IMPLEMENTATION OF GPS CONTROLLED HIGHWAY CONSTRUCTION EQUIPMENT – PHASE II

Project 02-12
January 2008

National Center for Freight & Infrastructure Research & Education
College of Engineering
Department of Civil and Environmental Engineering
University of Wisconsin, Madison

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Implementation of GPS Controlled Highway Construction Equipment Phase II

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Final Report

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Submitted to the Wisconsin Department of Transportation

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Technical Report Documentation Page

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16. Abstract

During 2006, WisDOT and the Construction Materials and Support Center at UW-Madison worked together to develop a specification and QC/QA procedures for GPS machine guidance on highway construction grading operations. These specifications and procedures are intended for incorporation in contracts on two to five pilot projects during the 2007 construction season. The 2006 work, and the 2007 pilot projects are the first two steps in a phased implementation plan that includes refinement of the specification and procedures after the 2007 pilots, additional pilots during 2008, and potential statewide implementation of optional GPS machine guidance for grading on 2009 contracts.

To be effective, the goals, objectives, and methods for data collection and analysis for the 2007 pilot projects must be well-articulated; the project sites must be carefully selected; and a set of deliverables and management plan for coordination of the effort must be developed.

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1. Background

During 2006, WisDOT and the Construction Materials and Support Center (CMSC) at UW-Madison worked together to develop a specification and QC/QA procedures (i.e., guidance language) for GPS machine guidance on highway construction grading operations. These specifications and procedures were incorporated as change orders in contracts on two pilot projects during the 2007 construction season. GPS machine guidance was also evaluated on a third 2007 construction project. Useful information was obtained from the third project, although it was not officially designated as a pilot.

One of the pilot projects was in WisDOT's Southwest Region (Wondra Excavating was the contractor) and the other was in WisDOT's Northeast Region (Hoffman Construction was the contractor). The third project was also in the Northeast Region (Mashuda Contractors was the contractor). The 2006 work and the 2007 pilot projects were the first two steps in a phased implementation plan that includes refinement of the specification and procedures after the 2007 pilots, additional pilots during 2008, and, ultimately, statewide implementation of optional GPS machine guidance for grading.

CMSC assisted WisDOT with evaluation of the specification and guidance language on the two pilot projects, with the goal of identifying and making any necessary modifications in a timely manner, so that revised versions were in place for bidding on the 2008 pilots.

2. Specifications and QC/QA Procedures

The Northeast Region (Hoffman) pilot project adopted the specification and guidance language as they appear in Vonderohe (2007a) and in Appendix A of this document. The Southwest Region (Wondra) pilot project incorporated a modified version of the specification (see Appendix B), but used the same guidance language. The primary difference between the two specifications is that the Southwest Region's required blue-top stakes on the first 3000 feet of subgrade and the Northeast Region's did not require any blue-top stakes.

3. Issues Intended to be Addressed by the Pilot Projects

General questions addressed on the pilot projects include:

Equipment:

1. What are the frequency, duration, and types of problems with operation of the technology (e.g., poor satellite geometry, loss of lock, multipath, software glitches, data entry and other human errors, technology incompatibilities)?
2. What are the vertical tolerances that are achievable using GPS Machine guidance?
3. What are the necessary knowledge and skill levels for project engineers, contractor project managers, and machine operators?
4. What other efficiencies are realized with GPS machine guidance?
5. What other difficulties arose with GPS machine guidance?
6. Is it necessary for the height modernization program to be completed in the area for GPS machine guidance grading to be successful? If not, what

additional project control is needed and what other challenges are encountered?

Department Responsibilities:

1. Are 3D model components provided by WisDOT readily usable by contractors?
2. What are the frequency and causes of revisions to three-dimensional models?
3. Are data exchange standards and rates sufficient for updating models during construction?
4. What is the appropriate spatial frequency for quality assurance checks and what are the appropriate tolerances?
5. Are there issues, during construction, with utility coordination, subcontractors, or others due to reduced staking requirements?

Contractor Responsibilities:

1. What is the appropriate control configuration for GPS site calibration?
2. What are the appropriate tolerances for GPS site calibration?
3. What is the appropriate frequency for GPS site calibration checking / re-calibration?
4. What is the maximum geographic extent over which a single GPS site calibration is valid?
5. What is the appropriate spatial frequency for quality control checks and what are the appropriate tolerances?
6. What needs to be staked and what staking can be eliminated?
7. What is the appropriate number of supplemental control points to be furnished by the contractor and what are the appropriate methods for development of supplemental control?
8. Do minor field changes need to be incorporated in the 3D model or is it more cost effective to have the machine operator override automatic controls for minor changes?
9. What types of field changes warrant changes in the 3D model?

4. Information Gathering Methods

Information from the pilot projects was gathered by the following means:

1. Project plans and schedules.
2. Telephone and face-to-face interviews with project personnel (both WisDOT region staff and contractor staff).
3. Attendance at pre-construction and weekly progress meetings.
4. Two rounds of site visits to the pilot projects and a site visit to the third project. The first site visit to the Wondra project was conducted on May 23, 2007. The second site visit to the Wondra project is scheduled for August 22, 2007. The first site visit to the Hoffman project was conducted June 19-20, 2007. The second site visit to the Hoffman project was conducted on August 1, 2007. The Mashuda project was also visited on August 1, 2007.
5. Acquisition of project data, including 3D models, GPS work plans, project engineer diary entries, contractor reports, and completed spreadsheets

containing measurements. The spreadsheet templates (see Appendix C) were developed by the author and distributed to project engineers and foremen.

6. Sets of questions and talking points, distributed to region staff and project personnel prior to the second site visit to each pilot project (see Appendices D and E). These were used to generate discussion during interviews. The questions and talking points differed for the two pilot projects because the projects operated under different specifications.

5. Northeast Region (Green Bay) Projects

Region Project Development Supervisor: Steven Noel
Region Data Manager for Pilot Projects: Brad Hollister
Region Project Manager for Pilot Projects: Dan Segerstrom
Region Design-Side Survey Coordinator: Mike Vandehei
Region Construction-Side Survey Coordinator: Dennis Keyzer

The Northeast Region's GPS machine guidance pilot project (Hoffman) was along STH 57 in Door County. The second project (Mashuda) in the Northeast Region was also along STH 57, adjacent to and north of the officially-designated pilot project.

The region developed breakline data from plans to provide to contractors on both these projects. By mid-May, the region had devoted approximately 40 person-hours to data development for each of the two projects, including mainline and side roads. Data can be developed along the mainline at a rate of approximately four hours per mile, but side roads are developed much more slowly. Side roads require more attention, in part, because match lines are sometimes done incorrectly with no closure between adjacent roadways or with slopes that do not intersect. As of August, no requests had been received by the region to modify any design because of flaws in the plans. However, there were numerous issues with formats for data exchange. The LandXML format in the pilot project specification is not really a "standard". Various software vendors have their own versions of this format. Therefore, LandXML could not be used as an exchange format for either the Hoffman or Mashuda projects. Through testing, it was determined that Autodesk's .dwg format provided the most complete and useful data exchange. Breakline data provided by WisDOT is not the final design surface model needed for GPS machine guidance. Development of the design models from the breaklines and other plan information is the responsibility of the contractor under the 2007 specification. The Methods Development Unit (MDU) checked the 3D model developed by the contractor. Procedures developed for processing the data were fully documented.

The region was interested in determining if GPS rover data can be used for pay measurement purposes. They were also interested in exploring possibilities for integration of WisDOT's roadway design system and WisDOT's field documentation system.

The Northeast Region has a design-side survey coordinator and a construction-side survey coordinator. Design-side surveying begins with aerial mapping, runs through right-of-way layout, and includes any survey work needed for design until the time of construction. It includes WisDOT-provided geodetic control. Construction-side surveying includes fulfilling project manager requests for surveys, borrow pits, and final details for quantities. Surveying operations use both in-house crews and consultants.

Geodetic control for both the Hoffman and Mashuda projects was established by a single consultant using rapid static GPS methods. This control consisted of 20 monumented points, well-distributed along a ten-mile corridor of the highway. Leveling was done for one-third of the monuments to check GPS-derived orthometric heights. The consultant's geodetic control was not tied directly to the HARN or to any height modernization control points. Rather, the control was tied to section corners whose coordinates had been determined ten years previously using rapid static GPS methods tied to the HARN. Vertical control points were tied to NGS benchmarks by a ten-year-old WisDOT survey. The consultant found a discrepancy in one of the WisDOT vertical control lines and distributed the error linearly along the line. The horizontal datum for geodetic control was NAD 83 (1991) and the vertical datum was NGVD 29. Horizontal positions were expressed in Door County coordinates.

Construction-side surveys are tied to known coordinates and elevations of right-of-way monuments, using total stations and levels. To compute final quantities, an as-built DTM is developed from detail survey data. Cross-sections are then cut through the DTM. The average-end-area method is then used to compute quantities from the cross-sections.

The first site visit to the Hoffman project was held in conjunction with an open house, on GPS machine guidance, hosted by the Northeast Region. There were 40-50 attendees Among presentations at the open house was one given by the author. WisDOT's Rick Larson also gave a presentation on issues with 3D models and data exchange. The open house included a field trip to the Hoffman project site.

5.1. Discussion Points Raised by the Region

For consideration for the 2008 specification and beyond, region personnel raised the following issues:

1. What will be WisDOT's commitment on provision of design-side data? Considerations include limited resources, the period of transition from CAiCE to Civil 3D, allotted time for making changes (e.g., some changes require more time than others), and compensable versus non-compensable changes in the data.

2. What is the best means for getting other WisDOT regions involved?

3. What effective educational mechanisms are there for WisDOT and contractor staff?

4. Will future GPS machine guidance grading specifications include slopes and ditches or will they continue to be confined to roadway subgrade?

5. When WisDOT goes to statewide options for bidding, will the regions have choices or will the option apply to all contracts?

6. Is it possible to use existing section corners for horizontal control?

5.2. Pilot Project 1480-08-76 (STH 57)

WisDOT Northeast Region Field Engineer: Barry Paye
Contractor: Hoffman Construction
Contractor Project Manager: Chris Goss
Contractor Project Foreman: Frank Laufenberg
Contractor Grading Foreman: Ken Bork

This project involved improving 5.2 miles of STH 57 from bi-directional to divided highway in southern Door County. The project ran from just south of the county line at station 600+00 to Truway Road at station 876+00. Considerable earthwork was included, with rock cuts as deep as 39 feet and fills as high as 25 feet. GPS machine guidance was used on the full length of the project.

Hoffman has been using GPS machine guidance for the past three years and has a number of dozers and graders outfitted with Trimble technology (see Figure 1). The grading foreman on the pilot project was quite familiar with GPS machine guidance and serves as an instructor on use of the technology for machine operators statewide. Hoffman subcontracted for staking on the project.

Figure 1.
Hoffman Grader Mounted with Trimble GPS Machine Guidance

NOTE: Two antennae mounted above the top of the blade give the blade coordinates, direction and roll angle. The pitch angle is computed, by the on-board software, from immediately-preceding blade positions.

The field engineer had experience with GPS machine guidance for both grading and base course, having worked with MinnDOT on field verification during its first GPS machine guidance project. Work began in early April, with the GPS machine guidance equipment arriving on site during the second week of May. Hoffman submitted their GPS work plan (see Appendix F) and conducted work accordingly. Initial site calibration was completed (see Figures 2 and 3) and the field foreman provided weekly calibration files and calibration check data to the field engineer. According to specification, control points not used in the initial calibration were used to check that calibration. Calibration checks were consistently within the specified tolerances of 0.10 ft horizontally and 0.05 ft. vertically, although one control point was found to be deficient and was not used. Hoffman did not have to densify the WisDOT-provided control. Appendix G contains the project's site calibration check values.

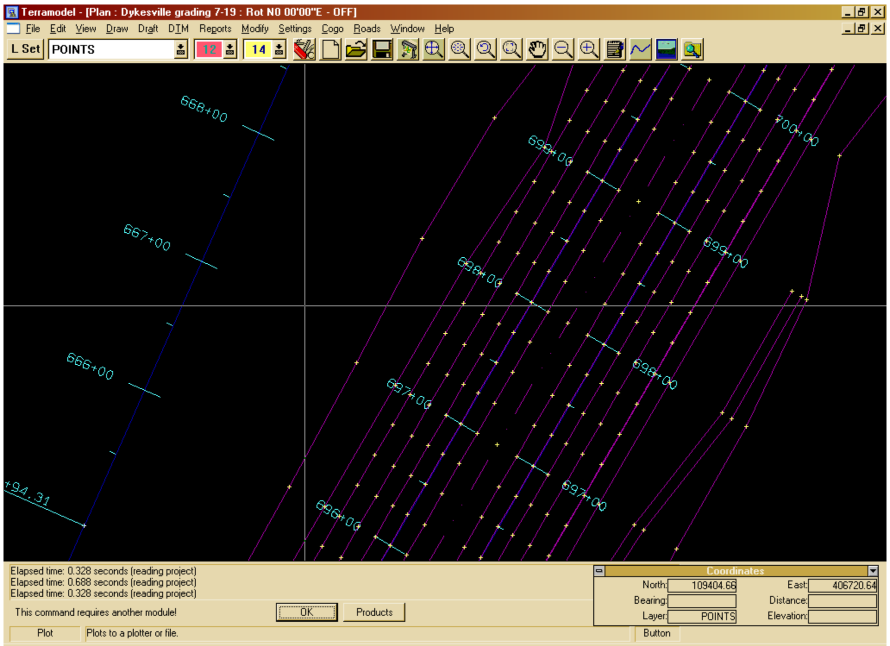
The Door County terrain is such that the base station radio range was approximately 1.5 miles. This could be boosted to three miles with a repeater. So, two base station locations were needed to cover the 5.2-mile job. After leaf-out in late May, there were some minor problems with satellite signal reception on steep back slopes and there are sometimes 15-20 minute periods of poor satellite geometry. The field engineer kept an electronic diary, including entries pertinent to GPS machine guidance aspects of the job.

Figure 2.
Hoffman's Base Station

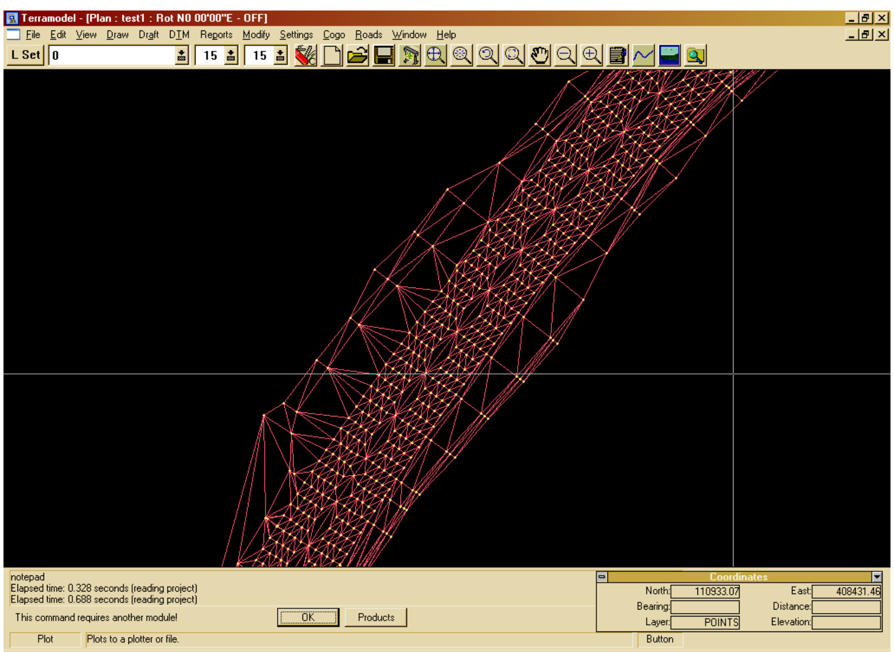
(a) (b)

Figure 3.
Ken Bork Performing a Calibration Check (a) and Calibration Check Results (b)

When breaklines, provided by WisDOT in LANDXML format, were imported into Trimble's Terramodel software, measurement units became confused. The software expected international feet and the data were in US survey feet. Also, LANDXML does not import either planimetric attributes or colors for line work. These problems do not exist if .dwg (AutoDesk) format is used for data exchange. Figure 4 provides two views of segments of the project data after the 3D model was constructed.



a. Breaklines and Stationing



b. Plan View of Surface Model

Figure 4.

Two Views of Segments of the Hoffman Data

The field engineer and region staff were not able to view Hoffman's 3D model directly because they did not have Terramodel. However, the region is supposed to check the 3D model. To facilitate this, Hoffman exported breaklines from Terramodel, and region staff imported those breaklines into CAiCE. CAiCE was then used to build a surface model from the breaklines. There was no guarantee that this was the same surface that Hoffman used because there are different algorithms for inserting breaklines in surfaces and it is not known if the two programs use the same algorithm. A further complication was that designs, prepared by consulting firms not using CAiCE, had to be compared on paper to slices through the CAiCE model.

For the required minimum of 20 subgrade checks per mile, Hoffman decided to identify random points and then move from each of those points to its nearest cross-section so that checks could be made directly against the plans and not against the design surface that was generated from the plans. Subgrade checks along the mainline began in August. The complete set of 230 subgrade check values appears in Appendix H. The largest positive difference is +0.24 ft. The largest negative difference is -0.13 ft. The mean of the check values is -0.01 ft and the standard deviation is ±0.06 ft. The 2007 specification required the contractor to inform the engineer if more than one of any five consecutive subgrade checks exceeded 0.10 ft. in absolute value. In only three instances was this specification exceeded:

1. At Sta 696+98 1.8R, the check value was +0.24 ft. At Sta 697+00, the check value was -0.11 ft. These were two consecutive checks made at nearly the same location.

2. At Sta 789+00 3.0L, the check value was -0.12ft. At Sta 796+00 6.0R, the check value was -0.11 ft. These two check points had three other check points between them with all three having absolute values less than 0.10 ft. The two offending check points were physically separated by 700 ft.

3. At Sta 821+00 51.0L, the check value was +0.12 ft. At Sta 822+00 51.0L, the check value was -0.13 ft. These two check points had two other check points between them, each of which had an absolute value less than 0.10 ft.

No blue top stakes were used on the Hoffman project.

Most of the slope and ditch grading on the Hoffman project was done using GPS machine guidance. Project engineers and foremen reported more-than-adequate results, with visually smooth linear features and surfaces (see Figure 5).

5.2.1. Discussion Points Raised on the Project

1. What is the best way to coordinate design changes with 3D model changes and who does what? What if the model is built by a third party (this was the case for the Mashuda project)?

2. The project engineer and region staff could not even view the model without the vendor's software.

Figure 5.
Slopes and Ditches Constructed with GPS Machine Guidance on Hoffman Project

3. Some minor design changes might not be incorporated in the 3D model, so it cannot be used for as-builts.

4. There are problems with using last-pass data from the machines to construct as-built surfaces. For example, data are collected whether the blade is cutting, flush with the ground, or above ground. Also, such data can be collected only as points. No breaklines or labels can be inserted, so the data would have to be interpreted and edited later with no information other than visual inspection on which points should be connected to form lines.

5. The 2007 specification allowed the engineer to require conventional staking if GPS machine guidance was producing unacceptable results. Should the contractor also have the option of going to conventional staking (e.g., equipment priorities)?

6. GPS work plan, site calibration check, and subgrade check requirements were good in the 2007 specification. Hoffman had no problem meeting the specified tolerances. The belief was that those tolerances are appropriate and should not be made more stringent.

7. Why is it necessary for the site calibration check points to be different from the control points used for calibration? If the site calibration checks once, could site calibration control points be used for future checks?

8. What is the appropriate number and configuration of control points for site calibration? Can the 2007 specification be reduced? Under the 2007 specification, there were only two project control points that could be used to check site calibrations.

9. Concerning the specified 20 subgrade check points per mile, this was a divided highway. Was the specified number per lane-mile or per linear mile?

10. Control points are used for other than GPS site calibration (e.g., checking pipe inverts), so dense control was appropriate.

11. Should initial staking and subgrade be separated in the specification?

12. Not all machines have GPS machine guidance, so initial staking is necessary. In addition, subcontractors (e.g., for clearing and grubbing) might not have the technology and need stakes. However, it might be possible to reduce initial staking to every other station (as a test) on the 2008 pilots.

13. The 2007 guidance language was not used on the project because of the experience of both the field engineer and the contractor. However, after the project, the guidance language was reviewed with the full weight of the project experience in mind.

5.3. Project 1480-08-77 (STH 57)

WisDOT Northeast Region Field Engineer: Kevin Derenne
Contractor: Mashuda Contractors
Contractor Project Manager: Tom Dobberthein
Contractor Project Foremen: Matt Mashuda and Mike Burt

This project involved improving 4.9 miles of STH 57 from bi-directional to divided highway in southern Door County. The project ran from Truway Road at station 876+00 to CTH N at station 1134+00. It abutted the Hoffman project which lay to the south. The project had cuts as deep as 18 feet and fills as high as 15 feet. A 100-acre mitigation site was included in the project. The project was not an official pilot because the specification was not incorporated into the contract. However, the contractor tested and used GPS machine guidance on the project and some useful information was obtained.

Mashuda has been using RTK GPS for surveys for the past three years. However, this project involved their first use of GPS machine guidance on construction equipment. Mashuda did side-by-side testing, on the project site, of Trimble and TOPCON on two dozers at the same time. Trimble was selected and installed on two dozers. They were used on slopes and ditches only (see Figure 6).

The field engineer did not have experience with GPS machine guidance. He kept an electronic diary, including entries pertinent to GPS machine guidance aspects of the job. Weekly project meetings were held in the field on Wednesday afternoons. The project schedule called for staging, such that grading operations were underway for much of the project. Mashuda subcontracted for staking on the project. Checks, against design, were made on slopes and ditches. Check values were consistently much less than ±0.2 ft.

The region provided breakline data in .dwg format and Mashuda subcontracted the 3D modeling to POB out of Stevens Point. POB built a single complete model for the entire project. Both Trimble and TOPCON were able to import these data during the side-by-side testing mentioned earlier.

Figure 6.
Slope and Ditch Work Using GPS Machine Guidance on the Mashuda Project

5.3.1. Discussion Points Raised on the Project

1. Is 3D model building going to be a bid item? Perhaps the initial 3D model, and some number of planned changes, should be a bid item and blue top staking should be eliminated as a bid item.

