

# APPLICATION OF THE GLOBAL POSITIONING SYSTEM TO BOND FORFEITURE RECLAMATION PROJECTS<sup>1</sup>

by

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**Abstract.** Reclamation projects performed over the last ten years have used the Global Positioning System (GPS) to realize cost and time savings. A cooperative project between the OSM Technical Information Processing System (TIPS) team and the state of Colorado serves as a model for the use of GPS and other computer technologies applied to real-world reclamation projects. The GPS technology was used in several project phases of the reclamation of the facilities area of an underground mine complex and associated roads. GPS work in the facilities area was used to: 1) georeference topographic site mapping, 2) direct the stake-out of earthmoving cut-and-fill depths to achieve the reclamation design, and, 3) monitor construction of the channel design. Road lengths and hydrologic structure placement were collected in real time from a survey vehicle, and served as the basis for preparation of contractor bid packages for subsequent reclamation work. Although the Colorado model was used to achieve bond forfeiture reclamation, the application to Abandoned Mine Land (AML) design and construction is readily apparent. In the Colorado example, the design was placed and constructed in a time-efficient manner. Cost savings realized by using the GPS technology were applied to earthmoving costs, and resulted in cost savings in a limited funding scenario. The application of GPS techniques to disturbed mine lands is a promising technique which produces rapid mapping of sufficient accuracy to guide reclamation efforts.

Additional Key Words: Abandoned Mine Lands, TIPS, OSM, georeference

## **Introduction**

The global Positioning System (GPS) is an emerging technology that is rapidly being embraced in coal mining and reclamation. The advantages of GPS use in surface coal mining are beginning to be realized through "precision mining", where the mine operator can literally track each bucket of material excavated. The efficiency of these modern operations, where the equipment operator can minimize push distances through use of GPS-guided cut-and-fill maps (Long, 1998), stands in contrast to past surface mining where earthmoving inefficiencies and the high associated costs sometimes resulted in abandonment before reclamation was completed. GPS technology offers the promise of cost and time savings to the reclamation professional through the rapid, low-cost mapping of unreclaimed surface mine landscapes. The techniques described here are equally applicable to abandoned Mine Land (AML) projects as well as bond forfeiture sites. The

Technical Information Processing System (TIPS) has offered GPS services to its customers for the last decade. A joint project between TIPS and the State of Colorado Department of Natural Resources (DNR) Reclamation Program illustrates the benefits of GPS in reclamation.

## **GPS Applications to Reclamation**

GPS techniques are of value in several areas of reclamation planning, design and construction activities. GPS is a powerful tool that can capture both spatial and descriptive data about minesite conditions and features. GPS software can produce plots or overlays of spatial data to any desired scale. The GPS data collected is export-friendly into a variety of Geographic Information System (GIS) and Computer-Aided Design (CAD) software.

## **GPS Mapping**

GPS map data can form the basis of highly detailed reclamation design and construction activities. Quick, relatively accurate, GPS mapping is of great advantage in the initial reconnoiter of the field site. The resulting maps are dimensionally-accurate, and can produce site maps for construction bid packages or serve as an overview map for more detailed surveying work. The advent of real-time correction services has provided significant ease-of-

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use and immediate field feedback for GPS mapping efforts. Real-time correction is accomplished through use of commercial terrestrial beacon or satellite broadcast correction signals.

Point features such as well locations, markers, seeps, and adits are mapped by static logging techniques employing GPS position averaging. The averaging technique relies on collection of multiple GPS position fixes at a single location to enhance the accuracy of the feature positional solution.

Areas and perimeter lengths of impoundments, pits, spoil and topsoil piles are easily calculated and displayed on modern GPS data loggers in the field. As area features are closed and saved to GPS files, the system-calculated area can be displayed on the view screen. The trace of the area perimeter can be viewed as it is established by collected GPS positions. Accuracy of GPS-derived areas calculated for three-acre parcels has been verified to be within one to three percent of the actual area, with an average error of only 1.7% (Jasumbeck et al, 1997).

Linear features such as roads, boundary lines, highwalls, and fence lines can be captured by single field users on foot or by an external GPS antenna mounted to the vehicle roof. Line lengths are calculated automatically by datalogger software in the field, and the line trace can be displayed as it is being traversed. GPS equipment is compatible with the RS-232 data protocol output by laser rangefinders, allowing the operator to collect data from a safe distance from hazardous highwalls.

