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An Accuracy and Agreement Assessment for Midwest Wetlands: An Example using the St. Mary's University NWI Update for Iowa

Midwest Wetlands Assessment and Advanced Wetlands Mapping Support for US Fish and Wildlife Service (US FWS) Region 3 Ecological Services

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I. Introduction and History - Project description

Evolution of the present National Wetlands Inventory (NWI) program began in the 1970s. Originally based upon human interpretation of high altitude aerial photographs at scales of 1:130,000 to 1:62,500, producing acetate overlays attached to those photographs, the program now utilizes advanced, computer-based GIS techniques. Initial expectations that the inventory would be completed in a few years were quickly outgrown, as it soon became apparent that such a national mapping program would be unable to maintain a complete, and accurate, inventory of the wetland resources of the United States.

The Emergency Wetlands Resources Act of 1986 (P.L. 99-645, as amended) essentially converted the modest program begun within the U.S. Fish and Wildlife Service (FWS) to a mandated program requiring the Secretary of the Interior, through the FWS, to produce and distribute digital maps of wetlands of the United States. The classification system developed for the FWS effort (Cowardin, et al., 1979) was adopted as the official Federal wetland classification standard by the Federal Geographic Data Committee (FGDC) in July 1996. Evolution continued as the NWI progressed and gradually became part of an emerging climate change debate. This long-term interest in wetlands is well summarized in the following quotation:

> *Due, in part, to their limited capacity for adaptation, wetlands are considered to be among the ecosystems most vulnerable to climate change.*
>
> (Bates et al., 2008)

This vulnerability to climate change makes frequent mapping of wetlands important to understanding our changing landscape. Because wetlands extend across watersheds, the importance of one seamless standard instead of multiple, inconsistent pieces, should be clear.

When, in 2009, the FGDC adopted mapping techniques developed for the NWI as the Federal Mapping Standard, the majority of the existing NWI data sets had been prepared without such guidelines. Currently, the NWI is a mosaic of the best available data based on *Classification of Wetlands and Deepwater Habitats of the United States* (Cowardin, et al., 1979), often referred to as the Cowardin Classification System. Frequent reductions in funding of the NWI within the FWS resulted in many of the data sets being compiled with external funding. Most of the current, updated datasets are funded or produced by other organizations, including state, tribal, and local governments, private companies (e.g., BP Pipelines), and non-governmental organizations (e.g., Ducks Unlimited).

The earliest and largest partner to fund a statewide NWI update was the State of Iowa. Under the leadership of Todd Bishop and Chris Ensminger, the Iowa Department of Natural Resources (IaDNR), recognized the need for an updated and improved NWI to support its conservation activities, including wetland and habitat restoration. Much of the original NWI for Iowa was nearly 20 years old and out-of-date due to development and agricultural impacts. The project began in 2002 with an original goal to complete the NWI update in about five years with the FWS Region 3 committed to paying 50% of the mapping cost. Reduced budgets made this goal impossible to achieve and delayed completion of the project.

The IaDNR recognized that they would need spring, leaf-off, aerial imagery for an effective update of the NWI. This was flown in 2002, at a nominal scale of 1:40,000, using color-IR film. St. Mary's University of Minnesota was awarded a contract by the Iowa DNR and the work began in 2003 under the direction of Barry Drazkowski and Andy Robertson. In the words of Andy Robertson from St. Mary's University of Minnesota from a May 6, 2012 email to the authors:

> "The first thing to understand is that this was an 'update' project as opposed to a re-mapping project (even though it really became a remap as the project progressed). As a result, our starting point for wetland delineation was the original NWI mapping (circa 1979/80) and a key assumption was that the original data was 'correct', even if a signature could not be detected on project imagery (2002 Iowa Statewide 1:40,000 CIR). In the vast majority of cases the original NWI polygons were reshaped, refined and reclassified based on the new imagery, however, there are polygons in the updated dataset that are from the original NWI and were not changed because no signature could be seen on the project imagery."
>
> "Secondly, we prepared a document that defined the updating standards for this project and presented it to both the US FWS and the IaDNR for approval following the completion of large pilot project in which the delineation and classification methods were refined. …. Collateral data sources that were used on the project to validate wetland calls included: soils (SSURGO, STASGO and local soil surveys); 1:24,000 DRG for topography, spot elevations and hydrology; 1992 USGS DOQQ imagery; and original NWI."
>
> "Third, the objectives of the Iowa DNR and the USFWS for this project were somewhat different. The DNR was interested in a complete NWI update for the state, however, they were also interested in identifying restorable wetland opportunities through the capture of farmed wetland polygons that were visible on the project imagery. These wetlands were identified in a variety of ways including wet soil signatures, location within a wetland drainage pattern, evidence of soil drainage (e.g. tiling or ditching), and/or presence of adjacent wetlands or wetland characteristics. These polygons were classified with different codes as the project progressed, however, the most common were Pf, PEMJf, PEMAf, nd PEMCf. Many of the polygons were also labeled with the little 'd' or partially drained modifier."
>
> "In addition to the farmed wetlands, the IaDNR was also interested in using the linear wetlands from the NWI update as input for the creation of a surface hydrology layer for the state. Since this layer was intended to become part of the development of NHD for Iowa, it was important to capture linears to a fine level of detail and to enforce connectivity across the landscape. This secondary

> purpose guided the development of some of the decisions rules that were used for capturing linear wetlands and also was an important consideration for the image interpreters."
>
> “Finally, it is important to note that this project predates the implementation of the new FGDC Federal Wetland Mapping standard and it was never intended to be assessed against that standard. Further, while there was opportunity to visit the field as part of a pre-mapping assessment of wetland signature/classes, there was insufficient funding in the budget to conduct any post mapping field review.“

As it is written in the title, this is an Accuracy AND Agreement report. Since wetland mapping involves human interpretation of aerial photography, it is very difficult to exactly match the training and methodologies over a multi-year span. The term ‘agreement’ is used to describe a process based on similar approaches which provides a level of comparison to the eventual outcome.

Additional significant points about the National Wetlands Inventory and this report that the authors considered were:

1) Users were and continue to demand updated ‘current’ NWI maps. Twenty to thirty year old NWI maps were not as useful anymore. Around 2002, the first large area (Southern Michigan) NWI map update in the Midwest region was started using a ‘heads-up’ process where original NWI polygons were digitally overlaid on orthophotography in a GIS workstation. Ideally, if funding was not an issue, digital photogrammetric workstations with multi-seasonal aerial imagery would have been employed but this approach would have cost significantly more compared to the ‘heads-up’ approach.
2) Widely available aerial photography from digital cameras did not begin until after 2004 with the USDA National Agriculture Imagery Program (NAIP).
3) NWI used to rely on USGS/USDA National High Altitude Program (NHAP) and National Aerial Photography Program (NAPP) aerial photo programs for leaf-off imagery which is more useful for wetland mapping. When NHAP and NAPP programs were discontinued in the 1990s, that left the NWI program without an optimal imagery source as well as funding to acquire its own imagery. NAIP imagery is taken in the middle of the summer and not as useful as compared to spring leaf off imagery.
4) FGDC did not adopt the NWI polygonal wetland standard until 2009. Even though the FGDC standard is referred to throughout this report, keep in mind this project was started years before the adoption of the standard. And as you will see, the FGDC accuracy standards still need to be refined since they are not achievable in many respects.
5) Farmed wetlands data from other federal agencies have limited availability. In many cases across the country, delineated farmed wetlands exist only as penciled dots on an enlarged aerial photography. USDA has the responsibility of monitoring farmed wetlands but is sensitive to access to individual farm data.

6) With the move from analog to digital imagery and mapping, it became apparent that one could zoom down to the resolution of the imagery and delineate polygon features such as streams instead of delineating them as linear features based on the width of a marking pen on an aerial photograph. The NWI program pushed for using more polygon delineations instead of lines to better represent wetlands starting in 2003.

a. Classification System

Of the five Wetland Systems defined in the Cowardin Classification System, only three are present in Iowa. Within these three major divisions, sub-division continues through Sub-system, Class, and Sub-class with some special modifiers.

Riverine Systems are divided into five Sub-systems, each further divided into eight Classes, many with multiple Sub-classes.

1. Tidal (not found in Iowa)
2. Lower Perennial
3. Upper Perennial
4. Intermittent
5. Unknown Perennial

Lacustrine Systems are divided into two Sub-systems, with four and seven Classes, respectively. Most of these Classes are further sub-divided into as many as six Sub-classes.

Palustrine Systems have no sub-systems, but nine Classes, each with multiple Sub-classes.

It is not necessary to define the entire classification system, here, but its complexity presented special challenges in assessing the accuracy of the work completed by St. Mary's University.

b. Standard Sizes

Features of at least 0.5 hectares in size and at least 10 meters wide, except for acute corners, were to be shown as polygons. Narrower features were to be shown as linear features, to the upper limit of channelized flow and were to be captured to a fine level of detail with enforced connectivity across the landscape.

c. Accuracy Assessment

Accuracy assessment was to be limited to the Class level of the Cowardin System, and focused primarily on wetland area (i.e., polygons rather than linear features). The Class level of the Cowardin System includes thirty possible classes, but only seven classes if confined to the System/Sub-system level.

Even though this project was begun prior to implementation of the Federal Geographic Data Committee Wetlands Mapping Standards distributed in 2009, mention of those standards is pertinent to the current study because they mandate accuracy levels more stringent than those applied to this project. FGDC Wetlands Mapping Standards (2009) state:

"The minimum standard for the completeness of the wetland classification system …. Is: ecological system, subsystem (with the exception of Palustrine), class, subclass (only required for forested, scrub-shrub, and emergent classes), water regime, and special modifiers (only required where applicable)," and classification accuracy of the final map product should be measured by Target Mapping Unit (TMU) and Producer's Accuracy (PA) metrics.

Target Mapping Unit

"The Target Mapping Unit (TMU) is an estimate of the size class of the smallest wetland that can be consistently mapped and classified . . . Wetlands which appear long and narrow (less than 15 feet wide at a scale of 1:12,000), such as those following drainage-ways and stream corridors, are excluded from consideration when establishing the TMU."

Recognizing limitations imposed by imagery with a ground resolution of one meter, we were instructed to use 10 meters as the minimum width of a polygon, except at acute corners of larger areas, for this assessment of the accuracy of the Iowa wetlands inventory.

Producer's Accuracy

"Producer's Accuracy (PA) measures the percentage of wetland features that are correctly classified on the imagery. PA is measured by both feature and attribute accuracy. Feature accuracy is the correctness of the identification of wetland vs. non-wetland. Attribute accuracy is the correctness of the wetlands using the FGDC Wetlands Classification Standard."

Accuracy assessment for this project was limited to the Class level of the Cowardin System and did not include Feature or Attribute variables.

The 2009 FGDC standards can be summarized as:

Minimum Standards:

TMU 0.5 acre (0.2 ha)

(All wetlands 0.5 ac, or larger, must be mapped)

Producer's Accuracy (PA)

Wetland ID	98%
Attribute Accuracy	85%

Congalton and Green (2009) indicate that assessment of Producer's Accuracy should be limited to about eight classes. The Cowardin classification system, even when limited to the Class level, includes thirty classes. Of these, eight classes included the majority of the wetland features found during the accuracy assessment.

Because ground verification was not possible for most parts of the state, assessment of the accuracy of the Iowa Wetland inventory was based on a comparison between what was interpreted by the MTRI interpreters and what was interpreted by the StMU interpreters. This resulted in an assessment that is more a measure of the agreement between the two interpretations than a traditional accuracy assessment.

d. Assessment Procedure

The St. Marys' University update to the Iowa NWI was based on color-infrared aerial photographs taken in the spring of 2002, and several ancillary data sources, including then existing NWI information. Because data sources were not originally digital, a pixel-based sampling scheme for assessing accuracy, similar to that described by Congalton and Green (2009), was not practicable.

Field checking to determine the existence and correct classification of all wetland features in any sampling unit was not practical because public access was limited or non-existent. This dictated an accuracy assessment procedure based on a reinterpretation of the aerial imagery used to generate the original inventory, with only limited field checks.

