COMMENTS ON THE:
A. FEASIBILITY STUDY; FINAL DRAFT REPORT AND
B. PROPOSED PLAN

Metamora Landfill Site
Lapeer County, Michigan

AUGUST 1990
REF. NO. 3298 (6)

CONESTOGA-ROVERS & ASSOCIATES
GRADIENT CORPORATION

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PREFACE

The 160 acre Metamora Landfill Site (Site) is located approximately 4,000 feet east of the Village of Metamora in Lapeer County, Michigan. The landfill is located in the northeast portion of the Site and covers an area of approximately 25 acres. The Site location is presented on Figure 1.1. A Site Layout Plan is presented on Figure 1.2.

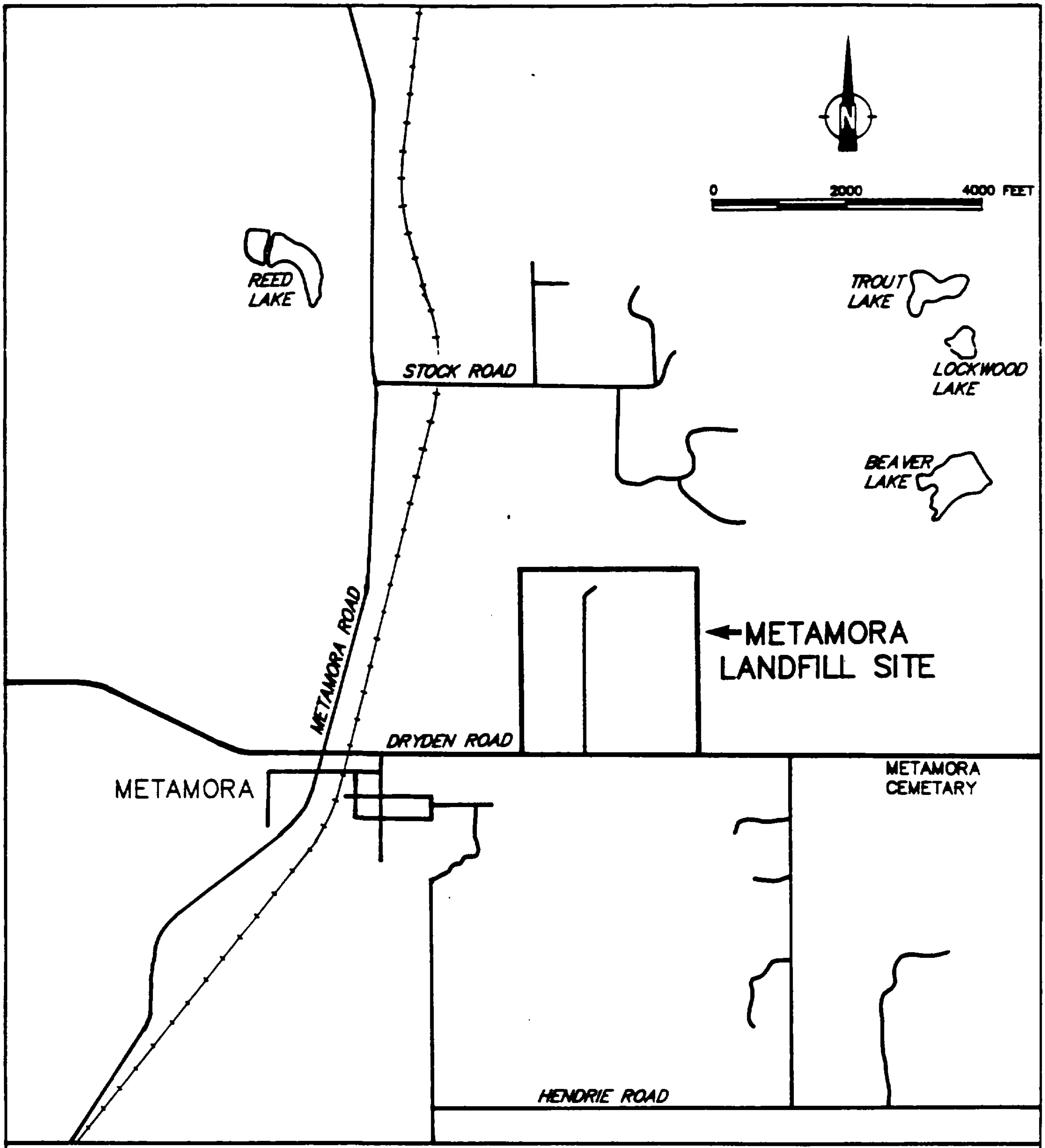
This report presents comments on the following documents:

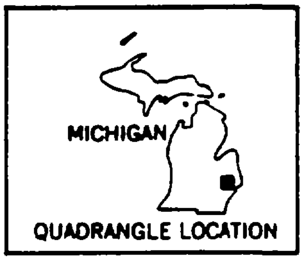
A. Feasibility Study (FS); Final Draft Report
Metamora Landfill Site
E.C. Jordan, April 1990

and

Remedial Investigation (RI); Final Report
Metamora Landfill Site
E.C. Jordan, March 1989

B. Proposed Plan
Metamora Landfill
Metamora, Michigan
U.S. EPA, July 1990





TRACED FROM: METAMORA, MI, QUADRANGLE; U.S.G.S. 7.5' SERIES TOPOGRAPHIC MAP, 1980.

figure 1.1

SITE LOCATION
METAMORA LANDFILL SITE
Lapeer County, Michigan

CRA

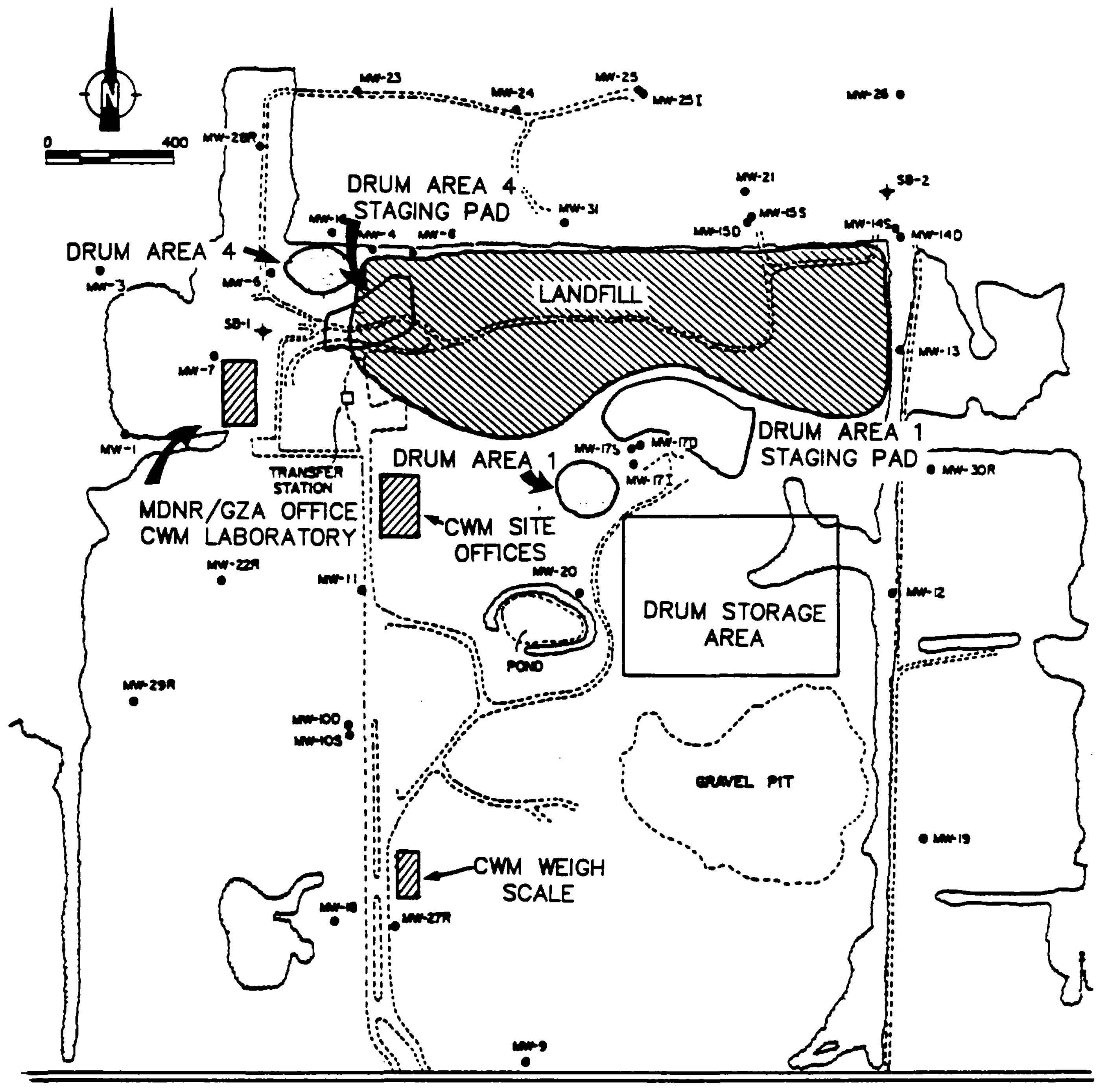


figure 1.2

OPERABLE UNIT NUMBER 1 SITE LAYOUT
METAMORA LANDFILL SITE
Lapeer County, Michigan

CRA

3298–04/05/90–4–0

Comments on the above-referenced documents are respectively presented in Parts A and B of this report and have been prepared by the Metamora Landfill Site Steering Committee (MLSSC) with the assistance of Conestoga-Rovers & Associates (CRA) of Waterloo, Ontario, and Gradient Corporation of Cambridge, Massachusetts.

The comments are presented in a manner consistent with the organization of each of the respective documents. For the FS report, the comments are organized on a section-by-section basis. General comments are provided on each section and are followed by specific comments. The general comments discuss the intent of each section while the specific comments are directed to identified pages. Comments on the FS are presented in Part A of this report. Section A of this report also presents comments on the RI and Baseline Public Health Risk Assessment as these documents are utilized by MDNR in support of their conclusions presented in the FS. A detailed re-evaluation of the Baseline Public Health Risk Assessment is presented in Appendix I.

Comments on the Proposed Plan are presented in Part B of this report and are organized on a page-by-page basis.

COMMENTING SUMMARY

The remedial action that MDNR proposes for Operable Unit 2 is: (1) implementation of a $9.9 million groundwater extraction and treatment system designed to capture a theoretical plume; and (2) installation of a $9.4 million hazardous waste cap to cover a municipal waste landfill. The preferred remedial action is inconsistent with the National Oil Pollution and Hazardous Substances Contingency Plan (NCP) and not required by Michigan Act 307 regulations (or any other State or Federal requirement).

The Baseline Public Health Risk Assessment (risk assessment) in the RI/FS is flawed because it uses unreasonable, unrealistic, and, in some instances, inappropriate assumptions and the crucial assumptions are contrary to U.S. EPA guidance. The risk assessment assumptions are improper, are not based on good science and are contrary to U.S. EPA guidance, because:

- there is no present exposure and future exposure to the chemicals in the shallow aquifer is unlikely, if not impossible, based on present and reasonably likely future land use. According to MDNR's own studies and the submissions of its contractors, there is a 150-foot thick confining layer between the shallow aquifer and the bedrock drinking water aquifer which will preclude the migration of chemicals in the shallow aquifer to the deeper aquifer (i.e. the drinking water aquifer);

- the risk assessment (and calculation of target cleanup levels (TCLs)) erroneously and contrary to U.S. EPA policy and good sense assume that a "reasonable" worst-case exposure would involve ingesting two liters of water per day for 70 years ftom the shallow aquifer <u>below a municipal waste landfill</u>. A municipal landfill is dedicated to use to contain municipal wastes and therefore the groundwater below a municipal landfill cannot be reasonably expected to be used as drinking water source.

If one assumes that the shallow aquifer directly below the Site must be used in the future as drinking water, then it follows that U.S. EPA and the State must clean up all other municipal landfills and other solid waste landfills in the country to the same extent. Therefore, the FS and Proposed Plan misrepresent the nature of the Site. It is and will continue to be a municipal landfill located in a mined out sand and gravel quarry, not an area suitable for residential development (see Appendix I and II);

- even if one assumed erroneously.and contrary to U.S. EPA policy and good sense that a "reasonable" worst-case exposure would involve ingesting two liters of water per day for 70 years from the shallow aquifer <u>below a municipal waste landfill</u>, vinyl chloride should not be considered in the risk assessment because: (1) it was only detected in 10% of the samples; (2) it was never detected in the landfill; and (3) MDNR used unusually high detection limit for vinyl chloride (i.e. a detection limit that is five (5) times higher than the maximum contaminant level (MCL) for vinyl chloride) that results in the calculation of an artificially high risk level despite MDNR's failure to detect it throughout the landfill and most of the Site;

- even if one assumed erroneously and contrary to U.S. EPA Policy and good sense that a "reasonable" worst-case exposure would involve ingesting two liters of water per day for 70 years from the shallow aquifer <u>below a municipal waste landfill</u>, arsenic should not be considered in the risk assessment because it is present in the shallow and deep aquifers at levels comparable to background levels;

- the risk value in the RI is erroneous because it is primarily driven by the incorrect concentrations used for arsenic and vinyl chloride and, as indicated above, neither measurement reflects the conditions at the Site; and

- even if one assumed erroneously and contrary to U.S. EPA policy and good sense that a "reasonable" worst-case exposure would involve ingesting two liters of water per day for 70 years from the shallow water table <u>below a municipal waste landfill</u>, and if one eliminated arsenic and vinyl chloride from the risk assessment and one used the correct method of calculating the average concentration of chemicals in wells, the "reasonable" worst-case risk level (3×10^{-5}) is below the 1×10^{-4} risk level, which according to U.S. EPA ***"is a standard that has been applied at numerous other Superfund Sites"*** [Final Risk Assessment Update, Westline Site, Westline, PA (prepared for U.S. EPA, August 2, 1989)]. Furthermore, U.S. EPA is repeatedly on record as accepting 10^{-4} residual risk levels at numerous Superfund Records of Decisions. U.S. EPA considers the 10^{-4} risk level to be "safe" from a public health point of view. (EPA, 1990a.)

The TCLs for groundwater in the FS have <u>not</u> been selected according to the criteria in the NCP (and, therefore, are incorrect) because:

- the NCP explicitly requires that MCLs be used unless the additive risk of the cleanup levels exceed the 10^{-4} risk level and that practical technical considerations, such as the practical quantitation limit (PQL) need to be considered. None of these factors require lowering the TCL below the MCLs and, in fact, support the alternate TCLs proposed by the PRPs (see Section A.4 and Appendix I);

- Michigan Act 307 Type C (risk based) groundwater cleanup levels should be selected for the Metamora Landfill area because the shallow aquifer is not used for drinking water and future exposure to chemicals in the shallow aquifer below the municipal landfill is unlikely (i.e. the landfill will not be developed for residential use). Furthermore U.S. EPA guidance does not require the same degree of cleanup at a municipal landfill as it does in a residential area (see similar points discussed above in applying U.S. EPA policy);

- there is no unacceptable risk, and, even if the unreasonable exposure scenario presented in the FS is adopted, the risk is below the standard used to trigger action at many other Superfund Sites;

- the extent of the groundwater contamination was not measured but estimated using a theoretical computer model that the National Academy of Science has specifically rejected for such an application;

- the proposed TCLs were erroneously selected (see above), and therefore, overestimate the extent of the groundwater that requires remediation;

- the treatment system is unlikely to achieve the inappropriate cleanup levels selected for the Site, and

- implementation of the system will not reduce the potential risk from ingesting the groundwater from the area because the actual risk from the background level of arsenic (6.9×10^{-5}) in the drinking water aquifer is greater than the worst-case risk from the Site.

The proposed hazardous waste cap is not required by any Federal or State ARAR, is unsupported by the record, unnecessary to protect public health, not justified by Site conditions and is not cost-effective when compared to a solid waste cap (i.e. Act 641 cap).

A summary of the major commenting issues is presented on Table 1.1.

The MLSSC believes that Site conditions when properly evaluated, in light of applicable law, regulations and policy justify implementation of the following remedial actions:

1. Act 641 Solid Waste Cap,
2. Groundwater extraction and treatment as necessary to prevent the off-Site migration of organic constituents, and
3. Groundwater monitoring.

TABLE 1.1

SUMMARY OF COMMENTING ISSUES

Issue	*Agency Position*	*PRP Position*
1) RI Completeness	RI complete	- RI incomplete since hydrogeologic conditions not defined.
2) Risk Assessment	Appropriate	- Inappropriate since the risk scenario does not reflect realistic current or future exposure scenarios.
3) Selection of Chemicals of Concern	Appropriate	- Inappropriate since the selection was based on an incomplete and inaccurate data base evaluation: (1) background condition ignored (i.e. arsenic and barium) (2) statistical evaluation incorrect (i.e., vinyl chloride)
4) Selection of TCLs	Appropriate	- Inappropriate, for example, these include the improper and unreasonable selection of cleanup standards below background levels.
5) Point of Compliance	Beneath the landfill in the shallow aquifer	- Inappropriate since the scenario that groundwater beneath the landfill is a potable water supply is inappropriate and unreasonable.
6) Landfill Cap	Act 64 cap	- Act 641 cap since the landfill is a MSW landfill and an Act 641 cap is protective of health and the environment.

PART A: COMMENTS ON THE FEASIBILITY STUDY, FINAL DRAFT REPORT

A.1.0 EXECUTIVE SUMMARY

The Executive Summary of the FS provides a synopsis of the Site history, RI/FS process and the selection procedure utilized by the MDNR to select a preferred remedy for shallow groundwater and the landfill at the Metamora Site.

The FS presents an analysis of the following Tasks which were identified for completion during the preparation of the FS:

"• ***identification of applicable or relevant and appropriate requirements (ARARs);***
- ***identification of remedial response objectives;***
- ***identification of preliminary and final target cleanup levels;***
- ***identification and screening of remedial technologies;***
- ***development of alternatives; and***
- ***detailed analysis of alternatives" [(page ES-2)].***

A.1.1 COMMENTS

A detailed review indicates that the FS is incomplete with respect to its analysis of the above outlined Tasks. In addition, the incorrect analysis and conclusions with respect to the development of ARARs and response objectives have resulted in a FS report which is fundamentally flawed in its analysis of the remedial alternatives presented for both the groundwater and landfill remediation. The major areas of commenting are discussed in the following subsections.

A.1.1.1 ARARs and Response Objectives

In order to determine whether a regulatory requirement is an "ARAR", one must divide the question into whether the requirement is "applicable" or "relevant and appropriate".

"Applicable" requirements are "***those Federal requirements that would be legally applicable, whether directly, or as incorporated by a Federally authorized State program, if the response actions were not undertaken pursuant to CERCLA section 104 or 106***" [40CFR§300.6.[1]] The proposed NCP states that a requirement is "applicable" if there is a "***one-to-one correspondence between the requirement and the circumstances at the Site***" [53 Fed. Reg. at 51,437; (NCP, 1990)]. For example, U.S. EPA drinking water standards are applicable to water supplied by a water supplier for potable drinking water purposes. These standards do not apply to groundwater not being used as drinking water. Few Federal requirements are "applicable" at the typical Superfund Site.

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[1] U.S. EPA interprets "applicable requirement" as "those cleanup standards, standards of control, or other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site." National Oil and Hazardous Substances Pollution Contingency Plan, 53 Fed. Reg. 51,394, 51,435, 51,475 (1988).

If there is no "applicable" requirement, U.S. EPA must determine whether a requirement is "relevant and appropriate," i.e., whether it:

> addresses problems or situations that are generally pertinent to the conditions at the Site (i.e., the requirement is relevant) and whether the requirement is well-suited to the particular site (i.e., the requirement is appropriate). [53 Fed. Reg. at 51,437, 51,436, also suggesting that the potential action, location or chemicals specified by the potential ARAR be compared to the conditions, the release or potential remedy at the Site); (NCP, 1990)].

"Relevant" requirements are not required unless their use is appropriate given the conditions at the site. National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 50 Fed. Reg. 47,912, 47,918 (1985). Whether a requirement is "appropriate" depends upon the nature of the substances at the site, the characteristics of the site, the circumstances surrounding the release and the ability of the remedial action specified in the Federal requirement to address the release. [53 Fed. Reg. at 51,436; NCP, 1990)]. The most important criteria used to assess whether a requirement is "appropriate" are whether: (1) the purpose or objectives for which the requirement was created is similar to the specific objectives of the CERCLA action; (2) the actions or activities regulated by the requirement are similar to the remedial action contemplated at the CERCLA Site. (NCP, 1990)

"Relevant" requirements are not ARARs unless their use is appropriate given the nature of the substances at the site, the characteristics at the site, the circumstances surrounding the release and the ability of the action to address the release. (NCP, 1990.) The most important criteria are whether the purpose for which the requirement was created is similar to the specific goals of the CERCLA action, and whether the actions or activities regulated by the requirement are similar to the remedial action contemplated at the CERCLA Site.

The pivotal criterion for chemical-specific requirements is whether the requirement at the CERCLA site sets a "health or environmental-based level based on an exposure scenario (including the medium) that is similar to the potential exposure at the CERCLA site."

If the quantity and frequency of exposure is substantially different than that which was used to develop the relevant requirement, then the requirement's use at the Site would not be "appropriate". For example, if a cap is necessary at a Site, it must be determined whether the State requirements for a solid waste landfill cap are ARARs or whether the U.S. EPA RCRA requirements for a hazardous waste landfill cap are ARARs.

Therefore, one must determine what type of action is necessary to remedy the conditions at the Site before determining whether an action-specific requirement is an ARAR. Once an action is determined to be necessary, then it can be determined whether a Federal or State requirement relevant to such an action is an ARAR.[2]

U.S. EPA has enunciated compelling technical, policy and legal reasons for determining the cleanup levels and remedial alternatives for municipal Sites. For example, *"comprehensive treatment options are less likely to be practicable"* for large municipal landfills and, therefore, *"the universe of viable alternatives might be reduced to a limited number of remedies involving treatment of the principal threats, engineering controls, institutional controls, or combinations of these approaches"*. [Proposed NCP, 53 Fed. Reg. at 51,427; EPA, Guidance For Conducting Remedial Investigations and Feasibility Studies Under CERCLA (Interim Final) (OSWER Directive No. 9355.3-01, October, 1988)].

Also, *"cost may be considered along with implementability factors to determine whether treatment of the principal threats posed by a large municipal landfill would be cost effective and practicable, relative to other remedial options"*. [Proposed NCP, 53 Fed. Reg. at 51,428]. The corrective action requirements of U.S. EPA's proposed solid waste landfill regulations specify the same site-by-site determination of remedies based on the same factors as used in CERCLA. The solid waste disposal corrective action requirements also explicitly rejected retrofitting municipal landfills with liners or leachate collection systems and excavation

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[2] Often an ARAR provides a performance standard rather than a design standard. In such circumstances, there is considerable discretion in the design. U.S. EPA or State guidance often describe a particular design that would be acceptable, but such guidance usually provides U.S. EPA personnel with the flexibility to choose alternative designs. Furthermore, guidance, by definition, is not binding.

of the solid wastes in the landfills, inter alia, because of costs and the risks. [Proposed SWD Criteria, 53 Fed. Reg. at 33,325, 33,334]. Similarly, Act 64 capping at this Site would not be cost effective or without potential health risks.

As to groundwater remediation, ARARs and response objectives are presented in the FS that are both irrelevant and based upon an incomplete RI which did not present the data requirements necessary to complete the FS. The lack of site-specific hydrogeologic information to the north of the landfill resulted in a situation which required the MDNR to analyze and propose requirements for a groundwater extraction system which were based solely on an improper groundwater computer model (see Appendix I). Secondly, the MDNR has developed TCLs which are based upon a risk assessment presented in the RI which is inadequate and fundamentally flawed with respect to the following key issues:

1. no demonstration of an exposure pathway in the shallow aquifer to the north of the Site has been defined; the shallow aquifer is not utilized in the vicinity of the Site for water supply and therefore this exposure pathway does not even exist,

2. it is unlikely that the shallow aquifer in the vicinity of the Site would ever be utilized for water supply,

3. the Site will not be developed for residential use,

4. an exposure to shallow aquifer groundwater will never occur on Site with the implementation of appropriate institutional controls,

5. the extent of affected groundwater, if any, has not been defined,

6. no hydrogeologic connection between the shallow aquifer and the bedrock drinking water aquifer has been demonstrated. This in combination with the 150-foot thick clay layer results in the conclusion that no connection between the shallow and deep aquifer exists, and

7. the TCLs are based upon an incorrect determination of residual risk levels.

The issue of whether U.S. EPA's drinking water standards are "relevant" and "appropriate" depends upon the nature and use of groundwater below a solid waste landfill. Nothing in the statute or its legislative history suggests that solid waste landfills must be cleaned to a degree that the Site could be used for residential purposes, i.e., with edible soil and drinkable groundwater within the boundary of the landfill. U.S. EPA's policy establishes ***"different degrees of protection for groundwaters based on their vulnerability, use, and value."*** [53 Fed. Reg. at 51,433; NCP, 1990]. U.S. EPA's goal is to return groundwater that is capable of being used as drinking water to drinking water quality.

U.S. EPA's regulatory scheme for the disposal of solid wastes defers land use decisions to local authorities. [Proposed SWD Criteria, 53 Fed. Reg. at 33,324]. The land (and therefore the groundwater) within the boundaries of the municipal landfill has been consciously dedicated to the disposal of municipal wastes. As a result, the groundwater within the boundary of the solid waste landfill is not available as a potential source of drinking water.

Only if the presence of wastes in the municipal landfill presents a significant adverse impact on the quality of groundwater outside the boundary of the landfill should a remedial action be required. For example, the point of compliance pursuant to U.S. EPA's proposed solid waste disposal regulations is at the boundary of the landfill. Corrective action is required only if there is a significant adverse impact outside the landfill boundary. [Proposed SWD Criteria, 53 Fed. Reg. at 33,325].

Groundwater within a solid waste landfill almost always contains chemicals at concentrations greater than U.S. EPA drinking water standards. [See U.S. EPA, Report To Congress: Solid Waste Disposal In The United States, Volume II, pp. 4-22 to 4-28, Tables 4-21 to 4-24 (EPA/530-SW-88-011B, October 1988); also see Appendix II these comments]. It would be inconsistent to permit the continued disposal of solid wastes in landfills, yet require the cleanup of the groundwater within the landfill to drinking water standards. Virtually all solid waste landfills, including municipal landfills, would require remediation if one interpreted Superfund as demanding the cleanup of groundwater within a solid waste landfill to drinking water standards. Such remediation would not be cost-effective given the minimal benefit that would be achieved.

In sum, drinking water standards are neither "relevant" nor "appropriate" for groundwater within the boundaries of a solid waste landfill. Therefore, the cleanup goal for the Metamora Landfill is to assure that groundwater leaving the Site is in compliance with Michigan Act 307 Type C cleanup criteria.

Similarly, the landfill remediation alternative presented in the FS relies solely on the incorrect assumption that the Metamora Landfill is a hazardous waste site. A review of the history of the Site and chemical conditions of the landfill area indicates that the landfill was utilized for the disposal of Municipal Solid Waste (MSW) and as such its capping under Act 641 is appropriate. The capping of this Site utilizing Act 64 provisions is inappropriate, excessive and unnecessary, and is unsupported by the data and an appropriate application of ARARs selection procedures. A detailed analysis of the capping provisions described within this report pursuant to proper ARARs selection methods, indicates that an Act 641 cap would meet the technical requirements for capping while providing a cost-effective approach.

A landfill cap utilizing Act 641 provisions will mitigate the presumed risks identified to affect terrestrial organisms while reducing infiltration to levels sufficient enough to minimize the generation of leachate.

An Act 641 landfill cap and an appropriate groundwater extraction system, pursuant to Michigan Act 307 cleanup criteria will result in the attainment of the technical performance requirements necessary to remediate the Site. The Act 641 landfill cap cleanup standards are the sole ARARs for this Site.

