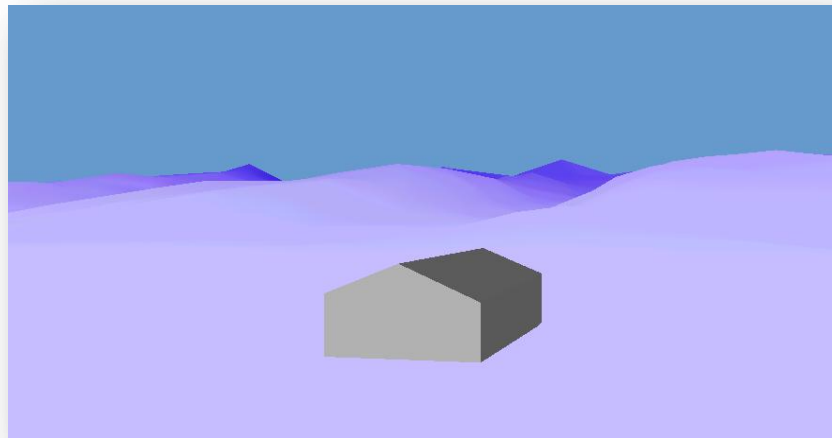


**ANALYZING RESIDENTIAL 3D ROOFTOP MODELS TO DETERMINE THE CAPACITY OF  
RAINWATER CAPTURE**



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## **Introduction**

3D modeling is becoming an integral part of the world. The use of 3D maps allows users to better communicate ideas and information about what is being analyzed by creating a 3D perspective of the environment of interest. ArcGlobe is an ArcGIS application that allows you to transform 2D data into 3D visualization models. Realistic models created in ArcGlobe can be used in planning and decision making scenarios, one example being rainwater harvesting.

Water availability is being affected by recent droughts and growing populations. Recent applications such as rainwater harvesting are becoming popular alternatives to help meet demand. As an area of study, Honolulu has very intense rainfall which makes it suitable for the collection of rainwater. This paper will focus on developing a 3D house model and using the model to determine the rainwater capture capacity within the city of Honolulu.

## **Objective**

The objective of this paper will be to develop a 3D model which will be used to determine the overall capacity of rainwater capture. An initial 3D model of residential buildings in Honolulu has been obtained from CyberCity3D. CyberCity3D is a 3D modeling company specializing in GIS products such as high resolution 3D buildings, solar roof measurements, and 3D building measurements information. The data provided includes all roof details that will aid in the analysis.

## **Method**

Data for the house model has been obtained from CyberCity3D. The first step taken was to study the files obtained and identify a house for the model. As seen in Figure 1, the file obtained covers a wide number of residential homes, a total of 2510 records. This company focuses on mapping high resolution 3D buildings which can be used in applications such as solar roof measurements. This project focused in their detailed basic roof information to recreate a feature class that can be regenerated by interested individuals.

The house geometry used is defined by EGID hwa00006917. Figure 2 shows the gable style roof model selected along with its measurements. The following steps cover the creation of the 3D model.



