Apr 1st, 8:00 AM

A Total-System View of Environmental Management

G. E. Clark
Member of Technical Staff, Research, Engineering, and Test, Space Division of North American Rockwell Corporation Downey, California

R. G. Crum
Project Engineer, Advanced Systems, Space Division of North American Rockwell Corporation Downey, California

W. L. Dowdy
Program Development Manager, Earth Resources, Space Division of North American Rockwell Corporation Downey, California

A TOTAL-SYSTEM VIEW OF ENVIRONMENTAL MANAGEMENT

W. L. Dowdy, Program Development Manager
Earth Resources

G. E. Clark, Member of Technical Staff
Research, Engineering, and Test

R. G. Crum, Project Engineer
Advanced Systems

Space Division of North American Rockwell Corporation
Downey, California

ABSTRACT

Man, vastly increasing in number and continuing to exploit his natural resources, has altered the quality of his environment until it is in danger of becoming unfit for human life. The reversal of this trend must begin with the formulation of a management system that encompasses the total cycle of man's environmental manipulation—from the extraction of raw materials and the production of goods to the eventual disposal of those goods. This paper describes how environmental quality can be managed on a large scale and outlines the methods for implementing this management through the total-system approach.

INTRODUCTION

A year ago concern about pollution of the environment was confined primarily to conservationists, scientists, political leaders, and small—but highly dedicated—groups of conscientious citizens. Today the issue is of primary concern to most Americans. The masses of people not only appreciate the seriousness of the problem but are demanding that the necessary steps be taken to restore the environment and to end the flagrant abuse of our natural resources.

Government agencies are reacting to this call for action. President Nixon, in his 1970 State of the Union message, pledged the Federal government's leadership in a multibillion-dollar anti-pollution program. The magnitude of this commitment has assuaged the concern about lack of funding and governmental involvement. The more relevant question now is, can we save our environment? Or, more optimistically, how can we save our environment?

It is true that air, water, and land pollution has increased to such an extent that a solution to the total problem will require a mammoth undertaking. But this does not mean that society should panic and resort to reactionary measures. We must seek a rational solution. Medical researchers, seeking cures for man's diseases and infirmities, have often faced problems of similar magnitude. In searching for environmental cures, we would do well to emulate the scientific techniques practiced in the medical laboratory. In short, we must study the causes and focus less attention on the symptoms.

The two major causes of pollution are not difficult to identify: nature's unpredictable forces and man's manipulative actions. Nature, of course, is the more difficult to control. The heat wave that forms the temperature inversion and produces stiffling smog, tidal waves that erode the shoreline, torrential rains that carry away valuable topsoil, the sustained drought that parches vegetation and deprives it of its natural growth—all are tragic and all are out of man's present domain of control. To increase our understanding of these forces, scientists are engaged in important studies of the oceans, the atmosphere, and the weather. But before they can conclude that it is even desirable to control certain aspects of the weather, for example, they must carefully examine the many consequences. Unfortunately, this is a monumental, time-consuming undertaking— one not likely to be resolved in time to meet immediate needs. Therefore, near-term solutions must be focused, for the most part, on man's manipulations.

Man is the builder and destroyer of nature, producer and consumer of nature's products, and planner and observer of the natural scene. He exploits natural resources and has become the most destructive predator in the earth's biosphere. Five basic trends have developed from his manipulations which have led to most of his environmental problems: (1) population growth, (2) urban expansion, (3) production increase, (4) technology advance, and (5) bureaucratic spread. Here is how these trends are intensifying environmental pressures:

1. Growing populations consume more resources and occupy more space.

2. Industrial societies increasingly congregate in urban centers, multiplying the pollution problems that result from concentrated populations.

3. Economically progressive societies enjoy high standards of living, placing increasing demands on productive capacity and resulting in greater consumption and discard of goods.

4. To maintain parity with production demands, growing populations, and improved standards of living, technology is being advanced at a record pace, and in the process products are being released into the environment before all the possible detrimental consequences have been considered.

5. Public institutions created to control natural resources and the environment have been unable, because of ill-defined and often conflicting goals and overlapping boundaries of jurisdiction, to maintain organizational pace with the changing environment, and have failed to provide a desirable level of quality.

In whatever depth these trends are discussed, the conclusion is almost always the same: the environmental problem reduces to one of lagging control. How do we save our environment? We start by improving our present form of environmental management.

In this paper, we are concerned with the management of man's environment—but not just an improvement in the present management structure. What is needed is a change in the total concept of management. The environment is a large, complex system, not necessarily constrained by political boundaries. In the past, government created "single problem-oriented" agencies, and these did a consistently good job. However, they treated their problem as if it had no relationship to any other. For example, if it was dam building, a bureaucracy formed around dam building, and vested interests emerged. In the process, the fundamental mission of the agency was forgotten and dams became the design solution to all problems. This tendency has been reflected in most government agencies, with the result that environmental problems have been dealt with on an agency-by-agency basis in which there is much overlap, some omission, and little cohesiveness. The separate elements of air, land, and water can no longer be treated effectively on a piecemeal basis. We must manage the problem at the interagency level as well as at the intra-agency level, by treating all the elements of the environment in a total system. Unless a total-system approach is adopted, results are certain to be less than satisfactory.

Some observers argue that the system approach is not new, that it is simply an application of common sense and good judgment. They are right. Telephone companies, oil companies, and electrical utility companies have used this approach for many years in the design and operation of the telephone system, oil refineries, and power-generating networks. More recently, the space program, with goals of landing men on the moon and sending automated packages into deep space, has added an important dimension to the system approach: it has provided the tools and techniques whereby functional relationships of all system elements can be optimally patterned, through tradeoffs and computerized analyses, in selecting the best approach among the many conflicting requirements. As a result, the system approach can now be applied to almost any large-scale problem. Some refinements may be necessary, however, when the approach is applied to social problems. Unlike the space-mission problem, which is generally one of technology, social problems defy quantification, and quantifiable terms are the major factors involved in the system approach. While environmental degradation is a social problem, it is also a political problem, a medical problem, a technical problem, and an economic problem. Its scope is so broad that it is necessary, by definition, to approach its solution only on a total-system basis. We must learn how to incorporate social factors into the approach. And to do this, we must first gain a responsive position of decision-making and control. In brief, we must manage the total environment.

FACTORS OF THE TOTAL SYSTEM

The factors involved in environmental management must be broadly conceived, touching on all aspects of the pollution problem—i. e., political, medical, technical, social, and economic. They must be organized into a total-system approach that provides a general framework for classifying key issues, making decisions, and moving toward the eventual solution of pollution problems. Above all, they must provide for a management system that can be structured into Federal, state, and local government organizations with the ability to gather information, make decisions on that information, and influence negotiations necessary to assure a high standard of quality.