II. Sampling Scheme for MTRI Agreement Assessment

a. Rationale

Using sampling units defined by Iowa County boundaries and Public Land Survey sections within a County proved impractical because many County boundaries are defined by water courses, one of the features to be inventoried. This necessitated creating an artificial sampling unit that could be randomly sampled. When creating artificial sampling units, it is desirable to have the variance within the sampling units relatively close to that of the population as a whole. This led to selection of a sampling unit size of approximately four square miles.

b. Design

The Universal Transverse Mercator (UTM) grid provided a sampling frame independent of the resource being inventoried, and one that can be implemented for any terrestrial area.

Using the ***fishnet tool*** in ESRI's Desktop ArcGIS, a standard UTM grid was created to cover all of Iowa. Based on the area of the state (55,857 mi^2), approximately 15,800 four square miles cells were defined. The grid was then edited to state boundaries, reducing the number of cells to 12,415.

A 1% sample including 122 cells was randomly selected using the ***calculate field tool*** in ArcGIS. A 95% confidence level of a population of 12,415 would usually require a sample size of approximately 370. Part of our objective was to understand if a 1% sample would yield sufficient information to perform a useful agreement/accuracy assessment (Wonnacott and Wonnacott, 1990). The random sampling procedure resulted in a sample with cells selected throughout the state, and in a majority of counties (Figure 1). These 122 cells were then given unique identifications, consisting of five digits that corresponded to their location within the grid. Each of these cells was interpreted by one of three interpreters, and the results compared with those submitted by the interpreters from St. Mary's University.

c. Time required

Time required to complete classification of an individual cell varied with the complexity of the wetland features within the cell, but averaged approximately one hour per cell. The larger the number of polygons whose outlines had to be identified, the longer it took to interpret any given cell.

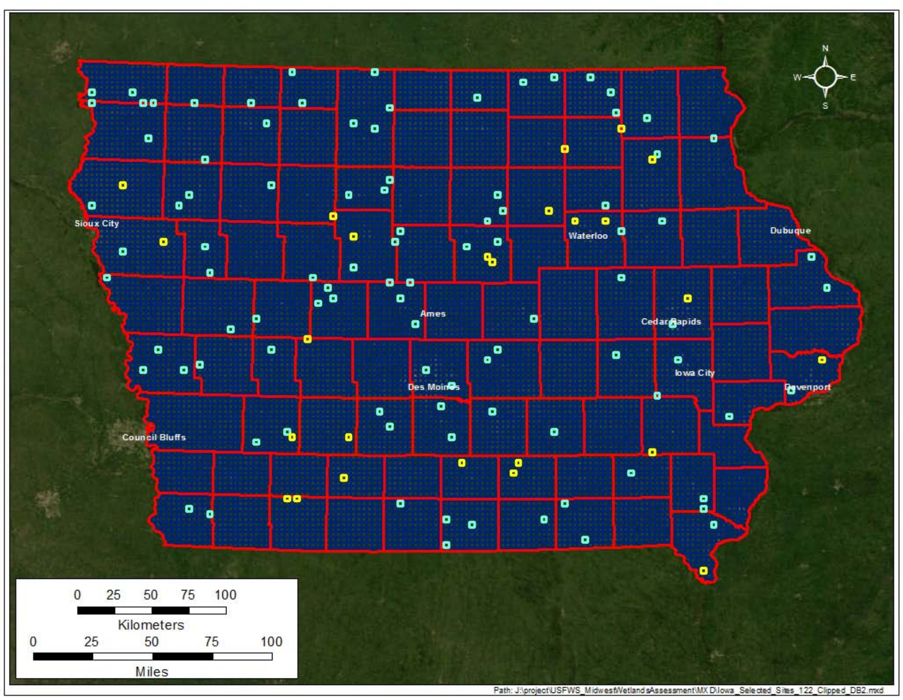

Figure 1. Locations of the 122 cells selected within the UTM grid including sites visited during fieldwork (yellow cells).

III. Field Checks

Sample units were selected in each of the four quarters of Iowa (SE, SW, NW, NE) and visited in the field (Table 1). The majority of the State of Iowa has a road network with roads on most section lines, as well as a public highway system. These roads provided the primary access to the selected sample units and were used to visit and verify as many locations within the selected cells as feasible. Because the sample units had little public property, field checking was largely limited to what was accessible from the public road network. This, and because field-checks were completed before most cells in the assessment sample had been interpreted, the field work served more as an advanced education procedure for the MTRI interpreters than as an actual field check of the bulk of the wetland features identified.

Table 1. Locations visited during field-checks in July 2012.

County	Cell No.	Date Visited
Washington	02343	July 9
Monroe	02077	July 9
Union	01683	July 10
Taylor	01198	July 10
Adair	02641	July 10
Guthrie	08140	July 10
Plymouth	09383	July 11
Woodbury	07872	July 11
Pocahontas	08602	July 11
Webster	08049	July 11
Hardin	07506	July 12
Hardin	07364	July 12
Butler	08784	July 12
Floyd	10377	July 12
Chickasaw	10883	July 12
Fayette	10139	July 12
Blackhawk	08516	July 12
Scott	04676	July 13
Linn	06381	July 13

Field checks in Iowa were completed during mid-July 2012, when the entire state was under severe drought conditions. Many streams were nearly dry, and ponds were substantially smaller than normal, or had completely dried/disappeared. Drought conditions were so severe that, in many places, crops were withering in the field. During field checks, a number of small, deeply incised stream channels – less than a foot wide at the top and more than two feet deep – were observed with water flowing in them. These channels are usually covered by tall grass leaning across the channel, making them difficult to detect and/or interpret from overhead imagery, especially when the resolution of the imagery is poorer than 0.4 meter (Figure 2). Similar deep incisions were observed along some small river courses where extensive flood-plains were observed as much as four feet higher than the water in the narrow (1 to 4 feet wide) stream channel (Figure 3).

Figure 2. Narrow, incised waterway with over-topping vegetation. Water was flowing in this channel under severe drought conditions.

Figure 3. Deeply incised drainage way, typical of most areas in Iowa.

Often the sides of the channel are steep and there is little traditional floodplain that is frequently flooded. The stream stays in its channel until flow increases to the point where it spreads out over fields. This appears to be the case over a wide range of stream sizes, and many have floodplains for events that occur every few years rather than annually. In one case, a plantation of walnut trees was found on flat ground approximately five feet higher than the water level in the adjacent stream, at the time of our field check (Figure 4).

Some river channels originally interpreted as having unconsolidated bottoms were observed with ORV tracks along the exposed bottom materials, indicating a very solid base within a few inches of the surface (Figure 5).

Figure 4. Walnut plantation on occasional flooded terrain, approximately five feet above existing water level.

Figure 5. River bed with extensive ORV tracks indicating a firm, consolidated bottom, observed in Lee County, Iowa (Grid Cell 00012).

Crop rotations that include pasture often lead to differences in wetland identification. Small watering ponds present in pastures are often eliminated when crop rotation takes a field from pasture to a cultivated crop. Such small ponds may have been recorded as wetlands in the previous NWI. Retaining them as wetlands because they showed as such in the previous NWI would be a mistake, as there is nothing remaining of the previous pond, not even hydric soils (Figure 6).

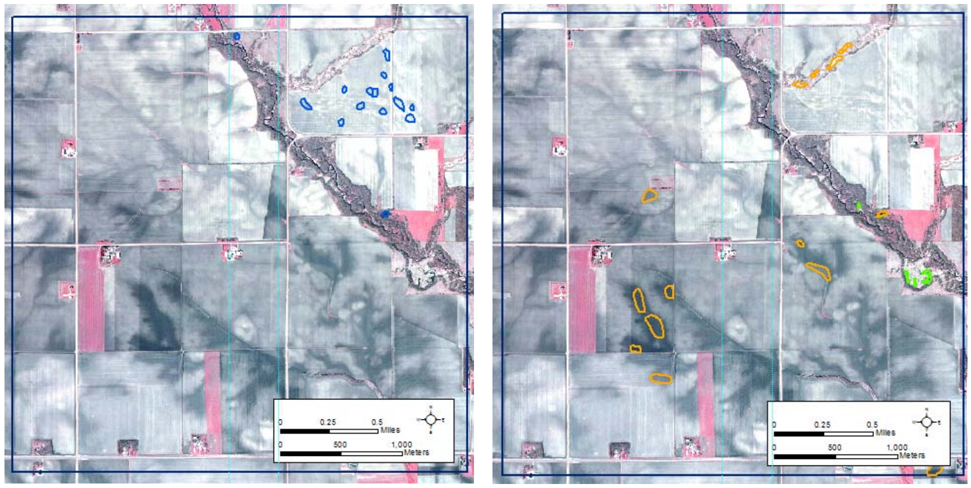

Figure 6. Example of NWI (left) small ponds, which are no longer present in newer imagery (blue polygons in the northeast corner); StMU (orange) and MTRI (green) (right).

IV. Accuracy/Agreement Assessment Results

Both data sets included wetlands recorded as polygons and linear features. Streams more than 10 meters wide were outlined and treated as polygons, even though FGDC standards indicate 15 feet. When the entire classification scheme is considered, there are more than eighty possible labels that can be placed on any given wetland feature, even though accuracy assessment was to be confined to the thirty choices at the Class level. This led to an incremental assessment of agreement between the two data sets.

Polygon area, grouping all wetland classes, provided one index of agreement between the two data sets. Within any sample unit, polygons common to both data sets, or omitted from one of the data sets, were compared. Because the boundaries of these polygons were not the same for both data sets, the area of the identified polygons was selected as the variable on which to base agreement. For the 122 cells interpreted by both the St. Mary's University interpreters and the MTRI Interpreters, the total area of polygons common to both records was 1,440.75 ha. The St. Mary's interpreters identified additional polygons with an area of 1,992.75 ha. that were omitted by the MTRI interpreters; but the MTRI interpreters identified additional polygons with 448.06 ha. that had been omitted by the St. Mary's interpreters. These results yield an agreement of 76% if based on the MTRI total area, but only 42% if based on the total area reported by the St. Mary's interpreters. Neither result was considered acceptable, and this led to a detailed analysis of thirteen example cells, one in each of thirteen different counties. Of these, only one of the cells had been visited during the July field-check.

Of the total number of possible labels at the Class-level of the Cowardin classification system, only eight were actually found in these thirteen cells. Of the 233 polygons identified by one group of interpreters or the other, only 58 were assigned the same label at the Class-level, an agreement of 25% (Table 2). Agreement was somewhat better for linear features, as 95 of the 184 possible linear features were assigned the same Class-level labels by both groups, an agreement of 52% (Table 3). While there were some differences, results did not vary greatly between interpreters. The major reason for the low agreements was omission of features by the interpreters. The MTRI interpreters, working without reference to the previous NWI data as part of assessing wetland presence independently of previous methods, were much more apt to omit features than were the StMU interpreters.

Table 2. Overall Agreement in Labeling Polygon Features in Thirteen Cells.

Polygon		StMU									
		R2UB	R2US	R3UB	R4SB	PUB	PEM	PFO	PSS	omit	Total
MTRI	R2UB	4								1	5
	R2US		2								2
	R3UB				1						1
	R4SB				5					9	14
	PUB					46	1			6	53
	PEM						1				1
	PFO										
	PSS										
	omit						124	32	1		157
	Total	4	2		6	46	126	32	1	16	233
								Agreement			0.25

Table 3. Overall Agreement in Labeling Linear Features in Thirteen Cells.

