

**UNDERGROUND STORAGE TANKS IN RHODE ISLAND:
A PREDICTIVE RISK MODEL**

by

Colin C. Macdonald
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the Center for Environmental Studies as satisfying
the Thesis requirements for the degree of Master of Arts

Date _____

Caroline Karp, Senior Lecturer
Center for Environmental Studies

Date _____

Ross Cheit, Associate Professor
Taubman Center for Public Policy &
American Institutions

Date _____

Thomas B. Hevner, P.E., L.S.P.
Project Manager, BETA Group, Inc.

Date _____

Brian A. Wagner, Esq.
RIDEM Office of Legal Services

Approved by the Graduate Council

Date _____

Peder J. Estrup
Dean of Graduate School and Research

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ABSTRACT

Underground Storage Tanks (USTs) are of particular concern because of their potential to lose tightness over time and leak their contents into the subsurface. This can result in severe contamination of soil and groundwater, and in the worst cases, impairs the ability of a groundwater aquifer to provide drinking water for entire communities. This study examines the potential for publicly available data to be distilled in a manner that advises the risk-abatement process for USTs.

It does so through an original model, developed and run in ArcView™ spatial analysis software, that integrates a suite of factors related to a given UST and its environmental setting. The model evaluates a UST's potential risk to critical drinking water resources of the State of Rhode Island, and according to this value, ranks every UST for which sufficient data exist.

Based upon the distribution of Overall Tank Risk values in the State - which is found roughly equivalent to a Gaussian distribution - Risk Tiers are delineated in an effort to better identify the highest-priority (Tier I) tanks according to the model. Current Rhode Island UST policy is then evaluated with respect to its treatment of risky USTs, and policy recommendations are made.

While current State policy is narrowly directed at gasoline USTs, the data suggest that a broadening of the definition of a 'high risk' tank may be beneficial. Further, this study finds that the Risk Tier system outlined herein could advise modifications of premiums, exclusions, and deductibles as currently employed in Rhode Island.

1.0 INTRODUCTION

The United States Environmental Protection Agency (EPA) defines an underground storage tank (UST) as "a tank and any underground piping connected to the tank that has at least 10 percent of its combined volume underground."¹ USTs are most frequently used to store petroleum products, and EPA estimates that there are 716,000 regulated USTs located at 269,000 sites nationwide. While retail gasoline outlets comprise the majority of UST sites, private and government parties often operate USTs for heating and fleet fueling needs².

USTs are of particular concern because of their potential to lose tightness over time and leak their contents into the subsurface. This can result in severe contamination of soil and groundwater, and in the worst cases, impairs the ability of a groundwater aquifer to provide drinking water for entire communities. Given widespread UST distribution and the fact that nearly half of the United States population relies upon groundwater for its drinking water supply³, it comes as no surprise that leaking underground storage tanks (LUSTs) have come to the forefront of public debate. Such deliberations revolve around how best to approach UST risk-abatement so that

potential harm to human health and the environment is minimized.

This study examines the potential for publicly available data to be distilled in a manner that advises the risk-abatement process. It does so through an original model, developed and run in ArcView™ spatial analysis software, that integrates a suite of factors related to a given UST and its environmental setting. The model evaluates a UST's potential risk to critical drinking water resources of the State of Rhode Island, and according to this value, ranks every UST for which sufficient data exist.

This study is designed to answer the thesis question: *Can an ArcView-based model be derived to advise policymakers in the abatement of UST-related drinking water risk in Rhode Island?* The paper will culminate in an analysis of the distribution of UST risk in Rhode Island, the current risk-abatement mechanisms in place, and how the UST Model proposed here might be used to advise State policy.

2.0 BACKGROUND

This section will discuss USTs, their historical effect upon the drinking water resources of Rhode Island, and the manner in which they are currently regulated by the State.

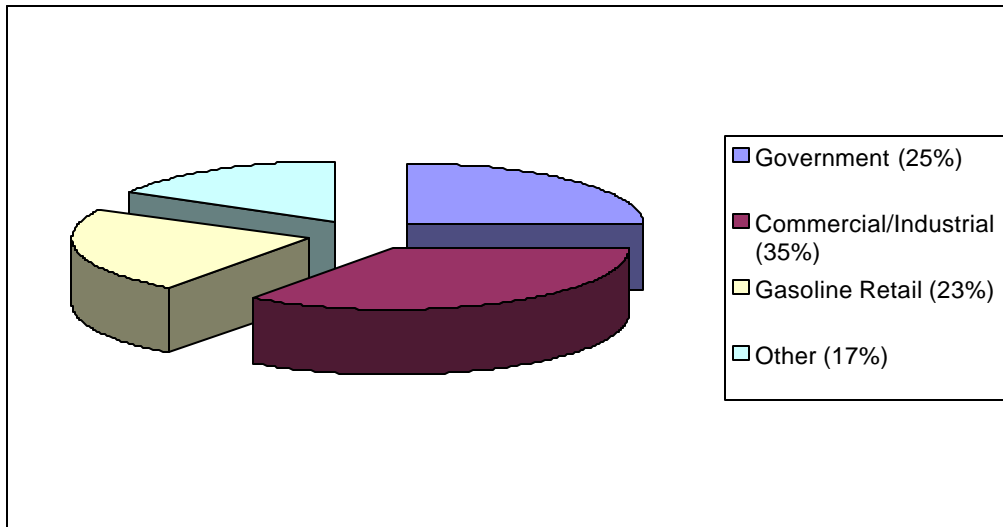
2.1 Underground Storage Tanks in Rhode Island

In the State of Rhode Island's most recent State of the State's Waters (305b) Report, the Department of Environmental Management (RIDEM) rated LUSTs as the highest priority threat to groundwater resources in the State⁴. When these tanks leak their contents into the subsurface, serious public health risks can result. Such is the current situation in Pascoag, a small hamlet in the Town of Burrillville. RIDEM believes that a leak in a gasoline UST at Main Street Mobil, on Main Street in Pascoag, is responsible for contaminating the town wells with methyl tertiary-butyl ether (MTBE), a volatile organic compound known by the EPA to have carcinogenic effects in laboratory animals⁵, and considered to be a potential human carcinogen at high doses⁶. From September 2001 thru January 2002, town residents were directed to minimize the use of their municipal water, which was found to contain *ten times* the EPA standard for MTBE⁷. In recent testimony before the

United States Senate, Jan Reitsma, Director of RIDEM, posited that millions of dollars may be necessary to remediate the aquifer⁸.

There is potential for similar public health risks in other parts of the State. The most recent 305b Report counts 3,463 actively used USTs registered in Rhode Island (note: this number does *not* include the thousands of home heating oil USTs that are less than 1,100-gallons and thus excluded from most RIDEM regulations⁹). The 3,463 USTs in Rhode Island are located at 1,847 facilities throughout the State. A breakdown of these facilities is displayed in Figure I below¹⁰:

Figure I: Owners of Rhode Island UST Sites

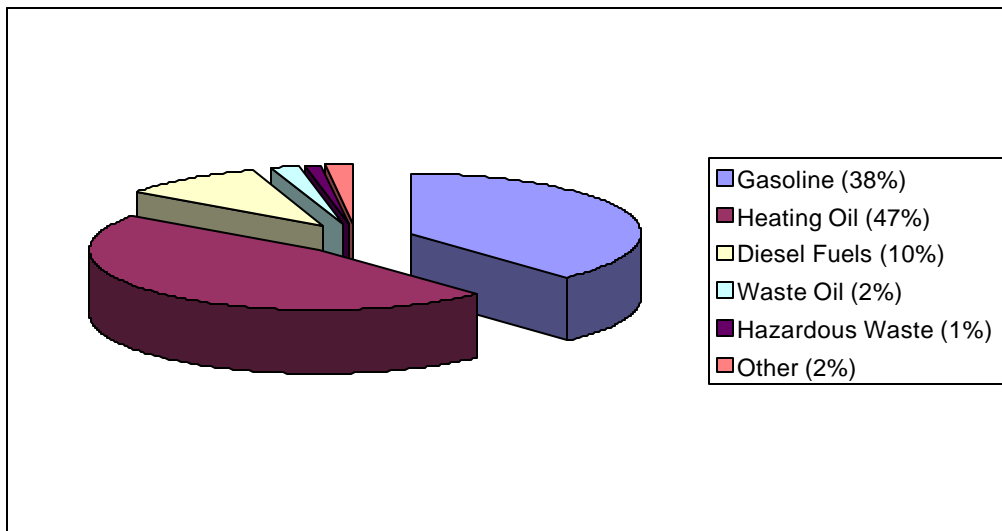


SOURCE: RIDEM State of State's Waters, 2000

Note that almost 60% of UST sites in Rhode Island are owned by the Commercial/Industrial and Gasoline Retail sectors.

