

PUBLIC

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## **THE BAHAMAS**

### **SOLID WASTE MANAGEMENT PROGRAM PHASE II**

**(BH-0008)**

### **ENVIRONMENTAL IMPACT ASSESSMENT**

**1997**



**Environmental Impact  
Assessment  
Harrold Road Waste  
Management Facility**

**New Providence Island  
The Bahamas**

**Solid Waste Management Program  
Phase II**

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## 1.0 INTRODUCTION

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## 1.0 INTRODUCTION

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### 1.1 BACKGROUND

The Government of The Bahamas is in the process of developing a national Master Plan for the management of solid wastes and hazardous materials for a period of twenty years. Pre-feasibility studies have been completed and a preliminary Master Plan has been developed, including potential sites for final disposal of solid wastes on New Providence Island and nine of the Family Islands.

A Phase II study, undertaken on behalf of the Government of The Bahamas and the Inter-American Development Bank (IDB), is being completed. The thrust of Phase II is to develop more detailed technical, economic, financial and institutional systems, and to prepare designs and specifications of the proposed physical systems. One of the objectives of Phase II of the project is the preparation of an Environmental Impact Assessment (EIA) focusing on key elements which will be carried to detailed design. This Report (EIA Report) presents the results of an environmental impact assessment of the Harrold Road waste disposal facility, which will be the site for final disposal of New Providence Island's solid wastes and hazardous materials.

### 1.2 OBJECTIVES

The overall objectives of the present Environmental Impact Assessment are:

- to identify and assess the significance of potential impacts (positive and adverse) to living and non-living components of the environment resulting from the proposed activities, and socio-economic impacts stemming from environmental threats; and
- to recommend measures for eliminating or reducing the risk and magnitude of adverse environmental effects (mitigation), and for detecting adverse effects in time to correct them (monitoring).

The specific objectives of the EIA are set out in Appendix C.

### 1.3 SCOPE

The EIA addresses potential impacts (positive and negative) on air quality, terrain, surface and ground water quality, and terrestrial ecosystems. The EIA also addresses

socio-economic impacts directly related to environmental impacts, such as odour, smoke, litter, pests, noise, aesthetics, and land use issues. To the extent feasible, the EIA will address the environmental economic costs and benefits of the proposed project.

The geographical scope is the land used for disposal operations, and an area of 1 mile radius around the disposal site, taking into consideration the total airshed, water movements and visual area of influence of the site.

In terms of the project components to be assessed, the EIA addresses potential impacts related to the new/expanded landfill facility at the Harrold Road site in New Providence and related operations (hereafter referred to as the "proposed new landfill"). It considers construction, operational and post-operational phases of the project. The proposed new landfill is described in Section 6.

A composting facility and a hazardous wastes management facility are also being contemplated for the Harrold Road site, but because the designs for these components are not complete, they are considered to be outside the scope of this particular Report.

The existing Public Disposal Site at the Harrold Road site (hereafter referred to as "existing landfill") is regarded in terms of defining a Base Case for assessing impacts of the new/expanded facility. This will assist the development of mitigation and monitoring plans aimed at overcoming problems that have been experienced in the past.



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## 2.0 HISTORICAL OVERVIEW

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## 2.0 HISTORICAL OVERVIEW

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The purpose of this Section is to provide a brief overview of solid waste management on New Providence Island, and to describe past and current operations at the Harrold Road landfill facility. The information is based on interviews with Department of Environmental Health Services (DEHS) management and staff, from discussions with other members of the Consultant's project team, and from observations made during site visits.

### 2.1 WASTE MANAGEMENT ON NEW PROVIDENCE ISLAND

The population of The Bahamas is distributed as 69% on New Providence Island, 15% on Grand Bahama Island and 17% on the remaining Family Islands. Thus, waste management issues in The Bahamas range from large volumes and major facilities on New Providence Island to very small volumes and systems on the Family Islands.

The economy of The Bahamas is highly dependent on tourism. As such, most of private industry of the islands is based on direct and indirect support of the tourist industry. As a result, there is a limited number of heavy industries, and waste flows, therefore, contain very little material from that source. Industrial waste makes up approximately 2.5% of the waste flow on New Providence Island (Pre-Investment Study). Except for approximately 20% construction and demolition waste, the balance of the waste flow is fundamentally of domestic and commercial origin. Ultimately, from an environmental perspective, this waste composition means that toxic materials or leachates that derive from industrial processes are not a prime concern, but rather less environmentally hazardous materials or liquid wastes (leachates) coming from domestic-type wastes.

New Providence Island generates approximately 560 tons of municipal solid waste per day, as received at the Harrold Road waste disposal facility (Phase II Inception Report).

## **2.2 DISPOSAL OPERATIONS AT THE HARROLD ROAD SITE**

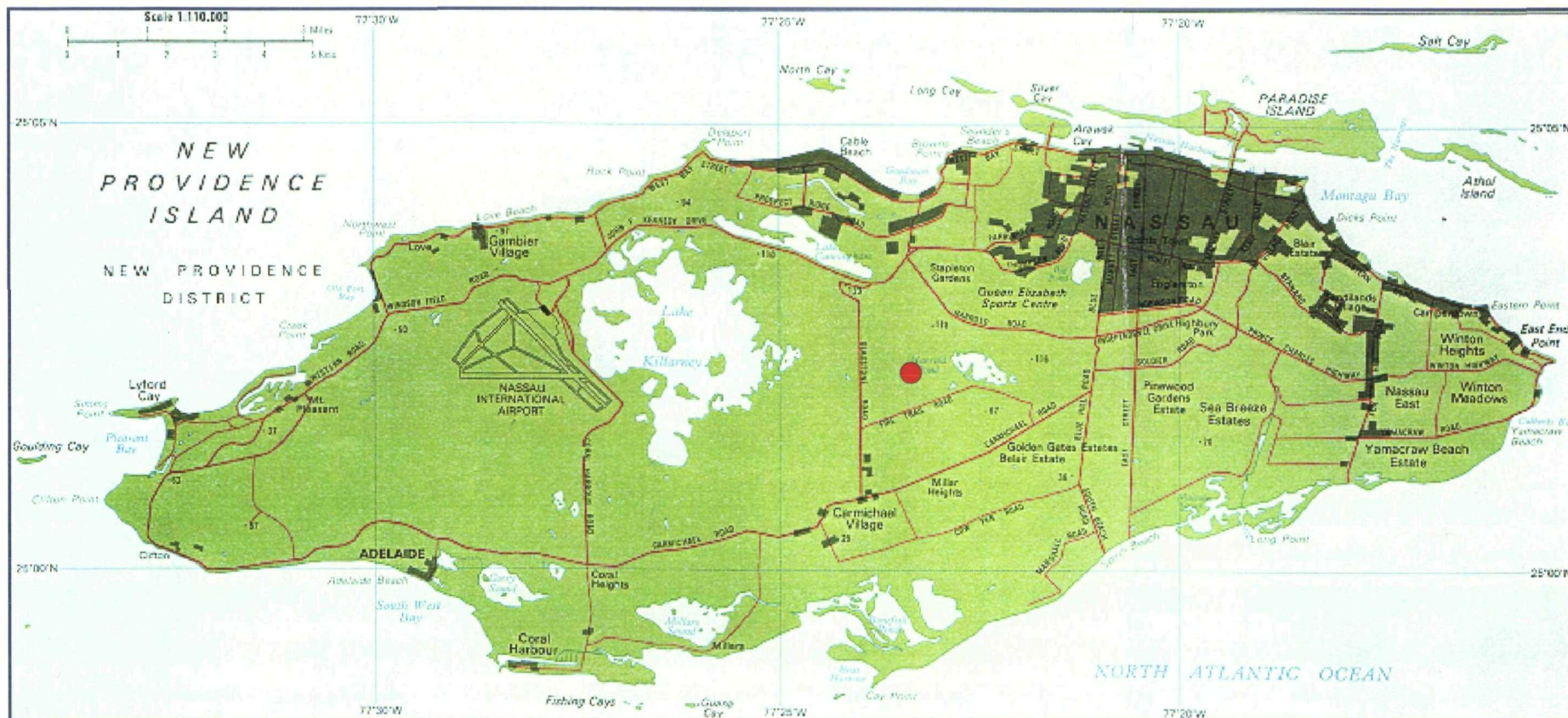
### **2.2.1 Overview**

The Harrold Road Waste Disposal Site has been in use since about 1977. Previous to this, authorized disposal of municipal solid waste occurred primarily at the Blue Hill Road site, where significant problems were encountered in relation to the high water table in that location. The location of the Harrold Road site is shown in Figure 2.1, and Figures 2.2 and 2.3 show the nature of the landfill itself.

While some of the area was excavated to some degree, the high watertable in the area restricts deep excavation. Most of the landfill area consists of a surface waste pile which has mainly been covered, apart from the active surface (area where waste is currently being deposited). Earlier in its history, the site was supplied with a garbage shredder, the purpose of which was to reduce the amount of space required for disposal and improve the compaction of the waste. However, this unit succumbed to a series of operational breakdowns and eventually its use was discontinued. The site also contains a weigh scale, weigh scale building, garages for equipment, and administration building.

As with any municipal solid waste landfill, the Harrold Road facility is subject to a number of issues, challenges and problems that it addresses on an ongoing basis. These are set out as follows:

- lack of cover material and odour control
- illicit dumping
- unofficial scavenging
- fire prevention and control
- security and access
- pests
- noise
- waste acceptance and sorting
- improper operational procedures
- control of wastes during transportation
- insufficient waste management staff training and equipment



BAHAMAS SOLID WASTE AND HAZARDOUS MATERIALS MANAGEMENT PROJECT

**FIGURE 2.1**  
**Location of the Harrold Road**  
**Waste Management Facility,**  
**New Providence Island**





**Figure 2.2** The existing landfill at the Harrold Road waste disposal site



**Figure 2.3** Waste pile at the existing landfill

The remainder of this Section focuses on how these issues have been addressed in the past and present. This analysis is intended to provide some background for the mitigation and monitoring measures for the proposed new landfill facility, which will be developed in Sections 9 and 10 of this Report.

### **2.2.2 Cover Material and Odour Control**

Part of proper procedure for sanitary landfill operation is the application of daily, intermediate and final cover material to the waste surface, in order to reduce odours, scattered litter, pests, etc., and to regularize the progress of microbiological decomposition of the waste. Cover material consists of some inert granular matter which can be spread over the waste pile surface, curtailing open contact with the atmosphere. Daily cover, as the name suggests, is applied each day to the waste surface, while intermediate cover is applied to each phase (cell) prior to progressing to another phase. Final cover is applied progressively to those parts of the landfill which have reached capacity and whose operational life is completed.

The acquisition of suitable cover material in reliable and sufficient quantities, is a difficult matter in The Bahamas, because of the coralline nature of the rock and the limited land space. In general, the acquisition of cover material for the Harrold Road facility has been mainly from the extraction and crushing of limestone rock, and from dredging activities, although for a short period (about one year) the on-site shredder provided some quantities of suitably small-particle waste. The recent Government national policy to curtail the excavation of ridges and hills on New Providence Island may make the first of these mechanisms more difficult.

Shortage of adequate cover material in the past has been blamed for recurrent problems with odour, fires and pests. During periods in which cover material was applied regularly, there were few or no complaints from nearby communities about odour, and the incidence of fire was substantially reduced. Apparently, most complaints from the public have been from the south and southwest, where there are relatively large neighborhoods (Mr. A. Roberts, D.E.H.S., pers. comm.). These areas are generally downwind from the landfill with respect to prevailing winds during much of the year (October-April), when the prevailing winds are from the north-east. However, during episodes of fire at the landfill, complaints about smoke odours have been voiced from as far away as Cable Beach, the Airport and virtually all parts of the Island. Odour complaints occur particularly when animal wastes (e.g., chicken blood and offal from chicken farms, animal carcasses, or condemned meat) are brought to

the landfill for disposal and are not adequately covered with inert material. Such shipments are received about four or more times per week. A certain amount of odour also emanates from quantities of waste that are either spilled during transportation, or illicitly dumped along the current access road or otherwise nearby.

### **2.2.3 Illicit Dumping**

Illicit/unauthorized dumping of garbage is a rampant problem on New Providence Island, particularly in lower income areas and vacant undeveloped areas on the island. The access road leading from Harrold Road to the current landfill facility (approximately 0.6 miles (1 km) in length), as well as areas all around the landfill site, are no exception in this respect. Figures 2.4 and 2.5 show evidence of illicit dumping along the access road to the Harrold Road waste disposal facility. This doubtlessly contributes to problems of odours and pests at the current landfill site in general.

### **2.2.4 Fire Prevention and Control**

The occurrence of fires on the current landfill facility is probably the largest cause of poor air quality and related complaints from the public. The causes of fires at the landfill have been attributed to various factors including the activities of the on-site scavenger population including cigarette smoking, cooking fires, and the ignition of piles of wire to remove the insulation material before recovering the copper. Other causes that have been implicated are related to the receipt of smoldering materials in the incoming waste, and ignition of landfill gas and/or combustibles in the waste by the action of sunlight focused by glass shards (Mr. M. Turner, DEHS, pers. comm.).

Once fires have occurred, major impediments to controlling them are the lack of sufficient inert cover material for smothering the fire, lack of a water supply for fire fighting and the number and operating condition of fire-fighting equipment (Mr. A. Roberts, DEHS, pers. comm.).

Several major fires have occurred over the last number of years, the most recent in March/April 1997, with each one generating considerable public attention.

### **2.2.5 Security and Access**

The current landfill facility is unfenced, and there are effectively no security measures to prevent people from walking onto the landfill site. Notable among non-staff users of the facility are a population of about 100 scavengers, about 20 of whom live on or





**Figure 2.4 Evidence of Illicit Dumping along the Access Road to the Harrold Road Waste Disposal Facility**



**Figure 2.5 Evidence of Illicit Dumping along the Access Road to the Harrold Road Waste Disposal Facility**



around the landfill property. These users collect a wide range of incoming materials, often directly from the vehicles as they off-load, including some glass bottles, cans, appliances, clothing, metal, food, and many other items. They have various marketing distribution systems in place, specific to certain types of materials, for example glass bottles and scrap metals. Figures 2.6 and 2.7 illustrate these activities. The scavengers operate with the knowledge of the Government, and to a large extent with the cooperation of the site operators. The activity of the scavengers represents a form of recycling and re-use of materials. As such, it achieves a useful purpose, although it is carried out unofficially.

The presence of the scavengers, however, presents several problems. First, there is the potential risk to human safety, with numbers of people being very close to heavy equipment as large quantities of waste are offloaded from them. Second, the activities of the scavengers lead to the potential for fires, as discussed above. Third, there may be some degree of interference with critical landfill operational activities such as the locations where wastes are dumped, the spreading of cover material and waste compaction. Fourth, the acceptance of biohazardous items such as condemned meat, biomedical wastes, etc., may lead to the transmission of disease off-site. If the scavengers are to continue to be allowed access and use of the proposed new landfill facility, it would be advantageous to use the opportunity to address the above issues through some combination of consultation, education, regulation and enforcement.

#### **2.2.6 Pests**

Pests currently frequenting the landfill include flies, rats, cattle egrets and dogs. These pests would be more or less typical for landfill sites that are unfenced and in which significant amounts of the waste are left exposed. Occasionally, complaints are received from nearby residents, about flies (Mr. A. Roberts, DEHS, pers. comm.). Various attempts to control certain pests have been made in the past, but there is not currently any concerted program to reduce pest numbers. The most effective means of controlling pests on the landfill is the frequent and adequate application of cover material.

#### **2.2.7 Noise**

Noise from the machinery operating at the landfill or bringing wastes to it, is not oppressive to nearby communities because of the distance from the landfill and because there are not a large number of machines operating at any given time. Few complaints concerning noise are received.

## **2.2.8 Waste Acceptance and Sorting**

During a site visit to the current landfill facility, it was evident that significant quantities of environmentally hazardous wastes are being admitted for landfilling. This includes such items as automobile batteries, automobile tires, insecticides, gas cylinders, asbestos containing items, paint and paint residues, solvents and their residues, oily wastes, grease, etc., pharmaceutical wastes, and animal tissues and carcasses. In general, such materials potentially increase the strength, variety and toxicity of the leachate that is produced by the landfill. The Phase II Solid Waste and Hazardous Materials Project now underway includes the development of a hazardous wastes treatment and disposal facility for New Providence Island which will also be located at the Harrold Road site ,

Potentially recyclable or re-usable materials are also accepted at the landfill. Primarily, this includes paper and cardboard, glass, plastic, and ferrous and non-ferrous metals. It is understood that the Government is considering the possibility of encouraging various recycling industries to accept and recycle/re-use some of these materials, but the plans are at a preliminary stage.

The landfill also accepts yard and garden waste (grass clippings, tree cuttings, stumps, etc.), which accounts for a total volume of some 20,000 tons/year. The Government is also considering the development of a composting facility (windrow type), which may at some future time be located at the new landfill facility at the Harrold Road site.

## **2.2.9 Waste Transportation**

Loss of loose waste material en route to the landfill site has been a problem, leading to an increase in the amount of litter on streets, roadsides and so forth. Efforts have been made to ensure that trucks are covered, either through the design of the vehicle or by the use of netting or similar material. However, it is evident that these efforts have not resulted in the covering of waste transportation vehicles. Although the regulations are in place, enforcement of these activities is not a high priority.



**Figure 2.6 Scavenging Activities at the Harrold Road Waste Disposal Facility**



**Figure 2.7 Scavenging Activities at the Harrold Road Waste Disposal Facility**

#### **2.2.10 Waste Management Staffing and Equipment**

The current Harrold Road waste disposal facility has about 25 staff, including 4 landfill site operators, 5 weigh bridge operators, 8 watchmen, 6 spotters (who direct the incoming truck drivers to spots where the loads are to be dumped), and 2 caretakers. The facility has 2 dump trucks, 2 tracked-type tractors and 3 hired tractors.

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## 3.0 PHYSICAL ENVIRONMENT

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## 3.0 PHYSICAL ENVIRONMENT

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### 3.1 PHYSICAL ENVIRONMENT OF THE BAHAMAS

#### 3.1.1 General

The Commonwealth of The Bahamas is located on the southwestern edge of the North Atlantic Ocean between 72° 35' and 80° 33' W and latitudes 20° 55' and 27° 25' N. It consists of an archipelago of approximately 700 islands and over 2000 rocks and cays. Its total land surface is approximately 13,934 km<sup>2</sup>. The islands are grouped according to the underlying shelves, which from north to south are: the Little Bahama Bank, the Great Bahama Bank and the Bight of Acklins.

#### 3.1.2 Climate

The climate of The Bahamas is semi-tropical with high temperature and moderate rainfall. Overall, mean monthly temperatures range from a high of 27.8°C and a low of 18.6°C in the north to a high of 28.1°C and a low of 23.3°C in the south. January average temperatures range from 14.4°C to 22.7°C in the north to 20°C to 26.1°C in the south. August temperatures range from 31.1°C to 24.4°C in the north to 31.1°C to 25°C in the south.

The average annual rainfall varies from about 40 to 55 inches (102 to 140 cm), with the rainfall in the more southerly islands lower than that in the more northerly islands of the group. On New Providence Island, mean annual precipitation varies from 37 to 73 inches (91 to 185 cm.). Approximately 75 percent typically occurs from May through October in the north and central islands.

The prevailing winds on New Providence Island from the months of May to September are from the east and south-east, while the prevailing winds for the rest of the year are from the north and north-east (Department of Climatology, Government of The Bahamas, pers. comm., 1997). Table 3.1 is a summary of climatic observations recorded 1958 - 69 at Nassau Airport. Monthly average wind speeds varied during this period, from 11.85 km/h (September) to 17.41 km/h (March).

Hurricanes may occur in the Caribbean during the months of May through November. Intense rainfall and high storm tides can occur during these storms.

### 3.1.3 Geology

The surface geology of The Bahamas consists of deposits of Pleistocene and more recent age which are basically of reefal limestone or its weathering products. Lithic materials therefore, consist of coral limestone, littoral deposits, dunal deposits, lagoonal materials and beach sands, all of which consist dominantly of calcium carbonate. Extensive downward fluctuations of sea level several times during the Pleistocene created numerous karst features, most noticeable of which are "blue holes" which are remnants of cave systems which conducted freshwater to the ocean during times of low sea level.

There are no occurrences of minerals in economic quantities documented in the literature reviewed. Quarrying of limestone does occur and it is used as fill and as aggregate.

Soils are generally very thin because they developed in place from the underlying calcareous materials. Weathering of the coralline deposits leaves virtually no residual materials; hence the upland soils contain only minor clay materials. Lowland soils reflect slow accumulation of clay materials along with abundant organic material.

### 3.1.4 Hydrogeology

The highly-porous limestone reef structures, combined with karst features which make up the geological environment of The Bahamas, support a freshwater lens which is used for groundwater supply. In its undisturbed state, this lens floats on the underlying salt water. Based on hydrostatic considerations, the base of the freshwater lens will extend approximately 40 ft (12 m) below sea level for each 1 ft (0.3 m) of hydraulic head above sea level. This relationship is shown diagrammatically on Figure 3.1. Exploitation of this lens requires careful withdrawal to avoid depressing the water table thereby inducing an upward movement of the freshwater/salt water interface. In reality, the simple static model is modified by tidal effects, groundwater flow conditions, pumping and dispersion at the interface between freshwater and salt water, the result of which is usually a thinner freshwater lens. In actual fact, the diagram in Fig. 3.1 is highly simplified, and the freshwater lens is dispersed throughout a matrix of porous substrate, with fissures, channels, and other variations. Because of the discontinuities in the formation, the results of groundwater sampling in one area may be quite different from those in another location.



The karst system which is present throughout the Bahamas was developed during the multiple periods of sea level lowering which occurred during Pleistocene glaciation. Concurrent subsidence of the Bahamas banks has created an extensive karst drainage system which is hypothesized to extend significantly deeper than the 400 to 600 ft (120 to 180 m) of sea level lowering which occurred during the Pleistocene. As a consequence of this karstification, hydraulic conductivities tend to be very large, ranging from 22 to 270,000 gal/d-ft<sup>2</sup> (0.9 to 13,000 m/d) (Whitaker and Smart, 1997). Whitaker and Smart (1997) document 17 hydraulic conductivities derived from pumping tests from New Providence Island which demonstrated a geometric mean of 8,800 gal/d-ft<sup>2</sup> (360 m/d) and a range of 160 to 22,000 gal/d-ft<sup>2</sup> (6.4 to 880 m/d). The mean hydraulic conductivity for New Providence Island was the second highest among the 14 Bahamian islands for which data was available.

Extensive groundwater withdrawal systems consisting of trenches and vertical wells have been developed in The Bahamas to carefully exploit this thin freshwater lens in order to serve the growing needs of New Providence Island. Weech (BWSC, pers. comm.) has estimated that there are 10,000 private wells on New Providence Island in addition to the many kilometres of trenches that constitute the public supply source.

Intrusion of salt water as a result of withdrawals is a problem on some islands in The Bahamas. For instance, on New Providence Island, the chloride concentration from the water supply trenches is currently so high that water of lower chloride concentration must be imported from Andros Island and blended to provide acceptable quality. This adds considerably to the cost of the New Providence Island supply.

Injection of liquid waste products into the salt water zone by means of wells has been an accepted practice in The Bahamas since the 1970's (Cant, 1992). On a formal, approved basis, these wells are commonly constructed to depths of 200 to 600ft (60 to 200 m), but waste liquids from septic tanks and stormwater runoff are also commonly disposed into shallower wells not subject to the approval process. Cant (1992) estimated that there were 300 disposal wells on New Providence Island. The Bahamas Water and Sewerage Corporation reviews each application for a waste disposal well and sets criteria for approvals for construction. However, there is not a set of regulations dealing with the process. Such approvals deal with depths of, and cementing of casings. There is little information regarding monitoring of the impact of this practice. Cant (1992) mentions one incident of casing failure in a sewage injection well which resulted in substantial subsurface contamination. It is common



knowledge that unapproved disposal of liquid wastes takes place by such means as surface infiltration, ditches, pits or wells of any depth.

### **3.1.5 Topography and Drainage**

Due to the nature of the island-forming processes, the topography of the Bahamian islands is generally quite subdued. Low relief, seldom exceeding 30 ft (10 m) above sea level, is generally the case. However, dune ridges, such as those on New Providence Island have elevations exceeding 100 ft (30 m) in places.

The generally high hydraulic conductivity of the limestone materials means that infiltration of precipitation is rapid and, as a consequence, there is virtually no surface runoff. Because of the lack of surface runoff, an integrated drainage system is generally not developed. There are very few stream courses discharging into the ocean.

Ponds and lakes of New Providence Island were formed between dunal ridges and have no outlets. They receive water from precipitation and minor surface runoff, but are quite brackish because of evaporation.

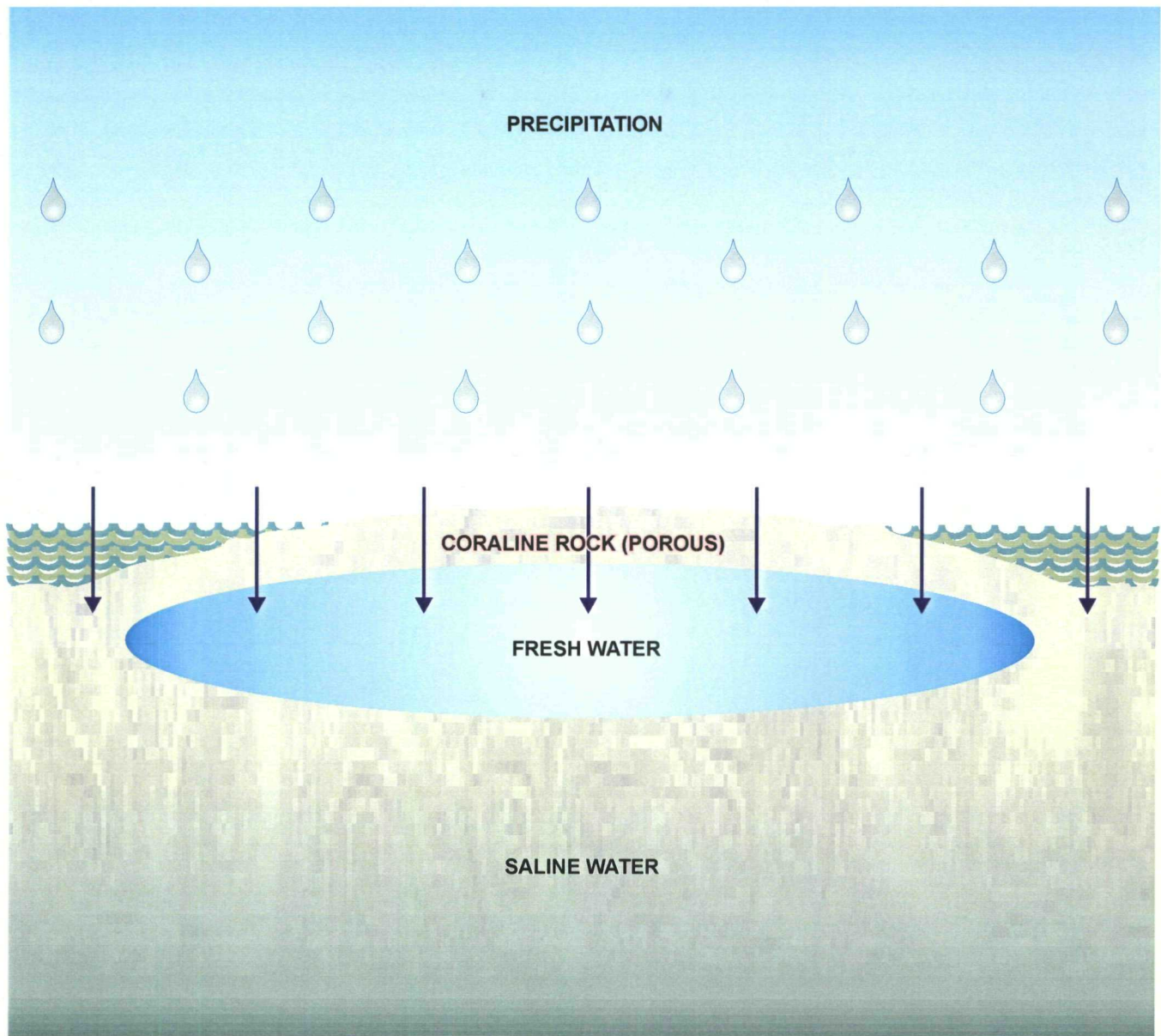
## **3.2 PHYSICAL ENVIRONMENT OF THE PROJECT SITE**

### **3.2.1 Site Location**

The site for the proposed new waste disposal site and sanitary landfill is located directly north, northwest and west of the existing landfill. It lies about 2000 feet (600 m) to the east of Gladstone Road at its nearest point, about 1500 ft (450 m) north of Fire Trail Road (at the closest point), and is bounded on the north and east by Harrold Road, John F. Kennedy Drive, and Milo Butler Drive. Wilson Pond lies about 2000 ft (600 m) from the eastern edge of the proposed site. The proposed site, including the landfill itself (75 acres or 31 ha), and an area to the south which may be used for compostable yard wastes (25 acres or 10.5 ha) comprises approximately 100 acres (41.5 ha) of surface area.

