2006 NAIP UT Pilot Project: Absolute Accuracy Summary Report

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Figures and Maps

Section 1 – Introduction

The National Agriculture Imagery Program (NAIP) is an aerial imagery acquisition program managed by the United States Department of Agriculture (USDA) Farm Service Agency (FSA) Aerial Photography Field Office (APFO). NAIP seeks to acquire peak growing season "leaf on" imagery in order to maintain the Common Land Unit (CLU) dataset and assist with crop compliance and a multitude of other farm programs. NAIP acquisition includes annual 2-meter resolution Natural Color (NC) or Color Infrared (CIR) imagery on a national scale, and 1-meter resolution NC or CIR on a 5-year refresh cycle, and delivers the imagery to the primary users, FSA and Service Center Agency (SCA) personnel in the field, as well as NAIP partners, in the same year of acquisition.

The horizontal accuracy of NAIP has always been tied to Government furnished baseline imagery datasets, where 1 meter Ground Sample Distance (GSD) imagery has an accuracy that matches the reference baseline imagery dataset within 5 meters (90% confidence), and 2 meter GSD imagery matches the baseline imagery within 10 meters (90% confidence). This type of accuracy is defined as relative accuracy, and the deliverable is not tied to true ground, rather another imagery dataset, which *was* tied to ground within a certain confidence.

The 2006 NAIP UT Pilot Project sought to tie NAIP imagery to true ground, rather than a reference imagery dataset. This avenue is termed absolute accuracy. This report documents the processes and procedures undertaken to accomplish this task, in an effort to move NAIP to absolute accuracy specifications in the future, resulting in an even more horizontally accurate product than what vendors participating in NAIP are currently required to produce.

Section 2 – Business Case

Why absolute accuracy over relative accuracy? In short, absolute accuracy is more accurate to true ground than relative accuracy, depending on specifications. A 1 meter resolution aerial image that meets 5 meter relative accuracy specifications means for NAIP that a given tested point/feature on the image is within 5 meters of the same feature on a baseline image. However, if that baseline image meets, say 5 meter accuracy specifications to true ground, the resulting NAIP image could be as much as 10 meters (5 + 5 meters) from true ground in the horizontal direction.

If the same NAIP image as above meets 5 meter accuracy specifications to true ground (absolute accuracy), the image is within 5 meters of true ground, not 10.

Why is relative accuracy not accurate enough? In most cases in the past it has been. However, as more GIS datasets are used in conjunction with NAIP, a higher accuracy is needed based on what NAIP data is used for by FSA, NAIP Partners, and private customers alike. More often than not, imagery is used by customers in a Geographic Information System (GIS) as a base layer, also known as a reference layer. The data is used to reference vector datasets, or to digitize upon them. To satisfy customer requirements these data need to spatially line up as well as possible so as to alleviate horizontal adjustments to those vector datasets and consequentially, future workload based on small base or reference imagery shifts from year to year; one way of accomplishing this is to have a more accurate to ground reference imagery layer to do work upon.

In the end, though, the most engaging factor is in satisfying customer requirements. Moving to absolute accuracy from relative creates a much more accurate, thus a more valuable dataset, and satisfies more customer requirements, which can mean more partnerships. Ultimately, a better product can be achieved for potentially fewer Federal dollars due to the realized increase/enhancement in partnerships with local, State, and Federal entities.

Section 3 – Horizontal Accuracy Specifications

As discussed in the introduction, NAIP has had relative accuracy specifications since program inception. The specifications remain today for most States. These specifications may be reviewed in the NAIP contract, which can be found by going to the USDA-FSA-APFO website, at http://apfo.usda.gov and clicking on the Contract Services link. The current (abridged) horizontal accuracy specifications are shown below:

1. The accuracy standard for the 1-meter orthorectified images requires that 90% of all well-defined points tested must fall within five (5) meters of the same location identified on Government furnished baseline orthophoto control imagery.
2. The accuracy standard for the 2-meter orthorectified images requires that 90% of all well-defined points tested must fall within ten (10) meters of the same location identified on Government furnished baseline orthophoto control imagery.

For the 2006 NAIP Utah Pilot Project, the horizontal accuracy specifications were absolute, and were:

1. 95% of points tested must fall within six (6) meters of pre-determined quality assurance ground control points.

This 6 meter number was arrived at based on a number of factors:

First, it met or exceeded National Map Accuracy Standards (NMAS), National Standard for Spatial Data Accuracy (NSSDA), and ASPRS Class 2 Standards for 1:12000 maps. It also exceeded current proposed Imagery for the Nation (IFTN) Standards.

Second, it was tighter than current NAIP *relative* horizontal accuracy standards (see Section 2, Business Case).

Third, it was deemed to be achievable by NAIP Vendors.

Lastly, it was accurate enough for the FSA State Office to continue to enhance the accuracy of their CLU datasets.

In 2007, an absolute accuracy standard has been contemplated for 2 meter resolution imagery as well, and will likely be set at 10 meters (95% of points tested).

Depending on the results of this Pilot, expect that more and more NAIP imagery will be moving to an absolute accuracy specification.

Section 4 – Acquiring and Maintaining Photo Identifiable Control

In order to quality check imagery tied to ground, one must have photo identifiable ground control points from which to inspect the horizontal accuracy of the imagery. APFO has begun construction of such a control point database, and was able to acquire/inspect over 400 points for the 2006 NAIP Utah Pilot. Acquiring photo identifiable control is not an easy or short term task, and should be thoroughly planned out. The following is documentation of the general process for taking on this task.

In an effort to document the process steps of the 2006 Utah National Agriculture Imagery Program (NAIP) absolute control pilot project, which moves NAIP from a relative to absolute accuracy standard for the State of Utah, the following is documentation of the process steps required in initially acquiring, then storing and maintaining photo identifiable ground control. This documents the general process not only for the pilot project, but also for future years expanding NAIP to absolute standards on a National level.

Note that when the term “photo identifiable” control is used, it refers to a point that is identifiable on a 1 meter resolution image in conjunction with the use of a detailed description, image, or sketch. When the term “APFO lead” is used herein, it refers to the assigned individual who plays the lead role at the Aerial Photography Field Office (APFO) in acquisition, storing and maintaining photo identifiable control.

Further, the same control points may be used in the Aerial Triangulation Solution *and* in the Quality Control process, but NOT in the same year. In other words, some control may be turned over to the vendor for use, however, that control will not be used for inspection.

<u>Select Project Area</u>

With regards to selecting photo identifiable absolute ground control, the “Project Area” always refers to a State; control points will ultimately be stored by State and by County utilizing appropriate naming conventions.

<u>Outreach to State GIS Coordinator/Specialist</u>

The Farm Service Agency (FSA) State GIS Coordinator/Specialist for the given Project Area knows the State better than the APFO lead; they are a valuable resource. The Coordinator/Specialist should do what they can within the State, through Federal, State, local, and private contacts to acquire *existing* photo identifiable control. At the same time they should also explore the possibilities of acquiring *new* photo identifiable control. Avenues may be explored that have an associated cost; however, other free means will be exhausted first, and funding for acquisition of control is not presently budgeted.

Whatever control the Coordinator/Specialist finds is then sent to APFO for evaluation, formatting, and storage, which are discussed later in this document.

Research and Identify Existing Control

While the State GIS Coordinators/Specialists are doing their work, the APFO lead is researching and identifying photo identifiable control from existing datasets. These datasets include but are not limited to United State Geological Survey (USGS), United States Forest Service (USFS), and National Geodetic Survey (NGS) control data, as well as web searches and interactions with major State agencies who may possess desired control, such as State Department of Transportation (DOT), or organizations such as Automated Geographic Reference Center (AGRC) in Utah, or other State GIS committees or networks. Some overlap in control searches may occur between the APFO lead and the State GIS Coordinator/Specialist, so communication is a key between these individuals.

Explore Acquisition of New Control

If sufficient control does not exist, and in many cases even if it does, the APFO lead will also explore acquisition (gratis or otherwise) of new photo identifiable control. This acquisition may occur through partnerships or possibly through commercial purchases if funding is available. The lead may discover a good deal of cooperation with NAIP partners or partners of NAIP partners regarding willingness to acquire this control, as a better more accurate NAIP product will result through this effort.

It is important to clarify further the cost of acquiring good photo identifiable control. Acquisition of truly new photo control, where a survey crew must be put foot on ground, can cost upwards of $450 per point, for the lower 48 States. Cost greatly depends on location, as personnel and travel costs are a huge factor. For example, acquiring a control point in a remote location in Alaska may cost upwards of $20,000, for a single point!

For 2006 NAIP Utah, only 87 of the 400+ points used for QC were new points, and those points were acquired through AGRC, at no realized cost to APFO or the Federal Government.

Point by Point Evaluation

At this juncture in the process, the APFO lead likely will have multiple control point datasets that require evaluation to determine usefulness/validity as photo identifiable control. The control points should be added to an ArcMap session, overlaid on at least two imagery datasets from different time periods (if available). For example, overlaying the control on both the Mosaicked Digital Ortho Quads (MDOQ) and a recent NAIP product would be viable. This is to ensure that the control points selected are still visible on newer imagery, but have longevity, as they are present on older imagery. Note that at times the control may only show up on newer imagery; if the point has staying power, and is represented by a permanent feature, it is still a valid point. Needless to say, if the point is visible on the older imagery but no longer exists on the newer, the point is not valid. Once all points that are valid have been identified, move to the formatting and storage phase.

Note that simply adding control to ArcMap obtained from various sources can at times be a challenge. Control may come as simple text files, tab or comma delimited text files, or other formats which may require at times extensive reformatting before addition to GIS becomes possible.

Formatting and Storage of Control

A standard format regarding field types and lengths, file types and associated files (.txt, .shp, .jpg, etc) has been identified, but is not discussed at length here. In short, there is a standard file naming and storage convention. Presently, the data is kept in a simple .dbf with associated supplemental data in a file structure. It will be the job of the APFO lead to format valid control fields appropriately. In the near future, the APFO IT Branch will database the control into an Oracle Table, and store supplemental information within fields in the table. The control will be stored in the appropriate location on the network for use in the inspection process. Updates to the database will be made by the APFO lead or designee with access and write permissions provided accordingly.

The Need for Securing Control Datasets

Control point datasets used for inspection are only useful if kept secured and secret from vendors. The need for securing and not passing these points out to the public is absolute (other than select points for AT solution as mentioned above); otherwise the vendor may use these specific QC points to rectify images, invalidating inspection processes.

Annual Acquisition and Maintenance

Control points, while having a semblance of permanency, are only valid if identifiable on imagery. Since the real world is ever changing, annual or bi-annual reviews of all photo identifiable control points is required. Annual review of these points may be done via population of a point ratings field during imagery inspection or by the APFO lead independently. The APFO lead will have overall responsibility, however, to ensure control is valid and useable from year to year. This lead will also have the responsibility for obtaining new control through any means listed above. This is an on going process; having too much photo identifiable control is not possible, while having too little puts inspection, and therefore standards of quality in jeopardy.

Time Commitment

Due to the on going nature of control acquisition and maintenance, it is the belief of the Service Center Support Section (SCSS) that the initial obtaining, validating, formatting, and storing of photo identifiable control on a national basis for the purposes of inspecting NAIP and other APFO delivered products is a job for 2-3 Full Time Equivalent (FTEs) for 2-3 years. After initial acquisition, the job likely becomes a half-time job for maintenance purposes as discussed above. The outlined timeline and personnel commitment is greatly dependent on timeframes to move NAIP to absolute control.

