



Determining Flood Risk in Iowa

STUDENT HANDOUT

2008 Flood Water Analysis

This learning unit will compare two sets of flood boundaries from the June 2008 flood in Cedar Rapids, Iowa. You will extract one set from Landsat Imagery using Esri ArcGIS 10 and the Normalized Difference Water Index (NDWI). The other set will show flooded areas derived from SPOT satellite imagery, developed by the Iowa Department of Natural Resources. The unit will introduce you to image analysis in ArcGIS, and you will use the ArcToolbox raster and Spatial Analyst tools to process the data. By comparing your Landsat analysis results with flood areas derived from SPOT imagery, you will be able to see some of the strengths and weakness inherent in Landsat imagery. You will also better understand scale comparisons since Landsat imagery has a 30-meter resolution, and the SPOT imagery of the flood has a 10 meter resolution.

Part 1 – Overview of Topic

Problem

In June 2008, Cedar Rapids, IA, experienced the worst flood on record. The Cedar River flood crested at over 32 feet Friday, June 13, 12 feet above the famously high flood boundaries of 1993. Water covered 1,300 city blocks, or 9.2 square miles. Linn County hired Pictometry to take aerial photos at the time of the flood, and county personnel digitized official flood boundaries from that imagery.

The USGS acquired flood imagery from Landsat 5 on June 16, 2008, one day after the water started to recede for Linn County. By processing the Landsat imagery and using ArcGIS to calculate a Normalized Difference Water Index (NDWI), it is possible to compare classified boundaries with hand-digitized boundaries. This will enable you to compare flood boundary accuracy using NDWI and determine what kinds of data are lost or misclassified.

Note: The Landsat imagery is from June 16, 2008, by special arrangement with Landsat using disaster funding. This is the imagery available closest to the actual flood crest on June 14, 2008.

In this learning unit you will use GIS to create base data including Cedar Rapids boundary, roads, and normal river boundaries. Landsat imagery from June 16, 2008 – a day after the water began to recede – will be categorized as *Wet* or *Not-Wet* and overlaid on a base map. A square-mile difference will be clipped out of the larger image. Finally, elevation contours will be made for the digital elevation models (DEMs) in an attempt to determine if the flood boundaries followed a specific contour.

Short Description

The Cedar River travels through Linn County, IA, from NW to SE. It bisects the downtown area of Cedar Rapids, IA. Part of the city is within the 500-year floodplain, meaning there is a 0.2% chance of flooding each year. Historically, Cedar Rapids flood levels have stayed within 19 feet. This learning unit will help you understand how GIS can be used to analyze flood situations. Using ArcGIS 10 with the Spatial Analyst extension, you will have an opportunity to look at Landsat imagery and determine flood areas. A



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comparison of the digitized flood boundaries and Landsat flood boundaries will help you discern the strength/weaknesses of both, and give you a better understanding of the importance of resolution in decision-making processes.

You will work with ArcGIS in order to document the floodwaters of 2008 and manipulate Landsat imagery to classify pixels as water or not water. This layer will be used as backdrop for the flood boundaries digitized by the city of Cedar Rapids, using aerial imagery flown at the time of the flood. By comparing differences in boundaries using the 0.5m aerial from the city of Cedar Rapids, as well as the city street files, you will be able to delineate areas for which Landsat Imagery was incorrectly classified.

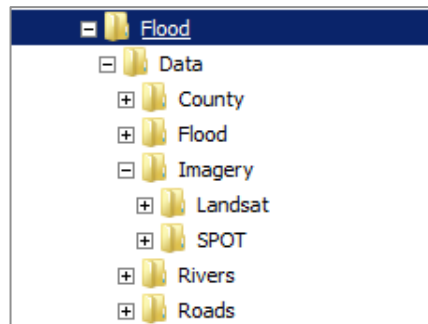
Introduction

Prior to working with Landsat images, it helps to have an idea of what comprises a pixel and what it signifies. Begin to read Chapter 1 and 2 of *The Fundamentals of Remote Sensing* (http://gcmd.nasa.gov/records/remote_sensing_tutorial-00.html), as assigned by your instructor.

ACTIVITY 1: Download and Explore Project Vector Data and Aerial Imagery

File Management:

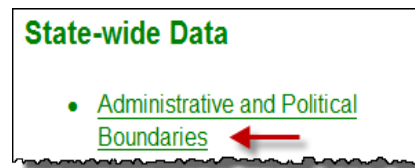
In your Projects folder (or where directed by your instructor) create a folder named **Flood** and one inside it named **Data**. Create the following folders in the **Data** folder, as shown here: County, Flood, Imagery, Rivers and Roads. Inside the Imagery folder, create two subfolders: One named Landsat, one named SPOT.



Download Vector and SPOT Satellite data for the project area:

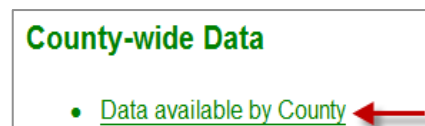
Before viewing satellite imagery, you will download other data for the area of interest. Go to the Iowa Natural Resources Geographic Information Systems Library: <http://www.igsb.uiowa.edu/nrgislib/>

1. On the left side of the website, under **State-wide Data** Click on **Administrative and Political Boundaries**.

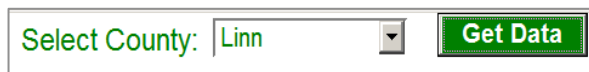


In the next window, Right-Click on **County** and choose **Save Target As**. Save the **County.zip** file in your Flood\Data\County folder.

2. Next, Under **County-wide Data**, Click on **Data available by County**.

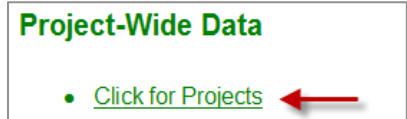


In the Select County drop box, select **Linn**, then click on **Get Data**.

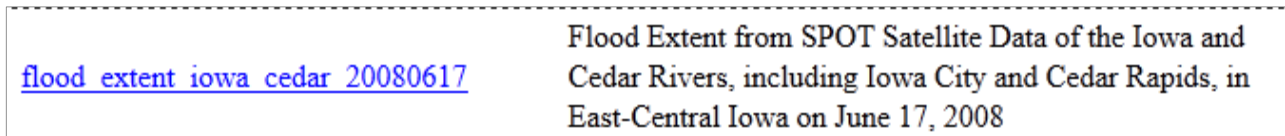


Scroll to select **roads_2006_57** and download to your Flood\Data\Roads folder. Repeat the process to download the **rivers_57** data, saving that in the Rivers folder.

3. Under **Project-Wide Data**, Click on **Click for Projects**. In the Select a Project drop-down menu, select **Flood of 2008** and Click on the **Retrieve Project Data** button.



Right-Click on “**Flood_extent_3class_iowa_cedar_20080617**” as shown below to download this SPOT Satellite data. Save in your Flood\Data\Imagery\SPOT folder for comparison with Landsat data later in the exercise.

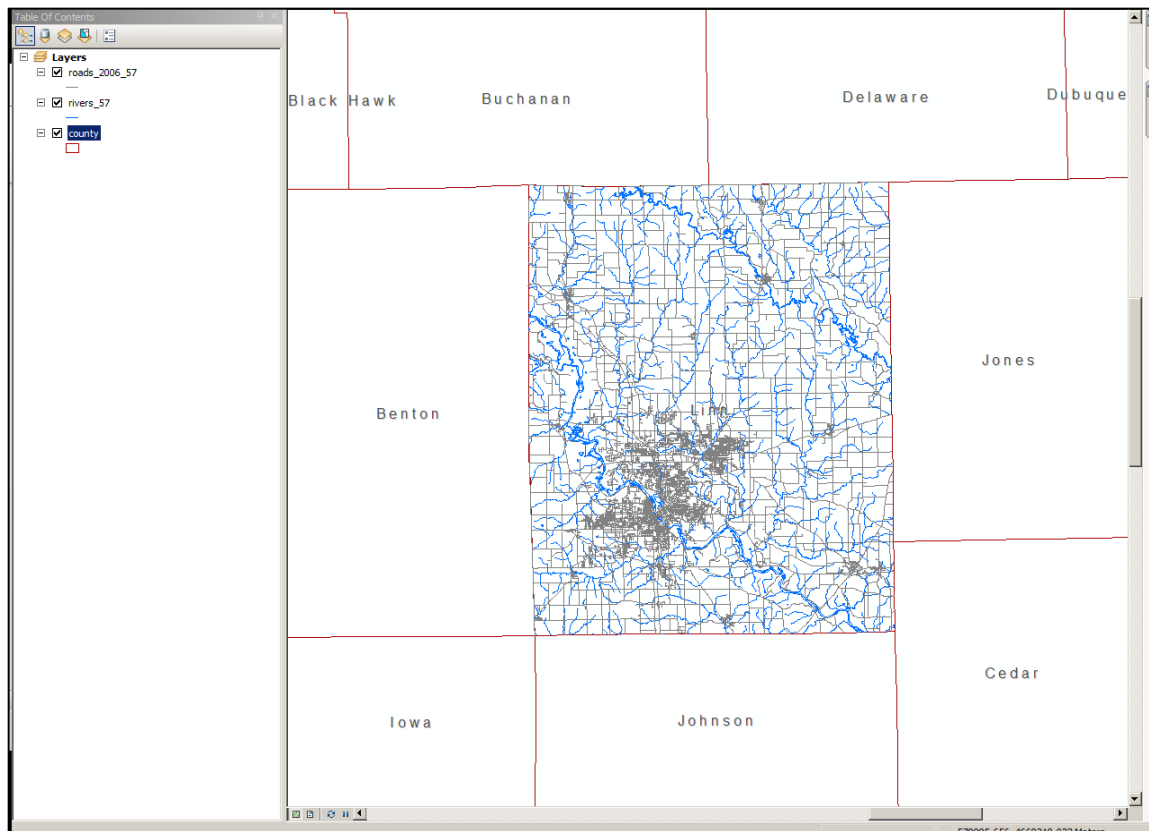


You now have all of the data downloaded for this project, except for the Landsat Image, which you will download from a different website.

