Priming the Pump—Stage II

Modeling and mapping concentration with fire response networks

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The article "Priming the Pump—Preparing data for concentration modeling with ArcGIS Network Analyst 9.2" published in the July–September 2007 issue of *ArcUser* magazine showed how the ArcGIS Network Analyst 9.2 extension was used to create four- and eight-minute travel areas for seven existing and three proposed fire stations in Fire District (FD) 37 that were located in and near the city of Kent in southern King County in Washington state. In the last section of this tutorial, 10 eight-minute polygon footprints were created for all stations.

This exercise picks up where the last exercise left off and shows how to build grids of each station's footprint that will be used to assess the concentration and effective response force (ERF) for the seven existing stations. After reviewing capabilities of the existing stations, the next step will be to add the three proposed stations.
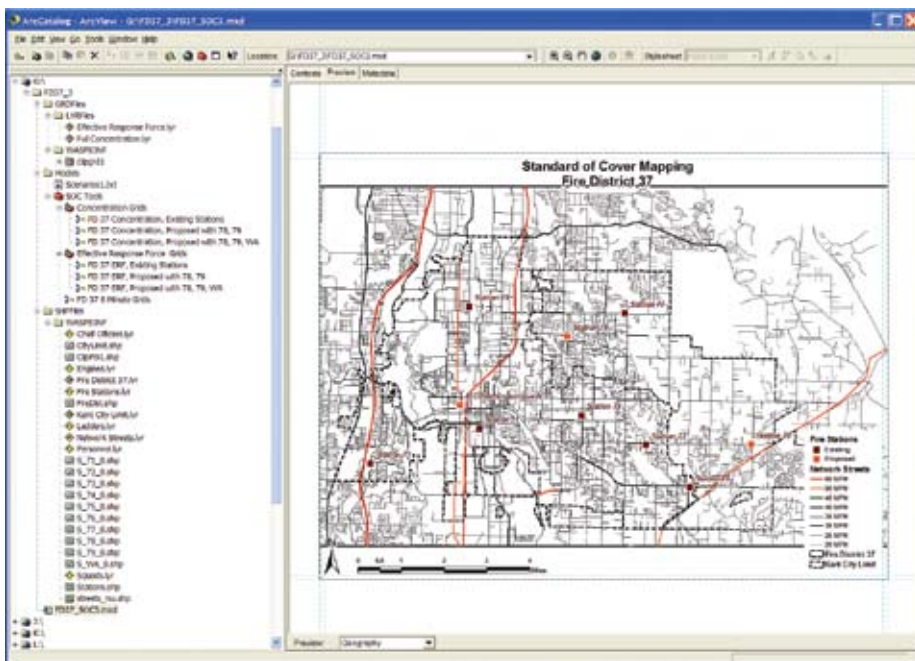
Although readers who completed the first half of this exercise could continue to use those datasets, it is better to use the data prepared for this exercise. This new data will also be used in upcoming national training sponsored by ESRI and the National Alliance for Public Safety GIS. To review modeling networks with the ArcGIS Network Analyst extension and distribution and concentration metrics, refer to the previous article.

Getting Starting

Download the sample dataset from the *ArcUser Online* Web site (www.esri.com/arcuser). Unzip the archive at or near the root directory of a local drive to create a folder called FD37_3. Explore the date in ArcCatalog and notice that there are still three subfolders named GRD-Files, Models, and SHPFiles. The GRDFiles and SHPFiles folders each contain a subfolder called WASP83NF. SHPFiles contains many shapefiles and layer files while GRDFiles contains only one clipping grid.

The Models folder contains new scripted models that will be used to prepare data and calculate and map concentration. The FD 37 8 Minute Grids model and two toolbox subsets contain models that build concentration and ERF for existing stations and two of the proposed sites. These Standard of Response Coverage (SOC) tools will be loaded into an ArcMap document.

