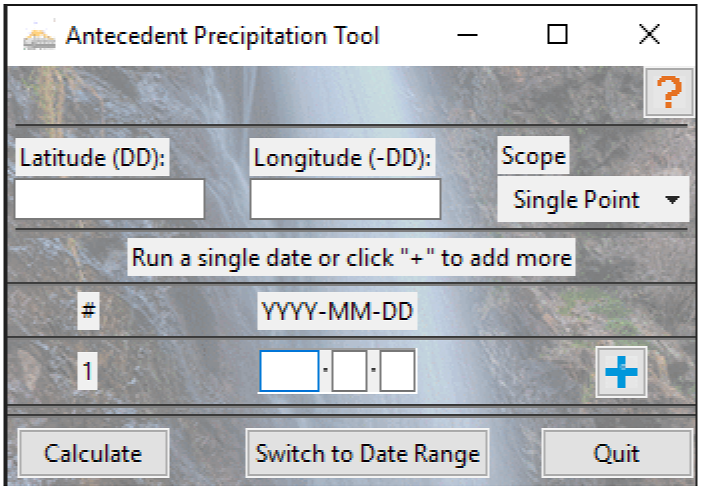
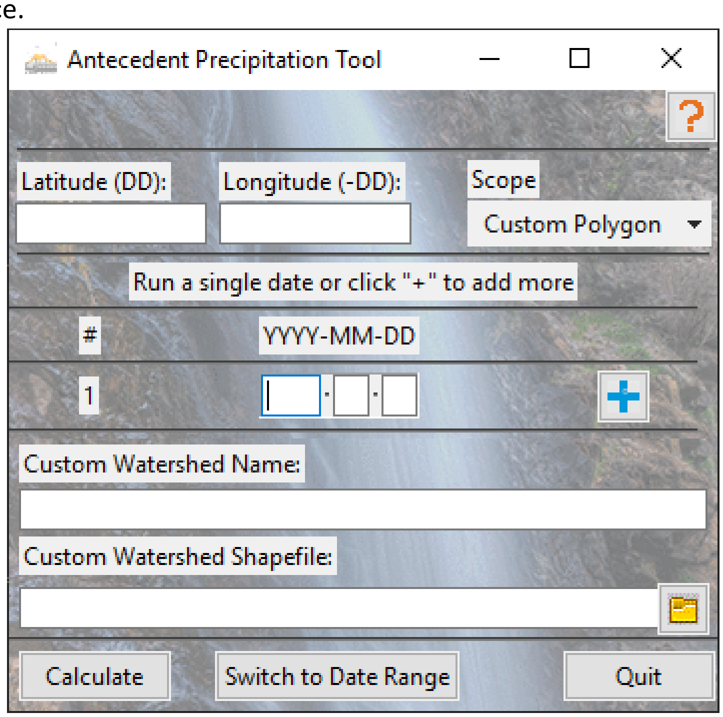
Antecedent Precipitation Tool (APT) v1.0.14 - Detailed Methodology

The Process of Running a Watershed Analysis or Single-Point Analysis for One or More Dates



1. Enter a latitude into the "Latitude" field in DD (Decimal Degree) format.
2. Enter a longitude into the "Longitude" field. In DD (Decimal Degree) format.
3. Click on the "Scope" drop-down menu (You actually click on the default value, "Single Point")
4. Select either HUC8, HUC10, HUC12, or Custom Polygon
5. Enter a date into the multi-part date field in the format "YYYY-MM-DD"
   a. Note: The following date values are not permitted
      i. Years older than 1910
      ii. Dates that do not exist, like February 29th 2019, or September 31st of any year.
      iii. Dates occurring less than 2 days prior to the current date. There is an approximately two-day delay on the upload of weather station data in NOAA's Global Historic Climatology Network (GHCN).
   b. If any of the invalid date entries above are entered, the date field will turn read, and the console will display the issue that must be corrected before you can proceed.
6. If Custom Polygon was chosen in the "Scope" drop-down menu, two more fields will be added to the tool's graphical user interface.



