

**DEPARTMENT OF TOXIC SUBSTANCES CONTROL
CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY**

**INVESTIGATION AND REMEDIATION
OF PLATING FACILITIES**

MAY 2011

PREFACE

The Department of Toxic Substances Control (DTSC) is issuing this guidance document for immediate use on investigation and cleanup of plating facilities. The approach described herein is designed to ensure safe, protective cleanup and to maintain DTSC's commitment to public involvement in our decision-making process.

DTSC fully expects that application of this guidance to investigation and cleanup of plating facilities will identify portions of the document that can be improved upon. As the guidance is implemented, issues may be identified which warrant document revision. DTSC will continue to solicit comments from interested parties for a period of one year (ending May 30, 2012). At that time, DTSC will review and incorporate changes as needed.

Comments and suggestions for improvement of *Investigation and Remediation of Plating Facilities* should be submitted to:

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ABBREVIATIONS AND ACRONYMS

ARAR	applicable or relevant and appropriate requirement
ASTM	ASTM International (formerly known as the American Society of Testing and Materials)
CA	conditional authorization
Cal/EPA	California Environmental Protection Agency
CCR	California Code of Regulations
CE	conditional exemption
CEQA	California Environmental Quality Act
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CMS	Corrective Measures Study
COC	chemical of concern
CUPA	Certified Unified Program Agency
CSM	conceptual site model
DQO	data quality objective
DTSC	Department of Toxic Substances Control
EE/CA	engineering evaluation/cost analysis
FRTR	Federal Remedial Technology Roundtable
FS	Feasibility Study
HSA	Hazardous Substance Account Act
HSC	California Health and Safety Code
HWCL	Hazardous Waste Control Law
IC	institutional control
IM	interim measure
ITRC	Interstate Technology and Regulatory Council
LUC	land-use covenant
MEK	methyl ethyl ketone
MNA	monitored natural attenuation
NAPL	non-aqueous phase liquid
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
O&M	operation and maintenance

ABBREVIATIONS AND ACRONYMS (CONTINUED)

PBR	Permit by Rule
PCB	polychlorinated biphenyl
PCE	tetrachloroethylene
PRB	permeable reactive barrier
PT&R	proven technologies and remedies
QAPP	quality assurance project plan
QA	quality assurance
QC	quality control
RAO	remedial action objective
RAP	Remedial Action Plan
RAW	Removal Action Workplan
RCRA	Resource Conservation and Recovery Act
RWQCB	California Regional Water Quality Control Board
SAP	sampling and analysis plan
SFRWQCB	San Francisco Regional Water Quality Control Board
SVE	soil vapor extraction
SVOC	semi-volatile organic compound
TCA	trichloroethane
TCE	trichloroethylene
USEPA	U.S. Environmental Protection Agency
VOC	volatile organic compound
WDR	Waste Discharge Requirement

EXECUTIVE SUMMARY

Approximately 15 percent of the hazardous waste cleanup projects managed by the Department of Toxic Substances Control (DTSC) include some type of metal finishing operation. Releases of chemicals from metal finishing operations (herein after referred to as plating operations) often result in impacts to soil, soil vapor, groundwater, and indoor air, as well as other environmental media. DTSC has developed *Investigation and Remediation of Plating Facilities* as a reference document for corrective action and remedial action (herein after referred to as the “cleanup process”) at sites impacted by releases from plating operations. Although applicable to all types of contaminants, the guidance highlights impacts from contaminants most commonly associated with plating facilities, including hexavalent chromium, other heavy metals, and volatile organic compounds (VOCs).

This guidance can be applied for cleanup of releases associated with plating operations at:

- operating or closing hazardous waste facilities,
- Permit by Rule (PBR) plating facilities that cannot be “clean” closed, and
- Brownfields sites.

Prior to applying this guidance to a site cleanup, the oversight agency should be consulted and should concur with its use.

The cleanup approaches described in this guidance can be conducted as interim or partial removal actions (also known as interim measures) or as the final remedy. The results achieved will depend on the scope of the activities and the site-specific remedial action objectives (RAOs). Some approaches discussed herein may not be the most suitable or effective method for a given site. Therefore, site-specific considerations and adjustments should be made as necessary to ensure effective and efficient site restoration.

The guidance provides an option for streamlining the cleanup process for metals and VOCs in soil by applying guidance documents previously developed for these contaminants under DTSC’s proven technologies and remedies (PT&R) initiative:

- *PT&R Guidance – Remediation of Metals in Soil* (DTSC, 2008)
- *PT&R Guidance – Remediation of Chlorinated Volatile Organic Compounds in Vadose Zone Soil* (DTSC, 2010)

In this guidance, proven technologies are defined as technologies demonstrated by engineering and scientific analysis of performance data that are consistently selected based on contaminant type, affected environmental media (e.g., soil, soil gas, groundwater), and potential risks.

As summarized in Figure ES-1, these PT&R guidance documents streamline the remedy selection process by focusing the site-specific evaluation of remedial

alternatives on proven technologies for soil. Contaminants that cannot be addressed by a proven technology are addressed through the standard remedy selection processes. The guidance also identifies likely technologies for cleanup of VOCs and hexavalent chromium in groundwater and technologies for cleanup of hexavalent chromium in soil (see Figure ES-1).

The objectives of this guidance are to:

- provide recommendations for characterizing the nature and extent of contamination, developing a conceptual site model (CSM), and collecting data needed to support the cleanup alternative(s);
- provide guidance for characterizing risk and establishing cleanup goals;
- as feasible, apply the proven technologies for soil identified in *PT&R Guidance – Remediation of Metals in Soil* (DTSC, 2008) and *PT&R Guidance – Remediation of Chlorinated VOCs in Vadose Zone Soil* (DTSC, 2010) to facilitate the cleanup of plating facilities;
- identify likely technologies for addressing hexavalent chromium in soil and hexavalent chromium and VOCs in groundwater;
- identify considerations for controlling site conditions, site cleanup, and site closure; and
- outline long-term stewardship requirements that may be applicable for some sites.

This guidance is organized around steps in DTSC's conventional cleanup process as described below. The main text of this guidance document is supported by appendices containing detailed discussions of selected topics. The document also includes resources to facilitate certain phases of the cleanup process and provides links to DTSC and other resources useful for investigation and cleanup of plating facilities. This guidance uses the public participation process identified in the *DTSC Public Participation Policies and Procedures Manual* (DTSC, 2003a; revision pending).

Project Planning. Project scoping is a key activity of the planning phase and includes objectives such as: identifying the objective(s) of cleanup activities to be undertaken, determining the regulatory framework for the remediation, developing a site cleanup and certification strategy, evaluating the applicability of the PT&R approach (see DTSC, 2008, 2010), identifying and assessing stakeholder comments and concerns, and establishing a management approach for the project. Coordination between all agencies with authority over the site, the cleanup, or the future use of the site should begin during the project planning phase.

Characterization. The characterization phase establishes the nature and extent of contamination in environmental media (e.g., soil, soil gas, groundwater). Other objectives of this phase could include addressing data gaps, establishing background concentrations of metals in soil and/or groundwater, obtaining information about the geologic and hydrogeologic setting, collecting data to formulate any fate and transport modeling efforts, and collecting data needed to support remedy selection and design.

As data are gathered, they are evaluated to help determine whether further site characterization, risk assessment, or cleanup may be necessary. The work associated with this phase begins with the formulation of the preliminary CSM which is refined during the characterization phase.

Risk Assessment. Evaluation of potential risks to human health and the environment posed by contaminants at the site is part of site characterization and supports the risk management decision-making process. Depending on the phase of site cleanup when this guidance is applied, some risk assessment steps may have already been conducted and may be sufficient to support subsequent activities. A human health risk assessment is conducted to characterize potential cancer risks and noncancer health hazards. A scoping level ecological risk investigation is conducted to evaluate the potential for complete exposure pathways between ecological receptors and constituents of concern. Depending on the findings of the scoping-level investigation, some sites may require further ecological assessment. The risk to groundwater quality is evaluated using measured groundwater concentrations and/or groundwater concentrations predicted by fate and transport modeling. These assessments of risk may be incorporated into characterization reports or cleanup plans, depending on the site. The results of the risk assessments are used to establish appropriate site-specific RAOs and risk-based cleanup goals.

Site-Specific Evaluation and Selection of Remedial Alternatives. The remedy selection document is drafted in accordance with the requirements applicable to the site or facility. The alternative evaluation should demonstrate that the RAOs identified for the site can be met. For metals in soil, the alternatives would generally include no action, excavation/disposal, and/or capping (DTSC, 2008). For VOCs in vadose zone soil, the alternatives would generally include no action, excavation/disposal, and/or soil vapor extraction (DTSC, 2010). Standard alternatives evaluations apply to other impacted media (e.g., groundwater) and contaminants (e.g., hexavalent chromium) that cannot be addressed by the proven technologies [as identified in DTSC (2008) and DTSC (2010)]. The necessary California Environmental Quality Act (CEQA) documents may be prepared concurrently with the remedy selection document. Typically, the draft remedy selection and CEQA documents are circulated concurrently for public comment. Some remedial approaches will require on-going operation and maintenance (O&M) until the RAOs are achieved, and therefore will require a regulatory oversight agreement.

Considerations for Site Closure. Site closure or closure of plating operations may or may not be an objective for a given site. It is beyond the scope of this document to provide detailed guidance on closure of plating facilities. Rather, the guidance identifies the regulations applicable to closure of various types of plating tanks. In addition, the guidance provides an annotated outline for a building demolition plan.

Considerations for Soil Cleanup. If shown to be applicable, the PT&R approach (DTSC, 2008; DTSC, 2010) can be used to address soil impacts. However, alternate soil cleanup approaches may be needed for a given plating facility. For example, additional measures may be needed to address hexavalent chromium in soil that poses

an on-going threat to groundwater and that cannot be addressed by excavation/disposal. The type of remedy selected, its effectiveness, and the selected cleanup goals will affect the long-term use of the site. For example, selection of capping to address impacts from immobile contaminants will require long-term stewardship.

Considerations for Groundwater Cleanup. The actions taken at a given site will depend on the cleanup status, but could include hydraulic containment of the plume, source control or removal, mass removal, and attainment of groundwater cleanup goals. Experience obtained over several decades has shown that optimization of the selected groundwater remedy likely will be needed at one or more junctures of a groundwater cleanup action. Initial actions might include establishing hydraulic control of the plume as well as source control or removal. More effective mass removal may become the focus as the groundwater cleanup matures. As groundwater cleanup objectives are approached, and source and nonaqueous phase liquid (NAPL) areas have been remediated, monitored natural attenuation may become viable. A groundwater monitoring program should be established with objectives such as allowing on-going evaluation of the nature and extent of the plume, plume stability, remedy effectiveness, and achievement of groundwater cleanup goals.

Consideration of the Vapor Intrusion Pathway. Sites with VOC impacts should be evaluated to determine whether there is potential for vapor migration from the subsurface into buildings. The *Guidance for the Evaluation and Mitigation of Subsurface Vapor into Indoor Air* (DTSC, 2005; revision pending) identifies the steps for completing a vapor intrusion pathway analysis. If the estimated risk posed by the vapor intrusion pathway is deemed unacceptable, the *Vapor Intrusion Mitigation Advisory* (DTSC, 2009a; revision pending) should be consulted for ways in which this risk can be mitigated while the subsurface contamination is remediated.

Certification / Completion. When the approved remedy has been fully implemented, DTSC will determine through performance metrics (including confirmation sampling) whether the RAOs established in the remedy decision document have been achieved. The possible determinations are: the RAOs have been achieved; the response action has been fully implemented, is operating successfully, and on-going O&M is needed until the RAOs are achieved; and/or additional remediation is necessary. Based on these findings, DTSC will issue a certification letter, a completion letter, or a letter requiring additional work to address site contamination.

Long-term Stewardship. Long-term stewardship applies to sites and properties where management of contaminated environmental media is necessary to protect human health and the environment over time. On-going controls (such as institutional controls for contamination remaining in place) and other measures will be needed, as discussed further in Section 8.0.

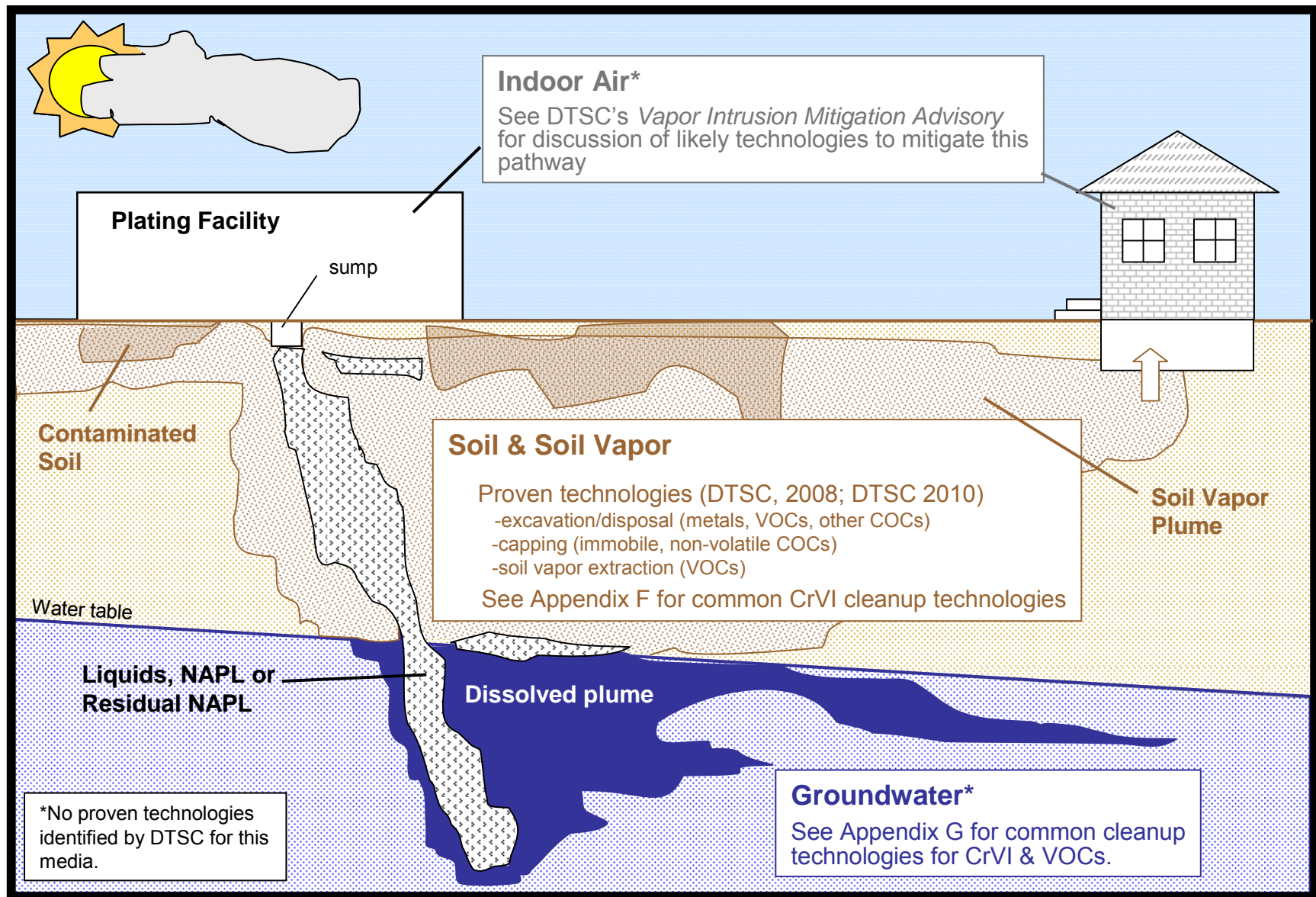


Figure ES-1. DTSC resources for identifying remedial technologies for cleanup and/or mitigation of environmental media impacted by plating operations

1.0 INTRODUCTION

Metal finishing, including electroplating, is a process of chemically or electrochemically coating an object made of one metal (such as steel) with another metal (such as chrome) to increase the object's hardness, corrosion resistance, and/or visual brilliance. As summarized in Table 1, the metal finishing industry uses a variety of specialty chemicals and additives, including heavy metals, chrome (hexavalent chromium), cyanide, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), acids, caustics, among other compounds. These chemicals or wastes can be released from metal finishing operations (herein after referred to as plating operations) to the environment in several ways such as through spills or leaks from process tanks and sumps, releases during handling of raw materials, and air emissions. Upon discharge to the soil, some plating chemicals or wastes are relatively immobile and remain close to the point of discharge (e.g., resulting in shallow soil impacts). Other plating chemicals or wastes have the potential to impact deeper soil (e.g., VOCs, hexavalent chromium, cyanide), groundwater, soil vapor (e.g., VOCs), and indoor air (e.g., VOCs).

Investigation and Remediation of Plating Facilities has been developed for use as a reference document for corrective action and remedial action (herein after referred to as the "cleanup process") at sites with soil, soil vapor, and/or groundwater contaminated by releases from plating operations. This guidance can be applied for cleanup of releases associated with plating operations at:

- operating or closing hazardous waste facilities,
- Permit by Rule (PBR) plating facilities that cannot be "clean" closed, and
- Brownfields sites.

The document applies proven technologies identified under the Department of Toxic Substances Control's (DTSC's) proven technologies and remedies (PT&R) initiative. The PT&R initiative defines proven technologies as cleanup approaches that have been determined to be effective based on engineering and scientific analysis of performance data from past site cleanups and review of the administrative records and procedures used to implement cleanup technologies. This guidance uses the following documents developed under the PT&R initiative:

- *PT&R Guidance – Remediation of Metals in Soil* (DTSC, 2008),
- *PT&R Guidance – Remediation of Chlorinated Volatile Organic Compounds in Vadose Zone Soil* (DTSC, 2010), and
- *Vapor Intrusion Mitigation Advisory* (DTSC, 2009a; revision pending).

When used with these earlier documents, this guidance document includes options for streamlining the cleanup process for a plating facility. Although much of this streamlining is achieved for metals and VOCs in soil, the information provided herein should facilitate cleanup of groundwater and other soil contaminants (e.g., hexavalent chromium), as well as mitigation of the vapor intrusion pathway (if necessary).

Table 1. Chemical Substances Potentially Used in, Generated by, or Emitted from Metal Finishing Operations (Modified from USEPA, 1999c)

Chemical Group	Chemical Name		
Metals	Aluminum Arsenic Barium Cadmium Chromium (Cr ⁶⁺ , Cr ³⁺)	Copper Iron Lead Manganese Mercury	Nickel Selenium Silver Tin-lead Zinc
Other Inorganics	Asbestos Chlorine	Cyanide Fluoride	Potassium nitrate Sulfur dioxide
Alkalis	Sodium hydroxide		
Acids	Chromic acid Hydrochloric acid	Hydrofluoric acid Nitric acid	Phosphoric acid Sulfuric acid
Volatile Organic Compounds (VOCs)	Acetone Benzene Carbon disulfide Carbon tetrachloride Chlorobenzene Chloroform Chlorinated fluorocarbons Cyclohexanone 1,2-Dichlorobenzene	1,4 Dioxane Ethyl acetate Ethyl benzene Ethyl ether Isobutanol Methylene chloride Methanol Naphthalene n-Butyl alcohol	2-nitropropane Tetrachloroethylene (PCE) Toluene 1,2,4-Trichlorobenzene 1,1,1-Trichloroethane (TCA) 1,1,2-Trichloroethane (TCA) Trichloroethylene (TCE) Trichlorofluoromethane Xylenes
Semi-Volatile Organic Compounds (SVOCs)	Cresols Nitrobenzene	Phenol	Polychlorinated biphenyls (PCBs) Pyridine
Other Organics	2-Ethoxyethanol Formaldehyde Glycols	Kerosene Ketones	Methyl ethyl ketone (MEK) Methyl isobutyl ketone Mineral oil

Note: This table should not be assumed to be all inclusive of potential contaminants that may be present at a given plating facility. The chemicals and potential contaminants associated with a given facility depend on the processes being performed.

1.1 PURPOSE AND OBJECTIVES

This document provides guidance for investigation and cleanup of plating facilities based on DTSC's experience and current industry practice. This guidance is intended for use by any government agency, consultant, responsible party and/or property owner addressing potential or known contamination at a plating facility. Prior to applying this guidance to a site, the oversight agency should be consulted for concurrence with its use.

The objectives of this guidance are to:

- provide recommendations for characterizing the nature and extent of contamination, developing a conceptual site model (CSM), and collecting data needed to support the cleanup alternative(s);

- provide guidance for characterizing risk and establishing cleanup goals;
- as feasible, apply the proven technologies for soil identified in *PT&R Guidance – Remediation of Metals in Soil* (DTSC, 2008) and *PT&R Guidance -- Remediation of Chlorinated VOCs in Vadose Zone Soil* (DTSC, 2010) to facilitate the cleanup of plating facilities;
- identify likely technologies for addressing hexavalent chromium in soil and groundwater;
- identify likely technologies for remediating VOCs in groundwater;
- identify considerations for site cleanup, site closure, and controlling site conditions posing an immediate risk; and
- outline long-term stewardship requirements that may be applicable for some sites.

1.2 TECHNICAL BASIS FOR GUIDANCE

1.2.1 Soil and Soil Vapor

Metals. As described in detail in the *PT&R Guidance – Remediation of Metals in Soil* (DTSC, 2008), DTSC conducted a study that reviewed and screened data for sites with metals-impacted soil. The study revealed that “excavation and offsite-disposal” (excavation/disposal) and “containment by capping” (capping) are proven technologies for cleanup of metals-impacted soil. Although the study focused on immobile forms of metals, the identified proven technologies would also be applicable to metals having greater mobility (such as hexavalent chromium) provided that appropriate site-specific adjustments are made. For example, the capping alternative discussed in *PT&R Guidance – Remediation of Metals in Soil* focuses on eliminating ingestion, inhalation, and dermal contact as complete routes of exposure and precluding contaminant dispersion through the air and surface water run-off. If a cap is considered for soils impacted by mobile forms of metals, the cap design and performance objectives should address the potential for migration. Other examples of site-specific adjustments to the approach described in *PT&R Guidance – Remediation of Metals in Soil* would be the selection of remedial technologies to address deeper vadose zone or groundwater impacts.

Application of the proven technologies for metals in soil may not be feasible for some sites. In these instances, other remedial technologies would need to be screened, evaluated, and selected. This guidance provides links to resources that can be used to assist with this effort. In addition, because hexavalent chromium is a common contaminant for plating facilities, this guidance includes appendices that identify technologies that might be applied to address hexavalent chromium. This guidance does not identify a proven technology specific to hexavalent chromium in soil.

VOCs. As described in detail in the *PT&R Guidance – Remediation of Chlorinated VOCs in Vadose Zone Soil* (DTSC, 2010), DTSC conducted a study that reviewed and screened data for sites with soil impacted by chlorinated VOCs. The study revealed that excavation/disposal and soil vapor extraction (SVE) are proven technologies for

cleanup of chlorinated VOC-impacted soil within the vadose zone. Although the study focused on chlorinated VOCs, the identified proven technologies would also be applicable to other VOCs with appropriate site-specific adjustments (such as the method used to treat VOCs removed via SVE). *PT&R Guidance – Remediation of Chlorinated VOCs in Vadose Zone Soil* emphasizes that many sites have chlorinated VOC impacts in both the vadose zone and groundwater and that groundwater impacts would need to be addressed by a separate remedial technology.

Application of the proven technologies for chlorinated VOCs in soil may not be feasible for some sites. In these instances, other remedial technologies would need to be screened, evaluated, and selected. The *PT&R Guidance – Remediation of Chlorinated VOCs in Vadose Zone Soil* includes an appendix summarizing remedial technologies for chlorinated VOCs. In addition, this guidance provides links to resources that can be used to identify remedial technologies for VOCs in soil.

Other Contaminant Types. Appropriate remedial technologies to address other types of soil contaminants should be screened, evaluated, and selected. This guidance provides links to resources that can be used to identify remedial technologies. As feasible (e.g., contaminants are co-located with metals, contaminants have chemical or physical properties similar to metals), excavation/disposal and capping could be used to address other contaminant types in soil.

1.2.2 Groundwater

A study conducted in conjunction with the development of this guidance document did not identify a proven technology for plating-related chemicals in groundwater. Therefore, this guidance discusses likely remedial technologies for groundwater based on DTSC experience, a review of recent literature, and current industry practice. The discussion focuses on hexavalent chromium and VOCs because these are common groundwater contaminants associated with plating facilities. The guidance provides links to resources that can be used to identify remedial technologies for other contaminant types.

1.2.3 Vapor Intrusion

The *Vapor Intrusion Mitigation Advisory* (DTSC, 2009a; revision pending) describes commonly used technologies for vapor intrusion mitigation. DTSC has not identified proven technologies for mitigation of the vapor intrusion pathway.

1.3 SCOPE AND APPLICABILITY

This document pertains to the cleanup of environmental impacts associated with plating facilities and focuses on impacts to soil, soil vapor, and groundwater. The cleanup approaches described herein can be conducted as an interim or partial removal action or as the final remedy. The results achieved will depend on the site-specific conditions and remedial action objectives (RAOs). Although the document focuses on common contaminant types associated with plating facilities (heavy metals, hexavalent chromium, and VOCs), the remedial technologies discussed can be applied to other

types of plating chemicals or wastes amenable to the selected cleanup technologies (e.g., SVE can recover other volatile chemicals in addition to VOCs, excavation/disposal can be effective for soil impacted by multiple contaminant types). Some of the remedial technologies discussed in this guidance may not be suitable or the best approach for a given site. If the proven technologies identified in *PT&R Guidance – Remediation of Metals in Soil* (DTSC, 2008) and *PT&R Guidance – Remediation of Chlorinated VOCs in Vadose Zone Soil* (DTSC, 2010) are applied to a plating facility cleanup, appropriate site-specific adjustments should be made.

This guidance can be applied to the cleanup of any type of plating facility, regardless of the federal or state laws under which the cleanup is conducted. For example, this guidance is also intended to support cleanup of releases associated with PBR tanks that cannot meet the clean closure performance requirements. However, prior to applying this guidance to a site cleanup process, the oversight agency should be consulted for concurrence with its use.

This guidance is not intended to replace the evaluation of innovative and new technologies. DTSC continues to encourage the use and evaluation of emerging technologies.

1.4 OVERVIEW AND ORGANIZATION

Cleanup of contaminated sites may be governed by one of several federal or state laws, including the:

- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
- Resource Conservation and Recovery Act (RCRA)
- Hazardous Waste Control Law (HWCL)
- Hazardous Substances Account Act (HSAA)

The applicable laws depend on such factors as the source and cause of the contamination and the oversight agency under which the site is being addressed. Regardless of the cleanup process, the remedies evaluated and selected must be: (1) protective of human health and the environment; (2) able to achieve cleanup objectives and standards; and (3) able to control or remediate sources of releases. The approach described in this guidance is consistent with DTSC's conventional cleanup processes. In a standard cleanup process, sites undergo:

- site characterization (also referred to as site investigation) and risk assessment;
- remedy screening and evaluation, such as under a Feasibility Study (FS) or Corrective Measures Study (CMS);
- remedy selection and design;
- implementation of the corrective action and/or remedial action; and
- operation and maintenance and/or long-term stewardship, if applicable.

This guidance is largely organized around these cleanup phases into the following sections:

Section 1.0 presents introductory information, including the purpose, objective, scope, applicability and organization of the guidance document.

Section 2.0 provides an overview of plating processes.

Section 3.0 addresses site assessment, including project scoping, public participation and coordination with other agencies.

Section 4.0 discusses site characterization and risk assessment.

Section 5.0 summarizes and documents the study and evaluation of cleanup technologies for plating facilities.

Section 6.0 discusses considerations for site cleanup and closure.

Section 7.0 addresses site closure and remedy completion.

Section 8.0 discusses long-term stewardship requirements.

Section 9.0 provides the references cited in the guidance.

The main text of this guidance document is intentionally brief and defers details for selected topics to appendices (e.g., risk assessment, development and use of a CSM, regulatory considerations for tank closure) or existing guidance documents. The document includes resources intended to facilitate certain phases of the cleanup process (e.g., annotated outline for pilot study workplan, annotated outline for a building demolition plan). The guidance document also provides links to DTSC and other resources useful for investigation and cleanup of plating facilities.

2.0 OVERVIEW OF PLATING OPERATIONS

Metal plating encompasses a broad range of processes that are performed on manufactured parts to alter the surface of the article, thus lending it properties not possessed in its “unfinished state” (Murphy, 1996; USEPA, 1995). Table 2 summarizes typical plating processes, commonly-associated steps, and typical waste streams. Wastewater is the largest waste stream generated by volume in plating operations because water is used throughout the operations (e.g., rinsing, washing away spills, air scrubbing, fluid replacement, cooling, quenching, and washing of equipment). Table 1 lists some of the chemicals that may be associated with plating operations.