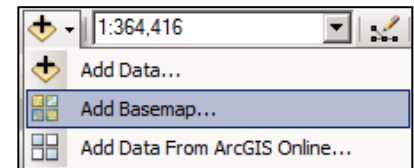
4. Before you download the Landsat data, use the extraction program available to you (likely 7-Zip, or Win-Zip) to unzip each of the files that you just downloaded.
5. Open up ArcMap with a new blank map. Add the **roads_2006_57**, **rivers_57** and **county** layer. Adjust the symbology and label the counties with the county names. Zoom in closer to Linn County, which is where Cedar Rapids is located, in the lower SW quadrant of the county. Your map should look similar to the one shown on the next page.

These data layers are in a Vector data structure and the file format is ESRI Shapefile. Examine the properties of each layer. What is the coordinate system and datum for each of these layers?

6. Save the project in your Flood folder, naming it **Flood.mxd**.



- Next, to become more familiar with the project area, you will add an ESRI Basemap to your project. ArcMap comes with the capability of adding various basemaps from ESRI via the “Add Data” button. Click on the small arrow on the right side of the Add Data button and select **Add Basemap...**

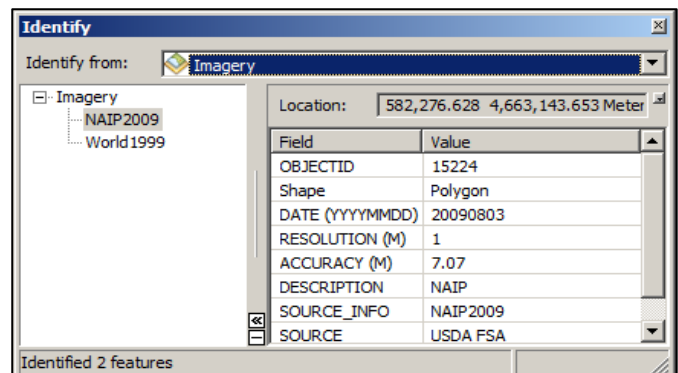


Note: If you have no internet connection, your instructor will tell you where to find the data you need.

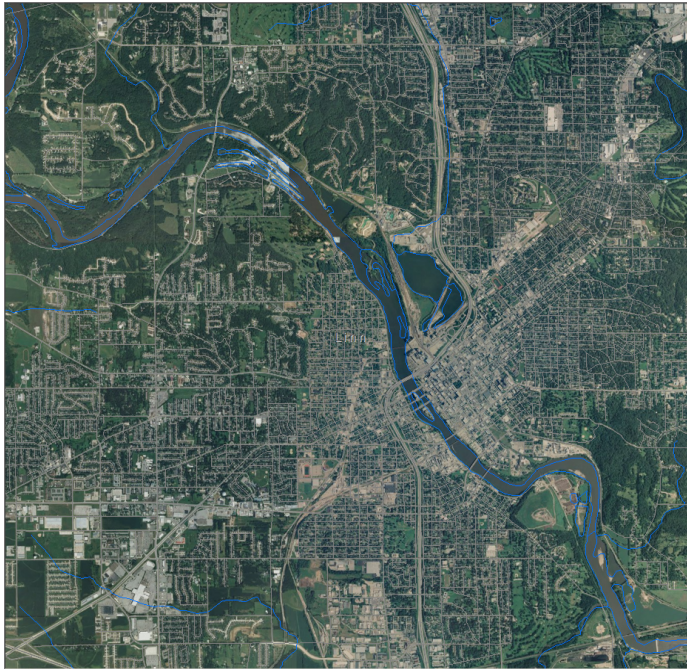
When the Add Basemap dialog comes up, select **Imagery**, then click **Add**. It will take a minute as the data does not reside “locally.” When the message comes up about being in a different geographic projection, close the dialog. The data will be reprojected on the fly.

Once you have added the data, you will see that a group layer is added to your TOC, which has the Imagery checked, and the Boundaries and Places and Transportation layers turned off.

- Right-click on the Imagery layer that you just added and select Properties. Read the Description to see where the data come from. To find out specifically where to find the data for the area you are studying, click the identify button anywhere on the image (but not over the vector data). We will need to be sure the Identify from in the Identify dialog is set to Basemap (Imagery). Be patient as it is retrieving information from the ArcGIS server and it will take a little time. You should see that the data source is the USDA FSA NAIP program from 2009.



9. Zoom into the area shown below, in the lower SW quadrant of Linn County to more closely examine this area of the Cedar River. Fill out the chart, below.



Question	NAIP 2009 aerial imagery
What is the spatial reference?	
What is the pixel size?	
What is the linear unit?	

ACTIVITY 2: Download and Explore Landsat Imagery

Before doing the analysis part of the exercise, you will learn how to download Landsat imagery and explore the closest post-flood Landsat image for the area of interest.

1. What is Satellite Imagery? Check out the website below:
NASA Landsat website: <http://landsat.gsfc.nasa.gov/about/>. Watch the Landsat Flyby video.
2. Download Landsat Imagery from the USGS Global Visualization Viewer (GloVis): Click on the link - <http://glovis.usgs.gov/>

On the menu bar at the top of the Viewer, **CLICK** on **Collection**. Then choose **Landsat Archive** and **CLICK** on **Landsat 4-5 TM**. Landsat 5 collected the best of the Landsat sensors for the time period needed.

In GloVis, there are several ways to zoom to the area of interest.

A. If you know the latitude longitude of your area, the coordinates can be entered in the upper left corner. The Grand Rapids, IA study area will be **41.8, -91.4**
OR

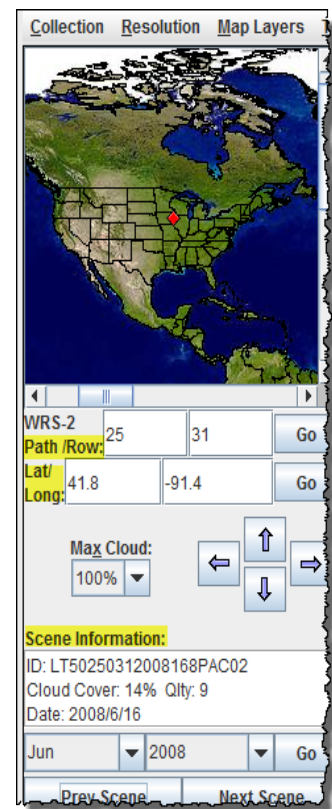
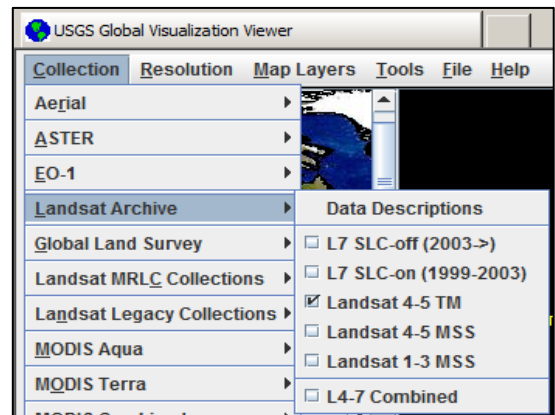
B. **CLICK** on the area of interest in the small map at the upper left of the viewer, in this case – Iowa. This will open a new window. To better locate where you are on the scene, it helps to see the cities located. To turn this layer on, **CLICK** on the **Map Layers** menu at the top of the Viewer. Select Cities layer. Then use the directional arrow buttons that are below the Lat/Long boxes to move scene by scene, if necessary, to get to the best scene extent for the study area.

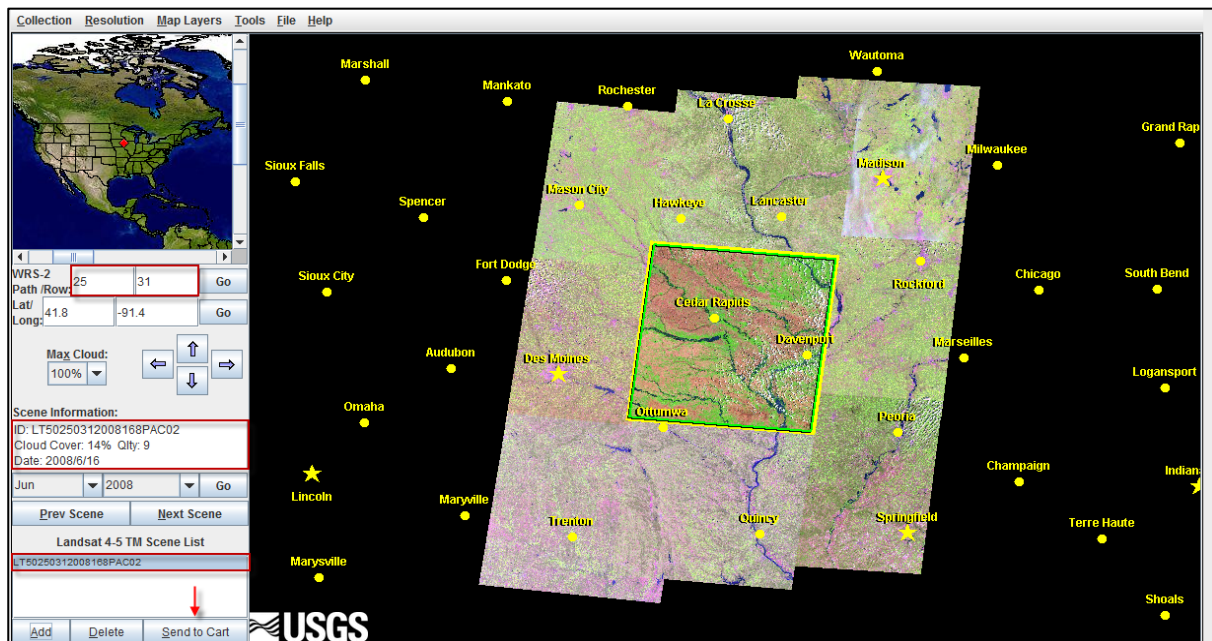
OR

C. A third way to go directly to the scene for your study area is to enter the path and row that your area of interest falls into. If you used either method A or B above, you will notice that the path and row were updated, automatically. To download Landsat data for this activity, you will want to be using: Path **25**, Row **31**.

