Coal Outcrop and Overburden Mapping with Kelsh Plotter

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The techniques developed for mapping coal seams and overburden using the Kelsh plotter are described. Applicable to terrain to be studied for highway relocation, the method is economical, utilizing the same photogrammetric materials used to produce the topographic map for the relocation study.

The coal seams were deposited under swampy conditions, the base describing an approximate plane which has been subjected to diastrophic forces. Determination of the dip and strike within the mapping limits is done by using existing geological information and photo interpretation of surficial coal manifestations.

Retrieval of the original coal base through leveling the Kelsh models results in a segmented mapping of the coals and overburden, each model leveled to the best information and connected to adjacent models in the flight strip.

•ACQUISITION OF rights-of-way for highway relocation can be an involved process. When mineral deposits occur in the landforms in the vicinity of the relocation, the determination of value, or damage, is even more difficult. Frequently the value of the mineral is many times the land value of adjacent tracts lacking the mineral deposit. Determination of the identity and areal extent of minerals and depiction in a measurable form was the objective of this project.

The original idea for mapping coal seams along proposed highway rights-of-way was formulated by Lloyd O. Herd of the Ohio Department of Highways.

Coal seams were deposited as vegetal matter in low swampy areas and the base of the coal originally occurred in an approximate plane. Subsequent diastrophic forces have both regionally and locally warped this depositional plane. In Ohio, the present dip of the rock strata is generally southeast, interrupted by gentle reversals and small anticlines. Resurrection of the original depositional coal base and leveling this plane in the Kelsh double projection plotter would permit mapping the coal's extent and the overburden.

The highway route selected for exploring and developing this technique was an 8-mi segment of proposed I-70 between the Guernsey County line and Morristown in Belmont County, Ohio. Topographic maps previously compiled at the scale of 1 in. = 200 ft by the Aerial Engineering Section, with the proposed centerline for I-70 superimposed, were available, as were the aerial photography, horizontal and vertical control, and the glass plate transparencies for Kelsh double projection instrument work.

The terrain is dissected sedimentary rock with valleys as low as 950 ft and hilltops frequently exceeding 1,300 ft. Exposed are upper Conemaugh and Monongahela, Pennsylvanian system, and lower Permian system rocks.

Before mapping the coal seams, information was gathered from the following sources:

1. Soil and rock reports by the Ohio Department of Highways Testing Laboratory which pertain to materials along the proposed centerline;

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2. Stratigraphic sections measured in the area and on file at the Geological Survey of Ohio;
3. Publications relating to geology of this area prepared by the Geological Survey of Ohio;
4. Coal outcrops delineated by the Geological Survey of Ohio on 1:62, 500-scale topographic maps of the 15-min quadrangle series for Pittsburgh No. 8 Coal and Meigs Creek No. 9 coal;
5. 1:24, 000-scale topographic maps in the 7½-min quadrangle series by the Geological Survey of Ohio;
6. Aerial photography by the U.S. Geological Survey; and
7. Aerial photography taken at the scale of 1 in. = 800 ft and 1 in. = 200 ft by the Ohio Department of Highways.

In the Ohio soil and rock reports, test cores containing coal were representatively plotted on a profile at the vertical scale of 1 in. = 10 ft and the horizontal scale of 1 in. = 200 ft. This profile constituted the basic framework for establishing the dip of the coal seams.

The first step in preparation for accomplishing the coal seam and overburden mapping was review of the available geological information to gain an overall concept of the highway route corridor. Primary objectives in making this review were to determine: (a) the major coal seams which outcrop within the limits of the corridor to be mapped; (b) intervals between coal seams; and (c) possible intermittent seams. The existence of the less persistent coal seams such as the Redstone 8a and the Fishpot was known. These seams are sometimes smut streaks or coal blossom and occasionally may thicken to a true coal which can be mined. Care was required to prevent correlating these coal seams with others of the stratigraphic column as this would have resulted in erroneous leveling in the mapping phase.

