Analyzing Beach Acreage Collection Methodologies in Pool 7 of the Upper Mississippi River

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Abstract

The Upper Mississippi River contains a major commercial navigation channel maintained by the U.S. Army Corp of Engineers, and the 261 mile long Upper Mississippi River National Wildlife and Fish Refuge, managed by the U.S. Fish and Wildlife Service. National policy requires partnering agencies to complete an environmental assessment for beaches in each Pool. This analysis concentrates on beaches in Pool 7 of the Upper Mississippi River to analyze if there are significant differences in beach acreage when data collection methods differ. Comparisons were made with GPS data from different years, digitized aerial imagery data from different years, and finally by comparing the methodologies of data collection for each year. Descriptive statistics indicated differences in beach acreages; the Mann-Whitney Rank Sum test was employed to test for statistically significant differences. Results of the analysis indicate no significant differences occurred in beach acreage over time, or with different data collection methods.

Introduction

Background

The Upper Mississippi River (UMR) is as ecologically unique as it is politically governed. Several agencies at the state and federal level work in partnership on a 261 mile long section of the UMR, known as the Upper Mississippi River National Wildlife and Fish Refuge (Refuge). Refuge lands are owned by the United States Army Corp of Engineers (USACE), and the United States Fish and Wildlife Service (FWS). The FWS is responsible for managing the Refuge (Upper Mississippi River Wildlife and Fish Refuge Act of 1924). Spanning from Pool 4 at Wabasha, MN, into Pool 14, near Rock Island, IL, the Refuge consists of a variety of habitats including beaches. This study focuses on the beaches of Pool 7 on the UMR bordering the states of Wisconsin and Minnesota.

Within the Refuge is an intensely used commercial navigation channel maintained by the USACE. Channel maintenance, diking, and damming of the UMR has been occurring since the mid-1800s (Chen and Simons, 1986). In 1963, a Cooperative Agreement signed between the Department of the Army and the Department of the Interior provided guidelines for the agencies to work in partnership. The USACE maintains a nine foot deep navigation channel within the Refuge for commercial barge traffic by removing dredged material from the main channel and depositing it at other locations along the river (Department of the Army and Department of the Interior, 2001). Sediment deposition in the UMR dates

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back to the 1830s when Europeans settled the Mississippi River watershed (Engstrom, Almendinger, and Wolin, 2009). While the FWS manages refuge lands for wildlife habitat, the USACE has an obligation to find areas along the river where dredge material can be deposited from the main navigation channel. Changes in policy at both the state and national level led to policies guiding partnering agencies to manage beach habitat.

In the 1980s, the FWS and USACE produced a joint document known as the Land Use Allocation Plan that sought to balance and enhance fish and wildlife management, recreation management, and maintain channel navigation (USACE and USFWS, 2011). As a result, a beach management plan was developed by an On-Site Inspection Team consisting of members of the River Resources Forum's Recreation Work Group including representatives of the FWS, USACE, Minnesota Department of Natural Resources, and the Wisconsin Department of Natural Resources. The plan recommends management strategies aiding in maintenance or restoration of beach sites on the Refuge along the 9 foot navigation channel of the UMR USACE St. Paul District (U.S. Army Corps of Engineers and U.S. Fish and Wildlife Services [USACE and USFWS], 2011).

The Refuge Comprehensive Conservation Plan outlines specific uses determined to be compatible on the Refuge – including the recreational use of beaches. Areas used for dredge material deposition increase in popularity for their use as recreational beach locations (U.S. Fish and Wildlife Service, 2006). In 2016, the FWS is responsible for reevaluating beach uses to make sure they are still in compliance with the Refuge Comprehensive Conservation Plan.

An additional policy, the National Environmental Policy Act (NEPA), requires partnering agencies to perform an environmental assessment on all Refuge beaches where there has been project and recreational use on the Refuge (NEPA, 2000). The final environmental assessment will determine if an overall significant impact to wildlife or their habitat exists. If wildlife or beach habitats are significantly impacted, NEPA requires an Environmental Impact Statement to identify causes and severity of impacts on the Refuge. An environmental assessment resulting in a Finding of No Significant Impact would allow the FWS and USACE to continue managing beaches as they have, allowing project and recreational uses (NEPA, 2000).

Significance of Study

The Refuge is required to provide an environmental assessment on refuge beaches in the year 2016 to serve as a baseline for NEPA compliance (Yager, 2015). As a result, districts of the Refuge identified, mapped, and calculated the number of acres of beach in Pools 4 through Pool 8. Pools 9, 10, and 11 beach acreages were estimated for the environmental assessment with aerial imagery using Geographic Information System (GIS) due to a lack of time and funding.

Purpose

This study uses beaches identified by the Land Use Allocation Plan to analyze if beach acreage in Pool 7 changed from 2000 to 2013 as a result of data collection methodologies. Pool 7 beach data were chosen for analysis because it was the most recently completed beach data set. Data were originally collected using a handheld Global Positioning System (GPS) unit during the summer of 2013. If different methodologies used to collect beach acreage estimates are not significantly different, this analysis could be used to support estimating beach acreage for an environmental assessment. Performing an environmental assessment with GIS has been shown to save time, reduce overhead costs, and have the potential to address multiple habitat and species concerns (Gerrard, Stine, Church, and Gilpind, 2001).

As a result of estimating beach acreage of Pools 9, 10, and 11 with aerial imagery, an underlying question arose. Is there a statistically significant difference in beach acreage, when comparing data collection methodologies using GPS and digitizing aerial imagery? Exploring this question could provide the FWS and other agencies with enough information to either accept or decline beach acreage estimates using aerial imagery for Pools 9, 10, and 11. Providing an acceptable acreage estimation procedure for beaches could alleviate several difficulties for the FWS. Difficult situations vary from accessing beaches during high water, inclement weather, and lack of time, funding, and personnel (Inskeep, Wagner, and Buchanan, 2011).

Analysis Location

Pool 7 of the UMR is contained by Lock and Dam 6 near Trempealeau, Wisconsin on the upstream end; it is bound on the south by Lock and Dam 7 near Dresbach, Minnesota. Spanning 11.5 miles, Pool 7 extends from the south river mile 702.5 to the north river mile 714 (Figure 1).

Methods

Data Collection

Data retrieval for this analysis included obtaining the available Pool 7 GPS beach feature classes, which were available for the years 2000 and 2013 (USACE and USFWS, 2011) (Table 1). Aerial imagery for the 2013 analysis was obtained through the Natural Resource Conservation Services online database (U.S. Department of Agriculture, Natural Resources Conservation Service, 2015).