### **3.2.2 Geology and Topography**

The location of the proposed new landfill is underlain by limestone deposits typical of The Bahamas. Descriptions of the general geology, as it applies to the landfill area, are given in the Bahamas Solid Waste Management Phase I Mid-Term Report (March 1996) Appendix A. Briefly, the area is underlain by soft white coralline limestone



which has been extensively karstified during the Pleistocene sea level fluctuations. Porosity varies significantly and can exist as small pores to large caverns. Water levels are influenced by oceanic tides.

The site for the proposed landfill lies on gently sloped land. There is a ridge bordering the east edge of the site, which runs approximately NW-SE. Due to the porous material typical of the region, there are no significant surficial drainage features, and no watercourses or ponds.

The soils of the area are largely organic, and very thin. The cover in the pine forest area consists largely of pine needles, with much of the vegetation growing out of depressions in the limestone rock.

Notable features of the general vicinity of the waste disposal site include Harrold Pond and Wilson Pond, a pair of waterbodies that lie about 2000 ft (600 m) to the east, in an area of lower elevation. Harrold Pond, the larger of the two, is approximately 0.3 by 0.9 miles (0.5 by 1.5 km), and is surrounded by a belt of wetland of varying width around the shore.

### 3.2.3 Hydrogeology

#### 3.2.3.1 Site Investigations

As part of the study program, groundwater investigations were carried out by Stanley International in 1996 and 1997. Appendix A contains the report of the 1997 investigation which summarizes the 1996 work as well. Chemical analyses were conducted on samples of:

- (i) groundwater taken from monitoring wells bored into the freshwater and saltwater zones at points surrounding the existing landfill and the proposed new landfill site, and
- (ii) samples taken from residential wells in the vicinity of the existing landfill. The remainder of this section provides a summary of this work, and interprets the findings in terms of the effects of the existing landfill on groundwater, and from this, the implications for the development of the new landfill site.

The existing landfill has been operated at the Harrold Road location for approximately 25 years. The facility has no liner or leachate collection system. Over the period of its existence, there has been concern that leachate was migrating away

from the facility and adversely affecting fresh groundwater. These concerns were not based upon observations, but rather upon expectations. No leachate had been observed at the margins of the landfill (as is occasionally found at other landfills) and no local wells have been determined to be impacted.

Programs designed to evaluate the current impact of the existing landfill were undertaken in 1996 and 1997 by Stanley International (1996a, 1996b, 1997). Details of these first two programs will not be repeated here; however the 1997 report is found in Appendix A.

A total of 15 observation wells were installed in the immediate vicinity of the existing landfill at ten different locations surrounding the facility (Figure 3.2). At five of these locations a single monitoring well was placed at depths between 13 and 40 ft (4 - 12 m). At the remaining five locations, two wells were installed at different depths in separate boreholes located approximately 10 ft (3 m) apart. Generally, these paired wells are approximately 20 to 55 ft (6 to 17 m) deep and are intended to sample the freshwater lens and the brackish water immediately below. The overall intention of this monitoring network is to determine whether leachate from the existing landfill is migrating laterally within the fresh groundwater toward existing domestic water wells or surface water bodies.

The observation well network was not designed to monitor migration of leachate moving downward beneath the existing landfill. The rationale for this was that if the leachate were migrating downward to the underlying saltwater, this was of no consequence to the issue of impact on nearby wells or surface water bodies. The reasoning behind this was that: 1) domestic wells tap the freshwater zone for domestic supply and would not be using saline water; and 2) surface water bodies would not be receiving discharge of saline water.

Sampling and water level measurements in the observation well network took place primarily in January 1996 and July 1997. Types of analyses are listed in the previously mentioned reports. Generally, the analyses consisted of major ions, metals, nutrients, volatile and semi-volatile hydrocarbon compounds, as well as carbon isotopes.

Carbon isotopes were utilized in an attempt to find a more definitive indicator of contamination than the standard analyses. It is known that biological decomposition of organic material produces carbonate and bicarbonate compounds with carbon

isotope ratios very different from sea water. If leachate were present, even in a diluted state, it was felt that the carbon isotopes would reveal its presence.

An injection well is in place at the septage and sludge handling facility located just north of the administration building at the existing landfill. This well receives decant liquid from the final treatment cell of this facility. Details of the construction of this well were not obtained for this investigation but since it was installed in 1995 or 1996 it will likely meet current policy with respect to depth and casing. Monitoring of this facility was not part of the mandate of the groundwater investigation surrounding the existing landfill.

#### 3.2.3.2 Groundwater Quality in the Project Area

The observation well network revealed several important facts regarding the hydrogeology of the vicinity of the existing landfill including hydraulic conductivity, water table and leachate migration.

Hydraulic conductivities could not be measured in the 51 mm diameter observation wells; however, indirect evidence during drilling and purging indicated very high hydraulic conductivities. This evidence included cavities during drilling, loss of circulation during air-lift drilling and high volume production during purging.

Water level measurements in the observation wells indicated water tables in the range of 0.7 ft (0.2 m) above sea level (ASL) to 3 ft (1 m) ASL. These same measurements also revealed a tidal range of up to 1.6 ft (0.5 m) in some wells. Ocean tides in The Bahamas range between 2 and 4 ft (0.6 and 1.2 m); therefore, the damping of the tidal influence is very minimal even though the site is located approximately 2 miles (3 km) from the sea. This lack of damping is a direct reflection of the high hydraulic conductivities of the limestone underlying New Providence Island.

The high hydraulic conductivities of the island, combined with the tidal fluctuations, produce a groundwater system that is in a continuous state of flux and in which water table maps have little, if any, meaning. The high hydraulic conductivities mean that, on the scale of the Harrold Road facility, gradients on the water table are not discernible and when this is combined with a tidal fluctuation which may radiate from subsurface karst features at unknown locations, the result is that water table slopes have no meaning in the conventional sense. Water table maps were judged to not be useful to the leachate migration issue and their production has been discontinued.

Chemical analyses undertaken in January, 1996 were not definitive with respect to the presence or absence of a leachate plume. The shallow observation wells generally showed comparatively fresh water adjacent to the existing landfill while the deeper wells showed more brackish water. The salinity of the water generally masked the common parameters utilized in a freshwater environment to identify landfill leachate plumes. Volatile organic compounds were not found; while metals and nutrients were generally quite low. It was concluded that leachate was not moving laterally at shallow depths. The sole anomaly within the well sampling was the presence of a significantly higher than normal temperature at the bottom of a deep well on the south side of the existing landfill. It was suspected that this temperature might have been elevated by the heat released by the decomposition process within the waste mass.

Additional observation wells were installed and sampled in July, 1997. This period of the year is typically wetter than the winter period and part of the rationale for sampling at this time was to contrast the wet and dry seasons. Chemical analyses undertaken at this time were substantially the same as previously, except that certain volatile organic compounds were dropped and replaced with hydrocarbon tests. Carbon isotope analyses were also undertaken.

Results of this second sampling revealed a strong indication of a contaminant plume at the deepest limits of observation on the south side and possibly on the west and east sides of the facility as well. Shallow observation wells surrounding the facility continued to lack any indication of leachate. The fundamental indicator of impact of leachate was the carbon isotope composition which showed a strong relationship to both bicarbonate and temperature. This pattern is consistent with fermentation of organic matter. As well, methane was detected in certain samples from south side wells, indicating fermentation was taking place nearby.

The second set of samples from the observation wells permitted relationships between certain chemical parameters and certain wells to be observed. Elevated chemical oxygen demand, total organic carbon, ammonia, total extractable hydrocarbon, certain metals, temperature and bicarbonate combined to indicate the likelihood of leachate at the deeper points of investigation on the south, west and east sides of the existing landfill.

Another aspect of the 1997 assessment program was to sample selected domestic water wells at homes located along Fire Trail Road. The chemical analyses applied to these samples were major ions and nutrients. Results failed to demonstrate any





impact attributable to the existing landfill. Nine of ten wells produced water which would meet Health Canada's test of potability (Health Canada, 1996); while one had elevated sodium and chloride - compounds which in this saline environment cannot be used as definitive indicators of leachate.

The logical conclusion of this information is that leachate is formed within the waste mass and is moving downward into the saltwater zone beneath the existing landfill. Observation wells placed at the edges of the waste are suspected to be intercepting only the upper margins of this plume. A corollary conclusion is that after 25 years of operation, the plume is in a steady state and is not spreading within the freshwater zone. It should not, therefore, represent a threat to that resource.



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## 4.0 THE BIOLOGICAL ENVIRONMENT

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## 4.0 THE BIOLOGICAL ENVIRONMENT

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### 4.1 BIOLOGICAL ENVIRONMENT OF THE BAHAMAS

#### 4.1.1 Plants

There are 1,371 species of plants found throughout The Bahamas Archipelago (Correll and Correll, 1982). Only 9% of the total species are actually endemic to The Bahamas.

There are four major groups of plants that are represented. There are 45 different species of ferns and fern-like plants (Pteridophyta). There are three species of coniferous (Gymnosperm) trees and shrubs found on the islands. These species are the West Indian Red Cedar, the Caribbean Pine and the Bayrush. There are 322 different species of monocotyledon plants in The Bahamas. This group consists of grasses, sedges, palms, lilies, irises, and orchids. The last group, which consists of trees and flowering plants (dicotyledons) has 1,001 species in The Bahamas.

#### 4.1.2 Animals

The Bahamas are inhabited by very few species of mammals (Hall and Kelson, 1959). The small size of the islands makes it hard for mammals to colonize there. The species that do occur in The Bahamas are not found on all of the islands.

Rats and mice are common mammals in The Bahamas and are found on virtually every island. Ingraham's hutia, which is a large rodent, is found only on Abaco Island. They were thought to be extinct until 1960 when the species was rediscovered. The Bahamian raccoon inhabits only New Providence and Grand Bahamas islands. There are twelve species of bats found throughout the islands. On a few of the islands, some of the domestic animals have turned wild. Wild pigs can be found on Andros, Abaco and Inagua islands. Wild dogs can be found on a few of the islands especially near the disposal sites. There are feral goats on many of the islands, and there are wild donkeys, horses and cows on Inagua.

The reptiles (Campbell, 1978) and amphibians (Harding, 1983) found in The Bahamas are:

- species of freshwater turtles found only on Cat and Inagua islands
- species of Rock Iguanas
- species of Anole lizards
- species of Geckos
- Striped lizard
- Curly-Tailed Lizard
- species of Fowl snakes
- Brown Racer snake
- species of Pygmy Boas
- species of worm snakes
- Greenhouse toad
- Eastern narrow-mouthed toad
- Squirrel treefrog
- Cuban treefrog
- Pig frog
- Southern Leopard frog

There is an abundance of bird species found in the Bahamas (Bond, 1979). Once again, not every bird species is found on every island. Many of these birds are found in The Bahamas all year long, but there are also many species of bird that are seasonal visitors or migrants to The Bahamas.

The families of birds that are represented in The Bahamas are:

- |                                       |                        |
|---------------------------------------|------------------------|
| ▪ Grebes                              | ▪ Gulls and Terns      |
| ▪ Shearwaters and Petrels             | ▪ Skimmers             |
| ▪ Pelicans                            | ▪ Pigeons and Doves    |
| ▪ Boobies and Cormorants              | ▪ Parrots              |
| ▪ Frigatebirds                        | ▪ Cuckoos and Anis     |
| ▪ Tropic-Birds                        | ▪ Owls                 |
| ▪ Herons and Bitterns                 | ▪ Nightjars            |
| ▪ Flamingos                           | ▪ Swifts               |
| ▪ Ducks and Geese                     | ▪ Hummingbirds         |
| ▪ Vultures, Hawks, Osprey and Falcons | ▪ Kingfishers          |
| ▪ Ibis and Spoonbills                 | ▪ Flycatchers          |
| ▪ Jaegers                             | ▪ Swallows             |
| ▪ Quails, Pheasant and Chukar         | ▪ Nuthatches and Wrens |

- Rails, Gallinules and Coots
- Oystercatchers
- Plovers and Turnstones
- Avocets and Stilts
- Sandpipers
- Limpkins
- Shrikes
- Starlings
- Pipits
- Mockingbirds and Thrushes
- Kinglets and Gnatcatchers
- Vireos
- Warblers
- Tanagers
- Orioles and Blackbirds
- Finches, Sparrows and Grosbeaks
- Honey Creepers
- Waxwings

Table 1 (Appendix B) gives a checklist of the birds recorded in The Bahamas, provided by the Bahamas National Trust.

There are also four species of large land crabs found on Andros Island. They inhabit the pine forests where they burrow deep into the soil. During May to August they migrate to the sea to release their young.

#### 4.1.3 Agriculture

Approximately 10% of the land in The Bahamas has agricultural potential. Most of this potentially arable land is on Abaco, Andros and Grand Bahama, where there are flat land and fresh water supplies. At present, only 1 to 2% of arable land is being used for farming. Limitations on soils for crops include alkaline conditions and low cation exchange capacity. This latter condition is due, in part, to low organic content.

Section 5 of this Report provides further information on agriculture in The Bahamas.

#### 4.1.4 Forestry

Past and present forests have existed on the northwestern islands of The Bahamas. Other islands tend not to have forests, but rather a mixture of low hardwoods and bush known as coppice.

Stands of Caribbean pine (*Pinus caribaea*) are only found on Grand Bahama, Andros, Abaco and New Providence islands (Henry, 1974). These "pine islands" were extensively logged in the first part of the twentieth century and today there are no virgin stands of the Caribbean pine left. The pine forests of today are secondary or tertiary. The Caribbean pine was found to be very commercially acceptable because it is a fast grower, is well adapted to fire, and makes good pulpwood; however, today the pine forests are mainly important because they provide habitats for birds and for the few mammals that are found on the islands. The distribution of *Pinus caribaea* in The Bahamas is shown in Figure 4.1 (Directorate of Overseas Surveys, 1973).

Other commodity trees, such as Cinnamon Bark, Cascarilla, Red Cedar and Brown Ebony, have been heavily logged and are now rare.

Section 5 of this Report provides further information on forestry in The Bahamas.

## **4.2 ENDANGERED SPECIES**

Researchers on both plants and animals have stated that the large number of small islands of The Bahamas create natural pressures on both plants and animals because of the limitation of habitat. Ecological communities cannot be very large in this setting and there is commonly not an abundance of alternate habitat for displaced plants or animals. When the pressure of human development is added to this pressure, it becomes especially important to understand the potential impacts of a new development on island ecosystems.

It is the purpose of this section to point out species of plants and animals which are endangered, rare or have a limited range such that they may need to be considered in planning waste management facilities.

### **4.2.1 Plants**

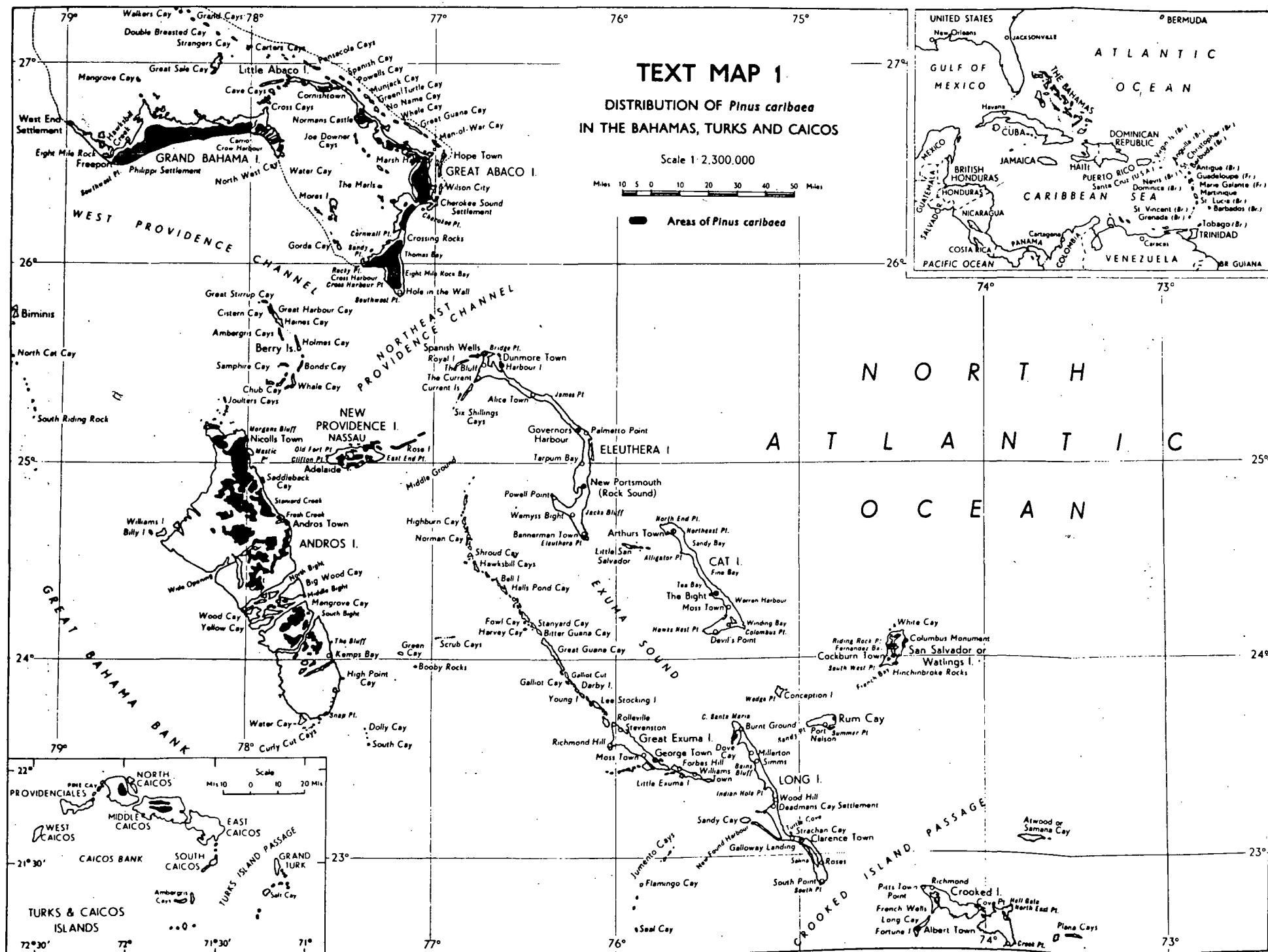
Popenoe (1984) listed seven species of monocots and 14 species of dicots as rare or threatened in The Bahamas. The rare plants of The Bahamas have been listed more recently in a 1995 Report on Biodiversity for the Bahamas (B.E.S.T. 1995). The list contains 21 species, and is shown in Table B2 (Appendix B), along with information on distribution within The Bahamas, and typical habitat. Only two are listed from New Providence Island.

### **4.2.2 Animals**

According to the International Union for Conservation of Nature and Natural Resources (IUCNNR, 1988), Groombridge (1981) and Lynn Gappe, (pers. comm.), the following animals are endangered, rare or vulnerable in The Bahamas:

#### **4.2.2.1 Mammals**

The Bahamas hutia is a rare species found on Abaco Island. The main predators are wild dogs. All 12 species of Bahamian bats are endangered.



#### 4.2.2.2 Birds

Several species of birds are endangered or have limited range in The Bahamas and therefore deserve consideration in the planning of waste management facilities. They include:

- The Bahamas parrot is endangered due to habitat destruction and uncontrolled predation by cats. The Bahama parrot burrows in the ground to make its nest, thus making it accessible to predators. It is now found only on Abaco and Inagua islands.
- The Kirtland's Warbler which winters in The Bahamas, is on the verge of extinction.
- The West Indian Red-Bellied Woodpecker, found only on Grand Bahama, Abaco and San Salvador islands.
- The West Indian Tree Duck, found in numbers on Long Island, but rare elsewhere.
- The Burrowing Owl and the Barn Owl.
- The West Indian Flamingo, which is considered rare, but that has made a remarkable comeback due to the efforts of the National Trust at the Inagua National Park.
- Osprey which are considered rare.

On New Providence Island, the only bird inhabiting the pine forest ecotype that would be considered to be rare, is the yellow throated warbler (Mr. Paul Dean and Ms. Sandra Buckner, National Trust, pers. comm.).

#### 4.2.2.3 Reptiles

A long list of reptiles are endangered or have limited range in The Bahamas and deserve consideration when planning waste facilities. These reptiles include:

- The Cat Island Terrapin, found only in freshwater ponds on Cat Island between the towns of Tea Bay and Knowles.
- The Inagua Island Terrapin, found in freshwater ponds and sinkholes in the northwestern portion of the island.
- The Hawksbill Turtle which is endangered throughout the world.

- The Green Turtle, which is still hunted in The Bahamas, however their status internationally is endangered.
- Allen's Cay Iguana, that lives on only two northern cays in the Exumas
- The Central Exuma Iguana, which is found on approximately six cays in the Exumas.
- The White Cay Iguana, found on only one Cay at the southern end of Little Exuma.
- The San Salvador Iguana, found only on several small cays off San Salvador.
- The Crooked/Acklins Iguana, found on only two cays in the Bight of Acklins.
- Bartch's Rock Iguana, which is reported only one Cay off Mayaguana Island.
- Three species and eight sub-species of boa constrictors that are found in The Bahamas, inhabiting all major islands except Grand Bahama and San Salvador.
- The Bimini Boa, which is listed as endangered.

### **4.3 CRITICAL ECOSYSTEMS**

#### **4.3.1 Mangrove Swamps**

Mangrove ecosystems represent a valuable resource of coastal zones throughout the world (Snedaker and Snedaker, 1984). They support fisheries, forest products, effect a control on water quality and contribute to coastal stability. The sheltered inter-tidal habitat provides a diverse ecosystem upon which many native organisms depend (Teas, 1983). Mangrove ecosystems are recognized world-wide because they are important as nurseries for many fish and crustaceans, as well as providing habitats for many species of birds such as herons, egrets and storks. Mangrove ecosystems are very susceptible to pollution from solid and toxic wastes and sewage, thus in many parts of the world they are considered as valued and sensitive ecosystems.

In The Bahamas there are about 233,200 hectares of mangrove forests (Maul, 1993). They occur in abundance on Andros, Grand Bahamas and Inagua islands. They grow in shallow tidal water on the sheltered sides of the islands where they are protected from wave action.



#### 4.3.2

#### Ponds and Lakes

Ponds and lakes in The Bahamas are subjected to considerable pressure from development. Landowners frequently fill them to gain more land. Formal and illicit dumping takes place on a regular basis.

Ponds and lakes support a substantially different ecosystem, one that depends upon the ocean surrounding each island. Most of these ponds and lakes contain brackish water - being neither saline nor fresh. Local and migrating birds use them extensively for nesting or resting places. On many islands the extent of these ecosystems is not great, and therefore they represent a unique resource.

The main lakes and ponds on New Providence Island are, in descending order of size: Killarney Lake, Lake Cunningham, Bonefish Lake (brackish water), Harrold Pond and Wilson Pond.

#### 4.4

#### BIOLOGICAL ENVIRONMENT AT THE PROPOSED SITE

##### 4.4.1

##### Vegetation Communities

The predominant vegetational community in the project zone vicinity is one of Pine forest, with some open bush. This type of vegetation community is common on New Providence Island. The Pine Forests are confined to four islands (The Pine Islands) in the northwest Bahamas, including New Providence Island. The Pine Forests are an ecosystem dominated by *Pinus caribaea* var. *bahamensis* ("Caribbean Pine") and an understorey dominated by thatch palms (mainly silver top palm) and various shrubs. The forests have actually been extensively logged and regenerated.

