PLUMBING VOLUME ESTIMATOR TOOL

Guidebook

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Abbreviations

CPVC: Chlorinated polyvinyl chloride
ft: foot
in: inches
mL: milliliter
mm: millimeter
Nominal size: Standard size designation
PEX: Cross-linked polyethylene
PSI: Pounds per square inch
PVC: Polyvinyl chloride
Sc80 (Sched 80): Schedule 80 (refers to the wall thickness of a pipe, schedule 80 has a thicker pipe wall than schedule 40)
Sc40 (Sched 40): Schedule 40 (refers to the wall thickness of a pipe)
SDR: Standard Dimension Ratio (the ratio of the outside diameter of a pipe, to wall thickness)

Introduction

This Excel file was created for the purpose of generating a plumbing map for a building. A plumbing map is comprised of all the various plumbing materials in a building along a specific water flow route. It includes the plumbing material types and lengths and calculates the volume of water contained within each section. This information can provide the user with a more realistic understanding of the volume of water along a length of plumbing (ex. from faucet tap to main) and allows the user to pinpoint lead source locations or potential lead source locations (ex. copper pipe with lead/tin solder, lead service line, galvanized iron pipe) by water volume.

This information can then be used to tailor meaningful water sampling for lead (or other contaminants), rather than relying on a static volume (such as first liter) (Triantafyllidou et al., 2021). For example, with this tool users will be able to calculate the volume of water at an individual residence between the resident's faucet tap and the water main. This reduces uncertainty in sequential (profile) sampling for lead sources as the user will be able to more accurately estimate the volume of, and number of bottles needed to capture all potential sources, improving laboratory estimates, and reducing costs by not overestimating supplies and analyses. Users will also be able to pinpoint lead sources and can therefore sample water that has sat stagnant with those identified sources of interest. An improvement over relying on static volumes that may not represent lead sources in an individual building being evaluated, as plumbing configurations vary (Triantafyllidou et al., 2021).

Configuration

The plumbing volume estimator tool is a Microsoft Excel file. Within the zip file there are two versions of the tool, one with macros to assist the user in data entry PlumbingVolumeEstimatorTool_Macro-Enabled.xlsm) and one non-macro version (PlumbingVolumeEstimatorTool_Non-MacroVersion.xlsx). The non-macro version is for use on platforms that do not support/allow use of macros. This tool was designed using Microsoft Excel for Microsoft 365 MSO 64-bit, on a Windows 11 Enterprise Operating System.

How to use the macro-enabled file

First, the user must "Enable Content" by clicking the "Enable Content" button shown in Figure 1. Then the user will have access to the macro-enabled "Mapping Tool" sheet.

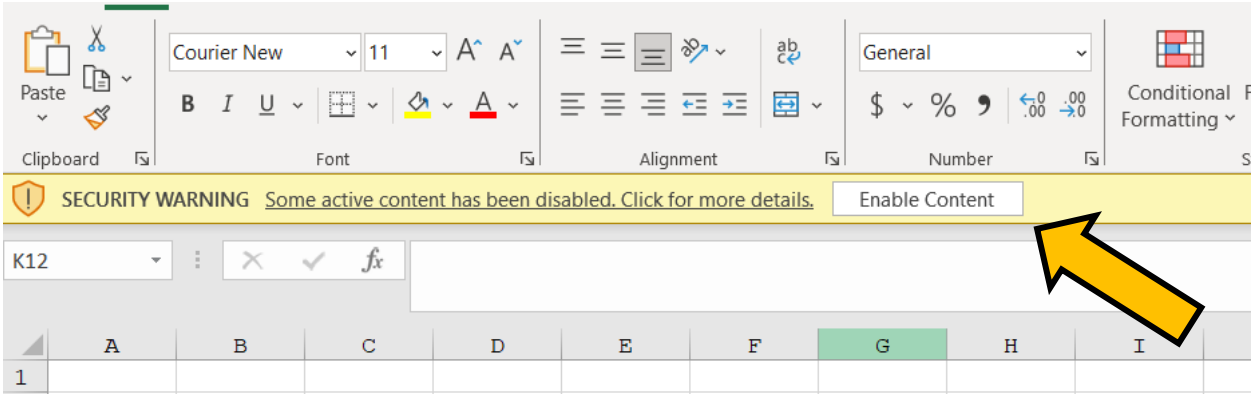

Figure 1. Opening screen- enable content for macro-enabled file.

Mapping Tool Tab

Mapping Tool Sheet: This sheet has 3 buttons that display the options for using this tool (Start, Save, and Clear Data) (Figure 2).

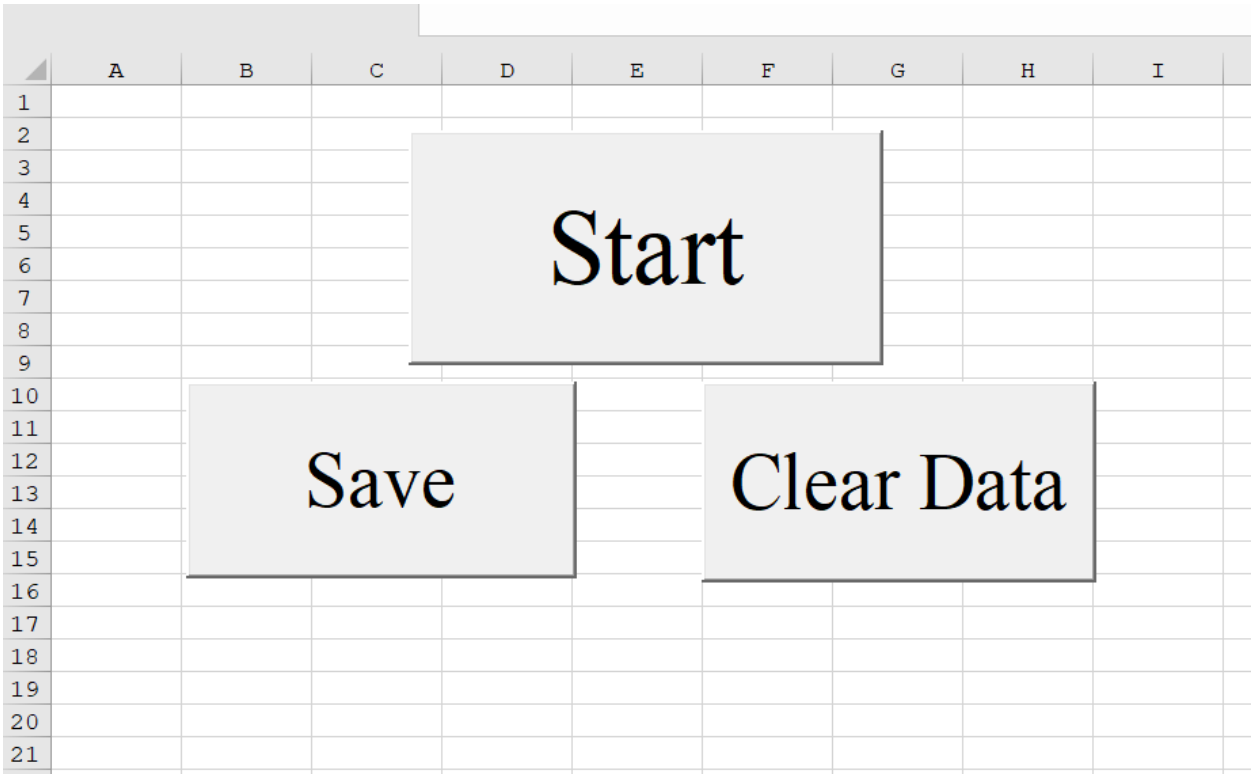

Figure 2. Opening screen- Mapping Tool Sheet tab.

Start button

This button opens a pop-up window (Figure 3) that allows for guided data entry.

Figure 3. Pop-up window for site details that comes up after the user clicks "Start".