Stratigraphic sections were studied and their location was annotated on the topographic maps at a scale of 1 in. = 200 ft, which served as a base for the coal seam mapping. Coal seams reported in the highway segment selected for such mapping were plotted on the profile at the longitudinal position and elevation where they occurred. Occasionally, positioning of the stratigraphic sections was complicated by antiquated descriptions with references to terrain features which no longer exist. Aneroid barometer measurements were used on older sections making vertical positioning less than precise.

Coal outcrop maps for the Pittsburgh No. 8 and the Meigs Creek No. 9 coal mining areas were examined. Recorded on the map are spot elevations at which the coal beds occur. These were recorded on the profile at the position indicated.

The 1:24, 000-scale topographic maps of the 7½-min quadrangle series, dated 1961, were an excellent source of information. Where coal has been stripped, the pit forms a water-filled basin between the high wall and the spoil bank. The maps, produced by photogrammetric methods, show the pit water and by interpolating the contours on the high wall and the spoil bank, a coal seam base was ascertained within 10 ft of its true elevation. Where two pits were mapped on the same slope, the approximate interval between the coal seams was determined and the seams were tentatively identified. This method was used to advantage in the valley of Stillwater Creek where slopes exceed 300 ft in elevation.

Coal pit elevations interpolated from the 1:24, 000-scale topographic maps were tentatively plotted on the profile wherever they were located within the proposed right-of-way corridor for the highway.

Photographs obtained from the U.S. Geological Survey, which had been used photogrammetrically to compile topographic maps in the 7½-min quadrangle series of 1:24, 000-scale, were used in conjunction with such maps. Slopes were examined stereoscopically for mine entries at the approximate elevation of the stripping. Pits located up to 3 mi left and right of the centerline of the proposed highway location aided in determining the strike on an areal basis. The term dip as used here is the descent of the coal seam along the proposed centerline and the strike is the descent at right angle to the centerline.

Coal seams and the average interval between them in the stratigraphic column (Fig. 1) as determined from the study were Waynesburg No. 11 to Uniontown No. 10, 50 ft; Uniontown No. 10 to Meigs Creek No. 9, 112 ft; Meigs Creek No. 9 to Fishpot, 24 ft; Fishpot to Redstone No. 8a, 35 ft; Redstone No. 8a to Pittsburgh No. 8, 31 ft; and a total interval from No. 9 to No. 8 of 90 ft.

Attention was next directed to the profile. The Testing Laboratory core information formed the basic framework for establishing the dip of the coal seams as the seams were precisely positioned. Tentative information from stratigraphic sections and pit elevations were subject to vertical revision when measured with the Kelsh plotter.

A crude but entirely satisfactory method of correlating the coal seam information on the profile was used. The profile was on an 18-ft long piece of paper laid out on a long table. A string was stretched from the lowest coal seam reported in a core at the west end of the profile to the lowest coal from the same source at the east end of the profile. The string represented the dip of the Pittsburgh coal along the proposed centerline between the exterior points. A significant anomaly was apparent at the west

