ACHIEVING OPTIMUM POST MINE RECLAMATION RESULTS THROUGH COMPUTER AIDED DESIGN[1]

by

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Abstract. Recent technological advances have made it possible to map and model disturbed mine areas to plan the most cost effective manner in which to reclaim post mine land. The process not only can reduce the cost to reclaim each acre, but also enhances regulatory compliance. Results from a 21 acre test at Texas Utilities Mining Company's Martin Lake-Oak Hill Mine have shown a significant reduction in dozer hours per acre to complete reclamation. A larger, more conclusive project has been completed at TUMCO's Monticello-Winfield North Mine. The new project includes approximately 350 acres of the C-Area final pit. Results of this project have resulted in substantial cost savings versus conventional reclamation planning methods.

KEY WORDS: Reclamation Planning, Computer Aided Drafting, Texas Utilities Mining Company, Global Positioning Satellite, Computer Modeling

Introduction

Reclamation costs constitute a significant portion of the overall cost in producing a ton of coal using surface mining methods. Reclamation activities can add 10 to 20 percent to the cost per ton of coal. It ranks just behind operating and maintenance expenses in terms of major cost components. From the beginning of mining activities in 1971 to the present, a commitment has been made by Texas Utilities Mining Company (TUMCO) to return disturbed land affected by its surface mining operations to a condition equal to or better than pre-mine. TUMCO demonstrated this commitment before the inception of the Federal "Surface Mining Control and Reclamation Act of 1977" and in Texas, the "Texas Surface Coal Mining and Reclamation Act" in 1979. These regulations call for returning post mine land to approximate original contour (AOC) and establishes minimum vegetative standards for determination of reclamation success. The focus for many mining companies has been in soil or vegetative studies and significant advancements in this area have been made. Equipment, technological advances, and improved reclamation techniques have made it possible to reclaim land more productively. However, similar improvements in reclamation planning are just now becoming available. Recent advances in computer technology have made it possible to map and model large areas of disturbed mine land to plan cost-effective reclamation. A plan using this new computer technology can reduce rehandle, predict the development of drainage structures and ponds, and enhance regulatory compliance, thus resulting in lower reclamation costs.

Regulatory

The planning process starts with an understanding of applicable regulations. Regulatory agencies such as the Office of Surface Mining (OSM), Mine Safety and Health Administration (MSHA), Corps of Engineers (COE), Environmental Protection Agency (EPA), and others are involved from the Federal level. In Texas, the Railroad Commission of Texas (RCT) has jurisdiction; however, other agencies such as the Texas Natural Resource Conservation Commission (TNRCC), and Texas Historical Commission (THC) have significant roles in the approval of surface mining permits. The regulations and guidelines of each agency must be incorporated into the planning effort.

Each surface mine has an approved mining permit through an appropriate agency. In Texas, which was the first state to be federally approved to regulate the state mining industry, the Railroad Commission of Texas is the primary regulatory agency. All permitting actions require RCT approval. Before any mining related disturbance can begin, the RCT must approve the mine plan, the surface water control plan, the conceptual nature of the post mine contour and slope, the post mine land uses, and a post mine vegetation plan. Any structures incorporated into reclamation, such as ponds, wetlands,

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roads, drainage ways, or drop structures must be designed and approved by the RCT before construction.

Reclamation Planning

Reclamation planning focuses all the elements of successful reclamation into a workable, cost-effective plan before actual implementation. It takes a thorough knowledge of engineering design, regulatory permitting, environmental issues, and surface mining operations to be most effective. The process starts with a mining permit that adequately addresses the intentions of the operator, but also allows the operator the flexibility to react efficiently to the dynamic environment of a mining operation. Recent developments at the state level in Texas, concerning flexible time and distance to achieve approximate original contour, offer greater opportunities to use reclamation planning techniques. The larger the planned area, the more effective planning can be.

Technological developments have made it possible to map and model large areas of unleveled mine disturbance. To be effective and to be compliant with approved backfilling and grading requirements, planning efforts must be able to react quickly with the dynamic nature of surface strip mining. The operator cannot afford to allow weeks or months to pass without a leveling plan. In the past, without the data collection and computer processing tools that are now available, this was an impossible task. With the advent of more sophisticated personal computers, Global Positioning Satellite (GPS) survey, and advanced modeling software, the turn around time can be relatively quick. This model, if successfully implemented in the field, can also be used to design other structures, such as ponds, drainage ways, or drop structures, as they develop.