Figure 1 illustrates a process for meeting these requirements. The outlined effort begins with the systematic analysis of historical data and future trends to identify waste problems, followed by a definition of pollutant sources, postulation of quantities released, investigation of natural forces, observation of biospheric responses, and determination of measures of quality. The effort continues with an examination and selection of a full range of equipment, including information systems as well as processing and control equipment. A parallel effort is conducted to create government agencies, establish quality standards, and pass required laws. The remaining activities are those of monitoring, controlling, and updating.

Keys to implementing such a process are as follows: (1) that appropriate outputs be generated on an actual or experimental basis throughout the effort (incorporating, detailing, changing, or eliminating presently noneffective management controls); (2) that details of the plan be rationally achieved over a period of time, permitting the actual observation of societal actions and reactions; and (3) that extensive involvement of government agencies, private groups, industry, and individual experts be required throughout the total effort.

Implementing such a process involves three major issues. First, what is the best institutional arrangement for managing environmental quality? What type of organization, functional responsibilities, degree of authority, and geographical boundaries should an agency have in order to gather information, decide upon alternatives, and enforce standards of quality?

Second, how can a desired level of quality be determined? This is very difficult. We must keep in mind that physical measures are not the only measures of quality: both physical and psychic health must be preserved. This aspect of the problem involves the establishment of public goals in conjunction with an intensive research effort to collect physical data on air, land, and water interchanges and intrachanges.

Third, what alternatives are available for maintaining quality standards within the environment, and what equipment is available, or will be available, to monitor, detect, measure, analyze, control, and eliminate pollution problems? There are many options that could be employed, but the problem is to select the best method (or set of methods) from a cost/benefit standpoint. Today we have most of the tools to cope with waste problems at the source, but we must learn to use them in the best-system configuration. We must also develop equipment to monitor or handle pollution at locations far removed from the source.

All of these questions are interrelated—e. g., the standards determined by the management agency are dependent on the quality desired, which is largely dependent on equipment performance, which is ultimately a function of cost versus benefits received. Not only do these questions help isolate the key issues, but they provide a convenient outline for discussion.

WHAT IS BEST MANAGEMENT ARRANGEMENT?

It will be difficult to develop the best form of environmental management. Substantial experimentation with new concepts, as well as broad modification of old arrangements, will be involved. The degree of success will depend to a great extent on the depth to which management is implemented and the conviction with which it is applied. Both have been lacking in the past.

Today the atmosphere is fouled with chemicals and particulate matter. Lakes and streams are overloaded with harmful liquid emulsions and suspended matter. Garbage does not receive proper disposal. Old automobiles are left laying around. Beer cans and trash litter the roadways. Noise is approaching the threshold of pain. Industrial odors are complicating the pattern of urban living. And acres of natural wonderland are giving way to the blade of earth-moving equipment. This pollution is the result of insufficient control and lack of understanding. Man has been operating without an environmental code of ethics. He would not throw trash onto his own front yard, but he throws it into a public stream—not realizing or not caring what the ill effects will be.

We all live downstream or downwind from somebody else. As we begin to understand this, we will also begin to realize that pollution control starts with the individual, and that the individual must look to government for leadership. He must

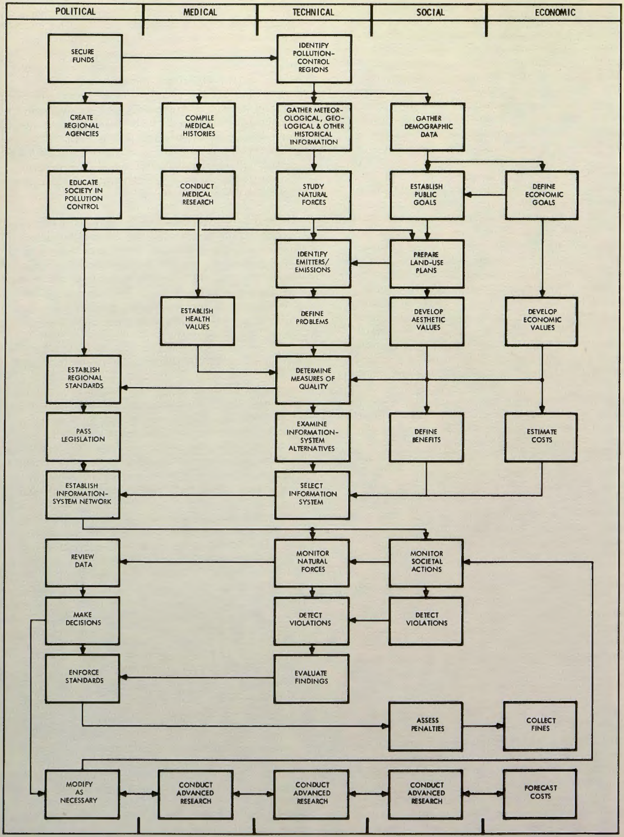


Figure 1. Activity Flow.

also look to government for dissemination of information on how to deal with pollution. And, above all, he must be willing to vest certain powers in government that will lead toward the formation of a management system that can deal effectively with environmental degradation and decay. The objective of such a system might be summarized as follows:

- To provide a basis for planning and action according to specific needs rather than arbitrary standards.
- To permit planning and scheduling of future projects in accordance with demonstrated needs within an allocated budget of beneficial resource uses.
- To provide a basis for controlling activities and operations to produce the required results.
- To fix the responsibility for adverse environmental-quality conditions.
- To assure compliance with the requirements of related Federal, state, and local agencies and laws.
- To determine, evaluate, and demonstrate the effectiveness of any program for environmental-quality improvement or pollution abatement and to continually restructure in accordance with flexible public goals.

Figure 2 shows an environmental-management cycle that could accomplish the above objectives. It encompasses the major functions of management: planning, organizing, directing, and controlling. These four functions span the evolutionary spectrum from system conception to operational control. The chart depicts this evolution in three iterative cycles, centering around implementation, monitoring, and control.

