North Carolina GIS PMP Tool Documentation

1. PMP Tools Description and Usage

The PMP Evaluation Tool employed in this study is based on a Python script designed to run within the ArcGIS environment. ESRI's ArcGIS Pro software is required to run the tool. The spatial Analyst extension is also required for some of the optional temporal functions. It is recommended that the most current version of the software is used. The PMP tool provides gridded output at a spatial resolution of 90 arc-seconds (equivalent to .025 x .025 decimal degrees) for a user-designated basin or area at user-specified durations. Standard outputs include gridded and basin average PMP depths and temporally distributed accumulations.

1.1 File Structure

The PMP tool, source script, and the storm databases are stored within the 'PMP_Evaluation_Tool' project folder. The file and directory structure within the 'PMP_Evaluation_Tool' folder should be maintained as provided, as the script will locate various data based on its relative location within the project folder. If the subfolders or geodatabases within are relocated or renamed, then the script must be updated to account for these changes.

The file structure consists of three subfolders: Input, Output, and Script. The 'Input' folder contains all input GIS files (Figure 1.1). There are four ArcGIS file geodatabase containers within the 'Input' folder: AEP.gdb, DAD_Tables.gdb, Non_Storm_Data.gdb, and Storm_Adj_Factors.gdb. The AEP.gdb contains all of the precipitation frequency raster files for the various return frequencies used in the AEP tool. The DAD_Tables.gdb contains the DAD tables (in file geodatabase table format) for each of the SPAS-analyzed storm DAD zones included in the storm database. The Storm_Adj_Factors.gdb contains a point feature class for each storm and stores the adjustment factors for each grid point as a separate feature. These feature classes are organized into feature datasets, according to storm type (General, Local, and Tropical). The storm adjustment factor feature classes share their name with their DAD Table counterpart. The naming convention is SPAS_XXXX_Y, where XXXX is the SPAS storm ID number and Y is the DAD zone number. In the case of a hybrid storm (i.e., a storm that is run as both a general and local storm type), there will be a suffix "_gen" or "_loc" to differentiate the storm type specific to the adjustment factors in the feature class. The Non_Storm_Data.gdb contains spatial data not directly relating to the input rainfall depth or adjustment factors such as the grid network vector files or transposition zones feature class.

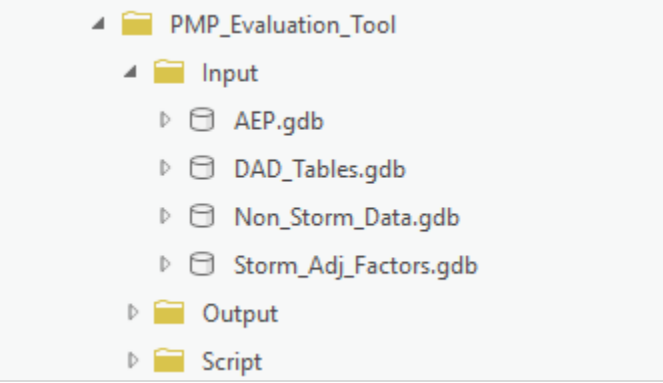

Figure 1.1: PMP tool file structure

The 'Script' folder contains an ArcToolbox called NorthCarolina_Final_PMP_Tools.tbx. The toolbox contains a script tool called 'Gridded PMP Tool' that is used to calculate PMP. The PMP Tool will calculate gridded all-season PMP depths in inches for a basin or user specified area size.

ArcGIS should be used for viewing the GIS tools file structure and interacting with the input and output geospatial data. A typical operating system's file browser does not allow access to the geodatabase containers and cannot be used to directly run the tool.

The tools are stored within the NorthCarolina_Final_PMP_Tools.tbx. ArcToolbox opens and runs the script within the ArcGIS Pro environment. In addition to running as a standalone tool, the tool can be incorporated into Model Builder or be called as a sub-function of another script.