It should be noted that the reclamation planning techniques described in this paper are not applicable in all circumstances. The primary areas where technological advances in reclamation planning are most applicable include: box pits, pit closures, disturbed areas within Temporary Cessation of Operations, areas with longer backfilling and grading time frames or areas with special drainage problems. These areas typically apply in 10 to 15 percent of the disturbed mine area. Traditional reclamation planning practices are used by TUMCO in most reclamation activities.

Planning Tools

The modeling process starts with an accurate survey of the proposed disturbance area. For larger areas (over approximately 50 acres in size) the best tool is aerial photography. Low level flights can accurately provide digital data at one foot contour intervals. From experience, an accuracy between two to five feet is sufficient. GPS surveys can provide sufficient data for smaller areas less than 50 acres. GPS is extremely accurate in disturbed mine areas because of the lack of a tree canopy, but it can be dangerous and a possible safety concern if traversing by foot in areas of steep sloping spoil with questionable stability. Either method can provide quick results in a format that can be easily down loaded into a computer.

The raw data can then be processed using conventional grid modeling techniques. Texas Utilities Mining Company (TUMCO) uses Eagle Point software as its modeling tool; however, many other software packages are available on the market. Eagle Point (Eagle Point 1995) is a comprehensive engineering design software package that includes survey data collection, coordinate geometry, surface modeling, site design, hydraulic modeling, and other engineering related modules. The survey and surface modeling/site design modules are the most applicable for reclamation planning. TUMCO uses Eagle Point within Microstation (Microstation 1995), a Computer Aided Drafting (CAD) software package. The development of GPS, personal computers with the memory and speed to process large quantities of data, and graphical software able to process the data into meaningful 3D models have made it possible to plan reclamation in areas that only a few years ago would have been time and cost prohibitive.

21 Acre Test Project

TUMCO initially started development of this new planning process on a small test area to determine the cost effectiveness of the program. The test area was located at TUMCO's Martin Lake Oak Hill Mine, located in Rusk County, Texas. The Oak Hill Mine is a two dragline, 6.5 million ton per year lignite mine. The Oak Hill Mine is part of the Martin Lake Mine that supplies fuel to the Martin Lake Steam Electric Station in Panola County. The mine uses conventional side cast stripping techniques to uncover a single lignite seam. Overburden ranges from 30 to 130 feet in depth.

The test area was approximately 21 acres in size (Figure 1). The area was bounded by the open pit to the north, a public road buffer zone to the east, a topsoil/access road to the south, and a haul road to the west. Disturbed post mine topography was obtained by GPS survey. The raw data was then processed to create a 3D model of the terrain. While the survey data was being collected, a review of all permit requirements was conducted. This review concluded that to maintain a surface water control plan, as provided in the approved

MARTIN LAKE

OAK HILL

DI- AREA ORIGINAL TOPO
21 ACRE STUDY AREA

TEXAS UTILITIES MINING COMPANY

DR. BY JCN	APPROVAL MJJ	DATE 1/97	SCALE: 1"=200'	FIGURE 1

permit, the drainage from this area needed to be directed to the west. In the field, it was not readily recognized which direction, west or south, was the most cost-effective direction in which to route drainage. After the permit review and an analysis of the dirt volumes to be moved, the most appropriate direction to establish drainage was determined. Simply recognizing this fact eliminated a compliance concern regarding the need to re-analyze the southern downstream surface water control structure and possibly saved spending additional money on enlarging this sedimentation pond.

Using Eagle Point software, a base line cross-section through the grid area was created. Cross sections on approximate 100 foot intervals perpendicular to the base line were also established. Each cross section was then evaluated for optimum slope and minimum cut and fill. Using operational insight and a knowledge of available mine equipment, a cut and fill plan view map was prepared. This information was reviewed with site personnel and minor adjustments were made. A finalized reclamation plan was then agreed upon and implemented in the field (Figure 2). The results of the reclamation plan allowed operations to optimize the productivity of the equipment used in the reclamation effort. Comparing the planned reclamation area versus historical equipment hours per acre showed that the planned area required approximately 40 percent fewer equipment hours.

350 Acre Reclamation Plan

The positive results of the test area at the Oak Hill Mine led to a larger, more involved reclamation planning project at TUMCO's Monticello-Winfield North Mine in Titus County, Texas. The Winfield North Mine is part of the Monticello Mine that supplies fuel to the Monticello Steam Electric Station, also in Titus County. Winfield North produces approximately 4 million tons of lignite per year utilizing two Bucyrus Erie 1350 draglines. The stripping operation uses simple side cast methods in combination with some extended bench in higher ratio areas. The overburden depth ranges from 30 to 135 feet.

