United States
Environmental Protection
Agency

Region VIII
1860 Lincoln Street
Denver, Colorado 80295

REPORT NO. 908/6 - 81-001

March 1981

Solid Waste

A TECHNICAL ASSISTANCE PROGRAM REPORT

SOLID WASTE DISPOSAL IN CLIMATICALLY SEVERE AREAS

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Prepared for:

U.S. Environmental Protection Agency
Region VIII
1860 Lincoln Street
Denver, Colorado 80295

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Public Law 94-580 - October 21, 1976

Technical assistance by personnel teams. 42 USC 6913

RESOURCE RECOVERY AND CONSERVATION PANELS

SEC. 2003. The Administrator shall provide teams of personnel, including Federal, State, and local employees or contractors (hereinafter referred to as "Resource Conservation and Recovery Panel") to provide States and local governments upon request with technical assistance on solid waste management, resource recovery, and resource conservation. Such teams shall include technical, marketing, financial, and institutional specialists, and the services of such teams shall be provided without charge to the States or local governments.

Project Officer: William Rothenmeyer

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EXECUTIVE SUMMARY

Severe climate areas present difficult operational problems to sound sanitary landfill management. To research the problems involved, an extensive literature search on the climate, geology, soils, and hydrology of climatically severe areas was conducted and ten landfill sites in climatically severe areas of U.S. EPA Region VIII were visited.

Common problems were found. For instance, the proper operation of landfills may be curtailed throughout much of the year due to freezing temperatures, deep snows, high runoff rates, insufficient cover material and/or high winds. Other common problems found were difficulty in maintaining landfill equipment, poor maintenance of proper surface runoff control measures, the potential for groundwater pollution, and blowing litter. Problems were typically exacerbated by the lack of environmentally appropriate sites, leading to the selection of only marginally suitable sites. Additional problems found were lengthy and difficult haul distances, seasonal variations in waste volumes (most commonly due to mining and/or tourism), and increased discomfort and health and safety risks to equipment operators.

Suggested solutions to some of these problems are as follows. Additional alternatives are given in Exhibit 14, Summary of Potential Climatic Alternatives, in Chapter VI of this report.

- Inadequate Cover Type and Quantities
  - procure off-site soils
  - utilize alternative cover types (ash, fixed sludges, mining wastes, etc.)
  - modify soils chemically (e.g., bentonite addition)
  - blend soils
  - increase compaction to improve the performance of a thinner layer

- reduce cover application rates

- limit landfill operations to a few days a week to reduce daily cover requirements

. Difficult Functioning of Landfill Equipment

  - alter cover stockpiling operations to minimize moisture intrusion and frost penetration

  - excavate and stockpile cover during dry, warm periods

  - provide a separate inclement weather area

  - use appropriately sized or specialized landfill equipment

  - vary landfilling methods according to conditions (e.g., using trench operations on windy days)

. Surface Runoff and Consequent Soil Erosion

  - provide proper grading on top and side slopes

  - select erosion-resistant soils (where possible)

  - provide on-site and off-site drainage and run-on diversion systems

  - treat the landfill surface (mulching, compaction, revegetation, fabric lining, etc.)

. Groundwater Pollution

  - physically contain leachate with a natural clay or synthetic liner

  - minimize surface water infiltration

. Blowing Litter

  - use the trench method, aligning trench axes perpendicular to the predominant wind direction

  - modify operating hours to best utilize low wind periods (early morning, late afternoon)

  - provide litter barriers (fences, nets, vegetation)

  - orient landfill layouts to take advantage of natural or constructed wind barriers

In addition to these environmental and subsequent operational problems in severe climate areas, a number of accessory general conditions were found to impinge on waste disposal in U.S. EPA Region VIII. These were the general lack of capital and operating funds, sparsely settled but large wasteshed areas, the predominance of government-owned lands which are often unavailable for waste disposal, and the large seasonal variations in populations and needs for services.

I. INTRODUCTION

A. OBJECTIVES

Landfill disposal of solid waste in climatically severe areas within EPA Region VIII poses difficult operational problems to local communities. Proper operation of landfills may be curtailed throughout much of the year due to freezing temperatures, deep snows, high runoff rates, insufficient cover material, and high winds. Further, mountainous areas generally have fewer appropriate sites available as landfill disposal areas. Operational problems due to steep slopes, nearness of surface waters, undesirable soil types, etc., result.

The purpose of this report is to characterize the operational problems of solid waste landfill disposal in severely cold, mountainous, or plains regions typical of the States of Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming, and to offer alternative approaches to these problems.

B. SCOPE

This report is limited to landfill disposal problems in severely cold, mountainous, or plains areas. The non-site-specific portions of this manual, Chapters I through IV, could serve as general guidelines for land-filling in most cold climate areas. Moreover, the types of landfills and communities to which this report is directed are small- to medium-sized, and have correspondingly small budgets. These communities may be impacted by mining and energy-related population growth, and by the seasonal population changes attended by tourism and recreation.

C. METHODOLOGY

The available literature on the climate, geology, soils, and hydrology in climatically severe areas, and their impact on landfill disposal problems was reviewed. Available literature specifically on cold climate solid waste disposal was found to be generally limited. The review was completed by researching landfill methodologies and climatic conditions commonly experienced throughout Region VIII.

To supplement and complement the general guidelines resulting from the literature review, the consultant team visited ten landfill sites in severe climate areas in the six state region. The actual site visits included analyses of (1) waste types and quantities; (2) waste collection area, procedures, and costs; (3) landfill site hydrogeology, soils, and climate; (4) landfill design, operation, equipment, personnel, and costs; (5) site permits, and compliance records; and (6) disposal problems and potential solutions available to landfill operators.

D. ORGANIZATION

The following chapters describe the problems and potential solutions available to site operators as well as to regulatory authorities in achieving environmentally adequate waste disposal at minimal cost. Chapter II highlights the severe climate conditions commonly found in western slope deserts, western slope mountains, eastern slope mountains, and Great Plains regions located throughout EPA Region VIII. Major natural climatic characteristics which inhibit proper land disposal include cold temperatures, inadequate soil supplies, high winds, steep slopes, difficult to control runoff conditions, etc. In addition to being located in severe climate areas, the selected landfill sites, as well as many other sites located throughout the region, exhibit a number of additional characteristics which similarly impact adequate waste disposal activities. These include land use development requirements, large variations in seasonal waste generation, limited site capacities, limited capital and operation budgets, and large, remote, and sparsely settled service areas.

Chapter III examines the range of operating problems most commonly experienced at the landfill site. Typical problems include inadequate soil cover types or quantities, difficult operating environments for landfill equipment and personnel, high soil erosion potential, high surface and ground water pollution potential, high blowing litter potential, leachate control problems, difficult waste hauling problems, and variations in seasonal waste volumes. In each case the problem is described and alternatives are discussed.

Chapter IV describes more general solutions which may apply to any severe climate landfill problem, particularly where upgrading of any one particular site might not be appropriate. These include utilization of alternate landfill sites, waste reduction through source separation, and materials and energy recovery.

Chapter V presents data from the landfill site visits conducted in EPA Region VIII. Specific sites which were examined included the following:

Location	State
Pagosa Springs	Colorado
Gunnison	Colorado
Meeker	Colorado
Summit County	Colorado
Telluride	Colorado
Silverton	Colorado
Delta	Utah
Bismarck	North Dakota
Forsyth	Montana
Laramie	Wyoming

The analyses present data (where available) concerning on-site locations, operational descriptions, waste quantities and characteristics, hydrogeology, operating problems, recommendations relating to severe climatic conditions, potential financial options, and other solid waste issues.

Chapter VI summarizes typical severe climate related problems experienced in Region VIII and identifies a number of additional conditions which negatively impact solid waste disposal in the region.

II. COMMONLY OCCURRING PROBLEMS IN CLIMATICALLY SEVERE ENVIRONMENTS

A. INTRODUCTION

The intent of this chapter is to define those naturally occurring phenomena which inhibit efficient and environmentally acceptable disposal of solid waste throughout Region VIII. The diversity of topography, altitude, solar aspect, and other factors makes it difficult to generalize about severe climate types within the region. However, several major climatic categories can be described which influence solid waste management practices i.e., high altitude, high plains and high deserts. Different conditions typify each depending upon their specific location (i.e., east or west of the continental divide, local topography, etc.). Climates vary significantly from region to region and, on a local scale, are actually composed of a great number of diverse micro-climates. There are several factors, however, which serve to distinguish the "highland climate" types from climatic types characteristic of lower elevations. These common factors are discussed separately below, after which the additional variables affecting local micro-climate differences are evaluated.

1. High Altitudes

Increasing altitude affects large-scale climatic conditions in several respects. First, on the average, air temperatures normally decrease 3.3°F per thousand feet increase in elevation. At the same time, solar radiation increases with elevation. Insulating aspects of the atmosphere are less at higher altitudes and as a result, both incoming visible radiation and outgoing infrared re-radiation pass more freely through the atmosphere with increasing elevation. This, in combination with decreased quantities of atmospheric water vapor, causes large variations in air temperature between night and day and shade and sunshine. A major implication of large diurnal temperature differences in generally cold areas is the increased frequency, amplitude, and rate of temperature fluctuation about the freezing point. This directly affects the incidence and severity of frost action at the ground surface, which impacts the relative ease by which cover material can be obtained. In addition, low temperatures often result in decreases in efficiency of operation for landfill equipment as well as for site operators.

In a very general sense, precipitation often increases with elevation, at least up to altitudes of several thousand feet, above which the "mountain barrier effect" common in Region VIII, may severely deplete the available atmospheric moisture. The proportion of total precipitation which falls as snow also increases with elevation. Depending upon their specific location within Region VIII, solid waste disposal sites incur a range of total precipitation ranging from 8" to 40" per year. (See Exhibits 1 and 2.)

Prevailing wind speeds at high altitudes are also usually greater than at lower altitudes. Highland prevailing wind directions may in some areas conform more nearly with regional circulation patterns. Chinook winds from the Northwest are also common along the Front Range.

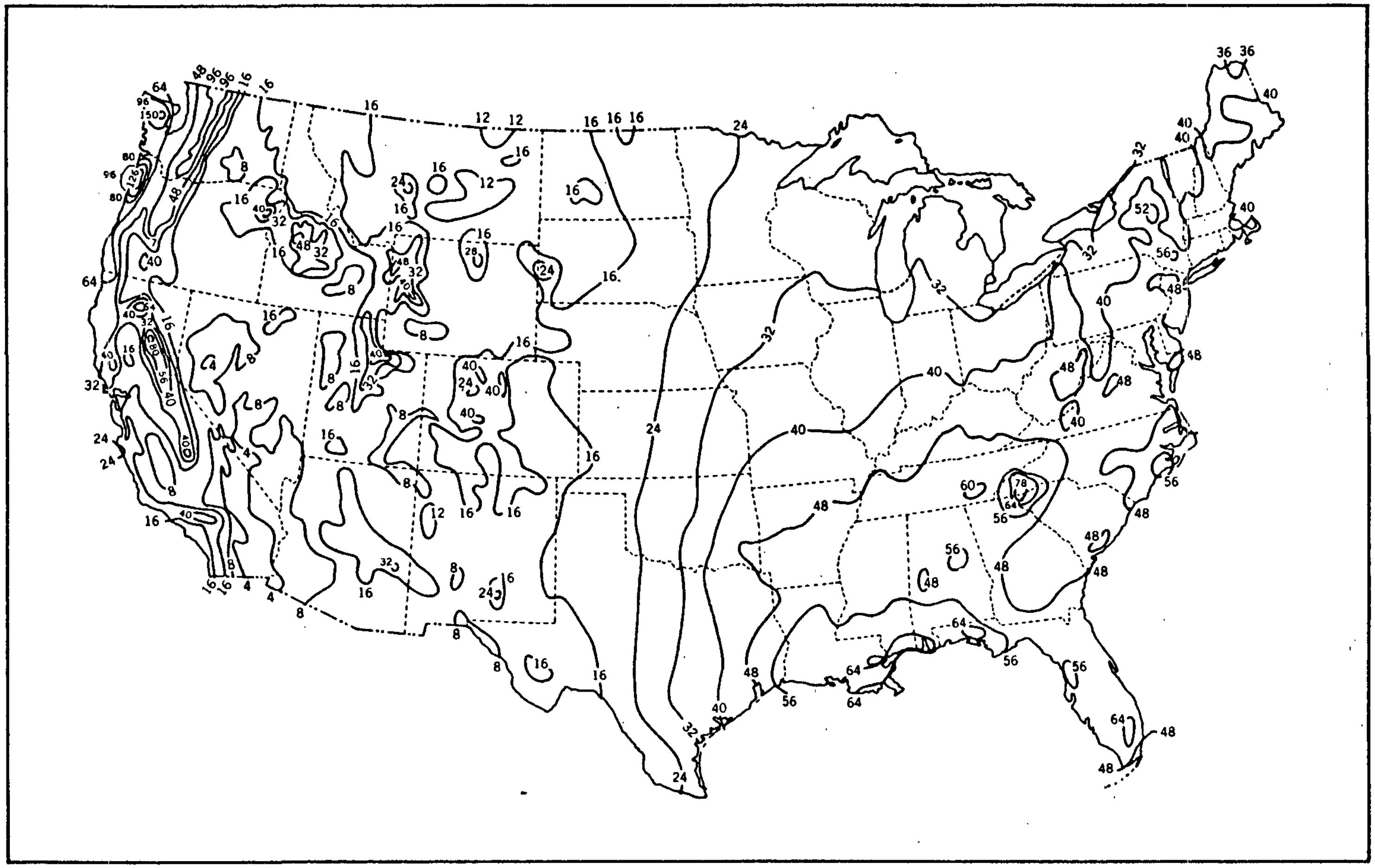
As indicated earlier, the general highland climatic characteristics (which derive mainly from the elevation factor alone) may be greatly modified on a local microclimatic scale, depending primarily on local relief and the regional "mountain barrier effect". For example, local relief may affect local temperatures by causing variations in the amount of insulation received by slopes of differing orientation. Since solar radiation is more intense at high elevations, these variations have greater implications for soil temperatures and vegetation growth than they do at lower elevations. Local relief may also alter prevailing wind speeds and directions in innumerable ways through the obstructing or channelling action of mountain ridges, valleys, and canyons.

2. High Plains and Deserts

High plains areas typically found in portions of Wyoming, Utah, Colorado, South Dakota, North Dakota, and Montana exhibit some of the same natural characteristics described in the previous section. However, local relief tends to be much more uniform, often resulting in a different set of landfilling operations problems. For example, blowing litter, caused by high winds, can be a severe problem.

EXHIBIT I

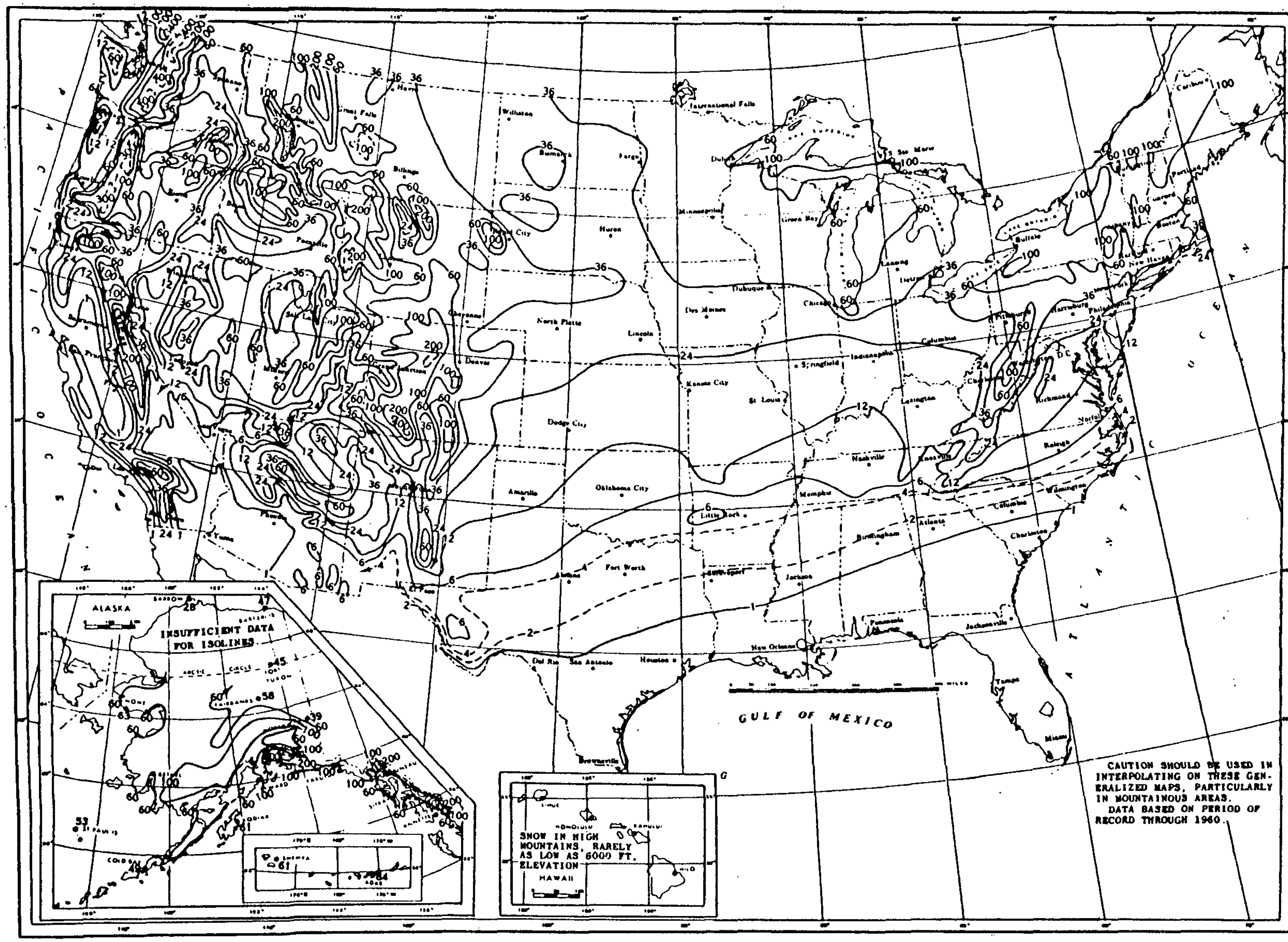
AVERAGE ANNUAL PRECIPITATION (IN INCHES)



Source: Linsley, Ray & Franzini, Joseph.
Water Resources Engineering.

EXHIBIT 2

MEAN ANNUAL TOTAL SNOWFALL (IN INCHES)



Source: Design and Construction of Covers for Solid Waste Landfills.
U.S. Environmental Agency Report, EPA 600/2-79-165, 1979.

A number of other differences are also generally evident. Perhaps the most important of these relates to the amount of available moisture. Site locations east of the continental divide generally exhibit low total annual precipitation, and as such runoff and groundwater pollution problems are less severe than at sites west of the continental divide. In addition, soil quantities are generally much greater at high plains sites than at sites located in high altitude, mountainous areas.

B. OTHER ENVIRONMENTAL CONSIDERATIONS

A number of other factors also inhibit proper waste management activities at landfill sites. These vary on a site-by-site basis and need to be considered in identifying site specific severe climate operational difficulties and potential solutions.

1. Topography

High altitude, mountainous areas, such as those found primarily in Wyoming, Utah, Colorado, and Montana, are obviously characterized by high elevation, severe local relief, steep slopes, etc. These factors have a number of implications relating to the ease of operating any specific landfill site. (High plains areas, on the other hand, are generally less characterized by severe local relief.)

2. Geology and Soils

The soils found on relatively steep slopes at high elevations tend to be shallower and less developed than soils lying at flatter or lower elevation locations. First, the climate at high altitudes may inhibit the growth of vegetation and deter microbial activity, both of which are processes critical to soil development. Second, strong winds combined with storm runoff on long, steep slopes and the lack of substantial vegetation in some areas, lead to a situation where soil is eroded as fast as it is developed. Finally, the fact that a soil is found on a steep mountain slope may indicate that it has had relatively less time to develop than soils found elsewhere.

Soils on the high plains, however, are usually deep and more developed but have the same potential for erosion if not managed properly.

3. Surface and Ground Water Hydrology

Shallow soils overlying bedrock on steep slopes often result in conditions consisting of high runoff or shallow sub-surface flow rates. This, in conjunction with seasonal snow melt, leads to greater peak runoff volume events. Greater runoff volumes, when combined with steep slopes and sparse vegetation, create high runoff velocities. This, in turn, results in substantially higher soil erosion, particularly on loose, poorly developed soils.