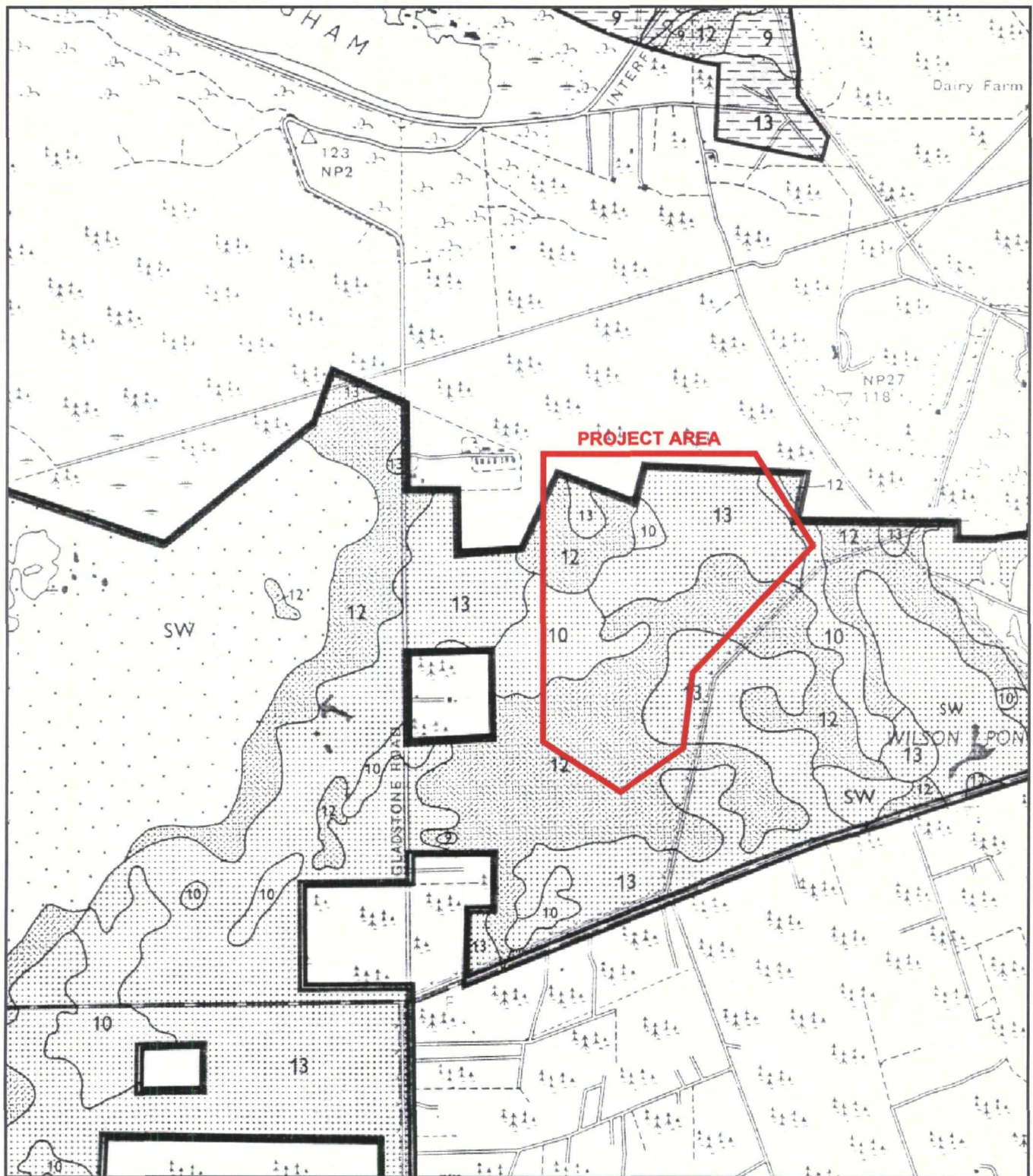
A map of the project area is given in Figure 4.2, taken from a survey of forest resource of The Bahamas published in 1974. The same area is shown in Figure 4.3 (aerial survey, 1995) which shows the outline of the proposed new landfill facility. The area proposed for the new landfill is overlain almost entirely by pine forest. Part of this area is classified as "pine forest area with good potential" ("dry" pine forest), and part is "pine forest area with poor potential" ("wet" pine forest). A small portion is "mixed hardwood with pines". An underlying factor that differentiates good potential pine forest from poor potential pine forest, is that the "poor potential" sites are usually associated with a higher water table.

Correll and Correll (1982) describe the "wet" pine forest as having an upper canopy of pine, with the low-standing *Sabal palmetto* as a sparse understorey, and scattered

with an association of trees and shrubs, including *Metopium toxiferum*, *Byrsonima lucida*, *Exostema caribaea*, *Coccoloba diversifolia*, *Guapira discolor*, *Pithecellobium keyense*, *Corchorus hirsuta*, *Bourreria ovata* and *Lantana involucrata*. Among the associated herbs and vines are *Rajania hastata*, *Smilax auriculata*, *S. havanensis*, *Rhabdadenia biflora*, *Dichromena colorata*, *Eustachys petraea* and *Andropogon spp.*

The above authors note that the "dry" and "wet" pine forest types are often intermixed. However, the "dry" forest is more frequently populated with *Coccothrinax argentata* (silver top palm) replacing the sabal palmetto. During the field surveys conducted in the area to be used for the new landfill, it was noted that the upper canopy of *Pinus caribaea* was about 20-25 m in height, with the understorey predominantly of *Coccothrinax/Thrinax* up to about 7 m tall. Correll and Correll (1982) list the following as being more prevalent in this type of forest: *Petitia domingensis*, *Duranta repens*, *Acacia choriophylla*, *Tetrazygia bicolor*, *Zanthoxylum fagara*, *Cordia bahamensis*, *Ernodea littoralis*, *Hypericum hypericoides*, *Turnera ulmifolia* and *Vernonia bahamensis*. The fern *Pteridium aquilinum* is common. The orchid *Bletia purpurea* is also often found in soil pockets or rock flats (Correll and Correll 1982).

Field observations of the area proposed to be used for the new landfill site, were made on foot during September/October 1997, and observations made on the type of vegetation, animals, rare species and so forth. Figures 4.4 and 4.5 are photographs of the vegetation typical of the area. The field observations indicate that the forested area presently occupying the site of the new landfill is mainly of the "dry" pine forest type, being secondary growth, apparently with frequent fire activity. The upper canopy and understorey are dominated by *Pinus caribaea* and *Coccothrinax* (silver top palm). Ground vegetation consists of a variety of bushes, herbs, and vines, with there being a layer of pine needles covering the substrate. To characterize the ecotype, some of the relatively common ones were identified from field samples collected at the site, and included: cinnecord (*Acacia choriophylla* [Leguminosae]); brasileto (*Caesalpinia vesicaria* [Leguminosae]); beefwood (*Guapira obtusa* [Nyctaginaceae]); pigeon plum (*Coccoloba diversifolia* [Polygonaceae]); poison wood (*Metopium toxiferum* [Anacardiaceae]); saffron (*Chrysophyllum oliviforme* [Sapotaceae]); wild guava (*Tetrazygia bicolor* [Melostomaceae]); and maidenhair anemia (*Anemia adiantifolia* [Schizeaceae]). In patches, the fern *Pteridium aquilinum* (Polypodiaceae) dominates the ground cover, indicating the influence of fire or other disturbance.

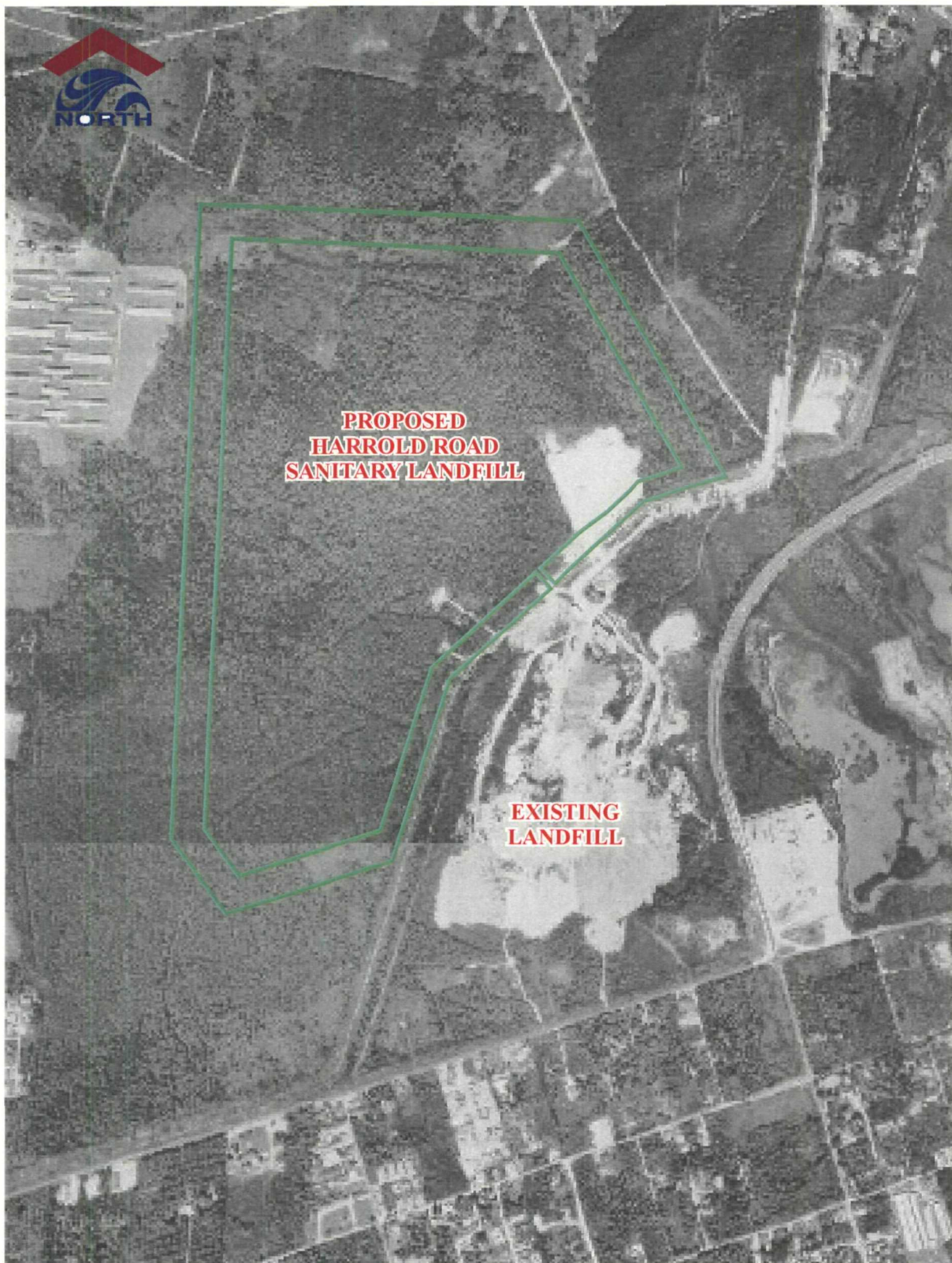


FROM LANDS AND RESOURCES  
SURVEY OF THE BAHAMAS, PART 4, 1974

BAHAMAS SOLID WASTE AND HAZARDOUS  
MATERIALS MANAGEMENT PROJECT

**FIGURE 4.2**  
**Project Area Map,**  
**Forest Classification**





There is a small area of mixed wood (hardwood and pine) near the east edge of the proposed new site. This area would typically contain mahogany, saffron, *Acacia*, brasileto, and wild guava (Mr. C. Russell, Lands & Surveys Department, Forestry Section, pers. comm.).

Table B2 (Appendix B) shows the rare plants known to exist in The Bahamas, along with information on distribution among the islands, and typical habitat. It can be seen from the table that only two of these species are known to occur on New Providence Island, viz., *Euphorbia brittonii*, and *Agave cacozele*. However, these plants prefer habitats that are quite different from that offered by the pine forest, i.e., sandy whitelands, and rocky margins of salt marshes, respectively. During field surveys, there was no evidence of rare plants in the area. Given this information, and the fact that this type of forest is quite abundant on New Providence Island and in the "pine islands" generally, it is highly unlikely that the fate of any rare or endangered species, on a regional or global basis, will be dependent on the tract of some 100 acres (41.5 ha) that will be used for the proposed project.

#### 4.4.2 Sites of Ecological Interest

Harrold Pond lies about 0.5 miles (0.8 km) to the east of the existing landfill site, with the smaller Wilson Pond lying immediately adjacent to its west end. Harrold Pond is an oblong lake, which has a belt of marshy wetland around its periphery. A view of the entire lake can be experienced from the church at the top of the ridge along Harrold Road, on the north side of the Pond (Fig. 4.6).

Harrold Pond supports a wide variety of waterfowl and other avian fauna. Various ducks, egrets and osprey are frequently seen there. Among the birds that nest there are several pairs of osprey.

A visit to the Ponds was made on October 5, 1997, along with several members of the National Trust Ornithology Group, including Mr. Paul Dean and Ms. Sandra Buckner. The area chosen was the area of wetlands adjacent to Diamond Farms on the southwest shore of Harrold Pond. In the approximately 2 hours spent there, a wide variety of native and migrant shorebirds, ducks, hawks, egrets, grebes, herons and passeriforms were observed. A list of species observed during the visit is given in Table B3 (Appendix B). Clearly, the Harrold and Wilsons Pond area has considerable potential for eco-tourism based on viewing avian life. The area, however, is presently scattered with miscellaneous domestic and agricultural wastes, which detracts considerably from its appeal and from the overall experience. A

cleanup of the area, followed by the development of walking paths and perhaps an observation tower, would be a relatively inexpensive means of providing a significant eco-tourism feature to attract both the serious and casual naturalist.

The Society of Caribbean Ornithology recently (August 1997) passed a resolution recognizing Harrold and Wilson Ponds as an important habitat for migratory and resident avian species and having potential as a significant eco-tourism site and for environmental education. The resolution recommended that the Government of The Bahamas set aside the area with a buffer zone under the protection of the Bahamas National Trust as a reserve area to be left in its natural state.





**Figure 4.4** Vegetation (pine forest) existing in the project area



**Figure 4.5** Vegetation existing in the project area, showing pine stand with understorey of palms and shrubs





**Figure 4.6** View of Harrold Pond, from the north



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## **5.0 THE SOCIO-CULTURAL ENVIRONMENT**

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## **5.0 THE SOCIO-CULTURAL ENVIRONMENT**

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### **5.1 SOCIO-CULTURAL ENVIRONMENT OF THE BAHAMAS**

#### **5.1.1 Population**

The population of The Bahamas grew from 53,735 in 1901, to 130,220 in 1963, and virtually doubled in the period 1963-1990, to 254,685 (1990 national census). The population profile shows a relatively young population, with some 50% of the population being 20 years old or less. The population is growing quickly, with an average yearly increase of 1.97% (1980-1990) (B.E.S.T. 1995).

The population of The Bahamas is concentrated into relatively few locations among the approximately 700 islands forming the archipelago. Nearly two-thirds of the population (171,542 persons) live on New Providence Island, which has a population density of 2,143 persons per km<sup>2</sup> (5,486 per square mile). Grand Bahama Island has a population of about 40,000, and the remainder of the total population is distributed among the 20 or so inhabited islands of The Bahamas (B.E.S.T. 1995).

In terms of population movements, the populations of the smaller islands have declined over the past years, as its young migrate to New Providence in search of employment.

#### **5.1.2 Tourism**

Tourism is the major business of The Bahamas, bringing approximately three million visitors to the nation each year. Sixty percent of Gross Domestic Product is derived from tourism. Long range planning by the government includes increasing this number, as several major hotel and casino projects have been approved. It has been estimated that more than half (52%) of the tourist population are cruise visitors (B.E.S.T. 1995), with 44% staying 24 hours or more ("stopovers"). The tourist market of The Bahamas caters primarily to the interests of Americans looking for a packaged vacation of 3-7 nights. The Government's priority is to encourage the growth of the "stopover" market, which accounts for more than 90% of all tourist expenditures in the country. The majority of these visitors are attracted by the favorable climate, the beaches and the seawater swimming.

The tourist market is largely dependent on a pleasant and clean environment. It is therefore evident that any waste management facility must be sized, sited and operated in a manner consistent with this planning objective. Principles involved from a tourism perspective include such direct aspects as visual and odor problems, as well as more indirect aspects, such as impact on ecosystems, which are the basis for the original desire of the tourists to visit The Bahamas.

### **5.1.3 Agriculture and Forestry**

Of the total land area of The Bahamas, only about 10% is considered to have good agricultural potential. Of these lands, 90% are located in the northern islands of Abaco, Andros and Grand Bahama (BEST 1995). The present total area of about 50,000 acres (20,200 ha) of farm land includes land in short-term crops and in permanent (tree) crops, improved and unimproved pastures, land under roads and farm buildings, and areas of pine or coppice on farms. The number of farmers was 1,760 in 1994 (1994 Agricultural Census). Farm holdings less than 10 acres (4 ha) comprised 78% of the total holdings, with 18% between 10 and 100 acres (40 ha).

Large-scale agriculture producing citrus, tropical fruits and vegetables, primarily for export, is found only on the northern islands. Grapefruit is the most important crop (4,709 acres or 1,906 ha planted), with there being 1,548 acres (626 ha) of sweet oranges and 653 acres (264 ha) of bananas. Small-scale agriculture is found throughout The Bahamas, with the production of staple crops by full-time and part-time farmers, producing corn, peas, cassava, sweet potatoes, beans, etc.).

Livestock is also raised by small-scale farmers. In 1994, for example, 34 farmers raised a total of 769 head of cattle; 227 farmers raised 6,292 head of sheep; 271 farmers raised 13,580 goats; and 122 farmers raised 4,777 pigs. Gladstone Farms Ltd. is the largest producer of broiler meat in The Bahamas.

New Providence Island has about 2,101 acres (850 ha) of farm lands, primarily small in scale. Some of the main crops produced in the island include tomatoes, cabbage, citrus fruits, bananas and sweet peppers (Mr. Stan Smith, DOA, pers. comm.). The Ministry of Agriculture is trying to promote the production of lettuce, cantaloupes and melons, through the development of hardier and resistant strains. The average size of farm on New Providence Island is approximately 3 acres, ranging up to about 16 acres (although several are 30 acres). Nitrogen is the major limiting nutrient, though phosphorus frequently occurs in biologically unavailable form. Organic matter must be added to the Island's thin limestone soils for successful cultivation. This is

accomplished in part, by the use of poultry manure. Gladstone Farms, for example, makes available substantial quantities of poultry manure for local farmers. Other poultry farms on the Island are Sunshine Farms, Rainbow Farms, and Diamond Farms.

The Pine Forests are confined to four islands (The Pine Islands) in the northwest Bahamas, including New Providence Island. The Pine Forests are an ecosystem dominated by *Pinus caribaea* var. *bahamensis* ("Caribbean Pine"). The forests have actually been extensively logged and regenerated, both by local and foreign companies, since the first licence was issued in 1906. However, logging stopped in the mid-1970s, leaving large areas regenerated from seed trees (BEST 1995). Economic returns to the government were extremely low during the period of licenced exploitation, and for this reason the pine forests have not been regarded as a valuable resource. In fact, a government land policy has identified 35,830 acres (14,500 ha) of forest regarded as being suitable for agricultural production, to be removed from the existing forest reserve. Although the market for locally produced timber products has been estimated at \$15 million per year, there are no locally based forest industries, apart from a few minor charcoal operations (BEST 1995). Uses of the forest resource on New Providence Island are minor, and include charcoal production and the fashioning of fencing material on a small-scale basis (Mr. Stan Smith, Department of Agriculture, pers. comm.).

#### 5.1.4 Parks

There are twelve National Parks totaling approximately 1300 km<sup>2</sup> in The Bahamas. These parks are administered by The Bahamas National Trust and range in size from a few hectares to approximately 750 km<sup>2</sup>. In addition, the Trust has proposed a number of "Natural Reserves" and "Protected Areas" which are not yet recognized, but which deserve consideration during siting of waste disposal facilities.

Although they are not parks, the following areas on New Providence Island have been recognized by National Trust as environmentally sensitive:

- Malcolm Creek
- Bonefish Ponds
- Lake Killarney
- Lake Cunningham

- Millars Sound
- Cory Sound
- Lightborne Creek

In addition, Harrold Pond and Wilson Pond have been recognized by the National Trust and the Caribbean Ornithological Society as deserving of protection. This has been reflected in the proposed Land Use Plan developed by Department of Physical Planning, Ministry of Public Works.

#### **5.1.5 Attitudes**

Local attitudes toward waste and waste management facilities are not characterized by high profile political, public and media debate. There has been little, if any, grass roots waste reduction movement as has occurred in North America and Europe; and the general population is not greatly sensitized to the resource use issues that drive this movement, nor to the issues of litter, illicit dumping and so forth. Accordingly, there is not a great public concern about controlling its root causes. Much of the population is pre-occupied with fundamental daily concerns with livelihood and consequently has little interest in waste reduction or recycling. However, with the importance of tourism to the market, the interest in opening up "niche" tourist markets that depend on the environment, and the competition from other tourist destinations such as Cuba, this level of interest may be expected to increase. The establishment of the Bahamas Environment, Science and Technology directorate (B.E.S.T.) and the post of national Ambassador for the Environment can be seen as direct evidence of a rapidly growing commitment to addressing environmental and related challenges by the Government of The Bahamas.

### **5.2 SOCIO-CULTURAL ENVIRONMENT OF THE PROJECT AREA**

#### **5.2.1 Land Use Zoning**

According to a proposed Zoning and Land Use Plan developed by The Bahamas Department of Physical Planning, Ministry of Public Works, there are four land use zones occurring in the vicinity of the existing and proposed Harrold Road waste disposal sites. The area containing the existing waste disposal site occurs in land that is zoned Institutional Public, intended by the Government for the purposes of siting waste management facilities.

Figure 5.1 shows a map of New Providence Island, with the land use planning zones referred to above. Figure 5.2 shows the land use zoning in the project area. Figure 5.3 (aerial photograph, 1995) shows the site of the proposed new landfill, and surrounding residential and commercial areas.

The area to the north and west of the existing landfill, extending westward to Gladstone Road and beyond it, and including the proposed new landfill site, is zoned Industrial. The Industrial zoning extends southward to Fire Trail Road. It also includes the Gladstone Farms, and Bahamas Youth Camp.

To the northeast of the proposed new landfill site, and just south of Harrold Road, is a small area zoned Single Family Residential, and to the east of that, between Harrold Road and Harrold Pond, is an area zoned Duplex, Multi-Family. Directly to the south of Fire Trail Road, is an area zoned Residential (Duplex, Multi-Family), Commercial and Institutional, although there is a small area zoned Single Family Residential. There is a small area zoned Residential (Duplex, Multi-Family) at the northwest corner of Gladstone Road and Fire Trail Road, where a new government-assisted housing development is being constructed.

In a band surrounding Harrold Pond, is an area designated as Open Space, which is being proposed as a natural area for the preservation of the wetland zone. A large Open Space area is also situated beginning just west of Gladstone Road, surrounding Lake Killarney and the Nassau International Airport.

Originally, the land on which the new landfill is proposed to be developed, was zoned as a forest reserve (Mr. Michael Major, Department of Physical Planning, pers. comm.). However, the land has since been re-zoned to Industrial, in order to accommodate waste management activities. As it does not overlie lands zoned as residential, agricultural, future use, or "open space", its development does not pose a land use conflict.

Figure 5.3 has been included to illustrate the existing development that lies within a distance of 1500 feet from the limit of the proposed landfill. This is a relatively arbitrary distance, within which development is typically restricted to compatible uses in North America. In this case, the developments that lie within this area are the existing landfill, the septage lagoons and some portions of the Gladstone chicken farm development; all of which are considered to be compatible uses. Reference to the land use zoning shown on Figure 5.2 also generally shows that future uses within this zone are compatible, excepting a small area in the northeast corner zoned for

single family development. It is suggested that the portion of this area lying within 1000 feet of the new landfill be rezoned so as to avoid housing being built nearer the site than this distance, to minimize the opportunity for nuisances to affect residents. This is much further away from the landfill than is the development that has occurred adjacent to the southerly limits of the existing site, which lie downwind from the site. The area to the northeast is also upwind, with respect to prevailing winds, and hence will be less subject to odours or smoke, if these were to arise.

Alternatively to rezoning, simply by withholding the area from development for a period of 8 years would allow completion of cell 2 of the new landfill, which lies closest to the land zoned for residential development, after which continued operating at the site will be further from potential future residential development in the area.

In terms of alternative land use, there are no significant competing options (M. Major, pers. comm.). Apart from charcoal exploitation, Christmas trees, and illicit harvesting activities, the forest resource of the island is not a significant contributor to the local economy. Furthermore, this type of stand is by no means rare on New Providence Island. For this reason, the clearing of the area (about 100 acres or 41.5 ha) to accommodate the new waste management facility is not a significant loss in socio-economic terms.

### **5.2.2 Residential Areas and Demographics**

The chief residential areas within a 1 mile (1.6 km) radius of the proposed new waste management site include:

- predominantly duplex/multi-family subdivisions south of Fire Trail Road, between Gladstone Road and Milo Butler Highway;
- predominantly duplex/multi-family subdivisions north and northeast of the proposed site and south of Harrold Road (e.g. Theodora Road);
- predominantly duplex/multi-family subdivisions south of Harrold Road and east of the BEC power line;
- scattered single-family estates and residences along the east side of Gladstone Road; and
- predominantly duplex/multi-family residences at the northwest corner of Gladstone Road and Fire Trail Road.



Fig. 5.4 shows the residential and commercial areas located in the vicinity of the existing Harrold Road waste disposal site and the proposed new landfill site. The residential areas included in the estimates are:

- Theodore Lane residential community;
- Tall Pines Cottage Colony;
- Tall Pines Estates;
- Stapledon Gardens Subdivision (southern portion);
- Fire Trail Close; and
- strip development along the southern side of Fire Trail Road.

Figs. 5.5, 5.6 and 5.7, respectively, portray typical residential neighbourhoods representative of the Theodore Lane, Tall Pines, and Fire Trail Close areas, which lie to the north, south-west and south of the Harrold Road waste disposal facility, respectively.

The current population within the indicated areas (1997) is approximately 4,700 persons, while the projected population for the same area (2007) is 7,500 persons (Mr. M. Major, Department of Physical Planning, pers. comm.). This represents a projected growth of approximately 69%. This information is based on the present zoning of remaining vacant lands in Stapledon Gardens in the north and land south of Fire Trail Road for multi-family residential development. The present trend is to subdivide original Crown Grants into small lots comprising 15-20 lots (Mr. M. Major, pers. comm.).

Most of the complaints received about odour and smoke problems from the existing waste disposal facility, have come from areas to the southwest of the facility (M. Major, Department of Physical Planning). This stands to reason, since the prevailing winds are from the northeast for much of the year (i.e., October - April).

### **5.2.3 Commercial and Institutional Facilities in the Vicinity:**

The following are the main businesses and institutions presently in the vicinity of the proposed waste management facility.

Along the east side of Gladstone, from north to south, there is a gas depot, Gladstone Farms (chickens), the Moss Gas Co., Kendal's Auto Care, a third gas depot, and the Bahamas Youth Camp. The Gladstone Chicken Farms plot is adjacent to the northwest corner of the proposed landfill site, while the Bahamas Youth Camp is adjacent to its southern half. Scattered among these businesses are predominantly single-family residences, while further south, at the intersection of Gladstone and Fire Trail Road, there is the residential area described above.

On the west side of Gladstone Road, with its entrance at the intersection of Gladstone and Fire Trail Roads, are Agro Industrial Park, and Bahamas Tropical Farms.

Directly to the southeast of the intersection of Gladstone Road and Fire Trail Road, there is a plantation of about 14 acres. Although there are several small commercial outlets along the south side of Fire Trail Road, the area is mainly residential.

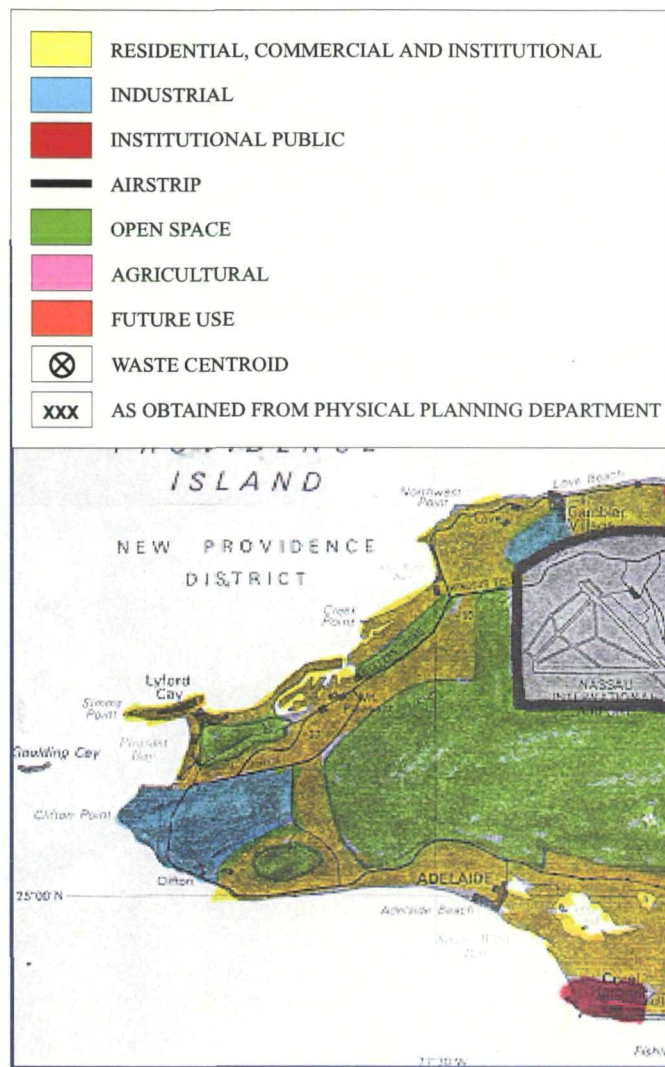
At the northeast corner of the intersection of Fire Trail Road and Milo Butler Highway, there is a gas outlet (Island Gas Co.). Further east along Fire Trail Road, there is a large farm (Diamond Farms) which produces chicken, sheep, goats, pigs and cows, and borders the south shore of Harrold Pond. Still further east, strung along Fire Trail Road, are various small residences.