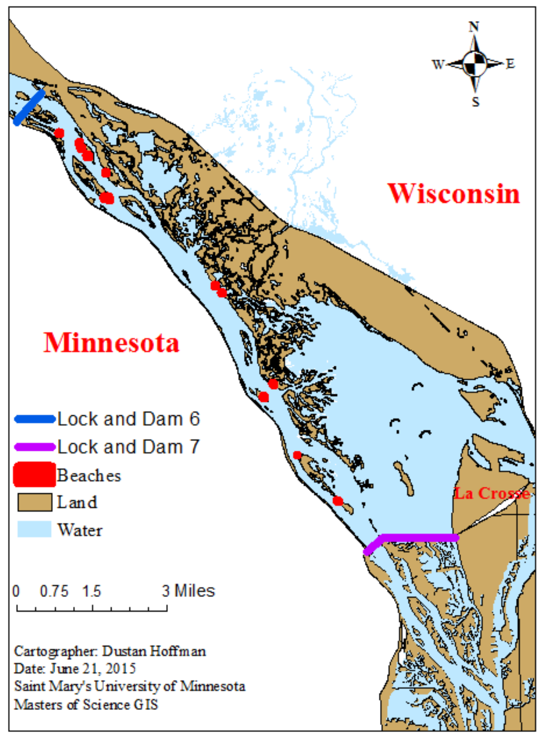

Figure 1. Analysis location, Pool 7 beaches of the Upper Mississippi River.

National Agriculture Imagery Program color aerial imagery was chosen due to its quality, availability, and use in published papers where land cover types have been successfully estimated (Davies, Peterson, Johnson, Davis, Madsen, Zvirzdin, and Bates, 2010). The 2000 aerial imagery used for the analysis was retrieved from the U.S. Geological Survey, Upper Midwest Environmental Sciences Center, Long Term Resource Monitoring Program (U.S. Geological Survey, 2000).

Table 1. This table provides metadata for the aerial imagery and GPS data used in the analysis.

Metadata	
GPS 2013	
Collection Unit	Garmin GPS 76
Signal Strength	Under 20 feet
Collection Date	August 16th, 22nd, 2013
Collector	U.S. Fish and Wildlife Service
GPS 2000	
Collection Unit	Unknown
Signal Strength	Unknown
Collection Date	More than one year
Collector	U.S. Fish and Wildlife Service
Aerial Imagery	
2013 Aerial Imagery	NAD_1983_UTM_Zone_15N
	Cell size (X,Y) 1, 1 meters
Source	United States Department of Agriculture
	Natural Resources Conservation Service
	National Agriculture Imagery Program (NAIP)
2000 Aerial Imagery	NAD_1927_UTM_Zone_15N
	Cell size (X,Y) 2, 2 meters
Source	U.S. Geological Survey
	U.S. GS Environmental Sciences Center (UMESC)
	Long Term Resource Monitoring Program (LTRMP)

Both aerial imagery data sets collected were examined using Esri's ArcCatalog to identify the collection date according to provided metadata. River stage levels were gathered for the collection dates of each aerial imagery data set and the two days the 2013 GPS data were collected (U.S. Army Corps of Engineers, 2015) (Figure 2). In addition, imagery was viewed in Esri's ArcMap to verify consistency in overlap and completeness of aerial coverage in the study area.

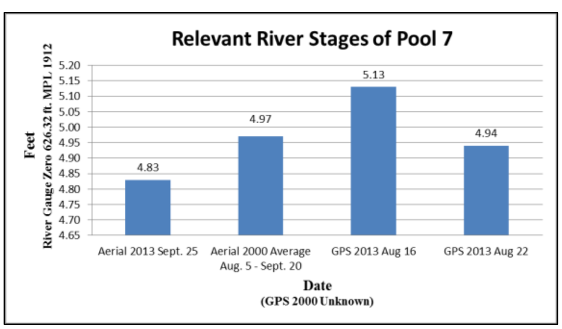

Figure 2. Available river stage levels for the aerial imagery data sets, and the 2013 GPS data. Dates for the 2000 GPS data were not available.

Data Construction

Analyzing beach acreage differences was accomplished with four different techniques. Since there were two GPS data sets available for different time periods, an analysis was completed to reveal change in beach acreage over time with GPS (Figures 3 and 4). Each of the GPS data sets were collected with the GPS unit using the coordinate system NAD 1983 UTM Zone 15N. Using aerial imagery

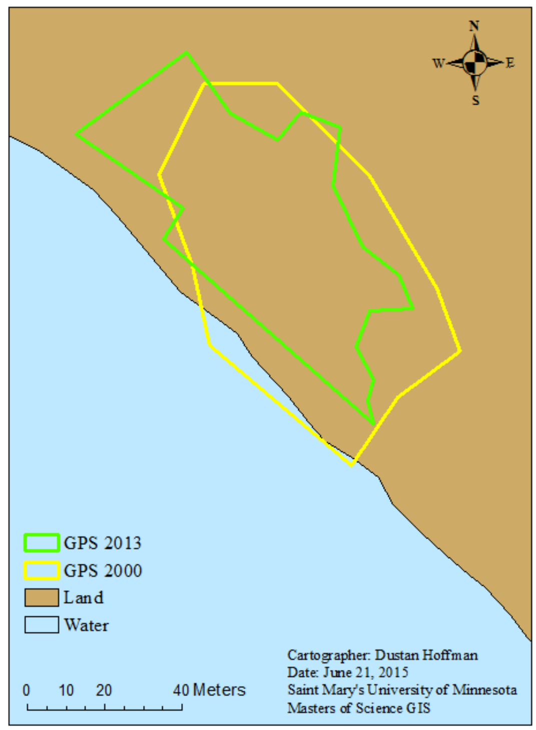

Figure 3. Depiction of the 2000 GPS and 2013 GPS beach data.

from the same set of years as the GPS data sets, a second analysis was completed to evaluate beach acreage differences over time with digitized polygons (Figures 5 and 6). Polygons digitized for the aerial imagery data were digitized on a scale of 1:500 meters – a scale consistent with Natural Resource Condition Assessments for the National Park Service (Stark, 2015).

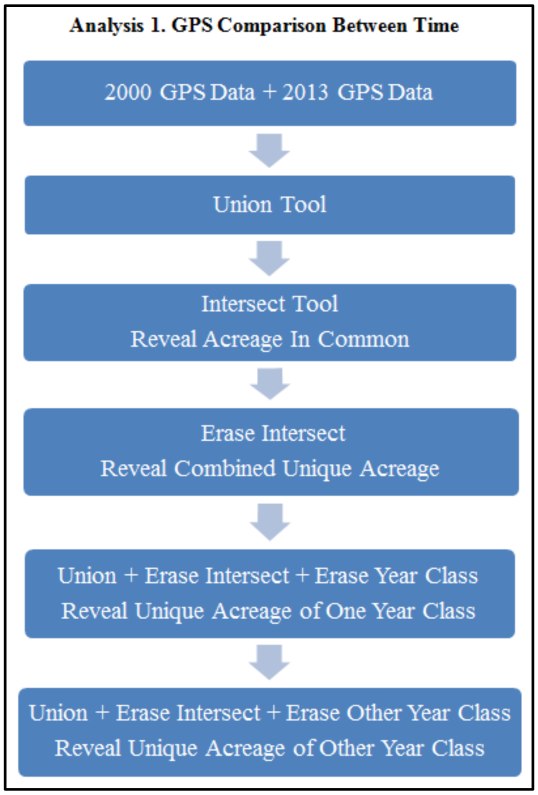

Figure 4. Methods used for GPS time analysis.