   a. In the "Custom Watershed Name" box, enter the name by which you intend to reference this watershed in any documentation within which you may cite this analysis.
   b. In the "Custom Watershed Shapefile" box, enter the file path to the shapefile containing your selected custom watershed shapefile. You may also click on the folder icon to browse for said shapefile. **Note:** The intent is to expand the range of file types this tool will accept in the future.
7. Once satisfied with the entries provided, click the "Calculate" button.
8. The first thing the tool will do is test the connection to NOAA's Global Historic Climatology Network servers. This is accomplished by attempting to download a small file titled readme.txt. This is a small file, so if it fails to download, something is wrong. The then informs the users that NOAA's server is offline, and that the request has been terminated because weather data is currently inaccessible. The user can retry the process at any time by clicking the "Calculate" button again.
9. The tool collects the data from the input fields, and runs a final series of tests on them to prevent errors. One such test is whether the supplied Latitude and Longitude falls within the boundaries of the United States. Though the GHCN network provides access to weather stations worldwide, reliable, high-resolution elevation data is accessible to the tool only through the USGS Elevation Point Query Service, which does not provide location data outside the United States. To perform this test, the tool uses the open-source OGR library in Python to open a shapefile containing a multi-part polygon of the United States and its territories. This shapefile is in the North American Datum 1983 (NAD83) geographic coordinate system. However, the tool assumes the coordinates provided by the user are in the World Geodetic System 1984 (WGS84) geographic coordinate system, as this is the coordinate system most users will be familiar with (default for Garmin Devices, Google Maps, Google Earth, and ESRI Basemaps provided in ArcMap and ArcGIS Pro. Accordingly, the tool transforms the latitude and longitude provide into NAD83 before creating a new point feature. With this test feature created, the tool tests whether or not the user-provided point falls within the United States boundary. If it does not, the user is informed provided with a message reading "Coordinates must be within the United States!" in the programs console. If this, or any other input error messages are displayed, no further processing will occur until the users modifies their inputs accordingly and then once again clicks the "Calculate" button.
10. If the selected scope is 'Single Point,' the tool will run for the selected coordinates on either a single date, or if many dates were provided through Individual Dates, Date Range, or CSV Upload interfaces, the tool will run a Single Point Analysis (SEE PAGE 4) for each date, and the results will be aggregated into a single PDF Portfolio containing the output for each date, as well as a CSV providing the data in tabular format.
    a. For information on:
       i. Reading the standard output, see APT – How to Read the Output of a Single-Point Analysis.pdf
       ii. Running the tool for a single date, see APT Walkthrough - Single Point - Single Date.pdf
       iii. The Individual Dates interface, see APT Walkthrough - Single Point - Multiple Dates.pdf
       iv. The CSV Input interface, see APT Walkthrough - Single Point - Many Dates Using CSV Input.pdf
       v. The Date Range interface, see APT Walkthrough - Single Point - Daily Frequency Date Range.pdf
11. If the selected scope is HUC8, HUC10, or HUC12:
    a. The tool will first use the built-in HUC2 dataset to determine which HUC2 Region the provided Latitude and Longitude falls within. As the HUC2 shapefile is also in the NAD83 coordinate system, coordinate transformation will be handled as described in Step 9 above. However, this time, in addition to confirming the point falls within a feature, the tool will also identify the contents of the "HUC2" field for said feature.
    b. Once the tool has the HUC2 value for the provided coordinates, it will determine whether or not it has already downloaded the Watershed Boundary Dataset (WBD) for that HUC 2 Region. The standard path is **[APT ROOT FOLDER]**\GIS\WBD**[HUC2 VALUE]**. If this folder is not found, it would be downloaded from the USGS hosting location, before being decompressed to the aforementioned folder.
    c. With appropriate dataset acquired and located, step a. above will be repeated for the appropriate WBDHU8.shp, WBDHU10.shp, or WBDHU12.shp to identify the watershed polygon and hydrologic unit code (HUC) of the feature within which the selected coordinates fall at the selected watershed scale.

