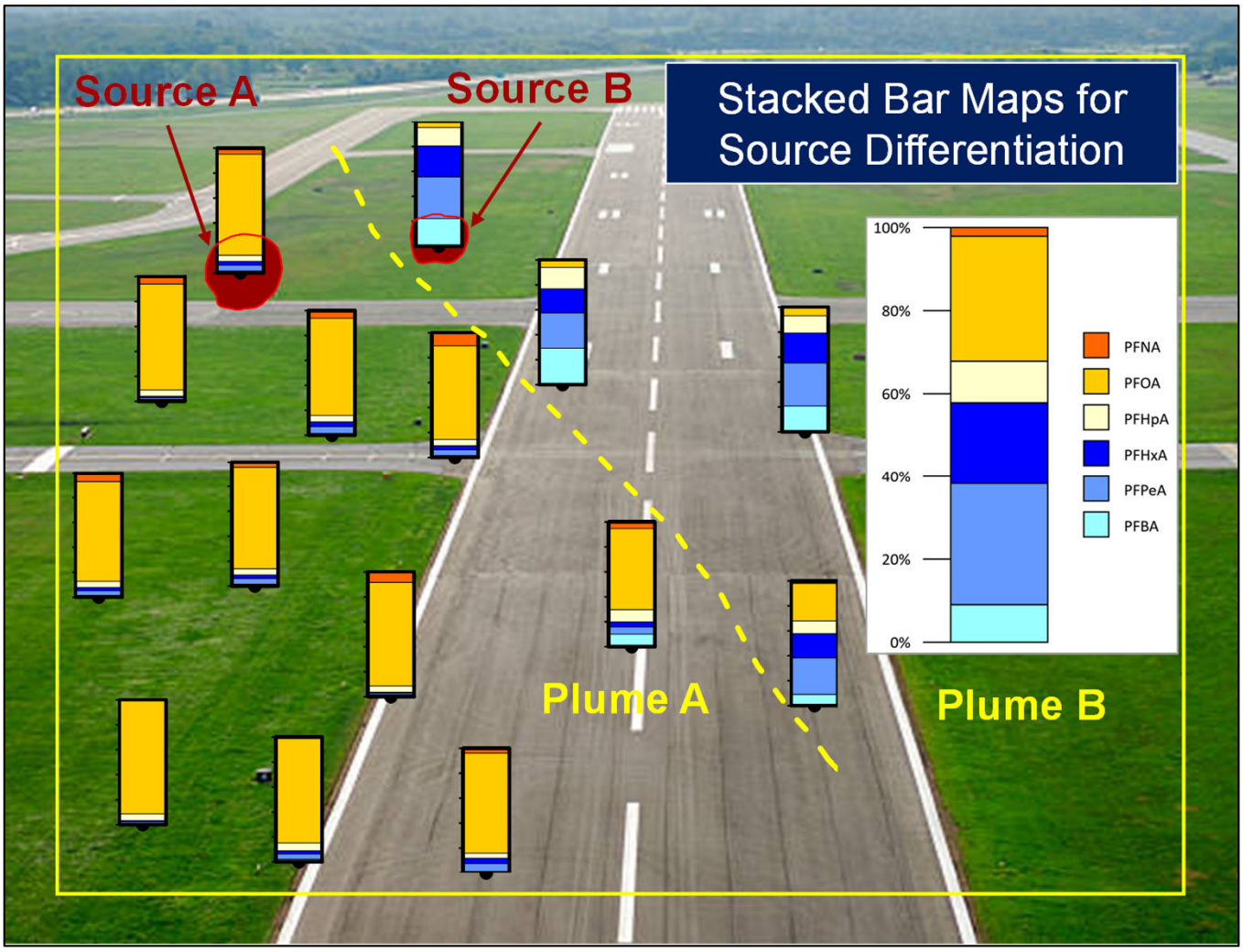
Visual PFAS™
Users Guide:

Stacked Bar Maps

Chapter 5



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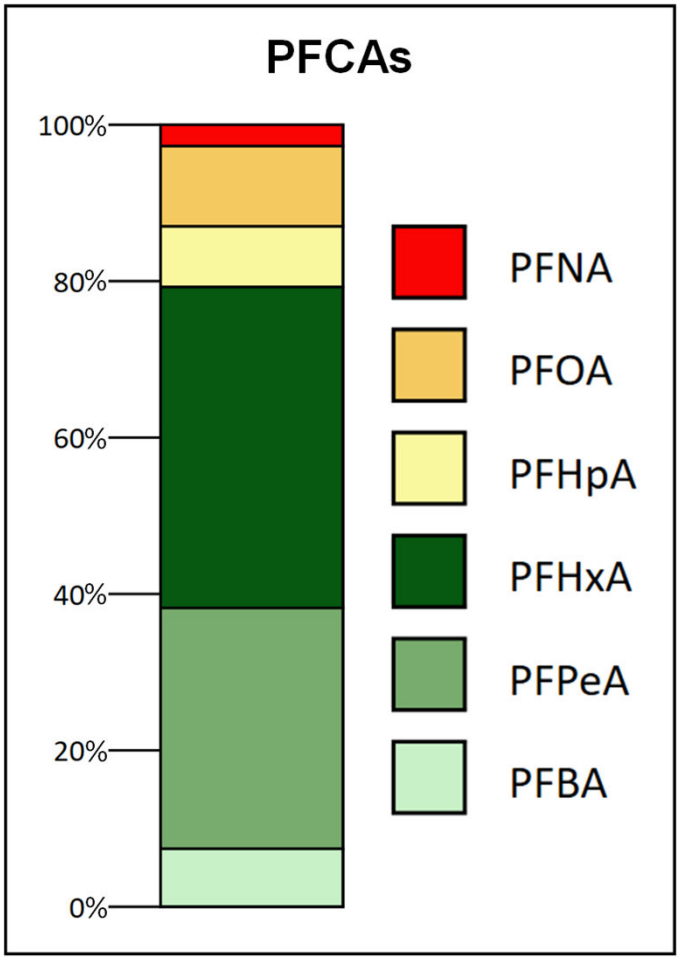
5.1 Introduction

Creating stacked bar charts in Microsoft Excel is a typical approach for evaluating PFAS trends. Visual PFAS™ takes this one step further by facilitating the plotting of stacked bar charts as overlays on a site map. Bar charts are placed at monitoring locations where groundwater, porewater, soil, or sediment samples were collected. This provides a powerful tool for users to conduct a more comprehensive spatial analysis of stacked bar trends across a site, or as a comparison of data extending over multiple sites.

An example of a simple stacked bar legend showing relative concentrations of short-chain and long-chain perfluorinated carboxylates (i.e., PFCAs) is shown below. Chemicals in the stacked bar include (in order of shortest to longest chain length): PFBA, PFPeA, PFHxA, PFHpA, PFOA, and PFNA. The stacked bar represents the proportion i.e., percent (X_i) of each chemical concentration relative to the total concentration of represented chemicals at a monitoring well location. In this manner, the stacked bar will always have a range of 0 to 100%.

Stacked bars are calculated using analytical results from a sample collected at a monitoring location during a single monitoring event. The equations used to construct this stacked bar are shown below.



The individual proportion of chemical *i* in the stacked bar is calculating using:

$$p_i = \frac{C_i}{\sum_{k=1}^{n} C_k}$$

where:

i and k = are chemical indices in order from the bottom to the top in the bar
p_i = proportion of chemical *i* relative to total
C_i = concentration of chemical *i*
n = number of chemicals in stacked bar

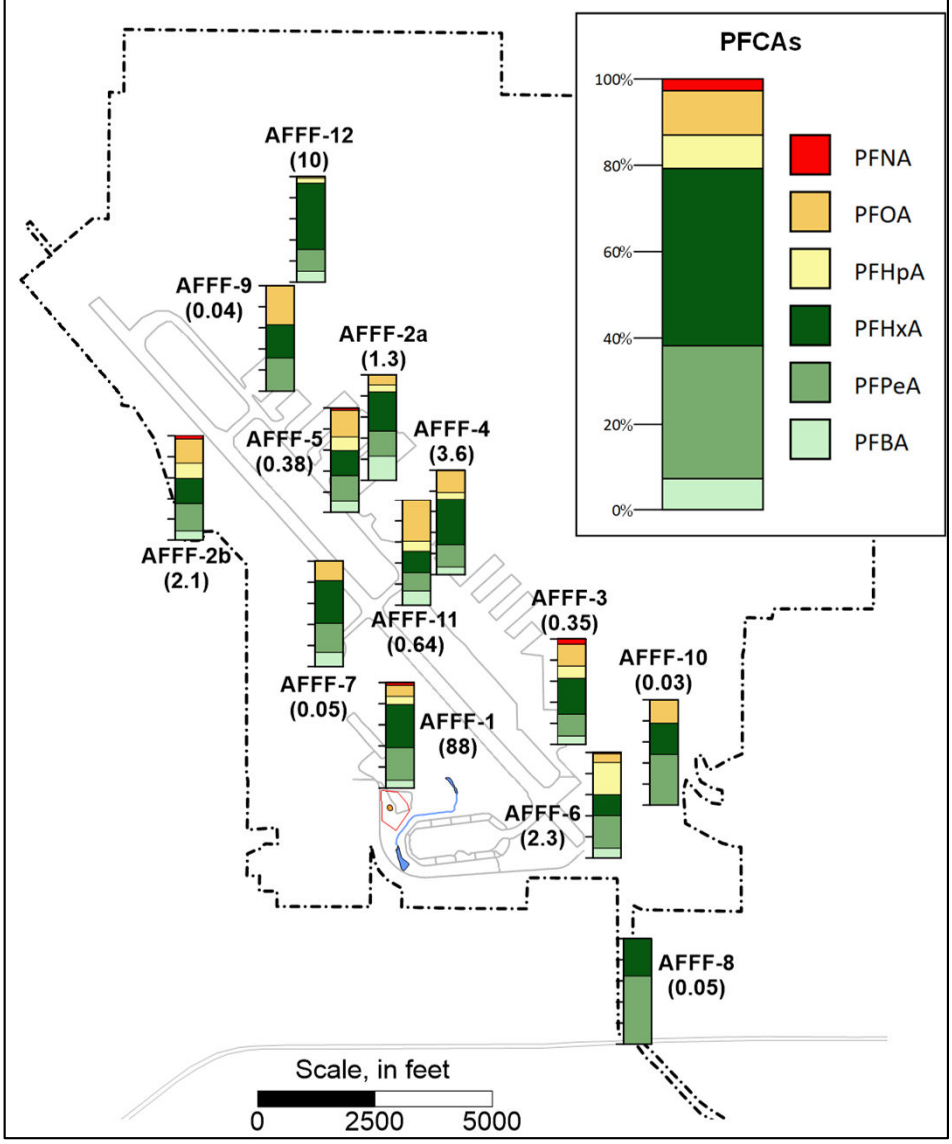
The cumulative proportion or percent (*Xi*) for *i* = 2 through *n* is determined using:

$$X_i = \sum_{j=1}^{i-1} p_j + \frac{C_i}{\sum_{k=1}^{n} C_k}$$

In Visual PFAS™, stacked bar legends are first created by the user with a specified sequence of chemicals such as the PFCAs example shown on the previous page. Then the stacked bars at each monitoring location are overlaid on the site basemap (see Chapter 2 for instructions on how to create a site basemap). The tutorial shown in the following sections provides a hands-on example using the **Demo-Airport** project for creating a stacked bar map.