Process Summary

Obtaining photo identifiable control is the backbone for inspecting deliverable imagery products produced to absolute standards, and is therefore an integral part of moving NAIP to these new more spatially accurate standards. A more spatially accurate and defensible product is a more valuable and long lived product. A diagram has been provided below to graphically display the outlined process.

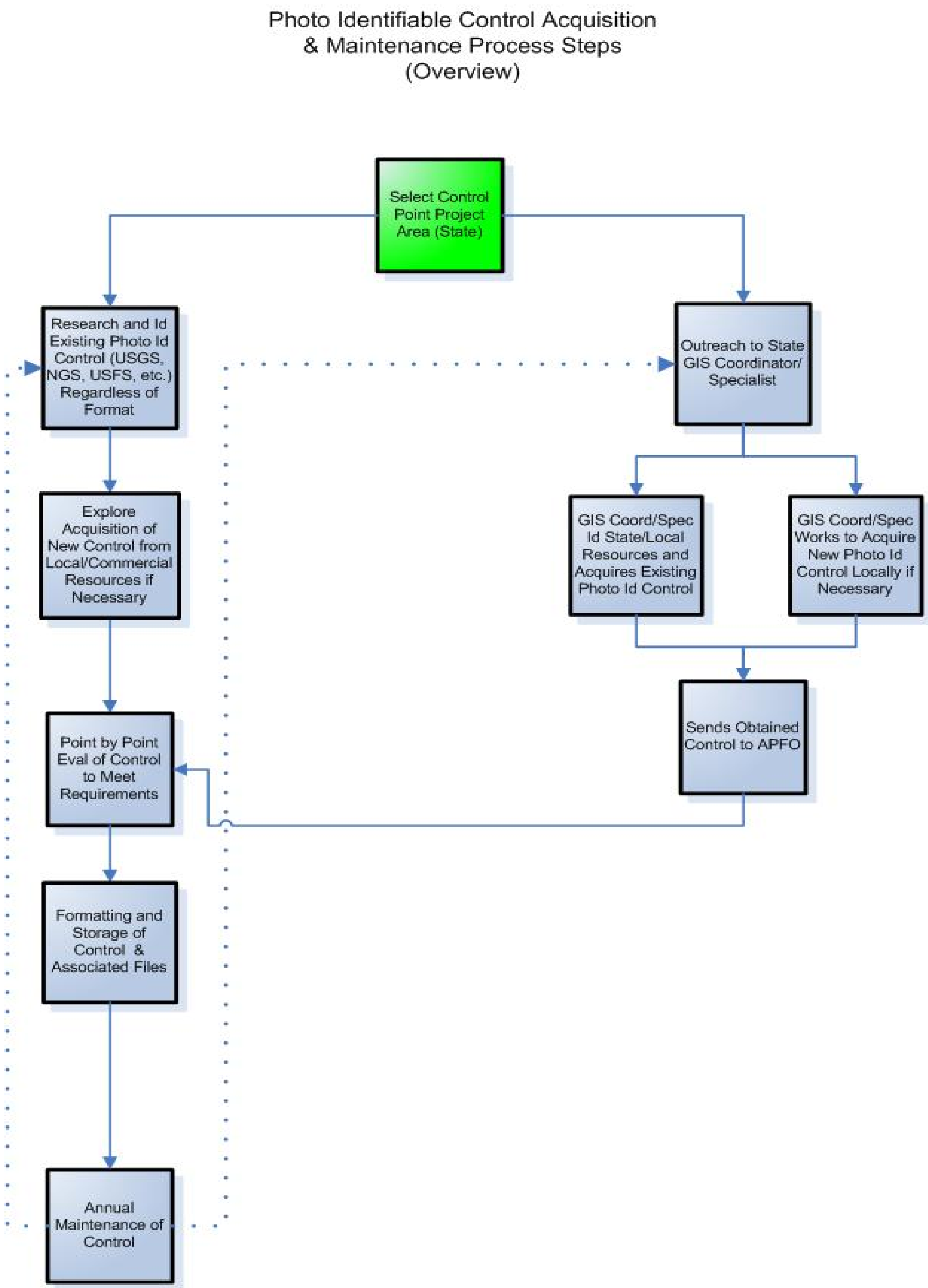


Figure 1 – Photo Identifiable Control Acquisition & Maintenance Process Steps

Section 5 – Photo Control Database Design

The following is a list of field names, descriptions, types, and lengths for the photo identifiable control point database built for the 2006 NAIP UT Pilot. This control database is maintained presently as a simple DBF, which may be modified/updated via MS Excel or via ArcMap by adding LAT, LON values, either enabling the creation of point shapefiles or through simple use of these spatially enabled 'events'.

Although the field types and lengths are not the most conducive to the smallest file size, they have been chosen to attempt to accommodate the most possible future control point formats and field lengths with the greatest ease of integration, as knowing the format of all existing and future photo identifiable control obtained through various means (even with a standard in place) is not plausible. Thus, most field lengths are much longer than necessary, and many are String fields, which will accommodate most any text regardless of format.

The terminal format of this database is an Oracle table, allowing the storage of all data, including supplementary data, such as .txt, .doc, or .jpg files, to be stored in a single location with minimal risk of loss. The Oracle table will also tolerate almost any type of expansion the database incurs as it grows and as coverage begins to encompass a larger geographic area.

POINT_ID1: Surveyor named identification of point (String 50)
POINT_ID2: Surveyor secondary identification of point (String 50)
APFO_ID: APFO's point identification name (String 50)
LAT: Latitude in Decimal Degrees (Double 19)
LON: Longitude in Decimal Degrees (Double 19)
ACCURACY: Survey accuracy information for point (String 50)
STATECTY: 5 digit FIPS of where the point is located (String 5)
ST: 2 digit State FIPS of where the point is located (Short 2)
DESCRIPT: textual description location of point (String 50)
UTM: UTM zone of where the point is located (Long 9)
COL_DATE: Original or most recent point collection/visit date (String 50)
MON: Is point monumented (String 50)
POS_DATUM: Positional datum (e.g NAD83) (String 50)
ELEV_DATUM: Elevation datum (String 50)
ELEV: Approx. elevation of point, ellipsoid height if available (String 50)
QUALITY: APFO populated quality assessment of point for specific purpose of inspection. Is the point easy to use for inspection? 1=Excellent, 2=Good, 3=Average, 4=Difficult, 5=Recommend Removal from Inspection Database. This field will allow for APFO to keep current a quality inspection point database, based on inspector observations (String 50)
ADD_DATE: Date point added to the APFO control database (String 50)
SUP_DATA1: supplemental data field, including hyperlinks to websites, images, sketches, detailed descriptions, etc. (String 100)

SUP_DATA2: Same as SUP_DATA1 (String 100)
SUP_DATA3: Same as above (String 100)
SUP_DATA4: Same as above (String 100)
SUP_DATA5: Same as above (String 100)
SUP_DATA6: Same as above (String 100)
DATA_SRCE: Source of the control data (USGS, NGS, USFS, etc.) (String 50)
CNTCT_NAME: Name of primary contact for control point (String 50)
CNTCT_PHON: Phone for primary contact for control point (String 50)
CNTCT_EMAL: Email for primary contact for control point (String 50)

Future suggested fields not currently in the database may include: a field noting whether the point has ever been used by a vendor for an Aerial Triangulation (AT) solution, and in what year(s); a field that identifies whether the point is valid for 2 meter resolution (or resolutions other than 1 meter) inspection; and a general comments field.

Section 6 – Inspection Process

Non-automated Inspection Process

For the 2006 UT NAIP Pilot Project, all horizontal accuracy inspection was completed based on a non-automated inspection process. This manual process is described below. The same process was completed by three independent inspectors, who present results in Section 7.

The following is brief documentation of the process used to measure horizontal accuracy of the 2006 NAIP Utah imagery. This process documentation is only for this pilot year, and only for Utah; in the future the process may be modified, standardized and automated in a manner similar to other already in place standardized NAIP inspection processes.

This “offline” process has been developed to accommodate changing requirements: measuring 2006 NAIP UT to absolute accuracy specifications rather than relative accuracy specifications, which are still in place for all States other than Utah.

Basic Process

1. An “inspection” point shapefile has been created for each inspector. There are three inspectors inspecting the horizontal accuracy of the 2006 NAIP UT imagery. The compressed county mosaics are the deliverable to be inspected.
2. Each inspection shapefile will be identical in structure and will consist of the following fields: POINT_ID1, QUALITY.
3. An inspection template will be set up. The inspection shapefile is added to an ArcMap session, then the x, y points from a copy of the photo_control_vxxx.dbf, the county boundaries shapefile, and lastly the NAIP imagery (Compressed County Mosaic) for a given county to be inspected. The coordinate system and projection are to be defined correctly in ArcMap (for Utah, this means NAD83 UTM12) for a given inspection location. By adding the inspection shapefile first, the projection should already be set correctly for Utah.
4. Each point from the photo_control_vxxx.dbf is zoomed into at a scale appropriate with seeing what the point represents on the 2006 NAIP imagery.
5. Editing will begin on the inspection shapefile. Each photo_control_vxxx.dbf inspection point (QC point) is evaluated in comparison to where the imagery should be with respect to it.
6. The inspector adds a point (edits) to the inspection shapefile where the feature described on the photo_control_vxxx.dbf actually exists on the imagery. Each inspection point is attributed in the two fields mentioned above (POINT_ID1, QUALITY). The POINT_ID1 field is populated with the exact same name as is in the POINT_ID1 field of the photo_control_vxxx.dbf. This is so that inspectors ensure each point gets inspected and there is a reference to the inspected point in the inspection shapefile. The POINT_ID1 field may be attributed easily using the

‘Attribute Transfer’ Tool in ArcGIS. The QUALITY field is populated with a code from 1-5 (1=Excellent, 2=Good, 3=Average, 4=Difficult, 5=Recommend Removal from Inspection Database), referencing how useful the inspector found each control point for horizontal accuracy inspection purposes. This field will be reviewed after inspection is completed, and points rated as 4’s or 5’s will be further evaluated to determine future use as inspection points. It is possible that a few points, due to changes in the landscape will be unusable for inspection. If this occurs, the inspector is to skip the point and note its APFO_ID; statistics will be adjusted accordingly at the end of the inspection process in determining if the dataset is within the prescribed accuracy specifications. It is also possible that some points represent features that are “barely” visible. If the MDOQ layer from the GDW can be used as reference only, than this is acceptable as long as inspection is done only based on the CCM versus the control points.

7. The inspector saves edits often. After the imagery is inspected at each control point (QC point) on the photo_control_vxxx.dbf, the inspector runs the “Point Distance” Tool from the ArcMap 9.1 Geoprocessing Toolset. The “Input Features” is the inspection shapefile; the “Near Features” is the photo_control_vxxx.dbf, the “Output Table” is named appropriately, and the “Search Radius” is 50 (units will be meters). The resulting table provides a set of point distances between each inspection point and its given location on the imagery.

8. Inspectors’ data is compared to each other and averaged as well, to minimize the affects of “human error” in the inspection process.

<u>Automated Inspection Process</u>

While modifications to the NAIP inspection process moving from relative control methodologies to absolute have not occurred yet, a modification to the automated inspection process will be required to streamline inspection and log results in a standardized manner.

Section 7 – Pilot Study Results and Comparison

The following section contains Pilot Study results and assessment by inspector. At the conclusion of the section, inspectors' data is compared for purposes of validating the inspectors' results. Each inspector has detailed the results in their own words.

Inspector 1 Results

Overall State Coverage

405 out of 410 photo control points were used for inspection. 5 points were omitted as they were deemed not capable of being inspected, due to changes in the physical landscape, such as tree removal, and road or tower construction or demolition.

