Quantitative Environmental Indicators of Contamination

A System For Tracking Environmental Results

Prepared by:
Environmental Indicators Quality Action Team
U.S. Environmental Protection Agency Region 2

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PREFACE

This document summarizes the results of work done to develop the Quantitative Environmental Indicators of Contamination (QEICs) developed by U.S. Environmental Protection Agency (EPA) Region 2's Environmental Indicator Quality Action Team (QA Team). The QA Team authors consist of the following EPA technical personnel: Henry Schuver, now with the Headquarters Office of Solid Waste-Permits and State Programs Divisions (OSW-PSPD*s*); Richard Krauser and Agathe Nadai, with Region 2's RCRA Programs Branch (RPB); and Anthony Kahaly, currently with the University of Pennsylvania, Philadelphia, PA.

The August 1997 draft paper was peer reviewed on March 2000. The current final edition reflects the comments of these peer reviewers. The peer reviewers are:

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EXECUTIVE SUMMARY

Since March 1989, EPA has embarked on changing the way the Agency's progress in protecting human health and the environment is measured. This change has involved a shift from using activity measures to using direct measures of environmental results.

In January 1995, EPA Region 2 formed an Environmental Indicators Quality Action Team (EI Team) to assist in the development of meaningful and accurate EIs as they could be applied, initially, to the RCRA Program. The EI Team, with technical and management input, determined the criterion to be used in developing these Region 2 EIs. This criterion required the use scientific measurements to determine changes in the quality of the environment. The quality of the environment is correlated with the amount and distribution of chemical contaminants within environmental media. These media are groundwater, soil, and groundwater transferred to surface water. The Region 2 EIs, as initially applied to the RCRA program, have been named *Quantitative Environmental Indicators of Contamination* (QEICs).

This report presents methods for analyzing and summarizing existing contaminant monitoring data that is displayed on maps and tables. The QEICs are designed to be communicable to the public, regulators and the regulated community for evaluating the environmental progress.

The QEICs based on measured contaminant values are also designed to be used as part of a multi-media mass-balance concept applied to individual industrial sites. The purpose is to allow the measured QEIC values to be used to derive estimates of contaminant values that are not otherwise measurable. These values estimate the rate of continuing sources of contaminants to groundwater, the rate of natural attenuation of contaminants in groundwater, and the minimum amount of unidentified sources of contaminants to groundwater. There area a total of ten QEICs.

The QEICs are organized into four levels, the first three levels represent QEICs that directly reflect measured values of contaminants. The fourth level consists of QEICs that are estimated contaminant values, and are derived from the relationship between the QEIC measures within a mass balance constructed for each specific industrial site.

Level 1 - Contains maps designed to provide an unambiguous view of soil and groundwater contaminants at specific sampled sites and show them relative to cultural and natural resources of the site and the surrounding community. The specific QEIC is:

Mapped Sample Results - maps of sampled locations at contaminated industrial sites, where the magnitude of contaminant concentrations exceed the applicable standards[1]; and tables of the concentration values for each contaminant at each sampled location.

[1] In place of the applicable standards the detection limits can be used, in which case the analytical method needs to be referenced.

Level 2 - Contains maps of the contoured aerial extent of groundwater and soil contaminant concentrations relative to natural and cultural features. The specific QEICs are:

Area of Groundwater Contamination - the area of groundwater that contains contaminants concentrations above standards for unrestricted use (e.g., residential) and applicable industrial use.

Area of Surface Soil Contamination - the area of the land where surface soil, less than two feet deep, contains contaminant concentrations above standards for unrestricted direct exposure use (e.g., residential) and applicable industrial direct exposure use.

Area of Leachable Soil Contamination - the area of soil with contaminant concentrations in excess of applicable standards for the protection of groundwater, i.e., leachable. These standards are for unrestricted use (e.g., residential) and applicable industrial use.

Level 3 - Contains calculations of the mass of contaminants that are contained in various media for a specific industrial site. The specific QEICs are:

Amount of Groundwater Contamination - the calculated mass of contaminants within the groundwater plume that are above applicable standards.

Amount of Extracted Groundwater Contamination - the calculated mass of contaminants physically extracted from the groundwater plume by active remediation per year.

Amount of Contamination Transferred from Groundwater to Surface Water - the calculated mass of contaminants, in excess of a facility's site specific groundwater standards, that are transferred (loaded) to surface waters per year.
Amount of Leachable Soil Contamination - The mass of contaminants in soil above applicable cleanup standards for the protection of groundwater, which is a potential long term source of groundwater contaminants.

Level 4 - Contains estimated values derived from site-specific mass balances that are based on measured QEICs.

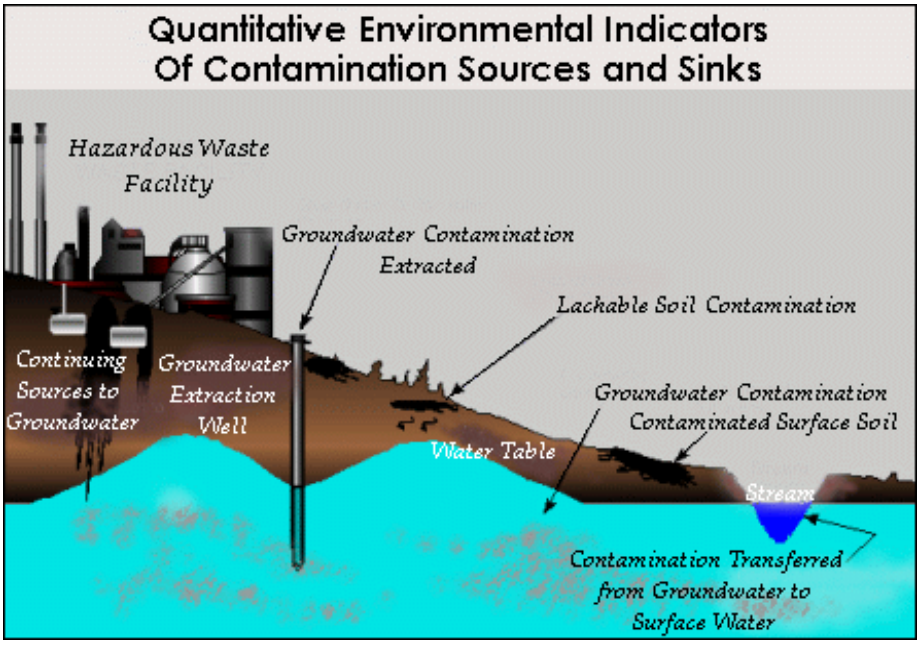
Amount of Continuing Sources/Natural Attenuation to Groundwater: The mass of contaminants added to the groundwater plume (continuing source) or removed from the groundwater plume (natural attenuation) after accounting for other known contaminant mass source or reduction processes.