A.1.1.2 Residual Risk Levels

The executive summary in the MDNR FS asserts that ***"the NCP suggests that TCLs for carcinogens be set as close to the 10^{-6} risk level as it is technically possible to achieve"***[ES-6]. This statement is not true because it does not accurately reflect either the NCP or U.S. EPA policy on the acceptable risk levels at Superfund sites. Therefore, it has no basis for inclusion in the FS.

U.S. EPA has acknowledged that the Superfund program does not require that all risks be eliminated from a Superfund site. The acceptable range of risks is considered by the NCP to be in the 10^{-4} to 10^{-6} range [(NCP, 1990, 40CFR 300.430(e)(2)(i)(A)(2), see also 55 Fed. Reg. 8669 (1990)]. This represents the residual risk levels which may be left after remediation has been completed. Any preference in the NCP for a 10^{-6} risk level ***"does not reflect a presumption that the final remedial action should attain such a risk level."*** [55 Fed. Reg. 8718(1990)].

U.S. EPA has accepted levels of residual risk in the range of 10^{-4} to 10^{-5} to be appropriate in numerous Superfund Records of Decisions (RODs). More generally, U.S. EPA has stated that a 10^{-4} risk level is presumed to be "safe" from a pubic health point of view (EPA 1990a). As a practical matter, technical feasibility, cost effectiveness, and other factors often result in risk levels on the order of 10^{-4} to 10^{-5} being accepted by U.S. EPA. The "average" level of residual risk considered acceptable by Federal Agencies in regulatory actions is 10^{-5}, and a risk level greater than 10^{-4} has been accepted in one-third of such actions (Travis 1987; Travis 1988; EPA 1990a).

Therefore, any "remediation goal" at a particular Superfund site that results in a residual risk of 10^{-4} to 10^{-6} (as do the MCLs for drinking water) should be acceptable based on protection of the public health and U.S. EPA's past practice.[1] Such a range is consistent with:

(1) EPA's definition of hazardous waste (10^{-5}) (EPA 1990b);
(2) other hazardous waste regulations (10^{-4} to 10^{-7}) (EPA 1988b; EPA 1987c);
(3) other Federal regulatory decisions (10^{-3} to 10^{-7}) (EPA 1988a; Rodricks 1987; Travis 1987; Travis 1988; EPA 1988f);
(4) the range of risks that society has accepted (10^{-2} to 10^{-4}) (EPA 1988b; Wilson 1987; EPA 1988a);
(5) the estimated risks presented by ambient conditions (10^{-3} from indoor air pollution alone) (EPA 1987b);
(6) published risk data by experts in the field (Ricci 1987; Milvy 1986; EPA 1988a);

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[1] U.S. EPA and other Federal agencies developed the quantitative risk assessment process because there is no scientific proof concerning whether or not very low concentrations of chemicals cause adverse health effects. (NRC 1983) There are respected scientists within the Federal government who doubt that any health effects are caused by exposure to very low concentrations of some, if not all, chemicals. (Kimbrough 1986) The risk assessment process is used as a matter of prudent public health policy, not because of its scientific accuracy or validity. The risk values estimated through U.S. EPA's risk assessment process are not a realistic prediction of the effect of exposure. (EPA 1986a) The true risk could be zero or perhaps as high as the upper bound estimate provided in the risk assessment. Also, EPA's risk assessment methodology estimates a higher risk for a given exposure concentration compared to the risk assessment methodology of other Federal agencies. (FDA 1985)

(7) residual risks to human health higher than 10^{-4} typically have been found to be acceptable for small populations. (EPA 1988b; Rodericks 1987; Travis 1987; Travis 1988; and

(8) the legal precedent.

Not surprisingly, given the method of derivation and the discretion provided to U.S. EPA personnel, "remediation goals" selected in past RODs and the action levels cited in advisories often vary widely, e.g. the soil "remediation goals" for PCBs range from the detection limit to 100 ppm (ROD Review 1990), the soil "remediation goals" for arsenic varies from 5 ppm to 200 ppm (although the most recent and thoroughly documented soil "remediation goals" are in the 100 ppm to 200 ppm range (ROD Review 1990), and the groundwater "remediation goals" for benzene varied from 0.1 ppb to 5 ppb (ROD Review 1990).

The wide variation in acceptable residual risk levels indicates that U.S. EPA applies cleanup levels on a site-specific basis. Based upon site-specific conditions and the application of these acceptable risk levels at other Superfund sites, it is inappropriate for residual risk levels to be set at a 10^{-6} level for the Metamora Site. The proposal to set a residual cleanup level of 10^{-6} is both unsupported by the database which exists for the Site and is contrary to the standards of practice being utilized at other sites. Section 300.430(e)(2) of the NCP states explicitly that ***"the 10^{-6} level shall be used as the point of departure for determining remediation goals for alternatives when ARARs are not available or are not sufficiently protective because of the presence of multiple contaminants at a site or multiple pathways of exposure".***

An example of a TCL cleanup level calculation in the FS which ignores Site conditions and therefore is inappropriate on its face is in regarding to arsenic. The Metamora RI reports the following ranges in arsenic levels for the various media which were investigated during the RI:

	Media	*Concentration Range (mg/kg)*
1.	Soils in Drum Area 1	5.2 to 18
2.	Soils in Drum Area 2	17 to 30
3.	Leachate Contaminated Soil	4.8 to 25.7
4.	Sediments	9.8 to 58.8
5.	Background Soil	0.1 to 88

At the Metamora Site the levels of arsenic in the bedrock aquifer, which is unaffected by the Site, are virtually identical to the levels in the shallow aquifer. It should be noted that arsenic levels at the Metamora Landfill Site are well below the remediation goals which have been established at other sites. It is improper and unreasonable to set a groundwater TCL for arsenic at 1 µg/L when background levels exist in the 15 to 20 µg/L range and the MCL is 50 µg/L.

A detailed evaluation of the risk assessment presented in the RI indicates a current actual risk in the bedrock aquifer (due to natural background levels of arsenic) on the order of 6.9×10^{-5} (detailed in Appendix II). This current actual risk due to background levels of arsenic in the bedrock aquifer renders remediation goals based on a 10^{-6} residual risk level as being impossible to achieve since background risk exceeds the cleanup goal.

The Metamora Landfill Site is located in a remote, sparsely populated area which exhibits no completed exposure pathway to human populations and has been shown to pose virtually no immediate or potential risk. As a result, and in accordance with the above discussion, acceptable Target Cleanup Levels (TCLs) should be established consistent with the application of risk based cleanups at other sites of similar nature and these certainly must include background risk at the Site. In the case of the Metamora Landfill Site, TCLs should be set which represent acceptable risk levels which rest in the 10^{-4} to 10^{-5} range (not 10^{-6} as discussed on page ES-6). The NCP explicitly requires that MCLs be used unless the additive risk of the cleanup levels exceeds a 10^{-4} risk level. Additionally, practical technical considerations require the evaluation of practical quantitation limits (PQLs) as TCLs. The residual risk level which shall be attained by achieving the proposed cleanup levels outlined above has been determined to be 2.7×10^{-5} (see Appendix I, page 21). This residual risk level is consistent with the NCP, appropriate for the Site conditions and is protective of public health.

A.1.1.3 Target Cleanup Levels

The NCP requires that practical limitations on meeting or monitoring "acceptable exposure levels" [(sections 300.430(e)(2)(i)(A)(3,4,5) of the New NCP)] be considered in setting TCLs, particularly the distinction between a "detection limit" and a "practical quantitation limit" (PQL). For example, the range of TCLs may be 0.5 ppb to 50 ppb, but limitations on the ability to reliably detect the chemical might require the use of 10 ppb as the TCL (NCP, 1990).

The "detection limit" should not be used to set a TCL because it is variable, not repeatable and provides a measurement in the area where the precision and accuracy of the instrument is lowest, i.e., there are more frequent false positives and false negatives. The detection limit is the lowest concentration that a particular measuring instrument on a particular day with a particular sample can measure above the instrument's normal random response (i.e., the signal measured when there are no chemicals present, called the "noise" level of the instrument.)

PQLs, on the other hand, are ***"the lowest concentration that can be reliably measured [by good laboratories] within specified limits of precision and accuracy during routine laboratory operating conditions."*** (EPA, 1989c). U.S. EPA regularly uses PQLs, rather than detection limits (which are typically five to ten times lower) to set the MCLs pursuant to the Safe Drinking Water Act (U.S. EPA, 1989c) and in the RCRA delisting program (EPA, 1989d), among other programs. Each of these programs are national and the levels are set to protect the health of 240 million people.

Inappropriate exposure scenarios have led MDNR to ignore MCLs as TCLs. It is appropriate and conservative that the U.S. EPA MCLs be utilized as TCLs in the shallow aquifer at a point of attainment which is downgradient of the Site boundary. Due to the remote possibility that the shallow aquifer could be utilized as a water supply aquifer, it is appropriate that MCLs (which are protective of human health) be utilized at some point of attainment downgradient where this hypothetical exposure may occur. It is unreasonable to consider the landfill as a developable site for water supply.

As a result of its relatively remote location, small size, absence of a groundwater exposure pathway (i.e. no receptors in the shallow aquifer), reasonably foreseeable property uses and other factors, it is appropriate that a site-specific risk assessment based cleanup be conducted at the Metamora Landfill Site. A review of the risk assessment presented in the RI and the TCLs developed in the FS is provided and detailed in Gradient's assessment, provided as Appendix I of this report and summarized below.

The risk assessment presented in the RI and reiterated in the FS is fundamentally flawed in both its assessment of risks posed to human populations by the shallow aquifer and the ecological risks posed to terrestrial animals on the landfill.

A re-evaluation by Gradient of the potential human health risks for a hypothetical shallow aquifer exposure results in a 4.8×10^{-6} risk for the most probable case, and a 3.3×10^{-5} risk for the reasonable worst case. Gradient's re-evaluation is detailed in Appendix I of this report, which also presents a thorough analysis of MDNR's risk assessment. MDNR's risk assessment is incorrect with respect to the identification and analysis of two key issues:

1. chemicals of concern, and

2. exposure pathways and concentrations.

A re-evaluation of the chemicals of concern indicates that the analytical results for arsenic, barium and vinyl chloride have been incorrectly evaluated by the MDNR.

A statistical analysis of the barium concentrations in the shallow aquifer indicates no statistically significant difference between barium concentrations up and downgradient of the Site. This analysis indicates that MDNR should not have included barium in the list of parameters of concern and, as a result, barium should be removed from the indicator parameter list for the Site (see Appendix I).

An analysis of the arsenic data for the shallow and bedrock aquifers indicates that arsenic exists at similar levels in both aquifers. This indicates that arsenic is a naturally occurring element in the hydrogeologic environment of the Metamora area. It should not be an indicator chemical or, at a minimum, the effect of natural background should be subtracted from human health risk estimations (see Appendix I).

The credibility of using vinyl chloride as an indicator parameter is also suspect because of the nature of the available data base. Vinyl chloride was only identified in 10 percent of the shallow aquifer samples and not at all in on-site monitoring wells. Moreover, the average concentrations assigned for vinyl chloride were incorrectly determined by MDNR because an analysis of the effect of elevated detection limits for non-detects was not completed. A log-probit analysis detailed in Appendix I presents an appropriate method to determine statistically sound averages for the vinyl chloride data. Therefore, if the suspect data on vinyl chloride is to be used in the risk evaluation, the log-probit analysis indicates that lower averages for vinyl chloride should be included in the risk assessment (see Appendix I).

An assessment of the exposure pathways indicates the inappropriate use of the shallow aquifer as a potentially completed pathway . It is inappropriate to assume that groundwaters in the shallow aquifer from directly beneath the Site would be used as a water supply. Since all domestic wells in the area use the bedrock aquifer, there is little reason to assume that the shallow aquifer would be utilized for a water supply, be it on or off-site.

It is important to note that the current actual risk from ingesting arsenic from the bedrock aquifer is 6.9×10^{-5}. This indicates that there is a current higher risk in the actual background domestic water supply (bedrock aquifer) than can even be hypothetically presumed in the shallow aquifer. The concentration of arsenic in the bedrock wells averaged 18.2 ppb. This is compared to an average of 17.6 ppb for the shallow aquifer (see Appendix I). Because arsenic and barium are at background levels, they are not proper indicator chemicals for this Site, and therefore the TCLs are inappropriate. For the revised list of indicator chemicals the TCLs shall be MCLs and PQLs (where there are no established MCLs).

A.1.2 SUMMARY

A summary of the key commenting issues on the executive summary is provided as follows:

- The RI is incomplete and does not provide the necessary data to support the FS,
- The use of inappropriate groundwater models using unsubstantiated input data can not be substituted for the lack of Site-specific hydrogeologic information,
- The incorrect interpretation of the data base led to the incorrect identification of chemicals of concern,
- The evaluation of remedial alternatives is based on incorrect interpretation of the NCP which does not require that TCLs be based on a risk level of 10^{-6},
- The risk assessment inappropriately assumes that the groundwater beneath the landfill is a potential supply of a potable water,
- The ecological risk assessment is unsubstantiated and based upon only the most cursory review of the biological resources of the area,

- The selection of TCLs ignores background conditions at the Site with the result that they are impossible to achieve by the application of any technology either by the PRPs or the MDNR, and

- The FS does not provide the detail required to adequately address or analyze the technologies and alternatives which are developed (i.e. groundwater extraction system).

Substantiation of the points outlined above is provided and detailed in the remainder of this report.

A.2.0 INTRODUCTION

Section 1.0 of the FS provides a summary of the RI/FS process and the results obtained for the Metamora Remedial Investigation (RI). As stated on page 1-1, the purpose of the RI/FS is to *"assess the impact of the contaminants released to the environment and to identify a means to effectively remediate the Site". [page 1-1].*

A.2.1 GENERAL COMMENTS

In attempting to address the purpose stated above, the FS report is hindered by an incomplete and inappropriate RI and absence of detail appropriate for the FS.

The objectives of the RI were to:

"1. *Undertake studies to evaluate the nature and extent of environmental contamination on Site,*

2. *Define pathways of contaminant migration from the Site to assess the potential impacts of contaminants on potential receptors such as local water wells, surface water biota, etc.,*

3. *Identify on-site and off-site features that could affect contaminant migration, containment, or cleanup,*

4. *Assess the public health and environmental risks posed by the Site, and*

5. *Provide information to identify a cost-effective, environmentally sound, acceptable, remedial program for the Site." [page 2-7, 2-8, RI].*

The review of the RI presented in Section 1.2.3 of the FS correctly indicates that the RI report failed to define the nature and extent of contamination in the hydrogeologic environment. This is evidenced by the lack of actual data on contaminant distribution in the shallow aquifer to the north of the Site, which resulted in an analysis of groundwater alternatives based on an inappropriate groundwater model. It must be stressed that a groundwater model is only as good as the data which is used to support it. At the Metamora Site, there is no data available to support any type of modelling exercise to evaluate the northern extent of groundwater contamination for remediation purposes.

The RI's failure to characterize the nature and extent of contamination to the north of the Site in the shallow aquifer has resulted in the RI being incomplete with respect to providing essential data and in satisfying the above-listed primary objectives. This, coupled with the use of an inappropriate computer model in the absence of Site-specific data, has resulted in two fundamental areas of uncertainty and concern in the FS. They are:

1. Actual measured concentrations of Site-related constituents and hydrogeological parameters in the shallow aquifer have not been

determined. These data are required to complete an analysis of the exposure pathway to potential receptors to the north of the Site. This lack of data results in an incomplete risk assessment. Consequently, unnecessary and unsupported assumptions were made to assess potential risks to public health. Additional RI work should have been completed during the RI to fully characterize the shallow aquifer plume and any risks posed by the Site.

2. Incomplete shallow aquifer definition also has resulted in a situation where a conceptual groundwater extraction well system can not be accurately configured for the purposes of the FS. Therefore, the RI failed its final objective of providing the necessary information to complete the FS. As a result, the groundwater extraction systems are based on a number of unsupported assumptions and simple mathematical modelling rather than on site-specific information that should have been collected to properly develop a site-specific model.

The RI assumed an inappropriate risk scenario using chemicals of concern selected based upon an incorrect data base evaluation. For example, the arsenic background concentration exceeds the TCL selected for arsenic. As a result, the FS is completed based on the following:

1. an inaccurate presentation of the risk posed by the Site, and

2. the selection of alternatives designed to address TCLs which are impossible to achieve.

A.2.2 SPECIFIC COMMENTS

Specific comments to the FS introduction are provided as follows:

- Page 1-1 - Characterization of Site hydrogeology is incomplete on Site, as indicated by the large number of question marks on the geologic cross-sections (see Figure 1-3 of the FS). Additionally, the characterization of off-site hydrogeology has not been completed. This is evidenced by the inappropriate reliance on a simplistic and unsupported computer model for remediation purposes.

- Page 1-1 - Evaluation of the nature and extent of groundwater contamination is incomplete, as indicated by the reliance on a poor quality simplistic computer model to define groundwater quality.

- Page 1-1 - The estimated number of buried drums is clearly incorrect and grossly understated. This fact has major implications for the Operable Unit Number 1 activities and indicates that a Site-wide remedy should have been and still should be developed.

- Page 1-5 - It is alleged that the Site geology ***"is very complex"***. However, soil data collection efforts contradict this assertion. The soil sampling intervals provided on Figures 1-3 through 1-6 indicate that soil sample collection was infrequent. If the geology was ***"very complex"***, more soil samples should have been collected. Soil samples should have been collected at a minimum of five-foot intervals (if not continuous sampling) for visual classification. The sampling plan has resulted in substantial data gaps which have led to unsupported and tenuous assumptions and inappropriate conclusions. MDNR's rationale for its soil sampling program has not been adequately discussed, appears to be inappropriate, and does not provide the necessary information to assess the stratigraphy both on and off Site.

- <u>Page 1-5</u> - Groundwater velocity is usually provided with the description of groundwater flow direction. The hydrogeologic conditions were not adequately defined during the RI and therefore do not provide the necessary detailed support to complete the FS. Additionally, no information is provided on the intermediate and bedrock aquifers and the aquitards which separate them. It should be noted that cross-contamination may have occurred in the intermediate aquifer as a result of drilling activities by MDNR's contractor at MW-17I.

- <u>Page 1-5</u> - Groundwater contamination from the landfill has not been adequately defined.

- <u>Figure 1.3 - Cross-Section A-A'</u> - The upper till unit illustrated on this figure (and other cross-sections) is arbitrarily depicted as discontinuous. The till unit, however, was encountered in every borehole where appropriate samples were collected. The till unit also supports a significant vertical groundwater gradient, as illustrated on Figure 1-3, which it could not do if it were not continuous. The RI indicated that the till unit was continuous and approximately 150 feet thick.

- <u>Page 1-13</u> - The extent of affected groundwater is inadequately defined. The measured horizontal limit of affected groundwater extends only 550 feet north of the Site. Inappropriate computer modelling was used to estimate that chemicals may have migrated 2,500 to 3,500 feet from the Site.

A February 1990 National Academy of Science report, *"Groundwater Models, Scientific and Regulatory Applications"* concluded that generic models such as the VHS model *"are useful as a tool for initial screening but can never be used as a replacement for site-specific models: [page 10].* Additionally, this report concluded that, *"The use of overly simplistic models, such as the vertical-horizontal spread (VHS) model, at Superfund Sites or other hazardous waste sites (1) would be an arbitrary distortion of the remedial selection process; (2) could reduce protection of the public health by misallocating finite cleanup resources, and (3) would result in the imposition of substantial costs with no commensurate environmental or public health benefit" [page 215].* (It should be noted that this report was co-sponsored by U.S.EPA).

The VHS model was first published by Domenico and Palcauskas in 1982, and extended to include longitudinal dispersion and decay terms in 1985 and 1986, respectively. The VHS model utilized by MDNR neglected all natural attenuation mechanisms which would occur in the groundwater environment and as a result may grossly over estimate the areal extent of chemical migration. These concerns are outlined as follows:

1. Current groundwater research has indicated that longitudinal dispersivity values may be significantly less than the value of 100 feet utilized by MDNR. This would result in a much reduced affected groundwater area than presented by MDNR.

2. Adsorption/desorption phenomena due to the presence of even small amounts of organic aquifer materials will result in the retardation of all organic constituents. Aquifer materials should have been analyzed during the RI to determine the fraction of organic carbon (Foc) such that this evaluation could have been completed.

3. Volatization of organic compounds into the unsaturated zone from the water table will result in a reduction of mass in the groundwater. This will result in lower concentrations of organic compounds in the groundwater.

4. Current research has indicated that a variety of organic compounds are biodegraded at a significant rate under similar environmental conditions. Benzene, toluene, ethylbenzene and xylene (BTEX) have been shown to be readily biodegraded under aerobic aquifer conditions.

   Additionally, chlorinated organics such as trichloroethylene have been reported as being biodegraded under anaerobic conditions. Considering, the presence of the landfill on-site and water table conditions off-site it is likely that Site related constituents are being biodegraded both under the landfill (anaerobic biodegradation) and outside the limits of fill (aerobic biodegradation). The roles of biodegradation in the attenuation of Site related constituents cannot be overstated.

It must be noted that the RI report presents a thorough analysis of potential environmental fate properties of Site related constituents, but does not utilize the information presented in the estimation of the chemical movement.

5. Other degradation reactions such as hydrolysis and oxidation may also result in the reduction of mass in the groundwater.

6. The reduction in the groundwater chemical concentrations due to recharge (infiltration of precipitation) have also been ignored.

Thus, there is no need to assume an absolute worst or impossible case scenario when the actual case can be readily ascertained. If the RI had produced the required information regarding the hydrogeological parameters of the shallow aquifer to the north of the Site and appropriate natural attenuation mechanisms were included, a Site-specific model could have been developed to more accurately model the transport of Site-related constituents in the groundwater. Generic models must be validated by comparing their predictions to actual Site conditions and as a result the VHS model has been misapplied at the Metamora Landfill Site.

The above conclusions regarding the VHS model indicate that it is inappropriate to use such a simplistic model for more than initial screening, especially for remedial design basis decisions. Such models should never be used as a replacement for site-specific models structured upon actual site data. It is imperative that additional hydrogeologic investigations be conducted to the north of the Site such that an appropriate conceptual design for the extraction system can be developed. The FS will remain incomplete until this has been accomplished.

- Page 1-13 - The report states that MDNR sampled shallow and intermediate wells, however, the results of these tests are not discussed.

- Page 1-13 - The soil samples discussed on page 1-13 show that the chemical characteristics of the Metamora Landfill are similar to Municipal Solid Waste (MSW) landfills in general (see Appendix B). As such, remedy component performance standards should be consistent with those requirements which are necessary to manage MSW landfills.

- Page 1-14 - The RI stated that 5,000 to 7,000 drums were buried in the drum disposal areas. The Proposed Plan states 18,000 drums are present. MDNR has recently indicated that over 20,000 drums have been excavated to date.

  These drum quantity estimates indicate that MDNR clearly did not have the appropriate data to adequately address the extent of drum disposal on-Site. This has resulted in an inadequate drum removal action.

  A detailed evaluation of the drum removal was previously submitted to U.S. EPA entitled, "Operable Unit No. 1, Technical Assessment Report".

This report, which is herein incorporated by reference, concluded that the drum removal activities are inappropriate, are resulting in excessive environmental contamination and will result in unnecessary and excessive expenditures to complete. These operations should be properly contained within the framework of a Site-wide remedy.

- Page 1-14 - Soils below the drum disposal areas will be handled as a third operable unit. The use of improper drum excavation and handling procedures and protocols by MDNR contractors has resulted in substantial chemical loading to soils under the drum disposal area. This represents a significant and documented source of additional and unnecessary contamination which was not the result of historical waste disposal practices (see MLSSC letter of June 7, 1990 to Nola Hicks of U.S.EPA).

  The drum removal operation by MDNR and its contractor were inappropriate and have been documented to result in the further spread of environmental contamination (CRA, 1990). The procedures being utilized at the Metamora Site should be modified to conform to the standard of practice which is required by sound engineering principles.

- Page 1-15 - The RI (Table 5.14) and the FS are unclear with respect to background levels both off-site and attributable to the Municipal Solid Waste (MSW) landfill area of the Site.

  An evaluation of the data base presented in the RI indicated that barium does not exist downgradient at levels which are statistically different than the upgradient levels. Additionally, the arsenic levels in the shallow aquifer compare to the natural background levels of arsenic which exist in the bedrock aquifer and regional soils. This analysis is detailed in Appendix I and indicates that both barium and arsenic must be removed from the list of indicator chemicals for the Site.

Moreover, review of landfill leachate chemistry presented in Appendix II indicates that the chemistry of the Metamora Landfill is similar to that of MSW landfills in general. This analysis indicates that it is appropriate to consider the landfill portion of this Site as a solid waste landfill and as such it should be closed according to Act 641 procedures.

- Page 1-16 - Figure 1-9 - The alleged extent of organic contamination presented on Figure 1-9 is based on the VHS groundwater contamination model. This model is considered extremely conservative in the scientific community, and was the subject of serious criticism in a February 1990 report by the National Academy of Sciences. The report concludes that generic models, such as the VHS model, are useful as a tool for initial screening, but can never be used as a replacement for site-specific models. Additional hydrogeologic studies must be completed to provide actual data on the nature and extent of the groundwater quality and the hydrogeologic parameters of the aquifer such that an appropriate extraction system can be configured and evaluated. The FS is incomplete without these additional studies.

- Page 1-20 - The discussion of any potential risk from shallow aquifer groundwater should acknowledge that there are no sources of drinking water presently finished or likely to be finished in the shallow aquifer in this locality, and it should be noted that the discussion refers to an incomplete exposure pathway. All drinking water sources are finished in the bedrock aquifer. According to all available data there is no hydrogeologic connection between the shallow and bedrock aquifers.

- Page 1-22 - The siltation pond should not be identified as an area of potential concern for the Ecological Risk Assessment. The siltation pond is part of the gravel washing operation conducted on the property and is located at a topographically higher elevation than the base of the landfill. Consequently, it has not been and will not be affected by the landfill.

  Additionally, during the summer of 1988 this pond dried up completely. This man-made pond, therefore, does not represent a permanent or stable ecosystem which wildlife depends upon on a consistent basis (see Appendix I).

A.3.0 DEVELOPMENT OF ARARs

As discussed in Section 2.0 of the FS, ARARs should properly be used as a guide to:

"1. *evaluate the appropriate extent to which the site is to be cleaned up;*

2. *scope and formulate remedial action alternatives; and*

3. *govern the implementation and operation of a selected response action" [page 2-1].*

A.3.1 GENERAL COMMENTS

Development of ARARs stimulates discussion of the range of environmental considerations and design standards that may apply to a particular site. ARARs should not, however, be applied arbitrarily in a checklist manner without due regard for technical and performance standards, particularly when a multi-component remedy is involved. In a multi-component remedy, overlapping remedial effects frequently mitigate part of the objective of other remedy components. Competing and complimentary remedy goals must be considered when evaluating individual remedy components which may be assembled to form an alternative.

The history of the Metamora landfill, coupled with the known landfill chemistry (Appendix II), indicates that this landfill is a MSW landfill. As such it is appropriate that the landfill be capped according to Act 641 provisions.

In light of the above discussion regarding the application of ARARs, it is appropriate to cap this Site using an Act 641 cap. An Act 641 cap will provide the necessary technical performance while being cost effective. An Act 641 cap will eliminate the unnecessary, excessive and costly requirement of the Act 64 capping provisions which are not required to obtain the objectives specified for this Site.

A.3.2 SPECIFIC COMMENTS

See general comments on the executive summary (Section A.1.1) regarding acceptable range for residual risk.

Acceptable ranges for residual risk at Superfund sites with similar physical and chemical characteristics are in the 10^{-4} to 10^{-5} range.

- Page 2-28 - The FS is fundamentally incomplete with respect to its lack of identification of the Michigan Environmental Response Act Type C cleanup criteria (P.A. 307, as amended) as an ARAR for the Site. Part 7 of P.A. 307 provides specific requirements for establishing cleanup criteria at ***"all known sites of environmental contamination"***: [Rule 107(1)].