Two colors are used to assist the user in the data entry process: the light blue filled buttons can be selected and filled out with information from the building being mapped. The light green filled buttons are where the user will move onto the next step until data entry is complete.

The first step is to enter site details by selecting "Site Information" (Figure 3), the user can input their own site ID and the physical address. A pop-up window will facilitate data entry beginning with site ID (Figure 4), then clicking "OK" will trigger the next pop-up window for site address entry and another "OK" will take the user back to the original pop-up window (Figure 3).

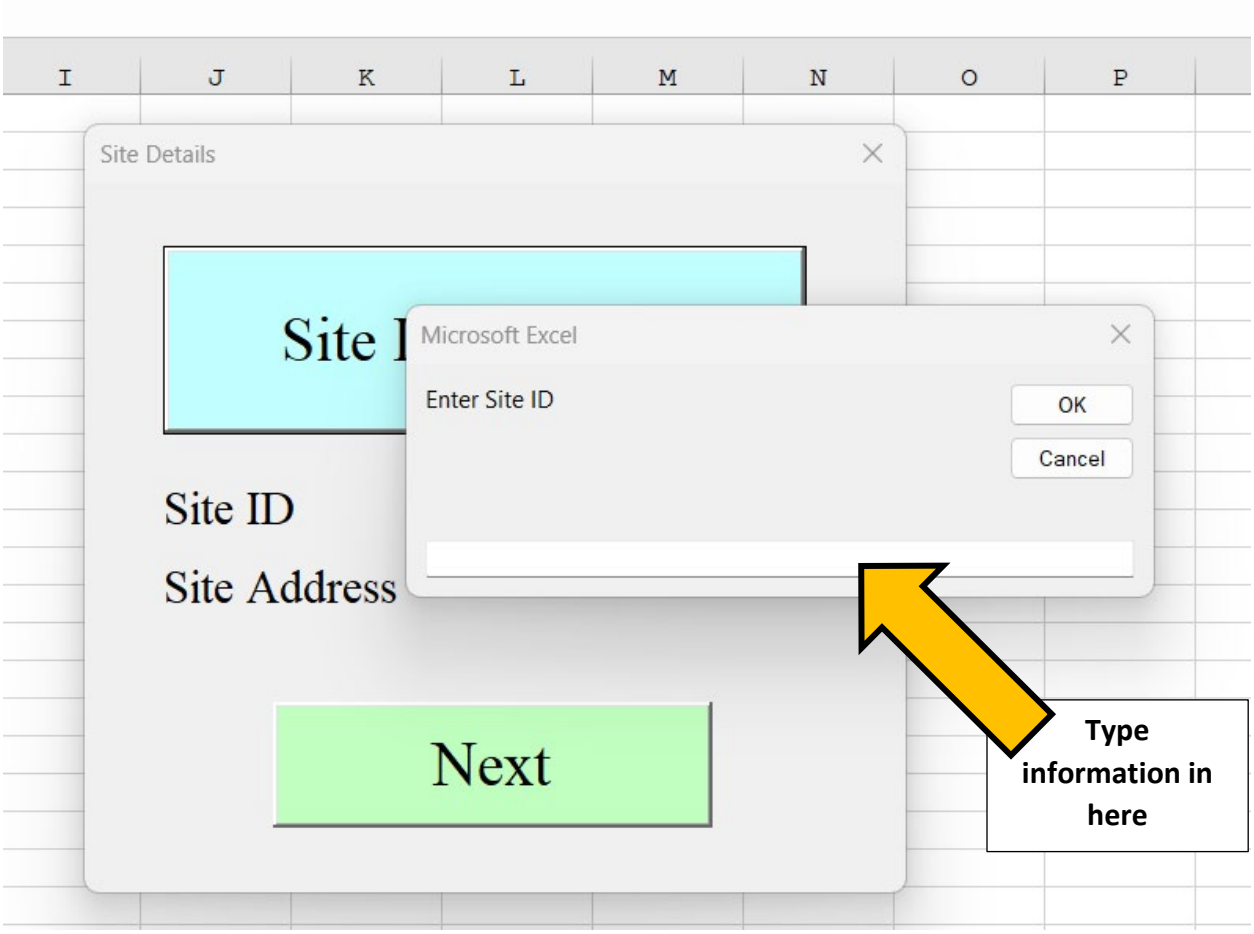

Figure 4. Pop-up window after clicking "Site Information" button.

Once the site information is completed the user will click “Next” (light green button on Figure 3) which will pop-up a starting location selector (Figure 5). This is where the user will indicate if the plumbing map measurements begin at either the resident’s faucet or out at the curb (ex. Water main/curbstop, somewhere outside the building).

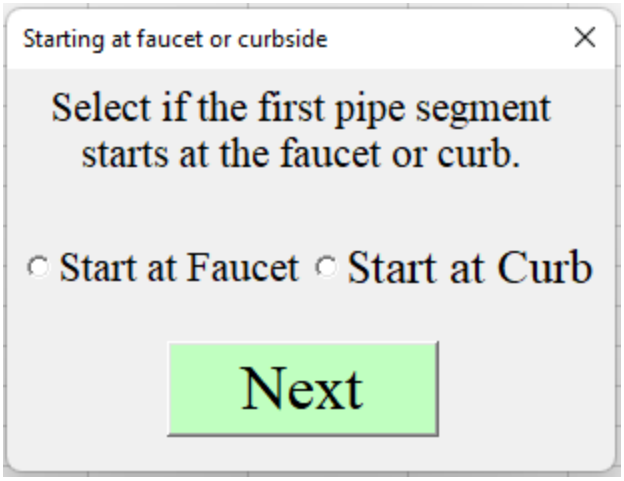

Figure 5. Starting location selector.

After selecting the starting location (a black dot will appear in the circle next to the selected starting point), the "Next" button (Figure 5) will bring up the "Internal Plumbing Information" pop-up window (Figure 6). This is the window where the user will be able to input all the plumbing sections of interest at a single location.

