AN EVALUATION OF ENVIRONMENTAL PROBLEMS ASSOCIATED WITH LOCAL DECISION-MAKING: A CASE STUDY OF MARSHALL LANDFILL, BOULDER, COLORADO

by

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ABSTRACT

In this thesis the incorporation of environmental quality variables into decision-making is examined in light of a case study. The focus is on how Boulder County, Colorado has responded to ground-water contamination resulting from a solid waste landfill within its jurisdiction. A descriptive model of environmental decision-making is developed and is used to analyze the major decision points which Boulder County faced during nearly twenty years of operations at the landfill. Three major criteria which affect environmental decision-making are analyzed. These are: the conflict between technical and institutional decision-making; the incremental nature of scientific decision-making; and the gap between an environmentally oriented decision and its implementation. It is shown that the incorporation of environmental quality variables into local government decision-making is many-faceted.

CHAPTER 1

INTRODUCTION

The management of solid waste has historically been a local government responsibility. Cities and counties have exercised this responsibility by designating sites for landfill operations, setting guidelines for the activities, and either contracting out or conducting the landfilling themselves.

In recent years the state and federal governments have become involved with solid waste management in response to environmental problems. With the Resource Conservation and Recovery Act of 1976 (P.L. 94-580) and the Solid Waste Disposal Act Amendments of 1980 (P.L. 96-482), the federal government published guidelines for sanitary landfilling of solid wastes and also encouraged states to do so. None of these acts, however, supersedes the local role.

The increasing involvement of the federal government in waste management problems is strongly related to the growth in scientific knowledge regarding the mechanics of landfill operations. This learning process has come in great part from the identification of failures at waste management sites (for examples, see Montague, 1982). The failures include the host of environmental problems associated with landfilling: leachate generation and consequent surface and groundwater contamination, methane generation and associated explosion

hazards, and accumulation of small quantities of hazardous waste with their potential for release into the environment.

This thesis will examine a local government's response to the environmental threat posed by improper sanitary landfill operations. It is hoped that such an analysis will shed light on the difficulties experienced by cities and counties in incorporating environmental quality concerns into what were formerly considered to be routine governmental decisions.

The focus of this thesis is on solid waste management at Marshall Landfill in Boulder County, Colorado. Originally, the site was an open dump used by county residents. Later, in 1965, it was officially designated as the county landfill. Since then, two expansions of the disposal operations have been permitted.

Environmental problems due to waste disposal at the site were first noted in 1975 when leachate was seen issuing from the toe of the landfill. Subsequent water quality investigations showed that both alluvial ground water and surface water were being contaminated from the leachate. Methods to collect and hold the leachate were undertaken. However, today the leachate is still in large part uncontrolled.

Although the landfill has been privately managed, Boulder County has regulated the operations, using such mechanisms as solid waste regulations, inspections, the site designation, and permits to expand the operations. Between 1965 and 1983, the County learned a great deal about landfill management. As this knowledge increased, the

County attempted to incorporate it into its management of the landfill in order to control the leachate problem.

A Model of Environmental Decision-making

Many factors may input to the process of local environmental decision-making. These factors include, but are not limited to, economics, public awareness, local politics, scientific knowledge, the media, other levels of government, local legislation, and the capabilities of government staff. Figure 1 shows schematically how these factors may input to an environmental decision and, in some instances, to an environmental problem.

Granted that an examination of all of these factors within one model would be extremely useful, such a model would be quite difficult to develop and cumbersome to use. As a first approach to describing environmental decision-making, this thesis will examine three of the inputs shown in Figure 1 by the boxes with the broken lines. These inputs are scientific knowledge, local legislation, and staff. The purpose of examining these three inputs is to describe how the structure of the local government, coupled with scientific knowledge, responds to environmental problems.

While also important as inputs to environmental decision-making, the other factors shown in Figure 1 are outside the governmental bureaucracy itself. They may input to the process of decision-making in many ways, such as in initiating the process or decreasing the time needed to reach a decision.

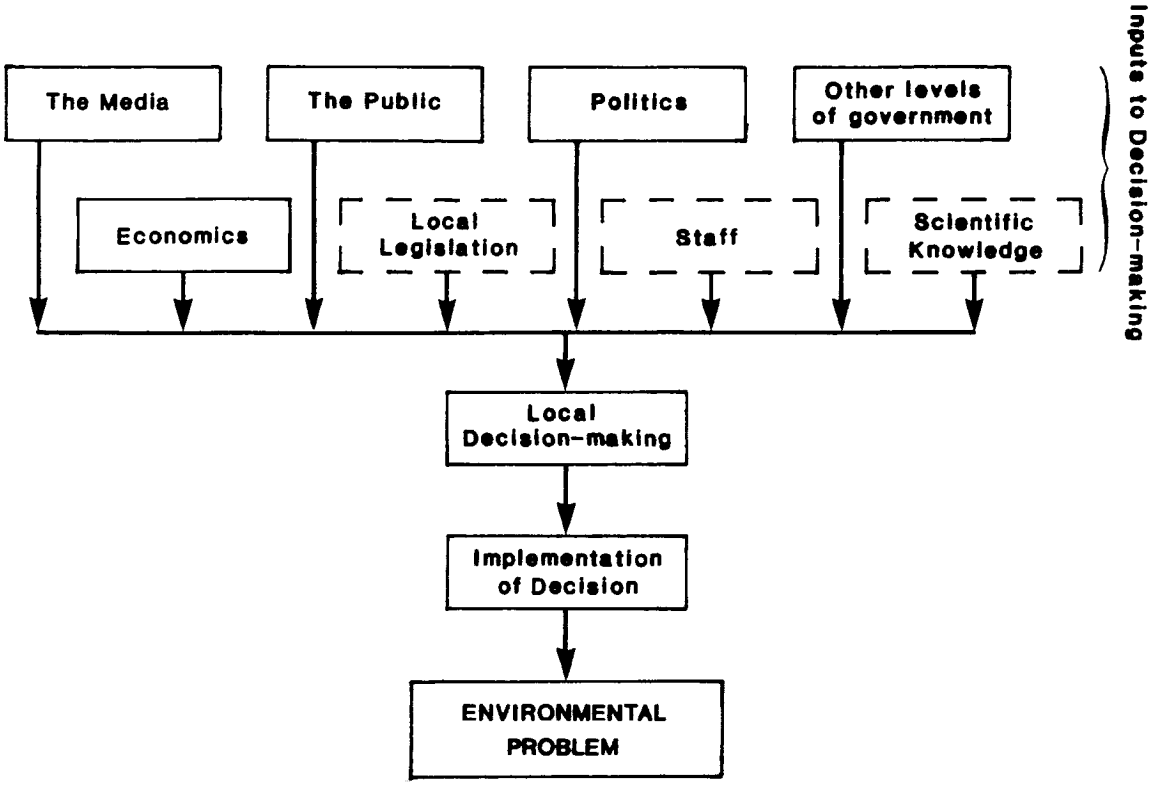

Figure 1. A Model for Evaluating Environmental Problems.

There are few descriptive models of local environmental decision-making. The inclusion of environmental quality variables in local decision-making has been examined, but generally in terms of media other than solid waste management. Some examples include sewage treatment and disposal (O'Riordan and O'Riordan, 1972), water quality planning (Menzel and Williams, 1978), floodplain management (Woodward-Clyde Consultants, 1979), and air quality planning (Bormann, 1982).

Several key criteria emerge from a review of these and other studies on local environmental decision-making. Together they form a conceptual model describes some of the inputs to local environmental decision-making. These criteria will be used in examining this case history.

Conflict between technical and institutional decision-making. Petak (1980) describes the differences betwen technical and institutional/planning aspects of environmental decision-making. His aim is to develop a better understanding of how to integrate these two approaches into effective environmental management. He characterizes the technical approach as classical scientific problem solving: focusing on a specific task, dealing quantitatively and objectively with variables, and using quantitative tools for analysis. On the other hand, the institutional/planning approach tends toward a holistic focus on decision-making, taking into account uncertainty, qualitative and subjective variables, and attempting to use multi-attribute decision analysis. The technical decision would affect, for example, a physical plant operations, while the institutional/planning decision

would focus on policy options of agency interrelationships. Petak also contrasts the two approaches as the differences between deductive-based and inductive-based models. The traditional technical approach (deductive) uses present or past data to forecast trends, while the institutional/planning approach (inductive) takes a more normative view and starts with desired alternative futures and works backward to a present decision. Because environmental knowledge is constantly increasing, Petak suggests that technical decisions must be incremental. The integration of technical and administrative decisions must lead to "living" plans.

O'Riordan and O'Riordan (1972) studied the incorporation of environmental quality variables in what had been a routine administrative function, sewage treatment and disposal. They note that once a situation has become sufficiently serious to pose an environmental problem, it is generally too late for the existing institutions and policies to correct it. They also discuss the conflict the decision-maker faces when confronted by both technical opinion and non-technical, often emotional, public opinion. In some instances this conflict arises betwen technical and administrative agencies within a local government.

On this latter aspect of conflict between technical and administrative agencies, Doerksen and Lamb (1979) write that one important element in decision-making is the bargaining among different agencies. They suggest that in most cases interagency decision-making involves "more coordination and adjustment than analysis."

Incrementalism as a necessary aspect of environmental decision-making. In planning terms, incrementalism has been described as a "piecemeal" approach characterized by adjustments of objectives to policies, and involving serial analysis and evaluations of issues (Faludi, 1973).

Because environmental knowledge is constantly increasing, many studies have viewed environmental decision-making as necessarily incremental (Doerksen and Lamb, 1979; Menzel and Williams, 1978; Petak, 1980; Woodward-Clyde Consultants, 1979). As technologies improve and environmental problems are better understood, new approaches in management are required.

Doerksen and Lamb (1979) studied the decision-making arena for the allocation of water for instream uses. They characterize decision-making there as "successive limited comparisons--incrementalism." Additionally, they write:

> The decision-maker is most likely to make decisions which are within his means. That is, he will decide for the short term based on his experience with past policy options. New laws do not change an entire set of past decisions, for in most cases the old precedents are in effect "grandfathered" in. Changes are only minor additions to all that has happened (Doerksen and Lamb, 1979: 1710).

Petak (1980) describes technical decision-making as incremental, and contrasts it to the planner's more holistic style. He stresses the need to integrate these two traditional approaches in order to develop an effective public policy in environmental areas.

