

# *Managing Leaking Underground Storage Tanks: A Spatial Database Approach*

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**Abstract** — *Leaking Underground Storage Tanks (LUST's) are a significant source of environmental contamination and may pose several threats to human health and safety. Functional management of the problem at local level is difficult due to the lack of regulatory personnel and the vast number of UST's facilities. Tracking the status of LUST's facilities is even more difficult due to the frequent abandonment and reuse of UST's systems. Spatial databases are suitable to organize location and attribute data for variables that are pertinent to the LUST management problem. A spatial database LUST management system was created and applied to a control group of 25 LUST facilities in the municipality of Bayamón, Puerto Rico. The system is effective to manage the LUST facilities problem in a proactive fashion and can be applied for UST inventory. Potential beneficiaries of this database may include environmental regulatory agencies, emergency management officials, gasoline distributors, and general public.*

**Key Terms** — *Leaking Underground Storage Tanks (LUST's), Management, Service Station, Spatial Database.*

## **INTRODUCTION**

On November 7, 1990 the Environmental Quality Board of Puerto Rico (EQBPR) approved the Regulation No. 4362 for the Control of Underground Storage Tanks. One of the purposes of this regulation according to Rule 102 was the implementation of a registry system and requirements for installation, operation and closure of facilities with UST's systems. In the 1990's the Environmental Protection Agency (EPA) installed a database prototype at the EQBPR headquarters to help them develop the UST's registry system. According to an interview with EQBPR UST program personnel, this database is only available

in one computer of the program area, and is outdated. Moreover, this database does not have an inventory of the Leaking Underground Storage Tanks (LUST).

On December 24, 2014 the EQBPR approved the new Regulation (No. 8546) for the Control of Underground Storage Tanks. Rule 802 of this new regulation requires to comply with the implementation of a permit system for facilities with UST's systems, instead of a registry system like the 1990's regulation established [1]. This new regulation has been diligently complied by the EQBPR. In addition, a new database has been developed to help with the new task at hand. Nevertheless, and according to interviews with the UST program staff, the new database does not work properly and does not provide geographical display of the UST data.

Moreover, the primary objective of an UST management database should be to prevent and/or mitigate soil and groundwater contamination caused by leaking UST's. Spatial databases can manage location and attribute data for variables such as tanks, urban areas, water bodies, and more that are pertinent to the UST management problem. Information layers can be updated to accommodate temporal changes in the attributes of UST facilities while retaining location properties [2]. These characteristics render spatial database well-suited to the UST management problem. The combination of using the spatial analysis capabilities of a Spatial Database Management System with its transactional registry and database cross-reference capabilities makes a Spatial Database Management System the most appropriate solution for this project.

This research developed a pilot project in order to manage the identification, location, attribute data and reporting permit status of LUST facilities

within the municipality of Bayamón, Puerto Rico based on a spatial database approach.

## **BACKGROUND**

The EQBPR estimates that there are 10,285 (operational and closed) regulated UST's systems in Puerto Rico (EQBPR, personal communication, May 2016). It has been estimated that 10 to 11 percent of those systems are leaking. Most of the UST's systems are used to storage petroleum substances, being the vast majority gasoline, or diesel fuel, at retail service stations. In that setting, 8,000 to 12,000 gallons capacity UST are common. For 2014, the percent of facilities in significant operational compliance with both prevention and release detection requirements was 49% [3].

Corrosion and improper installation and maintenance are the major causes of leaks [4]. The EPA has estimated that approximately 25 percent of the reported leaks from steel tanks are caused by corrosion and about 60 percent are caused by loose fittings or structural failure [5]. Breakage is the major cause of leakage in fiberglass tanks [6].

