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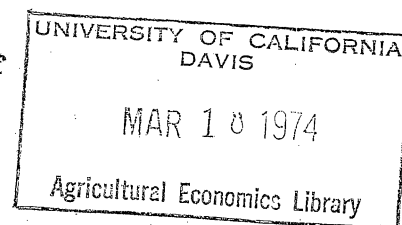
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An Economic Evaluation of the Application of
Sewage Sludge on Strip-Mined Land^{1/}

by

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The interface between agriculture and urban areas will continue to be an important generator of public issues. One of these issues concerns the use of the soil and the open space of agriculture as a receptor of municipal wastes. If a means of making beneficial use of the wastes in a politically acceptable manner can be found, it is clear that social welfare would be increased. This paper reports an analysis of a project that attempts to do this.

The Metropolitan Sanitary District of Greater Chicago (MSD) is charged with the treatment and disposal of the sewage waste of the city, its suburbs, and its industry. One of the products of this activity is over 900 dry tons of anaerobically digested sludge per day. In the past it was lagooned, dried, or incinerated, all of which are now impractical. As a result, the MSD searched for other means of disposal, including both carrying out experimental projects and supporting organized research efforts.

Fulton County, Illinois, located 170 miles southwest of Chicago, has had over 50 thousand acres of its land area disturbed by strip mining operations, and mining continues at the rate of about 2,000 acres per year. There is considerable public pressure within the county to put the disturbed acreage to some useful purpose, if possible to return it to row crop production as was the case prior to mining. The soils being stripped are generally of high quality. The over burden in the county is calcareous so that acid wastes are not a problem, and the establishment of a cover crop is not particularly difficult. Also, the material is free enough from large rocks to allow the operation of agricultural machinery if the slopes are sufficiently gentle.

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After some preliminary explorations by public officials in Fulton County concerning the alternative possible means of utilizing the sludge as a means of reclaiming the spoil land and some contact with the MSD, the MSD purchased a tract of approximately 7,000 acres. Additional land has been purchased subsequently. The general thrust of the project is that sludge will be applied on land that has been leveled and that row crops will be produced on the land.

Research by agronomists has indicated that pollution problems would not be a constraint in this type of operation. Heavy metals are not absorbed in the plants to levels that can be considered a problem. The constraint on the quantity of sludge applications is expected to be nitrogen which it contains in both organic and inorganic form. A system of capturing all surface water and monitoring ground water has been established to minimize the possibility of pollution episodes.

The Project and The Model

The disposal-reclamation project involves the shipment of sludge to Fulton County down the Illinois river by barge and piping it to one of three lagoons with a total storage capacity of over 8 million cubic yards. The possibility of constructing a pipeline from Chicago to Fulton County is being considered. The stripped land is leveled so that cropping operations are possible and surrounded with berms so that all runoff can be recycled in the event of water quality problems. The sludge is pumped out of the lagoons and sprayed on the prepared sites before planting and during the growing season, weather permitting. The crops grown will most likely be typical central Illinois row crops but the zero tillage practice will likely be used to reduce runoff and minimize the need to collect rocks.

The quantity of sludge applied over the life of the project will depend on the level of organic nitrogen in the soil initially; expected to be very low relative to normal soils, on the nitrogen removal from the soil in the form of

harvested crops and on the excess of nitrogen application over nitrogen removal possible while avoiding leaching problems.

In order to appraise the importance of the several variables influencing the operation of the project, a deterministic simulation, or multi-period cost and benefit accounting model, was constructed and applied with the support of the Illinois Water Resources Center. The model is less sophisticated than most simulation models in that in many cases it was constructed on point estimates of the relationship between variables. This was necessary when the only estimates available were the initial estimates available from the MSD. As experience is gained, in this project or in others, it will be possible to substantially improve the model. At this point, however, it is possible to begin to identify the variables that are important determinants of costs and benefits to the MSD and to the county.

