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Value added Benefits of High definition Surveying (Laser Scanning) in Contrast to In-Situ Surveying for Erosion of Hydrological Waterways

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Abstract
The purpose of this paper is to depict and illustrate the benefits of High Definition Surveying (HDS), also known as 3-dimensional laser scanning, in contrast to field surveying methods, such as Real-time Kinematic Global Positioning System (RTK-GPS), on a hydrologic study (topographic) application. This research investigates how the improvement of application software within laser scanning, coupled with constant advancements in computer processing as well as data acquisition methods, has made the use of HDS cost effective and applicable in the surveying community. The time and cost benefit aspects of HDS applications in comparison to RTK-GPS surveying methods were analyzed, and the efficacy of both methodologies were presented for an actual production project in the conclusion.

Keywords: value added Benefits, High Definition Surveying (HDS), Laser Scanning

Introduction
Technological advancements have improved smaller engineering and surveying companies to increase their safety, efficiency and profitability. Previous generational advancements in technology, like Global Position Systems (GPS), particularly Real Time Kinematic (RTK) methods of data acquisition have progressed the surveying industry. Surveyors utilize the new technology tools to decrease effort and improve efficiency. For example the applications of RTK-GPS when applied to real time geographic information systems (GIS) has shown to increase overall productivity (Okuno and Shikada, 2004). Laser Scanning or High Definition Surveying (HDS) technology has provided similar productivity to the surveying and mapping industry. Laser Scanners obtain 3D point clouds by orientation a sensor in the field and directing it scan an area with an active laser where the distance and angle computes the position. HDS was used in mapping the Dallas North Tollway, where a highway widening required a digital terrain model (DTM) and as-built survey without interrupting traffic flows(Stewart, 2005). Engineering / Surveying companies have been successful in 3D as-built laser scanning within the oil & gas industry (Dirdal, 2007) as well as when used for civil engineering applications (Coiner and Bruner, 2004). These projects illustrate how the use of HDS technology has improved the product, affordability and profitability. Specifically, there is an issue in closing highways in major cities so engineers can make survey measurements. These lane closures could impact the cities flow of commerce.
Laser scan can be used to collect the data without impacting and by passive information capturing. When mapping hydrological features it is difficult and time consuming to transect the waterway considering the high bank, erosion, and water barrier. The objective of this research is to compare and contrast an application of an engineering hydrologic drainage study while defining the value added benefits of HDS to RTK-GPS surveying methods.

Showing the viability of laser scanning technology to improve profits is investigated. Laser Scanning could improve surveying efficiency specifically in waterways where the path transects are difficult. The investment in a HDS system is significant based on the time required for training, the equipment and software prices. Improved technology continues to lower training times and are decreasing cost of the hardware and software will continue to improve overall cost. The data acquisition methods of HDS, requires baseline control points for orientation of the HDS scanner. Some traditional surveying methods must be used at the start of most projects. To contrast the technologies, both laser scanning and RTK-GPS methods were used independently of each other to perform a topographic survey.

The client had requested 30 meter cross sections of the hydrology drainage structure in the scope. Modeling the drainage structure requires that the ground profile be obtained in all dimensions. There were several areas of erosion (see Figure 4) that were to be focused on in this project. Limitation of the HDS scanner includes the fact that the laser does not penetrate the water to obtain the bottom profile. The limitation of the RTK-GPS is that the high bank or erosion area is difficult to transect and data collection required in-situ impact. The surveying proposal was written only considering the cost of using RTK-GPS methods based on the bottom profile limitation. This research’s intent is to utilize the HDS 3000 scanner (see Figure 1 for a photo of HDS 3000) to assess the time and data for a comparison method of data collection. The results will show the comparison of HDS and RTK-GPS model. Description of how both methods, results, time analysis to cost ratio and overall usability of both systems will be discussed. The expected results will show an increase in cost for the HDS data acquisition method (approximately 10-20%) as compared to the RTK-GPS method. Additionally, the lack of bottom profile makes the HDS not the best desired tool for hydrological waterway modeling.