Along Harrold Road, southeast of the road to the landfill facility, there are a number of commercial and institutional buildings, including Bahamian Paints, and the Workers Bank. Further north and west, there is another paint company (Sunburst Paints), and a construction company (Higgs Heavy Equipment).

North of the proposed site, along Theodora Lane and John F. Kennedy Drive, is Imperial Mattress, two churches, the Red Cross building, and at the intersection with Gladstone Road, a cemetery under construction.

#### **5.2.4 Agriculture and Forestry:**

In the vicinity of the proposed new waste management facility, agricultural operations include Gladstone Farms (to the west); Diamond Farms (to the southeast), a privately owned banana plantation of 14 acres (5.8 ha) just south of Fire Trail Road and just east of Gladstone Road, and various small-scale farming operations. There are no known or approved forest harvesting operations in the project area.



# BAHAMAS SOLID WASTE AND HAZARDOUS MATERIALS MANAGEMENT PROJECT

**FIGURE 5.1**

**Proposed Zoning and Land Use Plan developed by The Bahamas Department of Physical Planning, Ministry of Public Works ( Mr. M. Major, pers. comm.)**





BAHAMAS SOLID WASTE AND HAZARDOUS  
MATERIALS MANAGEMENT PROJECT

**FIGURE 5.2**  
**Land Use Zoning**  
**in Project Area**





BAHAMAS SOLID WASTE AND HAZARDOUS  
MATERIALS MANAGEMENT PROJECT  
**FIGURE 5.3**

**Aerial Photo Showing  
the Project Area  
(Range of 1500 ft.  
Around Proposed Landfill)**





**Figure 5.5** Theodore Lane community



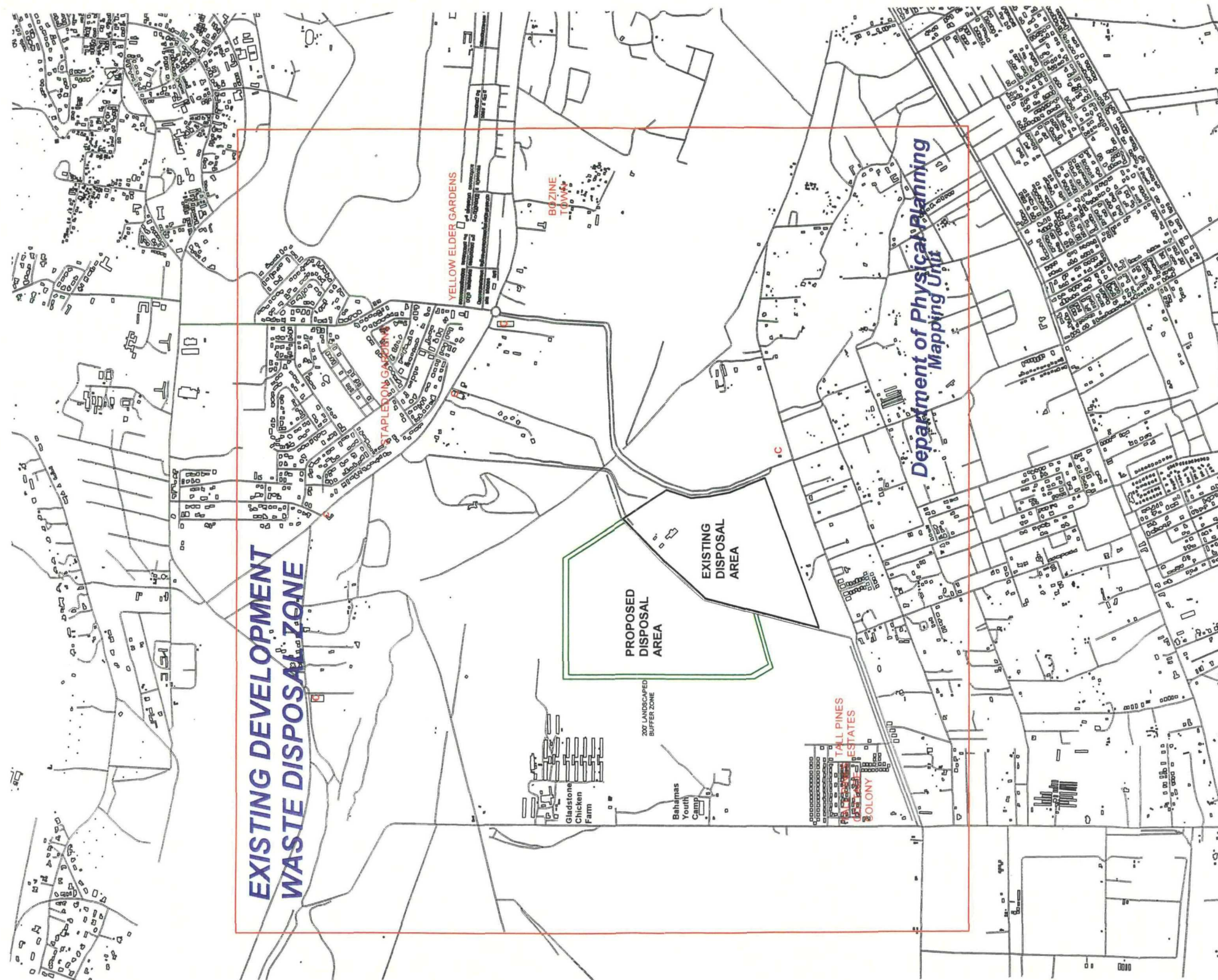
**Figure 5.6** Tall Pines community (older section, to the north of new development under construction)





**Figure 5.7** Fire Trail Close community





BAHAMAS SOLID WASTE AND HAZARDOUS  
MATERIALS MANAGEMENT PROJECT

**FIGURE 5.4**  
**Residential and Commercial Areas Located in the**  
**vicinity of the Harrold Road Waste Disposal Site**

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## **6.0 THE PROPOSED PROJECT**

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## 6.0 THE PROPOSED PROJECT

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### 6.1 OVERVIEW AND DEVELOPMENT

The proposed expansion to the waste disposal facility involves a new sanitary landfill, which will be located immediately to the north, northwest and west of the current Harrold Road landfill facility, operated by the DEHS. The location is shown in Figures 2.1 (Section 2) and 6.1.

The proposed landfill, divided into five cells, will be developed in stages, and operated as shown in Figure 6.2. The progression of solid waste filling will be in numerical order, with Cell 1 being filled first, and Cell 5 last. Each cell will have an expected life span of about four years. Hence, the landfill, overall, will have an expected life of some twenty years. This lifespan may be increased if various forms of waste diversion are adopted on New Providence Island, such as a yard and food waste composting program, a hazardous wastes treatment and disposal system, and recycling of waste paper, plastic, glass and other materials.

A total of about 100 acres of mainly forested area will be cleared for the landfill facility. This includes the landfill itself (75 acres for five cells) and an area directly to the south, which may be used for compostable yard waste or for additional landfill capacity (to extend the life of the landfill from 20 years to 25 years). The area to be cleared in the first phase of development (i.e., the first two cells) is about 40 acres (16.5 ha).

The maximum height of the landfill will rise to approximately 50 ft (15.5 m) above the existing surface at a 4:1 grade, and then a further 20 ft (6 m) at a 5% grade.

### 6.2 BUFFER ZONES

A 100-foot wide strip between the buffer zone and the cell area will be set aside for perimeter drainage, access and cover material (see below) stockpiling.

A buffer zone 200 ft in width and consisting of existing vegetation, will surround the landfill on all sides. There will be a "setback" of approximately 1,500 ft from the edge of the active zone of the landfill to the nearest institution (Bahamas Youth Camp) and an approximately equal distance from the nearest significant residential subdivision (Tall Pines Estates). The buffer zone, which will consist mainly of pines

20-25 m in height, will serve as a significant barrier to visual impact and noise from the landfill. In addition, the perimeter of vegetation will tend to arrest windblown litter, if it leaves the immediate site.

### **6.3 EXCAVATION GRADES**

Proposed excavation grades are shown in Figure 6.3. Almost all of the landfill development is designed to be above the expected high water table, minimizing potential construction problems associated with groundwater.

### **6.4 ANCILLARY STRUCTURES**

The existing paved road from Harrold Road to the landfill site will continue to be used as the access route to the new landfill. A main on-site access road will be an all-weather road with a paved and/or graveled surface. Temporary access roads to specific fill areas will be constructed progressively during the operational life of the landfill.

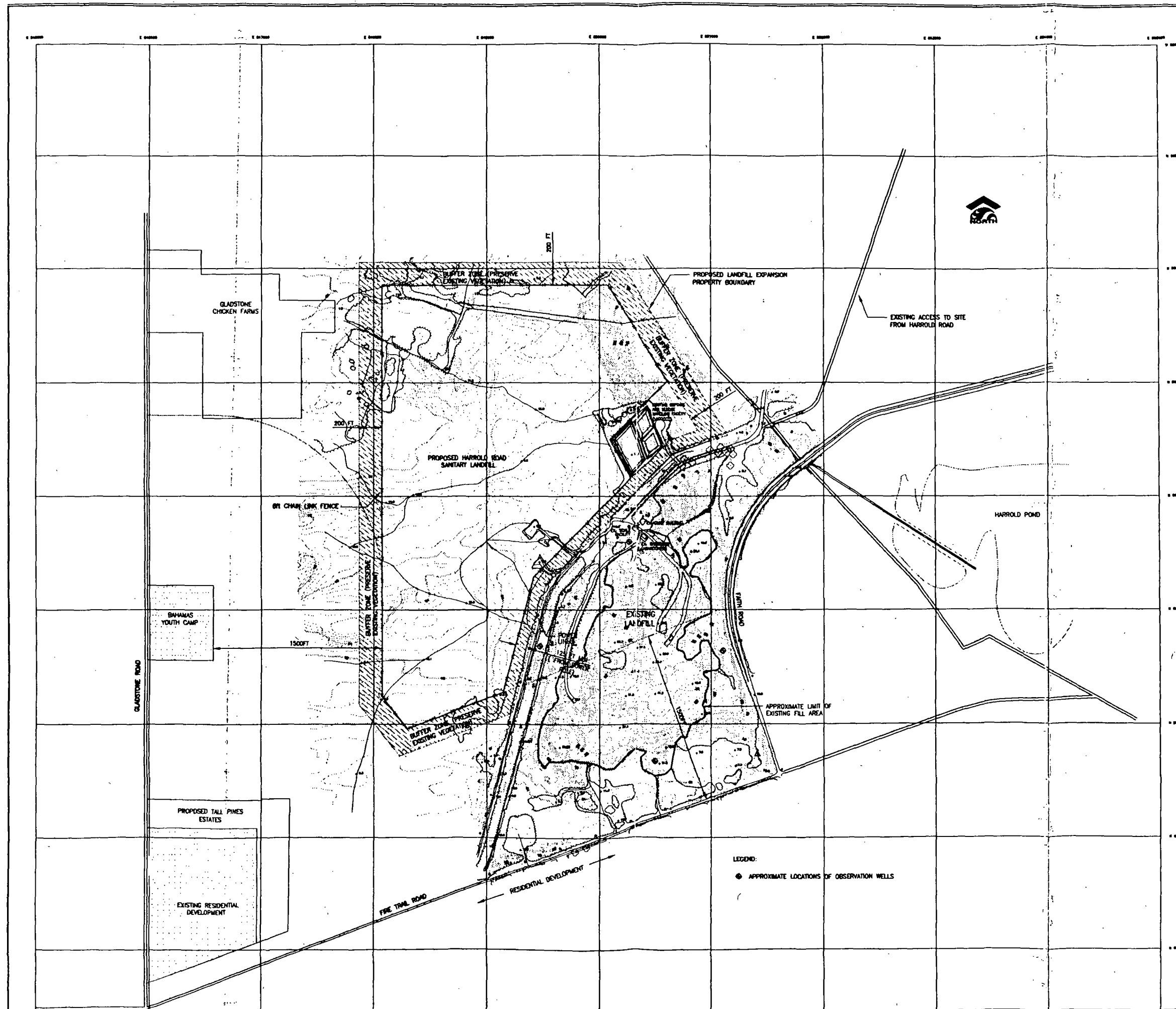
The existing weigh scale, which is used for measuring the mass of incoming waste in each collection vehicle, will be relocated for use at the new landfill. The site will also include a main administration building and weigh scale office.

### **6.5 LANDFILL DESIGN**

The landfill itself will be a sanitary landfill, i.e., one which is equipped with proper lining to prevent escape of liquids, and divided into cells that are covered with inert material after filling with waste. The sanitary landfill will be of the "active" type, that is, one in which the moisture content of the waste is kept near the optimum condition for microbiological activity to occur. This is done through appropriate sealing of the waste cell, and collection and recirculation of leachate within the waste pile. This has been shown to increase the rate at which waste materials are broken down, and consequently reduces the time required for the landfill to stabilize. This, in turn, shortens the time over which the landfill is producing landfill gas and leachate following closure.

A key component of the leachate collection system is an impervious liner that will underlie the bottom and sides of the landfill. The liner will be composed of 60 mil high-density polyethylene (HDPE), and a double layer of HDPE will be installed under the leachate collection trenches. The leachate collection system will entail a series of 6-inch diameter perforated collection pipes in gravel-filled trenches running






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		REVISION		

H	LINEAR SUBMISSION		
G	PLAN OF RECORD		
F	APPROVAL FOR CONSTRUCTION		
E	ISSUED FOR TENDER		
D	REGULATORY APPROVAL		
C	CLIENT APPROVAL	070610	NR
B	FINAL SUBMISSION		
A	PRELIMINARY SUBMISSION		
ISSUE	DESCRIPTION	TYMDD	APPRO

PERMIT	SEAL
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DESIGN BY: N. Richards

DRAWN BY: G.C. PAGE

CHECKED:

APPROVED:

DATE: Sept. 05, 1997

SCALE: 1" = 400'

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DATE OF PLOTTING: 1997 September 15, 4:13 p.m.

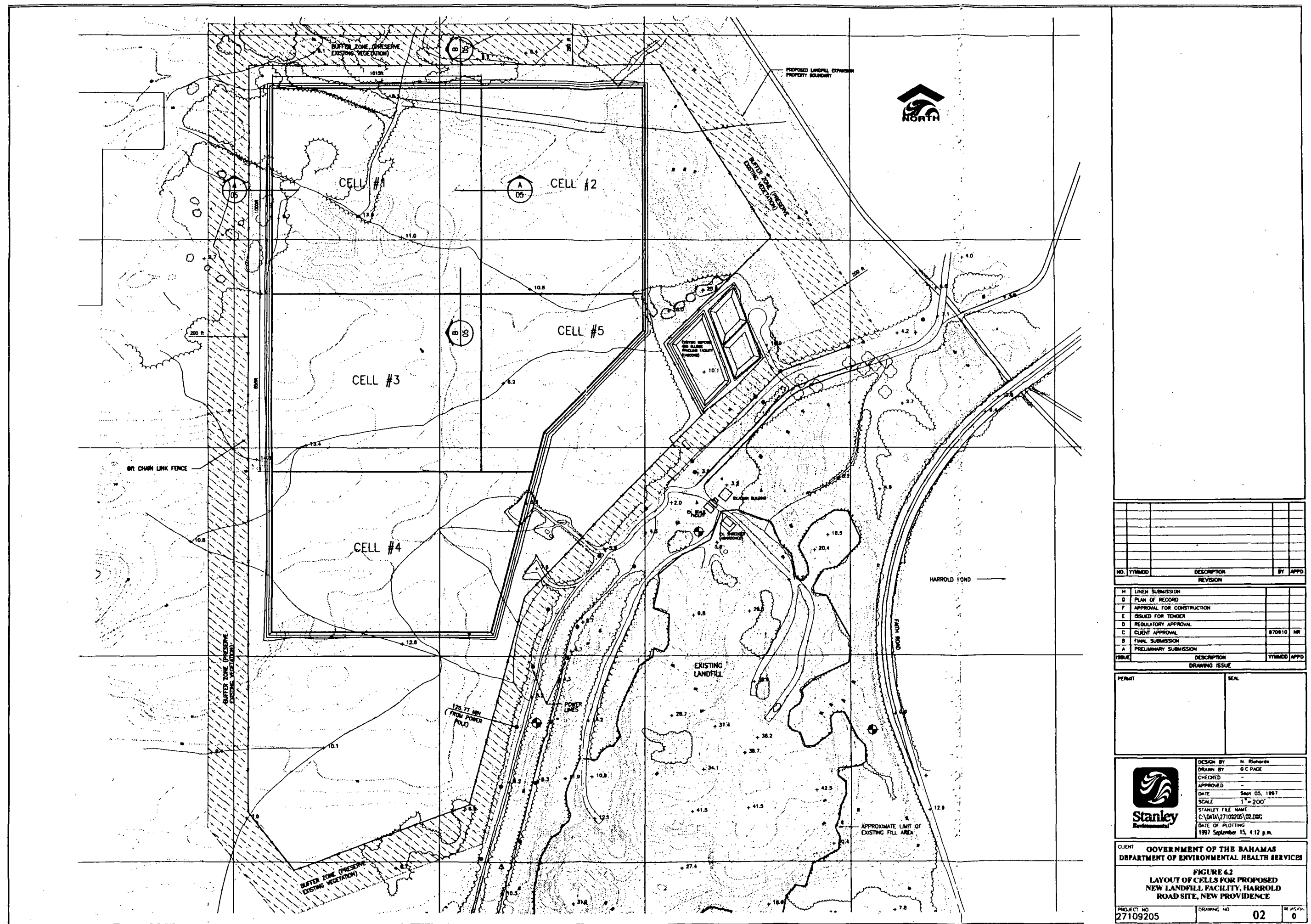
CLIENT: GOVERNMENT OF THE BAHAMAS  
DEPARTMENT OF ENVIRONMENTAL HEALTH SERVICES

FIGURE 6.1  
LAYOUT OF PROPOSED NEW  
LANDFILL FACILITY, HARROLD  
ROAD SITE, NEW PROVIDENCE

PROJECT NO: 27109205

DRAWING NO: 01


REVISION: 0



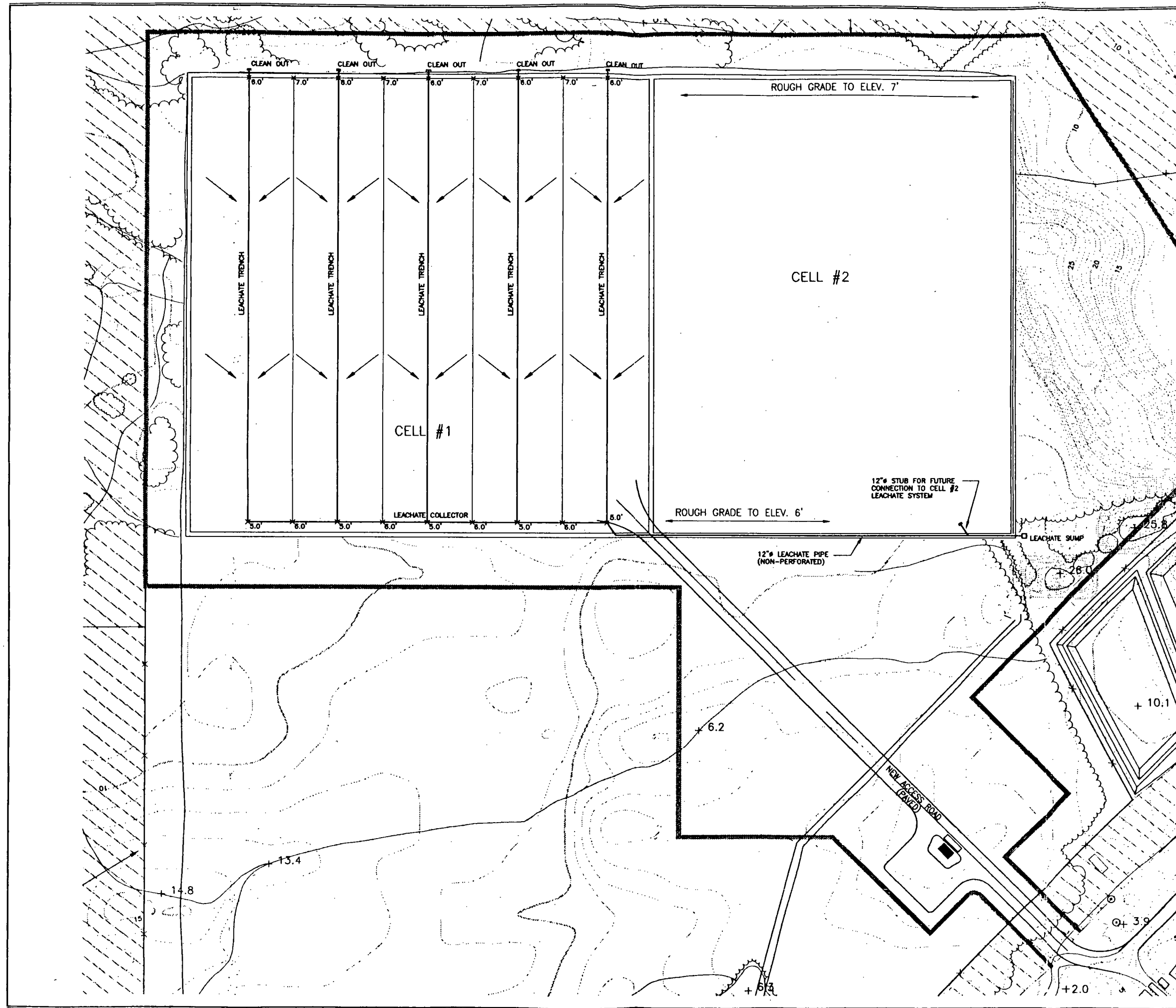
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N	LINEN SUBMISSION		
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D	REGULATORY APPROVAL		
C	CLIENT APPROVAL	870810	NR
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FIGURE 6.4  
EXAMPLE CELL CONSTRUCTION  
OF PROPOSED NEW LANDFILL FACILITY,  
HAROLD ROAD SITE, NEW PROVIDENCE

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parallel to each other, at a slight angle from the horizontal and about one foot below the base of the landfill (Figure 6.4). Flow in the leachate pipes will be driven largely by gravity, as the head of liquid builds in the leachate trenches. A main collector pipe, draining the collection pipes will drain to a concrete sump on east side of the landfill.

## **6.6 LEACHATE MANAGEMENT**

It is expected that all of the leachate will be re-circulated for at least the first 3-4 years, through direct application to the waste pile surface or infiltration into trenches constructed in the waste fill. This, however, will depend to a large extent on weather conditions, specifically the evapotranspiration rates at various times of the year. During periods when leachate re-circulation is not feasible (e.g. periods of high precipitation), the leachate will be disposed of in a deep injection well. The liquid waste injection well at the WSC Septage and Sludge Treatment/Disposal facility near the landfill may be used for this purpose.

## **6.7 COVER MATERIAL**

Part of proper procedure for sanitary landfill operation entails the application of daily, intermediate and final cover material to the waste surface, in order to reduce odours, scattered litter, pests, etc., and to regularize the progress of microbiological decomposition of the waste. Cover material can consist of various types of material, which can be spread over the waste pile surface, curtailing open contact with the atmosphere. Daily cover is normally applied each day to the waste surface, while intermediate cover is applied to each cell prior to progressing to another phase. Final cover is applied progressively to those parts of the landfill which have reached capacity and whose operational life is completed.

A source of adequate cover material, especially for daily cover, is a critical need for the new landfill, and it is therefore dealt with in some detail below. The acquisition of suitable cover material in reliable and sufficient quantities, is a difficult matter in The Bahamas, because of the coralline nature of the rock and the limited land space. In general, options for obtaining cover material on New Providence Island include the following:

- extraction and crushing of coralline rock;
- excavation of sufficiently decomposed waste from the old landfill;



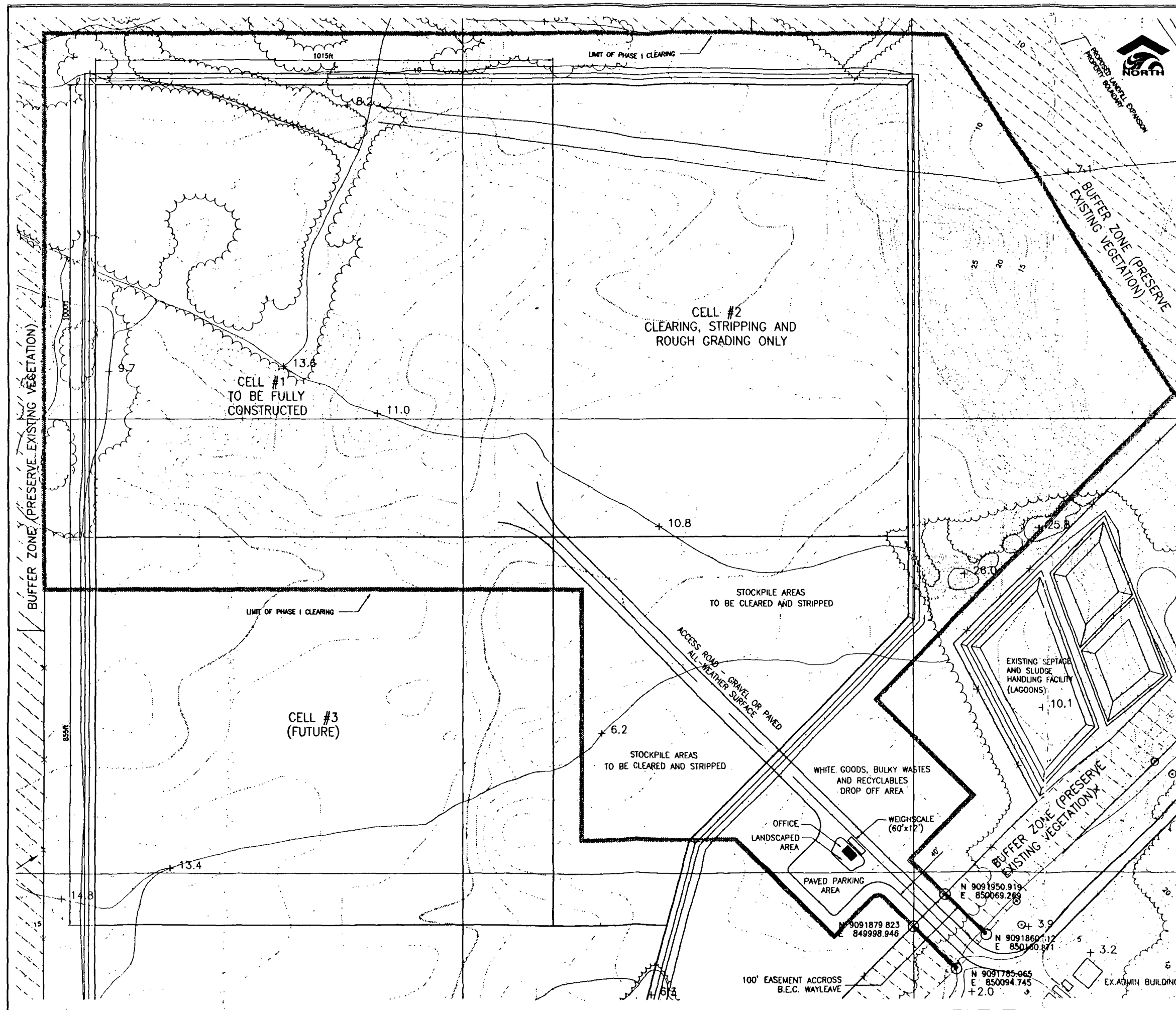
- dredging activities;
- use of vegetation material; and.
- use of manufactured Alternate Daily Cover (ADC) materials.

