Site Suitability and Modeling

10

Introduction

Site selection means finding the location that meets a specific condition or criteria. In ArcGIS, you can use different techniques and tools to find the most suitable site for a particular purpose. One of the straightforward procedures that can be used in GIS is modeling. Modeling helps to generalize or simplify an environmental setting and its processes. For example, to find suitable land for a certain purpose such as irrigation or residential building, you have to apply criteria in your analysis to evaluate where the land is most suitable for that particular use. Understanding the main input functions of the suitability modeling guarantees a successful model. The most important elements of the model progression are the following:

1. What is the problem that demands solving?
2. Define a well-articulated criteria for the analysis
3. Gather the necessary data to solve the problem
4. Select the GIS tool needed for the model
5. Create the model to diagram the activity flow

Determine the criteria that allows you to successfully collect the proper data and create the model.

Model 1

The following exercise allows you to use different aspects of functionality in GIS in order to find the most suitable area for building a greenhouse at the Jordan University campus.

Scenario 1: You are a GIS manager at Jordan University and you have been asked by the administrator to choose the best location to build a new Greenhouse on the north-east region of the campus (Fig. 10.1). To build the greenhouse, you have to take in consideration different criteria.

Data: The image was downloaded from Google Earth, and then clipped and georeferenced using the Palestine_1923_Palestine_Grid projection. The Landuse and Vegetation layers used in this exercise were digitized using the image after it had been rectified.

Electronic Supplementary Material: The online version of this chapter (https://doi.org/10.1007/978-3-319-61158-7_10) contains supplementary material, which is available to authorized users.

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Fig. 10.1 Areal image of the study area

The Criteria to Build the Greenhouse

1. The Greenhouse should be at least 50 m away from the sewer pipeline
2. The Greenhouse should be within a code of 400 of the landuse layer
3. The Greenhouse should be within a Veg_Code 1 or 2 of vegetation layer

GIS Approach

The work will be done using ArcToolbox and ArcMap.
Input files: **Landuse.shp, Pipeline.shp, StudyArea.shp**, and **Vegetation.shp**

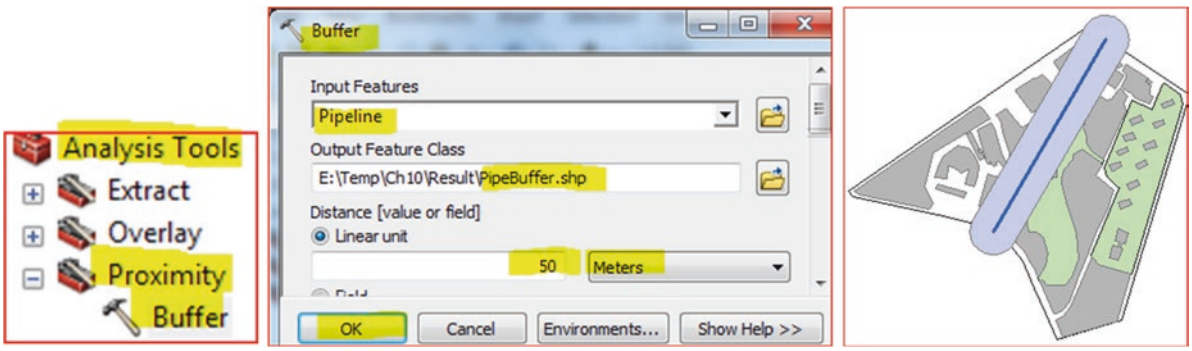
1. Start ArcMap and rename the Layer data frame "**Greenhouse**"
2. Connect to Ch10 folder
3. Click Add Data button browse to \\Ch10\Data\M1 folder
4. Highlight LandUse.shp, Pipeline.shp, StudyArea.shp, and Vegetation.shp and click Add
5. In the TOC, drag the StudyArea at the bottom
6. Change the color of the layers
   - Pipeline: Blue, width 2
   - LandUse: Grey 30%
   - Vegetation: Green
   - StudyArea: Hollow

7. Click the ArcToolbox icon in the Standard toolbar
8. Right-click an empty space at the bottom of ArcToolbox/Environment
9. Click Workspace
   - Current Workspace: \\Ch10\M1
   - Scratch Workspace: \\Ch10\Result
10. Click OK

First Criteria: The Greenhouse should be at least 50 m away from the sewer pipeline.

Buffer Analysis: The buffer function will create polygon around the pipeline at our specified distance of 50 m. The buffer shows the area around the pipeline that you can't use for the Greenhouse, as it is too close to the pipeline.

11. ArcToolbox/Analysis Tools/Proximity/
12. D-click Buffer
13. Input Features: Pipeline
14. Output Feature Class: PipeBuffer
15. Linear Unit: 50 m
16. Accept the rest of the default
17. OK

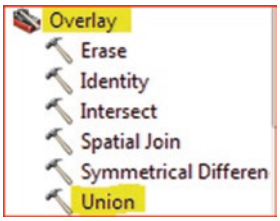


Result: The output buffer is a polygon feature 50 m around the pipeline and the attribute table of the **PipeBuffer.shp**, should have one record.

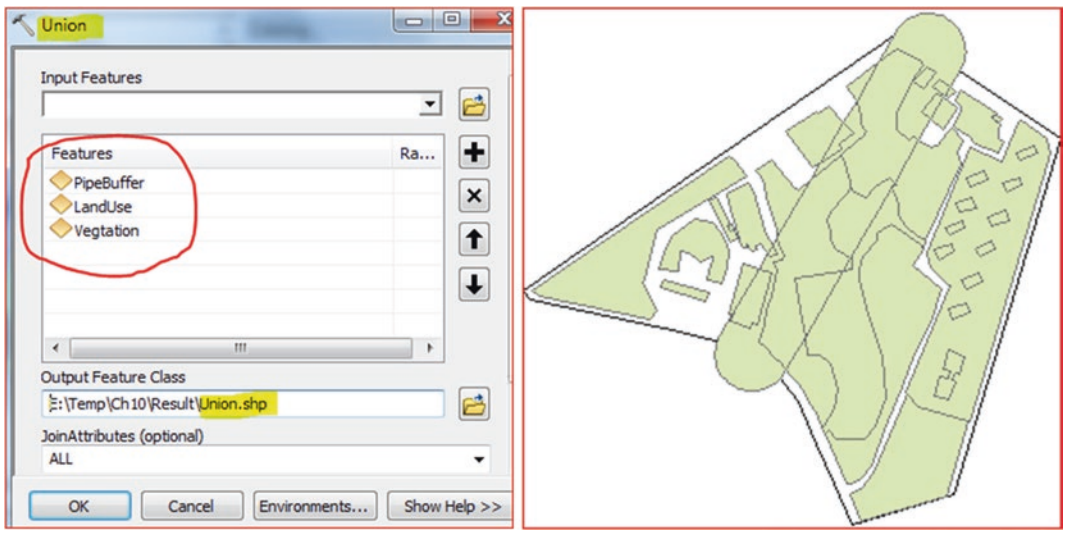
Overlay Analysis: Union

The Union function is a polygon to polygon overlay method that takes all the features from the input layers, and then calculates the geometric intersection of the layers. The output layer will be of that same geometry type. This means that a number of polygon feature classes and feature layers can be unified together. The output features will have the attributes of all the input features that overlap.
The Union tool will unified the 3-polygon layers: **PipeBuffer**, **Landuse**, and **Vegetation**.

18. ArcToolbox/Analysis Tools/Overlay/D-click on Union tool.



19. Input Features: **PipeBuffer.shp**, **Landuse.shp**, **Vegetation.shp**
20. Output Feature Class: **Union.shp**
21. Accept the default and click OK



Result: The output file "**Union**" includes all fields from the three input layers: **PipeBuffer.shp**, **Landuse.shp**, and **Vegetation.shp**. The **Union.shp** will be used to select the criteria to build the Greenhouse at the campus.

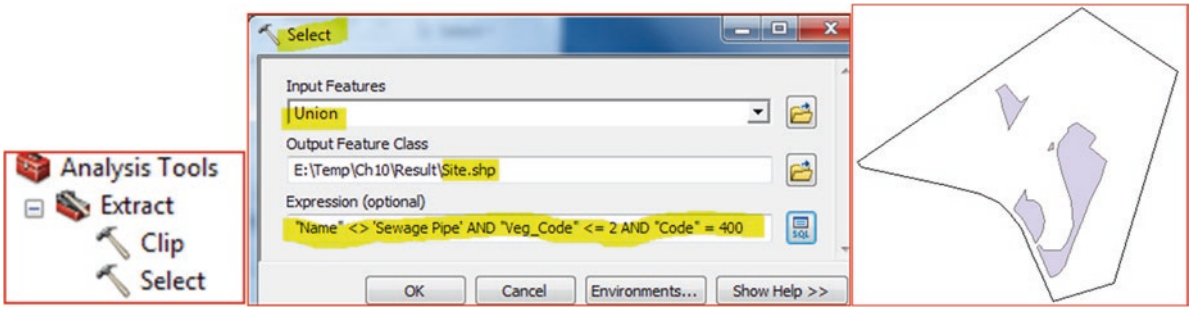
2nd–3rd Criteria: Greenhouse should be within a code of 400 of the landuse and within a Veg_Code 1 or 2 of vegetation layers.

Select Tool

The select function uses an expression to select features from the input and output layer, which ensures our Structured Query Language (SQL) meets the criteria for the suitability outlined for this assignment.

22. Analysis Tools/Extract/D-click Select
23. Input Features: **Union.shp**

24. Output Feature Class: **Site.shp**
25. SQL statement: "Name" <> 'Sewage Pipe' AND "Veg_Code" <= 2 AND "Code" = 400
26. Click OK/OK.
    Change the color of the Site layer into notable color (e.g. red).

