NOAA Technical Memorandum NWS WR-210

HYDROTOOLS

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ESSA Technical Memoranda (WRTM)

2 Climatological Precipitation Probabilities. Compiled by Lucianne Miller, December 1965.
3 Western Region Pre- and Post-FP-3 Program, December 1, 1965, to February 20, 1966. Edward D. Diemer, March 1966.
5 Station Descriptions of Local Effects on Synoptic Weather Patterns. Philip Williams, Jr., April 1966 (Revised November 1967, October 1969). (PB-17800)
8 Interpreting the RAREP. Herbert P. Benner, May 1966 (Revised January 1967).
11 Some Electrical Processes in the Atmosphere. J. Latham, June 1966.
17 A Digitalized Summary of Radar Echoes within 100 Miles of Sacramento, California. J. A. Youngberg and L. B. Overaas, December 1966.
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HYDROTOOLS

I. INTRODUCTION

The Service Hydrologist is called upon to answer a variety of hydrologic questions. HydroTools was developed to take advantage of the quick computing and "what-if?" capabilities of a spreadsheet to answer those questions. Though HydroTools was developed for the QUATTRO spreadsheet environment, it will run under 1-2-3 as well.

The Table of Contents lists various sheets. Instead of presenting the material in the form of chapters or topics, sheets were chosen because HydroTools is one large spreadsheet that runs several small sheets. Integrating all the small spreadsheets into a single large spreadsheet puts a great deal of computing power instantly at your fingertips.

The future of the NWS will bring the hydrologist and meteorologist professions closer together. The hydro toolkit is a device designed to help foster the merger. These sheets are not expected to replace the powerful modelling tools found at a typical RFC. Answers in these sheets are to be interpreted as estimates only. Probably the biggest benefit obtained in using these sheets will be the development of a better understanding of hydrology. For instance, do you know how long it would take to float river x for 10 miles? Sheet 1.1 can give you a rough idea. How about building a dam from a mud slide or ice jam; got any idea on the size and capacity of the resulting pool? HydroTools will likely stimulate many questions. A greater interest in and appreciation for hydrology should probably result.

On a personal note, this programmer was delighted with the speed and flexibility of programming in QUATTRO. The entire spreadsheet could have been written in a high level programming language like C, Basic, or FORTRAN, but experience shows the same results would have taken 10 to 20 times as long. Now that I have become heavily involved in spreadsheeting and really enjoy it, I, for one, will find it very difficult to write long computer codes to accomplish tasks that can be done so quickly and with so much fun. I am sold on spreadsheets!

Most of the formula used in the sheets were taken from Linsley/Kohler/Paulhus HYDROLOGY FOR ENGINEERS. The author welcomes comments and suggestions.

II. ENVIRONMENT, SETUP, AND RUNNING HYTOOLS

HydroTools is driven by QUATTRO or 1-2-3 on an IBM compatible machine running DOS 2.1 or higher. Needs: 512K of RAM, one floppy drive and a hard drive, a monochrome or color monitor. Although it is possible to setup Quattro or 1-2-3 on a dual floppy system with no hard drive, operation of the program is seriously degraded. No instructions are provided for non-hard drive users.

The distribution floppy should contain the following files:

HYTOOLS.WKQ - the QUATTRO spreadsheet version
HYTOOLS.WK1 - the 1-2-3 spreadsheet version
HYTOOLS.BAT - the QUATTRO/HYTOOLS start-up batch file
HYTOOLS.DOC - the HydroTools User's Guide

For QUATTRO Users:
Setup is easy. Copy HYTOOLS.WKQ and HYTOOLS.BAT to your Quattro directory. If /QUAT is the Quattro directory, then follow this example:

Put the HYTOOLS floppy in the A: drive.
From the A: prompt,

COPY HYTOOLS.WKQ C:\QUAT
COPY HYTOOLS.BAT C:\QUAT

While in the \QUAT directory, type HYTOOLS. In a moment the HydroTools spreadsheet will appear on the screen. To set up the screen defaults for color or monochrome, activate one of the following macros:

ALT X - monochrome
ALT Y - color

Unless you run the spreadsheet on a different monitor, the ALT-X or ALT-Y macros will not have to be run again. Proceed to the "How to Use HydroTools" section.

For 1-2-3 Users:
Copy HYTOOLS.WK1 to your 1-2-3 data directory. Bring up the 1-2-3 program, then select HYTOOLS.WK1 from the filer menu. In a few moments the spreadsheet will be on line. No provisions have been made to alter screen defaults using 1-2-3. Check your 1-2-3 User Manual for further details. Proceed to the "How to Use HydroTools" section.

How To Use HydroTools

```
                                                            ver. 3.7
                         HydroTools:
          Spreadsheet solutions to several hydrologic problems.

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         Sheet 1-2.....River Travel Time
         Sheet 2.......Synthetic Unit Hydrograph (Snyder Model)
         Sheet 3.......Discharge, Given: area, precip., time
         Sheet 4.......Equiv. Rainfall, Given: area, discharge, time
         Sheet 5-2.....Evaporation (Penman)
         Sheet 6.......Streamflow (Chezy-Manning)
         Sheet 7.......Reservoir Fill/Empty times
         Sheet 8.......Max Breach Outflow (Dam Break)
         Sheet 9.......Make a Dam (ice jam - earth slide)
         Sheet 10-2....Per Capita Water Consumption

         >input cell<                      <output cell>

   Home key for menu page...Page Up/Page Down keys to proper page (sheet).
   Arrow keys move to input cells.  Do not use delete key in output cells.
```

If the above menu page is not what you now see, then hit the Home key on the number pad (make sure the Num Lock is not engaged). Anytime you get lost in the spreadsheet, just hit the Home key to return to the home page. On the home page you will find a list of sheets available in the tool kit, instructions on how to use the cursor keys, and reminder of input vs. output cell appearance.

