US Army Corps of Engineers
Buffalo District

USACE REVIEW DRAFT

TECHNICAL MEMORANDUM

PRELIMINARY FATE, TRANSPORT AND EXPOSURE ANALYSIS MODEL

TOWN OF TONAWANDA LANDFILL

TONAWANDA, NEW YORK

March, 2001

TECHNICAL MEMORANDUM
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TOWN OF TONAWANDA LANDFILL FUSRAP SITE
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1.0 INTRODUCTION

A fate, transport, and exposure analysis model is required to be developed for the Town of Tonawanda Landfill FUSRAP Site. (Refer to Figures 1 through 3 for site location). Due to the nature of the contaminants and the media at the site, analytic modeling rather than numeric modeling will be performed. The movement of contaminants in the environment will be modeled conceptually from primary source(s) to media to which human and/or ecological receptors are exposed. The conceptual site model is a description of site attributes impacting how receptors are exposed to site-related contaminants. The conceptual and exposure analysis models will be presented in tabular as well as graphic form in the Remedial Investigation (RI) Report. The model developed for the RI Report will be developed utilizing data from previous reports and collected during field sampling activities and modified as additional site specific physical, chemical, and geological data becomes available.

This preliminary fate, transport, and exposure analysis model has been developed using existing data prior to field sampling activities. This "draft" model is submitted to the USACE as a Technical Memorandum. The purpose of this model is to document the current information available for the site, and potential exposure routes and pathways. No quantitative assessment of individual or population risk or health effects is made at this time. These will be assessed as part of the "final" model presented in the RI Report, into which data collected during the field activities will be incorporated.

The contaminants, radioactive material attributable to MED related activities, are evaluated as to their persistence in the environment, release and transport mechanisms, and the media in which they may impact potential receptors. Media evaluated includes, soil, surface water, groundwater, and air. Contaminant release mechanisms at the Tonawanda Landfill site include but are not restricted to, erosion by wind, erosion by water, biological uptake, and dissolution. Potential transport mechanisms include wind, surface water runoff, infiltration, groundwater flow, and inadvertent mechanical means.

The exposure analysis determines feasible exposure pathways. Dermal contact, external radiation, ingestion, and inhalation pathways will be evaluated. These pathways will be evaluated in the risk assessment during the exposure assessment as part of the RI. The analysis fate, transport, and exposure will be coordinated with the risk assessment to ensure relevant media, mechanisms, and pathways are evaluated and presented in the conceptual model for the Tonawanda Landfill site. The Superfund Exposure Assessment Manual (USEPA 1988a) will be followed where applicable.

Based on previous information on the site, there is a potential for chemical contaminants of concern (metals and organic compounds) to be present at the site commingled with MED generated materials. The Sampling and Analysis Plan (USACE, 2001) provides for the collection and analysis of soil and groundwater samples for TCL/TAL parameters as part of the proposed radionuclide sampling program. It may be necessary to include chemical contaminant fate and transport analyses with that of the radioactive material should field sampling results indicate the presence of chemical contaminants at elevated concentrations commingled with radioactive contaminants. This preliminary model, however, addresses only radioactive contaminants.

1.1 Background

The Landfill was designated as a FUSRAP vicinity property in 1992 based on field sampling and gamma survey results that indicate the presence of MED-like material at several locations in the now non-operational landfill (ORNL 1992). The MED-like material detected in the Landfill is believed to have been generated at the former Linde Air Products (Linde) Site, Tonawanda, NY and ended up being placed in the Landfill as part of a by-product of wastewater treatment, waste handling, and possibly dredging activities (DOE 1994a, 1994b). Contaminants associated with MED activities for this project consist of radionuclides generated during uranium processing activities at the former Linde site between 1942 - 1948. Contaminants of concern at the Landfill are primarily uranium-238 (U-238), thorium-230 (Th-230), and radium-226 (Ra-226). Based on the historical use of the Landfill, radiological and/or chemical contaminants unrelated to MED activities may also be present at the site, but may only be remediated by USACE if mixed with MED constituents. Previous investigations at the Landfill have indicated a minimum of three locations where MED–like material may be present at the site. (ORNL 1992) (Refer to Figure 4)

The Tonawanda Landfill Site (Site) is located approximately 1.5 miles north of the Linde (Praxair) FUSRAP Site in the Town of Tonawanda, New York (Figure 2). It is comprised of two main parcels – the Town of Tonawanda Landfill and the Mudflats (Refer to Figure 3). These are identified as separate operable units (OUs). The Landfill parcel is located at the northern end of East Park Drive and is bounded by the residential developments to the north and northwest, a railroad line to the east, and a right of way owned by the Niagara Mohawk Power Company (NMPC) to the south. The Mudflats portion of the property is located on the opposite side of the NMPC right of way that borders the Landfill. (Figure 3) The Mudflats parcel is approximately 115 acres and is bordered by the NMPC right-of-way to the north, a railroad line to the east, on the west by the former Town of Tonawanda incinerator, and to the south by the New York State Thruway property. A 48-inch diameter Erie County Water Authority (ECWA) water transmission line traverses through the NMPC easement. ECWA also has another easement for a second parallel 48-inch line through the NMPC right-of-way, for future use. Both properties are owned by the Town of Tonawanda, NY and the area is essentially zoned as commercial/ industrial except for the bordering residential areas referenced above.

2.0 DATA SUMMARY

2.1 Site History and Description

The Tonawanda Landfill Site (Site) is located approximately 1.5 miles north of the Linde (Praxair) FUSRAP Site in the Town of Tonawanda, New York (Figure 2). The Tonawanda Landfill site is approximately 170 acres in size and is divide into two parcels – the former Town of Tonawanda Landfill (55 acres) and the Mudflats (115 acres). Both parcels are owned by the Town of Tonawanda. The two properties are separated by a right of way belonging to the Niagara Mohawk Power Company (NMPC). (Wehran, 1994)

The Landfill parcel is located at the northern end of East Park Drive and is bounded by the residential developments to the north and northwest, a railroad line to the east, and a right of way belonging to the NMPC to the south. The Mudflats portion of the property is located on the opposite side of the NMPC right of way that borders the Landfill. The Mudflats parcel is approximately 115 acres and is bordered by the NMPC right of way to the north, a railroad line to the east, on the west by the former Town of Tonawanda incinerator, and to the south by the New York State Thruway property. One 48-inch diameter ECWA water transmission line traverses through the NMPC easement. (Figure 3) ECWA has an easement for the installation of a second water main. (Wehran, 1994)

In the early 1900s, the property contained a quarry reportedly in the northwest corner which was abandoned when groundwater was encountered some 60 ft below the surface. Landfill operations began in the mid-1930s and continued through October of 1989. During its operation, the landfill accepted a range of materials including household wastes, incinerator ash (from the incineration of sewage treatment plant sludge and municipal waste), and unburned municipal wastes. Although the landfill operated primarily as a sanitary landfill, it was operated prior to passage of the Resource Conversation and Recovery Act (RCRA), thus the types of materials that may have been disposed in the landfill is not well documented. Closure of the landfill has been delayed by the discovery of americium-241 (Am-241) contamination in the northeastern part of the landfill, and MED-like material along the western boundary of the landfill and in the mudflats area. (Wehran, 1994)

In 1984, a radiological flyover survey identified Am-241 in the northeastern portion of the Town of Tonawanda Landfill (See Figure 3) (EG&G 1984). The areas where Am-241 was found are indicated on Figure 4. Two flyovers at different elevation were conducted during this survey (100-ft and 300-ft). Based on these results, the Town of Tonawanda hired TMA/Eberline to characterize the extent of Am-241 contamination in 1987. The Am-241 waste probably originated from an Am-241 metal foil production facility and reached the landfill via the incineration and disposal of waste water treatment sludge (TMA/Eberline 1988). To date there has been no effort to remove Am-241-bearing material from the landfill.

Initial radioactive material surveys for the presence of MED-related contaminants at the Landfill and Mudflats were conducted by the DOE in 1990 as part of the Linde FUSRAP Site investigation. The intent of the survey was to assess whether any radioactive material had been transported and disposed of off-site in the general area surrounding the Linde facility. The preliminary survey was completed using a mobile gamma scanning van. An anomaly in the survey detected in the Mudflats during the mobile scanning activities was verified using handheld gamma screening devices. Subsequent soil samples collected from the area around the anomaly indicated elevated levels of U-238 and Ra-226 - two isotopes consistent with material expected to be in ore processing byproducts generated at the Linde Site (ORNL 1990).

In September of 1991, Oak Ridge National Laboratory (ORNL) conducted a survey of the Town of Tonawanda Landfill and the adjacent mudflats to determine if MED related material from Linde Air Products had been deposited in the landfill. The survey included a surface gamma scan and the collection of soil samples for radiological analyses. A total of 172 samples were collected by ORNL. The ORNL survey did identify material with "...technologically enhanced levels of U-238 not unlike the product material at the Linde plant" and other material "similar to the residues of byproduct of the refinery operation conducted at the Linde plant"(ORNL 1992). The Landfill and Mudflat were subsequently designated as a Vicinity Property of the Linde FUSRAP Site (DOE 1992).

DOE conducted additional soil sampling activities at the Landfill and Mudflats in 1994 to determine the vertical extent of the radiological contamination at the site. Analytical results obtained for subsurface soil, sediment, surface water, and groundwater samples indicated the radiological contamination was essentially limited to the upper 1.5 feet of soil. However, contamination was detected in one sample collected 11.5 feet below existing grade (BNI 1995a).

USACE completed a Radiological Human Health Assessment for the Landfill and Mudflats site in February, 1999. After reviewing several closure scenarios and the radiation doses and health risks associated with each alternative, USACE concluded that if the Landfill was closed with radiologically impacted soil left in place and if the Landfill is properly maintained after closure, risk of exposure to the public would be well within the acceptable CERCLA risk range. The assessment also concluded that if the Mudflats area is developed for industrial use it could pose a public health risk. Closure scenarios for the Landfill addressed during the assessment included capping the contaminated soil in place and excavation and removal of the impacted soil. Closure alternatives evaluated for the Mudflats area included no action, covering the impacted area with clean soil, and excavation and removal of impacted soil (USACE 1999b).

