COVID-19Surge (CDC)

Version 1 - Released 5/4/20

Summary

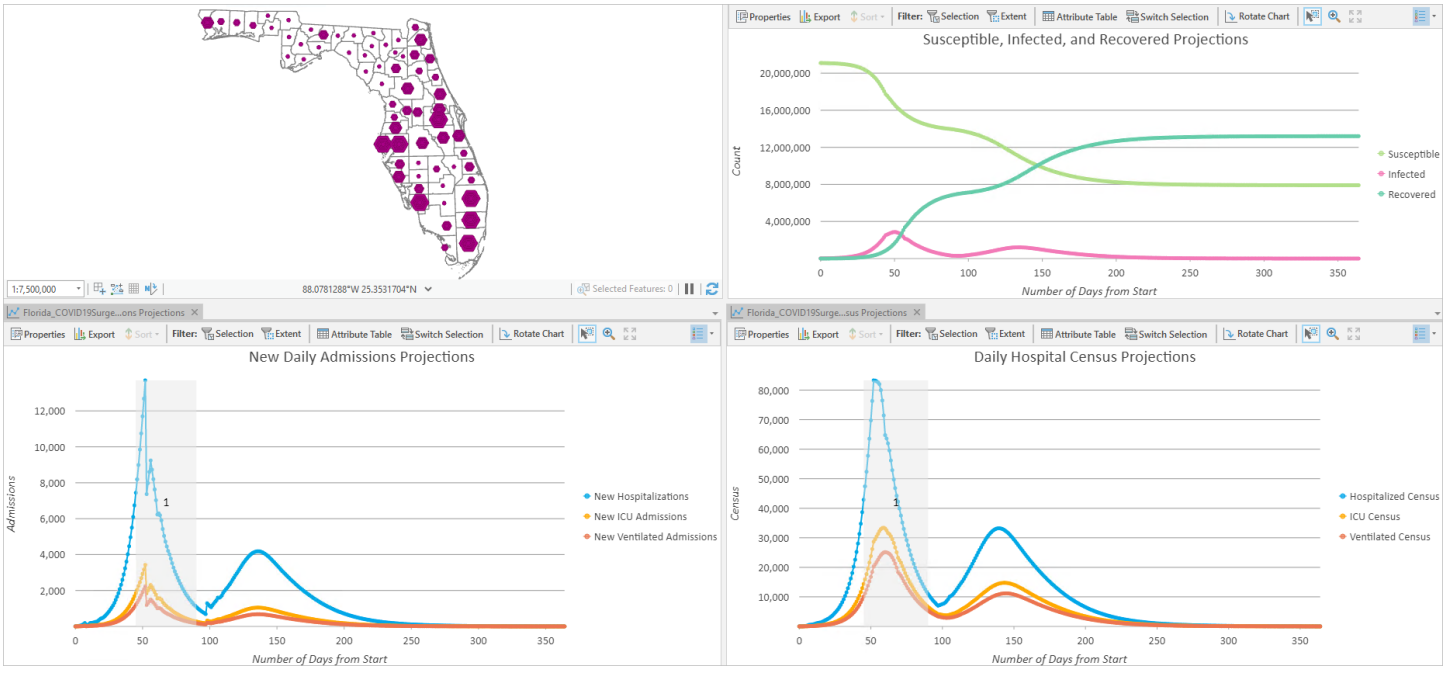
An implementation of Centers for Disease Control and Prevention's (CDC) COVID-19Surge for use in ArcGIS Pro 2.3 or later. This tool leverages SIICR (Susceptible, Infected, Infectious, Convalescing, Recovered) modeling to assist hospitals, cities, and regions with capacity planning around COVID-19 by providing estimates of daily new admissions and current inpatient hospitalizations (census), ICU admissions, and patients requiring ventilation based on the extent to which mitigation strategies such as social distancing or shelter-in-place recommendations are implemented.

This tool is based on COVID-19Surge. Learn more about how COVID-19Surge works

This tool requires ArcGIS Pro 2.3 (or later) to run.
Steps for upgrading ArcGIS Pro can be found here.

For questions, comments and support, please visit our COVID-19 GeoNet community.

Illustration



Potential Applications

- A hospital systems administrator needs a simple estimate of the number of patients the hospitals in the network will need to accommodate in the next 365 days due to COVID-19. You know the population served by each hospital and can estimate the total number of cases today and 14 days ago based on the number of patients that have been hospitalized with COVID-19 in each facility. Using your hospital point layer, you run the tool using constant values for **New Infections Per Case (R0)** and **Hospital Stays (Constant or Field-Based)** parameters, making the assumption that the current intervention strategies will not change, and all hospitals have similar epidemiological and hospitalization patterns.
- A hospital systems administrator needs to estimate how differences in the behaviors and population and expected changes to social distancing policies will impact the hospitalization patterns across the hospital network for the next 90 days. To simulate the different hospitalizations expected at each hospital in the network, you run the tool using a hospital polygon layer with field-based values for **New Infections Per Case (R0)** and **Hospital Stays (Constant or Field-Based)** parameters, and a constant **Intervention Policy**.
- An aid agency wants to estimate where and when resources will be required in the counties you serve. You know the population and number of COVID-19 cases today and 14 days ago in each county. You run the tool using your county polygon data, introducing an **Intervention Policy** and **New Infections Per Case (R0)** driven by fields to account for differences in anticipated social distancing policies and effectiveness between counties.
- A county wants to understand how the lessening or removal of interventions may impact hospital bed availability within the county. You create a county polygon layer with fields that reflect possible intervention effectiveness scenarios. You run the tool using these fields for each **Intervention Policy**, also adding **Hospital Resources** and checking **Add Additional Web App Fields in Summary**. You display the published results in the Capacity Analysis configurable app so intervention scenarios can be compared.

Best Practices and Usage Information

- This tool accepts either points or polygons. These features may correspond to specific hospital locations, hospital catchment areas, or counties.
- For each feature in the **Input Feature Class,** and for each of the **Number of Days to Project,** the tool provides an estimate of daily new hospitalization admissions, new ICU admissions, new ventilated hospitalizations, as well as the daily hospital census, daily ICU census, and the ventilated hospitalization census.
- The tool contains several parameters that can either be designated as fields (spatially-varying) or constants. A field can be chosen using the dropdown menu, or a constant can be typed directly into the parameter.
- The **Population** field should reflect the population assigned to each record in the **Input Feature Class** whether that represents a hospital, catchment area, or an administrative boundary. State and metropolitan statistical area population estimates can be obtained using the Enrich tool, from the U.S. Census Bureau or from state and local vital statistics offices.

- The **Intervention Policy** parameter can accept multiple non-overlapping interventions. This is different from the original CDC tool, which only allows a single intervention for each scenario. For guidance and descriptions of various community-level interventions, consult CDC'c Community Mitigation Strategies webpage.
- In the case that interventions were already in place during the start of the period of estimates (between the start date and 14 days before the start date), two adjustments can be made to the input parameters to improve the output estimates.
    - The **New Infections Per Case (R0)** parameter can be adjusted to reflect the new infections per case with the level of interventions at the initial **Start Date** and not the infections per case with a fully susceptible population. This adjustment can be made as follows:

      R0 = Ri * (1- eff) where Ri is the infection rate without any pre-existing intervention and eff is the effectiveness of the intervention.

      This adjustment only needs to be made for interventions that were in place before the **Start Date** specified for the analysis. Any interventions introduced in the **Intervention** parameter will be handled by the tool.

    - The **Effectiveness of Interventions (% Decrease in New Infections)** of any **Intervention Policy** should be relative to the level of interventions at the **Start Date**. Negative values can be used for the **Effectiveness of Interventions (% Decrease in New Infections)** parameter to account for an intervention that becomes less effective between the **Start Date** and the **Intervention Policy**. The ability to input negative values for the **Effectiveness of Interventions (% Decrease in New Infections)** is different from the CDC tool.
- Guidance on how the **New Infections Per Case (R0)** and **Effectiveness of Interventions (% Decrease in New Infections** can be estimated can be found in the Imperial College paper and the CDC COVID-19Surge Manual.
- To get the most accurate estimations, it is not recommended to subset your data for input to the **Population** field (such as only including the population from ages 6 to 8 or 65+) as COVID-19 can be spread between all subsets.
- If you do not have population data for your catchment or hospital area, you can use the Enrich tool to get Esri population data or use the Summarize Within tool or the Tabulate Intersection tool with the **Sum Fields** parameter to apportion the county data you do have to your catchment or hospital areas.
- The output of this tool includes a **Daily Output Feature Class** symbolized by the daily hospitalization census which can be time-enabled following the steps below. Informational messages and interactive charts are also provided.
- In the **Summary Output Feature Class,** when bed capacity is not reached the capacity date fields for hospitalizations, ICU, and ventilators will be populated with the date 1/1/1900 as a placeholder.
- Features missing data for any of the input variables will be dropped from the analysis and will not appear in the output. It is suggested to inspect your data for null values before running the tool. The Fill Missing Values tool can be used to replace missing values with estimated values.
- To compare the results of this tool with the results of the CHIME Model tool that is contained in the same toolbox, several input parameters must be converted. More can be read about how to do this

and the difference between the two tools in the COVID-19 Modeling Toolbox Documentation that ships with the toolbox.

Installation

The tool is available as a Python Toolbox (.pyt), which can be opened and used in the same manner as geoprocessing tools within ArcGIS Pro.

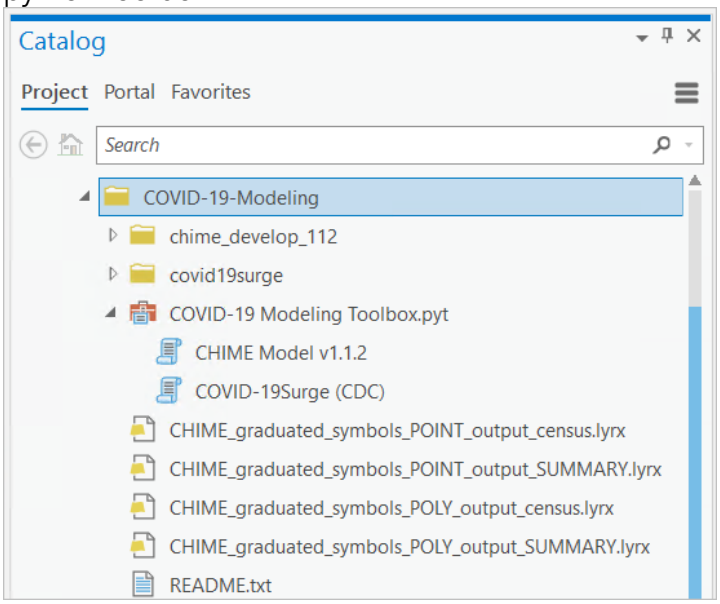
To install:

1. Download the Geoprocessing toolbox zip file.

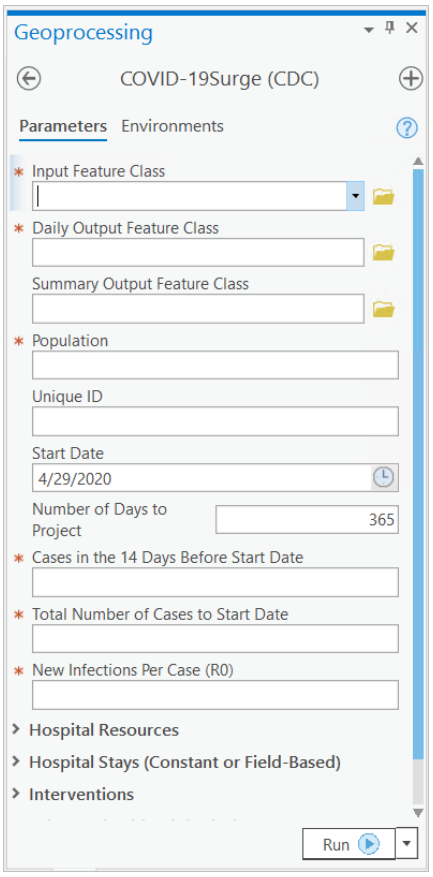
2. Unzip the file to a location in your local system.
   Note: The location must be accessible as a folder connection for ArcGIS Pro.