#### Attribute Collection

Another significant benefit to use of modern GIS-capable GPS equipment is the ability to collect attribute data in the field (Gilbert, 1994). Attributes are the descriptive data that are collected together with GPS features in the field. GPS software supports construction of a data dictionary –an attribute listing which can be loaded onto the GPS data logger. When a minesite feature is stored as a set of XY coordinates in the field, the operator can simultaneously record pertinent facts about the feature that have been programmed into the data dictionary. In this way, descriptions about mine features can be tagged to specific locations for later display or analysis.

#### Georeferencing

One of the most aggravating problems on abandoned sites is the lack of maps that are georeferenced to a recognized global coordinate system. Existing maps created in mine-specific local coordinate systems require software techniques to translate their coordinates to match outside data sources such as USGS topographic maps, digital line graph or digital raster graphic products.

GPS equipment can be used to fix accurate two-dimensional positions, or minesite control points. For control point collection, software averaging should enhance the accuracy of corrected GPS positions collected at a static location. Control points collected at multiple locations on the minesite can be used to georeference or translate the local site coordinates into a global system. GPS, GIS, or CAD software packages can perform the translation into global coordinates. These control points can then be used as starting points for local surveying of a site.

The coordinates derived by GPS averaging at these landmarks can be then used by translation routines in terrain modeling software or by image processing software to georeference the entire image.

#### GPS Spatial Monitoring

GPS monitoring of construction activities can aid in the quality control of material excavation and placement. After georeferenced site maps are produced by GPS-aided photogrammetry or coordinate translation, key site coordinates or engineering control stations can be loaded into GPS equipment as GPS waypoints.

Waypoints are pre-defined XY coordinates that are used as navigation targets. The construction monitor navigates to successive waypoints that are subject to quality control inspection, and can reoccupy them at various times throughout the inspection process, regardless of their appearance. The waypoint becomes a virtual flag or stake that cannot be damaged, removed or mislocated.

#### The Technical Information Processing System (TIPS) GPS Program

The TIPS program in the Office of Surface Mining (OSM) has partnered with its state, Tribal, and agency customers over the years to bring relevant digital technology to reclamation activities. TIPS involvement in GPS began during the time of the Gulf War in 1990. At that time of conflict, the

Department of Defense had scaled back the system-wide anti-spoofing errors that are a standard element of the current GPS system. Initial TIPS GPS prototyping therefore occurred in a low error environment. The realities and importance of GPS correction techniques and software capabilities were soon appreciated when the Gulf War ended and a more normal error rate was reintroduced into the GPS.

TIPS utilization of GPS technology continues today with the expansion of TIPS GPS capabilities to users nationwide. Currently 60 TIPS GPS units and accompanying software have been distributed to the TIPS user community. TIPS offers vendor-certified GPS training to its customers, and has a certified GPS trainer on staff. Over 400 TIPS users have been trained in GPS hardware and software over the last eight years through the TIPS Training Program. As an important part of the TIPS GPS technology support effort, project assistance has been an on-going activity. TIPS has provided GPS technical support over the last ten years on numerous projects.

#### TIPS GPS Capabilities

TIPS has procured and delivered 60 basic mapping and GIS-capable GPS units for its customers to use in reclamation work. These units require software post-processing correction of the raw GPS position data to remove system errors. Data collected with these Trimble GeoExplorerII units can be corrected through software post-processing when used within 300 miles (483 km) of a compatible GPS base station. This process requires field operators to have access to a portable computer loaded with the GPS software and modem to download base station correction data from an Internet file transfer protocol (ftp) site or a dial-in bulletin board access site.

The recent advent of real-time GPS correction services through satellite or terrestrial beacon transmission working in tandem with GIS-capable dataloggers has great potential in reclamation project work. In 1997, TIPS procured Trimble Navigation ProXRS 12-channel GPS equipment with correction beacon and satellite correction service capabilities. The Omnistar satellite correction service was selected to obtain effective nationwide and even international coverage. This comprehensive coverage provides corrections for those areas such as the Mountain Time Zone that generally have minimal reliable correction beacon coverage. The Omnistar service delivers real-time correction signals for GPS data collected in the field, in many cases without the

need for subsequent PC-software correction. The U.S. government is planning expansion of the beacon correction system through the Wide Area Augmentation System (WAAS) (Jasumback, 1996).