Rule 701 provides specific definition of three types of cleanup levels which may be applied to environmental contamination sites. They are:

Type A: *"the degree of cleanup which reduces hazardous substance concentrations such that those concentrations do not exceed background or method detection limits for a hazardous substance";*

Type B: *"the degree of cleanup which provides for hazardous substance concentrations that do not pose an unacceptable risk on the basis of standardized exposure assumptions and acceptable risk levels";* and

Type C: *"means the degree of cleanup which provides for hazardous substance concentrations that do not pose an unacceptable risk, considering a site-specific assessment of risks".*

It is appropriate that a Site-wide remedy including removal, treatment and containment components attains one or a combination of the Type A, B or C requirements.

The use of the P.A. 307 rules for establishing cleanup goals at the Metamora Landfill Site will result in an effective approach to establish cleanup goals for this Site. It must be emphasized, as stated in Rule 705, that the attainment of cleanup goals as specified in P.A. 307 will result in a remedial action which ***"shall be protective of the public health, safety and welfare and the environment and natural resources"***.

As discussed in the P.A. 307 rules Type A, B and C cleanups are universally applicable either independently or in combination such that the cleanup standard is protective of the public health. Type C cleanup criteria are comparable to U.S. EPA's site cleanup approach.

Rule 717 states explicitly that ***"Type C criteria shall be developed on the basis of a site-specific risk assessment"***. Rule 717(2)(a) states that risk based cleanups must be demonstrated to be appropriate for the site being considered. The risk assessment evaluation presented in Appendix I clearly demonstrates that appropriate TCLs can be developed for the groundwater environment which are protective of the public health.

The evaluation presented in Appendix I also indicates that it is not reasonably foreseeable that the groundwater in the shallow aquifer would ever be utilized as a domestic water supply. Additionally, the landfill property will not be developed for residential use. Rule 719(3) provides specific terms for placing institutional controls to ensure that human exposures to Site-related chemicals will not occur.

Utilizing a Type C risk based cleanup will allow a Site-wide remedy to be developed which is both cost effective (pursuant to Rule 717(2)(c)) while being protective of public health.

The existing RI database, along with additional hydrogeologic studies conducted to the north of the landfill will provide the necessary information to fully define the Type C cleanup criteria pursuant to the requirements of Rule 717(3)(a-q)(4)(5).

The alternate TCLs proposed in Section A.4.0 of this report conform to the requirements of P.A. 307, are protective of the public health and therefore are appropriate for the Metamora Landfill Site.

An Act 641 cap is appropriate for the Site, protective of public health, cost effective and will reduce leachate generation such that the TCLs may be more readily achieved.

The Site-wide remedy incorporating appropriate TCLs and an Act 641 cap will provide the necessary containment of the Site such that the remediation is protective of public health while being cost effective.

A.4.0 IDENTIFICATION OF REMEDIAL RESPONSE OBJECTIVES

The purpose of Section 3.0 of the FS is to present the development of the remedial response objectives for the Metamora Landfill Site. The response objectives are presented on page 3-2 of the FS and may be summarized as follows:

1. Reduce human health risks posed by the ingestion of affected groundwater from the shallow aquifer. According to MDNR, the RI data indicated that the shallow aquifer contains volatile organic compounds (VOCs), arsenic and barium.

   Arsenic and barium were found at natural background levels. Additionally, as discussed previously in this report, exposure to VOCs in the shallow aquifer has not been demonstrated to occur and is unlikely to ever occur. This eliminates any potential exposure pathway.

2. Control the release of landfill leachate, which has been identified as a chemical source into the shallow groundwater aquifer.

   The landfill leachate at the Metamora Landfill exhibits chemical characteristics which are essentially identical to that of all MSW landfills. It is incorrect to conclude that the landfill is a hazardous waste landfill.

It has been demonstrated that active aerobic and anaerobic bacteria at MSW landfills in general, effectively eliminate many of the organic constituents of leachate. Biodegradation and other natural attenuation mechanisms also have been shown to result in the development of steady state groundwater chemistry at other landfills of a similar nature. The steady state assumption indicates that the nature and extent of leachate effects in groundwater approach an equilibrium after some period of time after which the chemicals no longer migrate in the groundwater system to any significant degree. Therefore, it is appropriate to apply an Act 641 cap over the Site.

3. Reduce potential risks to terrestrial organisms posed by contact with leachate affected soils from the landfill.

A review of the ecological risk assessment detailed in Appendix I indicates that the potential risks to terrestrial animals are unsupported, and overemphasized.

A.4.1 GENERAL COMMENTS

The response objectives for the Metamora Landfill Site are based upon an assumed exposure to shallow aquifer groundwater, which is only remotely possible. An exposure to groundwater in this aquifer is unlikely to occur under the scenario presented in the RI and therefore does not represent a realistic worst-case scenario for potential future exposures. Moreover, current U.S. EPA guidance states that risk assessments should be based on estimated Reasonable Maximum Exposure (RME) (see Appendix I). This exposure scenario is inaccurate and unsupported, and the TCLs for groundwater developed under this unrealistic and inaccurate exposure scenario drive the selection of an inappropriate remedy. The following concerns with respect to this exposure scenario have been identified:

1. chemical distribution in the shallow aquifer has not been established at the point where an exposure may occur (i.e. the nature and extent of affected groundwater has not been identified at off-site residences),

2. the RI is incomplete in that it does not adequately characterize the shallow aquifer,

3. the shallow aquifer does not represent an aquifer currently used for water supply,

4. the till unit precludes chemical migration to lower aquifers (i.e. intermediate or bedrock aquifers) which are used for water supply,

5. a shallow aquifer drinking water well is unlikely to be developed in the future. Shallow aquifers are vulnerable to surface impacts and therefore are rarely used for water supply, especially when a protected aquifer of ample quantity and quality exists,

6. a shallow aquifer well will not be developed within the property boundaries. This will not occur because access to the Site will be restricted and continually managed for years to come,

7. it is improper to assume chemical exposure will occur at levels which are measured under the Site. TCLs should be applied to groundwaters at the Site boundary, and

8. natural attenuation and degradation will result in much lower concentrations of chemicals at off-site downgradient exposure points.

In general, the risk assessment should be re-evaluated so that appropriate TCLs, based upon realistic exposure scenarios, can be developed.

Gradient Corporation (Gradient), has prepared a detailed review of the RI risk assessment presented in the RI and the TCL development presented in the FS. Gradient's comments and assessment of the RI and FS documents are presented in Appendix I of this report. In general, Gradient's comments conclude that the risk assessment was incomplete, unsubstantiated, and seriously flawed statistically.

Gradient's evaluation of the risk assessment (Appendix I) presents a technical analysis indicating that the Target Cleanup Levels (TCLs) for the Metamora Landfill Site should be established in accordance with Michigan 307 Type C guidance. The Type C cleanup approach is consistent with U.S.EPA cleanup guidelines. Using Type C approach and implementing four evaluation criteria: 1) MCLs, 2) cancer risk, and 3) practical quantitation limits (PQL), it is proposed that the following alternate target cleanup levels are appropriate for the groundwater remediation:

Chemical	Proposed Cleanup Level ($\mu g/L$)	Criteria
Benzene	5.0	MCL
1,1-Dichloroethane	5.0	PQL-EPA Method 8240
1,2-Dichloroethane	5.0	PQL-EPA Method 8240
1,1-Dichloroethylene	7.0	MCL
1,2-Dichloroethylene	7.0	MCL
Ethylbenzene	700	MCL
Trichloroethylene	5.0	MCL
1,1,2-Trichloroethane	5.0	PQL-EPA Method 8240
Vinyl Chloride	2.0	MCL
Xylenes (total)	440	MCL

In developing these alternate cleanup criteria, it becomes apparent that the limiting factor in proposing a technically feasible approach for most of the chemicals is related to analytical chemistry aspects of the cleanup. Thus, recommended PQLs are those concentration levels associated with the appropriate U.S. EPA methods which are applicable to be implemented during monitoring of the effectiveness of the remedy.

These alternate cleanup levels are proposed for groundwater at the point of attainment. Furthermore, groundwater use restrictions in the shallow aquifer will be applied in accordance with institutional controls described in Rule 719(C) of Michigan Act 307.

The residual risk level which shall be attained by achieving the proposed cleanup levels outlined above has been determined to be 2.7×10^{-5} (see Appendix I, page 21). This residual risk level is consistent with the NCP and Michigan Act 307, appropriate for the Site and is protective of public health (see Section A.1.1.2).

A.4.2 SPECIFIC COMMENTS

The following provides specific comments:

- Page 3.25 - The NCP does not necessitate a 10^{-6} residual risk level for Superfund cleanups (see comments to the Executive Summary). The TCLs should be set consistent with U.S. EPA directives which suggest that a 10^{-4} to 10^{-5} residual risk level would be appropriate for the shallow aquifer. The reference to a 10^{-6} risk level is inappropriate, and as such should be changed to reflect current U.S. EPA practice.

- Page 3.25 - The TCLs were developed in the FS based upon an improper risk assessment (see Appendix I for Gradient's detailed analysis). As presented above, the alternate TCLs for the groundwater remediation are appropriate for this Site.

- Page 3.25 - The Site should be managed in a manner that is consistent with evaluating the incremental risks associated with hazardous waste disposal at this Municipal Solid Waste (MSW) landfill. A literature review of leachate quality associated with purely MSW sanitary landfills, presented in Appendix II, indicates similarlity between the chemicals identified at MSW landfills in general and the Metamora Landfill Site.

The analysis of the literature review of common MSW leachate characteristics indicates the presence of certain polynuclear aromatic hydrocarbons (PAHs) at the Metamora Landfill at levels greater than those which normally would be expected at a MSW Landfill. The source of the elevated PAH concentrations may be tires which were disposed at the Site. It has been reported that fires occurred on Site involving these tires. As tires burn, they release oily liquids which contain a variety of constituents, including volatiles and PAH. Specifically, PAH compounds such as pyrene, fluoranthrene and phenanthrene are released. These compounds were identified at the Metamora Landfill Site (Appendix II) as being above the level anticipated for a MSW landfill.

This analysis, along with other information previously provided to U.S. EPA, indicates that the generators who disposed of tires at this Site should be added to the PRP list for the Site.

- Page 3.25 - The TCLs presented in Table 3.6 are not appropriate for application to shallow groundwater existing below the Site. TCLs need to be developed which represent realistic exposure scenarios at downgradient locations in light of the discussions presented in this report. Type C cleanup levels should be developed pursuant to recently promulgated administrative rules for Michigan P.A. 307.

- Page 3.25 - There is no discussion as to whether the proposed TCLs in the FS are technically achievable, cost effective, or implementable. Additionally, a review of the risk assessment has indicated that the extremely low concentration levels of the proposed TCLs are not required to be protective of human health. The alternative TCLs presented in Section A.4.1 are technically achievable, cost effective, and implementable as well as being fully protective of human health. The alternative TCLs, therefore, are appropriate for the remediation of groundwater at the Site.

A.5.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

The purpose of Section 4.0 of the FS is to develop and screen various technologies based on the remedial objectives for the Site and the suitability of the technology for the conditions encountered at the Site. Only ***"those technologies whose use is clearly precluded by waste or site characteristics are eliminated from further consideration at this point"***. Various technologies are then combined to produce alternatives for the groundwater and the landfill components. With these objectives in mind, the following sections present comments on Section 4.0 of the FS.

A.5.1 GENERAL COMMENTS

The option of discharge of extracted groundwater to a surface water body was eliminated from further consideration solely because three of the closest surface water bodies are located on Boy Scout property. Other surface water bodies suitable for discharge exist in proximity to the Site. Based on the stated objectives of this section, surface water discharge is not ***"clearly precluded"*** and therefore was eliminated prematurely. Surface water discharge should be compared with the groundwater recharge technology. The comparison needs to include an evaluation of whether the increased cost associated with groundwater recharge is justified by the presumed reduction in aquifer cleanup time.

A.5.2 SPECIFIC COMMENTS

The following provides specific comments:

- Table 4.2 Discharge; Screening Status; Discharge to surface water Body should read . . . is significantly more costly than groundwater recharge).

- Table 4.5 Landfill Closure; Act 64 Landfill Cover Installation; Site Limiting Characteristics; ***"the availability of soils with a permeability less than 1 x 10^{-7} cm/sec must be assessed"***. This assessment is required to estimate the costs presented in Appendix B, Table B.10. The FS is incomplete in its assessment of the capping requirement for this Site. The lack of information with respect to the availability of capping materials needs to be addressed.

A.6.0 DEVELOPMENT AND SCREENING OF GROUNDWATER ALTERNATIVES

The purpose of Section 5.0 of the FS is to develop and screen various groundwater alternatives based on the remedial objectives for the Site. Alternatives are developed by combining technologies which are retained after the initial screening presented in Section 4.0.

A.6.1 GENERAL COMMENTS

The surface water discharge technology which was eliminated in Section 4.0 of the FS should have been retained and used to develop alternatives for the groundwater component of the remedy. The premature elimination of the surface water discharge technology makes the development and screening of groundwater alternatives incomplete.

Institutional controls are eliminated as an alternative on page 5-10 of the FS. It should be made clear on page 5-10, that although institutional controls, are eliminated as an alternative on their own, they are included with the other alternatives for the groundwater component, as indicated in Table 5.3.

It is apparent that the MDNR has considered groundwater and landfill alternatives separately. Given the fact that groundwater and landfill alternatives are implemented as components of the overall remedy, the evaluation of the groundwater alternatives must consider that other remedy components will be implemented at the Site. The approach used by the MDNR results in an overly conservative remedy selection which is not cost effective.

The evaluation of the groundwater alternatives must also be based on a reasonable public health risk evaluation. The exposure scenarios developed by the MDNR are unreasonable and result in an overly conservative, non-cost-effective remedy selection.

A.6.2 SPECIFIC COMMENTS

- Page 5-10 - A statement should be added to this evaluation stating that institutional controls are included in the other alternatives for the groundwater component as presented on Table 5.3. With the proposed institutional controls, the MDNR public health risk exposure scenarios assumed in the FS can not occur. Thus, the exposure scenarios are not realistic.

- Page 5-16 - Precipitation/flocculation would require disposal of sludge at an off-site RCRA facility which does not appear to be included in the Appendix B cost estimates. The MDNR has not conducted an evaluation of disposal options for the generated sludge, how the sludge generated could be disposed, the availability of disposal capacity for the sludge, or the cost of sludge disposal.

This incomplete evaluation may result in inappropriate remedy selection, and operation and management problems throughout the life of the remedy.

A.7.0 DEVELOPMENT AND SCREENING OF LANDFILL REMEDIATION ALTERNATIVES

Section 6.0 of the FS presents the development and screening of landfill alternatives. The fundamental criticism of this development and screening is that it appears to be done independently without consideration for its integration with other elements of a possible remedy. The approach used by the MDNR to evaluate groundwater and landfill remediation alternatives independently results in an overly conservative remedy selection which is not cost effective.

In addition the evaluation of the landfill cap does not consider the regrading that will be required to achieve final contours as well as the consideration of potential fill sources necessary to evaluate costs.

A.7.1 GENERAL COMMENTS

The proposed landfill cap has the highest capital cost of any remedy component under consideration. As a result, its selection needs to be based on technical considerations of performance in terms of reduced risks, on administrative consideration of rules and regulations and on other factors including cost effectiveness. The MDNR improperly eliminated all capping alternatives considered, with the exception of the Act 64 cap without any justification. Application of Act 64 requirements is not only inappropriate given the nature of waste disposed (primarily municipal refuse) in the landfill. It is appropriate that the landfill be capped utilizing an

Act 641 cap. An Act 641, modified as described below, cap will meet all response objectives as discussed below.

The primary purpose of a cap is to prevent direct contact with buried waste materials, control the release of gases generated by the decomposition of Municipal refuse, and reduce infiltration of precipitation into the underlying waste. The modified Act 641 solid waste landfill cap is appropriate because it achieves the above objectives. Furthermore, the Metamora landfill contains primarily municipal solid wastes.

The modified Act 641 cap consists of a $4\frac{1}{2}$ foot blanket of sand, soil, and clay which effectively prevents direct contact with the underlying wastes. Landfill gas releases and infiltration of precipitation will be mitigated by the presence of the impermeable clay barrier. Furthermore, with respect to infiltration, as described in Appendix III, the modified Act 641 cap is comparable to the Act 64 cap.

Therefore, the modified Act 641 cap meets the remedial action objectives of preventing direct contact with waste material, containing landfill gas and mitigating the infiltration of precipitation through the landfill cover.

A.7.2 SPECIFIC COMMENTS

Specific comments on Section 6 follow:

- Figure 6.2 - These figures do not show any topsoil. Topsoil is included in the cost estimate for the Act 64 cap in Table B.10. It should be noted that there is no source of topsoil available at the Site.

- Page 6.6 - The basis for capping the Site is a result of the response objectives presented in Section 3.0 of the FS. These include mitigating direct contact exposures to terrestrial organisms and reducing infiltration. An Act 64 cap is inappropriate considering the Site history and is not the only cap capable of meeting these response objectives. The landfill is essentially a MSW landfill. This is evidenced by the fact that leachate and groundwater constituents are similar in nature as to what may be expected at any MSW landfill (see Appendix II). Furthermore, the groundwater displays only very limited concentrations of Site chemicals and are within the concentrations range of groundwaters directly below typical MSW landfills. Consequently, an Act 64 cap is not appropriate and is not required to meet the response objectives as developed.

- Pages 6-11 to 6-13 - All landfill cap alternatives are eliminated solely because they do not comply with the Michigan Act 64; which is claimed to be an ARAR. This approach has prevented an unbiased evaluation of alternative capping options. The modified Act 641 cap consists of 2 feet of clay, 12 inches of sand, 14 inches of soil and 4 inches of topsoil. The major technical differences between the Act 64 cap and the modified Act 641 cap are that the modified Act 641 cap has 1 foot less clay and 2 inches more soil cover. The modified Act 641 cap provides 30 inches of frost protection to the clay barrier layer (as required in Lapeer County, Michigan). The Act 64 cap allows an average of 1.71 inches of infiltration (5.7 percent of precipitation) per year, and the modified Act 641 cap allows an average of 1.98 inches of infiltration (6.6 percent of precipitation) per year.

The modified Act 641 cap presented here to includes 14 inches of cover soil instead of 12 inches in order to provide 30 inches of frost protection to the clay layer (see Appendix III). Therefore, ARAR issues aside, an evaluation of landfill cap performance using the HELP model indicates that a modified Act 641 cap provides similar reduction in infiltration, enhanced frost protection and is more cost effective than an Act 64 cap.

A.8.0 APPROACH TO THE DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

Section 7.0 of the FS presents an outline of the approach utilized to complete the detailed analysis of alternatives. The approach presented is applicable to groundwater and landfill alternatives that passed the initial screening presented in Sections 5.0 and 6.0 of the FS.

A.8.1 SPECIFIC COMMENTS

The following provides specific comments:

- Page 7-8 - A 25 percent contingency, which has been applied as the northern extent of contamination, has not been fully explained. The RI cannot be considered complete if the northern extent of contamination has not been fully defined. The use of a simple mathematical model in conjunction with generalized assumptions in an area which is referred to as ***"geologically complex"*** is wholly inadequate. There is no substitute to accurate field data to predict the area of affected groundwater. Completing conceptual extraction system designs based on this inadequate data base is not appropriate and leads to erroneous conclusions. Applying a 25 percent contingency to account for a distinct lack of data is unacceptable and does not reflect sound engineering practice.

A.9.0 DETAILED ANALYSIS OF GROUNDWATER ALTERNATIVES

Section 8.0 of the FS presents the detailed analysis of groundwater alternatives developed in Section 5.0.

A.9.1 GENERAL COMMENTS

The principle shortcoming of the detailed evaluation of groundwater alternatives in the FS is that, without a complete RI data base, the conceptual designs of the groundwater extraction systems which are based on simple mathematical modelling, are or may be inappropriate. site-specific data regarding the nature and extent of contamination should have been collected before an appropriate conceptual design could be configured.

While the two conceptual plans which are presented (system A and system B) are described in the FS, a detailed evaluation and comparison between the two alternatives is not presented. System B (the "20 year system") is eventually selected in the Proposed Plan without adequate evaluation.

The detailed analysis of groundwater alternatives should include a detailed evaluation of surface water disposal options which were prematurely eliminated in Section 4.0 of the FS.

It must also be stressed that the TCLs must be developed utilizing realistic and reasonable exposure scenarios. This will allow the system to be designed with achievable TCLs as the goals. The TCLs developed in the FS are unlikely to be achieved for many years to come, if ever.

A.9.2 SPECIFIC COMMENTS

The following provides specific comments:

- Page 8-2 - Bench scale testing which is ***"typically conducted to assess groundwater treatment was not available"*** because it was not conducted by MDNR. Based on the schedule of submittals to MDNR and U.S. EPA, the alternatives array was first submitted in December 1988, which would have left sufficient time for bench scale tests. The tests, however, were not completed. As a result, an evaluation of groundwater treatment alternatives, particularly precipitation/flocculation and ion exchange, cannot be adequately completed. Bench scale test samples could have been analyzed using the CWM field laboratory which was acquired by MDNR for this project.

- Page 8.3 - improperly concludes that "plume" stabilization would likely occur well into the future only after Site related constituents have spread over a significantly larger area than is currently involved. The RI data base, however, does not contain any information regarding the area currently involved. There is no basis for discussing stabilization of a "plume" until there is good demonstration that a "plume" exists. Simple mathematical models are no substitute for accurate field data in determining the presence and extent of a plume.

- Page 8-14 - The FS states that five pore volumes must be removed to reach TCLs. It is very unlikely that the very low TCLs will be met at all, let alone after five pore volumes. The 20- year cleanup scenario has not been substantiated. The cost implications for not achieving the TCLs in a 20-year time frame should be evaluated.

- Figure 8.2 - there is no scale on this figure.

- Page 8-24 - states: ***"The capital and annual expenditures, as well as the time required to achieve TCLs, must be evaluated to evaluate which system can best serve the Metamora Site".*** There is no evaluation presented of how a 210 gpm system was selected. This selection is not presented in the FS. The Proposed Plan states that the shorter time period is preferred, but there is no evaluation between the two.

- Page 8-31 - The summary states that recharge will minimize extraction time and thereby speed up remediation of the Site. The cost of the surface water discharge alternative which was prematurely eliminated in Table 4.2 is not presented. The time saving of recharge over surface water discharge is insinuated, but not evaluated. The evaluation of the 20- and 40-year alternatives requires a cost-benefit analysis. Surface water discharge was prematurely eliminated and thus should be considered in the detailed analysis.

- Page 8-49 - It is unclear in the FS whether vapor phase treatment is expected to be needed at this time. Page 8-53 says "if deemed necessary", later on Page 8-56 it says: "because air stripping produces off gases that must be treated, a vapor phase carbon adsorption unit is added to the system". It is not clear at this time whether there is even a need for vapor phase treatment, as the contaminant plume and thus the mass of contaminants that will be removed from the aquifer, is unknown due to the incomplete RI data base.

- Page 8-54 - Vapor phase carbon treatment does not appear to be in Table B-6 capital cost estimate, however, it does appear in the annual cost. The annual costs do not appear to reflect operation in a four season climatic area.

- Page 8-62 - The laboratory studies required to determine ion exchange vs precipitation/flocculation should have been conducted as part of the FS.

- Page 8-65 - The report does not include an evaluation of how the liquid waste stream would actually be disposed of. Disposal costs do not appear in Appendix B, Table B-7.

- Page 8-66 - The report does not include an evaluation of how the sludge would actually be disposed. Disposal costs do not appear in Appendix B, Table B-8.

- Page 8-71 - The report does not indicate whether land disposal of the treatment sludge will be possible. An evaluation of alternative disposal options and the related costs is required.

A.10.0 DETAILED ANALYSIS OF LANDFILL ALTERNATIVES

Section 9.0 of the FS presents the detailed analysis of the landfill alternatives developed in Section 6.0 of the FS.

A.10.1 GENERAL COMMENTS

General comments on the technical performance required by a landfill cover were discussed in Section A.7.0 of this report.

A.10.2 SPECIFIC COMMENTS

The following provides specific comments:

- Page 9.7 - The description of the Act 64 cap does not include topsoil, however, the cost estimate includes four inches of topsoil. Topsoil is not available at the Site. The report should include an evaluation of possible topsoil sources in the area and the cost estimate should be revised based on this evaluation.

- Page 9.7 - The FS does not adequately describe the landfill area to be covered, and does not provide any details with respect to the areas to be capped and the volume of fill materials required to achieve desired grades. Considering the extreme topographic conditions present at the Site, it is necessary to provide additional details on the geometry of the cover system. In addition, there is no mention of stormwater management of runoff from the completed cap.

- Figure 9.1 - There is no basis provided for the areal extent of the cap.

- Figure 9.1 - Final elevations (contours) should be provided so that drainage requirements and cost estimates (quantities) can be evaluated.

- Page 9-7 - The source of the cap materials is not discussed. Considering that the Site exists on an extensive sand deposit, an evaluation of clay and topsoil sources is required. The cost estimates presented cannot be considered accurate unless an evaluation of clay and topsoil sources has been conducted.

- Page 9-11 - The description of the Act 64 cap does not include topsoil, however, the cost estimate includes four inches of topsoil.

- Page 9-12 - An Act 641 cap meets Site ARARs, achieves remedial objectives and is protective of human health and the environment; however, all caps except the Act 64 cap were eliminated prior to detailed analysis. The ARAR which governs the landfill cap at this Site should be Act 641 due to the nature of waste disposed in the landfill.

- Page 9-13 - The report should describe the existing cover and should present an evaluation of whether the existing cover could be included as part of the final cover.

- Figure 9.2 - This figure does not show topsoil, however, the cost estimate includes four inches of topsoil.

- Page 9-23 - Landfill gases can be safely vented to the atmosphere, as is common practice at most landfill sites. An evaluation of why flaring is considered to be necessary at this Site should be presented.

A.11.0 COMPARISON OF REMEDIAL ALTERNATIVES

Section 10.0 of the FS presents a comparison of the assembled alternatives.

A.11.1 GENERAL COMMENTS

A comparison of alternatives should eventually lead to a recommendation for the preferred alternative. The FS does not have a conclusion.

As described in earlier sections of these comments, certain alternatives such as surface water discharge and alternative landfill caps (such as an Act 641 cap) were prematurely and improperly eliminated from consideration and should be included in the final detailed analysis and comparison of alternatives.

An evaluation of the groundwater systems A and B is not completed in the FS. This evaluation is required, including a detailed evaluation of the sensitivity of the two systems, given the limited data that is available and the assumptions that are required to complete the conceptual designs. A technical analysis of the achievability of the TCLs in a 20-year or 40-year time frame should be provided.

A.11.2 SPECIFIC COMMENTS

Specific comments are as follows:

- Table 10.2 & 10.3 - It is clear from the data presented on these tables that groundwater system B (20-year plan) is much more sensitive to assumptions relating to efficiency than system A (40-year plan).

At an assumed 70 percent removal efficiency, with each pore volume removed, system B has a present worth which is $827,930 more than system A. With a drop in removal efficiency of only 10 to 60 percent with each pore volume removed, system B has a present worth which is $1,593,505 more than system A. These calculations are presented on the following table.

	70% Removal	*60% Removal*
System A (40-year)	9,020,295	9,680,487
System B (20-year)	9,848,305	11,273,992
Difference	828,010	1,593,505

FS Appendix B

- Based on the Preferred Groundwater Alternative presented in the Proposed Plan, a Cost Summary is presented as follows:

		Capital	*Annual*		*Present Worth*
1)	Extraction A	356,063	35,379	(40-yr)	963,135
	Extraction B	623,025	65,189	(20-yr)	1,435,423
2)	Recharge A	407,194	69,200	(40-yr)	1,594,604
	Recharge B	793,463	93,341	(20-yr)	1,956,697
3)	Air Stripping A	424,153	232,135	(40-yr)	4,407,380
	Air Stripping B	495,028	261,564	(20-yr)	3,754,691
4)	Precip/Floc A	474,188	92,137	(40-yr)	2,055,176
	Precip/Floc B	642,938	165,184	(20-yr)	2,701,494
Total Groundwater Alternative					
A		1,661,598	428,851	(40-yr)	9,020,275
B (1)		2,554,454	585,278	(20-yr)	9,848,205

Note:

(1) These costs are not the same as presented in the Proposed Plan. Costs in the Proposed Plan for Capital and Annual costs are incorrect. Present Worth Cost in Proposed Plan is correct.