This will have implications in the latter portion of this study, when policy recommendations are crafted to best address the conflict between site owners - who are often rational economic actors - and the society that incurs the costs of leaking tanks. Figure II below is a breakdown of the products stored in these tanks:

Figure II: Products Stored in Rhode Island USTs



SOURCE: RIDEM State of State's Waters, 2000

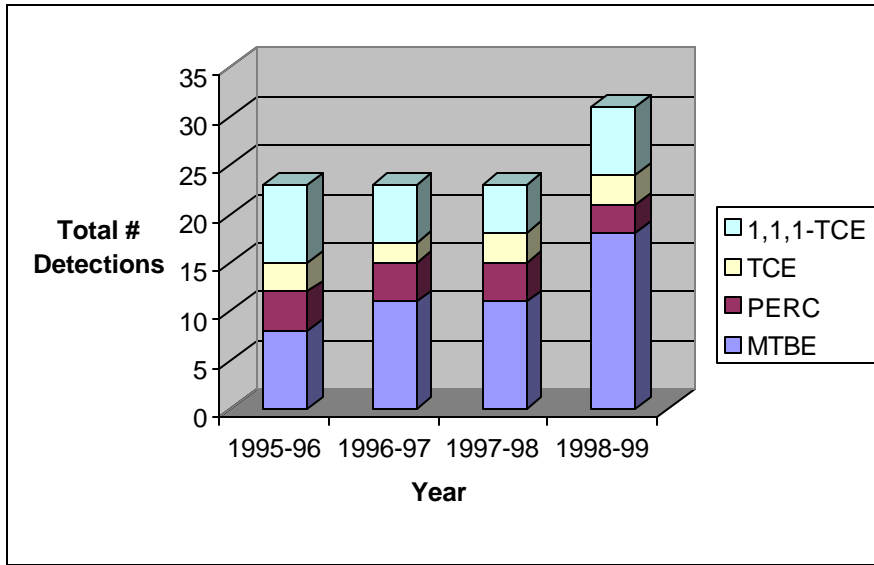
In the aggregate, heating oil, diesel and gasoline comprise 95% of all tanks in the State¹¹. Of these, gasoline tanks (38%) are of the greatest concern to those responsible for protecting human health and the environment, as they comprise a large proportion of the 1,183 LUST sites in the State (since 1985), and gasoline is known to be particularly dangerous in the subsurface relative to other petroleum products¹². The Discussion section of this study

will assess whether this focus on gasoline USTs has precluded committing regulatory resources to other non-gasoline USTs in the State.

MTBE, which comprises on average 11% of gasoline by volume, is the major contributor to gasoline's status as the riskiest UST content. Introduced in 1979 as an octane-enhancing replacement for lead, MTBE has seen increased use since the 1990 amendments to the Clean Air Act. Rhode Island is a voluntary participant in the EPA Reformulated Gasoline (RFG) program initiated by these amendments, which mandates that fuel oxygenates (not necessarily MTBE) be added to fuels in areas with the highest levels of air pollution¹³. Despite EPA findings that MTBE is detected in water roughly five times more often and at higher concentrations in areas participating in the RFG program¹⁴, the vast majority of urban centers have chosen to use MTBE to meet the oxygenate requirement (Chicago and Milwaukee are the only urban centers to use ethanol)¹⁵.

The trend for Rhode Island, displayed in Figure 3 below, is on par with the national trend of increasing MTBE detection:

Figure III: Commonly Detected VOCs in Community and Non-Transient Non-Community Public Water Supply Wells



SOURCE: RIDEM State of State's Waters, 2000

The detection of MTBE in public wells in Rhode Island has more than *doubled* over the period 1995-1999, and has made up an increasing proportion of all VOCs measured¹⁶. MTBE has displaced TCE - a solvent widely used in home and industrial applications, and historically the most detected VOC - as the primary VOC detected in Rhode Island wells. The fact that MTBE has been detected in the groundwater of Rhode Island with increasing frequency is not surprising, given its suite of chemical properties. It is highly hydrophilic and soluble, does not readily sorb to soil particles, and migrates faster and over greater ranges than do other gasoline constituents¹⁷. Additionally, it is quite resistant to biodegradation¹⁸. Thus, a leak from a UST containing MTBE-enhanced gasoline can be potentially

catastrophic to local water supplies, and can be costly and difficult to remediate. This has become all too relevant in Pascoag.

2.2 Statutory Law

USTs have been recognized by Congress for some time as an environmental and human health risk. As part of Subtitle I (1984) of the Resource Recovery and Conservation Act (RCRA), Congress directed EPA to promulgate UST regulations so as to protect human health and the environment. Subtitle I implemented requirements for UST site owners in the realms of tank registration, construction standards, reporting and record keeping for existing tanks, corrective action, and financial responsibility¹⁹.

In managing the federal UST program, EPA adopted a model of cooperative federalism, whereby EPA promulgates baseline technical and financial responsibility standards, but delegates final implementation and management primacy to the states (subject to funding and oversight). This allows states to tailor their regulations to the specific needs of the regulated community²⁰, but prevents the race of laxity²¹ by maintaining that all state programs be protective of human health and the environment. In a manner analogous to

the State Implementation Plans promulgated by the Clean Air Act, state UST programs need to be approved by the EPA, and cannot fall below minimum protective standards. For a state program to be approved, it must meet three major criteria:

1. Regulates at least the same USTs as regulated by federal law.
2. Meets EPA requirements for "adequate enforcement."
3. Sets standards for eight performance criteria that are no less stringent than federal standards:
 - a. New UST systems (design, construction, installation, and notification)
 - b. Upgrading of existing UST systems
 - c. General operating requirements
 - d. Release detection
 - e. Release reporting, investigation, and confirmation
 - f. Out-of-service USTs and closure
 - g. Release response and corrective action
 - h. Financial responsibility for UST systems containing petroleum

The Rhode Island UST program received federal approval on January 11, 1993 and was implemented on February 10, 1993²². Since then, 8,698 USTs have fallen under program jurisdiction²³; the LUST layer of Rhode Island Geographic Information Systems lists 1,187 tanks as having leaked historically.

The Rhode Island UST program employs a traditional 'command and control' model of regulation. Plater et al. characterize such regulatory paradigms as "programs of centralized regulatory commands issued in excruciating

detail via permits to pollution dischargers throughout a jurisdiction...²⁴" In the realm of USTs, Rhode Island follows this definition closely, dictating requirements for registration, tightness testing, leak detection, tank construction, and financial responsibility (among others) for new and existing tanks²⁵.

Additionally, financial responsibility requirements are dictated at the federal and state level. The EPA requires proof of financial responsibility for owners of UST facilities, with a few exceptions:

1. Residential USTs with a volume of less than 1,100-gallons, used for storage of No. 2 heating oil and servicing a one-, two-, or three-family dwelling
2. Farm USTs with a volume of less than 1,100-gallons, storing No.2 heating oil for non-commercial purposes²⁶

While EPA regulations require proof of financial responsibility for UST site owners, they do not prescribe a specific mechanism through which financial responsibility must be attained. EPA grants primacy to approved state programs in that regard, and states have reasonable latitude in terms of facilitating UST site compliance with federal regulations.

Rhode Island complies with federal financial responsibility standards by mandating proof-of-coverage for UST site owners of \$1,000,000 per release, or \$2,000,000

per site in aggregate²⁷. This is intended to ensure that funds are available for remediation efforts, as well as to address third-party compensation claims. Many states - Rhode Island included - have chosen to facilitate such financial responsibility compliance for in-state facilities by creating a state-sponsored fund. Rhode Island clearly had fiscal motivations for doing so: in effecting the statute that forms the basis of the fund, the State Assembly noted Rhode Island Economic Development Corporation estimations that failure to enact such a fund would have adverse effects upon the State economy to the tune of \$18,000,000 annually²⁸. Created in 1994, the Rhode Island Underground Storage Tank Financial Responsibility Fund is capitalized by a \$0.01 tax on every gallon of motor fuel sold in the State, as well as registration fees for those tanks not containing motor fuel²⁹.

2.3 Problem Formulation

Despite comprehensive regulation at the federal and state level, USTs continue to threaten human health and the environment in Rhode Island. The situation in Pascoag serves as a specter of risk from leaking tanks at its worst. This paper is inspired in part by the catastrophe

in Pascoag; it is aimed at preventing such catastrophe elsewhere. The objectives of this study are twofold:

1. To explore, by way of an original ArcView UST Risk model, the nature and extent of the risk posed by USTs to critical drinking water supplies of the State of Rhode Island.
2. To briefly examine the regulatory framework currently employed in Rhode Island as it relates to the distribution of risks in the State, and propose regulatory elements that may be advised by the UST Risk Model outlined here.

