



Culvert Analysis Toolkit

User Guide

Christian Gass and Benjamin Houston

CivicMapper and GroundPoint Engineering, 2023

Table of contents

1. Culvert Analysis Toolkit	3
1.1 Getting Started	3
1.2 Who is this toolkit for?	3
1.3 Credits/Contributors	3
2. Installing the Toolkit in ArcGIS Pro	5
2.1 1. Create a dedicated Python environment in ArcGIS Pro	5
2.2 2. Download the Culvert Analysis Toolkit installation file	5
2.3 3. Install	5
3. Handling Upgrades	6
3.1 Upgrading the toolkit	6
3.2 Upgrades to ArcGIS Pro	7
4. Data Prep Guides	8
4.1 Overview	8
4.2 Working with NAACC Culvert Data	10
4.3 Digital Elevation Model-derived Data	14
4.4 Generating a Curve Number Raster	16
4.5 Getting NOAA Rainfall Data	17
5. Analysis Guides	18
5.1 Toolbox Overview	18
5.2 The Capacity Calculator Workflow	20
5.3 Working with Capacity Calculator Results	24
6. Calculators	25
6.1 Peak Flow	25
6.2 Culvert Capacity	26
7. Developing the Toolkit	27
7.1 Setup Anaconda Python and dependencies	27
7.2 Project Structure	27

1. Culvert Analysis Toolkit

This documentation is a work-in-progress

The Culvert Analysis Toolkit is a collection of GIS tools designed to support analysis of culvert performance within their watershed. It uses a lightweight version of a [TR-55 Model](#) that leverages inputs derived from geospatial data to calculate peak-flow and culvert capacity.

This software has been developed by [CivicMapper](#) in collaboration with [GroundPoint Engineering](#), and encompasses work from a collaboration with the Cornell Soil & Water Lab (on GitHub @ [github.com/SoilWaterLab](#)) on their TR-55-based peak flow model. See [Credits/Contributors](#) for more information.

1.1 Getting Started

1. [Installation](#): get the Culvert Analysis Toolkit set up in ArcGIS Pro
 2. [Data Guides](#): walk-throughs of the types inputs the tool requires and how to prepare them
 3. [Analysis Guide](#): an overview of the tools and what they do, using the tool and working with the results
 4. Calculators: an explanation of the [peak-flow](#) and [capacity](#) calculators, with links to the underlying calculation code on GitHub
-

1.2 Who is this toolkit for?

The toolkit is designed to support understanding the efficacy of stormwater culvert infrastructure at a broad scale for planning purposes. To that end, the tool has two audiences:

- Planners, who can use the outputs to support decision-making
- Analysts, who are able to run the tool in GIS software and are comfortable wrangling the spatial datasets that are required inputs of the tools

1.2.1 What this toolkit is not

This toolkit is not:

- a replacement for engineering tools like HEC-RAS or SWMM
 - appropriate for supporting the design and engineering of individual culverts
-

1.3 Credits/Contributors

This software encompasses work originally developed by the Cornell Soil & Water Lab (on GitHub @ [github.com/SoilWaterLab](#))

This repository represents an evolution of a previous effort, the [Peak-Flow Calculator](#), which was a hard fork of the Water Lab's [CulvertEvaluation](#) repository.

Made in collaboration with the Cornell S&W lab, this repository includes additional updates to the science of the from [CulvertModel_2.1](#).

- Original peak flow analytics are based on the culvert evaluation model developed by Rebecca Marjerison at the Cornell Soil and Water Lab in 2013, as [CulvertEvaluation](#)
- David Gold, python script development, August 4, 2015
- Object-oriented structure and resiliency updates built by Noah Warnke, August 31 2016 (no formulas changed).
- Updated by Zoya Kaufmann June 2016 - August 2017
- Merged with older versions by Tanvi Naidu June 19 2017
- Fork, refactor, and creation of CLI and ArcMap interfaces by Christian Gass @ CivicMapper, Fall 2017, as [peak-flow-calculator](#)
- Updates for use within ArcGIS Pro by Christian Gass @ CivicMapper, Spring/Summer 2019, in [peak-flow-calculator](#)
- [CulvertModel_2.1](#) by Jo Archibald in 2019
- Drain-It repository by CivicMapper, 2021-2022

2. Installing the Toolkit in ArcGIS Pro

The Culvert Analysis Toolkit currently requires ArcGIS Pro version 3.

2.1 1. Create a dedicated Python environment in ArcGIS Pro

Note: If you already have a custom Python environment ready to go, you can skip this step and use that instead.

To use the toolkit, you'll need to install a custom Python environment for ArcGIS Pro.

1. [Clone the default ArcGIS Pro conda environment.](#)
2. [Switch the current ArcGIS Pro conda environment to the cloned environment using the Python Package Manager.](#)

For more information on working with Python environments in ArcGIS Pro, see [Esri's documentation](#).

Once you've done this, close ArcGIS Pro.

