Corpus Christi Bay, Galveston Bay, Mission-Aransas Bay, San Antonio Bay, and Sabine Lake Lower-Watershed Multi-year Land-Use and Land Cover Classifications and Curve Numbers

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by

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Introduction

Land use along the Texas coast has changed significantly in the past two decades. Land Cover and land use have a major impact on the amount of water that is absorbed by the soil, and ultimately on the amount of runoff that reaches the rivers and estuaries. This project aims to determine where land-use/Land Cover change has taken place in the lower drainage basins for Corpus Christi Bay (Corpus), Mission-Aransas Bay (Mission), San Antonio bay (Guadalupe), Galveston Bay (Galveston), and Sabine Lake (Sabine). It also determines the types of changes that have occurred. Of note, in the previous report, *Galveston and Lavaca Watershed Multi-year Land Use and Land Cover Classifications and Curve Numbers*, the Galveston watershed contained both the Galveston and Sabine watersheds. This report separates the two watersheds and provides the statistics for each individually. Below, the table shows the area of each watershed, including 150 meter buffer, and a reference map for the watersheds. Figure 1, on the next page, shows the study area.
Figure 1. Overview map of the study area.
Methods
The first step in creating the Anderson Level I classification was securing images that covered the required area during the given time periods. The National Aeronautics and Space Administration’s (NASA) satellite, LandSat Thematic Mapper (TM) images on the United States Geological Survey (USGS) website’s Global Visualization Viewer (GLOVIS) met these requirements. The area being studied required seven LandSat TM scenes. The path/row for the scenes being used are 24/39, 25/39, 25/40, 26/40, 26/41, 27/40, and 27/41. Having two time periods to classify this required fourteen LandSat TM scenes, seven scenes with two images per path/row. The dates for each scene are in the table below.

<table>
<thead>
<tr>
<th>Path</th>
<th>Row</th>
<th>Early Date</th>
<th>Late Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>39</td>
<td>03/10/1998</td>
<td>04/27/2004</td>
</tr>
<tr>
<td>25</td>
<td>39</td>
<td>03/17/1998</td>
<td>05/04/2004</td>
</tr>
<tr>
<td>25</td>
<td>40</td>
<td>03/17/1998</td>
<td>05/04/2004</td>
</tr>
<tr>
<td>26</td>
<td>41</td>
<td>03/08/1998</td>
<td>03/08/2004</td>
</tr>
<tr>
<td>27</td>
<td>40</td>
<td>03/31/2004</td>
<td>03/31/2004</td>
</tr>
<tr>
<td>27</td>
<td>41</td>
<td>03/31/2004</td>
<td>03/31/2004</td>
</tr>
</tbody>
</table>

Table 1. List of LandSat images used.

