waste feeds for the aquaculture industry. The Rangen Research Hatchery was built in 1963 near Hagerman, Idaho for the purpose of testing experimental feed diets on a production basis. The Research Hatchery was located downstream of the Curren Tunnel where the uniquely excellent spring water quality contributes to the feed research success. Feed formulas are tested to assure optimum feed conversion, low mortality, high health, optimum quality, excellent growth and economy in the raising of trout. The research that is performed and the trout that is produced is an important component of the success of Rangen Aquaculture.

## A.4. Rangen Water Rights and Water Call

Rangen owns five (5) water rights with the designated point of diversion as the Rangen Spring or Martin-Curren tunnel which issues from the Eastern Snake Plain Aquifer (ESPA). Table 1 shows the Rangen water rights.

**Table 1 Rangen Water Rights (Pg 2 Petition for Delivery Call Dec 13,2011)**

| **Water Right No.** | 36-00134B | 36-00135A | 36-15501 | 36-02551 | 36-07694 |
|---|---|---|---|---|---|
| **Priority Date:** | October 9, 1884 | April 1, 1908 | July 1, 1957 | July 13, 1962 | April 12, 1977 |
| **Beneficial Use:** | Irrigation (0.09 cfs) and Domestic (0.07cfs) | Irrigation (0.05 cfs) and Domestic (0.05 cfs) | Fish Propagation | Domestic (0.10 cfs) and Fish Propagation (48.54 cfs) | Fish Propagation |
| **Diversion Rate:** | 0.09 cfs | 0.05 cfs | 1.46 cfs | 48.54 cfs | 26.0 cfs |
| **Period of Use:** | Jan. 1 – Dec. 31 Domestic<br><br>Feb. 15 – Nov 30 Irrigation | Jan. 1 – Dec. 31 Domestic<br><br>Feb. 15 – Nov 30 Irrigation | Jan. 1 – Dec. 31 | Jan. 1 – Dec. 31 | Jan. 1 – Dec. 31 |

Rangen filed its first delivery call on September 23, 2003. Former Director Karl Dreher issued an order finding material injury to Rangen water rights 36-02551(priority July 13, 1962) and 36-07694 (priority April 12, 1977) caused by pumping by junior priority ground water irrigators on the ESPA. The Director recognized that the then current available discharge was about 10 cfs compared to the decreed water rights of 76.14 cfs. Figure 4 shows these water rights, the observed Rangen Spring flows, and the ESPAM 2.1 predicted spring flows. The Director found that there was continuing material injury to the Rangen water rights and issued an order on February 25, 2004 based on simulations of the ESPAM1.1 ground water model calling for curtailment of pumpers with priority water rights junior to July 13, 1962 in Water District 130 or for submittal of an acceptable mitigation plan for the injury. Subsequently, on May 19, 2005 the Director issued an amended order based on a re-calibrated ESPAM 1.1 model, in which he determined that the Rangen call was futile due to what was perceived uncertainty in the model based upon assumed river gauge error (+/- 10%, i.e. “trim line”).

Rangen filed a request for a hearing on the May 19, 2005 order. Rangen renewed that request on June 5, 2005 and again on March 31, 2009. The Department refused to act on Rangen’s repeated requests and failed to convene a hearing. Rangen submitted a new Petition for Delivery Call on December 13, 2011 which resulted in these proceedings.

# B. Evaluation of Historical Availability of Water Supply at Rangen

## B.1. Water Measurement Procedures and Data - Rangen Facility

Brockway Engineering PLLC (Brockway Engineering) and Leonard Rice Engineers (LRE) toured the Rangen Research Hatchery located at 2928 B South 1175 East, Hagerman, Idaho 83332 on multiple occasions. Rangen staff (Wayne Courtney, Joy Kinyon, and Dan Maxwell) and/or IDWR District 36A Water Master Frank Erwin provided tours of the Research Hatchery operations focusing on water sources and water use. Brockway Engineering and LRE photographed pertinent water features, observed standard flow measurement, and mapped water structures.

Water delivered to the Research Hatchery is supplied by the Curren Tunnel and spring water issuing from the talus slope beneath the tunnel (Figure 5). Neal Farmer of IDWR reported that the Current Tunnel elevation is 3,145 feet above mean sea level (FT AMSL), with lower elevation spring discharge in the talus slope down to approximately 3,100 FT AMSL (Farmer, 2009). Figure 6 shows that Rangen has inserted a pipeline into the tunnel for collection of higher quality water that is not degraded by open air exposure (IDWR Site ID 360410089). Rangen has also constructed a screen cover that prevents animals from getting into the tunnel. The Curren Tunnel water is piped down to the Research Hatchery building and is shown in Figure 5. Water flowing out of the Research Hatchery building is then routed either to the inlet for the 36 inch pipe or is discharged into the Lodge Pond. At the time of the site visits, there was not enough flow to operate the small raceways, leaving them dry. The limited flow also dried up three of the five large raceways and one of the four “CTR” raceways.

Additional spring water coming out of the Curren Tunnel and in the talus below the tunnel is collected into a concrete retaining structure. The retaining structure has several pipes coming out of it, labeled as the Candy (IDWR Site ID 360410038), Musser (WMIS #410040), and Morris/Crandelmire (WMIS # 410039) pipelines in Figure 7. These pipes are associated with irrigation water rights from the Curren Tunnel. Frank Erwin indicated that the Morris/Crandelmire pipe was diverting a small amount of water as a maintenance flow that prevents pipe creep due to thermal expansion and contraction. Figure 6 shows the location of discharge of the water where approximately 50 gallons per minute (0.1 CFS) is flowing into a waste ditch on the Morris Property. Frank Erwin indicated that the Musser pipeline has been sealed and unused since the Sandy Pipeline was constructed in 2004 to use Northside Canal Company water for these irrigation rights. Since that time, the Candy pipeline has been used to water trees at approximately 70 gallons per hour (0.003 CFS) and for watering a small residential grass area once a week during the summer. Since the Sandy Pipeline was constructed in 2004, it has always met the Morris needs except for one time in 2006 when approximately 1 CFS was diverted from the Curren Tunnel for one month.

Spring water from the Curren Tunnel and a lower discharge zone flows into and around the retaining structure, cascades down a talus slope, and into a natural drainage channel that delivers water (IDWR Site ID 360410041) to the top of the large raceways identified on Figure 5. Spring discharge is diverted by Rangen using a 6-inch PVC pipe in the Curren Tunnel, a 12-inch diameter steel pipe at the retaining structure, or a 36-inch concrete pipe in the channel. These pipes can convey 3.6, 14.3, and 59.0 CFS, respectively.

Water is taken out of the channel via the concrete pipeline intake structure and is routed into the large raceways. Water flows from the large raceways through a 36-inch underground concrete pipeline to the "CTR" raceways. Each of the raceway groups has a drain which can route cleaning flows into the Lodge Pond identified on Figure 5. These drains were not operational at the time of the visit and are reportedly used infrequently.

It is our opinion that, at the time of the visits, there was insufficient discharge available to adequately operate the raceways and the available Rangen spring flows were being utilized appropriately and efficiently according to the adjudicated water rights (Section A.5.). Flow measurement of Rangen's water rights are documented by combining the measured flow at the CTR raceways and Lodge Pond Dam locations indicated on Figure 5 (Dreyer, 2004).

During site visits LRE and Brockway Engineering observed Rangen employees collecting flow measurements. The discharge table used by Rangen employees 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. This would account for the fact that the 2 inch boards over which water flows are not sharp crested, as is assumed in the standard rectangular contracted weir formula. The use of a modified weir coefficient of 3.09 applied to board overflow is consistent with standard practice on aquaculture facilities.

Simplified weir flow calculations and a plot of the comparison of the Rangen discharge table and a standard rectangular contracted weir are presented in Appendix A along with the look up table that Rangen staff use. Review of the measurements indicates that the Rangen staff lookup tables are likely to be more accurate than the flow calculations presented in Appendix A. The standard rectangular weir discharge using a USBR weir flow calculations were within 8% of the Rangen staff reported flows. Additionally, Frank Erwin indicated that he has checked the Rangen staff measurements and that they are accurate. Furthermore, he has stated that Rangen measurements are more accurate than his own. (Deposition of Frank Erwin, Sept. 13, 2012)

## B.2. Evaluation of Alternatives

Rangen has evaluated alternative points of diversion which could possibly increase the water supply necessary for operation of their Research Hatchery. Rangen evaluated the following alternatives:

1. Divert Curren Tunnel water currently used for agricultural irrigation to the Rangen facility;

2. Withdraw water from a vertical well (or wells) located at the Rangen facility;
3. Construct a horizontal well (or wells) below and near the Curren Tunnel;
4. Augment Curren Tunnel flows using water from Weatherby Springs/Hoagland Tunnel;
5. Reduce possible downward vertical flow through existing wells in the area upgradient of the Curren Tunnel;
6. Treat and re-use water from the Rangen Research Hatchery.

Rangen submitted alternatives 1-3 as grant applications to the Idaho Department of Commerce and Labor's Eastern Snake Plain Aquifer Mitigation Program. (May, Sudweeks, and Browning, 2004) The Idaho Department of Commerce approved grant funding for the first alternative of diverting Curren Tunnel water to the Rangen facility instead of for irrigation uses. However, this grant funding was never needed or used because conveyance structures were built to deliver Sandy Pipeline water to the Candy property for irrigation use on lands previously irrigated by Curren Tunnel water.

Alternative 2 explores the possibility of using vertical wells to pump water from locations below the canyon rim at the Rangen facility. The geologic evidence supports current theories that the Curren Tunnel water is flowing through pillow basalts overlaying less permeable sediments. Any viable vertical well location would have to provide a sufficient quantity and quality of water from a source that would not further deplete the Curren Tunnel flows, or that is not currently collected by Rangen. The upgradient geology above the Rangen facility effectively funnels the high quality spring water to Rangen's collection points at the tunnel, the retaining structure below the tunnel, and at the pipe intake further down in the Billingsley Creek channel. Possible well locations with sufficient water quantity and quality would likely reduce the flow of water to the Curren Tunnel, or the spring flow in the talus slopes below. The other possible well locations would likely encounter less permeable sedimentary deposits with lower well yields, unsaturated basalts, or reduced water quality affected by overlying agricultural land use. Any location for possible vertical well drilling that isn't providing water to the current Rangen collection locations is unlikely to provide the quantity and quality of water necessary to make this a feasible option for an alternative point of diversion.

Alternative 3 evaluates the possibility of drilling a horizontal well below the Curren Tunnel. This alternative is subject to the same requirements listed above. A horizontal well must access water of sufficient quality and quantity that is not already available to Rangen. The geologic evidence and field observations show that ground water flow in the area above Rangen is discharging primarily at the Curren Tunnel and the talus below. Any water flow not coming to the Curren Tunnel discharges into the talus slopes below and is collected by Rangen's lower intake structure in the Billingsley Creek drainage. While a new horizontal well might increase flow at the Curren Tunnel location, it would reduce flow to the lower talus discharge area and it is therefore unlikely that it would increase flow to the Rangen facility. Furthermore, a horizontal well has the potential to injure the other Curren Tunnel water rights by drying up the tunnel flows (Erwin, 2012). A horizontal well alternative is not a feasible option for these reasons.

Alternative 4 assesses the possibility of piping water from the Hoagland Tunnel to the Rangen Research Hatchery. Rangen has researched this alternative and determined that only 0.7 CFS would be physically available for seasonal, inconsistent delivery to the Rangen facility. The expense of delivering this water to the Rangen Research Hatchery would be high. The water from the Hoagland Tunnel has been fully appropriated and would not be legally available for transfer to the Rangen Research Hatchery. For these reasons, an alternative that utilizes Hoagland Tunnel water at the Research Hatchery is not feasible.

Alternative 5 suggests investigation of a theory that shallow aquifer water is being moved deeper into the aquifer, or into a deeper aquifer, by downward gradients in existing wells. This is unlikely to show a significant impact on the Rangen Spring flows. A constant flow of water through wells deeper into the aquifer, or into deeper aquifers, is highly unlikely to be of a magnitude greater than that of the pumping out of the aquifer for irrigation use. The primary flow of water is horizontally through the aquifer. Seasonal variability in the aquifer water levels, pumping patterns, and spring flow are all correlated and discussed in Section E below.

Alternative 6 presents the idea of pumping back used water from below the Rangen Research Hatchery back up to the research building and raceways. This would require significant treatment of the water, redundant power systems, and could injure downstream senior water rights. Rangen's use of water has historically been non-consumptive and a sustainable pumpback system with sufficient water treatment would likely be an expensive system with some amount of water consumption.

It is our opinion that the current Rangen Research Hatchery diversion structures are reasonable and that they fully utilize available water to Rangen's water rights. The diversion structures are consistent with the industry standard for aquaculture facilities in the Magic Valley. Based upon our knowledge of other area facilities, the Rangen Research Hatchery is consistent with the industry standard of practice for conservation and beneficial use of available water and does not waste diverted water. Rangen has made significant efforts, and yet no alternative method of water diversion has been identified that would provide the Rangen facility additional water with a viable quantity and quality that isn't already being accessed by existing diversion structures.

# C. ESPAM 2.1

## C.1. ESPAM Development History

Initial ground water modeling of the Eastern Snake Plain Aquifer was performed by the U.S. Geological Survey (USGS) who built an analogue model of the aquifer in 1960's. This model was a research tool and, as with all hard-wired analogue models, was difficult to operate. The need for better analytical procedures for aquifer/Snake River relationship became evident in the early 1970's when IDWR was evaluating and planning for the first State Water Plan. The Idaho

Technical Committee on Hydrology (ITCH) conducted a water resources needs assessment in 1988 and identified an Eastern Snake Plain Aquifer ground water model update as a priority.

IDWR contracted with the University of Idaho Water Resources Research Institute (IWRRI) to develop a digital model of the ESPA aquifer. This effort was conducted at the University of Idaho Kimberly Research Center. The model was developed by a Civil Engineering graduate student from the Netherlands, Jos de Sonneville. The model code was a finite difference, non-proprietary code with cumbersome data management routines. This model was utilized by IDWR to better understand the aquifer responses to changes in water use and was manually calibrated. Subsequent additions and changes were made to this model, primarily by graduate students at the University of Idaho.

In 1999, the model code was converted to the USGS MODFLOW code since it was non-proprietary, supported by the USGS, and had been utilized on a significant number of modeling projects. This work was performed by IWRRI under the direction of Gary Johnson. Subsequently IDWR embarked on a major upgrade of the ground water model with funding assistance from various entities including canal companies. The upgrade was contracted to IWRRI and resulted in ESPAM 1.1 in 2004 which was calibrated with an automated calibration routine and was utilized both for planning purposes and for conjunctive administration. ESPAM 1.1 was re-calibrated in late 2004 and used by IDWR until another upgrade was initiated to improve the resolution of the model grid, revise input data and management routines, and improve calibration utilizing individual historical measured spring flows. This upgrade, ESPAM 2.0, was recommended by the ESHMC and adopted by IDWR in July 2012. The ESHMC recognized the improvements to the prior model and recommended that IDWR begin using ESPAM 2.0 instead of ESPAM 1.1.

In October 2012, a water balance mistake was found in the model inputs for Mud Lake. IDWR presented information regarding the mistake and the revised calibration results for model E121025A001 in the November 9th, 2012 ESHMC meeting. Since then, IDWR has accepted model E121025A001 as ESPAM 2.1. IDWR has provided ESPAM 2.1 calibration results, steady state response functions, a superposition model, curtailment scenarios, validation model runs, and is currently working on an analysis of predictive uncertainty. None of these exercises indicate that there is substantive difference regarding the comparison of ESPAM 2.0 to ESPAM 2.1 predictions for the Rangen spring. Director Spackman has indicated that ESPAM 2.1 is now being used for ground water modeling by IDWR and that it will be used to evaluate the Rangen call. (Rick Raymondi email to ESHMC dated November 27, 2012)

## C.2. IDWR Procedure for Determining Individual Spring Flow

The Department has the responsibility to evaluate material injury to senior water rights and to use the “best science available” when analyzing the impacts or interference caused by out of priority water rights. An advisory committee to IDWR, the Eastern Snake Hydrologic Modeling Committee (ESHMC), contributed to the ESPAM update and reviewed the procedure and final model.  The ESPAM 2.1 ground water model was adopted after a satisfactory calibration, validation, and comparison with the output from the ESPAM 1.1 model as requested by the Director of IDWR.

Brockway Engineering used the ESPAM 2.1 ground water model and IDWR curtailment methodology to simulate the impact of junior priority ground water rights to the latest Rangen priority water right (April 13, 1977) and July 12, 1962 for the Research Hatchery.   The procedure used the calibrated ESPAM 2.1 model to simulate the steady state change in individual spring flows, Snake River reach gains and aquifer water levels attributable to aquifer depletion changes.  Utilization of a ground water model in the superposition mode to simulate change in an output variable caused by changes in depletion within the aquifer is implicitly more certain than modeling differences in the simulation of the absolute value of the output with a fully populated model.  IDWR saves computing time by using the superposition version of ESPAM 2.1 to evaluate changes in spring flows due to curtailment instead of the fully populated model. The superposition mode requires only that differences in recharge or depletion be input at specific locations within the model and not the entire input data set.  The simulated differences using this method eliminates the need to run the fully populated model twice to determine the simulated impact of changes in specific input.

The evaluation of the depletive impact to the springs relied upon Rangen, utilizing the above IDWR procedure and the ESPAM 2.1 ground water model, shows an impact from curtailment of ground water pumping within the area of the model under water rights junior to July 13, 1962 of 17.9 CFS at steady state. It is estimated using the transient ESPAM 2.0 model that a recovery to 90% of the steady state value (16 cfs) will occur within approximately15 years.

## C.3.   ESPAM 2.1 Calibration

IDWR used PEST (Doherty, 2005) automated calibration software to calibrate ESPAM 2.1. Model calibration is the process of comparing actual observations with model output or predictions and adjusting the model input parameters until the error between observations and modeled predictions is minimized.  A model is well calibrated if the model output closely matches what is observed in historic time series data sets.   The quality of the overall model calibration depends on the quantity, location, time, and type (water level, flow, aquifer property) of observations compared to model results.  Model calibration quality varies spatially and temporally and is improved in those locations where observation data are available.

Adjustable input parameters used during ESPAM 2.1 calibration include aquifer transmissivity, aquifer storage coefficients, river bed conductance, drain conductance, non-irrigation recharge, evapotranspiration on surface water irrigated land, non-snake river seepage, tributary valley underflow, canal seepage, deep percolation, and soil moisture.

Calibration targets are real world observations used to compare to model predictions.  The selection and development of calibration targets reflects the intended predictive capacity of the model.  ESPAM 2.1 calibration targets include river reach gains, spring flows, aquifer water levels, base flow, and irrigation return flows.

The difference between each model prediction and calibration target is called a residual. During calibration, PEST attempts to minimize these residuals and reports a sum of squared residuals, also called the objective function or phi.  The objective function value is a primary measure of calibration quality and is used by modelers throughout the calibration process.

IDWR calibrated ESPAM 2.1 by starting with a steady state stress period consisting of average model inputs.  A transient "warm up period" follows from May, 1980 through April, 1985, where no calibration is attempted.  Transient model calibration occurs from May, 1985 through September, 2008.  Calibration is an iterative process, and IDWR developed several calibration runs.  The calibration of the ESPAM 2.1 model and validation procedures were reviewed by the ESHMC and comparisons of simulated historical individual spring discharge data sets were compared with model-simulated output.  In the November 9, 2012 meeting, ESHMC accepted calibration run E121025A001 as the final ESPAM 2.1 calibration run.

Based on the approved, calibrated model and the performance of the model in simulating individual spring historical flows, the ESPAM 2.1 model is capable of simulating impacts on individual springs, including the Rangen spring.  It is our opinion that the ESPAM 2.1 model is the 'best science available' to evaluate impacts on spring flows caused by pumping junior ground water rights in the ESPA..

ESPAM 2.1 utilizes the MODFLOW Drain Package to represent 90 spring discharges from the aquifer in the Snake River Canyon between Kimberly and King Hill.  The main input components of the Drain package include the elevation and hydraulic conductivity of the drain.  IDWR and ESHMC separated springs into groups A, B, and C.  Group A springs have flows measured and reported by the USGS or IDWR.  Group B springs are measured and reported by water users. Group C springs are all of the other springs in the model that have less reliable historic flow measurement data.

In the Thousand Springs area of the Snake River, selected springs with adequate measured historical discharge data were utilized as targets in the calibration process to which simulated output was matched as closely as possible by allowing PEST to adjust the internal parameters of the model such as hydraulic conductivity, storativity, target spring coefficients, target spring elevations, and external input parameters.  Examples of the use of target springs are shown in Appendix B, which contains IDWR calibration graphs of the measured discharges at the select springs versus the simulated output of the ESPAM 2.1 model for the same period.  Appendix B model comparisons of simulated and measured spring flow shows the simulated discharge at springs versus historical measured discharge for the ESPAM 2.1 calibration.  This close "fit" indicates the model, if calibrated properly, is capable of simulating the historical spring discharge from the model cell(s) representing the Blue Lakes springs. Similarly, the ESPAM 2.1 simulated output versus measured for the calibration period for Box Canyon Spring and all other spring targets are included in Appendix B.

Other springs in the Thousand Springs area of the Snake River (Milner to King Hill) were used as targets in the ESPAM 2.1 model calibration. They were designated as Class B and Class C springs and were chosen on the basis of adequate discharge measurements over the period of calibrations. Some of these springs were: Briggs Spring, Clear Lake Springs, Devils Washbowl, Devil's Corral, Thousand Springs, Rangen Spring, and Malad Gorge. Historical measured discharge of the Rangen Spring was also used as a calibration target for the ESPAM 2.1 ground water model calibration. The discharge measurements for Rangen Spring were submitted to IDWR by Rangen and included measurements from May, 1980 through October, 2008.

Use of the ESPAM 2.1 model as currently calibrated for simulation of impacts from junior ground water pumping is the "best science available" in our opinion. The Rangen Spring is the only spring in its' model cell (Row 42, Column 13). It has a long historical record of flow observations that were used as targets and resulted in a high quality calibration. IDWR's current update of the ESPAM model to ESPAM 2.1 improves the calibration input parameters credibility, and improves the procedures for crop evapotranspiration determination and distribution of irrigation sources. It also corrects some previous oversights in target spring flow determinations.

## C.4. Use of Historical Rangen Spring Flow Data for Calibration

Prior versions of ESPAM did not represent the Rangen Spring as an individual spring. The impact on Rangen Spring was represented as a fixed percentage of river gains in the Thousand Springs to Malad reach of the Snake River as a result of changes in ground water pumping or other depletion changes in the aquifer. ESPAM 1.1 was calibrated to match the calculated gains in each Snake River reach and also to match some of the major springs. Rangen Spring, and the remaining springs, were represented as percentages of river gains based on the published Covington and Weaver spring flow estimates. This approach to spring flow estimates is problematic because the Covington and Weaver estimates had not been substantiated. Furthermore, the magnitude and responses of river gains and spring flows are not similar and should not be grouped together

With contributions of work from IDWR and also individual ESHMC member stake-holders including Rangen, many more historical spring flow time series were calculated, reviewed and accepted by the ESHMC, and made available to the IDWR ESPAM modelers. Therefore in ESPAM 2.1, the calibration targets were expanded to include many more individual spring flows, reducing the calibration reliance on river reach gains calculations where possible. The improvement in the ESPAM 2.1 calibration and individual spring flow simulation performance was remarkable.

The evaluation of historical Rangen spring flows was presented by LRE (Jim Brannon) in the September, 2009 ESHMC meeting. These data, and historic flow data for other springs were approved by the ESHMC for IDWR use in calibrating the ESPAM 2.1 model. The historic Rangen spring flow data are shown in Figures 4 and 9.