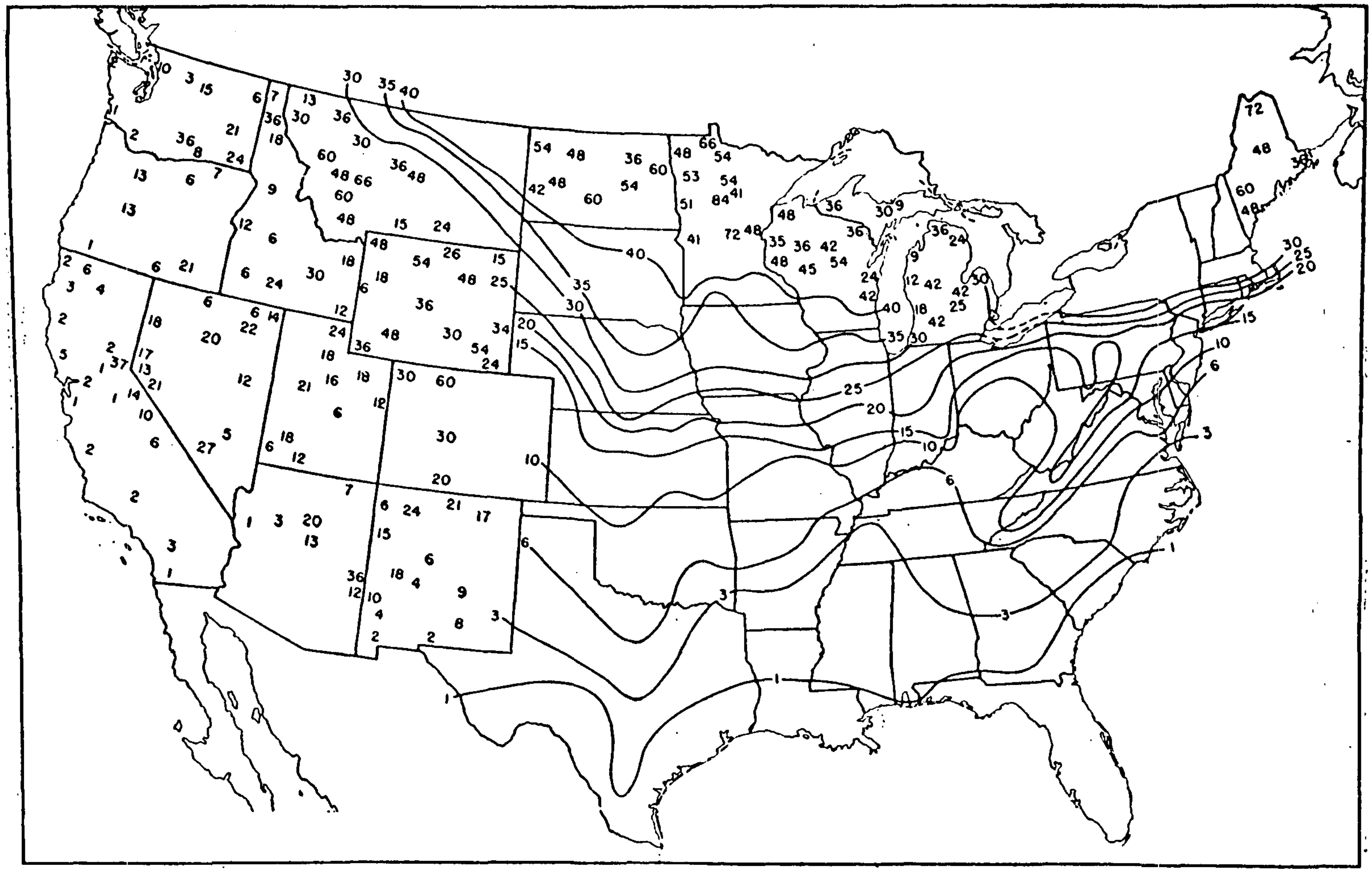
High plains areas may exhibit totally different surface and groundwater hydrologic characteristics than high areas with steep slopes. Shallower local relief generally results in lower runoff rates and high infiltration rates. Deeper soil depths and decreased annual precipitation rates also generally result in increased depths to groundwater and less potential for pollution.

4. Frost Action

Soil moisture near the ground surface freezes when the temperature remains below 32°F for periods longer than three to four days. The longer and colder the period of freezing, and the greater the ability of the soil to conduct heat, the greater the depth to which freezing occurs. Exhibit 3 maps the maximum depth of frost penetration in Region VIII. As a result of this freezing, layers of ice form beneath the soil and the surface of the ground rises. This phenomenon is called "frost heave". Frost heave can be very damaging to pavements, compacted earth layers, and small structures with shallow foundations. Upon thawing of the ice lenses, an excess of free water is left in the upper layers of soil until the lower layers also thaw and allow drainage by percolation. This temporary condition lowers the soil's strength and stability. The greater the frequency, rate, and amplitude of temperature fluctuation about the freezing point, the more severe

EXHIBIT 3

REGIONAL DEPTH OF FROST PENETRATION (IN INCHES)



Source: Design and Construction of Covers for Solid Waste Landfills.
U.S. Environmental Agency Report, EPA600/2-79-165, 1979.

the frost action. When sufficient quantities of soil moisture are available, frost action in both mountainous and high plains areas can result in fractioning of liners and soil covers and consequently increases the potential for pollution.

5. Ecology

Many organisms inhabiting high altitude areas have developed very specialized adaptations to their severe, fragile, and very localized environments. As a result, many of these plant and animal species have particularly slow growth rates and may be considered rare, threatened, or endangered. Consequently, revegetation efforts must be planned more thoroughly to ensure adequate closure of completed cells or sites.

III. POTENTIAL SPECIFIC LANDFILL PROBLEMS IN CLIMATICALLY SEVERE AREAS - THEIR CAUSES AND ALTERNATIVE APPROACHES

The following sections provide a description of the most common operational problems experienced at severe climate sites throughout Region VIII. Alternative approaches which can conceivably mitigate the described operational difficulty are presented. In a number of cases the same approach could be utilized to minimize operational problems in a number of areas. It is up to the landfill operator, designer, or appropriate regulatory official to determine the technical, environmental, economic, and/or legal applicability of each alternative for any site specific situation. In some cases, technological approaches not actively utilized in Region VIII, and generally more expensive than current practices, are presented. While perhaps not immediately economically attractive, increasingly stringent Federal and State environmental regulatory programs may result in eventual utilization of these approaches.

A. INADEQUATE COVER TYPE AND AVAILABLE QUANTITIES

1. The Problem

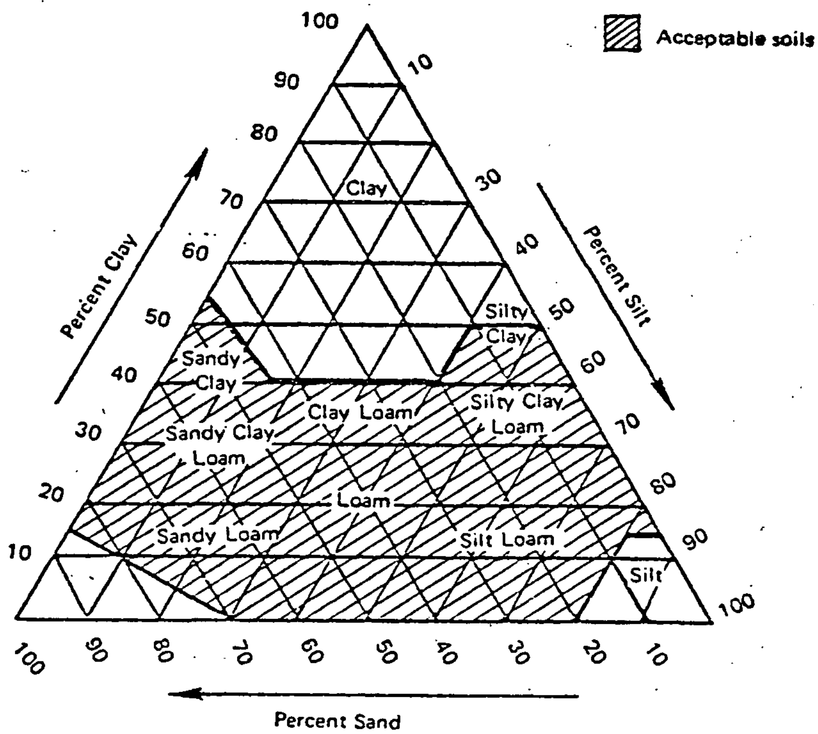
In mountainous areas an adequate supply of appropriate cover soils for daily application and final closure at landfills may be difficult to obtain.

Exhibit 4 presents information detailing the most appropriate types of cover soils. Characteristics most important in selecting a cover soil include workability and low permeability.

As discussed in Chapter II, the steep slopes and cold climate normally found at high altitudes in mountainous areas may combine to inhibit soil development. The typical result is a shallow, coarse soil not well suited for cover operations. Even where adequate supplies of appropriate soil types are available, the frozen ground and snow accumulation characteristics of highland areas may combine to make soil extraction and movement very

EXHIBIT 4

SUITABILITY OF SOILS FOR LANDFILL OPERATION



Suitability of General Soil Types as Cover Material.[a]

Function	Clean gravel	Clayey-silty gravel	Clean sand	Clayey-silty sand	Silt	Clay
Prevent rodents from burrowing or tunneling	G	F-G	G	P	P	P
Keep flies from emerging	P	F	P	G	G	E[b]
Minimize moisture entering fill	P	F-G	P	G-E	G-E	E[b]
Minimize landfill gas venting through cover	P	F-G	P	G-E	G-E	E[b]
Provide pleasing appearance and control blowing paper	E	E	E	E	E	E
Grow vegetation	P	G	P-F	E	G-E	F-G
Be permeable for venting decomposition gas[c]	E	P	G	P	P	P

[a] E–excellent; G–good; F–fair; P–poor.
[b] Except when cracks extend through the entire cover.
[c] Only if well drained.

Source: Brunner, Dirk R. and Danial J. Keller, Sanitary Landfill Design and Operation. U.S. Environmental Agency, Report, SW-65ts, 1971.

difficult. Typically, suitable off-site soils are often not available within economically acceptable haul distances.

On the high plains, larger quantities of soil are generally available for use as cover material. However, depending on the specific site, hard pan, sandy, or other coarse soils may not prove to be particularly effective as cover soils due to difficulties in extraction and/or high permeabilities.

2. Alternate Approaches

The following discussions are intended to present a number of potential solutions to the problem of inadequate cover soils in climatically severe regions.

a. Reduced Cover Application Rates

Alternatives to daily cover include a reduction in actual cover application, either in terms of the frequency of application or of the thickness of application. For example, during cold weather reducing cover application may be possible since the waste is susceptible to freezing due to the moisture content of the waste itself. The primary purpose of daily cover is to minimize blowing refuse and control vectors, fire hazards, gas and leachate generation, and surface runoff. In some instances freezing of the solid waste can reduce these problems by binding the waste, by inhibiting biological activity, and by minimizing infiltration. This method may have its drawbacks in terms of eventual leachate generation, since, on the average, larger quantities of moisture would infiltrate the fill. The degree to which cover application rates can be reduced safely must be assessed on a site-by-site basis, and will depend on many factors including waste moisture content; duration and intensity of freezing periods; precipitation or snowfall frequency, duration, and intensity; cover soil type and availability; site drainage; surrounding land uses; etc. Another option in small communities is to limit the operation of the landfill to one or two days per week. Cover material would then only be required on those days.

b. <u>Alternate Cover Design</u>

Typically recommended cover designs include 6 inches of compacted soil for daily cover, 12 inches of compacted soil for intermediate cover and 24 inches of compacted soil for final cover. A large number of variations or possible different design alternatives exist. For example, increased depth of final cover could result in decreased infiltration in the long run, and could result in decreased daily cover requirements.

Selection of different soil types for daily, intermediate, or final cover could also result in increased utilization of locally available soils. Blending of different available soil types could also result in a cover soil mix with more appropriate handling and permeability characteristics. Exhibit 4 provides additional detail with respect to suitability for landfill operation.

c. <u>Additional Compaction</u>

Additional compaction of existing soil cover to reduce permeability and increase bearing strengths could also assist in minimizing the amount required for daily cover. A few extra passes with conventional compaction equipment can achieve the required results with respect to vector, fire, leachate, gas, and runoff control, but with lower soil requirements.

d. <u>Dewatering</u>

Dewatering of stockpiled soil can help maximize the use of potential on-site cover supplies by greatly minimizing stockpile freezing during severe winter weather. By providing maximum slopes on stockpiles and surface diversion ditch systems, infiltration of water into the cover material can be minimized. This can result in the year-round availability of on-site cover and the potential utilization of otherwise marginal soil types.

An alternative approach to maintaining cold weather soil availability consists of placing cover into furrows approximately eighteen inches high. In situ soil drying generally results in non-uniform soil freezing which consequently results in a more readily worked soil source.

e. Chemical Modification

In severe climates, soil cover problems can be minimized through soil blending or chemical modification. Where appropriate cover types are in short supply or unavailable, the blending of soils of different textures that are available on or near the site can achieve the desired cover soil grain size distribution, permeabilities, or in some cases attenuation capabilities. This blending can be achieved through the addition of gravel, sand, silt, or clay, depending upon the needs of the particular landfill. Many other desired cover soil properties may be achieved artificially with chemical additives or cements. Cements serve as strengtheners or stabilizers and include soil-cement and soil-bitumen. Other cement-modified soils include bentonite cement-treated soil, lime-treated soil, fly ash-lime-treated soil, fly ash-treated soil, and fly ash-lime-sulfate-treated soil. Numerous chemical additives can serve as dispersants, swell reducers, freeze-point suppressants, water repellants, and dust palliatives. The advantages of any particular cover soil modification must be carefully weighed against increased operational costs.

f. Off-site Cover Procurement

Procurement of off-site soil for daily, intermediate, or final cover use is an alternative which should be considered if sufficient on-site soil is unavailable or inappropriate for use. However, because of transportation costs, costs of off-site soil increase dramatically with increasing distance from the site.

g. Alternate Cover Types

Complete substitution of soil cover materials by non-soil materials may also achieve the desired cover properties. These materials include fly ash, incinerator residue, foundry sand, mine wastes, dried and stabilized wastewater treatment sludge, dredged materials, composted sludges, or weathered shale. However, it should be noted that these materials constitute feasible alternatives only if there are sources in close proximity to the landfill site. In addition, each alternate cover material must be investigated for the following parameters prior to use: ease of handling, flexibility, cracking, deterioration, possible added pollution impacts, permeability, porosity, compaction potential, and other soil-related characteristics. It is particularly crucial that an alternative soil type be capable of achieving required design functions such as litter control, erosion control, minimization of infiltration, etc.

h. Alternate Landfill Equipment and Accessories

In cases where soil is unavailable for daily cover immediately adjacent to the working face, but is available from other areas of the site, equipment selection for cover transport is important. Scrapers or draglines are often used for procuring and transporting cover from one area of the site to another. Difficulties in excavating frozen soil can be minimized to some degree with the aid of machine accessories such as rippers and larger bucket blades or teeth. Larger equipment, i.e., heavier and higher horsepower outputs, can also be more effective in procuring frozen cover. Trucking soil in large dump trucks may also prove efficient. If the problem is consistent throughout the life of the landfill, purchase of such equipment may be feasible; however, if cover procurement from one area to another is only incidental, leasing or borrowing such equipment may be more economically feasible.

B. DIFFICULT FUNCTIONING OF LANDFILL EQUIPMENT

1. The Problem

A number of environmental factors characteristic of mountainous, windy, and cold climate regions can combine to make the actual landfill operations of waste placement and burial very difficult. These factors include snow accumulation, frozen ground, ice, and steep slopes, among others. The previous section dealt with these factors as they related to inadequate cover types and quantities. This section deals with these factors as they impact the operation of landfill equipment and the potential for and the control of environmental pollution.

2. Alternate Approaches

a. Alternate Landfill Design

Initial site design can minimize landfill operating difficulties by controlling surface runon and runoff (and thus wet or freezing working conditions), reducing fill and side slopes, sequencing fill operations to minimize haul distance, etc. These in turn all result in significantly improved operating efficiency. The following sections provide more detail in a number of these areas.

b. Alternate Cover Types

Many of the alternate cover types and combinations outlined in the previous section can assist in minimizing the difficulty of equipment operation at the working face. For example, some of these cover materials may be less susceptible to freezing than other types. Incinerator residues, fly ash, and other non-soil covers, specifically, may be less susceptible to freezing, and therefore will minimize difficulties at the working face. Alternate cover soils may also provide more traction for landfill equipment, i.e., loam soils are more tracticable than fine clayey soils.

c. Off-site Cover Procurement

Off-site procurement of cover materials can minimize strain on landfill equipment, since such cover is often selected due to ease of access.

d. Alternative Cover Handling Operations

Frost penetration in severely cold areas can be as deep as 6 feet or greater. As a result, to reduce equipment operating difficulties, cover material should be stockpiled in warm and preferably dry months to avoid having to procure cover material during heavy frost months. Although stockpiled material is also susceptible to freezing, a number of preventive measures can be instituted. To prevent water infiltration into the soil, the stockpile can also be covered with a synthetic liner. A number of commercially produced liners including butyl rubber, Hypalon, and chlorinated polyethylene are available. If properly utilized, snow cover may also act as an insulator and can assist in minimizing the depth of frost penetration.

As previously mentioned, cover soil modifications can also assist in minimizing landfill equipment difficulties. These include the application of chemical additives such as freezing suppressants (e.g., calcium chloride in solution or dry powder form) and surface water repellents (e.g., soil-cement and soil-bitumen).

e. <u>Alternate Landfill Equipment and Accessories</u>

Proper selection of the basic landfill equipment for day-to-day operations can also minimize operating difficulties. Often, since many solid waste service areas in Region VIII are quite small, landfill equipment serves a dual role--highway work and landfill operation. Two generalized types of motorized equipment have been developed which can be utilized in both instances with varying degrees of efficiency. Crawler mounted equipment is designed for operation on soft or uncompacted materials. The crawler tracks provide a large surface area to support the equipment's weight. Although versatile, crawler equipment is generally limited to top speeds of less than ten miles per hour and as such is most useful for moving large quantities of soil or waste materials distances of less than 200 to 300 feet.

Wheeled equipment types travel at much higher speeds (up to 30 mph) where surface traction is amenable and are generally best utilized at sites with lengthy on-site haul distances.

A number of specific equipment types, either crawler or wheel mounted, are typically used at landfill sites. Bulldozers are generally heavy front bladed pieces of equipment available in crawler or wheel mounted modes. The majority of dozers utilized at sanitary landfills, however, are crawler mounted. A number of additional accessories include refuse blades, track roller guards, sprocket seals, reversible fan blades, armor-protected hydraulic lines, cab roll bars, engine screens, radiator guards, crankcase guards, sheepsfoot roller attachments, and enclosed operator's cabs with heating and/or air conditioning options.

Front loaders (shovel loaders) are also available in wheeled or crawler versions. A single or double jawed bucket is provided for excavation and waste transport. Front loaders can be equipped with many of the same accessories as indicated for bulldozer equipment. Wheeled equipment is generally provided with steel cased tires with traction treads.

Power shovels perform large volume excavation and loading functions. A variety of power shovels are available including dipper shovels, dragline shovels, clamshell shovels and backhoes.

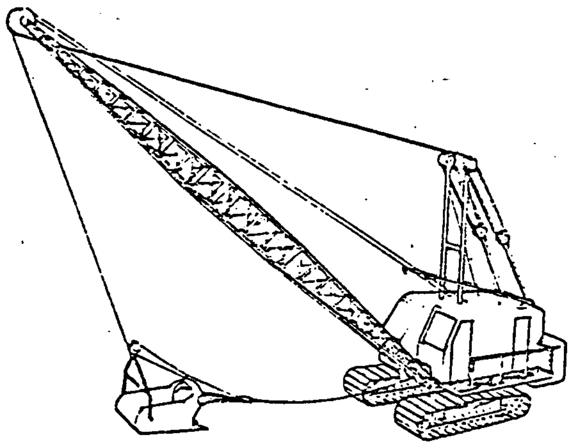
Scrapers perform large volume earth moving functions where soil materials must be moved long distances. Scrapers can be drawn by another piece of equipment or can be self-propelled units. Graders are also available in self-propelled or non-motorized models. Scrapers are capable of final contouring and shallow excavation activities.

Landfill compactors are generally modified highway compactor designs consisting of steel wheels with special compactor cleats. Compactors are not useful for excavation purposes but can serve to spread waste and coarse material via installation of a refuse blade.

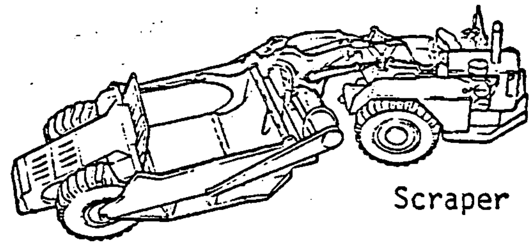
Exhibit 5 presents a schematic of common landfill equipment types. Equipment manufacturers, well aware of problems encountered when operating their products in severe climates, have produced a number of optional accessories to assist in minimizing these problems. Track or wheel-loaders have detachable rippers available with a standard 3-shank arrangement or an optional 5-shank arrangement, both capable of penetrating and loosening frozen ground to a maximum depth of 14 inches. A ripper linkage system, available for almost any size loader, is a necessity for landfills located in severe climate areas for cover procurement and other earthmoving functions. Landfill equipment used in cold climate areas should be provided with bucket teeth to assist in ripping and loosening frozen ground.

EXHIBIT 5

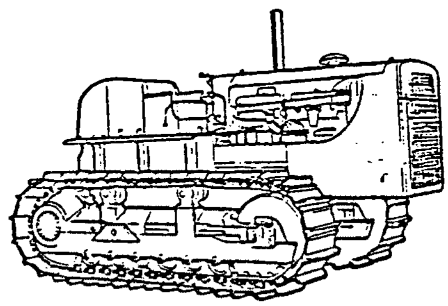
LANDFILL EQUIPMENT TYPES



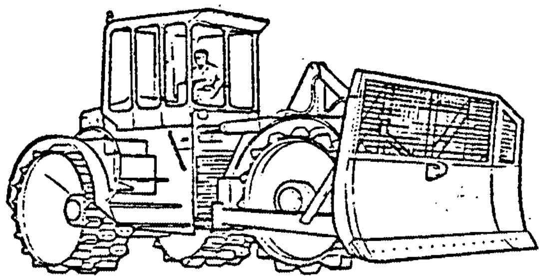
Dragline



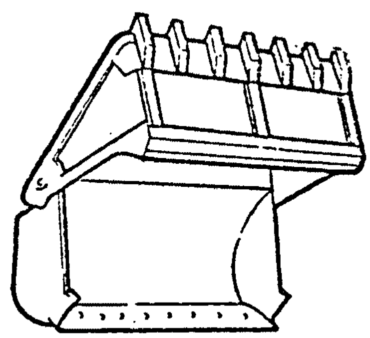
Scraper



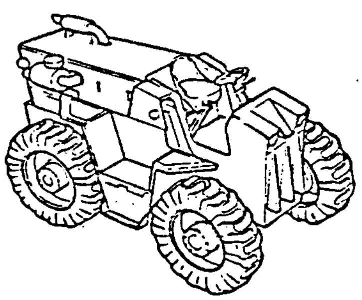
Crawler Tractor



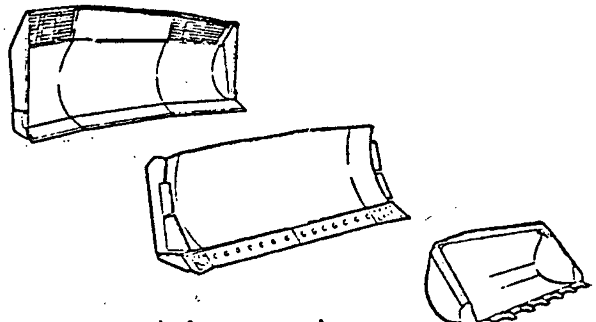
Steel-wheel Compactor



Multipurpose Bucket



Rubber-tired Tractor



Front-end Accessories

Source: Sorg, Thomas J. and H. Lanier Hickman, Jr.
Sanitary Landfill Facts, U.S. Dept. of H.E.W.
Report SW-4ts, 1970.