For the purposes of this project, only an Anderson Level I classification was needed. An Anderson Level I classification consists of generalized classes, including: 1) Urban, 2) Agriculture, 3) Rangeland, 4) Forest, 5) Water, 6) Wetland, 7) Barren Land, 8) Tundra, and 9) Perennial Snow or Ice. An Anderson Level II classification would break these generalized classes down to more specific ones, having the Urban class split into: 1) Residential, 2) Commercial and Services, 3) Industrial, 4) Transportation, Communications, and Utilities, 5) Industrial and Commercial Complexes, 6) Mixed Urban or Built-up Land, and 7) Other Urban or Built-up Land classes. This project only required the use of the first seven Anderson Level I classes because Tundra and Perennial Snow or Ice do not exist in the study area. The National Land Cover Data (NLCD) 1992 and NLCD 2001 are more in depth, analogous to an Anderson Level II classification, necessitating consolidation of some classes. Using Leica Geosystem’s image processing software, ERDAS Imagine, NLCD 1992 and NLCD 2001 were recoded to fit the parameters of an Anderson Level I classification. The classes being used are Agriculture, Barren Land, Forest, Rangeland, Urban, Water, and Wetland. Below are the class structures for NLCD 1992 and NLCD 2001 along with the class its Anderson Level I classification used in this study.
<table>
<thead>
<tr>
<th>Class Number</th>
<th>1992 NLCD</th>
<th>2001 NLCD</th>
<th>Anderson Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Open Water</td>
<td>Open Water</td>
<td>5) Water</td>
</tr>
<tr>
<td>12</td>
<td>Perennial Ice/Snow</td>
<td>Perennial Ice/Snow</td>
<td>Not Needed</td>
</tr>
<tr>
<td>21</td>
<td>Low Intensity Residential</td>
<td>Developed, Open Space</td>
<td>1) Urban</td>
</tr>
<tr>
<td>22</td>
<td>Heavy Intensity Residential</td>
<td>Developed, Low Intensity</td>
<td>1) Urban</td>
</tr>
<tr>
<td>23</td>
<td>Commercial/Industrial/Transportation</td>
<td>Developed, Medium Intensity</td>
<td>1) Urban</td>
</tr>
<tr>
<td>24</td>
<td>N/A</td>
<td>Developed, High Intensity</td>
<td>1) Urban</td>
</tr>
<tr>
<td>31</td>
<td>Bare Rock/Sand/Clay</td>
<td>Barren Land (Rock/Sand/Clay)</td>
<td>7) Barren Land</td>
</tr>
<tr>
<td>32</td>
<td>Quarries/Strip Mines/Gravel Pits</td>
<td>Unconsolidated Shore</td>
<td>7) Barren Land</td>
</tr>
<tr>
<td>33</td>
<td>Transitional</td>
<td>N/A</td>
<td>7) Barren Land</td>
</tr>
<tr>
<td>41</td>
<td>Deciduous Forest</td>
<td>Deciduous Forest</td>
<td>4) Forest</td>
</tr>
<tr>
<td>42</td>
<td>Evergreen Forest</td>
<td>Evergreen Forest</td>
<td>4) Forest</td>
</tr>
<tr>
<td>43</td>
<td>Mixed Forest</td>
<td>Mixed Forest</td>
<td>4) Forest</td>
</tr>
<tr>
<td>51</td>
<td>Shrubland</td>
<td>Dwarf Scrub</td>
<td>3) Rangeland</td>
</tr>
<tr>
<td>52</td>
<td>N/A</td>
<td>Shrub/Scrub</td>
<td>3) Rangeland</td>
</tr>
<tr>
<td>61</td>
<td>Orchards/Vineyards/Other</td>
<td>N/A</td>
<td>2) Agriculture</td>
</tr>
<tr>
<td>71</td>
<td>Grasslands/Herbaceous</td>
<td>Grasslands/Herbaceous</td>
<td>3) Rangeland</td>
</tr>
<tr>
<td>72</td>
<td>N/A</td>
<td>Sedge/Herbaceous</td>
<td>3) Rangeland</td>
</tr>
<tr>
<td>73</td>
<td>N/A</td>
<td>Lichens</td>
<td>3) Rangeland</td>
</tr>
<tr>
<td>74</td>
<td>N/A</td>
<td>Moss</td>
<td>3) Rangeland</td>
</tr>
<tr>
<td>81</td>
<td>Pasture/Hay</td>
<td>Pasture/Hay</td>
<td>2) Agriculture</td>
</tr>
<tr>
<td>82</td>
<td>Row Crops</td>
<td>Cultivated Crops</td>
<td>2) Agriculture</td>
</tr>
<tr>
<td>83</td>
<td>Small Grains</td>
<td>N/A</td>
<td>2) Agriculture</td>
</tr>
<tr>
<td>84</td>
<td>Fallow</td>
<td>N/A</td>
<td>2) Agriculture</td>
</tr>
<tr>
<td>85</td>
<td>Urban/Recreational Grasses</td>
<td>N/A</td>
<td>1) Urban</td>
</tr>
<tr>
<td>90</td>
<td>N/A</td>
<td>Woody Wetlands</td>
<td>6) Wetland</td>
</tr>
<tr>
<td>91</td>
<td>Woody Wetlands</td>
<td>Palustrine Forested Wetland</td>
<td>6) Wetland</td>
</tr>
<tr>
<td>92</td>
<td>Emergent Herbaceous Wetlands</td>
<td>Palustrine Scrub/Shrub Wetland</td>
<td>6) Wetland</td>
</tr>
<tr>
<td>93</td>
<td>N/A</td>
<td>Estuarine Forested Wetland</td>
<td>6) Wetland</td>
</tr>
<tr>
<td>94</td>
<td>N/A</td>
<td>Estuarine Scrub/Shrub Wetland</td>
<td>6) Wetland</td>
</tr>
<tr>
<td>95</td>
<td>N/A</td>
<td>Wetlands</td>
<td>6) Wetland</td>
</tr>
<tr>
<td>96</td>
<td>N/A</td>
<td>Palustrine Emergent Wetland</td>
<td>6) Wetland</td>
</tr>
<tr>
<td>97</td>
<td>N/A</td>
<td>Estuarine Emergent Wetland</td>
<td>6) Wetland</td>
</tr>
<tr>
<td>98</td>
<td>N/A</td>
<td>Palustrine Aquatic Bed</td>
<td>6) Wetland</td>
</tr>
<tr>
<td>99</td>
<td>N/A</td>
<td>Estuarine Aquatic Bed</td>
<td>6) Wetland</td>
</tr>
</tbody>
</table>