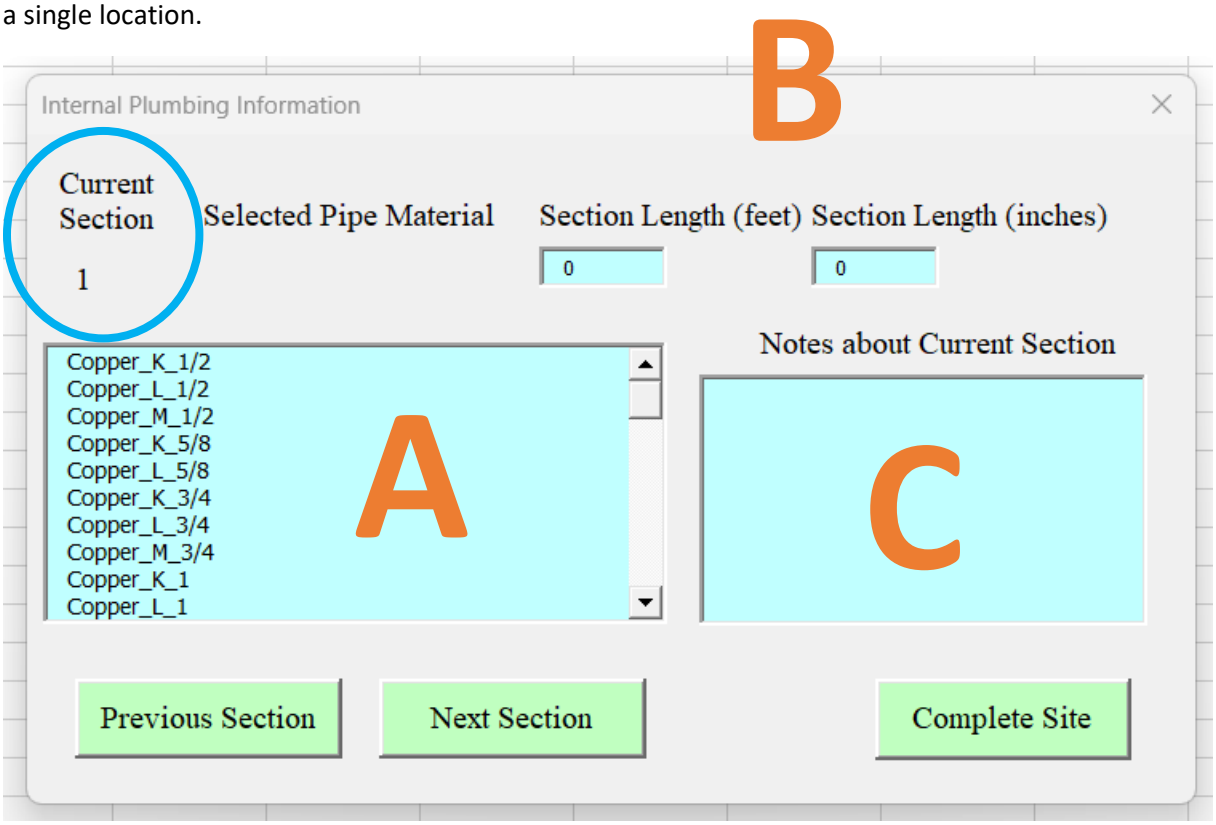

Figure 6. Internal plumbing information.

The user will start by selecting a pipe material from the scroll menu on the left-hand side of Figure 6, label A. Pipe material selections are organized by the material/fixture and include: copper, galvanized iron, brass, lead, PVC/CPVC, polyethylene, PEX, braided hose, water meter, and faucet. Additional qualifiers for the material will be listed to the right of the material/fixture type. Such as K, L, M types for copper, and "Sc40" or "Sc80" for brass indicating Schedule 40 or Schedule 80. Then for all pipe materials the nominal size in inches will be listed, ex. ½, ¾, 1 inch etc. See below for an example of how to interpret one of the pipe materials:

Example

Galvanized_Sc40_1/2 = ½" nominal size, Schedule 40, Galvanized Iron Pipe

Note that the nominal size does not always equate to the measured outside diameter of a pipe. For example, nominal sizes for copper tubing between ½ and 1 inch will have a measured outside diameter that is 1/8 inch larger than the nominal size. For a nominal size ½ inch copper pipe the outside diameter will measure 0.625 in, a difference of 1/8 inch between the nominal size and the actual size. These discrepancies in pipe dimensions are noted in the individual pipe material's standard (see *References* and CDA, 2024). The user may also encounter copper pipe in the field that has the nominal size written on the pipe itself (Figure 7). A size and type marking (K, L, or M) is common, additionally there are standard colors associated with the types of copper (Figure 7). Type M (red) copper is the thinnest wall and is commonly used in residences, type L (blue) has thicker walls than M copper and is usually found in outdoor or underground applications of copper pipe (CDA, 2024). Lastly type K (green) copper is the thickest wall type of copper and is generally used in underground applications where additional pipe integrity is needed (CDA, 2024).

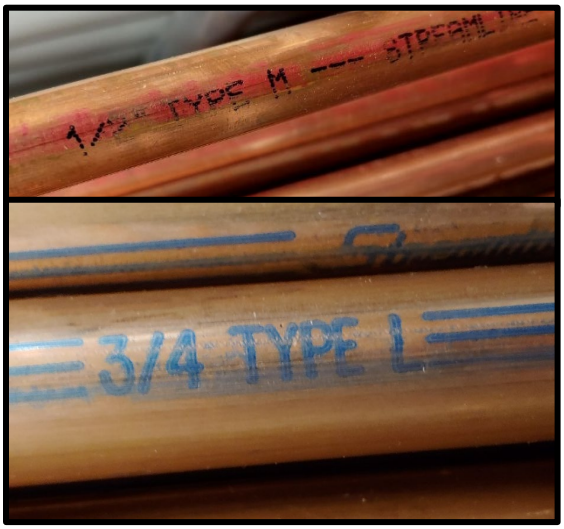

Figure 7. Examples of markings on 1/2" type M copper (top) and 3/4" type L copper (bottom).

The pipe materials/fixtures already loaded in the tool should serve as a good starting point for most buildings; however, other plumbing materials and sizing may exist. This tool does contain a feature for users to input custom materials, the steps to enter a new material are discussed in the *Entering new plumbing/pipe materials* section. Additionally, when "Faucet" or "Water Meter" is selected as a plumbing material, please see the sections on *Faucet Volume Estimations* and *Water Meters* for more information.

After selecting a pipe material, the user will enter the pipe section length in the boxes for either feet or inches (Figure 6, label B). Measurements can be entered using decimals. If the user inputs a length of 5.7 ft, once the section is submitted the measurement will be converted to inches and rounded to the nearest whole number (68 inches). If the user inputs a length of 5.7 inches the measurement will be rounded to the nearest whole number (6 in) once the section is submitted. The user can also add notes about the section if desired in the notes box (Figure 6, label C).

Once all information about the section is added the "Next Section" button will save the current section's data in the worksheet under the "Plumbing map sheet" tab and will move to the next section. If the next section is a new section, then the data entry fields will be blank and if it is a section that was previously filled out then that data will be visible. The "Previous Section" button will go backwards in the plumbing sections and will also save any work on the current section. The user can figure out which section is currently in edit by looking at the upper left-hand side, there will be a number under the heading "Current Section" (Figure 6, circled in blue). The number identified in the "Current Section" corresponds to the "Pipe Section" number in column A of the "Plumbing map sheet" (Figure 10). If a modification is needed after the data is initially input the user can return to the section, make modifications and then using either the "Next Section" or "Previous Section" buttons, save those edits. When all plumbing sections at a site have been entered the "Complete Site" button will save the current section and then close the pop-up window. Users will then be able to view their entered data on the "Plumbing map sheet" tab (see *Plumbing Map Sheet Tab* section for more information and Figure 10).

If further edits need to be made to the plumbing information after completing the guided entry on the "Mapping Tool" tab, those edits can be made directly on the "Plumbing Map Sheet Tab".

Save button

The Save button (Figure 2) will save the sheet "Plumbing map sheet" as a PDF and the PDF will automatically pop-up. The default file name will be the entered Site ID + "Plumbing Map.pdf" (Figure 8). The user can then save the PDF document within their own file structure.