As addressed in more detail in Appendix A, plating facilities have a variety of possible release mechanisms and the potential to impact multiple environmental media (e.g., soil, soil vapor, air, surface water, groundwater). Metals and cyanide compounds are often released when metal finishing solutions are spilled onto floors, or when wastewater and waste sludge are not properly managed. The secondary containment of the wastewater treatment systems, spillage collection features (such as trenches, channels, sumps, etc.), and hazardous waste storage areas may be a source of releases, particularly if these features (often concrete) are unlined, cracked, or damaged. Other potential release areas include chemical storage areas, onsite chemical laboratories, paint booths, paint mixing rooms, shipping and receiving areas, storage sheds, parking lots, wastewater storage areas (e.g., lagoons, surface impoundments), and other outside areas where chemicals may have been handled, stored, spilled or illegally discharged to the ground. Additional potential sources of contamination include pollution control equipment, transformers, compressors, hydraulic presses, and underground storage tanks. Airborne sources of metals and solvents include stack and fugitive emissions. Some metals (such as arsenic, cadmium, and lead) can volatilize during high-temperature processing and wet scrubbers are needed to control emissions. Stack emissions can be distributed over a wide area before they settle out of the air.

Building materials can be contaminated by fugitive emissions within the plant or through contact with liquids. Metal plating and polishing have the potential to emit cadmium, chromium, lead, manganese, and nickel via electrolytic and non-electrolytic plating and coating processes (e.g., electroplating, conversion coating, sealing, and phosphating), electroforming, dry mechanical polishing, and thermal spray (Federal Register, 73 FR Part 173 (37728-37749), July 1, 2008). Areas around vapor collection exhaust systems and walls may have residual concentrations of these metals. Process chemicals, plating solutions, liquid waste and leachate can contaminate structures and equipment. Poor housekeeping practices and improper handling of these liquids can lead to: corrosion and/or contamination of tanks, piping, pumps, floors, drains, sumps, trenches, and sewer lines; contamination of the flooring itself; and impacts to the underlying soil and groundwater. Any building constructed before 1970 may also contain lead-based paint and asbestos containing materials which may require special care during removal or renovation of these buildings (USEPA, 1999c).

Table 2. Types of Metal Finishing Operations and Associated Activities (after Murphy, 1996)

Activity	Description	Waste Streams
Plating Operation Types		
Chemical and Electrochemical Conversions	Designed to deposit a coating on a metal surface that performs a corrosion protection and/or decorative function. Processes include phosphating, chromating, anodizing, passivation, and metal coloring.	<ul style="list-style-type: none"> • Wastewater • Spent plating solutions • Exhaust scrubber solutions • Sludges
Case Hardening	Produces a hard wear-resistant surface over a metal core that remains relatively soft and ductile. Methodologies include carburizing, carbonitriding, nitriding, microcasing, and hardening using localized heating and quenching operations.	
Metallic Coatings	Provide a layer that changes the surface properties of the workpiece to those of the metal being applied. The workpiece becomes a composite material with properties generally not achievable by either material singly.	
Electroplating	Achieved by passing an electric current through a solution containing dissolved metal ions as well as the metal object to be plated. The metal object acts as a cathode in an electrochemical cell, attracting metal ions from the solution. Ferrous and nonferrous metal objects are typically electroplated with aluminum, brass, bronze, cadmium, chromium, copper, iron, lead, nickel, tin, and zinc, as well as precious metals such as gold, platinum, and silver.	
Electroless Plating	Similar to electroplating steps, but involves the deposition of metal on a metallic or non-metallic surface without the use of external electrical energy.	

Table 2 (Continued)

Activity	Description	Waste Streams
Associated Activities		
Machining Operations	Various metal cutting processes including drilling, grinding, reaming, and milling. Uses various tools and typically use metalworking fluids.	<ul style="list-style-type: none"> • Metal dust and shavings • Spoiled or contaminated metalworking fluids which contain oils and chemical additives (such as chlorine, sulfur and phosphorus compounds, phenols, creosols and alkalis).
Cleaning Operations and Surface Preparation	Integral to numerous processes in the manufacture of metal parts. Metal parts are cleaned with solvents which evaporate substantially during degreasing operations. Paint, oxidation and old plating are stripped from workpieces using caustics and abrasives. Workpieces in plating lines are cleaned several times using water, acids, caustics and detergents.	<ul style="list-style-type: none"> • Spent solvents • Chlorinated hydrocarbons and VOC emissions • Rinsewaters • Spent cleaning solutions. [Composition depends on cleaning media used, type of substrate, and the type of material removed (oils, greases, waxes, metallic particles, oxides, etc.).] • Possible contaminants include acids, alkalis, halogenated and nonhalogenated solvents, ketones, aromatic hydrocarbons, dissolved metal salt, silica metal, aluminum oxide, cyanide, oil-based contaminants, grease, and traces of cleaners and additives.
Other Activities	Painting, polishing, grinding, hot dipping, soldering, stripping, and etching	<ul style="list-style-type: none"> • VOC emissions • Paint • Wastewater • Solid waste • Spent polishing rouge • Anoxide dross • Spent acids and bases • Miscellaneous hazardous waste

3.0 PROJECT PLANNING

The investigation and cleanup of plating facilities can be a challenging endeavor given the complexity of many sites where plating operations have occurred or are on-going. Project planning facilitates the investigation and cleanup process and helps ensure that the desired outcome is achieved. This section discusses activities commonly conducted during the planning phase, including project scoping, stakeholder identification, public participation activities, and coordination with other agencies.

3.1 PROJECT SCOPING

The project scoping objectives typically include:

- establishment of a management approach for the project;
- assessment of the regulatory framework for closure or cleanup;
- development of a site characterization strategy;
- development of a site cleanup strategy which is protective of human health and the environment;
- development of a remedial project plan (i.e., the step-by-step strategy to be used for the site cleanup);
- identification of site conditions to be addressed during the cleanup process (e.g., cultural resources, sensitive human receptors);
- identification of stakeholders; and
- identification of appropriate public participation activities.

3.1.1 Scoping Meetings

Project staff and project proponents should hold one or more project scoping meetings to discuss topics such as:

- site background, physical setting, land uses (past, present, and future), and unique site characteristics;
- status of site investigation and cleanup;
- development of the CSM
 - types and locations of releases
 - affected environmental media (e.g., soil, soil vapor, groundwater, ambient or outdoor air, indoor air)
 - contaminant migration pathways
 - current and potential future receptors
 - exposure pathways (e.g., direct contact, inhalation, vapor intrusion into indoor air, drinking water)

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- potential risks;
- regulatory framework for site cleanup;
- initial scope of work for completing site characterization, filling data gaps, and cleaning up the site;
- potentially applicable remedial technologies;
- whether the approach for metals and/or chlorinated VOCs discussed in *PT&R Guidance -- Remediation of Metals in Soil* (DTSC, 2008) and *PT&R Guidance – Remediation of Chlorinated VOCs in Vadose Zone Soil* (DTSC, 2010) could be applied to part of the site cleanup;
- preliminary identification of response actions and the implications of these actions (e.g., restricted land use, long-term stewardship);
- preliminary RAOs and cleanup goals (e.g., as needed to achieve the conceptual preliminary response action);
- project planning, work phases (if applicable), schedule, and priorities;
- stakeholder identification and public participation activities; and
- anticipated benefits of the cleanup activity, including anticipated future uses.

If applicable, the scoping meeting should address how cleanup activities targeting different media and/or contaminants will be coordinated (e.g., coordination of a soil removal action with the groundwater remedy and/or vapor intrusion mitigation measures).

The outcome of the scoping meeting(s) may be summarized in a scoping document that includes:

- analysis and summary of site background and physical setting;
- summary of previous response actions, including all existing data;
- presentation of the CSM, human health risks, and data gaps;
- scope and objectives of remaining characterization and risk assessment activities;
- scope and objectives of the site cleanup;
- RAOs and cleanup goals;
- preliminary identification of possible response actions and data needed to support the evaluation of cleanup alternatives; and
- initial presentation of site remedial strategies.

3.1.2 Stakeholder Identification and Assessment

Stakeholder involvement is essential for the success of any cleanup action. At the onset of the proposed project, stakeholders should be identified and contacted for input. Stakeholders include any individuals, government organizations, non-governmental

organizations (such as environmental and other public interest groups), academic institutions, and businesses with an interest in the project. The identification of stakeholders is largely based on those entities or individuals who are already involved in the project, and contacting others with related interests or those who may be in close proximity to the site. Stakeholders provide information on the preferences of the community and may also identify unaddressed issues. Early identification of stakeholders is necessary to ensure effective and timely participation to meet stakeholder expectations and to enrich the decision-making process.

3.2 PUBLIC PARTICIPATION ACTIVITIES

This guidance document acknowledges the importance of early community outreach and uses the public participation process identified in the *DTSC Public Participation Manual* (DTSC, 2003a; revision pending). The manual addresses public participation components of the cleanup process and compliance with state and federal laws and regulations. The *DTSC Public Participation Manual* includes summaries of the public participation elements for each DTSC program, California Environmental Quality Act (CEQA), and various public outreach activities. Also provided are checklists and recommended content for the community profile, fact sheets, public notices, work notices, and other public outreach activities. Appendix E includes a link to sample public participation documents.

The vapor intrusion pathway may be a concern for some sites. If not already initiated, the public participation process should begin as soon as it is determined that VOCs are present and a vapor intrusion evaluation is necessary. The *Vapor Intrusion Mitigation Advisory* (DTSC, 2009a; revision pending) outlines public participation considerations for sites with vapor intrusion issues. DTSC expects to issue the *Vapor Intrusion Public Participation Advisory* in 2011 which will supplement DTSC's Vapor Intrusion Guidance (DTSC, 2005; revision pending) and address public participation considerations for sites with vapor intrusion issues.

3.3 COORDINATION WITH OTHER AGENCIES

The responsible party should coordinate with state and local agencies that have jurisdiction for cleanup of plating facilities (e.g., DTSC, Water Board, air pollution control district, air quality management district, local planning and building department, fire department). Local agency involvement should start early in the cleanup process to alleviate potential project delays. Overlapping regulatory authority or requirements by DTSC and other applicable agencies should be identified to ensure that the project strategies are compatible and requirements can be met. In cases where oversight authority may be overlapping or redundant, an agreement (such as a Memorandum of Understanding) should be made between the applicable entities for designation of a single oversight agency.

4.0 SITE CHARACTERIZATION

This section provides a general discussion of site characterization elements and is supported by the following appendices:

- Appendix A Conceptual Site Model for Plating Facilities
- Appendix B Sample Collection and Analysis Techniques
- Appendix C Hexavalent Chromium Analysis
- Appendix D Risk Assessment and Cleanup Goals
- Appendix E Links to Additional DTSC Resources

The primary objective of the characterization phase is to delineate the nature, extent, and distribution of contamination in environmental media (such as soil, soil vapor, and groundwater). Other characterization objectives could include addressing data gaps, establishing background concentrations of metals, providing information about the geologic and hydrogeologic setting, collecting data to support remedy selection and engineering design, and collecting data to support any fate and transport modeling efforts. As data is gathered, it may be compared to screening levels to help determine whether further site characterization, risk assessment, or cleanup may be necessary. The culmination of this step should be to prepare an updated CSM that supports media-specific RAOs and remedy decision making.

4.1 CONCEPTUAL SITE MODEL

Development and use of a CSM is one of the most effective ways of achieving characterization objectives. A CSM provides a framework to understand the site conditions, the distribution of contaminants in the environment, exposure pathways, and receptors. In guiding the site characterization process, the CSM provides:

- a detailed description of the site and its setting that is used to form a hypothesis about the release and fate of contamination;
- the locations of contaminant sources, potential chemicals of concern (COCs), and the affected media;
- an explanation of how contaminants may be migrating from the sources, and the media and pathways through which migration and exposure of potential human or environmental receptors could occur; and
- a framework for conducting an investigation, selecting a cleanup approach, or implementing a cleanup action that takes into account the future use of the site.

Section 2.0 and Appendix A identify common areas of concern and possible release mechanisms that should be evaluated, and if appropriate, considered in the CSM for a plating facility.

4.2 DESIGNING AN INVESTIGATION

The selection of sample locations, depths, quantities, and collection methods is based on the CSM, data quality objectives (DQOs), and sound professional judgment. A well-

conceived investigation strategy combined with extensive upfront project planning (see Section 3), innovative sampling methods, field-based analytical technologies (see Appendix B), and the ability to adapt the workplan in the field, have the potential to reduce the time and expense of performing a quality site characterization. This approach should yield better and timely information that supports informed decisions. The following guidance documents describe methodologies that can focus work towards rapid site characterization decisions:

- *Technical and Regulatory Guidance for the Triad Approach: A New Paradigm for Environmental Project Management* (ITRC, 2003)
- *Standard Practice for Expedited Site Characterization of Vadose Zone and Ground Water Contamination at Hazardous Waste Contaminated Sites* (ASTM, 2004)

Additional information about the Triad approach can be found in Appendix B and at the following link: www.triadcentral.org.

Establishment of DQOs is a key component of an effective site characterization strategy. The DQOs establish a range of decision points such as criteria for step-out sampling to address data gaps and exit strategies for completion of field work. DQOs, in combination with the CSM, serve as a planning instrument, as a modeling and data interpretation tool, and as a communication device among the project team, the decision-makers, the stakeholders, and the field personnel. A successful project DQO process results in:

- consensus on the nature of the problem and the desired decision shared by all the decision makers;
- planned approach to data collection, quality, and evaluation resulting in resource-efficient sampling and analysis design;
- quantitative criteria to determine when the site is sufficiently characterized and DQOs are met;
- sufficient characterization of site contamination and risks; and
- reduced uncertainty for decision makers.

Guidance for establishing project DQOs can be found in *Guidance on Systematic Planning Using the Data Quality Objective Process, EPA QA/G-4* (USEPA, 2006).

As feasible during the characterization phase, data should be collected to eliminate or minimize the need for additional field mobilizations during the site-specific remedy evaluation, selection, and design process. For example, data can be collected to support design of pilot studies for *in situ* groundwater remedies. Guidance on data needed to support design of excavation/disposal, capping, and SVE remedies can be found in *PT&R Guidance – Remediation of Metals in Soil* (DTSC, 2008) and *PT&R Guidance – Remediation of Chlorinated VOCs in Vadose Zone Soil* (DTSC, 2010).

Site characterization activities should be conducted in accordance with a DTSC approved work plan, including a field sampling plan and a quality assurance project plan (QAPP). Appendix E provides a link to an annotated outline for a characterization

workplan. General guidance for development of a QAPP can be found in *Guidance on Choosing a Sampling Design for Environmental Data Collection, for Use in Developing a Quality Assurance Project Plan, EPA QA/G-5S* (USEPA, 2002b). Appendix E provides a link to a suggested strategy for estimating background concentrations of metals in soils. Additional information useful for guiding site characterization may also be found in the *PT&R Guidance – Remediation of Metals in Soil* (DTSC, 2008) and *PT&R Guidance – Remediation of Chlorinated VOCs in Vadose Zone Soil* (DTSC, 2010).

Fate and transport modeling is often used during the characterization phase for the purpose of evaluating the movement of contaminants in the subsurface, assessing the potential for contaminant migration to groundwater, developing soil cleanup goals for protection of groundwater, estimating the potential risk posed to groundwater by vadose zone contaminants, and estimating the potential risk posed by vapor intrusion into indoor air. Therefore, the input parameter requirements for the models anticipated for use at a site should be considered during workplan development. For example, a site-specific screening analysis of the risk posed by the vapor intrusion pathway may require information regarding site stratigraphy and building parameters in addition to the following soil properties: bulk density, total porosity, grain size distribution, moisture content, fraction of organic carbon, and air permeability (DTSC, 2005; revision pending). Other fate and transport models may require additional site-specific parameters, such as hydraulic conductivity, effective porosity, estimated recharge or infiltration rates, geochemical parameters (e.g., oxidation/reduction potential), biodegradation rates, and chemical retardation factors.

4.3 RISK ASSESSMENT

Evaluation of potential risks to human health and the environment posed by contaminants at a site is part of the site characterization process and supports the risk management decision-making process to determine whether additional site investigation, further risk assessment, and/or remediation may be necessary. Risk assessments range from simple screening assessments to site-specific, comprehensive risk assessments. A human health risk assessment should be conducted to characterize the potential cancer risks and noncancer health hazards posed by COCs identified during site characterization. Depending on the phase of site cleanup when this guidance is applied, some risk assessment steps may have already been conducted and may be sufficient to support subsequent activities. A scoping-level ecological risk assessment should be conducted to determine whether further assessment of potential ecological impacts is necessary. Appendix D provides a detailed discussion of risk assessment for contaminants commonly found at plating facilities.

Generally, cleanup goals are established based on concentrations that do not pose an unacceptable risk or threat to human health and the environment, as discussed further in Appendix D.

5.0 EVALUATION OF CLEANUP TECHNOLOGIES

In a conventional cleanup action, if the results of the risk characterization and assessment indicate that a cleanup action is warranted, the next step is an evaluation of technologies appropriate for remediation of environmental impacts. This section describes the process for evaluating the feasibility of cleanup technologies for soil, soil vapor, indoor air, and groundwater impacted by plating operations.

5.1 SCREENING OF REMEDIAL TECHNOLOGIES

Depending on the site circumstances, screening of remedial technologies may be conducted independently for a given environmental media, or in a coordinated manner for each impacted environmental media. An integrated approach is particularly important when evaluating technologies applicable for impacts to multiple environmental media (e.g., VOCs impacts to soil, soil vapor, groundwater, and indoor air).

5.1.1 Metals and VOCs in Soil

Studies documented in *PT&R Guidance – Remediation of Metals in Soil* (DTSC, 2008) and *PT&R Guidance – Remediation of Chlorinated VOCs in Vadose Zone Soil* (DTSC, 2010) can be used to streamline the remedial technology screening process for immobile metals and chlorinated VOCs in vadose zone soil. These studies indicated that excavation/disposal and capping are proven technologies for immobile metals in soil and that excavation/disposal and SVE are proven technologies for chlorinated VOCs in vadose zone soil. The streamlined approach for evaluating remedial alternatives for soils impacted by immobile metals and chlorinated VOCs can be documented by including:

- pertinent sections of this guidance document in the administrative record¹ and
- a discussion regarding the use of the PT&R approach for the cleanup alternative selection in the decision document.

As discussed in Section 1.2.1, proven technologies for metals or chlorinated VOCs may not be applicable to, or appropriate for, cleanup of all or part of the metals or VOC impacts at a given plating facility. In these instances, other remedial technologies would need to be screened. Section 6.3 discusses DTSC resources that can be used to help identify technologies for screening. In addition, Appendix F summarizes technologies for hexavalent chromium in soil.

5.1.2 Other Contaminants in Soil

The scope of the remedial technology screening process may need to be expanded to address soils impacted by additional types of contaminants. Examples of site conditions that would warrant an expanded remedial technology screening process might include:

¹ Alternatively, the PT&R guidance may be included as an electronic appendix to a cleanup alternative evaluation document.

- contaminants that are not co-located with metals or VOCs and thus would not be removed by excavation/disposal;
- contaminants that cannot be addressed by one of the proven technologies;
- contaminants that may pose an on-going threat to groundwater (such as hexavalent chromium); and
- contaminants better addressed by another technology.

Modifications to the approach described in *PT&R Guidance – Remediation of Metals in Soil* (DTSC, 2008) and *PT&R Guidance – Remediation of Chlorinated VOCs in Vadose Zone Soil* (DTSC, 2010) to address additional types of contaminants should be documented in the administrative record and decision document. Section 6.3 provides links to resources that can be used to help identify technologies for screening.

5.1.3 Groundwater

A review of the administrative record for groundwater cleanups conducted in conjunction with the development of this guidance document did not identify a proven technology for cleanup of plating-related chemicals in groundwater. Therefore, the standard process for screening remedial technologies should be conducted for groundwater impacts. Section 6.5 discusses technologies for addressing groundwater contamination. Appendix G identifies technologies for addressing VOCs and hexavalent chromium in groundwater.

5.1.4 Vapor Intrusion

Vapor intrusion mitigation may be part of the interim action or final remedy for sites where VOCs are present in the subsurface at levels that pose a health risk via the vapor intrusion pathway. Because DTSC has not identified proven technologies for vapor intrusion mitigation, the *Vapor Intrusion Mitigation Advisory* (DTSC, 2009a; revision pending) describes common technologies for vapor intrusion mitigation. Whenever possible, the evaluation of vapor intrusion mitigation approaches should be integrated with the evaluation of remedies to address the subsurface vapor sources [see DTSC, (2009a; revision pending) for further discussion].

5.2 DETAILED ANALYSIS OF REMEDIAL TECHNOLOGIES

Under state and federal law, an analysis of alternatives is required for sites undergoing remediation. Following an initial evaluation (see Section 6.1), a more detailed analysis that considers the site characteristics must be conducted for the technologies identified in the screening evaluation.

5.2.1 Proven Technologies for Metals and VOCs in Soil

Because the cleanup alternative screening evaluation for metals and VOCs described in Section 5.1.1 was conducted in accordance with the initial screening requirements of a FS and CMS, it may be used in lieu of a site-specific initial screening evaluation,

provided that the PT&R screening evaluation is cited in the administrative record. Hence, for metals and VOCs, the detailed analysis may focus on the proven technologies. Focusing on the proven technologies is consistent with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) which indicates that: the number of alternatives evaluated for a site should be reasonable; the number of alternatives evaluated should be based on the scope, characteristics, and complexity of the site; and detailed analyses need only be conducted on a limited number of alternatives that represent viable approaches to the cleanup. Application of the proven technologies does not preclude consideration of additional cleanup alternatives if determined to be appropriate for a site. However, use of the proven technologies would still reduce the burden of the number of cleanup technologies to be screened and evaluated.

5.2.2 Contaminant Types and Impacted Media Without Proven Technologies

A traditional detailed analysis should be conducted for contaminant types and media for which proven technologies have not been identified (see Section 5.1) or for which the proven technologies are not appropriate. Impacts to groundwater and vapor intrusion mitigation will also require a separate detailed analysis.

5.2.3 Overview of Detailed Analysis

The detailed evaluation of remedial technologies involves a comparison of each approach or combination of approaches to a set of evaluation criteria. The criteria² for evaluating remedial technologies include:

Threshold Criteria

- 1) Overall protection of human health and the environment,
- 2) Compliance with federal/state/local requirements,

Balancing Criteria

- 3) Long-term effectiveness and permanence,
- 4) Reduction of toxicity, mobility or volume through treatment,
- 5) Short-term effectiveness,
- 6) Implementability based on technical and administrative feasibility,
- 7) Cost,

Modifying Criteria

- 8) State and local agency acceptance, and
- 9) Community acceptance.

If a RAW is prepared, then an engineering evaluation/cost analysis (EE/CA) is required and should consider some of the above-listed criteria (i.e., effectiveness, implementability, cost).

² Only the effectiveness, implementability, and cost criteria apply to the DTSC Removal Action Workplan (RAW) process.

Additional criteria may also be considered in the remedial alternative evaluation process for a given site. For example, an evaluation of the sustainability of each remedial alternative could be used to identify potential environmental stressors (e.g., resource depletion, physical disturbances) and their associated impacts. The *Interim Advisory for Green Remediation* (DTSC, 2009b) provides additional discussion regarding sustainability as a criterion in the remedy selection process.

The detailed analysis results provide a basis for identifying the remedial approach and documenting the rationale behind the decision. General or classical engineering evaluation criteria for the detailed evaluation of alternatives have been established for hazardous substance release sites in guidance and regulations (see Table 3). In addition, there are technology-based considerations which should be used to determine if approaches are feasible and can be carried through to an overall final response action decision that is protective and implementable.

The following elements should be included with the detailed evaluation of the remedial technologies:

- identification of applicable federal/state/local requirements (known as ARARs under the CERCLA process);
- establishment of RAOs and performance metrics;
- recordation of land use covenants (LUCs), if applicable;
- recognition of long-term responsibilities in maintaining financial assurance and compliance with the five-year review requirement (if applicable); and
- evaluation of the mitigation alternatives and the no action alternative against the applicable NCP criteria.

Appendix E provides links to DTSC resources for preparing a RAW, FS/RAP, and CMS Report. Regardless of the process used to evaluate and select the cleanup alternative for a site, the alternatives evaluation report generally should:

- discuss and present documentation showing that if used, the proven technologies are appropriate;
- identify and provide the rationale for the preferred alternative for the site;
- document the site-specific RAOs, regulatory requirements, and the detailed alternatives analysis; and
- include preliminary design information for implementation of the final remedy.

Evaluation of each remedial alternative for the site should include a determination of the estimated reduction in risk and of risk management measures for contamination remaining in excess of risk-based concentrations.

Necessary CEQA documents are usually prepared concurrently with the alternatives evaluation reports, if not sooner (see Section 5.4 for further discussion). Once approved by DTSC or a Regional Water Quality Control Board (RWQCB), the draft

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alternative analysis and draft CEQA documents are circulated for public comment (DTSC, 2003a; revision pending).

The administrative record for the site should, among other things, include the following elements:

- copy of pertinent sections of the PT&R guidance documents (alternatively, include the PT&R guidance as an electronic appendix to cleanup alternative evaluation document);
- responses to any comments pertaining to the decision to use the proven technologies; and
- other key documents considered in the decision.

Table 3. State and Federal Guidelines for Alternatives Evaluation

LAW	PROCESS	DESCRIPTION	SUGGESTED REFERENCE(S)
HSAA	Remedial Action Plan (RAP)	Process for developing, screening, and conducting detailed evaluation of alternative remedial actions for sites. Response action selection document under HSC §25356.1.	DTSC, 1995
	Removal Action Workplan (RAW)	Prepared when a proposed, non-emergency removal action or a remedial action is projected to cost less than \$2,000,000. Response action selection document under HSC §25356.1.	DTSC, 1993, 1998
CERCLA	Feasibility Study (FS)	Process for the development, screening, and conducting detailed evaluation of alternative remedial actions for sites. A FS is not required for the RAW process; however, the RAW should evaluate effectiveness, implementability, and cost of various removal alternatives.	USEPA, 1988, 1999a
	Engineering Evaluation/ Cost Analysis (EE/CA)	Analogous to, but more streamlined than, the FS. Identifies the objectives of the removal action and analyzes the effectiveness, implementability, and cost of various alternatives that may satisfy these objectives.	USEPA, 1993
RCRA or HWCL	Corrective Measures Study (CMS)	Mechanism used by the corrective action process to identify, develop, and evaluate potential remedial alternatives.	USEPA, 1991a, 1994a, 1997
HSAA, HWCL, RCRA, CERCLA	Interim Measures (IM) or Interim Actions	Actions to control and/or eliminate releases of hazardous waste and/or hazardous constituents from a facility prior to the implementation of a final corrective measure or response action.	

Notes:

CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act

HSAA – Hazardous Substance Account Act

HWCL – Hazardous Waste Control Law

RCRA – Resource Conservation and Recovery Act

5.3 DESIGN AND IMPLEMENTATION OF CLEANUP

The engineering, implementation, and operational plans for implementing the selected cleanup alternatives should be prepared and submitted to DTSC, either in the remedy selection document (if appropriate, such as in a RAW) or provided as separate submittals. The engineering plans contain the specific engineering design details of the proposed cleanup approach, including designs for any long-term structures (e.g., a cap). As applicable, the engineering plans should include the design criteria, process diagrams, and final plans and specifications for the structures as well as a description of any equipment to be used to excavate, handle, and transport contaminated soil. Implementation plans that address short-term risks posed by remediation activities (see Appendix D), construction quality assurance/quality control (QA/QC), and field sampling and analysis during implementation (such as confirmation sampling to demonstrate achievement of RAOs) should also be prepared.

5.4 CALIFORNIA ENVIRONMENTAL QUALITY ACT

Cleanups must meet all applicable local, state and federal requirements including the CEQA (Pub. Resources Code, sec. 21000 et seq.). CEQA requires public agencies carrying out or approving a project to conduct an environmental analysis to determine if project impacts could have a significant effect on the environment. Public agencies must eliminate or reduce the significant environmental impacts of their decisions whenever it is feasible to do so.

All proposed projects for which the DTSC has discretionary decision-making authority are subject to CEQA if they potentially impact the environment. Examples of approval actions which require CEQA review and documentation include: RAPs, interim measures, RAWs, and corrective actions. As shown by these examples, certain steps described in this guidance document are subject to CEQA. For further information, DTSC's CEQA-related policies and procedures are available on the DTSC web site (www.dtsc.ca.gov).

6.0 CONSIDERATIONS FOR SITE CLEANUP AND CLOSURE

This section discusses considerations for site cleanup and closure and applies to:

- interim or partial removal actions (also known as interim measures) taken while a final remedy is evaluated, selected, and designed, or actions taken prior to site closure;
- the final remedy for soil, groundwater, and other affected media; and
- implementation of a closure plan or decommissioning of site infrastructure (e.g., buildings, pipelines).