## C.5. Analysis of Rangen Spring Calibration Results

The Rangen Spring is a group B spring represented as a single drain set at an elevation of 3,138 feet. The drain hydraulic conductivity is an adjustable parameter that is estimated during the calibration process (see Section C.3., above). There are no other springs represented in the Rangen cell.

Figure 9 shows the E121025A001 (ESPAM 2.1) calibration results distributed by IDWR for the Rangen Spring. The top graph shows the measured and modeled spring flow from May, 1980 through September, 2008. There are multiple scales of patterns that emerge when reviewing the graph qualitatively. The longest pattern evident is a long term (multi-decadal) linear decrease in spring flows. The 1981 measured and modeled spring flows average approximately 32 and 30 CFS, respectively. The measured and modeled spring flows decrease to an average of approximately 14 and 19 CFS, respectively, in 2008. Through the 1980-2008 model run, the mean error is reported as 0.04 CFS with a mean absolute error of 4.57 CFS. The signal (prediction magnitude) to noise (error) ratio decreases as the spring flow decreases. However, the long term drop in average spring flow is modeled accurately by ESPAM 2.1 and indicates that the model is representing long term impacts to the spring flow. These impacts reflect well pumping changes, climate changes, and changes in irrigation practices.

Figure 9 shows a decadal scale, sinusoidal trend in observed spring flow that is matched well by the modeled spring flow predictions. Both data sets show decadal scale highs in 1987 and then again in 1998. The measured and modeled spring flows also show decadal scale lows in 1993 and 2005. The model matching these spring flow changes indicates that decadal scale impacts from changes in climate and irrigation practices are being accurately modeled.

Figure 9 also shows an annual seasonal and pumping-impacted variation in measured and modeled spring flows. In general, the model accurately represents both the magnitude and timing of seasonal and pumping-impacted spring flow fluctuations. This is represented in the lower center graph showing Average Monthly Spring Flow. The top graph shows seasonal measured versus modeled spring flow matches are better earlier in the calibration model run when average spring flow is higher and the seasonal magnitude of change is greater. This is another expression of the model signal to noise analogy discussed above. The seasonal variations in the spring flows are attributable to seasonal pumping and are accurately represented by the model.

The lower right graph on Figure 9 is a scatter plot showing modeled versus measured spring flow. These data remove the element of time from the evaluation and show the overall quality of modeled predictions compared to measured spring flows. The trendline of the scatter plot shows a coefficient of determination, or R-squared value, of 0.75. A perfect match would be a value of 1.0. The R-squared value is diminished by the quality of fit below 20 CFS on the modeled spring flow axis. This is another expression of the model having less accurate low flow predictions, as discussed above. Appendix B includes similar plots of ESPAM 2.1 calibration simulations compared to measured flows for Box Canyon, Crystal Springs, and Blue Lakes Spring with the same statistical parameters as shown in Figure 9 for Rangen Spring. The calibration or ‘fit’ for these springs shows that the ESPAM 2.1 model is well calibrated and adequately simulates the historical responses of the calibration target springs.

IDWR has stated in their ESPAM 2.1 final report that,“ Unlike ESPAM 1.1, ESPAM 2.1 was calibrated to the discharge of 14 springs, and spring cells without transient targets were calibrated using a ranking scheme, see section VI.C. Thus ESPAM 2.1 can be used to compute regional impacts on selected springs” (IDWR 2012). It is our opinion that the ESPAM 2.1 calibration quality at the Rangen Spring and other major springs is an indication that the model is an excellent predictor of long term individual spring flow changes and decadal spring flow changes. The Rangen Spring is one of the best points of prediction for the ESPAM 2.1 model because it was a calibration target, it is the only spring in the model cell, and it has excellent calibration results.

## C.6. Evaluation of IDWR Analysis of Uncertainty, Validation and Comparison to 1.1

In a letter to the ESHMC dated June 9, 2011, then Interim Director Gary Spackman indicated that before ESPAM 2 could be used for water management and administration, the model must undergo a series of quality evaluations.

> *“In order to accomplish the foregoing, I have instructed IDWR technical staff to subject ESPAM 2.0 to rigorous testing, including: 1) calibration; 2) validation; and, 3) uncertainty analysis. In addition, ESPAM 2.0 must be run using factual inputs and additional hypothetical factual inputs. Simulations from these inputs must be compared with the outcomes of the previous model version.”*

In an effort to comply with the Director’s request, and in some cases improve the model, IDWR performed uncertainty, validation, and comparison to ESPAM 1.1 exercises.

### C.6.1. Uncertainty

IDWR utilized the “dual calibration” predictive analysis mode of PEST software (Doherty, 2005) as a tool to explore predictive uncertainty in the model. “A comprehensive predictive uncertainty analysis could not be conducted in a reasonable timeframe, so the ESHMC chose to conduct a maximization/minimization uncertainty analysis. In lieu of a probability distribution, the maximization/minimization analysis provides upper and lower bounds for the probability distribution, with output from the ESHMC-chosen calibrated model supplying the most likely outcome. (IDWR Wylie 2012a)

This method relies on the modeler to induce a large stress on the aquifer at a distance from a prediction, and then PEST determines the minimum and maximum prediction values of specific output possible while keeping the model calibrated. The current IDWR uncertainty analysis procedure relies on allowing models to have a larger objective function, or worse calibration, and still be considered calibrated. Because of this, the original calibration model still provides the best predictions. This method of uncertainty analysis is useful in determining what parameters are well constrained by the observation data. It does show that utilizing models with different calibrations provide differing ranges of output of predictive values for specific output locations (specific springs or reach gains). However, there is no uniform range of output predictions at all locations and specifying a single uncertainty value to the entire model is not technically valid. It does show that utilizing models with different calibrations provide differing ranges of output of predictive values for specific output locations (specific springs or reach gains). However, there is no uniform range of output predictions at all locations and specifying a single uncertainty value to the entire model is not technically valid. It also provides information about the spatial variability in parameter uncertainty, and what impact that can have on predictions. The uncertainty results distributed by IDWR are valuable in guiding future data collection activities that will improve upon ESPAM 2.1. ;however, at this point, a complete uncertainty analysis has not been performed that can appropriately be used to apply a confidence interval range or probability distribution on the predictions of ESPAM 2.1. The best estimate of the impact on a spring or river reach by any change in depletion (pumping or recharge or other changes) is the unmodified prediction from the ESPAM 2.1 model. Any other result using the current model is statistically less probable and would be inappropriate to use.

Ground water models can and are regularly used without performing a comprehensive uncertainty analysis. Depending on the nature of the use of the model, availability of data for verification, computing facilities and time constraints and the modeling entity experience, comprehensive uncertainty analysis may or may not be performed. It is common in the industry to utilize a ground water model without validation or extensive uncertainty analysis. The model output should be the most reliable values and any modification of the output to qualify the results based on limited or no statistically evaluated procedures is not warranted.

In summary, our opinion is that the current uncertainty analysis has no bearing on the model predictions. Any output value other than the specific model output will provide a lower confidence level or more uncertainty because it results from a model with a less stringent calibration than the base model.

Although the limited uncertainty analysis performed by IDWR is useful in understanding some aspects of the model, it cannot be used to technically justify any range of model predictive results. A complete uncertainty analysis has not been performed that can appropriately be used to apply a confidence interval range or probability distribution on the predictions of ESPAM 2.1. The best available predictions of junior pumping impacts to the Rangen Spring are those made by calibrated model E121025A001 (ESPAM 2.1).

### C.6.2. Validation

Validation is an attempt to demonstrate a calibrated model's performance for a period of time outside the calibration period. The comparison period(s) must have independent observation data to which the modeled predictions can be compared. The result of a model validation assessment will not be validation of the model. Rather, the result of this assessment would only be to invalidate the model, or not invalidate the model.

ESPAM 2.1 validation was performed by using the accepted, calibrated model (E121025A001) to evaluate a two year period (2009-2010) after the calibration period (1985-2008). Another validation run was performed with ESPAM2.1for 1900 model inputs.

#### *C.6.2.1. 2009-2010 Validation*

IDWR contracted a statistician, Maxine Dakines, Ph.D., to develop statistical measures for evaluation of the validation results. Two of the measures she recommended using were the Root Mean Squared Error (RMSE) and the Median Absolute Deviation (MAD) (Dakines, 2012). These measures were applied to the 2009-2010 validation run results and the ESPAM 2.1 calibrated model.

Validation statistical results were within the range of calibration statistical analysis results except for the weighted spring discharge results. These results indicated that ESPAM 2.1 had a tendency to over predict spring discharges, which is consistent with review of the model calibration results

#### *C.6.2.2. 1900 Validation*

The 1900 validation run was based on input data and observation data from rough estimates and historic documents that are much less reliable than the calibration period data and the 2009-2010 validation data. For this reason, ESHMC members and IDWR agreed that the 1900 validation run was less significant. The nature of the 1900 data available precluded a statistical analysis of the results, and so only a qualitative description was provided by IDWR. IDWR concluded, and we agree, that the 1900 validation results do not limit the use of the model in any way (IDWR Wylie 2012b).

### C.6.3. Summary-Validation

IDWR's conclusion presented in their ESPAM 2.1 validation report (IDWR Wylie 2012b) stated that calibration results for ESPAM 2.1indicate that the validation evaluation raised no "*significant concerns or limitation regarding the use of ESPAM 2.1*." We agree with the IDWR conclusion and it is our opinion that these validation results further support the use of ESPAM 2.1 as the best available science

### C.6.4. Comparison of ESPAM 2.1 to ESPAM 1.1

IDWR completed a comparison of ESPAM 2.1 to the previous version used for administration, ESPAM 1.1. The procedure they implemented included a comparison of ESPAM 2.0 to 1.1 while being run as transient, fully populated and superposition models. This test was performed to determine if the simplified superposition model was accurate enough to complete curtailment scenarios. The superposition model predictions were less than 1% different from the transient, fully populated model. The superposition model was sufficiently accurate and so was used for each of the curtailment runs because it required fewer data, decreased computing time, and simplified the process.

IDWR used ESPAM 2.1 to run curtailment scenarios using five priority dates and where run as steady state models, 150 year transient models with average annual, and 10 year continuous curtailment models with seasonal average stresses. The process representing curtailment of junior well pumping is complicated by the relationships between real world well pumping, water rights databases, and the way well pumping is represented in the model. A detailed discussion of these issues follows in the next section.

Improvement in the estimates of model input and calibration target data for version ESPAM2.1 resulted in the consumptive use curtailed using ESPAM 2.1 being 17-21% higher than with ESPAM 1.1. This is generally attributed to increased confidence in model inputs and calibration targets, and their contribution to increased confidence in model output.

## C.7. Using ESPAM 2.1 to Simulate Impacts of Well Pumping Curtailments

With the successful calibration to the historical period data, the next phase of ESPAM 2.1 model use is to simulate responses of the aquifer system to conditions representing scenarios of interest to stake-holders in the basin. One common administrative water rights scenario of interest to many in the basin is the impact that curtailment of pumping and/or aquifer recharge projects would have on spring flows and reach gains.

### *C.7.1 2011 LRE method*

In late 2011, as ESPAM 2.0 was nearing its final calibration, LRE began using the available version of the ESPAM 2.0 model and the IDWR POD and POU water rights databases to simulate the impacts of pumping curtailment, especially on the Rangen spring. The objective was to obtain a general understanding of the hydrologic and hydraulic behavior of the systems as represented in the ESPAM model and data, and anticipate the spring flow responses to a pumping curtailment caused by a water right call with the Rangen priority date (July 13, 1962). These analyses have been superseded by IDWR work and are not being relied upon except as an independent, qualitative comparison of the appropriateness of the IDWR curtailment methodology.

Because the Rangen spring historical flows are explicit calibration targets, ESPAM 2.1 has proven to be an excellent model of the East Snake Plain Aquifer and Rangen spring flows. The pumping curtailment scenario is well within the ESPAM 2.1 historical model “state space” used during calibration, as the reduction in pumping would return water levels (and therefore spring flows) to values that are still well inside the historically observed range.

LRE (independently from IDWR) developed a spatial and logical algorithm using the IDWR 2011 POD and POU water rights databases that resulted in junior and senior water rights fraction values per ESPAM model cell based on a certain calling priority date. This algorithm was designed to handle the foreseen major water rights data management issues and also to be conservative in nature when water rights data was unclear or in error. These fractions were then used to adjust the ground water acreage values in the ESPAM 2.0 IAR files used by the MKMOD utility (MODFLOW data pre-processor). The MKMOD and MODFLOW programs were then rerun with the modified data and the model output (river reach gains, spring flows, etc.) compared to determine pumping curtailment impacts.

#### *C.7.2 2012 IDWR method*

During 2011 and 2012 IDWR created a set of data pre-processing tools based within the ESRI ArcGIS environment. One of the features completed during 2012 was a "pumping curtailment scenario" data creation tool.

The IDWR tool is also based on POD database data, but used a different algorithm. Rather than adjust an existing IAR file, it recreates the irrigated acreage data (and IAR file) from scratch using the base ESPAM 2.1 spatial and temporal data. It also includes additional refinements to the underlying data (such as ground water vs. surface water irrigated percentages) to improve the accuracy.

#### *C.7.3 Comparison of LRE and IDWR Curtailment Scenario Results*

When the IDWR tool became available, LRE acquired it and the necessary IDWR data. An ESPAM 2.0 pumping curtailment scenario identical to the previously developed scenario (using the LRE approach) was constructed and run through the ESPAM 2.0 model. The results showed excellent agreement, even though the systems were developed independently.
The excellent agreement verified LRE's earlier estimates of pumping curtailment spring flow impacts, and is an encouraging indicator of the robustness of the IDWR curtailment tools.
Brockway Engineering also completed simulations with the calibrated ESPAM 2.1 model and the IDWR algorithms for determining curtailment priority locations, which duplicated the IDWR process and results.
It is our opinion that the IDWR curtailment methodology is an accurate evaluation of impacts caused by junior ground water pumping and that it provides accurate input for the ESPAM 2.1 model.

# D. Benefits from Curtailment for Rangen Call

Evaluation of the benefits of curtailment of ground water rights junior to July 13, 1962 results in increases in Rangen Spring of approximately 17.9 cfs average annual flow at steady state. This evaluation was performed using the ESPAM 2.1 ground water model assuming curtailment to July 13, 1962, over the entire aquifer.

Utilization of the increased spring discharge within the Rangen Research Hatchery will allow increased fish production as well as rehabilitation of research facilities and historical fish propagation research. Additional benefits would also be realized by hundreds of water rights downstream of the Rangen Research Hatchery in the Billingsley Creek water rights system. (Erwin, 2012)

The Idaho Comprehensive Aquifer Management Plan and State Water Plan call for an additional 600,000 acre-feet per year of water to be returned to the ESPA. Curtailment to effect mitigation for historical decreases in Rangen Spring results in significant increases in discharge at other developed springs and benefits to water rights holders who utilize the increased discharge for irrigation or other uses. Table 2 shows the results of the ESPAM 2.1 curtailment scenario on Snake River reach-gain and the A, B, and C springs designated by IDWR as calibration targets in the ESPAM 2.1 development. Most of these springs are either fully developed for aquaculture purposes or have some non-aquacultural development. For instance, the Rangen Spring discharge, after the non-consumptive use for aquaculture by Rangen Inc, serves as the source of irrigation for water rights on Billingsley Creek, other fish producers, and canals diverting from the Creek. Increases in Malad springs benefit Idaho Power hydroelectric facilities and increases in Blue Lakes spring benefit two major fish hatcheries (Blue Lakes Trout and Pristine Springs), as well as the City of Twin Falls municipal water supply.

Similarly, increases in Upper Snake River reach-gains as a result of ground water pumping curtailment for Rangen Inc, benefit irrigators with senior water rights as well as fish producers utilizing spring water.

Table 2 shows that a total of 1,679 cfs (or 1.22 million acre feet annually) of enhanced Upper Snake River reach gain and flow in the A, B, and C springs in the Thousand Springs area will accrue from ground water pumping curtailment for the Rangen Spring. Increases of 389 cfs or 282,200 acre feet per year in the flow of named A, B, and C springs only will accrue from ground water pumping curtailment for the Rangen Spring. These increases represent only the target calibration springs which are the larger springs in the reach from Minidoka to King Hill. Other springs in the area which were not selected as target springs for ground water model calibration have some degree of development and benefit from increased discharge.

Snake River reach-gain increases as a result of curtailment for the Rangen Spring and those reach gains are beneficial for stabilizing existing water supplies for irrigation, for in-stream beneficial uses, including hydropower production increases. Reach-gains increase throughout the entire year, provide beneficial uses outside the irrigation season for water quality and fisheries enhancement.

Water levels within the ESPA will increase as a result of curtailment of junior ground water pumping. Simulation with ESPAM 2.1 of curtailment to July 13, 1962 priority water rights results in significant increases in water levels within the aquifer. It is estimated that full aquifer curtailment results in a decrease in ESPA depletion of 1,456,405 acre feet per year(AFA). The same simulation indicates that the average water level increase over the ESPA as a result of this curtailment may be as much as 24 feet.

**Table 2: Simulated River Reach/Spring Gain (ESPAM 2.1) from curtailment on entire ESPA with water rights junior to 7/13/1962**

| River Reach | | Gain (CFD)cubic feet/day | Gain (CFS) | Gain (AFA) |
|---|---|---|---|---|
| Ashton - Rexburg | | 13,632,890 | 158 | 114,312 |
| Heise to Shelley | | 17,841,178 | 206 | 149,598 |
| Shelley to Near Blackfoot | | 19,837,276 | 230 | 166,335 |
| Near Blackfoot to Minidoka | | 60,067,316 | 695 | 503,664 |
| **Specific Spring** | **Spring Class** | **Gain (CFD)** | **Gain (CFS)** | **Gain (AFA)** |
| BANBURY | C | 284,855 | 3.3 | 2,389 |
| BANCROFT | C | 59,840 | 0.7 | 502 |
| BIGSP | C | 612,377 | 7.1 | 5,135 |
| BIRCH | C | 5,764 | 0.1 | 48 |
| BLUELK | B | 1,729,410 | 20.0 | 14,501 |
| BOX | A | 5,939,274 | 68.7 | 49,801 |
| BRIGGS | A | 98,073 | 1.1 | 822 |
| CLEARLK | B | 3,614,815 | 41.8 | 30,310 |
| CRYSTAL | B | 3,952,452 | 45.7 | 33,141 |
| DEVILC | A | 638,568 | 7.4 | 5,354 |
| DEVILW | A | 489,835 | 5.7 | 4,107 |
| ELLISON | C | 9,951 | 0.1 | 83 |
| MALAD | B | 3,797,106 | 43.9 | 31,839 |
| NIAGARA | B | 2,762,952 | 32.0 | 23,167 |
| NTLFSHH | B | 982,322 | 11.4 | 8,237 |
| RANGEN | B | 1,545,320 | 17.9 | 12,957 |
| SAND | B | 1,583,856 | 18.3 | 13,281 |
| THOUSAND | B | 4,325,425 | 50.1 | 36,269 |
| THREESP | B | 1,125,718 | 13.0 | 9,439 |
| TUCKER | C | 97,535 | 1.1 | 818 |
| **Total** | | **33,655,448** | **389** | **282,200** |
| **Total Springs Below Milner** | | **145,034,108** | **1,679** | **1,216,109** |

# E. Alternative Procedures to Estimate Spring Discharges

## E.1. Individual Spring Simulation with ESPAM 2.1 Model

The primary hydraulic parameter affecting spring discharge is the water level in the aquifer immediately up-gradient from the spring outlet. The spring orifice or outlet acts like a weir in an open channel where discharge is a function of the head or water level difference between the weir crest and the upstream pool water level. The MODFLOW code for the ESPAM model incorporates an algorithm for treatment of spring outflow called the Drain Module (McDonald and Harbaugh, 1988) where the relationship between spring discharge and aquifer water level is given by;

$$Qd = Cd(h-d)$$

where

Qd = spring discharge or flow to a drain

Cd = drain conductance constant value

h = head(elevation of water level) in the aquifer

d = elevation of the drain(weir crest)

This equation is a linear equation which assumes that the coefficient Cd does not change with elevation and that the discharge changes proportionately with the change in aquifer water level(h) compared to the spring elevation. McDonald and Harbaugh (1988) indicate that the constant drain conductance incorporates converging flow lines, aquifer hydraulic conductivity and other hydraulic considerations of the spring geology. The drain module equation shows the dependence on an accurate determination of spring elevation in correctly modeling the response of a spring to water level elevations in the aquifer. The drain parameters are adjusted by the automatic calibration routine, PEST.

## E.2. Method 2: Regression of Spring Discharge vs. Aquifer Water Levels

The algorithm which is used to simulate spring flow in ESPAM 2.1 is essentially a form of weir equation for which the operating variable is water surface elevation up-gradient of the drain cell. Therefore, the expected response of the spring discharge must be related to changes in up-gradient water levels. With this as the hypothesis, the relationship between target spring flow versus historical measured water levels in wells up-gradient of the spring should be relatively well defined. If that is the case, the relationships developed by regression methods using historical measured water levels and measured spring flows should be adequate for estimating the spring discharge response.

There are several wells within the ESPA which are adjacent to and up-gradient of target springs in the Milner-King Hill reach of the Snake River. These wells have records of measured water levels with as much as 60 years of data and measured discharge at target springs began as early as 1950. Well data are available online from IDWR through Hydro.Online (http://www.idwr.idaho.gov/hydro.online/gwl/default.html).

As an example, to evaluate the relationship between up-gradient ground water levels and Rangen Spring flows, a correlation was performed between historical water levels in observation wells 06S13E25DBC1, 07S14E29CDC1, 07S15E12CBA4, 08S14E12CBC1,08S14E16CBB1, 08S15E32CBB1,and 08S16E17CCC1 which are up-gradient of the Rangen Spring (Appendix C) and measured discharge from the Rangen Spring.

The data set used included measured discharge and corresponding measured water levels in the well for the period of record for the observation wells. Appendix C contains figures that show the correlation between aquifer water level and discharge with a correlation coefficient. For example, observation well located at 07S15E12CBA4 has a correlation coefficient, C, of 0.8851; this coefficient indicates that over 88% of the variability in Rangen Spring discharge can be explained by the water level variability in a predictor well. Table 3 shows the regression data for the seven wells with Rangen Spring and the average regression fit to measured discharge for the wells.

This analysis corroborates the procedure of using a regression approach to estimating spring discharge. Further, it supports the current procedure for inclusion of Rangen Spring in the ESPA model and that the flow at Rangen Spring is from the regional aquifer. In addition, the well to spring regression procedure eliminates the concern of inaccurate drain elevations at springs and provides a statistically defensible confidence level to the estimate if the water level change is known.

Analyses and data evaluated by Koreny (2009) and previous work by Janzak (2001) and HRS (2007) suggested that relationships between water levels in the ESPA and spring flows might be developed with sufficient reliability to be utilized as alternative methods to estimate benefits to spring flows from curtailment of junior ground water pumpers. Dr. Wylie's testimony at hearing also supported such review and recommended that additional analysis would be necessary.(Deposition of Allan Haines Wylie, PhD. November 13, 2009, p51)

The physical justification and methodology of developing the regression relationships is outlined in detail in Appendix C. The conclusion of the investigation into utilization of aquifer level vs. spring discharge correlation is that the regression with observation wells is a justifiable alternative procedure to ESPAM 2.1 simulation to evaluate Rangen Spring discharge and provided additional validity to the use of ESPAM 2.1 for individual spring impact predictions.

# F. Summary of Opinions

This report presents the opinions of Jim Brannon, Chuck Brockway, and Dave Colvin regarding the evaluation of impacts by junior pumpers to Rangen's water rights, the application of these impacts to a determination of injury, and the appropriate use of the ESPAM 2.1 model. These opinions are couched to address the requirements contained in the Conjunctive Management rules.