In addition to the potential MED-related material identified in the Landfill and Mudflats areas of the site, a previous investigation conducted by the DOE in 1984 indicated the presence of a non MED-related radionuclide, Am-241, contaminated material in two locations in the Landfill portion of the site (EG&G 1984). The source of the Am-241 was found to be a nearby former radioactive components manufacturing facility that

discharged Am-241 contaminated material to the sanitary sewer which ultimately ended up in the wastewater sludge generated by the municipal water treatment plant. Wastewater sludge was commonly brought to the incinerator for incineration and then interned at the Landfill. The Am-241 material in the Landfill was attributed to the spread of contaminated ash generated by the incinerators (EG&G 1984). Subsequent investigations by the Town of Tonawanda (TMA/Eberline 1988) and others confirmed the presence of Am-241 contaminated material in the Landfill. A subsequent report also confirms the presence of a third area of Am-241 contaminated material (TMA/Eberline 1988). To date, there have been no removal or remedial actions associated with the Am-241 contaminated material identified in the Landfill. However, the Town and the State of New York have determined that the material will remain in the landfill, first covered with 3 feet of compacted fill followed by construction of the final cover system. (NYSDOH, 1989)

2.2 Process Description and Site Activities

Landfilling operations at the site began in approximately the mid-1930's and continued intermittently until October 30, 1989, when all landfilling activities ceased. The western half of the landfill has been basically unused since 1961 and is somewhat covered and vegetated, as previously noted. Since 1970, the eastern areas have been used primarily for disposal of household rubbish, construction and demolition (C&D) material, incinerator ash, incinerator bypass (refuse) and leaves. The only putrescible waste placed in the landfill came from the incinerator bypass between the years 1970 and 1982. During that time, approximately 750 tons were brought in. Since 1982, all putrescible wastes from the Town were taken to a private landfill located along River Road in the Town of Tonawanda or the Occidental Chemical Corporation energy from waste facility in Niagara Falls, New York. Only non-putrescible wastes have been disposed in the landfill since 1983, with approximately 9,000 tons/year of household rubbish, C&D material, yard wastes and approximately 2,300 tons/year of incinerator ash. All waste placement was conducted in approximate two foot horizontal lifts spread and compacted with a bulldozer. (Wehran 1994)

Although neither the Landfill nor the Mudflats were directly involved with activities normally covered under the FUSRAP program, the Site was designated a FUSRAP Vicinity Property (DOE 1992) due to the potential for MED-related material from the Linde Site having been placed in the Landfill. The Linde Site is the former location of ore processing activities by the Linde Air Products Division (Linde) of the Union Carbide Corporation of Tonawanda, New York. Linde performed these activities under contract to the MED and Atomic Energy Commission (AEC) between 1942 and 1948. Processing activity by-products consisted mainly of solid filter cake and liquid filtrate. Between 1942 and 1944, the liquid filtrate was discharged directly to the municipal sanitary sewer collection system for treatment by the Town WWTP. Sludges generated by the WWTP were either directly placed in the Landfill or incinerated at the Landfill and then interned (Wehran 1994)

Am-241 contamination has also been encountered at the Town of Tonawanda Landfill. This waste material is not MED-related and has not been found to be commingled with the MED-related material. It has been attributed to EAD Metallurgical, Inc., who received a license for use of radioactive materials in March 1977 from the State Department of Labor (DOL). The principle product was foil elements for use in smoke detectors. A commercial firm (ENSA) was hired by EAD in 1984 to complete the decontamination that EAD employees had begun. In the process of decontamination, ENSA found indications that there could have been releases of Am-241 to the sanitary sewers while EAD was in operation, or during earlier decontamination efforts, or both. (Wehran 1994)

The Town of Tonawanda has a relatively new sewage treatment plant, which includes an incinerator to effect a volume reduction in the sludge. Some of the ash from the incinerated sludge was used as a top cover at the nearby sanitary landfill. The NYSDEC representative obtained a sample of the ash from incinerator #2, shut down in July 1983, at the sewage treatment plant, and from an area in the landfill where the material was placed at the surface about two years prior. Both samples contained elevated levels of Am-241, the incinerator ash having 500 ±150 pCi/g and the two-year old ash having 300 ±100 pCi/g. (All samples, other than water and wipe samples, are reported in concentrations per dry weight.) (Wehran 1994)

Following the analysis of these samples, personnel from DOH and DOL visited the sewage treatment plant and landfill. At the plant, about 40 wipe samples were taken to determine the extent of in-plant contamination. Radiation instrument surveys were carried out throughout the landfill area, and areas were found where radiation levels were several times the background in the area. The finding of elevated radiation levels at the landfill, together with high levels of Am-241 in the incinerator ash indicated there was wide-spread contamination, which probably happened over a period of time, and was associated with the EAD operation, the only facility in Tonawanda using Am-241 in appreciable amounts. (Wehran 1994)

2.3 Historical Information

Radiological results for the Landfill are summarized in Tables 1 and 2. Locations of these borings and monitoring wells are shown in Figures 4, 5 and 6. Figure 7 shows the historic sample locations on the full plan of the Tonawanda Landfill Site.

The western edge of the Mudflats and the northwestern portion of the landfill have been identified as possibly containing MED-related contaminants. (Refer to Figure 4)

2.4 Physical Setting

The Tonawanda Landfill site is approximately 170 acres in size and is divided into two parcels – the former Town of Tonawanda Landfill (55 acres) and the Mudflats (115 acres). Both parcels are owned by the Town of Tonawanda. Preliminary grading by the Town of Tonawanda of the landfill portion of the site in preparation for closure was ongoing as of March, 2000.

2.4.1 Surface Topography

The landfill portion of the site is located north of the Mudflats area on the opposite side of the NMPC power line easement and bordered by a residential subdivision to the north and northwest, a railroad easement to the east, the NMPC easement to the south. The western portion of the landfill parcel has some hilling and mounding but is mostly sloping towards the west/northwest. Vegetative cover in the western portion of the landfill is limited to grass, scrub trees, and bushes. The eastern portion of the landfill parcel is more heavily vegetated than the western portion. Several large willow trees and brush consistent with wetlands overgrowth are present over a majority of the eastern half of the site. Portions of the western half of the landfill adjacent to the residential abutters have been maintained as lawn with a substantial grass base. The eastern portion of the landfill is gently sloping to the north/northeast with plateaued regions along the southern border of the parcel adjacent to the NMPC easement. A small stream was noted near the northern boundary of the parcel. Maximum change in elevation over the landfill parcel is estimated to be 20 feet. (Wehran 1994)

The Mudflats portion of the parcel is located south of the landfill on the opposite side of the NMPC easement. The parcel is bordered to the east by a railroad easement, the former Town of Tonawanda incinerator facility to the west, and the New York Thruway to the south. The Mudflats cover approximately 115 acres with very little topographic relief. Soil mounding was observed along the northern boundary the Mudflats parcel near the NMPC easement. Vegetative cover over the area mainly consists of overgrown grass, brush, and small scrub trees. A bank of large trees was noted along the southern border of the property. Ephemeral streams and ponding were noted at several locations at the site. The only building on the Mudflats parcel is the former Tonawanda incinerator structure. (Wehran 1994)

2.4.2 Geology

Previous test borings at the site indicate unconsolidated soil deposit depths between 56 and 95.5 feet. The deposits increase in thickness in an east to west direction over the site. Three geologic units have been noted during boring advancement at the site. The uppermost layer is composed of red/brown silty clay glacial till with layered thickness between 48 to 63 feet. Lacustrine silt and clay was encountered beneath the silty clay till layer in some locations throughout the site. Lacustrine silt and clay lenses ranged up to 25 feet in thickness. Several other locations where Lacustrine material was not detected

indicated layers of silty sand and gravel ranging between 8 and 12 feet thick. (Wehran 1994)

The red brown glacial till is mainly comprised of silt and clay size particles with some sand and gravel. The material is generally stiff and its layers were not continuous throughout the site. Tests on soil samples indicated mean hydraulic conductivity results of 7.5×10^{-6} cm/sec in the Landfill and 3.7×10^{-6} cm/sec in the Mudflats. (Wehran 1994)

Lacustrine deposits were gray in color and consisted mainly of clay with some silt and a trace of fine sand and gravel. Vertical hydraulic conductivity was measured at 2×10^{-8} cm/sec for a sample collected from this material. (Wehran 1994)

The silty sand and gravel layer consisted of sand and gravel with some silt and a trace of clay. Field permeability tests indicate a hydraulic conductivity of approximately 3×10^{-5} cm/sec. (Wehran 1994).

Bedrock is made up of Camillus Shale and slopes towards the west. The elevation of the bedrock ranges between 512 feet to 550 feet above mean sea level. Thin seams of gypsum were visible in core samples collected from one location. (Wehran 1994)

2.4.3 Hydrogeology

The Tonawanda Landfill site lies within the Erie-Ontario Lowlands Physiographic Province. Topography in the region is considered relatively low lying with little relief. Bedrock in the area is the Camillus Shale of Silurian Age. Regional bedrock slopes in southeasterly direction and is comprised of shale layers and nodules. Upper regions of the shale are highly weathered and pervious with high water yields. Glacial events over the past 10,000 years have left unconsolidated deposits over the bedrock (Wehran 1994).

The Niagara Falls End Moraine passes through a portion of the site in a northerly direction and consists of ablation and lodgment till. Lodgment till is noted to be more compact and less permeable than the ablation till. Till noted in the area consists mainly of silt, clay with some gravel and sand inclusions. Lacustrine deposits are also present in the area and consist of silt, sand, and clay. They are thinly bedded to massive and generally have a greater permeability in the horizontal direction along bedding planes than in the vertical direction. (Wehran 1994)

Groundwater flow in the glacial till at the site was found to be generally in a southerly direction. A groundwater mound was encountered in the landfill area due to increased infiltration through the landfill material resulting in higher water levels and lowered hydraulic gradients for this area. Depth to water was measured at 5 feet around the landfill and 5–10 feet in the Mudflats portion of the site. Horizontal groundwater gradients were measured at 0.003 feet/feet and 0.02 feet/feet in the Landfill and Mudflats, respectively. Average linear velocity of groundwater flow was 3.5 feet/year and 1.4 feet/year in the Landfill and Mudflats, respectively. (Wehran 1994)

The regional direction of deep groundwater flow in both the sand and gravel layers and bedrock were found to be in a generally northward direction toward the Niagara River. Average linear velocities in the sand and gravel layer was estimated at 2 feet/year. (Wehran 1994)

2.4.4 Hydrology

On March 6, 1989, Wehran performed a visual reconnaissance of the landfill site to monitor existing surface water conditions and check for leachate breakouts. The results of this inspection are summarized below:

- No perennial streams are located on the site.
- Natural drainage is provided along the north side of the site by existing swales which flow to both the east-southeast and west-northwest. Drainage along the south side is not channelized, but rather is a sheet-type flow to the south toward the Mudflats.
- The majority of the surface drainage is ultimately to Two Mile Creek located west of the site.
- Swampy areas occur in the north central and southeast portions of the site during wet times of the year due to poor drainage in these areas.
- Some minor leachate seeps were observed in the northwest and southeast corners of the landfill.

