Agreement on Implementation of John Martin Reservoir Revised Elevation-Area-Capacity Tables in the H-I Model

August 2015 as amended January 2024

I.   Introduction

This Agreement ("Agreement") was originally entered in August 2015 by the State of Colorado and the State of Kansas ("States") to modify the Hydrologic-Institutional Model ("H-I Model") and the area-capacity ("AC") information that is used by the model to recognize the resurveys of John Martin Reservoir ("JMR") in 1999 and 2006/2009 (used for administration in 2013). JMR was resurveyed in November 2017 and the revised information has been used for administration since November 2019. The States agreed to use new preliminary H-I Model coding and AC information developed by Colorado for the new survey in the H-I Model updates for years 2019 through 2021. In 2022, Colorado developed new H-I Model code so that only the RESR.DAT input file and not the code will need to be modified after future JMR resurveys. Kansas reviewed and has agreed to the revisions to the H-I Model AC information and code.

This amended Agreement along with the accompanying DVD reflects the changes described above. This Agreement will be referred to as the *2015 Agreement as amended 2024* in other documents. Integration of future resurvey information into the RESR.DAT text file will not be considered a "Substantive Change" under Amended Appendix B.1 of the Kansas v. Colorado Judgment and Decree (U.S. Original No. 105), as long as the States agree to the revised AC information. The revised H-I Model code and information has been integrated into the most current version of the model which includes revisions from the *Agreement on H-I Model Changes to Address Increases in Irrigation Efficiency or Pumped Groundwater (2011 Agreement as amended August 2015)*, this *2015 Agreement as amended 2024*, and an additional *Agreement on H-I Model Changes to Address LAWMA's Section II Accounts, X-Y Water Right, and Spill Factors (2024 Agreement)*.

II.   Background and Context

The Arkansas River and its tributaries transport a significant sediment load, and the process of sedimentation in JMR has been causing a steady decrease in storage capacity over time. The U.S. Army Corps of Engineers ("Army Corps") resurveys JMR approximately every 10 years. The H-I Model uses a progression of AC relationships to estimate evaporation based on storage and to limit the maximum Compact conservation storage volume. The original version of the H-I Model contained six AC relationships and eight maximum storage values which were applied for different date ranges with the last used information based on the 1994 resurvey.

JMR was resurveyed in 1999 and the resulting elevation-area-capacity ("EAC") table was used for administration from November 1999 through October 2013. The Army Corp dredged JMR around the outlet works in early 2006, completed a bathymetric survey of the reservoir in March 2006, and completed an aerial survey of the "out of water" areas in 2009. The Army Corp used a FORTRAN program for previous surveys, but Geographic Information System ("GIS") software was also used in 2013 to develop areas and volumes from mapped contour lines. The Army Corps completed the sedimentation resurvey report in 2013 which included a new EAC

table which was first used for administration in November of 2013. The original *August 2015 Agreement* integrated the 1999 and 2013 EAC information into the H-I Model.

In November 2017, the Army Corps resurveyed JMR using multi-beam Sonar and airborne LiDAR inside and outside the inundated areas, respectively. GIS was used to create a digital elevation model ("DEM") from the two data sets and develop EAC information using this DEM. The new EAC table was first used for administration in November of 2019. The 2019 EAC table indicates a larger maximum conservation storage than the 1988 through 2013 EAC tables, but the Army Corps is confident in the new higher capacity estimate due to the increased accuracies provided by multi-beam Sonar, Lidar, and DEM processing methods.

The Army Corps has discretized recent versions of the EAC tables to 0.01 foot elevations. To represent the EAC tables in the H-I Model, the following exponential function is used to estimate area as a function of volume for two volume ranges for each dataset using two coefficients that are fit using linear regression.

$$\log(\text{area in acres}) = a*\log(\text{volume in AF})+b$$

and

$$\text{area} = e\char`^(\log(\text{area})) = e\char`^(a*\log(\text{volume})+b)$$

where log = natural (base e) logarithm and e = Euler's number
(a and b are referred to as alpha and beta in the H-I Model code and Appendix C.1)

Coefficients have been developed by fitting lines using linear regression to a graph of log(area) versus log(volume) over two ranges of the data (above and below a reservoir elevation of 3800 feet has been used). Non-linear data at the lowest capacities has sometimes been excluded (i.e. below 3786 feet for 2019 EAC table). The area capacity (AC) and conservation storage information and applicable dates that were in the original H-I Model and have been developed for the subsequent resurveys are shown in Table 1. The H-I Model code and input file were modified to incorporate the relevant information in Table 1 into the input file, RESR.DAT.

