SGW-34760 Revision 0 S

Pipeline Removal vs. Characterization Study

Prepared for the U.S. Department of Energy Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the U.S. Department of Energy under Contract DE-AC06-96RL13200

FLUOR.

P.O. Box 1000 Richland, Washington

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SGW-34760 Revision 0 EDC #: HNF-EDC-07-34761 FMP #: N/A

Pipeline Removal vs. Characterization Study

Project No: N/A

Document Type: TR

Program/Project: SGWRP

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Date Published September 2007

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AUG 2 8 2007
AUG DATE: HANFORD RELEASE ID:

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Printed in the United States of America

Total Pages: 196

Executive Summary

The purpose of this document is to provide a decision support tool for comparing pipe excavation/removal costs with the costs to characterize a pipeline. Characterizing a pipeline involves obtaining and analyzing the number of samples required at different confidence levels to determine if action levels for contaminants are not exceeded. The decision support tool can be used to help predict the break point at which one method exceeds the cost of the other method. Determining which method is more cost effective results in the potential for cost avoidance.

The first part of this activity provides a statistical evaluation of the number of samples to demonstrate, at several confidence intervals, that action levels for contaminants are not exceeded. A range of confidence intervals is used to allow for the potential for demonstrating ability to meet action levels (AL) at levels of varying statistical rigor, with resulting potential for cost avoidance. The confidence levels of 80, 85, 90, and 95 percent upper confidence level are used and summarized from section 2.8 below.

Confidenc e Level	Width of Gray region	Alpha	Beta			Number of	of Samples		- Rive-
				1 sample t-test	1 sample Proportion	Wilcoxon Sign test	2 sample t-test	2 sample Proportion	Wilcoxon Rank Sum
80%	5% of AL	1%	20 %	380	1041	245	255	1526	106
85 %	5% of AL	1 %	15 %	428	1179	276	287	1719	119
90%	5% of AL	1%	10 %	492	1366	318	330	1979	137
95%	5% of AL	1%	5%	596	1667	386	399	2398	166

The statistical evaluation provides an estimate for the number of samples and costs needed to enable the stated confidence levels. As an example, the cost for analyzing 403 samples is \$4,608,305 (see Table 4 at a 95% confidence level).

The second part of this activity provides a cost estimate in dollars per linear foot for excavating pipeline types (materials of construction) and sizes and depths. Pipe materials include stainless and carbon steel, concrete and reinforced concrete, and vitrified clay pipe. Depths evaluated include 5, 10, 15, 20, and 25 feet below ground surface. For example, pipe excavation/removal costs range from \$2,608 to \$13,027 per foot (\$38.24 to \$8.49 per cubic foot) for vitrified clay pipe at different depths and diameters.

Pipe excavation/removal costs are compared to sampling and analysis costs. For the examples presented in this document, the cost to excavate vitrified clay pipe is compared to the cost for taking and analyzing a number of samples at various confidence levels. Excavation costs for the other pipe types, steel and concrete are similar to vitrified clay pipe. Based on the scenarios and examples presented in this document, the cost for sampling is more than the cost for excavation/removal. If the contaminated region is not known, the number of characterization samples required is independent of pipe length. This decision support tool can be used to help predict the break point at which the cost of sampling exceeds the cost for excavation.

The decision support tool is only as good as the inputs used in the Excel® spreadsheets. As described below the tool has limitations and areas for improvement. Further, the assumption that the contaminated volume is restricted to 2 pipe diameters from the pipe could be significantly different than actual conditions. This situation does not account for leaking pipelines and the possible need to chase or clean up the contaminated soil associated with a leak. Finally, the tool used for estimating the cost associated with the number of samples does not take into account the depth of the buried pipe, it only accounts for the contaminated region around the pipe. Samples taken at 25 foot depth are considerably more expensive than samples taken at a 5 foot depth. In some cases it might be necessary to exhume much of the waste site just to obtain the required samples. Finally, recent experience by Fluor Hanford has found that the costs of removing all types of piping 2 feet in diameter or below costs about the same, due to the physical realities of doing excavation and the fact that piping of any material of that diameter or below is easy to shear or size reduce. This experience implies that the estimate for pipes 2 feet in diameter and less (2 inches, 6 inches, 12 inches and 24 inches) can be combined into one estimate.

The decision support tool provides a method for comparing excavation/pipe removal costs with characterization sampling and analysis costs to aid in deciding whether to remove the pipe or leave it in place. While the actual costs will be situation-specific, the generalizations in this study provide good approximations for alternative analysis and can indicate where more detailed analyses are needed. The pipe excavation estimate spreadsheet developed for this study can easily be modified to evaluate situations on a case-by-case basis and provide more detailed cost estimates. Ultimately, the decision will be influenced by factors such as regulatory requirements, stakeholder interests, safety concerns, programmatic decisions, and risk reduction in addition to cost. The decision support tool does not assign values to these factors.

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Glossary, Acronyms, Definitions

AL	Action Level
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
DCGL	Derived Concentration Guideline Levels
DQO	Data Quality Objectives
DOT	Department of Transportation
EPA	Environmental Protection Agency
FH	Fluor Hanford
Width of gray region	UBGR - LBGR
LBGR	Lower Bound of the Gray Region
MARSAME	Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
RCRA	Resource Conservation and Recovery Act.
S&M	Surveillance and Maintenance
sow	Statement of Work
UBGR	Upper Bound of the Gray Region
WAC	Waste Acceptance Criteria

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1. Introduction

The Hanford Site is a former weapons-production complex managed by the U.S. Department of Energy (DOE). The 580 mi² Site, located in southeastern Washington State, produced about 60 percent of the United States' plutonium from the mid-1940s to the late 1980s to support national defense. In 1989 the DOE announced that the production facilities were being shut down and the Site mission was changing to environmental restoration. The Central Plateau portion of the Hanford Site covers approximately 75 mi² near the center of the Site. The legacy waste and contaminated materials from the Hanford Site defense production mission remain on the Central Plateau in canyon buildings, underground tanks, waste sites, and other structures. The waste and contaminated materials present a risk to remediation workers and the environment.

As a result of former waste disposal practices, high volumes of contaminants were discharged to more than 800 waste sites on the Central Plateau, including cribs, ponds, trenches, and burial grounds. Some of these contaminants present a risk to the underlying groundwater and the nearby Columbia River. Other contaminants present are not mobile enough to be considered groundwater concerns, but are present in sufficient quantities to present a hazard to human health and the environment.

Many of the waste sites include sections of buried pipeline of varying depths, piping materials, and contamination levels. Several hundred miles of pipeline are within these waste sites, resulting in significant work scope for whatever remediation methods are chosen. The overall remediation goal is to protect human health and the environment.

It is desired to minimize the costs associated with remediation efforts. Knowing the relative costs between removal and sampling to assess contamination extent to guide remediation paths may allow one or the other to be substantially avoided during remediation and thereby reduce costs, while achieving the same remediation goals. This study provides a Decision Support Tool to aid evaluating breakpoints where it becomes more cost effective to remove a subsurface pipeline rather that to characterize it sufficiently to prove that leaving in place is protective of human health and the environment.

1.1 Project Scope

Project scope for this report is in two parts. The first part provides a statistical evaluation of the number of samples for a given length of pipeline to demonstrate, at several confidence intervals, that action levels for contaminants are not exceeded. A range of confidence intervals is used to allow for the potential for demonstrating ability to meet action levels at levels of varying statistical rigor, with resulting potential for cost avoidance. The confidence levels of 80, 85, 90, and 95 percent upper confidence level are used. The statistical evaluation provides an estimate for the number of samples needed to enable the stated confidence levels.

The second part of this activity provides a cost estimate in dollars per linear foot for excavating various pipeline types (materials of construction) and sizes and depths. Depths evaluated include 5, 10, 15, 20, and 25 feet below ground surface. Pipeline materials of construction include:

- Vitrified clay
- Stainless and carbon steel
- Concrete masonry
- Reinforced concrete

Pipeline sizes vary from 2 to 48 inches in diameter. Table 1 provides a list of pipeline types and diameters. Combinations shaded in gray are excluded from this study because these combinations of diameter and material do not exist in the piping industry and therefore do not exist at the Hanford site. The combinations of diameter and material (shaded in yellow), while not explicitly determined to exist at the Hanford site, represent combinations used in the piping industry and therefore have a potential to exist at the Hanford site (potentially applicable). The combinations of diameter and material (shaded in green) are known to exist at the Hanford site as confirmed by site drawings/documents (definitely applicable). The cost estimate focused on the cost associated with clean and contaminated soil excavation and pipeline removal. Other costs such as fixed costs associated with mobilization and demobilization are included but should be tailored or modified to fit specific remediation jobs.

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Table 1 - Probable Underground Pipe Combinations

	Pipe Diameter (inches)							
Pipeline Material	2	6	12	24	36	48		
Vitreous Clay	A 100 CO			100000	1 Kilder spile	300		
Steel (stainless /carbon)	4652	Billion Rock			W 38-0	Accepted.		
Concrete Masonry	30 M	XXXXX	\$10.00E	- Charles of	N R R W	1000		
Reinforced Concrete	erozenia.	第二章 00年末期2	\$20 0 B	非国际协		La Madecia d		

= Not Applicable
= Potentially Applicable
= Definitely Applicable

Finally, the two estimating techniques are compared to provide a decision support tool to aid evaluating breakpoints where it becomes more cost effective to remove a subsurface pipeline rather that to characterize it sufficiently to prove that leaving in place is protective of human health and the environment.

1.2 Project Goals

The goal of this study is to provide a decision support tool addressing the question: for a given length, type of pipeline, and depth, will it be more cost effective to sample the piping to determine contaminant levels or to simply excavate and dispose of the piping (and any associated contaminated soil)?

It is desired to minimize the costs associated with remediation efforts. Knowing the relative costs between removal and sampling may allow one or the other to be substantially avoided during remediation and thereby reduce costs, while achieving the same remediation goals.

The goal of this task is to provide a decision support tool to allow objective cost evaluations of the separate pipeline remediation/closure activities of 1) removal and 2) sampling and characterization. The tool should be applicable to any section of subsurface pipeline on the Hanford Site. The objective of this task is to allow defensible comparisons of the costs associated with remediation of a site by 1) removal of subsurface pipeline sections (with subsequent disposal) versus 2) sampling and characterization of the pipeline (to support a range of possible remediation activities from no action to disposal).

1.3 Assumptions

The following list comprises assumptions used in the development of the Decision Support Tool. These assumptions form the basis for the Excel spreadsheets used in the statistical analysis to define the number of samples needed at various confidence intervals to remain below action levels for remediation and the Excel spreadsheets used to estimate the cost for excavating and removing various size buried pipe lines.

- All activities are governed by RCRA or CERCLA and applicable regulatory agreements, although some sites will be governed by an integrated RCRA/CERCLA approach.
- Wastes generated from sampling, characterization and excavation activities will be disposed at the Environmental Restoration and Disposal Facility (ERDF).
- · Sampling will be for alpha, beta, gamma, and chemical constituents.
- Pipe excavation cost includes excavation, removal and placement of the pipe in an ERDF roll off burial box or ERDF can. The point of termination for excavation cost is filled ERDF cans with soil or broken clay pipe or pipe debris. The standard ERDF can or roll off box will be used for disposal of contaminated waste at ERDF. The ERDF disposal box holds 13 bank cubic yards of soil. Excavated soil expands when it is loaded in the box and the ERDF box will hold 13 15 cubic yards. The ERDF box will hold larger volumes but is limited to 13 bank cubic yards due to weight limits.
- Contaminated pipe debris and soil will be disposed at ERDF. Clean excavated soil will be placed in spoil
 piles near the excavation and may be used for backfill after pipe removal. The trench volume excavated

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will be assumed to be clean soil down to a point two pipe diameters above the top outer diameter of the pipe. Below that point, all soil (plus piping) to a point two pipe diameters below the bottom outer diameter of the pipe will be considered contaminated and be removed.

- It is assumed that metal piping types will require in-trench size reduction (cut lengthwise), with heavy
 equipment to fit in disposal containers, while vitrified clay piping is assumed to be readily mechanically
 broken within the trench for disposal. Cost estimation includes these operations.
- Transuranic (TRU) waste has been excluded from the scope of this study
- Remote handled waste is not expected from pipe excavation (excluded from scope).
- Candidate piping systems include steam condensate, cooling water, process condensate, process waste, and chemical sewer lines.
- Excavated trench will include side sloping necessary to remove the pipe or provide personnel access to the trench for sampling and characterization. Slope will be 1.5 to 1 for Hanford soils. This slope is assumed to be adequate for safe personnel access and trench boxes or shoring will not be required.
- Costs for sampling need to be included in the cost estimate totals. Laboratory analytical cost per soil sample will be assumed for the purposes of this study to be \$11,385 per single soil sample. Any costs for sampling of actual piping or contaminated soil can also be provided (but is excluded from the scope). It is assumed that one pit and sampling collection (labor and materials) would cost \$12500 for the first sample, with \$600 for every additional sample. Note that one pit would take ~1 day but 3 pits could be done in 2 days due to economy of already mobilized forces. Therefore for example a 100' pipeline would take 3 pits and 2 days or \$25000 for the first sample in each of the 3 pits. On a per foot basis, the costs for the first sample would be \$250/foot, with a minimum of \$12500.
- Sampling may occur by bore hole, test pit or other means.
- Internal space of pipe will be sampled.
- Assume pipe systems are single pipe lines (no multiple line systems or encased systems).
- The following pipe sizes may be excluded since these are not known to exist on the Hanford site.

Stainless Steel pipe greater than 12 inches diameter

Carbon steel pipe greater than 24 inches

Concrete pipe less than 12 inches diameter

Vitrified clay pipe less than 12 inches and greater than 36 inches

- An excavation length of 100 ft was chosen for this evaluation for the following reasons:
 - It allows meaningful comparison between excavation and sampling activities.
 - It represents a median length of typical pipe runs.
 - It provides a good balance between fixed costs (i.e., mobilization and demobilization) and unit costs without inflating (or deflating) the fixed costs.

The ultimate result of the excavation estimate is to provide a cost per linear foot of pipe removed. The spreadsheet can be modified to input the exact pipe length if the scenario dictates a higher level of estimate fidelity.

- The estimate assumes that any crushing or flattening of pipe to eliminate void space will be performed at the disposal site. Cost associated with this is included in the waste disposal charge line item.
- Statistical analysis for sampling confidence will be performed based on the following references:
 - 1. EPA QA/G-9S, "Data Quality Assessment: Statistical Methods for Practitioners"
 - EPA QA/G-9R, "Data Quality Assessment: A Reviewers Guide"
 - 3. EPA OA/G-5S, "Guidance on Choosing a Sampling Design for Environmental Data Collection"
- Upper confidence levels evaluated are 80, 85, 90, and 95%.
- Action levels for specific contaminants of concern are not used in this analysis. If needed, reference 6.9
 provides examples of action levels.

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1.4 Contributors

Principal contributors to this study include:

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2. Statistical Sampling Evaluation

The purpose of this section is to provide a statistical evaluation of the number of samples required for a given length of pipeline to demonstrate, at several confidence levels, that the action levels for contaminants are not exceeded. A range of confidence levels is desired to allow for the potential for demonstrating ability to meet the action levels at varying levels of statistical rigor, with resulting potential for cost avoidance. The confidence levels of 80, 85, 90, and 95% upper confidence levels should be used, although alternate statistical treatments may be performed subject to approval by Fluor Hanford. The statistical evaluation should be representative of the number of samples needed to enable the stated confidence levels.

The purpose of this decision support tool is to provide decision-making activities as they pertain to the potential remedial action (RA) activities associated with pipe removal, sampling and characterization at the Hanford site and potential removal of contaminated soils. The former weapons production complex includes sections of buried pipeline of varying depths, piping materials and contamination levels. This study supports, and results in, a logical systematic approach to sampling the residual soils, and decision making. Data from this sampling effort will be used to minimize the costs associated with remediation efforts and comparison to regulated soil clean up levels to determine if additional soil remediation is required prior to formal site closure. The sections which follow provide the necessary information and decisions made by the site owner and regulators that result in a sampling approach that will satisfy all decision needs.

2.1 Action Levels

Action levels, if needed, will be consistent with Decisional Draft DOE/RL-2007-02, Rev 0, Appendix E Action Levels and DOE/RL-2002-14, Rev ! Work Plan. Specific action levels have not been applied to the development of the decision support tool.

2.2 Preliminary Activities

Preliminary activities affecting any area of concern are initially identified and investigated in the scoping or historical assessment stage. The activities may be reviewing historical data, performing additional surveys, determining no information is available, etc, which are explained in more detail below. These preliminary activities provide an informed identification of the initial scope and bound of the activities needed to characterize the pipe identified. The information and data obtained during these preliminary activities is essential to establishing the correct statistical parameters used to characterize the site.

2.2.1 Scoping Process

The scoping process is conducted by assigning responsibilities and completion target dates in the scoping checklist, Table 2. The objective of the scoping checklist is to provide a comprehensive tool that ensures that all relevant and available project information is obtained, analyzed, evaluated, and summarized. This checklist requires the investigator to determine information such as site history, risk drivers, operational concerns, safety concerns, radionuclides present, hazardous materials present and waste designations. The table allows tracking by providing space to put a check in column one when a task is completed. The scoping process results provide the basis for much of the statistical analysis decisions.

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Table 2 - Scoping Checklist

Completed	Item	Responsibility	Completion Date
1.	Historical site assessment		
2.	Study areas defined		
3.	Summary of existing data, surveys, lab results, monitoring results		
4.	Summary of recorded spills		
5.	Current facility conditions		
6.	Current environmental conditions		
7.	Current safety conditions		
8.	Radionuclides present		
9.	Hazardous materials present		
10.	Waste on site		
11.	Additional issues	10000	

2.2.1.1 Historical Site Assessment (HSA) or Initial Assessment

Provide a brief description of the history of the facility, site, or study area. Discuss when and why the facility, site, or study area was originally developed and how it has been used over the years to the present. Describe the general design and dimensions of the facility or survey area, year of construction, types of improvements, and reference facility drawings. Describe the process history for facility operations from the time the facility began operations until the time it ceased operations. Categorize the survey areas as impacted or non-impacted.

Identify all regulatory criteria pertinent to the site, including action level criteria or regulatory limits, which may be dose, risk or activity based. Identify applicable administrative limits associated with disposal site Waste Acceptance Criteria (WAC). Identify applicable Department of Transportation (DOT) requirements for shipping waste material.

2.2.1.2 Study Area Defined

Describe any previous areas which have been identified as needing investigation, remediation of further action. Provide specific information such as location, blue print or map reference. Also clearly identify areas which will not be included.

2.2.1.3 Summary of Existing Data

Discuss any existing data that is relevant to the facility, site, or study area and that might influence the way this study will be developed. Provide a summary of all existing analytical data, survey data, laboratory results or relevant information. A thorough understanding of these data is essential to the statistical process since it is the basis for defining the conceptual model. An understanding of the variance and other statistical parameters for the existing data may also be valuable to the sampling design. Identify all derived concentration guideline levels (DCGL) which have been developed for the site.

2.2.1.4 Summary of Recorded Spills

The historical site assessment and existing data review may cover this area in sufficient detail, however, if possible interview individuals who worked at the area prior to the initial acceptance of RCRA. This may bring to light previous activities in areas long forgotten.

2.2.1.5 Current Conditions

Discuss any steps that are currently being taken to maintain the facility, site, or study area, to prevent further contamination from occurring, and/or to minimize risk to human health and the environment. Identify the current housekeeping practices such as mopping or vacuuming floors to prevent dust buildup. This information is important to understand the potential migration of contaminant. Identify any outdoor actions which are present to prevent contaminant migration to the soil and to water pathways, such as silt fences and collection areas. Identify all safety concerns involved with the facility, building(s), and area. These should be useful in incorporating into job hazard

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analyses. Identify personnel protective equipment and measures needed to protect workers. Identify industrial hygiene sampling requirements.

2.2.1.6 Materials Present

Identify the scope of radionuclides present on the site from the HSA. Determine all hazardous materials on site and the associated quantities. Provide an inventory of waste on site by types and quantities.

2.2.1.7 Scoping Issues

Scoping issues are unresolved questions that surface while conducting the scoping process and that need to be resolved before the project can proceed. For example, historical documents may differ in their descriptions of the processes, radionuclides or chemicals used at a given site, or in a given area. If there are uncertainties regarding the processes or chemicals that were used, it will be difficult to develop a list of contaminants of concern.

2.2.2 Conceptual Model

If during the above steps information is not sufficient to support a complete decision of reuse, recycle, disposal or maintain as current, a conceptual model to support activities should be developed. This model describes the radioactivity suspected for the project. The determination of impacted or non-impacted should be supported by the model. The determination of data gaps and potential disposition strategies should be given.

2.2.3 Summary

At this step a summary of an area of concern is developed which ties all of the above items into a document that is useful for further planning. This document can cover one single area or may cover a group of related areas having similar characteristics. In developing areas of concern the Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual (MARSAME), Draft for comment, NUREG 1575, Supplement 1, EPA 402-R-06-002, DOE-EH-707, December 2006 uses the term categorization to determine if material or equipment are impacted or not impacted. This leads to an appropriate level of survey for disposition of the material from a survey unit. The survey unit provides the spatial boundaries for the disposition decision similar to the MARSSIM (NUREG 1575, Multi Agency Radiation Survey and Site Investigation Manual (MARSSIM), Rev. 1, August 2000). Guidance on classifying areas based on the potential level of residual radioactive material to provide the appropriate level of survey effort relative to the established the action level criteria. Survey and size requirements are specific to each class, Table 3, with more detailed requirements for those areas with potentially higher levels of contamination. The classifications and associated survey requirements are:

- Class 1 areas are: (1) those where residual contamination, prior to any remediation, are likely to exceed
 applicable unrestricted action level criteria; (2) have the highest potential for small areas of elevated
 contamination; and (3) insufficient evidence is available to reclassify the area as Class 2 or Class 3.
- Class 2 areas are: (1) those where the potential for residual contamination exists, but is unlikely to exceed
 the applicable unrestricted action level criteria; and (2) little or no potential for small areas of elevated
 contamination.
- Class 3 areas are: (1) those where measurable levels of residual contamination are unlikely above background; and (2) insufficient evidence to support categorization as non-impacted.

Table	3 - Area	Classification	n Requirements	
-	20.0	111.64	56	Va. 12

Classification	Area Size	Percent of Total Area
Class 1 structures	up to 100 m ² surface area	100%
Class I land areas	up to 2,000 m ²	100%
Class 2 land areas	2,000 m ² to 10,000 m ²	10% ¹ to 100%
Class 3 areas	2,000 m ² to 10,000 m ²	May be less than 10%

2.3 Decision Criteria

At this point areas of potential contamination have been determined and the question needs to be developed to determine what actions are needed. Consequences of these actions also need to be identified such that decision levels may start to be developed which are based on statistical decisions. The decision point of this study is to

¹ This percentage depends on the DQO process, reference 6.10.

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determine if it is more cost effective to remove a section of pipe without sampling or characterize the pipe without remediation and achieve the same remediation goals. These decision criteria will be developed for 4 separate decision levels (80%, 85%, 90%, 95% confidence level) based on statistical modeling.

The null hypothesis (H₀) tested for in this plan is that contamination exceeds the action level. The alternative hypothesis (H₂ or H₁) is that residual contamination meets the action level criterion. The statistical tests used will attempt to reject the null hypothesis.

Type I decision error: A decision error that occurs when the *null hypothesis* is rejected when it is true. The probability of making a *Type I decision error* is called *alpha* (a). This is termed a false positive error.

Type II decision error: A decision error that occurs when the null hypothesis is accepted when it is false. The probability of making a Type II decision error is called beta (β). This is termed a false negative error.

If the action level (AL) for the contaminant is not zero, the surveys are designed to provide sufficient evidence about the contaminant concentration (X) to disprove H_0 , with H_0 : $X \ge AL$ (see section 2.1 on action levels). Any decision criteria will require a combination of accepting a probability for both error types. The risk of deciding a contaminant is not present when it truly is present provides a more severe problem because the potential consequences of this decision error include risk to human health and the environment. Therefore, a more stringent limit is typically set for the α parameter than the β parameter.

2.3.1 Develop Limits on Decision Errors

The decision process starts with determining the region where relatively large decision error rates are considered tolerable. This is referred to as the gray region. The amount of data available influences the width of the gray region. This region can be revised depending on the power of the hypothesis test. A limit must be set for a tolerable false negative decision error rate and a tolerable false positive decision error rate. The combination of these limits will be very close to the 4 separate decision levels (80%, 85%, 90%, 95% confidence level) used here. The lower bound of the gray region (LBGR) is selected depending on data availability for the site. Further information on the LBGR can be found in References 6.3, 6.5, 6.7, and 6.8.

Determine data user's objectives for the contaminant of concern and relate it to a possible background level. Translate the data user's objectives into limits on Type I or Type II decision errors. If Data Quality Objectives (DQO's) have not been developed, document the probable tolerable limits on decision errors, width of gray region, and estimated preliminary values. If DQO's were developed, confirm the limits on decision errors.

2.3.2 Information Needs

The relevant information needed to make the decision will be tabulated and analyzed for usability. This information include items such as radionuclides of concern, chemicals of concern, standard deviation, lower and upper bound of the gray region, and other data collected in the DQO process, Additional samples may be required. The areas of concern will be isolated into individual survey units that will be treated as separate cases. Each individual case will be uniquely identified. Spatial and temporal components will be identified such that data collection and use will be representative of the population. It is very important to define the population clearly and exactly. The population is the total area, volume, and/or time interval that apply to the decision (once made). If the population is not well defined, it will be unclear to what the decision applies. Time is included to take into account potential migration into or out of the area.

2.3.3 Preliminary Data Review

The action levels for radionuclides and chemicals must be established and clearly identified prior to any sampling or remediation. These criteria assist in establishing decision levels with the statistical parameters used to test the hypothesis. These criteria may be regulatory or risk based parameters. The relationship of the data received to the action level needs to be established. This asks the question of whether the action level is "equal to" or "less than" the numerical value. This study uses confidence interval statistics at 80%, 85%, 90% and 95%.

When there is existing data it will be analyzed for applicability by determining the following statistical parameters for each radionuclide or chemical of concern:

- Measure of relative standing
- Measure of central tendency

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Measure of dispersion

Measures of association, where applicable

2.3.3.1 Measures of Relative Standing

Sometimes the analyst is interested in knowing the relative position of one or several observations in relation to all of the observations. Percentiles or quantiles are measures of relative standing that are useful for summarizing data. A percentile is the data value that is greater than or equal to a given percentage of the data values. Stated in mathematical terms, the p^{th} percentile is a data value that is greater than or equal to p^{th} of the data values and is less than or equal to (1-p)% of the data values. Therefore, if 'x' is the p^{th} percentile, then p^{th} of the values in the data set are less than or equal to x, and (100-p)% of the values are greater than x. A sample percentile may fall between a pair of observations. For example, the 75th percentile of a data set of 10 observations is not uniquely defined. Therefore, there are several methods for computing sample percentiles, the most common of which is described below.

Let $X_1, X_2, ..., X_n$ represent the *n* data points. To compute the p^{th} percentile, y(p), first rank the data from smallest to largest and label these points $X_{(1)}, X_{(2)}, ..., X_{(n)}$ so that $X_{(1)}$ is the smallest, $X_{(2)}$ is the second smallest, and $X_{(n)}$ is the largest). Let t = ap/100, and multiply the sample size n by t. Divide the result in to the integer part and the fractional part, i.e., let n = j + g where j is the integer part and g is the fraction part. Then the p^{th} percentile is calculated by:

if
$$g = 0$$
, $y(p) = (X_{(j)} + X_{(j+1)})/2$ (1 otherwise, $y(p) = X_{(j+1)}$

2.3.3.2 Measures of Central Tendency

Measures of central tendency characterize the center of a data set. The three most common estimates are the mean, median, and the mode. Directions for calculating these quantities are given below.

The most commonly used measure of the center of a data set is the sample mean, denoted by \overline{X} . The sample mean can be thought of as the "center of gravity" of the data set. The sample mean is an arithmetic average for simple sampling designs; however, for complex sampling designs, such as stratification, the sample mean is a weighted arithmetic average. The sample mean is influenced by extreme values (large or small) and the treatment of non-detects.

The sample median is the second most popular measure of the center of the data. This value falls directly in the middle of the ordered data set. This means that ½ of the data are smaller than the sample median and ½ of the data are larger than the sample median. The median is another name for the 50th percentile. The median is not influenced by extreme values and can easily be used if non-detects are present.

Another method of measuring the center of the data is the sample mode. The sample mode is the value that occurs with the greatest frequency. Since the sample mode may not exist or be unique, it is the least commonly used measure of center. However, the mode is useful for qualitative data.

Let $X_1, X_2, ..., X_n$ represent the n data points.

Sample Mean: The sample mean, \overline{X} , is the sum of the data points divided by the sample size, n:

$$\overline{X} = \frac{1}{n} \sum_{i=1}^{n} X_i \tag{2}$$

Sample Median: The sample median, X, is the center of the ordered data set. To compute the sample median, sort the data from smallest to largest and label these points $X_{(1)}, X_{(2)}, \ldots, X_{(n)}$. Then,

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$$\tilde{x} = \begin{cases} \frac{1}{2} \left[X_{(n/2)} + X_{((n/2)+1)} \right] & \text{if } n \text{ is even} \\ X_{((n+1)/2)} & \text{if } n \text{ is odd} \end{cases}$$
(3)

Sample Mode: The sample mode is the value in the sample that occurs with the greatest frequency. The sample mode may not exist or be unique. Count the number of times each value occurs. The sample mode is the value that occurs most frequently.

2.3.3.3 Measures of Dispersion

Measures of central tendency are more meaningful if accompanied by a measure of the spread of values about the center. Measures of dispersion in a data set include the range, variance, sample standard deviation, coefficient of variation, and the interquartile range. Directions for computing these measures are given below.

Let $X_1, X_2, ..., X_n$ represent the n data points.

Sample Range: The sample range, R, is the difference between the largest and smallest values of the data set, i.e., $R = \max(X_i)$ - $\min(X_i)$.

Sample Variance: To compute the sample variance, s^2 , compute:

$$s^{2} = \frac{\sum_{i=1}^{n} X_{i}^{2} - \frac{1}{n} \left(\sum_{i=1}^{n} X_{i} \right)^{2}}{n-1}$$
 (4)

Sample Standard Deviation: The sample standard deviation, s, is the square root of the sample variance,

$$s = \sqrt{s^2} \tag{5}$$

Coefficient of Variation: The coefficient of variation (CV) is the sample standard deviation divided by the sample mean i.e., $CV = s / \overline{X}$. The CV is often expressed as a percentage.

Interquartile Range: The interquartile range (IQR) is the difference between the 75th and the 25^{th} percentiles, i.e., IQR = y(75) - y(25).

The easiest measure of dispersion to compute is the sample range. For small samples, the range is easy to interpret and may adequately represent the dispersion of the data. For large samples, the range is not very informative because it only considers extreme values and is therefore greatly influenced by outliers.

Generally speaking, the sample variance measures the average squared distance of data points from the sample mean. A large sample variance implies the data are not clustered close to the mean. A small sample variance (relative to the mean) implies most of the data are near the mean. The sample variance is affected by extreme values and by a large number of non-detects.

The sample standard deviation is the square root of the sample variance and has the same unit of measure as the data. The coefficient of variation (CV) is a measure having no units that allows the comparison of dispersion across several sets of data. The CV (also known as the relative standard deviation) is often used in environmental applications because variability (when expressed as a standard deviation) is often proportional to the mean.

When extreme values are present, the interquartile range may be more representative of the dispersion of the data than the standard deviation. This statistical quantity is the difference of the 75th and 25th percentiles and therefore, is not influenced by extreme values.

2.3.3.4 Measures of Association

Data sets often include measurements of several characteristics (variables) for each sampling point. There may be interest in understanding the relationship or level of association between two or more of these variables. The

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relationship between two variables may not be applicable in all situations for this project. One of the most common measures of association is the correlation coefficient. The correlation coefficient measures the relationship between two variables, such as a linear relationship between two sets of measurements. It is very important to note that the correlation coefficient does not imply cause and effect. The analyst may say the correlation between two variables is high and the relationship is strong, but may not say an increase or decrease in one variable causes the other variable to increase or decrease without further evidence and strong statistical controls.

The Pearson correlation coefficient measures the strength of the linear relationship between two variables. A linear association implies that as one variable increases, the other increases or decreases linearly. Values of the correlation coefficient close to +1 (positive correlation) imply that as one variable increases, the other increases nearly linearly. On the other hand, a correlation coefficient close to -1 implies that as one variable increases, the other decreases nearly linearly. Values close to 0 imply little linear correlation between the variables. When data are truly independent, the correlation between data points is zero (note, however, that a correlation of 0 does not necessarily imply independence).

The correlation coefficient does not detect nonlinear relationships so it should be used only in conjunction with a scatter plot. A scatter plot can be used to determine if the correlation coefficient is meaningful or if some measure of nonlinear relationships should be used. The correlation coefficient can be significantly influenced by extreme values so a scatter plot should be used first to identify such values.

Pearson's correlation may be sensitive to the presence of one or two extreme values, especially when sample sizes are small. Such values may result in a high correlation, suggesting a strong linear trend, when only moderate trend is present. This may happen, for instance, if a single (X,Y) pair has very high values for both X and Y while the remaining data values are uncorrelated. Extreme values may also lead to low correlations between X and Y, thus tending to mask a strong linear trend. This may happen if all the (X,Y) pairs except one (or two) tend to cluster tightly about a straight line, and the exceptional point has a very large X value paired with a moderate or small Y value (or vice versa). As influences of extreme values can be important, it is again suggested to use a scatter plot in conjunction with a correlation coefficient.

An alternative to the Pearson correlation is Spearman's rank correlation coefficient. It is calculated by first replacing each X value by its rank (i.e., 1 for the smallest X value, 2 for the second smallest X value, etc.) and each Y value by its rank. These pairs of ranks are then treated as the (X,Y) data and Spearman's rank correlation is calculated using the same formulae as for Pearson's correlation.

Since meaningful (i.e., monotonic increasing) transformations of the data will not alter the ranks of the respective variables (e.g., the ranks for log (X) will be the same for the ranks for X), Spearman's correlation will not be altered by nonlinear increasing transformations of the Xs or the Ys. This desirable property, and the fact that Spearman's correlation is less sensitive to extreme values, makes Spearman's correlation a good alternative or complement to Pearson's correlation coefficient.

2.3.4 Identify Survey Units

To make a decision concerning the disposition of the pipe and associated surrounding soils the total must be divided into segments of the total that will be used to make an individual decision. This separate amount of material or equipment will require a separate disposition decision. These separate decision pieces are termed survey units with boundaries clearly defined to make data interpretations straightforward.

Typically the survey unit dimensions are not given in a regulation so the decision maker must make assumptions to develop action levels and survey unit boundaries based on physical characteristics such as physical dimensions, complexity, accessibility and inherent value. The size is primarily related to the scale of decision making defined by length, width and depth of soils or a related volume of material. This may allow the separation into impacted and non-impacted materials.

2.4 Select the Statistical Method

The intent here is to choose a statistical method and define the assumptions used to determine this method. Typically, there is existing data to support the method determination, however, if no data is available a determination may still be made.

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One division in the methods of this section is between parametric and nonparametric hypothesis tests. Parametric tests typically concern the population mean or quantile, use the actual data values, and assume data values follow a specific probability distribution, normal or lognormal. Nonparametric tests typically concern the population mean or median, use data ranks, and don't assume a specific probability distribution. Parametric tests will have more power than a nonparametric counterpart if the assumptions are met. However, the distributional assumptions are often strict or undesirable for the parametric tests and deviations can lead to misleading results. These will be discussed for each test.

The intent is to provide good statistical validity to defend the hypothesis testing being done at the end to determine the number of samples required to provide a reasonable statistical confidence the site is correctly represented. If the contaminant is present in the background, the multiple population method tests will be used to compare data to the release criteria or action level. If the contaminant is not present in the background the single population tests will be used.

The gray region is a range of values of the parameter of interest for a survey unit where the consequences of making a decision error are relatively minor. The upper bound of the gray region is set equal to the action level, and the lower bound of the gray region (LBGR) is a site-specific variable. The decision maker has the ability to select the width of the region. The lower bound of the gray region (LBGR) is initially set at 50% of the action level. A change in the LBGR will affect the relative shift and number of samples taken in a survey unit. This is reflected in the two types of errors associated with the data quality process:

Type I decision error: A decision error that occurs when the null hypothesis is rejected when it is true. The probability of making a Type I decision error is called alpha (α).

Type II decision error: A decision error that occurs when the *null hypothesis* is accepted when it is false. The probability of making a *Type II decision error* is called *beta* (β) .

The LBGR is subtracted from the action level and represents the width of the gray region and is referred to as the shift, delta (Δ). This can also be bound by the specified false rejection decision error limit minus the specified false acceptance decision error limit. The shift is used with the standard deviation, σ , of the measured values in the survey unit or the reference area to determine the relative shift, Δ/σ . The relative shift is an expression of the resolution of the measurement in units of measurement uncertainty. Expressed this way it is easy to see that relative shifts of less than one standard deviation, $\Delta/\sigma < 1$, will be difficult to detect. Conversely, relative shifts greater than 3 standard deviations, $\Delta/\sigma > 3$, will be easy to detect. The number of measurements required to achieve the two errors above depends on the value of the relative shift.

The standard deviation will be determined from existing survey data, as available, and estimated otherwise. Surveys may be done to establish a better standard deviation. Different types of surfaces, soils or reference areas will require different standard deviations be determined. When preliminary data is not available MARSSIM allows an assumed standard deviation on the order of 30% of the DCGL. These concepts are used to determine the number of samples needed to determine a specific statistical accuracy.

2.4.1 Single Population Methods

The methods of this section concern comparing a single population parameter to a regulatory value (i.e. a fixed number) or the estimation of the population parameter. If the regulatory or action-value was estimated, then a one-sample method is not appropriate and a two-sample test should be selected. An example of a one-sample test would be to determine if 95% of all soil samples of Pu-239 from the area are below a fixed regulatory level. For this example, the population parameter is a proportion and the threshold value is 95% (0.95). Comparing the mean contaminant concentration of a contaminated site to the mean concentration of a background area would be a considered a two-sample test.

The hypothesis tests discussed in this section may be used to determine if there is evidence that $\theta < \theta_0$, $\theta > \theta_0$, or $\theta \neq \theta_0$ where θ represents the population mean, median, proportion, or quantile, and θ_0 represents the threshold value. There are also confidence/tolerance interval procedures to estimate θ .