2.2 2. Download the Culvert Analysis Toolkit installation file

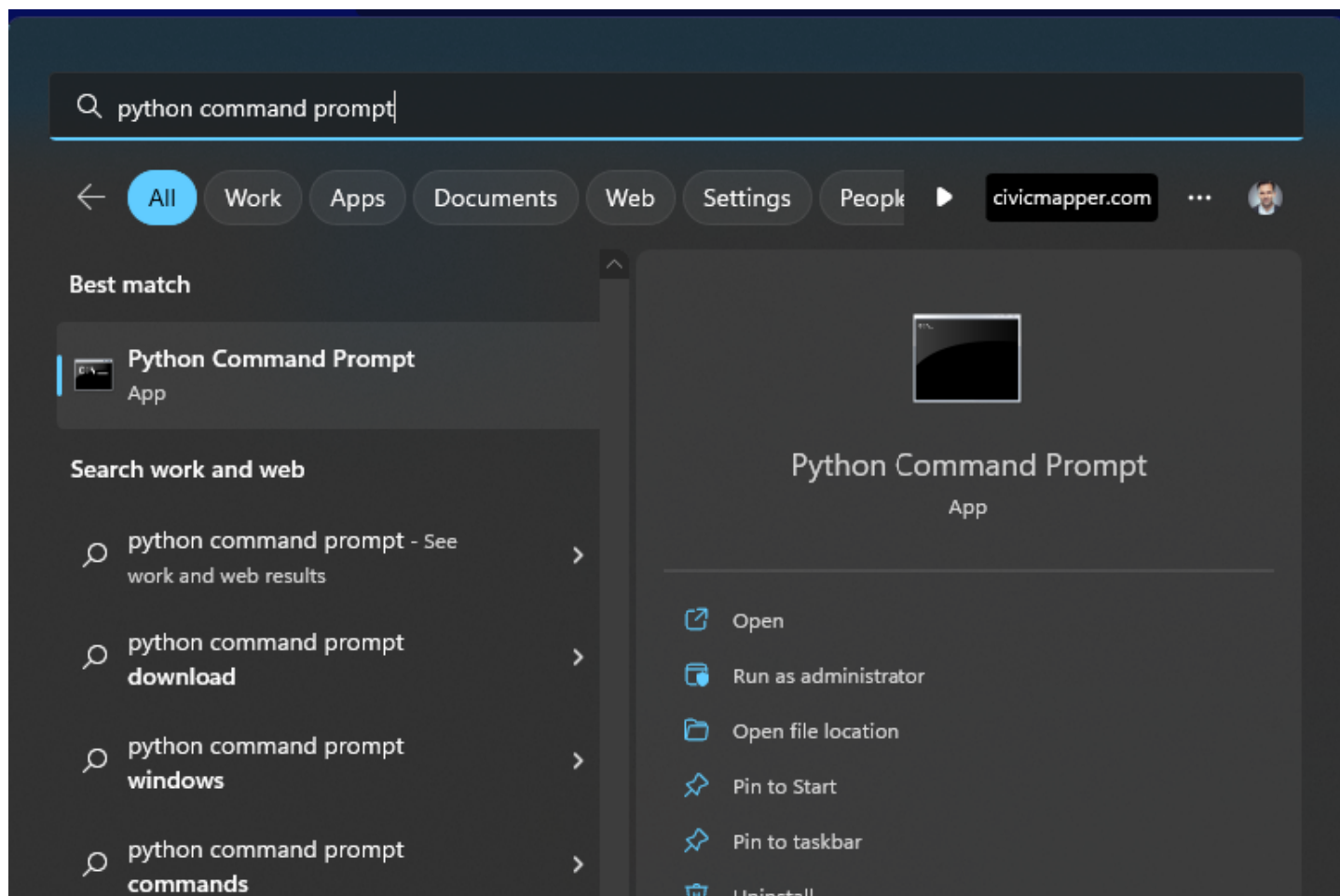
Download the latest install "wheel" [here](#).

2.3 3. Install

Now that you have the installation file and the custom Python environment, you can install the toolbox.

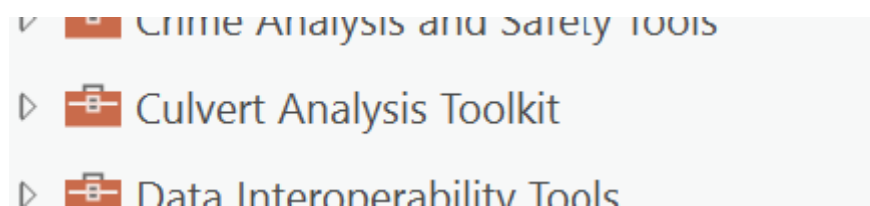
ArcGIS Pro comes with a "**Python Command Prompt**" shortcut available, which runs a batch script that automatically starts a command prompt with ArcGIS Pro's active Conda environment available.

Typically this gets added to your Windows Start Menu alongside the shortcut to ArcGIS Pro.



1. Open the Python Command Prompt that came with your ArcGIS Pro installation.
2. In the command prompt, run `pip install "<path-to-the-whl-file\drainit.whl>"`. You'll replace `"<path-to-the-whl-file\drainit.whl>"` with the full path to the wheel file you downloaded in the previous step. Include the quotes `"`.

Restart ArcGIS Pro. Open an existing or new project, and open the Geoprocessing you should see a `Culvert Analysis Toolkit` toolbox listed alongside other toolboxes in the ArcToolbox pane of ArcGIS Pro:



3. Handling Upgrades

3.1 Upgrading the toolkit

When a new release of the toolkit is available, you won't need to create a new dedicated Python environment as described in step #1 above. Download the new release (#2) and install (#3) in your existing custom environment to replace the older version of the toolkit.