There are limitations or conditions on each of the above options, however. The Government has recently established a policy to curtail the excavation of rock hills on New Providence Island but has made certain exemptions for the waste management program. The use of remaining quarry sites (e.g., directly to the northeast of the new site) would provide cover material for a relatively brief time period (perhaps about one year).

Some investigation of the feasibility of using waste excavated from the old landfill has been undertaken; however, the results indicate that the composition of the waste was quite heterogeneous and the distribution of new waste was more or less random, so that waste of different age (and therefore different degrees of decomposition) can occur in the same location. Since the waste must be fully decomposed to be suitable for cover material, this option would appear to have significant limitations as well. Thus, it could be considered as a partial means of supplying cover material, provided it is surveyed and tested carefully in advance. This option would be very labour intensive due to the heterogeneous nature of the waste, and would therefore be very expensive.

Sand and other granular material recovered from harbour/beach dredging activities could be used for cover material. This will depend upon the amount and timing of dredging activities that are foreseen. Careful scheduling of these projects could prove beneficial to the waste management program.


Vegetation material, or a mixture of it with inorganic granular material, could also be used for cover material. Possible sources of this include the product of a composting program for yard and garden waste as final cover material (if such is adopted as part of the Waste Management Program). Also, the use of uncomposted and chipped yard and garden wastes, or culled and chipped vegetation from site clearing for the landfill, could be used for daily and intermediate cover. The technical feasibility, the sufficiency and consistency of supply, and the economics of these options must be carefully evaluated before any are determined to be feasible in contributing to cover for the landfill.



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FIGURE 6.3  
CONTOURING FOR PROPOSED  
NEW LANDFILL FACILITY, HARROLD  
ROAD SITE, NEW PROVIDENCE

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At the end of the landfill's operational phase of some 20-25 years, the landfill surface will have been covered with a 2-3 feet soil cap and planted to a suitable vegetative cover, consistent with the intended long-term land use in the post-closure phase. A number of possible land use options are normally available, depending upon the surrounding land, socio-cultural environment, and priorities of the responsible government agencies, but usually include parkland (e.g. hiking areas), recreational (e.g. golf course, football field) or agricultural (e.g. grazing). Collection of landfill gas and leachate, however, normally needs to continue for a period of years, as the anaerobic decomposition of the waste goes to completion. Landfill gas could either be flared upon collection, or it could be collected for use as an energy supply for industrial or commercial purposes. Landfill gas collection/control mechanisms can best be implemented during later stages of landfill development.

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## **7.0 POTENTIAL ENVIRONMENTAL IMPACTS**

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## 7.0 POTENTIAL ENVIRONMENTAL IMPACTS

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### 7.1 INTRODUCTION

The evaluation of environmental and related socio-economic impacts related to the development and operation of the proposed expanded Harrold Road waste management facility will be done by examining each environmental component that is potentially affected by the proposed activities, and assessing:

- how likely the impact is to occur (likelihood or probability);
- the magnitude of the impact if it does occur, and whether it is positive or negative (significance);
- the timeframe over which the impact is likely to be experienced (long-term, short-term);
- whether the impact can be reduced (mitigation); and
- whether the impact can be prevented

This impact assessment analysis uses a matrix to identify potential environmental impacts from various facilities proposed as part of the waste management program. The characteristics and significance of the impacts identified, are discussed under each environmental component, in the remainder of this Section.

The environmental components are as set out below:

#### A. Physical Environment

- Groundwater
- Surface Water
- Air Quality
- Terrain and Soils (Geotechnical)

#### B. Biological Environment

- Terrestrial Ecosystems
- Aquatic Ecosystems
- Marine Ecosystems

### C. Socio-Economic Factors

- Land Use
- Tourism
- Agriculture
- Mineral Resources
- Transportation and Utilities
- Aesthetics
- Noise
- Local Acceptance
- Heritage Resources

In Table 7.1, each of the above environmental components is rated in a matrix against each of the impact factors. A qualitative rating of impact is applied to each environmental component for each of the five impact factors.

The four impact factors are explained further, below:

- *likelihood*; this is a qualitative judgment of how probable it is that there will be an impact created by the facility on that environmental component. Ratings used here are high, moderate, low and none, with "high" having the highest likelihood of occurrence.
- *magnitude*; this is the expected magnitude of the impact should it occur. Ratings used here are high, moderate, low and not applicable - high meaning a high level of impact. Impacts are identified as having an overall positive (beneficial) effect, or negative (adverse) effect on the environment or to human health and well-being. The rating system denotes positive impacts with a "plus" sign, and negative impacts with a "minus" sign.
- *timeframe*; this refers to the anticipated length of time that an impact might occur if it did occur. Ratings used are long-term, short-term, immediate-term, or not applicable (e.g., if no impact is expected). For purposes of discussion, immediate-term will be considered as being in terms of several days, short-term will be taken as several months, and long-term will be taken in terms of several years or more.
- *mitigability*; this means the ease and practicality of avoiding, reducing or compensating for the impact, should it occur. Ratings used here are high,

moderate, low, unmitigable and not applicable - high meaning very mitigable. It is generally considered that there is no desire to mitigate a positive impact and positive impacts are therefore rated as having a "not applicable" mitigability.

- *preventability*: whether it is feasible to prevent the impact from happening.

The term "risk" will be used in the discussion of impacts. For purposes of this discussion, "risk" is considered to be a factor, jointly, of "probability of occurrence" and "magnitude of impact should the impact occur". If an impact to groundwater, for example, is highly likely to occur, and the consequence of the impact is to significantly degrade the quality of water in public wells, then the risk can be said to be high. On the other hand, if a serious impact has only a minute probability of occurrence, then the risk can be said to be low.

It should be pointed out that all of the evaluations made in this Section are made on the basis of changes from current conditions caused by the proposed facility. In this sense, the current waste disposal facility at Harrold Road, and its mode of operation, will be considered as the Base Case.

In terms of mitigation built into the design, the expanded landfill will feature, among other things:

- a setback from residences and institutional/commercial facilities in the area;
- an impervious liner to contain leachate;
- a collection system for leachate;
- collection system for landfill gas generated during decomposition; and
- appropriate covering of the waste.

Collected leachate will be re-circulated and/or injected into deep disposal wells.

It should be pointed out that the existing waste disposal facility at the Harrold Road disposal site currently has some environmental impact resulting from the following operational practices:

- the site is not regulated with respect to types of wastes admitted;
- cover material is difficult to obtain and is applied infrequently;
- fires have occurred repeatedly on the landfill;

- pests such as rats, dogs and birds are uncontrolled and abundant;
- there has been extensive dumping over a large area surrounding the current disposal site; and
- contact with the waste by unauthorized and untrained individuals is substantial.

These practices have resulted in impacts on neighboring residents (i.e. disturbance from odour, smoke, etc.), terrestrial ecosystems and air quality components of the environment of New Providence Island. Measures to mitigate such impacts are listed in a later Section of this report. For purposes of this assessment, the mitigation measures listed above will be considered to be in effect, at the proposed new facility.

The level of risk of significant adverse impacts on the physical, biological and socio-economic components of the environment, after mitigation (i.e. residual impacts), are identified in Table 7.1 (far right column). A discussion of this assessment follows.

#### **7.1.1 Physical Environment**

##### **Groundwater**

Risks to groundwater will be defined for this assessment as those related to the freshwater resource. The proposed new landfill and its operation presents the following issues for which risks to fresh groundwater need to be assessed:

##### *Leakage of Leachate Through the Liner:*

The technology for placement and sealing of the high density polyethylene (HDPE) liner is well developed in the field of landfill construction. The probability is very low, therefore, that construction errors will lead to substantial movement of leachate through the liner. HDPE has been demonstrated to be a very stable material when used in this type of application. The probability is virtually nil that there would be substantial failure of this product during the active life of the landfill, provided the job is properly supervised, resourced and checked.

The consequences to fresh groundwater resources of any leak of leachate through the liner of the landfill can be deduced from the investigation of the current landfill described previously in this document and in Appendix A. Even in an unlined landfill, the only observable consequence of leachate movement is the impact on fresh



groundwater immediately below the landfill with no evidence that lateral migration takes place even after 25 years of operation.

The overall risk of leakage of leachate through the liner is vanishingly small because the probability of occurrence is very low and the consequences appear to be insignificant.

*Leakage of the Waste Disposal Well at Shallow Depths:*

A deep disposal well will be used for disposal of leachate. Failure of the casing of a deep disposal well could allow leachate to be injected at unanticipated locations (depths). If such a failure occurred within or just below the zone of fresh groundwater, then contamination could occur. As documented by Cant (1992), such a situation has occurred previously on New Providence Island, and therefore the probability that this could occur must be regarded as moderate, and the consequences substantial.

The risk of leakage from a waste disposal well impacting fresh groundwater is regarded as appreciable since the probability is moderate and the consequences are substantial. The timeframe of such an impact would be long.

Mitigability of the problem, if it did occur, would be low, but could be resolved by temporarily supplying water from the city system to the areas affected, and either repairing the leakage or utilizing/developing another injection site. Prevention of the problem, however, is quite feasible. If injection wells are selected for disposal of leachate they will be approved as to depth and construction by The Bahamas Water and Sewerage Corporation (WSC). The wells should incorporate adequate casing structures, and construction, and including a monitoring device for the early detection of leakage. Measures for mitigation and monitoring in this regard, are given in Sections 9 and 10 of this Report, respectively.

It is likely that any leachate contamination that might originate from leakage from the landfill or via deep well injection, would eventually enter the saline groundwater, and ultimately flow to the marine environment. In that sense, such leakage would be only one of many inputs to the seawater from a variety of sources, either via deep well disposal, seepage, or direct pollution at the surface. The possibility of disposed landfill leachate entering the seawater does not in itself pose a significant problem because of the relatively small volumes compared to the masses diluting it. However, it could be considered to be an incremental addition to the overall global issue of

marine environmental quality. Such issues are considered to be beyond the bounds of this assessment.

### **Surface Water Resource**

The high hydraulic conductivity of the coral limestone precludes the existence of an integrated surface drainage system. There are no drainage courses for the expanded disposal site to impact, and there are no ponds in the planned expansion area. As shown above, the risk to the subterranean freshwater resource is very low, and there is therefore an extremely low risk of any effects on Harrold Pond, Wilsons Pond or Cunningham Pond due to the contamination of groundwater with leachate and subsequent migration to these water bodies. The likelihood and magnitude of impact on either quality or quantity of surface water are therefore regarded as low.

### **Air Quality**

The expansion of the landfill has provisions for landfill gas collection and flaring. Landfill gas is a product of all municipal solid waste landfills, and occurs as a natural consequence of the microbial breakdown of the waste material. The flaring of landfill gas (or, if in sufficient quantities, its use as an energy supply) are accepted practices in contemporary landfill operation. Landfill gas contains primarily methane and carbon dioxide, with smaller amounts of hydrogen and various trace chemicals in small quantities. At an early stage of degradation, the proportion of carbon dioxide is high, but as a landfill ages, the process gives off a progressively higher proportion of methane. Flaring will burn the produced methane, converting it to carbon dioxide, heat and water vapor. Neither methane nor carbon dioxide are particularly harmful, although both are "greenhouse" gases, implicated as responsible for global warming. The actual quantities for a landfill of this size, however, are very small compared to the emissions from automobiles on local roads, for example, and in any case, the gases would escape through the landfill surface in the absence of collection and flaring. The decomposition and subsequent flaring will be slightly more beneficial to the environment than conventional practices of landfilling only. Flared landfill gas per se, does not result in unpleasant odours. The potential impacts of landfill gas on air quality are therefore judged to be insignificant.

The facility will create some dust resulting from vehicle movements; however there is provision for dust suppression in the operating plan. The likelihood of dust generation is high; however the impact will be low due to these measures. The

timeframe of the impact will be short as most of it will occur during the construction phase, and the dust issue during the operational phase is mitigable.

Odour emitting from the current landfill is significant in close proximity to the facility, under certain sets of circumstances. Odours occur primarily when chicken blood and offal is dumped without applying adequate cover material sufficiently soon; and when there are fires on the landfill (A. Roberts, DEHS pers. comm.). In this case, it is most likely that residents living or working to the south, southwest and west, will be disturbed by the odours, being downwind with respect to the prevailing winds.

Odours emanating from an expanded landfill will be less than is currently the case provided the recommendations of the Environmental Mitigation Plan articulated in Section 9 are fully implemented in respect to the daily application of cover material, and prevention of fires. If this is done, there will be a long-term, positive impact on air quality in respect to odour from the landfill.

### **Geotechnical**

Slope stability is a problem at many landfill sites, but should not be a problem with the expansion of the Harrold Road landfill, due to the nature of the underlying rock and thin soils.

Erosion of soils is regarded as only a potentially minor problem, as a result of major storm events, and because of the topography and the porous nature of the substrate, would be expected to be limited to the disposal site itself. Sediment carried by such erosion would not be expected to travel off site given the fact that settling ponds are specified in the operating plan. Likelihood of impact is therefore rated as low, as would be the magnitude of the problem. The timeframe would be short as the erosion would be highly mitigable.

## **7.1.2 Biological Environment**

### **Terrestrial Ecosystems**

Expansion of the landfill to adjacent land will remove some habitat, i.e., approximately 100 acres (41.5 ha) of forest and bush. Most of the area is occupied by "pine forest", which consists of regeneration *Pinus caribaea*, and is not virgin forest of significant heritage or commercial value. This ecotype is abundant on New Providence Island and in the four "pine islands" of The Bahamas generally, so it does

not represent the loss of a particularly threatened resource. According to Mr. C. Russell (Lands & Surveys, Forestry Division), there are about 4000-6000 acres of pine forest on Crown Land on New Providence Island; and thus the loss in terms of acreage represents to the order of 1.5 - 2.5%. The commercial use of the equivalent amount of forest for lumber or other purposes, is insignificant in the present and foreseeable future.

Consideration should be given to the type of land use to be accorded the landfill site after its operational life is completed. Major options would include agricultural (fruit trees or sheep/cattle grazing), or recreational (playing field or parkland). Some thought could be given to linking a park in this area, with eco-tourism facilities that might be set up at Harrold Pond (e.g., hiking trail, bird observatory). Consideration also needs to be given to the use of the pine and other wood from the cleared site. One option would be to chip the wood and use the material (particularly the pine bark) for mulching, or for walking paths. Another would be to cut the logs and use the material for path and observation platform structures at Harrold Pond (see Section 4). Still another use is for charcoal production and sale.

Field surveys and a review of the habitat preferences of known rare plants and animals in The Bahamas provided no evidence of rare species in the area to be used for the expanded landfill. Because the pine forest of this type is locally abundant, it is highly unlikely that the fate of any rare or endangered species of plant or animal will be dependent on the area that will be used for the proposed project. Therefore, there are no identified endangered plants or animals whose viability would be threatened by the proposed expansion. In terms of endangered ecosystems, there are no mangrove systems which will be removed or affected by the proposed expansion of the disposal site.

If the expanded disposal site is operated according to recommendations, the likelihood of attracting pests such as rats and wild dogs is regarded as low, as is the magnitude. Relative to current conditions, the impact would be positive, leading to fewer pests than at present. Any pest problems that do arise would be recognized and dealt with promptly under the plan, and therefore the timeframe would be short and the issue highly mitigable. Transmission of disease by pests would also be minimal under the operating plan. It is judged that there is a high likelihood of a moderately positive impact having a long timeframe if operating suggestions are followed.

Provided the recommendations of this report and the Waste Management Plan are implemented, it would seem that the loss resulting from the use of the forest/bush area under consideration for an expanded facility would be outweighed by the environmental benefits, in terms of an improved waste management system for the Island, and less litter, odour and pests.

### **Aquatic Ecosystems**

The high hydraulic conductivity of the coralline limestone results in rapid infiltration of precipitation and consequently a virtual lack of any integrated surface drainage system. There are several nearby brackish surface water bodies, including Harrold and Wilson Ponds, however these receive virtually no surface runoff, nor do they drain on the surface. There is little possibility that runoff from the landfill would reach these surface waterbodies from expanded activities. This component is therefore ranked low with respect to both likelihood and magnitude and as having a high degree of mitigability (using minor drainage modifications) if it should occur. The time scale of any such impact would similarly be short, since the operating plan calls for inspections for surface runoff.

### **Marine Ecosystems**

The expansion of the disposal site is not expected to have a significant impact on marine ecosystems.

## **7.1.3 Socio-Economic Environment**

### **Land Use**

The use of the land in the proposed expansion area for the purposes of constructing a landfill presents no potential conflict, since it is zoned Industrial and intended for the purposes of waste management. Consideration has been made for setback from dwellings and other operations on Gladstone Road.

### **Tourism**

The impact of an expansion of the existing landfill on tourism is judged to be low to none as there are very few tourists who would have occasion to actually see it. The only occasion in which the landfill activities present a negative impact to tourists is when odours become oppressive due to lack of cover, or (in particular) when the landfill is on fire. Improved landfill operation, as recommended in the Mitigation

Plan, should actually improve this situation. Furthermore, the improved system for collection and management, should reduce the amount of litter on the Island generally, and this would likely have a positive impact on tourism, through improved impressions of the surroundings.

In terms of eco-tourism and appreciation of natural ecosystems, the main attraction in the vicinity is Harrold and Wilsons Ponds. However, the new landfill will not present an intrusive visual impact from the perspective of shoreline activities. The shoreline and associated marshes, where the view of avian life is best, are mostly shielded from view of the landfill by topography and tree cover. The new landfill will be situated further distant, and as well, will have a buffer zone of trees. Noise from the landfill, which is not presently disturbing to the visitor to Harrold Pond, will not increase beyond current levels, and in fact will be somewhat further distant. Addressing the unpleasant spectacle currently presented by scattered wastes and odours on the south side of the Pond would be the primary task in making the area suitable for wildlife tours and related eco-tourism activities. Once this was done, the development of a walking trail and observation platforms, as well as the designation of it as a natural area, would make the location a valuable attraction to naturalists, since there is an outstanding variety of birdlife on the ponds.

Illicit dumping is not likely to become worse if the landfill remains at the current location. The imposition of tipping fees, however, could cause illicit dumping to increase, unless enforcement procedures are also instituted. The timeframe of such an impact on tourism would be long. The mitigability of such an impact is judged to be moderate and could probably be accomplished through an information campaign, emphasizing the many positive waste management programs being undertaken on New Providence Island and elsewhere in the country.

### **Agriculture**

A small amount of pine forest and bush will be used by expansion of the existing landfill. Therefore, some forest resources may be removed, however the magnitude of this loss will be low. It must be recognized that after some 20-30 years, the landfill will have completed its operational life, and can be restored to vegetated land. At that time, post-operational land use could include agricultural or related activities.

Provision has been made in the operating plan for the agri-businesses along Gladstone Road, and hence, from the agricultural perspective of crops and livestock, the expansion will have no significant impact.



## **Mineral Resources**

The relatively high water table and economical availability of other sources precludes the mining of limestone for fill or aggregate purposes in the proposed expansion area. The limestone ridge located north of the current disposal site represents a potentially mineable resource which may be utilized during the lifetime of these facilities. The landfill operations will not have any impact on the mineability of this ridge. Therefore, there is no likelihood of impact.

## **Transportation and Utilities**

Transportation patterns are well established and accepted for the current disposal site. Patterns and volumes of traffic will not change drastically with an expanded landfill but will be subject to growth due to general population increases. Improvement of the road system leading to the waste disposal facility would reduce traffic problems in the area, e.g., at the entrance to the facility from Harrold Road. Evaluation of the likelihood and magnitude of additional impact rates these factors as low, or with a positive impact, if the road systems are improved.

The BEC (Bahamas Electricity Corporation) power line lies between the existing landfill and the proposed new one. It is not considered necessary to move this power line, but the final design will need to be approved by the BEC. Potential conflicts with the new landfill activities may be resolved through the placement of a height restriction on landfill equipment or through adjusting the height of the transmission line. This matter is currently under discussion.

## **Aesthetics**

As noted previously, the visual impact presented by the new landfill will not be greater than the present situation, wherein the landfill is not visible from most points on local routes or from residences due to local topography and/or trees. Furthermore, the area of the new landfill will be surrounded by a buffer of 20-25 m pine. There will be no significant visual impact from the shoreline of nearby ponds or from the main local routes, due to topography and visual shielding provided by vegetation.

A major, existing impact on the Island is one of litter (scattered waste) and illicitly dumped waste. Generally, the aesthetic problem of litter is not created from the current facility itself, as wind-blown litter is trapped in surrounding vegetation before migrating off-site. The continued operation of this disposal site will not add to the

existing litter problem, except to the extent that the growth in population creates more vehicles traveling to the disposal site and more litter blowing off of them. Enforcement of existing regulations with respect to covering of loads and litter would improve the situation significantly. The likelihood and magnitude of increased litter is therefore judged to be low; however, to the extent that it may increase with population, it is a long-term impact. Litter problems are highly mitigable through information programs and enforcement.

### **Nuisances**

Noise issuing from the disposal site from heavy equipment operations will not significantly change with continued use of the site. A slight increase in equipment operations might result from population increases over time. The likelihood of a significant noise impact is regarded as low, as is the potential impact.

The expanded landfill is proposed to have controlled access for the general public. In addition, waste management recommendations contained in this report should have the effect of reducing bio-hazardous materials reaching the landfill. Both of these proposals present a high likelihood of a moderate positive impact on the transmission of disease by human vectors leaving the disposal site. The timeframe of such an impact is long and any negative impacts are likely the result of excursions from the operating plans and are therefore highly mitigable. There is no evidence of disease organisms leaving the current landfill by means of surface or groundwater.

### **Local Acceptance**

The location of the current landfill does not appear to be strongly opposed by any identifiable group or the media. It appears to be regarded as a necessary feature of the community and is sufficiently removed from direct impact on most people's lives that it is not an issue in its current state and location. An expansion, together with a commitment to address some of the operational problems experienced in the past, would have a likelihood of local acceptance as well. Measures to address and monitor these problems are set out in the Environmental Mitigation and Monitoring Plans of this Report. Since the expanded landfill will be operated to modern standards, it is believed that this acceptance will be long term and that any erosion of the acceptability would be highly mitigable through renewed efforts at meeting operational challenges, and/or a public information campaign.

## **Heritage Resources**

Historical resources of interest that might be encountered inland on New Providence Island include items from old plantations (loyalist era, 18th century); or pre-historic Lucayan artifacts such as pottery and other ceramics, spear and arrow heads, and various wooden artifacts (Dr. Saunders, Department of Archives, pers. comm.). Generally, in the proposed expansion area, there is not a strong probability of finding pre-historic items due to the nature of the rock, and the degree of human disturbance to which the area has been subject. There may have been an old plantation(s) to the west of the present landfill site, but not likely to the north/northwest of it. Although there does not seem to be a strong potential for artifacts of historic interest in the proposed area to be developed, the mitigation plan will include a clause to alert construction supervisors to the possibility of there being artifacts, and to inform the Director, Department of Archives, Nassau, in the event that such artifacts are encountered.

Due to its location, there is no likelihood of the expanded disposal site impacting national parks.

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## **8.0 REGULATORY ISSUES**

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## 8.0 REGULATORY ISSUES

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### 8.1 INTRODUCTION

There are a number of laws in The Bahamas that directly or indirectly cover components of solid waste management. These different aspects, however, are scattered among various Acts and Regulations, and what they cover is incomplete with respect to the entire question of collecting, transporting and disposing of solid waste. A key piece of legislation governing the management of municipal solid waste in The Bahamas is the *Environmental Health Services Act, 1987 (Section 217)*, and specifically under it, the *Collection and Disposal of Refuse Regulations*. These Regulations are currently in the late stages of drafting and review. However, it is useful in the context of this Report, to review the Regulations, as the waste management facility and the waste management program in general, will be at some point be subject to it.

This Section gives some background on the development and scope of current regulatory structure in The Bahamas relevant to solid waste management, and outlines the relevant regulations for some key topics. An overview of the draft *Collection and Disposal of Refuse Regulations* are then provided.

### 8.2 BACKGROUND ON CURRENT REGULATORY SITUATION

The existing legislation pertaining to solid waste and hazardous materials management in The Bahamas is as follows:

1. Section 216, Health Services, The Health Rules. - Subsidiary Legislation of the Bahamas;
2. The *Environmental Health Services Act, 1987*. - An Act to promote the conservation and maintenance of the environment in the interest of health, for proper sanitation in matters of food and drinks and generally, for the provision and control of services, activities and other matters connected therewith or incidental thereto; and
3. The *Local Government Act, 1996*. - An Act to make provision for local government in the Commonwealth of the Bahamas.

The Ministry of Health and Environment (the Ministry), acting under the authority of the *Environmental Health Services Act*, is charged with the responsibility of promoting and protecting the public health and ensuring and providing for the conservation and maintenance of the environment. DEHS, operating within the Ministry, and under the same Act, assists in carrying out these functions. The DEHS is now in the Ministry of Consumer Welfare & Aviation (as of April, 1997) and the legislation under review will be amended to reflect this change. With particular regard to solid waste, DEHS is responsible for the collection and disposal of solid waste on New Providence Island, including the operation and maintenance of the necessary equipment and vehicles. The Ministry is also charged with responsibility for the provision of certain environmental health services in the Family Islands, including the provision of solid waste management advisory services upon request.

In terms of landfill siting and operations, *The Health Services Act (Section 216) ("The Health Rules")* provides for the establishment of authorized dumps, but the design, siting and operation of a landfill or disposal site is not specified in detail. The same Act prohibits the discharge of deleterious substances to the environment, and allows the Minister to make regulations to this effect. Provisions prohibiting littering are found in *The Health Rules* and *the Environmental Health Services Act*. However, there appears to be little evidence of enforcement. Collection and transportation of solid waste is covered in *The Health Rules*, but only in a general fashion.

The provisions of the above Acts, where dealing with environmental concerns, are general in nature. To more clearly specify environmental protection standards the Government proposed amendments to the *Environmental Health Services Act* and the development of regulations coming under it. Regulations that are being considered and are in the stages of drafting or revision include:

- Nuisance Regulations;
- Licencing Regulations;
- Construction of Sanitary Appliances and Approval of Well Regulations;
- Effluent Limitation Regulations;
- Surface Water Quality Regulations;
- Air Emissions Regulations;
- Certificates of Approval Regulations;



- Exemptions and Variances Regulations; and
- Smoking in Public Places Regulations.