2.4.1.1 One Sample Student t-Test

This one sample test is used to compare the mean of the population to a threshold value or regulatory limit. This test assumes the contaminant being compared is not present in background. The test also assumes there is no variability

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in the regulatory limit. The test assumes independence of the data and the mean is approximately a normal distribution. A statistical test for normality of the data should also be done prior to performing this test. Consult a statistician to determine to what degree the data meets the normal distribution. Note that if the sample size does not meet the normal distribution this test may still be applied in a limited fashion. The t-test should be used with caution when outliers are present because the mean and standard deviation are sensitive to outliers.

If the data set has a large number of values that have been reported as less than the detection limit caution should be taken. Large numbers of values reported as less than the detection limit may cause the decision maker to throw out the data set or require additional samples be taken. Replacing the less than data with 50% of the detection limit has been considered acceptable in some cases.

The decision maker must determine the appropriate proportion for the parameters associated with this test. This information includes:

The null and alternative hypothesis, typically:

 $H_0 = \mu \ge \text{regulatory limit}$

H_A = μ ≤ regulatory limit

The gray region bound by a tolerable false negative decision error rate and a tolerable false positive decision error rate,

The false rejection error rate, α,

The false acceptance error rate, β.

This test is to be used when there are potential statistical outliers in the data. Outliers may represent hot spots in the distribution of contaminant. There are numerous statistical tests for outliers that may be appropriate to use at the start of the process.

Calculate the number of samples needed for the one sided t test using:

$$n = \frac{S_{Total}^2 \left(z_{1-\alpha} + z_{1-\beta} \right)^2}{\Delta^2} + 0.5 z_{1-\alpha}^2$$
 (6)

Where:

n = the number of samples,

S_{Total} = estimated standard deviation, total population,

 $z_{1-\alpha}$ = where $z_{1-\alpha}$ is the z statistic for the false rejection error rate, α ,

Table A-1 of Reference 6.8,

 z_{1-0} = where z_{1-0} is the z statistic for the false acceptance error rate, β ,

Table A-1 of Reference 6.8,

Δ = width of the gray region (the specified false rejection decision error limit

minus the specified false acceptance decision error limit).

It is customary to round sample size up to the next highest whole number.

2.4.1.2 One Sample Proportion Test

The one sample proportion test is used to compare a population proportion or percentile to a threshold value or regulatory limit. The population proportion is the ratio of the number of elements of a population that has some specific characteristic to the total number of elements. A population percentile is the percentage of elements of a population having values less than some threshold or regulatory limit.

This test assumes the contaminant being compared is not present in background. The test also assumes there is no variability in the regulatory limit. Note that for P = 0.5 this test is equal to the Sign test, however, this test is more powerful than the Sign test for symmetric distributions. The Wilcoxon signed rank test is preferred test when testing the median. The test is used to determine if the parameter being tested is a percentage (proportion) of the threshold value. The only assumption is that the samples represent a random sample. The distribution shape is valid for any underlying distributional shape.

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The decision maker must determine the appropriate proportion for the parameters associated with this test. This information includes:

The null and alternative hypothesis, typically:

Ho = P ≥ regulatory limit,

H_A = P ≤ regulatory limit,

The gray region, bound by a tolerable false negative decision error rate and a tolerable false positive decision error rate,

The false rejection error rate, a,

The false acceptance error rate, β,

Additional false rejection and acceptance error rates may be chosen.

This test is to be used when there are potential statistical outliers in the data. Outliers may represent hot spots in the distribution of contaminant. There are numerous statistical tests for outliers that may be appropriate to use at the start of the process, Reference 6.8.

Calculate the number of samples needed for the one sided test using:

$$n = \left(\frac{z_{1-\alpha}\sqrt{P_0(1-P_0)} + z_{1-\beta}\sqrt{P_1(1-P_1)}}{P_1 - P_0}\right)^2$$
 (7)

Where:

n = the number of samples,

z_{1-a} = where z_{1-a} is the z statistic for the false rejection error rate, a,

Table A-1 of Reference 6.8,

 $z_{l,\beta}$ = where $z_{l,\beta}$ is the z statistic for the false acceptance error rate, β ,

Table A-1 of Reference 6.8,

Po = the false rejection rate,

P₁ = the false acceptance rate.

Round the sample size up to the next highest whole number.

2.4.1.3 Wilcoxon Signed Rank Test

This test is good to test the mean or median of the population. The data are assumed to constitute a random sample from a symmetric population. If the population is not symmetric or normal consult a statistician for assistance. For populations where the sample size is greater than 50 the *t*-test is more robust than the Wilcoxon signed rank test. Sampling results should be reported with sufficient accuracy such that a large number of equal values are avoided. Negative numbers and estimated values for data below the detection limit (0.5 the detection limit) are used because the test relates the relative magnitude to the rest of the data.

To calculate the number of samples needed for the Wilcoxon signed test use:

$$n = \frac{\left(z_{1-\alpha} + z_{1-\beta}\right)^2}{4(Sign \ P - 0.5)^2} \text{ where } Sign \ P = \Phi\left(\frac{\Delta}{s_{Total}}\right)$$
(8)

Where:

the number of samples,

 $z_{1-\alpha}$ = where $z_{1-\alpha}$ is the z statistic for the false rejection error rate, α ,

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Table A-1 of Reference 6.8,

 $z_{1-\beta}$ = where $z_{1-\beta}$ is the z statistic for the false acceptance error rate, β , Table A-1 of Reference 6.8,

 $\Phi = \text{cumulative standard normal distribution function, } \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{z} e^{\frac{x^2}{2}} dx$

Δ = width of the gray region (the specified false rejection decision error limit minus the specified false acceptance decision error limit)

STotal = estimated total standard deviation.

Round the sample size up to the next highest whole number.

2.4.2 Multiple Population Methods

For two sample tests the hypothesis considered are different from the one sided test since a comparison is used. The comparison is between the reference area characteristics and the survey area characteristics. Multiple population methods are appropriate when the comparison population of the reference area has the constituent of concern naturally present. This is the case for radium, thorium and uranium in soil. It is important to be able to evaluate the variability of the background material in relation to the contaminant concentration. Multiple population methods allow this comparison. The decision maker must select the test to use.

For the hypothesis testing let μ_1 represent the mean for population 1 and μ_2 represent the mean for population 2 the hypotheses considered are:

Case 1: H_0 : $\mu_1 - \mu_2 \le \delta_0$ vs. H_A : $\mu_1 - \mu_2 > \delta_0$ and

Case 2: H_0 : $\mu_1 - \mu_2 \ge \delta_0$ vs. H_A : $\mu_1 - \mu_2 < \delta_0$

Where δ_0 is a specified value.

2.4.2.1 Two Sample Student t-Test

This test is robust for testing the means of two populations. This test assumes a random sample is drawn from each population and they are independent samples. The means for each population are assumed to be approximately normally distributed.

The decision maker must select the appropriate criteria and hypothesis case to test.

Additional information required includes:

The gray region, bound by a tolerable false negative decision error rate and a tolerable false positive decision error rate,

The false rejection error rate, α at δ_0 ,

The false acceptance error rate, β at δ_1 ,

Additional false rejection and acceptance error rates may be chosen.

To calculate the number of samples needed for the two sample t-test use:

$$n = \frac{2s^2 \left(z_{1-\alpha} + z_{1-\beta}\right)^2}{\left(\delta_1 - \delta_0\right)^2} + (0.25) z_{1-\alpha}^2$$
 (9)

Where:

n = the number of samples,

s = estimated standard deviation.

 $z_{1-\alpha}$ = where $z_{1-\alpha}$ is the z statistic for the false rejection error rate, α ,

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Table A-1 of Reference 6.8,

= where $z_{1-\beta}$ is the z statistic for the false acceptance error rate, β , Z1-B

Table A-1 of Reference 6.8.

δ, = the false rejection decision error rate,

δ, = the false acceptance decision error rate.

Round the sample size up to the next highest whole number.

2.4.2.2 Two Sample Proportion Test

This test considers hypotheses concerning two population proportions or percentiles. The population proportion is the ratio of the number of elements in a subset of the total population to the total number of elements, where the subset has some specific characteristic that the rest of the elements do not. A population percentile represents percentage of elements of a population having values less than some threshold value C.

The decision maker must decide on the hypothesis to use. If the decision is made to let P1 represent the true proportion for population 1 and P2 represent the true proportion for population 2 the hypotheses considered are:

Case 1: H_0 : $P_1 - P_2 \le \delta_0$ vs. H_A : $P_1 - P_2 > \delta_0$ and

Case 2: H_0 : $P_1 - P_2 \ge \delta_0$ vs. H_A : $P_1 - P_2 < \delta_0$

Where δ_0 is a specified value. An equivalent null hypothesis can be written for percentiles

Additional information required includes:

The gray region, bound by a tolerable false negative decision error rate and a tolerable false positive decision error rate,

The false rejection error rate, α at δ_0 ,

The false acceptance error rate, β at δ_1 ,

Additional false rejection and acceptance error rates may be chosen.

This test assumes a random sample is drawn from each population and they are independent samples. The test is robust for any underlying distributional shape and is valid to outliers

To calculate the number of samples needed for the two sample test for proportions use:

$$n = \frac{2(z_{1-\alpha} + z_{1-\beta})^2 \overline{P}(1-\overline{P})^2}{(P_2 - P_1)^2} \quad \text{where} \quad \overline{P} = \frac{P_1 + P_2}{2}$$
 (10)

Where:

= the number of samples,

= where z_{1-z} is the z statistic for the false rejection error rate, α , Zj-a Table A-1 of Reference 6.8,

= where z_{i-1} is the z statistic for the false acceptance error rate, β , Z1-6

Table A-1 of Reference 6.8,

= the proportion from sample population 1, Pı.

= the proportion from sample population 2.

Round the sample size up to the next highest whole number.

2.4.2.3 Wilcoxon Rank Sum Test.

This test is a distribution free test that compares the shape and location of the two distributions instead of a statistical parameter such as mean or median. The Wilcoxon Rank Sum Test uses the null hypothesis:

H_o: the distribution of population 1 and population 2 are identical (or the site is not more contaminated than background).

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The alternative hypothesis is:

H_A: part of the distribution of population 1 is located to the right of the distribution of population 2 (or the site is more contaminated than background).

This requires care in labeling populations 1 and 2 because of the structure of the hypotheses. This test, when applied with the Quantile test, results in the most powerful for detecting true differences between two populations. Random sampling and data independence are required for this test. This test is robust for outliers.

To determine the number of data points required use:

$$n = \frac{\left(z_{1-\alpha} + z_{1-\beta}\right)^2}{3(P_r - 0.5)^2} \quad where \quad P_r = \Phi\left(\frac{\Delta}{\sqrt{2s_{Total}}}\right)$$
 (11)

Where:

the number of samples in the reference and survey areas,

 $z_{1-\alpha}$ = where $z_{1-\alpha}$ is the z statistic for the false rejection error rate, α ,

Table A-1 of Reference 6.8,

 $z_{1-\beta}$ = where $z_{1-\beta}$ is the z statistic for the false acceptance error rate, β ,

Table A-1 of Reference 6.8,

Φ = the cumulative standard normal distribution function,

s_{Total} = the estimated total standard deviation

Δ = width of the gray region (the specified false rejection decision error limit minus the specified false acceptance decision error limit).

Round the sample size up to the next highest whole number.

2.5 Sampling Designs

The number of samples needed to accurately determine the characteristics of an area were determined using the methods in Section 2.4 above. It must be determined where to take these samples to benefit the most from the data received. Environmental sampling includes not only the number of samples but the geographic positioning of the samples and/or the time frame of sampling. All of this comes together to minimize the expenditure of resources associated with sample collection, analysis, and interpretation.

Environmental sampling designs are a complex subject which is dealt with in extensive detail in References 6.1, 6.3, 6.5, and 6.8. A simple listing of common sampling designs is given below:

Judgmental sampling

Simple random sampling

Stratified sampling

Systematic and grid sampling

Composite sampling

More innovative sampling designs include ranked set sampling and adaptive cluster sampling, Reference 6.5.

2.5.1 Judgmental Sampling

Here the selection of where to take the samples is based on knowledge of the features or condition under investigation. This method is based on professional judgment not statistical probability based sampling. For this study the restriction has been placed at two pipe diameters outside the pipe under investigation.

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2.5.2 Simple Random Sampling

In this sampling method the sampling locations are selected using random numbers that designate where to take the sample. This design is good for uniformly distributed contamination but is likely to miss "hot spots" of contamination. The results are statistically unbiased estimates of the mean, proportion and variability within the survey unit. Difficulty in defining the precise random location may cause difficulties with this method.

2.5.3 Stratified Sampling

This sampling design separates the target population into non-overlapping strata or sub populations that are known or thought to be homogeneous. The strata may be chosen on the basis of preexisting information or judgment about the site. This method may achieve greater precision in estimating the mean and variance and it also allows computation of reliable estimates for population subgroups of special interest

2.5.4 Systematic and Grid Sampling

This sample design uses regularly spaced intervals over space and time. It starts with a random location and rigorously defines the remaining locations over a grid, which may be square, rectangular, triangular or radial. This technique is good to determine hot spots and spatial patterns.

2.5.5 Composite Sampling

Composite sampling uses volumes of material from several selected sampling units in combination to obtain a mixed homogeneous sample. It is very cost effective by reducing the number of analyses required. It is used in conjunction with other sampling designs to estimate the population mean when spatial information is not needed.

2.5.6 Sampling Strategy

No single sampling strategy is adequate for the project outlined here so the combination of several different sampling strategies will be employed to provide the best sampling methodology. Judgmental sampling will be used to sample near the pipe and preferentially toward any suspected area such as a joint, leak, curve, or close to the building. Stratified sampling will be employed to get to the depth of the pipe of concern. Five foot intervals have been initially proposed, but professional judgment will be considered in this decision. A systematic or grid system will be used sample within two pipe diameters of the pipe

2.6 Impact of Gray Region and Standard Deviation

Variation in the width of the gray region and the standard deviation can significantly affect the number of samples. These parameters may not be known until a site is identified and some level of data gathering has been accomplished. Variation in these parameters is described in the following sections.

2.6.1 Effect of Different Widths of the Gray Region

There are two important statistical parameters that have significant impact on the costs associated with the number of samples, 1) the width of the gray region and 2) the standard deviation used. The width of the gray region is typically the upper bound of the gray region minus the lower bound of the gray region. The upper bound of the gray region is typically set at the action level while the lower bound of the gray region is somewhat subjective. The wider the width of the gray region the more error may be accepted. This is used in conjunction with the false positive and negative rates.

For example, if the contaminant was in the background and the proportion of the reference area activity is being tested, a two sample proportion test would be chosen. If we choose different widths of the gray region the number of samples changes, see Table 4 for results from the two sample proportion test. All variables are able to be changed in the spreadsheet and roll up to a total cost. The combined probability represents addition of the false positive and negative rates. You cannot choose a zero rate so one is used as a placeholder to get the percentages close to the specified 80%, 85%, 90%, and 95%.

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Table 4 - Example of Cost Variability with Different Statistical Parameters

(from Two Sample Proportion Test)

Width of Gray Region, (UBGR- LBGR)	Alpha	Beta	Number of Samples, n	Analytical Cost per Sample	Cost of Sampling Design for One Area	Combined Probability
0.1	0.01	0.01	553	\$11,435.00	\$6,323,555.00	
0.1	0.05	0.01	403	\$11,435.00	\$4,608,305.00	95%
0.1	0.01	0.05	403	\$11,435.00	\$4,608,305.00	95%
0.1	0.1	0.01	332	\$11,435.00	\$3,796,420.00	90%
0,1	0.01	0.1	332	\$11,435.00	\$3,796,420.00	90%
0.1	0.05	0.05	276	\$11,435.00	\$3,156,060.00	90%
0.1	0.2	0.01	256	\$11,435.00	\$2,927,360.00	80%
0.1	0.01	0.2	256	\$11,435.00	\$2,927,360.00	80%
0.15	0.01	0.01	246	\$11,435.00	\$2,813,010.00	
0.1	0.1	0.05	219	\$11,435.00	\$2,504,265.00	85%
0,1	0.05	0.1	219	\$11,435.00	\$2,504,265.00	85%
0.1	0.3	0.01	208	\$11,435.00	\$2,378,480.00	
0.1	0.01	0.3	208	\$11,435.00	\$2,378,480.00	
0.15	0.05	i i i i i i i i i i i i i i i i i i i	179	\$11,435.00	\$2,046,865.00	95%
0.15	0.01	(10)5	179	\$11,435.00	\$2,046,865.00	95%
0.1	0.1	0.1	168	\$11,435.00	\$1,921,080.00	80%
0.1	0.2	0.05	158	\$11,435.00	\$1,806,730.00	1955
0.1	0.05	0.2	158	\$11,435.00	\$1,806,730.00	
Stone:		0.01	148	\$11,435.00	\$1,692,380.00	90%
0.15	0.01	(.1	148	\$11,435.00	\$1,692,380.00	90%

This table shows the impact of changing the width of the gray region from 0.1 to 0.15 at the 95% and 90% level. The number of samples is 403 samples required at the 95% level with a width of 0.1 going down to 179 samples by widening the gray region width to 0.15. The effect of false positive and false negative rate is illustrated with the number of samples decreasing from 403 at 95%, 332 at 90%, and 256 at 80%.

If the contaminated region is not known, the number of characterization samples required is independent of pipe length. For the purpose of cost comparison with the excavation estimate, a method of comparing the assumed contaminated soil volume along the pipe length with the number of characterization samples is proposed.

2.6.2 Effect of Different Standard Deviations

If previous sampling data is available the simple sample standard deviation may be calculated. If data is not available MARSSIM uses suggested standard deviations. Choosing the appropriate standard deviation will have an influence on the number of samples and therefore the cost.

When actual data is used the effect of outliers on the number of samples may have significant cost implications. Outliers are values which lie so far away from the mean that one may suspect that the case in question is not representative of the population measured. A convenient definition of an outlier is a point which falls more than 1.5 times the <u>interquartile range</u> above the third <u>quartile</u> or below the first <u>quartile</u>. Using a histogram, box and whiskers plot, or scatterplot may be useful in visually identifying outliers. Justification for discarding outliers should be included in the data evaluation.

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An example of the effect of changing the standard deviation is given in Table 5. Table 5 is based on the two sample student t-test. As can be seen the tighter the distribution, i.e. the smaller the standard deviation the fewer number of samples needed for the same false positive or false negative rate. In the table the width of the gray region for the example remains the same.

Alpha	Beta	SD	Number of Samples, n	이 없는 것도 없는 대통이 기록하다.	SD	Samples,	Cost of Sampling Design for One Area
0.01	0.01	1.9	1628	\$ 18,616,180.00	1,1	547	\$ 6,254,945.00
0.01	0.05	1.9	1187	\$ 13,573,345.00	1.1	399	\$ 4,562,565.00
0.05	0.01	1.9	1186	\$ 13,561,910.00	1.1	398	\$ 4,551,130.00
0.01	0.1	1.9	980	\$ 11,206,300.00	1.1	330	\$ 3,773,550.00
0.1	0.01	1.9	979	\$ 11,194,865.00	1.1	329	\$ 3,762,115.00
0.05	0.05	1.9	814	\$ 9,308,090.00	1.1	274	\$ 3,133,190.00
0.01	0.2	1.9	756	\$ 8,644,860.00	1.1	255	\$ 2,915,925.00
0.2	0.01	1.9	755	\$ 8,633,425.00	1.1	253	\$ 2,893,055.00
0.05	0.1	1.9	645	\$ 7,375,575.00	1.1	217	\$ 2,481,395.00
0.1	0.05	1.9	644	\$ 7,364,140.00	1.1	217	\$ 2,481,395.00
0.01	0.3	1.9	612	\$ 6,998,220.00	1.1	207	\$ 2,367,045.00
0.3	0.01	1.9	611	\$ 6,986,785.00	1.1	205	\$ 2,344,175.00
0.1	0.1	1.9	494	\$ 5,648,890.00	1.1	166	\$ 1,898,210.00

Table 5 - Effect of a Different Standard Deviation on the Number of Samples and the Cost

2.7 Excel Spreadsheet Instructions

Each Excel spreadsheet (see attachments in Section 7) is set up the same way so the description given here applies to all of the sheets. These calculations are dependent upon a knowledgeable person choosing the appropriate variables used in these calculations. They should use available data and decision criteria based upon the proper regulatory guidance. This individual should choose the null and alternative hypothesis to be tested. These calculations assume the null hypothesis (H₀) tested for is that residual contamination exceeds the action level criterion. The alternative hypothesis (H_a) is that residual contamination meets the action level criterion. It is suggested to make a copy of the folder containing the spreadsheets and save each Rev 0 as the template to be used later.

Each Excel file has four worksheets:

Calculations
Size Formula Sheet

Cost

Totals

The worksheets are set up to interlink and provide the analysis for the "Totals" worksheet. The "Totals" worksheet provides the results for comparison of costs at different levels of risk which is determined through the number of samples needed. All worksheets have input cells surrounded with colored borders. Input variables should be chosen carefully with the appropriate level of justification and documentation.

Start with the "Calculations" worksheet where the level of the false positive error rate (alpha value,α) and the false negative error rate (beta value,β) are entered into the appropriate colored fields. The Action Level, Estimated Standard Deviation and the LBGR should be entered from existing data or with the appropriate guidance. This

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allows the calculation of the width of the gray region (Δ), the percentage of the Action Level and the number of samples using the appropriate z statistic.

The "Size Formula Sheet" is a tabular version of the "Calculations" worksheet in a manner that is easier to follow. The formula used in the calculation is shown along with references. No input is needed for this worksheet.

The "Cost" worksheet is a tabulation of costs associated with each sample. The sample collection cost (USC\$) is a single cell and should include all administrative, labor, materials and miscellaneous items associated with collection of the sample. The sample analysis cost (USA\$) table is set up to be a compilation of analytical costs summed at the top. These two costs are summed to give the aggregate unit sample collection and analysis cost (AUSCSA\$), which is used in the "Totals" worksheet.

The "Totals" worksheet provides the total sampling cost associated with the number of samples at a specified false positive and false negative rate for three different widths of the gray region. A sampling cost budget cell is used to differentiate the decision level of the total cost between in the red border or blue. Highlighted fields differentiate different gray regions.

2.8 Sampling Statistics Results

Statistical techniques can be chosen that determine the number of samples needed for different confidence levels of false positive or false negative rates. The number of samples can be used with the MARSSIM terminology to determine the volume of material that must be sampled. This allows the decision maker to determine a sample design that best suits the needs of the user. Historical data can be used to assist in a volume classification to change the number of samples required depending on known or suspected contamination.

The number determined can be correlated with sampling and analysis costs to get an idea of the cost and relate this to simple digging and disposal costs. Tables are set up in Excel spreadsheets to investigate different decision levels at different false positive and false negative error rates. The results for the four confidence levels 80, 85, 90, and 95 percent are summarized below in Table 6. Note that the number of samples identified in Table 4 and Table 6 differ due to a change in the percent of the action level used for the width of the gray region and the estimated proportion in the survey unit and the reference area.

Table 6 - Comparison of Sample Numbers by Confidence Level

80% Confidence Level

Width of Gray region	Alpha	Beta	l sample <i>t</i> test	1 sample Proportion	Wilcoxon Sign test	2 sample t-test	2 sample Proportion	Wilcoxon Rank Sum
5% of AL	1%	20 %	380	1041	245	255	1526	106
	20 %	1%	378	1106	245	253	1526	106
	10 %	10 %	248	703	161	166	999	70
	5%	15%	272	758	176	182	1093	76
	15%	5%	271	780	176	182	1093	76
10 % of AL	1%	20 %	97	268	68	65	382	30
	20 %	1%	95	299	68	64	382	30
	10 %	10 %	63	185	45	42	250	21
	5%	15%	69	198	48	46	274	22
- Hales	15%	5%	69	208	48	46	274	22
20 % of AL	1%	20 %	27	70	23	18	96	12
	20 %	1%	24	83	23	16	96	12
	10 %	10 %	17	50	15	11	63	9
	5%	15%	19	53	17	12	69	9
	15%	5%	18	57	17	12	69	9

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Table 6 (Continued)

85% Confidence Level

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Width of Gray region	Alpha	Beta	1 sample t-test	1 sample Proportion	Wilcoxon Sign test	2 sample t-test	2 sample Proportion	Wilcoxon Rank Surr
5 % of AL	1 %	15 %	428	1179	276	287	1719	119
	15 %	1%	426	1240	276	286	1719	119
	5%	10 %	324	908	209	217	1302	90
	10%	5%	323	923	209	217	1302	90
10 % of AL	1%	15%	109	305	76	73	430	34
	15 %	1 %	107	333	76	72	430	34
	5%	10%	82	238	57	55	326	27
	10%	5%	82	245	57	55	326	27
20 % of AL	1%	15 %	30	80	26	20	108	14
	15 %	1%	28	02	26	19	108	14
	5 %	10 %	22	64	20	15	82	11
	10%	5%	21	67	20	14	82	11

90% Confidence Level

	7/6 CORUM	PEUCE IAT	CI					
Width of Gray region	Alpha	Beta	1 sample	1 sample Proportion	Wilcoxon Sign test	2 sample t-test	2 sample Proportion	Wilcoxon Rank Sum
5% of AL	1 %	10 %	492	1366	318	330	1979	137
790 00000	10 %	1%	490	1418	318	329	1979	137
	5%	5%	408	1157	264	274	1645	114
10 % of AL	1%	10 %	125	355	87	84	495	40
	10 %	1%	124	379	87	83	495	40
	5%	5%	103	305	72	69	412	33
20 % of AL	1%	10 %	34	94	29	22	124	16
	10 %	1 %	32	104	29	21	124	16
	5%	5%	27	82	24	18	103	14

95	% Confide	nce Level			-			
Width of Gray region	Alpha	Beta	1 sample t-test	l sample Proportion	Wilcoxon Sign test	2 sample t-test	2 sample Proportion	Wilcoxon Rank Sum
5 % of AL	1 %	5%	596	1667	386	399	2398	166
	5%	1%	594	1705	386	398	2398	166
10 % of AL	1 %	5%	151	436	105	101	600	47
	5%	1 %	150	453	105	100	600	47
20 % of AL	1 %	5%	40	116	35	27	150	18
- 1	5%	1%	39	124	35	26	150	18

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3. Pipe Excavation and Removal Cost Estimate

The pipe excavation and removal cost estimate is summarized in dollars per linear foot for excavating pipeline types (materials of construction) and sizes and depths. Excavation depths, summarized in section 1.2 and shown in section 3.1 are 5, 10, 15, 20, and 25 feet below ground surface. Pipeline materials of construction include a) vitrified clay, b) stainless steel and carbon steel, c) concrete masonry, and d) reinforced concrete. Pipeline sizes vary from 2 to 48 inches in diameter. The cost estimate includes various combinations of depth, diameter, and materials of construction deemed applicable to the Hanford site. For the excavation estimate, it is assumed that the pipeline and surrounding soil within two pipe diameters from the outside surface of the pipe are contaminated with radionuclides or other hazardous substance in excess of action levels that require personnel protection in accordance with Occupational Safety and Health Administration (OSHA) level D standards (29 CFR 1910.120 Appendix B). Soil types surrounding the pipeline will range from fine sand to coarse gravel and sand/gravel mixtures.

The pipe excavation and removal cost estimate ExcelTM Spreadsheet (see section 7) consists of numerous parameters that include the various elements associated with soil excavation and pipe removal. These parameters are summarized in Table 7. The focus of this study has been on excavation of clean soil down to the pipe, contaminated soil excavation around the pipe, and pipe sectioning and removal. The other parameters in Table 7 can be tailored to specific job sites. The advantage of the Excel spreadsheet is that these parameters can be modified (cost elements added or deleted as necessary) to fit a particular pipe excavation and removal job.

	Table 7 - Cost Estimate Parameters
Mobilization	Mobilization of personnel and equipment includes relocation of resources to the job site.
Pipeline / Interference Location	Pipe excavation can start after the buried pipe and any interference such as buried utilities are identified to ensure the correct site is located.
Install Silt Barrier	Installation of a silt barrier provides runon / runoff control of silt and construction debris.
Paved Road Trenching	Cutting of asphalt or concrete paving prior to excavation of underlying soil. Estimate assumes no paved areas will require excavation.
Clean Excavation to Pipe	Clean excavation includes removal of soil overburden down to the contaminated zone.
Contaminated Soil Excavation	Contaminated soil excavation includes removal of the contaminated soil around the pipeline.
Pipe Section and Removal	Removal of the pipeline includes cutting or shearing metal pipe into sections or crushing or crumbling clay or concrete pipe and loading the resulting debris into ERDF cans for disposal.
Backfill, Compact and Grade	Once excavation is complete, this parameter provides the elements needed to backfill the excavated hole.
Demobilization	Demobilization of personnel and equipment includes relocation of resources away from the job site once the job is complete. Also includes removal of silt barrier and other project fencing.

3.1 Input Parameters

Input Parameters to the Tool:

- Excavation depths in 5 foot increments (5, 10, 15, 20, and 25 feet below grade)
- Pipeline materials of construction (vitrified clay, stainless and carbon steel, concrete masonry, and reinforced concrete)
- Pipe diameters from 2 to 48 inches (the estimate assumes 6 sizes e.g., 2, 6, 12, 24, 36 and 48 inches) in conjunction with the exclusions noted above.

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The decision support tool (Excel spreadsheet) is configured to allow a different input from each of the bullets above to result in a different cost estimate per lineal foot of pipe.

3.2 Excavation

Assumptions, any items specifically excluded, and methodology for excavated volume is included in the section on assumptions and the Excel spreadsheets (see section 7). Typical crew configurations and fiscal year (FY) 2007 labor costs by labor category for Fluor Hanford are given in Table 8 (based on the attachment to SOW).

Table 8 - Costs	Associated	with Pipe	Excavation
-----------------	------------	-----------	------------

Craft	<u>\$/hr</u>	# in Crew	Craft \$/hr
'Other' craft	67. 9 6	1	67.96
Laborer	54.14	6	324.84
Teamster (light vehicle driver)	54.35	5	271.75
Heavy Equipment Operator	64.86	2	129.72
Health Physics Technician	68.17	6	409.02
TOTAL	19 39 4	20	\$1203.29

Other assumptions:

- 1) 10 hour work day per crew for purposes of cost estimation
- 2) Estimate is based on 4 boxes per day at start, ramping up to 30 boxes per day at day 6
- 3) Soil and air sampling during excavation is assumed to be 25 % of the excavation costs.

3.3 Waste Packaging

The cost estimate is based on contaminated soil being placed or loaded into ERDF cans or roll-off containers for disposal at ERDF. Clean soil is placed in spoil piles and is assumed will remain at the excavation site for use in backfill of the excavation. ERDF waste handling and disposal fees are assumed to be 45 % of the excavation costs.

3.4 Calculations

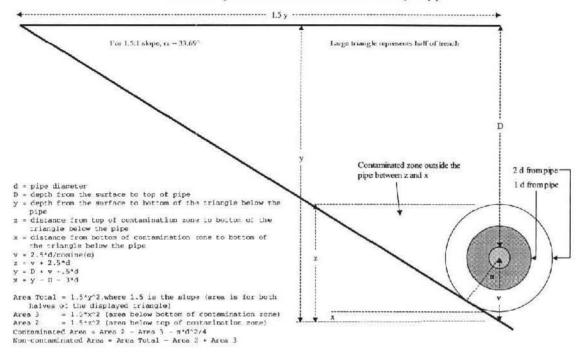
The volume of clean and contaminated excavated soil is based on Figure 1. The excavated area is based on a 1.5 to 1 slope. This results in a trapezoidal volume above the buried pipeline as the clean soil region. The contaminated region is based on the assumption that the contaminated volume is within 2 pipe diameters around the buried pipeline. The top of this 2 pipe diameter region is assumed to be a flat plane and forms another trapezoidal volume for the contaminated region.

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Figure 1 - Excavation Model

Model for trapezoid contamination zone 2 diameters beyond pipe



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Important note on model limitations:
When D is less than 2.5 d (e.g., D=5 feet & d > 24 inches) the contaminated zone is above the ground surface. In such cases the contaminated area is over-predicted and the non-contaminated area can be a negative number.

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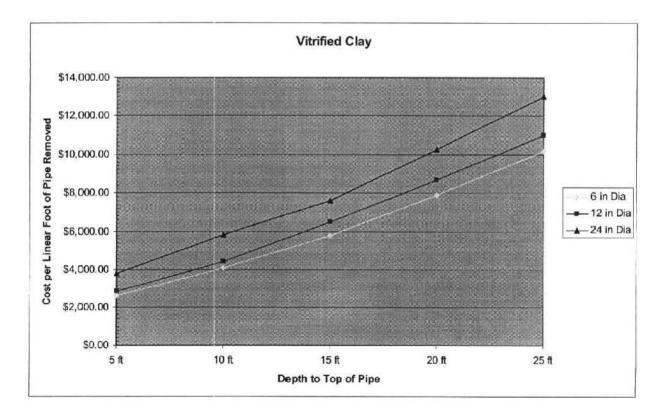
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3.5 Pipe Excavation Cost Estimate

The decision support tool provides a cost estimate for each of the parameters listed as an input for the estimate. Vitrified clay is used as an example and the results are summarized in Table 9 and Figure 2. Similar cost curves are obtained for the different pipe types, stainless and carbon steel, concrete and reinforced concrete, and are included in section 7.2. Each estimate includes 30% contingency as noted in section 7.2.

Depth	6 in Diameter	12 in Diameter	24 in Diameter
5 ft	\$2,607.64	\$2,866.94	\$3,794.76
10 ft	\$4,104.32	\$4,433.26	\$5,814.85
15 ft	\$5,763.51	\$6,476.57	\$7,614.11
20 ft	\$7,900.46	\$8,659.96	\$10,250.49
25 ft	\$10,175.93	\$11,005.08	\$13,026.94

Figure 2 - Excavation Cost per Lineal Foot for Vitrified Clay Pipe



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4. Decision Support Tool and Cost Comparison

For the examples presented in this document, the cost to excavate vitrified clay pipe is compared to the cost for taking a number of samples at the 95 % confidence level. This comparison can be made at the different confidence levels or different pipe types and depths. Excavation costs range from \$2,608 to \$13,027 per foot for vitrified clay pipe at different depths and diameters (from section 3.5). From Table 4 it is shown 403 samples are required for a 95% confidence level. The cost for analyzing 403 samples is \$4,608,305 (from section 2.6).

4.1 Decision Support Tool Results

Results of the decision support tool for vitrified clay are summarized in Table 9. The Excel spreadsheets in section 7.2 summarize the costs per foot for excavation for the different pipe types. These results for each pipe type at 12 inch diameter and 15 foot depth are summarized in Table 10.

Pipe Type	Costs per foot at 12 inch diameter and 15 foot depth
Vitrified clay pipe	\$6,477
Steel and stainless steel	\$6,517
Reinforced concrete	\$6,576
Concrete masonry	\$6,477

Table 10 - Excavation Costs per Foot at 12 inch diameter and 15 Foot depth

From Table 4 sampling costs range from \$4,608,305 @ 95 % confidence (403 samples) to \$1,921,080 @ 80% confidence (168 samples). Note the number of samples varies depending on the width of the gray region and the alpha and beta values. As noted in the assumptions the cost to obtain samples is \$25,000 for the first sample in each of three sample pits over a 100 foot length. Additional samples cost \$600 each. The cost for 403 samples over a 100 foot length is \$266,800 and 168 samples \$125,800. For rough comparison, the cost to excavate 100 feet of pipe (taken from Table 10) is about \$660,000 compared with a cost range of \$4,875,000 @95% confidence to \$2,050,000 @80% confidence for sampling and analysis. Based on the scenarios and examples presented in this document, the cost for sampling and analysis is more than the cost for excavation.

4.2 Issues and Limitations of the Tool

The decision support tool is only as good as the inputs used in the EXCEL spreadsheets. As described below the tool has limitations and areas for improvement.

4.2.1 Waste Area Vs. Volume

MARSSIM is designed for evaluation of contaminants on surfaces and surface areas. A method is proposed to use the concepts of MARSSIM and MARSAME to relate the number of samples required at various confidence intervals for a given waste volume associated with a pipe line. Further, the assumption that the contaminated volume is restricted to 2 pipe diameters from the pipe could be significantly different than actual conditions. This situation does not account for leaking pipelines and the possible need to chase or clean up the contaminated soil associated with the leak. In some cases it might be necessary to exhume much of the waste site just to obtain the required samples. The concept for relating the number of samples to a given length of pipe is outside the scope of this study and is a topic for future evaluation.

4.2.2 Cost Parameters, Inputs, and Comparison

The costs for sampling are based on the costs to obtain the samples and analytical costs and the pipe removal costs are based primarily on excavation costs per the Statement of Work (SOW). A better comparison of sampling compared to pipe excavation and removal will rely on a more comprehensive cost evaluation. For example, sampling costs will be more realistic and comparative if the costs can be related on a per lineal foot basis. In that manner the costs of sampling can be related or compared to the costs of excavation based on a common basis, e.g., costs per foot.

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4.2.3 Excavation of Piping Less than Two Foot Diameter

Recent experience by Fluor Hanford has found that the costs of removing all types of piping 2 feet in diameter or below costs about the same, due to the physical realities of doing excavation and the fact that piping of any material of that diameter or below is easy to shear or size reduce. This experience implies that the estimate for pipes 2 feet in diameter and less (2 inches, 6 inches, 12 inches and 24 inches) can be combined into one estimate.

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5. Conclusions

Choosing the statistical tool, allows for different types of statistical models to be used to evaluate the regulatory parameter of concern. The first section of this document compares a single population parameter to a regulatory value (i.e. a fixed number) or the estimation of the population parameter. If the regulatory or action-value was estimated, then a one-sample method is not appropriate and a two-sample test should be selected. For two sample tests the hypotheses considered are different from the one sided test since a comparison is used. The comparison is between the reference area characteristics and the survey area characteristics. Multiple population methods are appropriate when the comparison population of the reference area has the constituent of concern naturally present. There are six different statistical tests evaluated in this document.

The decision process starts with determining the region where relatively large decision error rates are considered tolerable. This is referred to as the gray region. The effect of varying the gray area provides a tool to determine the number of samples at different confidence interval and tolerable decision errors. The gray region is a range of values of the parameter of interest for a survey unit where the consequences of making a decision error are relatively minor. The upper bound of the gray region is set equal to the action level, and the lower bound of the gray region (LBGR) is a site-specific variable. The decision maker has the ability to select the width of the region. This section is useful at evaluating the impact of varying the decision error on the number of samples.

For the examples presented in this document, the cost to excavate vitrified clay pipe is compared to the cost for taking a number of samples at the 95 % confidence level for a 100 foot section of pipe. Excavation/removal costs range from \$2,608 to \$13,027 per foot for vitrified clay pipe at different depths and diameters. Results of the decision support tool for vitrified clay are summarized in Table 9 and Table 10. Sample and analysis costs to characterize a pipeline range from a few million to more than 20 million dollars. Based on the scenarios and examples presented in this document, the cost for sampling and analysis is more than the cost for excavation/removal (see section 4.1). The decision support tool can be used to predict the point at which the cost of sampling exceeds the cost for excavation.