Table 2. Comparison of Land Cover classes used in the 1992 and 2001 NLCD, and their classification in this study.


To have a baseline of locations of the Land Use/Land Cover classes, a new dataset was created from the recoded NLCD 1992 and NLCD 2001. Using the modeler in Leica Geosystem’s ERDAS Imagine 9.1, pixels that had the same class value kept their classification and pixels that did not have the same class value were masked out to 0. The resulting image will be referred to as the “Combined NLCD” image.

The Corpus, Guadalupe, and Mission watersheds are fairly small and border each other. They were treated as one watershed (referred to as CGM) to be split after classification. However, the watersheds fell on multiple scenes. Because of this, it was
necessary to align all of the scenes. Even though all the images were in the same projection, Universal Transverse Mercator (UTM) World Geodetic System 1984 (WGS84) Zone 14 North, they did not match up perfectly. To align the images a Texas transportation vector file was brought in. The transportation file was obtained from the Texas Department of Transportation (TXDOT) and shows the major roads of Texas. First, the transportation file was overlaid on the LandSat 27/40 and 41 images for both 1998 and 2004. The 2004 image was aligned with the transportation file, but the 1998 image was a little off so it was manually moved by adjusting the upper left X and Y using ERDAS. Once both images corresponded with each other and the transportation data, the other images and the Combined NLCD were adjusted. Each was done in the same manner as the 27/40 and 41 image for 1998. When all the adjusting was done, the images were aligned with both the other images of the same year and the corresponding image of the other year.

Using ERDAS, the watersheds were overlaid onto the LandSat TM scenes and Areas of Interest (AOI) were drawn around the area of the watershed, including a significant buffer within each scene. An AOI is a user defined region to be further examined. The images were clipped to the AOI for the CGM area. Three clipped images were made from this process. The Combined NLCD and Digital Elevation Models (DEM) were also clipped to the same AOI as well.

After clipping the Combined NLCD images, a set of random points were generated using ERDAS Imagine 9.0. Two sets of points were created according to the Combined NLCD for CGM, one for calibration and one for validation, with the same parameters. Equalized random sampling, with a requirement of a threshold of 9 pixels of a 3x3 window must belong to the same class, was used for all scenes. Each class received 10 points, except the “Barren Land” class because of its miniscule area, giving a total of 60 points per dataset. The “Barren Land” class was still included in the classification but not in the accuracy assessment.