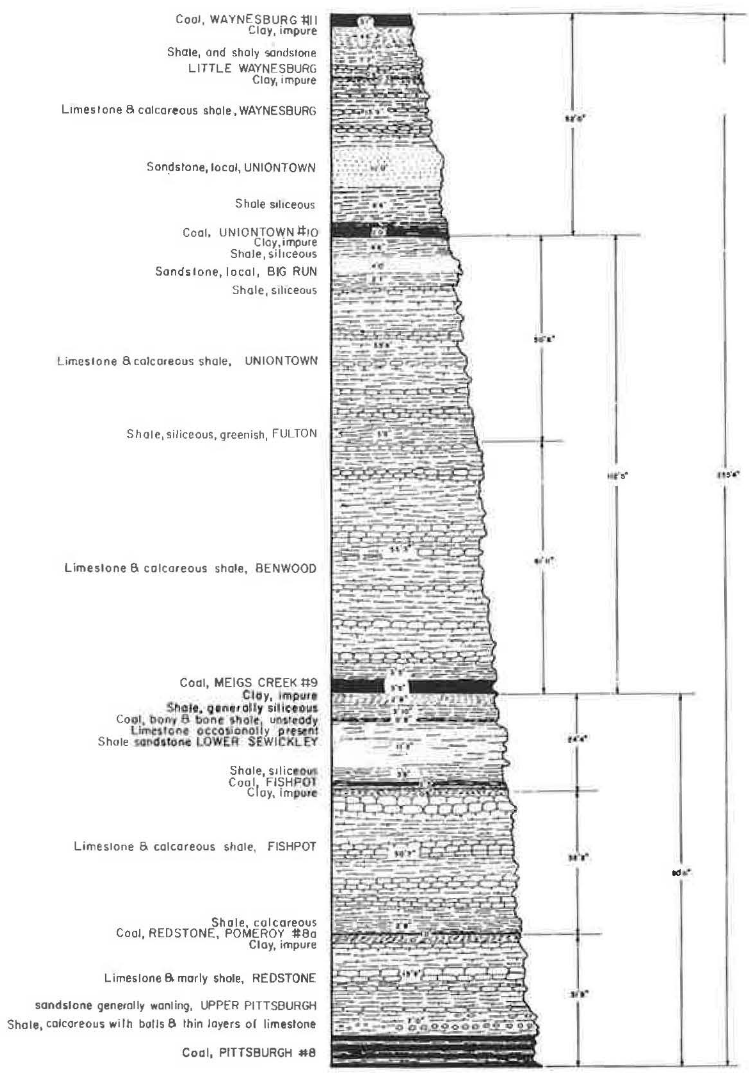

Figure 1. Stratigraphic column in Belmont County.

end of the profile. If the line representing the No. 8 coal was correct, the interval to the No. 9 was in excess of 120 ft. There was coal reported about 30 ft above the line and could have been the Redstone No. 8a. After adjusting the string to these coals, it was discovered that a small anticline existing at this point which rose about 30 ft, remained level for 4,000 ft, then resumed a normal dip. Along the remainder of the profile smaller anomalies were discerned. The string was adjusted to pass through the coal reported at the point where the anticline flank began to dip east. All evidence of coal seams which fell in the proximity of the string was labeled No. 8. The base of all these coal seams was connected to form the dip along the centerline, subject to change where Kelsh measurements were made on mine entries and pits, situated near the centerline.

The same procedure was repeated for the Meigs Creek coal seam. Knowledge of the general 90-ft interval was found reliable and correlation was simplified.

The Uniontown No. 10 and Waynesburg No. 11 coal seams were encountered in the eastern 1½ mi of this project near the proposed grade.

The Uniontown coal is erratic in thickness, content and vertical position. The line representing the Uniontown coal was an average taken from the four reported occurrences along the proposed centerline. A subsequent core recorded after map completion only served to substantiate the inconsistency of the Uniontown. On an areal basis, it is felt that the coal outcrop line mapped represented the best average within the mapping limits.

The Waynesburg No. 11 coal which outcrops in the hilltops at the east end of the area mapped was identified through the research, the core reports, and spot elevations from coal outcrop maps at a smaller scale.

PHOTO STUDY

On completion of this preliminary work, the aerial photography from which the Kelsh diapositives were produced was examined stereoscopically (Fig. 2). The manifestations of coal in the landforms were delineated and tentatively identified as to coal seam encountered. Evidence considered included strip mines, drift mine entries, tipples, and test pits.

The photo patterns of the strip mines with the unmistakable high wall, pit, and spoil make identification a simple task. Inherent in this simplicity are potential pitfalls. Not all strip mines are operated solely for coal recovery. Underlying most coal seams is a clay bed. In some operations, both the coal and the clay beneath are removed, resulting in a pit elevation well below the coal base.

