Gray to Green (G2G) User Guide and Documentation:

A decision support tool for transitioning to vegetation-based stormwater management

A product of the University of South Florida in partnership with the University of Florida and Thomas L. Singleton Consulting with grant funding assistance from the U.S. Forest Service

Contents

Introduction

Depleted and degraded water resources are driving communities to look for totally new systems for managing stormwater. These include systems where stormwater is recycled, rainwater is harvested, peak stormwater flows slowed down, and discharges to receiving waters from both pipes and land uses are significantly reduced or eliminated. Using these new systems, the natural and built environments within communities are being reconfigured to restore hydrological and ecological functions, provide for the water needs of the community, and protect the health of people and the environment that sustains them.

What is G2G?

The Gray to Green (G2G) decision support tool is a GIS-based toolkit that guides users in transitioning:

- *From* conventional "pipe and pond" (gray) stormwater management systems designed to drain, direct, and quickly dispatch and dispose of stormwater;
- *To* vegetation-based (green) stormwater management systems designed to slow, spread, soak, and manage stormwater as a valuable resource for people and the environment.

G2G follows a *volume-based approach* to manage stormwater. It promotes the protection of *green infrastructure* and the use of ecosystem services and trees to reduce stormwater runoff volumes, velocity, and pollutant loads. It utilizes GIS to help users identify potential areas for:

- Protecting and restoring green infrastructure and the natural pathways for water; and
- Siting 11 low impact development (LID) best management practices, including:

Green roofs	Pervious pavement	Constructed wetlands
Rainwater harvesting	Bioswales	Wet ponds
Tree plantings	Infiltration trenches	Dry ponds
Rain gardens	Infiltration basins	

It utilizes Excel to help users quantify water volume and pollutant load reductions as well as other benefits for different development scenarios. This is done as part of one continuous and strategically designed treatment train.

The strength of G2G is the scenario testing which allows users to see what happens when you maximize the use of green infrastructure and LID practices. It expands the understanding of what is possible for users both with and without practical experience using LID practices. It provides the necessary context for protecting green infrastructure and the natural pathways for water which is critical to defining problems and developing comprehensive solutions at the both the site and watershed scales. Although there are very sophisticated models for evaluating stormwater designs, they require special expertise to run and are not easily applied or commonly used for planning, regardless of the scale. Planners, resource managers, scientists, and engineers can use G2G to guide project planning for:

- Urban reforestation;
- New development and redevelopment;
- Stormwater retrofits for water quality enhancement and flood reduction; and
- Community resilience and adaptation to climate change.

G2G was developed by the University of South Florida, in partnership with the University of Florida and Thomas L. Singleton Consulting, with grant funding assistance from the U.S. Forest Service.

What is green infrastructure?

Green infrastructure is the green space or natural areas in a city. It comprises the natural pathways for water, including aquifers, springs, lakes, streams, rivers, estuaries, and bays, as well as wetlands, floodplains, riparian areas, open spaces, groundwater recharge zones, and forests. Green infrastructure benefits people by cleansing urban runoff, replenishing aquifers, absorbing floodwaters, scrubbing airborne pollutants, sequestering carbon, moderating microclimates, and sheltering wildlife. It also supports mobility, food, fiber, and water production, economic productivity, recreation, public health, cultural identity, and community cohesion.

Green infrastructure helps maintain the natural cycle of precipitation, vegetation, evaporation, water courses, and reservoirs, known as the hydrologic cycle. The quantity of water in each segment of the cycle—the water balance—defines the local landscape: the type and amount of vegetation, the type and prevalence of streams and surface water features, and the amount of water in the groundwater aquifer. Land use changes and development alter the hydrologic cycle and the natural water balance. Rainfall continues, but where impervious surfaces have replaced forests, a much larger percentage of the rainfall is converted to stormwater runoff. Because more water in the cycle is diverted as runoff, the volume of runoff increases dramatically, while the volume of groundwater recharge and evapotranspiration decreases. With intense urban development, there can be a five-fold increase, or more, in the amount of runoff; an 80 percent loss of deep infiltration; a 60 percent loss of shallow infiltration; and a 25 percent loss in evapotranspiration. Such changes to the water balance effectively short circuit the water storage capacity of the natural landscape, contribute to flooding, and reduce the amount of water available in the watershed for people and natural systems.

What is a volume-based approach to managing stormwater?

G2G helps users evaluate ways to reduce the amount of runoff associated with land development to restore a more natural water balance, using management practices that slow, spread and soak the land surface with rainfall. This approach creates opportunities to harvest rainwater, recycle stormwater, reduce and slow down peak stormwater flows, and reduce or eliminate piped discharges to receiving waters. This can reduce flooding and enhance water quality, water supply, and natural system protection. By working to restore the water balance through better planning and design, G2G can help development be a force of good or at least be less destructive.

Stormwater regulations have traditionally focused on controlling the rate of flow for larger storm events—not the volume of flow—to prevent flooding. This means the total volume of water leaving a site may increase dramatically, even if the water does not leave the site at a rate higher than it did before development. As a result, detention basins designed to meet these requirements do not reduce flooding—instead, they contribute to flooding. They increase the volume of runoff and extend the duration of flow which increases downstream flow rates and flooding. This effect is magnified at the watershed scale where the combined volume from many sites leads to increased flow rates and water levels (American Society of Civil Engineers, *Design of Urban Stormwater Controls*, 2012, pp. 63-66.). As a result, flood control—the primary goal of detention systems—is not achieved. This will only become more apparent and the problem made worse with increased urbanization, the buildout of watersheds, and the increased frequency of intense storm events throughout the US (Fig. 1). As Figure 1 shows, There is a clear national trend toward a greater amount of precipitation being concentrated in very heavy events, particularly in the Northeast and Midwest.

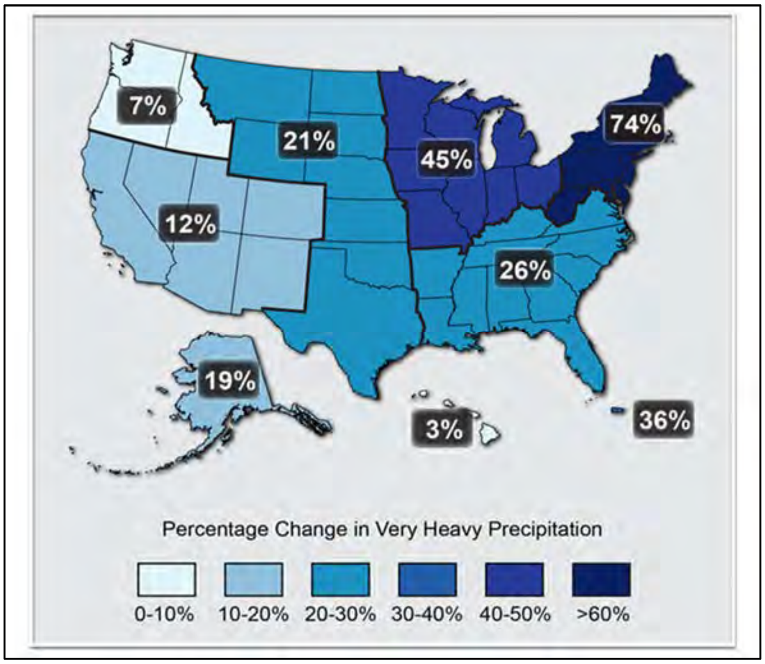


Figure 1. Observed change in very heavy precipitation. Percent changes in the amount of precipitation falling in very heavy events (the heaviest 1%) from 1958 to 2012 for each region (Melillo & Richmond 2014).

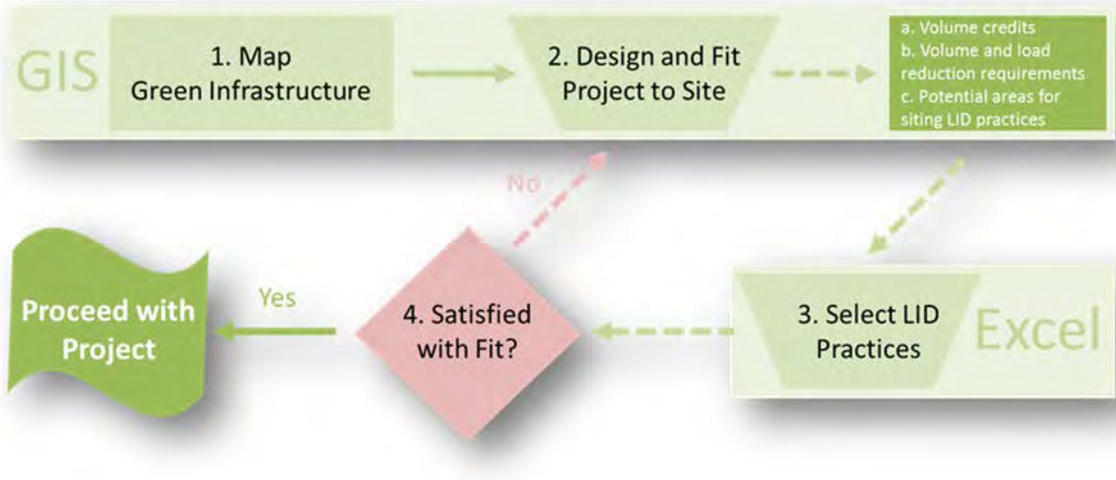
The "volume-based" approach used in G2G to manage stormwater, stands in stark contrast to the traditional "collect and convey at a controlled rate and flow" approach found in most stormwater regulations today. The design goals of G2G are to capture all the runoff from small storms (less than 1.5 inches of precipitation which comprise 90 percent or more of the rainfall events in most parts of the US), and as much runoff as possible from larger storm events. This dramatically reduces the volume of water discharged downstream and replicates the natural system response to rainfall (Table 1). This reduces both pollutant loading and downstream flooding. Captured rainfall is returned to the atmosphere through soils and vegetation, returned to the groundwater, and used to meet the needs of people and nature. Excess runoff from larger storms should be released at a rate that can be safely conveyed downstream without causing erosion or the receiving waters to overflow (in most cases, a flow rate not exceeding the 2-year, 24-hour storm, e.g., releasing runoff from a 10-year storm at a flow rate of a 1-year or 2-year, 24-hour storm).

Capturing runoff from the early part of a large storm is more effective than controlling the rate of flow at the height of a storm. As shown in Table 1, a volume-based approach that mimics the natural system response, as promoted using G2G, is far more effective at reducing the flooding impacts of larger storm events than the conventional approach of detention and conveyance.

Table 1. Comparison of the rainfall response of natural and altered landscapes, summarizing the advantages of mimicking natural systems in landscape design (Watson & Adams 2011).

Storm Size	Landscape Conditions	Rainfall Response
Very small storms (< 0.5 inches) In most areas, more than 65% of all rainfall events are less than 0.5 inches	**Natural** Interception by vegetation Infiltration into soils	No runoff – water returned to atmosphere or groundwater
	Altered Impervious surfaces increase volume and frequency of runoff	Nearly all rainfall on impervious becomes runoff
Small storm events (< 1.5 inches) In most areas, 95% of all rain events are less than 1.5 inches	**Natural** Depression storage Groundwater levels rise Headwater streams rise Infiltration into soils	Little or no runoff
	Altered Loss of forest and natural groundcover Increase in lawn, compaction of soils	Rainfall on landscape becomes runoff
Moderate storm events (> 1.5 inches) Varies by location, but generally between 1.5 inches and 4 inches	**Natural** Streams flow full Floodplains may flow	Runoff begins
	Altered Stream channel cuts down from too much runoff too often Floodplain is disconnected from channel	Increased runoff volume is greater than capacity of streams and floodplains
Larger storm events (> 2 year-24 hour)	**Natural** Local and watershed flooding	Floodplains slow flow and limit damage
	Altered Downstream flooding increases in frequency and level	Water is conveyed downstream faster and in greater amounts

Summary of the 4-step planning process used in G2G



The four-step planning process used in G2G, detailed in this user guide, can be summarized as follows:

1. **Map green infrastructure:**
    a. Start at the top of the watershed and work your way down to your site to identify critical hydrologic and habitat connections for protection and/or restoration;
    b. Use the GIS tools in G2G to map green infrastructure and prepare a digital elevation model (DEM) to identify the natural pathways for water that are contributing water to and flowing through the site.
2. **Design and fit the project to the site:**
    a. Start by placing structures and other impervious areas on the site in a way that protects green infrastructure and natural pathways for water;
    b. Use the GIS tools in G2G to map potential areas for siting LID practices.
3. **Select LID practices:**
    a. Start at the beginning: first, where rain falls on the roof, then on other impervious areas and, lastly, on land (pervious areas);

    b. Use the Scenario Analysis Tool in G2G and the potential areas for siting LID practices identified in **Step 2**, to select and evaluate multiple combinations of LID practices;
    c. G2G will walk you through the selection of practices to capture 100 percent of the runoff, first, from roof areas, then paved areas, and lastly open land (pervious areas), as part of one continuous and strategically designed treatment train as follows:
        - Select practices to slow, spread, and infiltrate rain water;

- o Plan for overflow routes and manage overflow as a resource;
- o Maximize vegetation and organic groundcover, including trees, to create a living sponge that increases infiltration and reduces evaporation, runoff, and erosion;
- o Stack functions to maximize beneficial relationships and efficiency; and
- o Devise strategies that solve one problem that simultaneously solves many other problems and create resources.

4. **Evaluate how well the project fits the site:**
   a. If the fit can be improved, modify your design using G2G as a guide and repeat **Step 3**.
      - o Practice adaptive management by reassessing the performance of your system after the project is completed and, if required, modify your design.
      - o Evaluate the capacity of the project to manage larger design storms to increase the adaptive and resilient capacities of the project and restore more of the natural water balance on your site.

Organization of this guide

The main chapters in this guide are organized into four parts corresponding to the four steps in the G2G planning process. The chapters in Step 1 (Chapters 1-6) include detailed instructions on using the **Green Infrastructure Mapping Tool**. Guidance on designing and fitting your project to the site are found in Step 2 (Chapter 7). Instructions on using the **Scenario Analysis Tool** to select LID practices are found in Step 3 (Chapters 8), while Step 4 (Chapter 9) provides guidance on evaluating how well the project fits the site.

The description and rationale for G2G are provided in the Introduction. Case studies from Tampa, Florida and Milwaukee, Wisconsin that illustrate the functions and utility of G2G can be found in the Appendices. The Appendices also include links to data sources and other supporting information. Video tutorials on using the tool and describing the case studies are available here________________________.

Once you become familiar with G2G, use the "**Quick Guide**," located at the end of this chapter, to get the answers to your questions.

The following is an overview of the chapters in this guide:

Step 1 – Mapping Green Infrastructure

> In *Chapter 1*, *Installing the Green Infrastructure Mapping Tool*, we review the GIS system requirements and instructions for installing the **Green Infrastructure Mapping Tool** along with the necessary addins and extensions. It also includes instructions for using the Mapping Tool on a Mac computer.
>
> In *Chapter 2*, *Using the Project Toolbar to Create a Project*, we introduce the **Project Toolbar** and provide guidance on creating new projects and creating a project folder for your GIS data, Green Infrastructure Map, Excel workbook, and PDF report outputs.
>
> In *Chapter 3, Assembling the Data to Map Green Infrastructure*, we identify the data layers, data sources, methods, and GIS outputs for creating the **Green Infrastructure Map**. We include

suggestions on securing, preparing, and using the data, including recommendations for user-generated data.

In *Chapter 4, Using the Data Toolbar*, we cover the functions found on the Green Infrastructure Mapping Tool's Data Toolbar, including the buttons for creating layers that can be added to your project.

In *Chapter 5*, *Adding Files to Your Project*, we go over how to add files to your project and adjust the units and cutoffs when appropriate.

In *Chapter 6*, *Generating Green Infrastructure Areas*, we go over creating the Green Infrastructure Map and areas for siting LID practices, along with other outputs from the tool.

Step 2 – Fitting the project to the site

In *Chapter 7*, *Strategies and practices for fitting the project to the site*, we provide streamlined objectives, strategies, practices, and a checklist as a guide for better site design.

Step 3 – Selecting LID practices

In *Chapter 8*, *Using the Scenario Analysis Tool*, we cover how to use the Scenario Analysis tool, including data inputs, as well as interpreting the runoff volume and pollutant load calculations, LID practice performance, and other scenario outcomes.

Step 4 – Evaluating the project fit

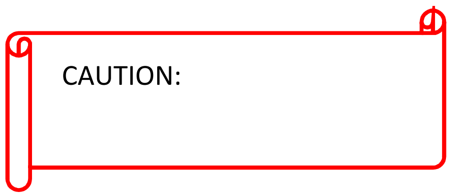
In *Chapter 9*, *A Checklist for Evaluating Project Fit*, we provide a comprehensive check list for assessing project fit using adaptive management strategies.

Conventions

There are many conventions used in this guide to present different types of information. These include font styles and icons. Specific buttons, toolbars, and other feature names which appear on the screen will be **bolded**.

The **TIP** icon below marks important tips, information or other user notes.

The **CAUTION** icon below marks steps in which the user may find some confusion. Pay attention to these notations – they can save you trouble and time.



Feedback and support

This tool was created as a collaborative effort to make a product that can be used to facilitate the transition to vegetation-based stormwater management systems. While we worked hard to make the tool and supplemental documentation accurate, clear and helpful, there is always the potential for mistakes. Please reach out to us with questions about the tool or any errors you may encounter so that we may address them. Contact Tom Singleton for software downloads and any questions you may have: tom@tlsingletonconsulting.com.

System requirements

- Windows® Operating System
- ArcGIS 10.2 – 10.4
- Spatial Analyst Extension
- Microsoft Excel (2000 or later)

Downloading the tool

Contact Tom Singleton for software downloads: tom@tlsingletonconsulting.com. Begin by downloading and opening the folder containing the G2G Decision Support Tool suite. The folder contains two modules:
1. The GIS-based **Green Infrastructure Mapping Tool** in the form of a GIS addin file (greeninfrastructurev2).

2. The Excel-based **Scenario Analysis Tool**.

G2G "Quick Guide"

Click on the hyperlinks below to get quick answers to your questions

Getting started

a. How do I . . . get the G2G macros for ArcGIS and the G2G Scenario Analysis Tool in Excel
b. How do I . . . load the G2G macros in ArcGIS

1. Mapping Green Infrastructure
   a. How do I . . . create a project
   b. How do I . . . get the GIS data layers I need
   c. How do I . . . enhance the resolution of raster data
   d. How do I . . . map potential areas for siting LID practices
   e. How do I . . . calculate the areas for each green infrastructure layer
   f. How do I . . . produce a pdf with viewable data layers for sharing results outside of GIS
   g. How do I . . . view the Green Infrastructure Map in Google Earth

2. Fitting the project to the site
   a. How do I . . . minimize impacts to water resources through design

3. Selecting LID practices
   a. How do I . . . export data from ArcGIS to the Scenario Analysis Tool in Excel
   b. How do I . . . use the slider bars to select LID practices
   c. How do I . . . get information about the LID practices
   d. How do I . . . save the results and prepare a report of my analysis
   e. How do I . . . run an analysis using a different (larger or smaller) design storm

4. Evaluating the project fit
   a. How do I . . . evaluate the project fit

5. Real world case studies using G2G
   a. Show me . . . an urban stormwater retrofit project to relieve flooding in Tampa, Florida
   b. Show me . . . new development projects in the Harbor District of Milwaukee, Wisconsin
   c. Show me . . . urban stormwater retrofit projects in Milwaukee, Wisconsin

Step 1: Mapping Green Infrastructure

In this step, you will use the **Green Infrastructure Mapping Tool** (Mapping Tool) to identify green infrastructure for protection and potential areas for siting LID practices on your project site. You will map the drainage boundaries proximal to your site and develop a digital elevation model (DEM) to characterize the hydrology of your site and understand how it is linked to the surrounding watershed. The drainage flow lines and contributing areas, defined in this step, will help you identify opportunities to restore and protect hydrologic connections. You can use the flow lines—the natural pathways for water—to link Green Infrastructure and LID practices on your site.

The Mapping Tool includes two toolbars: the Project Toolbar and the Data Toolbar. The **Project Toolbar** is used to create new projects, add and modify files, create the Green Infrastructure Map, and calculate the spatial area of mapped features, including green infrastructure and potential sites for locating LID practices. These outputs drive the selection of LID practices in Step 3. The **Data Toolbar** is used to create and modify data layers.

This part of the guide begins with the installation of the Mapping Tool and guidance on using the two toolbars to map Green Infrastructure and potential areas for siting LID practices. It then goes through the data requirements and steps for producing the maps and data outputs for use in Step 3 (Selecting LID practices).

Chapter 1: Installing the Green Infrastructure Mapping Tool

In this chapter, we review the GIS system requirements and instructions for installing the **Mapping Tool** along with the necessary addins and extensions. It also includes instructions for using the Mapping Tool on a Mac computer.

GIS System Requirements

- Windows® Operating System
- ArcGIS™ 10.2 – 10.4
- Spatial Analyst Extension

Installing the Mapping Tool

Begin by downloading and opening the folder containing the G2G Decision Support Tool suite. This folder contains the two modules:
1. The **Green Infrastructure Mapping Tool** in the form of a GIS addin file (greeninfrastructurev2). This includes two GIS toolbars to assist with project and data management.
2. The Excel-based **Scenario Analysis Tool**.

To use the Mapping Tool, you must install the addin with the two toolbars. Find the installation file (greeninfrastructurev2) and double-click on the addin (Fig. 1.1). Click **Install Add-In** to confirm (Fig. 1.2). Click **OK** to install the two toolbars in ArcMap™ (Fig. 1.3).

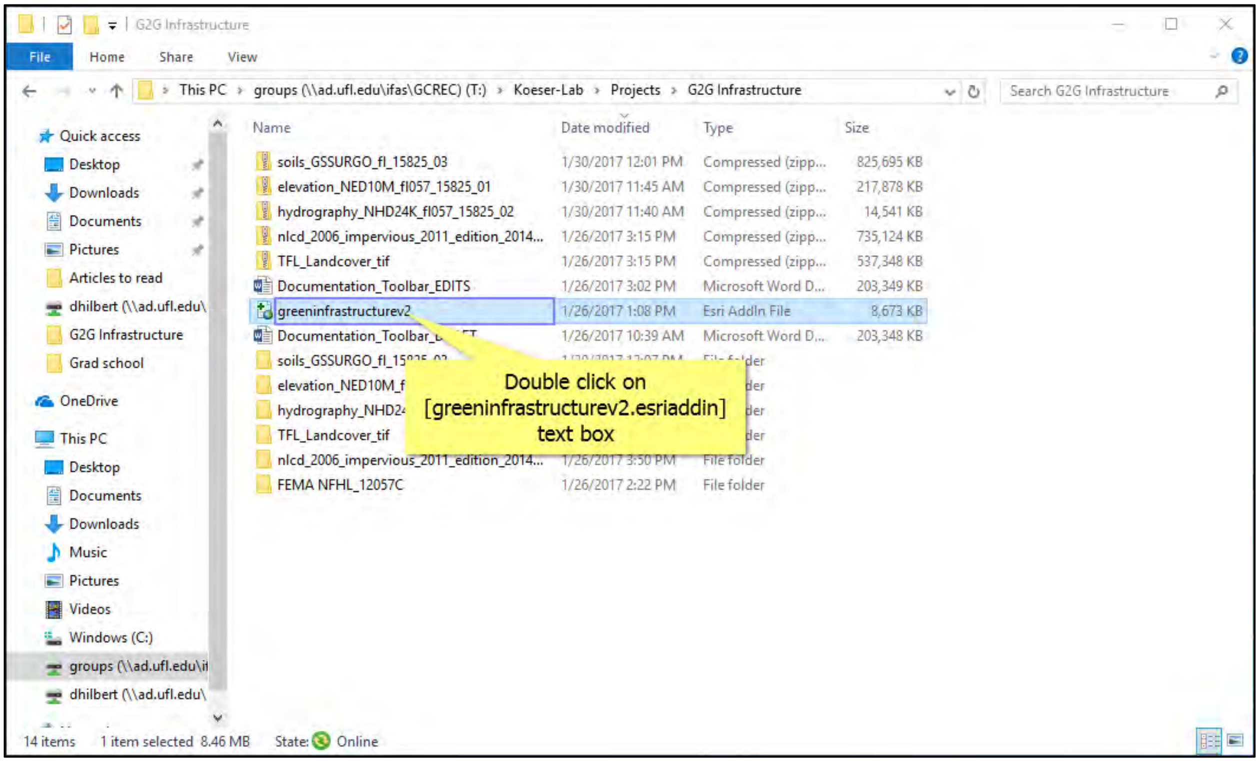


Figure 1.2. G2G addin for GIS.

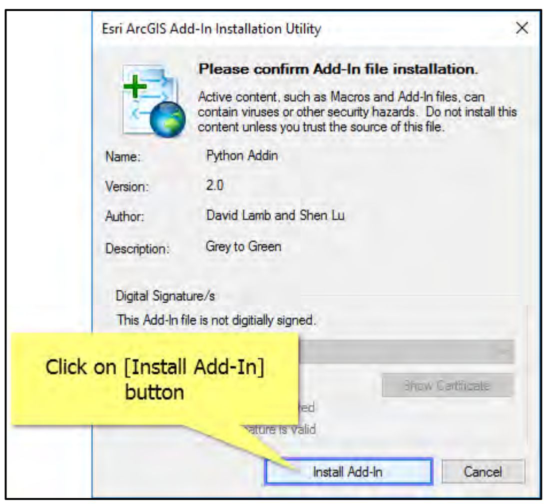


Figure 1.3. Install add-in button.

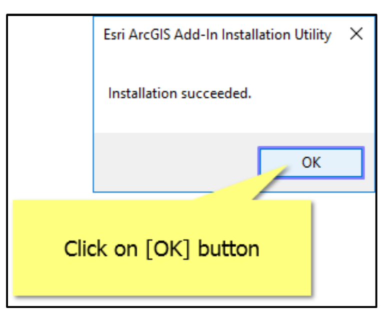


Figure 1.4. The Ok button to complete add-in installation.

Next, open ArcMap™ so you can add the toolbars to your document. Right-click on the empty gray space at the top of the window to open the toolbar drop-down menu (Fig. 1.4). Scroll down the menu to find the **GrayToGreenData** and **GrayToGreenProject** toolbars and click to select both (Fig. 1.5). Click and drag the toolbars to arrange them in your workspace in ArcMap™.

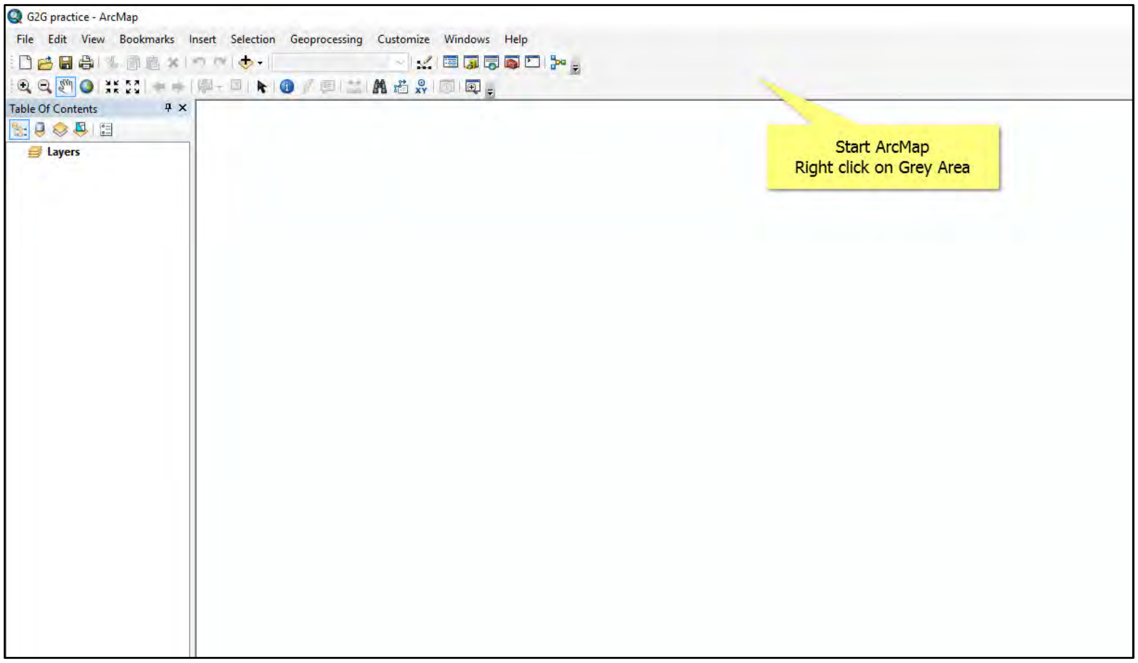


Figure 1.5. How to right-click to add toolbars to ArcMap™ document.

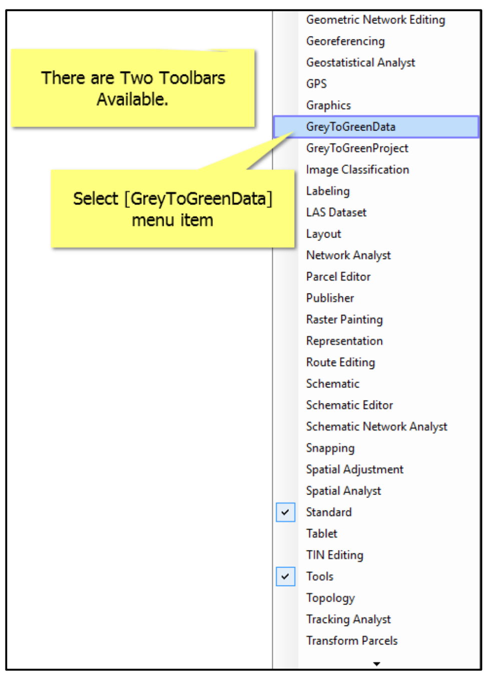


Figure 1.6. Drop-down menu with toolbars.

Enabling the Spatial Analyst Extension

To enable the **Spatial Analyst Extension**, select **Customize** from the toolbar at the top of the screen (Fig. 1.6). Select **Extensions…** from the menu (Fig. 1.7). Click the **Spatial Analyst** box (Fig. 1.8). Finally, click **Close** (Fig. 1.9). Now the toolbars should be functional within ArcMap™.

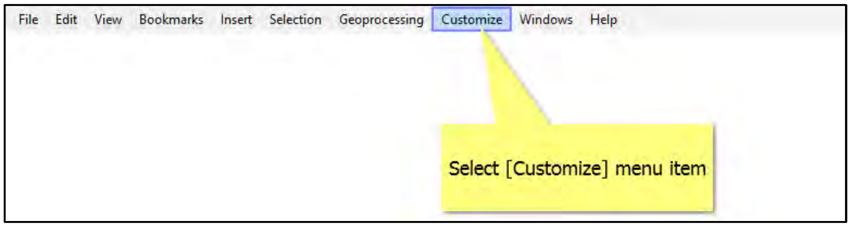


Figure 1.7. Customize menu in ArcMap™.

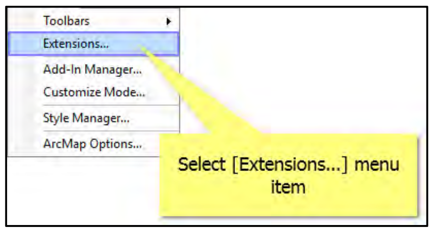


Figure 1.8. Extensions feature in the Customize menu.

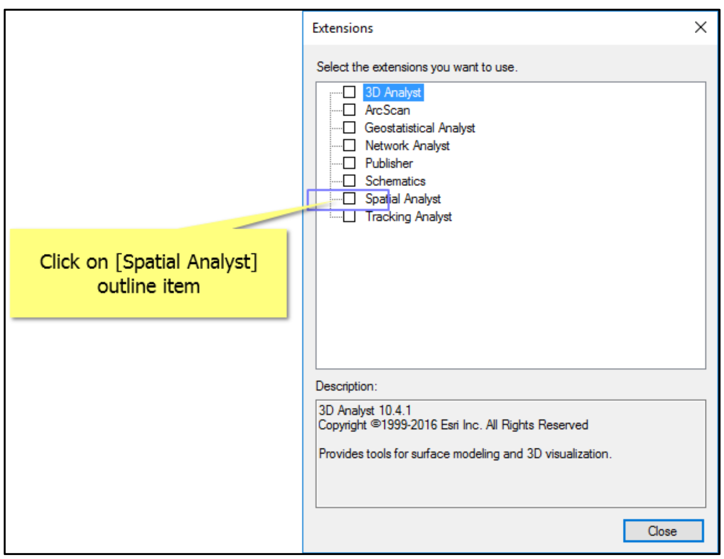


Figure 1.9. Spatial Analyst option in the Extensions window.

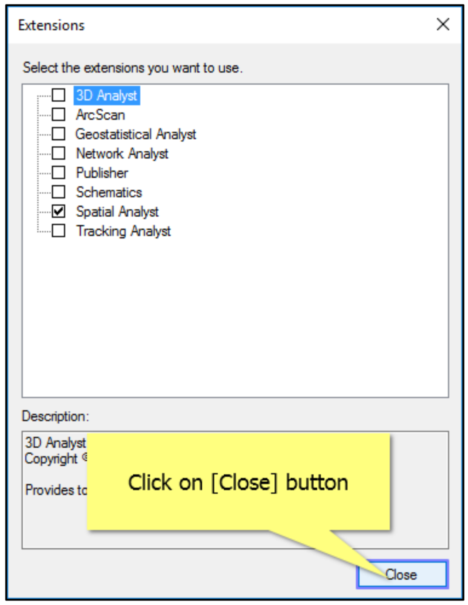


Figure 1.10. The Close button, which completes the selection of Spatial Analyst.

Running ArcGIS™ on a Macintosh
Can I run ArcGIS™ on my Mac?

ArcGIS™ is designed to work within a Microsoft Windows Operating System, but it can be run on a Macintosh computer. There are two ways to do this, both requiring the Mac to be set up to run Windows OS. The first is to use a free software called Boot Camp to run Windows, but the Mac OS cannot be run at the same time. The second way is to use a software that creates a virtual machine on your Mac, meaning you can run Windows at the same time as, or in parallel with, the Mac OS.

The following websites give more in-depth explanations of how to run Windows OS on a Mac and the system requirements:

https://blogs.esri.com/esri/arcgis/2016/03/08/arcgis-pro-in-mac-os-x/
http://gis.harvard.edu/services/blog/installing-arcgis-desktop-mac
https://support.apple.com/boot-camp
https://desktop.arcgis.com/en/arcmap/10.3/get-started/system-requirements/arcgis-desktop-system-requirements.htm

Chapter 2: Using the Project Toolbar to Create a Project

This chapter introduces the **Project Toolbar** and provides guidance on creating new projects and creating a project folder for your GIS data, Green Infrastructure Map, Excel workbook, and PDF report outputs.

> TIP: Working with data locally is faster than working across a shared network, especially as you progress through the next chapters.

The G2G Project Toolbar

The G2G Project Toolbar is used to create new projects, add and modify files to a project, and create the Green Infrastructure Map and other outputs. Below is a diagram of the toolbar showing each of its functions (Fig. 2.1).

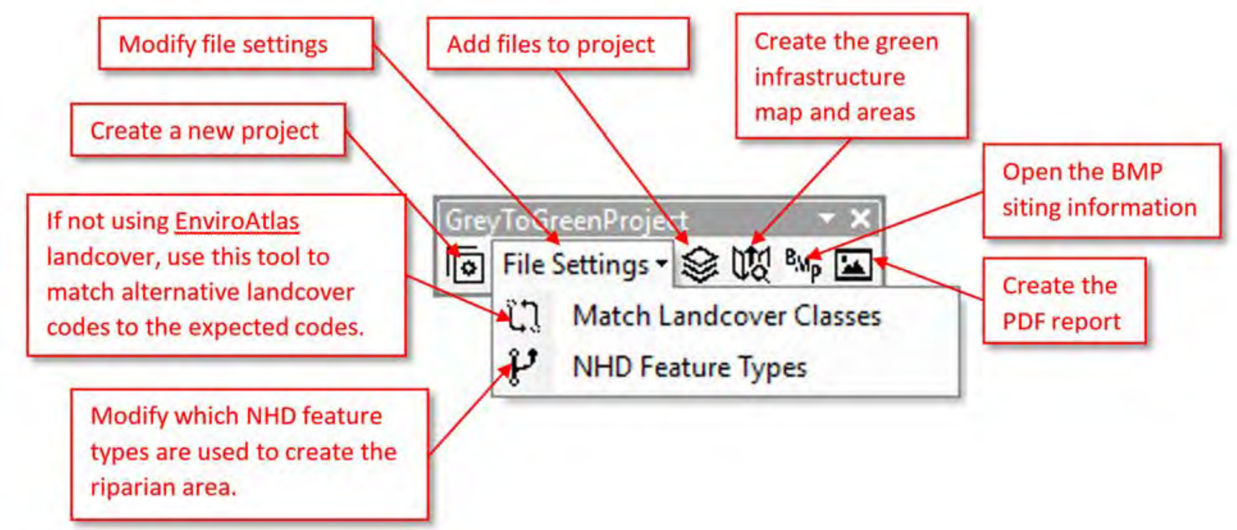


Figure 2.1. Labeled G2G Project Toolbar and its buttons.

Creating a project

Begin by opening a blank map document in ArcMap™. Check that the **GrayToGreenProject** toolbar has been added (Fig. 2.2 & 2.3). Next, click the **New Project** button on the toolbar (Fig. 2.4). The **New Project** tool window will open.

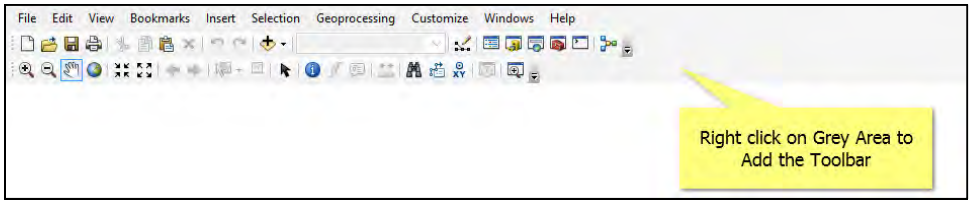


Figure 2.2. Where to right-click to add toolbar to ArcMap™ document.

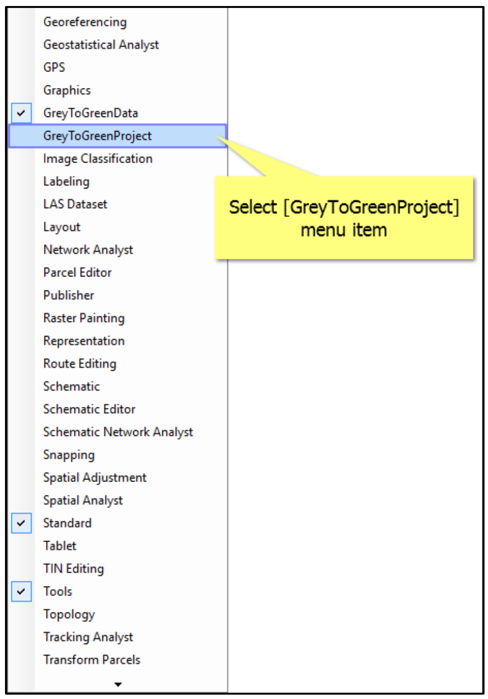


Figure 2.3. Drop-down menu with toolbars.

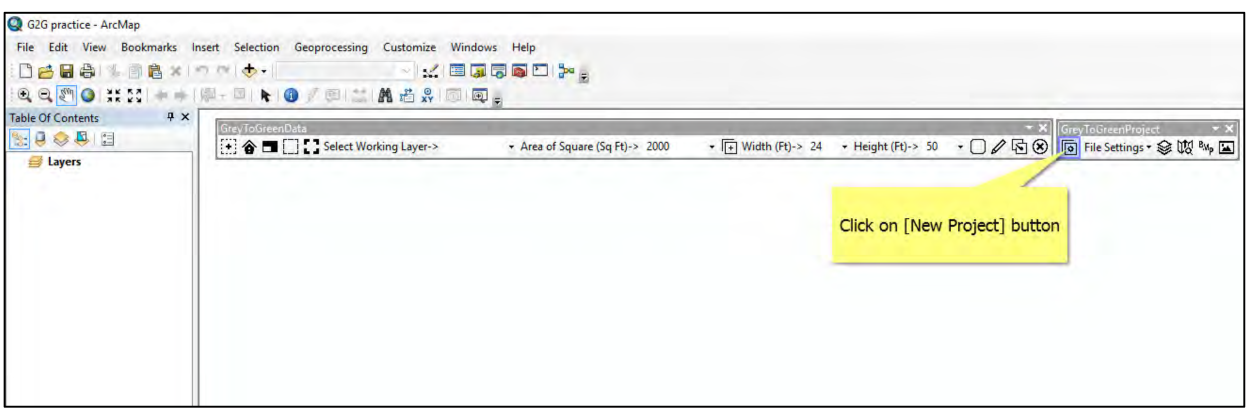


Figure 2.4. New Project button on the G2G Project Toolbar.

Click on the **Project Folder** icon at the top of the pop-up window (Fig. 2.5). Search for a folder where you want to save the project (Fig. 2.6). It does not have to be an empty folder. Once you have located a folder, click **Add** (Fig. 2.7).

TIP: Save every file created and changes made using the toolbar to one project database.

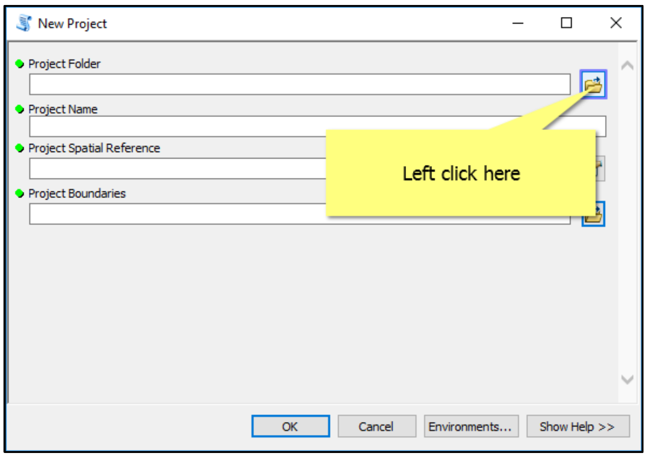


Figure 2.5. Project Folder search button in the New Project Tool window.

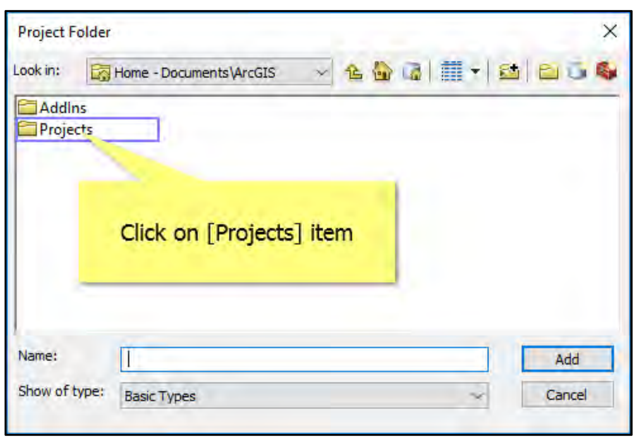


Figure 2.6. How to search for project folder using the Project Folder search button.

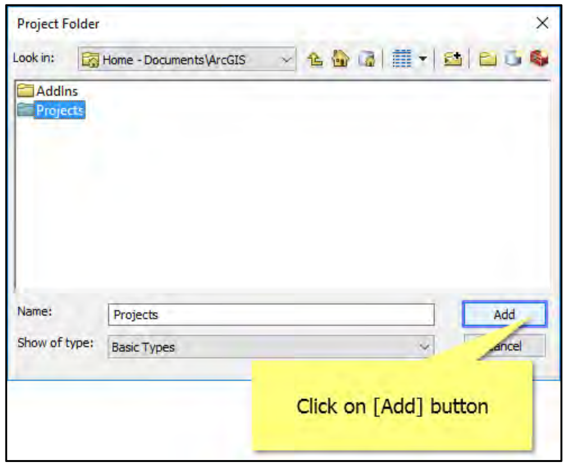


Figure 2.7. The Add button within Project Folder search function.

Create a **Project Name** in the next cell. Do not use spaces or symbols in the name.

Next, click on the icon next to **Project Spatial Reference** to select the spatial reference or coordinate system (Fig. 2.8). Use a projected coordinate system such as UTM or State Plane (Fig. 2.9). Do not use a latitude and longitude system. Click **OK** once it's selected.