Of the 405 points used, the average horizontal offset was **2.56** meters, with the maximum offset of 26.50 meters. The **sum** of all the offsets over the 405 points was **1037.55** meters. The RMSE for the offsets over the 405 points is approximately **3.26** meters.

Of the 405 locations inspected on the imagery, 15 locations were over the allowable horizontal threshold of 6 meters; 390/405 locations were within tolerance, which is **96.30%**. Per the contract, **"95% of points tested must fall within six (6) meters of pre-determined quality assurance ground control points".**

County by County Coverage

Utah has 29 Counties. If photo control inspection points are broken down on a County by County basis, imagery did not meet accuracy requirements in the following counties: Box Elder (49003), where imagery was within requirements on 28/32 points (87.50%); Salt Lake County (49035), where imagery was within requirements on 38/42 points (90.48%); Weber County (49057), where imagery was within requirements on 7/8 points (87.50%); Millard County (49027), where imagery was within requirements on 16/18 points (88.89%); Sanpete County (39039), where imagery was within requirements on 13/14 points (92.86%). Of the above Counties, Weber, Millard, and Sanpete have an insufficient number of test points (based on NSSDA standards) to be inspected as a project area on their own.

AGRC Points Only

AGRC acquired 3 points per County at the sub-foot accuracy level. These points also came with photos and sketches, eliminating any guesswork as to their exact locations during inspection; these were the best and easiest points to use during inspection. Of these 87 highly accurate points, the imagery was within the 6 meter tolerance on 86 of the points during inspection. This is equivalent to **98.85%** of the tested locations meeting specified requirements.

Quality Values of Photo Inspection Points

Each inspector rated the quality of the photo control inspection points on a scale from 1 to 5. A quality rating of 1 represents the easiest point to use for inspection, and would likely have a very well defined location and description, supplemental data, good contrast and/or right angles to geometric objects on the imagery. In other words, these points would be the most easy to define an exact location on the imagery with little or no subjectivity. A quality rating of 5 was the worst, an almost unusable point, as the features the point represented were too large for exact locations, barely visible, or possibly even removed recently. A quality rating of 3 was given to points that were of good quality and usable with little trouble, although they may not have significant supplemental data or sketches. Quality ratings are significant because as the rating approaches 5, human error increases in the inspection process due to the need to use inference during inspection.

Inspector 1 rated 50/405 points as a quality of 1. Of these points, imagery met the 6 meter accuracy requirements on all 50 (100%). Inspector 1 rated 59/405 as a quality of 2. Of these points, imagery met requirements on 58/59 (98.30%). Inspector 1 rated 244/405 as a quality of 3. Of these points, imagery met requirements on 237/244 (97.13%). Inspector 1 rated 42/405 as a quality of 4. Of these points, imagery met requirements on 37/42 (88.10%). Inspector 1 rated 10/405 as a quality of 5. Of these points, imagery met requirements on 8/10 (80.00%). The decrease in the success percentages above can likely be attributed at least partially to the human factor; the increase in the difficulty of inspection as the quality of selected inspection points decreases. There is a direct correlation between the subjective quality of the point and the horizontal accuracy of the imagery; the worse the quality of the point, the less likely (at least by %) the imagery was to meet accuracy requirements.

Inspector 1 Summary

If the State is inspected on the whole (a project area), it passes inspection with **96.30%** of inspected locations meeting horizontal accuracy requirements. If the State is inspected just based on the AGRC points, it passes inspection with **98.85%** of inspected locations meeting requirements. If only the highest quality (quality ratings of 1's and 2's) points are considered, the imagery passes inspection with **99.08%** of inspected locations meeting requirements. If the Counties are inspected on a County by County basis, 24/29 Counties pass, 5/29 Counties fail, however, 3 of *those* Counties have statistically insufficient samples to stand on their own during inspection.

The following maps and charts are graphical representation of the inspection results:

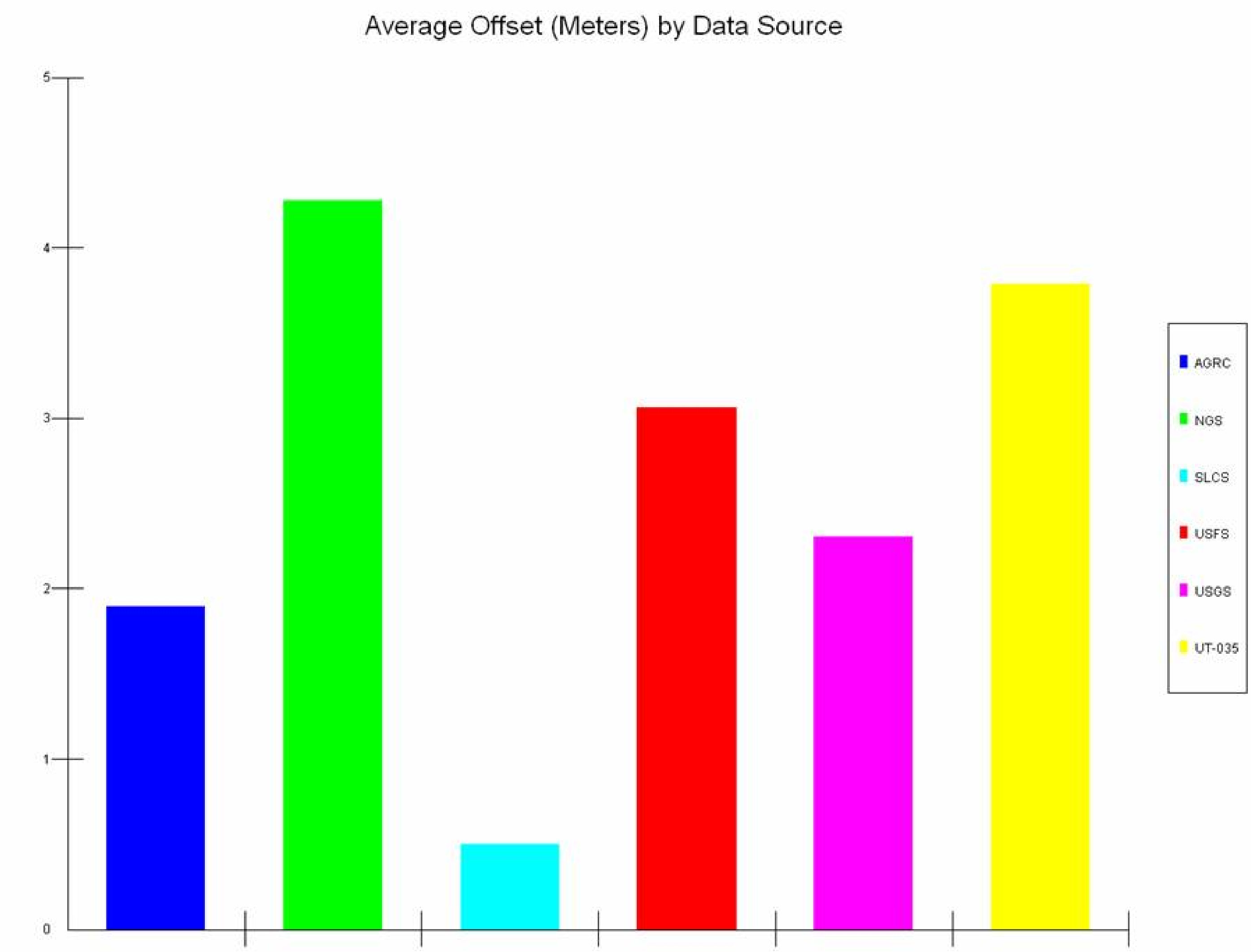


Figure 2 – Inspector 1 Average Offset by Data Source

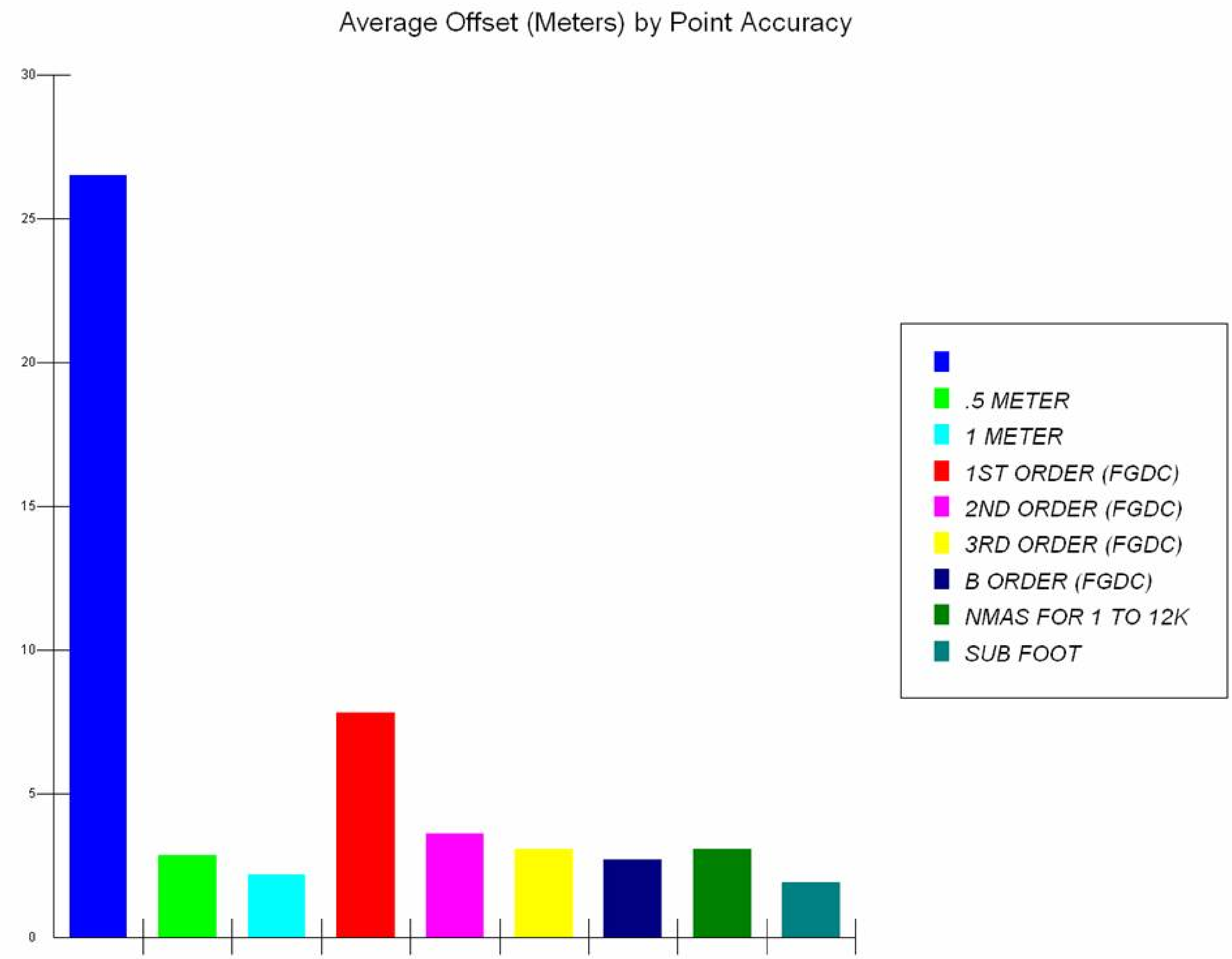
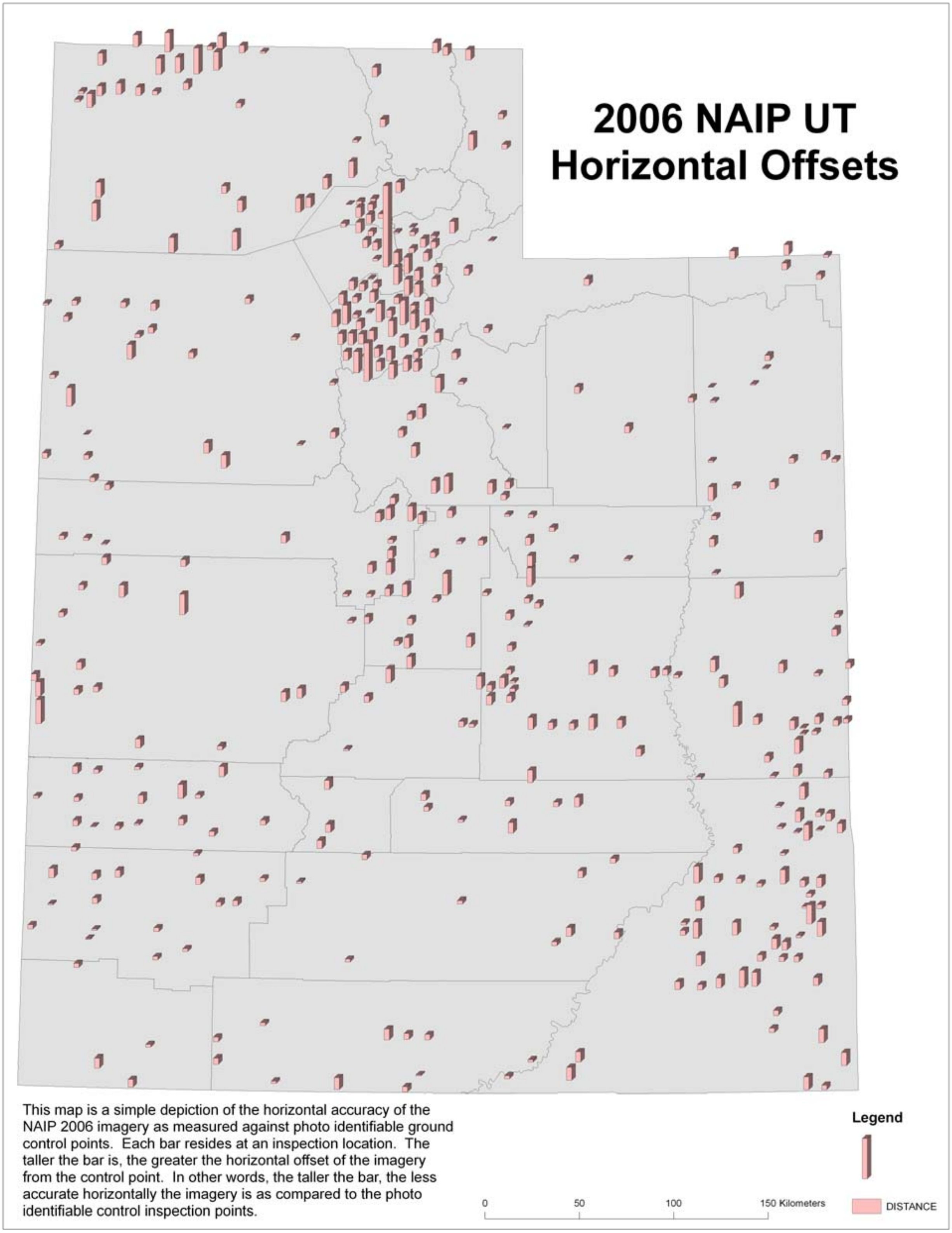
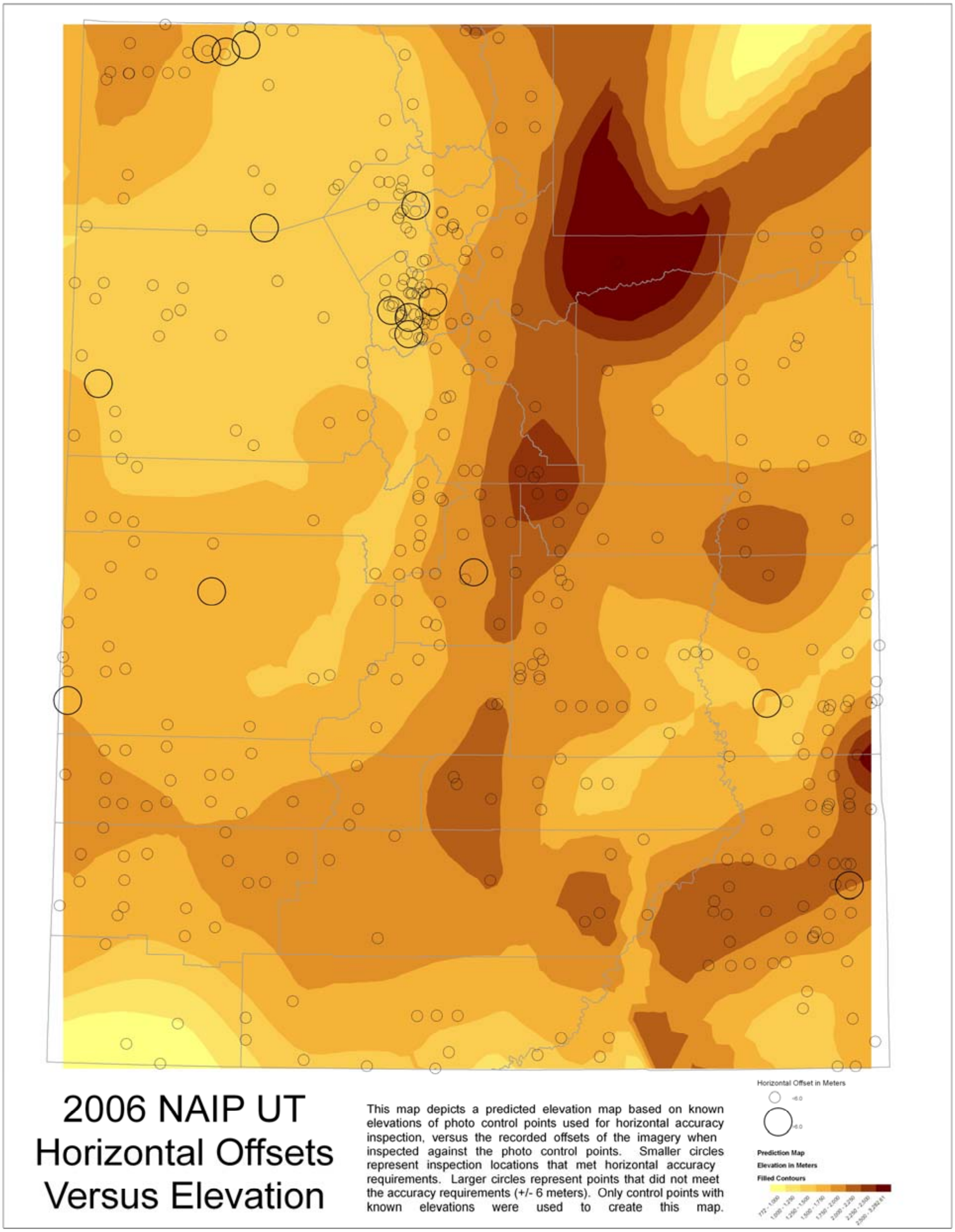


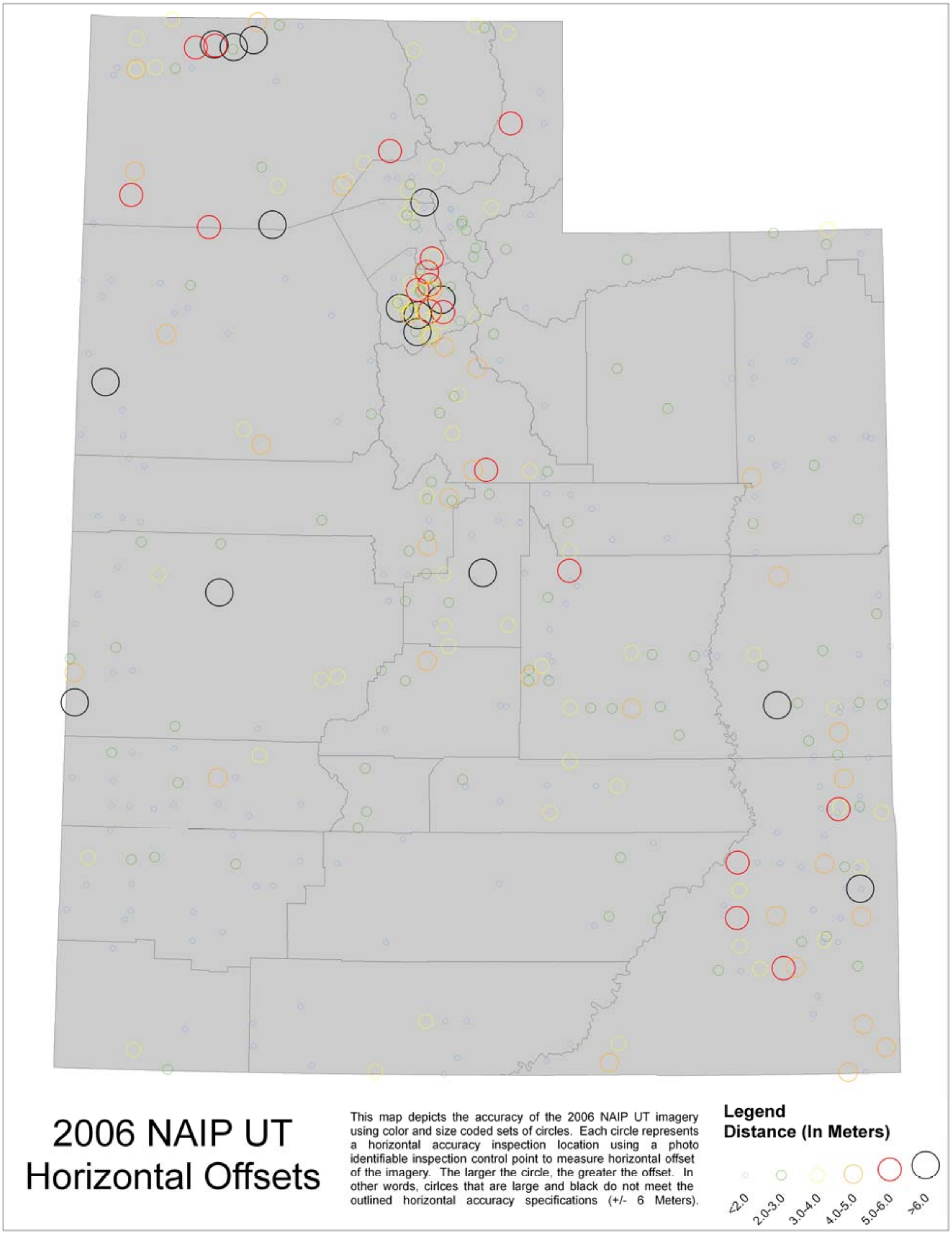
Figure 3 – Inspector 1 Average Offset by Point Accuracy



Map 1 – Inspector 1 Horizontal Offsets (Bar Map)



Map 2 – Inspector 1 Horizontal Offsets Versus Elevation



Map 3 – Inspector 1 Horizontal Offsets (Graded Circle)

Inspector 2 Results

<u>Overall data results</u>

A total of 410 ground control points were delivered to analyze the absolute accuracy on the Utah 2006 NAIP imagery. Of the 410 points, 400 were digitized on the NAIP imagery to determine the horizontal accuracy. The remaining 10 points were deemed unusable. Many of these 10 points were on ground features that no longer exist.

