Geospatial Applications in the Alaska AML Program -- Practical Examples and Results from an Alaskan User's Perspective[1]

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Abstract: Since 1995, this investigator has used the OSM TIPS' suite of analytical software and tools to perform inventory, design, and as-built documentation for the Alaska Abandoned Mine Lands (AML) Program. From 1995-2000, EarthVision was used to build OG, interim and as-built surface maps, create slope modification designs, generate plan sheets, and assess contract performance in corroborating pay quantities. In one project, disputed pay quantities were analyzed using cut and fill zone isopachs to determine quantities in and out of compliance, and expose contractor fraud. In 1996 we began using Trimble's GeoExplorer II GPS for on-the-ground inventory, design layout, and as-built documentation. Items mapped include vegetation coverages; highwall breaks; impoundment shorelines; project boundaries; road, path, stream, and RR alignments; cut/fill lines; terraces; monuments; and control points. In one project, map-grade GPS located features detected errors in a survey-grade surface model.

In 2000, CAD was phased into AML production work, and around 2002 we received one of the first Trimble Geo XTs provided to state programs. These tools were put to use in spoil fire mitigation work delineating hot spots, designing and laying out drillhole patterns, modeling bottom of combustible materials' structural surfaces, and calculating design volumetrics. Project sites lacking existing topography were modeled by combining autonomous GPS northings and eastings with terrestrial level work to generate original ground (OG) maps and spoil pile designs.

Recently-acquired tablet and Trimble GPS platforms running ArcPad and Terrasync incorporated air photo and georeferenced historic mine map rasters to aid inventory of existing and emergency hazards in Jonesville and Eska Mine districts--shafts, adits, subsidence featuress, historical structures, and hazardous equipment & facilities. Data was downloaded to GIS and CAD platforms for database compilation, feature and design rendering, access delineation, and measuring areas and distances for contract estimates.

Additional examples include gathering GPS vector data (road, stream crossings, points) for polynomial raster correction, and gravel permit boundary reconstruction using historical permit data. In 2006, seismic refraction surveys were conducted to model bedrock depth, which was incorporated into vertical opening closure planning and design.

This paper presents 13 years' worth of geospatial applications, showing analyses, applications, and results.

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Introduction

Since 1982, upon passage of the Alaska Surface Coal Mining Control and Reclamation Act (ASCMCRA), Alaska has participated as a SMCRA cooperator state with Title IV and V programs. This investigator began working with the Alaska Abandoned Mine Lands (AML) Program in 1995. For several preceding years, program reclamation focused on smaller projects including shaft and adit closures, spoil pile reshaping, and hazardous equipment and facilities removal. AML funds were not being fully spent, and grant monies were in danger of being lost due to lack of expenditure.

Large earthmoving projects to reclaim pre-SMCRA dragline pits in Knob Creek and Jonesville historic mining areas were needed. OSM TIPS was providing EarthVisions software and training for earthmoving design, but no expertise had existed in-house to run it. Upon joining the program, I was tasked with learning EarthVision to generate mass balance designs and plan sets for contacts. With some self-tutoring and attending a TIPS introductory EarthVision class, we were producing designs delivering results in the field.

Knob Creek Reclamation

Our first large bid contract was the 1996 Lower Knob Creek reclamation project. Forty seven acres were reclaimed at a cost of $1.1million to excavate and embank a mass balance design of 224,000 m^3, reclaiming two pits containing impoundments surrounded by dangerous highwalls 40-100 ft. high, and steeply sloping spoils forming abrupt shorelines. Some 500 meters of dangerous highwalls were buried, over 400 meters of shoreline laid back, and a nearshore underwater shelf added in the larger impoundment for safety. Highwall embankment in the smaller impoundment necessitated rerouting the stream channel, engineering the streambed to incorporate large aggregate and an impervious underliner.

Original ground mapping for Knob Creek and the entire Jonesville area was provided as a digital elevation model (DEM) from 1993 aerial photography by a local mapping contractor. Approximately six square miles were modeled in the local state plane coordinate system, using NAD83 horizontal and NAVD 88 vertical datums. The contractor also provided road, surface water, and vegetation information as vector line files in CAD dxf format. This information was

imported into EarthVision, then modeled to display existing ground elevation contours along with natural feature and cultural annotation. Project sheets were typically generated at a 1 meter contour interval to portray original ground, design, interim, and as-built surfaces.