6. Southwest Region (Madison) Pilot Project

6.1. Pilot Project 3576-07-71(STH 106)

WisDOT Southwest Region Project Manager: Teri Schopp
WisDOT Southwest Region Field Engineer: Jeff Kaarto
WisDOT Southwest Region Surveyor: Pat Krebs
Contractor: Wondra Excavating
Contractor Project Manager: Bob Mayer
Contractor Project Foreman: Matt Cameron

This project involved improving 9.9 miles of STH 106 in Jefferson County, just east of Ft. Atkinson. The project ran from Edgewater Road at station 12+47.65 to CTH CI at station 533+80.00. STH 106 is a bi-directional, two-lane roadway. The project consisted of six consecutive segments: 1) 2.5 miles of vertical alignment change and grading; 2) one mile of pavement replacement with no grading; 3) two miles of vertical alignment change and grading; 4) one mile of pavement replacement with no grading; 5) two miles of vertical alignment change with grading; and 6) 1.5 miles of pavement replacement with no grading. There are areas where excavation below subgrade (EBS) was required because of soft soil conditions. Maximum cut and fill depths and heights were nine feet. One mile of urban grading, within Ft. Atkinson, was also included.

The Southwest Region had no staff familiar with the LANDXML data exchange format required by the 2007 specification. They attempted unsuccessfully to import breakline and mass point data provided by WisDOT Central Office into CAiCE. As a result of the region not being able to examine the data, they served only as a conduit for data exchange between WisDOT Central Office and Wondra. The field engineer and region staff could not view the 3D model because they did not have the necessary software (TOPCON 3D Office).

The region project manager and field engineer did not have experience with GPS machine guidance. Therefore, the region elected to modify the specification provided for the 2007 pilot projects. The region's modification affected only subgrade staking aspects of the specification (see Appendix B). The first 3000 feet of the first grading segment required subgrade stakes, with the required number being reduced every 1000 feet. If the finished subgrade met tolerance at subgrade stakes in the first 3000 feet of the first segment, then the engineer could waive requirements for subgrade stakes on the remainder of the project. Wondra agreed to this modification of the specification.

The region surveyor developed geodetic control for the project and also placed slope stakes. RTK GPS methods were used for establishing control coordinates and for slope staking. The geodetic control was adopted from six-year-old control and painted photogrammetric targets that had been placed for an earlier mapping flight over the roadway. The existing mapping control had been tied to the HARN and, by three-wire leveling, to an NGS benchmark in Ft. Atkinson. All of the mapping control points were expected to be destroyed by the construction. So, the RTK GPS survey was used to establish four additional control points that would not be disturbed. The calibration for the new RTK GPS survey was referenced to a minimum of two three-dimensional points, four horizontal points, and two vertical points in the mapping control. Ultimately, the field engineer was provided with tie sheets and a listing for 23 mapping control points, seven photogrammetric targets, and the four new control points set by the region surveyor. All control points were within the STH 106 right-of-way. The horizontal geodetic datum is NAD 83 (1991). The vertical geodetic datum is NGVD 29. Wondra found the WisDOT-provided control to be sufficient and did not experience a need to densify it further.

The field engineer kept a hardcopy grading diary, including entries pertinent to GPS machine guidance aspects of the project. Project weekly meetings were on Wednesday mornings and included discussions of GPS machine guidance work.

Wondra had two TOPCON-equipped dozers on the project site (see Figure 7). They had been using RTK GPS for four years and GPS machine guidance since the fall of 2005. Wondra had used GPS machine guidance on county highway projects, but this was their first use of it on a WisDOT project. Grading operations on this pilot project began during the first week of May.


(a)


(b)


(c)

Figure 7.
Two Views of One of Wondra's TOPCON-Equipped Dozer (a,b)
and Its Tilt Sensor (c)

NOTE: The dual antennae, mounted on a single staff above the blade on the longitudinal axis of the machine, give the blade's coordinates, direction, and pitch angle. The roll angle is measured by the tilt sensor mounted on the blade. The tilt sensor is calibrated using a 4-foot carpenter's level, and the calibration is checked every two weeks.

Wondra submitted a GPS work plan (Appendix I) and proceeded accordingly. There was a single base station site for the entire ten-mile project. The base station (see Figure 8) was the top of a permanent post driven into the ground at a convenient central location (not an existing control point). Using a permanent post eliminated the need for leveling and centering the antenna above a ground point each workday morning. The base station's coordinates were established during site calibration. The base station's receiver was removed at the end of each day's work for security purposes. The base station's radio range was approximately seven miles. This could be increased with boosters. In an additional attempt to extend the range on the project site, the base station's broadcast antenna was mounted atop a nearby utility pole. The base station's broadcast frequency is not unique. Ordinary radio signals can sometimes interfere with those of the base station.

(a) (b)

Figure 8.
Wondra's Base Station (a) with Broadcast Antenna atop a Utility Pole (b)

TOPCON recommends that the geographic extent of work from a base station be no more than ten miles. It is expected that this limitation arises from the single scale factor computed during site calibration and from the assumption of consistent atmospheric conditions at the base station and rovers.

Site calibration was done for each of the three grading segments. The calibration file for the first segment was appended for the second segment and, then again, appended for the third. Site calibration was checked at least once per day when the base station was set up (see Figure 9). Additional checks were sometimes made during the lunch hour. The project foreman believed this practice to be adequate because TOPCON receives signals from GLONASS satellites in addition to GPS satellites. Wondra elected to subscribe to TOPCON's optional GLONASS service after realizing a 0.02-0.03 ft improvement in accuracy and, more importantly, elimination of down-time due to weak satellite geometry. The project foreman reported that there are usually no fewer than 12 GLONASS and GPS satellites visible to the receivers. Site calibration files were not provided to the field engineer because he had no way of reading them (they were in TOPCON proprietary format). Site calibration check values for the project appear in Appendix J. The largest absolute value in a horizontal check is 0.04 ft (tolerance = 0.10 ft). The largest absolute value in a vertical check is 0.04 ft (tolerance = 0.05 ft).

The project foreman was unable to import the WisDOT-provided LANDXML breaklines and mass points into TOPCON's software. Attempts produced multiple computer errors. The TOPCON vendor was also unable to import the WisDOT breaklines using two different versions of the Carlson CAD software. Horizontal alignments in LANDXML could be imported, but vertical alignments showed only VPIs with zero-length vertical curves. To move forward, the project foreman developed 3D models directly from the plans, using Autocad and TOPCON software. Data provided by WisDOT's Central Office was not used. The 3D models were built on-the-fly to stay ahead of the construction crews. Figure 10 provides four views of Wondra's 3D model, two being those of the machine operator.

Figure 9.
Matt Cameron and Brad Cunningham Making a Site Calibration Check

Wondra did not find any problems that required revisions to the project plans. There were minor changes such as saving trees that were designated for removal and moving of residential driveways, but none of these required revisions to the plans. Also, there were some minor design changes that were not incorporated into the 3D model. For example, an existing 80-ft culvert was encountered that did not appear in the design. To include the culvert in the 3D model, it would have been necessary to conduct a survey and reduce the data for inclusion in the model. It was easier to merely ask the machine operator to make the grade meet the culvert.

In the first 1000 ft of blue-topping, three stakes were set at each full station. In the second 1000 ft, every full station on only the centerline was staked. At the first two full stations, the subgrade was consistently 0.2 ft below the blue tops. No blade offset had been used during grading in this area because dirt was being removed (cut). Blade offsets are often used in fill areas that are expected to compact. The project foreman believes the material was so soft in this area that compaction occurred and a blade offset should have been used (see Figure 11). Appropriate blade offsets vary with soil conditions. The Hoffman foreman reported that blade offsets from 0.02 to 0.10 ft. are often used. Because the blue tops were missed at the first two stations, the project engineer decided to not completely waive blue-topping for the remainder of the project. On straightaways the remaining centerline was staked every 500 ft. All superelevated curves were staked three-across at all full stations.

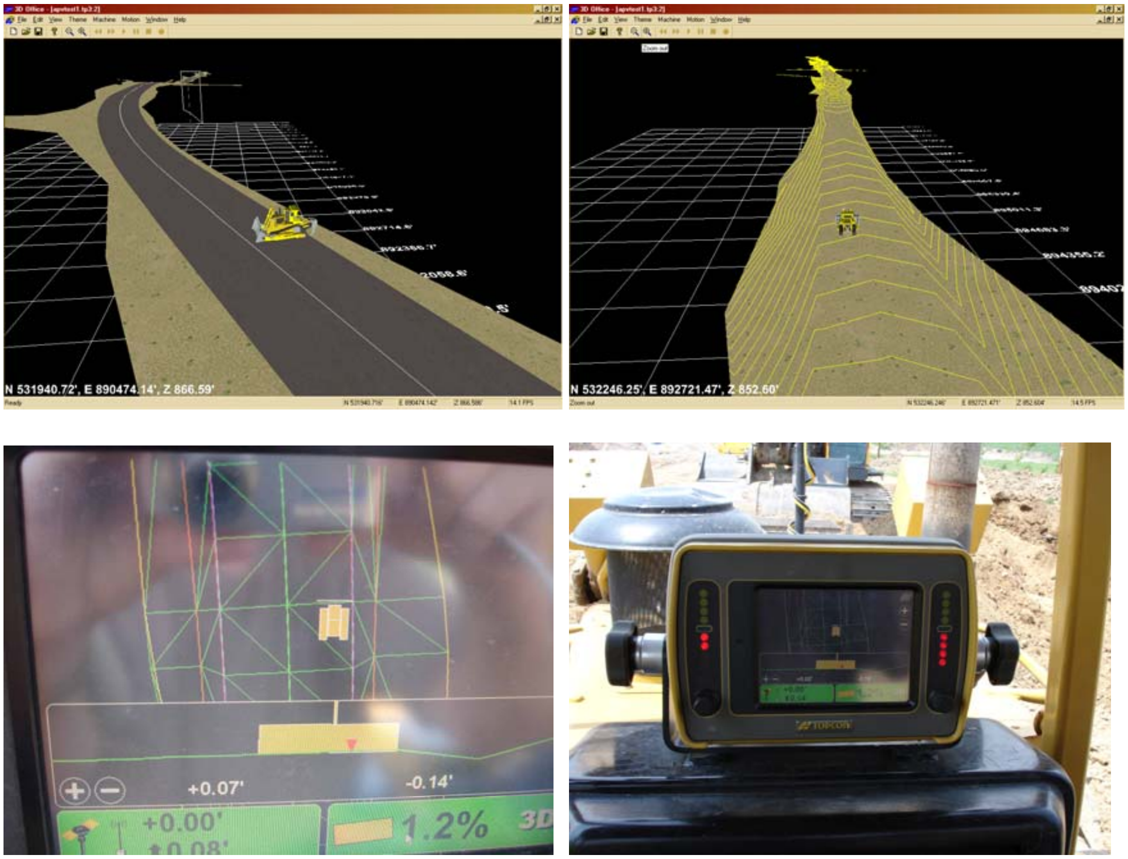


Figure 10.
Four Views of the Wondra 3D Model (Bottom Photos are inside the Cab of a Dozer)

Appendix K contains the full set of 114 subgrade checks for the project. The largest positive subgrade check difference is +0.15 ft. The largest negative subgrade check difference is -0.09 ft. The mean and standard deviation of the subgrade checks are +0.02 ft and ±0.05 ft, respectively. In only a single instance on the Wondra project did more than one of any five consecutive subgrade checks exceed 0.10 ft in absolute value. The two offending checks were separated by 1000 feet horizontally. Sta 240+00 (12.0L) checked at +.11 ft and Sta 250+00 (12.0L) checked at +0.13 ft. Between these two checks, there were three checks less than 0.10 ft.

Figure 12 shows the finished subgrade and slopes with and without base course placement on the Wondra project.

6.1.1. Discussion Points Raised on the Project

1. Data management issues were prevalent and need to be addressed.

2. Should blue-topping be at the option of the field engineer?

3. Is it necessary to check the site calibration twice a day?

Figure 11.
Soft Material on the Wondra Project Site

(a) (b)

Figure 12.
Finished Subgrade without (a) and with (b) Base Course Placement
On the Wondra Project

4. What are the appropriate ways for the contractor and the department to share electronic information in proprietary formats (e.g., site calibration files).

5. Last-pass data collected by the machines is not an efficient method for collecting as-built data. Some "last-passes" have to be passed over again because of rutting. Some slopes have smaller footprints than the machines. Collected data are unlabelled points. Breaklines would have to be constructed later. It would be difficult to track what was done, what needed to be done and what needed to be done over.

6. Slope staking should not be eliminated or even reduced. For example, topsoil stripping on this project was done without GPS machine guidance. The terrain was irregular with many transitions between cuts and fills. Therefore, the slope stakes were not uniform. Eliminating every other slope stake could lead to under-stripping or over-stripping.

7. Summary of Issues for Discussion

1. What will be WisDOT's commitment on provision of design-side data? Considerations include limited resources, the period of transition from CAiCE to Civil 3D, and allotted time for making changes (e.g., some changes require more time than others). There is an urgent need to address these and other data management issues such as whether or not 3D modeling should be a bid item, the impact of involvement of third parties (subcontractors for 3D modeling), and the role of the field engineer when not equipped with necessary software.

2. What is the best means for getting other WisDOT regions involved?

3. What effective educational mechanisms are there for WisDOT and contractor staff?

4. Will future GPS machine guidance grading specifications include slopes and ditches or will they continue to be confined to roadway subgrade? Are there aspects of the standard specifications that affect grading of slopes and ditches and should be addressed for GPS machine guidance?

5. When WisDOT goes to statewide options for bidding, will the regions have choices or will the option apply to all contracts?

6. Is it possible to use existing section corners for horizontal control?

7. There are problems with using last-pass data from the machines to construct as-built surfaces. For example, data are collected whether the blade is cutting, flush with the ground, or above ground. Also, such data can be collected only as points. No breaklines or labels can be inserted, so the data would have to be interpreted and edited later with no information other than visual inspection on which points should be connected to form lines. Furthermore, some "last-pass" data have to be passed over again (for example, because of rutting).

8. The 2007 specification allows the engineer to require conventional staking (blue tops) if GPS machine guidance is producing unacceptable results. Should there be more flexibility for the engineer (e.g., requiring some blue topping by choice)? Should the contractor also have the option of going to conventional staking (e.g., equipment priorities)?

9. Are 2007 tolerances too stringent or not stringent enough? Feedback from the projects indicated they are appropriate and should not be changed.

10. Why is it necessary for the site calibration check points to be different from the control points used for calibration? If the site calibration checks once, could site calibration control points be used for future checks? Can site calibration checks be reduced to one per day?

11. What is the appropriate number and configuration of control points for site calibration? Can the 2007 specification be reduced? Under the 2007 specification on the Hoffman project, there were only two project control points that could be used to check site calibrations.

12. Concerning the specified 20 subgrade check points per mile, what about divided highways? Is the specified number per lane-mile or per linear mile?

13. Should initial staking and subgrade be separated in the specification?

14. Not all machines have GPS machine guidance, so initial staking is necessary. In addition, subcontractors (e.g., for clearing and grubbing) might not have the technology and will need stakes. There are mixed opinions on whether or not slope staking can be reduced to every other station. Doing so could cause problems with, for example, topsoil stripping in non-uniform areas.

15. What are the appropriate ways for the contractor and the department to share electronic information in proprietary formats (e.g., site calibration files). This is separate from the 3D modeling data management issue.

8. Lessons Learned from 2007 Pilots

Shortly after submittal of this project's interim report (Vonderohe (2007b)), the project's Advisory Group was convened to consider issues raised during the pilot projects and make recommendations concerning revisions to the specification and guidance language. Those in attendance when the Advisory Group met were Ken Brockman (WisDOT), Jerry Zogg (WisDOT), Alan Rommel (WisDOT), Rick Larson (WisDOT), Mike Hall (WisDOT), Brad Hollister (WisDOT), Kris Sommers (WisDOT), Chris Goss (Hoffman Construction), Mike Bradley (Ayres & Associates), Matt Cameron (Wondra Excavating), and the author.

Because of the pervasiveness and depth of issues surrounding development and management of 3D models, a second "Data Management" Group was convened. Those in attendance at the time of the meeting were Ken Brockman (WisDOT), Jerry Zogg (WisDOT), Alan Rommel (WisDOT), Rick Larson (WisDOT), Brad Hollister (WisDOT), Kris Sommers (WisDOT), Chris Goss (Hoffman Construction), Matt Cameron (Wondra Excavating), Jason Pingel (POB), Mike Larenzo (Kapur & Associates), and the author.

As these groups discussed the issues, it became apparent that

1. The specified accuracy requirements can be met with GPS machine guidance.

2. There is still a need to do slope staking as slope stakes are used for visual reference and for applications other than grading. The question remains whether or not the frequency of slope staking can be reduced.

3. There is no need to set blue tops, but the department should continue to make independent checks of the subgrade.

4. The specification requires the contractor to make a GPS rover available to the engineer and to provide training. There is a need for a better longer-term solution for the engineer's access to the technology.

5. There is a need to clarify some aspects of the specification (e.g., minimum frequency of subgrade checks for divided highways.

6. Formats for data exchange should be made more flexible.

7. The capacity of WisDOT for provision of preliminary data for 3D modeling, through the Methods Development Unit, will be about 15 projects per year as the transition is being made to 3D design.

8. Roles and responsibilities, concerning 3D model data development and management, of central office staff, region staff, and contractors need to be well-described and understood.

9. The impact of WisDOT's continuously-operating reference stations (CORS) on GPS machine guidance has yet to be studied.

10. There are impediments to using "last pass" data from the machines to form as-built surface models for determining final quantities. These impediments need to be better understood.

9. Revisions to Specification

Based upon the deliberations and recommendations of the Advisory and Data Management Groups, some revisions were made to the 2007 specification. These include:

1. Reducing the required frequency of site calibration checks from one every five operating hours to one per day.

2. Adding language to emphasize that subgrade checks are to be made against <u>plan</u> elevations (i.e., elevations shown on the paper plans).

3. Specifying that a minimum of 20 subgrade checks per <u>roadway</u> mile are required.

4. Including .dwg or other engineer-approved format as acceptable for 3D data exchange.

5. Because the 2008 projects are bid with the specification for GPS machine guidance, the contractor is provided with the option of using conventional equipment, GPS machine guidance, or a combination of the two.

The 2008 pilot specification appears in Appendix L.

10. Revisions to Guidance Language

Based upon the deliberations and recommendations of the Advisory and Data Management Groups, some revisions were made to the 2007 guidance language. These include:

1. Describing the roles and responsibilities of central office staff and region staff in development and management of 3D model data.

2. Adding language concerning the engineer's responsibility in developing an archive of 3D model revisions.

3. Stating that the engineer should use technologies independent of the contractor's GPS installation to make initial subgrade checks. Total stations and / or differential leveling should be used until the engineer is satisfied that the GPS machine guidance technology is meeting requirements.

The 2008 pilot guidance language appears in Appendix M.

11. Summary of Issues Intended to be Addressed by the 2007 Pilot Projects

Here, the general questions identified in Section 3 are repeated along with notes on their status as a result of the 2007 pilot projects:

Equipment:

1. What are the frequency, duration, and types of problems with operation of the technology (e.g., poor satellite geometry, loss of lock, multipath, software glitches, data entry and other human errors, technology incompatibilities)?
   Systems that receive only GPS signals sometimes experience nearly-inconsequential downtimes of 15-20 minutes per day. Systems that receive GLONASS signals in addition to GPS signals experience less downtime. Multipath and GPS software glitches do not appear to cause problems. Final pass blade depths should be set to account for compaction. Unless resolved, data format incompatibilities inhibit timely data exchange.
2. What are the vertical tolerances that are achievable using GPS Machine guidance?
   The pilot specification tolerance of no more than one out of any five consecutive check points not exceeding 0.1 ft appears to be appropriate. Further monitoring on the 2008 pilot projects is recommended.
3. What are the necessary knowledge and skill levels for project engineers, contractor project managers, and machine operators?
   Machine operators need to be skilled in use of the technology, but probably do not need a great deal of understanding in how the technology works. Project managers and project engineers should not only know how to use the technology but also have enough background in its workings to judge data quality and solve problems that might arise. This issue needs further exploration to develop detailed recommendations.
4. What other efficiencies are realized with GPS machine guidance?

Less repeat work, less human judgment (subject to error), more visually-pleasing results.

5. What other difficulties arose with GPS machine guidance?
   No severe difficulties, beyond data exchange, were encountered. Further monitoring on the 2008 pilots is recommended.
6. Is it necessary for the height modernization program to be completed in the area for GPS machine guidance grading to be successful? If not, what additional project control is needed and what other challenges are encountered?
   None of the control for either project was tied to the height modernization network. The Wondra project had most of its control already in place from previous WisDOT work. The Hoffman project had its control tied to previously-established control points other than height modernization.

Department Responsibilities:

1. Are 3D model components provided by WisDOT readily usable by contractors?
   They were not until the parties began using .dwg format. LANDXML is not an industry-wide uniform standard.
2. What are the frequency and causes of revisions to three-dimensional models?
   Very few, if any, revisions were made to the models after initial development by the contractors and checking by WisDOT. No revisions to project plans were necessary on either pilot project. Further monitoring on the 2008 pilots is recommended.
3. Are data exchange standards and rates sufficient for updating models during construction?
   Models did not need updating because there were no plan revisions. Further monitoring on the 2008 pilots is recommended.
4. What is the appropriate spatial frequency for quality assurance checks and what are the appropriate tolerances?
   Checks made by the project engineers were not monitored. This question needs to be investigated thoroughly on the 2008 pilot projects.
5. Are there issues, during construction, with utility coordination, subcontractors, or others due to reduced staking requirements?
   Both pilot projects were fully slope staked.

Contractor Responsibilities:

1. What is the appropriate control configuration for GPS site calibration?
   The pilot specification of six control points or two per mile, whichever is greater, worked. However, further monitoring on the 2008 pilots is recommended.
2. What are the appropriate tolerances for GPS site calibration?
   The site calibration check tolerances of 0.1 ft horizontally and 0.05 ft vertically appear to be appropriate. Further monitoring on the 2008 pilot projects is recommended.
3. What is the appropriate frequency for GPS site calibration checking / re-calibration?
   It appears that one site calibration check per day is adequate.