Try moving the cursor with the cursor arrows. Notice the highlighted block moving around the screen. Notice a few sheets have a different numbering scheme: 1-2, 5-2.... Those sheets have side-pages as well. To get to a side-page just hold down Ctrl and the right arrow key on the number pad; to return: Ctrl left arrow. For now, let's just get used to moving around the sheets vertically.

Depress the Home key, then the Pg Dn key to page 1. Page down several times. Each page is a different sheet. Let's return to sheet 1 and begin doing some hydrology. Depress the Home key, then touch Pg Dn once.

A spreadsheet is interactive. You provide the data; the sheet does the computing. The only areas on the screen that can be changed or overwritten are the highlighted input cells enclosed in > < arrows. Move the cursor to the first input block on sheet 1.1. Turn to the Sheet 1 section of this manual.

To **EXIT** at any time: enter the following keystrokes **/QY**.

SHEET 1.1 RIVER TRAVEL TIME (flow is known)

```
Sheet 1.1 -----------------------------------------------------------------
   RIVER TRAVEL TIME (Pollution travel estimates, Given: Q, Ad, Aw)

            Q=AV THEREFORE V=Q/A    WHERE V=VELOCITY MILE/HR
                                          Q=CUBIC FEET/SEC
   INPUT:
            Q    =>      1200 <= cfs         A=AREA IN SQ. FT.
            Ad   =>         3 <= ft          Ad= average depth
            Aw   =>       200 <= ft          Aw= average width

                   distance =>          4 <= miles  |         6 <= hours
   OUTPUT:                                          |
                                   ARRIVAL          |  DISTANCE
   PCT ABOVE         VELOCITY        TIME           |  TRAVELLED
      FLOOR            MI/HR        HOURS           |    MILES
       100         <    1.30          3.1           |      7.8 >
        66         <    1.36          2.9           |      8.2 >
        50         <    0.82          4.9           |      4.9 >
        25         <    0.27         14.7           |      1.6 >
        00         <    0.07         58.7           |      0.4 >
```

PURPOSE:

To compute the amount of time to travel (float) a given stretch of river. Whether a chemical spill or someone that just wants to ride the river, knowing an estimate of the travel time is expected of a hydrologist. Your office may have thorough tables based on empirical studies. If it does not, Sheet 1.1 and 1.2 will provide useful estimates.

FORMULA USED:

$Q = AV$ therefore $V=Q/A$

where

Q is flow in cfs
V is velocity
A is area cross section

The cross section A was broken down into a rectangle with depth Ad and width Aw. A trapezoid would have been more accurate, an ellipse even more. But they would not have been fun! The flow can usually be obtained or estimated from a nearby gauge. The average depth and width can usually be supplied by an observer where the spill occurred.

APPLICATION:

Move the cursor to the Q input block Q => <= cfs. Using the number keys at the top of your keyboard (not the number pad keys), enter a flow in cfs, say 1350 cfs. Instantly the speed, arrival time, and distance travelled is computed. Changing the other input blocks will naturally result in different output values as well. For example, move the cursor to the distance block and enter 12 miles. Instantly the computed values change. The same thing occurs when the hours block is changed. Now enter the following values and see if we agree with Quattro:

Q	=	1200 cfs
Ad	=	3 ft
Aw	=	200 ft

distance	=	4 miles
hours	=	6 hours

The computed velocity on the water surface is 1.30 mi/hr, the arrival time 4 miles downstream is 3.1 hours, and the distance travelled for 6 hours is 7.8 miles. Notice the other values for different levels above the stream floor. In particular, note the fastest water is below the surface at the .66 percent level above the floor. The slowest speed, of course, is along the bottom at
the 0.00 level. The table allows for vertical position only - not horizontal.

If no flow is available, then let the computer figure it - hold down the Ctrl key and the right arrow. Another spreadsheet! Sheet 1.2 - for computing travel times when the flow is not known.

SHEET 1.2 RIVER TRAVEL TIME (flow is computed)

```
Sheet 1.2 ---------------------------------------------------------------
RIVER TRAVEL TIME (Pollution travel estimates, Given: Ad, Aw, slope, n)
INPUT:
             n:>      0.050 <==       manning coef.
         Ad   =>          4 <= ft     Ad= average depth
         Aw   =>        150 <= ft     Aw= average width
         slope:>      0.001 <==       ft./ft.

                distance =>        1 <= miles       24 <= hours
OUTPUT:
         q=       <     1628 > cfs est.

                                ARRIVAL          DISTANCE
PCT ABOVE          VELOCITY       TIME           TRAVELLED
   FLOOR            MI/HR        HOURS             MILES
    100         <    1.76         0.6              42.2 >
     66         <    1.85         0.5              44.4 >
     50         <    1.11         0.9              26.6 >
     25         <    0.37         2.7               8.9 >
      0         <    0.09        10.8               2.2 >
```

PURPOSE:

Unlike Sheet 1.1, this sheet does not assume you know the flow in cfs. This version will compute the flow if the slope and Manning friction coefficient are known. An average Manning value would be .035; see Sheet 6 for further details on the Manning number. The slope of the stream can be derived from a good quad map.