Carey et al. (2025) present a case study that includes the use of stacked bar maps for visualizing PFAS trends between AFFF source areas at a South Dakota Air Force Base. The figure below shows an example from this case study where a PFCAs stacked bar map was used to differentiate between the use of legacy and modern AFFF products across various AFFF source areas at the base. (Send an email to gcarey@porewater.com to request a copy of this paper.)

Figure 4. Stacked bar map representing PFCAs at AFFF source areas. Shaded bar intervals represent the proportion of PFBA, PFPeA, PFHxA, PFHpA, PFOA, and PFNA to the sum of these six PFCAs. Values in brackets below each source area label represent the sum of these PFCAs in units of ug/L.

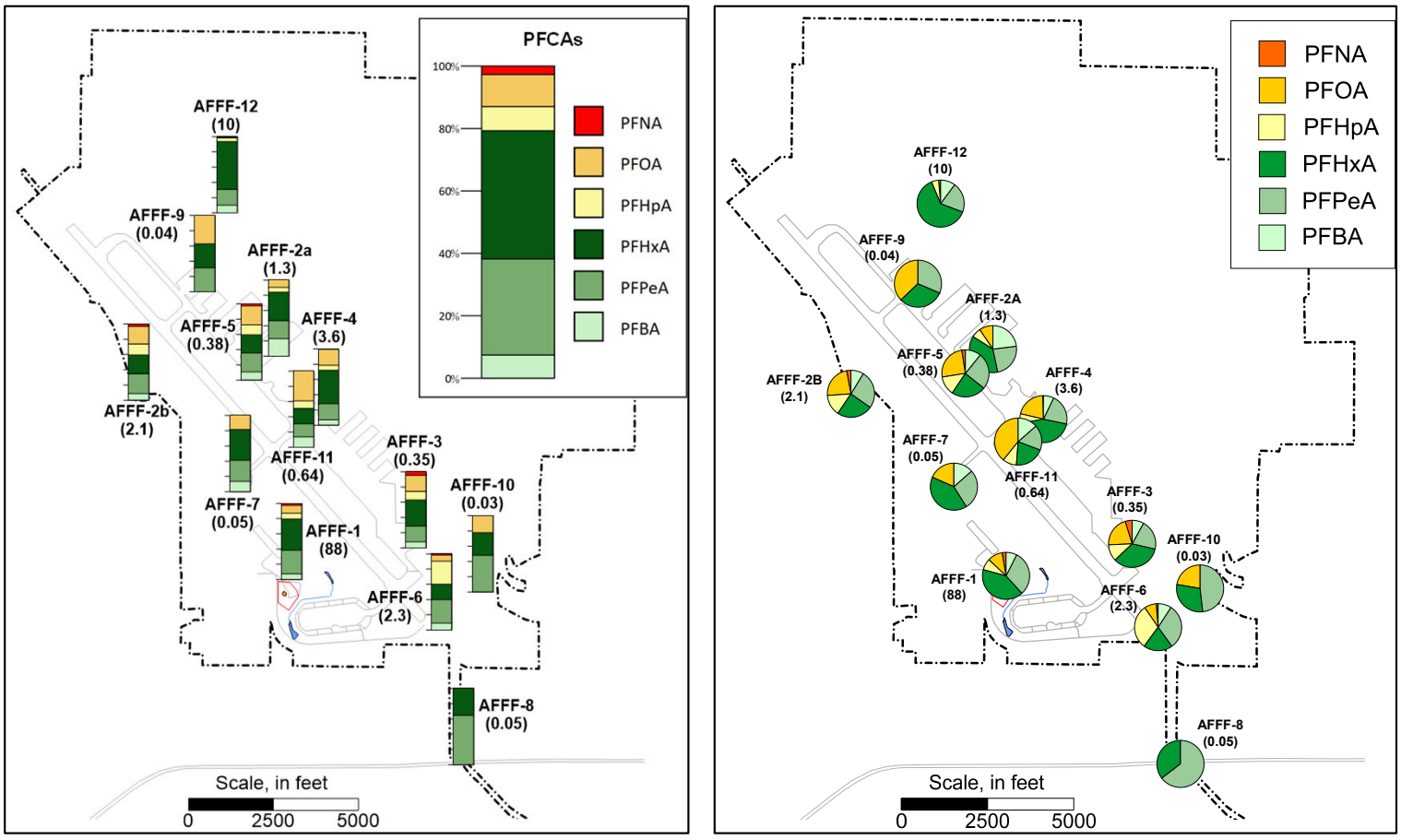


Note: Visual PFAS™ provides the option to show tick marks on stacked bars at each monitoring location. This facilitates estimation of the relative proportion of each chemical at each location.

Carey et al. (2025) conducted a side-by-side comparison of stacked bar and pie chart maps (see figures below), and noted the following three advantages associated with the use of stacked bars to represent proportional PFAS distributions:

1. It is easier to estimate the relative proportion of individual chemicals with stacked bars at each monitoring location, particularly when tick marks are shown to the left of the stacked bars. (There are no corresponding tick marks available to help with estimating the proportion of each species in pie charts.)
2. The stacked bars better convey the linear progression in chain length from C4 to C9 (i.e. from bottom-up in each stacked bar). The pies also show a progression in chain length in a clockwise direction, although the relative change in chain length concentrations is less evident in pie charts when compared to the stacked bar representation.
3. The stacked bars are also more effective for visualizing relative similarities and differences in PFAS concentrations between well locations.

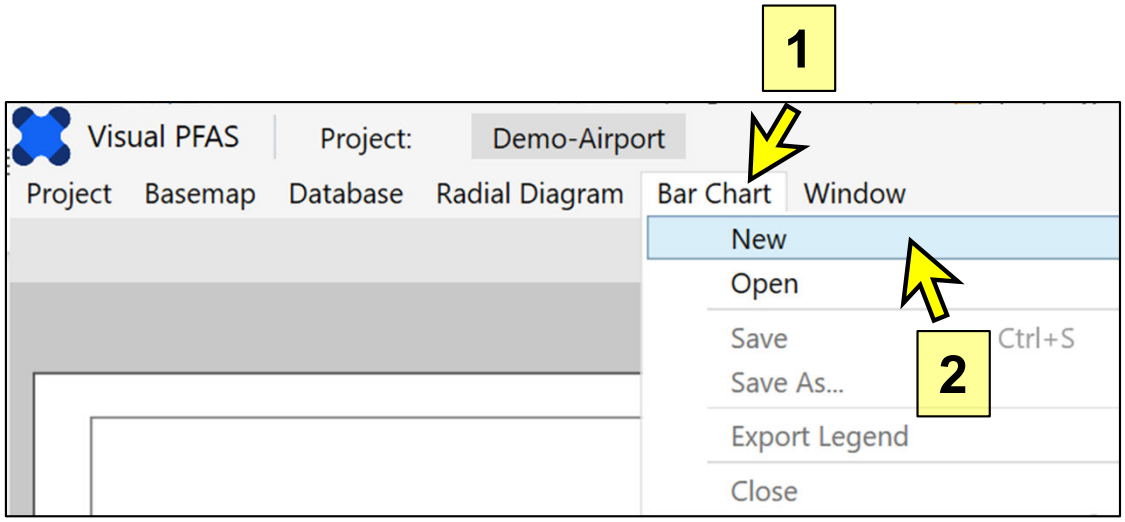
Comparison of Stacked Bar and Pie Maps



5.2 Creating a New Stacked Bar Map

To start the process of creating a new stacked bar map:

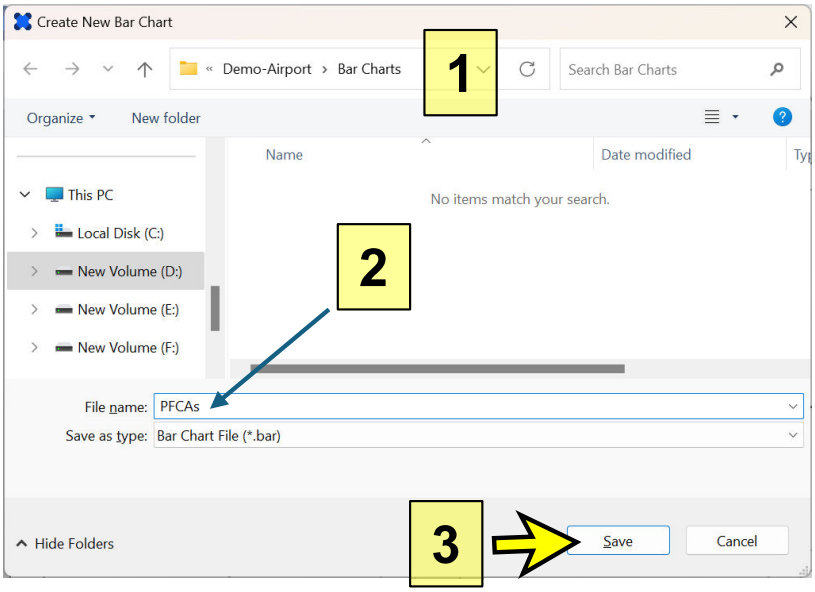
1. Click on **Bar Chart** in the main menu bar (see "1" below); and
2. Click on **New** to create a stacked bar properties file (see "2" below).