Land-use plans, public goals, quality standards, and appropriate legislation are all important elements of the implementation cycle, but perhaps the most important single element is that of agency formation. Pollution problems are generally confined to regions. For example, air pollution exists within a meteorologically defined air shed, water pollution develops within a river drainage basin, and land pollution occurs from local land uses. Agencies must be formed to treat a problem at its source. Since problems are regional in nature, it follows that a network of agencies must be formed at that level. Table 1 describes the regional distribution of water

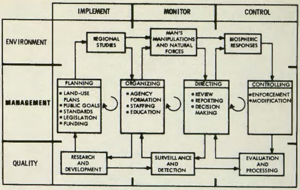


Figure 2. Environmental-Management Cycle.

problems. A cursory analysis reveals why a national agency with one overall set of standards and controls is not the best approach to solving water-quality problems. For example, in the southwestern area of the United States, water supply is the primary determinant of the degradation of water quality; while in the eastern United States, industrial and municipal wastes are the primary determinant.

Studies must be conducted to define regional basins in terms of relevant air, land, and water problems. Separate agencies will be needed, generally, for the single problem of air, land, or water, but combined-problem agencies, having management cognizance over the smaller single-problem agencies, will be required throughout the United States. In this context, "combined problem" means the integration of all air, land, and water problems relevant to a region. Each combined-problem agency should have the authority to deal effectively with problems occurring in its domain.

The Federal government should sponsor this alignment, creating a Cabinet-level agency which is responsible for chartering the various combined-problem agencies and acting as management overseer for the total network of agencies. In most cases, the regional agencies will overlap state, county, and local governmental jurisdictions. The regulations for handling such overlaps must be explicitly stated in the operating procedures of the regional agencies. When critical environmental problems occur, the regional agency must be able to respond rapidly without becoming entangled in jurisdictional disputes such as those handicapping the present fragmented management and control system.

The monitoring cycle of environmental management generally involves staffing, educating, reviewing, reporting, and directing—each of

Table 1. Water Problems

PROBLEM	REGIONS MOST AFFECTED	COMMENT
INEFFICIENT DISTRIBUTION		
• HEAVY CONSUMPTIVE USE	SOUTHWESTERN IRRIGATION AREAS	ADEQUATE WATER FOR CITIES AND INDUSTRIES WHERE RIGHTS ARE OBTAINABLE OR LONG-DISTANCE TRANSMISSION IS FEASIBLE. AGRICULTURAL EXPANSION LIMITED.
• LONG-DISTANCE TRANSMISSION	SOUTHWEST, CALIFORNIA, AND CERTAIN MOUNTAIN STATES; NEW YORK AND OTHER EASTERN AREAS	LARGE CONSTRUCTION PROJECTS REQUIRED, ESPECIALLY IN THE WEST.
INSUFFICIENT STORAGE		
• SEASONAL AND FLOOD FLOWS	GENERAL IN STATES WITHOUT GOOD LAKE OR GROUNDWATER SUPPLIES	WELL DEVELOPED IN ARID AREAS. MULTIPURPOSE PROJECTS RAISE NEW QUESTIONS OF PUBLIC POWER, LAND CONDEMNATION, AND RECREATION IN POPULOUS AREAS.
• FALLING WATER TABLES	CLOSED GROUNDWATER BASINS OF SOUTHWEST AND PACIFIC COAST; AROUND LARGER CITIES IN CENTRAL STATES; SOME MIDDLE ATLANTIC AREAS	GREATEST COST PRESSURE ON CHOICE IRRIGATION AREAS; LESSER, BUT IMPORTANT, EFFECT ON CITIES AND INDUSTRY.
MISGUIDED CONSERVATION		
• EVAPORATION FROM PLANTS, RESERVOIRS, AND STORAGE PONDS	ARID WEST AND WEST CENTRAL SECTIONS	CONTROL MAY BE CHEAPER THAN DEVELOPING NEW WATER SOURCES.
• WATERSHED TRASH VEGETATION	SOUTHWEST	FAIR POTENTIAL FOR INCREASING WATER YIELD BY ERADICATING TRASH PLANTS.
• SALT-WATER ENCROACHMENT	OVERPUMPED COASTAL AREAS; OCEAN OUTLETS OF BIG RIVERS	DESTROYING SOME WATER SOURCES AND LAND.
INADEQUATE RECLAMATION		
• DISPOSAL TO OCEANS	EAST, WEST, AND GULF COASTS	LARGEST AND CHEAPEST POTENTIAL SECONDARY WATER SOURCE; ATTRACTIVE TO INDUSTRY.
IRRESPONSIBLE WASTE DISPOSAL		
• CHEMICAL POLLUTION	HEAVILY POPULATED EAST, NEWLY INDUSTRIALIZED SOUTHEAST, MINING AREAS, AND OIL FIELDS	INCREASING STATEWIDE AND INTERSTATE CONTROL IS FORCING COSTLY CHANGES IN WATER SOURCES AND WASTE TREATMENT.
• SEWAGE POLLUTION	MOST COASTAL URBAN CENTERS; RESORT LAKES AND RIVERS	INCREASING CONSTRUCTION WITHOUT ADEQUATELY UPDATING LAND-USE CODES.

which is highly important—but decision making is perhaps the most vital. A well-conceived decision-making process should include the participation of private enterprises and societal organizations as well as government agencies. Since private enterprises are committed to profit making, they are highly responsive to consumer demands. Most consumers do not live near the industrial site and are primarily interested in low price. The local residents, who are not necessarily the major purchasers of the company's goods, are likely to be the major recipients of its waste products, and are understandably interested in quality of the environment. If unreasonably high standards of quality are imposed on industry, operational costs will rise, and the consumer will inevitably bear the cost. If a company finds itself at a competitive disadvantage because of higher prices, it may be forced to relocate its plant—or to go out of business. Either way, the community loses because of reduction in employment and net economic loss. To prevent economic losses of this nature, a system of decision making is required that examines all issues. Industry must have an active voice in this system.

For equally good reasons, societal organizations also should have a voice in decision making. Of course, the ultimate decision should lie with the governmental agency having the responsibility of managing the environment. But due to far-ranging effects upon industry and society, perhaps an organized forum could be established for the open discussion of critical matters affecting each region. And to assure a well-informed public, an information-gathering network should be implemented to provide timely and accurate information on key issues.

The last cycle of environmental management involves control. In this context, control means the active responses of management to enforce standards of quality and to modify and restructure policies and procedures to provide a constant updating of the system. In this process, the biospheric responses—i.e., aesthetic and health effects—will be constantly evaluated to provide an "early warning" system for problems and changes in the desired quality level.

WHAT IS DESIRABLE QUALITY LEVEL?