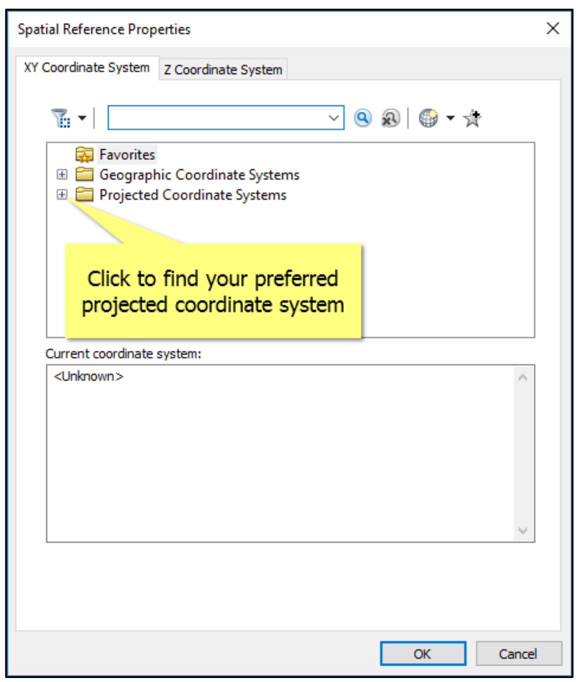


Figure 2.8. How to search for spatial reference type with Spatial Reference Properties window.

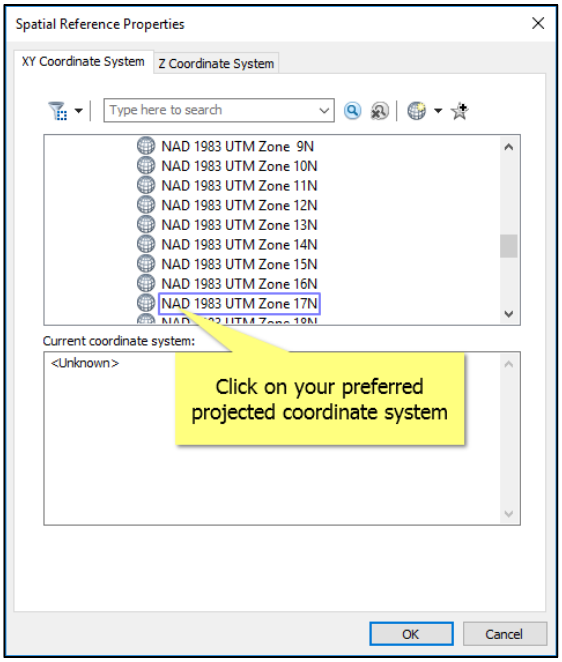


Figure 2.9. How to select the spatial reference system of your choice.

Finally, select the appropriate file for your *Project Boundary* (Fig. 2.10). This should be a user generated polygon that encloses the area to be developed. It may include protected (undisturbed) areas or drawn to exclude protected areas. Data layers will be clipped to the project boundary for estimating stormwater runoff volumes and loads and identifying potential areas for siting LID practices. If you do not have this file, use the **GrayToGreenData** toolbar to generate one (see Ch. 4).

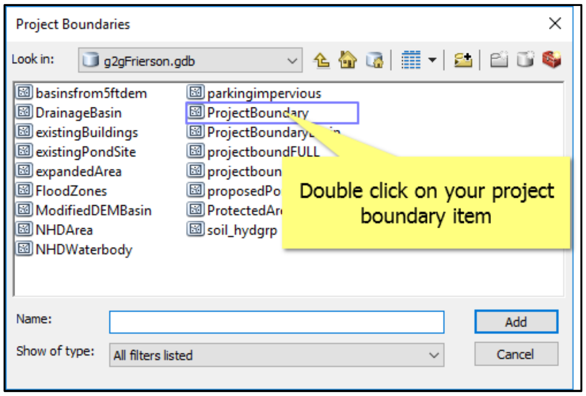


Figure 2.10. How to select a project boundary using the Project Boundaries search window.

TIP: For decision-making, it's helpful to make your *Data Boundary* larger than your *Project Boundary*. The Data Boundary, which defines the extent of data layers, should be larger than the drainage area encompassing your Project Boundary, but small enough to be processed in a reasonable amount of time. See Chapter 4 for instructions on mapping drainage areas using a digital elevation model (DEM).

After all options have been selected, click **OK**. Once the **New Project** tool completes, four new files will be added to the project folder (Fig. 2.11). You can open the folder to see the different files. First are the geodatabase files (*.gdb). The *.mxd file helps you view the results in ArcMap™. The project file (*.p) is used to store the project information and will be important in the following chapters. The Excel file (*.xlsx) includes the area available for each potential LID practice.

Close all the files, once you are done exploring them, before moving on to the next steps.

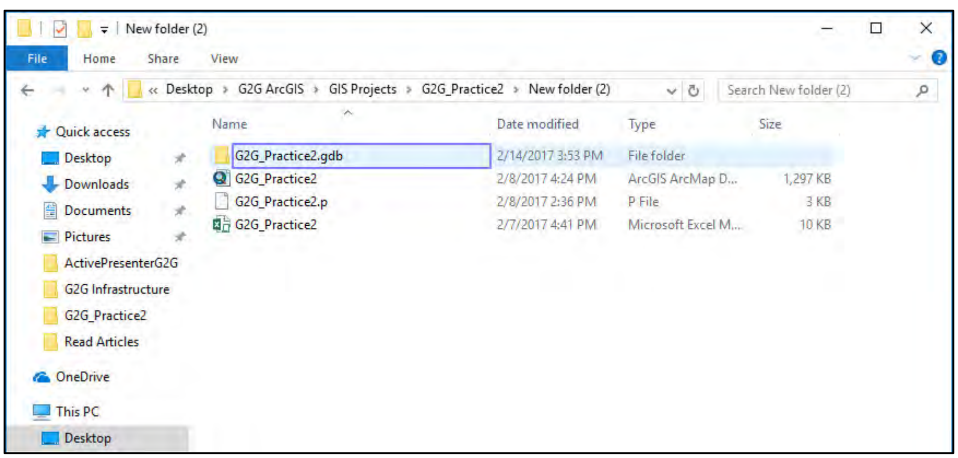


Figure 2.11. Project folder with the four new files that were added by the New Project tool in ArcMap™.

Chapter 3: Assembling the Data to Map Green Infrastructure

In this chapter, we identify the data layers, sources, and methods for creating the **Green Infrastructure Map**. The data layers include project level data and data to map green infrastructure:

- Project level
    - Project site
    - Drainage area
    - Project boundary – encompassing project site and drainage area
- Green infrastructure Map
    - Trees/forests
    - Riparian areas
        - Hydrography
        - Wetlands
        - Hydric soils
        - Floodplains
    - Groundwater recharge zones
    - Steep slopes
    - Pervious areas

In Table 2 on the next page, you will find definitions, sources, methods, and outputs for each data layer. Following the table is additional information on securing and preparing the data, including recommendations for user-generated data and using the preset file types in the Project Toolbar.

Table 2. *Summary of GIS data layers, definitions, inputs, methods, and outputs used in G2G.*

GIS Layer	Definition	Input	Methods	Output
Project Level				
Project Boundary	Area to be developed; may include protected (undisturbed) areas or drawn to exclude protected areas.	Polygon provided by user or created with G2G overlaid on Ortho Digital Quad or other georeferenced photography	Request ArcGIS to calculate area	Area of project site
Drainage Area	Drainage area inclusive of the Project Boundary; depending upon hydrologic connectivity to adjacent drainage areas may want to include multiple drainage areas	Polygon provided by user or derived from Digital Elevation Model (DEM) using G2G (see instructions for mapping Natural Drainage Ways, below)	Request ArcGIS to calculate area	Area of total drainage area
Data Boundary	Area encompassing Project Boundary and Drainage Area	Polygon created by user with G2G		
Green Infrastructure				
Trees/Forest	Tree cover and forested areas based on percentage of tree canopy	Polygons representing tree cover generated from NLCD 2011 USFS Tree Canopy cartographic or EnviroAtlas Community Landcover for participating communities or provided by user	Tree canopy > 50% considered forest; reclassify and convert	Polygon layer of Trees

GIS Layer	Definition	Input	Methods	Output
Riparian Areas	Defined as a combination of Hydrography, Wetlands, Soils (Groups C and D), and Floodplains (all Zone A)	Polygon processed from each of the different inputs, as specified below	Once the preprocessed layers are complete, merge (dissolve/union) the layers to create one complete polygon layer of Riparian Areas	Polygon layer of Riparian Areas
• Hydrography	Waterbodies except wetlands	National Hydrography Dataset (NHD) • nhd24kpt_p_ FTYPE 458 – spring/seep • nhd24kst_l_ FTYPE 460 – stream • nhd24kwb_a_ FTYPE 390 – lake/pond FTYPE 436 – reservoir FTYPE 493 – estuary • users can select other feature types FTYPE 336 – ditch FTYPE 558 – artificial path FTYPE 428 – pipeline FTYPE 334 - connector	Extract feature types from the 3 NHD layers; buffer these features by 100 feet; dissolve all polygons to create a single layer	Polygon layer of merged/buffered hydrography
• Wetlands	Wetlands – included as a separate layer because it is assumed NHD will not incorporate all wetlands	National Wetlands Inventory (NWI) polygons available at state or catchment level or use NHD classification for wetland, or user	Buffer wetland features by 100 feet	Polygon layer of buffered wetlands

GIS Layer	Definition	Input	Methods	Output
Riparian Areas (cont'd)		generated data; may merge multiple datasets together to create a wetlands layer		
• Hydric Soils	Soils – C and D Hydrologic Soil Groups	SSURGO (Geospatial Data Gateway) spatial and tabular data	Preprocess tabular database as required by the SSURGO; join spatial and tabular data using MUKEY to find soil groups; extract soils matching the soil groups	Polygon layer of extracted soil polygons
• Floodplain	100-year floodplains	User supplied data or FEMA Floodplain (FIRM) S_FLD_HAZ_AR available for county level; not all communities have a studied 100-year floodplain (zone AE, AO, etc.); Zone A have no base flood elevations (BFEs); Zone AO have depth	Extract all Zone A related 100-year floodplains and buffer by 100 feet	Polygon layer of buffered 100-year floodplains
Groundwater Recharge Zones	Areas that fall within soil groups A and B	SSURGO (Geospatial Data Gateway) spatial and tabular data	Preprocess tabular database as required by the SSURGO; join spatial and tabular data using MUKEY to find soil groups; extract soils matching the soil groups	Polygon layer of groundwater recharge zones

GIS Layer	Definition	Input	Methods	Output
Natural Drainage Ways	Flow lines and pathways derived from the natural topography of the study area; these may not be represented in the hydrography layer	Digital Elevation Model (DEM) Geospatial Data Gateway	User specifies drainage area (default in G2G set to 5 acres); flow direction, flow accumulation, and flow lines; buffer flow lines by 100 feet	Flow lines and polygon layer of natural drainage ways buffered by 100 feet
Steep Slopes	Slope percentage > 25	Digital Elevation Model (DEM) Geospatial Data Gateway	Calculate percent slope; reclassify slope by > 25% areas; buffer 100 feet	Polygon layer of buffered areas with > 25% slope
Pervious Areas	Areas within project area that do not fall within the Green Infrastructure polygons created above and are not Impervious	NLCD Percent Developed Impervious or EnviroAtlas Community Landcover for participating communities or supplied by user	NLCD or EnviroAtlas: reclassify Impervious to 0, and everything else 1; convert to polygon; erase areas that are in previous steps User supplied data: erase impervious areas from project boundary; erase areas that are in all previous steps	Polygon layer of pervious areas

Guidance on securing and preparing the data

Which datasets should I use?

Now you should have a better understanding of the data needed to create a Green Infrastructure Map. The next step is picking out which data you want to use. Outlined below are the recommended and substitute input layers for creating the Green Infrastructure Map, along with web addresses for securing the data.

> TIP: A detailed landcover raster layer such as EnviroAtlas community landcover can be used to provide data for multiple of the inputs.

Tree Area

Recommended Layer	URL Addresses	Substitute Layer	Notes
EnviroAtlas Community Landcover	https://www.epa.gov/EnviroAtlas/EnviroAtlas-data-download-step-2 *https://www.mrlc.gov/nlcd11_data.php* (NLCD 2011 USFS Tree Canopy cartographic)	Percent Tree Canopy from NLCD; User-generated Tree Cover (Raster, Value of 1 indicates Tree cover); User-generated Tree Cover areas (Polygon Vector); or Alternative Landcover data (please match to existing land cover types)	If EnviroAtlas is not available for your community you may supply alternative tree canopy layers. If using the NLCD percent tree canopy layer, select a cutoff value that best suits your area (default is 50%). If you have a tree cover raster layer, make it binary 1 for tree, 0 for not tree, or convert to a polygon layer where polygons represent tree cover. If using your own alternative Landcover dataset, match landcover codes for trees to value 40 and forested wetlands to value is 91. The NLCD landcover layer at 30m is not recommended for this tool.

Riparian Area

Recommended Layer	URL Addresses	Substitute Layer	Notes
EnviroAtlas Community Landcover	https://www.epa.gov/EnviroAtlas/EnviroAtlas-data-download-step-2 *https://www.fws.gov/wetlands/Data/State-Downloads.html* (National Wetlands Inventory)	Alternative Landcover data (please match to existing land cover types); or User-generated Wetlands Layer (Polygon Vector)	Match alternative landcover codes to predefined wetland codes 91 and 92. National Land Cover Dataset with 30-meter resolution is not recommended. You may consider using the National Wetlands Inventory instead, or your own wetland polygons.
FEMA Floodplain Layer (S_FLD_HAZ_AR)	https://msc.fema.gov/portal/advanceSearch#searchresultsanchor	User-generated 100-Year Floodplain	If using your own flood plain boundaries, they should be polygons and only for 100-year flood plain events. Otherwise use FEMA DFIRM layer S_FLD_HAZ_AR with the FLD_ZONE attribute.
NHD Water Points	https://nhd.usgs.gov/data.html	None	
NHD Area	https://nhd.usgs.gov/data.html	None	
NHD Water Bodies	https://nhd.usgs.gov/data.html	User-generated Water Bodies Layer (Polygon Vector)	You may use both if necessary.
NHD Flow Lines	https://nhd.usgs.gov/data.html	User-generated Stream Layer (Polyline Vector)	You may use both if necessary.
Polygon Soils Layer with HYDGRP Field	https://gdg.sc.egov.usda.gov/	Polygon Soils Layer with HYDGRP Field	Any polygon soil layer that has the field HYDGRP with values A, B, C or D. C and D are hydric soils used to map riparian areas. Can use SSURGO gridded data using MUPOLYGON joined to component table to retrieve HYDGRP. A polygon may have a null value for HYDGRP. In most cases this is because of Waterbodies, but is sometimes due to urban areas.

Groundwater Recharge Zones

Recommended Layer	URL Addresses	Substitute Layer	Notes
Polygon Soils Layer with HYDGRP Field	https://gdg.sc.egov.usda.gov/	Polygon Soils Layer with HYDGRP Field	Any polygon soil layer that has the field HYDGRP with values A, B, C, D, or Null will be acceptable. Can use SSURGO gridded data using MUPOLYGON joined to component table to retrieve HYDGRP. A polygon may have a null value for HYDGRP. In most cases this is because of Waterbodies, but is sometimes due to urban areas. Null values are not considered in the analysis, and you must change the data to be A, B, C, or D to retrieve results for these areas.

Natural Drainage Pathways

Recommended Layer	URL Addresses	Substitute Layer	Notes
Digital Elevation Model (Raster)	https://gdg.sc.egov.usda.gov/	Digital Elevation Model (Raster)	Ten meters and below resolution is recommended. Set the units for the elevation to either Feet or Meters. Use a raster dataset that is larger than the project bounds to adjust for drainage areas outside the project boundary.

Steep Slopes Output Area

Recommended Layer	URL Addresses	Substitute Layer	Notes
Digital Elevation Model (Raster)	https://gdg.sc.egov.usda.gov/	Digital Elevation Model (Raster)	Resolution of ten meters and below is recommended. Set the units for the elevation to either Feet or Meters.

Pervious and Impervious Areas Output Area

Recommended Layer	URL Addresses	Substitute Layer	Notes
EnviroAtlas Community Landcover	https://www.epa.gov/EnviroAtlas/EnviroAtlas-data-download-step-2 *https://www.mrlc.gov/nlcd11_data.php* (NLCD 2011 Land Cover or NLCD 2011 Percent Developed Imperviousness) *http://download.geofabrik.de/* (OpenStreetMap data for different regions)	Percent Impervious (NLCD); or Alternative Landcover data (please match to existing land cover types)	If EnviroAtlas is not available for your community, use either the NLCD percent impervious layer or an alternative landcover dataset matched to predefined impervious code 20. The NLCD landcover layer at 30m is not recommended for this tool. Select the appropriate percent cutoff for NLCD percent impervious (default is 50%).

The following is additional information on preparing and using selected data inputs, including guidelines for user-generated data.

Digital Elevation Model (Raster)
This is a raster layer for elevation data where each cell represents the height above sea level. A resolution of ten meters and below is recommended. Elevation units may be in Feet or Meters, which can be specified with the Add Files tool. Use a raster dataset that is larger than the project bounds to include drainage areas outside the project boundary. Elevation data is used to create the natural drainage and steep slopes layers of the Green Infrastructure Map. You can use any elevation raster layer, but a 3-meter cell size National Elevation Dataset is available for most of the US. The added layer matches the required file type called Digital Elevation Model (Raster).

Percent Tree Cover (NLCD or User-Defined)
This is a tree canopy cover layer either user-generated, which is preferred, or from the National Land Cover Dataset. Each cell of the raster layer indicates the percentage of Tree Canopy. Values range from 0 to 100. If using the NLCD percent tree canopy layer, select a cutoff value that best suits your area (default is 50%). If you have a tree cover raster layer, make it binary 1 for tree, 0 for not tree, or convert to a polygon layer where polygons represent tree cover. Trees are used to create the tree/forest layer of the Green Infrastructure Map. These may be derived from landcover codes (matched to EnviroAtlas code 40). If you are not using EnviroAtlas data, the alternative landcover data should be of a fine resolution. If you are not using landcover data at all, you can use percent tree canopy/cover data and the setting Percent Tree Canopy Cutoff. Added layers match the required file types called EnviroAtlas Community Landcover, Alternative Landcover data (please match to existing land cover types), User-generated Tree Cover areas (Polygon Vector), Percent Tree Cover (NLCD or User-Defined), or User-generated Tree Cover (Raster, Value of 1 indicates Tree cover).

National Hydrography Dataset (NHD)

- **NHD Areas**
  This is the National Hydrography Dataset for water areas. There is a required FTYPE field. This layer goes into to generating the riparian area layer that provides the basis for the Green Infrastructure Map. Added layers match the required file types called NHD Areas.
- **NHD Flow Lines**
  This is the National Hydrography Dataset for flow lines. There is a required FTYPE field. This layer goes into to generating the riparian area layer that provides the basis for the Green Infrastructure Map. You can use a user-generated streams layer in addition to this layer. Added layers match the required file types called NHD Flow Lines.
- **NHD Water Bodies**
  This is the National Hydrography Dataset for water bodies. There is a required FTYPE field. This layer goes into to generating the riparian area layer that provides the basis for the Green Infrastructure Map. You can use a user-generated water bodies layer in addition to this layer. Added layers match the required file types called NHD Water Bodies.
- **NHD Water Points**
  This is the National Hydrography Dataset for water points. There is a required FTYPE field. This layer goes into to generating the riparian area layer that provides the basis for the Green Infrastructure Map. Added layers match the required file types called NHD Areas.

FEMA Floodplain Layer (S_FLD_HAZ_AR)

This is the polygon layer representing flood zones for different types of rainfall events and may be obtained through FEMA's Map Service Center for most communities. The expected field name is FLD_ZONE with values like A, AE, or X. If using your own flood plain boundaries, they should be polygons and only for 100-year floodplain events. Otherwise use FEMA DFIRM layer S_FLD_HAZ_AR with the FLD_ZONE attribute.
Flood layers are used to generate the riparian area layer that provides the basis for the Green Infrastructure Map. Only one is required. Added layers match the required file types called User-generated 100-Year Floodplain or FEMA Floodplain Layer (S_FLD_HAZ_AR).

Polygon Soils Layer with HYDGRP Field

This is a polygon layer for soil information. This layer requires a field called HYDGRP that represents the hydrologic group with expected values: A, A/C, A/D, B, B/C, B/D, C, C/D, and D. Some polygons may contain a NULL or Blank value. In most cases this is because of Waterbodies, but sometimes due to urban areas. Null values are not considered in the analysis, and you must change the data to be A, B, C, or D to retrieve results for these areas. You can use a user-generated layer or SSURGO gridded data using MUPOLYGON joined to component table to retrieve HYDGRP. Soils are used to create the groundwater recharge layer of the Green Infrastructure Map. The added layer matches the required file type called Polygon Soils Layer with HYDGRP Field.

EnviroAtlas Community Landcover

This is the EnviroAtlas raster layer for landcover. It is the recommended landcover layer for use with this tool, but is only available for some communities. If EnviroAtlas is not available for your community you may supply alternative landcover data. If you are not using landcover data at all, you can use percent impervious and the setting Percent Impervious Cutoff (see Chapter 5). The added layer matches the required file type called EnviroAtlas Community Landcover, Alternative Landcover data (please match to existing land cover types), or Percent Impervious (NLCD).

Alternative Landcover data
This is a secondary source for landcover data if you are not using EnviroAtlas. It is a raster layer where each cell is classified as a landcover, and it should be of a fine resolution. If you have a small study site, having an alternative landcover layer that is detailed at 1-meter resolution might be preferable to the EnviroAtlas layer. This data is used to create the pervious and impervious areas layer of the Green Infrastructure Map. Pervious is treated as the opposite of Impervious. The layer can be derived from landcover, but the landcover codes need to be matched to the expected landcover values (i.e., EnviroAtlas code 20). See Chapter 5 for more information on matching landcover codes. If you are not using landcover data at all, you can use percent impervious and the setting Percent Impervious Cutoff (see Chapter 5). The added layer matches the required file type called EnviroAtlas Community Landcover, Alternative Landcover data (please match to existing land cover types), or Percent Impervious (NLCD).

Buildings
These are used to identify areas suitable for different LID practices and include proposed and existing building footprints that will be modified. You can use the Data Toolbar to create a buildings layer if you do not have one at the start of the project (see Chapter 4). The added layer matches the required file type called Buildings.

Parking and Roads Impervious Areas
This is a layer that provides the area of impervious parking. It is different from the impervious areas derived through NLCD or EnviroAtlas data. This may include impervious areas under new development separate from buildings. The layer is used to identify areas suitable for different LID practices. The added layer matches the required file type called Parking and Roads Impervious Areas.

Percent Impervious (NLCD)
This is the layer of impervious surfaces provided by the National Land Cover Dataset. Each cell of the raster layer indicates the percentage impervious. Values range from 0 to 100. Pervious is treated as the opposite of Impervious. The NLCD landcover layer at 30m is not recommended for this tool because a higher resolution is ideal. If EnviroAtlas is not available for your community, use either the NLCD percent impervious layer or an alternative landcover dataset matched to predefined impervious code 20. Select the appropriate percent cutoff for NLCD percent impervious (default is 50%). This data is used to create the pervious and impervious areas layer of the Green Infrastructure Map. If you are not using landcover data at all, you can use percent impervious and the setting Percent Impervious Cutoff (see Chapter 4). The added layer matches the required file type called EnviroAtlas Community Landcover, Alternative Landcover data (please match to existing land cover types), or Percent Impervious (NLCD).

The following file types are the user-generated layers that correspond to some of the layers mentioned and may be used in place of or in addition to national datasets, depending on the layer.

User-Defined Riparian Layer
This is a polygon layer provided by the user representing local riparian areas. This is often better than using national datasets because of the final resolution and better local accuracy. It is used to generate the riparian area layer that provides the basis for the Green Infrastructure Map. Added layers match the required file types called User-generated Riparian Layer.

User-generated 100-Year Floodplain
This is a polygon layer representing the 100-Year flood zones. Flood layers are used to generate the riparian area layer that provides the basis for the Green Infrastructure Map. Added layers match the required file types called User-generated 100-Year Floodplain or FEMA Floodplain Layer (S_FLD_HAZ_AR).

User-generated Stream Layer (Polyline Vector)
This is a polyline layer that represents the existing stream centerline. These are used to generate the riparian area layer that provides the basis for the Green Infrastructure Map. All or some of the files may be provided by the user. Added layers match the required file types called NHD Flow Lines, NHD Water Bodies, NHD Water Points, NHD Areas, User-generated Stream Layer (Polyline Vector), or User-generated Water Bodies Layer (Polygon Vector).

User-generated Tree Cover (Raster, Value of 1 indicates Tree cover)
This is a raster layer where each cell indicates tree canopy, tree cover, or tree with a value of 1, or 0 for no tree. You can use 0-100% for percent tree cover.

User-generated Tree Cover areas (Polygon Vector)
This is a polygon layer that represents areas of tree cover, canopy, or individual trees. You can use 0-100% for percent tree cover.

User-generated Water Bodies Layer (Polygon Vector)
This is a polygon layer that represents the shoreline of water bodies, or stream features. This can be used in addition to a NHD water bodies layer.

User-generated Wetlands Layer (Polygon Vector)
This is a polygon layer that represents the emerging and woody wetlands. Wetlands are used to generate the riparian area layer that provides the basis for the Green Infrastructure Map. Wetlands may be derived from landcover codes (matched to EnviroAtlas codes 91, 92). No other wetlands source is necessary if landcover is provided. Added layers match the required file types called User-generated Wetlands Layer (Polygon Vector), EnviroAtlas Community Landcover, or Alternative Landcover data (please match to existing land cover types).

Use the highest resolution data available

You will want to use data layers with the most detailed information you can get while maintaining a resolution that matches the size of your study area and scale of your map. National datasets exist for many of the required data, such as soils and landcover. However, the layers are often not as detailed as you may want, especially if you have a small study site. Therefore, user-generated layers are often preferable. Examples of user-generated layers that might be preferable to national ones are polyline layers of streams and wetlands. Table 3 gives some guidelines for choosing layers with resolutions that match your study area size and map scale. To find the appropriate scale, zoom to the study area, determine the scale, and divide the scale by 1000 and multiply the result times 2. This link provides additional guidelines for the raster resolution: https://blogs.esri.com/esri/arcgis/2010/12/12/on-map-scale-and-raster-resolution/.

Table 3*. Examples of how to choose layer resolutions that match study area size and map scale.*

Data Layer	Raster Resolution[1]	Study Area Size	Map Scale
Buildings	Dense Urban Area	< 54 km^2	
Raster Grid	30-meter Cell Size	> 4 km^2	>= 1:75,000
Raster Grid	<= 3-meter Cell Size	< 20,000 $meters^2$	<= 1:5,000
Raster Grid	10-meter cell size	0.5 km^2 to 4 km^2	1:5,000 to 1:75,000

[1]Where raster resolution (in meters) = map scale / 2 x 1000

Use the preset file types in the Project Tool bar

The Project Toolbar has preset file types that the user's input data must match. The image below shows the list of preset file types that appears when adding data (Fig. 3.1).

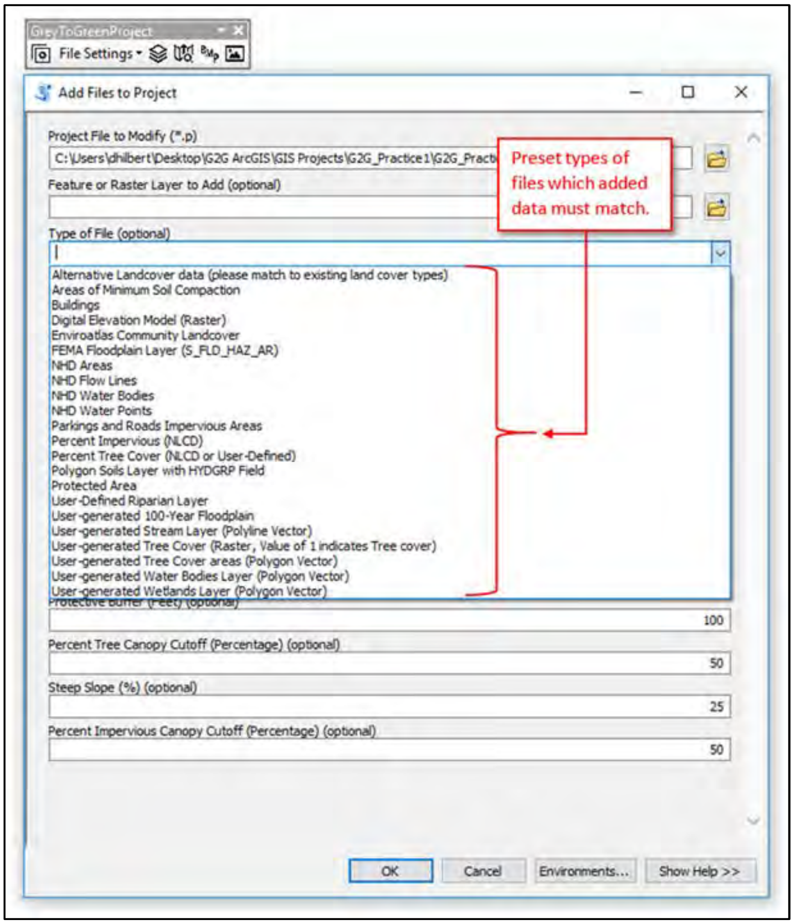


Figure 3.1. Preset File Types which added data must match.

Below is a table outlining the required input file types. This table can assist with choosing the proper category in which to put your feature or raster layer as it is added to the project. It can also be used as a checklist to make sure you have all the necessary files. The **Required Type of File** simply means the name of the file type specified by the dropdown menu in the Project Tool bar (Table 4). **Geometry Type** refers to what type of file it needs to be in for it to work with the GIS addins. **Required Field Name** corresponds to the type of file, and like **geometry type**, is a way of ensuring it is the correct file type to run in this tool.

Table 4. Required file types, geometry, field names, and descriptions, including user generated data.

Required Type of File	Geometry Type	Required Field Name	Description
Alternative Landcover data (please match to existing land cover types)	Raster		Raster layer where each cell is classified as a landcover. These landcover codes need to be matched to the expected landcover values.

Required Type of File	Geometry Type	Required Field Name	Description
Buildings	Polygon		Proposed or existing buildings within the project area.
Digital Elevation Model (Raster)	Raster		Raster layer for elevation data. Each cell represents the height above sea level. Elevation units may be in Feet or Meters. Provide this information in the Add Files tool.
EnviroAtlas Community Landcover	Raster		EnviroAtlas raster layer for landcover. Available for some communities.
FEMA Floodplain Layer (S_FLD_HAZ_AR)	Polygon	FLD_ZONE	Polygon layer representing flood zones for different types of event, may be obtained through FEMA's Map Service Center for most communities. Expected field name FLD_ZONE with values like A, AE, or X.
NHD Areas	Polygon	FTYPE	National Hydrography Dataset, areas. Required FTYPE field.
NHD Flow Lines	Polyline	FTYPE	National Hydrography Dataset Flow Lines. Required FTYPE field.
NHD Water Bodies	Polygon	FTYPE	National Hydrography Dataset Water Bodies. Required FTYPE field.
NHD Water Points	Point	FTYPE	National Hydrography Dataset, water points. Required FTYPE field.
Parking and Roads Impervious Areas	Polygon		Proposed or existing parking and roads
Percent Impervious (NLCD)	Raster		Either user-generated or from the National Land Cover Dataset. Each cell of the raster layer indicates the percentage Impervious. Values range from 0 to 100.
Percent Tree Cover (NLCD or User-Defined)	Raster		Either user-generated or from the National Land Cover Dataset. Each cell of the raster layer indicates the percentage of Tree Canopy. Values range from 0 to 100.

Required Type of File	Geometry Type	Required Field Name	Description
Polygon Soils Layer with HYDGRP Field	Polygon	HYDGRP	Polygon layer for soil information. Requires a field called HYDGRP that represents the hydrologic group with expected values: A, A/C, A/D, B, B/C, B/D, C, C/D, and D. Some polygons may contain a NULL or Blank value. In most cases this is because of Waterbodies, but sometimes due to urban areas. Null values are not considered in the analysis, and you must change the data to be A, B, C, or D to retrieve results for these areas.
Protected Area	Polygon		Undisturbed areas set aside for protection
User-Defined Riparian Layer	Polygon		Polygon layer provided by the user representing
User-generated 100-Year Floodplain	Polygon		Polygon layer representing the 100-Year flood zones.
User-generated Stream Layer (Polyline Vector)	Polyline		Polyline layer that represents the existing stream centerline.
User-generated Tree Cover (Raster, Value of 1 indicates Tree cover)	Raster		Raster layer where each cell indicates tree canopy, tree cover, or tree with a value of 1, or 0 for no tree.
User-generated Tree Cover areas (Polygon Vector)	Polygon		Polygon layer that represents areas of tree cover, canopy, or individual trees.
User-generated Water Bodies Layer (Polygon Vector)	Polygon		Polygon layer that represents the shoreline of water bodies, or stream features.
User-generated Wetlands Layer (Polygon Vector)	Polygon		Polygon layer that represents the emerging and woody wetlands.
Project Area Boundary	Polygon		User generated layer with polygons representing the entire project area.

CAUTION: Checks exist so that an error message will appear if the file type is incorrect.

Summary of the basic steps for preparing the data

Now you should have a better idea of the datasets needed to create the Green Infrastructure Map, including where to find the data.

The recommended steps for preparing the data are as follows:

1. Download, modify, or create necessary datasets. Some input layers can be created using the GrayToGreenData Toolbar. These layers include Buildings; Parking and Road Impervious Areas; Protected Areas; and Project Boundary. However, the functionality of the toolbar is limited, so it is recommended that you use ArcMap's Editor and Create Features tools.
2. Organize data into a single geodatabase with a Projected Coordinate System. Do not use a Geographic Coordinate System.
3. Clip raster layers to the project area boundary.

To get results for the Green Infrastructure Map, the bare minimum files that should be added include:

- Hydrography
- Wetlands
- Soils with an HYDGRP field
- 100-year floodplain layer
- Digital elevation raster
- Complete community landcover file like EnviroAtlas or NLCD (or a percent impervious dataset AND percent tree canopy).

To get results for siting LID practices, you will need the datasets listed above, plus parking, roads, and buildings. Instructions for preparing these three layers are provided in the next chapter (Chapter 4).

In this chapter, we go over the different functions found on the **GrayToGreenData** toolbar. The toolbar contains tools for creating layers that can be added to your project, such as the **Create Project Boundary Layer** and **Create Building Layer** tools. It also contains tools useful for project planning using the final map, including the **Create a Single Polygon** tool.

The GrayToGreenData Toolbar

Below is a diagram of the Data Toolbar (Fig. 4.1). If you cannot see the toolbar within your ArcMap™ document, follow the steps in Chapter 1 to view the toolbar.

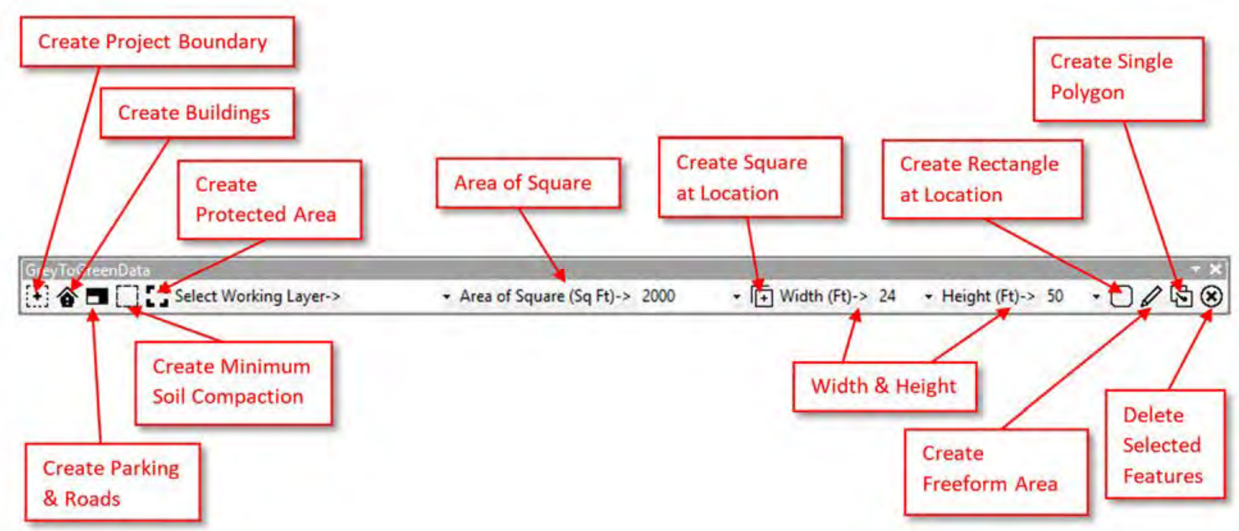


Figure 4.1. Labeled diagram of the G2G Data Toolbar and its features.

On the left side of the toolbar you can find the different tools for creating files to add to your project and Green Infrastructure Map. Here's an overview of these tools:

- **Create Project Boundary** Creates a layer containing the project boundary. This is useful if you do not have an existing boundary layer file to add to the project.
- **Create Buildings:** Creates a layer in which you can add buildings. This is useful if you need a **Buildings** layer file to add to your project for calculating impervious surfaces as well as potential rooftop garden sites.
- **Create Parking and Roads:** Creates a layer in which you can add buildings and roads. This is useful if you need a file for the **Parking and Roads Impervious** category used for calculating impervious surfaces.
- **Create Minimum Soil Compaction:** Creates a layer in which you can designate **Areas of Minimal Soil Compaction** for addition to your project.
- **Create Protected Area:** Creates a layer in which you can designate protected areas within your project area where no buildings, parking or roads can be placed. This layer can be added to your project under the **Protected Area** file type.

On the right side of the toolbar you can find the different tools for editing the files for your project or map, including tools for creating building and parking layers. The final sections of this chapter provide examples showing these buttons in action. Here's an overview of these tools:

- **Area of Square:** Select the area (sq. ft.) of a square that you want to add to the layer. You can also type in your own value.
- **Create Square at Location:** After selecting the area of a square, select this tool then click on the map where you want the object to be located, and it will be added there.
- **Width & Height:** Select the width and height (ft.) of a rectangle you want to add to the layer. You can also type in your own values.
- **Create Rectangle at Location:** After selecting the dimensions, select this tool then click on the map where you want your rectangular object, and it will be added there.
- **Create Freeform Area:** Allows you to create freeform polygons of unique shapes by clicking on the map. Double-click to finish outlining the polygon.
- **Create a Single Polygon from Selected:** Allows you to merge two or more selected polygons into a single one. The results may vary.
- **Delete Selected Features:** Delete selected features from the working layer.

Basic steps to create layers using the tools

1. Open a blank map document in ArcMap™.
2. Make sure the toolbar has been added.
3. Add a basemap of some kind, such as an aerial photograph, and make sure the data frame you are using has a map projection assigned.
4. Click one of the layer tool buttons on the left side of the toolbar to name and create an empty layer file.
5. Click on the **Select Working Layer** drop-down menu and select the file you just created. It will appear in the **Table of Contents** and **Catalog** with the other files. It is now your working layer and all changes made will be applied to this layer.
6. Use the functions on the right side of the toolbar to alter your layer.
7. When you're done, save your changes, exit, and add the file to your project using the steps outlined in Chapter 2.

Read on to see in-depth examples using the project boundary tool, buildings tool, and single polygon tool.

Project boundary tool

*How do I use the **GrayToGreenData** toolbar to create a project boundary layer?*

First, open a blank map document in ArcMap™. Make sure the toolbar has been added, and add a basemap, making sure the data frame you are using has a map projection assigned (Fig. 4.2).

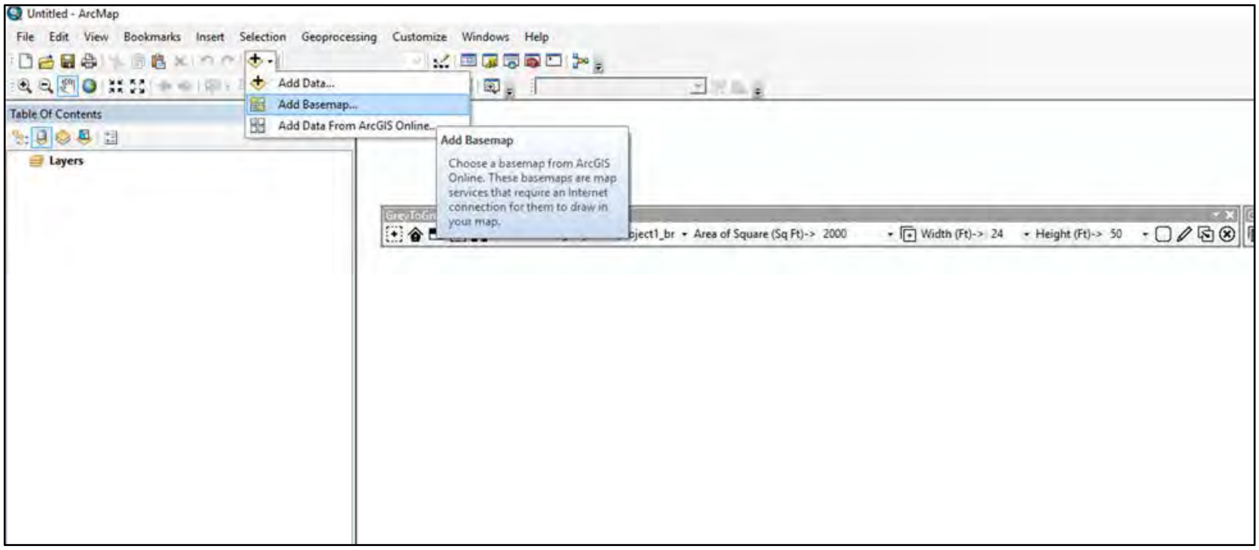


Figure 4.2. How to add a basemap to your blank document in ArcMap™.

Click the **Create Project Boundary Layer** button on the left side of the toolbar (Fig. 4.3). Select the folder or geodatabase where the layer will be saved, and change the file name if desired (Fig. 4.4). Click **Save** (Fig. 4.5).

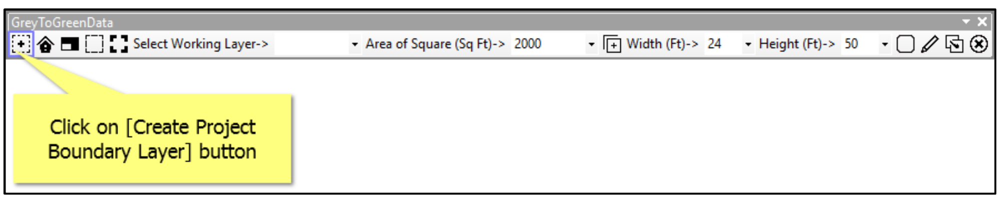


Figure 4.3. The Create Project Boundary button on the G2G Data Toolbar.

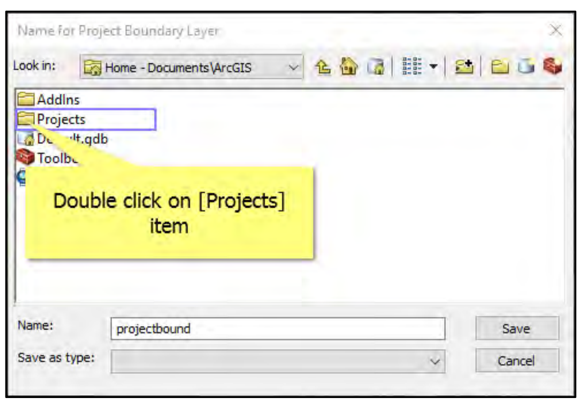


Figure 4.4. How to search for a folder to save the new project boundary layer in using the pop-up window.

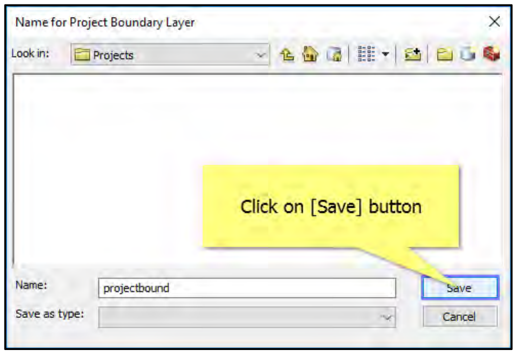


Figure 4.5. The Save button, which completes saving the boundary layer.

Next, click the **Select Working Layer** drop-down and select the correct layer that data will be added to (Fig. 4.6). Only polygon layers will show up in the list. In this example, select the **projectbound** layer (Fig. 4.7).