### TIPS GPS Assistance to the Coal Basin Reclamation Project

#### Site Conditions

The Coal Basin minesite is a high-altitude underground mine complex in Pitkin County, Colorado, located just outside the town of Redstone. The operation forfeited its bond, and became a long-term reclamation project for the State of Colorado DNR. The disturbed areas at the site encompassed multiple underground mine adits at elevations in excess of 10,000 feet (3,049 m), associated waste material, access and haul roads, and a preparation plant and facilities area.

#### Dutch Creek Re-establishment

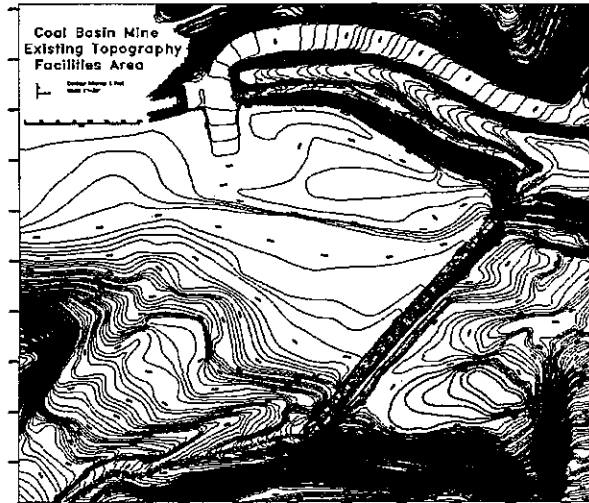
A major diversion of Dutch Creek, a perennial stream that formerly flowed through the facilities area, channeled the drainage from upslope of the facilities area into a concrete flume that joined the receiving stream some 60 feet above the elevation of Coal Creek. The resulting waterfall, although impressive, did not correspond to the pre-existing natural hydrologic regime. The natural drainages at these elevations carry large boulder-sized material in short-term high-volume discharge events (Pranger et al, 1996). As configured, the flume was in jeopardy of choking with this large-diameter bedload and overtopping and causing bank erosion at its upslope wing walls during spring runoff. A priority of the reclamation project was to return Dutch Creek to a stable, more natural profile and sinuosity while removing the flume and redirecting the drainage across the former facilities area.

#### Site Georeferencing

The initial application of GPS at this site was to establish local control for conventional surveying of the facilities area. The ProXRS GPS equipment was used with the Omnistar real-time satellite correction service. This source of differential correction signal is not sensitive to terrain attenuation, unlike other real-time correction services (Jasumback and Luepke, 1996). Despite the high topographic relief in this area along the Continental Divide, the GPS and Omnistar satellite visibility were both sufficient to allow rapid collection of position fixes. The ProXRS averaged point features at

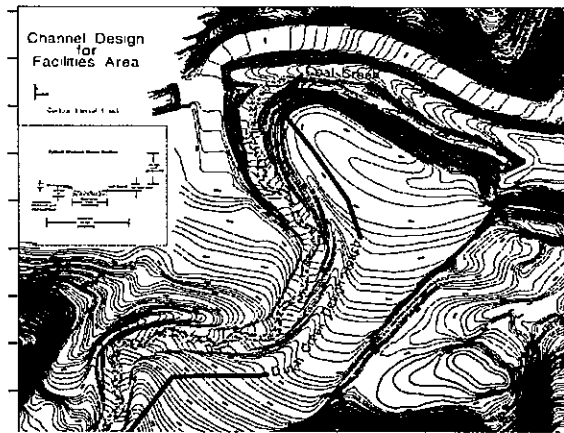
multiple locations on the minesite selected for their total station line-of-sight coverage of the area. Point features were averaged for one hour each, or approximately 3,600 GPS position fixes at a recording rate of one per second. The resulting GPS control points were translated through the Trimble Pathfinder Office software into the State Planar Coordinate System and North American Datum of 1927 coordinates from the standard GPS coordinate system of latitude, longitude and World Geodetic System of 1984. This translation allowed feet to be used as the XY units and matched the coordinate system of earlier maps of the area by the U.S. Geological Survey.