These objectives are designed to answer the thesis question: *Can an ArcView-based model be derived to advise policymakers in the abatement of UST-related drinking water risk in Rhode Island?*

3.0 METHODS

These methods are designed to achieve the two research objectives outlined within the Background section above. The present section firsts outlines a screening model aimed at characterizing the nature and extent of risk posed by USTs to the drinking water supplies of Rhode Island (surface waters and ecosystem services are not considered herein). This section concludes with a brief discussion of the methods employed to interpret the model outputs as they relate to both current and potential UST risk-abatement measures taken in Rhode Island.

3.1 Model Concept

As demonstrated above, LUSTs in Rhode Island have presented clear risks to human health and the environment. But what about future risks? This section will address the prospects of future risks, outline some of the factors involved in making a particular UST "risky," and outline a Risk-based Prioritization Model designed to take a *predictive* approach toward abating public health risks associated with USTs.

The model outlined here is predictive of risk in that it assesses, if a given UST were to leak, how damaging this leak could potentially be to critical drinking water

resources of the State. It does so by assuming a 'worst case' scenario: that a tank will leak its contents in a single catastrophic event. The model then determines the drinking water risk of a given UST through an additive calculation based upon the composition and volume of the tank; the characteristics (toxicity and solubility) of its contents; the transmissive, confining, or corrosive characteristics of the soil in which the UST is sited; the seasonal high water table; and the proximity of the UST to critical drinking water resources of the State.

The model was run in ArcView GIS 3.2a software³⁰, a spatial analysis package employed to geographically locate USTs with respect to the environmental variables noted above. The risk posed by USTs to drinking water supplies was determined by weighting parameters related to the tank and its contents, as well as parameters describing its environmental setting.

The model utilized the RIDEM UST database for all tank-specific information. Each UST was located in space ('geocoded') based upon its address in the database, and the weighted components of the Tank Risk parameter (described below) were then linked with each datum. Similarly, the entire State of Rhode Island was mapped with respect to the variables that comprise the Environmental

Risk parameter (also below). Environmental variables were weighted according to the scheme outlined in Sections 3.2-3.3, and their respective weights were additive in areas where multiple environmental factors co-occurred (e.g. a wellhead protection area with transmissive soils). The final Overall Risk value was arrived at by combining the weighted tank characteristics associated with each geocoded tank point and the suite of weighted environmental variables co-occurring at that same point. The higher the Overall Risk, the more catastrophic a leak from that tank would be.

The initial model run was limited to roughly sixty USTs in the Town of Burrillville, Rhode Island, and calibrated against RIDEM's LUST records for Burrillville. The model identified the gasoline USTs at Main Street Mobil, in the Pascoag wellhead protection area, as the highest priority tanks in the Town. Interestingly, a leak from these tanks - discovered in September 2001 - had devastating effects upon the Town drinking water (See Background section). Having proven reasonably accurate in Burrillville, this first-run model is the basis for the model described here, which has subsequently been applied to every registered UST in Rhode Island.

When the model was expanded to the rest of the State, several parameters were modified - and new parameters added - to reflect lessons learned in the first-cut model run for the Town of Burrillville, as well as input from RIDEM reviewers³¹. More specifically, elements of tank and piping composition were included, as well as environmental variables such as localized soil corrosivity and seasonal high water table. Tank contents, initially weighted only according to their toxicity, were considered according to their solubility as well. The 'Tank Age' parameter was dropped, due to the fact that RIDEM data reflect date of installation, rather than the more instructive date of most recent tank improvement. Finally, the 'Tank Volume' parameter was down-weighted, to address concerns that larger tanks were not necessarily of higher risk than smaller tanks. These changes allowed the model to better assess the risk of a given UST to critical drinking water supplies.

3.1.1 UST Risk

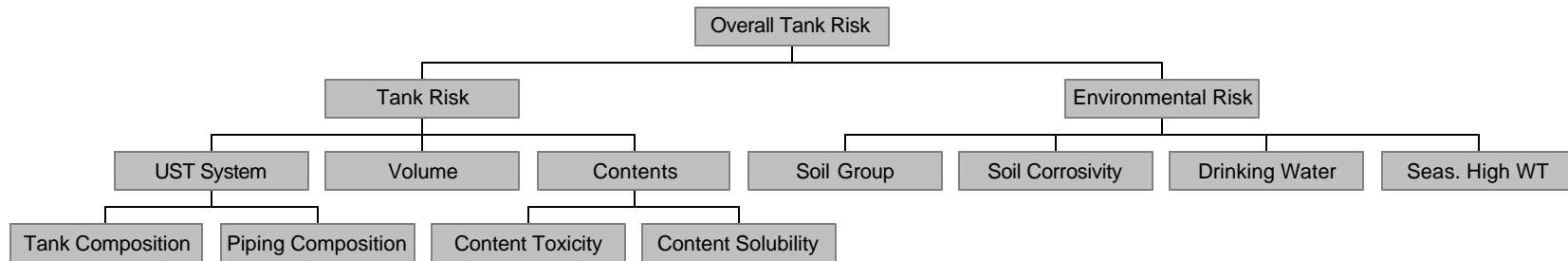
UST risk is most often associated with petroleum hydrocarbons, leaked into the subsurface, and transported by way of groundwater flow to an exposure endpoint: a wellhead or surface water. A general paradigm for

structuring a risk assessment breaks down risk into three distinct exposure pathways: dermal, inhalation, and ingestion³². Given the above, a UST is "risky" when it has the greatest potential to cause harm to human health and the environment through one (or more) of the accepted exposure pathways. This paper proposes a predictive model designed to prioritize tanks based upon their potential to cause such harm.

For the purposes of this model, the overall risk of a given UST is split into two major components: Tank Risk and Environmental Risk. These two categories are then subdivided into parameters related to the potential for exposing critical drinking water supplies to tank contents. The factors incorporated in this model are not meant to be exhaustive - surely there are an infinite number of variables that can potentially be incorporated into such a model. Rather, the factors chosen are representative of those variables for which data are reasonably available and reliable.

The model is structured according to Figure IV below:

Figure IV: Organizational Diagram



Note that the elements of this model interact additively. That is, the Environmental Risk value is the additive summation of the Soil Group, Soil Corrosivity, Drinking Water, and Seasonal High Water Table parameters; the Overall Risk is the additive summation of the Tank Risk and Environmental Risk. In short, the values are input at the bottom two levels of the model, and flow upward in an additive manner toward an eventual Overall Tank Risk for a given tank. The relative importance of each model parameter is determined by the number of "model points" it can possibly contribute toward the Overall Tank Risk. For example, the Tank Content parameter is relatively important: as is

detailed below, it is comprised of two contributing parameters (toxicity and solubility), each of which have 5 model points to contribute. The Tank Volume parameter is less important: it contributes a maximum of only 3 points toward the Overall Tank Risk. Sections 3.2 thru 3.4 explore in greater detail each parameter of the model, how it is weighted, and the manner in which it interacts with the other model parameters to assess the Overall Risk of a given UST to critical drinking water resources.

3.2 Tank Risk

The value for Tank Risk is comprised of parameters associated with the tank itself: its volume and contents, as well as the composition of the tank and its associated piping. Within this category, certain parameters are more important than others³³, and thus the associated weighting system is designed to reflect that. These parameters, as well as their respective weighting scheme, are outlined below in sections 3.2.1 thru 3.2.2.

3.2.1 Tank Volume

The quantity of contamination present was accounted for by dividing the universe of standard UST volumes into three categories, and assigning risk value premised on the

notion that higher quantities of contaminant pose a more catastrophic risk to human health and the environment.

Thus, the risk categories are as follows:

| TABLE 1: WEIGHTING - TANK VOLUME | |
|---|-----------------|
| Tank Volume | Weighting Value |
| < 1,100-gal (Below regulatory threshold ³⁴) | 0 |
| 1,100-9,999-gal | 1 |
| 10,000-19,999-gal | 2 |
| > 20,000-gal | 3 |

One objection to the above ranking is that the largest tanks may be so well-monitored that they are in fact *less risky* than some of the smaller tanks that looked after with less diligence³⁵. While this may be the case, the model makes the conservative assumption the mere presence of a UST poses potential risk to human health and the environment, regardless of monitoring frequency. In short: a greater volume of petroleum may lead to a more catastrophic release. However, by weighting this category to a maximum model input of 3, it is given relatively minor importance in the overall model.

