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Assessing the Extent of Land Flooded and the People Affected as a Result of the 2010 Indus River Floods

Problem

The country of Pakistan is subjected to torrential rainfall each year during monsoon season in the late summer, often resulting in countrywide flooding and casualties. In particular, the Indus River, the main river in Pakistan, is prone to perennial floods that spread across its floodplain depending upon the severity of the monsoon season. In 2010, the country experienced its worst flooding event in the past 80 years, where continued heavy rainfall submerged up to a fifth of the country (approximately 160,000 square kilometers) in flood waters according to some estimates and up to 2,000 deaths were reported. A mapping and analysis of the flooded area will allow the Pakistani government to better predict what areas will be affected by the next potential flooding event.

Goal

This project will assess the square kilometers of land that was submerged and the people affected as a result of the 2010 floods in Pakistan. To do this, I will use various mapping and census data from NASA and other sources utilized in ArcMap and Google Earth.

Data Used

-Shapefiles for country boundaries of Pakistan, rivers of Pakistan, provinces and districts of Pakistan (already set to GCS_ WGS_1984 spatial reference, from www.diva-gis.org) Several aerial photos of Pakistan from the same website were used initially, but were not used in the final map.

-Images of extent of flooding area in Pakistan from the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite (GCS_WGS_1984 spatial reference); Google Earth was used to view the images. **http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=45162**

-Census data from the Government of Pakistan (http://www.census.gov.pk/datacensus.php); from this data, the population density was used

Procedure

    A. Create a map area of Pakistan.

    B. Create polygons of the flooded areas in Pakistan using Google Earth using the Add Polygon tool.

    C. Digitizing the flood polygons created in Google Earth in ArcMap

    D. Calculate the square kilometers of land that were submerged by the flooding event.

    E. Add census data to ArcMap and assess the number of people displaced during the flood event from the attribute table.

    A. Creating a map of Pakistan

To get a better idea of the Indus River and other water sources as well as the districts that were affected by the flood event, a map of Pakistan should first be created with district boundaries and the water sources in pre-flood conditions.

    1. Open a blank map in ArcMap.

    2. Connect to the folder holding the data that will be used (Seme_proj folder)

    3. Add the "PAK_adm1" shapefile to the blank map. Select the add data tab>Folder Connection>seme_proj>seme_proj.mdb>PAK_adm>PAK_adm1.shp. This is the country boundary of Pakistan.