The subsequent total station survey of the facilities area was quite detailed, and the coordinate data from the total station was loaded into the Dynamic Graphics Earthvision terrain modeling software to produce a contour map of the existing facilities area topography (Figure 1).



**Figure 1. Pre-reclamation topography and Dutch Creek diversion at Coal Basin facilities area (after Pranger et al, 1996)**

The next step in the process involved the creation of a hydrologically-stable drainage configuration for the “new” reach of Dutch Creek. Following field characterization of the unaffected reach of Dutch Creek above the facilities area, OSM hydrologist Hal Pranger designed a complex yet stable channel design that incorporated an incised inner channel within a broader outer channel (Pranger et al, 1996). Earthvision was again used to transfer this channel design template to a topographic map of the design within the facilities area (Figure 2).



**Figure 2. Reclamation design topography and Dutch Creek re-establishment at Coal Basin facilities area (after Pranger et al, 1996)**

Cross-sections were also generated to serve as engineering control along the reach of the redesigned channel.

#### GPS Channel Design Stakeout

GPS waypoints were selected from the design map coordinates to allow for the trace of the inner and outer channel banklines to be transferred from the paper map to the ground. The waypoints were exported from Earthvision as an ASCII data file into the Pathfinder Office software waypoint manager module, where each waypoint could be assigned an identifying number. The resulting waypoint file was then uploaded into the GPS datalogger. The GPS operator then navigated to each of the stakeout waypoints and directed placement of stakes marking the inner and outer channel configuration on the site (Figure 3).



**Figure 3. Author performing construction control stakeout at Coal Basin facilities area**

More than 150 stakes were placed to delineate both the inner and outer channel designs in less than five hours.

### GPS Construction Monitoring

As construction progressed on the site, and stakes were removed or displaced during the earthmoving process, a GPS-equipped construction monitor re-occupied the waypoints to assure that the channel locations were being constructed as mandated by the design template. In some cases, stakes had to be replaced due to equipment traffic through the site. This task was easily accomplished by referring to the waypoint list on the data logger, finding the missing stake, and re-establishing it at its "virtual" location.

### Access and Haul Road and Spoil Area Mapping and Characterization

#### Road Mapping

The mining roads remaining on the Coal Basin site are the focus of future reclamation efforts. At the end of the 1999 field construction season, the Colorado DNR requested assistance from TIPS to map the roads, and to locate and categorize road features for reclamation in the 2000 field season. The maps will guide the preparation of the next construction season bid package.

Prior to mapping, a data dictionary was created using Pathfinder Office software on a laptop computer at the field site. Included were descriptions of road conditions affecting reclamation. These descriptions were summarized and entered as attributes, producing a "laundry list" of features of interest to the project. The data dictionary was then uploaded to the data logger for field use.

After a four-hour GPS refresher on the ProXRS, the Colorado project manager, Steve Renner, performed a road-mapping project in a day and a half that mapped 11 miles of roads and associated attributes. Proposed drainage control structures such as culverts and water bars were mapped from the vehicle as point features along the road trace, as indicating areas where erosion was occurring. Attribute descriptions such as depth and width of rills and gullies, and the presence of groundwater seeps or springs were keyed into the datalogger simultaneously with the GPS unit's collection of position fixes. The efficiency of attribute entry during collection of GPS fixes allowed significant time savings. The nesting of drainage control point

features along the road trace eliminates the need to backtrack during the mapping survey, and keeps the flow of data collection logically proceeding along the direction of travel.

#### Spoil area characterization

Spoil materials produced during mining operations and unstable slope areas were also logged in the fall of 1999 either as area features or point features, depending on the extent of area requiring reseeding. Areas logged as area features with the GPS unit are calculated in the software based on a flat map projection in Pathfinder Office. Elevations are not used in this routine to generate a slope area. Over extremely steep slopes at Coal Basin this calculation method caused a significant increase in the actual area for reseeding over the software-derived area.

### Conclusion

The future of GPS utilization in reclamation planning design, and construction is nearly limitless. The ability to rapidly and cost-effectively map and describe site conditions, as well as provide construction guidance and quality control are encompassed in a single technology in contrast to past techniques. As in any emerging technology, user training is essential to eliminate painful pitfalls that decrease user confidence. Use of the GIS-attributing capabilities and real-time correction techniques described here are growth areas that will bring GPS use into the mainstream in reclamation work, just as it has in other natural resource applications.

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