Table 1. John Martin Reservoir Data in the H-I Model

Sediment Survey	EAC Table	H-I Model Area Capacity Information for Evaporation							H-I Model Max Cons. Storage		
		Dates	Months	a2 if vol>	a1	b1	a2	b2	Dates	Months	maxstor
Oct-51	1956	1950-6/59	<=114	29216	0.6658	0.9478	0.6319	1.2869	1950-7/57	<=91	380858
Aug-57	1958								8/57-2/62	92<=146	365706
Mar-62	1962	7/59-12/65	115<=192	29204	0.6765	1.0992	0.6384	1.2034	3/62-7/68	147<=223	356038
Sep-66	1967										
Aug-68	1969	1/66-12/70	193<=252	23606	0.8388	-0.2694	0.5825	1.8865	8/68-2/72	224<=266	349292
Mar-72	1972	1/71-12/79	253<=360	24187	0.8311	-0.3301	0.5984	1.6973	3/72-5/80	267<=365	348101
Jun-80	1980								6/80-5/86	366<=437	341945
Jul-86	1988	1/80-6/90	361<=486	18468	0.7161	1.0008	0.5796	1.9503	6/86-5/94	438<=533	337166
Jun-94	1994	7/90-**12/96**	487<=**564**	18411	0.6900	1.2625	0.6061	1.6480	6/94-**10/99**	534<=**598**	335693
May-99	**1999**	**1/97-12/05**	**565<=672**	**17808**	**0.7011**	**1.0718**	**0.6131**	**1.5595**	**11/99-10/13**	**599<=766**	**333912**
Mar-06	**2013**	**1/06-12/16**	**673<=804**	**15614**	**0.6307**	**1.6871**	**0.6051**	**1.6691**	**11/13-10/19**	**767<=838**	**330703**
Nov-17	**2019**	**1/17-**	**805-**	**17178**	**0.5583**	**2.3023**	**0.6248**	**1.4420**	**11/19-**	**839-**	**338587**

Notes: bold/red=new data not in original H-I Model

III.   Scope

The H-I Model code and the input file, RESR.DAT, have been revised to incorporate the new 1999, 2013, and 2019 EAC tables that were developed for JMR by the Army Corps. AC coefficients and dates have been developed as detailed in Table 1 to incorporate this information into the H-I Model as agreed to by the States.

With the original H-I Model, the code itself had to be changed to incorporate new JMR AC information. The H-I Model code and input file, RESR.DAT, were revised so that all data are contained in the input file, and only the input file will need to be changed to incorporate future JMR resurveys. This Agreement will not need to be amended to incorporate future JMR resurveys as long as the States agree that the new EAC table used for administration is appropriately represented with new coefficients and dates in the RESR.DAT input file.

IV.   H-I Model Code Revisions

Revisions to the H-I Model code and input file, RESR.DAT, are detailed in the following section "A" and grouped by the following tasks:

1. Revisions to incorporate all AC information into the input file
2. Code revisions required for reading other data from the input file
3. Code revisions for variable declaration and dimensioning
4. Code revisions for reading of data from the input file
5. Code revisions to set the AC coefficients
6. Code revisions to set the maximum storage capacity

The States agree to make the changes to the H-I Model code and input file, RESR.DAT, as shown in section A. These changes have been incorporated into a version of the H-I Model code titled "update6eV1_22.for".

A. Revisions to the H-I Model Input File and H-I Model Code

1. Revisions to Incorporate All Area Capacity Information into the Input File

a. Deleted Portion of Original RESR.DAT Input File

```
0.6658     0.9478          -- COEFFICIENTS FOR JOHN MARTIN AREA-STORAGE
0.6765     1.0992
0.8388    -0.2694
0.8311    -0.3301
0.7161     1.0008
0.6900     1.2625
0.6319     1.2869
0.6384     1.2034
0.5825     1.8865
0.5984     1.6973
0.5796     1.9503
0.6061     1.6480
```

b. Revised Portion of RESR.DAT Input File

```
 9     -- COEFFICIENTS FOR JOHN MARTIN RESERVOIR AREA-CAPACITY
1956       114    29216.     0.6658     0.9478     0.6319     1.2869
1962       192    29204.     0.6765     1.0992     0.6384     1.2034
1969       252    23606.     0.8388    -0.2694     0.5825     1.8865
1972       360    24187.     0.8311    -0.3301     0.5984     1.6973
1988       486    18468.     0.7161     1.0008     0.5796     1.9503
1994       564    18411.     0.6900     1.2625     0.6061     1.6480
1999       672    17808.     0.7011     1.0718     0.6131     1.5595
2013       804    15614.     0.6307     1.6871     0.6051     1.6691
2019      9999    17178.     0.5583     2.3023     0.6248     1.4420
11     -- MAXIMUM CONSERVATION STORAGE FOR JOHN MARTIN RESERVOIR
1956        91    380858.
1958       146    365706.
1962       223    356038.
1969       266    349292.
1972       365    348101.
1980       437    341945.
1988       533    337166.
1994       598    335693.
1999       766    333912.
2013       838    330703.
2019      9999    338587.
```
Note: for the most current survey, the last month should be entered as 9999