After the list of points was generated, they were put into an Excel worksheet and converted to a .dbf file to bring them into ArcView GIS 3.3 to convert them to a shapefile. The points were overlaid on the Combined NLCD and the corresponding watershed images in ArcView. Each point was inspected individually to make sure it matched the class it was given in the Combined NLCD and then to make sure the points matched in both images. If the point did not match the Land Cover in both images, was on the edge of Land Cover, or was hard to determine what the Land Cover was, the point was manually moved to a large, easily identifiable area of contiguous Land Cover that also registered on the Combined NLCD location.

To perform the classification, Definien’s eCognition software was used. eCognition is an object oriented classification algorithm. An object-oriented classification algorithm first creates clusters of homogenous pixels through segmentation and then a supervised classification can be performed on the segmented image. eCognition allows the use of many different types of data to be used to create a classification. The layers used included all 7 bands of the LandSat TM image, DEM, and Normalized Difference Vegetation Index (NDVI) derived from the LandSat TM image. A NDVI layer is the ratio of the Red (R) and Near Infrared bands (NIR), represented by the equation below:

\[ NDVI = \frac{\text{NIR} - R}{\text{NIR} + R} \]
The NDVI responds to green biomass and helped to separate the difference between the Forest and Rangeland classes. Segmentation takes several factors into account: how much weight each layer has, scale parameter, color vs. shape, and compactness vs. smoothness. Layer weight determines how important each layer is in the segmentation process. Scale parameter is a variable that determines the size of the cluster; larger scale parameters create larger clusters. The color vs. shape variable is a scale the either puts more emphasis on the color (pixel value) or shape of the object (which is related to the next variable). Compactness vs. smoothness is the last variable, and is a sliding scale, like the color vs. shape variable. Compactness is a function of area to perimeter, with a more compact area having a higher area to perimeter ratio. Smoothness describes the similarity of the object to a square. The parameters used for the segmentation of all images in this project are provided below:

![Segmentation dialogue in Definien’s eCognition](image.png)

These parameters were chosen by trial and error. The composition of homogeneity criterion is the default setting, while the scale parameter was increased from 10 to 15. A scale parameter of 10 increased the number of objects significantly, almost to the point of being the same as a pixel-based classification. Scale parameters greater than 15 tended to be too large and contained pixels of different classes in one object. Using a scale parameter of 15 provided a large enough object to be more than just a pixel-based
classification while keeping the homogenous integrity of the object. Layers with greater variance were given greater weight.

To choose the training areas from the clusters created during segmentation, the Combined NLCD was overlaid on the corresponding image being classified and viewed in ERDAS. Training areas, in the object-based classification, are objects that are chosen because they are representative of a land use/land cover class. These chosen objects train the software package to know the spectral signature of the class so that it can make decisions to which class other objects belong. Objects were selected from areas that appeared in the Combined NLCD. After an adequate amount of training areas had been selected, a classification was performed. The accuracy assessment was done by exporting the classified image to ERDAS and using the accuracy assessment tool with the validation points created.

After classification, CGM’s three parts needed to be mosaicked. When doing the classification, residential areas were extremely difficult to separate from the Agriculture, Forest, and Rangeland classes because of the vegetation. To keep the Urban class consistent, some post classification processing was performed. The first step was to remove any unwanted Urban classifications from the 1998 image. To do this, the 1998 image was compared to the 2001 NLCD image. When a pixel was classified as Urban in 1998 but not in 2001 it was changed to the 2001 classification. This process removed spurious Urban pixels. Next, the Urban class for the 1992 NLCD image and 1998 classified image with spurious Urban areas removed were merged to create a 1998 image that contained all of the Urban from 1992, no Urban that was not Urban in 2001, and the Urban areas that had developed since 1992. The resulting image, “1998_urban_merged”, was used as the 1998 image. The Urban class from the newly created 1998 classification was then merged to the 2001 NLCD, with the resulting Urban class being merged with the 2004 classification. This made sure that anything that was classified as Urban in the previous classification was classified as Urban in the latter classification.