3. Open ArcGIS Pro, create a new project, and create a folder connection to your unzipped folder location.
   Note: You can drag and drop the unzipped folder your **Catalog** pane in ArcGIS Pro

4. From ArcGIS Pro's **Catalog** pane, open the folder and expand the **COVID-19 Modeling Toolbox** python toolbox.



5. Open the **COVID-19Surge (CDC)** tool.



Parameters

The tool uses parameters that describe the community affected as well as the spread and contact input information for the virus. Spread and contact input information can be specified in one of two ways: either as fields in the **Input Feature Class** or as constant values.

	Parameter	Explanation	Data type
0	Input Feature Class (in_fc) (Required)	The feature class containing information for each hospital, hospital catchment area, county or jurisdiction to be analyzed.	Feature Layer
1	Daily Output Feature Class (out_fc) (Required)	The output feature class to receive the analysis results. Descriptions of results provided in the output are described below.	Feature Class
2	Summary Output Feature Class (out_fc2d) (Optional)	This optional summary feature class includes information about input model parameters as well as peak dates and	Feature Class

		over capacity dates for hospitalized, ICU and ventilated census. Descriptions of results provided in the output are described below.	
3	Population (population) (Required)	The field representing the total population size of the catchment region of your hospital(s) or the total population size in each county or local jurisdiction. This affects the estimates or the number of infected people as well as the numbers requiring hospitalization, intensive care (ICU), and mechanical ventilation. If the field contains decimals, the value is rounded to the nearest whole number.	Field
4	Unique ID (unique_id) (Optional)	The field from the **Input Feature Class** representing unique IDs for each feature.	Field
5	Start Date (start_date) (Required)	The date used to represent a start point for calculating projections for number of hospitalizations, ICU admissions, and patients requiring mechanical ventilation. You may specify today's date or a different date representing the start of the analysis.	Date
6	Number of Days to Project (days) (Required)	The number of days to include in the output analysis estimates. This number should be between 30 and 365. The default is 365 days.	Long
7	Total Staffed Unoccupied Non-ICU Beds (bed_field) (Optional)	The total number of unoccupied non-ICU medical beds that are staffed and available immediately. This should not include beds that are used for only a portion of a patient's stay such as outpatient or emergency room beds. If the field contains decimals, the value will be rounded to the nearest whole number.	Field
8	Total Staffed Unoccupied ICU Beds (icu_beds_filed) (Optional)	The total number of unoccupied intensive care unit beds that are staffed and available immediately.	Field

		If the field contains decimals, the value will be rounded to the nearest whole number.	
9	Total Number of Ventilators Available (vent_field) (Optional)	The total number of ventilators available (currently used and unused). If the field contains decimals, the value will be rounded to the nearest whole number.	Field
10	Cases in the 14 Days before Start Date (cases_history) (Required)	The field representing the total new case counts in the 14 days up to the analysis **Start Date** for each hospital, hospital catchment area, county or jurisdiction in the **Input Feature Class**.	Field
11	Total Number of Cases to Start Date (tot_cases) (Required)	The field representing the total case counts up to the analysis **Start Date** for each hospital, hospital catchment area, county or jurisdiction in the **Input Feature Class**.	Field
12	New Infections Per Case (R0) (infected_per_case) (Optional)	The field or value representing the average number of people one infected person will infect at the analysis **Start** Date. This is also known as R0, the basic reproductive rate which indicates how infectious a disease is. These values should be adjusted to account for any decrease in transmission due to interventions already in place at the **Start Date**. This reduction is proportional to the effectiveness of the intervention. This adjustment can be made by as follows: R0 = Ri * (1- eff) where Ri is the infection rate without any pre-existing intervention and eff is the effectiveness of the intervention. This adjustment only needs to be made for interventions that were in place before the **Start Date** specified for the analysis. Any interventions introduced in the **Intervention** parameter will be handled by the tool.	String

13	Average % of Clinical Cases Admitted for Hospital Care (perc_hosp_adm_field) (Optional)	The average percentage of all infected cases that will need hospitalization. Note: There is a large amount of uncertainty surrounding this figure as hospitalization requirements may vary between regions.	String
14	Average Length of Non-ICU Hospital Stay (ave_hosp_stay) (Optional)	The average number of days spent in the hospital for non-ICU COVID-19 infected patients. If the field contains decimals, the value is rounded to the nearest whole number.	String
15	Average % of Admitted Cases Requiring ICU Care (perc_hosp_icu_field) (Optional)	The average percentage of cases that will be admitted to the intensive care unit. Note: There is a large amount of uncertainty surrounding this figure as hospitalization requirements may vary between regions.	String
16	Average Duration in ICU Without Ventilator (ave_icu_no_vent_stay) (Optional)	The average number of days spent in the intensive care unit for COVID-19 patients that do not require a ventilator. If the field contains decimals, the value is rounded to the nearest whole number.	String
17	Average % of Cases in ICU Requiring Ventilators (perc_icu_vent_field) (Optional)	The average percentage cases that will need ventilators. Note: There is a large amount of uncertainty surrounding this figure as hospitalization requirements may vary between regions.	String
18	Average Duration in ICU With Ventilator (ave_icu_vent_stay) (Optional)	The average number of days spent in the intensive care unit for COVID-19 patients that will require a ventilator. If the field contains decimals, the value is rounded to the nearest whole number.	String
19	Average Downtime per Ventilator (ave_vent_downtime) (Optional)	The average number of days a ventilator will be out of use due to decontamination or relocation. If the field contains decimals, the value is rounded to the nearest whole number.	String

20	Intervention Policy (intervention_table) (String)	Specify intervention strategies and timelines to determine the potential reduction in COVID-19 cases and the duration of the epidemic. Multiple non-overlapping interventions and durations can be specified. • **Start Date** – The start date of the new intervention. This **Start Date** does not have to match but cannot be earlier than the initial analysis **Start Date** specified. • **End Date** – The end date of the new intervention. • **Effectiveness of Intervention (% Decrease in New Infections)** – The anticipated decrease in infections of the new policy relative to the policy at the initial **Start Date**. The value can be negative which would mean the intervention is less effective than the intervention at the **Start Date**. This percentage is used to scale the **New Infections Per Case (R0)** parameter during the intervention period. If left empty 0 will be used.	String
21	Infected (Not Contagious) Period (time_infected) (Required)	A value representing the number of days a person is infected but is not yet infectious (regardless of whether the infected person is symptomatic or asymptomatic). The default is 3 days based on the Imperial College guidelines.	Long
22	Contagious Period (time_contagious) (Required)	A value representing the number of days a person can infect another person (regardless of whether the infected person is symptomatic or asymptomatic). The default is 5 days based on the Imperial College guidelines.	Long
23	Convalescent Period (Non-Hospitalized) (time_convalescent) (Required)	A value representing the number of days a person may have symptoms but are no longer spreading the virus. This period is the later stage of the illness where the patient is in the process of recovery, is no longer transmitting the disease and applies to non-hospitalized cases only.	Long

		For cases who are hospitalized, assume that they are non-contagious due to isolation and infection control measures. The default is 5 days based on the Imperial College guidelines.	
24	Days From Contagious Until Hospitalization (days_contagious_until_hosp) (Required)	A value representing the number of days a patient is infectious until they are admitted to the hospital. The default is 5 days based on the Imperial College guidelines.	Long
25	Additional Output Variable(s) (additional_fields) (Optional)	Additional fields can be appended to the **Summary Output Feature Class**.	[Field]
26	Add Additional Web App Fields in Summary (add_webapp_fields) (Optional)	This parameter is used to add necessary fields for the Capacity Analysis configurable app to the **Summary Output Feature Class**. • CREATE_WEB_FIELDS –The web app fields will be created. • NO_CREATE_WEB_FIELDS –The web app fields will not be created. If you choose CREATE_WEB_FIELDS the **Unique ID**, **Total Bed Capacity**, **Total Ventilator Capacity** and **Total ICU Bed Capacity** fields will be required.	Boolean

Running the Tool from Python

Like other geoprocessing tools, you may execute this tool via Python by using ArcPy. Since this tool is imported separately from other geoprocessing in ArcGIS Pro, an additional step is required to first import the toolbox. To do this, first run:

```
arcpy.ImportToolbox(r"YOUR PATH\COVID-19-Modeling\COVID-19 Modeling Toolbox.pyt")
```

Then execute the tool via ArcPy by using the following syntax:

```
arcpy.covid19.COVID19Surge (in_fc, out_fc, {outfc2d}, population, {unique_id}, start_date, days, {bed_field},
{icu_beds_field}, {vent_field}, cases_history, tot_cases, infected_per_case, {perc_hosp_adm_field},
{ave_hosp_stay}, {perc_hosp_icu_field}, {ave_icu_no_vent_stay}, {perc_icu_vent_field}, {ave_icu_vent_stay},
{ave_vent_downtime}, {intervention_table}, time_infected, time_contagious, time_convalescent,
days_contagious_until_hosp, {additional_fields}, {add_webapp_fields})
```

