FINAL MEMORANDUM

November 14, 2001

TO: File

FROM: Meg Frantz

SUBJECT: **CDSS Daily Yampa Model - Task 4 Recommendation for Full Basin Model**

Introduction

The objective of this task is to recommend a work plan for creating a daily model of the entire Yampa basin, considering the experience and results of Task 2, the pilot study in the Elk River basin. This memo recommends a specific approach to the daily model and describes the rationale for it. It also includes a task-by-task work plan for developing the daily model.

Background

The pilot project in the Elk River basin evaluated three approaches to creating a daily model, designated the Average Daily, Daily Pattern, and Daily Input approaches. Each is described in detail in the task memorandum **CDSS Daily Yampa Model – Task 2 Pilot Study.** The study concluded by recommending the Daily Pattern approach to generating daily data for a Yampa basinwide model, recognizing that a monthly model is already available. The pilot study demonstrated that:

1. The Average Daily approach offers little more information or detail than a monthly model.

2. The Daily Input approach is complex to assemble, due to the different relationships between daily and monthly data for 1) different types of data, 2) different types of structures, and 3) baseflow versus simulation runs. For example, daily flags in the diversion station file have different values depending on whether the structure is explicitly modeled or an aggregate. Also, different versions of the diversion station and reservoir station files must be used for the baseflow and simulation runs. This is because daily flags must assume values with respect to, for example, historical reservoir content data (used in the baseflow run) that are different from flags with respect to reservoir targets (used in the simulation run).

   The Daily Input approach requires daily historical diversion data, which is very often incomplete. Regression techniques satisfactory for filling monthly data do not generally produce good results with daily data, and the modeler is left to assume a relationship between monthly and daily data or between observations at the endpoints of a data gap, and the daily data in between. Furthermore, the daily data estimates need to be constrained to result in the same monthly total as the monthly data. These issues add to the data development aspects of the Daily Input approach.

3. The Daily Pattern approach produced very good results, similar to Daily Input results, with little effort relative to the Daily Input approach. Therefore the Daily Pattern approach is recommended for the full basin daily model of the Yampa River.

The remainder of this memo details how the Daily Pattern approach should be implemented with the Yampa River Water Resources Planning Model.

Study Period

In consultation with the State, it was decided that the period of study for the full basin model should be 1975-1996. This is the period for which monthly consumptive use data are available and diversion data are most complete. As the calibration period for all the CDSS water resources planning models, this period represents a standard for future daily models that can be met in all the basins. Consistency across basins is desirable because future applications may require linking models.

Daily Pattern Gages

A potential limitation on the Daily Pattern approach is the availability and applicability of daily gage information. Goodness of calibration for a full basin Daily Pattern model will depend on how well the available daily gage patterns represent baseflow throughout the Yampa River basin. This section describes how the Yampa gages were reviewed to determine which gages should serve as daily pattern gages, and which gages best represent which sub-basins of the Yampa River.

The Daily Pattern approach requires that the daily pattern data are available throughout the simulation period. Although daily data can be filled in where missing, high priority is placed on gages with a complete or nearly complete record. Periods of record within 1975-1996 are summarized in Figure 1 for the nineteen gages in the Yampa model. It shows there are six gages with complete records during the study period:

- 09239500 Yampa River at Steamboat Springs
- 09245000 Elkhead Creek near Elkhead
- 09251000 Yampa River near Maybell
- 09523000 Little Snake River near Slater
- 09255000 Slater Fork near Slater
- 09260000 Little Snake River near Lily

In addition, although the record for gage 09238900 Fish Creek at Upper Station is incomplete, it contains irrigation season data throughout the period and could potentially be filled during winter months. Similarly, gage 09241000 Elk River at Clark is missing only five years of data and could be filled so that it can serve as a pattern gage. Therefore, there are eight "candidate gages" for providing the daily pattern for baseflows in the daily Yampa model. The Willow Creek gage is not included in the list because, although it is missing only four years, two other complete gages are nearby and would provide similar observed information.

A second consideration is how well the gage represents baseflow conditions. **Table 1** lists the eight candidate gages and their average annual CDSS baseflow as computed for the monthly model, and historical flow for 1975-1996. The "Difference" column is an indicator of how much each gage is impacted by consumptive use within its drainage area. The final recommendations for daily pattern gages also considered reservoir storage and regulation above the gage.