To run the tools, the user navigates to North Carolina_Final_PMP_Tools toolbox, expands it, and opens the Gridded PMP tool. The dialogue window opens, and the user populates input parameters and clicks the 'OK' button. The tool will run in the foreground and display text output in the Messages window. Processing time can vary greatly depending on area of interest (AOI) size, the number of durations selected, and computer hardware. Most basins generally take 5 to 10 minutes to analyze all three storm types on a typical computer interface. The tools produce PMP output described in Section 1.4.

1.2 PMP Tool Usage

The tool requires several parameters as input to define the area and durations to be analyzed. The first parameter required by the tool dialogue is a feature layer, such as a basin shapefile or feature class, designed to outline the AOI for the PMP analysis. If the feature layer has multiple features (or polygons), the tool will use the combined area as the analysis region. Only the selected polygons will be used if the tool is run from the ArcMap environment with selected features highlighted. If the AOI shapefile extends beyond the project analysis domain, PMP will only be calculated for grid cells inside the project domain. The AOI shapefile or feature class should not have any spaces or symbol characters in the filename. The user then will need to set the 'Output Folder' path which provides the tool with the location to create the output PMP files. The user must have read/write privileges for this folder location. Note, the tool will overwrite the previous output if all input parameters are the same. The user then selects the durations to be run for each storm type. Individual durations can be run by checking each individual box or all durations can be run by clicking the "Select All" option (Figure 1.2).

The next parameter allows the user to either use the basins calculated area size or override the default to enter a custom area (in square miles) for areal-average PMP calculations. The user then has the option to have the tool perform a weighted analysis on the grid cells underlying the AOI boundary. If this option is checked each grid cell along the basin's boundary will be weighted by the portion of the cell's area inside the basin for the purpose of the basin average PMP table calculations. It is checked by default. If this option is disabled, the tool will output a basin average of all grid cells equally that intersect the basin boundary. There is an option to include sub-basin averages. This will calculate an average PMP depth for each feature in the input basin feature class from the overall basin PMP. The average sub-basin depths will be based on the exact area-size of the overall basin. If the 'weighted' option was selected above, it will also be applied to the sub-

basin averages. The user must select a field within the AOI to be used to identify each sub-basin. The field can be of numeric or text data type but must have a unique ID for each polygon. This option is disabled by default. The user can also choose to include a depth-duration chart .png image in the output folder for each storm type.

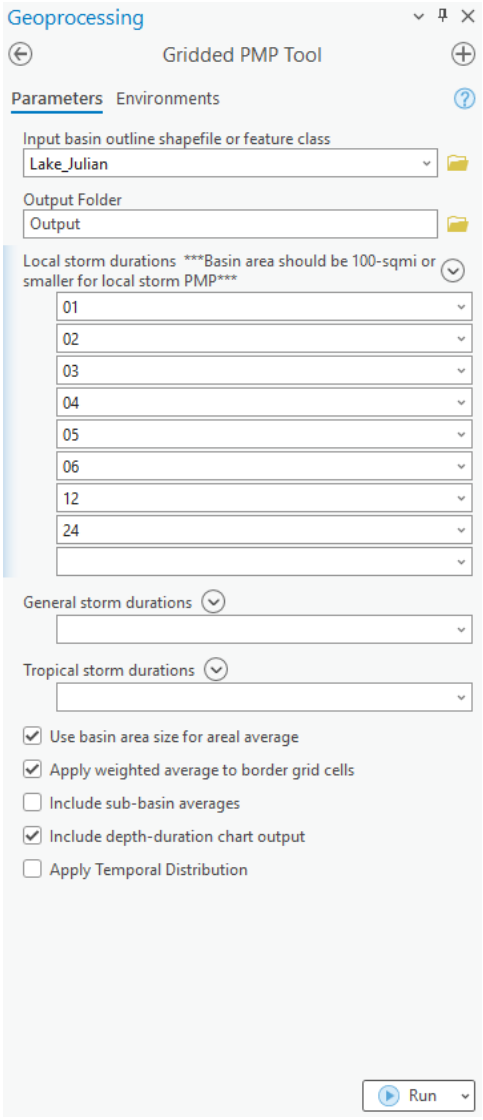

Figure 1.2: PMP tool input/output parameters with all local storm durations set to run.