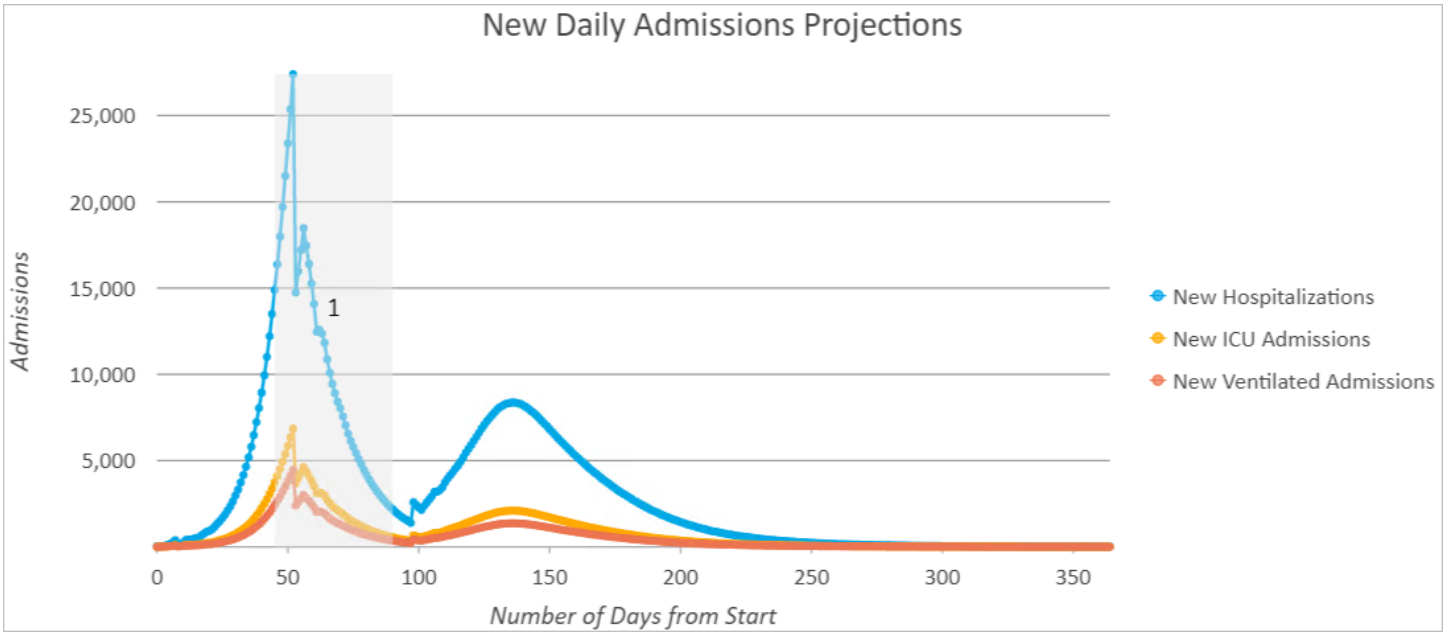
Interpreting the Outputs

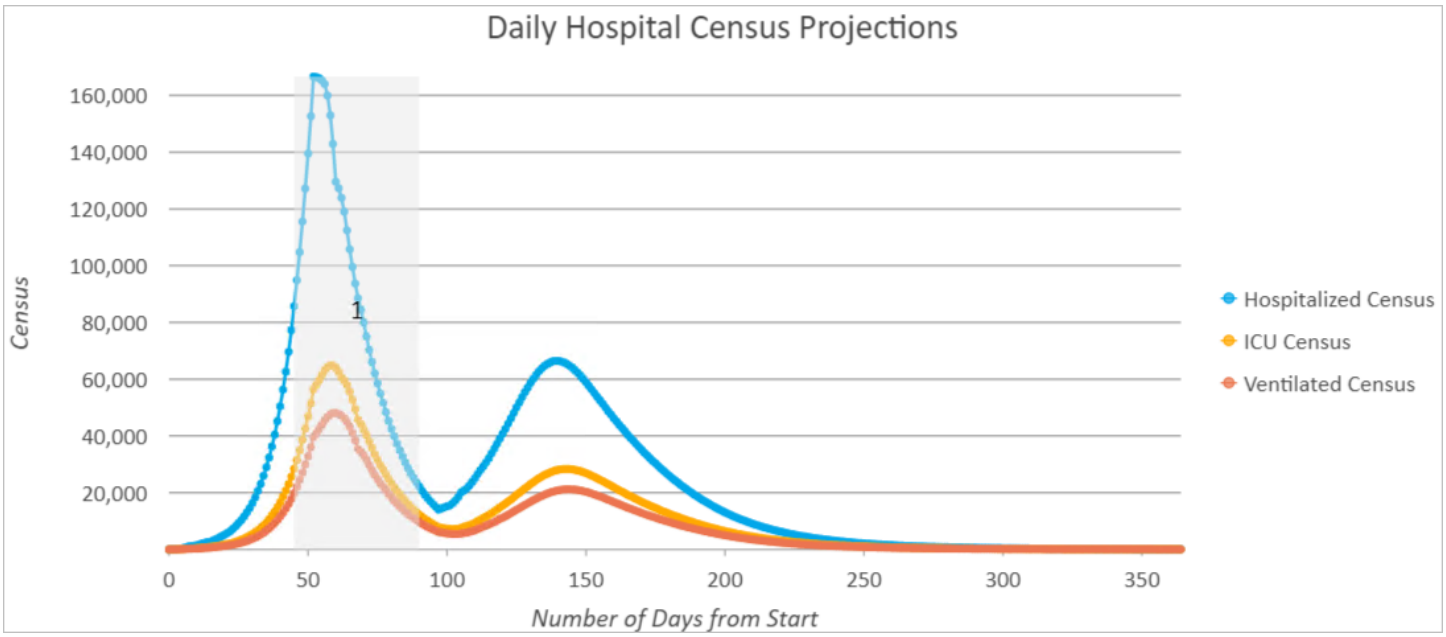
The tool provides a **Daily Output Feature Class** with fields and accompanying charts pertaining to each day's estimates for new daily admissions, and a census of inpatient hospitalizations, ICU admissions, and patients requiring ventilation, as well as each day's projected total susceptible, infected, and recovered in the provided population. The default symbology of this layer is the projected hospitalization census by day.

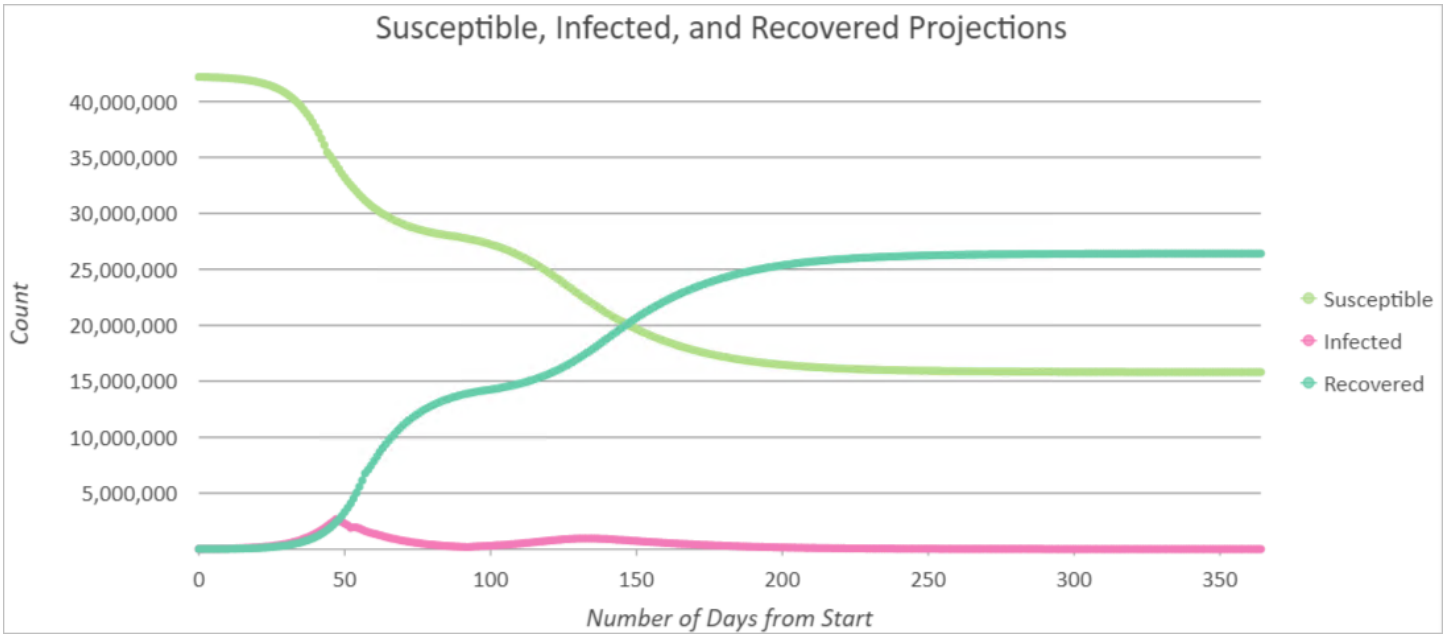
The geometry of the output features matches the geometry of its inputs; for example, if you are using a feature class of hospital points, the output is points, and if you are using a feature class of county polygons, the output is county boundaries.

Chart Outputs

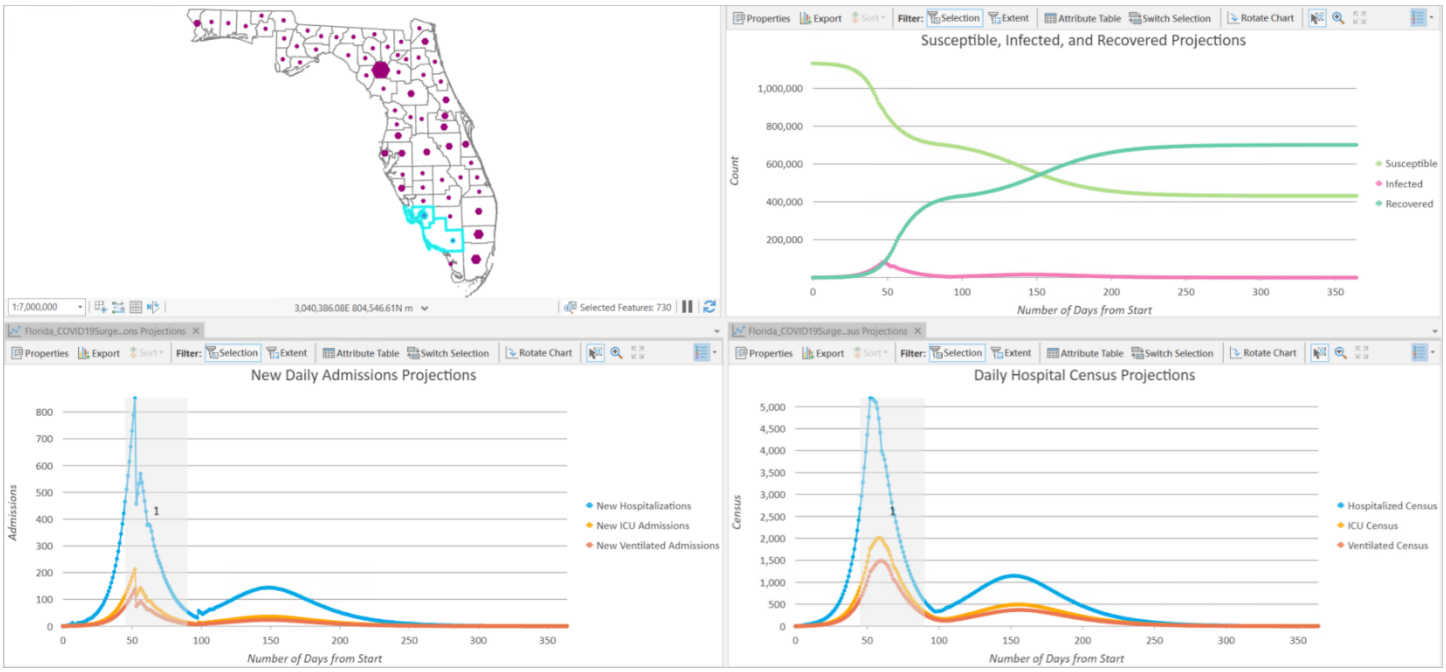
Three charts are created to visualize the outputs of the COVID-19Surge tool: **New Daily Admissions Projections**, **Daily Hospital Census Projections**, and **Susceptible, Infected, and Recovered Projections**. If one or more **Intervention Policy** is specified in the tool, the timespan of these are shown on the **New Daily Admissions Projections** and **Daily Hospital Census Projections** charts as chart guides (gray shaded areas), labeled by the consecutive intervention number.