Visual PFAS™ will use the **Bar Charts** sub-folder under the **Demo-Airport** project folder as the default location for stacked bar property files (*.bar extension). (see "1" below)

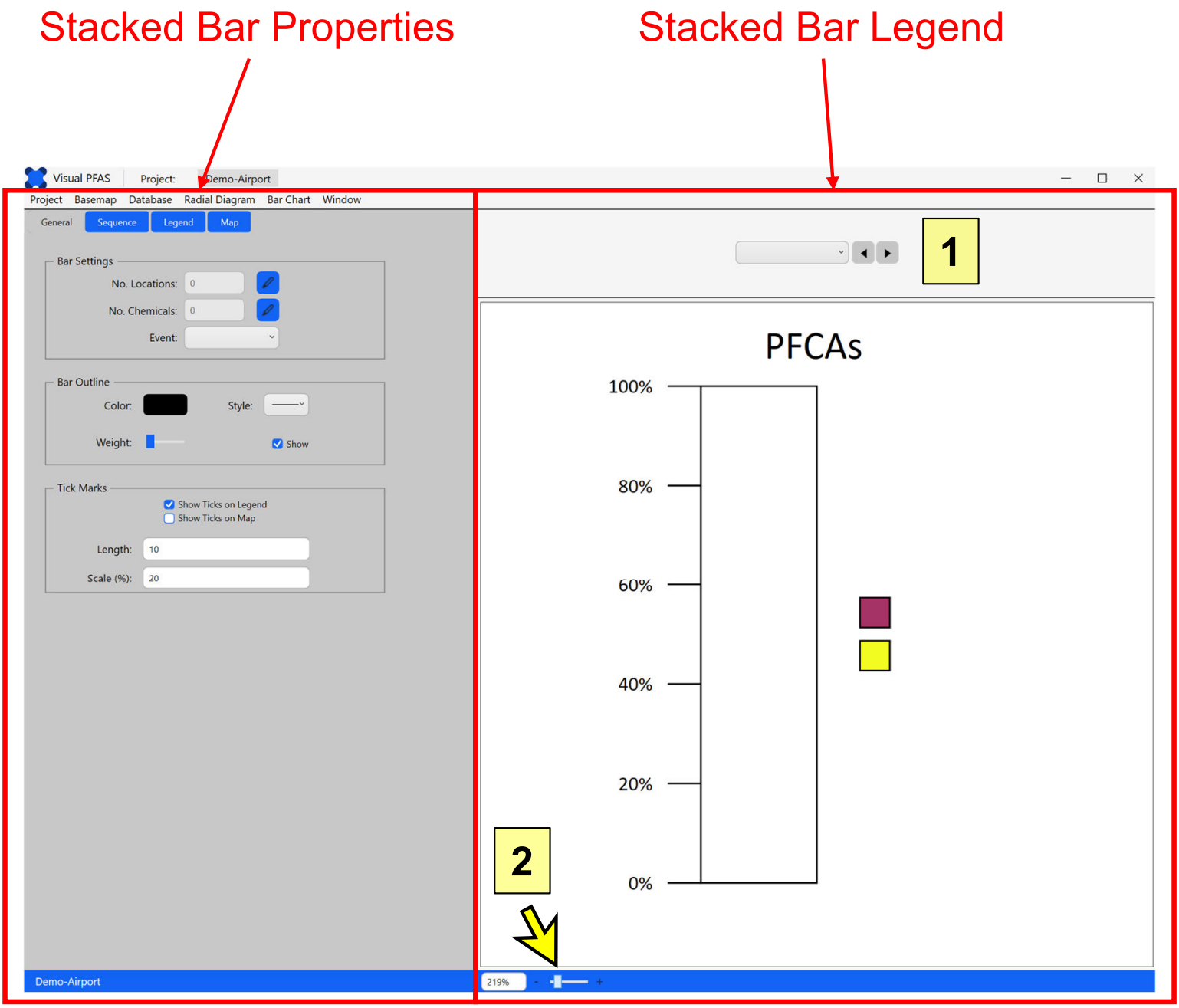
Enter the new stacked bar property filename: *PFCAs* (see "2" below). Then Click the **Save** button to create this new property file.

> **Note:** Users should not attempt to open these *.bar files outside of Visual PFAS™ as it may result in file corruption.



Upon creating a new property file, the stacked bar window below will appear as shown below with two components: Stacked Bar Properties on the left, and the Stacked Bar Legend on the right. There are no colors shown in the legend yet because we have not yet entered the list of chemicals, monitoring locations, and the monitoring event to use for the stacked bar as part of this tutorial. When selected, users can cycle through monitoring locations to view changes in the stacked bars between locations (see "1" below).

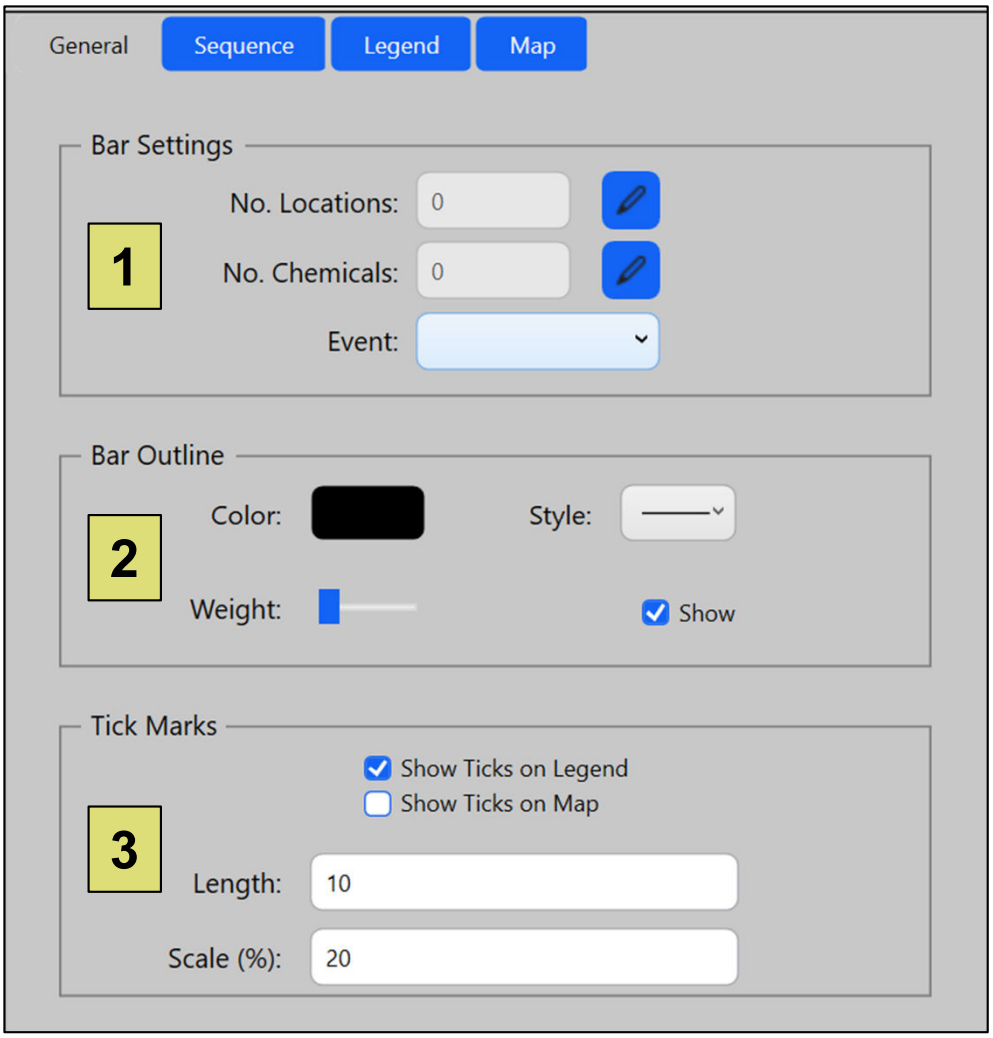
The stacked bar in the legend will initially appear as small on the screen to allow for small display screens. You can increase the size of the stacked bar by scrolling the size bar at the bottom of the legend (see "2" below).



5.3 General Properties

General properties for stacked bar maps are listed below, where the number coincides with the labels shown on the image below representing initial default settings for stacked bar maps.

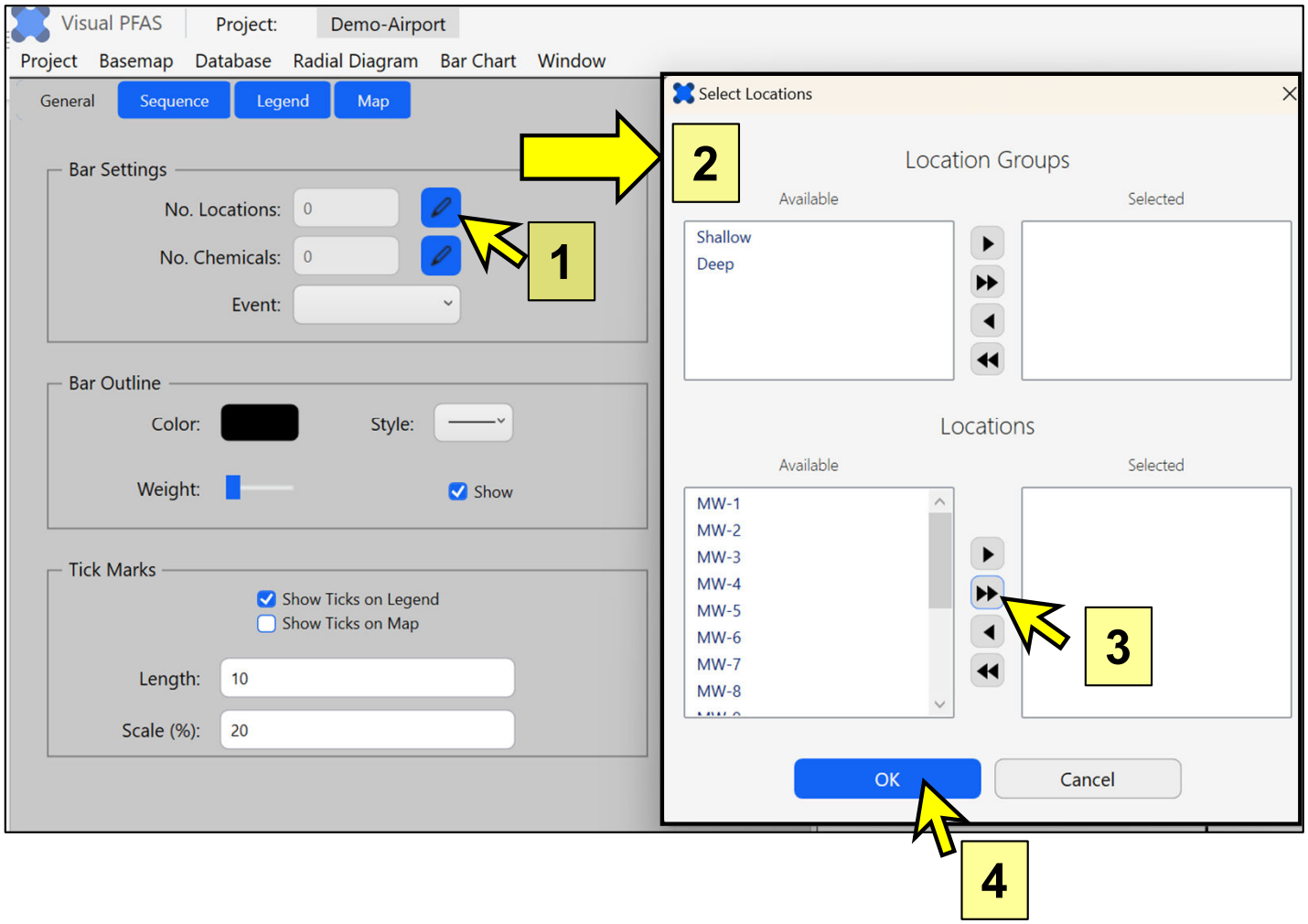
1. **Bar Settings** – including specification of:
    - Monitoring well or soil boring locations at which stacked bars will be shown on the basemap;
    - Chemicals to represent in the stacked bar; and
    - The monitoring event to be used for determining chemical concentrations in the project database.
2. **Bar Outline** properties (e.g., line color, style, weight, and show/hide); and
3. **Bar Tick Mark** properties (e.g., show/hide in legend; show/hide on map; length in map units; and tick mark scale i.e., intervals).



