V.3.3-API-HAR2 HARRISBURG (MARFC) API-RUNOFF OPERATION

Identifier: API-HAR2

Application: All Programs

Description: This Operation executes the redesigned and calibrated event-based MARFC API-type rainfall-runoff model.

It calculates Antecedent Precipitation Indices (API), Antecedent Evaporation Indices (AEI), Antecedent soil moisture Indices (AI) and runoff amounts for a given runoff zone. All these variables are expressed in units of length (MM). The data time interval of these variables can be 1, 2, 3, 4, 6, 8, 12 or 24 hours depending on the data time interval specified when the Operation is initialized. Input data are zonal potential evapotranspiration and zonal rain/melt.

Special provisions of this Operation include:

1. The minimum period for which this Operation can be executed is one day.

2. The data time interval for rain/melt and runoff can be 1, 2, 3, 4, 6, 8, 12 or 24 hours and is specified by the user when the Operation is initialized.

3. An adjustment factor is entered for each runoff zone to correct for differences between input potential evaporation(PE) data and the best estimate of PE for the watershed. If sky cover is used to calculate daily values of PE which are used as input to the Operation, the adjustment factor is used to correct for the bias between PE values calculated in this fashion and published values of evaporation from a free water surface found in NOAA Technical Report NWS 33. If minutes of sunshine is used in place of sky cover, the adjustment factor probably would become 1.0.

4. Initial carryover values may be specified by the user when the Operation is initialized for a particular runoff zone. These variables are: 12Z API, 12Z AEI, 12Z AI, 12Z storm API, 12Z storm AEI, 12Z storm AI, rain/melt from the current storm, runoff from the current storm, 24 hour rain/melt ending at 12Z, 24 hour runoff ending at 12Z and rain/melt for each period in the new storm window (up to 24 values).

5. The option is available to allow the user to request output time series containing storm API, storm AEI and storm AI values, with all three time series possessing the same data time interval as the rain/melt and runoff time series.

Background: In an attempt to more accurately describe the rainfall-runoff process in the mid-Atlantic region the MARFC redesigned its

event-based API model in 1991. This model contains several enhancements over its predecessor (see V.3.3-API-HAR).

1) Each season quadrant is defined by parametric equations which allow the API to approach a value of 0.00 during extended dry periods. In the previous MARFC API model, the season quadrants were defined by somewhat cumbersome table look-up schemes which were indeterminate when the API dropped below 0.10. This constraint aggravate the description of the surface runoff process during droughts because the greatest curvature in the season quadrant curves occurs at very low API values.

2) The use of parametric equations to describe the MARFC season quadrants instead of table look-up schemes eases the use of automatic optimization techniques during the calibration process.

3) When the API model was first introduced to the MARFC in the 1950s, week number was used in conjunction with API to define all 19 regional season quadrants. In the early 1960s, week number was replaced with another independent variable known as the Antecedent Evaporation Index (AEI). Instead of recalibrating each regional season quadrant based on this new index, the average AEI for each week of the year was calculated based on 10 years of lake evaporation data. The week number associated with each curve in the regional season quadrants was then replaced with the appropriate AEI value for that same week. This replacement necessitated two separate definitions of each regional season quadrant; one for the spring and summer months and another for the fall and winter months. The season quadrants associated with the new event-based MARFC API model are independent from season of the year and so just one season quadrant is required for each runoff zone.

4) The AEI is based on lake evaporation as estimated by the modified Penman equation located in the NWSRFS MAPE function. Unlike week number, lake evaporation is a sinusoidal function of time of the year. This factor enables the individual AEI curves in each season quadrant to be equally spaced, at least in the mid-Atlantic region, thus reducing the number of parameters needed to describe each season quadrant. Since the previous MARFC API model was originally designed with week number, its season quadrant curves are not evenly spaced.

5) In this new model, a precipitation quadrant has been developed for each calibrated runoff zone. A zone-specific precipitation quadrant permits the unique physiographic features of that zone to play a more active role in the description of surface runoff. It also provides smoother season quadrant curves and allows the AI to approach zero for each individual AEI curve in the season quadrant as API approaches infinity. This same boundary condition is employed in the Continuous API Model (see II.3-API-CONT).