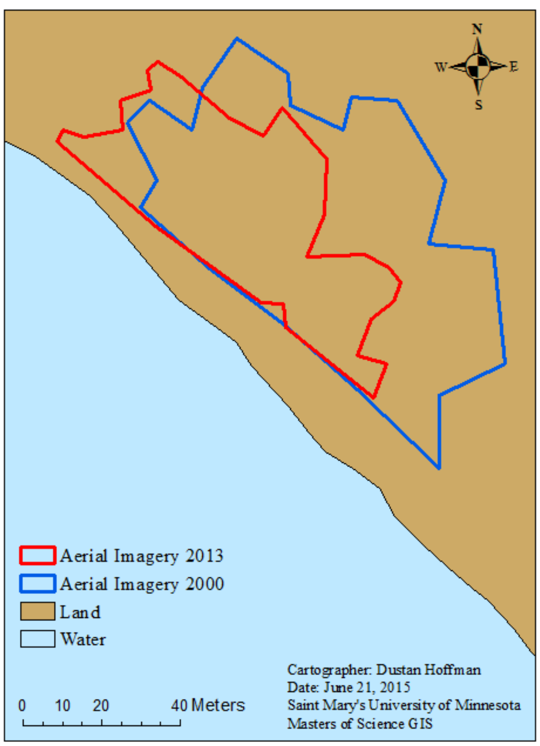

Figure 5. Map showing the digitized aerial imagery beach polygons, using the same projection as the 2000 aerial imagery.

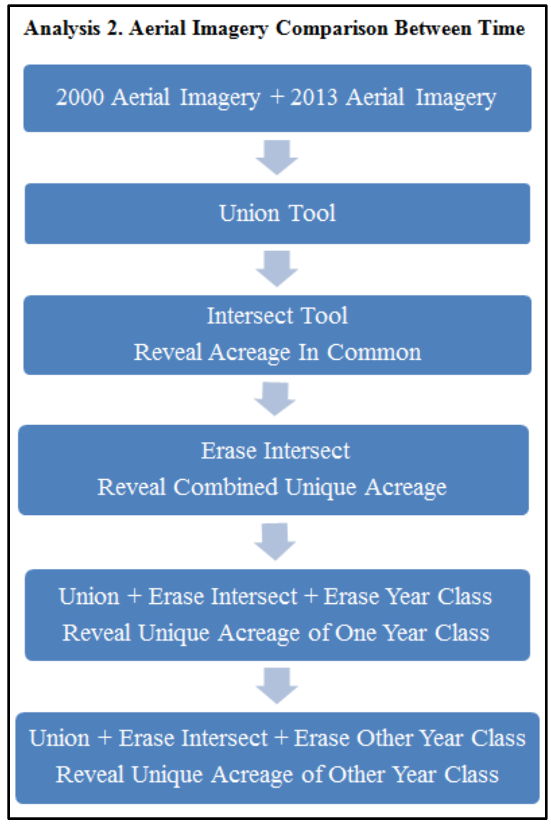

Figure 6. Methods for aerial imagery time analysis.

The third and fourth analyses used data created from digitizing beach polygons on aerial imagery data sets. Data from the 2000 GPS polygons and the 2000 aerial imagery polygons were used to analyze differences in beach acreage by methodologies conveyed in Figures 7 and 8. Similarly, the fourth analysis tested the 2013 GPS polygons and the 2013 aerial imagery digitized polygons for beach acreage differences (Figures 9 and 10).

Once analysis protocols were defined, data was verified using metadata and was overlaid in Esri's ArcMap to ensure areas were spatially consistent. By viewing the digital data, similarities and differences in beach acreage were revealed at face value. The Union tool was used to combine acreages for each analysis type (Figure 11). This was used to achieve accurate beach acreage totals. The Intersect tool was used to find the beach

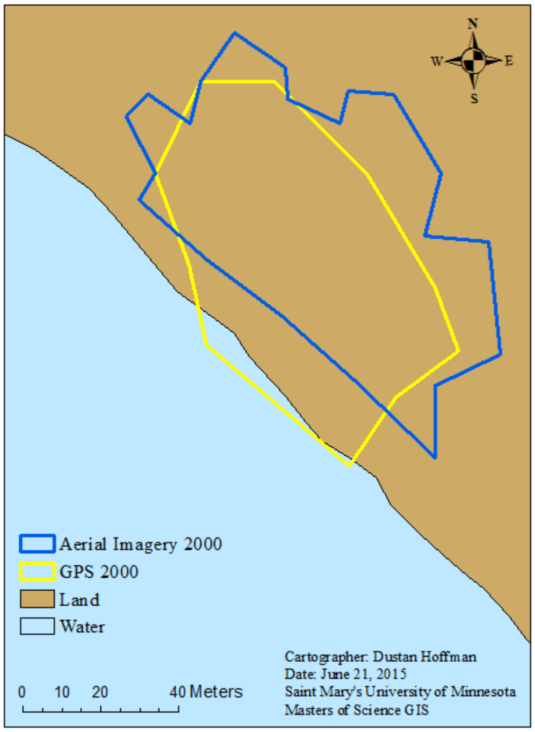

Figure 7. This map shows the 2000 GPS polygons, and the 2000 aerial imagery digitized polygons, which were used to look for significant differences in beach acreage by way of methodology.

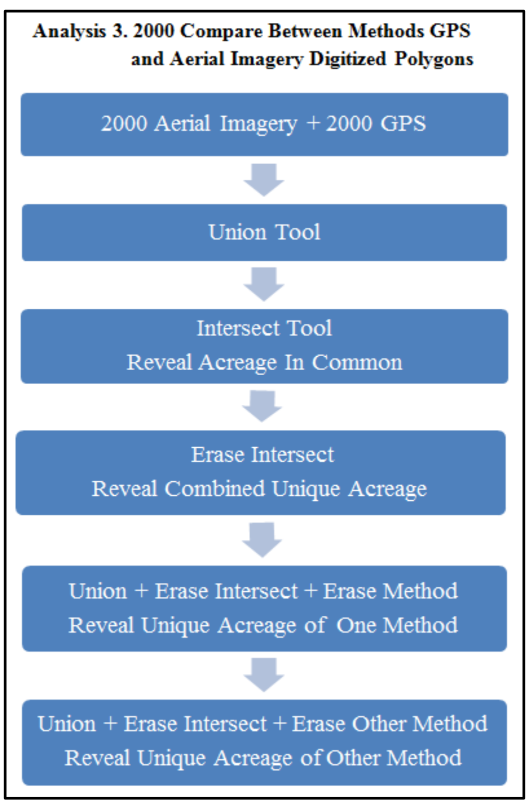

Figure 8. Steps to test the 2000 methodologies.

