

Prioritizing Operations Support Tool (POST)

A user guide for POST ArcGIS pro toolbox
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POST was developed by New Light Technologies Inc. for FEMA's Response Geospatial Office in 2018-2019. Contributors include: Ran Goldblatt, Chris Vaughan, Glen Russell, Madeline Jones, Carl Anderson, and Andrew Strauch.

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I. Introduction

During a disaster, first responders must quickly understand the magnitude and the nature of the event in order to effectively supply aid to impacted citizens and communities. Timely and accurate intelligence about the scope of the event are key for effective and successful response decisions such as deployment of resources, timeliness of rescue operations and containment of hazards. Yet, the damage and destruction caused by the very nature of such events often hinder the ability for responders to perform impact assessments on the ground. To optimize the value of remotely sensed data for disaster response and recovery, collection operations must be rapidly planned, organized and implemented.

The POST (Prioritizing Operations Support Tool) was developed to address the need for a systematic method to prioritize and manage response operations during disasters. While the tool was initially developed to guide collection efforts of satellite imagery in preparation for and in response to disasters, the methodology behind it is robust enough that the tool can be utilized to support the full lifecycle of an event, including search and rescue operations.

High priority (e.g. for collection of imagery or for search and rescue operations) is assigned to areas of interest (AOIs) that are most likely to be severely impacted or damaged, where communities are relatively more vulnerable and less capable of fully recovering. To standardize the representation of high priority AOIs through the aggregation of point-level and raster data, we implement the US National Grid System (USNG), which is commonly used for disaster response operations. The USNG is an alpha-numeric reference system that overlays the UTM coordinate system. A USNG spatial address is broken down into three parts: Grid Zone Designation (for a world-wide unique address); 100,000-meter Square Identification (for regional areas) and Grid Coordinates (for local areas). USNG data are available in GIS Shapefile format from the National Geospatial-Intelligence Agency (NGA) and from other providers¹. Currently, the tool uses 1km and 5km USNG grid cells (Figure 1).

¹ <https://usngcenter.org/>



Figure 1 USNG cells. The tool relies on 1km and 5km grid cells. Each cell is identified by a unique number.

For each USNG cell (1km² or 5km²), hazard probability score is calculated based on best available modeled and observed hazard data (e.g. flood depth grids, surge probability and wind speed). To estimate the event's impacts upon communities, this score is weighted by the number of residential parcels within a cell. A high score signifies a cell with a high number of residential parcels that are most likely to be severely affected or damaged. POST can also be run when hazard data (modeled or observed) is not yet available, for example, several days prior to a forecasted hurricane. In this case, prioritization will be determined according to the population vulnerability as well as

the density of residential parcels in the potentially affected area.

Socio-demographic characteristics collected by the American Community Survey (ACS) of the U.S. Census Bureau of Statistics are used to calculate the relative distribution of vulnerable population. The American Community Survey (ACS) is an ongoing survey that provides vital information on a yearly basis about the US and its citizens. For geographic areas with smaller populations, the ACS samples too few housing units to provide reliable single-year estimates. For these areas, several years of data are pooled together to create more precise multi-year estimates. Since 2010, the ACS has published 5-year data (beginning with 2005–2009 estimates) for all geographic areas down to the census tract and block group levels². The most recent 5-year estimates data release is the *2013-2017 ACS 5-year Estimates*.

A selection of ACS estimates, such as the number of elderly people, unemployment rate, number of people on public assistance or food stamps, number of mobile housing units etc., are disaggregated from the administrative block group division to the USNG division. This USNG dataset is the basis for any POST run. During a POST run, a weighted Population Vulnerability Score (PVS) is calculated for each of the affected USNG cells. A high PVS might signify a highly populated area with a high number of unemployed people on food stamps, or an area with a high density of mobile homes. Then, a weighted hazard and demographic score is calculated for each cell. This score is translated into corresponding collection and/or search and rescue priorities. High priority is given to cells where vulnerable population is expected to be most significantly affected. This methodology assumes that top priority should be given to areas (USNG cells) that are (1) most likely to be severely hit and (2) where the most vulnerable population is most likely to be affected.

These predictions are updated as new forecasted or observed hazard data become available and POST outputs are shared among the disaster response community as a public ArcGIS map service³ by FEMA's Response Geospatial Office during events.

Currently, POST can be run as a tool (Toolbox) in ArcGIS Pro. The outputs of the tool include USNG grids enriched with the following: (1) relative population vulnerability scores (ranging from 1 to 10) ; (2) relative hazard probability scores (ranging from 1 to 10) and (3) relative collection priorities (ranging from 1 to 3).

²

https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf

³ As example of the tool's outputs can be found here:

<http://fema.maps.arcgis.com/home/item.html?id=00c5f294fd47449d8b58c6eedb1851ea>

The 1km and 5km USNG grid cells have been enriched with demographic data estimates extracted from the American Community Survey (ACS) of the US Census Bureau of Statistics (2013-2017 ACS 5-year Estimates). These block-group demographic estimates were intersected with USNG cells to calculate the approximate fraction of overlap of the block-group within each cell. These fractions were then multiplied by the total demographic characteristics of each block group in order to estimate the proportion of demographics to attribute to each USNG cell. (Figure 2).

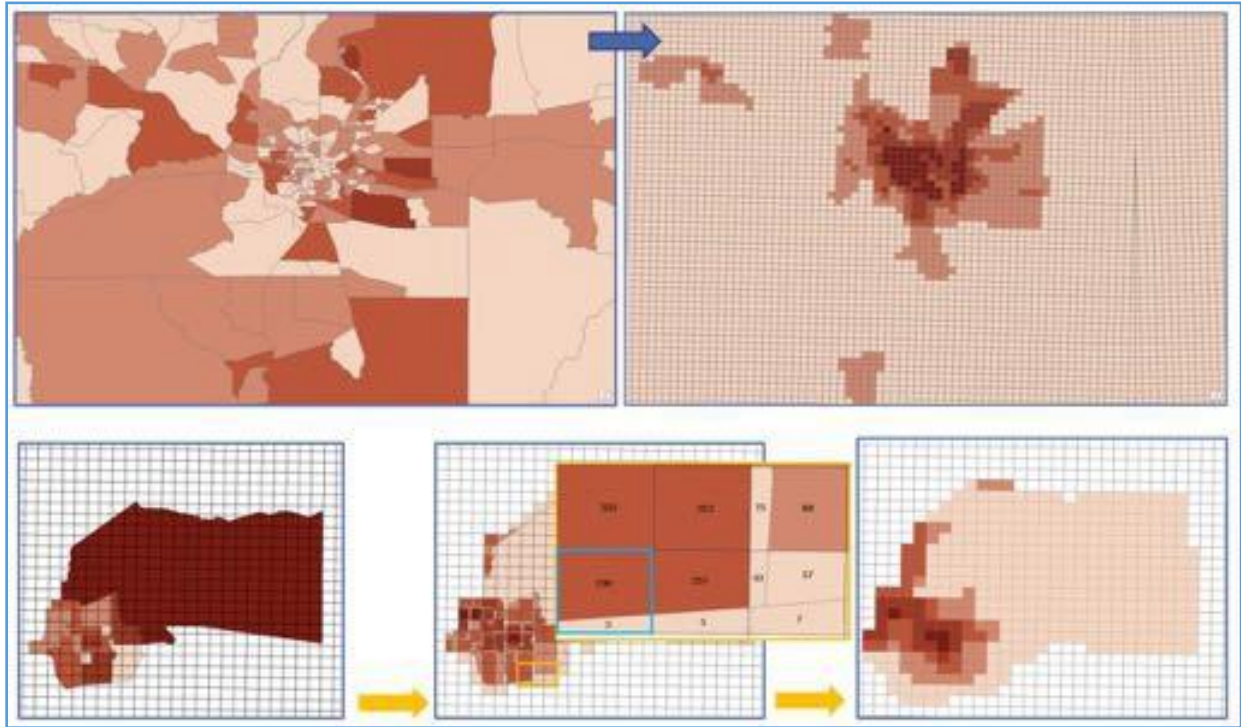


Figure 2 ACS 2017 5-year estimates are tabulated to level of the USNG division.