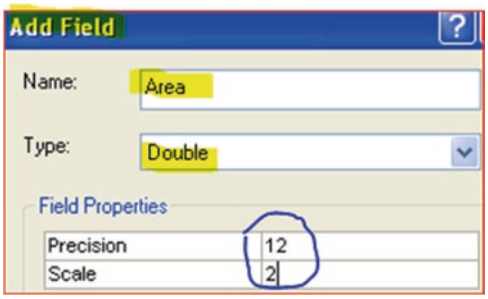


Result: The best potential location selected and consists of two pieces of lands.

Area Calculation

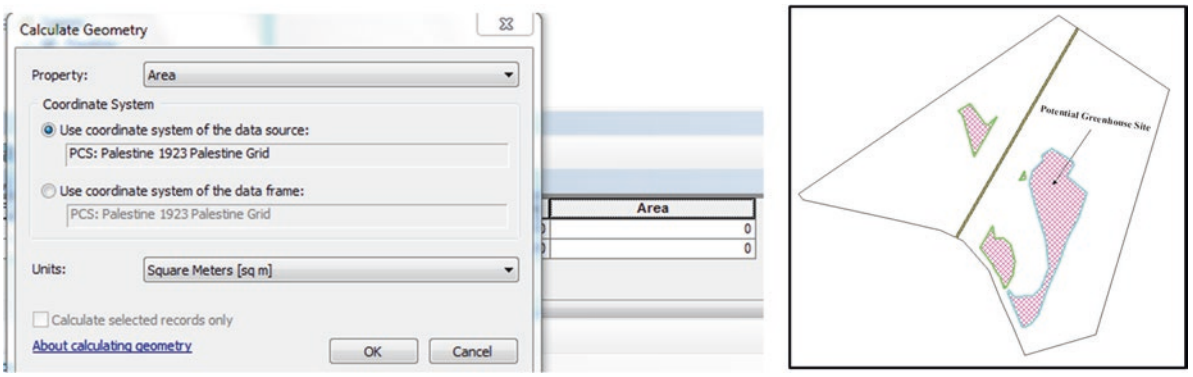
After you've presented the result to the administration, they asked you to calculate the area of the selected locations. The potential location should have a minimum area of 8000 m^2 as it is going to be used for building the greenhouse.

27. Right-click the Site layer and open the attribute table
28. Open the Table Option/Add Field
29. Name: Area
30. Type: Double
31. Precision: 12
32. Scale: 2
33. Click OK



34. Right-click the Area field
35. Calculate geometry/click Yes
36. Make sure the Property is Area and the Units is in Square Meters
37. Accept the other default
38. Click OK

Result: The eastern land will be used as a Greenhouse, as its area is more than 8000 m^2.



Result: The land that has an area greater than 8000 m^2 will be the one used for the Greenhouse (as shown in the image).

The area of suitability (pictured in red below) fits all the criteria, which requires the Veg_Code to be equal or less than 2, not within 50 m of the pipeline, and possessing an area of 18,246.01m^2 and is in code 400.

Geoprocessing Model for Spatial Analysis

The Geoprocessing Model is a graphical way of systematizing analysis. This means instead of running the tools from ArcToolbox repeatedly, you could automate your analysis as workflow through the geoprocessing model. The model is made up of a process, meaning that each tool is associated with input and output elements. The process consists of four states and each state has the following color:

1. Not ready to run White
2. Ready to run Yellow
3. Running Red
4. Has been run Yellow (drop shadow added to tools and outputs elements)

The model is saved in a created toolbox as a .tbx that can be placed in any folder or the root level of any geodatabase, and the user should have full-write access with it. The model that saved in the custom toolbox becomes a model tool.

ArcGIS allows you to use the ModelBuilder, which is a sequence of tools and data chained together. The output of one tool is fed into the input of another. When you save a model, it becomes a model tool. Models are stored in a user-created toolbox that has full write-access to it. It is recommended to set the environment when working with models, as it sets many parameters such as the output workspace, output spatial reference, and the processing extent.

Model 2

Find Best Suitable Location to Build Nuclear Power Plant

Site selection means finding the location that meets a specific condition or criteria. It is a generalized model that can be used in the GIS environment to find the most suitable site for a particular use. The modeling process identifies the main issue that needs to be answered based on specific criteria. For modeling analysis, the main input function to perform the work is to determine the proper data in order to find the ideal solution. To carry this model in ArcGIS, the exact GIS tool, and the procedures to be carried out, should be determined and understood in advance for an effective result.

Site suitability can be performed by using both raster and vector techniques. This task will be based on applying the vector mode, which relies greatly on proximity and overlay analysis. The main concept will be discerning the sensitive area from the study area and selecting an area that is most suitable.

This exercise allows you do use different aspects of GIS functionality in order to find the most suitable area for building a Nuclear Power Plant (NPP) in Dhuleil Area, Jordan.

The Criteria to Find Suitable Location to Build Nuclear Power Plant

Scenario 2: The Dhuleil area is proposed to be a location to build a Nuclear Power Plant (NPP), as it's an ideal location due to the presence of a plentiful amount of reclaimed water that can be used for cooling purposes. Nevertheless, the main question is: what's the possibility of building a Nuclear Power Plant in the area without affecting the local environment and the water resources?

Dhuleil is an agricultural area which has a major limestone and basalt aquifer. Many wells are tapping these two permeable formations and they have been used for irrigation since the 1960s. In the mid-1980s, a major Sewage Treatment Plant, named Khirbet AlSamra Wastewater Treatment Plant (KSWTP), was built to increase the water resources for irrigation and lessen the use of groundwater whose water quality and quantity had been deteriorated due to extensive use and over exploitation. The area has a network of drainage systems that shifted water from intermittent streams into perennial streams after the KSWTP started to discharge its treated water into the major Zarqa River, which ended up into King Talal Dam reservoir. The water stored into the reservoir was then released in order to irrigate the Jordan Rift Valley, which is one of the most important irrigated areas in Jordan. The surface water and groundwater should be protected from any potential contamination from the proposed NPP.

The Dhuleil area is also highly fractured, and the structure has some influence on the groundwater recharge from precipitation and surface runoff during the wet season. A previous study showed that the wells that are in close proximity to the fault have a slight elevated concentration of nitrate and salinity. Therefore, any NPP should be built at a suitable distance away from the fault system.

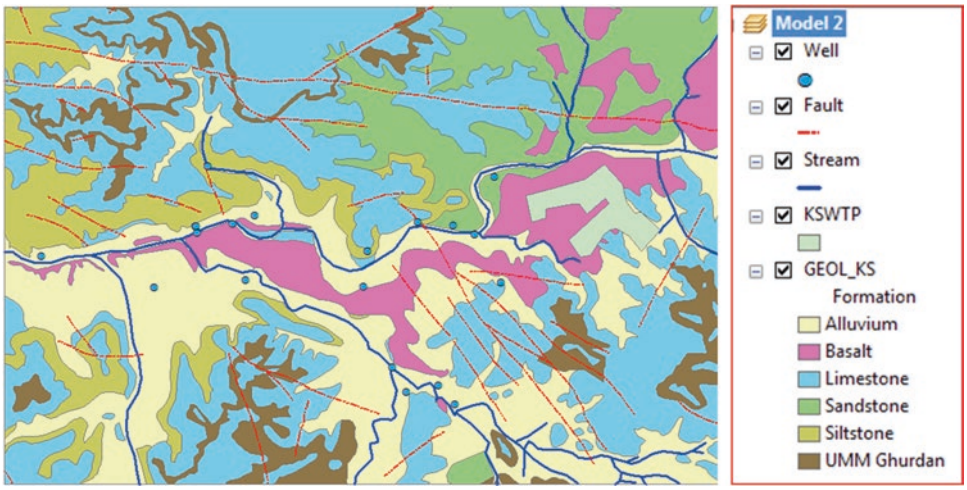
The surficial geology in the study area consists of basalt, limestone, alluvium, sandstone, siltstone, and marly limestone. The first four formations are considered highly permeable and are generally associated with moderate to high potential rates of local recharge from rain or surface runoff during wet seasons. The marly limestone and siltstone are considered impermeable surface deposits which have very low to low recharge potential with reduced rates of water movement into or out of these deposits. Therefore, any potential site for building the proposed NNP should be built within these two layers.

The criteria to find best site to build the NPP should be set as follow:

1. The NPP should be at least 300 m away from the main stream
2. The NPP should be at least 200 m away from the faults system
3. The NPP should be at least 500 m away from the groundwater wells
4. The NPP should be built within code 2 (Siltstone & Umm Ghurdan formations)

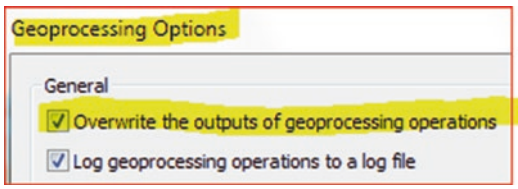
Building the Geoprocessing ModelBuilder

1. Launch **M2.mxd** from \\Ch10\Data\M2 folder



Result: The map open and it has five symbolized layers in the TOC (Well, Fault, Stream, KSWTP, and GEOL_KS).

2. Click Geoprocessing menu/Geoprocessing Options
3. Under General check the "Overwrite the outputs of geoprocessing operations"
4. Click OK

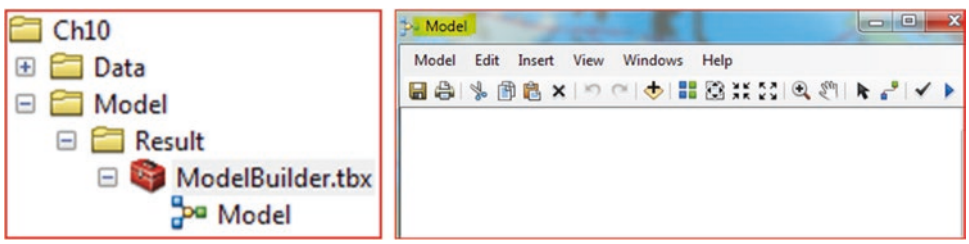


Create a New Toolbox

Create a new Toolbox and store the ModelBuilder inside it. By creating the Toolbox you will have full write to modify it.