A useful approach to explore and visualize COVID-19Surge estimates for individual features in your data is to enable **Filter by Selection** in your chart. Once enabled, you can select features and the corresponding charts will reflect projections for each selected hospital, catchment area, or administrative boundary.



Note: If comparing chart outputs across different results, it is recommended to lock the Y-axis of the charts.

Setting the Daily Output Feature Class as a Time Enabled Layer

The **Daily Output Feature Class** can be configured as a time-enabled layer by performing the following steps:

1. Double-click the output layer in the **Contents** pane to open the **Layer Properties** dialog box.
2. Click the **Time** tab.
3. For **Layer Time**, select **Each feature has a single time field** from the dropdown.
4. Make sure the **Time Field** is pointing to the **date** field.
5. Click **Calculate**.
6. Click **OK**.

Once this is set, the **Map** pane will display a time slider.

Daily Output Feature Class Fields

Field alias (field name)	Explanation
Day (day)	The incremental day of the estimate.
Date (date)	The date of the estimate.
New Hospitalizations (new_hosp)	Estimated new hospitalizations for the given day. This field is equivalent to the New admits (non-ICU) column of the critical calculations work sheet in the CDC Covid19Surge tool.

New ICU Admissions (new_icu)	Estimated new ICU admissions for the given day. This field is equivalent to the sum of New admits (ICU, no vent) and New admits (ICU, vent) columns of the critical calculations work sheet in the CDC Covid19Surge tool.
New Ventilated Admissions (new_vent)	Estimated new patients requiring ventilation for the given day. This field is equivalent to the New admits (ICU, vent) column of the critical calculations work sheet in the CDC Covid19Surge tool.
Hospitalized Census (cen_hosp)	Census of hospitalizations (non-ICU) for the given day. This field is equivalent to the Daily Bed Demand (non-ICU) column of the critical calculations work sheet in the CDC Covid19Surge tool.
ICU Census (cen_icu)	Census of ICU admissions for the given day. This field is equivalent to the Daily Bed Demand (ICU, all) column of the critical calculations work sheet in the CDC Covid19Surge tool.
Ventilated Census (cen_vent)	Census of patients requiring ventilation for the given day. This field is equivalent to the Daily Ventilator Demand column of the critical calculations work sheet in the CDC Covid19Surge tool.
Currently Incubating (incubating)	Estimation of the population currently in incubation period (infected but not contagious). This field is equivalent to the Currently Incubating column of the critical calculations work sheet in the CDC Covid19Surge tool.
Currently Infectious (infectious)	Estimation of the population currently in contagious period. This field is equivalent to the Currently Infectious column of the critical calculations work sheet in the CDC Covid19Surge tool.
Currently Convalescent (convlscnt)	Estimation of the non- hospitalized population currently in convalescent period. This field is equivalent to the Currently Convalescent column of the critical calculations work sheet in the CDC Covid19Surge tool.
Infected (infected)	Sum of estimation of the currently incubating, infectious, and convalescent population for the given day. This field is equivalent to the Active Cases column of the critical calculations work sheet in the CDC Covid19Surge tool.
Susceptible (susceptble)	Estimation of total susceptible in the population for the given day. This field is equivalent to the Ending Susceptible column of the critical calculations work sheet in the CDC Covid19Surge tool.
Recovered (recovered)	Estimation of total recovered in the population for the given day. This field is equivalent to the Total Recovered or Died column of the critical calculations work sheet in the CDC Covid19Surge tool.

Summary Output Feature Class Fields

In addition to the **Daily Output Feature Class**, the tool can also provide a **Summary Output Feature Class** containing a summary of each feature's peak values for the census of inpatient hospitalizations, ICU admissions, and patients requiring ventilation. The first 16 fields of this feature class (from **Population** to **New Infections Per Case (R0)**) summarize the inputs to the tool.

A field called **Doubling Time** is added to the output for each feature providing the median of the time it took for the new infections to double throughout the projection period. It is not possible to easily convert

R0 to doubling time, so the effective doubling time is reported in the **Summary Output Feature Class** for use in the CHIME Model tool where Doubling Time is required instead of R0.

If fields for the **Hospital Resources** parameters for **Total Staffed Unoccupied Non-ICU Beds, Total Staffed Unoccupied ICU Beds, or Total Number of Ventilators Available** were provided, the tool also calculates metrics for the maximum difference between projected needs and available resources, including the maximum difference as a total and as a percent, the day and date in which the highest difference occurred, and the amount of days in which total projected needs exceeded available resources.

Note: If Non-ICU, ICU, and/or Ventilator capacity is not surpassed by projected needs, a value of 1/1/1900 will be populated as a placeholder for the date fields.

If the **Add Additional Web App Fields in Summary** parameter is checked, the tool will add the fields required for the **Summary Output Feature Class** to be used in the Capacity Analysis configurable app.

The symbology of this output feature class reflects the peak census of inpatient hospitalizations and the geometry of the output features matches the geometry of its inputs (in a similar fashion to the **Daily Output Feature Class**.

Summary Output Feature Class Field Names

Field alias (field name)	Explanation
Peak Hospitalized Census (pk_hsp)	The highest number in the census of hospitalizations during the period of estimates.
Peak Day for Hospitalized Census (pk_day_hsp)	The incremental day containing the highest number in the census of hospitalizations during the period of estimates.
Peak Date for Hospitalized Census (pk_date_hsp)	The date containing the highest number in the census of hospitalizations during the period of estimates.
Peak ICU Census (pk_icu)	The highest number in the census of ICU admissions during the period of estimates.
Peak Day for ICU Census (pk_day_icu)	The incremental day containing the highest number in the census of ICU admissions during the period of estimates.
Peak Date for ICU Census (pk_date_icu)	The date containing the highest number in the census of ICU admissions during the period of estimates.
Peak Ventilated Census (pk_icu)	The highest number in the census of patients requiring ventilation during the period of estimates.
Peak Day for Ventilated Census (pk_day_icu)	The day containing the highest number in the census of patients requiring ventilation admissions during the period of estimates.
Peak Date for Ventilated Census (pk_date_icu)	The date containing the highest number in the census of patients requiring ventilation during the period of estimates.

Over Capacity Hospitalized Maximum Number (oc_hos_num)	The maximum difference between estimated hospitalizations and available hospital beds during the period of estimates.
Over Capacity Hospitalized Day (oc_hos_day)	The incremental day containing the maximum difference between estimated hospitalizations and available hospital beds during the period of estimates.
Over Capacity Hospitalized Date (oc_hos_dte)	The date containing the maximum difference between estimated hospitalizations and available hospital beds during the period of estimates.
Over Capacity Hospitalized Maximum Percent (oc_hos_pct)	The maximum difference as a percent between estimated hospitalizations and available hospital beds during the period of estimates.
Over Capacity Hospitalized Number of Days (oc_hos_day)	The number of days in which the feature was estimated to have more hospitalizations than available beds.
Over Capacity ICU Maximum Number (oc_hos_num)	The maximum difference between estimated ICU admissions and available ICU beds during the period of estimates.
Over Capacity ICU Day (oc_hos_day)	The incremental day containing the maximum difference between estimated ICU admissions and available ICUs during the period of estimates.
Over Capacity ICU Date (oc_hos_dte)	The date containing the maximum difference between estimated ICU admissions and available ICUs during the period of estimates.
Over Capacity ICU Maximum Percent (oc_hos_pct)	The maximum difference as a percent between estimated ICU admissions and available ICUs during the period of estimates.
Over Capacity ICU Number of Days (oc_hos_day)	The number of days in which the feature was estimated to have more ICU admissions than available ICUs.
Over Capacity Ventilated Maximum Number (oc_hos_num)	The maximum difference between estimated patients requiring ventilation and available ventilators during the period of estimates.
Over Capacity Ventilated Day (oc_hos_day)	The incremental day containing the maximum difference between estimated patients requiring ventilation and available ventilators during the period of estimates.
Over Capacity Ventilated Date (oc_hos_dte)	The date containing the maximum difference between estimated patients requiring ventilation and available ventilators during the period of estimates.
Over Capacity Ventilated Maximum Percent (oc_hos_pct)	The maximum difference as a percent between estimated patients requiring ventilation and available ventilators during the period of estimates.
Over Capacity Ventilated Number of Days (oc_hos_day)	The number of days in which the feature was estimated to have more patients requiring ventilation than available ventilators.
Web New Hospitalizations (web_nhosp)	Estimated new hospitalizations for all days in ascending order, separated by a pipe (|) delimiter. This is the same data as shown output in the **Hospitalized Census** field of the **Daily Output Feature Class**, and is created specifically for use in the Capacity Analysis configurable app.

Web New ICU Admissions (web_nicu)	Estimated new ICU admissions for all days in ascending order, separated by a pipe (|) delimiter. This is the same data as shown output in the **ICU Census** field of the **Daily Output Feature Class**, and is created specifically for use in the Capacity Analysis configurable app.
Web New Ventilated Admissions (web_nvent)	Estimated new ventilated admissions for all days in ascending order, separated by a pipe (|) delimiter. This is the same data as shown output in the **Ventilated Census** field of the **Daily Output Feature Class**, and is created specifically for use in the Capacity Analysis configurable app.
Web Number of Days (web_days)	The value set in the **Number of Days to Project** parameter. This field is created specifically for use in the Capacity Analysis configurable app.
Web Start Date (web_date)	The value set in the **Start Date** parameter. This field is created specifically for use in the Capacity Analysis configurable app.
Web Name (web_name)	This feature name for use in the Capacity Analysis configurable app. The name is derived from the value set in the **Unique ID** parameter.