6) The association of a unique precipitation quadrant with every season quadrant provides a more simple description of the precipitation quadrant itself. With help from OH, the MARFC has found that the PE term can be set to unity in the following equations, at least in the mid-Atlantic region:

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D = PA + PB*AI

AN = PC + PD*AI**PE

RO = (PCPN**AN + D**AN)**(1/AN) - D
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Since PA, PB, PC and PD are dimensionless and since AI and PCPN are in units of length, RO is also in units of length if PE is 1.0.

7) A unique season quadrant and precipitation quadrant has been developed for each significant runoff zone in the MARFC area of responsibility. Therefore, the runoff adjustment factor utilized in the previous MARFC API model is no longer needed.

Developed by: Middle Atlantic River Forecast Center

Allowable Data Time Intervals: 1, 2, 3, 4, 6, 8, 12 or 24 hours

Time Series Used: Time series used in this Operation are as follows:

General Type	Dimn	Units	Use	Required	Form of Output T.S.	Data Time Interval	Missing Values Allowed
Rain/melt	L	MM	I	yes	n/a	variable	no
Potential ET	L	MM	I	yes	n/a	24	no
Runoff	L	MM	O	yes	replaces	variable	no
Storm AI	L	MM	O	no	replaces	variable	no
Storm API	L	MM	O	no	replaces	variable	no
Storm AEI	L	MM	O	no	replaces	variable	no

Input Summary: The card input for this Operation is as follows:

Card	Format	Columns	Contents
1	2A4	1-8	Runoff zone identifier
	6X,5A4	15-34	Runoff zone name

Card	Format	Columns	Contents
	5X,I4	40-43	Runoff zone number; not used by Operation - for external use only; range is 0 through 1000
	6X,F5.2	50-54	Latitude (units of decimal degrees) of the centroid of the runoff zone; not used by Operation - for external use only; range is 36.00 through 43.50
	5X,F5.2	60-64	Longitude (units of decimal degrees) of the centroid of the runoff zone; not used by Operation - for external use only; range is 73.50 through 83.50
2	F5.2	1-5	AEI value for season quadrant wet curve (units of IN); range is 0.00 through 6.00
	F5.2	6-10	AI intercept for season quadrant wet curve (units of IN); range is 0.00 through 5.00
	F5.2	11-15	Curvature of season quadrant wet curve; range is 0.01 through 0.99
	F5.2	16-20	AEI value for season quadrant dry curve (units of IN); range is 0.00 through 12.00
	F5.2	21-25	AI intercept for season quadrant dry curve (units of IN); range is 0.00 through 10.00
	F5.2	26-30	Curvature of season quadrant dry curve; range is 0.01 through 0.99
3	F5.2	1- 5	Precipitation quadrant parameter PA; range is 0.01 through 5.00
	F5.2	6-10	Precipitation quadrant parameter PB; range is 0.01 through 5.00
	F5.2	11-15	Precipitation quadrant parameter PC; range is 0.01 through 5.00
	F5.2	16-20	Precipitation quadrant parameter PD; range is 0.01 through 5.00
	F5.2	21-25	Precipitation quadrant parameter PE; currently is always 1.00
4	F5.2	1- 5	Potential Evapotranspiration adjustment factor; range is 0.50 through 2.00

Card	Format	Columns	Contents
	F5.2	6-10	Maximum quantity of rain/melt allowed within the new storm window in order for a new storm to begin (units of IN); range is 0.00 through 1.00
	F5.2	11-15	24 hour API recession coefficient; range is 0.80 through 0.99
	I5	16-20	Data time interval of rain/melt and runoff time series (IDELTA) and of the AI, API and AEI time series if requested (units of HR); range is 1 through 24
	I5	21-25	New storm window (units of HR); range is 1 through 24 but must be an integer multiple of the basic data time interval (IDELTA)
	I5	26-30	Indicator if to save AI, API and AEI time series: 0 = no - do not save 1 = yes - save
	I5	31-35	Indicator if to read initial carryover values: 0 = no - use defaults 1 = yes - read input
5	2A4	1- 8	Internal identifier of rain/melt time series
	3X,A4	12-15	Data type code of rain/melt time series
	4X,2A4	20-27	Internal identifier of potential evapotranspiration time series
	3X,A4	31-34	Data type code of potential evapotranspiration time series
	5X,2A4	40-47	Internal identifier of runoff time series
	3X,A4	51-54	Data type code of runoff time series

Card 6 is needed if AI, API and AEI time series are to be generated. The API/AEI/AI time series output indicator (columns 26-30 of card 4) must contain a positive non-zero value if card 6 is to be read.