Finally, the user can select the option to apply the appropriate temporal distribution patterns to the basin average PMP for each storm type. This function needs all durations of PMP to be calculated, so if this option is selected the tool will automatically run all durations for all storm types regardless of what durations were selected by the user in the previous steps. If temporal distributions are applied, the user then has the option to export them to ascii or NetCDF format. The ascii or NetCDF functions do require the Spatial Analyst extension to run.

1.3 PMP Tool Output

Once the tool has been run, the output folder will be populated with the model results. The GIS files can then be brought into an ArcMap, or other compatible GIS environments, for mapping and

analysis.

Note, the tool is set to have overwrite capabilities; if output data exists, it will be overwritten the next time the tool is run, if the same output folder and same parameters are used.

A separate output folder is created for each storm type and the output is organized within sub folders by output type. Each output file geodatabase contains a feature class which stores each grid point centroid within the basin as a separate feature. Each feature has a field for the grid ID, latitude, longitude, analysis zone, elevation, PMP (for each duration), and the contributing storm ID and name. PMP raster files are also stored within the file geodatabase. The naming convention for the raster files is the storm type and duration (L for Local, G for General, and T for Tropical), followed by the input basin feature name, and ending with the rounded off basin area (in square miles). If temporal patterns were applied, the output tables would also be in the geodatabase along with a folder for the ascii and NetCDF files. A folder named CSV is also created and all the geodatabase tables are exported to csv files. An example of the output file structure is shown in Figure 1.8.

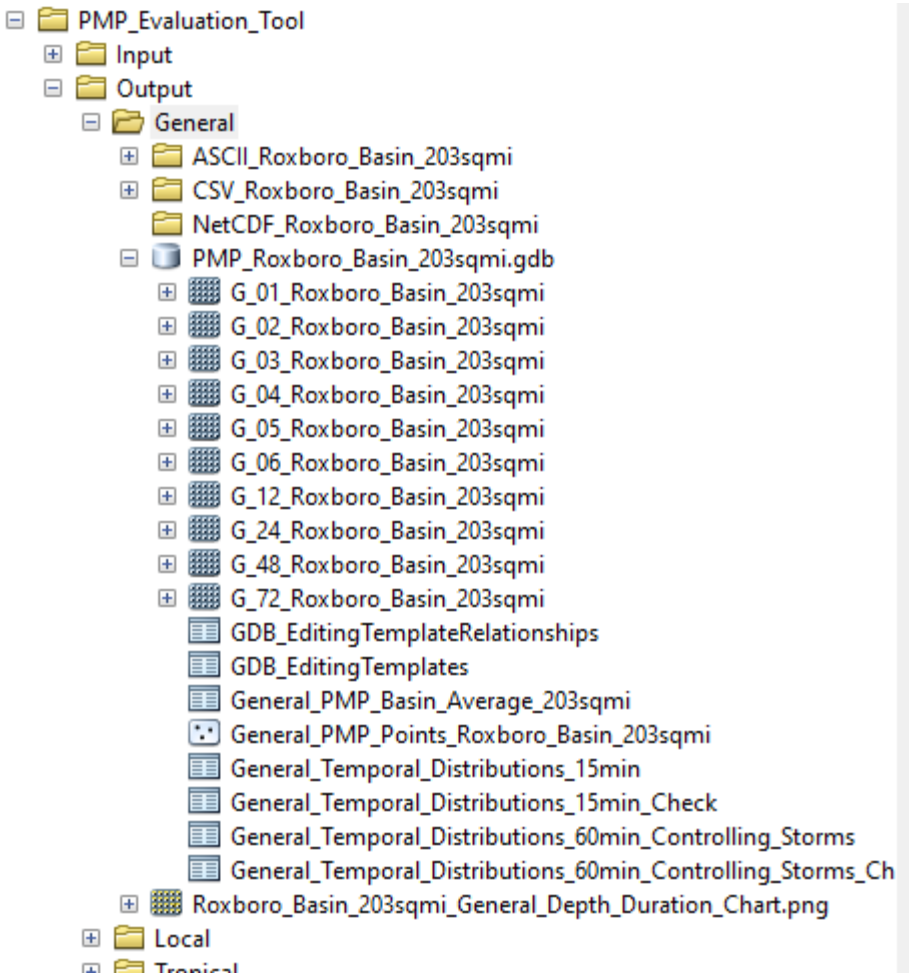

Figure 1.8: Example of the PMP tool output file structure

If the temporal patterns were applied, you will see a table named Temporal_Distribution_Check