PREFERRED LANDFILL ALTERNATIVE

Table B-10 Act 64 Cover

- error in seeding cost - the landfill area is 120,000 S.Y. not 13,500 S.Y. as presented.
- seeding cost should be $72,000.

		Capital	*Annual*		*Present Worth*
1)	Act 64 Cap	4,961,621	248,768	(30-yr)	9,785,807
2)	Passive Gas Collection	262,631	0	(30-yr)	262,631
3)	Flare	171,709	18,585	(30-yr)	457,407
Total Landfill Alternative		5,395,961	267,353	(30-yr)	9,505,845

Note:

Due to error in seeding cost, costs in Proposed Plan are incorrect.

PART B: COMMENTS ON THE PROPOSED PLAN

B.1.0 INTRODUCTION

B.1.1 GENERAL COMMENTS

The proposed plan for the Site has been selected on the basis of an incomplete RI data base, a public health risk evaluation which is fundamentally flawed, and inappropriate ARARs, without bench scale treatability test results.

The incomplete RI data base required MDNR to utilize inappropriate simple and unrealistic mathematical models to estimate the nature and extent of chemical migration from the Site. The fact that the dimensions and chemicals in the affected groundwater area, are not known, requires that assumptions be made regarding extraction well placement, recharge well placement, extraction well water quality, groundwater treatment, and off gas treatment which are all based on the groundwater modelling and therefore are inappropriate.

The public health evaluation presents exposure scenarios that do not exist and will not likely exist, thereby resulting in an overly conservative remedy selection which is not cost effective.

The selection of the landfill cap was based on the MDNR assumption that Act 64 applies to the landfill. Such an assumption is unsupported in the FS and is inappropriate. An evaluation of the Site history, types of wastes accepted, disposal practices, leachate quality and groundwater quality downgradient of the landfill indicates that the Metamora Landfill is typical of a MSW landfill and, as a result, Act 641 is the appropriate ARAR for the landfill. ARAR issues aside, a technical evaluation of the Act 641 cap, modified to include two additional inches of cover soil to provide frost protection for the clay layer, provides the same level of public health and environmental protection as the Act 64 cap.

The analysis of groundwater treatment options is based on an incomplete RI data base and is further compromised by the lack of site-specific bench scale treatability tests which the report states are "typically conducted to assess groundwater treatment". Considering the level of current presence on-site by the MDNR it would have been appropriate and cost effective for treatability studies to have been undertaken some time ago.

The use of detection limits as performance standards is inconsistent with U.S.EPA guidance, policy, good science and common sense.

U.S. EPA policy is that remediation levels should generally be attained throughout the area of affected groundwater, or at and beyond the edge of the waste management area when waste is left in place. (NCP, 1990)

The Metamora Landfill RI/FS violates this policy because it seems to require the cleanup of all groundwater, even the groundwater within the municipal landfill to below drinking water levels. Rather U.S. EPA should select an alternative point of compliance downgradient from the landfill. Such an alternative location is appropriate when a plume of groundwater is affected by releases from several distinct sources that are in close geographical proximity. In such cases, the most feasible and effective groundwater cleanup strategy may be to address the problem as a whole, rather than source-by-source, and to draw the point of compliance to encompass the sources of release. (NCP, 1990)

In the case of Metamora Landfill, there are three areas being remedied, area 1, area 4 and the landfill. Thus, an alternative point of compliance should be set up for this Site.

Finally, oversight activities conducted by the PRP of the Operable Unit No. 1 identified serious problems associated with the drum removal activities. These problems included the unnecessary breaching of drums on unprotected ground for the purpose of sampling drum contents which resulted in the release of large quantities of materials into the environment. It must be stressed that this activity will not only result in increased levels of contamination in the soils and groundwater, but will result also in increased costs to both remediate the groundwater (Operable Unit No. 2) and sub-drum disposal area soils (Operable Unit No.3).

B.2.1 SPECIFIC COMMENTS

- Page 4 - The soils surrounding the drum disposal areas were found to be affected to only a limited extent in the RI report. However, oversight activities conducted by the PRP during April 1990 indicated MDNR was conducting the drum removal activities in a manner which resulted in excessive leakage and spillage of drum contents onto the ground. (See June 7, 1990 MLSSC letter to Nola Hicks (U.S.EPA) This has resulted in a situation where there is more contamination on and in the soils directly beneath the drum disposal areas than there would have been prior to the initiation of drum removal activities. It must be stressed that the leakage and spillage of waste materials during the drum removal activities will result in a situation which requires the groundwater extraction and treatment system to be operated for a longer period of time and to handle a larger amount of mass. This will result in substantial additional costs to complete the groundwater remedy.

- Page 4 - The U.S. EPA is planning to designate the subsurface soils beneath the drum removal areas as Operable Unit Three. Considering that Drum Area Number 4 excavation has been completed for some time, it would be prudent to initiate the investigation of that area as soon as possible, as contaminants which are located in these soils may be continually leached further and deeper into the soil.

- Page 7 - a 20-year extraction plan with air stripping and precipitation/flocculation may be "preferred", however, an evaluation of the two alternatives (i.e. 20-year and 40-year plan) is required. The 20-year plan is much more expensive and is much more sensitive to the assumption that 70 percent of contaminants will be removed. The sensitivity is demonstrated in the following table:

	70% Removal	*60% Removal*
System A (40-yr)	9,020,275	9,680,487
System B (20-yr)	9,848,205	11,273,992
Difference	827,930	1,593,505

The cost difference between A and B is $827,930 for 70 percent removal assumption and $1,593,505 for 60 percent removal assumption.

- Page 9 - Alternative 5b costs are wrong. They should be:

Construction	2,554,454
Annual O&M	585,278
Present Worth	9,848,205

- Page 10 - Alternative LF-5a costs are wrong. Due to an error in seeding cost estimates, costs should be:

Construction	5,395,961
Annual O&M	267,353
Present Worth	9,505,845

- Page 10 - Alternative LF-5b costs are wrong due to an error in seeding cost.

- Page 10 - the determination of whether precipitation/flocculation will work should have been made by laboratory tests during the FS. The incremental costs to go to ion exchange are as follows:

	Precip/Floc	*Ion Exchange*	*Increase*
System A	$2,055,174	$3,551,293	$1,496,119
System B	$2,701,494	$4,773,666	$2,072,172

As indicated earlier, these costs estimates do not appear to include disposal of wastes generated by these treatment methods.

- Page 10 - Preferred Alternative

  This section should specify clearly that system B (20-year system) is selected as the preferred alternative.

- Figure 9 - This figure does not show topsoil which is included in the FS cost estimates.

- Page 14 - Capital and Annual costs are incorrect as indicated previously. They should be:

Capital	2,554,454
Annual O&M	585,278

- Page 15 - Costs for Alternative LF-5a are incorrect due to error in seeding cost. These should be:

Capital	5,395,961
Annual	267,353
Present Worth	9,505,845

- Page 16 - The Cost Summary is wrong. It should be:

Alternative	*Capital Cost*	*Annual Cost*	*Present Worth*
GW-5b	2,554,454	585,278	9,848,205
LF-5a	5,395,961	267,353	9,505,845
Total	7,950,415	852,631	19,354,050

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APPENDIX I

RISK ASSESSMENT REVIEW
GRADIENT CORPORATION

REVIEW OF E.C. JORDAN'S RISK ASSESSMENT FOR THE METAMORA LANDFILL

X.1 SUMMARY

This review examines the MDNR contractor's (E.C. Jordan Co., "Jordan") selection of chemicals of concern (indicator chemicals), the estimation of human health risk posed by the Metamora landfill ("baseline risk assessment"), and the estimation of ecological risk posed by the Site. The risk assessment results presented in Jordan's Feasibility Study report (FS) are a summary of the work presented in more detail in the Remedial Investigation report (RI). Hence, this review will reference the original presentation of this work in the RI.

The Baseline Public Health Risk Assessment (risk assessment) in the RI/FS is flawed because it uses unreasonable, unrealistic, and, in some instances, inappropriate assumptions and the crucial assumptions are contrary to EPA guidance. The risk assessment assumptions are improper, are not based on good science and are contrary to EPA guidance, because:

- there is no present exposure, and future exposure to the chemicals in the shallow aquifer is unlikely, if not impossible, based on present and reasonably likely future land use. The chemicals in the shallow aquifer will not migrate, because, according to MDNR's own studies and the submissions of its contractors, there is no substantial area of affected groundwater (just isolated pockets of chemicals in areas where the shallow aquifer is perched), and there is a 150-foot confining layer between the shallow aquifer and the drinking water aquifer;

- the risk assessment (and calculation of target cleanup levels (TCLs)), erroneously and contrary to EPA policy and good sense, assumes that a "reasonable" worst-case exposure would involve ingesting two liters of water per day for 70 years from the shallow aquifer <u>below a municipal waste landfill</u>. A municipal landfill is dedicated to contain municipal wastes and cannot be used as drinking water source. If one assumes that the shallow aquifer directly below the Site must be used in the future as drinking water, then it follows that EPA and the State must cleanup all of the municipal landfills and other solid waste landfills in the country to the same extent. Therefore, the FS and Proposed Plan misrepresent the nature of the Site. It is and will continue to be a municipal landfill located in a mined out sand and gravel quarry, not an area suitable for residential development;

- even if one assumed, erroneously and contrary to EPA policy and good sense, that a "reasonable" worst-case exposure would involve ingesting two liters of water per day for 70 years from the shallow aquifer <u>below a municipal waste landfill</u>, vinyl chloride should not be considered in the risk assessment because: (1) it was only detected in 10% of the samples; (2) it was never detected in the landfill; and (3) the unusually high detection limit for vinyl chloride (i.e., a detection limit that is higher than the maximum contaminant level - "MCL" for vinyl chloride) results in the calculation of an artificially high and inappropriate risk level despite failure to detect it throughout the landfill and most of the Site;

- even if one assumed, erroneously and contrary to EPA policy and good sense, that a "reasonable" worst-case exposure would involve ingesting two liters of water per day for 70 years from the shallow aquifer below a municipal waste landfill, arsenic should not be considered in the baseline risk assessment because it is present as a natural component of the lithosphere throughout the Metamora area and is found downgradient only at background levels;

- The risk value in the RI is erroneous because it is primarily driven by the erroneous concentrations used for arsenic and vinyl chloride and, as indicated above, neither measurement accurately reflects the conditions at the Site.

Soils at the Site pose no human health endangerment, according to the FS, but a potential for ecological endangerment from soils was speculated. This conclusion also is not credible because it lacked any Site-specific documentation.

Using revised indicator chemicals, exposure factors and representative concentrations, all of which are justified herein, Gradient recalculates that the potential human health risks from a hypothetical shallow aquifer domestic well would be 4.8×10^{-6} for the most probable case and 3.5×10^{-5} for a reasonable worst case. These risks are lower than current actual risks of 6.9×10^{-5} from naturally occurring arsenic in the bedrock aquifer (which is used as a domestic water supply).

This report will demonstrate that the TCLs recommended in the FS should be modified. Arsenic and barium should be deleted as Target Compounds because their presence is indistinguishable from background levels. Revised TCLs for the other chemicals are as follows:

Chemical	Proposed Cleanup Level (µg/L)
Benzene	5.0
1,1-Dichloroethane	5.0
1,2-Dichloroethane	5.0
1,1-Dichloroethylene	7.0
1,2-Dichloroethylene	7.0
Ethylbenzene	700
Trichloroethylene	5.0
1,1,2-Trichloroethane	5.0
Vinyl Chloride	2.0
Xylene (Total)	440

X.2 Reevaluation of Chemicals of Concern at Metamora Landfill

Of the 34 chemicals, total, found at the Metamora Site, Jordan selected 10 organic compounds and 2 trace metal elements to comprise a list of "chemicals of concern" (also referred to as "indicator chemicals" or "indicators"). This list was then used as the basis for human health risk evaluations; a modified list was used to evaluate ecological endangerment.

EPA guidelines for selecting chemicals of concern were claimed to be used by Jordan. However, there is no documentation provided, such as the worksheets or the results of scoring described in EPA's Superfund Public Health Evaluation Manual[1].

Gradient's reevaluation involved a critique of the process used in selecting chemicals of concern, as well as an assessment of the database and methods employed in the determination of representative concentrations. Two major errors of contention have been identified:

- Background concentrations were not adequately accounted for, including those due to natural ambient conditions, as well as those attributable to the adjacent "municipal" landfill <u>not</u> associated with industrial waste areas.

- Representative concentrations, including those for both the "most probable" and "realistic worst" case, indeed are <u>not</u> representative of conditions likely to occur either at present or in the future.

In addition, the Site is relatively uncontaminated as indicated by the large number of samples from the Metamora field data resulting in "non-detects" for many of the Site related compounds. This results in an extremely censored database (i.e., containing many data points with undetermined quantitative values) which requires special consideration during manipulations such as averaging and interpretation.

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[1] This guidance document has been updated recently ("Risk Assessment Guidance for Superfund", 1989) but Jordan would not have had the benefit of the new guidance at the time their work was performed.

X.2.1 CLASSIFICATION OF WELLS

As noted in the RI and FS, only the shallow aquifer contains contamination from the Site. Jordan has classified all of the wells in the shallow aquifer as either "background" or "downgradient" of source areas. The results of the groundwater monitoring phase of the RI confirm E.C. Jordan's groupings, because almost all of the chemicals that were analyzed for, were not detected in the wells that have been classified as background. Conversely, some chemical contamination was detected in all of the wells that were classified as downgradient.

On the other hand, wells should be further classified as being on Site and off Site in order to allow a fair evaluation of all remedy phasing and remedial alternatives including institutional controls. The following aggregation of the data would accomplish this:

- All on-Site wells;
- On-Site wells downgradient of waste sources;
- On-Site wells upgradient of waste sources (i.e., background); and,
- Off-Site wells downgradient of the Site.

Table 1 presents Gradient's assessment of which wells should be assigned to each category.

X.2.2 SELECTION OF INDICATOR CHEMICALS

Jordan's selection of indicator chemicals is reasonable, with some qualification, for the organics but not for the inorganics. Barium and arsenic should be deleted from the list of indicators. Vinyl chloride should be reconsidered in terms of its representative concentration due to the large number of non-detects and the unusually high detection limits arising from the analytical data. In fact, vinyl chloride was never detected in any on-Site wells, thus begging the question as to whether this chemical should be considered an indicator chemical at all. Table 2 summarizes the groundwater results for the entire shallow aquifer.

Barium was detected in 39 of 43 samples (91% detection frequency) from downgradient wells, but it was also detected in 27 of 31 samples (87% frequency) from background locations. All other indicator chemicals were detected very infrequently at background locations. In addition, the concentrations of barium detected at background locations were not statistically different from concentrations detected at downgradient wells, as determined by both the Student's t-test and the Mann-Whitney test[2]. Although downgradient well MW-16 contained concentrations of barium above the 1 ppm MCL, this was the single exception. The next highest measured downgradient concentration was 338 ppb, and a total of 31 samples had detected concentrations of less than 100 ppb. These observations indicate that barium is a natural component of the shallow aquifer and that the relatively high concentrations observed at MW-16 may be within the normal

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[2] Zar, J.H. 1984. Biostatistical Analysis. Prentice Hall, Inc., Englewood Cliffs, N.J.

range for this aquifer. A USGS survey[3] supports our contention that barium background concentrations are high, by stating: "groundwater in the southeastern part of the State tends to have larger concentrations of dissolved solids, hardness, ammonia, barium ... than elsewhere." Therefore, we argue that barium should be removed from the list of indicator chemicals for the groundwater scenarios.

Arsenic from natural ambient conditions can be expected to range in groundwater from 1 to 30 ppb with natural values observed as high as 4,000 ppb in some areas[4]. The average on-Site arsenic concentration (33 samples) was 15 ppb which is within this range. The average for all shallow aquifer wells was 17.6 ppb (63 samples). Although background wells in the shallow aquifer had arsenic levels below the detection limit, the bedrock aquifer averaged 18.2 ppb (11 samples). The striking similarity between arsenic levels in both the bedrock and shallow aquifers, despite the fact that the bedrock aquifer is not contaminated by the Site, demonstrates arsenic levels in the Site groundwater are within the range of regional, natural arsenic levels, and any levels above or below these averages are due to natural variations. This is further supported by the fact that waste evaluations presented in the RI (cf. Section 5.1.2.3) never even list arsenic as having been observed or of concern. Arsenic should be deleted from the list of chemicals of concern or, at a minimum, the effect of natural background should be subtracted from human health risk estimations.

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[3] USGS. 1986. National Water Summary 1986 - Hydrologic Events and Groundwater Quality. USGS Water Supply Paper No. 2325.

[4] Dragun, James, 1988. The Soil Chemistry of Hazardous Materials. Hazardous Materials Control Research Institute, Silver Spring, MD.

The credibility of using vinyl chloride as an indicator compound is also improper because of the nature of the available data. Vinyl chloride was detected only in 10% of the shallow aquifer samples (64 samples) and not at all in on-Site wells. Moreover, the average detection limit for vinyl chloride was so high, 10.9 ppb -- more than 5 times the MCL regulatory level of 2.0 ppb. Statistics such as averages rely on assigning quantitative estimates to non-detects and are mostly an artifact of the detection limit. In other words, the average concentration for vinyl chloride used by Jordan in its risk assessment is primarily a guess, strongly influenced by the high analytical detection limit. We conclude, therefore, that all risk evaluations in the RI/FS for vinyl chloride are highly inflated. A more statistically sound approach to deriving a representative concentration for vinyl chloride is needed if vinyl chloride is continued as an indicator compound. Such a method is set forth in Section X.2.3 on Log-Probit Analysis.

X.2.3 Estimation of Representative Exposure Concentrations for Groundwater Scenarios

The most striking characteristic of the Metamora groundwater database is the very large number of non-detects for all of the indicator compounds. This must be considered carefully when developing statistical representations of exposure concentrations.

Jordan developed representative concentrations by calculating an arithmetic average and identifying the maximum for each indicator for the "most probable" and "realistic worst" cases, respectively.

Non-detects were assigned a value of one-half the detection limit reported for each sample analysis. Although it is not clear from the RI report, presumably the data set used was that presented in Appendices D, I, and K of the RI for wells classified by Jordan as downgradient, shallow aquifer wells.

Some data were discarded for quality control reasons (e.g. contaminated blanks) and for physical reasons (e.g. from MW-4 were not used because it is in a perched aquifer). Recognizing these adjustments, Gradient attempted to reproduce Jordan's calculations with limited success. Some of the average concentrations for indicator compounds presented by Jordan could not be reproduced. A comparison is presented in Table 3.

Jordan's use of the maximum concentration of each indicator in groundwater to represent the "reasonable worst case" is not credible for long term, chronic exposures. Contaminant concentrations will vary over time and space and the assumption for estimating cancer risks that exposures to the single maximum concentration found anywhere at the Site will occur for an individual repeatedly <u>on a daily basis for an extended number of years</u> is <u>not</u> reasonable. A more realistic assumption is that the <u>mean</u> indicator concentration for the <u>most contaminated area</u> is representative of the long term "maximally exposed" condition. This would be the mean of the on-Site, downgradient (from the waste sources) well data.

In recalculating mean concentrations, Gradient discarded any samples that showed blank contamination or that were rejected by the laboratory because of QA/QC considerations. Estimated concentrations (marked with a 'J' in the data reports) were treated the same as detects in the determination of exposure concentrations. One downgradient well in the shallow aquifer (MW-6) had three screened intervals, each of which was sampled during three sampling events; thus, 9 samples from only three sampling events were taken from MW-6 during the RI. To avoid biases that could be introduced by the relatively large number of samples from MW-6 while maintaining conservative (i.e. protective of human health) assumptions in the risk assessment, we averaged values from the 3 depths for each sampling event for MW6. At well clusters (MW-10S/D, MW-14S/D, MW-15S/D, MW-17S/D) concentrations from the shallow and deep wells were averaged for each sampling event to provide a representative concentration at that location. The maximum value of duplicates was used.

In both the Jordan analysis and our analysis, samples from all appropriate wells and all sampling events were considered together (with the exception of MW-6, noted above). Not all of the wells, however, were sampled the same number of times. The shallow aquifer, downgradient wells each were sampled at least twice but no more than four times as part of the RI. Statistical inaccuracies are inherent with variable amounts of data from different point sources. A more appropriate procedure corrects for discrepancies in the number of samples from each well. However, for the Metamora database, this would limit too much the amount of data available to work with statistically. We also note that considering all samples from all sampling events together may not be the most appropriate methodology because there were four RI sampling events, the middle two of which occurred over a two month span of time, while the other two sampling events occurred roughly six months before and six months after the two middle events.

Tables 4 through 7 present arithmetic averages for indicators chosen by Jordan for various data aggregations ("areas"). The results from the groundwater monitoring phase of the RI show that most of the monitored chemicals, including most indicator chemicals, were detected in only a small fraction of the samples. All of the groundwater indicator chemicals at the Metamora site had at least 4 samples with non-detected concentrations. All of the groundwater indicator chemicals were not detected in at least 50% of the samples, except arsenic, barium, and 1,1-dichloroethane. For sample sets with large fractions of non-detectable samples, the calculation of an arithmetic average concentration for the entire sample set can be greatly affected by how the non-detects are treated. For situations with unusual data distributions, regulatory agency documents urge use of statistical methods beyond mere averaging[5]. In addition, EPA RCRA documentation[6] states "An owner or operator may wish to consult literature to determine what type of distribution the groundwater monitoring data or specific constituent are likely to follow. This may avoid unnecessary computations and make it easier to determine whether there is statistically significant evidence of contamination". We present, below, a more statistically sound alternative to the methodology used by Jordan in calculating mean exposure concentrations, given this unusual data set containing so many non-detects.

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[5] U.S. EPA 1989. Risk Assessment Guidance for Superfund. Human Health Evaluation Manual Part A. p. 6-19.

[6] U.S. EPA 1989. Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities. Interim Final Guidance, p. 4-5.

Log-Probit Analysis

Log-probit analysis is a statistical approach for estimating means which is appropriate when the underlying probability distribution is log-normal[7]. This is the case for the Metamora Site data. Log-probit analysis is most useful for determining the mean and variance of sample sets that contain censored data points, such as the groundwater data from the Metamora Site. The frequency of detection is implicitly considered when using log-probit analysis, unlike Jordan's analysis using one-half of the detection limit for non-detects. An additional advantage of log-probit analysis is that the detection limit, which can vary widely and be quite high for some samples, does not influence the mean. For sample sets with as many non-detects as found at Metamora, the EPA-recommended guidance of using one-half the detection limit for non-detects will be biased by the detection limit. Finally, log-probit analysis leads to less-biased estimates of the mean than using one-half the detection limit for non-detects.

To perform the log-probit analysis, the data for each indicator chemical were ranked from lowest concentration to highest concentration, with all non-detects receiving a lower ranking than the lowest detect. Examples are provided for both vinyl chloride and 1,2-dichloroethane in Tables 12 and 13, respectively. The percentile for each sample was then calculated by dividing the rank of the sample by one plus the number of samples (one plus the number of samples is the divisor because n samples divide an interval into n + 1 equal sub-intervals). The percentile for each

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[7] Travis, C.C. and M.L. Land, 1990. Estimating the mean of data sets with non-detectable values. Environ Science and Technologies 24(7): 961-962.

sample that had detectable concentrations was plotted against the associated concentration on log-probit paper. Again, examples for both vinyl chloride and 1,2-dichloroethane are given in Figures 1 and 2, respectively. If the assumption of a log-normal distribution is valid, the resulting plot on log-probit paper will be linear. In order to define the "best-fit" line, least-squares analysis was then performed by measuring linear x- and y-coordinates on the plot by superimposing a square grid over the log-probit plot. The mean concentration is defined by the point where the regression line crosses the 50 percentile lines.

Table 9 summaries these mean concentrations for the list of indicators and exposure conditions Gradient believes to be the most credible - with arsenic and barium deleted. The problem with Jordan's representative concentration for vinyl chloride, noted above, is solved with this log-probit approach so the concentration presented in Table 9 can be used with confidence in the risk calculations. In Table 9, the data aggregations will correspond to the following risk scenarios:

- On-Site - Most Probable, on-site
- Downgradient, Off-Site - Most probable, off-site
- Downgradient, On-Site - Reasonable Worst Case

X.3 Risk Assessment Critique and Recalculated Risks

In the context of the Metamora Landfill Site RI/FS, Jordan has performed a quantitative human health risk assessment for both a baseline (current) and a hypothetical (future) scenario. The current risks derive from potential oral and dermal exposure to soil; health effects, even under Jordan's "realistic worst-case," are very low: a carcinogenic risk of 1.8×10^{-8} and a sum hazard index of 0.00018.

The hypothetical (future) scenario includes potential exposure via use of groundwater from the shallow aquifer for drinking, showering, and bathing. If indeed such exposures occur simultaneously each day for a full lifetime (70 years), Jordan calculates that carcinogenic risks in their "most probable" scenario are 5.76×10^{-4}, and their "realistic worst-case" scenario are 2.14×10^{-3}. The corresponding Hazard Indices are 0.25 and 4.35, respectively. The only difference between the baseline (current) and the hypothetical (future) exposure scenarios is the hypothetical future use of the shallow aquifer for household water supplies. According to Jordan, the majority of the risk derives from the ingestion (drinking water) route of exposure, with minor contributions from showering or bathing. According to Jordan, the contaminants providing the dominant contributions to carcinogenic risk are arsenic, dichloroethane, and vinyl chloride (see Jordan's Tables 7-14 and 7-17 in the RI for specific figures).

X.3.1 Flaws in the E.C. Jordan Human Health Risk Assessment

Scenarios

A number of assumptions are made in the Jordan assessment of the Metamora Landfill Site. The most significant of these is that contaminated water from the shallow aquifer under the Site will be tapped for domestic or water supplies. Since all other wells in the area use the bedrock aquifer (which, according to the RI, exhibits no sign of Site-related impacts), there is little reason to assume that any new well in the area would not similarly use this the lower aquifer. With no human use of the shallow aquifer, risks from groundwater exposure are <u>nil</u> since no contact or ingestion exposures will occur. Even it we accept the highly unrealistic assumption that the shallow aquifer will be tapped for household water, the question remains as to what well concentrations are relevant to this scenario.

Furthermore, the risk assessment should take into account the fact that even drinking water wells in the bedrock aquifer have substantial concentrations of naturally-occurring arsenic, resulting in an existing cancer risk of 6.9×10^{-5}. As described earlier, these considerations result in alternative concentrations for the indicator compounds.

Indicator Compounds

Three issues arise from Jordan's selection and analysis of its indicator compounds. First, selection of indicator compounds was based only on intrinsic toxicological properties, concentration, persistence and mobility. No criteria with regard to "frequency of observation" or "significantly different from background" were applied. Likewise no criterion was applied as to whether a particular observation well could ever be considered a source of residential tap water. As noted in the prior section, application of the "significantly different than background" consideration reduces the number of contaminants of concern, in that barium and arsenic should be dropped from consideration.

Second, as far as concentrations for indicator compounds, Gradient's log-probit analysis yields median concentrations for indicator chemicals that are lower than the values used by E.C. Jordan in every case (Table 9). For several compounds evaluated, the change in the average concentration is less than one order of magnitude. For other compounds, the difference between our evaluation of the average concentration and Jordan's is one or more orders of magnitude.

If one works with the highly unrealistic scenario posed in Jordan's risk assessment of shallow aquifer drinking water wells, the impact of the changes in average concentrations of the indicator compounds can be evaluated. Gradient's revised indicator list and representative concentrations have a minor impact on the assessment for noncarcinogenic compounds. This occurs because under Jordan's "most probable" exposure scenario, where average concentrations are incorporated into the risk estimate for ingestion of groundwater, all individual hazard indices and the total hazard index values are already below unity. The cancer risk estimate, however, is impacted by the change in calculated average concentrations. The main impact is on the risk from exposure to 1,1-dichloroethane since this is the compound providing the major cancer risk, and under Gradient's analysis, the average concentrations of this compound are reduced compared to values from Jordan. A comparison of the Jordan and Gradient cancer risk results and hazard index results are presented in Tables 8A, B, C and 10A, B, C.