Each USNG cell includes the following information (the numbers are per cell):

1. Number of Housing units
2. Population age 65 and over
3. Population age 16+ and unemployed
4. Population 16+ not in labor force
5. Population American Indian or Alaska Native
6. Number of Households in poverty

7. Number of Households on disability and food stamps
8. Number of Households on disability no food stamps
9. Number of Households with food stamps/SNAP
10. Number of Households with public assistance
11. Number of Housing units that are mobile homes
12. Number of people
13. Number of Households

POST can be run under three scenarios:

1. **Only hazard extent is available:** in this scenario, hazard data (whether modelled or observed) is not yet available and the only available information is a general forecasted (or observed) extent of the event. Any type of geometry (polygons, points or lines) can be used to indicate the extent of the hazard. Examples include: a polygon representing a hurricane cone of uncertainty or a wildfire extent. When only hazard extent is available, the tool will calculate a relative population vulnerability score and a priority score for each cell that overlaps with the affected extent (not accounting for the spatial extent and distribution of the hazard). These outputs should be used with caution, as they only represent the vulnerability of the population in the entire area, without considering the magnitude and distribution of the hazard.
2. **A layer of structures in the affected area is available, without hazard data:** in this scenario, no modelled or observed hazard data is available yet. The only available information is locations of affected structures, such as residential parcels, without modeled or observed hazard data. Examples include: a point layer of affected residential parcels or structures within a hurricane cone of uncertainty (Figure 3) or within the boundaries of a wildfire extent. The tool will output a relative population vulnerability score and a priority score, which are also based on the spatial distribution (number and density) of structures in each cell. In this scenario, no attribute data is required for the structural layer.

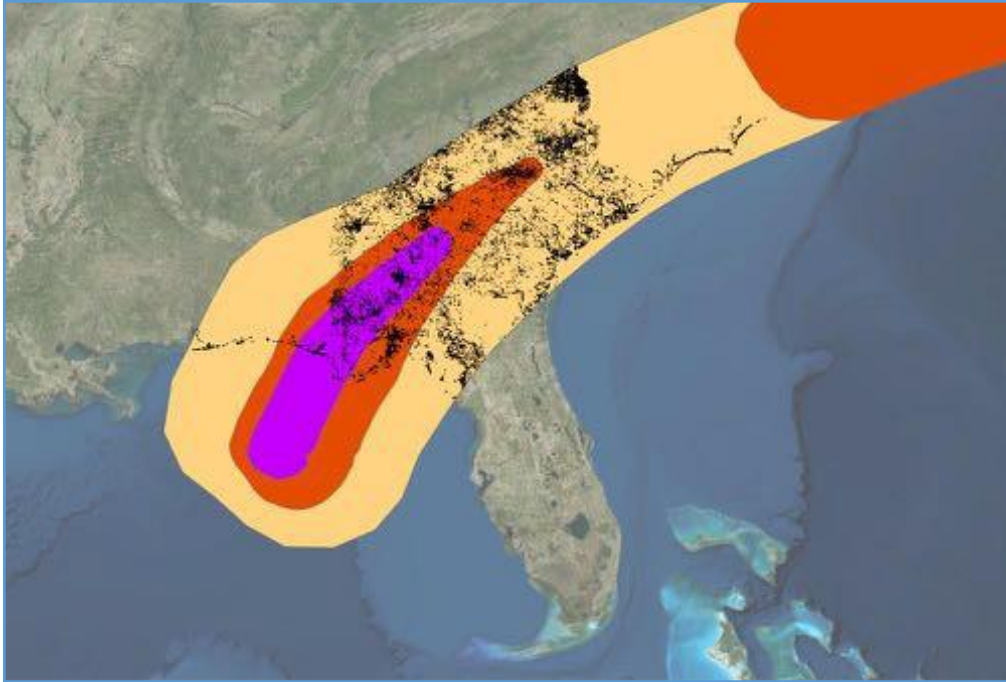


Figure 3 Illustration: Affected parcels within a hurricane's cone of uncertainty

3. **A layer of structures in the affected area is available, with hazard data:** in this scenario, an enriched structure layer (e.g. residential parcels) is available. Each structure is characterized by one or more hazard exposure scores (for example, per-parcel flood depth, surge probability, wind speed etc.). This layer is typically created during disasters as an input for FEMA's hazard exposure maps, by overlaying a point-on-structure layer with the hazard data (Figure 4). A relative prioritization score is calculated for each cell based on the hazard data, the number of structures per cell and population vulnerability. The tool expects to get as an input an enriched structure layer, i.e. a layer (shapefile or feature class) that stores the affected structures (points) within the disaster extent, which also include per-structure hazard data.

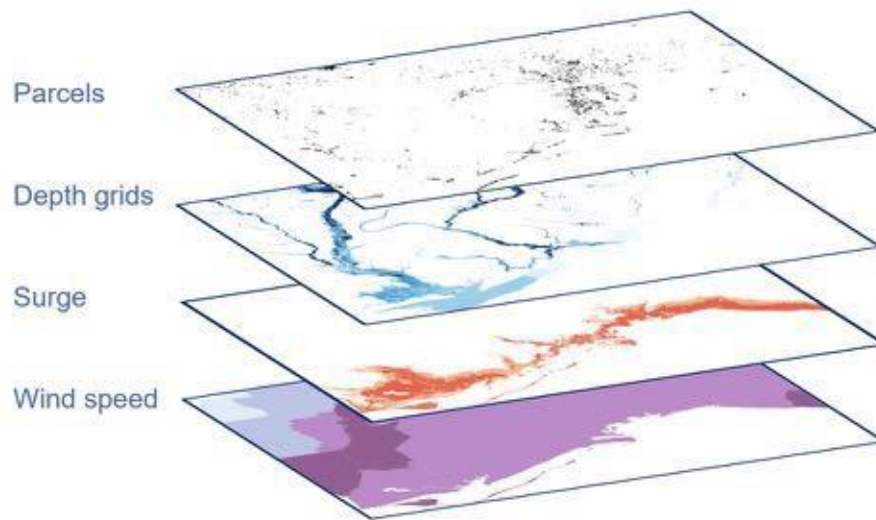








Figure 4 Enriching a point-on-structure layer with hazard data. Each parcel is characterized with a hazard score.

II. Running POST in ArcGIS Pro

POST should be run on the most updated version of ArcGIS Pro. The tool script parameters need to point the location of the ArcGIS Pro python file on your computer. These python scripts are included in the repo package downloaded from National Disasters site. Depending on which tool one is running: Hazard Extent - point the script parameter to SocialVulnerability_OnlyHazardExtent.py. Enriched Parcels - point to script parameter to SocialVulnerability_EnrichedParcels.py.