In summary, our opinions are as follows:

1. Pumping by junior ground water rights impacts the exercise of Rangen water rights 36-02551(priority July 13, 1962) and 36-07694 (priority April 12, 1977).
2. It is our opinion that there is insufficient spring flow available to operate the Rangen facility and that the available Rangen spring flows are being utilized appropriately and efficiently according to the adjudicated water rights. There is no evidence of wasted water.
3. It is our opinion that the best available science (ESPAM 2.1), predicted a steady state impact of 17.9 CFS from curtailment of ground water pumping within the area of the model, under water rights junior to July 13, 1962.
4. It is our opinion that the flow measurements collected at the Rangen facility are accurate and consistent with the industry practice.
5. It is our opinion that no alternative method of water diversion has been identified that would provide the Rangen facility additional water with a usable and acceptable quantity and quality that isn't already being accessed by existing Rangen intake structures.
6. It is our opinion that IDWR has appropriately developed the ESPAM 2.1 model and that the ESHMC has provided guidance and oversight of the modeling process.
7. It is our opinion that the ESPAM 2.1 model represents the best available science for simulating hydraulic behavior of the ESPA.
8. It is our opinion that the Mud Lake input data mistakes discovered in October 2012 did not have any significant impact on the ESAPM development process and that ESPAM 2.1 should be used for all IDWR ground water modeling at this time.
9. It is our opinion that the historic Rangen Spring flows presented to the ESHMC are accurate and that the ESHMC approved IDWR use of these data during calibration.
10. It is our opinion that the ESPAM 2.1 calibration quality at the Rangen Spring and other major springs and Snake River reaches indicates that the model is an excellent predictor of changes to spring flow an river reaches.
11. It is our opinion that the current IDWR ESPAM 2.1 uncertainty analysis is not sufficient or useful for quantifying the uncertainty of any particular model prediction. Its primary value will be to guide future calibrations and data collection efforts. The best available predictions of junior pumping impacts to the Rangen Spring are those made by calibrated model E121025A001 (ESPAM 2.1).
12. It is our opinion that the results of the IDWR Validation and Comparison to 1.1 exercises do not preclude the use of ESPAM 2.1 in any way.
13. It is our opinion that the IDWR curtailment methodology is reasonable and sufficient for calculating the impacts of curtailment on ESPA water levels and spring flows using the ESPAM 2.1 model..

14. It is our opinion that curtailment to mitigate injury to a senior water right is not a waste of the water resource. The relationships between ESPA water levels and Rangen Spring flows are well correlated. This correlation is an indication that ESPA well pumping and spring flows are hydraulically connected and that the spatial distribution of the correlated data indicates that the Rangen Spring source water is a large regional area.
15. It is our opinion that specific components of uncertainty (uncertainty in model inputs, calibrated aquifer parameters, observation target measurement, and numerical calculation) by themselves cannot be used as a definition of model prediction uncertainty.
16. It is our opinion that model predictive uncertainty has not been adequately quantified and that it would be inappropriate to use any adjustment to model predictions other than the calibrated ESPAM 2.1 model predictions.

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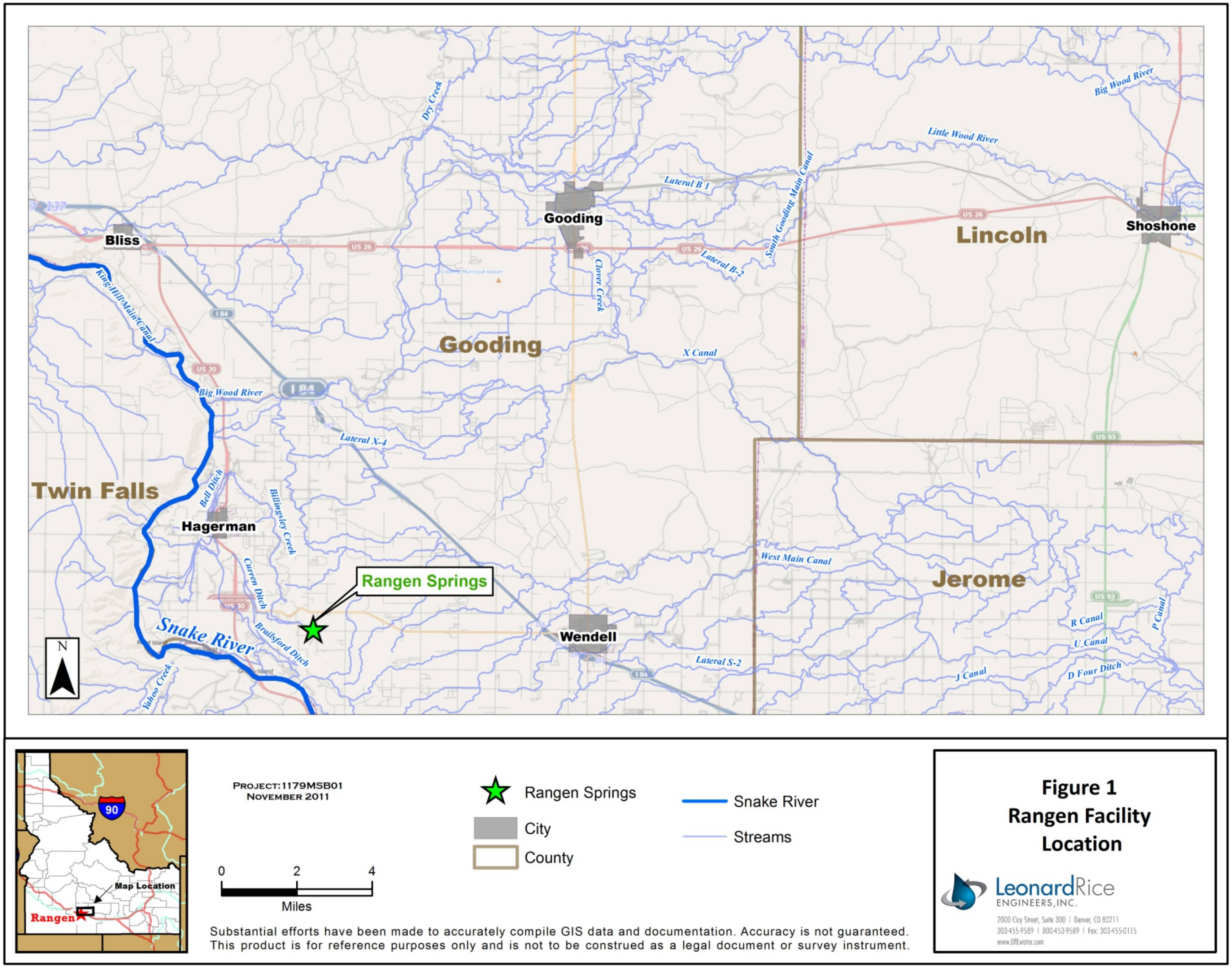


Figure 1
Rangen Facility Location

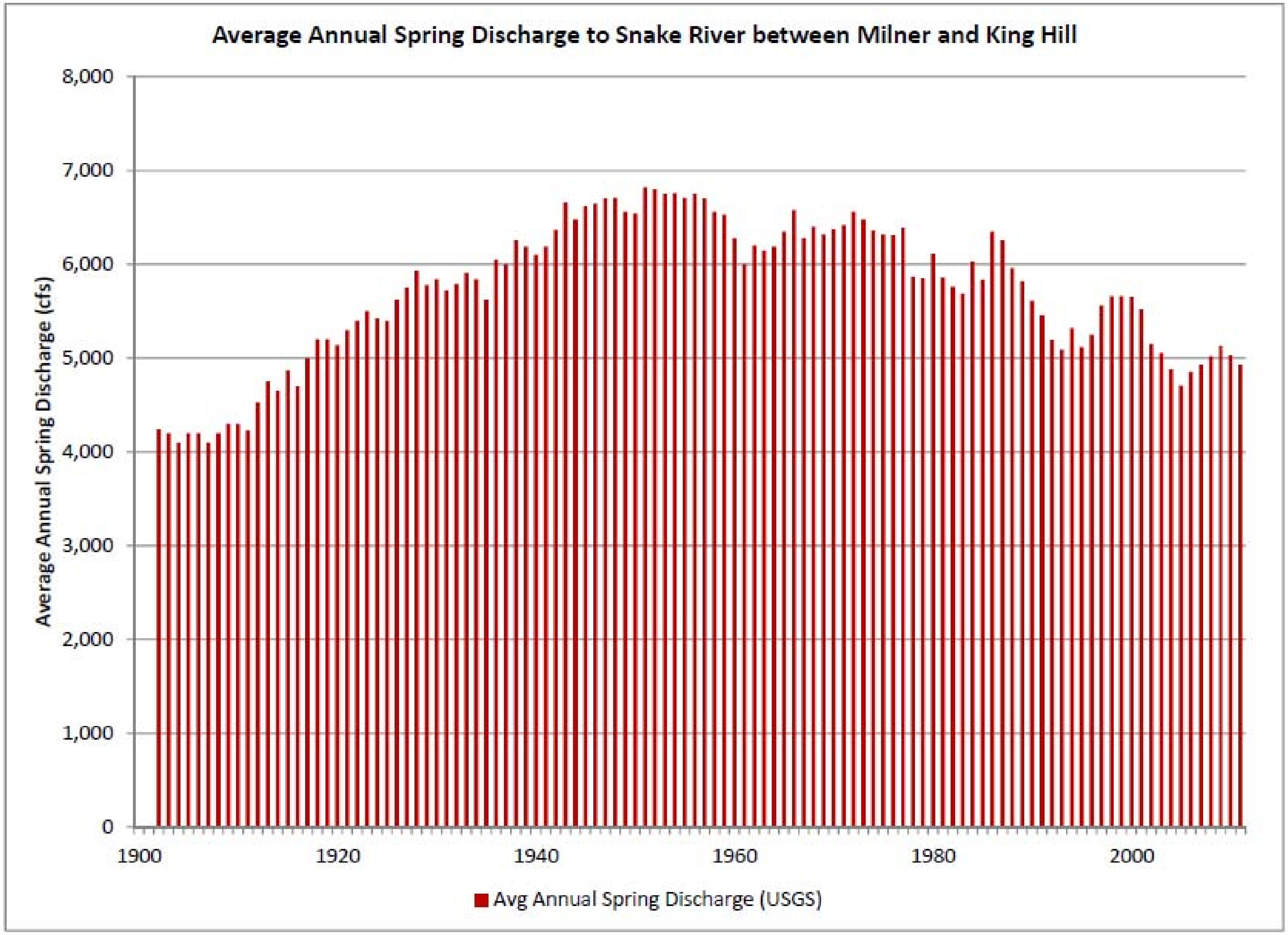


**Figure 2.** Total ESPA Spring Flow

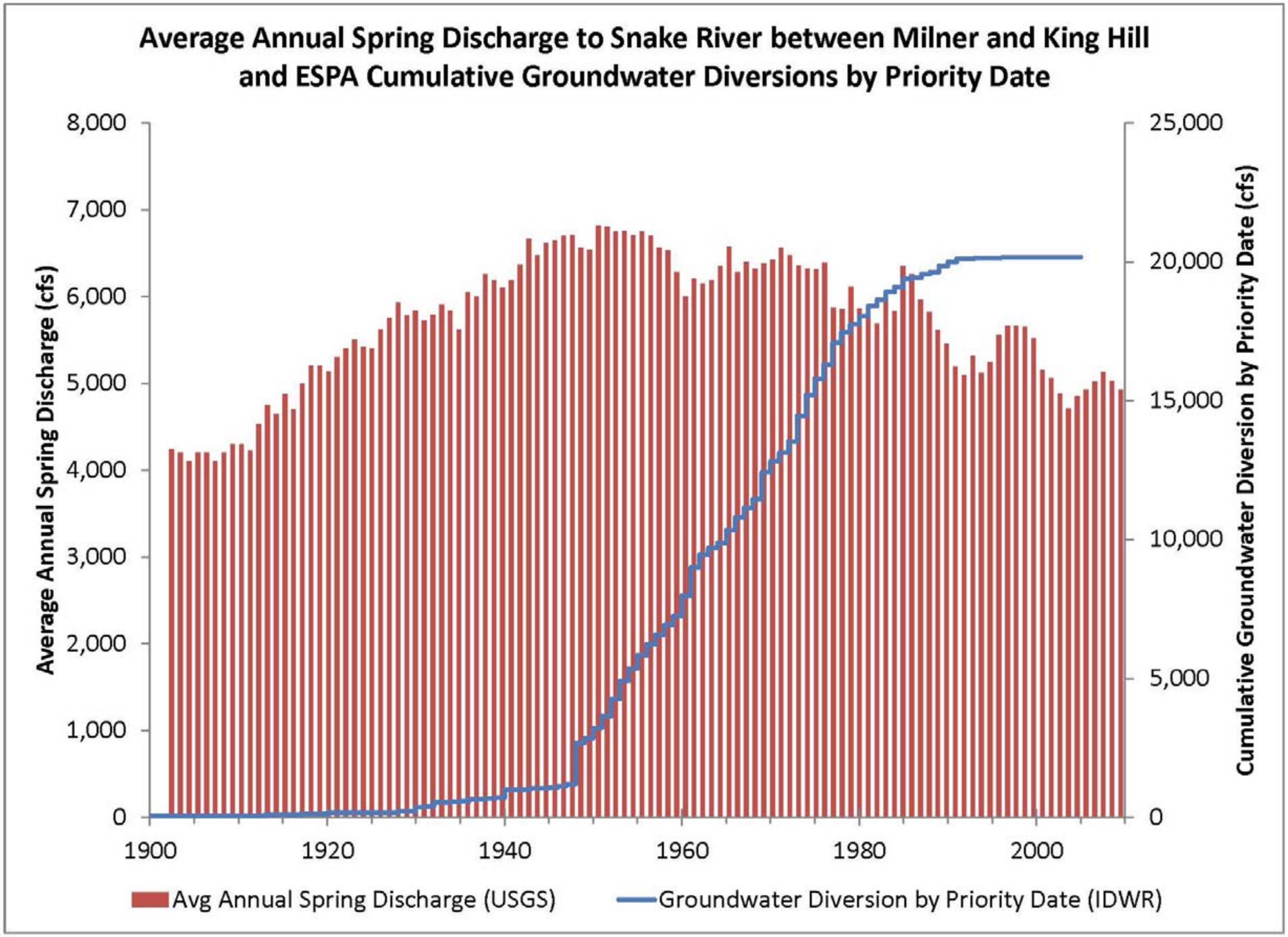


**Figure 3.** Eastern Snake River Plain Ground Water Rights vs. Estimated Northside Spring Flow

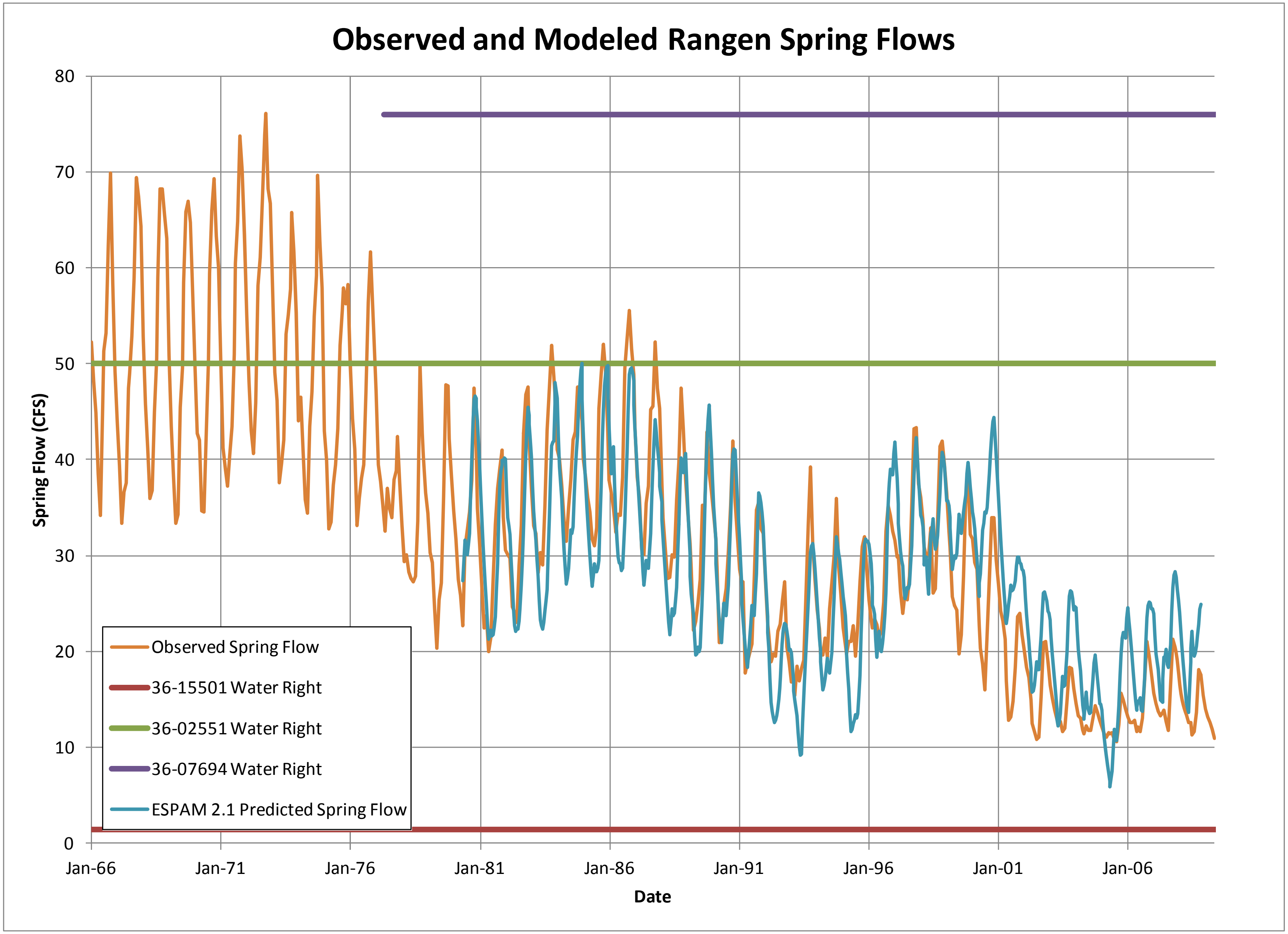


**Figure 4.** Rangen Spring Flows – Observed and Modeled


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www.LREwater.com

1179MSB01
SEPTEMBER 2012

Feet 0 125 250

Water Flow Direction

This product is for reference purposes only and is not to be construed as a legal document or survey instrument.
Path: U:\1179MSB_MaySdwkBrng\01_Rangen\00_GIS\mxd\201211_ExpRpt\HatcheryFlowDiagram.mxd