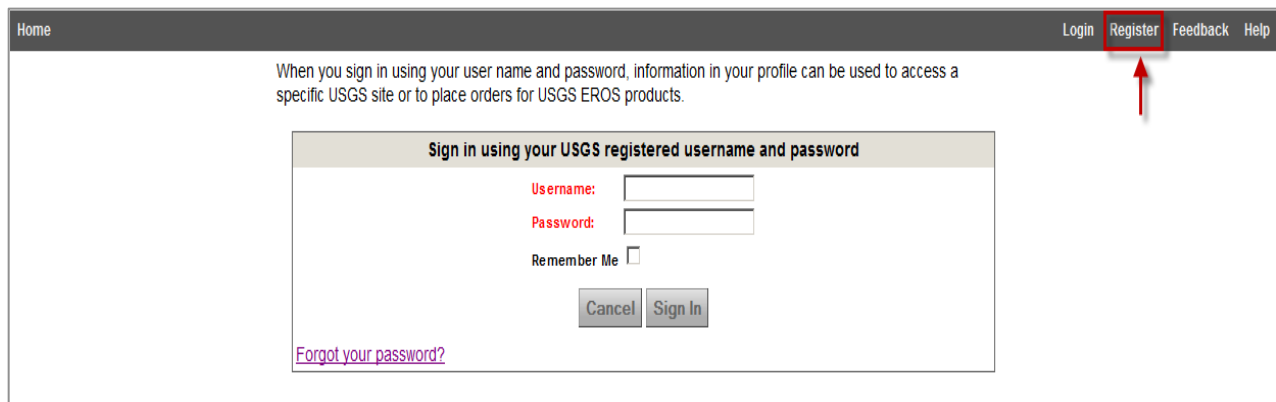
Select **June** for the month and **2008** for the year. Inspect the **Scene Information** (highlighted in yellow, above). Note that it indicates what the cloud cover was at the time the image was taken (14%), as well as the date (June 16, 2008). This was taken one day after the flood crested. To download a Scene (image), when you have found the correct image, click **Add** to display the file name in the Landsat 4-5 TM Scene List. Click “Send to Cart”.

Note: If the image is immediately Downloadable the word Downloadable will display in the upper left of the display window. Whether or not that information appears, the data is available free, but it may take longer to acquire images that don't say Downloadable, as they may go through processing first.





The Login Screen will come up. If it doesn't, you may need to move the GloVis window to see it. If you don't yet have a login and password for GloVis, you will need to register first. The Register link is at the top right of the sign in screen. Otherwise, you may log in directly .



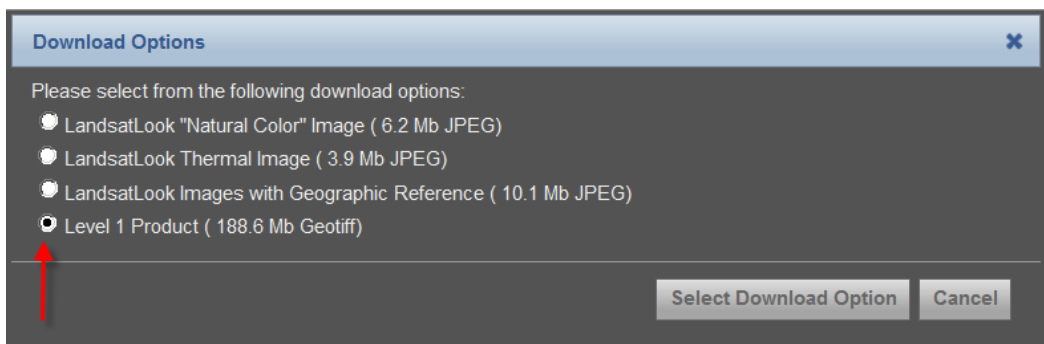
Once you have logged in, you will be at the Order screen. Under **Operations**, you will see an icon for download. The Price is Free.



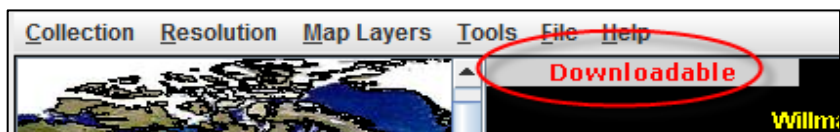
When you click on the download button, a window will come up with the download options. Click on the radio button for the Level 1 Product. If this option is not available, it is because it will take

the 1-3 days for processing before it is available. In that case you will get a message such as the one below:

Please Note - Delivery Times: Landsat requests are generally processed in 1 to 3 days; however, if there is a large queue for processing, wait times may be longer.



If you do have to wait, you will have to go back to GloVis again, and go through the same process to enter the Path/Row and the date. When you see the word Downloadable in the upper left of the window, an immediate download will be available. You will then Add to the Scene List and Send to the Cart.



In either case, be sure that you are downloading the Level 1 Product. Save it to your Flood\Data\Imagery\Landsat folder.

3. Unzip the **LT50250312008168PAC02.tar.gz** file that you just downloaded to your Landsat folder.

Name	Date	Type	Size	Tags
L5025031_03120080616_B10.TIF	10/1/2011 3:27 PM	TIFF Image	54,854 KB	
L5025031_03120080616_B20.TIF	10/1/2011 3:27 PM	TIFF Image	54,854 KB	
L5025031_03120080616_B30.TIF	10/1/2011 3:27 PM	TIFF Image	54,854 KB	
L5025031_03120080616_B40.TIF	10/1/2011 3:27 PM	TIFF Image	54,854 KB	
L5025031_03120080616_B50.TIF	10/1/2011 3:27 PM	TIFF Image	54,854 KB	
L5025031_03120080616_B60.TIF	10/1/2011 3:27 PM	TIFF Image	54,854 KB	
L5025031_03120080616_B70.TIF	10/1/2011 3:27 PM	TIFF Image	54,854 KB	
L5025031_03120080616_GCP.txt	10/1/2011 3:27 PM	Text Document	5 KB	
L5025031_03120080616_MTL.txt	10/1/2011 3:27 PM	Text Document	64 KB	
L5025031_03120080616_VER.jpg	10/1/2011 3:30 PM	JPEG Image	700 KB	
L5025031_03120080616_VER.txt	10/1/2011 3:30 PM	Text Document	79 KB	
LT50250312008168PAC02.tar	10/1/2011 3:31 PM	TAR File	384,850 KB	
LT50250312008168PAC02.tar.gz	10/2/2011 1:13 PM	GZ File	193,087 KB	
README.GTF	10/1/2011 3:31 PM	GTF File	9 KB	

[Explore the Landsat Header File](#)

(a) Understand the naming convention for the file:

LXSPPPRRRYYYYDDDGSIVV	L5025031_03120080616
L = Landsat	
X = Sensor	
S = Satellite	
PPP = WRS Path	
RRR = WRS Row (Start and End Rows for multi-scenes)	
YYYY = Year	
DDD = Julian Day of Year ¹	
GSI = Ground Station Identifier	
VV = Version	

(b) Open up Microsoft Word, and then open the Landsat image header file:
L5025031_03120080616_MTL.txt.