Several measures are implemented during UST installation to prevent leaks and spills or to mitigate the adverse effects of leaks to the environment. Typical prevention measures include corrosion protection (for steel tanks and pipes), spill and overflow devices, release detection systems and secondary containment [7]. Corrosion protection may include cathodic protection and fiberglass lining. Examples of spill and overflow devices include a spill containment bucket (commonly refer as spill bucket), which is a sealed unit around the fill pipe that prevent spills; a flow regulating device which automatically shuts off when 95 percent of the tank capacity is reached during filling, and a ball float ball or other flow restrictor [8]. As established on the new EQBPR regulation for UST [1], leak detection devices can include manual and automatic tank gauging, tank and lines tightness testing, interstitial monitoring, and statistical inventory reconciliation. Secondary containment structures may include a double-walled tank system, an exterior concrete vault, and a lined excavation zone.

Spatial databases can effectively manage data pertaining to the presence or absence of various leaks prevention measures at the numerous of UST facilities in Puerto Rico. A comprehensive LUST management system has both proactive and reactive capabilities [9]. Proactive assessment includes identifying facilities that pose an environmental threat hazard based on UST system characteristics, geology and proximity to water bodies or water supply wells. Examples are:

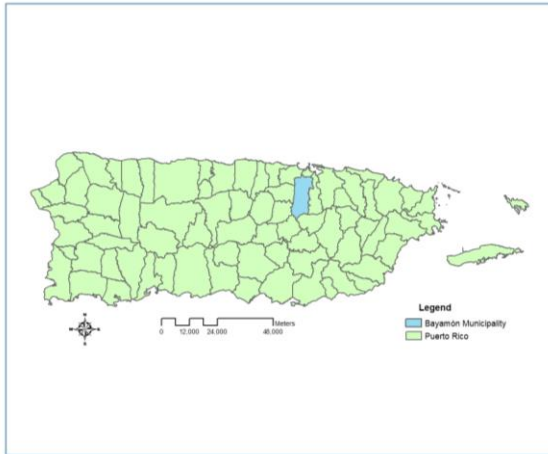
- current, abandoned, and reused UST systems;
- facilities that are not been monitored for leaking UST's within a specified period of time;
- prevention-deficient facilities;
- facilities that overlies highly permeable soils;
- facilities with one or more UST (s) older than specified age;
- facilities within a distance of water production wells or water bodies.
- nearby sanitary or stormwater sewer systems possibly impacted by leaked materials.

UST inventory is a fundamental component of a proactive assessment. Spatial Database Management System showing the locations of current and former facilities would enable public and private institutions to make effective decisions related to their specific interests. For example, and one of vital importance, local regulatory agencies could use the system to rapidly monitor and determine the compliance status of the thousands of UST facilities registered in Puerto Rico. One advantage of using a spatial database (and an important part of their justification) is the ability to record transactions. Create or improve a protocol, where the UST's facility owners report any incidents, making the relationship with regulatory agencies only transactional, taking the weight of the agency to go find the data.

### **Study Area**

The municipality of Bayamón sits on the Northern Coastal Plain region of Puerto Rico, Figure 1. For 2010, the population was estimated at 208,116 habitants, making it Puerto Rico's second-

largest municipality [10]. A total of 194 current and former UST facilities were identified within the study area [11]. Of these sites, over 35 facilities were included in the active LUST facilities [12] for 2010. Currently, this number of facilities might have tripled (personal communication with EQB staff).



**Figure 1**  
Study Area

Abandonment and reuse of UST/LUST facilities, makes difficult to track the status of the sites, even more to enforce remediation activities by owner and operators. A random sample of 25 active LUST facilities was selected in order to manage the identification, location, attribute data and reporting permit status of LUST facilities in the municipality of Bayamón, Puerto Rico based on a spatial database approach.

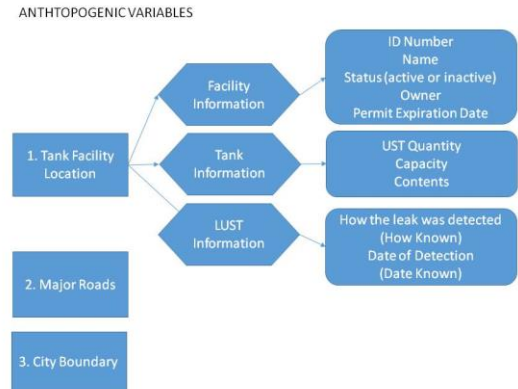
## METHODOLOGY

This was a constructive research in order to develop a pilot project to manage the identification, location, attribute data and reporting registry status of LUST facilities based on a Spatial Database.