Because of excessive thaw and wet conditions experienced in the spring months it may be beneficial to provide a winch system on some of the equipment to assist in freeing disabled landfill or collection equipment.

f. Surface Runoff Controls

Drainage systems help to remove excess surface runon and runoff prior to infiltration into the waste cells. In cold climate areas where spring thaw of the snow cover and the frozen ground yields large quantities of runoff, proper peripheral drainage around the working area must be maintained. Ditches and berms constructed as surface runoff controls should be lined either with synthetic material or seeded with appropriate vegetation to minimize erosion. A number of techniques to control drainage channel velocity and scour include adjustments in channel depth or width, and variations in vegetation type and slope design. Berms can also be protected with rip-rap, or gabions constructed on-site or commercially prefabricated.

To control runoff on previously filled areas, the surface should be properly graded to achieve adequate runoff, inhibit ponding, and reduce erosion. Generally a maximum slope of 20% and a minimum slope of 3% are recommended. In cold climate areas ponded water, particularly when frozen, hinders mobility over the landfill surface.

g. Inclement Weather Reserved Area

In severe climate areas, particularly during the winter and spring months, the working face should be kept as close to a good access road as possible. Waste delivered in inclement weather should be landfilled in such a way that the base of the working face is on original soil to avoid possible difficulties associated with previously disturbed or settled areas. Suitable soil cover should be maintained in close proximity to the designated inclement weather area. In cold climate areas, particularly severe weather conditions may warrant postponement of landfill operations. Landfill operators should make such judgements on a day-to-day basis.

h. Snow Removal Considerations

Landfill operations are often hindered by accumulations of snow. On access routes snow accumulations as little as six inches can hinder waste delivery. Snow removal is also necessary on the working face and on cover procurement locations. While all the pieces of landfill equipment previously discussed can be utilized in snow removal operations, tracked or wheel mounted equipment with dozer blades are the most efficient.

i. Alternate Landfill Methodologies

To minimize operating difficulty at the working face due to inclement weather it may be beneficial to alternate among landfill methods to resolve specific problems. For example, during snow storms and high winds the trench or valley method is superior, because it aids in providing a barrier for the operator at the working face. Cover material obtained when using the valley or trench method is also less likely to be frozen because it is often freshly excavated on a day-to-day basis. The borrow area is also protected from wind and snow because of the trench embankment. When using the trench method, it is imperative that the periphery of the excavated area be properly channeled to minimize the amount of runoff into the trench.

During the thaw season, the ramp or area methods of landfilling may be preferable because of wet conditions and mud throughout the site. The ramp method allows for a build up of an area higher than the existing contours, thus creating a drier working face.

Another simple approach which can minimize difficult operations due to severe climatic conditions is proper landfill operation sequencing. Naturally, cell sequencing should be considered in the site planning and design stages. However, a landfill operator may choose to reschedule landfilling operations in accordance with seasonal or daily weather conditions. In case of particularly difficult operating conditions, such as severe snow storms, site operations may be postponed and waste collection services delayed until landfill operation can be reinstated. Alternatively, on-site waste storage areas or "wet weather" operational areas could also be provided.

C. POTENTIAL FOR SURFACE RUNOFF AND EROSION

1. The Problem

Surface runoff and consequent soil erosion and stream sedimentation can be severe problems at landfill sites in high altitude/cold climate areas. The soils in these areas tend to be shallower, less developed, and more erodible since: (1) they lie on steep slopes; (2) they are more recent in origin; and (3) the cold climate hinders vegetation growth and soil microbial activity. In addition, these soils are subject to the relatively more powerful erosive forces of: (1) high winds; (2) surface runoff on long, steep, and often sparsely vegetated slopes; (3) surface runoff volume peaks due to snowmelt; and (4) frost action.

2. Alternate Approaches

a. Cover Soil Type Selection

Soil erosion on landfills can be minimized by selecting cover material types which are characteristically erosion-resistant. The parameters which are most important in determining potential soil erodability are particle size distribution, organic content, soil structure, permeability, and in some cases, soil chemical properties. Due to the remolding and mixing which occur during cover soil excavation and placement, the most important of these factors in soil cover selection is grain size. The larger the grain size, the less susceptible cover is to erosion. In cases where excessive erosion is evidenced, it may be beneficial to procure large grain-sized cover from off-site borrow areas.

Another erosion control measure is soil stabilization through chemical and cement additives. The approach is best used on areas where slopes cannot be limited and where high runoff rates are unavoidable.

b. Top and Side Slopes

Proper grading of top slopes assists in controlling erosion by rerouting flows and reducing flow velocities. In general, if possible, design recommendations suggest that surface slopes should be at least 2% to avoid ponding, but should not exceed 5% to avoid excessive erosion. Berms or swales should be constructed along the top of the slope to intercept runoff. These channels can be drained at various locations through spillways or vertical drops constructed from prefabricated material. Slopes can also be rip-rapped with rock or prefabricated materials if the slope is a permanent structure.

c. Surface Treatment and Vegetation

Surface erosion can be controlled through a number of methods including mulching, fabric lining, vegetation, surface smoothing, and compaction. Controls should be initiated as soon as possible after final cover application. Seeding can be a progressive operation, moving from one cell to another as landfilling proceeds. Mulch should be applied after seeding to minimize exposure, erosion and wind damage. A number of mulches that can be used in severe climate areas include shredded wooden bark, hay, and a number of commercial products and synthetic materials. The appropriate type of vegetation and mulching material should be selected in accordance with site-specific climatological and topographical conditions.

d. On-Site Drainage Features

Utilization of stabilized existing site contours for runoff control can be beneficial in that it reduces the amount of site work required. This option is very site-specific, and if possible should be incorporated into the overall site drainage plan.

Large volumes of water, in the form of precipitation or spring thaw, should be diverted with prefabricated or constructed ditches or swales around the landfill site. To minimize cost, swales or ditches constructed by landfill equipment and properly protected for scour velocity are effective. Pump operated systems at a landfill site should be employed only if absolutely necessary due to cold weather operating problems and long term energy and maintenance commitments.

e. Off-Site Runoff Diversion

It is beneficial to divert natural drainage upgradient of the site to minimize surface runon onto the landfill itself. To divert runoff, a ditch or swale constructed around the periphery of the site and discharging down gradient of the site is generally suitable. Care should be taken with discharge point design or problems like undercutting may result. In cases of excessive runoff, berms or dikes with appropriate channel protection may be required.

D. POTENTIAL FOR GROUNDWATER POLLUTION

1. The Problem

Groundwater and infiltrating surface water percolating through landfilled solid waste may produce leachate, a solution of dissolved and suspended matter and microbial waste products. Depending upon its composition, concentrations, and volume, this leachate may pose a danger of severe contamination of underlying groundwater and/or adjacent surface waters. In some instances, the potential for groundwater pollution due to leachate generated from landfilled solid waste can be high in severe climate areas.

For example, leachate migration volumes may reach temporary extremes with the onset of warmer weather and the thawing of precipitation stored as snow cover and ice lenses in frozen ground. In addition, cold weather during the winter months may hamper cover application operations and landfill operators may be forced to allow snow to fall directly on the waste mass. Thus, the thawing of frozen waste may compound the increased infiltration which occurs during the spring season.

2. Alternate Approaches

Alternate approaches to minimizing the potential for ground water pollution at climatically severe landfill sites include:

(1) various means of controlling surface runoff and infiltration;

(2) raising the landfill base with clean fill to increase the separation to adjacent high groundwater levels and to increase the soil depth through which leachate must percolate before reaching groundwater;

(3) physically containing the leachate with natural clay or synthetic liners;

(4) using a variety of direct leachate control measures including leachate collection, treatment, recycling, and monitoring; and

(5) utilizing an alternate landfill design and operating approach.

These potential solutions are discussed separately below.

a. Surface Runoff Control

If water quantities flowing over landfill areas are minimized, infiltration to the waste mass and the amount of leachate generated should also be minimized. Therefore, the measures outlined in Section C., "Potential for Surface Runoff and Erosion", are also applicable as solutions to minimizing groundwater pollution at landfills in climatically severe areas.

b. Raising Landfill Base with Clean Fill

When siting a landfill, the natural topographical and hydrogeological considerations which indicate the potential for groundwater pollution must be analyzed. Landfills should not be placed in direct contact with underlying groundwater aquifers. If local groundwater tables are high, one method of protecting groundwater is to raise the base of the landfill site with fill materials. Assuming that natural soils are available, soils best suited to such purposes are those with reduced permeability and/or high attenuation capacity.

c. Leachate Control Measures

Maintaining a physical separation between solid wastes and groundwater reduces the potential production of leachate and the potential contamination of surface water and groundwater by leachate. Vertical separation of the waste above the historical high groundwater level can prevent intrusion of groundwater into the waste and consequent leachate contamination. However, leachate has the potential for downward migration into groundwater systems and therefore, physical separation of the waste and groundwater supply is usually not totally adequate to prevent groundwater contamination. A natural clay or synthetic liner which can both minimize the downward movement of leachate pollutants and prevent direct intrusion of groundwater into landfilled solid wastes is clearly more effective.

Proper liner selection, design, and construction in severe climate areas depends upon several factors including climatic conditions, waste types and quantities, subsurface soil conditions, landfill type, current and projected regional water resource uses, the potential effect of leachate on groundwater quality, direction of groundwater movement, and the interrelationship of the aquifer with other aquifers and with surface water. To be effective, liners must be relatively impermeable to leachate and must be sufficiently durable to maintain their integrity over the expected period of landfill leachate generation. Specifically, in severe climate areas the liner must be capable of withstanding the stresses associated with freezing, thawing, wetting and drying, periodic shifts of the earth and subgrade settling, as well as stresses associated with liner installation and initial operation of equipment on the lined base.

Available synthetic liners are usually made of either polymeric or asphaltic materials. The asphalt group includes asphaltic concrete, emulsified asphalt, soil-asphalt mixtures, and asphalt seals. The polymeric group includes synthetic butyl rubber, PVC (polyvinylchloride), PE (polyethylene), and Hypalon. Synthetic liners must resist attack from ozone, ultraviolet radiation, soil bacteria, mold, fungus, and vegetation and must be compatible with the wastes deposited. The liner must be amenable to field splicing and to repair as necessary on a year-round basis. Furthermore, synthetic liners used in severe climates must resist cracking, laceration, abrasion, and puncture by the landfilling operation. Placing the liner between layers of sand, each layer being a minimum of six inches thick, will cut down on liner damage caused by the weight of waste and equipment from above. Damage, however, may also occur from the buildup under the liner of decomposition gas from previously filled areas underlying or in close proximity to the liner. Placing an impermeable soil layer under the bottom sand layer or installing a gas venting system would mitigate this problem. Exhibit 6 lists various synthetic liners and their advantages and disadvantages.

Another liner material is natural clay, either in situ or transported in and compacted. Natural clayey materials may offer an advantage in that they may exhibit attenuation properties for specific leachate constituents. Selection of a natural clay liner based upon specific attenuation properties for a particular waste type can therefore provide an additional degree of protection for adjacent groundwater supplies.

Clay liners, as well as synthetic liners, should be overlain by a sand layer. This layer, besides affording protection, acts to facilitate drainage of leachate. This layer may be six inches to two feet in thickness and can incorporate gravel or clay tile (or pipes of asbestos-cement, plastic, ductile iron, corrugated metal, or concrete) gravity drainage systems designed to channel leachate to the collection sumps. Once collected, the leachate may be treated immediately or pumped to a storage tank for eventual treatment or recycling. Leachate treatment methodologies are generally biological and/or physical-chemical. Land application of raw leachate, recirculation of leachate back through the fill, and piping leachate to a municipal wastewater treatment plant are alternative disposal methodologies.

Several wastewater treatment techniques have been tested, primarily on a laboratory scale, for their effectiveness in treating landfill leachate containing organic matter and inorganic ions. While many researchers have

EXHIBIT 6

UTILITY OF POLYMERIC MATERIALS AS LINER MATERIALS

Liner Material	Advantage	Disadvantage
Polyethylene	Expense Chemical Resistance Tensile Strength Low Temperature Handling	Weatherability Puncture Resistance Unexposable
Polyvinyl Chloride	Range of Manufactured Properties Available Chemical Resistance	Some Formulations Subject to Biological Degradation Low Temperature Handling Unexposable
Butyl Rubber	Low Permeability Exposable	Lack of Chemical Resistance to Hydrocarbons and Solvents Splicing Difficulty
Hypalon	Puncture Resistance Low Temperature Handling Chemical Resistance Exposable	Cost Tensile Strength
Ethylene Propylene Diene Monomer	Exposable Low Temperature Handling Weatherability	Lack of Chemical Resistance to Hydrocarbons and Solvents
Chlorinated Polyethylene	Tensile Strength Elongation Strength	Chemical Resistance

Source: Overview of Landfill Technology.
Fred C. Hart Associates, Inc., 1978.

EFFECTIVENESS OF LEACHATE TREATMENT PROCESSES

Character of Leachate				Processes					
COD/ TOC (1)	BOD/ COD (2)	Age of fill (3)	(mg/ℓ) COD (4)	Biological treatment (5)	Chemical precipitation (6)	Chemical oxidation (7)	Reverse osmosis (8)	Activated carbon (9)	Ion exchange resins (10)
>2.8	>0.5	Young (<5 yr)	>10,000	Good	Poor	Poor	Fair	Poor	Poor
2.0-2.8	0.1-0.5	Medium (5 yr-10 yr)	500-10,000	Fair	Fair	Fair	Good	Fair	Fair
<2.0	<0.1	Old (>10 yr)	<500	Poor	Poor	Fair	Good	Good	Fair

Source: Chian & Dewalle

been involved in landfill leachate treatability studies, this evaluation relies most heavily on the more recent and comprehensive investigations by Chian and DeWalle. Exhibit 7 summarizes the relative efficiencies of various leachate treatment methods for leachates from landfills of various ages. In addition to the methods listed, leachate can also be treated by recirculation back through the waste or by placement in evaporative lagoons. Recirculation, however, usually requires specialized landfill design and evaporative lagoons are technically possible only in arid regions.

Cold weather impacts on any of these treatment processes are at this point inconclusive because data on leachate treatment in severe climates are very limited. The most obvious effect that cold climate has on any treatment process is freezing and the resulting hindrance of mechanical equipment operation. Existing treatment facilities have resolved such problems by enclosing the whole treatment process in some type of a heated structure. As a result, the treatment process, either biological or chemical/physical, is contained in a controlled environment.

As an alternative to treatment and/or discharge, land application of landfill leachate has sustained little actual testing or experience to date as a viable leachate treatment process. However, results from land application of municipal wastewater can to some extent be extended to land application of landfill leachate. Key variables in evaluating the potential of this type of process include: soil type and attenuating capability, depth to groundwater, topography, application rates, season of application, climate, and the limitations that certain leachate constituents might place on the process. Because land application is seasonal, the use of this process in cold regions requires temporary leachate storage facilities or alternate treatment methods.

Leachate recycling is the controlled collection and recirculation of leachate through the landfill for the purpose of promoting rapid degradation of refuse and stabilization of leachate constitutents. Since recycling may result in the reduction of leachate strength it may also serve as a pretreatment arrangement prior to leachate treatment processes or direct leachate discharge. Leachate recycling is achieved via surface spraying with spray irrigation equipment in instances where the cover material is permeable. In instances where the cover is impermeable, recycling may be accomplished via irrigation fields placed below the cover.

The precise mode of operation of leachate recycling is still poorly understood since it has only recently been investigated in experimental landfill simulations; very little practical application of the concept has yet been achieved, especially with regard to severe climate areas. The generally hypothesized and accepted explanation is that recirculation of leachate through a landfill promotes faster development of an active population of anaerobic methane forming bacteria, which affect the bulk of the waste decomposition process. This, in turn, increases the rate and predictability of biological stabilization of the organic constituents in the waste. While initial recycling may result in higher leachate constituent concentrations than would normally be experienced, the potential increase in degradation rates theoretically should result in reduction of leachate constituents in a shorter time frame. A variety of constituents, particularly non-organics such as metallic ions, may remain relatively unaffected. Depending upon site specific considerations, requirements for long-term post-closure landfill leachate monitoring and management may be reduced in certain instances because of the stabilization that occurs.

Leachate recycling as a treatment process in severe climate areas is limited because of unfavorable weather conditions. Since the ground is frozen much of the year, recycling is limited to a few summer months unless more expensive below ground irrigation systems are installed. Alternatively, storage of all leachate generated during winter months could be provided. The construction of a retention pond with several months' capacity may require large capital investments as well as land commitments, which are both limited assets for small rural landfills typical of Region VIII.

In addition, groundwater monitoring facilities may be installed to protect groundwater and surface water resources adjacent to the landfill site. A properly designed monitoring program detects and evaluates pollution caused by leachate by periodically measuring and evaluating groundwater quality. This information can aid in determining the need for and nature of leachate controls, and in evaluating their effectiveness once they are implemented.

Groundwater monitoring techniques include monitoring in the zones of both aeration and saturation, field inspections and other methods. Monitoring in the zone of aeration can be done indirectly by measuring temperature or electrical conductivity, or can be done directly using suction devices, such as suction lysimeters, hollow fiber samplers, or membrane filter samplers. Monitoring in the zone of saturation involves periodical well sampling at a background station and at stations located downgradient in the path of groundwater flow. Prior to establishing a monitoring network, hydrogeologic studies should establish groundwater flow direction and depth, soil permeability and porosity, and typical background concentration levels.

This information is best determined by field inspection, but can be supplemented by already published information. From this site-specific data, a monitoring station network can be designed. A minimally acceptable monitoring network might consist of:

1. one line of three wells downgradient from the landfill and situated at an angle perpendicular to groundwater flow, penetrating the entire saturated thickness of the aquifer or aquifers which could potentially be contaminated;

2. one well immediately adjacent to the downgradient edge of the filled area, screened so that it intercepts the water table; and,

3. a well located in an area upgradient from the landfill so that it will not be affected by potential leachate migration.

The size of the landfill, hydrogeologic environment, climate, budgetary restrictions, and regulatory requirements are factors which will dictate the actual number of wells used. However, every effort should be made to have a minimum of three wells at each landfill and no less than one downgradient well for every 250 feet of landfill frontage. In locating test wells on landfills in severe climates, it is important to locate wells accurately and have them clearly marked for easy location during severe weather conditions. Wells should also be specifically located outside of highly trafficked areas to minimize potential well damage.

Establishment of the actual testing program should depend on waste types to be disposed of and on site specific conditions. For example, weather conditions may require testing only infrequently or not at all during the winter months.

E. POTENTIAL FOR BLOWING LITTER

1. The Problem

Prevailing wind speeds are normally greater in mountainous and high plains areas due to the lower frictional forces experienced by mass air movements at high elevations. In mountainous terrain, the local relief is the most important factor in controlling site-specific wind speeds and directions. In some site situations, the local topography may produce very gusty short-term conditions which make the control of landfill litter very difficult. High plains areas may also be subject to extended periods of high winds. Blowing litter at a landfill site presents both aesthetic and health problems and exacerbates public opposition to landfilling.

2. Alternate Approaches

The best means of controlling blowing litter at landfill sites is to minimize the quantity of litter exposed to wind forces. This can be accomplished with standard sanitary landfilling practices such as minimizing the area of the working face, minimizing the period of exposure of the working face to winds by application of daily cover and by minimizing disturbance of waste deposited on the face by limiting equipment operation to periods of low winds. Prohibition of open dumping must also be enforced vigorously to control blowing litter. Beyond these standard operational measures, a variety of other methods can be utilized. These include periodic clean-up operations, utilization of sheltered alternate working face locations, and utilization of litter fences or perimeter barriers. These are discussed below.

a. Clean-Up Operations

Clean-up of blown litter should be performed on a frequent basis. Because of high winds characteristic of severe climate areas, the clean-up operation may extend well beyond the daily working face area and should specifically include the waste receiving area and access routes into the site. Additional clean-up efforts may be required after excessive wind events.

b. Equipment Use and Accessories

If possible, compactors, dozers, and front end loaders should not be operated on the working face during periods of high wind conditions. Equipment operation under these conditions leads to breaking of garbage bags and results in proliferation of wind blown litter. Where practicable, equipment operation should be confined to low wind conditions, frequently in early morning and late afternoon periods.

Equipment accessories include a choice of a number of blade and bucket sizes. Where high winds are a problem, it is advisable to specify large blades and buckets to minimize blowing litter at the working face. Greater compactive efforts, achieved via completion of additional passes or operation of landfill compactors are also useful in reducing quantities of wind blown litter.

c. Litter Fences or Perimeter Barriers

Litter fences erected downwind of the working face are helpful in controlling blowing litter. Preferably, however, the litter fence should completely enclose the working face and should be re-positioned daily or as required to minimize litter. Litter fences from 6 to 8 feet in height are commercially available from manufacturers and have been specifically designed for such purposes. Successful operation requires judicial repositioning of the litter fences depending upon on-site wind conditions. Tree lines and other vegetation can also serve as wind buffers and minimize litter dispersion.

d. Alternate Landfill Methodologies

The use of alternate landfill methodologies, such as the valley or trench method, can assist in reducing blowing litter by utilizing the resulting contours as wind barriers. The valley method provides wind protection for refuse placement, as well as landfill equipment operations, by utilizing the surrounding higher original elevations as wind barriers. Further protection can be provided by placing a litter fence at the toe of the operation. The trench method is also commonly utilized. Trenches should be placed horizontally to the prevailing wind direction. Excavated side slopes inhibit wind movement along the working face. In any case, natural changes in topography should be utilized to the maximum extent possible to minimize blowing litter.