Figure 1 Yampa Basin Gage Coverage

Station No.	Station Name
09236000	Bear River near Toponas
09237500	Yampa River below Stagecoach Reservoir
09238900	Fish Creek at Upper Station near Steamboat Springs
09239500	Yampa River at Steamboat Springs
09241000	Elk River at Clark
09244410	Yampa River below diversion near Hayden
09245500	N. Fork Elkhead Creek near Elkhead
09245000	Elkhead Creek near Elkhead
09246920	Fortification Creek near Fortification
09247600	Yampa River below Craig
09249000	E. Fork of Williams Fork near Pagoda
09249200	S. Fork of Williams Fork near Pagoda
09249750	Williams Fork at mouth, near Hamilton
09251000	Yampa River near Maybell
09253000	Little Snake River near Slater
09255000	Slater Fork near Slater
09258000	Willow Creek near Dixon
09260000	Little Snake River near Lily
09260050	Yampa River at Deerlodge

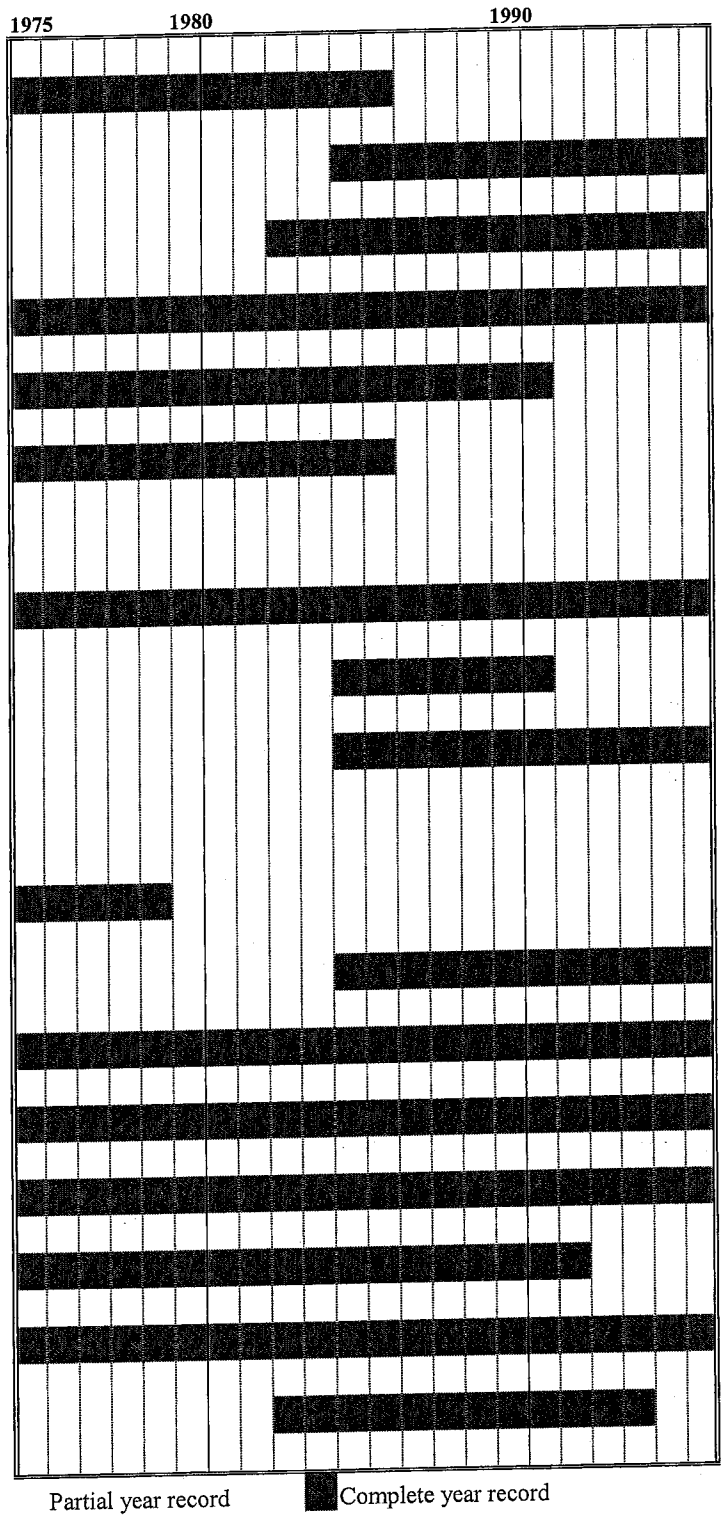

Table 1
Potential Pattern Gages for Yampa Daily Model

Station No.	Station Name	Period of Record	Average Annual Baseflow (af)[1]	Average Annual Historical Flow (af)[2]	Difference (%)
09238900	Fish Creek at Upper Station near Steamboat Springs	1983-1996	47,143	44,875	4.8
09239500	Yampa R. at Steamboat Springs	1975-1996	349,440	323,459	7.4
09241000	Elk River at Clark	1975-1991	238,231	231,396	2.9
09245000	Elkhead Creek near Elkhead	1975-1996	42,139	42,324	0.4
09251000	Yampa River near Maybell	1975-1996	1,244,142	1,137,216	8.6
09253000	Little Snake River near Slater	1975-1996	184,318	166,947	9.4
09255000	Slater Fork near Slater	1975-1996	64,126	60,922	5.0
09260000	Little Snake River near Lily	1975-1996	470,591	412,007	12.4

[1]Averaging period is 1975-1996, or subset matching available historical gage records; source is file *ym2001fx.xbm*, dated 3/16/01, provided by State.
[2]Averaging period is 1975-1996, or available subset of that period. Source is file *ym2001.rih,* dated 3/14/01, provided by State

Finally, selection of the pattern gages should consider how well the candidate gages represent specific sub-basins of the Yampa River. The Mixed Station Model's Summary Information file output (*YM2001F.sum*) from the State's Ym2001 model was useful for identifying how well baseflows from one gage correlate with gages in other areas of the basin. Other factors being equal, the potential pattern gage that correlates most strongly with a short term gage should be selected to