Figure 1: Honolulu Basic Roof Data Provided by CyberCity3D

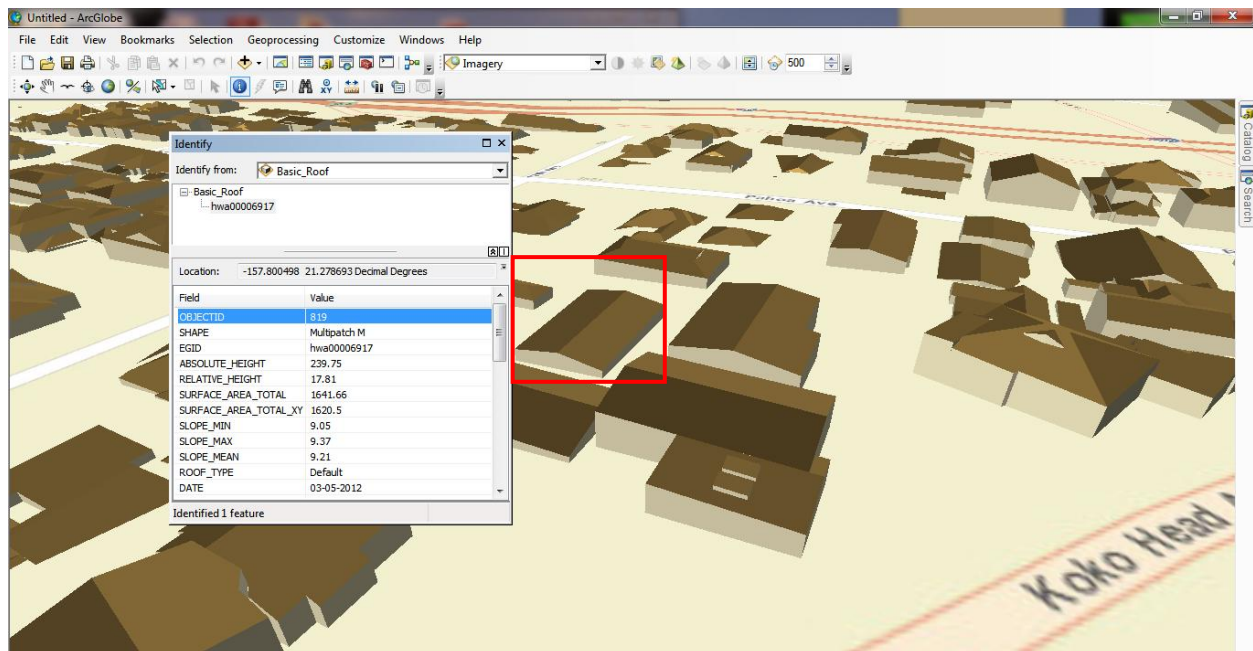


Figure 2: House model selected for study

The following are the steps needed to generate a 3D model.

- Research building measurements (obtained from CyberCity3D as indicated above).
- Create a 2D polygon feature class in ArcMap.
- Convert 2D polygon shapefile into a multipatch shape file.
- Use SketchUp to redefine building shape.
- Importing the SketchUp model created into ArcGlobe.

## Generating 3D Building

### Building Measurements (obtained from CyberCity3D as indicated above)

ArcScene was utilized to obtain specific length and height measurements since the measurements provided in the file obtained from CyberCity3D was based on total area. Detailed lengths are shown in Figure 3.

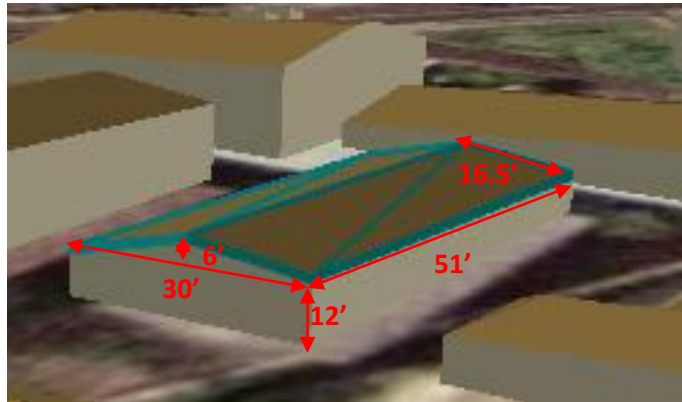


Figure 3: Measurements obtained using ArcScene

### Creating a 2D polygon Feature Class in ArcMap

A geodatabase was first created in order to store the feature class. Open ArcCatalog, find the folder where you want to save the geodatabase. Right click on the folder, click New>File Geodatabase>Type in Name . Create a Feature Dabaset to store the feature class in. Right click on the Geodatabase that was created>click New>Click New Feature Dataset> Type in Name and click Next. Choose the coordinate systems that is to be used for latitude and longitude coordinates. This project uses NAD\_1983\_StatePlane\_Hawaii\_3\_FIPS\_5103\_Feet since the home is located in Honolulu, as shown in Figure 6. Click on Next>Next>Finish.