5. Click Catalog window
6. Expand Ch10
7. R-click Model\New\Folder and call it Result
8. R-click Result folder\New\Toolbox and rename the new toolbox "**ModelBuilder.tbx**"
9. R-click **ModelBuilder.tbx**/New/Model

Result: The Model window opens in ArcMap.

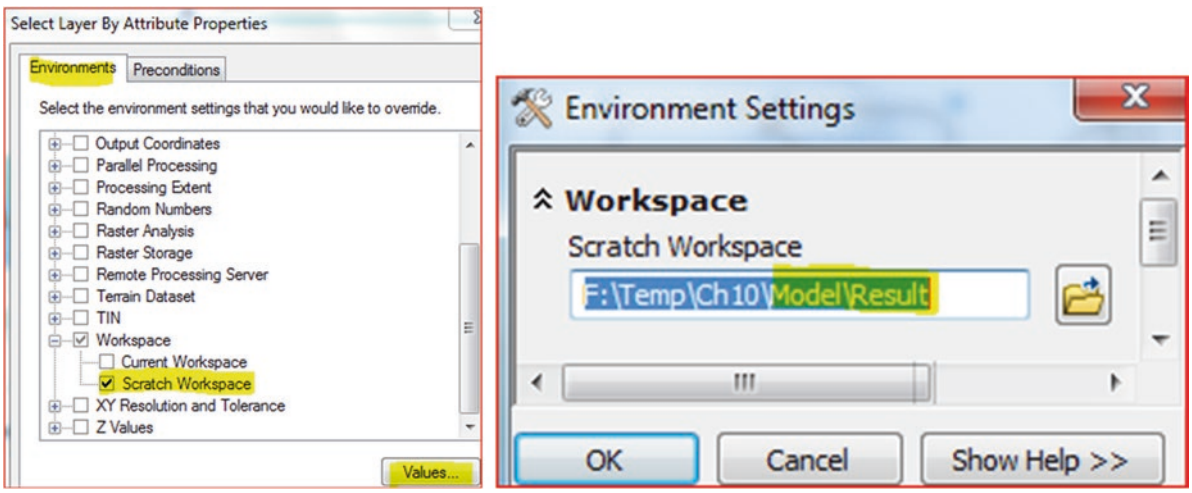


10. Click on the Search window and then type "**Select**".
11. From the displaying research list
12. Drag "Select Layer By Attribute" (Data Management) into the Model.

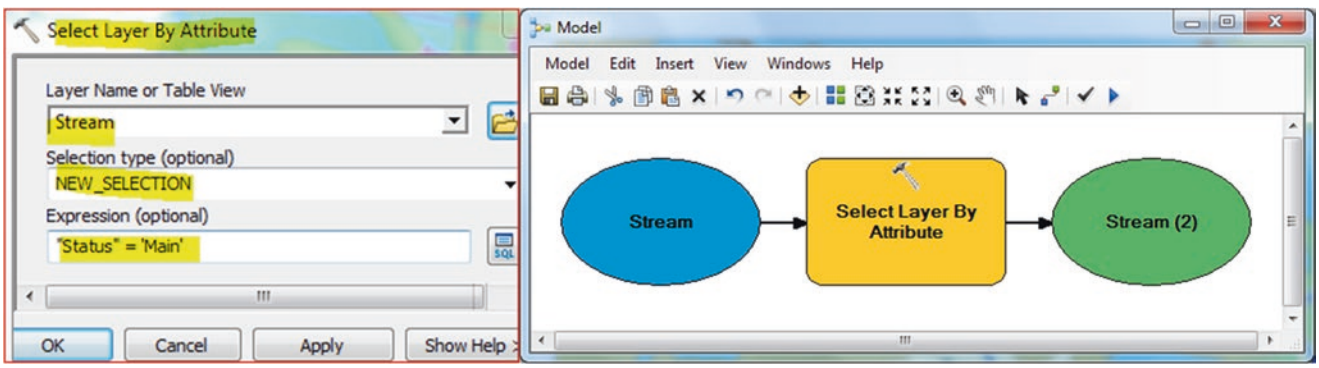
13. Right-click “Select Layer By Attribute” tool in the “Model”
14. Click Properties/click Environments tab/scroll down and Open the Workspace

15. Check Scratch Workspace/click Values/click 

to open the Workspace
16. Fill the Scratch Workspace \\Ch10\Model\Result
17. OK/OK

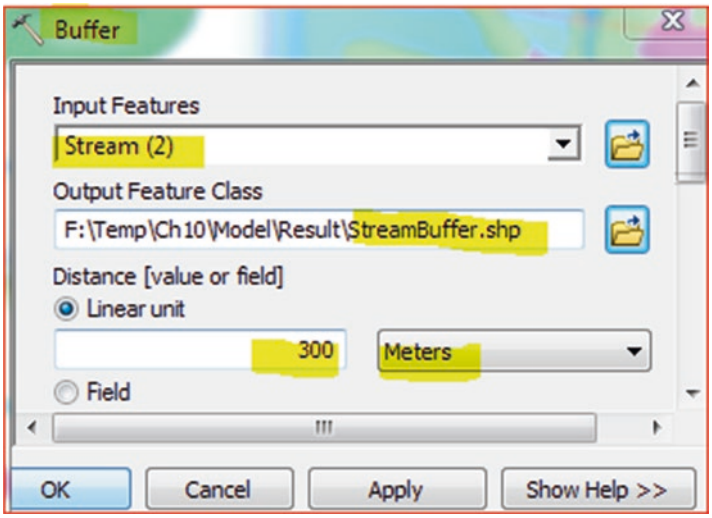


18. D-click “Select Layer By Attribute” tool in the “Model” and fill it with the following.
    - Layer Name or Table View: Stream
    - Selection type (optional): New_Selection
    - SQL: "Status" = 'Main'
19. Click OK.
20. Click Save  icon on the Model
21. Click Full Extent  icon on the Model



Result: The **process** (the tool and the input and output variables) is in a state **ready-to-run**.

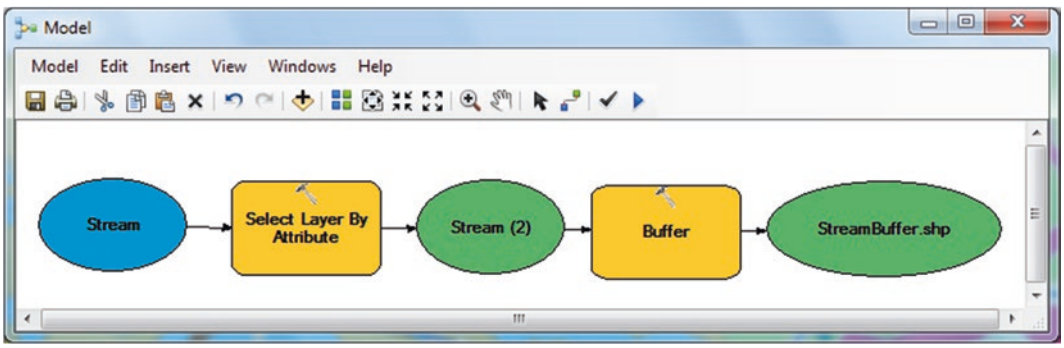
22. Search window/type Buffer
23. Drag Buffer (Analysis) into the Model that you created and place it below Select Layer By Attribute
24. Right-click Buffer tool in the "Model"
25. Properties/Environments tab/scroll down and Open the Workspace
26. Check Scratch Workspace/click Values/open the Workspace
27. Fill the Scratch Workspace \\Ch0\Model\Result
28. OK/OK
29. Double-click Buffer tool in the Model and fill it
    - Input Features: Stream (2)
    - Output Feature Class: \\Result\StreamBuffer.shp
    - Linear unit: 300 m
    - Accept the rest of the default and click OK.



30. Click Save icon on the Model

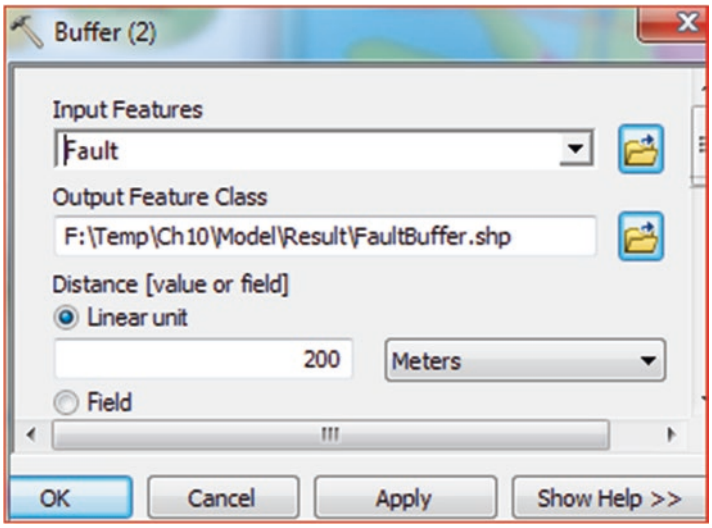
Result: The **process** is in a state **ready-to-run** and Stream (2) is connected to the Buffer tool.

Click Auto Layout  icon on the Model to rearrange the two processes and then click Full Extent button.



