GIS in Water Resources Midterm Exam Fall 2015
There are three questions on this exam. Please do all three. They are not all of equal weight.

Question 1. Map Projections and Distance (30%)

Following is information from ArcGIS on the UTM Projection that applies in Logan, Utah.

NAD_1983_UTM_Zone_12N
WKID: 26912 Authority: EPSG
Projection: Transverse_Mercator
False_Easting: 500000.0
False_Northing: 0.0
Central_Meridian: -111.0
Scale_Factor: 0.9996
Latitude_Of_Origin: 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_North_American_1983
Angular Unit: Degree (0.0174532925199433)
Prime Meridian: Greenwich (0.0)
Datum: D_North_American_1983
Spheroid: GRS_1980
Semimajor Axis: 6378137.0
Semiminor Axis: 6356752.314193356
Inverse Flattening: 298.257222101

The following map gives location information for Logan and Salt Lake City in geographic and projected UTM zone 12 coordinates.
a) What earth datum is used?
    North American Datum of 1983 (NAD 83)

b) What map projection is used?
    Transverse Mercator

c) Draw and label on the map the Central Meridian for the UTM projection. What is its X-coordinate value in meters?

\[ \text{X-coordinate value is False Easting} = 500000.0 \]

d) Calculate perpendicular distance in Km between Salt Lake City and the Central Meridian.

\[ \text{For Salt Lake City, } X = 421.466 \text{ in UTM Zone 12 coordinate system} \]

\[ \therefore \text{Distance to Central Meridian} = 500000 - 421466m \]

\[ = 78534m \]

\[ = 78.5 \text{ km} \]

e) Draw a diagram that shows the spheroid and its semimajor and semiminor axes. Label the length of these axes (Km)

![Diagram showing spheroid with labeled axes]

f) Calculate the distance (Km) from Logan to Salt Lake City based on the projected coordinate system.

\[ \text{Logan } (X_1, Y_1) = (430.493, 4621.240) \]

\[ \text{Salt Lake City } (X_2, Y_2) = (421.466, 4514.440) \]

\[ \text{Distance, } D = \left[ (X_2 - X_1)^2 + (Y_2 - Y_1)^2 \right]^{1/2} \]

\[ = \left[ (421.466 - 430.493)^2 + (4514.440 - 4621.240)^2 \right]^{1/2} \]

\[ = \left[ (-9.027)^2 + (-106.800)^2 \right]^{1/2} \]

\[ = \left[ 81.486 + 11406.24 \right]^{1/2} \]

\[ = 107.18 \text{ km} \]
Question 2. Land Cover Change (30%)

a) The map below shows the land cover distribution in Travis County, Texas in 2006. The grid has 30m cells. Determine the area of the County (Km$^2$), the area of Development (Km$^2$), and the percentage of the land cover that is in Development. These data were obtained from: http://www.mrlc.gov/nlcd2011.php

<table>
<thead>
<tr>
<th>LC_CLASS</th>
<th>Sum_Count</th>
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<tr>
<td>OpenWater</td>
<td>96820</td>
</tr>
<tr>
<td>Development</td>
<td>798533</td>
</tr>
<tr>
<td>SnowiceBarren</td>
<td>13548</td>
</tr>
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<td>Forest</td>
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<tr>
<td>ShrubScrubGrass</td>
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<tr>
<td>Agriculture</td>
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</tr>
<tr>
<td>Wetland</td>
<td>53081</td>
</tr>
</tbody>
</table>

Total number of cells = 2944947
Each cell is 30m x 30m

Area = $2944947 \times 30 \times 30$

Area of county = $2650.5 \text{ km}^2$

Area in Development = $798533 \times 30 \times 30 / (1 \times 10^6)$

Area Developed = $718.7 \text{ km}^2$

= $0.271 \times 100 = 27.1\%$
(b). The Land Cover distribution for Travis County in 2001 and 2011 is shown below, as measured by the Count of the total number of cells in each land cover class. A lookup table to convert land cover Value field to the LC_Class field is also given below.