in the csv folder and in the geodatabase. This is important as it evaluates the temporally distributed PMP values for each duration against the PMP value for that duration. The table has an "exceed" or "ok" check. If the temporally distributed PMP value exceeds the PMP at a given duration by more than 5%, the table will have "exceed" for that duration and this temporal pattern should not be applied when other temporal patterns are available for a given storm type which do not "exceed". The 5% tolerance is considered because in some situations all temporal patterns for a given storm type may exceed the temporal check. The user can also check the percentage of exceedance by investigating the table and comparing the temporally distributed values against the PMP depth for that duration(s). For durations where the exceedance is within 5% of the PMP for that duration(s), that temporal pattern can be applied. An example is shown in Figure 1.9. The Critically Stacked Temporal Pattern (USBR method) is included only as a backup and is to be used only if all other Temporal Patterns fail the checking process.

	PATTERN	PMP_01	MAX_01	CHEC...	PMP_02	MAX_02	CHECK...	PMP_03	MAX_03	CHECK_03	PMP_04	MAX_04	CHECK_04	PMP_05	MAX_05	CHECK_05	PMP_06	MAX_06	CHECK_06
1	GS_24HR_10TH_PERCENTILE	4.15	1.21	OK	5.38	2.35	OK	9.09	3.44	OK	9.09	4.48	OK	9.59	5.46	OK	12.91	6.37	OK
2	GS_24HR_90TH_PERCENTILE	4.15	0.99	OK	5.38	1.93	OK	9.09	2.84	OK	9.09	3.71	OK	9.59	4.54	OK	12.91	5.33	OK
3	GS_24HR_SYNTHETIC	4.15	1.36	OK	5.38	2.61	OK	9.09	3.83	OK	9.09	5.05	OK	9.59	6.12	OK	12.91	7.17	OK
4	Critically_Stacked_24h	4.15	4.14	OK	5.38	7.86	EXCEED	9.09	11.18	EXCEED	9.09	12.41	EXCEED	9.59	12.91	EXCEED	12.91	13.24	OK
5	GS_48HR_10TH_PERCENTILE	4.15	1.21	OK	5.38	2.35	OK	9.09	3.44	OK	9.09	4.48	OK	9.59	5.46	OK	12.91	6.37	OK
6	GS_48HR_90TH_PERCENTILE	4.15	0.99	OK	5.38	1.93	OK	9.09	2.84	OK	9.09	3.71	OK	9.59	4.54	OK	12.91	5.33	OK
7	GS_48HR_SYNTHETIC	4.15	1.36	OK	5.38	2.61	OK	9.09	3.83	OK	9.09	5.05	OK	9.59	6.12	OK	12.91	7.17	OK
8	Critically_Stacked_48h	4.15	4.15	OK	5.38	7.86	EXCEED	9.09	11.18	EXCEED	9.09	12.41	EXCEED	9.59	12.91	EXCEED	12.91	13.24	OK
9	GS_72HR_10TH_PERCENTILE	4.15	1.21	OK	5.38	2.35	OK	9.09	3.45	OK	9.09	4.48	OK	9.59	5.46	OK	12.91	6.37	OK
10	GS_72HR_90TH_PERCENTILE	4.15	0.99	OK	5.38	1.93	OK	9.09	2.84	OK	9.09	3.71	OK	9.59	4.54	OK	12.91	5.33	OK
11	GS_72HR_SYNTHETIC	4.15	1.36	OK	5.38	2.61	OK	9.09	3.83	OK	9.09	5.05	OK	9.59	6.12	OK	12.91	7.17	OK
12	Critically_Stacked_72h	4.15	4.15	OK	5.38	7.86	EXCEED	9.09	11.18	EXCEED	9.09	12.41	EXCEED	9.59	12.91	EXCEED	12.91	13.24	OK
	Click to add new row.																		