Control for the Lower Knob Creek project was surveyed using terrestrial instruments. Up until that time, project boundaries, vegetation, and other features and resources were being mapped by hand on field sketches or plan set drawings. Toward the end of the project, we began using a Trimble GeoExplorer II provided with training by OSM TIPS. This was used to map altered shorelines, road and creek alignments, and locate vegetation plots being studied by a University of Alaska specialist contracted to monitor revegetation progress. Rover *.ssf files were post-processed in Pathfinder Office by basefile correction, then exported as ASCII point files for each feature. These were converted into EarthVision point, line, or polygon annotation files by manipulating header code.

Upper Knob Creek

From 1997-2000 a number of equipment rental contracts were carried out in nine pits in the Upper Knob Creek area. About $2.4 million was spent to reclaim approximately 90 acres by reshaping several thousand lineal feet of footwall and spoil outslopes, filling several small impoundments, and removing or burying old equipment. During that period EarthVision and the Trimble Geo II were used for reclamation inventory, design, and as-built documentation work. By 1998 we had acquired external rangepole and vehicle antennas for the Geo II, which significantly increased signal gain and made it possible to collect data in more challenging environments, notably under tree canopy.

In one of the larger pits where cut and fill modification of a steep footwall was not feasible, we installed several levels of terraces, left vegetation islands, modified an impoundment shoreline, installed a small pond, and emplaced small boulder trains to act as barriers and encourage wind drop reseeding. These features were GPS mapped for documentation, with impressively detailed results. Geo II post-processed data is rated to 2-5 meters' accuracy, however corrected line files gathered using one-second interval data defined features smaller than one meter in size. Though absolute accuracy may have been coarser, relative proportion

and definition within features appeared more precise. Selective availability was operating at this time.

A local surveyor contracted for this job mapped original ground and as-built topography with survey-grade GPS. Map-grade features gathered with the Geo II drawn atop as-built topography in EarthVision revealed contours were uniformly offset relative to terraces and impoundments. The surveyor eventually realized he used the wrong local base station point to correct the survey, resulting in an x,y shift of over 7 meters southward. That was close to the amount of displacement observed on the map. This case demonstrated absolute GPS accuracy appeared better than the rated 2-5 meters for our map grade instrument, which detected errors in a survey-grade surface model.

North Jones Reclamation

From 1997-2001 our program designed and awarded several competitive bid contracts to reclaim three large dragline pit areas in North Jonesville. These pits collectively contained over a mile of dangerous highwalls ranging 100-270 feet high, 2,000 feet of steep footwall up to 150 ft. high, about 30 acres of steep unvegetated spoils outslopes, and two dangerous impoundments. Earthmoving and revegetation contracts to reclaim nearly 80 acres of mining disturbance totaled approximately $4M**.**

The North Jones Phase II project remediated a box cut with highwalls on three sides and a shallow impoundment at the base. The top of the highwall was accessible by vehicle. The job reclaimed 18 acres, moving 320,000 m^3 for a cut and fill reslope at a cost of $1.1 Million. At job's end, revegetation plots, photo points, and surface treatment areas were mapped using GPS, to aid revegetation monitoring.

North Jones III Project

In 1998 we awarded the North Jones III project, to remediate a 22 acre site with southern aspect located 470-530 meters in elevation. The mass balance design called for moving 350,000 m^3 of outslope spoils, devoid of vegetation since the 1960s, to fill a strip pit by embanking to

eliminate 1100 feet of dangerous highwall over 250 ft. high. The contract was awarded April 28, and the notice to proceed issued May 15, with a 120 day timeline to finish by Sept 22, 1998.

However, the contractor had problems. He began project work late, in mid-June, choosing to construct roads & pads, then proceed with scrapers. Dozer work was slow, moving only 60K m^3 in the first two months. After 50% of contract time had elapsed only 10% of the work was done. He constructed haul roads through June & July, then brought scrapers onsite the beginning of August, with ¾ of the contract time elapsed. He used poorly maintained equipment that suffered frequent breakdowns. He employed inadequately trained operators and supervisors which resulted in poor project coordination and performance. He also did not use grade control for finish elevations for the first 5 project months, which resulted in large amounts of material being stockpiled out of compliance.