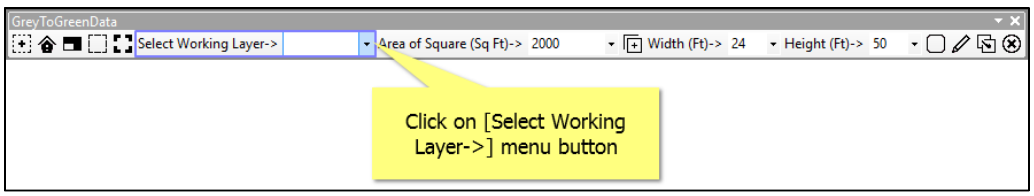


Figure 4.6. How to select the appropriate working layer on the G2G Data toolbar.

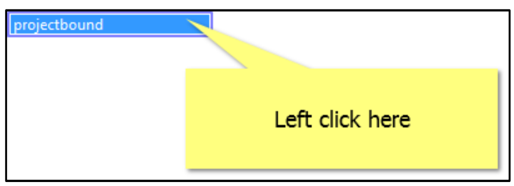


Figure 4.7. Option in the Select Working Layer drop-down menu on the G2G Data toolbar.

There are several options for creating polygons. In this case, we will use the **Freeform** tool to create our project boundary. First, click on **Create Freeform Area** on the right side of the toolbar (Fig. 4.8).

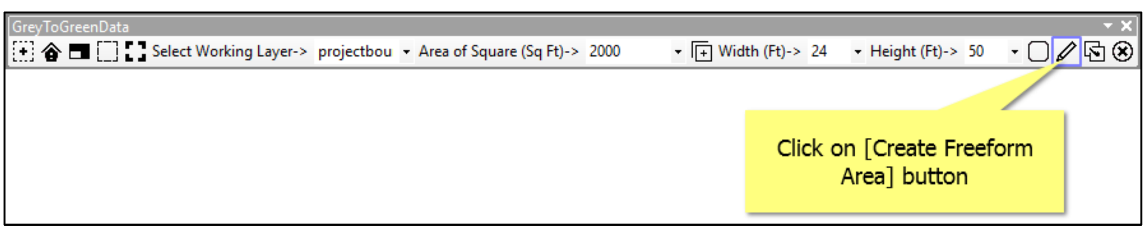


Figure 4.8. Create Freeform Area button on the Data toolbar.

Next, single-click on the screen to begin outlining your polygon (Fig. 4.9). Single-click to create corners. Double-click to complete the polygon and end the tool (Fig. 4.10).

Figure 4.9. How to begin drawing the project boundary onto your map.

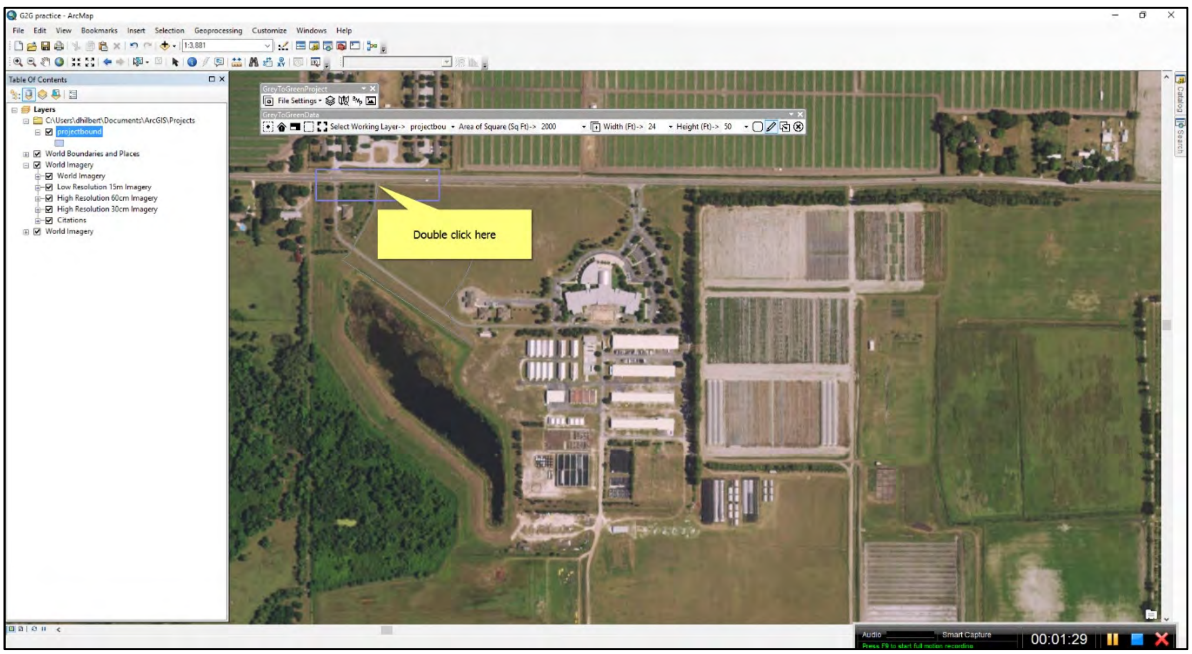


Figure 4.10. How to complete drawing the project boundary.

The tool will ask you to confirm that you want to add the new shape to the working layer. Check that the final form is what you want, then click **Yes** to confirm (Fig. 4.11).

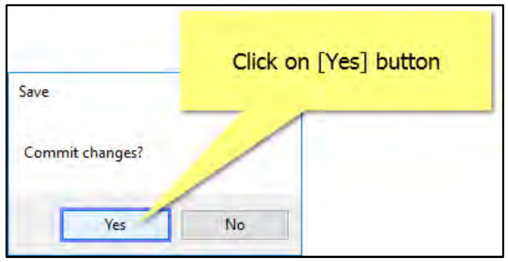


Figure 4.11. The Commit changes message appears after making changes to the map with the Data Toolbar.

TIP: For decision-making, it's helpful to make your *Data Boundary* larger than your *Project Boundary*. The Data Boundary, which defines the extent of data layers, should be larger than the drainage area encompassing your Project Boundary, but small enough to be processed in a reasonable amount of time. See Chapter 4 for instructions on mapping drainage areas using a digital elevation model (DEM).

Buildings layer tool

*How do I use the **GrayToGreenData** toolbar to create a layer with buildings?*

First, open a blank map document in ArcMap™. Make sure the toolbar has been added, and add a basemap, making sure the data frame you are using has a map projection assigned.

Click the **Create Building Layer** button on the left side of the toolbar (Fig. 4.12). Select a folder or geodatabase where the layer will be saved, create another empty layer or use an existing one. Change the file name if desired. Click **Save**. In this example, we create an empty buildings layer.

Figure 4.11. The Create Building Layer button on the Data toolbar.

Next, click the **Select Working Layer** drop-down and select the correct layer that data will be added to (Fig. 4.13). Only polygon layers will show in the list. In this example, select the **buildings** layer (Fig. 4.14).

Figure 4.13. How to select the appropriate working layer on the G2G Data toolbar.

Figure 4.14. The Select Working Layers drop-down menu with created layer names.

There are several options for creating polygons. In this case, we will use the **Create Square at Location** tool to create our buildings. You can create squares of a fixed area (sq. ft.) by clicking the **Area of Square** drop-down menu towards the center of the toolbar (Fig. 4.15). Select an area from the menu (Fig. 4.16). You can also type your own value into the cell (Fig. 4.17).

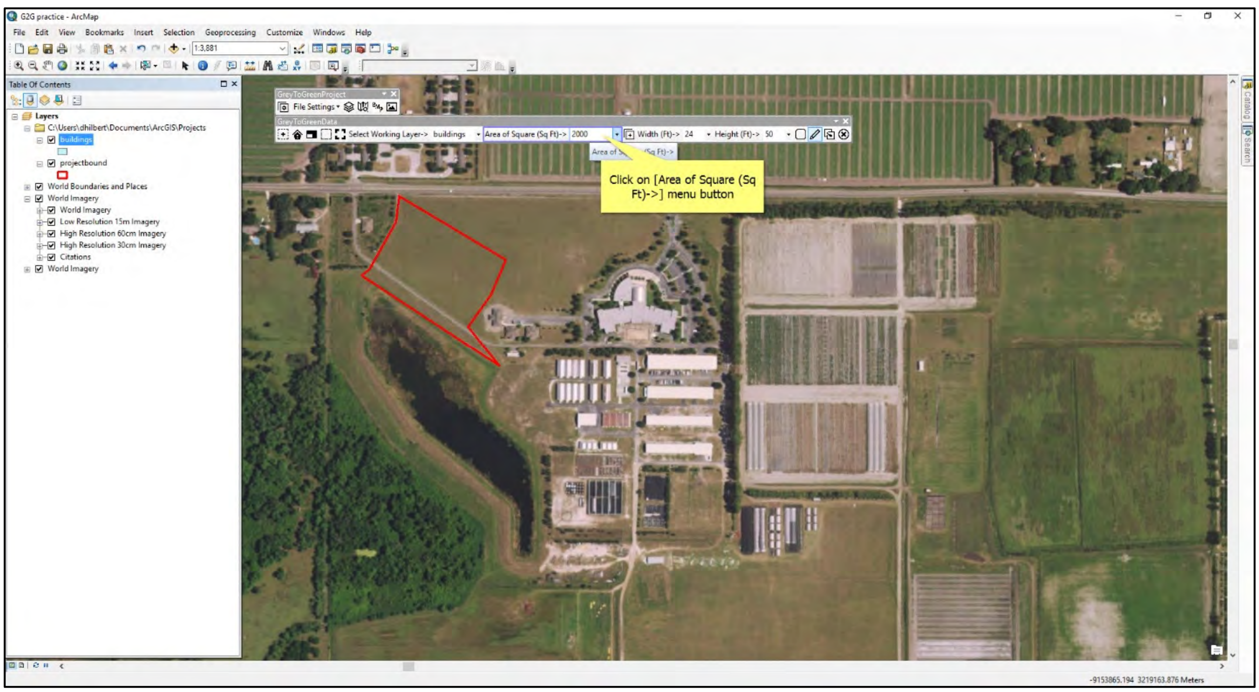


Figure 4.15. The Area of Square tool on the Data Toolbar.

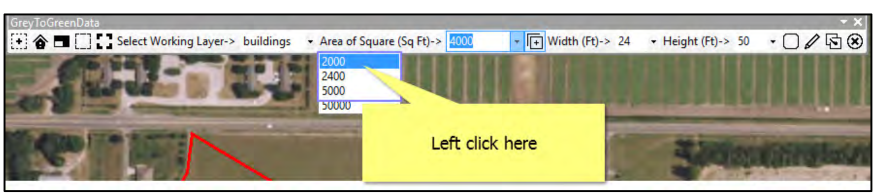


Figure 4.16. How to select an existing area from the Area of Square drop-down menu.

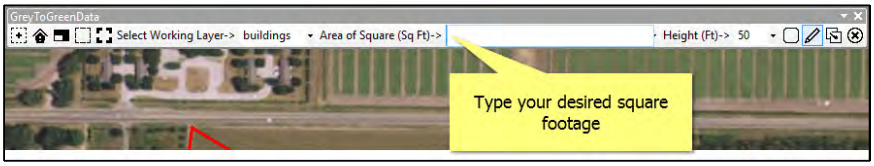


Figure 4.12. How to type your own area into the Area of Square tool.

Click the **Create Square at Location** button to the rigth of the area menu (Fig. 4.18). Next, click on the map at the location where you want the *center* of the square to be located (Fig. 4.19). This button will stay selected until you click another tool.

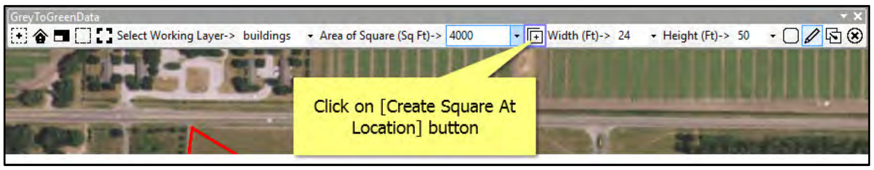


Figure 4.18. The Create Square at Location tool on the G2G Data Toolbar.

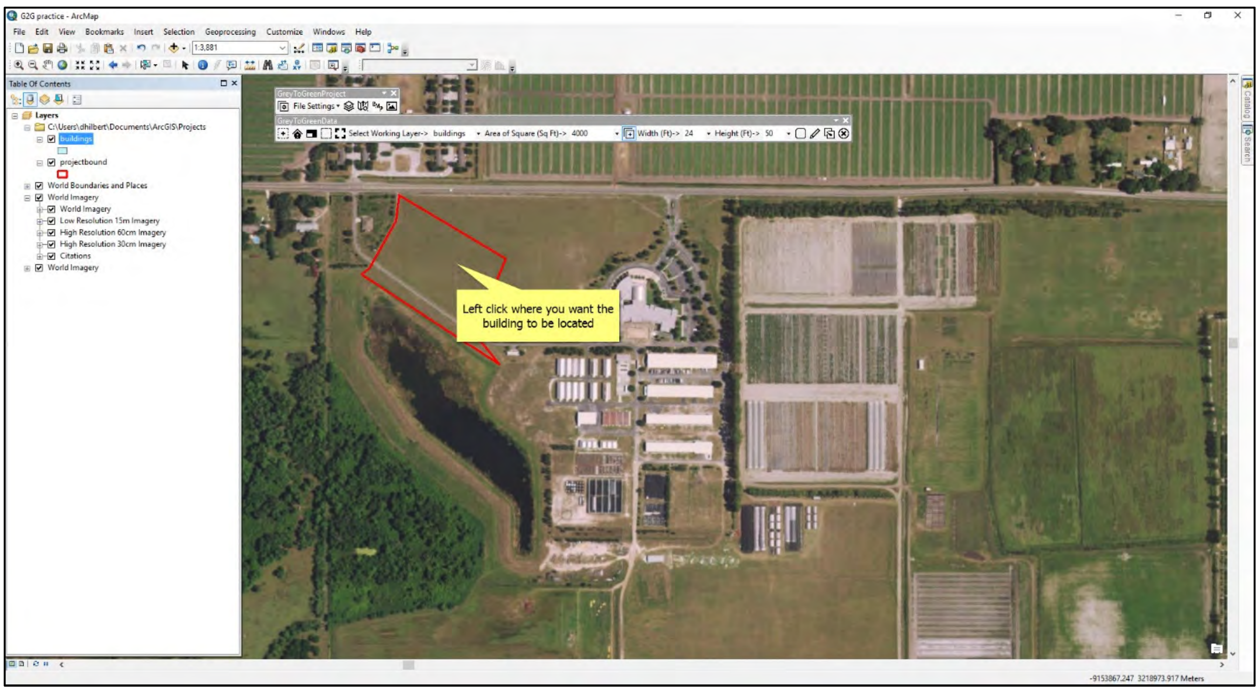


Figure 4.19. How to drop a square of desired area onto the map.

The tool will ask you to confirm that you want to add the new shape to the working layer. Check that the square is the size and location desired, then click **Yes** to confirm.

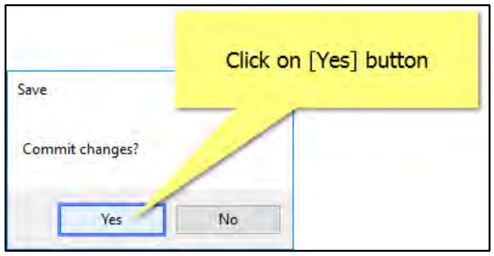


Figure 4.20. The Confirm changes window that appears after making a change to the map with the Data Toolbar.

Create single polygon tool
How do I use the ***GrayToGreenData*** *toolbar to merge polygons?*

Use the **Select Features** tool within ArcMap™ to select the features you want to combine (Fig. 4.21). Click on the features or click and drag to highlight multiple features (Fig. 4.22).

Figure 4.21. The Select Features tool within ArcMap™.

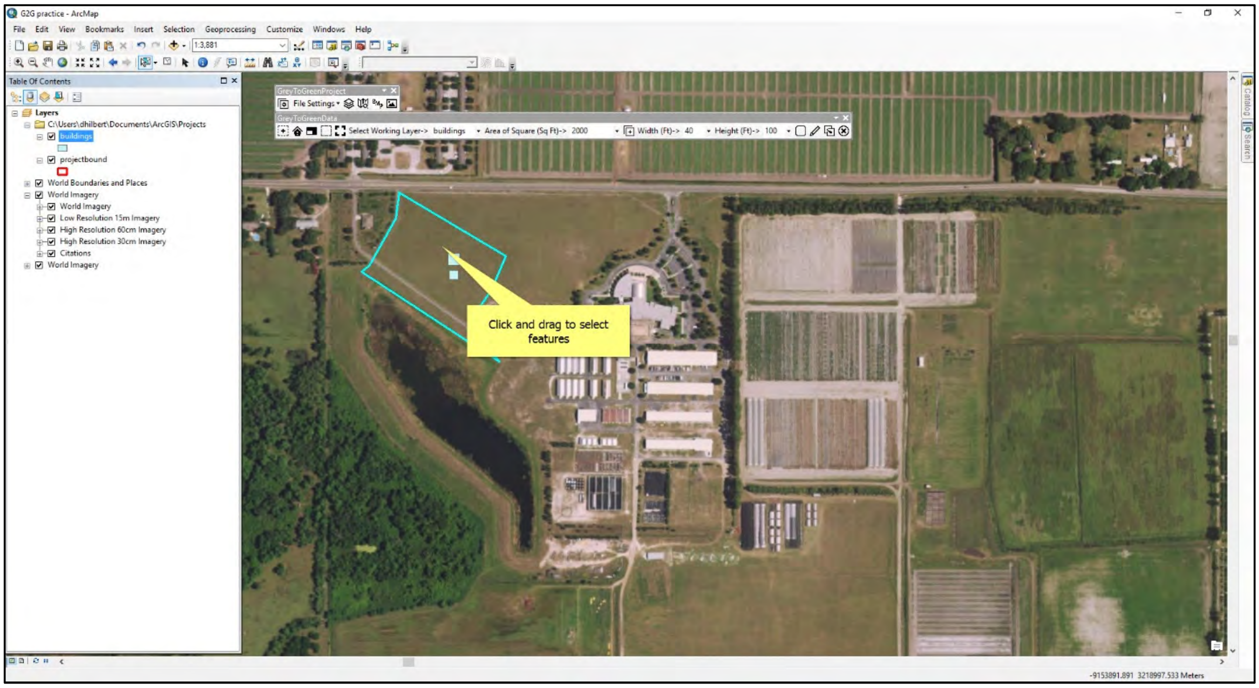


Figure 4.22. How to select multiple features to alter or delete within ArcMap™.

Click the **Create Single Polygon from Selected** button on the right side of the toolbar (Fig. 4.23).

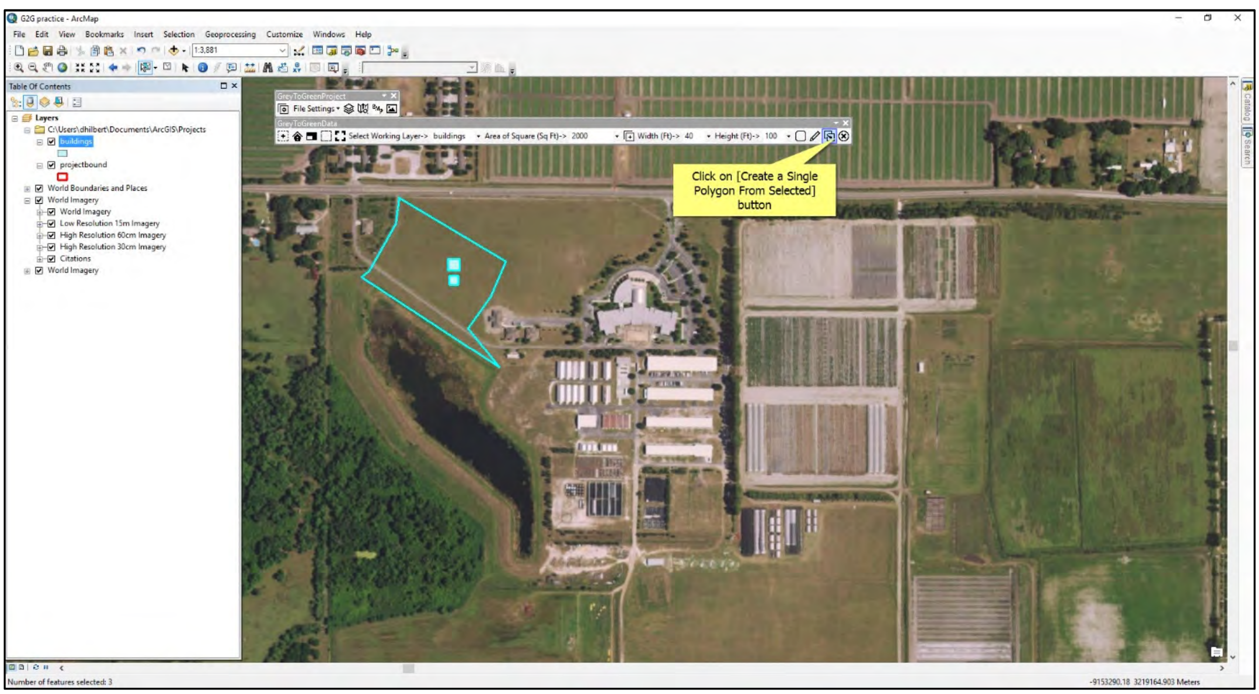


Figure 4.23. The Create Single Polygon…button on the Data Toolbar.

The tool will ask you to confirm that you keep the changes you made to the working layer. Click **Yes** to confirm (Fig. 4.24).

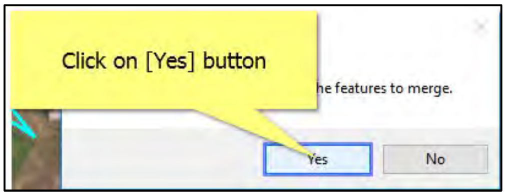


Figure 4.24. The confirmation window after merging features.

Delete selected features
*How do I use the **GrayToGreenData** toolbar to delete features I've created?*

Use the **Select Features** tool within ArcMap™ to select the features you want to delete (Fig. 4.25). Click on one or more features.

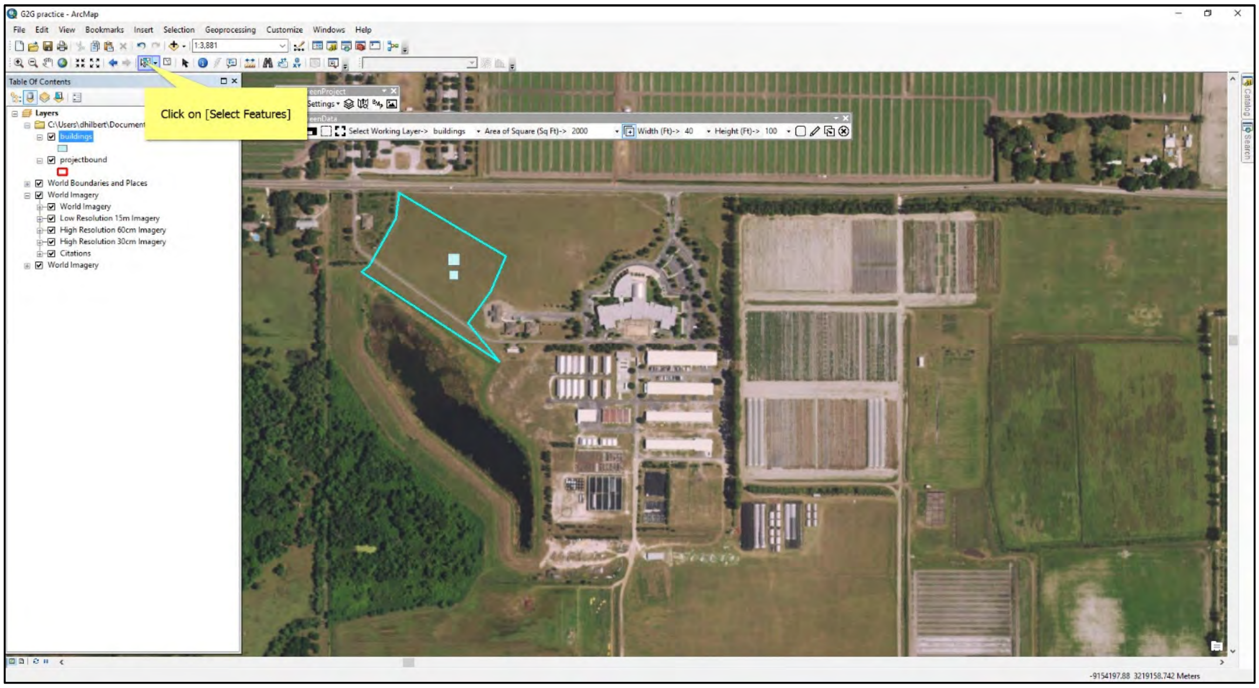


Figure 4.25. The Select Features tool within ArcMap™.

Click the **Select Features to Delete** button on the right side of the toolbar (Fig. 4.26).

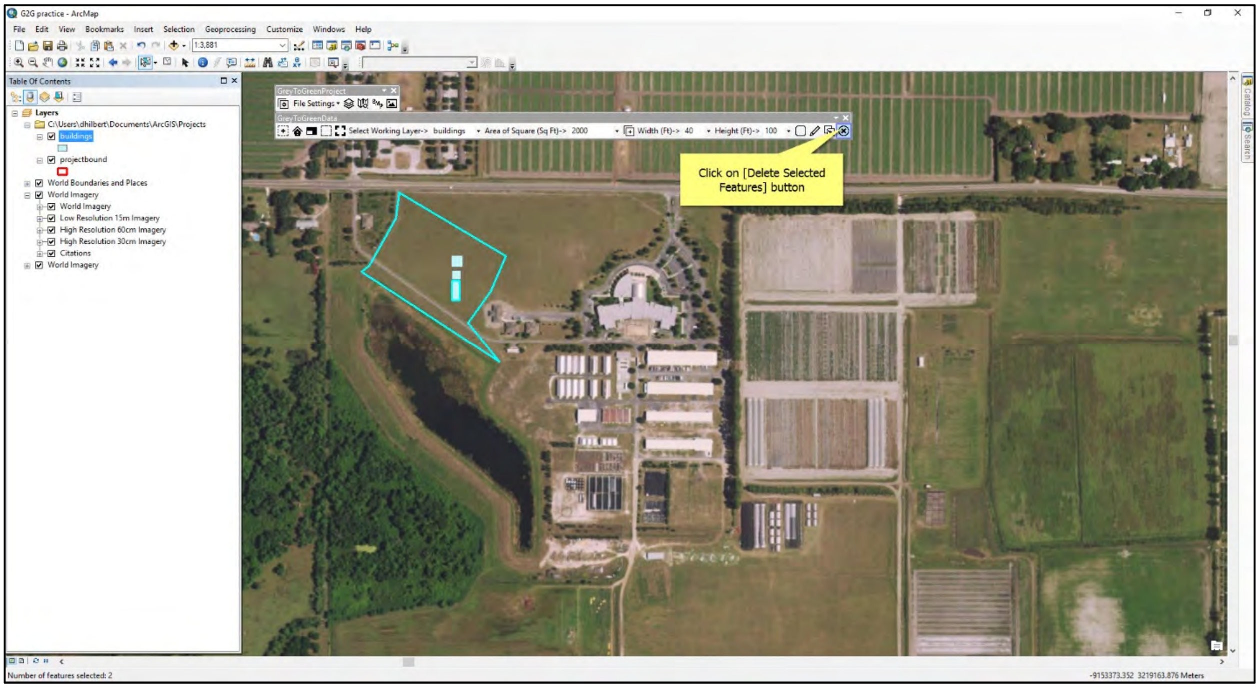


Figure 4.26. The Delete Selected Features button on the Data Toolbar.

The tool will ask you to confirm deleting your changes to the working layer. If you want to delete the features, then click **Yes** to confirm.

In this chapter, we will discuss how to add files to your project and adjust the units and cutoffs when appropriate. You will learn how to use the **File Settings** feature on the **GrayToGreenProject Toolbar** to match landcover data from different sources to the codes required by the tool. These steps collect and prepare your project data for creation of the Green Infrastructure Map. It's important that you read Chapter 4 on preparing GIS data and study the file descriptions to avoid confusion in the following steps.

The Add Files Tool

How do I add files to my project?

Open a blank map document in ArcMap™. Make sure the **GrayToGreenProject** toolbar has been added and is visible. Below is a diagram of the toolbar and each of its functions (Fig. 5.1). We will be focusing on the **Add Files to Project** button. There is also an image of the **Add Files to Project Tool** window and its features (Fig. 5.2).

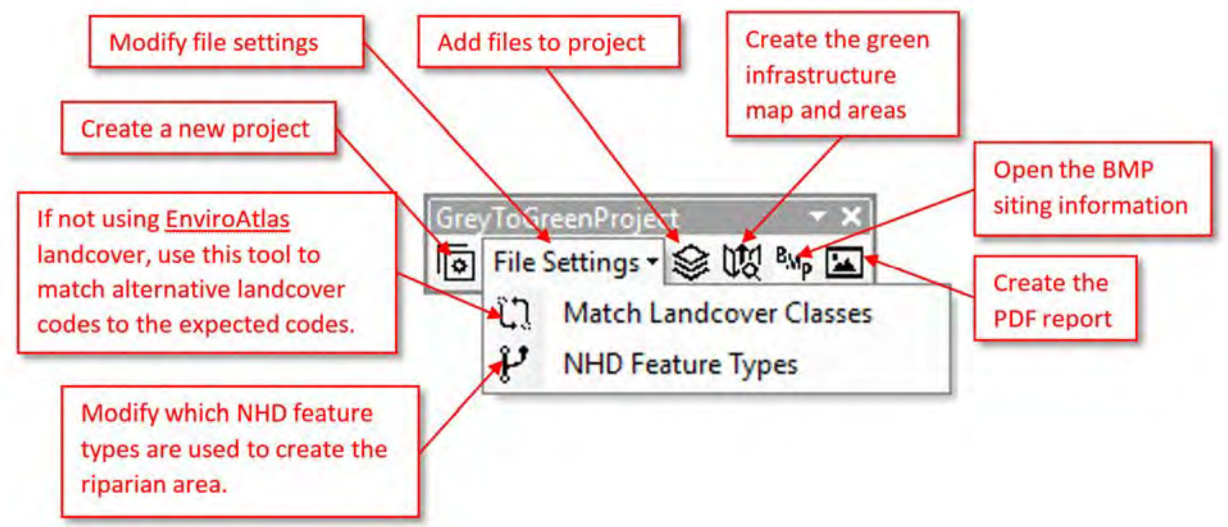


Figure 5.1. Labeled G2G Project Toolbar and its buttons.

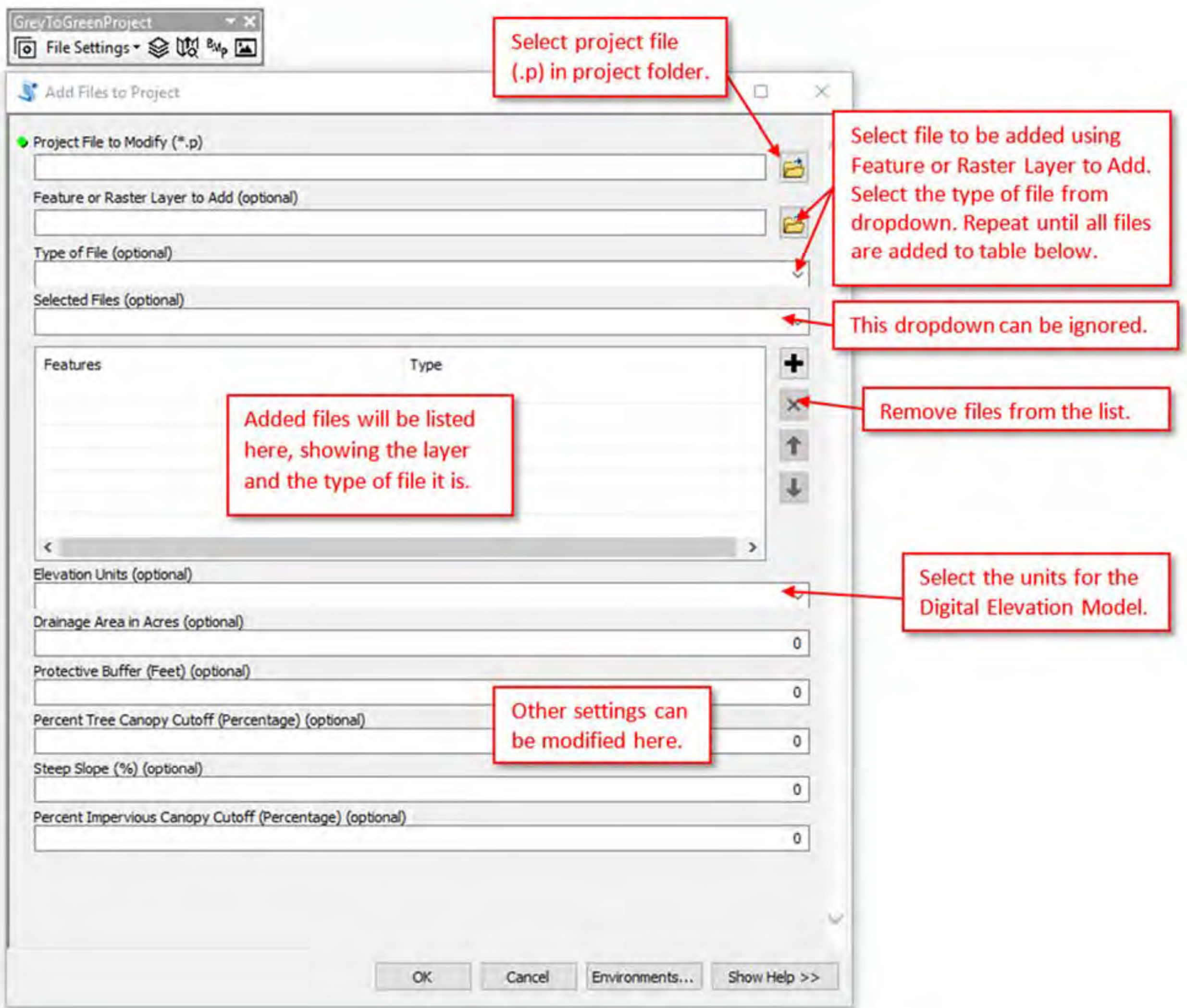


Figure 5.2. Labeled Add Files to Project tool and its different features.

The **Selected Files (optional)** dropdown menu should be ignored. It is a field that automatically gets put into new tools in ArcGIS™, but serves no purpose in the G2G tool itself.

The optional settings that appear below the **Features & Types** table include:

- **Elevation Units**: A digital elevation raster layer may have elevation in Feet or Meters above sea level. Select the correct units here.
- **Drainage Area…**: Drainage area is used to calculate the **Natural Drainage Pathways**, which are the stream pathways derived from the Digital Elevation Model. If you know the acreage of drainage area, it can be included here to create more accurate Natural Drainage Pathways, but it is optional.
- **Protective Buffer…**: A protective buffer is applied to layers creating the **Riparian Areas** layer. One hundred feet is the default and recommended value.
- **Percent Tree Canopy Cutoff…**: If using Percent Tree Canopy to derive information about trees, select the minimum percentage tree canopy. Anything above this cutoff is considered tree canopy. Typically, cutoffs between 25% and 35% are recommended. You want your cutoffs to create a layer that matches as closely as possible what aerial images of the tree canopy show.

- **Steep Slope…**: Select the cutoff for steep slopes. Anything above this cutoff is considered a steep slope. The default is 25%.
- **Percent Impervious Canopy Cutoff…**: If using Percent Impervious to derive information about trees, select the minimum percentage impervious. Anything above this cutoff is considered impervious canopy. Typically, cutoffs between 25% and 35% are recommended. You want your cutoffs to create a layer that matches what aerial images of the tree canopy show.

TIP: If you have questions about what each of the options within the **Add Files** tool mean, you can click the **Show Help >>** button in the bottom right of the tool window. This displays explanations for any features you click on, and is helpful when using new tools in ArcMap™.

Click on the **Add Files** button (Fig. 5.3). The **Add Files** tool will open. Click on the folder icon next to **Project File to Modify (*.p)** (Fig. 5.4). Select the project file (*.p) that was created in Chapter 2 (Fig. 5.5). Click **Open**.

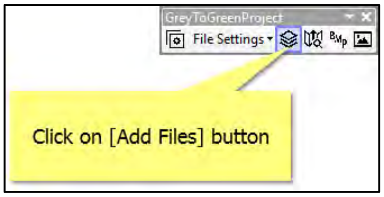


Figure 5.3. The Add Files button on the G2G Project Toolbar.

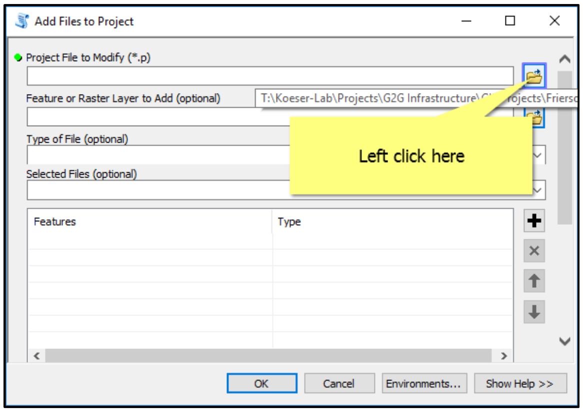


Figure 5.4. How to search for a project file using the Project File to Modify button.

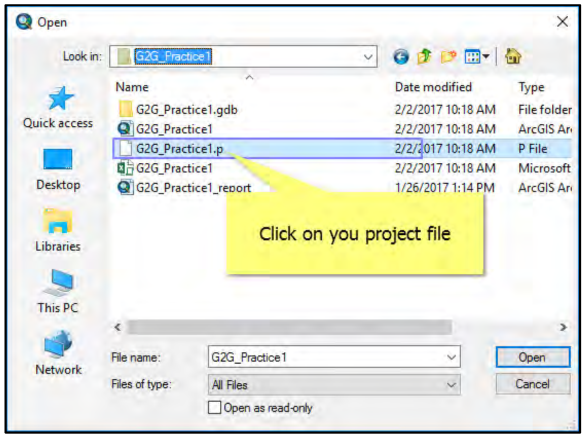


Figure 5.5. The project file (.p) within the project folder.

Now you can start adding files to the project by selecting the appropriate file from the **Feature or Raster Layer to Add** button (Fig. 5.6). In this example, we select an elevation raster (Fig. 5.7). Click **Add** to finish selecting the layer (Fig. 5.8). See Chapter 4 and Appendix C for help on picking the different types of files.

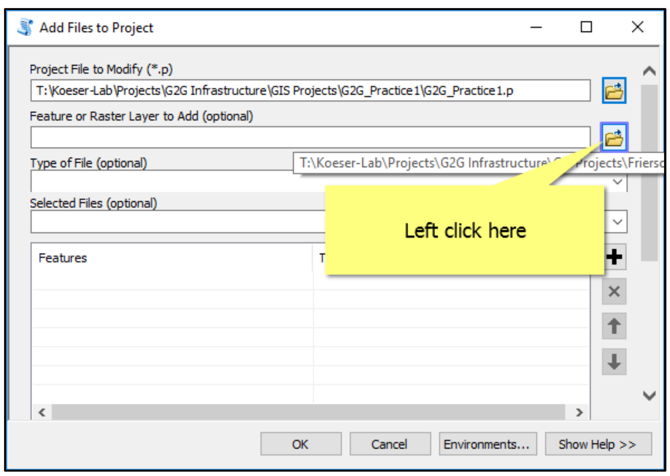


Figure 5.6. How to select the feature or raster to add to the project.

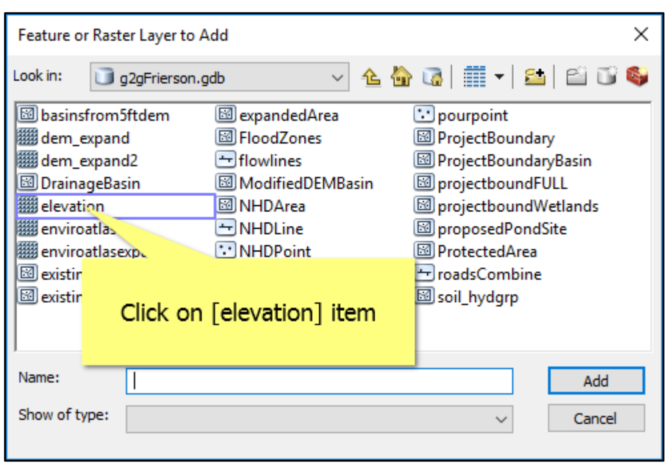


Figure 5.7. Different layers found using the Project Toolbar.

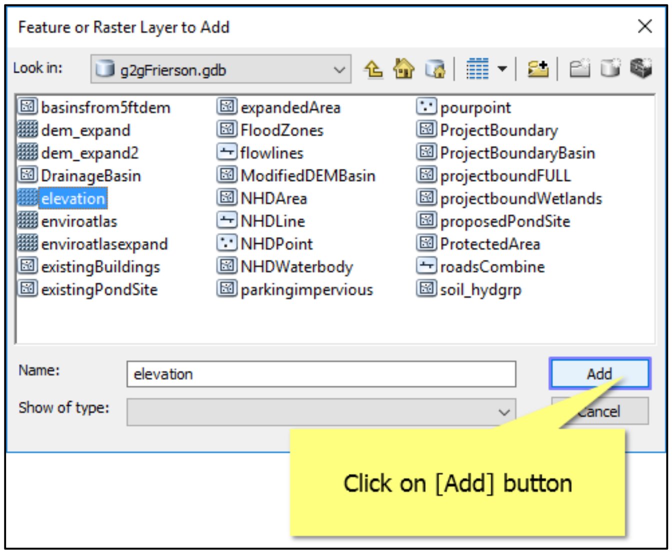


Figure 5.8. The Add button in the Feature or Raster Layer to Add search window.

Next, select the **Type of File** drop-down and match the file that was added to a file that is expected by the GrayToGreen Tool (Fig. 5.9).

CAUTION: Checks exist so that an error message will appear if the file type is incorrect. See Chapter 3 and Appendix C if you are having trouble selecting the correct files.

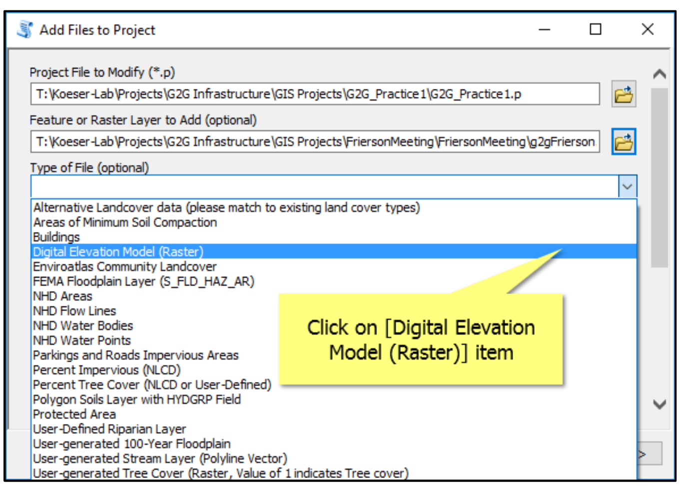


Figure 5.9. The Type of File drop-down menu in the Add Files to Project tool window.

In this example, an elevation raster layer is matched to the **Digital Elevation Model (Raster)** accounted for by the tool. Once you select the type of file, the values are added to the table, and the previous selections are cleared (Fig. 5.10). Continue the process of adding files to the project. The different layers that are added and will provide information for creating the Green Infrastructure Map and LID practice siting information.

CAUTION: You must match file land cover codes and join/alter components of layers *before* adding them to the project. See the next section on using the tool bar for matching land cover codes.