FORMULA USED:

V=Q/A

where

Q is flow in cfs
V is velocity
A is area cross section

and

Q= (1.49/n)*(AR^2/3)*(S^1/2)

where

n is the Manning Coef.
A is the cross sectional area
R is the hydraulic radius
S is the slope of the river

Note: the ^ convention means "to the power of".

APPLICATION:

Move the cursor to the INPUT box that you would like to change. Enter an appropriate value. Watch the OUTPUT values change instantly. Try a high friction value, then a low one. Observe the changes velocity, arrival times, and distances travelled.

Suppose you get a call that a chemical spill has occurred on the Windy River at City X. State officials would like some estimates of when the pollutants would arrive at City Y, 25 miles downstream. They would also like to know how far down river the pollutants would be in 48 hours.

enter:

.035	Manning
4	Ad - average depth
200	Aw - average width
7/5280	slope (7 feet per mile)
25	distance in miles
48	hours elapsed time

Notice the slope was entered "as is" 7/5280 - let the computer compute .0013. The tabled values below will give you some rough estimates of the velocity, travel time, and distance travelled. Remember to advise the officials these values are <u>rough</u> estimates based on <u>average</u> values.

To move to any other sheet, hit the Home key first, then Pg Dn to the appropriate sheet.

SHEET 2 SYNTHETIC UNIT HYDROGRAPH

```
Sheet 2 ----------------------------------------------------------------
SYNTHETIC UNIT HYDROGRAPH - SNYDER MODEL

INPUT:
                                          Basin:>       Cottonwood
                               Size (sq.miles):>               20 < sq mile
         Length of stream from outlet to divide:>              10 < miles
Length of main stream fm outlet to centroid:>                  4 < miles
          Slope & Storage ->  Ct (1.8 <> 2.2):>             2.00 <
     Flood Wave & Storage -> Cp (.56 <>.69):>               0.63 <
                                     Unit Time:>               3 < hours
                                 Unit Rainfall:>               2 < inches

OUTPUT:

 Lag-to-Peak of Unitgraph:<          6.5 > hours          tpR
           Peak discharge:<        122.6 > cfs/sq mi      qpR
 Peak discharge at outlet:<       2452.6 > cfs            QpR
```

PURPOSE:

To provide rough estimates of peak flow in cfs and the time to the peak flow, given basin geometry, time, and rainfall.

FORMULA:

Snyder's model was chosen:

tp = Ct(LLc)^.3
qp = CpA/tp

where

tp = lag time to peak discharge (lag is most frequently defined as time from the centroid of rainfall to the hydrograph peak)
Ct = coefficient varying from 1.8 to 2.2 that compensates for slope and storage (steeper slopes get lower values)
L = length of main stream from outlet to divide
Lc = stream distance from outlet to a point opposite the basin centroid (center of area)
qp = peak flow
Cp = coefficient varying from .56 to .69 - handles flood wave and storage factors
A = area of basin in square miles

NOTE: Snyder's methods are the results of extensive studies in the Appalachian Mountain region. The formulas have been tried elsewhere with mixed success.

APPLICATION:

You know a little about the basins in your service area - the length, width, and size of the basins. Suppose 3 inches of rain fell in 2 hours over the Basin X. Using Snyder's technique, give an estimate of the peak flow and time to peak discharge for the basin.

given:

basin size	=	20 sq. miles
length of stream	=	10 miles
center of basin	=	4 miles
average slope & storage	=	2.0
average flood wave & storage	=	.63
unit time	=	2 hours
unit rainfall	=	3 inches

the computed answers:

lag-to-peak of unitgraph	=	6.5 hours
peak discharge at outlet	=	2452.6 cfs

Adjusting the input one way or the other will help to build a better understanding of unitgraphs and runoff vs. rainfall.

SHEET 3 DISCHARGE: Given area, runoff (inches) and time (days)

```
Sheet 3 ---------------------------------------------------------------------

DISCHARGE: Given area, rainfall (inches) and time (days).

INPUT AREA SQ. MI.     ===>              454 < SQ. MI.
INPUT PRECIP. INCHES   ===>               35 < INCHES
INPUT TIME IN DAYS     ===>              365 < DAYS

OUTPUT:        Q (flow)    <           1,171 > CFS
OUTPUT:        volume      < 36,915,648,000 > TOTAL CF
OUTPUT:        volume      <         847,414 > ACRE FEET

DISCHARGE: Given area, rainfall (inches) and time (hours).

INPUT AREA SQ. MI.     ===>              454 < SQ. MI.
INPUT PRECIP. INCHES   ===>                1 < INCHES
INPUT TIME IN HOURS    ===>                5 < HOURS

OUTPUT:        Q (flow)    <          58,596 > CFS
OUTPUT:        volume      <  1,054,732,255 > TOTAL CF
OUTPUT:        volume      <          24,212 > ACRE FEET
```

PURPOSE:

How much flow and what volume of water results from a given rainfall in inches? Remember: rainfall and runoff are two different quantities. In some areas, very little runoff results from a given rainfall.

FORMULA:

$$Q = (Di*5280^2*A)/(86400*Td*12)$$

and

$$Q = (A*Di*645.4)/Th$$

where

Q = flow in cfs
Di = inches of rainfall
A = area in sq. miles
Td = time in days
Th = time in hours

APPLICATION:

During the past three days, 5 inches of rain has fallen over the Payette Basin (454 sq. miles).

