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Corrections to the Rangen Expert Report submitted by Charles E. Brockway, Dave Colvin, and Jim Brannon on December 20, 2013 " Expert Report in the Matter of Rangen Inc . –Availability of Spring Flow and Injury to Water Rights "

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The Expert Report submitted by Charles E. Brockway, Dave Colvin, and Jim Brannon on Dec ember 20, 2013 " Expert Report in the Matter of Rangen Inc . –Availability of Spring Flow and Injury to Water Rights " Section C3. outlined collective opinions regarding the adequacy of procedures utilized by Rangen in determining the historical measured discharge for the Rangen Hatchery. These corrections outline changes in the collective opinions on these procedures as well as explanations for the reasons for the opinion changes. Additional data and information on the historical measured discharge has been made available which indicates that the majority of the reported discharge measurements were based on a standard suppressed weir equation and coefficient of 3.33. For the period of about 2000 to 2008, which is the latter part of the ESPAM2.1 model calibration, the discharge was reported based on a weir coefficient of 3.06. Based on this data, it is our opinion that the coefficient of 3.06 or 3.09 results in computed discharge which meets the accuracy requirements of IDWR; however, a coefficient for a suppressed weir, 3.33, is the best selection for water measurement over the Rangen weir boards.

The total available discharge to the Rangen Hatchery is derived from Rangen Spring which includes diversions from the Martin/Curren Tunnel and the head of Billingsley Creek below the toe of the talus slope. Total flow is the sum of the flow through the last set of raceways, called the CTR raceways, plus the flow through the Lodge Pond structure. Both the CTR raceways and the Lodge Pond structure utilize check boards as weirs and the discharge is measured weekly by Rangen personnel.

The CTR check board structures and the Lodge Pond overflow are non- standard weirs as defined by published definitions by recognized water agencies such as the U.S. Bureau of Reclamation Water Measurement Manual. These structures, which are the most common type of measurement structures used in aquaculture facilities in Idaho, do not include sharp-crested weir blades (sharpened metal plates) on the overflow and normally do not include a permanent staff gage for head measurement at the required distance upstream of the weir. In addition, depending on how the check board is attached to the concrete sides of the raceway, there may be varying degrees of contraction at the ends of the boards. For these reasons, the weir coefficient in the standard weir equations such as the Francis formula (USBR Water Measurement Manual, 3rd Edition, 1997) may vary from the published weir coefficients obtained from laboratory studies. For high flows in narrow channels, the velocity of approach to the weir may be high enough to warrant modification of the standard formulas. The published equation for flow through a standard suppressed which is normally utilized for weirs in concrete channels with parallel sides is:

$Q= CLH^{3/2}$

Where: $Q=$ Discharge (cfs)

$C=$ Weir coefficient (standard is 3.33)

L= Length of weir (width of channel) (ft)
H= Head on weir (ft)

When water flows towards the boards, the velocity increases and the water surface height begins to decline at a distance upstream of the weir. That distance is normally not more than 4 times the value of the maximum head on the weir and a standard weir construction would mount a permanent staff gage at least 4 times the maximum expected head upstream to measure the head. Mounting permanent staff gages in raceways is not standard practice and most installations resort to measuring the head over the boards with a staff gage or ruler held on the upstream face of the top board with the wide, marked face of the gage pointing upstream. Placing the wide part facing upstream causes the velocity to force the water surface to 'run up' the front face of the staff gage. That " run up" places the top of the water surface at a distance above the top board equal to the elevation of the head which would be measured with a staff gage permanently mounted upstream of the weir. This procedure, called 'sticking the weir' is standard practice in Idaho and the west for irrigation facilities, aquaculture facilities and individual water users and is recognized as such by IDWR.

During the preparation of the Expert Report for Rangen, and evaluation of water measurement procedures currently used, the discharge table utilized by Rangen staff for measurement of flow over the CTR weir boards and the Lodge Pond weir boards was made available. Examination of this table indicated that the equation apparently used to develop the discharge table was not a standard weir equation and, in fact, utilized a lower weir coefficient than the standard 3.33. Statistical analysis indicated that a reasonable 'fit' to the table data for the CTR raceways was a contracted weir equation with a coefficient of about 3.09. This equation was plotted along with the tabular data from the Rangen table and indicated a reasonable fit to the tabular data (BCB Report Appendix A). Since the fitted coefficient of 3.09 is only 7.2% different that the standard 3.33 coefficient, it was our opinion that this table and discharges calculated from it were adequate and met the flow measurement requirements by IDWR. C.E. Brockway also remembered an analysis had been performed on the outflow from the Rim View fish hatchery owned by Idaho Trout Company (Earl Hardy) during which the flow over 42 weir boards at the ends of raceways had been compared with measured total flow and a similar weir coefficient calculated. For these reasons, and the fact that IDWR was utilizing the flow measurements made with this table for calibration of the ESPAM2.1 ground water model , it was our opinion that the utilization of the current Rangen discharge table meets all accuracy criteria for surface wagter measurement..