Soil data were downloaded from http://soildatamart.nrcs.usda.gov/ and then queried for the top layer of soil. The table below lists the curve numbers for each soil type (A, B, C, or D) for its corresponding Land Cover/ land use class.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>61</td>
<td>75</td>
<td>83</td>
<td>87</td>
</tr>
<tr>
<td>Agriculture</td>
<td>64</td>
<td>75</td>
<td>82</td>
<td>85</td>
</tr>
<tr>
<td>Rangeland</td>
<td>39</td>
<td>61</td>
<td>74</td>
<td>80</td>
</tr>
<tr>
<td>Forest</td>
<td>30</td>
<td>55</td>
<td>70</td>
<td>77</td>
</tr>
<tr>
<td>Water</td>
<td>98</td>
<td>98</td>
<td>98</td>
<td>98</td>
</tr>
<tr>
<td>Wetland</td>
<td>98</td>
<td>98</td>
<td>98</td>
<td>98</td>
</tr>
<tr>
<td>Barren</td>
<td>77</td>
<td>85</td>
<td>90</td>
<td>92</td>
</tr>
</tbody>
</table>

source: http://www.ecn.purdue.edu/runoff/documentation/scs.htm

Table 3. Curve numbers used for each land-use/Land Cover with the possible soil type.

The curve numbers for the Water and Wetland classes were provided by Texas Water Development Board (TWDB). Once the curve numbers to be used were known,
the classified images were combined with the soils data to generate a new image that used the curve numbers as the pixel values. The soil types are classified according to their drainage potential. Group A soils are deep and absorb water well, are well drained and composed of sand or gravel, therefore having lower curve numbers. Group D soils are at the other end of the continuum and do not absorb water well leading to higher curve numbers. They are thin layers of soil above bedrock or have a high percentage of clay near the surface.

**Results**

Several outputs were generated by this study: land-use classifications, land-use change detections, curve numbers, and statistics for each classification and change detection. First, accuracy assessments were needed for the classifications. Using eCognition with the parameters above the following accuracies were obtained and found to be adequate for this study:

<table>
<thead>
<tr>
<th>Watershed</th>
<th>1998 Accuracy</th>
<th>2004 Accuracy</th>
<th>CGM Accuracy</th>
<th>CGM Kappa</th>
<th>Galveston-Sabine Accuracy</th>
<th>Galveston-Sabine Kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watershed</td>
<td>86.67%</td>
<td>90.00%</td>
<td>86.67%</td>
<td>0.8411</td>
<td>91.67%</td>
<td>0.9000</td>
</tr>
<tr>
<td>Galveston-Sabine</td>
<td>91.67%</td>
<td>86.67%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Accuracy assessment

The accuracies reported for Galveston and Sabine are the same as the previous report. These accuracies were calculated using the validation points created earlier. Each point created was identified in the classified image and counted correct if it matched the validation point and incorrect if it did not correspond with the class given by the validation point. The Kappa is a statistic that quantifies agreement.

These classifications resulted in the following Land Cover percentages for the two Spatial Sciences Lab created classifications (1998 and 2004) and two NLCD classifications (1992 and 2001). (See Appendix A for larger charts and corresponding tables). The following table can be used to calculate the area for each land cover class, including 150 meter buffer.

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Area (sq. m.)</th>
<th>Area (sq. km.)</th>
<th>Area (acres)</th>
<th>Area (sq. mi.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corpus</td>
<td>2,330,938,831.40</td>
<td>2,330,938.83</td>
<td>575,987,528.02</td>
<td>899,980.52</td>
</tr>
<tr>
<td>Galveston</td>
<td>18,362,350,620.50</td>
<td>18,362,350.62</td>
<td>4,537,435,646.13</td>
<td>7,089,743.22</td>
</tr>
<tr>
<td>Guadalupe</td>
<td>3,717,056,311.51</td>
<td>3,717,056.31</td>
<td>918,504,616.05</td>
<td>1,435,163.47</td>
</tr>
<tr>
<td>Mission</td>
<td>7,249,508,662.76</td>
<td>7,249,508.66</td>
<td>1,791,392,600.17</td>
<td>2,799,050.95</td>
</tr>
<tr>
<td>Sabine</td>
<td>6,856,189,126.06</td>
<td>6,856,189.13</td>
<td>1,694,201,226.20</td>
<td>2,647,189.42</td>
</tr>
</tbody>
</table>

Table 5. Area calculation for each watershed in different units.
Figure 3. Percentage of land-use class per year for the Corpus watershed.