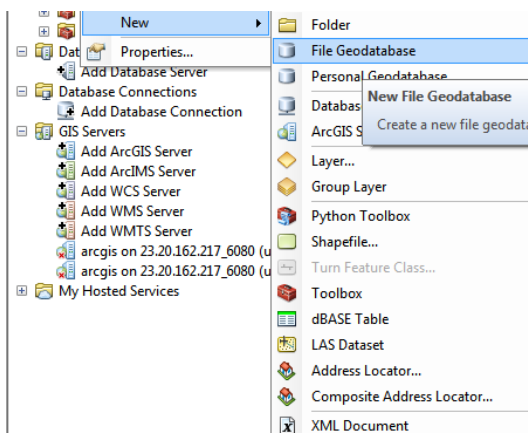


Figure 4: Generating a new File Geodatabase

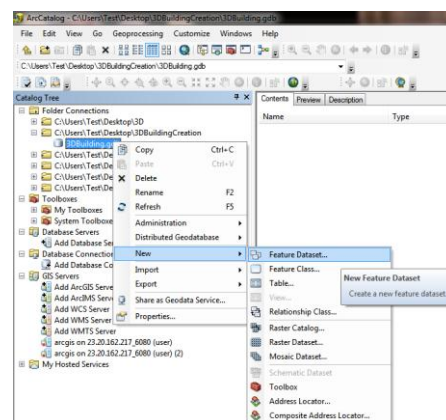


Figure 5: New Feature Dataset

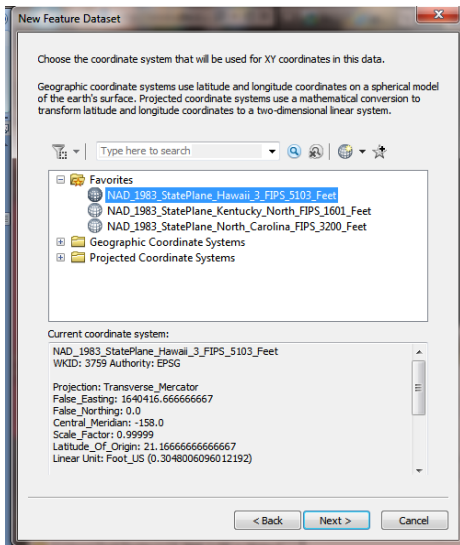


Figure 7: Choosing coordinate system under New Feature Dataset

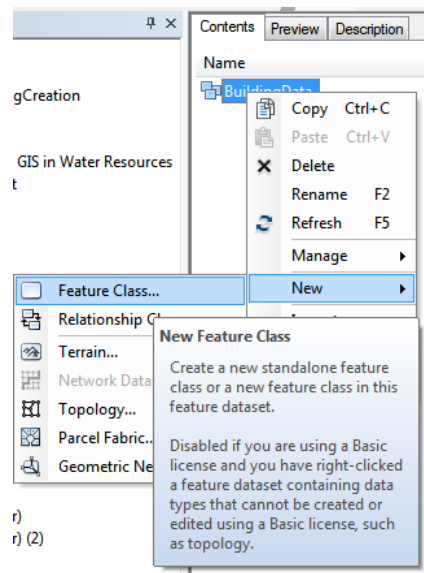


Figure 6: New Feature class

Right-click on the New Feature Dataset created and click New>Feature Class. Name the New Feature Class>Identify the type of features stored in this feature class as a Polygon Features>Click Next>Leave database storage configurations as Default>Click Next>Leave fields as is and click Finish.

The following steps were taken to generate a 2D footprint of the roof of the house.

Open ArcCatalog. Click Add Data and find the new feature class created. By using an image map, zoom in to the area of interest. Once it is loaded into ArcMap, right-click on the layer>Select Edit Features>Organize Feature Templates> Select the polygon layer>under Create New Templates Wizard make sure the polygon is selected and then hit Finish.

Under Customize tab make sure Editor toolbar is selected. This tool will be used to draw the polygon to create the shapefile. Click on the Editor drop-down menu>Start Editing. Disregard the warnings and click continue. A Create Features box should appear on the right-side of the screen. Click on your polygon layer, under Constructions Tools highlight Polygon. By using the Straight Segment tool on the Editor toolbox, trace over the outline of the roof by clicking once on each vertex of the polygon and double-clicking at the last one. On the Editor toolbox click Editor>Stop Editing>Save Edits.



Figure 8: Creating the shape of the polygon

## Convert 2D Polygon Shapefile into a Multipatch Shape File

Now that the polygon shapefile has been created, the next step is to transform it into a multipatch shape so that it can be modified using Google SketchUp.

Open ArcGlobe. ArcGlobe contains three different layer categories: Draped, Floating, and Elevation. Information defined under the draped layers is placed on the globe surface (e.g streams), Floating layers are set above or below the globe surface (e.g. air pollution concentration) and Elevation layers define surfaces of the globe. Since we need the feature class to be placed under the draped layer, under the Table of Contents>right-click Globe Layer>Add Data>Add Draped Data. Add the polygon created to ArcGlobe by finding and selecting the feature class.