It is to be noted that historically the landfill has not had any serious problems with leachate breakouts (NYSDEC records and files). However, it is understood that any leachate encountered during or following closure of the landfill will have to be handled properly. (Wehran 1994)

3.0 PRELIMINARY FATE, TRANSPORT AND EXPOSURE ANALYSIS MODEL

3.1 Fate and Transport Assessment

3.1.1 Contaminants

The MED-related contaminants of concern are U-238, Th-230 and Ra-226. Other, non-MED related contaminants, including Am-241 and chemical contaminants, are also present.

3.1.2 Persistence in the Environment

The MED-related radionuclides are characterized by a long radioactive half-life. Depending on the chemical form and the pH in the environment, their solubility can range from insoluble to fairly soluble.

Half-lives for the primary contaminants of concern are as follows (GE, 1983):

U-238:	4.468×10^9 years
Th-230:	7.54×10^4 years
Ra-226:	1600 years

3.1.3 Media and Receptors

3.1.3.1 Media

Soil

The soil at the Town of Tonawanda Landfill and the Mudflats is the primary medium for the radioactive contamination. Refer to Table 1 for a summary of radionuclide concentrations in the soil. Soil data is tabulated from the ORNL report (ORNL 1992), NYSDOH investigations (NYSDOH, 1989), Bechtel investigations (BNI 1995b) and Malcolm Pirnie waste/fill investigations (MP 2000).

Surface Water

There is no expected surface water contamination. The only available pathway is runoff from contaminated soil areas.

Groundwater

There is limited MED-related contamination of the shallow groundwater at the site. Samples collected in 1999 (MP, 2000) showed 35 pCi/L U-238 for a composite sample from wells L-11, L-2 and L-3, and 19 pCi/L U-238 for a sample from well BM-5. Refer to Table 2). Groundwater and leachate data is tabulated from Malcolm Pirnie quarterly sampling results and a leachate study (MP 1995, MP 1997, MP 2000).

Air

Air is a viable media for radon, generated from the decay of uranium, and for transport of particulates. No air measurements have been reported.

3.1.3.2 Receptors

The following receptors were considered for the 1999 Human Health Risk Assessment (USACE 1999a):

Receptor	Description
Nearest Resident	The nearest resident was not evaluated because the only direct exposure pathway available for a person who does not enter the site is the airborne dust pathway. The landfill is heavily vegetated thus minimizing potential dust emissions. When a remedial action is undertaken, appropriate air monitoring and controls will be initiated at the site prior to the remedial action to ensure compliance with applicable air regulations and to measure potential airborne radioactive dust that might be generated by the remedial activities. Mitigative measures will be instituted if monitoring detects unacceptable offsite migration.
Construction Worker	The construction worker scenario was chosen to estimate dose if the landfill is closed without removal of the radioactive materials. To model the construction worker scenario, the Town of Tonawanda Landfill closure proposal was used to establish the exposure conditions during landfill closure. Landfill closure plans call for placement of a geotextile membrane over the waste, covering the membrane with an 18 inch clay barrier layer, placing a 12 inch gravel barrier protection layer over that, then covering with 6 inches of topsoil to support vegetation. Each layer acts as a shield to reduce the workers' exposure during the construction of subsequent layers.
Recreational User	The recreational scenario is used to represent likely current and near-term future uses. There is some evidence that the area has been used for recreational purposes and many closed landfills have been subsequently developed as parks in the region. To model the recreational exposure, the fraction of time (percent of time) spent outdoors onsite was set to 0.011 (1.1%) representing 0.27 hours per day (USACE 1999a). The actual occupancy factor would likely be lower considering that the areas with elevated radioactivity are localized and isolated, so continuous exposures during recreational activity are unlikely. The recreational cases were modeled with and without cover. The no cover calculation represents current (baseline) conditions. For the future case, a cover depth of 0.9 m (3 ft) was assumed

Receptor	Description
	to represent the minimum depth if the landfill is closed in accordance with the current proposal. In the mudflats area, a 15 cm cover (6 in) is modeled as well as the no cover case.
Industrial Worker	The industrial worker is a likely future use exposure scenario for the mudflats. If the land is developed for commercial or industrial use, it will likely be paved, thus greatly reducing the potential for exposure to radioactive materials. The industrial worker is assumed to be onsite 8 hours per day, spending 1 hour outdoors and 7 hours indoors, for 250 days each year.
Remediation Worker	The remedial worker exposure is evaluated to assess the risk should the soils be excavated. The risk to the remedial worker is directly proportional to the volume of impacted soil (more soil equates to longer excavation times and more contact with radioactive material).

3.1.4 Release and Transport Mechanisms

3.1.4.1 Release Mechanisms

Erosion by Wind
Erosion by wind is a viable release mechanism. The presence of vegetative cover over most of the site minimizes this pathway. Engineering controls would have to be implemented to minimize dust generation during any work on site.

Erosion by Water
Erosion by water is a viable release mechanism. As noted in the previous section, the presence of vegetative cover over most of the site minimizes this pathway.

Biological Uptake
This is a low probability release mechanism, as the landfill and the mudflats are not sources of agricultural products or hunting animals. While uptake may occur to the plants and animals on the site, the pathway is not expected to reach the general population.

Dissolution
Dissolution of the contaminants and entry into the groundwater is possible. However, the groundwater in this region is not used as a drinking water supply, so the impact on the population is expected to be negligible.

3.1.4.2 Transport Mechanisms

Wind

Wind is a viable transport mechanism for the contaminants of concern. Workers, recreational users and offsite residents may be impacted by this pathway. The presence of vegetative cover over most of the site minimizes this pathway.

Surface Water Runoff

Surface Water runoff is a viable transport mechanism for the contaminants of concern. Exposure via this route is expected to be limited, however, as there are no surface water bodies nearby which are used for recreation. The presence of vegetative cover over most of the site also minimizes this pathway.

Infiltration

Infiltration of the contaminants is possible, however the exposure potential of infiltrated contaminants is expected to be extremely low.

Groundwater Flow

Transport of the contaminants of concern via the groundwater is possible. However, the groundwater in this region is not used as a drinking water supply, so the impact on the population is expected to be negligible.

Inadvertent Mechanical Means

This is a possible transport mechanism, primarily related to soils adhering to vehicles and being transported offsite or relocated onsite. Proper site access control and decontamination procedures will minimize the impact of this pathway.

3.2 Exposure Analysis

The exposure analysis determines feasible exposure pathways. Dermal contact, external radiation, ingestion, and inhalation pathways will be evaluated. These pathways will be evaluated in the risk assessment during the exposure assessment.

The following table presents the preliminary assessment of feasible exposure pathways, for each of the considered receptor groups:

Feasible Pathway Assessment

Exposure Pathway	Receptor				
	Nearest Resident	Construction Worker	Recreational User	Industrial Worker	Remediation Worker
Dermal Contact	No	Yes	Yes	Yes	Yes
External Exposure	No	Yes	Yes	Yes	Yes
Inhalation	Yes	Yes	Yes	Yes	Yes
Inadvertent Ingestion	No	Yes	Yes	Yes	Yes
Consumption	No	No	No	No	No

The pathways and release mechanisms are shown in Figure 8.

4.0 PRELIMINARY FATE, TRANSPORT AND EXPOSURE ANALYSIS

An analysis of the fate, transport and exposure of MED-related material at the Town of Tonawanda Landfill is not performed at this time. The information gathered during RI investigations planned for the spring of 2001 (USACE, 2001) will be incorporated into the existing body of information for the site to develop a more detailed model and to perform the analysis.

The analysis will utilize the RESRAD 6.0 (ANL, 2000) computer code to model the potential offsite effects of the radiological contamination at the site. Inputs required for the RESRAD code consist of the following:

- Contaminant location (surface area, volume, location relative to site boundary, location relative to groundwater table).
- Radionuclide isotopes and concentrations.
- Soil density and porosity.
- Hydraulic conductivity and hydraulic gradient.

Information which is planned to be collected (USACE 2001) includes the following:

- Gamma walkover survey.
- Collection of surface and subsurface soil samples. Soil will be analyzed for Ra, Th and U isotopic content. Selected samples will be analyzed for geotechnical parameters and TCL/TAL metals, volatile organic compounds, semi-volatile organic compounds, pesticides and PCBs.
- Collection of groundwater samples from existing wells within the confines of the Site. Groundwater samples will be analyzed for Ra, Th and U isotopic content, total alpha, and total uranium. Data from the wells will be used in conjunction with data from the Town's sampling rounds.
- Physical survey.

The information to be gathered, coupled with previous data from the site, is adequate to address the required inputs for the RESRAD 6.0 computer code.

If non-radiological contaminants are determined to be commingled with MED-related material, separate chemical consequence models will be used to determine the impact of those contaminants.

5.0 REFERENCES

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TABLES

Table 1
Town of Tonawanda Landfill
Radiological Results - Soil

Location	Depth (ft)	Ra-226		U-238		Th-230		Screening	Reference
		Dry Count pCi/g	± pCi/g	Dry Count pCi/g	± pCi/g	Dry Count pCi/g	± pCi/g	cpm (Spa-3)*	
NYSDOH A		1.7	0.7	<3	--	N/A	N/A	N/A	2
NYSDOH B		1.9	0.6	4.7	1.9	N/A	N/A	N/A	2
NYSDOH C		0.7	0.6	110	7	N/A	N/A	N/A	2
B-2-99	12-15	1.5	0.5	<0.5	--	N/A	N/A	N/A	3
B-3-99	14-18	2.2	0.6	0.9	0.5	N/A	N/A	N/A	3
B01-001	0-1.5	4.2	0.27	6.4	2.2	7.9	1.9	60	1
B01-002	1.5-3	2.4	0.32	20.8	5.9	3	0.69	100	1
B01-003	3-5	N/A	N/A	N/A	N/A	N/A	N/A	70	1
B01-004	5-7	N/A	N/A	N/A	N/A	N/A	N/A	80	1
B02-005	0-1.5	4.3	0.39	4.1	2.6	4	1.1	70	1
B02-006	1.5-3	N/A	N/A	N/A	N/A	N/A	N/A	100	1
B02-007	3-5	N/A	N/A	N/A	N/A	N/A	N/A	100	1
B02-008	5-7	N/A	N/A	N/A	N/A	N/A	N/A	80	1
B03-015	0-1.5	1.3	0.18	4.1	0	0.65	0.25	120	1
B03-016	1.5-3	N/A	N/A	N/A	N/A	N/A	N/A	100	1
B03-017	3-5	N/A	N/A	N/A	N/A	N/A	N/A	80	1
B03-018	5-7	N/A	N/A	N/A	N/A	N/A	N/A	80	1
B04-009	0-1.5	58.3	1.7	15	0	1.3	0.46	300	1
B04-010	1.5-3	1.8	0.27	7	0	1.5	0.49	100	1
B04-011	3-5	N/A	N/A	N/A	N/A	N/A	N/A	100	1
B04-012	5-7	N/A	N/A	N/A	N/A	N/A	N/A	80	1
B04-013	12.5-14.5	N/A	N/A	N/A	N/A	N/A	N/A	BKG	1
B04-014	14.5-16.5	N/A	N/A	N/A	N/A	N/A	N/A	BKG	1
B05-026	0-1.5	1.3	0.16	33.3	8.4	92	3.4	200	1
B05-027	1.5-3	557	14.7	230	60.7	376		2000	1
B05-028	3-5	124	3.1	585	148	158	38	6000	1
B05-029	5-7	19.1	0.73	244	60.2	25.5	6.4	500	1
B05-030	7-9	24.3	0.76	244	60.9	35.7	11.2	800	1
B05-031	9-11	8.4	0.35	220	55.5	2.9	0.84	20000	1
B05-032	11-11.5	8.1	0.36	96.8	24	3.6	0.9	80	1
B05-033	11.5-12.5	0.97	0.16	6.1	1.9	1.1	0.39	80	1
B06-019	0-2	N/A	N/A	N/A	N/A	N/A	N/A	80	1
B06-020	2-4	N/A	N/A	N/A	N/A	N/A	N/A	80	1
B06-021	4-6	N/A	N/A	N/A	N/A	N/A	N/A	90	1
B06-022	6-8	N/A	N/A	N/A	N/A	N/A	N/A	990	1
B06-023	8-10	N/A	N/A	N/A	N/A	N/A	N/A	100	1
B06-024	10-12	N/A	N/A	N/A	N/A	N/A	N/A	80	1
B06-025	20-22	N/A	N/A	N/A	N/A	N/A	N/A	80	1