2. H-I Model Code Revisions Required for Reading Other Data from the Input File

a. Lines Deleted from Original Code

```
      DO 370 I=1,12        0201
         READ(92,*)        0202
  370 CONTINUE             0203
```

b. Revised Code

```
         READ(92,814)NJMRAC      0200.1JMRKT
         DO 370 I=1,NJMRAC       0200.2JMRKT
            READ(92,*)           0200.3JMRKT
     370 CONTINUE                203
         READ(92,814)NJMRST      0203.1JMRKT
         DO 375 I=1,NJMRST       0203.2JMRKT
            READ(92,*)           0203.3JMRKT
     375 CONTINUE                0203.4JMRKT

     814  FORMAT(I4)             0242.1JMRKT
```

3. H-I Model Code Revisions for Variable Declaration and Dimensioning

```
2   MAXSPLI=100,MAXSPLJ=18,MAXJM=20)                               0293.1SPLKT/JMRKT
 REAL ALPHA(MAXJM,2),BETA(MAXJM,2),CFLOW(MAXDVT),DIVTD(MAXDVT),    0295JMRKT
1   SPLFACT(MAXSPLI,MAXSPLJ),JMRACA(MAXJM),JMRSTR(MAXJM)           0320.1SPLKT/JMRKT
5   ISPLUSER(MAXSPLI),ISPLYEAR(MAXSPLI),MJMRAC(MAXJM),MJMRST(MAXJM) 0325.1SPLKT/JMRKT
```

4. H-I Model Code Revisions for Reading of Data from the Input File

a. Lines Deleted from Original H-I Model Code Used to Read RESR.DAT Data File

```
    DO 360 IRANGE=1,2                                              0678
      DO 355 IPER=1,6                                              0679
        READ(92,913)ALPHA(IPER,IRANGE),BETA(IPER,IRANGE)          0680
  355   CONTINUE                                                  0681
  360 CONTINUE                                                    0682
```

b. Revised H-I Model Code Used to Read RESR.DAT Data File

```
    READ(92,814)NJMRAC                                            0677.1JMRKT
    DO 355 IJMR=1,NJMRAC                                          0677.2JMRKT
      READ(92,926)MJMRAC(IJMR),JMRACA(IJMR),ALPHA(IJMR,1),        0677.3JMRKT
   1       BETA(IJMR,1),ALPHA(IJMR,2),BETA(IJMR,2)                0677.4JMRKT
  355 CONTINUE                                                    0681
    READ(92,814)NJMRST                                            0681.1JMRKT
    DO 360 IJMR=1,NJMRST                                          0681.2JMRKT
      READ(92,927)MJMRST(IJMR),JMRSTR(IJMR)                       0681.3JMRKT
  360 CONTINUE                                                    0682

926  FORMAT(7X,I7,F10.0,4F10.4)                                   0731.1JMRKT
927  FORMAT(7X,I7,F10.0)                                          0731.2JMRKT
```

5. H-I Model Code Revisions to Set Area Capacity Coefficients
a. Lines Deleted from Original H-I Model Code Used to Set Area Capacity Coefficients

```
IF (IMONTH.LT.115) THEN                                        0886
   IPER=1                                                      0887
   IF (VOL.GT.29216.) THEN                                     0888
     IRANGE=2                                                  0889
   ELSE                                                        0890
     IRANGE=1                                                  0891
   ENDIF                                                       0892
ENDIF                                                          0893
IF (IMONTH.GT.114 .AND. IMONTH.LT.193) THEN                    0894
  IPER=2                                                       0895
  IF (VOL.GT.29204.) THEN                                      0896
     IRANGE=2                                                  0897
  ELSE                                                         0898
     IRANGE=1                                                  0899
  ENDIF                                                        0900
ENDIF                                                          0901
IF (IMONTH.GT.192 .AND. IMONTH.LT.253) THEN                    0902
  IPER=3                                                       0903
  IF (VOL.GT.23606.) THEN                                      0904
     IRANGE=2                                                  0905
  ELSE                                                         0906
     IRANGE=1                                                  0907
  ENDIF                                                        0908
ENDIF                                                          0909
IF (IMONTH.GT.252 .AND. IMONTH.LT.361) THEN                    0910
  IPER=4                                                       0911
  IF (VOL.GT.24187.) THEN                                      0912
     IRANGE=2                                                  0913
  ELSE                                                         0914
     IRANGE=1                                                  0915
  ENDIF                                                        0916
ENDIF                                                          0917
IF (IMONTH.GT.360 .AND. IMONTH .LT. 487) THEN                  0918
  IPER=5                                                       0919
  IF (VOL.GT.18468.) THEN                                      0920
     IRANGE=2                                                  0921
  ELSE                                                         0922
     IRANGE=1                                                  0923
  ENDIF                                                        0924
ENDIF                                                          0925
IF (IMONTH.GT.486) THEN                                        0926
   IPER=6                                                      0927
   IF (VOL.GT.18411.) THEN                                     0928
      IRANGE=2                                                 0929
   ELSE                                                        0930
   IRANGE=1                                                    0931
   ENDIF                                                       0932
 ENDIF                                                         0933
```