Figure 4. Percentage of land-use class per year for the Guadalupe watershed.
Figure 5. Percentage of land-use class per year for the Mission watershed.

Figure 6. Percentage of land-use class per year for the Galveston watershed.
Figure 7. Percentage of land-use class per year for the Sabine watershed.

All of the watersheds have significant increase in Urban areas with reductions usually in Forest, Rangeland, and Agricultural areas. Corpus, Guadalupe, and Mission are all still dominated by Agriculture and Rangeland, but all have had a significant percentage increase in Urban areas.

The last step was creating curve number maps. Using the curve number table referred to earlier, the classifications were recoded to represent the curve number for the land use/Land Cover class and soil type. Maps for the classifications, curve number maps, and change statistics tables are attached in the appendices. The change statistics tend to show the largest change between classes is consistently between Agriculture and Rangeland for Corpus; and for Guadalupe and Mission, Rangeland, Agriculture, and Forest consistently have the largest percentage of change. Galveston still has the largest amount of change between Forest and Agriculture while Sabine has significant change between Forest and Wetland. This may be because these were the classes, for their respective watersheds, that were the hardest to separate in the classification. It may be difficult to understand the change statistics charts, so tables are also shown to help interpret the charts. To read them, the full bar is the early classification and the segments of that bar are what the previous classification changed to. In the table, columns represent the percentage of that class for the early year and rows represent the latter year. For example, in the chart below (Figure 8), the full bar would represent the percentage of the 1992 classification that was Agriculture and each segment inside that bar represents the class the pixels were classified as in the 1998 image and their percentage. Looking at the Agriculture bar, in 1992 about 43% of the image was classified as Agriculture. Of those 43% of the image, 1% changed to Urban, 35% stayed Agriculture,
6% changed to Rangeland, 1% changed to Forest, and 1% changed to Wetland in 1998. This is also shown in Table 6 by looking in the Agriculture column.

![Corpus Landcover Change 1992-1998](image)

**Figure 8.** Land Cover change for the Corpus watershed from 1992 to 1998.

<table>
<thead>
<tr>
<th></th>
<th>Urban</th>
<th>Agriculture</th>
<th>Rangeland</th>
<th>Forest</th>
<th>Water</th>
<th>Wetland</th>
<th>Barren</th>
<th>Total After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>8.30%</td>
<td>0.75%</td>
<td>0.62%</td>
<td>0.19%</td>
<td>0.06%</td>
<td>0.07%</td>
<td>0.05%</td>
<td>10.03%</td>
</tr>
<tr>
<td>Agriculture</td>
<td>0.00%</td>
<td>34.81%</td>
<td>3.19%</td>
<td>0.60%</td>
<td>0.50%</td>
<td>0.75%</td>
<td>0.13%</td>
<td>39.98%</td>
</tr>
<tr>
<td>Rangeland</td>
<td>0.00%</td>
<td>5.66%</td>
<td>4.12%</td>
<td>1.36%</td>
<td>0.09%</td>
<td>1.16%</td>
<td>0.11%</td>
<td>12.50%</td>
</tr>
<tr>
<td>Forest</td>
<td>0.00%</td>
<td>0.53%</td>
<td>0.81%</td>
<td>1.75%</td>
<td>0.01%</td>
<td>0.27%</td>
<td>0.00%</td>
<td>3.38%</td>
</tr>
<tr>
<td>Water</td>
<td>0.00%</td>
<td>0.05%</td>
<td>0.04%</td>
<td>0.19%</td>
<td>25.01%</td>
<td>1.06%</td>
<td>0.04%</td>
<td>26.39%</td>
</tr>
<tr>
<td>Wetland</td>
<td>0.00%</td>
<td>0.61%</td>
<td>0.91%</td>
<td>1.04%</td>
<td>0.57%</td>
<td>3.88%</td>
<td>0.07%</td>
<td>7.08%</td>
</tr>
<tr>
<td>Barren</td>
<td>0.00%</td>
<td>0.12%</td>
<td>0.09%</td>
<td>0.02%</td>
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<tr>
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<td>26.38%</td>
<td>7.32%</td>
<td>0.54%</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