**FIGURE 5**
**RANGEN RESEARCH HATCHERY**
**HAGERMAN, ID**


**Figure 6.** Photo Showing Curren Tunnel

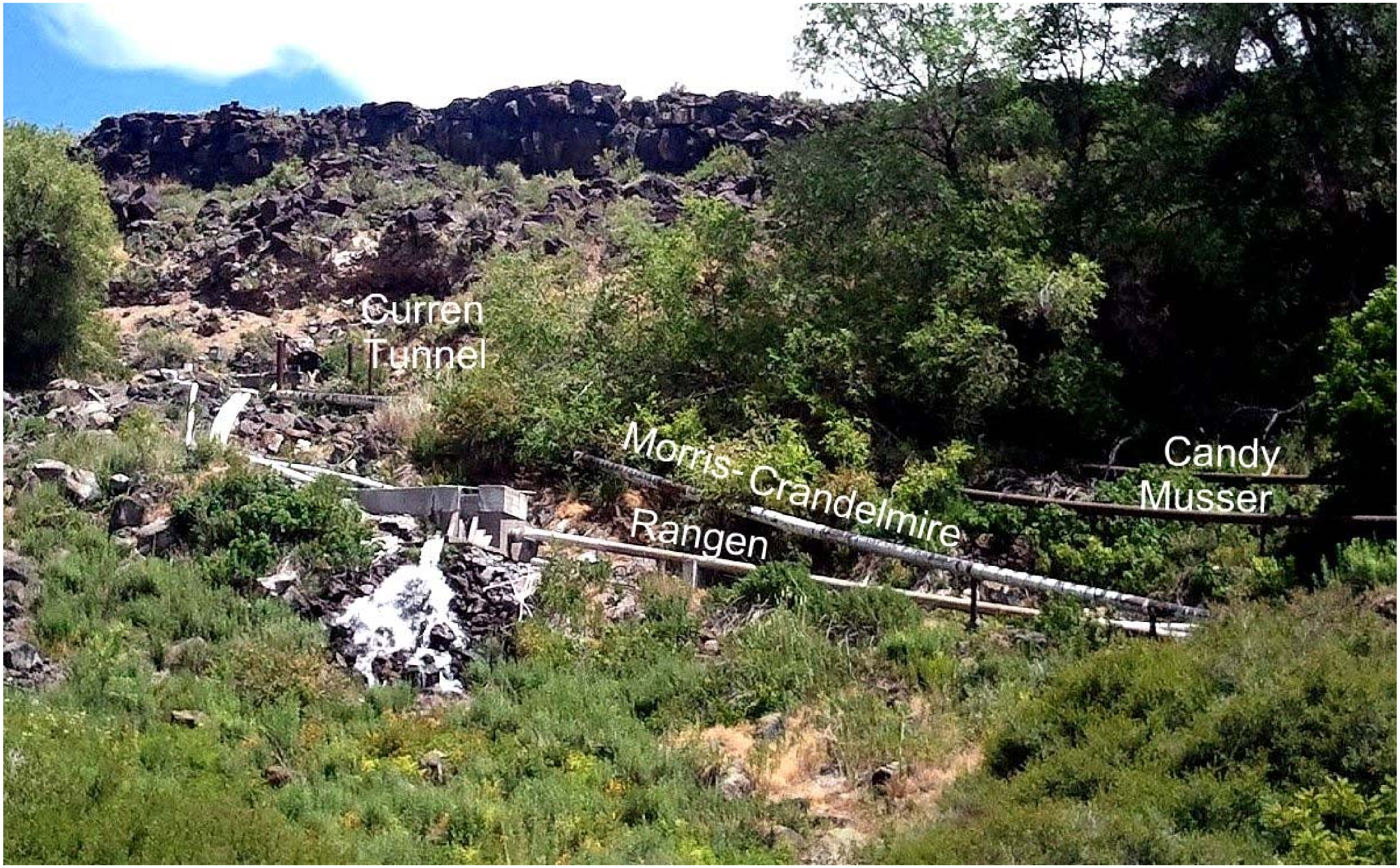



**Figure 7.** Photo Showing Curren Tunnel and Pipelines

**Figure 8.** Photo Showing Rangen Large Raceways Intake Structure

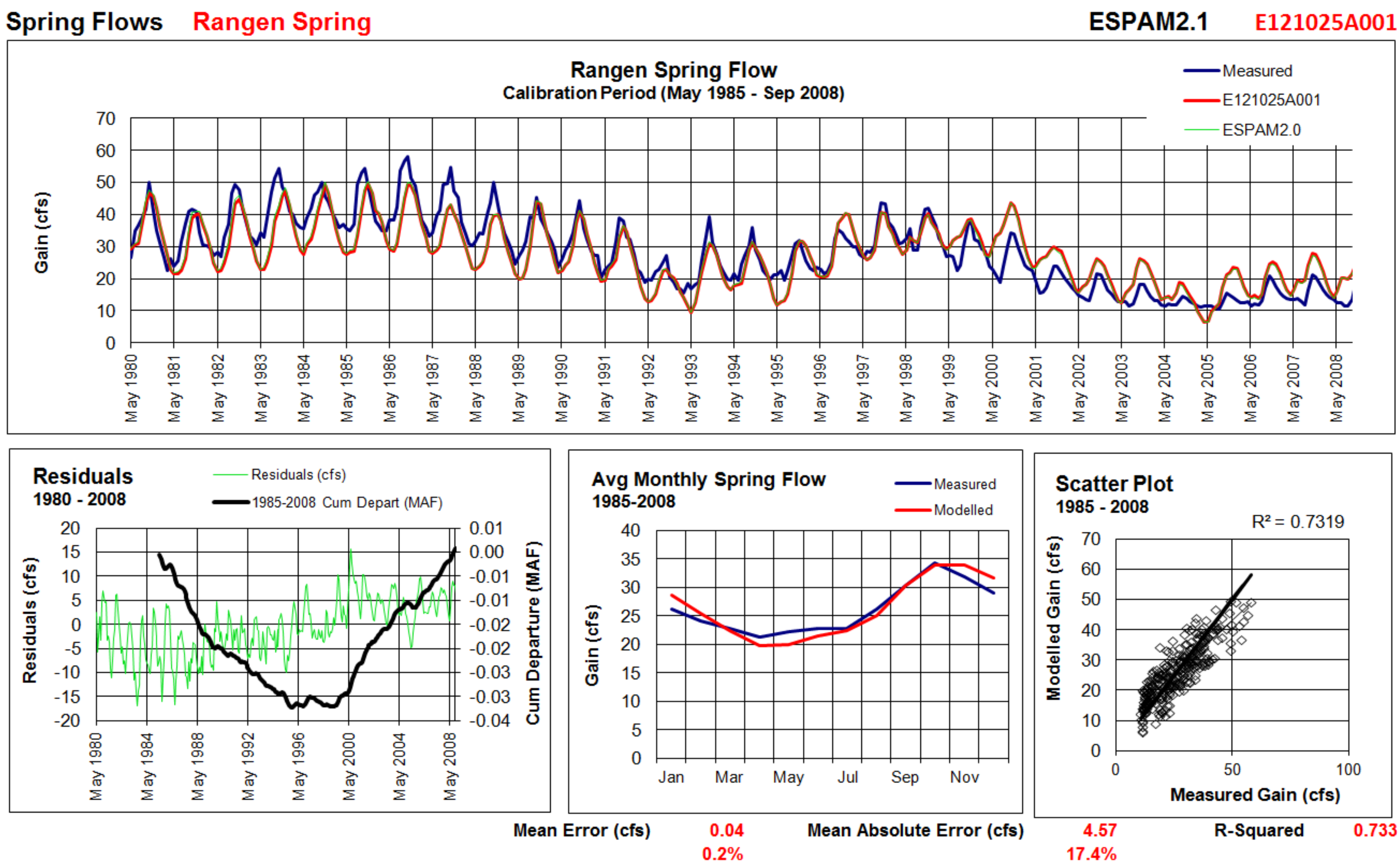



**Figure 9.** IDWR ESPAM 2.1 Rangen Spring Calibration Results (Adapted from IDWR, 2012)

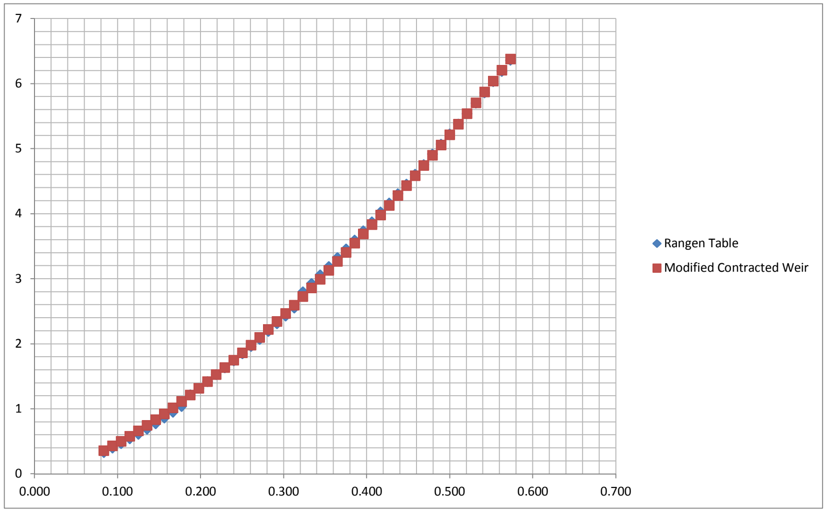
# Appendix A
Comparison of Rangen Weir Flow Calculations

RANGEN Appendix A Comparison of Rangen Weir Flow Calculations
Rangen CTR Raceway Discharge Rating
Head is measured over check boards at end of first bay of CTR Raceways
Only one Raceway was operating on 9/18/2012

As a suppressed weir

| | | | |
|---|---|---|---|
| Width | 58.5 inches | 4.875 ft | Rangen CTR keyways |
| Equation | Qs=3.33 *L*h^1.5 | (Francis Formula) | Std. Suppressed weir |
| | Qc=3.33 *(L-.2H)*h^1.5 | | Std Contracted Weir |
| | Qr | | Rangen Rating Table |

| H (inches) | H(feet) | Qs cfs | Qc | Qr | Qtc | Qts | Diff Qc-Qr |
|---|---|---|---|---|---|---|---|
| | | | | | 3.09 | 4 | Absolut % |
| 1 | 0.083 | 0.39 | 0.39 | 0.33 | 0.36 | 0.47 | 0.15 |
| 1 1/8 | 0.094 | 0.47 | 0.46 | 0.4 | 0.43 | 0.56 | 0.14 |
| 1 1/4 | 0.104 | 0.55 | 0.54 | 0.47 | 0.50 | 0.66 | 0.14 |
| 1 3/8 | 0.115 | 0.63 | 0.63 | 0.54 | 0.58 | 0.76 | 0.14 |
| 1 1/2 | 0.125 | 0.72 | 0.71 | 0.61 | 0.66 | 0.86 | 0.15 |
| 1 5/8 | 0.135 | 0.81 | 0.80 | 0.69 | 0.75 | 0.97 | 0.14 |
| 1 3/4 | 0.146 | 0.90 | 0.90 | 0.77 | 0.83 | 1.09 | 0.14 |
| 1 7/8 | 0.156 | 1.00 | 1.00 | 0.86 | 0.92 | 1.20 | 0.14 |
| 2 | 0.167 | 1.10 | 1.10 | 0.95 | 1.02 | 1.33 | 0.13 |
| 2 1/8 | 0.177 | 1.21 | 1.20 | 1.04 | 1.11 | 1.45 | 0.13 |
| 2 1/4 | 0.188 | 1.32 | 1.31 | 1.22 | 1.21 | 1.58 | 0.07 |
| 2 3/8 | 0.198 | 1.43 | 1.42 | 1.32 | 1.32 | 1.72 | 0.07 |
| 2 1/2 | 0.208 | 1.54 | 1.53 | 1.42 | 1.42 | 1.85 | 0.07 |
| 2 5/8 | 0.219 | 1.66 | 1.65 | 1.53 | 1.53 | 2.00 | 0.07 |
| 2 3/4 | 0.229 | 1.78 | 1.76 | 1.63 | 1.64 | 2.14 | 0.08 |
| 2 7/8 | 0.240 | 1.90 | 1.89 | 1.74 | 1.75 | 2.29 | 0.08 |
| 3 | 0.250 | 2.03 | 2.01 | 1.85 | 1.86 | 2.44 | 0.08 |
| 3 1/8 | 0.260 | 2.16 | 2.13 | 1.96 | 1.98 | 2.59 | 0.08 |
| 3 1/4 | 0.271 | 2.29 | 2.26 | 2.07 | 2.10 | 2.75 | 0.09 |
| 3 3/8 | 0.281 | 2.42 | 2.39 | 2.19 | 2.22 | 2.91 | 0.08 |
| 3 1/2 | 0.292 | 2.56 | 2.53 | 2.31 | 2.34 | 3.07 | 0.09 |
| 3 5/8 | 0.302 | 2.70 | 2.66 | 2.43 | 2.47 | 3.24 | 0.09 |
| 3 3/4 | 0.313 | 2.84 | 2.80 | 2.55 | 2.60 | 3.41 | 0.09 |
| 3 7/8 | 0.323 | 2.98 | 2.94 | 2.8 | 2.73 | 3.58 | 0.05 |
| 4 | 0.333 | 3.12 | 3.08 | 2.93 | 2.86 | 3.75 | 0.05 |
| 4 1/8 | 0.344 | 3.27 | 3.23 | 3.06 | 2.99 | 3.93 | 0.05 |
| 4 1/4 | 0.354 | 3.42 | 3.37 | 3.19 | 3.13 | 4.11 | 0.05 |
| 4 3/8 | 0.365 | 3.57 | 3.52 | 3.33 | 3.27 | 4.29 | 0.05 |
| 4 1/2 | 0.375 | 3.73 | 3.67 | 3.46 | 3.41 | 4.48 | 0.06 |
| 4 5/8 | 0.385 | 3.88 | 3.82 | 3.6 | 3.55 | 4.67 | 0.06 |
| 4 3/4 | 0.396 | 4.04 | 3.98 | 3.74 | 3.69 | 4.86 | 0.06 |
| 4 7/8 | 0.406 | 4.20 | 4.13 | 3.88 | 3.84 | 5.05 | 0.06 |
| 5 | 0.417 | 4.37 | 4.29 | 4.03 | 3.98 | 5.24 | 0.06 |
| 5 1/8 | 0.427 | 4.53 | 4.45 | 4.17 | 4.13 | 5.44 | 0.06 |
| 5 1/4 | 0.438 | 4.70 | 4.61 | 4.31 | 4.28 | 5.64 | 0.07 |
| 5 3/8 | 0.448 | 4.87 | 4.78 | 4.46 | 4.43 | 5.85 | 0.07 |
| 5 1/2 | 0.458 | 5.04 | 4.94 | 4.61 | 4.59 | 6.05 | 0.07 |
| 5 5/8 | 0.469 | 5.21 | 5.11 | 4.76 | 4.74 | 6.26 | 0.07 |
| 5 3/4 | 0.479 | 5.38 | 5.28 | 4.92 | 4.90 | 6.47 | 0.07 |
| 5 7/8 | 0.490 | 5.56 | 5.45 | 5.07 | 5.06 | 6.68 | 0.07 |
| 6 | 0.500 | 5.74 | 5.62 | 5.23 | 5.22 | 6.89 | 0.07 |
| 6 1/8 | 0.510 | 5.92 | 5.80 | 5.38 | 5.38 | 7.11 | 0.07 |
| 6 1/4 | 0.521 | 6.10 | 5.97 | 5.54 | 5.54 | 7.33 | 0.07 |
| 6 3/8 | 0.531 | 6.29 | 6.15 | 5.7 | 5.71 | 7.55 | 0.07 |
| 6 1/2 | 0.542 | 6.47 | 6.33 | 5.86 | 5.87 | 7.77 | 0.07 |
| 6 5/8 | 0.552 | 6.66 | 6.51 | 6.03 | 6.04 | 8.00 | 0.07 |
| 6 3/4 | 0.563 | 6.85 | 6.69 | 6.19 | 6.21 | 8.23 | 0.07 |
| 6 7/8 | 0.573 | 7.04 | 6.87 | 6.36 | 6.38 | 8.46 | 0.07 |
| | | | | | | AVG | 0.08 |




Remark: Discharge table used by Rangen employees appears to match most closely with a standard contracted weir formula with a coefficient of 3.09 rather than the standard 3.33 coefficient.
This would account for the fact that the 2 inch boards over which water flows are not sharp crested as is assumed in the standard rectangular contracted weir formula.
There are two minor step functions in the Rangen discharge table for which there is no apparent reason, at approximately H=.18 ft(2 1/8 in.) and 0.32 ft (3 7/8 in).

The use of a modified weir coefficient of 3.09 applied to board overflow is consistent with standard practice on aquaculture facilities

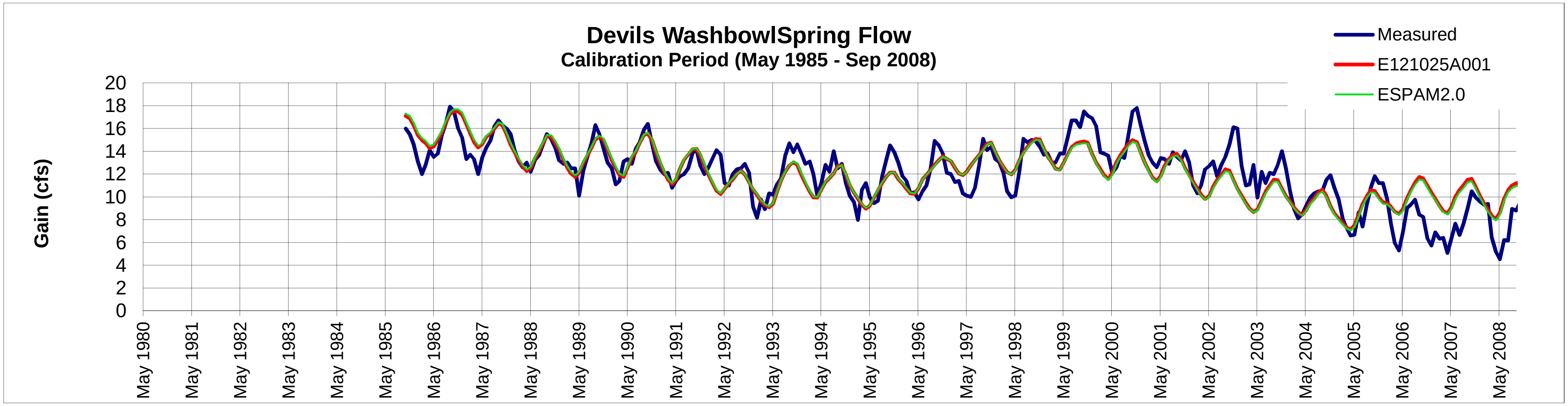
| INCHES | | LG RW | CTR | SM | DAM |
|---|---|---|---|---|---|
| 1 | 0 | 0.25 | 0.33 | 0.23 | 0.28 |
| 1 | 1/8 | 0.30 | 0.40 | 0.27 | 0.33 |
| 1 | 1/4 | 0.35 | 0.47 | 0.31 | 0.39 |
| 1 | 3/8 | 0.41 | 0.54 | 0.36 | 0.45 |
| 1 | 1/2 | 0.47 | 0.61 | 0.41 | 0.51 |
| 1 | 5/8 | 0.52 | 0.69 | 0.47 | 0.57 |
| 1 | 3/4 | 0.59 | 0.77 | 0.52 | 0.64 |
| 1 | 7/8 | 0.65 | 0.86 | 0.58 | 0.71 |
| | | | | | |
| 2 | 0 | 0.72 | 0.95 | 0.64 | 0.78 |
| 2 | 1/8 | 0.79 | 1.04 | 0.70 | 0.86 |
| 2 | 1/4 | 0.93 | 1.22 | 0.82 | 1.01 |
| 2 | 3/8 | 1.00 | 1.32 | 0.89 | 1.09 |
| 2 | 1/2 | 1.08 | 1.42 | 0.96 | 1.18 |
| 2 | 5/8 | 1.16 | 1.53 | 1.03 | 1.26 |
| 2 | 3/4 | 1.24 | 1.63 | 1.10 | 1.35 |
| 2 | 7/8 | 1.32 | 1.74 | 1.17 | 1.44 |
| | | | | | |
| 3 | 0 | 1.40 | 1.85 | 1.24 | 1.53 |
| 3 | 1/8 | 1.48 | 1.96 | 1.32 | 1.62 |
| 3 | 1/4 | 1.57 | 2.07 | 1.40 | 1.72 |
| 3 | 3/8 | 1.66 | 2.19 | 1.47 | 1.81 |
| 3 | 1/2 | 1.75 | 2.31 | 1.55 | 1.91 |
| 3 | 5/8 | 1.84 | 2.43 | 1.63 | 2.01 |
| 3 | 3/4 | 1.93 | 2.55 | 1.72 | 2.11 |
| 3 | 7/8 | 2.12 | 2.80 | 1.89 | 2.32 |
| | | | | | |
| 4 | 0 | 2.22 | 2.93 | 1.97 | 2.43 |
| 4 | 1/8 | 2.32 | 3.06 | 2.06 | 2.53 |
| 4 | 1/4 | 2.42 | 3.19 | 2.15 | 2.64 |
| 4 | 3/8 | 2.52 | 3.33 | 2.24 | 2.75 |
| 4 | 1/2 | 2.62 | 3.46 | 2.33 | 2.87 |
| 4 | 5/8 | 2.73 | 3.60 | 2.42 | 2.98 |
| 4 | 3/4 | 2.83 | 3.74 | 2.52 | 3.10 |
| 4 | 7/8 | 2.94 | 3.88 | 2.61 | 3.21 |
| | | | | | |
| 5 | 0 | 3.05 | 4.02 | 2.71 | 3.33 |
| 5 | 1/8 | 3.16 | 4.17 | 2.80 | 3.45 |
| 5 | 1/4 | 3.27 | 4.31 | 2.90 | 3.57 |
| 5 | 3/8 | 3.38 | 4.46 | 3.00 | 3.69 |
| 5 | 1/2 | 3.49 | 4.61 | 3.10 | 3.82 |
| 5 | 5/8 | 3.61 | 4.76 | 3.20 | 3.94 |
| 5 | 3/4 | 3.72 | 4.92 | 3.31 | 4.07 |
| 5 | 7/8 | 3.84 | 5.07 | 3.41 | 4.20 |
| | | | | | |
| 6 | 0 | 3.96 | 5.23 | 3.52 | 4.33 |
| 6 | 1/8 | 4.08 | 5.38 | 3.62 | 4.46 |
| 6 | 1/4 | 4.20 | 5.54 | 3.73 | 4.59 |
| 6 | 3/8 | 4.32 | 5.70 | 3.84 | 4.72 |
| 6 | 1/2 | 4.44 | 5.86 | 3.95 | 4.86 |
| 6 | 5/8 | 4.57 | 6.03 | 4.06 | 4.99 |
| 6 | 3/4 | 4.69 | 6.19 | 4.17 | 5.13 |
| 6 | 7/8 | 4.82 | 6.36 | 4.28 | 5.27 |

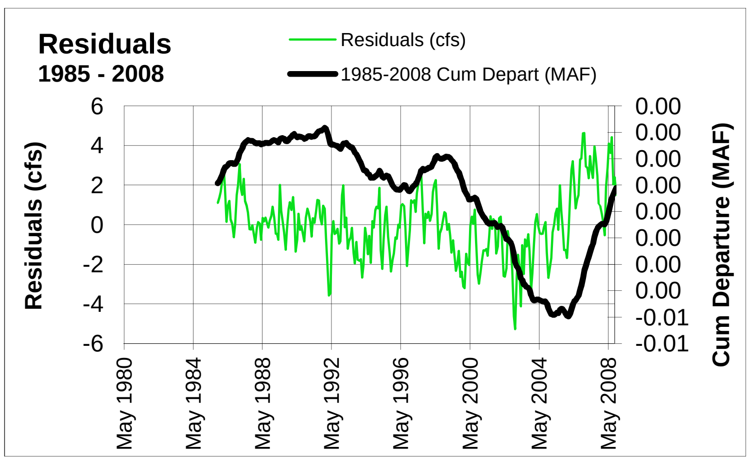
** table adjusted for measurement over 2" boards

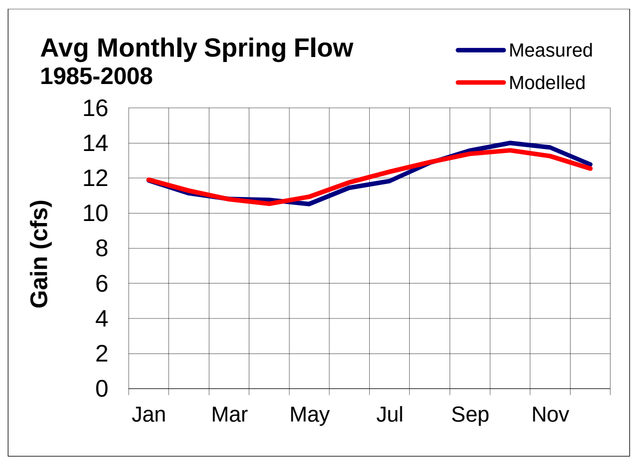
# Appendix B
IDWR ESPAM 2.1 Spring Statistics

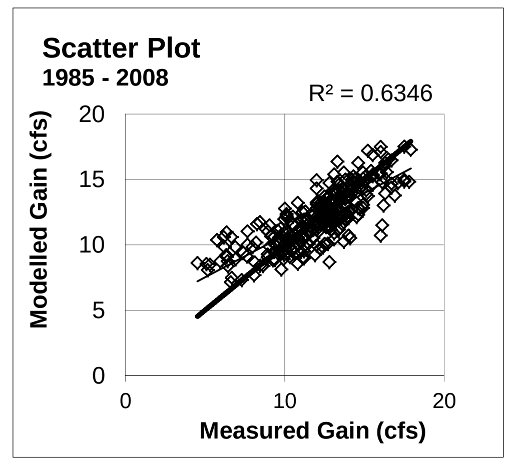
# ESPAM Calibration Charts
# Spring Flows

**Spring Flows** **Devils Washbowl Spring** **ESPAM2.1** **E121025A001**



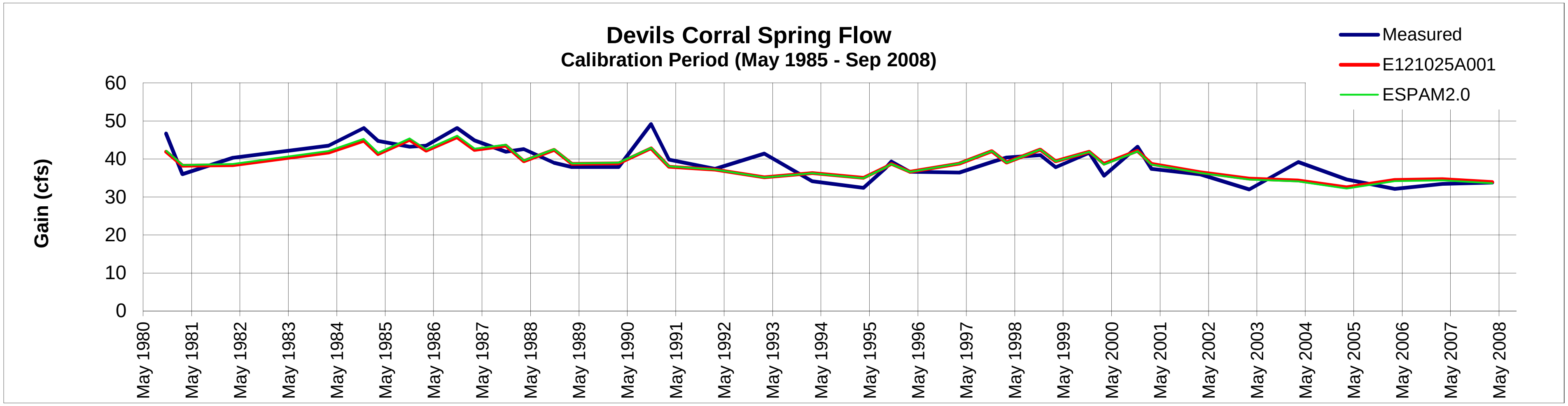



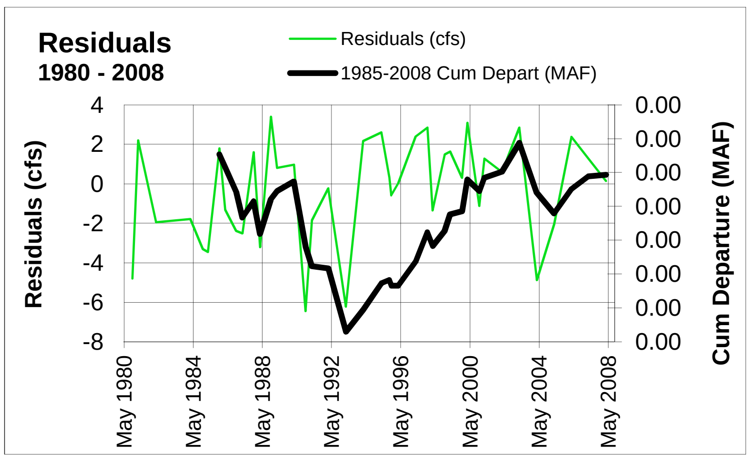



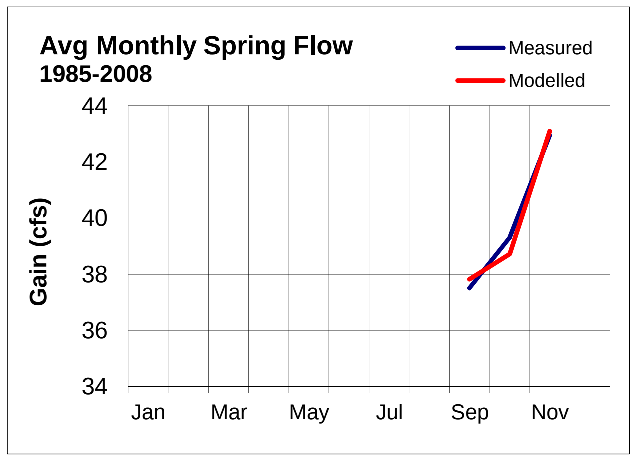

| | | | | | |
|---|---|---|---|---|---|
| **Mean Error (cfs)** | -0.01 | **Mean Absolute Error (cfs)** | 1.26 | **R-Squared** | 0.635 |
| | -0.1% | | 10.4% | | |