In a study of floodplain management, Woodward-Clyde Consultants note that the adoption of land use controls at the local level was

incremental. As more information was furnished to the community, land use controls became more specific.

Menzel and Williams (1978) moves beyond a simple incremental approach to environmental decision-making. In a study of water pollution control laws on a state level, they observe that there is a significant difference between environmental decision-making and traditional American policy making. The latter is charcterized by incrementalism which allows policy to develop "in tandem with technical knowledge, legislative and executive support, political advantage, and presumably greater certainty concerning the impact of a particular choice." In environmental decision-making, Menzel and Williams see an "escalation" factor. This type of policy exhibits "quantum leaps." They attribute this to a recent trend in overly optimistic decisions that have typified environmental activities. As a result of these giant steps in policy making, Menzel and Williams see a threefold impact: (1) efforts to reconcile environmental realities with escalated policies may result in setbacks to the environmental movement; (2) policy may be readjusted to reflect real world capabilities; and (3) frustration and disillusionment may result if little improvement is made toward readjusting escalated policies to environmental capabilities.

Gap between decisions and implementation. Implementation is the work done in a community to carry out an environmental decision.

Menzel and Williams' (1978) theory on the recent trends toward policy escalation in environmental areas defines problems associated with the gap between policy and implementation. They suggest that this

may be due to a lack of technical knowledge and/or an extreme economic burden required for implementation.

Woodward-Clyde Consultants (1979) carry Menzel and Williams' work further and examine how the gap between policy and implementation is bridged. They note that the capacity to implement a specific environmental policy depends on several resource and institutional factors. Their resource factors are primarily human-oriented: (1) the presence of local engineers and planners; (2) the educational level of staff; (3) the number of people who have technical expertise and use it as a main job; (4) comprehensive community plan; and (5) environmental legislation. Their institutional factors include: (1) whether other building codes are in effect; (2) whether other land use controls are in effect; and (3) the degree to which those workers involved in implementation can predict the outcomes.

These three criteria--the conflict between technical and administrative decision-making, incrementalism in environmental policy, and the gap between policy and implementation--constitute the conceptual model for this analysis of local government response to environmental threat.

Research Objectives

This research has two general objectives. The first is to present the history of environmental decision-making at the Marshall Landfill. The second is to examine the usefulness of the model in explaining what occurred.

Study Methods

This analysis is an historical case study of how a county government has responded to the threat of ground-water contamination. Specifically, it will look at how Boulder County, Colorado handled the original designation and subsequent permitted expansions of the county sanitary landfill, Marshall Landfill.

A case study is a useful method to evaluate the interaction of the aforementioned criteria both over time and in terms of one specific problem. It also helps to understand the county reaction to environmental degradation.

The plan of study included the following steps:

1. Examination of the public record from 1965 to 1983 to learn what policy decisions were made.
2. Review of the technical documents on the landfill to describe the hydrogeologic characteristics and to define the environmental problem.
3. Comparison of the level of knowledge at each decision point with the outcome of each decision in order to assess changes in environmental decision-making.

The public record on the Boulder County landfill consists of letters, memos, reports, technical documents, inspection reports, and photographs available in county, state, and federal agency files. The documentation was quite extensive for most of the landfill history. It shows that the county has been aware of the conditions at Marshall for many years.

The technical reports on the landfill are also extensive, yet not very comprehensive. The requests to expand the landfill tended to generate a flurry of reports. However, these focused on specific aspects of the landfill operation, rather than on the overall environmental suitability of the landfill site.

At several times between 1965 and 1983, the County made major decisions affecting Marshall Landfill. The landfill received special use permits to expand on two occasions. Several actions were initiated to enforce compliance with these permits. These decision points are the key areas for this analysis.

Organization

Information about sanitary landfilling, the physical environment of Marshall Landfill, and the nature of the environmental threat is presented in Chapter 2. This includes a definition of sanitary landfilling, the importance of proper location, the site characteristics at Marshall, and the determination of the environmental problem.

Chapter 3 covers the site history, describing County activities in response to site management, and the technical reports prepared over the years for the landfill operation. This history covers nearly twenty years of operation with five different operators.

Chapter 4 presents an analysis of the data based on the three criteria described in the model: (1) the conflict between technical and institutional elements; (2) the incremental nature of environmental decision-making; and (3) the gap between decision-making and implemen-

tation. The major decision points which the County faced will be analyzed based on these criteria.

Conclusions from this study are presented in Chapter 5.

CHAPTER 2

LANDFILL SITING AND ENVIRONMENTAL CONSEQUENCES

This chapter provides background material for the case study. First, aspects of sanitary landfilling pertinent to this case study are described. These include the consequences of improper siting and poor management, and the requirements of an environmentally sound site. Second, the physical characteristics, including topography, geology, and hydrology, of the Marshall Landfill site are presented. Third, current knowledge and the gaps in knowledge about the environmental threat are discussed.

Sanitary Landfilling and Site Considerations

Definition

A sanitary landfill is an engineering method of disposing of solid wastes on land. The operation involves the spreading of wastes in thin layers, compacting them to the smallest practical volume, and covering them with soil each working day in a manner that protects the environment (Brunner and Keller, 1972) (Figure 2).

A landfill is usually less expensive than other waste management technologies, such as incineration. However, landfilling should only be used if it is an environmentally sound option--when it is the least environmentally damaging of the waste management options available and where the proper hydrogeological conditions are present. In

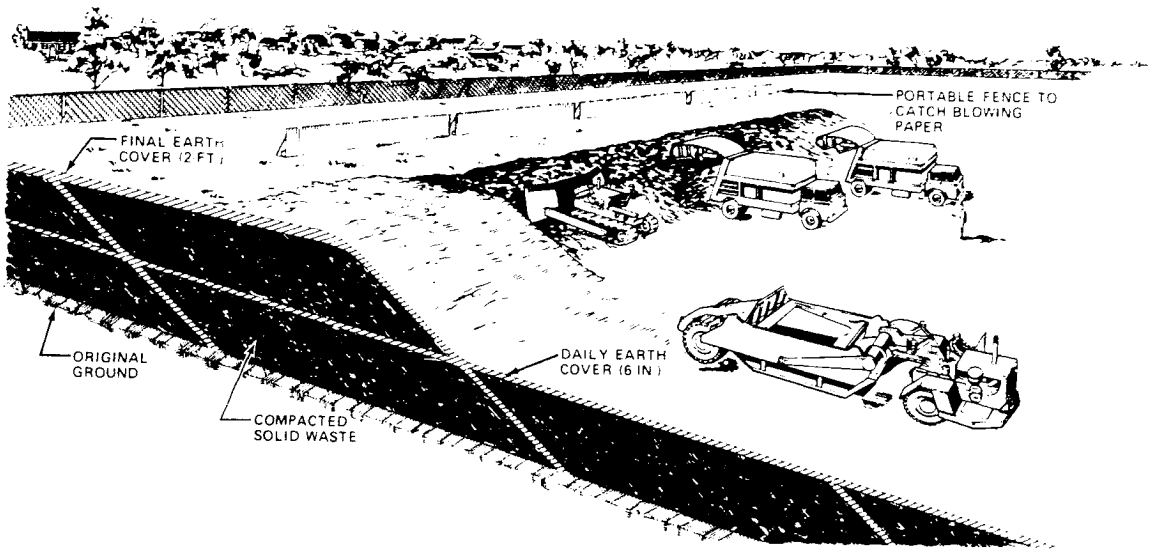

Figure 2. Design of a Sanitary Landfill (after Brunner and Keller, 1972).

addition, a landfill should not receive wastes that contain freestanding liquids (Conservation Foundation, 1983).

Proper planning and management at all stages, including site selection, design, operation, and completed use, are needed to achieve a successful sanitary landfill that will minimize the environmental impact. To understand what constitutes suitable conditions for siting and operating a sanitary landfill, it is first necessary to understand how solid wastes decompose. This involves the variables that affect the decomposition rate, the decomposition products, and how these may affect the surrounding environment.

Consequences of Sanitary Landfilling

Solid wastes deposited in a landfill degrade chemically and biologically to produce solid, liquid, and gaseous products. Some of the factors that affect degradation include the heterogeneous character of the wastes, their physical, chemical, and biological properties, the availability of oxygen and moisture within the fill material, and temperature (Brunner and Keller, 1972).

There are two significant products of solid waste decomposition--leachate and gas generation--both of which should be considered in the selection of a site for sanitary landfill.

Leachate. Leachate is a solution containing dissolved and finely suspended solid matter and microbial waste products. It is produced when ground water or infiltrating surface water moves through the fill material (Brunner and Keller, 1972). Leachate may move off the site to the ground surface as a seep, or it may percolate through

the soil and rock surrounding and underlying the landfill and eventually contaminate an aquifer.

The composition of the leachate is important in determining its potential effects on the quality of nearby surface and ground water. Contaminants carried by leachate depend on the types of wastes deposited within the landfill. Leachate from a landfill containing industrial liquid wastes may contain contaminants that seriously degrade nearby waters. Therefore, the hydrogeologic characteristics of the area surrounding the landfill and nearby water bodies are important to consider in selecting a site.

Leachate is not produced until all of the sanitary landfill, or a sizable portion of it, becomes saturated by water entering it from outside. It is, therefore, extremely important that sources of water, precipitation, surface runoff characteristics, evapotranspiration, and the location and movement of ground water in relation to the solid waste, be considered in selecting a site (Brunner and Keller, 1972).

Gas generation. Gas is produced naturally when solid wastes decompose. The quality generated and its composition depend on the types of wastes that are decomposing in the landfill. Methane and carbon dioxide are the major constituents of landfill decomposition gas (Brunner and Keller, 1972).

The potential movement of gas is an important element when selecting a landfill site. Methane can migrate to a nearby structure and explode. Mineralization of ground water can occur when carbon dioxide dissolves and forms carbonic acid. Factors to consider when

evaluating the gas generation hazard are the gas permeability of the soil and the location of nearby residences or industrial buildings.

The movement of landfill gas can be controlled. Construction of impermeable barriers around the fill materials and venting the gas can reduce the hazard to nearby buildings and to future uses of the site.

Site Selection

The adverse consequences described above that result from solid waste decomposition are leachate generation with its potential to contaminate surface and ground water, and gas movement with its associated explosion hazard. A knowledge of these consequences can aid in the designation of suitable landfilling sites.