3.2 Upgrades to ArcGIS Pro

Since version 3.0, ArcGIS Pro provides [a path for upgrading custom Python environments](#) made with previous versions. Depending on the changes to the Python version, that upgrade may or may not affect the toolbox.

4. Data Prep Guides

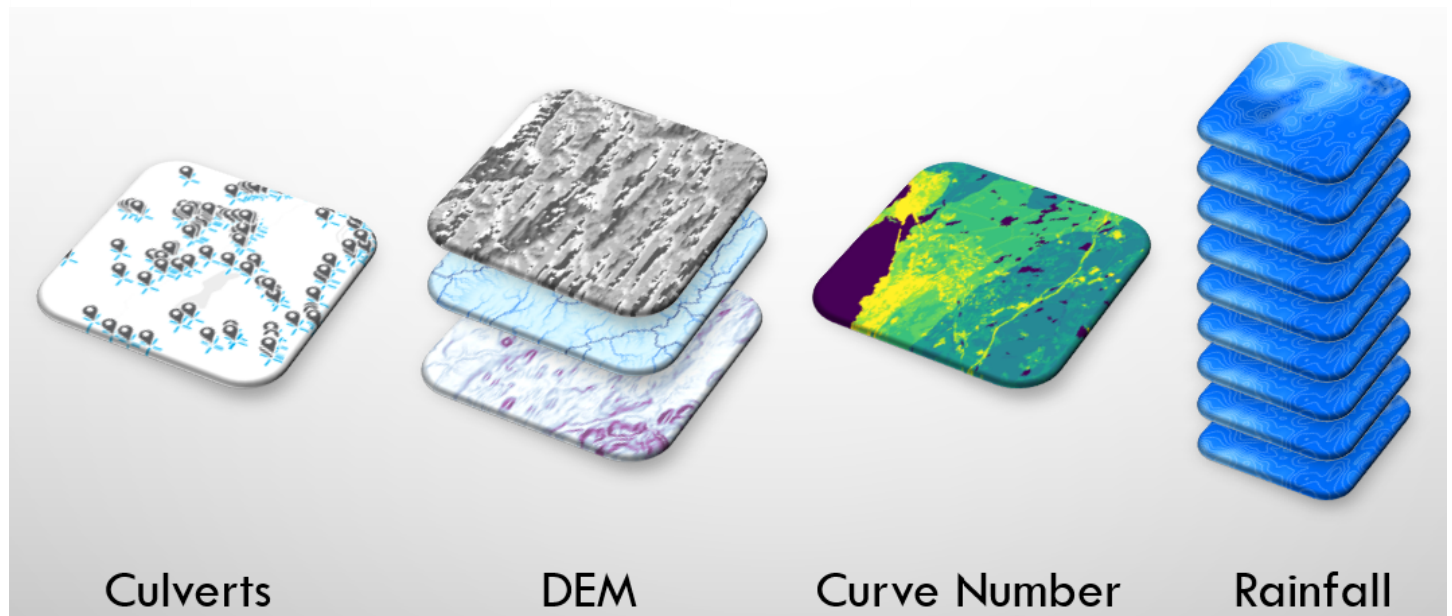
4.1 Overview

The calculators provided by the Culvert Toolkit rely on specific spatial datasets to derive location-specific parameters that are then used as inputs to stormwater runoff and culvert capacity models.

4.1.1 Types of Input Datasets

The section describes what, where, and how to acquire the various inputs required to run the tool.

Note that a number of these inputs require some basic competency in GIS to create, as they are not necessarily available off-the-shelf (depending on your area of interest).



NAACC culvert/crossing records

The culvert/crossing records available from NAACC provide the starting point for the analysis.

See [Working with NAACC Culvert Data](#) for more information.

Digital Elevation Model (DEM)

The DEM provides the data for determining what is upstream of a culvert/crossing, as well as some characteristics of that area that are important to calculating peak flow.

Sources for a DEM could be:

- Elevation raster
- Elevation TIN
- Elevation point clouds (i.e., from LiDAR)

From any of those sources, the analytical tools require one or more of the following rasters for your area of interest.

- slope
- flow direction
- flow length (optional)

See [Digital Elevation Model-derived Data](#) for more information.

Curve Number

The curve number represents the runoff potential of the contributing watershed above a culvert. It is derived from a combination of landcover and soil condition data.

Sources:

- Soils
- Landcover
- [TR-55 Manual Table 2.1](#)

See [Digital Elevation Model-derived Data](#) for more information.

Rainfall

Rainfall data is required in order to estimate peak flow.

See [Getting NOAA Rainfall Data](#) for more information.

Sources:

- NOAA rainfall rasters for your area of interest

4.2 Working with NAACC Culvert Data

NAACC provides a data standard for capturing culvert data. Much of this toolkit relies on input data having been provided according to that standard.

Follows is a process for getting

4.2.1 Initial Download and Clean-Up

Raw data from NAACC comes in the form of an Excel spreadsheet file (`.xls`). The sheet includes headers. For it to be readable by the toolkit, we need it to be purely tabular.