A vital element in environmental management is the determination of quality levels for the formulation of standards and decision making. This information will be used in all phases of the management procedure described previously. Base-line measurements of the environment are needed, as is the ability to monitor changes in the biosphere and to quantitatively predict consequences of change (especially those which are man-made). Required are measures of such types and over periods of time so that the stimuli of dissatisfaction with the quality of our environment can be meaningfully and quantitatively correlated to resource conditions and "pollution" emission levels. Does anyone really understand, for example, how much better the quality of our environment would be if auto exhaust standards were reduced from 3.2 grams per mile to, say, 1.5 grams? Someday, in a local area at least, the answer to that question can be in the affirmative. Although much information has been and continues to be taken in many fields, correlation to quality is little understood.

Environmental management will eventually result in the control and regulation of all man's activities that have a bearing on quality, no matter how small. This is a broad task, encompassing the sequence of activities from the extraction of raw materials to the production of goods to the eventual disposal of those goods. Figure 3 illustrates this cycle, identifying the major natural resources and man's manipulations that have to be considered. Here we face the issue squarely and begin to understand the necessity of relating the resultant quality of our environment with man's activities and public goals. It is no longer practical to allow our management policies to remain structured to an era when man had less influence on his environment, and, consequently, fewer controls on his activities. In fact, it is clearly undesirable to do this, because man is becoming capable of influencing his environment for his benefit. Manifestations of this influence are evolving from modern water-distribution systems and comprehensive land-use management programs. We must allow this influence to be factored into our programs of quality control and regulation. For accepting these controls and regulations, society has the right to expect that they will be based on the best possible scientific and economic data.

How and where can we best obtain and use data? Figure 4 suggests a starting point. In this illustration, the natural resources are grossly categorized as land resources, fresh-water resources, and ocean resources. Simplified resource interchange and intrachange cycles are shown. Through the thermodynamic laws of the ecosystem, nature continually uses resources as receivers, transporters, and transformers. Man uses these resources for life support, comfort, and convenience, or otherwise contacts them in various states of their dynamic interchange cycle. A high-quality environment is considered to exist

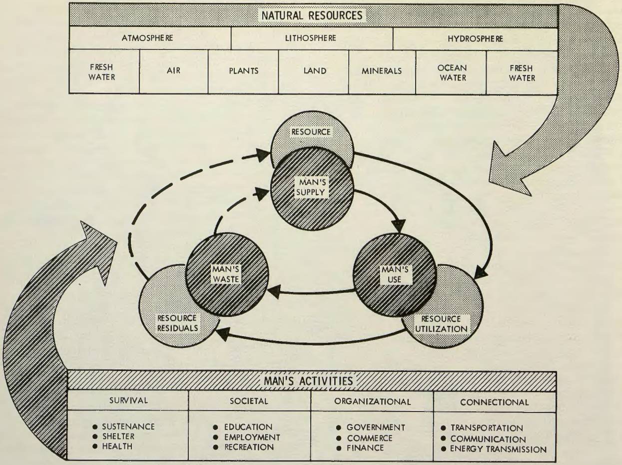


Figure 3. Resource Cycle.

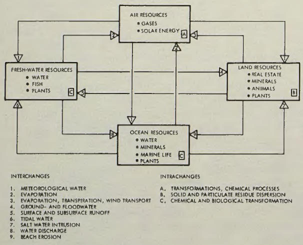


Figure 4. Inter- and Intrachanges of Resources.

when all resources are most beneficially used and all are in their proper places in proper proportions. A deteriorating environment implies that a resource is out of place. For example, floodwater is a resource out of place. Nitrogen compounds are a vital resource, but in certain forms in air and water they are detrimental to health and environmental aesthetics. So the arena of our discussion is much broader than the popular conception of the word "pollution."

A vast number of measurements, some sophisticated analyses, and the interpretation of data will be necessary to adequately ascertain which resources are sufficiently "out of place" in a locale to be inconsistent with the goals of environmental quality. The first and key information needed will be derived from the measurement of resource conditions which can be related to societal goals. The resultant beneficial resource-use budgets will allow the setting of standards of environmental quality. Next, emissions and extractions from the cycle, principally by man, must be determined and related to the local resource conditions. This will require a great deal more knowledge of the interchange cycles (reception, transport, transformation). This type of information is necessary to build up a rational relationship between absolute data and the stimuli of dissatisfaction or satisfaction with environmental quality.

Figure 5 extends the resource cycle by showing man's major uses of land, air, water, and ocean resources as a function of seven major environmental areas:

Agriculture/Farming
Municipal/Residential
Transportation/Circulation
Industry/Manufacturing
Resource Supply/Extraction
Energy Conversion/Power Generation
Recreation/Spatial Freedom

These environmental uses (often inappropriately classified under the general category of "land uses") result from man's activities in support of public goals.

Returns to the cycle must be accounted for separately. It is easy to see that returns are not of the same quantity nor of the same quality or condition as extractions; nor are they necessarily returned to the same places in the cycle from which the extractions came. Consider, for example, an oversimplified illustration of the motor vehicle exhaust problem:

- Through plant and animal deposition and other "natural" processes, olefin organics are formed (a land resource interchange).

- Man extracts, refines, and uses additives in these olefins, forming complex chemical substances (a land intrachange) to support his transportation activity. The substances are inefficiently oxidized by a process which dumps most of the residue into the atmosphere (an atmospheric intrachange and land-to-air interchange).

- The amount of these substances injected into the ecocycle is often of sufficient quantity and concentration that human goals of comfort, health, and aesthetics are compromised. In this example, a large number of stimuli of dissatisfaction with the environment have been introduced. Man at this point, however, does not know just how effectively a limitation of 1.5 grams of hydrocarbon emissions per mile (versus 3.2 grams) will reduce any of the stimuli of dissatisfaction. Nor does he know the effect of a reduction of lead content in gasoline from 4.2 to 2.6 grams per gallon (HEW informal agreements and Swedish statutory levels, respectively).

- The breathable atmosphere is not an ultimate receiver, or "sink," for these emitted substances. Most particles and vapors are either vented to the upper atmosphere, where they alter the reception of basic ecosystem energy from the sun (an atmospheric intrachange), or returned to the land and waters by precipitation (an air-to-other-resources interchange), where both animate and inanimate objects are affected. It should also be noted that some of the initial auto emissions are transformed, by little-understood processes, into new chemical substances.

Table 2 summarizes the major extractions and returns to the ecocycle as a function of man's environmental uses. It is important to note that there are extreme spatial and temporal variations in the distribution of the extractions and returns. This point alone illustrates the diversity of man-made environmental effects and the need to consider these locally within the context of a larger region.