Minimum Amount of Unidentified Sources to Groundwater: The estimated minimum amount of contaminants that have been added to the groundwater from sources other than calculated soil contaminants.

The determination of site-specific QEICs can be done manually or electronically. The increasing use of electronic data deliverables (EDDs) potentially allows calculation and mapping to be done automatically by the aid of various commercial and non-commercial programs.

The QEICs are also being used to support measures for the determination of Governmental Performance Result Act (GPRA) goals.

This project has been partially funded through a grant by the federal program entitled: Environmental Monitoring for Public Access and Community Tracking (EMPACT). EMPACT funding is for projects that use environmental monitoring to inform the public about environmental issues. The funding, initially provided to EPA's Office of Solid Waste (OSW), has been used by Region 2 to develop a cooperative agreement with the New Jersey Department of Environmental Protection - Site Remediation Division, as well as Region 2 contractors, to facilitate the calculation of site-specific QEICs using electronic data deliverables.



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INTRODUCTION

Since 1989, the United States Environmental Protection Agency (EPA) has been shifting its focus from activity measures to direct measurements of the environment. The objective of EPA Region 2's Environmental Indicators Quality Action Team (QA Team), created in 1995, has been to develop environmental indicators to serve as these direct measurements of the environment. The environmental indicators that have been developed are termed Quantitative Environmental Indicators of Contamination (QEICs). The QEICs are separate and distinct from the two environmental indicators developed by EPA Headquarters, Current Human Exposures Under Control (CA725) and Migration of Contaminated Groundwater Under Control (CA750).

QEICs are defined as: scientific measurements of change in the quality of the environment, with the quality of the environment being directly related to contamination in the media.

QEICs are designed to satisfy the following criteria:

- are readily implementable;
- are accessible through existing sources of information; and
- are quantifiable and communicable in descriptive terms to the public, regulators, and the regulated community.

The QA Team examined existing facility site data required for various EPA regulatory programs and developed 10 QEICs which are designed to fully describe environmental contamination at industrial facility sites and track changes in this contamination through time, within the constraints imposed by these data.

The 10 QEICs are organized into four groups (levels) of increasingly complex information about the facility site. The QEICs within each of these levels are designed to be building blocks for the QEICs of the succeeding level and to provide more detailed information about each facility site. The levels are:

Level 1 - which consists of maps of specific sampled locations at each facility site and data tables of contaminant concentrations in groundwater and soil at these sampled locations. These sampled locations are displayed on maps of cultural and natural resources of the facility site and the surrounding community.

Level 2 - which consists of maps of the contoured aerial extent of the contaminants concentrations in groundwater and soil relative to natural and cultural features. The contours are derived using appropriate electronic contouring programs.

Level 3 - which consists of data tables displaying the calculated mass of contaminants residing in the groundwater and soil of a facility site. The data tables also display the mass of contaminants in groundwater being transferred into surface

water and the mass of contaminants in the groundwater and soil being actively remediated (i.e., extracted) at a facility site.

Level 4 - which consists of data tables displaying the estimated mass of contaminants in groundwater and soil of a facility site that are not directly measurable. These estimates are derived from the mass of contaminants calculated for the Level 3 QEICs by the use of a contaminant mass-balance for each facility site.

The QEICs use data generated in accordance with existing data collection regulations and guidance. The QEICs are a practical approach for describing these available data and making them communicable. As such, the QEICs are designed to aid regulatory project managers in their assessment of changing site conditions through time, and to make these changes more clear to the concerned public. Because QEICs use only data generated by regulatory requirements, they are not intended to be viewed as research projects or definitive descriptions of physical and chemical conditions at facility sites. They are designed to be a valid way to more clearly identify and communicate trends in contamination levels at facility sites through time and are unique in that are based on scientific measures.

DESCRIPTION AND DISCUSSION OF INDIVIDUAL QEICs

Level 1 - Mapped Sample Results

This level consists of one QEIC measure.

1. Mapped Sample Results QEIC:

Definition and Description:

Maps of specific sampled locations within each facility site and accessible data tables of the concentration of each contaminant in the groundwater and soil for each sampled location. The data table results are separate for each sampling event. Sampled locations are displayed on maps of cultural and natural resources of the facility site and the surrounding community.

Data Sources and Procedures for Calculation:

These maps are intended to be generated at least annually from groundwater monitoring reports of water well samples. The location of these samples are shown relative to man-made and natural features. The magnitude of contamination concentration displayed are highlighted as differently colored dots if above applicable groundwater and soil standards. The size of the dots are proportional to the concentration of all contaminants above the soil and ground-water standards for the site (Figures 2 and 3).