A major consideration in selecting a site is the hydrology of the area. To a large extent, the hydrology will determine whether the formation of leachate will cause a problem of water contamination.

An appropriate site for a landfill should minimize, to the extent practical, the introduction of water into the fill material. For surface water, this is usually done by: (1) diverting upland drainage; (2) grading and sloping the daily and final covers to allow for runoff; and (3) decreasing the permeability of the cover material. In addition, surface water courses should be diverted away from the landfill, and the landfill should not be sited in flood-prone areas (Brunner and Keller, 1972).

It is important that ground water not be allowed to mix with solid waste. The first approach to achieving this is to separate

ground water and fill material by a specified distance. This distance is dependent on site characteristics, and this would vary from one locale to another. It should be based on such factors as: (1) the permeability of the underlying soils; (2) the depth to ground water; (3) current and projected use of the water resources of the area; (4) effect of leachate on ground-water quality; (5) direction of ground-water movement; and (6) interrelationship of this aquifer with other aquifers and surface waters in the area. In addition to these considerations, an impermeable liner may be used to control the movement of fluids, either out of the landfill or into the fill. Liners of both compacted natural clay soil and synthetic materials have been used. Another method is to lower ground-water levels surrounding the landfill by using drains, canals, and ditches to intercept ground water and to channel it to another area such as surface water or a recharge area that has a lower elevation than the landfill (Brunner and Keller, 1972).

In summary, a sanitary landfill is a method of disposing of solid wastes on land. The decomposition materials that result from sanitary landfilling are important considerations in site selection. In order to minimize leachate generation and migration, the fill material must be kept as dry as possible. Therefore, surface drainage and adequate soil cover are needed to prevent water from infiltrating into the fill. Potential mixing with ground water can be minimized by keeping the fill well above the ground-water level and by using liners and drains to reduce ground-water movement into the fill.

The decomposition gas is controlled by impermeable barriers around the fill material and by venting the gas to the atmosphere.

Physical Characteristics of Marshall Landfill

Because of the proximity to surface and ground water, the Marshall Landfill site is environmentally unsuitable for sanitary landfilling. In this section, these and other physical characteristics of the location will be presented.

Marshall Landfill is in the southeastern portion of Boulder County, Colorado (Figure 3). It is approximately one-quarter mile east of Marshall Lake, two miles west of Superior, and three miles southeast of the City of Boulder. The landfill comprises the West/4 of Section 23, Township 1 South, Range 70 West.

The landfill consists of an active and an inactive site, each of which covers 80 acres. The inactive site was operated from 1965 to 1974. It is bisected from west to east by Community Ditch, an unlined irrigation and public drinking water supply ditch. The active site, immediately south of the inactive portion, has been in operation since 1974.

The area surrounding the landfill is rural and is primarily used for cattle grazing. Two exceptions are the National Center for Atmospheric Research (NCAR), which stores research equipment on a parcel of land east of the active portion, and Superior Products, which operates a recycling and salvage operation to the north of NCAR and east of the inactive portion. To the west is Marshall Lake, a reservoir operated by the Farmers Reservoir and Irrigation Company

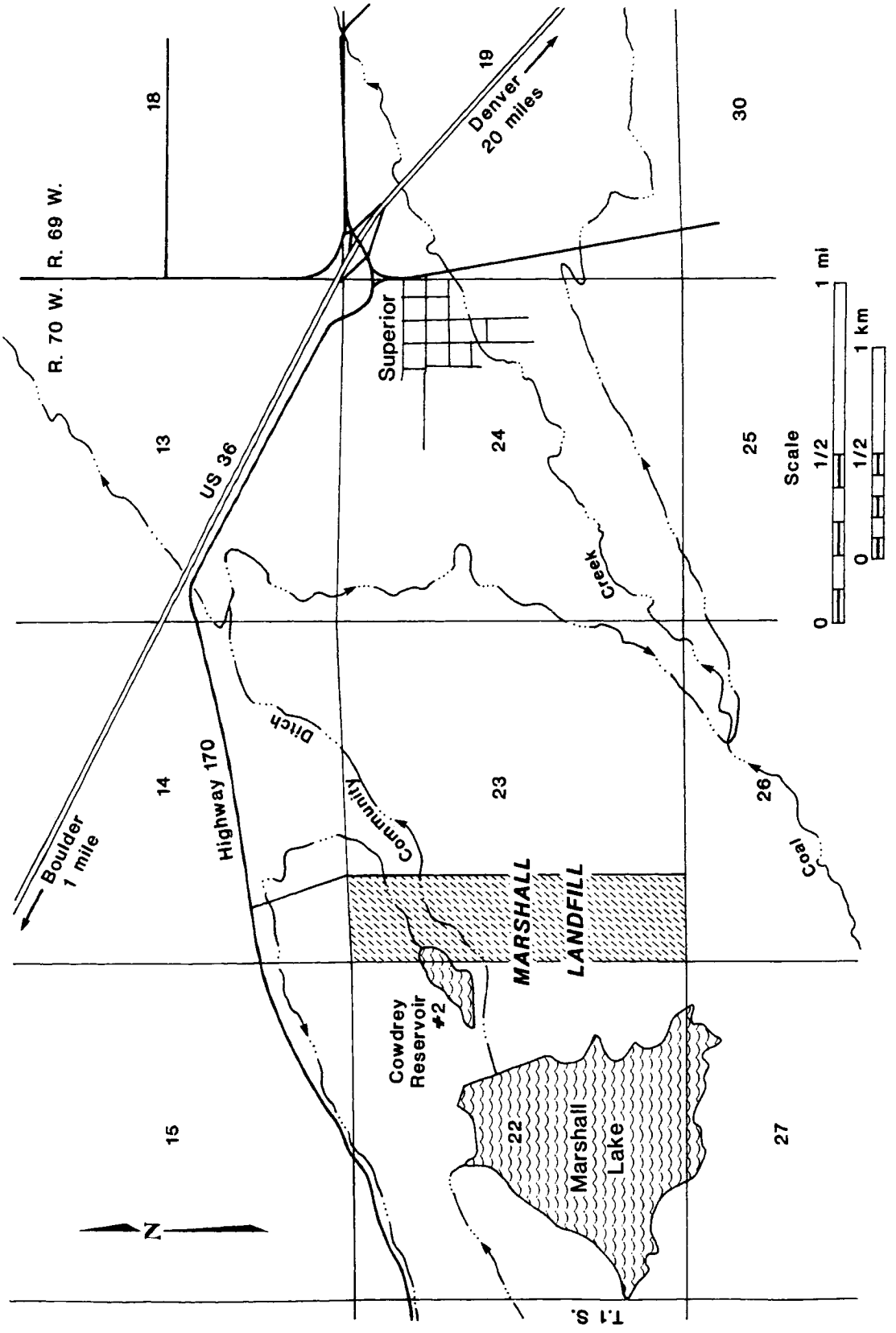

Figure 3. Marshall Landfill Location Map.

(FRICO), which stores irrigation and municipal drinking water. The property around the lake is used for recreational purposes by members of the Louisville Rod and Gun Club.

Surface Water Drainage

Surface water runoff from the landfill is diverted to the Marshall Lake drainage system, which is comprised of Marshall Lake, Cowdrey Reservoir No. 2, Community Ditch, and Davidson Ditch (Figure 4). Surface water runon is generally diverted by South 66th Street; from the south it is diverted west to Marshall Lake; and from the west it flows into Marshall Lake or north to Community Ditch (Black & Veatch Engineering-Architects, 1983).

Runoff from precipitaton falling directly on the active site flows north or northwesterly into Community Ditch. Runoff from the inactive portion south of Community Ditch flows either into two lagoons immediately south of Community Ditch or into Community Ditch. Runoff north of Community Ditch flows either into Cowdrey Reservoir No. 2 or into Davidson Ditch (Black & Veatch Engineering-Architects, 1983).

Water released from Marshall Lake flows via Community Ditch across the inactive portion from west to east. Water may also be diverted just below the Marshall Lake outlet to Cowdrey Reservoir No. 2. Community Ditch carries water to farmers and municipalities owning water rights in FRICO. When the City of Louisville needs water, supplies are diverted from Community Ditch at a point approximately one mile east of the landfill into Louisville Diversion, which empties into Louisville Reservoir. Other communities, including Boulder and