    4. Next, add the "PAK_adm3" shapefile to the map. This is a shapefile of all of the districts that lie within Pakistan.

    5. Next, add the "PAK_water_areas_dcw" shapefile to the map. This maps out the rivers and lakes of Pakistan.

    6. Add the aerial photos of Pakistan to the map and set it to be behind all of the other shapefiles.
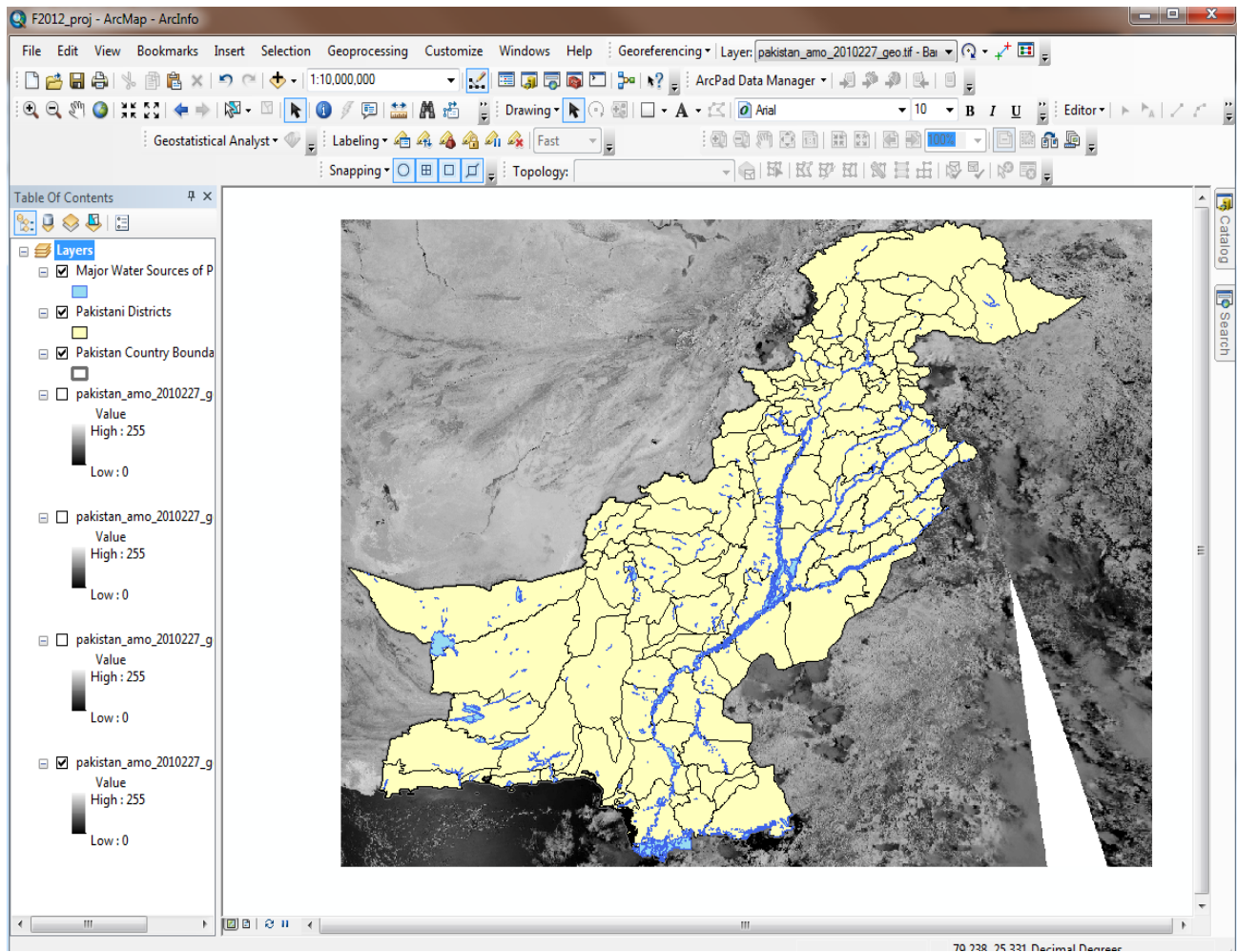
Figure 1. Map of Pakistan with its districts and water sources