	.gitignore	12/12/2019 3:16 PM	Text Document	2 KB
	POST_ArcGIS_Pro.tbx	12/12/2019 3:16 PM	ArcGIS Toolbox	39 KB
	POSTTutorial.docx	12/12/2019 3:16 PM	Microsoft Word Doc...	1,905 KB
	README.md	12/12/2019 3:16 PM	MD File	2 KB
	SocialVulnerability_EnrichedParcels.py	12/12/2019 3:16 PM	Python File	17 KB
<input checked="" type="checkbox"/> 	SocialVulnerability_OnlyHazardExtent.py	12/12/2019 3:16 PM	Python File	8 KB

Tool Properties: Social Vulnerability and Collection Priorities (only with hazard extent) X

General Parameters Validation	Name SVBasedOnExtent Label Social Vulnerability and Collection Priorities (only with hazard extent) Script File C:\FEMA\POST\POST-Population-Vulnerability-1.0\POST-Population-Vulnerability-1.0\codes\SocialVulnerability_OnlyHazardExtent.py Options <input type="checkbox"/> Import script <input type="checkbox"/> Set password <input checked="" type="checkbox"/> Store tool with relative path Learn more about script tools
--	---

OK
Cancel

ArcGIS Pro should first be installed.

Step 1:

Launch ArcGIS Pro and open a new (or existing) project (Figure 5).

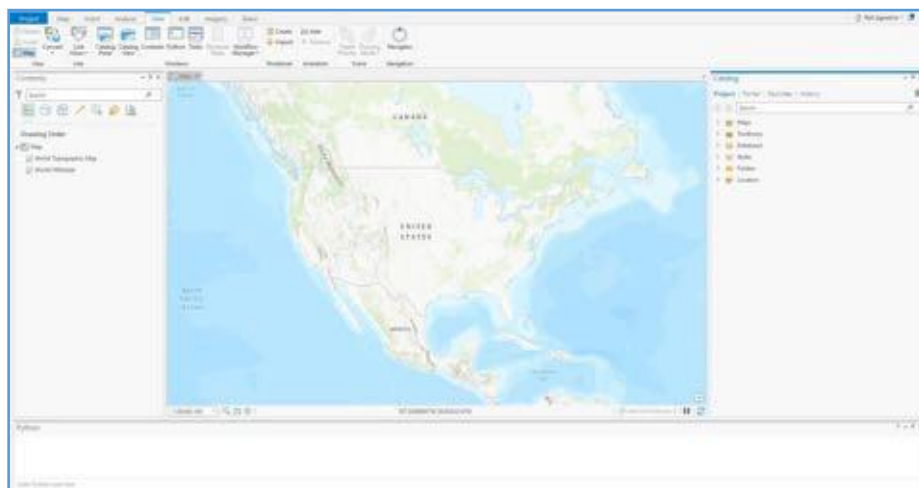



Figure 5

Step 2:

Make sure the Catalog pane is visible (Figure 6). If you do not see this pane in the project, click on the **catalog pane** icon (under: View  Catalog pane) (Figure 7).

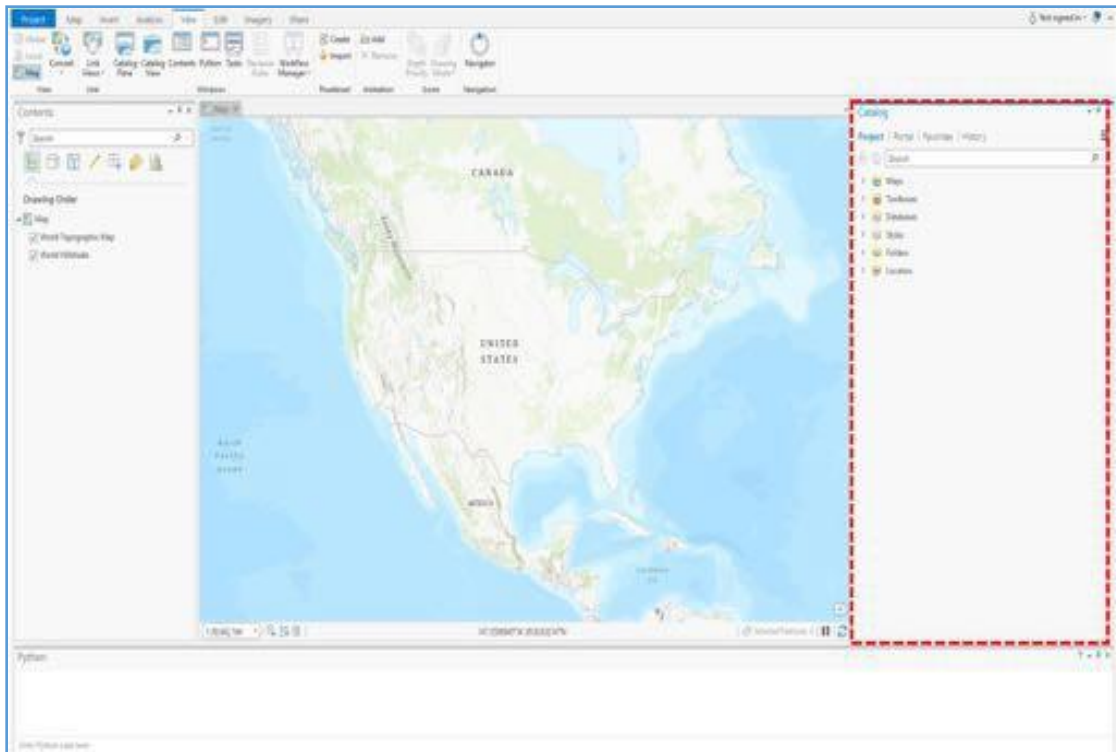


Figure 6

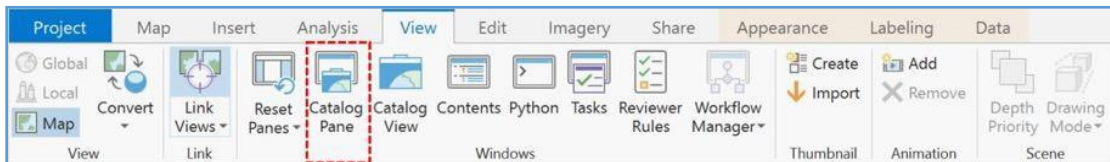


Figure 7

Step 4:

In the Catalog pane, right click on “Toolboxes” (Figure 8) and select “Add Toolbox” (Figure 9).