### Database Construction and Application

The Spatial Data applications in this research are associated with the municipality of Bayamón. Information was requested to the EQB for each one of the 35 facilities included in the active LUST facilities for 2010. A sample of 25 facilities was selected based on the available spatial data existent. Using a Microsoft Excel Spreadsheet, UST facility

location information was collected and organized. Other anthropogenic variables collected were major road and city boundary. The spatial variables were combined with various attributes to form different information layers, Figure 2.



**Figure 2**  
Information Layers

The pgAdmin (an open source administration and development platform for PostgreSQL) was used for the database construction because of its flexibility and adaptiveness at handling location and attribute characteristics for the UST management problem. Using, PostGIS, a database extender for the PostgreSQL, a query was performed to create the main database table, Figure 3.

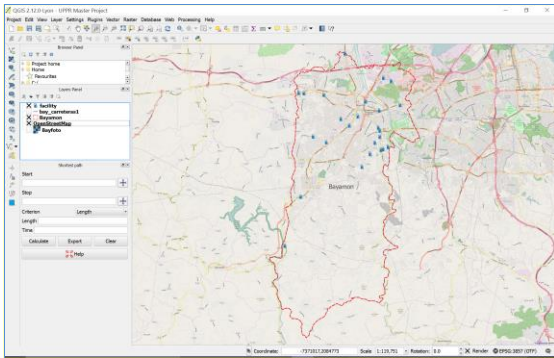
```
create table mlacruz.facility(
  id varchar(9) --Facility Identifier (UST number assigned by EQB)
  , lat numeric --Latitude, in accordance with the 1984 World Geodetic System (WGS84)
  , long numeric --Longitude, in accordance with the 1984 World Geodetic System (WGS84)
  , name varchar(25) --Facility Name
  , owner varchar(25) --Facility Owner
  , address varchar(25) --Facility Address
  , status varchar(9) --Facility Status (Active or Inactive)
  , howknown varchar(25) --How release/spill happened or was notified to EQB
  , dateknown date --Date release/spill occurred or was notified to EQB
  , releasedate date --If inactive, when the facility was inactive from LUST
  , permitdate_exp date --Expiration Date - Certificado de Registro or Permiso de Operación
  , ust numeric --UST Quantity at the Facility
  , ust1_capacity numeric --UST 1 Capacity
  , ust1_content varchar(9) --UST 1 Content
  , ust2_capacity numeric --UST 2 Capacity
  , ust2_content varchar(9) --UST 2 Content
  , ust3_capacity numeric --UST 1 Capacity
  , ust3_content varchar(9) --UST 1 Content
  , ust4_capacity numeric --UST 1 Capacity
  , ust4_content varchar(9) --UST 1 Content
);
```

**Figure 3**  
Query

Quantum GIS 2.12 (QGIS) was used to display and manage the initial spatial database. This software was selected because it is a user friendly Open Source Geographic Information System (GIS) and can be integrated seamlessly with the

PostgreSQL/PostGIS platform. A base map was developed using the current coordinate System for Puerto Rico [13].

In order to retrieve spatial data from PostGIS into desktop based application, and later on web based applications, a point map was developed to show/maintain the LUST facility layer, Figure 4, adding the PostGIS table created in the QGIS application.