The first part of the header file contains information about the image processing. Scroll down to the line GROUP = PRODUCT_METADATA. Scan through the lines after that and fill in the following table:

Date	Attribute Value
Sensor ID	
Acquisition Date	
WRS Path	
Starting/Ending Row	
Band Combination	
Upper Left Corner LAT/LON	
Upper Right corner LAT/LON	
Lower Left Corner LAT/LON	
Lower Right Corner LAT/LON	
Reference Datum	
Projection Group and Zone	
Sun Azimuth	
Sun Elevation	

ACTIVITY 3 – Visualization and Composite and Clip (subset)

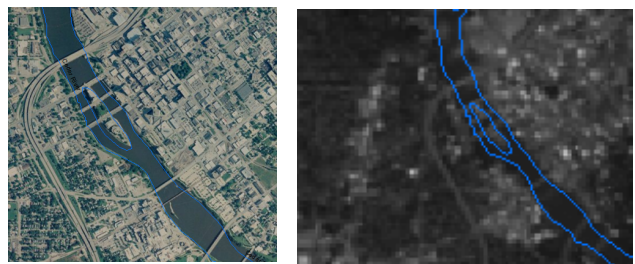
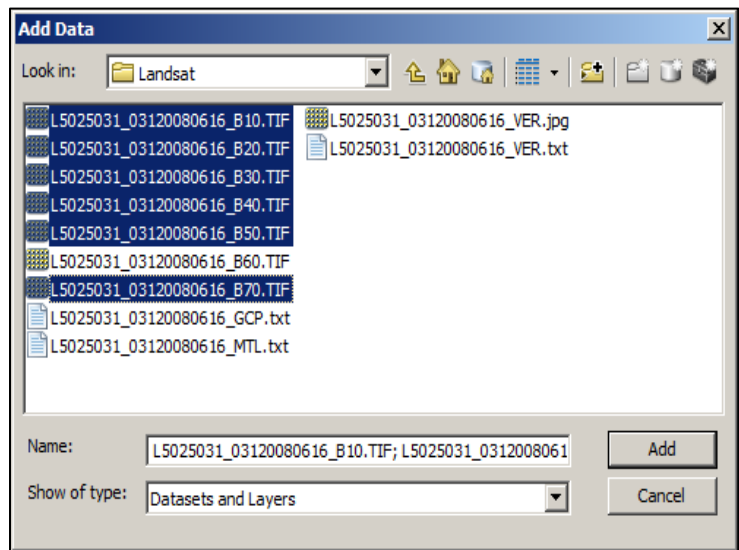
¹ Look up Julian Year on the internet and see what your Julian birthday is.

- Go to <http://landsat.gsfc.nasa.gov/education/compositor/>. Work through the pages by clicking on “Let’s learn more” link as you reach the bottom of each page. See how well you can answer the questions asked in the pages “Think” sections. When you get to the page on “invisible light”, fill in the chart below. This shows which part of the spectrum the different bands relate to in Landsat 7. These values are the same for Landsat 5 bands 1-7.

BAND	WAVELENGTH INTERVAL	SPECTRAL RESPONSE
1		
2		
3		
4		
5		
6		
7		

ArcGIS 10 software combines many common spectral image processing and image analysis tools to help you get meaningful information. The advantage for many GIS users is that the interface is already familiar. You will be processing images using the tools in ArcGIS, primarily in ArcToolbox, to prepare an image useful for separating wet from dry areas in order to determine the flood boundaries. The Landsat imagery is from June 16, 2008 and was taken two days after the flood crested.

- Open your Flood.mxd project. **Add** the Landsat image bands 1-5 and 7. Do not add band 6. For example, band 1 is: L5025031_03120080616_B10.TIF and band 2 will end in ..._B20.TIF. When prompted to create pyramids, click Yes.
- Click on only Band 1, so that it is the only one selected. Right click and select **Zoom to Raster Resolution**.
- Locate **Mays Island**. This is located in the Cedar River, in the downtown area of Cedar Rapids, IA. All of the bridges through town were under water and the first floors of many of the municipal buildings, on Mays Island, were flooded.
- Click on the arrows to move around the screen. Mays Island is located near 610275.0000E and 4647795.0000N. The NAIP 2009 image on the left shows Mays Island with normal water levels. In the Landsat image (band 3) on the right, *three bridges were under water at the time of the flood.*



Combining bands into a composite image.

6. Of the seven Landsat bands contained in the Landsat image folder, you will use bands 1, 2 and 3 for a 3, 2,1 “natural color” composite. Because this uses all of the visual bands, ground features appear in colors similar to their appearance to the human eye.

7. Open ArcToolbox . Right-click on the ArcToolbox icon (at the top of ArcToolbox) and select **Environment Settings**. In the Environment Settings dialog, box, click on **Workspace**. For the “Current Workspace” change to your **Landsat** folder. Do the same for the Scratch Workspace.

Still in Environment Settings, Scroll down and Click on **Processing Extent**. Set the Extent to be “Same as **L5025031_031200816_B40.TIF**”. Under Raster Analysis, set the Cell Size to be **L5025031_031200816_B40.TIF**. Click OK.

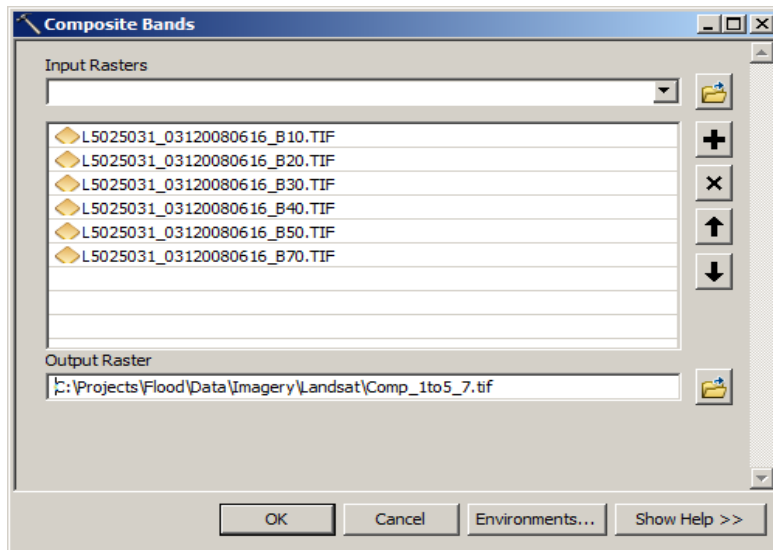
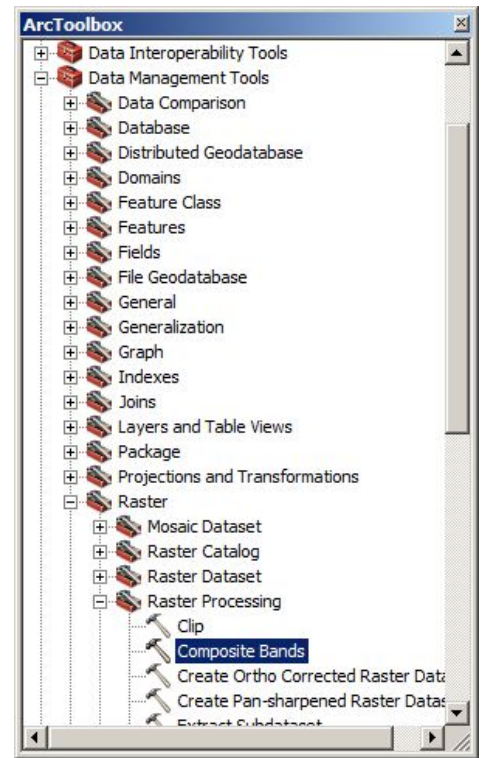
NOTE: The selection of this particular band was arbitrary. It is just important to just set the extent and cell size, which is the same for bands 1-5 and 7.

8. In ArcToolbox, Click on **Data Management Tools >> Raster >> Raster Processing >> Composite Bands**. Double-Click to open the **Composite Bands** tool.

In the Composite Bands dialog box do the following:
 For Input Rasters, Use the Input Rasters dropdown to add layers to bands 1, 2, 3, 4, 5, 7 into the Composite Bands box. Be sure to add them in order, with band 1 first. The order is very important. Use the arrow keys to adjust the order if necessary to match what you see, below.

For Output Raster: Save it to your Landsat folder and name it **Comp1to5_7.tif**. Click **OK**.

This will take a couple of minutes to process, and then the composite image will be automatically added to the TOC.

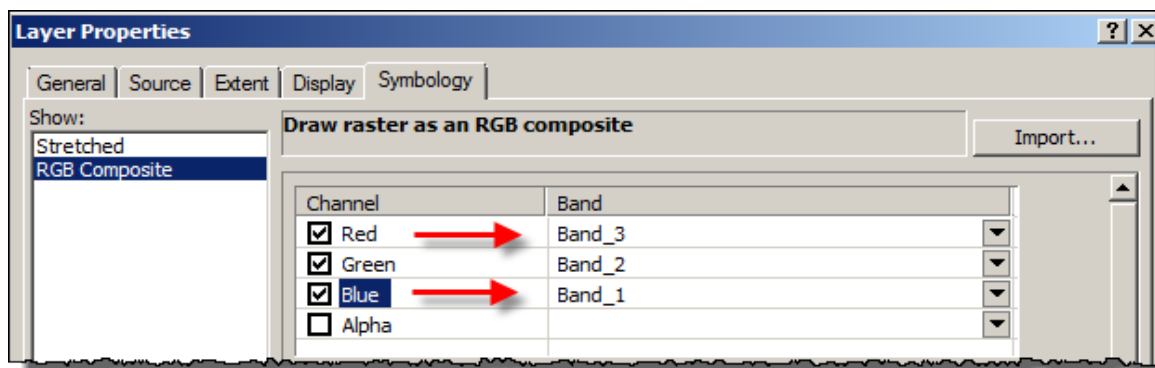


9. Examine the legend and notice the default RGB band assignments. Only three bands will display at a time. ArcGIS automatically assigns the first three incoming bands in the list to Bands 1, 2 and 3. Look at the image in the display. How well are you able to discern specific features?



Next, you will change which bands are assigned to the Red, Green and Blue (RGB) channels in order to enhance specific features in the landscape.

- Open the layer **Properties** >> **Symbology** tab for Comp_1to7. Under show, RGB should be selected already. Use the dropdown menus for each of the bands for the Red Green Blue channels to change the Channels to: **Red = Band 3, Blue = Band 1**. The Green channel stays the same. Click **OK**.