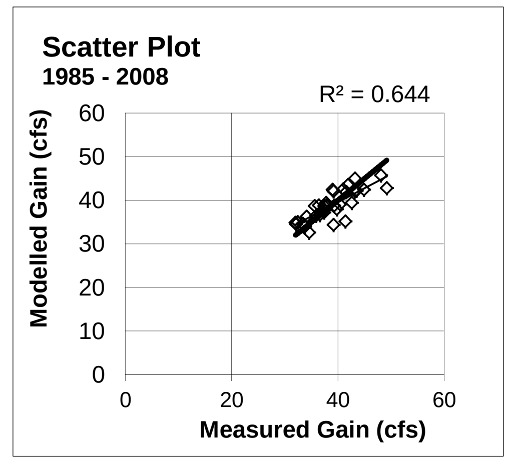
# ESPAM Calibration Charts
# Spring Flows

**Spring Flows** **Devils Corral Spring** **ESPAM2.1** **E121025A001**



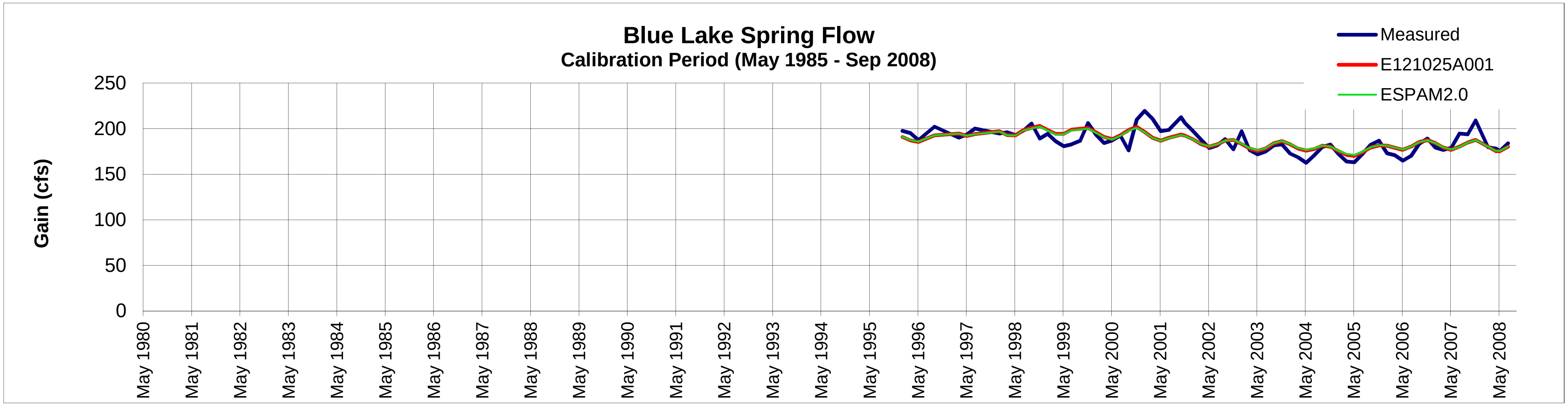



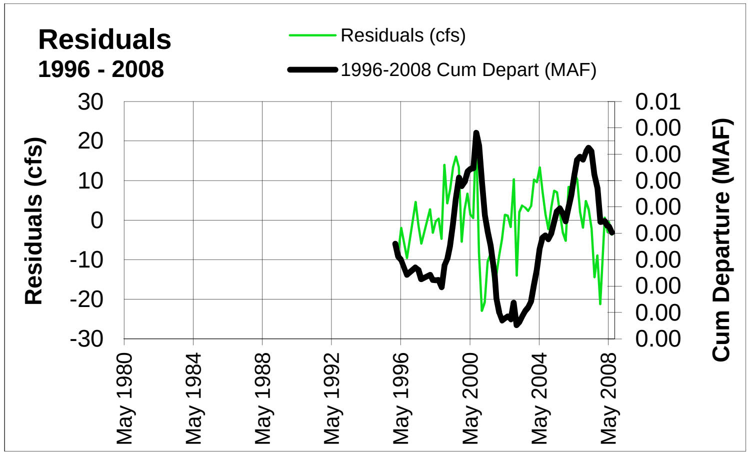



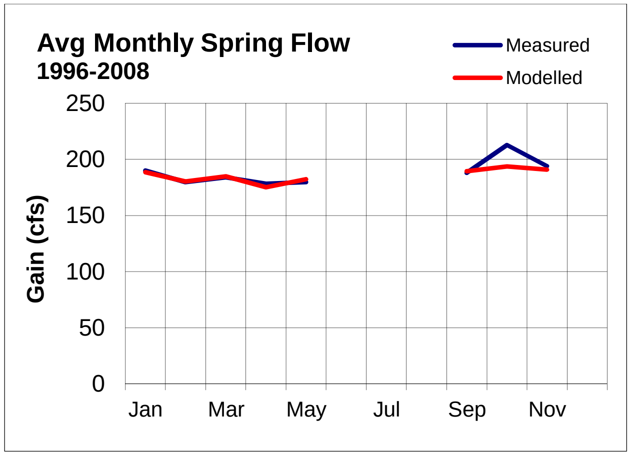

| | | | | | |
|---|---|---|---|---|---|
| **Mean Error (cfs)** | **-0.01**<br>**0.0%** | **Mean Absolute Error (cfs)** | **2.00**<br>**5.1%** | **R-Squared** | **0.644** |

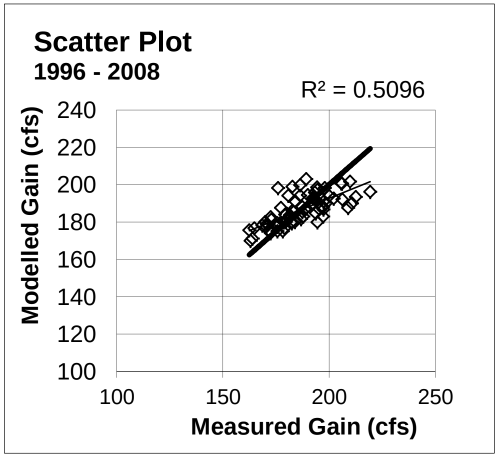
# ESPAM Calibration Charts
# Spring Flows

**Spring Flows** **Blue Lake Spring** **ESPAM2.1** **E121025A001**



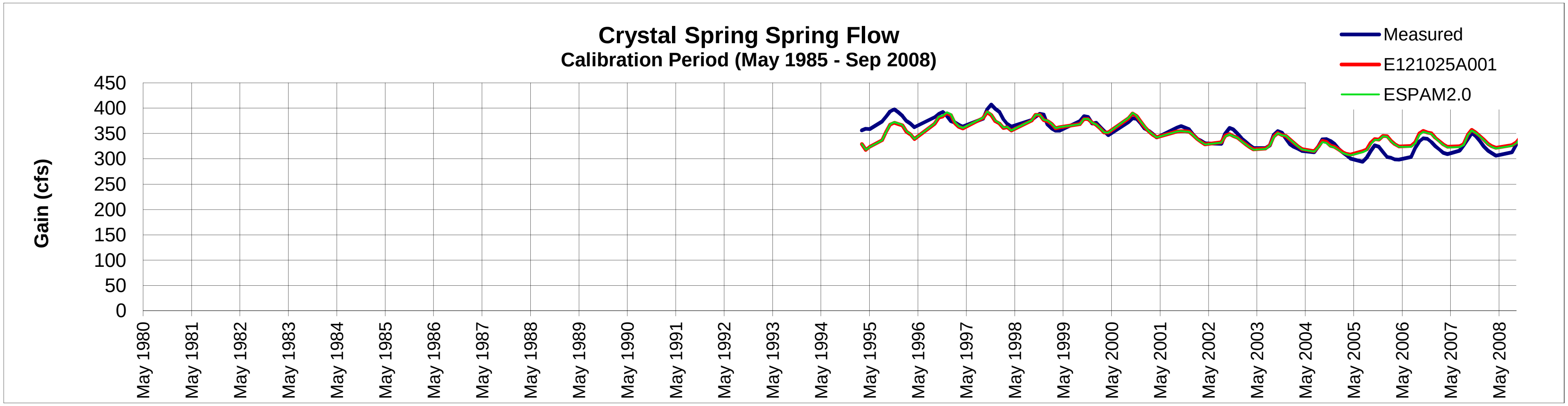



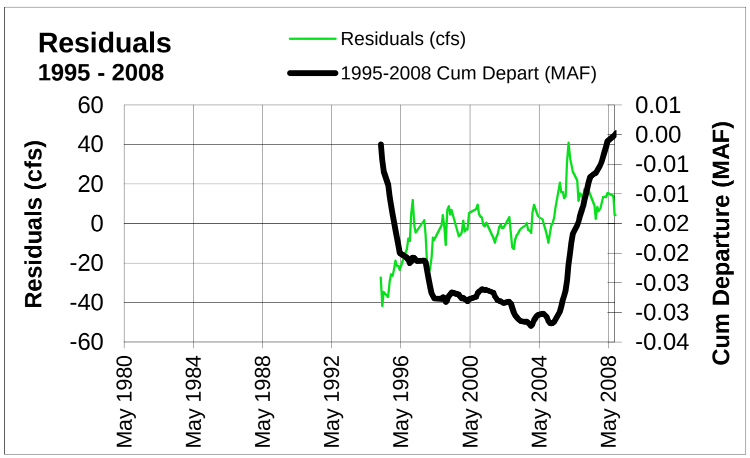



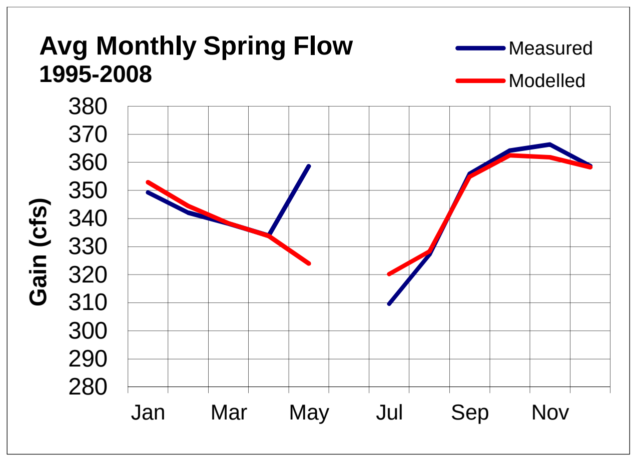

| | | | | | |
|---|---|---|---|---|---|
| **Mean Error (cfs)** | **0.01** | **Mean Absolute Error (cfs)** | **6.97** | **R-Squared** | **0.510** |
| | **0.0%** | | **0.0%** | | |

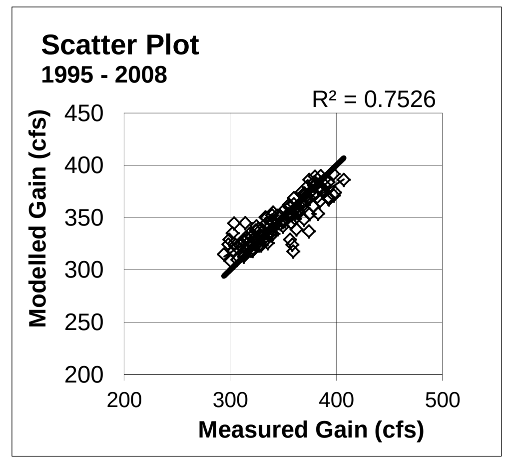
# ESPAM Calibration Charts
# Spring Flows

**Spring Flows** **Crystal Spring** **ESPAM2.1** **E121025A001**



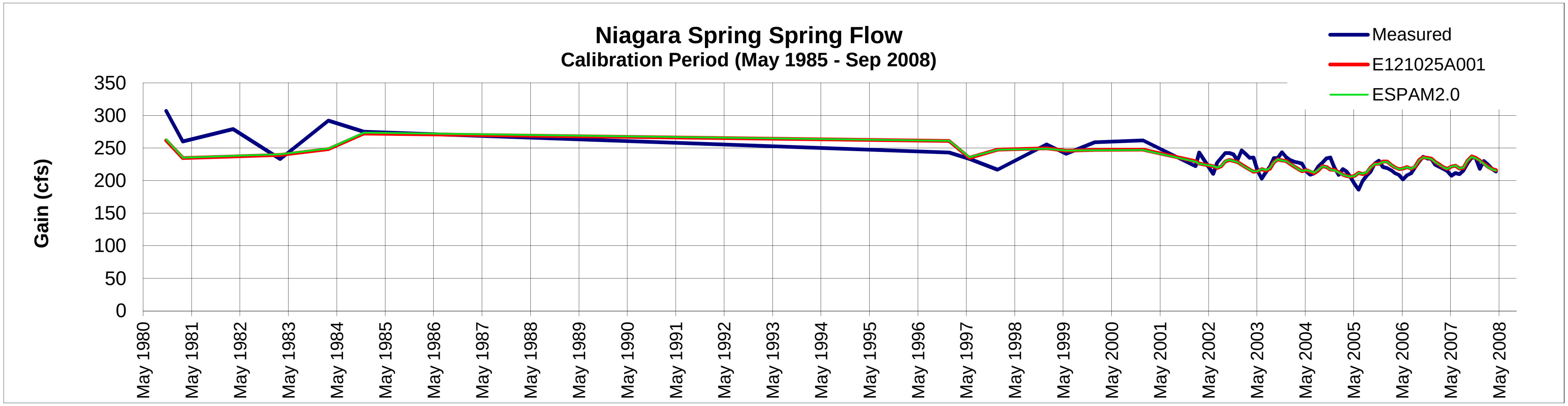



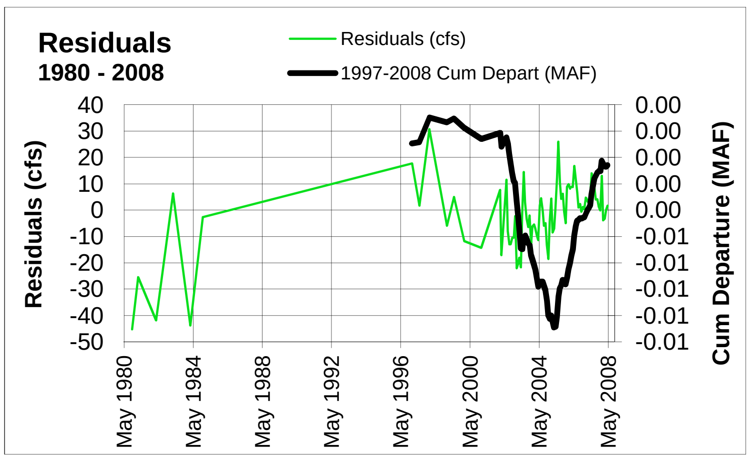



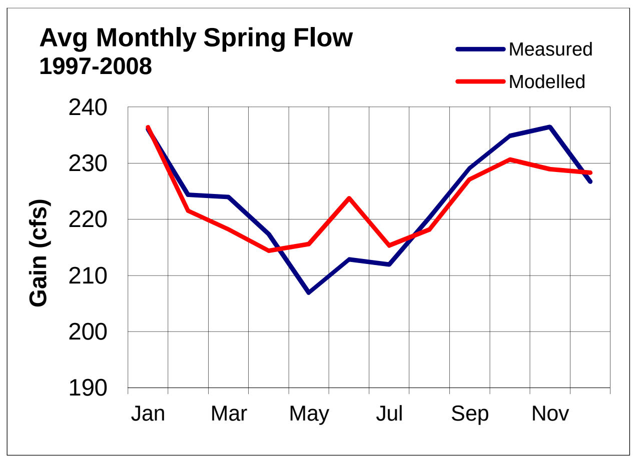

| | | | | | |
|---|---|---|---|---|---|
| **Mean Error (cfs)** | **0.03** | **Mean Absolute Error (cfs)** | **10.67** | **R-Squared** | **0.753** |
| | **0.0%** | | **3.1%** | | |

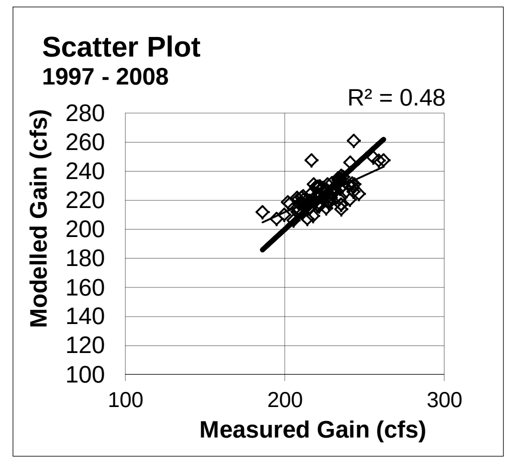
# ESPAM Calibration Charts
# Spring Flows

**Spring Flows** **Niagara Spring** **ESPAM2.1** **E121025A001**



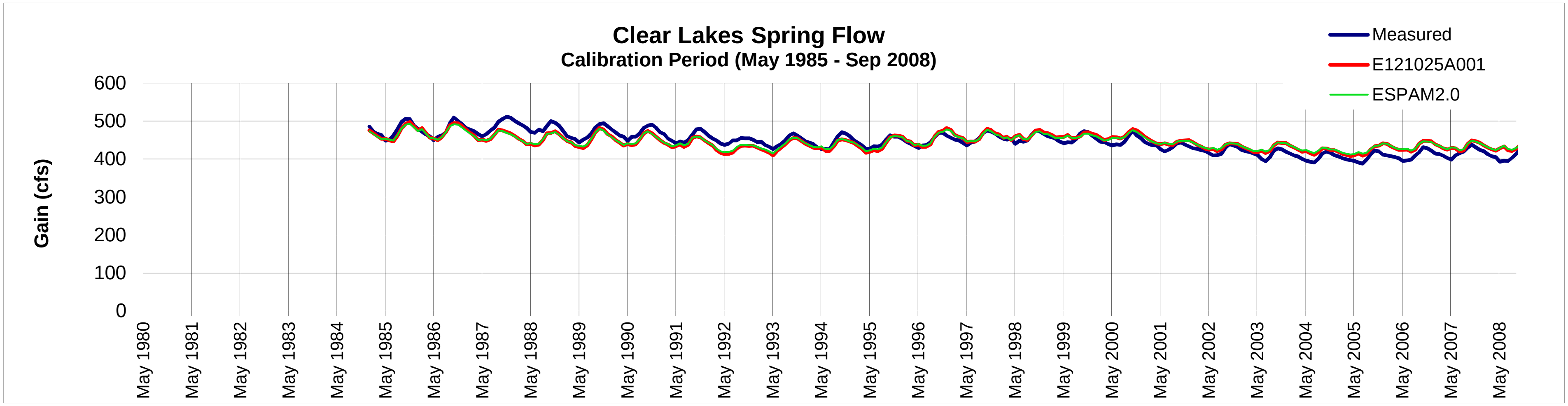



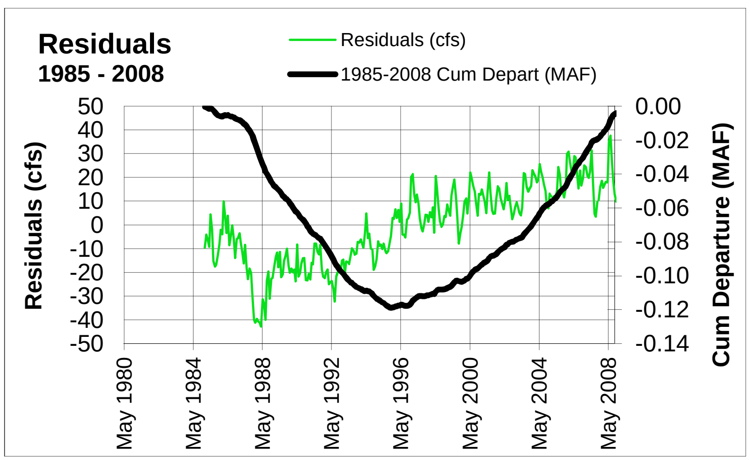



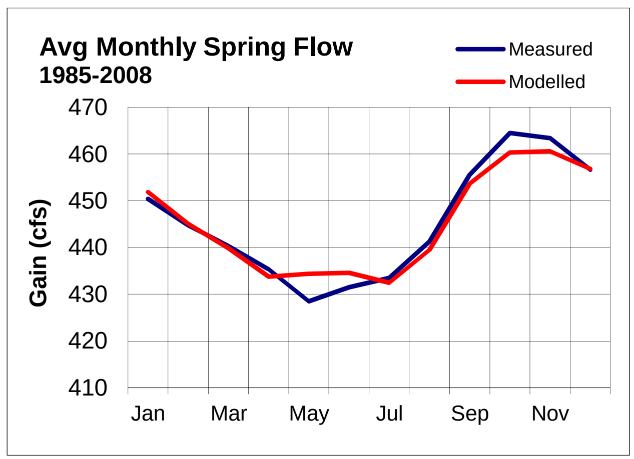

| | | | | | |
|---|---|---|---|---|---|
| **Mean Error (cfs)** | **-0.12**<br>**-0.1%** | **Mean Absolute Error (cfs)** | **8.12**<br>**3.6%** | **R-Squared** | **0.480** |

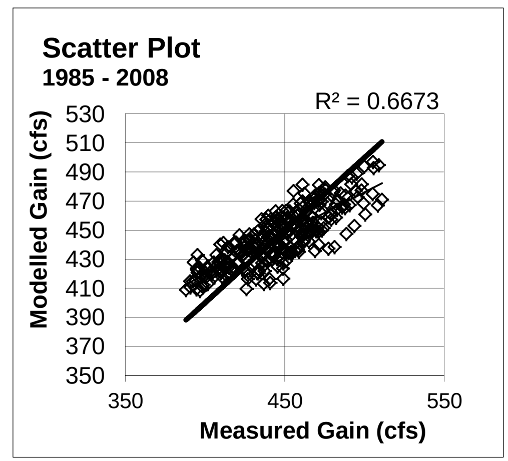
# ESPAM Calibration Charts
## Spring Flows