The reclamation project at Winfield North consisted of approximately 350 acres in the C-Area of the mine (Figure 3). Mining in the area was completed in July 1995, leaving a final pit and up to four remaining spoil peaks. The project area also included two spoil side ramps one located approximately in the middle of the pit and one on the east end. The final pit, running almost due east and west, was approximately 4,500 feet long. The width of the pit at the lignite seam was 120 feet. Overburden ranged from 70 to 135 feet in depth. The advancement of the pit was from north to south and was stopped due to the proximity of a railroad and an increasing stripping ratio. Auger mining was used to recover additional reserves along the south face of the final pit. As required by the regulations, each auger hole was plugged before final reclamation.

To provide adequate time to complete the reclamation in this area, a backfilling and grading extension of time was requested and subsequently approved by the RCT until September 1997. This allowed for additional time to design the project and complete the final grading over two warm weather construction seasons.

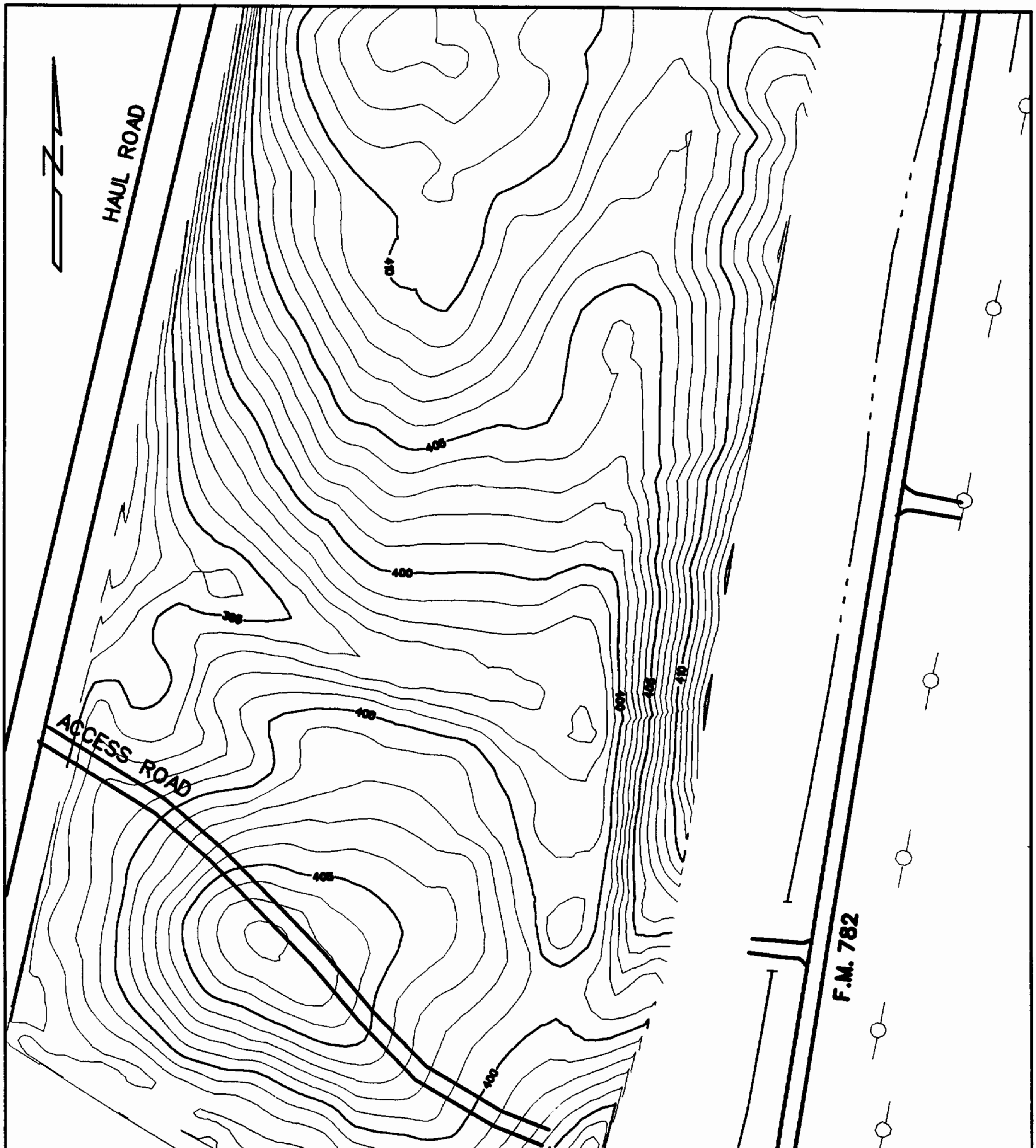
The pre mine topography of the study area was characterized by gently rolling terrain. The area was approximately 20 percent wooded, but consisted mostly of pasture land that is typical of northeast Texas. A perennial stream, Dragoo Creek, flowed from northwest to southeast across the area. Due to mining, a diversion was constructed north and east of the open pit to divert disturbed runoff into a sediment control pond. A second diversion, routed runoff coming from the south, along the north side of the railroad and away from the mining operation.

