Washington State Department of Ecology
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Updated procedures for Inflow Design Flood (IDF) computations for Dam Safety projects

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A new Precipitation Calculator has been developed to streamline the rainfall calculations for dam safety projects, also to be compatible with new computing technology.

Other than the new Calculator, design storm procedures are similar to the last Technical Note 3 revision in 2009.

The user will need to download two zip files from the DSO web site, one for the Calculator, and one for the storm hyetographs and other related spreadsheets.

In 2009, Dam Safety's Technical Note 3, ***Design Storm Construction***, was revised and updated in light of advances in computing technology and the storms in recent years that added to the catalog of extreme storms. Acknowledgement is made to Mel Schaefer and Bruce Barker of MGS Engineering for their work in updating Technical Note 3 in 2009, and especially to Bruce Barker for the look-up calculator that greatly simplified the precipitation computations.

A recent (2019) contract with Aspect Consulting and Bruce Barker of MGS Engineering developed this new Calculator to replace the previous look-up calculator spreadsheets to be more compatible with current computing technology. Precip calculations using the new Calculator are similar to calculations using the previous spreadsheets, with agreement to within 1 or 2 percent. Acknowledgement is made to Chris Bellusci and Mike Mills of Aspect Consulting for their work in developing the new Precip Calculator and the zip file for the DSO web site.

Getting started. The new Precip Calculator performs its calculations using the gridded data set files provided with the Calculator zip file. For the new Calculator, these data files are all internal to the Calculator, a considerable simplification from the previous spreadsheets.

The computation procedures require a representative project location, usually the centroid of the watershed, expressed as Latitude and Longitude in decimal degrees to 3 decimal places (or preferably to 4 decimal places). With that information, the Calculator will determine the applicable climatic region and perform the statistical computations for the precipitation depths for the various design steps. The Calculator will also identify the applicable storm hyetographs for the long, intermediate and short duration storms to use in the hydrology computer model used to perform the runoff and reservoir routing computations.

For computer models that are constrained to use only the NRCS storms, some procedures are offered for how to use the NRCS storm hyetographs to capture both the overall storm volume and the peak rainfall intensity of the Dam Safety storms.

The spreadsheets for the storm hyetographs and other supporting calculations are all Microsoft Excel 2013 format. If you have any questions regarding use of the Calculator or the spreadsheets or how they apply to your project, or other feedback regarding the DSO design storm procedures, please feel free to call or e-mail any DSO hydrologist. Names and contact information for DSO hydrologists are available on the DSO web site.

General computation sequence:

1. Dam failure analysis: Compute the dam breach flood and inundation area per Tech Note 1 and the separate self-extracting file from the DSO web site.

2. Compute the design step per Tech Note 2 and the DesStep spreadsheet based on the dam failure analysis.

3. Locate the centroid of the watershed, expressed as Latitude and Longitude in decimal degrees to 4 decimal places. Identify the General Storm PMP and Local Storm PMP from the PMP maps. Compute rainfall depths using the Precip Calculator.

4. Compute design storm hyetographs based on unit hyetographs per climatic region and precipitation depth per calculated design step. Elevations above 1,000 feet may need to consider snowmelt (separate calculation not considered in these spreadsheets).

5. Compute storm runoff from each of the three storm scenarios (i.e., three runoff computations). For developing watersheds, consider future (developed) conditions. Include flood routing through the pond or reservoir and over the spillway(s). Typically, these runoff analyses use the same watershed, pond/reservoir and spillway parameters as compiled for other hydrologic analyses for the project.

6. Identify which one of the three storm scenarios results in the highest water level in the pond or reservoir and the peak outflow over the spillway(s). This will be the Inflow Design Flood (IDF) for dam safety purposes.

7. Calculate required freeboard per Guidelines Part IV, Section 4.6, and the FreeBoard spreadsheet; compare to computed reservoir freeboard during IDF conditions.

Requirements for dam safety engineering reports are summarized in Guidelines Part II, *Project Planning and Approval* (separate PDF file), on pages 13 to 17. To more closely follow the logic presented above, feel free to reverse the order of the major subject areas listed in Part II; i.e., present the dam failure analysis (including downstream hazard class and design step computation) early in the report, followed by the hydrologic analysis, then the geologic/geotechnical analyses.

<u>Computation spreadsheets</u>. In addition to the output from the Precip Calculator, other spreadsheets needed to perform the hydrology calculations are included in the Storm Hyetographs zip file, described as follows:

DesStep -- Design step computation per Tech Note 2 and downstream hazard classification. 3 pages long.