Example Workflow

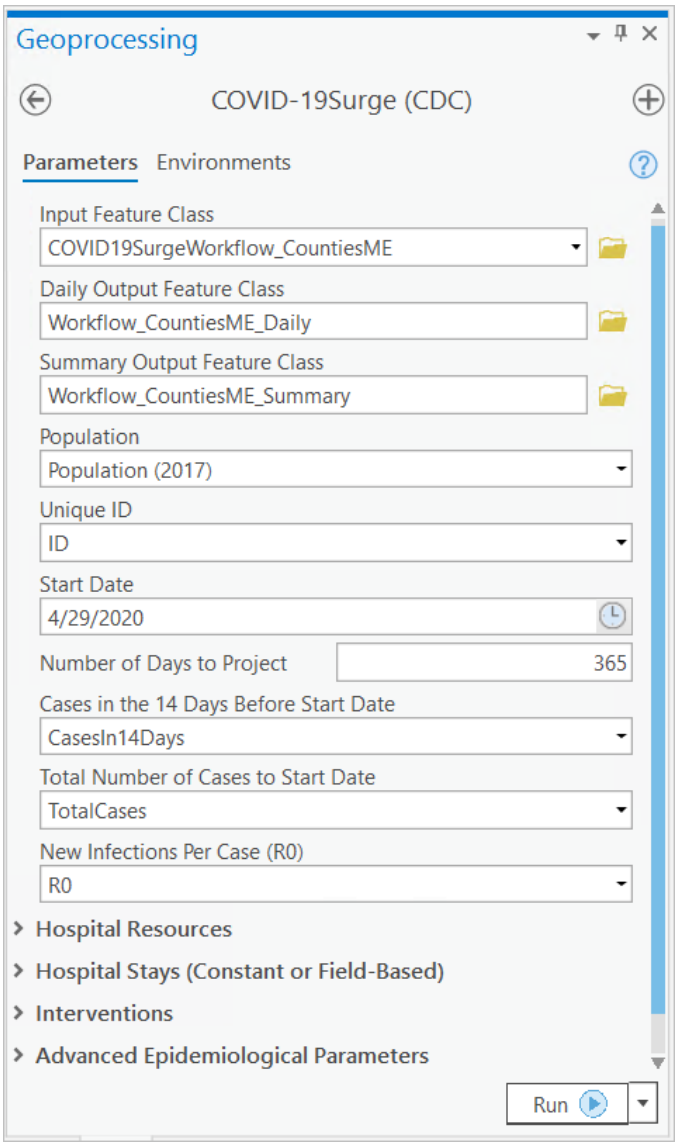
The following workflow is an example of how to use the tool with county polygon data. You can reference the sample data in the ExampleWorkflows.gdb file geodatabase.

1. Add the data COVID19SurgeWorkflow_CountiesME feature class from the ExampleWorkflows.gdb file geodatabase to a map in ArcGIS Pro. The Shape, County Name, State Name, and Population fields were derived from the USA counties layer in Living Atlas. All other fields in this dataset are artificial data created to demonstrate the functionality of this tool.

   Running COVID-19Surge using this tool in ArcGIS Pro allows you to run the tool for many locations at once, and to apply different tool parameters to each point or polygon (in this case counties), based on different characteristics of each area or location. Look at the attribute table of the Maine Counties data - you'll notice there are 16 records, one for each county, and that the fields such as TotalCases and Intervention2 vary by county.

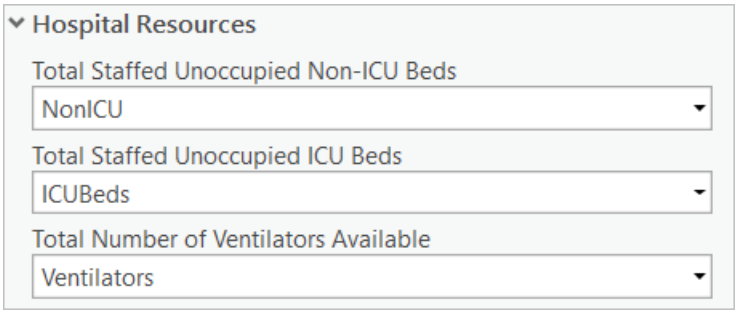
2. Open the **COVID-19 Surge (CDC)** tool. The Installation section of this document above explains the steps to install and open the tool.

3. Populate parameters of the tool as follows:



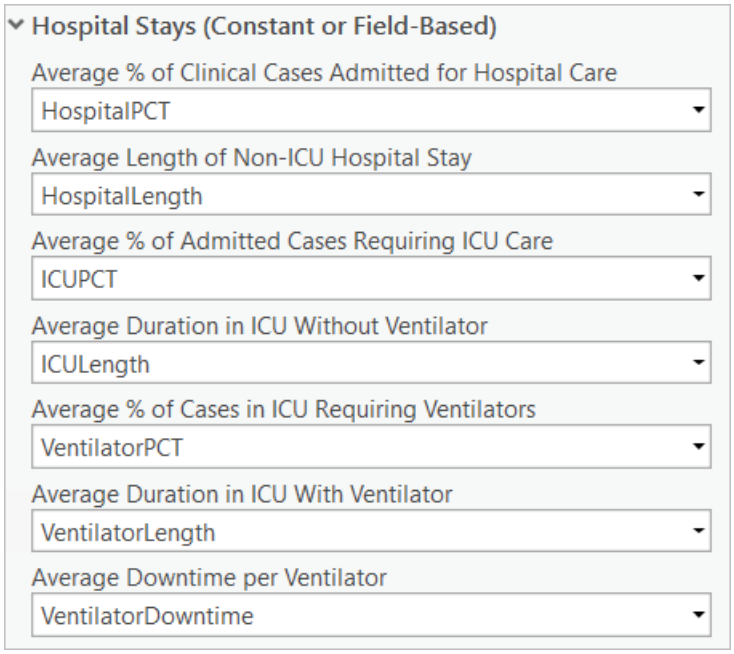
Note: When applying this tool to your study area, consult this Imperial College paper and the CDC COVID-19Surge Manual for help estimating the New Infections Per Case (R0).

4. Expand the **Hospital Resources** section of the tool to populate the parameters as follows:



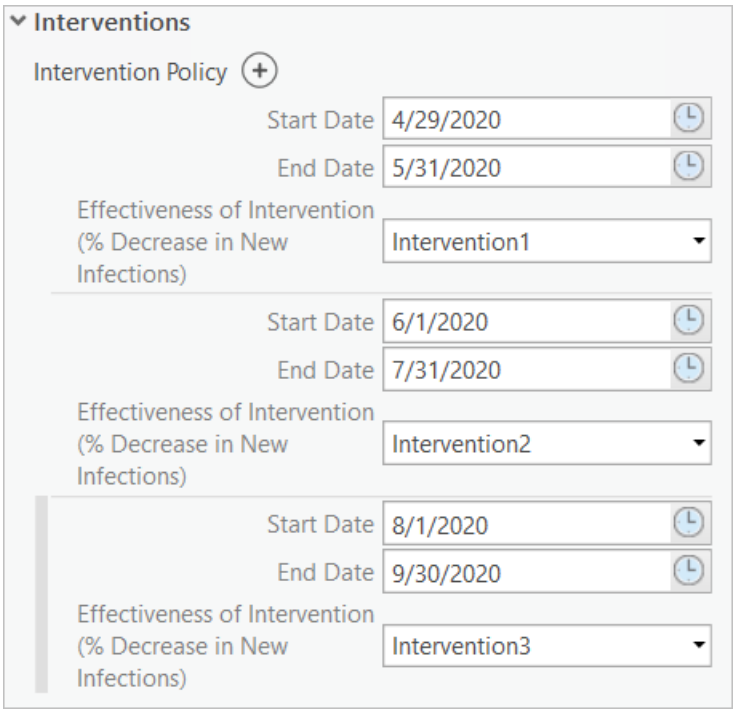
Note: When applying this tool to your own study area, consider using the Living Atlas USA Hospital Bed data to help understand hospital bed resources.

5. Expand the **Hospital Stays (Constant or Field-Based)** section of the tool to populate the parameters as follows:



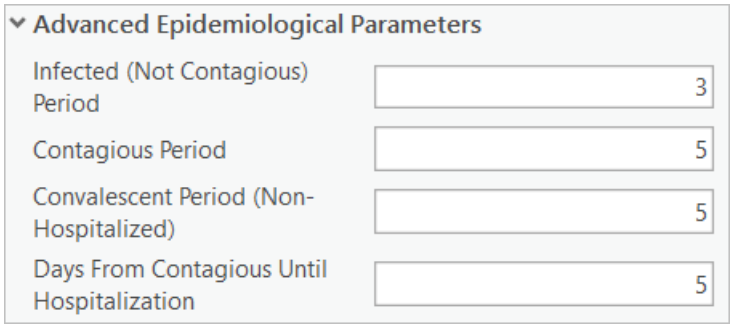
6. Expand the **Interventions** section of the tool and populate the parameters as follows.

   The Intervention Policy parameter allows you to specify multiple non-overlapping interventions, with different **Start Date**, **End Date**, and **Effectiveness of Intervention**. It is important to note that the **Effectiveness of Intervention** is relative to the intervention level at the start date. Therefore, this field can accept negative values to simulate an intervention at start date that was lessened or removed during the period of estimates. For the Maine workflow, we assume there was no intervention at start date.



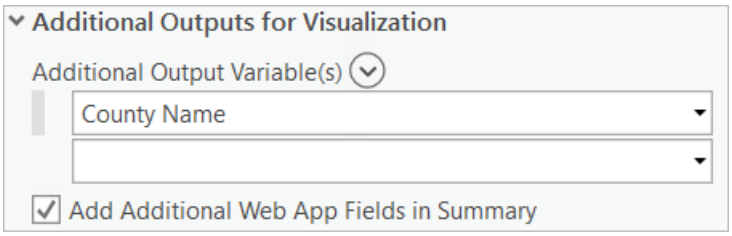
Note: When applying this tool to your study area, consult this Imperial College paper and the CDC COVID-19Surge Manual for help estimating the Effectiveness of Interventions.

7. Expand the **Advanced Epidemiological Parameters** section of the tool. These parameters define how long each stage of the disease lasts. The default values are sensible so they will not be changed.