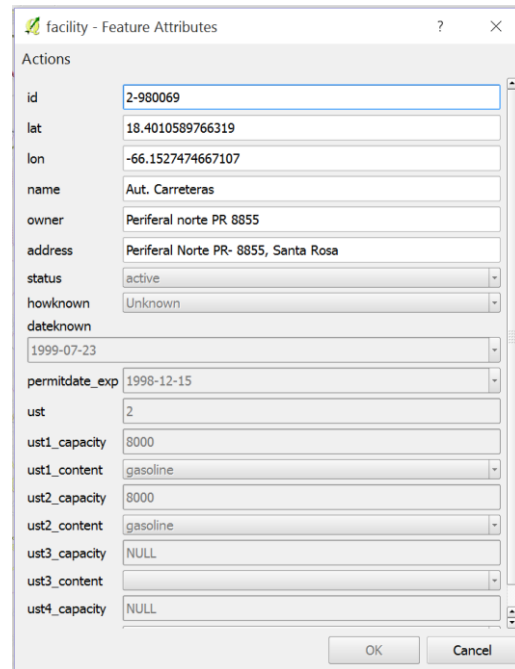
**Figure 4**  
**LUST Facility Layer View on Quantum GIS**

LUST locations were obtained from information gathered in field and through facility records maintained by the EQB. Unfortunately, leak prevention information was not available to add to the LUST facility layer, but the plan is to make sure it will be included for the future work of this database. Nevertheless, LUST facility attributes were used to store information on facility identification number, name, owner, address, LUST status, how the leak was reported (how known), date of leak (date known), and permit expiration date. UST attributes included number of UST's on site, UST capacity and content.

To facilitate the user experience of the LUST Management System, a data maintenance form was developed using QGIS' Form Design Functionality. The maintenance form improves usability when editing or adding new data to the database, Figure 5, especially when the user has no expertise using PostGIS software.

Other features included with the connection of the QGIS application with the LUST Database, were the capability to perform actions to each of the LUST facilities features. An action is something that happens when you click on a feature. It adds

extra functionality to your map, allowing the user to retrieve additional information about an object. For this database a total of three actions were added: Documents, Photos and Report.



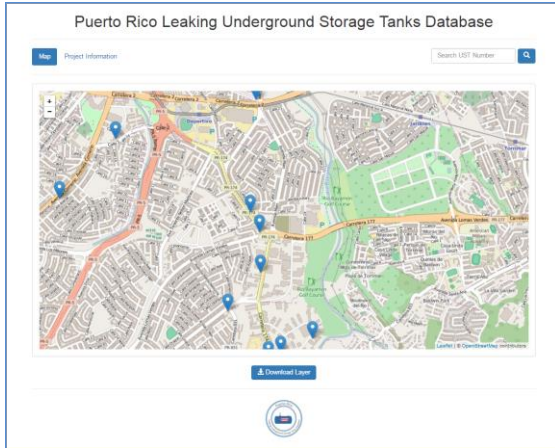
**Figure 5**  
**Example of a Data Maintenance Form**

The Documents actions opens the internet browser and display documentation for the LUST facility selected when click on the feature. The document to be display was obtained from the EQB facility file. A photo of the LUST facility selected is display in the same fashion, when the Photos action is selected. When the Report action is selected a full facility report as it was programmed in the web interface which will be discussed on the next section.

### Web Interface Development

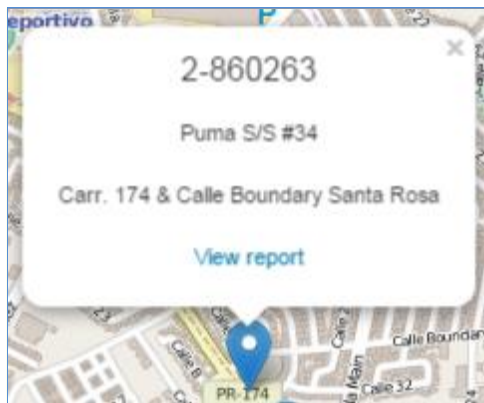
To provide of the user of the Spatial Database Management System multiple alternatives of use and portability, a web interface was developed, Figure 6. The emphasis of the web interface is an area which highlights the web mapping aspect. This section was developed with the Open Source libraries found in leaflet.js and in collaboration with the Open Street Map web mapping environment. This basemap was selected because its richness in land features, providing an excellent tool to identify

susceptible environmental receptors in order to prioritize remediation efforts for the LUST facilities. Future work could include the addition of land resources not available on Open Street Map, such as soil types and sewer systems, among others to the web basemap.