Linear		StMU									
		R2UB	R2US	R3UB	R4SB	PUB	PEM	PFO	PSS	omit	Total
MTRI	R2UB	9					1				10
	R2US	2									2
	R3UB	7					3			1	11
	R4SB				53		19	3	1	20	96
	PUB					30		1			31
	PEM				2		3				5
	PFO										
	PSS										
	omit				6	3	14	6			29
	Total	18			61	33	40	10	1	21	184
								Agreement			0.52

Accuracy, or agreement, is affected by both errors of omission and commission. In many cases, the MTRI interpreters did not identify wetland areas in the proximity of stream channels. Many of these were not apparent on the CIR air photos, and may have been included by the St. Mary's interpreters by comparison with the existing NWI. In addition, some of the polygons omitted by the MTRI interpreters appear to have been temporary wet spots remaining after recent rains, and others small ponds shown in the previous NWI that are no longer present. Because aerial photography is often flown shortly after passage of a cold front, areas photographed are often shown shortly after a rain event, and may show areas with standing water that has not yet drained away.

CIR imagery was flown and collected for the entire State of Iowa between March 16, 2002 and May 21, 2002. Based on climatological data received from the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NCDC) http://www.ncdc.noaa.gov/IPS/cd/cd.html), heavy rainfall occurred generally throughout the state on April 27-28, May 1-2, and May 11-13, 2002. Therefore any CIR photos taken on April 29-30, May 3-6, or May 12-15, would most likely show very wet fields and have residual areas of water or signfiicantly wet soils from the heavy rainfall.

In order to verify the assumption that StMU included temporary wet spots as wetlands, cells with flight lines that occurred during the days with the highest likelihood of such areas were further analyzed. Of the total 122 cells, 43 contained CIR imagery flown after the passage of one of the precipitation events listed above. These cells often had numerous dark spots, in which some were digitized by StMU (Figure 7). MTRI interpreters included the features that could be justified as wetlands. However, a majority of the dark spot features were omitted by MTRI due to the evidence that these were not always "wetlands."

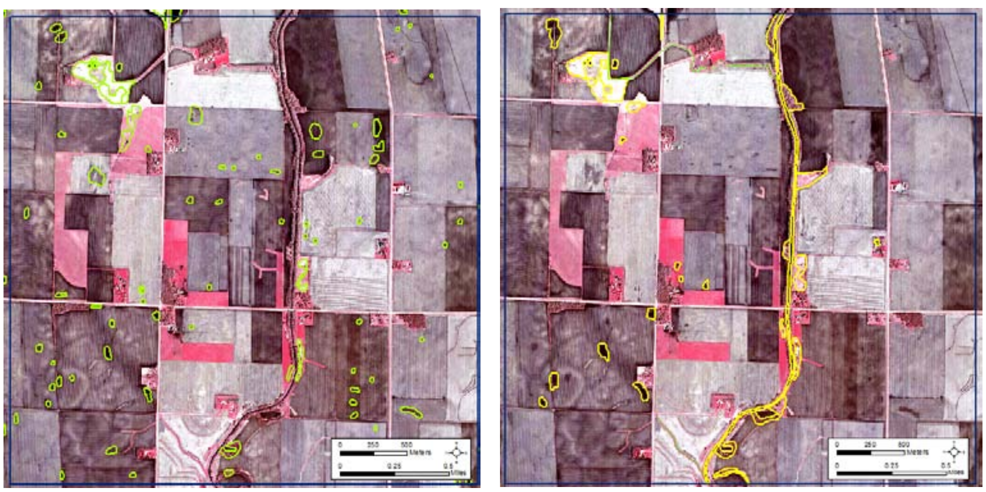

Figure 7. FID cell 10949 – Clay County, Iowa CIR imagery was collected on April 29, 2002, a day after a heavy precipitation event. The imagery includes numerous dark (wet) spots that StMU (left) included in their analysis, while MTRI (right) primarily excluded such features.

While St. Mary's indicated that it had approached this inventory as an update to the previous NWI, and assumed that all of the previous data were correct, there are many locations within the thirteen cells subjected to detailed comparisons where the St. Mary's interpreters altered the classification, or dropped, both linear and polygon features that previously were present in the original NWI classification.

Comparison of both StMU and MTRI results with the previous NWI record indicated that both groups carried the wetland identification farther upstream, but differences in classification of water regime may have been influenced by the MTRI field work, as the MTRI interpreters tended to carry Riverine classifications farther upstream than did the StMU interpreters.

Traditional image interpretation has relied heavily on the 3-D impression provided by stereo-viewing. Without this, when photos are viewed north-up with the shadows falling towards the top of the image, a majority of interpreters seem to see a pseudo-reverse 3-D, with hilltops looking like depressions. This tendency was overcome by at least some of the MTRI interpreters by placing the DEM layer beneath the photos being interpreted. It can also be overcome by rotating the photos so that the shadows fall towards the bottom of the screen, or by using a computer with 3-D monitor capability.

Many of the linear features omitted by the StMU interpreters were narrow features similar to those shown in Figure 2. Many streams are fairly deeply incised into the landscape. Often the sides of the channel are steep and there is little traditional floodplain that is frequently flooded. The stream stays in its channel until flow increases to the point where it spreads out over fields. This appears to be the case over a wide range of stream sizes, and can lead to misclassification of riparian wetlands.

V. Conclusions

As a more up-to-date product St. Mary's work resulted in a better representation of the Iowa wetlands than that portrayed by the original NWI, neither StMU nor MTRI interpreters achieved the 98% TMU, nor the 85% PA accuracies mandated by the FGDC standards, and it is unlikely that any group of interpreters relying solely on remotely sensed data can achieve these standards. This project section describes a method of comparing an NWI assessment with new, independent wetlands mapping to establish at least a level of agreement if not a full accuracy assessment. This method could be used to evaluate other state updates where a check of update methods and results is needed.

II. Accuracy/Agreement Assessment Using Additional Data Sets

I. Introduction

As described in the previous section, research scientists at the Michigan Tech Research Institute (MTRI) were tasked and completed an agreement assessment of St. Mary's University's update of the National Wetlands Inventory (NWI) for the State of Iowa in 2002. Taking into consideration polygon (e.g. open water) and linear (e.g. river/steam) features, the assessment was conducted on 122 four sq. mile cells, which encompassed the entire State of Iowa and a majority of its 99 counties. At the completion of the analysis St. Mary's University identified 76% of the polygon features that MTRI determined to be wetlands. This percentage did not achieve the minimum standard of 85 percent set forth by the Federal Geographic Data Committee (FGDC). During MTRI's analysis there were factors that arose which potentially affected the agreement percentage. Such examples include St. Mary's digitization of some features that were visually nonexistent within the color infrared (CIR) imagery, the inclusion of floodplains that were located next to a deeply incised river/stream, and a general reliance on existing NWI data.

To aid in reducing these limiting factors, MTRI restructured the CIR imagery reliant methodology to include an example analysis of additional data sets that would assist in the decision of mapping wetland features. This methodology included the following data sets: CIR imagery (used in the initial analysis), hydric soils, Light Detection and Ranging (LiDAR) derived digital elevation models (DEMs) and related hillshade visualizations, topographic wetness index, Phased Array type L-band Synthetic Aperture Radar (PALSAR) imagery, topographic digital maps, National Agriculture Imagery Program (NAIP) orthographic imagery, and a Bing Maps basemap layer now available through Desktop GIS software such as ArcGIS. The goal of expanding the methodology and assessment was to potentially assist MTRI in understanding why some wetland features were included within the St. Mary's analysis and help assess the value of including additional data sources in improving wetlands mapping.

II. Data sets

a. Color Infrared Imagery (CIR)

Color infrared imagery was the basis of both St. Mary's and MTRI's 2012 primary wetland analysis (GeoSpatial Services, 2005). Collected in early spring 2002, the imagery covers the entire State of Iowa, along with some borderline features of other states. As near-infrared energy interacts with water, it is absorbed, which makes all open bodies of water appear black. This makes digitization of such features very simple. However, the analysis is more complex when it comes to identifying polygon features that are not associated with an open body of water. For example, in Figure 8, there are multiple dark/wet features within the soil that have the potential of being digitized as wetlands due to their dark complexions. St. Mary's University included a majority of these features, whereas MTRI was not usually convinced that a dark spot necessarily signified the presence of a wetland (Figures 8 and 9).

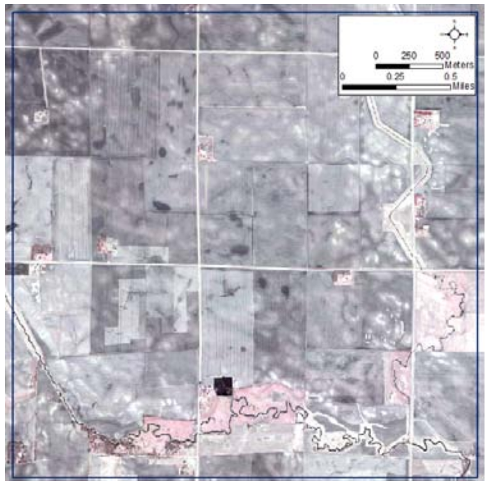

Figure 8. Color infrared imagery of Cell 10966-Kossuth County, located in north-central Iowa.

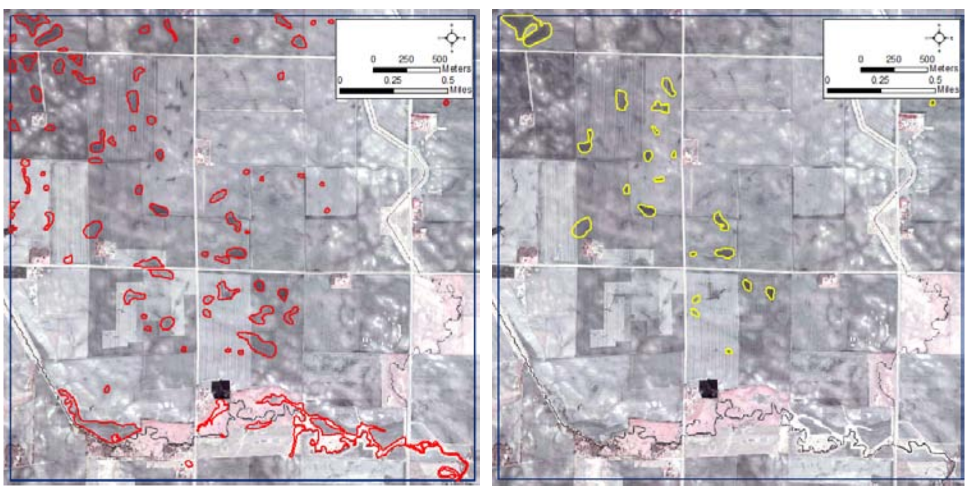

Figure 9. Side-by-side comparison of St. Mary's (left) and MTRI's (right) polygon wetland analysis. Notice how MTRI does not include as many dark spot features as compared to St. Mary's.

By only using the CIR imagery, wetland analysis of such features can be very difficult without extensive firsthand knowledge of the landscape. As previously stated, CIR imagery is often flown/collected after the passage of a cold front, causing potential misinterpretations when classifying wetlands based on the darkness of the land. MTRI decided that such instances should not be classified as wetlands. Whether the dark spots in Figures 8 and 9 are actually wetlands or only temporary standing of bodies of water cannot be determined by only using

CIR imagery. The other data sets mentioned earlier were able to help in the making the final decisions, based on what indications they gave about the land. In addition, field work that MTRI conducted help classify questionable wetland features.

b. Hydric Soils

Hydric soils are defined as being sufficiently wet in the upper section and able to develop anaerobic conditions during the growing season (Natural Resource Conservation Service - NRCS, http://soils.usda.gov/use/hydric/ntchs/tech_notes/note1.html). Such soils can often be identifiers of wetlands or conditions that are prominent in those areas. For this project, the county based soil data was received from the Soil Survey Geographic Database (SSURGO), which provided details about hydric soils within Iowa and other states. The data were then clipped to the selected study cells and all non-hydric soils were disregarded from the analysis. A spreadsheet containing descriptions of hydric the soils throughout the counties aided in determining which soil features were necessary.