At other locations, where only the clay is stripped, a visual comparison of the amount of spoil with that from coal stripping reveals a usable photo pattern. Clay stripping usually results in small quantities of spoil while the reverse is true for a coal operation.

Clay is also mined by drifting. Where this is done, there is no way of differentiating clay mine entries from coal mine entries with aerial photos. If kilns are seen during photo study, the existence of clay mining should be anticipated in the vicinity.

Tracing of old wagon roads and haul roads to their apparent termini made location of abandoned mines possible in some wooded areas. Easily located were those mine entries where piles of mine debris had been dumped on the slopes near the entry. They form an eroding anomaly on the slope which was generally bare of vegetation in contrast to the wooded area surrounding.

Test areas were bare soil areas where the soil had been removed along a slope seeking the coal seam.

MAPPING PROCEDURE

From the photo interpretation it was apparent that some stereoscopic models contained adequate coal base leveling control and others lacked it; consequently, bridging was required. The stereoscopic model with the best distribution of visual coal information was selected.

Figure 2. Stereo-pair showing surficial coal evidence; notations are 1, strip mines; 2, drift mines and debris; 3, test for coal; and 4, haul roads.

Using standard setup procedures for the Kelsh double projection instrument, the first model was scaled and leveled to the control used in producing the 1 in. = 200 ft topographic map.

The topographic map was aligned to the planimetric detail of the projected model and taped down. A semi-transparent Mylar sheet of the same length as the map was taped over it, permitting them to be moved as a unit when the model was releveled.

The proposed centerline, visible through the overlay, was plotted and stationed on the overlay. Subsequently, coal outcrop and overburden was mapped in relation to this proposed centerline.

At this time the model projected the terrain as leveled to the horizontal and vertical control used in making this segment of the topographic map. All visible pits, mine entries, and test pits were located in the model and plotted, and the elevations were recorded on the overlay.

The locations of cores containing coal, reported by the Ohio State Highway Testing Laboratory, were plotted on the overlay at the position indicated in the soil profile; for example, 80 ft right of Sta. 162+00. These locations were symbolized, and the "top of hole" and the "base of coal" elevations were recorded.

LEVELING TECHNIQUES—X DIRECTION

The next step was to level the model to conform to the Pittsburgh No. 8 coal using the information measured during the normal model projection and the dip indicated by the profile.

Leveling in the X direction (along the centerline) was accomplished in the following manner. Coal reported in the cores would not be visible for leveling, nor would coal base elevations gained from the profile. To permit the use of this underground information, several techniques were employed. For example, if at Sta. 107+00 the coal base was found at elevation 1102 and the terrain permitted, an identifiable object on a slope in the vicinity of that station at 1102 was plotted to represent one of the X direction leveling points.

Occasionally, a situation existed within a model where the terrain would not permit transfer of the coal elevations to hillside objects adjacent to the station. Sometimes this was due to a large landform occupying the area of the proposed centerline at one or both ends of the X direction. The leveling was done using the procedure shown in Figure 3. At Sta. 146+00 the ground elevation was 1020 and the coal base occurred at elevation 910. At Sta. 182+00 the ground elevation was 1,000 ft and the coal base occurred at elevation 895. The coal dipped 15 ft in the X direction. To level the coal