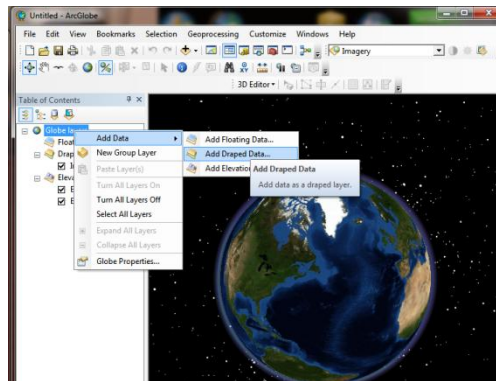


Figure 9: Adding feature class as a draped layer

Right-click on the polygon>Choose Properties>Globe Extrusion (as shown in Figure 10). Click on Extrude features in layer and under the extrusion value input the value by which the building is to be extruded by. The units used are meters so when setting the height of the building make sure to take this into consideration. The polygon is being extruded now and later it will be modified in the shape of a house.

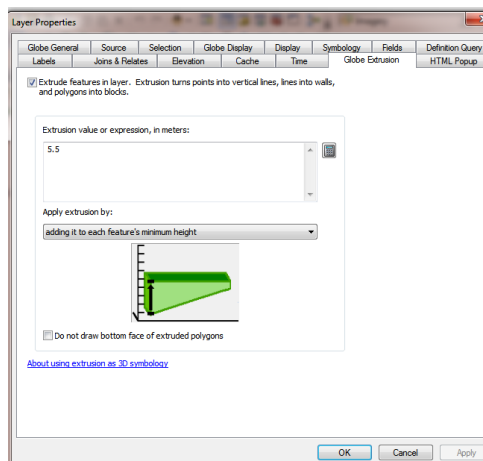


Figure 10: Extrusion of polygon

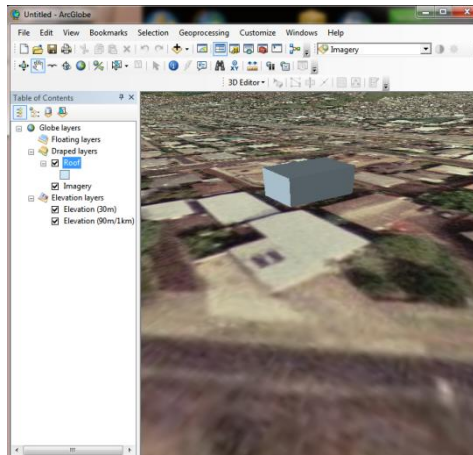


Figure 11: Polygon shape extruded to desired height

Figure 11 shows the results from extruding the polygon shape. Under layers properties you can also change the display options, for example making the building transparent so that you are able to see the base map underneath.

The next step is to transform the polygon shape feature class to a Multipatch by using “Layer to 3D Feature Class” tool. As shown in Figure 12, the tool is found under ArcToolbox>3D Analyst Tool>Conversion>Layer 3D to Feature Class.

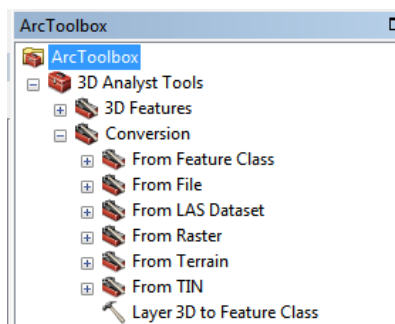


Figure 12: Layer 3D to Feature Class tool used to transform polygon to mutipatch

In order for this to work, the feature class has to be in a file geodatabase. The purpose of converting the feature class into a multipatch is to give the polygon the volumetric shape needed for the analysis. As shown in Figure 13, under Input Feature Layer choose the feature class made, in this case it was name Roof. Identify the name and location of the new multipatch under Output Feature Class, in this case it was named ROOF\_Z. The new multipatch feature class is not shown in the map because it was place under the Floating Layer. Right-click on the layer>click on redefine layer>choose Redefined Layer as Draped. This will place the multipatch on top of the map, as shown in Figure 14.