31. Drag Buffer (Analysis) once again into the Model window
32. R-click Buffer (2) tool in the "Model"
33. Properties/Environments tab/scroll down and Open the Workspace
34. Check Scratch Workspace/click Values/open the Workspace

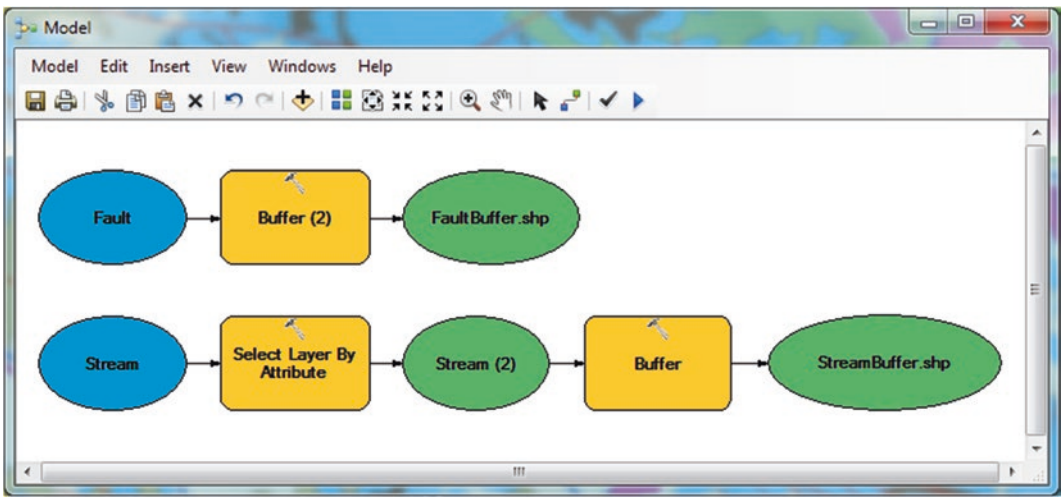
35. Fill the Scratch Workspace \\Ch0\Model\Result
36. OK/OK
37. D-click Buffer (2) tool and fill it
38. Input Features: Fault
39. Output Feature Class: \\Result\FaultBuffer.shp
40. Linear unit: 200 m
41. Accept the rest of the default and click OK
42. OK



43. Save the Model

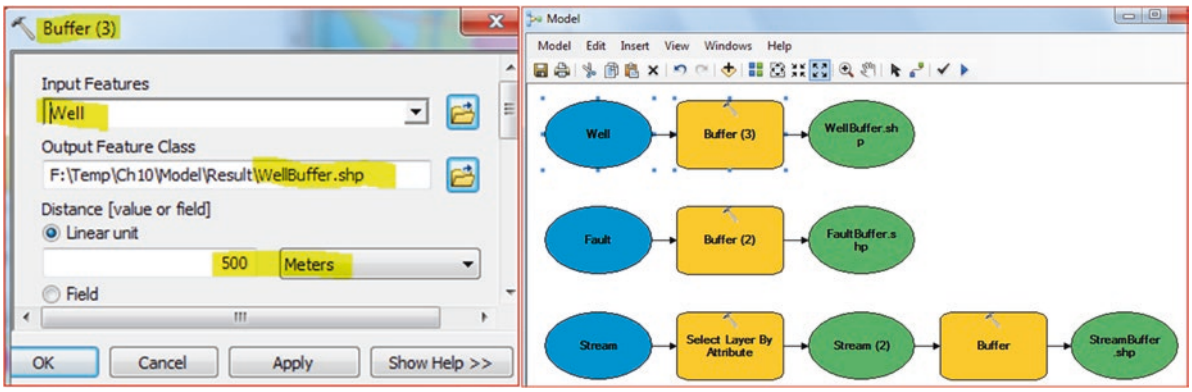
Result: The **process** is in a state **ready-to-run**.

44. Click Auto Layout icon to rearrange the three processes and then Full Extent icon



45. Drag Buffer (Analysis) once again into the Model window
46. R-click Buffer (3) tool in the "Model"
47. Properties/Environments tab/scroll down and Open the Workspace
48. Check Scratch Workspace/click Values/open the Workspace

49. Fill the Scratch Workspace \\Ch10\Model\Result
50. OK/OK
51. D-click Buffer (3) tool and fill it
    - Input Features: Well
    - Output Feature Class: \\Result\WellBuffer.shp
    - Linear unit: 500 m
    - Accept the rest of the default and click OK
52. OK
53. Click Auto Layout icon to rearrange the 4-processes and then Full Extent icon

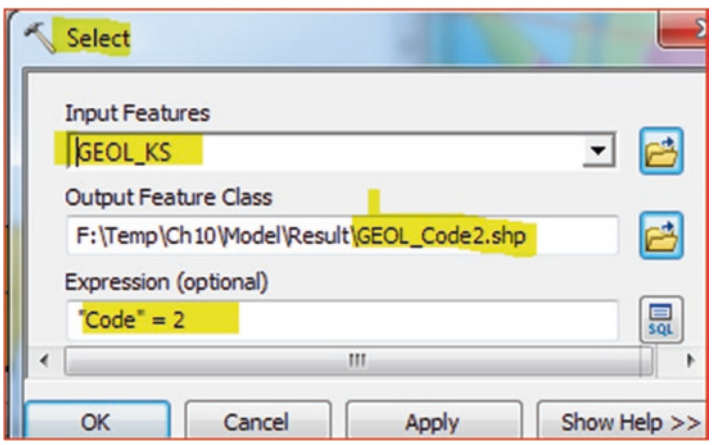


Result: The **process** is in a state **ready-to-run**.

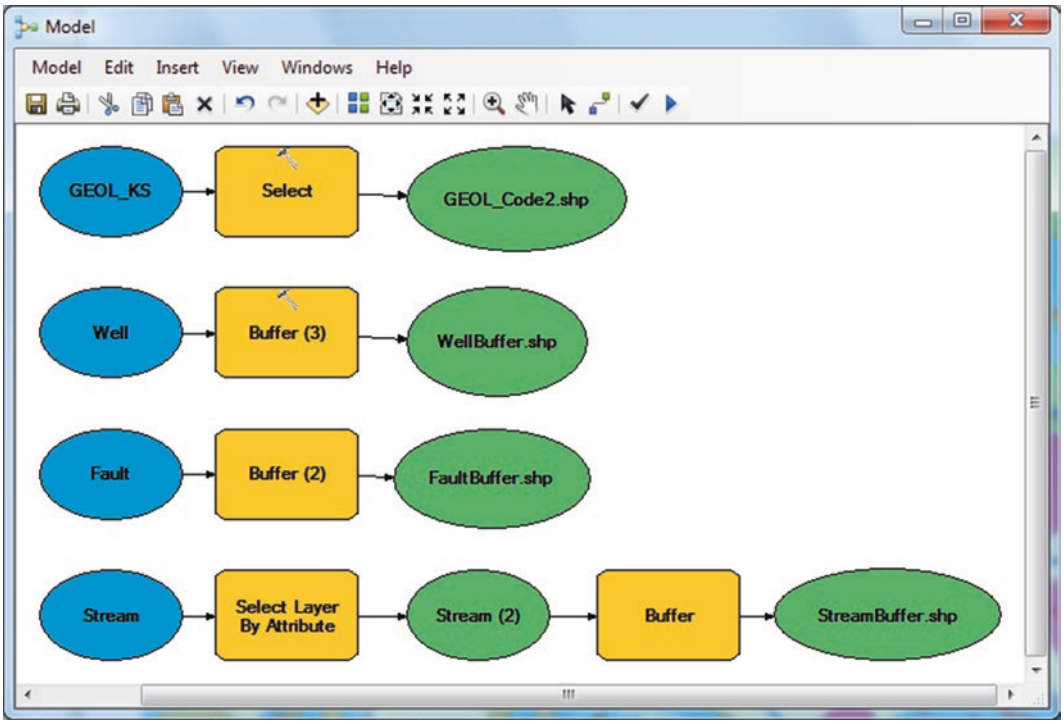
Select Tool

This step is to select the impermeable geological formations that consist of code 2.

54. Search window/Select
55. Drag Select (Analysis) into the Model
56. R-click Select tool in the "Model"
57. Properties/Environments tab/scroll down and Open the Workspace
58. Check Scratch Workspace/click Values/open the Workspace
59. Fill the Scratch Workspace \\Ch10\Model\Result
60. OK/OK
61. D-click Select tool and fill it
    - Input Features: GEOL_KS
    - Output Feature Class: \\Result\GEOL_Code2.shp
    - SQL: "Code" = 2
62. OK/OK