The model developed reflected the operation of the project from transportation of the sludge from Chicago to the site, storage, handling, and application on the land. It reflects costs of leveling the land prior to application and farming which will vary over sites as well as a constant per acre cost for runoff control. The productivity of the soil is determined by sludge applied and crop residues, which in turn determines the nitrogen present in the soil. The nitrogen requirement of the crops grown is compared with nitrogen present to determine annual sludge applications possible, if any.

Crops produced and land values determine crop expenses, yields determine gross crop revenues and the difference is net crop revenue to the MSD. The increases in land values due to changes in quality and the savings over other methods of sludge disposal are added to crop revenue to determine gross MSD benefits. The costs of transportation, storage, application, leveling, land purchases and monitoring are subtracted to determine net district benefits. Crop expenses and costs of operations carried out in the county determine initial county benefits, which are assumed to

have a multiplier effect on county income. All costs and benefits are calculated by year over a ten to twenty year horizon and are discounted.

Results Generated

In line with the objectives of the analysis those variables that have a significant impact on the performance will be identified, roughly in order of their importance.

Transportation Costs. At present, the sludge is being shipped 170 miles to Fulton County by barge under a contract with an independent firm. If the results under this contract are compared with the results assuming construction of a pipeline prior to project initiation, a substantial difference of more than \$2000 per acre over a ten year period and over \$3000 per acre over a twenty year period are observed. While it is possible that future bids for barge transportation may be lower and the actual cost of the shipment via pipeline may be higher than estimated, the clear advantage of a pipeline is evident.

Site Preparation Costs. The costs of clearing and leveling spoil bank land as a part of any reclamation project is a subject of considerable disagreement. This project differs only in that an additional operation of constructing berms or other devices for controlling water runoff is necessary. The MSD estimates this to be a constant \$300 per acre regardless of the nature of the specific site. This is added to the cost of clearing the site of brush or trees, if any are present, and of leveling. Depending on the roughness of the site, leveling and clearing is estimated to range from several hundred to several thousand dollars per acre. Most of the cost estimates for leveling operations are based on experimental, one time, projects carried out on sites of widely differing types. Over a period of years long enough to allow contractors to gain experience on the conditions found in Fulton County, the costs per acre may be reduced. That is a learning

curve may exist. A trade-off also exists between the leveling of progressively rougher land on sites already owned and the purchase of additional sites that include less rough spoils but are more distant from the storage lagoons. This aspect was not included in the model.

In this model the costs of site preparation are included as first year costs to the MSD. These costs are included in county benefits, in total or in part, depending on whether local contractors and local laborers are utilized. The specification of local operators for such activities has a significant impact on the level of income generated in the county.

The Nitrogen Budget. The third most important factor is the quantity of nitrogen applied. If the only project objective was sludge disposal, the most efficient technique would likely be very heavy applications on a small acreage, essentially the creation of lagoons or at least areas that would have levels of water and nitrogen too high for crop production. Given the second objective, that of crop production, the sludge disposal objective could be most effectively met by operating in the third stage of the production function, in terms of water or nitrogen applied. Presumably the nitrogen limit would be reached first and operation in the third phase would imply nitrogen pollution problems, although the relationship between nitrogen levels on farm land and nitrogen pollution is a subject of continuing controversy.

Since research is not available demonstrating the relationships among nitrogen application, crop production, and pollution on strip mine spoils, it was necessary to utilize the experience on normal soils which can be broken into stock and flow aspects. Normal fertile soils carry a stock of organic nitrogen, a portion of which becomes available to crops in each year through mineralization to an inorganic form which is also subject to leaching problems. Strip mine spoils have much less organic nitrogen present, in some cases it may be essentially void. Over half of the nitrogen present in sludge is in organic form and therefore sludge applications

will provide organic nitrogen, as will crop residues.

The flow aspects of this problem involve the application of inorganic nitrogen, the loss of nitrogen through volatilization, removal in the form of crops, and possible losses in the form of runoff or leaching into the ground water. It has been estimated that on normal Illinois soils approximately $1/3$ more commercial inorganic nitrogen is added than is removed by crops produced.