4. What is the maximum geographic extent over which a single GPS site calibration is valid?
   This question was not adequately addressed on the 2007 pilots. It is recommended that further investigation be done during 2008.
5. What is the appropriate spatial frequency for quality control checks and what are the appropriate tolerances?
   The pilot specification tolerance of 20 or more checkpoints per roadway mile and no more than one out of any five consecutive check points not exceeding 0.1 ft appears to be appropriate. Further monitoring on the 2008 pilot projects is recommended.
6. What needs to be staked and what staking can be eliminated?
   It is apparent that blue top staking can be eliminated. Slope staking is necessary for visual reference and for applications other grading. However, under some circumstances, it might be possible to reduce the frequency of slope staking.
7. What is the appropriate number of supplemental control points to be furnished by the contractor and what are the appropriate methods for development of supplemental control?
   Neither contractor needed to develop supplemental control. The control provided by WisDOT was adequate.
8. Do minor field changes need to be incorporated in the 3D model or is it more cost effective to have the machine operator override automatic controls for minor changes?
   The contractors found it more cost effective to make minor revisions in the field only, without revising the 3D models.
9. What types of field changes warrant changes in the 3D model?
   Although not fully addressed, it appears that only field changes leading to revisions in the plans warrant changes in the 3D model.

12. Plans for 2008

12.1. Potential 2008 Pilot Projects

As of the date of this report, the regions have proposed the following six projects as potential pilots for 2008:

NC Region:

1. Project ID 1166-01-70
   Kowalski Rd Overpass
   length = 0.5 miles
   Concept = Overpass expansion project (2 lanes to 4 lanes) rural grading.
   Let = 3/11/08

2. Project ID 1166-11-75/76
   USH 51/STH 29 Corridor- Wausau (Marathon County)
   Length = 0.9 miles urban (28 th Ave and Stewart Ave), 0.9 miles total rural (all ramps)
   Concept = Reconstruction project, structures, rural and urban grading.
   Let = 2/1/08

SE Region (Note: This project is within the CORS Phase 1 area):

3. Project ID 3180-11-70
   Burlington Bypass - STH 36 (South) to STH 83 (South) (Racine County)
   Length = 2.7 miles
   Concept = Grading
   Let = 11/13/07 (H James and Sons is contractor, Region is discussing a no cost CCO).

NE Region (Note: These three projects are within the CORS Phase 1 area)

4. Project ID 1154-01-73
   USH 41, Oconto Bypass (Oconto County)
   Length = 1.75 miles
   Concept = Grading
   Let = 3/11/08

5. Project ID 1154-01-74
   USH 41, Oconto Bypass (Oconto County)
   Length = 3.11 miles
   Concept = grading
   Let = 4/08/08

6. Project ID 1154-01-75
   USH 41 Pestigo Bypass (Marinette County)
   Length = 3.74 miles
   Concept = Grading
   Let = 2/12/08

Of these, one has already been bid and would be managed by change order. The other five have yet to be let and, consequently, would be bid under the 2008 specification at the option of the bidder. It is anticipated that more potential 2008 pilots will be identified and that not necessarily all identified projects will be bid for GPS machine guidance. Ultimately, the desirable number of 2008 pilot projects is 3-5.

12.2. Issues to be Addressed during 2008 Pilot Projects

Among the issues to be addressed during the 2008 pilot projects are:

1. What is the impact of WisDOT's CORS network on GPS machine guidance? Five of the projects identified above are within the CORS Phase 1 area. Phase 1 is expected to become operational during April, 2008, in time to be used during the construction season. Pilot project contractors would need to adopt CORS technology and services if their projects were to be used to address this issue.

2. Are the described roles and responsibilities for development, exchange, and revisions to 3D model data appropriate?

3. Are there other workflow, resource, or technological impediments to development and management of 3D model data?

4. Does the specification continue to perform adequately in the areas of GPS work plan, site calibration, site calibration checking, and subgrade checking?

5. Can project control requirements be reduced?

6. Is there a need to specify the maximum geographic extent of a single site calibration?

7. Can frequency of slope staking be reduced? Is the answer to this question site-dependent?

8. Can the amount of information placed on slope stakes be reduced?

9. What are the options for longer-term solutions to the GPS-rover-access problem for the engineer?

10. Are there training or educational needs that are not being addressed?

11. What are the details of the impediments to using “last pass” data from the machines for as-built purposes? The 2008 specification is silent on “last pass” data, but if contractors are interested in pursuing this question, then it bears consideration.

12. Are there issues with GPS machine guidance in urban areas that are not apparent in rural areas?

13. What can be learned from the experience of having GPS machine guidance as a bid option?

14. What is the appropriate spatial frequency for additional quality assurance checks by the project engineer and what are the appropriate tolerances?

12.3. Outreach

During 2007, the project team gave presentations on background, status, and plans for implementation of GPS machine guidance at 1) the open house sponsored by the Northeast Region, 2) two meetings of the WisDOT / WEMA Grading, Landscaping, and Sewer Committee, 3) a monthly WisDOT Project Development Staff meeting, and 4) the annual meeting of the Wisconsin Earth Movers Association. An additional presentation is planned for the 2008 annual meeting of WisDOT / WTBA in January. The 2007 final report (Vonderohe (2007a)) is available through the Construction Materials and Support Center’s web site (http://cmsc.engr.wisc.edu/). This report is also expected to be available through that website.

13. The Bigger Picture – A Period of Transition

Technology is constantly changing while institutions and cultures attempt to keep up. Implementation of GPS machine guidance for highway construction is engaged in a rapidly-evolving period of transition. Changes are being made on three major fronts:

1. The adoption of GPS machine guidance itself is a new way of doing business for both industry and government, with semi-intelligent machines knowing where they are in both real and virtual worlds.

2. The Global Positioning System itself is now being described as part of a larger Global Navigation Satellite System (GNSS) that includes the Russian GLONASS and European Galileo systems. All components of GNSS are undergoing technological upgrades. In addition, the revolutionary concept and technology of CORS for RTK GPS positioning have emerged in the last two years.

3. The engineering community, including WisDOT, is migrating from two-dimensional to three-dimensional design technology and thinking. This transition requires not only a change in the way of doing business but also a change in way we think about and describe the world.

These are exciting times. They are also challenging times. Human, institutional, and cultural changes are not easy. They take time. Technological change is easy. It happens over night. Whether or not we can more fully realize the true benefits of technological advances depends upon our ability to adapt our institutions, our culture, and our individual and collective thinking.

Acknowledgements

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List of References

Vonderohe, A.P., (2007a), “Implementation of GPS Controlled Highway Construction Equipment”, Final Report submitted to the Wisconsin Department of Transportation, Construction and Materials Support Center, University of Wisconsin – Madison, April.

Vonderohe, A.P., (2007b), “Implementation of GPS Controlled Highway Construction Equipment Phase II”, Interim Report submitted to the Wisconsin Department of Transportation, Construction and Materials Support Center, University of Wisconsin – Madison, August.

Appendix A.
Specification and Guidance Language for 2007 Pilot Projects (As Presented in Vonderohe (2007))

Specification and Guidance for 2007
Wisconsin Department of Transportation
GPS Machine Guidance Pilot Projects

NOTE: This document is intended for use on only the 2007 pilot projects for GPS machine guidance. The specification and guidance language are subject to change for the 2008 and later construction seasons. In addition, this document is subject to possible modification by WisDOT regions with 2007 pilot projects.

2007 PILOT PROJECT SPECIFICATION

Construction Staking Subgrade, Item 650.4500; Construction Staking Initial Layout, Item 650.9900
Conform to standard spec 650 as modified in this special provision.

Replace standard spec 650.3.3 with the following:

650.3.3 Subgrade

650.3.3.1 General

(1) Use global positioning system (GPS) machine guidance or conventional subgrade staking on designated portions of the contract as follows:

GPS Machine Guidance	Subgrade Staking
______________________	______________________
______________________	______________________
______________________	______________________

(2) The engineer may require the contractor to revert to conventional subgrade staking methods for all or part of the work at any point during construction if, in the engineer's opinion, the GPS machine guidance is producing unacceptable results. If the engineer revokes approval to use GPS machine guidance on all or part of the work for reasons beyond the contractor's control, the department will measure the additional subgrade staking required to successfully complete the work in those areas as specified in 650.4(2) of this special provision.

650.3.3.2 Subgrade Staking

(1) Set construction stakes or marks at intervals of 100 feet, or more frequently, for rural sections and at intervals of 50 feet, or more frequently, for urban sections. Include additional stakes at each cross-section as necessary to match the plan cross-section, achieve the required accuracy, and to support construction operations. Also set and maintain stakes as necessary to establish the horizontal and vertical positions of intersecting road radii, auxiliary lanes, horizontal and vertical curves, and curve transitions. Locate stakes to within

0.25 feet (75 mm) horizontally and establish the grade elevation to within 0.03 feet (10 mm) vertically.

650.3.3.3 GPS Machine Guidance

650.3.3.3.1 General

(1) No subgrade stakes are required for work approved for GPS machine guidance.

(2) Coordinate with the engineer throughout the course of construction to ensure that work performed using GPS machine guidance conforms to the contract tolerances and that the methods employed conform to the contractor's GPS work plan and accepted industry standards. Address GPS machine guidance issues at weekly progress meetings.

(3) Provide GPS rover equipment to department staff as requested to check the work. This equipment is not intended for exclusive use of the department and may be used by the contractor as needed on the project. Provide training for department staff designated to use the GPS rover. Training shall include but not be limited to hardware, software, and operation of GPS rover equipment. Provide a copy of the user manual for the supplied rover equipment. Provide routine maintenance of equipment provided for department use. The department is responsible for loss of, or damage (beyond normal wear and tear) to, the rover while in the engineer's possession.

650.3.3.3.2 GPS Work Plan

(1) Submit a comprehensive written GPS work plan for department review at least 10 business days before affected grading operations begin. The engineer will review the plan to determine if it conforms to the requirements of this special provision.

(2) Construct the subgrade as the contractor's GPS work plan provides. Update the plan as necessary during construction of the subgrade.

(3) The GPS work plan should discuss how GPS machine guidance technology will be integrated into other technologies employed on the project. Include, but do not limit the contents to, the following:

1. Describe the manufacturer, model, and software version of the GPS equipment.
2. Provide information on the qualifications of contractor staff. Include formal training and field experience. Designate a single staff person as the primary contact for GPS technology issues.
3. Describe how project control is to be established. Include a list and map showing control points enveloping the site.
4. Describe site calibration procedures. Include a map of the control points used for site calibration and control points used to check the site calibration. Describe the site calibration and checking frequency as

well as how the site calibration and checking information are to be documented.

5. Describe the contractor's quality control procedures. Describe procedures for checking, mechanical calibration, and maintenance of equipment. Include the frequency and type of checks performed to ensure that the constructed subgrade conforms to the contract plans.

650.3.3.3.3 Equipment

(1) Use GPS machine guidance equipment to meet the requirements of the contract.

(2) Perform periodic sensor calibrations, checks for blade wear, and other routine adjustments as required to ensure that the final subgrade conforms to the contract plans.

650.3.3.3.4 Geometric and Surface Information

650.3.3.3.4.1 Department Responsibilities

(1) The department will provide to the contractor the best available electronic files of survey and design information as described here in 650.3.3.3.4.1 and in CMM 3-1-10. The department incurs no additional liability, beyond that specified in standard spec 105.6 or standard spec 650, by having provided this additional information.

(2) The department will provide data to the contractor that include the following:

Data Type	Format
Reference Line Data	LandXML
Design Profile Data	LandXML
Proposed Cross Section Data	Land XML
Existing Surface DTM Data	LandXML DTM
Existing Topographic Data (excluding utilities)	LandXML
Superelevation Data	LandXML
Graphical Information	DGN or DWG

(3) The department will provide design surface data in the form of points and break lines derived from the cross sections in the contract in LandXML format. The points and break lines will be on the subgrade surface between the subgrade shoulder points, and will be on the finished surface in topsoiled areas. The department provides design surface data for information only, and has no contractual liability for it.

650.3.3.3.4.2 Contractor Responsibilities

(1) Develop and maintain the initial design surface DTM for areas of the project employing GPS machine guidance consistent with information the department provides. Confirm that the design surface DTM agrees with the contract plans.

(2) Provide design surface DTM information to the department in LandXML or other engineer-approved format.

650.3.3.3.4.3 Managing and Updating Information

(1) The department and contractor will agree on the design surface model before using it for construction. Provide a copy of the resultant design surface DTM to the engineer at least two business days before using that design surface DTM for construction.

(2) Notify the department of any errors or discrepancies in department-provided information. Provide information regarding errors or discrepancies in the existing surface DTM, identified in the field, to the department in LandXML format if a revision to the contract plans is required. If surveying work beyond that required to slope stake is required to re-define the existing surface, the department will pay for costs of that additional surveying as extra work.

(3 The department will determine what revisions may be required. The department will revise the contract plans and existing surface DTM, if necessary, to address errors or discrepancies that the contractor identifies. The department will provide the best available electronic files and other available information related to those contract plan revisions.

(4) Revise the design surface DTM as required to support construction operations and to reflect any contract plan revisions the department makes. Perform checks to confirm that the revised design surface DTM agrees with the contract plan revisions. Provide a copy of the resultant revised design surface DTM to the engineer. The department will pay for costs incurred to incorporate contract plan revisions as extra work.

(5) The department will maintain the existing surface DTM by incorporating needed revisions. The department will make the current existing surface DTM available, in LandXML DTM format, to the contractor throughout construction.

650.3.3.3.5 Site Calibration

(1) Designate a set of control points, including a total of at least 6 horizontal and vertical points or 2 per mile, whichever is greater, for site calibration for the portion of the project employing GPS machine guidance. Incorporate the department-provided control framework used for the original survey and design.

(2) Calibrate the site by determining the parameters governing the transformation of GPS information into the project coordinate system. Provide the resulting site calibration file to the engineer before beginning subgrade construction operations.

(3) In addition to the site calibration, perform site calibration checks. Perform these checks at individual control points not used in the initial site calibration. At a minimum, check the calibration at the start of each day and at least once for every 5 hours of continuous subgrade construction work. Report out-of-tolerance checks to the engineer. The measured position must match the established position at each individual control point within the following tolerances:

- Horizontally to 0.10 feet or less.
- Vertically to 0.05 feet or less.

(4) Provide the previous week's daily calibration check results to the engineer at the weekly progress meeting for monitoring the GPS work.

(5) The department will use the same calibration file the contractor uses.

650.3.3.3.6 Construction Checks

(1) Conduct calibration checks daily conforming to 650.3.3.3.5 of this special provision and consistent with the contractor's GPS work plan. Use a GPS rover to check the subgrade at 20 or more randomly selected locations per mile. Document all GPS rover subgrade checks and any auxiliary checks made using other technologies. Provide all documentation to the engineer.

(2) Ensure that at least 4 of any 5 consecutively-tested subgrade points are within 0.10 foot vertically of the plan elevation. Notify the engineer if more than one of any five consecutively-tested subgrade points differs by more than 0.10 feet from the plan elevation.

(3) The department will conduct periodic independent subgrade checks using the contractor supplied GPS rover or conventional survey methods. When using the GPS rover, the department will use the same calibration files and other hardware and software settings the contractor uses for subgrade checking. The department will notify the contractor if any individual check differs by more than 0.10 feet from the design.

Replace standard spec 650.3.12 with the following:

650.3.12 Initial Layout

(1) Set and maintain construction marks as required to support the method of operations consistent with third-order, class I horizontal and third-order vertical accuracy. Validate the department-provided horizontal and vertical control information and notify the engineer of any discrepancies. Provide

marks to establish and maintain intermediate vertical and horizontal control for reference line alignment, side road alignments, radius points, bench level circuits, slopes on the ground, and offsetting the horizontal roadway alignment. These marks constitute the field control used to govern and execute the work.

(2) For the portion of the project using GPS machine guidance, set and maintain supplemental control points sufficient to ensure that there are a minimum of 6 established control points per mile. Ensure that these control points are consistent with third-order, class I horizontal and third-order vertical accuracy. Establish vertical control by differential leveling.

(3) Verify the existing ground elevations as shown for all roadways on cross-section sheets for accuracy. If the elevation at the slope intercept is off by more than 0.4 foot (120 mm), notify the engineer. Take and document a minimum of 3 shots per roadway section. Set and maintain slope stakes on each side of the road at each cross-section location shown on the plans. Stake additional clearing and grubbing, and marsh excavation limits at locations where they vary from the slope stakes.

(4) Document and provide to the engineer complete descriptions and reference ties for the control points, alignment points, and benchmarks to allow for quick reestablishment of the plan data at any time during construction and upon project completion.

Replace standard spec 650.4 with the following:

650.4 Measurement

(1) The department will measure the Construction Staking bid items for base, concrete pavement, resurfacing reference, and initial layout by the linear foot acceptably completed, measured along each roadway centerline. The department will not measure construction staking for base underlying concrete pavement.

(2) The department will measure Construction Staking Subgrade by the linear foot of subgrade acceptably completed, measured along each roadway centerline. The department will base measurement on the length of acceptably completed subgrade whether that subgrade was constructed using GPS machine guidance or using conventional construction staking. The department will include the length of subgrade where GPS machine guidance is initially employed but subsequently suspended by the engineer for reasons beyond the contractor's control. The department will measure this work twice, once for the suspended GPS work and once for the conventional subgrade staking required to successfully complete the work. If the department suspends GPS work for reasons within the contractor's control, the department will measure work in the affected area only once.

(3) The department will measure Construction Staking Curb Gutter and Curb & Gutter by the linear foot acceptably completed, measured along the base of the curb face. The department will measure Construction Staking Concrete Barrier by the linear foot acceptably completed, measured along the base of the barrier. The department will not measure these bid items if abutting concrete pavement.

(4) The department will measure Construction Staking Storm Sewer System as each individual inlet catch basin, manhole, and endwall acceptably completed.

(5) The department will measure Construction Staking Pipe Culverts by each individual pipe culvert staked and acceptably completed.

(6) The department will measure Construction Staking Structure Layout as a single lump sum unit for each structure acceptably completed. The department will measure Construction Staking Electrical Installations as a single lump sum unit for all electrical installations acceptably completed on each project.

GUIDANCE FOR 2007
WISCONSIN DEPARTMENT OF TRANSPORTATION
GPS MACHINE GUIDANCE PILOT PROJECTS

GENERAL CONSTRUCTION AND PROJECT SELECTION

The candidate project should first be reviewed for suitability for GPS use; for example, projects with dense tree canopy or large vertical cuts may not prove suitable. The region surveyor would assist in this preliminary evaluation with the construction engineer. It may also be determined that only certain project segments would be suitable. Recommended pilot projects should be communicated to the region's project manager and forwarded to Ken Brockman, Bureau of Project Development (BPD) for final approval.

On the pilot projects, the item of machine control grading will be used to replace subgrade staking on the whole project or segments of selected roadway sections. The project or segments should be reviewed and agreed upon by the engineer and contractor. A no-cost change order would then be submitted to allow the machine control grading. The item for Staking Subgrade would be paid for in all segments where machine control is attempted.

It is recommended that projects using machine control grading would also include contractor staking items such as initial layout.

DESCRIBING PROJECT EXTENTS

The GPS machine guidance pilot project specification allows some or all of the construction project to be done with GPS machine guidance. If the entire project is to be done with GPS machine guidance, then the following location description table can be used:

GPS Machine Guidance	Subgrade Staking
Entire Project	None

If segments of the project are to be done with GPS machine guidance and the remaining segments are to be done using conventional construction methods, the segments using conventional methods must be subgrade staked. The extents of each GPS machine guidance segment and each subgrade staking segment need to be described. There are a number of methods for describing the extents of segments. Examples include project stationing (preferred), cross street (intersection) naming, and bridge identification.

The following location description table combines some of these methods to describe the extents of four segments:

GPS Machine Guidance	Subgrade Staking
From Sta 0+00 to Sta 56+50	From Sta 56+50 to the intersection with CTH N.
From the intersection with CTH N to the Elm Street overpass (B-05-151)	From the Elm Street overpass (B-05-51) to EOJ

ROLES AND RESPONSIBILITIES

Designer

The project designer is responsible for overall design and any subsequent changes.

The designer provides normal digital data exchange data including DTM information and would work with the Methods Development Unit (MDU) engineer to prepare XML format information to be used by the contractor. Some additional field verification of models and digital terrain models (DTMs) may be required as a quality assurance of this information.

The designer would make the necessary design changes in case of errors and work with the MDU engineer to provide changed DTMs.

Construction Engineer

Project Selection

For the pilot projects, the construction engineer would assist in the determination of the applicability of the use of machine control. The engineer should work with the region surveyor to evaluate the suitability of GPS technology and the availability of project control for the proposed project. The engineer, contractor, and region surveyor should agree on usage and limits of machine control grading, and a recommendation should go to regional & BPD management as noted above.

The engineer would lead the coordination of department-provided items and be the focal point for communication with the contractor.

Data and Surface Model Coordination

In order to prepare project data, DTMs, and surface model information for use by the contractor, there needs to be close coordination between the construction engineer, the designer, and the methods development unit (MDU) engineer. A meeting as noted below could help facilitate this.

Initial Coordination Meeting

Integral DOT/consultant staff that will provide information and guidance to the project should meet to discuss roles and responsibilities. This should include the design engineer, construction engineer, regional surveyor, methods development engineer, appropriate management, and may include contractor survey personnel. Some of the items to be addressed include provision of models and their formats, survey data and support, and project communications.

Pre-Construction Survey Meeting

Before the start of construction survey, it is recommended that a coordination meeting be held to aid in the passing of survey information to the contractor and discuss the contractors GPS work plan.

Pre-Survey Meeting

This meeting includes the contractor, contract surveyor, construction engineer, methods development engineer, and regional surveyor. At this meeting, the contractor should share and discuss their GPS work plan, project schedule, and survey schedule. The department should identify key personnel and methods for handling changes on the model, etc.

During Construction

Calibration checks are the responsibility of the contractor, but should be reviewed with the region surveyor to verify they are in reasonable tolerances and format.

The engineer should work with the region surveyor to develop a plan to perform construction checks. It is essential to provide some checks at project start-up to ensure contractor methods are meeting necessary tolerances. These checks can be performed using contractor-supplied GPS rover, independent GPS equipment, or conventional survey methods, and should meet specified tolerances. It is anticipated that once initial methods are working, construction checks could be performed using contractor-supplied rover. The department reserves the right to do added checks as needed.