B. Creating Polygons in Google Earth

It was decided that the best way to map out the extent of the flooding area was to create polygons in Google Earth using satellite photos captured on the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite at various times during the flooding event. Then the various photos were examined and the photo that best expressed the maximum flooding surface was chosen to create polygons with. This was done because the flooding started from the northern region of Khyber Pakhtunkhwa and made its way south until it reached the Indus River Delta in the Sindh region. In general, photos from later dates better captured the flooding extent in the south, while earlier photos were better suited for flooding surfaces in the northern areas, with some minor exceptions for both cases. The steps are listed on the page after Figs. 2 and 3.
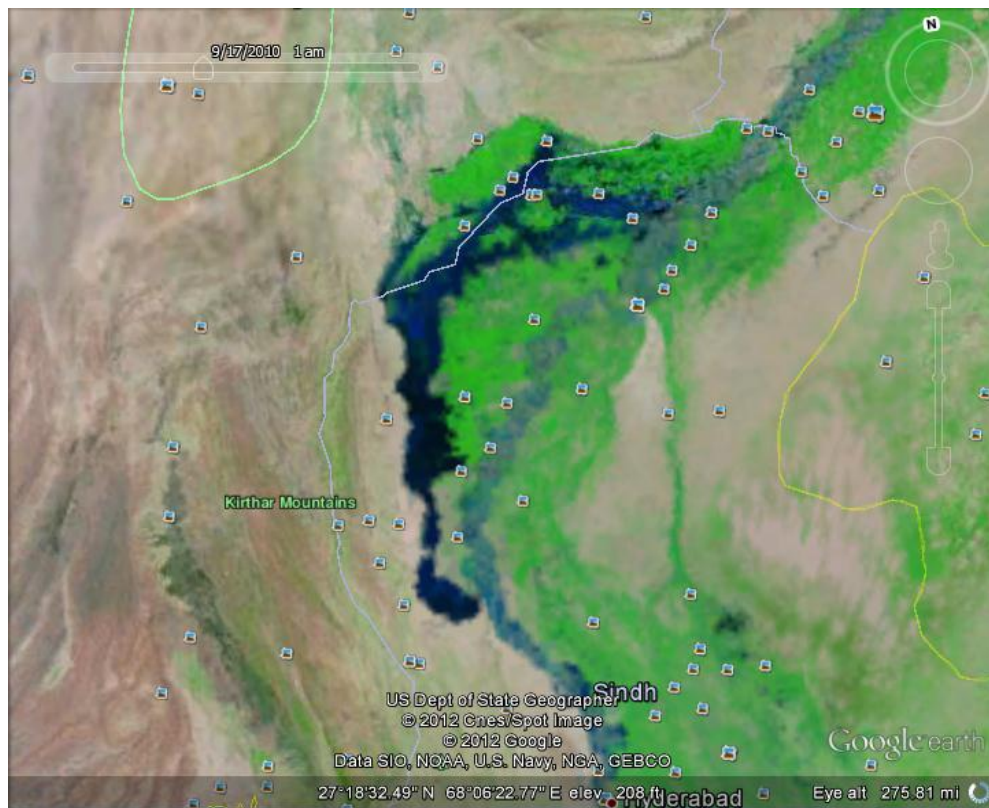
Figure 2. An example of the flooding surfaces over time as seen in Google Earth
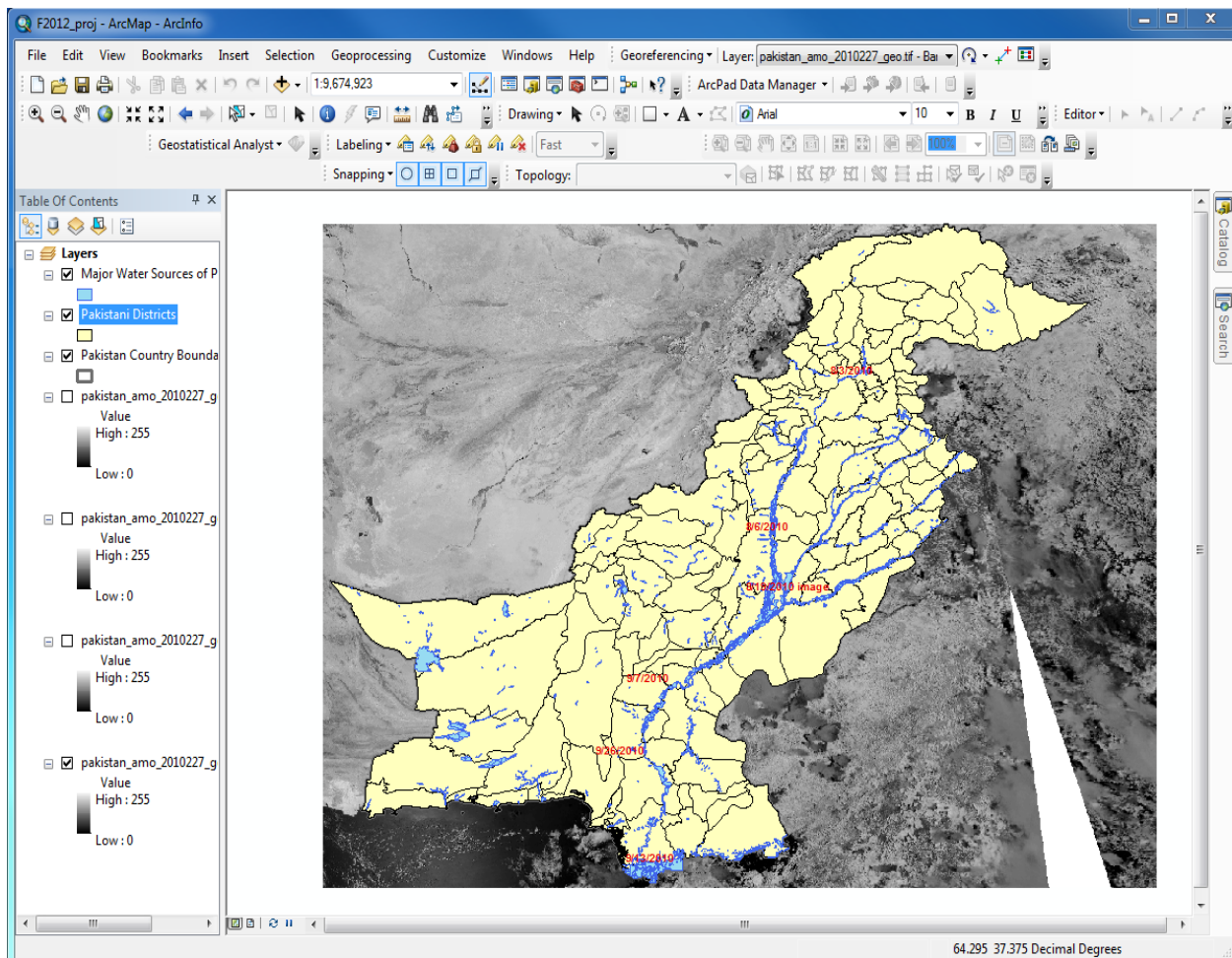
Figure 3. Map of Pakistan and its districts and major water sources. The dates listed in red relate to the photos I will use in Google Earth to create polygons to maximize the flooding surface area.