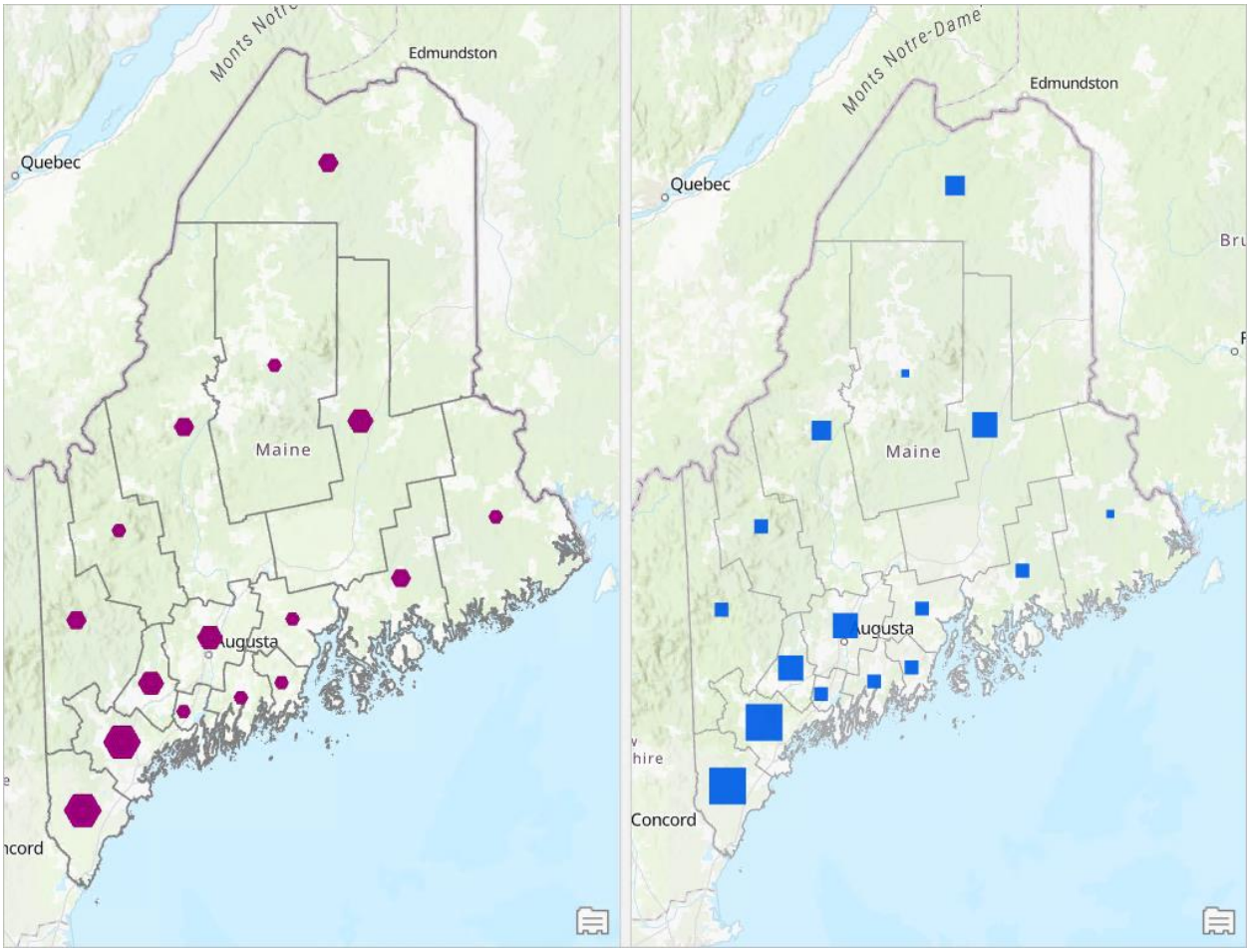


8. Expand the **Additional Outputs for Visualization** section and populate the parameters as follows.

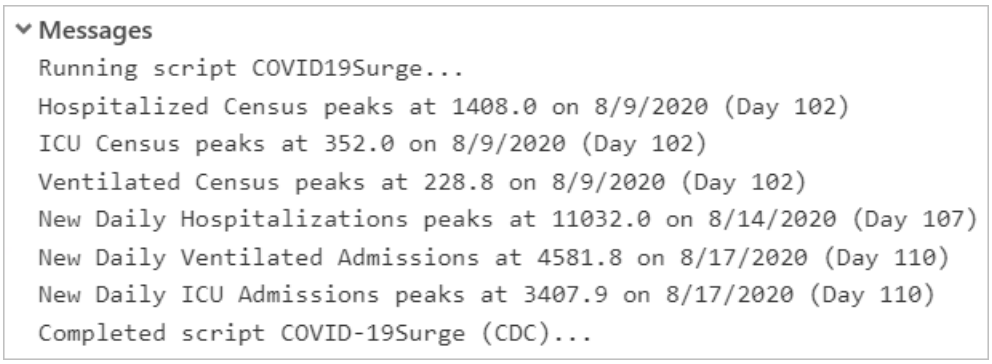
   The **Additional Output Variable(s)** are appended to the **Summary Output Feature Class**. Useful fields to append may include state or hospital names. The **Add Additional Web App Fields in Summary** parameter is used to add necessary fields for the Capacity Analysis configurable app to the **Summary Output Feature Class**.



9. Click **Run** in the **Geoprocessing** pane. The tool creates two output feature classes, called Workflow_CountiesME_Daily and Workflow_CountiesME_Summary. The layer Workflow_CountiesME_Daily has three charts: **New Daily Admissions Projections**, **Daily Hospital Census Projections** and **Susceptible, Infected, and Recovered Projections**. The layers should resemble the screenshot below.

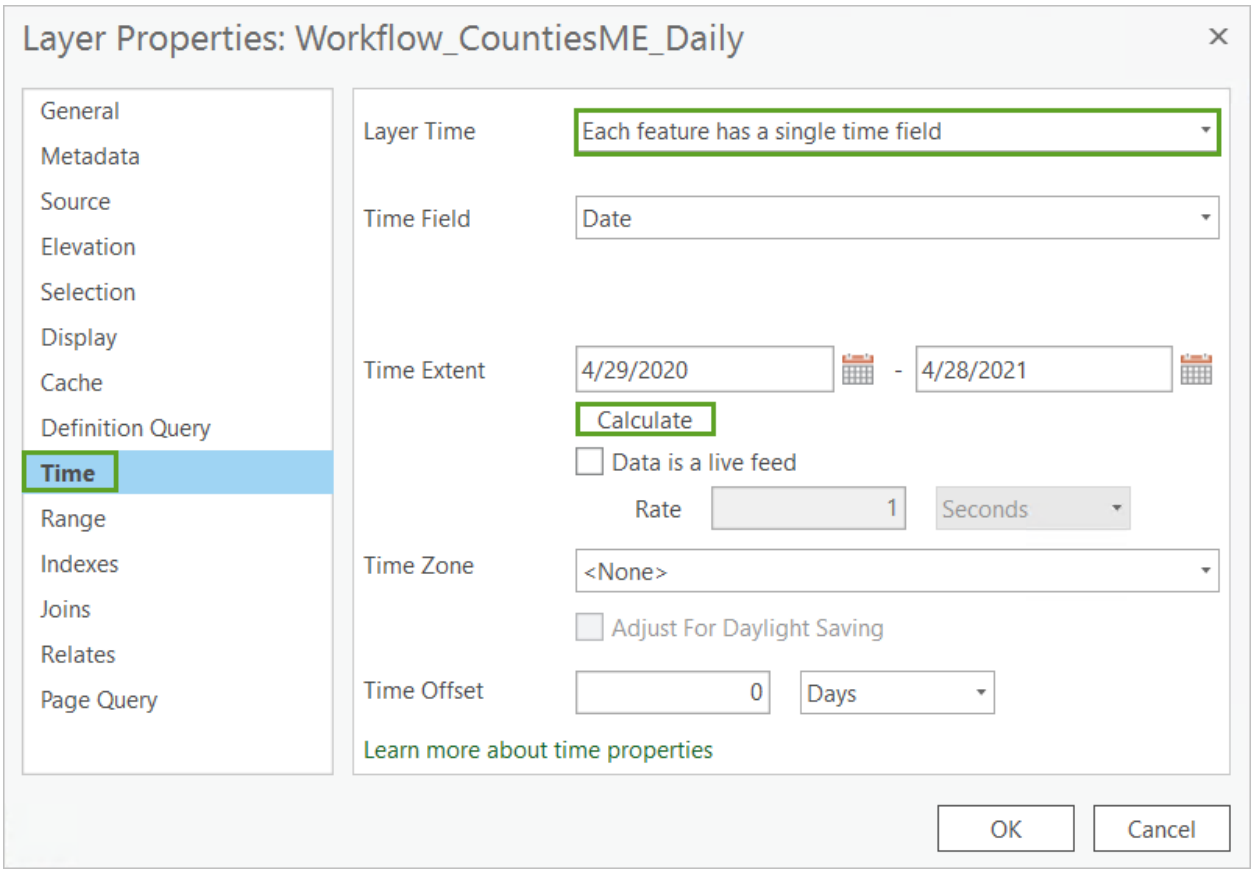


8. Click View Details at the bottom of the Geoprocessing pane. This opens the Geoprocessing Messages. Scroll down to the Messages section, where you can see a summary of the census and daily hospitalization peaks for all the counties combined.