supply the daily pattern in the vicinity of the short-term gage. The Summary Information file gives the correlation coefficient for log-transformed monthly regression models which predict baseflow at a given gage, using each other eligible gage as an independent variable. (For more information on the Mixed Station Model output, see Appendix E.8 of the Yampa River Basin Water Resources Planning Model report.) Identifying the best correlating gage was not a "cut-and-dry" determination, since some gages were the best predictors in some months but not others. In general, however, the review showed that for the sub-basins shown in Table 2, the "Recommended Pattern Gage" appears to be the best pattern gage for that sub-basin. In some cases, the table includes alternatives to pursue if the model turns out not to calibrate well with the recommended pattern gage. The sub-basins are illustrated in Figure 3, a simplified network diagram of the Yampa basin. Figure 3 is located at the end of this memorandum.

Table 2
Recommended Daily Pattern Gages for Yampa River Sub-basins

Basin subdivision	Recommended Pattern Gage
Yampa basin above Stagecoach Reservoir	09239500 Yampa River at Steamboat Springs, OR 09238900 Fish Creek at Upper Station
Yampa basin from gage 09244410 Yampa River near Hayden to Stagecoach Reservoir, excluding Fish Creek and Elk River basins	09239500 Yampa River at Steamboat Springs
Fish Creek basin	09238900 Fish Creek at Upper Station
Elk River basin	09241000 Elk River at Clark, OR 09253000 Little Snake River near Slater, if filled portion of Clark gage does not give credible results
Mainstem Yampa River below gage 09244410 Yampa River near Hayden	09251000 Yampa River near Maybell
Elkhead Creek	09245000 Elkhead Creek near Elkhead
Fortification Creek	09245000 Elkhead Creek near Elkhead
East Fork Williams Fork	09253000 Little Snake River near Slater
Williams Fork basin excluding East Fork Williams Fork	09251000 Yampa River near Maybell
Mainstem Little Snake River	09253000 Little Snake River near Slater
Slater Creek	09255000 Slater Fork near Slater
Willow Creek	09255000 Slater Fork near Slater

Work Plan and Budget

1. Fill gages 09238900 Fish Creek at Upper Station and 09241000 Elk River at Clark with daily data. Review any other daily data gaps that may occur within the month and fill using interpolation or forward fill techniques.