- Visually examine the resulting natural color (3, 2, 1) image. Notice that it looks similar to an aerial photograph and familiar to the human eye.
- Open the layer Properties again. This time set the bands for **Red = Band 4, Green = Band 3, Blue = Band 2** to display the image in False Color. What can you identify with this band combination? Review the Landsat Compositor website <http://landsat.gsfc.nasa.gov/education/compositor/> Click on the link for **Different Color Composites** on the left to read more about different band combinations.
- Repeat for band 7, 4, 2. IMPORTANT: Since you did not bring in band 6, band 7 was assigned the name band 6, so for a 7, 4, 2 you will need to select 6, 4, 2. What can you identify with this band combination?
- Repeat for bands 4, 5, 3 evaluate each combination. What can you identify with this band combination? Notice how much easier it is to view water. Compare this image with the NAIP basemap in the areas by the river. Are you able to see the flooded areas on the Landsat image? Are you able to tell the difference between water and the cloud shadows?

Study The Value Assigned To Each Pixel and Compare to feature on Aerial Image

- Find a feature of interest on the Landsat image that represents (such as agricultural field, water, buildings, etc.)
- Measure the pixel distance around the outside of the feature, in meters.
- View your feature on the Aerial image.

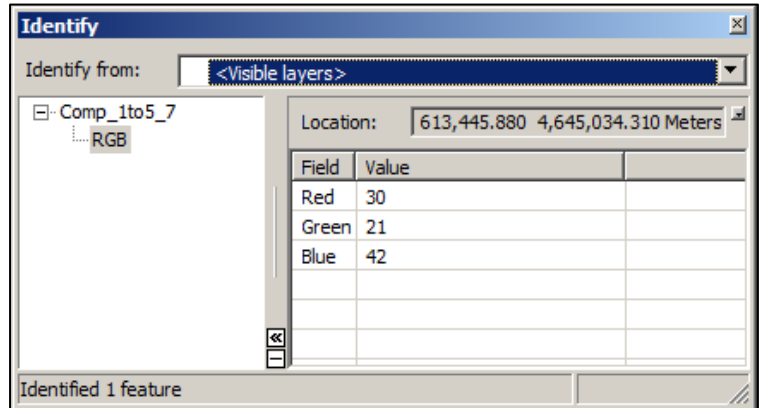
Do all the pixel boundaries at the edges of your feature perfectly line up?
Does information get lost due to pixel size and shape?
What might the consequences be for the user of this data?

Apply a stretch. This is another way to enhance the display of an image. Stretches apply an algorithm to the pixels, spreading the pixel values along a histogram, altering how the image displays. Some stretches will make it easier to identify different features.

18. Click on the ArcMap Help Menu. Choose ArcGIS Desktop Help. In the “Type a question...” box, type in **Stretches**, click the **ask** button. In the topics found, click on **Stretch function**. Read through the help, particularly paying attention to the Stretch types and image example.
19. Open the Comp_1to7 image layer Properties >> Symbology. The default stretch is set to Standard Deviation. Select the Min Max Stretch and apply. View the results to see if you find it easier to identify any of the features on the image, such as the river and planted fields. Try a Percent clip (linear stretch) and apply. View the results. Try no stretch, apply and view the results.
20. Return the image to the Standard Deviation stretch and click OK.

Pixel Values

21. With only the Comp_1to7 layer check marked in the TOC, use the identify tool to click around the image on various features, such as urban areas, planted fields, unplanted fields and water to see how the RGB values change. Be sure that the identify box is set to only display the results of the visible layers. Notice in the example below that the location of the pixel as well as the RGB values are shown.

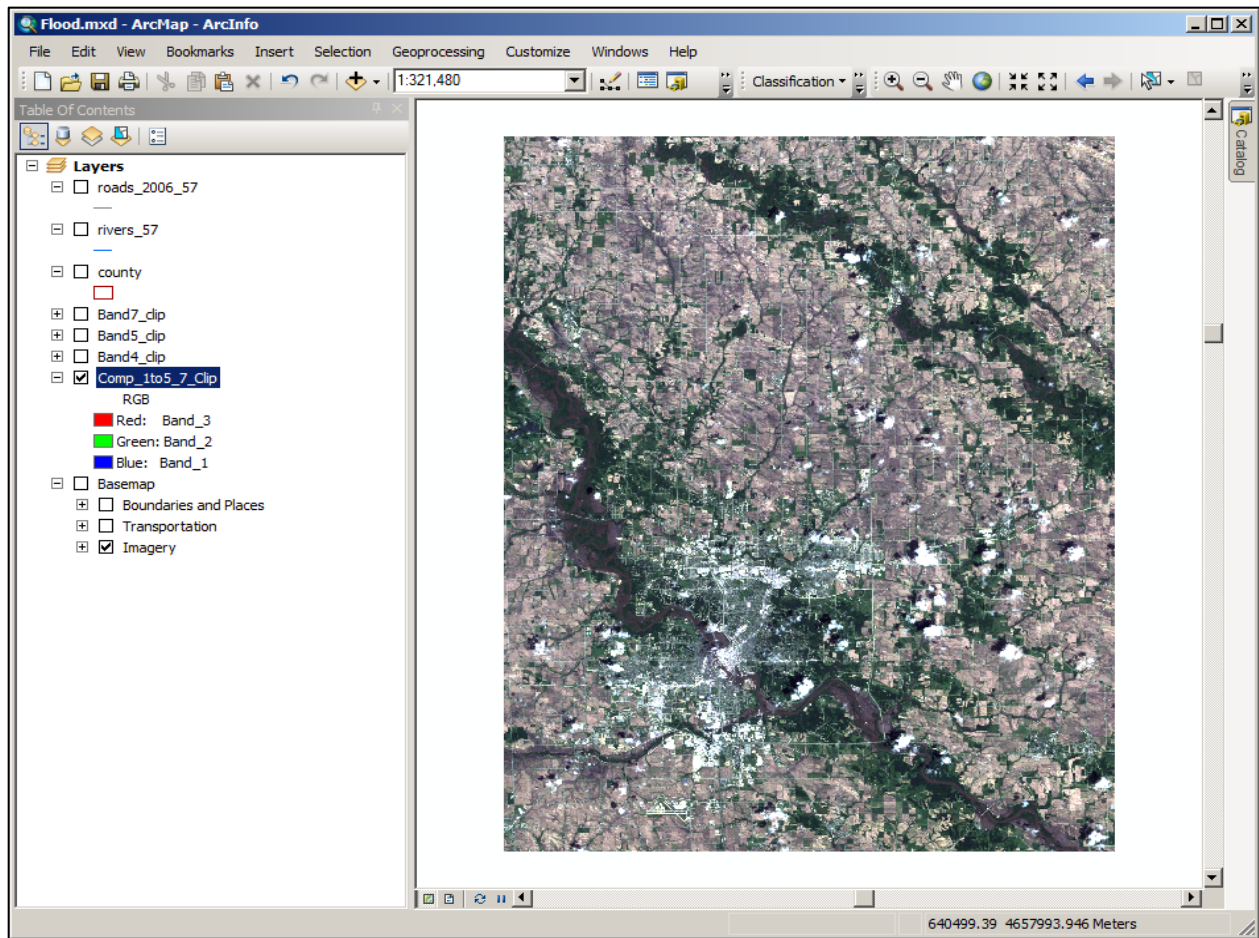


Clipping the image to the study area

To reduce the size of the image to the primary area of interest for this study, you will clip the composite image that you created.

22. Use the **ArcToolbox >> Data Management Tools >> Raster >> Raster Processing >> Clip** tool to clip the **Comp_1to5_7** image to the extent of the **Rivers_57** layer. Name the Output raster: **Comp_1to5_7clip**.
23. Remove the larger Comp_1to5_7 from the project.

24. Repeat the clip for each of the original bands 4, 5, 7, (L5025031_03120080616_B40.TIF...) also using the Rivers_57 layer for the extent. Name them: **Band4_clip.tif**, **Band5_clip.tif**, and **Band7_clip.tif**. You are only clipping these three bands as they are the only ones that you will work with for the next part of the exercise.
25. Remove all of the original bands 1 through ... band 7 (L5025031_03120080616_B10.TIF...) from the Project.
26. Your table of contents should look like the one below. **SAVE**.



ACTIVITY 4: Converting image pixels from Digital Numbers to Radiance numbers to Reflectance

The goal here is to make corrections for atmospheric effects caused by the journey through space. How reflectance is read by the satellite can easily be affected by weather (rain, snow, clouds) as well as where the sun was in the sky and how that might have affected reflectance values.

First, you will convert the DN in your Landsat image to radiance, the amount of energy in watts at the satellite's sensor for each pixel on the ground. The Landsat Sensor records the intensity of electromagnetic radiation at a given location as a DN for each spectral band. Landsat measures radiation on a 0-255 scale. When you convert the DN values to radiance, you are converting the digital number recorded by the sensor back to the actual physical energy units that the digital number represents (Watt, W).

To convert from DN to Radiance you will need the gain and bias information from of the sensor for the post-fire image. This information is in the metadata file (MTL) which was downloaded with the Landsat scene and is stored with the scene (band) files.

The equation to convert from DN to radiance is:

$$L_{\lambda} = ((LMAX_{\lambda} - (LMIN_{\lambda})) / (QCALMAX - QCALMIN)) * ((bBAND\# - (QCALMIN)) + LMIN_{\lambda})$$

L is the spectral radiance. So, **LMAX** and **LMIN** represent the highest and lowest possible values of spectral radiance, which varies with gain state.

QCALMAX and **QCALMIN** are the calibrated maximum and minimum cell values. These values are also listed for each band in the metadata.

bBAND# (or **QCAL**) = Is the digital number, or the pixel value to be calibrated. So for that term in the equation, you will specify the target band (i.e.: b4), and the program will use the pixel values in that band to calculate the radiance for each pixel.