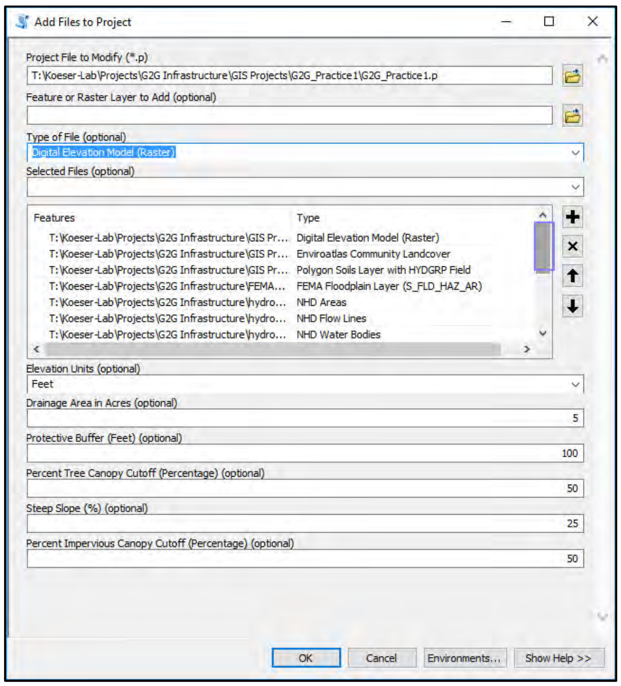


Figure 5.10. Image of the Add Files to Project tool window with added features.

To get results in the 6 final layers of the Green Infrastructure Map, the bare minimum files that should be added include the 3 (or 4 if you do NOT use EnviroAtlas) inputs below. You will get a "blockier" looking map if you use minimal data (Fig. 5.11).

- A soils layer with a HYDGRP field
- A digital elevation raster
- A complete community landcover file like EnviroAtlas (or a percent impervious canopy AND percent tree canopy dataset).

To get results for the LID practice siting information, you will need the 3-4 datasets listed above, plus layers that include parking, roads, buildings and the floodplain.

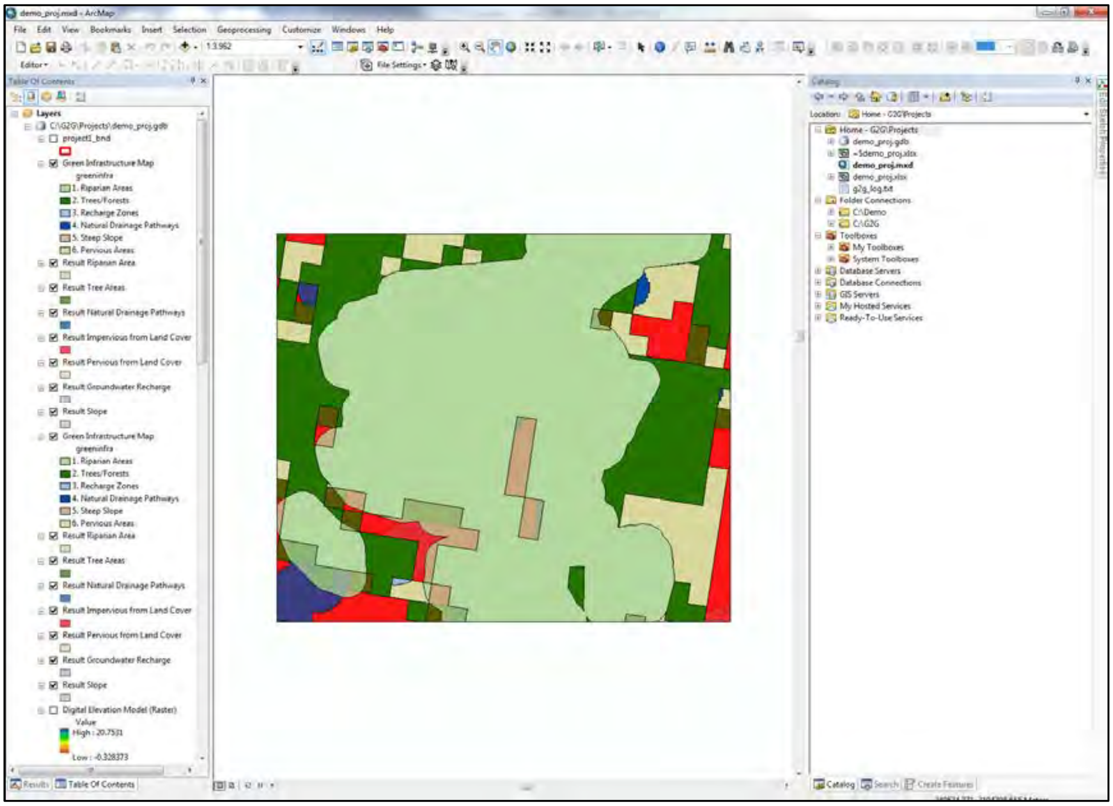


Figure 5.11. Example Green Infrastructure Map created with the bare minimum of input layers. Notice the "blocky" appearance.

The tool contains different settings the user can change for a project. Below the added features, there are options for data units and cutoffs (Fig. 5.12). Select the appropriate **Elevation Units** for the elevation raster that was added (feet or meters). The **Protective Buffer** is automatically set to 100 feet, which is recommended. The default for the **Percent Tree Canopy Cutoff** and **Percent Impervious Canopy Cutoff** is 50%.

In the next section, we go over what to do if you are not using EnviroAtlas for landcover data. One option is to use a percent impervious dataset and percent tree cover dataset to supply the necessary information. If you do this, you may want to adjust the cutoff values (Fig. 5.12). Typically, a cutoff of 25%-35% yields the best results, meaning the layers best match what aerial images typically show the tree canopy and impervious canopy to be. Anything greater than the cutoff percentages will be classified as **Percent Impervious Canopy** or **Tree Canopy**.

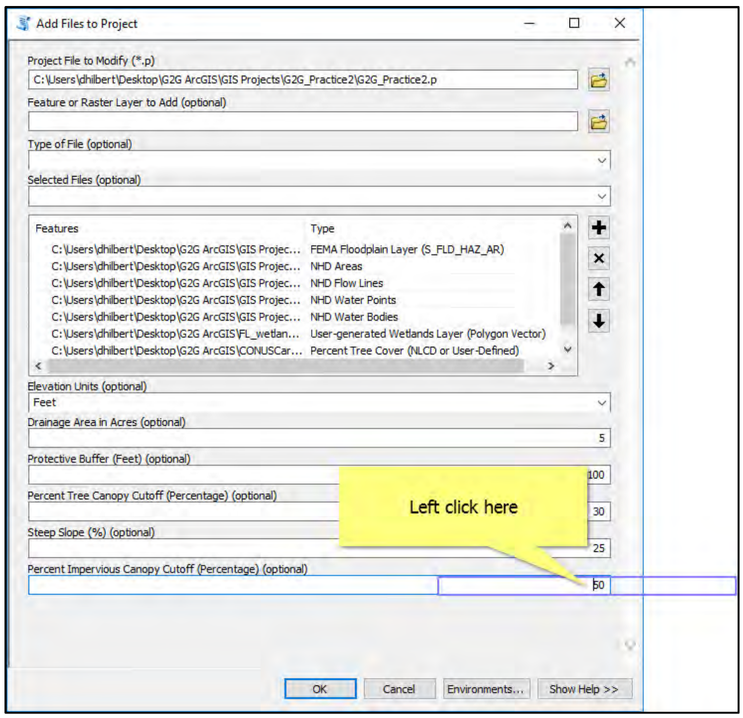


Figure 5.12. How to change percent impervious cutoff in the Add Files to Project tool window.

Once you have selected the files and adjusted the units and cutoffs, click **OK** (Fig. 5.13). The tool will locate the files and make a copy to use in the project. Click **Close** once the tool completes (Fig. 5.14).

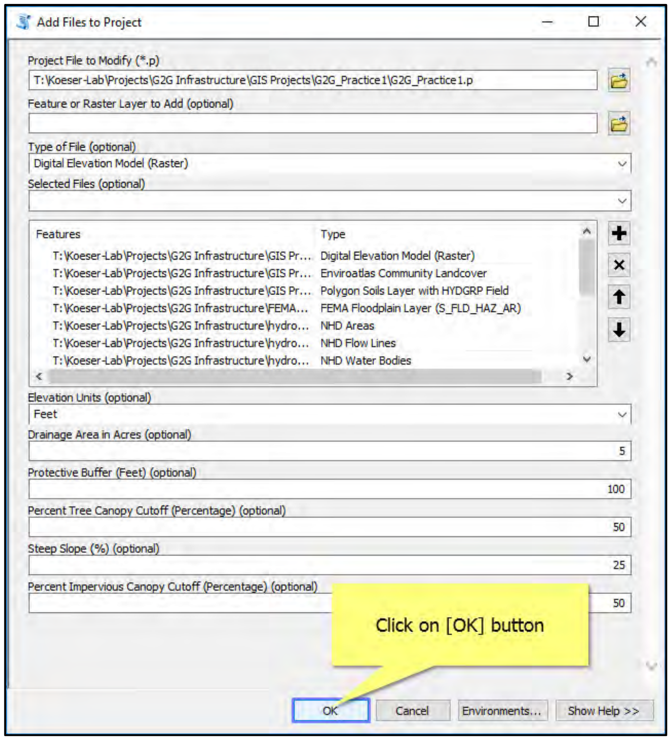


Figure 5.13. How to finish using the Add Files to Project tool window.

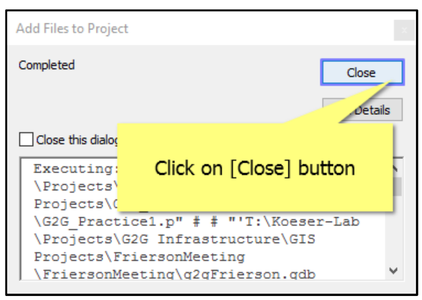


Figure 5.14. Add Files to Project calculation window.

Next, you can visit your project folder and open the map file (*.mxd) to view the newly added files in the map. The files will be clipped to fit the project boundary when the final Green Infrastructure Map is created. You can turn layers on and off to view them in the map (Fig. 5.15). If you look in **Catalog**, you can see the files that have been added to the project geodatabase.

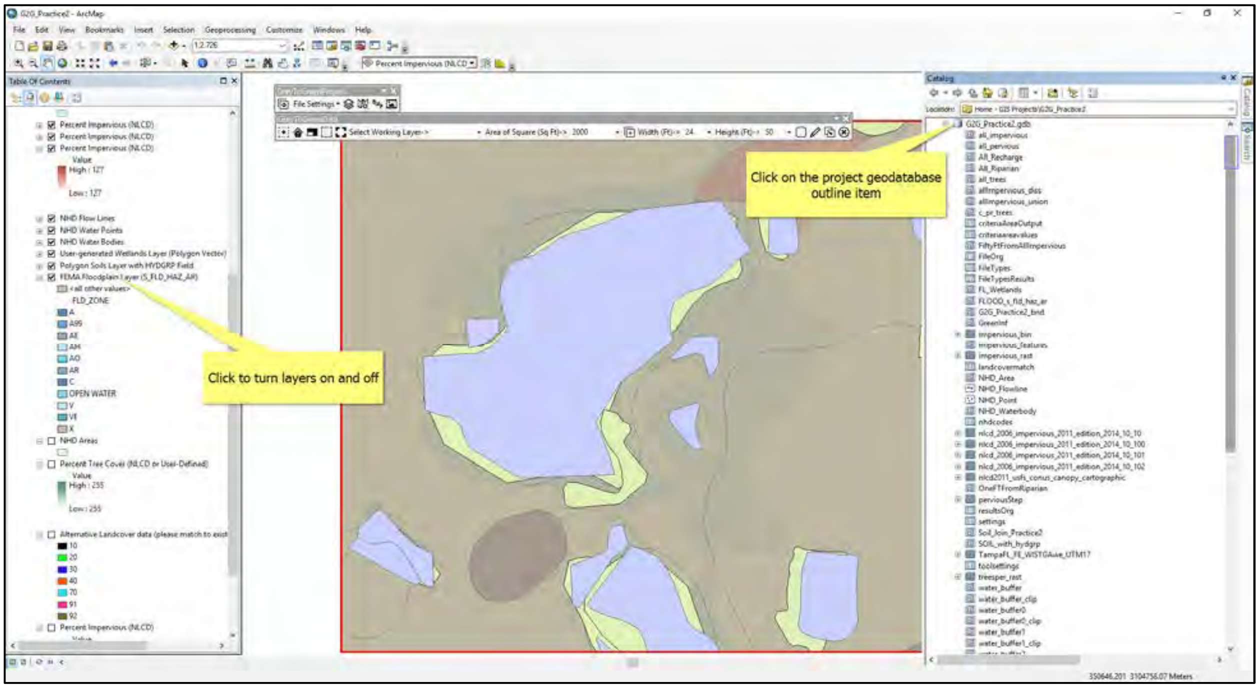


Figure 5.15. Map file (.mxd) created after adding files to project. The Table of Contents (left) and Catalog (right) are useful for exploring the layers that were added to your project.

Remember to close this map (*.mxd) file and the Excel file (*.xlsx) before moving on to the next step (Fig. 5.16).

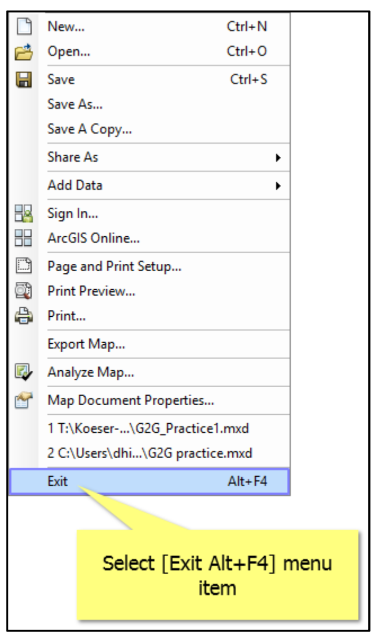


Figure 5.16. Exit button on the File dropdown in ArcMap™.

Using Alternate Landcover Data

What if I am NOT using EnviroAtlas for landcover data?

EnviroAtlas may not have datasets for your community. If this is the case, you can use both a percent impervious dataset and percent tree cover dataset or just an alternative landcover dataset to provide the tool with this information. The first option may require adjusting cutoff points within the **Add Files to Project** tool window. The second option requires matching the landcover codes to the categories expected by the Siting Tool. Both options are done using the **GrayToGreenProject** Toolbar while working in a blank map document in ArcMap™ and are detailed in the following examples.

Using impervious and tree canopy layers

To use an alternative impervious dataset and percent tree cover dataset to supply the necessary landcover information, you will use the **Add Files** button to add the raster files, following the steps laid out in the previous section. Typically, you can add files that are categorized as **Percent Impervious (NLCD)** and **Percent Tree Cover (NLCD or User-Defined)** from the USGS MRLC National Landcover Database. Any raster where the cell represents a percentage (0-100) can be used.

The default for the **Percent Tree Canopy Cutoff** and **Percent Impervious Canopy Cutoff** is 50%. Typically, a cutoff of 25%-35% yields the best results, especially when using NLCD datasets. Anything greater than the cutoff percentages will be classified as **Percent Impervious Canopy** or **Tree Canopy**. To adjust the cutoff percentages, click the cell and type in a cutoff other than the default (5.17). Adjust your cutoff values until the result canopy layers best match what aerial images (i.e., your basemap) show the tree canopy and impervious canopy to be. You will have to generate a new Green Infrastructure map each time you adjust cutoff values to view the different result layers.

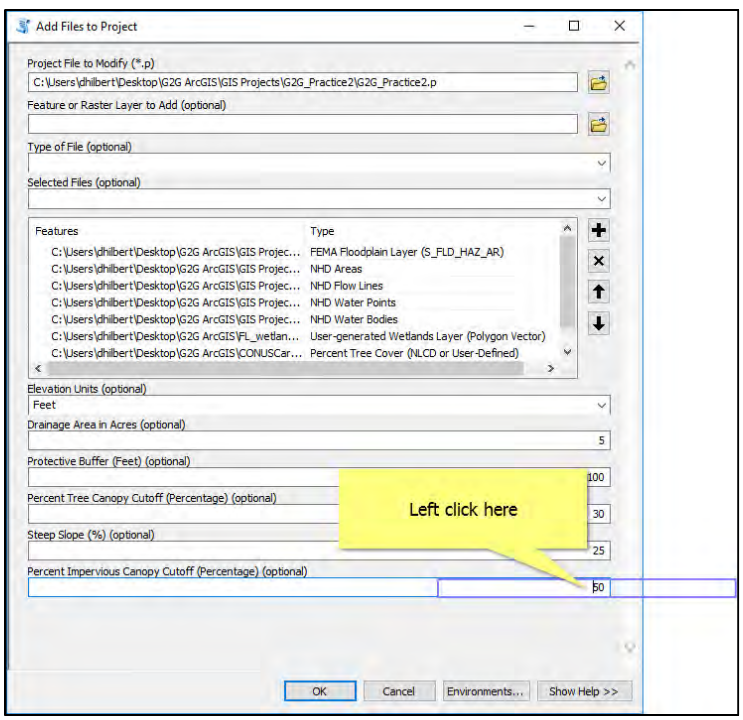


Figure 5.17. How to change impervious canopy cutoff percentage within Add Files to Project window.

For example, the cutoff can be adjusted to 30%, creating a tree layer that matches the existing tree canopy closely (Fig. 5.18) and an impervious canopy layer that matches the existing imperivious canopy of buildings, roads, parking lots, etc. (Fig. 5.19).

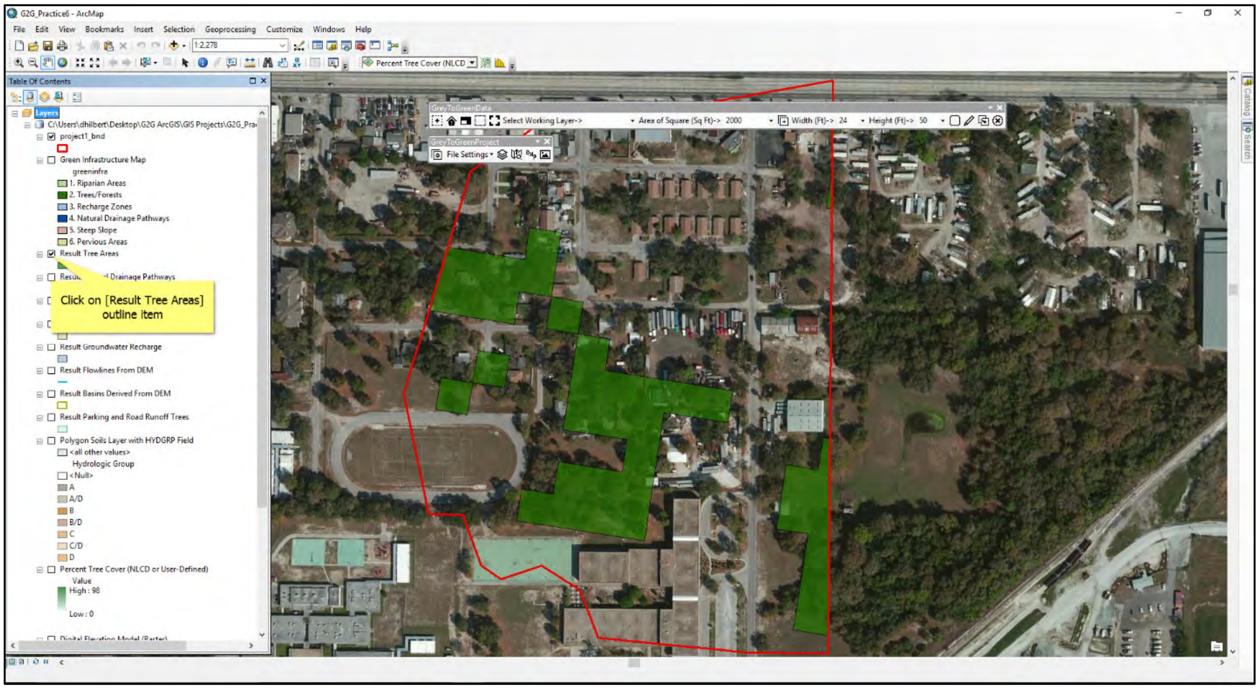


Figure 5.18. The Result Tree Areas layer when Percent Tree Canopy Cutoff is set to 30%.

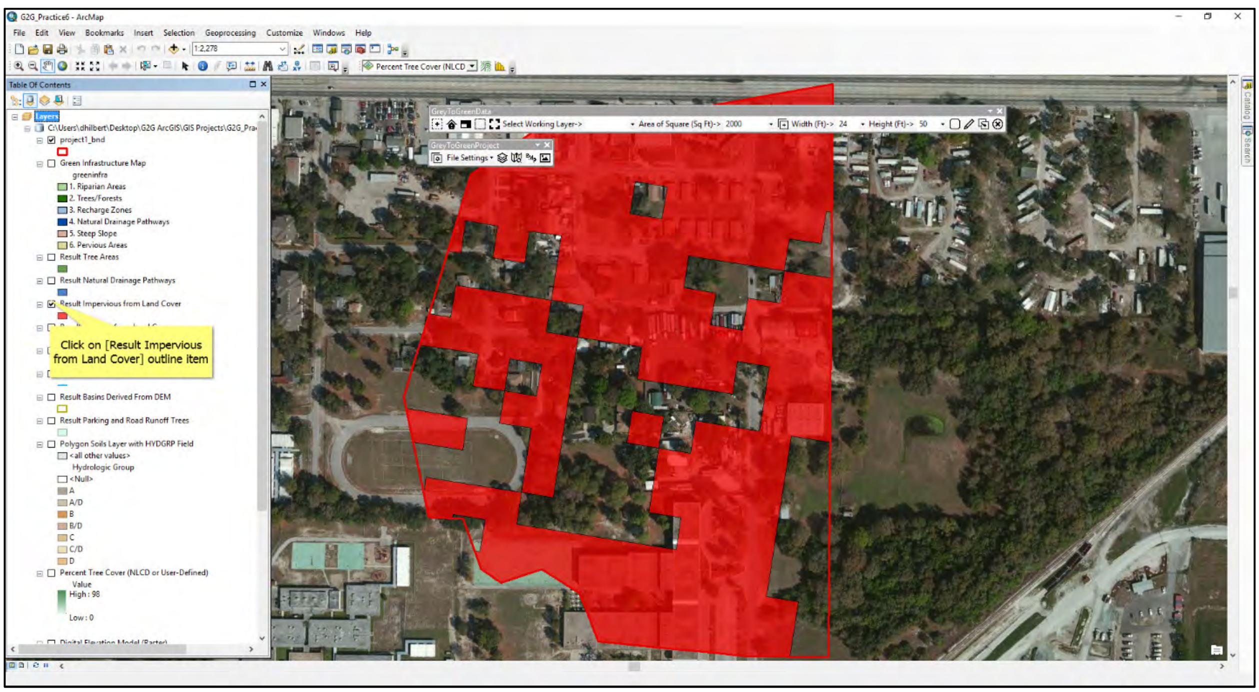


Figure 5.19. The Result Impervious layer when Percent Impervious Canopy Cutoff is set to 30%.

If the cutoff value is set too low, say 10%, the result tree canopy and impervious canopy layers will be larger than the actual at the site (Fig. 5.20). This is especially visible in Fig. 5.21 where the result impervious layer overlaps impervious canopy, but also pervious surfaces like trees and grass. You may have to test different cutoff values, and may even find that some cutoffs work better for the trees but not the imperivous canopy, and vice versa. Try picking a cutoff that gives a good result for both layers. If the input data resolution doesn't match your study site size, then it can be difficult to find a close match, regardless of the cutoff value. See Chapter 3 on preparing your data for more information on this.

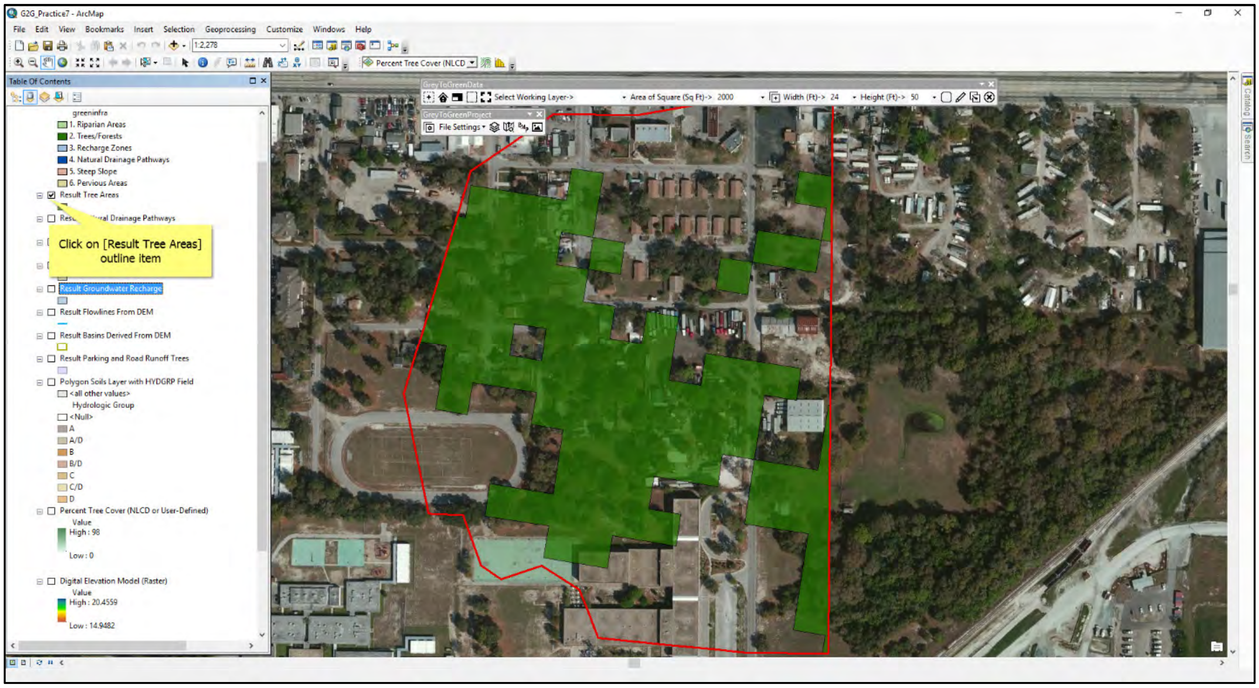


Figure 5.20. The Result Tree Areas layer when Percent Tree Canopy Cutoff is set to 10%.

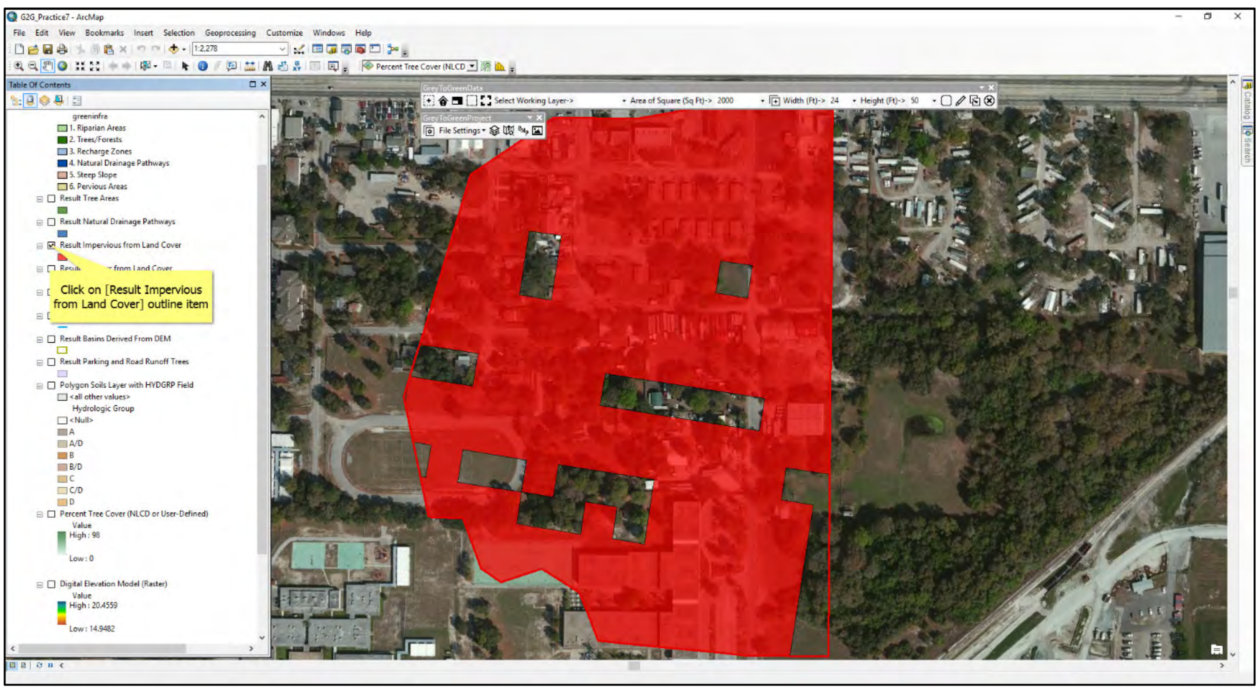


Figure 5.21. Result Tree layer when Tree Canopy Percent Cutoff is set to 10%.

Using an alternate community landcover dataset

When using an alternative landcover dataset, begin by clicking the **File Settings** drop-down menu (Fig. 5.22). Click **Match Landcover Classes** (Fig. 5.23). The **Match Landcover Classification** tool will open.

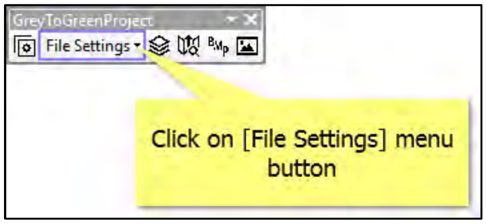


Figure 5.22. The File Settings menu in the Project Toolbar.

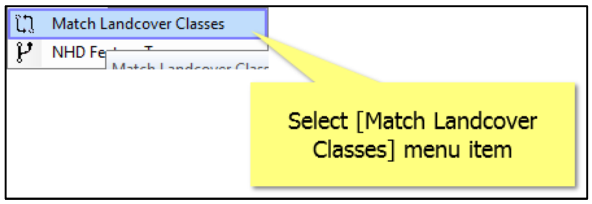


Figure 5.23. Options in File Settings drop-down menu in the Project Toolbar.

Select your project file. Then find a raster file that has your Landcover data in it (Fig. 5.24).

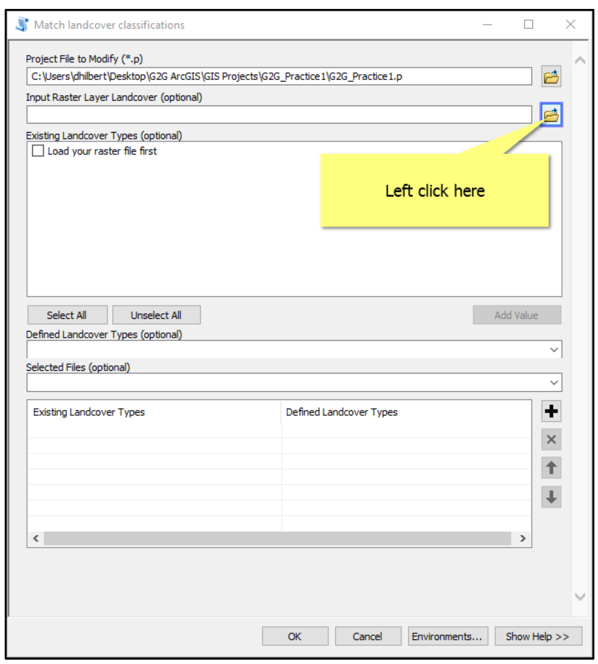


Figure 5.24. The Input Raster Layer Landcover file search button.

Once the raster is selected, the a unique set of codes will populate the list under **Existing Landcover Types** (Fig. 5.25).

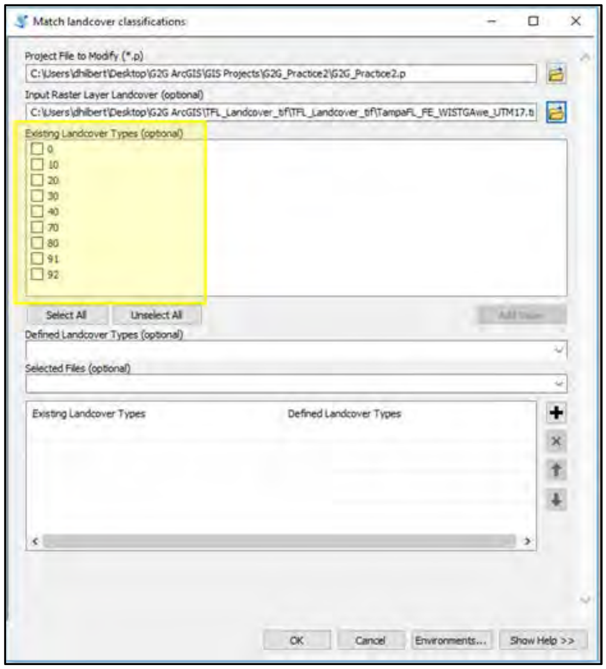


Figure 5.25. The list of codes that appears after selecting a landcover raster.

Now you can click on individual codes or select multiple ones. The codes are based on EnviroAtlas landcover categories. In this example, **code 20** from the list was checked off (Fig. 5.26).

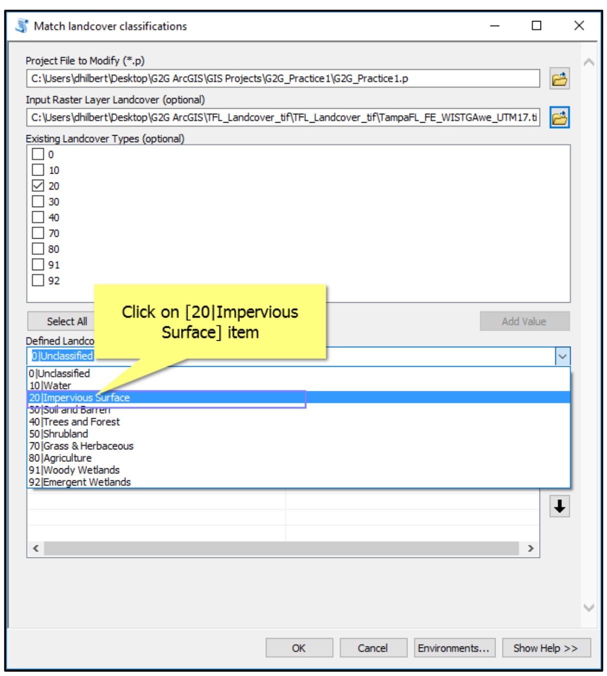


Figure 5.26. How to select a category to match the input raster's codes to existing codes.

After clicking on a code, select the appropriate category from the drop-down list to match them. You must match your landcover codes to the predefined landcover codes in the tool. For example, **code 20** is selected and matched with **Impervious Surface**. After matching the codes to the categories, click **OK** (Fig. 5.27).

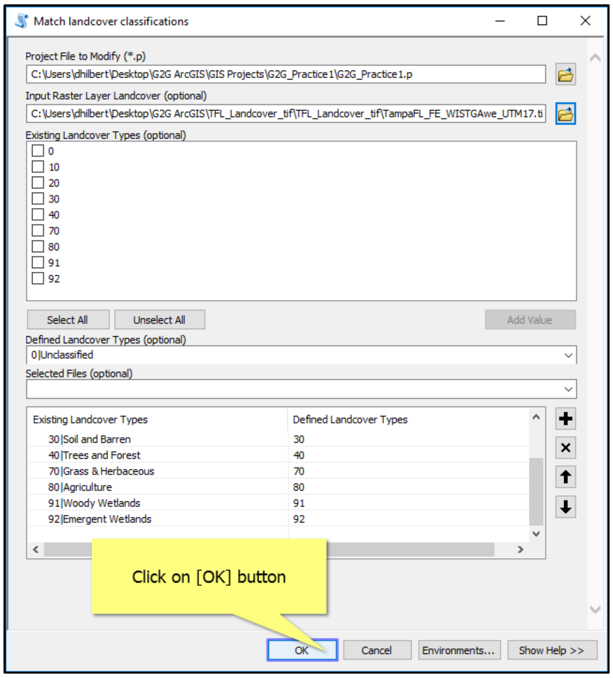


Figure 5.27. The OK button completes the process of matching landcover classifications.

The tool creates a modified copy of the selected raster file that is now ready to be added to the project following the instructions in the last section.

In this chapter, we will create the Green Infrastructure Map and LID practice siting information using the **Map Green Infrastructure** tool. We will go over the outputs from the tool and possible questions that may arise.

The Green Infrastructure Map

How do I create my final map using the toolbar?

Begin by opening a blank map in ArcMap™. Make sure that your project map (*.mxd) and Excel (*.xlxs) files are closed. Check that the **GrayToGreenProject** toolbar is open. As a reminder, below is a diagram of the toolbar and its different functions (Fig. 6.1).

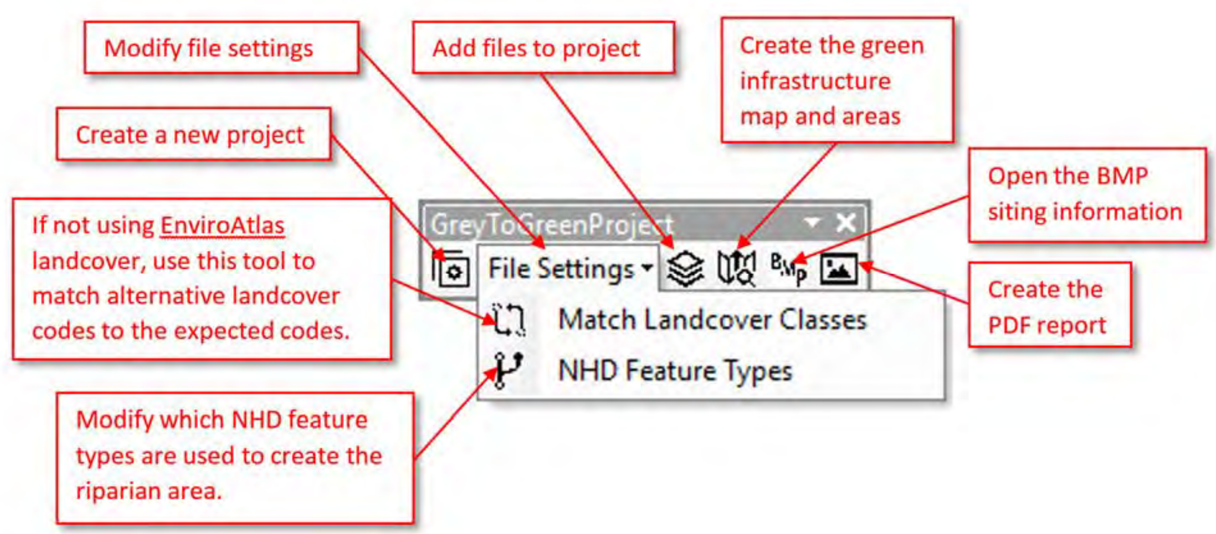


Figure 6.1. Labeled G2G Project Toolbar and its buttons.

Click the **Map Green Infrastructure** button on the right side of the toolbar, and the **Calculate Green Infrastructure** tool window will open (Fig. 6.2). Select the project file that you want to create a green infrastructure map for (Fig. 6.3). Click **OK** to run the tool (Fig. 6.4).

Figure 6.2. Map Green Infrastructure button on the Project Toolbar.

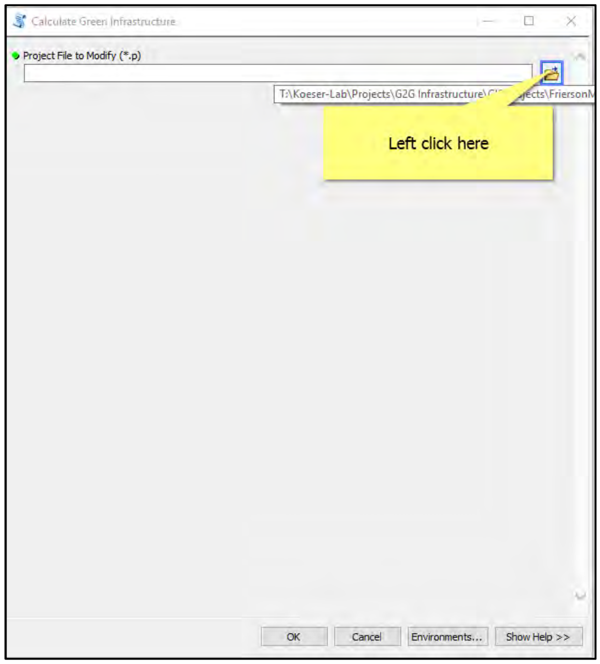


Figure 6.3. Project File to Modify search button.

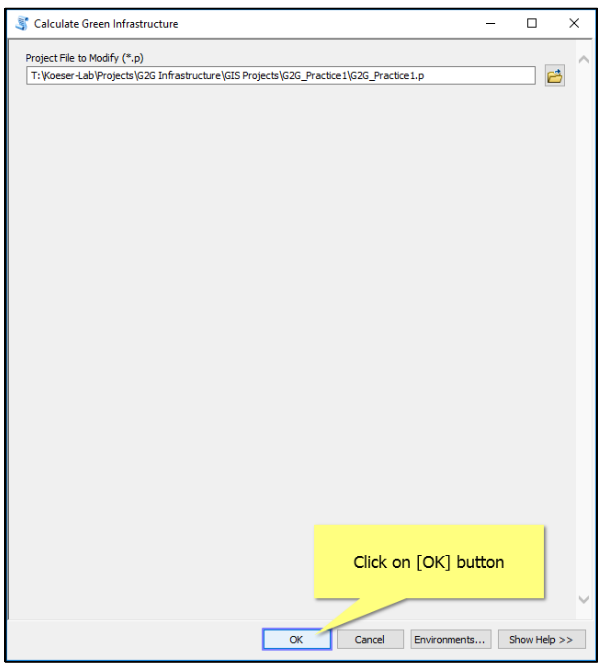


Figure 6.4. OK button in the Calculate Green Infrastructure window.

Once the tool completes the calculations, an Excel output, map and legends are generated and saved to the project folder you selected. The project map and Excel workbook will open automatically. Within the project map document, you can see the final Green Infrastructure Map with legends (Fig. 6.5). The map incorporates the six different categories discussed in Chapter 3 (Riparian Area, Trees, Groundwater Recharge Zone, Natural Drainage Pathways, Steep Slopes, and Pervious and Impervious Areas), which are shown as the **Results** layers. Depending on the data that was added to the project, not all categories may have a result.

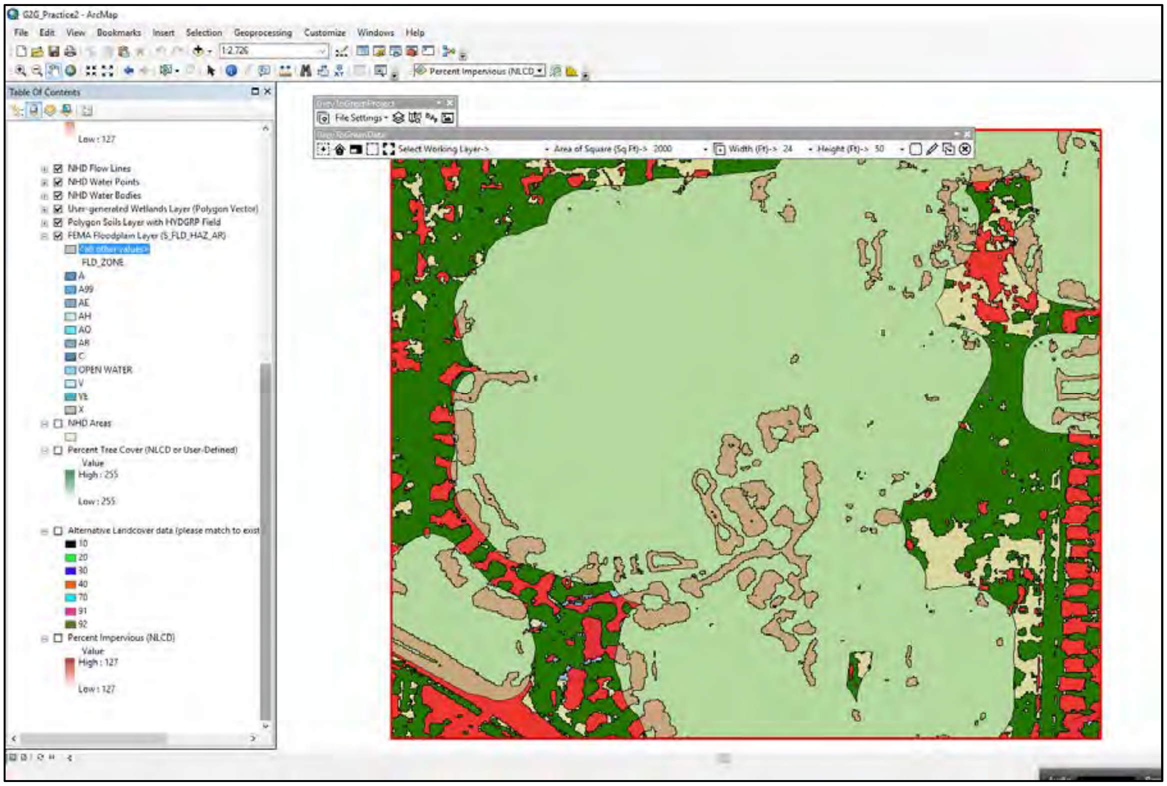


Figure 6.5. Generated Green Infrastructure Map with result layers and legends.