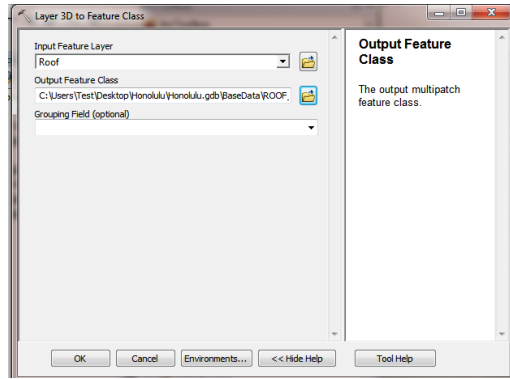


Figure 13: Defining attributes of Layer 3D to Feature Class

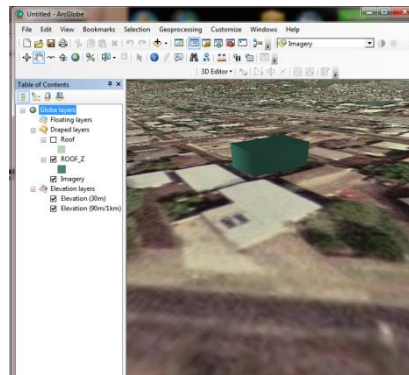


Figure 14: New multipatch feature class

As shown in Figure 14, the house is in the shape of an extruded polygon. To draw the roof the multipatch layer will be extracted to Google SketchUp for modifications. In order to export the shape to Google SketchUp the layer must first be converted to a Collada file. The tool needed is found by clicking ArcToolbox>Conversion Tools>To Collada>Multipatch to Collada (see Figure 15). This is a type of file that can be read by Google SketchUp.

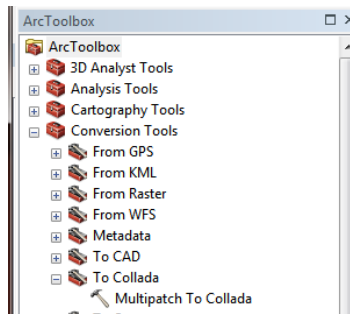


Figure 15: Multipatch to Collada Tool

Under the Multipatch To Collada window (Figure 16), input the ROOF\_Z feature class in Input Multipatch Feature. Under Output Collada Folder find a location to save the file and name it. Keeping the Prepend Source Name (optional) checked saves the new file as the Use field Name identified by the drop-down menu. Uncheck to have the file created as the one identified under the Output field.

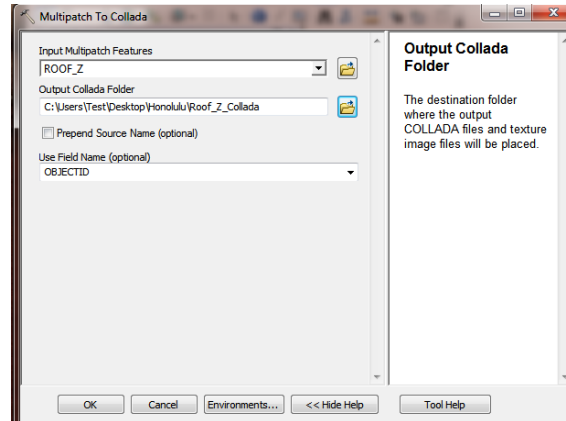


Figure 16: Defining Multipatch to Collada parameters

This tool will generate a new file folder with the new collada file inside.

### Use SketchUp To Redefine Building Shape

Google SketchUp was utilized to make the shape of the roof. This is a free program that can be downloaded at <http://sketchup.google.com/download/>. To import the collada file created, open SketchUp>Click on Start using SketchUp>Click on File>Import>find the folder generated by the collada tool and click on the .dae file created. Figure 17 shows a picture of the SketchUp program.