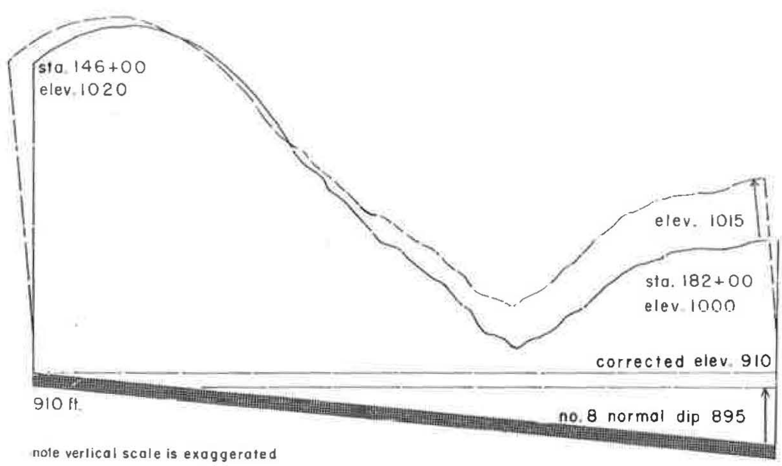

Figure 3. X direction leveling of No. 8 coal base; coal under cover.

base, the second point had to be raised 15 ft in the model. This was accomplished by indexing the floating mark at the ground elevation at Sta. 146+00 and raising the ground at Sta. 182+00 until it read 1015 on the counter. The coal base was then level in the X direction and was 110 ft below the index point at Sta. 146+00.

Variations of this technique were used where one or both X direction leveling positions were eroded below the coal base, but leveling in this direction was essential.

The model was next leveled in the Y direction using the visible coal manifestations previously listed (Fig. 4). After the usual small X and Y adjustments, the model was level to the best available coal information for that seam. The model projected a segment of terrain representing an area approximately 4,300 ft in the X direction and 7,200 ft in the Y direction.

The floating mark was indexed to the Pittsburgh No. 8 coal base and the tracing table was locked at this elevation. The No. 8 coal outcropped on all landforms where the floating mark encountered the slope. With the floating mark locked at this horizon, pass points (drop points) were located along the edges of the neat model (match lines). Small identifiable dots or a short line representing the coal base were plotted, to be used in the adjoining models. These were subject to adjustment when other models contained visual evidence indicating a change in the coal base elevation in the Y direction. Before mapping, these adjustments were prorated through the bridged models where visual Y direction information was lacking.

Actual mapping of the coal outcrop and overburden was performed if the model was considered leveled to sufficient control. With the floating mark locked at the coal base, the outcrop was plotted on the overlay and this pseudo-contour was labeled No. 8. The counter was then set so the floating mark encountered the landforms 10 ft above the coal outcrop line. This line represented the soil and oxidized coal within the landforms. Next a line 20 ft above the coal base was mapped, with this line representing 20 ft of coal, soil and rock overlying the coal base. In increments of 20 ft, these overburden lines were plotted to the top of the landform or to the next coal in the landform if one existed.

Mapping the Meigs Creek No. 9 coal base required releveling the model to the information available for this seam. Procedures followed were those cited for the No. 8 seam, but less visual information was found and the 90-ft interval was relied on extensively. Only slight modifications of the No. 8 setup were felt necessary due to the landforms being subjected to the same regional deformation.

The depositional variables which altered the interval between the No. 8 and No. 9 coals were virtually unknown except from the profile and direct measurements made with the Kelsh plotter on landforms containing evidence of both seams.

After all mapping was completed on the model, it was releveled to the vertical control used in topographic mapping, all pass points were measured, and their true elevations were recorded on the overlay. This completed the mapping for that model.

Succeeding models in the flight strip were worked when sufficient coal information occurred within the neat model. Where visible evidence of a coal seam elevation was