1. Download the Excel (`.xls`) file from [NAACC's website](#)

Select your area of interest:

Stream Crossing Explorer (SCE):
To analyze search results with the SCE, check the box before choosing your search parameters.
Note that **only** parameters still showing after checking the box will be used for your search. ☐

Location (choose multiple towns, watersheds):

Personnel:

Other:
Survey ID:
Crossing Code:

Dates:
"Date observed" is not available
Last updated from ...
Last updated until ...
Date observed from ...
Date observed until ...

Choose Data Sets (choose multiple):

Download the "detailed" type:

Data Set	GIS	Excel Reports		
NAACC (after 6/1/2015)	shapefile	simple	detailed	Not available

This will give you an `xls` file, which you can open in Excel or other spreadsheet software.

Do not download the shapefile available from NAACC. It does not have all the fields required for modeling and is limited to crossing locations only.

Identification

- `Survey_Id` is the ID of the crossing
- `Naacc_Culvert_Id` is the ID of the culvert

Both of these values together are used through the remainder of the tools to differentiate and aggregate records where necessary. To make compatible with some other GIS tools (specifically, raster process tools), we store IDs as integers (not text).

2. Clean-Up

Minimally, delete the file header (the first four rows) from the XLS file. The table needs to be in purely tabular format in order to be read and validated by other tools.

	A	B	C	D	E	F	G	H	I	
1	In the "NAACC (after 6/1/2015)" report below, crossings with multiple culverts are displayed on several rows, one row per culvert. Each row having the same crossing ID will have a different culvert displayed at the end of the row. A value of "-1" for the Aqua_Pass_Score equals "Missing data." Otherwise, the value "-1" equals "No data."									
2										
3										
4										
5	Survey_Id	Crossing_Code	Alignment	Aqua_Pass_Score	AOP	Approved	Bankfull_Width	Bankfull_Width_Confidence	Coordinator	Cro

Remove rows 1-4 containing the notice about crossing record structure. The column names should end up in row 1.

Optionally: Pre-process the NAACC records

You may want to pair back the download to records of interest or otherwise do some QA/QC on the raw NAACC data; for example:

- remove certain types of culvert, e.g., bridges, fords, or ones that don't have any capacity measurements.
- remove multiple older surveys for crossing locations, or pick the survey with the most complete information
- import this table into GIS and georeference it yourself, in order to move features to streams or flow lines on a digital elevation model

Regardless, as long as the original NAACC schema is preserved through your process, subsequent tools will be able to use it.

The [NAACC Table Ingest \(described below\)](#) will automatically flag records that aren't valid for capacity calculations, including those that aren't culverts or multi-culverts, or are missing measurements and classifications required for calculating capacity.

3. Save as a CSV file

Subsequent tools work on CSV files or feature classes in

4.2.2 Run the *NAACC Table Ingest* tool

The *NAACC Table Ingest* tool will read in, validate, and extend a NAACC-compliant source table, and save the output as geodata, i.e., an Esri file geodatabase feature class.

Use your prepared CSV as an input. Note that if you've imported that `CSV` to a file geodatabase table or feature class already, that feature class will also work as an input.

This tool will:

- validate the records (e.g., check if the measurements for dimensional fields are positive numbers)
- flag those that aren't valid inputs to the tool (either they aren't the right kind of infrastructure or they have invalid field values)
- add new toolkit-specific fields and extract-transform-load individual values to those fields, typically doing either a unit conversion (imperial to metric) or a text-based crosswalk (for certain descriptive fields like crossing, inlet, and outlet types)

What is changed in the data by this tool:

New fields related to data validation:

- `include`
- `validation_errors`

New fields for storing transformed copies of capacity model-specific attributes (e.g. values with unit conversion applied).

- *NAACC field: new field*
- `Crossing_Type` : `xing_type`
- `Crossing_Comment` : `comments`
- `Crossing_Structure_Length` : `length`
- `Road_Fill_Height` : `hw`
- `Inlet_Type` : `in_type`
- `Inlet_Structure_Type` : `in_shape`
- `Inlet_Width` : `in_a`
- `Inlet_Height` : `in_b`
- `Material` : `culv_mat`
- `Slope_Percent` : `slope`
- `Outlet_Structure_Type` : `out_shape`
- `Outlet_Width` : `out_a`
- `Outlet_Height` : `out_b`

New fields for storing calculator results:

- `culvert_capacity` : the capacity of the culvert
- `crossing_capacity` : the total capacity of the crossing (of which this culvert record may be one of many culverts). If just one culvert in the crossing, this is the same as `culvert_capacity`, otherwise it is the sum of `culvert_capacity` for all culverts in the crossing
- `max_return_period` : the max return period for the crossing

4.2.3 Optionally: Run the *NAACC Data Snapping* tool

Depending on your needs, you may find that the location precision of the supplied NAACC data was not adequate compared to the accuracy of your [hydrologically corrected DEM](#). In that case, you may have moved culverts manually or snapped points to streams.

If you need to update your NAACC table with better location data from an external table--a *Adjusted Geometry File*--use the *NAACC Data Snapping tool* to update the input NAACC-compliant source table with locations from another table.

This tool basically runs a reverse 1-to-many join, replacing geometry in one or more feature class records with a single geometry from feature in a reference table using a column-based match.