F. LOW RELIABILITY/HIGH MAINTENANCE REQUIREMENTS FOR LANDFILL EQUIPMENT

1. The Problem

Freezing temperatures, strong winds, steep slopes, and difficult excavating conditions experienced in severe climates can reduce the reliability and operating efficiency of landfill equipment, and increase maintenance down-time and costs. For many of the smaller landfills in Region VIII, which generally only utilize one piece of landfill equipment, equipment failure can result in cessation of adequate landfill operation for extended periods.

2. Alternate Approaches

Heated storage, frequent preventive maintenance, and utilization of cold weather accessories can aid in mitigating these problems. Failing these measures, utilization of more powerful landfill equipment may improve reliability and operation. These measures are discussed below.

a. Heated Storage

A heated storage area is the most effective winter protection measure for all landfill equipment. It may be beneficial for some sites to construct an appropriately sized maintenance garage where vehicles can be parked overnight. This option minimizes any morning startup problems that can be encountered during periods of excessive cold. Storage facilities and larger maintenance garages are easily constructed of either concrete block of pre-fabricated steel panels bolted to a steel-trussed frame. The cost-effectiveness of this option may be realized in minimized equipment downtime during the life of the landfill. The heated storage area also allows for ease of equipment maintenance.

Caution must be taken, however, due to potential methane gas migration into the buildings. Locating buildings away from buried wastes on top of impermeable foundations and periodic methane tests are recommended.

b. Frequent Preventive Maintenance

Frequent maintenance checks are recommended by the manufacturers of equipment planned for use in severe cold climate areas. Problems discovered prior to major breakdowns can save considerable amounts of money in repair costs, as well as down-time. Maintenance checks include tune-ups, oil filter changes, track tension checks, fluid level checks, periodic wear measurements, etc.

Each severe climate landfill should establish a preventive maintenance program to minimize equipment damage and down-time. At the end of each working day, the operator should inspect his/her vehicle for any vehicle damage, and report if any is found. Small repairs are easily performed, and are less costly than if the damage is overlooked and further aggravated. An inventory of standard parts such as oil filters, engine parts, radiators, fan belts, hydraulic parts and ripper teeth should be kept in stock to expedite small repairs. A portable welding unit may also be beneficial, since cracked and chipped steel parts are common occurrences in site and earthwork operations.

c. Cold Weather Accessories

Cold weather accessories should be specified for all landfill equipment. Accessories available include a cold weather starting kit, AC starters, block heaters and warming blankets for engines, radiators, and hydraulic mechanisms. Landfill equipment should also be specified with higher specification antifreeze (below -40° F) and fuel and oil additives. Because high altitudes are common to cold climate areas, it may also be beneficial to provide turbochargers on the landfill equipment to control the air/fuel mixture. Heavy duty batteries and crankcases are also recommended. Special underbody guards and seal waterproofing should be included on all movable parts to minimize ice formation and cracking of metal parts.

Since it is particularly important to monitor engine operating performance, a series of gauge systems including a tachometer, speedometer, hydraulic oil filter indicator, and oil pressure, water temperature, transmission pressure, and air/water temperature gauges are beneficial.

d. Alternate Equipment Section

When available, the use of larger equipment is advantageous because the larger products are more durable, and can be substantially more efficient at the working face. Large equipment is more capable of handling frozen cover and difficult wet weather operations, and is also often equipped with cold weather accessories which are provided only as optional equipment on smaller models.

G. LOW PERFORMANCE/HEALTH AND SAFETY RISKS FOR LANDFILL EQUIPMENT OPERATORS

1. The Problem

Landfill equipment operators in mountainous or climatically severe areas can be subject to a number of health and safety risks which are not normally encountered in other areas. The severe cold combined with high winds subjects equipment operators to more difficult daily operating conditions. Accidents may occur due to the steep slopes characteristic of mountainous areas, slope instability, and the lack of the traction created by frost action, snow accumulation and/or thawing of frozen ground and snow.

2. Alternate Approaches

A number of landfill equipment accident prevention and operator health protection measures can be taken at landfills in climatically severe areas. These are discussed separately below.

a. Enclosed Equipment Operator Cabs

Landfill equipment varies with specific job objectives. However, since an individual operator spends approximately six to seven hours daily operating equipment, comfort and safety are prime considerations in equipment selection. Equipment used for spreading, compacting, and covering daily waste should be provided, at a minimum, with an enclosed cab as protection from the wind and cold. In severely cold operating conditions, a heating unit within the cab is a necessity. Visibility is vital to proper operation and the heating unit should also contain a defroster fan system. Additional equipment for operator safety includes screening, sufficient lighting, and windshield wipers (front and back).

b. Roll-Over Protection

Most domestically manufactured earthwork equipment comes with a ROPS (Rollover Protection Structure) canopy as standard equipment. If not, the equipment can be separately installed.

c. Protection from Moving Parts

All hydraulic equipment on landfill machinery is manufactured to minimize safety risks from moving parts. However, landfill operators may specify additional screening and protection shields on movable parts to minimize the potential injury. These include rear screens for use with winches, crankcase guards, fan blast deflectors, hinged radiator guards, steering cylinder guards, engine and power guards, etc.

d. Back-Up Alarms

Back-up alarms are also standard equipment on all earthwork machinery. There is substantial activity around the working face with collection trucks dumping waste, dozers and compactors spreading and compacting waste, and scrapers spreading and compacting cover. Injuries and accidents can be minimized in this regard with the use of automatic back-up alarms.

e. Fire Extinguishers

Fire on landfills can be a hazardous occurrence and can result in substantive air and water pollution impacts. Fires can start when incoming refuse is already burning or when refuse is accidentally ignited by landfill visitors or operators. As such, all operating machinery should be equipped with portable fire extinguishers. The extinguishers should be maintained and checked periodically for proper operation.

f. First-Aid Kit

As an added precaution, first-aid kits should be on all landfill equipment to treat minor injuries. Landfill operators should also be specially trained in routine first-aid application.

g. Operator Communication Systems

Operator communication systems are advantageous in severe climate areas in that they allow the operator to remain in the heated cab while staying in contact with other equipment operators and with the operations manager or officer.

H. SOLID WASTE COLLECTION CONSIDERATIONS

1. The Problem

Rural, sparsely populated areas which are common in severe climate regions are often faced with collecting solid waste from a very large area. Additionally, in severe climate regions, land is either unsuitable for sanitary landfill operations or suitable land is unavailable due to either prohibition costs or incompatibility with adjacent land use patterns. The combination of these factors often make it advantageous to transport wastes out of the area for ultimate disposal. Regardless of the ultimate waste disposal site, most areas in severe climate regions utilize waste collection systems involving long haul distances.

The difficulties associated with lengthy haul distances for collection vehicles often impact the affected communities' waste collection disposal budget and as such exacerbate the provision of environmentally acceptable waste disposal. Because of non-concentrated populations and long haul distances, door-to-door collection service may be economically infeasible. Individual collection trucks carrying five to seven tons per trip to landfill sites in excess of 50 miles each way makes collection service unaffordable to most rural communities. As a result, illegal dump sites develop along rural roads, causing aesthetic, health, economic, and environmental problems.

Additionally, severe climate regions often encounter solid waste collection problems interdependently associated with long haul distances such as the following:

1) freezing wastes in collection containers and vehicles

2) operator difficulties resulting from freezing weather

3) access and/or manueverability difficulties associated with ice and snow and steep and winding roads.

2. Alternate Approaches

a. Long Haul Distances

Alternate approaches to reducing economic impacts of solid waste collection in large but sparsely populated regions include utilization of transfer stations, "Green Box" systems, and participation in regional landfill sites.

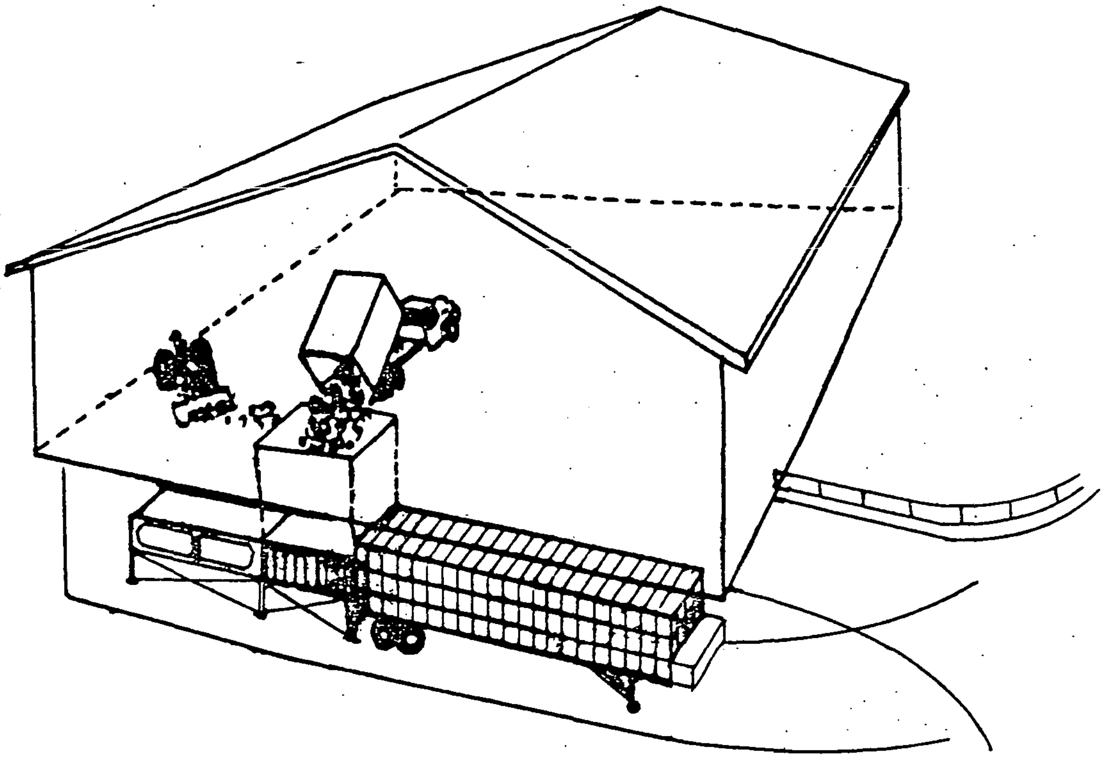
Transfer Stations. The problem of minimizing long haul distances by individual collection trucks to distant sites is best resolved by the use of centralized transfer stations. Individual collection trucks haul wastes to the transfer stations from which large capacity tandem-axle tractor trailers transfer the wastes to the ultimate disposal site.

Transfer stations are commonly designed to function in one of two ways (See Exhibit 8). One method is direct transfer (Direct Dump) of the wastes from the collection vehicles to the larger capacity transfer trucks. The second method consists of stockpiling the wastes from the collection vehicles and periodically moving the stockpiled wastes into the transfer vehicle. Generally, in cases involving small daily waste loads on the order of 50 tons per day (TPD) or less, simple collection truck to transfer vehicle transfers are the most cost-effective. Larger volume transfer stations - 50 to 250 TPD - usually utilize the stockpile method plus sophisticated transfer equipment. Additionally, transfer stations of this size have the potential to implement limited resource recovery operations (e.g. paper and aluminum can separation and recycling) to offset capital and operating costs. Transfer stations with various arrangements of optional equipment are commercially available from a number of nation-wide manufacturers, some of whom offer turn-key services.

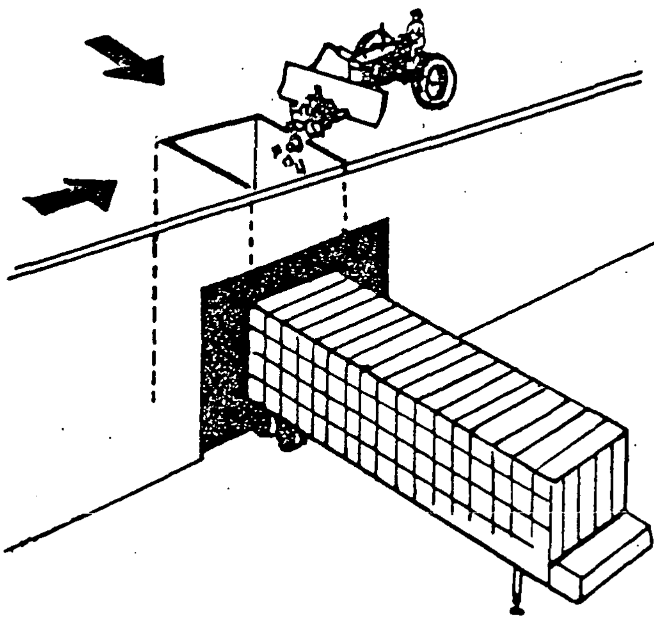
Regardless of the operational mode of the transfer station, it is in most instances practical and economical to have the transfer station itself

EXHIBIT 8

TRANSFER STATIONS



DIRECT DUMP TRANSFER STATION



STOCKPILE / FRONT END LOAD TRANSFER STATION

Source: Hegdahl, Tobias. Solid Waste Transfer Stations, U.S. Environmental Protection Agency Report (SW-99), 1973.

and/or the transfer vehicles equipped with compaction units to reduce the volume of the waste. Compaction decreases the number of vehicle trips taken to the ultimate disposal site, reducing energy usage and costs.

Two types of transfer vehicles are generally used with compaction equipment. The tilt frame/roll-off type is so named because of the moveable rail structure which is mounted directly on the truck chassis or separately on a trailer bed (see Exhibit 9). A roll-off container is collected (dropped-off) by "tilting" the rails and winching the entire container onto (off) the structure. When the container is to be emptied, the rear doors of the container are opened and the entire package is tilted so that the compacted refuse falls out.

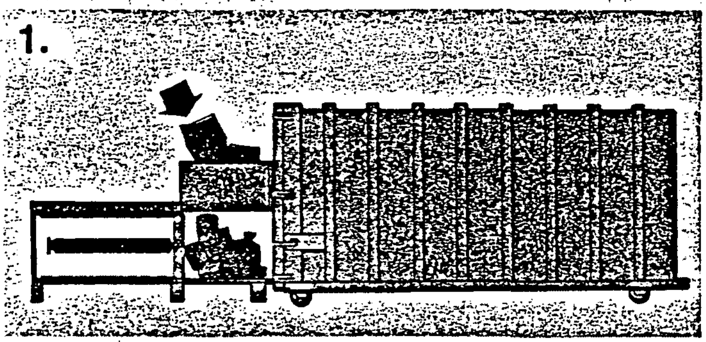
Commercially available tilt frame/roll-off transfer vehicles must be equipped with a separate refuse compactor. Refuse is deposited in a hopper feeding the compactor, which forces the wastes into the roll-off container. There is little compaction of refuse until the container is nearly full since, only then does the compactor exert a significant pressure. A typical ratio of compacted to loose refuse achievable by this type of system is 1.9 to 1 by weight.

In contrast to the external compactor associated with the tilt frame/roll-off type of trailer, the transfer trailer type of transfer vehicle has a hydraulic ejection ram mounted inside the trailer compartment (Exhibit 10). When emptying the trailer, the rear doors are opened and refuse is pushed out by the ram.

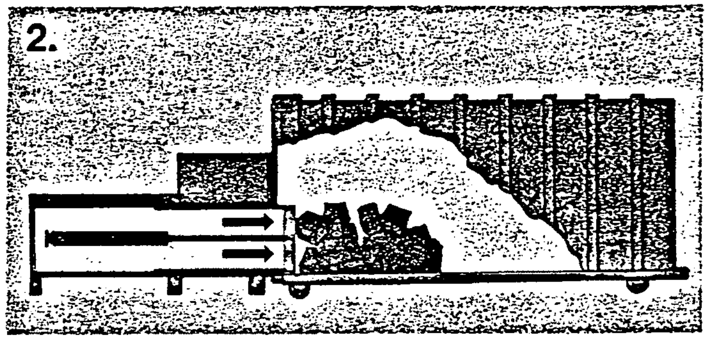
This ram provides a significant advantage for the transfer trailer as opposed to the roll-off system. The ram allows the transfer trailer to achieve a much higher density of wastes in one of two ways. If a separate compactor is utilized, it can work against the ejection ram which is extended at first and gradually retracted as the volume of contained wastes increases. Alternatively, the ejection ram can be used as a compaction device. In this system, wastes are introduced via a hopper into a "top dumping" trailer just behind the face of the ram. When a certain volume has been deposited, the operator can use the ram to compact the wastes against

EXHIBIT 9

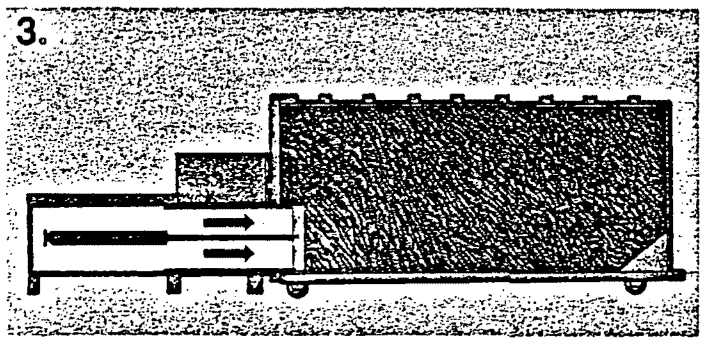
TILT FRAME/ROLL-OFF TRANSFER VEHICLE



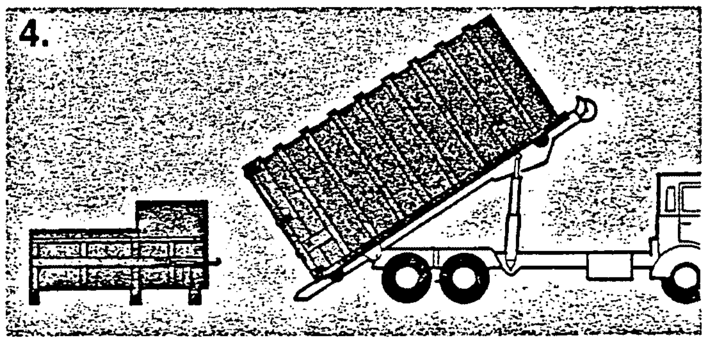
1. Refuse is inserted into the compactor hopper by various methods. Loading procedure can be selected to best suit each installation.



2. Simply activate pushbutton control and your trash is compacted and stored in a sanitary, closed system.



3. High compaction forces allow large volumes of refuse to be stored in the smallest space.

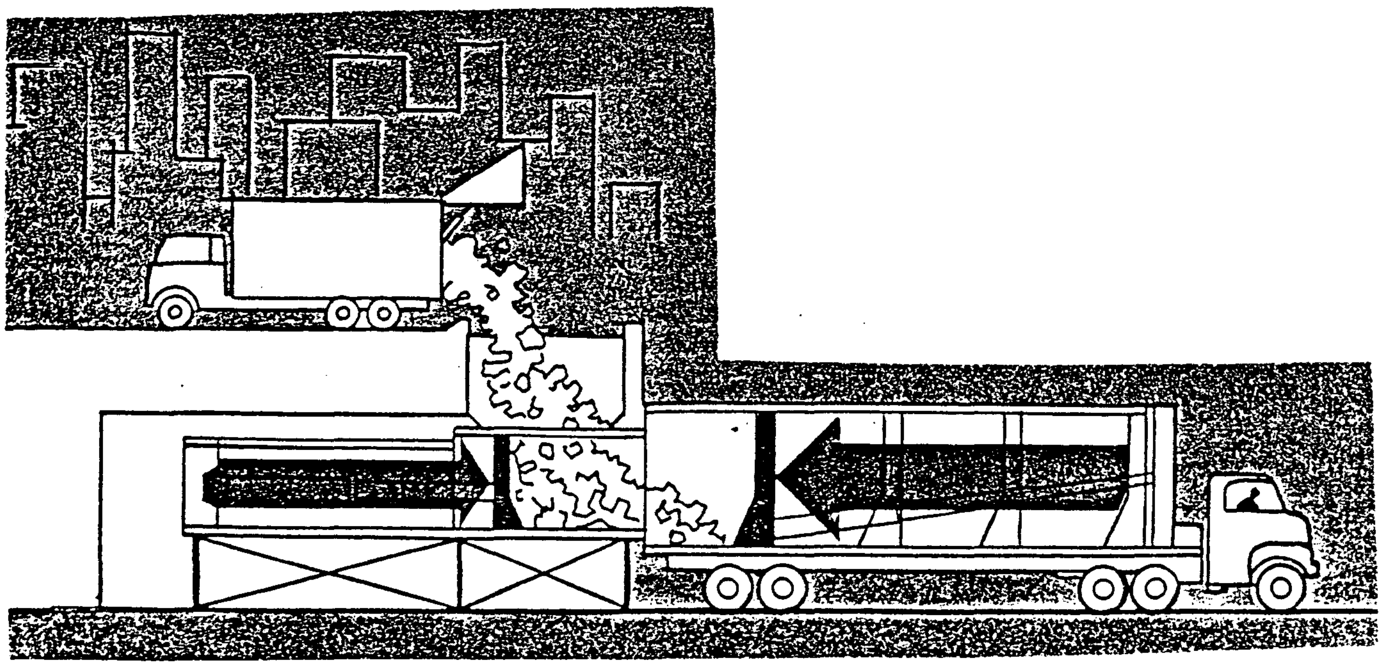


4. Your trash is removed by a roll-off truck when your receiving container is full and your system is ready for work again.

Source: Dempster Dumpster Systems, Knoxville, Tennessee.

EXHIBIT 10

TRANSFER TRAILER VEHICLE



Source:Dempster Dumpster Systems, Knoxville, Tennessee.

the rear door of the trailer. The advantage of this method is that no separate piece of equipment is required. All that the trailer requires is a source of hydraulic pressure which can be provided through a "wet-pack" hookup from the tractor rig or a stationary gas or electric hydraulic pump. A typical ratio of compacted to loose refuse obtainable by this method is 3 to 1 by weight.

Developing a transfer station involves a number of important design considerations that must be analyzed for each specific waste collection area. The primary considerations are: (a) service area; (b) population dispersement; (c) present collection methods; (d) system economics; (e) existing and projected design loads; (f) optimal location; (g) waste types; (h) seasonal variation in daily tonnage; (i) available vehicle types; (j) building design; and (k) facility layout.