### 8.3 **OUTLINE OF DRAFT COLLECTION AND DISPOSAL OF REFUSE REGULATIONS**

The Collection and Disposal of Refuse Regulations, presently in draft form, cover the following concerns, which relate directly or indirectly to the management of solid waste and environmental protection at an authorized landfill facility:

- transportation of wastes
- requirements for a proposed waste management facility
- application for a proposed waste management facility
- littering
- unauthorized disposal
- prevention of fires
- sanitary landfills
- acceptance, handling of industrial wastes

The above aspects of the draft Regulations are outlined below.

#### *Transportation of wastes:*

S.33 of the draft Regulations require that any vehicle used for conveying or storing waste have a suitable cover capable of preventing the dropping, spilling or blowing off of waste while it is being transported. S.59 prohibits refuse from being transported along streets etc., unless the vehicle is constructed and loaded so that no refuse can fall from the vehicle, or the vehicle is protected by a closed-in top or canvas cover, or the refuse is placed in containers and kept tightly closed during transportation. S.59 also requires the driver of any vehicle from which refuse has fallen during transportation, to immediately remove it from the street or roadway. In the terms of licencing specified in S.36, the applicant must provide a description of the means by which waste will be prevented from falling from or otherwise leaving the vehicle.

*Requirements and application for a proposed waste management facility:*

A party applying to construct or operate a waste management facility must provide the Department of Environmental Health Services ("the Department") with pertinent information, much of it relating to the potential for environmental impacts, and mitigation thereof. In granting the licence to construct or operate the facility, the Department must consider requesting the following:

- need for an environmental impact assessment;
- soil characteristics;
- water table and underground water;
- dust control;
- land use, including topography, geology and noise control;
- pollution control;
- operational requirements;
- site reclamation and restoration;
- reports and recommendations made by consultants or other experts; and
- regulations, standards and guidelines implemented in other jurisdictions.

The Department requires the following information from a proponent when making the above consideration:

- type of facility;
- operational plans;
- pollution control systems;
- land use of proposes site and adjacent areas;
- site reclamation and restoration;
- reports and recommendations made by consultants or other experts; and
- regulations, standards and guidelines implemented in other jurisdictions.

### *Littering and unauthorized disposal:*

S.54 prohibits any person from placing, depositing or permitting to be placed or deposited, any refuse on any street, path, road, lane, beach or other public place, except at a disposal site approved by the Department. The same section includes disused vehicles or domestic appliances in the prohibition, and makes it an offence for a property owner to allow such to remain on the premises.

### *Sanitary landfills:*

S.40 prohibits any person from depositing waste at any waste management facility unless the waste is deposited in accordance with the instructions of the operator of the facility, and in accordance with the appropriate signage. All waste must be deposited in a manner that will minimize scattering by wind.

### *Prevention of fires:*

In S.57, it is made an offence for any unauthorized person to cause any fire to be lit in any waste management facility. Likewise, it is prohibited for anyone to burn waste in a manner that is likely to create a health hazard or nuisance, such as smoke, odour, or the liberation of toxic substances, unless approved by the Director.

### *Industrial wastes:*

S.44 requires the completion of a manifest by generators and carriers of industrial waste, and compliance with its terms. No industrial waste is to be accepted at a waste management facility when its contents are unknown or the disposal procedure is in doubt.

## **8.4 APPROVAL REQUIREMENTS**

The approvals that will be required from Government regulatory agencies include the following:

Department of Environmental Health Services	• health and environment requirements
Water and Sewerage Corporation	• construction and operation of liquid disposal structures
Ministry of Public Works	• construction
Bahamas Electricity Corporation	• transmission lines safety

By virtue of this Environmental Impact Assessment, it is evident that the information requirements stipulated under the draft Collection and Disposal of Refuse Regulations have been addressed.

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## **9.0 ENVIRONMENTAL MITIGATION PLAN**

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## **9.0 ENVIRONMENTAL MITIGATION PLAN**

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### **9.1 INTRODUCTION**

The foregoing parts of this report involve an assessment of potential environmental impacts, as they affect surrounding air, water, soil, ecosystems, and human communities. In most cases, it is possible to prevent or mitigate significant impacts, either through effective design of the facility or through the institution of sound operational management of the facility. This Section proposes a set of design and operational measures to prevent or mitigate potential impacts related to the construction, operation and closure phases of the proposed expanded Harrold Road waste management facility.

### **9.2 SURFACE WATER DRAINAGE AND EROSION CONTROL**

1. Surface water run-on in the event of severe storm events, will be diverted around the perimeter of the site via surface water diversion channels and perimeter berms. The system will be designed for at least a 1-in-25-year return storm event over 24 hours, and will direct runoff away from areas where active landfilling is progressing.
2. Water collecting in the open face of the landfill should be retained, and treated as leachate.
3. For the post-operational phase, the landfill should be capped, recontoured, and vegetated appropriately, with full attention to providing effective drainage and erosion prevention.

### **9.3 LEACHATE CONTROL AND GROUNDWATER PROTECTION**

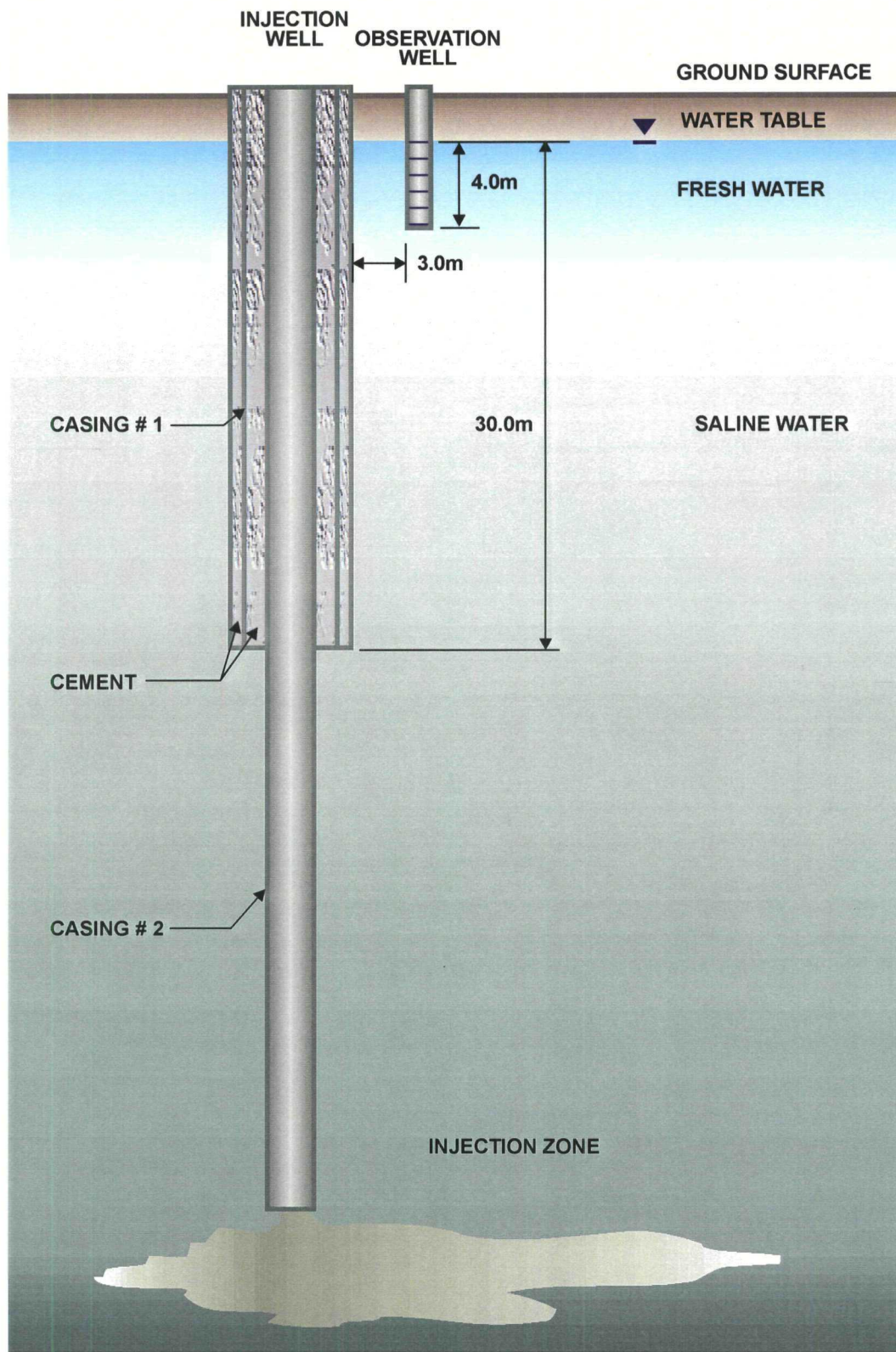
1. A suitable leachate collection system, consistent with accepted practice for sanitary landfills and of capacity sufficient to handle the predicted range in leachate production in the local climate, shall be installed on the base and sides of the landfill as necessary. The liner will include a synthetic (high density polyethylene) liner of minimum thickness 1.5 mm (60 mil) and of hydraulic conductivity approximately  $10^{-13}$ . The installation of the liner and configuration of the fill shall take into account the need to prevent lateral migration of leachate, as well as downward movement of leachate.



2. The landfill liner and leachate collection system shall be installed in accordance with accepted practice for sanitary landfills, and supervised by experienced professionals, bearing in mind the importance of avoiding tears, punctures, cracks, seam failures and related faults for synthetic liner components, and proper material selection and placement criteria for soil barrier layers.
3. The leachate shall be removed from the collection system at intervals and in quantities as necessary to ensure that a hydraulic head of no more than 0.3 m exists at the withdrawal point at any given time.
4. Raw leachate shall not be discharged to surface water or land. A suitable recirculation, treatment or off-site disposal system shall be in place for the routine management of leachate.
5. Disposal of leachate will normally be accomplished by re-circulation in the waste pile (which further decomposes various organic leachate compounds) or disposal via a suitable deep-well injection system.
6. Design of the deep waste injection well for leachate disposal will be approved by The Bahamas Water and Sewerage Corporation. The application to W&SC will state that at least two casings will be placed and pressure cemented into place in this well. Both casings will terminate no shallower than 30 m below ground surface. A schematic drawing of the well construction is shown in Figure 9.1. A schematic drawing of the landfill design, showing the leachate collection system and location of the disposal well, is shown in Figure 9.2.

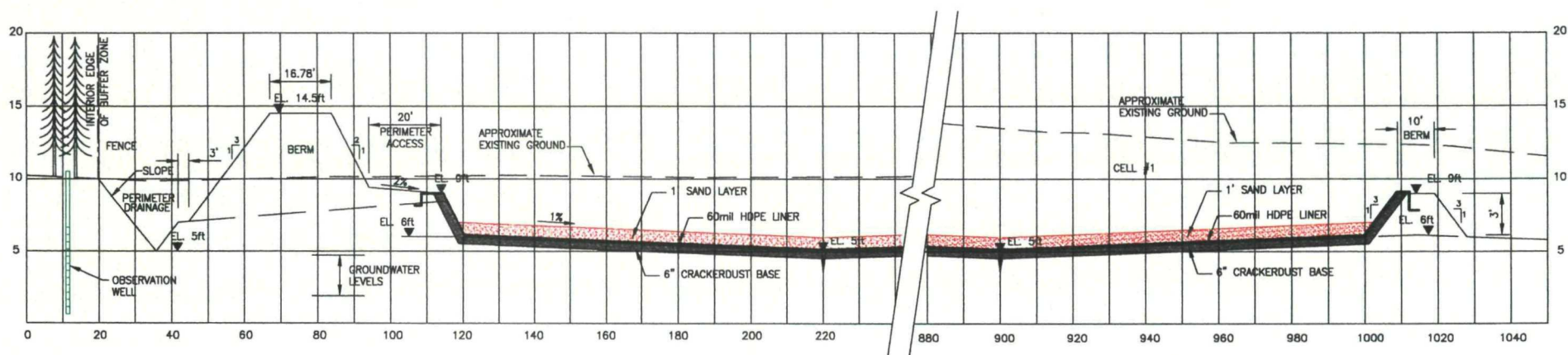
#### 9.4 LANDFILL GAS

1. The presence and levels of landfill gas (LFG) will be monitored quarterly for the first year of landfill operation, and thereafter twice per year or as shown to be necessary, using the ground water monitoring wells and surface gas detection probes.
2. If the LFG monitoring program indicates levels of gas that are building to levels that entail a risk of igniting, leading to dangerous on-site gas levels, or affecting adjacent vegetation, gas collection wells will be installed. The collected gas shall either be flared, using acceptable standards and guidelines, or used as an off-site energy source.



BAHAMAS SOLID WASTE AND HAZARDOUS  
MATERIALS MANAGEMENT PROJECT

**FIGURE 9.1**  
**Schematic Recommended Design for Deep**  
**Disposal Well for Recovered Leachate**



3. Lateral movement of landfill gas, which could affect surrounding vegetation, shall be prevented by the lining system at the sides of the landfill, but measures shall be in place to detect such movement as part of the monitoring program.
4. On-site and nearby off-site buildings and other enclosed structures shall be monitored regularly to determine whether LFG is seeping into them and introducing the risk of explosion.

## **9.5 ODOUR AND LITTER CONTROL**

1. The working face of the landfill will be confined to the extent possible, reducing the amount of fresh waste exposed to the air. The target area for the working face shall be 20 m x 40 m or less. The remainder of the active surface shall be covered with intermediate cover (0.3 m thick), or final cover (1.0 m thick) in areas that have been filled to final design grades.
2. Soil cover material shall be applied daily to the working face to a depth of six inches (15 cm), or other cover material alternatives which are determined to be appropriate and effective.
3. Intermediate cover shall be applied to the cells of the landfill that will not be actively worked for a period exceeding one or two weeks. Intermediate cover shall be applied to a depth of 1 foot (30 cm).
4. The waste should be compacted in lifts not exceeding 2 feet (0.6 m) thickness, and utilizing heavy tracked-type tractors or steel-wheeled landfill compactors completing 2-5 passes over the total area of each lift, in order to achieve the maximum waste density possible. This measure will increase the life of the landfill, as well as facilitating the application of cover material and enhancing its efficiency in preventing the escape of odorous substances. Compaction also serves to minimize the escape of windblown litter.
5. All incoming vehicles shall be covered (i.e. with tarps or netting), to avoid odour and litter problems at the final disposal site and en route to the site.
6. Site staff will be assigned as necessary to regularly retrieve litter which happens to escape from the landfill site or collect at its periphery.

**SMOKE AND DUST**

Smoke and dust coming from the landfill shall be controlled by proper operations of the facility. This operation will include maintaining the landfill equipment in proper running order, and when necessary applying water to internal access roads. Internal permanent access roads will be all-weather roads with a paved and/or graveled surfaces. Landfill fires shall be controlled using the facility fire fighting system and heavy equipment.

**FIRE PREVENTION AND CONTINGENCY**

1. Waste arriving at the landfill site will be monitored to ensure that explosive, burning or smoldering waste is not accepted for disposal. Such items will be treated on site with the available fire suppression equipment.
2. Flammable or explosive items that could pose a significant fire risk shall be removed from solid waste at the collection point.
3. Site rules will include appropriate fire prevention precautions, including restrictions on smoking and open flames on site. All burning activities (e.g. to remove insulation from copper wire) will be prohibited on the landfill site.
4. The potential for spontaneous combustion of wastes is real and should be considered in the landfill operations plan. For example, materials such as grass clippings, if left piled under the right conditions, can begin to burn just from the heat generated by rapid decomposition. Materials such as solvent soaked or oily rags can also spontaneously combust. Two approaches can be taken depending on the nature of the material:
  - in the case of highly degradable organic materials, such as grass clippings, the risk of fire can be virtually eliminated if the material is spread in thin lifts or intermixed with the wastes.
  - items such as oil soaked rags should be separated from the waste stream going to landfill, and dealt with in an appropriate manner.
5. A fire contingency plan shall be in place, and will include instructions for isolating and spreading waste using landfill equipment including dozer(s), compactor(s) and water tanker truck(s), and applying inert cover material or if appropriate, water, in such a way that the fire is not allowed to spread, and that

unnecessary loading of the landfill with water is avoided. Depending on the seriousness and extent of the fire, it may also be necessary to involve the local fire department.

## **9.8 BUFFER ZONE**

A buffer zone shall be maintained which will be 200 ft (61 m) from the edge of the actual landfill area, on all sides. This will be formed by leaving existing trees and other vegetation, thus providing a visual and noise barrier for neighboring residential areas, and commercial and institutional facilities.

## **9.9 UTILITIES**

The final design and operating plan for the landfill will need to be approved by the BEC (Bahamas Electricity Corporation) with respect to protecting the power line that lies between the existing landfill and the proposed new one. Any possible conflicts with the new landfill activities may be resolved through raising the power line and/or the placement of a height restriction on equipment. The possible issue of a fire occurring beneath the lines must also be allowed for.

## **9.10 STAFFING AND TRAINING NEEDS**

In order that the proposed new waste disposal facility is operated in a satisfactory and environmentally sound fashion, it is essential that operational staff are adequately trained and equipped to fulfill their functions. The following are some areas in which trained and qualified staff must be available for successful implementation of the Solid Waste Management Programme.

- fire control and prevention
- waste segregation and handling (if applicable)
- operation of landfill equipment
- leachate level monitoring
- leachate pumping equipment
- application of daily, intermediate and final cover material
- landfill gas collection, treatment and monitoring, and use of hardware
- ground water quality sampling and analytical procedures
- leachate sampling and analytical procedures



- general mechanical, electrical, and building maintenance

## **9.11 CLOSURE**

1. At the end of the landfill's active life, the landfill site shall be capped with suitable material and recontoured with design grades and features established to provide adequate drainage while limiting runoff velocities to minimize erosion of the cap. Such recontouring will be done in a manner that is harmonious with the surrounding landscape.
2. In designing the post-closure plan, sufficient allowance shall be given to the degree of subsidence of the landfill.
3. The land shall be revegetated appropriately, either with natural vegetation or as pasture land, according to the determined land use.
4. The type of land use for post-closure will be determined in consultation with appropriate government agencies and public groups, including the Office of Town Planning, Ministry of Agriculture, National Trust, and local citizens.
5. Ongoing monitoring and maintenance of the cap, the surface soil, and the vegetation shall be performed until such time as the landfill has stabilized and such proves to be no longer necessary. Landfill gas monitoring (and control if needed) shall continue until LFG production levels indicate that no further control or monitoring is necessary.

## **9.12 OTHER**

A suitable use of the trees and other vegetation that will be cleared to prepare the site in the initial construction phase, should be determined. This could include its use for lumber, or it could be chipped for path and construction and landscaping, or used for cover material. If practical, it could be used for construction of some basic path or observation tower structures at Harrold Pond.

Efforts will be made to ensure that trucks with incoming waste are covered, either through the design of the vehicle or by canvas or similar material. This will be done through consultation with law enforcement agencies and strengthening of DEHS enforcement training and capacity.

Scavengers operating at the site pose a potential safety issue. In addition, their activities may impede the efficiency of the site operators in their various tasks of allocating waste loads, applying cover material, preventing fires, and so forth. A program will be put in place to relieve these issues, through a combination of consultation, education, regulation and enforcement.

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## **10.0 ENVIRONMENTAL MONITORING PLAN**

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## **10.0 ENVIRONMENTAL MONITORING PLAN**

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### **10.1 INTRODUCTION**

This Section proposes a schedule of environmental monitoring requirements for the proposed new landfill facility at Harrold Road. These measures are intended to provide the environmental information necessary to ensure that pollution or related problems are discovered in time to prevent or repair adverse effects, and to evaluate the success of mitigative or preventive measures set out in the design.

### **10.2 LEACHATE MANAGEMENT AND GROUNDWATER PROTECTION**

Liquid in the leachate sump will be sampled quarterly and analyzed for the parameters listed in Appendix A. This sampling and analysis will continue until such time as the range of concentrations is sufficiently established or the parameter is established to be negligible.

A series of small-diameter observation wells will be installed at the outside boundaries of the landfill. Water samples will be taken at least annually from these wells for the first year after their construction and analyzed for the parameters listed in Appendix A. After the first year of operation, the analyses may be reduced to indicator parameters which are readily done at the Public Analyst or similar local laboratory. These indicator parameters will include, as a minimum, conductance, pH, iron and bicarbonate.

Monitoring wells will be installed at the mid-point of each outside boundary of each landfill cell prior to that cell becoming operational. Thus, Cell #1 will have monitor wells on the north and west sides, Cell #2 on the north and east side and so on with the remaining cells. This process will result in nine wells placed as shown in Figure 10.1. Each well will consist of a 51 mm ID PVC pipe extending to 4 m below the water table and screened over the entire bottom 4 m. Steel protective covers will be cemented in place at the surface to prevent vandalism.

In order to detect any leakage from the leachate disposal well at shallow depths, monitoring of the deep waste disposal well will consist of one observation well placed approximately 3 m from the disposal well. This well will have the same design as

described for the monitors for leakage through the liner. Water sampling and analysis will be the same as for those wells.

### **10.3 LANDFILL GAS**

1. The presence and levels of landfill gas (LFG) will be monitored quarterly for the first year of landfill operation, and thereafter twice per year or as shown to be necessary based on site soil conditions, proximity of structures, etc., using the ground water monitoring wells or surface gas detection probes.
2. On-site and nearby off-site buildings and other enclosed structures shall be monitored regularly to determine whether LFG is seeping into them and introducing the risk of explosion.

### **10.4 ODOUR, DUST AND LITTER**

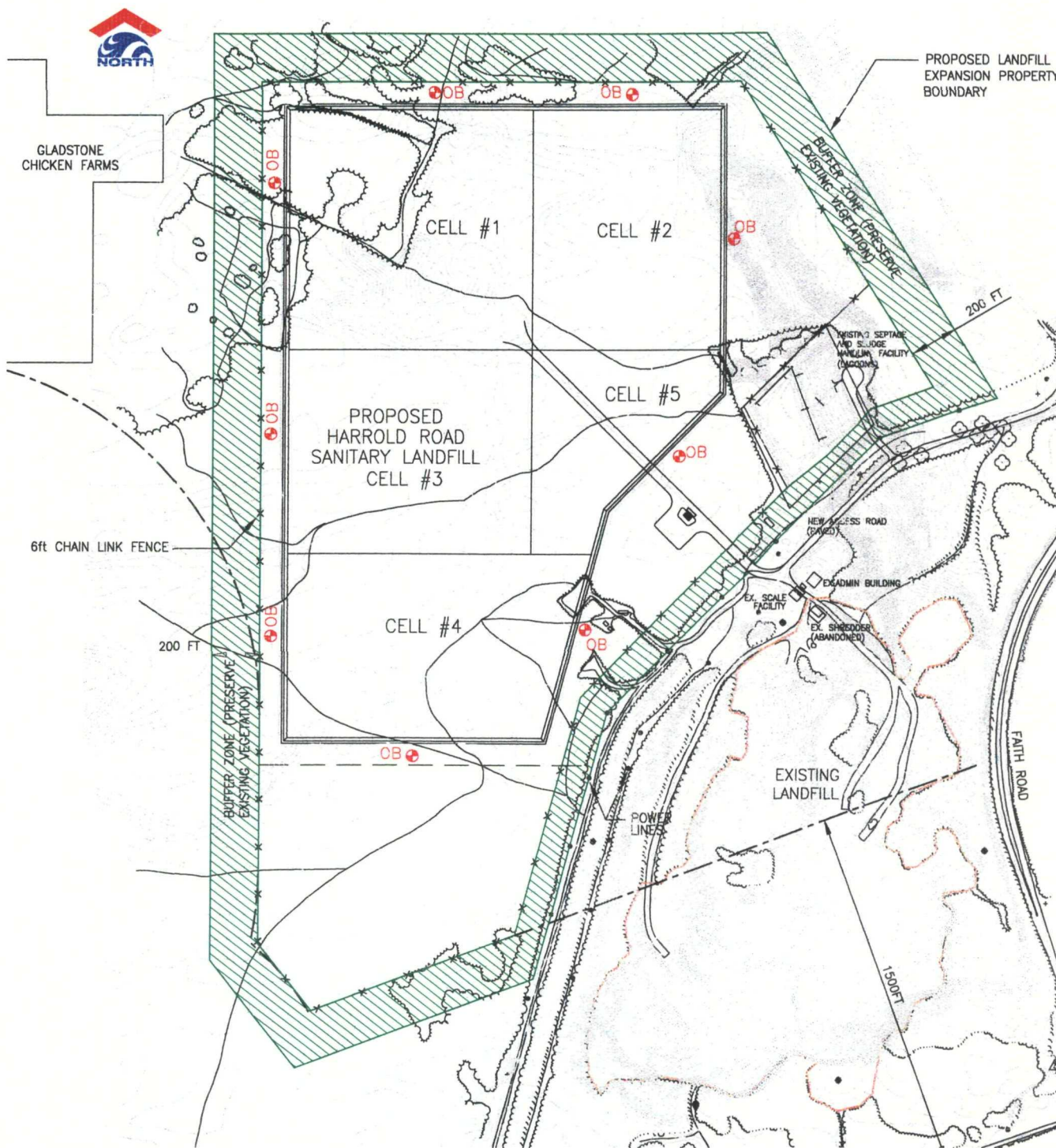
Levels of odour and dust downwind from the landfill will be assessed by site staff at least twice per week, in particular along Fire Trail Road and Gladstone Roads south, west and southwest of the landfill site. Records of observations will be maintained at the landfill site. Any complaints from the public or nearby commercial/institutional facilities will be recorded, noting the identity and location of the complainant if offered, the date and time, and the nature of the complaint.

### **10.5 HISTORIC RESOURCE**

The construction supervisor shall be aware of the possibility of encountering artifacts of historic interest, including remnants of old walls, pottery shards, arrow/spear tips, various ceramic and wooden artifacts. In the event that such items are encountered, the Director of Archives will be informed immediately (Tel: 393-2175; Fax: 393-2855), and the work in the immediate area shall halt temporarily, to allow an opportunity to briefly survey and collect remaining material.

### **10.6 POST-OPERATIONAL LIFE**

Ongoing monitoring and maintenance of the cap, the surface soil, and the vegetation shall be performed until such time as the landfill has stabilized and this proves to be no longer necessary. Landfill gas monitoring (and control if needed) shall continue until LFG production levels indicate that no further control or monitoring is necessary.



# **LEGEND**

**OB** LOCATION OF OBSERVATION WELL

## **SCALE**

1:25000 0 250 500 1000 1250m

## **BAHAMAS SOLID WASTE AND HAZARDOUS MATERIALS MANAGEMENT PROJECT**

**FIGURE 10.1**  
**Location of Observation Wells**  
**Surrounding Landfill Cells**



**REPORTING**

The landfill facility operator will submit annual written reports to the DEHS. These reports shall contain the following information:

- weight of material received, by type and period;
- volume or weight and type of materials rejected, and fate;
- ground water monitoring/analyses results;
- leachate monitoring/analyses results;
- landfill gas monitoring/analyses results;
- odour, litter, dust, noise monitoring records;
- records of complaints from neighboring public or businesses;
- documentation of any spills, emergencies, fires, or waste releases from the site;
- details of extraordinary discharges (leachate, run-on contact water, etc.);
- records of daily, intermediate and final cover applied;
- documentation of stabilization and vegetation of final cover, with indication of success or problems;
- documentation of landfill space occupied and amount remaining in current phase; and
- a summary of any operating problems and means of addressing.