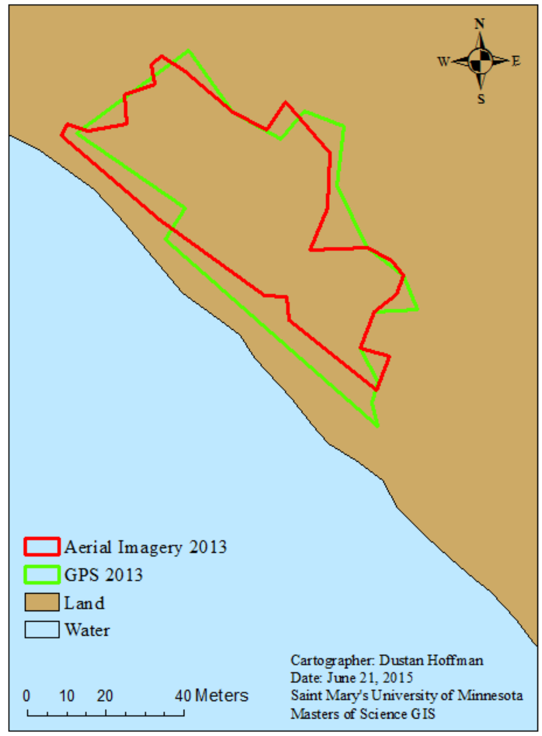

Figure 9. Map of the 2013 methodology analysis, comparing GPS data with aerial imagery data.

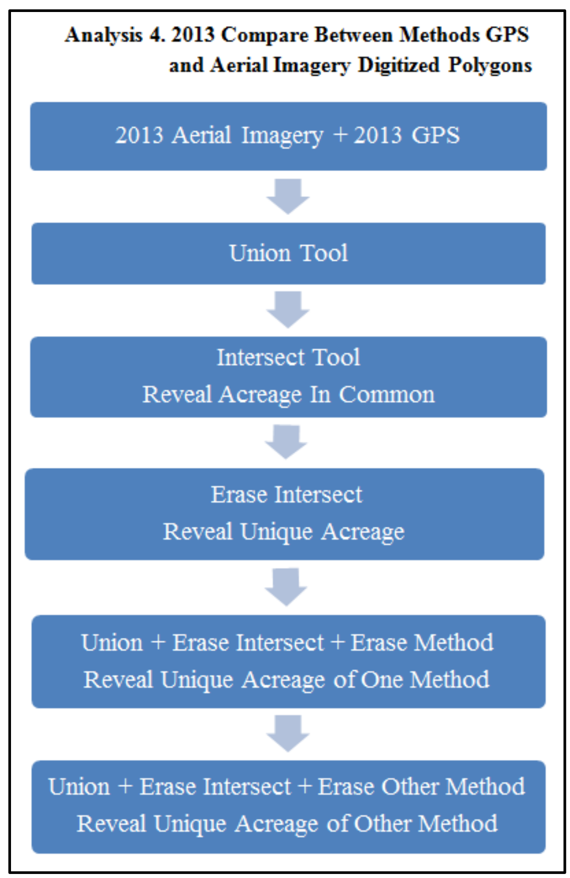

Figure 10. Steps to test the 2013 methodologies.

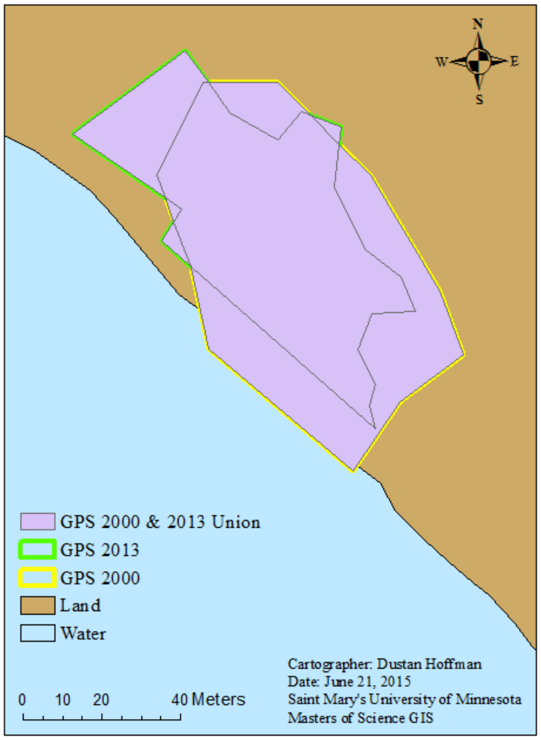

Figure 11. Map indicating the beach acreage when the Union tool was applied.

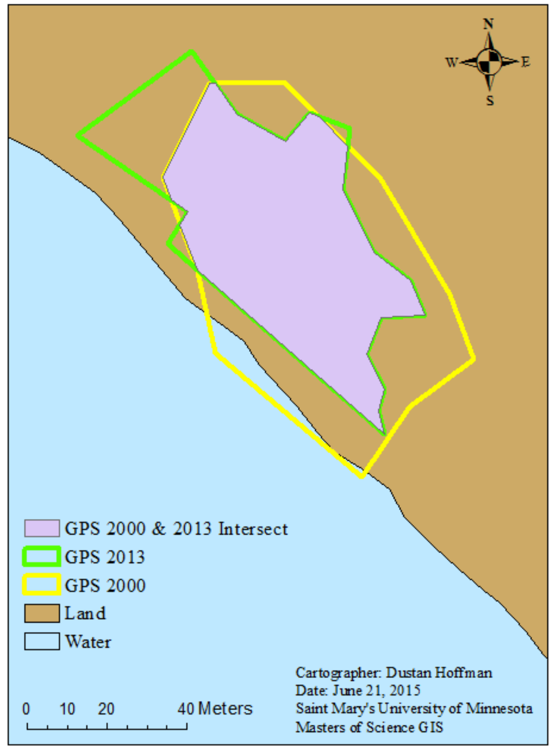

Figure 12. A map revealing the beach acreage in common from using the Intersect tool.

acreage in common between the different data types in each analysis (Figure 12). In order to isolate the amount of beach acreage unique to each data type, the Union, Intersect, and Erase tools had to be used in sequence. Erasing the intersecting acreage revealed the unique acreage of both data types (Figure 13). Identifying unique acreages was helpful in analyzing data to determine if high or low river levels were a potential cause of difference. The Erase tool was used in two additional steps to identify the amount of beach acreage unique to data types for each analysis (Figures 14 and 15). Each new feature class had to have the ACRES field in the Attribute table recalculated with Python code (Stack Exchange, 2015) (Figure 16). Using the Merge tool in ArcMap, each of the data feature classes were loaded into a single feature class (Figure 17) and corresponding attributes were summed for evaluation.