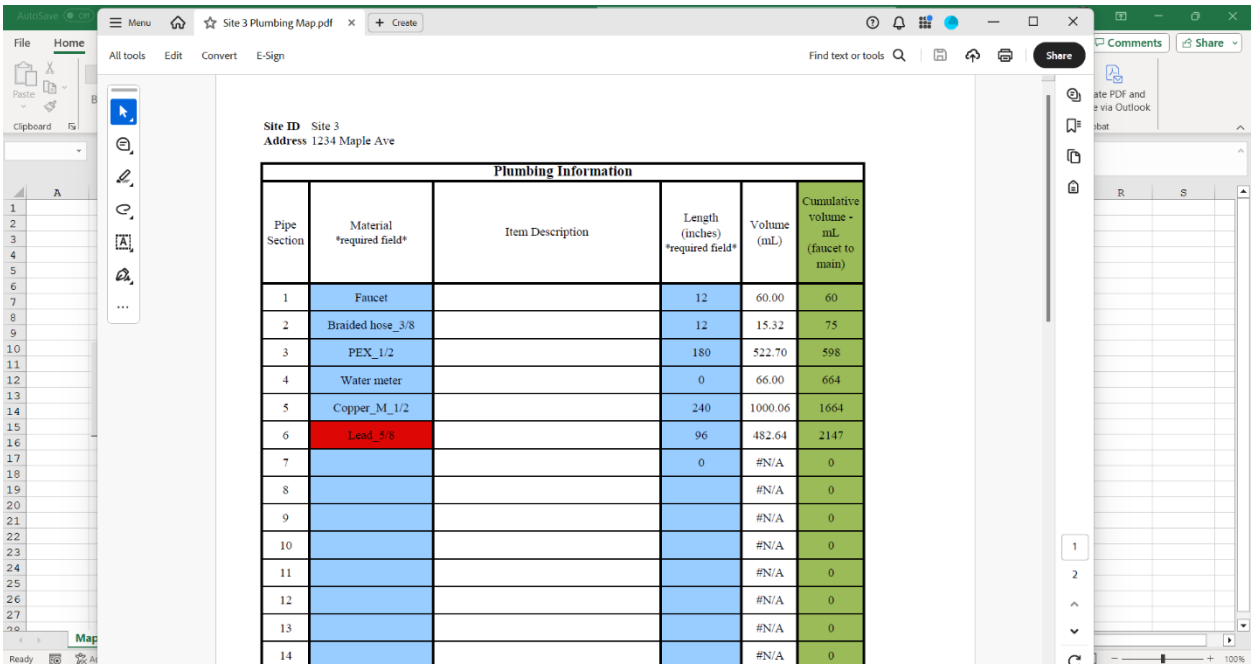

Figure 8. PDF pop-up file after user clicks "Save" button.

Clear Data button

The Clear Data button (Figure 2) will bring up a window asking if the user is sure if they would like to clear the data (Figure 9). If yes is selected, the program will then clear all data from the “Plumbing map sheet” tab.

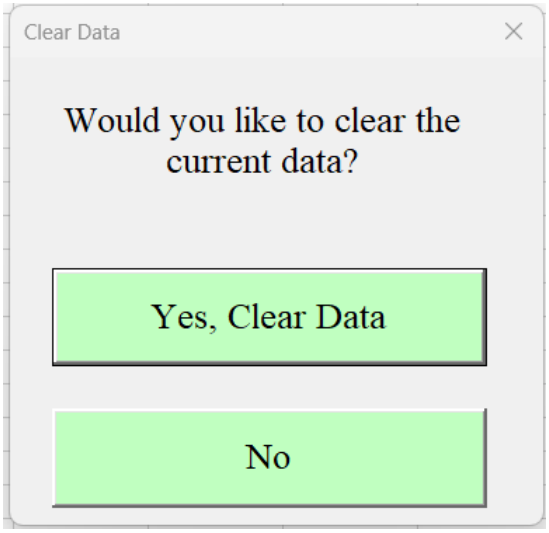

Figure 9. Clear Data button pop-up window.

Plumbing Map Sheet Tab

This sheet shows all the data the user has input for the site ID, address, pipe lengths and characteristics using the guided entry form on the "Mapping Tool" tab (Figure 10). When using the "Save" button on the "Mapping Tool" tab (Figure 2), the format of the "Plumbing Map Sheet" tab and the data included will be exported to a PDF. Additionally, if further edits need to be made to the plumbing information after completing the guided entry on the "Mapping Tool" tab, those edits can be made on the "Plumbing Map Sheet" tab.

For the non-macro enabled Excel file, the "Plumbing Map Sheet" is where the user will input all of their field measurements and observations. Columns B and E filled in blue ("Material" and "Length (inches)"), "Item Description" and column B next to "Site ID" and "Address" (in rows 1 and 2) can be edited manually on this sheet (Figure 10). "Site ID", "Address", and "Item Description" are all supplementary information. Whereas the columns for "Material" and "Length (inches)" are required fields for the calculation of volume. Notice in Figure 10 that "#N/A" appears in the "Volume (mL)" column if a material and length are not input.

	A	B	C	D	E	H	I
1	**Site ID**	Site 3					
2	**Address**	1234 Maple Ave					
3							
4	**Plumbing Information**						
5	Pipe Section	Material *required field*		Item Description	Length (inches) *required field*	Volume (mL)	Cumulative volume - mL (faucet to main)
6	1	Faucet			12	0.00	0
7	2	Braided hose_3/8			12	15.32	15
8	3	PEX_1/2			180	522.70	538
9	4				0	#N/A	0
10	5					#N/A	0

Figure 10. Plumbing Map Sheet tab.

Plumbing vol_ref Tab

This is a sheet that shows different material types and their standard measurements according to applicable design standards (Figure 11). The standard for each material's dimensions is referenced in the *Pipe Dimension Standards* section of this document. **Please note that some standards are updated yearly and while the dimensions generally do not change there may be slight adjustments that will not be captured by this tool.**

	A	B	C	D	E	F	G	H
1	Material-Type-Size	Type	Nominal Size (in	Outer Diameter (in)	Wall Thickness (in)	Inner Diameter (in)	Inner Diameter (mm)	mL/ft
2								
3	Copper_K_1/2	K (green)	1/2	0.625	0.049	0.527	13.4	43
4	Copper_L_1/2	L (blue)	1/2	0.625	0.040	0.545	13.8	46
5	Copper_M_1/2	M (red)	1/2	0.625	0.028	0.569	14.5	50
6	Copper_K_5/8	K (green)	5/8	0.750	0.049	0.652	16.6	66
7	Copper_L_5/8	L (blue)	5/8	0.750	0.042	0.666	16.9	69
8	Copper_K_3/4	K (green)	3/4	0.875	0.065	0.745	18.9	86
9	Copper_L_3/4	L (blue)	3/4	0.875	0.045	0.785	19.9	95
10	Copper_M_3/4	M (red)	3/4	0.875	0.032	0.811	20.6	102
11	Copper_K_1	K (green)	1	1.125	0.065	0.995	25.3	153
12	Copper_L_1	L (blue)	1	1.125	0.050	1.025	26.0	162
13	Copper_M_1	M (red)	1	1.125	0.035	1.055	26.8	172
14	Galvanized_Sc40_1/2	Sched 40	1/2	0.840	0.109	0.622	15.8	60
15	Galvanized_Sc40_3/4	Sched 40	3/4	1.050	0.113	0.824	20.9	105
16	Galvanized_Sc40_1	Sched 40	1	1.315	0.133	1.049	26.6	170
17	Galvanized_Sc80_1/2	Sched 80	1/2	0.840	0.147	0.546	13.9	46
18	Galvanized_Sc80_3/4	Sched 80	3/4	1.050	0.154	0.742	18.8	85
19	Galvanized_Sc80_1	Sched 80	1	1.315	0.179	0.957	24.3	141
20	Brass_Sc40_1/2	Sched 40	1/2	0.840	0.107	0.626	15.9	61
21	Brass_Sc40_3/4	Sched 40	3/4	1.050	0.114	0.822	20.9	104
22	Brass_Sc40_1	Sched 40	1	1.315	0.126	1.063	27.0	175
23	Brass_Sc80_1/2	Sched 80	1/2	0.840	0.149	0.542	13.8	45
24	Brass_Sc80_3/4	Sched 80	3/4	1.050	0.157	0.736	18.7	84

Mapping Tool | Plumbing map sheet | Plumbing vol_ref

Figure 11. Plumbing vol_ref Tab.

Column H, "mL/ft" (Figure 11) is used to calculate the volume per pipe section in the "Plumbing map sheet" tab. **Be aware that alterations of existing data in columns A-G will impact what is visible on the guided entry "Mapping Tool" tab. Specifically alterations of outer diameter, wall thickness, and inner diameter will change the volume calculation in column "H".**

Column "F" calculates the inner diameter of the pipe material:

Inner diameter = outer diameter – (2 * wall thickness)

Then the equation written into Excel for column "H" is the volume of a cylinder:

$$V = \pi(\frac{d}{2})^2 h$$

V= volume d= inner diameter of cylinder h= length of cylinder

Multiplied by the conversion of inches cubed to milliliters

$$V = \pi(\frac{d}{2})^2 h(16.38706)$$

If accidental edits are made to the numbers contained in the columns or a formula is altered that causes the tool to no longer work as described, basic troubleshooting may restore the file back to its original form (un-do button, exiting out and not saving changes, etc.). If basic troubleshooting does not restore the tool to its original form, please consider downloading a new file from EPA's website.