**Spring Flows** **Clear Lakes Spring** **ESPAM2.1** **E121025A001**



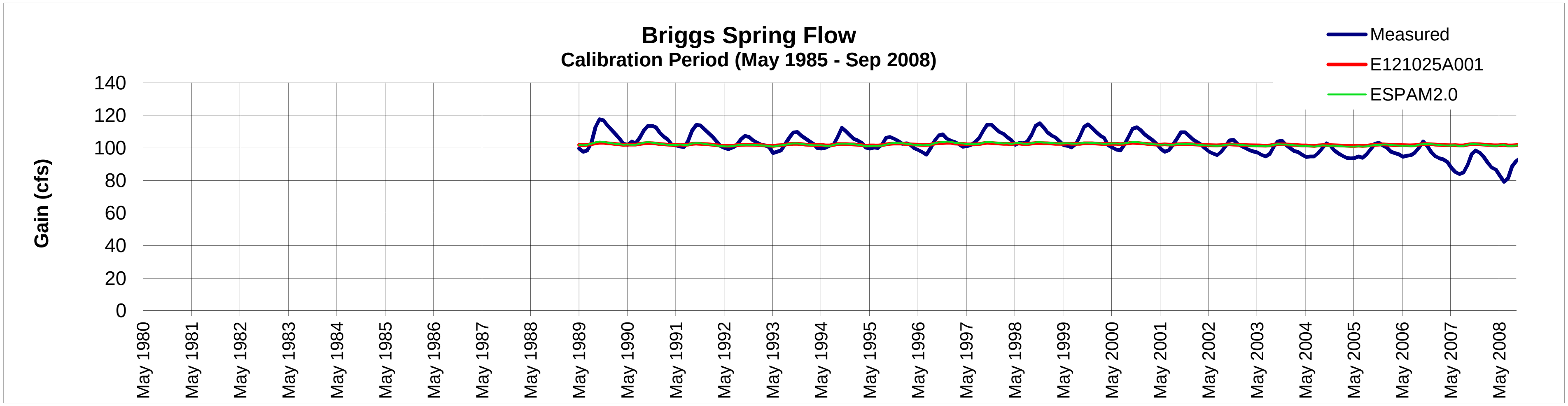



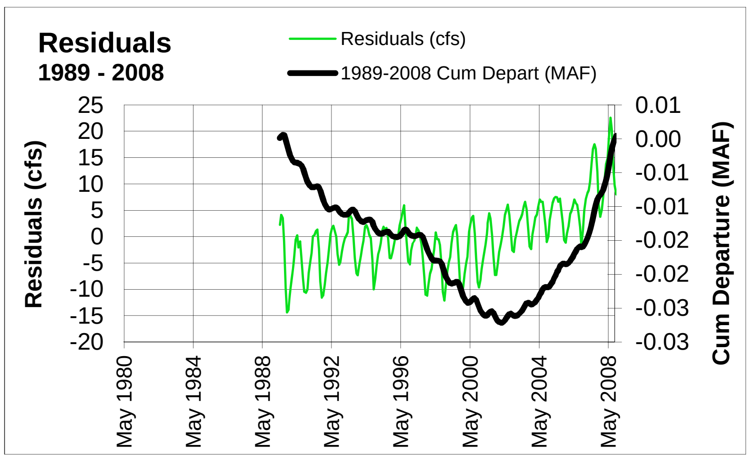



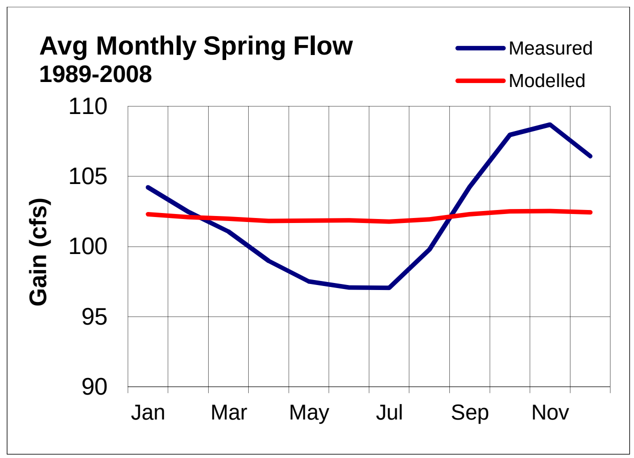

| | | | | | |
|---|---|---|---|---|---|
| **Mean Error (cfs)** | **-0.23** | **Mean Absolute Error (cfs)** | **13.97** | **R-Squared** | **0.667** |
| | **-0.1%** | | **3.1%** | | |

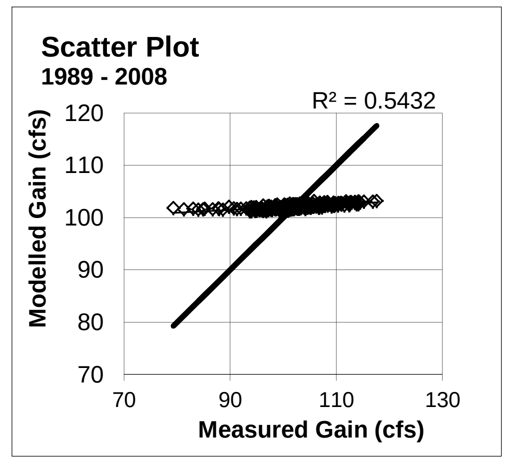
# ESPAM Calibration Charts
# Spring Flows

**Spring Flows** **Briggs Spring** **ESPAM2.1** **E121025A001**



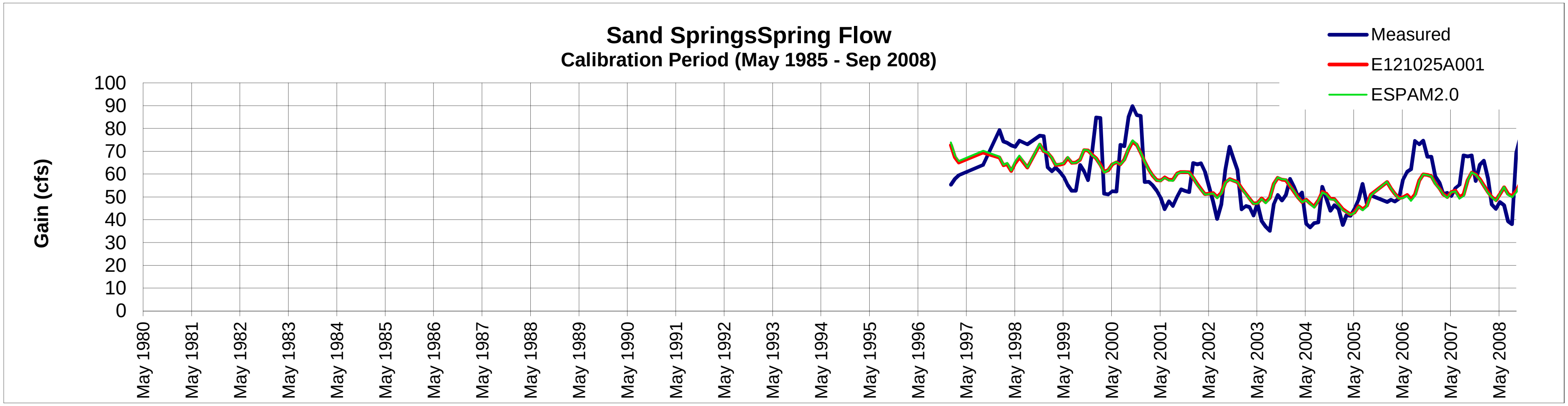



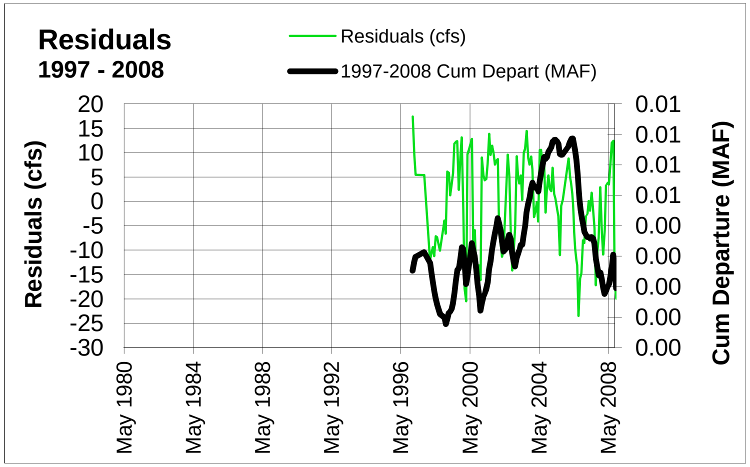



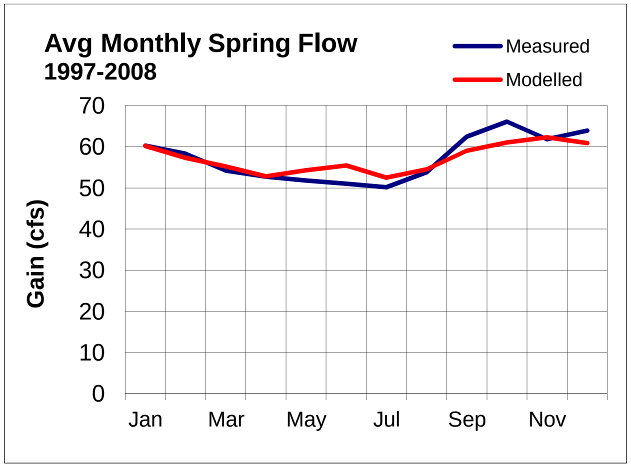

| Mean Error (cfs) | 0.03 | Mean Absolute Error (cfs) | 4.79 | R-Squared | 0.543 |
|---|---|---|---|---|---|
| | 0.0% | | 4.7% | | |

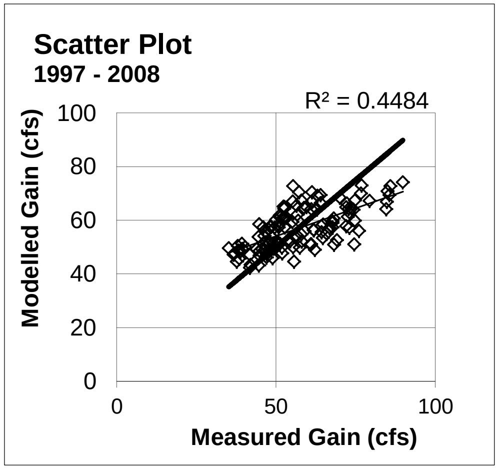
# ESPAM Calibration Charts
# Spring Flows

**Spring Flows** **Sand Springs** **ESPAM2.1** **E121025A001**



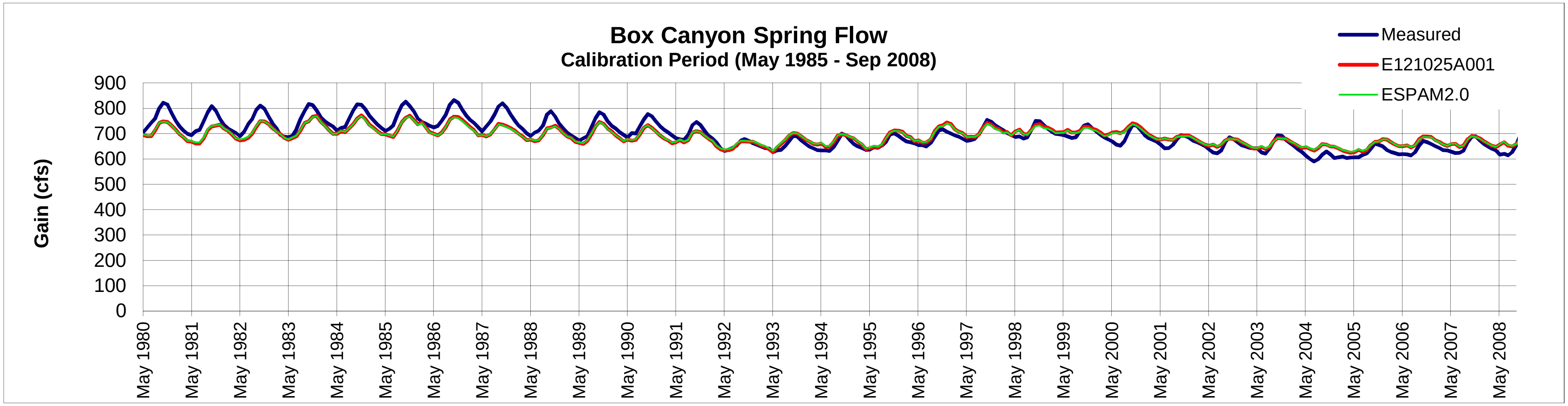



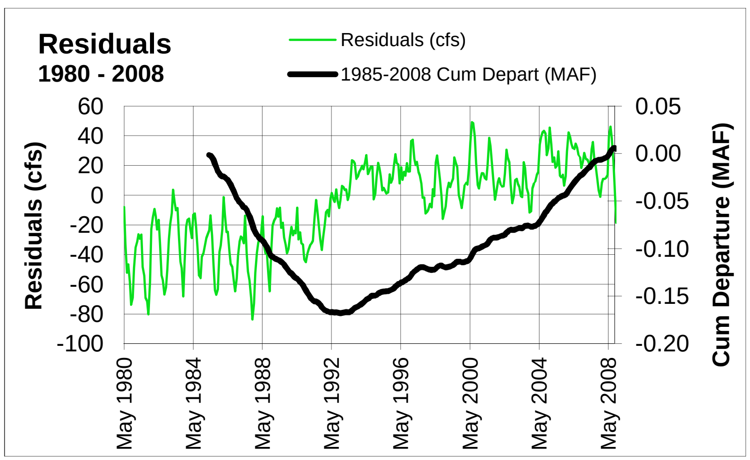



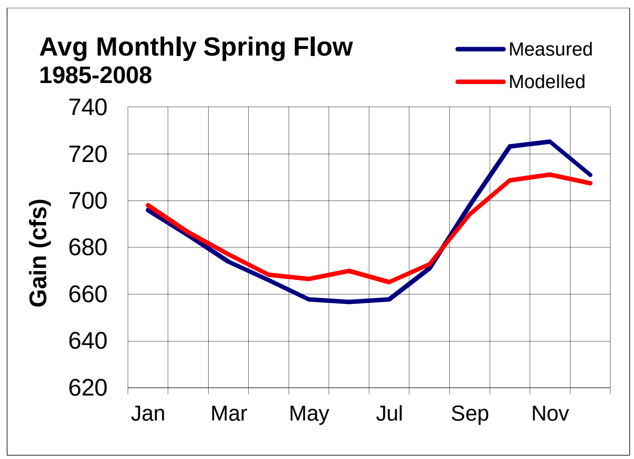

| Mean Error (cfs) | -0.01 | Mean Absolute Error (cfs) | 7.89 | R-Squared | 0.448 |
|---|---|---|---|---|---|
| | 0.0% | | 13.8% | | |

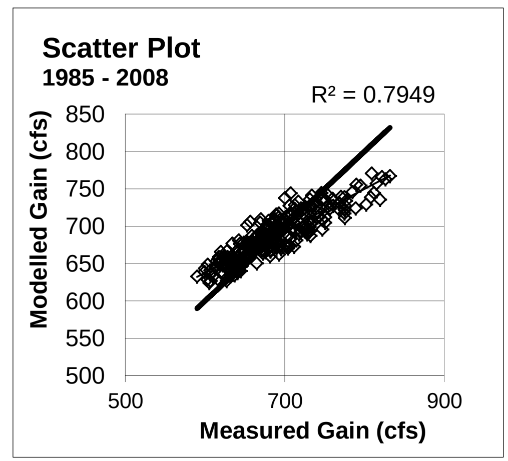
# ESPAM Calibration Charts
# Spring Flows

**Spring Flows** **Box Spring** **ESPAM2.1** **E121025A001**



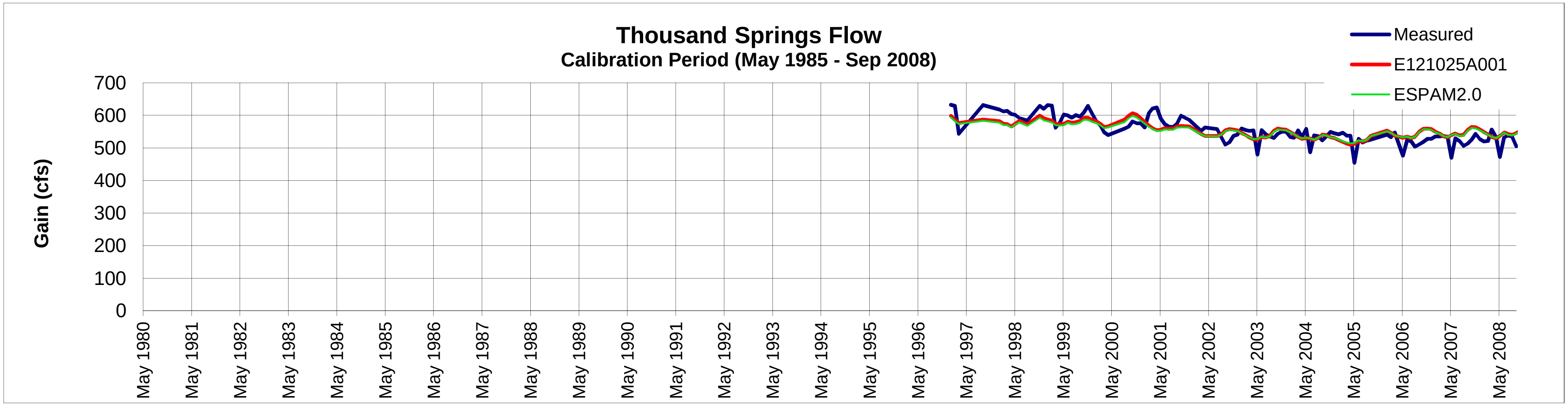



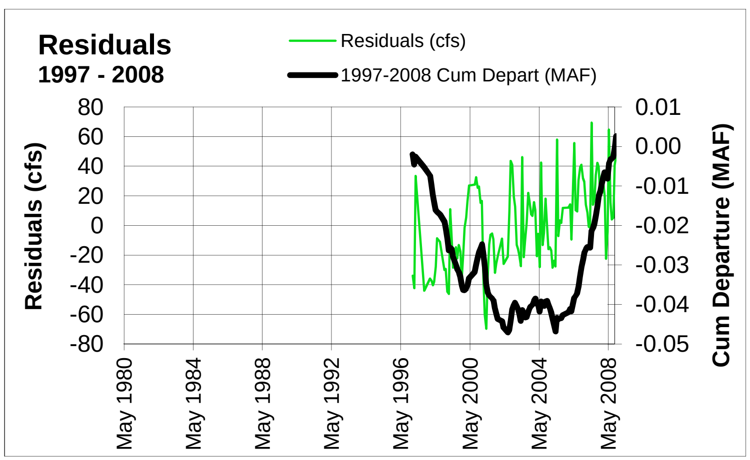



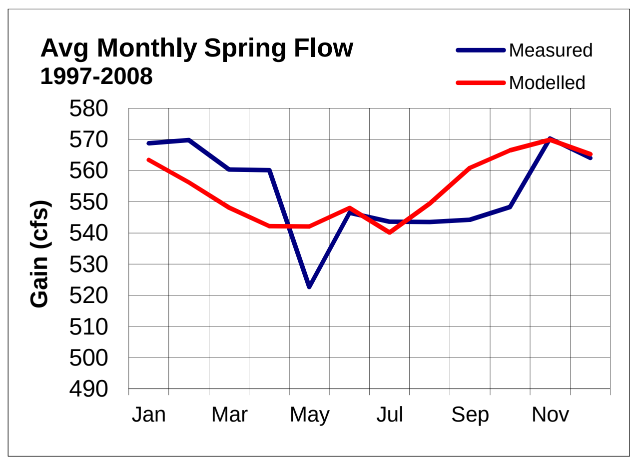

| | | | | | |
|---|---|---|---|---|---|
| **Mean Error (cfs)** | **0.37**<br>**0.1%** | **Mean Absolute Error (cfs)** | **21.11**<br>**3.6%** | **R-Squared** | **0.795** |

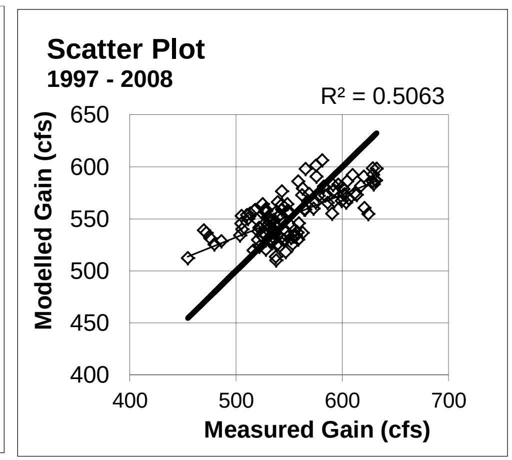
# ESPAM Calibration Charts
# Spring Flows

**Spring Flows** **Thousand Springs** **ESPAM2.1** **E121025A001**



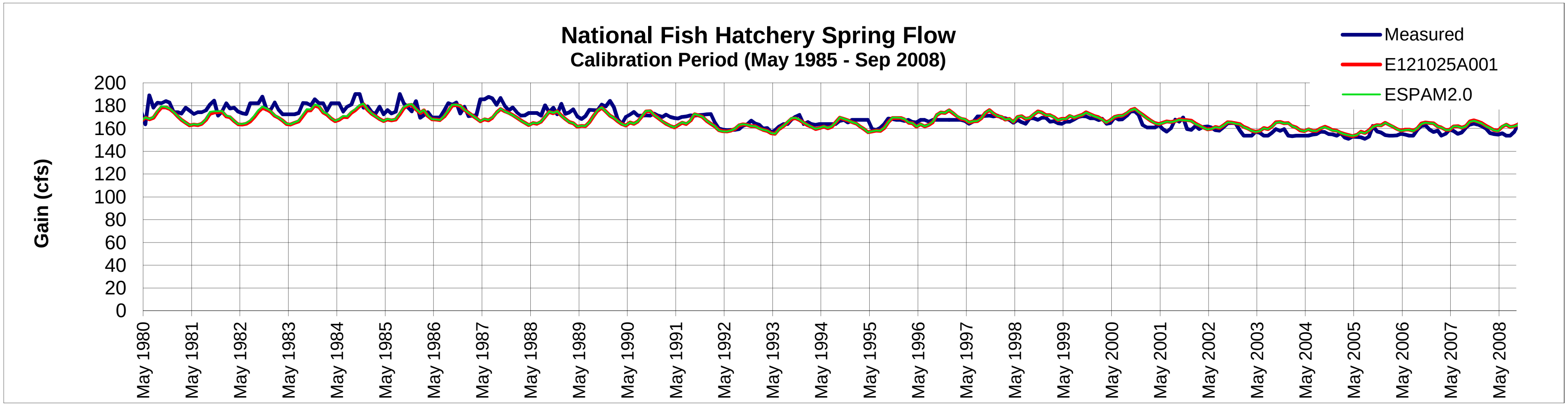



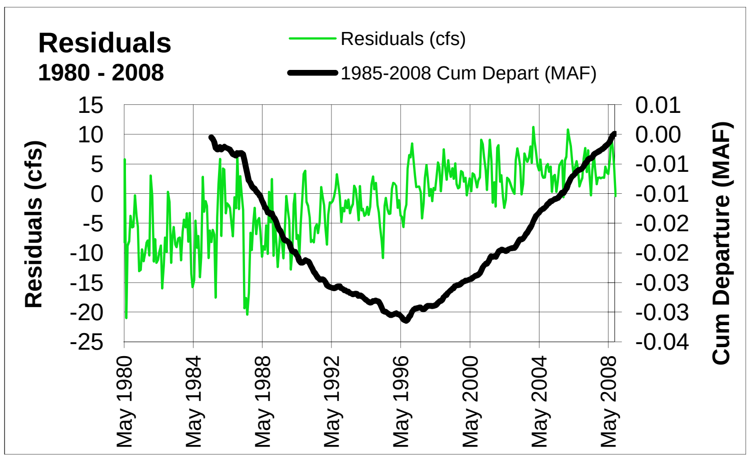



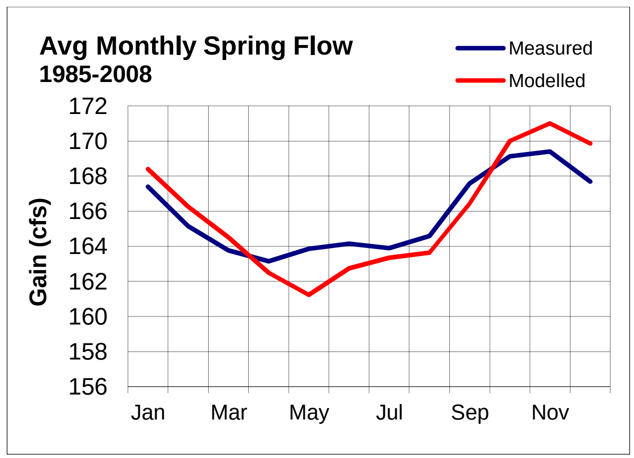

| Mean Error (cfs) | 0.36 | Mean Absolute Error (cfs) | 23.23 | R-Squared | 0.506 |
|---|---|---|---|---|---|
| | 0.1% | | 4.2% | | |