12. Now that the selected watershed polygon has been identified, either by locating the polygon in which the selected coordinate falls for the selected Watershed Boundary Dataset scale (HUC8, HUC10, or HUC12), or by directly submitting it in the Custom Polygon process, the tool will move on to the sampling phase. The tool will determine the minimum and maximum latitude and longitude values for the selected watershed polygon. It will then begin randomly generate points within those value ranges, and testing them against the sampling parameters. First, it will test whether the point falls within the polygon. After that, it will test whether it is closer to any of the previously selected sampling points than the default sampling point spacing distance, which is 3.75 miles. If those conditions are met, the point will be added to the sampling points until the required number of sampling points are met. The sampling point selections until the 3000 consecutive potential points fail the above tests, at which point the list of points is considered complete.
13. Now that the sampling points have been created, the main portion of the tool will run a Single Point Analysis (SEE PAGE 4) for each sampling point for the selected date.
    a. An output directory will be created at **[APT ROOT FOLDER]**Output\~Watershed**\[SCOPE]\[WATERSHED NAME]**
    b. The tabular results for each sampling point will be written to a CSV spreadsheet at: **[OUTPUT DIRECTORY]\[SELECTED DATE]** – **[WATERSHED NAME]** – Batch Result.csv
    c. The PDF outputs for each sampling point will be combined in a PDF portfolio located at: **[OUTPUT DIRECTORY]\[SELECTED DATE]** – **[WATERSHED NAME]** – Batch Result.pdf
    d. A Watershed Summary page will be inserted in front of the Batch Result.pdf providing the following
        i. The user inputs
            1. Coordinates
            2. Date
            3. Geographic Scope
        ii. Intermediate Data
            1. Hydrologic Unit Code or Custom Watershed Name
            2. Watershed Size
            3. # Random Sampling Points
        iii. Preliminary Result
            1. Average Antecedent Precipitation Score
            2. Preliminary Determination
        iv. Sampling point breakdown (Each unique combination of)
            1. Antecedent Precipitation Score
            2. Antecedent Precipitation Condition
            3. WebWIMP Water Balance derived Wet/Dry Season determination
            4. Palmer Drought Servility Index result
            5. The number of sampling points meeting this set of values

    For information on reading this output, see APT – How to Read the Output of a Watershed Analysis.pdf

Single Point Analysis Procedure

Definitions:

- Observation Location: Coordinates (Latitude and Longitude) selected by the user
- Observation Date: Date selected by the user
- Water year: Period ranging from October 1 of a given year through September 30 of the following year
- PRCP: Precipitation
- 30-day rolling total: Daily time series dataset wherein the value for a given date is the sum of the current day and the preceding 29 days of daily total precipitation time series dataset.

1. **Calculate the date ranges for the**
   a. Current Water Year: Water Year in which the Observation Date falls
   b. Normal Period: The 30 water years preceding the Current Water Year
   c. Entire Period: Date Range from 30 days prior to the Normal Period through Current Water Year
   d. Antecedent Period: The Observation Date and the 89 days preceding it
2. **Acquire Weather Station Data**
   a. Download the Nationwide List of GHCN Weather Stations
   b. Find and acquire data all stations within 30 miles of the Observation Location
      i. Note: If necessary, the search radius will be extended to 60 miles
3. **Rank Stations based on:**
   a. How far they are from the Observation Location
   b. How close they are in elevation to the Observation Location
4. **Find the Primary Station**
   a. Start with the best-ranked station
   b. Eliminate any station that does not have:
      i. Greater than 6000 complete records within the Normal Period
      ii. Greater than 68 complete records within the 90-day Antecedent Period
   c. Give a ranking preference to stations that have:
      i. Greater than 8000 complete records within the Normal Period
   d. Give a further ranking preference to stations that have:
      i. Greater than 10000 complete records within the Normal Period
5. **Create a time series dataset with blank PRCP values for each day of the Entire Period**

Date	PRCP
First day of Entire Period	BLANK
…	BLANK
Last day of Entire Period	BLANK