Entering new plumbing/pipe materials

Other pipe materials can be added to this tool by inserting a row below row 51 "Faucet" (Figure 12). In this newly inserted row, the user can type in information about the new "Material" and other applicable details as desired. For the tool to calculate a volume for the new material in the "Plumbing map sheet" tab, a volume in mL/ft must be added in column "H". If the user has information on the outer diameter and wall thickness the equation for the inner diameter calculation in column "F" can be copied. Once the inner diameter has been determined, the calculation for mL/ft in column "H" can then be copied and the sheet will calculate the volume of water contained within 1 ft of the specified new material.

Alternatively, if the user knows the volume of water contained within 1 ft of the new material (in mL/ft) that number can be directly added to column "H" without the need to input outer/inner diameter and wall thickness.

	Material-Type-Size	Type	Nomina	'Outer Diamet	' Wall Thic	'Inner Diame	Inner Diamet	mL/ft
41	PE_SDR9_1	SDR 9	1	1.125	0.125	0.875	22.2	
42	Polyethylene (HDPE)_1	200 psi	1	1.315	0.146	1.023	26.0	162
43	PEX_1/4		1/4	0.375	0.062	0.241	6.1	9
44	PEX_3/8		3/8	0.5	0.07	0.350	8.9	19
45	PEX_1/2		1/2	0.625	0.07	0.475	12.1	35
46	PEX_5/8		5/8	0.75	0.083	0.574	14.6	51
47	PEX_3/4		3/4	0.875	0.097	0.671	17.0	70
48	PEX_1		1	1.125	0.125	0.862	21.9	115
49	Braided hose_3/8		3/8					15
50	Water meter							66
51	Faucet							
52								
53								
54								

Figure 12. Inserting a new material on the Plumbing_vol_ref tab.

To ensure that the new plumbing material can be selected, switch back to the "Plumbing map sheet" tab and select all the drop down cells under the heading "Material". Then under the Excel "Data" tab along the top tool bar, navigate to "Data Tools", and "Data Validation" (Figure 13). In the data validation pop-up window that appears, adjust the "Source" cells to include the new material(s) added, and click "OK" (Figure 14). Then select the "Material" drop down list and the new material added should be available as a selection (Figure 15).

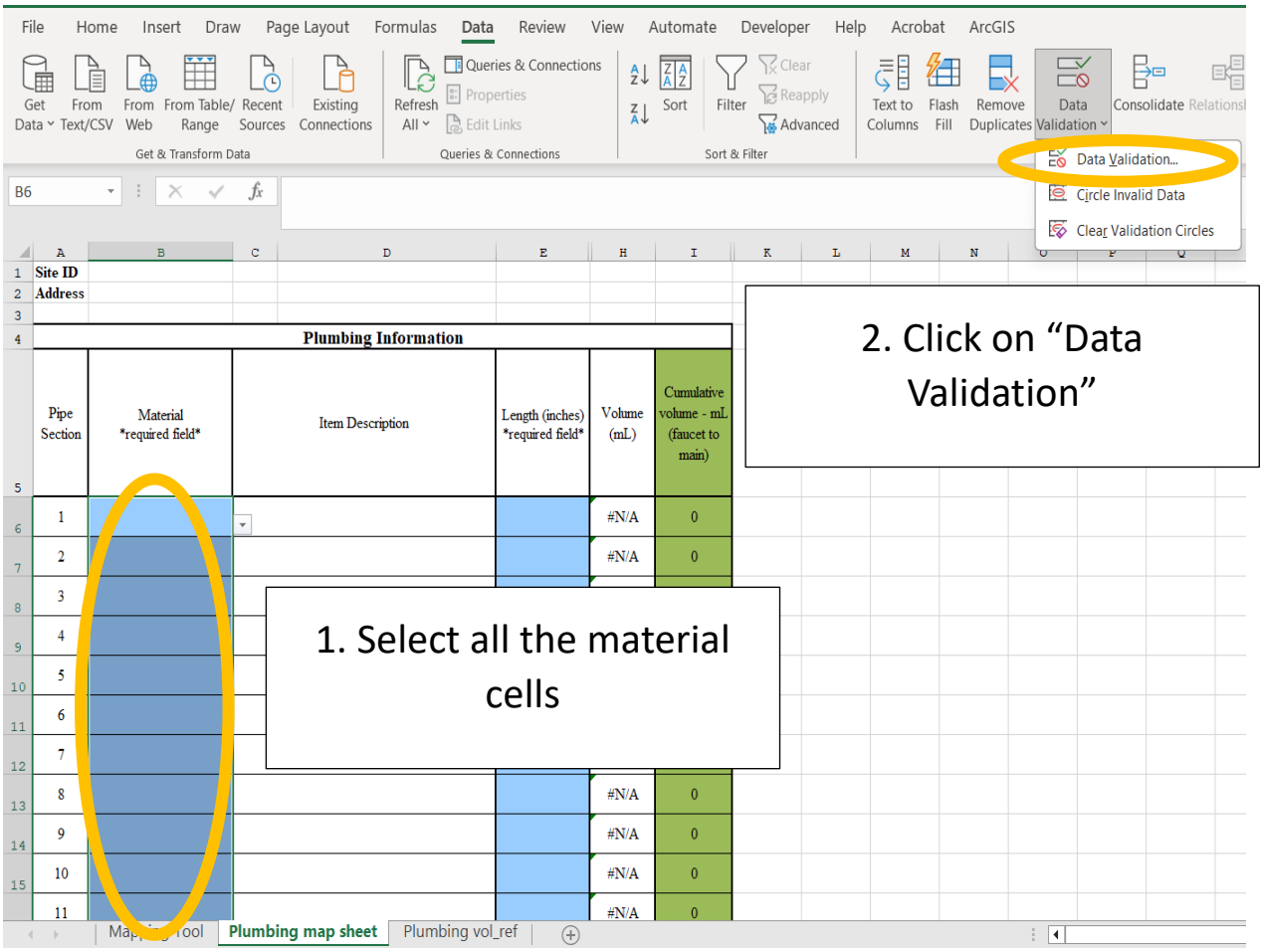

Figure 13. Updating material list, part 1.