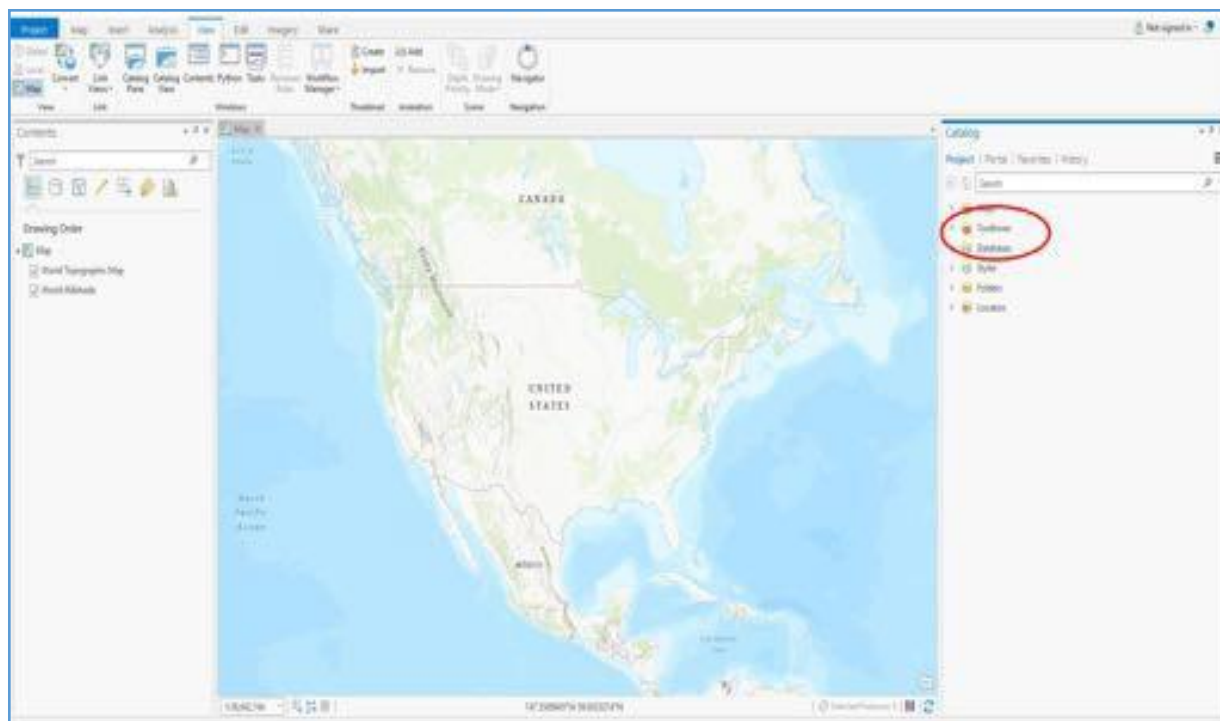


Figure 8

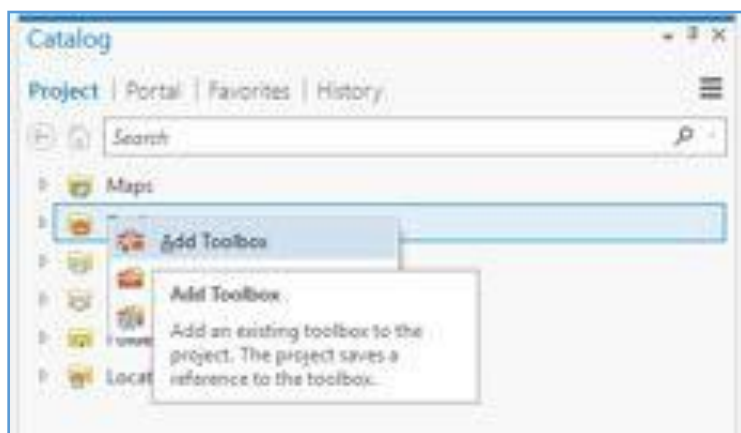


Figure 9

Step 5:

Point to the location of the POST toolbox (Figure 10). The name of the toolbox is: *POST_ArcGIS_Pro.tbx*. The toolbox is included in the repo package the user downloads.







 .gitignore	12/12/2019 3:16 PM	Text Document	2 KB
<input checked="" type="checkbox"/>  POST_ArcGIS_Pro.tbx	12/12/2019 3:16 PM	ArcGIS Toolbox	39 KB
 POSTTutorial.docx	12/12/2019 3:16 PM	Microsoft Word Doc...	1,905 KB
 README.md	12/12/2019 3:16 PM	MD File	2 KB
 SocialVulnerability_EnrichedParcels.py	12/12/2019 3:16 PM	Python File	17 KB
 SocialVulnerability_OnlyHazardExtent.py	12/12/2019 3:16 PM	Python File	8 KB

Figure 10

Click OK.

The toolbox (*POST_ArcGIS_Pro.tbx*) consists of two tools (Figure 11):

- I. **Social Vulnerability and Collection Priorities (only with hazard extent)** – this tool should be used when only the hazard extent is available (e.g. a polygon representing a hurricane extent).
- II. **Social Vulnerability and Collection Priorities (with parcels)** – This tool should be used when structural data (e.g. residential parcels) is available (enriched and not enriched)

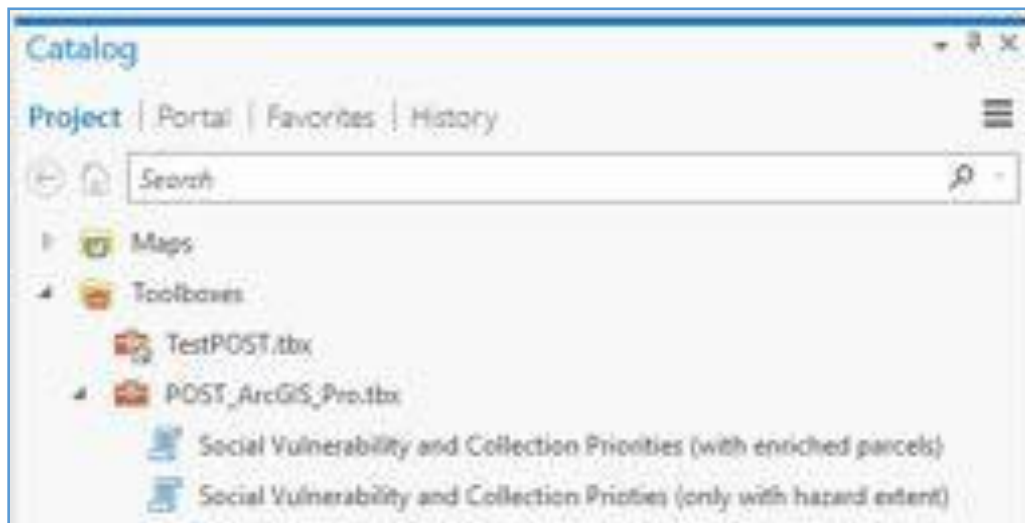


Figure 11

SCENARIO 1:

Parcel data is available (with or without hazard data)

in this scenario, a parcel layer (a point layer representing locations of structures) is available, with or without hazard data.

Under the toolbox (POST_ArcGIS_Pro.tbx), double click on the tool **Social Vulnerability and Collection Priorities (with enriched parcels)** (Figure 11).

The tool expects several parameters (Figure 12):

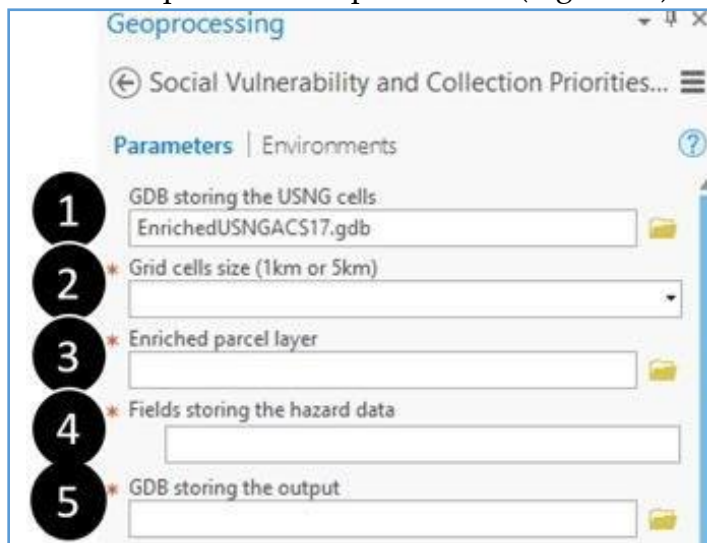


Figure 12

1 GDB storing the USNG cells:

The Geodatabase that stores the 1km and 5km USNG feature classes. The enriched USNG cells (i.e. USNG cells with ACS data) are located on the national disasters site. Will need login credentials to access:

<https://disasters.geoplatform.gov/publicdata/National/Data/POST/PopulationVulnerability/>