Green Box Systems. For rural and small urban areas where individual door-to-door waste collection service is not available, an economic solid waste collection alternative is the satellite collection system which is commonly called a "Green Box" system. This system consists of locating several small collection containers ("green boxes") varying from 3 to 8 cu. yds. throughout sparsely populated areas (See Exhibit 11). These containers are placed in locations which are readily accessible to the public including intersections of local highways, recreational areas, previous dump sites, and in or near small communities.

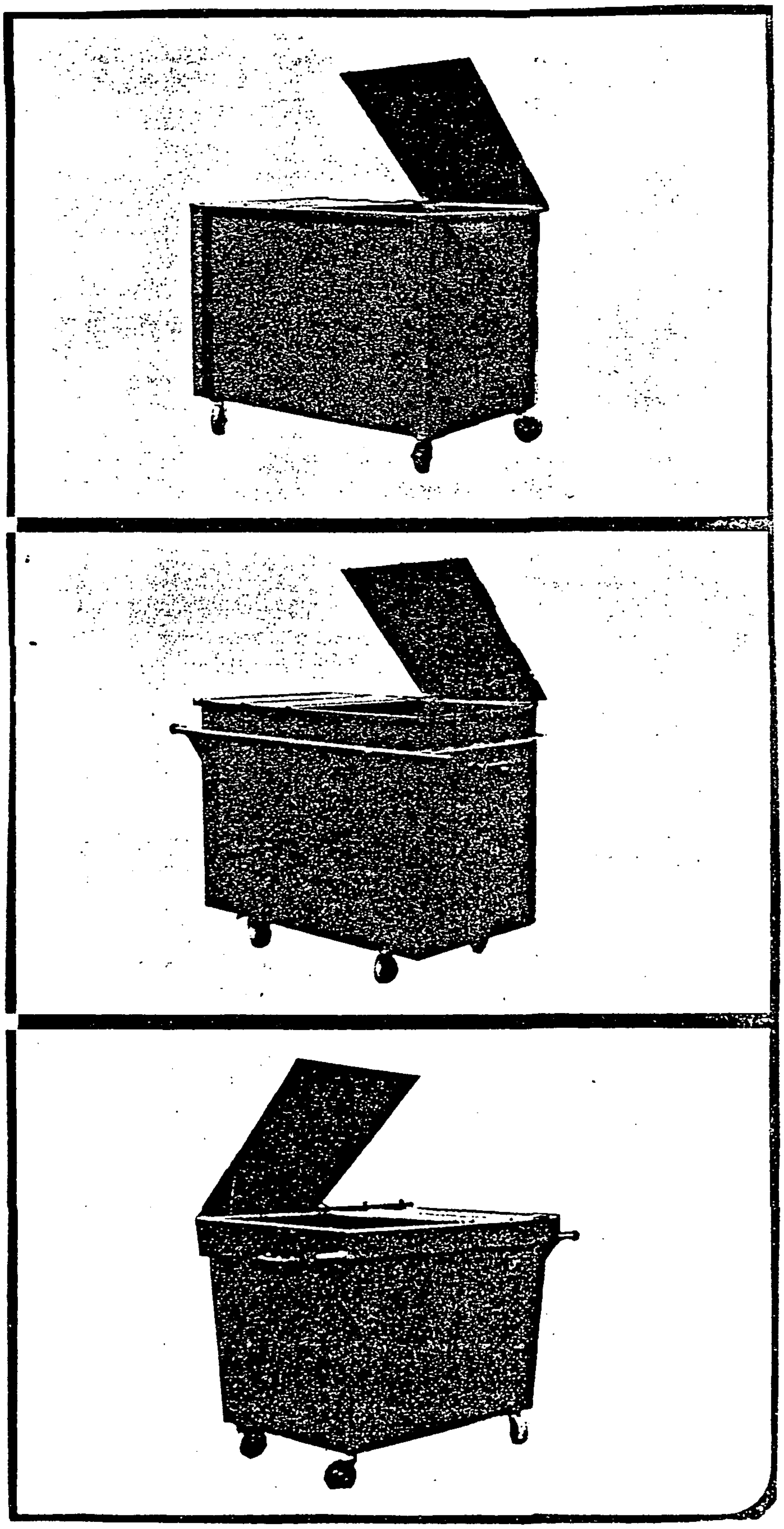
Stringent rules must be implemented and enforced by the appropriate authority to ensure proper operation of a green box system. Most importantly, the type of waste deposited in the green boxes must be controlled as follows:

a) Green boxes can accept

-residential household waste
-light commercial waste
-yard trimmings

EXHIBIT 11

GREEN BOXES



Source: George Swanson & Son, Inc. Arvada, Colorado.

b) Green boxes can not accept

- hot or burning materials
- dead animals
- industrial waste
- bulky waste (stoves, refrigerators, etc.), construction debris, tree trunks, etc.

These container systems can be designed such that the waste in the containers can be emptied into either a front loading or rear loading waste collection vehicle. (See Exhibit 12) By use of these specially-equipped vehicles, the containers are emptied periodically and the waste is then transported to either a transfer station or directly to an ultimate disposal facility. In many rural areas, a green box system has replaced several small indiscriminate dumps allowing for an economical waste disposal method which is in compliance with all local, State, and Federal laws.

Regional Landfill Sites. In a small number of cases selection of a landfill site or sites different from the existing landfill(s) can reduce problems and costs associated with long haul distances. Combining new centrally located landfill sites with optimally designed green box and/or transfer station systems can often result in significant cost savings for rural areas.

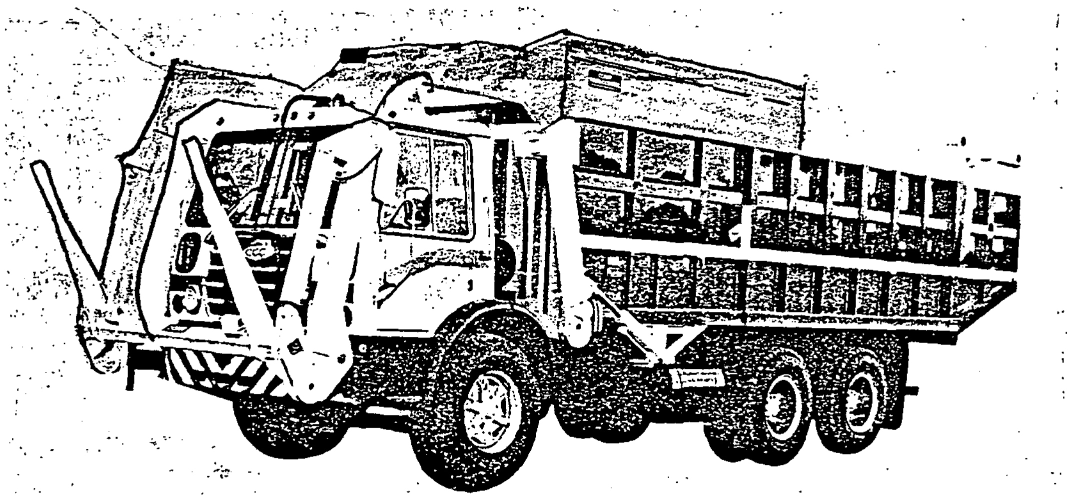
Additionally, large regional disposal sites may also replace a large number of individual facilities. Economies of scale at regional sites are realized in most aspects of landfill design and operation and are reflected in a reduced overall cost of disposal per ton of refuse, assuming that potential increases in transportation costs do not outweigh reductions in disposal costs. Large regional sites can often also incorporate more sophisticated disposal approaches such as incineration and resource recovery activities. Environmental, economic, and legal considerations of regional sites are discussed in more detail in Chapter IV.

b. Freezing Waste, Operator and Access Difficulties

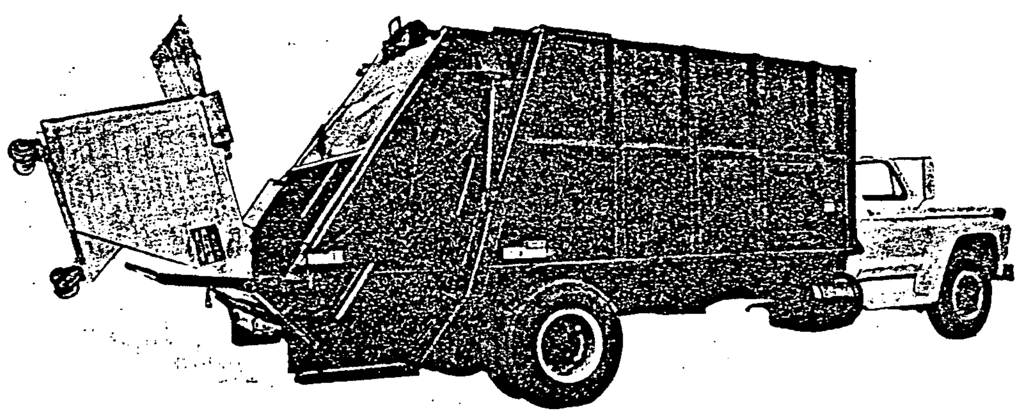
Freezing Waste. Waste collection vehicles and storage containers often have problems with freezing wastes in severe climate areas. This can result in loss of available capacity within the vehicle or container, deteri-

EXHIBIT 12

FRONT AND REAR-LOADING GREEN BOX COLLECTION VECHICLES



Source: Perfection-Cobey Co., Galion, Ohio.



Source: Dempster Dumpster Systems, Knoxville, Tennessee oration of the equipment, and, in extreme cases, equipment breakdowns. Generally, two operational procedures are utilized to minimize problems associated with freezing wastes:

1) ensuring that the collected or stored waste does not remain in the vehicle or container for the period of time required for the waste to freeze

2) if the waste does freeze, manually removing it from the vehicle or container by using a rake, shovel, or similar instrument

<u>Operator Difficulties</u>. Environmental conditions such as freezing weather, drifting snow, ice storms, and gusty wind conditions can make the already difficult job of collection and disposal operations even more difficult. Certain procedures and modifications can be implemented to minimize operator problems encountered in severe climate areas. These include using automated collection vehicles such as front or side loading compactor collection trucks, ensuring that operators are outfitted with cold weather attire, and providing insulated cabs and heaters and heated shelters for the collection and disposal operators.

<u>Access Problems</u>. Deep snow, ice, mud, and steep and windy roads present problems to collection vehicles in completing their collection routes and entering and exiting disposal sites. Most of these problems exist because the vehicle is not matched to the conditions or the vehicle is not properly equipped, i.e., it lacks snow chains, mud and snow tires, improper gear ratios, etc.

To minimize access and manueverability difficulties, collection vehicles must be initially properly selected or fitted with the necessary accessory equipment to be able to function in adverse conditions whether empty or loaded with waste. The operational advantages and disadvantages of front-wheel drive versus rear-wheel drive versus 4-wheel drive collection vehicles must be evaluated under the conditions which the vehicle will be utilized. Optimizing access considerations must be compared to the extra capital and operating costs associated with specially geared vehicles and accessory equipment. Additionally, optimizing vehicle usage during the winter season should not be done at the expense of incurring access and manueverability difficulties during the spring, summer, and fall seasons.

I. HIGH SEASONAL VARIATIONS IN WASTE VOLUMES

1. The Problem

Due to their rugged terrain, natural splendor, and abundant natural resources, severe climate areas offer excellent outdoor recreational opportunities, as well as large-scale resource activities such as mining operations. These areas often serve as seasonal vacation spots and are therefore subject to very substantial seasonal variations in solid waste generation. This seasonality of waste flow creates problems for landfill operation in terms of properly disposing of the peak waste volumes and in terms of achieving overall efficiency and economy of operation.

2. Alternate Approaches

a. Temporary Equipment and Personnel

If landfills consistently experience seasonal variations in solid waste generation volumes, it may be beneficial to hire operators and equipment on a part-time basis during high generation months. Construction equipment is often available on a rental basis from local dealers and contractors in almost all parts of the country. Similarly, landfill equipment may also be available. Collection trucks and drivers can be employed on a seasonal basis to handle additional loads. Scheduling is an important procedure in providing efficient solid waste service in high generation periods.

b. Alternate Equipment Selection

When landfill equipment will be called upon to perform a large variety of operations due to highly varying quantities of incoming waste, initial equipment selection should consider optimizing landfill operations via selection of equipment types suitable for several uses. For example, draglines and backhoes are generally only suitable for soil operations. Tractors with large capacity buckets can be utilized for both soil and waste movement operations.

c. Transfer/Storage Stations

Transfer stations can serve as an alternate approach when waste volumes vary seasonally. Transfer stations provide a reasonable way of controlling the rate at which refuse is delivered for landfilling. When refuse generation is high, the transfer station can be designed to operate as a temporary storage facility for the waste.

For health related reasons, however, temporary storage of municipal wastes should not occur for periods in excess of one or two days. This approach is most useful in smoothing weekend versus weekday operating peaks.

d. Operations Sequencing

Operations sequencing involves the rescheduling of landfill equipment and personnel assignments to perform tasks in a way that minimizes the displacement normally caused by a seasonal waste flow to the landfill. These techniques, for the most part, are dependent upon site-specific requirements, however, a number of basic common options are available to all landfill sites.

For example, site preparation functions can be performed by equipment and personnel during low volume months. These operations include grading, trenching, berm construction, drainage control, and cover stockpiling. Access roads can also be regraded and resurfaced.

Stockpiling cover is probably the most useful function that can be performed during low volume months. Because cover material is required throughout the year, and severe climatic conditions can hinder the availability of cover, proper stockpiling is beneficial and necessary in areas where cover would otherwise be unobtainable during the winter.

e. Alternative Landfill Methodologies

The valley method of landfilling provides advantages in situations of seasonal waste flows in that the surrouding topography can be used to minimize site construction requirements. Instead of constructing trenches, natural valleys or gullies are used at working faces. The waste is deposited directly into the valley where it is compacted and covered, as required. The valley method minimizes both construction equipment use as a well as required daily cover. However, the method is limited to regions where the natural contours allow for such operation. Specific disadvantages include more difficult surface runoff control and costs of access road development.

The trench method is also applicable in areas where high seasonal variations in waste volume are evident, because the trenches can be constructed during low volume months by otherwise idle operators and construction equipment.

IV. ADDITIONAL ALTERNATE SOLUTIONS TO LANDFILL PROBLEMS IN CLIMATICALLY SEVERE ENVIRONMENTS

In cases where existing landfill sites are not suitable for upgrading to meet local solid waste disposal requirements, alternative sites might be evaluated and selected for landfill development. In cases where alternative sites may not be available within the local wasteshed, materials or energy recovery alternatives may reduce the requirements for land disposal.

A. ALTERNATE LANDFILL SITES

Prudent landfill siting can aid in minimizing the risks and costs of landfill operation in severe climate regions. The factors considered in siting any landfill include waste composition and quantities; a number of natural environmental factors, such as site hydrogeology, soils, and topography; planning, zoning and other legal constraints; and various cost factors. The following discussion focuses on the opportunities and constraints the natural environment poses for cold climate landfill design and operation.

Selection of a locally available site, which may permit closure of an existing inadequate site, requires consideration of a number of natural environmental factors. These include availability of large quantities of suitable soil, depth to groundwater, topography, proximity of surface waters, prevailing wind direction, natural vegetation, site accessibility, etc. The selection process should thoroughly evaluate alternative sites with respect to minimizing costs as well as potential environmental degradation. Perhaps equally important, the chosen site should be capable of meeting all local, State and Federal regulations and, in severe climate areas, should be specifically selected to minimize severe climate operating difficulties.

For example, specific factors which might be considered include:

- selection of valley or lower elevation sites with developed soils
- selection of sites protected from prevailing winds by natural contours or vegetative barriers
- selection of sites with short access routes and minimal slopes
- selection of sites with surface drainage patterns requiring only minimal modifications
- selection of sites which are readily adaptible to seasonally varying incoming waste loads

Regional landfills can also be considered when a number of individual sites exhibit the same types of operating problems. Regional landfills are generally more cost-effective on a per-ton basis, depending on population density in the surrounding wasteshed. Naturally, selection of alternative regional sites must consider the same factors associated with any sanitary landfill siting process.

As distance to the landfill site increases, waste transport cost can eventually increase to the point where operational cost savings may be negligible. Then, the options of either a transfer facility or a system of two or more regional landfills should be considered.

B. WASTE REDUCTION

a. Source Separation

Source separation involves the segregation of waste products at the point of generation. The concept requires available markets, some volunteer labor, a central collection point and other subsidized amenities in order to function in Region VIII. Glass, paper, plastics, steel and aluminum cans are placed in individual containers or bins. Waste oil can also be recycled by taking it to waste oil collectors, usually gas stations. Separated wastes can then be sold to manufacturers who recycle the material and substitute this material in lieu of virgin raw material for product manufacturing. It is expected that demand for these wastes, especially waste oils, will increase. Source separation in severe climate areas would be beneficial in reducing quantities of waste generated and consequently the volume required for landfill operations.

b. Materials Recovery

Materials recovery is similar to source separation in that specific wastes are separated from the waste stream, resulting in disposal volume reduction and decreased demands on severe climate resources. However, materials recovery generally incorporates high technology processes at a centralized collection point, rather than voluntary separation at the point of waste origin. A variety of processes are available for sorting ferrous metal (magnetic separation), paper (shredding, wet and dry processes), glass (optical sorting and froth flotation), aluminum (eddy current separation), and other non-ferrous metals (mechanical separation) from mixed municipal waste streams. While there is considerable interest in materials recovery in Region VIII, high costs, unproven technologies, and the lack of available markets severely limits materials recovery processes at most severe climate sites.

C. ENERGY RECOVERY

Once solid waste is buried in a landfill, the energy potential contained in the waste is virtually lost. Average municipal solid waste has a heating value of approximately 4500 Btu per pound, or approximately one-half of the caloric value of coal. Obviously, this waste is a valuable energy resource which can be utilized and recovered through a number of alternative recovery systems. The feasibility of energy recovery is dependent upon the existence of markets for the recovered energy. Each energy recovery system must be analyzed in terms of economics as well as environmental, safety, and health impacts. Five categories of state-of-the-art energy recovery systems are discussed in the following subsections.

a. Incineration

Unprocessed municipal waste may be burned in waterwall furnaces, or for smaller daily waste quantities in modular incineration units. The resultant steam is further converted into either electric power, hot water, or chilled water. The uses of recovered steam through waste incineration is a common practice throughout the world, and a number of incinerators are commercially available for almost all applications. Modular prefabricated units anywhere from 10 to 1000 tons per day are available and can easily be included in a waste management program at large or small scale sites. Incineration is a cost effective process if a suitable local demand is available for use of recovered energy. Several modular units have potential applicability to a limited number of severe climate sites. (See Exhibit 13.)

b. Pyrolysis

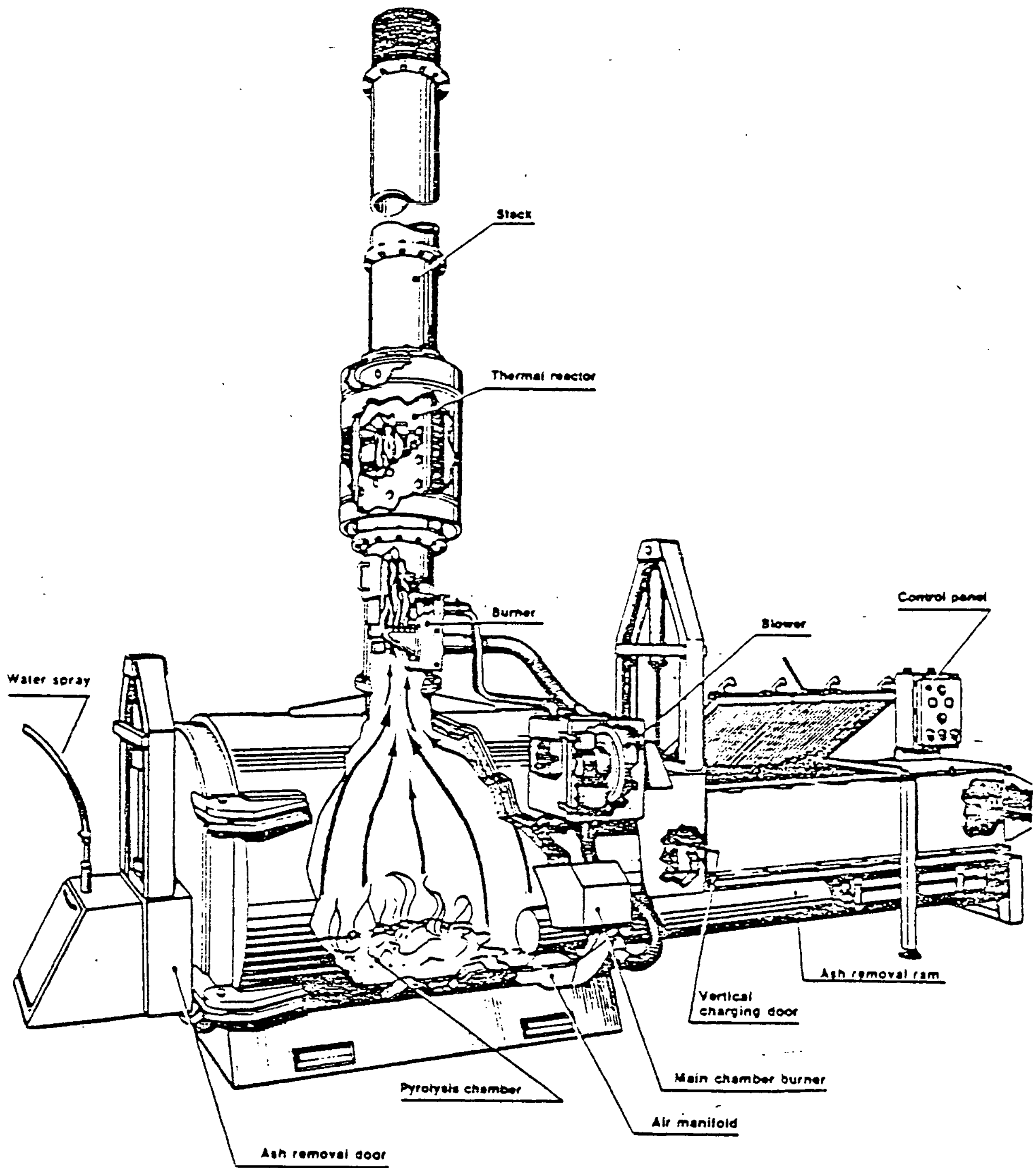
Pyrolysis is a thermal process in which solid waste is destroyed at elevated temperatures in an oxygen-deficient atmosphere. The resultant product is a mixture of combustible gases, solid residues and/or liquids, which are usable as fuel or chemical feedstocks. Pyrolysis products vary in character with changes in duration of burning, process temperature and pressure, oxygen content, particle size of waste, catalyst types, and auxillary fuel types. The fuels produced under various conditions include low Btu gas (100-150 Btu/ft^3), medium Btu gas (300 to 400 Btu/ft^3), and liquid pyrolysis oil (10,000 Btu/lb). The process itself is complicated and expensive. While a number of systems are currently in the developmental stage, pyrolysis is generally not a suitable alternative for Region VIII severe climate sites.

c. Refuse-Derived Fuel

Refuse-derived fuel (RDF) is the organic combustible portion of municipal waste which has been removed using a wet or dry process. The resultant fuel product can be either fluff RDF, densified RDF, or dust RDF. RDF is commercially produced at several plants throughout the country, and

EXHIBIT 13

SMALL MODULAR INCINERATOR



Source: Frounfelmer, Richard. Small Modular Incinerator Systems With Heat Recovery: A Technical, Environmental, And Economic Evaluation. U.S. Environmental Protection Agency Report (SW 797), 1979.

with resolution of some operating difficulties, the system shows promise as an efficient resource recovery system. However, given the high capital and operating costs and the large waste volumes required, the process is generally not adaptable to Region VIII severe climate sites.

d. Composting

Composting is a process that utilizes natural waste decomposition processes to reduce putrescible waste volume and concomitant disposal volumes. Composting systems can be operated in a passive mode or can be accelerated by waste mixing, bacterial seeding and/or utilization of moisture control and aeration systems. Only limited success to date has been experienced with composting in the United States largely because of the limited market for the product, which is best utilized as an agricultural additive. Due to the low seasonal temperatures in Region VIII, the lack of available acreage required for composting operation, the severe winds commonly encountered throughout the region, and the lack of available moisture in some areas, composting systems have very limited applicability for severe climate operations.

e. Methane Gas Recovery

Solid waste buried in a landfill results in natural biological decomposition. Anaerobic decomposition processes result in methane and carbon dioxide generation on a one to one ratio. In properly designed landfill cells, methane gas can be collected through piping systems and treated to remove moisture, hydrogen sulfide, and other contaminants leaving a quality methane gas. This methane gas is marketable and, if further treated, is equal in quality to natural gas. However, the treatment process is expensive and is generally not considered commercially available. Gas utilization requires a nearby market or an accessible gas distribution system. Untreated methane gas is readily usable on site primarily for building heating purposes.