To obtain the values that you need for the formula, you will need to use Microsoft Word or Word Pad to open the **L5025031_03120080616_MTL.txt** file that downloaded along with the Landsat image. For Band 5, the information that you need from this file is listed below. Double-check all of the numbers listed below to be sure they concur.

Date Acquisition Month: **June**

Date Acquisition Day: **16**

Date Acquisition Year: **2008**

Sun Elevation: **63.4905934**

LMAX_BAND5 = 30.200

LMIN_BAND5 = -1.370

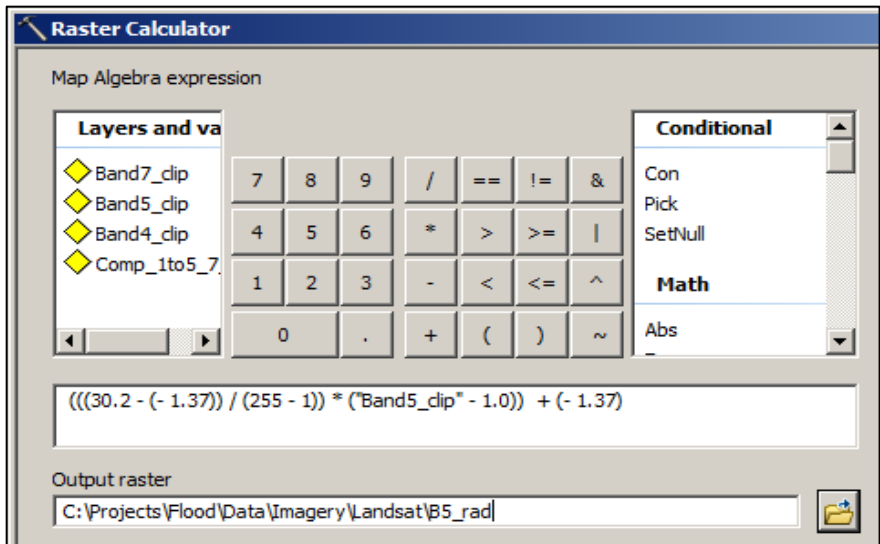
QCALMAX_BAND5 = 255.0

QCALMIN_BAND5 = 1.0

1. You will use the Raster Calculator in ArcToolbox to make the conversions. In ArcToolbox, go to the **Spatial Analyst tools >> Map Algebra >> Raster Calculator**

Using the buttons in the Raster Tool box (do not type the numbers in), enter the formula below in the raster toolbox work area. Be sure to Double-click on the Band5_clip layer to add it to the formula.

Save the Output raster in the Landsat Folder as **B5_rad**



2. Repeat steps 1 and 2 with band 4 and band 7, naming them B4_rad and B7_rad. The numbers to use for the formula for bands 4 and 7 are below. Verify the numbers, by checking the metadata file.

LMAX_BAND4 = **221.000**

LMIN_BAND4 = **-1.510**

QCALMAX_BAND4 = **255.00**

QCALMIN_BAND4 = **1.0**

LMAX_BAND7 = **16.500**

LMIN_BAND7 = **-0.150**

QCALMAX_BAND7 = **255.00**

QCALMIN_BAND7 = **1.0**

Convert the Radiance layers to Reflectance values

$$(\pi * bRADIANCE BAND\# * d * d) / (ESUN\lambda * \cos(\theta_s))$$

3. The variable **d** is the distance from the earth to the sun in astronomical units (AU). To find the value of **d**, you will first need to know the Julian day (also known as day of year) that the scene was taken <http://amsu.cira.colostate.edu/julian.html>. Then, use Table 3 below to find this value, interpolating as necessary. Visit this site for a table of Julian days; note that there is a separate table for leap years: <http://amsu.cira.colostate.edu/leap.html>.

Table 3. Earth-Sun Distance in Astronomical Units

Julian Day	Distance	Julian Day	Distance	Julian Day	Distance	Julian Day	Distance	Julian Day	Distance
1	.9832	74	.9945	152	1.0140	227	1.0128	305	.9925
15	.9836	91	.9993	166	1.0158	242	1.0092	319	.9892
32	.9853	106	1.0033	182	1.0167	258	1.0057	335	.9860
46	.9878	121	1.0076	196	1.0165	274	1.0011	349	.9843
60	.9909	135	1.0109	213	1.0149	288	.9972	365	.9833

Confirm that The Julian Day for the Landsat image you are using is: **167**

The closest Julian day to this day in the chart is 166, which is 1.0158 AU from the sun.

The next closest day is 182, which is 1.0167 AU from the sun.

4. To calculate the distance for Julian day 167, you will do the following calculation:
 $1.0167\text{AU} - 1.0158\text{ AU}/16\text{ days}$ (in between the two dates). This equals $.00005625\text{ AU}$ closer to the sun per day. Therefore, on Day 167 one day after 166, the sun is $1.0158\text{ AU} + .00005625\text{ AU} = 1.01585625$

5. You will also need the $ESUN_{\lambda}$ value, which is essentially the ambient light around the satellite that is picked up by the sensor. Using the chart to the left, you will see that for band 4, the value is **1044**.

Band	watts/(sqm * μm)
1	1969
2	1840
3	1551
4	1044
5	225.7
7	82.07
8	1368

From: Landsat Data Users Handbook
http://landsathandbook.gsfc.nasa.gov/handbook/handbook_toc.html

6. The next value that you will need for the reflectance formula is the solar zenith angle: $\cos(\theta_s)$. To find this value, find the sun's elevation in the metadata file and subtract the sun's elevation from 90° . The Sun Elevation for your data is: **63.4905934**
 $90^\circ - 63.4905934^\circ = 26.5094066^\circ$

When using the formula in the Raster Calculator an additional operation is required to convert θ_s from degrees to radians ($\text{atan}(1)/45$):

The first formula below is the band 4 radiance formula. The second one is that same formula with the proper numbers plugged into it and also in the proper Map Algebra expression syntax for the Raster Calculator.

$$(\pi * \text{bRADIANCE BAND\#} * d * d) / (ESUN_{\lambda} * \cos(\theta_s))$$

$$(3.14159 * \text{b4_rad} * 1.01585625 * 1.01585625) / (1044 * (\text{Cos}(26.5094066 * 3.14159/180)))$$

Open the **Raster Calculator** and input the expression (above), using the buttons in the Raster Calculator dialog box. For Output Raster, name it **b4_ref** and save it to your Landsat folder. Click OK.

NOTE: While you could attempt to copy and paste, this sometimes introduces error. But, if you want to try it that way first, go for it. Then, if you get an error, go back to inputting with the buttons.

IMPORTANT: The Raster Calculator is case sensitive, so be sure that you enter all alphanumeric characters as they are above. However, if you named your radiance layer differently this will need to be different. It is also critical that the Environment settings are correct, particularly defining the extent and the cell size. You did this in an earlier step, but if you continue to get error messages, this along with checking parenthesis and case, is another avenue of troubleshooting.

7. Before moving on, compare values of some of the pixels between the original band 4 that is in DN, the Radiance image and the Reflectance image. Fill in the chart below.

	DN	Radiance	Reflectance
Layer	L5025031_03120080616_B40.TIF	b4 rad	b4_ref
Pixel Value (lake) example	24	18.638544	.064680
Pixel Value (river)			
Pixel Value (vegetation)			
Pixel Value (urban area)			
Pixel Value (Cloud)			

Which feature pixel has the highest reflectance value? Do you notice that all of your reflectance values are less than 1.0? If they are not, then you may need to go back and re-run, making sure that the parentheses are all in the correct locations.

- Repeat the steps to create reflectance layers for bands 5 and 7. The only thing you need to change in the reflectance formula is the band name. All of the other values are the same for all of the bands. When you are done, fill in the charts below. You won't be on the exact same pixel for each feature, but if you get one that is for the same feature it will be close in value.

	DN	Radiance	Reflectance
Layer	L5025031_03120080616_B50.TIF	b5_rad	b5_ref
Pixel Value (lake) example	15	.494370	.001716
Pixel Value (river)			
Pixel Value (vegetation)			
Pixel Value (urban area)			
Pixel Value (Cloud)			

	DN	Radiance	Reflectance
Layer	L5025031_03120080616_B70.TIF	b7_rad	b7_ref
Pixel Value (lake) example	10	.439961	.001527
Pixel Value (river)			
Pixel Value (vegetation)			
Pixel Value (urban area)			
Pixel Value (Cloud)			

- Remove the b4_rad, b5_rad and the b7_rad layers from the project (TOC)

ACTIVITY 5 – Normalized Difference Water Index (NDWI)

Using the reflectance layers generated in the last section, it is now possible to calculate the normalized difference water index. “It is well known that the SWIR is absorbed by water. This can be free water bodies or the water contained in plant cells. To assess water content in a normalized way, the **NDWI (Normalized Difference Water Index)** was introduced by Ago (1996). This index increases with vegetation water content or from dry soil to free water.”²

Properties of the NDWI product

Formula	$\text{NDWI} = \frac{\text{NIR} - \text{SWIR}}{\text{NIR} + \text{SWIR}}$ $\text{NDWI} = \frac{\text{Band 4} - \text{Band 5}}{\text{Band 4} + \text{Band 5}}$ $\text{NDWI} = \frac{\text{Band 4} - \text{Band 7}}{\text{Band 4} + \text{Band 7}}$
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² VGT for Africa, <http://www.vgt4africa.org/ViewContent.do?pageId=27>, accessed Jul 29, 2008.