Under Gradients analysis, "most probable case" cancer risks have decreased by 2 orders of magnitude, to about 5 x 10^{-6} (Table 8A). A comparison of the "realistic worst case" concentrations generated by Gradient with the maximum concentrations used for evaluating the "realistic worst case" exposure scenario by E.C. Jordan indicates that Gradient's values are lower, and cancer risks have decreased more than two orders of magnitude from 2.14 x 10^{-3} to 3.5 x 10^{-5} (Table 8B).

The impact of these changes on the evaluation of noncancer health risks under the "worst case" scenario is to bring all hazard index values to well below unity, indicating that consumption of water from the aquifer would not be anticipated to result in any noncancer health effects.

It must be again emphasized that the likelihood of the development of the shallow aquifer as a drinking water source is very low. It is not certain whether the shallow aquifer has either the conductivity or the capacity to serve as a source for household tap water. Furthermore, the EPA has clearly recognized that institutional controls may be appropriate components of remedial action plans, and the Metamora Landfill Site can be restricted with respect to residential development. The MDNR 307 rules specify that these considerations need to be fully discussed in the risk assessment.

The third issue is that contaminants do not appear to be evenly distributed throughout the shallow aquifer. Rather, the data indicate there are some "hot spots" of contamination, and that the other monitoring locations are relatively clean. Therefore, even the Gradient "average exposure" scenario is a conservative estimate of exposure that could occur in the unlikely event the shallow aquifer were to be tapped. A more reasonable choice for exposure levels is to select only those wells that are representative of areas where future housing could be built.

Arsenic Toxicity

Although we believe arsenic concentrations are not significantly elevated above background, some points about arsenic toxicity should be emphasized. In other recent project work, Gradient has argued that EPA should reduce risk estimates for ingested arsenic by 1 or 2 orders of magnitude to account for nonlinearities in the dose-response curve (due to arsenic metabolism, excretion, and two-step genotoxicity), the non-lethality of arsenic-induced skin cancers, and the possible (but not proven) nutritional requirement for arsenic in animals. These considerations were taken into account to some degree in the assessment conducted by Jordan insofar as the Cancer Potency Factor (CPF) used in the assessment is one tenth of the value that appears in EPA's Integrated Risk Information System (IRIS). It would be reasonable to further reduce the CPF of arsenic by an additional factor of five.

Jordan's risk assessment fails to stress two important points about the arsenic contribution to risk. First, the Maximum Contaminant Level (in the Federal Clean Water Act drinking water standards) for arsenic is 50 ppb, and most of the monitoring wells at the Metamora Landfill Site fall far below this level. Secondly, examination of concentration data for arsenic in samples of water from the bedrock aquifer, which <u>is</u> used for drinking water, shows that average concentrations are

18.2 ppb. In fact, arsenic concentrations in wells specifically used for drinking water show an average concentration of 13.8 ppb. This translates into a cancer risk of 6.9×10^{-6}, if we use the same intake parameters that Jordan applied when arriving at an arsenic cancer risk contribution of 1.1×10^{-4} million for the average of Metamora Landfill wells. Assuming that the bedrock aquifer average arsenic concentration is the applicable one, the cancer risk is 9.1×10^{-6}. Hence, the cancer risk contribution from arsenic in the landfill wells is comparable to the background risk currently presented by non-impacted drinking water supplies in the area.

X.3.2 Alternative Risk Assessment Exposure Calculation Intake Parameters

Some of the input parameters used for the Jordon risk calculations are not in agreement with the EPA Exposure Factors Handbook and values from the EPA Risk Assessment Guide for Superfund. Table 11 lists the parameters where more appropriate values could be substituted. Proposed alternatives for the parameters, and an indication of the impact of the modification on the route-specific risk assessment are also tabulated. We have incorporated the two modifications appropriate to drinking water in presenting our calculated risks in Tables 8 and 10.

Scenarios Selected

In the risk assessment conducted by Jordan, health risks associated with exposure to chemicals at the Site were evaluated for two exposure scenarios; a "most probable" scenario, and a "realistic worst case" scenario. Current EPA guidance, however, states that actions and risk assessments at Superfund sites should be based on an estimate of the Reasonable Maximum Exposure (RME) expected to occur under both current and future land use conditions. The use of the RME is to supersede "worst case" exposure assumptions in risk assessments. This means that rather than merely using some statistical extreme, thought should be given to the pattern of groundwater wells that would give a "realistic maximum exposure". EPA guidance specifically rejects performing a "worst case" risk assessment because adjusting all parameters to their limiting value produces a scenario with no realistic chance of happening in the real world (Risk Assessment for Superfund, EPA, 1989).

Uncertainty Analysis for Assumptions

The risk measures used in risk assessments are not fully probabilistic estimates of risk, but conditional estimates that are based on a considerable number of assumptions about exposure and toxicity. It therefore is, important to fully specify the assumptions and uncertainties inherent in the risk assessment or place the estimates in proper perspective (Risk Assessment Guidelines for Superfund; EPA, 1989). Although the assessment conducted by Jordan contains comments regarding the uncertainty of their analysis scattered throughout the report, all of the uncertainties are not brought together in a coherent fashion in such a way as to inform the risk manager of the confidence surrounding the risk estimates.

EPA guidance requires the use of reasonable maximum estimates of exposure based on both current and future land use conditions for a site setting "remediation goals." (NCP, 1990.) The Agency has developed the concept of <u>reasonable</u> maximum exposure, which is designed to include all exposures that can be reasonably expected to occur, but does not focus on worst case exposure assumptions. (NCP, 1990; emphasis added).

The Superfund program requires an assumption of future residential land use in making cleanup decisions only when such use is reasonably likely. (NCP, 1990.) The <u>likelihood</u> of the "exposure actually occurring should be considered when deciding the appropriate level of remediation...." (NCP, 1990).

Otherwise, such assumptions "may not be justifiable if the <u>probability</u> that the site will support residential use in the future is small." (NCP, 1990.) EPA rejects "the use of unrealistic exposure scenarios and assumptions...." and believes "that the likelihood of the exposure actually occurring should be considered when deciding the appropriate level of remediation, to the degree that this likelihood can be determined." (NCP, 1990).

In practice, EPA is not cleaning up the vast majority of industrial sites, including many containing very toxic chemicals, by assuming residential exposure. The United States Court of Appeals for the First Circuit recently upheld a District Court's decision to reject EPA's demand that a PRP clean up an industrial site from a "quite clean" level to an "extremely clean" level at three to four times the cost.[8] EPA's rationale for the lower level was a risk assessment assuming, contrary to the evidence, that residential use was likely in the future. EPA's reasoning was rejected by the court precisely because it was grounded on a wholly improbable residential use in the future.

If there is little or no reasonable likelihood that the site would be used for residential purposes in the foreseeable future based on present or anticipated land use development patterns in the area, the TCLs should not be calculated assuming residential exposure.

X.4.0 Ecological Risk Assessment Critique

We concur with Jordan's ecological risk assessment that risks are insignificant for organisms inhabiting the siltation pond and the forested areas. However, the conclusion that wildlife will migrate onto the Site and that the leachate-containing soil may pose a risk to wildlife, lacks any documentation and violates the EPA's guidance on performing an ecological risk assessment.

No information was obtained by Jordan in the field survey which would indicate that migration of wildlife onto the site is occurring. In addition, soil samples collected from the site contained levels of metals which were at the lower end of the background concentration range,

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[8] United States v. Ottati & Gross, Inc., 1990 U.S. App. LEXIS 5137, *37 (to be published at 900 F.2d 429 (1st Cir. 1990) ("IMC's cleanup, reducing PCB and VOC soil levels to 50 ppm and 10 ppm respectively, cost about $2.6 million; to reduce those levels further, to 20 ppm PCBs and 1 ppm VOCs, will cost an additional $9.3 million. One might conclude from the cited portions of the record that this amounts to a very high cost for very little extra safety").

with the exception of zinc, which is not thought to be site related. While VOCs and PAHs were detected at part per billion to low part per million levels (which may also be attributable to background contamination), toxic effects of PAHs on wildlife at these low levels have not been documented and toxicity information for the VOCs with respect to wildlife is not available. An additional problem with Jordan's risk assessment is that, although the forested area northeast of the site was included in the characterization of the natural environment, the presence of perhaps the most significant wildlife habitat, a wetlands are available to the northwest of the site, was not addressed.

According to the EPA's Risk Assessment Guidance Manual for Superfund, Volume II, Environmental Evaluation Manual (RAGS), an ecological risk assessment should "provide a full accounting of the ecosystems and populations potentially exposed to contamination. This may be accomplished with a narrative description of each habitat (e.g. oak hickory forest, Spartina salt marsh, etc.), <u>accompanied by lists of tables of species collected or observed there</u>. The resident and transient flora and fauna should be described, or if catalogued, the table can be referenced. Where relevant, it should be noted if a cited species is: resident, breeding, or a rare or frequent transient, (e.g. migratory waterfowl), endangered or threatened, or a natural resource trustee concern." In Jordan's risk assessment, the habitats were described, but there was a general failure to observe, report or collect actual site data on <u>any</u> raptor, amphibian, reptile or mammalian species.

Jordan's ecological risk assessment merely presents lengthy lists of tables of species which could "potentially occur" in the general area; the sources of this information are books entitled A Field Guide to the Birds East of the Rockies, Michigan Mammals and The Reptiles and Amphibians of Alabama, which, at best, are not site-specific, and in the case of the third reference, is not relevant at all. Additionally, it is strongly recommended in the EPA's RAGS that the time frame and season in which chemical and biological data are collected be documented, so that the nature and depth of the investigation is evident. It would appear from Jordan's risk assessment that only a very cursory investigation was performed and one from which a quantitative characterization of risks to any species actually found on the site is not possible.

In constrast to Jordan's general, undocumented reviews, the flora and fauna of the Metamora area were surveyed by Dr. Lawrence Halfen of Environmental Consultations, Inc. in December 1988. The records of recorded observations of rare, threatened or endangered species as maintained by Mr. Tom Wiese, Endangered Species Coordinator of the MDNR, were reviewed. These files indicated that there were no records of threatened or endangered species being sighted in the area of the Metamora Landfill or in this portion of Lapeer County. This position was supported by Jordan in their Remedial Investigation, Final Report (March 1989). First-hand field evaluation of the Metamora Landfill and adjacent properties by Dr. Halfen confirm that there were no remarkable biological resources unique to these locations. In fact, the site ecology is so severely disturbed that it can barely support basic flora secession. However, the quality and substance of the wetland resource adjacent to the landfill property was considered to be a remarkable ecological resource.

The FS mentions that "white-tailed deer have been observed in the forest," but does not specify by whom this was observed nor when it was observed. It was noted by Dr. Halfen that the "white-tailed deer" which was sited, was in a forest area which is actually not part of the disturbed landfill area, where the seeps of leachate are located, and possibly not even on the Parrish property. However, the possible movement of deer through the landfill should not be discounted. If this type of movement can be documented, it could be easily controlled by the installation of a fence.

The second limitation of Jordan's ecological risk assessment is that is does not consider a wetlands habitat northwest of the Site which clearly will be preferred by wildlife in the Metamora area. It is suggested in RAGS that "other information upon the ecological effects of the site should be provided, such as current or projected land uses; proximity to population centers, industry, agriculture, or hunting areas."

The wetland northwest of the Site is bounded on the west by an old railroad right-of-way and on the north by developed agricultural lands which extend for some distance to the north of the wetland area. On the east side of the wetland area is a sharp escarpment which rises to the grade of the western aspects of the Parrish property, which comprises the Metamora Landfill. The land also rises on the southern aspect approaching the developed properties along Dryden Road. The grade falls off as the road enters the Village of Metamora. There has been recent clear cutting of older trees on the property around the wetland area to harvest the timber which was commercially valuable. The current and past owners of the property have considered development of the property as a housing tract. However, the wetlands occupy approximately 30 plus acres of this tract and are subject to evaluation and protection under the Michigan Wetlands Protection Act as administered by the Michigan Department of Natural Resources.

This wetland is based upon a series of lowland ponds which are surrounded by mixed hardwoods and scattered white pines and junipers, some of which had developed to, or past mature status. The open water areas are surrounded by areas of hydrophyte development, which display the typical zonation associated with communities of aquatic vegetation. The area is set back away from much of the cultural activity in the locality and is particularly isolated from activities to the west by the embankment of the former railroad right-of-way.

This wetland resource provides two considerations when evaluating the Metamora Landfill. The first is that, assuming the MDNR effectively administers the Michigan Wetland Protections Act, this area should be protected from development and exploitation as part of the wetlands program. This means that there will be an area of excellent and substantial habitat available immediately northwest of the landfill property which will be available for any organisms displaced by landfill activities. Indeed, the quality of habitat will be much improved over any available opportunities currently found on the landfill property.

The second consideration is that there is enough size and support capability in this wetland resource that it will draw organisms frequenting the area in a migratory fashion to the wetland location, rather than encouraging a large population to focus upon the landfill site. In contrast, the cover, forage and nesting opportunities associated with the disturbed character of the landfill are very limited in comparison. No significant numbers or communities of organisms are likely to permanently establish themselves in the landfill area when there are habitat options such as this wetland immediately adjacent to the Site. Although individual animals which may forage or nest on the Site may be adversely affected, it is unlikely that they would stay on site for a significant time period because of the paucity of food. Thus, while transient involvement must be considered for limited numbers of animals, neither populations nor duration of residence will be a serious factor at the landfill during remediation activities. This limits any environmental impacts on this ecological resource to a trivial level.

In conclusion, there is an extremely limited supportive capacity for wildlife populations on the Site presently, especially considering that a productive and biologically diverse habitat is situated adjacent to the Site. The disturbed condition of the landfill severely limits the variety and populations which can be supported on the property in any event. Given the presence of the wetlands to the northwest, the fact that there are no commercially valuable or exploitable fish or shellfish on Site, no rare or endangered species present, and the absence of any reported avifauna, amphibians, reptiles, or mammals, it is clear that a significant emphasis on a biological community concern due to contaminants at the Metamora Landfill

Site may be misplaced and largely meaningless as far as demonstrable risk is concerned. Thus, it would appear that the ecological risk due to contaminants at the Metamora Landfill Site is considerably less than the Jordan ecological risk assessment suggests. Jordan's conclusion that the Site soils endanger local wildlife is mere speculation and should be retracted.

X.5.0 Development of Target Cleanup Levels

This report presents a strong argument that because the health-based risks at the Metamora Landfill Site are nonexistent, the Target Cleanup Levels (TCLs) should be established in accordance with Michigan 307 Type C guidance. In addition, drinking water standards are neither "relevant" nor "appropriate" for groundwater within the boundaries of a solid waste landfill. We therefore propose cleanup levels for groundwater at the point of attainment (Site boundary). Furthermore, groundwater use restrictions in the shallow aquifer will be applied in accordance with institutional controls described in Rule 719(c) of Michigan Act 307. The State of Michigan already deems the water quality in the bedrock aquifer to be acceptable for drinking purposes. Although we strongly feel that the shallow aquifer should not be considered an exposure pathway, if cleanup is required for the shallow aquifer, cleanup levels should be based on MCLs and PQLs (for compounds for which MCLs have not been promulgated). Proposed cleanup levels have thus been developed based on either 1) MCLs, 2) background levels, or 3) practical quantitation limits (PQL). Proposed cleanup levels are:

Indicator Chemical	Proposed Cleanup Level (µg/L)	Criteria
Benzene	5.0	MCL
1,1-Dichloroethane	5.0	PQL-EPA Method 8240
1,2-Dichloroethane	5.0	PQL-EPA Method 8240
1,1-Dichloroethylene	7.0	MCL
1,2-Dichloroethylene	7.0	MCL
Ethylbenzene	700	MCL
Trichloroethylene	5.0	MCL
1,1,2-Trichloroethane	5.0	PQL-EPA Method 8240
Vinyl chloride	2.0	MCL
Xylenes (total)	440	MCL

For the carcinogens on the TCL list, the proposed cleanup levels translate into cancer risk as shown on the following table.

Chemical	Proposed Cleanup Level (µg/L)	Cancer Risk*
Benzene	5.0	3.8E-07
1,1-Dichloroethane	5.0	1.2E-06
1,2-Dichloroethane	5.0	1.1E-05
1,1-Dichloroethylene	7.0	1.1E-05
1,1,2-Trichloroethane	5.0	7.5E-07
Trichloroethylene	5.0	1.4E-07
Vinyl chloride	2.0	1.2E-05
Total		2.7E-05

Our report contends that arsenic and barium concentrations in the shallow aquifer are indistinguishable from background levels. Decisions on cleanup levels for the ten organic indicator chemicals are

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* Cancer risk estimates for groundwater use 1.4 liters/day water ingestion, 9-year residence time.

based on either MCL or PQL criteria. MCLs are appropriate because they are the national drinking water standards and the concern for the shallow aquifer, albeit a hypothentical one, is for drinking water exposures. The use of PQLs as criteria should be acceptable to MDNR because as Rule 721(a) states "If a hazardous substance is not detected in a sample and the method detection limit is higher than the criteria to be achieved for that substance, the criteria shall be considered to have been achieved." In addition, the NCP requires that practical limitations on meeting or monitoring "acceptable exposure levels" (sections 300.430(e) (2) (i) (A) (3,4,5) of the New NCP), be considered in setting TCLs, particularly the distinction between a "detection limit" and a "practical quantitation limit" (PQL).** For example, the range of TCLs may be 0.5 ppb to 50 ppb, but limitations on the ability to reliably detect the chemical might require the use of 10 ppb as the TCL (NCP, 1990).

The "detection limit" should not be used to set a TCL because it is variable, not repeatable, and provides a measurement in the area where the precision and accuracy of the instrument is lowest, i.e. there are more frequent false positives and false negatives. The detection limit is the lowest concentration that a particular measuring instrument on a particular day with a particular sample can measure above the instrument's normal random response (i.e. the signal measured when there are no chemicals present, called the "noise" level of the instrument.)

PQLs, on the other hand, are "the lowest concentration that can be reliably measured [by good laboratories] within specified limited of

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** A separate paper addresses EPA's policy for addressing situations where it is not scientifically feasible to achieve health-based "remediation goals" within a reasonable time frame.

precision and accuracy during routine laboratory operating conditions." (EPA, 1989c.) EPA regularly uses PQLs, rather than detection limits (which are typically five to ten times lower) to set the MCLs pursuant to the Safe Drinking Water Act (EPA, 1988d), among other programs. Each of these programs are national and the levels are set to protect the health of 240 million people. The final point to be made is whether vinyl chloride should be considered an indicator chemical since it has never been detected on site. Vinyl chloride has only been detected off site; thus, the presence of vinyl chloride may well be from a source other than the landfill. It has been retained in the list above at a level which, <u>from actual monitoring experience to date at the site</u>, is the PQL.

Table 1

Shallow-aquifer Well Classifications

Gradient's Classification				E.C.Jordan's Classification	
On-Site Wells	On-Site, Downgradient Wells	On-Site Upgradient Wells	Off-Site Wells	Downgradient Wells	Background Wells
MW-1		MW-1	MW-8	MW-4 *	MW-1
MW-3		MW-3	MW-13	MW-6	MW-3
MW-6	MW-6		MW-14S	MW-8	MW-7
MW-7		MW-7	MW-14D	MW-13	MW-9
MW-9		MW-9	MW-15S	MW-14S	MW-10S
MW-10		MW-10	MW-15D	MW-14D	MW-10D
MW-11		MW-11	MW-16	MW-15S	MW-11
MW-12		MW-12	MW-19	MW-15D	MW-12
MW-17S	MW-17S		MW-21	MW-16	MW-18
MW-17D	MW-17D		MW-23	MW-17S	MW-19
MW-20		MW-20	MW-24	MW-17D	MW-20
			MW-25	MW-21	
			MW-26	MW-23	
				MW-24	
				MW-25	
				MW-26	

* - E.C.Jordan did not use this well in calculating exposure concentrations, because it is drilled in a perched aquifer. Gradient has thus omitted it from consideration.

Table 2

Summary of Groundwater Results for the Entire Shallow Aquifer

Chemical	No. Samples	No. Non-Detects	Detection Frequency (%)	Avg. Detection Limit (ppb) (Note 7)	Avg. Conc. (NDs= 0.5*DL.) (ppb)
arsenic	63	42	33.3	4.1	17.6
barium	64	5	92.2	39.0	143.8
benzene	64	57	10.9	5.1	3.2
dichloroethane, 1,1-	64	41	35.9	5.5	7.8
dichloroethane, 1,2-	64	57	10.9	5.4	3.7
dichloroethylene, 1,1-	23	21	8.7	5.0	2.4
dichloroethylene, trans-1,2-	14	13	7.1	5.0	21.5
dichloroethylene, 1,2- (total)	49	34	30.6	5.0	11.3
ethylbenzene	64	56	12.5	5.1	63.9
trichloroethylene	64	58	9.4	5.3	3.0
trichloroethane, 1,1,2-	49	44	10.2	5.0	2.6
vinyl chloride	64	57	10.9	10.9	5.2
xylenes	61	54	11.5	5.1	281.6

NOTES:
1. Samples from all shallow-aquifer wells, including "background" and "downgradient" wells, were included in this analysis.
2. Samples that were rejected on QA/QC basis or that had contaminated blanks were not considered.
3. Samples with unusually high detection limits were not included in this analysis.
4. Only maximum concentration from a pair of duplicates/replicates was included in this analysis.
5. The depth-averaged concentration was used in this analysis for each sampling event from well clusters (MW-10S/D, MW-14S/D, MW-15S/D, MW-17S/D) or wells with multiple screens (MW-6, MW-7). Non-detects were included at half the detection limit when calculating depth averages. If any sample from a cluster or multiple-screen well had detectable concentrations for a given sampling event, then that well or cluster was treated as a detect for that sampling event in the analysis of detection frequency; otherwise, that well or cluster was treated as a non-detect for that sampling event.
6. Samples from MW-4 were not included, because MW-4 is in a perched aquifer.
7. Average detection limits are for "non-detect" samples.

Table 3

Comparison of E.C.Jordan Summaries with Gradient's Summary Using the Same Methodology for Wells Classified by E.C.Jordan as "Downgradient"

Chemical	# Samples-ECJordan	# Samples-Gradient	# Detects-ECJordan	# Detects-Gradient	Avg. Conc. (ppb)-ECJordan	Avg. Conc. (ppb)-Gradient	Max. Conc. (ppb)-ECJordan (Note 7)	Max. Conc. (ppb)-Gradient (Note 7)
arsenic	43	42	21	21	22.3	23.7	260.0	260.0
barium	43	43	39	39	162.0	182.0	2,170.0	2,180.0
benzene	43	42	4	4	3.0	3.1	11.0	11.0
dichloroethane, 1,1-	43	42	25	25	11.1	12.5	55.0	55.0
dichloroethane, 1,2-	43	41	15	7	4.2	4.4	19.0	24.0
dichloroethylene, 1,1-	43	14	2	2	2.1	2.4	2.1	2.1
dichloroethylene, trans-1,2-		9		1		32.2		270.0
dichloroethylene, 1,2- (total)	43	32	7	14	17.0	15.9	270.0	220.0
ethylbenzene	43	43	5	5	158.0	183.7	2,800.0	2,800.0
trichloroethylene	43	41	6	6	3.0	3.1	14.0	14.0
trichloroethane, 1,1,2-	43	32	5	5	2.6	2.7	6.0	6.0
vinyl chloride	43	41	6	6	4.9	4.8	6.0	6.0
xylenes	43	38	5	5	721.0	939.1	12,000.0	12,000.0

Notes:

1. For this analysis, Gradient averaged samples from different depths at MW-6 (a multi-screened well) for each sampling event. E.C.Jordan did not state how they treated these samples.
2. Gradient's results are based on data in Technical Memoranda 4,9, and 11 of the RI. Any data missing from these memoranda could explain discrepancies.
3. Both analyses use data from wells MW-6, MW-8, MW-13, MW-14S/D, MW-15S/D, MW-16, MW-17S/D, MW-21, MW-23, MW-24, MW-25, and MW-26.
4. Gradient discarded samples with unusually high detection limits. Apparently, E.C.Jordan followed the same procedure, otherwise the results shown above would not agree as well as they do; however, E.C.Jordan did not document that they had excluded any data.
5. Gradient discarded samples that were rejected because of QA/QC considerations or that showed blank contamination; the RI indicates that E.C.Jordan probably did so as well.
6. For samples with duplicates, Gradient considered only the maximum of the two values; E.C.Jordan did not state how they treated duplicates.
7. Gradient calculated the maximum concentration for samples with detected concentrations only. Apparently, E.C.Jordan did likewise, because several samples with non-detected concentrations had detection limits higher than the highest detected concentration.

Table 4

Summary of Groundwater Results for the Shallow Aquifer: On-Site Wells

Chemical	No. Samples	No. Non-Detects	Detection Frequency (%)	Avg. Detection Limit (ppb) (Note 6)	Avg. Conc. (NDs= 0.5*DL.) (ppb)
arsenic	33	26	21.2	5.0	15.0
barium	33	4	87.9	5.0	39.8
benzene	33	30	9.1	5.0	2.9
dichloroethane, 1,1-	33	30	9.1	5.0	4.3
dichloroethane, 1,2-	33	31	6.1	5.0	2.8
dichloroethylene, 1,1-	11	11	0.0	5.0	2.5
dichloroethylene, trans-1,2-	9	9	0.0	5.0	2.5
dichloroethylene, 1,2- (total)	24	22	8.3	5.0	2.7
ethylbenzene	33	28	15.2	5.0	120.5
trichloroethylene	33	32	3.0	5.0	2.5
richloroethane, 1,1,2-	24	24	0.0	5.0	2.5
vinyl chloride	33	33	0.0	5.0	5.0
xylenes	32	27	15.6	5.0	558.9

NOTES:

1. Samples from on-site shallow-aquifer wells only (MW-1, MW-3, MW-6, MW-7, MW-9, MW-10S/D, MW-11, MW-12, MW-17S/D, MW-20) were included in this analysis.
2. Samples that were rejected on QA/QC basis or that had contaminated blanks were not considered.
3. Samples with unusually high detection limits were not included in this analysis.
4. Only maximum concentration from a pair of duplicates/replicates was included in this analysis.
5. The depth-averaged concentration was used in this analysis for each sampling event from well clusters (MW-10S/D, MW-17S/D) or wells with multiple screens (MW-6, MW-7).
   Non-detects were included at half the detection limit when calculating depth averages. If any sample from a cluster or multiple-screen well had detectable concentrations for a given sampling event, then that well or cluster was treated as a detect for that sampling event in the analysis of detection frequency; otherwise, that well or cluster was treated as a non-detect for that sampling event.
6. Average detection limits are for "non-detect" samples.

Table 5

Summary of Groundwater Results for the Shallow Aquifer: On-Site, Downgradient Wells

Chemical	No. Samples	No. Non-Detects	Detection Frequency (%)	Avg. Detection Limit (ppb) (Note 6)	Avg. Conc. (NDs= 0.5*DL.) (ppb)
arsenic	7	0	100.0		62.4
barium	7	1	85.7	39.0	55.1
benzene	7	4	42.9	5.0	4.2
dichloroethane, 1,1-	7	4	42.9	5.0	10.9
dichloroethane, 1,2-	7	5	28.6	5.0	3.9
dichloroethylene, 1,1-	2	2	0.0	5.0	2.5
dichloroethylene, trans-1,2-	2	2	0.0	5.0	2.5
dichloroethylene, 1,2- (total)	5	3	40.0	5.0	3.4
ethylbenzene	7	3	57.1	5.0	558.8
trichloroethylene	7	6	14.3	5.0	2.5
trichloroethane, 1,1,2-	5	5	0.0	5.0	2.5
vinyl chloride	7	7	0.0	10.0	5.0
xylenes	7	3	57.1	5.0	2,544.6

NOTES:
1. Samples from shallow-aquifer, downgradient wells only (MW-6, MW-17S/D) were included in this analysis.
2. Samples that were rejected on QA/QC basis or that had contaminated blanks were not considered.
3. Samples with unusually high detection limits were not included in this analysis.
4. Only maximum concentration from a pair of duplicates/replicates was included in this analysis.
5. The depth-averaged concentration was used in this analysis for each sampling event from well clusters (MW-17S/D) or wells with multiple screens (MW-6). Non-detects were included at half the detection limit when calculating depth averages. If any sample from a cluster or multiple-screen well had detectable concentrations for a given sampling event, then that well or cluster was treated as a detect for that sampling event in the analysis of detection frequency; otherwise, that well or cluster was treated as a non-detect for that sampling event.
6. Average detection limits are for "non-detect" samples.