Figure 1.9: Example of the temporal check results

1.6 Known Issues and Troubleshooting

The GIS PMP tool has undergone a beta testing program during development. One goal of the beta testing program was to identify possible issues with the GIS tool. The following guidelines may prevent issues with running the GIS tool.

- Ensure ArcGIS Desktop is up to date with the most recent version release and maintenance is current.
- Ensure all file and path names do not have spaces or non-alphanumeric symbols (e.g., #, $, %). Underscores are acceptable and a good alternative to using spaces.
- Close any other applications or instances of ArcMap that may interfere with the current session, files, or file paths that will be used by the tool.
- Ensure that all file paths, input and output files, and ArcGIS Environment settings (including the Default.gdb and Scratch.gdb) are local and not set to a network location.

If the points above have been verified and issues persist, the user may try the following actions to address the issue:

- Close out all ArcMap sessions and all ArcGIS applications and restart session.
- Restart computer. This may be required to completely clear any locks on files or memory.
- Run the Repair Geometry tool on the AOI shapefile or feature class to correct any geometry issues within the file.

- Rename AOI file. Change tool and/or output folder paths.

If issues persist it may be necessary to contact ESRI support or perform a clean ArcGIS installation or upgrade.

GIS AEP Tool Documentation

North Carolina Statewide PMP Study

1. AEP Tool Description and Usage

The Basin AEP Tool extracts 6-hour and 24-hour basin-average precipitation for Annual Exceedance Probabilities (AEP) and corresponding Average Recurrence Intervals (ARI) estimates, and 5% and 95% confidence interval estimates, for user-defined drainage basin area. The development of the Annual Exceedance Probability is detailed in the report of the Probable Maximum Precipitation Study for North Carolina (2025).

The tool calculates an areal-reduction factor (ARF) based on duration and the basin location using a three-parameter log-logistic function. The tool exports Excel spreadsheet tables of basin average precipitation estimates for AEPs of 1 to $1x10^{-10}$. The tool also calculates the AEP of PMP for the basin using user-input PMP datasets. The resulting precipitation frequency estimates and AEP of PMP are plotted on charts as .png images.

The tool is compatible with ArcGIS Pro. It is recommended that the most current version of the software is used. The tool is accessed from the NorthCarolina_Final_PMP_Tools.tbx toolbox within the ArcGIS desktop environment.

1.1 File Structure

The Basin AEP Tool, and the gridded precipitation frequency datasets it utilizes are contained within the 'PMP_Evaluation_Tool' folder. The 'AEP.gdb' file geodatabase contains the precipitation frequency gridded datasets for each duration for every available return period. The AEP.gdb is located within the 'Input' sub folder. The script tool is located within the 'Script' subfolder, along with the PMP tool. See the PMP tool documentation for more information on the PMP tool and the overall file structure.

1.2 Usage

As a prerequisite to the AEP tool usage, the user should have downloaded the 'PMP_Evaluation_Tool' to a location on their local file system. A polygon feature class or basin shapefile is needed for input. Running the PMP tool with the basin is

not required unless the user chooses the option to calculate the AEP of PMP.

1.3 Input Parameters

The tool accepts the following input parameters.