With the absolute accuracy tolerance being set at 6 meters, only 15 of the points were measured more than 6 meters from absolute ground. The following table illustrates the 15 points (*Figure 4*).

INPUT_FID	NEAR_FID	DISTANCE
399	402	26.09404844370
33	28	8.62191586430
189	184	7.92515047624
30	29	7.78664304880
311	323	7.72405444454
235	258	7.55517414431
284	277	6.94024486483
282	276	6.54823678261
260	266	6.52792044390
41	44	6.51614755882
34	27	6.38207344575
278	287	6.32041234507
77	79	6.28993081629
71	71	6.04284058158
367	376	6.01315938697

Figure 4 – Inspector 2 Point Distance Table for Points out of Tolerance

Most of the points over 6 meters were very close to tolerance, except for one. The **mean** offset distance was **2.35 meters**, the **standard deviation** was **2.01 meters**, and the **median** was **1.91 meters**. This illustrates that most points were very good. The **RMSE** was **3.09 meters**.

Overall, the quality of the points was good. The control points provided by the Utah AGRC were the highest quality. All AGRC points were sub-foot accuracy and were very clear and easy to spot on the NAIP imagery. The USFS points were good quality. The accompanying data with these points was very helpful. USGS points were generally average quality. Some of the points were difficult to digitize. The NGS points were the most difficult to work with. Most of these points were on structures with high parallax. The quality rating system results are as follows:

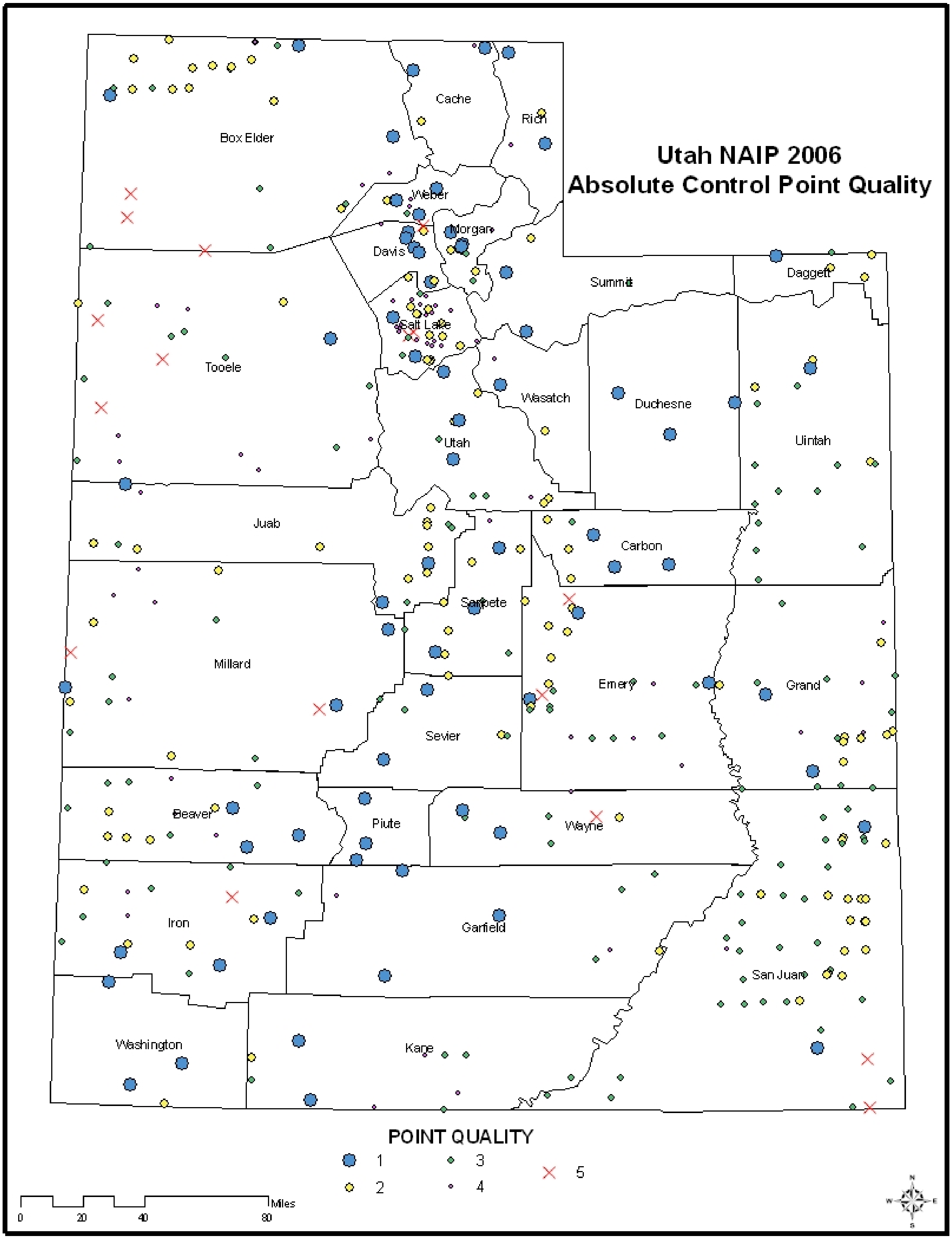
73 points were rated a “1”

113 points were rated a “2”
130 points were rated a “3”
67 points were rated a “4”
17 points were rated a “5”

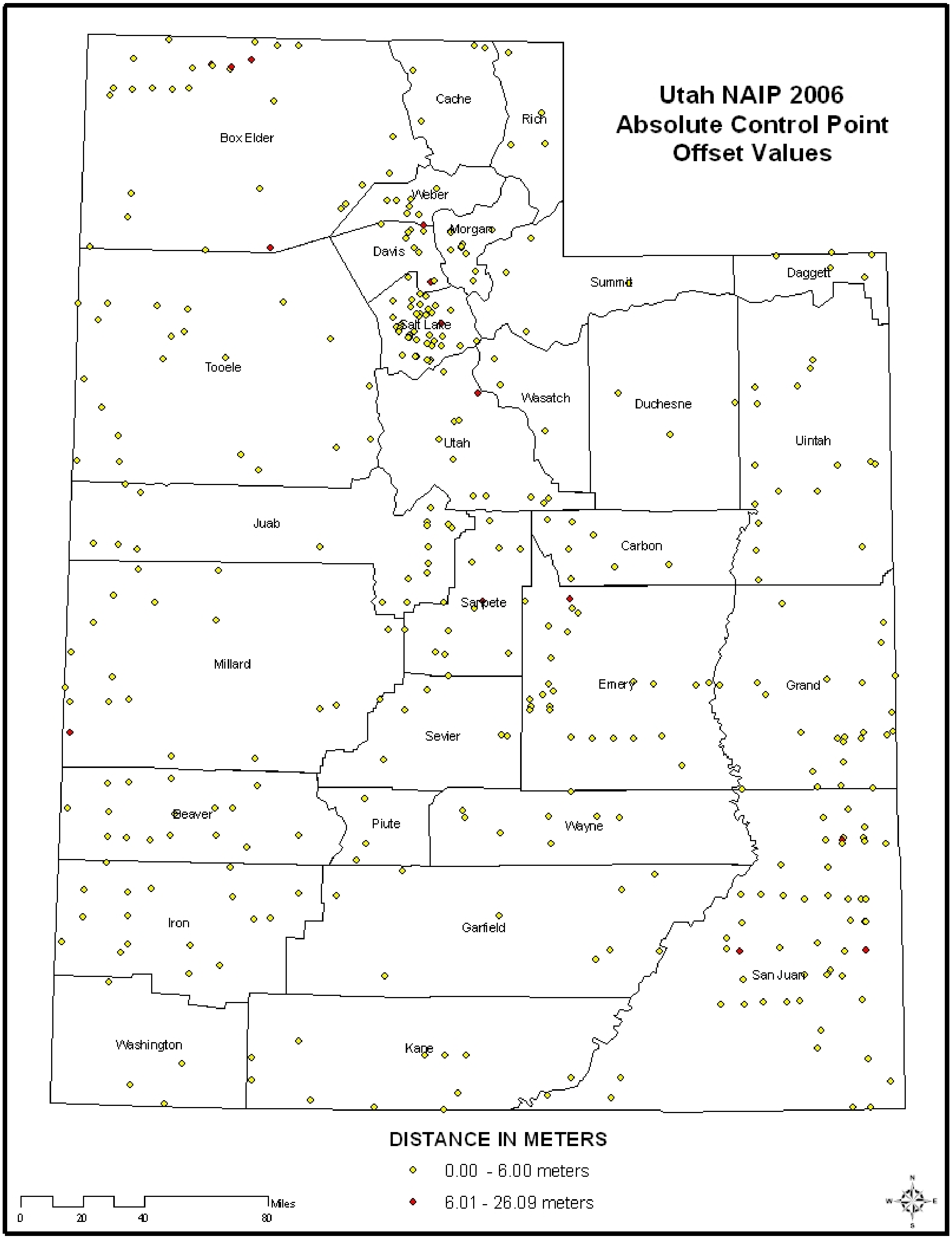
(1=excellent, 2=good, 3=average, 4=difficult, 5=recommend removal from inspection dbase)

Only 7 points had a quality rating of “3, 4, or 5” and were over 6 meters offset. None of these were collected by the AGRC.

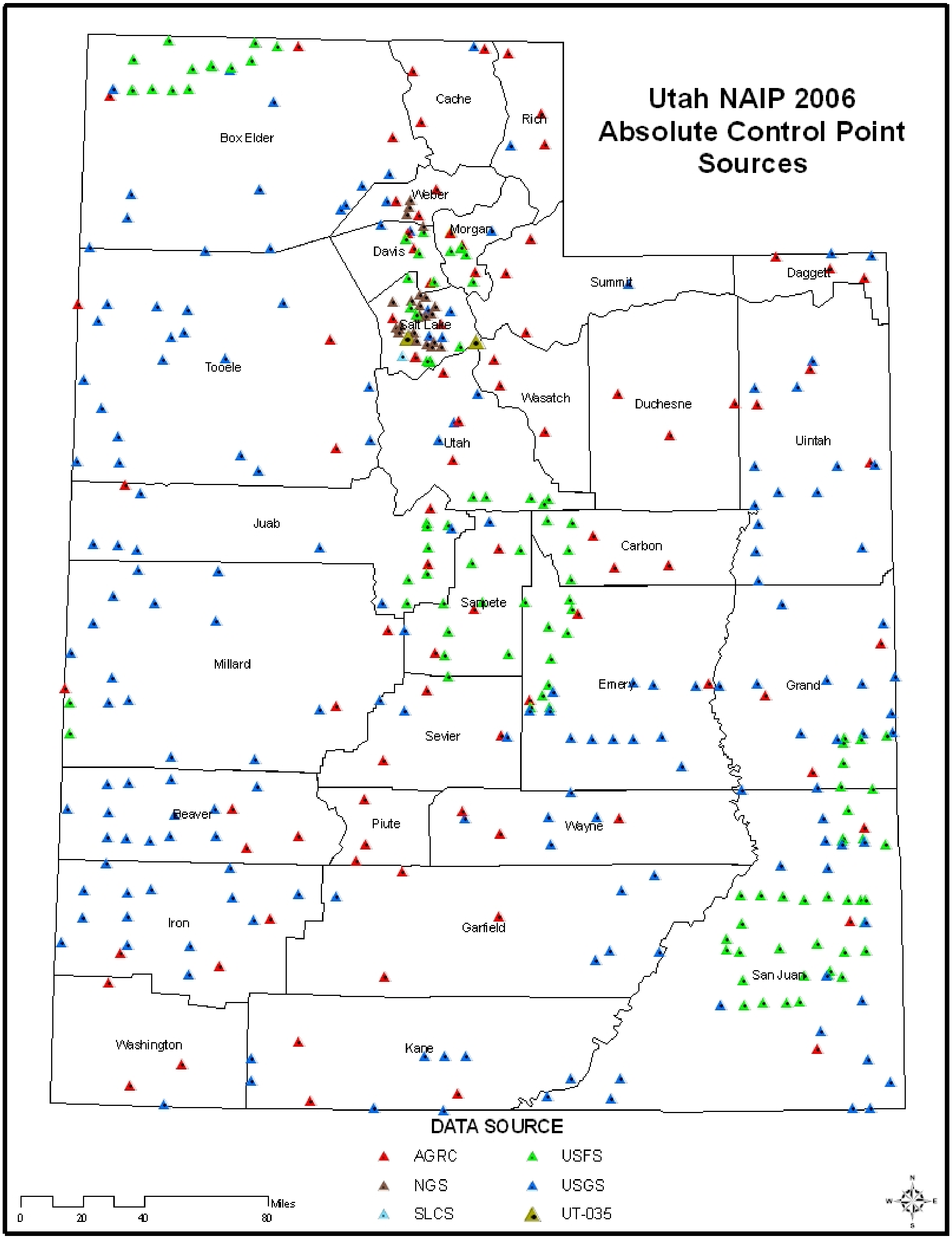
The following maps geographically represent the data collected from the Utah NAIP control point inspection:



Map 4 – Inspector 2 Absolute Control Point Quality



Map 5 – Inspector 2 Absolute Control Point Offset



Map 6 – Inspector 2 Absolute Control Point Sources

Conclusions drawn from the inspection

- Overall, 96% of the points digitized were within tolerance.
- AGRC points were of the highest quality.
- USGS were of the lowest quality (based on amount of 4s and 5s).
- Greater than 6 meter offset occurred mostly on points in the remote areas (e.g. west desert, canyonlands).
- As stated before, the NGS points were very difficult to work with because of parallax.
- Points that fall on crossroads or T-intersections need better descriptions as to where the point is. (except USFS)
- Control points on vegetation can be very difficult.
- The jpeg samples need to be clear so that an inspector can identify the feature being picked.
- A comment field should be added to the control point collection set so that the inspectors can identify "on the fly" problems that are encountered.
- The inspection, in its current "raw" form, took approximately 5 days to complete.

Suggestions for an automated "online" inspection

As the NAIP imagery is currently inspected using an efficient tool developed in ArcGIS, the new absolute control point inspection should be incorporated into this. Currently, with relative horizontal accuracy inspection, the points are picked on a reference image and on the NAIP image. There is interaction between the inspector and the inspection tool when doing this, but much of it is automated. With the new process, the same could apply. When digitizing a point, the automation could populate the fields in the attribute table automatically. Toggling between CCMs can be done with one button. Using the provided resource materials (e.g. jpgs, OPUS reports, etc.) could be done with the click of one button instead of navigating through directory structures. The "Point Distance" tool can be automated as well. When all the data is compiled, the update to a database can be accomplished with the click of a button.

The current software is very adequate for the NAIP absolute horizontal accuracy inspection. However, since the APFO has current license agreements with other software, there may be alternatives out there. **Socet for ArcGIS** or **Image Analysis for ArcGIS** are two examples of extensions that have robust features that would help the horizontal accuracy inspection.

Inspector 3 Results

The points in the Base Control file were from the following sources:

USGS: 182
USFS: 108
AGRC: 87
NGS: 30
SLCS: 1
UT-035: 2

404 points measured
6 points not measured
RMSE: 3.85
Median: 2.65
Mean: 3.14
Standard Deviation: 2.30

Range of Point Distance measurements:

0.150277 – 16.801489 meters

Point Distance:

1 -3 meters: 235
3 – 6 meters: 137
6 – 10 meters: 25
10 – 17 meters: 7.

Points out of Tolerance:

26.6% of NGS points (8 of 30)
9.9 % of USGS points (18 of 182)
7.4% of USFS points (8 of 108)
1.1 % of AGRC points (1 of 87)

Quality:

1 (best): 112 points
2: 117 points
3: 114 points
4: 40 points
5: (worst); 21 points

<u>Inspection Process</u>

The absolute control point test was done by measuring pre-selected locations on 2006 NAIP imagery, and comparing the points as measured, to the control point file. Each point measured was given a quality rating from 1-5: 1= excellent, 2 = good, 3 = average, 4 = difficult, and 5 = recommend removing from the database.

Calculating Statistics

After measuring the points, the inspection file was run against the Base Control file in the Point Distance tool from ArcGIS's Geoprocessing module. The resulting file was opened in Excel, where some basic statistics were calculated. The RMSE was calculated using the formula RMSE = $\sqrt{(\sum z^2)/n}$, where z is the point distance and n is the number of measurements. ("z" is of course the direct distance between the two points, the $\sqrt{(x^2 + y^2)}$).

The **RMSE** calculated was **3.852 meters**. When calculated using "**n-1**", the result was **3.856**. The **median** value was **2.65 meters**, and the **mean** was **3.14 meters** with a standard deviation of **2.227**. (This was calculated with the formula sd = $\sqrt{1/n \sum(x_1 - x_2)^2}$, where x_1 is the measured value, x_2 is the measured value (the mean), and n is the number of measurements.) When calculated using "n-1" the **standard deviation** was **2.30**. (Statistics in ArcGIS gave **2.227** as the **Standard Deviation**)

92% of the measured points **fell within the 6 meter tolerance** established for this imagery.

235 points (58%) were between 0 – 3 meters from the control, and 137 (34%) fell between 3 and 6 meters from the control.

25 points (6%) fell between 6 and 10 meters from the control and 7 (2%) were greater than 10 m.

The distribution of the measured points is shown below:

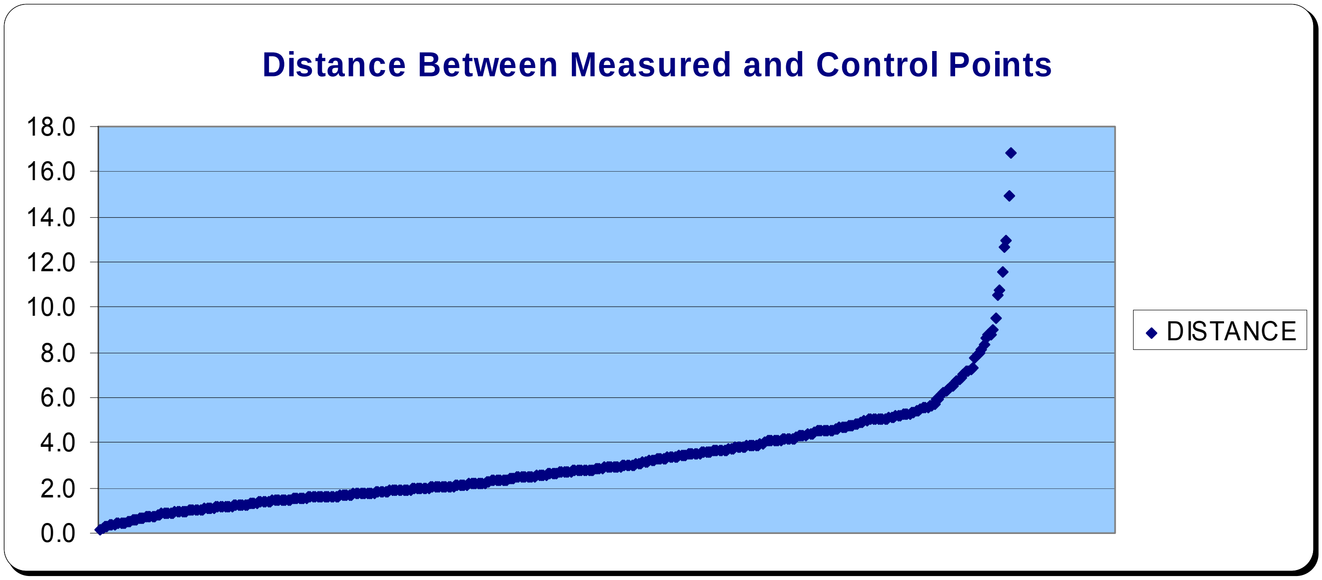
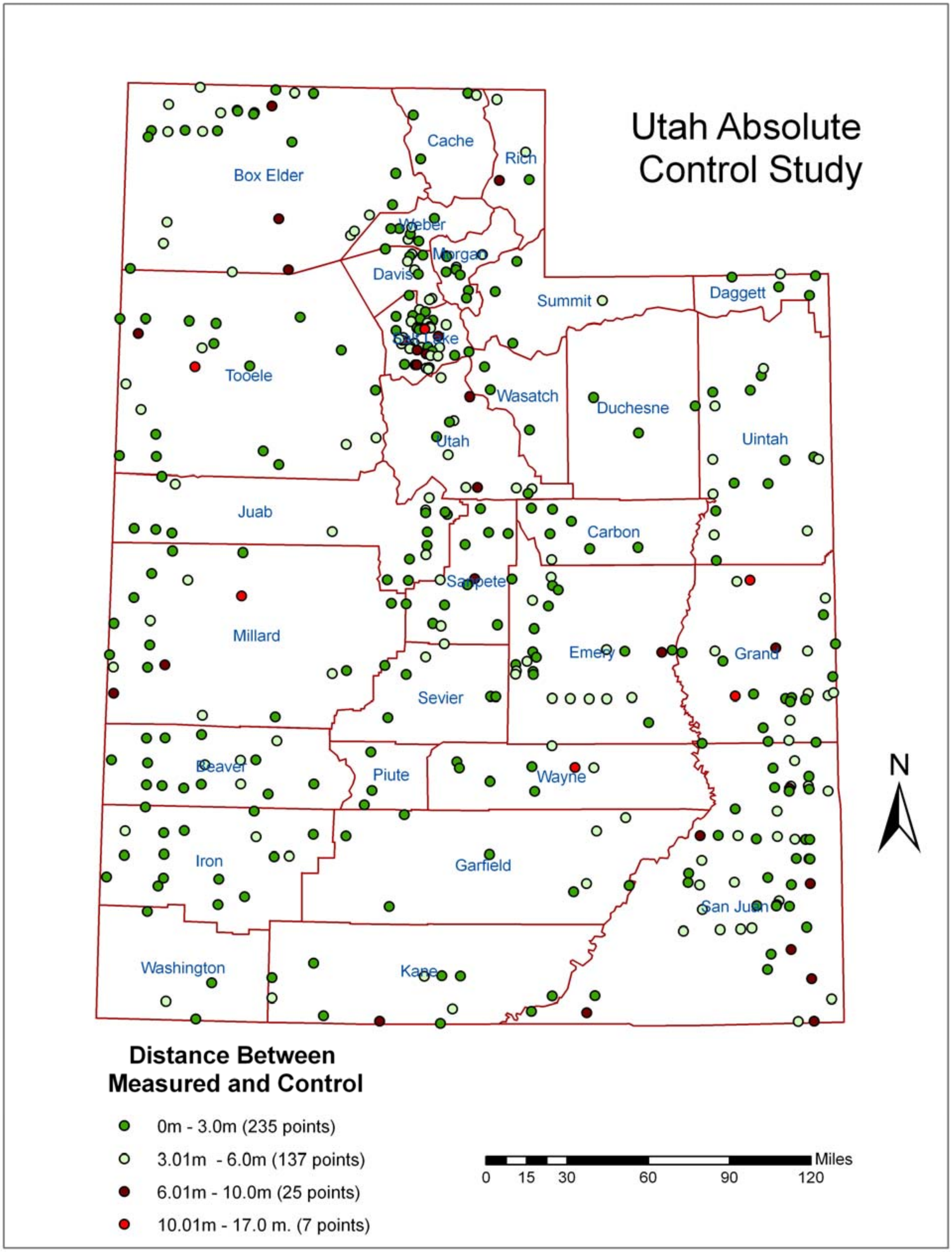