After the first season, using December 1998 interim survey data the DNR calculated moved material volumetrics of 291,956 m^3 of cut and 263,018 m^3 of fill. This corroborated the contractor's surveyor's quantity calculations of 290,237 m^3 of cut and 260,200 m^3 of fill. However, on October 29, 1998 the contractor notified the project engineer he believed contract quantities were in error, and gave notice of intent to file a claim. In December 1998 the contractor shut down for the winter.

DNR showed the contractor had 88,000 m^3 of fill out of compliance, with 63,000 m^3 out of +/- 1m tolerance. Volumes were assessed separately in cut and fill areas, divided by the 0 contour line on the existing vs. design isopach map. This must be done to parse all work categories, as the relationships between two surfaces delineate discrete categories in cut and fill areas.

Analyses were first made comparing original ground (OG) and intermediate surfaces. Material categories on the cut side included cut done to date (correct work) and fill <u>above</u> OG (out of compliance). Work on the fill side included fill done to date (correct work), and cut <u>below</u> OG (out of compliance).

Next comparison was made between intermediate and design surfaces. Material categories on the cut side included cut work remaining (correct work) and <u>excess</u> cut below design (out of compliance). Work on the fill side included fill done to date (correct work), and excess fill <u>above</u> design (out of compliance).

Four separate isopach maps were generated, yielding volumes for the eight work categories, four correct, four out of compliance. Totals from both OG vs. intermediate and intermediate vs. design maps of incorrectly placed cut (8.8K m^3) and fill (82.9K m^3) quantities were subtracted from gross work done to date (289.5 m^3cut, 263.8K m^3 fill) to calculate net work correctly done. Most of the cut (96.9%) was in compliance, but only 68.5% of the fill was in place.

A similar analysis of 12-98 interim vs. design surface volumes calculated work remaining, which added to work done to date summed to volumes that varied from the original design by 1.17% for the cut and 0.9% for the fill. The contractor had emplaced at least 63,000 m^3 of material out of compliance, much of it occupying road fill constructed through the middle of the project area.

The contractor was given a second construction season in 1999 to finish the job. He began in May, working mostly with three dozers making long uphill pushes through summer and fall. In October, his surveyor submitted pay quantities of 388,000 m^3, which was revised upward to 430,000 m^3. Neither the surveyor nor contractor would provide details of their method of calculation.

Work continued through wet and snow covered conditions with a single dozer through November and December, shutting down for good on January 11, 2000. On January 18 the contractor submitted pay-item quantities for 511,256 m^3 of cut. Survey data was given to DNR Parks and three outside engineering firms, who calculated cut pay quantities ranging from 325.4K m^3 – 350.1K m^3, agreeing within 8%. DNR requested the contractor's surveyor reconfirm their certifications and assumptions, and they resubmitted a quantity of 332,034 m^3, in agreement with DNR and independent contractor calculations.

At the end of 1999 construction season, another discrete volume analysis showed incorrectly placed stockpiles had been reduced to where 91% of embankment was in compliance. The amount of cut was almost unchanged, at 97.2%. About 63,000 m3 of material remained to be moved, which was successfully dealt with in a separate North Jones III Completion contract in 2000.

Subsequent claims filed by the original contractor were denied all the way through the Alaska Supreme Court. Our volumetrics withstood scrutiny thanks in large part to the technology provided to the state by TIPS.

North Jones III Revegetation

In winter 2003 we began designing terraces as part of the North Jones III revegetation project. Alignments were laid out in SurvCAD with a 1% slope toward downdrains. SurvCAD was then used to design trapezoidal and V-bottom berm ditches with mass balance. Principal invert alignment vertices were then uploaded into our Trimble GeoExplorer II and CE/XT units, then staked out in the field. On comparison, the CE/XT stake line appeared more uniform than and generally displaced about 2 meters north of the Geo II stakes.

Waypoint-located alignments were then resurveyed with the Geo II. When corrected, resurveyed alignments agreed within 0.5-1 meter of the original design along gentler slopes, but diverged by up to 4 meters in steeper areas. The larger variation was attributed to multipath distortion and partially blocked views of the sky.