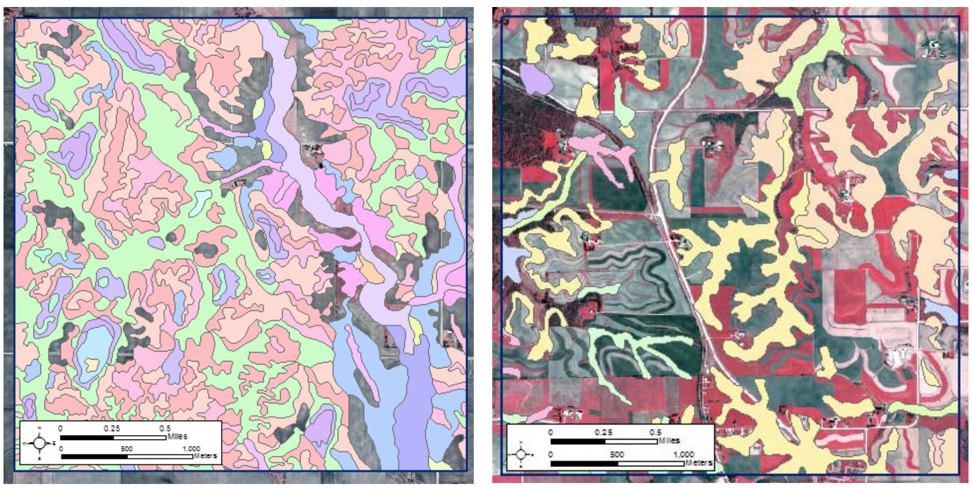

Figure 10. SSURGO data set indicating hydric soils in FID Cell 05594-Boone County, Iowa (left) and FID Cell 11149-Winneshiek County, Iowa (right). Each differently colored polygon represents a specific type of hydric soil.

Figure 10 illustrates the advantages and disadvantages of using hydric soils to aid in determining where wetlands exists. SSURGO data suggests that close to 4 sq. miles (the area of each FID cell) worth of soil in FID Cell 05594-Boone County are hydric. However, this does not necessairly indicate that all of this land should be classified as a wetland. Likewise the data in FID Cell 11149-Winneshiek County is also limiting. SSURGO indicates that less of the soil is hydric, therefore theroetically wetlands should be intermittent. FID Cell 11149 contains a small amount of wetlands, but it also possess features that exist outside of hydric soil boundaries. Overall, the hydric soil layer was useful in helping the interpreters determine where the majority of wetlands should exist. But with its limitations, such analysis cannot be the sole determining factor. Similar to CIR imagery, additional data sets were again necessary to digitize wetland boundaries.

c. Topographic Wetness Index

The Topographic Wetness Index (TWI) examines spatial scale effects on hydrological processes and identifies hydrological flow paths (Brooks et al., 2009). Topography affects the spatial distribution of soil moisture, which often follows the surface topography. Using a gridded elevation surface, algorithms calculated aspects concerning the landscape, such as the flow accumulation and slope. After processing the data though MTRI's TWI calculation, the results range from low (dry areas) and high (wet areas) values (Figure 11). Due to their nature, hilltops and ridgelines are often associated with lower TWI values, while footslopes and lower-valley slopes have high TWI values. However, streamlines have the highest values due to their catchment areas (Brooks et al., 2009).

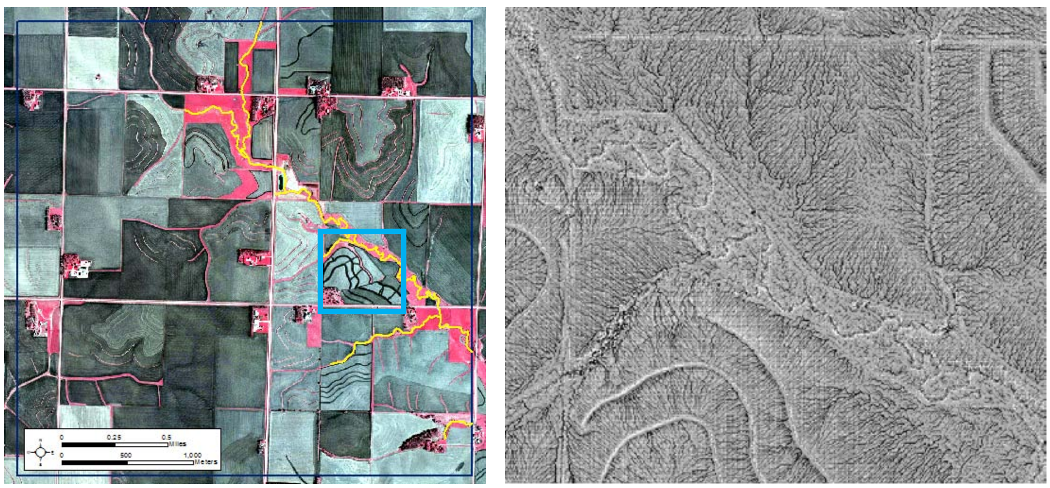

Figure 11. When combined with the hillshade layer, the TWI can easily indicate areas that are wet (e.g. river running diagonally; right) and dry (e.g. ridge/hilltops; right). This image is found in FID Cell 09129-Cherokee County, Iowa (blue box, left).

d. Hillshades

Elevation data and DEMs were created for cells that required further analysis. The DEMs were created by downloading Iowa's 2007 LiDAR data from the University of Northern Iowa GeoTREE program. LiDAR data was collected by an airborne system designed to measure the distance between the aircraft and ground surface with a high degree of precision (Hoensheid, 2012). The LiDAR dataset was used to generate DEMs by using Applied Imagery's Quick Terrain Modeler. The DEMs were then imported into ESRI's ArcMap, which converted the DEMs into hillshades for visualization and interpretation (Figure 12).

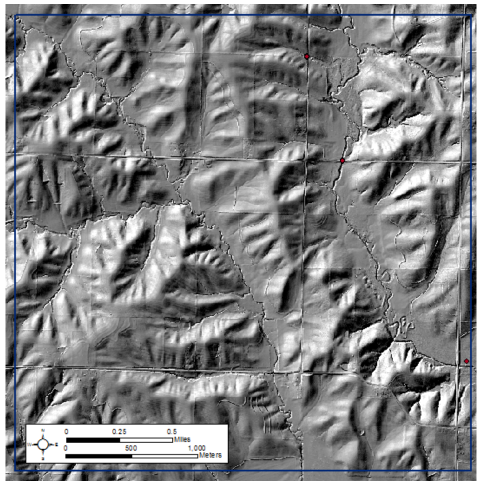

Figure 12. LiDAR based digital elevation model for FID Cell 02641-Adair County, Iowa.

Throughout the analysis hillshades proved to be one of the most useful data sets for the MTRI interpretation team. As Figure 12 shows, such imagery clearly indicates river, stream, and hillside boundaries. This proves especially useful when trying to determine if wetlands exist within floodplains. For example, St. Mary's analysis for FID Cell 02641-Adair County indicated numerous wetlands along the river boundary (Figure 13, red features). However MTRI's analysis, which is based on additional data sets including the hillshade and GPS-tagged pictures from fieldwork, indicated that the river is too deeply incised and therefore included fewer wetland features (Figure 13, yellow features).

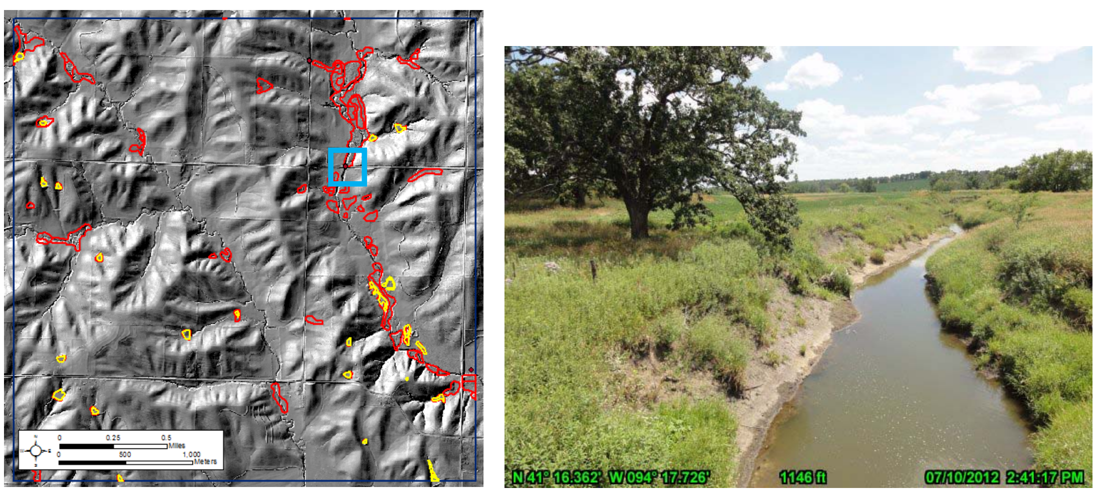

Figure 13. A comparison between St. Mary's (red) and MTRI's (yellow) wetland features along a deeply incised river (left). Field collected image of the deeply incised river located within the blue box found in Figure 13 (right).

e. PALSAR

Synthetic Aperture Radar (SAR) data have been used to detect flooding beneath vegetation canopies since the early 1980s. Single channel C-band (5.6 cm wavelength) satellite data are used to detect and map wetlands as well as monitor hydropattern and hydroperiod in south Florida herbaceous wetlands (Tanis et al. 1994, Kasischke et al. 1997). Longer wavelength L-band radar is more useful for mapping forested and high biomass herbaceous wetlands than C-band or X-band (Bourgeau-Chavez et al. 2008). C-band data have limited ability to map flooding beneath forest canopies, and are most useful in forests during leaf-off condition (Land, 2008). In Iowa, archival, spring Japanese Advanced Land Observing Satellite (ALOS) PALSAR L-band images from April 05, 2010 were processed and classified to discover forested wetland environments undetectable by remotely sensed EO data (Figure 14).

Processing began with downloading georeferenced 70km X 70km, 20 meter resolution PALSAR images from the Alaska Satellite Factory (ASF). These images were then processed through a 9 X 9 cell focal mean to remove speckle. The images are then passed through a National Land Cover Database (NLCD) derived urban filter to exclude confusion areas from building related high return levels. A conditional statement is then used to export an image consisting of forested wetlands and other.

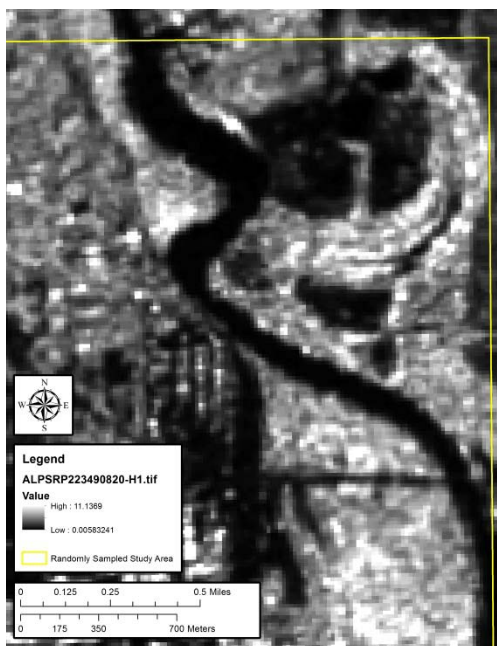

Figure 14. This ALOS PALSAR Image collected April 05, 2010, shows forested areas in lighter grays and wet forests as whites in FID Cell 06769-Boone County, Iowa.

This process does not take elevation into account while detecting forested wetlands and is therefore susceptible to confusion in high slope areas such as western Iowa. Therefore, this data set is to be considered ancillary in nature and should not be used for absolute delineation (Figure 15). When combined with the large library of other data sets, PALSAR-derived forested wetland maps can be useful in identifying areas previously not necessarily identified as wetlands.

