Attachment 1 to Appendix 8

Dworshak, Idaho Water Supply Forecast "Date-to-July" Standard Error Computations

Randal T. Wortman
Revised: February 2006

The statistical forecast equations developed for water supply forecasting by the Northwestern Division, US Army Corps of Engineers, were each developed for a fixed runoff season. Specifically, the Dworshak basin forecast equations were all fit to the same dependent variable, the April-to-July runoff volume. The standard error statistics all correspond to the regression equations for the April-to-July runoff season. Power planning studies, specifically, require consideration of other "seasons" than the specific season to which the forecast model was calibrated. The discussion that follows will first address various definitions of "standard error" for a statistical forecast, with the remainder of the paper presenting the author's perspective and recommendation on how to determine the "date-to-end-of-season" forecast for a variety of forecast dates, and the recommended procedure for calculating the standard error associated with this pseudo-forecast.

Standard Error for a statistical forecast model

There exists a variety of statistics and methods that could potentially be referred to as the "standard error" for a calibrated statistical forecast model. The most familiar standard error statistics are the following:

1. Standard Error of the forecast equation (SE)
2. Standard Error of Prediction for an individual forecast (SE_{pred})
3. Cross-validation standard error (CVSE), sometimes called the Jackknife Standard Error (JSE) or the Leave-One-Out Standard Error (LOO SE).

Legitimate purposes exist for the use of each of the above standard error statistics and all of the above statistics include a degrees-of-freedom adjustment that compensates for the number of predictor variables used in the regression equation. The traditional Standard Error (SE) is the root-mean-squared-error of the predictions from the regression equation fit to the full set of observations. This standard error is a constant and has the smallest value of the three standard errors presented. It also represents the error corresponding to a forecast derived from all predictor variables simultaneously being at their average values. The Standard Error of Prediction (SE_{pred}) is the technically correct standard error statistic to use when calculating the error bounds on a new forecast calculated from a new set of observations of the predictor variables. The SE_{pred} statistic *is not a constant* and is calculated using the SE term adjusted by a "leverage" factor derived from the current values of the predictor variables. Thus, the SE_{pred} varies, taking on a minimum value when the predictor variables simultaneously approach their mean value, and flaring to greater magnitudes as the predictor variables take on more extreme values. In a simple 1-variable regression analysis the confidence intervals for the SE plot as two lines parallel to the regression forecast line, and the confidence intervals for the SE_{pred} plot as mirror-image curves above and below the regression line.

The cross-validation standard error (CVSE) is the root-mean-squared-error of the leave-one-out predictions. The cross-validation predictions are calculated by iteratively dropping one observation from the data set and refitting the regression coefficients without that one observation in the model, then using the withheld observation with the leave-one-out calibration to generate a forecast. The leave-one-out forecast will always be slightly inferior to the full model forecast, and thus the CVSE will always be slightly larger than the SE and, unlike the SE_{pred}, take on a constant value.

All three of the above standard error statistics apply to a given statistical forecast equation fit to a set of specified predictor variables. Since it is not possible to incorporate non-existent observed values of the regression variables when working in a study scenario, the static CVSE provides a suitable alternative to the standard error of prediction SE_{pred}. The cross-validation standard error (CVSE) is believed to reflect the expected value of the error in a real-time forecasting environment more accurately than the SE, and unlike the SE_{pred}, the CVSE has a constant value independent of the values for the current set of predictor variables. The CVSE has been adopted by the NRCS and other forecasting agencies and is herein recommended as the preferred error statistic for use with developing confidence intervals on water supply forecasts for both real time operations and planning studies.