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## 11.0 SUMMARY OF CONCLUSIONS

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## 11.0 SUMMARY OF CONCLUSIONS

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### 11.1 BACKGROUND

The Government of The Bahamas is in the process of developing a Master Plan for solid waste management to direct the management of municipal and other solid waste in the country for a period of twenty years. Pre-feasibility studies have been completed and a preliminary Master Plan has been developed, including potential sites for final disposal on New Providence Island and nine of the Family Islands.

A part of the Master Plan is the preparation of an Environmental Impact Assessment (EIA) focusing on key elements which will be carried to detailed design. The objectives of the EIA are:

- (i) to identify and assess the significance of potential impacts (positive and adverse) to living and non-living components of the environment resulting from the construction and operation of the proposed new landfill, and socio-economic impacts stemming from environmental threats; and
- (ii) to recommend measures for eliminating or reducing the risk and magnitude of adverse environmental effects (mitigation), and for detecting adverse effects in time to correct them (monitoring).

This Report gives the results of an EIA of the Harrold Road waste disposal facility, which will be the chief site for final disposal for New Providence Island. The waste disposal facility will consist primarily of a sanitary landfill to be constructed directly to the north and northwest of the existing landfill at the Harrold Road site. The facility will feature, among other things, a leachate collection and disposal system, a landfill gas collection system, appropriate covering of the waste, and a monitoring system for groundwater quality.

### 11.2 POTENTIAL IMPACTS - THE PHYSICAL ENVIRONMENT

The consequences to fresh groundwater resources of any leak of leachate through the liner of the landfill was assessed from a field investigation involving the sampling and analysis of groundwater from various points adjacent to the existing landfill. Even in that unlined landfill, the only observable consequence of leachate movement was the

impact on fresh groundwater immediately below the landfill, with no evidence that lateral migration takes place even after 25 years of operation.

For the proposed new landfill, the overall risk of leakage of leachate through the liner is vanishingly small, as the technology, operation and effectiveness of the proposed type of liner is well established worldwide.

A deep disposal well will be used for disposal of leachate. Failure of the casing of a deep disposal well could allow leachate to be injected at unanticipated locations (depths). If such a failure occurred within or just below the zone of fresh groundwater, then contamination could occur, affecting fresh groundwater over a substantial area. This consequence can be rated as substantial.

The risk of leakage from a waste disposal well impacting fresh groundwater is regarded as appreciable since the probability is moderate and the consequences are substantial. The timeframe of such an impact would be long. Prevention of the problem, however, is quite feasible. If injection wells are selected for disposal of leachate they will be approved as to depth and construction by The Bahamas Water and Sewerage Corporation (WSC). The wells should incorporate adequate casing structures, including a monitoring device for the early detection of leakage. Measures for mitigation and monitoring in this regard, are given in the Mitigation and Monitoring Plans of this Report, respectively. If such measures are implemented, the risk of impact can be considered to be low.

In terms of surface water and aquatic systems, there are no drainage courses or ponds in the planned expansion area. As shown above, the risk to the subterranean freshwater resource is very low, and there is therefore an extremely low risk of any effects on nearby lakes or ponds due to the contamination of groundwater with leachate and subsequent migration to these water bodies.

The collection of landfill gas and subsequent flaring will be slightly more beneficial to air quality than conventional practices of landfilling only. Flared landfill gas per se, does not result in unpleasant odours. The potential impacts of landfill gas on air quality are therefore judged to be insignificant.

The facility will create some dust resulting from vehicle movements; however, there is provision for dust suppression in the operating plan.

Odours emanating from an expanded landfill will be less than is currently the case provided the recommendations of the Environmental Mitigation Plan are fully implemented in respect to the daily application of cover material, and prevention of fires. If this is done, there will be a long-term, positive impact on air quality in respect to odour from the landfill.

Erosion of soils is regarded as only a potential minor problem, occurring only as a result of major storm events. This is due to the nature of the topography and the porous nature of the substrate, and any effects would be expected to be limited to the disposal site itself. Sediment carried by such erosion would not be expected to travel off site given the fact that settling ponds are specified in the operating plan.

### **11.3 POTENTIAL IMPACTS - THE BIOLOGICAL ENVIRONMENT**

Expansion of the landfill to adjacent land will remove some habitat, i.e., approximately 100 acres (41.5 ha) of forest and bush. Most of the area is occupied by "pine forest", which consists of regeneration *Pinus caribaea*, and is not virgin forest of significant heritage or commercial value. The commercial use of the equivalent amount of forest for lumber, etc., is insignificant in the present and foreseeable future.

Based on field surveys, review of literature on rare and endangered species of plants and animals in The Bahamas, and because the pine forest of this type is locally abundant, it is highly unlikely that the fate of any rare or endangered species of plant or animal would be threatened by the proposed expansion.

Provided that the expanded disposal site is operated according to recommendations, the likelihood of attracting pests such as rats and wild dogs is regarded as low. Relative to current conditions, the impact would be positive, leading to fewer pests than at present.

The expansion of the disposal site is not expected to have an impact on marine ecosystems.

### **11.4 POTENTIAL IMPACTS - THE SOCIO-CULTURAL ENVIRONMENT**

The use of the land in the proposed expansion area for the purposes of constructing a landfill presents no land use conflict, since it has been zoned Industrial and intended for the purposes of waste management. Consideration has been made for setback from dwellings and other operations on Gladstone Road.

The impact of the proposed new landfill on tourism is judged to be low to none, as there are very few tourists who would have occasion to actually see it. The only occasion in which the landfill activities present a negative impact to tourists is when odours become oppressive due to lack of cover, or when the landfill is on fire. Improved landfill operation, as recommended in the Mitigation Plan, should actually improve this situation. Furthermore, the improved system for collection and management, should reduce the amount of litter on the Island generally, and this would likely have a positive impact on tourism, through improved impressions of the surroundings. In terms of eco-tourism and appreciation of natural ecosystems, the main attraction in the vicinity is Harrold and Wilsons Ponds. However, the new landfill will not present an intrusive visual impact from the perspective of shoreline activities.

Illicit dumping is not likely to become worse if the landfill remains at the current location. The imposition of tipping fees, however, could cause illicit dumping to increase, unless enforcement procedures are also instituted.

Transportation patterns are well established and accepted for the current disposal site. Patterns and volumes of traffic will not change drastically with an expanded landfill but will be subject to growth due to general population increases. Improvement of the road system leading to the waste disposal facility would reduce traffic problems in the area.

The BEC (Bahamas Electricity Corporation) power line lies between the existing landfill and the proposed new one. It is not considered necessary to move this power line, but the final design will need to be approved by the BEC. Any possible conflicts with the new landfill activities may be resolved through the placement of a height restriction on equipment.

The visual impact presented by the new landfill will not be greater than the present situation, wherein the landfill is not visible from most points on local routes or from adjacent residences due to local topography and vegetation. Furthermore, the area of the new landfill will be surrounded by a buffer of 20-25 m pine. There will be no significant visual impact from the shoreline of nearby ponds or from the main local routes, due to topography and visual shielding provided by vegetation.

Noise issuing from the disposal site from heavy equipment operations will not significantly change with continued use of the site. A slight increase in equipment operations might result from population increases over time.



The expanded landfill is proposed to have controlled access for the general public. In addition, waste management recommendations contained in the Plan should have the effect of reducing bio-hazardous materials reaching the landfill. Both of these proposals will tend to lower the transmission of disease by human vectors leaving the disposal site.

It is unlikely that historic resources will be lost or damaged as a result of the proposed activities, in terms of historic or pre-historic artifacts. Due to its location, there is no likelihood of the expanded disposal site impacting national parks.

## **11.5 ENVIRONMENTAL MANAGEMENT**

An Environmental Mitigation Plan proposes a set of design and operational measures to prevent or mitigate potential impacts related to the construction, operation and closure phases of the proposed expanded Harrold Road waste management facility. The Plan proposes measures relative to the following, and other, potential concerns:

- surface water drainage and erosion control;
- leachate control and groundwater protection;
- landfill gas collection and treatment;
- odour and litter control;
- smoke and dust control;
- fire prevention and contingency;
- aesthetics and establishment of buffer zone;
- protection and accommodation of utilities;
- staffing and training needs;
- closure and post-operational land use;
- use of cleared vegetation;
- contingency equipment;
- incoming waste; and
- scavenging activities.

An Environmental Monitoring Plan proposes measures to ensure that pollution or related problems are discovered in time to prevent or repair adverse effects, and to

evaluate the success of mitigative or preventive measures set out in the design. Among other things, the Plan addresses the following items:

- leachate management;
- groundwater quality protection;
- landfill gas production and movement;
- odour, dust and litter control;
- protection of historic resources;
- closure and post-operational life; and
- reporting.

## 11.6 CONCLUSION

Provided that the recommendations of the Mitigation and Monitoring Plans of this report and the Solid Waste Management Plan in general are implemented, the loss resulting from the use of the forest/bush area under consideration for an expanded facility would be outweighed by the environmental benefits, in terms of an improved waste disposal facility for New Providence Island, and an improved waste management system resulting in less litter, odour and pests. Risks of significant adverse impacts to other components of the environment, after mitigation, are judged to be low.

The location of the current landfill does not appear to be strongly opposed by any identifiable group or the media. It appears to be regarded as a necessary feature of the community and is sufficiently removed from direct impact on most people's lives that it is not an issue in its current state and location. An expansion, together with a commitment to address some of the operational problems experienced in the past, would have a likelihood of local acceptance as well.

Because of the upgrade of the existing landfill to a modern landfill with the necessary environmental controls and monitoring systems, the balance of environmental costs and benefits would appear to be significantly in favor of proceeding.

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## 12.0 LIST OF CONSULTATIONS

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## 12.0 LIST OF CONSULTATIONS

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## 13.0 REFERENCES

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## 13.0 REFERENCES

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## ACKNOWLEDGEMENTS

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**APPENDIX A      TECHNICAL  
MEMORANDUM TA4-TM2  
FROM APPENDIX C OF THE  
PHASE II - INTERIM  
REPORT**

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BAHAMAS SOLID WASTE  
MANAGEMENT STUDY  
PHASE II

TECHNICAL  
MEMORANDUM  
NO. TA4-TM2

<i>Prepared by:</i> Doug Hackbarth	<i>Approved by:</i> Ken Hamman	<i>Issue Date:</i> August 22, 1996
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REPORT OF GROUNDWATER QUALITY ADJACENT TO HARROLD ROAD  
DISPOSAL SITE

1.0 INTRODUCTION

This Technical Memorandum has been prepared as a result of the work undertaken by Dr. D.A. Hackbarth during his visit to New Providence Island from June 14 to 21 and July 8 to 19, 1997. The purpose of these visits was to plan activities, to supervise drilling and installation of the Harrold Road waste disposal site monitoring wells and to collect groundwater samples from the monitoring wells and from selected domestic wells in the residential neighborhood located south of the existing Harrold Road waste disposal site. This report documents the drilling and installation of the waste disposal site monitoring wells, presents results of chemical analyses and reaches conclusions **with respect to the impact of the Harrold Road waste disposal site on adjacent groundwater resources.**

Two reports prepared during Phase I of the project (Stanley International, 1996a, 1996b) documented the results of a similar installation and sampling program conducted in January, 1996. This Technical Memorandum builds on that base of knowledge, utilizing many of the observation wells installed during the previous study (plus additional observation wells) as well as analyses from local domestic wells.

Generally, the activities undertaken during this time included the following:

- Drilling and installation of monitoring wells
- Preparation of new and existing monitoring wells for sampling
- Collection of groundwater samples for analysis

## **2.0 DRILLING PROGRAM**

### **2.1 Overview**

The drilling and monitoring well installation took place from July 8 to 12, 1997. Sentinel Drilling of Nassau supplied an auger rig for the installation. The plan called for the installation of six new observation wells at five locations. The locations of these five sites are shown on Figure 1. Two observation wells were installed at different depths at the location designated as "SW". The three wells west of the waste disposal site were primarily installed for purposes of determining water levels in the area of the new landfill, however, they were also anticipated to function as monitors of background water quality conditions.

Drilling of each borehole was accomplished with a carbide-tipped auger bit of 15 cm diameter. This did not produce significant drill cuttings as the soft limestone turns to powder during drilling, however, the geology of the area was already sufficiently well known from the previous drilling program. After augering to the desired depth, each hole was pumped clean using an air-lift assembly consisting of 10 cm ID PVC pipe to which had been attached a 2 cm ID airline. After cleaning the borehole in this manner, 51 mm ID PVC pipe was installed in the borehole. The bottom 1.5 m of the pipe was perforated with saw cuts. Silica sand was subsequently poured into the borehole to cover the saw slots and the balance of the hole filled with clean crushed limestone. Details of the construction of the six observation wells are found in Annex I.

Development of each observation well was accomplished by pumping with Waterra hand pumps until the water produced from the well was clear. In most cases, the water flowed clear within a few minutes.

### **2.2 Installations**

Details of the geological logs and monitoring wells are found in Annex I.

Table 1 summarizes the water level elevations observed in July, 1997 and in 1996. It should be noted that the depth (in feet) of each monitoring well is indicated by the numeral following the site designation, for instance, well N14 is 14 feet deep.

## **3.0 SAMPLING AND ANALYTICAL PROGRAM**

The sampling program in the observation and adjacent residential domestic wells took place on July 15, 16, and 21, 1997.

The latter date of sampling was necessary because several sample bottles were broken during shipment to Edmonton and the wells were resampled. Details of construction of the domestic wells were not available, however, it is safe to

assume that all were less than 6 m deep since salinity increases substantially below this depth and the wells are intended for household use.

The design of the analytical program for 1997 differed in some aspects from that of the 1996 program. Differences and their rationale are as follows:

- An expanded suite of metals was available at reasonable costs
- Three of the volatile compounds (trichloroetene, tetrachloroethelyne, 2-butanone) analyzed for in 1996 were eliminated in favor of analysis for benzene, toluene, ethylbenzene and xylene (BTEX). These component of gasoline were thought to be more likely to be present than the other volatile compounds.
- The 1996 program did not analyze for typical non-volatile hydrocarbon compounds. It was decided that an analysis for these should be added to the 1997 program and the parameter total extractable hydrocarbon was added. This test determines the combined presence of compound in the C11 to C30 range and therefore includes the heavier portions of gasoline, diesel fuels and many lubricating oils.
- The assessment for leachate in 1996 was complicated by the fact that the traditional (freshwater environment) parameters used to determine its presence are unusual abundance of the major ions( calcium, magnesium, sodium, potassium, bicarbonate, chloride, sulfate) however this approach is indeterminate in a saltwater environment such as exists in The Bahamas. The use of isotopes of carbon offered a potential solution to this problem. Seawater has a distinctive carbon isotope composition which will be very much different from the carbon isotope composition of water affected by decomposition processes such as occur in a landfill. It was therefore decided to collect samples for carbon isotope analysis to determine if this technique would be useful.

Table 2 gives field and laboratory parameters measured on July 15 and 16, 1997 and for January 1996 samples taken from the waste disposal site observation wells. Table 3 presents the results of the chemical analysis of the water samples taken from the residential domestic wells. The approximate locations of the domestic wells are shown on Figure 1 along with the reference numbers from Table 3.

Samples for all of the above analyses, except carbon isotopes, were sent to Enviro-Test Laboratories in Edmonton. Analysis for carbon isotopes was done at the Earth Sciences Department at the University of Alberta in the laboratory of Dr. Karlis Muehlenbachs.



Total extractable hydrocarbon (TEH) is a measure of the combined and undifferentiated presence of hydrocarbon compounds in the C11 to C30 range. This includes the heavier ends of gasoline, diesel, fuel oil and many lubricating oils. These those are not as volatile as compounds containing lighter hydrocarbons and may be more long-lasting in the warm groundwaters of The Bahamas.

## **4.0 DISCUSSION**

### **4.1 Water Levels**

Substantial rainfall occurred on New Providence Island in the period following July 12. This caused flooding of access routes within the waste disposal site and substantially curtailed planned water level monitoring activities. It was not possible to take one set of readings in a short time period in order to characterize the configuration of the watertable during the period of this visit.

The measurements of water levels made on 11 July, 1997 were carried out several hours after high tide. It is noted that these are all higher than any value recorded in 1996. This may be largely due to record rainfall in June, 1997; however, relative tidal stage may also be a factor.

Previous detailed measurements of water levels in 1996 had been inconclusive with respect to directions of groundwater flow because of the substantial tidal influence. The fact that measurements could not be taken in all wells during a short time period is therefore not considered to be detrimental to the conclusions of the project.

### **4.2 Groundwater Quality - Observation Wells**

Table 4 presents guidelines for drinking water quality established by Health Canada. The table expresses these guidelines in terms of three types of criteria:

- Maximum Acceptable Concentration (MAC) - This represents values that are well established to cause adverse health effects.
- Interim Maximum Acceptable Concentration (IMAC) - This represents values for compounds for which the adverse health effects are poorly known but suspected to exist.
- Aesthetic Objective (AO) - This represents a value for which annoyances to the user, but not health effects, begin to occur.

While many constituents, such as chloride, sodium and bicarbonate, are characteristic of municipal waste leachate in freshwater environments, the saline environment of The Bahamas precludes the use of many of these as definitive

indicators of impact of municipal landfill leachate. Given the presence of the salt water lens and the low level of industrialization on New Providence Island, it is anticipated that ammonia, chemical oxygen demand, total organic carbon, iron, manganese and extractable hydrocarbons are potentially definitive indicators for the presence of leachate. Elevated bicarbonate is also likely to be found due to large amounts of carbon dioxide produced during decomposition of organic matter in the waste. Other parameters are interfered with by the presence of salt water or are not likely to be present due to small quantities of industrial wastes delivered to the waste disposal site. It should be kept in mind in reviewing the water quality data that below a depth of 10 to 20 m (30 to 60 feet) depending on land surface elevation, the groundwater can change from fresh to brackish quite quickly and that we are never quite certain how this occurs at any particular location.

Table 2 presents the results of the analyses of water quality from the waste disposal site observation wells conducted under this program. The availability of what may be called background wells (97-1, 97-2, 97-1), plus the second set of samples from nearly all of the wells, allows for different conclusions to be reached regarding the impact of the facility on adjacent groundwater than was able to be drawn in the previous investigation (Stanley International, 1996a, 1996b). Many well sites now show conditions different from background conditions which are considered to be likely indications of impact from the waste disposal site. The following discussion, focusing on the indicator compounds noted above, will deal with the background wells followed by comments on each individual well site:

**Table 4**  
**Health Canada Drinking Water Guidelines**

Test Description	Units	MAC	IMAC	AO
Temperature	Celcius			
pH	pH			6.5 - 8.5
Chloride	mg/L			250
Nitrate+Nitrite (N)	mg/L	10		
Sodium (Na)	mg/L			200
Sulfate (SO <sub>4</sub> )	mg/L			500
TDS (Calculated)	mg/L			500
Cyanide(CN)	mg/L	0.2		
Barium (Ba)	mg/L		1	
Boron (B)	mg/L		5	
Cadmium (Cd)	mg/L		0.005	
Chromium (Cr)	mg/L		0.05	
Copper (Cu)	mg/L			1.
Iron (Fe)	mg/L			0.3
Lead (Pb)	mg/L	0.01		

**Table 4**  
**Health Canada Drinking Water Guidelines**

Test Description	Units	MAC	IMAC	AO
Manganese (Mn)	mg/L			0.05
Zinc (Zn)	mg/L			5
Arsenic (As)	mg/L		0.025	
Mercury (Hg)	mg/L	0.001		
Selenium (Se)	mg/L	0.01		
Benzene	ug/L	0.005		
Toluene	ug/L			0.0024
Ethylbenzene	ug/L			0.0024
Xylenes	ug/L			0.3
Trichloroethene	ug/L	0.05		
Tertachloroethelyne	ug/L	0.03		

MAC - maximum acceptable concentration

IMAC - Interim maximum acceptable concentration

AO - Aesthetic objective

#### 4.2.1 Background

At the background wells at a depth of approximately 6 m (20 feet), the concentration of bicarbonate is slightly less than 300 mg/L, ammonium less than 0.05 mg/L, COD between 10 and 16 mg/L, TOC in the 2 to 4 mg/L range, iron at approximately 0.02 mg/L and manganese as high as 0.005 mg/L. There are no detectable BTEX or TEH compounds at these sites.

It is noted that mercury concentrations in all three of these wells exceeds drinking water guidelines. The reason for this is not clear given the generally low concentrations of all other constituents.

#### 4.2.2 Well Site E

The water at these two wells shows elevated levels of COD, TOC, ammonia, iron and TEH relative to the background sites. As well, elevated concentrations of phosphorus and potassium may indicate impact from municipal waste. Aside from common constituents of salt water, mercury in E35 slightly exceeds Canadian drinking water guidelines (Health Canada, 1996) and the undefined compounds in TEH may indicate impact of leachate.

#### **4.2.3 Well Site SE**

Ammonia concentrations at this site exceed background concentrations. As well, magnesium appears elevated with respect to background. No parameters exceed drinking water guidelines except for sodium and chloride.

#### **4.2.4 Well Site S**

The deeper well (S37) at this site shows significant probable impact from waste disposal site. Five of the six indicators substantially exceed background levels. In addition, bicarbonate, magnesium, potassium, sulfate, molybdenum, phosphorus and arsenic show substantially elevated concentrations. Temperatures in excess of others in the area possibly reflect heat produced by decomposition within the refuse.

Ammonia concentrations are high in S37 and nitrate is high in S14.

Mercury concentrations in S37 exceed the drinking water guideline by a factor of 150 times.

Wells E56 and S37 were terminated at approximately the same elevation below sea level (Table 3), yet S37 generally has higher concentrations of parameters than E56. Well W46 is completed approximately 2 m deeper than well S37, yet parameters such as COD, bicarbonate and potassium are notably higher in concentration in the shallower S37 well.

There appears to be substantial reason to believe that there is a southward and downward movement of leachate.

#### **4.2.5 Well Site SW**

COD, TOC and ammonia substantially exceed background levels in SW35. In addition, bicarbonate, potassium and phosphorous appear significantly elevated relative to background sites.

The sampling point in well SW35 is slightly higher in elevation than E56 and yet this well produces water of higher concentration of many parameters than E56.

#### **4.2.6 Well Site W**

Of the indicator constituents, only ammonia shows substantial elevation above background conditions, while TEH is slightly elevated above detection limits. Nitrate concentrations are quite high in W15 while magnesium, potassium and sulfate are elevated as well. Sulfate and mercury exceed drinking water guidelines.

#### 4.2.7 Well Site N

The two original wells at this site were destroyed in Spring, 1997. Well N37 was drilled approximately 80 m north to serve as a replacement. With the exception of ammonia, water from N37 shows no notable differences from background conditions.

#### 4.2.8 Carbon Isotopes

Carbon atoms commonly have an atomic weight of 12, however an isotope with a weight of 13 does exist. The water in the oceans of the world have a rather constant ratio of carbon 13 to carbon 12 in their dissolved carbonate and bicarbonate ions. Biological processes which utilize these carbon-containing ions tend to selectively use one isotope over another and will even have a characteristic ratio of these two isotopes. Isotope specialists use a common standard of the seawater carbon 13 to carbon 12 ratio to relate to other ratios. The unit of this comparison is referred to as "delta C13" which is the difference between this ratio in the water in question from seawater, divided by the seawater constant, and expressed as a percentage.

During the course of the carbon isotope analysis, Dr. Muehlenbachs determined that the samples from S37 and SW 35 had exsolved small, but significant quantities of methane. These methane observations were not based on rigorous procedures and therefore the results are not presented in Table 3.1. Methane is produced during fermentation of organic matter. Its presence is significant to the processes as will be explained later in this section.

The relationship of temperature and bicarbonate to the carbon isotope ratio at the Harrold Road site are particularly revealing with respect to leachate generation and migration. These relationships are shown in Figures 2 and 3. These figures demonstrate a strong and consistent relationship, showing that the deeper wells on the south southwest and east sides of the Public Dump have high temperature, high bicarbonate and higher delta C13 ratios than the background site (97-3), the north well and some of the shallow wells.

The correlation of higher temperatures with higher delta C13 values indicates that the heat of the decaying waste is creating a thermal plume which is observed at least in the area south of the Public Dump.

Oxidation processes in the waste material, if present, would cause exactly the opposite trend in the relationship between delta C13 and bicarbonate to that which is seen on Figure 3. This means that the slope of the correlation trend for oxidation would have been downward to the right rather than upward to the right.

The presence of methane confirms that the former fermentation process is taking place.

#### **4.3 Groundwater Quality - Domestic Wells**

Table 3 presents the result of analyses of water from the residential area domestic wells. The construction of these wells is not known. Only the B. Tynes well shows concentrations of compounds which may possibly be originating at the Waste disposal site which is located north across Fire Trail Road. Elevated levels of bicarbonate, chloride, magnesium, potassium, sodium and sulfate with respect to other domestic wells and with respect to the background wells may indicate an impact. They may, however, also indicate a well that is slightly too deep or that is pumped at too great a rate.

It is noted that the two Forbes wells and the D. Miller well do not appear to show any impact from the waste disposal site, even though they are also quite close to the facility.

None of the other domestic well sampled show effects which could be attributed to leachate.

#### **5.0 SUMMARY**

This program assessed water analyses collected in January, 1996 and July, 1997 from 13 observation wells at nine separate locations around the outside boundaries of the waste disposal site. The observation wells ranged in depth from 4 to 20 m and were intended to identify groundwater flow direction and to evaluate the presence of leachate migrating away from the waste disposal site. In addition, this program assessed water analyses from ten private domestic wells located south of the waste disposal site along Fire Trail Road and southwest of the waste disposal site in a subdivision located at the intersection of Gladstone and Fire Trail Roads.

Based on a variety of indicators, it appears that leachate from the waste disposal site may be moving downward and southward. There are some weaker indications that there may be easterly and westerly movements as well. Generally, however, it is suspected that any impact from leachate is taking place at sufficient depth such that it is below the zone of potable water and in the underlying brackish or saline water. The shallow wells adjacent to the waste disposal site generally show little to no influence which might be attributed to leachate, indicating that fresh water from precipitation lies on top of slightly deeper water which has been affected by leachate.

It is postulated that this phenomena may be more observable during periods of high precipitation as compared to periods of low precipitation. Abundant precipitation during the rainy season may create and flush leachate from the refuse such that it is more observable at that time than during periods of low precipitation.

Sampling of the domestic water wells along Fire Trail Road south of the waste disposal facility produced no definitive result with respect to potential contamination. One well immediately south of the facility had elevated concentrations of various parameters but this could also be indicative of the influence of salt water.

## **6.0 RECOMMENDATIONS**

Due to the indication that leachate may be moving downward and possibly to the south from the waste disposal site, it is recommended that one new observation well be installed at sites S, E and W at an elevation of approximately 30 m below sea level. This will allow sampling of deeper water to determine if this hypothesis is correct.

Sampling of the entire network, including the recommended new wells, should be continued twice per year for a selected number of parameters, during the wet and dry seasons. The length of the sampling program should depend upon the results obtained.

## **7.0 REFERENCES**

CCME 1991a; The Development of Canadian Marine Environmental Quality Guidelines: Canadian Council of Ministers of the Environment, Task Force on Water Quality Guidelines, 51 pp.

CCME 1991b; Interim Canadian Environmental Quality Criteria for Contaminated Sites: Canadian Council of Ministers of the Environment, Report CCME EPC-CS34, 20 p.