You can view each result layer individually or in different combinations. You can also compare the results of individual layers with their input data to see how the inputs were combined by the tool. For example, the **Result Riparian Area** layer is compared against the **Floodplain** layer to see how the protective buffer affects the input layers (Fig. 6.6).

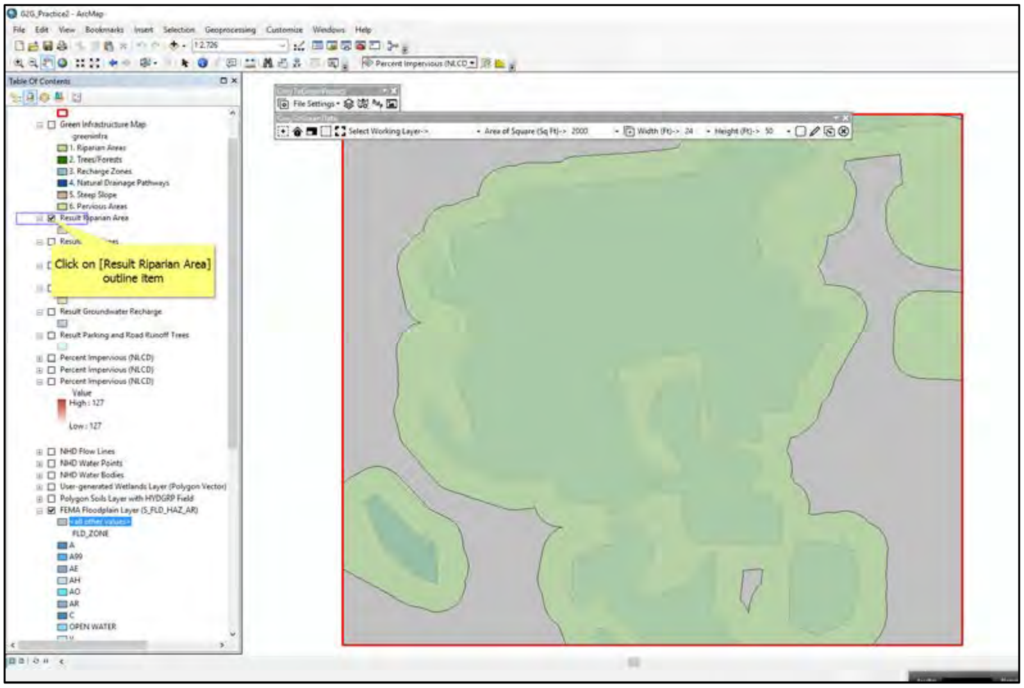


Figure 6.6. Green infrastructure map showing the Result Riparian Area layer and FEMA Floodplain layer. The protective buffer created by the tool extends the Result Riparian layer beyond the input Floodplain layer.

Table 6.1 outlines the different **Green Infrastructure Map** outputs that result from mapping the green infrastructure areas using the Siting Tool. The total area for each element is automatically calculated and generated in an Excel file, along with the areas for siting LID practices, as discussed in the next section (**LID practice siting information**).

Table 6.1. GIS outputs generated by mapping green infrastructure areas.

Output Name	**Type**	**Description**
Green Infrastructure Map	Polygon	The main output of the G2G siting tool. This combines six categories in this order: Riparian Areas, Trees, Groundwater Recharge Zones, Natural Drainage Pathways, Steep Slopes and Pervious Areas. The layers higher up are prioritized and removed from areas lower in the order. Finally, Impervious Areas are removed from the entire Green Infrastructure Map.
Result Riparian Area	Polygon	The full riparian area result used in the Green Infrastructure Map.
Result Tree Areas	Polygon	The full tree area result used in the Green Infrastructure Map.
Result Groundwater Recharge	Polygon	The full ground water recharge areas result used in the Green Infrastructure Map.

Result Natural Drainage Pathways	Polygon	The full Natural Drainage Pathways result used in the Green Infrastructure Map (area encompasses flow lines and 100-foot buffer).
Result Slope	Polygon	The full slope result used in the Green Infrastructure Map.
Result Impervious from Land Cover	Polygon	The full Impervious result used in the Green Infrastructure Map. The label “from Land Cover” is meant to distinguish this layer from the impervious areas that are used in siting new development projects (parking and road areas).
Result Pervious from Land Cover	Polygon	The full pervious area result used in the Green Infrastructure Map.
Result Basins Derived From DEM	Polygon	Basins derived from the DEM and may be useful in determining retrofit projects.
Result Flowlines From DEM	Polyline	Flowlines derived from the DEM and the Drainage area (default is 5 acres and may be changed in the Add Files tool). These are the basis for the Natural Drainage Pathways pre-buffered.

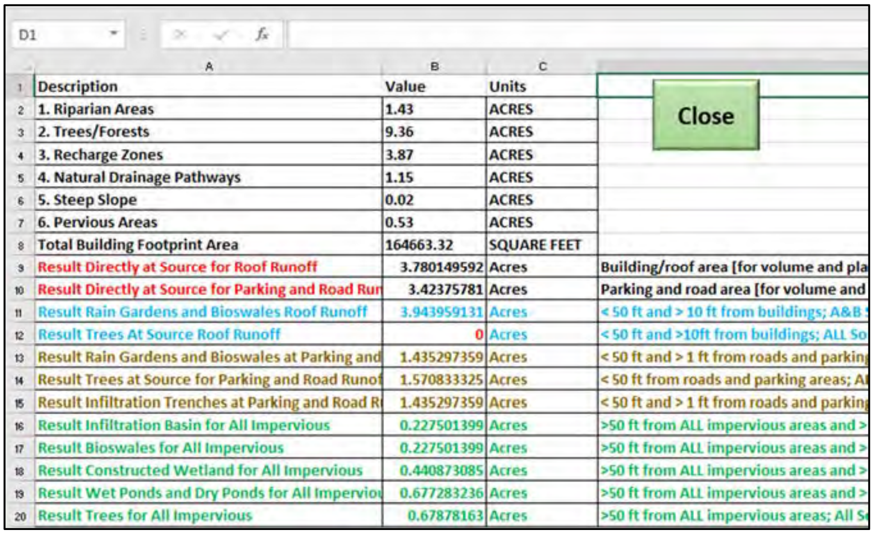
LID practice siting information

What are the criteria for siting LID practices and where do I get the areas available for siting each practice?

The criteria for siting LID practices is provided in Table 6.2. It includes criteria for siting practices proximal to roofs and parking/roads, and pervious areas located greater than 50 feet from impervious areas. The GIS Tool automatically maps and generates an Excel table identifying the total potential areas for siting each LID practice. The Excel table will open automatically when you use the **Map Green Infrastructure** tool. You can also find the file in your project folder, and you can open it directly from the **GrayToGreenProject** toolbar using the **Open BMP** tool. As shown in Figure 6.7, the Excel table provides the total potential area within your project boundary that is available for siting each LID practice (Fig. 6.7). It also provides the total area for each element of green infrastructure. In Part 3, Selecting LID Practices, we will provide directions on how to import this information into the Scenario Analysis Tool.

Table 6.2Criteria for siting LID practices proximal to roofs and parking/roads, and pervious areas located greater than 50 feet from impervious areas.

GIS Output	Output Description
Result Directly at Source for Roof Runoff	Building/roof area [for volume and placement of Green Roof and Rainwater Harvesting]
Result Directly at Source for Parking and Road Runoff	Parking and road area [for volume and use of pervious pavement]
Result Rain Garden Roof Runoff	< 50 ft and > 10 ft from buildings; ALL Soils; <5% slope, excluding all impervious areas [for placement of Rain Garden]
Result Bioswale Roof Runoff	< 50 ft and > 10 ft from buildings; ALL Soils; <5% slope, excluding all impervious areas [for placement of Bioswale]
Result Trees at Source Roof Runoff	< 50 ft and >10ft from buildings; ALL Soils; ALL slope, excluding all impervious areas [for placement of Trees to manage roof runoff]
Result Rain Garden at Parking and Road Runoff	< 50 ft and > 1 ft from roads and parking areas; ALL Soils; <5% slope; excluding ALL impervious areas and ALL areas <50 ft of a building [for placement of Rain Garden]
Result Bioswale at Parking and Road Runoff	< 50 ft and > 1 ft from roads and parking areas; ALL Soils; <5% slope; excluding ALL impervious areas and ALL areas <50 ft of a building [for placement of Bioswale]
Result Infiltration Trench at Parking and Road Runoff	< 50 ft and > 1 ft from roads and parking areas; ALL Soils; <5%; excluding ALL impervious areas and ALL areas <50 ft of a building [for placement of Infiltration Trench]
Result Trees at Source for Parking and Road Runoff	< 50 ft from roads and parking areas; ALL Soils; <5% slope; excluding ALL impervious areas and ALL areas <50 ft of a building [for placement of Trees]
Result Infiltration Basin for All Impervious	>50 ft from ALL impervious areas and > 1 ft from riparian areas; ALL Soils; <5% slope [for placement of Infiltration Basin]
Result Bioswale for All Impervious	>50 ft from ALL impervious areas and > 1 ft from riparian areas; ALL Soils; 5% slope [for placement of Bioswale]
Result Constructed Wetland for All Impervious	>50 ft from ALL impervious areas and > 1 ft from riparian areas; ALL Soils; <15% slope [for placement of Constructed Wetland]
Result Dry Pond for All Impervious	>50 ft from ALL impervious areas and > 1 ft from riparian areas; ALL Soils; <15% slope [for placement of Dry Pond]
Result Wet Pond for All Impervious	>50 ft from ALL impervious areas and > 1 ft from riparian areas; ALL Soils; <15% slope [for placement of Wet Pond]
Result Trees for All Impervious	>50 ft from ALL impervious areas; ALL Soils; <5% slope [for placement of Trees]



	A	B	C	D
1	Description	Value	Units	Close
2	1. Riparian Areas	1.43	ACRES	
3	2. Trees/Forests	9.36	ACRES	
4	3. Recharge Zones	3.87	ACRES	
5	4. Natural Drainage Pathways	1.15	ACRES	
6	5. Steep Slope	0.02	ACRES	
7	6. Pervious Areas	0.53	ACRES	
8	Total Building Footprint Area	164663.32	SQUARE FEET	
9	Result Directly at Source for Roof Runoff	3.780149592	Acres	Building/roof area [for volume and pla
10	Result Directly at Source for Parking and Road Run	3.42375781	Acres	Parking and road area [for volume and
11	Result Rain Gardens and Bioswales Roof Runoff	3.943959131	Acres	< 50 ft and > 10 ft from buildings; A&B
12	Result Trees At Source Roof Runoff	0	Acres	< 50 ft and >10ft from buildings; ALL So
13	Result Rain Gardens and Bioswales at Parking and	1.435297359	Acres	< 50 ft and > 1 ft from roads and parkin
14	Result Trees at Source for Parking and Road Runof	1.570833325	Acres	< 50 ft from roads and parking areas; Al
15	Result Infiltration Trenches at Parking and Road R	1.435297359	Acres	< 50 ft and > 1 ft from roads and parkin
16	Result Infiltration Basin for All Impervious	0.227501399	Acres	>50 ft from ALL impervious areas and >
17	Result Bioswales for All Impervious	0.227501399	Acres	>50 ft from ALL impervious areas and >
18	Result Constructed Wetland for All Impervious	0.440873085	Acres	>50 ft from ALL impervious areas and >
19	Result Wet Ponds and Dry Ponds for All Imperviou	0.677283236	Acres	>50 ft from ALL impervious areas and >
20	Result Trees for All Impervious	0.67878163	Acres	>50 ft from ALL impervious areas; All S

Figure 6.7. The Excel tab showing the result green infrastructure (top 8 rows in black text) and associated LID practice siting areas (colored text) generated by the Siting Tool.

CAUTION: Not all categories in the Excel table may have results. There could be "0's" in some of the cells. This is okay, as the GIS tool creates outcomes based on the data supplied and what is in the project area. For example, if you do not include stream lines, then there will not be a result for stream buffer areas. Likewise, if your project area doesn't have streams, then no stream buffer areas will be calculated, even if you supplied stream data layers.

Creating a PDF of the Green Infrastructure and LID Practice Map

How do I create a PDF using the GIS tool?

You can generate a PDF of the Green Infrastructure and LID Practice Map, with viewable data layers, by clicking the **PDF Report** tool on the **GrayToGreenProject** toolbar (Fig. 6.8). Select the project file, click **Open**, and click **OK** to finish and create the report.

Figure 6.8. The PDF Report button on the Project Toolbar.

A PDF file, including the map and layers, will be generated and saved in your project folder (Fig. 6.9). You can use the PDF file to share the results of your analysis with others without access to ArcGIS™ (Fig 6.10).

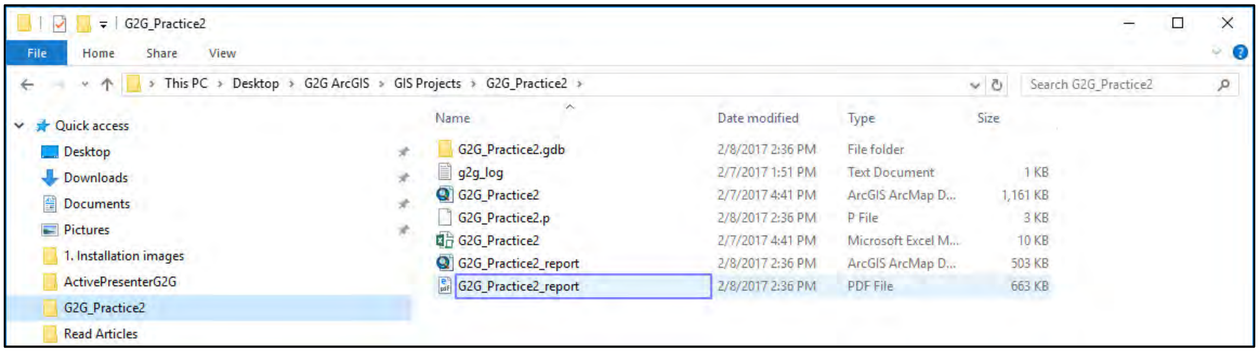


Figure 6.9. The project folder with the new PDF report highlighted.

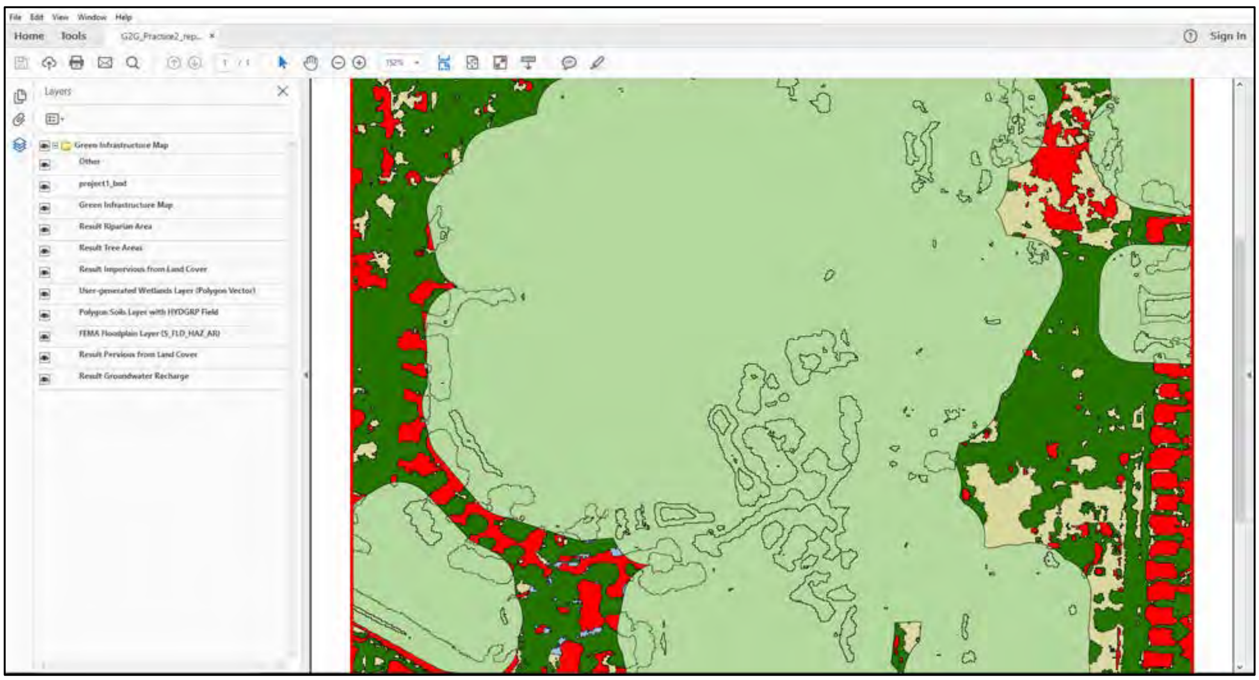


Figure 6.10. The PDF report generated by the Project Toolbar. The Layers button on the left side of the screen allows you to view different layers within the PDF version of the Green Infrastructure Map.

Viewing the Green Infrastructure Map in Google Earth
How do I view the results using Google Earth?

An alternative to using the PDF document for reports is to produce a Google Earth file (kml or kmz). ArcMap includes a tool that will convert your map document (mxd file) to a Google Earth file (kmz). You first create a PDF report using the **PDF Report** button pictured below (Fig. 6.11). This button is found on the **GrayToGreenProject** toolbar (Fig. 6.8).

Figure 6.11. The G2G PDF Report button.

This creates a new mxd file with the project name and "_report.mxd" suffix and extension. You can open this new map document and add some of the original input layers like the land cover and digital elevation model. Move these new layers to the bottom of the table of contents. You can also add a legend to the map. Save the document. This will be exported as an image that is viewable in Google Earth.

In ArcMap, find the **Map to KML toolbox** (Fig. 6.12). As of version 10.3, this tool was located **in System Toolboxes -> Conversion Tools -> To KML -> Map to KML**. Open this tool.

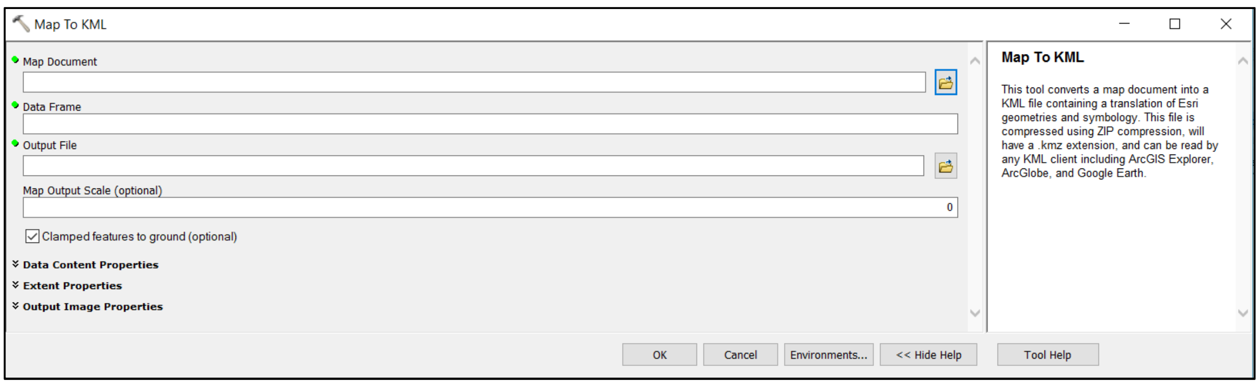


*Figure 6.12. **Map to KML** toolbox in ArcMap.*

Select the "_report.mxd" map document that was created and saved earlier. The **Data Frame** option will fill automatically. You can change the **Output File** location and name. The default values should work fine for the output.

Open the file in Google Earth to review it. The layers may overlap or hide behind the elevation in Google Earth. You can manually change an individual layer's **Altitude** (to raise them up) in the Google Earth's layers properties. You can change colors and symbols this way, as well.

Step 2: Fitting the Project to the Site

This step is important to identifying the opportunities that exist in every project to use green infrastructure, LID practices, and water sensitive design to avoid and minimize impacts to water resources and reduce project costs. Planners, resource managers, scientists, and engineers can use G2G to guide planning for:

- Urban reforestation;
- New development and redevelopment;
- Stormwater retrofits for water quality enhancement and flood reduction; and
- Community resilience and adaptation to climate change.

The "fit" for each project type is optimized through project re-designs and multiple iterations of the G2G planning process.

Chapter 7: Strategies and Practices for Fitting the Project to the Site

The way a site is developed is fundamentally important to the volume and pattern of runoff it creates and the pollutants it carries. The objectives of a well-designed integrated stormwater management system are detailed below (Water Environment Federation & American Society of Civil Engineers/ Environmental and Water Resources Institute 2012):

- Minimization of runoff by reduction of impervious area and project footprint, protection of native soils to maintain infiltration capacity, and protection of native vegetation to maintain evapotranspiration potential.
- Source controls implemented at the point where precipitation reaches the ground to prevent stormwater from contacting pollutants and minimize runoff by promoting infiltration and evapotranspiration.
- Control systems distributed throughout the drainage system, close to the sources of runoff, to capture stormwater, remove pollutants, promote further infiltration and evapotranspiration, enable rainwater harvesting, and slowly discharge remaining runoff.
- Resource protection such as vegetated setbacks to protect the habitat and assimilative capacity of waterbodies while protecting the surrounding development from flooding and erosion.
- Protection of public safety, health, and welfare.
- Protection of infrastructure and public property by reducing flood hazards and erosion.
- Community enrichment by blending stormwater controls into the built environment to enhance active and passive recreation features, wildlife habitat, property value, pedestrian and bicycling trails, playgrounds parks, and other assets that support livable communities and connect the public to natural resources.
- Technical feasibility, cost-effectiveness, public acceptance, and practicality.

Some design elements and strategies for fitting the project to the site in a way that minimizes impacts to water resources include the following (Singleton 2015):

- ***Open spaces and natural infrastructure*** – Identify, preserve, and restore wetlands, floodplains, recharge zones, riparian areas, open spaces, forests, and native habitats, as valued assets that benefit people by cleansing urban runoff; replenishing aquifers; absorbing floodwaters; scrubbing airborne pollutants; sequestering carbon; moderating microclimates; sheltering wildlife; supporting mobility, food, fiber, and water production, economic productivity, recreation, public health, cultural identity, and community cohesion; and helping maintain the natural cycling of water for water resource sustainability and resilience to help mitigate and adapt to the impacts of climate change, including increased heat, drought, flooding, and sea level rise.
- ***Strategic location*** – encourage infill development that is within or directly connected to existing communities. Support the "recycling" of developed land through revitalization.
- ***Compact design*** – support compact community form in the design of buildings, neighborhoods, and the community.
- ***Mixed use development*** – Mix appropriate land uses (horizontally and vertically) and development types to support compact community form, increased density, and reduced travel distances and automobile dependency.
- ***Transportation network and street design*** – Support interconnected transportation networks with complete street designs that encourage all types of mobility, support the needs of all types of users, increases safety, and incorporates natural drainage practices.
- Water Friendly Landscape – Design all aspects of landscaping from the selection of plants to soil preparation, and the installation of irrigation systems and fertilizer use to reduce water demand, retain runoff, decrease flooding, and recharge groundwater.

These elements and strategies are interdependent and mutually reinforcing. In combination, they shape land use patterns and community forms that support water resource protection and watershed health at all scales of community development.

Some nonstructural practices for fitting the project to the site include the following (Carhill 2012):

- Lot configuration and clustering
    - Reduce lot size
    - Concentrate/cluster lots
    - Configure lots to avoid or protect green infrastructure and natural drainage ways
    - Configure lots to fit topography and avoid earthwork
- Minimize disturbance and maintenance
    - Define and limit disturbance zones
    - Protect green infrastructure and natural drainage ways
    - Minimize earthwork, cut, and fill
    - Minimize soil compaction
    - Reforest and revegetate
- Reduce and minimize impervious cover
    - Reduce road widths

- Reduce cul-de-sac diameter and open center
    - Reduce parking
    - Reduce parking footprint by going vertical
    - Share parking between uses
    - Use porous pavements
    - Design single sidewalks; use porous pavements
    - Reduce building footprint by going vertical
    - Place structures to maximize infiltration systems
- Disconnect, distribute, decentralize
    - Disconnect roof downspouts from impervious surfaces
    - Disconnect directly connected impervious areas from surface waters
    - Use rain barrels, cisterns, swales, and rain gardens
    - Design stormwater conveyance elements that infiltrate
- Source control
    - Street sweeping
    - Lawn chemical application avoided, minimized with native vegetation
    - Irrigation only with captured runoff and minimized with drought tolerant native vegetation

You can use the following checklist, incorporating these objectives, strategies and practices as a guide for better site design (Singleton 2015). The first goal of the checklist is to minimize stormwater runoff. The second goal is to mitigate any stormwater runoff generated by the project.

1. Minimize stormwater runoff
    - **Use hydrology as the integrating framework**
        - Reproduce predevelopment hydrology (peak discharge and volume);
        - Create a multifunctional landscape that incorporates stormwater features into the landscape; and
        - Use surface water elements as focal civic spaces.
    - **Preserve and emulate natural drainage**
        - Utilize existing flow paths;
        - Fit development to the terrain; and
        - Restore the drainage and/or biological capacity of damaged or lost soils through mechanical improvements or soil amendments.
    - **Protect site characteristics**
        - Incorporate smaller lot sizes to minimize total impervious area;
        - Confine construction and development to least critical/sensitive areas;
        - Preserve open space and natural areas, including floodplains, wetlands, lakes;
        - Reduce limits of clearing and grading;
        - Stage construction to limit the area of exposure on the site at any one time; and
        - Minimize soil compaction.
    - **Assess impervious surfaces**
        - Reduce;
        - Minimize; and
        - Disconnect.
2. Mitigate stormwater runoff
    - **Micromanage**

- Control runoff at the source;
  - Minimize runoff by maximizing infiltration, evapotranspiration, and filtration; and
  - Employ natural processes for water quality improvement.
- **Design and link stormwater controls as an integrated system**
  - Utilize simplistic, non-structural methods; and
  - Use redundant runoff treatment systems.

Once the project is designed, you are ready to add it to your GIS project and map the "protected" Green Infrastructure (undisturbed and undeveloped areas) and map and calculate the area of the project requiring stormwater management and areas for siting LID practices.

Step 3: Selecting LID Practices

In this step, you will use the **Scenario Analysis Tool** in G2G, and the potential areas for siting LID practices identified in Step 2, to select and evaluate multiple combinations of LID practices. G2G will walk you through the selection of **low impact development (LID) practices** to capture 100 percent of the runoff from a selected rainfall event, first, from roof areas, then paved areas and, lastly, the land (pervious areas), as part of one continuous and strategically designed treatment train as follows:

- Select practices to slow, spread, and infiltrate rain water;
- Plan for overflow routes and manage that overflow as a resource;
- Maximize vegetation and organic groundcover, including trees, to create a living sponge that increases infiltration and reduces evaporation, runoff, and erosion;
- Stack functions to maximize beneficial relationships and efficiency; and
- Devise strategies that solve one problem that simultaneously solves many other problems and create resources.

The Scenario Analysis Tool is Excel-based and allows the user to estimate the water storage and treatment capacity of potential LID practices. It can be used with or without the **Mapping Tool**.

Chapter 8: Using the Scenario Analysis Tool

In this chapter, we cover using the Excel-based Scenario Analysis Tool to select LID practices. The goal is to capture 100 percent of stormwater from a selected rainfall event. The **Analysis Tool** guides the user through three multiple zones, moving from the impervious roof areas to the impervious paved areas surrounding the building, and finally to the pervious land surrounding the site (Fig. 8.1).

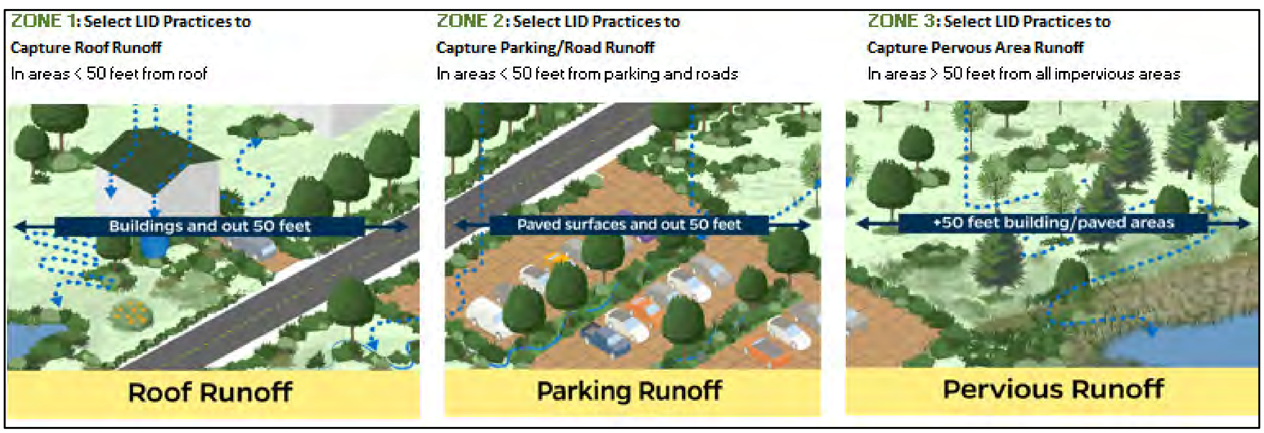


Figure 8.1. The different spatial zones explored using G2G Scenario Analysis Tool.

You begin by opening the tool in Excel (Fig. 8.2). From this page (Start page), you can review the Introduction to the tool, access this User Guide, and other Training Materials and Documentation, including video tutorials. You press the **Start** button to start the tool. This opens the **SETUP** page (Fig. 8.3), where you:

- Input the **Project Name** and **Location**
- **Select a Storm** (2-year, 10-year, 25-year, 50-year, or 100-year, 24-hour design storms; design storm for runoff volume and load calculations)
- Input **GIS Outcome** data from the GIS Mapping Tool
- Access information used in the tool regarding the:
    - **Volume and Load calculations**
    - **LID Practice Performance**
    - **Lookup Tables**

*Figure 8.2. **Start** page of G2G Scenario Analysis Tool.*

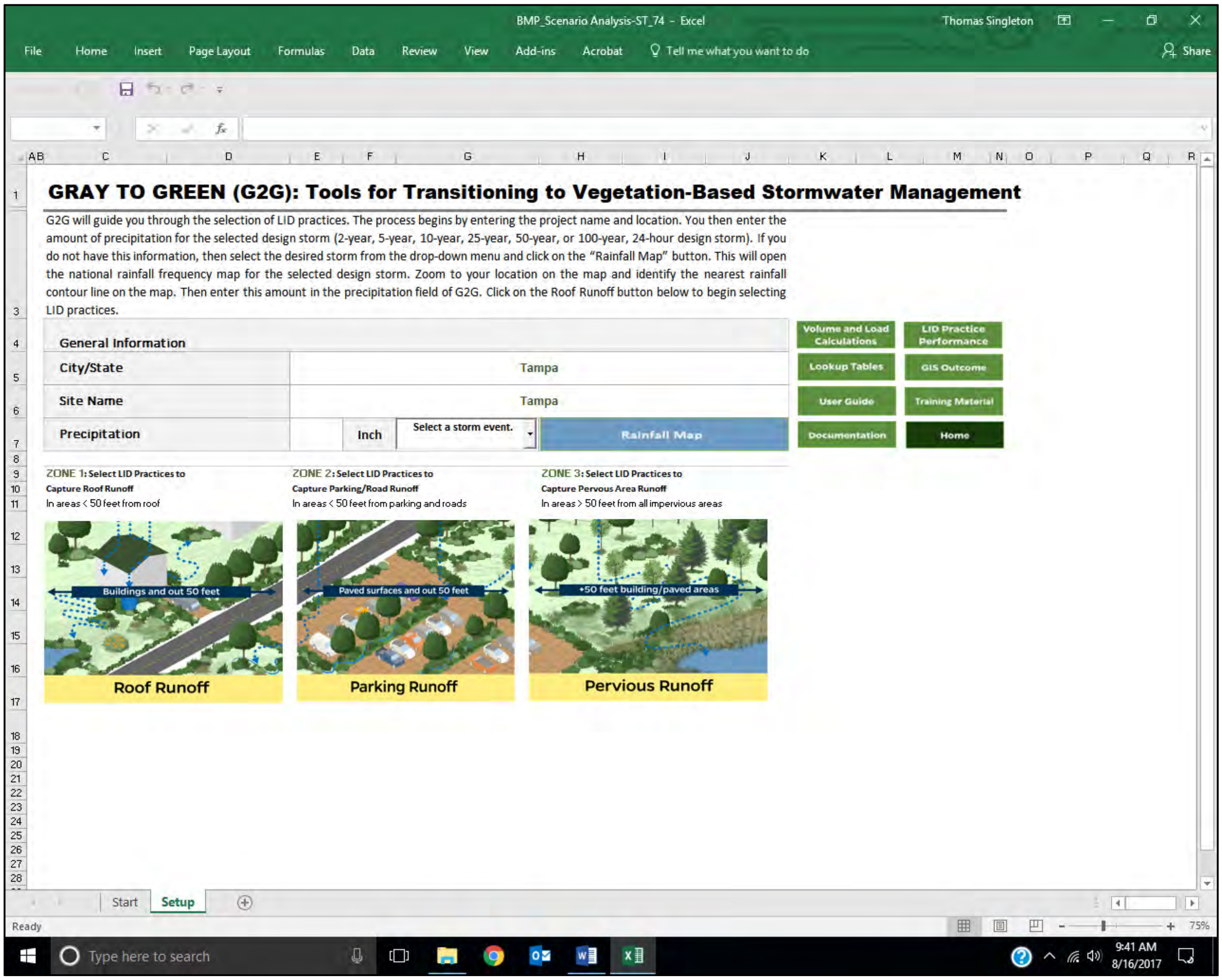


Figure 8.3. ***Setup*** *page of G2G Scenario Analysis Tool. This is the first step in entering information into the tool.*

Select a storm event

Setup, is where you select the desired design storm (2-year, 10-year, 25-year, 50-year, or 100-year, 24-hour design storms) from the drop-down menu and input the amount of rainfall in inches (Fig 8.4). If you do not know the amount of rainfall for your area, you can click on the **Rainfall Map** button. A rainfall frequency map will open up (Fig. 8.5). The map shows contour lines at intervals of 0.5 inches. Use the zoom buttons to zoom in on your location. Then find the line closest to your location or, if you are in between two lines, take the average of two lines (Fig. 8.6). This is the amount of rainfall you will enter into the tool. If you forget to select the desired storm event prior to clicking on the **Rainfall Map**, a new message window will open, asking you to close the window and select a storm event, first (Fig. 8.6). Once you enter the desired storm event, the selected rainfal map will open when you click on the **Rainfall Map** button.

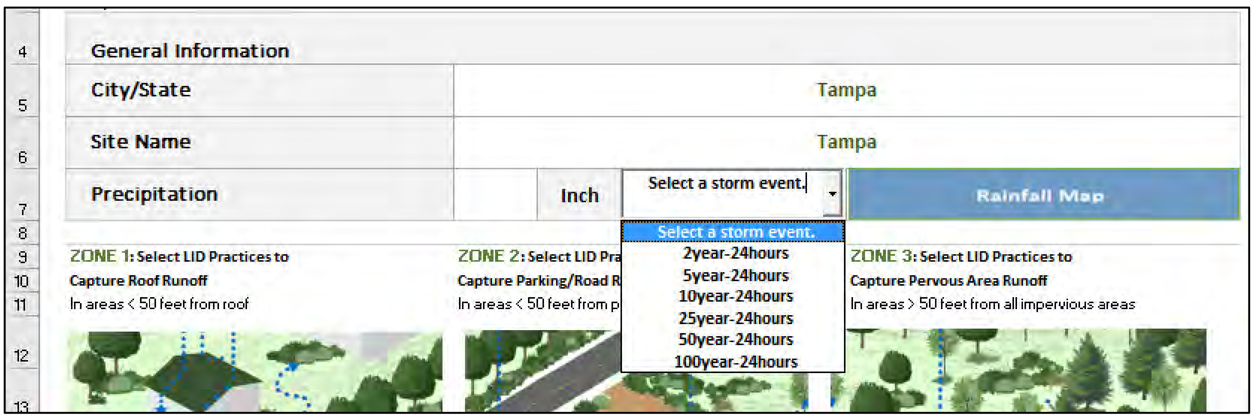


*Figure 8.4. **Setup** page of G2G Scenario Analysis Tool.*

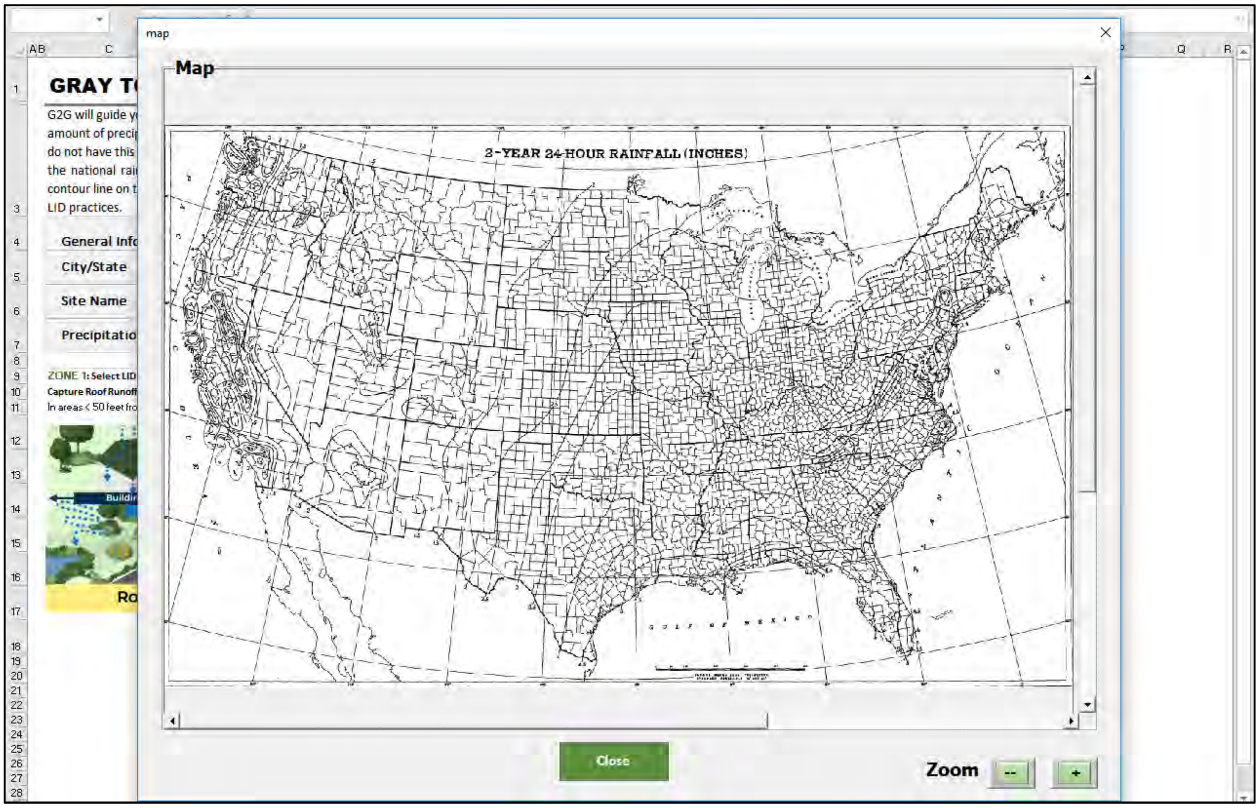


Figure 8.5. Rainfall map for 2-year, 24-hour storm. Use the zoom button to zoom in on your location to get the amount of rainfall for your site.

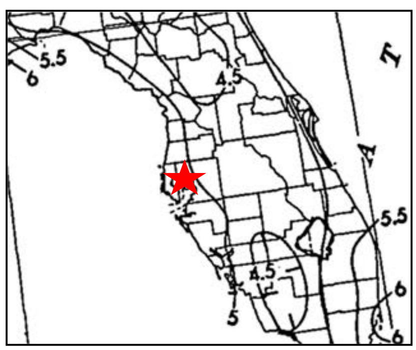


Figure 8.6. Rainfall frequency map for 2-year, 24-hour storm zoomed in to show Tampa (star) closest to 5 inches of rain.

TIP: Regulations may require you to manage the volumes and loads for a 2-year, 24-hour, but you may want to evaluate larger design storms once you see how well the LID practices perform.

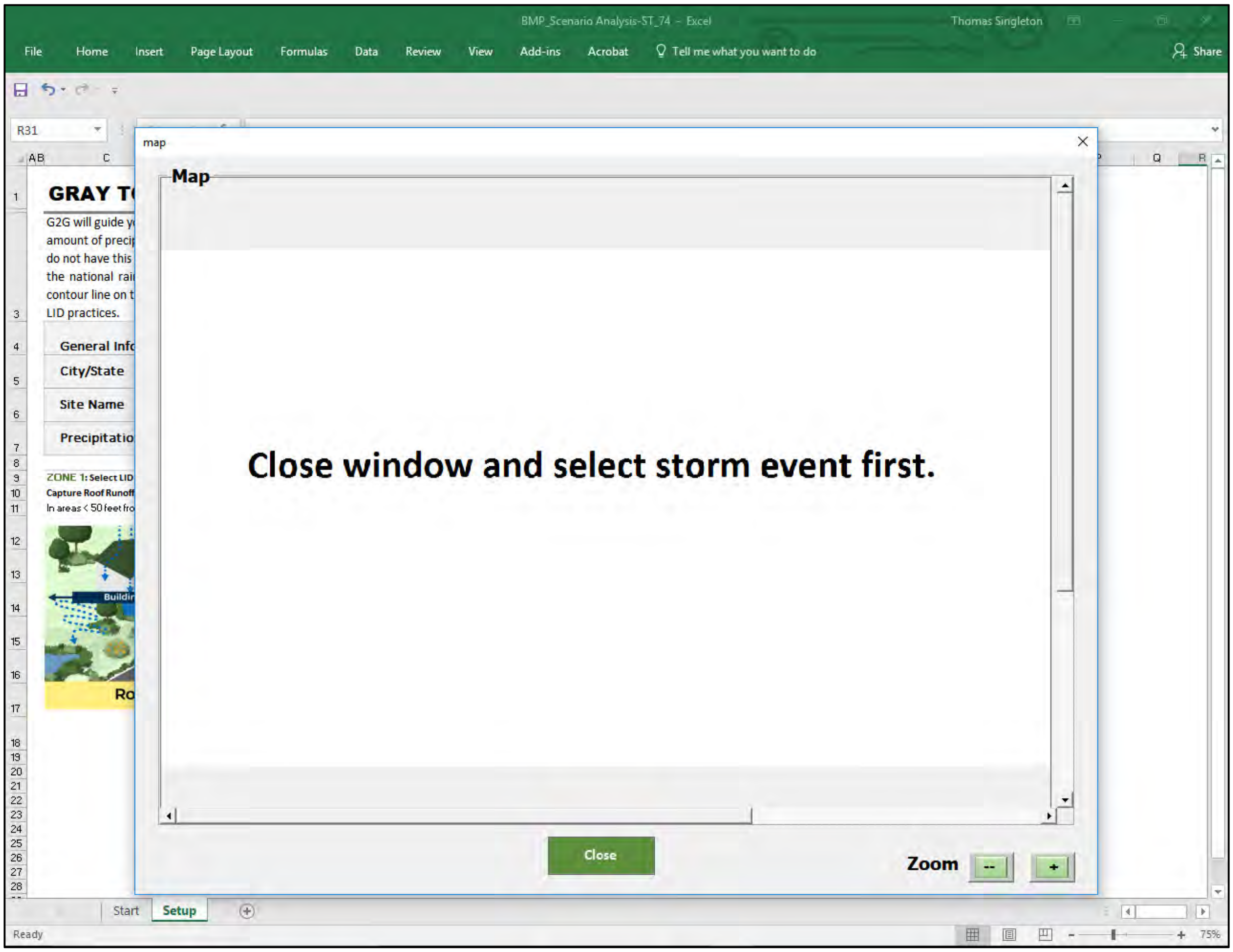


Figure 8.7. If you forget to select a design storm, a new message window will open, asking you to close the window and select a storm event.