Creating polygons (cont.)

1. Open Google Earth, and open the photo set "Flooding in Pakistan"
2. Determine the number of areas that have been flooded by comparing the NASA photos to the original satellite photos in Google Earth.
3. Choose the photos that best express the maximum flooding surface for each flooding area.
4. Create as many polygons as necessary for each designated flooding area.
5. Once all necessary polygons have been created, save the polygons in .kml format in the appropriate folder for the project.
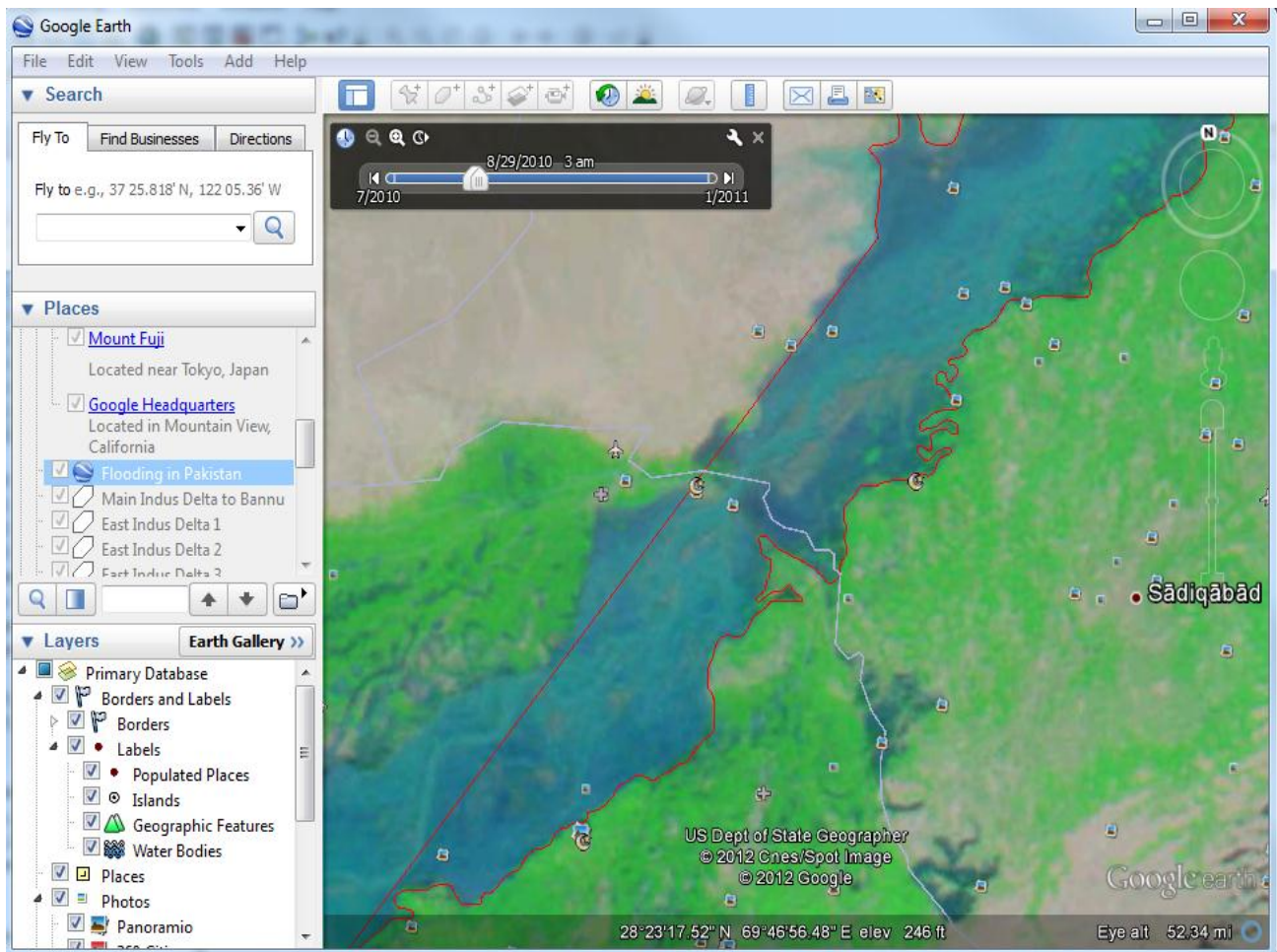
Figure 3. Section of the Indus River in the process of becoming a polygon in Google Earth. This is one of many polygons that will be brought into ArcMap. The smaller flooded areas will be polygons as well.