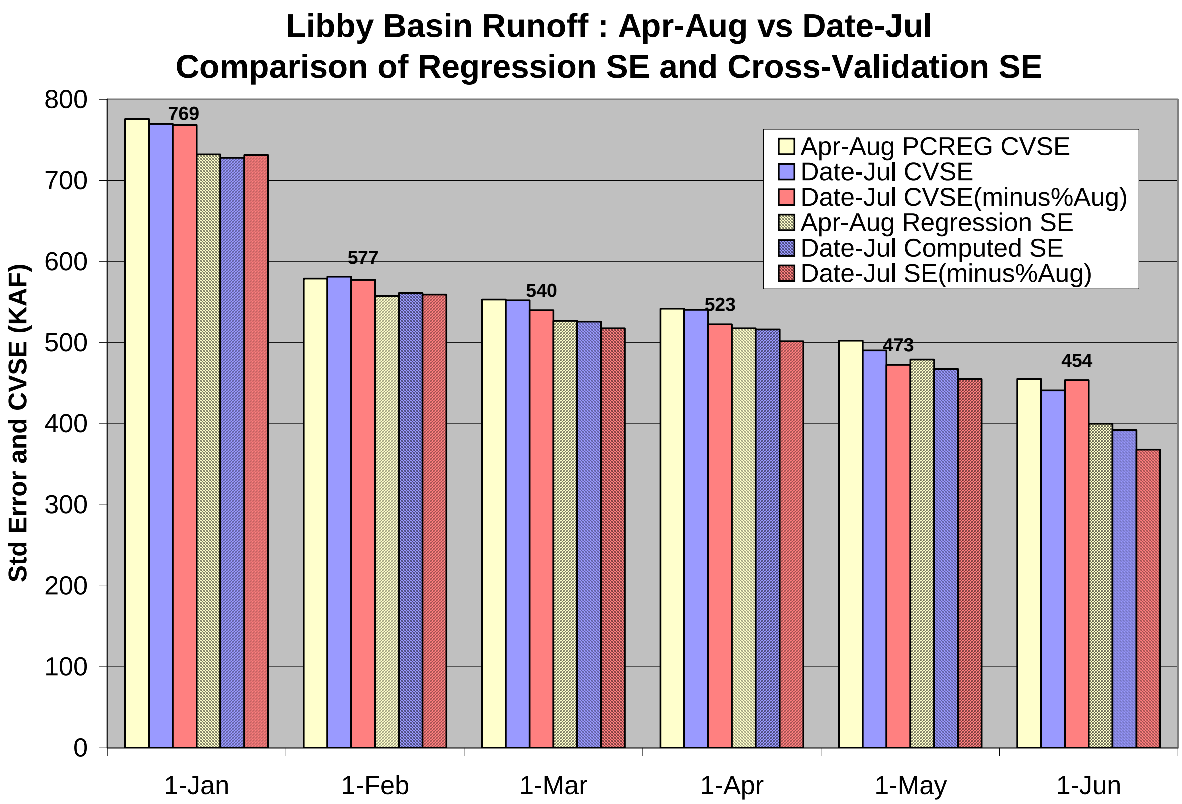
Derivation of Date-to-July forecasts

A variety of computations could be devised to transform the April-July volume forecast into the "Date-to-July" pseudo forecast desired for various power and flood control studies. The following alternatives can be combined in four different ways, providing four different calculations to compute the date-to-July forecast series for each of the winter forecasts (1-Jan, 1-Feb, or 1-Mar):

1. April-July Volume from statistical model
   a. Use regression model (full dataset) forecast values
   b. Use cross-validation (leave-one-out) regression forecast values
2. Adjustment to change April-July volume into "Date-July" volume
   a. For any months prior to April add historic average volumes
   b. For any months prior to April add historic average volumes weighted by "percent of average" value for current April-August forecast

Comparison of Standard Error statistics for Date-to-July forecasts for Libby project

Forecasts and forecast errors were previously calculated and analyzed **for the LIBBY forecasts** for five of the eight "date-to-July" possible combinations and the root-mean-squared-error (RMSE) of those "date-to-July" forecast errors were compared with the RMSE of the April-August cross-validation forecast error (i.e. the Apr-Aug forecasts CVSE) **for Libby**. The following figure shows the RMSE value for each monthly forecast. The first three series utilize the cross-validation forecast, while the last three series utilize the standard regression forecast. Series 2, 3, 5, and 6 are from "date-to-July" forecasts developed using option 2a, above (average volumes used for winter months). Series 2 and 5 used option 3a, above (average August) and series 3 and 6 used option 3b, above (average August weight by the forecasts percent-of-normal).