For those who completed the first exer-

Open the FD37_SOC3.mxd file from the sample dataset and make sure the ArcGIS Spatial Analyst extension is available and its toolbar is visible.

cise, the shapefiles and layer files in SHPFiles\WASP83NF will look familiar. Carefully study the 10 station footprint polygons. Each polygon name begins with the letter "S." In the previous exercise, the fire station attributes were joined to the 8 Minute Network Analyst polygons and exported to preserve the join and named S_71_8 through S_WA_8. These travel footprints will be used to model the effective eight-minute coverage for all existing and proposed stations. It is important to retain these shapefile names because they will be called by procedures in the SOC models.

Modeling in ArcMap

Start an ArcMap session and verify that the ArcGIS Spatial Analyst extension is available. Navigate to the FD37_3 folder and load FD37_SOC3.xmd. Switch to Layout View and inspect the map. The FD 37 model includes seven existing stations (71–77) and three proposed stations (78; 79; and 407 Washington, WA). Make the layers for Squads, Chief Officers, Ladders, Engines, and Personnel visible. View the stacked symbology and colored labels indicating the available apparatus

Before loading SOC custom tools, change the document properties so geoprocessing operation outputs will be overwritten and added to the display.

and staff for stations existing and proposed. Table 1 summarizes this information.

Compare the information in the table with the Fire Stations attribute table. Fields E_01, E_02, L_01, BC01, and S_01 list the available apparatus at each station. The STAFF_T field

lists each station's available response personnel that will be used to calculate ERF. Look at the table's SOC Code column, which contains a three-digit numeric code that represents apparatus availability. In this code, "1" represents available engines, "10" indicates ladders, and the "100" counts the battalion chiefs. This numeric coding is a key to this model. Maximize the mapping area by switching back to Data View.

Preparing the Modeling Environment

Before loading the custom SOC tools, make sure the ArcMap document will use relative data paths when searching for and storing data. ModelBuilder will streamline the workflow but it requires a specific environment and particular operating rules. The next steps are very important so follow them carefully.

1. Choose File > Document Properties and click the Data Source Options button. In the next dialog box, click the radio button next to Store relative path names to data sources.

2. Next, tell ModelBuilder to overwrite the products of earlier calculations—because building and testing the model will most likely require several iterations—by clicking Tools in the ArcMap menu and selecting Options.

3. Locate the Geoprocessing tab and inspect its contents. In the General area, place a check in the Overwrite the outputs of geoprocessing options box. (Note: It may be necessary to disable file overwriting later.)

4. In the Display/Temporary Data area, check Add the results of geoprocessing options to

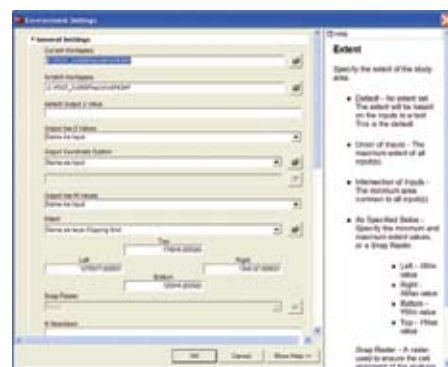the display. Uncheck the box next to Results are temporary by default.

5. Open ArcToolbox by clicking the ArcToolbox icon and place it immediately to the right of the Table of Contents.

6. Access the model's Environment by right-clicking in an empty area of ArcToolbox and clicking Environments. Open the General Settings drop-down, click on the button with the folder icon, and change the Current Workspace and Scratch Workspace by browsing to ..\FD37_3\GRDFiles\WASP83NF.

7. Scroll further in the Environment dialog box and use the Extent drop-down to set the analysis extent to Same as Layer Clipping Grid. Minimize the Environment Settings.