b. Revised H-I Model Code Used to Set Area Capacity Coefficients

```
      DO 435 IJMR=1,NJMRAC                                        0885.1JMRKT
        IF (IMONTH.LE.MJMRAC(IJMR)) THEN                          0885.2JMRKT
          IPER=IJMR                                               0885.3JMRKT
          IF (VOL.GT.JMRACA(IJMR)) THEN                           0885.4JMRKT
            IRANGE=2                                              0885.5JMRKT
          ELSE                                                    0885.6JMRKT
            IRANGE=1                                              0885.7JMRKT
          ENDIF                                                   0885.8JMRKT
          GO TO 436                                               0885.9JMRKT
        ENDIF                                                     0885.10JMRKT
435     CONTINUE                                                  0885.11JMRKT
436     CONTINUE                                                  0885.12JMRKT
```

6. H-I Model Code Revisions to Set Maximum Storage Capacity

a. Lines Deleted from Original H-I Model Code Used to Set Maximum Storage Capacity

```
      IF (IMONTH.LT.92) STRMAX(1)=380858.                         1041
      IF (IMONTH.GE.92 .AND. IMONTH.LT.147) STRMAX(1)=365706.     1042
      IF (IMONTH.GE.147 .AND. IMONTH.LT.224) STRMAX(1)=356038.    1043
      IF (IMONTH.GE.224 .AND. IMONTH.LT.267) STRMAX(1)=349292.    1044
      IF (IMONTH.GE.267 .AND. IMONTH.LT.366) STRMAX(1)=348101.    1045
      IF (IMONTH.GE.366 .AND. IMONTH.LT.438) STRMAX(1)=341945.    1046
      IF (IMONTH.GE.438 .AND. IMONTH.LT.534) STRMAX(1)=337166.    1047
                                                                  1048
C--Actual conservation storage capacity as of June 1994          1049
                                                                  1050
      IF (IMONTH.GE.534) STRMAX(1)=335693.                        1051
```

b. Revised H-I Model Code Used to Set Storage Capacity

```
      DO 465 IJMR=1,NJMRST                                        1040.1JMRKT
        IF (IMONTH.LE.MJMRST(IJMR)) THEN                          1040.2JMRKT
          STRMAX(1)=JMRSTR(IJMR)                                  1040.3JMRKT
          GO TO 466                                               1040.4JMRKT
        ENDIF                                                     1040.5JMRKT
465   CONTINUE                                                    1040.6JMRKT
466   CONTINUE                                                    1040.7JMRKT
```

IX.   General Terms

The States agree to modify the H-I Model code and input file, RESR.DAT, as described in this agreement; incorporating all area-capacity information for John Martin Reservoir into the input file and including new information for the 1999, 2013, and 2019 elevation-area-capacity tables produced by the U.S. Army Corps of Engineers.

The new H-I Model code will not need to be revised to incorporate future resurveys of John Martin Reservoir. The States agree that integration of future resurvey information into the H-I Model input file, RESR.DAT, will not be considered a "Substantive Change" under Amended Appendix B.1 of the Kansas v. Colorado Judgment and Decree (U.S. Original No. 105), and this Agreement will not need to be amended to incorporate future resurveys, as long as the States agree to the representation of a new elevation-area-capacity table with new area capacity information in the RESR.DAT input file.

The States agree that the changes will be implemented with the 2023 H-I Model annual update performed in 2024. The results of the ten year Compact compliance for years prior to the 2023 H-I Model annual update will remain unchanged.

This Agreement shall become effective when both States have approved it by the signatures of their Engineers as provided for below or on counterpart copies, and after telecopies or electronic versions of the same have been received by the other State.

STATE OF COLORADO

Tracy L. Kosloff
Digitally signed by Tracy L. Kosloff
Date: 2024.01.15 09:58:11 -07'00'

_____
Tracy Kosloff
Colorado State Engineer

Date: _____

STATE OF KANSAS

_____
Earl Lewis
Kansas Chief Engineer

Date: _January 26, 2024_