**Figure 6**  
**Web Interface**

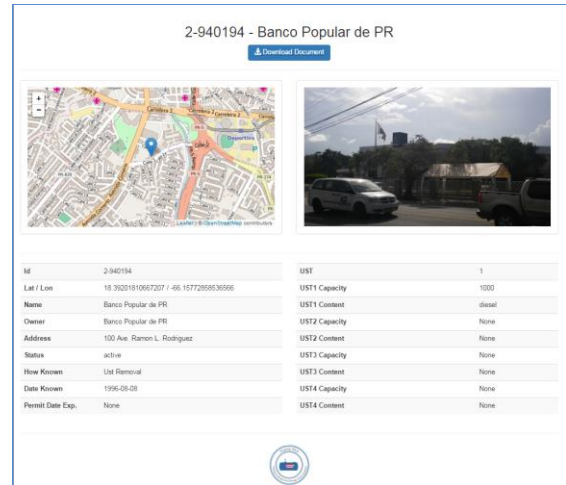
The web design is divided into two pages: Map and Project Information. Map or Home page displays the Open Street Map basemap with the LUST facilities markers and a Search bar. When any marker is selected, a marker tooltip provides the Facility Id, Name, Address and the View Report option, Figure 7.



**Figure 7**  
**Marker Tooltip**

If the View Report Option is selected, a facility report is generated with provides the same information as the QGIS form, but adds a location map, a site photo and a download document option, Figure 8. This report is the same one that is generated when the Report action is selected for

any facility features on the QGIS application. More so, any feature edits or additions will be instantly visible on the web interface.



**Figure 8**  
**Report Example**

The Project Information displays a brief summary of this research and provides a Download Final Paper option.

For the purpose of showing the functionality of this project, the project's web interface can be accessed by using any internet browser via the following address: <http://g-codes.us:5000/mlcruz>

## DISCUSSION

Potential beneficiaries of this Spatial Database LUST Management System may include environmental regulatory agencies (municipal and state), emergency management officials, planning companies, lending institutions, gasoline distributors, oil companies, and general public. This initiative can eventually be presented to the EQBPR to be adopted or to be used as a model for developing a spatial version of their database system. Regulatory officials could use the management system to rapidly determine the compliance of hundreds of LUST facilities in addition to prioritize remediation efforts. In addition, the web interface will provide updated facility information during compliance inspections.

Emergency management officials could use the database to obtain information on the distribution of fire and explosion hazards.

Lending institutions and others private companies could also use the information contained in the database system. As an example, access to a spatial database could assist the scheduling of maintenance procedures that are considered into the setting of liability insurance premiums. Gasoline and oil distributors could use the proactive capabilities of the database system to avoid costly subsurface remediation.

The provision of a web interface for the management system created provides access to the general public, in addition to allow the download of up-to-date layers of information without affecting the database integrity.

In summary, the pilot LUST management system created facilitates proactive and reactive measures necessary to mitigate adverse environmental effects. In addition, the management system can be updated to track compliance and record transactions of the thousands UST facilities in Puerto Rico.

## CONCLUSIONS

Spatial data should be a vital component of a comprehensive UST management system. The spatial database management system created for this project has the capability to store numerous information layers, facilitating proactive assessment of environmental hazard for the existing LUST facilities in Puerto Rico. The system also supports a reactive phase to the LUST problem by answering questions about a particular facility in the event of a leak, such as environmental sensitive surroundings; promoting efficient management and prioritization of remediation efforts in order to minimize environmental impacts.

This pilot project represents a first step in developing a comprehensive state-wide database that would integrate geohydrologic variables, land use, utilities, environmental sensitive areas, and other public information necessary to promote compliance, risk management and remediation activities at UST facilities in Puerto Rico.

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