The major costs in a HDS system are the equipment, time commitment of time, and pay of the operator. RTK-GPS has a lower equipment cost, has less time (based on transect sampling rate) and can be operated by lower trained employee. The offset in cost will be minimal when contrasting the amount of data acquired which will provide a more thorough modeling capability of the existing conditions, therefore bolstering the clients design capabilities. The ideal situation would be to charge more for laser scanning services, but in this research the cost analysis will be based on a proposal written with the intent of performing the work using traditional surveying methods (RTK-GPS) even though both methods will be used and contrasted.
Background
HDS, allows for the ability to remotely collect information quickly and accurately (Stewart, 2005). HDS uses a green laser to measure slope distance at a distance of 4 mm and orientation to a positional accuracy of 6 mm model in 3-dimensions the surroundings by taking 4000 points/second. The resultant effect is a 3-dimensional model with an ultimate modeled surface precision of 2 mm at one sigma, which can be used for various applications (Coiner and Bruno, 2004). HDS still requires sound fundamental surveying techniques. Typical surveying methodology is essential for HDS data that is collected in the field, and subsequently adjusted to the appropriate coordinate system. If the survey for a laser scan job is incorrect or has large errors, all of the laser scan data (point clouds) are considered unusable. Point clouds are groups of individual points that have x, y, z information that represent objects in 3D space.

Quality Assurance / Quality Control (QA/QC) in a laser scanning project is of paramount importance. In a 3D scan project, the features acquired can be used to create many types of end products depending on the client’s needs (Coiner and Bruno, 2004). HDS ability to remotely capture highly accurate as-built conditions is a great advantage for safety reasons (Jacobs, 2005). A good example of HDS is the capability of performing topographic and as-built conditions for hydrology studies, roads and highways (Dunn, 2005). The finished product can be considered a complete representation as-built of the conditions based on the scanning fidelity. Using good QA/QC procedures will make the final product of HDS meet the full cost savings.

HDS technology true modeling capabilities have applications in civil engineering, architectural, asset management, forensic, mechanical, fabrication, manufacturing, topographic historical and construction (Jacobs 2005). Today’s typical small surveying companies generally tend to use available technology if it has been proven to increase productivity and therefore the bottom line (Coiner and Bruno, 2004). With the increase computing power in desktop computers the ability to make HDS more productive is increasing. HDS creates large datasets of point clouds that require computing power and storage.

In a surveying context, the requirement of meeting specifications for the quality control of HDS data is important. The data must meet tolerances required by the scope of work being performed and in some cases the rules governed by a regulatory board for surveying, if tied to a boundary.

There are several aspects of accuracy when considering HDS instrumentation, as follows (Boehler and Marbs, Andreas, 2003):
• angular accuracy,
• range accuracy,
• resolution,
• edge effects and
• environmental effects
The quality of the laser scan is dependent on sound fundamental surveying procedures. The survey tolerances, depending on the scope of work, can range from + 2mm for the fabrication of retrofit heat exchangers to +25mm for volume calculations (earthwork) (Stewart, 2005). The application comparison of this research will show the value added benefits of HDS versus traditional surveying for this hydrology study with an expected result of a slight increase in the cost of performing the laser scan method as opposed to the traditional surveying method, but with value added that greatly outweighs the traditional surveying method.

**Methodology**

The research for this study was carried out on a channel that is ~640 meters long and encompasses 3 bridges. A flaw in the design of the existing drainage had led to increased rate of erosion (see Figure 1 for example of erosion). The initial scope was for a cross-sectional measurement at increments of 30 meters. This process encompasses taking a survey shot for the natural ground (NG) showing elevation changes across the channel. A series of shots are taken including top of channel, toe of channel and flow line (FL) of channel for each side (see Figure 2 for a cross sectional representation of RTK-GPS acquired data).

![Figure 1. Photo of highly eroded area of hydrology study](image)
Figure 2. Actual Cross Section of RTK-GPS Acquired Data

Figure 3. Point Cloud Data of highly eroded area of hydrology study
Point cloud data for the photo in Figure 4 is shown in Figure 5. Note that the box culvert structure below the bridge is picked up with great detail, also the trees and overhead electric line locations. Staying away from electrical lines is of vital importance for the general public and as well for surveying field crews. Often clients request utility locations in order to facilitate their design plans. Safety parameters must be built into daily field surveying practices. Laser Scanning makes possible the acquisition of accurate as-built data with added benefits of surveying field crew safety.

The intent of the survey projects was to collect approximately 21 cross-sections with extra survey shots to be taken in the erosion areas and the three bridge structures. The project was to be delivered in Texas Coordinate System, North America Datum 1983, South Zone 4205 for horizontal and North American Vertical Datum 1988 for vertical. A proposal was delivered to the client that included 30 hours of field work and 20 hours of office work. The proposal was written only taking into account the use of RTK-GPS surveying method.

The survey data for the laser scan is first processed in scanner software to ensure the required tolerance levels are met for the job. After the survey is verified and found to be adequate, each laser scan setup is imported into scanner software. This process is called “registration”. The survey binds the laser scan data together allowing the laser scan data to be rotated and translated to the base survey. The results are a survey grade combined point cloud that has a density of 25mm at 150m. This point cloud is a representation of the ground conditions.