6	2A4	1-8	Internal identifier of AI time series
	3X,A4	12-15	Data type code of AI time series
	4X,2A4	20-27	Internal identifier of API time series

Card	Format	Columns	Contents
	3X,A4	31-34	Data type code of API time series
	5X,2A4	40-47	Internal identifier of AEI time series
	3X,A4	51-54	Data type code of AEI time series

Cards 7 and 8 are needed if actual carryover values are to be input. The input carryover indicator (columns 31-35 of card 4) must contain a positive non-zero value if these cards are to be read. If any values are entered all must be entered. If initial carryover values are not read default values are used. Defaults are 1.00 for 12Z API and Storm API, 5.00 for 12Z AEI and Storm AEI, 2.60 for 12Z AI and Storm AI and 0.00 for all other variables.

7	F5.2	1- 5	12Z API (units of IN); range is 0.00 through 15.00
	F5.2	6-10	12Z AEI (units of IN); range is 1.00 through 11.00
	F5.2	11-15	12Z AI (units of IN); range is 0.00 through 8.00
	F5.2	16-20	12Z storm API (units of IN); range is 0.00 through 15.00
	F5.2	21-25	12Z storm AEI (units of IN); range is 1.00 through 11.00
	F5.2	26-30	12Z storm AI (units of IN); range is 0.00 through 8.00
	F5.2	31-35	Rain/melt in current storm (units of IN); range is 0.00 through 60.00
	F5.2	36-40	Runoff in current storm (units of IN); range is 0.00 through 60.00
	F5.2	41-45	24 hour rain/melt ending at 12Z (units of IN)
	F5.2	46-50	24 hour runoff ending at 12Z (units of IN)
8	12F5.2	1-60	Rain/melt for each period in the new storm window (units of IN); number of values needed is equal to the new storm window divided by the basic data time interval (IDELTA); if more than 12 values are needed repeat card 8

Sample Input and Output: Sample input is shown in Figure 1. Sample

output from the parameter print routine is shown in Figure 2. There is no execution routine output.

Error and Warning Messages: The error and warning messages generated by this Operation and the corrective action to take when they occur are as follows:

1. ** ERROR **
INVALID SEASON QUADRANT COEFFICIENT(S).
AT LEAST ONE OF THE FOLLOWING VALUES IS OUT OF RANGE:

COEFFICIENT	RANGE	VALUE ENTERED
AEIWET	0.00 - 6.00	XX.XX
BWET	0.00 - 5.00	XX.XX
CWET	0.00 - 0.99	XX.XX
AEIDRY	0.00 - 12.00	XX.XX
BDRY	0.00 - 10.00	XX.XX
CDRY	0.00 - 0.99	XX.XX

Action: Determine which coefficient is bad and reenter. More than one value may be wrong.

2. ** ERROR **
INVALID PRECIPITATION QUADRANT COEFFICIENT(S).
AT LEAST ONE OF THE FOLLOWING VALUES IS OUT OF RANGE:

COEFFICIENT	RANGE	VALUE ENTERED
PA	0.01 - 5.00	XX.XX
PB	0.01 - 5.00	XX.XX
PC	0.01 - 5.00	XX.XX
PD	0.01 - 5.00	XX.XX
PE	1.00	XX.XX

Action: Determine which coefficient is bad and reenter. More than one value may be wrong.

3. ** ERROR ** INVALID EVAPOTRANSPIRATION ADJUSTMENT FACTOR : XX.XX
PROGRAMMED RANGE IS 0.50 TO 2.00.

Action: Change the Potential Evapotranspiration Adjustment factor on card 4.