5.3.1 Selecting Monitoring Locations

To select all site monitoring wells for this tutorial:

1. Click the **Edit** icon next to No. Locations (see "1" below).
2. The **Select Locations** window will pop-up (see "2" below). This is where you select which well locations will have stacked bars shown on the basemap. (See pages 4.13 to 4.15 in Chapter 4 with more information on how to select locations and use location groups in this window.)
3. Click the ⏩ button to move all monitoring well locations from the **Available** list to the **Selected** list (see "3" below).
4. Click OK to close the Select Locations window (see "4" below).



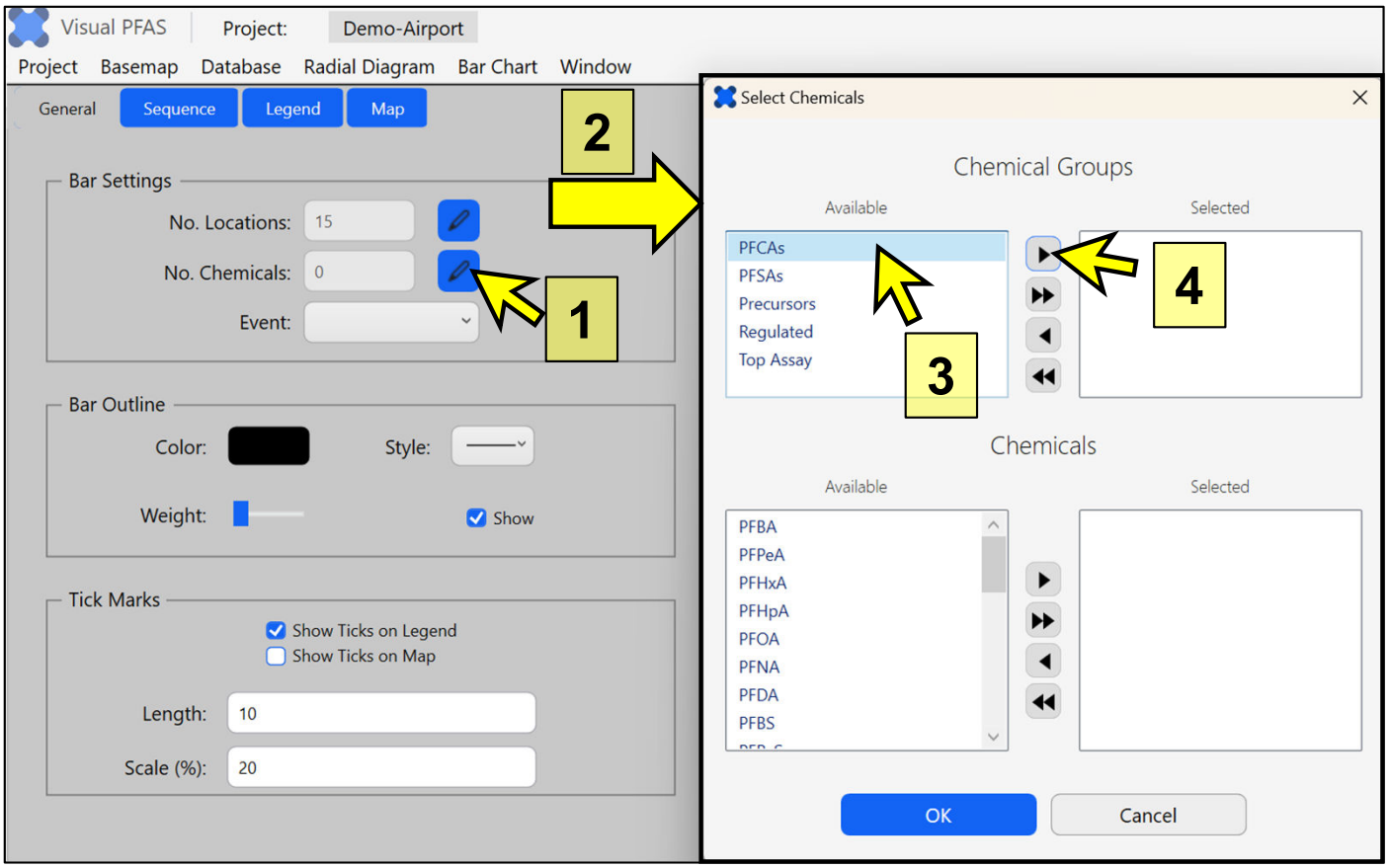
After closing the Selection Locations window, the No. Locations textbox will change to 15 as shown in the image on the left.

5.3.2 Selecting Chemicals

To select the chemicals to be represented in the stacked bar:

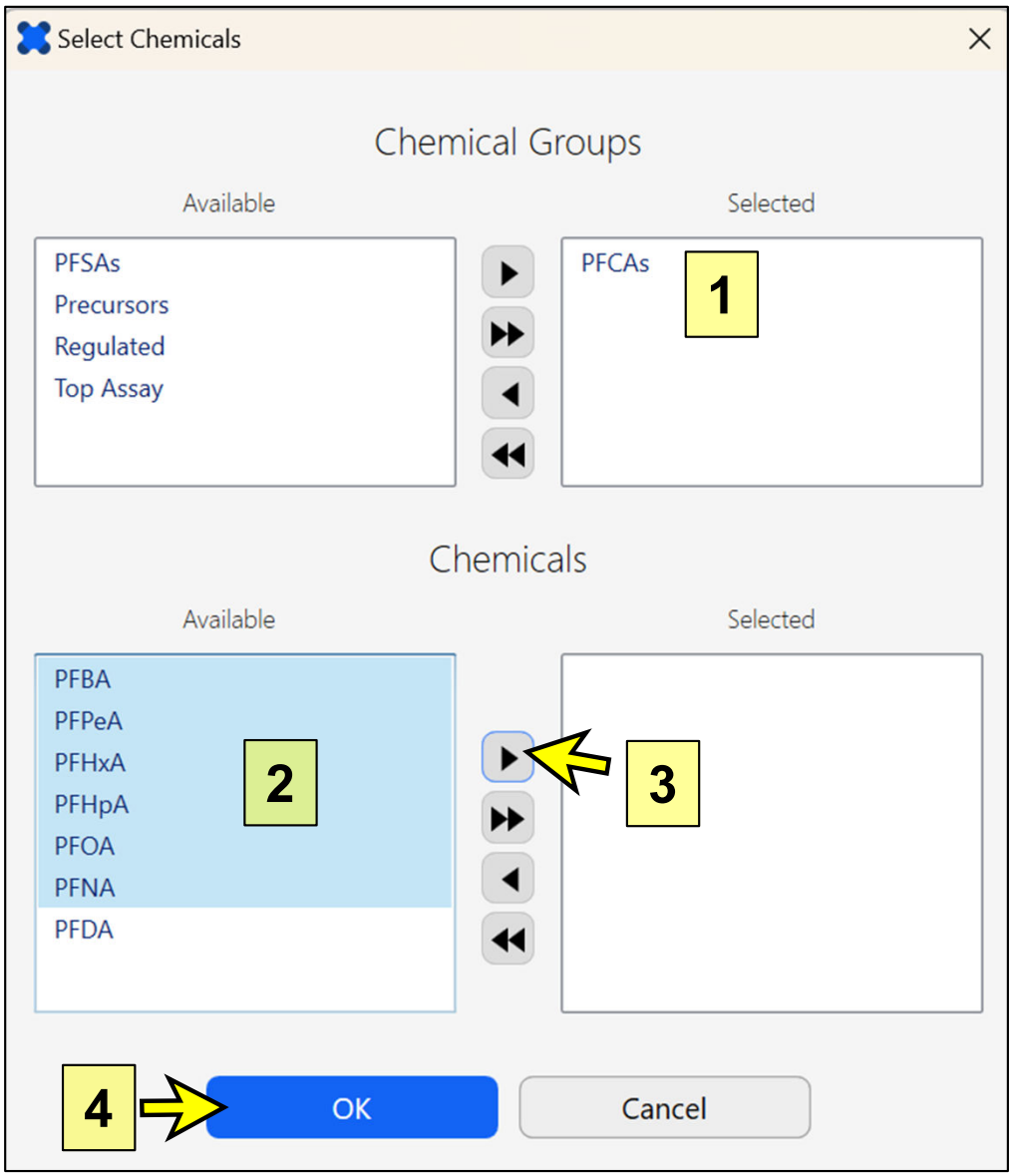
1. Click the **Edit** icon next to No. Chemicals (see "1" below).
2. The **Select Chemicals** window will pop-up (see "2" below). This is where you select which chemicals are to be included in the stacked bars.
3. Click on PFCAs in the Available Chemical Group list, so this row is highlighted in blue (see "3" below).
4. Click the ▶ button associated with the Chemical Groups lists to move this group from the **Available** list to the **Selected** list (see "4" below).

> **Note:** The order of chemicals selected does not matter at this point – you will specify the sequence for chemicals in the stacked bar later in the tutorial.



After selecting PFCAs as the chemical group (see "1" below), the list of **Available** chemicals will be filtered to only show the chemicals that are included in this group. For the stacked bar in this tutorial, we want to select the first six PFCAs in the **Available** list (see "2" below) because PFDA typically has lower concentrations at AFFF-impacted sites.

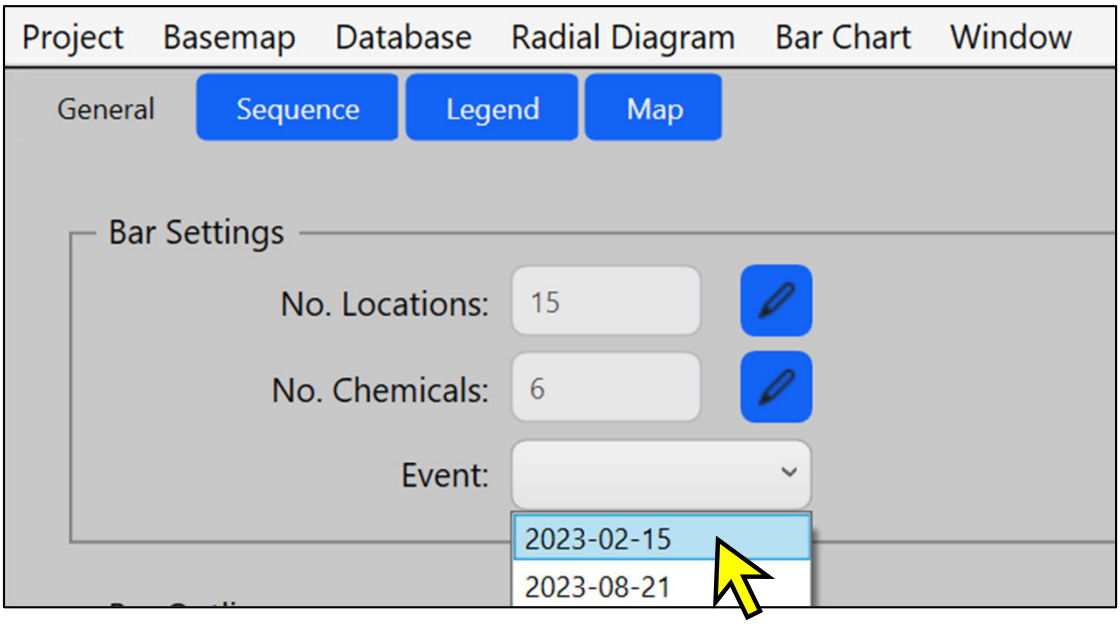
To select six of the seven PFCAs, click on *PFBA* and then hold the shift key before clicking PFNA (and then release the shift key). This will select all chemicals between *PFBA* and *PFNA* in the **Available** list as shown with the blue highlighting below (see "2"). Then click the ▸ button to move these chemicals to the **Selected** list (see "3" below), and click **OK** to save the selection (see "4" below).