Figure 5 – Inspector 3 Distribution of Point Distance Measurements (the x axis has no value)

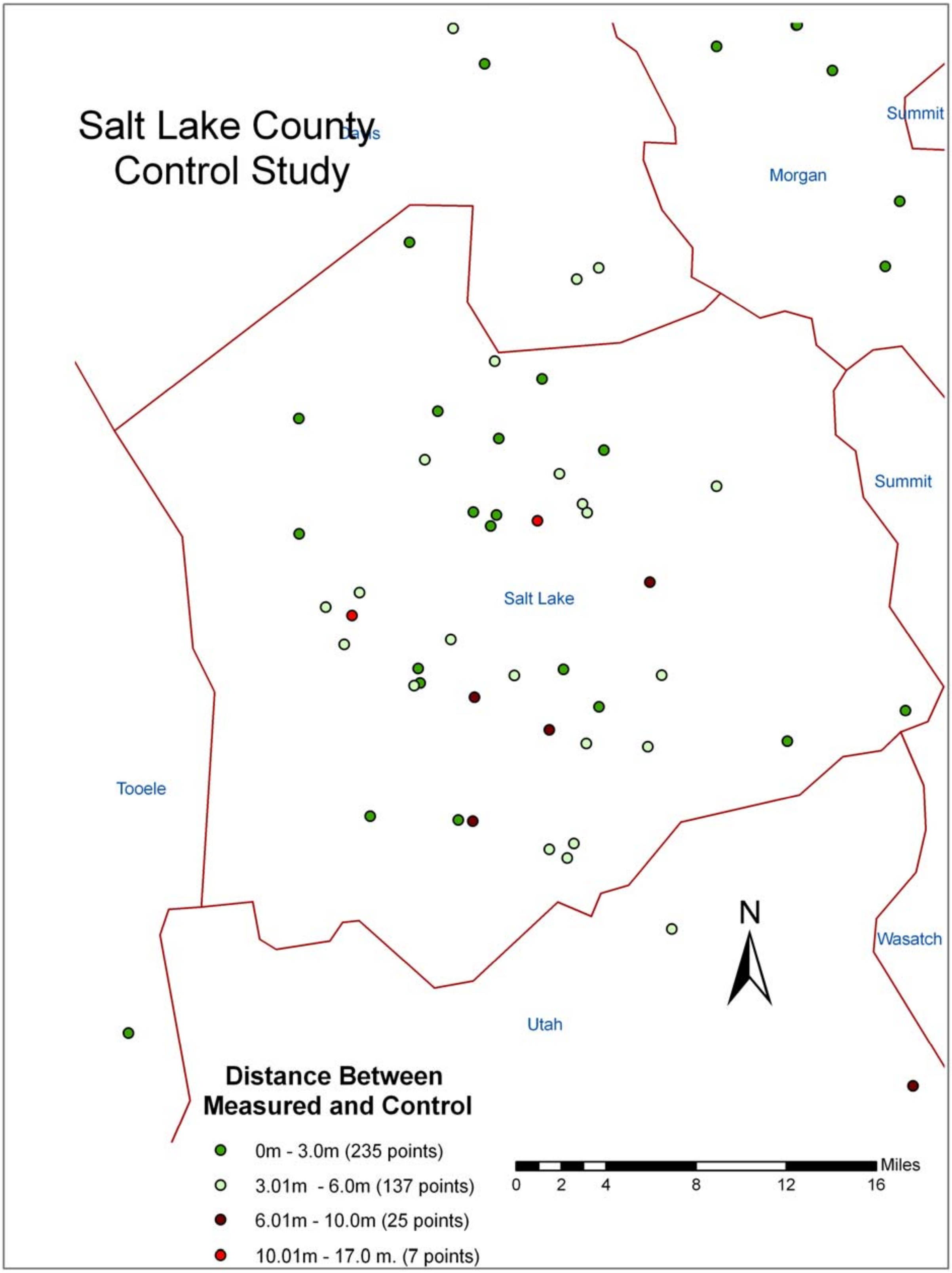
Of the 32 points over the tolerance, 18 came from USGS, 8 each from NGS and USFS, and 1 from AGRC. Of the seven points measured at over 10 meters from the base, all were from USGS except two in Salt Lake County collected by NGS.

Points Not Measured

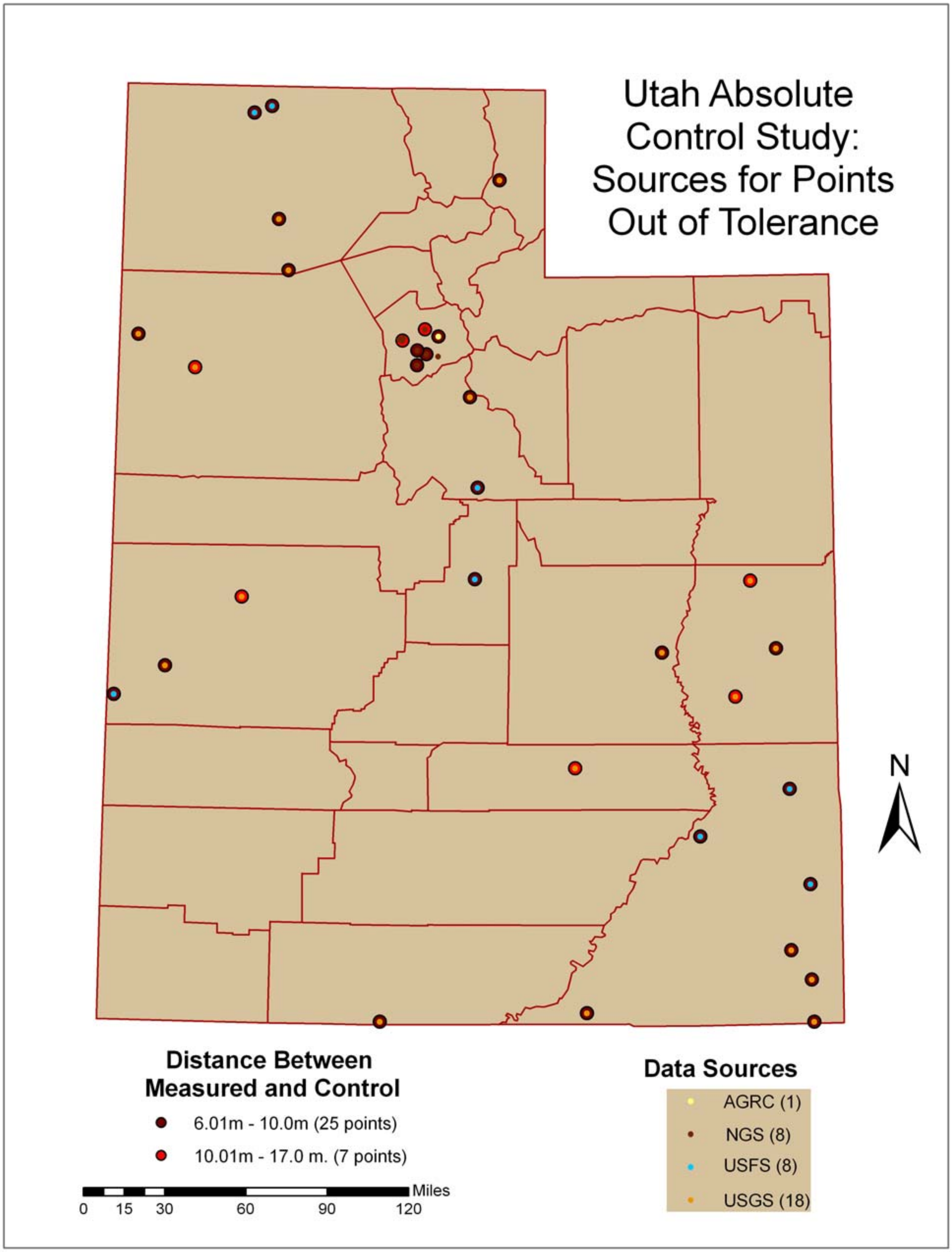
MR0539: feature, a concrete base, was not visible to me (NGS)
95-1225: cattle guard no longer visible (USFS)
95-234: bush no longer visible (USFS)
LO0950: tower no longer visible (NGS)
305065: tree no longer visible (USGS)
900459: tree no longer visible (USGS)



Map 7 – Inspector 3 Absolute Control Distance Between Measured and Control

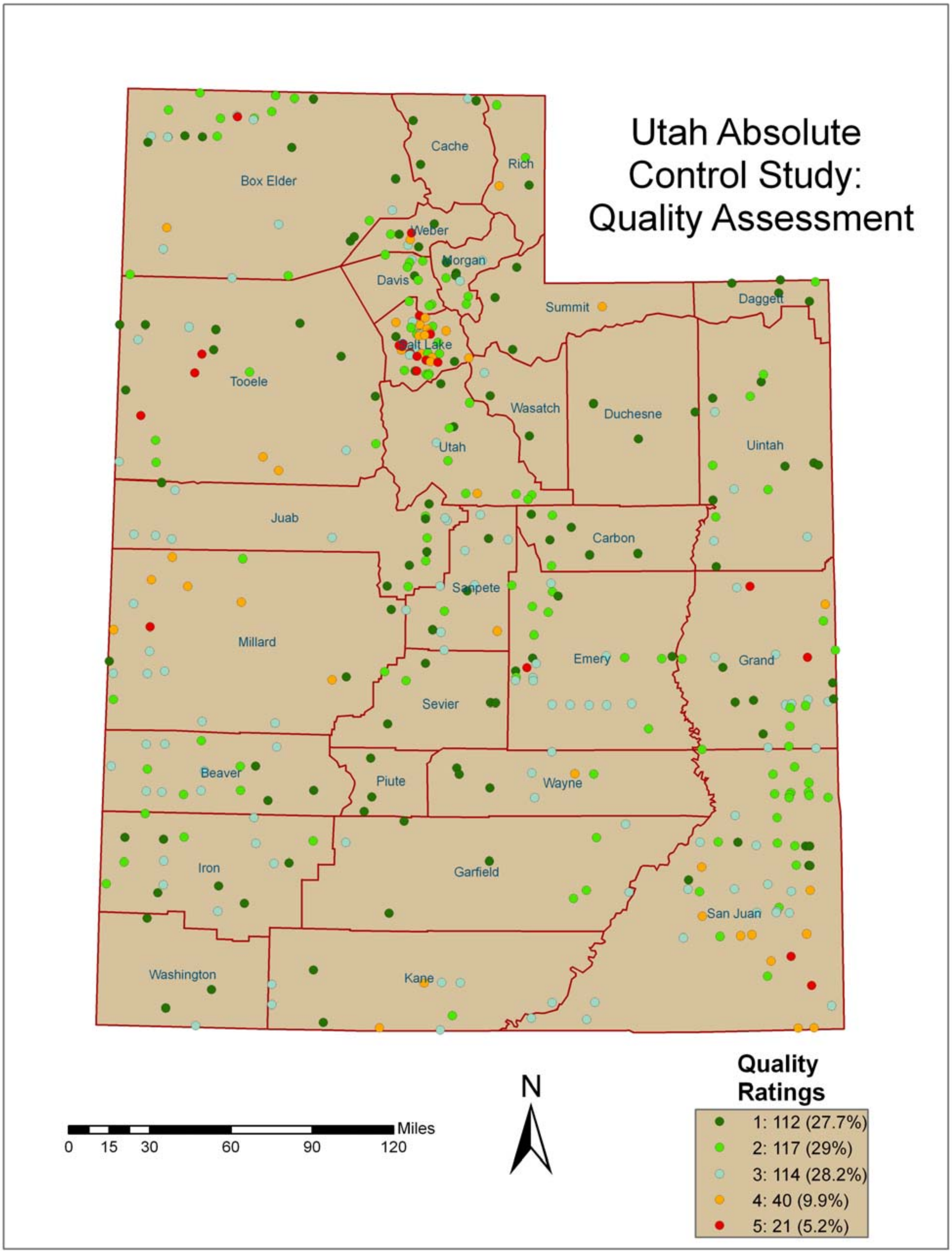


Map 8 – Inspector 3 Absolute Control Distance Between Measured and Control (Salt Lake County)



Map 9 – Inspector 3 Sources for Points Out of Tolerance

The points measured at over 10 meters from the base were almost all given a quality rating of 4 or 5. The points falling within 6 -10 meters from the base showed no pattern of quality assessment. However, this rating is for the quality of the points as an inspection tool, and not for the accuracy of the imagery.