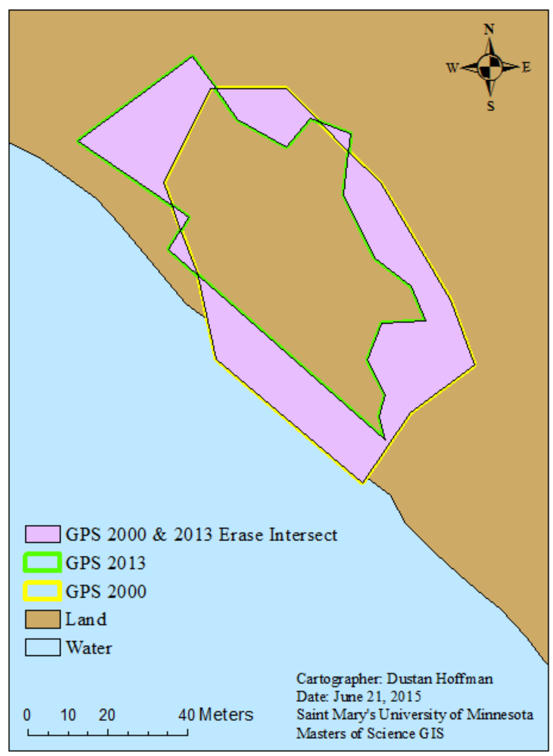

Figure 13. Beach acreage unique to both data types, found by erasing the intersecting acreage.

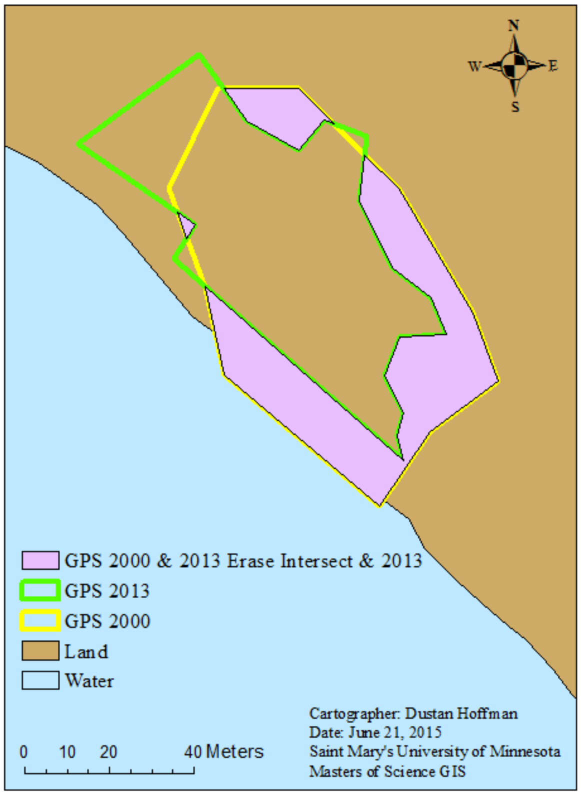

Figure 14. Using the Erase tool to identify the acreage unique to one data type.

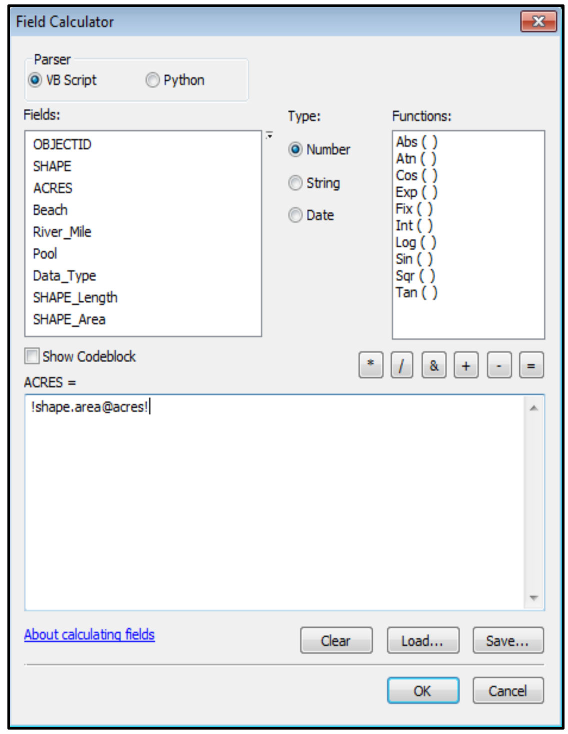

Figure 16. Python code was used to recalculate the beach acreage in the ACRES field of the Attribute table. A total of twenty new feature classes had their acres recalculated.

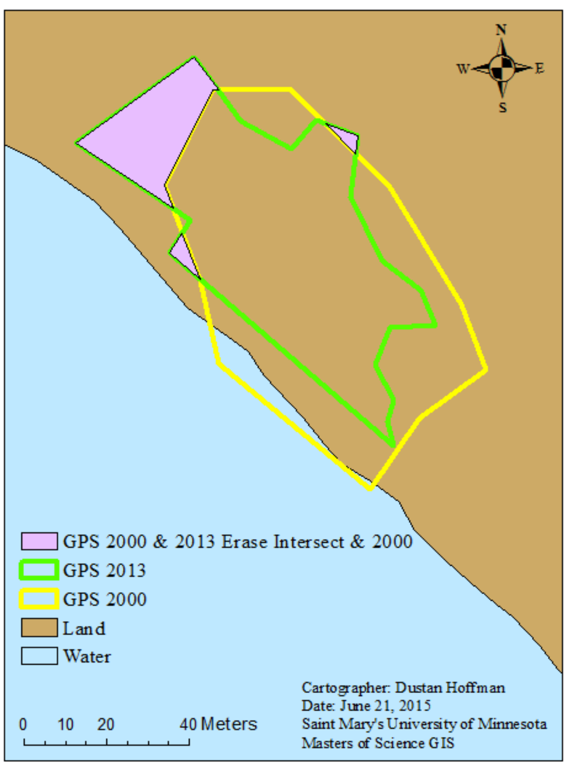

Figure 15. A map showing the Erase tool used to identify the acreage unique to one data type.

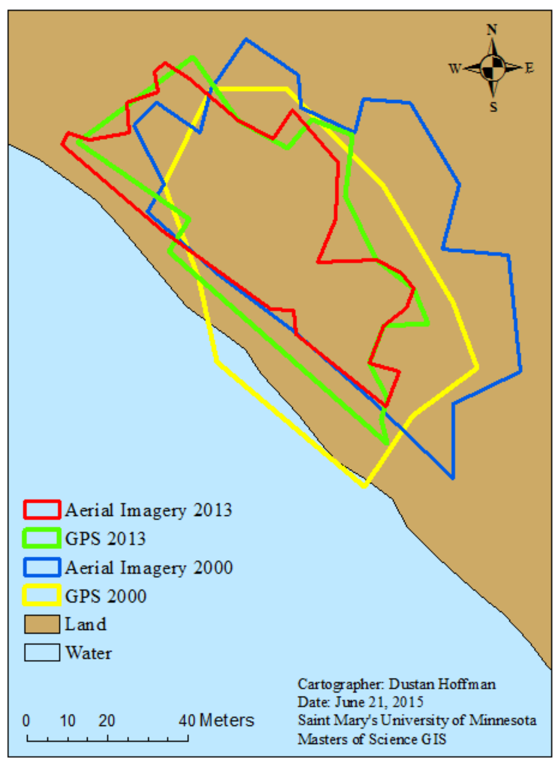

Figure 17. A map showing the polygons of the GPS and aerial imagery data types shown together.