Input data

How do I input my GIS data from Step 1 in the Scenario Analysis Tool?

To input your GIS data from Step 1, click the **GIS Outcome** button on the **Setup** page (Fig. 8.8). A spreadsheet will open, along with a message window providing instructions on how to enter your data. As noted in the instructions, you can either manually input the numbers in the table or use the **Upload** button (Fig. 8.9).

Figure 8.8. Click the GIS Outcome Button to enter your GIS data.

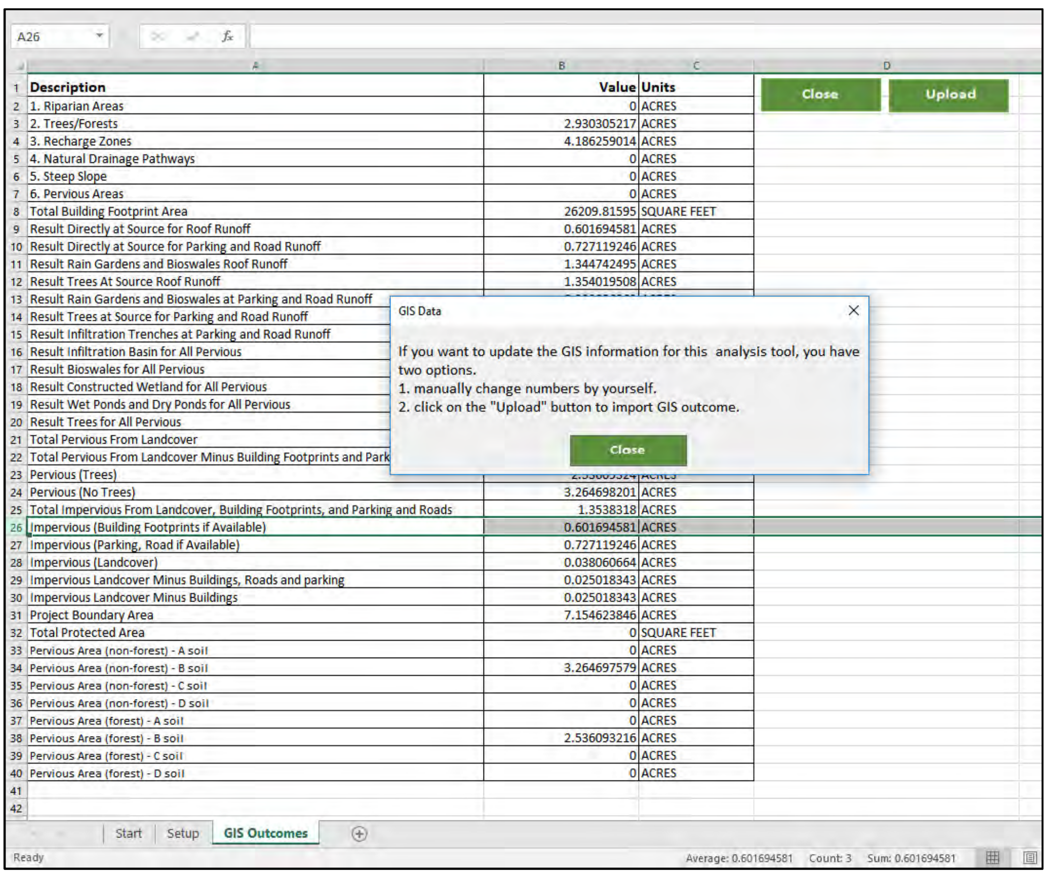


Figure 8.9. GIS Outcome page with instructions for inputting data.

If you want to use the Upload button to load your GIS data, then close the message window and click on the **Upload** button (Fig. 8.10). This will open search file function on your computer. From there, you can browse the files on your computer to locate the data. Then select the desired file and click the Open button to upload the file. Once the upload is complete, a message window will open letting you know that the upload has finished (Fig. 8.11). Close the message window and the **GIS Outcome** page to return to the **Setup** page.

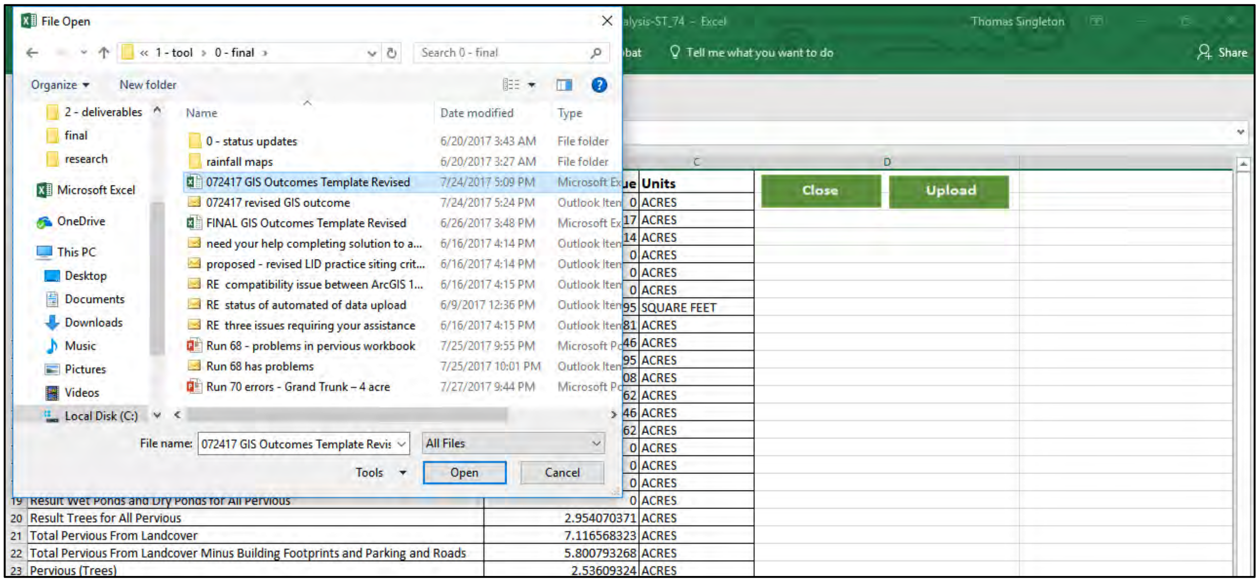


Figure 8.10. Clicking the Upload button will open the browser on your computer so that you can locate your GIS data file.

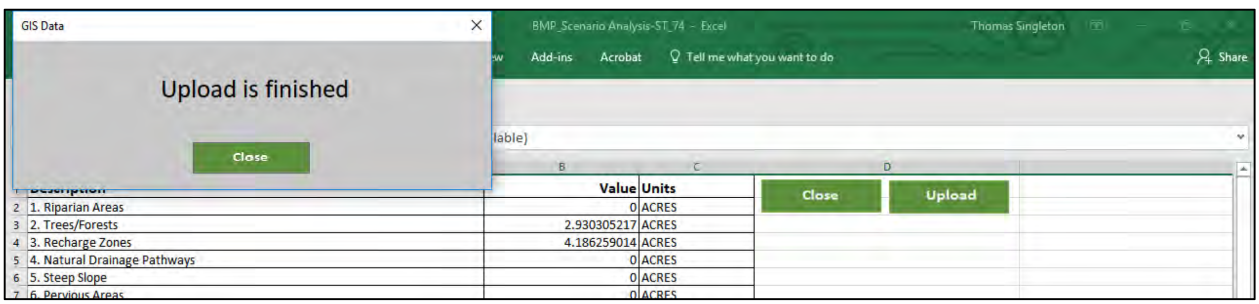


Figure 8.11. When the GIS data upload is complete.

Formulas and assumptions used in runoff volume and load calculations

Before we begin using to Scenario Analysis Tool to select LID practices, we will review the formulas and assumptions used in the **Volume and Load Calculations** and associated **Lookup Tables** and **LID Practice Performance** calculations. You can get this information by clicking the green buttons located to the right of the **Setup** page (Fig. 8.12).

Figure 8.12. Buttons on the Setup page which provide supplemental help and information.

Once you are finished viewing one of the tabs opened by a button, click **Close** to exit and close the tab.

Volume and Load Calculations and Lookup Tables

Click the **Volume and Load Calculations** button to reveal the curve numbers (CN) and formulas used to calculate the runoff volume and loads (Fig. 8.13). The methodology and CN for pervious (forest and non-forest) and impervious areas are taken from *Urban hydrology for small watersheds* (USDA Soil Conservation Science 1986).

Click the **Lookup Tables** to get the CN and event mean concentrations**Error! Bookmark not defined.** (EMC) used to calculate pollutant loads for pervious (forest, fertilized plantings, and native vegetation) and impervious areas (rooftops and parking lots) (Fig. 8.14). The EMC are taken from *Low Impact Development and Sustainable Stormwater Management* (Carhill 2012).

TIP: You can edit the CN and EMC in the **Lookup Tables** using locally derived values. You can restore the default values by clicking the **Default** button (Fig 8.14).

Runoff Volume and Pollutant Load Calulations

Close

Calculation of Weighted Average Curve Number (CNtotal)

Land-use Category	Area (Acre)	CN	Area*CN	CNtotal
Pervious Area (non-forest) - A soil	0.00	49	0.00	69
Pervious Area (non-forest) - B soil	3.26	69	225.26	
Pervious Area (non-forest) - C soil	0.00	79	0.00	
Pervious Area (non-forest) - D soil	0.00	84	0.00	
Pervious Area (forest) - A soil	0.00	30	0.00	55
Pervious Area (forest) - B soil	2.54	55	139.49	
Pervious Area (forest) - C soil	0.00	70	0.00	
Pervious Area (forest) - D soil	0.00	77	0.00	
Impervious (Roof)	0.60	98	58.97	98
Impervious (parking/Road)	0.75	98	73.71	98

Calculation of Runoff Volume

Land-use Category	Area (Acre)	CN	S	Ia	Runoff Volume (ft3)
			(1000/CN)-10	0.20*S	Q=A*((P-Ia)^2)/(P-Ia+S)
Pervious Area (non-forest/ fertilized)	3.26	69	4.49	0.90	0.06
Pervious Area (forest)	2.54	55	8.18	1.64	0.09
Impervious (Roof)	0.60	98	0.20	0.04	0.00
Impervious (parking/Road)	0.75	98	0.20	0.04	0.00
Open water					
Total Runoff Volume					**0**

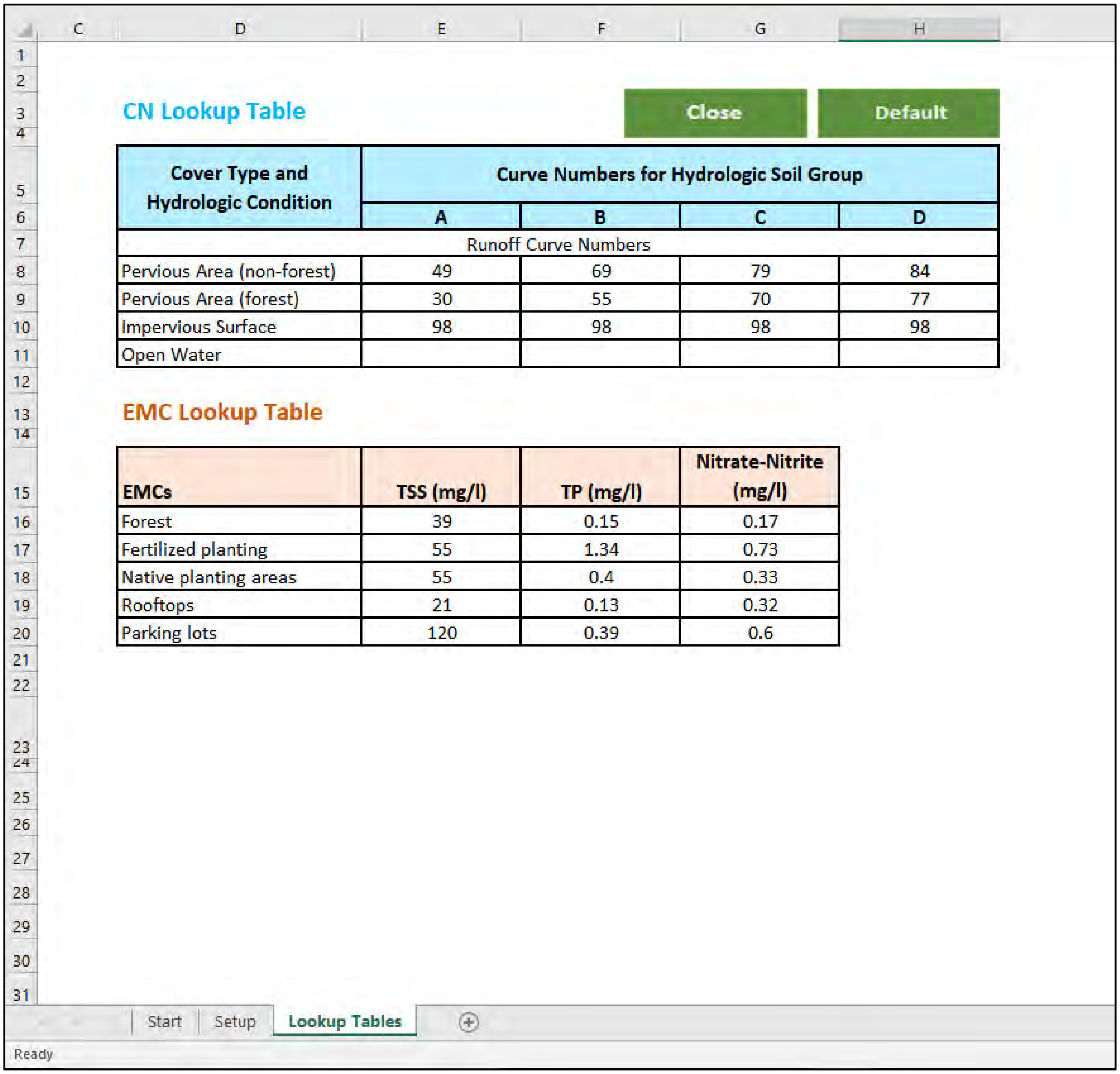
Calculation of Pollutant Load

Land-use Category	Runoff Volume (ft3)	Pollutant Load= q*EMC		
		TSS (LB)	TP (LB)	Nitrate-Nitrite (LB)
Pervious Area (non-forest/ fertilized)	2662	9	0.2	0.1
Pervious Area (forest)	3766	9	0.0	0.0
Impervious (Roof)	22	0	0.0	0.0
Impervious (Parking/Road)	28	0	0.0	0.0
Total Pollutant load		**19**	**0.26**	**0.2**

Start | Setup | Volume and Load Calculations

Ready

Figure 8.13. Methodology and curve numbers for pervious (forest and non-forest) and impervious areas taken from Urban Hydrology for Small Watersheds (*USDA Soil Conservation Science 1986).*



CN Lookup Table

Cover Type and Hydrologic Condition	Curve Numbers for Hydrologic Soil Group			
	A	B	C	D
Runoff Curve Numbers				
Pervious Area (non-forest)	49	69	79	84
Pervious Area (forest)	30	55	70	77
Impervious Surface	98	98	98	98
Open Water				

EMC Lookup Table

EMCs	TSS (mg/l)	TP (mg/l)	Nitrate-Nitrite (mg/l)
Forest	39	0.15	0.17
Fertilized planting	55	1.34	0.73
Native planting areas	55	0.4	0.33
Rooftops	21	0.13	0.32
Parking lots	120	0.39	0.6

Figure 8.14. Event mean concentrations (EMC) used to calculate pollutant loads taken from Low Impact Development and Sustainable Stormwater Management *(Carhill 2012).*

LID Practice Performance

Click the **LID Practice Performance** button on the **Setup** page to reveal the EMC and removal efficiencies for LID practices receiving runoff from roofs, parking/roads, and pervious areas, respectively (Fig. 8.15 and 8.16). These values, derived from the International Stormwater Database (2017), are used to calculate the runoff volume and load reductions associated with each LID practice.

Figure 8.15. Buttons on the Setup page which provide supplemental help and information.

TIP: You can edit the EMC for the LID practices using locally derived values. You can restore the default values by clicking the **Default** button (Fig 8.16).

Close Default

Roof Runoff EMC and BMP Removal Efficency

LID Practice	EMC (mg/L)			Removal Efficiency (%)		
	TSS	TP	Nitrate	TSS	TP	Nitrate
Green Roof	21	0.13	0.32	85	85	30
Rainwater Harvesting	21	0.13	0.32	100	100	100
Rain Garden	21	0.13	0.32	85	85	30
Bioswale	21	0.13	0.32	85	85	30
Tree Planting	21	0.13	0.32	85	85	30

Parking/Road Runoff EMC and BMP Removal Efficency

LID Practice	EMC (mg/L)			Removal Efficiency (%)		
	TSS	TP	Nitrate	TSS	TP	Nitrate
Pervious Pavement	120	0.39	0.6	85	85	30
Bioswale	120	0.39	0.6	85	85	30
Rain Garden	120	0.39	0.6	85	85	30
Infiltration Trench	120	0.39	0.6	85	85	30
Tree Planting	120	0.39	0.6	85	85	30

Pervious Runoff EMC and BMP Removal Efficency

LID Practice	EMC (mg/L)			Removal Efficiency (%)		
	TSS	TP	Nitrate	TSS	TP	Nitrate
Infiltration Basin	55	1.34	0.73	85	85	30
Constructed wetland	55	1.34	0.73	85	85	30
Bioswale	55	1.34	0.73	85	85	30
Tree Planting	55	1.34	0.73	85	85	30
Wet Pond	55	1.34	0.73	75	50	50
Dry Pond	55	1.34	0.73	66	22	14

Start | Setup | EMC & BMP Removal Efficiency

Ready

Figure 8.16. EMC and removal efficiencies for LID practices receiving runoff from roofs, parking/roads, and pervious areas, respectively. These values are derived from the International Stormwater Database (2016).

Select LID practices

How do I select LID practices using the Analysis Tool?

Once you have entered the site information, amount of precipitation, and selected the design storm, you can begin selecting LID practices. First, click the **Roof Runoff** button (Fig. 8.17). This will open a new tab called **Roof Runoff** which contains features that allow you to select LID practices while calculating the runoff volume and pollutant load reductions (Fig. 8.18).

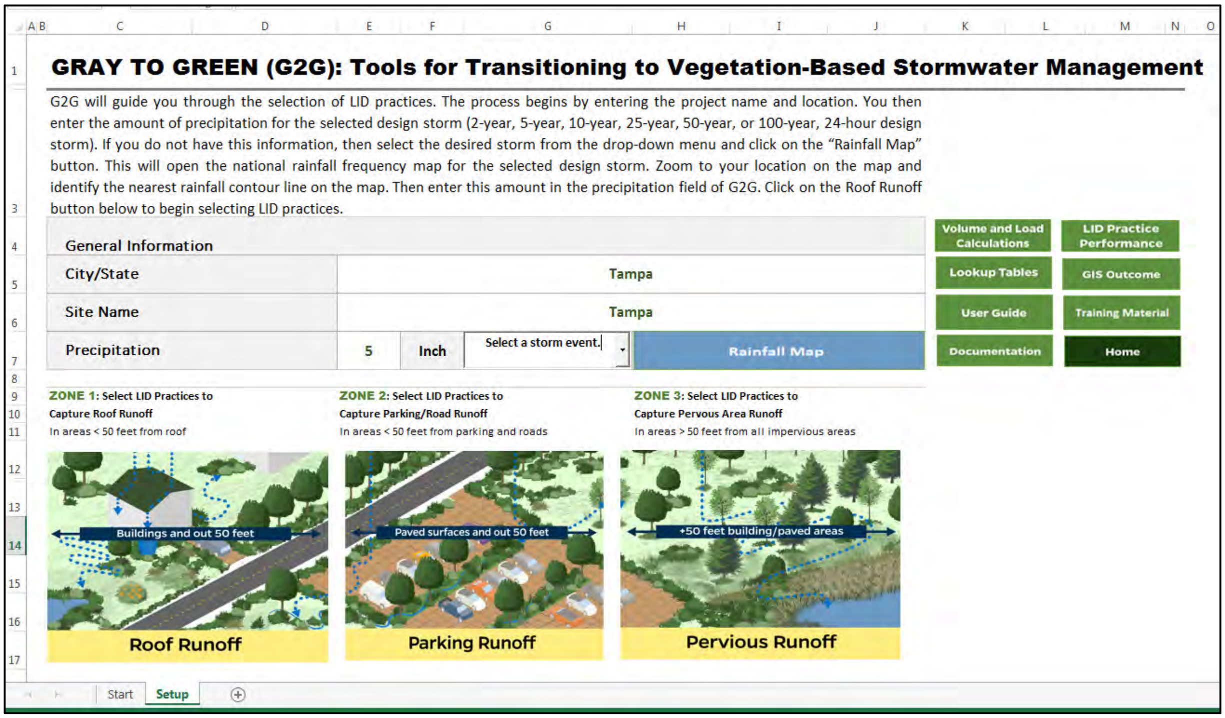


Figure 8.17. The buttons on the Setup tab that will take you to the different zones for selecting LID practices. Always start with roof runoff, followed by parking runoff, and then pervious runoff.

TIPS: In selecting LID practices:

- Start at the beginning, where water falls on the roof, then on other impervious areas, and finally on the land
- Pick practices to slow, spread, and infiltrate rainwater
- Plan for overflow routes and manage overflow as a resource
- Maximize vegetation and organic groundcover, including trees, to create a living “sponge” that increases infiltration and reduces evaporation, runoff, and erosion
- Maximize efficiency and benefits by paying attention to how LID practices complement each other

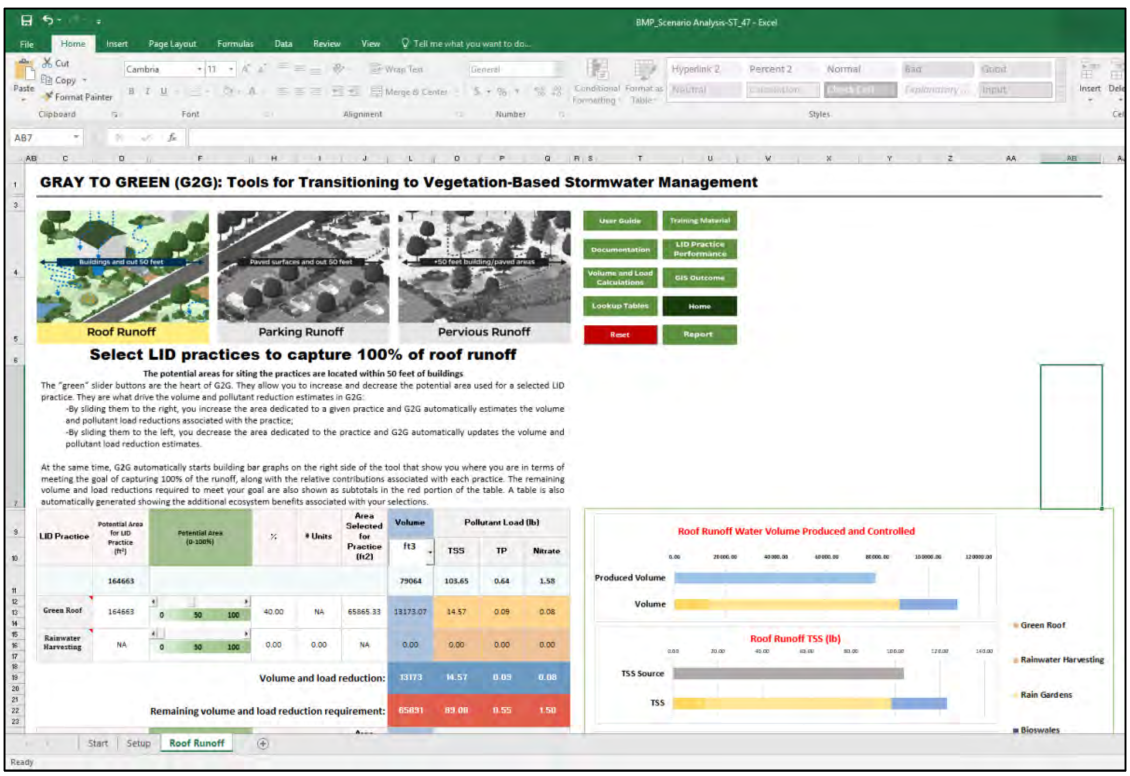


Figure 8.18. The Roof Runoff tab where you can select different LID practices and see the resulting changes in managed water volume and pollutant loads.

The new tab contains tables on the left for calculating runoff volume and pollutant load reductions for different LID practices. The first half of the table is for LID practices that are installed directly at the source, in this case the roof. The second half of the table is for LID practices that are installed within 10 to 50 feet from the buildings. To learn more about the different LID practices, you can hover over the cell to see a quick description, or you can click on the name of the practice for a full definition and description of benefits (Fig. 8.19). The columns in these tables are:

- **LID Practice:** These are the green infrastructure BMPs you can choose from.
- **Potential Area for LID Practice (ft^2):** This is the potential area within your site where you can place certain LID practices. This is based on either the siting information outputs from mapping your green infrastructure and impervious areas in GIS or from your own estimates entered manually into the Scenario Analysis Tool.
- **Potential Area (0-100%):** These are sliding bars that allow you to increase or decrease the percent of the potential area dedicated to certain LID practices. Sliding the bar will automatically change the results in the **Volume** and **Pollutant Load** columns.
- **%:** This displays the percentage of potential area you've selected using the sliding bar described above.
- **# Units:** The approximate amount of a certain LID practice that corresponds to the percentage selected.
- **Area Selected for Practice (ft^2):** The area used by a certain LID practice based on the percentage selected.
- **Volume (acre-ft or ft^3):** The volume of rainwater collected by the LID practice based on the percentage selected. You can change the unit using the drop-down menu at the top of the table. The default units are acre-ft. The value in the cell immediately below the dropdown menu is the total volume of water that must be controlled.
- **Pollutant Load (lb):** This is the amount of pollutant load reduction in pounds for each LID practice based on the percentage area selected. It is broken down into the following categories:
    - **TSS:** Total Suspended Solids, which is the dry weight of particles obtained when filtering water.
    - **TP:** Total Phosphorus in stormwater.
    - **Nitrate:** Total Nitrate in stormwater.

  The values in the three cells immediately below the three pollutants types are the pollutant loads generated by your project for the selected storm event which must be controlled.

Figure 8.19. The descriptions for different LID practices that can be found by hovering over or clicking on a practice name.

Work through different LID practices to try and capture 100% of the roof runoff in areas up to 50 feet from buildings. The slider bars allow you to increase and decrease the potential area used for a selected LID practice. They are what drive the volume and pollutant reduction estimates in the tool. As you move the slider buttons, the tool automatically updates bar graphs on the right side of the tool which show you the amount of the runoff and pollutant loading from your project, along with the relative volume and pollutant load reductions associated with each practice (Fig. 8.20). The remaining volume and load reductions required to meet your goal are also shown as subtotals in the portion of the table shown in red (Fig. 8.21). A measles chart is also automatically generated showing the additional ecosystem benefits associated with your selections (Fig. 8.22).

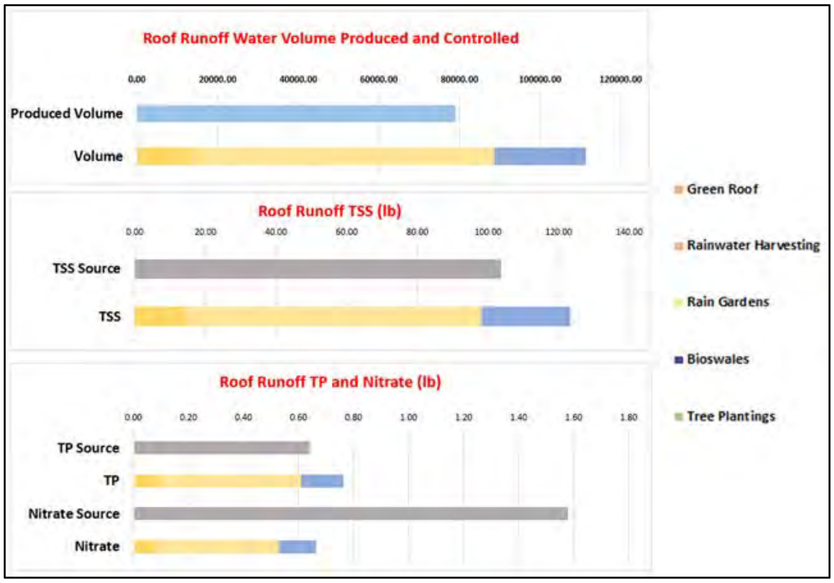


Figure 8.20. Graphs showing total volume of water produced by rainfall event, as well as the volume and pollutant loads managed by selected LID practices.

NOTE: Some LID practices are "mutually exclusive," i.e., their selection will automatically reduce the area available for siting other practices, as follows:

- **Roof Runoff:** The potential areas for Rain Gardens and Bioswales are mutually exclusive. If you slide the slider toolbar for Rain Gardens to the right, the area dedicated to Bioswales will automatically decrease.
- **Parking Runoff:** The potential areas for Bioswales, Rain Gardens and Infiltration Trenches are mutually exclusive. If you slide the slider toolbar for Bioswales to the right, the area dedicated to Rain Gardens and Infiltration Trenches will automatically decrease.
- **Parking Runoff:** The potential areas for Infiltration Basins and Bioswales are mutually exclusive. If you slide the slider toolbar for Infiltration Basins to the right, the area dedicated to Bioswales will automatically decrease. The same is true for Wet Ponds and Dry

LID Practice	Potential Area for LID Practice (ft^2)	Potential Area (0-100%)	%	# Units	Area Selected for Practice (ft2)	Volume	Pollutant Load (lb)		
						ft3	TSS	TP	Nitrate
	164663					79064	103.65	0.64	1.58
Green Roof	164663	0 50 100	40.00	NA	65865.33	13173.07	14.57	0.09	0.08
Rainwater Harvesting	NA	0 50 100	0.00	0.00	NA	0.00	0.00	0.00	0.00
					Volume and load reduction:	13173	14.57	0.09	0.08
					Remaining volume and load reduction requirement:	65891	89.08	0.55	1.50

LID Practice	Potential Area for LID Practice (ft^2)	Potential Area (0-100%)	%	# Units	Area Selected for Practice (ft^2)	Volume	Pollutant Load (lb)		
						(ft3)	TSS	TP	Nitrate
	171799								
Rain Gardens	171799	0 50 100	20.00	3.94	34359.77	75591.50	83.63	0.52	0.45
Bioswales	137439	0 50 100	50.00	85.90	68719.54	22677.45	25.09	0.16	0.13
Tree Plantings	171799	0 50 100	0.00	0.00	0.00	0.00	0.00	0.00	0.00
					Volume and load reduction:	98269	108.73	0.67	0.58
					Remaining volume and load reduction requirement:	-32378	-19.65	-0.12	0.92

Figure 8.21. The red highlighted portion of the LID tables shows the remaining volume and load reduction requirements for your project and updates automatically as you adjust LID areas using the slider bars.

LID Practice	Volume Controlled	Ecosystem Benefits					
		Water Management	Energy Usage	Air Quality and Co2	Urban Heat Island	Habitat and Greenspace	Social Benefits
Green Roof	16.66%	•	•	•	•	•	
Rainwater Harvest	0.00%						
Rain Gardens	95.61%	•	•	•	•	•	•
Bioswales	28.68%	•		•	•		
Tree Plantings	0.00%						

Figure 8.22. Chart depicted the different ecosystem benefits achieved by the LID practices selected. The volume of stormwater controlled by the LID practices is also shown in the column next to the practice name.

Once the table shows you have captured 100% of the **Roof Runoff**, then click **Parking Runoff** to select LID practices for capturing runoff in parking areas and roads within one to 50 feet of the paved areas. The first half of the table includes practices that can be applied directly at the source (the paved areas), while the second half of the table is for those practices that can be installed 1 to 50 feet from parking and roads

Finally, once the table shows that you have captured 100% of the **Parking Runoff**, then click **Pervious Runoff** and follow the same steps for selecting LID practices. On this tab, the table includes practices that can be used more than 50 feet from impervious surfaces and more than 1 foot from riparian areas that include a buffer of 100 feet. Click the red **Reset** button in the upper right-hand side of the runoff sheet if you want to clear the changes you've made (Fig. 8.23).

Figure 8.23. The red Reset button clears changes made to the LID practice tables.

Saving and reporting results

How do I save the results of my analysis and prepare a report?

Once you have captured the maximum amount of stormwater runoff and are content with your selection of LID practices, you will need to save your results by creating a report. To create a report, click on the **Report** button in the upper right-hand portion of the sheet next to the red **Reset** button (Fig. 8.18.). This will open up a report with the results of your analysis. You will want to name and save this document to your computer. The report includes the tables and charts shown in Tables 8.1 and 8.2 which summarize the volume and load reductions associated with your selections. You will need to create and save a report for each design storm and set of LID practices you evaluate.

CAUTION: Be sure you create and save a report to your computer for each design storm and set of LID practices you evaluate. You can then compare the results of these evaluations, as illustrated in the case studies in Appendices A and B of this guide.

Table 8.1. Scenario analysis for 2-year, 24-hour design storm (5.0 inches of rain) showing that 100% of the roof and parking and road runoff can be captured using LID practices. LID practices can also capture 61% of the pervious runoff.

	2-year, 24-hour Design Storm (5.0 inches of rain)				
Runoff Area / LID Practice	**Runoff Generated (acre-feet)**	**Potential Area Available for Practice (ft2)**	**% of Potential Area Selected for Practice (%)**	**Runoff Captured (acre-feet)**	**Runoff Captured (%)**
Roof Runoff buildings and out 50 ft	1.5 acre-feet				
Rain Garden		199,128	15%	1.5	100%
Trees		253,035	100%	0.48	32%
Parking Runoff paved areas and out 50 ft	4.8 acre-feet				
Pervious Paving		149,139	34%	1.4	29%
Rain Garden		67,054	100%	3.39	71%
Trees		68,442	100%	0.13	3%
Pervious Runoff +50 ft building/paved areas	3.46 acre-feet				
Constructed Wetland		29,515	100%	1.36	39%
Bioswale		27,235	100%	.63	18%
Trees		29,580	100%	.14	4%

Table 8.2. Scenario analysis for 25-year, 24-hour design storm (9.5 inches of rain) showing that 100% of the roof runoff can be captured using LID practices. LID practices can also capture 81% of the parking and road runoff and 20% of the pervious runoff. This additional capacity would increase the flood level of service to the neighborhood.

	25-year, 24-hour Design Storm (9.5 inches of rain)				
Runoff Area / LID Practice	**Runoff Generated (acre-feet)**	**Potential Area Available for Practice (ft2)**	**% of Potential Area Selected for Practice (%)**	**Runoff Captured (acre-feet)**	**Runoff Captured (%)**
Roof Runoff buildings and out 50 ft	2.92 acre-feet				
Rain Garden		199,128	29%	2.92	100%
Trees		253,035	100%	0.48	32%
Parking Runoff paved areas and out 50 ft	9.33 acre-feet				
Pervious Paving		149,139	100%	4.11	44%
Rain Garden		67,054	100%	3.39	36%
Trees		68,442	100%	0.13	1%
Pervious Runoff +50 ft building/paved areas	10.16 acre-feet				
Constructed Wetland		29,515	100%	1.36	13%
Bioswale		27,235	100%	.63	6%
Trees		29,580	100%	.14	1%

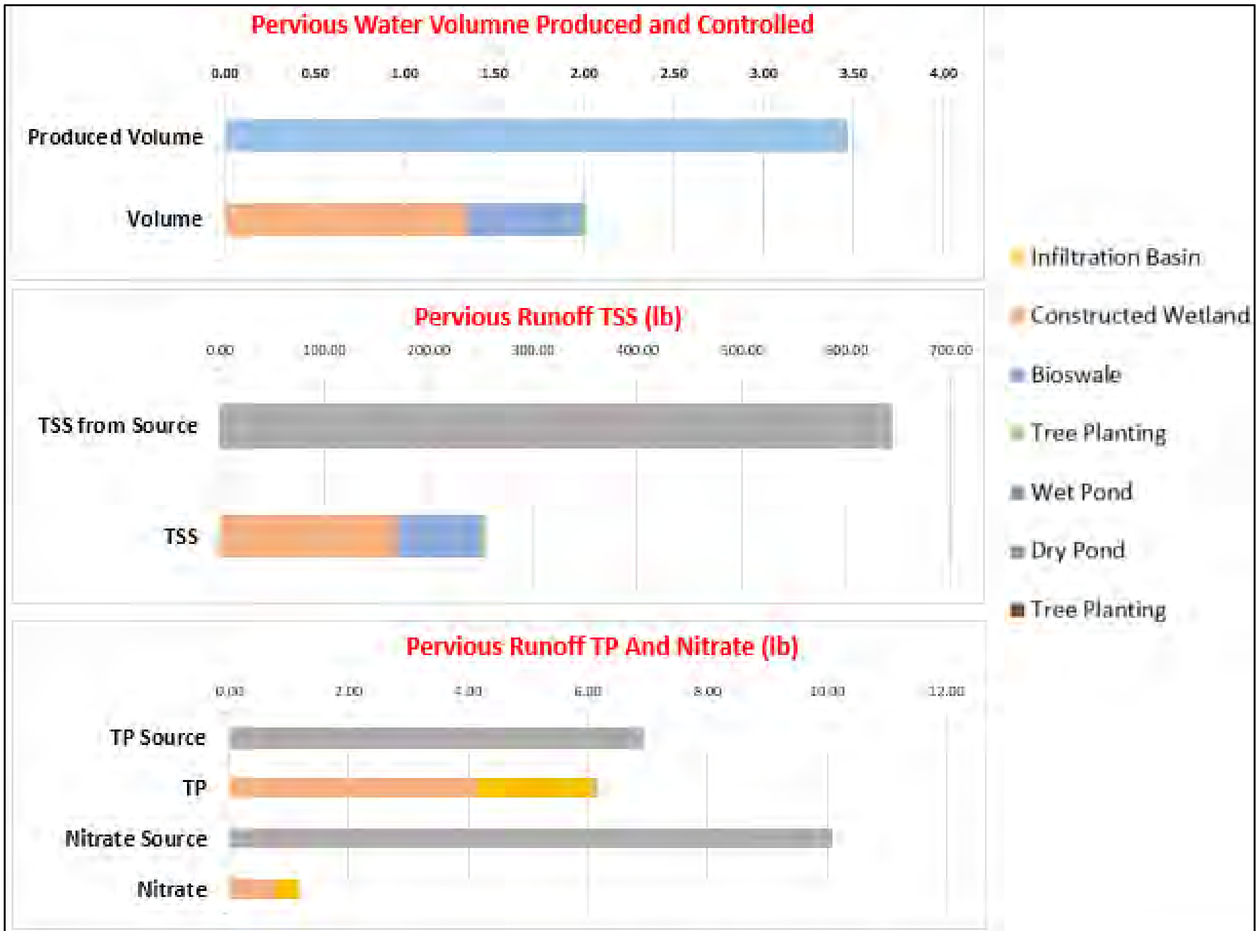
Figures 8.24-8.26, show the water quality and other ecosystem benefits associated with each LID practice for the 2-year, 24-hour design storm (5 inches of rain), starting first with roof runoff (Figure 8.24), then parking and road runoff (Figure 8.25) and, finally, pervious runoff (Figure 8.26).

LID Practice	Volume Controlled	Ecosystem Benefits: Water Management	Energy Usage	Air Quality and Co2	Urban Heat Island	Habitat and Greenspace	Social Benefits
Green Roof	0.00%						
Rainwater Harvest	0.00%						
Rain Garden	100.54%	•	•	•	•	•	•
Bioswale	0.00%						
Tree Planting	32.26%	•	•	•	•	•	•

Figure 8.24. Estimated pollutant load reductions and other ecosystem benefits from roof runoff for selected LID practices for the 2-year, 24-hour design storm.

LID Practice	Volume Controlled	Ecosystem Benefits: Water Management	Energy Usage	Air Quality and Co2	Urban Heat Island	Habitat and Greenspace	Social Benefits
Pervious Pavemen	29.10%	•	•	•	•		
Bioswale	0.00%						
Rain Garden	70.55%	•	•	•	•	•	•
Infiltration Trench	0.00%						
Tree Planting	2.73%	•	•	•	•	•	•

Figure 8.25. Estimated pollutant load reductions and other ecosystem benefits from parking and road runoff for selected LID practices for the 2-year, 24-hour design storm.



LID Practice	Volume Controlled	Ecosystem Benefits					
		Management	Energy Usage	Air Quality and Co2	Urban Heat Island	Hab and Greenspace	Social Benefits
Infiltration Basin	0.00%						
Constructed Wetla	39.12%	•	•	•	•	•	•
Bioswale	18.05%	•	•	•	•		
Tree Planting	0.82%	•	•	•		•	•
Wet Pond	0.00%				•		
Dry Pond	0.00%						
Tree Planting	0.00%						

Figure 8.26. Estimated pollutant load reductions and other ecosystem benefits from pervious runoff for selected LID practices for the 2-year, 24-hour design storm.

Step 4: Evaluating the Project Fit

Chapter 9: A Checklist for Evaluating Project Fit

The following is a checklist you can you use to evaluate the fit of your project to the site:

1. Avoid and minimize stormwater runoff:
   - **Use hydrology as the integrating framework**
     - Reproduce predevelopment hydrology (peak discharge and volume);
     - Create a multifunctional landscape that incorporates stormwater features into the landscape; and
     - Use surface water elements as focal civic spaces.
   - **Preserve and emulate natural drainage**
     - Utilize existing flow paths;
     - Fit development to the terrain; and
     - Restore the drainage and/or biological capacity of damaged or lost soils through mechanical improvements or soil amendments.
   - **Protect site characteristics**
     - Incorporate smaller lot sizes to minimize total impervious area;
     - Confine construction and development to least critical/sensitive areas;
     - Preserve open space and natural areas, including floodplains, wetlands, lakes;
     - Reduce limits of clearing and grading;
     - Stage construction to limit the area of exposure on the site at any one time; and
     - Minimize soil compaction.
   - **Assess impervious surfaces**
     - Reduce;
     - Minimize; and
     - Disconnect.
2. Mitigate stormwater runoff:
   - **Micromanage**
     - Control runoff at the source;
     - Minimize runoff by maximizing infiltration, evapotranspiration, and filtration; and
     - Employ natural processes for water quality improvement.
   - **Design and link stormwater controls as an integrated system**
     - Utilize simplistic, non-structural methods; and
     - Use redundant runoff treatment systems.

If the fit can be improved, modify your design using G2G as a guide and repeat **Step 3**. You will want to evaluate the capacity of the project to manage larger design storms to increase the adaptive and resilient capacities of the project and restore more of the natural water balance on your site. Practice adaptive management by reassessing the performance of your system after the project is completed and, if required, modify your design.

Appendices

Appendix A: Case Study I – Frierson Pond Flooding, Tampa, FL

A stormwater retrofit project to relieve urban flooding

A step-by-step review of a case study in Tampa, Florida, shows users how to setup a project and use G2G. It also illustrates the strategic approach, functions, and utility of G2G in guiding project design.

Background

In this project, the G2G DST was used to evaluate alternatives to expanding an existing stormwater retention pond to relieve acute and chronic flooding in an approximately 31-acre drainage basin with no known outfall, a closed drainage basin (Fig. A-1). The proposed pond expansion, which requires the acquisition and demolition of 12 homes and the closing and demolition of a public road, would increase the flood level of service to something less than a 2-year, 24-hour design storm (approx. 5 inches of rain in 24 hours).

Figure A-1. Photos showing the area of flooding in the Tampa, Florida, case study.

The G2G evaluation in Tampa identified three alternatives to expanding the existing pond:

- **Restore natural drainage pathways** – divert floodwaters to an adjacent dewatered wetland to restore an historic hydrologic connection severed by construction of a road:
    a. The wetland is estimated to have more storage capacity than the expanded pond which would allow storage of runoff for larger storms, i.e., larger than a 2-year, 24-hour storm;
    b. The cost of implementation would include the purchase of a conservation easement or fee simple title to the wetland and several hundred feet of piping.
- **Low impact development (LID) best management practices** – introduced upstream of the flooding area (i.e., the area contributing to the flooding), including rain gardens, bioswales, infiltration basins, infiltration trenches, trees, and constructed wetlands
    a. The LID practices provide more storage capacity than the pond which would allow storage of runoff for larger storms, i.e., larger than a 2-year, 24-hour storm;
    b. The cost of implementation would include the construction of LID practices.

- **Combination of LID practices and restoring natural drainage pathways** – would maximize storage to capture runoff from even larger storms.