After Construction

The contractor, construction engineer, and surveyor should meet to review the effectiveness of the machine control grading operations and identify benefits and issues to be addressed.

The construction engineer should prepare a final report evaluating the machine control usage. Evaluation items could include overall project impacts, specification improvements, construction administration issues and other pertinent items. This evaluation should be submitted to the machine control grading steering team; Ken Brockman in the Bureau of Project Development is the designated lead for submittals.

Region Surveyor

The region surveyor is responsible for providing control points and technical support on the project.

Control Points

For the pilot projects, the region's survey unit would provide a minimum of 6 control points or 2 points per mile for use during the project. These points should be constructed or located outside the anticipated construction footprint. They should be type 1 or equivalent and should be set 15 degrees clear to the horizon with 360-degree access desirable at 6 foot height.

Control points should have horizontal and vertical project coordinates published. These points should be available two weeks before the preconstruction conference.

Technical Support

The region surveyor should assist in initial evaluation of the project for potential GPS use. The surveyor could also assist in the development of a plan for providing construction checks.

The contractor is required to do their own project calibrations and check their work as it progresses. However, there may be questions that arise from the construction engineer related to GPS operations and calibrations. It is expected that the regional surveyor would be available to lend technical guidance as warranted.

The surveyor should assist in evaluation of the pilot and provision of specific feedback on issues to be resolved, etc.

EARTHWORK QUANTITIES

The region surveyor should work with the construction engineer and contractor to obtain as-built data and/or construction surface models for computing final quantities. The surveyor would work with the MDU engineer and the construction engineer to develop informational quantities for comparison to conventional quantity computations.

SITE CALIBRATION AND CHECKS

The contractor performs site calibration and site calibration checks. The contractor provides data collected during these activities to the construction engineer. The following is intended for both the contractor and the construction engineer as guidance in configuring the control points used for site calibration, interpretation of site calibration and check data, and appropriate procedures to follow if either of the specified site calibration check tolerances is exceeded. The construction engineer can also consult with the regional surveyor on these matters.

Site Calibration

Site calibration, sometimes referred to as “localization”, for GPS machine guidance is a process that results in computation of parameters for transforming measured GPS coordinates into the coordinate system of the project control points. Good site calibration and checking are vital to the success of GPS machine control operations.

Control Point Configuration

The GPS machine guidance pilot project specification requires that a minimum of six control points be used for site calibration and that the site calibration be periodically checked at control points not used in the calibration itself. The control points used for site calibration should envelop the project and be well distributed around its perimeter. Control points in close proximity to one another should be avoided. Long, narrow configurations of control points should be avoided. There should be control points near the corners of the project and approximately midway along its boundaries.

Error Estimates

Horizontal and vertical tolerances are specified for the site calibration checks but not for the site calibration itself. Once the site calibration measurement process is complete, the RTK GPS software will report estimates for the horizontal and vertical errors at each of the site calibration control points. A majority of the horizontal error estimates should be 0.10 feet or less in magnitude. A majority of the vertical error estimates should be 0.05 feet or less in magnitude. If any horizontal error estimate is greater than 0.15 feet, or if any vertical error estimate is greater than 0.08 feet, it is indicative (but not conclusive) that there might be later difficulties in meeting the site calibration check tolerances at the independent control points. These tolerances are 0.10 feet (horizontal) and 0.05 (vertical).

Site Calibration Checks

If any site calibration check exceeds the specified tolerances (i.e., 0.10 horizontally or 0.05 feet vertically), there is a sequence of steps that should be followed:

1. The check should be re-measured at the same independent control point to ensure there is no problem with the check measurement.

2. A second and, perhaps, a third independent control point should be used to check the site calibration. If tolerances are met at these additional independent control points, then a problem is indicated with the first check control point.
3. If check tolerances are not met at two or more independent control points, then a problem is indicated with the site calibration and the site calibration measurement and computation procedure should be repeated to ensure that there is no problem with the initial site calibration measurements. If site calibration problems persist, vendor supplied manuals or guidance might also need to be consulted.
4. If the repeated site calibration measurements are in close agreement with the initial site calibration measurements, then a problem is indicated with one or more of the site calibration control points. The site calibration should then be performed while excluding the control point with the largest horizontal and / or vertical error estimate. It is likely that such error estimates will be larger than 0.10 feet horizontally or 0.05 feet vertically.
5. If a problem with a site calibration control point is identified in step 4, that control point should be replaced by another, and the site calibration procedure and checking should be repeated. The above control point configuration guidelines should be followed in selecting replacement control points.

CHANGES/ERRORS

Specifications direct the contractor to immediately notify the engineer of any errors during staking and construction. Noted errors should be investigated as quickly as possible and may result in changes to the project model. The machine control specifications give guidance on handling model changes. It will be necessary to coordinate with the design engineer and the MDU engineer to make model changes.

In cases of significant errors and changes, further consideration may have to be given to the continued use of the machine control operations on the project. Current pilot specifications provide that should the machine control technology prove to be unworkable, the engineer would pay the item of subgrade staking for the section attempted and revert back to conventional staking.

Appendix B.
WisDOT Southwest Region's Revision to Specification

Construction Staking Subgrade, Item 650.4500; Construction Staking Initial Layout, Item 650.9900
Conform to standard spec 650 as modified in this special provision.

Replace standard spec 650.3.3 with the following:

650.3.3 Subgrade

650.3.3.1 General

(1) Use global positioning system (GPS) machine guidance and verify with conventional subgrade staking on the following designated portions of the contract as follows:

GPS Machine Guidance

1) Within 399+80 to 499+50

Conventional Subgrade Staking

1) First 1000' will require 3 stakes every 100'
2) Second 1000' cl stakes every 100' and 3 stakes every 100' in and out of superelevations
3) Third 1000' cl stakes every 500' and 3 stakes every 100' in and out of superelevations
4) Remainder will evaluate when first 3000' is complete or near complete.

If the first 1000' section is acceptable to the engineer then the number of stakes can be reduced in the second 1000' section and so on. If the first section is not acceptable to the engineer then the same conventional staking intervals will be required to continue.

(2) The engineer may require the contractor to revert to conventional subgrade staking methods for all or part of the work at any point during construction if, in the engineer's opinion, the GPS machine guidance is producing unacceptable results.

Appendix C.
Record-Keeping Forms
and Examples Distributed to Pilot Project
Engineers and Foremen

Site Calibration / Localization Form

Project ID =

Date =

Table of Control Point Error Estimates

NOTE: Under "Control Point Type", enter H for horizontal, V for vertical, or B for Both.

NOTE: Enter error estimates corresponding with control point types (e.g., do not enter a vertical error estimate for a horizontal control point)

Control Point ID	**Control Point Type**	**Horizontal Error Estimate (ft)**	**Vertical Error Estimate (ft)**

Site Calibration / Localization Form

Project ID = 14-691234

Date = 5/22/07

Table of Control Point Error Estimates

NOTE: Under "Control Point Type", enter H for horizontal, V for vertical, or B for Both.

NOTE: Enter error estimates corresponding with control point types (e.g., do not enter a vertical error estimate for a horizontal control point)

Control Point ID	**Control Point Type**	**Horizontal Error Estimate (ft)**	**Vertical Error Estimate (ft)**
22A	H	0.05	
3	V		0.04
BILL	H	0.02	
5C7	H	0.04	
445	B	0.02	-0.03
15CARL	B	0.01	0.02
MMM	B	0.02	-0.04
142	V		0.01

Site Calibration / Localization Check Form

Project ID =

Table of Control Point Checks

NOTE: Under "Control Point Type", enter H for horizontal, V for vertical, or B for Both.

NOTE: Enter check values corresponding with control point types (e.g., do not enter a vertical check value for a horizontal control point)

Date	**Control Point ID**	**Control Point Type**	**Horizontal Check Value (ft)**	**Vertical Check Value (ft)**

Site Calibration / Localization Check Form

Project ID = 14-691234

Table of Control Point Checks

NOTE: Under "Control Point Type", enter H for horizontal, V for vertical, or B for Both.

NOTE: Enter check values corresponding with control point types (e.g., do not enter a vertical check value for a horizontal control point)

Date	Control Point ID	Control Point Type	Horizontal Check Value (ft)	Vertical Check Value (ft)
5/24/2007	5123	B	0.03	-0.04
5/24/2007	5123	B	0.01	-0.02
5/25/2007	5123	B	0.02	-0.02
5/25/2007	5123	B	0.03	0
5/26/2007	JAMES	H	0.04	
5/26/2007	MIKE	V		0.04
5/26/2007	JAMES	H	0.02	
5/26/2007	MIKE	V		0.02
5/27/2007	143	B	0	-0.03
5/27/2007	143	B	0.01	-0.02

Subgrade Check Form

Project ID =

Table of Subgrade Checks

Date	Station	Offset	Subgrade Check Value (ft)

Subgrade Check Form

Project ID = 14-691234

Table of Subgrade Checks

Date	Station	Offset	Subgrade Check Value (ft)
6/22/2007	300+15.25	55.36L	-0.06
6/22/2007	300+84.33	32.56R	0.03
6/22/2007	301+44.22	10.99R	0.08
6/22/2007	301+66.88	11.44L	0.05
6/22/2007	302+14.16	25.78L	-0.07
6/22/2007	302+77.95	8.27R	0.05
6/23/2007	303+14.44	5.33R	-0.03
6/23/2007	303+52.46	22.82L	-0.06

Appendix D.
Questions and Talking Points for Second Site Visit to Hoffman Project

Talking Points for Second Site Visit
To STH 57 – Hoffman

NOTE: This document is a list of questions and talking points for the second site visit during August, 2007. It is not a questionnaire to be filled out and returned. The questions and talking points focus upon selected, specific aspects of the specification and guidance language for the pilot project.

1. The specification allows the engineer to require conventional subgrade staking if GPS machine guidance is producing unacceptable results. In such cases, if the GPS problems are beyond the contractor's control, WisDOT will measure the additional subgrade staking for payment.

    Is this a good idea? Was there a need to revert to conventional staking on the pilot project? Does this part of the spec need any modification?

2. No subgrade stakes are required for work approved for GPS machine guidance.

    Does this part of the spec need any modification?

3. The spec requires coordination throughout the course of construction between the contractor and engineer to ensure that GPS machine guidance conforms to contract tolerances and that methods conform to the contractor's GPS work plan. This includes addressing GPS machine guidance issues at weekly progress meetings.

    What was your experience with this coordination on the pilot project? Does this part of the spec need any modification?

4. The spec requires provision by the contractor of a GPS rover, along with training, to the project engineer for use as needed on the project.

    What was your experience with this aspect of the spec on the pilot project? Does this part of the spec need any modification?

5. The spec requires submittal of a GPS work plan by the contractor to the engineer at least 10 business days before the beginning of affected grading operations. The spec goes on to describe necessary components of the GPS work plan.

    What was your experience with this aspect of the spec on the pilot project? Does this part of the spec need any modification?

6. The spec requires periodic sensor calibrations, checks for blade wear, and other routine adjustments.

    How often were these equipment checks and sensor calibrations performed? What was checked? What was calibrated? Does this part of the spec need any modification?

7. The spec requires provision of design surface data by WisDOT in LandXML format, development of the 3D model by the contractor, confirmation by the contractor that the 3D model agrees with the plans, and provision of the 3D model to the project engineer. Furthermore, errors in department-provided information are to be reported in LandXML format. WisDOT determines if revisions to the plans are required. If revisions to the plans force revisions to the 3D model, WisDOT pays for the revisions to the 3D model. The contractor is to provide the current 3D model to the engineer.

   We quickly learned that LandXML did not work as a data exchange format. Please describe what was done to develop and maintain the 3D model on the pilot project. Were any errors in the plans detected? Was it ever necessary to revise the plans? Did revisions to the plans force revisions to the 3D model? What are your recommendations concerning this aspect of the specification?

8. For site calibration / localization, the specification requires at least 6 horizontal and vertical control points, or two per mile, whichever is greater.

   Is this number sufficient? Is it over-specified? Does this part of the spec need any modification?

9. Site calibration checks are required at the start of each day and at least once for every five hours of continuous subgrade construction work. Horizontal tolerance is 0.10 ft or less. Vertical tolerance is 0.05 ft or less.

   Is this frequency appropriate for site calibration / localization checking? Are the tolerances appropriate? Did any site calibration / localization check fail to meet tolerance? If so, what was done? Does this part of the spec need any modification?

10. Daily site calibration / localization checks results are to be provided to the engineer at weekly progress meetings.

    Does this part of the spec require any modification?

11. A GPS rover is to be used by the contractor to check the subgrade at 20 or more randomly selected locations per mile. At least 4 of any 5 consecutively-tested subgrade points must be within 0.10 ft (vertically) of the plan elevation. If otherwise, the engineer must be notified. The engineer makes periodic independent subgrade checks and notifies the contractor if any individual check differs by more than 0.10 ft from design.

    How did the contractor select the check points? Were there any failures of the 4-out-of-5 0.10 ft tolerance? If so, what was done? Did any of the engineer’s checks fail the 0.10 ft tolerance? If so, what was done? Does this part of the spec require any modification? Can the check tolerance be tightened up, say to 0.07 ft or 0.08 ft?

12. In initial layout, the specification requires a minimum of 6 established control points per mile. These control points are to be consistent with third-order, class I horizontal and third-order vertical accuracy. Vertical control is to be established by differential leveling.

    Is the number of control points appropriate? Is the accuracy requirement appropriate? Is the differential leveling method appropriate? Does this part of the spec require any modification?

13. Is there any other aspect of the specification that needs attention? Are there unnecessary redundancies in the specification? Is there anything left out of the specification? What else can be done to improve the specification?

14. Have you reviewed the guidance language? Was it necessary to rely upon any of the guidance language during the pilot project? If so, did you find it useful? Even if you did not need to use the guidance language on the pilot project, do you think it is useful in its current form? Is there anything missing from the guidance language? Are there any unnecessary redundancies in the guidance language? Is there anything that is unclear or confusing in the guidance language? What else can be done to improve the guidance language?

Appendix E.
Questions and Talking Points for Second Site Visit to Wondra Project

Talking Points for Second Site Visit
To STH 106 - Wondra

NOTE: This document is a list of questions and talking points for the second site visit during August, 2007. It is <u>not</u> a questionnaire to be filled out and returned. The questions and talking points focus upon selected, specific aspects of the specification and guidance language for the pilot project.

1. The specification allows the engineer to require conventional subgrade staking if GPS machine guidance is producing unacceptable results. The STH 106 spec requires some conventional subgrade staking in the first 3000 feet of the project.

    Was there a need to revert to conventional staking on other parts of the pilot project? If so, why?

    What is your recommendation for 2008 pilot projects? Should conventional subgrade staking be at the discretion of the engineer in case GPS machine guidance is not working well? Should there be any required subgrade staking (as in the 2007 STH 106 spec) or subgrade staking at the discretion of the engineer, even if GPS machine guidance is working well?

2. The spec requires coordination throughout the course of construction between the contractor and engineer to ensure that GPS machine guidance conforms to contract tolerances and that methods conform to the contractor's GPS work plan. This includes addressing GPS machine guidance issues at weekly progress meetings.

    What was your experience with this coordination on the pilot project? Does this part of the spec need any modification?

3. The spec requires provision by the contractor of a GPS rover, along with training, to the project engineer for use as needed on the project.

    What was your experience with this aspect of the spec on the pilot project? Does this part of the spec need any modification?

4. The spec requires submittal of a GPS work plan by the contractor to the engineer at least 10 business days before the beginning of affected grading operations. The spec goes on to describe necessary components of the GPS work plan.

    What was your experience with this aspect of the spec on the pilot project? Does this part of the spec need any modification?

5. The spec requires periodic sensor calibrations, checks for blade wear, and other routine adjustments.

How often were these equipment checks and sensor calibrations performed? What was checked? What was calibrated? Does this part of the spec need any modification?

6. The spec requires provision of design surface data by WisDOT in LandXML format, development of the 3D model by the contractor, confirmation by the contractor that the 3D model agrees with the plans, and provision of the 3D model to the project engineer. Furthermore, errors in department-provided information are to be reported in LandXML format. WisDOT determines if revisions to the plans are required. If revisions to the plans force revisions to the 3D model, WisDOT pays for the revisions to the 3D model. The contractor is to provide the current 3D model to the engineer.

    We quickly learned that LandXML did not work as a data exchange format. Please describe what was done to develop and maintain the 3D model on the pilot project. Were any errors in the plans detected? Was it ever necessary to revise the plans? Did revisions to the plans force revisions to the 3D model? What are your recommendations concerning this aspect of the specification?

7. For site calibration / localization, the specification requires at least 6 horizontal and vertical control points, or two per mile, whichever is greater.

    Is this number sufficient? Is it over-specified? Does this part of the spec need any modification?

8. Site calibration checks are required at the start of each day and at least once for every five hours of continuous subgrade construction work. Horizontal tolerance is 0.10 ft or less. Vertical tolerance is 0.05 ft or less.

    Is this frequency appropriate for site calibration / localization checking? Are the tolerances appropriate? Did any site calibration / localization check fail to meet tolerance? If so, what was done? Does this part of the spec need any modification?

9. The site calibration / localization file is to be provided to the project engineer. Daily site calibration / localization checks results are to be provided to the engineer at weekly progress meetings.

    Does this part of the spec require any modification?

10. A GPS rover is to be used by the contractor to check the subgrade at 20 or more randomly selected locations per mile. At least 4 of any 5 consecutively-tested subgrade points must be within 0.10 ft (vertically) of the plan elevation. If otherwise, the engineer must be notified. The engineer makes periodic independent subgrade checks and notifies the contractor if any individual check differs by more than 0.10 ft from design.

How did the contractor select the check points? Were there any failures of the 4-out-of-5 0.10 ft tolerance? If so, what was done? Did any of the engineer's checks fail the 0.10 ft tolerance? If so, what was done? Does this part of the spec require any modification? Can the check tolerance be tightened up, say to 0.07 ft or 0.08 ft?

11. Is there any other aspect of the specification that needs attention? Are there unnecessary redundancies in the specification? Is there anything left out of the specification? What else can be done to improve the specification?

12. Have you reviewed the guidance language? Was it necessary to rely upon any of the guidance language during the pilot project? If so, did you find it useful? Even if you did not need to use the guidance language on the pilot project, do you think it is useful in its current form? Is there anything missing from the guidance language? Are there any unnecessary redundancies in the guidance language? Is there anything that is unclear or confusing in the guidance language? What else can be done to improve the guidance language?

Appendix F.
GPS Work Plan Submitted by Hoffman Construction

Work Plan

HOFFMAN CONSTRUCTION CO.

123 CTH A
Black River Falls, WI 54615
Phone (715) 284-2512 Fax (715) 284-9698
www.hoffmanconstructionco.com

GPS Machine Guidance Specification Pilot
South County Line to Truway Road
Green Bay to Sturgeon Bay Road
STH 57
Door County

Equipment

Design:
- Trimble Terramodel v. 10.43

Staking:
- Base Station: Trimble SPS750
- Rover: Trimble SPS780
- Data Collector: Trimble TSC2
- Staking Software: Trimble SCS900 v. 2.11

Machine Control:
- Caterpillar D6R Dozer
- Caterpillar 14H Motor Grader
- System on Machines: Trimble GCS900 v. 6.0

People

Ken Bork
Hoffman Construction Company

Six years of grade staking and data preparation using robot total stations, GPS instruments, and design/survey software.
Six years of teaching grade staking classes using total stations and GPS instruments at Local 139 Union School in Coloma.
Role in Specification: Primary contact for GPS Pilot Spec. He will be on-site daily, and will be handling data flow and field operations for the pilot.

Chris Goss
Hoffman Construction Company

Twelve years of construction layout, data preparation, and property surveying using total stations, GPS instruments, design/survey software, and cad software.
Role in Specification: Oversight and support to field and data operations.

Mike Windsor
Hoffman Construction Company
Two years of grading using Trimble GPS machine control motor graders.
Role in Specification: Operator of Caterpillar 14H Motor Grader equipped with Trimble GCS900.

Dan Stewart
Hoffman Construction Company
Two years of grading using Trimble GPS machine control D6R Dozer.
Role in Specification: Operator of Caterpillar D6R Dozer equipped with Trimble GCS900.

Joe Broullire
Superior Staking
Construction Staking Contractor for the project.
Role in Specification: Create and maintain on-site control points.

Project Control

For this project, the department has provided a list of control (Attachment A) that was established by Coleman Engineering. This control shall be used as the primary control for this project. Hoffman Construction Company ("HCC") will use these points in the site calibration. Some points will not be used in the site calibration; these points will be reserved to be used as daily checks throughout the duration of the project.

Site Calibration

Site calibration will be performed using the calibration function in Trimble SCS900. The points used in the site calibration will envelope the site. The entire project will be included in one site calibration. Each point in the calibration will be observed statically for 15 seconds. The resulting precision of the site calibration shall fall within 0.10 ft. horizontally and 0.05 ft. vertically. A hard copy of the resulting site calibration data from SCS900 will be given to the engineer.

HCC will perform control checks daily. HCC's typical workweek will be 5 days per week, 50 hours per week. HCC will perform two control checks per workday. One will be done at the start of work, and the other will be done during the last half of the work day. Those checks shall fall within 0.10 ft. horizontally and 0.05 ft. vertically. Those control checks will be recorded using SCS900. A hard copy of that record will be reported weekly to the engineer.

A list of points used in the site calibration and used as checks, and their location can be found in Attachment B.