Statistical analyses were first attempted using a parametric un-paired t-test, as a parametric test is more commonly preferred in statistical analyses over a non-parametric test (Dytham, 2011). A t-test was chosen based on its use to identify statistically significant differences between two data sets. With the failure of a normality test, a parametric t-test could not be used for the rest of the analysis. SigmaPlot 12 automatically gave the option of using a non-parametric test when t-test parameters failed. The Mann-Whitney Rank Sum test was used to analyze if there was a significant difference in the beach acreage between time and methodology. Mann-Whitney Rank Sum test has the capability of providing results based on means, and has been referred to as the non-parametric version of the t-test (Dytham, 2011).

Results

Results for this analysis were compiled using attribute table information, Microsoft Excel Pivot tables and graphs, and SigmaPlot 12. Descriptive statistics were compiled using an Excel Pivot table revealing the common number of beaches for each data type, the sum and mean of acres, and the variance and standard deviation for data types (Table 2). Beach

Table 2. Descriptive statistics for beach data.

	Aerial 2000	Aerial 2013	GPS 2000	GPS 2013
Count of Beach	14	14	14	14
Sum of Acres	6.67	4.28	7.62	4.41
Average of Acres	0.48	0.31	0.54	0.32
Std. Dev. of Acres	0.63	0.46	0.72	0.4
Variance of Acres	0.4	0.21	0.51	0.16
Minimum of Acres	0.01	0.01	0.08	0.04
Maximum of Acres	2.37	1.75	2.82	1.54

acreage sums were graphed resulting in a high acreage for the 2000 GPS data of 7.62 acres, and the lowest acreage of 4.28 acres for the 2013 aerial imagery data type (Figure 18). Neither of the methodologies used to gather beach acreage were responsible for both the two highest or two lowest acreages. The statistical software package SigmaPlot 12 was used to run a Shapiro-Wilk normality test, where all four data type beach acreages failed to show normal distribution, only having fourteen samples each (Table 3). The requirements for a Shapiro-Wilk normality test, and several other normality tests are that the sample size exceeds 50 samples (Systat Software, 2010).

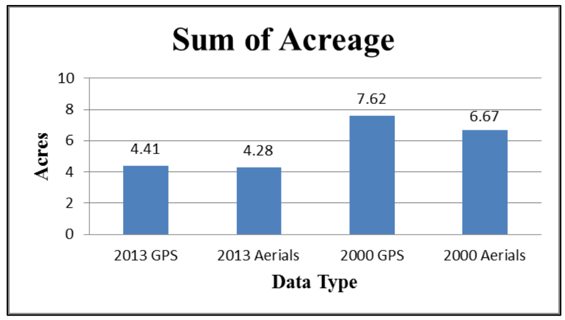

Figure 18. A graph showing the sum of beach acreage for each analyses data type.

Table 3. Table indicating each data type failed the Shapiro-Wilk normality test for the t-test, which resulted in using a non-parametric test.

Normality Test (Shapiro-Wilk)

Aerial_2000:	W-Statistic = 0.656	P < 0.001	Failed
Aerial_2013:	W-Statistic = 0.598	P < 0.001	Failed
GPS_2000:	W-Statistic = 0.623	P < 0.001	Failed
GPS_2013:	W-Statistic = 0.646	P < 0.001	Failed

A test that fails indicates that the data varies significantly from the pattern expected if the data was drawn from a population with a normal distribution.

A test that passes indicates that the data matches the pattern expected if the data was drawn from a population with a normal distribution.

Comparative Analysis

An analysis was completed to test if there was a significant difference in beach acreage between the 2000 GPS data and the 2013 GPS data (Figures 19 and 20). With a P-value of 0.14, the Mann-Whitney Rank Sum test found there was not a significant difference in beach acreage. A difference of 3.21 acres existed between the two GPS data sets. Similarly, an analysis compared the beach acreages of the digitized aerial imagery polygons from the 2000 and 2013 aerial imagery data sets. Beach acreage for the 2000 aerial imagery totaled 6.67 acres, while the 2013 aerial imagery totaled 4.28 acres. The Mann-Whitney Rank Sum test showed there was not a significant difference in beach acreage, with a P-value of 0.12 (Figure 21 and 22).

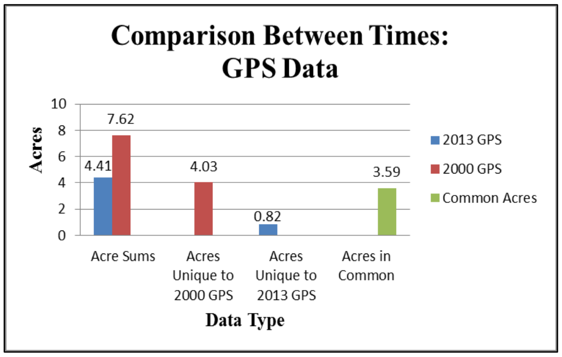

Figure 19. A graphical representation of the differences in beach acreage for the 2000 and 2013 GPS data types.

T-test (parametric)
Normality Test (Shapiro-Wilk) Failed ($P < 0.050$)
Test execution ended by user request, Rank Sum Test begun

Mann-Whitney Rank Sum Test (non-parametric)

Group	N	Missing	Median	25%	75%
GPS_2000	14	0	0.274	0.156	0.639
GPS_2013	14	0	0.170	0.0950	0.327

Mann-Whitney U Statistic= 65.000

T = 236.000 n (small) = 14 n (big) = 14 (P = 0.135)

The difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.135).

Figure 20. Test results indicating the 2000 GPS and 2013 GPS data did not have a statistically significant difference in beach acreage.

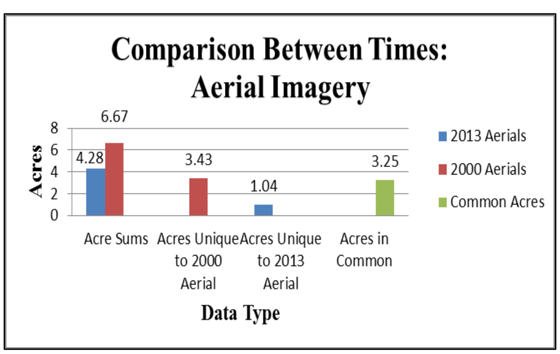

Figure 21. The differences in beach acreage for the 2000 and 2013 digitized aerial imagery data types.