Project earthwork construction and revegetation was carried out in May and June 2003, at a cost of $147K. The following September, both GPS units were used to survey berm inverts as built. Raw and corrected alignments from both units were then compared in a CAD drawing. The Geo II raw and corrected lines both showed up to 5.5 meters of multipath displacement in steeper areas; and raw-to-corrected line displacements of 1.5-3.25 meters. The CE/XT exhibited no multipath distortion, and lower and more consistent raw-to-corrected line displacements of 1.5-2 meters. This suggests the CE/XT would yield better results acquiring and post-processing rover data.

Jonesville Fires Projects

In 2001 we began planning to remediate underground burning in approximately 45 acres of Jonesville mine spoils. The project area includes a local airstrip on the north side of Slipper Lake, which was used by the mine since the 1950's. The general area receives extensive public use for ATV/ORV (All Terrain Vehicle, Off-Road Vehicle) riding, hunting and fishing, camping, shooting, snowmachining, skiing, hiking and fossil collection, all of which increase annually.

Old miners related these piles had been burning for many years, since spoils dumping began. Wash plant reject was disposed of or used for construction material throughout the nearby area,

and spoils fires often threatened to ignite wooden wash plant buildings. No major extinguishment efforts had been made over the years.

A portion of these burning spoils lie within an active coal permit area. Over the last decade, permitees tried water flooding and sand and gravel cover extinguishment, which resulted in further subsidence and ground crack development. Underground fires ignited a forest fire in May 1999, burning approximately ½ acre.

A survey was contracted to provide topography and control, and surface and subsurface definition was begun for remediation design. Surface features definable as work area targets included two major spoil piles, one within the active permit area, and two dumps. GPS data was gathered to define natural and cultural features--access routes, vegetation stands, historic railroad bed alignments, and berms. Data was exported as *dxf files and displayed in CAD with existing topography and road and surface water annotation to construct a base map. Feature data were used to define project boundaries. GPS vegetation polygons were used to calculate acreage for engineer's cost estimates for the Jonesville Fires Phase projects.

To assess subsurface properties, several issues were identified for definition—the thickness and lithologies of coaly spoils, depth to natural ground underlying spoils, distribution and degree of burning spoils in three-dimensional space, and distribution of carbon-containing spoils with the potential to burn.

To define drilling targets, we first mapped hot spot distribution on the surface. In winter 2002 the Trimble GeoExplorer II was used to map polygons around ablation areas where snow would not accumulate. These were exported to the CAD drawing and targeted for drilling. A first phase of 25 boreholes was drilled, concentrated within hot spots along the crest of the northern pile. Their as-built locations were GPS mapped, post-processed, and exported to the drawing.

A second phase of 33 borehole sites was plotted to explore the remainder of the northern pile, which became the Jonesville Fires Phase I project area. Drill site locations were uploaded into the GeoExplorer II and waypoint-located in the field. Afterward, as-built drillholes were located with GPS, post-processed, and put in the drawing. When compared, as-built locations were within 2-3 meters of design locations.

Temperatures taken inside the boreholes revealed that heat distribution in the pile was not predictable based on surface hot spot distribution. Temperatures exceeded the 120°F threshold

used to define presence of combustion over about 10% of the total borehole length. This was visualized by gridding the data in the EarthVision 3D viewer and running isoshell contour volumetrics. Because of the irregular and unpredictable distribution of burning material, we decided to dig up and treat the entire spoils mass.

The Jonesville Fires Phase I project reclaimed 22 acres, excavating, extinguishing, and reembanking 761K m^3 of burning spoils during the 2002-2003 construction seasons, at a cost of $2.5M.

Phase II, MatSu Dump Topographic Mapping

These processes were repeated to define project surface features and subsurface properties beneath the south pile, for a 2nd phase of remediation in the Jonesville Fires Phase II project. We decided to stockpile treated spoils to cover a tract of land that was an attractive nuisance for illegal dumping, shooting, and burning stolen vehicles. This area had not been mapped for topography, so we devised a hybrid approach combining conventional leveling and GPS to map features and elevations.

In April 2004 we used the Trimble CE/XT to map dump disturbance limits and vegetation lines. Backsighting a point of known elevation in the adjacent project area, we conducted a level survey to measure point elevations. Northings and eastings for each point were read autonomously by the rod man carrying the CE/XT. Point x, y, and z data were assembled in a spreadsheet, imported into SurvCAD, and used to contour existing topography, using breaklines to delineate slope crests and toes.