In Region VIII, several factors conspire against methane recovery. First, few landfills exist in areas which provide for sealed conditions.

Thus, methane gas can escape and atmospheric oxygen can intrude into the waste mass. Second, most landfills are too shallow and too small to make methane recovery economical. Third, methane recovery systems are most efficient when constructed in new, rather than existing landfills.

V. SITE-SPECIFIC CASE HISTORIES

The following sections are intended to provide the results of the field trips and waste disposal analyses completed for several landfill disposal sites impacted by severe climate operating conditions. In each case information, where available, is presented relating to disposal methods, operating problems associated with the site, and recommendations relating to severe climate operation. Where applicable, other solid waste issues, such as impending regulatory impacts, on-going planning efforts, and financial options are also presented.

Sites with potential operational problems were selected as a result of contractor, State and EPA suggestions. For each site, varying impacts due to severe climate conditions were experienced and are documented as follows.

A. PAGOSA SPRINGS, COLORADO

1. Site Location

The Pagosa Springs solid waste site is located two miles south of the town of Pagosa Springs, in the county of Archuleta, Colorado. The site has been designated a county landfill site. The Colorado Department of Health File # is 04016.

2. Operational Description

The Pagosa Springs solid waste landfill is a 20 acre site located two miles southwest of the downtown area on a ridge consisting of an outcropping of Mancos Shale and Dakota Sandstone. Most of the wastes received at the site are delivered directly by town and county residents. However, one local trash service collects from the downtown area and the more densely populated areas primarily along Route 160.

Access to the site is a steep, paved all-weather road off Route 160. The on-site access is a dirt road leading up and into previously filled areas.

The waste received at the site is essentially municipal and commercial in character, with a significant portion of construction waste. (Septic tank pumpings are hauled to the Pagosa Springs sewage treatment lagoons.)

The operation basically is a dumping area where wastes are deposited on the edge of a twenty to thirty foot embankment built up by previously deposited waste. Cover is applied irregularly (perhaps two to four times per month by town road and bridge crews and consists primarily of waste road construction materials (primarily air-eroded shale). Bulky wastes are scattered along and below the embankment area. A landfill operator is generally not present. A total of approximately $5000 is spent annually on site operation by the town and county. In addition, about $20,000 worth of "in kind" funding comes from the town in equipment and labor.

3. Waste Quantities and Projections

Waste is currently received from an average baseline population of 4,000 county residents. Summer tourism results in contributory wastes from an estimated additional 500 persons. Approximately 85% of the county population lives within ten miles of downtown Pagosa. Population growth has averaged approximately four to five percent per year since 1970.

Incoming quantities of waste are not recorded at the landfill site. Based upon a statewide average of 4 lb. per person per day, total annual tonnage to the site would be approximately 3000 tons.

4. Hydrogeologic Data

As previously indicated, the site overlies an area of Mancos Shale and Dakota Sandstone. Surface soils have been categorized as Valto stony loam, a shallow brownish sandy soil ranging from ten to twenty inches in depth. The soil type is highly permeable.

Local water supplies are obtained from the San Juan River and from the Mancos Shale and Dakota Sandstone aquifers. A number of wells downgradient and within one-half mile of the site have been drilled into the aquifers or into the overlying alluvium. Groundwater quality from the bedrock aquifers is typically poor with high dissolved solids including sodium, calcium, iron and sulfate. Groundwater flow in the bedrock aquifers is largely the result of fracture porosity.

Surface hydrology of the site is characterized by a slow runoff rate easterly towards the San Juan River, approximately one-half mile away.

5. Operating Problems Associated With Severe Climate Conditions

Daily operating problems due to severe climatic conditions are quite limited on-site. High winds have resulted in some degree of littering. Access is generally available through the winter months due to regular plowing operations. Cold conditions are not particularly critical since an on-site operator is not present and since very little activity, with the exception of waste delivery and some salvage operations, actually occurs on-site. Spring runoff conditions result in surface drainage through the site from a relatively limited acreage.

Three additional problems are evident, however.

a. Existing soil types are not available in sufficient quantity to provide a source of cover material;

b. Open burning is commonly practiced;

c. A possibility exists that surface and groundwater movement could potentially result in contamination of the downgradient private wells. Existing data on well construction was not obtained, however very limited well testing to date (coliforms) has not indicated potential contamination due to landfill operation (clearly not a positive test).

6. Recommendations Relating to Severe Climate Conditions

A number of recommendations have been developed for the Pagosa Springs landfill site relating to the minimization of operational problems relating to severe climatic conditions. These include:

a. Collection of all uncovered waste materials, particularly downslope of the embankment, and relocation to the active face. Regrading of the embankment active face to a maximum 3:1 slope. Estimated cost is approximately $2,000.

b. Placement of a minimum of two feet of low permeability cover material over the active site. Projected cost for five acres is $35,000. The unit cost of $4.30 per cubic yard assumes that an appropriate cover soil is available within a haul distance of two miles. Investigations for appropriate cover soils should most appropriately include Soil Associations 53, 56, 61 and 119.

c. Prohibition of open burning.

d. Construction of a surface runoff control system consisting of approximately 1000 ft. of drainage ditch located upgradient of the site at a projected cost of $2250.

e. Construction of two downgradient monitoring wells to identify potential downgradient aquifer contamination. Expected construction cost would be on the order of $6000.

Consideration of the construction of a downgradient leachate collection system was also considered. However, the shallow depth to bedrock, the infeasibility of an on-site treatment system, and the potential problems relating to pumping the collected leachate to the Town sewage treatment plant (distance, shallow depth to bedrock, process compatibility) resulted in the development of the above recommendations.

7. Potential Financial Options

Unfortunately, the Town of Pagosa Springs may not currently be in a financial position which will permit completion of the recommended work tasks. A number of specific financial options include:

a. Implementation of a user charge system whereby site users are charged on the basis of weight, volume and/or type of wastes.

b. Increase in the general taxing rate for the town.

c. Creation of a disposal district with specific taxing powers.

d. Contractual cost-sharing with the County.

e. Utilization of Rural Communities Assistance funds as authorized by RCRA Section 4009.

Unfortunately, a number of difficulties would be encountered in implementation of any of the above measures. Both user charges and increases in tax rates have been opposed by local residents and could result in some degree of indiscriminate littering. Formal County participation would be useful, approximately two-thirds of the total contributory population lives outside the town limits. In addition, RCRA Section 4009 Rural Communities Assistance funds have not yet been appropriated for use at the local level.

8. Other Solid Waste Issues

The State of Colorado is currently completing the open dump inventory as defined by RCRA Section 4004. The Pagosa Springs solid waste site will in all likelihood be categorized as an open dump. Further analysis relating to the potential health impacts of the site would clarify whether the site would require closure of whether upgrading procedures might be most appropriate. However, given the situation, the Town of Pagosa Springs should evaluate the following items:

a. The potential closure requirements for the site and expected costs;

b. The potential for remedial clean-up and continued use of the site;

c. The potential for utilization of another site in close proximity to the town;

d. The potential for utilization of a central transfer station with final disposal of the waste at the Durango landfill or some other site.

With respect to the first item, potential closure requirements would have to be negotiated with the State Department of Health.

With respect to the second item, the option would, at least temporarily, eliminate the need to site a new facility. In addition, landfill impacts would be limited to one location. A specific disadvantage for continuing use of the present site is that the acreage, should it become available to private investors, is a prime area for residential development.

With respect to the third option, the town has completed a preliminary investigation of alternate sites. Forest Service and Bureau of Land Management lands occupy a large portion of the county and are not available for landfill purposes. In addition, one-third of the county is an Indian Reservation. One potential site, located in the Mill Creek area, has been investigated in detail and would appear to be potentially suitable. However, the site is controlled by the Board of Land Commissioners and previous applications to utilize the site have been denied by the Board. In addition, development costs could be high. The site would require substantial clearing, grading, and access development. Capital and operational costs under RCRA regulations have been estimated as high as $20.00 per ton for this size landfill. Given the potentially high cost of development and the possibility that the Board of Land Commissioners will not permit the application, it would appear that the town should re-evaluate existing private lands within five to ten miles of the downtown area, with particular focus on areas having soils most suitable for landfill development.

The fourth option has not been previously evaluated by the town. Potential requirements would include a covered unloading station, a stationary compactor, and a transfer trailer with cab. Total expected capital costs would be approximately $60,000.

B. GUNNISON, COLORADO

1. Site Location

The landfill which serves the City of Gunnison, the town of Crested Butte, and other municipalities and federal facilities in Gunnison County is located just outside the limits of the City of Gunnison.

2. Operational Description

The landfill owned and operated by the City of Gunnison is a 43 acre site on a bluff overlooking the Gunnison River Valley. The bluff is composed of sorted and non-sorted fluvial and alluvial deposits, a conglomerate composted soil cap, and glacial till. The bedrock is sandstone.

Wastes are hauled by City trucks, private haulers, and individuals. Varying rates are charged to non-residents based on incoming volumes. The County currently has no involvement in regulating or operating the landfill but plans to become involved at the City's request.

Access to the site is provided by a dirt access road which travels at an 8 to 10% grade. A paved road connects this dirt access road to County Highway Route 135. Residences have been built on either side of the landfill site in recent years and along the route to the landfill from the County Highway.

All waste types are received at this site with the exception of sewage treatment plant sludge which is lagooned. Industrial waste is only minimally generated in the area. Through the summer of 1980, Crested Butte will operate its own construction/demolition waste site, with commercial, residential, and bulky wastes being hauled to the Gunnison landfill. After 1980, all waste from the Crested Butte - Mount Crested Butte area will be hauled to the Gunnison landfill.

The landfill operation is a ramp type whereby wastes are deposited at the toe of the working face and pushed up to the head. The width of the working face is over 40 feet. Each cell is excavated 15 feet into the ground and waste is piled 35 feet high above the original ground surface. One cell is laid atop of another as the landfill moves south to north while cover material is excavated from a nearby hill. The Public Works Department provides the services of its equipment for excavation and the stockpiling of cover material when needed. Cover is applied daily and consists of glacial and alluvial deposits. When cover soil freezes in the winter, sawdust and woodchips are used. During high winds, additional cover is scattered over the waste on an as needed basis. Most of the construction or demolition waste is separated and placed to the north of the landfill. Bulky wastes are dumped at the working face where they are compacted by an Allis-Chalmers - 16 dozer with a trash blade and ripper. The site operator is permitted to scavenge bulky wastes. The existing operating budget is $29,426.

3. Waste Quantities and Projections

The population which generates residential, commercial and construction wastes in Gunnison County, is 9,300, based on projections for 1980. The current census should assist in establishing the baseline population. Total County acreage is 3,200 square miles. The City of Gunnison has a population of roughly 7,500 persons including those in attendance at Western State College. Recreational winter visitors swell the County population an average of 2,000 per day with peaks of up to 3,800 additional persons per day, most of whom congregate in the upper end of Gunnison Valley at Crested Butte and Mount Crested Butte. In the summer, the waste stream is augmented 10% by contributions from the National Forest Service which maintains nearby Blue Mesa Reservoir recreational facilities.

No records are kept of waste volumes and types accepted at the landfill. However, unofficial estimates were provided by the Director of Public Works. Calculations by the contractor, using the estimates of the City, yield an annual tonnage of roughly 13,500 tons including construction wastes, and a daily volume of 130 yd^3 in winter to 150 yd^3 in summer (at 500 lbs./yd^3). The operation, in 1970, completed one "ramp" or cell every three to four days; currently, the landfill completes one ramp per day according to both the operator and the director of Public Works.

4. Hydrogeologic Data

The landfill sits atop glacial till with a conglomerate cap, below which are river alluvium including clay strata. The bedrock is sandstone at about 150 feet depth. Existing wells, located within Gunnison in the Quarternary Valley fill and glacial deposits, can yield 200 to 1,000 gallons of water per minute.

Surface runoff is to the west, downhill from the landfill site towards the Gunnison River. In general, ground and surface water quality is good due to the location of most aquifers in the glacial and alluvial materials of the Gunnison Valley.

5. Operating Problems Associated With Severe Climate Conditions

Gunnison exhibits several problems with the collection system and landfill disposal of solid wastes. Collection problems center around weather, animals and the choice of collection containers. The City packer trucks traverse narrow alleys between blocks and often are prevented from completing routes by snow accumulations. Gusts of wind knock lids off or blow over cans, at which point the contents are available for scattering and consumption by local dogs and other vectors. The residents do not cooperate with the City in either clearing away snow or cleaning up scattered refuse. When access to the waste is blocked by snow, the trucks can not complete their routes, and the wastes pile up in the alleys or in public containers on main thoroughfares. In addition, "pirate" disposers collect trash and charge customers in place of the licensed P.U.C. haulers. These pirate haulers disrupt the rate schedules in effect for commercial waste generators and the P.U.C. haulers who collect within and without the City limits.

The City faces closure of its current landfill site within 3 to 5 years. This implies a siting problem even though an EPA study in 1975 identified 17 potential sites. The politics of selecting the new site have not been favorable. In regard to severe climate related problems, wind has caused trash to blow around the site on occasion but this is an unusual occurrence. Cover material is stockpiled and used in winter mixed with sawdust and woodchips; should the soil be frozen beyond use, woodchips alone are used as cover material. The landfill operator has a small shed which can be used for protection from the elements in winter. The difficulties expected from severe climate conditions on this site are not extensive.

The problems for Crested Butte and Mount Crested Butte involve transportation and the lack of an adequate solid waste disposal site in the upper Gunnison River Valley and Slate River Valley. Sunshine Trash Co., the licensed P.U.C. hauler, faces the difficult task of collecting wastes in deep snow for a five month period, and hauling the waste roughly 30 miles to the Gunnison City landfill. After 1980 when Crested Butte closes its construction/demolition waste dump, the bulky wastes will also have to be hauled to the City of Gunnison landfill site for disposal.

6. Recommendations Relating to Severe Climate Conditions

The following recommendations have been developed for the City of Gunnison landfill which will mitigate the impact of those few problems identified stemming from severe climatic conditions:

(a) Seasonal cover material stockpiling at the landfill to minimize blowing litter and lack of cover availability; and

(b) Phasing in a side loading waste collection pickup system to minimize the problems associated with the narrow alleys and wind blown trash. A side loading system is high in initial capital costs but has relatively low operating costs as a single operator can both drive the vehicle and remotely collect the waste. Additionally, the collection containers themselves are less prone to being knocked over by winds or dogs.

7. Potential Financial Options

An optimistic note relating to the financial status of the Gunnison collection and disposal system was struck recently when the County of Gunnison decided to support the operation of the landfill and the ongoing replacement site selection process. The County has been made aware of its responsibility, from the public health standpoint, for disposal of solid wastes. Also, since increasingly greater portions of the total waste stream are contributed by the population outside the City, the County has recognized the service performed by the City and its responsibility to assist in the disposal effort. Some county funds will be appropriated for operation of the existing site and more will be budgeted for the selection, construction, and operation of the new landfill site. The new landfill will be a joint City/County enterprise.

Given those circumstances, a county-wide charge for the landfill should be assessed all homeowners in the County. All commercial establishments should pay for the landfill either directly by the volume of waste disposal or indirectly via the commercial hauler who will charge for his/her services. However, this is a political decision to be made by the County Commissioners. Generally, local support exists for safe, environmentally sound disposal of waste.

C. MEEKER, COLORADO

1. Site Location

The Town of Meeker is located in the eastern part of Rio Blanco County in the Northwest corner of the State of Colorado on the White River. This area is high, rugged, and very arid with a dispersed population, most of which lives in the small towns of Meeker, Rangely, and Rio Blanco. Tremendous growth has been projected for this part of Colorado due to the valuable deposits of oil shale. Growth will be constrained by lack of public services such as waste management, water supply, and distribution.

The Meeker landfill is located 4 3/4 miles south of town, 1/4 mile east of Colorado State Route 13 on private lands. The permit is listed as File No. 52026, M S-6, Category B (less than 5,000 population). The 12 acre landfill serves the town of Meeker and surrounding rural population, but is managed by the County Department of Health. The County also has the responsibility for the Rangely landfill and is assisted by the state District Sanitarian. The County Commissioners act as the County Board of Health and both landfills are operated in loosely defined join venture with the towns. No person has had responsibility of the landfills for at least five years. The current landfill, constructed in 1979, is "new" and is under the authority of the County Engineer.

2. Operational Description

The Meeker landfill is a 12-acre site, located between two sandstone and conglomerate scarps, where intense weathering has left considerable amounts of sandy-clay soil. Most of the waste disposed at the site is hauled in by residents, with the P.U.C. hauler, Valley Sanitation, hauling the commercial fraction. The landfill itself is a large, wide trench about 30 feet deep which has been dug into a hillside. There is no daily cover nor compaction of the wastes. At the time of the site visit several piles of refuse were burning and there was evidence of prior burning. Downhill from the trench, there were two large pits into which sewage sludge had been disposed. The site was enclosed by berms and diversion ditches and there was evidence of runoff from the sludge lagoons into the diversion ditch to the west of the site, downhill, which becomes an intermittent stream. There is no fence around the site, but there was no evidence of blowing trash due to the wind break shelter provided by the scarps, the hillside, and trees. The site is listed as open most of the day (8am-6pm) but it was locked for several hours on the day of the field visit. Access to the site is a graded, dirt road, with gravel placed on its surface when conditions are wet.

All wastes are received at the site, and only the sludges are segregated from the solid waste and are disposed of in separate lagoons. (Industrial wastes are usually not generated in the area.) Estimates of daily tonnage center around 8 to 10 tons per day. There is no separation of bulky or construction wastes from residential and commercial wastes. The County Road and Bridge Department occassionally covers the refuse piles with soil under windy conditions, upon receiving complaints or when the fires get out of control. The Department developed this site in 1979 at a cost of $90,000; no operational costs have been calculated for the intervening 12 month period.

3. Waste Quantities and Projections

No landfill records are kept for this site, but estimates based on population estimates suggest about 8 to 10 tons of waste are generated daily. Also, a great deal of controversy exists over population projections by the Regional Council of Governments which has been projecting extreme growth, due to oil shale development, for many years. However, the Sanitarian and County Engineer assured the contractor that the current Meeker area population does not exceed 4000 persons.

4. Hydrogeologic Data

Meeker is located in a very arid zone on Colorado's Western Slope and receives roughly 16.5 inches of precipitation per year of which 8 to 10 inches are snow.

The topographic relief in the area varies from gentle to relatively steep (32%) with most of the area sloped moderately. Drainage channels in the landfill area carry water only intermittently. Most of the landfill area is covered by scrub brush and grass with trees and bushes on the slopes to the east.

The site is located on steeply dipping sedimentary rocks of the Williams Fork Formation, composed of sandstone and shale. The sandstone forms a prominent hogback immediately east of the site. Part of the site will occupy a valley where the shales have been eroded away. The soils in the area are mostly gravelly, clayey sand with occasional silty layers and cobbles. There is generally 20 feet or more soil cover over the bedrock. There is sufficient clay matrix material in the soil so that when compacted, the soil will be relatively impermeable.

There are no perennial streams through the landfill area. The main channel, a dry wash, occupies a gully that is 14 feet deep in places, drains an area of about 161 acres and normally carries large quantities of runoff during intense rainstorms. Most of the area, however, is not heavily gullied, and the predominant form of runoff is sheet wash.

Groundwater is not present in the surficial deposits. Permeabilities of the soil from test borings ranged from 7 to 1200 feet per year, indicating that some infiltration of surface waste will occur during storms. This will normally be in the form of percolation through unsaturated soil.

5. Operating Problems Associated With Severe Climate Conditions

There are only limited operating problems at the Meeker landfill associated with severe climate conditions. The size of the population and its waste volume are so small that a lack of concern about waste management is the more critical problem.