5.3.3 Selecting the Monitoring Event

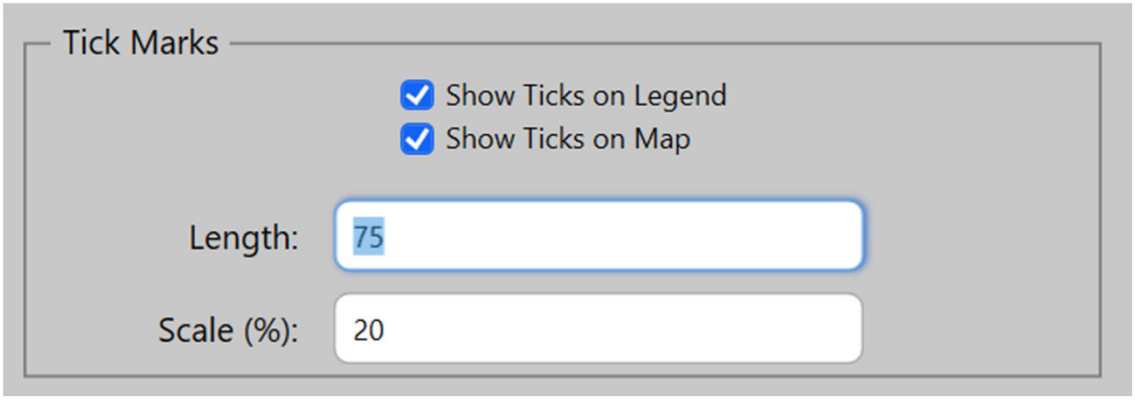
After selecting the chemicals, the No. Chemicals textbox will change automatically to 6.

To select the monitoring event, click on the Event dropdown box and select the 2023-02-15 event from the list (see arrow below).



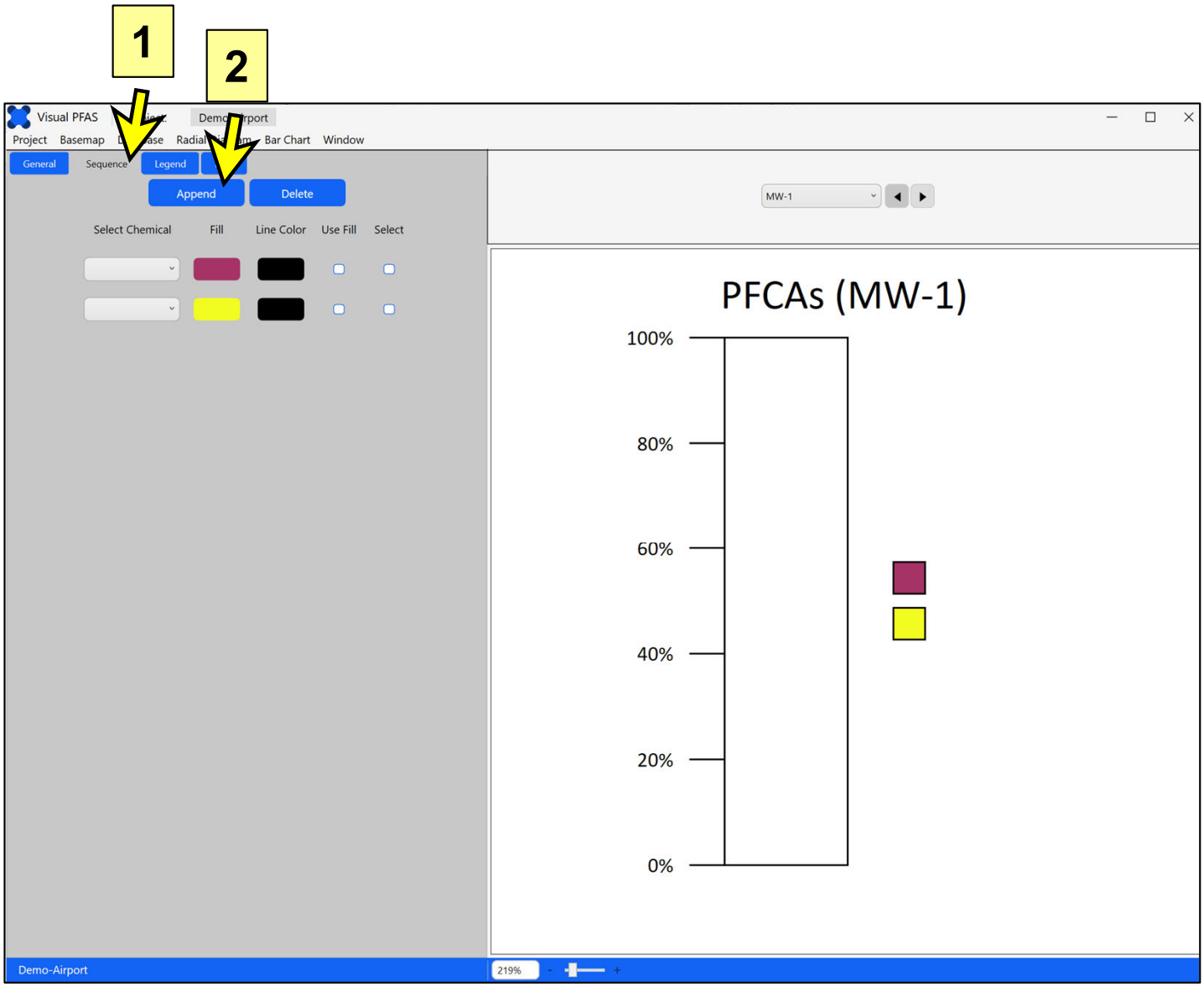
To finish the specification of general properties, click the Show Ticks on Map checkbox to turn this on (i.e., with a checkmark showing) and change the tick mark length to 75 map units as shown below.

The tick mark length needs to be sufficiently large on the basemap that it will be seen when viewing the site basemap. It may take several iterations to find the tick mark length (in map units) that works best.



5.4 Chemical Sequence Properties

The next step is to specify the order of chemicals that are to be represented in the stacked bar. The image below shows what you will see when first clicking on the **Sequence** tab (see "1" below), prior to the specification of chemicals.

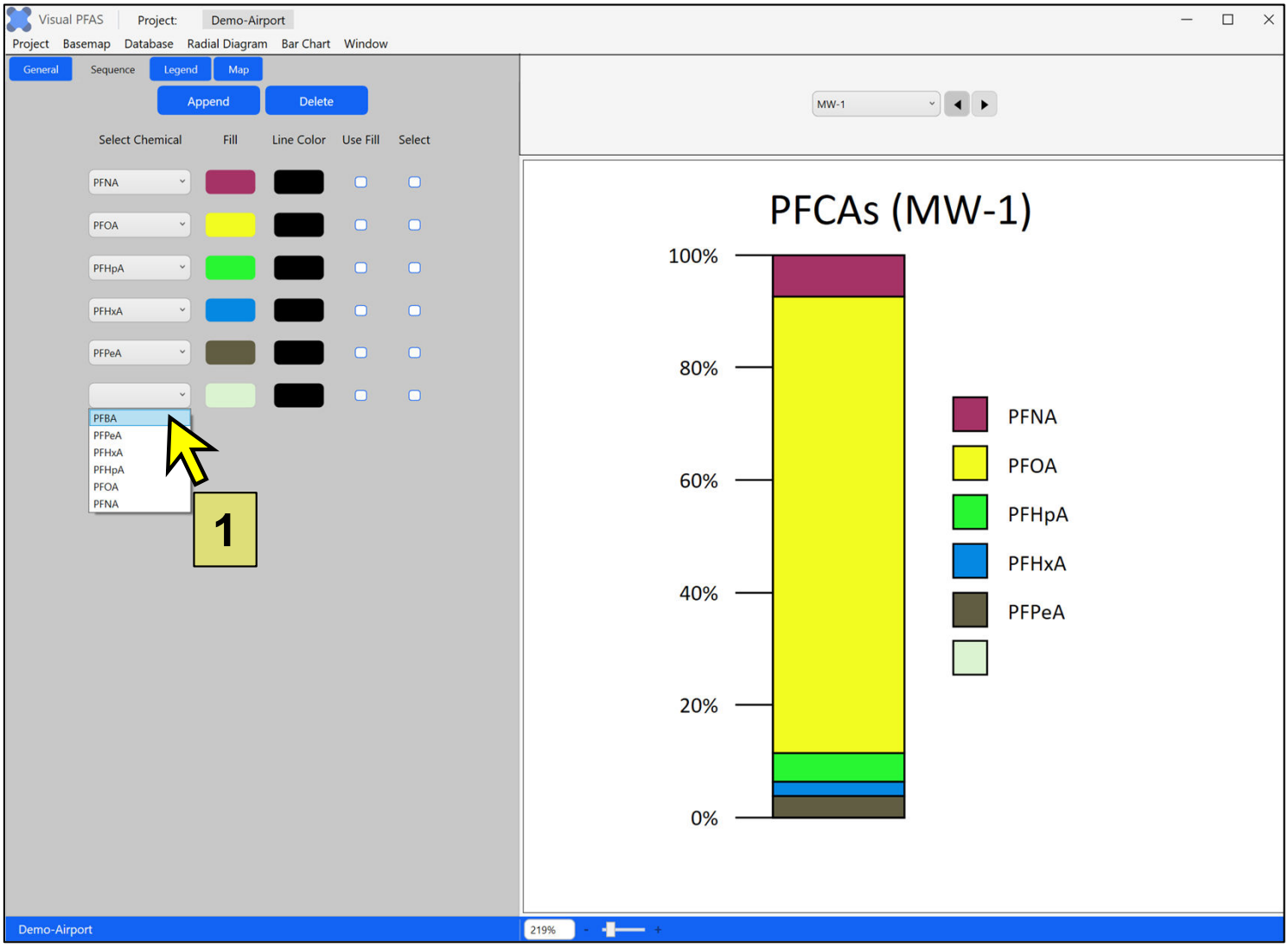


Then click the **Append** button (see "2" above) four times, so that there is a total of six dropdown boxes shown. Colors will be randomly picked for each of these six chemical series, similar to the approach used in Microsoft Excel when data series are added to a chart.

Chemical dropdown boxes are used to selecting each the six chemicals from the list previously specified in Section 5.3.2. The dropdown boxes are listed in a top-down sequence corresponding to the chemicals to be shown in top-down order in the stacked bar.