FreeBoard -- Freeboard computations per Guidelines Part IV, Section 4.6. 2 pages long.

ResvWaves -- Graphs of wave heights vs. reservoir fetch length (input data to the freeboard computations). 3 pages long in 3 worksheets.

As an item of data input, the Calculator will also ask for either the 24-hour General Storm PMP (Probable Maximum Precipitation) or the 1-hour Local Storm PMP, in order to calculate a comparison of the dam safety storm rainfall to the PMP. Maps showing PMP distributions across the state are provided in the Storm Hyetographs zip file, or directly from the DSO web site. Each PMP map is one page, 11x17 size, in PDF format. The map names should be self-explanatory.

<u>Design storm unit hyetographs</u>. The spreadsheets containing the design storm unit hyetographs are located in the **DSO Storms by Regions** folder. The storm hyetographs are grouped together by climatic regions, so that once the Calculator has determined which climatic region the project is located in, the hyetographs for all three dam safety storm scenarios for that region are in the spreadsheet for that region. There is a separate tab for each storm scenario: Long, Intermediate (Intm), and Short.

These hyetographs have already been normalized to make the incremental ordinates (column C) add up to 1.0000, as shown in the cumulative mass curve (column E). This convention is similar to the typical convention for the NRCS storms, where the storm hyetograph is just a straight multiplication of the total storm depth times each incremental ordinate of the unit hyetograph. Although HEC-HMS does not have this limitation, some other hydrology computer models in common usage can only accept a normalized unit hyetograph, so these unit hyetographs have been normalized to make them easier to use in a wider range of hydrology models. Consistent with this, the Calculator will calculate the total storm depth for direct input to the hydrology model.

Also included in the Storm Hyetographs zip file are some recommended protocols for using the NRCS storms for the dam safety inflow design flood, for use with hydrology computer models that are hard-wired for the NRCS storms and cannot accept a separate user-specified storm hyetograph. The protocols are intended to produce a combination of sequential NRCS storms that will capture both the volume of the dam safety long duration storm and the peak intensity of the dam safety short duration storm. These items are located in the **NRCS storm calculations** folder.

Using the Precip Calculator:

The Precip Calculator is intended to be simple and straight-forward, just follow the prompts and enter the data requested.

On the Run Calculation tab in the Calculation Variables section, input items about the storm include:

- The storm scenario (long, intermediate, or short). The Calculator will determine the total storm duration and the storm index period based on the storm scenario.
- The design step as calculated separately using the DesStep spreadsheet and the protocols from Tech Note 2.
- The design factor. For most projects, especially new dams, the design factor is 1.15.
- PMP for the 24-hour General storm and/or the 1-hour Local storm. Calculations for the Long duration storm will need the 24-hour General storm PMP. Calculations for the Short duration storm will need the 1-hour Local storm PMP. Calculations for the Intermediate storm will need both the 24-hour General storm PMP and the 1-hour Local storm PMP.

On the Run Calculation tab in the Calculation Variables section, input items about the watershed include:

- Watershed location (usually the watershed centroid), expressed as Latitude and Longitude in decimal degrees to 4 decimal places.
- The drainage area for the watershed, in square miles. (The conversion factor from acres is 640 acres per square mile.)
- An average or representative elevation for the watershed.

The Calculator has some flexibility in how it does the calculations from the gridded data sets. DSO typically uses the Inverse Distance Weighting method of grid cell interpolation, with a value of 1 entered in that input box.

After the storm and watershed data are input to the Calculator, the user should push the Run Calculation button to perform the calculations. After that, the output results will display in the Calculation Initial Results box on the right side of the Run Calculation tab, and on the Multipliers, Calculation Results, Detailed Results 1, and Detailed Results 2 tabs.

Using the spreadsheets:

For the calculation spreadsheets, cells that need information entered into them are shown in light green, and many of the cells that need numerical input are also outlined so they appear as a box.

In some cases, "dummy" numbers need to be replaced with real data, or a selection needs to be made from several possible values or answers. The specific item of data needed is usually listed nearby so that a printout of the spreadsheet will serve as file documentation of the calculations that were performed.