Clearly, however, the general operation of the site, apart from consideration of severe climate conditions, needs to be upgraded. Several inadequacies exist. They are:

1) lack of daily cover

2) inadequate fire control and control of dumping of burning items

3) lack of machinery for compaction or cover

4) lack of a sequenced operation plan

5) lack of consideration of the potential problems to be incurred due to oil-shale and other energy growth

These operational issues stem from the low priorities set for solid waste management at local and county levels. It has been the custom that disposal was a matter of "dump and burn", and this custom was reinforced by the local climatic and geologic factors.

6. Recommendations Relating to Severe Climate Conditions

While specific problems associated with the landfill are primarily due to the lack of proper emphasis on proper solid waste management rather than severe climatic conditions, a number of recommended improvements can be made. These include:

(a) utilization of daily cover (at approximately $.50 per cubic yard or $0.40 per ton of waste disposed based on conditions at the landfill and assuming on-site soil suitability);

(b) cessation of open burning;

(c) provision of at least part-time availability of a crawler dozer;

(d) improvement of the sludge disposal operation by mixing the sludge with the residential and commercial wastes and/or applying and incorporating it into a level piece of ground; and

(e) development of a detailed operational plan including provisions for significant increases in annual or seasonal waste quantities.

Any operational plan should follow, as a minimum, the guidelines and regulations of the Colorado Department of Health. For example, the plan should include the name of the person(s) in charge, a listing of equipment, the hours of operation, methods for controlling fires, provisions for compacting and covering the wastes, and means to control litter, rodents, and insects. The plan should also include details of the different disposal practices for sludge and bulky wastes.

7. Potential Financial Options

The County Department of Health should consider implementing a countywide charge for waste services for home owners and commercial establishments.

D. LARAMIE, WYOMING

1. Site Location

The City of Laramie is located in southeast Wyoming, 45 miles west of the State Capital, Cheyenne and 30 miles east of Medicine Bow National Forest and the Snowy Range. The University of Wyoming is located in the City, which is a railroad center and focus for energy and recreational developments in Albany County. Laramie is one of the largest population centers (30,000) in the state (400,000) and manages the disposal of wastes from most of the settlements in Albany County. The City is currently seeking cooperation and financial support from the County for the services provided.

The landfill site is located one mile north of the City limits on the extension of Ninth Avenue onto incorporated County lands. The City of Laramie owns and operates the 90 acre site and has an interim permit from the State, awaiting the formulation of the State Solid Waste Management Plan.

2. Operational Description

The 90 acre landfill is owned and operated by the City of Laramie for the benefit of its residents and the unintended benefit of the County. The site is located on very thick deposits of alluvial clay and sandy, silty clay, and has only limited potential for groundwater problems. The City, at one time, contracted out the excavation of trenches and the stockpiling of cover materials but currently handles those operations with city personnel. Bulky wastes and construction and demolition wastes are disposed of in a separate trench, oil and solvents are disposed in a pit, and there is a separate area for junked automobiles. The non-residential/commercial wastes comprise approximately 30% of the total waste stream. The landfill is open seven days per week, nine hours per day, and is closed on holidays. A vehicle counter sits in a movable shed at the entrance to the fill and records traffic flow into the landfill.

The landfill operates large trenches, about 100 feet wide and 40 feet deep, which are laid out in parallel. The currently utilized trench is just north of the older cells and the new trench for late 1980 and 1981 use has already been excavated. Unfortunately, the cells are aligned roughly east while the prevailing winds are from the west and northwest. This means that the cells are operated with the open ends facing the wind.

Several trash haulers, including the City, dump at the site, as well as individuals, construction contractors, and the University. Laramie acts as the receptor for all wastes in the area (except sewage sludge) including potentially hazardous wastes such as used oils and spent solvents. A single groundwater monitoring well, left in place for 18 months beginning in 1977, showed no evidence of contamination, however.

3. Waste Quantities and Projections

Population projections for the City of Laramie currently show 30,000 persons in 1980; the 1980 census counted 28,700. These figures included the student and faculty of the University of Wyoming. The wasteshed is the area around Laramie in Albany County. The operator estimated that 1000 to 1500 homes outside the City are served by the landfill with individuals and contractors hauling residential and construction wastes from as far away as Bosler and Centennial. The wasteshed population is estimated at roughly 40,000. Growth has not been explosive in the past decade but projections suggest a rate of growth greater than the previously recorded 4.3% over the next decade, perhaps reaching 10 to 15% between 1980 and 1990.

Good estimates exist for residential/commercial waste quantities disposed at the landfill. In 1970, about 14,500 yd^3 were disposed. This had grown to 29,000 cubic yards by 1978 and is currently running at an annual rate of 43,500 yd^3. Construction, demolition and bulky wastes are projected to reach 20,000 yd^3 annually in 1980.

The City began to charge for waste disposal in 1967 when it instituted an annual charge of $1.25 per household. Currently those charges are broken down into landfill charges and collection charges and are assessed quarterly in advance. The landfill charge is $10.00 per year per household and the dump fee is $7.80 per quarter per household or roughly $2.60 per month. This service covers three 20 gallon cans twice a week plus bound waste such as newspaper. Commercial establishments are charged more for servicing of containers ranging from 2 cubic yards ($16.84 per quarter) to 6 cubic yard ($39.84 per quarter). There are 140 containers in service by the City. The University pays the City $1200 per year for dumping privileges while the National Forest Service pays only $500 per year.

The City budget for collection in 1979 was $266,686 of which $250,000 was used. The actual revenue collected was only $240,000, indicating a $10,000 shortfall. The landfill budget for 1979 was $140,097 which matched the amount spent while revenues were projected at $130,000. Budget deficits are made up by general revenues.

4. Hydrogeologic Data

The landfill is located on thick deposits of alluvium and loess. The soil types are tight, red clay and a yellow-brown, sandy, silty clay. The former is difficult to work and operate upon in wet weather conditions. The latter is preferred as cover and base material. There is very little surface or shallow ground water flow in this area (annual precipitation is 14 inches) due to arid conditions; the snow cover in winter blows off to the east. The Laramie River runs to the north about 1½ miles west of the landfill; local water supplies are taken from surface impoundments upstream.

5. Operating Problems Associated With Severe Climate Conditions

The major climatic problem faced by the operators of the Laramie landfill is continuous high winds; minor problems include snow and extended periods of freezing temperatures. Wind velocities approach 70 miles per hour and have blown trash several hundred feet into the air above the site. Trash fences do not aid in keeping airborne paper from leaving the site due to the altitudes achieved. The City constructed, from old collection equipment, mobile trash nets which are pulled around on the crest of the berm surrounding the working face. The fence units extend about 6 feet above the mobile dumpster units, but have not had success in trapping blowing litter.

The City has recently constructed "fence-sleds", with 6 inch pipe and cyclone fencing, which are about 10 feet in height. It is hoped that these fence units can collect the refuse blowing from the working face. The alternative of closing the landfill on severe windy days has not worked because individuals continue to haul refuse to the site and, finding the landfill closed, dump their waste on the roadside leading to the landfill.

The snow cover causes problems of traction for haulers, while freezing temperatures make excavation of cover material and the landfill trenches difficult. Also, upon encountering ice of any thickness, the compactor unit digs itself down into the ice either until the steel wheels reach ground or have dug themselves into the ice to the height of the axles. This has occurred several times at the Laramie site. Thawing of snow but not ground frost causes ponding at the site. The State issued violations to the City for this and for blowing litter as recently as March 5, 1980.

6. Recommendations Relating to Severe Climate Conditions

A number of potential alternatives are available to minimize on-site operational difficulties. These include:

(a) re-orientation of new trenches to minimize wind impact;

(b) increasing surface runoff controls (via berms, diversion ditches, etc.) to minimize surface ponding;

(c) increasing access road maintenance particularly during snowfall conditions;

(d) utilizing built-up cells for windbreaks;

(e) utilizing cover stockpiles as wind breaks;

(f) planting vegetation barriers;

(g) sprinkling cover material on the working face throughout the day to confine wastes;

(h) covering and compacting wastes late or early in the day during low wind conditions;

(i) utilization of nets over the trench operations as litter control devices; and

(j) minimizing the area of the working face.

7. Potential Financial Options

The City of Laramie could generate additional operating revenue and capital funds by 1) tightening its collection of assessments to City residents and commercial establishments, 2) researching costs and making the assessments fit better to collection and disposal costs, and 3) most importantly, charging those haulers and individuals who bring in refuse from outside the City limits a fair price for the privilege of disposal. This latter proposal implies the cooperation of the County in rewriting ordinances and the support of the County in making assessments to residents outside City limits.

Alternatively, since the tax base is not yet strained, and the assessment has not yet attained its constitutional maximum, the mill-levy could be raised. This, however, is an action of last resort, considering the slack in the utilities assessment and the free disposal given out-of-town haulers. More importantly, political resistance to raising taxes is very great and could prove counter-productive to solid waste management activities.

8. Other Solid Waste Issues

Other solid waste issues relate to the adequacy of the current oils and solvents disposal site, given upcoming State and Federal regulations for hazardous waste disposal. The City should initiate consideration of upgrading the particular disposal approach, developing an alternate disposal site and/or encouraging recovery and/or reuse.

E. BISMARCK, NORTH DAKOTA

1. Site Location

Bismarck is one of the larger cities in North Dakota and is the State Capital. Of the states dominated by agriculture, North Dakota is fortunate also to have reserves of energy resources in its western part which contribute to prosperity and growth. Bismarck has planned for future needs in solid waste management by expanding its site and developing collection and disposal operations which are flexible enough to adapt to regional development.

The landfill is adjacent to the east side of the City, immediately south of Interstate 94, off Exit 37. The site is owned and operated by the City of Bismarck, and is located in Section 25 of Township 139N of Range 80W and Section 30 of Township 139N of Range 79W in Burleigh County. The Permit Number is 017.

2. Operational Description

The site encompasses approximately 461 acres of rolling grasslands. The site is located above a variety of clay and shale strata with interspersed but infrequent sand lenses. The active portions of the site and all boundaries along private property have been planted with trees, both coniferous and deciduous, to slow the wind, catch trash, and hide the site from view. The site has a seasonal stream next to waste disposal cells but, no water supplies are threatened. The landfill has a gate operator who collects fees from haulers and residents of Burleigh County who live outside the City. Commercial and industrial wastes are hauled in by the individual or by District Sanitarian Service, Inc. or Dakota Sanitation, Inc. Access is provided by a paved road to the gate and then an all-weather road leading to the various disposal areas. From April 16 to November 14 the landfill is open 7 days per week from 7 am to 6 pm and Sundays and holidays, noon until 6 pm. From November 15 until April 15, the landfill is closed Sundays and holidays and is open 7 am to 4 pm six days per week.

Almost all waste types are disposed at the Bismarck landfill with the following exceptions:

- all liquids uncommon to normal household refuse
- septic tank pumpings

- raw or digested sewage sludges
- hazardous wastes, unless specifically approved
- material originating outside Burleigh County

Drinking water treatment plant sludges are accepted, however.

Ramp, area, and trench methods of landfill disposal are employed by the City, depending upon the season, weather and waste. On the day of the site visit, the trench method was in use because of the high winds. A working face, perhaps 40 feet wide, was protected by a berm and a large natural hill which would eventually be cut for cover material. Disposal cell trenches vary in length from 100 to 1000 feet and in depth from 8 to 16 feet. The usual disposal site was not in operation except for the disposal of filtration wastes from the drinking water plant. Construction debris was separated from the residential/commercial fraction and disposed in its own area next to Apple Creek. Engine oil wastes are deposited in an underground tank and then collected by a commercial recycling firm. Yard wastes were mixed into the municipal waste stream since the same trucks and haulers pick up both types. It was evident that several areas had been built up over the years by adding cells on top of older cells in specific areas. The building of elevated areas aids in controlling, to a degree, the impact of the continous winds. There is an abundance of cover material and several stockpiles were serving as windbreaks. As areas are excavated, the overburden is used as cover for closure of completed cells. The operation is well managed and shows the results of long-term planning and concern for environmental and aesthetic values.

The landfill equipment in use had been purchased new, obtained as surplus or bought in a used condition and brought back into service. Specific items include:

1 Caterpillar 966 Rubber tired 4 yd^3 front end loader
1 Cat D-7 dozer
1 Cat 619 scraper
1 Cat 621 scraper
2 Clark 290 rubber tired dozers

On the day of the site visit, the equipment was constantly in use. The City employs one director of operations, five persons at the landfill, and 26 persons on the collection routes. Landfill personnel include three equipment operators, one fee collector, one assistant foreman, and one foreman. The City operates eight compactor trucks in the winter and nine in the summer with one driver and two laborers per each vehicle. In addition, two paper pickers are employed and fill in on the collection routes when needed.

Landfill charges to users were recorded from December 1976 through April 1978 by the City. The total for the year 1977 was $142,560 or $11,880 per month. The traffic shows a definite seasonal trend with a high in June ($21,640 collected) and a low in December ($7,150 collected). The major contributors for the high months June and May were the industrial haulers who logged 71.2% and 75.7% of revenue respectively those months. The total landfill charges for the fiscal year July 1979 to June 1980 were $178,940 or $14,910 per month.

3. Waste Quantities and Projections

The population of Bismarck, based on 1975 data was 41,500; the City study (1978) measuring waste volume used a figure of 44,000 persons to calculate per capita generation. The waste generation figure is probably higher since the landfill serves the surrounding parts of Burleigh County. Projections into the next two decades vary from a low of 55,000 to a high of 79,500 persons by 2000 A.D.

Figures from the City on waste generation show differences between waste volumes generated in 1977 and 1978. The total waste generated per capita, based on summer volume (week of July 10, 1978) was estimated at 4.77 pounds per day for the residential/commercial fraction. If construction debris, trees and dirt, and water treatment plant sludge were to be figured into the residential/commercial data, then the per capita figure jumps to 15.93 pounds per day, with construction waste contributing the bulk of that (8.55 lbs/per capita per day). The per capita residential/commercial fraction generation rate for 1977 is 4.58 lbs/day or 100 tons per day received at the landfill.

The figures for July of 1978 reflect summer waste volumes and are not representative of the yearly pattern. Figures for 1977 are based on counts of domestic loads hauled and recorded in 1977 and volume estimates of 20 yd^3 per load, based on the capacity of the packer trucks at a density of 535 pounds per cubic yard. Other figures were derived from landfill charges which were recorded at the landfill gate and back calculated using average capacity and density figures. As such, the figures for 1977 and 1978 can give only a rough outline of actual waste generation rates. The landfill operator estimated that the landfill accepts between 115-120 tons of residential and commercial wastes each day.

4. Hydrogeologic Data

The City engineer reports that the site sits atop generally impermeable clay and shale; silty sand and clayey sand appear as lenses throughtout the clay deposit. The topography can be described as rolling hills with intermittent and perennial creeks cutting down through the erodable materials. Apple Creek runs through the site but is enclosed and covered by five feet of compacted clay along some of its length. Runoff from the site is diverted from the Creek by means of diversion structures. Two drainage ditches carry runoff; tests indicate that leachate is not present in either of these ditches nor in a so called "coulee" which is located to the south of the site. Some trash, however, does blow into the "coulee" at times. The State believes the potential for surface water contamination is minimal at this site.

Local water supplies are obtained from the Missouri River and are treated at the City water treatment plant which dumps its waste sludges at the landfill. Clay deposits tend to isolate the shallow, perched aquifers from the deeper aquifers; the State DEWMR is not concerned with the low potential for groundwater contamination due to the deep soil profiles.

5. Operating Problems Associated with Severe Climate Conditions

The major problem in site operations is associated with the continuous wind movements across the Northern Great Plains. Problems of secondary importance include frozen cover and frozen garbage. The wind problem appears to be potentially more severe here than in other locations of Region VIII due to the long "fetch" over which the wind can flow in traversing Canada and the Great Plains. The winds rarely cease to blow and only then to change direction. Winds average speeds of 17 mph in winter, usually blowing out of the northwest or west. Trash can be blown a hundred feet or more into the air creating litter problems in surrounding areas, if not managed properly.

Cold temperatures cause problems with cover and with garbage. Cover can be frozen solid and rendered unusable if not properly managed. Garbage can be frozen and kept cold enough for long enough over the year to substantially limit the biological decomposition processes normally occurring in landfills elsewhere. Cold temperatures and wind also have a great impact on landfill operators and equipment.

6. Recommendations Relating to Severe Climate Conditions

The City of Bismarck has approached the severe climate problem of high winds in a unique way. Rather than employing one trench location for disposal and trash fences for containment on days of high winds, the operators of the landfill use a variety of techniques to mitigate the impacts of wind on the operation. These techniques include:

1) shifting the disposal of waste from the main operation of an area method to one of several trench operations

2) utilizing one of several trench operations oriented in different directions to minimize wind effects

3) using built-up cells as wind breaks by planning their placement initially

4) using stockpiles of cover material as wind breaks

5) using natural bluffs, planted trees, and other features as windbreaks and trash catchers

6) sprinkling of cover material throughout the day to hold waste down until it can be compacted and covered

7) covering and compacting wastes late at night or early in the morning after the day of disposal

For example, normally the fill operation is an area method. On days of high wind, the working face of the area fill is covered, the disposal trucks are rerouted, and the front end loader is moved to one of the trenches already in place around the site. Next, depending upon wind strength, duration, and direction, one of the cells is utilized for disposal. The choice is based on the orientation of the cell and on which windbreaks would be most helpful. As outlined above, the windbreaks include a variety of natural and man-made features. With regard to cells placement, the first cell to be built in a row of cells is aligned crosswise to the prevailing wind direction and cells are added in the row downwind. The next level begins again at the leading edge upwind. Stockpiled cover is constantly being excavated and moved around to provide both a windbreak and to minimize freezing. Cells are located at the foot of steep embankments on large natural features which are a benefit at this particular site. Planted trees disrupt wind flow upwind and perform an excellent job of catching ground hugging blown litter downwind of the working face.

On especially windy days, as trash is disposed of on the working face of that day's trench, the equipment operator will distribute a thin layer of cover material over the waste to hold it down. The operator will not compact the waste until late in the day as winds slow or until early the next morning when winds should be at their slowest. The State sanitarian and the landfill foreman indicated that wastes were compacted and covered daily even if it meant a very early operation the next morning. This practice met the State landfill requirements for daily cover. Apparently litter fences have not been suitable for operations of this type.

With regard to extended periods of low temperatures, the practices used to mitigate freezing impacts are simple. Cover material is excavated, stockpiled in the sun to dry in summer and roughed up into ridges throughout the fall. It is worked over constantly throughout the frost periods. In order to keep wastes from freezing solid, they are covered as soon as practicable and other wastes disposed on top to provide insulation and lower the length of the period of exposure to the cold. To the greatest extent possible, the working face is kept dry. The equipment is stored in a sheltered area protected by trees and in a large shed. The landfill operators have a heated workshop and shed on site while the gatekeeper has a heated house at the landfill entrance. Most pieces of the equipment have electric engine block heaters.

F. SUMMIT COUNTY, COLORADO

Summit County is the focus for extensive all-season recreational development. As a result, the resident population has been growing at 10 to 12% annually since 1970 and the seasonal influx of tourists, skiers, boaters and second-home owners increases each year. The County supports four downhill skiing areas, Dillon Reservoir (a summer boating area), several mining and touring towns, and much National Forest land. The County is the first encountered after passing through the Continental Divide and so, attracts much attention. It serves as the gateway from Denver to Vail and Eagle County and to Leadville and Lake County, since the major Interstate runs through the center of Summit County and a number of State Highways cross it. The conditions being as they are, there is increasing pressure on the existing solid waste management system. Complicating the pressures of growth is the land-use related mandate from the National Forest Service (NFS), on whose land the Summit County landfill is located, to limit waste imports. The order, issued to the County in November 1979, requires that the volume of municipal solid wastes disposed at the county site be reduced by 50% based on the waste volumes disposed in 1978.

1. Site Location

The Summit County landfill is located 1/2 mile north of U.S. Route 6, 1 mile west of the Keystone Ski Area and Village on National Forest Service land. The landfill site is permitted by both the Colorado Department of Health and by the U.S. Forest Service. A sludge disposal permit was granted in late 1978.

2. Operational Description

The Summit County landfill occupies 22 acres of National Forest land on a shoulder of a foothill to the Continental Divide, overlooking the Snake River and Blue River Valleys and Dillon Reservoir. The site is operated by the Summit County Road and Bridge Department and employs two full-time personnel, an equipment operator and a landfill gate attendant. Most of the residential/commercial waste stream is disposed by Summit Disposal, Inc., from the town of Breckenbridge, Keystone, Dillon, Silverthorne, Frisco, Blue River, and Wheeler Junction, but many rural individuals haul to the landfill and are charged on a basis of volume as determined by vehicle type size. Construction wastes make up a large fraction of the total waste stream and are often hauled privately.

The County Engineer labels the operation a "progressive slope method or a modified trench/cell design". The landfill is open 8 hours a day, seven days per week, and daily cover is provided. A Caterpillar D-8 bulldozer strips and stockpiles topsoil and then digs a trench 15 to 20 feet deep or until the soil becomes too difficult to work. The waste is dumped at the top of the working face, and is spread up the face and compacted by the D-8. Cover material for the pass over the face is obtained from the progressing trench, excavated from immediately at the toe of the working face. Upon completion of a trench, the stored topsoil is spread over the fill and compacted. The final depth of the fill ranges from 20 to 25 feet. Sometimes the County Road and Bridge Department scraper is used to clear off topsoil and loose subsoil.

Access to the site is provided by a winding, steep all-weather dirt and gravel road. On-site access is a shale road leading up and over filled areas and down to new cells and the sludge lagoons.

All types of waste are accepted at the landfill, but only sewage sludge is currently separated, although recommendations have been made to separate construction/demolition wastes from the residential/commercial fractions.

The current (1979) landfill budget is estimated at $81,000, of which $30,000 is labor and fringe. Equipment operations and maintenance costs, plus depreciation, are approximately $44,000 per year and the rental of the scraper unit costs about $7,000 per year.