This tool generates a new feature class. An additional field `moved` is added indicating whether the culvert has been moved based on a match with the *Adjusted Geometry File*.

What is changed in the data by this tool:

- updated geometry
- new field: `moved` : a boolean field indicating if the record has been re-snapped based on the supplied reference geometry.

4.3 Digital Elevation Model-derived Data

A good digital elevation model (DEM) is key to good culvert model outputs, particular for estimating peak flow. This section covers sourcing elevation data, the importance of hydrological correction, and the kinds of data you can expect to need to derive from your elevation data.

4.3.1 Sourcing elevation data

The sourcing of elevation data is typically locale-specific. The various tools in the Culvert Toolkit that use this data require them in raster format, and you may be able to acquire raster DEM data directly. If not, rasters derived from contour data or a LiDAR point cloud can suffice (though how to do that is beyond the scope of this help documentation).

When acquiring elevation data for this toolkit, there are two primary considerations:

- the DEM must have complete watershed/basin coverage for your area of interest (otherwise the delineations may be cut-off); and,
- the spatial accuracy must be consistent with other datasets

4.3.2 Hydrologically-correct DEMs

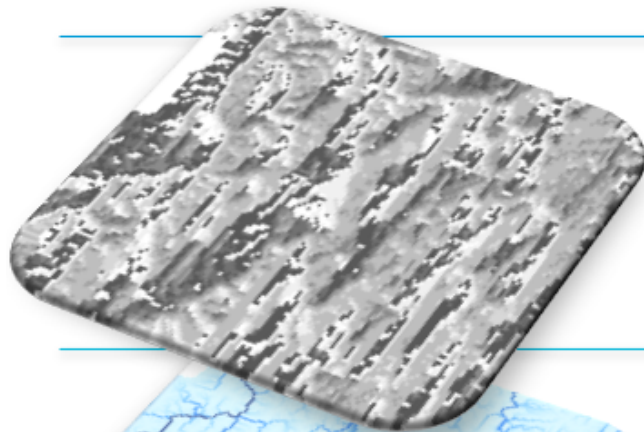
For the purposes of peak-flow modeling, the hydro-correctedness of the elevation data is important.

You'll need to determine the trade-off between speed and accuracy based on your use case:

- Ideal: full hydrologic correction of the DEM and re-locating of culverts with LIDAR and imagery
- Workable: fill sinks in DEM; burn hydro lines into the DEMs; snap culverts to available hydro stream lines;

The best approach for determining DEM hydrologic-accuracy and NAACC location-correctedness depends on your use case.

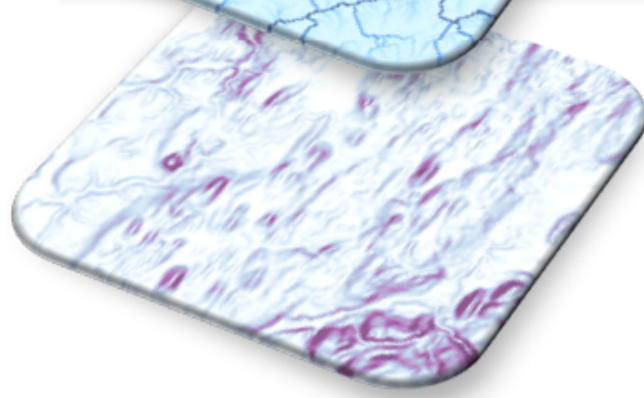
4.3.3 Derived Data for use in the tools



Flow Direction



Flow Length (m)



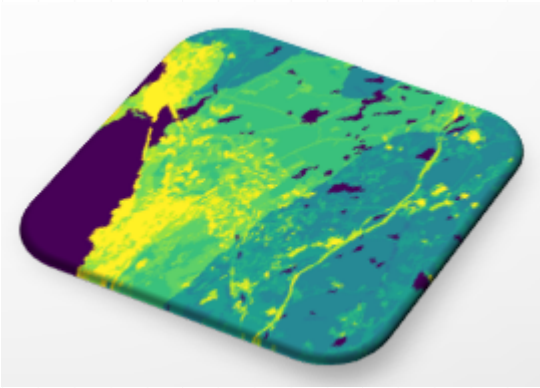
Slope (%)

The tools in this toolkit use the following rasters derived from the elevation raster:

- Flow Direction (derive from hydro-corrected DEM)
- Flow Length (derive from hydro-corrected DEM)
- Slope (use original, un-hydro-corrected DEM)

When deriving these rasters, ensure that all rasters are "snapped" to their source: their extents, cell sizes, and positioning should match each **exactly**.

4.4 Generating a Curve Number Raster



The curve number represents the runoff potential of the contributing watershed above a culvert. It is derived from a combination of landcover and soil condition data.

4.4.1 Sources

- Soils
- Landcover
- [TR-55 Manual Table 2.1](#)

4.4.2 Methods

(to be completed)

4.5 Getting NOAA Rainfall Data

Location-specific rainfall measurements from NOAA are required inputs for the tool. Specifically: rainfall rasters from [NOAA's National Weather Service - Hydrometeorological Design Studies Center - Precipitation Frequency Data Server \(PFDS\)](#) are used to calculate average rainfall over the upstream contributing area to a culvert, which is used to calculate peak-flow at the culvert.