Technological advancements, including GPS has helped surveying become more viable by making it efficient and a cost effective profession. GPS is a tool that is an effective
alternative to total station surveying. Line of sight surveying is not necessary when using
GPS. Long range surveying is now possible without having to traverse like in a typical
line of sight survey. There are limits when using GPS. Satellite signals are not strong
enough to penetrate canopies such as trees and structural obstructions. Limited view of
the sky does affect the accuracy and precision of data acquired using GPS methods.
Surveying has evolved from steel chains, magnetic compass, and theodolites to satellite
measurements. Like GPS and HDS is now, in its time the electronic distance
measurement (EDM) device was cutting edge because it reduced the time it took to
stretch a steel tape for measurements. The reduced time and increased precision was
epecially beneficial over long distances.

The technological advancements of GPS have had the same effect when considering
the time saved compared to line of sight surveying. Surveyors can take measurements
much faster and with great skill utilizing new technology. For this hydrologic study, in
order to contrast the laser scanned data, RTK-GPS method was used at 30 m cross
sections. Traditional surveying methods were used to acquire this data, namely a base
and rover set up with a radio signal sent from the base to the rover for differential
corrections. The GPS data was locally calibrated to monuments, meeting the
aforementioned tolerances (25mm or 0.08'). The eroded areas were tied in using this
method as best as possible. The eroded areas had a very steep slope. The
measurements of the eroded areas consisted of a NG tie at the top and a subsequent
shot at the toe. A kayak was used to tie in the flow line of the channel. The subsequent
30 meter cross sections were modeled (TIN) and contours smoother interpolation
created.

Conclusions
This job was proposed using the 'lump sum' type of proposal. If the work can be
estimated accurately, then the lump sum method can be beneficial when pricing out
traditional survey method jobs while utilizing laser scan technology. Matt Dunn states
that “This approach avoids the need to add a separate line item for hourly “scanner
usage”, which some clients find confusing and may not react well to.” (Dunn, 2005). The
results were very close to what was expected, the overall cost of the laser scan
methodology was 11% higher than the RTK-GPS survey method based on the
equipment cost and user time. Although there was an increase in the cost, the value
added benefits of the HDS method are prevalent. It must be noted that the office time for
the HDS method, namely the registration and point cloud data reduction took 25% more
time than the conventional RTK-GPS data reduction and must be completed by a more
experienced higher paid professional. With additional software that is more geared
towards mapping aspects of data manipulation, the amount of time required for HDS /
point cloud data reduction will be decreased. As the complexity of the entire system
reduces the cost will overcome the cost of traditional. It can be seen that the benefits of
the final product is evident in the Figures 3 and 5.

The amount of data created for the laser scanned in comparison to the traditional
surveying method was substantial. The file size of the laser scanned data was nearly 1.0
Gb of data compared to 200Kb for RTK-GPS. The value added by the laser scan method
is apparent in that 25 mm cross sections can be created as opposed to the 30 meter cross section from the traditional survey method. A density of 25mm laser scan shots allows for a much better modeled triangular irregular network and hence much better representation of contour lines for the hydrology study area. Point Cloud data for the hard to reach areas were also easily acquired. The accuracy and speed, coupled with the density of the point cloud is a viable alternative to traditional surveying methods (Bu and Zhengpeng, 2008).

Value added benefits of using HDS are the ability to deliver 3D point cloud to the client. Even if the deliverable was a 2D map with contours, the point cloud data can be utilized by the client in a variety of formats. One format of viewing a 3D point cloud is in virtual modeling software. Virtual modeling software allows the end user to view the point cloud with the ability to zoom or pan the 3D data. Tools within the software allow for quick and accurate measurements of objects in the point cloud. This allows for a virtual walk through of the jobsite right from a computer screen. The database can be set up on a server and can be accessed from anywhere that has internet connection.

Users can pick out coordinates and measure distances precisely. The ability to markup a project from a remote location allows for time and cost savings. The markups can be saved and delivered to clients. The accurate measurements add great benefits. Projects can be efficiently managed from long distances. The convenience of QA/QC from remote locations can be cost beneficial by saving time and money on trips to the jobsite.

Many value added benefits are apparent in the use of HDS including but not limited to the high levels of detail captured in the point cloud. The value added benefits allow for a more complete, efficient, and superior end product. It should be noted that once a field laser scan has been completed, every object within sight and range view of the laser scanner is positioned in 3D. This eliminates subsequent jobsite field trips for data acquisition which often reduces profit margins. Overall the advantages of using laser scanning technology over traditional surveying methods are evident in this case study. Value added to the client is apparent. In the very near future, HDS / laser scanning will be as common as GPS is today.

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