3. Waste Quantities and Projections

The most recent census records by the Colorado Division of Planning, Demographic Section, have indicated the Summit County permanent resident population has increased from 2,700 in 1970 to 5,500 in 1975 to 9,400 in 1979. Projections for future years predict a decrease, however, to 7,500 in 1980. The county planner indicated that this projection is in error as building permits, water and sewer hookups, etc. have increased this past year as much as in recent years. There has been recently a proposed moratorium on and then an increase in new sewer hookup charges in order to pay for construction and capital costs of new treatment plants. The approved increase mandated a change in fees from $1200 to $3500 in order to keep pace with growth. The County expects a resident population of 10,500 to be recorded in the 1980 census. In addition, the skier/boater/recreation population seasonally swells the county population. With four major ski areas in the county, the daily peaks can reach nearly 12,000 persons using the slopes and another 2,000 to 3,000 persons in recreation housing.

County estimates of waste volume for 1979 center around 40 tons per day on an annual basis. Construction, yard waste, and spring cleaning wastes boost summer waste totals as ski wastes increase winter volumes. This bimodal distribution totals about 14,600 tons per year (1979 estimates). These estimates are based on the calculation of volumes in vehicles as recorded by the gate attendant, and may be inaccurate. The County estimated the average bulk density of wastes disposed at its landfill to be 250 pounds per cubic yard.

4. Hydrogeologic Data

The landfill is sited on a shoulder of a glacially scoured valley. The soil at the altitude of the landfill is very thin. This thin soil, the southern exposure, and the arid nature of the area once the snow has melted encourage only a sparse vegetative growth around the landfill. The soil profile is comprised of gradations of weathered shale; this fractured rock serves as cover material for the landfill. At depths of 20 to 25 feet, the Mancos shale becomes too difficult to rip with the D-8 Caterpillar dozer and serves as a bedrock liner for the landfill. However, numerous faults can potentially conduct percolating water down through the strata to deep aquifers.

The 40 inches of annual precipitation is mostly in the form of snow which moves as runoff during thaws to Dillon Reservoir. The mean length of the frost free period in Summit County is 30 days.

5. Operating Problems Associated with Severe Climate Conditions

The major operations problems stemming from severe climatic conditions are the long periods of freezing temperatures and snow cover. Continuous low temperatures affect nearly every facet of the landfill operation. Cover material and the solid waste itself tend to freeze and become unworkable. Equipment wear increases. Landfill personnel are also severely affected by the cold. Snow cover makes operations difficult for hauling and dumping the waste at the site. Snow gets mixed in with the waste during compaction and covering, thus increasing the volume of material to be covered. During the spring thaw, the water contained in the landfill cell percolates down through the solid waste and forms leachate.

6. Recommendations Relating To Severe Climate Conditions

Suggestions for modifying the operation at the landfill face include: (a) shifting the dumping location during periods of snow cover to minimize traction problems; (b) utilization of a trash compactor to compact the municipal waste to a 4 to 1 ratio to minimize volume requirements; (c) utilization of summer and fall stockpiling of cover material; (d) better placement of trenches, access roads, and trench access ramps; (e) segregating construction wastes in a separate trench.

7. Potential Financial Options

With the growth of the resident population and the throughput of the recreation economy, there are opportunities for revenue generation to support the landfill operation. In February, 1980, the rate schedule for dumping was revised to reflect operational cost increases; the new rates are comparable with those at other landfills.

8. Other Solid Waste Issues

In an attempt to resolve the volume reduction requirements of the National Forest Service, a citizens' report on the situation of the required volume reduction and the status of the recycling program was completed in April, 1980. This report was reviewed in October, 1980 by Fred C. Hart Associates, Inc. under a Technical Assistance Panels contract. The citizens' report recommended the purchase of an air curtain destructor for burning wood, paper, and yard wastes and possibly municipal wastes, and the expansion of the recycling program. The Hart report, however, came to the conclusions that an air curtain destructor, if used, should not be used for municipal waste and that the recycling program should continue only if markets were defined and funding continued. Instead, it was recommended that the depth of the landfill be increased and that there be better planning in the placement of wells, access roads, and trench access ramps. In addition, it was recommended that increased compaction be achieved through use of a steel-wheeled compactor, gentle working slopes, and very thin (less than two feet thick) landfill lifts.

Another solid waste issue at this site is the presence of the Roberts Water Supply Tunnel located 470 to 600 feet below the surface. This tunnel carries water used for drinking purposes. The tunnel, however, is concrete lined and pressure fed and the potential for contamination appears small.

G. TELLURIDE, COLORADO

1. Site Location

The Town of Telluride is in San Miguel County in southwestern Colorado. It lies in the narrow and nearly straight valley of the San Miguel River, which flows westward out of the nearby San Juan Mountains. Near Telluride, the valley floor averages about 2000 feet in width and about 8750 feet in elevation. Access to the town is from State Highway 145 from the south and northwest. The economy of the area is based primarily on tourism, mining, and agriculture and is also entirely dependent on vehicular transportation modes. Due to the surrounding mountainous terrain, there is little potential for development of alternative transportation modes in the future. The town of Telluride originally requested this technical assistance panel's effort.

2. Operational Description

Currently, there is no existing landfill in the Town of Telluride. A perviously utilized dump site has been closed for approximately five years. The old site, which was located in an area of high ground water levels, is currently being utilized primarily as a parking lot for the ski lift area.

The present method of refuse disposal for the Telluride region requires that refuse be hauled out to a site near Norwood, Colorado, a round trip distance of 120 miles. Burbridge Trash Service currently hauls the waste on a twice weekly basis to this site run by San Miguel County.

A summary of Burbridge Trash Service accounts in Telluride is as follows:

a. Number of trash customers within town corporate limits:

329 Residential, billed $5.00 per month	$19,740
57 Commercial, billed on volume (see below)	14,891
	$34,631

The actual cost from the hauler is $4.50 per household per month for 2 cans per week @ 30 gallons each for 2 pickups per week. The town charges $0.50 per household per month for administration; $0.25 is charged for each additional container per week.

b. 3 Truck loads per week in low season @ $20yd^3$ compactor
4 Truck loads per week in peak season @ $20yd^3$ compactor

c. Special Rates
Seasonal residents: ½ monthly rate
Senior citizens: ½ rate but pick-up every other week
Two major summer events are handled through separate "special call" contracts @ 22.00 per hour, portal to portal.

d. Monthly commercial charges are as follows:

Container Service	Collections Per Week (1)	(2)	(3)
1 yd^3 container	$18.00	$27.00	$36.00
2 yd^3 container	20.00	30.00	40.00
3 yd^3 container	22.00	33.00	44.00
4 yd^3 container	24.00	36.00	48.00

3. Waste Quantities and Projections

Waste is currently received from an average baseline population of 500. Summer tourism results in contributory wastes from an additional 1500 persons. Winter tourism results in contributory wastes from an additional 3500 persons. Seasonal growth peaks have been relatively recent and have increased steadily since the opening of the ski area in 1969. Very substantial increases in both residential and tourist populations are projected in the near future due to the areawide growth of the ski industry.

Based upon a statewide waste generation average of 4 lbs. per person per day, the Telluride area currently produces a range of from one to seven tons of waste per day.

4. Hydrogeologic Data

The valley bottom is underlain mainly by unconsolidated deposits of alluvium. The alluvium is highly permeable in places, but in turn is underlain and bounded laterally by sedimentary rocks whose permeability is probably several orders of magnitude lower than that of the alluvium. The permeability of the alluvial deposits is underscored by the problem of hexavalent chromium contamination in certain ground and surface waters in the valley.

5. Operating Problems Associated with Severe Climate Conditions

While the town of Telluride does not currently operate its own landfill facility (and while that particular option is being considered), a number of problems relating to severe climatic conditions have impacted solid waste disposal servies. Winter weather conditions and the long travel distance traversed by Burbridge Trash Service trucks have resulted in a level of service which many town residents feel is inadequate. Specific problems include inconsistent scheduling, spillage, trash dispersal by wind and vectors, potential public health concerns, and potential sharp increases in trash pickup and disposal costs.

6. Recommendations Relating to Severe Climate Conditions

Since the bulk of the severe climate related problems are an outgrowth of the lengthy haul distances to the landfill site, several solutions center around reduction of the travel distance. These options include development of a Telluride landfill, utilization of a transfer trailer scheme which would require few travel trips to the Norwood site, or installation of a modular incinerator system for potential energy recovery and volume reduction.

The first option has been examined in some detail by the City of Telluride. A consultant of the town assisted in the identification of nine potential landfill sites. Eight of the sites were located in the Mancos Shale formation which exhibits moderate permeability rates on the order of 105 cm/sec. The sites, however, all generally located at elevations of from 9000 to 9400 feet, posed potential land use conflicts with existing or planned ski areas, required significant access development costs, and are currently privately owned.

The second option consisted of development of a transfer station/compactor trailer scheme which would reduce the number of required trips to the landfill site. Currently, this approach would reduce the number of truck trips to the landfill by approximately two trips per week and would also require storage of the municipal waste stream for two to four days at the transfer station. This could potentially present a health and odor hazard during the summer months. While less attractive as a disposal option in the immediate future, should population growth projections be achieved, this option would become more amenable in later years.

The third option to install a modular incinerator would eliminate the waste transport problems assuming a method for disposing of ash residues could be developed. This option, however, would require:

(1) a capital investment of at least $100,000 for the incinerator equipment;

(2) development of a town-operated collection service with one to two compaction trucks; and

(3) operating costs ranging from $15 to $150 per ton, depending on system selection, system efficiency, disposal costs, collection costs, etc.

To resolve uncertainties associated with each of the above options, a more detailed analysis should be completed for each of the options identified. Each option should be investigated for technical and environmental feasibility and should include definition of expected disposal costs in both the short and long term.

7. Potential Financial Options

The town of Telluride may be in a position to capitalize on increasing revenues available as a result of increasing tourism in the area. As such, a number of financial mechanisms might include:

a. Implementation of a user charge system whereby site users are charged on the basis of weight, volume and/or type of wastes.

b. Increase in the general taxing rate of the town.

c. Creation of a Disposal District with specific taxing powers.

d. Contractural cost-sharing with the County, particularly since County residents are not currently for waste disposal.

H. SILVERTON, COLORADO

1. Site Location

The Town of Silverton is located in the north-central portion of San Juan County. The landfill disposal site is located immediately north of the town on Route 110.

2. Operational Description

The Silverton disposal site is a five acre site located at the edge of a much larger active mine tailings pond. All types of waste are received at the site with a separate disposal area available for bulky wastes and construction debris. On-site access is a dirt road paralleling the edge of the mine disposal pond. Since the tailings disposal site increases in size and depth yearly, it is expected that the present location will last another one to two years. As both tailings and solid waste disposal continue, the actual location of solid waste disposal will gradually move upslope from the tailings pond.

The operation consists of delivery of residential wastes by the local residents, twice weekly compaction by an Allis Chalmer HD-11 or a Caterpillar 950 Loader. Cover is applied generally once yearly in the early Fall. A site operator is available approximately one-half time for spreading and compacting of wastes.

Total annual cash outlays for site operation are approximately $1,000 per year.

3. Waste Quantities and Projections

The site receives wastes from approximately 800 residents per day. At a per capita generation rate of four pounds per day, approximately 1.6 tons per day or 11 tons per week are received at the site. The town is currently experiencing little or no growth.

4. Hydrogeologic Data

No site specific data is available on subsurface conditions, although general geologic conditions would suggest alluvial deposits over less permeable sedimentary rocks. The site's location, immediately next to the tailings pond, as well as surface runoff from upland areas, generally results in wet operating conditions.

Limited investigation of the potential for leachate migration through the soil substrata to the immediately adjacent Animas River also indicates the potential permeability of subsurface soils.

5. Operating Problems Associated with Severe Climate Conditions

The most obvious problems associated with the present site include lack of daily cover and inadequate surface runoff control. A more minor problem relates to on-site access, particularly during Spring thawing conditions.

6. Recommendations Relating to Severe Climate Conditions

If the Silverton site were hydrogeologically separate from the mine pond tailings disposal site, a number of specific recommendations should be considered. These could include more frequent application of cover material, improvements in surface runoff control, and improvements in on-site access. Since the magnitude of any potential leaching of contaminants from the mill pond far exceeds potential pollution from the landfill site, it is suggested that only the later two recommendations be implemented.

7. Potential Financial Options

The limited amount of upgrading required (i.e., construction of approximately 500 feet of diversion ditch to improve site operating conditions, and improvement of the access road via crushed shale or gravel application) would not generate a need for large capital or operating outlays. Should the town be in a position to consider recovery of solid waste costs from Town and County residents, two specific options are available. These include users fees and increases in ad valorem tax rates. While Town residents have apparently indicated a preference for users' charges rather than an increase in the tax base, a user charge system for such a small population would require significantly higher operating costs, since personnel would have to be assigned to the site full-time.

8. Other Solid Waste Issues

The potential pollution of the Animas River by the mine tailings pond far outshadows potential impacts due to the Silverton waste disposal facility.

I. DELTA, UTAH

1. Site Location

Delta, Utah is located in the northeast corner of Millard County, Utah, which is in the west-central portion of the state. Delta is roughly 150 miles south-southwest of Salt Lake City. The high desert climate and physiographic conditions sharply limit the agricultural and economic activities in the Sevier Basin. The 40 acre disposal site is situated one mile northeast of Delta. The town and county and provide periodic cleanup and fire protection at the site but no operational routine exists. One trash collection service is available for commercial and residential pick-ups.

2. Operational Description

The one trash hauling service, Don's Sanitary Service, hauls the waste from the town's 80 residential and 20 commercial customers to the town site in an open pick-up truck. Most often, individuals haul and dump their own wastes at whatever location they choose since the town provides no operator. Occasionally, the city will use a backhoe to bury dead animals as they are disposed, but often the number of dead animals and wastes from the nearby rendering plant exceed the capability of the backhoe operation. The county provides a bulldozer on occasion to relocate wastes when the access road becomes impassable. At times, city or county workers will clean up the dump area by removing blowing trash. No cover is provided. Sewage sludge is also disposed at the site.

3. Waste Quantities and Projections

Delta's 1980 population stands at 2,387 and has been increasing approximately 5% per year since 1970. Based upon the Intermountain Power Project Study, which analyzed power plant generation requirements, the 1985 population is expected to grow to 5,728. (The MX Missile development was not considered.)

Delta is surrounded by a number of smaller settlements, each of which contributes to the total waste volume. Total additional population is on the order of 1,500.

Waste quantities generated in the Delta area would be consistent with the national averages (a total of four to five tons per day currently), except in the categories of old farm machinery, feedlot and corral waste, demolition debris, and pesticide containers. Large volumes of discarded baling wire are also common, as well as dead farm animals, especially cattle.

4. Hydrogeologic Data

The Sevier Desert region is situated over ancient lake laid silts, clays and sands with a slope of 0 to 3 percent. The soil is heavily alkaline and permeabilities are low. Groundwater is generally located four to eight feet below the surface but groundwater levels adjacent to the site vary due to a salt removal tile drainage system installed in the 1920's and 1930's and abandoned in the 1950's. The system currently operates intermittently.

5. Operating Problems Associated with Severe Climate Conditions

The disposal approach is generally an unplanned operation. The aridity significantly slows down waste decomposition processes with little volume reduction over time. Winds are a critical problem, as is fire.

6. Recommendations Relating to Severe Climate Conditions

The existing fill operation should be consolidated to the minimum area possible and it is recommended that a minimum of twelve inches of final cover material be applied to completed sections to minimize water infiltration, blowing litter, and rodent and insect problems. Continued operations should be governed by an operational plan which should be developed and should include a cell construction schedule, provisions for securing and applying daily cover, provisions for fire fighting capability and provisions for segregation of animal carcasses to a separate disposal cell.

7. Potential Financial Options

The city should consider implementing an ad valorem or user charge fee system for both residential and commercial customers.

8. Other Solid Waste Issues

The city should initiate development of a contingency plan due to potential development of the MX missile facility.

J. FORSYTH, MONTANA

1. Site Location

In 1976, the City of Forsyth decided that operation of its existing disposal site was not economical. It initiated construction of the transfer facility which was completed in 1979. However, the rate of growth in the Forsyth area is so large due to coal mining and power plant operation that it is feared that the capacity of the facility will soon be exceeded.

2. Operational Description

The City operates the enclosed transfer station from noon to 7:30 pm weekdays and 9 am to 5 pm on Saturdays. The city operates two 20 cubic yard rear loading packer trucks which dump wastes on the tipping floor. A skid-steer bobcat dozer is used to push the refuse into the hopper. Wastes are compacted in a 70 cubic yard compactor trailer which is hauled on the average once a day to a landfill site located in Miles City, Montana. This site is permitted by the State. Since opening in January, trips to the dump have increased substantially; from 10 in January, 14 in February, 16 in March, to 24 in April. The city does not levy a fee for dumping but assesses the citizens of Forsyth and other towns participating in the use of the station.

Opertional costs are currently averaging $34,000 per year for the collection system and about $4,000 per year for the transfer station. This charge is distributed proportionately among the communities using the transfer facility based on the records of the station operator and his estimates of volumes dumped at the facility by the residents and/or trucks of the surrounding communities.

Capital costs for the transfer station included $88,000 for the building, $32,000 for the trailer with compaction ram and $10,000 for the bobcat skidder. The dump costs at the landfill are $83.00 per load for 75 cubic yards.

3. Waste Quantities and Projections

The estimated 1980 population of Forsyth is 2,800, up from 2,476 in the special census of 1976. Continued growth is expected due to the constant expansion of Montana Power Company in coal mining and electric power generation. The collection wasteshed includes Forsyth, Ashland, and other parts of Rosebud and Treasure counties. The disposal rate in April was roughly 75 cubic yards of compacted wates hauled daily.

4. Hydrogeologic Data

The transfer station is located on the Yellowstone River alluvial deposits well out of the floodplain. No contamination via leachate is anticipated from the transfer facility.

5. Operating Problems Associated with Severe Climate Conditions

Freezing of the compactor unit and the trailer occurs fairly often. Wastes also freeze in the containers placed in the rural areas. Other problems not associated with severe climatic conditions include the disposal of bulky items in the green boxes assigned for residential and commercial solid waste. These items are separated from the municipal waste stream at the transfer facility by the operator.

6. Recommendations Relating to Severe Climate Conditions

Several alternatives have been tried and several suggested. Pending more detailed analyses, a small disposal site located three miles northeast of town on high bluffs just off of a dirt and gravel road could be reactivated. The surrounding area is sparsely populated and consists largely of ranches. A new landfill, located in an abandoned part of a coal mine in Colstrip, is being developed at this time. Monitoring wells are being installed and necessary finance agreements are being worked out. Should continued growth tax the capacity of the transfer station, one of these sites should be considered for solid waste disposal or the transfer station capacity should be increased.

In order to handle the problem of equipment freezing, oil should be sprayed periodically in a thin layer over the equipment parts most likely to be frozen.

VI. CONCLUSIONS

Chapters III and IV present potential technical solutions to the problems of landfill waste disposal as they relate to severe climatic conditions. Chapter V presented a variety of information on ten specific case studies and presented a series of recommendations for each site relating to resolution of severe climatic problems.

Exhibit 14 provides a summary of the most commonly experienced problems and the potential solutions that owners, operators, designers, and regulatory authorities should consider when trying to resolve severe climate-related disposal problems. However, in the completion of this analysis, it has become very evident that a number of additional general conditions impinge on successful waste disposal in areas of severe climate. These include:

(1) the general lack of capital and operating funds due to low watershed populations;

(2) the difficulty of providing adequate collection and disposal due to natural transportation problems (weather, geography, etc.) and the sparsely settled but large wasteshed areas;

(3) the predominance in some areas of State and Federal lands which are often unavailable for waste disposal; and

(4) the availability of a variety of natural resources (i.e., minerals, steep slopes, aesthetic attractions, etc.) which in the last few years has led in many locations to drastic increases in seasonal populations and corresponding demands for services in all sectors.

Both the severe climatic problems identified in Chapters II and III, and the more general characteristics identified above, go hand-in-hand; and, in fact, are mutually prevalent in Region VIII. This combination of conditions would suggest that additional consideration be given to resolving some of the solid waste disposal problems induced by those general characteristics noted above. More specifically, consideration should be given to:

(1) providing additional technical and financial assistance to rural communities impacted by the above conditions;

(2) reconsidering policy decisions relating to State and Federally-owned lands; and

(3) regulating or alleviating growth impacts and increased demands for services at the local level due to local tourist or industry generated population growth.

EXHIBIT 14

SUMMARY OF POTENTIAL CLIMATIC ALTERNATIVES

Problem Areas	Potential Solutions
Maintaining Adequate Cover Supply and Type	A,B,C,D,E,F,G,H
Equipment Function	F,G,I,J,K,L,M,N
Surface Runoff & Erosion	B,O,P,Q,R
Groundwater Pollution	L,S,T
Blowing Litter	H,I,U,V
Equipment Failure	H,W,X
Low Performance and Health & Safety Risks for Operators	H
Lengthy and Difficult Haul Distances	Y,Z,AA
Seasonal Variation in Waste Volume	H,I,Y,BB,CC
Waste Volume Reduction	DD,EE,FF

Key to Solutions

A. Reduce Cover Application Rates
B. Alternate Cover Design
C. Additional Compaction
D. Dewatering
E. Chemical Modification
F. Off-Site Cover Procurement
G. Alternate Cover Types
H. Alternate Landfill Equipment & Accessories
I. Alternate Landfill Design
J. Alternate Cover Handling Operations
K. Stockpile Covering
L. Surface Runoff Controls
M. Inclement Weather Reserved Area
N. Snow Removal
O. Top and Side Slopes
P. Surface Treatment and Vegetation
Q. On-Site Drainage Features
R. Off-Site Runoff Features
S. Raising Landfill Base
T. Leachate Control
U. Cleanup Operations
V. Litter Fences
W. Heated Storage
X. Frequent Preventative Measures
Y. Transfer/Storage Stations
Z. Satellite/Greenbox Systems
AA. Maintenance of Access Roads
BB. Temporary Equipment and Personnel
CC. Operations Sequencing
DD. Source Separation
EE. Materials Recovery
FF. Energy Recovery

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16. ABSTRACT

This report characterizes the operational problems of solid waste landfill disposal in severely cold, mountainous, or plains regions typical of the States of Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming, and offers alternative approaches to these problems. An extensive literatrue search on the climate, geology, soils, and hydrology of climatically severe areas was conducted and ten landfill sites in climatically severe areas of U.S. EPA Region VIII were visited.

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