Table 1 - AEP Tool input parameters

Parameter # (in script)	Display Name	Data Type	Type	Direction	MultiValue
0	Input basin outline shapefile or feature class	Feature Layer	Required	Input	No
1	AEP Durations	String	Required	Input	Yes
2	Output Folder Path	Folder	Required	Input	No
3	Estimate AEP of PMP	Boolean	Optional	Input	No
4	"PMP Points" feature class for each storm type	Feature Layer	Optional	Input	Yes

Table 1 shows tool input parameters. The first parameter required by the tool dialogue is a feature layer, such as a basin shapefile o r feature class, designed to outline the area of interest (AOI) for the precipitation frequency estimates. The tool will calculate the basin area size in square miles. If the feature layer has multiple features (or polygons), the tool will use the combined area as the analysis region. Only the selected polygons will be used if the tool is run from the ArcPro environment with selected features highlighted. If the AOI shapefile extends beyond the project analysis domain, AEP will only be evaluated for grid cells inside the project domain. The AOI shapefile or feature class should not have any spaces or symbol characters in the filename or the file path.

The user then selects the precipitation durations to be evaluated. At least one duration is needed.

The user will need to set the 'Output Folder' path which provides the tool with the location to create the output AEP files. The user must have read/write privileges for this folder location.

Finally, the user has the option to calculate the AEP of PMP for the basin. If the user selects this option, they will need to provide the "PMP_Point" feature class(es) produced by the Basin PMP Tool. The tool can accept a separate feature class for each storm type (see example in Figure 1).

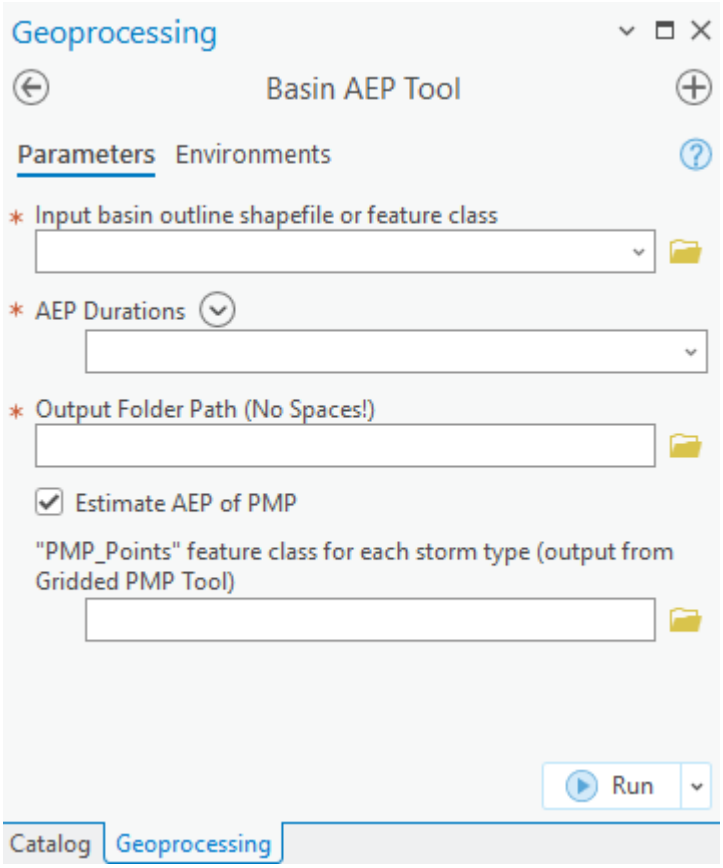

Figure 1 - The Basin AEP Tool input dialogue window

1.4 Tool Output

Once the tool has been run, the output folder will be populated with the results. For each duration the tool will produce an Excel (.xls) spreadsheet containing the basin average precipitation frequency estimates. An example is shown in Table 2. The tool will also produce a logarithmic frequency curve plot showing the basin average precipitation and the 95% confidence bounds. Additionally, if the option to calculate the AEP of PMP was chosen, the PMP depths will be plotted on the chart and a table of the AEP of PMP values will be plotted on the image. An example of this plot is shown in Figure 2.