Table 3 enumerates the causal relationships of air pollutants. The information needed to manage this aspect of the environment includes the general source, the specific emitter, the extent of the emission, the resultant conditions of the resources during the interchange cycle, and their general effects on health, economics, and aesthetics. For example, lead-arsenic fumes may result from a metallurgical-process emission or from an agricultural pest-control program. The specific emitter in an area can be ascertained, and extent of emissions measured. The local conditions of air, land, and water will be affected to some extent (as a function of the initial conditions and dynamics of the basic resources—namely, meteorology). In an open agricultural area, it may be found that lead-arsenic emissions within certain limits are an acceptable (and perhaps beneficial) use of the air resource in terms of area goals and activities relating to food production. Key measurements would indicate the desirability of controlling the method of application and even the allowable level of eventual buildup. The effect of particular pesticides on local and regional waters could then be weighed against potential benefits. The main point is that pollution abatement per se is not the objective; rather, the key is the correlation of beneficial

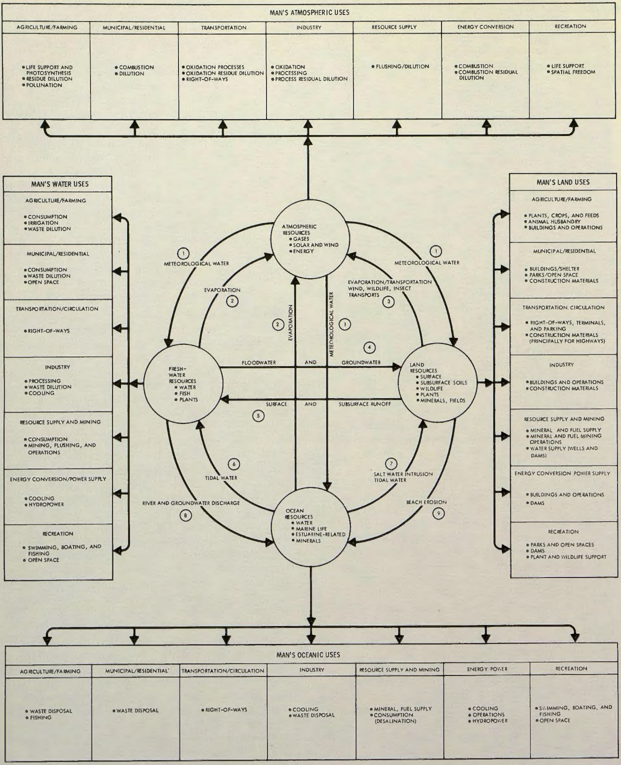


Figure 5. Major Uses of Resources.

Table 2. Resource Extractions and Returns

LAND (SPATIAL) USE ACTIVITY	MAJOR RESOURCE USES AND ENVIRONMENTAL MANIPULATIONS	DIRECTLY RETURNED RESOURCES AND RESOURCE RESIDUALS	APPROXIMATE AMOUNTS OF RETURNS PER YEAR (1970) - SPATIAL AND TEMPORAL VARIATIONS ARE LARGE
AGRICULTURE/FARMING	LAND: PLANTING CROPS, FORESTRY, FEEDS, ETC. ANIMAL HUSBANDRY BUILDINGS AND OPERATIONS AIR: LIFE SUPPORT AND PHOTOSYNTHESIS DILUTION OF DUSTS, COMBUSTION PRODUCTS, AND OVERSPRAYS POLLINATION WATER: CONSUMPTION BY HUMANS AND ANIMALS IRRIGATION WASTE DILUTION OCEAN: WASTE DISPOSAL (INDIRECT) FISHING	LAND: MANURE, DECAYED VEGETATION, AND SOLID WASTES PESTICIDE AND FERTILIZER RESIDUES IRRIGATION WATER RUNOFF AND PERCOLATION AIR: PESTICIDE OVERSPRAY IRRIGATION WATER EVAPORATION AND TRANSPIRATION WATER: WATER-DILUTED WASTES OCEAN: WATER-DILUTED WASTES (INDIRECT) PROCESSED OR UNPROCESSED DIRECT WASTES	2 BILLION TONS NOT WELL KNOWN 10 TRILLION GALLONS NOT WELL KNOWN 15 TRILLION GALLONS 500 BILLION GALLONS —— NOT WELL KNOWN
MUNICIPAL/RESIDENTIAL	LAND: BUILDINGS AND SHELTER PARKS/OPEN SPACE CONSTRUCTION MATERIALS AIR: LIFE SUPPORT DILUTION OF DUSTS AND COMBUSTION PRODUCTS COMBUSTION WATER: CONSUMPTION OPEN SPACE WASTE DILUTION OCEAN: WASTE DISPOSAL	LAND: SOLID WASTES--RUBBISH, GARBAGE, STREET CLEANINGS, ETC. RESIDUAL WATERS, OVERFLOW, AND SPILLAGE AIR: WATER SUPPLY RESERVOIR EVAPORATION SPACE-HEATING PRODUCTS REFUSE INCINERATION PRODUCTS WATER: WASTE-CONTAINING WATER OCEAN: WASTE-CONTAINING WATER (COASTAL CITIES, DIRECT)	150 MILLION TONS 700 BILLION GALLONS 700 BILLION GALLONS 10 MILLION TONS 4 MILLION TONS 7 TRILLION GALLONS 500 BILLION GALLONS
TRANSPORTATION/ CIRCULATION	LAND: RIGHT-OF-WAYS, TERMINALS, AND PARKING CONSTRUCTION MATERIALS AIR: OXIDATION OXIDATION PRODUCTS AND RESIDUALS DILUTION WATER: RIGHT-OF-WAYS WATERCRAFT WASTE DISPOSAL OCEAN: RIGHT-OF-WAYS WATERCRAFT WASTE DISPOSAL	LAND: SOLID WASTES AND RESIDUAL EQUIPMENT AIR: COMBUSTION RESIDUALS AND BY-PRODUCTS, FUEL RESIDUALS WATER: SOLID WASTES AND EXCREMENTS FUEL RESIDUALS AND SPILLAGE OCEAN: FUEL RESIDUALS AND SPILLAGE	20 MILLION TONS 100 MILLION TONS NOT WELL ESTABLISHED, NOT WELL ESTABLISHED (CONSIDERED SIGNIFICANT) NOT WELL ESTABLISHED
INDUSTRY/ MANUFACTURING	LAND: BUILDINGS AND OPERATIONS CONSTRUCTION MATERIALS AIR: PROCESSING COMBUSTION SUPPORT COMBUSTION PRODUCTS AND RESIDUALS DILUTION WATER: PROCESSING COOLING WASTE DILUTION OCEAN: COOLING WASTE DISPOSAL	LAND: SOLID WASTES AND PROCESS RESIDUALS RESIDUAL WATER, OVERFLOW AND SPILLAGE AIR: PROCESSING AND COMBUSTION RESIDUALS WATER: HEATED WATER WASTE-CONTAINING WATER OCEAN: HEATED WATER, WASTE-CONTAINING WATER, SOLID WASTES (SHORELINE INDUSTRIES)	50 MILLION TONS 500 BILLION GALLONS 25 MILLION TONS 2.5 TRILLION GALLONS 20 TRILLION GALLONS NOT AVAILABLE NOT AVAILABLE NOT AVAILABLE
RESOURCE SUPPLY/ MINING	LAND: MINERAL AND FUEL SUPPLY WATER SUPPLY AND TRANSPORT, AND DAMS OPERATIONS AIR: PROCESSING FLUSHING PARTICLE DILUTION WATER: CONSUMPTION FLUSHING AND MINE PERCOLATION OPERATIONS OCEAN: CONSUMPTION (DESALINATION) OPERATIONS	LAND: OVERBURDEN AND GANGUE FROM MINING WATER SUPPLY TRANSPORT OVERBURDEN EARTH-FILLED DAM MATERIALS AIR: DUST AND PARTICULATE MATTER WATER SUPPLY RESERVOIR EVAPORATION WATER: FLUSHING AND PROCESS WATER GANGUE OCEAN: RETURN WATER	1.5 BILLION TONS —— —— NOT WELL ESTABLISHED, LOCALLY SIGNIFICANT 700 BILLION GALLONS 7 TRILLION GALLONS ? ?
ENERGY CONVERSION/ POWER GENERATION	LAND: BUILDINGS AND OPERATIONS, AND DAMS AIR: COMBUSTION COMBUSTION PRODUCT AND RESIDUAL DILUTION WATER: COOLING HYDROPOWER OCEAN: COOLING OPERATIONS HYDROPOWER	LAND: —— AIR: COMBUSTION BY-PRODUCTS AND FUEL RESIDUALS RADIONUCLIDES EVAPORATED WATER WATER: HEATED WATER HYDROPOWER RETURN OCEAN: HEATED WATER	20 MILLION TONS ? 150 BILLION GALLONS 45 TRILLION GALLONS 200 TRILLION GALLONS ?
RECREATION/SPATIAL FREEDOM	LAND: PARKS, OPEN SPACE, AND DAMS AIR: LIFE SUPPORT SPATIAL FREEDOM WATER: SWIMMING, BOATING, AND FISHING OPEN SPACE OCEAN: SWIMMING, BOATING, AND FISHING OPEN SPACE	MOSTLY IN SITU USES, SOLID AND LIQUID WASTES TO LAND ARE MOSTLY NUISANCE. RESERVOIR SURFACE AREAS, INCREASED IN SIZE AND WITHOUT SURFACE SPRAYS TO INCREASE RECREATIONAL ASPECTS, INCREASE EVAPORATION TO AIR SIGNIFICANTLY. BOATING CAUSES FRESH WATER AND OCEAN WASTES (FUELS, EXCREMENTS, AND GARBAGE) IN SIGNIFICANT AMOUNTS, ESPECIALLY IN RELATIVELY CLEAN RECREATIONAL WATER.	