Click on the upper-most chemical dropdown box and select *PFNA*. This is the chemical that will be shown at the top of the stacked bar.

Then proceed sequentially down the list from top to bottom, selecting in the order of longest to shortest chain length after PFNA: PFOA, PFHpA, PFHxA, PFPeA, and PFBA (see "1" below).



After specifying the sequence of chemicals for the stacked bar, the next step is to specify fill colors for each chemical interval. (The default line color is black.)

Using the color dialog box functions described in Section 3.3.1 of Chapter 3, specify the following RGB fill colors for the six chemicals top-down order in the stacked bar:

- PFNA: 250, 3, 3
- PFOA: 244, 202, 96
- PFHpA: 250, 248, 148
- PFHxA: 7, 88, 17
- PFPeA: 120, 172, 110
- PFBA: 200, 241, 199

RGB color codes

Note: As discussed in Section 3.3.1, RGB colors may be specified by right-clicking in the color palette of the color selection window, then clicking the RGB menu option, and finally, entering the RGB color codes directly.

Note: Using a black line color is typical in stacked bars so that each chemical interval is easier to see on a site map. Users can change the line color if desired, including specifying that the line color is the same as the fill color. To specify that the chemical interval line color is to be the same as the fill color, click the **Use Fill** checkbox to turn on this option. The line color will automatically change to be the same as the fill color.

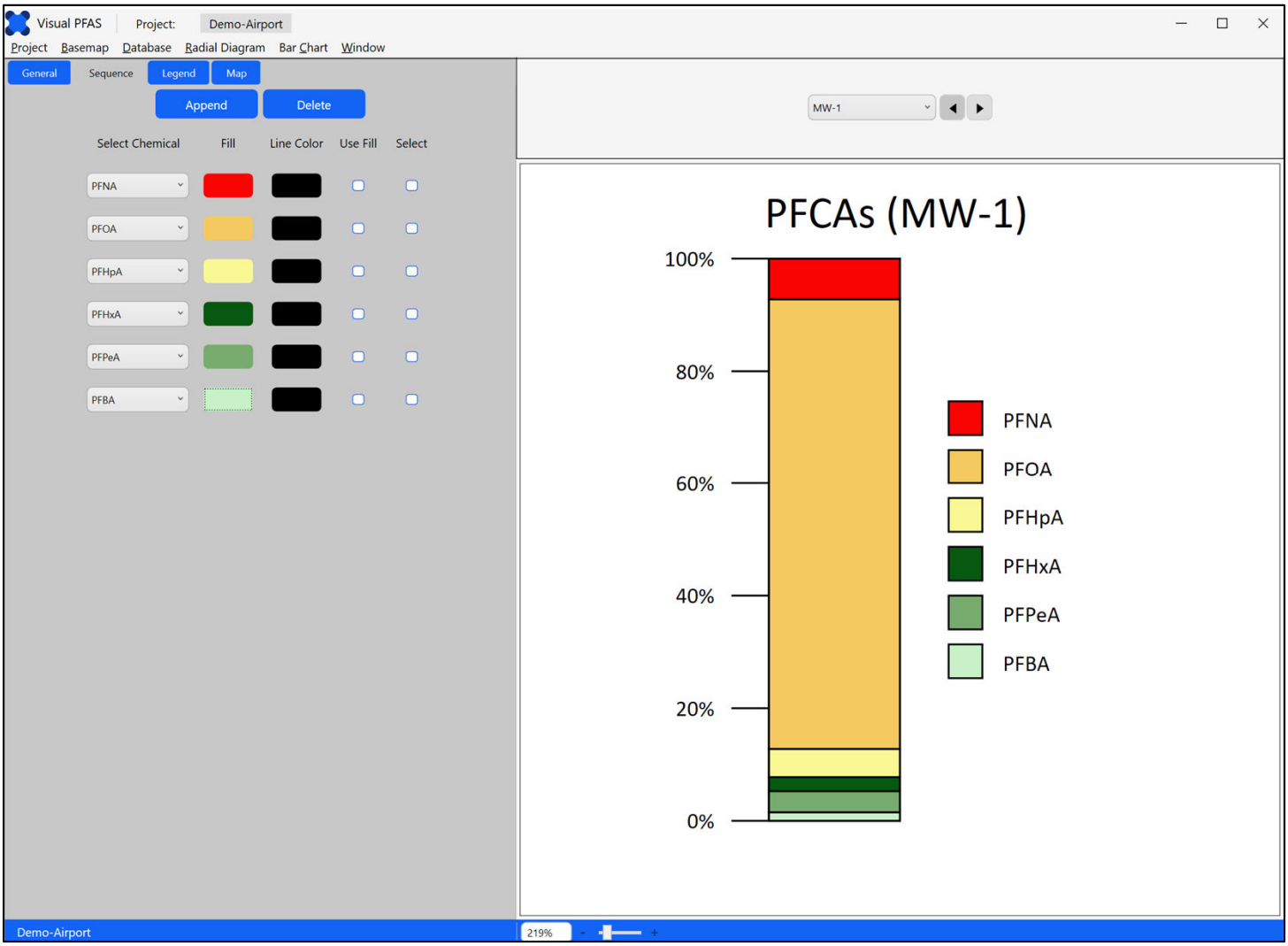
If the fill color is changed, then this **Use Fill** checkbox will automatically be switched off so that the line color does not change unless you click this checkbox again.

Using the RGB color codes specified on the previous page, the stacked bar for MW-1 will look like the bar in the image below.

Note how the short-chain PFCAs were all assigned a green shade (from light to dark for shortest to longest chain of these three species). The long-chain PFCAs were assigned shades of yellow, orange and red from lightest to darkest for shortest to longest chain.

Using grouped colors like this helps to more quickly distinguish between total short- and long-chain PFAS concentrations in stacked bar maps.

Note: Users can click the monitoring location dropdown box at the top of the stacked bar legend to change which location is shown in the legend. Alternatively, users can use the right or left arrows next to the location dropdown box to cycle forwards or backwards through the list of selected monitoring locations in the legend. This provides a quick and simple approach for viewing stacked bars separately for each monitoring location before plotting these on the basemap.



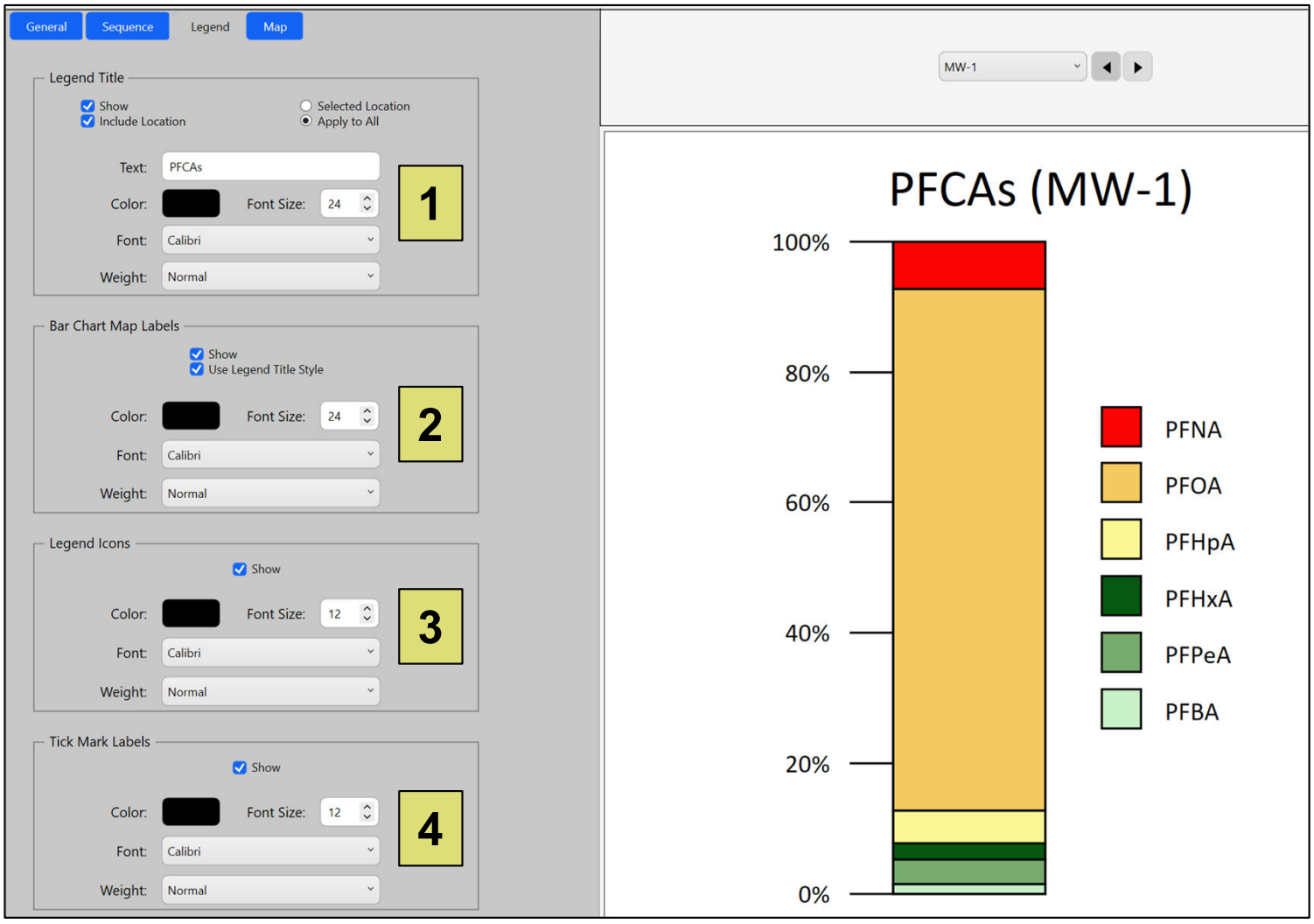
5.5 Legend Properties

Legend properties include options for the features listed below, which correspond to the numeric labels shown on the image at the bottom of the page:

1. Changing the appearance of the legend title;
2. Showing location labels above each stacked bar on the basemap, and properties associated with the labels such as font color, size, style, and weight;
3. Showing the color intervals legend and font properties; and
4. Tick mark labels (show/hide and font properties).

You can try changing some of these legend properties to view the corresponding effects on the legend appearance.