The above figure shows that from 1-January to 1-May it would be problematic to argue that there is a statistical significance in the results for a given forecast date or that any one method is superior to any other.

Recommended Dworshak date-to-July forecasts and standard error computations

It is recommended that the Dworshak Date-to-July calculation follow the same methodology as the Libby forecast, although the Dworshak forecast does not require the adjustment to subtract out the August volume. In order to provide the best consistency with the CVSE statistic used with the full April-July forecast model, **it is recommended that the Date-to-July forecasts and errors be constructed using the methodology whereby the Corps' Dworshak April-July first-of-month cross-validation forecasts are adjusted by adding in the historical average winter month volumes.**

This method provides the following Date-to-July "standard errors" for the Dworshak runoff volumes:

Dworshak Runoff Forecast

Forecast Date	1-Jan	1-Feb	1-Mar	1-Apr	1-May	1-Jun
Date-Jul CVSE	740	569	407	305	262	161

The recommended equations for computation of the Dworshak Date-to-July forecasts are as follows:

1-Jan Forecast = Jan Avg + Feb Avg + Mar Avg + 1-Jan Apr-Jul Cross-Validation Forecast

1-Feb Forecast = Feb Avg + Mar Avg + 1-Feb Apr-Jul Cross-Validation Forecast

1-Mar Forecast = Mar Avg + 1-Mar Apr-Jul Cross-Validation Forecast

1-Apr Forecast = 1-Apr Apr-Jul Cross-Validation Forecast

1-May Forecast = 1-May May-Aug Cross-Validation Forecast

1-Jun Forecast = 1-Jun Jun-Aug Cross-Validation Forecast

Date-Jul CVSE from Excel Workbook: C:\ Documents and Settings\g0pdwrtw\My Documents\Excel Spreadsheets\Dworshak Forecasts\PCREG\DWR_PCREG_FinalForecasts.xls

Chart from (Wortman) Excel Workbook: C:\Documents and Settings\g0pdwrtw\My Documents\Excel Spreadsheets\Libby Forecast\Libby Forecasting Models 2004\PCREG_AllModelForecasts_and_Errors.xls

Attachment 2 to Appendix 8

Libby, Montana Water Supply Forecast "Date-to-July" Standard Error Computations

Randal T. Wortman
Revised: February 2006

The statistical forecast equations developed for water supply forecasting by the Northwestern Division, US Army Corps of Engineers, were each developed for a fixed runoff season. Specifically, the Libby basin forecast equations were all fit to the same dependent variable, the April-to-August runoff volume. The standard error statistics all correspond to the regression equations for the April-to-August runoff season. Power planning studies, specifically, require consideration of other "seasons" than the specific season to which the forecast model was calibrated. The discussion that follows will first address various definitions of "standard error" for a statistical forecast, with the remainder of the paper presenting the author's perspective and recommendation on how to determine the "date-to-end-of-season" forecast for a variety of forecast dates, and the recommended procedure for calculating the standard error associated with this pseudo-forecast.

Standard Error for a statistical forecast model

There exists a variety of statistics and methods that could potentially be referred to as the "standard error" for a calibrated statistical forecast model. The most familiar standard error statistics are the following:

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2. Standard Error of Prediction for an individual forecast (SE_{pred})
3. Cross-validation standard error (CVSE), sometimes called the Jackknife Standard Error (JSE) or the Leave-One-Out Standard Error (LOO SE).

Legitimate purposes exist for the use of each of the above standard error statistics and all of the above statistics include a degrees-of-freedom adjustment that compensates for the number of predictor variables used in the regression equation. The traditional Standard Error (SE) is the root-mean-squared-error of the predictions from the regression equation fit to the full set of observations. This standard error is a constant and has the smallest value of the three standard errors presented. It also represents the error corresponding to a forecast derived from all predictor variables simultaneously being at their average values. The Standard Error of Prediction (SE_{pred}) is the technically correct standard error statistic to use when calculating the error bounds on a new forecast calculated from a new set of observations of the predictor variables. The SE_{pred} statistic *is not a constant* and is calculated using the SE term adjusted by a "leverage" factor derived from the current values of the predictor variables. Thus, the SE_{pred} varies, taking on a minimum value when the predictor variables simultaneously approach their mean value, and flaring to greater magnitudes as the predictor variables take on more extreme values. In a simple 1-variable regression analysis the confidence intervals for the SE plot as two lines parallel to the regression forecast line, and the confidence intervals for the SE_{pred} plot as mirror-image curves above and below the regression line.