Disasters Public Files

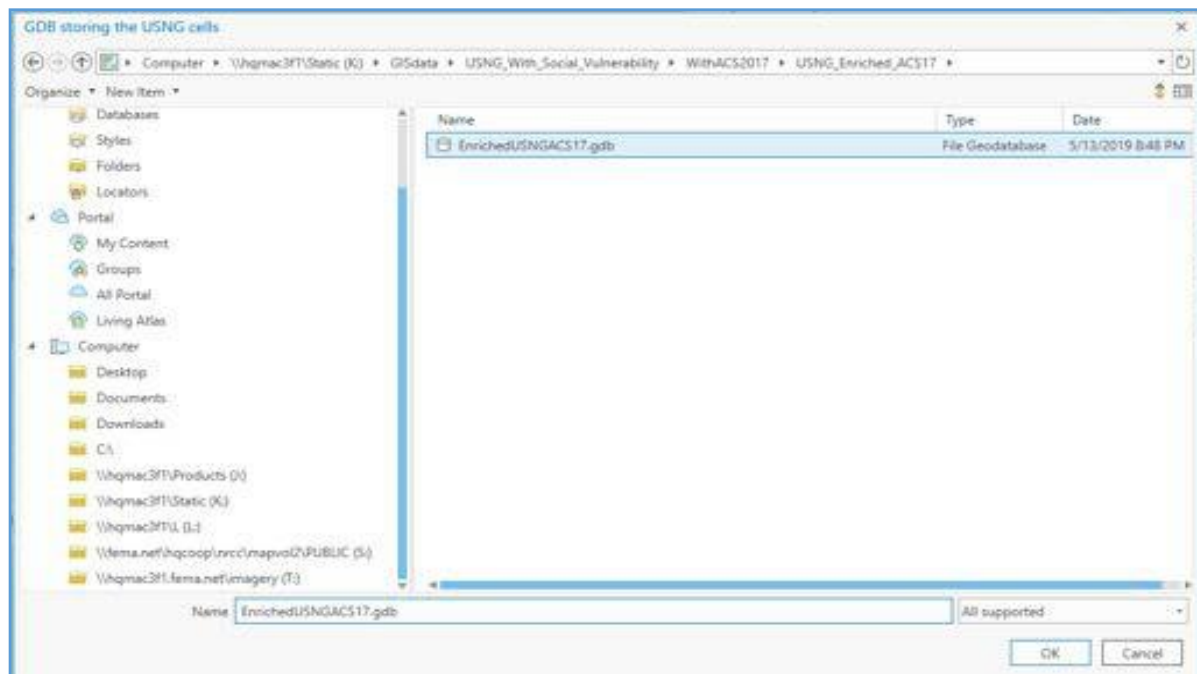
[Disasters Public Files](#) >> [National](#) >> [Data](#) >> [POST](#) >> [PopulationVulnerability](#)

Welcome to the Disasters Public Files

Files:

[EnrichedUSNG.zip](#) - 1.31 gb -- 2019-12-12 20:12:47

Folders:



2 Grid cells size (1km or 5km):

This is the size of the USNG cells that will be used to determine priorities. Select either "1" (for 1km) or "5" (for 5km) (Figure 14).

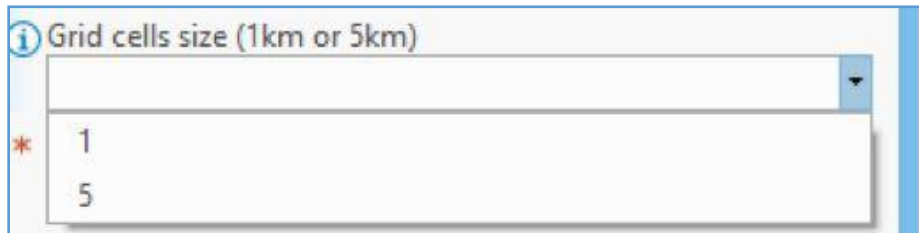


Figure 14

3 Enriched Parcel Layer:

Point to the location of the structure data layer (e.g., residential parcels, either a shapefile of a feature class), with or without per-structure hazard data (see, for example, Figure 15).

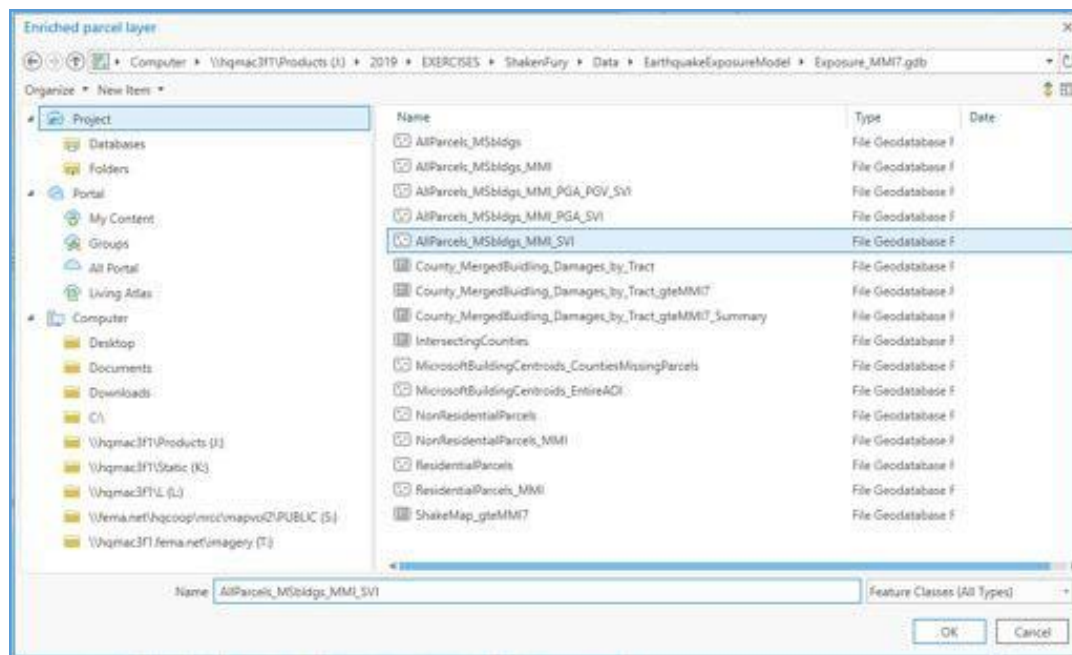


Figure 15

3 Fields storing the hazard data:

Select one or more fields (properties) in the parcel layer that store the hazard data (if available) (Figure 16). You may select one or more hazard fields (e.g. depth grid, surge probability, wind speed) or a pre-calculated hazard score (which is typically calculated prior to the creation of FEMA's hazard exposure maps). Note, that this field should be an integer. If the parcel layer does not include hazard data, disregard this step.

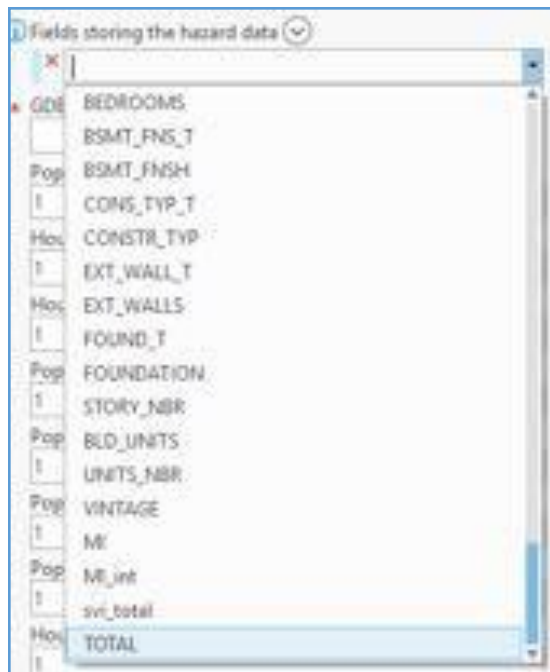


Figure 16

5 GDB storing the output:

Point to a geodatabase (GDB) that will store the tool's outputs (see, for example, Figure 17).