Figure 2

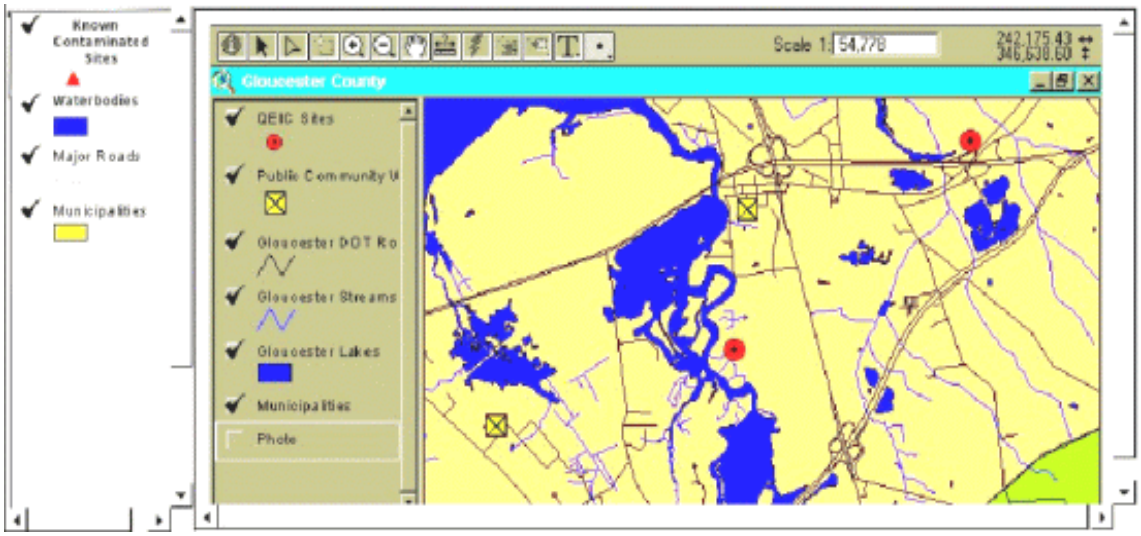
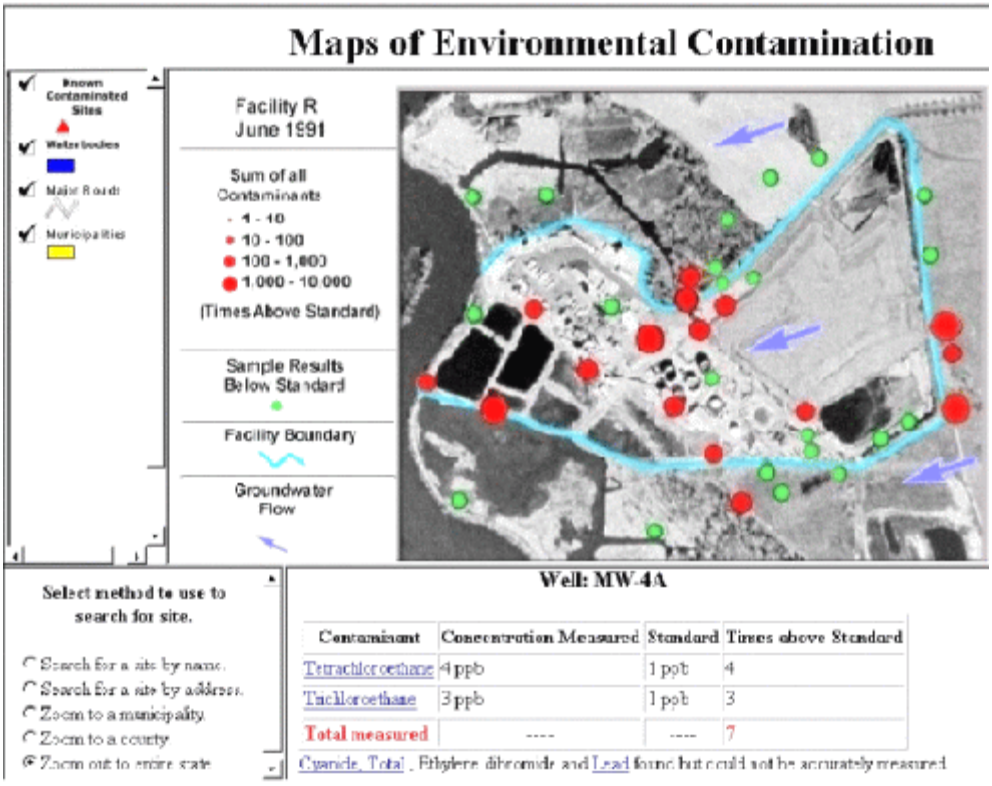


Figure 3



Discussion:

If one sampled location is sampled at multiple depths, the concentration displayed is the highest, regardless of depth. The maps are designed to display, with a minimum of interpretation, the basic sampling results upon which the iso-concentration contour maps are based.

Level 2 - Area QEICs

This level consists of three QEIC measures.

2. Area of Groundwater Contamination QEIC**:**

Definition and Description:

The Area of Groundwater Contamination QEIC displays and provides calculations of the area of the contaminated groundwater plume that contains any contaminant above applicable groundwater standards (e.g., 9 acres). [2]

The QEIC record consists of both the current area of the contaminated groundwater plume and the percent change per year (e.g., 10 percent decrease per year). The data is recorded on tables and maps.

Example QEIC record = (9 ac, -10%/yr).

Data Sources and Procedures for Calculation:

The areal extent of the plume is determined by the maximum extent of groundwater containing contaminants above an appropriate standard (e.g., Drinking Water Standards), as indicated on iso-concentration contour maps. These maps are intended to be generated at least annually from data submitted in groundwater monitoring reports. The data may reflect contamination in unconfined aquifers (e.g., water table aquifers) and confined aquifers. If two or more constituent plumes exist, representing different aquifers, the areal extend of the plume is delineated by the maximum extent of the combined constituent plumes. This QEIC can include both dissolved and measurable free-product contaminants.

Contouring packages, approved by the overseeing regulatory agency, are intended to be used to insure that standard assumptions and methodologies are used in contouring. At a minimum, data points should be located to insure that all contours can be closed by interpolating between data points that are both above and below the appropriate standards. Deviations from mathematically determined contour locations, based on professional judgement, should be noted as such.