4.5.1 NOAA Rainfall Raster Downloader

The Culvert Analysis Toolkit includes a tool that automatically downloads the correct rasters for your area of interest: **NOAA Rainfall Raster Downloader**.

The NOAA Rainfall Raster Data Downloader does just that: it downloads rainfall rasters for your study area from NOAA's National Weather Service - Hydrometeorological Design Studies Center - Precipitation Frequency Data Server (PFDS).

By default, this tool acquires rainfall data for 24hr events for frequencies from 1 to 1000 years. All rasters are saved to a user-specified folder.

This tool creates a precipitation source configuration JSON file in the output folder. The JSON file is used as a required input to other tools—specifically those that calculate runoff/peak-flow.

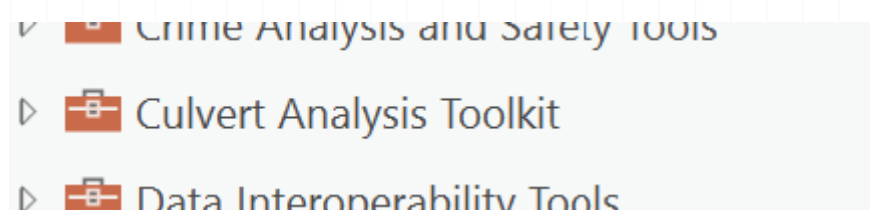
Note that NOAA Atlas 14 precip values are in 1000ths of an inch; the capacity calculator and other tools convert the values to centimeters on-the-fly.

NOAA rainfall rasters cover a large geographic area, so you may only need to use this tool occasionally.

5. Analysis Guides

5.1 Toolbox Overview

The Culvert Analysis Toolkit is currently implemented as ArcToolbox for use in ArcGIS Pro



Each tool in the toolbox contains built-in help text to explain tool functionality, inputs, and outputs. Summaries of tool usage follow.

5.1.1 NOAA Rainfall Raster Data Downloader

The *NOAA Rainfall Raster Data Downloader* does just that: it downloads rainfall rasters for your study area from [NOAA's National Weather Service - Hydrometeorological Design Studies Center - Precipitation Frequency Data Server \(PFDS\)](#).

By default, this tool acquires rainfall data for 24hr events for frequencies from 1 to 1000 years. All rasters are saved to a user-specified folder.

This tool creates a precipitation source configuration `JSON` file in the output folder. The `JSON` file is used as a required input to other tools—specifically those that calculate runoff/peak-flow.

Note that NOAA Atlas 14 precip values are in *1000ths of an inch*; the capacity calculator and other tools convert the values to *centimeters* on-the-fly.

NOAA rainfall rasters cover a large geographic area, so you may only need to use this tool occasionally.

5.1.2 NAACC Table Ingest

The *NAACC Table Ingest* tool will read in, validate, and extend a NAACC-compliant source table, saving the output as geodata (e.g., a file geodatabase feature class) for use in other culvert analysis tools, like the NAACC Culvert Capacity Calculator

5.1.3 NAACC Data Snapping

The *NAACC Data Snapping* tool can be used to reposition features in a NAACC-compliant feature class to locations in another feature class; e.g., move the NAACC culvert records to point features that have been snapped to streams on a hydrologically corrected DEM.

5.1.4 Curve Number Generator

(planned; previously implemented in the stand-alone [Peak Flow Calculator toolbox](#))

5.1.5 NAACC Culvert Capacity

The *NAACC Culvert Capacity* tool measure the capacity of culverts to handle storm events using a lightweight version of a TR-55 model. It does this by:

- calculating the capacity of the culvert(s) at a crossing
- calculating peak flow at the culvert over a hydrologically corrected digital elevation model for 24 hour storm events with frequencies of 1 to 1000 years
- comparing capacity of individual culverts and all culverts at a crossing to each peak-flow, and flagging the event at which the culverts and crossings exceed capacity.

Culvert location data must be NAACC schema-compliant.

See the [Workflow Guide](#) for more information on using this tool.

5.1.6 Peak-Flow Calculator

(planned; currently implemented with the NAACC Culvert Capacity tool)