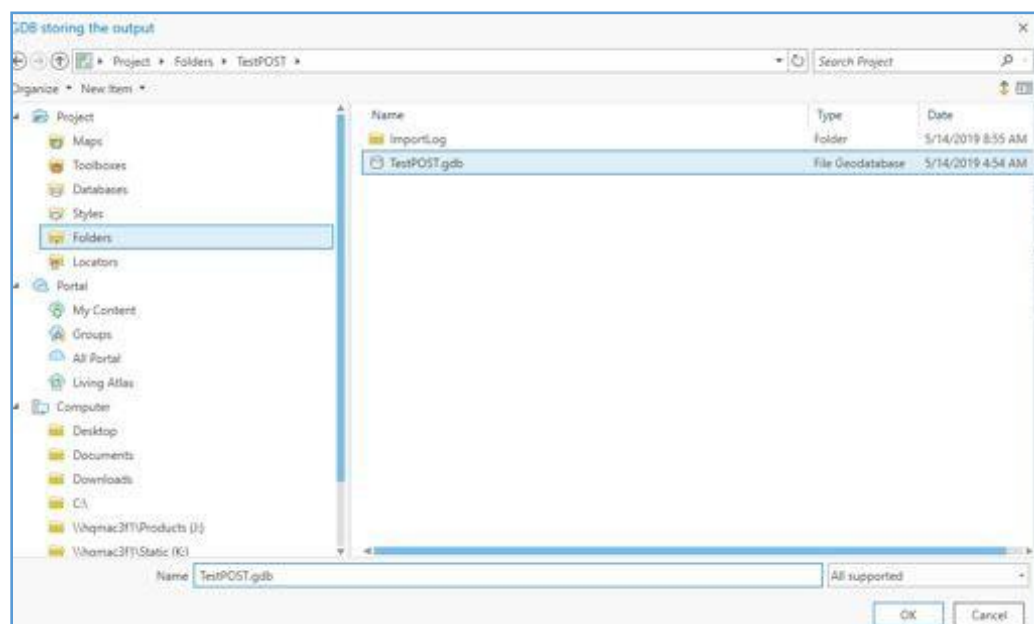


Figure 17

An aggregated population vulnerability score is calculated for each of the USNG cells, using the following formula:

$$\text{Population Vulnerability Score} = \text{pop}_{\text{pr}} * w + \text{hholds}_{\text{pr}} * w + \text{hunits}_{\text{pr}} * w + \text{age65}_{\text{pr}} * w + \text{unemp16}_{\text{pr}} * w + \text{nolaborforce16}_{\text{pr}} * w + \text{amalask}_{\text{pr}} * w + \text{hpov}_{\text{pr}} * w + \text{hdisfs}_{\text{pr}} * w + \text{hdisnfs}_{\text{pr}} * w + \text{hfssnap}_{\text{pr}} * w + \text{hpa}_{\text{pr}} * w + \text{humb}_{\text{pr}} * w$$

Where pr is a percentile rank of each criterion and w is a user defined relative weight of the criterion (0-10):

- Population (pop)
- Number of Households (hholds)
- Number of Housing units (hunits)
- Population age 65 and over (age65)
- Population age 16+ and unemployed (unemp16)
- Population 16+ not in labor force (nolaborforce16)
- Population American Indian or Alaska Native (amalask)
- Number of Households in poverty (hpov)
- Number of Households on disability and food stamps (hdisfs)
- Number of Households on disability no food stamps (hdisnfs)
- Number of Households with food stamps/SNAP (hfssnap)
- Number of Households with public assistance (hpa)
- Number of Housing units that are mobile homes (humb)

By default, the tool assumes an equal weight ($w = 1$) for each criterion. However, you can select different weights for each criterion (or to exclude one or more criterion from the analysis). A high value means a high weight for the criterion when calculating the population vulnerability score.

You can change the relative weight of each criterion (ranging between $w = 0$ and $w = 10$) (Figure 18).

Population (weight)
1

Households By Presence Of People Under 18 (weight)
1

Housing units (weight)
1

Population age 65 and over (weight)
1

Population age 16+ and unemployed (weight)
1

Population 15+ not in labor force (weight)
1

Population American Indian or Alaska Native (weight)
1

Households in poverty (weight)
1

Households with disability and food stamps (weight)
1

Households with disability, without food stamps (weight)
1

Households with food stamps/SNAP (weight)
1

Households with public assistance (weight)
1

Run

Population (weight)

1
2
3
4
5
6
7
8
9
10
Population American Indian or Alaska Native (weight)

Figure 18

SCENARIO 1:

Only hazard extent is available

Under the toolbox (*POST_ArcGIS_Pro.tbx*), double click on the tool **Social Vulnerability and Collection Priorities (only with hazard extent)** (Figure 19).

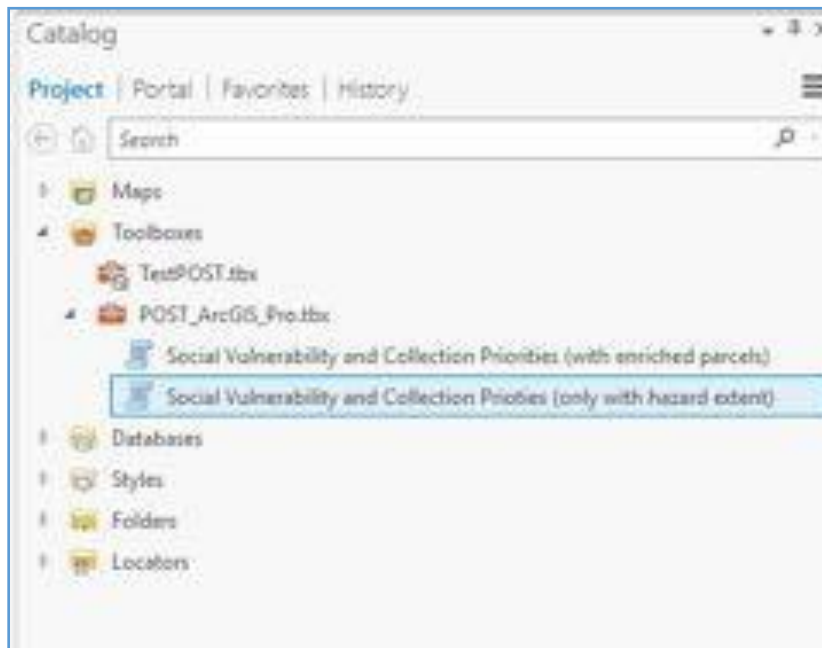


Figure 19

The tool expects to get several parameters (Figure 20):

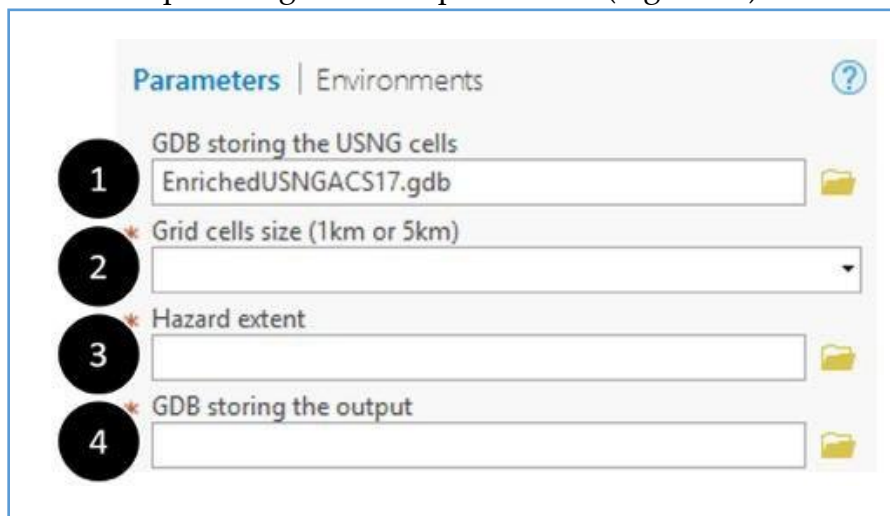


Figure 20

1 GDB storing the USNG cells:

The Geodatabase that stores the 1km and 5km USNG feature classes. The enriched USNG cells are located on the K drive (\\hqmac3f1\Static) (Figure 21). this parameter points, by default, to the following path:

\\hqmac3f1\Static\GISdata\USNG_With_Social_Vulnerability\WithACS2017\USNG_Enriched_ACS17

Typically, you will not need to change this value.