Figure 15. This image shows areas delineated as forested wetlands in red overlaid onto a Bing maps image. Notice the classification included the low-lying forested areas as well as the broken channel.

f. Orthographic (NAIP imagery), Topographic and Bing Maps

2004 Orthographic NAIP imagery, USGS topographic and Bing maps were also used to assist in wetland boundary digitization. The 2004 NAIP imagery was scarcely used because of the nature of its data. For example, the imagery was flown two years after the color infrared imagery, from which the assessment is based upon. By comparing 2002 and 2004 orthoimagery, it became clear that some land areas had changed within two years, as expected. In addition, NAIP imagery is collected during the agricultural growing season, which can hinder the identification of wetlands.

Topographic maps were primarily used during the beginning of the assessment, when color infrared imagery was the only data set being analyzed. These maps can help show if there were wetland features within areas that are heavily vegetative. In addition, these maps were also useful when linear wetland features were partially obscured by wooded areas. However, topographic maps are limiting due to their older publication dates, cause misrepresentations of wetland boundaries.

Bing Maps basemaps were used as a quick-reference and advantageous, modern data set. Particularly, it came into use when the other data sets could not provide a clear indication of wetland features. However, Bing Maps is also more up to date than the 2002 CIR imagery. Therefore, caution had to be taken to exclude features that existed in the Bing Maps imagery but not the 2002 CIR data.

III. Updated Agreement Assessment Methodology

As mentioned earlier, the first accuracy/agreement assessment only took into account the color infrared imagery, with the assistance of the NAIP imagery and topographic maps. With the analysis of St. Mary’s data completed, MTRI believed that a more accurate and precise assessment could be achieved by including the data sets mentioned above. Due to the availability of data and time limitations, only four cells were selected and analyzed from the group of 122 with the additional data sets. Although each of these cells were analyzed using the same data sets, there was not a single defined methodology. This is because each location contains wetlands that are spatially different. However, a base methodology was used that defined how and when each data set should be used.

Similar to the previous methodology, CIR imagery was the initial data set used to digitize wetland boundaries. All open bodies of water, along with rivers and streams were easily identified. After digitizing each wetland, it was given a classification based on its features (see Cowardin et al., 1979). When a concern arose regarding the feature’s boundaries or classification while digitizing, the additional data sets were referenced for further clarification.

One of the additional data sets first referenced was the hydric soils layer. As previously explained, the SSURGO soils layer helped interpreters roughly determine where wetlands should exist. However, it was too generalized and some wetland features appeared in non-hydric soils. Therefore this data set was used as a reference and wetland features were not digitized based solely on the results.

Typically the next data set referenced was the hillshade layer. Extracted and created from LiDAR DEM data, this assisted the interpreter in visualizing what the landscape's elevation changes look like. In addition, it assists in determining where rivers meander in heavily wooded areas. However, the LiDAR data from which these hillshades were derived from were created with first return data, which includes features such as trees and buildings. Therefore, the hillshades could not assist in determining where rivers and streams were located in such areas. Overall however, this layer proved to be the most helpful, especially when digitizing floodplains. Caution had to be taken though due to the fact that the LiDAR data was flown in 2007, potentially detecting wetland features that were not present in 2002. As with the other data set layers, the interpreters were not solely reliant upon these data.

The TWI aided in determining the potential wetness of an area of land, as compared to its surroundings. For this assessment it was especially useful for rivers and streams, but did not assist in the verification of questionable polygon wetlands. In addition, the digitization of features was not completed using the TWI layer, due to the fact that it does not clearly indicate wetland boundaries. The TWI methods used in this project have been further adapted by Dr. Joe Knight's Geospatial Science Group (http://knightlab.org/). To determine if a polygon feature should be considered a wetland, additional data sets such as PALSAR were referenced.

PALSAR data proved useful for cells that contained major extensive rivers and floodplains, or farming landscapes. For cells that contained extensive farming landscapes, PALSAR data helped identify areas that were wet due to vegetation, and not necessarily because of recent rain event, which color infrared imagery picks up easily. In addition, fieldwork conducted at some of these sites also helped in the decision process. As stated earlier, PALSAR does not directly take elevation into account, producing some false detects. Therefore, the interpreters had to use caution when digitizing wetlands existing in wooded areas or by buildings. And for this reason, PALSAR data had to be incorporated with additional datasets in order to produce the most accurate wetland digitization.

IV. Results

Agreement analysis of the improved methodology indicated that the additional data sets mainly had a positive influence in delineating wetland features (Figure 16). In three of the five FID cells the areas in common between St. Mary's and MTRI's interpretations increased (from 13.28 ha to 16.75 ha in cell 02661 for St. Mary's agreement level with MTRI results, from 18.0 ha to 18.51 ha of agreement for cell 07917, and from 5.12 ha to 5.51 ha for cell 08851), while FID cell 09301 decreased in common area due to the exclusion of a wetland that MTRI determined was not a wetland. Overall, for these four cells the total area of agreement increased a total of 1.90 ha from 39.99 ha to 41.89 ha (a 4.75% increase in agreement area).

Regarding the overall St. Mary's agreement percentages, two FID cells had improvement (an increase from 92.0% to 95.1% agreement for cell 02661 and from 98.0% from 98.3% for cell 09301 when comparing the St. Mary's agreement level with MTRI results), while FID cells 07917 and 08851 decreased in their overall agreement (from 89.8% to 86.2% for cell 07917 and from 88.4% to 74.46% for cell 08851). Closer analysis indicated for FID cells 07919 and 08851, MTRI's omitted polygon areas increased after completing the improved wetland mapping methods, which may be a cause for the smaller agreement percentages. These results may indicate that additional data can be valuable in particular areas (or with particular cover types, such as forested wetlands from PALSAR image analysis), but overall, using this set of 4 analysis cells did not indicate a clear improvement trend from using the additional data. Additional analysis of all 122 FID cells using the additional data sets would be likely to provide a more clear picture the influence of a methodology that includes more types of data layers for mapping wetland locations and types.

02661		
PolyArea	StMarys	MTRI
2261		
Common	13.3	13.3
Omitted	59.9	1.2
Total	73.2	14.4
Agree	92.0 %	18.1%
PolyArea	StMarys	MTRI
Common	16.8	16.8
Omitted	56.5	0.9
Total	73.2	17.6
Agree	95.1 %	22.9 %

07917		
PolyArea	StMarys	MTRI
7917		
Common	18.0	18.0
Omitted	7.4	2.0
Total	25.4	20.0
Agree	89.9 %	71.0 %
PolyArea	StMarys	MTRI
Common	18.5	18.5
Omitted	6.9	3.0
Total	25.4	21.5
Agree	86.2 %	73.0 %

08851		
PolyArea	StMarys	MTRI
Common	5.1	5.1
Omitted	1.5	0.7
Total	6.6	5.8
Agree	88.4 %	77.6 %
PolyArea	StMarys	MTRI
Common	5.5	5.5
Omitted	1.1	1.9
Total	6.6	7.4
Agree	74.5 %	83.4 %

09301		
PolyArea	StMarys	MTRI
Common	3.59	3.59
Omitted	21.35	0.07
Total	24.93	3.66
Agree	98.0 %	14.4 %
PolyArea	StMarys	MTRI
Common	1.1	1.1
Omitted	23.8	0.0
Total	24.9	1.1
Agree	98.3 %	4.5 %

Figure 16. The agreement assessment tables (polygon area only) of the four FID cells that were analyzed using all data sets. *The top part of the tables are from the original analysis, while the bottom part of the tables are indicative of the assessment using the additional data sets.*

V. Conclusions

Upon completing an accuracy/agreement assessment of St. Mary's wetland digitization, MTRI determined that in order to conduct the best assessment, an analysis of the value of integrating additional data sets into MTRI's mapping of wetland type and extent should be completed. However, it is important to note that with every outside source consulted by the analyst, the time and costs required to complete the interpretation/classification also increases. Balancing cost and time is complicated, especially when the inclusion of such data and instruments will not guarantee an improved accuracy. With all of the additional data sets incorporating and supplementing the assessment, there was a 4.75% increase in total agreement area, but of the four test cells analyzed, two had increases in the agreement percentage, two saw a decrease. Additional research and evaluation is essential to help determine how each data set complements the other and the best methodology for integrating them.

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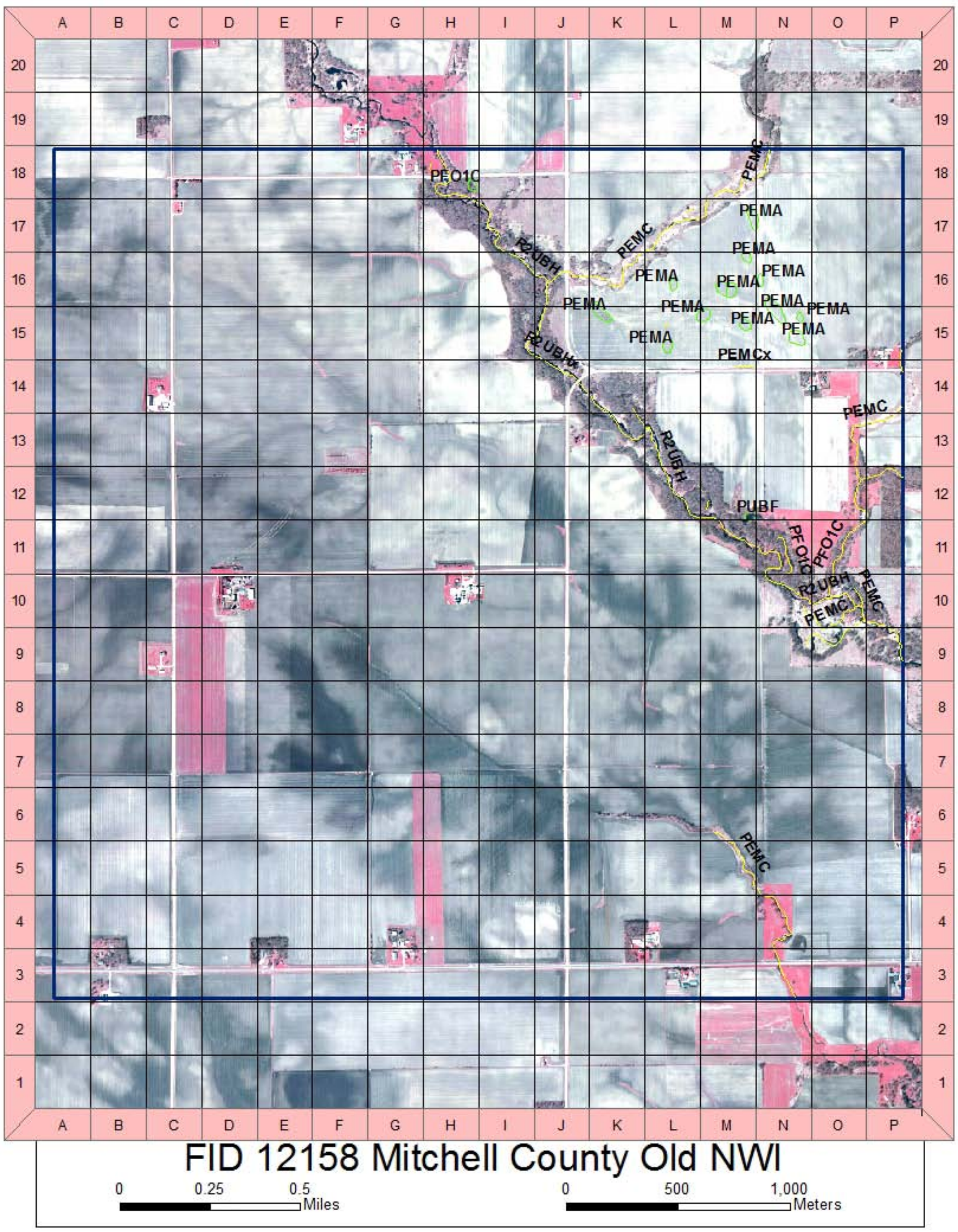
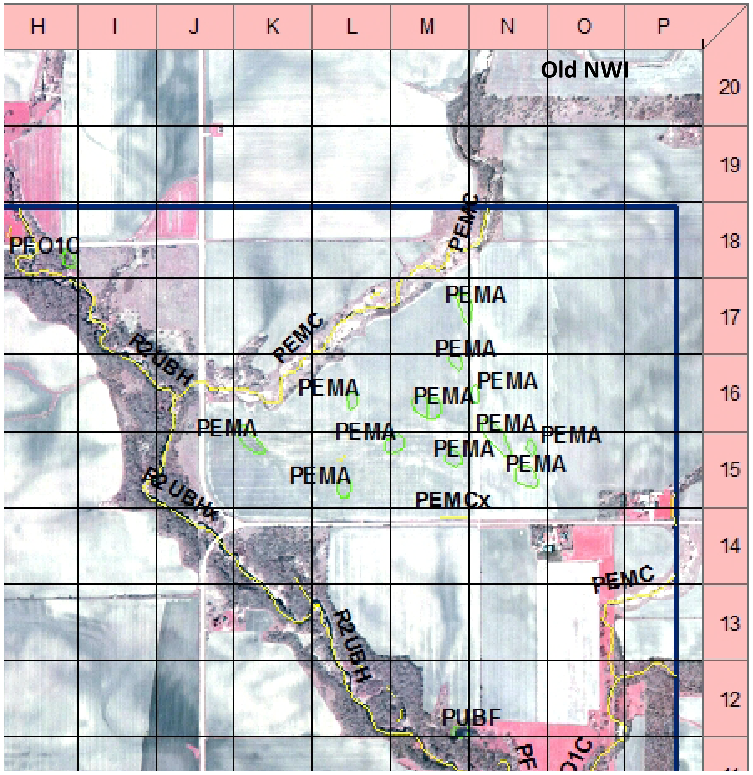
IV. Appendix A: Detailed Analyses of Sample Units