Table 3. Sources and Effects of Air Pollutants

CAUSES			GENERAL EFFECTS									
			HEALTH HAZARDS			ECONOMIC DAMAGES				AESTHETIC DETRACTORS		
SOURCE	EXAMPLE	POLLUTANT	LUNG DISEASE	CANCER	EYE INJURY	METAL CORROSION	STONE EROSION	RUBBER DETERIORATION	VEGETATION INJURY	VISUAL	SOIL	ODOR
CRUSHING, GRINDING, AND SCREENING DEMOLITION MILLING	ROAD MIX PLANTS URBAN RENEWAL GRAIN ELEVATORS	MINERAL AND ORGANIC PARTICULATES	X		X	X	X				X	
FUEL BURNING MOTOR VEHICLES REFUSE BURNING	HOME HEATING AND POWER PLANTS AUTOS, BUSES, AND TRUCKS COMMUNITY AND APARTMENT HOUSE INCINERATORS AND OPEN BURNING DUMPS	OXIDES OF SULFUR, OXIDES OF NITROGEN, CARBON MONOXIDE, SMOKE, FLY ASH, ORGANIC VAPORS, METAL OXIDE PARTICLES, AND ODORS	X	X	X	X	X	X	X	X	X	X
METALLURGICAL PLANTS CHEMICAL PLANTS WASTE RECOVERY	SMELTERS, STEEL MILLS, AND ALUMINUM REFINERIES PETROLEUM REFINERIES, PUMP MILLS, SUPER-PHOSPHATE FERTILIZER PLANTS, AND CEMENT MILLS METAL SCRAP YARDS, AUTO BODY BURNING, AND RENDERING PLANTS	METAL FUMES (LEAD, ARSENIC, AND ZINC), FLUORIDES, AND OXIDES OF SULFUR HYDROGEN SULFIDE, OXIDES OF SULFUR, FLUORIDES, ORGANIC VAPORS, PARTICLES, AND ODORS SMOKE, SOOT, ORGANIC VAPORS, AND ODORS	X		X	X	X		X	X	X	X
CROP SPRAYING AND DUSTING FIELD BURNING FROST-DAMAGE CONTROL	PEST AND WEED CONTROL STUBBLE AND SLASH BURNING SMUDGE POTS	ORGANIC PHOSPHATES, CHLORINATED HYDRO-CARBONS, ARSENIC, AND LEAD SMOKE, FLY ASH, AND SOOT	X			X			X	X	X	
SPRAY PAINTING INKS SOLVENT CLEANING	AUTOMOBILE ASSEMBLY AND FURNITURE AND APPLI-ANCES FINISHING PHOTOGRAVURE AND PRINTING DRY CLEANING AND DEGREASING	HYDROCARBONS AND OTHER ORGANIC VAPORS	X			X			X			X
ORE PREPARATION FUEL FABRICATION NUCLEAR FISSION SPENT-FUEL PROCESSING NUCLEAR DEVICE TESTING	CRUSHING, GRINDING, AND SCREENING GASEOUS DIFFUSION NUCLEAR REACTORS CHEMICAL SEPARATION ATMOSPHERIC EXPLOSIONS	URANIUM AND BERYLLIUM DUST FLUORIDE ARGON 41 IODINE 131 RADIOACTIVE FALLOUT (STRONTIUM 90, CESIUM 137, AND CARBON 41)	X						X		X	

resource-use budgets with prevailing and projected conditions, and the management "alternative-selection" process implied herein would be handicapped without this information—which is compiled primarily from measurements.