The potential impact of the two variables, the initial level of organic nitrogen present and the relationship between the nitrogen applied and that removed is quite significant. If the original stock is assumed to equal levels present in normal fertile soil and the maximum allowable application of nitrogen is equal to that removed by the crops, only 53 dry tons of sludge can be applied over a ten year period. If the original stock value is zero and twice as much nitrogen can be applied as is removed by the soil, 195 tons can be applied over ten years. The original stock of nitrogen present is slightly more important than the relationship between annual applications and removals.

Cropping Systems. A variety of crop rotations, continuous single cropping and continuous double cropping options were analyzed. Generally systems using large amounts of sludge nitrogen are the most desirable. The economic benefits from using heavier levels of sludge outweigh the differences in net revenue from cropping operations. For this reason the double cropping operations are superior to single cropping. Both of these are superior to the crop rotations.

One problem with crop rotations is that the inclusion of crops with low nitrogen requirements lower the MSD benefits, as noted. But also, nitrogen pollution problems are an apparent threat with rotations. This is due to the build up of soil organic nitrogen levels through applications in the years when crops demanding high levels of inorganic nitrogen are grown. Then when crops with low nitrogen demands are grown, more nitrogen is converted from an organic to an

inorganic form than is utilized by the crop. The excess may leach into the ground water.

The cropping systems which the model suggests will perform best are: corn-rye double cropping, for grain or silage; sorghum-sundangrass; and corn single cropped. For example, almost 50% more sludge is applied over ten years with the corn-silage-rye system than with a corn-soybeans-wheat-alfalfa rotation.

Labor Use. The use of local labor and local contractors to carryout the physical activities of the project is an important determinant of county income. Without an income multiplier (or a multiplier of 1), the present value of income generated in the county over 10 years is \$113 per acre when outside contractors and labor are utilized. If local labor is used by outside contractors this jumps to almost \$500. If both local contractors and local labor are used, this increases to \$626.

The existence of a multiplier will further increase these benefits. A multiplier of 1.11, as was estimated for Fulton County, would increase this to \$695. If it equalled 2.0, the benefits would double from \$626 to \$1252.

Other Variables. The remaining aspects of the project are, at least in relative terms, not highly significant determinants of project performance. The costs of the storage lagoons, pumping and application systems, etc. are large but the impact of changes of these costs over reasonable ranges is not significant. Variations in the discount rate from 4 to 12 per cent did not significantly influence project performance due to the high cost load in the first year of the project.

Selected Results and Conclusions

Since the estimates on which this analysis is based are approximate, the results are less than exact. Some of the results will be presented, however,

in order to provide a general understanding of the project.

Based on assumptions that appear reasonable for the level of nitrogen present and crop utilization, the following can be reported. Almost 150 dry tons per acre of sludge could be applied in the first ten years, with another 100+ tons being applied in the following ten years. The net present value cost of the project to the district would be about \$68 per dry ton using current transportation methods and about \$39 per ton if a pipeline were constructed. The project would generate economic activity in the county amounting to \$600 to \$1200 per acre depending on the multiplier and assuming that local labor and contractors are used.

It seems that it is reasonable to conclude that a project of this nature is economically feasible. The MSD will be able to dispose of significant quantities of sludge, and if the pipeline is constructed, be able to do so at a lower cost than with previous methods. The county will realize benefits in that significant acreages of strip mined land will be reclaimed and significant levels of income will be generated. It is this anticipated benefit by both parties that resulted in the initiation of the project.

Of course, additional research needs to be done. These estimates are rather crude. The presumption of no heavy metals pollution is accepted in this analysis, but will need to be monitored, as will the nitrogen levels in the water environment. In addition, the project involves the heavy use of herbicides in a zero-till cropping system.

While the possibility of problems which would stop this operation exists, it appears that it should be successful. It may well demonstrate that a profitable interaction between agriculture and urban centers is a realistic goal.