The cross-validation standard error (CVSE) is the root-mean-squared-error of the leave-one-out predictions. The cross-validation predictions are calculated by iteratively dropping one observation from the data set and refitting the regression coefficients without that one observation in the model, then using the withheld observation with the leave-one-out calibration to generate a forecast. The leave-one-out forecast will always be slightly inferior to the full model forecast, and thus the CVSE will always be slightly larger than the SE and, unlike the SE_{pred}, take on a constant value.

All three of the above standard error statistics apply to a given statistical forecast equation fit to a set of specified predictor variables. Since it is not possible to incorporate non-existent observed values of the regression variables when working in a study scenario, the static CVSE provides a suitable alternative to the standard error of prediction SE_{pred}. The cross-validation standard error (CVSE) is believed to reflect the expected value of the error in a real-time forecasting environment more accurately than the SE, and unlike the SE_{pred}, the CVSE has a constant value independent of the values for the current set of predictor variables. The CVSE has been adopted by the NRCS and other forecasting agencies and is herein recommended as the preferred error statistic for use with developing confidence intervals on water supply forecasts for both real time operations and planning studies.

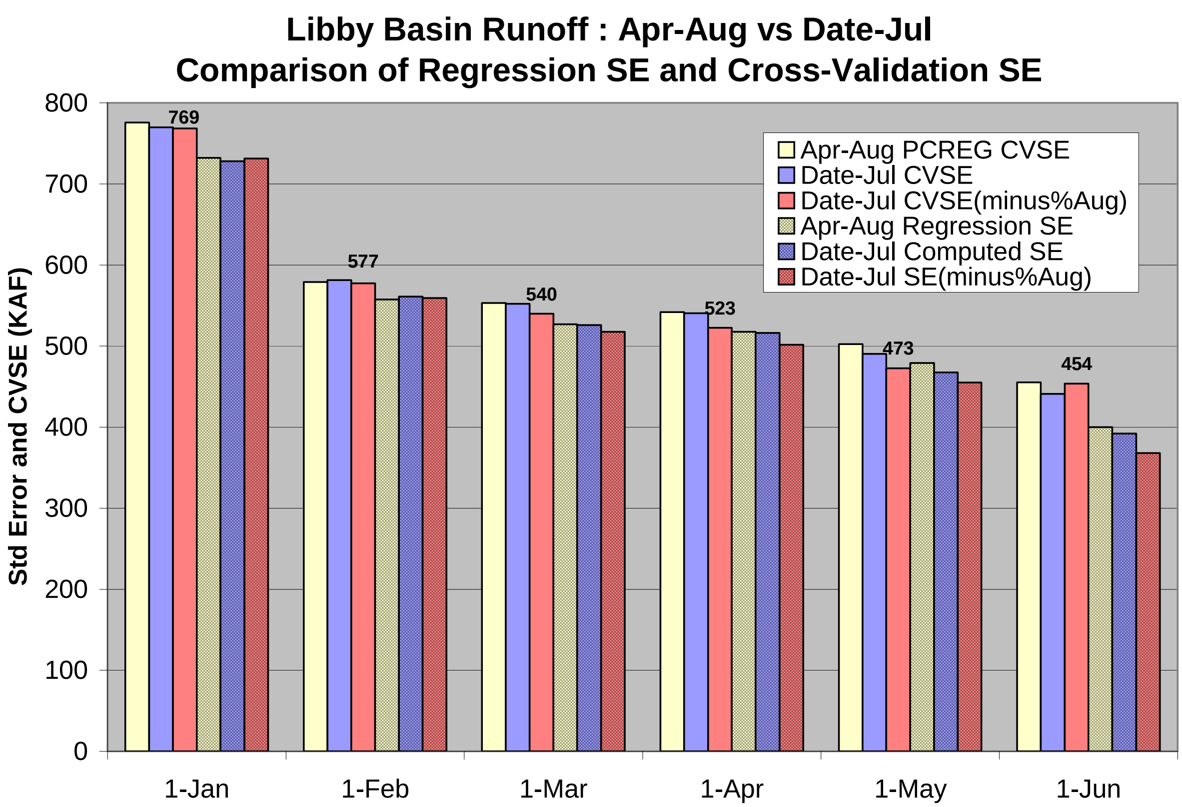
Derivation of Date-to-July forecasts

A variety of computations could be devised to transform the April-August volume forecast into the "Date-to-July" pseudo forecast desired for various power and flood control studies. The following alternatives can be combined in eight different ways, providing eight different calculations to compute the date-to-July forecast series for each of the winter forecasts (1-Jan, 1-Feb, or 1-Mar):

1. April-August Volume from statistical model
   a. Use regression model (full dataset) forecast values
   b. Use cross-validation (leave-one-out) regression forecast values
2. Adjustment to change April-August volume into "Date-August" volume
   a. For any months prior to April add historic average volumes
   b. For any months prior to April add historic average volumes weighted by "percent of average" value for current April-August forecast
3. Adjustment to change forecast volume into "Date-July" volume
   a. Subtract average August volume