WHAT ARE ENVIRONMENTAL ALTERNATIVES?

If the management system is to be totally effective, all possible environmental alternatives for achieving a desired level of quality must be considered. Figure 6 is a generalized diagram of the pollution cycle together with control options that may be exercised at various points in the cycle. Natural forces and societal actions are jointly responsible for most pollutants, but societal actions, through man's manipulations, present the better control point for near-term solution. Emissions are discharged from stationary or mobile sources and enter a natural system of receivers. They are transported and transformed by natural processes and eventually reveal, through man's observation and measurement, the ill effects that degrade the environment. At least four major control alternatives are available along the route:

- Waste-generating activities can be reduced by activities such as increasing the lifetimes of consumer products (thus reducing discarded goods), controlling construction practices (thus reducing topsoil runoff and discarding of demolition material), and modifying recreational habits (thus reducing land abuse).

- Operational efficiency of stationary and mobile emitters can be improved through methods such as burning high-grade coal (thus reducing sulfur dioxide emissions), modifying internal-combustion processes (thus reducing nitrogen oxide and carbon dioxide emissions), and developing more efficient production processes (thus reducing raw-material waste).

- Wastes can be modified or reclaimed by activities such as more efficiently recovering raw materials from industrial wastes, creating new products from used materials (for example, pressed logs from waste paper), and designing products that can be more easily recycled (for example, all-aluminum beer cans).

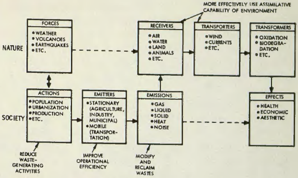


Figure 6. Antipollution-Program Alternatives.

- The assimilative capacity of the environment can be better utilized by developing practices such as artificial reaeration of water bodies to reduce biological oxygen demand problems, regulating the flow of streams so that an effective volume of water is in the stream beds at all times, and controlling the distribution of effluents over spaces and time to attain optimum handling capacities.

Implementation of these options can vary from a simple one-step operation to a complex multistep processing system, such as required by industry. The problems arising from industrial pollution are more complex than those created by other areas, and much of the antipollution war is being waged against industry. This complexity is due to the diversity of processes that a single industry or multi-industrial complex may encompass. Figure 7, an oversimplified closed-loop cycle of industrial inputs and outputs, begins to illustrate the point. Each industrial type generates wastes peculiar to itself and the product it manufacturers. Some

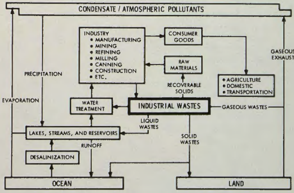


Figure 7. Industrial Cycle.

large processing plants may create hundreds of different waste problems, each requiring a separate solution to meet air, water, and land pollution standards. In any case, a complicated network of equipment may be required to handle the problem.

Figure 8 shows most of the options currently available. Wastes are classified into three basic categories: gases, solids, and liquids. Waste gases may contain liquids and solids, but these are removed in processing (the same is true of solids and liquids). The first step in selecting alternatives is to identify recoverable wastes; the second step is to consider the controls required to modify and discharge nonrecoverable wastes. When waste characteristics are known, available methods and equipment can be assessed leading to the determination of the most technically satisfactory system.

The foregoing discussion outlines only the processing-equipment alternatives of industrial-waste control, which is only a small part of the overall "alternative-selection" process involved in environmental management. However, it does help to define the scope of the management responsibility.

Adding to this scope is the need for a cost/benefit analysis, which must be conducted concurrently with the technical assessments. All benefits cannot be measured in dollar terms, so the costs to achieve different levels of quality must be estimated. Then a value must be assigned to the various increments of increased quality (or benefit). Eventually, program costs can be compared. One straightforward comparison involves the cost of two basic types: the first is damages incurred by users if no control is exercised, the

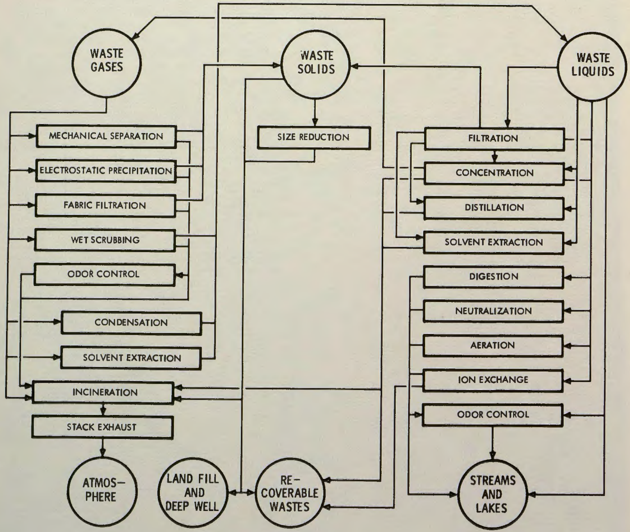


Figure 8. Alternatives for Processing Industrial Wastes.

second is the cost of controlling pollution to prevent damage to the user. Figure 9 shows a simplified relationship of this comparison. Obviously, managment's task is to seek the minimum sum of the two.

So far, we have discussed only the alternatives of reducing pollution. Equally important is the information system required to monitor, measure, and report the environmental conditions. This system also must be tailored for each region and local area. To be responsive, it should not be too complex. A massive monitoring network, for example, may yield a volume of information that could not be used because the costs for data processing, handling, and interpretation would be prohibitive. Average values often must be avoided, since the problem may be local in nature. It would be rather difficult, for example, to convince the local populace that the level of nutrients in the San Francisco Bay-Delta may be at a low relative value, on the average, when the shoreline is covered with foam and algae slime. On the other hand, the value assigned to the source of pollution may be relatively unimportant if the environmental medium can assimilate the pollutant.

Figure 10 shows a generalized equipment-selection rationale to account for these factors.

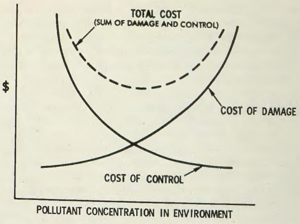


Figure 9. Cost Comparison.