To design the side slopes at 3:1, I used SurvCAD to generate a 3D boundary polygon draped onto existing topography along the project edge. SurvCAD's Pad template was then used to construct a 3:1 surface from that line upwards to generate side slopes. Our revegetation expert advised installing a ditch and berm, which was cut into the side of the pile at a 2% gradient, exiting to a rock downdrain. This design was included in plan sets and built as part of the Jonesville Fires Phase II treated spoils embankment in 2006.

Phase II Topographic Survey Error Detection and Correction

The south pile treated in Jonesville Fires Phase II was heaped nearly 20 meters high. Efficient remediation required it be spread at reduced thickness over a larger end-of-project footprint. Two dump areas and a fairly flat 8-acre area to the east were targeted to receive treated spoils. The eastern area was unmapped, so we conducted a theodolite electronic distance meter (EDM) survey to map topography and set control.

Survey data downloaded into CAD appeared good, but rotated approximately 15° out of position. I uploaded control point locations into the Trimble CE/XT and went to the field to investigate. GPS waypoints indicated the control point used as the transit location for all topographic shots was erroneously located in the survey solution by 14 meters. Presuming backsight error, I took GPS point locations on all control and reference points set by our survey.

Back in the office on the CAD drawing, GPS-recorded control and reference point locations were compared to erroneous survey locations. All showed rotational error of about the same angular displacement. GPS control and reference point locations were used to rotate all survey points into proper position. Existing topography generated from this data was used to calculate volumetrics and generate design surfaces. The Jonesville Fires Phase II project reclaimed 20 acres, excavating, extinguishing, and reembanking 495K m^3 of burning spoils during the 2006 construction season, at a cost of $3.1M.

Gravel Extraction Area Assessment & Permit Reconstruction

An Alaska Department of Transportation sand & gravel pit near the project area was used for borrow material on several AML projects from 1993-2003. In 2003, disturbance limits shown by 1993 aerial mapping were out of date. An April 2004 GPS survey of disturbance limits showed the excavation area had enlarged about 3.5 times. We wanted to determine if sufficient extractable gravel remained within the permit area to supply the 2005 AML spoils fire reclamation project, and whether excavation had strayed outside the permit boundary.

It is always good practice to collect GPS locations of roads, structures, and utilities near areas of interest, which can prove useful when compared with plats, engineering plans, or geographic data. We had collected GPS road centerline and ditch edge alignments for this site. Our engineer located a copy of the 1960 gravel site extraction permit which gave site and road ROW dimensions.

To reconstruct plat boundaries in CAD, two sides of the plat were constructed using ROW offsets from road centerlines. From these, opposite sides were located using parallel orthogonals drawn at corresponding side dimensions, then drawing construction lines along their endpoints to locate the opposite corner by resection. Orthogonals drawn from the corner to the road ROW boundaries completed the plat reconstruction.

Results showed that borrow activity had largely remained within the permit boundary. The reconstructed permit acreage was within 0.02 acres of the 1960 recorded plat area. We calculated about 7900 m^2 of remaining undisturbed area within the permit boundary, which would supply more than enough gravel for the 2005 AML fires project firebreak and road construction. Since this reconstruction, the southwestern 1/16th corner of this plat was GPS located, which plots 1.17 meters from the reconstructed corner location.

West Wishbone Mine Inventory

Mined circa 1912-1925, the West Wishbone mining district extends for six miles along the northwest side of Wishbone Hill anticline, comprising 10 mines, some with several names. In summer 1998 our program spent several days on the ground conducting GPS field inventory of mining features and gathering road vector data, but was hampered by midsummer leaf-out conditions.

In November 2006 we conducted an ATV inventory in low temperatures and thin snow cover. This survey had the advantage of using previously gathered vector data, plus newly acquired 2005 USDA color aerial photography, USGS topographic rasters, and a 1940s mine map of the entire area. The USDA photography and USGS TIFFs were subsampled for project area coverage. The mine map was georeferenced using USGS topo section corners. All maps were reprojected from UTM 6N to NAD83 SP4, then loaded with vector files into ArcPad for field inventory.

Inventory was conducted using an Xplore Technologies iX104TD Tablet PC and Trimble Recon GPS platforms. Both machines worked well until temperatures fell to +15°F, then screens became nonfunctional. The iX104 screen could not be seen in direct sunlight. Though visibility through the vegetation was good, low temperatures and snow slowed inventory work, and few features were found. The trip primarily served as a reconnaissance mission.