Given the above information, answer the following questions:

1. What is the average discharge (flow) of the original 5 inches?
2. What volume in acre feet could end up in reservoirs, if all the rainfall was runoff?

enter:

454	= area of basin in sq. miles
5	= inches of rain
time	= 5 days

computed answers:

flow	12,208	= cfs (entire basin, not just in river)
volume		= cf
volume	121,059	= acre feet

Another What If?
Suppose half the basin had an average 3 inches of SWE (snow water equivalent) in snowpack. Very warm temperatures melted all the snow in 12 hours. What would be the most you could expect from a meltdown in local reservoirs (assume no evaporation or infiltration)?

Using the lower part of the sheet for time period hours,

enter:

454/2	= area of basin in sq. miles
3	= inches of snowmelt
12	= hours

computed answers:

flow	36,623	= cfs
volume	xxx	= cf
volume	36,318	= acre feet

SHEET 4 EQUIVALENT RAINFALL

```
Sheet 4 ---------------------------------------------------------------
EQUIVALENT RAINFALL: Given area, discharge (cfs), and time (days).

INPUT AREA SQ. MI.      ===>              454 < SQ. MI.
INPUT DISCHARGE CFS     ===>              183 < CFS
INPUT TIME IN DAYS      ===>                2 < DAYS

OUTPUT:            Di    <               0.03 > EQUIV RAINFALL IN INCHES
                         <         31,622,400 > TOTAL CUBIC FEET
                         <                726 > ACRE FEET

EQUIVALENT RAINFALL: Given area, discharge (cfs), and time (hours).

INPUT AREA SQ. MI.      ===>               20 < SQ. MI.
INPUT DISCHARGE CFS     ===>              163 < CFS
INPUT TIME IN HOURS     ===>               48 < HOURS

OUTPUT:            Di   <                0.61 > EQUIV RAINFALL IN INCHES
                        <          28,166,400 > TOTAL CUBIC FEET
                        <                 647 > ACRE FEET
```

PURPOSE:

To give an estimate of the equivalent rainfall from a given flow.

FORMULAS:

Di = (84400*Td*Q*12)/(A*5280^2)

where

Di = equiv. rainfall (discharge) in inches
Td = time in days
Q = flow in cfs
A = area of basin in sq. miles

and

Di = (86400*Th/24)*(Q*12)/(A*5280^2)

where

Th = time in hours

Note: for easier comprehension, the formulas have not been reduced.

APPLICATION:

Runoff from recent rains caused an average increase in flow of 200 cfs in the Payette River for 15 days. What is the equivalent rainfall for a 500 sq. mile basin? Remember, unless the ground was impervious and there was zero evaporation, we are really estimating <u>runoff</u> in inches.

enter:

500	=	area of basin in sq. miles
200	=	discharge in cfs
15	=	days

computed answers:

0.22	=	inches
259,200,000	=	total cubic feet
5,950	=	total acre feet

Ah, but the actual rainfall was 5 inches not 0.22 inches. Does that say something about antecedent soil conditions?

The same scenarios can be run on the bottom-half of Sheet 4 with a time period of hours.

SHEET 5.1 PENMAN EVAPORATION FORMULA

```
Sheet 5.1 ----------------------------------------------------------
PENMAN EVAPORATION FORMULA (English units)

INPUT:
DAILY MAX TMP        Tx   =>            90 <=   deg F
DAILY MIN TMP        Tn   =>            70 <=   deg F
AVG DEW PT           Td   =>            45 <=   deg F
AVG WND SPD               =>             8 <=   mph
SOLAR RAD            Qs   =>           440 <=   cal/cm^2/day
DAYS IN MONTH             =>            30 <=

OUTPUT:
AVG AIR TEMP         Ta   =>            80 >   deg F
WIND MILE            Vp   =>           192 >   est. miles per day

          PAN        Ep     <         0.38 > inches/day
          EVAP.             <        11.36 > inches/month

     SHALLOW LK      El     <         0.27 > inches/day
          EVAP.             <         7.95 > inches/month
```

PURPOSE:

Compute evaporation for Class A pans and shallow lakes.

FORMULA: (as in Linsley/Kohler/Paulhus)

$$E = (\text{delta}/(\text{delta}+\text{gamma}))Qn + (\text{gamma}/(\text{delta}+\text{gamma}))Ea$$

where

$$Ea = ((es-ea)^{.88})\,(.37+.0041vp)$$

where

$$Qn = (2.81\times10^{-4})Qs + (6.90\times10^{-8})Qs(Ta)^{1.87} + (1.55\times10^{-7})Qs^{2} - (3.14\times10^{-11})QS^{2}(Ta-45)^{2} - .040$$

$$(es-ea) = (.0041Ta + .676)^{8} - (.0041Td + .676)^{8} \quad Td >= 16°F$$

and

$$\text{delta} = (.00252Ta + .4149)^{7} \quad Ta >= -13°F$$
$$\text{gamma} = .011 \text{ in Hg}/°F$$

also

$$\text{delta}/(\text{delta}+\text{gamma}) = [1 + .011/(.00252Ta + .4149)^{7}]^{-1}$$
$$\text{gamma}/(\text{delta}+\text{gamma}) = 1 - \text{delta}/(\text{delta}+\text{gamma})$$

vp = wind movement miles per day
Td = dew point °F
Ta = air temp. °F
QS = daily solar radiation in cal./sq cm

I bet you are wondering how all these equations fit into the few input and output cells indicated on Sheet 5.1. Well, they didn't.

I used a little of the side page. Development of this sheet was not as involved as it may appear. Transplanting textbook formulas is not hard, if you are careful.

APPLICATION:

Gathering all the input parameters should be easy except for average solar radiation. The following table may help.

