THE DEVELOPMENT OF A LAND USE INVENTORY FOR REGIONAL PLANNING USING SATELLITE IMAGERY

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ABSTRACT

Under provisions of Section 208 of the Federal Water Pollution Control Act Amendments of 1972, the Ohio-Kentucky-Indiana Regional Council of Governments (OKI) received a grant of $1.9 million for water quality planning for a nine county area centered around Cincinnati, Ohio. Similar grants have been made by the U. S. Environmental Protection Agency to councils of government in other metropolitan areas. The purpose of 208 water quality planning is to identify all sources of water pollution in major urban-industrial concentrations and to develop effective programs to reduce such pollution. The planning process includes not only a study of public sewerage systems and industrial pollution, but also an analysis of agricultural and urban stormwater runoff. Because water quality is in large part determined by land use activities and patterns, detailed up-to-date land use data is needed. Traditional land use inventory techniques are too time consuming. Land use data generated by computer processing of satellite imagery offers a viable alternative for obtaining the needed information. This report explains the need for land use data for water quality planning, problems which might be encountered in the use of satellite imagery, and the generally favorable results obtained by OKI.

INTRODUCTION

The Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) created several programs to fight water pollution. Under provisions of Section 208 of that act, regional councils of government such as OKI were given the opportunity and the funding to undertake regional water quality planning. Before beginning the discussion of OKI's experience in the use of a land use inventory generated through computer processing LANDSAT-1 digital tapes in the water quality planning process, it would be useful first to take a look at regional planning in general, the present level of regional planning activity in this country, and water quality planning in particular.

REGIONAL PLANNING

Regional Planning was born out of a realization that many of the problems and opportunities which face local government, particularly in metropolitan areas, cannot be met individually be each county, city, village and township. These problems and opportunities cover a wide range of public concern, and include such things as highways, mass transit, housing, health services, parks and recreation, water supply, solid waste, air quality, sewage disposal and coastal zone management. These are problems that do not respect political boundaries which, in most cases, were chosen long ago and without regard to the efficient and adequate provision of public services. For example, in the ten county OKI region (only nine counties are participating in the water quality program) centered around Cincinnati there are 128 municipalities, 81 townships and an even larger number of special districts. Regional councils of government, such as OKI, were created in the belief that communities should be able to achieve

through collective action the goals that none can achieve alone.

As of July 1, 1971, there were 247 Standard Metropolitan Statistical Areas in the United States, each centered around a central city of 50,000 or more population. Most have a regional council of governments or regional planning authority. In addition, most states have broken down their area into sub-state multi-county planning districts with councils of governments. According to the 1974 Regional Council Directory published by the National Association of Regional Councils, there are over 600 councils of governments in the United States.

Each has undertaken planning activities in various functional areas to one degree or another. OKI, for example, has completed an overall development plan, as well as plans for highways, housing, open space, water supply, sewage disposal and solid waste. Currently, the OKI staff is working on a mass transit plan and a water quality plan as well as updating other plans.

Because satellite imagery is furnished by NASA for scenes covering a rather large area and because of other economies of scale inherent in the interpretative process, the development of a land use inventory from satellite imagery is most practical if done at a fairly large scale. Regional planning areas fall within the scale, and regional councils of governments are an obvious and substantial market for the use of data generated from satellite imagery.

WATER QUALITY PLANNING

OKI was one of the first regional councils of governments to receive a grant from the U. S. EPA for 208 regional water quality planning. At present, some 45 agencies have either begun work on 208 plans or have been assured of EPA funding. As many as 100 additional agencies will be funded before the end of the current fiscal year. The new 208 program differs from past HUD-financed water and sewer planning in that this new EPA-administered program deals with all sources of water pollution, not just pollution from municipal sewerage systems. Other sources of water pollution for which planning responsibility is given are industrial discharges and what are termed "non-point" sources. These non-point sources include sedimentation and runoff of pesticides and fertilizers from agricultural areas, urban runoff, erosion from construction sites, and leachates from septic tanks.

THE LAND USE ELEMENT OF WATER QUALITY PLANNING

A major task of the 208 planning program is the prediction of water quality in the rivers and lakes resulting from existing and future land uses. This will lead to the formulation of new land use policies which reflect the need to improve water quality. To achieve this, OKI has developed a model capable of predicting sediment and nutrient flow into the waterways of the region. An essential input to the model is an accurate map of land use. OKI needs to know how much acreage of each land use type is within each of 225 drainage areas within the study area. Other variables include slope and soil type.

Each land use type has a special characteristic which is important in the calculation of the quantity and quality of stormwater runoff. For example, land used for growing crops is often tilled in the spring when rainfall is heaviest. Much of the rainfall is absorbed into the earth, but erosion can be significant under such circumstances, resulting in

sedimentation in nearby streams. Pesticides and fertilizer substances may also be washed into the stream. This differs from what happens in a central city area where virtually all of the ground is covered by pavement and buildings. Little or none of the water is absorbed into the earth. Instead, it flows rapidly into storm sewers, carrying with it dirt from streets and buildings.