The primary questions are as follows: What quality is desired and what information is needed to make a correlation? Where in the interchange cycle will key measurements be significant? How can these be made? If then follows that equipment must be selected which conforms to prescribed performance specifications. Sensor location, sensitivity, and operational period, or lifetime, are important. State of the art of available equipment and the status of research in the equipment area must be surveyed. It may be necessary to conduct further research and

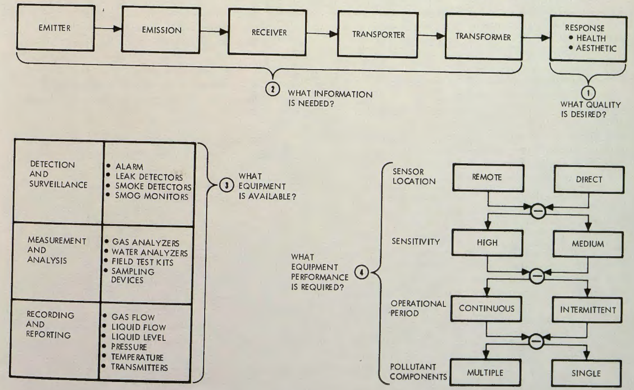


Figure 10. Equipment-Selection Process.

development to fill gaps that may be found in the requirements/availability matrix. In most cases, the management action involved is a major determinant of equipment requirements and availability. Sensitive laboratory equipment may be available to measure the condition of a resource sample, but instrumentation may not be available to detect and monitor the source contaminating that resource.

In addition to the numerous conventional data-collection and transfer devices currently available, technology is providing a host of rather attractive systems and techniques. Examples of these are space, aerial, and terrestrial systems for collecting and transferring data; advanced multispectral sensing equipment for the collection systems; and data collection, transfer, storage, retrieval, interpretation, evaluation, and dissemination systems to provide timely information. Each of these areas warrants separate treatment because of its significance. Here, however, we offer only enough examples to illustrate the potential for overall environmental management.

Remote sensors, operating throughout the electromagnetic spectrum, can economically cover large areas, ascertaining resource conditions not visually discernible. Sensors are available which operate in the ultraviolet, discrete portions of the visible, infrared, microwave, and radar frequencies. Their uses span the gamut of information needs for all types of resources and environmental conditions.

Figure 11 illustrates the use of airborne remote sensing for the detection and surveillance of both thermal and oil pollution off the coast of California. The imagery was obtained with a scanning device operating in the thermal infrared region. Temperature anomalies are distinguishable by gray-scale tone differences. In this case, the light areas indicate that hot water is being discharged into the ocean from a power-generation facility. The dark areas are concentrations of spilled oil that are floating on the surface of the water.

Under development for detecting atmospheric parameters such as water vapor, density, temperature, and distribution of aerosols and particulates is a remote probe using the principle of radar applied to a high-powered pulsed laser. The LIDAR has been used to measure solid pollutants, haze layers, dust clouds, and the rise and diffusion of stack plumes, and to detect and track invisible aerosols. Figure 12 shows typical returns under varying atmospheric conditions.

Another remote sensing device, developed by the Space Division of North American Rockwell to identify resource quality, uses the derivative spectrometry principle. The usefulness of this technique lies in the fact that, in many instances, the derivative spectrum provides a more distinctive identification than does the original spectrum. Figure 13 shows an example of reflectance as a function of wavelength for both the original analog signal and its first derivative.

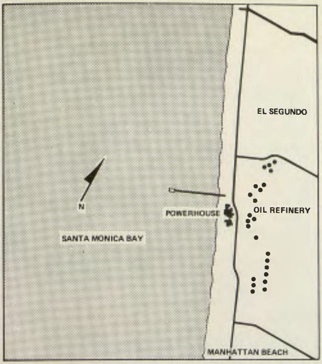
An in situ device for measuring and monitoring pollution loads in rivers and streams has been developed by the Rocketdyne Division of North American Rockwell for the FWPCA. Named the Pyrographic Organic Analyzer, it is capable of quantitatively and qualitatively analyzing the total organic content of water. Such analyses can be used to identify pollution sources.

A total listing of candidate equipment would be quite lengthy and is beyond the scope of this discussion. Suffice it to say that this phase of the management cycle will require extensive investigation and analysis to effectively utilize the broad, ever-advancing technology available for the solution of environmental-quality problems.

SUMMARY

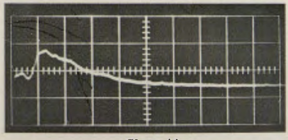
A program to restore our environment has been started, but the path on which we are embarked appears to be the wrong one. We must change this approach and establish a long-range plan that will lead to an effective solution of the total environmental-quality problem. We must manage the entire problem by:

- Treating the major elements (air, land, and water) as a total system
- Identifying and assessing environmental-quality problems at their source
- Establishing regional agencies to deal with problems within the natural boundaries of their source.
- Determining desired quality level for each region
- Establishing and updating the standards required to assure the desired quality
- Identifying the possible alternatives for meeting the standards

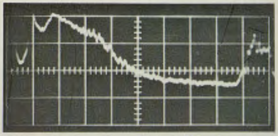


8-14μ (thermal) infrared daytime scanner imagery of El Segundo, California coastline. Anomalies shown include *hot-water discharge from power plants; oil spills from loading dock.*

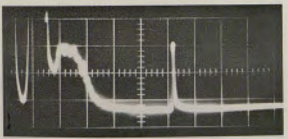
Figure 11. Remote Detection of Pollution.



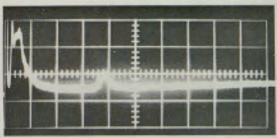
Clear Air



High Cirrus Clouds



Cloudy Haze



High, Thin Overcast

Figure 12. Typical LIDAR Backscatter Display.

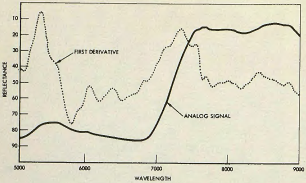


Figure 13. Derivative Spectrometer Output.

- Determining the cost/benefit relationship for each alternative
- Selecting the best alternative that will provide the desired quality
- Determining the action necessary to implement the best alternative
- Monitoring and controlling to assure that quality standards are met

Pessimists argue that no plan, even if implemented today, can save our environment. The authors do not share that opinion. We do have a choice in what happens to our environment. However, we must put ourselves in a position to view the total picture before making decisions. No longer can we afford the luxury of tentative and piecemeal approaches to the problem. Pollution of our environment is massive, and nothing less than a total, integrated, system-management program can turn it back. The natural resources at stake are not unlimited...nor is the time remaining for us to act.