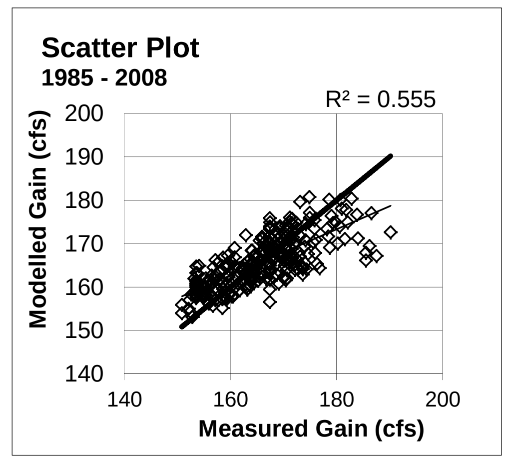
# ESPAM Calibration Charts
# Spring Flows

**Spring Flows** **National Fish Hatchery** **ESPAM2.1** **E121025A001**



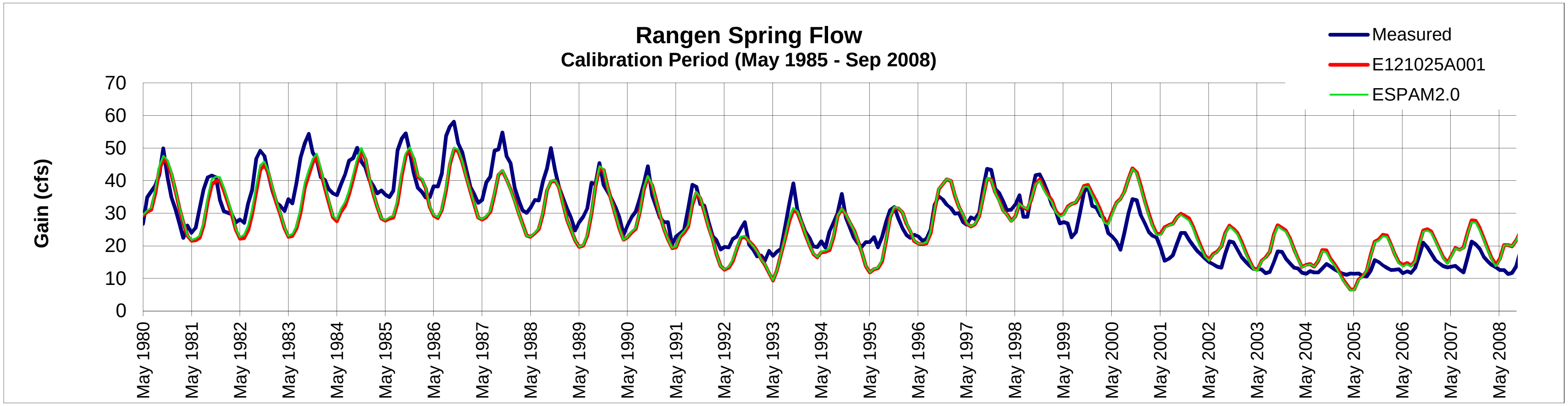



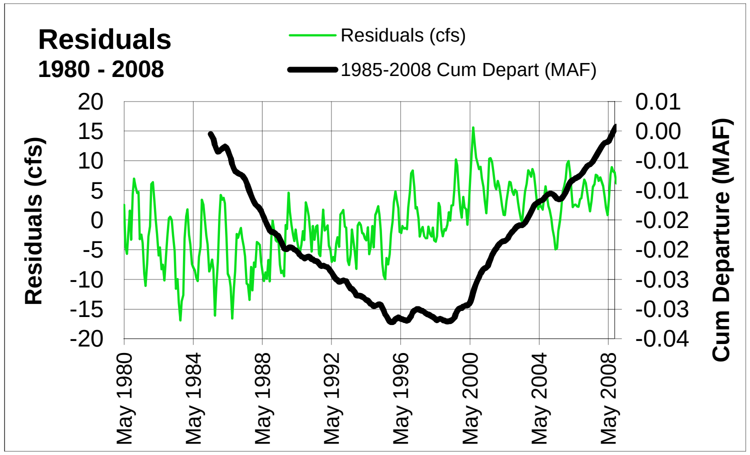



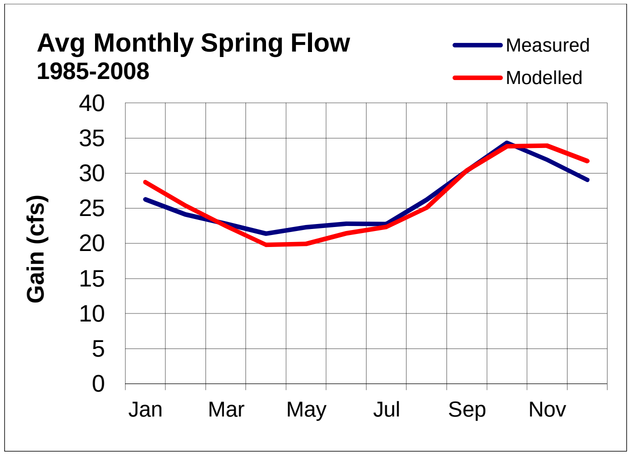

| Mean Error (cfs) | 0.00<br>0.0% | Mean Absolute Error (cfs) | 4.25<br>2.6% | R-Squared | 0.555 |
|---|---|---|---|---|---|

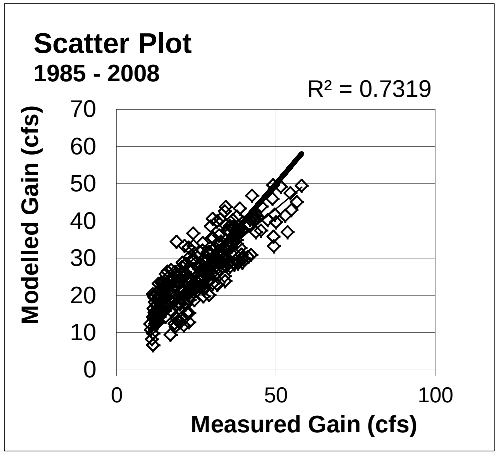
## ESPAM Calibration Charts
## Spring Flows

**Spring Flows** **Rangen Spring** **ESPAM2.1** **E121025A001**



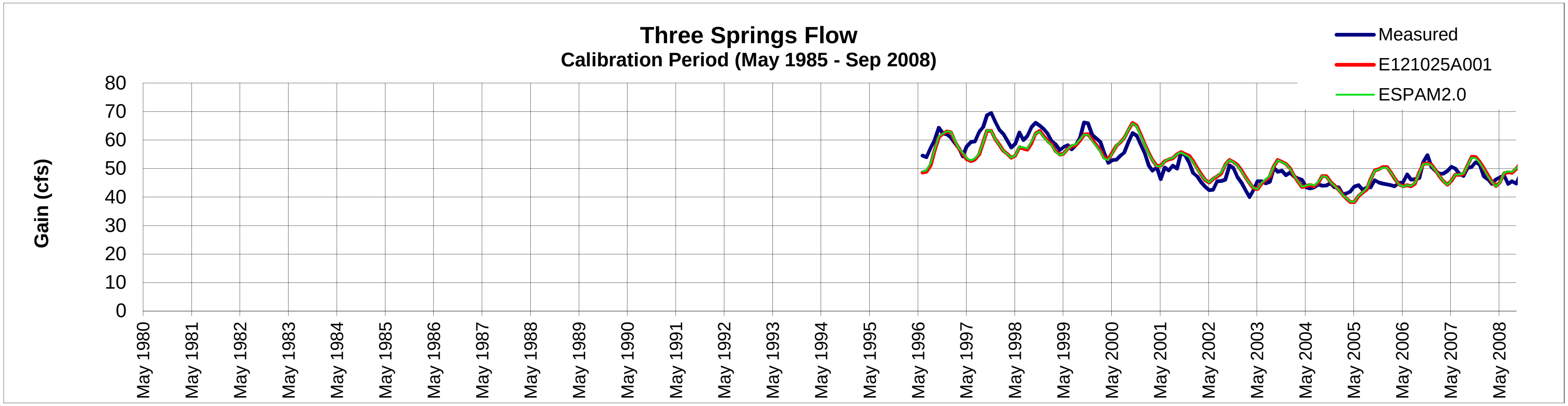



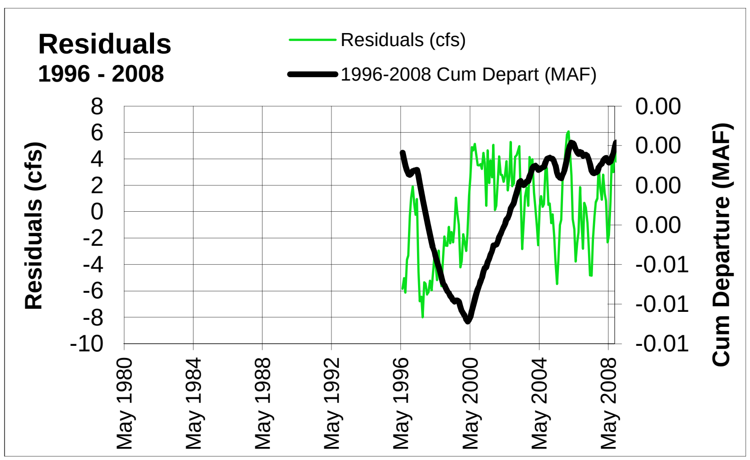



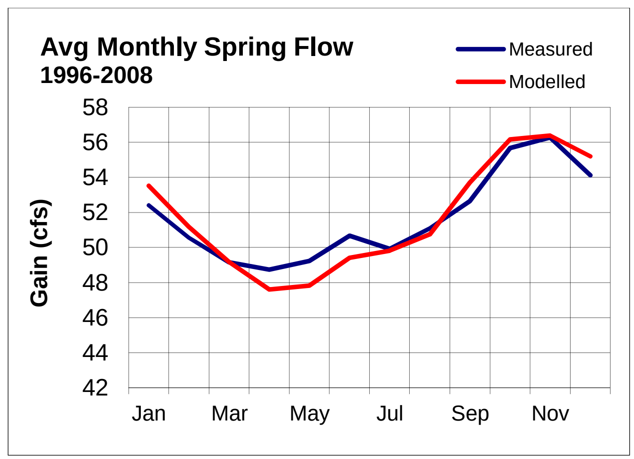

| Mean Error (cfs) | 0.04 | Mean Absolute Error (cfs) | 4.57 | R-Squared | 0.733 |
|---|---|---|---|---|---|
| | 0.2% | | 17.4% | | |

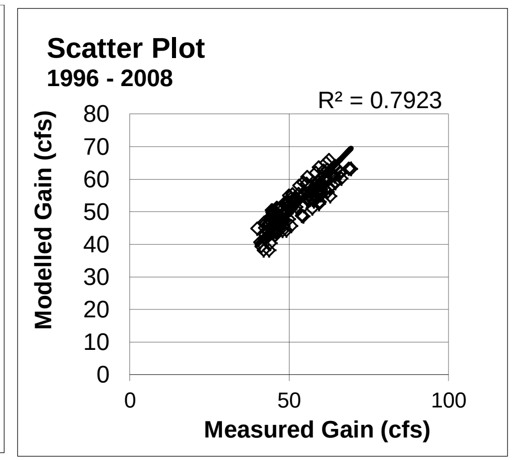
# ESPAM Calibration Charts
# Spring Flows

**Spring Flows** **Three Springs** **ESPAM2.1** **E121025A001**



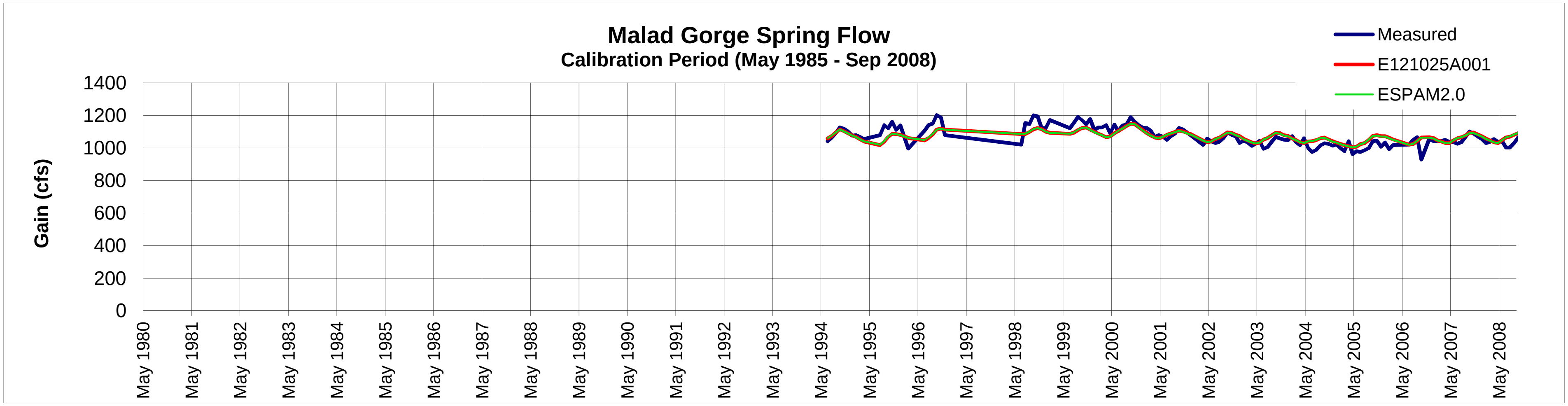



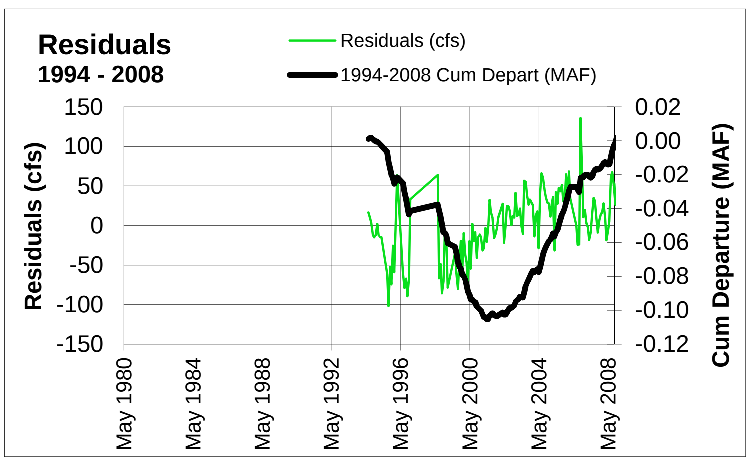



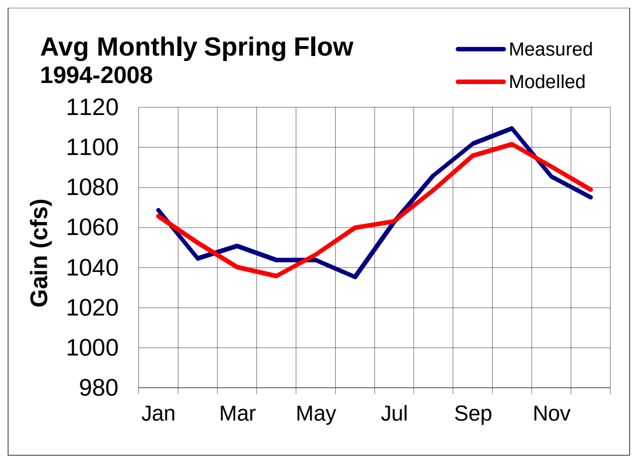

| | | | | | |
|---|---|---|---|---|---|
| **Mean Error (cfs)** | 0.02<br>0.0% | **Mean Absolute Error (cfs)** | 2.84<br>5.5% | **R-Squared** | 0.792 |

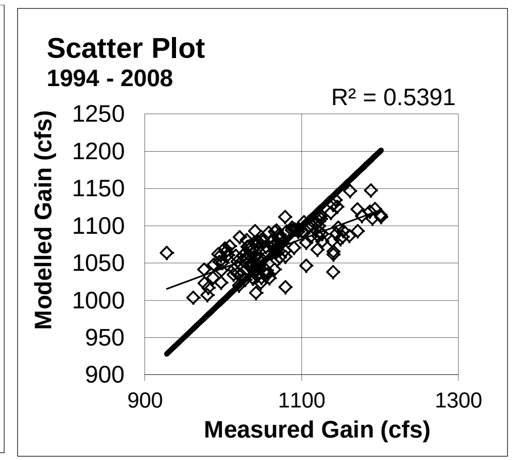
# ESPAM Calibration Charts
# Spring Flows

**Spring Flows** **Malad Gorge** **ESPAM2.1** **E121025A001**



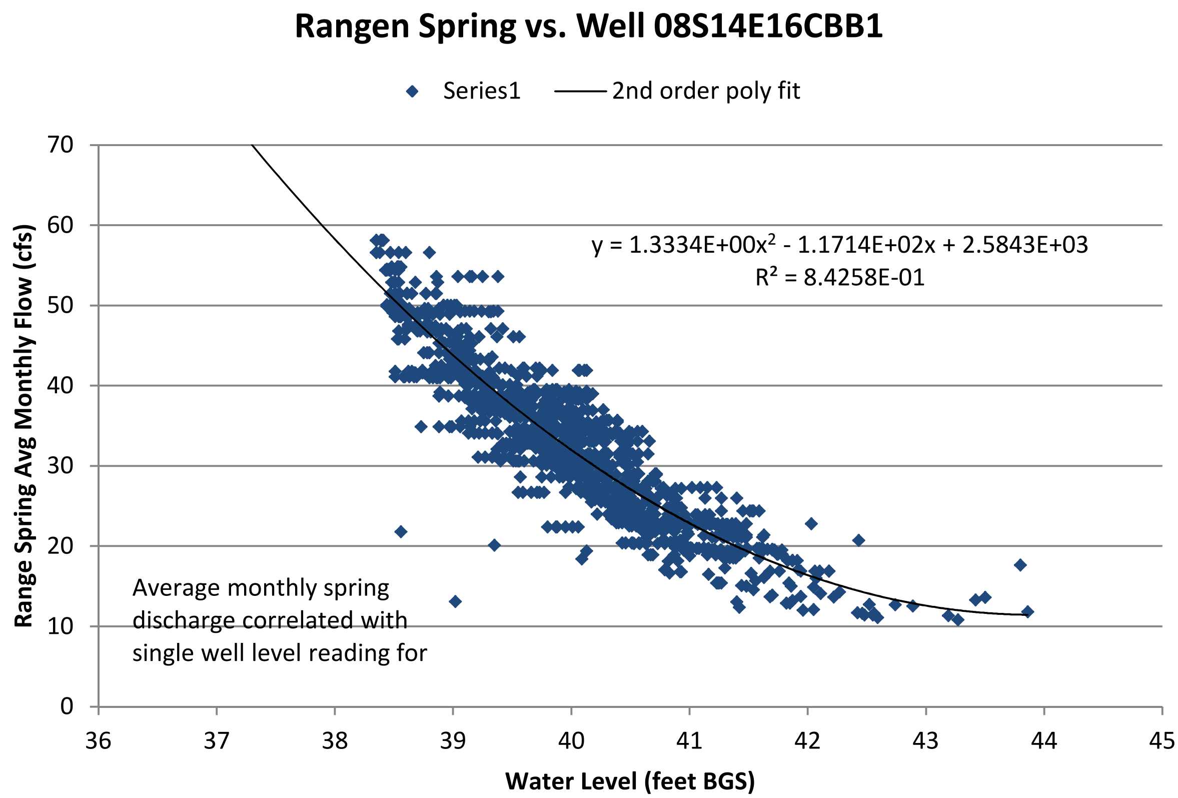



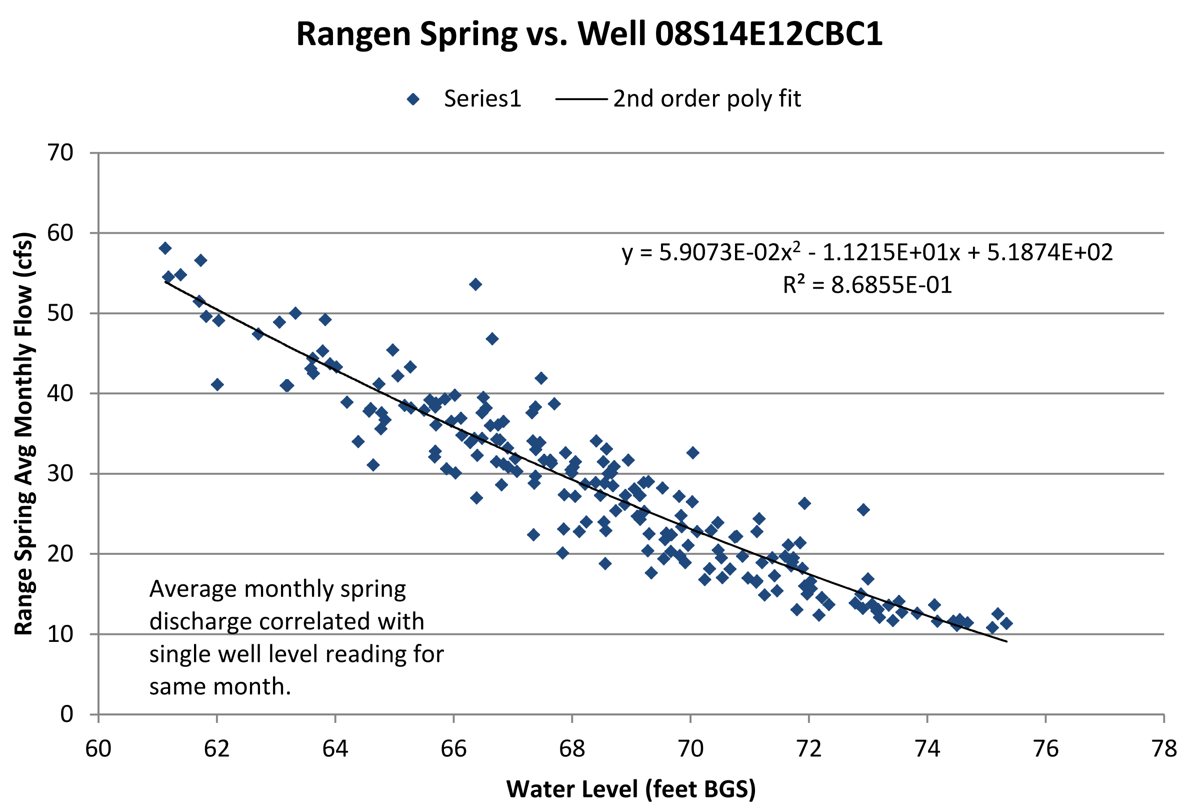



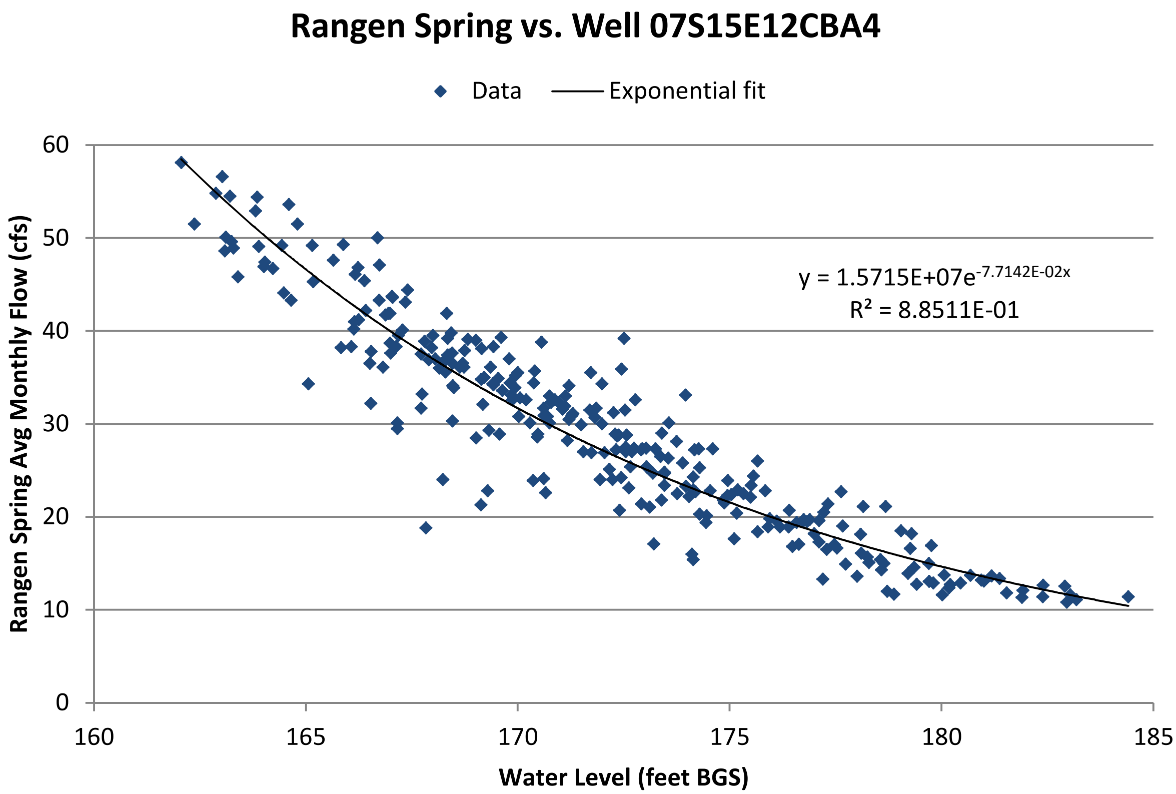

| | | | | | |
|---|---|---|---|---|---|
| **Mean Error (cfs)** | **0.23** | **Mean Absolute Error (cfs)** | **31.93** | **R-Squared** | **0.539** |
| | **0.0%** | | **3.0%** | | |