   b. Subtract average August volume, weighted by "percent of average" value for current April-August forecast

Comparison of Standard Error statistics for Date-to-July forecasts for the LIBBY forecast

Forecasts and forecast errors were calculated for five of the eight "date-to-July" combinations presented above, and the root-mean-squared-error (RMSE) of those "date-to-July" forecast errors were compared with the RMSE of the April-August cross-validation forecast error (i.e. the Apr-Aug forecasts CVSE). The following figure shows the RMSE value for each monthly forecast. The first three series utilize the cross-validation forecast, while the last three series utilize the standard regression forecast. Series 2, 3, 5, and 6 are from "date-to-July" forecasts developed using option 2a, above (average volumes used for winter months). Series 2 and 5 used option 3a, above (average August) and series 3 and 6 used option 3b, above (average August weight by the forecasts percent-of-normal).



The above figure shows that from 1-January to 1-May it would be problematic to argue that there is a statistical significance in the results for a given forecast date or that any one method is superior to any other.

Recommended Libby date-to-July forecasts and standard error computations

In order to provide the best consistency with the CVSE statistic used with the full April-August forecast model, **it is recommended that the Date-to-July forecasts and errors be constructed using the methodology of the third series, whereby the Corps' Libby April-August first-of-month cross-validation forecasts are adjusted by adding in the historical average winter month volumes, then further adjusted by subtracting out the average August volume weighted by the April-August forecast percent-of-average factor.**

This method provides the following Date-to-July "standard errors" for the Libby runoff volumes:

Libby Runoff Forecast

Forecast Date	**1-Jan**	**1-Feb**	**1-Mar**	**1-Apr**	**1-May**	**1-Jun**
Date-Jul CVSE	769	577	540	523	473	454

The recommended equations for computation of the Date-to-July forecasts are as follows:

1-Jan Forecast = Jan Avg + Feb Avg + Mar Avg + 1-Jan Apr-Aug Cross-Validation Forecast – (JanFcstPct * AugAvg)

1-Feb Forecast = Feb Avg + Mar Avg + 1-Feb Apr-Aug Cross-Validation Forecast – (FebFcstPct * AugAvg)

1-Mar Forecast = Mar Avg + 1-Mar Apr-Aug Cross-Validation Forecast – (MarFcstPct * AugAvg)

1-Apr Forecast = 1-Apr Apr-Aug Cross-Validation Forecast – (AprFcstPct * AugAvg)

1-May Forecast = 1-May May-Aug Cross-Validation Forecast – (MayFcstPct * AugAvg)