The relationship of land use planning to water quality planning, then, becomes quite obvious. The inventory of present land use together with population projections will serve as a basis for developing a future land use map. Given future land use, the water quality model will be run again to determine the impact of future development on water quality. This analysis will lead to an identification of critical areas, areas where alternatives will have to be developed to minimize any deleterious impact on water quality. This may involve redirecting growth to other areas where the impact might not be so severe or changing the character of the growth to minimize any harmful impact on water quality. The water quality plan will, in effect, contain a significant land use planning element. The 208 water quality planning program may provide the most rational basis for land use planning available to date.

Because the 208 program involves planning agencies in a type of planning with which they have not previously dealt, new data systems must be developed. This is particularly true in regard to land use data.

Land use information currently available to planning agencies is generally not adequate for water quality planning purposes. In almost every case, agricultural forest and vacant land has been lumped into one category-miscellaneous, and urban land uses often are not identified in terms usable for water quality planning. Often, the data is not current, not consistent for the entire study area or not capable of being tabulated by drainage area. Therefore, new region-wide land use inventories are needed.

The OKI Region, like most regional planning areas, is fairly large. It covers 2700 square miles. For this reason, the traditional techniques for land use inventory - field inspection and manual interpretation of aerial photographs - were judged to be impractical in that they are too costly and more importantly, too time consuming. Time is critical because the water quality program is only a two year effort, and a land use inventory is an input which is needed very early in the program. Given this need to produce a land use inventory in the shortest possible time, the OKI staff looked for and found a much faster method - the use of satellite imagery.

THE DECISION TO USE SATELLITE IMAGERY

None of the OKI staff had any experience with satellite imagery. The staff first heard about the potential applications of satellite imagery in regional planning at the annual meeting of the American Institute of Planners in October, 1974. Subsequently, representatives of various private firms which market the interpretation of satellite imagery as a service met with the OKI staff. Examples of data and visual aids from previous studies convinced the staff that a satisfactory land use inventory could be obtained. Most impressive of all was the fact that the resultant data is very detailed both in terms of the categories which can be identified and in that the dominant land use can be determined for each 1.12 acre cell or "pixel". Also the data can be displayed in a visually attractive format with color coded acetate overlays or a color coded composite map. This is important to public agencies such as OKI which are committed to public involvement in their planning programs. Another major advantage of this technique is that

the interpreted images are already computerized and the data can be summarized by county, drainage basin or other statistical unit.

The next step was to obtain approval from the OKI Executive Committee (OKI's governing body composed mainly of elected officials) that the expenditure would be a wise one. The staff had earlier estimated the cost of generating a land use inventory using traditional techniques of aerial photo interpretation and field inventory. Therefore, the staff was able to show that a land use inventory generated from computer processed satellite imagery would not only be comparable in terms of cost, and possibly even lower, but that a significant savings in time could be achieved, possibly as much as six months. Based on this information, the OKI Executive Committee unanimously agreed to approve the use of satellite imagery.

The U. S. Environmental Protection Agency requires that OKI obtain its approval before entering into any contract exceeding $2,500. After a reasonable review period, EPA approved OKI's contract with the Bendix Aerospace System Division without revision.

THE RESULTS

The final product is a 10 - category land use map of the OKI Region at a scale of 1" = 5000' showing the following land use activities: grassland, idle cropland, active cropland, water, two categories of forest land, and four densities of urban development defined in terms of the percent of ground covered by pavement and buildings. In addition to a composite map, OKI also received separate acetate overlays for each land use category. Since these overlays are reproducible, they are particularly useful as work maps.

OKI's experience in the development of a land use inventory has been a successful one. The total acreage for each drainage area as measured from the satellite data matched very closely the acreage measured by using a planimeter. Field checks and interviews with farmers and agricultural agents have shown that the categorization has been accurate within a reasonable level of tolerance.

OKI has also learned more about the limitations of such data and problems which might be encountered in generating this information. For example, even though the two LANDSAT satellites now circling the globe each pass over the OKI Region once every eighteen days, it was necessary to use LANDSAT images from April 14, 1973, because none of the more current images were taken on cloudless days. While a 1973 image is quite acceptable, and certainly more up-to-date than anything otherwise available, one should not count on using images taken last week, for example.

Also, delays can be expected in obtaining the LANDSAT-1 tapes from NASA. It may take as much as a month. This delay can be embarrassing if promises of delivery of the final product have been made to local planners, committees, or other interested parties.

Then, too, the data itself may require some manual interpretation. For example, the data received by OKI presented the acreage for cropland as significantly less than that identified in various agricultural surveys. After some investigation, it was discovered that the cropland category only included row crops such as corn and soybeans, and not wheat or alfalfa which were shown as part of the grassland category. Other problems were encountered because unrelated land uses were found to have the same spectral characteristics.