The decision support tool provides a quick method for comparing excavation/pipe removal costs with characterization sampling and analysis costs to aid in deciding whether to remove the pipe or leave it in place. While the actual costs will be situation-specific, the generalizations in this study provide good approximations for alternative analysis and can indicate where more detailed analyses are needed. The pipe excavation estimate spreadsheet developed for this study can easily be modified to evaluate situations on a case-by-case basis and provide more detailed cost estimates. Ultimately, the decision will be influenced by factors such as regulatory requirements, stakeholder interests, safety concerns, programmatic decisions, and risk reduction in addition to cost. The decision support tool does not assign values to these factors.

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6. References

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Pipeline Removal Vs. Characterization Study - Decision Support Tool

7. Attachments

7.1 Statistical Calculations

The following pages contain a copy of the statistical spreadsheets used to determine the number of samples at various confidence intervals. The statistical tests or methods used include six tests below as described in section 2.4.

- One Sample Student t-Test
- One Sample Proportion Test
- Wilcoxon Signed Rank Test
- Two Sample Student t-Test:
- · Two Sample Proportion Test
- Wilcoxon Rank Sum Test

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Pipeline Removal Vs. Characterization Study - Decision Support Tool

7.1.1 One Sample Student t-Test

Calculations for One-Sample t-Test Sampling Design

User inputs are shaded areas. Null = Contaminated

For Delta = 0.31 ,		Alpha Values							
(5%	AL)	α 1	α 2	α 3	a 4	α 5			
		0.01	0.05	0.10	0.20	0.30			
Values	$\beta 1 = 0.01$	816	594	490	378	306			
/al	$\beta 2 = 0.05$	596	408	323	233	177			
8	$\beta 3 = 0.10$	492	324	248	170	123			
Beta	$\beta 4 = 0.20$	380	234	171	107	71			
_	$\beta 5 = 0.30$	308	179	124	71	42			

Action Level (AL)	6.20	6.20	6.20
LBGR	5.89	5.58	4.96

Delta 0.31 0.62

1.24

Delta as percent of AL

5%

10%

20%

Estimated Std Dev. 1.9

 $\mathbf{Z}_{\text{(1-Alpha)}}^2$ 2.326348 1.644854 1.2815516 0.841621 0.524401 0.5 $(\mathbf{Z}_{\text{(1-Alpha)}})^2$ 2.705947 1.352772 0.8211872 0.354163 0.137498 $\mathbf{Z}_{\text{(1-Beta)}}$ 2.326348 1.644854 1.2815516 0.841621 0.524401

For I	For Delta = 0.62 ,		Alpha Values							
(10%	AL)	α 1	α 2	α 3	α 4	α 5				
		0.01	0.05	0.10	0.20	0.30				
nes	$\beta 1 = 0.01$	207	150	124	95	77				
'a	$\beta 2 = 0.05$	151	103	82	59	45				
-	$\beta 3 = 0.10$	125	82	63	43	31				
Beta Values	$\beta 4 = 0.20$	97	60	44	27	18				
_	$\beta 5 = 0.30$	80	46	32	18	11				

For Delta = 1.24 ,		Alpha Values							
(20%	óAL)	α 1	α 2	α 3	α 4	a 5			
24		0.01	0.05	0.10	0.20	0.30			
Values	$\beta 1 = 0.01$	54	39	32	24	20			
[B]	$\beta 2 = 0.05$	40	27	21	15	12			
	$\beta 3 = 0.10$	34	22	17	11	8			
Beta	$\beta 4 = 0.20$	27	16	12	8	5			
	$\beta 5 = 0.30$	22	13	9	5	3			

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Pipeline Removal Vs. Characterization Study - Decision Support Tool

Size-Sample Equation for One-Sample t-Test

Null = Contaminated

$$n = \frac{s_{Total}^{2} \left(z_{1-\alpha} + z_{1-\beta}\right)^{2}}{\Lambda^{2}} + 0.5z_{1-\alpha}^{2}$$

Values are rounded upwards (EPA 2000, p. 3-8). The equation is from (EPA 2000, p. 3-7).

	Mistakenly Concluding < Action Level								
	$\alpha = 1\%$	$\alpha = 5\%$	$\alpha = 10\%$	$\alpha = 20\%$	$\alpha = 30\%$				
Estimated Std. Dev = 1.9	s = 1.9	s = 1.9	s = 1.9	s = 1.9	s = 1.9				

Width of the Gray I	$Region (\Delta) = 0.31 (5\% c)$	f AL)				
	β = 1%	816	594	490	378	306
Mistakenly	β = 5%	596	408	323	233	177
Concluding > = Action Level	$\beta = 10\%$	492	324	248	170	123
	$\beta = 20\%$	380	234	171	107	71
	β = 30%	308	179	124	71	42
Width of the Gray I	Region (Δ) = 0.62 (10%	of AL)				
Andrew Control of the	β = 1%	207	150	124	95	77
Mistakenly	β = 5%	151	103	82	59	45
Concluding > =	$\beta = 10\%$	125	82	63	43	31
Action Level	$\beta = 20\%$	97	60	44	27	18
	β = 30%	80	46	32	18	11
Width of the Gray I	legion (Δ) = 1.24 (20%	of AL)				
	β = 1%	54	39	32	24	20
Mistakenly	β = 5%	40	27	21	15	12
Concluding >=	β = 10%	34	22	17	11	8
Action Level	β = 20%	27	16	12	8	5
	β = 30%	22	13	9	5	3

References

EPA. 2000. Guidance for Data Quality Assessment.
EPA QA/G-9, U.S. Environmental Protection Agency, Washington DC.

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Pipeline Removal Vs. Characterization Study - Decision Support Tool

NULL = Contaminated

Sampling Collection and Analysis Costs

 Unit Sample
 Unit Sample
 User inputs are shaded areas.

 Collection
 Analysis

 Cost
 Cost

 Dollars
 Dollars

 USC\$ + USA\$ (Sum) = \$\frac{1}{3}\$ AUSCSA\$

 \$50.00+
 \$11,385.00 = \$\frac{1}{3}\$\$\$\$\$\$\$\$\$11,435.00

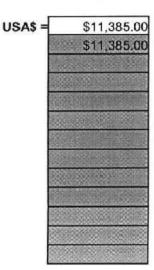
Definitions:

USC\$Unit sample collection cost in dollars
USA\$Unit sample analysis cost in dollars
USA\$ (SUM)Unit sample analysis cost for all analytical methods in dollars
AUSCSA\$Aggregate unit sample collection and sample analysis cost in dollars

USC\$ =		\$50.00
		\$50.00 \$50.00
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	gan in Kar	
		w4500050006
i	-(No.0, 956-W	(3)

Summed from cells below

Enter costs associated with each item for taking the sample



Summed from cells below

Enter analytical cost for each analytical method in the cells in column C

NULL =	Total (24	0 0	4 T4	Camanillana	D:
Contaminated	l otal (Jost for	One-Sample	t-Test	Sampling	Design

11710000000000000 1 38888	ng-Cost Budget		000,	000.00		User inputs are areas.		ded
Width of Gray Region, (UBGR- LBGR)		Beta	SD	Number of Samples, n	AUSCA \$	Total Cost of Sampling Design		
0.31	1%	1%	1.9	816	\$11,435.00	\$9,330,960.00		
0.31	1%	5%	1.9	596	\$11,435.00	\$6,815,260.00	95%	confident residual contaminant meets the action level criterion
0.31	5%	1%	1.9	594	\$11,435.00	\$6,792,390.00	95%	confident residual contaminant exceeds the action level criterion
0.31	1%	10%	1.9	492	\$11,435.00	\$5,626,020.00	90%	confident residual contaminant meets the action level criterion
0.31	10%	1%	1.9	490	\$11,435.00	\$5,603,150.00	90%	confident residual contaminant exceeds the action level criterion
0.31	5%	5%	1.9	408	\$11,435.00	\$4,665,480.00	90%	5% confident volume meets the action level criterion and 5% confident exceeds
0.31	1%	20%	1.9	380	\$11,435.00	\$4,345,300.00	80%	confident residual contaminant meets the action level criterion
0.31	20%	1%	1.9	378	\$11,435.00	\$4,322,430.00	80%	confident residual contaminant exceeds the action level criterion
0.31	10%	5%	1.9	323	\$11,435.00	\$3,693,505.00	85%	10% confident volume exceeds the action level criterion and 5% confident volume meets criterion
0.31	5%	10%	1.9	324	\$11,435.00	\$3,704,940.00	85%	5% confident volume exceeds the action level criterion and 10% confident volume meets criterion
0.31	1%	30%	1.9	308	\$11,435.00	\$3,521,980.00		
0.31	30%	1%	1.9	306	\$11,435.00	\$3,499,110.00		
0.31	10%	10%	1.9	248	\$11,435.00	\$2,835,880.00	80%	10% confident volume exceeds the action level criterion and 10% confident volume meets criterion
0.31	5%	20%	1.9	234	\$11,435.00	\$2,675,790.00		
0.31	20%	5%	1.9	233	\$11,435.00	\$2,664,355.00		
0.62	1%	1%	1.9	207	\$11,435.00	\$2,367,045.00		
0.31	5%	30%	1.9	179	\$11,435.00	\$2,046,865.00		
0.31	30%	5%	1.9	177	\$11,435.00	\$2,023,995.00		
0.31	20%	10%	1.9	170	\$11,435.00	\$1,943,950.00		
0.31	10%	accept on the standard or the se-			\$11,435.00	\$1,955,385.00		
0.62			1.9		\$11,435.00	\$1,726,685.00	95%	confident residual contaminant meets the action level criterion
0.62	man man and bud designed	1%	1.9	150	\$11,435.00	\$1,715,250.00	95%	confident residual contaminant exceeds the action level criterion
0.31			1.9	124		0 \$1,417,940.00		Ç.
0.31		Committee of the second				0 \$1,406,505.00		The state of the s
0.62		M65464956886						confident residual contaminant meets the action level criterion
0.62		THE R. P. LEWIS CO., LANSING, LAS.	1.9					confident residual contaminant exceeds the action level criterion
0.31	20%	20%	1.8	107	\$11,435.00	0 \$1,223,545.00		2

0.62	5%	5% 1.	9 103	\$11,435.00	\$1,177,805.00	90%	5% confident volume meets the action level criterion and 5% confident volume exceeds criterion
0.62	1%	20% 1.	9 97				confident residual contaminant meets the action level criterion
0.62	20%	1% 1.	9 95				confident residual contaminant exceeds the action level criterion
0.62	10%	5% 1.	9 82	\$11,435.00			10% confident volume exceeds criterion and 5% confident volume meets criterion
0.62	5%	10% 1.	9 82	\$11,435.00			5% confident volume exceeds the action level criterion and 10% confident volume meets criterion
0.62	1%	30% 1.	9 80	\$11,435.00	\$914,800.00		
0.62	30%	1% 1.	9 77	\$11,435.00	\$880,495.00		
0.31	30%	20% 1.	9 71	\$11,435.00	\$811,885.00		
0.31	20%	30% 1.		\$11,435.00	\$811,885.00		
0.62	10%	10% 1.	9 63	\$11,435.00	\$720,405.00	80%	10% confident volume exceeds the action level criterion and 10% confident volume meets criterion
0.62	5%	20% 1.	9 60	\$11,435.00	\$686,100.00		
0.62	20%	5% 1.		\$11,435.00	\$674,665.00		
1.24	1%	1% 1.		\$11,435.00	\$617,490.00		
0.62	5%	30% 1.		\$11,435.00			
0.62	30%	5% 1.		\$11,435.00	[18] SANGAN BANG MINANG MAKANANAN PAR		
0.62	20%	10% 1.		\$11,435.00			
0.62	10%	20% 1.		\$11,435.00			
0.31	30%	30% 1.		\$11,435.00			
1.24	1%	5% 1.		\$11,435.00	댓		confident residual contaminant meets the action level criterion
1.24	5%	1% 1.		\$11,435.00	and the second s		confident residual contaminant exceeds the action level criterion
1.24	1%	10% 1.		\$11,435.00			confident residual contaminant meets the action level criterion
0.62	30%	10% 1.		\$11,435.00			
0.62	10%	30% 1.		\$11,435.00	함 '뭐겠게 맛있게 뭐겠다면데 맛있다.		
1.24	10%	1% 1.		\$11,435.00	A CONTRACTOR OF THE PROPERTY O		confident residual contaminant exceeds the action level criterion
0.62	20%	20% 1.		\$11,435.00			
1.24	5%	5% 1.		\$11,435.00			5% confident volume meets the action level criterion and 5% confident volume exceeds criterion
1.24	1%	20% 1.		\$11,435.00	그 - 이유지(1111) 12 12 15 15 15 15 15 15 15 15 15 15 15 15 15		confident residual contaminant meets the action level criterion
1.24	20%	1% 1.		\$11,435.00			confident residual contaminant exceeds the action level criterion
1.24	5%	10% 1.		\$11,435.00			
1.24	10%	5% 1.		\$11,435.00			5% confident volume exceeds the action level criterion and 10% confident volume meets criterion
1.24	1%	30% 1.		\$11,435.00		85%	10% confident volume exceeds criterion and 5% confident volume meets criterion
1.24	30%	1% 1.		\$11,435.00			
0.62	30%	20% 1.		\$11,435.00			
0.62	20%	30% 1.		\$11,435.00			NAME OF THE PARTY
1.24	10%	10% 1.		\$11,435.00	하는 그리면 이번에 가장하다 하다 사람이 없었다.	80%	10% confident volume exceeds the action level criterion and 10% confident volume meets criterion
1.24	5%	20% 1.	9 16	\$11,435.00	\$182,960.00		\$6

1.24	20%	5%	1.9	15	\$11,435.00	\$171,525.00
1.24	5%	30%	1.9	13	\$11,435.00	\$148,655.00
1.24	30%	5%	1.9	12	\$11,435.00	\$137,220.00
1.24	20%	10%	1.9	11	\$11,435.00	\$125,785.00
1.24	10%	20%	1.9	12	\$11,435.00	\$137,220.00
0.62	30%	30%	1.9	11	\$11,435.00	\$125,785.00
1.24	10%	30%	1.9	9	\$11,435.00	\$102,915.00
1.24	30%	10%	1.9	8	\$11,435.00	\$91,480.00
1.24	20%	20%	1.9	8	\$11,435.00	\$91,480.00
1.24	20%	30%	1.9	5	\$11,435.00	\$57,175.00
1.24	30%	20%	1.9	5	\$11,435.00	\$57,175.00
1.24	30%	30%	1.9	3	\$11,435.00	\$34,305.00

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7.1.2 One Sample Proportion Test

Calculations for One-Sample Proportion Test Sampling Design User inputs are shaded areas. Null = Contaminated

For Delta = 0.04, (10% AL)			Alpha Values						
		α 1	α 2	α 3	α 4	α 5	Z _(1 - Beta)		
		0.01	0.05	0.10	0.20	0.30			
Values	$\beta 1 = 0.01$	3182	2310	1902	1462	1180	2.326348		
la/	$\beta 2 = 0.05$	2327	1591	1256	903	685	1.644854		
1.75	В 3 = 0.10	1925	1262	966	660	476	1.281552		
Beta	$\beta 4 = 0.20$	1490	915	666	417	273	0.841621		
777	$\beta 5 = 0.30$	1210	699	484	276	162	0.524401		

Action Level (AL) 0.40	0.40	0.40
LBGR 0.36	0.32	0.28

Delta 0.04 0.08 0.12

Delta as percent of AL 10% 20% 30%

 $Sqrt(P_0(1-P_0)) \quad 0.489898 \quad 0.489898 \quad 0.4898979$

Sqrt(P₁(1 - P₁)) 0.48 0.466476 0.4489989

Z_(1-Alpha) 2.326348 1.644854 1.2815516 0.841621 0.524401

For Delta = 0.08, (20% AL)							
		α 1	α 2	α 3	α 4	α 5	7
2425		0.01	0,05	0.10	0.20	0.30	$Z_{(1-Beta)}$
alues	$\beta 1 = 0.01$	774	559	459	351	282	2.326348
/al	$\beta 2 = 0.05$	569	387	305	218	164	1.644854
а	$\beta 3 = 0.10$	472	308	235	160	115	1.281552
Beta	$\beta 4 = 0.20$	367	225	163	102	66	0.841621
	$\beta 5 = 0.30$	300	173	119	68	40	0.524401

For Delta = 0.08, (30% AL)							
		α 1	α 2	α 3	α 4	a 5	7
		0.01	0.05	0.10	0.20	0.30	$Z_{(1-Beta)}$
'alues	$\beta 1 = 0.01$	332	238	195	148	118	2.326348
la/	$\beta 2 = 0.05$	245	166	130	92	69	1.644854
y s	$\beta 3 = 0.10$	205	133	101	68	49	1.281552
Beta	$\beta 4 = 0.20$	160	98	71	44	28	0.841621
Post .	$\beta 5 = 0.30$	132	76	52	30	17	0.524401

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Size-Sample Equation for One-Sample Proportion Test

$$n = \left(\frac{z_{1-\alpha}\sqrt{P_0(1-P_0)} + z_{1-\beta}\sqrt{P_1(1-P_1)}}{P_1 - P_0}\right)^2$$

Null = Contaminated

Values are rounded upwards (EPA 2000, p. 3-8). The equation is from (EPA 2000, p. 3-19).

	- Canada	Mistakenly Concluding < Action Level						
	49.0	a = 1%	a = 5%	$\alpha = 10\%$	$\alpha = 20\%$	$\alpha = 30\%$		
Width of the Gray I	Region (Δ) = 0.04 (1)	0% of AL)	Andrews Inc.					
	β = 1%	3182	2310	1902	1462	1180		
Mistakenly	β = 5%	2327	1591	1256	903	685		
Concluding >=	β = 10%	1925	1262	966	660	476		
Action Level	$\beta = 20\%$	1490	915	666	417	273		
	$\beta = 30\%$	1210	699	484	276	162		
Width of the Gray F	Region (Δ) = 0.08 (20	0% of AL)						
	β = 1%	774	559	459	351	282		
Mistakenly	β = 5%	569	387	305	218	164		
Concluding >=	β = 10%	472	308	235	160	115		
Action Level	$\beta = 20\%$	367	225	163	102	66		
	β = 30%	300	173	119	68	40		
Width of the Gray F	$Region (\Delta) = 0.12 (30)$	0% of AL)	- 12-22			7		
	β = 1%	332	238	195	148	118		
Mistakenly	β = 5%	245	166	130	92	69		
Concluding > =	β = 10%	205	133	101	68	49		
Action Level	$\beta = 20\%$	160	98	71	44	28		
	$\beta = 30\%$	132	76	52	30	17		

References

EPA. 2000. Guldance for Data Quality Assessment.

EPA QA/G-9, U.S. Environmental Protection Agency, Washington DC.

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Pipeline Removal Vs. Characterization Study - Decision Support Tool

NULL = Contaminated

Sampling Collection and Analysis Costs

 Unit Sample
 User inputs are shaded areas.

 Collection
 Analysis

 Cost
 Cost

 Dollars
 Dollars

 USC\$ + USA\$ (Sum) = AUSCSA\$

 \$50.00+
 \$11,385.00 = \$11,435.00

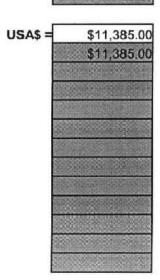
Definitions:

USC\$Unit sample collection cost in dollars
USA\$Unit sample analysis cost in dollars
USA\$ (SUM)Unit sample analysis cost for all analytical methods in dollars
AUSCSA\$Aggregate unit sample collection and sample analysis cost in dollars

SC\$ =	\$50.00
	\$50.00 \$50.00
	in a party fraging
	Chamilla Thirty British Shirty

Summed from cells below

Enter costs associated with each item for taking the sample



Summed from cells below

Enter analytical cost for each analytical method in the cells in column C

NULL = Total Cost for One-Sample Proportion Test Sampling Design

Samp	oling-Cost		200 00		User input	s are sh	naded
Width of Gray Region, (UBGR- LBGR)	Alpha	Beta	Number of Samples,	AUSCA\$	areas. Total Cost of Sampling Design		
0.04	1%	1%	3182	\$11,435.00	\$36,386,170.00		
0.04	1%	5%	2327	\$11,435.00	\$26,609,245.00	95%	confident residual contaminant meets the action level criterion
0.04	5%	1%	2310	\$11,435.00	\$26,414,850.00	95%	confident residual contaminant exceeds the action level criterion
0.04	1%	10%	1925	\$11,435.00	\$22,012,375.00	90%	confident residual contaminant meets the action level criterion
0.04	10%	1%	1902	\$11,435.00	\$21,749,370.00	90%	confident residual contaminant exceeds the action level criterion
0.04	5%	5%	1591	\$11,435.00	\$18,193,085.00	90%	5% confident volume meets action level criterion and 5% confident volume exceeds criteri
0.04	1%	20%	1490	\$11,435.00	\$17,038,150.00	80%	confident residual contaminant meets the action level criterion
0.04	20%	1%	1462	\$11,435.00	\$16,717,970.00	80%	confident residual contaminant exceeds the action level criterion
0.04	5%	10%	1262	\$11,435.00	\$14,430,970.00	85%	5% confident vol. exceeds action level criterion and 10% confident volume meets criterion
0.04	10%	5%	1256	\$11,435.00	\$14,362,360.00	85%	10% confident vol. exceeds action level criterion and 5% confident volume meets criterion
0.04	1%	30%	1210	\$11,435.00	\$13,836,350.00		
0.04	30%	1%	1180	\$11,435.00	\$13,493,300.00		
0.04	10%	10%	966	\$11,435.00	\$11,046,210.00	80%	10% confident vol. exceeds action level criterion and 10% confident volume meets criterio
0.04	5%	20%	915	\$11,435.00	\$10,463,025.00		
0.04	20%	5%	903	\$11,435.00	\$10,325,805.00		
0.08	1%	1%	774	\$11,435.00	\$8,850,690.00		
0.04	5%	30%	699	\$11,435.00	\$7,993,065.00		
0.04	30%	5%	685	\$11,435.00	\$7,832,975.00		
0.04	10%	20%	666	\$11,435.00	\$7,615,710.00		
0.04	20%	10%	660	\$11,435.00	\$7,547,100.00		
0.08	1%	5%	569	\$11,435.00	\$6,506,515.00	95%	confident residual contaminant meets the action level criterion
0.08	5%	1%	559	\$11,435.00	\$6,392,165.00	95%	confident residual contaminant exceeds the action level criterion
0.04	10%	30%	484	\$11,435.00	\$5,534,540.00		
0.04	30%	10%	476	\$11,435.00	\$5,443,060.00		
80.0	1%	10%	472	\$11,435.00	\$5,397,320.00	90%	confident residual contaminant meets the action level criterion
0.08	10%	1%	459	\$11,435.00	\$5,248,665.00	90%	confident residual contaminant exceeds the action level criterion
0.04	20%	20%	417	\$11,435.00	\$4,768,395.00		confident residual contaminant meets the action level criterion confident residual contaminant exceeds the action level criterion

				100				
0.04	20%	20%	417	\$11,435.00	\$4,768,395.00			
0.08	5%	5%	387	\$11,435.00	\$4,425,345.00	90%	5% confident vol. meets action level criterion and 5% confident volume exceeds criterion	
80.0	1%	20%	367	\$11,435.00	\$4,196,645.00	80%	confident residual contaminant meets the action level criterion	
0.08	20%	1%	351	\$11,435.00	\$4,013,685.00	80%	confident residual contaminant exceeds the action level criterion	
0.12	1%	1%	332	\$11,435.00	\$3,796,420.00			
0.08	5%	10%	308	\$11,435.00	\$3,521,980.00	85%	5% confident vol. exceeds action level criterion and 10% confident volume meets criterio	
80.0	1%	30%	300	\$11,435.00	\$3,430,500.00			
0.08	10%	5%	305	\$11,435.00	\$3,487,675.00	85%	10% confident vol. exceeds action level criterion and 5% confident volume meets criterio	
0.04	20%	30%	276	\$11,435.00	\$3,156,060.00			
0.04	30%	20%	273	\$11,435.00	\$3,121,755.00			
0.08	30%	1%	282	\$11,435.00	\$3,224,670.00			
0.12	1%	5%7	245	\$11,435.00	\$2,801,575.00	95%	confident residual contaminant meets the action level criterion	
0.08	10%	10%	235	\$11,435.00	\$2,687,225.00	80%	10% confident vol. exceeds action level criterion and 10% confident vol. meets criterion	
0.12	5%	1%	238	\$11,435.00	\$2,721,530.00	95%	confident residual contaminant exceeds the action level criterion	V
80.0	5%	20%	225	\$11,435.00	\$2,572,875.00			ξ
0.08	20%	5%	218	\$11,435.00	\$2,492,830.00			ç
0.12	1%	10%	205	\$11,435.00	\$2,344,175.00	90%	confident residual contaminant meets the action level criterion	Ù
0.12	10%_	1%	195	\$11,435.00	\$2,229,825.00	90%	confident residual contaminant exceeds the action level criterion	4
80.0	5%	30%	173	\$11,435.00	\$1,978,255.00			1
0.04	30%	30%	162	\$11,435.00	\$1,852,470.00			S
80.0	10%	20%_	163	\$11,435.00	\$1,863,905.00			-
0.12	5%	5%	166	\$11,435.00	\$1,898,210.00	90%	5% confident vol. meets action level criterion and 5% confident volume exceeds criterion	S
0.12	1%	20%	160	\$11,435.00	\$1,829,600.00	80%	confident residual contaminant meets the action level criterion	4
80.0	30%	5%	164	\$11,435.00	\$1,875,340.00			0
0.08	20%	10%	160	\$11,435.00	\$1,829,600.00			
0.12	the same and the same and the same	1%3	148	\$11,435.00	\$1,692,380.00	80%	confident residual contaminant exceeds the action level criterion	
0.12	1%	30%	132	\$11,435.00	\$1,509,420.00			
0.12		10%	133	\$11,435.00	\$1,520,855.00	85%	5% confident vol. exceeds action level criterion and 10% confident vol. meets criterion	
0.12	10%	5%	130	\$11,435.00	\$1,486,550.00	85%	10% confident vol. exceeds action level criterion and 5% confident vol. meets criterion	
0.08	10%	30%	119	\$11,435.00	\$1,360,765.00			
80.0	30%	10%	115	\$11,435.00	\$1,315,025.00			
0.12	30%	1%	118	\$11,435.00	\$1,349,330.00			
80.0	20%	20%	102	\$11,435.00	\$1,166,370.00	0001		
0.12	M	10%	101	\$11,435.00	\$1,154,935.00	80%	10% confident vol. exceeds action level criterion and 10% confident vol. meets criterion	
0.12	5%	20%	98	\$11,435.00	\$1,120,630.00			

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0.12	10%	20%	71	\$11,435.00	\$811,885.00
0.08	20%	30%	68	\$11,435.00	\$777,580.00
0.12	30%	5%	69	\$11,435.00	\$789,015.00
0.12	20%	10%	68	\$11,435.00	\$777,580.00
0.08	30%	20%	66	\$11,435.00	\$754,710.00
0.12	10%	30%	52	\$11,435.00	\$594,620.00
0.12	30%	10%	49	\$11,435.00	\$560,315.00
0.12	20%	20%	44	\$11,435.00	\$503,140.00
0.08	30%	30%	40	\$11,435.00	\$457,400.00
0.12	20%	30%	30	\$11,435.00	\$343,050.00
0.12	30%	20%	28	\$11,435.00	\$320,180.00
0.12	3004	30%	17	\$11.435.00	8404 305 00

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Pipeline Removal Vs. Characterization Study - Decision Support Tool

7.1.3 Wilcoxon Sign Test

Calculations for MARSSIM Sign Test Sampling Design User inputs are shaded areas. Null = Contaminated

For Delta - 0.31,							
(5 %	AL)	α 1	α 2	α 3	α 4	α 5	Z _(1-Beta)
320		0.01	0.05	0.10	0.20	0.30	
Values	$\beta 1 = 0.01$	1547	1127	930	718	581	2.326348
'al	$\beta 2 = 0.05$	1127	774	612	443	338	1.644854
	$\beta 3 = 0.10$	930	612	471	323	234	1.281552
Beta	$\beta 4 = 0.20$	718	443	323	203	135	0.841621
_	$\beta 5 = 0.30$	581	338	234	135	80	0.524401

Action Level (AL)	6.20	6.20	6.20
LBGR	5.89	5.58	4.96

Delta 0.31 0.62 1.24

Delta as percent of AL 5% 10% 20%

Estimated Std Dev.

Inflation %

1.9

MARSSIM default is 20%

Z_(1-Alpha) 2.326348

1.644854

.644854 1.2815516 0.841621 0.52440 0.743003

Sign P 0.564803 0.627907

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For Delta = 0.62, (10 % AL)							
		α 1	α 2	α 3	α 4	α 5	7
		0.01	0.05	0.10	0.20	0.30	Z _(1 - Beta)
alues	$\beta 1 = 0.01$	398	290	239	185	150	2.326348
Ta /	$\beta \ 2 = 0.05$	290	200	158	114	87	1.644854
а	$\beta 3 = 0.10$	239	158	122	83	60	1.281552
Beta	$\beta 4 = 0.20$	185	114	83	53	35	0.841621
	$\beta 5 = 0.30$	150	87	60	35	21	0.524401

For Delta = 1.24, (20% AL)								
		α 1	α 2	α 3	α 4	a 5	7	
		0.01	0.05	0.10	0.20	0.30	Z _(1 - Beta)	
Values	$\beta 1 = 0.01$	111	81	68	52	42	2.326348	
[R	$\beta 2 = 0.05$	81	56	45	33	24	1.644854	
	$\beta 3 = 0.10$	68	45	34	24	17	1.281552	
Beta	$\beta 4 = 0.20$	52	33	24	15	10	0.841621	
	$\beta 5 = 0.30$	42	24	17	10	6	0.524401	

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Pipeline Removal Vs. Characterization Study - Decision Support Tool

Size-Sample Equation for MARSSIM Sign Test

Null = Contaminated

$$n = \frac{\left(z_{1-\alpha} + z_{1-\beta}\right)^2}{4\left(Sign\ P - 0.5\right)^2} \text{ where } Sign\ P = \Phi\left(\frac{\Delta}{s_{Total}}\right)$$

where Φ is the cummulative stand, norm, dist. function.

Values are rounded upwards (EPA 2000, p. 3-8). The equation is from (EPA 2000, p. 5-33).

	Mistakenly Concluding < Action Level						
	$\alpha = 1\%$	$\alpha = 5\%$	$\alpha = 10\%$	$\alpha = 20\%$	$\alpha = 30\%$		
Estimated Std. Dev = 1.9	s = 1.9	s = 1.9	s = 1.9	s = 1.9	s = 1.9		

Width of the Gray I	Region (Δ) = 0.31 (5%)	of AL)		100000	2000	
	$\beta = 1\%$	1547	1127	930	718	58
Mistakenly	β = 5%	1127	774	612	443	338
Concluding >=	β = 10%	930	612	471	323	234
Action Level	β = 20%	718	443	323	203	138
	$\beta = 30\%$	581	338	234	443 323 203 135 185 114 83 53 35 52 33 24 15	80
Width of the Gray I	Region (Δ) = 0.62 (10%)	of AL)				
	β = 1%	398	290	239	185	150
Mistakenly	β = 5%	290	200	158	114	87
Concluding > =	β = 10%	239	158	122	83	60
Action Level	β - 20%	185	114	83	53	35
	β = 30%	150	87	60	185 114 83 53	21
Width of the Gray I	Region (Δ) = 1.24 (20%)	of AL)				1000
8	β = 1%	111	81	68	52	42
Mistakenly	β = 5%	81	56	45	33	24
Action Level Width of the Gray I Mistakenly Concluding > =	$\beta = 10\%$	68	45	34	24	17
Action Level	$\beta = 20\%$	52	33	24	15	10
	$\beta = 30\%$	42	24	17	10	

References

EPA. 2000. Guidance for Data Quality Assessment.
PA QA/G-9, U.S. Environmental Protection Agency, Washington DC.

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Pipeline Removal Vs. Characterization Study - Decision Support Tool

NULL = Contaminated

Sampling Collection and Analysis Costs

 Unit Sample
 User inputs are shaded areas.

 Collection
 Analysis

 Cost
 Cost

 Dollars
 Dollars

 USC\$ + USA\$ (Sum) = \$11,385.00 = \$11,435.00

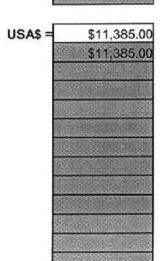
Definitions:

USC\$Unit sample collection cost in dollars
USA\$Unit sample analysis cost in dollars
USA\$ (SUM)Unit sample analysis cost for all analytical methods in dollars
AUSCSA\$Aggregate unit sample collection and sample analysis cost in dollars

	\$50.00
4000	\$50.00
(100 A) A)	
	1.20
na la mai d	

Summed from cells below

Enter costs associated with each item for taking the sample



Summed from cells below

Enter analytical cost for each analytical method in the cells in column C

NULL = Contaminated Total Cost for MARSSIM Sign Test Sampling Design

Sami		t Budge	t \$2,0	00,000.00		User inputs	are sha	ded areas.
Width of	Western Street, Street			Number	жиной			
Gray				o.f		Total Cost of		
Region,	Alpha	Beta	SD	Samples,	AUSCA\$	Sampling Desig	n	
(UBGR-				n				
LBGR)	4.07	40/	1.0	1517	014 425 00	\$17,689,945.00		
0.31	1%	1%	1.9	1547		\$12,887,245.00	95%	confident residual contaminant meets the action level criterion
0.31	1%	5%	1.9	1127		The second secon	95%	confident residual contaminant meets the action level criterion
0.31	5%	1%	1.9	1127		\$12,887,245.00		confident residual contaminant exceeds the action level criterion
0.31	1%	10%	1.9	930		\$10,634,550.00	90%	
0.31	10%	1%	1.9	930		\$10,634,550.00	90%	confident residual contaminant meets the action level criterion
0.31	5%	5%	1.9	774	(4)	\$8,850,690.00	90%	5% confident volume meets the action level criterion and 5% confident volume exceeds or
0.31	1%	20%	1.9	718	\$11,435.00		80%	confident residual contaminant exceeds the action level criterion
0.31	20%	1%	1.9	718	\$11,435.00		80%	confident residual contaminant meets the action level criterion
0.31	5%	10%	1.9	612	\$11,435.00		85%	5% confident volume exceeds the action level criterion and 10% confident volume meets
0.31	10%	5%	1.9	612	\$11,435.00		85%	10% confident volume exceeds the action level criterion and 5% confident volume meets
0.31	1%	30%	1.9	581	\$11,435.00			<u> </u>
0.31	30%	1%	1.9	581	\$11,435.00		1220	10% confident volume exceeds the action level criterion and 10% confident volume meets
0.31	10%	10%	1.9	471	\$11,435.00		80%	
0.31	5%	20%	1.9	443	\$11,435.00			S Z
0.31	20%	5%	1.9	443	74	\$5,065,705.00		7
0.62	1%	1%	1.9	398	\$11,435.00			6
0.31	5%	30%	1.9	338	\$11,435.00			Ó
0.31	30%	5%	1.9	338	\$11,435.00			
0.31	10%	20%	1.9	323	\$11,435.00	\$3,693,505.00		So the second se
0.31	20%	10%	1.9	323	\$11,435.00	\$3,693,505.00		confident residual contaminant meets the action level criterion
0.62	1%	5%	1.9	290	\$11,435.00	\$3,316,150.00	95%	confident residual contaminant meets the action level criterion
0.62	5%	1%	1.9	290	\$11,435.00	\$3,316,150.00	95%	confident residual contaminant exceeds the action level criterion
0.62	1%	10%	1.9	239	\$11,435.00	\$2,732,965.00	90%	confident residual contaminant meets the action level criterion
0.31	10%	30%	1.9	234	\$11,435.00	\$2,675,790.00		
0.62	10%	1%	1.9	239	\$11,435.00	\$2,732,965.00	90%	confident residual contaminant exceeds the action level criterion
0.31	30%	10%	1.9	234	\$11,435.00	\$2,675,790.00		
0.31	20%	20%	1.9	203	\$11,435.00	\$2,321,305.00		
0.62	5%	5%	1.9	200	\$11,435.00	\$2,287,000.00	90%	5% confident volume meets the action level criterion and 5% confident volume exceeds of

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0.62	5%	5%	1.9	200	\$11,435.00	\$2,287,000.00	90%	5% confident vol. meets action level criterion and 5% confident vol. exceeds criterion
0.62	1%	20%	1.9	185	\$11,435.00	\$2,115,475.00	80%	confident residual contaminant meets the action level criterion
0.62	20%	1%	1.9	185	\$11,435.00	\$2,115,475.00	80%	confident residual contaminant exceeds the action level criterion
0.62	5%	10%	1.9	158	\$11,435.00	\$1,806,730.00	85%	5% confident vol. exceeds action level criterion and 10% confident vol. meets criterion
0.62	10%	5%	1.9	158	\$11,435.00	\$1,806,730.00	85%	10% confident vol. exceeds action level criterion and 5% confident vol. meets criterion
0.62	1%	30%	1.9	150	\$11,435.00	\$1,715,250.00		
0.62	30%	1%	1.9	150	\$11,435.00	\$1,715,250.00		
0.31	20%	30%	1.9	135	\$11,435.00	\$1,543,725.00		
0.31	30%	20%	1.9	135	\$11,435.00	\$1,543,725.00		
0.62	10%	10%	1.9	122	\$11,435.00	\$1,395,070.00	80%	10% confident vol. exceeds action level criterion and 10% confident vol. meets criterion
0.62	5%	20%	1.9	114	\$11,435.00	\$1,303,590.00		
0.62	20%	5%	1.9	114	\$11,435.00	\$1,303,590.00		
1.24	1%	1%	1.9	111	\$11,435.00	\$1,269,285.00		
0.62	5%	30%	1.9	87	\$11,435.00	\$994,845.00		
0.62	30%	5%	1.9	87	\$11,435.00	\$994,845.00		
0.62	10%	20%	1.9	83	\$11,435.00	\$949,105.00		
0.62	20%	10%	1.9	83	\$11,435.00	\$949,105.00		
0.31	30%	30%	1.9	80	\$11,435.00	\$914,800.00		
1.24	1%	5%	1.9	81	\$11,435.00	\$926,235.00	95%	confident residual contaminant meets the action level criterion
1.24	5%	1%	1.9	81	\$11,435.00	\$926,235.00	95%	confident residual contaminant exceeds the action level criterion
1.24	1%	10%	1.9	68	\$11,435.00	\$777,580.00	90%	confident residual contaminant meets the action level criterion
0.62	10%	30%	1.9	60	\$11,435.00	\$686,100.00		
1.24	10%	1%	1.9	68	\$11,435.00	\$777,580.00	90%	confident residual contaminant exceeds the action level criterion
0.62	30%	10%	1.9	60	\$11,435.00	\$686,100.00		
1.24	1%	20%	1.9	52	\$11,435.00	\$594,620.00	80%	confident residual contaminant meets the action level criterion
1.24	5%	5%	1.9	56	\$11,435.00	\$640,360.00	90%	5% confident vol. meets action level criterion and 5% confident vol. exceeds criterion
0.62	20%	20%	1.9	53	\$11,435.00	\$606,055.00		
1.24	20%	1%	1.9	52	\$11,435.00	\$594,620.00	80%	confident residual contaminant exceeds the action level criterion
1.24	1%	30%	1.9	42	\$11,435.00	\$480,270.00		
1.24	5%	10%	1.9	45	\$11,435.00	\$514,575.00	85%	5% confident vol. exceeds action level criterion and 10% confident vol. meets criterion
1.24	10%	5%	1.9	45	\$11,435.00	\$514,575.00	85%	10% confident vol. exceeds action level criterion and 5% confident vol. meets criterion
1.24	30%	1%	1.9	42	\$11,435.00	\$480,270.00		
0.62	20%	30%	1.9	35	\$11,435.00	\$400,225.00		
0.62	30%	20%	1.9	35	\$11,435.00	\$400,225.00		
1.24	10%	10%	1.9	34	\$11,435.00	\$388,790.00	80%	10% confident vol. exceeds action level criterion and 10% confident vol. meets criterion
1.24	5%	20%	1.9	33	\$11,435.00	\$377,355.00		

1.24	5%	30%	1.9	24	\$11,435.00	\$274,440.00
1.24	10%	20%	1.9	24	\$11,435.00	\$274,440.00
1.24	30%	5%	1.9	24	\$11,435.00	\$274,440.00
1.24	20%	10%	1.9	24	\$11,435.00	\$274,440.00
0.62	30%	30%	1.9	21	\$11,435.00	\$240,135.00
1.24	10%	30%	1.9	17	\$11,435.00	\$194,395.00
1.24	30%	10%	1.9	17	\$11,435.00	\$194,395.00
1.24	20%	20%	1.9	15	\$11,435.00	\$171,525.00
1.24	20%	30%	1.9	10	\$11,435.00	\$114,350.00
1.24	30%	20%	1.9	10	\$11,435.00	\$114,350.00
1 24	30%	30%	1.9	6	\$11,435.00	\$68,610,00

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Pipeline Removal Vs. Characterization Study - Decision Support Tool

7.1.4 Two Sample Student t-Test

Calculations for Two-Sample t-Test Sampling Design

User inputs are shaded areas.