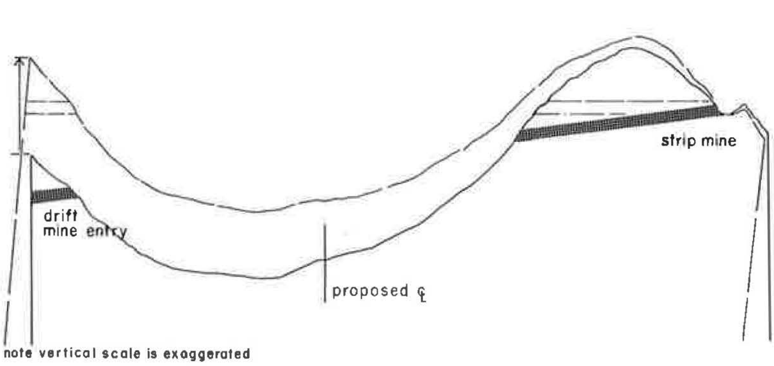

Figure 4. Y direction leveling of No. 8 coal base.

measured within the proximity of the centerline, a correction was made to the tentative dip originally established for the profile in that vicinity.

BRIDGING PROCEDURE—Y DIRECTION

Bridging across models lacking Y direction leveling information was accomplished as indicated in the following example. The figures used are not the true elevations for the No. 8 coal, and are used only for illustration. Visual coal measurements were plotted on the profile at their true position. For example: 2,300 ft left of Sta. 120+00, the No. 8 coal base was measured in a mine entry at elevation 1110. In another model, 2,100 ft left of Sta. 200+00, a pit measured 1078. The model lying between these stations lacked any indication of coal for leveling left of the centerline. A line was drawn on the profile connecting the coal measurements cited. The line intersected Sta. 160+00 at elevation 1094. A terrain point 2,200 ft left of Sta. 160+00 at elevation 1094 was located in the model and the model was leveled to this point (in the Y direction).

This example is a simplification of the procedure. Sometimes the bridging spanned two or more models. Landform conditions similar to those encountered in leveling in the X direction, namely, coal under deep cover or one end of the model occupied by a valley, also occurred in the Y direction. The methods described for leveling in the X direction were used in Y direction leveling where necessary.

The use of the procedures developed, where applicable, resulted in a model-by-model mapping operation. Each segment of the strip depicted the coal outcrops and overburden in relation to the proposed centerline as dictated by the evidence gathered from all the sources mentioned (Fig. 5).

At this time, construction is in the beginning stages. One cut in the vicinity of Sta. 53+00 uncovered weathered coal between the No. 9 outcrop line and the 10-ft overburden line.

An unexpected check on the dip of the No. 8 coal materialized when the Department of Highways Testing Laboratory secured a core 1½ mi east of the easternmost No. 8 coal used in producing the profile. The coal base dip was projected east along the profile to the core location without benefit of any adjustments. The projected No. 8 dip intersected the core 11 ft above the true base of the No. 8 coal. No other checks of

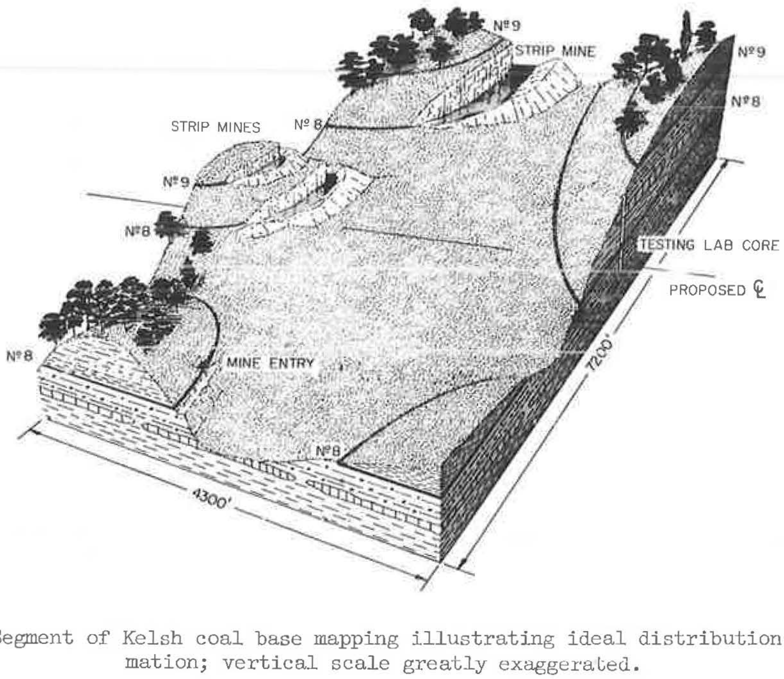

Figure 5. Segment of Kelsh coal base mapping illustrating ideal distribution of information; vertical scale greatly exaggerated.