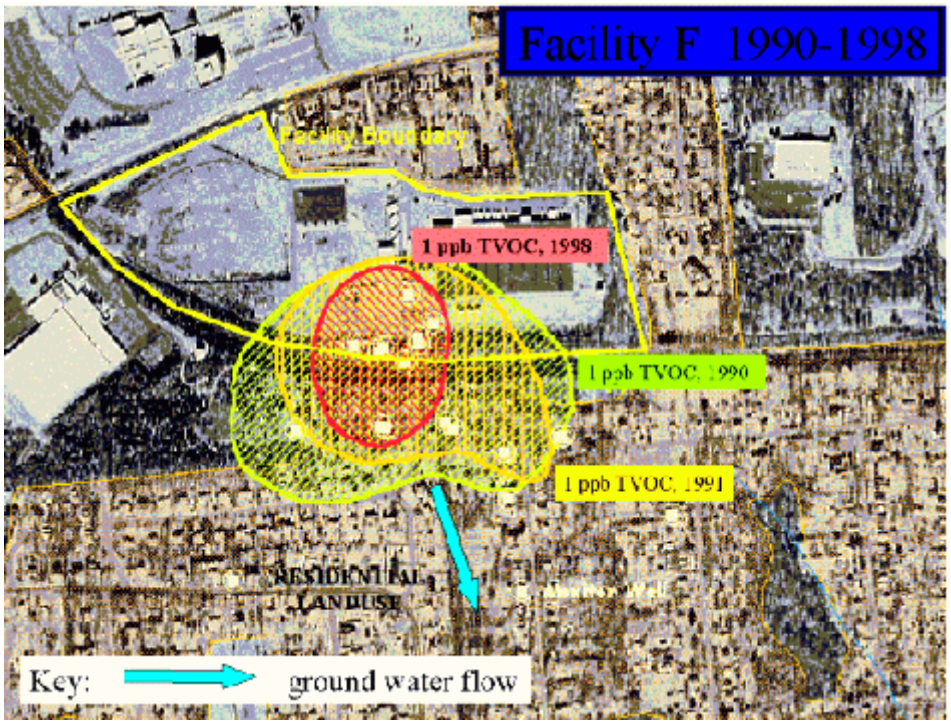
[2] Or any metric scale suited for the purpose of characterizing the contamination.

Discussion:

Isoconcentration contour maps also display the proximity of the plume to cultural features and to topography. These views are an integral part of this QEIC. They allow an appreciation of the potential impact of the plume on human and environmental receptors, on the availability of groundwater resources, and the impact of remediation activities.

The measured percent change in area is calculated by comparing the most recent calculation of area with that from the previous report. The frequency of these reports is assumed to be annual. For each facility, it is expected that over time a table of records will be developed demonstrating yearly changes in both the rate of change and size of the plume (Figure 4).

Figure 4



The Area of Groundwater Contamination QEIC is designed to:

- provide an unambiguous areal view of contoured groundwater contamination relative to cultural and natural resources of the site and the surrounding community;
- document the area affected and changes in area affected through time (numerically and graphically);
- document the results of remedial activities;

- summarize critical elements required by a groundwater quality investigation, including: areal extent, direction and rate of migration of the plume, and identification of contaminants. The iso-concentration contour maps also provide easily accessible summaries of information contained in, for example, a RCRA Facility Investigation (RFI);

- be consistent with current environmental measurement activities explored by EPA and the States;

- provide a measurement for the determination of Governmental Performance Result Act (GPRA) goals and the Environmental Indicator (EI) CA750 (Groundwater Releases Controlled Determination); and

- be easily visualized by the use of mapping and therefore communicable.

3. Area of Surface Soil Contamination QEIC:

Definition and Description:

The Area of Contaminated Surface Soil QEIC is the area of land where surface soil contains contaminants above unrestricted use standards (e.g., residential) for direct contact exposure (e.g., 1.6 acres).

The QEIC record consists of both the current area of the contaminated surface soil and the percent change per year (e.g., 10 percent decrease per year). The data is recorded on tables and maps.

Example QEIC record = (1.6 ac, -10%/yr).

Surface soil is defined as soil within two feet of the surface. Soil is defined as all unsaturated loose solid media, excluding waste, occurring above the water table.

Data Sources and Procedures for Calculation:

The data needed to determine this QEIC consist of contamination concentration results

from the analyses of samples of surface soil. The concentration values contoured are those above appropriate soil standards for direct contact. Site-specific risk-based standards should be noted as such.

The area of surface soil contamination is calculated by using isoconcentration contour maps to delineate the maximum extent of soil contaminated above unrestricted use standards. Relative to groundwater, the contours for soil are likely to be discontinuous and be highly irregular in shape. When remediated, it is recognized that the soil is not

expected to be removed gradually, but will often achieve substantial removal within an area within a short period of time (see Figure 5).

Figure 5

FACILITY J

Aerial Extent of Remediated Soil Contamination

Discussion:

This QEIC measures the current area of the surface soil contamination (e.g., in acres). It is designed to document the area of land that is unavailable for unrestricted land use and that requires land use controls because of the presence of contamination above standards for direct contact exposure. It is also designed to track changes in this area through time.

This QEIC is intended to track all surface soil contamination above standards for unrestricted land use, even if the site is intended to be remediated to industrial standards. The reason is that while a site may be remediated for restricted use, this QEIC will maintain a record of any residual contamination should this land use designation change.

Institutional controls, which would be required of all sites with residual contamination in excess of a unrestricted use scenario, will be noted and tracked as part of this QEIC. The types of these controls, whether administrative or physical (e.g., deed covenants, landfill caps, etc.), will also be tracked. Their presence will be verified each year to insure that they remain in place as long as they are required.

Physical controls that reduce or eliminate direct contact exposure through covering with uncontaminated soil will be considered an exposure control rather than remediation (i.e., corrective action). While this "capping" activity may satisfy regulatory requirements for restricted use of the site, this activity would not cause the QEIC record of soil contamination above unrestricted use to disappear from the system. Instead, the site would be acknowledged as having been controlled. The QEIC record would remain in the system as long as the contamination remains in case the contamination is inadvertently exhumed at some time in the future.

This QEIC is separate from the Amount of Leachable Soil Contamination QEIC that tracks the soil's potential as a contaminant source to groundwater, and is discussed below.

This QEIC can be used to verify (annually) the surface soil component of the Human Exposure Controlled Determination Environmental Indicator (CA725).