Map 10 – Inspector 3 Distribution of Quality Scores

Quality Ratings by Source

AGRC (87 Total):
- 1: 71 (81.6%)
- 2: 13 (14.9%)
- 3: 3 (3.4%)
- 4: 0
- 5: 0

USFS (108 Total):
- 1: 15 (13.9%)
- 2: 56 (53.7%)
- 3: 26 (24.1%)
- 4: 7 (6.5%)
- 5: 2 (1.9%)

USGS (182 Total):
- 1: 26 (14.3%)
- 2: 46 (25.3%)
- 3: 80 (44.0%)
- 4: 21 (11.5%)
- 5: 8 (4.4%)

NGS (30 Total)
- 1: 0
- 2: 1 (3.3%)
- 3: 5 (16.7%)
- 4: 11 (36.7%)
- 5: 11 (36.7%)

UT-305 (2 Total):
- 1: 0
- 2: 0
- 3: 1 (50%)
- 4: 1 (50%)
- 5: 0

SLCS (1 Total)
- 1: 0
- 2: 1 (100%)
- 3: 0
- 4: 0
- 5: 0

Reasons for Quality Ratings

Good quality scores went to almost all of the points collected by AGRC. These were easy to locate exactly because they were documented with a series of shots showing the points from the air, from all cardinal directions, and from directly above in a close-up photo. It was generally very easy to locate precisely where this was supposed to be. The error in these cases would be from hand-eye coordination in measuring the point. Displacements for these points most likely came from offsets in the NAIP imagery itself.

Many of the points from USFS also received good scores. They were often documented with hand drawn sketches and brief but clear descriptions. Some of these were vague; a designation of the centerline of a crossroads is not nearly as precise as the corners of grass and sidewalk picked by AGRC.

Points were easy to locate when they were smaller features – a sidewalk, cattle guard, or very small bush. Wide driveways or roadways, and large trees were difficult to select accurately. In some cases it was possible to guess from context or older imagery where the feature had been located, but these points would be recommended for removal.

Difficulties in measuring came from the following:

1) Features had vague descriptions, like “dark spot.” Sometimes the description in the attribute table was the only identifier, and it was not clear.
2) Features were too large to locate precisely, such as a large tree. Often it was difficult to distinguish the tree from its shadow.
3) Something was obstructing the location (such as large vehicles parked on top of the precise curb corner AGRC had measured)
4) There was a lack of contrast between the feature and its surroundings. An example was an AGRC point where the measured curb corner did not stand out against the parking area. From the accompanying pictures it was evident that the parking area had been resurfaced sometime between the point collection and the NAIP flying.
5) The feature was impossible to locate from the description, the control’s location, or comparing the control to the MDOQ. One example was a concrete base for a sign located off I-84 near the entrance to Weber Canyon.
6) The control point to be measured against was not on the ground. Because of parallax, the feature was not displayed at its ”true” location. It was often difficult to find even the displaced top of the tower, and even more difficult to ascertain where it should have been if the image were a “true ortho”, and the control point displayed directly above its position on the ground.

Human error would come primarily from misinterpreting where the control points were supposed to be. With better screening of control in the future (collecting points similar to AGRC’s in quality), the possibility of error would be greatly reduced. Providing better documentation would improve inspector accuracy. Many of the points would be rated as “1” if they had a more clear description. The points themselves are very good.

Since 26.6% of NGS points were measured as out of tolerance, they should be used with reservations.

Future Data Collection

Guidelines for selecting control points were specified in *NAIP Control Point Requirements*, written January 2007. The following recommendations were noted from this inspection. Points should be:

1) On the ground.
2) On the smallest feature possible
3) On features that are likely to be permanent.
4) On features that are unlikely to be obscured by shadows, vehicles parking above them, etc.
5) In an area of good contrast between the feature and its surroundings
6) Well distributed geographically.

The points should have good documentation. This is crucial for accurate measurement. Photos of the GPS unit from all four directions, plus a close-up and a report, were more than enough information to locate the exact spot being surveyed.

Ideas for Inspection

I created a small customized toolbar with some of the icons used frequently, to eliminate searching through menus. This included: *Start and Stop Editing, Save edits, Zoom to Selected Feature,* the *Attribute Transfer* tool, and the *Attributes* editing box. An automated process would undoubtedly have the tools easily accessible. The inspection file (and possibly the project itself) would probably be pre-made. It would probably include a means to drive from one feature to another, and perhaps to automatically load the imagery. It might calculate the Point Distances as they are being measured, and add the measurement to the Attribute table of the inspection file. It would be easier to inspect if the point selection tool were transparent, or simply a crosshair, so that selecting the precise location of the point would be easier. It would be helpful to have the documentation photos linked to the control point, and easily accessed without digging through the folders to find them.

Overall, this process seems to be one that can be used successfully as we make a transition to using Absolute Control. Even an “offline” inspection process would be easy to do. It might be a good idea to train inspectors to do it in this way in case something goes wrong with a program.

Comparison of Inspector Results

The table below is a simple summary of overall results from all three inspectors:

Inspector	Points Inspected	Points Within Tolerance	Percent In Tolerance	RMSE (meters)	Mean Offset (meters)
1	405	390	96.30%	3.26	2.56
2	400	385	96.25%	3.09	2.35
3	404	369	91.34%	3.85	3.14

Figure 6 – Summary of Inspectors' Results

Inspector 1 Versus Inspector 2 Selected Points

Of the 400 control locations selected for inspection common to both inspectors, 258 points selected by the inspectors were within one meter of each other. That is to say, that regardless of where the control point actually fell in reference to the physical feature represented on the imagery, Inspector 1 selected 258 points on the imagery within one meter of the same location Inspector 2 selected his/her point.

The average distance between Inspector 1 and Inspector 2 selected points was 1.12 meters, which is only slightly larger than the size of one pixel. This indicates that Inspector 1 and Inspector 2 chose very spatially similar points throughout the inspection process.

Inspector 2 Versus Inspector 3 Selected Points

Of the 398 common locations used by both inspectors, 190 points were less than one meter from each other. The average offset was 1.76.

Inspector 1 Versus Inspector 3 Selected Points

Of the 401 common locations used by both inspectors, 189 points were less than one meter for each other. The average offset was 1.75.

Section 8 – Implementation on a National Scale

Based on the results of the Pilot, steady implementation of absolute accuracy standards is recommended on a National scale, moving forward at the pace that the limiting factors, such as access to control, allows.

Specifications for the Upcoming NAIP Contract

A new NAIP Contract is about to be issued. Within this contract specifications allow for both relative and absolute accuracy standards to be applied on a project area by project area (State by State) basis. This will allow for controlled implementation of absolute accuracy standards and smooth transition from one standard to another.

Database Design and Storage

While all the kinks are not worked out in the final design of the control point database, this should not be a limiting factor in implementation of the new absolute accuracy specification.

Acquisition of New Photo Identifiable Control Points

Acquisition of new control points (gratis or otherwise) is discussed in Section 4. Having enough points to QC deliverables is a limiting factor in implementation, unless the Government decides to take a leap of faith, and NOT inspect deliverables, or use an inspection process that includes accuracy and process reports from the vendor in addition to sampling of select sites for image inspection. Acquisition of points for the lower 48 States could take many years, and depends on cooperation with local, State, and Federal Agencies, data sharing and accessibility, manpower, and possibly levels of funding.

Maintenance of Control Point Database

Maintenance of the database cannot be overstated. While this may not be an obvious limiting factor, if the database is not continuously maintained, and points continuously evaluated for viability of use in the inspection process, the database will over time become old and useless. Maintenance is connected to acquisition, and part of the maintenance piece is the replacement of points when points are no longer of use for inspection. This occurs when there are changes in the landscape that render the point no longer visible, such as tree removal, demolition or construction.

Imagery for the Nation (IFTN) Cost Estimate

Given that NAIP looks to be entering a new 5 year cycle, and not knowing cycles that IFTN may or may not be a part of, the following cost estimate has been provided over a 5 year continuum, with regards to the acquisition and maintenance of a photo identifiable control point database.

From experience (both via UT AGRC and Private Vendor Quotes), it is safe to say that each new photo control point costs anywhere from $300-450 to acquire in the lower 48 States. 3 points per County for 2006 UT NAIP pilot were used. Over approximately 3000 Conus Counties, at a conservative $400/point, this is a total of $1,200,000. As a safe estimate, one could likely obtain 50% of the points from other gratis sources (State partnerships, USGS, USFS, local sources, etc.), so the total drops to approximately $600,000. Note this cost is based on a County structure for acquisition rather than a given geographic area, which is a more realistic model.

Regarding personnel costs, in the first few years, the "cost" of obtaining, ingesting, testing, formatting, maintenance, db management, development of inspection processes, etc., of the control points and supplemental data could be between 2-3 FTE positions. After such time it will likely be 1/2-1 FTE to maintain and keep in good current working order the data, ensuring format, upkeep, currency of points, etc. Assume 2 FTE for this estimate per year for the first 3 years, then a 1 FTE after that, at 100K/year (includes benefits).

Given the above factors and unknowns, here is a best guess conservative quote:

Year 1 - Bulk Purchase of Points ($600,000) + 2 FTE ($100,000/FTE) = $800,000
Year 2 - 2 FTE ($100,000/FTE) = $200,000
Year 3 - 2 FTE ($100,000/FTE) = $200,000
Year 4 - 1 FTE ($100,000/FTE) = $100,000
Year 5 - 1 FTE ($100,000/FTE) = $100,000

Five Year Total = $1,400,000

General Recommendations

1. Finalize horizontal accuracy specifications in NAIP contract. This task has been completed for the 2007 solicitation.
2. Nail down the control point database design. Bring the present state of the database to a “final” or end state format, and allow for simple tools to update and maintain said database. In short, move from dbf and file based to Oracle table design, and transfer current points to new format. Further, develop simple procedures to enter new points into the Oracle table and maintain data within the table.
3. Develop a procedure to standardize and test for validity new control points prior to being entered into the database. Develop a schedule and procedure to test and validate current points to ensure continued viability for use as control.

4. Develop active plan and procedure to acquire through partnerships, existing database, or procurement, new control points to ensure continued population of valid control for future use.

5. Further develop and standardize/automate the absolute horizontal accuracy inspection process within the APFO inspection architecture.