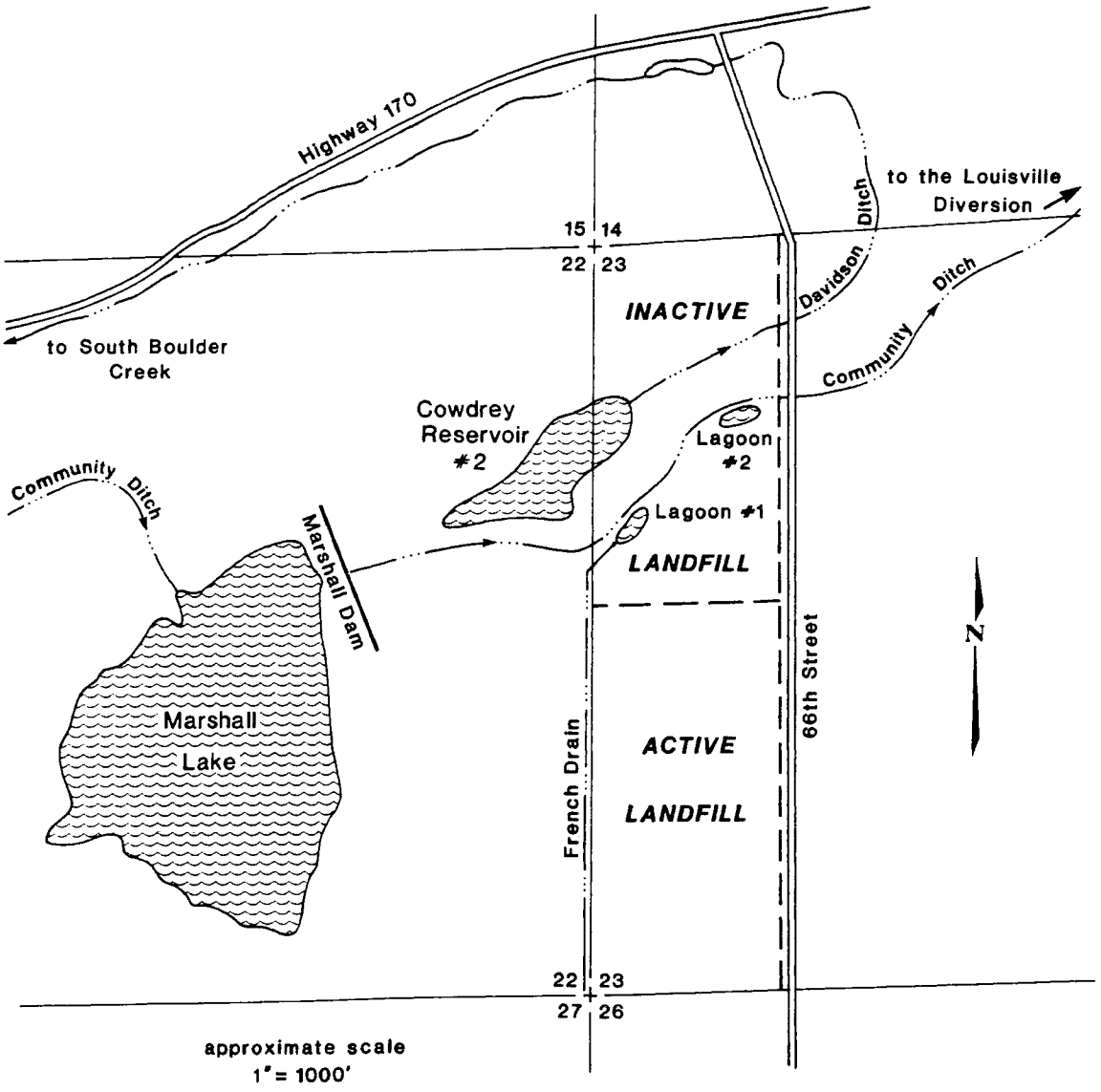

Figure 4. Marshall Landfill Site Details.

Lafeyette, have water rights on Community Ditch, but have not exercised these rights for many years (Farmers, 1982).

Geology

Marshall Landfill lies near the western edge of the Colorado Piedmont section of the Great Plains physiographic province. The area near the landfill consists largely of northeast trending mesas that have a local relief of 100 to 300 feet. The site is on Lake Mesa. At the landfill, the topography varies from approximately 5,730 feet at the southern end of the active portion to approximately 5,620 feet along Davidson Ditch in the central part of the inactive portion.

Unconsolidated fill material overlies the bedrock at the site and varies in thickness from 40 feet on the eastern edge of the active portion to less than 10 feet in other areas. The fill material is composed of terrace and alluvial deposits of gravel, sand, silt, and clay-size sediments that are generally poorly stratified (Fox Consulting Engineers and Geologists, 1983).

The bedrock formations that outcrop at the site are the Laramie and the Fox Hills formations. The Laramie formation overlies the Fox Hills and has two parts. The upper part consists largely of shales interbedded with siltstone, sandstone, and coal. The lower part is composed of sandstone and is approximately 100 feet thick and water-bearing in the vicinity of the site (Spencer, 1961).

The Fox Hills formation is composed of fine- to coarse-grained, slightly calcareous sandstone. The formation is roughly 140 feet thick in the vicinity of the landfill. It is a major drinking water aquifer

for rural areas of Boulder County. Because of the similarities between the lower sandstone unit of the Laramie formation and the sandstone of the Fox Hills, the units together are named the Laramie-Fox Hills aquifer (Spencer, 1961).

Two high-angle, northeast trending faults called the Crown-Davidson and the North Lake Mesa exist beneath the unconsolidated material at the site. As a result of the faulting, the Fox Hills formation subcrops beneath the site, as shown in Figure 5. The Fox Hills aquifer is the uppermost bedrock unit beneath the southern part of the inactive portion and the extreme northern part of the active portion. Figure 5 also shows the general subsurface geology and the locations of the faults.

Ground Water

Ground water exists beneath the site in the landfill material, in the unconsolidated materials, and in the Laramie-Fox Hills aquifer (Glaze, 1983).

Ground water in the unconsolidated sediments and landfill material flows north-northwesterly through the active portion into the inactive site. The ground water surfaces at different locations in the inactive site: (1) just south of and upgradient to Community Ditch (as seepage); (2) into Community Ditch; and (3) into Cowdrey Reservoir No. 2 and Davidson Ditch. Two lagoons on the inactive portion just south of Community Ditch serve to collect much of the surface seeps from that area. Shallow ground water in the unconsolidated sediments probably

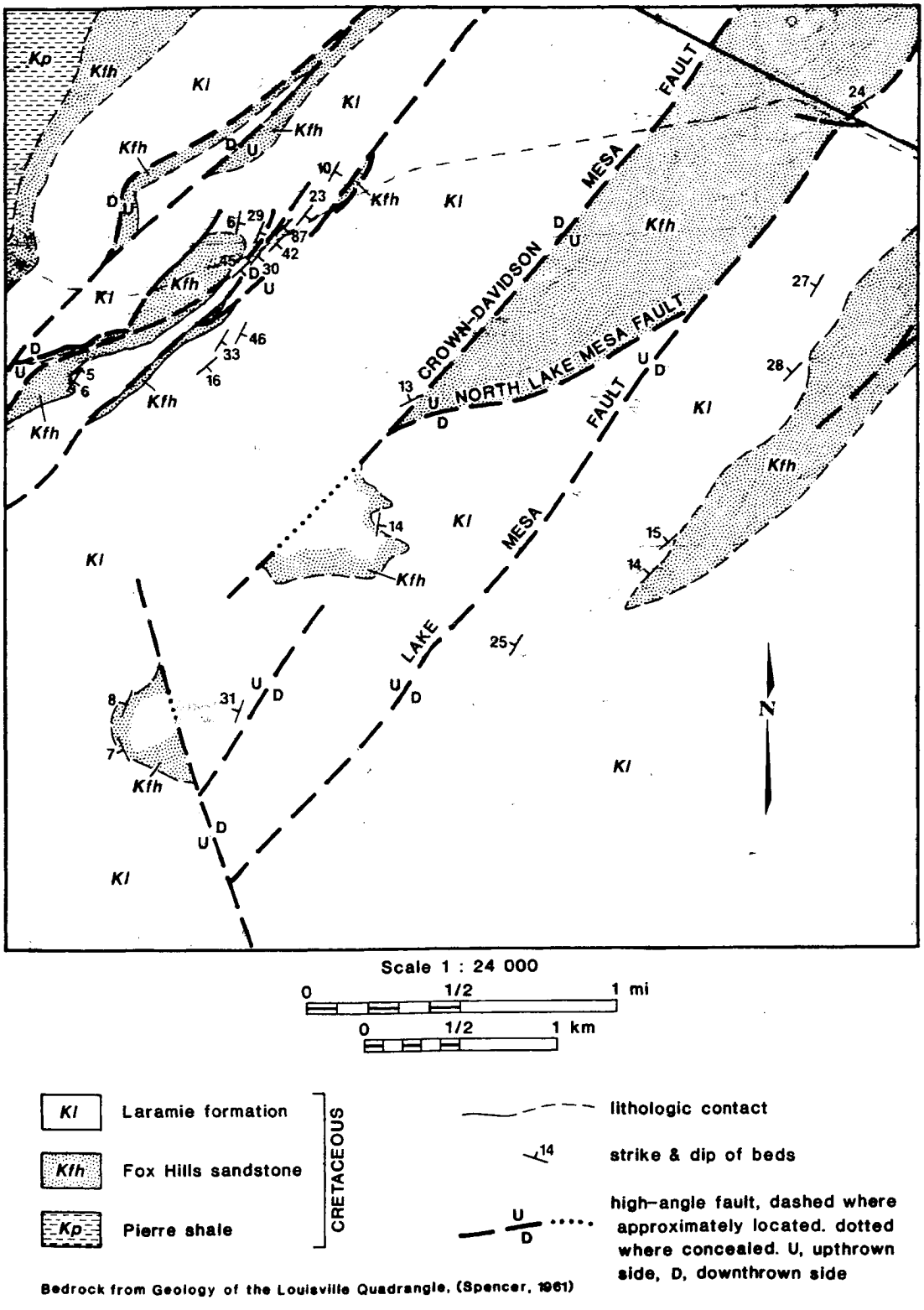

Figure 5. Marshall Landfill Geology and Fault Locations.

flows out of the site in a northeasterly direction along Davidson Ditch (Glaze, 1983).

Available geologic log information indicates that the movement of the shallow ground water, at least in part, is controlled by the upper bedrock surface of the Laramie formation. This is the base for most of the landfill (Figure 5). The Laramie consists of layers of clay, shale, and coal materials that characteristically have very low hydraulic conductivities and, therefore, act to retard vertical ground-water movement. Geologic information indicates that this upper bedrock surface slopes to the north over the active site. North of Davidson Ditch, however, the bedrock surface appears to reverse its slope. This reversal could explain seeps that have been observed north of Davidson Ditch (Black & Veatch Engineering-Architects, 1983).

Recharge to the shallow ground water occurs from infiltration and percolation of precipitation and from the movement of shallow ground water from the south. Shallow ground-water recharge also could be coming significantly from the west, influenced by Marshall Lake, and, to a lesser extent, from the southeast (Wells, 1980a). In 1979 a clay tile French drain was constructed along three-quarters of the western edge of the active portion and one-quarter of the inactive portion. It was designed to intercept shallow ground-water flow onto the landfill from the west (Marshall Lake). Samples taken from this drain in two places in March, 1982, show that the drain water contains compounds similar to those found in the landfill leachate. Therefore, the drain is collecting water from the landfill as well as intercepting ground-water flow from the west to the landfill. The amount of

recharge coming from the west is probably dependent on both the French drain and the elevation of Marshall Lake, which varies considerably (Bohlender, 1982).

Ground-water flow in the bedrock at the site has not been studied. As a result, the influence of the two faults on ground-water movement (either as barriers or aids to flow) and the potential for direct percolation of leachate into the underlying Fox Hills aquifer are unknown.

This section has summarized the physical characteristics of the location of the Marshall Landfill. The site is in close proximity and upgradient to surface water in Community Ditch and Cowdrey Reservoir No. 2. In addition, the hydrogeology of the site is complex. Due to faulting, a drinking water aquifer, the Fox Hills, subcrops beneath the site. Shallow ground water surfaces in the northern part of the site along Community Ditch, Cowdrey Reservoir No. 2, and Davidson Ditch. Ground-water movement in the bedrock has not been studied.