T-test (parametric)
Normality Test (Shapiro-Wilk) Failed ($P < 0.050$)
Test execution ended by user request, Rank Sum Test begun

Mann-Whitney Rank Sum Test (non-parametric)

Group	N	Missing	Median	25%	75%
Aerial_2000	14	0	0.208	0.162	0.619
Aerial_2013	14	0	0.123	0.0893	0.306

Mann-Whitney U Statistic= 64.000

T = 237.000 n (small) = 14 n (big) = 14 (P = 0.124)

The difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.124).

Figure 22. Test results indicating the 2000 and 2013 digitized aerial imagery beach polygons did not have a statistically significant difference in beach acreage, with the Mann-Whitney test.

A comparison of methodologies used to gather data was completed comparing the beach acreages of the GPS data, and the beach acreages of the aerial imagery, for the years 2000 and 2013. Results of the Mann-Whitney Rank Sum test indicated no significant difference in beach acreage when methods of collecting differed. The 2000 methodology test scored a P-value of 0.73, while acreage sums were 7.62 acres for the GPS data, and 6.67 acres for the aerial data (Figures 23 and 24). Acreage sums of the 2013 methodology test were least in difference, with only 0.13 acres of beach acreage. A P-value of 0.60 showed there was no statistical difference in beach acreage (Figure 25 and 26).

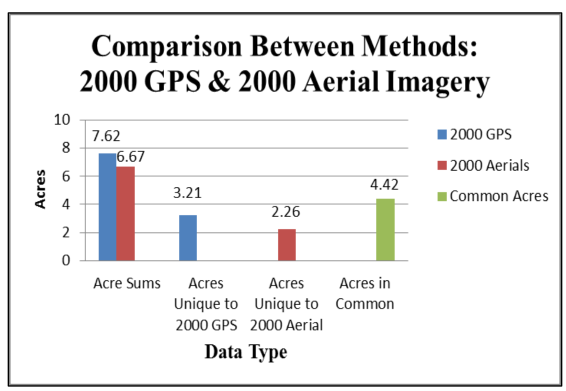

Figure 23. A graph showing the differences in beach acreage for the 2000 GPS and 2000 digitized aerial imagery data types.

T-test (parametric)
Normality Test (Shapiro-Wilk) Failed ($P < 0.050$)
Test execution ended by user request, Rank Sum Test begun

Mann-Whitney Rank Sum Test (non-parametric)

Group	N	Missing	Median	25%	75%
Aerial_2000	14	0	0.208	0.162	0.619
GPS_2000	14	0	0.274	0.156	0.639

Mann-Whitney U Statistic= 90.000
T = 195.000 n (small) = 14 n (big) = 14 (P = 0.730)

The difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.730).

Figure 24. Table indicating that there was not a significant difference in beach acreage when data collection methods differed for the 2000 data types.

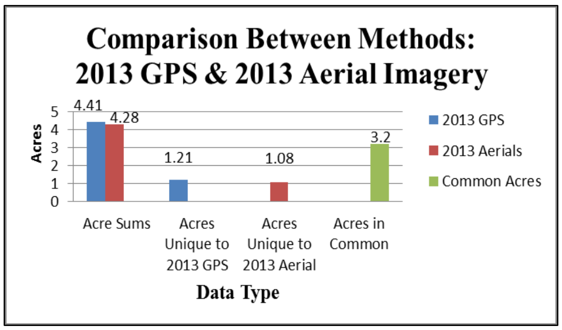

Figure 25. Comparison of beach acres for the 2013 GPS and 2013 digitized aerial imagery data types.

T-test (parametric)
Normality Test (Shapiro-Wilk) Failed ($P < 0.050$)
Test execution ended by user request, Rank Sum Test begun

Mann-Whitney Rank Sum Test (non-parametric)

Group	N	Missing	Median	25%	75%
Aerial_2013	14	0	0.123	0.0893	0.306
GPS_2013	14	0	0.170	0.0950	0.327

Mann-Whitney U Statistic= 86.000

T = 191.000 n (small) = 14 n (big) = 14 (P = 0.597)

The difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.597).

Figure 26. Mann-Whitney Rank Sum test results showing there was a significant difference in beach acreage between the 2013 GPS and 2013 data sets.

Graphs were developed to visually show differences and similarities of beach acreage for each of the four analyses (Figures 27 and 28). The difference from highest acreage in common to lowest acreage in common was 1.22 acres for the four analyses. Figure 28 shows the most and the least amount of unique acreage were both found in the comparison of time with the GPS methodology. An additional graph was developed to give the percent difference for all four beach acreage comparisons (Figure 29). The percent difference on the low end was 2.99% in the 2013 methodology test, while the comparison of the GPS data over time was highest at 53.36%.

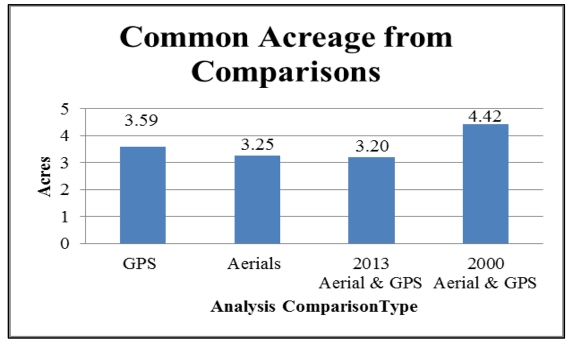

Figure 27. Acres in common found using the Intersect tool in four different analyses.

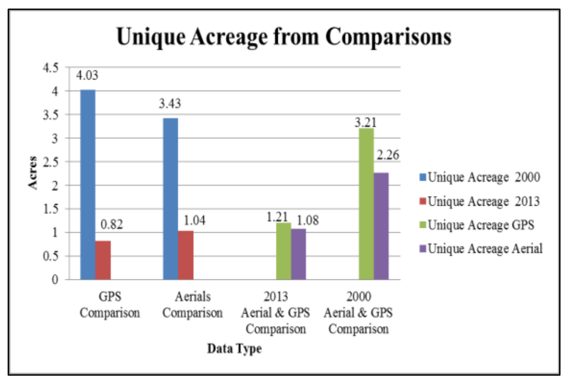

Figure 28. Graph showing amount of acreage unique to each data type in comparison.

Results of the analysis indicate that with the Mann-Whitney Rank Sum test, there are no statistically significant differences in beach acreages over time, or with the methods of data collection. Based on these explorations, the FWS may consider using this analysis to justify using aerial imagery to estimate beach acreages of Pools 9, 10, and 11 for the environmental assessment.

Discussion

Incomplete metadata missing from the 2000 GPS data could have been used to help identify possible trends in higher or lower river levels with differences in beach acreage. Data in Figure 29 shows the methodology test for 2013 having the lowest percent difference in beach acreage. A possibility that the percent difference is 10% less than the 2000 methodology test could be due to improvements in technology, accuracy with GPS units, and aerial imagery quality. Data from the analysis over time with the GPS data shows the highest percent difference in acreage sums at 53.36% (Figure 29).