In summary, the Area of Contaminated Surface Soil QEIC is designed to quantify the area of land that is not available for residential use because of direct contact soil exposure. It is designed to:

- document the area affected and changes in the area affected (numerically and graphically);
- documents the results of any remediation (corrective action);
- be easily visualized by the public, and allow them to readily understand their community's environmental conditions;
- be consistent with current environmental measurement activities explored by EPA and the States,
- serve as a measurement for the surface soil EI for the determination of Governmental Performance Result Act (GPRA) goals, CA725 (Human Exposure Controlled Determination); and
- allow areas of direct contact risk to be visualized.

4. Area of Leachable Soil Contamination QEIC

Definition and Description:

The Area of Leachable Soil Contamination QEIC is the area of soil with contamination in excess of applicable standards for the protection of groundwater, i.e., leachable (e.g., 9 acres).

The QEIC record consists of both the current area of leachable soil contamination and the

percent change per year (e.g., 10 percent decrease per year). The data is recorded on tables and maps.

Example QEIC record = (9 ac, -10%/yr).

This QEIC is designed to map the area and location of contaminated soil that is a potential source of contamination to groundwater. A lack of correlation between the area of this QEIC and the area of the underlying groundwater contaminant plume may signal either the possibility of an unidentified source of contamination to the groundwater, or that leachable soil contamination has not impacted groundwater yet, or that the behavior of contaminants in the unsaturated zone is complex.

Data Sources and Procedures for Calculation:

Soil sampling data, at all appropriate depths, will be used to determine the area of leachable soil contamination. These data will be used to generate maps which will delineate the maximum extent of contamination with concentrations in excess of standards for the protection of groundwater. The map would have a similar look to the map for the Area of Surface Soil Contamination, but the actual delineated extent of contamination can be expected to be different.

Discussion:

The Area of Leachable Soil Contamination QEIC includes soil at all depths, including surface soil. Any correlation with the Area of Surface Soil Contamination QEIC record would be coincidental because the two areas would be based on different exposure scenarios and different concentration-based standards.

This QEIC allows the subsurface area of contamination to be tracked. Although this tracking is principally for the purpose of monitoring a source of groundwater contamination, it is also potentially useful in tracking soil contamination that may become a future source of direct contact exposure, e.g., through excavation below two feet in depth.

The Area of Leachable Soil Contamination QEIC:

- Documents the area affected and changes in the area affected (numerically and graphically); and

- Documents the results of remedial activities.

Level 3 - Amount QEICs

The following four QEICs are direct measures of the amount (mass) of contamination in the environment.

5. Amount of Groundwater Contamination**:**

Definition and Description:

The Amount of Groundwater Contamination QEIC is the calculated mass of contaminants within the groundwater plume above applicable standards (e.g., 181 kilograms).

The QEIC record consists of both the measured mass of dissolved contaminants, including the measurable free-product contaminants in the groundwater and the percent change per year (e.g., 5 percent decrease per year).

Example QEIC record = (181 kg, -5%/yr)

Data Sources and Procedures for Calculation:

The data needed to calculate the Amount of Groundwater Contamination QEIC are contaminant concentration values from groundwater monitoring wells and physical measurements of aquifer properties. These calculations can be done by the use of available electronic programs that have been approved by the regulatory agency.

If these electronic programs are not available, the amount (mass) of the contaminants within the dissolved plume can be estimated by multiplying the area, which was previously determined in the Area of Groundwater Contamination QEIC, by the depth of the plume and by the porosity of the aquifer.

That is to say,

> Amount (mass) of Groundwater Contamination (m_{gw}) = Volume (v) x Concentration (c); or, m_{gw} = vc; where
>
> Volume (v) = Area of Groundwater Contamination QEIC (a) x Depth of Plume (d) x Porosity of Aquifer (n); or, v = and

Discussion:

This QEIC directly measures the amount of dissolved mass and measurable free-product. Contaminants that cannot be measured directly, e.g., non-measurable free product or adsorbed contaminants, are addressed in the Level 4 - Derived QEICs**.**

The Amount of Groundwater Contamination QEIC is designed to summarize the status of a

plume of groundwater contaminants in a way that concentration-based data cannot. The conversion on contaminants from concentration to mass values allows the contaminant to be tracked regardless of medium in which the contaminants are contained. A mass-based approach can be used to establish full accountability for groundwater contamination problems by treating the plume as a closed system. As with the other QEIC, it is assumed that the methodology for characterizing and monitoring contaminants in the groundwater and soil are adequate. If this QEIC cannot be effectively calculated, it would imply that the plume is not adequately characterized (Figures 6 and 7).

Figure 6

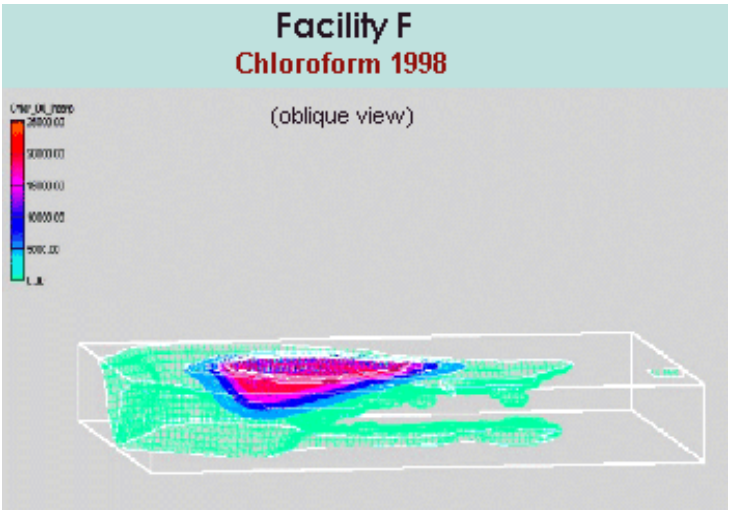
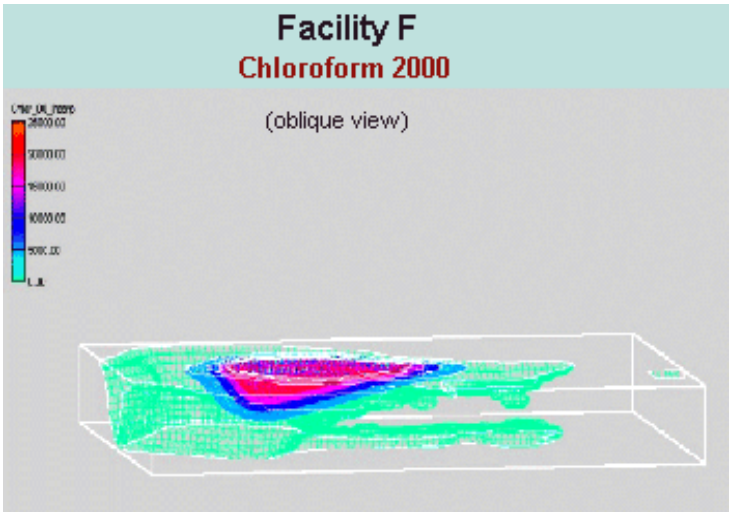