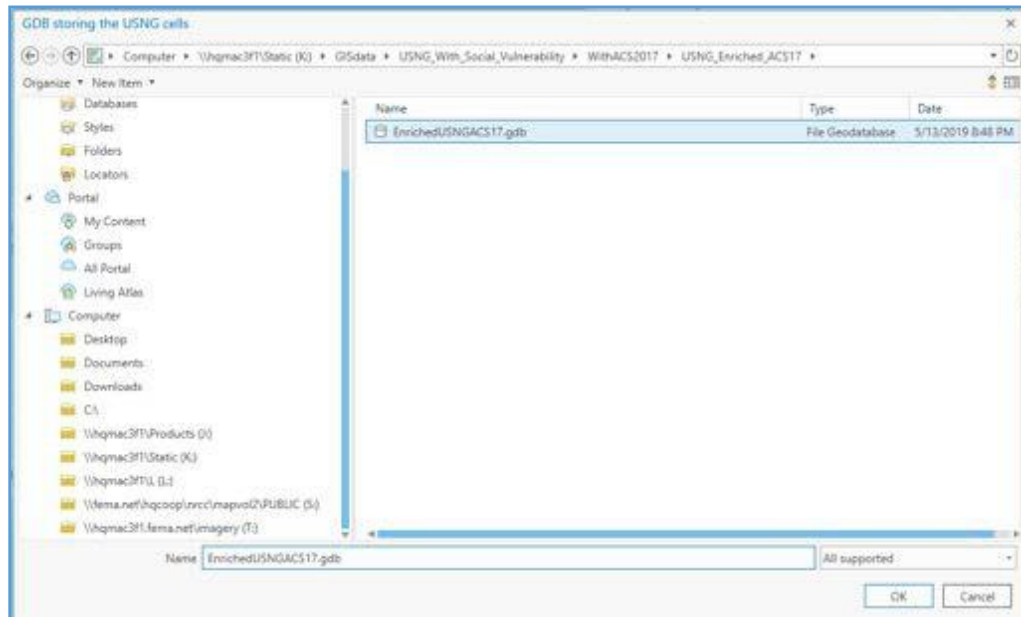


Figure 21

2 Grid cells size (1km or 5km):

This is the size of the USNG cells that will be used to determine priorities. Select either "1" (for 1km) or "5" (for 5km) (Figure 22).

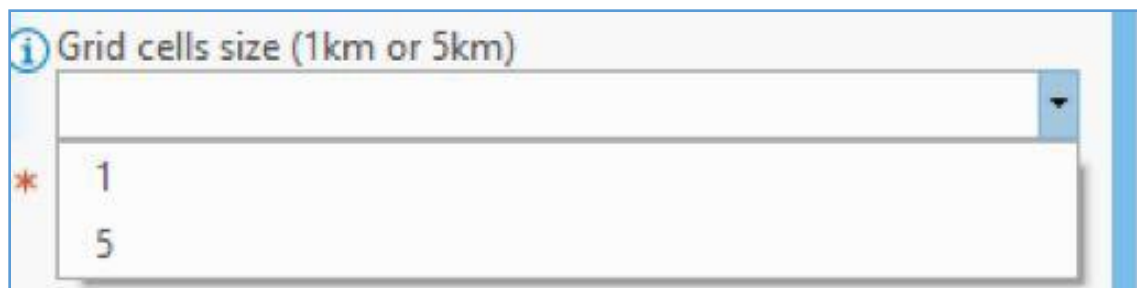


Figure 22

3 Hazard extent:

Select the layer that stores the extent of the hazard. This can be either a shapefile or a feature class, a point, polygon or a line geometry. (See, for example, Figure 23).

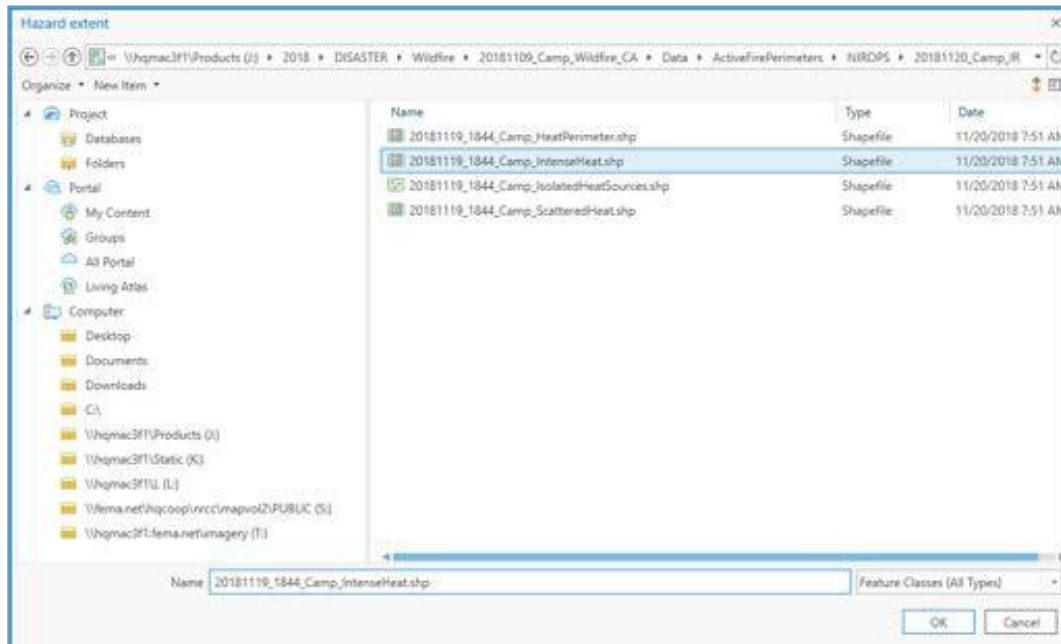


Figure 23

4 GDB storing the output:

Point to a geodatabase (GDB) that will store the tool's outputs (see, for example, Figure 24).