Detailed analyses of thirteen sample units (FID Cells) were completed to try to obtain a better understanding of differences between the St. Mary’s University and MTRI interpreters. In each case, the record of the original, pre-St. Mary's update NWI was overlain with a grid to provide a more convenient way to identify specific features. One such image is shown below. In the detailed analyses that follow, only about a quarter of the gridded image is shown, so that all images will be large enough to view clearly.





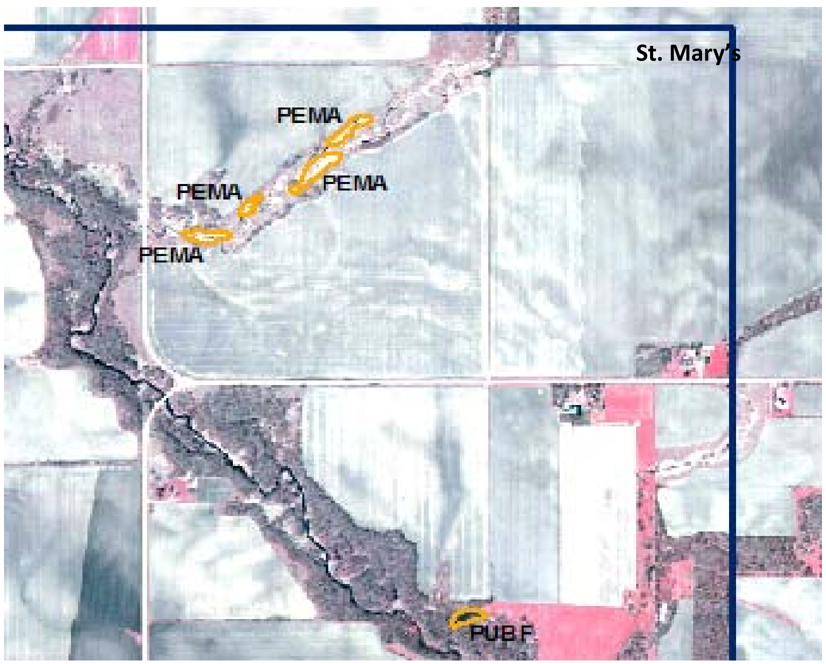
FID 12158 Mitchell County, IA

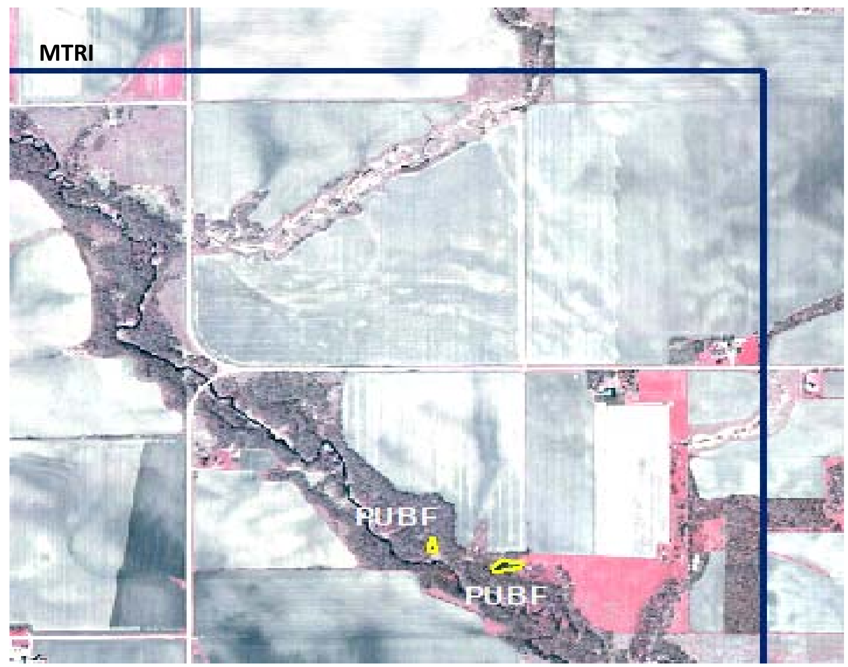
The NE corner of Cell 12158 includes 12 PEMA polygons on the Old NWI that were omitted by both St. Mary's and MTRI interpreters.

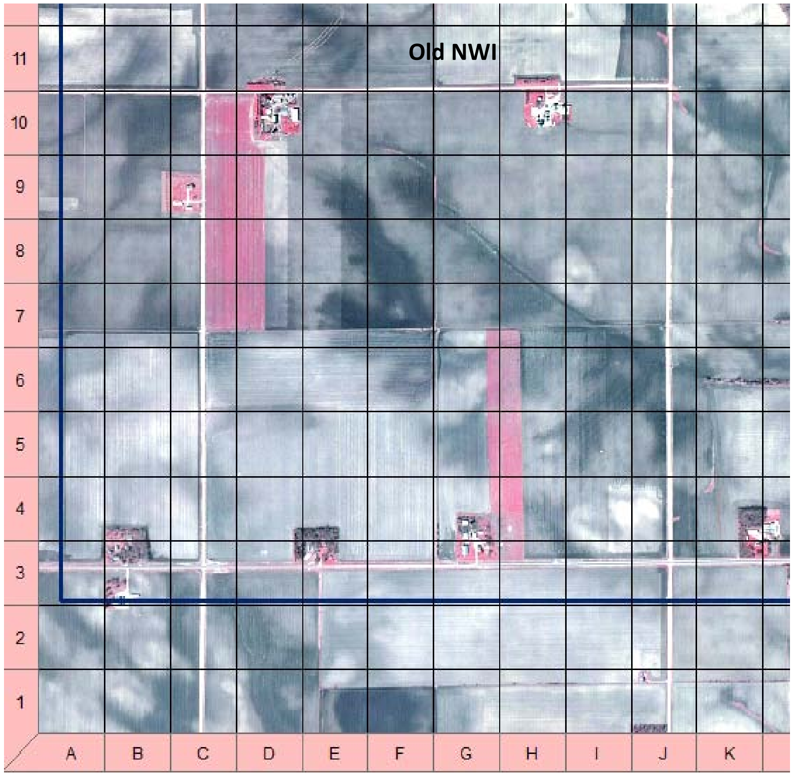
Along the stream course in grid cells K16 to M18, the Old NWI shows several small polygons. Four such polygons are shown in grid cells K16 and L17 by the St. Mary's interpreters, but were omitted by MTRI.

In grid cell H18, the Old NWI indicates a polygon labeled PF01C that was omitted by both the St. Mary's and MTRI interpreters.

At the SE corner of grid cell M12, the Old NWI indicates a polygon labeled PUBF that was included by both the St. Mary's and MTRI interpreters; but, in the SW quarter of the same cell, the MTRI interpreter was the only one to detect a second polygon and labeled it PUBF, also.