<table>
<thead>
<tr>
<th>CoverLookup</th>
<th>VLCD2001Albers</th>
<th>NLCD2011Albers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>LC_CLASS</td>
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</tr>
<tr>
<td>11</td>
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<tr>
<td>90</td>
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</tr>
<tr>
<td>95</td>
<td>Wetland</td>
<td>15</td>
</tr>
</tbody>
</table>

Determine the following:

1. Area of land cover class Development in 2001 (Km²) = 665.0
2. Area of land cover class Development in 2011 (Km²) = 771.2
3. Change in Area in land cover class Development 2001 to 2011 (Km²) = 106.2
4. Percent Area in Travis County that is in Development in 2001 = 25.1%
5. Percent Area in Travis County that is in Development in 2011 = 29.1%

For 2001: # cells = \( \frac{368516 + 192648 + 117954 + 59699}{10^6} = 665.0 \) km²

Area Developed in 2001 = \( \frac{738817 \times 900}{10^6} = 665.0 \) km²

For 2011: # cells = \( \frac{363603 + 223276 + 186327 + 83730}{10^6} = 771.2 \) km²

Area Developed in 2011 = \( \frac{856936 \times 900}{10^6} = 771.2 \) km²

Change in Area Developed = 771.2 - 665.0 = 106.2 km²

In 2001, % area developed = \( \frac{665.0}{2650.5} = 0.251 = 25.1\% \)

In 2011, % area developed = \( \frac{771.2}{2650.5} = 0.291 = 29.1\% \)

By how much does the percent area in Development change each five years in Travis County?

- In 2001 25.1%
- 2006 27.1% increase by 2.0% in each five year period
- 2011 29.1%
Question 3. Raster Analysis of DEMs (40%) 

a) The following diagram gives elevation values on a 10 m DEM grid. Identify any pits by shading them and indicate the elevation to which they need to be raised to fill them so that the DEM is hydrologically conditioned and they can drain.

```
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<thead>
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<th>9</th>
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<td>9</td>
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<td>10</td>
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<td>18</td>
</tr>
</tbody>
</table>
```

b) Determine the D8 flow direction for the circled grid cell in the diagram above, and draw it as an arrow on the diagram. Calculate the hydrologic slope along its flow direction.

```
Vertically upward:

Slope = \frac{15-12}{10} = \frac{3}{10} = 0.3

Diagonal to NW:

Slope = \frac{15-11}{10\sqrt{2}} = \frac{4}{10\sqrt{2}} = 0.283

Flow Direction is \uparrow, Slope = 0.3
```
c) The following diagram gives flow directions evaluated from a DEM with 1 Km cell size. Delineate the watershed draining to the circled basin outlet and sketch it on the diagram.

<table>
<thead>
<tr>
<th>Northing (m)</th>
<th>78000</th>
<th>76000</th>
<th>74000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastings (m)</td>
<td>42000</td>
<td>44000</td>
<td>46000</td>
</tr>
</tbody>
</table>

\[\text{Flow Accumulation shown above}\]

- **d)** Write on the diagram the values of flow accumulation for each grid cell in the watershed you delineated by counting how many grid cells drain into each grid cell (as ArcGIS does it).

- **e)** Calculate the drainage area of the watershed you delineated (Km²)

\[\text{Area} = 11 \text{ cells} = 11 \text{ km}^2\]

- **f)** Draw on your diagram the stream that would be defined with a flow accumulation threshold of 4 Km², assuming that the stream connects the centers of the cells satisfying this criterion. Determine the length of this stream, and calculate the drainage density of the watershed draining to the circled grid cell.

\[\text{Length of Stream} = 2 \text{ km}\]

\[\text{Drainage density} = \frac{2}{11} \text{ km}^{-1} = 0.182 \text{ km}^{-1}\]
g) Assume that mean annual precipitation for the same area as (c) is given in the following raster with a 2 Km cell size. The south west corner of this raster aligns with the south west corner of the flow direction raster above. Precipitation values are mean annual values in mm. Use dashed lines to draw the grid cells that you used in part (c) on this grid. Draw a solid line along your watershed boundary from part (c).

h) Calculate the mean annual precipitation (mm) over the watershed you delineated in (c).

\[
\text{Mean annual precip} = \frac{860 + 870 \times 4 + 890 + 850 \times 2 + 860 \times 2 + 870}{11} = \frac{9520}{11} = 865.5 \text{ mm}
\]

i) Determine the corresponding volume of precipitation (m³/year).

\[
\text{Volume} = \frac{865.5 \text{ mm}}{1000} \times 11 \times 10^6 = 9.520 \times 10^6 \text{ m}^3
\]

j) If the mean annual flow measured at the circled grid cell in (c) is 0.08 m³/s, calculate the runoff ratio.

\[
\text{Volume runoff} = 0.08 \times 3600 \times 24 \times 365.25 = 2.524 \times 10^6 \text{ m}^3
\]

\[
\text{Runoff ratio} = \frac{2.524 \times 10^6}{9.520} = 0.265
\]