The spectral range of Band 4 is 780–900 μ , and is primarily used to estimate biomass, although it can also discriminate water bodies and soil moisture from vegetation. Band 5 has a spectral range of 1550–1750 μ , and is particularly responsive to 15 variations in biomass and moisture.³

You will calculate a NDWI for the NIR and SWIR Band 5. Then, you will repeat with the NIR Band and SWIR Band 7.

1. Open the Raster Calculator and enter the expression, below.

$$\text{b4_ref} - \text{b5_ref} / \text{b4_ref} + \text{b5_ref}$$

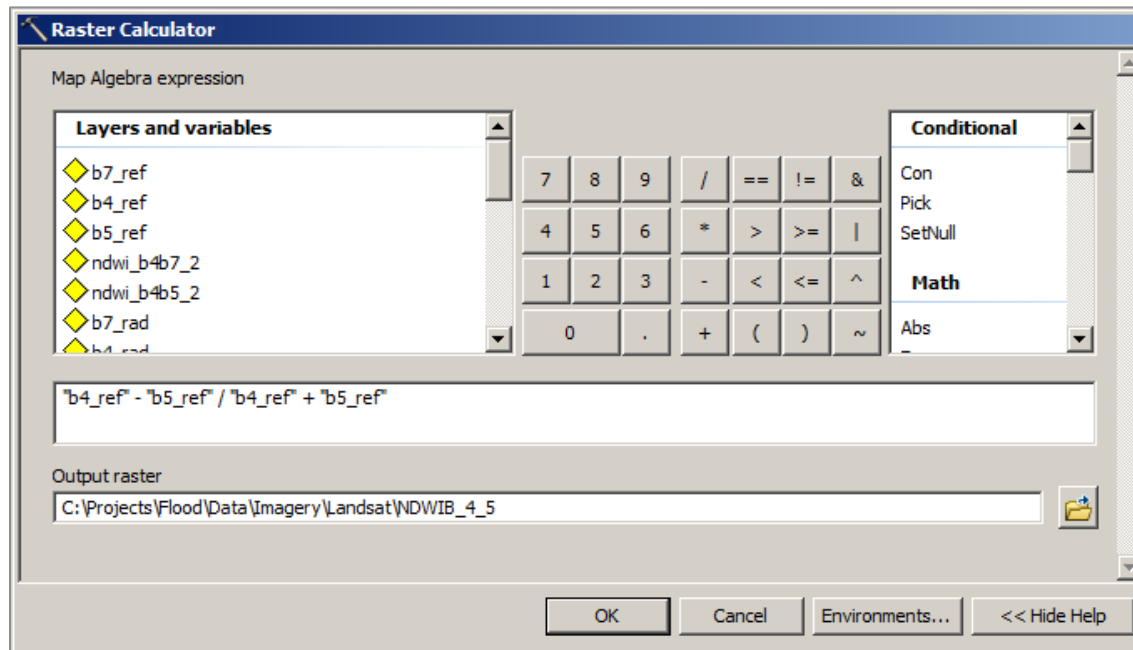
Note: Be sure to use the raster calculator buttons to enter all numbers and operators. Double-click on the appropriate layer in the layer and variable's list. Be sure you are using the reflectance layers.

Save the Output raster as **NDWI_4_5** in your Landsat folder.

2. Repeat the NDWI calculation using band 7 this time for the SWIR band.

$$\text{b4_ref} - \text{b7_ref} / \text{b4_ref} + \text{b7_ref}$$

Save the Output rasters as **NDWIB_4_7** in your Landsat folder.



3. Take a few minutes to examine the new NDWI layers. In Layer Properties >> Source, scroll down to view the Statistics.

What are the Min/Max values? _____

Which areas have the highest NDWI? _____

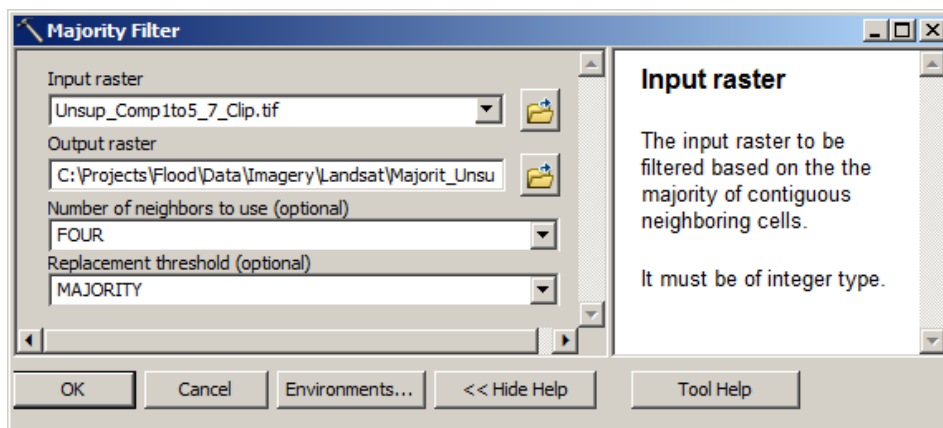
Which areas are lowest in NDWI? _____

³ *Unsupervised classification of saturated areas using a time series of remotely sensed images*, D. A. DeAlwis1, et al, *Hydrol. Earth Syst. Sci. Discuss.*, 4, 1663–1696, 2007 www.hydrol-earth-syst-sci-discuss.net/4/1663/2007/ accessed November 3, 2008.

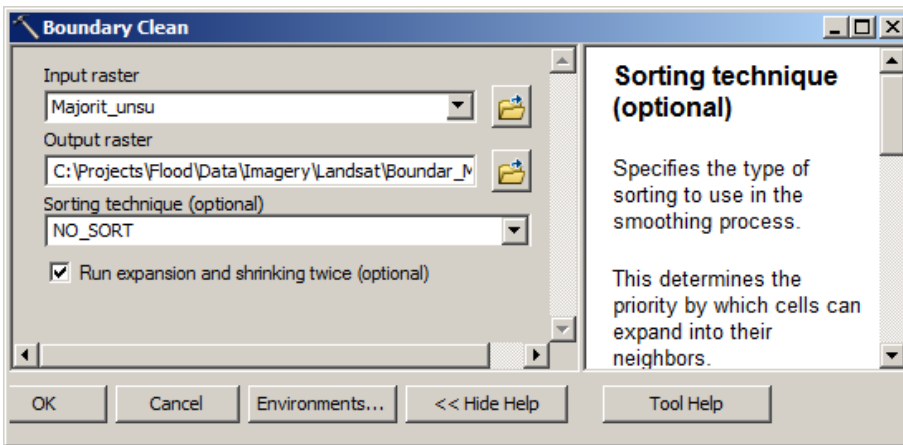
ACTIVITY 6 - Unsupervised Classification

Classifying the image will create classes of pixels that have similar spectral signatures. You will use an unsupervised classification which uses clustering routines to create the number of classes that you specify. An advantage of using an unsupervised classification is that it doesn't require you to preselect training classes; however the results will be more generalized. It helps to have knowledge of the area in order to know if the computer-assigned classes make sense. Since you are just looking for wet and non-wet areas in the final analysis and will be guided by this activity, this method will suffice. If you have time after you finish the activity, you may want to attempt a supervised classification and compare the results. For more information on Classification see the NASA remote sensing tutorial online at http://rst.gsfc.nasa.gov/Sect1/Sect1_16.html and ArcGIS online help.

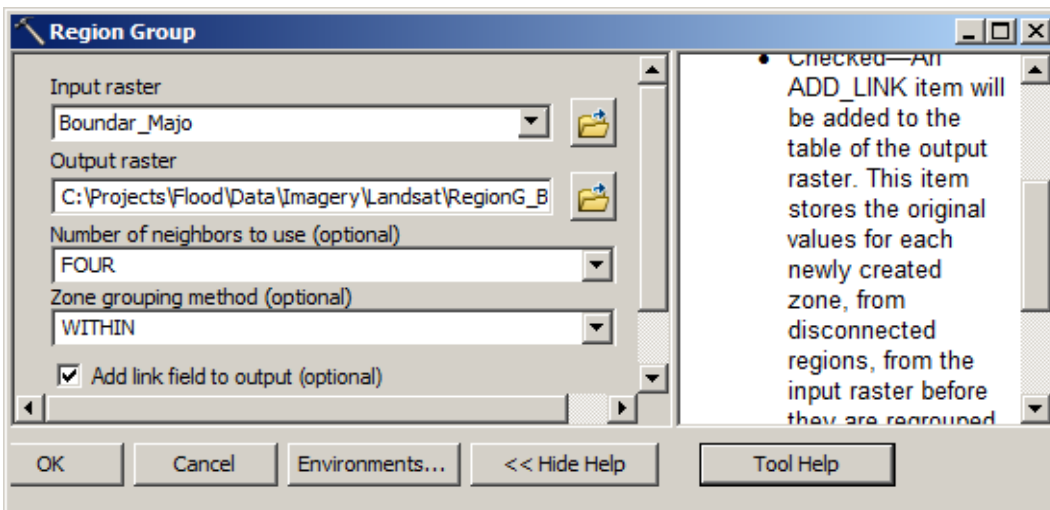
1. From the **Customize** menu, choose **Toolbars**. Checkmark **Image Classification** to add the Classification toolbar to ArcMap.
2. From the Classification toolbar, select **Iso Cluster Unsupervised Classification**. In the Iso Cluster Unsupervised Classification dialog box, choose **Comp_1to5_7clip** for the Input Raster. For number of classes put **14**. Name the Output classified raster **Unsup_Comp_1to5_7clip**. For minimum class size put **60** (10 x number of bands in input file), for sample interval put **2**. Do not save a signature file.
3. Take a few minutes to examine the results. Zoom in around the Cedar River and notice which pixels primarily represent the river. Next, you will improve the results of the classification before reclassifying it. As you work through the steps, open ArcGIS help to read more about each of the tools.
4. Use a Majority Filter tool to remove small, isolated groups of pixels, sometimes referred to as speckling or noise. ArcToolbox >> Spatial Analyst Tools >> Generalization >> Majority Filter. For Input raster, select **Unsup_Comp_1to5_7clip**. For Output raster save it as **Majorit_unsu**