63. Click Auto Layout icon to rearrange all processes and then Full Extent icon

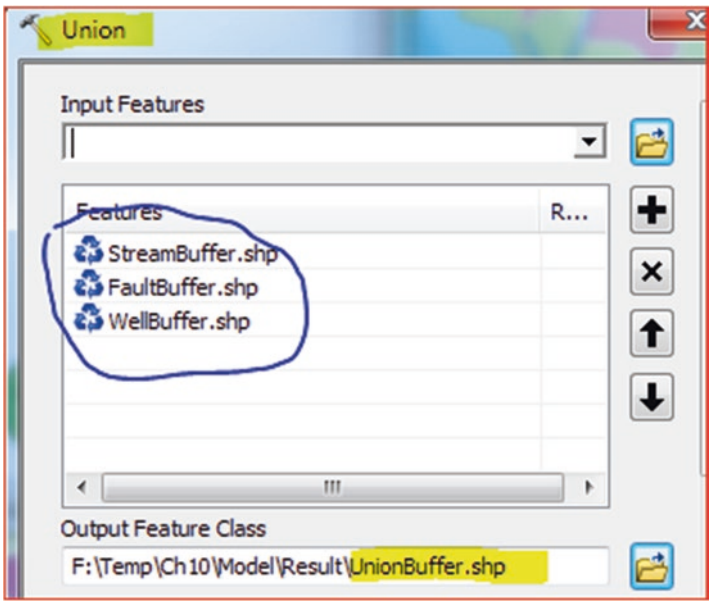


64. Save the Model

Union Tool

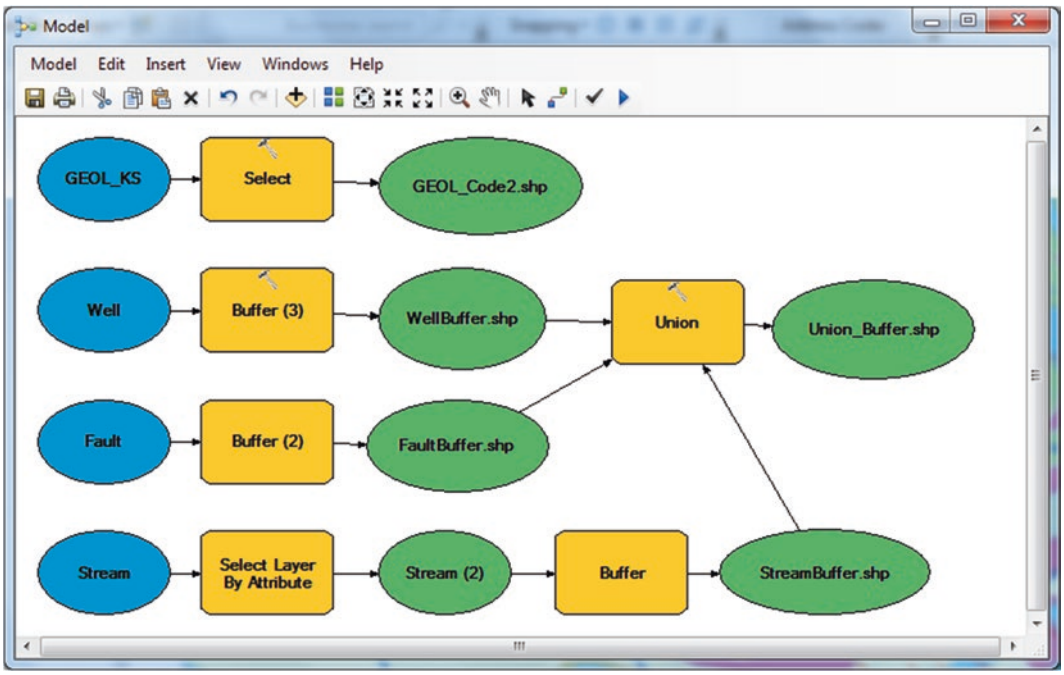
Now, you are going to perform a geometric union of the 3-input features (**StreamBuffer.shp**, **FaultBuffer.shp**, and **WellBuffer**). All features and their attributes will be written to the output feature class. The Union tool will only work on polygon feature classes. This step is required in order to combine all the buffers that have been created for the wells, faults, and stream and make them one polygon. Once these features are united, you can then use it in the next step, which will be the erase function.

65. Search window/Union
66. Drag Union (Analysis) into the Model that you created
67. R-click Union tool in the "Model"
68. Properties/Environments tab/scroll down and Open the Workspace
69. Check Scratch Workspace/click Values/open the Workspace
70. Fill the Scratch Workspace \\Ch10\Model\Result
71. OK/OK
72. D-click Union tool and fill it
    - Input Features: StreamBuffer.shp, FaultBuffer.shp, WellBuffer.shp
    - Output Feature Class: \\Result\UnionBuffer.shp
    - Accept the default
73. OK



Result: Two things happen.

- The **process** is in a state **ready-to-run**
- The **Union** tool is connected to StreamBuffer.shp, FaultBuffer.shp, and WellBuffer.shp

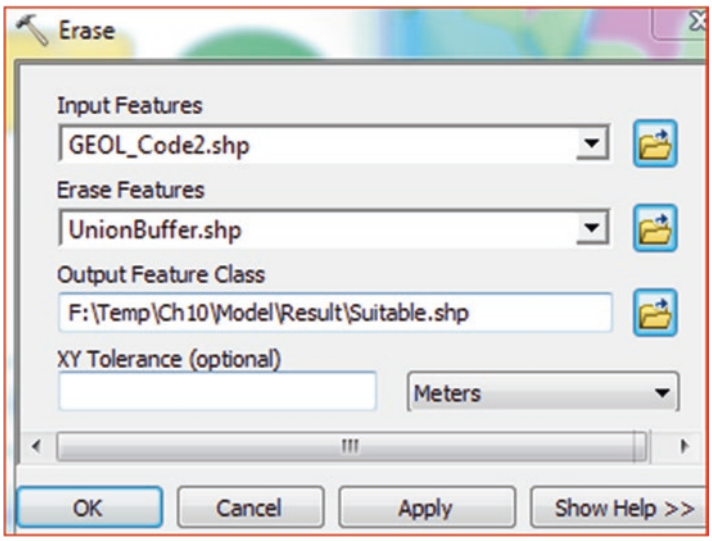


74. Click Auto Layout icon to rearrange all processes and then Full Extent icon

Erase Tool

The Erase tool creates a feature class by overlaying the input features "**UnionBuffer**" that are created from three united layers (**StreamBuffer.shp**, **FaultBuffer.shp**, and **WellBuffer**) with the impermeable geological formation of code 2 (**GEOL_Code2.shp**). Only those portions of the input features that fall outside boundaries of the **UnionBuffer** are copied to the output feature class.

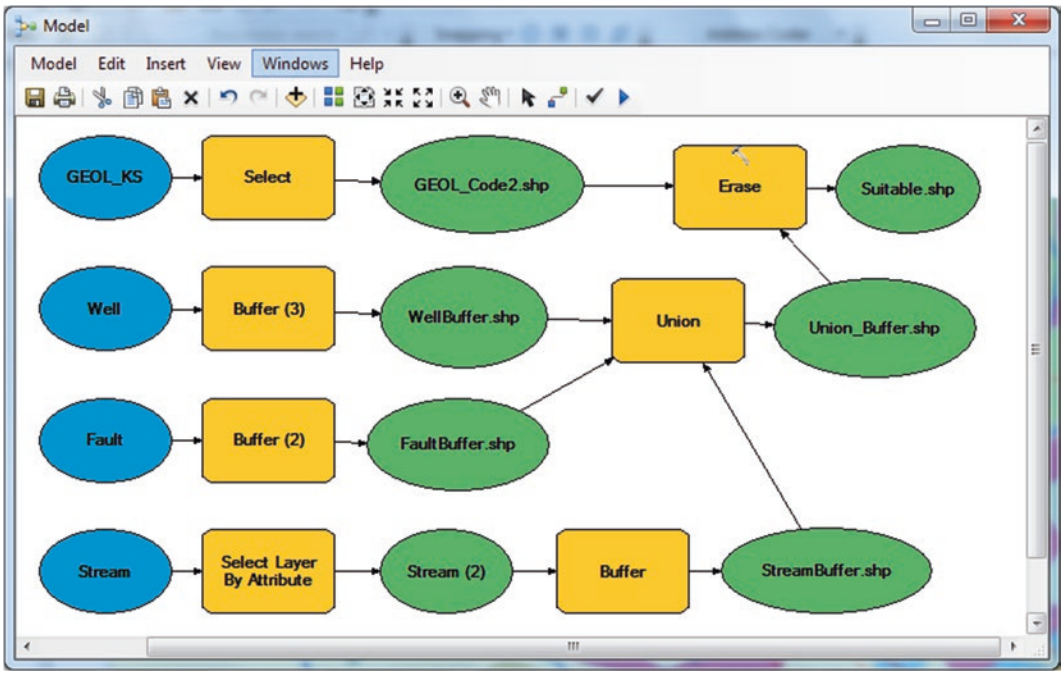
75. Search window/Erase
76. Drag Erase (Analysis) into the Model that you created
77. R-click Erase tool in the "Model"
78. Properties/Environments tab/scroll down and Open the Workspace
79. Check Scratch Workspace/click Values/open the Workspace
80. Fill the Scratch Workspace \\Ch10\Model\Result
81. OK/OK
82. D-click Erase tool and fill it
    - Input Features: GEOL_Code2.shp
    - Erase Features: UnionBuffer.shp
    - Output Feature Class: \\Result\Suitable
83. OK



OR you can use the **Connection button**  (3rd icon from last)
Use Connection button

84. In the Model window, select the Connect icon 
85. Click and Drag a connection from the **GEOL_Code2.shp** to the **Erase** tool
86. From the pop-up menu/select "Input Features"
87. Click and drag a connection line from the **UnionBuffer.shp** to the **Erase** tool
88. From the pop-up menu/select "Erase Features"
89. R-click Suitable.shp/check Add to Display
90. Save the Model window

Result: The Erase process connected and the Model is ready to run.



Validate and Run the ModelBuilder in Model Window

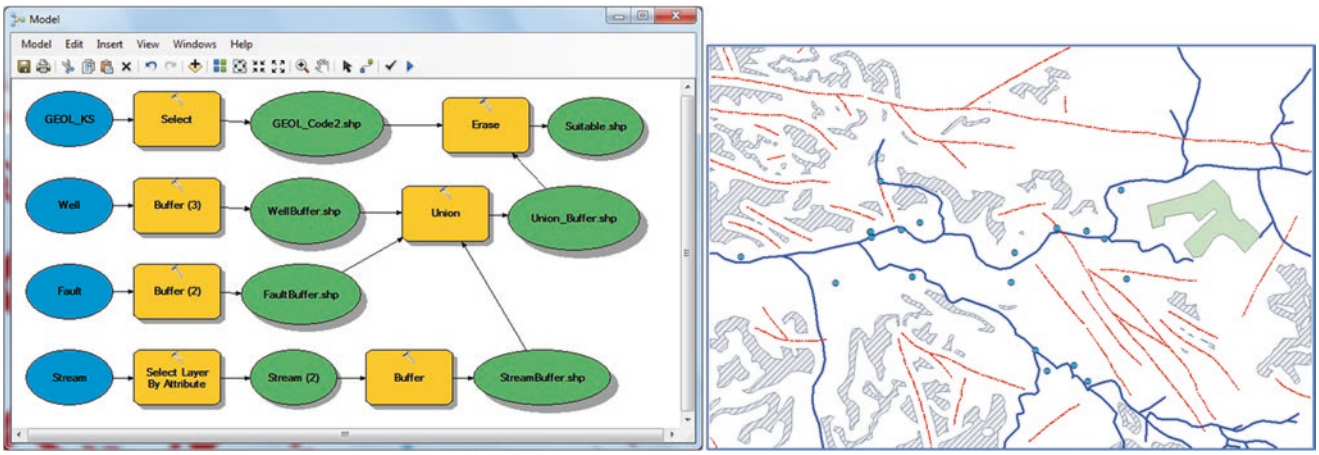
When validating the model, the system makes sure that all model processes (tools and the input and output features) are valid to be run properly. If all the variables and tools are validated, then the model will run. If some tools and their variables are not validated, the model will not run. Therefore, if something is wrong, you should open either the variable, or the tool and fix it by providing the correct values. Also, the entire model can be run from the following locations:

1. Model window
2. Model tool dialog box (this should have parameters)
3. Python window
4. In a Script

91. On the Model window, click the Run icon (last icon)

Results: Two things happen after running the Model.