6.1 SCOPE OF CLEANUP ACTIVITIES

The results achieved by a cleanup will depend on the site-specific RAOs and the scope of the site cleanup. Response actions can have a variety of RAOs such as:

- removing as much contaminant mass as feasible prior to application of other remedial technologies;
- removing contaminant mass to decrease VOC emissions during a subsequent soil excavation;
- removing contaminant mass posing an on-going threat to groundwater;
- controlling vapor flow or mass removal around a building having a vapor intrusion risk; and
- achieving risk-based cleanup goals.

The range of possible RAOs results in different performance metrics that are used to evaluate the success of the action and to determine whether the action has been completed. For some RAOs, the performance metric could be based on the estimated mass remaining in the subsurface and/or a mass removal rate. For other RAOs, the performance could be based on demonstrating achievement of risk-based cleanup goals (i.e., acceptable residual concentrations of contaminants).

6.1.1 Interim Removal Actions

Interim removal actions could be undertaken to address an immediate threat to human health and the environment such as soil concentrations that pose a threat to human health or groundwater, soil vapor concentrations that pose an indoor air risk or an ongoing threat to groundwater, or a groundwater plume that may be threatening a water supply well. These actions could also be implemented to cleanup accessible areas of an active plating facility while other areas are deferred until the facility is closed (such as non-volatile contaminants beneath a building foundation). The outcome of implementing an interim removal action is completion of the response action and achieving the objective of protecting human health and the environment until the final remedy can be implemented.

6.1.2 Final Remedies

Final remedies typically have a more complex scope than interim removal actions. Final remedies are more likely to address multiple impacted media and may require sequencing of the cleanup activities. For example, VOC plumes in soil vapor and groundwater have the potential to interact during the cleanup action. Off-gassing from groundwater can act as an on-going source of VOCs to the vadose zone. Likewise, a vapor plume can contribute VOC mass to shallow groundwater. RAOs for final remedies are often developed such that the cleanup activities achieve risk-based cleanup goals. The desired outcome of implementing the final remedy is cleanup to levels that meet the established RAOs, which depending on the residual contamination remaining after remedy implementation, may require on-going controls or cleanup to levels that allow unrestricted use of the site.

6.1.3 Transitioning from Interim to Final Remedies

Remedies implemented as an interim removal action may or may not be included as part of the final remedy. Some may be excluded from the final remedy because the RAOs were achieved during the interim removal action or the technology may have proved to be ineffective. For example, the interim removal action may have included excavation of shallow soil impacts, but the final remedy focuses on deeper contamination that cannot be addressed by excavation. Technologies in addition to those used for the interim removal action may be considered in the alternatives analysis for the final remedy. For example, a groundwater pump-and-treat system installed as an interim removal action may be retained as part of the final remedy because it is needed to maintain hydraulic control of the plume.

6.2 SITE CLOSURE

6.2.1 Tank Closure

Closure of hazardous waste management tanks at plating facilities should be conducted in accordance with applicable regulatory requirements (see Appendix H). Tanks used to accumulate hazardous waste (generator tanks holding hazardous waste less than 90 days), or tanks authorized for onsite treatment under conditional authorization (CA) or conditional exemption (CE) may be closed without a closure plan. Notifying the appropriate regulatory agency and meeting the closure standards for hazardous waste generators are, however, required for these tanks. Processing tanks that held hazardous materials are not subject to hazardous waste closure requirements.

Plating facilities operating tanks under Permit by Rule (PBR) regulations must comply with the closure requirements identified in California Code of Regulations, title 22, section 67450.3(c)(11). Closure of a PBR tank requires the removal and decontamination of all hazardous waste, waste residues, containment system components, soils and other structures or equipment contaminated with hazardous waste. The Certified Unified Program Agency (CUPA) must be notified in writing at least 15 days prior to completion of closure. The *Fact Sheet: Fixed Treatment Unit*

Operating Under Permit By Rule (DTSC, 2003b) summarizes the regulatory requirements for closure of PBR tanks.

Hazardous waste regulations include special considerations if a tank is determined to be hazardous waste and is destined to be disposed or reclaimed. These alternate tank standards are applicable to process tanks, generator tanks, and tanks authorized under CA, CE, or PBR (Cal. Code Regs., tit. 22, §67383.3).

6.2.2 Building/Infrastructure Demolition

Site closure requiring demolition of facility infrastructure and/or buildings should be conducted in accordance with a plan that identifies the logistical procedures and site activities associated with building and infrastructure demolition. Major topics for a building demolition plan include:

- description of site
- nature and extent of contamination
- purpose, objectives, and scope of plan
- project organization and schedule
- pre-demolition activities
 - permits
 - utility checks
 - site control measures
 - site inspection
 - building waste removal (e.g., asbestos-containing materials, lead-based paint)
- detailed, sequenced description of demolition activities
- cover placement (if applicable) and site demobilization
- preparation of a demolition completion report
- applicable supporting documents, such as:
 - site-specific health and safety plan
 - community air monitoring plan
 - public participation plan
 - transportation plan

Appendix I provides an annotated outline for a demolition plan.

6.3 SOIL AND SOIL GAS IMPACTS

This section describes the remedial measures implemented to address impacts to soil and soil gas. Based on the nature of contamination, depth of impact, and spatial distribution of contamination, multiple measures may be required. When contaminants

are co-located, measures such as excavation/disposal and an appropriately designed cap³ could be used to address all contaminants.

The type of remedy selected, its effectiveness, and the selected cleanup goals will affect the long-term use of the site. For example, use of a cap to control exposures and/or limit migration to groundwater will require long-term stewardship and a land-use covenant (LUC). The risk posed by residual concentrations may necessitate on-going administrative and engineering controls (e.g., LUC, vapor intrusion mitigation), as discussed further in Section 8.0.

6.3.1 Metal-Impacted Soil

The approach described in the *PT&R Guidance – Remediation of Metals in Soil* (DTSC, 2008) may be used to address metals-impacted soil. Removal of the impacted soils via excavation/disposal could be used to address both immobile and mobile metals where the impacts are shallow and/or co-located. Isolation under a cap may eliminate the potential for human contact with the soils, dispersion of contaminants, and/or impacts to surface water runoff. Depending on site-specific circumstances, isolation under an engineered cap may also be used to reduce the potential for metals to migrate to groundwater. Where metals migration to groundwater is of concern, the capping remedial alternative described in the *PT&R Guidance – Remediation of Metals in Soil* could be used in conjunction with appropriate RAOs, performance metrics, and monitoring to ensure that the cap is effective in reducing the mass of metals migrating toward groundwater. Refer to *PT&R Guidance – Remediation of Metals in Soil* for details regarding the design and implementation of the excavation/disposal and capping alternatives.

Excavation/disposal or capping of metals may not achieve RAOs for a given site. Appendix C of *PT&R Guidance – Remediation of Metals in Soil* summarizes other remedial approaches (both *in situ* and *ex situ*) that may be used to address metals in soil. Examples of these approaches include soil washing, soil flushing, chemical treatments, solidification/stabilization, and vitrification.

Because of its mobility, another remedial approach may be needed to address hexavalent chromium in soil. Appendix F identifies technologies specific to hexavalent chromium in soil.

6.3.2 VOC-Impacted Soil and Soil Gas

The approach described in *PT&R Guidance -- Remediation of Chlorinated VOCs in Vadose Zone Soil* (DTSC, 2010) may be used to address VOC-impacted soil and soil gas, using excavation/disposal and/or soil vapor extraction (SVE). Refer to *PT&R Guidance – Remediation of Chlorinated VOCs in Vadose Zone Soil* for details regarding the design and implementation of the excavation/disposal and SVE alternatives.

³ Use of a cap to address VOC-impacted soil may require a gas collection system, venting, monitoring for gas phase migration, and other appropriate RAOs.

If excavation/disposal or SVE will not achieve the RAOs for a given site, Appendix B of *PT&R Guidance -- Remediation of Chlorinated VOCs in Vadose Zone Soil* summarizes other remedial approaches for VOCs in soil and soil gas. Examples of these approaches include *ex situ* treatment (e.g., slurry phase bioremediation, chemical extraction), thermally-enhanced SVE, thermal desorption, soil flushing, and chemical treatment.

The health risk associated with residual VOC concentrations should be evaluated via confirmation sampling (soil and/or soil gas) after remedy implementation (see Appendix D). The *PT&R Guidance -- Remediation of Chlorinated VOCs in Vadose Zone Soil* discusses confirmation sampling strategies for VOCs for soil excavations and SVE systems. Appropriate site controls (e.g., LUC, vapor intrusion mitigation system, no build zone) may be needed depending on the residual risk estimate.

6.3.3 Other Contaminant Types

As feasible, other contaminant types (e.g., SVOCs, cyanide) could be addressed in conjunction with remedies used to address metals and VOCs (e.g., excavation/disposal, SVE, capping). However, depending on the nature and extent of contamination and other considerations for a site, additional remedial technologies may be required to address the contaminants. Resources for identifying appropriate technologies for other contaminant types can be found on the U.S. Environmental Protection Agency (USEPA) web sites (www.clu-in.org, www.epa.gov), the Interstate Technology and Regulatory Council (ITRC) web site (www.itrcweb.org), and the Federal Remedial Technology Roundtable (FRTR) web site (www.frtr.gov), among others.

6.4 VAPOR INTRUSION PATHWAY

Sites with soil, soil gas, and/or groundwater impacted by volatile chemicals should be evaluated to determine whether there is potential for migration from the subsurface into buildings. The *Interim Final Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air* (DTSC, 2005; revision pending) identifies the steps for completing a vapor intrusion analysis. If the estimated risk posed by the vapor intrusion pathway is deemed unacceptable, the *Vapor Intrusion Mitigation Advisory* (DTSC, 2009a; revision pending) should be consulted for ways in which this risk can be mitigated while the subsurface contamination is addressed.

6.5 GROUNDWATER IMPACTS

The primary groundwater cleanup objectives for a site typically include:

- hydraulic control of the plume
- source control or removal
- mass removal
- attainment of groundwater cleanup goals

Interim actions are often implemented to achieve hydraulic control of a groundwater plume and/or to control an on-going source to groundwater while the full scale remedy

is being evaluated, selected, and designed and while the nature and extent of contamination in groundwater is further evaluated. Table 4 and Appendix G identify technologies that are often applied to address hexavalent chromium and VOC impacts in groundwater. If other groundwater contaminants are present, resources for identifying an appropriate remedial technology can be found at the USEPA web sites (www.clu-in.org, www.epa.gov), the ITRC web site (www.itrcweb.org), and the Federal Remedial Technology Roundtable web site (www.frtr.gov), among others. As applicable, the feasibility of a given remedial approach should have been demonstrated through the pilot study process. An on-going groundwater monitoring program (see Section 6.5.5) should be established to allow evaluation of the nature and extent of the groundwater plume, to allow evaluation of remedial progress, to support remedy optimization, and to demonstrate achievement of RAOs.

Table 4. Likely Groundwater Remedies for Hexavalent Chromium and VOCs

<p>Removal & <i>Ex situ</i> Treatment</p> <ul style="list-style-type: none"> ▪ Excavation (above and/or below water table)^{3,4} ▪ Soil vapor extraction (SVE)^{1,4} ▪ Air sparging / SVE¹ ▪ Pump-and-treat ▪ Multi-phase extraction¹
<p>Containment</p> <ul style="list-style-type: none"> ▪ Impermeable barrier (e.g., slurry wall) ▪ Pump-and-treat
<p><i>In situ</i> Treatment</p> <ul style="list-style-type: none"> ▪ Bioremediation¹ ▪ Chemical oxidation¹ ▪ Chemical reduction (chemical fixation)² ▪ Permeable reactive barriers (PRBs) ▪ Thermal desorption / SVE¹ ▪ Electrical resistance heating / SVE¹
<p>Administrative Controls</p> <ul style="list-style-type: none"> ▪ Site controls ▪ Land-use restrictions ▪ Restrictions on groundwater usage

¹ VOCs only

² Hexavalent chromium only

³ See *PT&R Guidance – Remediation of Metals in Soil* (DTSC, 2008)

⁴ See *PT&R Guidance – Remediation of Chlorinated Volatile Organic Compounds in Vadose Zone Soil* (DTSC, 2010)

6.5.1 Hydraulic Control of Plume

Containment of the dissolved plume (such as through pump-and-treat systems) is a widely used strategy to prevent further spreading of contaminants (such as to nearby water supply wells) or to control the contaminant source. The objective of hydraulic containment is control of plume migration rather than mass removal. Hydraulic control is achieved by pumping groundwater at the down-gradient portion of the target containment zone (also known as a target capture zone), treating the water in an

aboveground treatment system, and discharging or reinjecting the water. Selected USEPA references for design and operation of pump-and-treat systems include:

- *Design Guidelines for Conventional Pump-and-Treat Systems* (Cohen et al., 1997);
- *Elements for Effective Management of Operating Pump and Treat Systems* (USEPA, 2002a);
- *Methods for Monitoring Pump-and-Treat Performance* (USEPA, 1994b); and
- *A Systematic Approach for Evaluation of Capture Zone at Pump and Treat Systems* (USEPA, 2008).

Extracted groundwater may require treatment before it is used, discharged, or reinjected. Examples of technologies that can be used for treating and removing VOCs include air stripping, granular activated carbon, and ion exchange resins. Additional references for pump-and-treat systems can be found on the USEPA web-page (www.epa.gov/superfund/health/conmedia/gwdocs/pum_tre.htm).

6.5.2 Source Control and Mass Removal

The strategies for controlling or removing groundwater sources depend on the types of source materials and contaminants. Sources of groundwater plumes can consist of solids (e.g., sludge, sediment, waste, soil), liquids (e.g., waste, NAPL), and vapors (e.g., soil vapor plumes). Strategies for source control typically consist of its removal, isolation, or *in situ* treatment. Access restrictions and population relocation may also be viable interim source control measures.

Table 4 summarizes likely options for controlling, containing, or removing groundwater contaminant sources and for achieving mass removal. Appendix G provides additional information and resources for the likely technologies for VOCs and hexavalent chromium, including the advantages and disadvantages of each technology. The type of groundwater remedy selected will depend on the nature of the groundwater impacts, the hydrologic conditions and, for some technologies, the groundwater geochemistry.

Some remedial technologies (e.g., excavation, impermeable barriers) are relatively straightforward and can be readily implemented provided that the site is sufficiently characterized (see Section 4.0). As discussed further in Section 6.5.4, other technologies (such as *in-situ* treatment technologies) may be implemented as a pilot study within a limited area of the site to evaluate the feasibility of the technology as a final remedy. Bench scale and treatability studies may be required prior to field-scale application. The need for RWQCB Waste Discharge Requirements (WDRs) is another consideration for *in situ* treatment technologies. Some RWQCBs have pre-approved WDRs for *in-situ* treatment technologies, making it easier to obtain a WDR permit.

6.5.3 Bench-Scale and Pilot Studies for *In-Situ* Treatment Technologies

In-situ technologies involve introduction of material into the subsurface to transform the contaminants into less toxic or non-toxic compounds. The transformation could be caused by chemical oxidation, chemical reduction or biological degradation by

microorganisms. The *in-situ* treatment technologies effective for hexavalent chromium reduce the metal to the less toxic trivalent form which precipitates out of solution. Typically, removal of hexavalent chromium from solution (as trivalent chromium) is considered to be permanent because the trivalent form is relatively insoluble, provided that it will not reoxidize under current and projected geochemical conditions at a site. *In-situ* treatment technologies have the potential to degrade VOCs to harmless compounds, provided that the reaction fully progresses to the innocuous end products. If the reaction stalls, the *in-situ* treatment processes may accumulate toxic daughter products (such as cis-1,2-dichloroethene and vinyl chloride).

Laboratory and field studies are necessary because the success of *in-situ* technologies relies on the effectiveness of the material in treating the contaminant as well as on the delivery and distribution of the material within the contaminated zone. Bench-scale laboratory studies are conducted to verify that the contaminants can be effectively transformed to less harmful compounds by the given chemical oxidant, chemical reductant or electron donor (biochemical reactant). The treatability study provides data regarding: oxidant, reductant, or electron donor demand; the reaction rate; and information about undesirable reaction byproducts that have to be managed. Data from the bench-scale and treatability studies are used in designing the pilot field demonstration studies.

The objectives of pilot studies are to assess the delivery of the injected material to the targeted area in the plume and to obtain information for designing the full-scale implementation. Pilot studies gather data to augment information obtained during the characterization phase (see Section 4), such as: feasible injection method, travel time, distribution, contaminant mobilization, reaction byproducts, adequacy of monitoring program, preliminary performance evaluation, fouling of wells, and cost.

Resources that may assist with the scoping and design of bench-scale and pilot-scale studies include:

- *Guide for Conducting Treatability Studies Under CERCLA* (USEPA, 1992);
- *Engineering Issue Paper, In-Situ Chemical Oxidation* (Huling and Pivetz, 2006);
- *In Situ Bioremediation of DNAPL Source Zones* (Moretti, 2005);
- *In Situ Bioremediation of Chlorinated Ethene DNAPL Source zones: A Resource Guide* (ITRC, 2007a);
- *Design Guidance for Application of Permeable Reactive Barriers for Groundwater Remediation* (Gavasker et al., 2000);
- *In Situ Permeable Reactive Barrier for the Treatment of Hexavalent Chromium and Trichloroethylene in Groundwater: Volume 1, Design and Installation* (USEPA, 1999b).

Additional resources are available at the USEPA, ITRC, and FRTR web sites (www.clu-in.org; www.itrcweb.org, www.frtr.org).

6.5.4 On-Going Groundwater Monitoring Program

A groundwater monitoring program should be established to allow periodic monitoring of groundwater impacts. This program is typically documented in a sampling and analysis plan (SAP) which identifies the frequency of sampling, analyses to be performed, gauging frequencies, reporting, and other program elements. Typical monitoring objectives include on-going evaluation of the nature and extent of the plume, assessment of plume stability, assessment of remedy effectiveness, and monitoring of sentinel wells. *Monitoring Well Design and Construction for Hydrogeologic Characterization* (Cal/EPA, 1995) provides guidance on monitoring well design and installation. *Representative Sampling of Groundwater for Hazardous Substances* (Cal/EPA, 2008) provides guidance on generating effective, meaningful, and representative groundwater chemistry data, including selection of sampling devices and analytical methods, recommended QA/QC procedures, and a standardized approach for the presentation of the resulting data. The document also identifies key references useful for development of a site-specific groundwater monitoring program.

6.5.5 Remedy Optimization

Decades of experience have shown that optimization (i.e., measures taken to improve the effectiveness of an existing remedy) of the selected groundwater remedy will be needed at one or more points in the lifespan of the groundwater cleanup. Optimization is particularly needed when remedy performance data indicate asymptotic (stabilized) concentrations remain above RAOs and/or that additional measures are needed for timely or cost-effective cleanup. Data collected since remedy selection may also drive remedy optimization. The *Remediation Process Optimization: Identifying Opportunities for Enhanced and More Efficient Site Remediation* (ITRC, 2004) provides general guidance for conducting remedial process optimization. Additional resources for remedy optimization can be found on the ITRC web-site (www.itrcweb.org).

Historically, the most common optimization effort has involved groundwater pump-and-treat systems, particularly as environmental practitioners realized the limitations of this technology in achieving mass removal and groundwater cleanup goals. Various guidance documents for optimization of groundwater pump-and-treat systems are available on the USEPA web-site.⁴

Other remedial approaches may also require optimization. For example, enhancements can be made to a multiphase extraction system to better recover VOCs from the capillary fringe that continue to serve as source of the groundwater or soil vapor plume. As another example, enhanced *in situ* bioremediation may require injection of additional substrate to ensure that reducing conditions are maintained until the plume is fully degraded. These optimization measures should be implemented according to the strategy outlined in the O&M plan (see Section 6.7.5) and as needed to meet the performance criteria established for the groundwater remedy.

⁴ www.clu-in.org/techfocus/default.focus/sec/Remediation_Optimization/cat/Guidance/page/3/#

Optimization may also entail the evaluation, selection, and implementation of an additional or alternate remedial approach. For example, it is not uncommon to change from a pump-and-treat remedy to an *in situ* treatment technology (see Table 4) or to non-treatment remedies such as institutional controls (ICs) or monitored natural attenuation (see next paragraph for further discussion). Common reasons for changing a pump-and-treat remedy include changes in the estimated plume extent or concentrations, hydrogeologic conditions, preference for a more effective *in situ* treatment remedy, and high costs (USEPA, 2007).

Monitored natural attenuation (MNA) may be a feasible approach for achieving the final remediation of a groundwater plume after completion of source removal (such as through excavation or SVE), NAPL removal, and primary mass removal. Several factors should be considered in a decision to use MNA, including (ITRC, 2007b): acceptable risks; plume stability; sustainability of conditions that enable natural attenuation; acceptable remediation timeframe; and acceptable cost-benefits. Some sites may require measures that enhance attenuation processes (via technologies designed to reduce source flux and/or increase the attenuation capacity or rate) in order to achieve cleanup goals within a reasonable timeframe (ITRC, 2007b). Additional guidance for evaluating the suitability of MNA at a given site can be found at the USEPA and ITRC web sites (www.clu-in.org; www.itrcweb.org).

6.5.6 Exit Strategy

Typically, the groundwater remedy decision document, and documents incorporated by reference, establish the framework for determining remedy completeness for a site. This framework is comprised of the nature and magnitude of estimated human health risks driving the remedy, the RAOs, the remedial approach, the remedy performance metrics, and a performance monitoring program. As the groundwater remedy progresses, the project team should evaluate (ITRC, 2006):

- whether the updated CSM and estimated risks (using data obtained since issuing the remedy decision document) affect the framework (e.g., estimated risks remain the same);
- cleanup progress (achievement of performance metrics) as demonstrated through confirmation sampling;
- remedy optimization needs (see Section 6.5.5); and
- contingencies that will facilitate timely remedy completion.

This process is often captured in a detailed yet succinct document referred to as the “exit strategy” (ITRC, 2006). See *Exit Strategy – Seeing the Forest Beyond the Trees* (ITRC, 2006) for additional discussion of exit strategies.

For sites in the San Francisco Bay area where groundwater impacts are derived primarily from VOCs, the *Draft Final Assessment Tool for Closure of Low-Threat*

Chlorinated Solvent Sites (SFRWQCB, 2009) is another resource that may be useful for consideration by an exit strategy.⁵ The document allows “low-threat closure” based on:

“the understanding that cleanup standards can be met under natural conditions within a reasonable timeframe, once adequate source control and plume remediation are complete and considering site-specific conditions, the future land use, and the likelihood of and timeframe for actual beneficial use of the affected water resources.”

The tool includes nine criteria for site closure that pertain to: (1) CSM development; (2) mitigation of risks to human health, the environment, and water resources; and (3) the need for source control and evaluation of potential adverse affects to future beneficial uses. The assessment tool recommends source evaluation and site characterization using high-resolution methods, demonstration of plume stability and decreasing extent, and appropriate monitoring timeframes that consider natural variability, post-remediation rebound, and MNA processes. The assessment tool also includes an evaluation of future groundwater use.

6.6 SITE CONTROL

While the interim removal action or final remedy is implemented and until the site is fully remediated, site conditions may warrant placement of controls to limit potential exposure to hazardous substances that may pose a health risk. These controls could consist of measures such as a site health and safety plan, site operations plan, and/or institutional controls (such as a LUC). Examples of site controls include:

- controlled entry to affected site areas,
- fencing and posting of the site,
- vapor intrusion mitigation,
- restrictions on excavation,
- surface water control measures, and
- paving of impacted surface soils.

For groundwater impacts, controls could be put in place to prevent activities that would contact impacted groundwater. In some cases, the controls may require a moratorium on water supply wells, whether as continued operation of existing wells or installation of new wells. These controls should be placed within the plume as well as surrounding areas and zones in which groundwater pumping may affect plume migration.

Guidance on risk evaluation during interim removal action or final remedy implementation, and thus determining the types of site controls needed, can be found in *Risk Assessment Guidance for Superfund (RAGS) Part C* (USEPA, 1991b).

⁵ Note that this document applies only to sites overseen by the San Francisco Bay Regional Water Quality Control Board (SFRWQCB). It is not a state-wide document.

6.7 DOCUMENT SUBMITTALS

This section describes various documents that may need to be submitted for agency review and approval during the process of evaluating, designing, and implementing an interim removal action or final remedy. Please recognize that some documents discussed below may not be applicable to a given site. Each of these documents should include title and signature pages (with appropriate signatures and stamps/licensure) and a table of contents. The documents should be prepared by professionals with appropriate technical expertise and licensure.

DTSC has developed a secured portal on its EnviroStor public web site for the electronic submission of documents and data. Information about DTSC's electronic submittal process can be found at the following link:
www.envirostor.dtsc.ca.gov/public/esi.asp.

6.7.1 Sampling and Analysis Plans

SAPs may be needed for various elements of remedy design, implementation, and O&M (e.g., for an on-going groundwater monitoring program, for confirmation sampling). SAPs should be submitted for agency review and approval prior to implementation. These plans should detail testing, sampling methods, sample analysis, DQOs, QA/QC protocols, and frequency of sampling. Appendix B provides additional discussion of sample collection and analytical techniques and identifies useful references for developing a SAP. Appendix E provides a link to an example SAP for site characterization activities.

6.7.2 Pilot Study Documents for *In-Situ* Treatment Technologies

Pilot studies for *in situ* treatment technologies should be conducted under an approved workplan. The results of these studies should be documented in a report and submitted for agency review. Appendix J includes annotated outlines for a generic pilot study workplan and report.

6.7.3 Design Documents

Design documents should be prepared for interim removal actions and the final remedy. Typically, these design documents should include the content discussed in this section. However, the actual content should be based on site-specific considerations, based on the subsurface cleanup objectives, and made in consultation with the DTSC project team. The design document should include a discussion of other documents that may be required for its proper implementation. Some design components offer an opportunity to consider green remediation concepts. For additional discussion, see the *Interim Advisory for Green Remediation* (DTSC, 2009b).

- **Introduction.** Identify the project, the purpose of the document, and the regulatory basis for the design.

- **Project Background.** Identify the rationale for the remedial technology, current and future property land use considerations, COCs, and other general project considerations. If appropriate, this section should also indicate how the interim removal action or final remedy is integrated with other subsurface remediation efforts and site activities.
- **Site Conditions Summary.** This section may reference previous documents (e.g., current conditions report, summary reports). However, an overview of the pertinent information should be provided along with references to other documents. The CSM should include the following:
 - site geology and hydrogeology
 - previous sampling efforts
 - list of COCs with maximum detected concentrations in each media
 - remediation efforts and cleanup goals
 - potential remediation treatment / degradation by-products
 - ambient air quality considerations
 - estimations of the risk associated with potential exposure pathways
- **Cleanup Goals and Objectives.** Identify the target area for remediation, technology-specific RAOs, COCs, cleanup goals, performance metrics, and contingency measures for the selected remedial technology. This section should identify how the goals and objectives will be monitored and tested and may identify general IC requirements and/or use restrictions.
- **Design Basis.** Identify the design assumptions and criteria to be met by each remedial technology. Describe the technology expectations by media based on the CSM and RAOs. Develop performance metrics to be used for remedy optimization.
- **Construction Methods.** Identify the construction methods to be used once the design has been approved, including:
 - construction specifications
 - minimum material requirements
 - installation procedures
 - construction QC procedures
 - post-installation testing procedures
- **Design Calculations and Drawings.** Include the design calculations and drawings for the remedial technology.
- **Conceptual Drawings.** Include conceptual drawings indicating building locations, prescribed building envelopes, streets, driveways, hard-scape areas, utility easements, and other infrastructure considerations.
- **Remediation Approach.** Provide a detailed description of the proposed remediation approach, including phasing (tier approach) concepts and the following information:

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- technical basis for the system design
 - construction and implementation requirements
 - any contingent systems which may be required
 - component specifications and verification of ability to meet performance measures
 - detailed testing procedures including on-the-job instructions
 - permit requirements from other agencies (such as a permit to construct or a permit to a vapor treatment system)
 - reporting requirements
 - applicable engineering drawings and system diagrams
- **Implementation Mechanism.** Identify the implementation mechanisms, such as LUC requirements, deed restrictions, and soil management plans.
 - **Health and Safety Plan.** Include a worker health and safety plan that addresses such topics as worker training requirements, protective gear, and monitoring procedures.
 - **Operation and Maintenance Plan.** Include an O&M plan that, among other provisions, includes the O&M requirements, monitoring and reporting, implementation mechanisms, responsibilities for tasks, and obligations. See Section 6.7.5 for recommended content.

Based on the project needs, a “conceptual” plan submittal and approval may be necessary prior to submittal and approval of the final system engineering plans. The review and approval of the system design may require a phased approach and may include the need for pilot-scale testing, system validation and startup testing, and agency review prior to final approval.