3.2.2 Tank Contents

The characteristics of tank contents are an important component of the Tank Risk input to the model. The two

characteristics of concern here are the toxicity and solubility of tank contents. The toxicity is of obvious concern, as it is related to the health effects associated with exposure to the subject contaminant. The solubility of the tank contents is equally important, as the subsurface mobility of petroleum products is intimately linked to its ability to be taken up into solution and transported to a wellhead. This model assesses the relative risk of differing tank contents by determining values for their toxicity and solubility, and combining the model inputs additively to determine a single Tank Content Risk value for model input. (Note that non-petroleum-based hazardous material USTs are not included in the model, as the wide variations in solubility and toxicity within the universe of such substances would clutter the model considerably.)

3.2.2.1 Tank Content Toxicity

This element of the model is based upon a document produced by the Massachusetts Department of Environmental Protection, which details a VPH/EPH (Volatile Petroleum Hydrocarbons/Extractable Petroleum Hydrocarbons) approach for characterizing the risks associated with petroleum contamination³⁶.

The document recommends compositional hydrocarbon fractions of particular fuels, as well as rates the toxicity of those fractional ranges by comparing them to "surrogate compounds" with similar composition and a known Reference Dose³⁷. This model takes this one step further, calculating a "Tank Content Toxicity" rating for a given fuel by weighting the hydrocarbon fractions that comprise the fuel by the Reference Dose for the corresponding surrogate compound each respective hydrocarbon range. Thus, the formula for calculating the Toxicity Risk of a given petroleum product is as follows:

$$TR = (FC_1)(RfD_1) + (FC_2)(RfD_2) + \dots + (FC_k)(RfD_k)$$

Where:

FC_n = Fractional Composition of hydrocarbon range *n*
 RfD_n = Known Reference Dose for surrogate compound that corresponds to hydrocarbon range *n*

Tables 2 and 3 below detail the specific FC_n and RfD_n values used in the Toxicity Risk calculations:

| TABLE 2: FRACTIONAL HYDROCARBON COMPOSITION OF IMPORTANT UST CONTENTS ³⁸ | | |
|---|---|-------------------|
| Petroleum Product | Fractional Hydrocarbon Composition (FC _n) | |
| | C11-C22 Aromatics | C9-C18 Aliphatics |
| Kerosene/Jet Fuel | 0.3 | 0.7 |
| Diesel/ #2 Fuel Oil | 0.6 | 0.4 |
| No.4 & No.6 Fuel Oil | 0.7 | 0.3 |

| TABLE 3: HYDROCARBON GROUPS AND THEIR CORRESPONDING TOXICITY SURROGATE ³⁹ | | |
|--|--------------------|---|
| Hydrocarbon Group | Toxicity Surrogate | Reference Dose (RfD _n) for Toxicity Surrogate (mg/kg/day) |
| C11-C22 Aromatics | Pyrene | 0.03 |
| C9-C18 Aliphatics | n-Nonane | 0.6 |

To give a brief example, a calculation of the TCR for a diesel fuel UST would look like this:

$$\begin{aligned}
 \text{TCT} &= (\text{FC}_1)(\text{RfD}_1) + (\text{FC}_2)(\text{RfD}_2) + \dots + (\text{FC}_k)(\text{RfD}_k) \\
 &= (\text{FC}_{\text{C11-22 Aromatics}})(\text{RfD}_{\text{Pyrene}}) + (\text{FC}_{\text{C9-18 Aliphatics}})(\text{RfD}_{\text{n-Nonane}}) \\
 &= (0.6)(0.03) + (0.4)(0.6) = 0.258
 \end{aligned}$$

For the purposes of the model, greater TCT values correspond to fuels of higher toxicity. Thus, the TCT values are divided into 1, assigning higher a higher TCT value to the most toxic fuel. One might notice that gasoline is a major omission within the TCT parameter. Due to widespread variations in distillation processes (and thus fractional hydrocarbon content), gasoline was not covered by the EPH/VPH document. However, gasoline is widely considered to be the most perilous of all petroleum UST contents. This is due to its composition; gasoline constituents such as benzene and naphthalene are highly toxic. Moreover, gasoline in Rhode Island is infused with methyl tert-butyl ether (MTBE), a volatile organic compound

and oxygenate that aids in more complete combustion of fuel. The characteristics of MTBE are discussed in detail within the Background section.

For these reasons, gasoline is weighted highest in the model. The most toxic fuel rated by the EPH/VPH document, #3-#6 Fuel oil, received a TCT value of 4.975. To reflect gasoline's particularly risky nature, it was conservatively assumed to have a TCT value of 10, roughly twice the TCT value of its nearest "competitor."

The final step was to calibrate the TCT values to the other parameters of the model, all of which have maximum values of 5. The final TCT values are listed below in Table 4:

| TABLE 4: TCT VALUES | |
|---------------------------------|----------------------------|
| Petroleum Product | Toxicity Risk Value |
| Kerosene/Jet Fuel | 1.16 |
| Diesel/ #2 Fuel Oil | 1.9375 |
| No.4 & No.6 Fuel Oil | 2.4875 |
| Gasoline | 5 |

Note that for calibration, all TCT values were divided by two, bringing gasoline's TCT value to 5, with the rest of the fuels assigned proportionally lesser values.

3.2.2.2 Tank Content Solubility

The solubility of UST contents is related to their ability to migrate through the subsurface toward potential exposure endpoints. In assigning these values for model input, solubilities of various petroleum compounds were assigned on a 1-5 scale, with higher model input values corresponding to fuels with greater solubility (and thus greater ease movement in the subsurface). Table 5 displays these values:

| TABLE 5: TCS VALUES⁴⁰ | |
|---|------------------------------|
| Petroleum Product | Solubility Risk Value |
| No.4 & No.6 Fuel Oil | 1 |
| Diesel/ #2 Fuel Oil | 3 |
| Kerosene/Jet Fuel | 5 |
| Gasoline | 5 |

It should be noted that these solubility values are adapted from a NOAA document that rates relative solubility on a scale of High-Moderate-Low; these are translated into 5-3-1, respectively, for the purposes of this model.

Once the TCT and TCS values are computed, they are combined additively to comprise a single value for Tank Content Risk. Table 6 displays these values:

| TABLE 6: FINAL TCR VALUES | |
|----------------------------------|--------------------------------|
| Petroleum Product | Tank Content Risk Value |
| No.4 & No.6 Fuel Oil | 3.4875 |
| Diesel/ #2 Fuel Oil | 4.9375 |
| Kerosene/Jet Fuel | 6.16 |
| Gasoline | 10 |

The TCR values above are the numbers actually plugged into the model, and interact in the manner depicted in Figure 4.

3.2.3 UST System Characteristics

The construction and composition of a UST system are major components of its potential to leak, and thus are weighted highly in the model. Since the tank itself is often of different composition than its associated piping, the model treats them separately, but adds their respective risk ratings to arrive at a single risk value for UST System Characteristics.

3.2.3.1 Tank Composition

The composition of the tank itself assumes a range of values within the RIDEM database for USTs. Upon request, RIDEM personnel rated each unique composition for risk of leaking⁴¹:

| TABLE 7: TANK COMPOSITION RISK VALUES | |
|--|--|
| Tank Composition | Tank Composition Risk Value |
| Composite Steel | 1 |
| Epoxy Coated Steel | 1 |
| Fiberglass Reinforced Plastic | 1 |
| Polyethylene Tank Jacket | 1 |
| Cathodically Protected Steel | 2 |
| Concrete | 3 |
| Asphalt Coated or Bare Steel | 5 |

Values range from '1' for composites and plastics to '5' for asphalt coated or steel tanks. It is important to note the composition of the pipes for these tanks as well.

3.2.3.2 Piping Composition

Similar to the Tank Composition, the composition of the piping varies from tank to tank. Again, RIDEM rated each of these according to risk of leaking⁴²:

| TABLE 8: PIPING COMPOSITION RISK VALUES | |
|--|--|
| Piping Composition | Piping Composition Risk Value |
| Fiberglass Reinforced Plastic | 1 |
| Galvanized Steel | 4 |
| Copper | 4 |
| Bare Steel | 5 |

Note once again that bare steel is rated by RIDEM as the riskiest piping material, while more corrosion resistant material is rated as least risky.

3.3 Environmental Risk

While the Tank Risk value reflects characteristics of the UST itself, the value for Environmental Risk accounts for the environmental setting in which the tank is situated. The elements incorporated are the proximity to critical groundwater resources, the corrosive properties of the soil, the seasonal high water table, and the ability of the area-specific soils to facilitate subsurface movement of a contaminant plume.