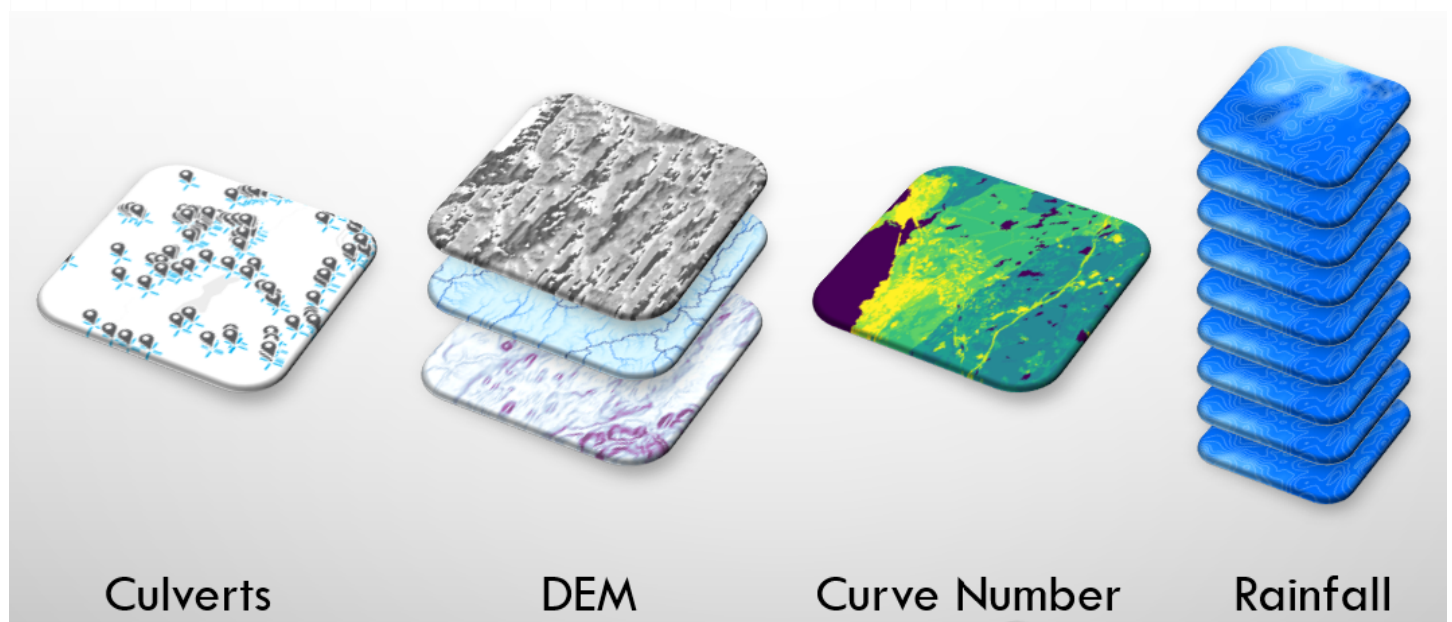
Calculate peak-flow for one or more points over a hydrologically corrected DEM. Points do not need comply with any predefined data model (such as NAACC).

5.2 The Capacity Calculator Workflow

The NAACC Culvert Capacity tool measure the capacity of culverts to handle storm events using a lightweight version of a TR-55 model created by the Cornell Soil & Water Lab. It does this by:

- calculating the capacity of the culvert(s) at a crossing
- calculating peak flow at the culvert over a hydrologically corrected digital elevation model for 24 hour storm events with frequencies of 1 to 1000 years
- comparing capacity of individual culverts and all culverts at a crossing to each peak-flow, and flagging the event at which the culverts and crossings exceed capacity.

5.2.1 Data Preparation



1. Get and pre-process the NAACC table: [Working with NAACC Culvert Data](#)
2. Create (or get) Digital Elevation Model-derived rasters: flow direction, slope, and (optionally) flow length: [Digital Elevation Model-derived Data](#)
3. Create (or get) a Curve Number raster: [Generating a Curve Number Raster](#)
4. Download rainfall data from NOAA: [Getting NOAA Rainfall Data](#)

Data Preparation processes are covered on the [Data Overview](#) page in more detail.

5.2.2 Tool Usage (ArcToolbox)

The ArcToolbox implementation of the **NAACC Capacity Calculator** uses the inputs described above.

The screenshot shows the 'Geoprocessing' window with the tool 'NAACC Culvert Capacity' selected. The 'Parameters' tab is active, and the 'Environments' tab is also visible. The tool has several input parameters grouped under expandable sections: 'Culverts', 'DEM', 'Curve Number', 'Rainfall', and 'Outputs'. Each parameter is represented by a text box with a dropdown arrow and a folder icon to its right, indicating it's a file path or selection. The 'Run' button is at the bottom right.

Geoprocessing NAACC Culvert Capacity

Parameters Environments

▼ **Culverts**

Culvert Points
4. NAACC Culverts, snapped (naacc_points_snapped)

▼ **DEM**

Flow Direction
Flow Direction - flow_direction.tif

Flow Length
Flow Length - flow_length.tif

Slope
Slope - slope.tif

▼ **Curve Number**

Curve Number
3. Curve Number - curveno.tif

▼ **Rainfall**

Precipitation Configuration File
\\inputs\rainfall\sample_rainfall_rasters\rainfall_rasters_config.json

▼ **Outputs**

Result Points
output_culverts_demo

Run

Note that the Rainfall input isn't the rainfall rasters, but the configuration `JSON` file generated by the **NOAA Rainfall Download** tool.

The only **output** parameter is the location of the output point feature class that will include the analysis results. Note that from the name specified, the name for an additional polygon feature class is derived. More on outputs below.

5.2.3 Results



Two feature classes are produced by the calculator:

Analyzed culverts

This is an outpoint point feature class, containing culvert records with capacity and peak flow analysis results.

This does not include all of the fields from the original NAACC table. Only those added during the NAACC table ingest process (see [Working with NAACC Culvert Data](#)) and additional fields for the peak flow analysis are shown.