6.7.4 Construction Completion/Final Installation Report

A report detailing the cleanup technology installation and startup should be submitted for agency review and approval after system construction. The report content should reflect project-specific considerations and should be developed in consultation with the DTSC project team. Typically, these reports include:

- record documents of all system components and monitoring points
- copies of permits
- brief account of field activities associated with the system installation and startup
- baseline data (if any)
- initial post-startup test data and monitoring results
- description of any deviations from the approved design
- description of any issues associated with startup
- complete analysis and interpretation of the data

- raw data (in a format requested by the oversight agency)

6.7.5 Operation and Maintenance Plan

An O&M plan should be developed for interim or final actions that require on-going operation (e.g., SVE system, groundwater pump-and-treat system). The O&M plan should identify the specific performance goals for the remedy as well as the methods by which the performance goals will be tested and verified. The plan should provide the O&M strategy, operational guidelines, monitoring parameters, and system modification considerations. The O&M plan should be as flexible as possible and should include contingencies for possible operational problems and system failure, including appropriate notifications. The elements of the O&M plan will depend on the type of remedial approach. In general, the plan should include the following elements:

- O&M strategy (including the general goals and objectives, a hazard summary, personnel roles and responsibilities, and costs)
- description of the site and remediation system
- remedy objectives
- performance goals and associated performance metrics
- anticipated timeframes for achieving the remedy objectives and conducting remedy optimization
- O&M activities, including routine inspections, responses to unplanned events, system maintenance and repair
- operation schedule
- considerations for system evaluation, modification, and optimization
- performance assessment methods
- optimization strategy
- decision process for improving remedy performance
- criteria for system shutdown and judging remedy completion
- methods for confirming achievement of RAOs
- monitoring
- reporting and recordkeeping
- site access
- references

Appendix E includes a link to a sample O&M plan for a cover/cap. O&M plan elements for a SVE system are discussed in *PT&R Guidance – Remediation of Chlorinated VOCs in Vadose Zone Soil* (DTSC, 2010). Additional O&M plan references are available on the USEPA web-site (www.epa.gov/superfund/cleanup/postconstruction/operate.htm).

6.7.6 Periodic Monitoring Reports

An appropriate monitoring and reporting program should be established to:

- evaluate remedy progress, including the efficiency and effectiveness at meeting the RAOs
- evaluate whether the remedy is operating as designed
- assure protection of potentially exposed receptors
- monitor changes in site conditions
- support decisions regarding the need to optimize the remedy
- demonstrate progress toward achieving RAOs using established performance metrics
- demonstrate achievement of cleanup goals and RAOs
- evaluate any concentration rebound after shutdown of active systems
- support site closeout

Periodic monitoring reports on the cleanup technology operations and cleanup status should be submitted for agency review and approval. The content of these reports will depend on the type of technology and the environmental media, but will generally include:

- introduction that identifies the purpose and scope, the authority under which the monitoring is conducted, and SAP under which the monitoring is conducted
- description of the cleanup technology and monitoring program (e.g., monitoring locations, parameters, frequency)
- description of system operations for the monitoring period (e.g., mass removed, concentration decreases, volume treated)
- field and laboratory data (including summary tables, appropriate figures, graphs, lab data sheets, and comprehensive tables)
- field documentation (e.g., chain of custody, sample collection forms)
- inspection results and documentation (e.g., system infrastructure, well condition)
- description of deviations from the approved field sampling plan or O&M plan
- interpretation and discussion of data, including whether the system is meeting performance metrics
- recommendations for system operations, modifications, and ongoing monitoring

6.8 OPERATION AND MAINTENANCE

As discussed further in Section 8.0, long-term stewardship applies to sites and properties where on-going management of contaminated environmental media is necessary to protect human health and the environment. The mechanism under which

O&M is conducted depends on the type of site. O&M requires several components, including:

- **Institutional Controls.** ICs such as LUCs will be required when hazardous substances are present at concentrations which pose a risk to human health and the environment. Further discussion of ICs and LUCs is provided in Section 8.0.
- **Financial Assurance.** If applicable, financial assurance can be accomplished by several mechanisms and will be required to assure that sufficient monies are available to implement required cleanup activities and on-going O&M activities and to pay the regulatory oversight costs associated with those activities and IC implementation. Because the acceptable types of mechanisms are limited, DTSC should be consulted prior to securing financial assurance.
- **Regulatory Oversight Agreement.** A regulatory oversight agreement will be required for as long as O&M activities are necessary to protect human health and the environment. Examples include Corrective Action Consent Agreements and O&M agreements.
- **O&M Plan.** The regulatory oversight agreement should reference or include the approved O&M plan that outlines the procedures and requirements for on-going O&M of the interim action. Section 6.7.5 outlines the general content of an O&M plan.
- **Contingency Plan.** The regulatory oversight agreement should reference or include a contingency plan that will be implemented in the event that a response action is required to ensure protection of human health and the environment. The contingency plan may be a standalone document or may be included as an element of the O&M plan.

7.0 CERTIFICATION / COMPLETION

When the approved remedy has been fully implemented, DTSC will confirm through review of performance metrics (including confirmation sampling) that the RAOs have been achieved. The possible determinations are:

- the RAOs have been achieved;
- the response action has been fully implemented, is operating successfully, and ongoing O&M is needed until the RAOs are achieved; and/or
- additional cleanup is necessary.

Based on the findings, DTSC will issue a certification letter, a completion letter, or a letter requiring additional work to address impacts related to plating operations.

7.1 SITE CERTIFICATION

When DTSC determines that the approved remedy has been fully implemented, DTSC certifies the satisfactory completion of remedial action activities at the site. The certification will have one of the following outcomes:

- When DTSC determines that the approved remedy has been fully implemented and the remediation results in a site restored to unrestricted residential standards, DTSC certifies that the required remedy has been completed and that no further remediation is necessary, unless new information is obtained. The site status on DTSC's EnviroStor database is changed from "Active" to "Certified".
- If the site has been remediated to standards appropriate for restricted use of the property, DTSC issues a certification letter that the site environmental media has been restored to levels agreed upon in the regulatory decision document. The certification letter is issued after any requirements for a LUC and/or O&M agreement and O&M plan are met. The site status on DTSC's EnviroStor database is changed from "Active" to "Certified/O&M - Land Use Restrictions Only".
- If the approved remedy includes actions requiring operation, maintenance, and monitoring (e.g., SVE systems), DTSC certifies that the remedy has been implemented once: (1) sufficient information has been submitted to verify that the remedy has been implemented and is functioning as proposed in the remedy selection document and in design plans; and (2) any LUC, O&M agreement, and O&M plan requirements have been met. The DTSC certification letter will describe the remedy implemented and will state that DTSC has continuous oversight and the responsible party is required to operate and maintain the measures necessary for on-going protection of public health and the environment. The Site status on DTSC's EnviroStor database is changed from "Active" to "Certified/Operation and Maintenance".

7.2 COMPLETION LETTER FOR INTERIM ACTIONS / INTERIM MEASURES

Removal actions may be implemented as interim actions or interim measures taken to begin the cleanup process while the final remedy is being evaluated and selected. Examples of this include actions taken to reduce the mass of contaminants, actions taken to address soil contaminants while remedies for groundwater are being evaluated, and measures taken to mitigate vapor intrusion. For these cases, the site is not ready for certification following the implementation of these actions. DTSC will issue a completion letter acknowledging that the removal action has been implemented and that additional actions are required to address contaminants remaining at the site.

7.3 ADDITIONAL ACTIONS NEEDED

Achievement of the RAOs outlined in the remedy decision document may not be possible. For these cases, DTSC will issue a letter acknowledging that the removal action was implemented, noting that the RAOs were not achieved, and requiring that the remaining contamination should be addressed through a subsequent response action.

8.0 LONG-TERM STEWARDSHIP

Long-term stewardship applies to sites and properties where long-term management of contaminated environmental media is necessary to protect human health and the environment over time. This includes sites where remediation may take place over several years and sites where contaminated media will remain in place for a much longer period of time. This section discusses elements that may be required to meet the needs of long-term stewardship. The elements included below may not apply to all sites based on site-specific conditions and remedial timeframes.

In addition to the following discussion, information regarding long-term stewardship can be obtained from the:

- U.S. Environmental Protection Agency
(www.epa.gov/landrevitalization/ltstf_report/whatis_longterm_stewardship.htm)
- Association of State and Territorial Solid Waste Management Officials
(www.astswmo.org/resources_longtermstewardship.htm)

Also, DTSC is developing guidance on long-term stewardship. When available, the guidance will be posted on DTSC's web-site (www.dtsc.ca.gov).

8.1 INSTITUTIONAL CONTROLS FOR CONTAMINATION REMAINING IN PLACE

ICs are used to stop or reduce the exposure of human and environmental receptors to residual contamination. ICs are non-engineering mechanisms used to ensure that the intended future land use is consistent with site cleanup and engineering controls, and that these measures maintain their integrity and effectiveness.

For sites at which ICs are necessary, California Code of Regulations, title 22, section 67391.1 requires the property owner to enter into a LUC to ensure that DTSC will have authority to implement, monitor, and enforce the protective restrictions. LUCs allow on-going use of the property as long as the remedy is not compromised by current or future development. LUCs are intended to protect public health and the environment by preventing inappropriate land use, increasing the probability that the public will have information about residual contamination, ensuring that long-term mitigation measures are carried out by protecting the engineering controls and remedy, and ensuring that subsequent owners assume responsibility for preventing exposure to contamination. The LUC should provide for an annual inspection and annual report to ensure that the LUC continues to be protective. The LUC should also provide for preparation and submittal of five-year reviews.

LUCs may include, or incorporate by reference, soil management plans to ensure that contaminated soil remaining in place after remedy implementation is properly managed and handled in such a way to prevent human and ecological exposure. These plans address soil excavation, soil stockpiling, stockpile characterization, soil disposal, soil reuse, construction dewatering, worker training, health and safety, and site inspection.

California Code of Regulations, title 22, section 67391.1 requires that a LUC imposing appropriate limitations on land use shall be executed and recorded with the local county recorder's office when hazardous materials, hazardous wastes or constituents, or hazardous substances will remain at the property at levels which are not suitable for unrestricted land use. The regulation requires DTSC to clearly set forth and define land use limitations or covenants in a remedy decision document prior to approving or concurring with any facility closure, corrective action, remedial or removal action, or other response actions. In addition to these regulatory requirements, it may also be prudent to coordinate with the local planning department regarding the LUC requirements. Further information regarding LUCs is available on the DTSC web site (www.dtsc.ca.gov). After the LUC is recorded, if a proposed use of the property is inconsistent with the LUC requirements and/or would increase the risk of exposure to contaminants at the site, additional actions must be conducted to ensure that the property meets cleanup standards appropriate for the proposed use. Additional sampling and risk characterization for further cleanup actions may be required, and the LUC may be rescinded or modified as appropriate.

8.2 REGULATORY OVERSIGHT AGREEMENT

A regulatory oversight agreement will be required for the period during which the remedy is operated and maintained. Examples include Corrective Action Consent Agreements and O&M Agreements.

8.3 OPERATION AND MAINTENANCE PLAN

Any regulatory oversight agreement should reference or include the DTSC-approved O&M plan that outlines the procedures and requirements for on-going O&M of the remedy. Section 6.7.5 describes selected elements of an O&M plan.

8.4 CONTINGENCY PLAN

Any regulatory oversight agreement should reference or include a contingency plan that will be implemented in the event that an immediate response action is required to ensure protection of human health and the environment. Also, the contingency plan should address steps to be taken if performance assessment indicates that the removal action is insufficient and/or will not achieve the RAOs. The contingency plan may be a stand-alone document or may be included as an element of the O&M plan.

8.5 FINANCIAL ASSURANCE

Financial assurance can be accomplished by several mechanisms and will assure that sufficient monies are available to implement any required corrective action activities and on-going O&M activities, conduct necessary five-year reviews, and pay the regulatory oversight costs associated with those activities and IC implementation. These on-going costs should be included in the cost calculation utilized in the remedy selection process.

8.6 FIVE-YEAR REVIEW

The regulatory oversight agreement and the O&M plan should include provisions for conducting five-year reviews.⁶ The purpose of the five-year review is to ensure that the remedy remains protective of human health and the environment, is functioning as designed, and is maintained appropriately by O&M activities. The review generally addresses the following questions:

- Is the remedy functioning as intended?
- Are the cleanup objectives, goals, and criteria used at the time of cleanup alternative selection still valid?
- Have there been significant changes in the distribution or concentration of impacted soils at the site?
- Are modifications needed to make the remedy or the O&M plan more effective?

The five-year review may also include a remedy optimization evaluation (e.g., sustainability assessment), as discussed further in the *Interim Advisory for Green Remediation* (DTSC, 2009b).

The scope of the five-year review may be outlined in the O&M plan or in a separate workplan developed for a specific review. The following should be incorporated into the five-year review:

- notification of the community that the review is being conducted;
- inspection of the remedy;
- review of the data demonstrating the performance of the system;
- review of other components of the remedy; and
- preparation of a report that details the findings and recommendations of the review.

The *Comprehensive Five-Year Review Guidance* (USEPA, 2001) may be a useful resource when conducting these reviews.

Depending on site-specific considerations, the inspection and/or technical assessment may be conducted by DTSC and/or the responsible party. DTSC will review the report and make recommendations, if necessary, to ensure that the remedy remains effective, to identify milestones toward achieving or improving effectiveness, and to provide a schedule to accomplish necessary tasks.

The five-year review report should be prepared in conformance with standard geologic and engineering principles and practice using appropriately State of California licensed and experienced professionals.

⁶ Five-year reviews are not applicable to corrective action sites.

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⁷ Revision pending. Check DTSC's web site (www.dtsc.ca.gov) for the latest version.

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GLOSSARY

ARARs. Section 121(d) of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) requires that onsite remedial actions attain or waive federal environmental “applicable or relevant and appropriate requirements” (ARARs), or more stringent State environmental ARARs, upon completion of the remedial action. The 1990 National Oil and Hazardous Substances Pollution Contingency Plan (NCP) also requires compliance with ARARs during remedial actions and during removal actions to the extent practicable.

Background. Metals concentrations that represent only pristine or natural conditions often are referred to as “background” concentrations. In some instances, nonspecific offsite sources may also have contributed to the “background” concentration (i.e., ambient sources). For the purposes of this guidance document, the general term “background” will be used to refer to soil or groundwater that has not been affected by site-related releases.

Brownfields. Brownfields are properties that are contaminated, or thought to be contaminated, and are underutilized due to perceived remediation costs and liability concerns. Redeveloping urban brownfields properties optimizes the use of existing infrastructure and protects state resources.

Capillary fringe. Zone of soil immediately above the water table in which the soil pores in this zone act like capillary tubes casing groundwater to rise within the pore. The water in this zone is retained under suction (e.g., lower pressure). At the base of the capillary fringe most soil pores are completely filled with water. At the top of the capillary fringe, only the smallest soil pores are filled with water.

Capping. Impacted soils are isolated by placement of a barrier to prevent exposure and/or reduce surface water infiltration.

CERCLA. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as Superfund, was enacted by Congress on December 11, 1980, and amended in 1986, by the Superfund Amendments and Reauthorization Act (SARA). CERCLA provided broad federal authority to respond directly to releases or threatened releases of hazardous substances that may endanger public health or the environment. CERCLA established prohibitions and requirements concerning closed and abandoned hazardous waste sites, provided for liability of persons responsible for releases of hazardous waste at these sites; and established a trust fund to provide for cleanup when no responsible party could be identified.

CEQA. The California Environmental Quality Act (Public Resources Code, §21000 et seq) requires public agencies to disclose and consider the environmental implications of their decisions, and to eliminate or reduce the significant environmental impacts of their decisions whenever it is feasible to do so.

Chemicals of concern. Chemicals of concern (COCs) are the compounds exceeding screening levels and are included into the risk assessment.

Cleanup goal. Concentration value against which the success or completeness of a cleanup effort is evaluated.

Conceptual site model (CSM). Tool to help organize and communicate information about the site characteristics. The CSM summarizes how and where contaminants are expected to move, what receptor(s) might be exposed, what the problem is, and why a response is needed.

Corrective Measures Study. The corrective measures study is the mechanism for the development, screening, and detailed evaluation of alternative response actions under the corrective action process.

Feasibility Study. Under the National Contingency Plan process (used by DTSC under California HSC Chapter 6.8), the feasibility study is the mechanism for the development, screening, and detailed evaluation of alternative remedial actions.

HSAA. Hazardous Substances Account Act, Health and Safety Code, division 20, chapter 6.8.

HWCL. Hazardous Waste Control Law, Health and Safety Code, division 20, chapter 6.5.

Institutional Control. Institutional controls are actions, such as legal controls, that help minimize the potential for exposure to contamination by ensuring appropriate land or resource use.

Interim Actions. Interim actions are short-term response actions performed pursuant to CERCLA or HSAA to control on-going risks while site characterization is underway or before a final response action is selected.

Interim Measures. Interim measures are short-term response actions performed pursuant to RCRA or HWCA to control on-going risks while site characterization is underway or before a final response action is selected.

Land Use Covenant. Written instruments used to require compliance with certain obligations and restrict use of property. Land use covenants are recorded at the county recorder's office so that they will be found during a title search of the property deed.

Metals. Metals are defined as any element that has a characteristic luster, is usually in solid form, is malleable and ductile, and is usually a good conductor of heat and electricity. These elements are referred to by various terms, including alkali metals, alkaline earth metals, transition metals, trace metals, heavy metals, micronutrients, and toxic metals. For the purposes of this document, metalloids (e.g., arsenic, antimony, selenium) are also considered metals because these elements exhibit metallic properties.

National Contingency Plan. The National Oil and Hazardous Substances Pollution Contingency Plan [40 Code of Federal Regulations sections 300.1 - 300.920], more commonly called the National Contingency Plan or NCP, is the federal government's blueprint for responding to both oil spills and hazardous substance releases. The NCP includes a framework for responding to hazardous substance spills.

Optimization. Actions taken to improve the effectiveness and efficiency with which a response action reaches its stated goals.

Performance metrics. Criteria used to measure of the performance of a response action.

Proven technology. Technologies demonstrated by engineering and scientific analysis of performance data that are consistently selected for various types of sites based on contaminants, environmental media, extent of impacts, and potential risks.

RCRA. The Resource Conservation and Recovery Act, an amendment to the Solid Waste Disposal Act to address the huge volumes of municipal and industrial solid waste generated nationwide. Under RCRA, USEPA has the authority to control hazardous waste from the "cradle-to-grave." This includes the generation, transportation, treatment, storage, and disposal of hazardous waste. RCRA also sets forth a framework for the management of non-hazardous wastes. [Title 40 of the Code of Federal Regulations, Parts 239 through 282]

Remedial Action Plan. Under the HSAA, the RAP is the response action selection document for a remedial action for which the capital costs of implementation are projected to cost \$2,000,000 or more.

Removal Action Workplan. Under the HSAA, the RAW is the response action selection document for a nonemergency removal action that is projected to cost less than \$2 million at a hazardous substance release site.

Response action. Activity undertaken to prevent, minimize, or mitigate damage which may result from a release or threatened release.

Risk Assessment. The scientific process used to estimate the likelihood that a chemical detected at a site may be harmful to people or the environment.

Risk Management. The process of evaluating alternative regulatory and non-regulatory responses to risk and selecting among them. The selection process necessarily requires the consideration of scientific, legal, economic and social factors.

Site characterization. Process of determining the type, quantity, and location of contaminant releases at a site. Also includes assessment of site characteristics that affect how and where the contaminant may move and the how human health and the environment are or may be affected.

Soils. Loose material on the surface and in the subsurface consisting of solids (i.e., mineral grains, organic matter), water, and air.

Soil vapor. Air or gas in soil pore spaces.

Soil vapor extraction (SVE). SVE is used to remediate vadose zone soil by applying a vacuum that induces the controlled flow of air to remove volatile and some semivolatile organic contaminants from the soil.

Vadose zone. The unsaturated zone between the land surface and the top of the groundwater table. Water within this zone is referred to as soil moisture.

Waste Discharge Requirements (WDRs). Permit issued by the appropriate Regional Water Quality Control Board for waste discharges to California's surface, coastal, or groundwater.

APPENDIX A
CONCEPTUAL SITE MODEL FOR PLATING FACILITIES

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CONCEPTUAL SITE MODEL FOR PLATING FACILITIES

A conceptual site model (CSM) is a representation of the nature, extent, and fate of chemicals of concern (COCs) based on the currently available information for a given plating facility. The CSM is developed early and updated throughout the site characterization process. It continues to be refined and updated based on information gathered during remedy selection and remedy implementation.

The CSM is a scientific hypothesis that is tested, modified, and refined until confident decision-making is possible. During the characterization phase, the CSM is a useful communication tool to direct risk-specific sampling at the site. The CSM also allows assessment of the potential exposures to contamination. Stakeholders use the CSM to evaluate strategies to protect public health and the environment.

Typically, a CSM integrates subsurface characterization with a pathway-exposure assessment, and contains the following elements: contaminant sources; potential release mechanisms; affected environmental media; exposure pathways; and human and ecological receptors. A valid CSM should reflect an understanding and include a description of the following:

- data quality objectives (DQOs);
- nature of the release (such as substances, timing, duration, volume, and location);
- contaminated and potentially-impacted environmental media;
- transport mechanisms [such as: advection; diffusion; dispersion; colloidal and suspended transport; adsorption; desorption; volatilization; gravity-driven flow of non-aqueous phase liquid (NAPL) or highly-concentrated solutions; cross-media transfer (e.g., from soil gas to perched groundwater, from soil gas to shallow groundwater)];
- migration pathways, taking into consideration surface topography, surface water, geologic units, and man-made structures;
- receptors (including humans, supply wells, sensitive flora and fauna, groundwater, surface water, sediment, and existing structures).

Additional information for the development of a CSM can be found in USEPA (1996), USEPA (2008), DTSC (2008), and DTSC (2010).

AREAS OF CONCERN AND CHEMICALS OF CONCERN

A preliminary CSM identifies COCs and areas of concern (AOCs) within the context of the environmental setting and discusses the rationale for such identification. Table A-1 identifies common AOCs for plating facilities and similar commercial/ industrial operations. Table 1 of the main text lists some of the chemicals that may be associated with these AOCs.

POTENTIALLY-IMPACTED ENVIRONMENTAL MEDIA

Soil. Soils can be contaminated as a result of seepage of contaminated liquids through cracks in the foundation or piping and/or contact with solid waste sludge deposits. Spillage may occur when workpieces are moved from tank to tank. Indirect releases may include: liquid waste or wastewater in unlined concrete pits, sumps, clarifiers, ditches, or ponds; leaking tanks or containers in storage areas or process areas; and cracked, corroded, and uncoated floors. Floors, walls, or sewer lines that are cracked or severely corroded may be an indication of potential routes for migration to soils. Solid waste sludge accumulated in unlined waste pits/piles can be a source of soil contamination. Particulates escaping a point source emission release location are often distributed by natural air currents before settling out due to gravity and resulting in surface soil impacts. Airborne metals and VOCs can be distributed over a wide area, generally downwind from the facility.

Soil Vapor and Indoor Air. Some chemicals used in plating operations are volatile in nature and, when released, may form vapor plumes in soil. These vapor plumes may pose a threat to human health and the environment (such as vapor intrusion into indoor air).

Surface Water, Sediment, and Groundwater. Compounds used in plating processes and associated activities may have been flushed down drains and/or sumps and released to the stormwater collection system, thus impacting surface water and sediment within the system. Stormwater runoff from maintenance areas and/or other paved areas may contain compounds (e.g., oils, solvents, and grease) associated with activities conducted in these areas (USEPA, 1999). Surface runoff in contact with contaminated soils or soils/sludges in unlined waste piles with leachable levels of metals or organics can lead to contaminated surface water, sediment, and/or groundwater. Deposition of airborne contaminants from plating operations may also contaminate surface water. Wastewaters discharged to onsite lagoons (or surface impoundments) could have resulted in sediment and groundwater contamination.

CSM EVOLUTION DURING SITE CHARACTERIZATION

The CSM is the starting and ending point for any investigation and evolves throughout the site characterization process. When developing an early CSM, the environmental professional should consider all potential release mechanisms and environmental behavior for the COCs associated with each AOC. Table A-1 presents common AOCs for plating facilities and identifies possible release mechanisms and locations that should be considered. Completion of the *Tiered Permitting Phase I Environmental Assessment Checklist* (DTSC, 1999) may provide additional information for inclusion in the CSM. Often, existing information from the site may be readily available and can be utilized to enhance the CSM. Examples of this information include:

- depths and thickness of subsurface geologic units based on boring logs, cone penetrometer logs, and geophysical logs
- depth to groundwater, flow direction(s), and possible interaction with surface water bodies (including initial and time-series measurements of depth to ground water)

INVESTIGATION AND REMEDIATION OF PLATING FACILITIES

- existing soil, groundwater, and soil gas analytical data

Once the preliminary CSM has been completed, the next step is to define the investigation purpose and develop decision criteria. Common investigation purposes include:

- finding the source(s) of contamination
- identifying and characterizing the geologic zones and hydrostratigraphic units beneath the site, including the development of geologic cross-sections, measurement of hydraulic properties, and estimation of contaminant migration rates
- determining the nature, distribution, and extent of contamination
- assessing potential risks to human health and the environment
- identifying likely or potential future use of the site
- determining the type of cleanup action(s) required
- tracking the long-term effectiveness of remediation systems

The CSM and investigation purpose will determine the types of sample collection and analytical techniques (see Appendix B).

The CSM is updated based on data collected during each phase of investigation. The CSM is often used to determine when the investigation is complete. A complete site characterization should provide data of sufficient quantity and quality to develop and support a CSM that explains the distribution of contaminants in the context of the geologic and hydrologic framework, as well as the cultural setting, and how this distribution changes over time. The CSM continues to be used after completion of the characterization phase.

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Table A-1. Common Areas of Concern for Plating Facilities

COMMON AOCs	POSSIBLE RELEASE MECHANISMS	EXAMPLES OF LIKELY RELEASE LOCATIONS APPROPRIATE FOR SAMPLING & ANALYSIS
Floor Drains, Trenches, and Sumps, Clarifiers	Leaks through cracks, joints, or pervious sections of drains, and through pipe fittings and bends	Beneath and/or adjacent to the drain, trench, or sump at cracks, joints, and pervious sections, and beneath and/or adjacent to pipe fittings and bends
Interior Material Handling/Use Areas (e.g., metal machining, degreasing, plating)	Chronic drips, spills, and leaks to floor	Beneath and/or adjacent to handling/use areas at stained floors, cracks, or joints
	Leaks through associated floor drains, trenches, piping, and sumps	Beneath and/or adjacent to the drain, trench, or sump at cracks, joints and pervious sections, and beneath and/or adjacent to pipe fittings and bends
Interior Chemical Storage Areas	Leaks, spills from overfill containers, leaks from spigots, accidental container punctures	Beneath stains on floor, and/or in the immediate area of the stored materials. Beneath joints or cracks in the floor through which released substances may have preferentially migrated (e.g., joint between building wall & floor)
Septic Tanks, Leaching Fields, Drywells, Wastewater Treatment Facilities	Leaks from septic tanks, piping and distribution boxes	Beneath and/or directly adjacent to the tanks, solid piping and distribution boxes, and at pipe fittings and bends
	Designed discharges to leaching beds, galleries, drywells	Beneath and/or directly adjacent to leaching components and drywells
Loading Docks and Delivery Areas	Spills	Cracks in the pavement/asphalt, low lying areas, areas of stained soil and/or stressed vegetation
Aboveground Storage Tanks	Tank Leak	Beneath and/or near tank at nearest downslope, low lying, pervious area
	Piping/valve/dispenser leaks	At/beneath fittings and pipe segments subject to leakage
	Overfills	Beneath and/or adjacent to the fill pipe/dispenser, at nearest downslope, low lying, pervious area

Table A-1 (Continued)

COMMON AOCs	POSSIBLE RELEASE MECHANISMS	EXAMPLES OF LIKELY RELEASE LOCATIONS APPROPRIATE FOR SAMPLING & ANALYSIS
Underground Storage Tank Systems	Tank Leak	Underlying native soil at each end of tank, sidewall samples at depth of tank bottom
	Piping/valve/dispenser leaks	In the vicinity of buried pipe fittings and swing joints, beneath product lines along the piping run, beneath the dispenser island, particularly when no dispenser pans are present
	Overfills	Beneath and/or adjacent to the fill pipe/dispenser, at nearest downslope, low lying, pervious area
Exterior Chemical Storage Areas	Leaks, spills from overfull containers, leaks from spigots, accidental container punctures	Beneath and/or near storage area at nearest downslope, low lying, pervious area, near entrances Beneath joints or cracks through which released substances may have preferentially migrated
Transformers, capacitors and other equipment with polychlorinated biphenyls	Leaks, explosions, spillage	Beneath and/or near equipment, at nearest downslope, low lying, cracks/joints, pervious area
Dumpsters/Waste Containers	Leaks, overfills, spillage	Beneath and/or near equipment, at nearest downslope, low lying, cracks/joints, pervious area
Buried and Above Ground Piping (e.g. sewer, process)	Pipe Leaks	Beneath and/or adjacent to the piping, at fittings, bends, and segments subject to corrosion
	Pipe discharge points to ground surface or surface water	At the discharge point
Door/Window Disposal Areas	Spills and waste “dumping”	At nearest downslope, low lying, cracks/joints, pervious area, likely disposal areas
Landfill, waste piles, pits, trenches, ponds, lagoons, and fill areas	Intentional placement, often in accordance with acceptable practice during a prior time	Within the placed materials
Roof drains, air vents	Fallout of airborne COCs and/or condensation from process exhaust vents directly to ground or to roof tops and with subsequent entrainment into roof runoff	Beneath and/or downslope of nearest vents and/or roof drain outlets, taking into consideration air flow and runoff patterns

APPENDIX B
SAMPLE COLLECTION AND ANALYTICAL TECHNIQUES

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SAMPLE COLLECTION AND ANALYTICAL TECHNIQUES

This appendix addresses methods and procedures used to collect and analyze samples for chemicals of concern (COCs) associated with plating facilities or similar commercial/industrial operations. See Appendix A for discussion regarding the determination of areas of concern (AOCs) and COCs. As discussed in Section 4.2 of the main text, the characterization workplan is considered the data collection and analysis program for a specific site.