3.3.1 Proximity to Drinking Water Resources

Since groundwater is the primary migration pathway by which subsurface contamination is conveyed, the location of a given tank with respect to key drinking water resources is a major component of the predictive model. Based upon this characteristic, tanks were segregated into four classes and weighted by the potential for exposure; greater risks are associated with higher numbers:

| TABLE 9: WEIGHTING - PROXIMITY TO DRINKING WATER | |
|--|-----------------|
| Proximity | Weighting Value |
| Of minimal concern for ingestion pathway; within GB/GC-rated groundwater ⁴³ | 0 |
| Within groundwater recharge area or drinking water basin ⁴⁴ | 3 |
| Within GA/GAA-rated groundwater ⁴⁵ | 5 |
| Within wellhead protection area ⁴⁶ | 10 |

Tanks in wellhead protection areas were rated highest because the proximity to public wells facilitates an exposure pathway to a relatively large population. Tanks within areas of GA/GAA-rated groundwater were weighted at half of that, as the potential exposure endpoints (i.e. people drawing off the well) are generally a fraction of that of a public well. Tanks in groundwater recharge areas or drinking water basins were ranked lower still, as contamination may have the chance to naturally attenuate between the leak point and the exposure endpoint.

For tanks in overlapping categories (e.g. a tank located in a wellhead protection area as well as a groundwater recharge area), the values are additive within the model structure. Thus, this same tank within a wellhead protection area and groundwater recharge area would receive a weighting of 13.

3.3.2 Soil Group

As part of the Source Water Assessment Program, a joint effort between University of Rhode Island and Rhode Island Department of Health, risk factors were assigned to Soil Groups based upon a composite of key characteristics related to facilitation of groundwater contamination⁴⁷. This predictive model uses these risk factors to weight tanks according to the Soil Group in which they are situated. The weighting is as follows:

| TABLE 10: SOIL GROUP VALUES | |
|------------------------------------|------------------------|
| Soil Group | Weighting Value |
| Minimal Risk | 2 |
| Low Risk | 3 |
| Moderate Risk | 4 |
| High Risk | 5 |

Though there were only four categories identified by the URI/DOH document, they were scaled to meet the model norm of either a 5- or 10-scale for a parameter.

3.3.3 Soil Corrosive Properties

The RIGIS program has rated soils in terms of their ability to corrode uncoated steel⁴⁸. These ratings are important for this model because they affect the prospects of a leaking tank or line, especially when the tank or line is composed of steel.

| TABLE 11: WEIGHTING - SOIL CORROSIVE PROPERTIES | |
|--|------------------------|
| Soil Group | Weighting Value |
| Low Risk | 0 |
| Moderate Risk | 3 |
| High Risk | 5 |

It is important to note that these values were interpreted to numeric form for the purposes of facilitating model input.

3.3.4 Seasonal High Water Table

Through properties such as corrosion-inducement and freeze-thaw cycles, the seasonal high water table value clearly plays a role in the potential for a tank to leak. The RIGIS program has rated seasonal high water table for the State⁴⁹. The values below represent depths to water table; the corresponding risk rating is grounded on the premise that lower water tables are less risky, as they subject tanks to less potential corrosion and freeze-thaw dynamics.

| TABLE 12: WEIGHTING - SEASONAL HIGH WATER TABLE | |
|--|------------------------|
| SHWT | Weighting Value |
| > 6 feet below grade | 1 |
| 1.5-3.5 feet below grade | 2 |
| 0-1.5 feet below grade | 3 |
| 0-1 feet below grade | 4 |
| Standing Water | 5 |

These values were input to the model and combined additively as part of the calculations for Environmental Risk.

3.4 Model Output

The model output is a list of every UST in the State for which RIDEM data were complete, prioritized by risk to critical drinking water resources. The operative term is 'complete' - the extent of the output was limited the completeness of the data. Tank listings were incompatible with the model if:

1. Address not recognized by the geocoding program⁵⁰ used to spatially locate USTs
2. Tank contents not listed
3. Tank composition unknown
4. Tank falls under the 1,100-gal regulatory threshold⁵¹

Most of the above exclusions apply to tanks for which RIDEM data were incomplete or inaccurately entered. Of roughly 3,500 tanks on the initial database, roughly 2,500 were successfully geocoded. Of those tanks, approximately 2,000 were above regulatory thresholds and free of data complications. Tanks below the regulatory threshold often had complete data, but were not input to the model.

3.5 *Uncertainties*

As with all scientific inquiry, it is important to note several sources of uncertainty. First, when working with a dataset as large as the RIDEM UST database (roughly 3,500 records, each with 15 columns), it is inevitable that an occasional datum has been entered incorrectly. This source of uncertainty is very difficult - if not impossible - to control for. Second, the geocoding program uses an algorithm based upon cross streets and block numbers, and may not precisely locate the property, let alone the exact point on the property under which the subject UST is situated. In cases where a site is divided between areas of differing Environmental Risk, imprecise tank placement can either over- or under-rank a UST's risk. This is clearly an area where improvements in GIS technology (e.g. GPS mapping of individual addresses, more precise data layers) will allow for incrementally greater confidence in model outputs; for the present, this study is limited in this regard.

An additional source of uncertainty involves the exclusion from this analysis of USTs below the regulatory threshold of 1,000-gallons. The 1,100-gallon threshold is an artificial threshold imposed by regulators, and it is certainly reasonable to posit that the risk posed by a

1,000-gallon UST is virtually indistinguishable from that posed by a 1,100-gallon UST. However, by virtue of the fact that they are largely unregulated, data were not available for all tanks below the 1,000-gallon regulatory threshold in Rhode Island. Even if (hypothetically) data were available on such USTs, current statutory and judicial infrastructure provide little means by which such tanks could be targeted by the mechanisms recommended in this study.

While this model is not intended to predict if/when a given tank will leak, there are certain elements of the model that may be capable of doing just that. Model parameters such as *Soil Corrosivity* and *Seasonal High Water Table*, viewed in concert with *Tank Composition* (e.g. bare steel tank), may have an element of predictive risk in the sense of determining the likelihood of leaking tank. However, further refinement is necessary before the model outlined here can be employed for such purposes. Statistical testing - included in Appendix A - failed to show predictive value for environmental variables and historical leaking tanks.

3.6 *Potential Detractions*

Critics might raise environmental justice issues concerning the model's seeming underestimation of ingestion risk to urban populations for which groundwater is not a source of drinking water. This criticism can be dismissed by citing that those populations in Rhode Island not reliant on groundwater for drinking water are generally reliant upon surface water reservoirs instead. As lands surrounding reservoirs are usually owned and strictly protected by towns or water resource boards (e.g. Scituate Reservoir owned by City of Providence), USTs are generally very strictly regulated, if not prohibited altogether⁵². Thus, urban populations may actually be subjected to *less* UST-related drinking water risk than are rural residents solely reliant upon groundwater.

Urban residents may, however, be disproportionately affected by alternative forms of UST risk: namely subsurface migration of petroleum vapors into adjoining basements. Critics could again discredit this model on environmental justice grounds, arguing that the most industrialized areas of the State (and thus greater number of USTs) are also those in which proportionally greater minority populations dwell. While environmental justice is certainly a valid concern in this case, it is important to

note that this model is strictly limited to the ingestion pathway, and further limited therein to exposure associated with ingestion of drinking water. Expansion of the model to incorporate inhalation would better address concerns about environmental justice, but would necessitate a series of (site-specific) assumptions about migration of subsurface vapors, airflow dynamics of buildings, and myriad other factors. In short, designing a UST risk model around inhalation exposure could be a separate - and quite interesting - thesis of its own.

A final criticism of the model is that it fails to take into account several measures of the relative importance of a wellhead. More specifically, critics point to persons/wellhead and wellheads/system as potential indices of how many potential exposure endpoints exist, and how catastrophic the effects of a single contaminated well would be, respectively. A well with more persons reliant upon it, or a well that is the sole source of water for a community, would ideally be weighted higher by the model. USTs in the proximity of such wells would be higher priority as a result.

This criticism is perfectly valid, and the model would surely benefit from additions of this nature. However, the practical reality of data availability is enough to make

such improvements impossible for the present; while RIDOH maintains data for number of persons served by a given water system, it does not distill data into number of persons/wellhead or number of wellheads/system. Further work should definitely pursue this end.

3.7 Evaluation of Model

The model output details the nature and extent of the risk posed by USTs to drinking water supplies in Rhode Island. The analysis of the current regulatory framework is driven by a comparison of the tanks deemed high-risk by the model versus the tanks that are most actively regulated by the State. Ideally, State resource allocation should be weighted heavily toward the riskiest tanks.