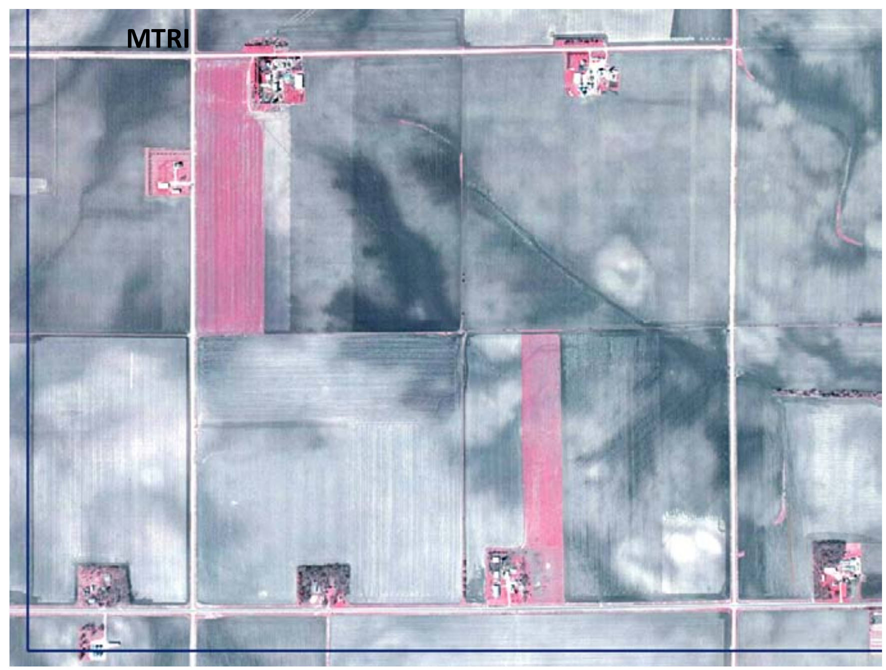






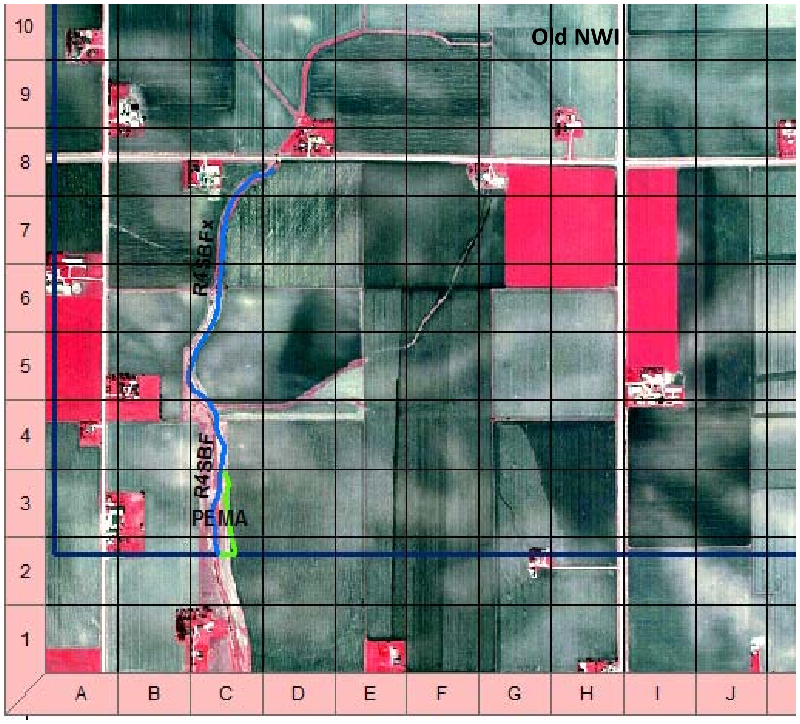
FID 12158 Mitchell County, IA

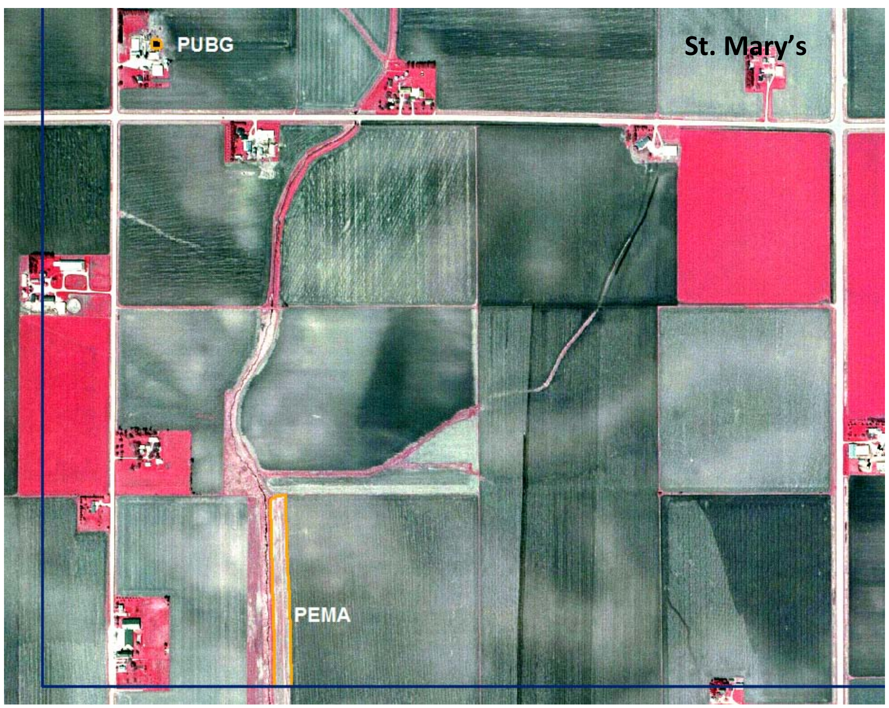
In the SW quarter of this sample unit, the St. Mary's interpreter identified seven polygons, labeled PEMJf, that were not on the Old NWI and were omitted by the MTRI interpreter. These appear to have been wet spots in fields following significant precipitation, rather than true "wetlands."

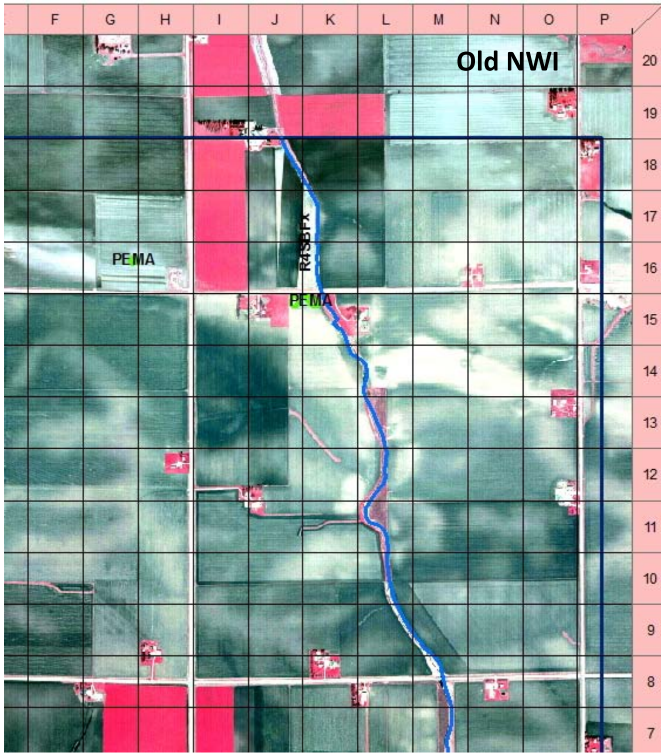


FID 08934   Bremer County, IA

In the SW quarter of this sampling unit, both the St. Mary's and MTRI interpreters identified the polygon in grid cell B9, differing only in the modifier (PUBG vs. PUBFh), but the MTRI interpreter omitted the PEMA polygon in grid cell C3 that is also shown on the Old NWI.





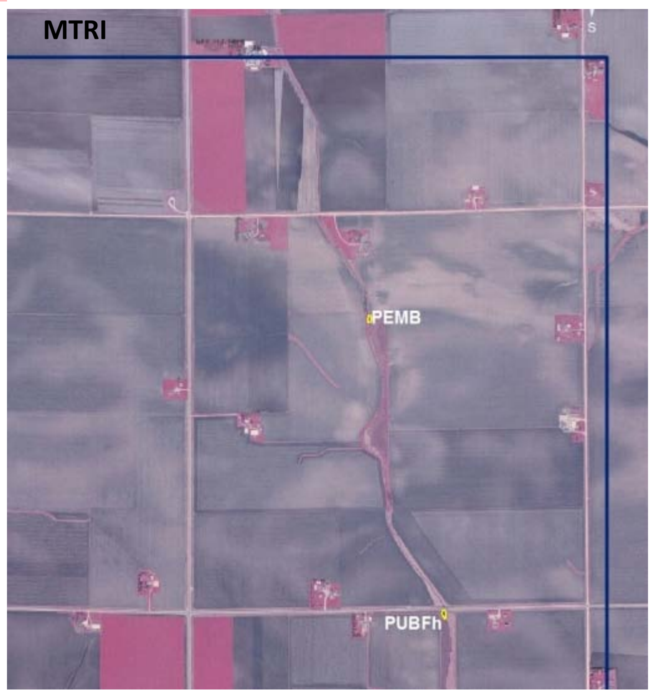


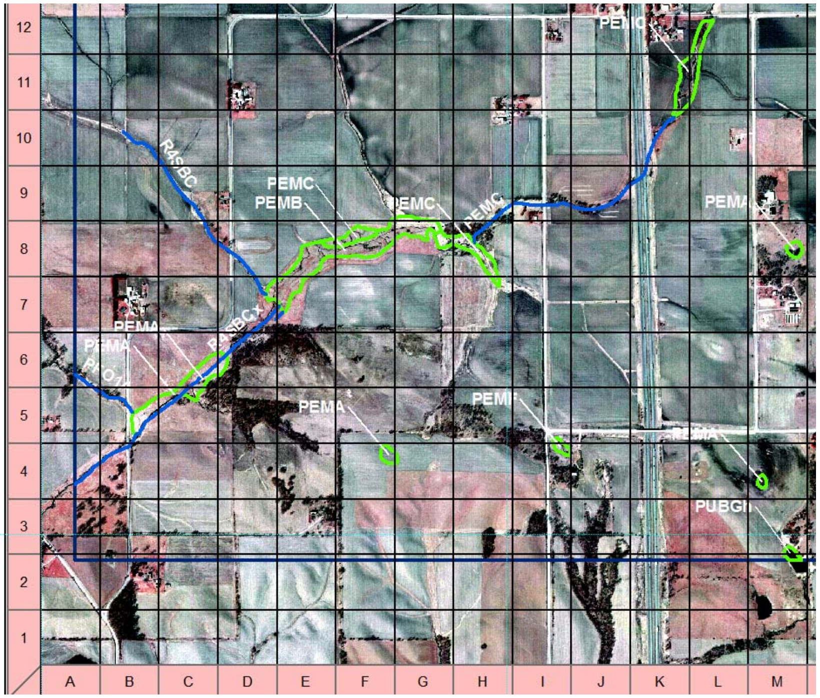
FID 08934 Bremer County, IA

In grid cell H16, the Old NWI has a polygon labeled PEMA that was omitted by both the St. Mary's and MTRI interpreters.

In grid cell L13, the MTRI interpreter identified a polygon and labeled it PEMB, but this was omitted by the St. Mary's interpreter.

In gird cell M8, the MTRI interpreter identified a polygon as PUBFh, but this was omitted by the St. Mary's interpreter.



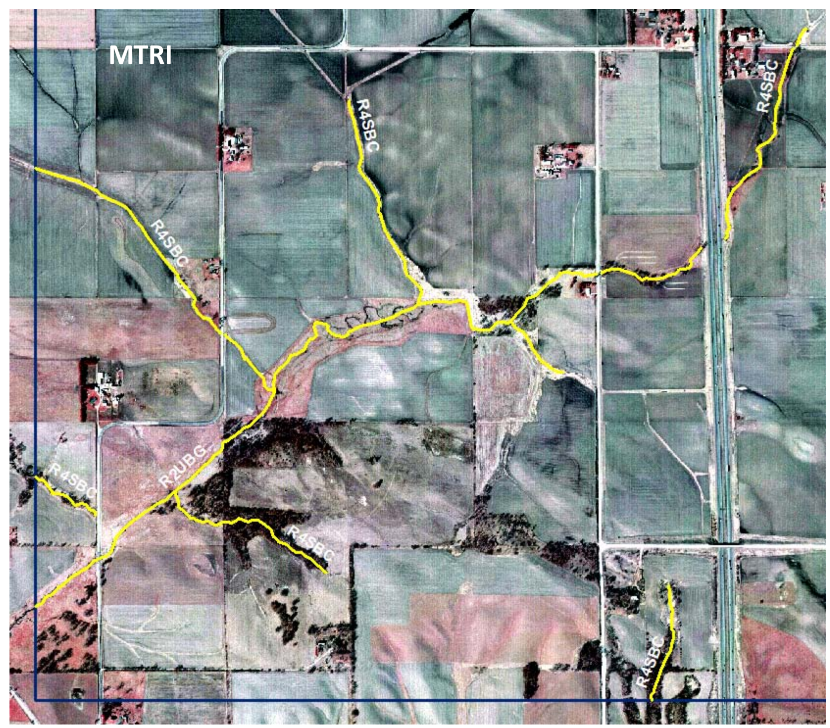


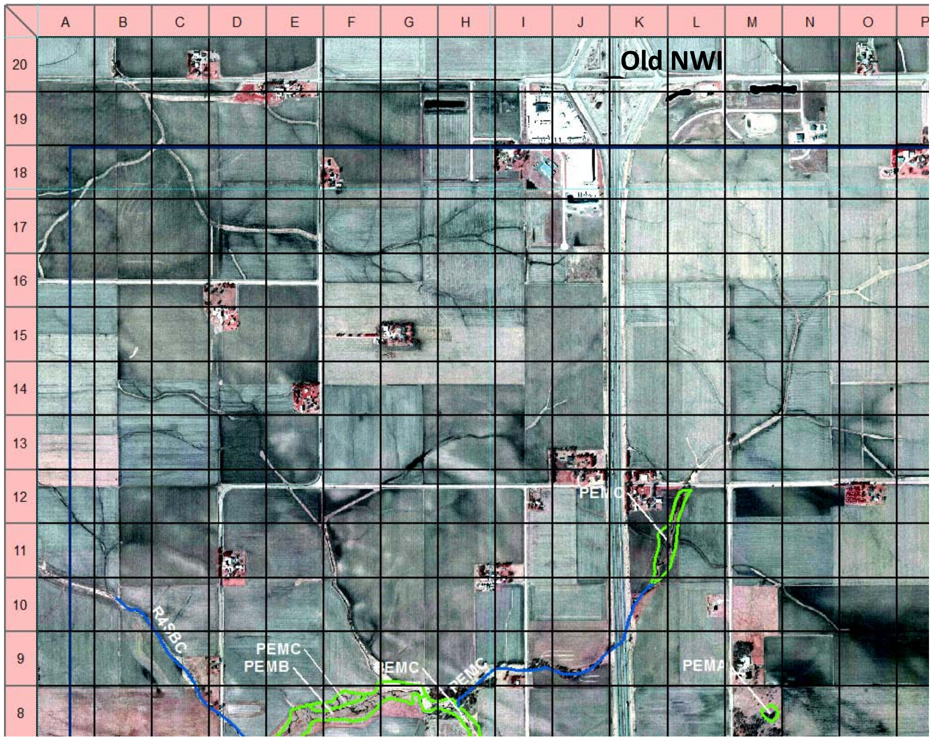
FID 04648 Johnson County, IA

This sampling unit illustrates some of the differences in stream classification that affect the overall agreement figures. The stream stretching from grid cell A4 to grid cell L12 was treated differently by different groups. The old NWI interrupts the linear feature from grid cell D7 to grid cell H8 by including it as a polygon. Both the St. Mary's and MTRI interpreters treated the entire stream as a linear feature, but labeled it differently. That southwestern end of the stream is labeled R4SBCx in the Old NWI, relabeled R2UBFx by St. Mary's, and R2UBG by MTRI. The upper end of this stream (grid cells H8 to L12) is labeled PEMC in both the Old NWI and by St. Mary's, but was labeled R4SBC by MTRI.