In May 2007 we took to the air to conduct aerial inventory of hard-to-reach features such as bridges and railroad remnants in Moose Creek, and Jonesville airshaft openings along the high ridgelines of Wishbone Hill. Previously assembled ArcPad data was augmented with a georeferenced Jonesville underground mine map. A point shapefile was generated denoting all airshaft openings with large easy-to-see point features.

Our acquisition platform consisted of a Fujitsu 5022D tablet connected by Bluetooth to a Trimble® GPS Pathfinder® XB receiver. We contracted a local air service and flew out in a Robinson R44, with the Trimble XB receiver in the front of the helicopter bubble for good sky view, and the tablet operator in the shaded back seat for better screen visibility. We flew to the area, circled and noted several bridge ruins along Moose creek, but saw no additional openings or mining features from several hundred feet above the trees throughout the rest of Buffalo mining district. No new openings were found in the high country of Jonesville mine on repeated passes.

Eska Inventory Work

In October 2005 we conducted an inventory of mining features in the historic Eska mining area. Literature searches and mine maps indicated multiple coal seams were underground mined in the district from 1910 through the mid 1940s, leaving a variety of mining hazards behind, including shafts, adits, hazardous old mining equipment and buildings. The fledgling Alaska AML program removed much of the equipment and buildings associated with the Eska processing plant in the mid 1980s, and closed the main mine adits. In 1993 the program closed several dangerous vertical shafts along the North Jonesville Road associated with Eska underground mining.

This investigation sought to find and document remaining hazards in the Eska mining area, using target descriptions compiled from maps and literature by AML staff. Over 70 potential target location points delineated in a CAD layer were exported to a shapefile for ArcPad use. Raster backgrounds were derived from IKONOS imagery polynomial-corrected in ERDAS, USGS topographic map TIFFs, and a scanned and georeferenced 1943 USGS mine map. These images were used as MrSID and TIFF images for ArcPad inventory. A ‘found AML features’ point file was created in ArcPad with forms for entering attribute information, which would

export dimension, condition, and time visited data as a Geographic Information System (GIS) shapefile table.

This suite of ArcPad files was uploaded into the AML program's Trimble Recon for field use. Target locations were then sought by walking approximately 1.2 square miles of the Eska mine area throughout October 2005. Daily tracklogs were collected to show all areas visited. Particular effort was made to walk areas underlain by adits and tunnels, looking for shafts and subsidence features. Local residents provided valuable feature and historical information.

About 40 of the original 70 targets were found. A total of over 150 features were found, described in the ArcPad forms, photographed, and noted in a field notebook. On return to the office, all data was exported from ArcPad into ArcMap. Surveyed features were described in a field report, using GIS table attribute data, photographs, and field notes.

Of these, 13 proved hazardous enough to qualify for AML remediation. They included seven partially filled airshafts with vertical drops of 6-12 feet, a 10-foot deep recently active sinkhole, a water-filled shaft, an open borehole, a framed underground opening, and two adits in the Eska Creek canyon bottom being kept open by use as active bear dens. Section corners GPS located in the field were used to adjust georeferenced mine map registration, creating better alignment between mapped underground workings and found features, notably vertical openings.

Eska Remediation Planning Work

In ArcMap, land ownership percentages for entry into the Abandoned Mine Land Information System (AMLIS) were calculated using MatSu Borough parcel ownership data. All parcels lying within the PAD boundary were segregated out, then parsed to calculate government, tribe, and private ownership areas and percentages. Access conditions and distances to remediation sites were used to calculate engineer's estimates and secure rights of entry.

Seismic Refraction Bedrock Depth Surveys

OSM closure experts stress that where vertical openings in bedrock or lined shafts are overlain by unconsolidated overburden, designers need to know depths to shaft collars that act as

control surfaces in case of catastrophic downhole collapse. Safe surface setback distances are determined based on angle of repose of overlying materials. This point is graphically illustrated by accounts of large-scale overburden failures pouring into vertical openings, such as the 1982 Pinebrook shaft collapse involving loss of life in Scranton, PA.

Our program planned remediation to close 8 vertical openings in the Eska mining area in 2007. Most of these manifested as surface depressions 6-13 feet deep, some with soft bottom zones. As bedrock was known to be shallow beneath some features and suspected to be similarly situated below others, we decided against a separate drilling program to determine bedrock opening depths and dimensions. Closure design combined exploration and remediation, excavating to daylight any subsurface openings, stopper them with boulders, then backfill with large to small dimension graded aggregate.