	ESTIMATED SOLAR RADIATION (cal/cm^2/day)						
Jun 22	300	430	525	500	450	400	325
Dec 22	390	220	110	20	0	0	0
	0	15	30	45	60	75	90
	Equator			Lat (°N)			North Pole

Suppose the following conditions existed on June 22:

enter:

90	=	max temp
52	=	min temp
45	=	average dew-point
8	=	average wind speed mph
500	=	solar radiation
30	=	days in June

the computed evaporations should be:

.34	=	pan evap. inches/day
10.18	=	pan evap. inches/month
.24	=	shallow lake evap. inches/day
7.13	=	shallow lake evap. inches/month

If you prefer to let the spreadsheet interpolate a value of solar radiation between dates, then use Spread 5.2 - the side page.

SHEET 5.2 ESTIMATING SOLAR RADIATION

```
Sheet 5.2 ----------------------------------------------------------------
Estimating solar radiation for a given latitude:

INPUT:   (use Ctrl D for date input)

         Rad. on 12/22    >        50 < cal/cm^2/day     (use table) r12
         Rad. on 06/22    >       500 < cal/cm^2/day     (use table) r6
         January 1        > 01/01/90 < (should be 01/01 of current year)
         Date to Compute  > 06/22/90 <

OUTPUT:

                  Julian  <       173 > day
                    SINE  <      1.00 >
    ESTIMATED SOLAR RAD   <       500 > cal/cm^2/day
```

PURPOSE:

Compute the Julian day, then estimate solar radiation.

FORMULA:

Julian day	= today's date - January 1 (in Quattro)
Sine	= used to interpolate solar radiation on days other than 12/22 & 6/22
	= ABS(@SIN(@RAD(360-(Julnday+9)/365)*360)/2))))
Solar Radiation	= SINE*(r6-r12)+r12

APPLICATION:

Find the ranges of solar radiation that apply to your latitude and enter for 12/22 and 06/22. If the January 1 date is not for this year, then change it to 1/1 of the current year (Ctrl D then 1/1). Using the Ctrl D entry mode for dates, enter the date to compute.

Example:

	50	rad on 12/22
	500	rad on 06/22
Ctrl D	1/1	January 1 this year
Ctrl D	3/15	Compute for this date

will compute the Julian day, sine of the day of the year, and estimated solar radiation for March 15.

SHEET 6 STREAMFLOW

```
Sheet 6 ------------------------------------------------------------------
STREAMFLOW:          Chezy-Manning Formula
                     q= (1.49/n)(AR^2/3 * S^1/2)

INPUT:                                        A= cross sec. area (sq ft)
                                              R= hydraulic radius (ft)
      n:>   0.035 <==                         S= energy slope   (ft/ft)
av dpth:>       1 <==
av wdth:>      50 <==                         n values:
  slope:>   0.014 <==                         .018 smooth earth
                                              .020 firm gravel
                                              .029 clean, strt, no pools, FS
OUTPUT:                                       .035 weeds, stones, FS
A=       <     50 > sq ft                     .039 winding, pools, clean, FS
R=       <  0.962 > ft                        .042 like .029 but LS
wet prm:<      52 > ft                        .052 like .035 but LS
                                              .112 very sluggish & weedy
q=       <    249 > cfs est.
                                              NOTE: error of .001 n = 3% q
```

PURPOSE:

Compute streamflow in cfs, given slope, Manning friction coefficient, average depth, and average width of a river.

FORMULA:

The Chezy-Manning Formula

q = (1.49/n)(AR^2/3)(S^1/2)

where

q = flow in cfs
n = Manning coefficient
A = cross sectional area
R = hydraulic radius
S = slope
wet prm = wetted perimeter
FS = full stage
LS = low stage

NOTES:

1. The wetted perimeter is that portion of the stream channel in contact with the water.
2. The hydraulic radius is the cross sectional area divide by the wetted perimeter.

APPLICATION:

Assuming a gauging station is not available and the flow of a stream or river is needed; estimates of the flow can be made from the above formula. Varying any of the input parameters will affect the flow. See how juggling the input affects the output.

You just passed an ungauged stream on a field trip. The stream appeared to have a normal amount of rocks and vegetation along the channel, average depth was 2 feet, average width 80 feet, and from a quad map the slope is 40 feet per mile. What is the flow?

enter:

.035	= n
2	= avg. depth
80	= avg. width
40/5280	= slope

At the bottom of the screen the answer appears instantly. Suppose the depth was in question. Enter a range of values from 1.5 to 2.5. Notice the changes. Remember, you never need a calculator with a spreadsheet; the slope is entered "as is" 40/5280. Let your spreadsheet compute the value.

SHEET 7 RESERVOIR LEVELS

```
Sheet 7 ---------------------------------------------------------------------------
RESERVOIR LEVELS:
INPUT:                                                          OUTPUT:
       Current Volume:>              210,000 < ac ft
             Capacity:>              280,000 < ac ft                75%> full
         inflow (cfs):>                    2 < cfs
        outflow (cfs):>                    0 < cfs
         project days:>                    0 < days
   reservoir sfc area:>                   25 < sq miles         16000 > acres
    daily evaporation:>                 0.20 < inches

OUTPUT:
        Daily increase:   <                4 > ac ft
       Daily out (ac ft): <                0 > ac ft
      Daily loss to evap: <              267 > ac ft
             Net change:  <             -263 > ac ft
                 Volume:  <          210,000 > ac ft in >        0 days

          days to empty:  <              799 > days
           days to fill:  <                  > days
```

PURPOSE:

Tedious arithmetic makes keeping track of our reservoir levels a cumbersome task. Sheet 7 turns the process into fun. This sheet will project a fill or empty time based on inflow/outflow or evaporation as a function of surface area. Use your results from Sheet 5 for the shallow lake evaporation rate.