For the peak flow analysis, four new fields will be added for every storm event frequency modeled: 1, 2, 5, 10, 25, 50, 100, 200, 500, and 1000-year storms. The four new fields are:

1. `yX_culvert_peakflow_m3s` : peak flow at the culvert for that event
2. `yX_culvert_overflow_m3s` : the culvert "overflow" for that event: how much the culvert is under or over capacity given peak flow. A negative number indicates that the culvert is under-capacity.
3. `yX_crossing_peakflow_m3s` : crossing peak flow for that event
4. `yX_crossing_overflow_m3s` : the crossing "overflow" for that event: how much all the culverts at the crossing are under or over capacity given peak flow to their common location. A negative number indicates that the crossing is under-capacity.

`x` stands in for the storm event frequency number. All values are in cubic meters/second.

Delineated catchment areas

An output polygon feature class, containing delineation areas for each culvert, with all values derived from the input layers used for the peak flow analysis. This includes:

- area (square kilometers)
- average rainfall (1000ths/inch) for each storm event frequency
- average slope (%)
- flow length (meters)

5.3 Working with Capacity Calculator Results

(to be completed)

6. Calculators

6.1 Peak Flow

Runoff peak discharge of given point's watershed is determined using the SCS graphical curve number method. For more information on this method, see [Technical Release 55](#).

6.1.1 In the code

The time of concentration equation used in this tool is located in `src/drainit/calculators/runoff.py`, in the `time_of_concentration_calculator` function

The peak flow calculator function in this tool is located in `src/drainit/calculators/runoff.py`, in the `peak_flow_calculator` function.

6.2 Culvert Capacity

Culvert Capacity is calculated using an equation from [USDOT FHA Publication No. FHWA-HIF-12-026, Equation A.3, pg 191](#).

The equation, expressed in [Python](#), is as follows:

```
capacity = (
    culvert_area_sqm * math.sqrt(
        culvert_depth_m * (
            (
                head_over_invert / culvert_depth_m
            ) - coefficient_y - coefficient_slope * slope_rr
        ) / coefficient_c
    )
) / si_conv_factor
```

Variables shown above are as follows:

- `culvert_area_sqm` : internal surface area of the culvert
- `head_over_invert` : Hydraulic head above the culvert invert, meters
- `culvert_depth_m` : Culvert depth. Diameter or dimension b, (height of culvert) meters
- `slope_rr` : slope rise/run (meters)
- `coefficient_slope` : slope coefficient from FHWA engineering pub HIF12026, appendix A. -0.5, except where inlet is mitered in which case +0.7
- `coefficient_y` : coefficient based on shape and material from FHWA engineering pub HIF12026
- `coefficient_c` : coefficient based on shape and material from FHWA engineering pub HIF12026
- `si_conv_factor` : adjustment factor for units (SI=1.811), defaults to 1.811

The equation returns `capacity` : capacity in cubic meters / second (m³/s)

Constants `coefficient_c`, `coefficient_y`, `coefficient_slope` are set based on the culvert entrance shape and material, from FHWA engineering pub HIF12026, appendix A.

6.2.1 In the code

The capacity calculator module in this tool is located in [src/drainit/calculators/capacity.py](#)

7. Developing the Toolkit

7.1 Setup Anaconda Python and dependencies

Development requires access to the `arcpy` library include with ArcGIS Pro, and a ArcGIS Pro-derived Conda environment that includes the dependencies listed in `setup\requirements.txt`

7.2 Project Structure

The project is structure so there is a fairly clear separation of concerns between the code that handles

- the science behind the calculators
- the geoprocessing tools used to derive spatial statistics from the various map layers
- the specific i/o requirements and interfaces expected in end-user workflows

7.2.1 src/

The folder contains external-facing interfaces that use the `drainit` package. It includes:

- `CulvertToolbox.pyt` and associated `xml` metadata.
- legacy `drainit.tbx` file (replaced by `CulvertToolbox.pyt`)
- `tbx_*.py` scripts, which are workflow-specific and map 1:1 with tools in the ArcGIS Pro toolbox `drainit.tbx`.

7.2.2 src/drainit/

This is the top-level package.

It contains a few scripts:

workflows.py

Contains the code for executing analytical workflows at the highest level of abstraction. A single workflow is represented by a single python class.

All workflow classes inherit from a base class that contains properties and methods for reading/writing workflow state to a JSON configuration file.

cli.py

Command line interface to the scripting tools (WIP).

config.py and settings.py

Constants used for script execution.

models.py

Internal data models used throughout the package.

calculators/

Module containing the science and business logic of the various calculators available in the package:

- [runoff/peak flow](#)
- [culvert capacity](#)

services/

Scripts for interacting with third-party domain-specific data sources (e.g., NOAA rainfall data, NAACC culvert data) and geoprocessing tools (e.g., Esri ArcPy, Whitebox tools).

gp/

Geoprocessing services designed on specific provider tools (e.g., ESRI, Whitebox) and exposed through a generic class that is called by the workflow tools. This ensures `workflow.py` can run GP tools without needing to know exactly what underlying geoprocessing library is being used.

esri/

This folder contains the built ArcGIS Pro Python toolbox, its metadata, and an `arcpy` interface script.

These are automatically created during the build process and do not need to be manually edited under normal circumstances.

Scripts: `noaa` and `naaccc`

These are data provider-specific scripts that do domain-specific work with specific data types.

7.2.3 tests/

Integration tests for workflows and tasks within workflows.