- The "Suitable" is added to the table of content.
- Drop shadows will appear around all tools and all output variables. The shadows around the tools and output variables means that the **Model** is in **Has-been-run** state.



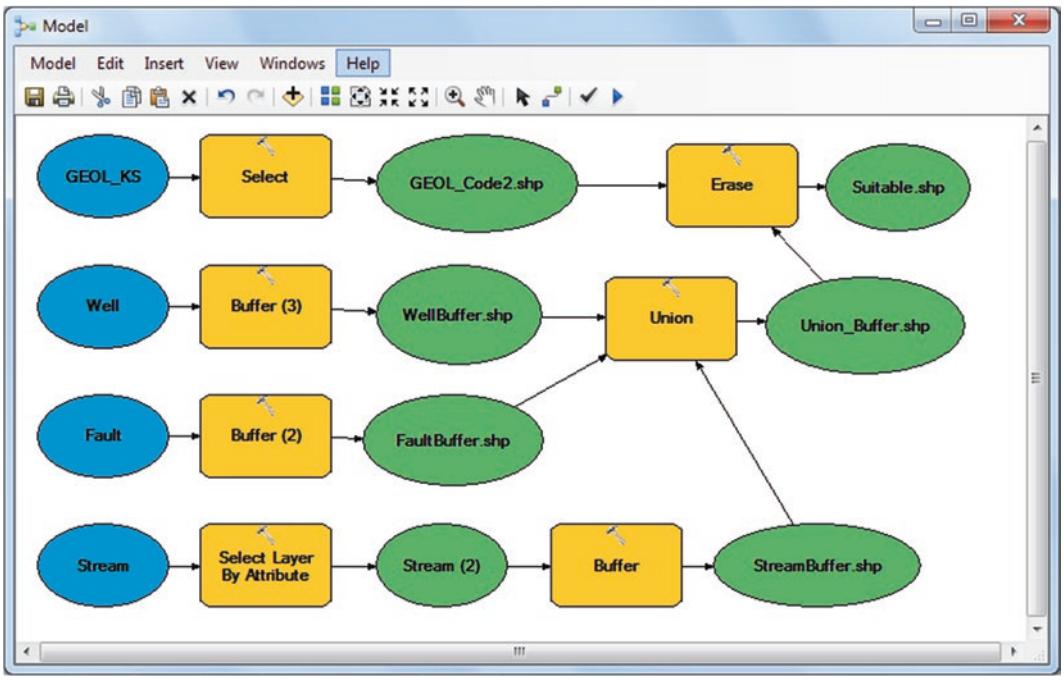
Validate the Model

92. From the Model menu/Click Validate Entire Model

Results: The shadow around the tools and the output variables will be removed.

93. From the Model menu/Click Run Entire Model

Results: The shadow around the tools and the output variables will be restored again

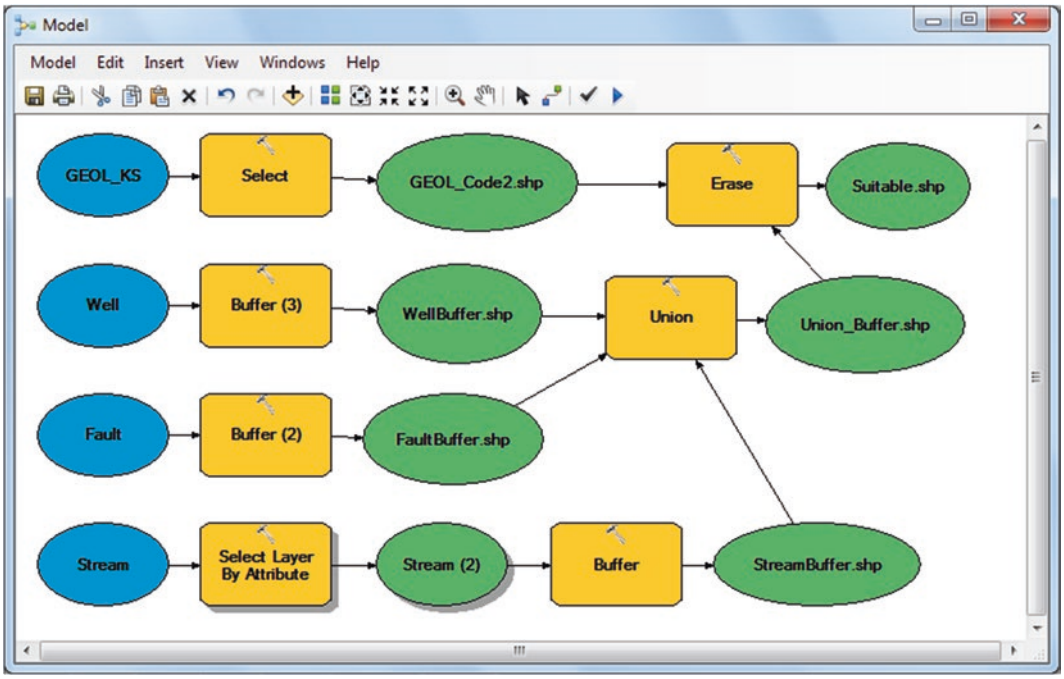


Intermediate Model: In the Model, some of the data is considered intermediate data because once the Model run, the data is no more needed. For example, the "**WellBuffer**" is only created to select the area that's at least 500-meters away from the wells. After that, this variable is no more needed.

94. From the Model menu/Click Delete Intermediate Data

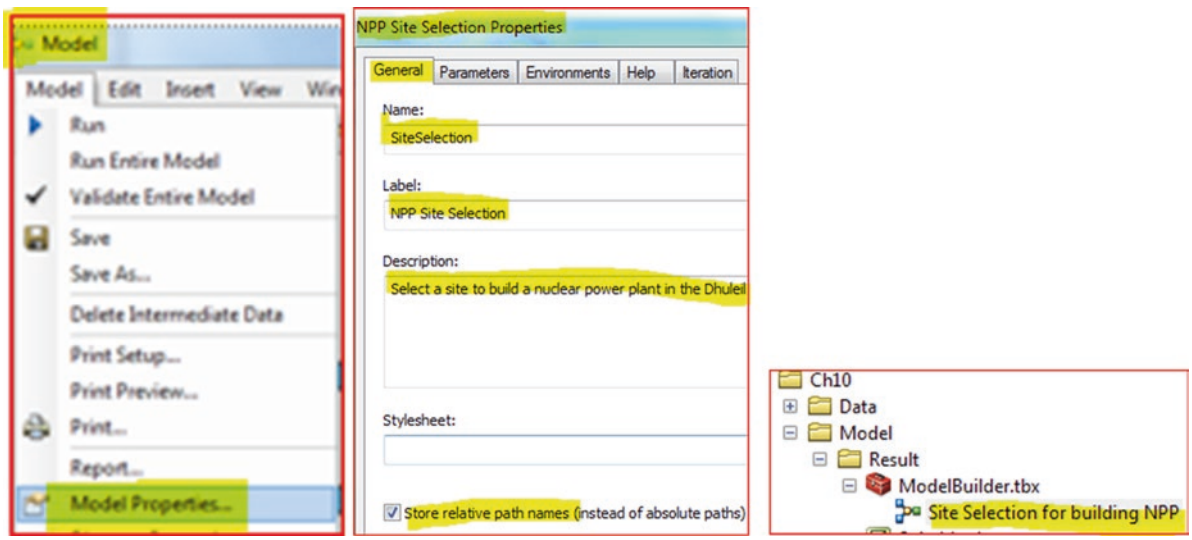
Results: The shadow around the tools (Buffer, Select, Union, and Erase) and all the output variables (with the exception of Stream (2) will be removed. This means the following:

- The Buffer, Select, Union, and Erase are reset because they generate intermediate data.
- The Select Layer By Attribute does not create intermediate data.



Add Model Name

95. From the Model menu/Click Model Properties/General tab
    a. Name: "**SiteSelection**" (no space is allowed)
    b. Label: NPP Site Selection
    c. Description: Select a site to build a nuclear power plant in the Dhuleil area
    d. Check the Store the relative path name
96. Apply/OK



97. Save the Model/then click Model menu and close

Result: The Model will change its name in the Catalog window.

98. Save ArcMap in the \\Result folder and call it NPP.mxd

Set Model Parameters and Run ModelBuilder in Model Tool

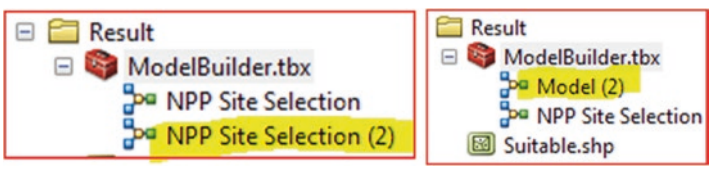
The **model tool** is accessed and run through the Catalog window. Prior to run the model, you need to set some model parameters. Till now, the model that you created is a set of connections between the variables (input and output features) and the tools. In the model window, the user can create the needed parameters and these parameters can be used or replaced without changing the model.