2. Create a daily model data set, beginning with the monthly *ym2001* Calculated data set provided by the State. Specifically, create a new river station file with flags set to the gage id's of the recommended daily pattern gages. Add daily flags of zero in the diversion, reservoir, and instream flow station files. (These tell Statemod to use the average daily value determined from the monthly diversion demand, reservoir target content, and instream flow demand files, respectively.) Create the daily streamflow file containing daily flows for all the pattern gages.

3. Execute the Daily Pattern model for the period 1975-1996. Compare modeled and historical daily gage flows at key gages. Compare modeled and historical daily diversions for key diversions. Test an alternative approach for Elk River and the upper Yampa if initial results are implausible or

conflict with available historical information. Meet with the State to review results, and recommend further calibration if warranted. Calibration will consist of modifying the daily pattern gage selections. It will not include modifying things that were calibrated in Phases II, IIIa, and IIIb, such as operating rules or irrigation return flow points.

4. Carry out additional calibration as determined in Step 3.

5. Document the daily model in a task memorandum.

Deliverables will consist of a draft and final task memorandum, and model input files.

Steps 1 through 4 are covered in the contract scope as Task 5 and have a total budget of $27,800. Step 5 corresponds to Task 6. Budget is summarized in **Table 3** as a preliminary indication of the level of effort for each step.

Table 3
Daily Yampa Model Budget Summary

Step 1. Fill daily data where needed	$ 3,600
Step 2. Create initial daily data set	$ 5,225
Step 3. Execute daily model, review, and determine calibration needs	$ 13,300
Step 4. Calibrate per Step 3 review	$ 5,675
Step 5. Document model	$ 3,120
Total	$ 30,920

Conclusions

Based on the **CDSS Daily Yampa Model – Task 2 Pilot Study** the Daily Pattern approach is recommended for developing a daily model of the entire Yampa River Basin. Stream gages to be used to define the daily pattern throughout the Yampa River Basin are summarized in **Table 2**. They are based on consideration of three factors: 1) completeness of the gage record, 2) minimum impact of consumption and regulation above the gage, and 3) correlation with other areas the gage is to represent. . A work plan and budget have been developed that indicates a daily model can be developed for the entire Yampa River basin using a 1975-1996 study period for $30,920.

Comments

1. The two gages that need to be filled (09238900 and 09241000) will be filled using the monthly regression models used in Phase IIIa. Monthly results will be distributed to daily flow using either a nearby gage or a typical pattern identified in the gage's own history.

2. The Steamboat Springs gage (09239500) is anticipated to be the best pattern gage for the basin above Stagecoach Reservoir, even though it has more consumptive use above it than the Fish Creek gage (09238900). This is because the monthly relationships between the Fish Creek gage and the upper Yampa gages (09236000 and 09237500) are not as strong as the relationships between the Steamboat Springs gage and the upper Yampa gages. (This could reflect Fish Creek Reservoir operations above the Fish Creek gage.) Furthermore, the Fish Creek daily data will need to be filled. The Fish Creek gage will be filled as part of the basinwide modeling effort, and used, at a minimum, on Fish Creek itself. It can then easily be tested in the upper basin if results using the Steamboat Springs gage are unsatisfactory.

3. The difference between baseflow and historical flow for gage 09245000 Elkhead Creek near Elkhead is low (see **Table 2**), suggesting it should be used as a pattern gage wherever possible. We recommend its use in the Elkhead and Fortification Creek basins, and not elsewhere however, because the Mixed Station Model output shows it didn't correlate well with other areas.

4. Based on the pilot study, we know that the Clark gage on the Elk River will provide excellent results as the pattern gage on the Elk River itself, for 1975 through 1991. It will not be clear until we do sensitivity testing whether overall results (i.e., for the entire study period) are better by filling in the Clark gage for 1992-1996, or using a different gage (09253000 Little Snake River near Slater) as the pattern gage for 1975-1996.