For the purposes of this study, two major areas of State resource allocation are considered:

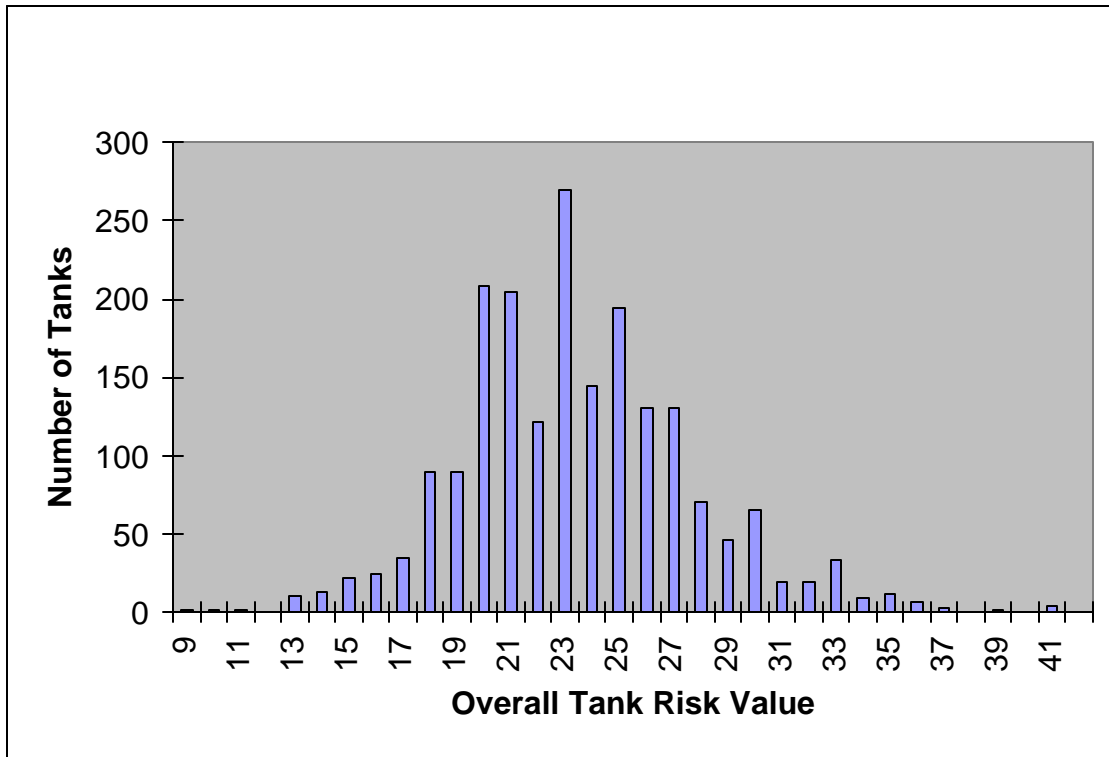
1. Monitoring and enforcement actions
2. Disbursements made by the UST Financial Responsibility Fund (State Fund)

While State resources are expended elsewhere in the realm of UST risk-abatement, these are the two areas for which the model outputs could be compared to reasonably accountable State activities.

4.0 RESULTS

The primary result of this study - the model output - is a ranked list of every UST in Rhode Island for which sufficient data exist. The tanks were ranked according to the Overall Tank Risk parameter of the model. A frequency histogram of the *Overall Tank Risk* values is displayed below in Figure V:

Figure V: Frequency Histogram - Overall Tank Risk



The distribution of OTR values assigned by the model is roughly Gaussian (symmetric and unimodal), which facilitates a brief statistical review of the findings, and allows for recommendations grounded in statistical

reasoning. The defining characteristics of the distribution are summarized below in Table 13:

| TABLE 13: CHARACTERISTICS OF THE DISTRIBUTION OF OVERALL RISK VALUES | |
|---|--------------|
| Parameter | Value |
| Sample Size (n) | 1,980 |
| Geometric Mean (μ) | 23.44 |
| Standard Deviation (σ) | 4.23 |
| Maximum Value Assigned | 41 |
| Minimum Value Assigned | 9 |

The Empirical Rule of Statistics states that, for a normal distribution, roughly 95% of the values are bound by two standard deviations on either side of the geometric mean⁵³. The empirical rule will be employed to delineate 'Risk Tiers' based upon this characteristic of the distribution. Since model output is reported as integer data, it was necessary to round values for Risk Tiers. These values are reported below in Table 14:

| TABLE 14: DELINEATION OF RISK TIERS | | |
|--|--|-----------------------|
| Tier | Delineation | Values |
| Tier I | $OTR > \mu + 2\sigma$ | $OTR \geq 32$ |
| Tier II | $\mu + 1\sigma < OTR \leq \mu + 2\sigma$ | $28 \leq OTR \leq 31$ |
| Tier III | $\mu \leq OTR \leq \mu + 1\sigma$ | $24 \leq OTR \leq 27$ |
| Tier IV | $OTR < \mu$ | $OTR < 24$ |

This analysis will make recommendations aimed at the USTs in the upper ranges of the distribution (Tier I USTs). A breakdown of these USTs is below in Table 15:

| TABLE 15: DEMOGRAPHICS OF TIER I USTs | |
|--|--------------|
| Parameter | Value |
| Sample Size (n) | 88 |
| % Gasoline USTs | 67% |
| % Non-gasoline | 33% |
| % Government Owned | 8% |

The key finding here is that 1/3 of the riskiest tanks in Rhode Island (according to this risk model) are *non-gasoline*; the rest are primarily No. 2 fuel oil. It is important to note that this proportion is sensitive to the weighting given to gasoline in the model (discussed in greater detail in the Sensitivity Analysis below). In order to address concerns that gasoline was not weighted high enough in the Total Content Risk parameter - that is in fact more dangerous than given credit for - the model was run a second time, with gasoline weighted 2-points (=20% of TCR) higher than in the initial model run. The demographics in the Tier I USTs changed due to model sensitivity to the TCR value; the new demographics are shown below:

| TABLE 16: DEMOGRAPHICS OF TIER I USTs (Gasoline Re-weighted) | |
|---|--------------|
| Parameter | Value |
| Sample Size (n) | 71 |
| % Gasoline USTs | 83% |
| % Non-gasoline | 17% |
| % Government Owned | 2% |

The increased weight given to gasoline USTs had marked changes upon the composition of the group of Tier I USTs. The number of tanks rated at Tier I decreased (due to changes in μ and σ), and gasoline USTs comprised an increased proportion of the population. However, non-gasoline USTs still comprise almost 1/5 of the Tier I tanks.

A complete list of Tier I USTs, for both the initial model run and the second model run (with gasoline re-weighted), is included in Appendices A and B, respectively.

4.1 Sensitivity Analysis

The objective of the Sensitivity Analysis was to further explore the effects of individual parameter weighting upon Overall Tank Risk value. The effect of a given parameter is intimately linked to the number of model points it can potentially contribute. This concept is represented graphically in Figure VI Below:

Figure VI: Sensitivity Analysis

| | | | <u>POINTS CONTRIBUTED</u> | | | |
|---------------|---------------|-----------------|------------------------------|--------------|------------------|--------------|
| | | | TOTAL | | | |
| | | | 51 | | | |
| | | | | | | |
| TANK | | | | ENVIR | | |
| 23 | | | | 28 | | |
| | | | | | | |
| SYSTEM | VOLUME | CONTENTS | | SWAP | CORR_SHWT | WATER |
| 10 | 3 | 10 | | 5 | 10 | 13 |
| | | | | | | |
| PIPE | | TOX | | CORR | | |
| 5 | | 5 | | 5 | | |
| | | | | | | |
| TANK | | SOL | | SHWT | | |
| 5 | | 5 | | 5 | | |
| | | | | | | |
| | | | | | | |
| | | | <u>RELATIVE CONTRIBUTION</u> | | | |
| | | | | | | |
| | | | TOTAL | | | |
| | | | 100.00% | | | |
| | | | | | | |
| TANK | | | | ENVIR | | |
| 45.10% | | | | 54.90% | | |
| | | | | | | |
| SYSTEM | VOLUME | CONTENTS | | SWAP | CORR_SHWT | WATER |
| 19.61% | 5.88% | 19.61% | | 9.80% | 19.61% | 25.49% |
| | | | | | | |
| PIPE | | TOX | | CORR | | |
| 9.80% | | 9.80% | | 9.80% | | |
| | | | | | | |
| TANK | | SOL | | SHWT | | |
| 9.80% | | 9.80% | | 9.80% | | |

Figure VI is presented in two parts. The upper portion details the model points allocated to each parameter.

These points are additive from bottom to top, and sum to 51

total possible Overall Tank Risk points for a UST. The maximum OTR value assigned to any UST was 41.

The bottom portion of Figure VI further distills these data, detailing the relative contribution of each parameter to the model. Note that the characteristics of the tank itself (45.10%) are set roughly equal to the environmental setting of the tank (54.90%). Further, note that the proximity to critical drinking water resources ('WATER') is the greatest contributor to the model, with roughly one quarter of the model points assigned to it. The tank and piping characteristics contribute roughly one fifth of the model points, and are weighted equivalent to the tank contents.