99. In the Catalog window/R-click the NPP Site Selection/Open

Result: The "NPP Site Selection" Model tool indicates that it has no parameters.

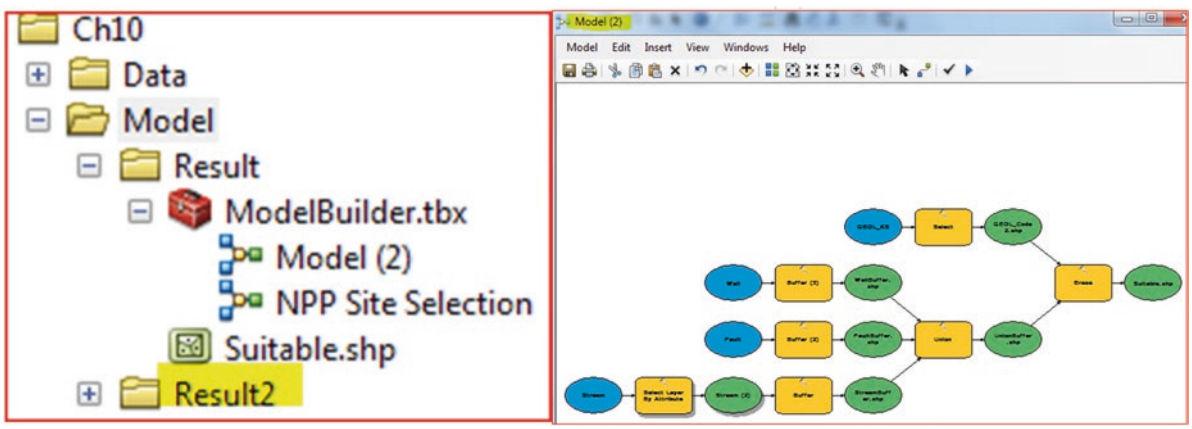
NOTE: ***Do not click the Ok, clicking Ok will run the model***.

100. Click Cancel to close the "**NPP Site Selection**" Model tool
101. In Catalog window R-click "**NPP Site Selection**"/Copy
102. R-click ModelBuilder.tbx/Paste
103. Rename the "**NPP Site Selection (2)**" to Model2



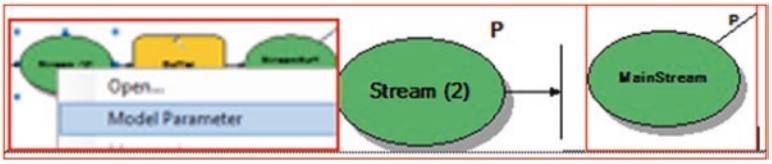
Result: The Model 2 is copied.

100. R-click \\Ch10\Model\New Folder, call it **Result2**
101. R-click Model 2/click Edit to open it in Model window
102. R-click the variable "Stream (2)" and click Model Parameter



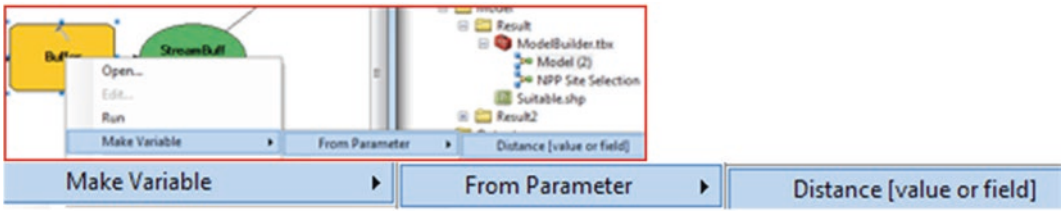
Result: A small letter "P" appear above the element (Stream (2), which indicates that the "**Stream (2)**" element now is designated as an input layer). Therefore, when you are going to run the Model tool in the Catalog window, ArcGIS will ask you to browse for an input layer.

103. R-click the variable "**Stream (2)**" and click Rename and rename it "**MainStream**"/then click OK



Note: When you ran the buffer tool previously on the stream, you used a 300 meter buffer distance because the distance is an important input function when running the buffer. Therefore, you are going to make the distance as a variable for the Buffer tool and set it as a model parameter. So when you run the Buffer tool, ArcGIS will ask you to specify the distance.

104. R-click the Buffer tool/Make Variable/From Parameters/Distance [value or field]



105. Click the Auto Layout icon
106. R-click the variable "**Distance [value or field]**" and click **Model Parameter**

Result: A small letter "P" appear above the "**Distance [value or field]**".

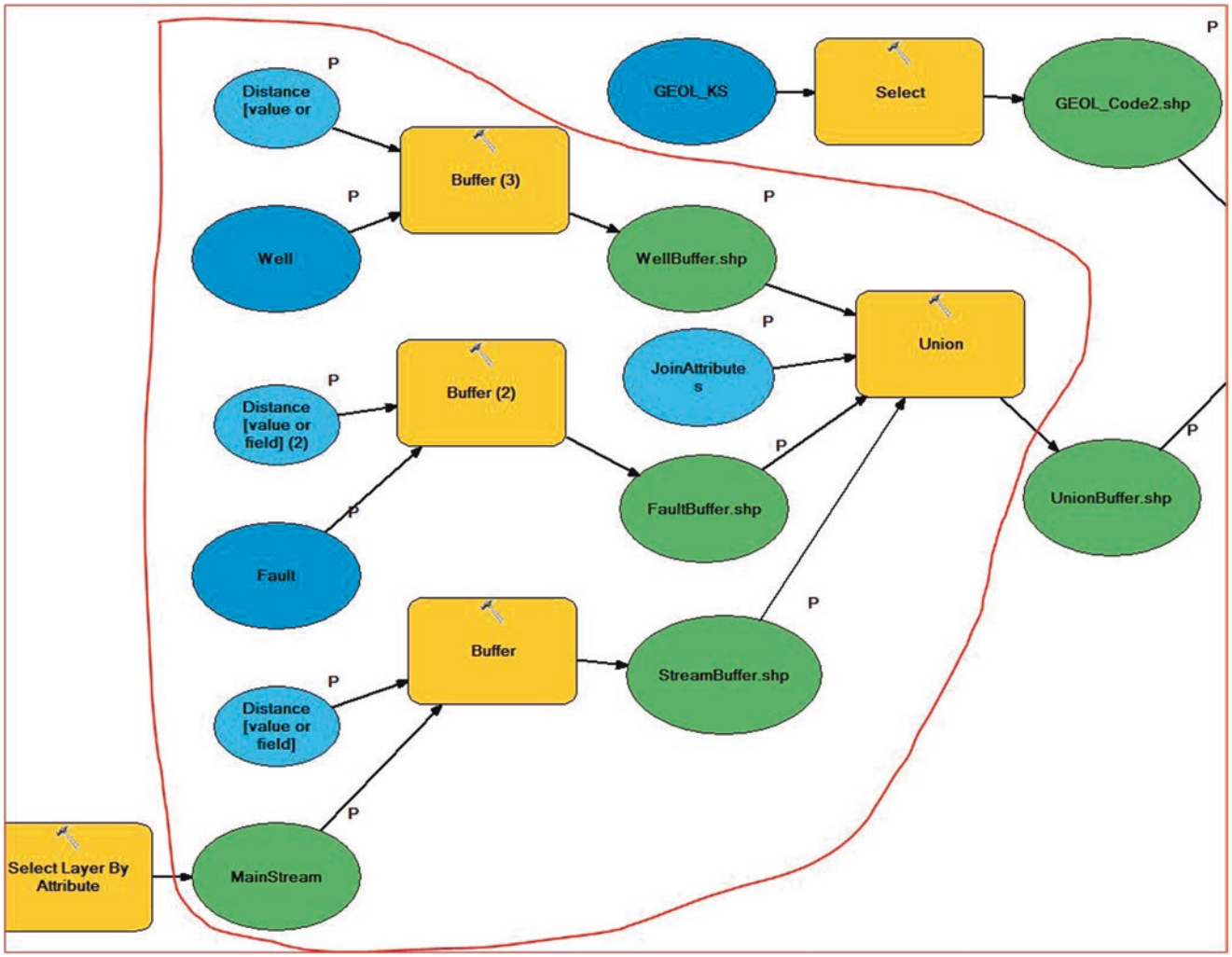
Note: Now you are going to repeat the previous steps on the buffering of the faults and wells.