Null = Contaminated

For I	Delta = 0.31,	Alpha Values					
(5%	AL)	α 1	α 2	α 3	α 4	a 5	
//**		0.01	0.05	0.10	0.20	0.30	
Values	$\beta 1 = 0.01$	1628	1186	979	755	611	
/al	$\beta 2 = 0.05$	1187	814	644	465	354	
	$\beta 3 = 0.10$	980	645	494	339	246	
Beta	$\beta 4 = 0.20$	756	466	340	214	141	
	$\beta 5 = 0.30$	612	355	246	141	83	

Action Level (AL)	6.20	6.20	6.20
LBGR	5.89	5.58	4.96

Delta 0.31

0.62

1.24

Delta as percent of AL

5%

10%

20%

Estimated Std Dev. 1.9

 $Z_{\text{(1-Alpha)}}$ 2.326348 1.644854 1.2815516 0.841621 0.524401 0.5 $(Z_{\text{(1-Alpha)}})^2$ 2.705947 1.352772 0.8211872 0.354163 0.137498 $Z_{\text{(1-Beta)}}$ 2.326348 1.644854 1.2815516 0.841621 0.524401

For I	Delta = 0.62 ,	Alpha Values				
(10%	6 AL)	α 1	α 2	α 3	α 4	α 5
2500		0.01	0.05	0.10	0.20	0.30
Values	$\beta 1 = 0.01$	408	297	245	189	153
/al	$\beta 2 = 0.05$	298	204	162	117	89
	$\beta 3 = 0.10$	246	162	124	85	62
Beta	$\beta 4 = 0.20$	190	117	86	54	36
	$\beta 5 = 0.30$	154	90	62	36	21

For I	Delta = 1.24,		Al	pha Va	lues	
(20%	AL)	a 1	α 2	α 3	α 4	α 5
9220		0.01	0.05	0.10	0.20	0.30
nes	$\beta 1 = 0.01$	104	75	62	48	39
la/	$\beta 2 = 0.05$	76	52	41	30	23
22	$\beta 3 = 0.10$	63	41	32	22	16
Beta Values	$\beta 4 = 0.20$	49	30	22	14	9
	$\beta 5 = 0.30$	40	23	16	9	6

Size-Sample Equation for Two-Sample t-Test

Null = Contaminated

$$m = n = \frac{2s_{total}^{2} \left(z_{1-\alpha} + z_{1-\beta}\right)^{2}}{\Delta^{2}} + 0.25z_{1-\alpha}^{2}$$

Values are rounded upwards (EPA 2000, p. 3-8). The equation is from (EPA 2000, p. 3-24.

		Mistakenly Concluding < Action Level					
	$\alpha = 1\%$	$\alpha = 5\%$	$\alpha = 10\%$	$\alpha = 20\%$	$\alpha = 30\%$		
Estimated Std. Dev = 1.9	s = 1.9	s = 1.9	s = 1.9	s = 1.9	s = 1.9		

Width of the Gray I	Region (Δ) = 0.31 (5%)	of AL)				
Widdi of the Gray I	$\beta = 1\%$	1628	1186	979	755	611
Mistakenly	β = 5%	1187	814	644	465	354
Concluding >=	β = 10%	980	645	494	339	246
Action Level	$\beta = 20\%$	756	466	340	214	141
	$\beta = 30\%$	612	355	246	465 339 214 141 189 117 85 54 36 48 30 22 14	83
Width of the Gray I	Region (Δ) = 0.62 (10%)	of AL)		24		
	β = 1%	408	297	245	189	153
Mistakenly Concluding > =	β = 5%	298	204	162	117	89
Concluding > =	β = 10%	246	162	124	85	62
Action Level	β = 20%	190	117	86	54	36
	β = 30%	154	90	62	465 339 214 141 189 117 85 54 36 48 30 22	21
Width of the Gray I	$Region (\Delta) = 1.24 (20\%)$	of AL)				
	β = 1%	104	75	62	48	39
Mistakenly	β = 5%	76	52	41	30	23
Concluding > =	β = 10%	63	41	32	22	16
Action Level	$\beta = 20\%$	49	30	22	14	9
	$\beta = 30\%$	40	23	16	9	6

References

EPA. 2000. Guidance for Data Quality Assessment. EPA QA/G-9, U.S. Environmental Protection Agency, Washington DC.

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NULL = Contaminated

Sampling Collection and Analysis Costs

Unit Sample	ι	Init Sample		User inputs are shaded area	ıs.
Collection	F	nalysis			
Cost		Cost			
Dollars	[Oollars			
USC\$	+	USA\$ (Sum)	=	AUSCSA\$	
\$50.0)()+	\$11,385.00	=	\$11,435.00	

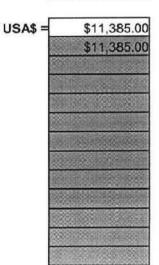
Definitions:

USC\$Unit sample collection cost in dollars
USA\$Unit sample analysis cost in dollars
USA\$ (SUM)Unit sample analysis cost for all analytical methods in dollars
AUSCSA\$Aggregate unit sample collection and sample analysis cost in dollars

JSC\$ =	\$50.00
	\$50.00 \$50.00
	02/09/2005
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Summed from cells below

Enter costs associated with each item for taking the sample



Summed from cells below

Enter analytical cost for each analytical method in the cells in column C

NULL = Total Cost for Two-Sample t-Test Sampling Design Contaminated

246 \$11,435.00 \$2,813,010.00

Sampl	ing-Cost	Transcon von Araba				User inputs	are s	haded
	Budget	\$2,000	00.00			areas.		
Width of Gray				Number of		Total Cost		
Region, (UBGR- LBGR)	Alpha	Beta	SD	Samples, n	AUSCA	\$ Sampling Design	j	
0.31	1%	1%	1.9	1628 \$11	,435.00 \$	18,616,180.00		
0.31	1%	5%	1.9	1187 \$11	,435.00 \$	13,573,345.00	95%	confident residual contaminant meets the action level criterion
0.31	5%	1%	1.9	1186 \$11	,435.00 \$	13,561,910.00	95%	confident residual contaminant exceeds the action level criterion
0.31	1%	10%	1.9	980 \$11	,435.00 \$	11,206,300.00	90%	confident residual contaminant meets the action level criterion
0.31	10%	1%	1.9	979 \$11	,435.00 \$	11,194,865.00	90%	confident residual contaminant exceeds the action level criterion
0.31	5%	5%	1.9	814 \$11	,435.00	\$9,308,090.00	90%	
0.31	1%	20%	1.9	756 \$11	,435.00	\$8,644,860.00	80%	confident residual contaminant meets the action level criterion
0.31	20%	1%	1.9	755 \$11	,435.00	\$8,633,425.00	80%	confident residual contaminant meets the action level criterion
0.31	5%	10%	1.9	645 \$11	,435.00	\$7,375,575.00	85%	10% confident vol. exceeds action level criterion and 5% confident volume meets criterion (
0.31	10%	5%	1.9	644 \$11	,435.00	\$7,364,140.00	85%	5% confident vol. exceeds action level criterion and 10% confident volume meets criterion W
0.31	1%	30%	1.9	612 \$11	,435.00	\$6,998,220.00		Ž.
0.31	30%	1%	1.9		, , , , , , , , , , , , , , , , , , , ,	\$6,986,785.00		~
0.31	10%	10%	1.9	494 \$11	,435.00	\$5,648,890.00	80%	10% confident vol. exceeds action level criterion and 10% confident vol. meets criterion
0.31	5%	20%	1.9	466 \$11	,435.00	\$5,328,710.00		O
0.31	20%	5%	1.9			\$5,317,275.00		Rev. O
0.62	1%	1%	1.9	408 \$11	,435.00_	\$4,665,480.00		Š.
0.31	5%	30%	1.9	355 \$11	,435.00	\$4,059,425.00		0
0.31	30%	5%	1.9	354 \$11	,435.00	\$4,047,990.00		· ·
0.31	10%	20%	1.9	340 \$11	,435.00	\$3,887,900.00		
0.31	20%	10%	1.9	339 \$11	,435.00	\$3,876,465.00		
0.62	1%	5%	1.9	298 \$11	,435.00	\$3,407,630.00	95%	confident residual contaminant meets the action level criterion
0.62	5%	1%	1.9	297 \$11	,435.00	\$3,396,195.00	95%	confident residual contaminant exceeds the action level criterion
0.62	1%	10%	1.9	246 \$11	,435.00	\$2,813,010.00	90%	confident residual contaminant meets the action level criterion
0.31	10%	30%	1.9	246 \$11	,435.00	\$2,813,010.00		
0.62	10%	1%	1.9	245 \$11	,435.00	\$2,801,575.00	90%	confident residual contaminant exceeds the action level criterion

0.31

30%

10%

1.9

Pipeline Removal Vs.	Characterization	Study - Decision	Support Tool

0.31	20%	20%	1.9	214 \$11,435.00	\$2,447,090,00		
0.62	5%	5%	1.9	204 \$11,435.00		90%	5% confident vol. meets action level criterion and 5% confident volume exceeds criterion
0.62	1%	20%	1.9	190 \$11,435.00		80%	confident residual contaminant meets the action level criterion
0.62	20%	1%	1.9	189 \$11,435.00		80%	confident residual contaminant exceeds the action level criterion
0.62	5%	10%	1.9	162 \$11,435.00		85%	5% confident vol. exceeds action level criterion and 10% confident volume meets criterion
0.62	10%	5%	1.9	162 \$11,435.00			10% confident vol. exceeds action level criterion and 5% confident volume meets criterion
0.62	1%	30%	1.9	154 \$11,435.00			To your service of the control of the foliated by confident voiding means chiarion
0.62	30%	1%	1.9	153 \$11,435.00			
0.31	20%	30%	1.9	141 \$11,435.00			
0.31	30%	20%	1.9	141 \$11,435.00			
0.62	10%	10%	1.9	124 \$11,435.00		80%	10% confident vol. exceeds action level criterion and 10% confident vol. meets criterion
0.62	5%	20%	1.9	117 \$11,435.00	\$1,337,895.00		The second of th
0.62	20%	5%	1.9	117 \$11,435.00	\$1,337,895.00		
1.24	1%	1%	1.9	104 \$11,435.00			۸2
0.62	5%	30%	1.9	90 \$11,435.00			Solo
0.62	30%	5%	1.9	89 \$11,435.00	\$1,017,715.00		3
0.62	10%	20%	1.9	86 \$11,435.00	\$983,410.00		Ĭ.
0.62	20%	10%	1.9	85 \$11,435.00	\$971,975.00		confident residual contaminant meets the action level criterion
0.31	30%	30%	1.9	83 \$11,435.00	\$949,105.00		7.
1.24	1%	5%	1.9	76 \$11,435.00	\$869,060.00	95%	confident residual contaminant meets the action level criterion
1.24	5%	10 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	1.9	75 \$11,435.00	\$857,625.00	95%	confident residual contaminant exceeds the action level criterion
1.24	11%	10%	1.9	63 \$11,435.00	\$720,405.00	90%	confident residual contaminant meets the action level criterion
0.62	10%	30%	1.9	62 \$11,435.00	\$708,970.00		confident residual contaminant exceeds the action level criterion
1.24	THE PERSON NAMED IN COLUMN	Market 11,11, 11, 111, 111, 111, 111, 111, 1	1.9	62 \$11,435.00	\$708,970.00	90%	confident residual contaminant exceeds the action level criterion
0.62	30%	10%	1.9	62 \$11,435.00	\$708,970.00		Ċ
1.24 1.24	1%	20%	1.9	49 \$11,435.00	\$560,315.00		confident residual contaminant meets the action level criterion
			1.9	52 \$11,435.00	\$594,620.00	90%	5% confident vol. meets action level criterion and 5% confident volume exceeds criterion
0.62	20%	20%	1.9	54 \$11,435.00	\$617,490.00		
1.24	THE PERSON NAMED IN COLUMN	Marie and Andrea of	1.9	48 \$11,435.00	\$548,880.00	80%	confident residual contaminant exceeds the action level criterion
1.24	1%	30%	1.9	40 S11,435.00	\$457,400.00		
1.24	5%		1.9	41 \$11,435.00	\$468,835.00		5% confident vol. exceeds action level criterion and 10% confident volume meets criterion
1.24	10%	manufacture of the latest and the la	1.9	41 \$11,435.00	\$468,835.00	85%	10% confident vol. exceeds action level criterion and 5% confident volume meets criterion
1.24	30%	1%	1.9	39 \$11,435.00	\$445,965.00		
0.62	20%	30%	1.9	36 \$11,435.00	\$411,660.00		
0.62	30%	20%	1.9	36 \$11,435.00	\$411,660.00		
<u>.</u> 1.24 <u>.</u>	10%	※10%	1.9	32 \$11,435.00	\$365,920.00	80%	10% confident vol. exceeds action level criterion and 10% confident vol. meets criterion

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1,24	20%	5%	1.9	30 \$11,435.00	\$343,050.00
1.24	5%	30%	1.9	23 \$11,435.00	\$263,005.00
1.24	10%	20%	1.9	22 \$11,435.00	\$251,570.00
1.24	30%	5%	1.9	23 \$11,435.00	\$263,005.00
1.24	20%	10%	1.9	22 \$11,435.00	\$251,570.00
0.62	30%	30%	1.9	21 \$11,435.00	\$240,135.00
1.24	10%	30%	1.9	16 \$11,435.00	\$182,960.00
1.24	30%	10%	1.9	16 \$11,435.00	\$182,960.00
1.24	20%	20%	1.9	14 \$11,435.00	\$160,090.00
1.24	20%	30%	1.9	9 \$11,435.00	\$102,915.00
1.24	30%	20%	1.9	9 \$11,435.00	\$102,915.00
1.24	30%	30%	1.9	6 \$11,435,00	\$68,610.00

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Pipeline Removal Vs. Characterization Study - Decision Support Tool

7.1.5 Two Sample Proportion Test

Calculations for Two Sample Proportion Test Sampling Design User inputs are shaded areas. Null = Contaminated

For Delta = 0.04, (10% AL)							
		α 1	a 2	α 3	α4	a 5	7
1/20/01		0.01	0.05	0.10	0.20	0.30	Z(I - Beta)
Values	$\beta 1 = 0.01$	553	403	332	256	208	2.326348
/al	$\beta \ 2 = 0.05$	403	276	219	158	120	1.644854
	$\beta 3 = 0.10$	332	219	168	115	84	1.281552
Beta	$\beta 4 = 0.20$	256	158	115	73	48	0.841621
	$\beta 5 = 0.30$	208	120	84	48	29	0.524401

Delta as percent of AL	20%	30%	40%
Width of Gray Region, Delta	0.1	0.15	0.2
Action Level (Specified difference of proportions	0.5	0.5	0.5
Estimated Proportion in Reference Area, P ₂	0.1	0.1	0.1
Estimated Proportion in Survey Unit, P ₁	0.2	0.2	0.2

Pooled

Proportion 0.15

PBar(1 - PBar) 0.1275

Z_(1-Alpha) 2.326348 1.6448541.2815516

For Delta = 0.08 ,							
(20%	6 AL)	α 1	α 2	2 α 3 α 4 α 5 7		7	
		0.01	0.05	0.10	0.20	0.30	$Z_{(1-Beta)}$
Values	$\beta 1 = 0.01$	246	179	148	114	93	2.326348
/al	$\beta 2 = 0.05$	179	123	98	71	54	1.644854
	$\beta 3 = 0.10$	148	98	75	52	37	1.281552
Beta	$\beta 4 = 0.20$	114	71	52	33	22	0.841621
	$\beta 5 = 0.30$	93	54	37	22	13	0.524401

For Delta = 0.08 ,								
(30%	6 AL)	α 1	α 2	α 3	α 4	α 5	Z _(1 - Beta)	
		0.01	0.05	0.10	0.20	0.30		
alues	$\beta 1 = 0.01$	139	101	83	64	52	2.326348	
Val	$\beta 2 = 0.05$	101	69	55	40	30	1.644854	
110	$\beta 3 = 0.10$	83	55	42	29	21	1.281552	
Beta	$\beta 4 = 0.20$	64	40	29	19	12	0.841621	
	$\beta 5 = 0.30$	52	30	21	12	8	0.524401	

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Pipeline Removal Vs. Characterization Study - Decision Support Tool

Size-Sample Equation for Two-Sample Proportion Test

Null = Contaminated

$$n = \frac{2(z_{1-\alpha} + z_{1-\beta})^2 \overline{P}(1-\overline{P})}{(\delta_0 - \delta_1)^2} \text{ where } \overline{P} = \frac{P_1 + P_2}{2}$$

Values are rounded upwards (EPA 2000, p. 3-8). The equation is modified from (EPA 2000, p. 3-29). See Gilbert et al. 2000 pp 3.14, 3.15

			Mistakenly	Concluding <	Action Level	
4.50		$\alpha = 1\%$	$\alpha = 5\%$	$\alpha = 10\%$	$\alpha = 20\%$	$\alpha = 30\%$
Width of the Grav I	Region (Δ) = 0.1 (20)	% of AL)		ACRIMETE		
	$\beta = 1\%$	553	403	332	256	208
Mistakenly	$\beta = 5\%$	403	276	219	158	120
Concluding > =	$\beta = 10\%$	332	219	168	115	84
Action Level	$\beta = 20\%$	256	158	115	73	48
	$\beta = 30\%$	208	120	84	48	29
Width of the Gray I	Region (Δ) = 0.15 (3)	0% of AL.)				
	β = 1%	246	179	148	114	93
Mistakenly	β = 5%	179	123	98	71	54
Concluding > =	β = 10%	148	98	75	52	37
Action Level	$\beta = 20\%$	114	71	52	33	22
	$\beta = 30\%$	93	54	37	22	13
Width of the Gray F	Region (Δ) = 0.2 (40)	% of AL)	Less and the second			Associal Control of the Control of t
1.	β = 1%	139	101	83	64	52
Mistakenly	β = 5%	101	69	55	40	30
Concluding > =	$\beta = 10\%$	83	55	42	256 158 115 73 48 114 71 52 33 22	21
Action Level	$\beta = 20\%$	64	40	29	19	12
	$\beta = 30\%$	52	30	21	256 158 115 73 48 114 71 52 33 22 64 40 29 19	8

References

EPA. 2000. Guidance for Data Quality Assessment. EPA QA/G-9,

U.S. Environmental Protection Agency, Washington DC.

Gilbert, RO, JR Davidson, JE Wilson, BA Pulsipher. 2001. Visual Sample Plan (VSP) Models and Code Verification. PNNL-13450, Pacific Northwest National Laboratory, Richland, Washington.

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Pipeline Removal Vs. Characterization Study - Decision Support Tool

NULL = Contaminated

Sampling Collection and Analysis Costs

Unit Sample Unit Sample User inputs are shaded areas.

Collection Analysis

Cost Cost

Dollars Dollars

USC\$ + USA\$ (Sum) = AUSCSA\$

\$50.00+ \$11,385.00 = \$11,435.00

Definitions:

USC\$Unit sample collection cost in dollars
USA\$Unit sample analysis cost in dollars
USA\$ (SUM)Unit sample analysis cost for all analytical methods in dollars
AUSCSA\$Aggregate unit sample collection and sample analysis cost in dollars

C\$ =	\$50.00
	\$50.00
	3,000
	186
100	

Summed from cells below

Enter costs associated with each item for taking the sample

USA\$ = \$11,385.00 \$11,385.00

Summed from cells below

Enter analytical cost for each analytical method in the cells in column C

NULL =

Contaminated

Total Cost for Two-Sample Proportion Test Sampling Design

	ng-Cost		0,000.00	3	User inpu shaded a		
Width of Gray Region, (UBGR- LBGR)		Beta	Number of Samples n	AUSCA\$	Total Cost of Sampling Design	1	
0.1	1%	1%	553	\$11,435.00	\$6,323,555.00		
0.1		1%	403	\$11,435.00	\$4,608,305.00	95%	confident residual contaminant exceeds the action level criterion
0.1	1%	5%	403	\$11,435.00	\$4,608,305.00	95%	confident residual contaminant meets the action level criterion
0.1	10%	1%	332	\$11,435.00	\$3,796,420.00	90%	confident residual contaminant exceeds the action level criterion
0.1	1%	10%	332	\$11,435.00	\$3,796,420.00	90%	confident residual contaminant meets the action level criterion 5% confident volume meets the action level criterion and 5% confident volume
0.1	5%	5%	276	\$11,435.00	\$3,156,060.00	90%	exceeds criterion
0.1	20%	1%	256	\$11,435.00	\$2,927,360.00	80%	confident residual contaminant exceeds the action level criterion
0.1	1%	20%	256	\$11,435.00	\$2,927,360.00	80%	confident residual contaminant meets the action level criterion
0.15	1%	1%	246	\$11,435.00	\$2,813,010.00		
0.1	10%	5%	219	\$11,435.00	\$2,504,265.00	85%	10% confident volume exceeds the action level criterion and 5% confident volume meets criterion 5% confident volume exceeds the action level criterion and 10% confident volume
0.1	5%	10%	219	\$11,435.00	\$2,504,265.00	85%	meets criterion
0.1	30%	1%	208	\$11,435.00	\$2,378,480.00		
0.1	1%	30%	208	\$11,435.00	\$2,378,480.00		
0.15	5%	1%	179	\$11,435.00	\$2,046,865.00	95%	confident residual contaminant exceeds the action level criterion
0.15	1%	5%	179	\$11,435.00	\$2,046,865.00	95%	confident residual contaminant meets the action level criterion 10% confident volume exceeds the action level criterion and 10% confident volume
0.1	10%	10%	168	\$11,435.00	\$1,921,080.00	80%	meets criterion
0.1	20%	5%	158	\$11,435.00	\$1,806,730.00		
0.1	5%	20%	158	\$11,435.00	\$1,806,730.00		
0.15	10%	1%	148	\$11,435.00	\$1,692,380.00	90%	confident residual contaminant exceeds the action level criterion
0,15	1%	10%	148	\$11,435.00	\$1,692,380.00	90%	confident residual contaminant meets the action level criterion
0.15	1%	1%	139	\$11,435.00	\$1,589,465.00		
0.15	5%	5%	123	\$11,435.00	\$1,406,505.00		

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							5% confident volume meets the action level criterion and 5% confident volume exceeds
0.1	30%	5%	120	\$11,435.00	\$1,372,200.00	90%	criterion
0.1	5%	30%	120	\$11,435.00	\$1,372,200.00		
0.1	20%	10%	115	\$11,435.00	\$1,315,025.00		
0.1	10%	20%	115	\$11,435.00	\$1,315,025.00		
0.15	20%	1%	114	\$11,435.00	\$1,303,590.00	80%	confident residual contaminant exceeds the action level criterion
0.15	1%	20%	114	\$11,435.00	\$1,303,590.00	80%	confident residual contaminant meets the action level criterion
0.2	5%	1%	101	\$11,435.00	\$1,154,935.00	95%	confident residual contaminant exceeds the action level criterion
0.2	1%	5%	101	\$11,435.00	\$1,154,935.00	95%	confident residual contaminant meets the action level criterion
	14.5	i i i mana ana			Ment of the state		10% confident volume exceeds the action level criterion and 5% confident volume meet
0.15	10%	5%	98	\$11,435.00	\$1,120,630.00	85%	criterion
555 C	100 PM						5% confident volume exceeds the action level criterion and 10% confident volume meet
0.15	5%	10%	98	\$11,435.00	\$1,120,630.00	85%	criterion
0.15	30%	1%	93	\$11,435.00	\$1,063,455.00		
0.15	1%	30%	93	\$11,435.00	\$1,063,455.00		S S S S S S S S S S S S S S S S S S S
0.1	30%	10%	84	\$11,435.00	\$960,540.00		É
0.1	10%	30%	84	\$11,435.00	\$960,540.00		· ·
0.2	10%	1%.	83	\$11,435.00	\$949,105.00	90%	confident residual contaminant exceeds the action level criterion
0.2	1%	10%	83	\$11,435.00	\$949,105.00	90%	confident residual contaminant meets the action level criterion
				- Training Control of the Control			10% confident volume exceeds the action level criterion and 10% confident volume meets criterion
0.15	10%	10%	75	\$11,435.00	\$857,625.00	80%	meets criterion
0.1	20%	20%	73	\$11,435.00	\$834,755.00		
0.15	20%	5%	71	\$11,435.00	\$811,885.00		to the second se
0.15	5%	20%	71	\$11,435.00	\$811,885.00		
				011 105 00			5% confident volume meets the action level criterion and 5% confident volume exceeds
0.2	5%	5%	69	\$11,435.00	\$789,015.00	90%	criterion
0.2	20%	1%	64	\$11,435.00	\$731,840.00	80%	confident residual contaminant exceeds the action level criterion
0.2	1%	20%	64	\$11,435.00	\$731,840.00	80%	confident residual contaminant meets the action level criterion
0.2	10%	5%	55	614 425 00	6620 025 00	050/	10% confident volume exceeds the action level criterion and 5% confident volume meet
9.4	1070	0.76	55	\$11,435.00	\$628,925.00	85%	criterion
0.2	5%	10%	55	\$11,435.00	\$628,925.00	85%	5% confident volume exceeds the action level criterion and 10% confident volume meet criterion
0.15	30%	5%	54	\$11,435.00	\$617,490.00	00 /0	Official
0.15	5%	30%	54	\$11,435.00	\$617,490.00		
0.2	30%	1%	52	\$11,435.00	\$594,620.00		
0.2	1%	30%	52	\$11,435.00	\$594,620.00		
0.15	20%	10%	52	\$11,435.00	\$594,620.00		
3.10	_0 /0	. 0 10	OL	\$11,700.00	VVV-1,02.0.00		

0.15	10%	20%	52	\$11,435.00	\$594,620.00	
0.1	30%	20%	48	\$11,435.00	\$548,880.00	
0.1	20%	30%	48	\$11,435.00	\$548,880.00	
450		1.5				
0.2	10%	10%	42	\$11,435.00	\$480,270.00	80%
0.2	20%	5%	40	\$11,435.00	\$457,400.00	
0.2	5%	20%	40	\$11,435.00	\$457,400.00	
0.15	30%	10%	37	\$11,435.00	\$423,095.00	
0.15	10%	30%	37	\$11,435.00	\$423,095.00	
0.15	20%	20%	33	\$11,435.00	\$377,355.00	
0.2	30%	5%	30	\$11,435.00	\$343,050.00	
0.2	5%	30%	30	\$11,435.00	\$343,050.00	
0.2	20%	10%	29	\$11,435.00	\$331,615.00	
0.2	10%	20%	29	\$11,435.00	\$331,615.00	
0.1	30%	30%	29	\$11,435.00	\$331,615.00	
0.15	30%	20%	22	\$11,435.00	\$251,570.00	
0.15	20%	30%	22	\$11,435.00	\$251,570.00	
0.2	30%	10%	21	\$11,435.00	\$240,135.00	
0.2	10%	30%	21	\$11,435.00	\$240,135.00	
0.2	20%	20%	19	\$11,435.00	\$217,265.00	
0.15	30%	30%	13	\$11,435.00	\$148,655.00	
0.2	30%	20%	12	\$11,435.00	\$137,220.00	
0.2	20%	30%	12	\$11,435.00	\$137,220.00	
0.2	30%	30%	8	\$11,435.00	\$91,480.00	

10% confident volume exceeds the action level criterion and 10% confident volume meets criterion

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Pipeline Removal Vs. Characterization Study - Decision Support Tool

Wilcoxon Rank Sign (WRS) Test 7.1.6

Calculations for MARSSIM WRS Test Sampling Design

User inputs are shaded areas. Null = Contaminated

For I	Delta – 0.31,						
(5 % AL)		α 1	α 2	α 3	α. 4	α 5	Z _(1 - Beta)
· ·		0.01	0.05	0.10	0.20	0.30	∠(1 – Beta)
Values	$\beta 1 = 0.01$	228	166	137	106	86	2.326348
/al	$\beta 2 = 0.05$	166	114	90	65	51	1.644854
5.0	$\beta 3 = 0.10$	137	90	70	48	35	1.281552
Beta	$\beta 4 = 0.20$	106	65	48	30	21	0.841621
_	$\beta 5 = 0.30$	86	51	35	21	12	0.524401

Action Level (AL)	6.20	6.20	6.20
LBGR	5,89	5.58	4.96

0.31 0.62 1.24 Delta

5% Delta as percent of AL 10% 20%

Estimated Std Dev. 0.62

Inflation % 20% MARSSIM default is 20%

> 2.326348 0.524401 1.644854 1.2815516 0.841621 Z_(1-Alpha) P_r 0.92135

0.638163 0.76025

61

For l	Delta = 0.62,						
(10 % AL)		α 1	α 2	α 3	α 4	a 5	7
-		0.01	0.05	0.10	0.20	0.30	Z _(1 - Beta)
alues	$\beta 1 = 0.01$	65	47	40	30	24	2.326348
[E/	$\beta 2 = 0.05$	47	33	27	20	15	1.644854
E	$\beta 3 = 0.10$	40	27	21	15	11	1.281552
Beta	$\beta 4 = 0.20$	30	20	15	9	6	0.841621
5000	$\beta 5 = 0.30$	24	15	11	6	4	0.524401

For I	Delta = 1.24,		Alpha Values					
(20% AL)		α 1	α 2	α 3	α 4	α 5	Z _(1 - Beta)	
9000		0.01	0.05	0.10	0.20	0.30	∠(1 – Beta)	
alues	$\beta 1 = 0.01$	26	18	16	12	10	2.326348	
/a]	$\beta 2 = 0.05$	18	14	11	8	6	1.644854	
8	$\beta 3 = 0.10$	16	11	9	6	5	1.281552	
Beta	$\beta 4 = 0.20$	12	8	6	4	3	0.841621	
	$\beta 5 = 0.30$	10	6	5	3	3	0.524401	

Size-Sample Equation for MARSSIM WRS Test

Null = Contaminated

$$N = n + m = \frac{\left(z_{1-\alpha} + z_{1-\beta}\right)^2}{3\left(P_r - 0.5\right)^2} \text{ where } P_r = \Phi\left(\frac{\Delta}{\sqrt{2}s_{Total}}\right) \text{ and}$$

 $\Phi(z)$ = the cumulative std. normal dist. function, $\frac{1}{\sqrt{2\pi}} \int_{-\infty}^{z} e^{-\frac{x^2}{2}} dx$

$$n = m = N/2$$

n = number of samples in a sample area, i.e., survey unit

m = number of samples in the reference area

Values are rounded upwards (EPA 2000, p. 3-8). The equation is from (EPA 2000, p. 5-28).

		0.5	Mistakenl	y Concluding <	Action Level	-1280) PL 30
	Fighth of the Gray Region (Δ) = 0.31 (5%) β = 1% β = 1% β = 5% β = 10% β = 30% Fighth of the Gray Region (Δ) = 0.62 (10%) β = 30% Fighth of the Gray Region (Δ) = 0.62 (10%) β = 1% β = 10% β = 30% Fighth of the Gray Region (Δ) = 1.24 (20%) β = 1% Fighth of the Gray Region (Δ) = 1.24 (20%) β = 1% Fighth of the Gray Region (Δ) = 1.24 (20%) β = 1% Fighth of the Gray Region (Δ) = 1.24 (20%) β = 5%	$\alpha = 1\%$	$\alpha = 5\%$	$\alpha = 10\%$	$\alpha = 20\%$	$\alpha = 30\%$
Estimated Std. Dev = 0.62		s = 0.62	s = 0.62	s = 0.62	s = 0.62	s = 0.62
711 C. C. 3	S : 24\ 0.21/5	0/ 5.473				20 3830
Width of the Gray I			400	107	400	
Mistalconle	3 30 0000000	228	166	137	106	86
	β = 5%	166	114	90	65	5
Concluding > = Action Level Width of the Gray R	$\beta = 10\%$	137	90	70	48	35
	$\beta = 20\%$	106	65	48	30	21
	$\beta = 30\%$	86	51	35	21	12
Width of the Gray I	Region (Δ) = 0.62 (1)	0% of AL)	,			
	$\beta = 1\%$	65	47	40	30	24
Mistakenly	β = 5%	47	33	27	20	15
4.7	$\beta = 10\%$	40	27	21	15	11
Action Level	$\beta = 20\%$	30	20	15	9	6
	$\beta = 30\%$	24	15	11	6	
Width of the Gray I	Region (Δ) = 1.24 (2)	0% of ΛL)				
	β = 1%	26	18	16	12	10
Mistakenly	$\beta = 5\%$	18	14	11	8	6
Concluding >=	$\beta = 10\%$	16	11	9	6	5
Action Level	$\beta = 20\%$	12	8	6	4	3
	$\beta = 30\%$	10	6	5	3	3

References

EPA. 2000a. Guidance for Data Quality Assessment. EPA QA/G-9, U.S. Environmental Protection Agency, Washington DC.

EPA. 2000b. Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM). EPA 402-R-97-016, Rev.1. Environmental Protection Agency. Washington DC.

Note on Rounding

After N is calculated using the above equation, the following equation is used to divide N by 2, round up (ceiling function), increase the size by 20%, and round up to the nearest integer. Using the ceiling function first on the initial sample size and then on the inflated sample size follows the method used by Visual Sample Plan 1.0 and 2.0. Final Sample Size = ceiling(1.2 * ceiling(N/2))

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Pipeline Removal Vs. Characterization Study - Decision Support Tool

NULL = Contaminated

Sampling Collection and Analysis Costs

 Unit Sample
 Unit Sample
 User inputs are shaded areas.