FORMULA:

daily increase/decrease	= current volume * days * net change (in acre feet)
daily loss to evap.	= daily evap. * sfc area (convert volume to acre ft)

APPLICATION:

White Peak Reservoir holds 280,000 acre feet of water and has a surface area of 25 sq. miles. It's current volume is 210,000 acre feet. With 1230 cfs coming in and 1812 cfs going out. What will be the volume in 15 days? How long will it take to empty?

Suppose nothing was going in or out. How long will take to evaporate the reservoir with a daily evap. rate of .25 inches?

Would it be better, with respect to evaporation, to have a deeper reservoir or a shallower one? Juggle the surface area and find out.

If the basin was 800 sq. miles, how many inches of runoff would you need to fill White Peak Reservoir? Use Sheet 3 to determine the answer.

SHEET 8 MAX BREACH OUTFLOW (DAM BREAK)

```
Sheet 8 -----------------------------------------------------------------------
MAX BREACH OUTFLOW DISCHARGE:

GIVEN:
                 Qbmax=Qo+Br(C/(tf/60)+(C/h^2))^3
       where
                 C=23.4As/Br

INPUT:
Reservoir surface area      >            3 <  As   acres
Dpth max pool abv brch      >            5 <  h    feet
Avg final breach width      >           60 <  Br   feet
Time of Failure             >           15 <  tf   minutes
Added flow spill/turbine    >          150 <  Qo   cfs

OUTPUT:

                     Qbmax  <          794 >  cfs
```

PURPOSE:

A dam break, however remote, is always a possibility. Most large dams have Emergency Action Plans, so there is no need for max flow estimates. However, there are many dams that have no studies for max flow. Also, what about all the potential dams resulting from an earth slide or ice jam. Do you have a feel for the max flow that would result from a breach? Sheet 8 will give you estimates.

FORMULA:

The Broad-Crested Weir Equation:

Qbmax = Qo + Br(C/(tf/60)+(C/h^2))^3

where

C = 23.4AS/Br

APPLICATION:

The person reporting a dam failure usually has the vital statistics of the dam that you need to run the model. Probably the toughest statistic to get would be the surface area. See Sheet 9 Make-a-Dam for surface area estimates.

Example:

A small power dam along the Boise River is getting ready to fail. Failure time is estimated on the scale of weeks. A site inspection revealed the following observations and possibilities:

surface area of pool behind dam = 5 acres	(obsvd.)
maximum depth of pool above breach = 10 feet	(1 possibility)
average final breach width = 60 feet	(1 possibility)
failure time = 15 minutes	(5 minutes to several hours)
added flow through spillway = 150 cfs	(given)

With the following list of inputs, a single estimated value will quickly appear in the output section of the sheet. Make a note of this input vs. out. Enter several other possibilities. It may never happen but at least you will have something.

SHEET 9 MAKE-A-DAM

```
Sheet 9 ------------------------------------------------------------------------
MAKE-A-DAM:  (determine volume of resulting wedge-shaped reservoir
               from ice jam or earthslide across river.)

INPUT:
                 height of dam: >              10 <= feet
                  width of dam: >            1200 <= feet
                slope of river: >          0.0114 <= ft/ft
                 flow into dam: >             450 < = cfs

OUTPUT:
                length of pool: <             880 > = feet
                length of pool: <            0.17 > = miles

                volume of pool: <       5,280,000 > = cu ft
                volume of pool: <             121 > = acre ft

                 pool sfc area: <              24 > = acres

                 full pool time:<            3.26 > = hours             .1 days
```

PURPOSE:

Rivers can be dammed-up from a variety of causes; mud slides, log jams, and ice jams, to name a few. This sheet was designed to answer several questions regarding the pool that forms behind the dam; its volume, surface area, and length. Answers to all those questions are vital to flood and flash flood planning.

FORMULA:

A wedge-shaped reservoir is the design pool.

length of pool = height * (1/slope)
volume of pool (wedge) = .5 * ht. * length * width
sfc area (acres) = length * width/43560

APPLICATION:

A mud slide has caused a 30 feet dam across the Payette River. The dam is 600 feet wide. Slope from a quad map is 50 feet/mile. Current flow is 450 cfs. Estimate the length of the pool, volume, surface area, and time to fill.

enter:

30	= height in feet
600	= width of dam
50/5280	= slope
450	= flow into dam

The answers could help you decide several things:

1. The area above the dam for a flood watch/warning.
2. Spill over and possible breach time.

SHEET 10.1 RUNOFF VS. PER CAPITA WATER CONSUMPTION

```
Sheet 10.1 ----------------------------------------------------------------
RUNOFF vs. PER CAPITA WATER CONSUMPTION:

INPUT:
                     annual runoff: >               1 < = inches
                        basin size: >            4000 < = sq. miles
       per capita water consumption: >            150 < = gal/person/day

OUTPUT:
 millions of gallons/basin/year: <              9,293 > = mil. gallons
             gallons/person/year: <             54,750 > = gallons
number of people basin supports: <            169,732 > = people
```

PURPOSE:

Determine the number of people a basin can support given runoff in inches and per capita consumption.