8. Click on Raster Analysis Settings and set Cell Size to Same as Layer Clipping Grid. Notice that our model cells will be 50 feet, the approximate width of a four-lane city street. Click OK to apply changes.
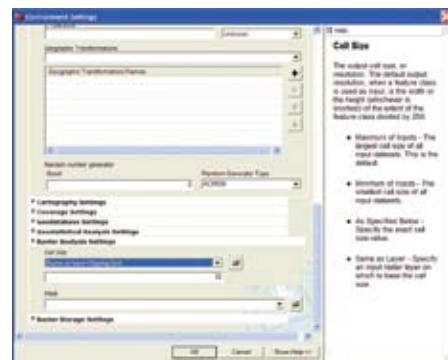
Loading and Inspecting a Custom SOC Toolbox

Now load a custom toolbox that contains utilities to process the 10 station travel polygons and calculate concentration and ERF.

1. Right-click on the ArcToolbox header and select Add Toolbox and navigate to\FD37_3\Models and load SOC Tools. Open all tools in the SOC Tools and study their names.

2. Float the cursor over the tool names to reveal the entire name. SOC Tools contains one model named FD 37 8 Minute Grids that will

Set the Current Workspace and Scratch Workspace in the Environment Settings dialog box.

On the Raster tab of the Environment Settings dialog box, set the Cell Size to Same as Layer Clipping Grid.

Station	Status	Engine	Ladder	BC	Squad	Total Staff	SOC Code
71	Existing	E 71			S 71	5	1
72	Existing	E 72				3	1
73	Existing	E 73			S 73	4	1
74	Existing		L 74	BC 1	S 74	6	110
75	Existing	E 75				3	1
76	Existing	E 76				3	1
77	Existing	E 77				3	1
78	Proposed	E 78				3	1
79	Proposed	E 79				3	1
WA	Proposed	E 70		BC 2	S 70	6	101

Table 1: Apparatus and personnel assignments for existing and proposed stations

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be run first to process the travel areas.

3. Two toolsets, Concentration Grids and Effective Response Force Grids, each contain three models to assess existing stations and two proposed scenarios.

4. Right-click the FD 37 8 Minute Grids toolset and select Edit (not Open) from the context menu. Use View > Zoom > Full Extent to display the entire model. Count the executable lines. This model processes 10 travel area polygons by first converting them to single stacked grids and then reclassifying them. Once reclassified, these grids will display a value of 1 for all cells traversed within eight minutes and 0 for cells not reached in eight minutes.

5. Double-click on Polygon to Raster 10 and inspect the inputs and outputs for this operation. This step converts the Washington Station's travel area to a grid with the polygon's FID (Feature ID) value in all traversed cells, while setting all untraveled cells to Null. Check Output Raster Dataset to verify that the intermediate grid is stored in ..\FD37_3\GRD-Files\WASP83NF as a permanent grid named Temp1_WA_8. Click Cancel to close.

6. Double-click and inspect Reclassify 10. This step reclassifies the Temp1 grid, assigning a value of 1 to all FID values of 0 through 99. It reassigns all 0 to all NoData cells and saves the reclassified grid as rc_wa_8.

7. Click Cancel to close again and save the project.

This model creates 10 individual grids, using names and locations that may be edited by a user. When modeling SOC for fire agencies, these outputs can be expanded, contracted, and renamed to accommodate actual station counts and names.