Since no single parameter has predominant influence on Overall Tank Risk, there is an element of flexibility to the model. There are many parameters from which the Overall Tank Risk value is derived, and a shortfall in one parameter may be compensated for by a high risk value in another. That is, the model is structured such that a tank need not be a gasoline tank to be prioritized as Tier I, so long as it is sufficiently risky in other areas. In essence, the model recognizes that the universe of risky USTs is diverse, and is not delineated by tank contents alone.

5.0 DISCUSSION

Rhode Island currently employs fairly straightforward command and control UST regulation, as discussed in the Background section. Despite such regulation, USTs persist as the single greatest cause of all new groundwater contamination instances in Rhode Island⁵⁴. The predictive risk model outlined here might provide a more streamlined assessment of groundwater threats from USTs than is currently in practice.

This study proposes two ways in which the Risk Tiers of this UST model could be applied: prioritization of monitoring and enforcement efforts, and rethinking of the current financial responsibility requirements for USTs in the State. Especially given the UST Compliance Act of 2001, which proposes \$1.2 Billion over the next five fiscal years for just such innovation⁵⁵, this model is a timely addition to the body of knowledge concerning UST risk-abatement.

5.1 Monitoring and Enforcement

The RIDEM website lists 12 staff⁵⁶ as responsible for managing the nearly 3500 active USTs in Rhode Island⁵⁷. The implications are clear: there simply aren't enough hours in the workweek for these individuals to personally see to it

that each of these tanks is in perfect compliance. In fact, RIDEM Director Jan Reitsma, in recent testimony before the US Senate, placed the time between RIDEM inspections for a given tank in Rhode Island at seven years⁵⁸. With the situation as such, the efficient use of RIDEM resources is of paramount importance. In recognizing this, RIDEM is targeting its monitoring and enforcement resources at gasoline stations in the State, as gasoline USTs are generally considered to be riskiest when they leak⁵⁹.

This study suggests that other tanks may be worthy of attention. Of the Tier I risks outlined in the Results section, 67% are gasoline tanks; the rest contain primarily No. 2 heating oil. Thus, by focusing narrowly on the gasoline USTs, RIDEM is potentially overlooking roughly 1/3 of the riskiest tanks in Rhode Island. This paper proposes a strategy that uses the UST risk model outlined here, which employs a more comprehensive suite of tank attributes, to direct RIDEM monitoring and enforcement efforts. While the model parameters are surely not perfect assessors of UST risk, they constitute a more refined approach than simple targeting of gasoline tanks. The argument here is *not* that gasoline tanks are benign; conversely, this study proposes that some non-gasoline

tanks may be just as dangerous as gasoline USTs, and may be off the RIDEM radar at present.

Given that State inspectors are only able to get to tanks once every seven years at present⁶⁰, placing Tier I tanks as highest priority - and setting inspection requirements accordingly - would constitute a necessary change toward more efficient use of RIDEM resources. Such a 'hotspot' approach would add an innovative element to a heretofore command and control system, and may pay dividends in the form of preventing future LUSTs in sensitive areas (e.g. Pascoag).

5.2 The RI State UST Fund & the Deterrent Value of Insurance

Recall from the Background section that the State Fund is capitalized by a \$0.01 tax on every gallon of motor fuel sold in the State, as well as registration fees for those tanks not containing motor fuel⁶¹. Note that the drivers of Rhode Island - and not the UST site owners - are providing the bulk of the capital to support the State Fund. By essentially providing a free insurance policy, the State Fund is providing little incentive for UST site owners to undertake risk-abatement actions. Insurance literature refers to such a situation as the problem of "moral hazard" - whereby the very fact that a party is insured against

risk induces that party to underallocate capital to loss prevention; in essence, to treat the insurance policy as a good that can be consumed for free⁶².

5.2.1 *Insurance and Moral Hazard*

Insurance has long been recognized as an effective means of managing environmental risk. In 1985, EPA described its position on the possibility of harnessing the insurance market for risky practices⁶³, describing insurance as:

An effective market force mechanism to help regulate and reduce the risk of environmental damage...by demanding responsible environmental management as a condition and cost of insurance.

While moral hazard is often an ancillary cost of insurance, there are certain means by which insurance, as a mechanism, can combat it. The key to thwarting moral hazard is pricing insurance to reflect the risk posed by the activity in question (in this case, storing hazardous substances where they may leak and cause harm to human health and the environment). Relevant literature cites three major mechanisms of pricing insurance to reflect risk: premiums, exclusions, and deductibles⁶⁴.

5.2.1.1 Premiums

Premiums are yearly fees assessed to insureds "based upon the predictable risk that the insured will suffer a loss."⁶⁵ Insurers can assess higher premiums to riskier firms, and reward loss control measures by charging lesser premiums to firms that undertake such measures ('feature rating' of premiums). Patrick Rounds, of the Petroleum Marketers Mutual Insurance Company, notes that "if the owner pays a premium based upon the risk the UST system presents, the owner will make financial decisions about whether to pay a higher premium or put money into better operation of the tank system"⁶⁶. Thus, premiums can affect industry behavior by tugging harder upon the purse strings of riskier actors, providing economic incentives to commit more capital to loss control efforts. By linking premiums to a firm's regulatory history (i.e. assessing higher premiums to site owners with a history of noncompliance - called 'experience rating'), similar effects can be achieved.

5.2.1.2 Exclusions

An insurer limits situations under which it will pay by placing an exclusion upon specific situations that it deems uninsurable. Many insurance policies have exclusions

for acts of war or acts of God; others, especially in the realm of environmental liability insurance, often have exclusions for losses at times during which the insured is not in compliance with applicable state or federal law⁶⁷. In theory, exclusions that preclude coverage for out-of-compliance insureds will encourage good-faith compliance with state and federal law, thereby having a mitigating effect upon moral hazard.

5.2.1.3 Deductibles

A deductible is a provision of insurance coverage that forces the insured to bear partial responsibility for a loss suffered under the policy by specifying an amount to be deducted from the sum otherwise payable to the insured⁶⁸. Its purpose is to "ensure that insurance is only partial"⁶⁹. Deductibles reduce moral hazard by making certain that any loss will affect the insured before it affects the insurer⁷⁰. Before forgoing investment in loss control that goes above the bare minimum required by law, the insured must then weigh the cost of the deductible against the cost of the additional loss control measures. An appropriately set deductible will be costlier than reasonably available *non-required* loss control measures, making it a rational economic decision to invest in *additional* loss control to

prevent a loss that will involve assessment of the deductible.

5.3 Rhode Island UST Financial Responsibility: Shortcomings and Remedies

The Rhode Island State Fund is not officially an insurance company, but stands to learn from the mechanisms outlined above. Each of these three elements is present in the structure of the State Fund--only the non-compliance exclusion is employed as it potentially could be: as a modifier on UST site owner behavior. Insofar as the risk associated with operating a UST is not reflected in the cost of ownership of doing so, the Rhode Island regulations allow UST owners to externalize risk. The following sections revisit the insurance mechanisms outlined above and evaluate Rhode Island's use of each.

5.3.1 Premiums in Rhode Island

The Rhode Island State Fund is capitalized by two means: assessment of flat fees on tank owners⁷¹, and a flat \$0.01-per-gallon tax on every gallon of motor fuel sold in the State⁷². As such, there is no link between the potential for a loss (i.e. leaking tank) and the cost associated with insuring the tank; the owner pays no

premium, and the yearly registration fee is not associated with the risk posed by the UST. Since there is no relationship between the risk and the cost of coverage under the State Fund, there is no incentive for owners to undertake loss-prevention measures, such as tank re-lining or installation of secondary containment. Tank owners are essentially given a zero-premium insurance policy in Rhode Island, covering up to \$1,000,000 per release.

5.3.2 Exclusions in Rhode Island

According to the General Laws of Rhode Island, for a site owner to apply for State Fund dollars, he or she must be in full compliance with "all state and federal technical requirements" for USTs at the time of the release⁷³. As written, this is a powerful tool against moral hazard; a tank owner must be in strict compliance, or else expose his business to unchecked risks. Such out-of-compliance exclusions are standard fare for environmental liability insurance and state funds alike. However, this dictum of strict compliance is slightly weakened by a clause in the Rhode Island UST Review Board Regulations⁷⁴ that provides a loophole for out-of-compliance tanks to gain eligibility for fund dollars:

Any claim resulting from a release from a UST...determined not to be in compliance with the UST Regulations, as of the date the release was discovered, shall not be eligible for reimbursement from the Fund. *Provided, however, should a claimant come into compliance, said claimant may become eligible to submit a claim for reimbursement.* [Italics added]

This clause essentially allows site owners to operate out-of-compliance tanks until they leak, remediate and otherwise bring the site into compliance, and retroactively apply for reimbursement of the remedial expenses⁷⁵. It has the potential to severely undermine the moral hazard-deterrent properties of the out-of-compliance exclusion. If the cost to remain in compliance were more than the cost of the RIDEM fine, then it would be a rational economic decision to operate a UST out-of-compliance in Rhode Island. But it usually isn't, because gaining retroactive compliance involves entering into a consent agreement with RIDEM--and paying the concomitant penalty, which is calculated to be substantial enough to remove any economic benefits reaped through noncompliance. It is important to note that deterring noncompliance through consent agreements is heavily reliant upon accurate assessment of penalties; if a penalty is underestimated or negotiated downward by lawyers representing the site owner, then individual bad actors may still profit from noncompliance.