Table 6

Summary of Groundwater Results for the Shallow Aquifer: Off-Site Wells

Chemical	No. Samples	No. Non-Detects	Detection Frequency (%)	Avg. Detection Limit (ppb) (Note 7)	Avg. Conc. (NDs= 0.5*Dl.) (ppb)
arsenic	27	16	40.7	3.6	4.3
barium	28	1	96.4	39.0	247.5
benzene	28	27	3.6	5.2	2.6
dichloroethane, 1,1-	28	9	67.9	5.0	11.2
dichloroethane, 1,2-	28	23	17.9	5.0	4.6
dichloroethylene, 1,1-	11	9	18.2	5.0	2.4
dichloroethylene, trans-1,2-	5	4	20.0	5.0	56.0
dichloroethylene, 1,2- (total)	23	11	52.2	5.0	20.8
ethylbenzene	28	28	0.0	5.2	2.6
trichloroethylene	28	23	17.9	5.0	3.3
trichloroethane, 1,1,2-	23	18	21.7	5.0	2.8
vinyl chloride	28	22	21.4	10.5	4.8
xylenes	26	26	0.0	5.2	2.6

NOTES:
1. Samples from off-site wells only (MW-8, MW-13, MW-14S/D, MW-15S/D, MW-16, MW-19, MW-21, MW-23, MW-24, MW-25, MW-26) were included in this analysis.
2. Samples that were rejected on QA/QC basis or that had contaminated blanks were not considered.
3. Samples with unusually high detection limits were not included in this analysis.
4. Only maximum concentration from a pair of duplicates/replicates was included in this analysis.
5. The depth-averaged concentration was used in this analysis for each sampling event from well clusters (MW-14S/D, MW-15S/D). Non-detects were included at half the detection limit when calculating depth averages. If any sample from a cluster of well had detectable concentrations for a given sampling event, then that cluster was treated as a detect for that sampling event in the analysis of detection frequency; otherwise, that well or cluster was treated as a non-detect for that sampling event.
6. Samples from MW-4 were not included, because MW-4 is in a perched aquifer.
7. Average detection limits are for "non-detect" samples.

Table 7

Summary of Groundwater Results for the Shallow Aquifer: Using Wells Classified as Downgradient by ECJordan

Chemical	No. Samples	No. Non-Detects	Detection Frequency (%)	Avg. Detection Limit (ppb) (Note 7)	Avg. Conc. (NDs= 0.5*DL.) (ppb)
arsenic	24	10	58.3	4.1	5.7
barium	25	2	92.0	39.0	268.8
benzene	25	25	0.0	5.2	2.6
dichloroethane, 1,1-	25	10	60.0	5.0	9.9
dichloroethane, 1,2-	25	22	12.0	5.0	4.4
dichloroethylene, 1,1-	9	8	11.1	5.0	2.4
dichloroethylene, trans-1,2-	6	5	16.7	5.0	47.1
dichloroethylene, 1,2- (total)	19	11	42.1	5.0	21.9
ethylbenzene	25	25	0.0	5.2	2.6
trichloroethylene	25	21	16.0	5.0	3.4
trichloroethane, 1,1,2-	19	17	10.5	5.0	2.7
vinyl chloride	25	20	20.0	10.5	4.9
ylenes	24	24	0.0	5.2	2.6

NOTES:

1. Samples from downgradient shallow-aquifer wells only (MW-6, MW-8, MW-13, MW-14S/D, MW-15S/D, MW-16, MW-17S/D, MW-21, MW-25, MW-26) were included in this analysis.
2. Samples that were rejected on QA/QC basis or that had contaminated blanks were not considered.
3. Samples with unusually high detection limits were not included in this analysis.
4. Only maximum concentration from a pair of duplicates/replicates was included in this analysis.
5. The depth-averaged concentration was used in this analysis for each sampling event from well clusters (MW-14S/D, MW-15S/D, MW-17S/D) or wells with multiple screens (MW-6). Non-detects were included at half the detection limit when calculating depth averages. If any sample from a cluster or multiple-screen well had detectable concentrations for a given sampling event, then that well or cluster was treated as a detect for that sampling event in the analysis of detection frequency; otherwise, that well or cluster was treated as a non-detect for that sampling event.
6. Samples from MW-4 were not included, because MW-4 is in a perched aquifer.
7. Average detection limits are for "non-detect" samples.

Table 8A

CANCER RISK

GROUNDWATER INGESTION, ONSITE, MOST PROBABLE CASE
Comparison of Gradient's and Jordan's most probable ground water concentrations and cancer risk results

Compound	E.C.J. Ave Conc (ppb)	E.C.J. Cancer Risk	Modified Ave Conc (ppb)	Modified Risk
Benzene	3.0	2.5E-06	4.9	3.7E-07
1,1-Dichloroethane	11.1	2.9E-05	4.7	1.1E-06
1,2-Dichloroethane	4.2	1.0E-05	6.0	1.3E-06
1,1-Dichloroethylene	2.1	3.6E-05	0.4	6.2E-07
1,1,2-Trichloroethane	2.6	4.3E-06	0.2	3.0E-08
Trichloroethylene	3.0	9.4E-07	0.1	2.9E-09
Vinyl Chloride	4.9	3.2E-04	0.3	1.8E-06
TOTAL				5.2E-06

Table 8B

CANCER RISK

GROUNDWATER INGESTION, ONSITE, REALISTIC WORST CASE
Comparison of Gradient's and Jordan's realistic worst case groundwater concentrations and cancer risk results

Compound	E.C.J. Max Conc (ppb)	E.C.J. Cancer Risk	Modified Max Conc (ppb)	Modified Risk
Benzene	11.0	9.1E-06	5.9	1.5E-06
1,1-Dichloroethane	55.0	1.4E-04	13.5	1.5E-05
1,2-Dichloroethane	19.0	4.9E-05	6.7	7.5E-06
1,1-Dichloroethylene	2.1	3.6E-05	0.4	2.9E-06
1,1,2-Trichloroethane	6.0	9.8E-06	0.2	1.4E-07
Trichloroethylene	14.0	4.4E-06	0.1	1.4E-08
Vinyl Chloride	6.0	3.9E-04	0.3	8.4E-06
TOTAL				3.5E-05

Table 8C

CANCER RISK

GROUNDWATER INGESTION, OFFSITE, MOST PROBABLE CASE -
ground water concentrations and cancer risk results

Compound	Modified Ave Conc (ppb)	Modified Risk
Benzene	4.9	3.7E-07
1,1-Dichloroethane	6.5	1.5E-06
1,2-Dichloroethane	1.9	4.1E-07
1,1-Dichloroethylene	0.4	6.2E-07
1,1,2-Trichloroethane	0.2	3.0E-08
Trichloroethylene	0.1	2.9E-09
Vinyl Chloride	0.3	1.8E-06
TOTAL		4.8E-06

Table 9

Exposure Concentrations Estimated from Log-Probit Analysis for Different Groupings of Wells: Comparison to Concentrations Used in the RI

Chemical	On-Site Conc. (ppb)	On-site Downgradient Conc. (ppb)	Off-Site Conc. (ppb)	Conc. used in RI - Most Probable Case (Downgradient Wells, on- and off-site) (ppb)	Conc. used in RI - Realistic Worst Case (Maximum conc. from any shallow well) (ppb)
arsenic	.3 C	37.3 C	2.3 C	22.3	260.0
barium	C	C	C	162.5	2,170.0
benzene	4.9	5.9	4.9 B	3.0	11.0
dichloroethane, 1,1-	4.7	13.5	6.5	11.1	55.0
dichloroethane, 1,2-	6.0	6.7	1.9	4.2	19.0
dichloroethylene, 1,1-	.4 A	.4 A	.4	2.1	2.1
dichloroethylene, trans-1,2-					
dichloroethylene, 1,2- (total)	.8	2.5	1.2	17.3	270.0
ethylbenzene	230.0	690.0	230.0 A	158.4	2,800.0
trichloroethylene	.1 B	.1 B	.1	3.0	14.0
trichloroethane, 1,1,2-	.2 A	.2 A	.2	2.6	6.0
vinyl chloride	.3 A	.3 A	.3	4.9	6.0
xylenes	1,340.0	3,300.0	1,340.0 A	721.7	12,000.0

NOTES:
- A. No samples in this group had detectable concentrations. The minimum of the average concentrations for the other two groups was used.
- B. Only one sample in this group had detectable concentrations. The minimum of the average concentrations from the other two groups was used.
- C. Arsenic and barium were not included as indicator chemicals in this assessment (see text).

Table 10 A

HAZARD INDEX

GROUNDWATER INGESTION, MOST PROBABLE CASE
Comparison of Gradient's and E.C. Jordan's
ground water concentrations and hazard indices

Compound	E.C.J Ave Conc (ppb)	E.C.J. Hazard Index	Modified Ave Conc (ppb)	Hazard Index
1,1-Dichloroethylene	2.1	6.4E-03	0.4	8.6E-04
1,2-Dichloroethylene	17.3	5.0E-02	0.8	1.6E-03
Ethylbenzene	158.4	4.5E-02	230.0	4.6E-02
Xylenes	721.7	1.0E-02	1340.0	1.3E-02
	Total:	1.1E-01	Total:	6.2E-02
	Proper Tot*:		Proper Tot*:	
	organics	1.0E-01	organics	4.9E-02
	xylene	1.0E-02	xylene	1.3E-02

*(xylene has a different endpoint of toxicity than the others, and should not be added)

Table 10 B

HAZARD INDEX

GROUNDWATER INGESTION, REALISTIC WORST CASE
Comparison of Gradient's and E.C. Jordan's
groundwater concentrations and hazard indices

Compound	E.C.J Max Conc (ppb)	Hazard Index	Modified Max Conc (ppb)	Hazard Index
1,1-Dichloroethylene	55.0	1.8E-01	0.4	1.3E-03
1,2-Dichloroethylene	270.0	7.7E-01	2.5	7.1E-03
Ethylbenzene	2800.0	8.0E-01	690.0	2.0E-01
Xylenes	12000.0	1.7E-01	3300.0	4.7E-02
	Total:	1.9E+00	Total:	2.5E-01
	Proper Tot*:		Proper Tot*:	
	organics	1.7E+00	organics	2.1E-01
	xylene	1.7E-01	xylene	4.7E-02

*(xylene has a different endpoint of toxicity than the others, and should not be added)

Table 10 C

HAZARD INDEX

GROUNDWATER INGESTION, OFFSITE, MOST PROBABLE CASE ground water concentrations and hazard indices

Compound	Modified Ave Conc (ppb)	Hazard Index
1,1-Dichloroethylene	0.4	8.6E-04
1,2-Dichloroethylene	1.2	2.4E-03
Ethylbenzene	230.0	4.6E-02
Xylenes	1340.0	1.3E-02
	Total:	6.3E-02
	Proper Tot*:	
	organics	4.9E-02
	xylene	1.3E-02

*(xylene has a different endpoint of toxicity than the other ogranics, and should not be added)

Table 11

Listing of Exposure Parameters Used by E.C. Jordan that May Require Modification --Suggested Alternatives and Impact

	Best Estimate				Worst Case			
Source	Assumption	Proposed Modification	Reference	Impact	Assumption	Proposed Modification	Reference	Impact
Ground Water								
Ingestion	70-year exposure	9-year exposure	EPA EFH	0.13	70-year exposure	30-year exposure	EPA EFH	0.43
	2 liters/d	1.4 liters/d	EPA RAGS	0.7	2 liters/d	No modification		
Shower	70-year exposure	9-year exposure	EPA EFH	0.13	70-year exposure	30-year exposure	EPA EFH	0.43
	1.3cu.m/hr vent. rate	0.6cu.m/hr	EPA EFH "light act."	0.46	1.3cu.m/hr vent. rate	0.6cu.m/hr	EPA EFH	0.46
	10 min duration	7 minutes duration	EPA EFH	0.7	15 min duration	12 minutes duration	EPA EFH	0.80
Bath	70-year exposure	9-year exposure	EPA EFH	0.13	70-year exposure	30-year exposure	EPA EFH	0.43
Direct Contact, Soils								
	60 event/yr frequency	4 event/yr	once/week 1 months	0.07	150 event/yr frequency	13 events/yr	once/week 3 months	0.09
	50 mg/event ingested	10 mg/event	Calabrese, 1989	0.2	215 mg/event ingested	10 mg/event	Calabrese, 1989	0.05
	10-yr duration	1 year duration		0.1	10-yr duration	No modification		

Table 12

Vinyl Chloride - Off-Site Samples - Rankings for Log-probit Analysis

Sample Designation (1)	Sample Location (1)	Det. lim. (ppb)	Det? (2)	Rank	Percentile	Conc. (ppb)	Tech. Mem. #	Table # (1)	Sampling Period
	MW-14	10.0	n	1	3.4		9		Jan 88
	MW-15	10.0	n	2	6.9		4		Apr 87
	MW-15	10.0	n	3	10.3		9		Jan 88
DUP-1	MW-19	10.0	n	4	13.8		9	9-23	Jan 88
DUP-2	MW-16	10.0	n	5	17.2		9	9-22	Jan 88
MW-13	MW-13	10.0	n	6	20.7		4	4-5	Apr 87
MW-13	MW-13	10.0	n	7	24.1		9	9-21	Jan 88
MW-13	MW-13	10.0	n	8	27.6		9	9-5	Dec 87
MW-16	MW-16	10.0	n	9	31.0		4	4-5	Apr 87
MW-16	MW-16	10.0	n	10	34.5		9	9-6	Dec 87
MW-19	MW-19	10.0	n	11	37.9		9	9-7	Dec 87
MW-21	MW-21	10.0	n	12	41.4		9	9-23	Jan 88
MW-23	MW-23	10.0	n	13	44.8		9	9-23	Jan 88
MW-23	MW-23	10.0	n	14	48.3		9	9-8	Dec 87
MW-24	MW-24	10.0	n	15	51.7		9	9-23	Jan 88
MW-25	MW-25	10.0	n	16	55.2		11	11-6	Jun 88
MW-25	MW-25	10.0	n	17	58.6		9	9-24	Jan 88
MW-25	MW-25	10.0	n	18	62.1		9	9-8	Dec 87
MW-26	MW-26	10.0	n	19	65.5		9	9-24	Jan 88
MW-26	MW-26	10.0	n	20	69.0		9	9-8	Dec 87
MW-8	MW-8	10.0	n	21	72.4		9	9-21	Jan 88
MW-8	MW-8	20.0	n	22	75.9		4	4-4	Apr 87
MW-21	MW-21		j	23	79.3	1.0	9	9-8	Dec 87
MW-24	MW-24		j	24	82.8	2.0	9	9-8	Dec 87
MW-8	MW-8		j	25	86.2	3.0	9	9-5	Dec 87
	MW-14		d	26	89.7	3.5	9		Dec 87
	MW-14		d	27	93.1	3.8	4		Apr 87
	MW-15		d	28	96.6	5.5	9		Dec 87

NOTE: (1) Samples from well clusters (MW-14S/D, MW-15S/D) were averaged. Because the data for these samples came from different locations in the technical memoranda, the Sample Designation and Table # columns were left blank.

(2) n = not detected, j = estimated concentration (detected), d = detected

Table 13

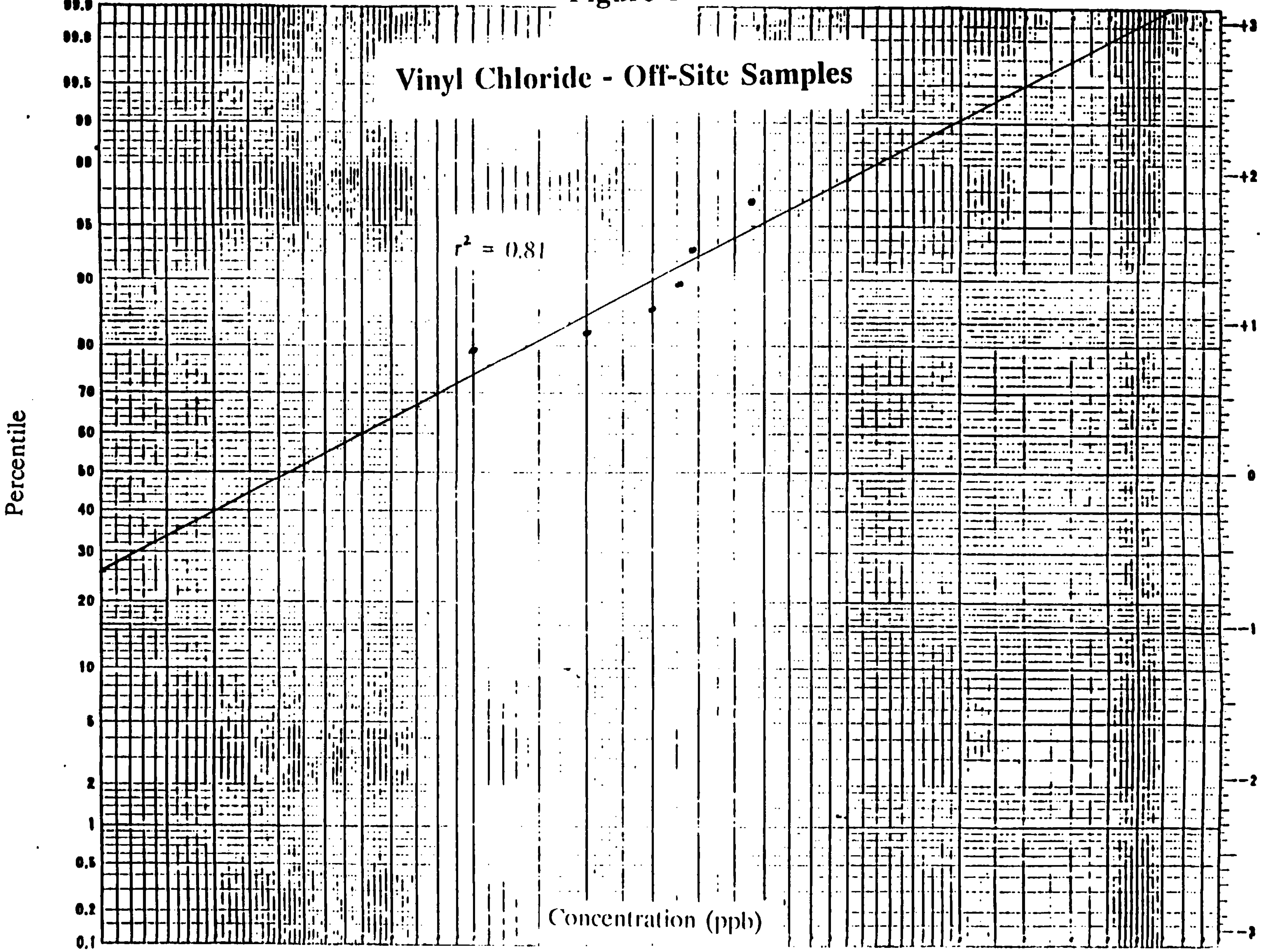
1,2-Dichloroethane - Off-Site Samples - Rankings for Log-Probit Analysis

Sample Designation (1)	Sample Location (1)	Det. lim. (ppb)	Det? (2)	Rank	Percentile	Conc. (ppb)	Tech. Mem. #	Table # (2)	Sampling Period
	MW-14	5.0	n	1	3.4		4		Apr 87
	MW-14	5.0	n	2	6.9		9		Dec 87
	MW-14	5.0	n	3	10.3		9		Jan 88
	MW-15	5.0	n	4	13.8		4		Apr 87
	MW-15	5.0	n	5	17.2		9		Dec 87
	MW-15	5.0	n	6	20.7		9		Jan 88
DUP-1	MW-19	5.0	n	7	24.1		9	9-23	Jan 88
DUP-2	MW-16	5.0	n	8	27.6		9	9-22	Jan 88
MW-13	MW-13	5.0	n	9	31.0		4	4-5	Apr 87
MW-13	MW-13	5.0	n	10	34.5		9	9-21	Jan 88
MW-13	MW-13	5.0	n	11	37.9		9	9-5	Dec 87
MW-16	MW-16	5.0	n	12	41.4		4	4-5	Apr 87
MW-16	MW-16	5.0	n	13	44.8		9	9-6	Dec 87
MW-19	MW-19	5.0	n	14	48.3		9	9-7	Dec 87
MW-21	MW-21	5.0	n	15	51.7		9	9-23	Jan 88
MW-21	MW-21	5.0	n	16	55.2		9	9-8	Dec 87
MW-23	MW-23	5.0	n	17	58.6		9	9-23	Jan 88
MW-23	MW-23	5.0	n	18	62.1		9	9-8	Dec 87
MW-25	MW-25	5.0	n	19	65.5		11	11-6	Jun 88
MW-25	MW-25	5.0	n	20	69.0		9	9-24	Jan 88
MW-25	MW-25	5.0	n	21	72.4		9	9-8	Dec 87
MW-26	MW-26	5.0	n	22	75.9		9	9-24	Jan 88
MW-26	MW-26	5.0	n	23	79.3		9	9-8	Dec 87
MW-24	MW-24		d	24	82.8	7.0	9	9-8	Dec 87
MW-24	MW-24		d	25	86.2	9.0	9	9-23	Jan 88
MW-8	MW-8		d	26	89.7	12.0	9	9-21	Jan 88
MW-8	MW-8		d	27	93.1	19.0	9	9-5	Dec 87
MW-8	MW-8		d	28	96.6	24.0	4	4-4	Apr 87

NOTE: (1) Samples from well clusters (MW-14S/D, MW-15S/D) were averaged. Because the data for these samples came from different locations in the technical memoranda, the Sample Designation and Table # columns were left blank.

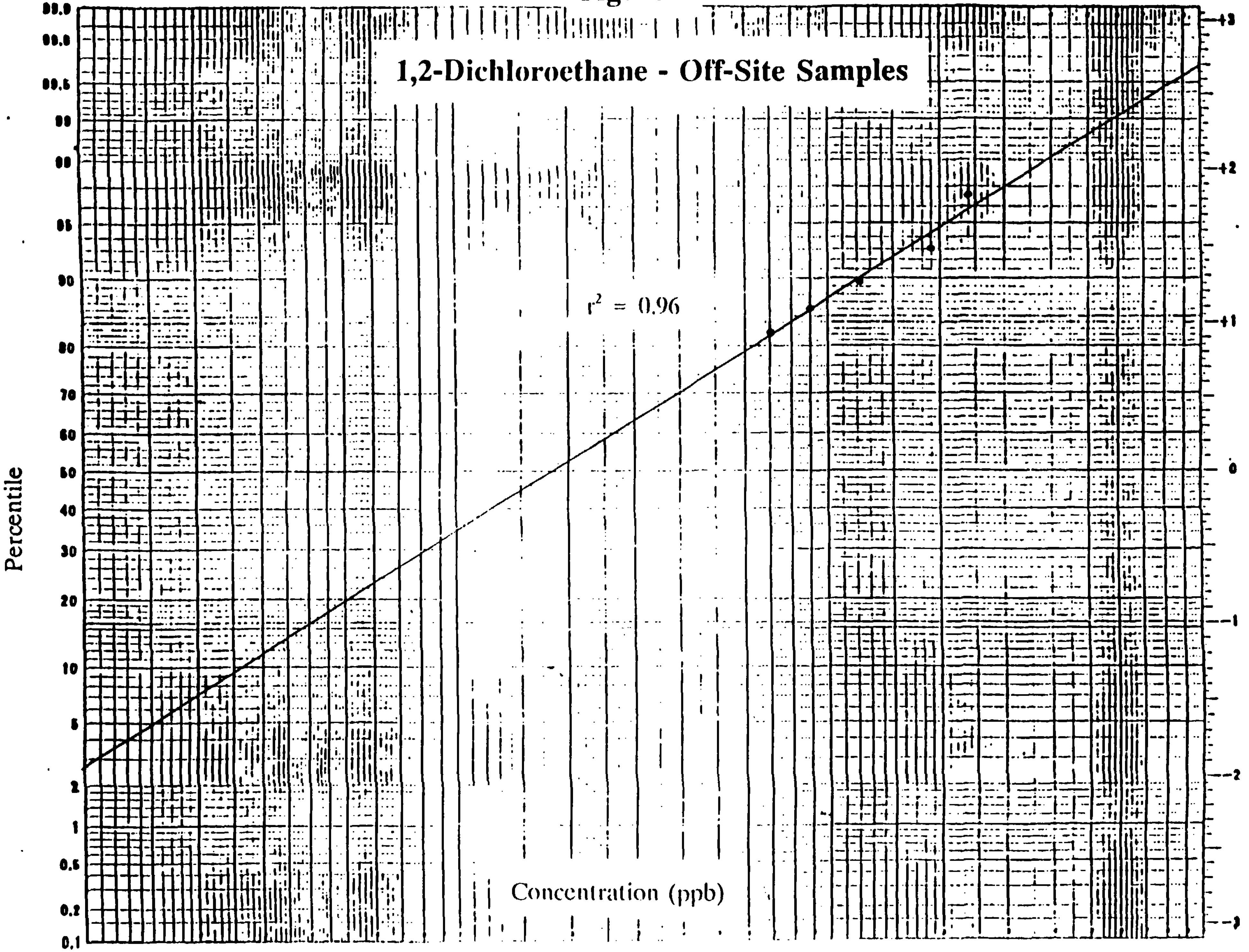
(2) n = not detected, j = estimated concentration (detected), d = detected

Figure 1



Vinyl Chloride - Off-Site Samples

Figure 2



1,2-Dichloroethane - Off-Site Samples
r² = 0.96
Concentration (ppb)
Percentile
99.9
99.8
99.5
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
0.5
0.2
0.1
+3
+2
+1
0
-1
-2
-3

APPENDIX II

LITERATURE REVIEW
CHEMICAL CHARACTERIZATION OF MSW LANDFILLS

TABLE OF CONTENTS

LIST OF TABLES

1.0 INTRODUCTION

Landfills have served for many decades as the ultimate disposal location for many types of societal wastes. This includes residential, commercial and industrial wastes which may be either innocuous or hazardous in nature. One consequence of landfilling is the generation of leachate which can subsequently migrate into the surrounding land and water. Leachate from municipal solid waste (MSW) landfills may contain a variety of inorganic and organic compounds in widely ranging concentrations. The purpose of this discussion is to present a review of the scientific literature which is specific to the quality and chemical characteristics of MSW landfill leachate. This discussion summarizes the investigations of several researchers and is presented in the following sections.

Section 2.0	Leachate Production
Section 3.0	Chemical Characterization
Section 4.0	Specific Landfill Chemical Characterization
Section 5.0	Metamora Landfill Leachate Quality

Section 2.0 presents a general discussion regarding leachate production in MSW landfills.

Section 3.0 presents the typical chemical characteristics of leachate from MSW landfills.

Section 4.0 presents specific information regarding the chemical characterization of leachate from several landfills.

Finally, Section 5.0 presents a review and evaluation of the chemical characterization of the leachate at the Metamora Landfill in comparison to the leachates commonly occurring at other MSW landfills.

2.0 LEACHATE PRODUCTION

Leachate is produced when moisture enters the refuse in a landfill, extracts contaminants into the liquid phase and produces a moisture content sufficiently high to initiate liquid flow. Sources of moisture entering the landfill include liquid present in the refuse at placement, precipitation falling on refuse at placement and infiltrating before and after cover application and intrusion of groundwater from outside into the landfill. The percolating water mobilizes salts and various other organic and inorganic compounds. These compounds may have been present in the original solid waste, generated by the action of microbial agents, or produced by physical-chemical reactions.

The types, amounts and production rates of leachate constituents at a landfill site are influenced by refuse type and composition. The composition of MSW based on the information presented by several researchers throughout Canada and the United States is presented, in summary fashion, on Table 2.1.