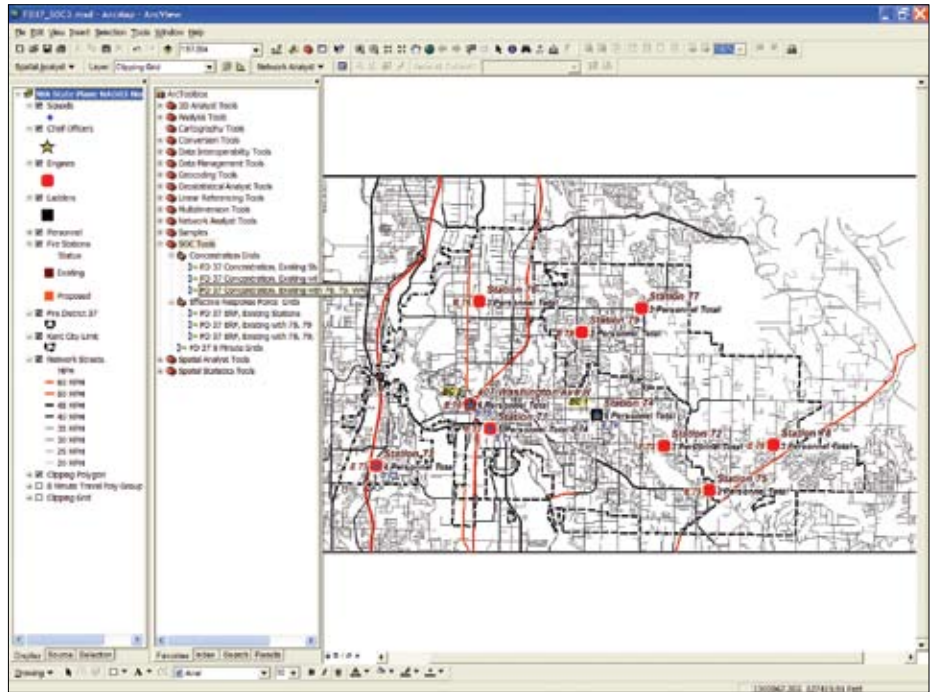### Building Individual 8 Minute Travel Grids
The next operation is the most tedious one in this model, but it is easy with ModelBuilder. If ModelBuilder was not used, each grid would have to be created individually. For a large city or a county, this could mean converting and reclassifying as many as 50 footprints.

1. With FD 37 8 Minute Grids model open, choose Model > Run Entire Model from the menu.

2. Watch as 20 separate processes run and the 10 reclassified grids appear in the Table of Contents (TOC). Depending on processing and disk access speed, it can take up to five minutes to run.

3. When the model finishes running, close it. It is not necessary to save any changes to the FD 37 8 Minute Grids model.

4. Individually inspect each reclassified grid. Do they look reasonable (i.e., do they contain

Load the SOC Tools toolbox, which contains two toolsets: Concentration Grids and Effective Response Force Grids.

only 0 and 1 values)?

5. Shift-click to select all grids and group them into a single TOC object. Name it 8 Minute Travel Grid Group. Contract legends for individual grids and make the master group not visible. If necessary, move the group to the bottom of the TOC, just above the Clipping Polygon.
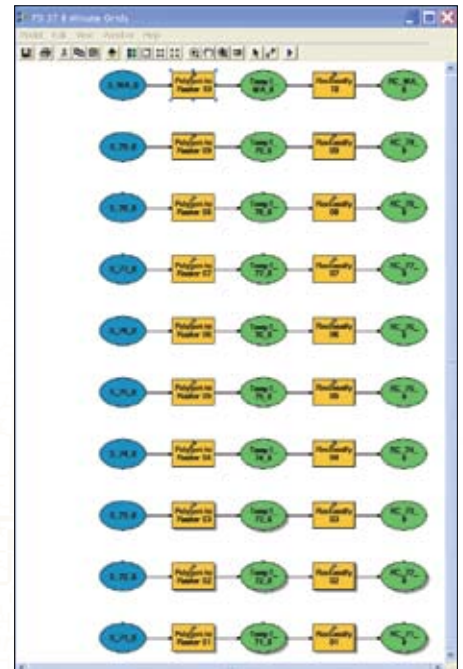
6. Save the project.

Defining and Modeling Full Concentration
With individual travel footprints in the TOC, the next step is calculating concentration and ERF.