NUMBER AND LOCATION OF SAMPLES

The appropriate number and location of samples for an AOC should be based on the sampling strategy selected. The sampling strategy (e.g., grid, focused/biased) should be based on the level of detail known about the AOC and potential release mechanisms. Typically, focused sampling is appropriate where observations and existing data indicate that a release is most likely to be detected, whereas grid sampling is appropriate when the specifics about a potential release are not known. It is recommended that sampling strategies be developed in consultation with the DTSC project team. Some strategies (e.g., multi-increment sampling, composite sampling, confirmation sampling) may warrant discussions with and concurrence from the DTSC project team prior to being proposed in a sampling workplan.

The selection of sampling locations and depths should consider the release mechanisms (see Appendix A) and fate and transport of contaminants. The depths at which samples will be collected should be based on the depth at which a release is most likely to be detected. Some examples of fate and transport and migration pathways to consider in the sampling plan design include:

- Liquid spills to exterior paved surfaces may flow downslope to a nearby low-lying area, where the liquid may accumulate and permeate into the underlying soils. Hence, analyzing samples from immediately below the release point alone may not be sufficient. Analyzing samples from the low-lying area is often warranted.
- Non-aqueous phase liquid (NAPL) and other liquid substances will generally migrate vertically through relatively small preferential pathways that can be difficult to detect in a site investigation. The NAPL or liquid substances may spread laterally at stratigraphic changes, the capillary fringe, or the water table [see Appendix A of *PT&R Guidance – Remediation of Chlorinated VOCs in Vadose Zone Soil* (DTSC, 2010) for further discussion of NAPL migration]. To address these migration mechanisms, sample collection should occur where the NAPL or other liquid is most likely to have collected or reached.
- Volatile organic compounds (VOCs) from a release to the ground surface may have volatilized from the uppermost soil horizon and may only be detectable in a lower interval. The fate and transport and rate of biodegradation of VOCs are highly dependent upon the media, available oxygen, and the toxicity of the chemical to microorganisms. Continuous vertical sampling and field screening for related COCs may be used to help select the appropriate sampling interval for analytical testing.

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- Releases of high or low pH solutions may result in changes in the natural pH in the subsurface and/or mobilization of historical COCs. Analysis for pH can be useful for assessing whether a release has occurred.
- The geology of a site will control where contaminants migrate. Once the geology is defined at a particular site, predicting where the contaminants may migrate becomes more reliable.

The design of a site characterization plan should understand and consider:

- the COCs and contaminant migration pathways,
- fate and transport characteristics of each COC,
- the potential preferential pathways,
- the potential chemical and physical changes to the COCs, and
- how COCs from a potential release could be affected by, or interact with, the environment.

An understanding of physical, chemical, and biological processes provides insight into the migration pathway of contaminants, rate of COC degradation, and rate of transport. This insight is important to understand the spatial and temporal distribution of contamination and to predict the potential impact of contamination on receptors. Factors that affect the spatial distribution include the rate and direction of migration and preferential pathways. Factors that affect the temporal variations of contaminant concentration and distribution include physical or chemical processes (such as advection, adsorption, absorption, dilution, phase transfer, oxidation/reduction, biodegradation, dispersion, and diffusion). Compounds produced by contaminant degradation should also be considered in determining the degree and extent of contamination at the site.

INVESTIGATION APPROACHES

Once the types of contaminants and potential locations have been established, the mechanical collection of soil matrix, vapor, or groundwater samples can begin. In many cases, site investigations can be streamlined using systematic planning, dynamic work strategies, and field-based measurements.

Onsite decision making by experienced environmental professionals can be coordinated ahead of time through scoping meetings and specified in the workplan with mutually agreeable review and work schedules. The workplan should include decision criteria for guiding field decisions. The field team should include a senior authority that has the confidence of the project team to effectively transmit information and to execute project decisions in the field. Recent advances in communication technologies and communication plans support modern dynamic strategies. Conference calls, mobile telephones, wireless email, and Internet access, decision support software, videostreaming, and faxes, are among the tools that can be applied to facilitate communication among team members.

Low-cost passive or real-time measurement technologies (such as passive soil gas sampling, membrane interface probes, grab groundwater sampling, or X-ray fluorescence) may be useful techniques for characterizing sites. These techniques allow for data collection programs covering a wider areal or vertical extent over shorter time frames than can be achieved by traditional methods. The techniques can then be followed by higher quality data collection methods (e.g., active soil gas sampling, permanent vapor monitoring well installation, permanent groundwater monitoring well installation) to characterize the site, support the risk assessment, and the remedy design.

Field-based analytical methods are one of the key tools of dynamic field investigations. A broad range of analytical methods can be applied on site for sample collection activities, including methods that can be used outdoors with hand-held equipment or more rigorous methods that require the controlled environments of a mobile laboratory. Field-based analytical methods (such as direct-push sampling technology, gas chromatography, mass spectrometry detectors, immunoassay test kits, x-ray fluorescence, ultra-violet fluorescence, and laser-induced fluorescence) can deliver immediate results.

Field screening methods provide preliminary information regarding the distribution of contamination, the selection of samples for analysis, and the selection of additional sampling locations. Examples of common field screening methods include:

- observations of staining or evidence of NAPL
- devices that quantify the concentrations of specific compounds in real time [such as photoionization detector (PID), flame ionization detector (FID), and portable gas chromatographs (GCs)]
- x-ray fluorescence equipment
- field test kits that can detect the presence and/or magnitude of chemical compounds
- water-soil shake tests
- dye tests
- screening samples for compounds that fluoresce under ultra-violet blacklight
- composite sampling techniques

Direct push technologies use sensors on the tip of the rod to collect continuous depth profiles of geological and chemical information as the probe penetrates the subsurface. Some drilling techniques can be applied to collect soil, soil vapor, or water samples at discrete depths. The probe can be withdrawn while exuding grouting material so that the borehole is sealed. The process is relatively fast (one borehole in minutes to hours depending on the site geology) and does not leave a permanent well in place to monitor.

Mobile labs give the flexibility of providing analytical results on site with a 24-hour or less, turnaround for results. Although use of mobile labs can be more expensive than sending the samples to an offsite laboratory, the shortened overall investigation time

can offset the cost differential, particularly if a large number of samples are collected in a given sampling day. If contamination is discovered or found to be more extensive than expected, a mobile lab allows flexibility in the field program to analyze additional samples to identify the extent of the problem.

Although use of real-time measurements can maximize information value while minimizing costs, decision-makers should ultimately focus on the best analytical and sampling strategy for conducting an investigation. Often, the best analytical and sampling strategy will involve 'mixing and matching' various sampling and analytical techniques.

GUIDANCE DOCUMENTS FOR SITE INVESTIGATIONS

Because there are numerous guidance documents available to assist with the design and implementation of site investigations, this appendix does not include an extensive discussion of site characterization. The following references may be useful for designing site investigations at plating facilities. (Note: Links for these resources are provided in the references to this appendix.)

- *Preliminary Endangerment Assessment Guidance Manual* (DTSC, 1994; revision pending)
- *Guidance Document for the Implementation of U.S. Environmental Protection Agency Method 5035: Methodologies for Collection, Preservation, Storage, and Preparation of Soils to be Analyzed for Volatile Organic Compounds* (DTSC, 2004)
- *Interim Final Guidance for Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air* (DTSC, 2005; revision pending)
- *Advisory – Active Soil Gas Investigations* (DTSC/LARWQCB, 2003; revision pending)
- *Representative Sampling of Groundwater for Hazardous Substances* (Cal/EPA, 2008)
- *Data Quality Assessment: A Reviewer's Guide, EPA QA/G-9R* (USEPA, 2006a)
- *Data Quality Assessment: Statistical Methods for Practitioners, EPA QA/G-9S*. (USEPA, 2006b)
- *Expedited Site Characterization. Innovative Technology Summary Report, OST Reference #77* (USDOE, 1998)
- *Rapid Site Assessment Applied to the Florida Department of Environmental Protection's Dry-Cleaning Solvent Cleanup Program* (Applegate and Fitton, 1997)
- *Standard Practice for Expedited Site Characterization of Vadose Zone and Groundwater Contamination at Hazardous Waste Contaminated Sites, D6235-98* (ASTM, 1998)
- *Site Characterization Guidance Document* (CTDEP, 2007)
- *Guidance Manual for Groundwater Investigations* (Cal/EPA, 1995)

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Additional resources available on the DTSC, U.S. Environmental Protection Agency (USEPA), and Interstate Technology Regulatory Council (ITRC) web sites (www.dtsc.ca.gov, www.epa.gov, www.itrcweb.org), as well as at the following links:

- Brownfields Technology Support Center (<http://www.brownfieldstsc.org/>)
- Direct Push Technologies (www.epa.gov/superfund/programs/dfa/dirtech.htm)
- DOE Preferred Alternatives Matrix (www.em.doe.gov/define)
- USEPA Decision Support Software (www.epa.gov/superfund/programs/dfa/decsupp.htm)
- USEPA Dynamic Field Activities (www.epa.gov/superfund/programs/dfa/index.htm)
- USEPA Field Analytical Technologies Encyclopedia (fate.cluin.org)
- USEPA Hazardous Waste Cleanup Information Internet Site (cluain.org)
- USEPA Remediation and Characterization Innovative Technologies (REACHIT) (www.epareachit.org/)
- Field Based Analytical Methods (www.epa.gov/superfund/programs/dfa/fldmeth.htm)
- Federal Remediation Technologies Roundtable (FRTR) Field Sampling and Analyses Technologies Matrix and Reference Guide (www.frtr.gov)
- State Coalition for Remediation of Dry Cleaners (drycleancoalition.org)

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**APPENDIX C
HEXAVALENT CHROMIUM ANALYSIS**

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HEXAVALENT CHROMIUM ANALYSIS

The purpose of this appendix is to describe the currently available analytical techniques for hexavalent chromium. The appendix will be updated when the techniques described herein are modified or additional techniques are developed.

At present, discussions are underway regarding regulatory standards or goals for hexavalent chromium (e.g., Maximum Contaminant Level, Public Health Goal). The regulatory standards or goals could potentially be lowered to levels below those that can be reliably evaluated by current analytical capabilities. If this occurs, consultation with a DTSC risk assessor is recommended (see also Appendix D).

A broad range of chemical techniques and instrumentation are available for analysis of samples for hexavalent chromium (CrVI). The U.S. Environmental Protection Agency's (USEPA's) *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846* (SW-846; USEPA, 1996) lists five methods for CrVI testing. Table C-1 summarizes the technical details of each method listed in SW-846 along with their major advantages and disadvantages. Of these methods, EPA methods 7196 and 7199 are the most commonly used. The selection of a method to use depends on various factors including: laboratory capabilities, cost, anticipated sample concentration, reporting limit required, and possible interferences in the samples.

In addition to the methods listed in SW-846, other analytical techniques available for CrVI analysis include ion chromatography (IC) with inductively coupled plasma-mass spectrometric (ICP-MS) detection, high performance liquid chromatography (HPLC) with ICP-MS detection, and capillary electrophoresis (CE) with ICP-MS detection (APHA et al., 2005; Csuros and Csuros, 2002; Smith 2003). These techniques have not been fully validated and official methods have not been promulgated for them.

AQUEOUS SAMPLES

Sample Handling. Samples for CrVI analysis must be collected separately from other metals. Unlike ordinary metal samples, acid is never added as a preservative to samples intended for CrVI analysis because the acid will reduce any chromium in the hexavalent state (CrVI) to its trivalent state (CrIII).

At least 500 milliliters (ml) of water sample are needed for CrVI analysis. Samples should be collected in plastic containers (high density polyethylene or polypropylene) with the proper caps. Glass containers with PTFE (Teflon[®]) lined caps can also be used. Metal containers, especially stainless steel, should be avoided because CrVI is used in metal production.

Samples should be transported to the analytical laboratory as soon as possible. During transportation and storage, the samples should be maintained at 4°C.

Holding Time. The stability of CrVI in water samples is variable depending on the pH and other constituents are present in the water. Because of the instability of the dissolved CrVI, the holding time for sample analysis is within 24 hours after collection. Ideally, samples should be analyzed as soon as they are collected.

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USEPA has issued a *Methods Update Rule* (MUR; USEPA, 2007) which, in conjunction with EPA Method 218.6 (equivalent to Method 7199), allows the holding time to be extended from 24 hours to 28 days for CrVI testing, provided that the samples are preserved to pH 9 to 9.5 with ammonia-ammonium sulfate buffer. However, the MUR applies only to those samples analyzed under the Clean Water Act and Safe Drinking Water Act; this holding time extension is based on experience with clean drinking water samples and wastewater samples where the constituents are well-characterized. For the types of samples that are expected with plating facilities, the constituents are more varied and unknown. As a consequence, the stability of CrVI in those samples is not known and therefore this practice is not recommended. The MUR should only be used under special circumstances where an extended holding time is needed. If the MUR is to be used, all parties involved in the project should agree to the practice with the understanding that the results may not be reliable. To determine the reliability of using the MUR holding time to a given plating facility, preliminary validation studies may be needed.

Given the limited holding time for CrVI samples, it is critical that the project manager and others involved in CrVI sampling and analysis plan ahead and coordinate the timing of the sampling, transport, and analysis of the samples. The project manager should give advance notice to the analytical laboratory to expect CrVI samples at the specified date and time. With advance warning, the analytical laboratory should initiate instrument calibration and other procedures necessary for immediate analysis upon receipt of the samples. The planning and coordination will assure that the samples will be analyzed as soon as possible after collection, thus generating more defensible results.

SOIL SAMPLES

Extraction is needed for the analysis of CrVI in soil samples. Soil samples are heat extracted with an alkaline solution causing CrVI to be released and extracted into an aqueous solution. The alkaline extraction procedure is outlined in EPA Method 3060A (*Alkaline Digestion for Hexavalent Chromium*). The procedure involves solubilizing both water-insoluble and water soluble hexavalent compounds in solid samples. The alkaline digestion procedure is carefully monitored (i.e., pH and temperature) to assure that any dissolved CrVI is stabilized against reduction to CrIII. The resulting solution is analyzed as a liquid sample using either the colorimetric method (EPA Method 7196) or the IC method (EPA Method 7199).

The holding time for samples intended for CrVI analysis is up to 30 days after collection. The alkaline digestates from soil samples can be held up to seven days. As with water samples, soil samples should be digested and analyzed as soon as possible after collection.

EXTRACTION TESTS

Extracts from the Toxicity Characteristic Leaching Procedure (TCLP; EPA Method 1311) and the California Waste Extraction Test (WET; California Title 22, CCR Division 4.5, Chapter 11, Article 5, Appendix II) *should not be used for CrVI*, except under the

conditions described in the next paragraph. Both of these extraction tests are performed under acidic conditions¹ which will reduce any CrVI to CrIII. Hence, acidic extracts from extraction tests for CrVI will yield no usable data.

Non-acidic extracts can be analyzed for CrVI under the following circumstances. For TCLP, if the sample contains less than 0.5% by weight of solids, then the liquid portion of the sample, after filtration, is considered to be the TCLP extract. This extract can be analyzed for CrVI provided it is not acid preserved. For the WET, if deionized water is used as the extraction solution, as per California Title 22, CCR Division 4.5, Chapter 11, Article 5, Appendix II(f), then the WET extract can be analyzed for CrVI using the appropriate method.

QUALITY ASSURANCE/QUALITY CONTROL

All analytical laboratories must have a quality assurance (QA) program in place to ensure that all data generated are valid, defensible and of known precision and accuracy. QA is the sum of all field and laboratory procedures and activities that are undertaken to ensure the generation of accurate and reliable results (Dux, 1986). Those procedures and activities include: sample collection; sample preservation; sample transport; sample storage; data review; laboratory certification, etc. Quality control (QC) is the set of procedures and samples used to monitor sample analysis. QC procedures include the documentation of sample and standard preparations. QC samples may include method blanks, laboratory control samples (LCS), duplicates, and matrix spikes (MS). The USEPA definitions for some common QC samples are summarized in Table C-2.

The specific QC requirements depend on the method selected for analysis. Because each method involves different instruments and/or different chemistry, the QC requirements may differ as a result of differences in interferences encountered, nature of the chemical reactions, and/or selectivity of the instrumentation. Be sure to review the method for the specific QC procedures and samples required.

DETECTION LIMITS AND REPORTING LIMITS

For the purpose of this guidance, the detection limit (DL) is defined as the “...*minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix type containing the analyte*” (USEPA, 1992).

The reporting limit (RL) is defined as the lowest concentration of an analyte that can be detected in a sample by the given analytical procedure taking into account sample matrix, interferences, dilution factor and the lowest point of the calibration curve. Laboratories should use RL in their analytical reports since it is a more reliable indicator of the limit of detection. In practice, the RL is usually 10 to 20 times the DL. The appropriate RLs to be used on a specific project should be based on the project data

¹ The extraction fluids for TCLP are at pH 2.88 and 4.93 depending on the alkalinity of the samples being extracted. For the WET test, the extraction solution has a pH of 5.0.

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quality objectives (DQOs) taking into consideration various factors such as: matrix, sampling protocols, sample size, analytical method(s) to be used and other DQOs needed for risk assessment.

The analytical detection ranges listed in the methods table are the ranges listed in each respective method. The actual laboratory ranges may vary depending on laboratory capabilities and instrumentation. Consult with the analytical laboratory before the initiation of a project to verify the expected reporting limit based on DQOs.

VALIDATION

Project DQOs should dictate the selection of the method to use for CrVI testing. However, other factors such as cost and method availability may also be involved. If possible, the parties involved in the project should perform preliminary performance tests (i.e., trial runs) using one or more of the possible methods to determine the best method to use.

After a method has been selected for use, it should be validated before field use. Validation involves demonstrating that the method is applicable and appropriate for the analysis of CrVI in the matrix at the desired DQOs (reporting limits, precision, accuracy, etc.). Preliminary samples should be run with the necessary QC samples to determine the precision and accuracy of the methods. Matrix spikes should also be run to determine if the expected matrix has any interferences that may affect the results.

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Table C-1. SW-846 Analytical Methods for Hexavalent Chromium

METHOD/ PARAMETER	EPA 7195	EPA 7196	EPA 7197	EPA 7198	EPA 7199
METHOD TITLE	CrVI (Cocprecipitation)	CrVI (Colorimetric)	CrVI (Chelation/Extraction)	CrVI (Differential Pulse Polarography)	Determination of CrVI in Drinking Water, Groundwater and Industrial Wastewater Effluents by Ion Chromatography
METHOD SUMMARY	CrVI is separated from solution by coprecipitation of PbCrO ₄ with PbSO ₄ . Supernate with CrIII (after separation) is drawn off and precipitate washed to remove occluded CrIII. CrVI is reduced and resolubilized in HNO ₃ and quantified as CrIII by either Flame or Furnace atomic absorption spectroscopy.	CrVI reacts with diphenylcarbazide (DPC) in acid solution to produce a violet color solution. Absorbance of the red-violet product is measured photometrically at 540 nm. Absorbance is proportional to concentration.	CrVI chelates with ammonium pyrrolidine dithiocarbamate (APDC) and extraction with methyl isobutyl ketone (MIBK). Extract analyzed by flame atomic absorption spectroscopy.	CrVI is reduced to CrIII at a dropping mercury electrode during a differential pulse voltage ramp. Differential Pulse Polarograph (DPP) measures peak current from reduction.	Filtered sample is introduced into the ion chromatograph (IC). CrVI is separated on an anion exchange column. Post-column derivatization of CrVI with diphenylcarbazide followed by detection of colored complex at 530 nm.
APPLICABILITY	Ground water, domestic and industrial wastes and EP extracts.	Ground water, domestic, industrial wastes, alkaline extracts from soils, and EP and TCLP extracts.	Ground water, domestic and industrial wastes and EP extracts.	Natural waters, wastewaters and EP extracts.	Drinking water, groundwater, industrial wastewater effluents, and alkaline extracts from soils.

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Table C-1 (Continued)

METHOD/ PARAMETER	EPA 7195	EPA 7196	EPA 7197	EPA 7198	EPA 7199
OPTIMUM ANALYTICAL RANGE¹	> 5 µg/L	0.5 to 50 mg/L	1.0 to 25 µg/L	10 µg/L to 5 mg/L	1 µg/L to ppm levels
INTERFERENCES	Extracts with SO ₄ ⁻² or Cl ⁻ > 1,000 ppm should be diluted before analysis.	Positive interferences from other colored materials in the sample or other metals that can form colored complexes with DPC.	High concentrations of other metals may interfere.	Copper ion is a potential interference in peak current reading. Reductants such as Fe ⁺² , S ⁻² and SO ₃ ⁻² will reduce CrVI to CrIII.	High levels of anionic species (e.g., SO ₄ ⁻² & Cl ⁻) may cause column overload. High levels of organics, sulfides (S ⁻²) or other reducing species can cause rapid reduction of soluble CrVI to CrIII. Contamination from reagents and glassware.
SAMPLE COLLECTION, PRESERVATION AND HANDLING	Ship and store at 4°C in plastic containers ² .	Ship and store at 4°C in plastic containers.	Ship and store at 4°C in plastic containers	Ship and store at 4°C in plastic containers.	Filtration and pH adjustment at time of collection or ASAP after collection. Ship and store at 4°C in plastic containers.
HOLDING TIME	Within 24 hours after collection. For EP extracts, analyze ASAP.	Within 24 hours after collection. For extracts, 24 hours after extraction.	Within 24 hours after collection. For EP extracts, analyze ASAP.	ASAP and within 24 hours after collection.	Within 24 hours after collection.

INVESTIGATION AND REMEDIATION OF PLATING FACILITIES

Table C-1 (Continued)

METHOD/ PARAMETER	EPA 7195	EPA 7196	EPA 7197	EPA 7198	EPA 7199
CALIBRATION	Blank and at least four calibration standards.	Standards are treated as samples. Number of calibration standards not specified. Recommend at least three calibration standards.	Blank and at least three calibration standards. New calibration for each set of samples and each hour of continuous sample analysis.	Blank and at least three calibration standards. MSA for sample quantitation with three standard additions.	Blank and three standards. A quality control sample (QCS) analyzed at beginning of a run to validate calibration.
QA/QC	At minimum per sample batch: Interference verification check sample One method blank Calibration check standard (from second source) every 15 samples. One duplicate every ten samples. One matrix spike every ten samples. MSA used for EP extracts.	At minimum per sample batch: Interference verification check sample. One method blank. Calibration check standard (from second source) every 15 samples. One duplicate or matrix spike duplicate per batch. One matrix spike every ten samples. MSA used for EP extracts. Absorbance of standards and samples are corrected by subtraction of reagent blank absorbance.	At minimum per sample batch: Chelation interference verification check sample. One method blank. Calibration check standard (from second source) every 15 samples. One duplicate per batch. One matrix spike every ten samples. MSA used for EP extracts.	At minimum per sample batch: Blank at the beginning and every ten samples. Quantitation by MSA. Calibration check standard (from second source) every 15 samples. Standard compare to reference routinely.	At minimum per sample batch: One method blank One duplicate One matrix spike Lab blank and calibration check standard every ten analysis.

Table C-1 (Continued)

METHOD/ PARAMETER	EPA 7195	EPA 7196	EPA 7197	EPA 7198	EPA 7199
METHOD ADVANTAGES	Alternative to other methods if interferences are problematic.	Relatively simple sample preparation. Few interferences when used on alkaline digestates from soil samples.	Alternative to other methods if interferences are problematic.	Alternative to other methods if interferences are problematic.	Minimal sample preparation required. Method has the capability to cover a large dynamic concentration range from ppb to ppm levels. Calibration curves are prepared to bracket anticipated sample concentration ranges. Low detection limit. Few interferences when used on alkaline digestates from soil samples.
METHOD DISADVANTAGES	Complex sample preparation and analytical steps which may result in sample loss and lower recoveries.	Subject to interferences.	Complex sample preparation and analytical steps. Calibration curve may not be stable; method requires a new calibration curve with each batch of samples and every hour of continuous sample analysis.	Method uses elemental mercury which has to be disposed off properly after use. Instrument not widely used by laboratories. Requires multiple analyses (MSA) for each sample. Limited QA/QC.	Susceptible to interferences (see Interferences section)

INVESTIGATION AND REMEDIATION OF PLATING FACILITIES

Table C-1 (Continued)

METHOD/ PARAMETER	EPA 7195	EPA 7196	EPA 7197	EPA 7198	EPA 7199
EQUIVALENT METHODS	EPA Method 218.5	Standard Methods ³ 3500-Cr B	EPA Method 218.4		Standard Methods 3500-Cr C EPA Method 218.6
COMMENTS	Not a commonly used method.	Commonly used method. Used to analyze alkaline digestates from soil samples.	Not a commonly used method.	Not a commonly used method.	Commonly used method especially for drinking water and wastewater samples. Used to analyze alkaline digestates from soil samples.

ASAP is as soon as possible

CrIII = trivalent chromium

CrVI = hexavalent chromium

EP = Extraction Procedure Toxicity Characteristic

MSA = Method of Standard Addition

TCLP = Toxicity Characteristic Leaching Procedure

¹ Analytical range as indicated in the method. Analytical range may vary depending on laboratory capabilities and instrumentation.

² High density polyethylene or polypropylene containers with appropriate closures. Glass containers with PTFE (Teflon[®])-lined caps can also be used.

³ Standard Methods for the Examination of Water and Wastewater, 21st Edition.

Table C-2. Common Quality Control Samples

Sample Type	Description
Method Blank	An analyte-free matrix to which all reagents are added in the same volumes or proportions as used in sample processing. The method blank should be carried through the complete sample preparation and analytical procedure. The method blank is used to document contamination resulting from the analytical process.
Laboratory Control Sample	A known matrix spiked with compound(s) representative of the target analytes. This is used to document laboratory performance.
Duplicate	An intra-laboratory split sample which is used to document the precision of a method in a given sample matrix.
Matrix Spike	An aliquot of sample spiked with a known concentration of target analyte(s). The spiking occurs prior to sample preparation and analysis. A matrix spike is used to document the bias of a method in a given sample matrix.

APPENDIX D
RISK ASSESSMENT AND CLEANUP GOALS

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RISK ASSESSMENT AND CLEANUP GOALS

Evaluation of potential risks to human health and the environment posed by contaminants at a plating facility is part of the site characterization process. The evaluation supports the risk management decision-making process of determining whether additional site investigation, further risk assessment, and/or remediation may be necessary. Cleanup goals are generally established based on concentrations that do not pose an unacceptable risk or threat to human health and the environment.

ECOLOGICAL RISK ASSESSMENT

Although this appendix focuses on health risk assessment, a scoping-level ecological investigation should be conducted to characterize the chemical, physical, and biological aspects of a site and to evaluate the potential for complete exposure pathways between ecological receptors and chemicals of concern (COCs) (DTSC, 1996ab; USEPA 1997). Ecological risk should be further evaluated if the results of this qualitative assessment indicate further assessment is necessary (e.g., Phase I predictive assessment). Even if no currently-complete exposure pathways for ecological receptors are identified, the biological characterization of the site may become an important consideration for risk management decisions. For example, removal actions to protect human health may adversely impact ecological receptors or critical portions of their habitat.

HEALTH RISK ASSESSMENT

Following the site characterization, a human health risk assessment for COCs should be conducted to estimate the potential cancer risks and noncancer health hazards. The potential risks and hazards associated with the COCs are used in the risk management decision-making process to determine whether further site characterization, risk assessment, or cleanup may be necessary for the site. The point of departure for risk management decisions for cancer risk is 1×10^{-6} and for noncancer risk is a hazard index of 1. Sites with risks in excess of these points of departure may require remediation.

The risk assessment process includes:

- identification of COCs and affected environmental media;
- identification of exposure pathways, land use, and potential human receptors;
- determination of exposure point concentrations (EPCs);
- selection of toxicity criteria; and
- calculation and characterization of potential cancer risks and noncancer hazards.