outcrop accuracy have been made. During construction, when the coals are exposed in the cuts, the map will be systematically checked using photogrammetric methods.

NEW APPLICATIONS OF PROCEDURES

Original research frequently results in extensions of the original work. For example, after the dip of a coal seam is established, the stratigraphic sections reporting coal in the measured column can be positioned with the coal located at its true position. All other rock strata reported are properly placed vertically by this technique. Where two or more coal seams are reported, the technique serves to bracket the strata. With this information, predictions of rock types in proposed cuts is aided. The subsequent boring program can be planned with greater efficiency and economy by selective investigations based on the stratigraphic profile. Vertical delineation of stratigraphic rock types will also aid in slide prone slope analysis.

Consideration is being given to future coal outcrop mapping. On the preliminary survey maps at a scale of 1 in. = 200 ft, abandoned coal mine maps, as well as the location of the proposed centerline for the highway, will be superimposed. The coal mine maps are on file at the U. S. Bureau of Mines and are at various scales. All mine maps, however, can be brought photographically to the scale of 1 in. = 200 ft, and would then be of value where the highway grade line is at or near the elevation of a coal seam.

For highway design and construction plan preparation, topographic maps are compiled at a scale of 1 in. = 50 ft. Using the coal profile, the coal outcrop line can be delineated on these maps using the techniques to level the stereoscopic models in the X and Y directions employed for similar work at the 1 in. = 200 ft scale previously explained. Then within each property boundary and the right-of-way lines the amount of coal actually taken by the highway from mining possibility can be determined.

On completion of the coal seam and overburden mapping at the scale of 1 in. = 200 ft, an analysis was made of the advantages of this research and the results attained.

The coal seam mapping was found to be inexpensive. All necessary photography, mapping control, glass plate transparencies printed from the photography, and the base map were available. The supporting literature and core information regarding the coal seams and their overburden were procured very cheaply.

The topographic maps at the 1 in. = 200-ft scale covered a route band of topography approximately 1 mi wide and 8 mi long. Within the mapped area are leased tracts of land in which the strippable coal seams will be interrupted by the new highway, thereby affecting continuity of stripping operations. Large stripping machinery will be isolated on one or the other part of originally continuous tracts of land containing the coal seams. The possibility of litigation is anticipated.

Other products of this endeavor include: (a) coal seam and overburden outlined by contours on a 1 in. = 200-ft scale map of the highway route corridor approximately 1 mi wide and 8 mi long; (b) identity of coal seams affected; (c) extent of coal seams affected; (d) overburden measurements; (e) location of possible drift mine entries; and (f) location of strip mines.

The coal seam mapping techniques reported herein were developed by a geologist-photographic interpreter with extensive experience in operation of a Kelsh stereoscopic plotter. Although this combination is ideal, the same procedures can be used by people with one or more of these skills working with others who have complementing skills. To achieve the best coal outcrop line, numerous small decisions were made while the coal seam and overburden mapping was being done. Considerable time is saved if all skills required are possessed by the Kelsh instrument operator.

APPLICATIONS IN OTHER FIELDS

The techniques and procedures listed can be used in a regional coal study where long-range planning of availability is required to supply a facility.

Establishment of dip and strike on an areal basis will permit economical positioning of test borings. Leasing will be expedited.

Where coal mining has been conducted at proposed dam sites, procedures discussed can aid in locating mine entries, air shafts, and in geological investigation.

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