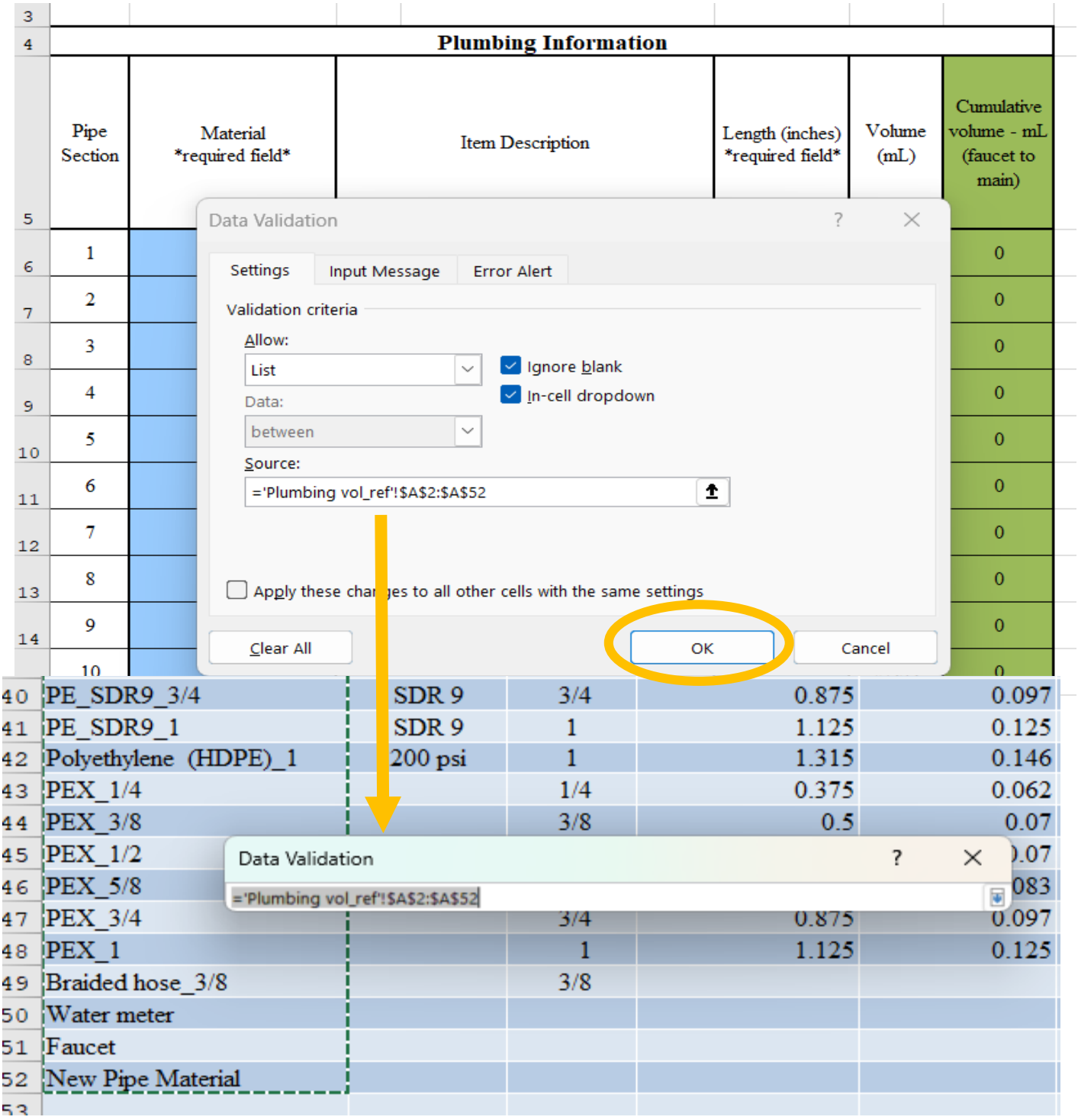

Figure 14. Updating material list, part 2.

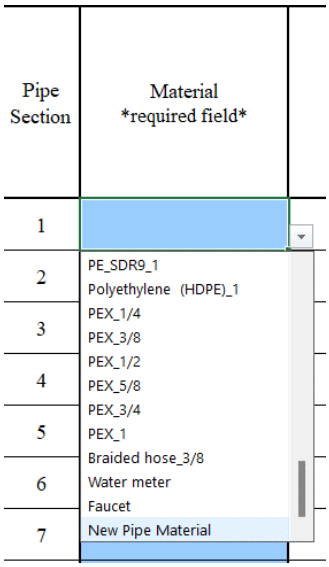

Figure 15. Updating material list, part 3.

Faucet Volume Estimations

When selecting "faucet" on the Internal Plumbing Information pop up (Figure 6) a prompt will pop up that will ask the user to input an estimated volume of the faucet in mL (Figure 16). In the non-macro version, selecting "faucet" from the drop down will generate a volume of 0 mL, the user must type a volume in column H of the "Plumbing map sheet" tab.

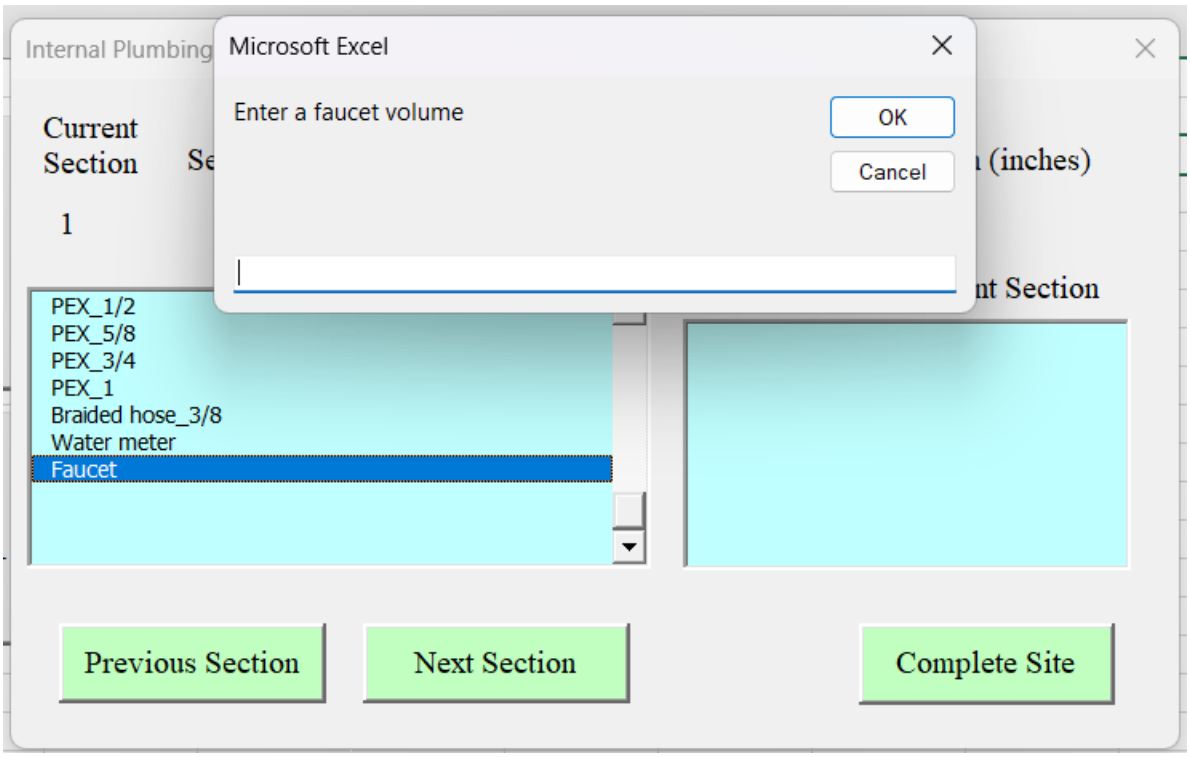

Figure 16. Faucet volume pop-up for user volume entry.

Below are two types of common faucets and their approximate volumes that can aid users in determining a volume to input for the faucet encountered (Figure 17 and Figure 18).

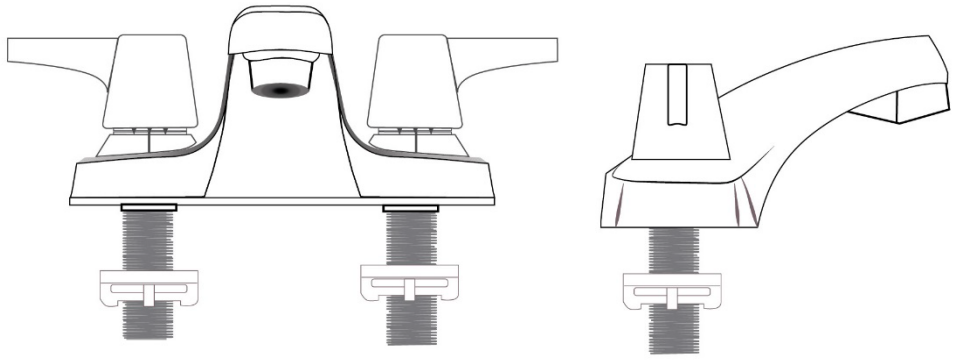

Figure 17. Simple bathroom faucet fixture.

A rough estimate of the average volume contained within the faucet in Figure 17 is about 25 mL.