6. **Replace BLANK precipitation values with Primary Station values:**
   a. Report the number of remaining BLANK values
   b. Save the metadata for the Primary Station for the Stations Table
   c. Save a copy of the station's PRCP record
      i. File Path: "…\Antecedent Precipitation Tool\Output\{COORDINATES}\{STATION NAME}.csv"
   d. The Primary Station will not cover every date, so you will still see something like the following:

Date	Precipitation
First day of Entire Period	0.001
…	0.001
Last day of Entire Period	BLANK

7. **Recalculate the Rank of remaining stations based on:**
   a. How far they are from the PRIMARY STATION
   b. How close they are in elevation to the PRIMARY STATION

8. **Replace BLANK precipitation values with remaining station values**
    a. Start with the best-ranked station
    b. Attempt to replace BLANK values
    c. Check / Report the number of remaining BLANK values
    d. If any BLANK values are replaced
        i. Save the metadata for the Primary Station for the Stations Table
        ii. Save a copy of the station's PRCP record
            1. File Path: "…\Antecedent Precipitation Tool\Output\{COORDINATES}\{STATION NAME}.csv"
    e. Repeat steps a through d until no BLANK values remain

Date	Precipitation
First day of Entire Period	0.001
…	0.005
Last day of Entire Period	0.000

Note about Linear Interpolation:

a. In very rare cases, a small number of BLANK values may persist after 10 stations have contributed data
b. At such a point, the APT will estimate the value for these dates using linear interpolation.
c. If this happens, you will see the words, "LINEAR INTERPOLATION" on the bottom row of the Station Table
d. Most common cause - Data not yet available
    i. By and large, GHCN PRCP data is available two days after it is recorded
        1. This is why the APT forces the Observation Date to be at least 2 days prior to the current date
    ii. However, occasionally the delay can be a week or two.
    iii. If this is the problem, the "LINEAR INTERPOLATION" row of the Stations Table will show
        1. "0" in the Days (Normal) column
        2. A non-zero number in the Days (Antecedent) column
    i. Solution - Shift your Observation Date back a few days, or wait for the data to become available.
e. Some cases may still require interpolation due to a lack of weather stations or a lack of complete records at available stations.
    i. To combat this issue, the Corps has contributed funds to NOAA for the development of a new Daily version of their Gridded Precipitation Dataset, which will be incorporated into the APT when it becomes available.
    ii. In the meantime if you are having consistent issues with the APT's station selection decisions at a given point, please submit that information to the APT-Report-Issue@usace.army.mil mailbox.
    iii. Similar submissions of from Regulatory Project Managers (PMs) all around the country are what shaped the APT's current Station Selection Methodology.
        1. When reports indicated the tool was allowing too great of a difference in elevation between weather stations and the observation location, I increased the negative effect it had on the station ranking.
        2. Conversely, when reports indicated that the tool was looking too far away to select stations at similar elevations, distance was given additional weight in the rankings.
        3. When the increasingly-strict distance/elevation optimizations made the APT prefer to evenly mix together three "poor-record" stations in close proximity rather than a single station with a "perfect-record" just a little farther away, I instituted a minimum record completeness requirement for the Primary Station.
        4. When the aforementioned completeness requirements forced the tool to travel much too far away in areas with poor station availability, I found that the problem could be assuaged by setting a fairly easy bar for minimum record completeness, while also allowing stations to "earn" different degrees of preference in the distance/elevation rankings as their records approached perfectly complete.

5. These (and other) mechanics were adjusted countless times in early iterations, but the past three+ years have seen no reports of the APT selecting stations in a manner inconsistent with the best professional judgment of a PM.
6. I am sure there are still unique scenarios the APT has yet to encounter, and I strongly encourage everyone to bring even small issues to my attention so that I can continue to make improvements.