G2G Evaluation

After gathering information on the project site and using the GIS-based Siting Tool, we generated a Green Infrastructure Map. We exported the map to a PDF file for analysis and reporting. To begin analysis, we turned off (de-selected) all the data layers in the PDF, then turned on the individual layers one at a time.

The first layers we looked at were the drainage basin (black line) and flooding area (blue polygon) provided by Tampa and the drainage basin (yellow line) and flow lines (blue lines) derived from the digital elevation model (DEM) in G2G (Fig. A-2).

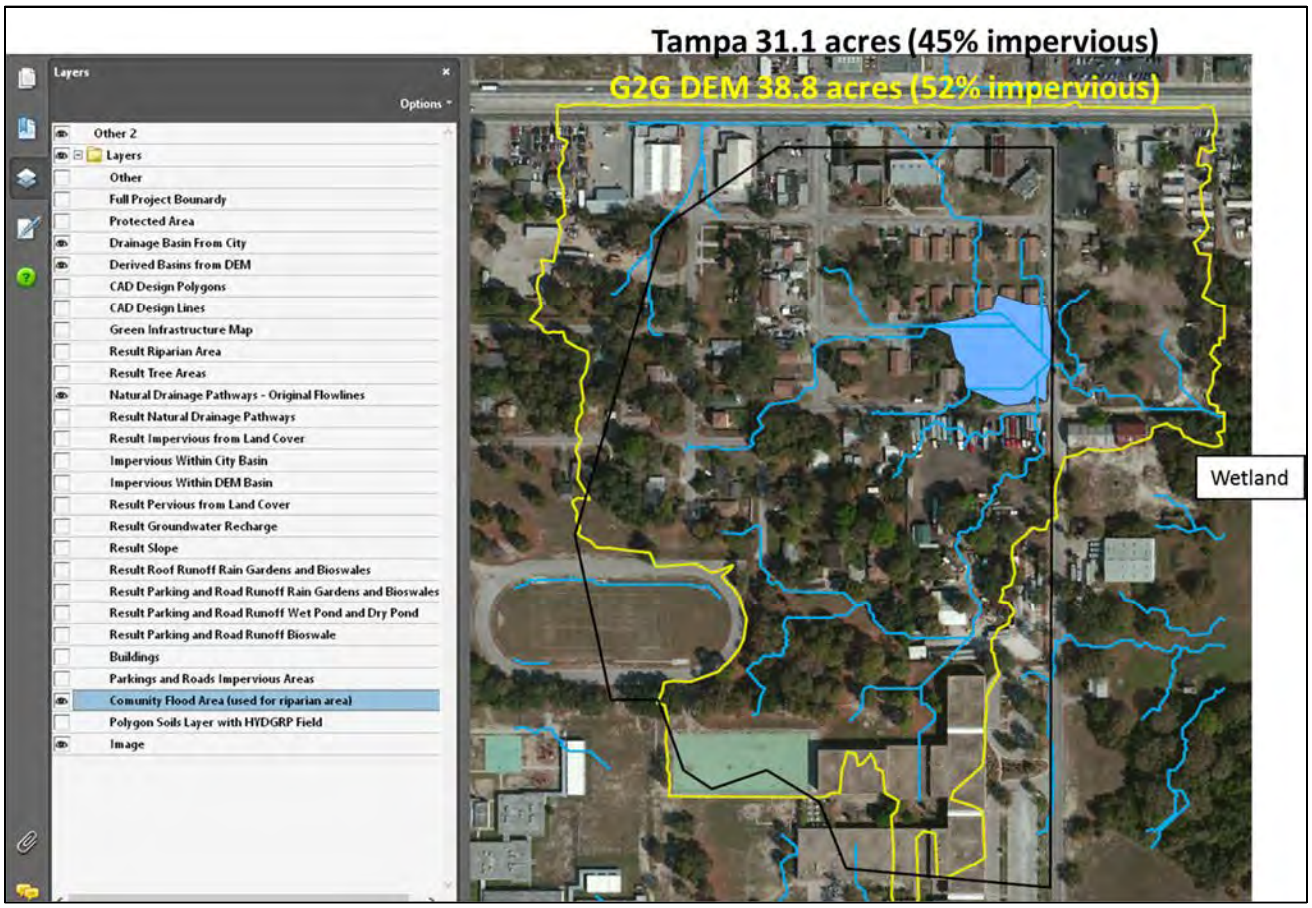


Figure A-2. Drainage area, flow lines, and flooding of the Frierson's Pond case study. This map is the PDF file exported by the G2G Siting Tool.

The map revealed the following:

- The drainage area provided by Tampa (black line) is smaller than the area derived in G2G (yellow line)
- The G2G drainage area, which extends east of Tampa's boundary, has an outfall to an adjacent wetland;
- As expected, the area of flooding (blue polygon) is located at the low point of the drainage area and at the confluence of the natural drainage pathways (blue lines)
- The north-south road located on the east side of the flooding area blocks the historic flow of water out of the basin to the adjacent wetland (confirmed by site visit); and
- Many of the natural drainage pathways in the basin have been paved over by existing development.

After discussing these findings with Tampa, the drainage basin was modified, and the evaluation of alternatives was expanded to include the wetland basin to the east. The areas to the north and east of the dashed yellow lines were determined to drain to the street on the north side and the wetland basin to the east. This change increased the size of the drainage basin by 1.1 acres (from 31.1 acres to 32.2 acres) (Fig. A-3).

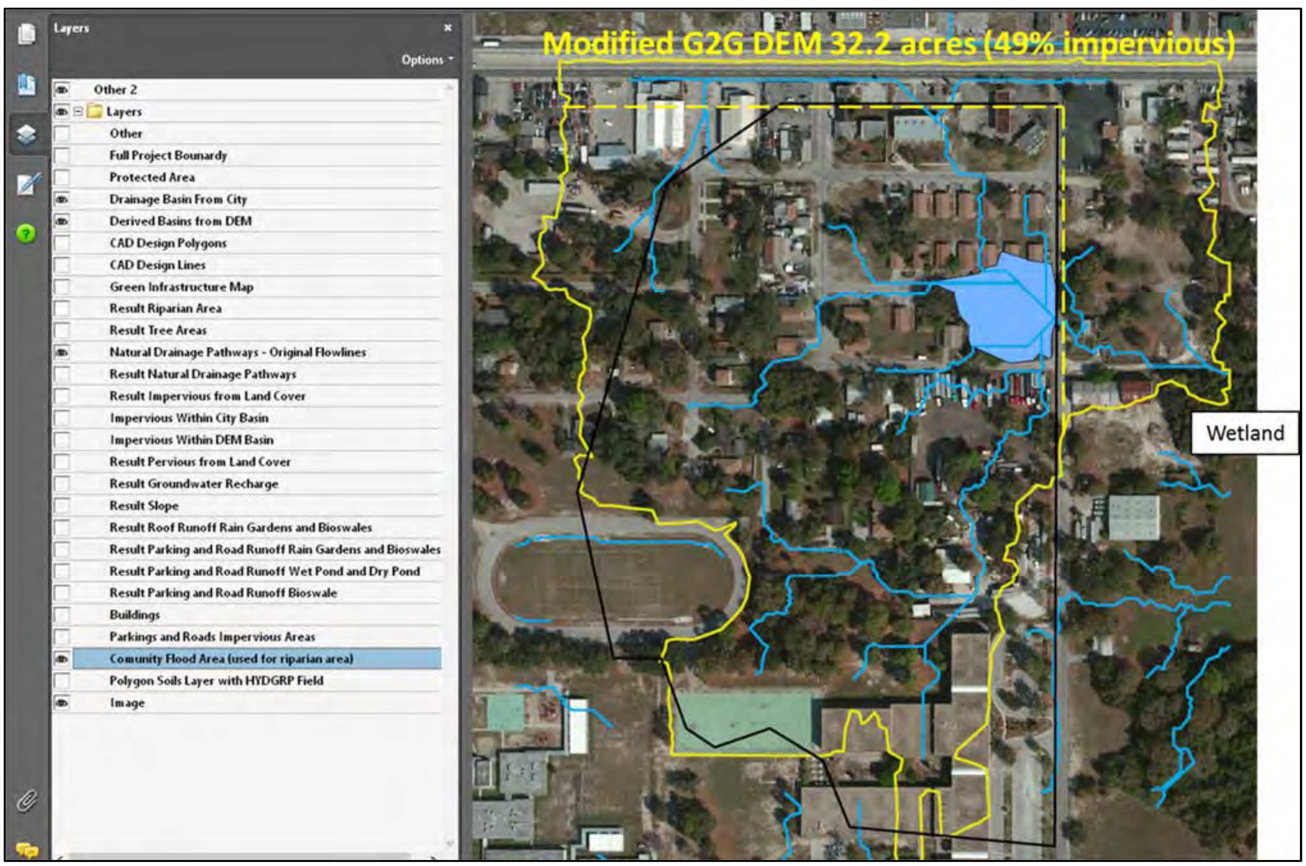


Figure A-3. Modified drainage basin.

After modifying the drainage basin, we viewed the Green Infrastructure Map with its multiple data layers, including trees, riparian areas, groundwater recharge zones, natural drainage ways, steep slopes, and pervious areas (all remaining areas that are not impervious) (Fig. A-4). The data layers were viewed individually in the process of designing and fitting the project to the site, detailed in the next step. The portions of the green infrastructure map that are not developed, i.e., covered by building, parking, or roads, were then identified as potential areas for siting LID practices. The impervious areas for the site are shown in Figure A-5.

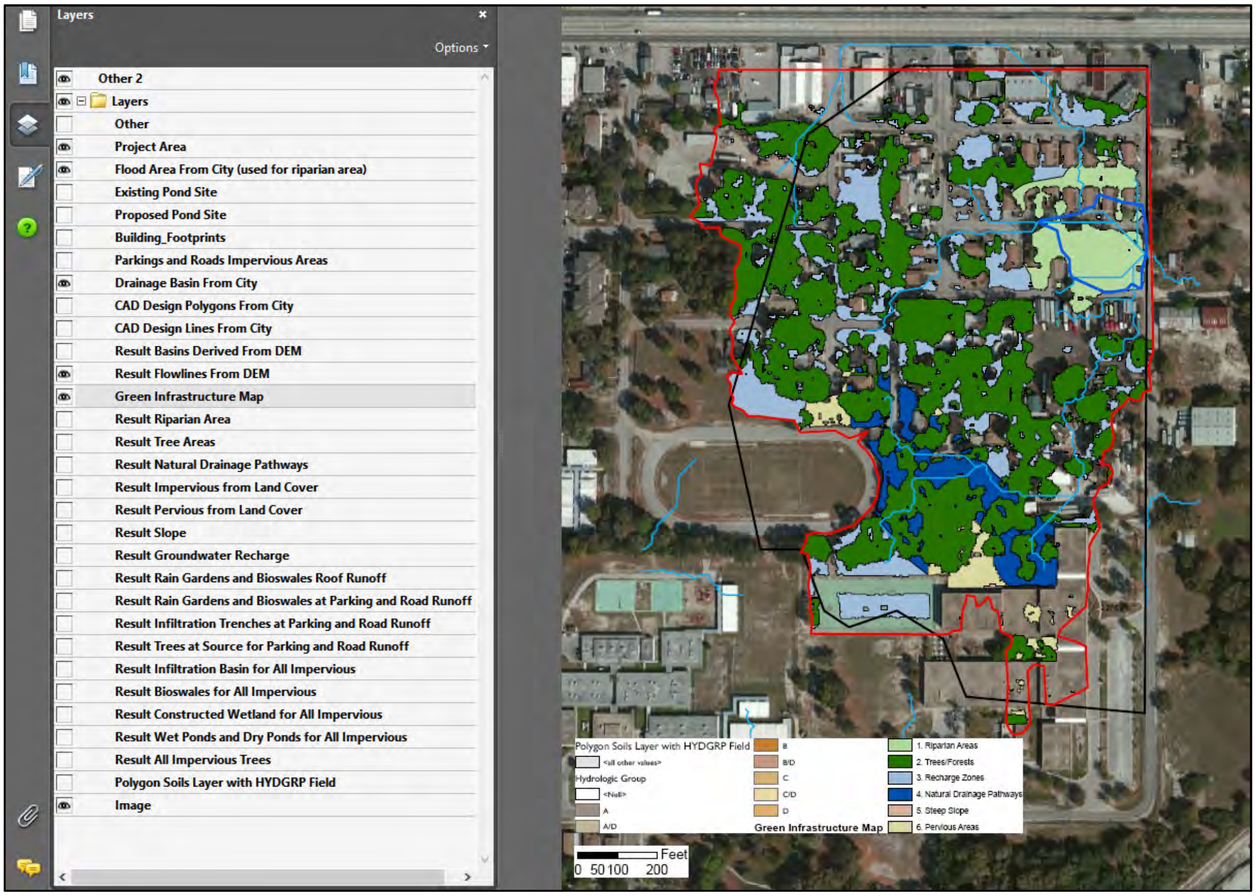


Figure A-4. Green Infrastructure Map of case study area viewed as a PDF report.

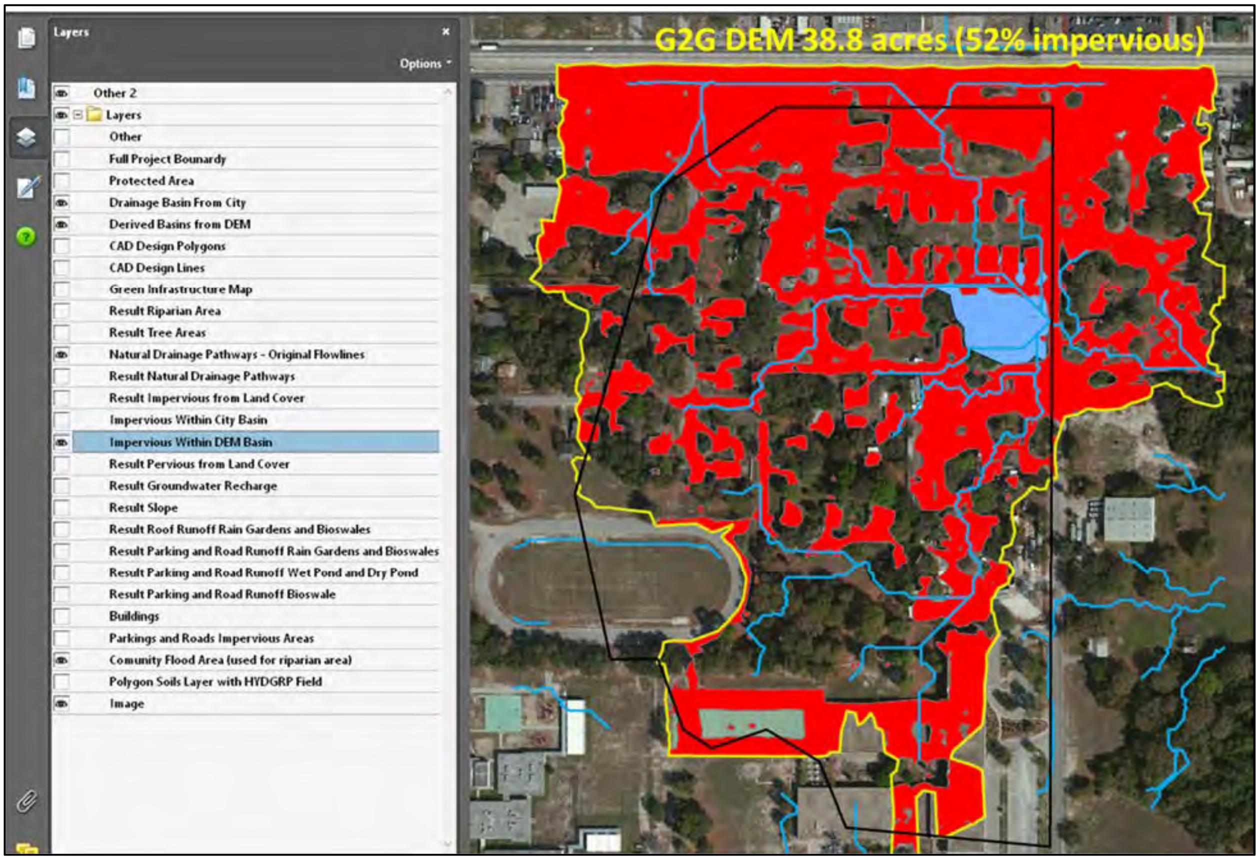


Figure A-5. This is the impervious area map for the contributing watershed in Tampa.

Figure A-6 shows the historic hydrologic linkage between the flooding area and the adjacent dewatered wetland and drainage basin. This information was used to evaluate the option of diverting floodwaters to the wetland.

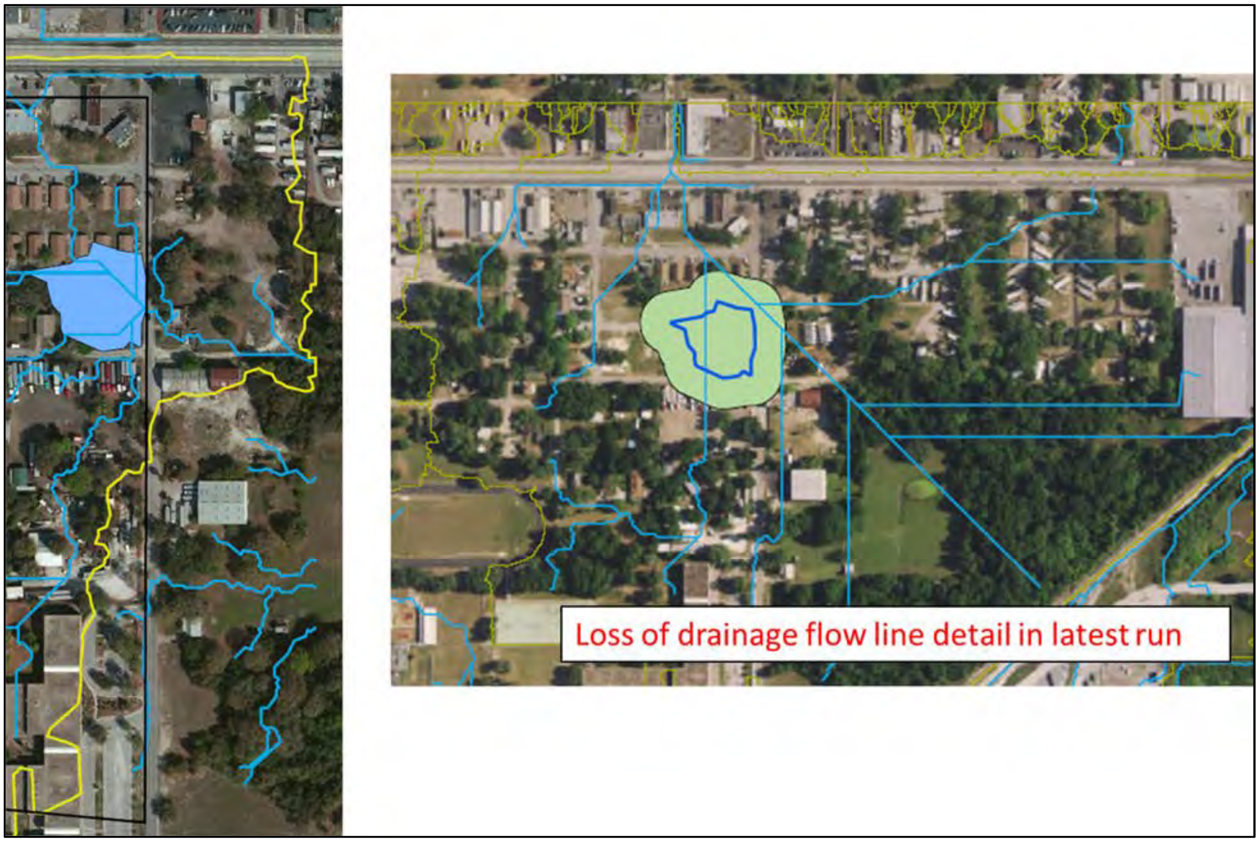
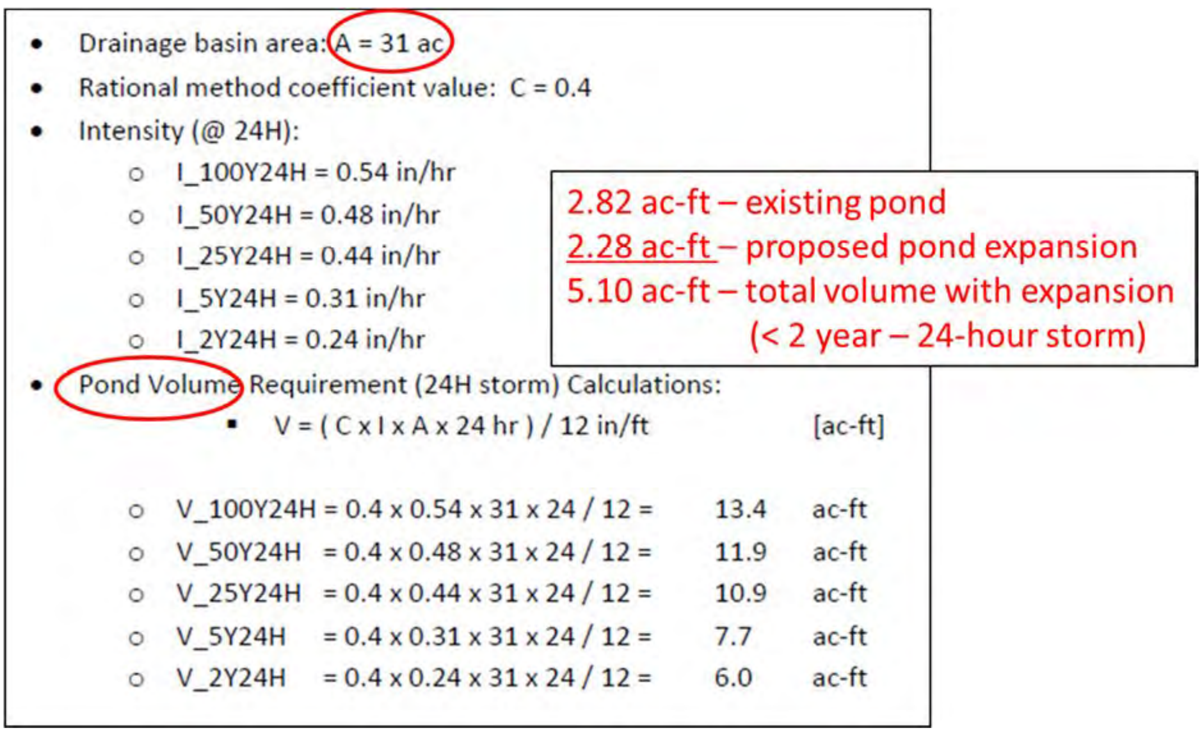


Figure A-6. Expanded DEM including adjacent wetland.

Since the Tampa case study is a retrofit of existing development to reduce flooding, the options were to:

- Expand the existing pond to hold some or all the floodwater, as proposed by Tampa; and/or
- "Push" the floodwater from the low point of the watershed back up into the higher parts of the watershed by slowing, spreading, and infiltrating the stormwater closer to the sources (building, parking lots, and roads) where it is generated using the LID practices in G2G; and/or
- Create a way for the floodwaters to flow out of the watershed to the adjacent watershed and wetland, as they did historically.

Prior to the analysis in G2G, Tampa estimated the runoff produced in the watershed at various rainfall intensities to determine the storage volume requirements of expanding the existing stormwater pond (Fig. A-7). The proposed pond expansion, which requires the acquisition and demolition of 12 homes and the closing and demolition of a public road, would increase the flood level of service to something less than a 2-year, 24-hour design storm (approximately 5 inches of rain in 24 hours).



- Drainage basin area: A = 31 ac
- Rational method coefficient value: C = 0.4
- Intensity (@ 24H):
  - I_100Y24H = 0.54 in/hr
  - I_50Y24H = 0.48 in/hr
  - I_25Y24H = 0.44 in/hr
  - I_5Y24H = 0.31 in/hr
  - I_2Y24H = 0.24 in/hr
- Pond Volume Requirement (24H storm) Calculations:
  - V = (C x I x A x 24 hr) / 12 in/ft [ac-ft]
  - V_100Y24H = 0.4 x 0.54 x 31 x 24 / 12 = 13.4 ac-ft
  - V_50Y24H = 0.4 x 0.48 x 31 x 24 / 12 = 11.9 ac-ft
  - V_25Y24H = 0.4 x 0.44 x 31 x 24 / 12 = 10.9 ac-ft
  - V_5Y24H = 0.4 x 0.31 x 31 x 24 / 12 = 7.7 ac-ft
  - V_2Y24H = 0.4 x 0.24 x 31 x 24 / 12 = 6.0 ac-ft

2.82 ac-ft – existing pond
2.28 ac-ft – proposed pond expansion
5.10 ac-ft – total volume with expansion
(< 2 year – 24-hour storm)

Figure A-7. Runoff estimations for different storm intensities. The inset red values show the total volume the expanded pond could retain, 5.10 ac-ft, which was still less than the pond volume requirement for a 2-year, 24-hour storm, 6.0 ac-ft.

Figure A-8 shows the potential areas for siting LID practices. The total area available for siting practices is approximately 7.4 acres. We will use these areas to estimate the water storage and water quality treatment capacities of the practices using the Scenario Analysis Tool.

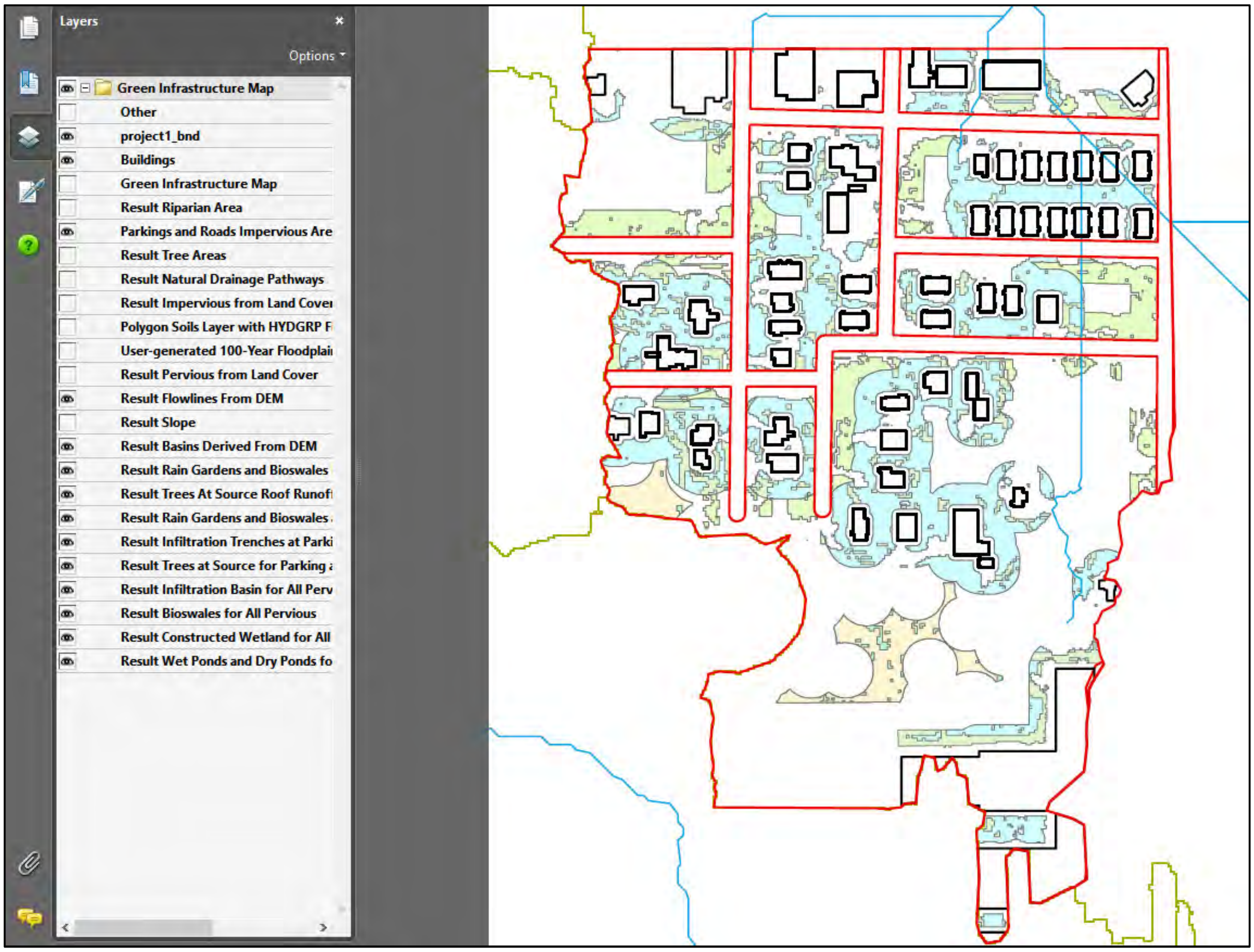


Figure A-8. Potential areas for siting LID practices.

We used the Scenario Analysis Tool to estimate the amount of runoff that could be captured using different LID practices. Tables A-1 provides summary results for the 2-year, 24-hour storm (5.0 inches of rain). It shows that 100% of the roof and parking runoff (6.3 acre-feet) can be captured using LID practices. LID practices can also capture 61% of the pervious runoff from the site. The 1.33 acre-feet of runoff not captured could be captured in the existing pond which has a capacity of 2.82 acre-feet.

This solution would increase the flood level of service beyond that provided by expanding the existing pond. Unlike the pond expansion, it would not require the acquisition and demolition of 12 homes or the closing and demolition of a public road.

Table A-2 provides summary results for the 25-year, 24-hour storm (9.5 inches of rain). This analysis suggests that the flood level of service could be increased even more using more LID practices.

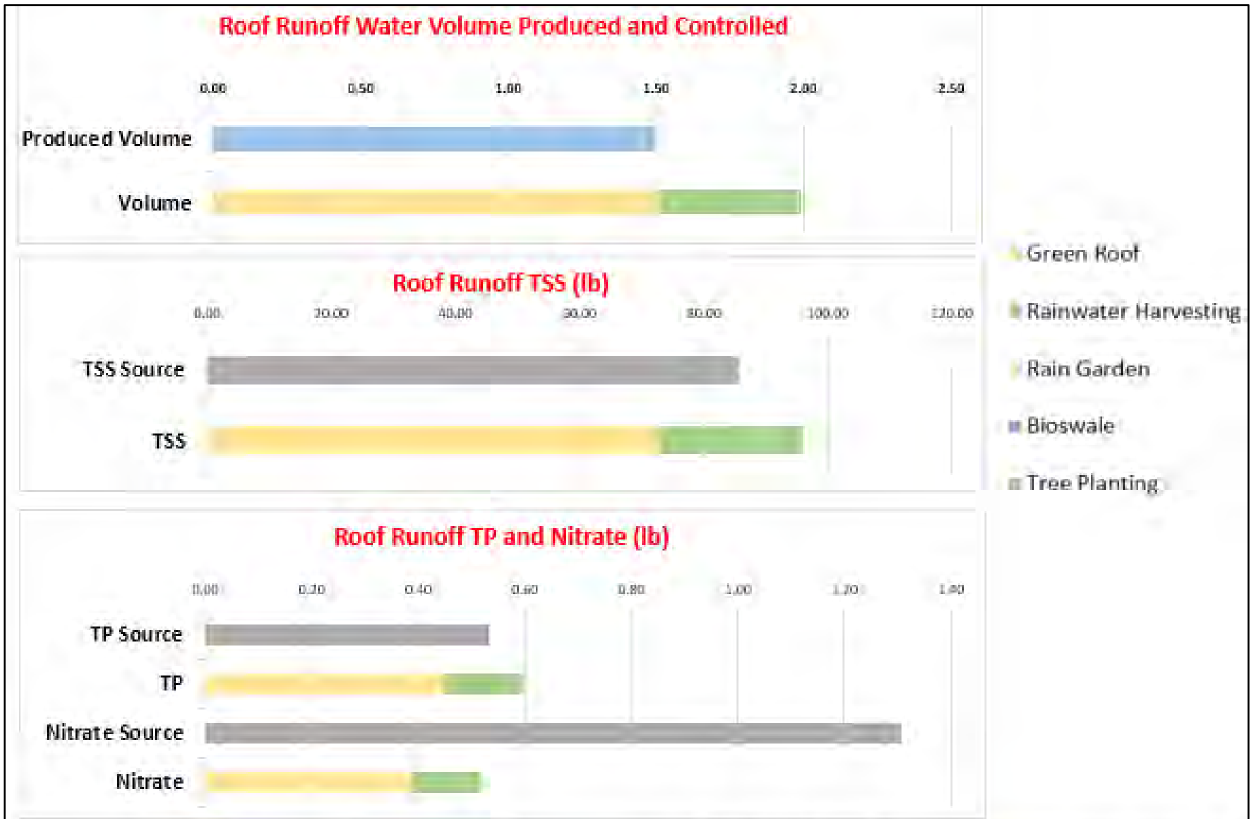
Table A-1. Scenario analysis for 2-year, 24-hour design storm (5.0 inches of rain) showing that 100% of the roof and parking and road runoff can be captured using LID practices. LID practices can also capture 61% of the pervious runoff.

	2-year, 24-hour Design Storm (5.0 inches of rain)				
Runoff Area / LID Practice	**Runoff Generated (acre-feet)**	**Potential Area Available for Practice (ft2)**	**% of Potential Area Selected for Practice (%)**	**Runoff Captured (acre-feet)**	**Runoff Captured (%)**
Roof Runoff buildings and out 50 ft	1.5 acre-feet				
Rain Garden		199,128	15%	1.5	100%
Trees		253,035	100%	0.48	32%
Parking Runoff paved areas and out 50 ft	4.8 acre-feet				
Pervious Paving		149,139	34%	1.4	29%
Rain Garden		67,054	100%	3.39	71%
Trees		68,442	100%	0.13	3%
Pervious Runoff +50 ft building/paved areas	3.46 acre-feet				
Constructed Wetland		29,515	100%	1.36	39%
Bioswale		27,235	100%	.63	18%
Trees		29,580	100%	.14	4%

Table A-2. Scenario analysis for 25-year, 24-hour design storm (9.5 inches of rain) showing that 100% of the roof runoff can be captured using LID practices. LID practices can also capture 81% of the parking and road runoff and 20% of the pervious runoff. This additional capacity would increase the flood level of service to the neighborhood.

	25-year, 24-hour Design Storm (9.5 inches of rain)				
Runoff Area / LID Practice	**Runoff Generated (acre-feet)**	**Potential Area Available for Practice (ft2)**	**% of Potential Area Selected for Practice (%)**	**Runoff Captured (acre-feet)**	**Runoff Captured (%)**
Roof Runoff buildings and out 50 ft	2.92 acre-feet				
Rain Garden		199,128	29%	2.92	100%
Trees		253,035	100%	0.48	32%
Parking Runoff paved areas and out 50 ft	9.33 acre-feet				
Pervious Paving		149,139	100%	4.11	44%
Rain Garden		67,054	100%	3.39	36%
Trees		68,442	100%	0.13	1%
Pervious Runoff +50 ft building/paved areas	10.16 acre-feet				
Constructed Wetland		29,515	100%	1.36	13%
Bioswale		27,235	100%	.63	6%
Trees		29,580	100%	.14	1%

Figures A-9, A-10, and A-11, show the water quality and other ecosystem benefits associated with each LID practice for the 2-year, 24-hour design storm (5 inches of rain), starting first with roof runoff (Figure A-9), then parking and road runoff (Figure A-10) and, finally, pervious runoff (Figure A-11). As you can see, there are significant pollutant load reductions for Total Suspended Solids (TSS), Total Phosphorous (TP), and nitrate for each type of runoff.

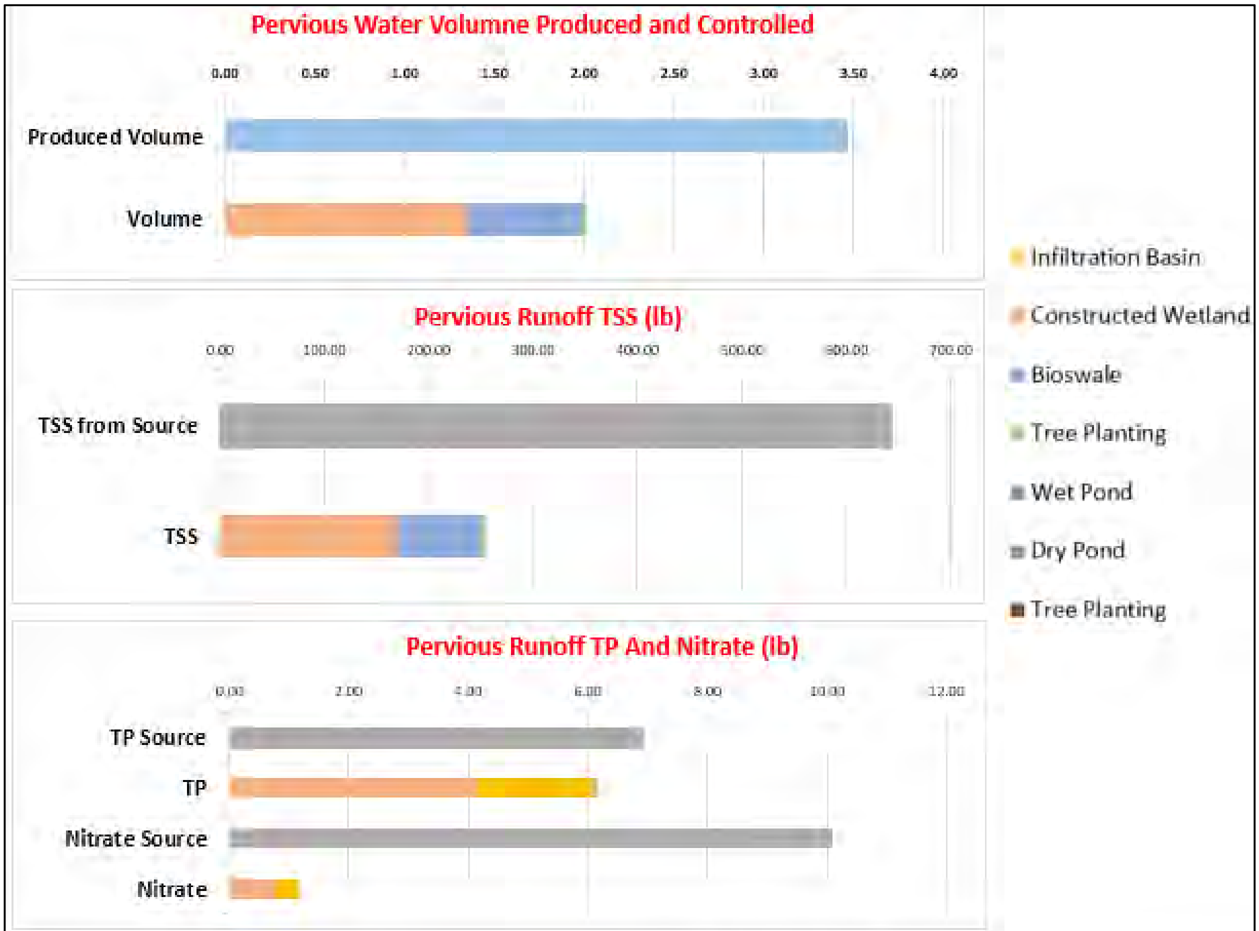


LID Practice	Volume Controlled	Ecosystem Benefits: Water Management	Energy Usage	Air Quality and Co2	Urban Heat Island	Habitat and Greenspace	Social Benefits
Green Roof	0.00%						
Rainwater Harvest	0.00%						
Rain Garden	100.54%	•	•	•	•	•	•
Bioswale	0.00%						
Tree Planting	32.26%	•	•	•	•	•	•

Figure A-9. Estimated pollutant load reductions and other ecosystem benefits from roof runoff for selected LID practices for the 2-year, 24-hour design storm.

LID Practice	Volume Controlled	Ecosystem Benefits					
		Water Management	Energy Usage	Air Quality and Co2	Urban Heat Island	Habitat and Greenspace	Social Benefits
Pervious Pavemen	29.10%	•	•	•	•		
Bioswale	0.00%						
Rain Garden	70.55%	•	•	•	•	•	•
Infiltration Trench	0.00%						
Tree Planting	2.73%	•	•	•	•	•	•

Figure A-10. Estimated pollutant load reductions and other ecosystem benefits from parking and road runoff for selected LID practices for the 2-year, 24-hour design storm.



LID Practice	Volume Controlled	Ecosystem Benefits					
		Managemen t	Energy Usage	Air Quality and Co2	Urban Heat Island	Hab and Greenspac e	Social Benefits
Infiltration Basin	0.00%						
Constructed Wetla	39.12%	•	•	•	•	•	•
Bioswale	18.05%	•	•	•	•		
Tree Planting	0.82%	•	•	•		•	•
Wet Pond	0.00%				•		
Dry Pond	0.00%						
Tree Planting	0.00%						

Figure A-11. Estimated pollutant load reductions and other ecosystem benefits from pervious runoff for selected LID practices for the 2-year, 24-hour design storm.

Beyond the analysis in G2G, other factors that Tampa might consider in selecting a solution to the flooding include the:

- Desired level of service (LOS) for flood protection, e.g., 2 year-24-hour storm or larger;
- Additional project benefits provided, including water quality, water supply, and natural resource/habitat enhancement;
- Project beneficiaries;
- Sources and availability of funding; and
- Cost.

An urban revitalization and wetland restoration project

This case study in the Harbor District of Milwaukee illustrates the functions and utility of G2G in guiding project planning and design. It includes summary results for three revitalization projects (Fig. A-12).

Figure A-13. Harbor District of Milwaukee revitalization location.

Background

As Figures A-13, A-14, and A-15 illustrate, change has defined the Harbor District in Milwaukee. Located on the west shore of Lake Michigan, the area has transitioned from a broad floodplain wetland in the 1800's to a hardened industrial port with severely depressed land values today. Change will continue to define the Harbor, as Milwaukee seeks to revitalize the area as a gateway to the community. The red rectangle in each figure encompasses the three revitalization projects evaluated in this case study.

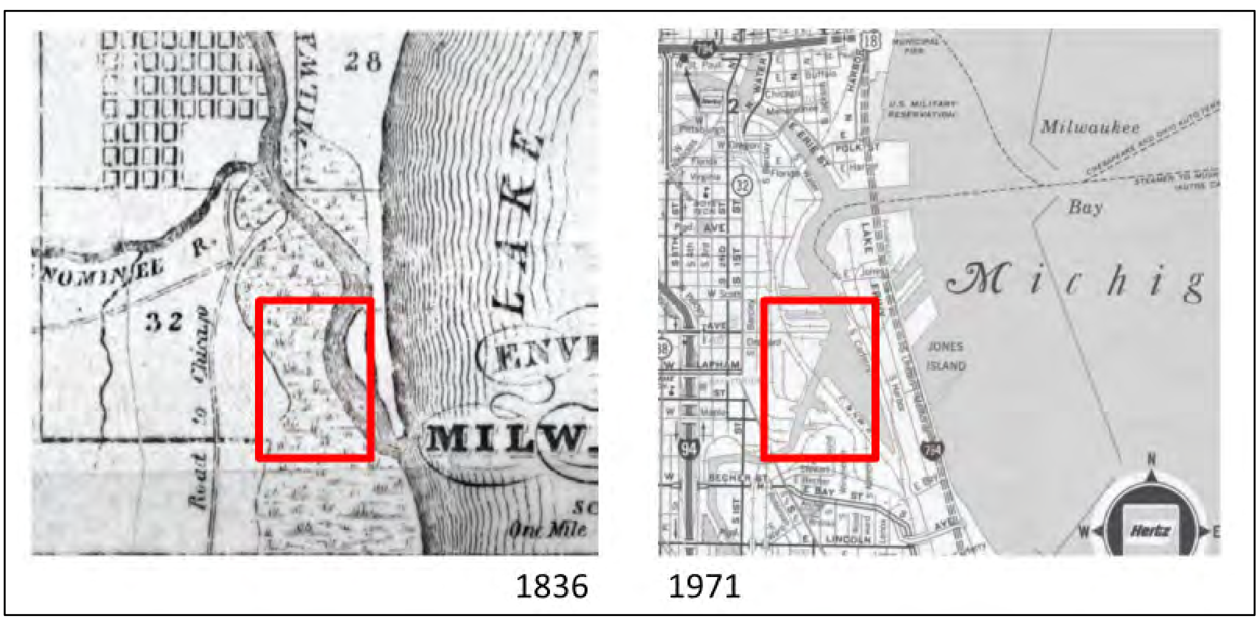


Figure A-143. Early maps of the Harbor District in Milwaukee showing changes to the area between 1836 and 1971.