Additional QC Procedures

Machines:

GCS900 v. 6.0 has two equipment checks that shall be done:

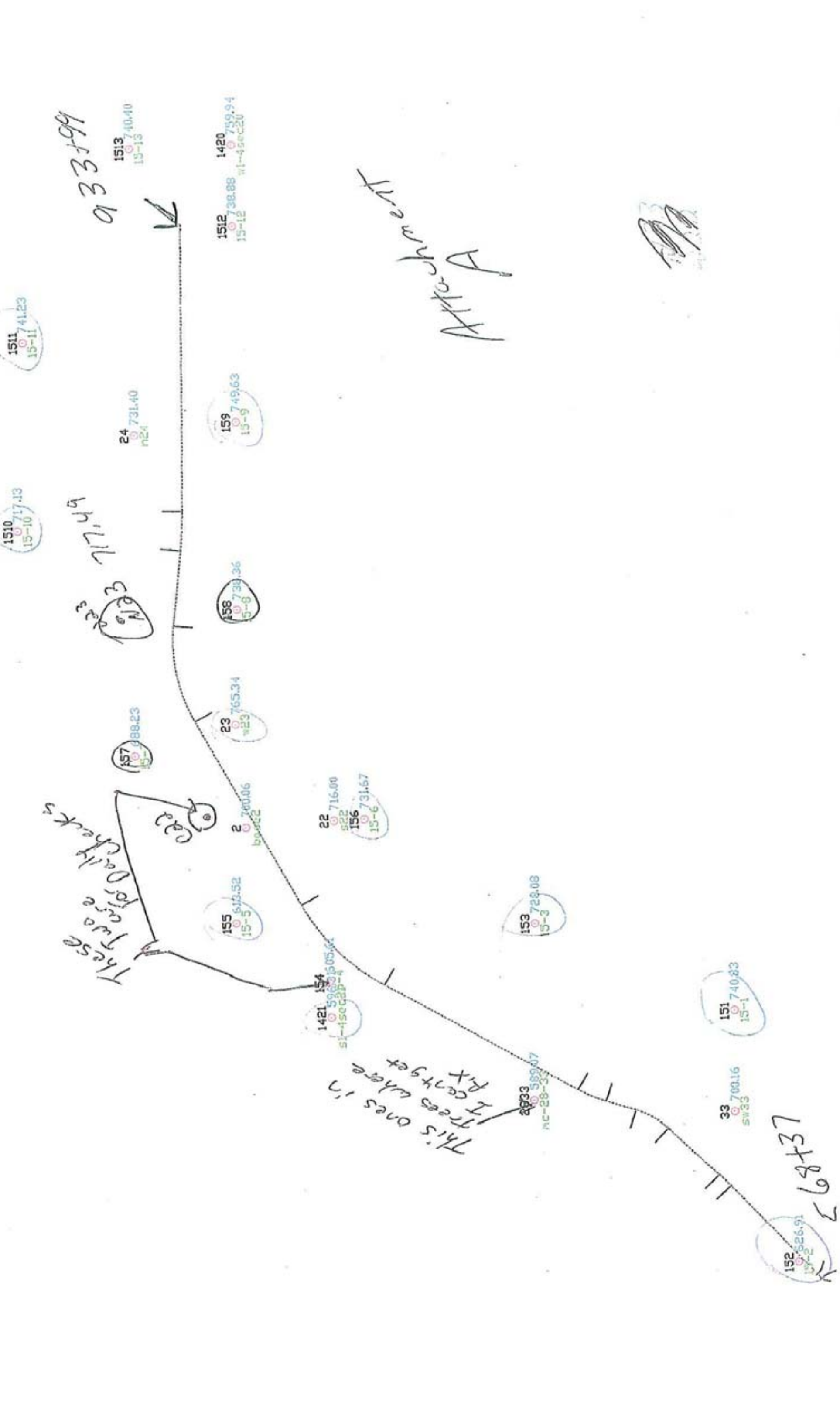
First is the valve calibration. This procedure will be typically done twice per year, or when something changes with the hydraulics of the machine, i.e. replacing of hydraulic fluids, valves, or pumps. This shall be done once before the machine does any finish grading on the project. This procedure requires the machine to be stationary. The machine will go through a series of lifts and drops of the blade to calibrate the valves. The valve calibration shall be done after the machine has been operated. The calibration shall not be done at first start-up. HCC will notify the engineer when the valve calibration will occur. HCC will document to the engineer that the valve calibration has occurred.

Second is the blade wear check. Blade wear is a series of simple measurements that are taken along the cutting edge of the blade. There will be three measurements taken along the blade (quarter points). Those three measurements will be averaged and entered into GCS 900. This measurement shall be done at a minimum of once per workweek during finish grade operations. The measurements will be documented to the engineer. If the measurements vary by 0.08 ft. then HCC will make efforts to true up the cutting edge or replace it.

Grade Checks:

HCC will perform random grade checks on the subgrade (between shoulder points) at a rate of 20 checks per mile. The checks will be done on even stations to allow for ease in the verification with the plans. The point data will be recorded using SCS900. A hard copy of the recorded data and precision will be given to the engineer on a weekly basis when finish grade operations are occurring.

As in the past, HCC grade foremen will be continually working and checking with the crews to ensure that the grade is being constructed to the plan lines and grades. This everyday checking will not be recorded, but it will aid in the accuracy of the grade.



Attachment A
933+99
568+37
717.49

15-1	101258.7	406621	740.83
15-2	99675.06	399829.5	626.91
15-3	106448.8	409109.5	728.08
15-4	111861.2	407638.4	605.61
15-5	114275.5	409283.1	613.52
15-6	110879.9	412043	731.67
15-7	116845.8	413872.7	688.23
15-8	114123.3	417800.3	738.36
15-9	114067.1	422874.2	749.63
15-10	119798.2	420022.7	717.13
15-11	119584.8	425119.9	741.23
15-12	114061.3	428189.1	738.88
15-13	116715.4	430352.2	740.4
15-14	114104.7	435639.8	816.86
15-15	118370.1	438256.2	726.31
15-16	121943.7	433525.6	750.98
15-17	124387.9	441023.6	713.55
15-18	127042.6	440930.2	741.87
15-19	127661.5	446291.4	650.57
15-20	131008.2	446296.6	668.42
c22	114321.1	412051.6	704.33
mc-28-33	106556.3	404367.3	589.07
n23	116796.5	417337.4	717.49
n24	116736.9	422562.6	731.4
nesec20	116669.9	435676	788.49
s1-4sec21	111825.8	406697.8	596.31
s1-4sec3	126992.1	443616.1	679.84
s22	111675.6	412019.5	716
sw33	101297.5	403921.2	700.16
swsec9	121968.7	435679.7	752.03
w1-4sec10	124411.7	440975.9	716.08
w1-4sec20	114046.3	430413.7	759.94
w23	114213	414672.8	765.34

Attachment B

Appendix G.
Site Calibration / Localization Checks for Hoffman Project

Two Pages of Calibration Checks

Barry

Open WO	Work Order Name	calibration 8-2
	Date	8/2/2007
	Time	7:56:37 AM
	Operator Name	Ken Bork
	Site	hwy 57 701 4-5-07
	Design Folder	
	Underlying Surface Design	
Open WO	Work Order Name	calibration 8-2
	Date	8/2/2007
	Time	8:42:41 AM
	Operator Name	Ken Bork
	Site	hwy 57 701 4-5-07
	Design Folder	
	Underlying Surface Design	
System Check	Date	8/2/2007
	Time	8:43:32 AM
	Base Name	base2
	Control Point Name	15-4
	Precision-Horz	0.02 usft
	Precision-Vert	0.02 usft
	Base Latitude	---
	Base Longitude	---
	Base Height	---
Open WO	Work Order Name	calibration 8-2
	Date	8/3/2007
	Time	6:11:41 AM
	Operator Name	Ken Bork
	Site	hwy 57 701 4-5-07
	Design Folder	
	Underlying Surface Design	
System Check	Date	8/3/2007
	Time	6:12:27 AM
	Base Name	base2
	Control Point Name	15-4
	Precision-Horz	0.03 usft
	Precision-Vert	0.04 usft
	Base Latitude	---
	Base Longitude	---
	Base Height	---
Open WO	Work Order Name	calibration 8-2
	Date	8/6/2007
	Time	7:44:59 AM
	Operator Name	Ken Bork
	Site	hwy 57 701 4-5-07
	Design Folder	
	Underlying Surface Design	
Rover Setup	Date	8/6/2007
	Time	7:45:32 AM
	Base Name	base2
	Corrections Received Via	Radio
	Radio Network	15
	Base Ant. Height(APC)	5.20 usft
	Base Latitude	44°42'42.73815" N
	Base Longitude	87°41'31.04583" W
	Base Height	576.46 usft
System Check	Date	8/6/2007
	Time	7:46:27 AM
	Base Name	base2
	Control Point Name	15-4
	Precision-Horz	0.02 usft
	Precision-Vert	[illegible]

	Base Name	base2
	Control Point Name	15-4
	Precision-Horz	0.01 usft
	Precision-Vert	0.00 usft
	Base Latitude	---
	Base Longitude	---
	Base Height	---
Open WO	Work Order Name	calibration 8-2
	Date	8/8/2007
	Time	10:03:55 AM
	Operator Name	Ken Bork
	Site	hwy 57 701 4-5-07
	Design Folder	
	Underlying Surface Design	
System Check	Date	8/8/2007
	Time	10:04:32 AM
	Base Name	base2
	Control Point Name	15-4
	Precision-Horz	0.02 usft
	Precision-Vert	0.01 usft
	Base Latitude	---
	Base Longitude	---
	Base Height	---
Open WO	Work Order Name	calibration 8-2
	Date	8/8/2007
	Time	1:32:55 PM
	Operator Name	Ken Bork
	Site	hwy 57 701 4-5-07
	Design Folder	
	Underlying Surface Design	
System Check	Date	8/8/2007
	Time	1:34:08 PM
	Base Name	base2
	Control Point Name	15-4
	Precision-Horz	0.03 usft
	Precision-Vert	0.00 usft
	Base Latitude	---
	Base Longitude	---
	Base Height	---
Open WO	Work Order Name	calibration 8-2
	Date	8/9/2007
	Time	7:05:54 AM
	Operator Name	Ken Bork
	Site	hwy 57 701 4-5-07
	Design Folder	
	Underlying Surface Design	
System Check	Date	8/9/2007
	Time	7:06:31 AM
	Base Name	base2
	Control Point Name	15-4
	Precision-Horz	0.02 usft
	Precision-Vert	0.02 usft
	Base Latitude	---
	Base Longitude	---
	Base Height	---
Open WO	Work Order Name	calibration 8-2
	Date	8/10/2007
	Time	6:49:11 AM
	Operator Name	Ken Bork
	Site	hwy 57 701 4-5-07
	Design Folder	
	Underlying Surface Design	
System Check	Date	8/10/2007
	Time	6:50:07 AM

Appendix H.
Subgrade Checks for Hoffman Project

SCS Report Utility v2.01

Import Record ①	Quick View ④
Reports ②	Change Tolerances ⑤
Outputs ③	Clear Workbook ⑥

Hoffman Construction C.

123 CTH A
Black River Falls, WI 54615
PH(715)284-2512 FAX(715)284-2512

WorkOrder: *beginning job*

First access: 6/9/1999 4:26:40 AM
Last access: 9/5/1999 9:05:31 AM

Client : -

Ab

Station Format 0+00.00

Record type	Sub type	Point Name	Measured N	Measured E	Measured Elv	Prec. H	Prec. V	Precision Type	Design N	Design E	Design Grade	Cut/Fill (+/-)	Horiz. Deviation	Design Station	Design Offset	Measured Station	Measured Offset	Tolerance Check	High Tolerance	Low Tolerance	Antenna Ht	Local Time
Stakeout	Surface	StakedPt1	101173.03	401580.41	630.34	0.03	0.03	RTK			630.37	-0.04									6.56	7:46:32 AM
Stakeout	Surface	StakedPt2	100522.29	400990.25	632.04	0.02	0.04	RTK			632.02	0.02				590+00.45	28.57				6.56	1:14:18 PM
Stakeout	Surface	StakedPt3	100519.99	400992.28	631.97	0.02	0.04	RTK			631.96	0.01				590+00.39	31.64				6.56	1:14:35 PM
Stakeout	Surface	StakedPt4	100676.66	401119.94	632.38	0.02	0.04	RTK			632.36	0.02				592+00.41	2.81				6.56	1:15:38 PM
Stakeout	Surface	StakedPt5	101005.09	401496.90	631.21	0.03	0.06	RTK			631.26	-0.04				597+00.19	16.43				6.56	1:17:58 PM
Stakeout	Surface	StakedPt6	101289.94	401777.48	629.81	0.03	0.07	RTK			629.85	-0.04				600+99.55	-3.15				6.56	1:19:32 PM
Stakeout	Surface	StakedPt7	101411.89	401935.44	629.77	0.02	0.06	RTK			629.82	-0.04				602+98.36	14.10				6.56	1:24:34 PM
Stakeout	Surface	StakedPt8	101420.56	401926.82	629.56	0.02	0.04	RTK			629.58	-0.03				602+97.88	1.88				6.56	1:24:48 PM
Stakeout	Surface	StakedPt9	101134.24	401512.19	631.03	0.03	0.05	RTK			630.96	0.07				597+98.91	-68.24				6.56	1:30:00 PM
Stakeout	Surface	StakedPt10	101018.53	401349.13	631.22	0.02	0.04	RTK			631.21	0.01				596+00.57	-93.52				6.56	1:31:16 PM
Stakeout	Surface	StakedPt11	100943.65	401283.56	631.73	0.03	0.05	RTK			631.72	0.01				595+01.61	-82.83				6.56	1:32:01 PM

SCS Report Utility v2.01

1 Import Record | 4 Quick View
2 Reports | 5 Change Tolerances
3 Outputs | 6 Clear Workbook

Hoffman Construction Co.

123 CTH A
Black River Falls, WI 54615
PH(715)284-2512 FAX(715)284-9698

About

WorkOrder: *roadtop 8-28*

First access: 8/20/1999 12:55:03 PM
Last access: 8/5/1999 11:44:59 AM

Client :

Station Format 0+00.00

Record type	Sub type	Point Name	Line Name	Point code	Measured N	Measured E	Measured Elv	Prec. H	Prec. V	Precision Type	Design N	Design E	Design Grade	Cut/Fill (+/-)	Horiz. Deviation	Design Station	Design Offset	Measured Station	Measured Offset	Tolerance Check	High Tolerance	Low Tolerance	Antenna Ht
Stakeout	Surface	StakedPt143			101763.79	402145.96	629.72	0.02	0.03	RTK			629.70	0.02				606+96.03	-93.10				6.56
Stakeout	Surface	StakedPt139			101815.61	402379.85	631.90	0.02	0.03	RTK			631.92	-0.02				608+97.31	37.14				6.56
Stakeout	Surface	StakedPt141			102104.30	402518.13	634.40	0.02	0.03	RTK			634.42	-0.02				612+00.04	-66.86				6.56
Stakeout	Surface	StakedPt140			102057.02	402566.50	634.75	0.04	0.06	RTK			634.69	0.05				612+00.26	0.76				6.56
Stakeout	Surface	StakedPt118			102181.61	402583.56	635.56	0.02	0.05	RTK			635.65	-0.10				613+01.04	-74.46				6.56
Stakeout	Surface	StakedPt119			102167.94	402599.37	635.26	0.04	0.08	RTK			635.35	-0.09				613+02.36	-53.64				6.56
Stakeout	Surface	StakedPt142			102176.60	402593.80	635.56	0.02	0.04	RTK			635.58	-0.02				613+04.65	-63.69				6.56
Stakeout	Surface	StakedPt117			102184.48	402723.32	637.26	0.03	0.05	RTK			637.33	-0.07				614+01.14	23.07				6.56
Stakeout	Surface	StakedPt120			102237.99	402672.84	638.60	0.02	0.05	RTK			636.61	0.00				614+03.85	-50.44				6.56
Stakeout	Surface	StakedPt121			102403.38	402781.65	639.43	0.02	0.05	RTK			639.53	-0.10				615+98.04	-86.96				6.56
Stakeout	Surface	StakedPt122			102460.88	402870.61	641.20	0.04	0.08	RTK			641.29	-0.09				617+01.42	-65.92				6.56
Stakeout	Surface	StakedPt116			102408.83	402924.44	642.16	0.02	0.03	RTK			642.18	-0.02				617+02.10	8.96				6.56
Stakeout	Surface	StakedPt115			102547.70	403063.29	645.22	0.03	0.05	RTK			645.31	-0.09				618+98.48	10.47				6.56
Stakeout	Surface	StakedPt123			102976.26	403343.46	650.60	0.03	0.05	RTK			650.66	-0.06				624+00.44	-90.58				6.56
Stakeout	Surface	StakedPt114			103035.60	403573.53	655.69	0.03	0.05	RTK			655.92	-0.02				626+00.51	32.11				6.56
Stakeout	Surface	StakedPt112			103361.60	403813.01	657.08	0.01	0.04	RTK			657.03	0.05				630+00.60	19.33				6.56
Stakeout	Surface	StakedPt113			103377.68	403791.51	655.45	0.01	0.05	RTK			655.45	0.00				630+05.50	-7.44				6.56
Stakeout	Surface	StakedPt111			103543.28	403886.36	655.12	0.03	0.10	RTK			655.07	0.05				631+97.11	-8.59				6.56
Stakeout	Surface	StakedPt125			103650.25	403889.64	654.41	0.03	0.05	RTK			654.47	-0.06				632+95.92	-52.99				6.56
Stakeout	Surface	StakedPt124			103669.36	403853.92	652.06	0.03	0.05	RTK			652.08	-0.02				632+98.29	-93.44				6.56
Stakeout	Surface	StakedPt126			103842.32	403927.53	651.32	0.05	0.10	RTK			651.38	-0.06				634+94.78	-90.80				6.56
Stakeout	Surface	StakedPt127			103927.93	403999.58	652.57	0.03	0.05	RTK			652.48	0.10				636+01.10	-49.50				6.56
Stakeout	Surface	StakedPt110			103901.29	404084.60	653.96	0.02	0.07	RTK			653.88	0.08				636+01.90	30.59				6.56
Stakeout	Surface	StakedPt128			104025.74	404030.67	651.18	0.04	0.08	RTK			651.24	-0.06				637+03.73	-50.01				6.56
Stakeout	Surface	StakedPt108			104102.04	404105.15	650.19	0.01	0.05	RTK			650.17	0.02				637+99.24	-2.61				6.56
Stakeout	Surface	StakedPt109			104104.18	404098.58	650.05	0.04	0.06	RTK			650.03	0.02				637+99.26	-9.53				6.56
Stakeout	Surface	StakedPt107			104388.77	404198.93	645.56	0.03	0.04	RTK			645.61	-0.05				641+00.91	-1.59				6.56
Stakeout	Surface	StakedPt129			104502.80	404163.12	645.01	0.06	0.09	RTK			645.03	-0.02				641+98.40	-70.75				6.56
Stakeout	Surface	StakedPt130			104594.97	404206.40	643.45	0.05	0.07	RTK			643.45	0.00				642+99.42	-57.92				6.56
Stakeout	Surface	StakedPt131			104703.28	404224.45	642.61	0.03	0.05	RTK			642.60	0.01				644+07.48	-74.17				6.56
Stakeout	Surface	StakedPt134			104971.32	404348.73	637.88	0.03	0.04	RTK			637.91	-0.03				646+97.30	-51.86				6.56
Stakeout	Surface	StakedPt133			104971.80	404347.80	637.85	0.03	0.05	RTK			637.96	-0.11				646+97.38	-52.90				6.56
Stakeout	Surface	StakedPt132			104990.85	404312.94	639.67	0.03	0.05	RTK			639.73	-0.05				647+01.36	-92.42				6.56
Stakeout	Surface	StakedPt106			105139.13	404472.68	635.25	0.05	0.08	RTK			635.20	0.05				648+96.66	-7.92				6.56
Stakeout	Surface	StakedPt105			105210.28	404562.31	631.71	0.03	0.04	RTK			631.74	-0.03				650+03.90	40.30				6.56
Stakeout	Surface	StakedPt104			105494.96	404663.37	630.14	0.04	0.05	RTK			630.13	0.01				653+02.60	-11.15				6.56
Stakeout	Surface	StakedPt103			105641.12	404808.14	627.38	0.02	0.04	RTK			627.43	-0.05				655+01.93	40.53				6.56
Stakeout	Surface	StakedPt135			105719.13	404690.08	627.66	0.03	0.04	RTK			627.73	-0.07				655+10.02	-100.74				6.58
Stakeout	Surface	StakedPt136			105872.72	404801.75	625.91	0.03	0.05	RTK			625.85	0.06				656+98.93	-81.40				6.56
Stakeout	Surface	StakedPt102			105834.25	404871.91	625.46	0.04	0.05	RTK			625.47	-0.01				657+00.93	-1.42				6.56
Stakeout	Surface	StakedPt101			105902.39	404953.94	624.32	0.06	0.08	RTK			624.32	-0.01				658+01.08	35.25				6.58
Stakeout	Surface	StakedPt137			106136.11	404943.48	623.06	0.05	0.08	RTK			623.08	-0.03				659+97.88	-91.27				6.56
Stakeout	Surface	StakedPt138			106463.86	405174.37	621.78	0.04	0.07	RTK			621.86	-0.06				663+97.26	-56.41				6.56
Stakeout	Surface	StakedPt100			106437.56	405225.45	621.87	0.04	0.05	RTK			621.94	-0.07				664+00.20	0.96				6.56
Stakeout	Surface	StakedPt99			106518.32	405283.96	622.18	0.03	0.04	RTK			622.21	-0.03				664+99.42	10.96				6.56
Stakeout	Surface	StakedPt97			106601.65	405341.49	622.33	0.03	0.04	RTK			622.31	0.02				666+00.38	18.80				6.56
Stakeout	Surface	StakedPt98			106600.26	405349.57	622.18	0.03	0.05	RTK			622.17	0.02				666+03.24	26.49				6.56
Stakeout	Surface	StakedPt62			106744.59	405293.32	622.22	0.03	0.06	RTK			622.29	-0.07				666+99.74	-94.69				6.56
Stakeout	Surface	StakedPt60			106815.84	405373.57	622.80	0.02	0.03	RTK			622.82	-0.02				668+01.67	-61.12				6.56
Stakeout	Surface	StakedPt61			106815.88	405373.57	622.87	0.02	0.04	RTK			622.82	0.05				668+01.70	-61.14				6.56
Stakeout	Surface	StakedPt96			106949.15	405536.91	623.59	0.05	0.07	RTK			623.59	-0.01				669+99.02	13.07				6.56
Stakeout	Surface	StakedPt95			107119.53	405647.65	623.95	0.03	0.05	RTK			623.98	-0.03				672+02.07	23.34				6.56
Stakeout	Surface	StakedPt59			107255.21	405611.05	624.40	0.03	0.05	RTK			624.40	0.01				673+00.87	-76.68				6.56
Stakeout	Surface	StakedPt92			107283.03	405757.99	624.20	0.04	0.06	RTK			624.29	-0.09				673+98.78	36.37				6.56
Stakeout	Surface	StakedPt93			107283.83	405758.57	624.29	0.04	0.05	RTK			624.29	0.00				673+99.76	36.46				6.56
Stakeout	Surface	StakedPt94			107282.28	405761.33	624.20	0.04	0.06	RTK			624.23	-0.03				673+99.81	39.63				6.56
Stakeout	Surface	StakedPt57			107689.06	405859.90	625.72	0.04	0.06	RTK			625.80	-0.08				678+01.01	-79.62				6.56
Stakeout	Surface	StakedPt58			107684.25	405868.52	625.94	0.03	0.06	RTK			625.91	0.04				678+01.19	-69.75				6.56
Stakeout	Surface	StakedPt91			107721.75	406002.86	625.97	0.03	0.04	RTK			625.93	0.03				679+01.13	27.54				6.56
Stakeout	Surface	StakedPt90			108063.49	406208.00	626.76	0.05	0.07	RTK			626.72	0.04				682+99.67	33.10				6.56
Stakeout	Surface	StakedPt56			108107.34	406135.43	626.71	0.02	0.04	RTK			626.73	-0.02				683+01.11	-51.67				6.56
Stakeout	Surface	StakedPt89			108345.72	406320.76	626.79	0.04	0.07	RTK			626.75	0.03				686+00.34	-11.28				6.56
Stakeout	Surface	StakedPt88			108421.63	406393.80	627.06	0.03	0.05	RTK			627.09	-0.02				687+02.67	13.71				6.56
Stakeout	Surface	StakedPt87			108602.31	406477.14	626.36	0.04	0.06	RTK			626.42	-0.06				689+00.76	-5.07				6.56
Stakeout	Surface	StakedPt55			108800.00	406538.19	625.82	0.03	0.05	RTK			625.78	0.04				691+02.36	-51.85				6.56
Stakeout	Surface	StakedPt85			108839.26	406625.07	625.93	0.02	0.04	RTK			625.78	0.14				691+79.96	3.71				6.56
Stakeout	Surface	StakedPt86			108857.95	406637.66	625.73	0.06	0.09	RTK			625.75	-0.02				692+02.45	5.20				6.56
Stakeout	Surface	StakedPt84			109020.31	406726.60	625.10	0.03	0.04	RTK			625.10	0.00				693+87.51	0.48				6.58
Stakeout	Surface	StakedPt79			109205.33	406832.33	624.32	0.03	0.05	RTK			624.43	-0.10				696+00.61	-1.11				6.56
Stakeout	Surface	StakedPt80			109205.46	406832.46	624.35	0.02	0.04	RTK			624.43	-0.08				696+00.79	-1.07				6.56