9. Calculate the 30-day Rolling Total of the PRCP values for the Normal Period

Date	30-Day Rolling Total
First day of Normal Period	Sum of PRCP values for this date and the preceding 29 days
…	Sum of PRCP values for this date and the preceding 29 days
Last day of Normal Period	Sum of PRCP values for this date and the preceding 29 days

10. Calculate 30-Year Normal Range for each day of the water year

a. Create table with columns for each day of the water year (Oct 1, Oct 2, etc.)
b. Populate the rows the Normal Period 30-day rolling total
c. Calculate the upper and lower limits of the "normal range" for each day of the year

	October 1	…	September 30
First Water Year in the Normal Period	Rolling Total	Rolling Total	Rolling Total
…	Rolling Total	Rolling Total	Rolling Total
Last Water Year in the Normal Period	Rolling Total	Rolling Total	Rolling Total
30th Percentile (Lower Limit of Normal Range)	30th Percentile of All 30 Values For October 1	30th Percentile of All 30 Values For …	30th Percentile of All 30 Values For September 30
70th Percentile (Upper Limit of Normal Range)	70th Percentile of All 30 Values For October 1	70th Percentile of All 30 Values For October 1	70th Percentile of All 30 Values For September 30

11. Calculate the Current Water Year 30-day rolling PRCP total dataset

12. Create the figure:

a.

13. Calculate the Antecedent Precipitation Condition

a. An interactive figure is created, in the upper two-thirds of which a graph is placed.
   1. The X axis represents days of the year at the time of observation.
   2. The Y axis is millimeters of precipitation
b. The Normal High and Normal Low values are represented on a graph by filling the space between the two values in partially transparent orange.
c. The 30-day rolling total of the current water year is represented by plotting a blue line over the normal values.
d. An annotation is created showing the 3 points on the 30-Day Rolling Total line.
   1. The 1st Prior 30 marker refers to the observation date.
   2. The 2nd Prior 30 marker refers to the date 30 days prior to the observation date.
   3. The 3rd Prior 30 marker refers to the date 60 days prior to the observation date.
   4. Note: Since it is a 30-day rolling total, these three points actually represent the full 90 days of data.
e. Below the graph a table is created that lists the following information about the observation point.
   1. Coordinates
   2. Observation Date
      1. This can be the date of a satellite image, site visit, sampling point collection, or any other event.

3. Elevation
    1. The elevation of the observation point is calculated using a web service.
4. Image or Event Name
    1. If provided, the name of the image or event is placed here to conveniently link the figure to the document for which it is providing evidence.
5. Source
    1. If provided, the source of the image is placed here.

f. To the right of the aforementioned table, a table is created to document the procedure for determining if the image or event was "Drier than Normal", "Normal", or "Wetter than Normal".

g. For each of the three points discussed in step 13 above, a row is created with the following columns:
1. 30th %ile (Low)
    1. Value of the 30th percentile line at the specified date, or
    2. Value greater than 30% of the previous 30 years of 30-day rolling precipitation totals for that date, or Normal low value.
2. 70th %ile (High)
    1. Value greater than 70% of the previous 30 years of 30-day rolling precipitation totals for that date, or Normal high value.
3. Observed Rainfall
    1. The sum of the precipitation for the 30 days preceding the date of the annotation point.
4. Wetness Condition
    1. If the Observed Rainfall falls between the Normal Low and Normal High values, the condition is listed as Normal.
    2. If the Observed Rainfall is greater than the Normal High value, the condition is listed as Wet.
    3. If the Observed Rainfall is less than the Normal Low value, the condition is listed as Dry.
5. Condition Value
    1. Correlated Values: Dry = 1, Normal = 2, Wet = 3
6. Weight Value
    1. The most recent month has the highest weight. The first month = 3, the second = 2, the third = 1.
7. Product of Values
    1. Condition Value multiplied by the Weight Value.

h. A final 'Result' row is then created
1. It displays the sum of the three 'Product' column values, and the final result of the calculation (The actual conditions on the observation date).
2. If the product sum is 6-9, the actual condition is 'Drier than Normal.'
3. If the product sum is 10-14, the actual condition is 'Normal.'
4. If the product sum is 15-18, the actual condition is "Wetter than Normal.'

i. A final Table is created on the bottom of the figure to document the station selection criteria as well as the number of records that were used from each station to calculate both the Normal Range and the 30-Day Rolling Total for the observation date's water year.