 Collection
 Analysis

 Cost
 Cost

 Dollars
 Dollars

 USC\$ + USA\$ (Sum) = \$11,385.00 = \$11,435.00

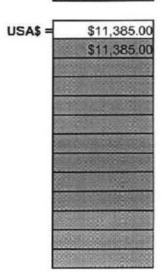
Definitions:

USC\$Unit sample collection cost in dollars
USA\$Unit sample analysis cost in dollars
USA\$ (SUM)Unit sample analysis cost for all analytical methods in dollars
AUSCSA\$Aggregate unit sample collection and sample analysis cost in dollars

SC\$ =	\$50.00
	\$50.00
8888	(Eq. Vigita Signature
1000	
28	

Summed from cells below

Enter costs associated with each item for taking the sample



Summed from cells below

Enter analytical cost for each analytical method in the cells in column C

NULL = Contaminated Total Cost for MARSSIM WRS Test Sampling Design

Samp	ling-Co	st Bud	get	\$2,000,000	.00	User ing	outs are	shaded areas.	
Width of Gray		D 4	00	Number of		Total Cost of			
Region, (UBGR- LBGR)	Alpha	Beta	SD	Samples, n	AUSCA\$	Sampling Design			
0.31	1%	1%	0.62	228	\$11,435.00	\$2,607,180.00			
0.31	1%	5%	0.62	166	\$11,435.00	\$1,898,210.00	95%	confident residual contaminant meets the action level criterion	
0.31	5%	1%	0.62	166	\$11,435.00	\$1,898,210.00	95%	confident residual contaminant exceeds the action level criterion	
0.31	1%	10%	0.62	137	\$11,435.00	\$1,566,595.00	90%	confident residual contaminant meets the action level criterion	i
0.31	10%	1%	0.62	137	\$11,435.00	\$1,566,595.00	90%	confident residual contaminant exceeds the action level criterion	
0.31	5%	5%	0.62	114	\$11,435.00	\$1,303,590.00	90%	5% confident vol. meets action level criterion and 5% confident volume exceeds criterion	S
0.31	1%	20%	0.62	106	\$11,435.00	\$1,212,110.00	80%	confident residual contaminant meets the action level criterion	3
0.31	20%	1%	0.62	106	\$11,435.00	\$1,212,110.00	80%	confident residual contaminant exceeds the action level criterion	3
0.31	5%	10%	0.62	90		\$1,029,150.00	85%	5% confident vol. exceeds action level criterion and 10% confident volume meets criterion	n 1
0.31			0.62		\$11,435.00	\$1,029,150.00	85%	10% confident vol. exceeds action level criterion and 5% confident volume meets criterion	
0.31		30%	0.62	. 86	\$11,435.00	\$983,410.00			7
0.31			0.62			\$983,410.00			~
0.31					miles and other property of the same of the same of	\$800,450.00	80%	10% confident vol. exceeds action level criterion and 10% confident vol. meets criterion	0
0.31						\$743,275.00			C
0.31	20%	5%	0.62	65	\$11,435.00	\$743,275.00			20
0.62	1%	1%	0.62	65	\$11,435.00	\$743,275.00			Rev.
0.31	5%	30%	0.62	51	\$11,435.00	\$583,185.00			
0.31	30%	5%	0.62	51	\$11,435.00	\$383,185.00			0
0.31	10%	20%	0.62	48	\$11,435.00	\$548,880.00			
0.31	20%	10%	0.62	48	\$11,435.00	\$548,880.00			
0.62	1%	5%	0.62	2 47	\$11,435.00	\$537,445.00	95%	confident residual contaminant meets the action level criterion	
0.62	5%	1%	0.62	2 47	\$11,435.00	\$537,445.00	95%	confident residual contaminant exceeds the action level criterion	
0.62	1%	10%	0.62	2 40	\$11,435.00	\$457,400.00	90%	confident residual contaminant meets the action level criterion	
0.31		30%	0.62	35	\$11,435.00	\$400,225.00			
0.62	10%	1%	0.62	2 40	\$11,435.00	\$457,400.00	90%	confident residual contaminant exceeds the action level criterion	
0.31	30%	10%	0.62	2 35	\$11,435.00	\$400,225.00			
0.31	20%	20%	0.62	2 30	\$11,435.00	\$343.050.00			
0.62	5%	5%	0.62	2 33	\$11,435.00	\$377,355.00	90%	5% confident vol. meets action level criterion and 5% confident volume exceeds criterion	í

	0.62	1%	20% 0.62	30	\$11,435.00	\$343,050.00	80%	confident residual contaminant meets the action level criterion	
	0.62	20%	1% 0.62		\$11,435.00	\$343,050.00	80%	confident residual contaminant exceeds the action level criterion	
	0.62	5%	10% 0.62		\$11,435.00	\$308,745.00	85%	5% confident vol. exceeds action level criterion and 10% confident vol. meets criterion	
	0.62	10%	5% 0.62	27	\$11,435.00	\$308,745.00	85%	10% confident vol. exceeds action level criterion and 5% confident vol. meets criterion	
	0.62	1%	30% 0.62		\$11,435.00	\$274,440.00	0070	10 // Comindent vol. Coccess action cred enterior and o // Comindent vol. modes attended	
	0.62	30%	1% 0.62		\$11,435.00	\$274,440.00			
	0.31	20%	30% 0.62	21	\$11,435.00	\$240,135.00			
	0.31	30%	20% 0.62		\$11,435.00	\$240,135.00			
	0.62	10%	10% 0.62		\$11,435.00	\$240,135.00	80%	10% confident vol. exceeds action level criterion and 10% confident vol. meets criterion	
	0.62	5%	20% 0.62		\$11,435.00	\$228,700.00			
	0.62	20%	5% 0.62		\$11,435.00	\$228,700.00			
	1.24	1%	1% 0.62		\$11,435.00	\$297,310.00			
	0.62	5%	30% 0.62	15	\$11,435.00	\$171,525.00			4
	0.62	30%	5% 0.62	15	\$11,435.00	\$171,525.00			3
	0.62	10%	20% 0.62	15	\$11,435.00	\$171,525.00			SGW-
	0.62	20%	10% 0.62	15	\$11,435.00	\$171,525.00			
	0.31	30%	30% 0.62	12	\$11,435.00	\$137,220.00			w
	1.24	1%	5% 0.62	18	\$11,435.00	\$205,830.00	95%	confident residual contaminant meets the action level criterion	347
	1.24	5%	1% 0.62	18	\$11,435.00	\$205,830.00	95%	confident residual contaminant exceeds the action level criterion	00
	1.24	1%	10% 0.62	16	\$11,435.00	\$182,960.00	90%	confident residual contaminant meets the action level criterion	0
	0.62	10%	30% 0.62	11	\$11,435.00	\$125,785.00			T
	1.24	10%	1% 0.62	16	\$11,435.00	\$182,960.00	90%	confident residual contaminant exceeds the action level criterion	Rev.
	0.62	30%	10% 0.62		\$11,435.00	\$125,785.00			7
	1.24	1%	20% 0.62	12	\$11,435.00	\$137,220.00	80%	confident residual contaminant meets the action level criterion	0
	1.24	5%	5% 0.62	14	\$11,435.00	\$160.090.00	90%	5% confident vol. meets action level criterion and 5% confident volume exceeds criterion	1
I have been a state of the stat	0.62	20%	20% 0.62	9		\$102.915.00			
	1.24	20%	1% 0.62		\$11,435.00	\$137,220.00	80%	confident residual contaminant exceeds the action level criterion	
0.0000000000000000000000000000000000000	1.24	1%	30% 0.62		\$11,435.00	\$114,350.00			
	1.24	5%	10% 0.62		\$11,435.00	\$125,785.00	85%	comb. of 10% conf. cont. meets action level criterion and 5% conf. cont. exceeds criterion	or
	1.24	10%	5% 0.62		\$11,435.00	\$125,785.00	85%	comb. of 5% conf. cont. meets action level criterion and 10% conf. cont. exceeds criterio	n
	1.24	30%	1% 0.62		\$11,435.00	\$114,350.00			
	0.62	20%	30% 0.62		\$11,435.00	\$68,610.00			
	0.62	30%	20% 0.62		\$11,435.00	\$68,610.00			
	1.24	10%	10% 0.62		\$11,435.00	\$102,915.00	80%	10% confident vol. exceeds action level criterion and 10% confident vol. meets criterion	
	1.24	5%	20% 0.62	8	\$11,435.00	\$91,480.00			
	1.24	20%	5% 0.62	8	\$11,435.00	\$91,480.00			

65

1.24	5%	30% 0.62	6	\$11,435.00	\$68,610.00
1.24	10%	20% 0.62	6	\$11,435.00	\$68,610.00
1.24	30%	5% 0.62	6	\$11,435.00	\$68,610.00
1.24	20%	10% 0.62	6	\$11,435.00	\$68,610.00
0.62	30%	30% 0.62	4	\$11,435.00	\$45,740.00
1.24	10%	30% 0.62	5	\$11,435.00	\$57,175.00
1.24	30%	10% 0.62	5	\$11,435.00	\$57,175.00
1.24	20%	20% 0.62	4	\$11,435.00	\$45,740.00
1.24	20%	30% 0.62	3	\$11,435.00	\$34,305.00
1.24	30%	20% 0.62	3	\$11,435.00	\$34.305.00
1.24	30%	30% 0.62	3	\$11,435,00	\$34,305.00

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Pipeline Removal Vs. Characterization Study - Decision Support Tool

7.2 Excavation Cost Estimate Excel Spreadsheets

The following pages contain a copy of the Excel Workbooks used to determine the cost for excavating and removing various types of pipe at various different diameters and depths. Types of pipe analyzed include the following.

- Vitrified Clay Pipe (5, 10, 15, 20, and 25 foot depths with 6, 12, and 24 inch diameter examples).
- Steel and Stainless Steel (5 and 15 foot depths with 2 and 12 inch diameter examples).
- Reinforced Concrete Pipe (5 and 15 foot depths and 12 inch diameter examples).
- Concrete Masonry (5 and 15 foot depths and 12 inch diameter examples).

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\$10,175.93 \$11,005.08 \$13,026.94 25# \$7,900.46 \$10,250,49 Excavation/Removal Cost per Linear Foot Depth to Top of Pipe \$5,763.51 \$6,475.57 \$7,614,11 15 ft \$4,104.32 \$5,814.85 10 # \$2,607.84 \$2,866.94 \$3,794.76 54 Pipe Diameter (in) 38 24 48 48 Pipe Material itrified Clay itrified Clay itrified Clay Atrified Clay

Estimate Assumptions

Pipeline Removal Vs. Characterization Study - Decision Support Tool

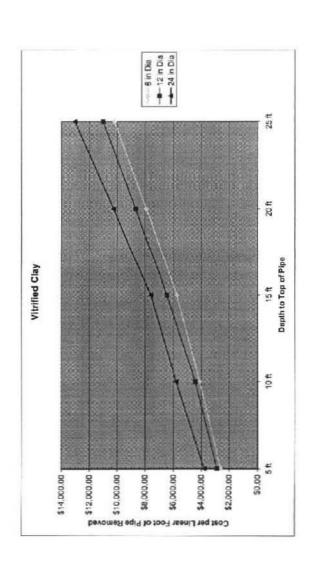
= Scenario not applicable to Hanford site.

Assume pipe cumbles apart during excavation.

Pipe debris removal included in contaminated soil excavation activity labor

General Assumptions Clean soil removed from trench and stockpiled close to excavation site for reuse as backfill material. Contaminated soil loaded into lined ERDF boxes for disposal. All scenarios do not involve any paccavation of paved arreas.	Sit fencing calculated based on $(2.5 \times L) + (4 \times y)$; where L is the length of pipe to be removed, and y is depth from the surface to bottom of the triangle below the pipe (from geometry calcs).
---	--

				57 \$7,614,11		
1				56,478,57		**
	8 in Da	\$2,607.64	\$4,104.32	\$5,783.51	\$7,900.46	\$10,175.93
		5.4	10 1	157	20 #	25 ft



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Vitrified Clay Pipe

Pipeline Removal Vs. Characterization Study - Decision Support Tool

	Lonor	1	TVE	Grew Activity	Crew	Crave	Rates
-	Supervaor	\$76.00			Size		
174	General Laborer	\$54.14		Mobiliza	1	Suparvisor	76.00
**	Fourtillor	364.35			9	Canarai Laborar	84.14
*	Heavy Egpmt Operator	564.00			100	Teamster	54.35
10	HP Technician	568.17			2	Heavy Enpmit Ope	64.86
	Burnar/Pipaffitar	\$67.06			9	HP Technician	68 17
1	Other Craft	\$67,96				Burnari P peritter	67.06
88	Spars					Other Craft	87.90
٥	Spare		6.4	Pipeline / Interference Location	-	Supervisor	75.00
10	Spare				3	Gerwin Laborer	54.14
						Teameter	54.35
						Heavy Eqpmt Ope	64.00
	Values Used Throughout	and the second				HP Technician	68.17
Estimating Conf	Contingency	30%				Burner Pipe/titler	67.00
abor Hour	Hours per Work Shift	10				Other Oraft	67.96
Construction	onstruction Consumables (% of direct labor)	3.6%	0	Inotal Sit Berrior		Supervisor	75.00

	2000		2	CLEW ACTIVITY	2	- Links
-	Supervisor	\$76.00			Size	
174	General Laborer	\$54.14		Mobiliza	1	Suparvisor
***	Courrellor	364.35			w	Ceneral Laborar
4	Heavy Egpmt Operator	564.86			10	Teamstor
10	HP Technicien	568 17			2	Heavy Egpmt Opd
40	Burnar/Pipefitter	\$67.96			9	HP Technolen
1	Other Creft	\$67.96				Burnari Poeffitar
œ	Spare					Other Craft
a	Spare		es	Pipeline / Interference Location	-	Supervisor
10	Spare				3	Gerrera Laborer
						Teamelar
						Heavy Egpirit Ope
1	Values Used Throughout	The second second				HP Technician
Estimating	Estimating Contingency	30%			900000	Burner Pipefitter
Labor Hour	abor Hours per Work Shift	10				Other Oraft
Constructio	construction Consumation (% of direct labor)	3.6%	0	frotal Sit Berrior	Section 2	Supervisor
Excession	Excavation Air Sampling (% of total cost)	35.5			,	General Laborar
ERDF LLW	ERDF LLW disposal (% of total cost)	45%				- semiser
Soil Expent	Soil Expansion Factor	28%				Heavy Egpmt Ope
Pipe Rubble Factor	• Factor	40%			GLASH STATE	HP Technician
Steel Pipe	Steel Pipe Lengths for Removal, maximum (ft)					Burner Pipelitier
						Other Craft
-	Unit Prices (2007 8)		*	Paved Road Trenching		Supervisor
Unit	Description	33				General Laborar
each	50 feet sit brace	\$500				Teamster

	HOUSE CAL DAILING	4	STATE AND ADDRESS OF THE PARTY	20.00	
		4	General Laborar	57.75	
		T	samster	54.35	i
		Ŧ	Heavy Egpmi Ope	64.88	
		I decision	HP Technician	68.17	Field (V
		9	Burner Provillar	07.965	Sit Barr
		Ŏ	Other Craft	67.06	Paving
L	Payed Road Trenching	Ē	Supervisor	76.00	Steel P
		Ď	General Laborar	54.14	ROPIN
			Teamster	64.36	Usckfill
		Ĭ	Heavy Egpmt Ope	04.80	
		Ī	HP Technican	68.17	
		Ď	Burner/Pipelitter	67.96	
		Ō	Other Craft	67.00	
6	Clean Excevation to Pipe	1 8	Supervisor	76.00	
		6 6	General Laborer	54.14	CYC
			Teamsier	54.35	Вохов
			Heavy Eapmt Ope	64.86	Boxe
		10	10	58.17	
		B. B.	Burnec/Piperitter	95.26	
		1 0	Other Craft	87.96	
	Contaminated Soil Excavation	'S 1	Supervisor	75.00	
		8 0	General Laborez	54.14	
		5 T	Tournster	54.35	
		8	Heavy Egpmt Ope	64.60	
		T O	HP Technician	56.17	
		9	Burner/Pipel Bar	67.96	
			Other Craft	67.00	
_	Pipe Seution & Remove	8	Supervisor	75.00	
		4	General Laborer	54.14	
		T	Teamster	54.35	
		H	Haavy Eqpmt Opd	64.80	
		7 9	HP Technician	68.17	
		ŧ,	Burner/Pipelitter	67.95	
			ther Craft	00.70	
	Backfill, Compact, Grade		Supervisor	76.00	
			General Laborer	7	
		9	Teamster	54.35	
			Hoavy Egpmi Opi	04.80	
		±	HP Technican	66.17	
		8	Burner/Pipelitter	67,965	
		0	Other Craft	07.90	
	Demobilize	S	Supervisor	76.00	
		4 6	General Laborar	54.14	
			Tournster	64.36	
			Haavy Egpmt Ope	64.90	
		*	HP Technician	16.17	
			Burner/Pipelitter	07.80	
		\$	Water Crash	A7 GAI	

Drums
Plywood (4'x8' 3/4 odx exterior)
Drum Patiets

P par 25-b box 8 5-k section 4 5-k section 2 5-k section 2 5-k section 2 5-k section 2 5-k section 3 5-k section 3 5-k section

Grow	Graw Ratu	
blize	\$1,210.33	Probable Undergo
olma / Interference	\$305.59	
tall Silt Berner	\$366 42	
ved Road Trenching	\$0.00	Pippline Material
an Excavation to Pil	\$1.278.20	Witnecus Clay
rdaminated Sol Exc	\$1,278 29	Stoe (stainiess (carbon)
e Section & Ramow	\$697.06	Concrete Mesonry
oxfill Compact Grad	\$747.36	Reinforced Congrata
mobilite	\$629.10	

	\$366 42	\$0.00	\$1.278.20	\$1,278.29	\$697.06	\$747.38	\$629.10
Install Sitt Berner Pawol Rous Trendring Clean Economics to Per Contains alred Sol Exc Contains alred Sol	Paved Road Torrching Clean Exervation to Pil Contaminated Soil Eco Contaminated Soil Eco Per Section & Remove Beachtt Compact, Great Camphine	Clean Expansion to Pt Conteminated Sol Exc Pige Section & Removi Backill Compact, Grin Camobinto	Contaminated Sol Exc Pipe Section & Removi Backfll Compact, Grad Camobilitie	Pipe Section & Removi Backfill Compact, Grad Demobilitie	Backill Compact, Grad Camobility	Camobitte	
n+ a o > o o	v . o > o o	a	0 - 0 3	~ 0 0			

craw Rate	\$1,210.33	\$305.59	\$056 42	30.00	1 \$1,278.20	Q \$1,278.29	A \$697.06	\$747.38	\$620.10
	Probable Under			Pipeline Material	Wirecus Clay	Stoo (stain eas /carbon	Concrete Mesonry	Reinforced Congrata	

and Pipe Combinations at the Harderst Sits

	Name	
	Mobilize	\$1,210.33
1	Pipoline / Interference	\$305.59
	natali Sill Barrer	SOSB 42
1	Paved Road Trenching	\$0.00
L	Class Excavation to Pil	\$1,278.20
	Contaminated Sol Exc	\$1,278 29
I	Pipe Section & Ramovi	\$697.06
	Back'll Compact Grad	\$747,38
I	Camobilte	\$629.10

				H	2	02.		Reinfo	
Graw Ratu	\$1,210.33	\$305.59	SOS6 42	\$0.00	\$1,278.20	\$1,278.29	\$697.06	\$747,38	\$629.10
Grow	Mobilize	Pipoline / Interference	natal Sut Berrer	Paved Road Trenching	Clean Excevation to Pil	Contaminated Sof Exc	Pipe Section & Removi	Back'll Compact, Grad	Camobilte
2	_	-		Ļ	L		_		

K	ž
	_

SGW-34760 Rev. 0

Pipe Excavation Estimate

Hanford Project ID No. Project Title

Pipeline Removal Vs. Characterization Study - Decision Support Tool

Pipe Material: Vilreous Clay

Gerathicidon Caracunables
Constitution Consumations 304 \$1100 in it \$18.00
Construction Consumables
Construction Consumables
Construction Consumables
Construction Consumption
Garatruction Consurrubles

Input		
Depth to top of pipe	5	ft
Pipe Diameter	6	in
Trench Slope	1.5	: 1
Pipe Length	100	ft
Excavation Vo	lume Results	CY
	ft ³	
Excavation Vo Contaminated Volume Clean Volume	1,107 5,712	

Input Pipe Diameter	0.5	ft
Slope down angle	33.7	degrees
2.5/cos(alpha)	3.00	
V	1.50	ft
z	2.75	ft
у	6.75	ft
×	0.25	ft
Total Area	68.39	sq ft
Pipe Area	0.20	sq ft
Area 3	0.10	sq ft
Area 2	11.36	sq ft
Outer contaminated Area	11.27	sq ft
Net Contaminated Area	11.07	sq ft
Non-Contaminated Area	57.12	sq ft

Excavation I	Duration Ca	ilculation Re
	Days	No. Boxes
Contaminated Volume	1.0	3
Clean Volume	3.0	900000000000000000000000000000000000000
(for scenario Input Pipe Length)		

Day 1 cans per day	4		
Day 6 cans per day	30		
yds per can	13 (b	ank volume)	i e
5 2 -	CY	Days	Roundup days
Clean Volume	212	2.214	3.000
Total Volume,	253	2.433	3.000
Contaminated Volume	41	0.219	1.000

Day	Boxes Per Day	Yards Per Day	Cumulative Boxes	Cumulative Yards	Delta Yard
1	4	52	4	52	52
2	9.2	119.6	13.2	172	120
3	14.4	187.2	27.6	359	187
4	19.6	254.8	47.2	B14	255
5	24.8	322.4	72	936	322
6	30	390	102	1,326	390

Pipe Diamete	minated Area r	
inch		sq ft
2	0.500	11.1
6	0.5	11.1
12	1	44.3
24	2	177.1
36	3	398.6
48	4	708.5

Calculated ERDF Disposal Cost: \$1,294.93 /CY

S6W-34760 Rev. 0

Pipe Excavation Estimate

Pipeline Removal Vs. Characterization Study - Decision Support Tool

1>1	, VC6						Pipe	Material: V	Pipe Material: Vitrecus Clay					
Crew Rate Duration (SMr) (Hours)	Bole	9 (2	Labor Cost	Materials	- \text{\text{\text{TO}}	INIT	4	Cost	Equipment	ŧ	i i		ě	Total Activity
0.33			\$6,061.65		BEN				Pickup Truck		š	00 013	\$50.00	\$8.101.88
\$306.59		176	\$63,676.62	Construction Consumables				\$1,605.04 Pickup Truck	okup Truck	-	4	\$10.00	\$1,763.00	\$57,524,16
\$366.42	1	1.8	\$641.56	Construction Consumables Sit Barrier & Stakes	344	\$7100 to R	\$36.00	\$22.45 P	Pickup Truck Backhoe		Shr Shr	\$10.00	\$18.00	\$908.41
			OF T	Construction Consumables				12.5	Paving Sew Water Truck		3.5	\$30.00		
\$1,278,29	-	05	\$63,914.50	\$63,914.50 Construction Consumation				\$2.237.01 C	CAT Excession Dump Track Water Track	(4 T	***	\$80.00 \$30.00 \$30.00	\$6,000.00	10,100,162
\$1,278.25	a	0.	\$12,782.90	Cohatrurilen Consumables				247.40	1447.40 CAT Excension ERDF Box Truck Water Truck	14 H	5 5 5	00 005 00 005	\$1,606.00	\$16,330.30
\$697.06			o I	Construction Consumation				O	CAT Excevator wi Attechment		5	280.00		
\$747.38	100	ê.	90.858,	\$11,968.08 Construction Consumables Fill Marterial				\$418.53	S CY Lander 300-hp Dozer Dump Truck Water Truck		5555	\$30.00 \$30.00	\$1043.00 \$2,400.00 \$480.00	\$16,808.87
\$629.10	0	01	\$6,291,00					2	Pickup Truck	-	Shr.	\$10.00	\$100.00	86.391.00
30%	ш									Ш		Ш		\$46.428.91 \$55.572.04 \$54.714.98
	_	_	\$155,515.20		_	_	_	\$6,181.04		_	_	-	\$25,049.40	\$410,431,57

Pipeline Removal Vs. Characterization Study - Decision Support Tool

		Roundup days	5.000	5.000	1.000																	
	13 (bank volume)	Days	4.347	4,475	0.127		Delta Yards	52	120	187	255	322	390									
30	13 (1	CY	726	767	41	Cumulative	Yards	52	172	359	614	936	1.326									
Day 1 cans per day Day 6 cans per day	yds per can	1	Clean Volume	Total Volume,	Contaminated Volume	Cumulative	Boxes	4	13.2	27.8	47.2	72	102	_		sq ft	111	11,1	44.3	177.1	398.6	708.5
Day 1 Day 6	5				Contamir	Yards Per	Day	52	119.6	187.2	254.8	322.4	390	Net Contaminated Area			0.500	0.5	۳	2	3	4
						Boxes Per	Day	4	9.2	14.4	19.6	24.8	30	Net Contar	Pipe Diameter	inch	2	9	12	24	36	48
							Day	-	2	60	4	5	9									

ft degrees

Input Pipe Diameter Slope down angle 2.5/cos(alpha)

Excavation Volume Results

At 1,107

Insted Volume 19,591

Iume 20,698

Contaminated Volume Clean Volume Total Volume

100 1.5

9

Depth to top of pipe ipe Diameter rench Slope ipe Length

Input

2 ea	
urea 0.20	
0.10	
Area 2 11,36 sq.ft	
Outer contaminated Area 11.27 sq.ft	
Net Contaminated Area 11.07 sq ft	
Non-Contaminated Area 195.91 sq.ft	
Excavation Duration Calculation Results Days No. Boxes	n Results oxes
Contaminated Volume 3.0	
Clean Volume 5.0	
(tot scenario lubrit Hibe Length)	

0.5 33.7 3.00 1.50 2.75 11.75 0.26 0.20 0.20 0.10 11.36 11.37

Calculated ERDF Disposal Cost: \$2,038.16 /CY

S6W-34760 Rev. 0

Pipe Excavation Estimate

Pipeline Removal Vs. Characterization Study - Decision Support Tool

Pipe Material: Vilreous Clay

Hanford Project ID No. Project Title

st Cost	\$60.00	\$6,101.65	\$2.512.00		\$61,000.08		\$20.00	\$96.00			\$11,200,00	\$8,400,00			\$1,600.00	\$1,200,00				\$1.056.00	\$2.145.00	4,950.00	\$990.00		\$100.00	\$6,397,00		\$65,198.05	\$117,356.49	\$133,004,02	616.226.00
P. Cost	\$10.00		\$10.00		000		\$10,00	\$48.00	\$18.00	\$30,00	\$80,00						\$30.00	\$80.00	NESS!		\$66.00				210 00			-			424
IT U.P.			+																					-			-				
QIY UNIT	1 \$/hr		1 S.hr	1			1 S.hr	1 \$Ahr	\$/hr	\$/hi	2 \$Mr	4 \$7hr	1 \$Au	-		4 Silve	1 Sibr	\$thr		1 SAr	1 SAP		1 \$/hr	4	-			10000	-		_
Compinent	Pickup Truck		Plokus Truck		THE PROPERTY OF THE PARTY OF TH			Backhoe	Paving Saw	Weter Truck	CAT Excavator	Dump Truck	Water Truck			ERDF Bax Truck	Water Truck	CAT Excevetion w/ Attachment		S CY Loader		Dump Truck	Water Truck		Pickup Truck						
Cost			\$2.687.82				\$24.05	\$140.00			\$3,131.81				\$447.40					\$863.22											67 985 30
.din	00000000			Zalan Sala	COMMISSION		3	\$38.00	FESTIVATION OF THE	SCHOOL STATE	COOK BE			S S S S S S S S S S S S S S S S S S S	200000000000000000000000000000000000000	O DESCRIPTION OF THE PERSON OF									THE STATE OF THE S						
UNIT					No.	Charles All		\$/100 In ft	Sympanical	SOUTH SO		SAME THE PARTY OF									000000000000000000000000000000000000000										
QIV							1000	384		0.00000			1000																		
mideendis	With the second		Construction Consumables		16.4		Construction Consumables	Sill Barrier & Stakes	Construction Consumables		Construction Consumables				Construction Consumables			Construction Consumables		Construction Consumables	Fill Material							SECOND SE			
Labor Cost	\$6,051,85		\$76,794,77			٦	\$712.84	531			\$89,480.30			7	\$12,782.90	_				\$24.083.54					\$6.291.00						\$316.777.00
(Hours)	s		251				20				7.0				10					33	100				0						
(S/Hr)	\$1,210.33		\$305.59				1356.42				\$1,278.20				\$1,278.29			\$697.06	200 5000	\$747.38	The state of the s				\$629,10					30%	
Activity	1 Mobilize		Z Pipeline / interference Location			-	3 Install Sit Barrier		4 Paved Road Trenching		5 Clean Excavation to Pipe			ı	Contaminated Soil Excavation			7 Pipe Section & Remove		8 Backfill, Compast, Grada				1	A Demobiliza			Excavation Air Sampling	ERDF LLW Disposal	Estimating Contingency	TOTAL PROJECT COST

Excavation Duration Calculation Results

Contaminated Volume Clean Volume (for scenario Input Pipe Length)

Pipeline Removal Vs. Characterization Study - Decision Support Tool

					ray	nay I can's bei day			
Input					Day (Day 6 cans per day	30		
Depth to top of pipe	15					yds per can	13	13 (bank volume)	
Pipe Diameter	9					1	ςλ	Days	Roundup days
Trench Slope	1.5	-				Clean Volume	1,517	6,491	7.000
Pipe Length	100	_				Total Volume.	1,558	6.596	7.000
Excavation Volume Resul	olume Results				Contam	Contaminated Volume	41	0.105	1.000
Contaminated Volume Clean Volume	1,107	41	Day	Boxes Per Day	Yards Per Day	Yards Per Cumulative Day Boxes	Cumulative Yards	Delta Yards	
Total Volume	42,076	1,558	-	4	52	4	52	52	
			2	9.2	119.6	13.2	172	120	
			60	14.4	187.2	27.6	359	187	
Input Pipe Diameter	0.5	#	4	19.6	254.8	47.2	614	255	
Slope down angle	33.7	degrees	2	24.8	322.4	72	936	322	
2.5/cos(alpha)	3.00		9	30	390	102	1,326	380	
>	1.50	*							
N	2.75	7		Net Conta	Net Contaminated Area				
Α.	16.75	#		Pipe Diameter	_				
×	0.25	#		inch		ag ft			
Total Area	420.98	sq fl		7	0.500	11.1			
Pipe Area	0.20	sq fl		9	0.6	11.1			
Area 3	0.10	sq ft		12	-	44.3			
Area 2	11.38	n ps		24	2	177.1			
Outer contaminated Area		sq ft		38	69	398.6			
Net Contaminated Area		sqf		48	4	708.5			
Non-Contaminated Area	409.69	Soft							

Calculated ERDF Disposal Cost: \$2,862.10 /CY

56W-34760 Rev. 0

Pipe Excavation Estimate

Pipeline Removal Vs. Characterization Study - Decision Support Tool

Hanford Project ID No. Project Title

Pipe Material: Vifreous Ciny

Cost	\$60.00	Se 101 05	T	\$3,203.00	640.6 467 hr	0.004.0014	\$22.00	200	\$1,114,17					00 00	\$12.000.00	\$3,000.00		\$1,000.00	\$1,200.00					B+ 900.00	60 SEA SEA	SAT 779 81	20000		\$100.00	\$8.391.00		\$80.371.80	\$160,869.04	\$182,318.24	652 075 50	
Cost								ľ		200	000	00									100							L		100		1			0 639	
U.P.	\$10.00			\$10.00			2012	200000	940	SIMILES	\$18.00	\$300		880.0	\$30.00	\$30.00		\$80.00	\$30.0	\$300	DO ORS			20000	8 6	00 00.5	630.0		\$10.00							
JUNIT.	\$/JA			\$An			+		971		\$/hr	\$/hr		+	-	S/hr		\$/ve	\$/Ja	\$Wr	Shu			400	1	L	L		3/hr							-
QTY	1			+			•	Ì	1					-	*			2	7	۳	June			+		•			-				+			-
Cost	Pickup Truck			53,489.99 Pickup Truck			SO7 44 Policin Track	1 3	ento od deposice		Paving Saw	Water Truck		S4 474 02 CAT Excavator		Water Truck		\$447.40 CAT Excavator	ERDF Box Truck	Water Truck	CAT Excesses of Attechment			100 M	And the Date of	Dame Touch	Wales Truck		Ptokup Truck						\$411 D69 66	
U.P.	12000							-	75 076		5000000						0.000000																			-
UNIT	1000						T	4	announce announce								Section 1		MINORAL SE		I				I						1					-
OTY							I	1	1	STEP AND S												200000														
PRESENTATION				Construction Consumables			Construction Consumables	The state of the s	oli baillet a diana		Construction Consumables			Construction Consumables				Construction Consumables			Construction Consumables			Construction Construction	M Marterial							TO THE REAL PROPERTY OF THE PARTY OF THE PAR				
Labor Cost	\$6,051.85			\$09,714.02	2	la-t.	3734 42E	•	9		0	100	540	\$127.829.00[2		100	_	\$12,782.90				1	101	200 200 102	_				\$6,291.00						8.204 KGR KG	
(Hours)	\$			326			3.3							100				10						3	1				10							
(SHr)	\$1,210.33			\$305.69			CF #362							\$127828				\$1,278.29			\$897.06			67.17.70	0001618				\$629.10					30%		
Activity	Mobilizo			2 Pipeline / Interference Location			3 Install Sill Barrier				4 Paved Road Trenching			5 Clean Excavation to Pipe			1	6 Contaminated Soil Expansion			7 Pipe Section & Remove			S Hackell Command Charles					9 Damabiliza			Excavation Air Sameline	ERDF LLW Disposal	Estmating Contingency	TOTAL PROJECT COST	

Input		_
Depth to top of pipe	20	ft
Pipe Diameter	6	in
Trench Slope	1.5	: 1
Pipe Length	100	ft
Excavation V	olume Resu ft ³	lts CY
Excavation V Contaminated Volume		

Input Pipe Diameter	0.5	ft
Slope down angle	33.7	degrees
2.5/cos(alpha)	3.00	* 10.0 1 .1000
V	1.50	ft
z	2.75	ft
y	21.75	ft
x	0.25	ft
Total Area	709.74	sq ft
Pipe Area	0.20	sq ft
Area 3	0.10	sq ft
Area 2	11.36	sq ft
Outer contaminated Area	11.27	sq ft
Net Contaminated Area	11.07	sq ft
Non-Contaminated Area	698.48	sq fl

Excavation I	Duration Ca	alculation Resu
	Days	No. Boxes
Contaminated Volume	1.0	3
Clean Volume	10.0	
(for scenario input Pipe Length)		

Day 1 cans per day	4		
Day 6 cans per day	30		
yds per can	13 (b	ank volume)	
	CY	Days	Roundup days
Clean Volume	2,587	9.233	10.000
Total Volume,	2,628	9.338	10.000
Contaminated Volume	41	0.105	1.000

Day	Boxes Per Day	Yards Per Day	Cumulative Boxes	Cumulative Yards	Delta Yards
1	4	52	4	52	52
2	9.2	119.6	13.2	172	120
3	14.4	187.2	27.6	359	187
4	19.6	254.8	47.2	614	255
5	24.8	322.4	72	938	322
6	30	390	102	1,326	390

inch		so ft
2	0.500	11.1
6	0.5	11.1
12	1	44.3
24	2	177.1
36	3	398.6
48	4	708.5

Calculated ERDF Disposal Cost: \$3,923.28 /CY

SGW-34760 Rev. 0

Pipe Excavation Estimate

Pipe Ex

Hanford Project ID No. Project Title

Pipeline Removal Vs. Characterization Study - Decision Support Tool

Pipe Material: Vitreous Clay

Total Activity U.P. Cost Cost	\$10.00	\$0.101.08	\$10,00 \$4,013.00	\$150,008.43	\$10.00 \$24.00	\$48.00 \$115.20 \$1,100.55		\$18.00	\$30,00		\$30.00 \$16,600.00		\$80,000.03		\$300.00	SBO CO		Ш	\$5,395,00	\$30,00 \$12,450,00 \$87,194,58		\$10.00		\$115.112.38	8207.202.20	\$234,629.20	570 693.30
UNIT	\$.fhr		\$/hr		\$/Ja	ž		3Vn	\$Wr	SAu	SArt	2 8 5	SAr	Shr	Sihr	Shr		\$.hr	Sthr	\$.hr	Shr	\$/hr					
ΩTY			-		1	+	Ī			52	7	-	2	7	-					9	1			I	I		
Equipment	Pickup Truok		7 15 Piokup Truck		\$20.04 Plakup Truck	\$175.00 Backhoe		Perving Saw	WaterTruck	0.22 CAT Excavator	Dump Truck	Waler Truck	\$447.40 CAT Expension	ERDF Box Truck	Water Truck	CAT Remounts of Allachance?		\$2,171.14 5 CY Loader	300-hp Dozer	Dump Truck	Water Truck	Pipkup Truck					1 100
Cost			\$4,202.18							\$5,016.22			\$44					\$2,17									\$12.931 86
u.P.	0.0000000000000000000000000000000000000		The same			\$35.00		MODE COLUMN			0.0350000000000000000000000000000000000						THE STATE OF	05500K806						THE CONTRACTOR OF THE CONTRACT			
UNIT	35.07				100000	\$/100 In ft		913000000						100000					A SECOND								
QTY			1		(1)00(12)	464																			L		
Materials			Construction Consumables		Construction Consumables	Sil Barrier & Stakes		Construction Consumables		Construction Consumables			Construction Consumables			Construction Consumables		\$62,032 54 Construction Consumables	Fill Material					STREET STREET STREET STREET			
Labor Cost	\$6,051.85		\$122,633.27		\$855.41					\$166,177,70	Charles Callebrate		\$12,782.90					\$62,032.54				\$6.291.00					\$376.824.67
(Hours)	9		401		2.4					130			10					63				10					
Crew Rate (S/Hr)	\$1,210.33		\$306.59		\$356.42					\$1,278.20			\$1,278.20			SAD7 OA		\$747.38				\$629.10	4000000			30%	
Activity	Mobiliza		Pipeline / interference Location		Irstall Sill Burrier			Paved Road Trenshing		Clean Excavation to Pipa			Contaminated Soil Expansion			Pipa Saction & Remove		Backfill, Compact, Grade				Demobilize		Excavation Air Sampling	ERDF LLW Disposal	Estmating Contingency	TOTAL PROJECT COST

Input		
Depth to top of pipe	25	ft
Pipe Diameter	6	in
French Slope	1.5	:1
Pipe Length	100	ft
Funnishing V	olume Results	5
	ft³	CY
Contaminated Volume	ft³ 1,107	CY 41
	ft ³ 1,107 106,226	CY 41 3,934

Input Pipe Diameter	0.5	ft
Slope down angle	33.7	degrees
2.5/cos(alpha)	3.00	
V	1.50	ft
Z	2.75	ft
У	26.75	ft
x	0.25	ft
Total Area	1073.53	sq ft
Pipe Area	0.20	sq ft
Area 3	0.10	sq ft
Area 2	11.36	sq ft
Outer contaminated Area	11.27	sq ft
Net Contaminated Area	11.07	sq ft
Non-Contaminated Area	1062.26	sq ft

Excavation I	Duration Ca	Iculation Res
	Days	No. Boxes
Contaminated Volume	1.0	3
Clean Volume	13.0	17057700000000
(for scenario Input Pipe Length)	A THE STREET OF STREET	

Day 1 cans per day	4		
Day 6 cans per day	30		
yds per can	13 (bank volume)	
Ye	CY	Days	Roundup days
Clean Volume	3,934	12.688	13.000
Total Volume.	3,975	12.793	13.000
Contaminated Volume	41	0.105	1,000

Day	Boxes Per Day	Yards Per Day	Cumulative Boxes	Cumulative Yards	Delta Yards
1	4	52	4	52	52
2	9.2	119.6	13.2	172	120
3	14.4	187.2	27.6	359	187
4	19.6	254.8	47.2	614	255
5	24.8	322.4	72	936	322
6	30	390	102	1,326	390

inch		sq ft
2	0.500	11.
8	0.5	11.
12	1	44.
24	2	177.
36	3	398.
48	4	708.