Subsequent to the submittal of the BCB Expert Report for Rangen, a search of the Brockway Engineering archives provided the field data and a letter report documenting the procedure utilized for a 1979 evaluation of the weir coefficient for Rim View raceway outflows which were nominal 2 inch boards. This analysis resulted in an estimated average weir coefficient of .306 when the length, L, in the equation is expressed in inches as requested by the manager of Rim View, or:
$Q= .306LH^{3/2}$
Where: Q= Discharge (cfs)
C= .306 Weir coefficient

L= Length of weir (width of channel) (inches)
H= Head on weir (ft)

Brockway remembered, prior to the submittal of the BCB Report, the 3.06 number and not .306 and therefore believed that the fitted coefficient, 3.09 , which appeared to have been used in the Rangen facility was reasonable.

An examination of the data and further review of the geometry of the Rim View and Rangen board outflows indicates that the hydraulic conditions are not identical and does not justify the use of the Rim View calculated C values at Rangen. Because flow conditions over boards do not approach a sharp crested weir, at low heads, the flow will tend to impinge on the top of the boards which results in a lower C value that the standard 3.33. However, when the head, H, increases to a sufficient height so that the total energy in the flowing water is sufficient to cause the nappe of water over the front edge of the board to spring free, then the C value approaches a value of a standard sharp crested weir or 3.33. (Figure 1). Brater and King indicate that, when the ratio of the head (H) to the board thickness(B) reaches 1 to 2, the nappe becomes detached and the weir performs almost like a sharp crested weir. (Brater and King, p 5-25). For a board thickness of 1.5 inches, a head of 1 to 2 inches results in a ratio of ($.67<H/B>1.33$).

After the Expert Report (BCB) was submitted, additional data was made available on the field discharge measurements made by Rangen staff for the period 1989-2012 which includes most of the period used for calibration of the ESPAM 2.1 model. For individual measurements, the data, head measurements, and calculated discharge were recorded. No discharge rating tables are available or equations utilized to calculate the recorded discharge. However, utilizing the recorded head and discharge, a weir coefficient can be calculated and was calculated for various dates during the above period. This analysis indicates that for the period prior to about 1997, the equation and weir coefficient used were the standard equation and equation for a suppressed weir using a coefficient of 3.33. For the period after at least 1997 but at least from about 2003 through 2012, the equation used was a suppressed weir and the weir coefficient was 3.06. The suppressed weir equation with the 3.06 coefficient was subsequently verified from an Excel spreadsheet showing the actual equation and calculated values which match the Rangen discharge table known to be used at the present time. Figure 2 shows a plot of the calculated weir coefficients for various dates during the reported discharge period used for model calibration and through the present time. This plot indicates that the weir coefficient used by Rangen for the majority of the model calibration period was the standard suppressed weir coefficient of 3.33 and changes from 3.33 to 3.06 sometime between 1998 and 2002. Field data is not available for the 1998 through 2002 period.

A frequency analysis of historical measured heads over the Rangen raceway boards was performed for the period 1989 through 2012 and indicates that the average head on the CTR raceway weir boards at operational depth is 4 5/8 inches which would provide a head to breadth ratio of at least 4.0/1.5 or 2.67. Figure 3 shows the histogram of measured heads of the Rangen CTR raceway boards. It is expected that for normal operations the head on these boards is higher than the head required to cause detachment of the nappe from the top of the boards and cause the boards to perform similar to a sharp crested weir. An examination of the weir boards on the CTR raceways where discharge measurements are performed indicates that the upstream edges of the boards are reasonably sharp which promotes nappe springing free of the boards. Therefore, it is our opinion that, even though use of a suppressed weir coefficient of 3.06 to 3.09 meets the IDWR requirement for accuracy of surface water measurements, a better approximation of the average weir coefficient is the standard sharp crested coefficient of 3.33. Figure 4 is a plot of the calibration data set for Rangen Spring utilized for the ESPAM2.1 ground water model showing the difference in measured flow compared to the simulated flow when the weir coefficient for boards is 3.06 compared to 3.33. An examination of the reported discharge hydrograph appears to indicate that perhaps the change occurred just prior to the year 2000 where the variability between the simulated and reported measured discharge increased.

The difference between the blue line and red line in Figure 4 for the period 2000 through 2008 indicates that the higher coefficient, 3.33, results in a better 'fit' between the measured and simulated discharge for Rangen spring.

Our opinion is that a coefficient of 3.06 and a suppressed weir equation , which was used by Rangen for the majority of the model calibration period, results in discharge which meets the IDWR accuracy requirements for surface water measurements. However, that standard suppressed weir coefficient of 3.33 is the best selection for water measurement over the Rangen weir boards. It is recognized that for heads below about 1.0 inches, the weir coefficient is likely lower than 3.33 due to the breadth of the boards as compared to a sharp crested weir plate; however, the normal range for the head on the CTR raceway weir boards is greater than 2 inches and the H/B ratio is above 2 so the coefficient should approach that of a standard suppressed weir.