Determination of the Environmental Threat

The environmental threat posed by Marshall Landfill is the present contamination of surface and ground water and the potential for migration of this contamination. The determination of the extent of this threat has been problematic due to a lack of full investigation of the problem. This section will describe what is presently known about the nature and extent of the contamination and what data is still needed for a complete understanding of the environmental threat from the landfill.

Environmental concern at Marshall Landfill has historically focused on the contamination of both surface and ground water, including the shallow alluvial and deeper bedrock aquifers. Although a complete investigation has not been done, areas that need to be considered are: (1) contamination of the Laramie-Fox Hills aquifer from direct percolation of landfill leachate; (2) surface water contamination from leachate seepage into Community Ditch; and (3) users of ground water and surface water in the vicinity.

The shallow ground water beneath the site presently exhibits elevated levels of inorganic and organic contaminants, primarily volatile organics and metals. Monitoring wells along the boundary between the active and the inactive portions, the French drain, a monitoring well in the inactive portion, numerous seeps, the two lagoons, Community Ditch, and Cowdrey Reservoir No. 2 have all shown varying levels of contaminants. These include 1,2-dichloroethane, toluene, methylene chloride, 1,1,1-trichloroethane, dichloroethylene, tetrachloroethylene, and trichloroethylene (Glaze, 1983).

The sampling was done over a period of four years. However, due to the lack of coordinated planning and the multiplicity of investigators (federal, state, local, and private), the sampling was conducted at different locations using different parameters. As a result, it is difficult to assess, at any one point in time, the overall quality of ground water in the landfill.

Another problem of determining the environmental threat has been the lack of documentation on the local use of the shallow ground

water. Off-site shallow wells have not been sampled to ascertain migration of the contamination.

Furthermore, the hydrogeologic relationship of the saturated landfill material to the underlying Fox Hills aquifer is not known. The Fox Hills formation in the vicinity of the landfill is a confined aquifer. A deep well at the nearby Superior Products site, drilled through the Laramie into the Fox Hills, is artesian. A regional peizometric map for the Fox Hills shows a ground-water low at the landfill site (Robson et al., 1981). This may correspond to either a recharge or a dischage zone for the formation beneath the landfill. In addition, the influence of the two faults, the North Lake Mesa and the Crown-Davidson, on ground-water movement in the Fox Hills aquifer is not understood. Both of these processes need to be studied to understand the potential for contaminant migration.

At the present, it is not known whether the Fox Hills is contaminated. No monitoring wells have been drilled into the Fox Hills aquifer where it subcrops at the landfill. Private wells nearby have not been sampled for the compounds of concern. Because the ground water in the Fox Hills serves as a drinking water source for many rural areas in Boulder County, including rural areas of Boulder, Superior, and Louisville, information on how this aquifer may have been impacted by the landfill is needed.

Along with the ground-water issues, the threat to surface water users has not been adequately defined. The water in Community Ditch has been analyzed as far downstream as the Louisville reservoir (approximately three miles). Samples taken in 1980 did not detect any

contamination at the point the water reached the reservoir. As a result, the state epidemiologist declared Louisville water safe to drink (Kreiss, 1981). However, this decision is currently being re-evaluated, as Louisville plans for both increased use of Community Ditch water and a closer intake plant (Mathews, 1982).

This section has described many of the data gaps which must be filled for a complete determination of the environmental threat at Marshall Landfill. Although the extent of on-site shallow ground-water and surface water contamination has been described, the migration of the leachate beyond the site and the threat to water users still requires study.

Summary

This chapter has identified the importance of the physical setting in landfill operations, the unsuitability of the Marshall site for a landfill, and the complexities involved in defining the nature and extent of an environmental threat.

The first section of this chapter stressed the need for a landfill site where the fill material is isolated from surface and ground water. Leachate generation and migration are minimized by keeping the fill as dry as possible. Methods for controlling surface water infiltration include drainage techniques and the use of impermeable cover materials. Ground-water flow can be minimized by maintaining the fill a specified distance above the ground-water level and by subsurface drains and ditches to intercept flow onto the site.

The second section described the physical characteristics of the Marshall Landfill. Several key factors emerged from this discussion. Both the ground water and surface water in the vicinity of the site are used. The hydrogeology of the site is complex, with a drinking water aquifer subcropping beneath part of the landfill. An unlined ditch carrying municipal drinking water flows right through the landfill. The potential environmental problems which migration of leachate off the site would cause are contamination of a major drinking water aquifer in rural Boulder County and of the water supply for the City of Louisville.

The third section of this chapter described why the determination of the environmental threat has been problematic. This is due to incomplete investigation of the site. Certain key elements, such as the influence of the two faults on ground-water movement in the bedrock and the hydrologic relationship between the fill material and the Fox Hills aquifer, have never been studied.

CHAPTER 3

A HISTORY OF ENVIRONMENTAL DECISION-MAKING

Marshall Landfill has been actively used for solid waste landfilling for over 20 years. During that time, there have been many changes in operations and the types of wastes received. Although a definite environmental problem surfaced nearly 10 years ago, the area is still used for landfilling.

This chapter will trace the history of the site by focusing on key County decisions affecting the landfill. At each of these points, the discussion will present the problem, how the County responded, and the results of the County decision. The mechanisms which the County used in response include solid waste regulations, permits to operate, inspections, and compliance orders. Table 1 summarizes the major issues at each of the decision points: designation (1965), expansion (1974), operational and environmental concerns (1974-1983), and expansion (1983).

Designation: 1965

Problem

An unsupervised, open dump in the area of Marshall Landfill existed from approximately 1955 to 1965. It had been used by the City and County of Boulder during that time period (Brower, 1980). No

Table 1. Key Decisions at Marshall Landfill.

1965	Landfill designation	Site chosen for landfill was unsuitable.
1974	Landfill expansion	Decision to expand ignored site characteristics.
1974-1983	Response to operational and environmental problems	Operations plan not followed. Permit not enforced. Leachate control not adequate.
1983	Landfill expansion	Substantial permit conditions imposed but site allowed to expand.

records were kept of the kinds of waste left at the dump. This type of practice was common then.

In 1965, Boulder County chose to designate a 320-acre tract around the dump for a county landfill and to contract to a private firm for its operation.

Issues

Guidance in making this landfill designation came from the county "Solid Waste Disposal Sites, Regulation #7" (1965). Two requirements in this document specifically addressed the need to examine the potential for surface water and ground-water contamination:

1. Sufficient and adequate geological or hydrological tests shall be prepared to reasonably ascertain that the landfill or composting will not contaminate surface ground water [sic].

2. Drainage. The operator shall provide and maintain any necessary drainage facilities. Any evidence of ground-water or surface water contamination created by the sanitary landfill operation shall cause landfill operation to be moved or contamination source removed.

The regulation required one inspection to be conducted by the County Health Officer prior to site approval. Its purpose was to determine the site's suitability for the proposed operation based on the land use in the vicinity "as it is located to nearness of homes and farms, streams, ponds, water courses, flood plain levels, and other pertinent data."

The requirements of this inspection are especially relevant to the 320-acre tract selected by the County for the landfill. An unlined ditch, Community Ditch, bisects this tract, and Cowdrey Reservoir No. 2 lies in the northwest corner at the lowest point topographically. In

spite of this clear proximity to surface water, the inspection apparently went well, for the site was approved as the county landfill.

Results

At the time of designation, Richland Company of Colorado Springs, Colorado, contracted with the County to dispose of solid waste at the site. The contract stipulated that the majority of wastes would be processed through grinding and composting operations.

However, the Richland Company did not fare well in this operation. Because it accepted municipal solid wastes, raw sewage (septic tank wastes), raw wastewater treatment plant sludges, and industrial liquids, the company had to contend with a great deal of liquid material. In addition, the company began to have economic problems. Consequently, because of liquid waste and management problems, grinding and composting were not used substantially. Between 1965 and 1969, probably less than 20% of the wastes were disposed of this way. The remainder of the wastes were simply landfilled (Black & Veatch, Engineering-Architects, 1983).

After one change of operator in 1969, the landfill activities were taken over by Urban Waste Resources, Inc. (UWR) in 1970. This firm continued at the site until 1974. UWR accepted the same types of waste as Richland. The problem of handling the high liquid content of the wastes persisted (Kean, 1983).

Expansion: 1974

Problem

In 1973, UWR realized that it was running out of room, and estimated three to four months of landfill space remaining. UWR approached the County informally to discuss expansion of the landfill area. The County suggested that UWR expand to the south. Subsequently, UWR and Mesa Sand and Gravel made a formal application for a Special Use Permit on a 80-acre tract to the south. Their request was for a joint gravel mining and sanitary landfill operation.

The application was accompanied by a site and procedures plan for the joint use operation. The UWR report described the potential for leachate generation. It noted that possible sources of recharge to the alluvial ground water and fill material were percolation of rain and snowmelt and seepage from Marshall Lake. The plan recommended that a French drain be installed along the western border of the proposed landfill to intercept seepage from Marshall Lake. The report also identified the potential for ground-water contamination and recommended that the Fox Hills aquifer be protected by an impervious clay liner where it subcrops. This would serve to minimize seepage into the aquifer (Black & Veatch, Consulting Engineers, 1973).

Issues

The County reviewed the joint application using the guidance from the "Solid Waste Disposal Sites, Regulation #711 described in the previous section. In a memo to the file, the County Engineer regretted the lack of adopted criteria for reviewing sanitary landfill requests.

He noted that reviewers would have to rely heavily on comments from other agencies and on guideline materials available through federal and state offices (Barstow, 1973).

After several months of meetings and negotiations between different County agencies and with UWR, in 1974 the County gave the company a Special Use Permit to run a joint gravel mining and sanitary landfill operation on the 80-acre tract directly to the south of the previous site. The Permit was granted based on the operation procedures recommended in the proposed site plan. To assure a better operation, the County ordered UWR to take four additional steps to minimize the potential for ground-water contamination:

1. Install a subsurface drain on the west side of the property (the French drain).
2. Install an impervious cover over the North Lake Mesa Fault.
3. Install three monitoring wells.
4. Obtain engineering supervision of the initial refuse cell construction

The County directed UWR to use the services of an engineering consultant during implementation of these tasks. The City and County agreed to monitor the wells.