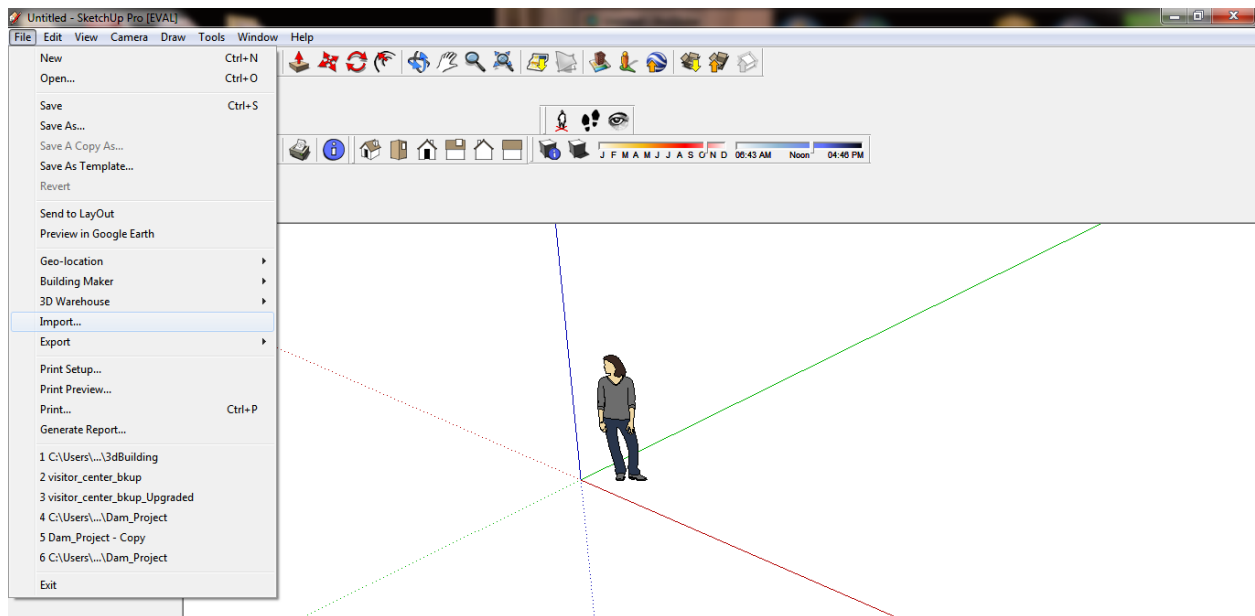


Figure 17: Google SketchUp 8

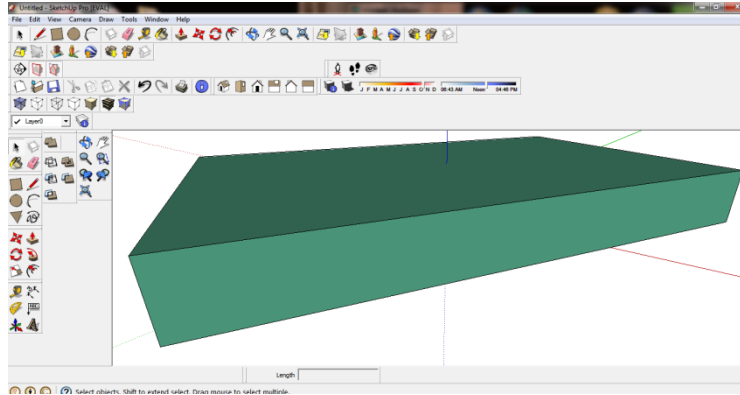


Figure 18: Collada file imported to Google SketchUp

Figure 18 shows the imported layer. The necessary modifications to the structure were made by utilizing the following tools in the program: Rectangle, Line, Push-Pull, Move, Tape Measure, and Orbit. There are many online tutorials that can help in using the program. This author is not very familiar with Google SketchUp so the house structure created, shown in Figure 19, is not very detailed. Only the necessary adjustments were made to construct the basic structure. Google SketchUp also lets you change the texture of the house and make a more realistic design; the drawings can be as detailed and exact as an individual can make it. Many 3D buildings found in Google Earth were created using this program. Once a building or a structure is created individuals can share their drawings with the online community by uploading into Google Earth or ArcGIS.