Record type	Sub type	Point Name	Line Name	Point code	Measured N	Measured E	Measured Elv	Prec. H	Prec. V	Precision Type	Design N	Design E	Design Grade	Cut/Fill (+/-)	Horiz. Deviation	Design Station	Design Offset	Measured Station	Measured Offset	Tolerance Check	High Tolerance	Low Tolerance	Antenna Ht
Stakeout	Surface	StakedPt81			109205.55	406832.42	624.38	0.03	0.05	RTK			624.42	-0.06				696+00.84	-1.14				6.56
Stakeout	Surface	StakedPt82			109205.67	406832.41	624.37	0.02	0.04	RTK			624.42	-0.05				696+00.94	-1.21				6.56
Stakeout	Surface	StakedPt83			109205.70	406832.38	624.38	0.03	0.04	RTK			624.42	-0.04				696+00.95	-1.26				6.56
Stakeout	Surface	StakedPt78			109288.44	406883.97	624.43	0.03	0.05	RTK			624.19	0.24				696+98.41	1.75				6.56
Stakeout	Surface	StakedPt76			109290.99	406883.43	624.04	0.02	0.04	RTK			624.15	-0.11				697+00.34	0.00				6.56
Stakeout	Surface	StakedPt77			109291.15	406883.31	624.08	0.02	0.03	RTK			624.15	-0.06				697+00.42	-0.18				6.56
Stakeout	Surface	StakedPt54			109329.30	406824.75	624.37	0.02	0.04	RTK			624.34	0.04				697+03.96	-69.98				6.56
Stakeout	Surface	StakedPt53			109426.08	406848.40	623.52	0.02	0.03	RTK			623.57	-0.05				697+99.52	-98.17				6.56
Stakeout	Surface	StakedPt52			109583.36	406963.51	623.23	0.03	0.05	RTK			623.25	-0.01				700+03.40	-60.43				6.56
Stakeout	Surface	StakedPt51			109595.97	406963.22	623.29	0.03	0.05	RTK			623.23	0.06				700+04.10	-84.31				6.56
Stakeout	Surface	StakedPt50			109662.77	407039.32	622.77	0.02	0.04	RTK			622.79	-0.02				701+00.11	-52.10				6.56
Stakeout	Surface	StakedPt49			109667.44	407031.59	622.99	0.04	0.06	RTK			622.97	0.02				701+00.25	-61.13				6.56
Stakeout	Surface	StakedPt48			109678.48	407013.48	623.02	0.02	0.04	RTK			622.98	0.04				701+00.69	-62.34				6.56
Stakeout	Surface	StakedPt47			109848.58	407117.82	622.45	0.05	0.08	RTK			622.48	-0.03				703+00.19	-77.63				6.56
Stakeout	Surface	StakedPt75			110064.85	407345.45	621.58	0.05	0.07	RTK			621.65	-0.07				706+01.57	10.44				6.56
Stakeout	Surface	StakedPt46			110452.98	407470.80	620.52	0.03	0.05	RTK			620.58	-0.06				710+00.11	-76.28				6.56
Stakeout	Surface	StakedPt73			110493.19	407600.80	619.44	0.04	0.06	RTK			619.48	-0.04				711+00.47	15.17				6.56
Stakeout	Surface	StakedPt74			110493.26	407600.83	619.46	0.03	0.04	RTK			619.48	-0.02				711+00.54	15.16				6.56
Stakeout	Surface	StakedPt45			110629.79	407570.13	620.47	0.02	0.03	RTK			620.52	-0.04				712+00.17	-82.50				6.56
Stakeout	Surface	StakedPt44			110629.85	407570.15	620.39	0.04	0.07	RTK			620.52	-0.13				712+00.23	-82.52				6.56
Stakeout	Surface	StakedPt43			110797.18	407686.40	620.16	0.04	0.06	RTK			620.11	0.05				714+01.08	-76.55				6.56
Stakeout	Surface	StakedPt72			110837.96	407804.51	619.59	0.05	0.07	RTK			619.65	-0.05				715+01.08	-2.52				6.56
Stakeout	Surface	StakedPt71			110837.94	407804.56	619.56	0.04	0.08	RTK			619.64	-0.09				715+01.07	-2.47				6.56
Stakeout	Surface	StakedPt69			110983.52	407943.89	618.85	0.03	0.05	RTK			618.95	-0.09				717+01.20	24.19				6.56
Stakeout	Surface	StakedPt70			110983.59	407943.81	618.89	0.03	0.04	RTK			618.95	-0.06				717+01.21	24.08				6.56
Stakeout	Surface	StakedPt42			111130.18	407915.63	620.79	0.04	0.07	RTK			620.86	-0.07				717+99.50	-87.78				6.56
Stakeout	Surface	StakedPt68			111145.19	408045.73	620.20	0.03	0.04	RTK			620.01	0.19				718+91.76	4.51				6.56
Stakeout	Surface	StakedPt67			111154.42	408048.86	620.15	0.04	0.06	RTK			620.15	0.00				719+00.89	1.12				6.56
Stakeout	Surface	StakedPt66			111149.74	408055.77	619.84	0.05	0.07	RTK			619.88	-0.04				719+01.63	9.43				6.56
Stakeout	Surface	StakedPt41			111572.38	408341.37	621.97	0.03	0.05	RTK			621.93	0.05				724+05.13	-58.77				6.56
Stakeout	Surface	StakedPt64			111606.74	408443.17	622.56	0.04	0.06	RTK			622.60	-0.05				725+00.62	-10.66				6.56
Stakeout	Surface	StakedPt65			111606.79	408443.26	622.55	0.03	0.04	RTK			622.60	-0.05				725+00.71	-10.63				6.56
Stakeout	Surface	StakedPt63			111668.90	408523.01	622.70	0.04	0.06	RTK			622.64	0.06				726+01.09	0.54				6.56
Stakeout	Surface	StakedPt40			111861.60	408617.70	624.52	0.06	0.09	RTK			624.45	0.07				728+00.09	-76.72				6.56
Stakeout	Surface	StakedPt23			111938.84	408817.39	625.57	0.04	0.07	RTK			625.50	0.07				730+00.39	-4.95				6.56
Stakeout	Surface	StakedPt22			112240.89	409092.20	630.48	0.03	0.05	RTK			630.51	-0.03				733+99.76	-75.95				6.56
Stakeout	Surface	StakedPt24			112181.41	409135.61	629.76	0.03	0.04	RTK			629.80	-0.03				734+00.34	-2.31				6.56
Stakeout	Surface	StakedPt25			112184.57	409133.75	629.87	0.04	0.06	RTK			629.92	-0.05				734+00.67	-5.96				6.56
Stakeout	Surface	StakedPt21			112292.72	409181.92	631.54	0.05	0.07	RTK			631.62	-0.08				735+01.68	-66.64				6.56
Stakeout	Surface	StakedPt19			112514.61	409518.12	638.33	0.04	0.06	RTK			638.40	-0.07				738+99.67	-72.17				6.56
Stakeout	Surface	StakedPt20			112522.37	409518.75	638.68	0.02	0.03	RTK			638.70	-0.02				739+02.41	-79.55				6.56
Stakeout	Surface	StakedPt27			112530.51	409740.84	640.89	0.03	0.05	RTK			640.87	0.02				741+00.32	24.09				6.56
Stakeout	Surface	StakedPt26			112561.76	409725.14	641.75	0.02	0.04	RTK			641.80	-0.05				741+01.49	-10.88				6.56
Stakeout	Surface	StakedPt18			112695.07	409679.83	646.17	0.03	0.04	RTK			646.23	-0.06				743+00.86	-54.77				6.56
Stakeout	Surface	StakedPt17			112695.10	409679.87	646.13	0.04	0.05	RTK			646.23	-0.10				743+00.92	-54.77				6.56
Stakeout	Surface	StakedPt28			112745.43	410080.32	650.56	0.03	0.04	RTK			650.51	0.05				745+01.25	-3.96				6.56
Stakeout	Surface	StakedPt16			112875.91	410122.29	653.21	0.03	0.05	RTK			653.23	-0.02				746+00.10	-98.90				6.56
Stakeout	Surface	StakedPt29			112776.61	410177.43	653.25	0.03	0.04	RTK			653.27	-0.01				746+01.52	14.67				6.56
Stakeout	Surface	StakedPt15			112900.54	410222.95	656.17	0.06	0.08	RTK			656.21	-0.04				747+00.40	-72.82				6.56
Stakeout	Surface	StakedPt30			112956.91	410532.65	662.92	0.03	0.05	RTK			662.95	-0.03				749+99.76	24.52				6.56
Stakeout	Surface	StakedPt14			113034.33	410491.38	663.42	0.02	0.03	RTK			663.40	0.02				750+00.16	-63.22				6.56
Stakeout	Surface	StakedPt31			112944.37	410540.16	662.69	0.03	0.04	RTK			662.68	0.01				750+00.42	39.11				6.56
Stakeout	Surface	StakedPt32			113031.60	410605.71	665.30	0.03	0.04	RTK			665.31	-0.01				750+99.50	-6.57				6.56
Stakeout	Surface	StakedPt13			113092.34	410574.73	666.01	0.04	0.05	RTK			665.99	0.01				751+01.06	-74.74				6.56
Stakeout	Surface	StakedPt12			113119.48	410675.25	668.20	0.03	0.04	RTK			668.11	0.09				752+02.42	-50.93				6.56
Stakeout	Surface	StakedPt33			113308.28	411138.39	679.91	0.04	0.06	RTK			679.81	0.09				756+99.69	2.63				6.56
Stakeout	Surface	StakedPt11			113388.99	411095.37	679.89	0.03	0.05	RTK			679.84	0.04				757+00.12	-88.83				6.56
Stakeout	Surface	StakedPt34			113462.10	411396.76	686.17	0.02	0.03	RTK			686.12	0.05				760+00.11	-10.17				6.56
Stakeout	Surface	StakedPt35			113427.63	411415.51	686.23	0.02	0.03	RTK			686.22	0.00				760+00.25	29.06				6.56
Stakeout	Surface	StakedPt10			113519.96	411386.60	686.66	0.04	0.06	RTK			686.62	0.04				760+01.01	-75.41				6.56
Stakeout	Surface	StakedPt9			113580.96	411446.54	688.34	0.03	0.04	RTK			688.37	-0.03				761+00.32	-91.18				6.56
Stakeout	Surface	StakedPt8			113597.93	411551.73	690.46	0.03	0.05	RTK			690.48	-0.02				762+00.97	-56.21				6.56
Stakeout	Surface	StakedPt7			113654.80	411634.03	692.68	0.03	0.04	RTK			692.67	0.01				763+00.40	-67.21				6.56
Stakeout	Surface	StakedPt36			113646.09	411751.41	694.33	0.02	0.03	RTK			694.33	0.00				763+99.60	-3.85				6.56
Stakeout	Surface	StakedPt37			113608.33	411773.84	694.06	0.02	0.03	RTK			694.12	-0.06				764+01.42	40.03				6.56
Stakeout	Surface	StakedPt38			113664.93	411855.90	696.23	0.02	0.04	RTK			696.23	0.00				765+00.51	29.14				6.56
Stakeout	Surface	StakedPt6			113788.14	411902.85	698.14	0.03	0.04	RTK			698.16	-0.02				766+00.30	-57.03				6.56
Stakeout	Surface	StakedPt5			113871.43	411970.50	699.74	0.04	0.06	RTK			699.72	0.01				766+99.37	-98.25				6.56
Stakeout	Surface	StakedPt39			113761.41	412030.61	699.95	0.02	0.04	RTK			699.94	0.01				767+00.08	27.12				6.56
Stakeout	Surface	StakedPt3			113952.84	412155.40	703.57	0.03	0.05	RTK			703.56	0.02				769+00.75	-82.18				6.56
Stakeout	Surface	StakedPt4			113953.06	412155.27	703.62	0.03	0.04	RTK			703.55	0.07				769+00.75	-82.43				6.56
Stakeout	Surface	StakedPt2			113952.85	412155.44	703.54	0.02	0.03	RTK			703.56	-0.02				769+00.80	-82.17				6.56
Stakeout	Surface	StakedPt1			113952.84	412155.49	703.49	0.03	0.05	RTK			703.56	-0.07				769+00.83	-82.14				6.56

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Hoffman Construction

City A
Black River Falls
701 Dyckesville

WorkOrder: *773+00 - 813+00 shots*

First access: 8/2/2007 8:11:59 AM
Last access: 8/16/2007 9:51:40 AM

Client : -

Station Format 0+00.00

Record type	Sub type	Point Name	Line Name	Point code	Measured N	Measured E	Measured Elv	Prec. H	Prec. V	Precision Type	Design N	Design E	Design Grade	Cut/Fill (+/-)	Horiz. Deviation	Design Station	Design Offset	Measured Station	Measured Offset	Tolerance Check	High Tolerance	Low Tolerance	Antenna Ht
Stakeout	Surface	StakedPt1			114150.63	412729.58	713.22	0.03	0.05	RTK			713.26	-0.03				775+00.03	16.15				6.56
Stakeout	Surface	StakedPt2			114259.75	412898.02	716.00	0.04	0.06	RTK			715.97	0.03				777+00.08	0.03				6.56
Stakeout	Surface	StakedPt3			114533.78	413431.86	721.68	0.06	0.09	RTK			721.71	-0.03				783+00.02	12.11				6.56
Stakeout	Surface	StakedPt4			114594.57	413512.84	721.89	0.04	0.06	RTK			721.87	0.02				784+00.15	-2.98				6.56
Stakeout	Surface	StakedPt5			114831.85	413952.79	722.12	0.05	0.07	RTK			722.23	-0.12				789+00.02	-3.09				6.56
Stakeout	Surface	StakedPt6			114857.29	414052.98	721.92	0.04	0.06	RTK			722.02	-0.09				790+00.27	22.06				6.56
Stakeout	Surface	StakedPt7			115087.93	414495.98	718.34	0.06	0.09	RTK			718.35	-0.01				794+99.66	29.24				6.56
Stakeout	Surface	StakedPt8			114861.57	414050.24	722.07	0.05	0.08	RTK			722.12	-0.05				789+99.89	16.99				6.56
Stakeout	Surface	StakedPt9			115156.00	414573.40	717.41	0.06	0.09	RTK			717.52	-0.11				796+00.12	6.05				6.56
Stakeout	Surface	StakedPt10			115169.42	414566.27	717.20	0.04	0.06	RTK			717.26	-0.06				796+00.21	-9.14				6.56
Stakeout	Surface	StakedPt11			115223.52	414764.01	714.65	0.04	0.06	RTK			714.67	-0.01				797+99.94	37.06				6.56
Stakeout	Surface	StakedPt12			115380.69	415019.31	711.86	0.05	0.08	RTK			711.87	-0.01				801+00.11	12.14				6.56
Stakeout	Surface	StakedPt13			115368.06	415025.04	711.38	0.04	0.07	RTK			711.41	-0.03				800+99.97	26.01				6.56
Stakeout	Surface	StakedPt14			115417.41	415112.45	710.66	0.07	0.11	RTK			710.67	-0.01				802+00.43	17.07				6.56
Stakeout	Surface	StakedPt15			115721.52	415957.62	702.30	0.04	0.07	RTK			702.32	-0.02				811+00.30	-11.00				6.56
Stakeout	Surface	StakedPt16			115397.13	414900.16	713.85	0.04	0.07	RTK			713.92	-0.07				800+00.22	-54.19				6.56
Stakeout	Surface	StakedPt17			115390.17	414789.51	716.32	0.04	0.07	RTK			716.38	-0.07				799+00.07	-68.01				6.56
Stakeout	Surface	StakedPt18			115236.22	414530.25	718.03	0.04	0.06	RTK			718.09	-0.06				796+00.19	-85.04				6.56
Stakeout	Surface	StakedPt19			115049.78	414176.11	721.23	0.04	0.06	RTK			721.29	-0.05				791+99.99	-88.95				6.56
Stakeout	Surface	StakedPt20			114899.51	413916.20	722.60	0.04	0.06	RTK			722.67	-0.06				788+99.91	-80.01				6.56
Stakeout	Surface	StakedPt21			114847.79	413830.64	722.83	0.04	0.06	RTK			722.91	-0.08				788+00.05	-75.08				6.56
Stakeout	Surface	StakedPt22			114748.39	413656.91	722.79	0.05	0.09	RTK			722.84	-0.05				785+99.95	-70.02				6.56
Stakeout	Surface	StakedPt23			114157.43	412499.07	709.60	0.03	0.06	RTK			709.67	-0.07				773+00.36	-99.20				6.56

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About

Hoffman Construction

City A
Black River Falls
701 Dyckesville

WorkOrder: *814+00-877+00 checks*

First access: 8/2/2007 11:24:07 AM
Last access: 8/16/2007 10:38:09 AM

Client :