Results

In 1979, UWR began landfilling on the site and began to implement the four additional requirements which the County had placed on the Special Use Permit. A subsurface drain was installed on the western border of the landfill according to the design specifications

of the involved engineering consultants. The ground was quite wet at the depth for the drain, which made the installation difficult (LeMire, 1982). In spite of the requirement of the Permit, the actual construction was carried out without the supervision of the consulting engineers (LeMire, 1982).

The other three tasks required in the Permit were never completed, and the impervious cover over the Fox Hills aquifer was never installed (Ziebarth, 1983). This is noted in a letter from the engineering consultants to UWR: "It is obvious that the landfill operation was started before site development work had been completed and before the site was ready to receive waste" (Black & Veatch, Engineering-Architects, 1974).

Operational Problems and Ground-Water Contamination: 1974-1983

Problem

Both operational and environmental problems plagued the landfill from 1974 until 1982, when another expansion was requested. These problems began when UWR started to landfill at the newly permitted area without completing the required site preparation. As discussed in the previous section, UWR failed to: (1) install an impervious cover over the subcropping Fox Hills aquifer; (2) install three monitoring wells; and (3) obtain engineering supervision of the initial refuse cell construction.

Environmental problems became apparent at the site in 1975. Leachate exiting from the site is first mentioned in the public record that summer. Inspection reports note separate from the toe of the land-

fill, lagoons filled with leachate, and leachate entering directly into Community Ditch and Cowdrey Reservoir No. 2. One report by the Boulder County Health Department (BCHD) estimated the flow of leachate: "Leachate entering retention pond at 5 gpm estimated. Dewatering trench flow at 20 gpm. Overflow from pond over Community Ditch in P.C.V. [sic] 4" pipe. Previous agreement with Mr. Kean (UWR) to irrigate not being honored. Leachate is flowing from joint in irrigation pipe into Cowdrey Reservoir" (July 18, 1975). The "dewatering trench" is the French drain.

Issues

Within a month of this inspection, the County took the first official action regarding the leachate problem. The Commissioners issued a Notice of Violation to UWR, informing it that UWR was not in compliance with the engineering and operations plan which formed the basis for the Certificate of Designation and Special Use Permit. Regarding the leachate problem, the County noted that the leachate impoundment lagoon was not approved as part of the engineering plan, that there was seepage into Community Ditch, and that there was no contingency plan for handling an increased volume of leachate. The County gave UWR less than 30 days to correct the problems creating the need for the leachate lagoon. As part of this remedial action, UWR was directed to install a dewatering trench and permanent pumping arrangement on the north side of the active landfill to capture ground water before it entered the inactive area.

In October 1975, UWR sold the landfill operations to Landfill, Inc. Mesa Sand and Gravel continued its gravel business. This change of management, however, is not clearly defined in the public record. BCHD found both UWR and Landfill, Inc. conducting activities on the site in November, 1975. At that time, UWR assured the inspectors that it would correct the problem of leachate entering into Community Ditch.

It appears that the County was never formally informed of the transfer. A letter from BCHD to UWR in December 1975 states that BCHD is "not in receipt of the contractual arrangements between (UWR) and (Landfill, Inc.)." In addition, the letter acknowledged that the work being done in response to the Notice of Violation was being conducted "improperly."

Results

After this period of County activity in enforcing the Notice of Violation issued to UWR, the County took no further action on it.

As a result of continued concern about the leachate generation, in 1978 Boulder County hired a consultant to analyze the potential contamination problem. His report recommended lining Community Ditch with concrete to prevent direct seepage into the ditch.

In response to this report, the County decided to line the ditch and attempted to initiate a cooperative effort, including UWR, Landfill, Inc., the City of Boulder, and the County. This was not fruitful. Consequently, in 1979 the County approved a surcharge on all users of the landfill to fund the lining of the ditch. However, within

a few months problems arose. FRICO, the City of Louisville, and the County could not agree on how the actual lining was to be done.

At this point, the County, seeking a solution to the leachate problem, initiated several studies:

1. A 1979 request for technical assistance from the Environmental Protection Agency (EPA). EPA recommended a full-scale study of the leachate problem with the involvement of the many associated parties (landowners, landfill operator, BCHD, Louisville, FRICO, County) in discussing possible actions (EPA, 1979).
2. A 1980 methane gas study by BCHD under contract to the State. The conclusion was that off-site migration of methane was occurring but that the potential hazards were minimized by the relative isolation of the landfill. The report recommended regulating future development on and near the landfill. It also suggested further monitoring on a monthly basis (Brower, 1980).
3. A 1980 study of the feasibility of capturing the leachate issuing from the toe of the inactive landfill just south of Community Ditch. An interceptor drain, with a clay dike to cut off seepage to Community Ditch, was suggested for collecting leachate from the landfill. The report did not state what should be done with the collected leachate (Wells, 1980a).
4. A 1980 study to evaluate alternatives to eliminate the contaminated seepage from the landfill. It suggested four solutions: (1) construct a terrace-soil interceptor drain on the west, south, and east sides of the fill to divert flow onto the site;

(2) remove the old fill and abandon the site; (3) remove the old fill, install a subdrain and clay layer, then reuse the old landfill; or (4) intercept the seepage, treat it, and release it to a natural drainage course. The report did not discuss treatment methods and costs, nor did it recommend simple remedial actions, such as improved surface drainage to prevent ponding and erosion (Wells, 1980b).

In addition to these studies, BCHD sent a letter to Landfill, Inc. in 1980, apprising it of its responsibility to correct the problem of leachate contamination into Community Ditch. Landfill, Inc. was ordered to prepare a "plan of compliance which will result in the isolation of the landfill site and the prevention of leachate flow into the Community Ditch." The plan was to be submitted to BCHD within 30 days. Whether this was done is not in the public record.

From 1979 to 1982, the County, the State, and EPA conducted several sampling efforts at Marshall Landfill. As discussed previously, the samples were not done consistently. Different areas were sampled each time, and often the parameters for analysis varied (Glaze, 1983).

The County continued activities at the landfill, such as inspections and sampling. Many "band-aid" types of actions were taken by both the County and Landfill, Inc. to control overflow into Community Ditch from the leachate lagoons (Mathews, 1983).

In 1982 the State and EPA submitted Marshall Landfill for inclusion on the National Priorities List for sites requiring remedial

action under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (P.L. 96-510) ("Superfund"). The State designated Marshall as its top priority site for clean-up.

Expansion: 1983

Problem

In the summer of 1982, Landfill, Inc. applied to Boulder County for a Special Use Permit to expand the active landfill vertically by adding lifts, to a maximum of an additional 70 feet. Landfill, Inc. estimated that the site had only six months of operating space left. At the time of this request, seepage of leachate off the inactive portion of the landfill was still uncontrolled. Ground-water from monitoring wells between the active and inactive sites exhibited elevated levels of organics similar to those found in ground water on the inactive site. In addition, Marshall Landfill was a Superfund site, as published on the National Priorities List.

Issues

In response to this request to expand the active landfill, the County proceeded to review extensively the proposed plans. For guidance, the County used the following five documents:

1. Solid Waste Disposal Sites, Regulation #7 (1965) defines what a sanitary landfill is and states that a permit is needed to operate such a facility for public disposal. It sets forth standards and requirements for a sanitary landfill operation, including the requirement for an operating plan. It states that the health officer will inspect the proposed site,

although it does not state what inspections shall take place after the facility is in operation.

2. Boulder County Zoning Resolution (amended, 1982) specifies what uses may be permitted in designated districts upon approval by the County Commissioners. It states what information must be presented to the Commissioners for review, and that a public hearing is required. The Resolution also sets standards for the Commissioners to use. Two standards significant to a Special Use Permit for a sanitary landfill are "that the contemplated development/use . . . (9) will not cause significant air, water, or noise pollution; . . . and (11) will not otherwise be detrimental to the health, safety, or welfare of the present or future inhabitants of Boulder County."

3. By-laws of the Boulder County Planning Commission explain the procedure for obtaining a Special Use Permit. This includes the submittal date for all information, review staff for the permit, public notice and public hearing dates, compliance and enforcement aspects, and the actual requirements for the site report.

4. Review Criteria for Public Sanitary Landfills (draft) expand on the previous document and detail how an application should be reviewed. This guidance discusses the following categories for the review: (1) description of the proposed operation; (2) geology, soils, and ground water; (3) drainage and flood control; (4) public health concerns; (5) fire protection; (6) wind information; (7) utilities; (8) access and traffic; (9)

safety; (10) reclamation, landscaping and aesthetics; (11) disposal of hazardous wastes; (12) disposal of sewage sludge or septic tank wastes; (13) resource recovery; (14) rubble disposal; and (15) other considerations. The Criteria describe each one of these categories in detail. It actually serves, therefore, not so much as a review document but more as a prescriptive guidance document, specifying how a sanitary landfill shall be operated in Boulder County. For example, under "(3) drainage and flood control," one of the items specifies that "there shall be no landfilling within 25 feet of a creek, stream, ditch, lake, or other water storage area."

5. Solid Waste Management Goals and Policies (1982) declare an overall goal of eliminating or reducing as much as possible environmental degradation to prevent potential harm to life, health, and property. More specifically, it states that the criteria for planning, design, operation, and enforcement will be updated as needed. It recommends the development and maintenance of a county-wide solid waste management plan. It asserts that the County shall set performance goals and requirements for sanitary landfills. Two important aspects of the document for this case study are: (1) quality control should be maintained through the Special Use Permit contract specifications for the operation; and (2) the County should provide adequate technical staff and continue to support the Boulder County Solid Waste Advisory Committee.

In 1982, a sanitary landfill required two permits, a Certificate of Designation from BCHD (which has to be coordinated with the State Health Department) and a Special Use Review and Permit required by the Planning Commission. As suggested by the draft Review Criteria, the County Land Use Department coordinates these two permit reviews.

Results

After several months, in April 1983, the County conditionally approved the request, subject to 20 conditions, and limited the vertical expansion to 30 feet. Eight of these conditions related directly to the concern about surface water and ground-water contamination. They specified:

1. That the following substances be prohibited from disposal at the landfill:
   - sewage sludge
   - septage waste
   - chemical toilet waste
   - radioactive materials
   - oil and gas exploration waste
   - hazardous or toxic wastes as defned by regulations of the U.S. Environmental Protection Agency.
2. That if any part of the approved proposal or operation in any area of the approved proposal is shown to cause additional water contamination, the approval for that part or area becomes void, and all activities in that area except approved remedial actions or placement of final cover shall immediately cease.