Figure 7



This model for mass calculation, without a dense population of monitoring wells at various depths assumes, by default, vertical boundaries for the plume. This is rarely true. Therefore the usefulness of this QEIC lies in the rate of change in the mass of contaminants in the plume. This trend should remain valid if the plume has been adequately characterized, even if some of the assumptions do not reflect the natural setting of the aquifer.

6. Amount of Extracted Groundwater Contamination QEIC:

Definition and Description:

The Amount of Extracted Groundwater Contamination QEIC is the mass of contaminants physically extracted from the plume by active remediation per year (e.g, 90 kilograms per year).

The QEIC record consists of both the mass of extracted contaminants removed from the dissolved phase and undissolved phase in the groundwater plume, per year, and percent change in this mass per year (e.g., 9 percent increase per year).

Example QEIC record = (90 kg/yr, + 9%/yr)

Data Sources and Procedure for Calculation:

The mass of contaminants extracted from the plume per year is calculated by multiplying the volume of water extracted per year by the average concentration of the water extracted.

That is to say,

> Extracted Mass (m_e) = Extracted Volume (v) x Contaminant Concentration (c); or $m_e = vc$.

This QEIC can include dissolved phase and undissolved phase (free product) contaminants.

Discussion:

The Amount of Groundwater Contamination Extracted QEIC documents the amount of contaminants physically extracted from the plume by active remedial actions (e.g., pumping) per year. This QEIC documents and tracks the efforts toward actively cleaning up a plume (Table 1.)

Table 1

Facility F
June 1990 - December 1991

C	D	E
Site Name:	Facility F	
Contaminant:	VOCs	
Date Range:	June 1990 - December 1991	
	Groundwater	
Area @ Time 1 (ft2)	**1,625,872.63**	
Area @ Time 2 (ft2)	**1,116,697.90**	
Change in Area (ft2)	-509,174.73	
Mass @ Time 1 (g)	108,291.59	
Mass @ Time 2 (g)	136,375.07	
Change in Mass (g)	28,083.48	
	Contaminant Movement	
Mass Extracted (g)	1,662,851.64	
Mass into SW (g)	0.00	
Mass from Soils (g)		
	Derived QEICs	
GW Extraction		
[illegible]	-0.01689	
Continuing Sources		
or Nat. Remediation		
Mass (g)	1,690,935.12	
Percentage		
a positive number suggests a continuing source a negative number suggests natural attenuation		
Minimum amount of		
unidentifed sources:		
Mass (g)	#REF!	
Percentage		

Facility F
December 1991 - January 1998

C	D	E
Site Name:	Facility F	
Contaminant:	VOCs	
Date Range:	December 1991 - January 1998	
	Groundwater	
Area @ Time 1 (ft2)	1,116,697.90	
Area @ Time 2 (ft2)	476,700.63	
Change in Area (ft2)	-639,997.27	
Mass @ Time 1 (g)	136,388.62	
Mass @ Time 2 (g)	8,915.74	
Change in Mass (g)	-127,472.88	
	Contaminant Movement	
Mass Extracted (g)	6,182,916.86	
Mass into SW (g)	0.00	
Mass from Soils (g)		
	Derived QEICs	
GW Extraction		
	0.02062	
Continuing Sources		
or Nat. Remediation		
Mass (g)	6,055,443.98	
Percentage		
a positive number suggests a continuing source a negative number suggests natural attenuation		
Minimum amount of		
unidentifed sources:		
Mass (g)	#REF!	
Percentage		

7. Amount of Contamination Transferred from Groundwater to Surface Water QEIC

Definition and Description:

The Amount of Contamination Transferred from Groundwater to Surface Water QEIC is the mass of contaminants, in excess of a facility's site specific groundwater cleanup standards, that is transferred (loaded) to surface waters per year (e.g., 54 kilograms per year).

The QEIC record consists of both the measured mass of contaminants transferred from groundwater to surface water per year, and the percent change per year (e.g., 10 percent decrease per year).

Example QEIC record = (54 kg/yr, -10%/yr)

This QEIC is applicable to both point and non-point sources.

Data Sources and Procedure for Calculation:

The data needed to calculate the mass of contaminants transferred from groundwater to surface water are contaminants concentration values from groundwater monitoring wells and selected physical characteristics of the aquifer. Ideally, the groundwater monitoring wells will be located on the landward side of the boundary between groundwater and surface water. This QEIC can include dissolved and undissolved phases (free product) contaminants.

Determination of the mass of contaminants transferred is done by calculating the volume of groundwater flowing to surface waters, within a specified period of time, multiplied by the average concentration of dissolved contaminants for that portion of the plume entering surface waters. The volume of groundwater transferred (i.e., the hydraulic discharge) is determined by using the Darcy equation.

That is to say,

> Amount of Groundwater Contamination Transferred to Surface Water (m_{sw}) = Hydraulic Discharge (Q) x Concentration (c); or, $m_{sw} = Qc$; where
>
> Hydraulic Discharge (Q) = Hydraulic Conductivity (K) x Hydraulic Gradient (i or dh/dl) x Cross-Sectional Area of the Groundwater Plume Discharging to Surface Waters (A); or, $Q = KiA$

This QEIC may also record the amount of groundwater contamination transferred from surface water <u>to</u> the groundwater, which may be permanent or occur seasonally. Net contaminant transfer to the groundwater is recorded in the QEIC record as a negative value (e.g., -54 kg/yr).