Station Format 0+00.00

Record type	Sub type	Point Name	Line Name	Point code	Measured N	Measured E	Measured Elv	Prec. H	Prec. V	Precision Type	Design N	Design E	Design Grade	Cut/Fill (+/-)	Horiz. Deviation	Design Station	Design Offset	Measured Station	Measured Offset	Tolerance Check	High Tolerance	Low Tolerance	Antenna Ht
Stakeout	Surface	StakedPt1			115595.20	422039.01	743.77	0.03	0.05	RTK			743.82	-0.05				872+00.06	-99.83				6.56
Stakeout	Surface	StakedPt2			115573.18	421238.90	742.02	0.05	0.07	RTK			741.95	0.07				864+00.26	-88.49				6.56
Stakeout	Surface	StakedPt3			115556.82	421038.69	741.85	0.03	0.05	RTK			741.86	-0.01				862+00.25	-49.79				6.56
Stakeout	Surface	StakedPt4			115565.57	420938.65	742.27	0.06	0.08	RTK			742.28	-0.01				861+00.12	-57.37				6.56
Stakeout	Surface	StakedPt5			115601.01	420738.94	742.74	0.03	0.05	RTK			742.72	0.02				859+00.01	-90.49				6.56
Stakeout	Surface	StakedPt6			115611.59	420539.05	742.96	0.03	0.05	RTK			742.94	0.02				857+00.01	-98.73				6.56
Stakeout	Surface	StakedPt7			115604.54	420539.09	743.05	0.04	0.05	RTK			743.08	-0.04				857+00.13	-91.69				6.56
Stakeout	Surface	StakedPt8			115618.80	420142.25	743.44	0.03	0.05	RTK			743.47	-0.03				853+00.05	-95.57				6.56
Stakeout	Surface	StakedPt9			115644.85	419647.20	741.12	0.03	0.04	RTK			741.14	-0.02				849+00.29	-89.28				6.56
Stakeout	Surface	StakedPt10			115634.89	419646.35	741.38	0.07	0.09	RTK			741.34	0.03				849+00.30	-79.28				6.56
Stakeout	Surface	StakedPt11			115679.44	419351.20	738.04	0.03	0.04	RTK			738.01	0.03				845+00.70	-94.49				6.56
Stakeout	Surface	StakedPt12			115668.55	419349.29	738.32	0.03	0.04	RTK			738.22	0.10				844+99.94	-83.47				6.56
Stakeout	Surface	StakedPt13			115699.09	419152.13	735.47	0.04	0.05	RTK			735.39	0.09				843+00.66	-93.21				6.56
Stakeout	Surface	StakedPt14			115747.57	418553.37	723.67	0.04	0.05	RTK			723.59	0.08				837+00.12	-78.78				6.56
Stakeout	Surface	StakedPt15			115755.43	418554.67	723.52	0.03	0.05	RTK			723.42	0.10				837+00.49	-87.73				6.56
Stakeout	Surface	StakedPt16			115758.17	418554.29	723.47	0.05	0.08	RTK			723.42	0.05				837+00.13	-87.43				6.56
Stakeout	Surface	StakedPt17			115770.19	418254.06	716.76	0.06	0.08	RTK			716.71	0.06				834+00.08	-99.96				6.56
Stakeout	Surface	StakedPt18			115778.57	418154.49	714.37	0.05	0.07	RTK			714.34	0.03				833+00.18	-67.88				6.56
Stakeout	Surface	StakedPt19			115772.07	418053.35	711.79	0.03	0.04	RTK			711.76	0.04				832+00.28	-50.83				6.56
Stakeout	Surface	StakedPt20			115832.76	417556.60	703.07	0.05	0.11	RTK			703.05	0.03				829+99.90	-59.23				6.56
Stakeout	Surface	StakedPt21			115490.68	422437.71	745.58	0.03	0.08	RTK			745.53	0.02				875+99.95	0.04				6.56
Stakeout	Surface	StakedPt22			115482.77	422337.66	745.53	0.07	0.16	RTK			745.48	0.06				875+00.00	9.12				6.56
Stakeout	Surface	StakedPt23			115485.96	422337.70	745.31	0.06	0.14	RTK			745.26	0.06				875+00.24	25.92				6.56
Stakeout	Surface	StakedPt24			115491.48	421937.86	743.79	0.03	0.08	RTK			743.71	0.08				871+00.12	5.07				6.56
Stakeout	Surface	StakedPt25			115502.05	421738.38	742.65	0.07	0.16	RTK			742.58	0.08				868+00.54	-3.19				6.56
Stakeout	Surface	StakedPt26			115473.35	421437.42	741.78	0.03	0.08	RTK			741.76	0.03				865+99.93	29.02				6.56
Stakeout	Surface	StakedPt27			115511.82	421438.32	741.76	0.04	0.09	RTK			741.67	0.09				866+00.38	-9.46				6.56
Stakeout	Surface	StakedPt28			115481.46	421137.63	741.81	0.06	0.16	RTK			741.87	-0.06				863+00.07	24.40				6.56
Stakeout	Surface	StakedPt29			115513.49	420837.97	742.57	0.06	0.16	RTK			742.56	0.00				860+00.06	-4.13				6.56
Stakeout	Surface	StakedPt30			115584.36	419239.95	737.36	0.03	0.07	RTK			737.40	-0.04				844+00.01	11.70				6.56
Stakeout	Surface	StakedPt31			115589.11	419138.14	735.41	0.05	0.12	RTK			735.50	-0.08				843+00.35	37.52				6.56
Stakeout	Surface	StakedPt32			115636.41	418843.19	730.23	0.05	0.14	RTK			730.27	-0.04				839+99.98,	1.44				6.56
Stakeout	Surface	StakedPt33			115652.73	418744.29	728.02	0.05	0.14	RTK			728.06	-0.04				838+99.92	-4.43				6.56
Stakeout	Surface	StakedPt34			115644.23	418642.94	726.09	0.05	0.14	RTK			726.09	-0.01				838+00.00	14.62				6.56
Stakeout	Surface	StakedPt35			115672.74	418444.92	721.35	0.04	0.09	RTK			721.42	-0.07				836+00.09	6.95				6.56
Stakeout	Surface	StakedPt36			115678.90	418244.32	716.61	0.04	0.10	RTK			716.68	-0.07				833+99.95	21.85				6.56
Stakeout	Surface	StakedPt37			115671.46	418143.35	714.02	0.02	0.06	RTK			714.02	0.00				833+00.31	39.80				6.56
Stakeout	Surface	StakedPt38			115765.96	417549.77	703.17	0.05	0.12	RTK			703.19	-0.02				827+00.10	7.93				6.56
Stakeout	Surface	StakedPt39			115863.96	417053.72	697.61	0.02	0.05	RTK			697.75	-0.13				822+00.08	-51.04				6.56
Stakeout	Surface	StakedPt40			115861.92	417054.10	698.33	0.04	0.11	RTK			698.34	-0.01				821+99.96	-69.00				6.56
Stakeout	Surface	StakedPt41			115867.95	417054.34	698.53	0.04	0.11	RTK			698.54	-0.01				822+00.02	-75.02				6.56
Stakeout	Surface	StakedPt42			115866.06	416952.48	697.34	0.03	0.07	RTK			697.22	0.12				820+99.95	-51.38				6.56
Stakeout	Surface	StakedPt43			115907.22	416850.88	698.21	0.04	0.10	RTK			698.24	-0.03				820+00.14	-63.04				6.56
Stakeout	Surface	StakedPt44			115874.52	416749.93	697.10	0.02	0.06	RTK			697.09	0.01				819+00.08	-63.07				6.56
Stakeout	Surface	StakedPt45			115888.41	416749.69	697.56	0.04	0.10	RTK			697.55	0.01				819+00.36	-76.97				6.56
Stakeout	Surface	StakedPt46			115895.55	416846.92	697.90	0.04	0.10	RTK			697.98	-0.08				817+99.90	-89.13				6.56
Stakeout	Surface	StakedPt47			115910.45	416748.66	698.22	0.04	0.10	RTK			698.28	-0.06				819+00.18	-99.03				6.56
Stakeout	Surface	StakedPt48			115845.20	416345.35	698.50	0.02	0.06	RTK			698.48	0.02				815+00.08	-67.09				6.56
Stakeout	Surface	StakedPt49			115848.02	416242.25	699.76	0.04	0.10	RTK			699.83	-0.06				814+00.01	-84.02				6.56
Stakeout	Surface	StakedPt50			115803.50	416552.46	697.48	0.03	0.06	RTK			697.38	0.09				817+00.16	-4.03				6.56
Stakeout	Surface	StakedPt51			115793.19	416852.44	696.54	0.03	0.07	RTK			696.48	0.06				819+99.89	20.99				6.56
Stakeout	Surface	StakedPt52			115800.06	417051.99	697.59	0.03	0.07	RTK			697.62	-0.02				822+00.17	12.90				6.56
Stakeout	Surface	StakedPt53			115795.03	417151.54	698.30	0.02	0.05	RTK			698.29	0.01				823+00.13	14.00				6.56

Appendix I.
GPS Work Plan Submitted by Wondra Excavating

WONDRA
EXCAVATING, INC.

W2874 Graylog Road
Iron Ridge, WI 53035
(920) 387-5840 • Fax (920) 387-4734

3576-07-71 STP 2007 001
Fort Atkinson – East County Line Road
(Edgewater Road – CTH CI)
STH 106, Jefferson County

GPS Work Plan

Global Positioning System (GPS) machine guidance technology will be used on portions of this project to construct the subgrade to the plan. The subgrade prepared using the GPS machine guidance will be verified with conventional subgrade staking.
The portion of the project from Station 399+80 to 499+50 will be verified as follows:

1. The first 1,000' will be constructed using conventional subgrade staking methods, which require 3 stakes every 100'.
2. The second 1,000' will require CL stakes every 100' and 3 stakes every 100' in and out of superelevations.
3. The third 1,000' will require CL stakes every 500' and 3 stakes every 100' in and out of superelevations.
4. The subgrade staking requirements for the remainder of this portion of the project will be evaluated based on the results of the first 3,000', as described above.

The engineer may require the contractor to revert to conventional subgrade staking methods for all or part of the work at any point during construction if, in the engineer's opinion, the GPS machine guidance is producing unacceptable results.

The GPS equipment that will be utilized on this project is manufactured by Topcon Positioning Systems, Inc. The base station consists of a PG-A1 satellite antenna, a Legacy-E satellite receiver, and a PDL radio. The equipment for the machine guidance consists of 2 PG-A1 satellite antennas mounted on a single pole on the bulldozer blade. The product number of the control box/display is 9168. The product number of the satellite receiver/radio box is 9902. The software used on the machines is Topcon's 3DMC software. The version we are using is either 4.12.21 or 6.04.

Wondra Excavating, Inc. has been using GPS technology on our projects for 4 years, with the machine control being brought in within the last 2 years. Many of Wondra's employees are familiar with using the GPS technology, although at different levels. Some of our operators have used GPS technology at other companies and have 3-4 years of experience using the machine control. Others are being trained as needed. Matt Cameron is the primary contact for GPS issues and he can be reached at (920) 210-4375. Matt is the one who creates the 3D models, localizes the project and oversees all aspects of GPS use, from the machine control to using a rover for staking and layout.

The control for this project has been established by WisDOT. A listing and map of control points is included for reference. The procedure for the site calibration/localization is as follows.

1. Find a suitable site for the GPS Base Station. Some factors to consider when selecting a site include, but are not limited to:
    a. Location within the project. Is the site near the center of the project?
    b. Elevation of the proposed site. A higher elevation means greater radio range, as topography can interfere with radio reception between the base station and the GPS receivers on machines or rovers.
    c. Objects nearby that obstruct the sky. If the base station has objects obstructing the sky and thus hindering its satellite reception, the rest of the GPS equipment on the jobsite suffers. If the base station is not able to receive a signal from enough satellites, due to obstructions, a radio correction signal is not transmitted to the GPS receivers on the jobsite and the GPS will not work.
2. For each control point, locate it and set the GPS rover rod on top of the control point. Once the rod is plumb, proceed with the calibration from within the software.
3. Check the error values for each control point. If one seems to have a larger error, re-calibrate that control point. If the error is not corrected, do not use that point in the calibration.

The site calibration is checked by shooting a control point not used in the site calibration, and observing or recording the errors. The site calibration is checked after the base station is set up. The horizontal and vertical check values are recorded for each daily check.

The measurements and calibration of the GPS on the machine is checked every couple of weeks, or as conditions warrant. Blade wear is usually very minimal, unless work is being done in aggregate material. The blade slope is calculated by a slope sensor, mounted on the back of the blade. The sensor does not have to be mounted horizontally level. When the sensor is first installed, the blade is leveled and the sensor is “zeroed”, to give an accurate slope reading. This slope sensor is also checked every couple weeks to be sure blade wear is consistent across the blade, and not just wearing on one side of the blade.

Once machine control grading is begun, checks and adjustments need to be made to account for the compaction of the material being worked with. The subgrade is usually graded slightly high, so after compaction, it will be at the actual subgrade. Because different materials compact differently, this offset between the grading and the subgrade varies. Typically, the operator selects an offset that he thinks would be a good starting point. After grading a section and it is compacted, the subgrade is checked by either using a rover or by setting the blade on the compacted subgrade and observing the difference. Adjustments are made as necessary.

Appendix J.
Site Calibration / Localization Checks for Wondra Project

Site Calibration / Localization Check Form

Project: **3576-07-71** **STP 2007 001**
Fort Atkinson - East County Line Road
STH 106, Jefferson County

Date	Control Point	Horizontal Check Value (FT)	Vertical Check Value (FT)
5/17/2007	601	0.02	-0.01
5/18/2007	601	0.03	0.01
5/21/2007	601	0.03	0.02
5/22/2007	601	0.02	0.01
5/23/2007	601	0.04	0.02
5/24/2007	601	0.02	-0.02
5/25/2007	601	0.03	0.04
5/28/2007	601	0.04	0.02
5/29/2007	601	0.03	0.03
5/30/2007	601	0.04	0.02
5/31/2007	601	0.02	-0.01
6/1/2007	601	0.02	0.00
6/4/2007	601	0.02	-0.02
6/5/2007	601	0.01	-0.01
6/6/2007	601	0.02	0.01
6/7/2007	601	0.01	-0.02
6/8/2007	601	0.04	0.00
6/11/2007	601	0.04	0.02
6/12/2007	601	0.03	0.01
6/13/2007	601	0.04	0.02
6/14/2007	601	0.02	0.01
6/15/2007	601	0.01	-0.02
6/18/2007	601	0.03	0.00
6/19/2007	601	0.02	0.01
6/20/2007	601	0.04	0.02
6/21/2007	601	0.03	0.01
6/22/2007	601	0.03	0.03
6/25/2007	601	0.02	0.00
6/26/2007	601	0.03	0.02
6/27/2007	601	0.04	0.01
6/28/2007	601	0.04	0.03
6/29/2007	601	0.04	0.01
7/2/2007	601	0.03	0.00
7/3/2007	601	0.02	0.01
7/4/2007	601	0.04	0.02
7/5/2007	601	0.03	0.02
7/6/2007	601	0.03	0.01
7/9/2007	601	0.03	0.03
7/10/2007	601	0.03	0.03
7/11/2007	601	0.02	0.02
7/12/2007	601	0.02	0.01
7/13/2007	601	0.03	0.00
7/16/2007	601	0.03	-0.01
7/17/2007	601	0.03	0.01

7/18/2007	601	0.03	0.01
7/19/2007	601	0.03	0.01
7/20/2007	601	0.04	0.03
7/23/2007	601	0.02	0.02
7/24/2007	601	0.03	0.02
7/25/2007	601	0.02	0.03
7/26/2007	601	0.04	0.01
7/27/2007	601	0.04	0.02
7/30/2007	601	0.03	0.03
7/31/2007	601	0.04	0.01
8/1/2007	601	0.03	0.02
8/2/2007	601	0.03	0.00
8/3/2007	601	0.03	-0.01
8/6/2007	601	0.03	0.01
8/7/2007	601	0.02	0.01
8/8/2007	601	0.02	0.00
8/9/2007	601	0.04	0.02
8/10/2007	601	0.03	0.03
8/13/2007	601	0.03	0.02
8/14/2007	601	0.03	0.02
8/15/2007	601	0.03	0.01
8/16/2007	601	0.02	0.00
8/17/2007	601	0.03	-0.01
8/20/2007	601	0.02	-0.02
8/21/2007	601	0.01	-0.01
8/22/2007	601	0.02	0.01
8/23/2007	601	0.04	0.03
8/24/2007	601	0.02	0.01
8/27/2007	601	0.01	0.04
8/28/2007	601	0.03	0.03
8/29/2007	601	0.01	-0.02
8/30/2007	601	0.02	-0.02
8/31/2007	601	0.01	-0.02
9/3/2007	601	0.01	-0.01
9/4/2007	601	0.02	-0.01
9/5/2007	601	0.01	0.03
9/6/2007	601	0.04	-0.02
9/7/2007	601	0.03	0.02
9/10/2007	601	0.04	0.01
9/11/2007	601	0.01	-0.02
9/12/2007	601	0.03	0.04
9/13/2007	601	0.02	0.03
9/14/2007	601	0.01	0.01
9/17/2007	601	0.03	0.04
9/18/2007	601	0.04	0.04
9/19/2007	601	0.02	0.03
9/20/2007	601	0.01	0.04
9/21/2007	601	0.02	-0.01
9/24/2007	601	0.04	-0.01
9/25/2007	601	0.01	0.04
9/26/2007	601	0.02	0.00
9/27/2007	601	0.01	0.00

9/28/2007	601	0.04	0.03
10/1/2007	601	0.04	0.02
10/2/2007	601	0.04	0.04
10/3/2007	601	0.03	0.00
10/5/2007	601	0.01	-0.02
10/8/2007	601	0.04	0.00
10/9/2007	601	0.02	-0.02
10/10/2007	601	0.01	-0.01
10/11/2007	601	0.02	0.00
10/18/2007	601	0.04	0.04
10/19/2007	601	0.04	0.01

Appendix K.
Subgrade Checks for Wondra Project

Subgrade Checks - Rural

Project: **3576-07-71, STP 2007 001**
Fort Atkinson - East County Line Road (Edgewater Road - CTH CI)
STH 106, Jefferson County

Station	Offset	Subgrade Elevation	Proposed Elevation	Difference
165+50	13.5	824.28	824.32	0.04
166+01	3.0	824.68	824.74	0.06
167+04	-11.0	824.70	824.70	0.00
168+00	6.0	824.48	824.54	0.06
169+00	10.0	823.73	823.80	0.07
170+01	-4.0	822.84	822.89	0.05
170+97	-11.5	821.63	821.70	0.07
172+03	-4.0	820.68	820.69	0.01
173+03	4.0	819.51	819.60	0.09
174+02	13.5	818.32	818.33	0.01
191+00	1.0	820.79	820.84	0.05
192+00	-9.5	819.85	819.92	0.07
193+00	-1.0	818.79	818.87	0.08
194+02	14.0	817.00	816.96	-0.04
195+99	-13.0	814.62	814.73	0.11
197+00	-2.5	815.07	815.09	0.02
198+08	-13.5	815.98	816.05	0.07
198+95	7.0	817.59	817.65	0.06
201+06	-11.0	821.09	821.18	0.09
201+94	2.0	822.77	822.87	0.10
203+03	9.0	824.53	824.59	0.06
219+00	12.0	830.64	830.73	0.09
220+00	18.0	830.57	830.60	0.03
223+40	0.0	827.51	827.53	0.02
224+50	0.0	825.43	825.44	0.01
226+00	0.0	823.32	823.42	0.10
227+00	-11.0	822.85	822.83	-0.02
228+00	-11.0	823.26	823.24	-0.02
229+00	-12.0	823.94	824.02	0.08
232+62	0.0	827.06	827.14	0.08
235+60	-12.0	827.28	827.22	-0.06
237+00	12.0	826.43	826.52	0.09
240+00	-12.0	827.62	827.73	0.11
243+80	12.0	832.08	832.13	0.05
246+00	0.0	836.14	836.16	0.02
248+00	0.0	839.18	839.21	0.03
250+00	-12.0	841.90	842.03	0.13
252+00	12.0	845.06	845.09	0.03
257+00	12.0	850.91	850.87	-0.04

261+00	0.0	849.04	849.03	-0.01
262+00	0.0	847.93	847.88	-0.05
263+00	-12.0	846.65	846.56	-0.09
264+00	0.0	846.39	846.33	-0.06
265+00	12.0	846.31	846.32	0.01
266+00	0.0	847.05	847.11	0.06
267+00	-12.0	847.42	847.42	0.00
268+00	0.0	848.23	848.22	-0.01
269+00	12.0	848.25	848.29	0.04
295+00	-22.0	842.34	842.29	-0.05
296+00	21.0	844.04	844.16	0.12
297+00	-21.0	843.15	843.10	-0.05
298+00	22.0	846.31	846.32	0.01
299+00	-21.0	844.57	844.66	0.09
300+00	22.0	847.87	847.87	0.00
301+00	-21.0	846.23	846.22	-0.01
302+00	21.0	849.22	849.37	0.15
303+00	21.0	850.10	850.15	0.05
304+00	0.0	849.67	849.75	0.08
305+00	-21.0	850.07	850.10	0.03
306+00	-16.0	850.94	850.99	0.05
307+00	0.0	852.12	852.09	-0.03
308+00	22.0	852.38	852.43	0.05
309+00	12.5	853.41	853.40	-0.01
310+00	0.0	854.44	854.43	-0.01
311+00	-15.0	854.92	854.91	-0.01
312+00	-15.0	855.47	855.40	-0.07
313+00	0.0	855.81	855.73	-0.08
314+00	15.0	855.01	855.01	0.00
352+00	-15.0	843.54	843.53	-0.01
353+00	-17.0	843.64	843.70	0.06
353+00	0.0	844.03	844.03	0.00
353+00	12.0	843.79	843.80	0.01
354+00	16.0	843.61	843.61	0.00
354+00	0.0	843.91	843.92	0.01
354+00	-12.0	843.65	843.68	0.03
355+00	-15.0	843.13	843.21	0.08
355+00	0.0	843.55	843.51	-0.04
355+00	20.0	843.12	843.11	-0.01
356+00	26.0	842.36	842.41	0.05
356+00	0.0	842.95	842.93	-0.02
356+00	-20.0	842.54	842.53	-0.01
357+00	-20.0	842.01	841.96	-0.05
357+00	0.0	842.41	842.35	-0.06
357+00	30.0	841.82	841.75	-0.07
358+00	29.0	841.24	841.19	-0.05
358+00	0.0	841.88	841.78	-0.10

Subgrade Checks - Urban

Project: **3576-08-71, STP 2007 003**
Sherman Avenue, City of Fort Atkinson (Robert St - Edgewater Rd)
STH 106, Jefferson County

Station	Offset	Subgrade Elevation	Proposed Elevation	Difference
697+50	-17.7	796.34	796.36	0.02
698+49.8	11.9	797.85	797.93	0.08
698+99.8	-0.1	798.65	798.64	-0.01
699+49.7	13.6	798.62	798.60	-0.02
700+00	0.0	798.89	798.89	0.00
700+84.7	10.4	798.12	798.20	0.08
726+62.5	-14.0	790.72	790.76	0.04
727+05	5.2	791.31	791.36	0.05
732+10	16.0	797.65	797.68	0.03
734+00	0.0	796.15	796.19	0.04
735+50	-12.0	795.41	795.42	0.01
736+50	-14.0	795.06	795.03	-0.03
738+00	0.0	794.65	794.61	-0.04
739+50	15.0	792.16	792.19	0.03
740+76	0.0	789.67	789.72	0.05
741+37	-27.0	790.72	790.78	0.06
741+85	-10.3	787.16	787.13	-0.03
742+07	3.4	786.89	786.86	-0.03
742+12	-28.5	789.62	789.65	0.03
742+69	-28.0	788.80	788.84	0.04
742+75	13.0	785.74	785.70	-0.04
743+16	-14.0	785.29	785.32	0.03
743+52	-1.3	785.34	785.37	0.03
743+79	17.8	784.97	784.93	-0.04
744+81	0.0	784.87	784.88	0.01
746+00	-17.0	784.43	784.47	0.04
747+50	0.0	785.22	785.29	0.07
748+50	18.0	784.69	784.75	0.06
749+70	0.0	784.72	784.70	-0.02

Appendix L.
Specification for 2008 Pilot Projects

Construction Staking Subgrade, Item 650.4500; Construction Staking Supplemental Control, Item 650.9910

Conform to standard spec 650 as modified in this special provision.

Replace standard spec 650.3.3 with the following:

650.3.3 Subgrade

650.3.3.1 General

(1) The contractor may use either global positioning system (GPS) machine guidance or conventional subgrade staking on designated portions of the contract as follows:

______________________	______________________
______________________	______________________
______________________	______________________

Use conventional subgrade staking on the remainder of the contract.

(2) The engineer may require the contractor to revert to conventional subgrade staking methods for all or part of the work at any point during construction if, in the engineer's opinion, the GPS machine guidance is producing unacceptable results. If the engineer revokes approval to use GPS machine guidance on all or part of the work for reasons beyond the contractor's control, the department will measure the additional subgrade staking required to successfully complete the work in those areas as specified in 650.4(2) of this special provision.

650.3.3.2 Subgrade Staking

(1) Set construction stakes or marks at intervals of 100 feet, or more frequently, for rural sections and at intervals of 50 feet, or more frequently, for urban sections. Include additional stakes at each cross-section as necessary to match the plan cross-section, achieve the required accuracy, and to support construction operations. Also set and maintain stakes as necessary to establish the horizontal and vertical positions of intersecting road radii, auxiliary lanes, horizontal and vertical curves, and curve transitions. Locate stakes to within 0.25 feet (75 mm) horizontally and establish the grade elevation to within 0.03 feet (10 mm) vertically.