Table 2 - Example basin AEP table output

OBJECTID	Annual Exceedance Probability	Precip (in) 50% conf.	Precip (in) 5% conf.	Precip (in) 95% conf.
1	1	1.36	1.19	1.52
2	0.5	2.63	2.38	2.92
3	0.2	3.56	3.25	3.93
4	0.1	4.26	3.87	4.69
5	0.04	5.26	4.72	5.76
6	0.02	6.08	5.4	6.72
7	0.01	6.99	6.14	7.79
8	0.005	7.98	6.93	8.98
9	0.002	9.43	8.05	10.7
10	0.001	10.67	8.99	12.22
11	0.0002	14.02	11.43	16.31
12	0.0001	15.7	12.61	18.59
13	0.00001	22.61	17.27	28.47
14	0.000001	32.08	23.15	43.11
15	0.0000001	45.06	30.68	64.62
16	0.00000001	62.87	40.25	96.77
17	0.000000001	87.27	52.41	144.62
18	1E-10	120.74	67.9	215.65

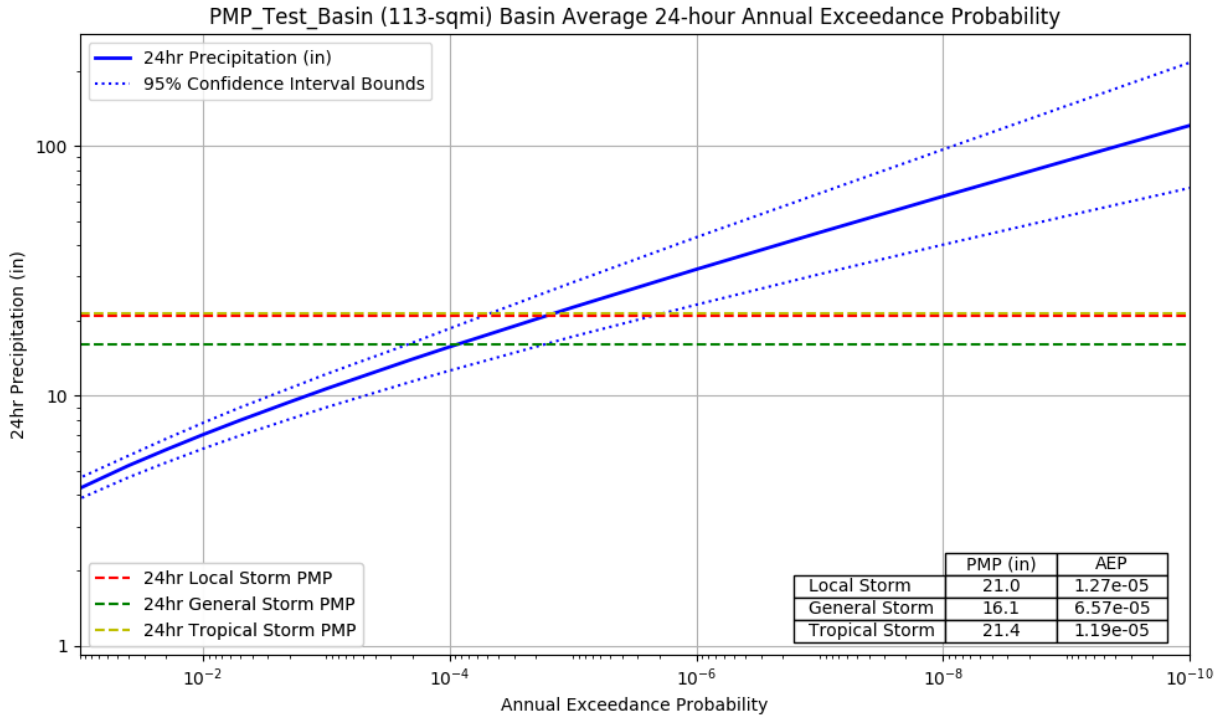

Figure 2 - Example basin precipitation frequency curve and AEP of PMP plot output

1.5 Recommendation for Temporal Patterns

The AEP Tool does not provide Temporal Patterns. The same temporal patterns developed for the PMP (for the most critical storm type) are recommended to be applied to the AEP for recurrence intervals of 100-year or rarer. For more frequent recurrence intervals (50-yr, 25-yr, 10yr, etc), applying NOAA Altas 14 (or similar documents that replace NOAA Atlas 14) temporal patterns is recommended.