Calculated ERDF Disposal Cost: \$5,053.26 /CY

56W-34760 Rev. 0

Pipe Excavation Estimate

Hanford Project ID No. Project Title

Pipeline Removal Vs. Characterization Study - Decision Support Tool

Pipe Material: Virgous Clay

Total Activity P. Cost Cost	\$10.00 \$50.00	\$6.101.65	\$10.00		\$41,634.05		\$10.00		0000000		\$18.00	130.00	63.60	480 CO 54,800.CO	\$30,00	2800 00		ı	\$1,600.00	\$1,600.00	\$16,000.00 \$1,000.00 \$1,000.00 \$300.00 \$300.00	\$1,200.00	\$1,600,00 \$1,200,00 \$300,00	\$1,000,00 \$1,200,00	\$1,200.00 \$4,000.00 \$3,000.00 \$2,000.00	8 00 000 18 00 000 19 100 000 8 00 000 18 00 000 18	\$1,000.00 \$1,200.00 \$3,000.00 \$2,500.00 \$1,500.00 \$1,500.00 \$1,500.00	\$1,000.00 \$1,000.00 \$1,000.00 \$288,00 \$1,000.00 \$1,000.00 \$1,000.00 \$1,000.00 \$1,000.00 \$1,000.00	\$ 1,000.00 \$1,000.00 \$1,000.00 \$285,00 \$130.00 \$100.00 \$100.00 \$100.00 \$100.00 \$100.00	\$ 1,000.00 \$1,000.00 \$1,000.00 \$250.00	\$ 1,000.00 \$1,000.00 \$1,000.00 \$250.00 \$250.00 \$270.00 \$1,000.00 \$270.00 \$1,000.00 \$1,	8 1,000,001 8 1,000,002 8 20,000 8 20,0	8 1,000.00 1,00	\$ 1,000.00 \$ 1,000.00 \$ 1,000.00 \$ 2,000.00 \$ 1,000.00 \$ 1,000.00
i up.			L			TOTAL STREET		2		1	1	1							Ц															
DIY UNIT	1 \$Mr		1 Shr		2000	200 State	1 SAN	1. 875			3	\$		\$A.			CXIII	ŀ		2 4	3 5 5													
Cont	Pickup Truck		\$1 304.78 Pickup Truck				\$1 9.96 Pickup Triack	\$140.00 Backhoe			Paying Saw	Water Truck		\$1,342.20 CAT Excavator	Dump Truck	Water Truck		THE PERSON NAMED IN COLUMN TWO IS NOT THE OWNER.	S447.40 CAT Excevator	\$447.40 CAT Expansion ERDF Box Truck	\$447.40 CAT Extravator EPOF Box Truck Vister Trock	\$447.40 CAT Expension ENGE Box Truck Water Truck CAT Expension of Attachment	\$447.40 CAT Expansion ERGP Box Truck Water Truck CAT Expension of Machineral	\$447.40 CAT Extravitor ERGE Box Truck Water Truck CAT Extravitor of Attachment	S447 At C. P. Cantwintor EROF Eos Track Wales Truck Wales Truck CAT Expousion of Mischment S226 42 6 CY Leadler	5447 40 CAT Expension EROD Box Track Wister Track Wister Track CAT Exceptable w Attachment CAT Exceptable w Attachment S236 12 6 CY Leuder S236 12 6 CY Leuder S300-tp Enzier	\$447.40 CAT Extervator ERQD Box Truck Water Truck Water Truck CAT Extervator of Attachment CAT Extervator of Attachment S226.42 6 Cy Luador S226.42 F Cy Luador Suche Darrer Champ Truck	\$447.40 CAT Extravator ERQD Box Truck Waley Took Waley Took CAT Extravator of Attachment CAT Extravator of Attachment S226.42 6 CY Leader Dump Truck Water Truck	\$447.40 CAT Extervator ERQD Box Truck Water Truck Water Truck CAT Extervator W Attachment CAT Extervator W Attachment S226.42 5 CY Leader S226.42 FCY Leader Owner Truck Plokup Truck Plokup Truck	\$447.40 CMT Externation EROF Box Track Waiter Truck Waiter Truck CAT Exterusion of Attachment CAT Exterusion S236.42 6 CM Leadler S236.42 Forest Dump Truck Waiter Truck Fickup Truck	\$447.40 CMT Externation EROF Box Track Waiter Truck Waiter Truck CAT Exterusion of Mischment CAT Exterusion S236.42 6 CM Leudler S236.42 Fortunist Dump Truck Wester Truck Fickup Truck	\$447.40 CMT Extravitor EROP Box Track Water Track CAT Extravitors of Machinent CAT Extravitors of Machinent Soot-to Biozer Marey Track Plokup Track Plokup Track	\$447.40 CAT Extervator EROP Box Track Water Track CAT Extervator w Attachment CAT Extervator w Attachment CAT Extervator w Attachment Cat Extervator Society Exter Cate Cate Cate Cate Cate First Product First First First	\$447.40 CAT Extervator ERQD Box Truck Water Truck Water Truck CAT Extervator w/ Attachment S236.42 6 CY Leader Sock-tp Entere Charte Truck Water Truck Pickup Truck
UNIT U.P.				STREET, STREET				\$/100 in ft \$36.00	South Mary Commercia																									
en vro								318 \$/10		788 75560					To see					Ì														
Materials			Construction Consumables				Construction Consumables	Sill Barrier & Stakes			Construction Consumables			Construction Consumatiles			4	CONSTRUCTION CONSUMESTIMES				Construction Consumatives	Corse buction Consumables	Ons bucken Consumables	Consituation Consumables Consituation Consumables	Come buction Consumables Construction Consumables Construction Consumables	Zona buction Consumative Zona buction Consumative Jonathudien Consumative	Zona bucition Consumatives Zonahudion Consumatives il Material	Zens buction Consumation Construction Consumation	Construction Consumation Construction Consumation Il Material	Construction Consumation Construction Consumation Il Malecial	Cera buction Consumables Cerabuction Consumables Il Marieral	Zens buction Consumstins Zenstrudion Consumstins il Material	Zons buction Consumatives Zonshudion Consumatives il Majorial
Labor Cost	\$6,051.85		\$38 003 2810				\$570.27		Gass I					\$38,348.70			000000000	\$12,782.90							\$6,728.42	2	12	13	2 8	2 8	8 2	2 8	2 8	2 8
Duration (Hours)	s		128				1.6							30				2							a	a	o.	o.	a 2	a 0	a 0	o- 0	o 0	e 2
Crum Rate (S/Hr)	\$1,210.33		£305.60				\$366.42							\$1,278.20			100	91,270.28				\$697.08	\$697.08	\$697.00	8697.06	\$697.00 \$747.38	8677.08	\$697.06	\$697.06	\$607.06	\$697.06	\$607.00	\$627.06	\$747.39
Activity	Mobilize		2 Pipeline / Interference Location				3 Install Sit Barrier				Paved Road Tranching			Class Excavation to Pipa			4	Contaminated Soil Expavation				Pipe Section & Remove	Pipe Section & Remove	Plos Section & Remove	Pipe Section & Remove Backfil, Compact, Crede	Pice Section & Remove Backfill, Compact, Crefe								Pipe Section & Remove Backfill, Compact, Grete Demobilize Extraobilize Extraobilize Extraobilize Extraobilize Extraobilize Extraobilize Extraobilize

Input		
Depth to top of pipe	5	ft
Pipe Diameter	12	in
Trench Slope	1.5	: 1
Pipe Length	100	ft
-	luma Pacult	s
Excavation Vo	ft ³	CY
	ft ³	0.000,000
Contaminated Volume Clean Volume	ft ³ 4,428 6,342	0.000,000

Input Pipe Diameter	1	ft
Slope down angle	33.7	degrees
2.5/cos(alpha)	3.00	
V	3.00	ft
z	5.50	ft
у	8.50	ft
x	0.50	ft
Total Area	108.49	sq ft
Pipe Area	0.79	sq ft
Area 3	0.38	sq ft
Area 2	45.45	sq ft
Outer contaminated Area	45.07	sq ft
Net Contaminated Area	44.28	sq ft
Non-Contaminated Area	63.42	sq ft

Excavation D	uration Cal	culation Results
	Days	No. Boxes
Contaminated Volume	1.0	13
Clean Volume	3.0	
(for scenario Input Pipe Length)		

Day 1 cans per day	4		
Day 6 cans per day	30		
yds per can	13 (b	ank volume)	į.
	CY	Days	Roundup day
Clean Volume	235	2.338	3.000
Total Volume,	399	3.157	4.000
Contaminated Volume	164	0.819	1.000

Day	Boxes Per Day	Yards Per Day	Cumulative Boxes	Cumulative Yards	Delta Yards
1	4	52	4	52	52
2	9.2	119.6	13.2	172	120
3	14.4	187.2	27.6	359	187
4	19.6	254.8	47.2	614	255
5	24.8	322.4	72	936	322
6	30	390	102	1,326	390

inch		sq ft
2	0.500	11.
6	0.5	11.
12	1	44.3
24	2	177.
36	3	398.
48	4	708.9

Calculated ERDF Disposal Cost: \$355.92 /CY

S6W-34760 Rev. D

Pipe Excavation Estimate

Pipeline Removal Vs. Characterization Study - Decision Support Tool

Pipe Material: Vitrecut Clay

Hanford Project ID No. Project Title

Hoteless High of St. Hig	Activity	(SMr)	(Hours)	Labor Cost	MATERIATIO	OTY	UNIT	0.P	Cost		ΩL	TINI	0.0	Cost	Cost
\$1.271.25 10 \$10.271.25 Construction Consumables 20.211.05 Policy Trust 1 45	TO	\$1,210.33	92	\$6,051,65						Pickup Truck		\$hr	\$10.00	20.003	
STATE STATE STATE STATE Constitution Consumation STATE S							THE STATE OF	000000000000000000000000000000000000000							22 +0+ 66
\$1,270.25 \$10.00															00'10'10#
\$1.270.25 \$1.0 \$1															
\$1.277.29 \$1.277.29 \$1.277.29 \$1.277.29 \$1.277.29 \$1.277.20 \$1.277	ne / Interference Location	\$306.59	203		Construction Consumables				\$2,166.94	Pickup Truck.	-	S.hr	\$10.00	\$2,026,00	
\$1.271.26 30 \$86.3 11.0 Continued Consumation							TO STORE OF	100							\$56,105,47
S1 270 25 1.0 S1 17 12 S S S S S S S S S															
\$1,270.29 \$10,270.20 \$10,000.00 \$10,	Salt Barrian	CA NACA	1.8	15	Construction Communished	I			\$4.003	Pickin Taick	٠	\$300	\$10.00	\$18.00	
\$1.270.29 \$1.270.29 \$1.270.29 \$1.270.29 \$1.270.29 \$1.270.29 \$1.270.29 \$1.270.29 \$1.270.29 \$1.270.29 \$1.270.29 \$1.270.29 \$1.270.20 \$1.270.29 \$1.270.29 \$1.270.29 \$1.270.29 \$1.270.29 \$1.270.20 \$1.270	1			1	Day of the County of the Count	т	A STANAS	626.00	W. 04.0	Barbina .	-	630	646 00	\$183 AFI	10000000
\$1,270.26 50 \$80,914.0 Construction Construction Construction Construction Construction Construction Construction Construction Construction Const					ON DOLLIN & OLDRAN	_	2000	-	200				200000	2	\$908.41
St. 279 26 St. 271 10 St. 271 25 Connectivation Connectiva										CAN THE RESIDENCE OF THE PARTY	200		THE STATE OF THE S		
## \$1.279.29 50 \$80.314.09 Cemetrotifor Construction Cons	d Road Trenching				Construction Consumables	SUCCEPT	NAME OF THE OWNER, WHEN			Paving Saw		\$.hr	\$18.00		
\$1,278.29 \$9 \$11,722 \$0										Water Truck		\$Ar	\$30.00		
\$1.278.28 10 \$1.2.78.29 Constitution Consumables															
## \$1.278.29 Connthuotien Connumbios S11.792.90 Connumbios S11.792.90 Connthuotien Connumbios S11.792.90 Connumbios Con	Excavation to Pino	\$1 278 29	05	Ş	Construction Consumabilias				\$2 237 01	CAT Fanavahr	2	SAr	\$80.00	\$8 000 00	
\$1.278.29 10 \$12.78.29 Christiuniden Communition \$1.600.00										Duma Truck	7	SAV	\$30.00	\$6,000,00	Charles Comment
\$1.279.29 10 \$12.70.29 Constitución										Water Truck	-	S.b.r	\$30.00	\$1,600.00	\$81,661,51
\$1270.29 \$11.70.29 Constitucion Constitution \$11.70.29 Constitucion Constitution \$11.70.20 ERCO Trials \$11.70.20 \$11.20.															
\$697.06 Sept. 06	minated Soil Expandion	\$1,278.29	10	8	Construction Consumation		The same	2000	\$447.40	CAT Expavator	2	SAr	\$90.00	\$1,600.00	
\$657.06 Constituction Consumables \$575.49 \$CT Loader 1 \$thr \$500.00 \$100.00				K TOTAL COLOR						ERDF Box Truck	•	S/hr	\$30.00	\$1,200,00	00 000 000
\$697.06 \$747.38 22 \$16,442.36 Construction Consumables \$575.49 \$CV Loader 1 \$thr \$20,00 \$714.00										WaterTruck		SAhr	830.00	\$300.00	00000001414
\$637.06 Construction Consumables \$575.40 CV Leader 4 \$40.00 \$747.38 22 \$16.442.36 Construction Consumables \$575.40 CV Leader 1 \$40.00 Fill Lateral Construction Consumables \$575.40 CV Leader 1 \$40.00 White Truck \$10.00 \$17.00 White Truck \$10.00 \$17.00 S62.21.0 10 \$6.291.00 \$17.00 \$17.00 The Se6.00.60 \$55.89.20 The Se6.00.60 \$55.89.20 S66.00 \$10.00 \$10.00 S66.00 \$10.00 \$10.00 S66.00 \$10.00 S66.						Town more									
\$677.40 SCY Loader 11 Shr EXX 00 STOLOGO	Soction & Remaye	\$697.06			Construction Consumables					CAT Excavator w/ Attachment		SAr	280.00		
## \$777.38 22 \$16.442.36 Construction Consumables \$575.46 CV Langer 1 \$th \$20.00 \$774.00 \$77															
\$622.10 10 \$6.291.00 \$10.0000 \$1.0000				7									244 244	000000	
\$622.10 10 \$6291.00 THE Laboral Thick Thic	at, compact, grade	2747.38	77	8	Construction Consumatives	-			\$5/5.40	S C 1 LOBOSE		ame.	00.75	20.00.00	
\$622.10 10 \$6.291.00 \$3.300.00 \$3.300.00 \$3.300.00 \$3.300.00 \$3.300.00 \$3.300.00 \$3.300.00 \$3.300.00 \$3.300.00 \$3.300.00 \$3.300.00 \$3.00					Fill Material	Marco and		0.000		300-hp Dozer	-	SArr	265.00	\$1,430.00	Caranta de
\$622.10 10 \$6.291.00 \$10.00 \$1							TO SOLUTION OF THE PARTY OF THE			Oump Truck	2	SAr	\$30.00	\$3,300.00	\$23,111,84
\$622.10 10 \$6.291.00 \$10.00 \$1										Water Truck	-	SA	\$30.00	2660.00	
30% \$5,589.26 \$5,589.26 \$5,589.26	- Parities	070004	9							Of the Parch	·	200	440.00	OCCUPA-S	
30% 30% 555.69.26 555.69.26 555.69.26 555.69.26 555.69.240	ATION	0. 2704	2											200	231,000000000000000000000000000000000000
30%															\$6.391.00
30% \$5,589.26 \$5,589.26 \$5,589.26 \$5,589.26															
30% \$5.589.26 \$5.589.26 \$5.589.26	ration Air Sampling														\$50.150.05
30% \$468,036.50 \$55,549.28 \$55,549.28	LLW Disposal														\$90.270.08
\$5,589.20	nting Contingency	30%													\$102,306,08
0.000,000											-			616 074 40	and case
	AL PROJECT COST	_		9166,036.50		_	_		\$5,549.40		_	_		970'374	\$440,066,41

Input		
Depth to top of pipe	10	ft
Pipe Diameter	12	In
French Slope	1.5	: 1
Pipe Length	100	ft
Excavation Vo	olume Results	CY
Excavation Vo	ft ³	50,000
	ft ³ 4,428 22,849	CY

Input Pipe Diameter	1	ft
Slope down angle	33.7	degrees
2.5/cos(alpha)	3.00	100
V	3.00	ft
Z	5.50	ft
y x	13.50	ft
×	0.50	ft
Total Area	273.56	sq fl
Pipe Area	0.79	sq ft
Area 3	0.38	sq ft
Area 2	45.45	sq ft
Outer contaminated Area	45.07	sq ft
Net Contaminated Area	44.28	sq fl
Non-Contaminated Area	228.49	sq ft

Excavation I	Duration Ca	Iculation Re
	Days	No. Boxes
Contaminated Volume	1.0	13
Clean Volume	5.0	0 8000000000000000000000000000000000000
or scenario Input Pipe Length)		-

-			
Day 1 cans per day	4		
Day 6 cans per day	30		
yds per can	13	(bank volume)	
	CY	Days	Roundup days
Clean Volume	846	4.722	5.000
Total Volume,	1,010	5.190	6.000
Contaminated Volume	164	0.469	1.000

Day	Boxes Per Day	Yards Per Day	Cumulative Boxes	Cumulative Yards	Delta Yards
1	4	52	4	52	52
2	9.2	119.6	13.2	172	120
3	14.4	187.2	27.6	359	187
4	19.6	254.8	47.2	814	255
5	24.8	322.4	72	936	322
6	30	390	102	1,326	390

Pipe Diamete	er	
inch		sq ft
2	0.500	11.1
6	0.5	11.1
12	1	44.3
24	2	177.1
36	3	398.6
48	4	708.5

Calculated ERDF Disposal Cost: \$550.38 /CY

56W-34760 Rev. 0

Pipe Excavation Estimate

AND THE PERSON NAMED IN

Pipeline Removal Vs. Characterization Study - Decision Support Tool

70.12

Hanford Project ID No. Project Title

Pipe Material: Vitreous Clay

Cost		\$6.101.65				\$90,576.00			27 1003						\$130,642.41			OR OLD DAY						\$42,021,53			\$6 391 00		\$73.264.40	\$101,875,91	\$149,459,37	\$647,657.25
Cost	\$50,00				\$2,776,00			\$20.00	\$96.00				640 650 00	912,000.00	\$5,600.00	\$2,400.00	\$1,600.00	\$1,200.00	\$300.00			\$1.280.00	\$2,600,00	\$6,000.00	\$1,200.00	\$100.00						\$42,022.00
U.P.	\$10.00				810.00	T. STATE OF THE ST		\$10.00	\$48.00		\$18.00	\$30.00	440.00	00000	\$ 50.00	\$30.00	\$80.00	\$30.00	130.00	\$80.00		\$32.00	\$66.00	\$30.00	\$30.00	\$19.00						
UNIT	Sihr				TW	Ī		\$Au	SAhr		Sihr	SAR	46.		100	She	SAV	SAN	\$WK	SAu		Shr	S.hr	\$.hr	N/S	SAN						
ďΒ					-	ļ		-	Ť				c	1	4		8	4				-	-	2	-	r						
Cost	Pickup Truck				S2 869 11 Prokup Truck			\$24.95 Pipkup Truck	\$140.00 Backhoe		Paving Saw	Weter Truck	CONTRACTOR OF STREET		Dump Truck	Water Truck	\$447.40 CAT Excurutor	ERDF Box Truck	Water Truck	CAT Expandator of Attachment		\$1 046 33 5 CY Loader	300-ho Dozer	Dump Touck	Water Truck	Pickup Truck						\$8,207.01
ď'n	AND THE	100 Carlot	444100 160	CALL WORK OF THE			September 1		\$35.00	200	Second St.		Total Carlo		100000							SECORE L	55,100,00	200000000				Delication of the last of the				_
UNIT				1	Ī	Ì			\$/100 in It				İ												lig.				1			
OT?					1		100		398 3						1			500000										1				
					Construction Consumables			Construction Consumables	ill Barrier & Stakes		Construction Consumishins		Santa Ann Constitution	OTHER OCCUPANTIONS			Construction Consumables			Construction Consumables		Construction Consumables	Fill Material									
Labor Cost	\$6,051.65		31	7	\$84,631,78			\$712.84					C 000 000 001	2			\$12,782.90				Edu	\$29.895.2010			ball	\$6.291.00						\$242,828.67
(Hours)	9				278			2.0					0	8			10					40				10						
(SAIr)	\$1,210.33			-	8308 88			\$356.42					64 978 30	4.0.4.0			\$1,278.29			\$697.06		\$747.38	1			\$629,10					30%	
Activity	Mobiliza				Program Interference Location			Install Silt Barrier			Pavod Road Transhing		Court Bernsonline to Dies	DOLLAR MARKET BOOK AND			Continuinted Soil Excavation			Pipe Section & Remove		Backfill Compact Grade				Demobilize			Excavation Air Sampling	ERDF LLW Disposal	Estmating Contingency	TOTAL PROJECT COST

Input		
Depth to top of pipe	15	ft
Pipe Diameter	12	in
Trench Slape	1.5	; 1
Pipe Length	100	ft
Excavation Vo	olume Result ft ³	CY
	ft ³	
Excavation Vo Contaminated Volume Clean Volume	ft ³ 4,428 46,856	

Input Pipe Diameter	1	ft
Slope down angle	33.7	degrees
2.5/cos(alpha)	3.00	
٧	3.00	ft
z	5.50	ft
У	18.50	ft
×	0.50	ft
Total Area	513.63	sq ft
Pipe Area	0.79	sq ft
Area 3	0.38	sq ft
Area 2	45.45	sq ft
Outer contaminated Area	45.07	sq ft
Net Contaminated Area	44.28	sq ft
Non-Contaminated Area	468.56	sq ft

Days	No. Boxes
1.0	13
8.0	S ROSTILINOS SERVICIOS SE
	1.0 8.0

Day 1 cans per day	4		
Day 6 cans per day	30		
yds per can	13	(bank volume)	
The second of the second of	CY	Days	Roundup days
Clean Volume	1,735	7.050	8.000
Total Volume,	1,899	7.470	8.000
Contaminated Volume	164	0.421	1.000

Day	Boxes Per Day	Yards Per Day	Cumulative Boxes	Cumulative Yards	Delta Yard
1	4	52	4	52	52
2	9.2	119.6	13.2	172	120
3	14.4	187.2	27.6	359	187
4	19.6	254.8	47.2	614	255
5	24.8	322.4	72	936	322
6	30	390	102	1,326	390

Net Conta Pipe Diamete	minated Area	1
inch		sq ft
2	0.500	11.1
6	0.5	11.1
12	1	44.3
24	2	177.1
36	3	398.6
48	4	708.5

Calculated ERDF Disposal Cost: \$804.05 /CY

SGW-34740 Rev. D

Pipeline Removal Vs. Characterization Study - Decision Support Tool

VC-12

Hanford Project ID No. Project Title

Pipe Material: Vitreous Clay

\$865,996.59 \$865,145.50 \$8,659,90 \$176,333.94 \$176,333.94 \$199,045,14 \$6,101.65 \$1,114.17 \$67,234,45 \$115,048,32 \$170,633.32 \$16,330,30 \$8,397,00 Total Activity Cost \$58,731.60 \$17,800.00 \$13,200.00 \$3,300.00 \$1,000 00 \$4 160.00 \$6 800.00 \$1 920.00 \$106.60 8.86.00 8.86.00 8.30.00 8.30.00 \$10,00 \$30.00 \$30.00 \$30.00 \$30.00 \$80.00 U.P 143 143 143 143 2 \$fhr 4 \$fhr 1 \$fhr SAhr S/hr \$/hr S/re SAr SAr SAr Sfr ğ CAT Excavator ERDF Box Truck Water Truck 5 CY Londer 300-hp Dozer Dump Truck Watter Truck \$27.44 Pickup Truck \$175.00 Backhoe \$1.674.13 \$4,021.42 \$11,016.68 \$447.4 Cont \$36.00 900 \$/100 in ft 438 PTO netruction Consumstrios \$47,832.32 Construction Consumables \$107,75103 Construction Corsumable Construction Consum Silt Barrier & Stakes \$6,291.00 \$322,104.93 \$12,782.90 Labor Cost 22 2 2 Grew Rate (SPhr) 81,210.33 \$747.38 \$029.10 \$366.42 \$1,278.29 \$697.00 30% Contaminated Soil Exervation Excavation Air Sampling ERDF LLW Disposal Estmating Confingency TOTAL PROJECT COST Backfill, Compact, Grade Activity Demobilize 1 Mobilize

Calculated Cost per Linear Foot of Pipe removed

3476

0

Rev.

0

Input		
Depth to top of pipe	20	n
Pipe Diameter	12	in
rench Slope	1.5	: 1
Pipe Length	100	ft
Excavation Vo	ft ³	CY
	ft ³	
Excavation Volume Contaminated Volume Clean Volume	4,428 78,363	CY

Input Pipe Diameter	1	ft
Slope down angle	33.7	degrees
2.5/cos(alpha)	3.00	100 March 190
٧	3.00	ft
v z	5.50	ft
У	23.50	ft
x	0.50	ft
Total Area	828.70	sq ft
Pipe Area	0.79	sq ft
Area 3	0.38	sq ft
Area 2	45.45	sq ft
Outer contaminated Area	45.07	sq ft
Net Contaminated Area	44.28	sq ft
Non-Contaminated Area	783.63	sq ft

Excavation	Duration Calculation Results
	Days No. Boxes
Contaminated Volume	1.0 13
Clean Volume	11.0
(for scenario Input Pipe Length)	· · · · · · · · · · · · · · · · · · ·

Day 1 cans per day Day 6 cans per day 30 yds per can 13 (bank volume) CY Days Roundup days Clean Volume 2,902 10.042 11.000 11.000 Total Volume, 3,066 10.462 Contaminated Volume 164 0.421 1.000

Day	Boxes Per Day	Yards Per Day	Cumulative Boxes	Cumulative Yards	Delta Yards
1	4	52	4	52	52
2	9.2	119.6	13.2	172	120
3	14.4	187.2	27.8	359	187
4	19.6	254.8	47.2	614	255
5	24.8	322.4	72	936	322
6	30	390	102	1,326	390

e Diamete inch	и	sq ft
HICO:		sq it
2	0.500	11.
6	0.5	11.
12	1	44.3
24	2	177.
36	3	398.
48	4	708.

Calculated ERDF Disposal Cost: \$1,075.11 /CY

5GW-34760 Rev. O

Pipe Excavation Estimate

Hanford Project ID No. Project Title

Pipeline Removal Vs. Characterization Study - Decision Support Tool

Pipe Material: Vitreous Clay

Total Activity Cost	56.101.65		\$7.910.92F8		\$1,179.56					\$228 R24 22			(F) (F) (F) (F) (F) (F)	or acceptance				\$1.100,262			\$6.391.00		\$124.491.90	\$224 085 42	52253,903,48	\$1,100,508.40
Cost	00 058	\$4276.00		\$24.00	\$115.20				\$22,400.00	\$10,000.00	\$4,200.00	\$1,600.00	\$1,200,00	\$300.00		\$3,040.00	\$6,175.00	\$14,250.00	\$2,850 03	\$100.00		Ī				\$77,380.20
U.P.	00.0TS	\$10.00		\$10.00	\$48.00	\$18.00	\$30.00		\$60.00	\$30.00	\$30.00	\$80.00	\$30.00	230.00	280,00	\$32.00	\$65.00	\$30.00	\$30.00	\$10.00						
TIMU	Sylvi	75		SArc	Z.	Shr	Shr		Shr	Shir	š	S/hr	S/hr	SVIE	SAu	SAhr	SAL	SAr	秀	Shr						
QTY		+		-	7				2	•	-	2	4	+		-	-	40		-						_
Equipment	Plokup Trient	Piekup Truek		Pickup Truck	Dackhoe	Paving Saw	Water Truck			Dump Truck	Water Truck	CAT Excavator	ERDF Box Truck	Water Truck	CAT Excavator w Atlachment	1 5 CY Loader	300-hp Dozer	Oump Truck	Water Truck	Piokup Truck						
Cost		\$4,573,46		\$29.94	\$175.00				\$6,263,62			\$447.40				\$2,485.04										\$13,974.48
U.P.					\$36.00								MASSAGE			200	STREET, ST									
TINO					\$/100 to R					STONE		10000	Dell Son													
QTV				ll seed in	478																					_
Materials		Construction Consumables		Construction Consumables	Sit Barrier & Stakes	Construction Consumables			Construction Consumables			Construction Consumables			Construction Consumables	Construction Consumables	Fill Material									
Labor Cost	\$6.051.65	\$130,670.28		\$866.41	01		STATE OF	SSID	\$178.950,60			\$12,782.90				\$77,007.10		1000		\$6,291.00						\$406,612.94
(Hours)	Q	428		2.4	1				140			10				28				10						
Crew Rate (S/Hr)	\$1,210.33	\$305.59		\$356.42					\$1,278.29			\$1,278.29			\$697.06	\$747.38				\$629.10					30%	
Activity	Mobilize	Pipeline / Interference Location		Install Silt Barrier		Paved Road Trenching			Clean Excavation to Pipe			Contaminated Soil Expanation			Pipe Section & Remove	Backfill, Compact, Grade.				Demobiliza			Excavation Air Sampling	ERDF LLW Disposal	Estimating Cantingenay	TOTAL PROJECT COST
		2		3		4			un.			9			-	80				σ						

Input		
Depth to top of pipe	25	ft
Pipe Diameter	12	in
rench Slope	1.5	: 1
Pipe Length	100	ft
Excavation V	olume Result	S CY
		5 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
Excavation Volume Contaminated Volume Clean Volume		5 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

Input Pipe Diameter	1	ft
Slope down angle	33.7	degrees
2.5/cos(alpha)	3.00	
V	3.00	ft
y z	5.50	ft
У	28.50	ft
×	0.50	ft
Total Area	1218.77	sq ft
Pipe Area	0.79	sq ft
Area 3	0.38	sq ft
Area 2	45.45	sq ft
Outer contaminated Area	45.07	sq ft
Net Contaminated Area	44.28	sq ft
Non-Contaminated Area	1173.70	sq ft

Days	No. Boxes
1.0	13
14.0	0.000.2014000
	1.0 14.0

Day 1 cans per day	4		
Day 6 cans per day	30		
yds per can	13	(bank volume)	
	CY	Days	Roundup days
Clean Volume	4.347	13.746	14.000
Total Volume,	4,511	14.167	15.000
Contaminated Volume	164	0.421	1.000

Day	Boxes Per Day	Yards Per Day	Cumulative Boxes	Cumulative Yards	Delta Yards
1	4	52	4	52	52
2	9.2	119.6	13.2	172	120
3	14.4	187.2	27.6	359	187
4	19.6	254.8	47.2	614	255
5	24.8	322.4	72	936	322
6	30	390	102	1,326	390

inch		sq ft
2	0.500	11.
6	0.5	11.
12	1	44.3
24	2	177.
36	3	398.6
48	4	708.5

Calculated ERDF Disposal Cost: \$1,366.25 /CY

SGW-34760 Rev. 0

Pipe Excavation Estimate

Pipeline Removal Vs. Characterization Study - Decision Support Tool

Pipe Material: Vitreous Clay

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Hanford Project ID No. Project Title

Shr Shr	100	10.0	\$10.00 \$448.00 \$18.00 \$30.00 \$30.00 \$30.00 \$30.00 \$30.00					\$18.00 \$10.00 \$18.00 \$10.00 \$1
99	Shr Shr Shr							
		2						
\$22 45 Plekup Truck \$140.00 Backhoe	22 4.5 Pitakup Trutk 40.00 Saethbre Paving Saw. Water Truck	\$22.45 Pickup Truck \$140.00 Backhoe Peving Saw Water Truck Water Truck Water Truck Water Truck	\$22.45 Plekup Truck \$1.40.00 Bacchboe Peving Sew Water Truck Water Truck Ump Truck Water Truck	22 45 Plekup Truck 10.00 Barckhee Paving Sew Water Truck Dump Truck Water Truck Water Truck Water Truck Water Truck Water Truck CAT Exceivator CAT Exceivator CAT Exceivator	S22 45 Pickup Truck S140.00 Backhoe Paving Saw Water Truck	22 45 Pekup Truck 00.00 Bacchboe Pavking See Waiver Truck Public Disperse Dump Truck Public Truck Water Truck Water Truck	22 45 Pekup Truck 00.00 Backboe Pavking See Water Truck Pulkup Truck Pulkup Truck	22 45 Pekup Truck 00.00 Backboe Pavking See Water Truck Water Truck Marier Truck Water Truck Pebup Truck Pebup Truck Pebup Truck
n \$35.00								
16 S/100 in ft	CONTRACTOR OF THE CONTRACTOR O			er en en er				** ** * * * * * * * * * * * * * * * *
mables 346								
Construction Consumables Sit Barrier & Stakee	Construction Consumations Still Berrier & Stakes Construction Consumation	Construction Consumables Sitt Barrier & Stakes Construction Consumables Construction Consumables	\$641.56 Construction Consumables SIR Barrier & Slakes Construction Consumables \$25,666.80 Construction Consumables \$38,348.70 Construction Consumables	Construction Consumables Sitt Barrer & States Construction Consumables Construction Consumables Construction Consumables	Construction Consumables Sitt Barrier & Slakee Construction Consumables Construction Consumables Construction Consumables Construction Consumables Fill Malerial	Construction Consum Sitt Barrier & Stakes Construction Consum Construction Consum Construction Consum Construction Consum Fill Malariel	Construction Consum Sitt Barrier & Stakes Construction Consum Construction Consum Construction Consum Construction Consum Fill Malaries	Construction Consum Sitt Barrior & Station Construction Consum Construction Consum Construction Consum Construction Consum Fit Moleries
\$641.56	\$ 5641.56	\$561.50	\$25.566.890	\$25.566.80	\$25,666,800 \$38,348,705	11.56	86.80 86.80 91.00	11.56 36.80 36.80 31.00
1		2 8	8 8	. 8 8	2 8 8 14	2 8 8 2	. 8 8 5	2 08 44 9
		\$1,278.29	\$1,278.29	\$1,278.29	\$1,278.29 \$1,278.29 \$697.06	\$1,278.29 \$1,278.29 \$687.06 \$747.38	\$1,278.29 \$1,278.29 \$5897.06 \$747.38	\$1,278.29 \$1,278.29 \$5897.06 \$529.10
	load Trenching	oad Trenching cavation to Pipe	cad Trenching Karvation to Pipe nated Soil Excavation	cavation to Pipe reled Soil Excavation	Road Trenching Excavation to Pipe minated Soll Excavation ection & Remove	Road Trenching Excavation to Pipe minated Soil Excavation ection & Remove	Road Trenching Excavation to Pipe Excavation inhaled Soil Excavation ection & Ramove i. Compact, Grade	Paved Road Trenching Clean Excavation to Pipe Contaminated Soil Excavation Pipe Section & Romove Backill, Compact Grade Excevation At Sampling EXCEVELO At Sampling EXCEVEDE LLW Disposal Exitinating Contingency

Pipeline Removal Vs. Characterization Study - Decision Support Tool

Input		40
Depth to top of pipe	5	ft
Pipe Diameter	24	in
Trench Slope	1.5	:1
Pipe Length	100	ft
Excavation Vo	lume Resul	lts CY
Excavation Vo	ft ³	10000
	17,714 3,606	CY

Input Pipe Diameter	2	ft
Slope down angle	33.7	degrees
2.5/cos(alpha)	3.00	
٧	6.01	ft
z	11.01	ft
y	12.01	ft
×	1.01	ft
Total Area	216.33	sq ft
Pipe Area	3.14	sq ft
Area 3	1.53	sq ft
Area 2	181.81	sq ft
Outer contaminated Area	180.28	sq ft
Net Contaminated Area	177.14	sq ft
Non-Contaminated Area	36.06	sq ft

Excavation I	Duration Ca	ilculation Re
	Days	No. Boxes
Contaminated Volume	3.0	50
Clean Volume	2.0	10000000000000000000000000000000000000
for scenario Input Pipe Length)		

Day 1 cans per day 4 30 Day 6 cans per day 13 (bank volume) yds per can CY Days Roundup days Clean Volume 134 1.682 2.000 Total Volume 790 4.546 5.000 656 Contaminated Volume 2.864 3.000

Day	Boxes Per Day	Yards Per Day	Cumulative Boxes	Cumulative Yards	Delta Yards
1	4	52	4	52	52
2	9.2	119.6	13.2	172	120
3	14.4	187.2	27.6	359	187
4	19.6	254.8	47.2	614	255
5	24.8	322.4	72	936	322
6	30	390	102	1,326	390

Net Contaminated Area Pipe Diameter								
inch		sq ft						
2	0.500	11.1						
6	0.5	11.1						
12	1	44.3						
24	2	177.1						
36	3	398.6						
48	4	708.5						

Calculated ERDF Disposal Cost: \$117.78 /CY

S6W-34760 Rev. 0

Pipe Excavation Estimate

Pipeline Removal Vs. Characterization Study - Decision Support Tool

Pipe Material: Vitreous Clay

Hanford Project ID No. Project Title

Cost		SR 101 85			\$83,268,10			\$993.79						107 081 51	10.100.164			C12 660 60							536,718.30			\$6.391.00	O a Colfons	565,778 31	S118,401.86	\$134,188.78	SER1 484 71	
Cost	\$50.00			\$2,552.00			\$20.00	\$96.00					\$9,600.00	\$7,200.00	\$1,800.00		\$3,200.00	\$2,400.00	\$600.00				\$1,088.00	\$2,210.00	\$5,100.00	\$1,020.00	\$100.00						E37 036 00	
U.P.	\$10.00			\$10.00			\$10.00	\$48.00		618 00	430.00	# Shirt Straight Straight	\$80.00	\$30.00	\$30.00		\$80.00	\$30.00	\$30.00		\$80.00		\$32.00	\$65.00	\$30.00	\$30.00	\$10.00							
UNIT	\$Jhr			S.F.C			Sthr	alus Sur		4.00	, P.		\$/hr	\$/br	\$/hr		Σ¥	\$Ar	Shr		S.		Sthr	Shr	Sthr	SAu	SAr							
Q1Y	1			-				-		I			2	4			5	4		4		-	÷		2					1	1	-		-
	Pickup Truck			\$2,729.53 Pickup Truck			\$24.95 Pickup Truck	\$140.00 Backhoe		Davidor Court	Wester Transfe		\$2,684.41 CAT Expaveror	Dump Truck	Water Truck		\$894.80 CAT Excevator	ERDF Box Truck	Water Truck		CAT Excevetor w/ Attachment		\$889.38 & CY Loador	300-hp Dozer	Dump Truck	Water Truck	Pickup Truck							
Cost				\$2,729.53			\$24.95	\$140.00					\$2,684.41	200			\$894.80						\$889.38										27 262 07	
U.P.								\$35.00																										_
UNIT								\$/100 lm fl																										
OTY								386		House																								-
cited by testing				Construction Consumables		is the second of	Construction Consumables	Sill Barrier & Stakes		Contraction Contraction	COLDENS COLD SECTION OF THE COLD SECTION OF TH		Construction Consumables				Construction Consumables				Construction Consumables		Construction Consumables	Fill Material										
Labor Cost	\$6,051.85		 П	\$77.986.57			\$712.84		i ali				\$76,697.40			П	\$25,565.80						\$25,410.92				\$6,291.00						85 344 8563	
(Hours)	10			255			2.0						09				20						8	00000			10							
(S/Hr)	\$1,210.33			\$306.59			\$356.42						\$1,278.29				\$1,278.29				Se87.06		\$747.38				\$629.10					30%		_
Activity	Mobilize			Pipeline / Interference Location			Install Silt Barrier			David Boad Transfer	Burney and a poor		Clean Excevation to Pipe				Contaminated Soil Excavation				Pipa Saction & Remove		Backfill, Compact, Grade				Demobilize			Excavation Air Sumpling	ERDF LLW Disposei	Estimating Contingency	TOTAL PROJECT COST	
	-			2			E			,			NI.				w				7		80				6							