Figure 5. Google Earth photo with all of the polygons created along the Indus River floodplain.

C. **Digitizing the polygons made in Google Earth in ArcMap**
    1. Use the 'KML to Layer' tool to convert the Google Earth file into something usable in ArcMap.
    2. However, the layer automatically inserted into the map is not the polygon needed. To find the polygon needed, go to the newly created geodatabase for the polygon, select the "Placemarks_polygon" feature class, and insert it into the map.
    3. After all polygons has been uploaded into ArcMap, use the "Append" tool (In ArcToolbox, under Data Management Tools) to combine all of the flood polygons into one layer.
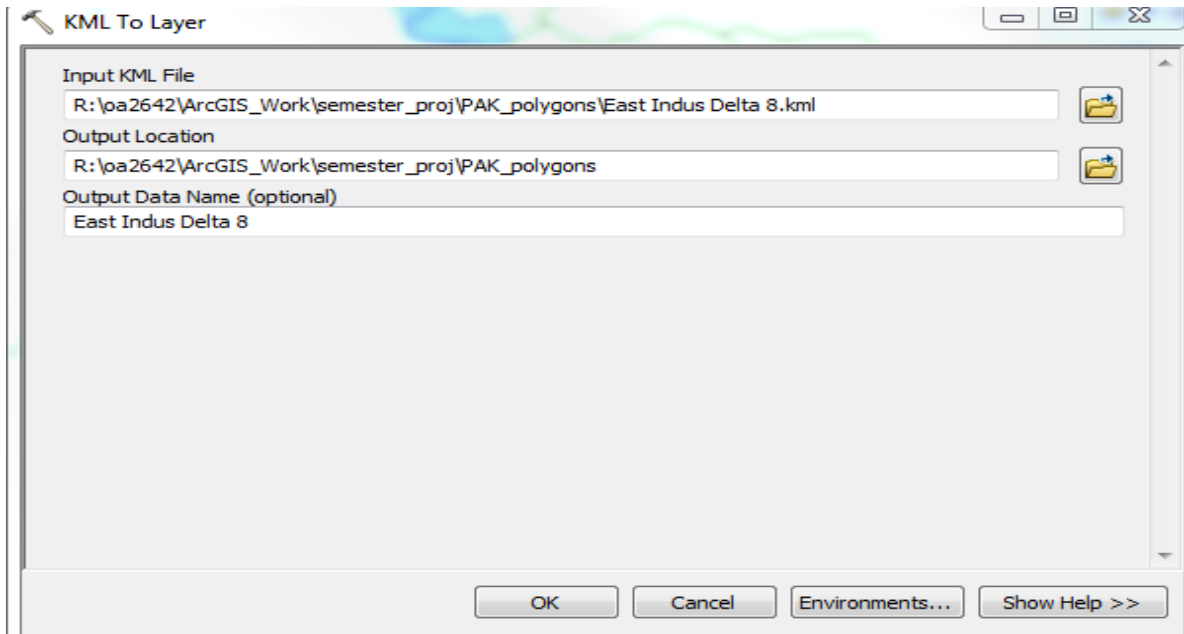
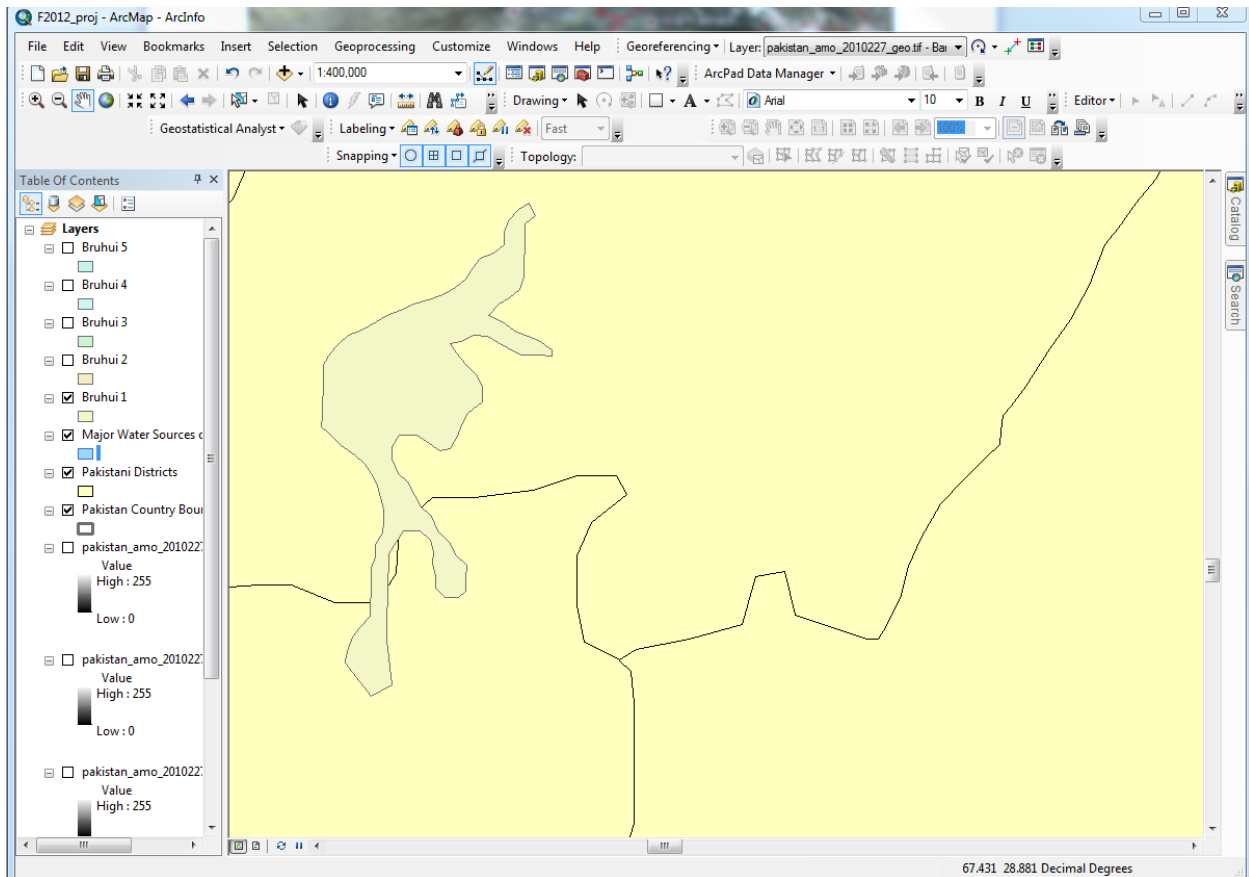**Figure 6. Using the "KML to Layer" tool to upload polygons into Arcmap.**