650.3.3.3 GPS Machine Guidance

650.3.3.3.1 General

(1) No subgrade stakes are required for work approved for GPS machine guidance.

(2) Coordinate with the engineer throughout the course of construction to ensure that work performed using GPS machine guidance conforms to the contract tolerances and that the methods employed conform to the contractor's GPS

work plan and accepted industry standards. Address GPS machine guidance issues at weekly progress meetings.

(3) Provide GPS rover equipment to department staff as requested to check the work. This equipment is not intended for exclusive use of the department and may be used by the contractor as needed on the project. Provide training for department staff designated to use the GPS rover. Training shall include but not be limited to hardware, software, and operation of GPS rover equipment. Provide a copy of the user manual for the supplied rover equipment. Provide routine maintenance of equipment provided for department use. The department is responsible for loss of, or damage (beyond normal wear and tear) to, the rover while in the engineer's possession.

650.3.3.3.2 GPS Work Plan

(1) Submit a comprehensive written GPS work plan for department review at least 10 business days before affected grading operations begin. The engineer will review the plan to determine if it conforms to the requirements of this special provision.

(2) Construct the subgrade as the contractor's GPS work plan provides. Update the plan as necessary during construction of the subgrade.

(3) The GPS work plan should discuss how GPS machine guidance technology will be integrated into other technologies employed on the project. Include, but do not limit the contents to, the following:

1. Describe the manufacturer, model, and software version of the GPS equipment.
2. Provide information on the qualifications of contractor staff. Include formal training and field experience. Designate a single staff person as the primary contact for GPS technology issues.
3. Describe how project control is to be established. Include a list and map showing control points enveloping the site.
4. Describe site calibration procedures. Include a map of the control points used for site calibration and control points used to check the site calibration. Describe the site calibration and checking frequency as well as how the site calibration and checking information are to be documented.
5. Describe the contractor's quality control procedures. Describe procedures for checking, mechanical calibration, and maintenance of equipment. Include the frequency and type of checks performed to ensure that the constructed subgrade conforms to the contract plans.

650.3.3.3.3 Equipment

(1) Use GPS machine guidance equipment to meet the requirements of the contract.

(2) Perform periodic sensor calibrations, checks for blade wear, and other routine adjustments as required to ensure that the final subgrade conforms to the contract plans.

650.3.3.3.4 Geometric and Surface Information

650.3.3.3.4.1 Department Responsibilities

(1) The department will provide to the contractor the best available electronic files of survey and design information as described here in 650.3.3.3.4.1 and in CMM 3-1-10. The department incurs no additional liability, beyond that specified in standard spec 105.6 or standard spec 650, by having provided this additional information.

(2) The department will provide data to the contractor that include the following:

Data Type	Format [1]
Reference Line Data	LandXML
Design Profile Data	LandXML
Proposed Cross Section Data	Land XML or DWG
Existing Surface DTM Data	LandXML DTM or DWG
Existing Topographic Data (excluding utilities)	LandXML
Superelevation Data	LandXML
Graphical Information	DGN or DWG

[1] The department will provide data in whichever listed format the contractor chooses.

(3) The department will provide design surface data in the form of points and break lines derived from the cross sections in the contract in LandXML or DWG format at the contractor's option. The points and break lines will be on the subgrade surface between the subgrade shoulder points, and will be on the finished surface in topsoiled areas. The department provides design surface data for information only, and has no contractual liability for it.

650.3.3.3.4.2 Contractor Responsibilities

(1) Develop and maintain the initial design surface DTM for areas of the project employing GPS machine guidance consistent with information the department provides. Confirm that the design surface DTM agrees with the contract plans.

(2) Provide design surface DTM information to the department in LandXML or other engineer-approved format.

650.3.3.3.4.3 Managing and Updating Information

(1) The department and contractor will agree on the design surface model before using it for construction. Provide a copy of the resultant design surface DTM

to the engineer at least two business days before using that design surface DTM for construction. Use the resulting design surface DTM to ensure that the work conforms to the plans, but the department's approval of the design surface DTM does not supercede the lines, grades, and cross-sections the plans show.

(2) Notify the department of any errors or discrepancies in department-provided information. Provide information regarding errors or discrepancies in the existing surface DTM, identified in the field, to the department in LandXML format if a revision to the contract plans is required. If surveying work, beyond that required under the Construction Staking Slope Stakes bid item, is required to re-define the existing surface the department will pay for costs of that additional surveying as extra work.

(3 The department will determine what revisions may be required. The department will revise the contract plans and existing surface DTM, if necessary, to address errors or discrepancies that the contractor identifies. The department will provide the best available electronic files and other available information related to those contract plan revisions.

(4) Revise the design surface DTM as required to support construction operations and to reflect any contract plan revisions the department makes. Perform checks to confirm that the revised design surface DTM agrees with the contract plan revisions. Provide a copy of the resultant revised design surface DTM to the engineer in LandXML or other engineer-approved format. The department will pay for costs incurred to incorporate contract plan revisions as extra work.

(5) The department will maintain the existing surface DTM by incorporating needed revisions. The department will make the current existing surface DTM available, in LandXML DTM or DWG format, to the contractor throughout construction.

650.3.3.3.5 Site Calibration

(1) Designate a set of control points, including a total of at least 6 horizontal and vertical points or 2 per mile, whichever is greater, for site calibration for the portion of the project employing GPS machine guidance. Incorporate the department-provided control framework used for the original survey and design.

(2) Calibrate the site by determining the parameters governing the transformation of GPS information into the project coordinate system. Use the full set of control points, designated under 650.3.3.3.5 (1), for the initial site calibration. Provide the resulting site calibration file to the engineer before beginning subgrade construction operations.

(3) In addition to the site calibration, perform site calibration checks. Perform these checks at individual control points not used in the initial site calibration. At a minimum, check the calibration at the start of each day. Report out-of-tolerance checks to the engineer. The measured position must match the established position at each individual control point within the following tolerances:

- Horizontally to 0.10 feet or less.
- Vertically to 0.05 feet or less.

(4) Provide the previous week's daily calibration check results to the engineer at the weekly progress meeting for monitoring the GPS work.

(5) The department will use the same calibration file the contractor uses.

650.3.3.3.6 Construction Checks

(1) Conduct calibration checks daily conforming to 650.3.3.3.5 of this special provision and consistent with the contractor's GPS work plan. Use a GPS rover to check the subgrade against the plan elevation at 20 or more randomly selected locations per roadway mile. Document all GPS rover subgrade checks and any auxiliary checks made using other technologies. Provide all documentation to the engineer.

(2) Ensure that at least 4 of any 5 consecutively-tested subgrade points are within 0.10 foot vertically of the plan elevation. Notify the engineer if more than one of any five consecutively-tested subgrade points differs by more than 0.10 feet from the plan elevation.

(3) The department will conduct periodic independent subgrade checks using the contractor supplied GPS rover or conventional survey methods. When using the GPS rover, the department will use the same calibration files and other hardware and software settings the contractor uses for subgrade checking. The department will notify the contractor if any individual check differs by more than 0.10 feet from the design.

Replace standard spec 650.3.12 with the following:

650.3.12 Supplemental Control

(1) Set and maintain construction marks as required to support the method of operations consistent with third-order, class I horizontal and third-order vertical accuracy. Check the department-provided horizontal and vertical control information and notify the engineer of any discrepancies. Provide marks to establish and maintain intermediate vertical and horizontal control for reference line alignment, side road alignments, radius points, bench level circuits, and offsetting the horizontal roadway alignment. These marks constitute the field control used to govern and execute the work.

(2) For the portion of the project using GPS machine guidance, set and maintain supplemental control points sufficient to ensure that there are a minimum of 6

established control points per mile. Ensure that these control points are consistent with third-order, class I horizontal and third-order vertical accuracy. Establish vertical control by differential leveling.

(3) Document and provide to the engineer complete descriptions and reference ties for the control points, alignment points, and benchmarks to allow for quick reestablishment of the plan data at any time during construction and upon project completion. Document additional control on forms described as a part of the contractor staking packet in CMM 3-1-10.

Replace standard spec 650.4 with the following:

650.4 Measurement

(1) The department will measure the Construction Staking bid items for base, concrete pavement, resurfacing reference, and slope stakes by the linear foot acceptably completed, measured along each roadway centerline. The department will not measure construction staking for base underlying concrete pavement.

(2) The department will measure Construction Staking Subgrade by the linear foot of subgrade acceptably completed, measured along each roadway centerline. The department will base measurement on the length of acceptably completed subgrade whether that subgrade was constructed using GPS machine guidance or using conventional construction staking. The department will include the length of subgrade where GPS machine guidance is initially employed but subsequently suspended by the engineer for reasons beyond the contractor's control. The department will measure this work twice, once for the suspended GPS work and once for the conventional subgrade staking required to successfully complete the work. If the department suspends GPS work for reasons within the contractor's control, the department will measure work in the affected area only once.

(3) The department will measure Construction Staking Curb Gutter and Curb & Gutter by the linear foot acceptably completed, measured along the base of the curb face. The department will measure Construction Staking Concrete Barrier by the linear foot acceptably completed, measured along the base of the barrier. The department will not measure these bid items if abutting concrete pavement.

(4) The department will measure Construction Staking Storm Sewer System as each individual inlet catch basin, manhole, and endwall acceptably completed.

(5) The department will measure Construction Staking Pipe Culverts by each individual pipe culvert staked and acceptably completed.

(6) The department will measure Construction Staking Structure Layout as a single lump sum unit for each structure acceptably completed. The department

will measure Construction Staking Electrical Installations as a single lump sum unit for all electrical installations acceptably completed on each project. The department will measure Construction Staking Supplemental Control as a single lump sum unit for all control marks acceptably completed on each contract.

Appendix M.
Guidance Language for 2008 Pilot Projects

GUIDANCE FOR 2008
WISCONSIN DEPARTMENT OF TRANSPORTATION
GPS MACHINE GUIDANCE PILOT PROJECTS

GENERAL CONSTRUCTION AND PROJECT SELECTION

The candidate project should first be reviewed for suitability for GPS use; for example, projects with dense tree canopy or large vertical cuts may not prove suitable. The region surveyor would assist in this preliminary evaluation with the construction engineer. It may also be determined that only certain project segments would be suitable. Recommended pilot projects should be communicated to the region's project manager and forwarded to Ken Brockman, Bureau of Project Development (BPD) for final approval. Be sure to coordinate with Ken Brockman to make sure the appropriate special provisions are inserted because the bid items will change with the December 2007 let.

On the pilot projects, the item of GPS machine guidance will be used to replace subgrade staking on the whole project or segments of selected roadway sections. The project or segments should be reviewed and agreed upon by the engineer and contractor. On a select number of projects, the GPS machine guidance will be bid. In other cases, a no-cost change order would be submitted to allow the use of GPS machine guidance. The item for Staking Subgrade would be paid for in all segments where machine guidance is attempted.

It is recommended that projects using GPS machine guidance would also include contractor staking items.

DESCRIBING PROJECT EXTENTS

The GPS machine guidance pilot project specification allows some or all of the construction project to be done with GPS machine guidance. If the entire project is to be done with GPS machine guidance, then the following location description table can be used:

GPS Machine Guidance	Subgrade Staking
Entire Project	None

If segments of the project are to be done with GPS machine guidance and the remaining segments are to be done using conventional construction methods, the segments using conventional methods must be subgrade staked. The extents of each GPS machine guidance segment and each subgrade staking segment need to be described. There are a number of methods for describing the extents of segments. Examples include project stationing (preferred), cross street (intersection) naming, and bridge identification.

The following location description table combines some of these methods to describe the extents of four segments:

GPS Machine Guidance	Subgrade Staking
From Sta 0+00 to Sta 56+50	From Sta 56+50 to the intersection with CTH N.
From the intersection with CTH N to the Elm Street overpass (B-05-151)	From the Elm Street (B-05-51) to EOJ

ROLES AND RESPONSIBILITIES

Designer

The project designer is responsible for overall design and any subsequent changes.

The designer provides normal digital data exchange data including DTM information and would work with the Methods Development Unit (MDU) engineer to prepare XML or DWG format information to be used by the contractor. Some additional field verification of models and digital terrain models (DTMs) may be required as quality assurance of this information.

The designer would make the necessary design changes in case of errors and work with the MDU engineer to provide modified DTMs.

Construction Engineer

Project Selection

For the pilot projects, the construction engineer would assist in determination of the applicability of machine guidance. The engineer should work with the region surveyor to evaluate the suitability of GPS technology and the availability of project control for the proposed project. The engineer, contractor, and region surveyor should agree on usage and limits of GPS machine guidance, and a recommendation should go to regional and BPD management as noted above.

The engineer would lead the coordination of department-provided items and be the focal point for communication with the contractor.

Data and Surface Model Coordination

To prepare project data, DTMs, and surface model information for use by the contractor, there needs to be close coordination between the construction engineer, the designer, and the methods development unit (MDU) engineer. A meeting as noted below could help facilitate this.

Initial Coordination Meeting

Integral DOT/consultant staff who will provide information and guidance to the project should meet to discuss roles and responsibilities. These should include the design engineer, construction engineer, regional surveyor, methods development engineer, and appropriate management, and may include contractor survey personnel. Some of the items to be addressed include provision of models and their formats, survey data and support, and project communications.

Pre-Construction Survey Meeting

Before the start of construction survey, it is recommended that a coordination meeting be held to aid in the passing of survey information to the contractor and to discuss the contractor's GPS work plan.

Pre-Survey Meeting

This meeting includes the contractor, contract surveyor, construction engineer, methods development engineer, and regional surveyor. At this meeting, the contractor should share and discuss their GPS work plan, project schedule, and survey schedule. The department should identify key personnel and methods for handling changes in the model and related matters.

During Construction

Site calibration checks are the responsibility of the contractor, but should be reviewed with the region surveyor to verify they are within specified tolerances.

The engineer should work with the region surveyor to develop a plan to perform construction checks. It is essential to provide some independent checks at project start-up to ensure contractor methods are meeting necessary tolerances. These checks should be performed using independent GPS equipment or conventional survey methods (e.g., total station or level), and should meet specified tolerances. It is anticipated that once initial methods are working and checked using independent technology, construction checks could be performed using a contractor-supplied rover. The department reserves the right to do added checks as needed. The number of site calibrations performed by the contractor should be limited. It is preferred that a single site calibration be used for the duration of the project, but there might be circumstances under which follow-up site calibrations are necessary. In such cases, independent construction checks should be made after each site calibration.

The engineer is responsible for maintaining an archive of DTM revisions and dates for future reference. The archive should include the DTM files and the time period for which each was active on the project.

After Construction

The contractor, construction engineer, and surveyor should meet to review the effectiveness of GPS machine guidance operations and identify benefits and issues to be addressed.

The construction engineer should prepare a final report evaluating the machine guidance usage. Evaluation items could include overall project impacts, specification improvements, construction administration issues and other pertinent items. This evaluation should be submitted to the GPS machine guidance steering team; Ken Brockman in the Bureau of Project Development is the designated lead for submittals.

Region Surveyor

The region surveyor is responsible for providing control points and technical support on the project.

Control Points

For the pilot projects, the region's survey unit would provide a minimum of 6 control points or 2 points per mile for use during the project. These points should be constructed or located outside the anticipated construction footprint. They should be type 1 or equivalent and should be set 15 degrees clear to the horizon with 360-degree access desirable at 6 foot height.

Control points should have horizontal and vertical project coordinates published. These points should be available two weeks before the preconstruction conference.

Technical Support

The region surveyor should assist in initial evaluation of the project for potential GPS use. The surveyor could also assist in development of a plan for providing construction checks.

The contractor is required to do their own project calibrations and check their work as it progresses. However, there may be questions that arise from the construction engineer related to GPS operations and calibrations. It is expected that the region surveyor would be available to lend technical guidance as warranted.

The surveyor should assist in evaluation of the pilot and provision of specific feedback on issues to be resolved.

DATA DEVELOPMENT AND EXCHANGE

Model Development

The processes for model development are outlined below.

1. WisDOT Methods Development will provide the breaklines and points to assemble a proposed model for all of the 2008-targeted GPS machine guidance projects. The design breaklines and points will be created from the best available digital design data. This information will not include details such as side road radii, entrances, gore areas, and other areas not easily extracted from normal plan and cross section information. It will include information necessary to build a subgrade surface, as well as information needed to build the surface out to the slope intercepts.
2. The proposed model information will be given to the region project staff early in the construction season. If the region project staff does not feel comfortable sharing the data with the contractor, they can request the contractor work directly with the Methods Development engineer assigned to their project.
3. The contractor must supplement the proposed model information provided to them to fill in those areas missing from the Methods Development-provided proposed model. The contractor must verify their proposed model.
4. The contractor must pass the complete and verified proposed model to the region project staff. Region project staff will pass the proposed model information to the assigned Methods Development engineer. If the region project staff does not feel comfortable sharing the data with the contractor, they can request the contractor work directly with the Methods Development Engineer assigned to their project.
5. The Methods Development engineer assigned to the project will review the contractor's proposed model. They will do spot checks by projecting known points generated from the plan cross sections (station / offset / elevation converted to northing / easting / elevation) onto the proposed model and generate an error report.

   It is expected the Methods Development engineer will check five points per mile in the blue top areas and random points on the outside slope areas. The error report will be shared with the contractor and region project staff. If significant errors occur, the Methods Development engineer will notify the region project staff and contractor of the problem areas. Steps 3 - 5 must be repeated until the model is verified.

6. If there are plan errors and plan changes necessary, steps 1-5 must be followed once the updated plan information has been created for those affected areas.

SITE CALIBRATION AND CHECKS

The contractor performs site calibration and site calibration checks. The contractor provides data collected during these activities to the construction engineer. The following is intended for both the contractor and the construction engineer as guidance in configuring the control points used for site calibration, interpretation of site calibration and check data, and appropriate procedures to follow if either of the specified site calibration check tolerances is exceeded. The construction engineer can also consult with the regional surveyor on these matters.

Site Calibration

Site calibration, sometimes referred to as “localization”, for GPS machine guidance is a process that results in computation of parameters for transforming measured GPS coordinates into the coordinate system of the project control points. Good site calibration and checking are vital to the success of GPS machine control operations.

Control Point Configuration

The GPS machine guidance pilot project specification requires that a minimum of six control points be used for site calibration and that the site calibration be periodically checked at control points not used in the calibration itself. The control points used for site calibration should envelop the project and be well distributed around its perimeter. Control points in close proximity to one another should be avoided. Long, narrow configurations of control points should be avoided. There should be control points near the corners of the project and approximately midway along its boundaries.

Error Estimates

Horizontal and vertical tolerances are specified for site calibration checks but not for site calibration itself. Once the site calibration measurement process is complete, the RTK GPS software will report estimates for horizontal and vertical errors at each of the site calibration control points. A majority of the horizontal error estimates should be 0.10 feet or less in magnitude. A majority of the vertical error estimates should be 0.05 feet or less in magnitude. If any horizontal error estimate is greater than 0.15 feet, or if any vertical error estimate is greater than 0.08 feet, it is indicative (but not conclusive) that there might be later difficulties in meeting site calibration check tolerances at independent control points. These tolerances are 0.10 feet (horizontal) and 0.05 (vertical).

Site Calibration Checks

If any site calibration check exceeds specified tolerances (i.e., 0.10 horizontally or 0.05 feet vertically), there is a sequence of steps that should be followed:

1. The check should be re-measured at the same independent control point to ensure there is no problem with the check measurement.
2. A second and, perhaps, a third independent control point should be used to check the site calibration. If tolerances are met at these additional independent control points, then a problem is indicated with the first check control point.
3. If check tolerances are not met at two or more independent control points, then a problem is indicated with the site calibration and the site calibration measurement and computation procedure should be repeated to ensure that there is no problem with the initial site calibration measurements. If site calibration problems persist, vendor-supplied manuals or guidance might also need to be consulted.

4. If the repeated site calibration measurements are in close agreement with the initial site calibration measurements, then a problem is indicated with one or more of the site calibration control points. The site calibration should then be performed while excluding the control point with the largest horizontal and / or vertical error estimate. It is likely that such error estimates will be larger than 0.10 foot horizontally or 0.05 foot vertically.
5. If a problem with a site calibration control point is identified in step 4, that control point should be replaced by another, and the site calibration procedure and checking should be repeated. The above control point configuration guidelines should be followed in selecting replacement control points.

SUBGRADE CHECKS

The machine guidance specification requires the contractor to perform 20 or more randomly-selected subgrade checks per roadway mile against plan elevations. According to the definition of roadway in standard spec 101.3, a divided highway has two or more roadways.

CHANGES/ERRORS

Specifications direct the contractor to immediately notify the engineer of any errors during staking and construction. Noted errors should be investigated as quickly as possible and may result in changes to the project model. The machine guidance specifications give direction on handling model changes. It will be necessary to coordinate with the design engineer and the MDU engineer to make model changes.

The Construction and Materials Support Center (CMSC) is housed in the Department of Civil and Environmental Engineering on the University of Wisconsin-Madison campus. The CMSC was formed in partnership with the Wisconsin Department of Transportation (WisDOT) to focus on implementing research findings within the department and other local, state, and federal transportation agencies. In addition, the CMSC functions as a service and applied research group to deliver timely solutions to construction management and materials engineering problems for a variety of organizations. The mission of the Center is to develop research implementation strategies and tools to help WisDOT, public agencies, and industry rapidly implement new and relevant technologies throughout the project development process. The Center draws upon university expertise to collaborate with department personnel and the private sector to find solutions to problems, minimize delays to construction, and improve the quality and efficiency in which materials are used throughout the construction process. Emphases areas for the Center are:

- Accelerated construction techniques
- Construction project management
- Innovative project delivery processes
- Materials performance and production

The Center is staffed to conduct research, develop tools and techniques to enhance project cost-control and minimize scheduling delays in project construction, identify methods and processes to accelerate project delivery and construction activities, create strategies for departments of transportation and others to implement new techniques and technologies, assess new construction materials and create project specifications.

Services include training staff on new techniques and processes, developing application guidance tools for inclusion in manuals, and holding workshops and seminars. Academic staff incorporate the field applications and lessons learned into undergraduate and graduate level engineering courses taught at the UW-Madison.

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