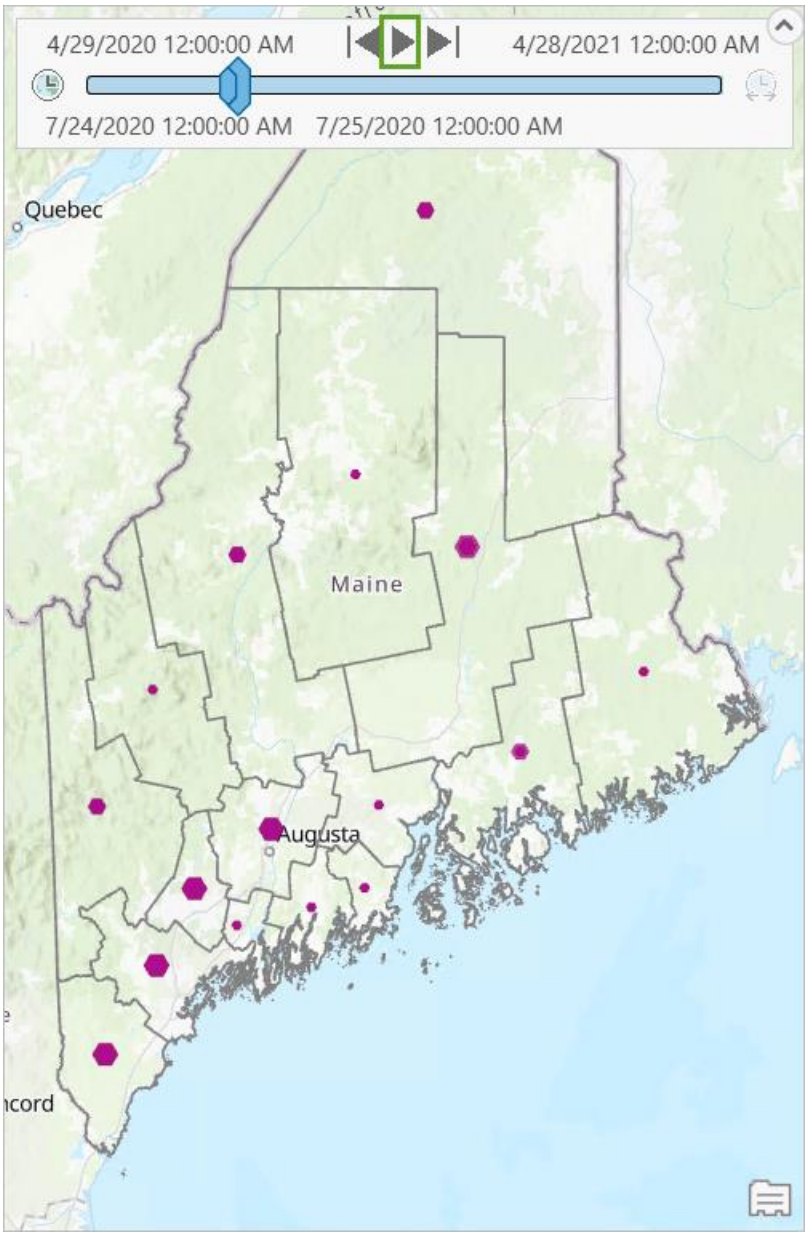
9. Open the attribute table for the layer Workflow_CountiesME_Daily. You'll notice there are 5,840 rows-this is the **Number of Days to Project** (365) multiplied by the number of records in the **Input Feature Class** (16). This means that for each location on the map, there are 365 coincident polygons - one for each projected day.

10. Right-click the output layer in the **Contents** pane, click **Properties**, and click **Time**. For **Layer Time**, choose **Each feature has a single time field**. Then in the **Time Extent**, click **Calculate**. Click **OK** to close the window.



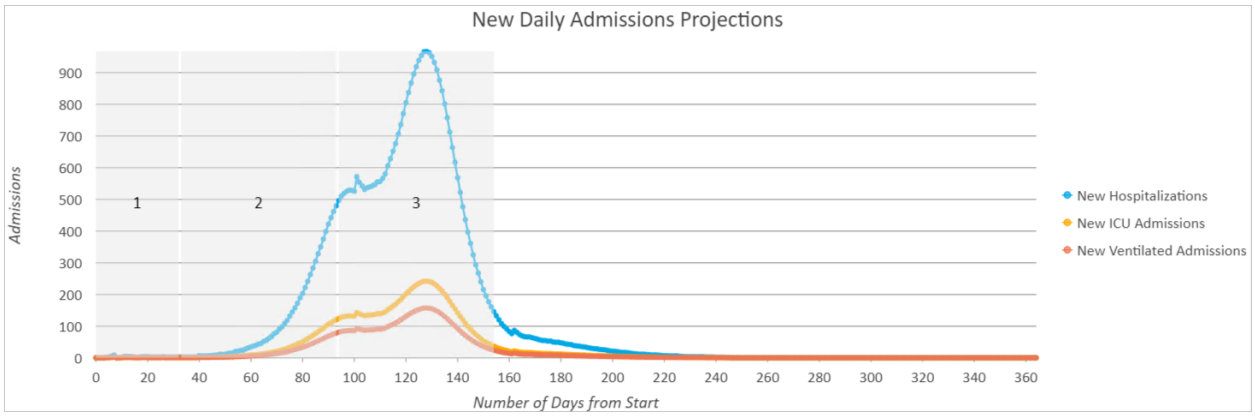
11. The output layer is now time enabled. The time slider appears on your map. Click play, and the layer sequences through each day on the map. While this happens, your attribute table is filtered to only show the records of the current time range.

    You can read more about using time in the ArcGIS Pro documentation on using Temporal data.



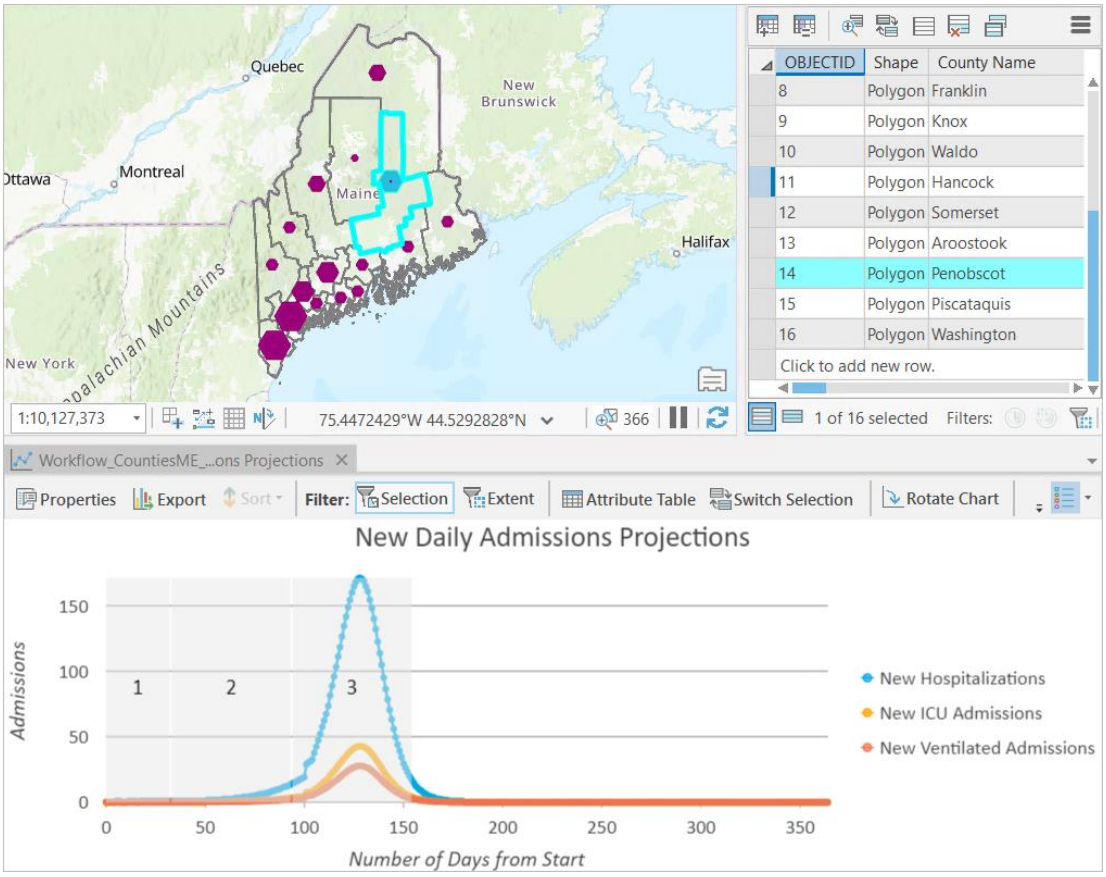
12. Click the **Disable Time** button on the time slider to revert to the full temporal range of the data.

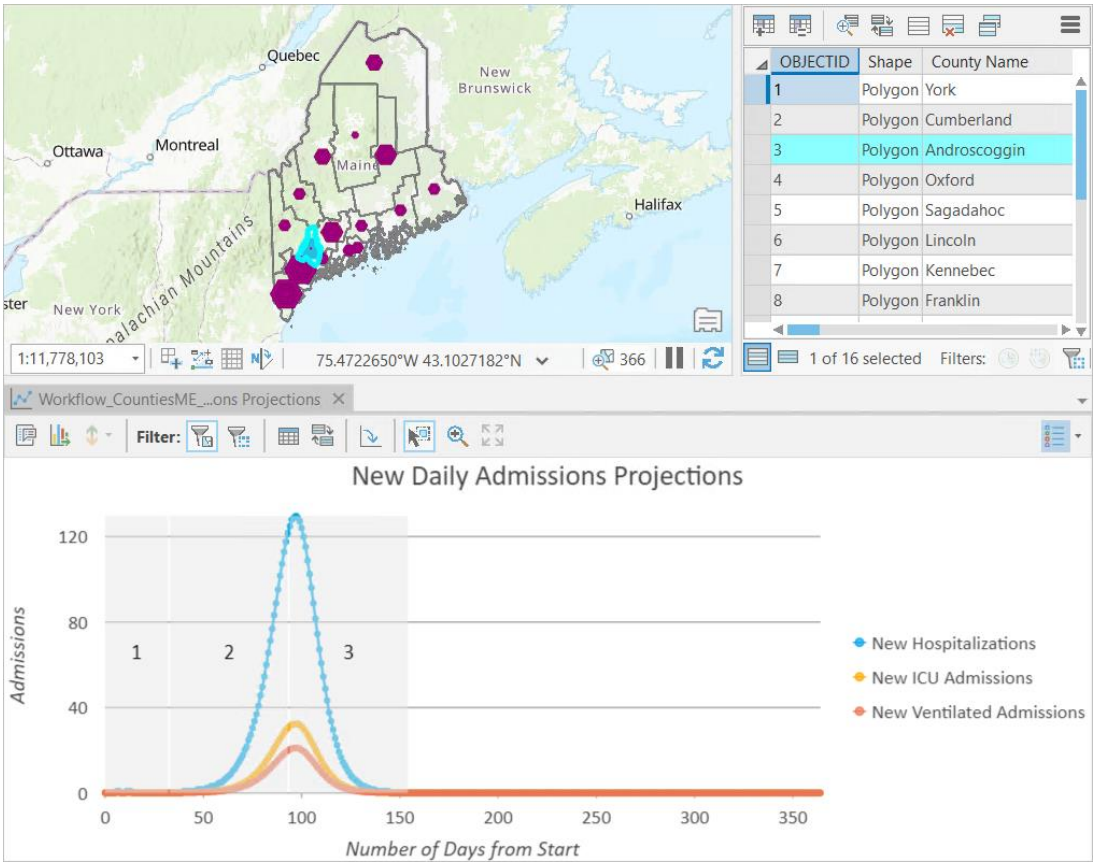
13. Open the chart **New Daily Admissions Projections** created by the tool. This chart shows three series: the number of new patients hospitalized, new patients hospitalized in the ICU, and new patients hospitalized with ventilation on each estimated day. The chart guides (gray shaded areas) show the timespan of each intervention specified in the **Interventions** section of the tool.