1. In the Concentration Grids toolset, right-click FD 37 Concentration, Existing Stations and select Edit.
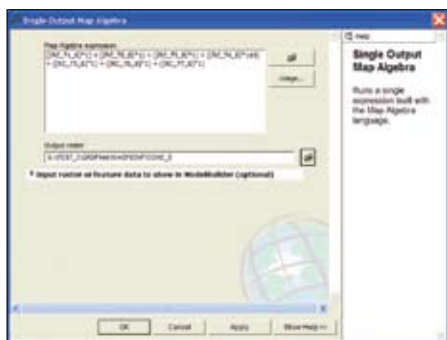
2. Double-click the Single Output process to open the Single Output Map Algebra dialog box. Study the simple calculation and notice how it multiplies all existing station grids by the appropriate battlion chief (BC), ladder, and engine SOC Code listed in Table 1. All Map Algebra expressions are stored in a text document as ..\FD37_3\Models\Scenarios1.txt. Most existing stations contain one engine with an SOC Code of 1. Station 74 includes a BC and a ladder; its Code is 110. All factored grids are summed, and the resulting grid is stored as CONC_E. Cancel back to the model and run it. Close the model when finished and save again.

Right-click on the FD 37 8 Minute Grids in the Concentration Grids toolset and select Edit.

3. Close the Single Output Map Algebra dialog box and run the model.

4. Inspect the resulting grid. Existing station values range from 0 to 114. A Full Concentration requires that one chief officer, one ladder, and three engines all be on scene in less than eight minutes from time of departure.

Double-click on the Single Output process to open the Single Output Map Algebra dialog box to inspect the calculation it performs.

Therefore, the lowest model code for Full Concentration is 113. All lower values fall short of the required force. Rather than creating a new legend for this grid, apply the standard legend from the Concentration.lyr file included in the sample dataset.

5. Load the Concentration symbology by right-clicking on conc_e and opening Properties.

6. Click the Symbology tab and change the Show: type from Unique Values to Classified (this is very important).

7. Click Import, browse to ..\FD37_3\GRDFiles\LYRFiles, and select Full Concentration.LYR.

8. In the General tab, rename this grid to Concentration, Existing Stations.

This legend is customized for Fire District 37. Notice that the legend accommodates up to two BCs and maps areas accessed by three to five or more engines. Since the model does not include a second ladder, only one is mapped. Green colors show that full concentration is now achieved in much of the Kent City area, but there are some gaps. Save the project.
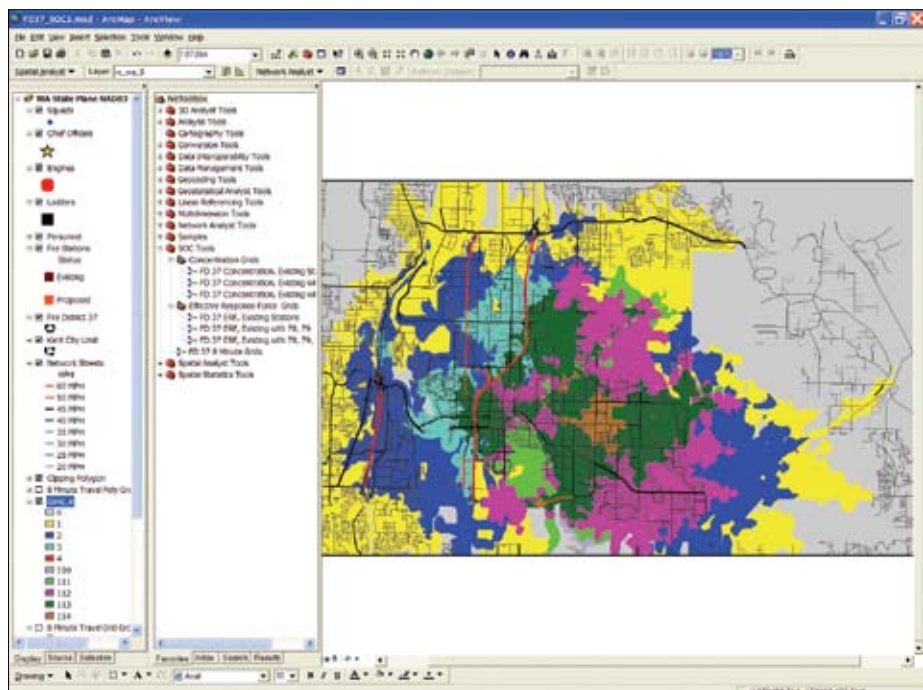
Repeat the process for proposed stations. Run FD 37 Concentration; Existing with 78, 79 model; apply the Full Concentration.lyr file to the output; and rename the FD 37 Concentration, Existing with 78, 79. Follow the same steps with the Concentration, Existing with 78, 79, WA model. Arrange the grids in a group of three with 78, 79, WA and Existing on the bottom.