14. Determine if the Observation Date falls within the Wet Season or the Dry Season for the Observation Location

a. Use the Web-based, Water-Budget, Interactive, Modeling Program (WebWIMP)
1. Terms:
    1. DIFF is the rainfall and estimated snowmelt minus the adjusted potential evapotranspiration (mm/month).
    2. DST is the estimated change in soil moisture from the end of the previous month to the end of the current month (mm/month).
    3. DEF is the estimated deficit or unmet atmospheric demand for moisture (mm/month).

b. Follow the instructions for determining the Wet Season and the Dry Season found in Section 5 of the Regional Supplement to the Corps of Engineers Wetland Delineation Manual.

Excerpt from ERDC/EL TR-08-28
Regional Supplement to the Corps of Engineers Wetland Delineation Manual
Arid West Region (Version 2.0)
Section 5 - Difficult Wetland Situations in the Arid West
Wetlands that periodically lack indicators of wetland hydrology:

"...
3. Use one or more of the following approaches to determine whether wetland hydrology is present and the site is a wetland. In the remarks section of the data form or in the delineation report, explain the rationale for concluding that wetland hydrology is present even though indicators of wetland hydrology described in Chapter 4 were not observed.
a. Site visits during the dry season. Determine whether the site visit occurred during the normal annual dry season. The dry season, as used in this supplement, is the period of the year when soil moisture is normally being depleted and water tables are falling to low levels in response to decreased precipitation and/or increased evapotranspiration, usually during late spring and summer. It also includes the beginning of the recovery period in late summer or fall. The Web-Based Water-Budget Interactive Modeling Program (WebWIMP) is one source for approximate dates of wet and dry seasons for any terrestrial location based on average monthly precipitation and estimated evapotranspiration (http://climate.geog.udel.edu/~wimp/). In general, the dry season in a typical year is indicated when potential evapotranspiration exceeds precipitation (indicated by negative values of DIFF in the WebWIMP output), resulting in drawdown of soil moisture storage (negative values of DST) and/or a moisture deficit (positive values of DEF, also called the unmet atmospheric demand for moisture). Actual dates for the dry season vary by locale and year.

Terms:

- DIFF is the rainfall and estimated snowmelt minus the adjusted potential evapotranspiration (mm/month).
- DST is the estimated change in soil moisture from the end of the previous month to the end of the current month (mm/month).
- DEF is the estimated deficit or unmet atmospheric demand for moisture (mm/month).

Mon	DIFF (mm/month)	DST (mm/month)	DEF (mm/month)	Conclusion
Jan	126	0	0	Wet Season
Feb	122	0	0	Wet Season
Mar	108	0	0	Wet Season
Apr	65	0	0	Wet Season
May	8	-2	0	Wet Season
Jun	-33	-32	0	Dry Season
Jul	-20	-20	0	Dry Season
Aug	-35	-27	7	Dry Season
Sep	-6	-5	2	Dry Season
Oct	8	8	0	Wet Season

Nov	82	78	0	Wet Season
Dec	132	0	0	Wet Season

15. Determine if the Observation Location was experiencing Drought Conditions on the Observation Date

a. Use NOAA's Climate Division scale Palmer Drought Severity Index (ftp://ftp.ncdc.noaa.gov/pub/data/cirs/climdiv)

i. This is the monthly value (index) that is generated indicating the severity of a wet or dry spell. This index is based on the principles of a balance between moisture supply and demand. Man-made changes were not considered in this calculation. The index generally ranges from -6 to +6, with negative values denoting dry spells and positive values indicating wet spells. There are a few values in the magnitude of +7 or -7. PDSI values 0 to -.5 = normal; -0.5 to -1.0 = incipient drought; -1.0 to -2.0 = mild drought; -2.0 to -3.0 = moderate drought; -3.0 to -4.0 = severe drought; and greater than -4.0 = extreme drought. Similar adjectives are attached to positive values of wet spells. This is a meteorological drought index used to assess the severity of dry or wet spells of weather.