Assumptions

From the outset, it was clear that the primary planning focus of this area was to be centered around the reclamation of the final pit. The equipment fleet available for this project consisted of three Caterpillar D10 dozers (two dozers with wide reclamation blades), three Caterpillar D9 dozers, two Caterpillar 637 scrapers, a Hitachi EX1800 backhoe and two Caterpillar 777 End Dumps. The plan was envisioned so that only dozers would be required to complete the final reclamation. All cuts and fills called for by the plan would be designed to limit maximum haul distances to 300 feet to enhance dozer productivity. In order to minimize costs, scrapers and end dumps would be used to handle any long haul yardage in any unforeseen situations, such as the filling of minor low areas, which may hold water.

Data Collection

Data collection on an area 350 acres in size is best accomplished with aerial photography. The C-Area reclamation project was flown and digital topography was provided on an one foot contour interval. At this contour interval it was quickly realized that there was more information than what was actually required. A more practical contour interval would be in the two to five foot range, depending on the size of the reclamation project. During the data collection period, research was conducted to identify any permitting or regulatory considerations.



MARTIN LAKE

OAK HILL

DI- AREA FINAL TOPO
21 ACRE STUDY AREA

TEXAS UTILITIES MINING COMPANY

DR. BY JCN	APPROVAL MJJ	DATE 1/97	SCALE: 1"=200'	FIGURE 2

MONTICELLO MINE WINFIELD NORTH							
WINFIELD NORTH ORIGINAL TOPO 350 ACRE STUDY AREA							
TEXAS UTILITIES MINING COMPANY							
DR. BY RI	APPROVAL	MJJ	DATE 1/97	SCALE: NTS		FIGURE 3	

This review did not identify any significant reclamation considerations. The post mine land use was anticipated to be similar to the pre-mine condition. The land was proposed to be restored as pasture with a mix of wooded and natural habitats.

Once the data was collected and a thorough review of the permit and regulatory obligations was completed, the planning process could begin. The process required a broad understanding of permitting, operational, engineering, and environmental disciplines. As an example, to approximate original contour, the slope of the post mine condition is an important factor. It requires an understanding of what slope percentages are allowable (permitting), what type of equipment can efficiently operate or create the desired slope (operational), what slopes are acceptable from a slope failure or erosion perspective (engineering), and what plant species can grow and maintain suitable ground cover on a given slope (environmental).

Computer Modeling

The digital topography information was down loaded into a personal computer. The data was processed and contoured using Eagle Point within Microstation. Eagle Point models survey data using Triangulated Irregular Networks or TINs. From the tinned data, a 3D contour model of the actual field conditions of the reclamation area was created (Figure 3).

Plan/profile views of the 3D model are easily generated by the Eagle Point software. From these views, water courses and ponds were conceptually identified. Strategic elevations at known points around the disturbed area were set and served to define the perimeter of the reclamation plan. From these elevations, preliminary nonerosive drainage grades were established. This in turn established pond water surface elevations within the disturbance area. Approximate pond configurations could then be identified. A conceptual plan for positive drainage was then complete. This in turn was double checked with the approved permit. Features not in agreement with the permit were recognized as potential permit revisions. In this case, a permit renewal application was already being prepared; therefore, the conceptual plan was incorporated into the renewal application. Planning for and recognizing these changes saved the operator potentially significant future compliance concerns.