Input		
Depth to top of pipe	10	ft
Pipe Diameter	24	in
rench Slope	1.5	: 1
Pipe Length	100	ft
Excavation Vo	lume Result	CY
Contaminated Volume		ACM DOM
Excavation Vo Contaminated Volume Clean Volume		CY

Input Pipe Diameter	2	ft
Slope down angle	33.7	degrees
2.5/cos(alpha)	3.00	
v	6.01	ft
Z	11.01	ft
У	17.01	ft
x	1.01	ft
Total Area	433.97	sq ft
Pipe Area	3.14	sq ft
Area 3	1.53	sq ft
Area 2	181.81	sq ft
Outer contaminated Area	180.28	sq ft
Net Contaminated Area	177.14	sq ft
Non-Contaminated Area	253.69	sq ft

Excavation D	Juration Ca	Iculation Results
	Days	No. Boxes
Contaminated Volume	2.0	50
Clean Volume	6.0	A CONTRACTOR CONTRACTOR
(for scenario Input Pipe Length)		

Day 1 cans per day	4		
Day 6 cans per day	30		
yds per can	13	(bank volume)	
<u></u>	CY	Days	Roundup days
Clean Volume	940	5.009	6.000
Total Volume,	1,596	6.691	7.000
Contaminated Volume	656	1.682	2.000

Day	Boxes Per Day	Yards Per Day	Cumulative Boxes	Cumulative Yards	Delta Yards
1	4	52	4	52	52
2	9.2	119.6	13.2	172	120
3	14.4	187.2	27.6	359	187
4	19.6	254.8	47.2	614	255
5	24.8	322.4	72	936	322
6	30	390	102	1,326	390

Pipe Diamete	er	
inch		sq ft
2	0.500	11.1
6	0.5	11.1
12	1	44.3
24	2	177.1
36	3	398.6
48	4	708.5

Calculated ERDF Disposal Cost: \$180.47 /CY

56W-34760 Rev. 0

Pipe Excavation Estimat

Hanford Project ID No. Project Title

Pipeline Removal Vs. Characterization Study - Decision Support Tool

Pipe Material: Vitreous Clay

Court		\$0,101,05			\$107,739,52			60 000 03						B460 249 44	a low priest			\$32,660,60						100	860.688,888			\$6.391.00		\$86.132.81	\$155,038.52	\$175,710.32	£764 444 3B	1
Cost	\$50.00			\$3,302,00	I	T	\$22.00	\$105.60		t			\$12.800.00	\$9,000.00	\$2,400,00	40, 100, 40	45,200.00	***	00 0098				\$1,824,00	\$3,705,00	\$8,650 00	\$1,710.00	\$100.00			l			260 368 60	
U.P.	\$10.00			\$10.00	No.	000000	\$10.00	\$48.00		618.00	\$30.00	000000000000000000000000000000000000000	\$80.00	\$30.00	\$30.00	240.00	990.00	900.00	\$30.00	\$80.00			\$32.00	\$85.00	\$30.00	\$30.00	\$10,00							•
UNIT	SAr			SAu			SAN	SAhr		SAN	SA		SAu	\$the	*		and a	aure	Sthr	SAN			š	. \$0m	SAu	Shr	₹₩							
ντο	F		İ	1		İ				ļ			2	•	٠		,		-		ļ		٠	•	2	ē	ŀ			ļ				-
Cost	Pickup Truck			\$3,531.70 Pickup Truck.			\$27 44 Pickup Truck	\$175.00 Backhoe		Pavino Sau	Water Truck		\$3,579.21 CAT Excavator	Dump Truck	Water Truck	L. Service Contract C	SCHOOL CALCACTURE	END DOX 1 OX	Water Truck	CAT Excevelor w/ Attachment			\$1,491.02 5 CY Landor	300-hp Dozer	Dump Truck	Water Truck	Pickup Truck						\$0 800 40	
	100	100	13		983	200	200	\$35,00	100			1,000		5000			4		-				•	200					500					
u.p.	10/11/01															No.								2000000						L	L			
UNUT								\$/100 fn ft																							L			
OTY								420															2000											
				Construction Consumables			Construction Consumation	Silt Berrier & Stakes		Construction Consumabilities		Months of the second	Construction Consumables				CONSTRUCTION CONTRIBUTION			Construction Consumables		73W	Construction Consumables	fill Material										
Labor Cost	\$6,061.66			\$100,906.82			\$784.12						\$102,263.20			200 200 200	\$20,000.00						\$42,600.66				\$6,291,00						\$284 489 25	
(Hours)	sp.			330			2.2						980			-	2						23				10							
(SHr)	\$1,210.33			69'900\$			\$356.42						\$1,278.29				W. 2.0.20			\$697.00			\$747.38				\$829.10					30%		
Activity	1 Mahiliza			2 Ppelins / Interference Location			3 Install Sit Barrier			4 Payed Road Treathles			5 Clean Excavation to Pipe				CONTRIBUTION SON EXCENSION			7 Pipe Section & Remove		- 1	8 Sackfill, Compard, Grade				9 Demobilize			Excavation Air Sampling	ERDF LLW Disposal	Estimating Contingency	TOTAL PROJECT COST	

Input		
Depth to top of pipe	15	n
ipe Diameter	24	in
Trench Slope	1.5	: 1
Pipe Length	100	ft
Excavation V	olume Result	CY
Contaminated Volume	17.714	656
Contaminated Volume	17,714 54,633	656 2,023

Input Pipe Diameter	2	ft
Slope down angle	33.7	degrees
2.5/cos(alpha)	3.00	(34)
V	6.01	ft
z	11.01	ft
y	22.01	ft
x	1.01	ft
Total Area	726.61	sq ft
Pipe Area	3.14	sq ft
Area 3	1.53	sq ft
Area 2	181.81	sq ft
Outer contaminated Area	180.28	sq ft
Net Contaminated Area	177.14	sq ft
Non-Contaminated Area	546.33	sq ft

Excavation	Duration Cal	culat	ion Results
	Days	No.	Boxes
Contaminated Volume	2.0		50
Clean Volume	8.0		222 (A) (A)
(for scenario Input Pipe Length)			

Day 1 cans per day	4		
Day 6 cans per day	30		
yds per can	13 (8	ank volume	
	CY	Days	Roundup day
Clean Volume	2,023	7.788	8.000
Total Volume,	2,680	9.471	10.000
Contaminated Volume	656	1 682	2 000

Day	Boxes Per Day	Yards Per Day	Cumulative Boxes	Cumulative Yards	Delta Yards
1	4	52	4	52	52
2	9.2	119.6	13.2	172	120
3	14.4	187.2	27.6	359	187
4	19.6	254.8	47.2	614	255
5	24.8	322.4	72	936	322
8	30	390	102	1,326	390

inch		sq ft
2	0.500	11.1
6	0.5	11.1
12	1	44.3
24	2	177.1
36	3	398.6
48	4	708.5

Calculated ERDF Disposal Cost: \$236.32 /CY

56W-34760 Revio

Pipe Excavation Estimate

Pipeline Removal Vs. Characterization Study - Decision Support Tool

Pipe Material: Viveous Clay

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(Hours) Labor Cost		Materials		νто	UNIT	U.P.	Cost	Equipment	λto	TINU	U.P.	Cost	Cost
s		\$6,061.65						Pickup Truck		ă II	\$10.00	\$00.00	\$6,101,85
406		\$123,825.07	Construction Consumables				\$4,353.88	8 Pickup Truck	-	¥\$	\$10.00	14,052,00	\$132,210.06
2.4		\$655 41	Construction Consumables Sit Berrier & Stakes	466	\$/100 ln ft	\$35.00		828.94 Pickup Truck 1:75.00 Backrice		745 245	\$10.00	\$118.30	\$1,199.55
			Construction Consumables					Paving Saw Water Truck		\$ \$	\$18.00 \$30,00		
120		\$153,394.80	\$153,394.80 Construction Consumables				\$5,368 82	2 CAT Excavalor Dump Truck Water Truck	N U T	# # #	\$30.00 \$30.00	\$14,400.00 \$3,400.00	\$196,962.62
50		\$25,565,80	Combuction Consumative				\$854.80	O CAT Excevenior ERDF Box Truck Water Truck	10 4 C	SAL SAL	\$30.00	\$3,200.00	000000000000000000000000000000000000000
	1		Construction Consumables					CAT Excavator of Attachment		š	\$60.00		
S		\$63,527,300	Construction Consumables Fil Material				\$2.223.4	\$2.223.46 d CV Lander 300-kp Doore Dum Truck Water Truck		5555	\$32.00 \$05.00 \$30.00 \$30.00	\$2,720.00 \$6,525.00 \$12,750.00 \$2,550.00	\$69.295.76
01		\$6,291.00						Piekup Trvak	-	158	\$10.00	\$100.00	\$6,397.00
				Ш	Ш				Ш	П			\$115,955.78
		\$379.511.03					\$13,025.89	9			T	\$71,286.20	\$236,549,79

Input		
Depth to top of pipe	20	ft
Pipe Diameter	24	in
Trench Slope	1.5	: 1
Pipe Length	100	ft
Excavation Vo	lume Results	CY
Excavation Vo	ft ³	
	17,714 91,397	CY

Value Vietne (EVIETNAM)	-	
Input Pipe Diameter	2	ft
Slope down angle	33.7	degrees
2.5/cos(alpha)	3.00	
v	6.01	ft
z	11.01	ft
y	27.01	ft
×	1.01	ft
Total Area	1094.25	sq ft
Pipe Area	3.14	sq ft
Area 3	1.53	sq ft
Area 2	181.81	sq ft
Outer contaminated Area	180.28	sq ft
Net Contaminated Area	177.14	sq ft
Non-Contaminated Area	913.97	sq ft

Excavation D	Ouration Ca	Iculation Res
	Days	No. Boxes
Contaminated Volume	2.0	50
Clean Volume	12.0	
(for scenario Input Pipe Length)		

Day 1 sams per day	4		
Day 1 cans per day	4		
Day 6 cans per day	30		
yds per can	13 (b	ank volume)	
<u> </u>	CY	Days	Roundup days
Clean Volume	3,385	11.280	12.000
Total Volume,	4,041	12.962	13.000
Contaminated Volume	656	1.682	2.000

Day	Boxes Per Day	Yards Per Day	Cumulative Boxes	Cumulative Yards	Delta Yards
1	4	52	4	52	52
2	9.2	119.6	13.2	172	120
3	14.4	187.2	27.6	359	187
4	19.6	254.8	47.2	614	255
5	24.8	322.4	72	936	322
6	30	390	102	1,326	390

ipe Diamete	minated Area er	
inch		sq ft
2	0.500	11.1
6	0.5	11.1
12	1	44.3
24	2	177.1
36	3	398.6
48	4	708.5

Calculated ERDF Disposal Cost: \$318.14 /CY

SGW-34760 Rev. 0

Pipe Excavation Estimate

Pipeline Removal Vs. Characterization Study - Decision Support Tool

VC-24

Hanford Project ID No. Project Title

Pipe Material: Vitreous Clay

\$1,302,694.29 \$1,302,694.29 \$13,026,04 \$1,310,03 \$6,391.00 \$126,014.08 \$0,101,05 \$261,284.82 \$32,050,50 \$156,682.37 Total Activity Cost \$3,508.00 \$7,736.00 \$17,850.00 \$3,570.00 \$124.80 \$19,200.00 \$3,200.00 \$2,400.00 \$600.00 \$4,802.50 Cost \$30.00 \$30.00 \$18.00 \$30.00 \$30.00 \$80.00 \$48.00 \$30.00 U.P. S/hr S/hr S/hr SAr Sthr s. Shr Shr S.fhr Ę CAT Excavator w/ Attachment CAT Excevator ERDF Box Truck Water Truck 5 CV Lander 300-hp Dozer Dump Truck Water Truck Pickup Truck Pickup Truck Pickup Truck \$16,544.55 \$5,136.06 \$804.80 \$3,112.84 \$7,158.42 Cost \$35.00 5/100 in ft 909 Į, \$204,524 40 Construction Consumables matruction Consumables Construction Consumables Fill Material retruction Consumables \$146,744.32 Committudian Consumables Labor Cost \$6,051.85 \$88.030.ZZ \$6,291.00 \$479,044.08 \$25,555.80 480 160 118 2.6 8 2 \$1,276.29 \$629.10 5697,08 \$747.38 5305.69 \$1,278.20 30% Contaminated Soil Excevator Excavation Air Sampling ERDF LLW Disposal Estimating Contingency TOTAL PROJECT COST Backfill, Compact, Grada Paved Road Trwnching Activity 3 Install Sill Burrier

Calculated Cost per Linear Foot o' Pipe removed:

Input		
Depth to top of pipe	25	ft
Pipe Diameter	24	in
French Slope	1.5	: 1
Pipe Length	100	ft
Excavation Vo	olume Result	S CY
A TOTAL TO A STATE OF THE STATE		72472
Excavation Vo Contaminated Volume Clean Volume		CY

Input Pipe Diameter	2	ft
Slope down angle	33.7	degrees
2.5/cos(alpha)	3.00	
V	6.01	ft
z	11.01	ft
У	32.01	ft
×	1.01	ft
Total Area	1536.89	sq ft
Pipe Area	3.14	sq ft
Area 3	1.53	sq ft
Area 2	181.81	sq ft
Outer contaminated Area	180.28	sq ft
Net Contaminated Area	177.14	sq ft
Non-Contaminated Area	1356.61	sq ft

Excavation	Duration Ca	Ilculation Re
	Days	No. Boxes
Contaminated Volume	2.0	50
Clean Volume	16.0	
(for scenario Input Pipe Length)		

Calculated ERDF Disposal Cost: \$404.31 /CY

Day 1 cans per day	4		
Day 6 cans per day	30		
yds per can	13 (t	ank volume)	
523 5	CY	Days	Roundup days
Clean Volume	5,024	15.483	16.000
Total Volume,	5,681	17.165	18.000
Contaminated Volume	856	1 882	2 000

Day	Boxes Per Day	Yards Per Day	Cumulative Boxes	Cumulative Yards	Delta Yards
1	4	52	4	52	52
2	9.2	119.6	13.2	172	120
3	14.4	187.2	27.6	359	187
4	19.6	254.8	47.2	614	255
5	24.8	322.4	72	936	322
6	30	390	102	1,326	390

Net Conta Pipe Diamete	minated Area	1
inch		sq ft
2	0.500	11.1
6	0.5	11.1
12	1	44.3
24	2	177.1
36	3	398.6
48	4	708.5

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Pipeline Removal Vs. Characterization Study - Decision Support Tool

Steel and Stainless Steel Pipe

100

24 in Dia \$3,835.49 \$5,855.59 \$7,654.85 \$10,291.23 \$13,067.68

12 in Dia \$2.907.68 \$4.474.00 \$6.517.31 \$8,700.69 \$11,045.82

6 in Dia \$2,648.38 \$4,145.05 \$5,804.25 \$7,941.20 \$10,216.67

2 in Dia \$2,548.38 \$4,145.05 \$5,804.25 \$7,941.20 \$7,941.20

Pipeline Removal Vs. Characterization Study - Decision Support Tool

Estimate Scenario	cenario		Dept	Depth to Top of Pipe		
Pipe Material	Pipe Diameter (in)	# 10	10 ft	15#	20 ft	25 ft
Steal	2	\$2,648.38	\$4,145.05	\$5,804.25	\$7,941.20	\$10,216.67
Steal	60	\$2,648.38	\$4,145.05	\$5,804.25	\$7,941,20	\$10,216.67
Steal	12	\$2,907.68	\$4,474.00	\$6,517.31	\$8,700.69	\$11,045.82
Steal	24	\$3,835.49	\$5,855.59	\$7,654.85	\$10,291.23	\$13,067,68
Steal	36					
Steel	48					

Estimate Assumptions

= Scenario not applicable to Hanford site.

Additional labor allocated for shearing, removal, and loading pipe sections into ERDF boxes. Pipe sheared in trench with excavator-mounted hydraulic shear.

Pipe cut into 8 ft long sections. Pipe NOT crushed pror to ERDF box loading.

General Assumptions. Clean solid interval and stockniked done to excavalion sits for reuse as backfill material. Clean soil removed from trench and Stockniked done for disposal. Contaminated soil loaded into lined ERDF boxes for disposal. All scenarios do not involve any excavation of perved traces. All scenarios do not involve any excavation of perved traces. Sit fearing to pipe to be removed, and γ is depth from the surface to bottom of the triangle below the pipe (from geometry cacs):

		-	Cara
		-	110

	→ 2 in Dia © 6 in Dia → 12 in Dia → 24 in Dia	
		25 11
Steel		20 1
Stainless and Carbon Steel		15 II Depth to Top of Pipe
215		10#
	\$13,000.00 \$11,000.00 \$11,000.00 \$1,000.00 \$3,000.00 \$5,000.00 \$4,000.00 \$3,000.00 \$1,000.00	50.00 5 ft

able Underground Pipe Combinations at the Harrlord Site

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Pipeline Removal Vs. Characterization Study - Decision Support Tool

	Supervisor	\$75.00			Size		
23	General Laborer	\$54.14	-	Mobilitie		Supervisor	75.0
0	Tnamatar	\$54.35			•	General abover	54.1
*	Heavy Egpret Operator	864.86			æ	Teamster	54.35
40	HP Technician	\$68.17			2	Heavy Eqpmt Opd	64.86
9	Burner/Pipefitter	\$67.06			9	HP Technician	68.17
-	Other Craft	\$67.06			Standard St	Burner/Piper/tter	67.96
8	Spare					Officer Craft	67.06
а	Spare		2	Pipeline / Interferance Location		Supervisor	75.00
10	Spare				3	General Laborer	64,14
						Teamster	54.3
	Values Head Theory and					Heavy Egpint Ope	04.90
Estimating Confineency	Confinence	300%				Rivner/Dinefities	0.70
Labor Hours	abor Hours per Work Shift	10				Other Craft	87.96
Construction	Consumplies (% of direct labor)	3.6%	2	Inatal Sat Barrier		Supervisor	75.00
Excavation	Ar Sampling (% of total cost)	20%			,	General Laborer	64.1
WITH JONES	ERDF LLW disposal (% of lotal cost)	45%				Teamake/	54.35
Sol Expension Fector	on Fector	28%			Carp Brook	Heavy Espirit Ope	04.00
Pipe Rubble Factor	Factor	40%				HP Technician	68.1
Steel Page L	Steel Pipe Lengths for Removal, manimum (ft)					Burner/Pippetitler	67.96
					CHARLES OF	Other Craft	67.96
	Unit Prices (2007 S)		4	Paved Road Trenching		Superview	75.0
	Description	2				Cerseral Laborar	54.14
T	50 feet sill brace	2000				en ste	54.35
Der day	CAT 320 Extramor Hental	91,000				Hoovy Edpmit Cpd	64.85
Т	Ferch box	0000				THE INCHINION	00.17
The mouth	Commenters	00078				DUTHE POPULAR	04/70
The month	total Trailor	2003	1	Clean Branchion in Blos	ŀ	Superulace	78,07
Ī	Dell Res	11 000	•	BC CI COURT BOOK INDICA	•	German above	E4 14
	Duma Truck	8280			4	Tearrelar	84.38
por day	Grader	\$250			2	Heavy Eqpmt Ope	64.86
J par day	Roller	1250				HP Technician	68.17
	Front-and Loader	1250				Burnar/Pipefitter	67.04
Г	TADA - 6"	\$400.00			-	Other Craft	67.06
M CASA	Table 2	\$160.00	۰	Contaminated Sol Exervation		Schretor	75.0
w 2	Searing	64.00				General Laborer	64.14
100-1-001	Plantic Shaeting	\$050.00			10	Toarrister	64.36
P par	Cloves	\$6.53			5	Heavy Egpmt Ope	64.86
Q 2540 box	Rage	\$130,00			9	HP Technician	68.17
	Tools	\$600.00			KI CO	Burner/Pipelifler	67.5
	Casing	\$1,000,00			-	Other Craft	67.04
	Spirit Spoons	82 600.00	-	Pipe Section & Remove	-	Supervisor	75.0
U each	Soft Spoon Linera	\$20.00		Control to the section of the control of the contro	*	General Laborer	54,14
V psir	Laundry	\$26.00				Teameier	64.38
П	Cable	\$10.00			•	Hodvy Egpmt Opd	84.86
X anch	Retooling	\$100.00			•	HP Technolan	00.17
wund Y	Drume	\$66.36				Burner/Pipelitter	07.PB
Z per shoot	Plywood (4'x8' t/4 cdx axterior)	\$25,00			50,534,040	Other Craft	67.9
AA BBCh	Orum Pallets	\$36.00		Saek'll Compact Grada		Supervisor	75.00
AB each	2×48	89.00			7	General Laborer	54.14
AC \$	Rope	\$100.00			9	Teamster	54.38
AD biank	Signa	\$20.00			2	Heavy Egpmt Ope	64.60
AE yd	Grave	\$40.00				HP Technician	51.99
AF per nour	CAT 329 Expavator	\$30.00			100000	Burner/Pipefiller	67.96
AG Day hour	Shuttle Durry Truck	\$30.00				Other Creft	87.06
AH per hour	Water Truck	\$30.00	0	Demobiliza		Supervisor	75.0
Al perhou	Paving Saw	\$18.00				General Laborer	54.1
	Backhoe	\$48.00				Teametar	54 36
AK 100-ft roll	SAL Percing at Sukee	\$36.00				Heavy Ergent Ope	54 56
A		-			*	HP Technician	68.17
						1	

	Name	The second second		
Mobiler		\$1,210.33		Prob
Pipeline	Pipeline / Interference I	\$305.59		
Install 8	Sitt Barrior	\$366.42		
Paynd	Payed Hond Trenching	\$0.00		Pipeline Mat
Cean	Clean Expavation to Pi	\$1.278.29		Vibrous Clay
Contain	Contaminated Soff Exc.	\$1.278.29		Steet (stainle
Pipe Se	Pipe Section & Ramow	\$667.06		Concrete Ma
Backfill	Backfil, Compact, Grad	\$747.38		Reinforced C
Damabil 28	97.0	\$629.13		
Astiv	Artivity Duration Constitution	Dermian	Unit	
(Miss Uliky) a	gnusk	20	II* per hour	
errier cotalist	llation	200	in fl per hour	
g Saw Trenot	Trensh Cutting	20	In ft por hour	
Pipe Sectioning	ng & Ramoval	***	in it per hour	
pe Sectioning	4 Removel	400	he fl. per nous	
		09	CY per hour	
Exca	Excavation Duration Calculation Basis	Salculation B	all a	
County per EROF Box	ADF Box		13	

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Pipe Excavation Estimate

Pipeline Removal Vs. Characterization Study - Decision Support Tool

Hanford Project ID No. Project Title

Pipe Material: Carbon / Stainless Steel

Cost		\$6,101.05			47.000.74	* 7300'00*			\$623.03					CALL DOZ DO	2			\$10,330,30			\$1,843,35			***************************************	\$6,303.23			Contract of	96,381.00		\$29,959.05	\$53,926,29	\$61,116.46	CORE NAMED	526.2 a 18.01
Cost	\$50.00			\$1,013.00			Can in	210.00	\$76.80	Ī			\$4,800.00	\$3,600.00	\$300.00	81 800 00	\$1,200,00	\$300.00		\$184.00			\$192.00	\$380.00	\$300.00	\$ 180.00	\$100.00							\$18 501 BD	
n.b.	\$10,00			\$10,00			Can no	200014	348.00	STREET, STREET	\$18.00	\$30.00	\$90.00	\$30.00	\$30.00	\$80.00	\$30.00	\$30.00		\$80.00			\$32.00	\$65.00	\$30.00	\$30.00	\$10.00	ON SERVICE OF							
INI	s.ms			shr	CONTRACTOR OF		242		200		\$/hr	3VK	Shr	\$/Ja	\$VA	Ehr	8/4	\$frit		Sthr			Shr	\$mr	1/hr	\$thr	\$.hr								•
Ė	٠			-			ŀ	1					2	4	+	2		÷					1		0	-	-								
	Plokup Truck			\$1,083.47 Piokup Truck			Section Stands	Pickup Intok	\$140 to Becahoe		Paving Saw	Water Truck	\$1,342.20 CAT Excevator	Dump Truck	Water Truck	KAAT 40 CAT Faceworks	ERDF Bax Truck	Wafer Truck		CAT Excavator w/ Attachment			\$158.95 5 CY Loader	300-trp Dozer	Dump Truck	Water Truck	Pickup Truck								
Cost				\$1,083.47			90014	DO NO.	\$140.00				\$1,342.20			\$447.40				\$58.11			\$156.95											81 948 to	
d'in	DOM:			U CONTROL O	Selling	No.		-	838.80				0.0000000					September 1	HERSKOL			1000									11				
INO			Ī			STATE OF THE PARTY			\$7100 In II				Continue						WINDOWS STREET	0.000		2000000	STATE OF						1000 N	THE COLUMN					
¥1a				1000			2000	1	ğ		CHARLES AND A		100		0.215				0.00000	O COL		STORY OF	0000000	SEEDING R	Section										
				Construction Consumables				CONSTRUCTION CONSUMBLINE	Sill Barrier & Stakes		Construction Consumables		Construction Consumables			Construction Construction				Construction Consumables			Construction Consumables	Fit Material											
Labor Cost	\$6,051.05			\$30,956.27			20.000						\$38,348.70			CE 087 G13				\$1,603.24			\$4,484.28				\$6.201.00							540+088-34	
(Hours)	9			101				9					30			9				2.3			9				10	2							
	\$1,210.33			\$306.59			40.00	\$300.42					\$1,278.20			£1 978 50				\$697.06			\$747.38				of peak	20000					3/0%		
Activity	Mobilize			Pipeline / Interference Location			Total Car	Marie Sill Darrier			Paved Road Trenching		Clean Excavation to Pipe			Contaminated Soil Evoquation				Pipe Section & Remove			Baddill, Compact, Grade				Demobilize				Excavation Air Sampling	ERDF LLW Disposal	Estimating Contingency	TOTAL PROJECT COST	
	-			~				4			4		st.							4							0								

L				Days	Day 6 cans per day	30							
Depth to top of pipe				^	yds per can	13	13 (bank volume)						
Pipe Diameter	2				1		Days	Roundup days	N.				
Tranch Stope	1.5			Clean	Clean Volume, yds	212	2.214	3.000					
Pipe Length	100			_	Total Volume	253	2.433	3.000					
Excavation Volume Results				ontaminated	Contaminated Volume, yds	41	0.219	1.000					
Contaminated Volume Clean Volume Total Volume	1,107 41 1,107 41 5,112 212 6,819 223	D - S	Boxes Per Day 4	Yards Per Day 52 119.5	Cumulative Boxes 4 13.2	Cumulative Yards 52 172	Delta Yards 52 120						
	4 4 4	6	14.4	187.2	27.6	359	187						
Input Pipe Diameter		* 1	19.0	254.6	47.2	410	000						
Siope down angle	33.7 degrees	e u	24.8	322.4	100	135	325						
l'ou sale	6 00 7		3		****	Awari							
	275 #		Net Contar	Net Contaminated Area	_								
	675 #		Pipe Diameter	TO STATE OF THE PARTY OF THE PA									
	0.25 #		inch		\$Q.ff								
Total Area	68.39 sq.ft		2	0.500	11.1								
Pipe Area			60	0.5	11.1								
			12	-	44.3								
Area 2			24	2	1771								
Outer confaminated Arm	11.27 sqft		36	m	398.6								
Net Contaminated Area	11.07 sqft		48	4	708.5								
Non-Contaminated Area	57.12 sq.ft			2									
Excavation Dun	Excavation Duration Calculation Results	Box Dimensions	SIONS				Box Weight Capacity	4	8 inch soil healding required for demo debris.	ding required	for demic debri		
			L(ft)	W(ft)	H	Vol (CY)	suos	<u>123</u>	L(3)	W(ft) H	H(ff) Vol (ff		Soil Density
E	Days No. Boxes		20	œ	9	36.56	20	40,000	20	ori.	0.5 80		113 thril
Clean Volume	000	Based on Volume	/olume					30,960	Ibs soil bedding Ibs Available Weight Capacity	Welcht Cap	ACITY		
or scenario Input Pipe Length)		Pipe	Pipe out to length:	80								7.00	
		Numb	Number laid in box end-to-end.	end-to-end.	7						Hipe Da	a from Crane 1	Pipe Data from Crane Technical Manual No. 410
	1		Number of p	spe sections	Number of pipe sections that fit in box:	406					(Assumi	(Assume pipe is SCH 40)	
Pipe Debris	Vol (CY) No. Boxes	Number of	boxes require	d for scenario	Number of boxes required for scenario pipe length:	0.031	Based on Volume capacity	capacity				Diameter	3.65
(for scenario Input Pipe Length)		Section of the sectio	Africated									es Ç	18.97
		the important	hayas somile	of for ocentral	Minmber of hoves required for scanner and another	0.049	Based on Wainbl capacity	caracilo.				24	171.20
		IN LIGHTINGS OF	DOXOG SERVICE	CO CO CO CO CO		D.O.O.	Made of the state	Contract of Colors				2.4	

culated ERDF Disposal Cost. \$1,312,57 /CY

5GW-34760 Rev. O

Pipe Excavation Estimate

Pipeline Removal Vs. Characterization Study - Decision Support Tool

Pipe Material: Cerbon / Stainless Steel

Hanford Project ID No. Project Title

CS/SS-12

Cont Cont	\$50.00	\$6 101 65	\$2,776.00		06.070.088		\$20.00	\$590.00				\$12.800.00	\$0,600.00	\$2,400.00	81 800 00		\$300.00		\$184.00	\$1,843.35		\$1,280,00	\$2,600.00	\$6,000.00	\$1,200.00	\$100.00	\$6.301.00	\$73,725,23	\$132,706.42	\$150,300.48	\$42,206.00 \$651,731.06	
ď'n	\$10.00		\$10.00				\$10.00	\$48.00		\$18,00	\$30.00	\$80.00	\$30.00	\$30.00	00 088	\$30.00	\$30.00	700000	\$60.00		000000	\$32.00	\$65.00	830.00	830.00	\$10.00						
	\$Pric		\$Ar		inesetti.		S.fric	Shr		\$Aur	SAn	\$Aur	\$/hr	\$fbr	\$Arr	Shr	\$thr		\$fbr			\$0,0	S/br	\$.B.r	\$Pr	\$.fbr					Ī	
A iii	-		-				•	+				2	9		2	7			•				-	2	-	-						
Cost	Pickup Truck		\$2,969,11 Pickup Truck				524.96 Pickup Truck	\$140.00 Backhoe		Paving Stew	Wale Took	\$3,579.21 CAT Excavator	Dump Truck	Water Trook	\$447.40 CAT Excavator	ERDF Bex Truck	Water Truck		\$56.11 CAT Excevator wi Attachment			\$1,046.33 5 CY Loader	300-tp Dozar	Dump Truck	Water Truck	Pickup Truck					\$9.203.12	
U.P.	2007/00/20		GEORGE CO.	2000000	0000000			\$36,00	10000000000000000000000000000000000000	(HS) IT THE		0.0000000000000000000000000000000000000	1000000		STATE OF THE PARTY	000000000000000000000000000000000000000	佐藤田田	9038800	2000000	SOUTH		20000	0.000	2000								
UNIT								\$/100 to ti		Stories Stories					I	I							10000	Distribution				Ī				
ΔĬ	1000		İ				100	396							T. J. W.			A STATE OF		Ī												
			Construction Consumables				Construction Consumables	Sit Barrier & Stakes		Canalityotion Canaumabies		Construction Consumstiles			Construction Consumations				Construction Consumstries			Construction Consumables	Fill Material									
Labor Cost	\$8,051.85		\$64,831,75	6		\neg	\$712.84	971	da			\$102,283.20	- Company		\$12 782 90 0				\$1,603.24	al to		\$29,885,20	-1		-1,	\$6,291.00					\$244,431.81	
(Hours)	9		278	Table 1			5.0					00	2		10				23			9				10						
(\$/Hr)	\$1,210.33		\$306.60	- Carcons			\$356.42					\$1,278.29			\$1.278.29				8697.06			\$747.38				\$629.10				30%		
Activity	Mobifize		Piceline / Interference Location				Instell SIR Barrier			Paved Road Trenching		Clean Excavation to Pipe			Contaminated Soll Expendition				Pipe Section & Remove			Backfill, Compact, Grade				Demobiliza		Excavation Air Sampling	EROF LLW Disposal	Estmaling Confingency	TOTAL PROJECT COST	

Signature 158 1780 178	130 Fraction Volume 130 Fraction	1.13	150 1736 1	Input Depth to top of pipe	15 nt = 12		Day 6 cans per day Day 6 cans per day yds per can		4 30 13 (bank volume) Days	Ro	kep dnpur	Roundup days	skep dopur	s dep disput
100 m	100 m	100 II	100 R	Trench Slope			Clean Volume, yd	Ĩ		8.000	9	00	00	000
Contaminated Volume Results Contaminated Volume Volume Volume Results Contaminated Volume Results Contaminated Volume Volume Results Contaminated Volume Volume Results Contaminated Volume Volume Results Contaminated Volume Volume Results Contaminated Volume Volume Results Contaminated Volume Volume Volume Results Contaminated Area Contaminate	Second Paris Contaminated Volume, visa Fig. Contaminated Volume, visa Fig. Contaminated Volume, visa Fig. Contaminated Volume, visa Fig. Contaminated Volume, visa Fig. Contaminated Area Contaminated Volume Results Contaminated Volume V	Solution Volume Results Contamination Volume, vide Contamination Vol	Pipe Length	100		Total Votume	8.5		8.000	0	0	0	0	
Volume	Volume	March Marc	Note Aut	Excavation Volum	702	0	Contaminated Volume, yd			1,000	c	c	c	c
March Marc	March Marc	Sizes 1,898	Secretary Secr	Volume			Yards Per Cumulative Day Boxes		Delta Yards					
Second Columb Second Colum	Second color of the color of	Section 1	Post Length Post Length	2				173	52					
The control of the	The content of the	1	Place 337 Place 472 514 255 200					350	187					
State 33.7 degrees 5 24.8 322 7.2 936 322 322 330 4 300 4	918 937 degrees 5 248 3224 72 936 322 932 930 93	State 33.7 degrees 5 24.8 3224 72 5956 322 322 320 420 420 420 420 420 44.25 34 42.8 34.8 44.28 34 44.28 34 44.28 34 44.28 34 44.28 34 44.28 34 44.28 34 44.28 34 44.28 34 34.00	State Stat	out Pipe Diameter	=-			614	255					
100	100	100	300 ft Net Contaminated Area	ope down angle				936	322					
300 ft	3.00 ft	3.00 ft	3.00 ft	//cos(alpha)	3.00			1,326	390					
55.0	18.50 11 Net Containmented Area 55.01 11.1 2 0.50 11.1 2 0.50 11.1 2 0.50 11.1 2 0.50 11.1 2 0.50 11.1 2 0.50 11.1 2 0.50 11.1 2 0.50 11.1 2 0.50 11.1 2 0.50 11.1 2 0.50 11.1 2 0.50 11.1 2 0.50 11.1 2 0.50 11.1 2 0.50 11.1 2 0.50 11.1 2 0.50 11.1 2 0.50 0.50	18.50 11	18.50		300 #			-						
10.50 11	10.50 11	0.50 11	10.50 11 11 11 11 12 13 14 14 14 14 14 14 14		E 4	Net Contan	ninated Area							
513.85 sqr	513.85 sq.	513.85 sq 11 1.1	513.85 30 11.1 1		H 00.51	Pipe Usamen								
0.79 saft 0.79 saft 0.5 11.1 0.79 saft 0.79 saft 0.50 saft 0	0.79 sq. t 0.79 sq. t 0.70	0.79 sq. tr. 0.79	0.79 sq. t 44.3 11.1 1.1 1.2 1.1 1.1 1.1 1.1 1.1 1.1 1.1 1.1 1.2 1.1	al Area		2	- 7							
0.36 sq it 44.3 44.3 44.5 44.3 44.5	0.36 sq it 44.3 44.3 44.3 44.5 44.3 44.5	0.36 sq it 44.3 44.3 44.5	0.39 sq it 44.3 44.3 44.3 44.5	e Area		4 W								
45.45 sq ft 42.54 sq ft 44.26 sq ft 44.26 sq ft 44.26 sq ft 44.26 sq ft 44.26 sq ft 46.8.56 sq	45.45 sq ft 46.85 sq ft	45.45 sq ft 45.45 sq ft 44.20 sq ft 44.20 sq ft 44.20 sq ft 44.20 sq ft 44.20 sq ft 44.20 sq ft 46.8.56 sq ft 46.8.56 sq ft 46.8.56 sq ft 46.8.50 sq ft 46.8.50 sq ft 46.8.50 sq ft 46.00 sq ft 46	45.67 54 ft 4.68 5 5.98 5 5.98 6 4 7.08 5 5.98 6 4.4 7.08 5 5.98 6 4.4 7.08 5 5.98 6 4.4 7.08 5 5.98 6 4.4 7.08 5 5 5 5 5 5 5 5 5	Area 3		12	4	en.						
44.26 sq.tt 46 4 7008 5 398 6 4 7008 5 44.26 44.26 44.26 44.26 44.26 44.26 44.26 44.26 44.26 44.26 44.26 44.26 42.26	44.26 sq.tt 46.56 5 398.6	44.26 sq.tt 46.8 5 3.98 6 4 7008 5 3.98 6 4.12 6.8 6 3.8 6 4.12 6.9 6 6.9	44.26 sq. ft 4.68 5 3.98 6 4 7006 5 5 5 5 5 5 5 5 5	es 2		24		-						
44.2B sq.ft 46.55 sq.ft 46.556 sq.ft A6.556 sq.ft Days No Boxes 20 8 6 35.56 20 40.00 8.040 8.040 8.040 8.040 8.040 8.040 8.040 8.040 8.040 8.040 8.040 8.040 8.040 8.040 8.040 8.040 8.040 8.040	44.2B sq.ft 46.55 sq.ft 46.55 sq.ft A6.55 sq.ft A0.50 Days No. Boxes Days No. Boxes Days No. Boxes Days No. Boxes Days No. Boxes Days No. Boxes Days No. Boxes Days No. Boxes Days No. Boxes Days No. Boxes Days No. Boxes A0.000 30.960 No. CCY) tons 40.000 30.960 30.960	Facewardion Duration Calculation Results	44.28 sq ft	uter contaminated Area		96		9						
On Duration Calculation Results Box Dimensions L (#) W (#) H (#) Vol (CY) Sone Use Days No. Boxes 20 8 6 35.56 20 40,000 1.0 13 5 5 5 5 5 5 8.0 13 5 6 35.56 20 40,000 9,040 8.0 13 5 6 36.56 20 40,000 9,040	Days No. 63 Days No. 63 Days No. 64 Days No. 65	Excevetion Duration Results Box Dimensions L(R) W (R) H (R) Vol (CV) Tone Ubs	Duration Calculation Results	viol Contaminated Area Non-Contaminated Area		97		κņ.						
Days No. Boxes L (m) W (m) H (m) Vol (CY) tons bs 1.0 13 8 6 36.56 20 40,000 8.040 8 6 36.56 20 40,000 8.040 8 6 36.56 20 8,040 8.040 8 6 36.56 20 9,040 8.040 8 6 36.56 20 9,040	Days No. Boxes	L (II) W (II) H (II) Vol (CY) Fore Ibs L (II) W (II) H (II) Vol (CY) Fore Ibs L (II) W (II) H (II) H (II) Fore Ibs L (II) W (II) H (II) H (II) H (II) Fore H (II) L (II) M (III) M (III) M (III) H (III) M (III) M (III) L (II) M (III) M (I	Days No. Boxes	Excavation Dua	turation Calculation Results	Box Dimensions			Box Weight Cap	A.D.	9	soil bedding requir	6 inch soil bedding required for demo debris	soil bedding required for demo debris
Days No. Boxes 20 8 6 35.56 20 40,000 1.0 13 Based on Volume 8 6 35.56 20 40,000 8.04 30.46 30.46 30.46 30.46 30.46	No. Boxes 20 8 6 35.56 20 40,000 20 41,00 30,360	Column	1.0 1.5			(H) T		Vol (CY)	tons		7	W (F)	1) W(ft) H(ft) Vol(ft ³)	II) W(ft) H(ft) Vol(ft²) Soil Density
1.0 13 Based on Volume 30.960 30.960	1.0 13 Based on Volume 9 040 9 040	Action A	1.0			20		35.56	20	40,000	20	00	00	0.5
Based on Volume 34,960	Pipe Langer) Pipe Langer) Pipe Cult blength: B rit Number lad in blength: 2	Description Description	Passed on Volume Passed on V	Volume	題					8,040	lbs soil	lbs soil bedding	bedding	bedding
	Number laid in box end-to-end:	Vol (CV) No. Boxes Number of pipe sections that fit in box 100 Vol (CV) No. Boxes Number of bipe sections that fit in box 100 Vol (CV) No. Boxes Number of boxes required for scenario pipe length 0.125	Vol (CY) No. Boxes Vol (CY) No. Boxes Number of pipe sections that fit in box 100 Number of boxes required for scenario pipe length 0.125 Based on Vicibility Number of boxes required for scenario pipe length 0.173	1	R.0	Based on Volume	a			30,960	Ibs Ava	liable Weight C	ibs Available Weight Capacity	liable Weight Capacity
that fit in box:		2.9 8.173 Number of boxes required for scenario pipe length 0.125	Number of boxes required for scenario pipe length, 0.125 Bassat on Vieight Number of boxes required for scenario pipe length: 0.173		Vol (CY) No. Boxes									Diameter 15/ft
Vot (CY) No. Boxes. 100	Vol (CY) No. Boxes		Basset on Walght Number of boxes inquired for scenario pipe langth: 0.173	Pipe Debris		Number of baxes require	ed for scenario pipe lengt		Based on Volum	e capacity				
Number of pipe sections that fit in box 100 Vol (CY) No. Boxes Vol (CY) No. Boxes Number of boxes required for scenario pipe length: 0.125	Vol (CY) No. Boxes 2.9 0.173 Number of boxes required for scenario pipe length: 0.125		0.173			Based on Weight			1.000000000000000000000000000000000000					
Vol (CY) No. Boxes Number of pipo sections that fit in box: 100 ZB 0.173 Based on Weight	Voi (CY) No. Boxes Number of boxes required for scenario pipe length: 0.125 Based on Weight					Number of baxes require	ed for scenario pipe lengt		Based on Weigh	t capacity				24 171.29

Cakulated ERDF Disposal Cost: \$795.01 /CY

SGW-34760 Rev. D

Pipeline Removal Vs. Characterization Study - Decision Support Tool

Reinforced Concrete Pipe

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SGW-347GD Rev. O

Pipeline Removal Vs. Characterization Study - Decision Support Tool

Estimate Scenario	enario		Dept	Depth to Top of Pipe		
Pipe Material	Pipe Diameter (in)	#	40+	15 ft	20 #	25 ft
Reinforced Concrete	2					100000
Reinforced Concrete	9					
Reinforced Concrete	12	\$2,968.13	\$4,532.45	\$6,575.76	\$8,759.14	\$11,104,27
Reinforced Concrete	24	\$3,893.94	\$5,914.04	\$7,713.30	\$10,349.68	\$13,126.13
Reinforced Concrete	36	1000	\$7,004.20	\$9,617.36	\$12,346.60	\$15,215.92
Reinforced Concrete	48		\$8,885.26	\$11,230.39	\$14,414,18	\$17,759,71

Estimate Assumptions

= Scenario not applicable to Hanford site.