Table 1
Town of Tonawanda Landfill
Radiological Results - Soil

Location	Depth (ft)	Ra-226		U-238		Th-230		Screening	Reference
		Dry Count pCi/g	± pCi/g	Dry Count pCi/g	± pCi/g	Dry Count pCi/g	± pCi/g	cpm (Spa-3)*	
B07-034	0-2	N/A	N/A	N/A	N/A	N/A	N/A	100	1
B07-035	2-4	N/A	N/A	N/A	N/A	N/A	N/A	120	1
B07-036	8-10	N/A	N/A	N/A	N/A	N/A	N/A	100	1
B07-037	10-12	N/A	N/A	N/A	N/A	N/A	N/A	100	1
B07-038	12-14	N/A	N/A	N/A	N/A	N/A	N/A	80	1
B07-039	14-16	0.32	0	25.1	2.8	2	0.53	80	1
B07-040	16-18	1.2	0.15	27.1	6.9	1.4	0.37	180	1
B07-041	20-22	0.51	0.13	3.4	0	1.5	0.48	80	1
B08-046	0-2	N/A	N/A	N/A	N/A	N/A	N/A	80	1
B08-047	2-4.5	N/A	N/A	N/A	N/A	N/A	N/A	80	1
B08-048	4.5-7	N/A	N/A	N/A	N/A	N/A	N/A	100	1
B08-049	7-9.5	N/A	N/A	N/A	N/A	N/A	N/A	80	1
B08-050	9.5-12	N/A	N/A	N/A	N/A	N/A	N/A	80	1
B08-051	12-14.5	N/A	N/A	N/A	N/A	N/A	N/A	100	1
B08-052	17-19.5	N/A	N/A	N/A	N/A	N/A	N/A	100	1
B08-053	19.5-22	1.7	0.18	18.6	4.9	1.9	0.49	80	1
B08-054	22-24.5	0.7	0.1	3.1	1.1	1.5	0.53	80	1
B09-055	0-2.5	N/A	N/A	N/A	N/A	N/A	N/A	80	1
B09-056	2.5-5	N/A	N/A	N/A	N/A	N/A	N/A	80	1
B10-057	0-2.5	N/A	N/A	N/A	N/A	N/A	N/A	80	1
B10-058	2.5-5	N/A	N/A	N/A	N/A	N/A	N/A	80	1
SD1-042	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1
SD2-043	N/A	521	45.7	48.2	12.9	0.2	0.27	N/A	1

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Location	Depth (ft)	Ra-226 Dry Count pCi/g	Ra-226 ± pCi/g	U-238 Dry Count pCi/g	U-238 ± pCi/g	Th-230 Dry Count pCi/g	Th-230 ± pCi/g	Screening cpm (Spa-3)*	Reference
SYSTEMATIC SAMPLES - LANDFILL - WESTERN PORTION									
S1	0-0.5	0.8	0.02	<2.5	N/A	<7.7	N/A	N/A	4
S2	0-0.5	0.92	0.02	<2.0	N/A	<6.3	N/A	N/A	4
S3	0-0.5	0.93	0.02	1.5	0.6	<4.5	N/A	N/A	4
S4	0-0.5	1	0.03	3.3	1	<8.8	N/A	N/A	4
S5	0-0.5	0.9	0.02	1.2	0.5	<4.6	N/A	N/A	4
S6	0-0.5	0.77	0.02	1	0.8	<6.1	N/A	N/A	4
S7A	0-0.5	0.85	0.02	1.2	0.8	<6.1	N/A	N/A	4
S7B	0.5-1	0.99	0.02	1.6	0.5	<4.0	N/A	N/A	4
S7C	1-1.5	0.94	0.02	1.1	0.7	<8.3	N/A	N/A	4
S8	0-0.5	0.92	0.02	0.92	0.8	<8.6	N/A	N/A	4
S9	0-0.5	1	0.03	2	0.5	<12	N/A	N/A	4
S10	0-0.5	0.96	0.02	1.5	0.5	<4.7	N/A	N/A	4
S11	0-0.5	0.96	0.02	1.4	0.8	<8.4	N/A	N/A	4
S12	0-0.5	0.95	0.02	<1.5	N/A	<7.6	N/A	N/A	4
S13	0-0.5	1.7	0.02	2.3	0.8	<11	N/A	N/A	4
S14A	0-0.5	0.96	0.02	1.1	0.8	<9.5	N/A	N/A	4
S14B	0.5-1	0.9	0.03	2.1	0.7	<15	N/A	N/A	4
S14C	1-1.5	0.79	0.03	1.2	0.9	<7.8	N/A	N/A	4
S15	0-0.5	0.75	0.02	0.52	0.3	<3.2	N/A	N/A	4
S16	0-0.5	1.1	0.02	1.4	0.4	<12	N/A	N/A	4
S17A	0-0.5	0.79	0.02	<1.4	N/A	<8.4	N/A	N/A	4
S17B	0.5-1	0.95	0.03	0.98	0.7	<7.1	N/A	N/A	4
S17C	1-1.5	0.76	0.02	1	1	<7.4	N/A	N/A	4
S18	0-0.5	0.89	0.02	1.4	0.9	<8.0	N/A	N/A	4
S19	0-0.5	0.85	0.02	1.4	0.6	<4.7	N/A	N/A	4
S20	0-0.5	0.6	0.02	0.92	0.6	<5.2	N/A	N/A	4
S21	0-0.5	0.89	0.03	1.8	1	<7.1	N/A	N/A	4
S22	0-0.5	0.8	0.04	1.4	0.4	<11	N/A	N/A	4
S23	0-0.5	0.62	0.02	1.1	0.5	<3.8	N/A	N/A	4
S24A	0-0.5	0.85	0.02	1	0.4	<4.3	N/A	N/A	4
S24B	0.5-1	0.87	0.02	1	0.6	<4.9	N/A	N/A	4
S24C	1-1.5	0.8	0.02	1.8	0.7	<4.9	N/A	N/A	4
S25	0-0.5	1.7	0.02	2.2	0.8	<9.3	N/A	N/A	4
S26A	0-0.5	1	0.02	<2.4	N/A	<8.4	N/A	N/A	4
S26B	0.5-1	0.85	0.02	<1.1	N/A	<9.0	N/A	N/A	4
S26C	1-1.5	0.84	0.02	1	0.6	<8.5	N/A	N/A	4
S27	1-1.5	0.82	0.02	1.1	0.4	<4.1	N/A	N/A	4
S28A	0-0.5	0.81	0.02	0.74	0.5	<4.3	N/A	N/A	4
S28B	0.5-1	0.81	0.02	1.1	0.5	<4.4	N/A	N/A	4
S28C	1-1.5	0.86	0.03	1.1	0.9	<8.6	N/A	N/A	4
S29	0-0.5	0.99	0.02	1.4	0.9	<11	N/A	N/A	4
S30	0-0.5	0.83	0.02	<1.5	N/A	<9.0	N/A	N/A	4
S31	0-0.5	0.87	0.02	1.2	0.6	<7.0	N/A	N/A	4
S32	0-0.5	1.4	0.02	1.6	0.8	<8.8	N/A	N/A	4
S33	0-0.5	0.79	0.02	<1.2	N/A	<8.1	N/A	N/A	4
S34	0-0.5	0.82	0.02	0.88	0.5	<4.3	N/A	N/A	4
S35	0-0.5	1.1	0.03	2.9	1	<8.1	N/A	N/A	4
S36A	0-0.5	0.85	0.02	0.98	0.3	<4.3	N/A	N/A	4
S36B	0.5-1	0.84	0.02	1.1	0.7	<6.8	N/A	N/A	4
S36C	1-1.5	0.85	0.02	0.98	0.5	<4.3	N/A	N/A	4
S37	0-0.5	0.77	0.02	<1.2	N/A	<5.1	N/A	N/A	4
S38	0-0.5	0.84	0.02	0.83	0.3	<3.2	N/A	N/A	4
S39A	0-0.5	0.64	0.02	1.4	0.8	<6.8	N/A	N/A	4