Health Canada 1996; Guideline for Canadian Drinking Water Quality - Sixth Edition: Supply and Services Canada, Ottawa, 90 pp.

Stanley International 1996a; Bahamas Solid Waste and Hazardous Materials Management Project - Pre-Investment Report - Mid-Term Report: March, 1996.

Stanley International 1996b; Bahamas Solid Waste and Hazardous Materials Management Project - Pre-Investment [Report] - Final Report: July, 1996.



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**APPENDIX B      PLANTS & ANIMALS OF  
THE BAHAMAS**

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# TABLE 1

## CHECKLIST OF BAHAMIAN BIRDS

OBSERVER \_\_\_\_\_

LOCATION \_\_\_\_\_

WEATHER CONDITIONS \_\_\_\_\_

TOTAL SPECIES OBSERVED \_\_\_\_\_

DATE \_\_\_\_\_

Please check off each species observed and return list to Bahamas National Trust (P.O. Box 4106, Nassau) by 31 October 1993. Thank you!

### GREBES

- ☐ Least Grebe
- ☐ Pied-billed Grebe

### SHEARWATERS AND PETRELS

- ☐ Audubon's Shearwater
- ☐ Wilson's Storm Petrel
- ☐ Leach's Storm Petrel

### TROPIC-BIRDS

- ☐ White-tailed Tropicbird

### PELICANS

- ☐ White Pelican
- ☐ Brown Pelican

### BOOBIES AND CORMORANTS

- ☐ Blue-faced Booby
- ☐ Brown Booby
- ☐ Double-crested Cormorant
- ☐ Olivaceous Cormorant

### FRIGATEBIRDS

- ☐ Magnificent Frigatebird

### HERONS AND BITTERNS

- ☐ Great White Heron
- ☐ Great Blue Heron
- ☐ Green Heron
- ☐ Little Blue Heron
- ☐ Cattle Egret
- ☐ Reddish Egret
- ☐ Great Egret
- ☐ Snowy Egret
- ☐ Tricolored Heron
- ☐ Black-crowned Night Heron
- ☐ Yellow-crowned Night Heron
- ☐ Least Bittern
- ☐ American Bittern

### IBISES AND SPOONBILLS

- ☐ Wood Stork
- ☐ Glossy Ibis
- ☐ White Ibis
- ☐ Roseate Spoonbill

### FLAMINGOS

- ☐ American Flamingo

### GEESSE AND DUCKS

- ☐ Snow Geese
- ☐ West Indian Tree Duck
- ☐ Fulvous Tree Duck
- ☐ Mallard
- ☐ Gadwall
- ☐ Northern Pintail
- ☐ Bahama Pintail
- ☐ Green-winged Teal
- ☐ Blue-winged Teal
- ☐ Cinnamon Teal
- ☐ American Widgeon
- ☐ Northern Shoveler
- ☐ Wood Duck
- ☐ Redhead
- ☐ Ring-necked Duck
- ☐ Lesser Scaup
- ☐ Ruddy Duck
- ☐ Masked Duck
- ☐ Hooded Merganser

### HAWKS, FALCONS AND THEIR ALLIES

- ☐ Turkey Vulture
- ☐ Sharp-shinned Hawk
- ☐ Red-tailed Hawk
- ☐ Marsh Hawk
- ☐ Osprey
- ☐ Peregrine Falcon
- ☐ Merlin
- ☐ American Kestrel

### GAMEBIRDS (introduced)

- ☐ Northern Bobwhite
- ☐ Chukar
- ☐ Ring-necked Pheasant

### LIMPKINS

- ☐ Limpkin

### RAILS, GALLINULES AND COOTS

- ☐ Clapper Rail
- ☐ Sora
- ☐ Black Rail
- ☐ Purple Gallinule
- ☐ Common Moorhen
- ☐ American Coot

### OYSTERCATCHERS

- ☐ American Oystercatcher

### PLOVERS AND TURNSTONES

- ☐ European Lapwing
- ☐ Semipalmated Plover
- ☐ Piping Plover
- ☐ Snowy Plover
- ☐ Wilson's Plover
- ☐ Killdeer
- ☐ American Golden Plover
- ☐ Black-bellied Plover
- ☐ Ruddy Turnstone

### STILTS

- ☐ Black-necked Stilt

### SANDPIPERS

- ☐ Common Snipe
- ☐ Wimbrel
- ☐ Upland Sandpiper
- ☐ Spotted Sandpiper
- ☐ Solitary Sandpiper
- ☐ Dunlin
- ☐ Greater Yellowlegs
- ☐ Lesser Yellowlegs
- ☐ Red Knot
- ☐ Willet
- ☐ Pectoral Sandpiper
- ☐ White-rumped Sandpiper
- ☐ Least Sandpiper
- ☐ Semipalmated Sandpiper
- ☐ Western Sandpiper
- ☐ Buff-breasted Sandpiper
- ☐ Sanderling
- ☐ Short-billed Dowitcher
- ☐ Silt Sandpiper
- ☐ Northern Phalarope
- ☐ Hudsonian Godwit

### JAEGERs

- ☐ Pomarine Jaeger
- ☐ Parusoid Jaeger

### GULLS AND TERNS

- ☐ Herring Gull
- ☐ Ring-billed Gull
- ☐ Laughing Gull
- ☐ Bonaparte's Gull
- ☐ Gull-billed Tern
- ☐ Foster's Tern
- ☐ Common Tern
- ☐ Roseate Tern
- ☐ Bridled Tern
- ☐ Sooty Tern
- ☐ Least Tern
- ☐ Royal Tern
- ☐ Sandwich Tern
- ☐ Black Tern
- ☐ Brown Noddy
- ☐ Black Skimmer

### PIGEONS AND DOVES

- ☐ White-crowned Pigeon
- ☐ Mourning Dove
- ☐ Zenaida Dove
- ☐ White-winged Dove
- ☐ Common Ground Dove
- ☐ White-bellied Dove
- ☐ Key West Quail Dove
- ☐ Ring-necked Dove

### PARROTS

- ☐ Bahama Parrot

### CUCKOOS AND ANIS

- ☐ Mangrove Cuckoo
- ☐ Yellow-billed Cuckoo
- ☐ Black-billed Cuckoo
- ☐ Great Lizard Cuckoo
- ☐ Smooth-billed Ani

### OWLS

- ☐ Barn Owl
- ☐ Burrowing Owl

### NIGHTJARS

- ☐ Chuck-will's-widow
- ☐ Common Nighthawk

### SWIFTS

- ☐ Chimney Swift

### HUMMINGBIRDS

- ☐ Cuban Emerald
- ☐ Bahama Woodstar
- ☐ Ruby-throated Hummingbird
- ☐ Rufous Hummingbird

### KINGFISHERS

- ☐ Belted Kingfisher

### WOODPECKERS

- ☐ Fernandez's Flicker
- ☐ West Indian Red-bellied Woodpecker

- ☐ Yellow-bellied Sapsucker
- ☐ Hairy Woodpecker

### TYRANT FLYCATCHERS

- ☐ Eastern Kingbird
- ☐ Gray Kingbird
- ☐ Western Kingbird
- ☐ Giant Kingbird
- ☐ Loggerhead Kingbird
- ☐ Scissor-tailed Flycatcher
- ☐ Great-crested Flycatcher
- ☐ Eastern Phoebe
- ☐ Stolid Flycatcher
- ☐ Eastern Wood Pewee
- ☐ Greater Antillean Pewee
- ☐ Acadian Flycatcher

### SWALLOWS

- ☐ Bahama Swallow
- ☐ Tree Swallow
- ☐ Purple Martin
- ☐ Bank Swallow
- ☐ Rough-winged Swallow
- ☐ Barn Swallow
- ☐ Cliff Swallow

### NUTHATCHES

- ☐ Brown-headed Nuthatch

### WRENS

- ☐ House Wren

### THRASHERS AND MOCKINGBIRDS

- ☐ Northern Mockingbird
- ☐ Bahama Mockingbird
- ☐ Pearl-eyed Thrasher
- ☐ Gray Catbird
- ☐ Brown Thrasher

### THRUSHES

- ☐ American Robin
- ☐ Red-legged Thrush
- ☐ Hermit Thrush
- ☐ Wood Thrush
- ☐ Swainson's Thrush
- ☐ Gray-cheeked Thrush

### KINGLETS AND GNATCATCHERS

- ☐ Ruby-crowned Kinglet
- ☐ Blue-gray Gnatcatcher

### PIPITS

- ☐ Water Pipit
- ☐ Sprague's Pipit

### WAXWINGS

- ☐ Cedar Waxwing

### SHRIKES

- ☐ Loggerhead Shrike

### STARLINGS

- ☐ European Starling

### Bahamas Birdwatch

This event is being organized as part of World Birdwatch '97, coordinated by Birdlife International. World Birdwatch '97 is a worldwide educational event designed to raise public awareness of bird populations and conservation. Over one million people are expected to participate worldwide. Participants in The Bahamas are urged to contribute to this effort by recording the birds they see on October 4 and 5 using the handy checklist provided here. The list includes bird species most commonly seen in The Bahamas. It is based on previous checklists of Bahamian birds with revisions according to *The Birds of the Bahama Islands* (Brudenell-Bruce 1975) and *Birds of the West Indies* (Bond 1975). The list is not intended to be a complete and precise catalogue of Bahamian avifauna, rather, a working list for the World Birdwatch event. Please excuse any inaccuracies and enjoy your day!

Table 2: Rare flora known from The Bahamas (B.E.S.T., 1995), with annotations on distribution, type of habitat, and plant form (taken from Correll and Correll 1982).

Species	Distribution <sup>1</sup>	Habitat	Form
Agave acklinicola	-	-	
Agave millspaughii	6	low coppice, scrubland	acaulescent
Borreria inauguensis	2	crevices in open rock flats	herb, shrubby plant
Ernodia gigantea	3	open coppices	shrub, 2m
Euphorbia brittonii	8	sandy whitelands	herb, 5-7 cm
Nashia inaguensis	2	scrublands	shrub, 2 m
Agave cacozeia	8	rocky margins of salt marshes	acaulescent
Agave indigatorum	4,5	rocky soil in coastal coppices	acaulescent
Agave nashii	2	dwarf shrub area, scrublands	acaulescent
Ateleia popenoei	6	coppice-covered rocky ridges	tree, 5 m
Chiococca stricta	7	along trail through coppice	shrub
Erythroxylum reticulatum	6,9	whitelands, coppices, pinelands	tall shrub
Euphorbia proctorii	2	sandy soils	herb
Polygala wilsonii	Salt Cay Bank	-	herb
Torulinium correllii	10	in sand above beach	cespitose
Borreria felis-insulae	7	sandy, open soil	flat, spreading mats
Erithalis salmeoides	2	open coppices	compact shrub
Eupatorium correlliorum	10	low coppice flats, assoc. pinelands	shrub, 1-2.5 m
Matelea correllii	4	low thickets	vine
Psidium androsianum	9	open or dense coppices	shrub or sapling, 5 m
Vanilla correllii	10	in coppices	epiphytic

<sup>1</sup> Information from Correll and Correll 1982; see Map attached for distribution code. Number indicates distribution in The Bahamas. Note that only those with a numeral 8 are known from New Providence Island.

# TABLE 3

## GREBES

- ☒ Least Grebe
- ☒ Pied-billed Grebe

## SHEARWATERS AND PETRELS

- ☐ Audubon's Shearwater
- ☐ Wilson's Storm Petrel
- ☐ Leach's Storm Petrel

## TROPIC-BIRDS

- ☐ White-tailed Tropic-bird

## PELICANS

- ☐ White Pelican
- ☐ Brown Pelican

## BOOBIES AND CORMORANTS

- ☐ Blue-faced Booby
- ☐ Brown Booby
- ☐ Double-crested Cormorant
- ☒ Olivaceous Cormorant

## FRIGATEBIRDS

- ☐ Magnificent Frigatebird

## HERONS AND BITTERNS

- ☐ Great White Heron
- ☒ Great Blue Heron
- ☒ Green Heron
- ☒ Little Blue Heron
- ☒ Cattle Egret
- ☐ Reddish Egret
- ☒ Great Egret
- ☒ Snowy Egret
- ☒ Tricolored Heron
- ☐ Black-crowned Night Heron
- ☐ Yellow-crowned Night Heron
- ☒ Least Bittern
- ☐ American Bittern

## IBISES AND SPOONBILLS

- ☐ Wood Stork
- ☒ Glossy Ibis
- ☐ White Ibis
- ☐ Roseate Spoonbill

## FLAMINGOS

- ☐ American Flamingo

## GEESE AND DUCKS

- ☐ Snow Goose
- ☐ West Indian Tree Duck
- ☐ Fulvous Tree Duck

- ☐ Mallard
- ☐ Gadwall
- ☐ Northern Pintail
- ☐ Bahama Pintail
- ☐ Green-winged Teal
- ☒ Blue-winged Teal
- ☐ Cinnamon Teal
- ☐ American Widgeon
- ☐ Northern Shoveler
- ☐ Wood Duck
- ☐ Redhead
- ☐ Ring-necked Duck
- ☐ Lesser Scaup
- ☐ Ruddy Duck
- ☐ Masked Duck
- ☐ Hooded Merganser

## HAWKS, FALCONS AND THEIR ALLIES

- ☐ Turkey Vulture
- ☐ Sharp-shinned Hawk
- ☐ Red-tailed Hawk
- ☐ Marsh Hawk
- ☒ Osprey
- ☐ Peregrine Falcon
- ☐ Merlin
- ☒ American Kestrel

## GAMEBIRDS (INTRODUCED)

- ☐ Northern Bobwhite
- ☐ Chukar
- ☐ Ring-necked Pheasant

## LIMPKINS

- ☐ Limpkin

## RAILS, GALLINULES AND COOTS

- ☐ Clapper Rail
- ☐ Sora
- ☐ Black Rail
- ☐ Purple Gallinule
- ☒ Common Moorhen
- ☒ American Coot

## OYSTERCATCHERS

- ☐ American Oystercatcher

## PLOVERS AND TURNSTONES

- ☐ European Lapwing
- ☐ Semipalmated Plover
- ☐ Piping Plover
- ☐ Snowy Plover
- ☐ Wilson's Plover
- ☒ Killdeer
- ☐ American Golden Plover

- ☐ Black-bellied Plover
- ☐ Ruddy Turnstone

## STILTS

- ☐ Black-necked Stilt

## SANDPIPERS

- ☒ Common Snipe
- ☐ Whimbrel
- ☐ Upland Sandpiper
- ☐ Spotted Sandpiper
- ☒ Solitary Sandpiper
- ☐ Dunlin
- ☒ Greater Yellowlegs
- ☒ Lesser Yellowlegs
- ☐ Red Knot
- ☐ Willet
- ☒ Pectoral Sandpiper
- ☐ White-rumped Sandpiper
- ☐ Least Sandpiper
- ☒ Semipalmated Sandpiper
- ☒ Western Sandpiper
- ☐ Buff-breasted Sandpiper
- ☐ Sanderling
- ☒ Short-billed Dowitcher
- ☐ Stilt Sandpiper
- ☐ Northern Phalarope
- ☐ Hudsonian Godwit

## JAEGERS

- ☐ Pomarine Jaeger
- ☐ Parasitic Jaeger

## GULLS AND TERNS

- ☐ Herring Gull
- ☐ Ring-billed Gull
- ☐ Laughing Gull
- ☐ Bonaparte's Gull
- ☐ Gull-billed Tern
- ☐ Forster's Tern
- ☐ Common Tern
- ☐ Roseate Tern
- ☐ Bridled Tern
- ☐ Sooty Tern
- ☐ Least Tern
- ☐ Royal Tern
- ☐ Sandwich Tern
- ☐ Black Tern
- ☐ Brown Noddy
- ☐ Black Skimmer

## PIGEONS AND DOVES

- ☒ White-crowned Pigeon
- ☐ Mourning Dove
- ☐ Zenaida Dove
- ☐ White-winged Dove
- ☒ Common Ground Dove

- ☐ White-bellied Dove
- ☐ Key West Quail Dove
- ☒ Ring-necked Dove
- ☒ Rock Dove

## PARROTS

- ☐ Bahama Parrot

## CUCKOOS AND ANIS

- ☐ Mangrove Cuckoo
- ☐ Yellow-billed Cuckoo
- ☐ Black-billed Cuckoo
- ☐ Great Lizard Cuckoo
- ☒ Smooth-billed Ani

## OWLS

- ☐ Barn Owl
- ☐ Burrowing Owl

## NIGHTJARS

- ☐ Chuck-will's-widow
- ☐ Common Nighthawk

## SWIFTS

- ☐ Chimney Swift

## HUMMINGBIRDS

- ☐ Cuban Emerald
- ☒ Bahama Woodstar
- ☐ Ruby-throated Hummingbird
- ☐ Rufous Hummingbird

## KINGFISHERS

- ☒ Belted Kingfisher

## WOODPECKERS

- ☐ Fernandina's Flicker
- ☐ West Indian Red-bellied Woodpecker
- ☐ Yellow-bellied Sapsucker
- ☐ Hairy Woodpecker

## TYRANT FLYCATCHERS

- ☐ Eastern Kingbird
- ☒ Gray Kingbird
- ☐ Western Kingbird
- ☐ Giant Kingbird
- ☐ Loggerhead Kingbird
- ☐ Scissor-tailed Flycatcher
- ☐ Great-crested Flycatcher
- ☐ Eastern Phoebe
- ☐ Stolid Flycatcher
- ☐ Eastern Wood Pewee
- ☐ Greater Antillean Pewee
- ☐ Acadian Flycatcher

## SWALLOWS

- ☐ Bahama Swallow
- ☐ Tree Swallow
- ☐ Purple Martin
- ☐ Bank Swallow
- ☐ Rough-winged Swallow
- ☒ Barn Swallow
- ☐ Cliff Swallow

## NUTHATCHES

- ☐ Brown-headed Nuthatch

## WRENS

- ☐ House Wren

## THRASHERS AND MOCKINGBIRDS

- ☐ Northern Mockingbird
- ☐ Bahama Mockingbird
- ☐ Pearly-eyed Thrasher
- ☐ Gray Catbird
- ☐ Brown Thrasher

## THRUSHES

- ☐ American Robin
- ☒ Red-legged Thrush
- ☐ Hermit Thrush
- ☐ Wood Thrush
- ☒ Swainson's Thrush
- ☐ Gray-cheeked Thrush

## KINGLETS AND GNATCATCHERS

- ☐ Ruby-crowned Kinglet
- ☐ Blue-gray Gnatcatcher

## PIPITS

- ☐ Water Pipit
- ☐ Sprague's Pipit

## WAXWINGS

- ☐ Cedar Waxwing

## SHRIKES

- ☐ Loggerhead Shrike

## STARLINGS

- ☐ European Starling

## VIREOS

- ☒ Thick-billed Vireo
- ☐ White-eyed Vireo
- ☒ Yellow-throated Vireo
- ☐ Solitary Vireo
- ☐ Black-whiskered Vireo
- ☐ Red-eyed Vireo
- ☐ Philadelphia Vireo

## WOOD WARBLERS

- ☒ Black and White Warbler
- ☐ Prothonotary Warbler
- ☐ Swainson's Warbler
- ☒ Worm-eating Warbler
- ☐ Golden-winged Warbler
- ☐ Blue-winged Warbler
- ☐ Bachman's Warbler
- ☐ Tennessee Warbler
- ☐ Orange-crowned Warbler
- ☐ Nashville Warbler
- ☒ Northern Parula
- ☒ Yellow Warbler
- ☒ Magnolia Warbler
- ☒ Cape May Warbler
- ☒ Black-throated Blue Warbler
- ☐ Yellow-rumped Warbler
- ☐ Black-throated Green Warbler
- ☒ Yellow-throated Warbler
- ☐ Olive-capped Warbler
- ☐ Pine Warbler
- ☐ Cerulean Warbler
- ☐ Blackburnian Warbler
- ☒ Chestnut-sided Warbler
- ☐ Bay-breasted Warbler
- ☒ Blackpoll Warbler
- ☒ Prairie Warbler
- ☐ Kirtland's Warbler
- ☒ Palm Warbler
- ☒ Ovenbird
- ☒ Northern Waterthrush
- ☐ Louisiana Waterthrush
- ☐ Kentucky Warbler
- ☐ Connecticut Warbler
- ☐ Hooded Warbler
- ☐ Wilson's Warbler
- ☐ Canada Warbler
- ☒ American Redstart
- ☐ Mourning Warbler
- ☒ Common Yellowthroat
- ☐ Bahama Yellowthroat
- ☐ Yellow-breasted Chat

## HONEYCREEPERS

- ☒ Bananaquit

## WEAVER FINCHES

- ☐ House Sparrow

## TANAGERS

- ☐ Western Tanager
- ☐ Stripe-headed Tanager
- ☒ Scarlet Tanager
- ☐ Summer Tanager

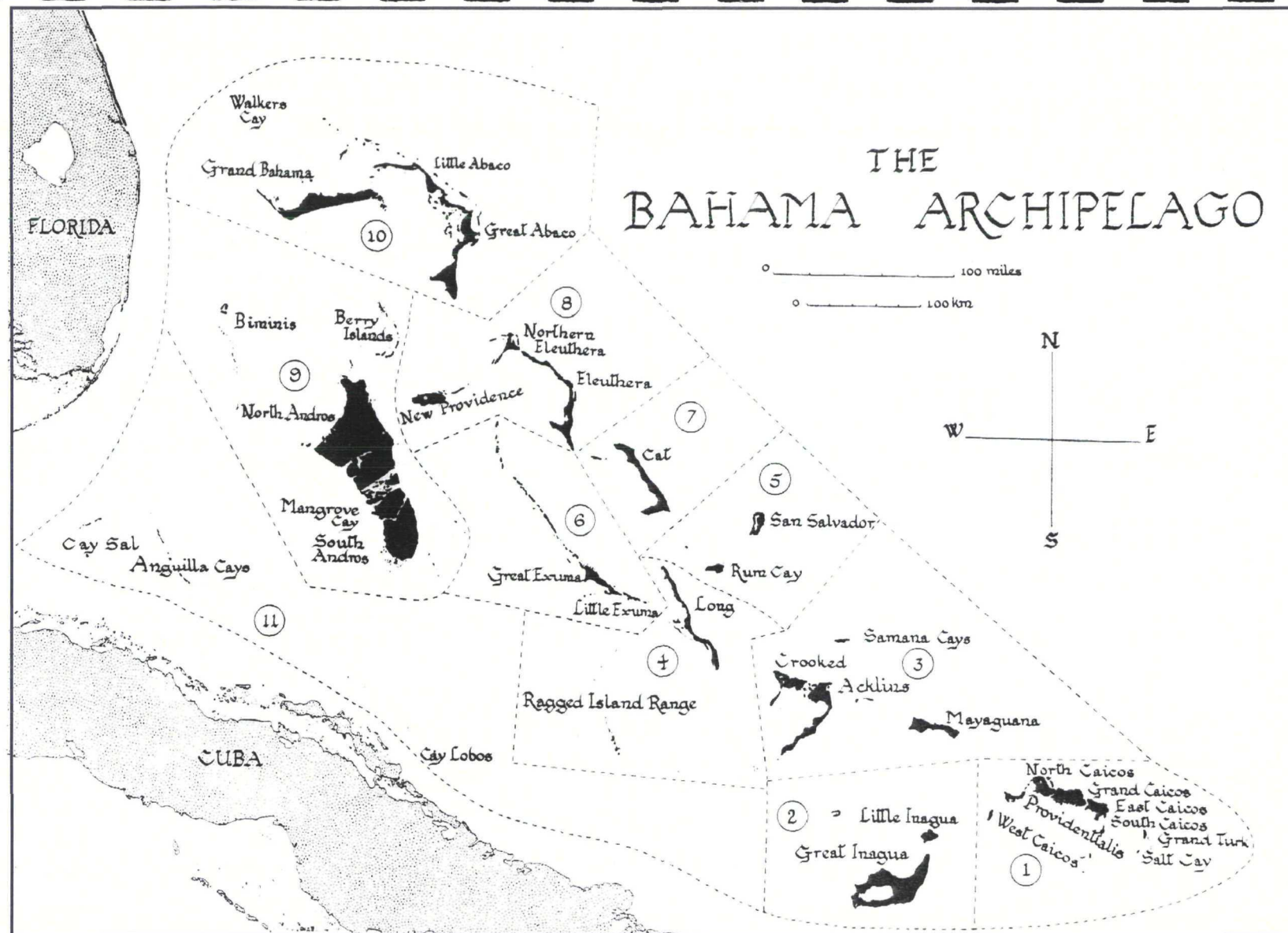
## ORIOLES AND BLACKBIRDS

- ☐ Bobolink
- ☐ Yellow-headed Blackbird
- ☐ Black-cowled Oriole
- ☐ Northern Oriole
- ☒ Red-winged Blackbird
- ☐ Rusty Blackbird
- ☐ Brewer's Blackbird
- ☐ Brown-headed Cowbird

## GROSBEAKS, FINCHES AND THEIR ALLIES

- ☐ Greater Antillean Bullfinch
- ☐ Black-faced Grassquit
- ☐ Rose-breasted Grosbeak
- ☐ Blue Grosbeak
- ☒ Indigo Bunting
- ☐ Painted Bunting
- ☐ Dickcissel
- ☐ American Goldfinch
- ☐ Savannah Sparrow
- ☐ Grasshopper Sparrow
- ☐ Vesper Sparrow
- ☐ Lark Sparrow
- ☐ Dark-eyed Junco
- ☐ Chipping Sparrow
- ☐ Clay-colored Sparrow
- ☐ White-crowned Sparrow
- ☐ Lincoln's Sparrow
- ☐ Swamp Sparrow
- ☐ Song Sparrow
- ☐ Snow Bunting
- ☐ Yellow-faced Grassquit
- ☒ Cuban Grassquit
- ☒ Cackatoo

NOTE: Please indicate on this form those sightings for which you are unable to make a positive identification.



FROM CORREL AND CORRELL, 1982

BAHAMAS SOLID WASTE AND HAZARDOUS MATERIALS MANAGEMENT PROJECT

**FIGURE B1**  
**Map of Distribution Areas in**  
**The Bahamas**

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<b>APPENDIX C</b>	<b>SPECIFIC OBJECTIVE OF THE EIA</b>
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## **APPENDIX C**

### **SPECIFIC OBJECTIVE OF THE EIA**

In carrying out the Environmental Impact Assessment for the proposed Harrold Road Waste Disposal Facility, the following aspects should be taken into consideration:

- an historical review of waste management practices in New Providence Island and in particular, the existing waste disposal operations at the Harrold Road site;
- identification and description of the physical environmental with respect to the locations of other operations and activities;
- identification and description of the biological environmental with respect to the flora and fauna ecosystems, sensitive habitats, rare and endangered and community species, unique or unusual landscapes, views, vistas, potential protection areas, etc.;
- identification and description of the socio-cultural environmental including any historical and cultural sites, demographic character of the area in question, planned development activities, and the associated problems with scavenging on the existing waste disposal site;
- identification and description of any existing and proposed legislative and regulatory framework which influence the solid waste management program at the site;
- identification and description of any positive and negative environmental, social and economic impacts resulting from the construction and operation of the existing and proposed waste management facilities at the site;
- development of a mitigation and management plan to include recommended feasible and cost effective physical, institutional and educational measures which can be taken to prevent, reduce and/or compensate for unavoidable negative impacts resulting from the proposed facilities; and
- development of a plan to monitor the mitigation and any impacts which may result from the construction and operation of the new sanitary landfill at the Harrold Road site.