A screening level health risk assessment may be sufficient, depending on factors such as the complexity of the site, the degree of characterization of site contamination, and the anticipated remedy. Guidance for conducting a risk screening evaluation is provided in the following:

- *Preliminary Endangerment Assessment Guidance Manual* (PEA Manual; DTSC, 1994; revision pending);

- *Use of California Human Health Screening Levels (CHHSLs) in Evaluating Contaminated Properties* (Cal/EPA, 2005b)¹;
- *Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air* (Vapor Intrusion Guidance; DTSC, 2005a; revision pending);
- *PT&R Guidance – Remediation of Metals in Soil* (DTSC, 2008);
- *PT&R Guidance – Remediation of Chlorinated VOCs in Vadose Zone Soil* (DTSC, 2010); and
- U.S. Environmental Protection Agency (USEPA) Regional Screening Levels (RSLs)², used as described in:
 - Human Health Risk Assessment Note 3 – DTSC Recommended Methodology for Use of U.S. EPA Regional Screening Levels (RSLs) in Human Health Risk Assessment Process at Department of Defense Sites and Facilities (DTSC, 2009b; update pending)
 - Human Health Risk Assessment Note 4 – Screening Level Human Health Risk Assessments (DTSC, 2009c; update pending)

Complex sites (such as those with multiple contaminants, impacts to multiple environmental media, and/or complex features) may require a site-specific comprehensive risk assessment subsequent to, or in lieu of, a screening risk assessment. General guidance for conducting a site-specific comprehensive risk assessment is provided in *Risk Assessment Guidance for Superfund: Volume I--Human Health Evaluation Manual, Part A, Baseline Risk Assessment* (USEPA, 1989). Additional guidance for conducting risk assessments is available at the following agency web sites:

- U.S. Environmental Protection Agency (USEPA):
www.epa.gov/oswer/riskassessment/risk_superfund.htm
- Department of Toxic Substances Control (DTSC):
www.dtsc.ca.gov/AssessingRisk/index.cfm.

Chemicals of Concern and Background Metals

Generally, all organic contaminants (such as volatile organic compounds [VOCs] and semi-volatile organic compounds [SVOCs]) detected in soil, soil gas, and/or groundwater are considered COCs in the risk assessment. Similarly, all anthropogenic inorganic contaminants (e.g., cyanide) detected in soil or groundwater are considered COCs in the risk assessment. COCs for risk evaluation should include transformation products associated with detected chemicals (e.g., vinyl chloride is a transformation product associated with trichloroethene) and chemicals suspected to be present based on site information. For sites impacted by ambient levels of contamination, the COCs

¹ The CHHSLs were developed using standard exposure assumptions and chemical toxicity values published by the USEPA and Cal/EPA and are occasionally updated to incorporate new toxicity information of referenced chemicals.

² www.epa.gov/region09/superfund/prg/index.html

are included for risk assessment and relative contributions by ambient contributions and the site are characterized. Ambient concentrations should not be used to “screen-out” COCs for risk evaluation.

Because metals may occur naturally in soil, metal concentrations should be compared to background and/or ambient concentrations to determine if the metals present on the site exceed these values and may therefore indicate a release. Appendix B of the *PT&R Guidance – Remediation of Metals in Soil* (DTSC, 2008) provides guidance on estimating and using background concentrations of metals in soil. *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities: Unified Guidance* (USEPA, 2009b) provides guidance on estimating and using background concentrations of metals in groundwater. All metal COCs present above background and/or ambient levels should be retained for further evaluation to fully account for the potential cumulative risk (even if the COCs individually do not pose a significant risk). A few metals, most notably arsenic, may pose potential health risks at background concentrations.

Exposure Pathways and Land Use Scenarios

All potential exposure pathways and receptors identified in the CSM for current and potential future uses of the property should be described in the risk assessment. The land use and risk assessment exposure scenarios evaluated for this guidance are (1) residential and (2) industrial or commercial. Evaluation of offsite receptors or exposure scenarios other than default residential and industrial/commercial scenarios for the baseline risk assessment requires additional consultation with the DTSC.

Exposure to COCs in shallow soil can occur by several pathways, including inhalation of outdoor air, direct contact with soil (incidental ingestion and dermal contact), ingestion of food products contaminated with COCs, and inhalation of volatile COCs that have migrated from the subsurface into indoor air.

Exposure to COCs that have migrated from vadose zone soil to groundwater, or are predicted to reach groundwater, should also be evaluated. Exposure pathways for COCs in groundwater include, but are not limited to, ingestion, dermal contact during showering/bathing, and inhalation of vapors released indoors from household use of groundwater.

DTSC should be consulted regarding evaluation of soil and groundwater exposure pathways.

Exposure Point Concentration

Soil

The PEA Manual (DTSC, 1994; revision pending) recommends use of the maximum concentration of each COC for initial risk screening purposes. Other statistical approaches may also be appropriate, including the calculation of the 95 percent upper confidence limit (95% UCL) on the arithmetic mean concentration. Statistical programs,

such as ProUCL software (USEPA, 2009a), can be used to calculate the exposure concentration and data should be transformed where necessary. Censored data (i.e., concentrations reported as “not detected”) should be included at one-half the detection limit, provided that the detection frequency for the COC is greater than 50 percent. Appendix B of *PT&R Guidance – Remediation of Metals in Soil* (DTSC, 2008) identifies techniques for working with data sets that have a detection frequency less than 50 percent.

Use of the 95% UCL statistic is dependent on the size of the data set (a minimum of ten samples are necessary), the distribution of contamination on the site, and the possible existence of localized hot spots. The selection of the EPCs for soil should be justified based on whether soil contamination is limited to localized areas (hot spots), spread across the site, or contained within a defined area of concern. It is not appropriate to statistically minimize soil concentrations by including soil data from large areas of the site that are not impacted. If it is unclear whether the site characterization data supports the use of the 95% UCL, the maximum concentrations should be used in risk estimates. Consideration of overall risk from the whole site may be addressed in the post-cleanup evaluation.

For sites with high concentrations of VOCs, soil matrix data can be used to identify locations with VOC concentrations exceeding saturation limits for the soil and provide concentration data for soil exposure assessments. For sites at which the soil saturation limit for a VOC is exceeded, the evaluation of vapor intrusion risk requires additional consultation with DTSC. Maximum detected concentrations of VOCs in shallow soil matrix samples should be used for screening-level soil risk assessments (DTSC, 1994; revision pending). In consultation with DTSC, the estimated average concentration (95% UCL of the arithmetic mean) may be used at sites with sufficient characterization of VOCs in soil matrix.

Soil Gas

The maximum detected concentration of each COC in soil gas should be used as the EPC for vapor intrusion risk assessment (DTSC, 2005a; revision pending; Cal/EPA, 2005b). DTSC approval is required for use of any other metric for the EPC. Alternatively, point estimates of risk might be calculated using concentrations of COCs for each sampling location. Point estimates of risk are useful for spatial evaluation of contamination and risk at sites with multiple contaminants, and can be useful for evaluating remedial alternatives. For soil gas samples in which a site COC was not detected because of elevated detection limits, the detection limit for the COC should be used as a proxy concentration (DTSC, 2005a; revision pending). The distribution and extent of contamination at the site and the possible existence of localized areas of higher concentrations (i.e., hot spots) must be considered in both risk assessment and risk management.

Groundwater

EPCs for COCs in groundwater should be based on concentration data collected from monitoring wells over a period of time that allows assessment of temporal trends. For sites at which COCs have not yet reached groundwater, concentrations predicted by modeling can be used to support risk estimates (see Section 4.2). A combination of monitoring data and modeling might be appropriate for estimating EPCs at some sites. The maximum measured or model-predicted concentration of COCs in groundwater should be used. DTSC approval is required for use of other metrics for the EPC.

The data quality objectives (DQOs) for data used to support the EPC for groundwater will depend on the exposure pathways being evaluated (e.g., vapor intrusion, drinking water). For example, evaluation of vapor intrusion focuses on concentrations at the water table (DTSC, 2005a; revision pending). Both groundwater and soil gas data should be used to develop the EPC for the vapor intrusion pathway. Data from both media should be used to estimate the indoor air exposure concentration and the higher predicted EPC should then be used for assessing vapor intrusion risks (DTSC, 2005a; revision pending).

Health Risk Assessment

Soil

Risks associated with exposures to COCs in soil matrix should be evaluated for shallow soil (0 to 15 feet below ground surface). Elevated VOC concentrations in soil may also warrant evaluation of emissions into outdoor air. DTSC should be consulted regarding evaluation of exposures to COCs in soil and application of DTSC guidance. Generally, the PEA Manual (DTSC, 1994; revision pending) and updated exposure factors provided in *DTSC Human Health Risk Assessment Note 1: Recommended DTSC Default Exposure Factors for Use in Risk Assessment at California Military Facilities* (HHRA Note 1; DTSC 2005b) should be followed. The most current toxicity criteria available from California Environmental Protection Agency (Cal/EPA) and USEPA should be used.

Groundwater

The PEA Manual (DTSC, 1994; revision pending) should be used for assessment of risks associated with exposure to COCs in groundwater. Updated exposure factors provided in HHRA Note 1 (DTSC, 2005b) and the most current toxicity criteria available from Cal/EPA and USEPA should be used.

Vapor Intrusion into Indoor Air

The Vapor Intrusion Guidance (DTSC, 2005a; revision pending) should be followed for conducting preliminary and/or site-specific screening evaluation of risks associated with VOCs. The Vapor Intrusion Guidance provides default attenuation factors for estimating indoor air concentrations from soil vapor concentrations for use in preliminary screening

risk assessments and also describes procedures for estimating site-specific soil vapor attenuation factors and predicting indoor air VOC concentrations and risks. Current USEPA vapor intrusion guidance is provided in *Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils* (USEPA, 2002). The most current toxicity criteria available from the Cal/EPA and USEPA should be used. Cumulative cancer risks and noncancer hazards should be calculated for sites with multiple VOCs.

Although soil gas data are preferred for evaluation of vapor intrusion, preliminary risk screening with groundwater monitoring data might be conducted in limited cases. When groundwater data is used, the Vapor Intrusion Guidance should be followed and the vapor intrusion risk associated with both soil gas and groundwater should be evaluated. Soil sampling might be necessary at some sites, such as those with high concentrations of VOCs and/or where site conditions preclude soil gas sampling. In consultation with DTSC, an approach can be developed for evaluation of the soil vapor intrusion into indoor air pathway.

Human Health Screening Levels

Human health screening levels are risk-based concentrations of chemicals in specific environmental media (e.g., soil, soil gas, groundwater). Risk-based concentrations (also referred to as health-based concentrations) are developed using a target cancer risk or noncancer hazard quotient. The calculations rely on multiple assumptions and factors for estimating contaminant environmental fate and transport and receptor exposures for a hypothetical (or specific) site. Generally, conservative default exposure assumptions are used to derive these screening levels. For carcinogens, risk-based concentrations are developed for both cancer risk and noncancer hazard, and the lesser (more protective) concentration is selected as the screening level.

Screening levels based on default assumptions can be used for screening risk assessments. Site-specific risk-based concentrations may also be developed. Screening-level and/or site-specific risk-based concentrations are often used in development of remedial action objectives (RAOs) and cleanup goals.

For risk assessments based on screening levels, cancer risk and hazard are estimated by dividing the maximum concentration of each COC by the corresponding medium-specific screening level. The ratio of the EPC to the risk-based concentration is multiplied by the target risk or hazard quotient from which the risk-based concentration was calculated (10^{-6} risk and hazard quotient of 1 for screening assessments). When using risk-based screening levels for assessing risks, both cancer risk and hazard must be evaluated for carcinogenic COCs, and cumulative risk and hazard for multiple COCs and exposure pathways must be presented. For the vapor intrusion into indoor air pathway, the maximum detected concentration of each COC in soil gas is compared with the corresponding screening level for soil gas.

For risk assessments based on screening levels, risk-based concentrations for the residential scenario should be used. In addition to the residential scenario, risk assessments for industrial, commercial, and other land use scenarios might be

conducted for the evaluation of remedies and the risk management decision process. Sites with individual chemical or cumulative cancer risks greater than 1×10^{-6} or noncancer hazards (hazard index) greater than 1 for the residential scenario should be considered for further risk management evaluation.

Screening Assessment for VOCs in Soil Gas

The Vapor Intrusion Guidance (DTSC, 2005a; revision pending) should be used to develop risk-based screening levels for VOCs in soil gas. Default soil gas attenuation factors provided in the Vapor Intrusion Guidance can be used to develop generic risk-based screening levels. Alternatively, the USEPA spreadsheet version of the Johnson and Ettinger model for vapor intrusion into indoor air and certain assumptions for building properties provided in the Vapor Intrusion Guidance can be used with data for site-specific soil properties to derive soil gas attenuation factors and screening levels.

For sites or areas for which soil matrix samples are necessary in addition to soil gas data, Appendix E of the Vapor Intrusion Guidance provides procedures for using soil matrix data to estimate soil gas concentrations. The Vapor Intrusion Guidance also discusses the limitations and uncertainties in using soil matrix data.

California Human Health Screening Levels

California Human Health Screening Levels (CHHSLs) are based on standard exposure assumptions and chemical toxicity values published by Cal/EPA and the USEPA, and can be used for evaluation of VOCs in soil gas and the evaluation of metals and other COCs in soil (Cal/EPA, 2005ab). Currently there are no CHHSLs for groundwater or surface water.

Toxicity criteria used for the CHHSLs should be reviewed prior to use and updated (i.e., adjust the screening level) as necessary. The current list of CHHSLs can be found on the Cal/EPA web site at (www.oehha.ca.gov/soil.html). The guidance document on use of CHHSLs for screening risk assessments (Cal/EPA, 2005b) should be consulted. A spreadsheet calculator is also available on the Cal/EPA web site.

Metals and non-VOCs. EPCs for COCs in soil should be compared to CHHSLs. Cumulative (multiple chemical) cancer risks and noncancer hazards should be calculated according to the guidance. Either individual chemical risk or cumulative cancer risks greater than 1×10^{-6} or noncancer hazards (hazard index) greater than one should be considered for further risk management evaluation.

VOCs. The CHHSLs for VOCs are risk-based concentrations for soil gas for the vapor intrusion/indoor air exposure pathway only. Soil gas CHHSLs were developed using the USEPA spreadsheet version of the Johnson and Ettinger model for soil vapor intrusion into indoor air. The CHHSLs might not be adequately protective for estimating impacts to indoor air in structures with: basements; significant openings to the subsurface; preferential pathways for vapors (such as utility openings); or substandard ventilation systems. Sites with conditions significantly different from those assumed for the

CHHSLs warrant a site-specific evaluation using the Vapor Intrusion Guidance (DTSC, 2005a; revision pending).

Soil Screening Levels for Soil Matrix

Risk-based screening levels for contact exposure pathways for COCs in soil can be developed using the PEA Manual (DTSC, 1994; and updates) and current exposure parameter values recommended in HHRA Note 1 (DTSC, 2005b). As applicable, CHHSLs for non-VOCs present at the site may be used for soil exposure pathways in the screening risk assessment. If a site-specific screening level or CHHSL is not available for a given compound, USEPA Regional Screening Levels (RSLs) for soil matrix may be used for screening evaluation of soil exposure pathway risks for COCs (ingestion, dermal contact, inhalation of outdoor air). DTSC guidance on use of RSLs (DTSC, 2009bc and updates), including adjustments for Cal/EPA toxicity criteria, should be followed. Consultation with a DTSC risk assessor is recommended to ensure application of RSLs at a site is appropriate. As with other screening levels, both cancer risk and hazard must be evaluated for carcinogenic COCs, and cumulative risk and hazard for multiple COCs must be estimated. The RSLs do not include the vapor intrusion pathway, and therefore should be used in conjunction with an appropriate vapor intrusion assessment.

Screening Levels for Groundwater

Health risk screening evaluation of groundwater can also be accomplished by comparing appropriate groundwater concentrations to a risk-based screening level for drinking water. Risk-based screening levels for evaluation of groundwater include:

- Risk-based concentrations developed using the PEA Manual (DTSC, 1994; and updates);
- Cal/EPA Public Health Goals (PHGs) for drinking water; and
- USEPA RSLs for tap water.

PHGs are concentrations of drinking water contaminants at which adverse health effects are not expected to occur from a lifetime of exposure. The California Safe Drinking Water Act of 1996 (Health and Safety Code Section 116365) requires the Cal/EPA Office of Environmental Health Hazard Assessment (OEHHA) to adopt PHGs based exclusively on public health considerations. PHGs are considered by the California Department of Health Services in establishing drinking water standards (state Maximum Contaminant Levels [MCLs]). Although PHGs are not enforceable (e.g., as applicable or relevant and appropriate requirements [ARARs]), the intent of the PHG is to provide a health-based concentration for the development of state MCLs. Site-related concentrations may be compared to currently available PHGs for the purposes of health risk assessment. The current list of PHGs can be found on the Cal/EPA web site (www.oehha.ca.gov). Consultation with a DTSC risk assessor is recommended to ensure application of PHGs at a site is appropriate.

If depth to groundwater is relatively shallow (e.g., within 50 feet of the ground surface), the Vapor Intrusion Guidance (DTSC, 2005a; revision pending) should be used to develop risk-based screening levels for VOCs in groundwater. A partitioning model should be used to estimate groundwater concentrations from the risk-based soil vapor concentrations. For exposures to VOCs in groundwater via other pathways (ingestion, dermal contact from bathing, inhalation of vapors emitted into indoor air from household use of groundwater), the PEA Manual (DTSC, 1994; revision pending) and updated exposure factors provided in HHRA Note 1 (DTSC, 2005b) should be used for development of risk-based concentrations of VOCs in groundwater.

USEPA RSLs for tap water may be used for screening evaluation of groundwater exposure pathway risks for COCs (ingestion, inhalation of vapors emitted into indoor air from household use of groundwater). DTSC guidance on use of RSLs (DTSC, 2009bc and updates), including adjustments for Cal/EPA toxicity criteria, should be followed. As with other screening levels, both cancer risk and hazard must be evaluated for carcinogenic COCs, and cumulative risk and hazard for multiple COCs must be estimated. The RSLs for tap water do not include dermal exposure or the groundwater vapor intrusion pathway, and therefore they should be used in conjunction with one of the aforementioned risk assessment approaches.

CLEANUP GOALS

Cleanup goals are generally developed based on concentrations that do not pose an unacceptable risk or hazard to human health and the environment. Exceptions to this approach include metals that occur naturally in soil or groundwater at levels which may pose a potential health risk.

This appendix focuses on human health risk. If potential impacts to ecological receptors or surface water are present, additional approaches for establishing cleanup goals will be needed, which are beyond the scope of this appendix. Contact DTSC for further consultation.

Cleanup Goals for Protection of Human Health

Factors that are considered in the development and selection of cleanup goals include the health impact endpoint (cancer risk and/or noncancer hazard), the intended use of the property (e.g., residential, industrial/commercial), exposure pathways, and the number and nature of COCs. Cleanup goals based on anything other than unrestricted use (i.e., residential use) may require institutional controls, such as land use restrictions and operation and maintenance plans.

As a starting point for development of risk-based cleanup goals, an initial cleanup goal of 1×10^{-6} cancer risk should be calculated for each carcinogenic COC. For noncancer hazard, the risk-based cleanup goal for each COC should be less than or equal to a cumulative hazard index of 1. When a site has multiple COCs that contribute significantly to calculated excess total risk or hazard, the risk-based cleanup goal for each COC may need to be adjusted to a lower concentration to reduce the overall

cumulative risk and/or hazard to an acceptable range. Risk management decisions that would allow cleanup goals with greater risks or hazards may be made on a site-by-site basis, using the characterization of site risks as a guide.

Selection of a cleanup goal is dependent on the most probable use of the property, considering current and potential future uses. For the purpose of this appendix, two exposure scenarios are considered. The first is a residential or unrestricted land use and the second is an industrial/commercial land use. Default exposure pathway assumptions for persons who may come into contact with the site media are available for both of these land use scenarios. For the purposes of this appendix, these exposure assumptions should be consistent with the assumptions used in the development of CHHSLs or the PEA Manual (updated exposure factors provided in HHRA Note 1; DTSC, 2005b). The most current toxicity criteria available from Cal/EPA and USEPA should be used. When properties are remediated to commercial or industrial cleanup goals or waste is left in place under a cap, institutional controls are required to ensure the continued health protectiveness of the selected solution.

Human-health screening levels such as CHHSLs may be considered as risk-based cleanup goals to streamline the remedy selection process. CHHSLs for COCs in soil are based on the direct exposure of humans to contaminants via incidental soil ingestion, dermal contact, and inhalation of dust in outdoor air. CHHSLs for VOCs are risk-based concentrations for soil gas for the vapor intrusion/indoor air exposure pathway only. The OEHHA web site (www.oehha.ca.gov/risk/soil.html) should be consulted for chemical-specific and other updates to the CHHSL document.

Development of a cleanup goal other than the CHHSL or risk-based concentration may be necessary in the following instances:

- CHHSL values for certain metals (e.g., arsenic) may be less than background concentrations, and therefore, the cleanup goal may be based on the estimated background and/or ambient concentrations. Appendix B of *PT&R Guidance – Remediation of Metals in Soil* (DTSC, 2008) provides a strategy for estimating background metals concentrations and for developing ambient cleanup goals.
- Some agencies may not concur with the proposed use of CHHSLs. The use of CHHSLs as cleanup goals requires concurrence of both the responsible party and agencies.
- Instances may arise where a value less than the CHHSL is needed to address regulatory requirements, environmental concerns, cumulative impacts, or CEQA considerations.
- Current and/or future use of the site requires evaluation of an alternative exposure scenario (other than residential/unrestricted or industrial/commercial).
- The risk-based concentration for a COC might not be attainable for technical or economic reasons at a site.

For sites where groundwater has become contaminated, cleanup goals should consider federal and state MCLs, health-risk based PHGs and/or background levels of metals in

groundwater. Because the MCL for hexavalent chromium may be changing, check with DTSC for information regarding the appropriate risk-based value in groundwater.

Background-Based Cleanup Goals

For some metals, establishment of a cleanup goal will require the consideration of naturally-occurring concentrations of the metal in soil and/or groundwater (i.e., background concentration). DTSC does not require cleanup of sites to concentrations that are less than background.

Metals in Soil

The *PT&R Guidance – Remediation of Metals in Soil* (DTSC, 2008) provides guidance for establishing background concentrations in soil.

Although there are several metals in soil which may fall into this category, arsenic is the predominant metal where background concentrations usually need to be considered in developing appropriate cleanup goals. Remediation of arsenic contamination in soil has occurred at many sites, and the calculated health-based cleanup goal can be an order of magnitude below background levels. While DTSC recognizes that there are many outstanding scientific questions about the differing forms and sources of arsenic (including arsenic in water versus arsenic in soil) and the bioavailability and bioaccessibility of arsenic in soil, these issues are not currently factored into this guidance. Several study groups are investigating these potential impacts on risk assessments and development of cleanup goals. As new DTSC guidance concerning arsenic becomes available, the approaches in this document may be modified. DTSC has used a strategy for developing cleanup goals based on the entire site data set for arsenic which is described in *Arsenic Strategies, Determination of Arsenic Remediation Development of Arsenic Cleanup Goals* (DTSC, 2009a). The same approach may be used for other metals at sites where the health-based cleanup goals are significantly below background levels. Briefly, the strategy utilizes the complete data set from a site, including relevant background samples, to statistically determine feasible site-specific cleanup goals. Several statistical approaches are outlined in the guidance.

Metals in Groundwater

Background concentrations of some metals (e.g., arsenic, hexavalent chromium) may need to be considered in developing appropriate cleanup goals because risk-based levels may be considerably below background levels in groundwater in some areas. In these cases, background levels of these metals in groundwater may be used to establish the cleanup goal. *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities: Unified Guidance* (USEPA, 2009b) provides guidance for establishing background concentrations in groundwater.

Soil Cleanup Goals for Protection of Groundwater

If the response action is being implemented to decrease or eliminate an on-going threat to groundwater posed by contaminants in vadose zone soil, the process of establishing cleanup goals should also consider soil and soil gas concentrations necessary to protect water resources. Cleanup goals protective of groundwater are established based on site-specific considerations and applicable policies, statutes, and regulations. Potentially applicable policies, statutes, and regulations include:

- State and federal statutes and regulations;
- California State Water Resources Control Board (SWRCB) and California Regional Water Quality Control Board (RWQCB) policies;
- water quality control plans adopted by the SWRCB and RWQCB; and
- relevant standards, criteria, and advisories adopted by State and federal agencies.

DTSC has not identified a single methodology that can be used to establish soil cleanup goals for protection of groundwater. Examples of methods that could be used to establish cleanup goals include use of unsaturated zone fate and transport modeling (Section 4.2) and "lookup" tables of screening levels (e.g., USEPA RSLs for Soil for Protection of Groundwater). The method used for a given site should be selected in consultation with, and with the approval of, the regulatory agencies overseeing the site cleanup.

Final Cleanup Goals

The objectives of the cleanup should be clearly identified prior to development of the final cleanup goals and evaluation of remedial alternatives. Development of final cleanup goals for a site involves consideration of risk-based cleanup goals and other criteria or requirements, including technical and economic feasibility, regulatory criteria, and community concerns. Evaluation of each remedial alternative for the site should include a determination of the estimated reduction in risk and of risk management measures needed for contamination remaining in excess of risk-based concentrations.

Risk Management

The final cleanup goal and remediation strategy is a risk management decision based on numerous factors. The risk-based point of departure for risk management decisions is 1×10^{-6} for cancer risk and a hazard index of 1 for noncancer risk. Sites with individual chemical risk or cumulative risk from multiple COCs in excess of these points of departure may require remediation. In general, risks that are less than 1×10^{-6} are called *de minimus* and are not considered to require regulatory intervention. The range of risk (excess cancer risk posed by a site) that is considered as potentially acceptable for risk management decisions starts at 1×10^{-6} (one in a million) and goes up to 1×10^{-4} (one in ten thousand).

Development of RAOs and final cleanup goals at a site involves consideration of the following:

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- nature and magnitude of human health risks and uncertainties,
- current and future land use,
- risk-based cleanup goals and other criteria or requirements (including the RAOs),
- potential impact to ecological receptors and/or habitat,
- technical and economic feasibility,
- regulatory criteria, and
- community concerns.

Many factors are considered in the final risk management decisions and the acceptable risk for a project may be greater than the point of departure. Evaluation of each remedial alternative for the site should include an estimate of the reduction in risk and a determination of risk management measures needed for contamination remaining in excess of risk-based concentrations. Risk management decisions (including mitigation and control of potential exposure) and technical supporting information are presented in remedy selection documents.

Risk management decisions pertaining to groundwater may consider MCLs, the federal or state standards for drinking water quality. The current list of federal and state MCLs can be found at:

- water.epa.gov/drink/contaminants/index.cfm#List
- www.cdph.ca.gov/certlic/drinkingwater/Pages/Chemicalcontaminants.aspx

Short-term Risks During Remediation

Short-term risks associated with implementation of a remedy should be considered during evaluation of remedial alternatives. For many sites, a qualitative evaluation of risks associated with implementation of remedial alternatives is sufficient, but other sites will require a more quantitative evaluation (USEPA, 1991ab). Releases of VOCs from soil and emissions of particulates containing COCs (fugitive dust) during cleanup activities might pose significant risks to people who live or work in the vicinity of the site and to workers who are involved in the site cleanup. Evaluation and selection of remedial alternatives should identify and consider measures to monitor and control short-term exposure and risks. This evaluation should include consultation with local agencies (e.g., air quality management district). Site safety plans should be developed and implemented. Implementation of certain remedies might require perimeter monitoring of vapors and/or airborne particulate contamination. Community concerns associated with short-term risks are addressed through the public participation process.

Post-Cleanup Evaluations

Confirmation sampling may be needed to evaluate residual concentrations of COCs to determine whether the RAOs for the remedy have been achieved and to support the assessment of residual risk, if necessary. A post-cleanup evaluation may be appropriate for lead and VOCs, as discussed below. Post-cleanup evaluations for other COCs may be recommended on a site-specific basis.

Confirmation Sampling

Confirmation sampling is used to determine whether the RAOs established in the remedy decision document have been achieved. Confirmation sampling approaches for soil excavations and SVE systems are discussed in the *PT&R Guidance – Remediation of Metals in Soil* (DTSC, 2008) and *PT&R Guidance – Remediation of Chlorinated VOCs in Vadose Zone Soil* (DTSC, 2010). Confirmation sampling for groundwater remedies is discussed in Section 6.5. Appendix B also discusses possible confirmation sampling methods.

Post-Cleanup Evaluation for Lead

OEHHA developed revised soil screening levels for lead, based on a method that differed from previous approaches for lead exposure and risk assessment (Cal/EPA, 2009). The resulting screening levels for the residential and industrial scenarios are lower than previous screening levels and CHHSLs used by DTSC. Therefore, a more complete evaluation of the residual lead concentrations may be recommended for characterization, management and communication of risk. When the soil cleanup is completed, the residual lead concentrations across the site should be lower than the established cleanup goal.