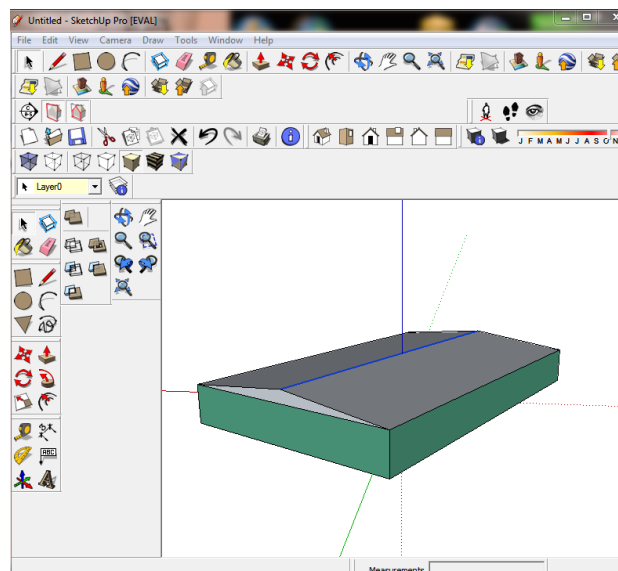


Figure 19: House structure constructed using Google SketchUp

Once the drawing is finished, go to File>click on Export>3D Model. Save the new file.

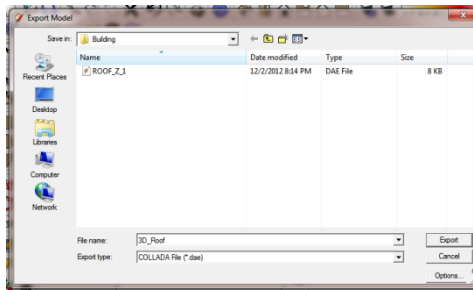


Figure 20: Exporting 3D model created in Google SketchUp

### Importing Google SketchUp Model Created Into ArcGlobe

Now that the new model was created, it needs to be imported back to ArcGlobe to replace the old shape. Right-click on the multipatch feature class>Edit Features>Start Editing. On the 3D Editor toolbar click on Edit Replacement Tool and then click on the polygon, ROOF\_Z in this case. Once the feature class is highlighted then pull-down the 3D Editor menu and select Replace with Model (Figure 21).

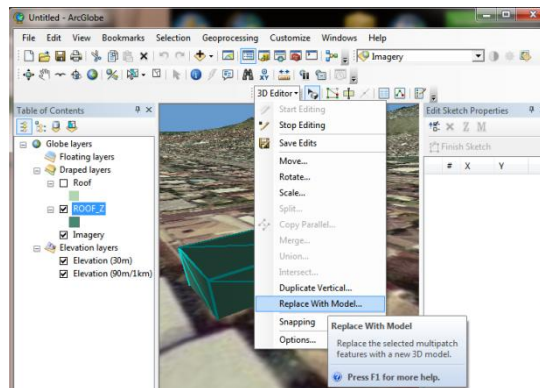


Figure 21: Replacing old multipatch feature class with the newly created drawing in Google SketchUp

Select the SketchUp model created from the opened window (Figure 22).



Figure 22: New house drawing generated in SketchUp

Shown in Figure 23 is the new drawing that was generated in SketchUp. The old multipatch polygon is shown in opaque green and the new drawing is shown in dark green for comparison. The new drawing replace the older one perfectly because the drawing created in SketchUp was done using the exact measurements identified at the beginning of the report.

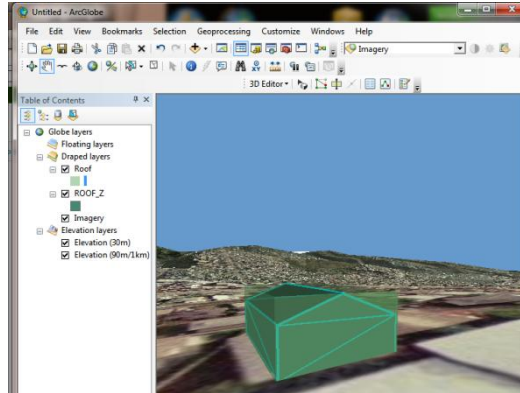


Figure 23: SketchUp model imported to replace old feature class

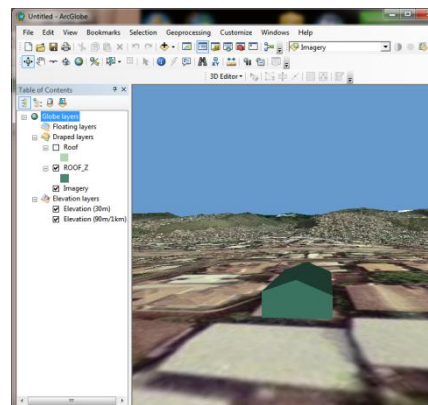


Figure 24: Final feature class

Figure 24 shows the final drawing created using the combination of various programs: ArcCatalog, ArcMap, ArcScene, ArcGlobe and Google SketchUp. This report focused on creating a 3D structure from beginning to end. Exact measurements were used in creating the shapes in Google SketchUp but exact measurements were not added to the feature class in ArcGIS. The next step of this report will focus on adding dimensions to the feature class and calculating the amount of water that can be captured.