4. ** ERROR ** INVALID STORM BREAK THRESHOLD VALUE : XX.XX
PROGRAMMED RANGE IS 0.00 TO 1.00.

Action: Change the Storm Break Threshold value on card 4.

5. ** ERROR ** INVALID 24-HOUR API RECESSION COEFFICIENT : XX.XX
PROGRAMMED RANGE IS 0.80 TO 0.99.

Action: Change the API Recession Coefficient on card 4.

6. ** ERROR ** INVALID COMPUTATIONAL TIME STEP INTERVAL (IDELTA) : XXIX
PERMITTED VALUES : 1, 2, 3, 4, 6, 8, 12 or 24 HOURS.

Action: Change IDELTA on card 4.

7. ** ERROR ** THE NUMBER OF HOURS USED TO DEFINE THE NEW STORM WINDOW IS NOT A POSITIVE, NON-ZERO INTEGER MULTIPLE OF THE COMPUTATIONAL TIME STEP INTERVAL (IDELTA). THIS MEANS THAT THE TIME INTERVAL OVER WHICH THE API - HAR2 OPERATION CHECKS FOR A STORM BREAK MAY NOT BE WHAT IS ACTUALLY DESIRED. THE RESPECTIVE VALUES OF THESE VARIABLES JUST READ IN ARE XXIX AND XXIX.

Action: Adjust the new storm window and/or the computational time step interval on card 4.

8. ** ERROR ** THE NUMBER OF PERIODS CALCULATED FROM THE SPECIFIED NEW STORM WINDOW IS LESS THAN 1 : XXX.XX
PROGRAMMED RANGE IS 1 THROUGH 24.

Action: Change the time step interval and/or the new storm window on card 4.

9. ** ERROR ** THE NUMBER OF PERIODS CALCULATED FROM THE SPECIFIED NEW STORM WINDOW IS GREATER THAN 24 : XXX.XX
PROGRAMMED RANGE IS 1 THROUGH 24.

Action: Change the time step interval and/or the new storm window on card 4.

10. ** ERROR ** INVALID 12Z API CARRYOVER VALUE : XXX.XX
PROGRAMMED RANGE IS 0.00 THROUGH 15.00 INCHES.

Action: Change the 12Z API value on card 7.

11. ** ERROR ** INVALID 12Z AEI CARRYOVER VALUE : XXX.XX
PROGRAMMED RANGE IS 1.00 THROUGH 11.00 INCHES.

Action: Correct the 12Z AEI value on card 7.

12. ** ERROR ** INVALID 12Z AI CARRYOVER VALUE : XXX.XX
PROGRAMMED RANGE IS 0.00 THROUGH 8.00 INCHES.

Action: Correct the 12Z AI value on card 7.

13. ** ERROR ** INVALID 12Z STORM API CARRYOVER VALUE : XXX.XX
PROGRAMMED RANGE IS 0.00 THROUGH 15.00 INCHES.

Action: Correct the 12Z Storm API value on card 7.

14. ** ERROR ** INVALID 12Z STORM AEI CARRYOVER VALUE : XXX.XX
PROGRAMMED RANGE IS 1.00 THROUGH 11.00 INCHES.

Action: Change the 12Z Storm AEI value on card 7.

15. ** ERROR ** INVALID 12Z STORM AI CARRYOVER VALUE : XXX.XX
PROGRAMMED RANGE IS 0.00 THROUGH 8.00 INCHES.

Action: Correct the 12Z Storm AI value on card 7.

16. ** ERROR ** INVALID STORM RAIN/MELT CARRYOVER VALUE : XXX.XX
PROGRAMMED RANGE IS 0.00 THROUGH 60.00 INCHES.

Action: Correct the Storm Rain/Melt value on card 7.

17. ** ERROR ** INVALID STORM RUNOFF CARRYOVER VALUE : XXX.XX
PROGRAMMED RANGE IS 0.00 THROUGH 60.00 INCHES.

Action: Change the Storm Runoff Carryover value on card 7.

18. ** ERROR ** INVALID RAIN/MELT TOTAL IN THE NEW STORM WINDOW :
XXX.XX
PROGRAMMED RANGE IS 0.00 THROUGH 60.00 INCHES.