TABLE 2.1

TYPICAL MUNICIPAL SOLID WASTE COMPOSITION (FARQUHAR, 1989)[1]

	Component	*Composition Range % Wet Weight*
(A)	Food	5 - 20
	Garden Residue	15 - 25
(B)	Paper	40 - 50
	Plastic	1 - 5
	Wood	2 - 5
	Other Organics	2 - 10
(C)	Iron	5 - 10
	Other Metals	1 - 1
(D)	Glass	5 - 10
	Other Inorganics	2 - 5
	Moisture Content	20 - 30

Notes:

1 Professor G. Farquhar, Department of Civil Engineering, Water Resources Group, University of Waterloo.

3.0 CHEMICAL CHARACTERIZATION

The chemical characterization of the leachate is dependent on the composition of the refuse in the landfill. Attachment A presents a comparison of the chemical characteristics of three different types of facility derived leachates. This includes MSW, codisposal and hazardous waste landfill leachates.

3.1 GENERAL CHEMISTRY

Category A from Table 2.1 consists of readily biodegradable food and garden wastes which produce high concentrations of organic matter (as BOD or TOC) and total kjeldahl nitrogen in the leachate. Category D from Table 2.1 includes non-metallic inorganic components such as glass, soil and salts which degrade into the common anions (chloride, sulfate, phosphate and carbonate). Tables 3.1 and 3.2 present the general chemical characteristics for typical sanitary landfill leachates.

3.2 ORGANICS

Categories A and B from Table 2.1 would contribute to the organic composition in the leachate. Table 3.3 presents the Volatile Organic Compounds (VOCs) and Base Neutral/Acid Extractables (BNAs) for a typical sanitary landfill leachate. Attachment A presents additional information regarding the organic compounds associated with MSW landfill leachates.

TABLE 3.1

SUMMARY OF GENERAL CHEMISTRY OF LEACHATE CHARACTERISTICS

Parameter		***Typical Sanitary Landfill Leachate***			
		1. Freeze et al (1979)	***2. Byer, ed. (1980)***	***3. McGinley et al (1984)***	***4. Johansen et al (1976)***
General Water Quality					
Chemical Oxygen Demand	(mg/L)	1,000 to 90,000	1,340 to 42,000	62 to 97,900	110 to 9,425
Chloride	(mg/L)	300 to 3,000	1.95 to 2,260	2 to 5,590	68 to 680
Fluoride	(mg/L)			0.74	
Ammonia as N	(mg/L)	10 to 1,000	117 to 950	ND to 359	10.2 to 227
Nitrite/Nitrate as N	(mg/L)	0.1 to 10		ND to 250	0.01 to 0.79
Total Kjehldahl Nitrogen	(mg/L)	10 to 1,000	1240	2 to 1,850	
Sulfate	(mg/L)	10 to 1,000	<0.01 to 1,280	ND to 1,800	10 to 100
Total Dissolved Solids	(mg/L)	5,000 to 40,000			
Total Organic Carbon	(mg/L)	200 to 3,000	5000		30 to 1,700
Turbidity	(mg/L)				

Notes

1) ND - not detected

TABLE 3.2

CONTAMINANT CONCENTRATION RANGES IN LEACHATE REPORTED IN THE LITERATURE (McGINLEY AND KMET 1984)

	George (1972)	*Chian DeWalle (1977)*	*Metry Cross (1977)*	*Cameron (1978)*
pH	3.7 - 8.5	3.7 - 8.5	3.7 - 8.5	3.7 - 8.5
Alkalinity	0 - 20,850	0 - 20,850	310 - 9,500	0 - 20,900
Acidity				0-9,590
Total Solids		0 - 59,200		
TDS	0 - 42,276	584 - 44,900	100 - 51,000	0 - 42,300
Total Susp Solids	6 - 2,685	10 - 700	13 - 26,500	
Specific Conductance		2,810 - 16,800	100 - 1,200	
BOD	9 - 54,610	81 - 33,360	2,200 - 720,000	9 - 55,000
COD	0 - 89,520	40 - 89,520	800 - 750,000	0 - 9,000
TOC		256 - 28,000		
Bicarbonate			3,260 - 5,730	
Hardness	0 - 22,800	0 - 22,800	35 - 8,700	0 - 22,800
Chlorides	34 - 2,800	4.7 - 2,467	47 - 2,350	34 - 2,800
Fluorides				0 - 2.13
Sulfates	1 - 1,826	1 - 1,558	20 - 1,370	0 - 1,826
Sulfide				0 - 0.013
Total-K-Nitrogen	0 - 1,416			
NH3-Nitrogen	0 - 1,106	0 - 1,106	0.2 - 845	0 - 1,106
Organic Nitrogen			2.4 - 550	
NO3-Nitrogen	0 - 1,300	0.2 - 10.29	4.5 - 18	
Total Phosphorus	1 - 154	0 - 130		
Ortho-phosphorus		6.5 - 5	0.3 - 136	0 - 154
Aluminum				0 - 122
Arsenic				0 - 11.6
Barium				0 - 5.4
Beryllium				0 - 0.3
Boron				0.3 - 73
Cadmium		0.03 - 17		0 - 0.19
Calcium	5 - 4,080	60 - 7,200	240 - 2,570	5 - 4,000
Total Chromium				0 - 33.4
Copper	0 - 9.9	0 - 9.9		0 - 10
Cyanide				0 - 0.11
Iron	0.2 - 5,500	0 - 2,820	0.12 - 1,700	0.2 - 5,500
Lead	0 - 5.0	<0.10 - 2.0		0 - 5.0

TABLE 3.2

CONTAMINANT CONCENTRATION RANGES IN LEACHATE REPORTED IN THE LITERATURE (McGINLEY AND KMET 1984)

	George (1972)	*Chian DeWalle (1977)*	*Metry Cross (1977)*	*Cameron (1978)*
Magnesium	16.5 - 15,600	17 - 15,600	64 - 547	16.5 - 15,600
Manganese	0.06 - 1,400	0.09 - 125	13	0.06 - 1,400
Mercury				0 - 0.064
Molybendum				0 - 0.52
Nickel				0.01 - 0.8
Potassium	2.8 - 3,770	28 - 3,770	28 - 3,800	2.8 - 3,770
Sodium	0.77	0 - 7,700	85 - 3,800	0 - 7,700
Titanium				0 - 5.0
Vanadium				0 - 1.4
Zinc	0 - 1,000	0 - 370	0.03 - 135	0 - 1,000

All concentrations in mg/L except pH(std units) and Sp. Cond. (umhos/cm).

TABLE 3.3

SUMMARY OF ORGANIC PARAMETERS OF LEACHATE CHARACTERISTICS

		Typical Sanitary Landfill Leachate		
Parameter		1. ***McGinley et al (1984)***	2. ***Sabel et al (1980)***	3. ***Shuckrow et al (1982)***
VOCs				
1,1-dichloroethane	(µg/L)	510 to 6,300	0.6 to 46	45 to 194
1,2-dichloroethane	(µg/L)	13 to 11,000	5.5	
1,2-dichloropropane	(µg/L)	54	2.0 to 8.1	
2-butanone	(µg/L)		110 to 27,000	
2-hexanone	(µg/L)			
4-methyl-2-pentanone	(µg/L)		10 to 740	
Acetone	(µg/L)		140 to 13,000	
Benzene	(µg/L)	19	17 to 540	
Chlorobenzene	(µg/L)		1.5 to 60	
Chloroethane	(µg/L)	170		<10 to 18
Chloromethane	(µg/L)	170		
Ethylbenzene	(µg/L)	100 to 250	12 to 820	
Methylene Chloride	(µg/L)	106 to 20,000	64 to 1,300	61 to 200
Styrene	(µg/L)			
Tetrachloroethane	(µg/L)	26 to 60		35 to 162
Toluene	(µg/L)	280 to 1,600	7.5 to 600	<10 to 20
trans-1,2-dichloroethane	(µg/L)	96 to 2,200	3.8 to 88	
Trichloroethene	(µg/L)	160 to 600		10 to 53
Vinyl chloride	(µg/L)	61		<10 to 14
Total xylenes	(µg/L)		12 to 170*	
Other VOCs	(µg/L)			

Notes:

1) * o-and p-xylenes only

TABLE 3.3

SUMMARY OF ORGANIC PARAMETERS OF LEACHATE CHARACTERISTICS

		Typical Sanitary Landfill Leachate		
Parameter		1. ***McGinley et al*** *(1984)*	2. ***Sabel et al*** *(1980)*	3. ***Shuckrow et al*** *(1982)*
BNAs				
1,4-dichlorobenzene	(µg/L)		7.7 to 16	
2,4-dimethylphenol	(µg/L)			
4-methylphenol	(µg/L)			
4-nitrophenol	(µg/L)			
benzo (b) fluoranthene	(µg/L)	17		
benzo (g,h,i) perylene	(µg/L)			
bis (2-ethylhexyl) phthalate	(µg/L)	34 to 150		<10 to 12
dibenz (a,h) anthracene	(µg/L)			
di-n-butyl phthalate	(µg/L)	12 to 150		
indeno (1,2,3-cd) pyrene	(µg/L)			
naphthalene	(µg/L)	19		
pentachlorophenol	(µg/L)	3		
phenanthrene	(µg/L)			
pyrene	(µg/L)			
p-chlor-m-creosol	(µg/L)			
phenol	(µg/L)	221 to 5,790		
other BNAs	(µg/L)			

3.3 INORGANICS

Category C from Table 2.1 includes metallic wastes composed mainly of iron, aluminum and zinc. When these materials are degraded or leached various inorganics are added to the leachate. The alkaline earth metals (calcium, magnesium, sodium and potassium) arise from the decomposition of the nonmetallic inorganic components in Category D. Table 3.4 present inorganic concentrations for typical sanitary landfill leachates. The general chemistry constituents derived from the breakdown of Category D wastes were presented on Table 3.2.

TABLE 3.4

SUMMARY OF METALS OF LEACHATE CHARACTERISTICS

Parameter		*Typical Sanitary Landfill Leachate*			
		1. *Freeze et al (1979)*	**2.** *Byer et al (1980)*	**3.** *McGinley et al (1984)*	**4.** *James, S.C. (1977)*
Metals					
Aluminum	(mg/L)			ND to 85	
Antimony	(mg/L)			ND to 2.0	
Arsenic	(mg/L)		0.11	ND to 70.2	
Barium	(mg/L)			ND to 2.0	
Boron	(mg/L)		29.9	4.6 to 5.1	
Cadmium	(mg/L)		1.95	ND to 0.4	0.001 to 0.073
Calcium	(mg/L)	100 to 3,000	354.1 to 2,300	200 to 2,100	
Chromium	(mg/L)		<0.1	ND to 5.6	0.01 to 0.29
Cyanide, total	(mg/L)			ND to 0.4	
Hex. Chromium	(mg/L)				
Cobalt	(mg/L)				
Copper	(mg/L)	<10	<0.1	ND to 3.56	0.004 to 1.54
Iron	(mg/L)	1 to 1,000	4.2 to 1,185	0.06 to 1,500	6.5 to 1,500
Lead	(mg/L)	<5	4.46	ND to 1.2	0.01 to 0.33
Magnesium	(mg/L)	100 to 1,500	233 to 410	120 to 780	
Manganese	(mg/L)	0.01 to 100	0.04 to 58	ND to 20.5	
Nickel	(mg/L)	0.001 to 1	0.3	ND to 3.3	
Potassium	(mg/L)	200 to 1,000	500 to 1,890	31 to 560	
Selenium	(mg/L)				
Silver	(mg/L)			ND to 0.196	
Sodium	(mg/L)	200 to 1,200	160 to 1,375	33 to 1,240	
Tin	(mg/L)			0.08 to 0.16	
Vanadium	(mg/L)				
Zinc	(mg/L)	0.1 to 100	18.8 to 67	ND to 162	0.07 to 33
Other metals	(mg/L)				

Notes:

1) ND - Not Detected

4.0 SPECIFIC LANDFILL CHEMICAL CHARACTERIZATION

Tables 4.1 and 4.2 present the chemical characterization of leachate for three landfills in Illinois. Tables 4.3 and 4.4 present an overall summary of the chemical characteristics of MSW leachates as reported in Wisconsin.

TABLE 4.1

SUMMARY OF LEACHATE CHARACTERISTICS IN WAUCONDA LANDFILL, ILLINOIS
(CRA, NOVEMBER 1987)

Parameter		*Wauconda Landfill, Illinois Leachate*
General Water Quality		
Chemical Oxygen Demand	(mg/L)	930 to 36,000
Chloride	(mg/L)	1,800 to 4,500
Fluoride	(mg/L)	0.04 to 0.7
Ammonia as N	(mg/L)	460 to 760
Nitrite/Nitrate as N	(mg/L)	0.2 to 1.4
Total Kjehldahl Nitrogen	(mg/L)	220 to 600
Sulfate	(mg/L)	ND to 1,400
Total Dissovled Solids	(mg/L)	5,800 to 25,000
Total Organic Carbon	(mg/L)	380 to 14,000
Turbidity	(NTU)	48 to 120

Notes:

1) ND - Not Detected
2) Wauconda leachate data represented by LW503, LS1, LS2, LS3, LS4, WS002, WS401.

TABLE 4.1

SUMMARY OF LEACHATE CHARACTERISTICS IN WAUCONDA LANDFILL, ILLINOIS (CRA, NOVEMBER 1987)

Parameter		*Wauconda Landfill, Illinois Leachate*
VOCs		
1,1-dichloroethane	(μg/L)	ND to 190
1,2-dichloroethane	(μg/L)	ND to 480
1,2-dichloropropane	(μg/L)	ND to 190
2-butanone	(μg/L)	ND to 22,000
2-hexanone	(μg/L)	ND to 380
4-methyl-2-pentanone	(μg/L)	ND to 490
Acetone	(μg/L)	ND to 25,000
Benzene	(μg/L)	ND to 70
Chlorobenzene	(μg/L)	ND to 12
Chloroethane	(μg/L)	ND to 91
Chloromethane	(μg/L)	ND to 18
Ethylbenzene	(μg/L)	ND to 140
Methylene Chloride	(μg/L)	ND to 11,000
Styrene	(μg/L)	ND to 19
Tetrachloroethane	(μg/L)	ND to 120
Toluene	(μg/L)	ND to 550
trans-1,2-dichloroethane	(μg/L)	ND to 730
Trichloroethene	(μg/L)	ND to 200
Vinyl chloride	(μg/L)	ND to 77
Total xylenes	(μg/L)	BDL to 430
Other VOCs	(μg/L)	ND

Notes:

1) ND - Not Detected
2) BDL - Below Detection Limit

TABLE 4.1

SUMMARY OF LEACHATE CHARACTERISTICS IN WAUCONDA LANDFILL, ILLINOIS (CRA, NOVEMBER 1987)

Parameter		*Wauconda Landfill, Illinois Leachate*
BNAs		
1,4-dichlorobenzene	(µg/L)	ND to 30
2,4-dimethylphenol	(µg/L)	ND to 42
4-methylphenol	(µg/L)	ND to 9.8
4-nitrophenol	(µg/L)	ND to 90
benzo (b) fluoranthene	(µg/L)	ND to 25
benzo (g,h,i) perylene	(µg/L)	ND to 25
bis (2-ethylhexyl) phthalate	(µg/L)	ND to 11
dibenz (a,h) anthracene	(µg/L)	ND to 25
di-n-butyl phthalate	(µg/L)	ND to 26
indeno (1,2,3-cd) pyrene	(µg/L)	ND to 25
naphthalene	(µg/L)	ND to 27
pentachlorophenol	(µg/L)	ND to 25
phenanthrene	(µg/L)	ND to 25
pyrene	(µg/L)	ND to 25
p-chlor-m-creosol	(µg/L)	ND to 20
phenol	(µg/L)	BDL
other BNAs	(µg/L)	ND
Pesticides/PCBs		
All Parameters		ND

Notes:

1) ND - Not Detected
2) BDL - Below Detection Limit

TABLE 4.1

SUMMARY OF LEACHATE CHARACTERISTICS IN WAUCONDA LANDFILL, ILLINOIS (CRA, NOVEMBER 1987)

Parameter		*Wauconda Landfill, Illinois Leachate*
Metals		
Aluminum	(mg/L)	ND to 12.5
Antimony	(mg/L)	ND to 0.024
Arsenic	(mg/L)	0.012 to 0.179
Barium	(mg/L)	0.268 to 0.788
Boron	(mg/L)	6.1 to 23
Cadmium	(mg/L)	ND to 0.0011
Calcium	(mg/L)	37.5 to 2,600
Chromium	(mg/L)	ND to 0.165
Cyanide, total	(mg/L)	ND to 0.043
Hex. Chromium	(mg/L)	ND to 0.076
Cobalt	(mg/L)	ND to 0.37
Copper	(mg/L)	ND to 0.035
Iron	(mg/L)	4.57 to 1,180
Lead	(mg/L)	ND to 0.047
Magnesium	(mg/L)	81.8 to 706
Manganese	(mg/L)	0.104 to 22
Nickel	(mg/L)	0.06 to 0.589
Potassium	(mg/L)	49.5 to 692
Selenium	(mg/L)	ND to 0.027
Silver	(mg/L)	ND to 0.049
Sodium	(mg/L)	1,450 to 3,280
Tin	(mg/L)	ND to 0.035
Vanadium	(mg/L)	ND to 0.159
Zinc	(mg/L)	0.1 to 44.2
Other metals	(mg/L)	ND

Notes:

1) ND - Not Detected

TABLE 4.2

COMPOSITION OF LEACHATE AND GROUNDWATER FOR CRYSTAL LAKE AND SAVANNA LANDFILL, ILLINOIS (JOHNSON AND CARTWRIGHT, 1980)

	Crystal Lake Landfill, Illinois		Savanna Landfill, Illinois	
Parameter	***Leachate (mg/L) (1)***	***Groundwater (mg/L)***	***Leachate (mg/L) (1)***	***Groundwater (mg/L)***
Calcium	6,200	47	5,600	75
Iron	350	0.4	450	0.3
Mercury	<0.2 ppb	<0.2 ppb	<0.2 ppb	<0.2 ppb
Potassium	650	0.5	85	3.5
Magnesium	1,660	19	900	19
Sodium	1,030	2	820	5
Lead	0.4	<0.01	0.1	<0.01
Zinc	46.5	0.6	0.9	0.08
Alkalinity (CaCO3)(2)	11,800	240	440	223
Chloride	1,602	6	1,326	16
COD	32,000	4	1,944	15
Ammonia as N	–	–	240	0.3
Nitrate as N	7.9	3.9	0.7	0.4
pH	5.65	7.48	6.8	7.05
Specific Conductance	12,000	520	6,200	600
Sulfate	992	40	6	25
Total Dissolved Solids	22,900	400	5,583	320

Notes:

1) Except for Hg, (ppb), pH and SC (μm hos)
2) Field measurement

TABLE 4.3

OVERALL SUMMARY FROM THE ANALYSIS OF MUNICIPAL SOLID WASTE LEACHATES IN WISCONSIN (JOHNSON AND CARTWRIGHT, 1980)

Parameter	*Overall Range (1)*	*Typical Range (range of Site Medians) (1)*	*Numer of Analyses*
TDS	584 - 50,430	2,180 - 25,873	172
Specific Conductance	480 - 72,500	2,840 - 15,485	1,167
Total Suspended Solids	2 - 140,900	28 - 2,835	2,700
BOD	ND - 195,000	101 - 29,200	2,905
COD	6.6 - 97,900	1,120 - 50,450	467
TOC	ND - 30,500	427 - 5,890	52
pH	5 - 8.9	5.4 - 7.2	1,900
Total Alkalinity (CaCO3)	ND - 15,050	960 - 6,845	328
Hardness (CaCO3)	52 - 225,000	1,050 - 9,380	404
Chloride	2 - 11,375	180 - 2,651	303
Calcium	200 - 2,500	200 - 2,100	9
Sodium	12 - 6,010	12 - 1,630	192
Total Kjeldahl Nitrogen	2 - 3,320	47 - 1,470	156
Iron	ND - 1,500	2.1 - 1,400	416
Potassium	ND - 2,800	ND - 1,375	19
Magnesium	120 - 780	120 - 780	9
Ammonia-Nitrogen	ND - 1,200	26 - 557	263
Sulfate	ND - 1,850	8.4 - 500	154
Aluminum	ND - 85	ND - 85	9
Zinc	ND - 731	ND - 54	158
Manganese	ND - 31.1	0.03 - 25.9	67
Total Phosphorus	ND - 234	0.3 - 117	454
Boron	0.87 - 13	1.19 - 12.3	15
Barium	ND - 12.5	ND - 5	73
Nickel	ND - 7.5	ND - 1.65	133
Nitrate-Nitrogen	ND - 250	ND - 1.4	88
Lead	ND - 14.2	ND - 1.11	142
Chromium	ND - 5.6	ND - 1.0	138
Antimony	ND - 3.19	ND - 0.56	76
Copper	ND - 4.06	ND - 0.32	138
Thallium	ND - 0.78	ND - 0.31	70
Cyanide	ND - 6	ND - 0.25	86
Arsenic	ND - 70.2	ND - 0.225	112
Molybdenum	0.01 - 1.43	0.034 - 0.193	7
Tin	ND - 0.16	0.16	3
Nitrate-Nitrogen	ND - 1.46	ND - 0.11	20
Selenium	ND - 1.85	ND - 0.09	121
Cadmium	ND - 0.4	ND - 0.07	158
Silver	ND - 1.96	ND - 0.024	106
Beryllium	ND - 0.36	ND - 0.008	76
Mercury	ND - 0.01	ND - 0.001	111

(1) All concentrations in mg/L except pH (standard units) and special conditions (umhos/cm)

TABLE 4.4

ORGANIC PRIORITY CONTAMINANTS IN LEACHATE (SAMPLES FROM 9 WISCONSIN MSW LANDFILLS, FROM McGINLEY AND KMET 1984)

Contaminant	*% Samples Contaminate*	*Maximum Concentration (mg/L)*
Halogenated Aliphatics		
• methylene chloride	79	20.0
• trichloroethane	30	2.4
• chloroform	25	1.3
Monocyclic Aromatics		
• toluene	91	3.2
• benzene	74	1.08
• chlorobenzene	22	0.01
Phenols		
• total phenol	70	11.3
• pentachlorophenol	13	0.47
Other		
• napthalene	30	0.33
• ethyl phthalate	70	0.27

5.0 METAMORA LANDFILL LEACHATE QUALITY

Leachate seeps were identified and sampled during the Metamora Landfill Site RI.

Twelve organic chemicals were detected in the three leachate-contaminated soil samples analyzed during the RI. These results are summarized on Table 5.1. Acetone and methylene chloride were not considered Site-related because acetone was found in the lab blank and methylene chloride is a common laboratory solvent.

The inorganic constituents detected in the leachate contaminated soils are summarized on and compared to background levels on Table 5.2.

A qualitative comparison of the leachate-contaminated soil analytical results at the Metamora Landfill Site with the typical MSW landfill leachate indicates that all constituents are within the range which would be expected for MSW landfills in general, with the exception of three parameters, phenanthrene, fluoranthene and pyrene.

TABLE 5.1

ORGANIC CHEMICALS IN LEACHATE-CONTAMINATED SOILS AT THE METAMORA LANDFILL SITE

Parameter	
Methylene Chloride	16 - 30
Acetone	240 - 710
1,1-Dichloroethane	12
Trans-1,2-dichloroethene	20
2-Butanone	150 - 920
Trichloroethene	2
Tetrachloroethene	12
Toluene	35 - 46
Ethylbenzene	13
Phenanthrene	400 - 920
Fluoranthene	700 - 1,500
Pyrene	980 - 1,300

Notes

1. All concentrations in ug/kg.

TABLE 5.2

INORGANICS IN LEACHATE-CONTAMINATED SOIL AT THE METAMORA LANDFILL SITE

Parameter	*Metamora Landfill Site, Michigan*	*Background (4) Concentration Range*
Aluminum	1,060 - 1,850	1,110 - 10,750
Arsenic	4.8 - 25.7	0.1 - 88
Barium	10 - 28	5.2 - 291
Cadmium	2.3 - 2.9	0.1 - 3.5
Calcium	35,600 - 57,300	NA
Chromium	4.8 - 6.5	1.0 - 53.0
Cobalt	1.9 - 4.6	2.5 - 13.0
Copper	5.5 - 8	1.2 - 82.5
Iron	9,600 - 14,900	2,320 - 21,900
Lead	4.8 - 6.9J	1.2 - 56.0
Magnesium	9,300 - 16,800	NA
Manganese	105 - 256	31.0 - 835.0
Nickel	4.6 - 9	1.6 - 53.0
Potassium	140 - 229	NA
Vanadium	8.4 - 124	NA
Zinc	31 - 333	4.7 - 90

Notes

1. All concentrations in mg/kg.
2. J - an estimated value.
3. NA - not available.
4. Background concentration range reported by MDNR (12/21/87) for Michigan soils.

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ATTACHMENT A

Differences in quality of leachate from municipal, codisposal and industrial hazardous waste facilities are presented on Table A.1 and Figure A-1. The data shown were compiled by Waste Management Inc. (1987) from analyses of leachate from MSW landfills, codisposal landfills, and hazardous waste landfills. The column labeled "N" refers to the number of samples analyzed at each type of facility. Measurements reported as "O" should be interpreted as non-detectable concentrations.

Table A.1 Chemical Concentrations in Leachates at Sanitary, Codisposal and Industrial Waste Facilities (ppb) SOURCE: Waste Management, Inc., 1987.