Table 1
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Location	Depth (ft)	Ra-226		U-238		Th-230		Screening	Reference
		Dry Count pCi/g	± pCi/g	Dry Count pCi/g	± pCi/g	Dry Count pCi/g	± pCi/g	cpm (Spa-3)*	
S39B	0.5-1	0.36	0.02	1.2	0.6	<6.2	N/A	N/A	4
S39C	1-1.5	0.44	0.02	<1.5	N/A	<5.8	N/A	N/A	4
S40	0-0.5	0.89	0.02	1.4	0.7	<10	N/A	N/A	4
S41A	0-0.5	1	0.03	1.5	1	<15	N/A	N/A	4
S41B	0.5-1	1	0.03	1.5	0.9	<15	N/A	N/A	4
S41C	1-1.5	1	0.02	1.7	1	<11	N/A	N/A	4
S42	0-0.5	0.7	0.01	0.58	0.3	<2.9	N/A	N/A	4
S43	0-0.5	0.8	0.02	0.81	0.3	<4	N/A	N/A	4
S44	0-0.5	0.82	0.02	1.1	0.7	<10	N/A	N/A	4
S45A	0-0.5	0.78	0.02	0.9	0.6	<9.1	N/A	N/A	4
S45B	0.5-1	0.82	0.02	1.1	0.8	<8.0	N/A	N/A	4
S45C	1-1.5	0.81	0.02	1.5	1	<11	N/A	N/A	4
S46	0-0.5	1.5	0.02	2	0.9	<9.8	N/A	N/A	4
S47A	0-0.5	1.3	0.02	2.5	1	<11	N/A	N/A	4
S47B	0.5-1	1.1	0.03	1.8	1	<9.1	N/A	N/A	4
S47C	1-1.5	1.4	0.03	2	1	<17	N/A	N/A	4
S48A	0-0.5	0.91	0.02	1.6	0.8	<9.4	N/A	N/A	4
S48B	0.5-1	0.87	0.03	1.3	1	<7.6	N/A	N/A	4
S48C	1-1.5	0.9	0.02	1.4	0.8	<11	N/A	N/A	4
S49	0-0.5	0.98	0.02	1.9	1	<7.6	N/A	N/A	4
S50	0-0.5	0.68	0.02	0.87	0.4	<3.6	N/A	N/A	4
S51	0-0.5	0.82	0.02	<1.5	N/A	<6.9	N/A	N/A	4
S52	0-0.5	0.76	0.02	0.89	0.5	<4.2	N/A	N/A	4
S53	0-0.5	0.59	0.02	1.5	0.9	<6.6	N/A	N/A	4
S54	0-0.5	1.5	0.08	56	4	<26	N/A	N/A	4
S55	0-0.5	1	0.03	1.4	1	<19	N/A	N/A	4
S56	0-0.5	0.84	0.02	1.5	1	<7.8	N/A	N/A	4
S57A	0-0.5	0.96	0.02	<2.4	N/A	<7.7	N/A	N/A	4
S57B	0.5-1	0.84	0.02	1	0.9	<7.4	N/A	N/A	4
S57C	1-1.5	0.84	0.02	1.9	1	<8.5	N/A	N/A	4
S58	0-0.5	0.81	0.02	0.82	0.7	<6.9	N/A	N/A	4
S59A	0-0.5	0.83	0.02	0.89	0.4	<4.6	N/A	N/A	4
S59B	0.5-1	0.88	0.03	1.8	1	<7.2	N/A	N/A	4
S59C	1-1.5	0.92	0.02	1.4	0.8	<13	N/A	N/A	4
S60	0-0.5	0.66	0.02	1.5	1	<6.7	N/A	N/A	4
S61	0-0.5	0.74	0.02	1.4	1	<7.6	N/A	N/A	4
S62A	0-0.5	1.1	0.03	8.8	0.9	<6.4	N/A	N/A	4
S62B	0.5-1	1.1	0.04	9.6	1	<9.5	N/A	N/A	4
S62C	1-1.5	1	0.03	5.5	1	<6.8	N/A	N/A	4
S63	0-0.5	0.84	0.02	1.3	0.5	<4.2	N/A	N/A	4
S64	0-0.5	0.8	0.02	1.1	0.8	<7.2	N/A	N/A	4
S65	0-0.5	0.72	0.03	1.4	0.9	<7.5	N/A	N/A	4
S66A	0-0.5	0.89	0.02	1.9	1	<9.1	N/A	N/A	4
S66B	0.5-1	0.82	0.02	1.6	0.8	<8.4	N/A	N/A	4
S66C	1-1.5	0.78	0.02	0.33	1	<6.7	N/A	N/A	4
S67	0-0.5	0.8	0.02	2.1	1	<7.1	N/A	N/A	4
S68	0-0.5	0.94	0.02	0.62	0.4	<3.8	N/A	N/A	4
S69A	0-0.5	0.92	0.02	1.9	1	<15	N/A	N/A	4
S69B	0.5-1	1	0.02	1.4	0.8	<10	N/A	N/A	4
S69C	1-1.5	1.2	0.03	2.6	1	<16	N/A	N/A	4
S70	0-0.5	0.63	0.02	2.2	0.9	<6.5	N/A	N/A	4
S71	0-0.5	0.99	0.02	1.2	0.5	<4.7	N/A	N/A	4
S72	0-0.5	0.95	0.03	1.2	1	<8.3	N/A	N/A	4
S73	0-0.5	0.95	0.02	1.6	0.6	<4.9	N/A	N/A	4

Table 1
Town of Tonawanda Landfill
Radiological Results - Soil

Location	Depth (ft)	Ra-226 Dry Count pCi/g	Ra-226 ± pCi/g	U-238 Dry Count pCi/g	U-238 ± pCi/g	Th-230 Dry Count pCi/g	Th-230 ± pCi/g	Screening cpm (Spa-3)*	Reference
BIASED SAMPLES - LANDFILL - WESTERN PORTION									
B3A - ORNL	0-0.5	2.2	0.04	1.8	1	<22	N/A	N/A	4
B3B - ORNL	0.5-1	2.2	0.04	4	2	<11	N/A	N/A	4
B3C - ORNL	1-1.5	1.4	0.03	1.4	0.7	<7.4	N/A	N/A	4
B4A - ORNL	0-0.5	240	0.9	<15	N/A	820	200	N/A	4
B4B - ORNL	0.5-1	5.2	0.05	1.3	1	<9.3	N/A	N/A	4
B5A - ORNL	0-0.5	440	2	<32	N/A	1300	300	N/A	4
B5B - ORNL	0.5-1	120	0.7	78	20	660	100	N/A	4
B5C - ORNL	1-1.5	2.4	0.03	<2.2	N/A	<13	N/A	N/A	4
B3A - NYSDEC	0-0.5	1.5	0.2	2.5	1	N/A	N/A	N/A	4
B3B - NYSDEC	0.5-1	1.7	0.2	0	1	N/A	N/A	N/A	4
B3C - NYSDEC	1-1.5	1.2	0.1	2.2	1	N/A	N/A	N/A	4
B4A - NYSDEC	0-0.5	240	750	0	10	N/A	N/A	N/A	4
B4B - NYSDEC	0.5-1	1.2	1	0	0.9	N/A	N/A	N/A	4
B5A - NYSDEC	0-0.5	2200	4	0	2	N/A	N/A	N/A	4
B5B - NYSDEC	0.5-1	280	1	0	8	N/A	N/A	N/A	4
B5C - NYSDEC	1-1.5	57	0.77	0	3	N/A	N/A	N/A	4
B6A	0-0.5	300	1	57	20	<300	N/A	N/A	4
B6B	0.5-1	75	0.3	18	4	<47	N/A	N/A	4
B6C	1-1.5	11	0.06	4.9	0.8	<9.6	N/A	N/A	4
B7A	0-0.5	170	0.5	120	7	<58	N/A	N/A	4
B7B	0.5-1	2000	6	150	60	4300	400	N/A	4
B7C	1-1.5	1000	9	310	50	<820	N/A	N/A	4
B7D	1.5-2	46	0.7	290	20	<150	N/A	N/A	4
B7E	2-2.5	21	0.5	1800	200	<72	N/A	N/A	4
B8	0-0.5	1.2	0.02	1.3	0.8	<9.9	N/A	N/A	4
B9	0-0.5	3.7	0.04	1.6	1	<9.7	N/A	N/A	4
B10A	0-0.5	2.6	0.04	7.2	1	<15	N/A	N/A	4
B10B	0.5-1	2.6	0.04	5.2	2	<12	N/A	N/A	4
B11A	0-0.5	2.6	0.04	4.2	1	<8.4	N/A	N/A	4
B11B	0.5-1	2.1	0.02	2.4	0.9	<11	N/A	N/A	4
B12A	0-0.5	1.6	0.08	220	7	<82	N/A	N/A	4
B12B	0.5-1	1.5	0.1	170	7	<46	N/A	N/A	4
B12C	1-1.5	2.8	0.1	89	7	<89	N/A	N/A	4

Table 1
Town of Tonawanda Landfill
Radiological Results - Soil

Location	Depth (ft)	Ra-226 Dry Count pCi/g	Ra-226 ± pCi/g	U-238 Dry Count pCi/g	U-238 ± pCi/g	Th-230 Dry Count pCi/g	Th-230 ± pCi/g	Screening cpm (Spa-3)*	Reference
SYSTEMATIC SAMPLES - MUDFLATS AREA (NEAR INCINERATOR)									
S74	0-0.5	1.1	0.02	<2.0	N/A	<11	N/A	N/A	4
S75A	0-0.5	0.96	0.03	1.7	0.6	<5.5	N/A	N/A	4
S75B	0.5-1	0.86	0.02	1	1	<8.0	N/A	N/A	4
S75C	1-1.5	0.86	0.02	1.4	0.7	<5.0	N/A	N/A	4
S76	0-0.5	0.83	0.02	0.79	0.5	<4.3	N/A	N/A	4
S77A	0-0.5	1.9	0.03	2	0.8	<8.0	N/A	N/A	4
S77B	0.5-1	1.3	0.02	1.7	0.9	<11	N/A	N/A	4
S77C	1-1.5	0.97	0.02	1.4	0.6	<4.9	N/A	N/A	4
S78	0-0.5	0.99	0.02	<2.4	N/A	<13	N/A	N/A	4
S79	0-0.5	0.9	0.02	1.4	0.5	<4.3	N/A	N/A	4
S80	0-0.5	0.81	0.02	0.81	0.4	<4.1	N/A	N/A	4
S81A	0-0.5	1.1	0.03	<2.4	N/A	<7.8	N/A	N/A	4
S81B	0.5-1	0.98	0.02	1.5	1	<7.9	N/A	N/A	4
S81C	1-1.5	0.97	0.03	1.7	1	<7.9	N/A	N/A	4
S82	0-0.5	0.97	0.02	1.2	0.9	<10	N/A	N/A	4
S83	0-0.5	0.83	0.02	1.6	1	<7.6	N/A	N/A	4
S84	0-0.5	1.1	0.03	1.5	1	<7.2	N/A	N/A	4
S85A	0-0.5	0.89	0.02	1.5	0.8	<9.5	N/A	N/A	4
S85B	0.5-1	0.94	0.02	1.6	1	1.4	8	N/A	4
S85C	1-1.5	0.91	0.02	1.2	0.8	<11	N/A	N/A	4
S86A	0-0.5	0.89	0.02	1.2	0.5	<4.3	N/A	N/A	4
S86B	0.5-1	1	0.02	<2.5		<11	N/A	N/A	4
S86C	1-1.5	1	0.02	1.2	0.8	<9.8	N/A	N/A	4
S87	0-0.5	0.93	0.02	1.1	0.5	<4.3	N/A	N/A	4
S88	0-0.5	0.97	0.02	1.3	0.5	<4.4	N/A	N/A	4