Once a broad conceptual strategy was outlined, detailed computer modeling was applied. In the 350-acre planning area, a base line cross section was established from the digital topography along the length of the final pit. Cross sections were then computer generated every 100 feet perpendicular to the base line progressing from west to east. This progression was chosen because the elevations naturally decreased in this direction and operational axioms dictate that this is a more efficient use of earthmoving equipment. Additionally, the western boundary of the planning area was established by drainage features with elevations that could not be altered.

Each cross section was analyzed starting from fixed elevations along the perimeter. Using the CAD capabilities of Microstation, lines representing maximum, minimum, or optimum slopes were overlaid on each section. When the optimum slope lines appeared graphically correct, area measurements between the original ground (OG) profile and the design profile were calculated. Using area measurement calculation tools within Microstation, the cuts and fills were balanced by adjusting the slope projection lines (Figure 5). This process was repeated for each section. In pond locations, slopes were projected approximately 10 feet below the design water surface elevation and then allowed to steepen to the natural angle of repose. A minimum of 4 feet of suitable material was placed over any potential acid forming (AFM) and toxic forming materials (TFM). After each section was completed, the design surface was processed and contoured to create a new 3D model of the proposed reclamation (Figure 4). This information was reviewed with site operations and minor changes were completed.

The Reclamation Plan

The reclamation plan called for the reestablishment of the Dragoo Creek channel. The channel would be routed through several ponds to enhance the hydraulic features of the reclamation area. Three new ponds would be constructed within the 350 acres. Pond CR-44 would be constructed in an area that was formerly a haul road ramp in the center of the pit. Another pond, CR-37, would be constructed in the location of the haul road ramp on the east end of the pit. A third and substantially larger pond, CR-38, would be constructed in the final pit. Dragoo Creek would be routed through all three proposed reclamation ponds to C-20 Sedimentation Pond, which is the final discharge pond for this disturbed watershed area. Routing Dragoo Creek through all three ponds serves to improve the hydraulic characteristics of the creek channel. Drainage from Dragoo Creek would insure an adequate source of water to maintain the design water surface of each pond and each pond would serve to flatten the overall gradient of the creek channel and provide detention during extreme precipitation events. Drainage from the south would be directed through CR-38 and CR-37 ponds to C-20 Pond. All three ponds, as well as C-20 Pond, would be proposed

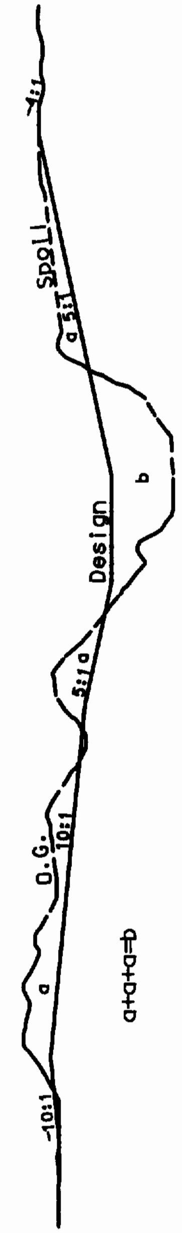
MONTICELLO MINE

WINFIELD NORTH

WINFIELD NORTH FINAL TOPO
350 ACRE STUDY AREA

TEXAS UTILITIES MINING COMPANY

DR. BY RI	APPROVAL MJJ	DATE 1/97	SCALE: NTS	FIGURE 4



MONTICELLO MINE

WINFIELD NORTH

WINFIELD NORTH TYPICAL CROSS SECTION
350 ACRE STUDY AREA

TEXAS UTILITIES MINING COMPANY

DR. BY	APPROVAL	DATE	SCALE:	
RI	MJJ	1/97	NTS	FIGURE 5

as permanent impoundments. The Dragoo Creek channel was designed as a wide flat trapezoidal channel with a minimum bottom width of 50 feet and side slopes not to exceed 5h:1v. The gradient of the channel was designed to maintain non-erosive velocities less than 6 feet per second. Velocities greater than 6 feet per second are considered erosive for Bermuda grass lined channels. Due to a significant enlargement of the watershed to the final discharge pond, C-20, a re-analysis of this structure would be required. To accomplish this, C-20 Sedimentation Pond was analyzed in series with CR-37 Pond. A combination of both structures provided adequate detention time and sediment storage to satisfy applicable effluent limitations.

When nonerosive gradients could not be achieved, concrete trapezoidal drop structures were constructed. Energy dissipaters, such as end sills, chute blocks, and baffle piers, were installed to force the hydraulic jump to occur as close as possible to the drop. This allowed the downstream apron length to be designed with an apron length to exit depth ratio (L_t/d_2) of 3 (Peterka 1984), effectively reducing the length of the concrete apron by half.