Pipe demolished in trench with excavator-mounted pneumatic hammer

Additional labor allocated for pipe demolition.

Removal of pipe debris (and loading into ERDF boxes) included in contaminated soil excavation activity labor. Contaminated soil volume includes increased volume from pipe debris for duration calculations. Pipe debris estimated at 40% of in-situ volume.

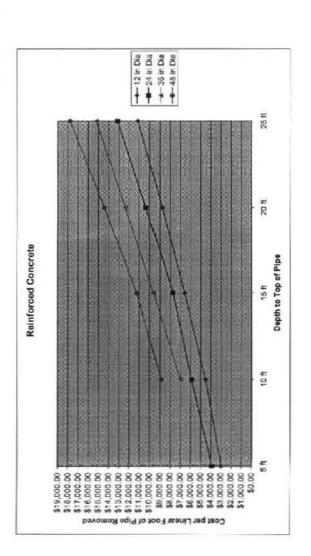
Clean soil removed from tranch and stockpiled close to excavation sits for reuse as backfill material. Contaminated soil loaded into lined ERDF boxes for disposal.

All scenarios do not involve any excavation of paved areas.

All scenarios do not involve any excavation of paved areas.

Sit fancing calculated based on (2.5 x L) + (8 x y); where L is the length of pipe to be removed, and y is depth from the surface to bottom of the triangle below the pipe (from geometry calcs).

		Piol	Data	
	12 in Dia	24 in Dia	36 in Dia	48 in Dia
5#	\$2,966.13	\$3,893.94		
10 11	\$4,532.45	5 \$5,914.04	\$7,004.3	\$8,885.28
15#	\$6,575.76	\$7,713.30	\$9.617.	\$11,230,39
20 11	\$8,759.14	510,349.68	12,348.6	\$14,414.18
25.8	\$11,104.27	\$13,126,13	15.215.9	\$17,759.7



SGW-34760 Rev. 0

Pipeline Removal Vs. Characterization Study - Decision Support Tool

	Labor	4	Lype Type	Green Activity	Grew	Crus	Rate
+	Supervisor	\$76.00			Size		
2	General Laborer	\$54.14	Mobiliza	92	1	Supervisor	76.00
ez	Teamster	\$54.35	1		10	General Laborer	54.14
4	Heavy Egpmi Operator	\$54.86			40	Teamster	54,35
9	HP Technician	\$68.17			2	Heavy Eqpmt Ope	64.86
9	Burner/Pipefilter	\$67.96			0	HP Technician	68,17
	Other Creft	\$67.96				Burner/Pipefitter	67.96
80	Spare					Other Craft	67.96
5	Spare		1 Pipeline / I	e / Interterence Location		Supervisor	75.00
10	Spare					General Laborar	54.14
						Teamarer	54.35

	Andrew areas	Size	****	
-	Mobiliza	1	Supervisor	76.00
		9	General Laborer	54.14
		9	Teamster	54,35
		2	Heavy Eqpmt Ope	64.86
	6-2	9	HP Technician	68.17
			Burner/Pipelitter	67.96
			Other Craft	67.96
2	Pipeline / Infertenence Location		Supervisor	75.00
53			General Laborar	54.14
			Teamster	54.35
			Heavy Eqpmt Ope	64.86
			HP Technician	68.17
			Burnar/P pafitar	67.96
			Other Craft	87.96
-	Install Sit Barrer		Supervisor	75.00
		*	Ganeral Laborar	54.14
			Teamster	54.35
		10 Post (2)	Heavy Egpmt Ope	64.86

		DWIIIS-0	-	
	0.10	Heavy Egpmt Ope	64.96	THE REAL PROPERTY.
		HP Toghnican	68.17	Field (Miss
		Burner/Pipelitter	67.98	Sil Barrier
		Other Creft	67.96	Paving Saw
Paved Brad Transhipe		Superpinor	25.00	Steal Pine
Market Concerns		2000		L C
		Center Paporer	4 4 4	200
		1 damste	0.40	OBC CITE
		Heavy Egpmt Ope	64.86	
		HP Technician	68 17	
		Burner/Piperitter	87.96	
		Other Craff	57.96	
Clean Excaveton to Pipe		Supervisor	75 00	
		General Laborer	54 14	CY (bank
	9	Teametar	54 35	Boxes p
	2	Heavy Eqpmt Opd	84.86	Boxes pa
	В	HP Technician	58.17	
		Burner/Piperitter	87.96	
The second secon		Other Craft	87.06	
Confaminated Sof Excavation	2	Supervisor	75.00	
	9	General Laborer	54 14	
		Teamster	54.36	
	(N	Heavy Egpmt Dpe	B4.86	
	0	HP Technician	68.17	
		Burner/Piperiller	87.96	
		Other Craff	87.36	
Pipe Section & Remove	-	Supervisor	75.00	
		Germral Laborer	54.14	
		Teamster	54.35	
		Heavy Eqpmt Dpe	64.86	
	*	HP Technician	58,17	
		Surmer/Pipelitter	67.96	
		Other Craft	67.96	
Backfill, Compact, Grada	F	Supervisor	75.00	
	4	Gerreral Laborer	54.14	
	9	Teamster	54.35	
	CM	Heavy Egpmt Ope	64.86	
		HP Technician	68.17	
		Burner/Pipefiller	67.98	
	10.500	Other Craft	67.95	
Овторііде		Supervisor	75.00	
		General Laborer	54.14	
		Teamster	54.35	
	-	Hasvy Eqpmt Ope	64.85	
	7	HP Technician	68.17	
		Burner/Pipofiller	67.98	
		Other Orst	67.96	

Crew	Crew Rate
Namis	
Mobiliza	\$1 210,33
Pipeline / Interference	\$305.59
netal Silt Barrier	\$356.42
Paved Road Trenoning	\$0.00
Clean Excavation to Pa	\$1,278.29
Contaminated Soll Exp	\$. 278.29
Pipe Section & Remove	\$597.06
Backfill, Compact, Gran	\$747.38
Demobilize	\$829.10

Activity Duration Constan	n Constants Buration	Unit
Hold (Miss Jülky) Survey	20	ft* per hour
Sill Barrier Installation	200	in ft per hour
Daving Saw Trench Cutting	20	in it per hour
Steel Pipe Sectioning & Removal	44	in it per hour
3C Pipe Sectioning & Ramova	18	in ft per hour
Backfill	9	CY per hour

	datorial	tay	ness (carbon)	VARSONY
20 C C	Pipeline Ma	Varacus Cla	Steel (stainle	Change Mi

tions at the Hanford Site

			Unit	ft² per hour	in fi per hour	in fi per hour	in ft per hour	in fit per hour	CY per hour
\$697.06	\$747.38	\$829,10	Constants	50	200	20	44	18	909
Pipe Section & Remove	Backfill, Compact, Grad	Demobilize	Activity Duration Constants Activity Duration	J (Miss Utility) Survey	Barrier Installation	Ing Saw Trench Cutting	Il Pipe Sectioning & Removal	Pipe Sectioning & Removal	
1	9	0		J (Mis	Barrie	Ing S	di Pip	80	IIIP

Activity Duration Constant	Constants	Unit
old (Miss Utility) Survey	50	ft² per hour
Barrier Installation	200	in fl per hour
F	20	in fi per hour
sal Pipe Saptioning & Removal	44	in ft per hour
Pipe Sectioning & Removal	18	in it per hour
III PO	9	CY per hour

56W-34760 Rev. O

Pipe Excavation Estimate

Hanford Project ID No. Project Title

Pipeline Removal Vs. Characterization Study - Decision Support Tool

Pipe Malerial: Reinforced Concrete

		(Hours)	Labor Cost	e de la companie de l	an	UNET	up.	Cost	annual man-	ATQ.	UNIT	u.p.	Cost	Cost
-	\$1,210.33	10	\$6,051.86		1000	10 11 11 11	Septiment of		Piokup Truck		\$11.8	\$10.00	\$50.00	
							C4000000				0.00000	00000000000000000000000000000000000000		\$6.101.65
	\$305.59	128	\$38,003.25	Construction Consumables				51,364.76	6 Pickup Truck	+	Sitre	\$10.00	\$1,276.00	
							2000				200			44.674.05
			······································											
	\$356.42	1,6	\$570.27	Construction Consumables				\$19.96	6 Pickup Truck	-	3Au	\$10.00	\$16.00	
	The same of the sa				318	\$/100 in ft	\$36,00		\$140 00 Backhoe	-	SAN	\$48.00	\$76.80	\$823 03
				Construction Consumables					Paving Saw		\$Av	\$18.00		
									Water Truck		\$Arr	\$30.00		
	\$1,278,29	30	\$38,348.70	Construction Consumables				\$1,342.2	\$1,342.20 CAT Expansion	2	\$Arr	\$80.00	\$4,800.00	
		17.00							Dump Toods	4	\$Arr	\$30.00	\$3,600.00	- 10 000 07e
			Il						Water Truck	1	\$Arr	\$30.00	\$900.00	On Onnione
	64 278 90	4	E49 789 90	Construction Consumation				6447 4	6447 40 6 AT Eventualist	2	£.Auc	00 083	00.000	
		2		***************************************					RECEIPT Box Touch		2.02	90000	11 200 00	
	_								Water Truck	+	SAN	\$30.00	\$300.00	\$16,330.30
											Charles and	0.0000000		
	\$607.06	5.6	\$3,903.54	Construction Consumables	2000 S	2020000	000000000	\$130.02	2 CAT Excevator w/ Attachment	-	SAN	\$80.00	\$449.00	
														\$4,488.16
	\$747.38	0	\$6.726.42	Construction Consumables				\$236.4	\$236 42 6 CV Loador	-	SAN	(32.00	\$285.00	
	100000						200000000000000000000000000000000000000		300-ho Dozer		SAN	\$65.00	\$585.00	
						00000000	10000000E		Dump Truck	9	SAN	\$30.00	\$1,350.00	59,454.84
									Water Truck	+	s.Vr	\$30.00	\$270.00	
	\$629.10	10	\$6,291.00		2000				Pickup Truck	-	SAL	\$10.00	\$100.00	
														\$6,391.00
													I	
										L				\$33,553.49
														\$60,396.27
	30%													\$68,440.11
			\$113.667.76					\$3.686.38					\$16.859.80	\$296,612.81
		•					•							

Input		4
Depth to top of pipe	5	ft
Pipe Diameter	12	in
Trench Slope	1.5	: 1
Pipe Length	100	ft.
Excavation Vo (excluding pipe debris)	lume Result	CY
	lume Result ft ³ 4,428	770
(excluding pipe debris)	4,428 6,342	CY

Input Pipe Diameter 1	Tl.
Slope down angle 33.7	degrees
2.5/cos(alpha) 3.00	2334
v 3.00	ft
z 5.50	ft
y 8.50	ft
x 0.50	ft
Total Area 108.49	sq ft
Pipe Area 0.79	sq ft
Area 3 0.38	sq ft
Area 2 45.45	sq ft
Outer contaminated Area 45.07	sq ft
Net Contaminated Area 44.28	sq ft
Non-Contaminated Area 63.42	sq ft

Excavation I	Ouration Ca	Iculation Re
	Days	No. Boxes
Contaminated Volume	1.0	13
Clean Volume	3.0	
(for scenario Input Pipe Length)		

	Vol (CY)	No. Boxes
Pipe Debris	1.2	0.090
(for scenario input Pipe Length)		

Calculated ERDF Disposal Cost: \$365.64 /CY

Day 1 cans per day	4		
Day 6 cans per day	30		
yds per can	13	(bank volume)	
	CY	Days	Roundup days
Clean Volume	235	2.338	3.000
Total Volume (including pipe debris)	400	3.162	4.000
Contaminated Volume (including pipe debris)	165	0.824	1.000

Day	Boxes Per Day	Yards Per Day	Cumulative Boxes	Cumulative Yards	Delta Yards
1	4	52	4	52	52
2	9.2	119.6	13.2	172	120
3	14.4	187.2	27.6	359	187
4	19.6	254.8	47.2	614	255
5	24.8	322.4	72	936	322
6	30	390	102	1,326	390

Pipe Diamete	er	
inch		sq ft
2	0.500	11.1
6	0.5	11.1
12	1	44.3
24	2	177.1
36	3	398.6
48	4	708.5

\$6,101.66

U.P.

\$10,576.90

\$2,776.00

1,6663

\$20.00

\$48.00

\$30.00

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\$16,330,30

\$1,600 0 \$1,200.0 \$300.0

\$30,00 \$30,00

\$4,488.10

\$448.00

24.5

\$130,642,41

\$12,800.00 \$9,000.00 \$2,400.00

00 003 00 003

Pipe Excavation Estimate

Pipeline Removal Vs. Characterization Study - Decision Support Tool

- - S 48 SArr SArr Shr Shr \$/hr OTY Pipe Material: Reinforced Concrete Equipment Pickup Truck Hokup Truck \$2,969.11 \$36.00 \$/100 ln III 398 ΩŢ Labor Cost \$8,051.85 278 2.0 90 5 Grew Rate (S/Hr) \$1,210.33 \$305.50 \$358.42 \$1,278.29 RC-12 Contaminated Soil Excavabon Hanford Project ID No. Project Title Install Sill Borrior

\$657,576,09	\$667,676.09	\$6,575.76
\$42,479,00		Calculated Cost per Linear Foot of Pipe removed:

\$8,343.63

\$246,732,11

30%

Excavation Air Sampling ERDF LLW Disposal Estimating Contingency

TOTAL PROJECT COST

86,391,00

\$42,021.63

\$1,280,00 \$2,600,00 \$4,000,00 \$1,200,00

\$32.00 \$30.00 \$30.00

Sthr Sthr Sthr

\$1,046.33

\$29,895.20 Canstruction Consumables Fill Material

40

8.6

\$607.06

\$6,291.00

9

\$629.10

\$10.00

\$72,386.44 \$133,895,58 \$151,748,33

112

Input	,	· ·
Depth to top of pipe	15	rt
Pipe Diameter	12	in
Trench Slope	1.5	: 1
Pipe Length	100	ft
Excavation Vo	lume Result	s CY
(excluding pipe debris)	II.	
(excluding pipe debris) Contaminated Volume	4,428	164
(excluding pipe debris) Contaminated Volume Clean Volume	4,428	164

Input Pipe Diameter	1	ft
Slope down angle	33.7	degrees
2.5/cos(alpha)	3.00	9-0-10-00-00-00-00-00-00-00-00-00-00-00-0
y	3.00	ft
z	5.50	ft
у	18.50	ft
×	0.50	ft
Total Area	513.63	sq ft
Pipe Area	0.79	sq ft
Area 3	0.38	sq ft
Area 2	45.45	sq ft
Outer contaminated Area	45.07	sq ft
Net Contaminated Area	44.28	sq ft
Non-Contaminated Area	468.56	sq ft

Excavation I	Ouration Cal	culation Results	
Contaminated Volume	Days	No. Boxes	
Clean Volume (for scenario Input Pipe Length)	8.0		

	Vol (CY)	No. Boxes
Pipe Debris	1.2	0.090
Character to 1 miles 1 and 1		

Calculated ERDF Disposal Cost: \$810.61 /CY

4		
30		
13	(bank volume)	
CY	Days	Roundup days
1,735	7.050	8.000
1,901	7.473	8.000
165	0.424	1.000
	30 13 CY 1,735 1,901	30 13 (bank volume) CY Days 1,735 7.050 1,901 7.473

Day	Boxes Per Day	Yards Per Day	Cumulative Boxes	Cumulative Yards	Delta Yards
1	4	52	4	52	52
2	9.2	119.6	13.2	172	120
3	14.4	187.2	27.6	359	187
4	19.6	254.8	47.2	614	255
5	24.8	322.4	72	936	322
6	30	390	102	1,326	390

Pipe Diamete	ir .	
inch		sq ft
2	0.500	11.1
6	0.5	11.1
12	1	44.3
24	2	177.1
36	3	398.6
48	4	708.5

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Pipeline Removal Vs. Characterization Study - Decision Support Tool

Concrete Masonry Pipe

152416.doc 114

Estimate Scenario	cenario		Dept	Depth to Top of Pipe		
Pipe Material	Pipe Diameter (In)	# 5	10#	15 #	20 ft	25 ft
Concrete Masonry	2					
Concrete Masonry	9					
Concrete Masonry	12	\$2,866.94	\$4,433.26	\$6,476.57	\$8,659.96	\$11,005.08
Concrete Masonry	24	\$3,794.76	\$5,814.85	\$7,614.11	\$10,250.49	\$13,026.94
Concrete Masonry	36		\$6,905.01	\$9,518.17	\$12,247.42	\$15,116.74
Concrete Masonry	48		\$8,786.07	\$11,131.20	\$14,314.99	\$17,860.52

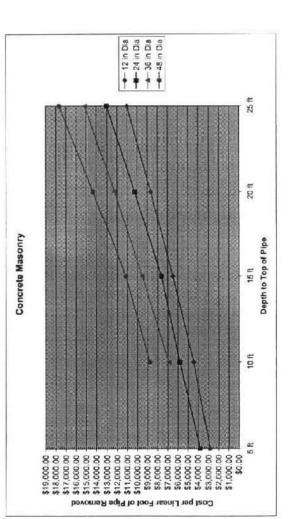
Estimate Assumptions

= Scenario not applicable to Hanford site.

Removal of pipe debris (and loading into ERDF boxes) included on contaminated soil excavation activity labor. Contaminated soil volume includes increased volume from pipe debris for duration calculation. Pipe demolished by excavator bucket during excavation operation. Pipe debris estimated at 40% of in-situ volume.

General Assumptions
General Assumptions
General Assumptions
Glean soil removed from trench and stockpilled close to excavation site for reuse as backfill material.
Contaminated soil loaded into lined ERDF boxes for disposal.
All scenarios do not linvolve any excavation of paved areas.
Silt fencing calculated based on $(2.5 \times L) + (8 \times y)$; where L is the length of pipe to be removed.
Silt fencing calculated based on $(2.5 \times L) + (8 \times y)$; where L is the length of pipe to be removed, and y is depth from the surface to bottom of the triangle below the pipe (from geometry calcs).

		Pod	Data	
	12 in Dia	24 in Dia	36 in Dia	48 in Dia
	\$2,856.94	\$3,794.76		
#	\$4,433.26	\$5,814,85		\$8,786.07
#	\$8,476.57	\$7,614.11		\$11,131.20
20.4	\$8,659.96	\$10,250.49	\$12,247.42	\$14,314.99
#	\$11,005.08	\$13,026.94	77	\$17,660.52



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Pipeline Removal Vs. Characterization Study - Decision Support Tool

-	Supervisor	\$75.00	ž	Crew Activity	Size	Side Side	die.	
2	General Laborar	\$54.14		Wobiliza	Special Section	Supervisor	75.00	
m	Teemster	\$54.36			ю	Gerveral Laborer	54.14	
٠	Heavy Egpmt Operator	\$64.96			20	Teamster	54.35	
w	HP Technician	\$68.17			2	Heavy Egpmt Ope	84.86	L
9	Burner/Pipelitter	\$67.96			•	HP Technician	68.17	
1	Other Craft	\$67.96				Burner/Pipelitier	67,98	_
100	Spare					Other Craft	67.96	
(30)	Spare		5	Pipeline / interference Location		Supervisor	75.00	
10	Spare				3	General Laborer	54.14	
						Teamster	54.35	
		4				Heavy Egpm; Ope	64.86	
	Values Used Throughout					HP Technician	68 17	
Estimating	Estimating Contingency	30%			the Callberra	Burner/Pipefitter	87.96	
Labor Hour	Labor Hours per Work Shift	40		The second secon		Other Craft	87.96	
Constructio	Construction Consumables (% of direct labor)	3.6%	(*)	Install Sitt Barrior		Supervisor	75.00	
Excavation	Expavation Air Sampling (% of total cost)	25%				Ganeral Laborar	54.14	
ERDF LLW	ERDF LLW disposel (% of total cost)	45%			SOME AND ADDRESS OF	Teamster	5435	
Soil Expansion Factor	sion Factor	25%				Heavy Eqpmi Ope	84.86	
Pipe Rubble Factor	Factor	%0%				HP Technician	68.17	Field
Steel Pipe	Steel Pipe Lengths for Removal, maximum (ft)	80				Burner/Pipefitter	67.96	Silt Ba
						Other Craft	87.98	Paving
	Unit Prices (2007 \$)		4	Paved Road Trenching	Strong and a	Supervisor	75.00	5188
Type Unit	Description	***				General Laborer	54.14	RC P
1000	50 feet sitt brace	\$500				Teamster	54.36	Backfill
per day	CAT 320 Excavator Rental	\$1,500				Heavy Egpmt Ope	64.96	
each	Trench box	\$550				HP Technician	68.17	_
	Forkift	\$1,000			200	Burnar/Pipelitter	67.9e	
E permonth	Generators	\$500				Other Craft	67.96	
F permonth	Job Trailer	\$500	ıo.	Clean Excavation to Pipe		Supervisor	75.00	
G permonth	Drill Rig	\$1,000			9	General Laborer	54,14	δ
	Dump Truck	\$250			MP2	Teamster	54.36	Эоко
per day	Grader	\$250			3	Heavy Egpmt Ope	64.86	Boxe
per day	Roller	\$250			9	HP Technolan	68.17	
K pordsy	Front-and Loader	0523				Burner/Pipefitter	67.96	
	Tape • 6*	\$400.00		The state of the s		Other Craft	67.95	ŀ
M Case	Tape - 2"	\$180.00	0	Contaminated Soil Excavation		Supervisor	75.00	
	Siseving	\$4.00			9	General Laborer	54.14	
O 100-ft roll	Plastic Sheeting	\$650.00		100	9	Teamster	5435	
	Gloves	\$6.53			2	Heavy Eqpmt Ope	64.85	
G 254b box	Rage	\$130.00		avail	9	HP Technician	68.17	
	Tools	\$500.00			THE RESERVE	Aurnar/Planfitter	67.95	

			Canada Laborat	200	
			Teamster	5435	4 (11/1
			Heavy Eqpmi Ope	94 98	Activity
			HP Technician	68.17	Field (Miss Littly) Su
		78	Burner/Pipefitter	67.96	Silt Barrier Installatio
ł			Other Craft	87.98	Paving Saw Tranch
4	Paved Road Trenching		Supervisor	75.00	Steel P pe Sectioning
			General Laborer	54.14	RC Pipe Sectioning
			Teamster	54.36	Backfill
			Heavy Egpmt Ope	64.86	
			HP Technician	68.17	
			Burnar/Pipefitter	67.BE	
			Other Craft	67.96	Excha
10	Clean Excavation to Pipe		Supervisor	75.00	
		9	General Laborer	54.14	CY (bank) per ERC
	** or.	M2	Teamster	54.36	Boxes per day @
		2	Heavy Egpmt Ope	64.86	Boxes per day @ [
		9	HP Technolan	68.17	
			Burner/Pipefiller	67.96	
	State of the state		Other Craft	67.96	
0	Contaminated Soil Excavation		Supervisor	75.00	
		9	General Laborer	54.14	
		9	Teamster	54.35	
		2	Heavy Egpmt Ope	64.85	
	Clean	9	HP Technician	68.17	
			Burner/Pipefitter	67.95	
Ì			Other Oraft	67.96	
1	P pe Section & Ramove	3.8	Supervisor	75.00	
			General Laborer	54.74	
			Teamater	54.35	
		-	Heavy Eqpmt Ope	64.86	
		*	HP Technician	68.17	
		+	Surner/Piperitter	67.96	
			Other Craft	87.98	
m	Backfill, Compact, Grade		Supervisor	75.00	
		**	General Laborer	54.14	
		9	Teemster	54 35	
		2	Heavy Equal Ope	64.86	
			HP Technician	68.17	
			Sumer/Pipefitter	67.96	
			Other Craft	67.96	
m	Demobilize	1	Supervisor	75.00	
		*	General Laborar	54.14	
	7/-01		Teamster	54.35	
	600	•	Heavy Egpmi Ope	64.88	
	0.000	þ	HP Technician	68.17	
		0000 37450	Burner/Pipefitter	67.96	
		CONTRACTOR OF THE PARTY OF THE	Other Call	87.98	

Material 2 6 12 24 36 Clay	
Clay	36
airless /carbon)	
• Masonry	
od Concreto	

	Constants	
d (Miss Utility) Survey	20	ff per hour
Barrier Installation	200	In it per hour
ring Saw Tranch Cutting	09	In ft per hour
el Pipe Sectioning & Removal	4	in the par hour
Pipe Sectioning & Removal	69	In f. per hour
oxfill	09	CY per hour

Activity	Duration	Unit
(Miss Littly) Survey	02	ft² per hour
arrier Installation	200	In it per hour
a Saw Trench Cutting	09	In the per hour
P pe Sectioning & Remova	1	in it por hour
pe Sectioning & Removal	60	In f. per hour
-	09	CY per hour
Excavation Duration Calculation Basis	Calculation	Saula
(bank) per ERDF Box		
kes per day @ Day 1		þ
wes per day @ Day E		30

Pipe Excavation Estimate

	Total Activity U.P. Cost Cost	\$10.00	\$6,101.55	\$10,00 \$1276.00	\$41,634.05	\$10.00			\$18,00	00.000	San oo oo sa noo oo	\$3.600.00	\$30.00 \$000.00 \$48,880.50	\$80.00 \$1,000.00	\$1,200,00	\$30,000 \$300,000	\$80.00				\$30.00 \$1,350.00 \$8,454.64		\$10.00 \$100.00	\$6,301.00	00000	\$32,431.45	20.07.000	201 101 200
	UNIT U	\$.hr \$		Sthr		Sthr		H	Syhr		Sahr		Sthr	+		S/hr.	Shr			Zun.		H	S/hr 1			1	+	
	OTY I	+		·		-					٥			2	7	1					9 +		-					
	Equipment	Pickup Truck		\$1,364.76 Pickup Truck		\$ 19.06 Pickup Truck	\$140.00 Backnos		Paving Saw	Water Truck	64 340 00 CAT FVANABLE		Water Truck	\$447 40 CAT Expension	ERDF Box Truck	Water Truck	CAT Expandior w/ Attachment		\$235.42 5 CY Loader	300-hp Dozer	Dump Truck		Pickup Truck					
	aro.						\$35.00	00000	10000	September		DIMMIC			Sme			5000	001100	200000				SHARE		+	+	
	U TINU						S/100 In fi								OTAL SELECTION	K				10 SEE SEE SEE SEE SEE SEE SEE SEE SEE SE	1		ÿ.					
	VIO					Section 1	318 \$7							I	STORES												1	
	Materials			Construction Consumables		Construction Consumables	Sill Burrier & Stehen		Construction Consumables		Construction Communication			Construction Consumables			Construction Consumables		Construction Consumables	Fill Meterial					TOTAL STORY			
	Labor Cost	\$6.051.66		\$38.993.28		\$570.27			<u> </u>		DE SAN SER			\$12,782.90		des			\$6,726.42				\$6,29100					
	Duration (Hours)	s		128		1.6					O.	2		10					a				10					
CM-12	Grew Rate (\$/Hr)	\$1,210.33		8306.89		\$356.42					00 000 00			\$1,278.29			\$697.06		\$747.38				\$629.10				MARK	20.30
Project Title	Activity	1 Mobilize		2 Pipaline / interference Location		3 Install Sitt Barrier			4 Paved Rasd Trenching		Clean Personalism to Direc			6 Contaminated Soil Excavation			7 Pipe Saction & Remove		8 Backfill, Compact, Grade				9 Demobiliza			Excavation Air Sampling	ERUT LLW Disposal	Community Controllency

Input					Day	Day 6 cans per day	30		
Depth to top of pipe	2					yds per can	13	13 (bank volume)	
Pipe Diameter	12	u					CY	Days	Roundup days
Trench Slope	1.5	-				Clean Volume	235	2.338	3.000
Pipe Length	100			Total Vol	ume (includir	Total Volume (including pipe debris)	400	3.162	4.000
Excavation Vo	Excavation Volume Results		S	taminated Vol	ume (Includir	Contaminated Volume (Including pipe debris)	165	0.824	1.000
(excluding pipe debris) Contaminated Volume	4,428	CY		Boxes Per	Yards Per	Boxes Per Yards Per Cumulative	Cumulative		
Clean Volume	6,342	235	Day	Day	Day	Boxes	Yards	Delta Yards	
Total Volume	10,771	398	-	4	52	4	52	52	
			7	9.2	119.6	13.2	172	120	
			63	14.4	187.2	27.6	359	187	
Input Pipe Diameter	-	2	4	19.6	254.8	47.2	614	255	
Slope down angle	33.7	degrees	2	24.8	322.4	72	936	322	
2.5/cos(alpha)	3.00		9	30	390	102	1,326	390	
	3.00	£							
2	5,50	£		Nel Conta	Net Contaminated Area				
>	8.50	¥		Pipe Diameter	_				
×	0.50	#		inch		sq ft			
Total Area	108.49	sq ft		2	0.500	11.1			
Pipe Area	0.79	sq ft		g	0.5	11.1			
Area 3	0.38	sq ft		12	۳	44.3			
Area 2	45,45	sq ft		24	2	177.1			
Outer contaminated Area	45.07	sqft		36	8	398.6			
Net Contaminated Area	44.28	sq ft		48	4	708.5			
Mon-Contaminated Area	CA 52	63.6							

ted Volume 1.0 The put Pipe Length) Vol (CY)	Volume (Pipe Length)		Days	No. Boxes
pul Pipe Lengin)	Poe Lergh)	ontaminated Volume	1.0	13
pul Pipe Length)		lean Volume	3.0	CHEST SERVICE
	- Novi -		77	
1.2 0.090		The state of the s	VOI (CT)	No. Boxes
	1.2 0.090	Pipe Debris	1.2	0.090

Calculated ERDF Disposal Cost: \$353.42 / CY

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Pipe Excavation Estimate

Pipeline Removal Vs. Characterization Study - Decision Support Tool

Pipe Material: Concrete Masonry

Hanford Project ID No. Project Title

Total Activity Cost Coul	\$50.00	\$6,101.65	\$2,776.00	\$90,578.90		\$96.00	70.00			\$12,800,00		\$2,400,00	\$1,600.00	\$1,200.00				\$1,280,00				\$100.00	\$8,301.00		\$73.264.40	\$131,875.91	200 - 10 P - 10
U.P.	\$10.00		\$10.00		\$10.00	548 00		\$18.00	\$30.00	\$80.00	\$30.00	\$30.00	\$80.00	\$30.00	\$30.00		\$60.00	\$32.00	\$65.00	\$30.00	\$30.00	\$10.00	Profile, still				
UNIT	AVS		SAhr		SAur	5/hr		\$/hr	Whe	Shr	\$mr	\$/1/8	2008	\$/Ju	S/hr		No.	SAN	SAN	SAu	SArr	SAu					
arv	-		-		ŀ	+		Off Present		2	4	•	2	4					*	10	1	+			-		
Cost	Pickup Truck		\$2,969.11 Pickup Truck		\$24 96 Pickup Truck	\$140 00 Backhoe		Paving Saw	Water Truck	\$3,579.21 CAT Excavator	Oump Truck	Woler Track	\$447.40 CAT Excavator	ERDF Bax Trusk	Water Truck		CAT EXCOVABOL WI ALIBICATION	\$1,046.33 5 CV Loader	300-ftp Dozer	Dump Truck	Water Truck	Pickup Truck					
0.6						\$36.00			2000000		A COLUMN							2000	000000	0000				CONTROL OF THE PERSON NAMED IN			
UNIT						\$1100 In ft																		1	T		
ONY					1	398 \$/										100000									T		
Materials			8 Construction Consumables		Construction Consumables	Silt Barrier & Stakee		Construction Consumables		20 Construction Consumables			Construction Consumables				Constitution Consumistion	Construction Consumables	Fill Mederical								
Labor Cost	\$6,051.65		\$84,831,78		\$712.84					 \$102.263.20			\$12,782.90					\$29,895.20				\$6,291.00					
(Hours)	in		278		2.0					980			10					07				10					
Crew Rate (\$PHr)	\$1,210,33		\$305.69		\$356.42					\$1,278.29			\$1,278.29				\$697.06	\$747.38				\$629.10					30%
Activity	1 Mobiles		2 Pipuline / Interference Location		3 Install Sit Barrier			A Paved Road Trenching		5 Clean Excavation to Pipe	The Court of the C		6 Conteminated Soil Excevation			1	Pipe Section & Remove	8 Backfill, Compact, Grado				9 Demobilize			Expevation Air Samoling	ERDF LLW Disposal	Estimating Contingency

Roundup days 8.000 8.000 1.000

7.050

0.424

13 (bank volume)

S

30

Day 1 cans per day Day 6 cans per day

Pipeline Removal Vs. Characterization Study - Decision Support Tool

Day 6 cans per day	yds per can	Clean Volume	Total Volume (including pipe debris)	cluding pipe debris)	Per Cumulative	y Boxes	4	.6 13.2	2 27.6		.4 7.2			d Area		ad ft		11.1	44.3	1.771		708.5
			Total Volume (in	Contaminated Volume (including pipe debris)	Boxes Per Yards Per Cumulative	Day Day		9.2 119.6			24.8 322.4	30 380		Net Contaminated Area	Pipe Diameter	inch	2 0.500	6 0.5	12 1	24 2		48
				Con		Day	•	2	က	4	5	9										
		-			Ç	1,735	1,899			#	degrees		#	#	#	#	sq ft	sq ft	sq ft	sq ft	sq ft	sq ft
	12 H		100 ft	Excavation Volume Results	ft ² CY					4	33.7 degrees	3.00	3.00 ft	5.50 ft	18.50 ft	0.50 ft						

Delta Yards 52 120 187 255 322 390

52 172 369 614 936 1,326

	Days No. Boxes	
Contaminated Volume	1.0	
Clean Volume	8.0	
for scenario Input Pipe Length)		

	Vol (CY)	No. Boxes
Pipe Debris	1.2	0.090
(for scenario Input Pipe Length)		

Calculated ERDF Disposal Cost: \$798.39 / CY