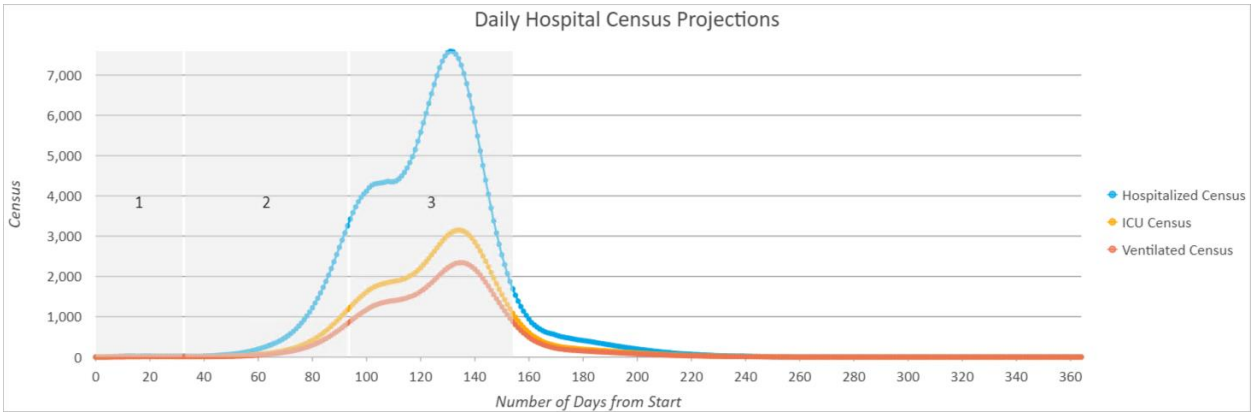
14. The shape of the series in the **New Daily Admissions Projections** chart looks unusual – notice that there appears to be more than one peak in each series. This is because the chart is aggregating the data for all the counties in Maine. You can view how the chart varies by county by selecting each county on the map.

    Click the **Filter by Selection** button at the top of the chart window. The chart temporarily appears blank. Then use the selection tool to select the coincident polygons in the output feature class for one of the counties on the map. The chart displays only the selected county's values. You can use this method to compare the time series for each county. These charts are shown below for Penobscot and Androscoggin counties. Notice how the peak hospitalization dates differ by around 1 month between these counties.

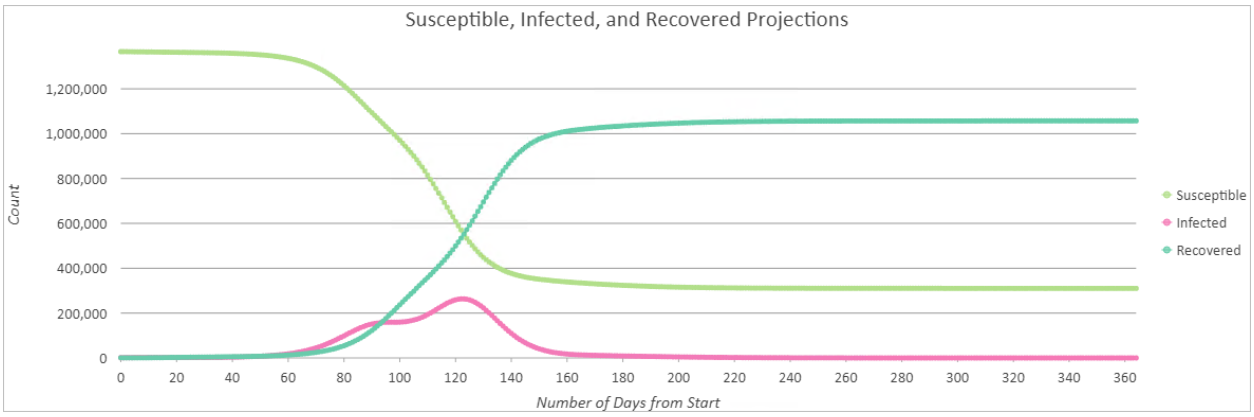




15. Open the chart **Daily Hospital Census Projections**. This chart shows three series of a similar shape to the **New Daily Admissions Projections** chart, but for this chart these pertain to the total number of people hospitalized, in ICU, and on ventilation for each day - otherwise known as the hospital census.

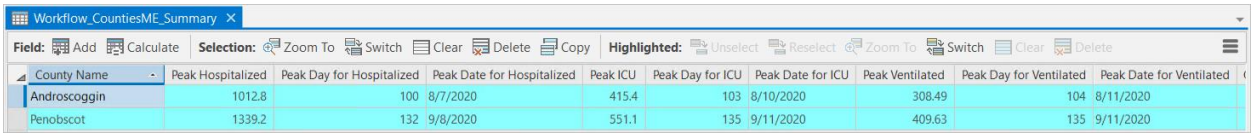


16. Open the chart **Susceptible, Infected and Recovered Projections**. This chart shows the number of susceptible, infected, and recovered or dead individuals in the **Population** for each day. The number of Susceptible and Recovered begins to invert around day 120.

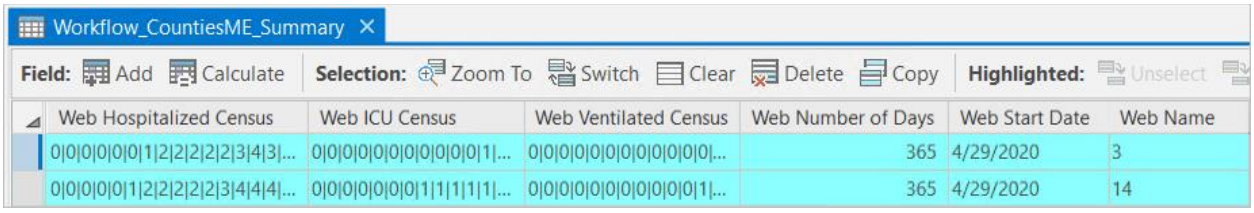


17. Open the attribute table for the layer Workflow_CountiesME_Summary. This table helps you understand when the peaks in hospitalization will occur, and when and by how many the hospital beds will be over capacity.

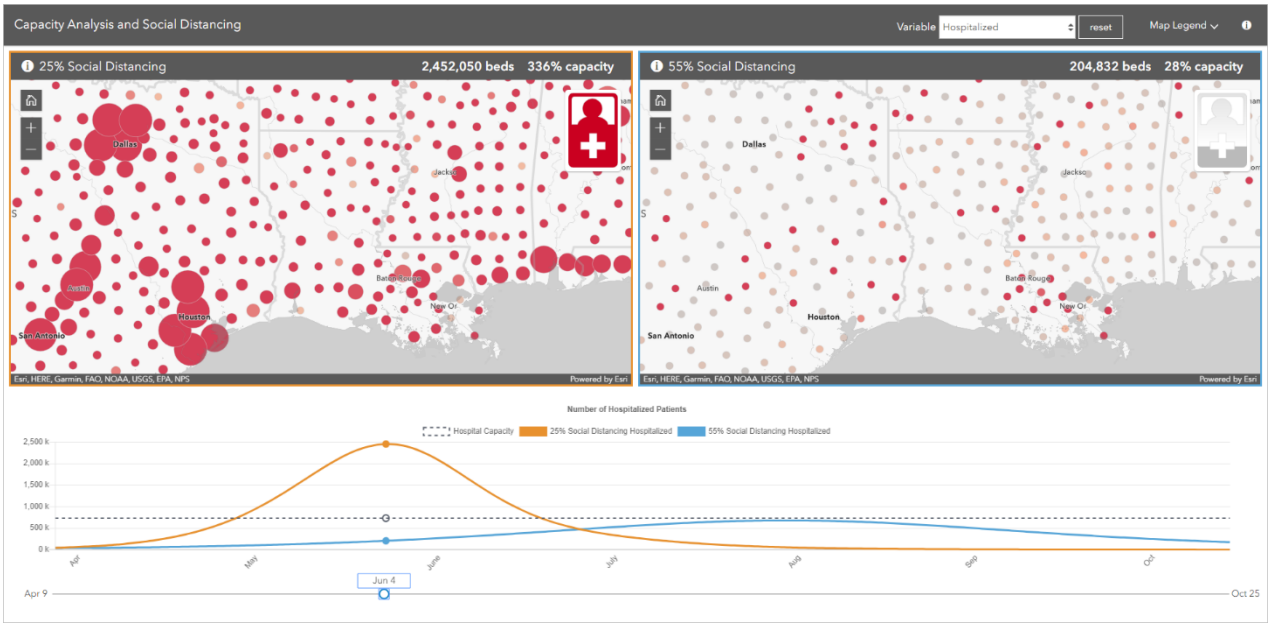
    The screenshot below shows Penobscot and Androscoggin counties (the same counties from step 14). You can see that with this fictional data, the peak hospitalization would occur on 8/7/2020 and 9/8/2020, respectively.



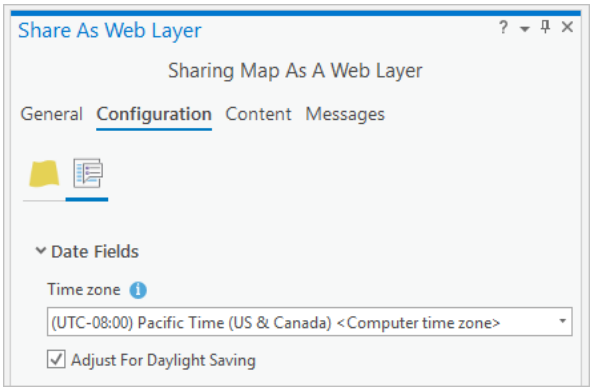
18. Scroll to the right of the attribute table. You will see six fields with names beginning with the word Web. These fields are configured specifically for use in the optional Capacity Analysis configurable app which can be published in ArcGIS Online and ArcGIS Enterprise to allow easy comparison of COVID-19Surge or CHIME Model results in a web application.



    The Capacity Analysis configurable app requires two layers – one for the left pane and one for the right pane – and is designed to compare two results with different parameters but the same geography. So, to use the Maine results in the app, you could edit the Maine data to simulate a different scenario (for example, 20% less intervention effectiveness in each county) then run the tool again. Then, you'd publish the two results as different layers, and use these layers in each pane in the app.



Note: When publishing the layers for the Capacity Analysis configurable app, the service will assume the date fields are in UTC format. For the correct dates to appear in the chart in the app, you should specify the time zone that the data was created in within the Configuration tab of the Sharing pane.



Known Issues

- This tool requires ArcGIS Pro 2.3 (or later) in order to run successfully.

References

- This tool is an implementation of the COVID-19Surge spreadsheet-based tool developed the Centers for Disease Control and Prevention's U.S. Department of Health and Human Services.
- Adhikari BB, Fischer LS, Greening B, Jeon S, Kahn EB, Kang GJ, Rainisch G, Meltzer MI, Washington ML. COVID19Surge: a manual to assist state and local public health officials and hospital administrators in estimating the impact of a novel coronavirus pandemic on hospital surge capacity (Beta test version). Centers for Disease Control and Prevention, U.S. Department of Health and Human Services; 2020.

- For questions, comments, and support, please visit our COVID-19 GeoNet community.