# Appendix C

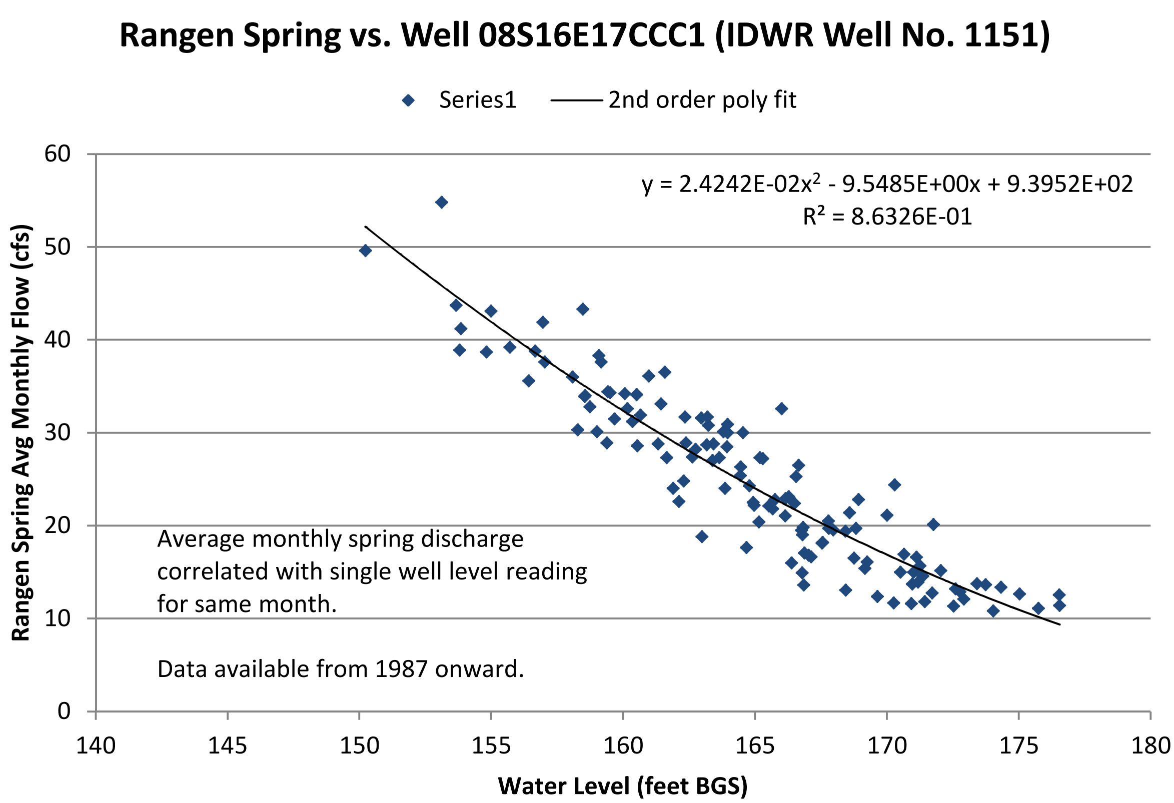
Development of Relationships between Groundwater Levels and Rangen Spring Discharge and map of Candidate Wells


Rangen Spring vs. Well 08S14E16CBB1
Series1
2nd order poly fit
y = 1.3334E+00x² - 1.1714E+02x + 2.5843E+03
R² = 8.4258E-01
Range Spring Avg Monthly Flow (cfs)
Average monthly spring
discharge correlated with
single well level reading for
Water Level (feet BGS)
70
60
50
40
30
20
10
0
36
37
38
39
40
41
42
43
44
45

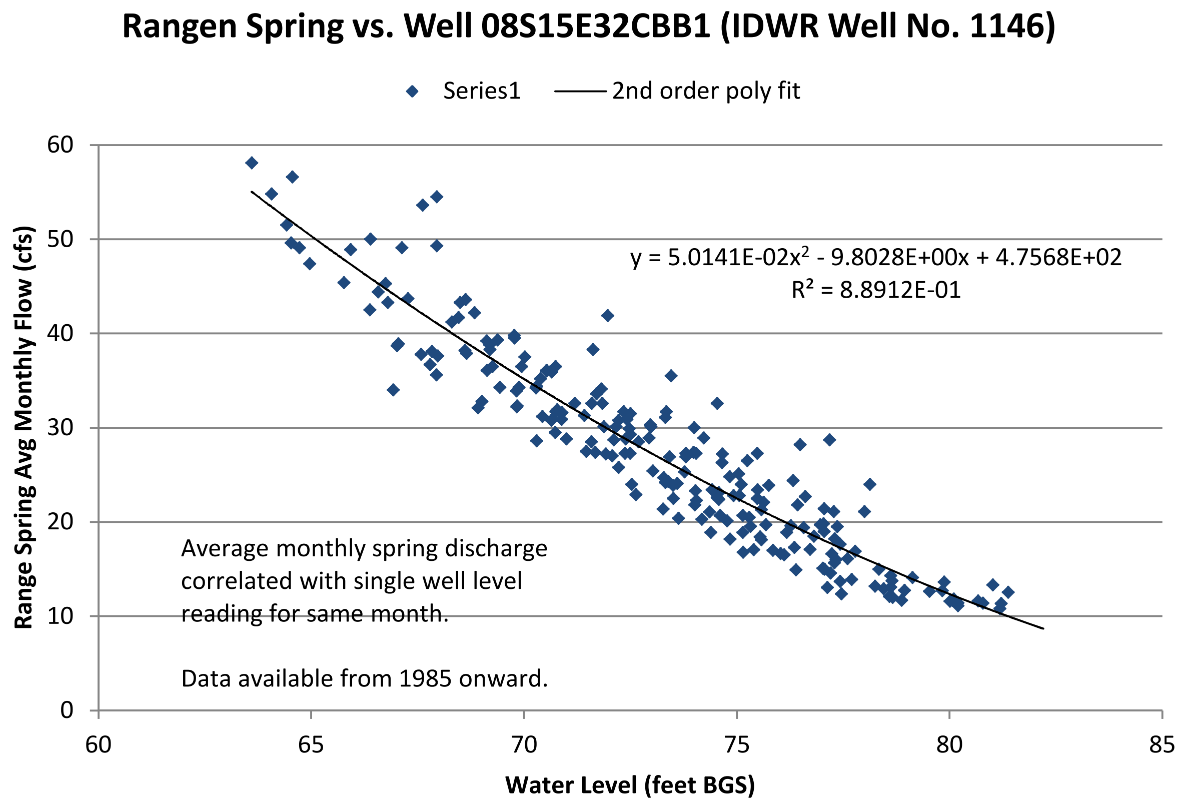

Rangen Spring vs. Well 08S14E12CBC1
Series1
2nd order poly fit
y = 5.9073E-02x² - 1.1215E+01x + 5.1874E+02
R² = 8.6855E-01
Range Spring Avg Monthly Flow (cfs)
Average monthly spring
discharge correlated with
single well level reading for
same month.
Water Level (feet BGS)
70
60
50
40
30
20
10
0
60
62
64
66
68
70
72
74
76
78



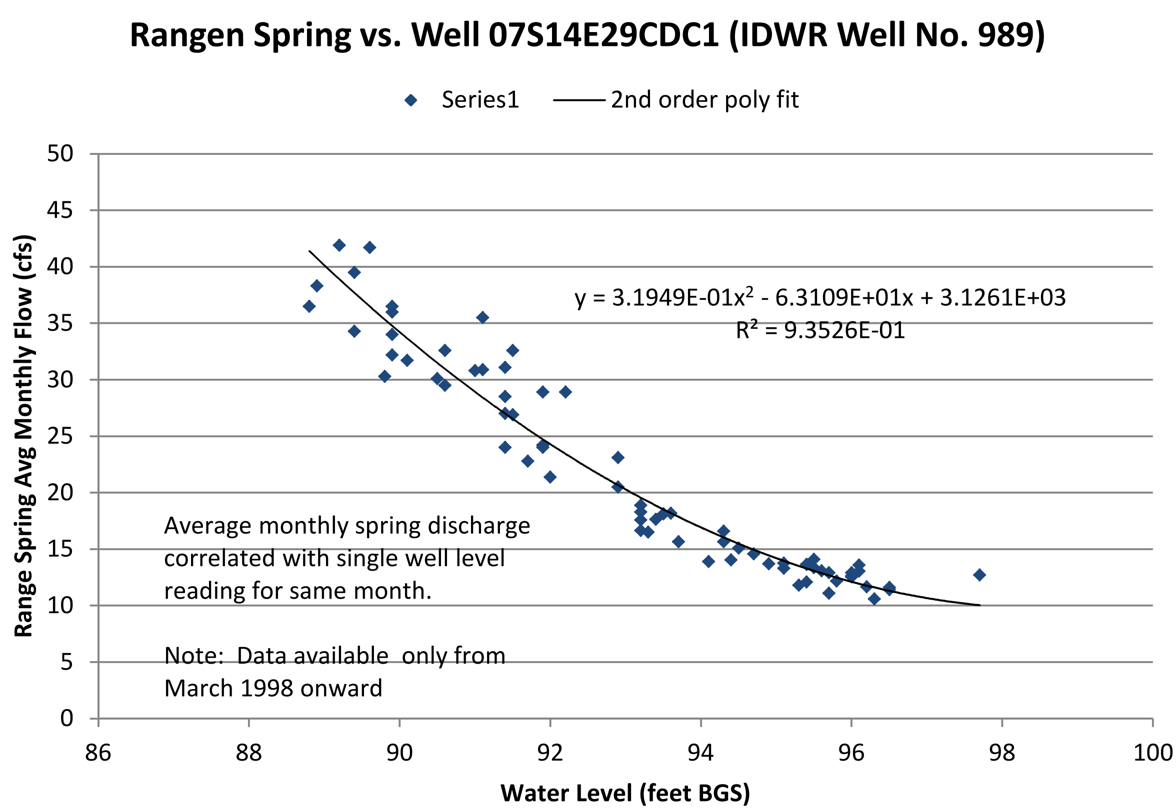
Rangen Spring vs. Well 07S15E12CBA4
Data
Exponential fit
y = 1.5715E+07e-7.7142E-02x
R² = 8.8511E-01
Rangen Spring Avg Monthly Flow (cfs)
60
50
40
30
20
10
0
160
165
170
175
180
185
Water Level (feet BGS)

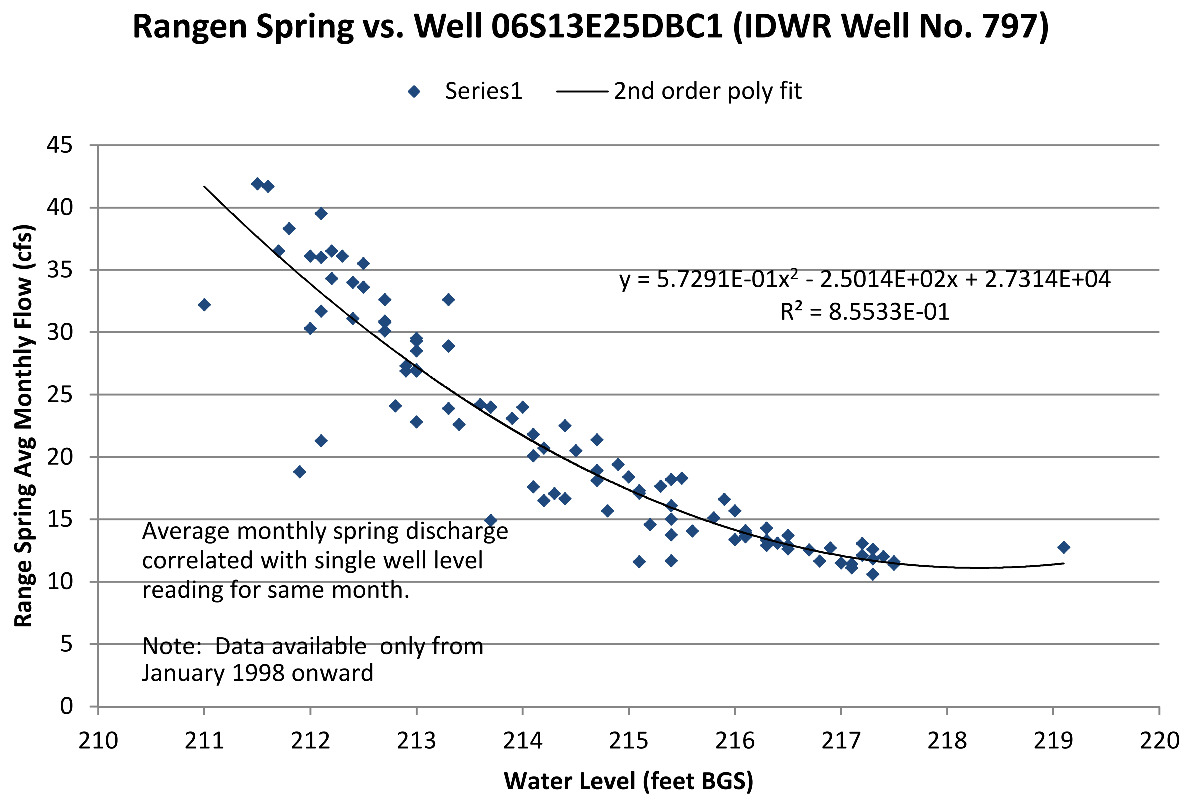
Rangen Spring vs. Well 08S16E17CCC1 (IDWR Well No. 1151)
Series1
2nd order poly fit
y = 2.4242E-02x² - 9.5485E+00x + 9.3952E+02
R² = 8.6326E-01
Average monthly spring discharge
correlated with single well level reading
for same month.
Data available from 1987 onward.
Rangen Spring Avg Monthly Flow (cfs)
60
50
40
30
20
10
0
140
145
150
155
160
165
170
175
180
Water Level (feet BGS)



Rangen Spring vs. Well 08S15E32CBB1 (IDWR Well No. 1146)
Series1
2nd order poly fit
y = 5.0141E-02x² - 9.8028E+00x + 4.7568E+02
R² = 8.8912E-01
Average monthly spring discharge correlated with single well level reading for same month.
Data available from 1985 onward.
Range Spring Avg Monthly Flow (cfs)
Water Level (feet BGS)
0 10 20 30 40 50 60
60 65 70 75 80 85

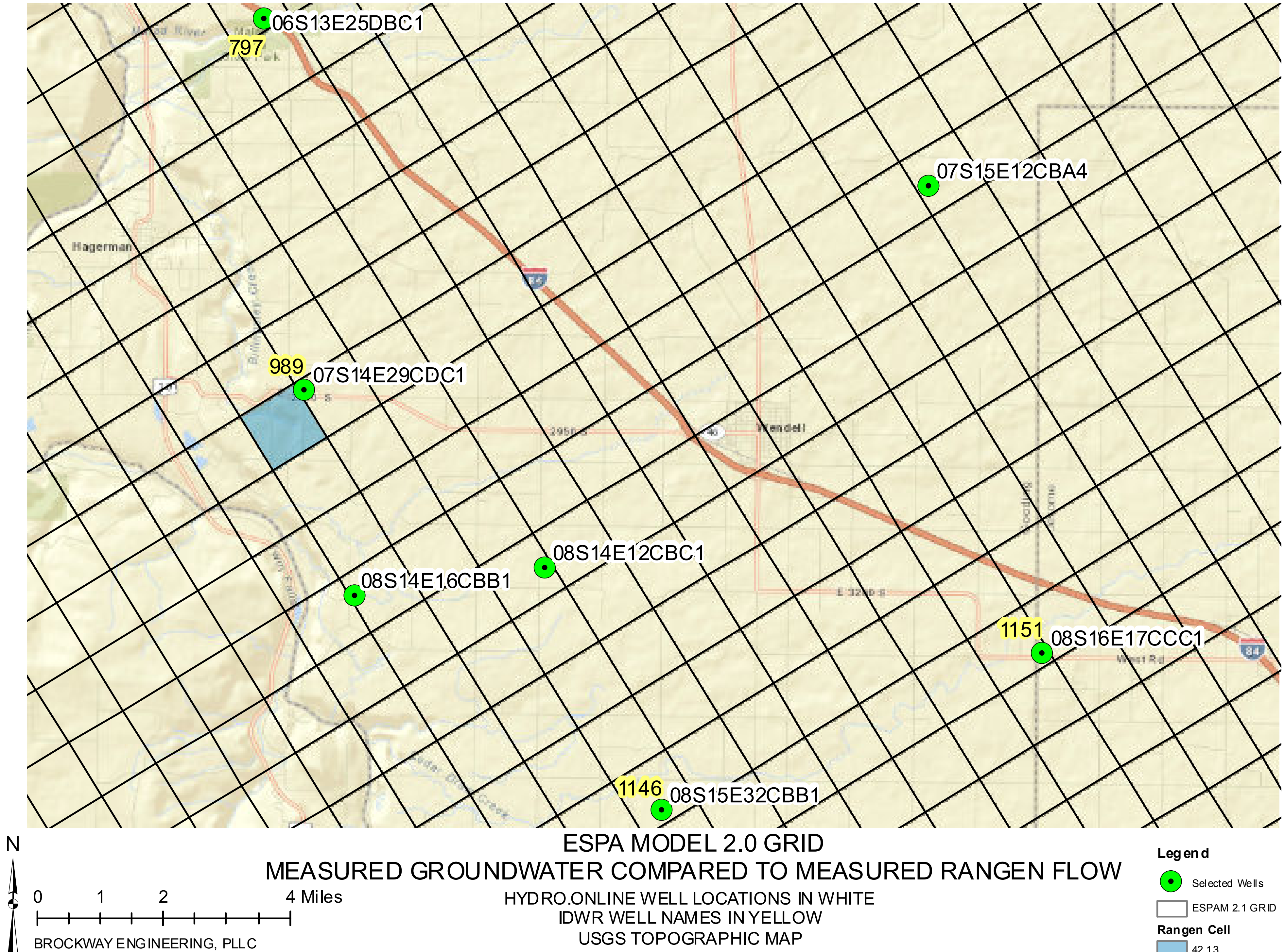



Rangen Spring vs. Well 07S14E29CDC1 (IDWR Well No. 989)
Series1
2nd order poly fit
y = 3.1949E-01x² - 6.3109E+01x + 3.1261E+03
R² = 9.3526E-01
Average monthly spring discharge correlated with single well level reading for same month.
Note: Data available only from March 1998 onward
Range Spring Avg Monthly Flow (cfs)
Water Level (feet BGS)
0 5 10 15 20 25 30 35 40 45 50
86 88 90 92 94 96 98 100



Rangen Spring vs. Well 06S13E25DBC1 (IDWR Well No. 797)
Series1
2nd order poly fit
y = 5.7291E-01x² - 2.5014E+02x + 2.7314E+04
R² = 8.5533E-01
Average monthly spring discharge correlated with single well level reading for same month.
Note: Data available only from January 1998 onward
Range Spring Avg Monthly Flow (cfs)
Water Level (feet BGS)
45
40
35
30
25
20
15
10
5
0
210
211
212
213
214
215
216
217
218
219
220

Path: F:\Projects\Rangen, Inc\Arcview Maps\REGRESSION_MAP.mxd




ESPA MODEL 2.0 GRID
MEASURED GROUNDWATER COMPARED TO MEASURED RANGEN FLOW
HYDRO.ONLINE WELL LOCATIONS IN WHITE
IDWR WELL NAMES IN YELLOW
USGS TOPOGRAPHIC MAP

Legend
Selected Wells
ESPAM 2.1 GRID
Rangen Cell
42,13

BROCKWAY ENGINEERING, PLLC
GEP - SEP. 25, 2012

APPENDIX C
Table 3 Rangen Spring Discharge vs. Aquifer Water Levels for Seven Nearby Wells

Summary-Analysis of Water level vs Rangen Spring Flow
Brockway Engineering, PLLC December 2, 2012
Regression Analysis See atached map for well locations
Average Monthly Rangen Spring Discharge vs Single Well Elev. Same Month

| **Well Number** | **Type of Fit** | **$R^2$** |
|---|---|---|
| 08S14E16CBB1 | 2nd order poly | 0.8426 |
| 08S14E12CBC1 | 2nd order poly | 0.8686 |
| 07S15E12CBA4 | Exponential | 0.8851 |
| 08S16E17CCC1 | 2nd order poly | 0.8633 |
| 08S15E32CBB1<br>IDWR #1146 | 2nd order poly | 0.8891 |
| 07S14E29CDC1<br>IDWR #989 | 2nd order poly | 0.9353 |
| 06S13E25DBC1<br>IDWR #797 | 2nd order poly | 0.8553 |
| | Average | 0.8770 |