5.3.3 Deductibles in Rhode Island

Rhode Island UST site owners must demonstrate \$20,000 of eligible expenditures before being covered by the UST fund⁷⁶. This is a relatively sizeable deductible: the UST site mutual insurance system running in Iowa offers a *maximum* \$10,000 deductible⁷⁷. Deductibles are important because they force a site owner to weigh the cost of non-required loss control expenditures against the cost of the deductible. If the cost of loss control efforts that can prevent a substantial loss is greater than the cost of the deductible, then it is rational for a UST site owner to invest nothing in additional loss control and suffer a loss, paying only the deductible and allowing the State Fund to pick up the rest of the tab.

5.4 Rhode Island UST Fund Recommendations

A more equitable policy would link the costs of owning and operating the tank with the cost of a potential leak from that tank through better use of the risk deterrent properties of premiums, exclusions, and deductibles. The UST model outlined here could advise certain elements of the process.

Given the current zero-premium situation presently enjoyed by tank owners, any move toward more equitable

premiums would involve assessing fees to site owners for the privilege of protection by a \$1,000,000 policy. This end could be achieved by incorporating aspects of feature and experience rating into premium assessment. The Risk Tier system could serve as a composite barometer of feature rating and environmental setting of a UST. Sites falling at the bottom of the frequency distribution for Overall Tank Risk could be rewarded by lesser premiums, and Tier I sites could be assessed premiums that drain profits such that loss control becomes rational. Further, linking premiums to compliance history would provide long-term incentive for site owners to keep up to date with tank improvements.

To remedy the weakened exclusion policy, the UST Review Board should consider amending its Regulations to remove the clause allowing retroactive compliance. Although valid during the early years of the State Fund, when mandating strict compliance may have landed many "judgment-proof" defendants in default, the tightening of the UST regulations in 1998 foretold a new era of UST risk management; State Fund eligibility requirements could benefit from following suit. It should be made clear that RIDEM consent agreements are a healthy mechanism for bringing sites into compliance, and should still allow for

a "clean slate" in terms of future UST fund claims. However, the practice of granting retroactive compliance should be reconsidered in light of its possible encouragement of underallocation to UST safety. Without strict enforcement of compliance - and in combination with its current zero-premium structure - the State Fund may become a patsy to UST site owners, who will act rationally when they allow their tanks to leak, only to be bailed out by the avuncular State Fund. While the State Fund has yet to have a site exhaust its \$1,000,000/release rights, continued generosity toward bad-faith actors will only place more stress upon the State Fund's limited resources.

So as to make loss control efforts more attractive, the minimum deductible should be set even higher, and loss control efforts should be subsidized by the State Fund. The modified deductible value should be set high enough such that site owner will be induced to invest in additional loss control, rather than wait for a leak, pay \$20,000, and start the cycle anew. When investing in additional UST safety becomes economically rational, Rhode Island will have framed a regulatory system that will very nearly run itself. It will be unprofitable to be irresponsible.

Finally, the UST model outlined here could be used to restructure insurance requirements. The body of USTs in the State could be viewed in terms of the model output. Certain tanks - by virtue of their contents, lack of loss control investment, and environmental setting - could be deemed high risk.

In the Results section, statistical analysis was employed to identify those USTs within the top 2.5 percentiles of the distribution of Overall Risk values. For these Tier I risks, financial responsibility requirements should follow a philosophy that recognizes the risk inherent to situating a risky tank within an environmentally sensitive area. Insurance requirements, now at \$1,000,000 per release, should be raised significantly for Tier I tanks. Such increases will more accurately reflect potential losses associated with decontaminating a drinking water supply, and will force owners of Tier I sites to seek supplemental insurance. The UST fund could then have very strict Best Available Technology (BAT) stipulations built into the supplemental insurance underwriting process, or could simply choose not to insure such tanks at all - leaving Tier I risks the option of either seeking insurance on the private market (where such strict underwriting already exists), or ceasing

operations. The cost of owning a Tier I tank would finally reflect the risk posed by its operation.

5.5 Potential Detractions

It is justifiable to object to the above recommendations on economic grounds: clearly, corporate (or "flagged") stations would be in a better position to come into compliance than would single-station owners ("Mom & Pop"). However, if the recommendation of instituting premiums were implemented in addition to retaining the current gasoline tax, the newfound money in the coffers of the State Fund could be put to use mitigating economic hardship for single-station owners. An auditing process could determine financial capacity to comply with BAT standards, and subsidies could be posted to those stations demonstrating "considerable hardship."

Of course, some might postulate that such subsidies would only serve as a life support system for firms that have no business operating risky USTs in the first place. The act of making the cost of UST operation commensurate with the risk posed is seen by these individuals as long overdue. If doing so forces unstable firms out of business, so be it. There is reasonable logic to this argument. In a healthy market, the collapse of one firm

will induce the entry of another firm; this may translate to flagged stations supplanting Mom & Pops. While a consumer advocate might fear such oligopolistic structure within the petroleum market, an environmental advocate would gladly consolidate the firms operating (and thus likely pay more for gasoline), so long as those firms each possess the resources to comply with BAT standards.

Another objection to the above recommendations might be that Tier I firms wouldn't pay at all; that the added costs would merely be passed along to the consumer. This may be true, but the targeted nature of these added costs is such that riskier operations would have more costs to pass along, increasing the price of their fuel at the pump, and placing them at a competitive disadvantage in the market. The price of fuel at a given station would more accurately reflect the risk posed by that station's USTs, and consumers would surely take notice.

6.0 CONCLUSIONS

This study examined the potential for publicly available data to be distilled in a manner that advises the risk-abatement process. It did so through an original model, developed and run in ArcView spatial analysis software, that integrated a suite of factors related to a given UST and its environmental setting. The model roughly determined a UST's potential risk to critical drinking water resources of the State of Rhode Island, and according to this Overall Tank Risk value, ranked every UST for which sufficient data exist. Based upon the distribution of Overall Tank Risk values in the State - which was roughly equivalent to a Gaussian distribution - Risk Tiers were delineated in an effort to better focus upon the highest-priority (Tier I) tanks.

While current State policy is narrowly directed at gasoline USTs, the data suggest that a broadening of the definition of a 'high risk' tank may be beneficial. The initial model run identified one-third of Tier I USTs as non-gasoline tanks; a second model run, modified to give added weight to gasoline tanks, identified nearly one-fifth of Tier I tanks as non-gasoline. In either case, it is concluded that a significant fraction of the riskiest USTs in Rhode Island are under-prioritized by virtue of the fact

that they are non-gasoline. This study finds that all Tier I tanks, regardless of contents, should be held to more stringent inspection requirements. The Risk Tier system might also be used to incrementally relax inspections on tanks in lower Risk Tiers. This strategy will target RIDEM resources at those tanks riskiest to the critical drinking waters of the State.

This study also finds that the UST Fund regulations should be reconstructed in light of the distribution of risk in Rhode Island. The overall approach is to make the costs owning and operating a risky UST more accurately reflect the potential adverse effects of doing so, and use the UST model as the barometer of risk. The Risk Tier system could advise rethinking of premiums, exclusions, and deductibles currently in effect, and it is postulated that the universe of USTs in Rhode Island could be better regulated as a result.

Given the uncertainty associated with the model itself (discussed earlier in Section 3.5), and in consideration with the magnitude of economic hardship outlined in Section 5.5, it is important to incorporate a right of appeal into the Risk Tier system. Such appeals would require best professional judgment (BPJ) of a certified professional engineer, and could override model output through

consideration of site-specific factors (e.g. bedrock, confining soil layers, etc.) not weighed by the risk model. Allowing for such dynamic assessment of site conditions would likely allay concerns of impacted UST owners.

In Sum, this study represents a fresh perspective on managing UST risk Rhode Island. By diverging from traditional regulatory mechanisms that treat each tank equally or give special attention to a group of tanks based upon a single attribute, this approach offers a more comprehensive - and potentially a more effective - means of risk-abatement. The drinking water supplies of the State stand to benefit from its implementation.

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