Table 1
Town of Tonawanda Landfill
Radiological Results - Soil

Location	Depth (ft)	Ra-226		U-238		Th-230		Screening	Reference
		Dry Count pCi/g	± pCi/g	Dry Count pCi/g	± pCi/g	Dry Count pCi/g	± pCi/g	cpm (Spa-3)*	
BIASED SAMPLES - MUDFLATS AREA (NEAR INCINERATOR)									
B3A	0-0.5	11	0.1	18	3	N/A	N/A	N/A	4
B3B	0.5-1	5.4	0.06	16	1	N/A	N/A	N/A	4
B13A	0-0.5	16	0.2	30	4	27	40	N/A	4
B13B	0.5-1	14	0.1	35	2	<21	N/A	N/A	4
B13C	1-1.5	19	0.2	35	4	31	40	N/A	4
B13D	1.5-2	33	0.2	34	4	<67	N/A	N/A	4
B13E	2-2.5	22	0.1	20	2	<20	N/A	N/A	4
B14A	0-0.5	13	0.1	12	3	<26	N/A	N/A	4
B14B	0.5-1	22	0.1	158	2	<22	N/A	N/A	4
B14C	1-1.5	12	0.1	16	1	<15	N/A	N/A	4
B14D	1.5-2	20	0.2	13	3	<28	N/A	N/A	4
B15A	0-0.5	120	0.7	78	20	660	100	N/A	4
B15B	0.5-1	3.5	0.04	2.6	1	<9.9	N/A	N/A	4
B15C	1-1.5	3.4	0.04	3.4	1	<17	N/A	N/A	4
B15D	1.5-2	2.8	0.04	3	1	<17	N/A	N/A	4

References

1. FUSRAP Technical Memorandum No 129-95-002, R1, Sims to Newberry. 11/20/95
2. NYSDOH, 1989
3. Malcolm - Pirnie, 2000
4. ORNL, 1992

* Highest level of range is listed.

Indicating counting error is at the 95% confidence level (± 2σ)

Shading indicates measurement + 2σ exceeds criteria.

Table 2
Town of Tonawanda Landfill
Radiological Results - Leachate/Groundwater

Location	Ra-226		U-238		Th-230		Gross Alpha		Gross Beta		Reference
	pCi/L	± pCi/L	pCi/L	± pCi/L	pCi/L	± pCi/L	pCi/L	± pCi/L	pCi/L	± pCi/L	
Area 1*	3.4	0.7	35.4	5.6	N/A	N/A	124	17.1	278	14.3	2
Area 2**	1.3	0.5	0.8	0.4	N/A	N/A	<22.3	N/A	175	15.9	2
Area 3***	1.1	0.5	19.3	3.2	N/A	N/A	87.2	12.9	143	10.3	2
Area 4****	<0.9	N/A	0.4	0.3	N/A	N/A	27.5	10.4	147	11	2
BM-4 ('96)	N/A	N/A	N/A	N/A	N/A	N/A	14	1.1	18	0.5	4
BM-7 ('95)	N/A	N/A	N/A	N/A	N/A	N/A	<3	N/A	<4	N/A	3
BM-7 ('96)	N/A	N/A	N/A	N/A	N/A	N/A	<5	N/A	<3	N/A	4
BM-13S ('95)	N/A	N/A	N/A	N/A	N/A	N/A	<7	N/A	9.1	3.5	3
BM-13S ('96)	N/A	N/A	N/A	N/A	N/A	N/A	<1	N/A	98.3	3.8	4
BM-13D ('95)	N/A	N/A	N/A	N/A	N/A	N/A	<4	N/A	5.4	2.7	3
BM-13D ('96)	N/A	N/A	N/A	N/A	N/A	N/A	<6	N/A	7.6	3	4
BM-14S ('95)	N/A	N/A	N/A	N/A	N/A	N/A	<6	N/A	11	3	3
BM-14S ('96)	N/A	N/A	N/A	N/A	N/A	N/A	<8	N/A	9.2	3.4	4
BM-14D ('96)	N/A	N/A	N/A	N/A	N/A	N/A	<8	N/A	11	0.4	4
BM-15 ('95)	N/A	N/A	N/A	N/A	N/A	N/A	<7	N/A	10	4	3
BM-15 ('96)	N/A	N/A	N/A	N/A	N/A	N/A	<10	N/A	9.8	3.8	4
BM-16 ('95)	N/A	N/A	N/A	N/A	N/A	N/A	11	9	16	5	3
BM-17 ('95)	N/A	N/A	N/A	N/A	N/A	N/A	15	10	20	5	3
BM-17 ('96)	N/A	N/A	N/A	N/A	N/A	N/A	<10	N/A	15	0.5	4
BM-18 ('95)	N/A	N/A	N/A	N/A	N/A	N/A	<10	N/A	15	5	3
BM-18 ('96)	N/A	N/A	N/A	N/A	N/A	N/A	<20	N/A	17	0.5	4
BM-19 ('95)	N/A	N/A	N/A	N/A	N/A	N/A	12	10	14	5	3
BM-19 ('96)	N/A	N/A	N/A	N/A	N/A	N/A	<10	N/A	18	0.5	
DW-1 ('95)	N/A	N/A	N/A	N/A	N/A	N/A	<5	N/A	<9	N/A	3
DW-1 ('96)	N/A	N/A	N/A	N/A	N/A	N/A	<7	N/A	12	0.4	4
DW-2 ('95)	N/A	N/A	N/A	N/A	N/A	N/A	<4	N/A	20	4	3
DW-2 ('96)	N/A	N/A	N/A	N/A	N/A	N/A	<6	N/A	13	0.3	4
DW-3 ('95)	N/A	N/A	N/A	N/A	N/A	N/A	<3	N/A	12	3	3
DW-4R ('95)	N/A	N/A	N/A	N/A	N/A	N/A	<5	N/A	24	4	3
DW-4R ('96)	N/A	N/A	N/A	N/A	N/A	N/A	<7	N/A	15	0.4	4
Surface Water	521	45.7	48.2	12.9	0.2	0.27	N/A	N/A	N/A	N/A	1
B04-059	12.1	3.3	20.2	5.5	2.4	0.84	N/A	N/A	N/A	N/A	1
B05-060	4.1	2.4	4328	1154	693	0.28	N/A	N/A	N/A	N/A	1

1. FUSRAP Technical Memorandum No 129-95-002, R1, Sims to Newberry. 11/20/95
2. Malcolm - Pirnie, 1999
3. Malcolm Pirnie, 1995
4. Malcolm Pirnie, 1996

* Composite of wells L-1, L-2 and L-3
** Composite of wells L-4 and L-5
*** BM-5
****Composite of wells B-1, B-2, B-3 and B-4
Shading indicates measurement + 2σ exceeds criteria.
Indicating counting error is at the 95% confidence level (± 2σ)

FIGURES

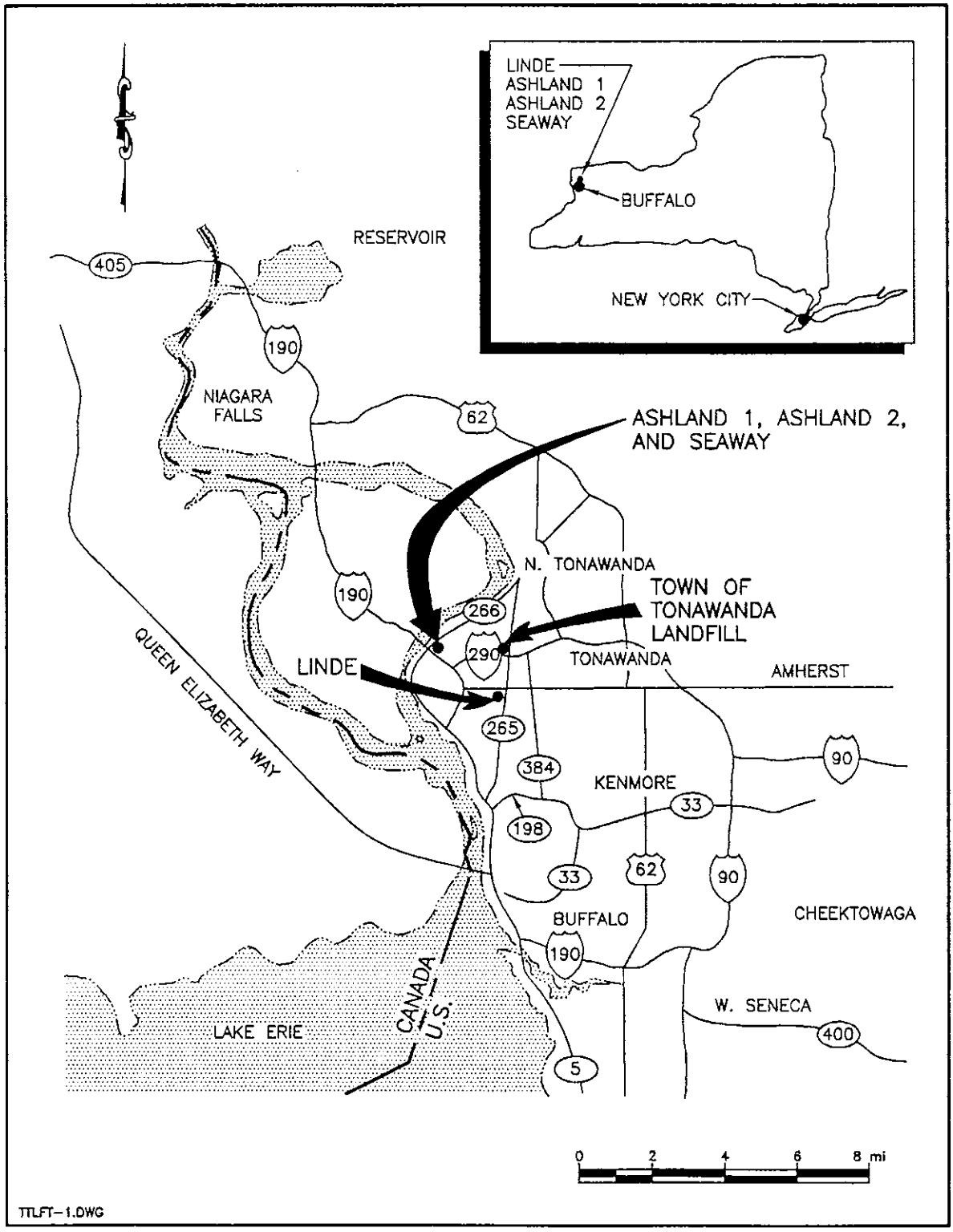
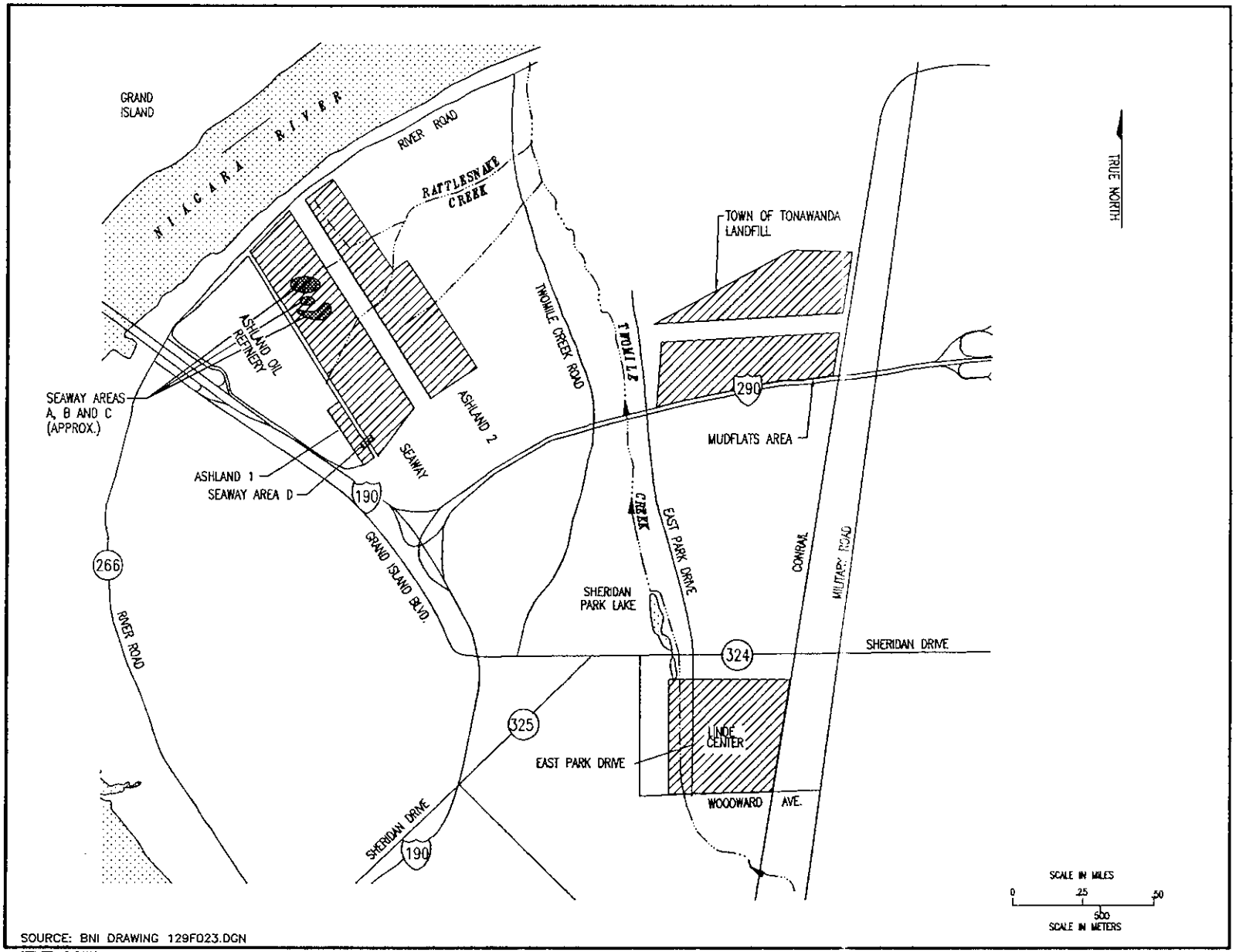