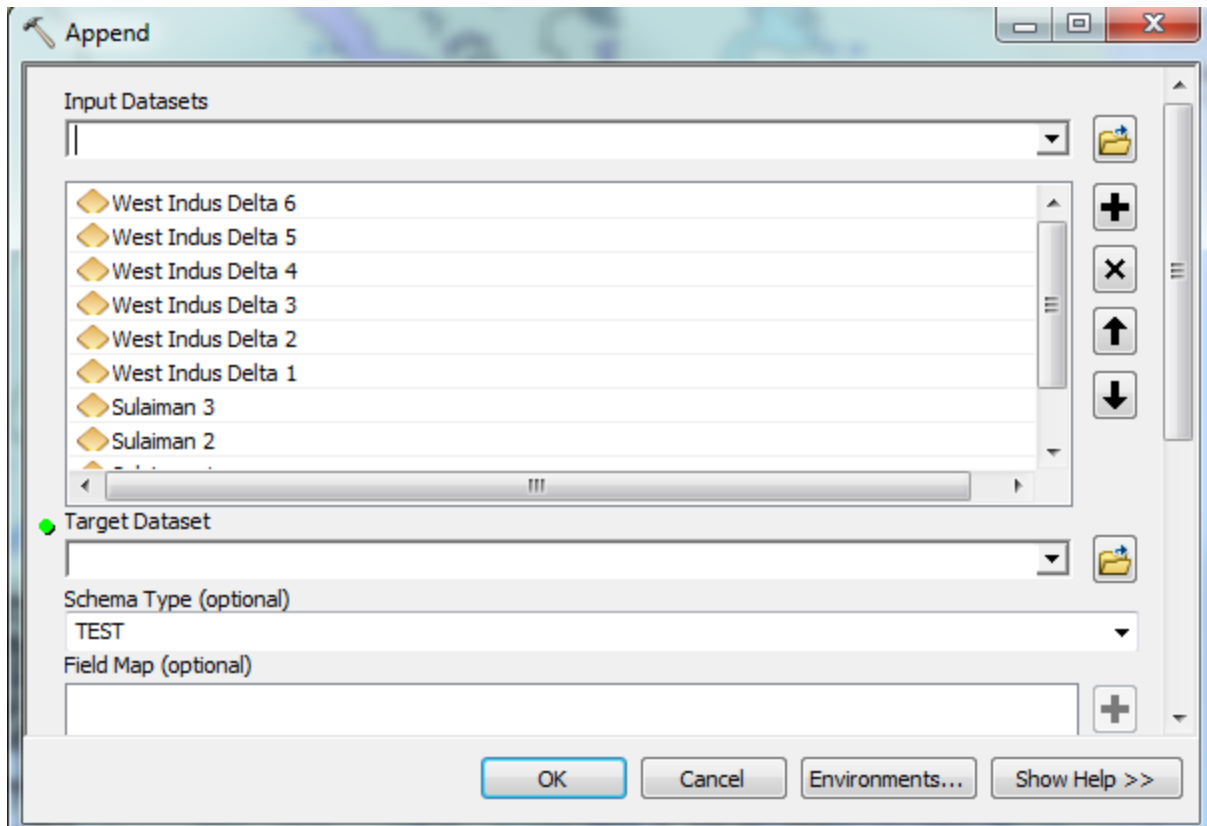**Figure 7. Polygon digitzed in ArcMap.**