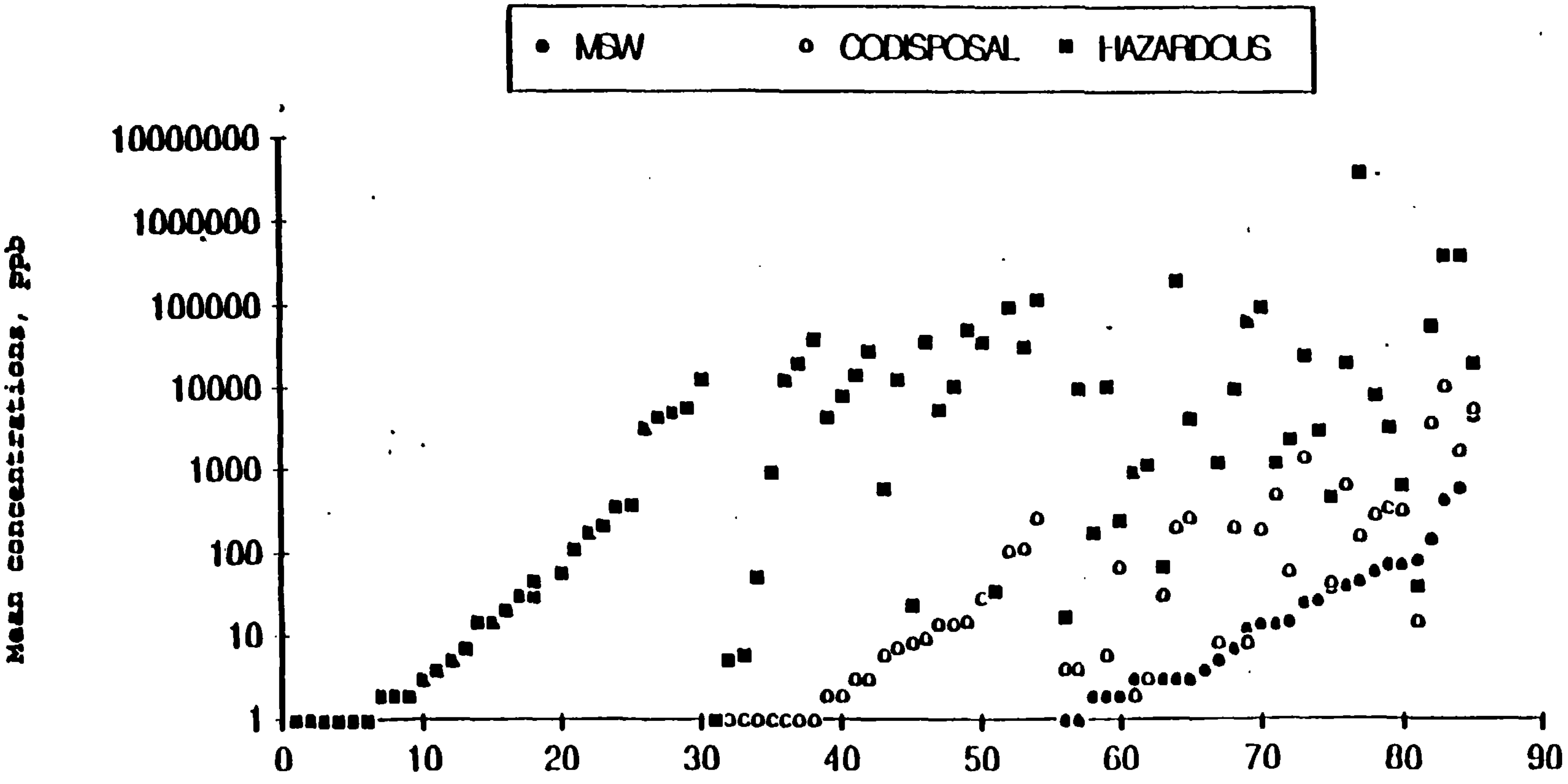
Analyte No	Analyte Name	MSW FACILITIES				CODISPOSAL FACILITIES				HAZARDOUS WASTE FACILITIES			
		N	Mean	Range	S.D.	N	Mean	Range	S.D.	N	Mean	Range	S.D.
NP*	bis (chloromethyl) ether	70	0	0	0	295	0	0	0	747	0	0	0
NP	bromoform	70	0	0	0	301	0	0	0	747	0	0	0
NP	chlorodibromomethane	70	0	0	0	301	0	0	0	747	0	0	0
NP	2-chloroethylvinyl ether	70	0	0	0	300	0	0	0	722	0	0	0
NP	dichlorobromomethane	70	0	0	0	301	0	0	0	747	0	0	0
NP	methyl bromide	70	0	0	0	300	0	0	0	747	0	0	0
NP	4,6-dinitro-o-cresol	29	0	0	0	225	0	0	0	200	0	0	0
NP	2,4-dinitrophenol	29	0	0	0	225	0	0	0	200	0	0	0
NP	benzidine	27	0	0	0	221	0	0	0	199	0	0	0
NP	bis(2-chloroisopropyl)ether	27	0	0	0	221	0	0	0	196	0	0	0
NP	4-bromophenyl phenyl ether	27	0	0	0	221	0	0	0	198	0	0	0
NP	4-chlorophenyl phenyl ether	27	0	0	0	221	0	0	0	194	0	0	0
NP	n-nitrosdi-n-propylamine	27	0	0	0	221	0	0	0	198	0	0	0
NP	aldrin	26	0	0	0	226	0	0	0	199	0	0	0
NP	alpha-BHC	26	0	0	0	222	0	0	0	199	0	0	0
NP	chlordane	26	0	0	0	224	0	0	0	199	0	0	0
NP	4,4-DDT	26	0	0	0	226	0	0	0	199	0	0	0
NP	4,4-DDD	26	0	0	0	218	0	0	0	199	0	0	0
NP	endosulfan I	26	0	0	0	218	0	0	0	199	0	0	0
NP	endosulfan II	26	0	0	0	218	0	0	0	199	0	0	0
NP	endosulfan sulfate	26	0	0	0	217	0	0	0	195	0	0	0
NP	endrin aldehyde	26	0	0	0	218	0	0	0	195	0	0	0
NP	heptachlorexpoxide	26	0	0	0	222	0	0	0	199	0	0	0
NP	toxaphene	41	0	0	0	233	0	0	0	203	0	0	0
NP	n-nitrosodimethylamine	27	0	0	0	221	0	0	0	198	0	16	1
NP	gamma BHC	26	0	0	0	227	0	0	0	199	0	0-15	1
NP	3,3-dichlorobenzidine	27	0	0	0	221	0	0-17	1	199	0	0-17	1
NP	heptachlor	26	0	0	0	224	0	0	0	199	0	0-8	1
1	n-nitrosodiphenylamine	27	0	0-3	1	221	0	8	1	198	1	252	18
2	beta-BHC	26	0	0	0	222	0	0	0	199	1	0-132	10
3	bis(2-chloroethoxy)methane	27	0	0	0	221	0	0	0	196	1	0-168	13
4	1,2-diphenyl hydrazine	27	0	0	0	221	0	0	0	198	1	0-171	12
5	cis-1,3- dichloropropylene	70	0	0	0	303	0	0	0	708	1	0-754	28
6	dieldrin	26	0	0	0	226	0	0	0	199	1	0-96	9
7	PCB1221	60	0	0	0	245	0	0	0	590	2	0-1090	45
8	dibenzo(a,h)anthracene	27	0	0	0	227	0	0	0	198	2	0-191	16
9	4,4 DDE	26	0	0	0	218	0	0 /	0	199	2	0-360	26
10	PCB1232	60	0	0	0	245	0	0	0	590	3	0-1100	47
11	delta BHC	26	0	0	0	220	0	0	0	199	4	0-490	43

*NP = not plotted (on Figure A.1)

Analyte No	Analyte Name	MSW FACILITIES				CODISPOSAL FACILITIES				HAZARDOUS WASTE FACILITIES			
		N	Mean	Range	S.D.	N	Mean	Range	S.D.	N	Mean	Range	S.D.
12	2,6-dinitrotoluene	27	0	0	0	221	0	0	0	198	5	0-671	51
13	2,4-dinitrotoluene	27	0	0-26	5	227	0	0	0	198	7	0-1080	79
14	hexachloroethane	27	0	0	0	227	0	0	0	543	15	0-1930	128
15	hexachlorocyclopentadiene	27	0	0	0	227	0	0	0	543	15	0-2660	165
16	PCB1016	60	0	0	0	245	0	0	0	590	20	0-12000	494
17	bis(2-chloroethyl)ether	27	0	0	0	227	0	0-20	2	196	31	0-1330	148
18	hexachlorobenzene	27	0	0	0	227	0	0	0	543	31	0-6240	287
18	2,4,6-trichlorophenol	29	0	0	0	225	0	0	0	200	45	0-6190	444
20	hexachlorobutadiene	27	0	0	0	227	0	0-2	0	543	57	0-24000	1032
21	pentachlorophenol	29	0	0	0	225	0	0-12	1	197	107	0-9380	762
22	2-nitrophenol	27	0	0-26	5	219	0	0-27	2	200	180	30600	2179
23	2-chloronaphthalene	27	0	0	0	221	0	0-5	0	543	211	0-31000	1715
24	PCB1260	60	0	0	0	245	0	0	0	590	366	0-100000	5195
25	PCB1248	60	0	0	0	245	0	0	0	590	381	0-200000	381
26	1,1,2,2-tetrachloroethane	70	0	0	0	303	0	0	0	723	3339	0-1000000	52795
27	benzo(g,h,i)perylene	27	0	0	0	221	0	0-48	3	198	4557	0-900000	63960
28	indeno(1,2,3-c,d)pyrene	27	0	0	0	220	0	0	0	194	5162	0-1000000	71795
29	PCB1254	60	0	0	0	245	0	0-18		590	5802	0-600000	36655
30	PCB1242	60	0	0-23	4	245	0	0	0	590	12800	0-1000000	90238
31	endrin	41	0	0	0	227	1	0-311	21	270	1	0-311	
32	acenaphthylene	27	0	0	0	228	1	0-45	5	198	5	0-481	35
33	p-chloro-m-cresol	29	0	0	0	225	1	0-124	9	198	6	0-674	54
34	2-chlorophenyl	29	0	0	0	225	1	0-134	9	200	52	2260	258
35	carbon tetrachloride	70	0	0	0	303	1	0-307	18	723	923	0-300000	13257
36	benzo(a)pyrene	27	0	0	0	227	1	0-105	8	199	13226	0-1000000	100000
37	benzo(k)fluoroanthene	27	0	0	0	221	1	0-110	8	199	20710	0-4000000	300000
38	benzo(a)anthracene	27	0	0	0	227	1	0-131	9	199	39198	0-6000000	400000
39	1,1,2-trichloroethane	70	0	0	0	303	2	0-705	41	723	4535	0-700000	41304
40	1,2,4-trichlorobenzene	27	0	0	0	227	2	0-288	20	566	8308	0-4000000	200000
41	chrysene	27	0	0	0	227	3	0-155	16	199	14861	0-2000000	100000
42	anthracene	27	0	0	0	221	3	0-122	13	199	27797	0-3000000	300000
43	2,4-dichlorophenol	29	0	0	0	225	6	0-1120	75	200	591	26900	3106
44	acenaphthene	27	0	0	0	222	7	0-342	28	199	12480	0-2000000	200000
45	nitrobenzene	27	0	0	0	227	8	0-1260	87	199	23	0-1940	193
46	fluorene	27	0	0	0	221	9	0-184	29	199	37404	0-4000000	400000
47	1,2-dichlorobenzene	27	0	0	0	227	14	0-672	53	566	5670	0-2000000	93277
48	di-n-octyl phthalate	27	0	0	0	221	14	0-1149	92	198	10699	0-2000000	100000
49	pyrene	27	0	0-2	0	221	15	0 432	53	199	51790	0-6000000	500000
50	fluoranthene	27	0	0 2	1	227	28	0-1520	129	199	36165	0 7000000	500000

Analyte No	Analyte Name	MSW FACILITIES				CODISPOSAL FACILITIES				HAZARDOUS WASTE FACILITIES			
		N	Mean	Range	S.D.	N	Mean	Range	S.D.	N	Mean	Range	S.D.
51	1,3-dichlorobenzene	27	0	0-3	1	227	32	0-6890	457	543	34	0-3000	245
52	phenanthrene	27	0	0	0	221	106	0-15600	1055	199	100000	0-10000000	1000000
53	1,2-dichloroethane	70	0	0-53	7	303	110	0-29000	1671	725	32550	0-3000000	300000
54	chloroform	70	0	0-45	6	303	261	0-73800	4243	725	119906	0-2000000	100000
55	3,4-benzofluoranthene	27	0	0	0								
56	1,2-dichloropropane	70	1	0-29	8	301	4	0-385	32	723	17	0-11300	421
57	butyl benzyl phthalate	27	1	0-41	9	221	4	0-475	35	199	9844	0-2000000	100000
58	4-nitrophenol	29	2	0-83	16	225	0	0	0	200	173	14000	1240
59	di-n-butyl phthalate	27	2	85	17	221	6	0-540	43	199	10693	0-3000000	100000
60	2,4-dimethylphenol	29	2	0-66	13	225	64	0-2320	273	200	244	10700	939
61	dimethyl phthalate	27	3	0-45	11	222	2	0-70	8	198	926	0-200000	12720
62	trichlorofluoromethane	70	3	0-122	19	298	3	0-313	26	704	1151	0-200000	17747
63	1,4-dichlorobenzene	27	3	0-17	5	227	30	0-1240	114	543	67	0-9300	551
64	bis(2-ethylhexyl)phthalate	27	3	0-54	13	221	205	0-7900	851	196	200000	0-30000000	2000000
65	chlorobenzene	70	3	0-48	9	303	254	0-33100	1972	723	4346	0-3000000	26182
66	methyl chloride	70	4	0-302	36	303	0	0-14	1	747	0	0-158	6
67	chloroethane	70	5	0-182	25	301	8	0-377	36	723	1208	0-500000	21302
68	tetrachloroethylene	70	7	0-334	41	303	197	0-57200	3286	710	10122	0-1000000	85865
69	dichlorodifluoromethane	70	12	0-373	55	292	8	0-1320	86	718	67284	0-30000000	1000000
70	naphthalene	27	14	0-229	44	228	191	0-2750	436	199	100000	0-10000000	1000000
71	Benzene	70	14	0-374	46	303	486	0-100000	7582	723	1272	0-300000	14705
72	vinyl chloride	70	15	0-265	46	303	57	0-3000	296	710	2372	0-200000	9827
73	1,1,1-trichloroethane	70	24	0-360	75	303	1416	0-400000	22943	725	24220	0-3000000	200000
74	1,1-dichloroethylene	70	27	0-1970	236	303	0	0-19	1	724	3167	0-300000	34064
75	isophorone	27	37	0-324	69	220	41	0-629	101	194	467	0-6400	1167
76	trichloroethylene	70	38	0-1460	180	303	641	0-200000	10118	711	20786	0-2000000	100000
77	ethylbenzene	70	45	0-834	109	301	155	0-200000	14109	717	4E+06	0-17924	200000
78	1,1-dichloroethane	70	58	0-942	141	303	273	0-44500	2598	725	8276	0-500000	67152
79	total cyanide	6	68	160	70	48	338	7300	1268	186	3274	82000	12251
80	1,2-trans-dichloroethylene	70	72	0-1180	173	301	309	0-20100	1469	725	644	0-70900	3534
81	diethyl phthalate	27	80	0-738	155	222	15	0-332	48	198	38	0-4050	344
82	phenol	29	144	0-1090	255	226	3654	0-200000	16760	198	57162	0-3000000	300000
83	toluene	70	431	0-7130	977	303	10912	0-2000000	100000	712	400000	0-50000000	4000000
84	methylene chloride	70	606	0-7010	1262	303	1709	0-100000	8002	726	400000	0-60000000	3000000
85	total phenolics	6	4653	12000	4617	39	5373	39000	8404	300	20858	1000000	95509

Figure A-1. Mean Concentrations of 85 chemicals (analytes) detected in leachates from MSW, co-disposal, and hazardous waste landfills. See Table A-1 and text for explanation.



Analyte number (see Table A-1 for chemical identities)

APPENDIX III

HELP MODEL RESULTS

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METAMORA LANDFILL          CAP-ACT 64
METAMORA, MICHIGAN
AUGUST 2,1990

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                              GOOD GRASS


                               LAYER 1
                               -------

        VERTICAL PERCOLATION LAYER
        THICKNESS                          =    16.00 INCHES
        EVAPORATION COEFFICIENT            =     3.800 MM/DAY**0.5
        POROSITY                           =     0.4420 VOL/VOL
        FIELD CAPACITY                     =     0.2560 VOL/VOL
        WILTING POINT                      =     0.1330 VOL/VOL
        EFFECTIVE HYDRAULIC CONDUCTIVITY   =     2.81399989 INCHES/HR


                               LAYER 2
                               -------

        LATERAL DRAINAGE LAYER
        SLOPE                              =     3.00 PERCENT
        DRAINAGE LENGTH                    =   200.0 FEET
        THICKNESS                          =    12.00 INCHES
        EVAPORATION COEFFICIENT            =     3.400 MM/DAY**0.5
        POROSITY                           =     0.4300 VOL/VOL
        FIELD CAPACITY                     =     0.1610 VOL/VOL
        WILTING POINT                      =     0.0600 VOL/VOL
        EFFECTIVE HYDRAULIC CONDUCTIVITY   =     2.77999997 INCHES/HR


                               LAYER 3
                               -------

        BARRIER SOIL LAYER
        THICKNESS                          =    36.00 INCHES
        EVAPORATION COEFFICIENT            =     3.100 MM/DAY**0.5
        POROSITY                           =     0.5200 VOL/VOL
        FIELD CAPACITY                     =     0.4500 VOL/VOL
        WILTING POINT                      =     0.3600 VOL/VOL
        EFFECTIVE HYDRAULIC CONDUCTIVITY   =     0.00014200 INCHES/HR


                       GENERAL SIMULATION DATA
                       -----------------------

        SCS RUNOFF CURVE NUMBER            =       73.90
        TOTAL AREA OF COVER                = 1080000. SQ. FT
        EVAPORATIVE ZONE DEPTH             =       10.00 INCHES
        EFFECTIVE EVAPORATION COEFFICIENT  =        3.800 MM/DAY**0.5
        UPPER LIMIT VEG. STORAGE           =        4.4200 INCHES
        INITIAL VEG. STORAGE               =        1.9450 INCHES

     CLIMATOLOGIC DATA FOR     E. LANSING          MICHIGAN

            MONTHLY MEAN TEMPERATURES, DEGREES FAHRENHEIT

  JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
  -------     -------     -------     -------     -------     -------
   23.10       24.95       32.83       44.62       57.15       67.09
   71.75       69.90       62.02       50.23       37.70       27.76

           MONTHLY MEANS SOLAR RADIATION, LANGLEYS PER DAY

  JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
  -------     -------     -------     -------     -------     -------
  121.19      185.29      206.98      399.01      491.38      539.31
  529.98      465.88      364.19      252.15      159.79      111.85

                       LEAF AREA INDEX TABLE

                         DATE         LAI
                         ----         ----
                            1         0.00
                          126         0.00
                          142         1.23
                          158         2.01
                          173         2.01
                          189         2.01
                          205         2.01
                          221         2.01
                          237         1.81
                          252         1.31
                          268         0.64
                          284         0.34
                          366         0.00

                           GOOD GRASS
```

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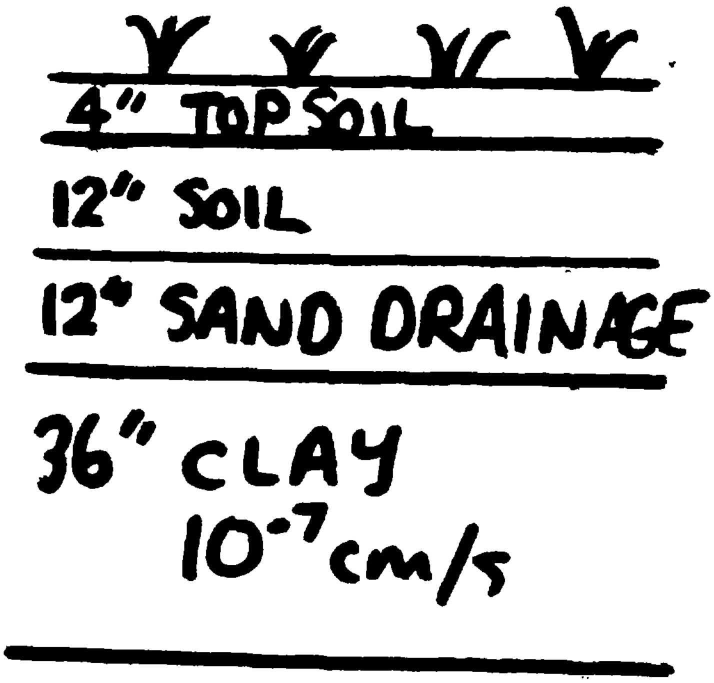
*ACT 64 CAP



```
                    WINTER COVER FACTOR =    1.20


 ****************************************************************


   AVERAGE MONTHLY TOTALS FOR    74 THROUGH    78

                              JAN/JUL FEB/AUG MAR/SEP APR/OCT MAY/NOV JUN/DEC
                              ------- ------- ------- ------- ------- -------

 PRECIPITATION (INCHES)         2.19    1.67    2.99    2.95    2.34    3.26
                                2.03    3.66    2.81    1.61    2.30    2.20

 RUNOFF (INCHES)               0.000   0.000   0.000   0.435   0.024   0.022
                               0.003   0.342   0.000   0.000   0.000   0.000

 EVAPOTRANSPIRATION            0.812   1.108   2.282   2.215   2.622   2.130
      (INCHES)                 1.844   1.824   1.967   1.101   0.935   0.797

 PERCOLATION FROM BASE         0.1140  0.0991  0.1201  0.1560  0.1558  0.1480
 OF COVER (INCHES)             0.1506  0.1511  0.1496  0.1551  0.1530  0.1562

 DRAINAGE FROM BASE OF         0.383   0.277   0.308   0.772   0.711   0.585
 COVER (INCHES)                0.608   0.607   0.647   0.674   0.666   0.671

 ****************************************************************



 ****************************************************************


   AVERAGE ANNUAL TOTALS FOR    74 THROUGH    78
  -----------------------------------------------------------------
                                         (INCHES)    (CU. FT.)    PERCENT
                                         --------    ---------    -------
   PRECIPITATION                          30.00      2700181.     100.00

   RUNOFF                                  0.826       74298.       2.75

   EVAPOTRANSPIRATION                     19.637     1767365.      65.45

   PERCOLATION FROM BASE OF COVER          1.7084     153760.       5.69

   DRAINAGE FROM BASE OF COVER             6.910      621923.      23.03
 ****************************************************************



 ****************************************************************
             PEAK DAILY VALUES FOR    74 THROUGH    78
     -------------------------------------------------------
                                          (INCHES)     (CU. FT.)
                                          --------     ---------

      PRECIPITATION                         3.08        277200.0

      RUNOFF                                1.339       120535.0

      PERCOLATION FROM BASE OF COVER        0.0132        1189.1

      DRAINAGE FROM BASE OF COVER           0.064         5763.6

      HEAD ON BASE OF COVER                  28.0

      SNOW WATER                              6.53      587810.8


      MAXIMUM VEG. SOIL WATER (VOL/VOL)         0.4420

      MINIMUM VEG. SOIL WATER (VOL/VOL)         0.1328
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page 1 of 2

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METAMORA LANDFILL MODIFIED ACT 641 CAP
METAMORA, MICHIGAN
AUGUST 2,1990

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**********************************************************************




                         GOOD GRASS


                          LAYER 1
                          -------

          VERTICAL PERCOLATION LAYER
          THICKNESS                          =      18.00 INCHES
          EVAPORATION COEFFICIENT            =       3.800 MM/DAY**0.5
          POROSITY                           =       0.4420 VOL/VOL
          FIELD CAPACITY                     =       0.2560 VOL/VOL
          WILTING POINT                      =       0.1330 VOL/VOL
          EFFECTIVE HYDRAULIC CONDUCTIVITY   =       2.81399909 INCHES/HR


                          LAYER 2
                          -------

          LATERAL DRAINAGE LAYER
          SLOPE                              =       3.00 PERCENT
          DRAINAGE LENGTH                    =     200.0 FEET
          THICKNESS                          =      12.00 INCHES
          EVAPORATION COEFFICIENT            =       3.400 MM/DAY**0.5
          POROSITY                           =       0.4300 VOL/VOL
          FIELD CAPACITY                     =       0.1610 VOL/VOL
          WILTING POINT                      =       0.0600 VOL/VOL
          EFFECTIVE HYDRAULIC CONDUCTIVITY   =       2.77999997 INCHES/HR


                          LAYER 3
                          -------

          BARRIER SOIL LAYER
          THICKNESS                          =      24.00 INCHES
          EVAPORATION COEFFICIENT            =       3.100 MM/DAY**0.5
          POROSITY                           =       0.5200 VOL/VOL
          FIELD CAPACITY                     =       0.4500 VOL/VOL
          WILTING POINT                      =       0.3600 VOL/VOL
          EFFECTIVE HYDRAULIC CONDUCTIVITY   =       0.00014200 INCHES/HR


                     GENERAL SIMULATION DATA
                     -----------------------

          SCS RUNOFF CURVE NUMBER            =         73.90
          TOTAL AREA OF COVER                = 1080000. SQ. FT
          EVAPORATIVE ZONE DEPTH             =         10.00 INCHES
          EFFECTIVE EVAPORATION COEFFICIENT  =          3.800 MM/DAY**0.5
          UPPER LIMIT VEG. STORAGE           =          4.4200 INCHES
          INITIAL VEG. STORAGE               =          1.9450 INCHES

      CLIMATOLOGIC DATA FOR    E. LANSING          MICHIGAN

            MONTHLY MEAN TEMPERATURES, DEGREES FAHRENHEIT

  JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
  -------     -------     -------     -------     -------     -------
   23.10       24.95       32.83       44.62       57.15       67.09
   71.75       69.90       62.02       50.23       37.70       27.76

           MONTHLY MEANS SOLAR RADIATION, LANGLEYS PER DAY

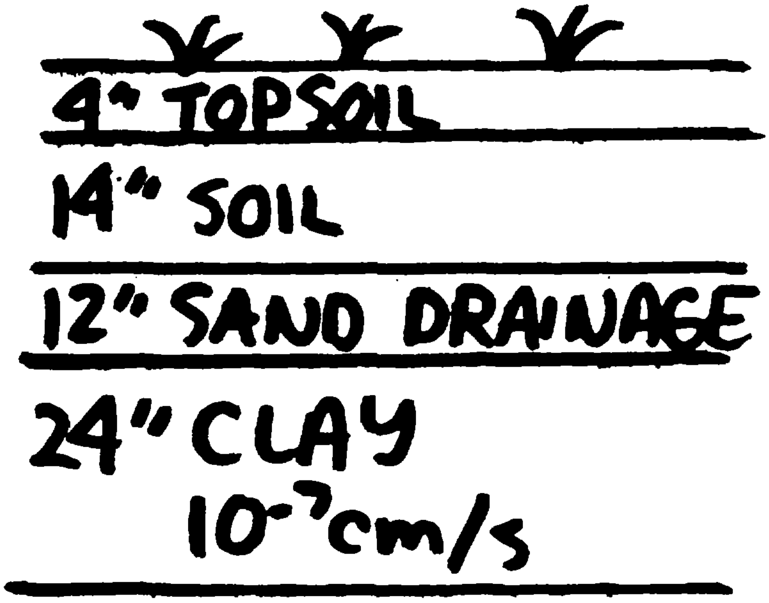
  JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
  -------     -------     -------     -------     -------     -------
  121.19      185.29      286.98      399.01      491.38      539.31
  529.98      465.88      364.19      252.15      159.79      111.85

                     LEAF AREA INDEX TABLE

                       DATE       LAI
                       ----       ----
                          1       0.00
                        126       0.00
                        142       1.23
                        158       2.01
                        173       2.01
                        189       2.01
                        205       2.01
                        221       2.01
                        237       1.81
                        252       1.31
                        268       0.64
                        284       0.34
                        366       0.00

                         GOOD GRASS
```

*MODIFIED ACT 641 CAP



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                   WINTER COVER FACTOR =    1.20


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   AVERAGE MONTHLY TOTALS FOR    74 THROUGH    78

                        JAN/JUL FEB/AUG MAR/SEP APR/OCT MAY/NOV JUN/DEC
                        ------- ------- ------- ------- ------- -------

PRECIPITATION (INCHES)     2.19    1.67    2.99    2.95    2.34    3.26
                           2.03    3.66    2.81    1.61    2.30    2.20

RUNOFF (INCHES)           0.000   0.000   0.000   0.223   0.013   0.022
                          0.003   0.316   0.000   0.000   0.000   0.000

EVAPOTRANSPIRATION        0.812   1.108   2.282   2.222   2.492   2.088
     (INCHES)             1.789   1.811   1.954   1.010   0.929   0.796

PERCOLATION FROM BASE    0.1292  0.1100  0.1318  0.1835  0.1848  0.1727
OF COVER (INCHES)        0.1761  0.1762  0.1754  0.1827  0.1785  0.1827

DRAINAGE FROM BASE OF     0.389   0.279   0.306   0.790   0.752   0.628
COVER (INCHES)            0.647   0.642   0.678   0.708   0.692   0.695

   ****************************************************************




*******************************************************************


   AVERAGE ANNUAL TOTALS FOR    74 THROUGH    78
  -----------------------------------------------------------------
                                     (INCHES)    (CU. FT.)   PERCENT
                                     --------    ---------   -------
   PRECIPITATION                      30.00       2700181.   100.00

   RUNOFF                              0.577        51949.     1.92

   EVAPOTRANSPIRATION                 19.294      1736463.    64.31

   PERCOLATION FROM BASE OF COVER      1.9837      178537.     6.61

   DRAINAGE FROM BASE OF COVER         7.205       648495.    24.02
*******************************************************************




*******************************************************************

          PEAK DAILY VALUES FOR    74 THROUGH    78
     ------------------------------------------------------
                                       (INCHES)    (CU. FT.)
                                       --------    ---------

        PRECIPITATION                   3.08       277200.0

        RUNOFF                          1.214      109268.1

        PERCOLATION FROM BASE OF COVER  0.0154       1387.8

        DRAINAGE FROM BASE OF COVER     0.066        5919.5

        HEAD ON BASE OF COVER            30.0

        SNOW WATER                        6.53     587810.8


        MAXIMUM VEG. SOIL WATER (VOL/VOL)       0.4420

        MINIMUM VEG. SOIL WATER (VOL/VOL)       0.1329

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