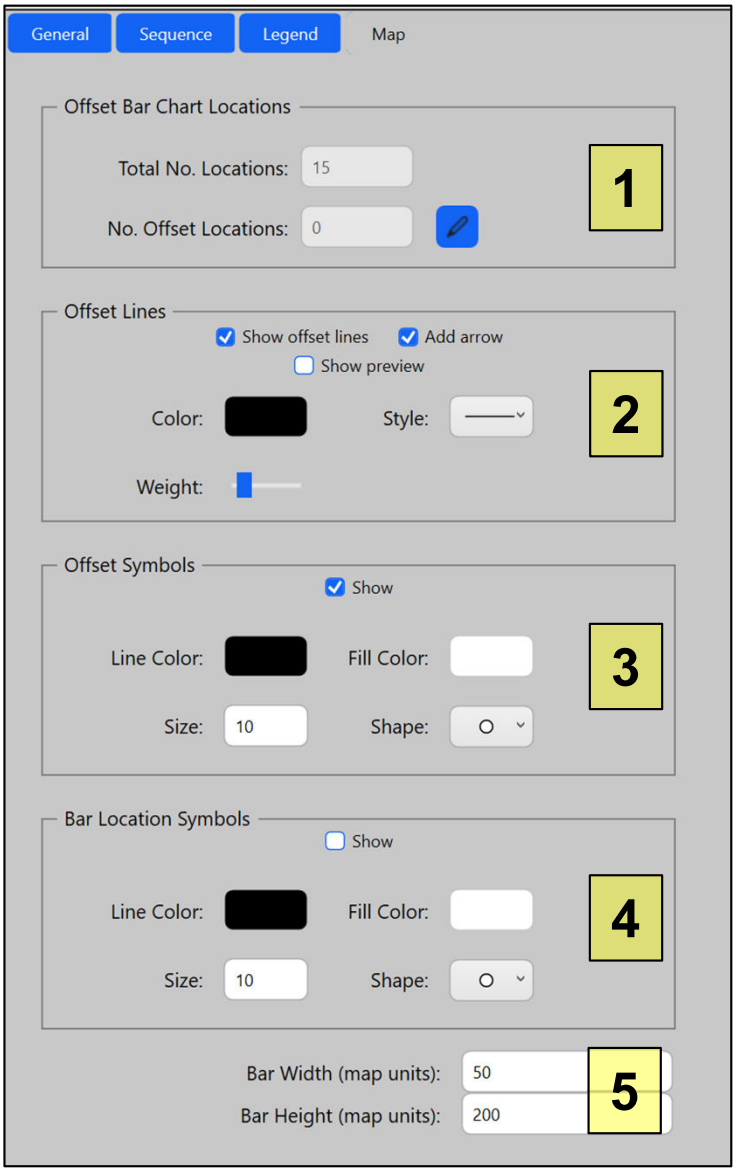
Note: Changing the Bar Chart Map Labels (see "2" below) will only affect the labels shown on the stacked bar basemap; these changes will not be reflected in the legend.



5.6 Map Properties

Click on the **Map** tab to view map properties related to the following categories which correspond to the numeric labels shown in the image below.

1. **Offset Bar Chart Locations** from the original locations, to avoid overlapping of bars at locations that are adjacent to each other.
2. **Offset Lines** (or arrows) that are optionally shown between the offset bar(s) and the original location(s).
3. **Offset Symbols** which are plotted to show the original location(s) that have been offset to avoid overlap with adjacent locations.
    - The symbol size is in map units. If offset symbols do not appear to be shown on the basemap, it may be that this size is too small. The size should reflect the symbol size in map units (e.g., feet or meters).



4. Bar location symbols which are optionally shown at the bottom of each stacked bar on the basemap, to illustrate that the monitoring location is at the bottom-center of each stacked bar.

Offsetting stacked bars is based on the same process described in Chapter 4 for offsetting radial diagram locations (see p. 4.33 to 4.38 for a tutorial example).

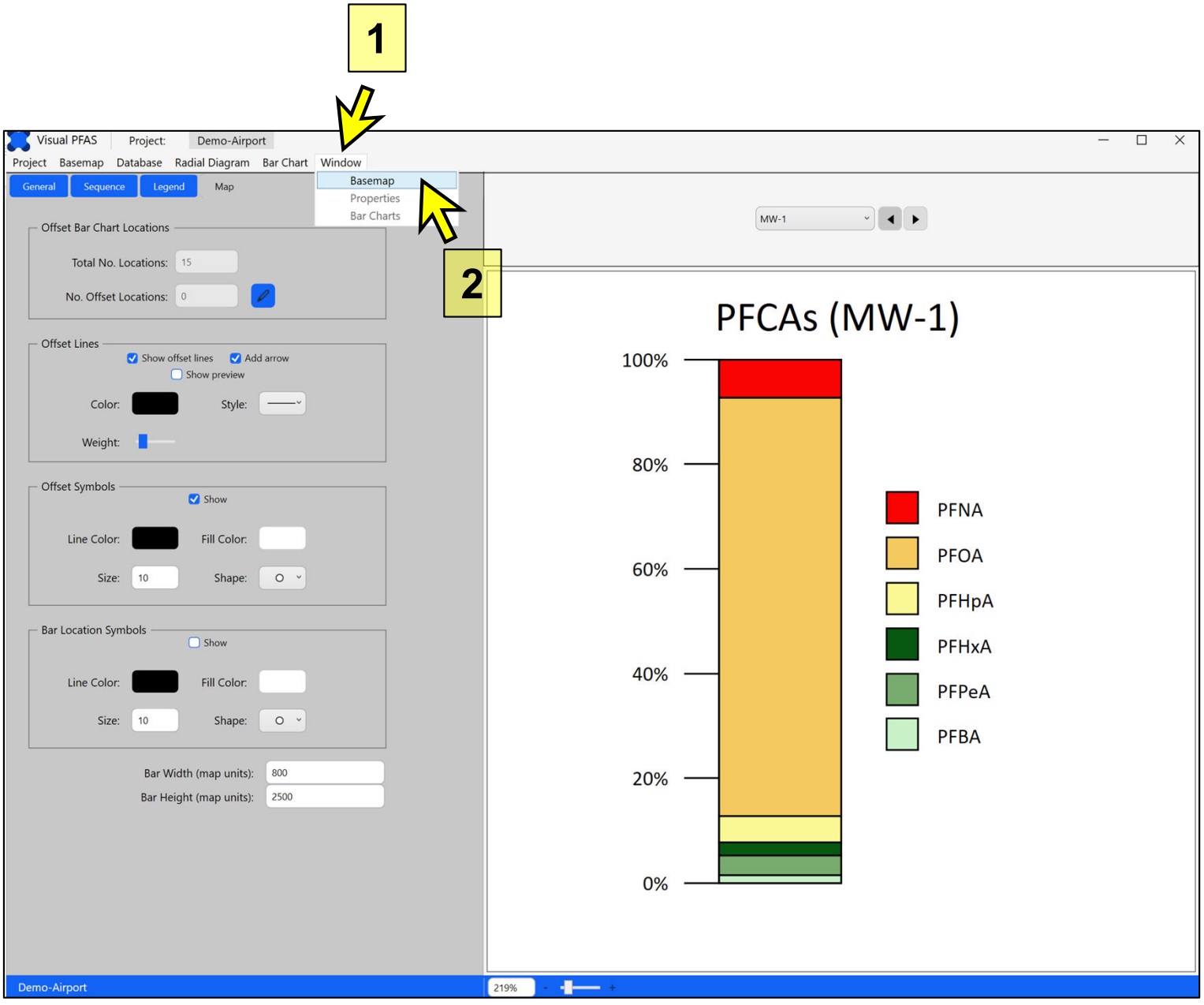
The width and height of the bar (in map units) are shown at “5” in the image on the left. The bar width and height can also be changed from the basemap window directly, which reduces the number of iterations required to go back-and-forth between the stacked bar basemap and property windows.

For this tutorial, change the bar width to 800 ft (map units) and the bar height to 2500 ft at “5” on the left.

5.7 Viewing the Stacked Bar Map

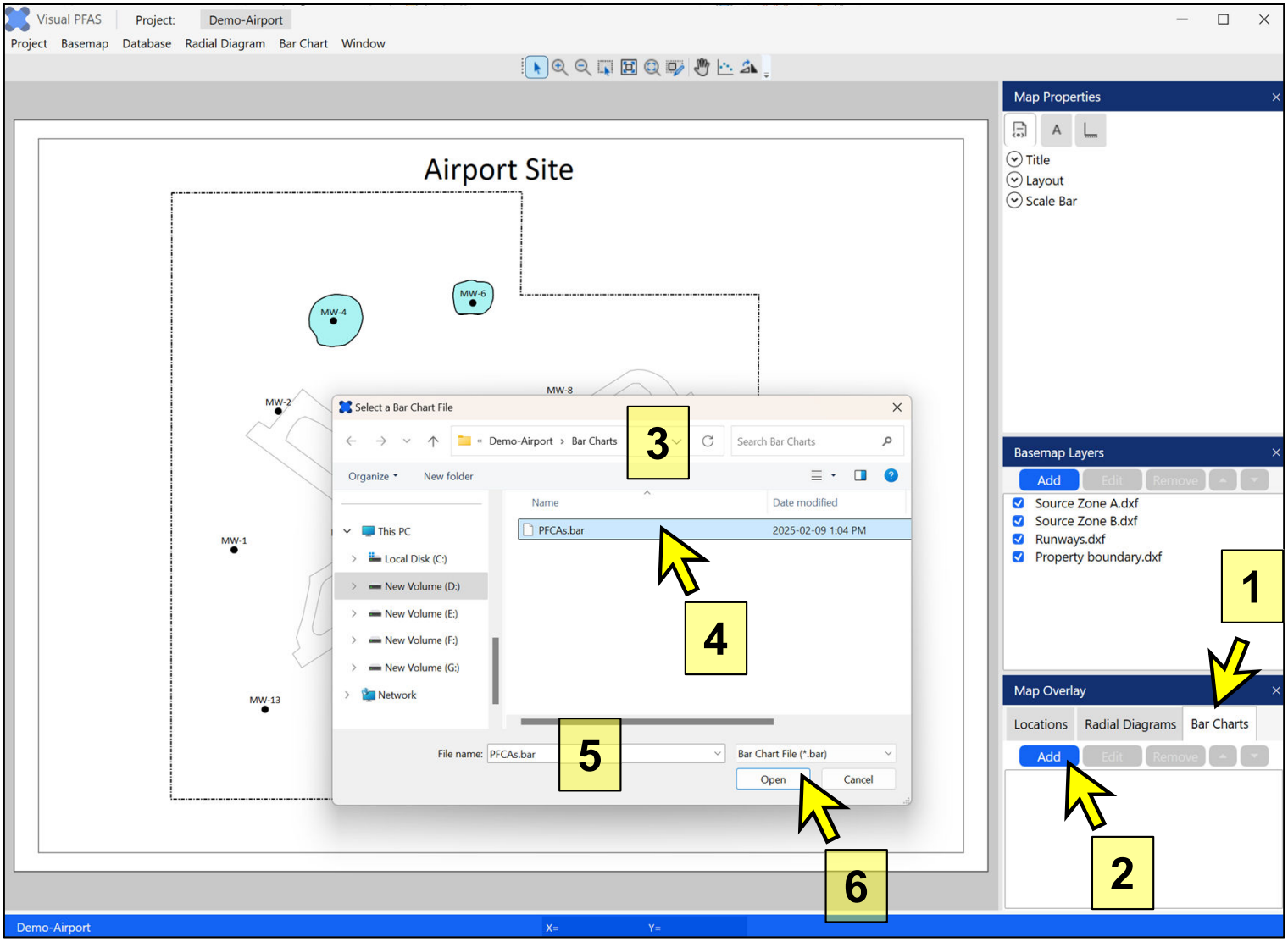
While Visual PFAS™ does incorporate an Auto-save function, it is good practise to save the properties during an editing session. This is done by clicking on the **Bar Chart** menu option at the top and clicking **Save** *PFCAs*.