Figure 8. Using the 'Append' tool to combine all polygons into one layer.

D. Calculating the Number of Square Kilometers of Land Submerged
1. Open the attribute table for the Flood Polygons layer.
2. Before any area calculations can be made, the map must be switched to a projected coordinate system. Set the Data Frame to the "WGS_1984_World_Mercator" coordinate system.
3. Add another field, "Square_km", to the attribute table. Next, right click at the top of the "Square_km" column and select 'Calculate Geometry'. Select Area under the Property menu and Square Kilometers under Units before calculating.
4. After the calculation, select Statistics to find the sum of the polygons and the total square kilometers of land submerged by the flooding event. In this case, it was calculated to be 61,364 square kilometers.
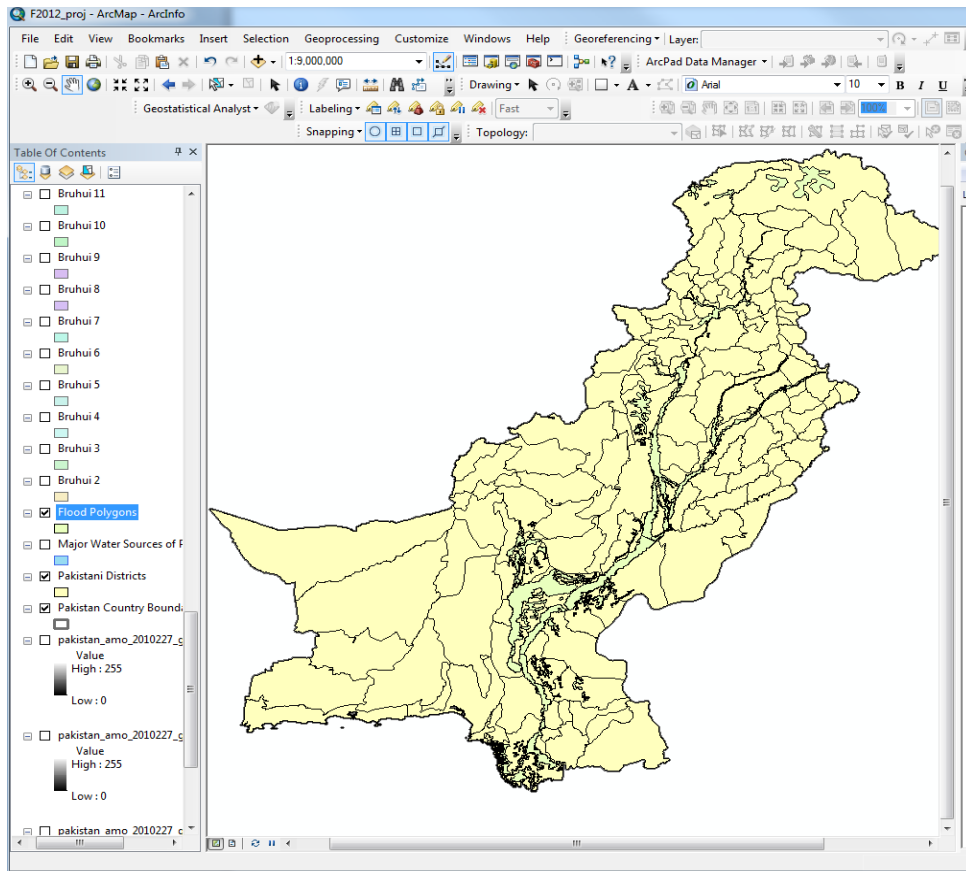
Figure 9. Map of Pakistan and the digitized flood polygons