107. R-click the variable "**Fault**" and click Model Parameter
108. R-click Buffer (2) tool/Make Variable/From Parameters/Distance [value or field]

109. Click the Auto Layout icon
110. R-click the variable "**Distance [value or field] (2)**" and click **Model Parameter**

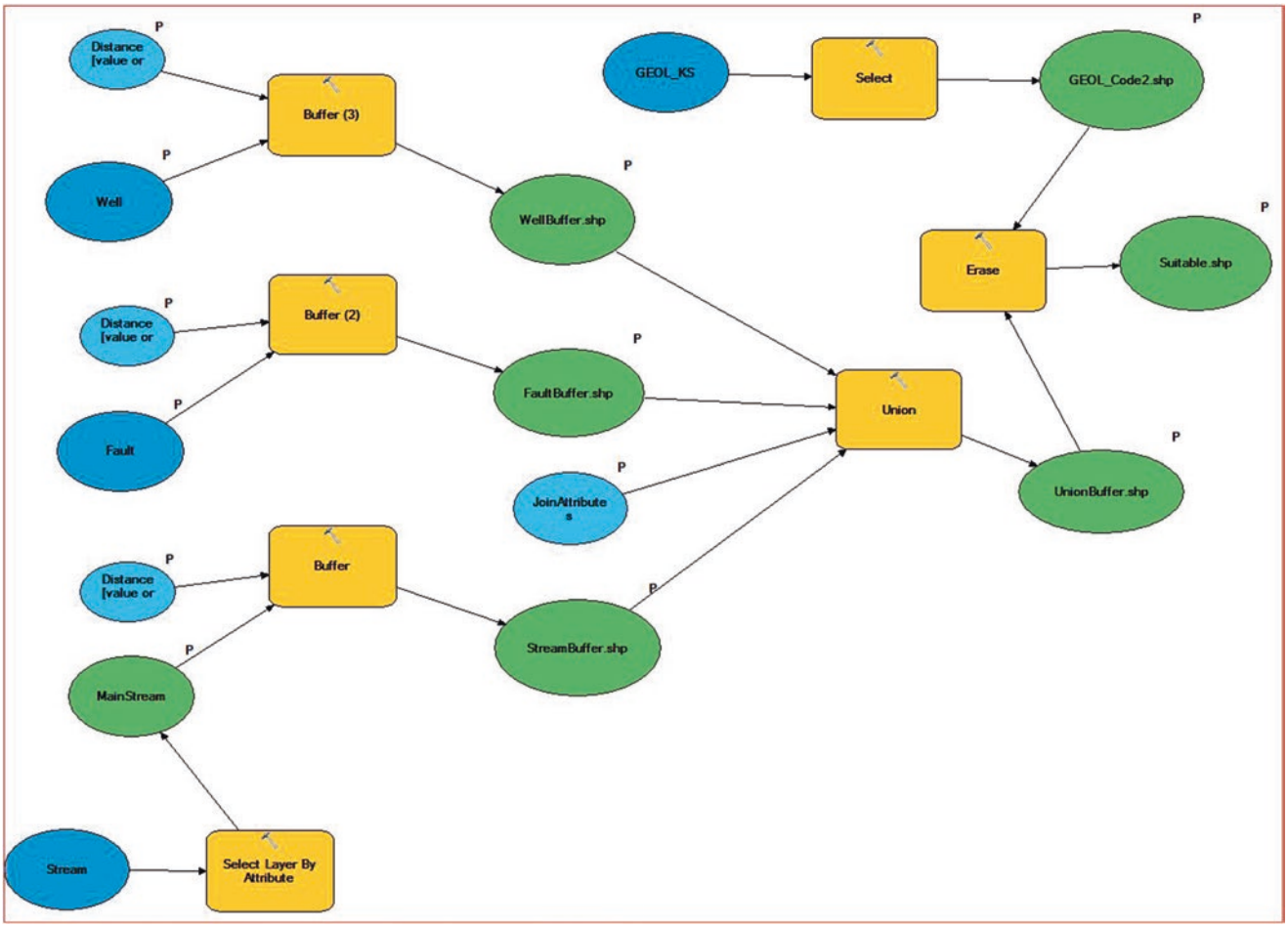
111. R-click the variable "**Well**" and click Model Parameter
112. R-click Buffer (3) tool/Make Variable/From Parameters/Distance [value or field]

113. Click the Auto Layout icon
114. R-click the variable "**Distance [value or field] (3)**" and click **Model Parameter**



115. R-click the variable "StreamBuffer" and click Model Parameter
116. R-click the variable "FaultBuffer" and click Model Parameter
117. R-click the variable "WellBuffer" and click Model Parameter
118. R-click Union tool/Make Variable/From Parameters/JoinAttributes Click the Auto Layout icon
119. R-click JoinAttributes and click Model Parameter
120. R-click Union_Buffer.shp and click Model Parameter
121. R-click GEOL_Code2.shp and click Model Parameter
122. R-click Suitable and click Model Parameter
123. R-click Suitable/Add to Display

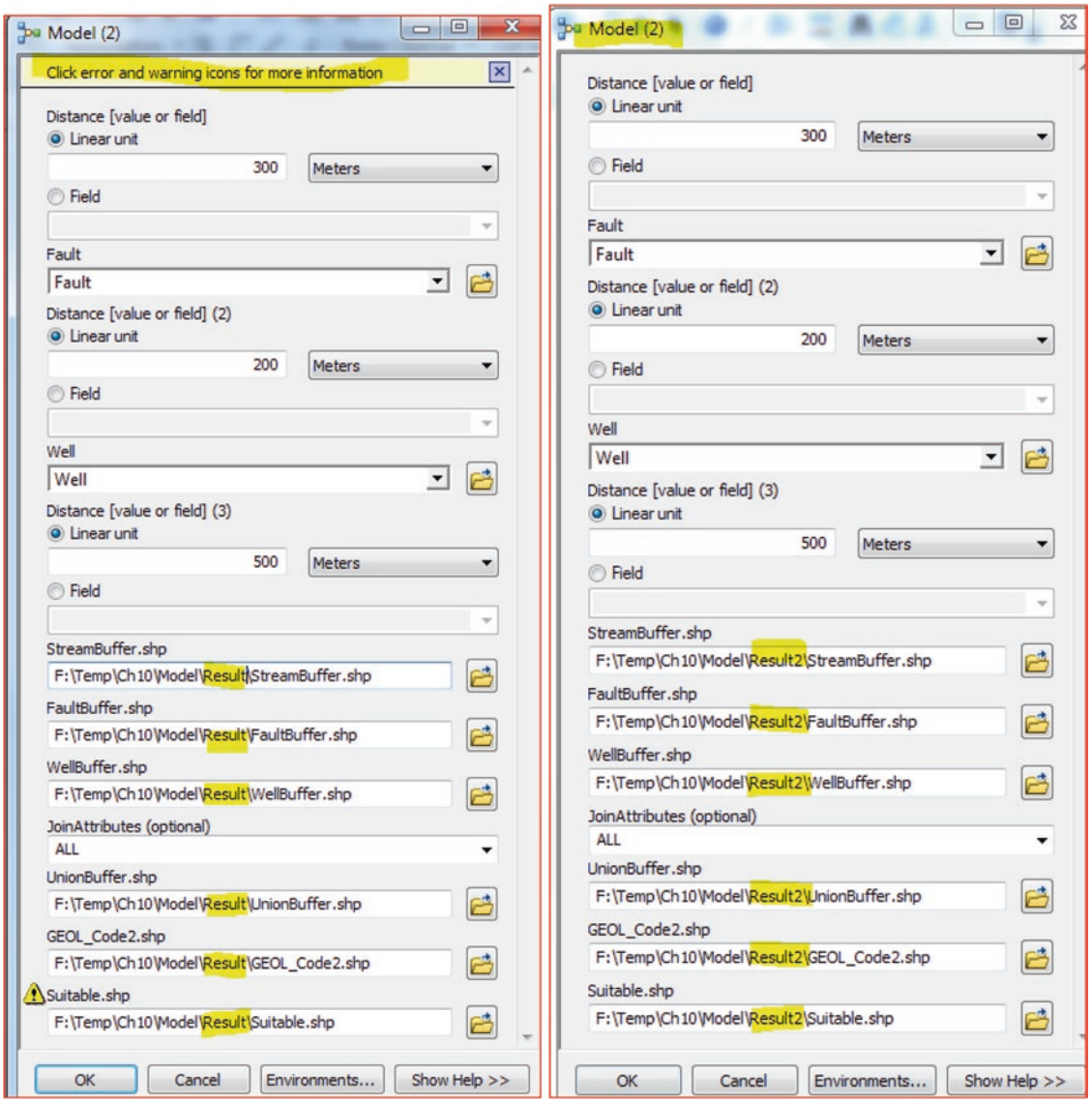
124. Click the Auto Layout icon and then Full Extent
125. Click Model menu and click Validate Entire Model
126. Save the Model and Close



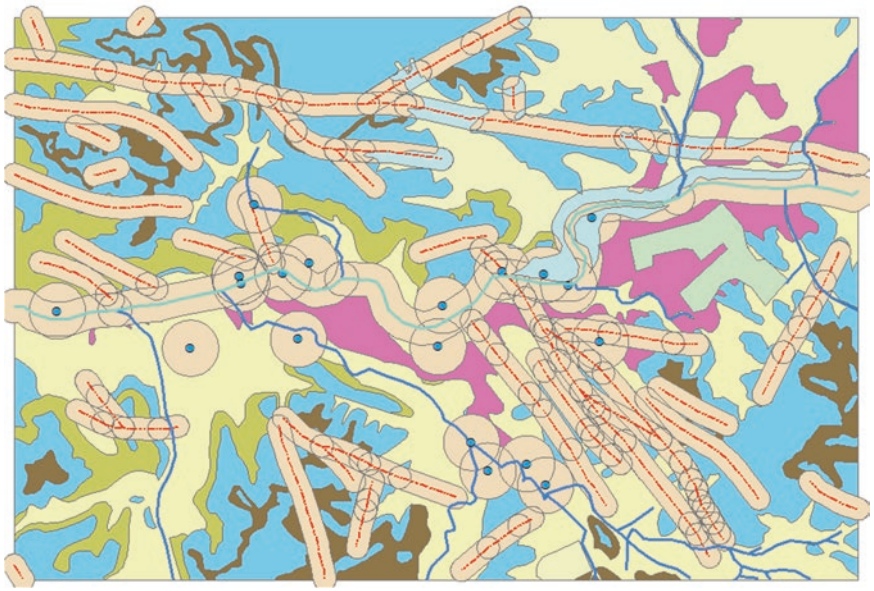
Run the Model Tool

127. In the Catalog window/R-click Model2 and click Open

Result: The Model open and the model parameters appear in the tool dialog box. The error icon appears because the output feature class already exists.



128. Change the path from \\Result into \\Result2
129. Click OK to run the Model tool
130. Click close



Result: The "**Suitable.shp**" and other output layers are added to TOC.