Now we're ready to plot the stacked bar layer on the site basemap. Click the **Window** option at the top menu (see "1" below and click the **Basemap** menu option (see "2" below) . This allows you to switch to the **Basemap Window**. You can also do the reverse process to return to the **Bar Chart Window** shown below.



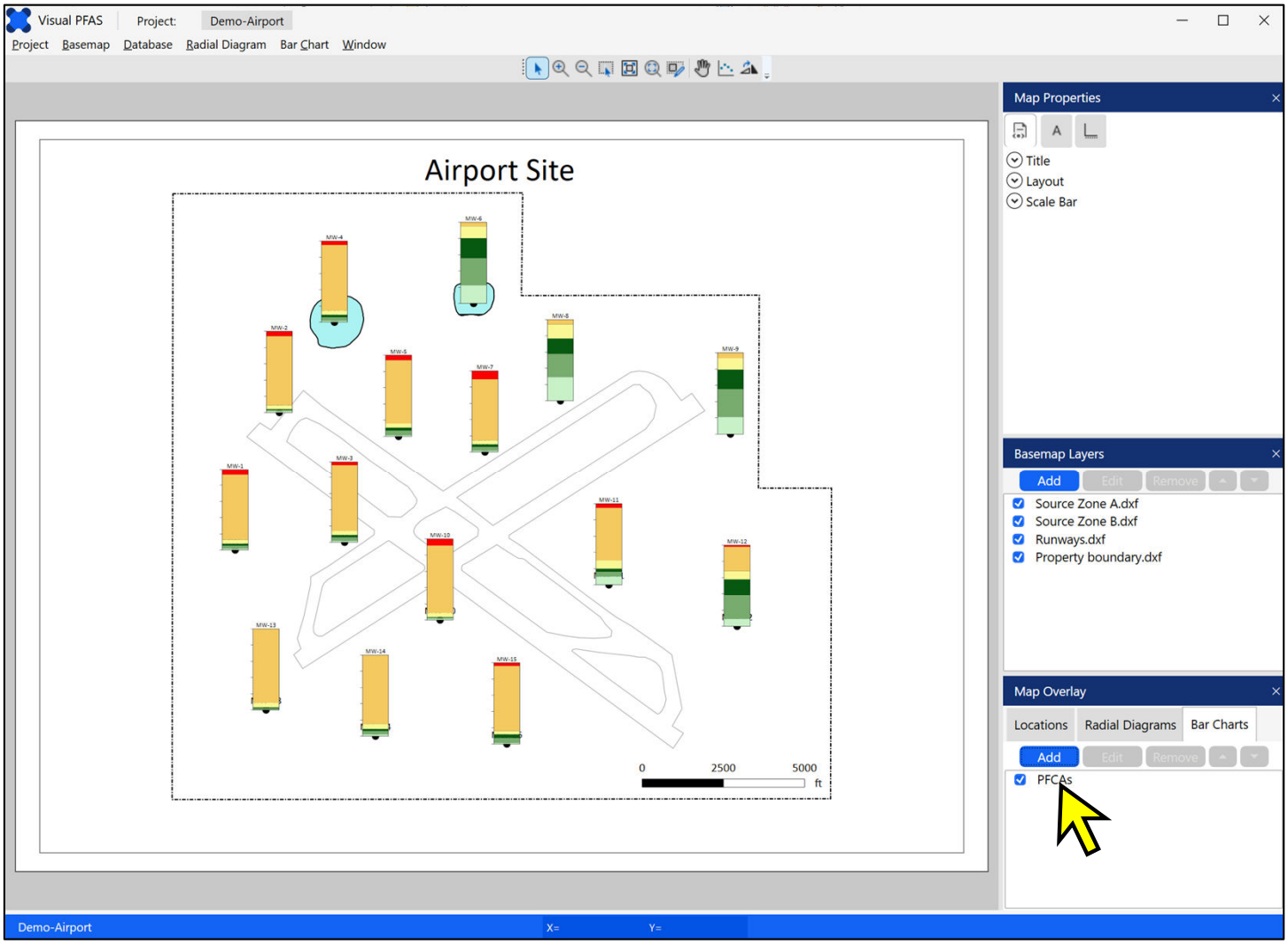
From the **Basemap Window**, click on the **Bar Charts** tab in the **Map Overlay** section at the bottom-right of the window (see “1” below). Then click the Add button to overlay a stacked bar layer on the basemap (see “2” below).

A file explorer window will pop-up and will automatically show the available stacked bar property files in the **Bar Charts** sub-folder (see “3” below) under the current project folder. Click on the *PFCAs.bar* file just created in the previous section of this tutorial (see “4” below); this will automatically fill the **File name** text box below (see “5”). Then click **Open** to add this stacked bar layer as an overlay to the basemap (see “6” below).

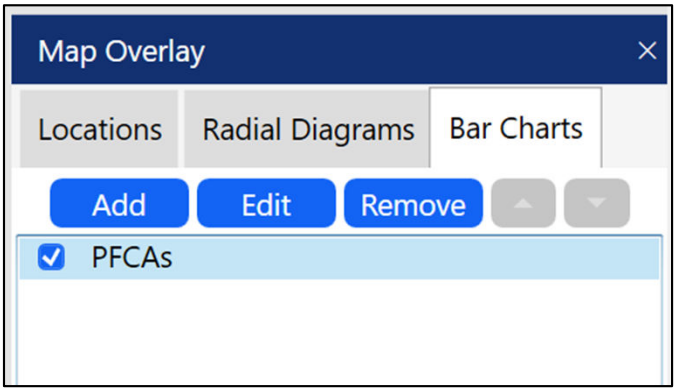


The Basemap Window will now show the stacked bar layer (see below).

To edit several stacked bar properties from this window, click on the PFCAs stacked bar layer in the Map Overlay section (see arrow below).



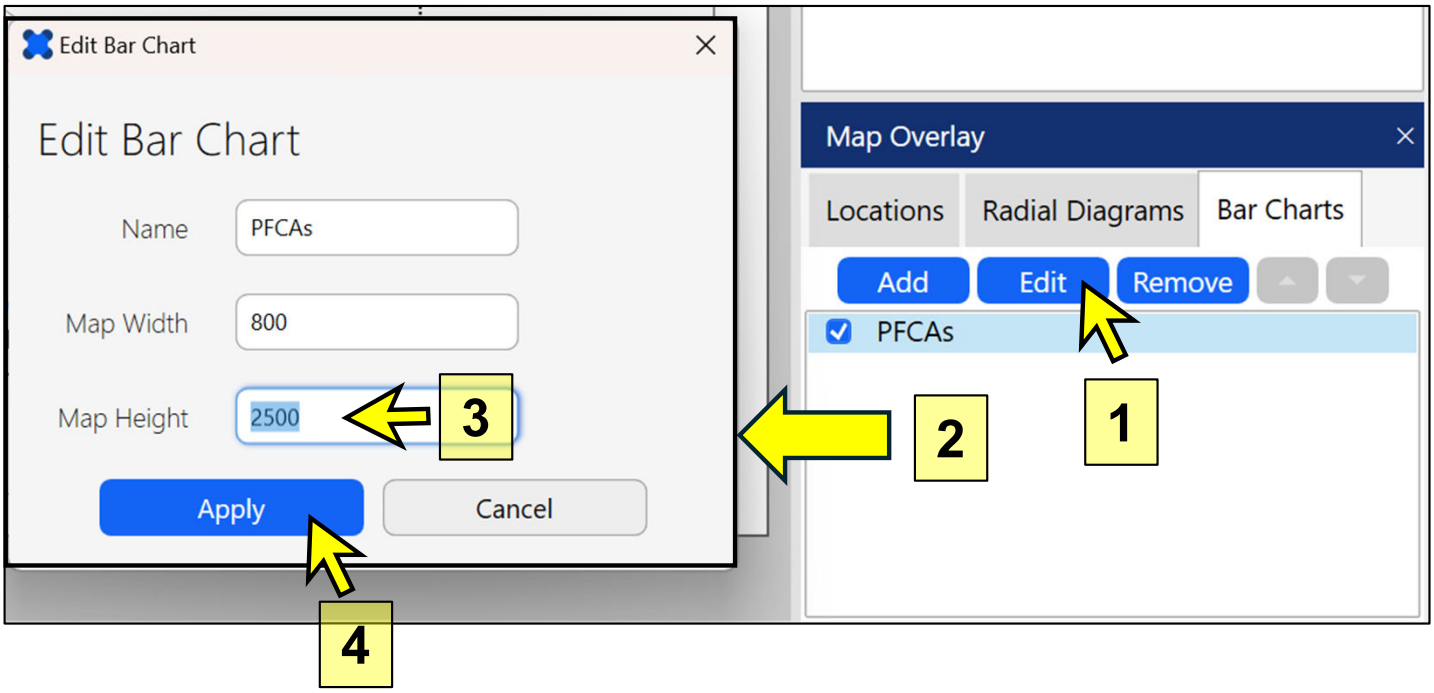
Once you have selected PFCAs as the current stacked bar layer, the **Edit** and **Remove** buttons change to blue from being grayed out, as shown below. This means that the **Edit** and **Remove** buttons are now enabled because a stacked bar layer has been selected.



Click the **Edit** button (see "1" below), which will cause the **Edit Bar Chart** window to pop-up (see "2"). This allows you to quickly change the bar width and/or height and see the effects immediately on the basemap after making the change. In this manner, you can avoid having to return to the Bar Charts Window, making the change on that form, and then using the Window menu to return back to the Basemap Window.

Select the original height defined (2500) as shown at "3" below, and change this to 3000 so that the bar height will increase slightly. Larger bars on the map make it easier to visualize trends between monitoring locations and source areas. It may take several iterations to finalize the bar height and width for a site basemap.

Click Apply to save this change (see "4" below). The stacked bar layer on the basemap will change immediately to reflect this new height.



5.8 Printing and Exporting Stacked Bar Maps

The stacked bar map **Print** and **Export** options are the same as those described previously for basemaps (see Section 3.7), and for radial diagrams (see Section 4.9).

When printing a basemap to PDF or a printer, it will include any stacked bar and/or radial diagram layers currently shown on the basemap. The same applies if a basemap is exported to an image or PDF file.

When exporting stacked bar maps to a CAD DXF or Surfer bln file, only the stacked bar layer will be exported to the respective file type. Separate DXF or bln files will be created for the stacked bar outline and bar tick marks, and one file will be exported to represent each chemical series. This allows users to import these files as different layers to CAD, GIS, or Surfer and apply different line and/or polygon properties to each. Offset location symbols (if applicable) will be saved to an x,y text file (*.dat).

The stacked bar legend can be exported separately to an image file or PDF by choosing the Bar Chart → Export Legend menu option. The exported stacked bar basemap and legend can be combined using software such as Microsoft PowerPoint for making a presentation or final report figure.