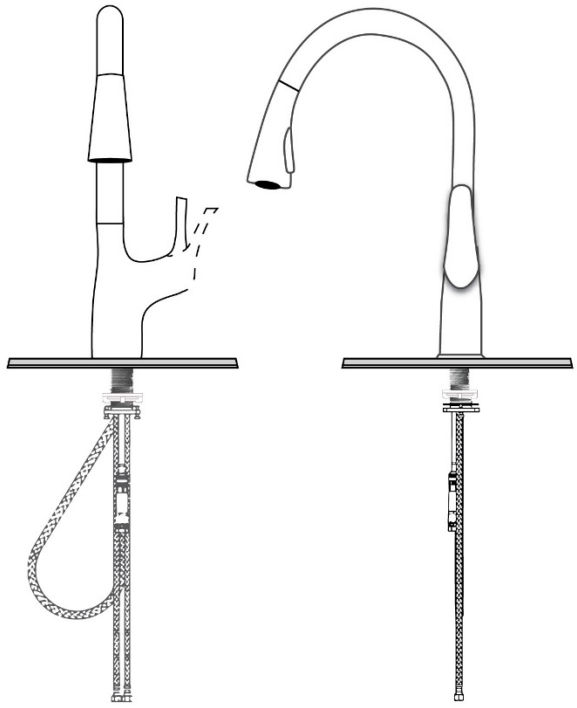

Figure 18. Gooseneck type kitchen faucet.

A rough estimate of the average volume contained within the faucet in Figure 18 is about 60 mL. Note that this faucet has additional tubing located below the counter that adds volume to the fixture observed at the sink level.

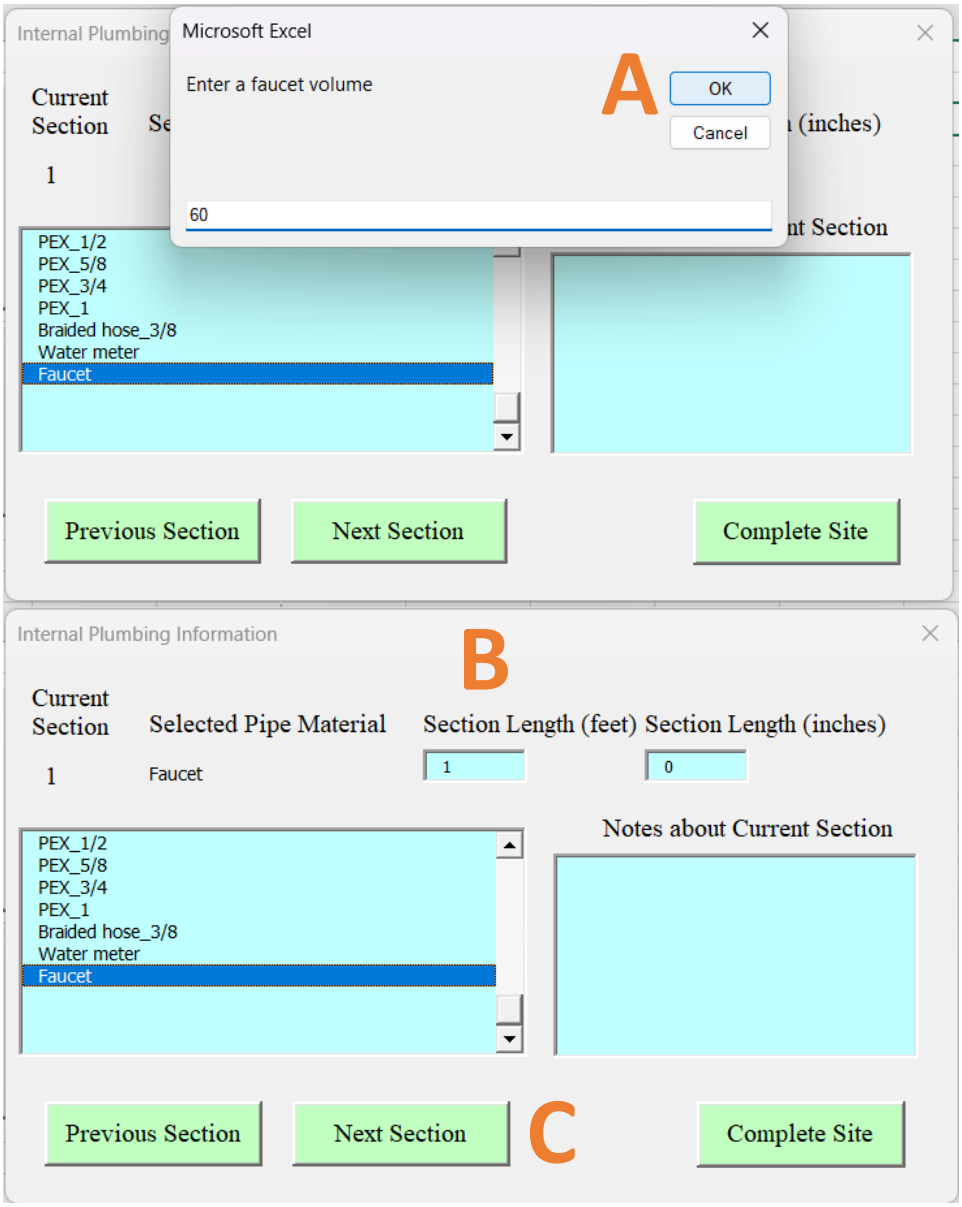

Figure 19. Sequence of events to enter a faucet volume.

After the user enters a volume (in mL) and selects "OK" (Figure 19, label A) the pop-up will close and the user will see "1" in the "Section Length (feet)" (Figure 19, label B), do not change the number. In order to save the volume the user input for the faucet and to move on, the user should select the "Next Section" or "Complete Site" button (Figure 19, label C).

Water Meters

Water meters (if installed) may or may not be visible along a run of plumbing. These devices may be found in basements just as the water service line comes through the foundation or out at the curb in a meter box (Figure 20). Placement of water meters (when present) can be community and house specific.

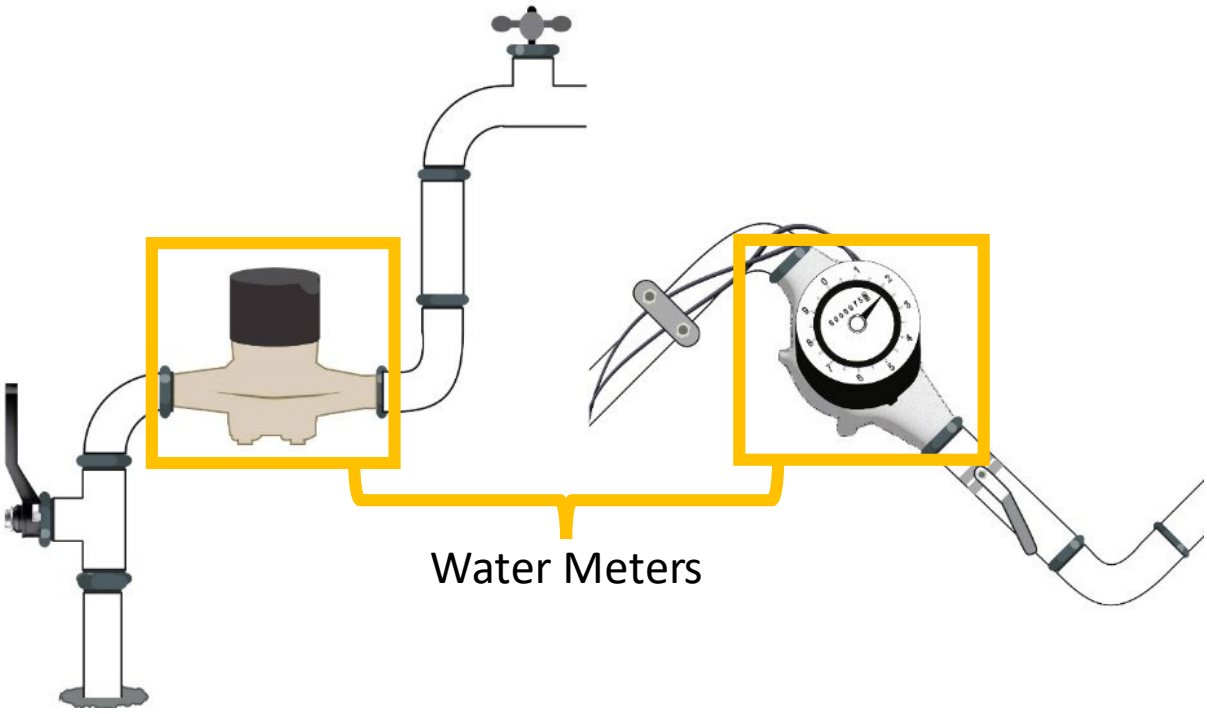

Figure 20. Two generalized views of what an installed water meter may look like in a building.