3. That approval of the expansion does not constitute grounds for any reduction or relief from any remedial action which may be required to alleviate ground-water contamination caused by earlier activities on the site.
4. That the ground-water sampling and monitoring program established by the application be continued with quarterly reporting of all parameters to Public Works and Health Departments until two years after final closure and semi-annually for 19 years thereafter.
5. That the applicants or their engineering representatives submit to the Public Works Department engineer certified reports of the progress of the project and its compliance with the approved plan on a quarterly schedule during normal operation and more frequently during critical construction phases.
6. That the applicant understand that no further expansion of landfill operation in the Marshall area will be considered by Boulder County unless the area is shown by a county landfill siting study such as the currently ongoing study to be an acceptable landfill site.
7. That any change of operator shall be subject to review and approval by Boulder County.
8. That the applicant agrees to complete and, together with other parties, sign an agreement among themselves, Boulder County, Colorado Department of Health, City of Louisville, and other relevant parties, to alleviate ground-water contamination caused by earlier activities on and near the site. The

agreement should include commitments for remedial work on seepage control and Community Ditch, and a Superfund equivalent ground- water investigation and remedial measure definition (Boulder County Planning Department, letter to Landfill, Inc., April 5, 1983).

Many of these special conditions relate directly to problems that have occurred with the operations at Marshall Landfill, as well as to the general increase in knowledge of solid waste management.

In response to the eighth condition above, Landfill, Inc. signed an agreement in June, 1983, with the parties identified in order to alleviate the ground-water contamination caused by earlier activities at the landfill.

Summary

This case history has described the operational growth of Marshall Landfill from an open dump prior to 1965 to a poorly operated site in the late 1960s to a sanitary landfill up through the present. It has focused on the major decisions which the County faced over this time span. In 1965, the County designated an open dump for the landfill, even though that site was not suitable as defined by the County inspection requirement. In 1974, the County granted a Special Use Permit to the operator to expand the site. This permit was based on many engineering requirements which were not implemented. From 1974 to 1983, the County was faced with repeated instances of non-compliance with the required site plan and with the environmental threat of leachate migration. Both situations eluded County control. In 1983,

the County again permitted an expansion to the landfill, although this time it carefully conditioned the operations.

CHAPTER 4

ANALYSIS OF DECISIONS

Between 1965 and 1983, Boulder County was faced with four major decisions regarding Marshall Landfill. First, it had to decide whether to designate the site as the official county landfill; twice it had to decide whether to permit the site to expand; and for almost 10 years, it had to decide how to handle the persistent problem of surface water and ground-water contamination. The conceptual model of environmental decision-making described in Chapter 1 will be used to analyze the key County decisions. This analysis will examine to what extent the decisions were made as the model would suggest. The four major decision points described in the site history will thus be analyzed in terms of the conflict between technical and institutional decision-making, the incremental nature of environmental decision-making, and the gap between decisions and implementation.

Designation: 1965

The issues surrounding the initial designation of Marshall Landfill in 1965 are not well documented, since the landfill record began at this time. Two factors do emerge from the case history: (1) the inspection of the site which was required prior to designation did not adhere to the technical criteria of the inspection; and (2) the

landfill area had been used from 1955 to 1965 as an unsupervised open dump.

Conflict between technical and institutional decision-making. Conflict between technical and institutional decision-making interpreted broadly is seen in the discrepancy between County guidance on solid waste mangement and the decision to designate the Marshall area as a landfill. The "Solid Waste Disposal Sites, Regulation #7" clearly requires the consideration of nearby surface water uses in evaluating a site for a landfill. Two water bodies within the proposed area, Community Ditch and Cowdrey Reservoir No. 2, were certainly close enough to be impacted from landfill activities. However, in spite of this proximity, a consideration supported by the technical guidance, the County chose to permit the operation of a landfill at Marshall. This decision suggests that technical and administrative staff within the County were not working in accord.

Incrementalism as a necessary aspect of environmental decision-making. The decision to designate the site as the County landfill appears to be incremental for two reasons. First, the technical expertise to conduct the site inspection was lacking. In spite of the County guidance, "Solid Waste Disposal Sites, Regulation #7," which required an inspection prior to the designation to determine the suitability of the site in terms of nearby land uses, such as water bodies, the site was approved. Both Community Ditch and Cowdrey Reservoir No. 2 were within the site area, and both received recharge from ground water moving through this location. The significance of these facts apparently did not register with the County.

The second reason that this decision appears incremental is based on the fact that an unsupervised open dump already existed at the site. The County was accustomed to thinking of the site as a landfill; the residents and businesses were in the habit of driving out there to leave off their waste; and the area was already "spoiled" by open dumping. In making the official designation, the County simply sanctioned what had already been occurring. Inertia reinforced the ignorance.

Gap between decisions and implementation. This is closely tied to some of the incremental factors. In adopting Regulation #7, the County had adopted basic guidance in regulating sanitary landfill operations. Yet, it appeared to ignore the implementation of this guidance. One important element was a lack of expertise in knowing how to apply this document and recognizing the importance of doing so. Because of the isolated nature of the location, another element was the lack of a constituency with an immediate interest in enforcing the guidance or preventing the designation.

Expansion: 1974

In 1974, the County was requested to allow an expansion of Marshall Landfill to the south. In its approval of this expansion, the County added specific engineering requirements, such as a subsurface drain and an impervious liner to the Special Use Permit. These additional activities required of the operator suggest that the County had not only increased its technical knowledge of ground-water movement and

the mechanics of landfilling, but also had undertaken a more careful institutional review of the application.

Conflict between technical and institutional decision-making. Conflict within the County government over the expansion review is evident in the memo written by the County Engineer, in which he regrets the lack of criteria at the County level to guide the reviewers of the application (Barstow, 1973). He suggests that federal and state guidelines be used. However, the lack of County criteria, coupled with a lack of legislative authority, prevented the County from developing an integrated response and enforcement action.

The lack of integration in coordinating the expansion is again evident when the landfill began operating at the expanded site without fulfilling the technical requirements of the Special Use Permit. Although UWR was acting improperly, the fact that it so blatantly violated the permit without a County response suggests that the County was not in control, perhaps as a result of a lack of integration between technical, enforcement, and planning departments within the County.

Incrementalism as a necessary aspect of environmental decision-making. The activities of review, negotiation, and permit writing in 1973-1974 show the incremental nature of environmental decision-making. Whereas the same basic guidance document (Regulation #7) was used in both 1965 and 1974, the County had more knowledge in 1974 to process the review. Therefore, it added to the permit certain requirements for a subsurface drain, an impervious cover over a fault, monitoring wells,

and engineering supervision. These showed a "quantum leap" in knowledge and technology.

The addition of these requirements specified in the Special Use Permit marked the first time that the County recognized the need to protect the environment from the landfill operations. No such concern for the possibility of ground-water contamination is seen in the public record prior to this point.

However, the inertia affecting the County's initial designation of the landfill appears again. The expanded landfill was no more suitable than the original site. In effect, the engineering report pointed this out by recommending that a drainage system be installed to intercept ground-water flow from the west into the fill material. The County allowed the landfill to expand, believing that compliance with the engineering recommendations would protect the environment.

Gap between decisions and implementation. The approval of and conditions for the landfill expansion constitute the County's decision on the matter. The reality that these requirements were not implemented is shown by UWR's noncompliance with the approved operations plan and permit requirements. The site preparatory work was not completed before landfilling began, and the monitoring wells were not installed.

Although Menzel and Williams (1978) suggest that many decisions are not implemented because of the discrepancy between technical realities and the decisional requirements, that is not the case here. Woodward-Clyde's (1979) measures for determining the capability to

bridge the gap between decisions and implementation are more appropriate.

Although UWR was a less than desirable operator, the County may not have had the human and institutional resources to carry out its decision. Three examples of this are: (1) the lack of technical expertise to review adequately the site plan and to foresee the problems resulting from the site hydrogeology; (2) sparse environmental legislation; and (3) the lack of technical training within the County to oversee the required activities. (A County employee was present at the time the French drain was incorrectly installed on the western border of the landfill. He did not prevent the improper installation nor the violation of the requirement to have professional engineering supervision) (LeMire, 1982). It appears that the lack of these types of resources was the main factor in the County's inability to implement its decision in 1974.

Operational Problems and Ground-Water Contamination: 1974-1983

During this time period, the County made several decisions intended to affect the operations at Marshall Landfill. Two key factors characterize these decisions: (1) the County attempted to gain more technical knowledge of conditions at the site; and (2) there were severe difficulties in implementing the decisions which were made.

Conflict between technical and institutional decision-making. The period from 1974 to 1983 was characterized by both an attempt to gain greater technical understanding of problems and their possible solutions and a failure of institutional (enforcement) support for many

of these technical activities. The County initiated five studies and several sampling efforts during this time. It also issued a Notice of Violation to UWR in 1975 and a Compliance Order to Landfill, Inc. in 1980. These actions specified the technical violations of the permit.

An example of an action typical of this time which shows how the County was plagued by lack of integration was the attempt to require action on lining Community Ditch. The County first urged a cooperative effort. When that failed, it approved a surcharge on users of the landfill to fund the lining of the ditch. Although the funds were amassing to pay for the remedial work, the institutions involved could not agree on how to do the actual lining.

Doerksen and Lamb's (1979) comment that in most cases interagency decision-making involves "more coordination and adjustment than analysis" seems appropriate here. In spite of the attention given to technical aspects, the County failed to achieve many results. It could not integrate the institutional and technical interests to line the ditch nor could it develop the institutional support necessary to enforce the technical compliance orders.

An attempt to resolve this conflict can be seen in the many studies initiated at this time. These sought to define better what the problems were at the landfill, so they would be clearly recognized and understood by others in the County.

Incrementalism as a necessary aspect of environmental decision-making. Using Faludi's (1973) definition of incrementalism as a "piecemeal" approach characterized by adjustment of objectives to policies and involving serial analysis and evaluations of issues, the

period of decision-making from 1974 to 1983 at the Marshall Landfill appears incremental. The County initiated a number of activities that were very object-oriented, such as sampling a certain area or studying a specific problem. These activities, therefore, failed to be comprehensive and could not provide an overall picture of the problems at the landfill.