Figure A-154. Project maps of the Harbor District in Milwaukee in 1910 and 2010 from the City of Milwaukee's project plan.

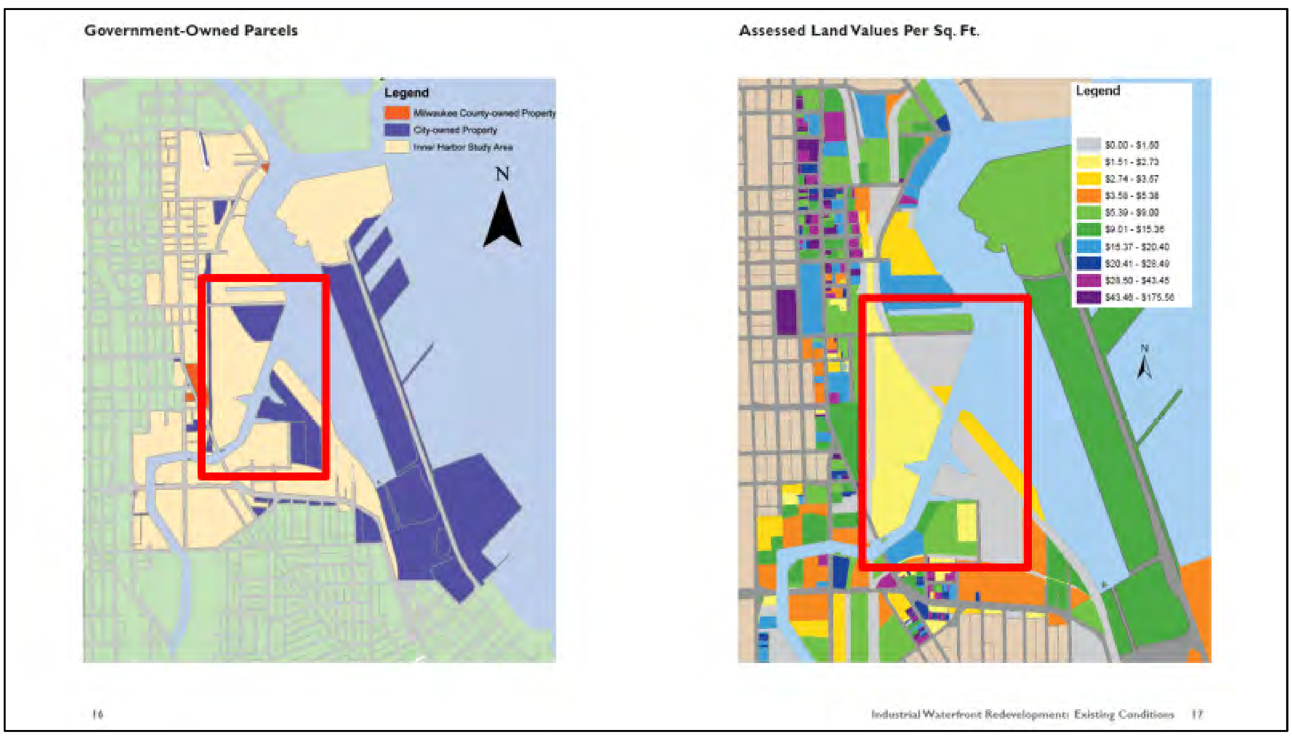


Figure A-165. Images depicting the government-owned parcels of the district (left) and the land values per square feet (right).

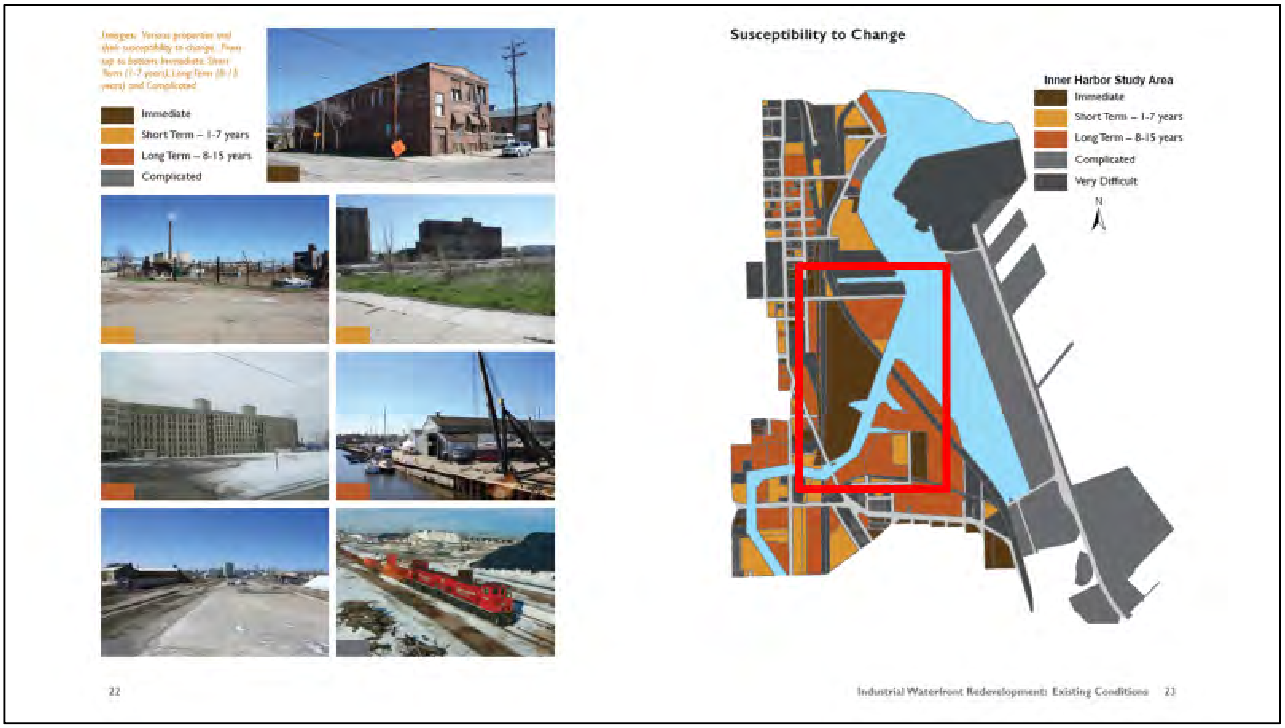


Figure A-176. Various properties in the district and their susceptibility to change.

1. Grand Trunk Wetland Restoration project

Figure A-17. Site of part 1 of the Harbor District revitalization, the Grand Trunk Wetland restoration project (Google Earth).

As shown in the artist renderings that follow, the Grand Trunk site includes a proposed 10-acre wetland and a 7-acre development.

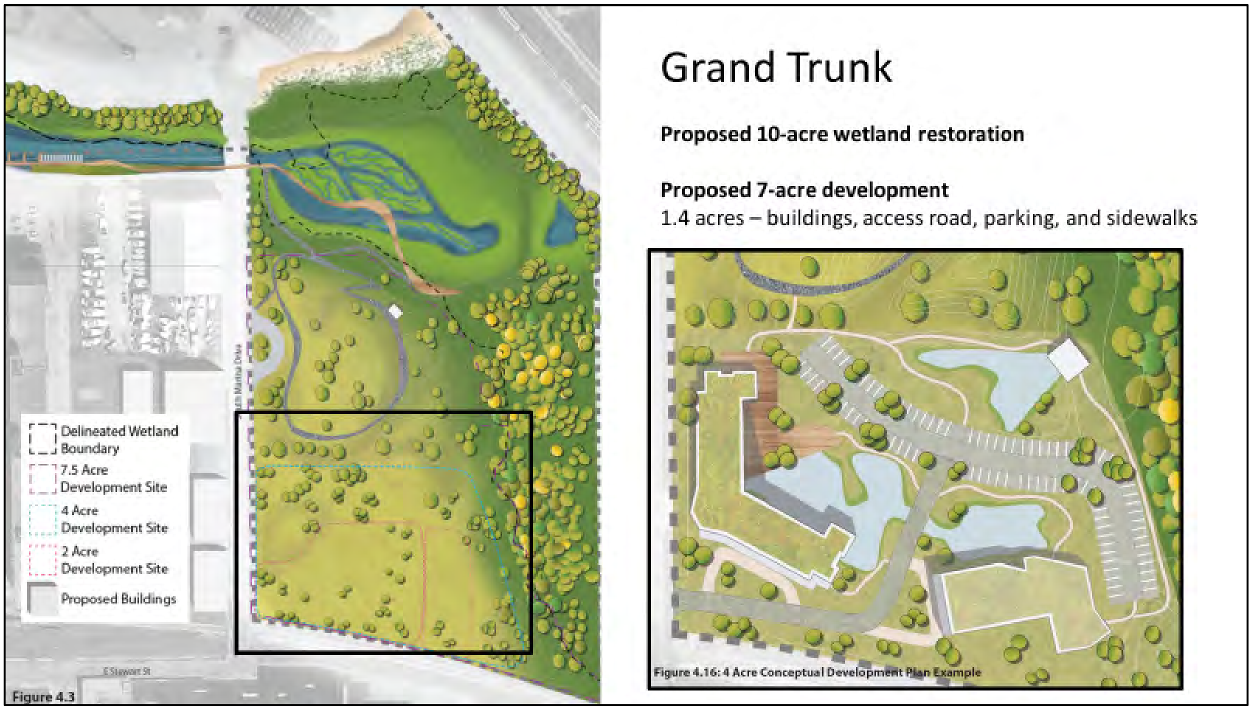


Figure A-18. Artist renderings of Grand Trunk wetland restoration project.

As shown in the figure on the left, taken from Google Earth, the Project Team used G2G to digitize the buildings and roads shown in the development plan (Fig. A-19). The potential areas for siting LID practices proximal to the buildings, roads, and parking areas are shown in various shades of green.

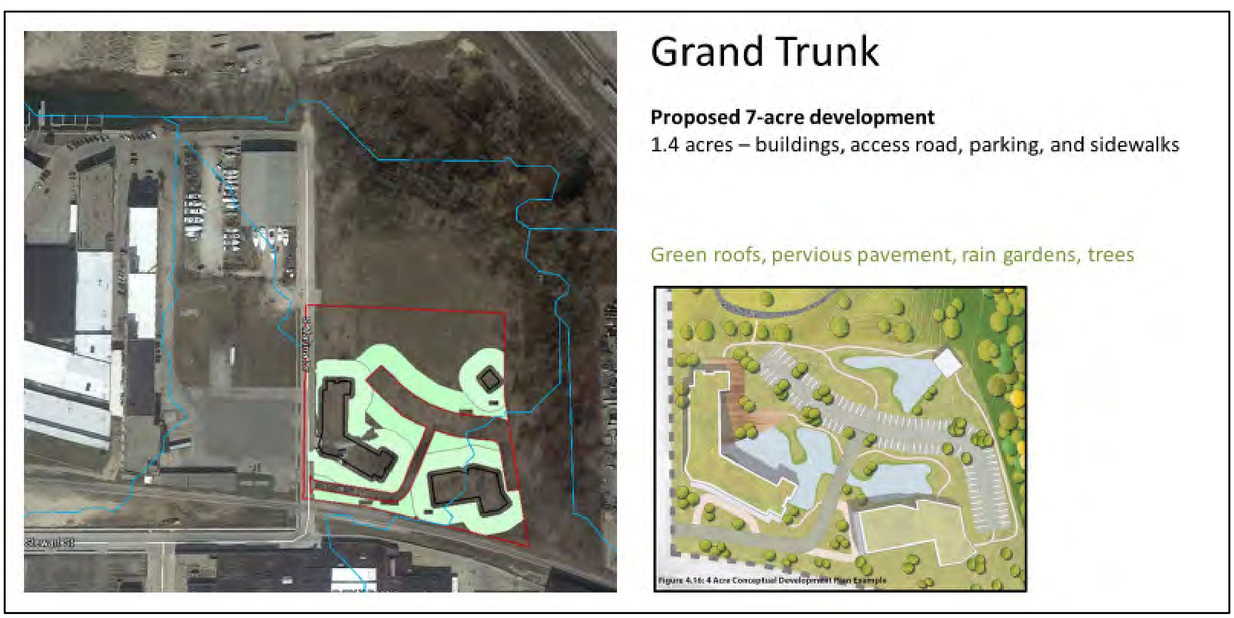
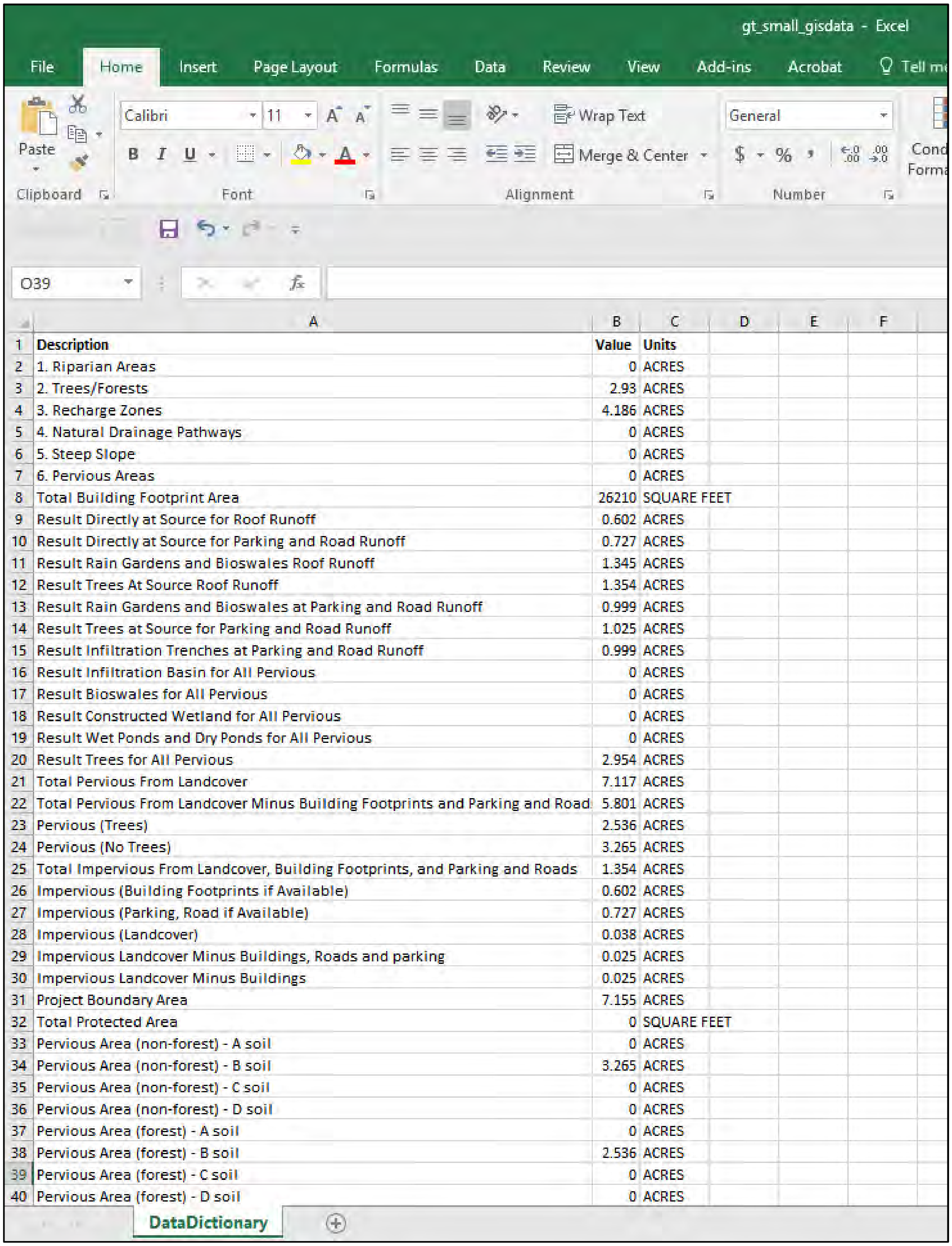


Figure A-19. Location and artist rendering of proposed 7-acre development of Grand Trunk Wetland.

The GIS outcomes produced using the GIS Tool in G2G are shown in Figure A-20 below. It includes the total potential area for siting each LID practice, as well as the total area for each element of green infrastructure on the site.



	Description	Value	Units
2	1. Riparian Areas	0	ACRES
3	2. Trees/Forests	2.93	ACRES
4	3. Recharge Zones	4.186	ACRES
5	4. Natural Drainage Pathways	0	ACRES
6	5. Steep Slope	0	ACRES
7	6. Pervious Areas	0	ACRES
8	Total Building Footprint Area	26210	SQUARE FEET
9	Result Directly at Source for Roof Runoff	0.602	ACRES
10	Result Directly at Source for Parking and Road Runoff	0.727	ACRES
11	Result Rain Gardens and Bioswales Roof Runoff	1.345	ACRES
12	Result Trees At Source Roof Runoff	1.354	ACRES
13	Result Rain Gardens and Bioswales at Parking and Road Runoff	0.999	ACRES
14	Result Trees at Source for Parking and Road Runoff	1.025	ACRES
15	Result Infiltration Trenches at Parking and Road Runoff	0.999	ACRES
16	Result Infiltration Basin for All Pervious	0	ACRES
17	Result Bioswales for All Pervious	0	ACRES
18	Result Constructed Wetland for All Pervious	0	ACRES
19	Result Wet Ponds and Dry Ponds for All Pervious	0	ACRES
20	Result Trees for All Pervious	2.954	ACRES
21	Total Pervious From Landcover	7.117	ACRES
22	Total Pervious From Landcover Minus Building Footprints and Parking and Road	5.801	ACRES
23	Pervious (Trees)	2.536	ACRES
24	Pervious (No Trees)	3.265	ACRES
25	Total Impervious From Landcover, Building Footprints, and Parking and Roads	1.354	ACRES
26	Impervious (Building Footprints if Available)	0.602	ACRES
27	Impervious (Parking, Road if Available)	0.727	ACRES
28	Impervious (Landcover)	0.038	ACRES
29	Impervious Landcover Minus Buildings, Roads and parking	0.025	ACRES
30	Impervious Landcover Minus Buildings	0.025	ACRES
31	Project Boundary Area	7.155	ACRES
32	Total Protected Area	0	SQUARE FEET
33	Pervious Area (non-forest) - A soil	0	ACRES
34	Pervious Area (non-forest) - B soil	3.265	ACRES
35	Pervious Area (non-forest) - C soil	0	ACRES
36	Pervious Area (non-forest) - D soil	0	ACRES
37	Pervious Area (forest) - A soil	0	ACRES
38	Pervious Area (forest) - B soil	2.536	ACRES
39	Pervious Area (forest) - C soil	0	ACRES
40	Pervious Area (forest) - D soil	0	ACRES

Figure 20. GIS outcomes from the G2G GIS Tool for the Grand Trunk Wetland restoration project.

The G2G scenario analysis for 100-year, 24-hour design storm (5.5 inches of rain) shows that 100% of the roof and parking runoff can easily be captured using LID practices (Table A-3). Note that in this scenario only 1% of the potential area for siting Rain Gardens is required to capture 100% of the roof runoff, and only 38% of the potential area for siting pervious paving is required to capture 100% of the parking and road runoff. Trees can capture 13% of the pervious runoff, with the remainder runoff contributing flows to the wetland restoration. It is also interesting to note that utilizing 100% of the available area for rain gardens and trees to capture parking and road runoff greatly exceeds the capture requirements of the 100-year storm.

Table A-3. Scenario analysis for 100-year, 24-hour design storm (5.5 inches of rain) for the Grand Trunk Wetland restoration project.

	100-year, 24-hour Design Storm (5.5 inches of rain)				
Runoff Area / LID Practice	**Runoff Generated (acre-feet)**	**Potential Area Available for Practice (ft2)**	**% of Potential Area Selected for Practice (%)**	**Runoff Captured (acre-feet)**	**Runoff Captured (%)**
Roof Runoff buildings and out 50 ft	0.26 acre-feet				
Green Roof		26,210	100%	0.12	46%
Rain Garden		58,577	1%	0.03	12%
Trees		58,981	100%	0.11	42%
Parking Runoff paved areas and out 50 ft	0.33 acre-feet				
Pervious Paving		31,673	38%	0.33	100%
Rain Garden		43,519	100%	2.20	667%
Trees		44,661	100%	0.90	273%
Pervious Runoff +50 ft building/paved areas	0.90 acre-feet				
Trees		128,679	100%	0.12	13%

2. Solvey Coke; and
3. Coal Pile

The Project Team used G2G to digitize the buildings and roads shown in proposed development plans for the Solvey Coke and Coal Pile project sites (Fig. A-21). The potential areas for siting LID practices proximal to the buildings, roads, and parking areas are shown in various shades of green, beige and purple. As with the Grand Trunk site, the potential area for siting LID practices would easily accommodate large storm events, including the 100-year, 24-hour design storm.

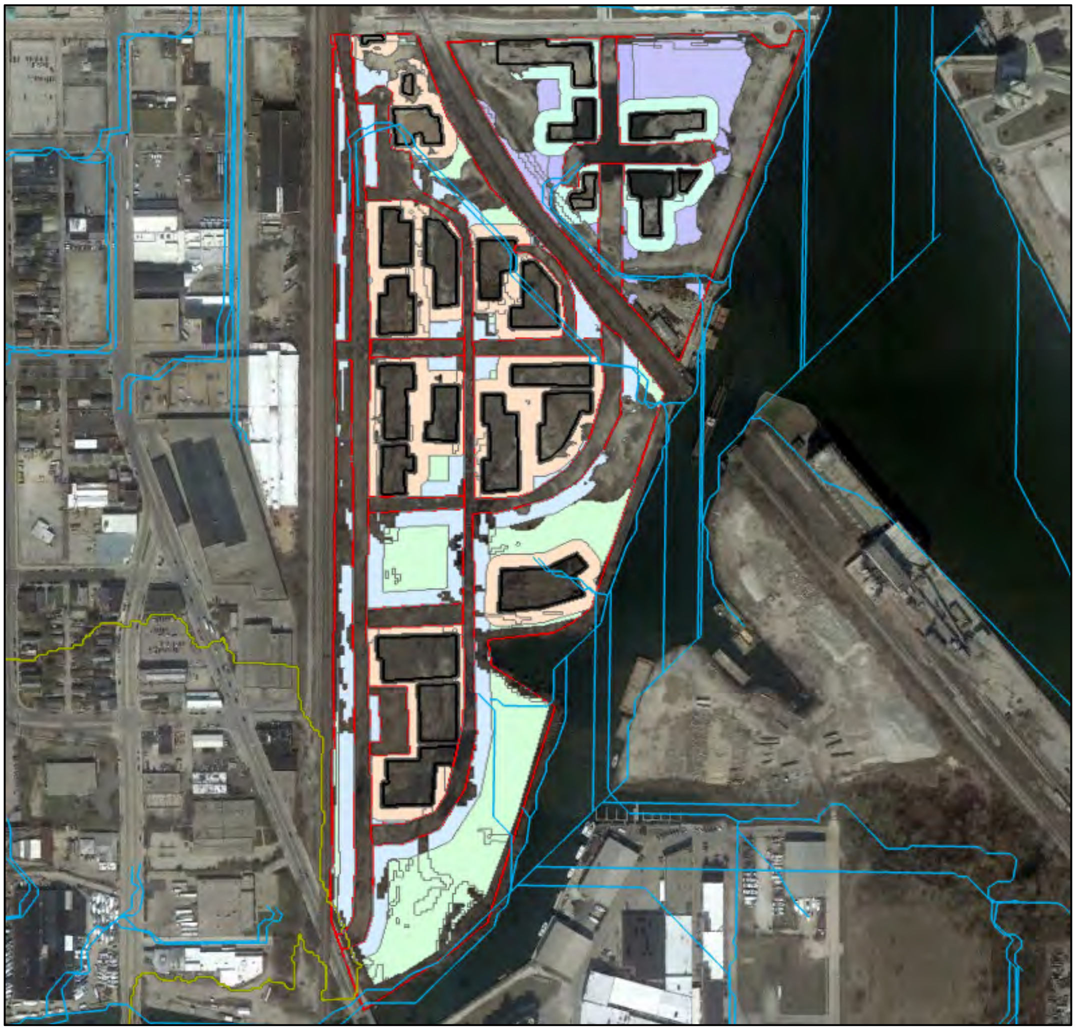


Figure A-21. Potential sites for LID practices generated by G2G tool for Solvey Coke and Coal Pile project sites.

A stormwater retrofit project to relieve urban flooding

This case study in the 30th Street Corridor of Milwaukee illustrates the functions and utility of G2G in guiding project planning and design.

Background

Milwaukee received a record 8.31 inches of rain in 24 hours on July 22, 2010 that resulted in widespread flooding. The event caused basement flooding in over 4,400 homes in the City and several homes were destroyed. The northern part of the 30th Street Industrial Corridor shown in this map was especially impacted, with over $32 million in damages in the private sector alone. Significant flooding impacts are, unfortunately, not unusual for this area. Numerous factors including limited storm sewer system capacity, lack of defined and continuous overland flow paths, and limited capacity of the receiving system contribute to the flooding problems in the area.

Flooding also contributes to significant inflows and infiltration into the City's wastewater collection system, causing the sanitary sewer system to overflow. However, an evaluation of the sewer system in July 2002 by the state legislative, found that the system is vulnerable to even small storm events. For example, stormwater inflow from a storm in April 1999 that generated 3.3 inches of rain over a 36-hour period produced an overflow of 784.1 million gallons of untreated wastewater. This has led the City to evaluate the use of LID practices to capture stormwater runoff and reduce inflow into the wastewater collection system. This case study will explore that potential in the residential neighborhood located immediately west of the 30th Street Industrial Corridor. This area, shown in the red box, below, was subject to some of the worst flooding caused by the July 22, 2010 storm event (Fig. A-22).

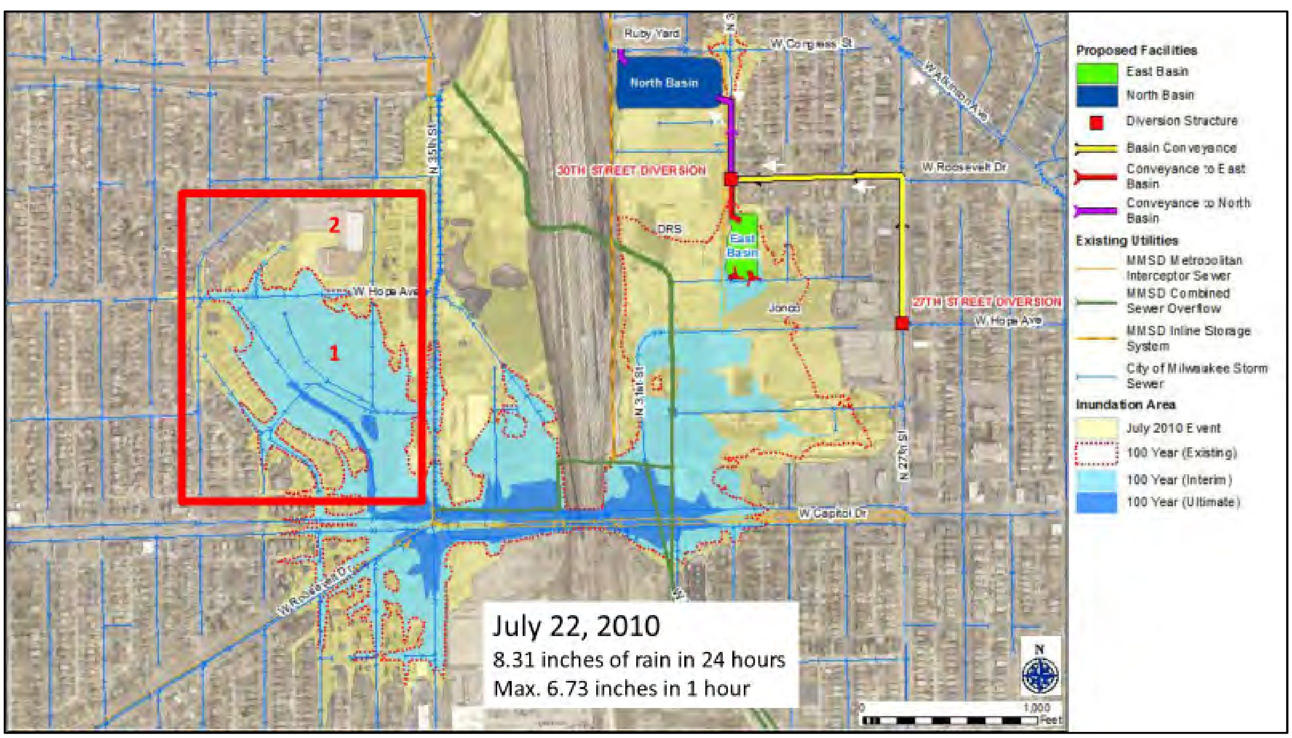


Figure A-22. Map of the 30th Street Corridor Flooding area in Milwaukee, WI.

As shown in Figure A-23 below, the residential neighborhood includes a large linear park. There is also a school located on the north side of the neighborhood with buildings and paving that cover almost 100% of the school site. The linear park and paved areas are ideal for siting LID practices.

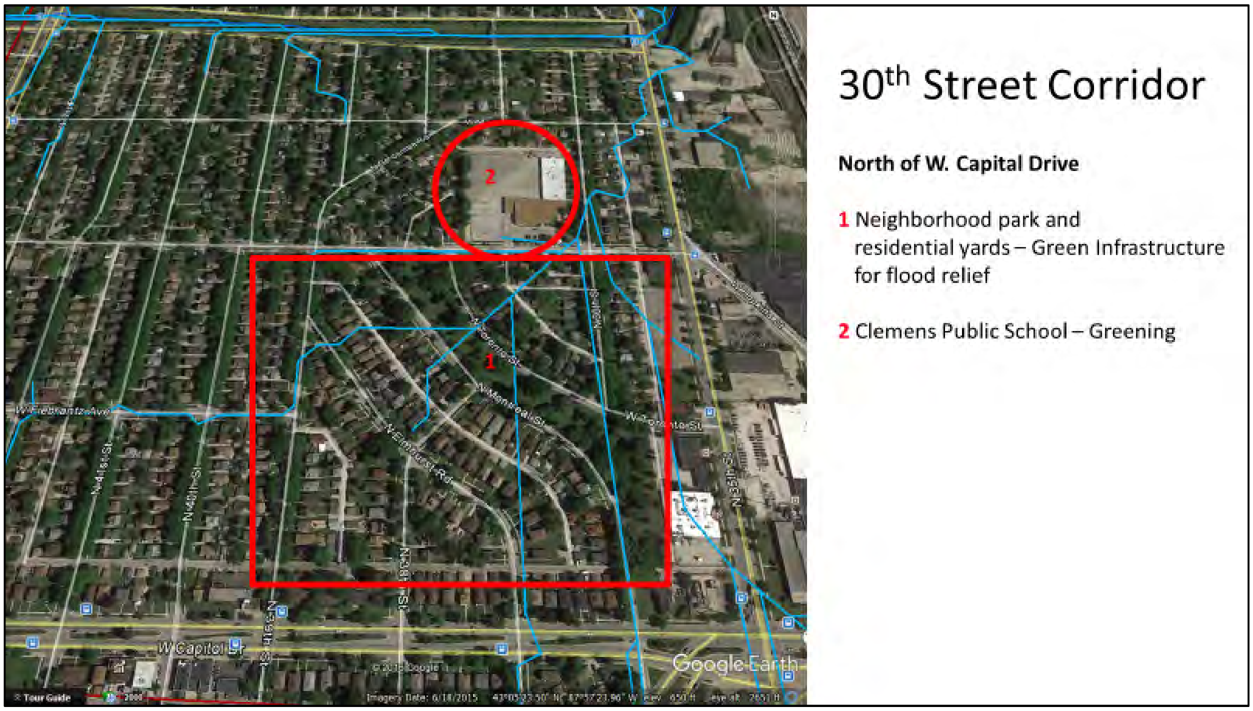


Figure A-23. Map of the 30th Street Corridor showing potential areas for using LID practices.

As shown below (Fig. A-24), the Project Team used G2G to map the buildings and roads and identify potential areas for siting LID practices. The areas for siting LID practices proximal to the buildings, roads, and parking areas are shown in various shades of green.

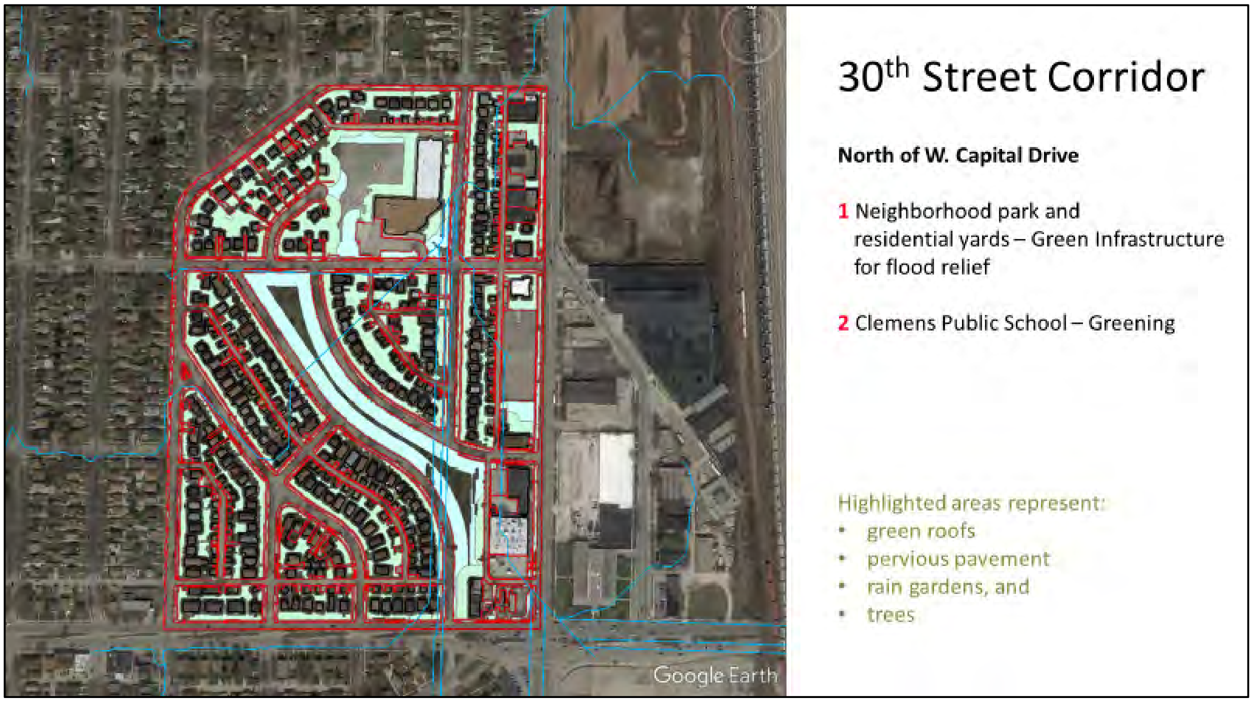
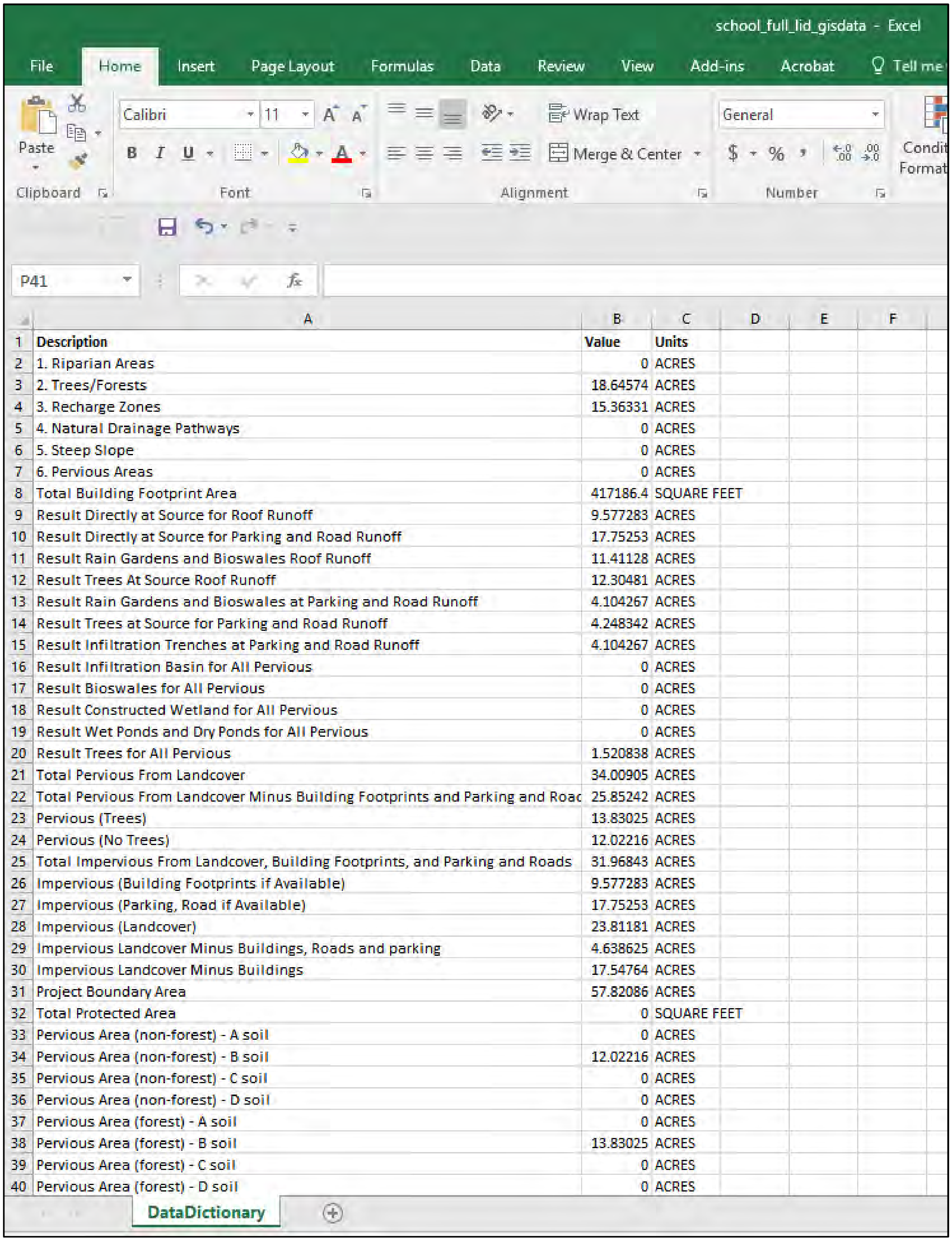


Figure A-24. Potential sites for LID practices generated by G2G tool for the 30th Street Corridor in Milwaukee, WI.

The GIS outcomes produced using the GIS Tool in G2G are shown in the figure that follows (Fig. A-25). It includes the total potential area for siting each LID practice, as well as the total area for each element of green infrastructure on the site.



	Description	Value	Units
2	1. Riparian Areas	0	ACRES
3	2. Trees/Forests	18.64574	ACRES
4	3. Recharge Zones	15.36331	ACRES
5	4. Natural Drainage Pathways	0	ACRES
6	5. Steep Slope	0	ACRES
7	6. Pervious Areas	0	ACRES
8	Total Building Footprint Area	417186.4	SQUARE FEET
9	Result Directly at Source for Roof Runoff	9.577283	ACRES
10	Result Directly at Source for Parking and Road Runoff	17.75253	ACRES
11	Result Rain Gardens and Bioswales Roof Runoff	11.41128	ACRES
12	Result Trees At Source Roof Runoff	12.30481	ACRES
13	Result Rain Gardens and Bioswales at Parking and Road Runoff	4.104267	ACRES
14	Result Trees at Source for Parking and Road Runoff	4.248342	ACRES
15	Result Infiltration Trenches at Parking and Road Runoff	4.104267	ACRES
16	Result Infiltration Basin for All Pervious	0	ACRES
17	Result Bioswales for All Pervious	0	ACRES
18	Result Constructed Wetland for All Pervious	0	ACRES
19	Result Wet Ponds and Dry Ponds for All Pervious	0	ACRES
20	Result Trees for All Pervious	1.520838	ACRES
21	Total Pervious From Landcover	34.00905	ACRES
22	Total Pervious From Landcover Minus Building Footprints and Parking and Roac	25.85242	ACRES
23	Pervious (Trees)	13.83025	ACRES
24	Pervious (No Trees)	12.02216	ACRES
25	Total Impervious From Landcover, Building Footprints, and Parking and Roads	31.96843	ACRES
26	Impervious (Building Footprints if Available)	9.577283	ACRES
27	Impervious (Parking, Road if Available)	17.75253	ACRES
28	Impervious (Landcover)	23.81181	ACRES
29	Impervious Landcover Minus Buildings, Roads and parking	4.638625	ACRES
30	Impervious Landcover Minus Buildings	17.54764	ACRES
31	Project Boundary Area	57.82086	ACRES
32	Total Protected Area	0	SQUARE FEET
33	Pervious Area (non-forest) - A soil	0	ACRES
34	Pervious Area (non-forest) - B soil	12.02216	ACRES
35	Pervious Area (non-forest) - C soil	0	ACRES
36	Pervious Area (non-forest) - D soil	0	ACRES
37	Pervious Area (forest) - A soil	0	ACRES
38	Pervious Area (forest) - B soil	13.83025	ACRES
39	Pervious Area (forest) - C soil	0	ACRES
40	Pervious Area (forest) - D soil	0	ACRES

Figure A-25. GIS outcomes from the G2G GIS Tool for the 30th Street Corridor in Milwaukee, WI.

The G2G scenario analysis for the 100-year, 24-hour design storm (5.5 inches of rain) shows that 100% of the roof and parking/road runoff can easily be captured using LID practices (Table A-4). Note that in this scenario only 17% of the potential area for siting Rain Gardens is required to capture 100% of the roof runoff, and only 46% of the potential area for siting pervious paving is required to capture 100% of the parking and road runoff. It is also interesting to note that 92% of the parking and road runoff could also be captured by utilizing 100% of the potential area for siting rain gardens. With this additional capacity, it would be possible to capture runoff from even larger storm events.

Table A-4. Scenario analysis for 100-year, 24-hour design storm (5.5 inches of rain) for the 30th Street Corridor project.

	100-year, 24-hour Design Storm (5.5 inches of rain)				
Runoff Area / LID Practice	**Runoff Generated (acre-feet)**	**Potential Area Available for Practice (ft2)**	**% of Potential Area Selected for Practice (%)**	**Runoff Captured (acre-feet)**	**Runoff Captured (%)**
Roof Runoff buildings and out 50 ft	4.20 acre-feet				
Rain Garden		497,075	17%	4.27	100%
Trees		535,997	100%	1.03	25%
Parking Runoff paved areas and out 50 ft	9.82 acre-feet				
Pervious Paving		773,300	46%	9.80	100%
Rain Garden		178,782	100%	9.03	92%
Trees		185,058	100%	0.35	4%
Pervious Runoff +50 ft building/paved areas	3.76 acre-feet				
Trees		66,248	100%	0.06	2%

The following table compares the percent of runoff captured for the 2-year and 100-year, 24-hour design storms (2.5 and 5.5 inches of rain, respectively), as well as the July 22, 2010 storm event, using 100% of the potential areas for siting LID practices (Table A-5). It effectively shows the excess capacity that could be tapped for even the largest storm events, including the July 22, 2010 storm. For example, if 100% of the potential area for siting rain gardens was used to capture roof runoff, the capacity would exceed the required storage by a factor of almost 4 (390%).

These results, along with the results presented in the preceding table, support the City's active pursuit of LID practices to capture stormwater runoff and reduce flooding and inflow into the wastewater collection system.

Table A-5. Comparison of percent of runoff for 2-year and 100-year, 24-hour design storms (2.5 and 5.5 inches of rain, respectively), as well as the July 22, 2010 storm event, using 100% of the potential areas for siting LID practices.

Runoff Area / LID Practice*	**Percent of Runoff Captured in Selected Design Storms**		
	2-year, 24-hour (2.5 inches)	100-year, 24-hour (5.5 inches)	July 22, 2010 (8.31 inches in 24 hours)
Roof Runoff buildings and out 50 ft			
Green Roof	106%	46%	30%
Rain Garden	1387%	598%	390%
Trees	57%	25%	16%
Parking Runoff paved areas and out 50 ft			
Pervious Paving	502%	217%	141%
Rain Garden	213%	92%	60%
Trees	8%	4%	2%
Pervious Runoff +50 ft building/paved areas			
Trees	12%	2%	1%

*Used 100% of the potential areas for each of the LID practices listed

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