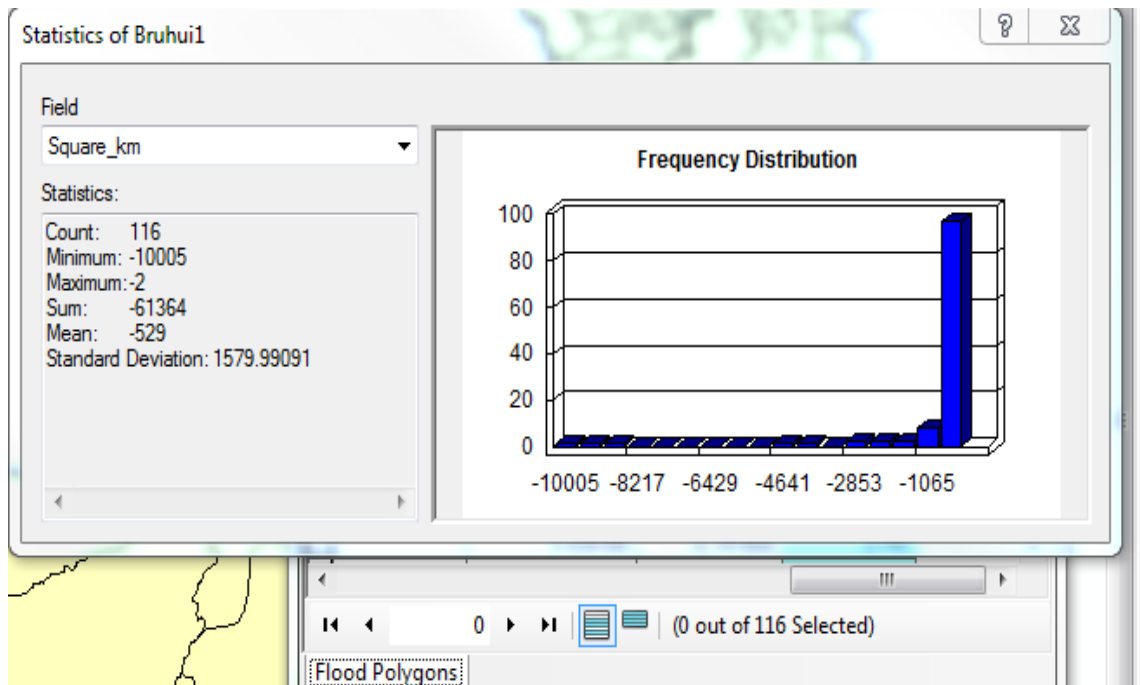**Figure 10. Attribute table after calculating square kilometers**

Figure 11. Statistics showing the square kilometers of land underwater (sum)

E. Calculating the Number of People Affected by the Floods

1. With the calculated value for square kilometers, multiply the value by the value of population density at the time of the flooding event, which was 225.19 people/km^2 in 2010. The number of people calculated to be affected by the flooding event is 13,818,559 people.

Conclusions and Problems

The calculated values from the project are 61,364 square kilometers of land were submerged as a result of the 2010 Pakistan floods, affecting 13,818,559 Pakistani citizens. Both of these values are below the reported estimates, though there are several reasons for these findings. First, the polygons digitized in Google Earth were done based on the assumption that only blue areas were flooded. The ASTER satellite had an exaggerated color scheme, with dark blue for submerged areas, green for vegetation, and various shades of cyan for precipitation. This scheme affected the construction of polygons and their respective sizes. It could have been assumed that more land with a deep-green to a blue-green color could have flooded, particularly the floodplain areas. Second, the cyan colors for precipitation consistently blocked certain regions of the county in the photos, especially the northern region of Gilgit-Baltistan, for which the fewest number of polygons were created. This is not surprising considering the photos were taken during monsoon season, but the color scheme did adversely affect the creation of polygons. Third, while the number of people affected is closer to the reported estimates, it is also due to another critical assumption: that the population density is the same throughout the country. While the floods did affect some major cities, the majority of the flooding affected rural areas which are more sparsely populated. Despite the values calculated, the general trend for which flooding occurred is established, and the government can take steps to prepare for the next flooding event.

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Map of Flooded Areas and Affected Districts of Pakistan

Legend:
- Flooded Areas
- Pakistani Districts
- Country Boundary

N

0   100 200   400
Kilometers
1:12,000,000