FIGURE 1

REGIONAL LOCATION OF THE TOWN OF TONAWANDA, NEW YORK AND THE ASHLAND 1, ASHLAND 2, SEAWAY, LINDE AND THE TOWN OF TONAWANDA LANDFILL SITES



SOURCE: BNI DRAWING 129F023.DGN
TTLFT--2.DWG

FIGURE 2
LOCATIONS OF ASHLAND 1, ASHLAND 2,
SEAWAY, LINDE AND THE TOWN OF TONAWANDA LANDFILL SITES

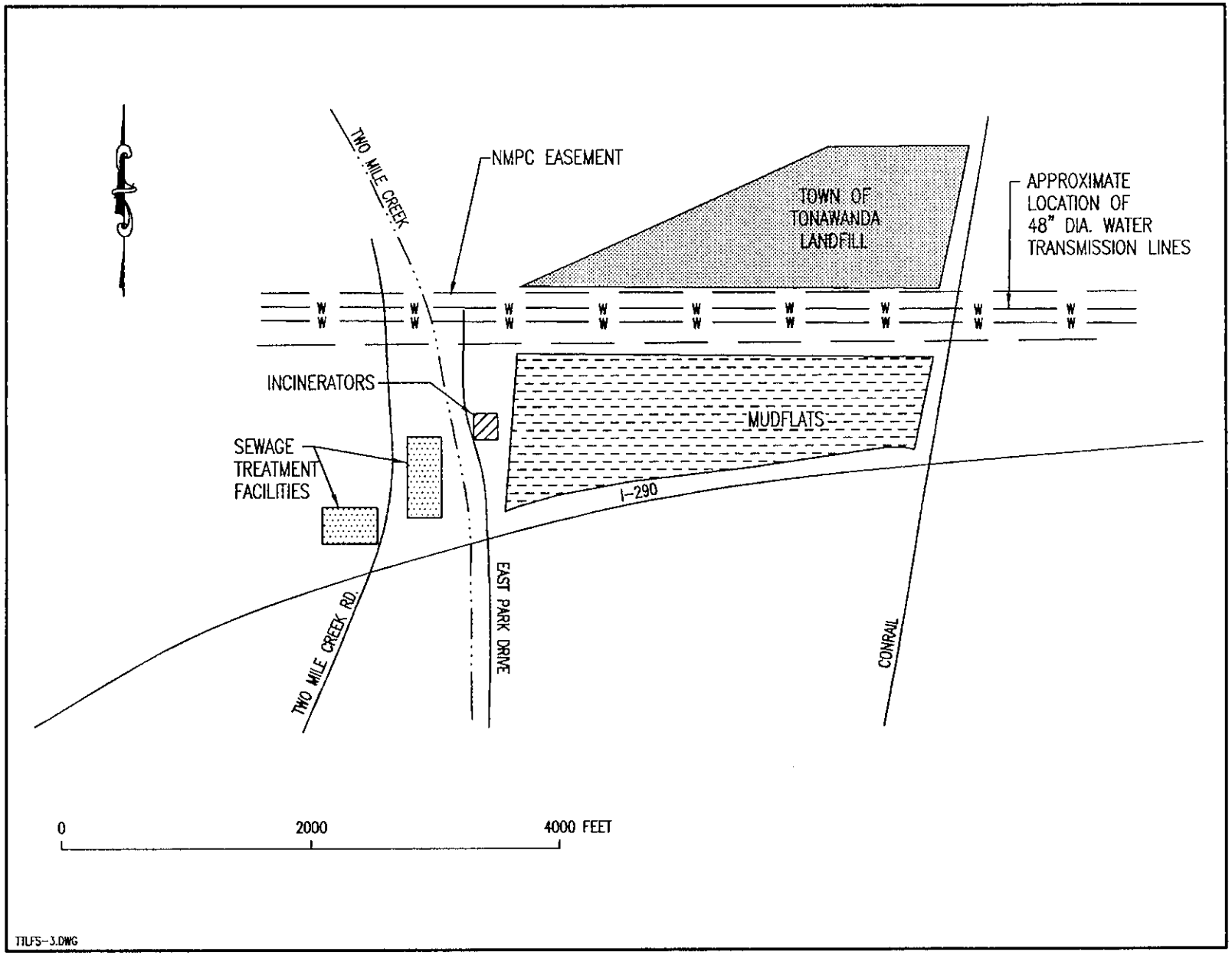


FIGURE 3
TOWN OF TONAWANDA LANDFILL APPROXIMATE LOCATIONS

LEGEND

- ⊗ B-1 — PREVIOUS BORING BY OTHERS
- ● B-1 — BORING BY MALCOLM PIRNIE
- ◆ BM-7 — EXISTING SHALLOW OVERBURDEN WELL BY OTHERS
- ◐ BM-19 — SHALLOW OVERBURDEN WELL BY MALCOLM PIRNIE
- ■ DW-1 — EXISTING DEEP OVERBURDEN WELL BY OTHERS
- ◧ DW-4 — DEEP OVERBURDEN WELL BY MALCOLM PIRNIE
- ⊙ P-1 — PIEZOMETER
- • WP-1 — WELLPOINT
- ✳ LCH-1 — LEACHATE SEEP
- ★ USDOE WASTE DETECTED (FROM ORNL, 1992)
- ▨ AREAS OF AMERICIUM-241 DISPOSAL
- ▨ TARGET AREAS (SEE FIGURES 5 AND 6 FOR GROUND SAMPLE LOCATIONS)

TOWN OF TONAWANDA LANDFILL

NIAGARA MOHAWK POWER CORP.

MUDFLATS AREA

NOTE: THIS DRAWING IS BASED ON PLANS "TONAWANDA LANDFILL SITE PLAN" BY MALCOLM PIRNIE, INC. DATED JUNE 1999 AND "TOWN OF TONAWANDA LANDFILL TEST SITES", BY ENGINEER'S OFFICE, TOWN OF TONAWANDA, N.Y., REV. 1, DATED 9-19-83.