Discussion:

This QEIC measures the loading of contaminants associated with groundwater, either in dissolved or undissolved phases. It can be used to track the cumulative mass loadings of non-point discharges to surface water through time, in a similar fashion to those of point sources.

8. Amount of Leachable Soil Contamination QEIC:

Definition and Description:

The Amount of Leachable Soil Contamination QEIC is the mass of contaminants in soil above applicable cleanup standards for the protection of groundwater (e.g., 68 kilograms).

The QEIC record consists of both the measured mass of contaminants and the percent change per year (e.g., 15 percent decrease per year).

Example QEIC record = (68 kg, -15%/yr)

The term soil is used for all unsaturated loose solid media, excluding waste, above the water table. This QEIC measures the mass of contaminants contained in soil in concentrations that are predicted to leach and contaminate the groundwater at concentrations higher than groundwater standards.

Data Sources and Procedure for Calculation:

The data needed to calculate the Amount of Leachable Soil Contamination QEIC are contaminant concentrations in the soil above applicable cleanup standards for the protection of groundwater, and soil physical characteristics (including density). The Amount of Leachable Soil Contamination QEIC is calculated for contaminants at all depths of soil above the zone of groundwater saturation.

The mass of leachable soil contaminants is calculated by multiplying the mass of contaminated soil by the average concentration of contaminants above applicable standards. The mass of contaminated soil is determined by multiplying the volume of contaminated soil by the bulk density of the soil. The volume of contaminated soil is determined by multiplying the area of the soil, as previously determined in the Area of Leachable Soil Contamination QEIC, by the depth of the leachable contamination.

That is to say,

> Amount of Leachable Soil Contaminants (m_l) = Mass of Soil with Leachable Contamination (m_s) x Concentration of Leachable Soil Contamination (c) above groundwater protection standards; or, $m_l = m_s c$; where
>
> m_s = Volume of Leachable Soil (v) x soil bulk density( ); and v = Area of Leachable Soil Contamination (a) x Depth of Leachable Soil Contamination (d); or, $m_s = ad$

Discussion:

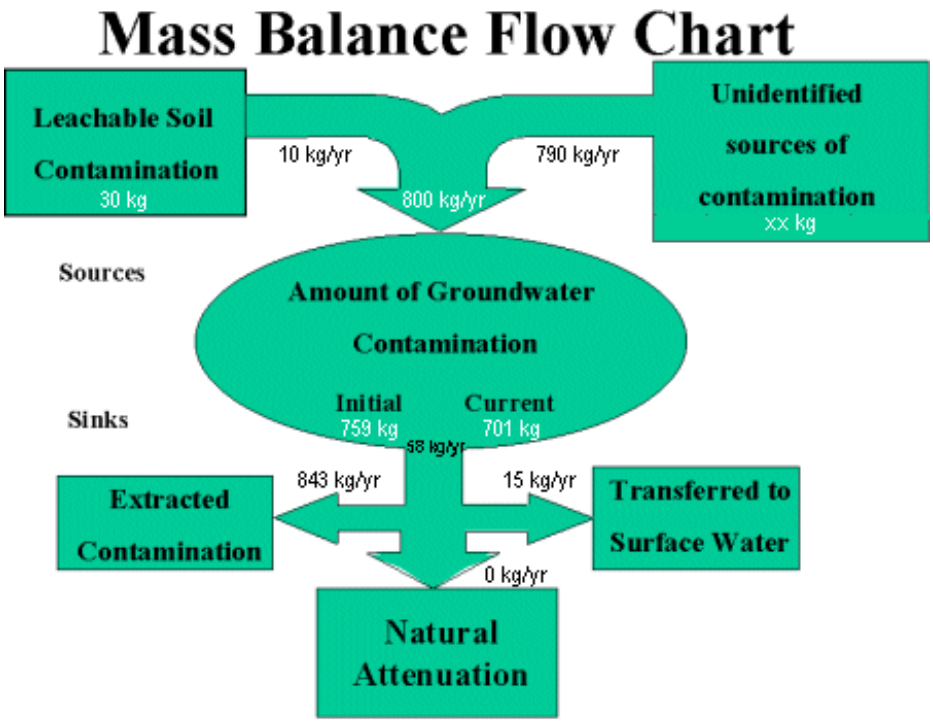
The measurement of the current amount of leachable soil contamination (e.g., in kilograms) documents the mass of contaminants in soil that is available as a contaminant source for

groundwater.

Level 4 - Derived QEICs

The QEICs previously discussed are based on direct measures of the environment, specifically contaminants in groundwater and soil. The following two QEICs are not directly measurable and must be derived from the measured QEIC values. They are able to be derived from the directly measured values when environmental contamination is seen as part of a closed system (see Figure 8.)

Figure 8



New York Case Example

A mass balance for a facility site is constructed using contaminant sources (inputs) and sinks (outputs). When the mass of contaminants in the groundwater changes, this should be explainable by the corresponding balance between the mass of contaminant inputs and the mass of contaminant outputs from the groundwater. When those mass values do not balance, as often happens, the existence of other operating processes can be inferred and their values derived, even though not directly measurable. These derived QEICs consist of two QEIC values:

9. Amount of Continuing Sources/Natural Attenuation for Contaminants in Groundwater QEIC:

Definition and Description:

The Amount of Continuing Sources/Natural Attenuation of Contaminants in Groundwater QEIC is either the mass of contamination added to, or removed from, the groundwater plume after accounting for known processes affecting contamination in the groundwater, per year (e.g., 23 kilograms per year).

The QEIC record consists of both the measured mass of dissolved contaminants added to (as in the example) or removed from the groundwater, per year, and the percent change per year (e.g., -6 percent decrease per year).

Example QEIC record = (23 kg/yr, -6%/yr)

If, during two sampling periods, the mass of contaminants remaining in the groundwater plume is more than the mass predicted by the known contaminants removal processes, specifically, the Amount of Extracted Contamination QEIC and the Amount of Contaminants Transferred to Surface Water, the excess mass can be reasonably ascribed to an unknown continuing source. The nature, location and amount of this continuing source cannot be determined. However, if it is large, this QEIC can support the need for a further investigation.