After the remedy has been implemented, one option is to include a statistical summary of residual lead concentrations for the site (pre-remediation concentrations in non-remediated soil and confirmation sample concentrations) in the completion report. Considerations for the statistical summary include:

- exclusion of data for soil removed or in capped areas
- combining lead concentration data from any capping material with data for uncapped areas (if not spatially biased)
- separate evaluation of lead concentration data for any capping material

Typically, the statistical summary should include the minimum and maximum values, the mean value, the 95% UCL, and the corresponding cleanup goal. Appendix E provides a link to an example of a post-cleanup evaluation for lead.

The concentration of lead in soil exceeds risk-based concentrations at many Brownfields sites. Ambient concentrations of lead at some sites may exceed the risk-based concentration. Therefore, development of the site-specific cleanup goal, post-remediation evaluation, and risk management for lead requires close consideration of expected land use, the distribution and extent of contamination, exposure areas, and cumulative risk (all COCs and exposure pathways). For sites at which containment/capping is the remedy, concentrations of lead (and other non-volatile COCs) may not be reduced, but the risk is reduced by mitigation of potential exposure pathways.

Evaluation of Residual VOC Concentrations

Post-remediation evaluation of VOCs in soil can be a complex and lengthy process. Typically, rebound studies and periodic soil gas sampling (monitoring) are necessary (DTSC, 2010). The residual VOC concentrations across the site should be lower than the established cleanup goal. Residual concentrations exceeding acceptable health risk levels via the vapor intrusion pathway may require mitigation. Guidance for evaluating the health risk posed by the vapor intrusion pathway can be found in the Vapor Intrusion Guidance.

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³ Revision pending. Check DTSC web-site (www.dtsc.ca.gov) for most current version.

APPENDIX E

LINK TO ADDITIONAL DTSC RESOURCES

The following resources available in the *PT&R Guidance – Remediation of Metals in Soil* (DTSC, 2008) and *PT&R Guidance – Remediation of Chlorinated VOCs in Vadose Zone Soil* (DTSC, 2010) may be useful for investigation and cleanup of plating facilities. The resources identified below can be downloaded at the following link:

www.dtsc.ca.gov/SiteCleanup/PTandR.cfm

PT&R Guidance – Remediation of Metals in Soil

- Technology Screening for Metals in Soil
- Characterization Phase Workplan
 - (Outline, including field sampling plan and quality assurance project plan)
- Annotated Outline for Site Characterization Report
- Conceptual Site Model (including general CSM overview and checklist)
- Strategies for Establishing and Using Background Estimates of Metals in Soil
- Soil Confirmation Sampling Plan
- Example for Bridging Memorandum
- Remedial Action Plan Sample
- Removal Action Workplan Sample
- Scope of Work for Corrective Measures Study
- Scope of Work for Interim Measures
- Example for Statement of Basis
- Excavation, Disposal, and Restoration Plan Sample
- Transportation Plan (Outline)
- Annotated Outline for Excavation Completion Report
- Example Post-cleanup Evaluation for Lead
- Annotated Outline for Containment/Capping Design and Implementation Plan
- Operation and Maintenance Plan Sample for a Cap
- Annotated Outline for Containment/Capping Completion Report
- Public Participation Sample Documents

PT&R Guidance – Chlorinated VOCs in Vadose Zone Soil

- Technology Screening for Chlorinated VOCs in Soil
- Conceptual Site Model for Chlorinated VOCs
- Design and Implementation of SVE Systems
- Confirmation Sampling for Chlorinated VOCs in Soil Excavations

APPENDIX F

SOIL CLEANUP TECHNOLOGIES FOR HEXAVALENT CHROMIUM

TECHNOLOGY	DESCRIPTION	APPLICABILITY	ADVANTAGES	LIMITATIONS / CONSTRAINTS
Excavation / Disposal	Impacted soil is excavated and placed within an engineered disposal unit	<ul style="list-style-type: none"> • Most soil types • Accessible soils 	<ul style="list-style-type: none"> • Established technology 	<ul style="list-style-type: none"> • Requires appropriate disposal unit design and monitoring of unit performance
Containment	Impacted soil is isolated beneath an engineered cap and/or horizontal or vertical barriers	<ul style="list-style-type: none"> • Applicable to most soils • Soil that has been treated to reduce CrVI mobility • Temporary containment of CrVI-impacted soil while final remedy is tested and implemented or until facility closure 	<ul style="list-style-type: none"> • Established technology 	<ul style="list-style-type: none"> • Mobility of CrVI is a concern • Requires appropriate containment system design • Requires effectiveness monitoring to detect any CrVI migration • Likely not protective if groundwater is shallow • Long-term maintenance • Land use restrictions
<i>In Situ</i> Chemical Treatment (also known as Geochemical Fixation, In Situ Stabilization, In-place Inactivation or Geochemical Fixation)	Amendments (reductants) are applied to soils via mixing or percolation to convert CrVI to CrIII. Example reductants include calcium polysulfide and sodium metabisulfite. Requires ferrous iron to catalyze the reaction.	<ul style="list-style-type: none"> • Soil texture appropriate for incorporating amendments • Impacted soils accessible to tilling equipment • Ability to place reductants in contact with impacted soil • Assess applicability through treatability study using site-specific materials. 	<ul style="list-style-type: none"> • Generally inexpensive and easy to implement • May create fewer operational hazards than more conventional remedial methods 	<ul style="list-style-type: none"> • Limited demonstration in field-scale studies • Most research has focused on lead in soil • Long-term fixation of CrIII uncertain if geochemical conditions change • Treatment effectiveness best evaluated by sampling soil pore water (e.g., via lysimeters) • Treatment may mobilize CrVI downward and further degrade groundwater

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TECHNOLOGY	DESCRIPTION	APPLICABILITY	ADVANTAGES	LIMITATIONS / CONSTRAINTS
Phytoremediation	Plant uptake is used to recover CrVI from soil.	<ul style="list-style-type: none"> • Low to moderate concentrations • Shallow contamination • Soil conditions favorable to plant growth 	<ul style="list-style-type: none"> • May be applied over large surface areas cost effectively • Produces relatively low quantities of waste • May be used as follow-up remedy to remediate residual concentrations 	<ul style="list-style-type: none"> • Plant growth limitations at high CrVI concentrations or undesirable soil conditions • Potentially long timeframe to remediate for higher concentrations • CrVI may leach outside the root zone and migrate downward to the saturated zone • CrVI impacts must be in rooting zone
Vitrification	Mobility of CrVI is decreased by high-temperature treatment of contaminated area. The high temperature component of the process destroys/ removes organic materials. CrVI is retained within the vitrified product.	<ul style="list-style-type: none"> • Applicable to most soils • Particularly well suited for treatment of chromium • Sites with moisture content <25%. • Soil should be able to carry a current and solidify as it cools • <i>In situ</i> or <i>ex situ</i> approaches 	<ul style="list-style-type: none"> • Long-term effectiveness • Can address high CrVI concentrations • Can address mixtures of contaminants 	<ul style="list-style-type: none"> • High energy requirements and cost • <i>Ex situ</i> approaches are complex processes that typically includes excavation, pretreatment, mixing, feeding, melting, and vitrification. Requires off-gas collection and treatment as well as forming/casting the product. • <i>In situ</i> approaches still in demonstration phase, but have lower energy requirements and cost • Limited commercial availability • Maximum <i>in situ</i> treatment depth is 20 feet. • Not appropriate for metal concentrations exceeding solubility limit in glass

INVESTIGATION AND REMEDIATION OF PLATING FACILITIES

TECHNOLOGY	DESCRIPTION	APPLICABILITY	ADVANTAGES	LIMITATIONS / CONSTRAINTS
Soil Washing	Water-based process for scrubbing soils to remove contaminants by dissolving CrVI or suspending Cr in wash solution or concentration into smaller volume of soil through particle size separation, gravity separation, and attrition scrubbing.	<ul style="list-style-type: none"> • Assess applicability with bench scale treatability study. • Applicable to coarse grained soils (<20% of particles with diameters <2 mm) • Most easily implemented when a single metal contaminant occurs in a particular insoluble fraction of soil that can be separated by particle size classification • Economically feasible with >5,000 tons of soil 	<ul style="list-style-type: none"> • Long-term effectiveness • Can address high concentrations 	<ul style="list-style-type: none"> • Commercialization of process not yet extensive • Complex waste mixtures make formulating washing fluid difficult • High humic content in soil may require pretreatment • Aqueous stream will require treatment at demobilization • Multiple treatment steps may be required to address washing solvent remaining in treated residuals • Some soil fractions may still require disposal in an engineered unit

INVESTIGATION AND REMEDIATION OF PLATING FACILITIES

TECHNOLOGY	DESCRIPTION	APPLICABILITY	ADVANTAGES	LIMITATIONS / CONSTRAINTS
Soil Flushing	Water is used to flush CrVI from vadose zone soil. Resulting leachate typically is recovered from underlying groundwater by pump-and-treat methods. Flushing solution can be applied by surface flooding, sprinklers, leach fields, vertical or horizontal injection wells, basin infiltration systems, or trench infiltration systems.	<ul style="list-style-type: none"> • Water-soluble metals such as CrVI • Ability to capture mobilized CrVI • High permeability soils • Aquifers having low specific yields 	<ul style="list-style-type: none"> • Can be effective for remediating CrVI source zones • Surfactant-enhanced extraction can be used to expedite the removal of chromium • No soil excavation, handling, or disposal 	<ul style="list-style-type: none"> • Concerns over groundwater degradation • Associated risk of contamination of underlying aquifer with unrecovered flushing solution that contains dissolved contaminants • Higher costs associated with interim containment, depth of contamination, and operational time • May be difficult to apply to sites with multiple contaminants • Limited field demonstrations
Electrokinetics	A direct current is applied to the soil creating a voltage gradient. The gradient causes CrVI in soil-water to migrate to the oppositely charged electrode. Bulk flow of soil-water is induced toward the cathode. CrVI concentrates in solution around electrodes. CrVI can be removed from this solution by electroplating or precipitation/ coprecipitation at the electrodes.	<ul style="list-style-type: none"> • Water soluble contaminants such as CrVI • Soil moisture content must be high enough to allow electromigration • Fine-grained soils • Low permeability soils • Heterogeneous soils • Most efficient when salinity and cation exchange capacity are low • <i>In situ</i> or <i>ex situ</i> approaches 	<ul style="list-style-type: none"> • Limited site disturbance for <i>in situ</i> applications • May be able to treat inaccessible soils • Applicable in soils of low hydraulic conductivity, particularly with high clay content 	<ul style="list-style-type: none"> • Limited demonstration in field-scale studies • Energy costs • Process may not be efficient when CrVI concentration is low and nontarget ion concentration (background) is high • Requires presence of a conducting pore fluid to mobilize contaminants • Heterogeneities or subsurface features may reduce removal efficiencies • Specialized equipment required for <i>in situ</i> treatment

Cr is chromium
 CrVI is hexavalent chromium
 CrIII is trivalent chromium

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APPENDIX G

GROUNDWATER CLEANUP TECHNOLOGIES FOR HEXAVALENT CHROMIUM AND/OR VOLATILE ORGANIC COMPOUNDS

TECHNOLOGY	DESCRIPTION	APPLICABILITY	ADVANTAGES	LIMITATIONS / CONSTRAINTS	REF.
Pump and treat	Groundwater is pumped and treated above ground. Treatment for VOCs includes liquid phase GAC, air stripping with vapor treatment (vapor phase GAC, thermal/ catalytic oxidizer), chemical/ UV oxidation, Treatment for CrVI includes <i>ex situ</i> chemical reduction, precipitation, and ion exchange	VOCs CrVI	<ul style="list-style-type: none"> • Effective in containing plume migration and removing dissolved contaminants 	<ul style="list-style-type: none"> • Long remediation time • May not be most effective or efficient approach for mass removal, particularly in source areas • Not cost effective for long-term operation • After initial removal of COCs from dissolved phase, diffusion from adsorbed phase, DNAPL, or low permeability zone slows remedial progress • May require transition to alternate remedy 	3-7, 23
Multi-Phase Extraction (MPE) (also known as dual-phase extraction, vacuum-enhanced extraction, and bioslurping)	Vacuum system is used to remove various combinations of groundwater, LNAPL, and vapors, lowering water table around well. VOCs in newly exposed vadose zone are then accessible to vapor extraction. Once above ground, extracted vapors or liquid-phase organics and ground water are separated and treated.	VOCs	<ul style="list-style-type: none"> • Most applicable in fine sands to silty sands • Effective in moderate to low permeability soils • Addresses dissolved VOCs, vapor-phase VOCs, and LNAPL • Addresses VOCs in vadose zone, saturated zone, and capillary fringe • Can shorten cleanup time compared to other remediation approaches • Useful with pump-and-treat systems in high yield aquifers 	<ul style="list-style-type: none"> • Potential depth limitations • Requires both water treatment and vapor treatment • Initial startup and adjustment periods may be longer than conventional pump and treat • Potentially higher capital costs than conventional pump and treat • May need to be used in combination with complementary technologies (e.g., as pump and treat) 	1, 2, 8

INVESTIGATION AND REMEDIATION OF PLATING FACILITIES

TECHNOLOGY	DESCRIPTION	APPLICABILITY	ADVANTAGES	LIMITATIONS / CONSTRAINTS	REF.
Permeable Reactive Barriers (PRBs)	Treatment materials are placed, via trenching or injection, across groundwater flow path. Treatment materials include zero-valent metals, chelators, sorbents, and microbes. Target contaminants react with treatment materials to form benign residues or less toxic or non-toxic compounds.	VOC CrVI	<ul style="list-style-type: none"> • Treats VOCs, SVOCs, and inorganics • <i>In situ</i> mass reduction • Preferential flow through barrier allows migration control • Passive remediation (no ongoing energy input) • Limited maintenance • Limited surface structures • Can remediate plumes even if source cannot be located • No disposal requirements or costs 	<ul style="list-style-type: none"> • Installation limitations on depth and width of barrier • Clogging of the barrier due to precipitation or biological activity • May lose their reactive capacity, requiring replacement of treatment materials • Requires continuous aquitard at a depth within vertical limits of wall installation equipment • Treatment medium costs may be excessive • Plume and hydrogeology must be well characterized and delineated 	2, 9-14, 17, 23
<i>In-situ</i> chemical oxidation (ISCO)	Introduction of chemical oxidizing reagents (e.g., permanganate, ozone, peroxide, persulfate) to react with VOCs and form less toxic or non-toxic compounds	VOCs	<ul style="list-style-type: none"> • Potential to result in rapid and complete chemical destruction • Potential to treat both higher and lower permeability materials through advection and direct injection, respectively • Can destroy high concentration VOC plumes and NAPL otherwise not treatable via bioremediation • Does not generate large volumes of waste material • Low O&M costs if treatment is effective 	<ul style="list-style-type: none"> • Oxidant delivery problems due to reactive transport and heterogeneity • May not be cost effective for large target volume, large oxidant requirements, and/or low contaminant concentrations • Potential to mobilize metals (e.g., oxidizing CrIII to CrVI) or NAPL • Excess oxidant or byproduct may exceed water quality levels • Short persistence of some oxidants due to fast reaction rates • Health and safety concerns (handling strong oxidants) 	1, 2, 7, 15-18, 23

INVESTIGATION AND REMEDIATION OF PLATING FACILITIES

TECHNOLOGY	DESCRIPTION	APPLICABILITY	ADVANTAGES	LIMITATIONS / CONSTRAINTS	REF.
<p><i>In-situ</i> chemical reduction (ISCR)/ Geochemical Fixation</p>	<p>Introduction of chemical reducer (such as calcium polysulfide or sodium metabisulfite) to react with CrVI and form CrIII that fixes (immobilizes) onto the aquifer solids</p>	<p>CrVI</p>	<ul style="list-style-type: none"> • Potential to result in timely, complete conversion of CrVI to CrIII • Does not generate large volumes of waste material • Low O&M costs if treatment is effective • Reagents can be mixed with carbon substrates to enhance chemical reduction of CrVI 	<ul style="list-style-type: none"> • Delivery and mixing of reductant to desired treatment zone • Geochemical conditions that allow permanent fixation as CrIII • Potential clogging of aquifer pore space • Excess reductant or byproduct may exceed water quality goals 	<p>2, 7, 9, 15, 17, 18, 23</p>
<p>Reactive Zones/ Enhanced Bioremediation</p>	<p>Reactive zones are created by injecting reagents (such as molasses, vegetable oil, lactate) into groundwater plume to form reducing conditions. Reducing conditions are necessary to convert CrVI to CrIII. For VOCs, reducing conditions and availability of carbon substrates are necessary to initiate dechlorination processes that can result in the formation of less toxic or non-toxic compounds.</p>	<p>VOCs CrVI</p>	<ul style="list-style-type: none"> • Accelerates natural biodegradation process • Can be less expensive (less equipment and labor) than other groundwater remediation technologies • Most reagents are food-grade products, lowering health and safety risks associated with product handling, mixing, and transport to the site 	<ul style="list-style-type: none"> • Delivery and mixing of reductant or carbon substrate to treatment zone • Potential for fouling of wells • Potential to mobilize metals (e.g., arsenic) or affect water quality levels • Faster cleanup of higher permeability zones • May require groundwater circulation system to keep contaminants in areas of active biodegradation • Above-ground treatment system may be needed prior to re-injection or disposal • Demonstrating effective treatment rather than plume dilution • Intermediate degradation products may be more mobile or toxic than original contaminants 	<p>1, 7, 20-23</p>

INVESTIGATION AND REMEDIATION OF PLATING FACILITIES

TECHNOLOGY	DESCRIPTION	APPLICABILITY	ADVANTAGES	LIMITATIONS / CONSTRAINTS	REF.
<i>In Situ</i> Thermal Treatment	Heat is applied via electrical resistance heating, radio frequency heating, dynamic underground stripping, thermal conduction, or injection of hot water, hot air, or steam. Heat application destroys or volatilizes VOCs which can be collected via SVE or multi-phase extraction wells and treated aboveground.	VOCs	<ul style="list-style-type: none"> • Effective in low permeability zones • Can be an effective approach for NAPL • No excavation and transportation costs • Adverse impacts to groundwater quality are unlikely to occur because reagents are not required 	<ul style="list-style-type: none"> • Target temperatures hampered by cold water influx • Energy costs • Treatment time • Ability to demonstrate effective treatment • Potential to mobilize contaminants in groundwater • Buried infrastructure can hinder cleanup • Higher energy demand and longer cleanup time for high moisture content, high organic content, and lower permeability soils • Residual liquids and spent activated carbon may require further treatment 	1, 2
Air Sparging	Air is injected under pressure below the water table to strip out VOCs from groundwater. Volatilized VOCs are captured by SVE or multi-phase extraction systems and treated aboveground.	VOCs	<ul style="list-style-type: none"> • Effective in high permeability soils • Encourages microbe growth which can facilitate bioremediation • Simple to install and maintain • Can be used to treat NAPL zones at or below capillary fringe 	<ul style="list-style-type: none"> • Contaminant depth • Development of air flow within contaminated zone • Non-uniform air flow in saturated zone • Less effective under heterogeneous conditions • Sensitive to minor permeability changes • Long-term performance cannot be predicted via short-term tests • Uncertainty in degree and rate of cleanup achievable at a given site 	1, 2, 24, 25

INVESTIGATION AND REMEDIATION OF PLATING FACILITIES

TECHNOLOGY	DESCRIPTION	APPLICABILITY	ADVANTAGES	LIMITATIONS / CONSTRAINTS	REF.
<p>Monitored Natural Attenuation (MNA)</p>	<p>Relies on natural processes (e.g., biodegradation, sorption, volatilization, dispersion, dilution, chemical or biological stabilization) to clean up or attenuate contaminants in groundwater (as verified through on-going groundwater monitoring).</p>	<p>VOCs CrVI</p>	<ul style="list-style-type: none"> • Limited waste generation • Less intrusive • May be just as effective as other remedial approaches for a given site • May be used in conjunction with, or as a follow-up to active remedial approaches • Overall cost can be lower than active remediation depending on monitoring well distribution, monitoring frequency, and parameters 	<ul style="list-style-type: none"> • Typically requires source removal, especially if NAPL is present • Typically requires demonstration of a stable plume configuration (ensure contaminant degradation prior to migration) • May not provide timely cleanup • Usually requires contaminant fate and transport modeling and evaluation of degradation rates, and demonstration that natural processes will achieve RAOs • Intermediate degradation products may be more mobile / toxic than original contaminant • Not appropriate where imminent site risks are present (e.g., where plume may intersect water supply wells) • ICs may be required • Often perceived as a “no action” remedy 	<p>1,2, 26-30</p>

INVESTIGATION AND REMEDIATION OF PLATING FACILITIES

TECHNOLOGY	DESCRIPTION	APPLICABILITY	ADVANTAGES	LIMITATIONS / CONSTRAINTS	REF.
Containment (Physical Barriers)	Impermeable barriers (horizontal and/or vertical) are used to isolate the contamination to prevent the migration of contaminants and block any direct route of exposure, thus reducing risk. Examples of barriers include caps, slurry walls, sheet piles, cement-bentonite walls, grouted barriers,	VOCs CrVI	<ul style="list-style-type: none"> • Established technology, particularly for source control • Uses standard heavy construction equipment and methods • Commonly applied to source areas when economic, technical, or site-specific factors make it impractical to address source in any other way • Can substantially reduce mass flux and source migration potential 	<ul style="list-style-type: none"> • Verifying barrier integrity after installation • Placement depth limitations (generally about 100 feet) • Monitoring barrier performance to ensure contaminants are not migrating outside of zone targeted for isolation • Potential to mobilize NAPL during emplacement • Uncertain or limited long-term effectiveness of some barrier types • Often used in conjunction with other remedial technologies • Does not remove contaminant mass • To be effective, vertical barriers often need to be keyed into a low-permeability zone • Uncertain long-term integrity of some barrier types • Cost rises with increased depth of barrier placement 	1, 31

Notes:

- | | | | |
|-------|--------------------------------|------|--------------------------------|
| COC | constituent of concern | O&M | operation and maintenance |
| CrIII | trivalent chromium | RAO | remedial action objective |
| CrVI | hexavalent chromium | SVE | soil vapor extraction |
| DNAPL | dense non-aqueous phase liquid | SVOC | semi-volatile organic compound |
| GAC | granular activated carbon | UV | ultraviolet |
| LNAPL | light non-aqueous phase liquid | VOC | volatile organic compound |
| NAPL | non-aqueous phase liquid | | |

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APPENDIX H
REGULATORY CONSIDERATIONS FOR TANK SYSTEM
CLOSURES AT PLATING FACILITIES

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REGULATORY CONSIDERATIONS FOR TANK SYSTEM CLOSURES AT PLATING FACILITIES

This appendix briefly outlines closure and corrective action requirements associated with tank systems at plating facilities. As shown in Figure H-1, multiple types of tank systems are typically present at plating facilities. Specific hazardous waste requirements for closure will vary depending on the regulatory status of the tanks being closed. The Certified Unified Program Agency (CUPA) is generally responsible for overseeing closure activities at generators and Tiered Permitted facilities within their jurisdiction.

HAZARDOUS WASTE MANAGEMENT TANKS

The hazardous waste management tanks at plating facilities may be authorized as generator accumulation tanks, Conditionally Exempt (CE) tanks, Conditional Authorization (CA) tanks, or Permit by Rule (PBR) tanks. The documentation and financial responsibility requirements under each of these regulatory schemes is different, but all units are required to meet closure requirements. See Table H-1 for the closure requirements for tank systems. Process tanks are not listed in this table because unless a process tank becomes a hazardous waste at the end of its useful life, there are no hazardous waste requirements for process tanks.

PERMIT BY RULE FOR WASTEWATER TREATMENT

Water is a major resource at a plating facility and is associated with every operation during plating processes. As much as 90 percent of the water usage is in rinsing of work pieces. This rinse water eventually ends up as wastewater which is often hazardous waste due to the low concentrations of metals carried by the work pieces into the rinse. California law prohibits the discharge of hazardous wastes to sewers. Consequently, because of the large volume of hazardous waste generated, most plating facilities must obtain authorization for the onsite treatment of hazardous wastewater. In most cases, PBR is the appropriate permit tier for neutralization, precipitation, or cyanide destruction of wastewater.

PERMIT BY RULE CLOSURE PLAN

Plating facilities that operate tanks under PBR regulations must comply with the closure requirements¹ and must prepare and maintain a written closure plan throughout the active life of the regulated unit². The CUPA generally performs the PBR closure plan review.

This closure plan describes how and when the PBR tank will be closed, as required by California Code of Regulations, title 22, section 67450.3(c)(11)(B)(1) and 66265.114. The closure plan documents how hazardous waste removed will be characterized for

¹ California Code of Regulations, title 22, section 67450.3(c)(11)

² California Code of Regulations, title 22, section 66450.3(c)(11)(B) and (C)

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proper offsite treatment. The closure plan also documents the sampling plans to confirm a clean closure. The closure sampling plan must include closure performance standards for the tank systems (tanks, secondary containment, piping and other ancillary equipment), site structures (concrete, sumps, trenches, containment system), and soils to confirm the site will be clean after closure of the tank (clean closure). If the results of the sampling confirm that no significant contamination is found, then the PBR tank closure is complete and no further characterization work is necessary.

Plating facilities that discontinue an authorized PBR tank or relocate a PBR tank will need to implement their written closure plan.

FACILITY-WIDE CLOSURE PLAN

Because PBR wastewater treatment units are important for the successful operation of a plating facility, it would be highly unlikely to close all PBR wastewater treatment units without closing the entire facility. Plating facilities that cease all hazardous waste activities will need to meet closure requirements for all generator units and authorized treatment units, even though a written closure plan is not required. Note that the 180 day time limit applies to hazardous waste units, but not to process units.

CORRECTIVE ACTION

All plating facilities generate hazardous waste. Corrective action (site investigation and site cleanup) is required for any sites where hazardous waste or hazardous waste constituents have been released to the environment. These releases require investigation and cleanup. If at any time during the life of the plating facility, a facility owner finds that a release of hazardous waste or hazardous waste constituents has occurred, the extent of the contamination must be investigated. Discovery of contamination can occur as a result of a facility inspection during a Phase 1 Site Assessment, or if the source of nearby groundwater contamination is traced back to the facility. The facility is required to investigate all releases on the property under the control of the owner or operator (fence to fence). Additionally, corrective action may encompass cleanup beyond the facility boundary if contamination has migrated offsite. Releases from PBR and CA units that can be remediated as part of the closure activities and achieve the closure performance standard do not require corrective action. However, if the release can not be cleaned up under closure for hazardous waste units, then further site characterization and corrective action is required. No matter how the contamination is found, any corrective action or site remediation requires oversight from DTSC or a CUPA who has been delegated corrective action authority under Health and Safety Code section 25404.1. Oversight of corrective action is usually performed under a corrective action order or consent agreement.