FORMULA:

millions of gal/basin/year = runoff inches * 2323200 * sq. miles / 10^6
gallons/person/year = per cap wtr consum. * 365
people basin supports = (mil. gals. / gal/pers/year) * 10^6

APPLICATION:

A new city is being planned in a dry region. Runoff is only 1 inch/year. If every drop in the 400 sq. mile basin went into home use, how many people could the basin support?

annual runoff = 1 inch
basin size = 400 sq miles
per capita water consum. = 150 gals./person/day

What if the community was conservative and only used 125 gallons/person/day?

SHEET 10.2 WHERE IS ALL MY WATER GOING?

```
Sheet 10.2 ------------------------------------------------------------------
WHERE IS ALL MY WATER GOING?
INPUT:                                                              CONSUMPTION
                   people in household: >       4 < = 5 or older
               no. weeks to water lawn: >       0 < = weeks
  water the lawn (nozzle wide open): >          0 < = hours/week             0
                                 baths: >       1 < = no./wk/person         20
                     3-minute showers: >        7 < = no./wk/person        560
                        toilet flushes: >       5 < = no./day/person       100
                        run dishwasher: >       1 < = no./day                5
                    wash dishes by hand: >      3 < = no. times/day         33
               no. large laundry loads: >       8 < = no./week              96
                              wash car: >       1 < = no./week            12.5
                            misc./day: >        0 < = gal/day                0
                          misc./month: >        0 < = gal/month              0
OUTPUT:
        Water consumption: <      236 > gal/day          no watering
                         : <    1,655 > gal/wk           no watering
                         : <    7,091 > gal/mon          no watering
                         : <   84,143 > gal/yr           no watering
                         : <   84,143 > gal/yr           no watering
```

PURPOSE:

Per capita water consumption described in 10.1 can be determined using a sheet similar to 10.2. The real purpose of "Where is all my water going?" was to give Quattro users a chance to experiment with spreadsheet development.

The answers above were based on a "typical" American home - the Egger house. Whenever you are brave enough, the basic values that go into each formula can be adjusted for your household.

FORMULA:

water the lawn	=>	600 gal * hours per week
bath	=>	20 gal * number * persons
3-minute showers	=>	5 gal * number * persons
toilet flushes	=>	5 gal * number * persons
dishwasher	=>	5 gal * number per day
hand dishwash	=>	11 gal * number per day
large laundry loads	=>	11 gal * number per week
car wash	=>	12.5 gal * number per week

The consumption numbers appearing along the right margin of the sheet are the results of the above formula. The total water consumption formulas at the bottom of the sheet are summations of the above with appropriate multipliers for the respective time period.

APPLICATION:

The purpose of this sheet was to get your feet wet with spreadsheeting (Quattro users only). Instead of entering numbers and watching the results, let's adjust the formula to fit your home. By the way, I noticed an error in one of the formulas. While we are at it, let's fix it. Before we begin editing the spreadsheet, turn on the column and row headers and turn protection off. To make this easy, I developed a macro - ALT E.

Turn off protection, turn on cell labels, and prepare to edit.

ALT E

Move the cursor to cell O206 (column O and row 206), you are going to fix my mistake, then we'll go into edit/fix mode with the F2 function key.

F2

Notice the formula in the upper right hand corner of the screen. It should appear as +L207*20. This means, take the contents of cell L207 and multiply it by 20. To put another way, multiply the number of baths per week per person times 20 gallons. The error was neglecting to multiply by the number of people in the family (L204). You are in the edit mode. Type this now *L204.

*L204

The upper right should now appear as +L207*20*L204. Hit enter.

Enter

The formula has changed; so should the answers. Any of the formulas can be adjusted by moving through the **locate, F2, edit, enter** steps.

The formulas mentioned earlier have constants in them. I invite you to adjust the constants to suit your home. When you are all done, return HYTOOLS to its original configuration.

ALT X for monochrome screens
or
ALT Y for color screens

Remember, to **EXIT** HYTOOLS at any time enter the following keys **/QY**.