For safety reasons and to determine how far we needed to dig to size equipment, I wanted to confirm bedrock depths around features that had raveled or showed signs of recent activity. In October 2006, six seismic refraction lines were surveyed at three closure sites--one 6 foot deep surface pit next to an ATV trail (christened the ATV pit), a pair of adjacent pits 6 and 9 feet deep, and a 10-ft. deep recently active sinkhole.

Two spreads were surveyed at each site, crossing at nearly perpendicular angles close to target openings. Geophone spacing varied from 4-10 feet based on line length. Shot impulse energy was generated by a 4-pound sledgehammer striking an aluminum plate. A reed switch attached to the sledge handle provided 0 time initiation to the seismograph. A 12-channel Geometrics ES-1225 was used to gather first-arrival data, and shots were stacked to optimize returns on each channel. Geophone traces and acquisition parameters were output to aluminized paper strips on the seismograph's electrostatic printer. First-arrival times were noted on printer tapes in the field with the aid of the seismograph display.

Shots were fired on the line ends, off the ends, and spaced within line interiors to assure overlap of first arrivals from each refracting layer in both directions. This facilitates delay-time depth computation for each layer interface beneath each geophone.

Geophone and shotpoint locations for all lines were GPS located as Terrasync point features, post-processed, and exported to a CAD drawing and GIS map. Geophone and shotpoint elevations were level surveyed. Elevations were calculated in Excel, benchmarked off GPS

elevations for one of the phones at each survey site. Point surface elevations were used to construct local site topographic contours in SurvCAD.

Back in the office, arrival times on printer tapes and geophone distances were put into Excel spreadsheets. Time-distance graphs were plotted, refractors picked, apparent velocities determined, and ballpark depths calculated using simple critical time and critical distance formulas.

Next, the SIPT (Seismic Interpretation Program Two, Scott et al., 1972) program was used to calculate interface depths beneath each shotpoint and geophone. This routine uses the delay-time method to obtain a first approximation of layer depths. Iterative ray tracing is then used to refine the model, by comparing field-measured travel times against computed ray travel times for the model. Iterative adjustments are made to minimize discrepancies between measured and computed times (Scott et al., 1972).

First-arrival data was input, time-distance graphs displayed, refractor arrivals picked, and analyses run until solutions converged.

Depth data were used to determine structural bedrock elevations. Interface depths beneath shotpoints and geophones were subtracted from their topographic elevations to generate structural elevation points on the bedrock surface. This data was used to construct bedrock structural contours and TIN surfaces in SurvCAD.

Seismic Interpretation Results

ATV Pit

An east-west line surveyed next to the ATV pit across the slope with a 9-ft geophone spacing produced a time-distance graph suggesting three layers. The top layer was thin, 1.5-3.5 ft thick with an average velocity of 1227 feet per second (fps). The middle layer had variously modeled velocities from 1520-1930 fps, with the bottom interface ranging 9-18 feet deep. The bottom layer had modeled velocities from 5300-5650 feet per second, typical of the friable to moderately indurated coaly shales and sandstones of the coal-bearing Chickaloon Formation. Most solutions calculated bedrock depths of 13-14 feet near the pit.

A north-south spread with an 8-foot phone spacing produced a time-distance graph suggesting two layers. The top layer had weighted average velocities of 1294-1298 fps, the 2nd

layer 4208 fps. Laid up and down the hill slope, modeled bedrock depths increased from 9 feet at the uphill end to 19.7 feet deep at the downhill end, and ranged 14.7-16.5 deep feet near the pit.

Differences in modeled bedrock depths between the two lines near the pit are probably due to different line layout locations. The E-W line was located on the uphill side of the pit, where the N-S line modeled shallower bedrock. Also, higher overburden velocities in the E-W line may have produced thinner layer solutions. In May 2007, a second pit suddenly opened about 20 feet west and a few feet downhill of the ATV pit, alongside the north-south seismic line location. Trees laid on bedrock as part of an earlier closure effort measured 15 feet below the surface, in general agreement with nearby seismic-modeled bedrock depths of 13.5-16.7 feet.