SAIC
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SAIC ENGINEERING, INC.
101 East Grove Street
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DRAWING TITLE: AREAS OF CONTAMINATION AND SAMPLE LOCATIONS

PROJECT: FUSRAP
TOWN OF TONAWANDA LANDFILL
TONAWANDA, NEW YORK

CLIENT: USACE – BUFFALO DISTRICT

SCALE: 1"=350'
DATE: 1-12-01
DRAWN BY: VAL
DRAWING NO.: FIGURE 4
PROJECT NO.: 01-0801-08-1165-200

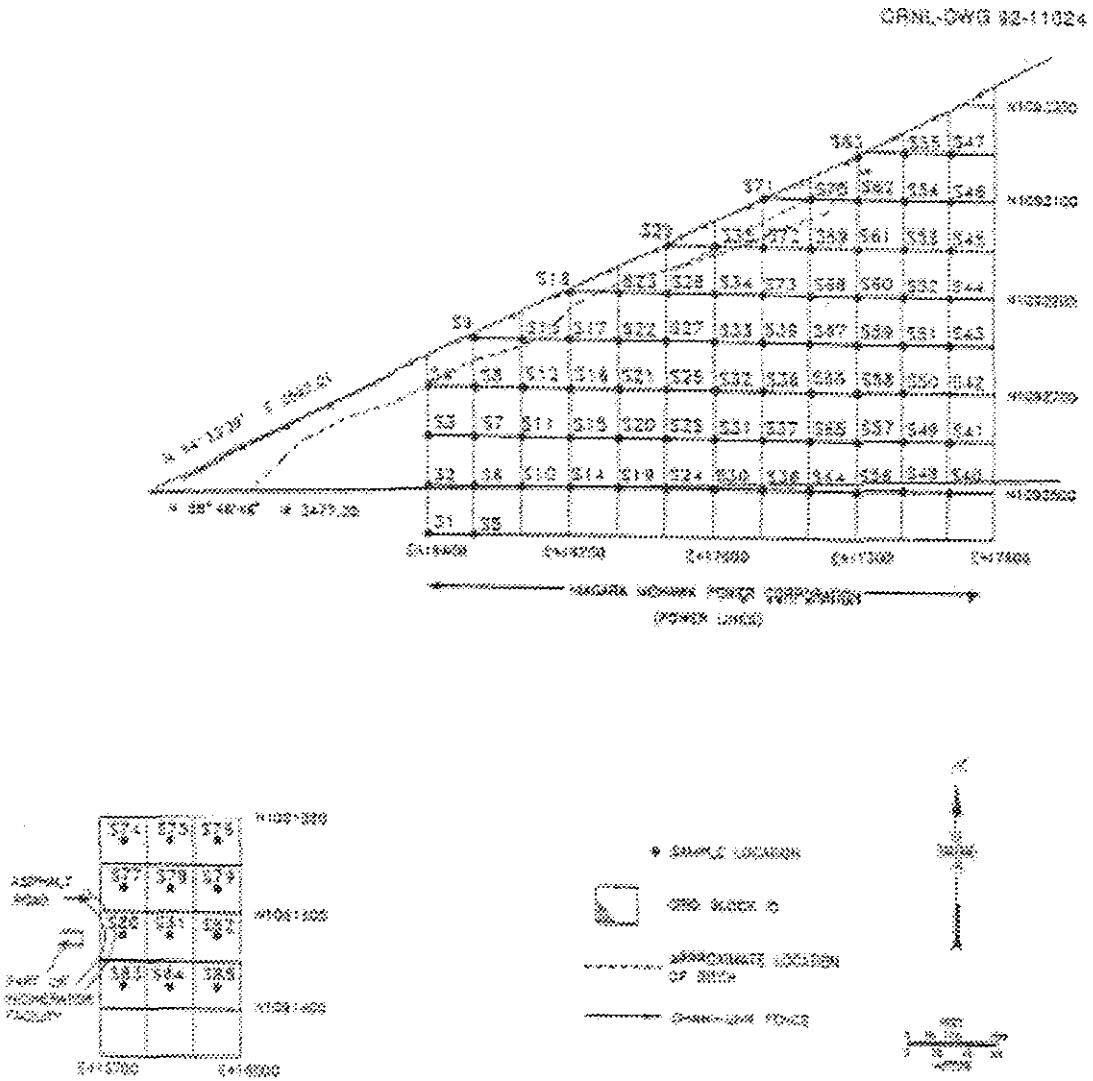

Figure 5

Systematic Soil Sample Locations at the Town of Tonawanda Landfill
(Figure 12 from ORNL 1992)

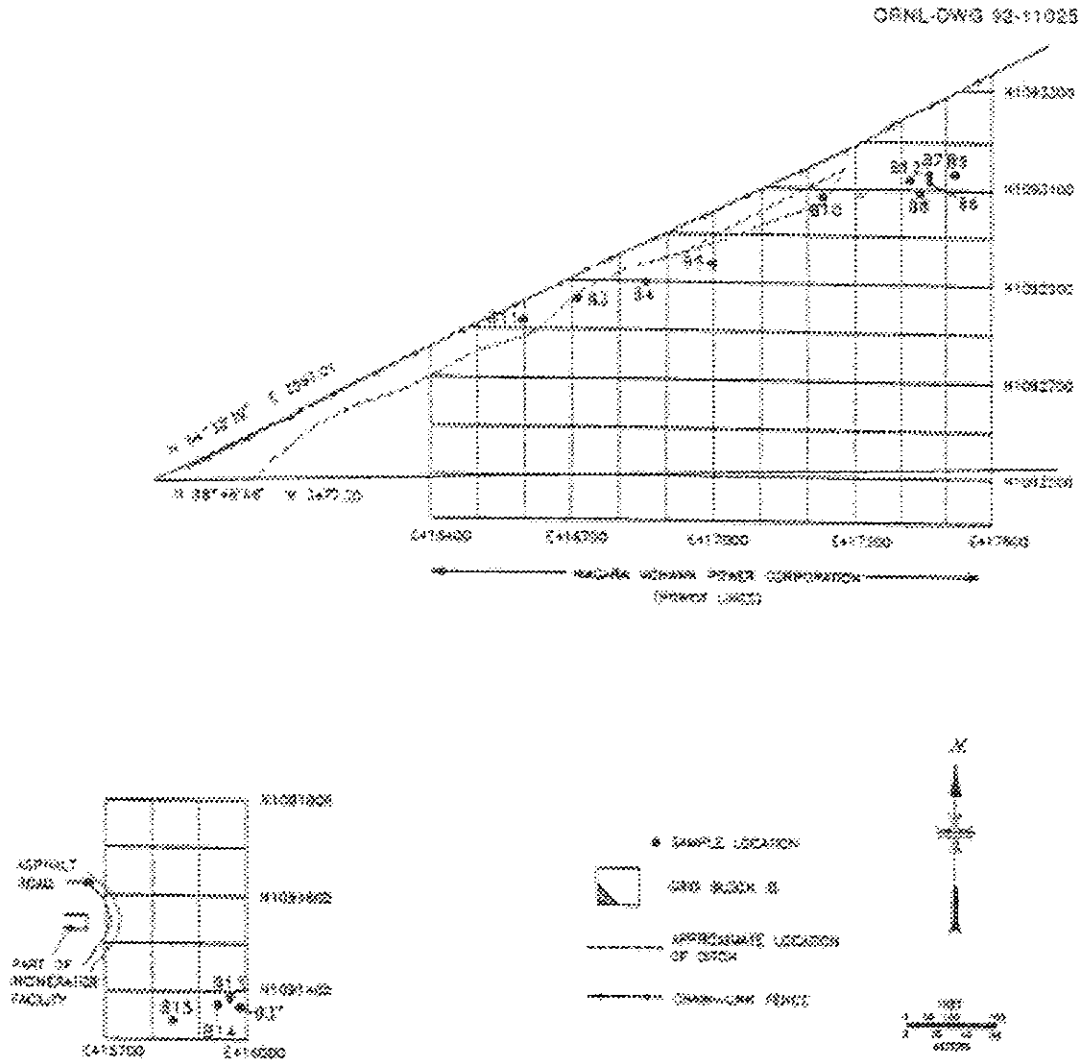

Figure 6

Biased Soil Sample Locations at the Town of Tonawanda Landfill
(Figure 14 from ORNL 1992)

LEGEND

⊗ B-1	PREVIOUS BORING BY OTHERS
● B-1	BORING BY MALCOLM PIRNIE
◆ BM-7	EXISTING SHALLOW OVERBURDEN WELL BY OTHERS
◐ BM-19	SHALLOW OVERBURDEN WELL BY MALCOLM PIRNIE
■ DW-1	EXISTING DEEP OVERBURDEN WELL BY OTHERS
◧ DW-4	DEEP OVERBURDEN WELL BY MALCOLM PIRNIE
⊙ P-1	PIEZOMETER
• WP-1	WELLPOINT
✳ LCH-1	LEACHATE SEEP
★	USDOE WASTE DETECTED (FROM ORNL, 1992 BIASED LOCATIONS)
◒ BM-19	ORNL, 1992 SYSTEMATIC SAMPLE LOCATIONS
▨	AREAS OF AMERICIUM-241 DISPOSAL
▨	TARGET AREAS

TOWN OF TONAWANDA LANDFILL

NIAGARA MOHAWK POWER CORP.

MUDFLATS AREA

NOTE: THIS DRAWING IS BASED ON PLANS "TONAWANDA LANDFILL SITE PLAN" BY MALCOLM PIRNIE, INC. DATED JUNE 1999 AND "TOWN OF TONAWANDA LANDFILL TEST SITES", BY ENGINEER'S OFFICE, TOWN OF TONAWANDA, N.Y., REV. 1, DATED 9-19-83.

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DRAWING TITLE
AREAS OF CONTAMINATION AND HISTORIC SAMPLE LOCATIONS

PROJECT
FUSRAP
TOWN OF TONAWANDA LANDFILL
TONAWANDA, NEW YORK

CLIENT
USACE – BUFFALO DISTRICT

SCALE: 1"=350'
DATE: 3-28-01
DRAWN BY: VAL
DRAWING NO.: FIGURE 7
PROJECT NO.: 01-0801-08-1165-200

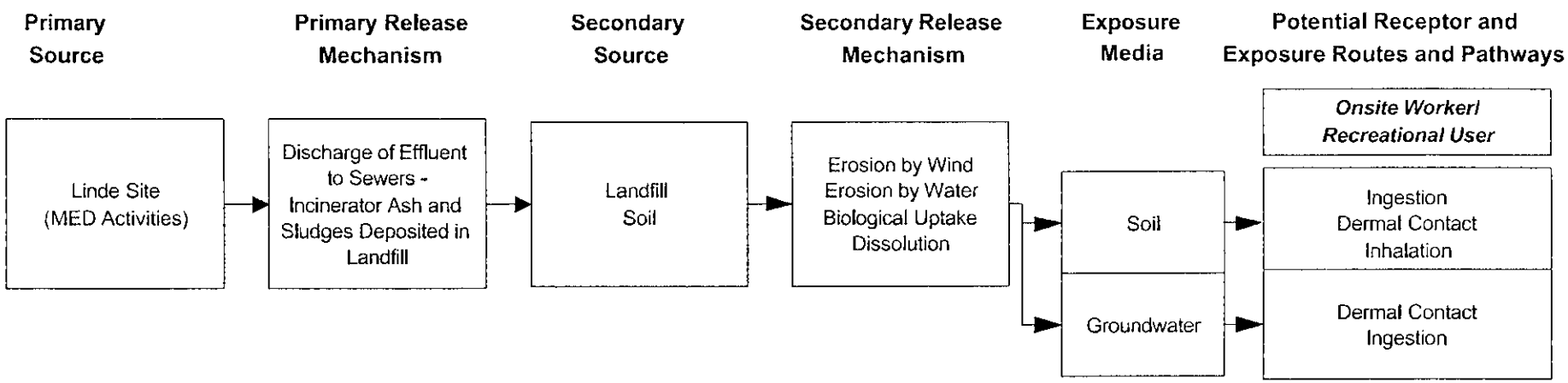

Figure 8

Town of Tonawanda Landfill – Site Conceptual Model