1. Select all three new grid layers by clicking and holding down the Control key.
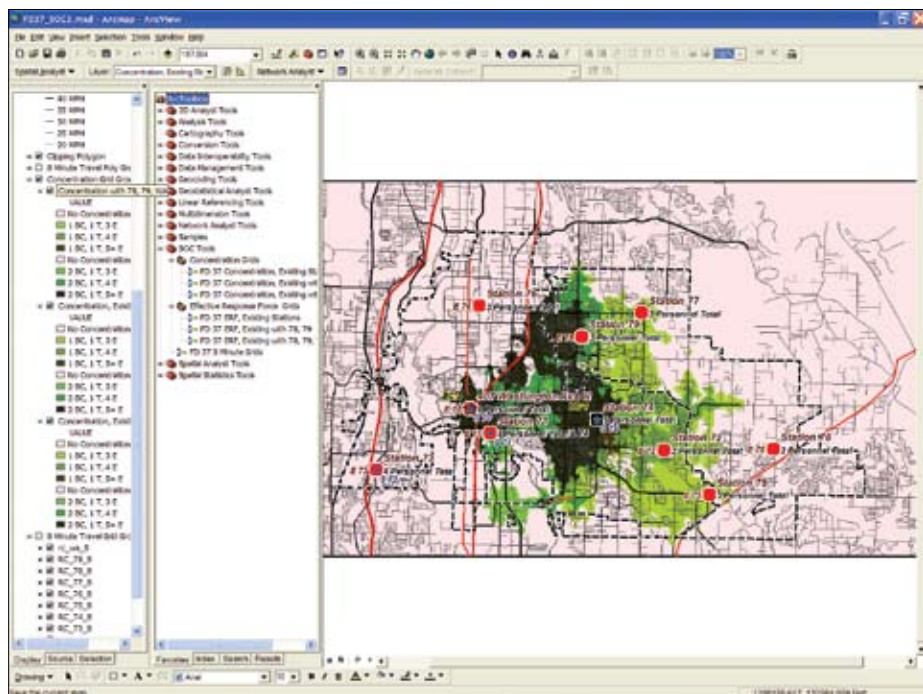
2. Right-click on any layer and choose Group from the context menu to create a Group Layer.

3. Name the Group Layer Concentration Grid Group. Save again.

Station 78 brings one engine and three staff on line; Station 79 adds another engine and three staff members. The WA Station, added in

Apply the Full Concentration Layer file to symbolize the output of the FD 37 8 Minute Grids tool.

Run the tools for the two additional scenarios and apply the Full Concentration Layer file to the resulting grids.

the second proposal, includes an engine, a battalion chief, and six staff. Do you agree with the improvements? What is the effect of adding a second BC at the WA Station? Now let's count the Response Force. Minimize and turn off all groups.