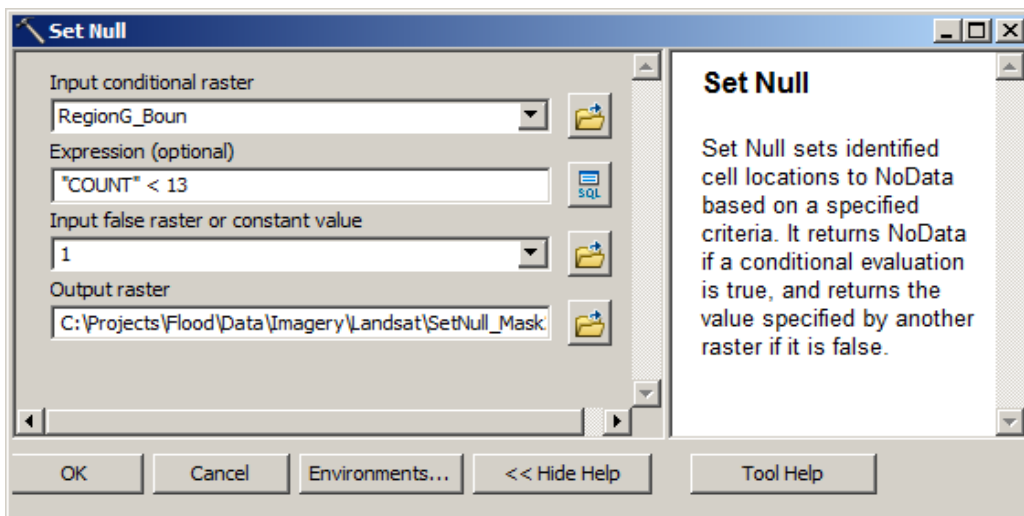
5. Next, you will run the Boundary Clean tool to smooth the ragged edges of class boundaries and to clump the classes. This will allow adjacent areas that belong to the same class to be connected. ArcToolbox >> Spatial Analyst >> Generalization >> **Boundary Clean**. For Input raster, use **Majorit_unsu**. For Output raster save it as **Boundar_Majo**.



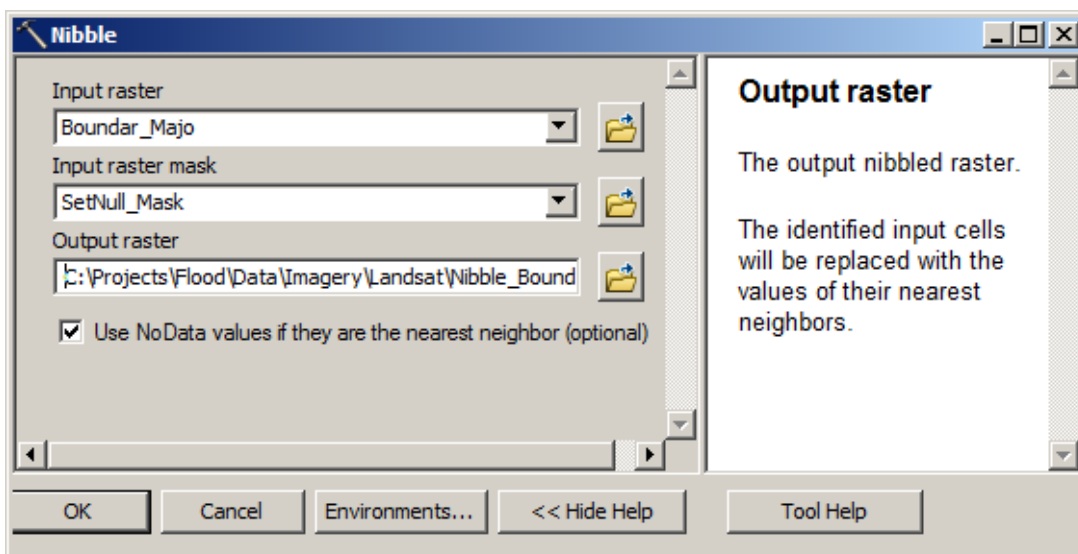
- Now you will run generalization tools. First run Region Group tool to identify groups that are very small. This process removes small isolated regions from a classified image. Regions that are larger than a certain number of pixels will remain on the image. In ArcToolbox open >> Spatial Analyst >> Generalization >> **Region Group**. For Input raster, choose **Boundar_Majo**. For Output raster, save it as **RegionG_Boun**.



- Open the **RegionG_Boun attribute table**. Notice that you have many groups of pixels that have only a few pixels per group. The next steps will remove these very small groups of pixels.
- Before you remove the very small groups of pixels, you need to create a mask raster, using the Set Null tool. Go to the Windows menu and select Search. Type Set Null, and then click on Tools. This will bring up the **Set Null** tool. Click to open it. For Input conditional raster, choose **RegionG_Boun**. For Expression, click on the SQL button and enter the expression “**Count**” < **13**. For the constant value, enter **1**. For Output raster save as **SetNull_Mask**. Examine the results.



9. Now, you are ready run the Nibble tool. ArcToolbox >> Spatial Analyst >> Generalization >> **Nibble**. Under Input raster, choose **Boundar_Majo**, for Input raster mask, choose **SetNull_Mask**. For Output raster, save as **Nibble_Bound**.



10. Examine the resulting layer from the Nibble process. Change the symbology to grayscale – with low values dark and high values light. Compare to the **Unsup_Comp_1to5_7clip** layer to see how the processing changed the original classified layers. You should see a significant reduction in speckling.
11. Turn off all layers except for the Nibble_Bound and comp_1to5_7_Clip and the Basemap Imagery layer. Assign the Comp_1to5_7_clip bands to 4, 5, 3 so that water stands out well. Compare the areas close to the river, inside the City of Cedar Rapids, as zoomed in below.



Reclass

Now, you will reclass the 9 classes according to wet or not-wet.

13. You will be going back and forth between your original Comp_1to5_7_clip, so first assign those bands to a 4, 5, 3 so that water stands out well.
14. Find the classes of pixels on the Unsup_cNDWI and assign them as “wet” (new class 1) or “not wet” (new class 2) and continue.

Hints:

- Do the obvious first, such as river pixels.
- Add the USA Topo map basemap from Esri to verify that an area really is low enough to likely be wet.
- Turn on the rivers_57 layer.
- Most of the classes will be not-wet.
- Turn the classes that you determine are not wet to “no color” as you go along.
- Use the identify tool to examine the values.

Fill in the chart.

Old (original) class values	Status	New class values
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		

- From ArcToolbox, select Spatial Analyst Tools → Reclass → **Reclassify**. In the Reclassify dialog box, for Input raster, select **Nibble_Bound**, for Reclass field, select **Value**, for Output raster save as **Reclass_Nibb**. Under Reclassification enter the values from the table above.
- When the resulting raster appears in the TOC, change the values in the legend so that 1 = light blue and 2 = no color.

ACTIVITY 7 – Raster to Vector Conversion and Flooded Areas Comparison between Landsat and SPOT

Add the FloodedAreas_Project shapefile that you downloaded earlier from the Iowa State website. Choose a contrasting color for the outline and be sure it is above the reclassified. Turn on the Basemap imagery layer. Your screen image will resemble the one below. It may not be exactly the same.

Convert reclassified image to a shape file.

1. Open ArcToolbox >> Conversion Tools >> From Raster >> **Raster to Polygon** tool. For Input raster, select **Reclass_Nibb**, for Field, accept the default, **VALUE**, for Output polygon features, save to your Data folder as **Wet_Areas**. The results will look similar to what you see here, although likely a different color. Examine the attribute table and notice that there is a field “GRIDCODE”, with values of 1 or 2.



2. Change the symbology of the **wet_areas** layer to display wet areas (GRIDCODE value 1) in a dark blue color and the non-wet areas (GRIDCODE value 2) with no color.
3. From your Image\SPOT folder, add “**Flood_extent_iowa_cedar_20080617**” to your project. Open up the attribute table to view the fields. Notice the field GRID_CODE contains values 1, 2 or 3. These indicate the type of flooding: 1- Flooded, 2 - Flooded Forest, and 3 - Saturated. Pan up and down the Cedar River area of the flood_extent_iowa_cedar_20080617 layer to see where the two layers match fairly well and also locations where they do not. Turn the Flood_extent_iowa_cedar_20080617_clip layer on and off (it should be on top of the wet_areas layer) to compare them more easily, or use the swipe tool.

The wet_areas data was derived from the processes you conducted on the Landsat imagery, which is at 30 meters resolution. Answer the questions, below:

a. The SPOT data is at what resolution? _____

b. Which layer would you anticipate to be most accurate? Why?

Recall that the flood boundaries from the SPOT imagery are from the 16th, while the Landsat Image is from the 17th, after the water started receding. There will be differences in the coverage, because the Flood_extent_iowa_cedar_20080617 is not clipped to the flooded areas boundary.