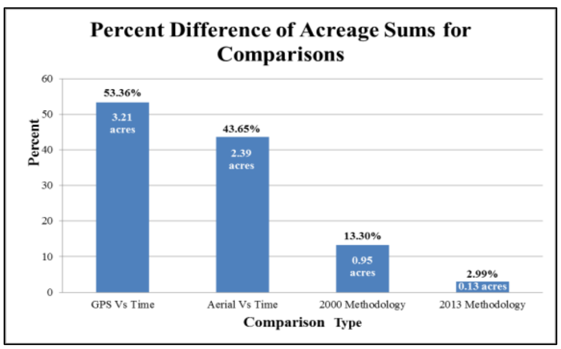

Figure 29. Graph showing the percent difference in acreage sums for data types tested in the four different analyses.

Data Limitations

Some of the reasons for this high percent difference could be due to GPS unit accuracy, or GPS users having different opinions about what they considered beach while collecting data. Comparing aerial imagery over time, such as this analysis has, can have indeterminate results considering unmeasurable data, undetectable error, and sources of technical error. Aerial imagery has been known to have error due to orthorectification, co-registration, and spatial error propagation (Hughes, McDowell, and Marcus, 2006).

Errors of orthorectification are less likely to occur in a large-scale river system such as the UMR, because of the occurrence of flood events tapering the landscape. Errors of co-registration have the potential to skew results in this analysis due to potential inaccuracies with the aerial imagery. Aerial imagery used to research later channel movement has been georectified with consistencies of five meters (Hughes *et al.*, 2006). Spatial error propagation is known to occur more frequently when imagery is comprised of larger pixel size, and when vegetation covers the landscape (Arbia, Griffith, and Haining, 2003). This analysis used aerial imagery with pixel sizes of 1x1 meters for the 2013 aerial imagery, and 2x2 meter pixels for the 2000 aerial imagery. Differences for the aerial imagery comparison in Figure 29 reveal a difference of 43.65% difference of acreage over time. Spatial error may be one reason for the differences in aerial imagery due to pixel size differences.

References

Chen, Y.H., and Simons, D.B. 1986. Hydrology, Hydraulics, and Geomorphology of the Upper Mississippi River System. *Hydrobiologia*, *136*, 5-20. Retrieved April 28, 2015 from http://link.springer.com/article/10.1007%2FBF00051500.

Davies, K., Peterson, S., Johnson, D., Davis, D., Madsen, D., Zvirzdin, D., and Bates, J. 2010. Estimating Juniper Cover From National Agriculture Imagery Program, Imagery and Evaluating Relationships Between Potential Cover and Environmental Variables. *Rangeland Ecology and Management*

*(63)*6, 631-634. Retrieved July 14, 2015 fromhttp://oregonstate.edu/dept/eoarc/sites/default/files/673.pdf.

Department of the Army Corps of Engineers and the Department of the Interior, U.S. Fish and Wildlife Service, 1963, 2001. Amended Cooperative Agreement. Retrieved March 12, 2015 from http://www.mvr.usace.army.mil /Portals/48/docs/Recreation/ODM/pdf/CoopAgreementAmendmentFull.pdf.

Dytham, C. 2011. *Choosing and using statistics; a biologists guide* (3rd ed). Wiley-Blackwell. West Sussex, UK.

Engstrom, D.R., Almendinger, J.E., and Wolin, J.A. 2009. Historical Changes in Sediment and Phosphorus Loading to the Upper Mississippi River: Mass-balance Reconstructions from the Sediments of Lake Pepin. *Journal of Paleolimnology*, 4, 563-588. Retrieved May 2, 2015 from ftp://brrcrftp.cr.usgs.gov/pub/sstackpoole/Engstrom_2009_MISS_JOPL.pdf.

Gerrard, R., Stine, P., Church R., and Gilpind, M. 2001. Habitat Evaluation Using GIS; A Case Study Applied to the San Joaquin Kit Fox. *Landscape and Urban Planning*, 52, 239-255. Retrieved April 15, 2015 from http://eurekamag .com/pdf/010/010733012.pdf.

Hughes, M.L., McDowell, P., and Marcus, W.A. 2006. Accuracy Assessment of Georectified Aerial Photographs, Implications for Measuring Lateral Channel Movement in a GIS. *Geomorphology*, 76, 1-16. Retrieved July 13, 2015 from http://www.geog .uoregon.edu/envchange/reprints/pdfs/Hughes-et-al_2006_Geomorphology.pdf

Inskeep, D., Wagner, A., and Buchanan, B. 2011. Estimating Canopy Cover Using Aerial Photography for a Mixed Conifer Zone, Northern, New Mexico. Paper Presented at the National Meeting of the American Society of Mining and Reclamation, Bismarck, ND, June 12-16, 2011. Retrieved July 13, 2015 from http://www.asmr.us/Publications/Conference%20Proceedings/2011/0306-Inskeep-NM.pdf.

Stack Exchange. 2015. Python code for calculating acreage. Retrieved April 19, 2015 from http://gis.stackexchange .com/questions/102180/calculating-acreage-using-arcgis-field-calculator.

Stark, K. 2015. Verbal Consultation. Saint Mary’s University of Minnesota, GeoSpatial Services. June 5, 2015.

Systat Software. 2010. SigmaPlot 12 User’s Guide. Systat Software Inc. 2010

Upper Mississippi River National Wildlife and Fish Refuge Act of 1924. Retrieved March 12, 2015 from http://uscode .house.gov/view.xhtml?path=/prelim@title16/chapter8&edition=prelim.

U.S. Army Corps of Engineers and U.S. Fish and Wildlife Services [USACE and USFWS]. 2011. Upper Mississippi River Land Use Allocation Plan. Retrieved March 12, 2015 from http://www .mvp.usace.army.mil/Portals/57/docs/Recreation/UpperMissLandUse/UMRL_Allocation_Plan.pdf.

U.S. Army Corps of Engineers. 2015. River Gages.com, Water Levels of Rivers and Lakes. Retrieved April 27, 2015 from http://rivergages.mvr.usace .army.mil/WaterControl/new/layout.cfm.

NEPA. 2000. United States. Congress. National Environmental Policy Act (NEPA). Congressional Bill. Washington, DC: Service, 2000. Retrieved March 12, 2015 from http://www.epw .senate.gov/nepa69.pdf.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2015. Retrieved April 2015 from https://gdg.sc.egov.usda.gov/.

U.S. Fish and Wildlife Service. 2006. Upper Mississippi River National Wildlife and Fish Refuge, Comprehensive Conservation Plan. Retrieved March 12, 2015 from

http://www.fws.gov/midwest/planning/uppermiss/.
U.S. Geological Survey. 2000. Upper Midwest Environmental Sciences Center, Long Term Resource Monitoring Program. Land Cover Upper Mississippi River 2000. Retrieved June 15, 2015 from http://www.umesc.usgs.gov/resource_mapping_team.html.
Yager, T. 2015. Verbal Consultation. U.S. Fish and Wildlife Service. August 8, 2015.