Mapping Effective Response Force

Now it is time to run the models for ERF. Return to the SOC Tools and expand the Effective Response Force Grids toolset.
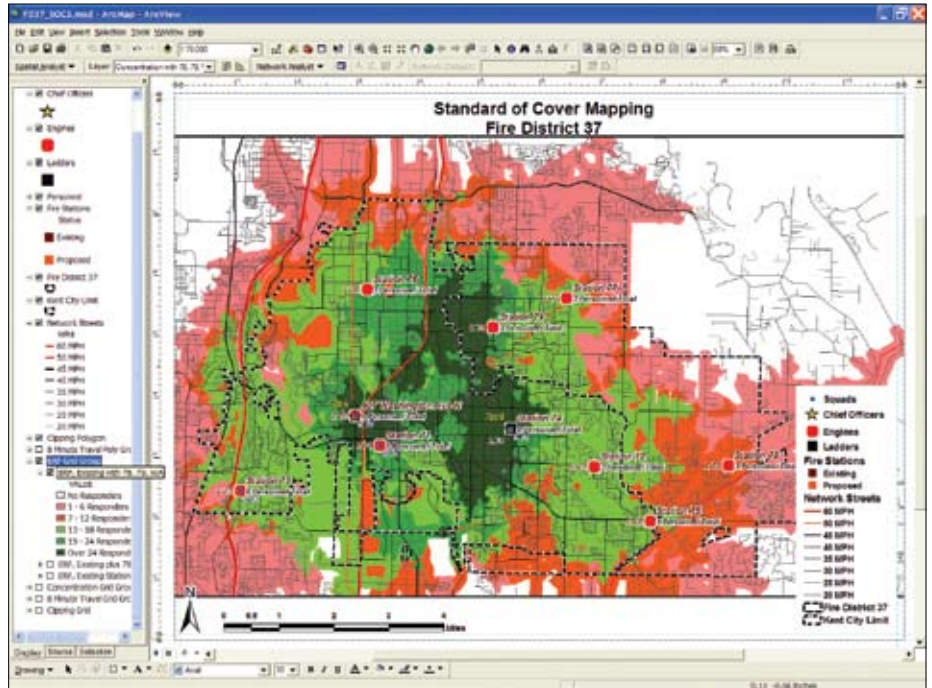
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1. Click Edit (not Open) for the FD 37 ERF, Existing Stations model.

2. Double-click on Single Output and notice that this Map Algebra expression multiplies each station grid by the number of available firefighters before adding them together. The resulting grid is named EFF_E.

3. Close the Map Algebra dialog box, run the model, and inspect the results. The output grid shows that as many as 21 firefighters may be available in various model areas.

4. In the TOC, rename this layer ERF, Existing Stations and import symbology from Effective Response Force.lyr. Notice that the graduated color scheme, transitioning from red to green, accommodates up to 30 firefighters. Save the document.

5. Run the Existing Stations, 78 and 79, and Existing Stations, 78, 79, and WA and apply the Layer file to each.

6. Create a layer group of all three grids and name it ERF Grid Group.

7. Save the project and switch to Layout View.

After running the ERF tools and symbolizing the outputs, switch to Layout view.

Summary

Now pretend that you must make a presentation to the district that demonstrates and justifies the addition of two, and possibly three, stations. This exercise created eight-minute travel grids for 10 existing and proposed stations and modeled concentration for one existing station and two proposed ones. ERF was also modeled for all scenarios.

This training dataset is adapted from actual Fire District 37 data. It has been modified slightly for training use. Fire District 37 has actually modeled nearly 20 different deployment and personnel scenarios using these stations and others, too. At FD 37, fire prevention professionals experiment with different apparatus and staffing scenarios, weighting them against changing values at risk, cost, and deployment timetables. The staff also experiments with different travel times to achieve optimum concentration effect.

Acknowledgments

The author thanks, once again, the administration and staff of Fire District 37 in South King County in Washington and the many FD 37 and Kent City staff who provided data for this exercise. The author also thanks the National Alliance for Public Safety GIS, the Commission on Fire Accreditation, ESRI business partner ESCi, and ESRI's public safety marketing group for their support of new developments in Standard of Cover GIS mapping.