The DesStep spreadsheet is based substantially on the worksheet provided in Tech Note 2, so the instructions and sources of data for that worksheet apply to this spreadsheet also. Similarly, the sources of data for the FreeBoard spreadsheet are found in the Guidelines Part IV, Section 4.6. The ResvWaves spreadsheet has graphs of wave heights vs. reservoir fetch length to assist the interpolations of wave heights for reservoir fetch lengths that fall between the specific distances listed in Table 2 of Guidelines Part IV, Section 4.6, on page 4-41.

The storm hyetograph spreadsheets are the electronic versions of the hyetographs presented in graphical form in Tech Note 3. This electronic format should expedite this element of data entry into the hydrologic computer model used for the storm runoff computations, just copy and paste. In most cases, the incremental hyetograph is used in the hydrology computer model. In the storm hyetograph spreadsheets, this is the column for the Dimensionless Hyetograph Ordinates; these cells are also outlined to help identify this specific column. The time intervals are 15 minutes for the Long and Intermediate duration storms and 5 minutes for the Short duration storms. The Long storm hyetographs have 288 ordinates for a 72 hour storm. The Intermediate storms have 72 ordinates for an 18 hour storm. The Short storms have 48 ordinates for a 4 hour storm.

Computation procedures are similar to those used with the NRCS storm hyetographs; i.e., the hyetograph indicates the rainfall distribution during the storm and a separate data entry indicates the total precipitation depth. Typically, the computer program internally spreads the total precipitation depth over the storm hyetograph to compute the rainfall during each time interval.

On the Calculation Results tab, the Calculator output will show the total rainfall depth for the entire 72-, 18- or 4-hour total storm duration for the Long, Intermediate or Short duration storm. This is the rainfall depth that should be used in the hydrology model calculations, or as input to snowmelt calculations for rain-on-snow scenarios (separate calculations not considered in these spreadsheets).

For those interested, calculations of the 24-, 6- or 2-hour index period scaling precipitation are shown as output on the Detailed Results 1 tab. Comparisons of point and basin average precip are shown as output on the Detailed Results 2 tab, as well as peak intensity for the design storm.

For inclusion in the project hydrology report, screen shots of the various Calculator tabs may be copied and pasted as images into a word processor or on a spreadsheet. DSO trial runs have had success with pasting into a word processor program with a landscape page orientation, one page in the word processor for each tab in the Calculator. (Yes, not very sophisticated, but it captures and conveys the information.)

<u>IDF computations using NRCS storms</u>. For computer models that are constrained to use only the NRCS storms, some procedures are offered for how to use the NRCS storm hyetographs to

capture both the overall storm volume and the peak rainfall intensity of the Dam Safety storms. The recommended protocols are described in three PDF documents located within the **NRCS storm calculations** folder, with the file names intended to convey the applicable NRCS storm hyetograph (type 1A or type II) and the applicable climatic regions. The spreadsheet NRCS-IDF is also included to perform the calculations described in the three Recommended Protocols documents.

Just to clarify, these calculations only apply to hydrology models using the NRCS storms. Hydrology models using the DSO storm hyetographs should not do these calculations.

For the NRCS-IDF spreadsheet, the general computation sequence is as follows. First, input the project name, project and watershed location, and other input data on the Print-Out worksheet (Print-Out tab) as copied from the Precip Calculator. On the Multipliers worksheet (Multipliers tab), manually adjust the cell references in the Hyetograph and Multiplier input cells (outlined and shaded green) to correspond to the line in the table above the input cells that corresponds to the climatic region listed as the Region for this project. These updated values from the Multipliers worksheet are read back to the Print-Out worksheet to perform the calculations, and are listed on the Print-Out worksheet to verify that they have been adjusted correctly on the Multipliers worksheet.

For inclusion in the project hydrology report, my expectation is that a copy of the Print-Out worksheet would suffice. The relevant information from the Multipliers worksheet is also shown on the Print-Out worksheet, so a copy of the Print-Out worksheet for the report should be adequate for documentation purposes. Again, these calculations only apply to hydrology models using the NRCS storms. Hydrology models using the DSO storm hyetographs should not do these calculations.

Worked examples. At this time, we do not have any worked examples to illustrate the new Precip Calculator and storm calculation protocols. Our hope is that the Calculator would be self-explanatory and straight-forward, just follow the prompts. If you find this is not the case, please let us know.

Technical assistance. If you have any questions regarding use of the Precip Calculator or these spreadsheets or how they apply to your project, or other feedback regarding these new protocols, please don’t hesitate to call or e-mail. My contact information is given on page 1, and the contact information for all of the DSO hydrologists is available on the DSO web site. Early and open communication helps all of us.

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