As others have stressed, environmental decision-making is necessarily incremental, because environmental knowledge is constantly increasing (Doerksen and Lamb, 1979; Menzel and Williams, 1978; Petak, 1980; Woodward-Clyde, 1979). Through the studies and enforcement actions, Boulder County was trying to get a better handle on the environmental threat, while at the same time improving the County's management of a problem situation. As of today, these efforts are continuing.

Gap between decisions and implementation. During this period, there was a definite gap between decisions and implementation. This was most clearly seen in the inability of the County to enforce compliance with the requirements of the landfill permits. The reasons for this may be explained by Woodward-Clyde's (1979) measures of what is needed to bridge the gap between decisions and implementation. As discussed above, the County lacked the necessary human and institutional resources at the time of the 1974 landfill expansion. Environmental legislation was minimal. The County did not develop a comprehensive plan for dealing with the problems at Marshall. Instead, it took a "piecemeal" approach. The technical sophistication of County staff, if judged by their inability to develop a comprehensive study to

define and resolve the environmental threat, was less than what was needed.

Another major factor in the implementation of decisions during this time was the unclear definition and perception of the environmental threat. O'Riordan and O'Riordan (1972) state that "the nature of the problem, its identification, measurement and possible consequences" is a necessary factor in the decision-making process. The environmental threat, including its measurement and possible consequences, was not clearly defined in the period from 1974 to 1983. Since many crucial questions remain unanswered, this has made implementation of decisions, especially for enforcement actions, problematic.

Expansion: 1983

There is as yet no data by which to evaluate the County's most recent decision to expand the landfill. However, the extensiveness of the permitting process shows significant changes in how the County made its decision. It is useful to evaluate these changes to see how they fit the criteria which affect environmental decision-making.

Conflict between technical and institutional decision-making. It appears from the record that this conflict is being resolved. Several factors support this. A mechanism for the integration of technical and institutional reviews has been defined. The "Review Criteria for Public Sanitary Landfills (draft)" suggest that the County Land Use Department coordinate the reviews needed for the Special Use Review and Permit and for the Certificate of Designation. In addition,

the plethora of documents, described in Chapter 3, which now guide and prescribe the review process, show the integration of technical criteria into institutionalized areas.

Incrementalism as a necessary aspect of environmental decision-making. The incremental growth of technical knowledge and its correspondingly incremental incorporation into environmental management is seen in the number of documents available to the County in 1983 to review the application for the landfill expansion. Actually, the escalation of documents between 1973 and 1983 looks more like Menzel and Williams' (1978) "quantum leaps" than gradual incrementalism.

The special conditions attached to the landfill expansion permit also clearly show the incremental nature of environmental management. The eight conditions cited in Chapter 3 read like a litany of past problems. Their incorporation shows the response by the County to environmental problems at the landfill. For example, the County is finally controlling what wastes are accepted at the site.

Gap between decisions and implementation. Woodward-Clyde (1979) describes resource and institutional factors which are useful in assessing a government's ability to act on a decision. They note that the capacity to implement a decision depends on these factors, which include educational level of staff, technical expertise, comprehensive environmental planning, zoning regulations, and environmental legislation. If these factors are present, it is more likely that a decision will be implemented in the manner intended.

As shown by the comprehensive review given to Landfill, Inc.'s request to expand the site, Boulder County has strengthened many of

these factors. Staff to review the permit has been augmented. In addition, several documents on environmental planning and management have been adopted. These documents, such as the 1982 zoning resolution and the review criteria for sanitary landfills, in turn serve as mechanisms to strengthen County resources. For example, they recommend that adequate technical staff be provided and that a county-wide solid waste plan be implemented.

Summary

This chapter has analyzed the decisions which the County made in response to conditions at Marshall Landfill. These decisions were examined in light of three criteria affecting environmental decision-making: the conflict between technical and institutional decision-making, the incremental nature of environmental decision-making, and the gap between decisions and implementation.

In 1965 Boulder County chose the site of an unsupervised open dump as the County landfill and contracted for its private operation. Given that the area was unsuitable for landfilling and that County guidance discouraged such use of the area, the County's decision exhibits the three criteria of the model. Clearly, technical and institutional elements of the government were not in agreement. There may also have been limited knowledge of the mechanics of landfilling. Finally, the decision to permit the landfill is very different from that which adherence with the solid waste disposal site regulations would have directed.

The model is also useful in explaining how Boulder County permitted the landfill expansion in 1974. Although technical and institutional elements appeared to work together, in reality there was a lack of technical understanding of the physical characteristics of the site as well as a lack of institutional guidance in evaluating the request to expand the area. In addition, the implementation of the Permit requirements was severely distorted by UWR, which carried out only one of these requirements.

The environmental and management problems that occurred and re-occurred between 1974 and 1983 are well explained by the model. County administration did not support the technical staff in requiring compliance with the Permit. The technical staff itself was occupied in trying to define simultaneously the leachate problem and possible solutions. The implementation of decisions during this time period was not straightforward. Short-term decisions, such as to initiate a study, were clearly implemented. However, the implementation of more far-reaching decisions, such as enforcing the requirements of the Permit, seemed to become "lost" over time. In any event, this distortion of clear implementation of a decision is still an implementation.

The 1983 decision to expand the landfill shows that Boulder County has gained greater control over environmental decision-making. Mechanisms to integrate technical and institutional elements, such as environmental legislation, have been adopted. Increased knowledge of sanitary landfilling and of the site considerations at Marshall have been incorporated into the special conditions of the Permit. The capability to implement a decision has been strengthened by the addition of

both improved resources and institutional mechanisms to oversee land-filling activities.

CHAPTER 5

CONCLUSIONS

In this chapter, conclusions on both the case study and the usefulness of the model in describing environmental decision-making will be presented. While the conclusions are specific to the Boulder County experience, this situation is not unique. Other small communities across the country have probably faced similar situations.

Conclusions on the Case Study

There are four major conclusions from this case study: (1) the landfill site was unsuitable environmentally from the beginning; (2) County actions were incremental, rather than comprehensive, in attacking the problem; (3) the nature of the leachate problem has not yet been satisfactorily defined; and (4) the County had great difficulty in implementing its decisions.

The landfill site was unsuitable environmentally from the beginning. An unlined ditch, carrying both irrigation and municipal drinking water, bisects the site. A reservoir to the west of the site may serve as a steady source of recharge to the alluvial system and the fill material. A drinking water aquifer subscrops beneath the site. Despite these conditions, the County designated this area for the landfill. Lack of understanding of the environmental situation and inertia seemed to motivate this decision. As a result, it was easier

to keep using the same general area for landfilling. It was also economic, since no studies had to be funded to evaluate the suitability of the site.

The County acted incrementally, rather than comprehensively, in responding to the environmental threat. As scientific knowledge about the mechanics of landfilling and ground-water movement increased nationwide, the County incorporated its greater awareness of environmental considerations into its management of the landfill. This was done through both the special conditions added to the landfill permits and the studies which focused on different aspects of the leachate problem. Although an incremental approach almost seems inevitable, improved resources within the County, such as technical, institutional, and financial, might have resulted in a more comprehensive approach in the County response. As it was, the County's disjointed effort has led to a slow resolution of the problem.

The nature of the leachate problem, "its identification, measurement and possible consequences" (O'Riordan and O'Riordan, 1972) has not yet been identified. This is basic. It is hard to resolve a problem that is unknown; a problem must be defined before remedial measures should be attempted. For several reasons, no comprehensive analysis of the extent of the leachate contamination was conducted. Rather, very specific, object-oriented studies were conducted, looking at the leachate problems in a piecemeal fashion. It seems safe to assume that at this time most parts of the country were taking similar disjointed attacks on landfill problems. Another reason for the lack of definition may be due to inadequate resources--technical expertise,

planning ability, and adequate funding--in the County to design, implement, and monitor the comprehensive environmental study of the landfill that was needed.

The County had great difficulty in implementing its decision. The gap between decisions and implementation seemed to be due to a lack of an integrated approach on the part of the County to environmental management. For example, the technical enforcement actions were not adequately supported to achieve positive results. This too may be due to a lack of resources, human and institutional, as well as to an unclear definition of what the problem was. However, implementation did occur after a decision was made, although it may not have reflected the County's original intention. Rather, it shows that there was a distortion of the decision. This distortion may be a result of insufficiencies in any of the thee criteria which describe the mode of environmental decision-making used here.

Conclusions on the Usefulness of the Model

The model was used in this case study to describe a local government's response to environmental decision-making and to environmental problems. Of the many inputs to local decision-making (Figure 1), this model evaluated only three: local legislation, staff, and scientific knowledge. Basically, the model was used to evaluate the bureaucratic response to environmental threat. The usefulness of the model lies in its ability to describe why a decision was made and, thus, to diagnose why an environmental problem was allowed to persist

uncontrolled. This specific application of the model may prove useful to other communities.

Three criteria which characterize environmental decision-making were used in the model to examine the case history. These criteria--the conflict between technical and institutional decision-making, the incremental nature of environmental decision-making, and the gap between decision and implementation--quite adequately described the inputs to the County decision-making, including the lack of control in implementing a decision.

The aspect of conflict between technical and institutional decision-making was very useful in describing the obvious discrepancies between a County document or decision and actions taken. Technical and institutional elements continued to integrate their work in 1983 after a long decade of separately trying to cope with the environmental and management problems at Marshall Landfill.

The incremental nature of environmental decision-making is evident in this case study. As the County gained more knowledge of solid waste landfilling, it incorporated more specific requirements at each expansion time.

Because this case study focused on the County's response to environmental threat, the most useful criterion in describing what happened is the gap between decision-making and implementation. Woodward-Clyde's (1979) resource factors for estimating the capability of a government to bridge the gap between decision and implementation were very appropriate. The measures helped to explain why at the several decision points the County acted, or did not act, to resolve

the environmental threat. In addition, the other two criteria depended on this one--the resource and institutional base--to determine how adequately a technical problem would be studied, as well as how easily a conflict between agencies could be resolved.

Another way of viewing this gap between decision and implementation as intended is that implementation did occur, however, in a distorted form. For example, the fact that the Notice of Violation to UWR was not enforced suggests that another (undocumented) decision had been made. This distortion of the decision and its implementation limits the effectiveness of local government response to an environmental threat.

In future case studies of local government response to environmental threat, it would be appropriate to focus on the government resources to implement a decision in a straightforward fashion. Issues of lack of technical knowledge or conflict between competing agencies within a government are really secondary to the government's ability to act to implement a decision.

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