Both the St. Mary's and MTRI interpreters identified the three lateral channels on the north side of the main stream, but the third (grid cells F9 to F11) was labeled PEMCx by St. Mary's and R4SBC by MTRI.

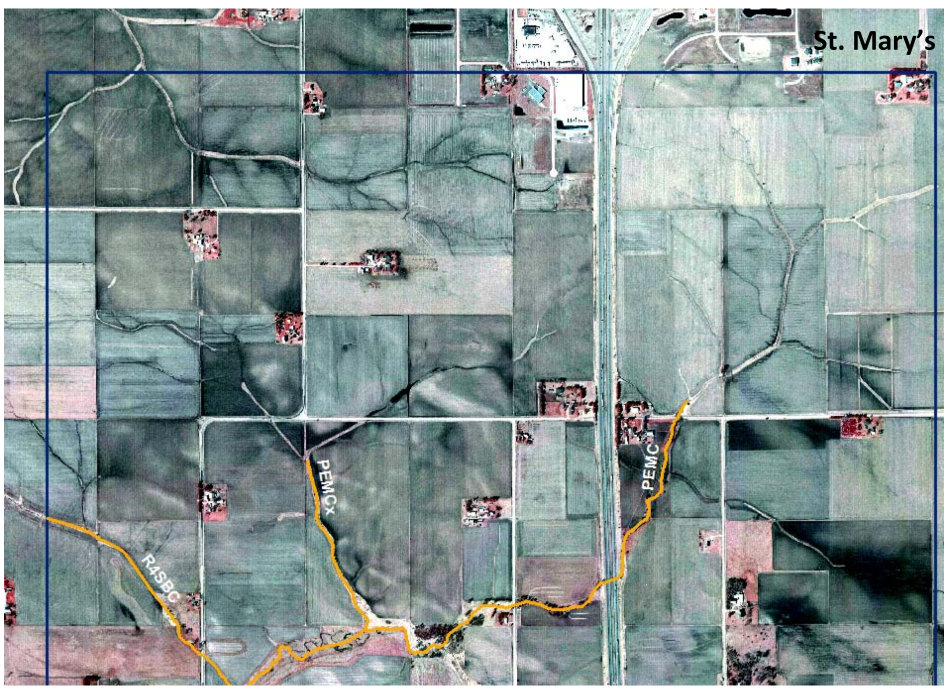
Only the MTRI interpreter identified two short tributaries on the south side of the main channel (grid cells D5 and H8).

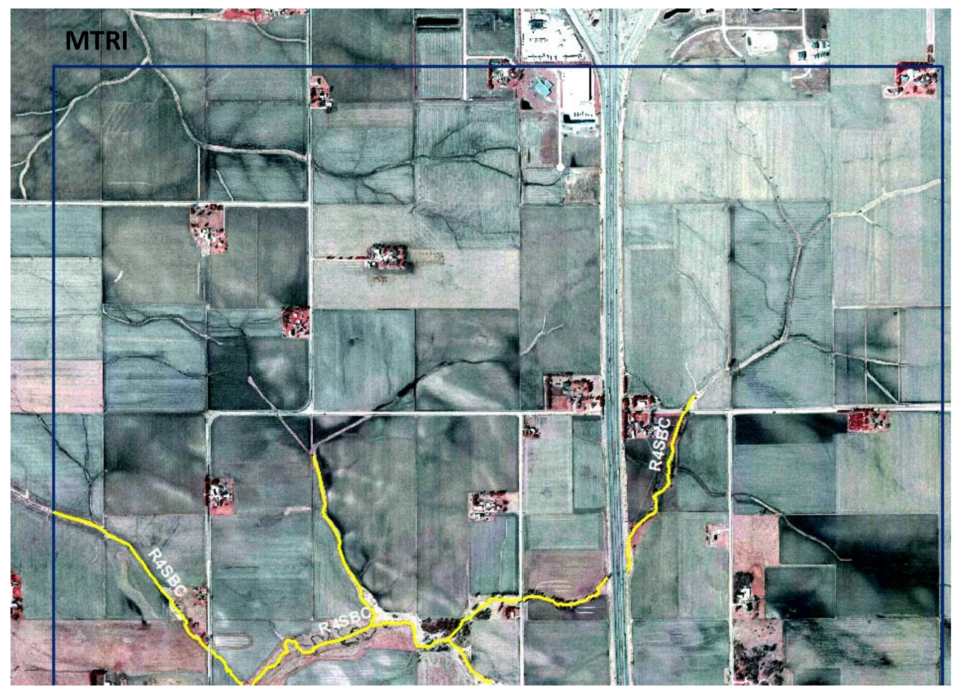




FID 04648 Johnson County, IA

This sampling unit illustrates some of the variability in interpretation that has implications for accuracy assessment. The obvious drainage pattern in the NW quarter of this sampling unit, and the northeasterly extension of the stream channel from grid cell L12, are not identified as wetland features on the Old NWI, nor by either the St. Mary's or MTRI interpreters. Yet, linear features were to be extended to the upper limit of stream flow.





V. Appendix B: Agreement Matrices for Thirteen Sample Units

Detailed analyses of thirteen sample units (FID Cells) were completed to try to obtain a better understanding of differences between the St. Mary's University and MTRI interpreters. The methodology used is indicated in Appendix A.

During the analyses of these thirteen cells, records were kept of the number and labels attached to each linear segment and each polygon, by both the St. Mary's and MTRI interpreters. Only eight different labels – to the Class Level of the Cowardin System – were found in these thirteen cells. Agreement matrices for both linear and polygon features are included in this appendix.

It should be noted that long linear features that maintained the same label throughout their length were treated as a single item and given no more weight than a short tributary of the same feature. An analysis that awarded multiple scores to long features might have resulted in different "Agreement" metrics.

OVERALL AGREEMENT BY INTERPRETER

MTRI Interprter: Carter

Linear

		StMU R2UB	R2US	R3UB	R4SB	PUB	PEM	PFO	PSS	omit	Total
MTRI	R2UB										
	R2US	2									2
	R3UB	4					3				7
	R4SB				1		9	3		3	16
	PUB					30		1			31
	PEM										
	PFO							0			
	PSS										
	omit					3	3	6			12
	Total	6			1	33	15	10		3	68
								Agreement			0.46

Polygon

		StMU R2UB	R2US	R3UB	R4SB	PUB	PEM	PFO	PSS	omit	Total
MTRI	R2UB	3								1	4
	R2US		2								2
	R3UB				1						1
	R4SB				5					9	14
	PUB					6	1			3	10
	PEM						1			2	3
	PFO										
	PSS										
	omit				3	2	28	15	1		49
	Total	3	2		9	8	30	15	1	15	83
								Agreement			0.20

Based on Cells:

00012	Lee County
04776	Iowa Count'
05594	Boone County
12158	Mitchell County

OVERALL AGREEMENT BY INTERPRETER

MTRI Interprter: Dean

Linear — StMU

		R2UB	R2US	R3UB	R4SB	PUB	PEM	PFO	PSS	omit	Total
MTRI	R2UB	4					1				5
	R2US										
	R3UB	3								1	4
	R4SB				27		1			2	30
	PUB										
	PEM										
	PFO										
	PSS										
	omit				4		9				13
	Total	7			31		11			3	52
								Agreement			0.60

Polygon — StMU

		R2UB	R2US	R3UB	R4SB	PUB	PEM	PFO	PSS	omit	Total
MTRI	R2UB										
	R2US										
	R3UB										
	R4SB										
	PUB					14				1	15
	PEM									1	1
	PFO										
	PSS										
	omit					4	53	7			64
	Total					18	53	7		2	80
								Agreement			0.18

Based on Cells:

01198 Taylor County
06898 Calhoun County
08934 Bremer County

OVERALL AGREEMENT BY INTERPRETER

MTRI Interprter: Banach

Linear StMU

		R2UB	R2US	R3UB	R4SB	PUB	PEM	PFO	PSS	omit	Total
MTRI	R2UB	3									3
	R2US										
	R3UB										
	R4SB				25		7		1	14	47
	PUB										
	PEM				2						2
	PFO										
	PSS										
	omit				1		1				2
	Total	3			28		8		1	14	53
								Agreement			0.53

Polygon StMU

		R2UB	R2US	R3UB	R4SB	PUB	PEM	PFO	PSS	omit	Total
MTRI	R2UB	1									1
	R2US										
	R3UB										
	R4SB										
	PUB					25					25
	PEM						13			3	16
	PFO										
	PSS										
	omit					2	15	10			27
	Total	1				27	28	10		3	69
								Agreement			0.57

Based on Cells:

01042 Henry Count

03835 Scott County

04648 Johnson County

06161 Greene County

08493 Franklin County

OVERALL AGREEMENT BY INTERPRETER

MTRI Interprter: Garwood

Linear

		StMU									
		R2UB	R2US	R3UB	R4SB	PUB	PEM	PFO	PSS	omit	Total
MTRI	R2UB	2									2
	R2US										
	R3UB										
	R4SB						2			1	3
	PUB										
	PEM						3				3
	PFO										
	PSS										
	omit				1		1				2
	Total	2			1		6			1	10
								Agreement			0.50

Polygon

		StMU									
		R2UB	R2US	R3UB	R4SB	PUB	PEM	PFO	PSS	omit	Total
MTRI	R2UB										
	R2US										
	R3UB										
	R4SB										
	PUB					1					1
	PEM										
	PFO										
	PSS										
	omit						28				28
	Total					1	28				29
								Agreement			0.03

Based on
Cell:
10845 Kossuth County

OVERALL AGREEMENT FOR THIRTEEN CELLS FROM FOUR INTERPRETERS

Linear

		StMU									
		R2UB	R2US	R3UB	R4SB	PUB	PEM	PFO	PSS	omit	Total
MTRI	R2UB	9					1				10
	R2US	2									2
	R3UB	7					3			1	11
	R4SB				53		19	3	1	20	96
	PUB					30		1			31
	PEM				2		3				5
	PFO										
	PSS										
	omit				6	3	14	6			29
	Total	18			61	33	40	10	1	21	184
								Agreement			0.52

Polygon

		StMU									
		R2UB	R2US	R3UB	R4SB	PUB	PEM	PFO	PSS	omit	Total
MTRI	R2UB	4								1	5
	R2US		2								2
	R3UB				1						1
	R4SB				5					9	14
	PUB					46	1			6	53
	PEM						1				1
	PFO										
	PSS										
	omit						124	32	1		157
	Total	4	2		6	46	126	32	1	16	233
								Agreement			0.25

Based on Cells from four Interpreters

David Banach

- 01042 Henry County
- 03835 Scott County
- 04648 Johnson County
- 06161 Greene County
- 08493 Franklin County

David Dean

- 08493 Bremer County
- 01198 Taylor County
- 06898 Calhoun County

Justin Carter

- 00012 Lee County
- 04776 Iowa County
- 05594 Boone County
- 12158 Mitchell County

Gordon Garwood

- 10845 Kossuth County