When selecting "Water meter" on the Internal Plumbing Information pop up (Figure 6) the user can add a water meter to the plumbing map. In this tool water meters have a set volume of 66 mL, based on experimental measurements for one type of water meter. The user can change this volume to match frequently encountered meters by editing the water meter volume in column "H" (mL/ft) of the "Plumbing_vol_ref" tab. **Note that a modification to the water meter volume in column "H" will not be reset to 66 mL if the user selects "Clear Data" on the "Mapping Tool" tab, any change in volume will remain in the tool until the file is closed (and not saved) or the user changes the volume in column "H" again.**

How to use the non-macro file

The “Plumbing Map Sheet” is where the user will input all of their field measurements and observations. Columns B and E filled in blue (“Material” and “Length (inches)”), “Item Description” and column B next to “Site ID” and “Address” (in rows 1 and 2) can be edited manually on this sheet (Figure 21). Pipe sections are automatically numbed in sequential order down column A. The user can start at row 6 to input plumbing materials beginning with the faucet, first selecting a material in column B by clicking the drop-down arrow (noted by the yellow arrow in Figure 21) and scrolling through the choices. The user must then input a length in inches in column E, for subsequent volumes in columns H and I to be calculated. Additional materials and lengths can be added until the user reaches the water main. The user can also start from the water main and work towards the faucet, however, the text and calculations in column I “Cumulative volume- mL (faucet to main)” will need to be edited.

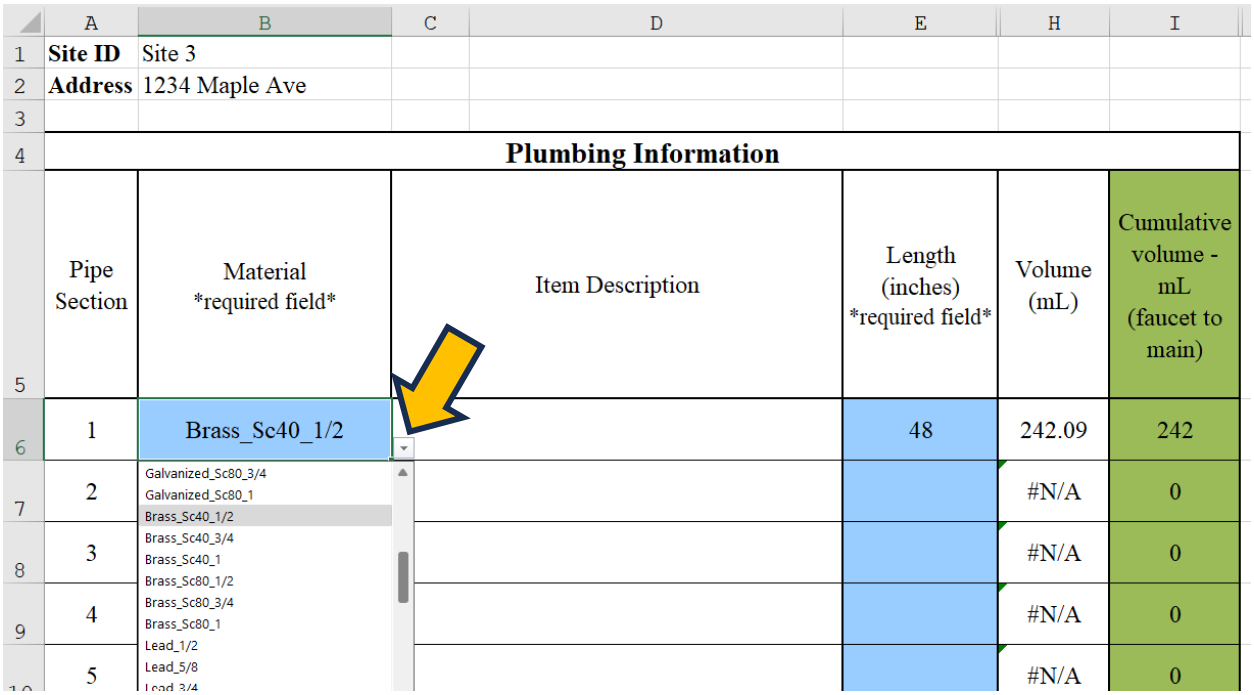

Figure 21. Non-macro file "Plumbing map sheet" tab.

“Site ID”, “Address”, and “Item Description” are all supplementary information. Whereas the columns for “Material” and “Length (inches)” are required fields for the calculation of volume. Notice in Figure 21 that “#N/A” appears in the “Volume (mL)” column if a material and length are not input.

Users of the non-macro file may also want to review the following macro-enabled file sections: *Plumbing vol_ref Tab, Faucet Volume Estimations*, and *Water Meters* for additional helpful information. Bearing in mind to disregard information about the automatic pop-ups associated with the macro-enabled internal plumbing information window.

Limitations of this tool

This tool has limitations in that the pipe volumes are only based on dimensions gathered from applicable/available design standards. The volumes calculated by this tool are theoretical and based on dimensions defined in each pipe material's standard specification (see *References*

Pipe Dimension Standards). Scales (corrosion or deposited) are known to accumulate in all pipe materials used for the conveyance of drinking water (AWWARF-TZW, 1996, Harmon et al. 2022). Over time some pipes, particularly galvanized iron or other iron-based materials can experience the development of mounds of material on the pipe surface from the corrosion of iron (AWWARF-TZW, 1996, McNeill & Edwards, 2001). These mounds are known as tuberculation and can constrict the pipe's available inner diameter for water flow (AWWARF-TZW, 1996). This restriction can reduce the volume of water that a pipe is able to hold, making the theoretically calculated volume in this tool an overestimation.

Additionally, there will be errors associated with measurements collected and input into the tool. Pipes in buildings are not always visible or easily accessible for measuring or assessing the material type or size. Pipes run between floors and through walls, and while lengths can be estimated, it will be a source of potential error. The variety of small plumbing components such as elbows, tees, valves, connectors, etc. will also introduce inaccuracies in the final volume calculated as these components are not captured in the tool. However, despite these limitations, this tool should still provide the user with an estimation of the volume contained within the plumbing measured that will allow the user to collect more meaningful drinking water samples. Users may also be able to reduce costs, conserve sampling supplies, and reduce the number of analyses needed by targeting specific volumes of water associated with lead sources based on the plumbing map generated.

Disclaimer

This software/application has been approved for release by the U.S. Environmental Protection Agency (USEPA). Although the software has been subjected to rigorous review, the USEPA reserves the right to update the software as needed pursuant to further analysis and review. No warranty, expressed or implied, is made by the USEPA or the U.S. Government as to the functionality of the software and related material nor shall the fact of release constitute any such warranty. Furthermore, the software is released on condition that neither the USEPA nor the U.S. Government shall be held liable for any damages resulting from its authorized or unauthorized use.

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Pipe Dimension Standards

ASTM Standard A53/A53M-22. 2022. *Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless.* ASTM International, West Conshohocken, PA. DOI: 10.1520/A0053_A0053M-22.

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