On the other hand, if, during two sampling periods, the mass of contaminants remaining in the groundwater plume is less than the mass predicted by the known contaminants removal processes, specifically, the Amount of Extracted Contamination QEIC and the Amount of Contaminants Transferred to Surface Water, the excess reduction in mass can be reasonably ascribed to an unknown reduction process, like natural attenuation.

Data Sources and Procedures for Calculation:

The Amount of Continuing Sources/Natural Attenuation to Groundwater QEIC ($m_{cs/na}$) is calculated by taking the change in the initial and the current Amount of Groundwater Contamination QEIC ($m_{initial} - m_{current}$) over the past measurement period, and then adding the combined total for the Amount of Groundwater Contamination Extracted QEIC (m_e) plus the Amount of Contamination Transferred from Groundwater to Surface Water QEIC (m_{sw}).

That is to say:

$$m_{cs/na} = (m_{current} - m_{initial}) + (m_e + m_{sw})$$

Positive values for $m_{cs/na}$ indicate the dominance of continuing sources to groundwater (adding contaminants to the groundwater). Negative values for $m_{cs/na}$ indicated the dominance of natural attenuation in groundwater (removing contaminants from the groundwater).

Three hypothetical examples have been developed to illustrate three sets of conclusions that can be drawn from this approach. They are included in Attachment 1.

Discussion:

The Amount of Continuing Sources/Natural Attenuation to Groundwater QEIC value documents only the dominant process operating, either the effect of continuing sources or natural attenuation. Both processes may be operating, but only the dominant one will have the observable (measurable) effect.

For example, continuing sources may be present and continuing to release (supply) contaminants to the groundwater but this would not be observable if the rate of natural attenuation exceeded the rate of contaminant releases (then only Natural Attenuation would be measurable). Similarly, a significant amount of contaminant reduction due to natural attenuation may be occurring but none would be observable if the amount of continuing sources to groundwater exceeded the amount of reduction due to natural attenuation processes.

The Amount of Continuing Sources/Natural Attenuation QEIC is useful for:

- initiating additional investigations for the unidentified continuing sources that can now be demonstrated to exist This information can be used to understand why remedial efforts such as groundwater contaminant extraction efforts are not effective (e.g., because additional sources are replacing the dissolved contaminants, perhaps even at a rate greater than they are being removed by the extraction system). This estimated value, provides knowledge of one of the most important elements for understanding of the nature of the contaminant setting, the overall environmental quality that can be expected in the future (because of the presence and magnitude of ongoing sources); or

- supporting demonstrations that natural attenuation processes are effective in reducing the contaminant mass within groundwater plumes, even though some continuing sources may still exist, without any further intervention.

10. Minimum Amount of Unidentified Sources to Groundwater QEIC:

Definition and Description:

The Minimum Amount of Unidentified Sources to Groundwater QEIC is the estimated minimum amount of contamination that is added to the groundwater from sources other than measured soil contamination, per year (e.g., 40 kilograms per year).

The QEIC record consists of both the measured minimum mass of contaminants from unidentified sources added to the groundwater and the percent change per year (e.g., 5 percent decrease per year).

Example QEIC record = (40 kg/yr, -5%/yr)

If it is demonstrated that contaminants continue to be contributed to the groundwater, then this mass may be from any number of unidentified sources. One of these sources may be from contaminants in the soil medium. This QEIC attempts to estimate the mass of contaminants that are actually leaching into the groundwater during a specified period of time (e.g., one year). This is a separate value from the mass of contaminants potentially available to leach to the groundwater (i.e., the Amount of Leachable Soil Contamination QEIC).

The true rate at which these contaminants are being released from the soil to the groundwater is unknown. However, this rate can be estimated. The accuracy of this estimate will depend on the amount and quality of the data available for the facility site. As a working assumption, the rate used here is that a maximum of one-third of the total mass of leachable soil contaminants will leach into groundwater during a one-year period. This value, or another one derived from site-specific data, is then subtracted from the mass of unaccounted for contaminants in the groundwater. The remaining mass value is then an estimate of the mass of contamination from the remaining unidentified sources to the groundwater. It is this mass that can serve as justification for the further investigation and location of unidentified contaminants sources to groundwater.

For example,

> if the Amount of Leachable Soil Contamination QEIC = 150 kg, then an estimate of the reasonable maximum value of the Amount of the Leachable Soil Contamination QEIC that could have leached over the last one-year period is one-third of that, or
>
> 50 kg/yr
>
> and, if the total Amount of Continuing Sources/Natural Attenuation QEIC is
>
> +300 kg/yr
> (i.e., a continuing source)
>
> then the Estimated Amount of Unidentified Sources to Groundwater QEIC is
>
> 250 kg/yr

Data Sources and Procedures for Calculation:

The Estimated Amount of Unidentified Sources to Groundwater QEIC (m_{us}) is calculated by taking the amount of continuing sources from the Amount of Continuing Sources/Natural Attenuation to Groundwater QEIC ($m_{cs/na}$) and subtracting one-third of the Amount of Leachable Soil QEIC (m_l).

That is to say,

$$m_{us} = m_{cs/na} - 1/3\ m_l$$

Discussion:

The mass of contaminants able to be leached, within a one year period, of one-third the total mass available to be leached is a reasonable worst-case assumption. The amount of leachable soil contamination is typically measured in soil where the contamination has been present for some number of years. It is unlikely that more than one-third of the measured soil contamination would leach out over the most recent one-year period, unless the release was very recent and still mobile. A situation of very highly mobile contaminants may call for more immediate interim remedial actions rather than simple analysis for characterization purposes.

The one-third mass assumption, as a maximum value, will usually be an over-estimate. The Estimated Amount of Unidentified Sources to Groundwater QEIC, based on this assumption, will therefore usually yield a minimum value. The purpose of this estimate is to document the basis for initiating an investigation into the nature and location of these unidentified sources.