Two Pits

A north-south line with a 6-foot geophone spacing laid up and down a mild slope next to the pits produced a time-distance graph modeled with two layers. The top layer had weighted average velocities of 1135-1153 fps, the 2nd layer 4514-4594 fps. Bedrock depth along the line was fairly uniform, modeling from 9.3 feet deep at the uphill end to 10.5 feet deep at the downhill end. Bedrock was calculated to be 9.2-10.4 feet deep near the pits.

An east-west spread laid transverse to the slope with a 4-foot phone spacing also produced a time-distance graph suggesting two layers. The top layer had weighted average velocities of 1136-1206 fps. The 2nd layer produced modeled velocities of 5514-6238 fps. Bedrock depth models were fairly uniform, ranging 9.5 to12.8 feet deep across the spread, and 10.5-12.6 feet near the pits.

Estimated bedrock depths of 10-11 feet beneath the pits were reported by the contractor during excavation.

Active Sinkhole

An east-west spread was surveyed over flat ground alongside the sinkhole with a 10-foot phone spacing. Data plots produced a time-distance graph suggesting two layers. The top layer had weighted average velocities of 1117 fps, the 2nd layer produced modeled velocities of 6959 fps. Bedrock depth models were fairly uniform, ranging 17.4-22 feet deep across the line, and 20.2-21.3 feet deep near the pits.

A north-south line with an 8-foot phone spacing was surveyed, with data plots suggesting three layers. The top layer had weighted average velocities of 1120 fps. The 2nd layer produced modeled velocities of 1998 fps, and ranged 6.9-9.3 ft thick. The 3rd, bedrock layer produced modeled velocities of 4925 fps. Bedrock varied from 13.2- 27.3 deep along the line, and modeled 21.9-22.8 feet deep near the sinkhole. A few 2-layer models of this line produced the similar bedrock depth solutions of 20.8-23.1 feet.

In the course of remediation, top-of-bedrock depth was measured 20-21 feet below land surface. The sinkhole was underlain by an adit about 5 feet wide that bottomed in hard rock 26 feet deep. While cleaning the adit, the excavator disinterred several bucketloads of short butt-cut timbers and a crude 9 foot long ladder that may have exited via an airshaft no longer evident.

Applications

SIPT-modeled bedrock depths were used to anticipate digging depths to aid closure designs and engineer's estimates, and suggest safe working surface setback distances to contractors.

Road Alignment Recovery

Two sites remediated in Eska Phase II closures lay in a more remote area, accessible by mining roads been mapped by 1993 aerial photography. Some road segments were little used, overgrown, and difficult to find and follow during a September 2007 pre-bid visit. Once contract work was underway in October, the contractor requested our help to find and trace primitive road alignments so he could develop access.

To this end, 1993 road annotation lines were exported from CAD as a shapefile, imported into Pathfinder Office as an *.imp file, then uploaded into the CE/XT. In the field, the import file was displayed as a background file, which we followed and marked, and the contractor then developed for heavy equipment access.

Land Ownership Clarification

Several landowners granted our program access across their property for Eska Phase II construction. As part of our agreement, one private owner requested we block a nearby primitive

road to discourage ATV and snowmachine trespass across his land. GIS raster and parcel data showed the road lay on State land close to his property, so we agreed to his terms. However, as the contractor was installing berm and ditch barriers along the road, said landowner showed up protesting, claiming he had wanted it left open and we weren't honoring our agreement. After discussing our agreement, I decided to document the barrier locations.

GPS traces exported to GIS confirmed the road and all barriers were installed on State land, coming within 35 meters of the private parcel. Because of its proximity, I loaded the parcel boundary into the CE/XT, went to the field and flagged the boundary to demonstrate his property was not involved.

Conclusion

From 1996 to the present, OSM TIPS-provided geospatial software packages including EarthVision, AutoCAD, SurvCAD, Terrasync, ArcPad, and numerous Trimble and tablet PC hardware platforms have played a leading role in inventory, design, construction monitoring, and as-built documentation of Alaska's AML projects. Since 1996 in the Knob Creek, Jonesville, and Eska mining districts, this technology was instrumental in effecting efficient reclamation of 11,200 feet of highwall, resloping and revegetating 215 acres of spoils, extinguishing 42 acres of combusting coal spoils, eliminating 4 dangerous impoundments, and closing seven vertical openings and one subsidence feature, at a cost of $14.5 million.

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