## Calculating Rainwater Capacity

After adding the dimensions to the model the total flow was calculated by using the following formula provided by Dr. Maidment:

$$q = \frac{iL}{\sqrt{1 + S_0^2}}$$

q= unit flow per unit width that is traveling down the roof

i= rainfall intensity, in/hr

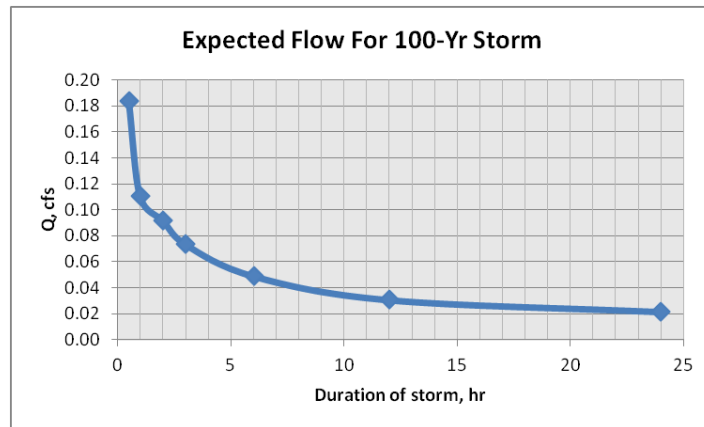
L=length along the roof, ft

S<sub>0</sub>=slope

The water depth along the roof changes as rainfall travels down the roof. A follow-up to this project would need to consider this into the analysis.

**Table 1: Rainfall intensities for 100-Yr Storm**

Time, hr	Rainfall, in	Intensity in/hr	Intensity, ft/sec	Length, ft	S <sub>0</sub>	Width, ft	Q, cfs
0.5	2.5	5.00	0.000116	16	0.092	51	0.1836
1	3	3.00	0.000069	16	0.092	51	0.1102
2	5	2.50	0.000058	16	0.092	51	0.0918
3	6	2.00	0.000046	16	0.092	51	0.0735
6	8	1.33	0.000031	16	0.092	51	0.0490
12	10	0.83	0.000019	16	0.092	51	0.0306
24	14	0.58	0.000014	16	0.092	51	0.0214



**Figure 25: Flow to be expected for 100-year storm**

Rainfall intensities listed in Table 1 were obtained the U.S. Department of Commerce Weather Bureau report. Rainfall depths were obtained from isohyetal maps. The results are listed in Table 1 and Figure 25. The maps for Oahu are small therefore the exact rainfall was approximated as best as possible. The mean annual rainfall for the study area is about 29.58 inches. As shown in Figure 26, the study area experiences rainfall throughout the year. This makes it an ideal place for rainwater capture.



**Figure 26: Rainfall information obtained from Rainfall Atlas of Hawai'i**

## **Conclusion**

The objectives of this project were to develop a 3D model of a structure and determine rainwater capacity. My original objective was to come up with a model that could calculate the amount of rainfall that could be captured by considering a more realistic representation of how the water depth changes as it travels down the roof. The flow was found but more work needs to be done in order to accomplish the more realistic way of the water flow.

Learning how to model 3D data was one of the most useful parts of this project. This class was focused on ArcMap, but by doing this project I was also able to learn how to use ArcGlobe. Most of this paper focuses on how to begin the analysis from beginning to end, creating a feature class to drawing the 3D structure. As detailed in the paper, various programs are needed to create the 3D structure. These programs, and others out there, are helping develop a 3D map of the world that can be assessed by anyone and used in different parts of the industry and community. It has motivated me to continue learning the programs so that I can do future analysis in areas that do not yet have 3D modeling structures, outside of the U.S.

This project focused on learning how to generate a 3D house model. There is still much more work that can be accomplished and researched. A good way to expand this paper would be to continue the development of a small residential community and adding the 3D perspective of its geologic features.

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