1-Jun Forecast = 1-Jun Jun-Aug Cross-Validation Forecast – (JunFcstPct * AugAvg)

with

JanFcstPct = 1-Jan Apr-Aug Cross-Validation Forecast / Average Apr-Aug Forecast

FebFcstPct = 1-Feb Apr-Aug Cross-Validation Forecast / Average Apr-Aug Forecast

MarFcstPct = 1-Mar Apr-Aug Cross-Validation Forecast / Average Apr-Aug Forecast

AprFcstPct = 1-Apr Apr-Aug Cross-Validation Forecast / Average Apr-Aug Forecast

MayFcstPct = 1-May Apr-Aug Cross-Validation Forecast / Average May-Aug Forecast

JunFcstPct = 1-Jun Apr-Aug Cross-Validation Forecast / Average Jun-Aug Forecast

Chart from (Wortman) Excel Workbook: C:\Documents and Settings\g0pdwrtw\My Documents\Excel Spreadsheets\Libby Forecast\Libby Forecasting Models 2004\PCREG_AllModelForecasts_and_Errors.xls

Graph Variables:

Forecasts: F = PC Regression model forecast (Apr-Aug)
F' = PC Regression cross-validation (leave-one-out) forecast (Apr-Aug)

Errors: E = Obs – F
E' = Obs – F'
E1 = (Jan+Feb+Mar+Apr+May+Jun+Jul)-(Jan+Feb+Mar+F-Aug)
E1% = (Jan+Feb+Mar+Apr+May+Jun+Jul)-
(Jan+Feb+Mar+F - (F/AvgAprAug)*Aug)
E1' = (Jan+Feb+Mar+Apr+May+Jun+Jul)-(Jan+Feb+Mar+F'-Aug)
E1'% = (Jan+Feb+Mar+Apr+May+Jun+Jul)-
(Jan+Feb+Mar+F' - (F'/AvgAprAug)*Aug)

Plot 1: RMS(E')
Plot 2: RMS(E1')
Plot 3: RMS(E1'%)
Plot 4: RMS(E)
Plot 5: RMS(E1)
Plot 6: RMS(E1%)

Attachment 3 to Appendix 8

Monthly Distribution Factors
Used to Compute Monthly Streamflows for the TSR

(originally submitted to CRTOC in May, 2006 by Patti Low, USACE)

Monthly distribution factors for runoff volumes of Date-July are computed for projects where monthly streamflows/volumes are submitted by BPA and the Corps for the TSR. The distribution factors are based on the mean 71-year volumes and represent the mean 71-year shape. A forecast volume for Date-July is multiplied by the appropriate monthly distribution factor to obtain a monthly volume.

As an example, the following shows the Libby monthly mean and Date-July mean volumes.

Libby 71-year mean monthly volumes (Kaf)

JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL
0.20	0.18	0.22	0.18	0.35	1.73	2.26	1.26

Libby 71 year mean month-July volumes (Kaf)

JAN-JUL	FEB-JUL	MAR-JUL	AP1-JUL	AP2-JUL	MAY-JUL	JUN-JUL
6.37	6.17	5.99	5.77	5.60	5.25	3.52

To compute each month's distribution factor which will be applied to a Jan-Jul volume, each period mean is divided by the Jan-Jul mean. For example, January's distribution factor is 0.2/6.37=.031 and February's distribution factor is 0.18/6.37 = .028.

To compute each period's distribution factor that will be applied to a Feb-Jul volume, each monthly mean is divided by the Feb-Jul mean. For example, February's distribution factor is 0.18/6.17 = .029, and March's distribution factor is 0.22/6.17 = .036.

Calculations are likewise for applying to March-Jul, 1 Apr-July, 16 Apr-July, May-July, and June-July volumes. The following table shows all of the distribution factors for Libby.

Libby Distribution Factors

	Jan	Feb	Mar	Ap1	Apr	May	Jun	Jul
Jan-Jul	0.031	0.028	0.035	0.028	0.055	0.272	0.355	0.198
Feb-Jul		0.029	0.036	0.029	0.056	0.280	0.366	0.204
Mar-Jul			0.037	0.030	0.058	0.289	0.377	0.210
1 Ap1-Jul				0.031	0.060	0.300	0.391	0.218
16 Apr-Jul					0.062	0.309	0.404	0.225
May-Jul						0.330	0.431	0.240
Jun-Jul							0.642	0.358