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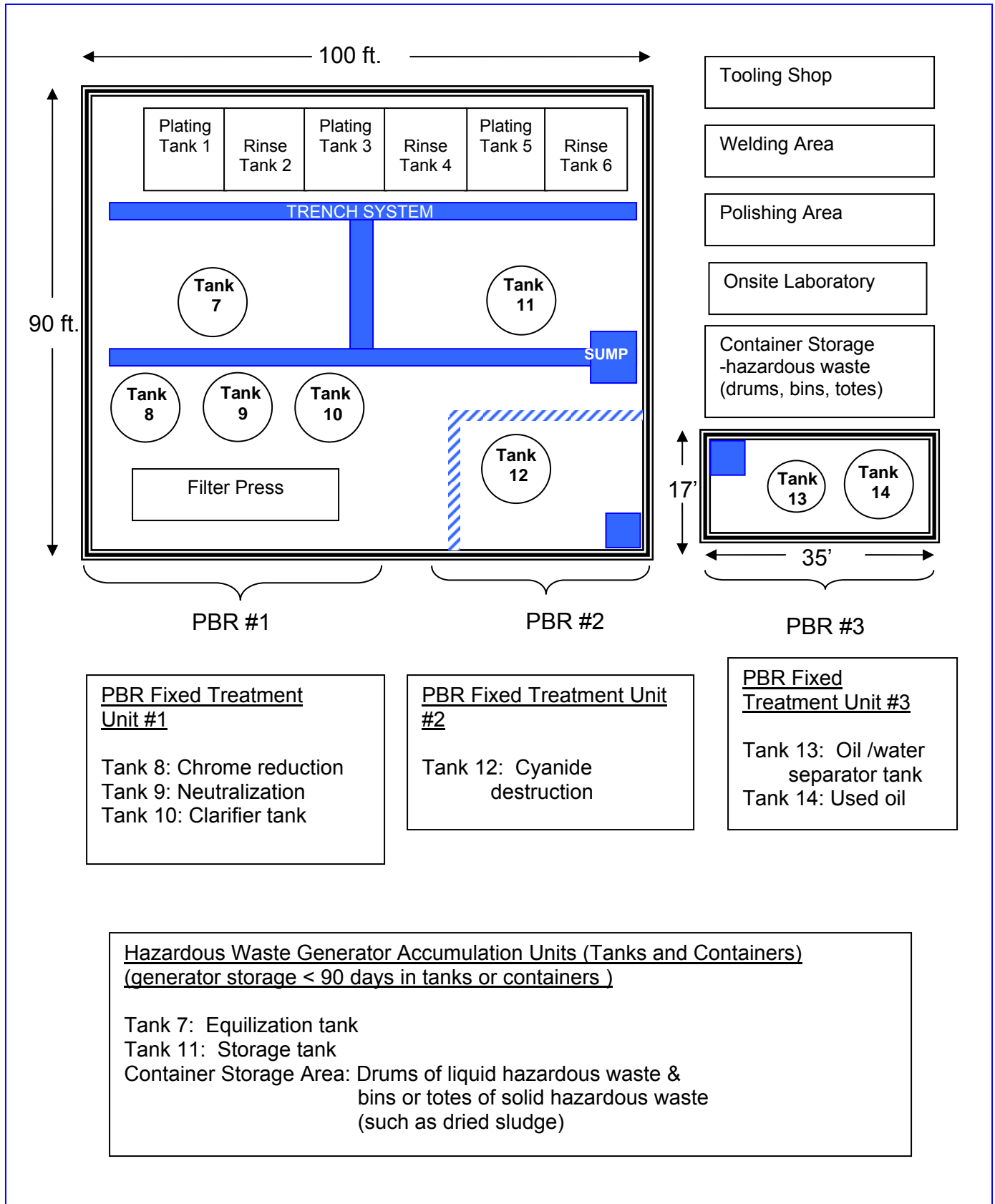


Figure H-1. Example Schematic of Typical Plating Shop Tank System

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Table H-1. Closure Requirements for Hazardous Waste Tank Systems

CATEGORY	HAZARDOUS WASTE GENERATOR ACCUMULATION TANK ¹	HAZARDOUS WASTE TANK CONDITIONAL EXEMPT ² (CE) TANK	HAZARDOUS WASTE TANK CONDITIONAL AUTHORIZATION ² (CA) TANK	HAZARDOUS WASTE TANK PERMIT BY RULE ² (PBR) FIXED TREATMENT UNIT (FTU) ³
Closure Requirements	CCR 66262.34(a)(1) CCR 66265.197(a)&(b) CCR 66265.111 CCR 66265.114	CCR 66262.34(a)(1) CCR 66265.197(a)&(b) CCR 66265.111 CCR 66265.114 HSC 25201.5(d)(8) & (9)	CCR 66262.34(a)(1) CCR 66265.111 CCR 66265.114 HSC 25200.3c(1) & (g)(1)	CCR 67450.3(c)(11)(A) CCR 67450.3(c)(11)(D) CCR 67450.3(c)(11)(E) CCR 66265.198 CCR 66265.111(a)&(b) CCR 66265.114
Written Closure Plan	Not required	Not required	Not required	CCR 67450.3(c)(11)(B) CCR 67450.3(c)(11)(C) CCR 66265.112(c)
Notification of Closure	May be required for some local ordinances	HSC 25201.5(d)(8)(B)	HSC 25200.3(g)(2)	CCR 67450.3(c)(11)(F)
Closure Certification	May be required by some local ordinances	May be required by some local ordinances	HSC 25200.3(l)	CCR 67450.3(c)(11)(G)
Financial Responsibility	Not required	Not required	HSC 25245.4(b)(1)(B)CCR 67450.13	HSC 25245.4(a)(1)(B) CCR 67450.13
Corrective Action ⁴ /Site Remediation	HSC 25187	HSC 25187 HSC 25200.10(e) HSC 25201.5(d)(8)(A)	HSC 25187, HSC 25200.3(c)(3) HSC 25200.14(a)-(e)	HSC 25187 HSC 25200.10(b) HSC 25200.14(a)-(e) CCR 67450.7

Notes:

- 1 90 day generators
- 2 Onsite facilities
- 3 See Section 6.2.1 for further discussion
- 4 Not required if clean closure of the facility is verified.

CCR means California Code of Regulations, title 22

HSC means California Health and Safety Code

APPENDIX I

ANNOTATED OUTLINE

BUILDING DEMOLITION PLAN

Preface: The following annotated outline identifies potential content for a building demolition plan. The plan identifies suggested headings and subheadings and includes instructions (in italics) regarding the potential content. Example text (indented, plain text) is provided for Section 3.0 (Detailed Demolition Sequence).

This outline is not intended to be prescriptive and should be adjusted as appropriate for site-specific conditions. Some elements identified may apply to your site, while others may not. Additional elements than are addressed by the outline may also be needed. This outline is for guidance only, and is applicable on a case-by-case basis.

1.0 INTRODUCTION

Instructions: Present an overview of the entire demolition plan in a manner that is clear and concise, yet gives the reviewer a basic understanding of the site, the nature and extent of contamination, potential receptors, and the proposed demolition action. Briefly summarize the purpose of the plan, site name and location, site description, and chemical and physical hazards. The site description should address the physical features, buildings, site history of ownership and site operations, and include a description of the scope and role of the remedy. Identify the proponent or regulatory entity responsible for the project including the regulatory oversight official and contractor personnel in responsible charge of all or significant portions of the project. Describe the relationship of the proponent to the site. The plan objectives should be specific, measurable, attainable, realistic and time-based statements. The objectives should consider factors such as local ordinances and air pollution control requirements.

1.1 Site Location and Information

Instructions: List the common name, street address, and provide a location map. Include a description of the physical features at the site, any other buildings, a summary of the ownership and site operation history. Identify the proponent or regulatory entity responsible for the project including the regulatory oversight official and contractor personnel in responsible charge of all or significant portions of the project. Describe the relationship of the proponent to the site.

1.2 Purpose and Objectives

Instructions: Briefly summarize the purpose of the plan and the chemical and physical hazardous present. Objectives should be well defined (specific, measurable, attainable, realistic and time-based) statements that describe the desired outcome. For example, "The objective of this plan is to demolish the building that once was the location of the XYZ Plating shop six weeks after this

plan is approved while employing dust and emission control measures to meet local air pollution control requirements, properly disposing of asbestos-containing materials, properly disposing of contaminated wallboard, properly disposing of cyanide-containing concrete, capture and recycling of refrigerant in the HVAC equipment, and proper containment of lead-based paint.” The objectives should consider factors such as local ordinances and air pollution control requirements.

1.3 Site Management Plan

Instructions: List and describe responsibilities of the primary person in charge of the work and the safety officer. Additional personnel may be listed depending on the complexity and size of the effort.

1.4 Report Organization

2.0 PLAN OVERVIEW

2.1 Project Scoping

Instructions: Define the work to be performed in sufficient detail to allow implementation of the plan. Present all aspects of the work to be performed, permits required, and a preliminary project schedule. Identify the critical path elements to be completed during the demolition. Conduct appropriate file reviews or research (such as local agency permitting requirements or regulatory status for the building). Such reviews and research are often useful for identifying identify potential roadblocks or activities that may affect the project schedule.

2.2 Project Management

Instructions: Identify key project staff, their duties, and responsibilities. Outline the project management plan, including a project communication plan and contact information (names, titles, company/agency, address, office telephone number, e-mail address, and facsimile number). Once construction commences an updated list should be prepared that includes cellular telephone numbers and other emergency contact information. However, this should not be distributed to the general public.

2.3 Project Permitting

Instructions: Identify all permits to be obtained for the building demolition, including permit type, issuing agency, approximate amount of time to obtain, reporting requirements and term. Permits likely will be required for demolition, air quality during demolition, lead-based paint (LBP) abatement, asbestos-containing materials (ACM) removal, sidewalk closure, alleyway closure; restricting parking on the street in front or behind the site; utility abandonment; HVAC system removal; air quality monitoring; fire hydrant use, and site restoration activities (e.g., fencing, landscaping, lighting, capping).

Identify permits with limited terms or requiring specialized licenses, insurance, and/or bonding. Also, identify permit requirements that may affect the demolition plan (e.g., local air permits may have requirements that affect work hours, restrict the number and types of heavy-duty engines operating at the site, or require specific air monitoring protocol). Outline the schedule for obtaining each permit to ensure adequate time for agency review. Include contingencies for the permitting agency to request additional information or review by an associated agency (e.g., building and safety agencies often request assistance from their associated environmental health officer).

2.4 Underground Utility Check

Instructions: Identify the procedures for checking utilities (e.g., Underground Service Alert). Please note that many of the members of USA North or USA South will not enter private property or structures. To ensure that all potential pipelines and conduits are identified, the services of an underground utility locator service are often retained.

2.5 Project Sequence

Instructions: Present the framework for the implementation of the plan. Present a detailed sequence of events to ensure that the project can progress without delay once implementation commences. The sequence of events for a plating facility should be detailed to ensure logical progression and adequate protection of public health and environmental resources. An overall project sequence for a plating facility might be:

- 1) Mobilization and site preparation*
- 2) Establish site control*
- 3) Pre-demolition waste removal*
- 4) Pre-demolition inspection*
- 5) Demolition*
- 6) Debris removal*
- 7) Pre-foundation removal inspection*
- 8) Foundation removal*
- 9) Post-foundation removal inspection*
- 10) Cover placement (if applicable) or soil excavation and grading (if applicable)*
- 11) Demobilization*
- 12) Demolition Completion Report*

2.6 Health and Safety Plan (HASP)

Instructions: Prepare a project-specific HASP that describes the project and the potential safety hazards. Identify the individuals responsible for maintaining safety during the project (e.g., demolition project manager, site safety officer). Comply with state and federal occupational safety requirements as defined in the applicable sections of Title 8 of the California Code of Regulations (8 CCR) and Title 29 of the Code of Federal Regulations (29 CFR). Provide information and guidance on the potential hazards that may be encountered during project activities, and the measures and

controls to be implemented to eliminate or reduce the impact of potential hazards. Include the following content: levels of personal protective clothing necessary and the associated decontamination and doffing procedures; procedures for monitoring air in the work zone and determining if respiratory protection is required for the workers; forms to document the daily tailgate safety meetings; logs for recording the personnel at the site; logs to record air monitoring data obtained in the workers breathing zone.; emergency procedures; and a list of required safety equipment.

3.0 DETAILED DEMOLITION SEQUENCE

Instructions: Outline the sequence of tasks for building demolition. Identify what equipment is needed at the site at a particular time. If large caches of equipment cannot be placed at the site without limiting the available work space, consider a sequence that results in "just in time" delivery of equipment to prevent excessive cost for equipment rental or lengthy storage of waste onsite. Identify specific tasks that ensure adequate work is available so that contractor personnel are properly utilized throughout the project. Provide sufficient details to ensure logical task progression and adequate protection of public health and environmental resources.

3.1 Establish Site Control

- a) Establish site perimeter and secure site with temporary fencing (at least one diagram in the plan should illustrate the approximate location of the fencing).
- b) Place all detour signage and barriers in conformance with the approved sidewalk closure plan to prevent unauthorized access to the work area and to comply with the Americans with Disabilities Act.
- c) Place air monitors and collect baseline or other preliminary samples as required. No other work should be performed until the baseline is established.
- d) Place a secured, locked construction container to store supplies, construction and safety equipment.
- e) Establish an onsite location where safety-related documents, monitoring records and a worker sign-in log will be found.
- f) Inspect and identify whether all utilities have been disconnected.
- g) Establish required safety stations and place fire extinguishing equipment.
- h) Post appropriate safety signage (i.e., hard hat required, no unauthorized access).
- i) Post safety notices (emergency phone numbers and map to nearest emergency room)

3.2 Pre-Demolition Waste Removal

- a) Establish safe entrance and egress to the building, where necessary portable lighting should be available.
- b) Remove main electrical panel and have utility company disconnect (if needed) and abandon the power line at a nearby junction or utility pole.
- c) Inspect and ensure all equipment is de-energized. (Note: Some equipment used in electroplating has components such as capacitors that store electrical energy which may cause injury if discharged.)
- d) Place markings, barriers and signage in areas where ACM is to be removed.
- e) Remove and package for proper disposal all mercury containing thermostats and sensors.
- f) Perform decontamination of the building interior by vacuuming dusts and wiping down surfaces.
- g) Contain and remove ACM (to the extent possible) under the supervision of a person who holds a valid certification for ACM removal as required by Title 8, California Code of Regulations, Article 2.6, Section 351.15.
- h) Perform underground utility survey.
- i) Remove, trim or protect landscaping near the building.
- j) Prevent the deposition of LBP contaminated material deposition by covering exposed soil and plants in areas around the building.
- k) Remove LBP under the supervision of a person certified for LBP removal pursuant to Health & Safety Code Section 105254 in a manner consistent with lead work practice standards.
- l) Remove, collect, and package all fluorescent tubes in light fixtures within the building.
- m) Examine, collect, and remove lighting ballasts. Properly manifest and dispose of ballasts which contain polychlorinated biphenyls (PCB). Recycle the remaining ballasts.
- n) Remove large HVAC appliances in a manner that ensures that the refrigerants are properly reused or recycled.
- o) Remove remaining solid waste from the interior of the building.
- p) Remove the drywall saturated with plating contaminants.
- q) Remove all glass windows.

3.3 Pre-Demolition Inspection

- a) Inspect and clear the building.
 - i. Include photographic documentation indicating that pre-demolition actions are complete.
 - ii. Focus on whether demolition can safely proceed, if all pre-demolition actions are complete, if work is proceeding in a satisfactory manner, and if equipment and supplies are available to safely begin the next phase of work.
 - iii. Prepare a “punch-list” that describes any actions that are incomplete or unsatisfactory.
- b) Perform the tasks required by punch-list.
- c) Repeat pre-demolition inspection until no items are noted on the inspection punch-list.

3.4 Demolition

- a) Deconstruct the roof. Given the potential for wood to have been saturated by acid or metal containing mists, all wood should be removed and disposed of, and should not be recycled or shredded for ground cover. Containerize, label, manifest and remove the waste as necessary.
- b) Remove the remaining interior walls. Containerize, label, manifest and remove of waste as necessary.
- c) Remove the first wall. Direct the wall towards the interior of the building to minimize impact on adjacent properties. Containerize, label, manifest and remove of waste as necessary.
- d) Score the foundation using a concrete or masonry saw to minimize the use of jack hammers once foundation removal begins.
- e) Remove the second and third walls. Direct the walls towards the interior of the building to minimize impact on adjacent properties. Containerize, label, manifest and remove of waste as necessary.
- f) Remove the fourth wall. Direct the wall towards the interior of the building to minimize impact on adjacent properties. This will leave the site with no physical barrier between the plating facility and the adjoining property. Once the wall is removed an additional barrier, in most cases, plastic tarps or sheeting will be attached to the fence line. Containerize, label, manifest and remove of waste as necessary.

3.5 Pre-Foundation Removal Inspection

- a) Inspect the progress of the project and the quality of the result.
 - i. This inspection should be performed by the responsible person for the demolition, regulatory agency project manager, permit inspector(s), and supervisors of any contractor working at the site.
 - ii. Include photographic documentation to demonstrate site conditions after removal of the roof and walls.
 - iii. Focus on whether additional debris removal is necessary, if work is proceeding in a satisfactory manner, and if equipment and supplies are available to safely begin the next phase of work.
 - iv. Prepare a “punch-list” that describes any actions that are incomplete or unsatisfactory.
- a) Perform the tasks required by punch-list.
- b) Repeat pre-foundation removal inspection until no items are noted on the punch-list.

3.6 Foundation Removal

- a) Delineate work areas where jackhammers and backhoes will be operating.
- b) Conduct a safety briefing to emphasize safety procedures around the backhoe and the importance of hearing protection when jackhammers or other impact equipment is in use.
- c) Break and load foundation concurrently.
- d) Perform dust suppression as needed taking care not to create “mud bogs” which can lead to contaminant “drag-out” on equipment tires and pose an enhanced slip and fall hazard.

3.7 Post-Foundation Removal Inspection

- a) Inspect the performance thus far, and through previous observation and current site conditions, determine if it is appropriate to progress to the next phase (e.g., place a temporary cover over exposed soil, begin contaminated soil excavation).
 - i. This inspection should be performed by the responsible person for the demolition, regulatory agency project manager, permit inspector(s), and supervisors of any contractor working at the site.
 - ii. Include photographic documentation to demonstrate site conditions after foundation removal.
 - iii. Focus on whether additional debris removal is necessary, if work is proceeding in a satisfactory manner, and if equipment and supplies are available to safely begin the next phase of work.
 - iv. Prepare a “punch-list” that describes any actions that are incomplete or unsatisfactory.

- b) Perform the tasks required by punch-list.

3.8 Cover Placement and Site Demobilization

- a) In the event that the demolition is not immediately followed by excavation, place a temporary or semi-permanent cover that is sufficiently durable to remain serviceable until preparations for excavation are complete.
- b) Develop a schedule for the inspection of the temporary cover.
- c) Reconfigure the fence to encompass the covered area and protect the cover.
- d) Post signs on the fencing with contact information so that concerned citizens can contact personnel who can repair the temporary cover, report vandalism, and assist in maintaining site security.
- e) Restore landscaping near the building.
- f) Remove all demolition related equipment.
- g) Check the area, sweep the sidewalks, dispose of rubbish.
- h) Remove sidewalk detour and reopen the sidewalk.
- i) Decommission air monitoring stations.

4.0 DEMOLITION COMPLETION REPORT

Instructions: Identify the demolition plan and the date of agency approval. Describe all permits (type of permit, issuing agency, permit number, date of issuance and date of permit closure). Include all data generated from air quality monitoring. Identify variations or addenda to the plan. If possible, summarize the results of the project debrief (what went right? What went wrong? What would you do differently? What would you include in future projects?).

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**ANNOTATED OUTLINE
PILOT STUDY WORKPLAN FOR *IN SITU* GROUNDWATER TREATMENT**

Preface: The following annotated outline identifies potential content for a pilot study workplan for *in situ* treatment of a groundwater VOC or hexavalent chromium plume. This outline is not intended to be prescriptive and should be adjusted as appropriate for site-specific conditions. Some elements identified may apply to your site, while others may not. Additional elements than are addressed by the outline may also be needed. This outline is for guidance only, and is applicable on a case-by-case basis.

1.0 INTRODUCTION

Instructions: Provide a general description of the site and pilot study area. Present the purpose and scope of the pilot study, including the regulatory framework under which it is being conducted. Identify the response agency. Outline the workplan organization.

- 1.1 Site Location and History
- 1.2 Scope and Objectives of Pilot Study
- 1.3 Workplan Organization

2.0 SUMMARY OF PREVIOUS INVESTIGATIONS

*Instructions: Summarize the hydrogeologic conditions in the pilot study area, including factors that affected the study design and that may affect the effectiveness of the selected *in situ* technology. Describe the nature and extent of impacted groundwater. If multiple water-bearing zones are present, indicate the contaminant concentrations in the zone to be treated as well as how the pilot study may affect other water-bearing zones. Support the section with appropriate figures, tables, and appendices. If applicable, describe the results of previous bench-scale or treatability testing relevant to the pilot study.*

- 2.6 Site Hydrogeologic Setting
- 2.7 Nature and Extent of Impacted Groundwater
- 2.8 Summary of Previous Bench-Scale / Treatability Testing (if applicable)

3.0 OVERVIEW OF *IN-SITU* TECHNOLOGY

*Instructions: Describe the selected *in-situ* treatment technology. If applicable, identify the injectant options that were considered and the rationale for choosing the selected injectant. Identify the reaction processes between the injectant and contaminants to be addressed as well as the potential by-products and geochemical effects. Describe how the injectant will be delivered and distributed. Indicate how the injectant dosage was (or will be) determined and/or the basis for the selected injectant dosage. Provide supporting calculations for the injectant dosage.*

INVESTIGATION AND REMEDIATION OF PLATING FACILITIES

- 3.1 Technology Description
- 3.2 Injectant Selection
- 3.3 Reaction Process
- 3.4 Injectant Delivery System

4.0 PILOT STUDY OBJECTIVES AND OVERVIEW

Instructions: Discuss the pilot study objectives, including the performance measures and data to be collected. Provide a general overview of the pilot study approach and planned sequence of events.

- 4.1 Objectives
- 4.2 General Overview

5.0 PRE-IMPLEMENTATION ACTIVITIES

Instructions: Describe how the pilot study location was (or will be) selected and identify any access constraints or considerations (e.g., ecological habitat, sensitive receptors, cultural resources). Identify the permitting, regulatory, and notification requirements for the pilot study. If applicable, describe any data collection activities to be conducted prior to study implementation (e.g., characterization of in situ geochemical characteristics needed to support study design). Describe how the site will be controlled during the pilot study and how pilot study materials will be staged and handled.

- 5.1 Selection of Pilot Study Location
- 5.2 Special Considerations for Pilot Study Location
- 5.3 Access Agreements
- 5.4 Permitting and Regulatory Requirements
- 5.5 Notifications
- 5.7 Pre-Study Data Collection
- 5.8 Support Facilities and Site Control
- 5.9 Material Staging and Handling

6.0 IMPLEMENTATION PLAN

Instructions: Describe the specifications for and installation / construction of the pilot study infrastructure, including wells (extraction, injection, monitoring, piezometers), the injection system, and other equipment. Address any hydrogeologic testing and tracer testing to be conducted prior to injection, including the field and data evaluation procedures. Identify the requirements and procedures for system start-up, operation, and operation and maintenance. If not addressed in Section 3.0, indicate how the injectant dosage was / will be determined. Describe how the injectant distribution will be

monitored during the pilot study. Describe the monitoring activities to be conducted prior to, during, and after the pilot study.

- 6.1 Well Installation
 - 6.1.1 Well Drilling and Construction
 - 6.1.2 Well Development and Sampling
 - 6.1.3 Groundwater Elevation Monitoring
 - 6.1.4 Surveying
- 6.2 Hydrogeologic / Tracer Testing
- 6.3 Injection System Construction
 - 6.3.1 Equipment and Controls
 - 6.3.2 Injectant Mixing and Metering System
 - 6.3.3 Injection Equipment
 - 6.3.4 Electrical Installation
 - 6.3.5 Equipment Shakedown
 - 6.3.6 Demobilization
- 6.4 Pilot Study Operations
 - 6.4.1 System Startup
 - 6.4.2 Injection
 - 6.4.3 Operation and Maintenance
- 6.5 Monitoring
 - 6.5.1 Baseline
 - 6.5.2 Injectant Distribution
 - 6.5.3 Validation of Reaction Processes
 - 6.5.4 Contaminant Concentration Trends

7.0 SAMPLING AND ANALYSIS PLAN

Instructions: Provide a detailed description of the data quality objectives developed for the pilot study. Describe the sampling and analytical methods to be performed during the pilot study. Identify the site document providing detailed sampling and analysis procedures or include the procedures as an appendix to the workplan.

- 7.1 Background
- 7.2 Data Quality Objectives
 - 7.2.1 State the Problem
 - 7.2.2 Identify the Decisions
 - 7.2.3 Identify Inputs to Decisions
 - 7.2.4 Define Study Boundaries
 - 7.2.5 Develop Decision Rules
 - 7.2.6 Specify Tolerance Limits on Decision Errors
 - 7.2.7 Optimize Design for Obtaining Data
- 7.3 Groundwater Sampling Requirements
- 7.4 Quality Control Samples
- 7.5 Laboratory Analytical Requirements
- 7.6 Data Validation

8.0 WASTE MANAGEMENT AND EQUIPMENT DECONTAMINATION

Instructions: Describe the waste materials that will be generated by pilot study activities and how these materials will be managed. Describe the equipment decontamination requirements for the pilot study. Reference the site document providing detailed waste management and decontamination procedures or include detailed procedures as an appendix.

8.1 Investigation-Derived Waste Management

8.2 Equipment Decontamination

9.0 SITE HEALTH AND SAFETY PLAN

Instructions: Identify the health and safety plan under which the pilot study will be conducted. If using an existing site health and safety plan, discuss any hazards specific to pilot study activities (such as reagent transport, handling, mixing, and disposal).

10.0 CONTRACTOR QUALITY CONTROL PLAN

Instructions: Describe the roles and responsibilities of personnel who will be involved with installing pilot study infrastructure and conducting the pilot study. Identify the key tasks and deliverables.

11.0 REPORTING

Instructions: Indicate how pilot study progress and results will be shared with the oversight agency during and after pilot study implementation. Identify reporting frequencies and submittal schedules. Outline the content of status / progress reports, interim data reports, and the pilot study report of results.

11.1 Status / Progress Reports

11.2 Interim Reports

11.3 Pilot Study Report of Results

12.0 SCHEDULE

Instructions: Provide and discuss the schedule for implementing the pilot study, including the anticipated sequencing and duration of discrete tasks.

13.0 REFERENCES

Instructions: Provide the references cited in the workplan and used as the basis for any calculations.

TABLES

- Well Information Summary
- Material Specifications
- Sampling and Analysis Schedule
- Sample Container, Preservation, Holding Time, and Storage Requirements
- Analytical Methods, Parameters for Analysis, and Quantitation Limits
- Precision and Accuracy Goals
- Quality Control Samples

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- Pilot Study Layout
- Proposed Pre-Implementation Data Collection Locations
- Proposed Pilot Study Well Locations
- Typical Well Construction Diagrams
- Conceptual Drawing of Injectant Distribution System
- Piping and Instrumentation Diagram
- Electrical Diagram
- Project Schedule
- Project Organization Chart

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- Estimates / Calculations of Injectant Requirements
- Injectant Modeling Results (if applicable)
- Health and Safety Plan
- Activity Hazard Analysis
- Procedures

ANNOTATED OUTLINE
PILOT STUDY REPORT OF RESULTS FOR *IN SITU* GROUNDWATER TREATMENT

Preface: The following annotated outline identifies potential content for a report of results from a pilot study for *in situ* treatment of a groundwater VOC or hexavalent chromium plume. This outline is not intended to be prescriptive and should be adjusted as appropriate for site-specific conditions. Some elements identified may apply to your site, while others may not. Additional elements than are addressed by the outline may also be needed. This outline is for guidance only, and is applicable on a case-by-case basis.

EXECUTIVE SUMMARY

1.0 INTRODUCTION

Instructions: Provide a general description of the site and pilot study area. Identify the purpose, scope, and objectives of the pilot study. Identify the performance measures and applicable data metrics. Indicate the regulatory framework under which the study is being conducted. Identify the responsible agency. Outline the report organization. Reference the pilot study workplan.

- 1.1 Site Location and History
- 1.2 Purpose and Scope of Pilot Study
- 1.3 Report Organization

2.0 BACKGROUND INFORMATION

Instructions: Briefly orient the reader to the site and provide sufficient background information so that the reader can evaluate the pilot study results. Refer reader to existing site documents for further details. If applicable, describe the results of any investigation activities conducted to support pilot study design or implementation. Support this section with appropriate figures and tables.

- 2.1 Site Hydrogeologic Setting
- 2.2 Nature and Extent of Impacted Groundwater
- 2.3 Results of Investigations Conducted to Support Pilot Study

3.0 PILOT STUDY DESCRIPTION, OBJECTIVES, AND PROCEDURES

Instructions: Provide an overall description of the pilot study, including the objectives, equipment, and procedures. Also describe any departures or exceptions from the pilot study workplan. Describe the results of hydrogeologic testing and/or tracer testing.

INVESTIGATION AND REMEDIATION OF PLATING FACILITIES

- 3.1 *In Situ* Treatment Technology Description
- 3.2 Pilot Study Objectives
- 3.3 Pilot Study Infrastructure
 - 3.3.1 Wells and Piping
 - 3.3.2 Equipment
 - 3.3.3 Injectant Mixing and Metering System
 - 3.3.4 Injection Equipment
 - 3.3.5 Electrical Equipment and Controls
- 3.5 Hydrogeologic / Tracer Testing
- 3.6 Baseline Sampling and Analysis
- 3.6 System Startup
- 3.7 Injection
- 3.8 Monitoring

4.0 PILOT STUDY RESULTS

Instructions: Describe the monitoring results for the pilot study. Provide interpretations of the results. Support discussion with appropriate tables, graphs, figures, and appendices.

- 4.1 Baseline Sampling and Analysis Results
- 4.2 Injectant Distribution Monitoring Results
- 4.3 Observed Reaction Processes
- 4.4 Contaminant Concentration Trends
- 4.5 By-Products and Induced Geochemical Effects

5.0 CONCLUSIONS AND RECOMMENDATIONS

Instructions: Discuss the findings and whether there is a need for additional work. Indicate whether the technology is suitable for full-scale implementation. If applicable, describe the design basis for the full-scale system. Provide recommendations for on-going monitoring to evaluate long-term effects of the pilot study.

- 6.1 Overall Effectiveness of Technology
- 6.2 Needs for Further Study
- 6.3 Design Basis for Full-Scale System (if applicable)
- 6.4 Recommendations for On-going Monitoring in Pilot Study Area

6.0 REFERENCES

Instructions: Provide the references cited in the report and used as the basis for any calculations.

INVESTIGATION AND REMEDIATION OF PLATING FACILITIES

TABLES

- Equipment List
- Well Construction Details
- Pilot Study Chronology
- System Flow Rates
- Injectant Quantities
- Sampling and Analysis Strategy
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- Tracer Test Results
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- Sample Collection Forms
- Analytical Results
- Chain-of-Custody Records