**Table 6.** Land cover change for the Corpus watershed from 1992 to 1998.
Conclusion

There is significant land use and Land Cover change throughout the study period. Urban sprawl is evident by looking at the maps and statistics for each classification. Agriculture is also growing, while Forest, Rangeland, and Wetland areas are shrinking.

One difficulty of this project was the NLCD classifications. The 2001 NLCD, specifically, tended to over represent Agriculture and Wetland areas while under representing Forest areas. This may account for changes in classes between 1998 and 2001, and 2001 and 2004.

The 1992 and 2001 NLCD were created differently and had different classes, as shown in Figure 2, were. The use of the different class scheme may have led to more being classified as one class than they should have been. This is most evident in the 2001 Galveston classification. The Wetland class dominates the Forest class. This could be due to the multiple classes for Wetlands used in the 2001 NLCD. With the Wetlands class expanding its scope, what can be classified as Forest is reduced. This is especially true for woody wetlands.

The statistics and maps for Galveston and Sabine used the previous report’s classification and then split the two watersheds.
2004 Corpus, Guadalupe, and Mission Land Use/Landcover

Legend:
- Pink: Corpus Watershed
- Green: Forest
- Orange: Guadalupe Watershed
- Blue: Water
- Dark Red: Mission Watershed
- Purple: Wetland
- Yellow: Agriculture
- Light Brown: Rangeland

Scale: 0 5 10 20 30 40 Kilometers

Projection: UTM Zone 14 North
Datum: WGS84
Created by Jared Stukey
Corpus

<table>
<thead>
<tr>
<th>Year</th>
<th>Urban</th>
<th>Agriculture</th>
<th>Rangeland</th>
<th>Forest</th>
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</tbody>
</table>
Guadalupe

Year | Percentage of Landcover
--- | ---
1992 | 38.00% Urban, 17.00% Agriculture, 30.00% Rangeland, 13.00% Forest, 2.00% Water, 0.00% Wetland, 2.00% Barren
1998 | 37.00% Urban, 17.00% Agriculture, 30.00% Rangeland, 13.00% Forest, 2.00% Water, 0.00% Wetland, 2.00% Barren
2001 | 38.00% Urban, 17.00% Agriculture, 30.00% Rangeland, 13.00% Forest, 2.00% Water, 0.00% Wetland, 2.00% Barren
2004 | 37.00% Urban, 17.00% Agriculture, 30.00% Rangeland, 13.00% Forest, 2.00% Water, 0.00% Wetland, 2.00% Barren
### Corpus Classification Statistics

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### Guadalupe Classification Statistics

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Mission Classification Statistics

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<td>0.03%</td>
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</tbody>
</table>
Galveston

Year | Urban | Agriculture | Rangeland | Forest | Water | Wetland | Barren
--- | --- | --- | --- | --- | --- | --- | ---
1992 | 5.00% | 30.00% | 40.00% | 35.00% | 20.00% | 10.00% | 0.00%
1998 | 10.00% | 30.00% | 35.00% | 25.00% | 20.00% | 15.00% | 5.00%
2001 | 15.00% | 25.00% | 20.00% | 15.00% | 10.00% | 5.00% | 0.00%
2004 | 20.00% | 20.00% | 15.00% | 10.00% | 5.00% | 0.00% | 0.00%
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<td>0.53%</td>
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Sabine