Overall maximum 5h:1v slopes were maintained throughout the project area. The only exception was the south slope of CR-38 Pond. Due to the location of the final pit near an existing railroad line, room to flatten the approach slopes to CR-38 was limited. A 100 foot buffer zone was maintained from the railroad right-of-way. From this point slopes were projected to the pond. Slightly steeper slopes averaging 4h:1v were established along this face. The south slope of CR-38 Pond, due to its long narrow shape and limited access, is proposed to be planted in trees. Trees will provide a natural habitat feature for indigenous wildlife species.

Leveling

The reclamation plan for the 350-acre plan area was proposed with post mine land uses in the following categories; pasture (73%), developed water resources (11%), forest (10%), and wildlife habitat (6%), which compared favorably with the pre mine land use with additional water resources. Wetland features will develop throughout the major drainage ways.

When the plan was completed, the data from the new design surface was downloaded into a GPS unit. Using Trimble software, the loaded data was then taken back out to the field and actual cut and fill stakes were set representing the new design surface. The equipment operators, working with a plan laid out on the ground, could then complete the leveling process.

A staked reclamation design in the field gives the equipment operator a plan in which to follow. It eliminates the guess work and keeps all the equipment operators working toward the same goal. By knowing exact cuts and fills, rehandle can virtually be eliminated. Reduction of rehandle is a direct savings to the mine operator. Slopes can be established which are non-erosive. The ultimate goal being to reduce yardage while achieving AOC and to produce a post mine topography that is both productive and aesthetic.

From a comparison of the digital models, cut and fill yardage volumes can be calculated. The total yardage can then be used to plan for the appropriate equipment fleet and the time necessary to complete the project. In the 350 acre planned project, the available equipment was already known, so therefore the reclamation plan was designed to accommodate the equipment fleet. Either way, a cost estimate for the entire project can then be calculated by knowing the unit cost per piece of equipment and applying it toward the time proposed for completion.

Results

As of the date of completing this paper, approximately 80 percent of the project area has been completed. The equipment dedicated to this reclamation area was rescheduled and assigned to another area. At this time, the equipment required to complete the project is not scheduled to return until June 1997, with final completion planned before the expiration of the backfilling and grading time period in September 1997.

The currently completed reclaimed area compares favorably with the proposed plan. Minor deviations occurred, as expected, without a significant alteration to the overall conceptual proposal. No unforeseen problems were reported. The preliminary results indicate a 33 percent reduction in the cost per acre when comparing 1996 average reclamation costs versus the planned 350 acre reclamation project.

Conclusion

Based on the preliminary results of the 350 acre reclamation project, reclamation planning is proving to be an effective tool in reducing leveling costs in disturbed mined lands. Water courses and pond/wetland features can accurately be predicted. Knowing that these features are developing within the spoil can reduce earth moving. Steeper slopes at safe elevations can be left below pond water surfaces. Spillway locations can be pre-determined so that drainage ways can be constructed at a non-erosive grade. Drop structures can be planned at strategic locations to reduce earth moving and reduce erosive conditions.

Reclamation planning also enhances regulatory compliance by achieving approximate original contour and maintaining acceptable slope gradients. Environmental issues such as erosion control and repair are reduced by reclamation planning methods through grade optimization. Sedimentation control structures can expect lessened sediment loads. This reduces costly pond clean outs and reduces future pond construction. Post mine land designated for uses that can sustain greater slopes can be planned for in advance. Greater slopes generally require less grading, thus reducing costs. Plant species best suited for varying terrain features can be planted with greater expectations of survival.

From the reclamation plans generated to date, several key points have been identified. Reclamation planning works best in large reclamation areas. Economies of scale apply to the collection of data, the areas within longer backfilling and grading time periods, processing time, and the final result. It is more cost effective and timely to aerially photograph large acreages. The alternative is to spend many man-hours traversing raw spoil peaks. Computers can now process large quantities of data in relatively short periods. Planning techniques work best in areas that take longer to develop such as box pits, pit closures, disturbed areas within a Temporary Cessation of Operations (TCO), or any area with special drainage concerns.

As with maintenance and operational planning, reclamation planning, used in the right applications, can significantly contribute to lowering the cost per ton at surface mine facilities. Reduced costs realized from reclamation planning can enable the mine operator to remain competitive with alternative fuel sources while preserving the environment.

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