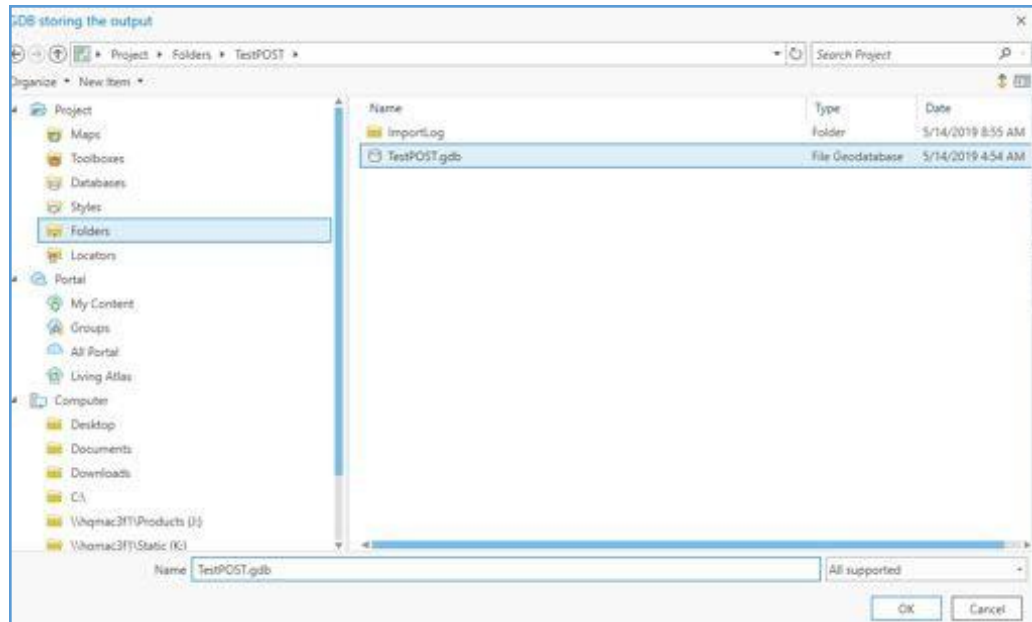


Figure 24

An aggregated population vulnerability score is calculated for each of the USNG cells, using the flowing formula:

$$\text{Population Vulnerability Score} = \text{pop}_{pr} * w + \text{hholds}_{pr} * w + \text{hunits}_{pr} * w + \text{age65}_{pr} * w + \text{unemp16}_{pr} * w + \text{nolaborforce16}_{pr} * w + \text{amalask}_{pr} * w + \text{hpov}_{pr} * w + \text{hdisfs}_{pr} * w + \text{hdisnfs}_{pr} * w + \text{hfssnap}_{pr} * w + \text{hpa}_{pr} * w + \text{humb}_{pr} * w$$

Where pr is a percentile rank of each criterion and w is a user defined relative weight of the criterion (0-10):

- Population (pop)
- Number of Households (hholds)
- Number of Housing units (hunits)
- Population age 65 and over (age65)
- Population age 16+ and unemployed (unemp16)
- Population 16+ not in labor force (nolaborforce16)
- Population American Indian or Alaska Native (amalask)
- Number of Households in poverty (hpov)
- Number of Households on disability and food stamps (hdisfs)
- Number of Households on disability no food stamps (hdisnfs)
- Number of Households with food stamps/SNAP (hfssnap)
- Number of Households with public assistance (hpa)
- Number of Housing units that are mobile homes (humb)

By default, the tool assumes an equal weight ($w = 1$) for each criterion. However, the user can select different weights for each criterion (or to exclude one or more criterion from the analysis). A high value means a high weight for the criterion when calculating the population vulnerability score.

You can change the relative weight of each criterion (ranging between $val = 0$ and $val = 10$) (Figure 25).

The figure consists of two screenshots of a software interface. The left screenshot shows a list of 14 criteria, each with a dropdown menu currently set to '1'. The criteria are: Population (weight), Households By Presence Of People Under 18 (weight), Housing units (weight), Population age 65 and over (weight), Population age 16+ and unemployed (weight), Population 16+ not in labor force (weight), Population American Indian or Alaska Native (weight), Households in poverty (weight), Households with disability and food stamps (weight), Households with disability, without food stamps (weight), Households with food stamps/SNAP (weight), and Households with public assistance (weight). A 'Run' button is visible at the bottom right. The right screenshot shows a dropdown menu for 'Population (weight)' with a list of numbers from 1 to 10, where '1' is selected.

Figure 25

III. Post outputs

The output of POST is a polygonal layer which stores the USNG cells that overlap with the extent of the hazard (or with the affected parcels).

The layer includes the ACS properties, i.e.:

1. Population (per cell)
2. Number of Households (per cell)
3. Number of Housing units (per cell)
4. Population age 65 and over (per cell)
5. Population age 16+ and unemployed (per cell)
6. Population 16+ not in labor force (per cell)
7. Population American Indian or Alaska Native (per cell)
8. Number of Households in poverty (per cell)
9. Number of Households on disability and food stamps (per cell)
10. Number of Households on disability no food stamps (per cell)
11. Number of Households with food stamps/SNAP (per cell)
12. Number of Households with public assistance (per cell)
13. Number of Housing units that are mobile homes (per cell)

As well as the following properties:

14. **usng1km** OR **usng5km** – The unique ID of the USNG cells
15. **HazardTotalScore** – Per-cell hazard score (calculated as the sum value of the hazard score of all the parcels in a cell)
16. **HazardRank** – A relative hazard score, which ranges between 1 and 10. This score indicates the percentile rank of a cell's hazard score within all the cells in the affected area.
17. **TotalPopScore** – Per-cell population vulnerability score (calculated as the sum score of the 13 population vulnerability criteria in each cell), assuming an equal weight for each criterion.
18. **TotalPopScoreWeighted** – Per-cell population vulnerability score (calculated as the sum score of the 13 population vulnerability criteria in each cell). Per- cell population vulnerability scores are multiplied by given weights.
19. **SV_Score_Rank_NonWeighted** – A relative population vulnerability score. This score is a percentile rank of a cell's population vulnerability score within all the affected cells, assuming an equal weight for each population vulnerability criterion. This rank ranges between 1 and 10.

20. **SV_Score_Rank_Weighted** – A relative population vulnerability score. This score is a percentile rank of a cell's population vulnerability score within all the affected cells, also accounting for the weight of each population vulnerability criterion. This rank ranges between 1 and 10.
21. **Collection_Priority_Non_Weighted** – This score ranges between 1 and 3. It is calculated by grouping the *SV_Score_Rank_NonWeighted* scores into three categories (0,1,2,3 → **3**; 4,5,6,7 → **2**; 8,9,10 → **1**). Priority "1" represents the highest priority (See, for example, Figure 26).
22. **Collection_Priority_Weighted** – This score ranges between 1 and 3, and is calculated by grouping the scores stored in the *SV_Score_Rank_Weighted* property into three categories (0,1,2,3 → **3**; 4,5,6,7 → **2**; 8,9,10 → **1**). Priority "1" represents the highest priority.

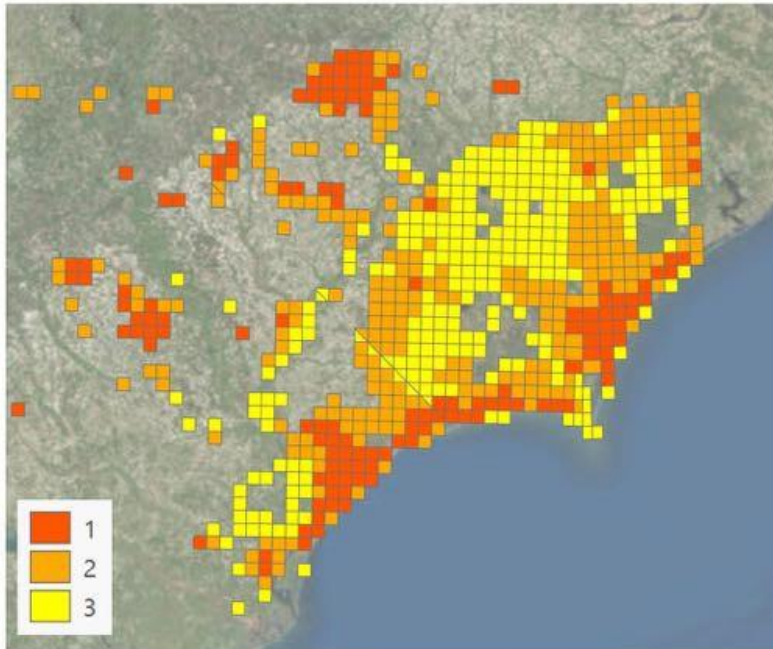


Figure 26 Relative priorities rank