Action: Change the Rain/Melt total on card 7.

Carryover Transfer Rules: The following rules are used during the carryover transfer process for this Operation:

1. Checks are made to see if the computational time step interval and the new storm window have been changed:

   a. If the computational time step interval has changed, all rain/melt values in the new storm window are set to zero, regardless of what may have happened to the size of the new storm window.

   b. If the new storm window has increased (while the computational time step interval has remained constant), the existing rain/melt values within the new storm window are padded with zeros.

   c. If the new storm window has decreased (while the computational time step interval has remained constant), the extraneous rain/melt values within the new storm window are set to zero.

   If changes have been made to either the computational time step interval or the new storm window the Operation should be executed for as far back in time as possible to update the carryover.

2. No validity checks or alterations are made to any of the other values during the carryover transfer process.

Punched Card Limitations: The punched card rules for this Operation are as follows:

1. The format of punched cards is identical to those described in

the Input Card Summary of this documentation.

2. No checks are made for the validity of the parametric or carryover data during the punching process.

3. Carryover values may be defaulted if desired. In this case, cards 7 and 8 will not be punched for a given runoff zone. The input carryover indicator (columns 31-35 of card 4) will correspondingly be punched with a zero value.

Figure 1. Sample card input for Operation API-HAR2

```
                                    - Column -
    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80
----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+
API-HAR2    WIBSE
WIBSE          BLUERIDGE-WILIAMSBRG       46      39.80     78.40
  3.0  1.5  .50  8.5  4.0  .70
  0.9 1.50  1.5  .80  1.0
  .90  .10  0.9    6   12    0    1
WIBSE      RAIM    PWA         MAPE     WIBSE      INFW
 1.00 4.50 0.75 0.00 1.00 0.00 0.00 0.00 0.00 0.00
  0.0  0.0
```

Figure 2. Sample output from Operation API-HAR2 print parameter routine

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 ********************

 API-HAR2 OPERATION     NAME=WIBSE        PREVIOUS NAME=

 ********************

         OPERATION VERSION :     1

          RUNOFF            RUNOFF            RUNOFF     CENTROID LAT   CENTROID LONG
          ZONE ID           ZONE NAME        ZONE NUMBER    (DEG DEC)      (DEG DEC)
         WIBSE       BLUERIDGE-WILIAMSBRG         46          39.80          78.40

         SEASON QUADRANT COEFFICIENTS :
          AEIWET    BWET    CWET    AEIDRY    BDRY    CDRY
            3.00    1.50    0.50      8.50    4.00    0.70

         PRECIPITATION QUADRANT COEFFICIENTS :
            PA      PB      PC      PD      PE
           0.90    1.50    1.50    0.80    1.00

         OTHER VARIABLES NEEDED BY THIS OPERATION :
          POTENTIAL ET ADJUSTMENT FACTOR   :   0.90
          STORM BREAK PRECIP THRESHOLD     :   0.10
          24-HR API RECESSION COEFFICIENT  :   0.90
          COMPUTATIONAL TIME STEP INTERVAL :     6
          NEW STORM WINDOW (HOURS)         :    12
          NEW STORM WINDOW (PERIODS)       :     2

         TIME SERIES USED BY THIS OPERATION :
               CONTENTS          TS I.D.        TYPE        TIME INTERVAL
             RAIN/MELT          WIBSE           RAIM           6 HOURS
             POTENTIAL ET       PWA             MAPE          24 HOURS
             RUNOFF             WIBSE           INFW           6 HOURS

         CARRYOVER VALUES FOR THIS OPERATION :

                                          STORM   STORM   STORM
          12Z API    12Z AEI    12Z AI      API     AEI      AI
            1.00       4.50       0.75      0.00    1.00    0.00

            STORM      STORM       24-HR      24-HR
          RAIN/MELT    RUNOFF    RAIN/MELT    RUNOFF
             0.00       0.00        0.00       0.00

          RAIN/MELT FOR EACH PERIOD WITHIN THE NEW STORM WINDOW (OLDEST PERIOD IS FIRST) :
           0.00    0.00
```