OKI was, however, able to overcome these difficulties through manual interpretation and division of certain land use categories. It was found that the categories can be more accurately defined through the use of more detailed ground truth data.

CONCLUSION

The OKI project has clearly shown an important practical application of LANDSAT data. Indications are that our success has already encouraged several of the other existing and potential water quality planning agencies to consider the use of LANDSAT generated data. Furthermore, the planning applications need not be limited to water quality analysis. As the interpretative process becomes more sophisticated and as planners become more aware of the potential uses of such data, the scope of its use will undoubtedly expand to include other environmental planning activities. For example, satellite imagery may be the best way to monitor suburbanization or land absorption. The extent to which satellite imagery and related services will be used for regional planning in the future may depend upon improved communications and the establishment of a closer working relationship between the users and the researchers.

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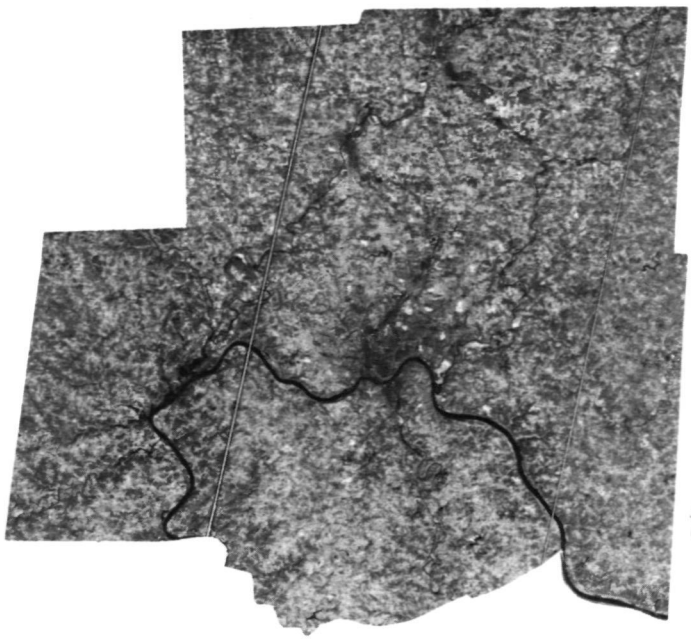
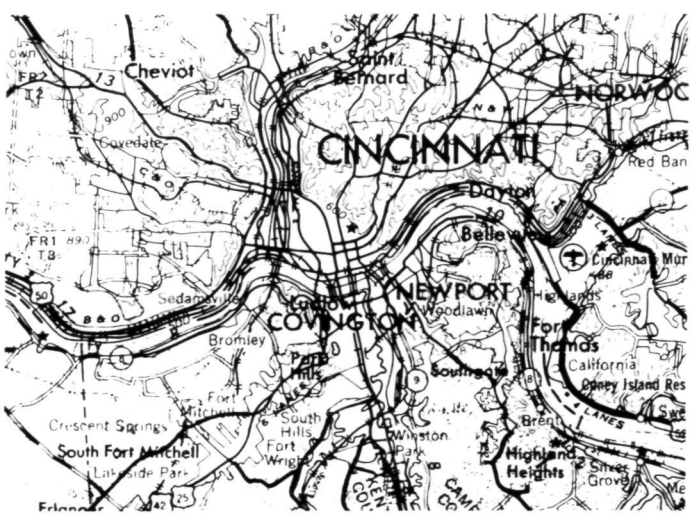
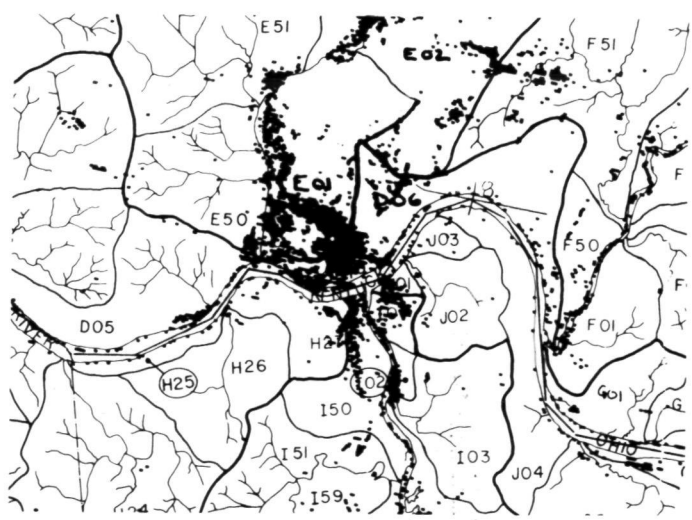


LANDSAT-1 BAND 7 IMAGE
OF APRIL 14, 1973 SHOWING
THE OKI REGION

COUNTIES AND MAJOR
RIVERS
OF THE OKI REGION



MAP OF PORTION OF THE
OKI REGION NEAR CINCINNATI



CORE CITY/INDUSTRIAL
CATEGORY OVER WATERSHED MAP