142 The Usefulness of Data from Mountaintop Fire Lookout Stations in Determining Atmospheric Stability. Jonathan W. Corey, April 1979. (PB298899/AS)
143 The Depth of the Marine Layer at San Diego as Related to Subsequent Cool Season Precipitation Episodes in Arizona. Ira S. Brenner, May 1979. (PB298817/AS)
144 Arizona Cool Season Climatological Surface Wind and Pressure Gradient Study. Ira S. Brenner, May 1979. (PB298900/AS)
146 The BART Experiment. Morris S. Webb, October 1979. (PB80 155112)
147 Occurrence and Distribution of Flash Floods in the Western Region. Thomas L. Dietrich, December 1979. (PB80 160344)
149 Misinterpretations of Precipitation Probability Forecasts. Allan H. Murphy, Sarah Lichtenstein, Baruch Fischhoff, and Robert L. Winkler, February 1980. (PB80 174576)
150 Annual Data and Verification Tabulation - Eastern and Central North Pacific Tropical Storms and Hurricanes 1979. Emil B. Gunther and Staff, EPHC, April 1980. (PB80 220486)
151 NMC Model Performance in the Northeast Pacific. James E. Overland, PMEL-ERL, April 1980. (PB80 196033)
152 Climate of Salt Lake City, Utah. Wilbur E. Figgins (Retired) and Alexander R. Smith. Fourth Revision, March 1989. (PB89 180624/AS)
153 An Automatic Lightning Detection System in Northern California. James E. Rea and Chris E. Fontana, June 1980. (PB80 225592)
154 Regression Equation for the Peak Wind Gust 6 to 12 Hours in Advance at Great Falls During Strong Downslope Wind Storms. Michael J. Oard, July 1980. (PB91 108367)
155 A Raininess Index for the Arizona Monsoon. John H. Ten Harkel, July 1980. (PB81 106494)
156 The Effects of Terrain Distribution on Summer Thunderstorm Activity at Reno, Nevada. Christopher Dean Hill, July 1980. (PB81 102501)
157 An Operational Evaluation of the Scofield/Oliver Technique for Estimating Precipitation Rates from Satellite Imagery. Richard Ochoa, August 1980. (PB81 108227)
158 Hydrology Practicum. Thomas Dietrich, September 1980. (PB81 134033)
159 Tropical Cyclone Effects on California. Arnold Court, October 1980. (PB81 133779)
160 Eastern North Pacific Tropical Cyclone Occurrences During Intraseasonal Periods. Preston W. Leftwich and Gail M. Brown, February 1981. (PB81 205494)
161 Solar Radiation as a Sole Source of Energy for Photovoltaics in Las Vegas, Nevada, for July and December. Darryl Randerson, April 1981. (PB81 224503)
162 A Systems Approach to Real-Time Runoff Analysis with a Deterministic Rainfall-Runoff Model. Robert J.C. Burnash and R. Larry Ferral, April 1981. (PB81 224495)
163 A Comparison of Two Methods for Forecasting Thunderstorms at Luke Air Force Base, Arizona. LTC Keith R. Cooley, April 1981. (PB81 225393)
164 An Objective Aid for Forecasting Afternoon Relative Humidity Along the Washington Cascade East Slopes. Robert S. Robinson, April 1981. (PB81 23078)
165 Annual Data and Verification Tabulation, Eastern North Pacific Tropical Storms and Hurricanes 1980. Emil B. Gunther and Staff, May 1981. (PB82 230336)
166 Preliminary Estimates of Wind Power Potential at the Nevada Test Site. Howard G. Booth, June 1981. (PB82 127036)
167 ARAP User's Guide. Mark Mathewson, July 1981, Revised September 1981. (PB82 196783)
168 Forecasting the Onset of Coastal Gales Off Washington-Oregon. John R. Zimmerman and William D. Burton, August 1981. (PB82 127051)
169 A Statistical-Dynamical Model for Prediction of Tropical Cyclone Motion in the Eastern North Pacific Ocean. Preston W. Leftwich, Jr., October 1981. (PB82195298)
170 An Enhanced Plotter for Surface Airways Observations. Andrew J. Spry and Jeffrey L. Anderson, October 1981. (PB82 153883)
171 Verification of 72-Hour 500-MB Map-Type Predictions. R.F. Quiring, November 1981. (PB82 158098)

172 Forecasting Heavy Snow at Wenatchee, Washington. James W. Holcomb, December 1981. (PB82 177783)
173 Central San Joaquin Valley Type Maps. Thomas R. Crossan, December 1981. (PB82 196064)
174 ARAP Test Results. Mark A. Mathewson, December 1981. (PB82 198103)
176 Approximations to the Peak Surface Wind Gusts from Desert Thunderstorms. Darryl Randerson, June 1982. (PB82 253089)
177 Climate of Phoenix, Arizona. Robert J. Schmidli, April 1969 (Revised December 1986). (PB87 142063/AS)
178 Annual Data and Verification Tabulation, Eastern North Pacific Tropical Storms and Hurricanes 1982. E.B. Gunther, June 1983. (PB85 106078)
179 Stratified Maximum Temperature Relationships Between Sixteen Zone Stations in Arizona and Respective Key Stations. Ira S. Brenner, June 1983. (PB83 249904)
180 Standard Hydrologic Exchange Format (SHEF) Version I. Phillip A. Pasteries, Vernon C. Bissel, David G. Bennett, August 1983. (PB85 106052)
181 Quantitative and Special Distribution of Winter Precipitation along Utah's Wasatch Front. Lawrence B. Dunn, August 1983. (PB85 106912)
182 500 Millibar Sign Frequency Teleconnection Charts - Winter. Lawrence B. Dunn, December 1983. (PB85 106276)
183 500 Millibar Sign Frequency Teleconnection Charts - Spring. Lawrence B. Dunn, January 1984. (PB85 111367)
184 Collection and Use of Lightning Strike Data in the Western U.S. During Summer 1983. Glenn Rasch and Mark Mathewson, February 1984. (PB85 110534)
185 500 Millibar Sign Frequency Teleconnection Charts - Summer. Lawrence B. Dunn, March 1984. (PB85 111359)
186 Annual Data and Verification Tabulation eastern North Pacific Tropical Storms and Hurricanes 1983. E.B. Gunther, March 1984. (PB85 109635)
187 500 Millibar Sign Frequency Teleconnection Charts - Fall. Lawrence B. Dunn, May 1984. (PB85 110930)
188 The Use and Interpretation of Isentropic Analyses. Jeffrey L. Anderson, October 1984. (PB85 132694)
189 Annual Data & Verification Tabulation Eastern North Pacific Tropical Storms and Hurricanes 1984. E.B. Gunther and R.L. Cross, April 1985. (PB85 1878887AS)
190 Great Salt Lake Effect Snowfall: Some Notes and An Example. David M. Carpenter, October 1985. (PB86 119153/AS)
191 Large Scale Patterns Associated with Major Freeze Episodes in the Agricultural Southwest. Ronald S. Hamilton and Glenn R. Lussky, December 1985. (PB86 144474AS)
192 NWR Voice Synthesis Project: Phase I. Glen W. Sampson, January 1986. (PB86 145604/AS)
193 The MCC - An Overview and Case Study on Its Impact in the Western United States. Glenn R. Lussky, March 1986. (PB86 170651/AS)
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