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<tr>
<td>1998</td>
<td>Urban: 5.00% Agriculture: 10.00% Rangeland: 15.00% Forest: 20.00% Water: 25.00% Wetland: 30.00% Barren: 35.00%</td>
</tr>
<tr>
<td>2001</td>
<td>Urban: 5.00% Agriculture: 10.00% Rangeland: 15.00% Forest: 20.00% Water: 25.00% Wetland: 30.00% Barren: 35.00%</td>
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<tr>
<td>2004</td>
<td>Urban: 5.00% Agriculture: 10.00% Rangeland: 15.00% Forest: 20.00% Water: 25.00% Wetland: 30.00% Barren: 35.00%</td>
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### Sabine Classification Statistics

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Appendix B

Curve Numbers
2004 Galveston Curve Numbers
1992 Sabine Curve Numbers
Appendix C

Land Use and Land Cover Change
### 1992 – 1998 Corpus Land Cover Change Statistics

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<th>Agriculture</th>
<th>Rangeland</th>
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<th>Water</th>
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<th>Barren</th>
<th>Total After</th>
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<td><strong>Before</strong></td>
<td>8.30%</td>
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<td>0.19%</td>
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<td>0.07%</td>
<td>0.05%</td>
<td>10.03%</td>
</tr>
<tr>
<td><strong>After</strong></td>
<td>10.03%</td>
<td>39.98%</td>
<td>12.50%</td>
<td>3.38%</td>
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</table>

### 1998 – 2001 Corpus Land Cover Change Statistics

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<th>Rangeland</th>
<th>Forest</th>
<th>Water</th>
<th>Wetland</th>
<th>Barren</th>
<th>Total After</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Before</strong></td>
<td>10.03%</td>
<td>39.98%</td>
<td>12.50%</td>
<td>3.38%</td>
<td>26.39%</td>
<td>7.08%</td>
<td>0.64%</td>
<td>100.00%</td>
</tr>
<tr>
<td><strong>After</strong></td>
<td>14.79%</td>
<td>38.22%</td>
<td>6.90%</td>
<td>4.24%</td>
<td>25.97%</td>
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### 2001 – 2004 Corpus Land Cover Change Statistics

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<th>Water</th>
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<th>Barren</th>
<th>Total After</th>
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<td>11.40%</td>
<td>2.20%</td>
<td>23.94%</td>
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<td>2.60%</td>
<td>100.00%</td>
</tr>
</tbody>
</table>
Corpus Landcover Change 2001 - 2004

2001 Landcover Classification

- Barren
- Wetland
- Water
- Forest
- Rangeland
- Agriculture
- Urban

2001 Landcover Percentage

- Barren
- Wetland
- Water
- Forest
- Rangeland
- Agriculture
- Urban

<table>
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<tr>
<th></th>
<th>Urban</th>
<th>Agriculture</th>
<th>Rangeland</th>
<th>Forest</th>
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### 1998 – 2001 Guadalupe Land Cover Change Statistics

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### 2001 – 2004 Guadalupe Land Cover Change Statistics

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Guadalupe Landcover Change 2001 - 2004

2001 Landcover Classification

2001 Landcover Percentage

Urban  Agriculture  Rangeland  Forest  Water  Wetland  Barren

Barren  Wetland  Water  Forest  Rangeland  Agriculture  Urban

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<td>14.19%</td>
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<td>0.01%</td>
<td>0.04%</td>
<td>0.02%</td>
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<td>0.06%</td>
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<td>0.01%</td>
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Mission Landcover Change 2001 - 2004

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62

1992 Landcover Classification

1992 Landcover Percentage

- Urban
- Agriculture
- Rangeland
- Forest
- Water
- Wetland
- Barren
Galveston Landcover Change 2001 - 2004

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### 1998 – 2001 Galveston Land Cover Change Statistics

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<tr>
<td>Barren</td>
<td>35.00%</td>
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</tbody>
</table>

Sabine Landcover Change 2001 - 2004

2001 Landcover Classification

Urban Agriculture Rangeland Forest Water Wetland Barren

2001 Landcover Percentage

0.00% 5.00% 10.00% 15.00% 20.00% 25.00% 30.00% 35.00% 40.00% 45.00%

Legend:
- Blue: Barren
- Purple: Wetland
- Green: Water
- Black: Agriculture
- Red: Urban