BROADBENT
8 West Pacific Ave., Henderson, NV 89015
[T] 702-563-0600 [F] 702-563-0610
broadbentinc.com

Creating Solutions. Building Trust.

April 15, 2013

Project No. 04-01-101-001

Mr. Michael Friend, P.E.
Staff Engineer III
Special Projects Branch
Bureau of Corrective Actions
Nevada Division of Environmental Protection
2030 E. Flamingo Road, Suite 230
Las Vegas, Nevada 89119-0818

Re: Titanium Metals Corporation
Henderson, Nevada Facility
NDEP Facility ID # 000537
Response to NDEP's March 6, 2013 Comments on TIMET's Monitored Natural Attenuation Work Plan

Dear Mr. Friend:

Please find attached a response to the Nevada Division of Environmental Protection's (NDEP's) comments on the *Monitored Natural Attenuation Work Plan* for the Titanium Metals Corporation (TIMET) facility. The response has been authored by Mr. Jay Snyder of EA Engineering, Science, and Technology, Inc.; Ms. Victoria Tyson of Tyson Contracting; and me.

If you have any questions regarding this submittal, please do not hesitate to contact me at (702) 563-0600.

Sincerely,
BROADBENT & ASSOCIATES, INC.

Kirk J. Stowers, EM-1549 (exp. 10/11/14)
Principal Geologist

JURAT: I, Kirk J. Stowers, hereby certify that I am responsible for the services described in this document and for the preparation of this document. The services described in this document have been provided in a manner consistent with the current standards of the profession and to the best of my knowledge comply with all applicable federal, state and local statutes, regulations and ordinances.

cc: David Hadzinsky – PCC Airfoils, LLC, hard copy and on disk
Victoria Tyson-Bloyd – Tyson Contracting, Inc., hard copy and on disk
Shannon Harbour, Nevada Division of Environmental Protection, Carson City, Nevada, on disk
JD Dotchin, Nevada Division of Environmental Protection, Las Vegas, Nevada, on disk
BMI Compliance Coordinator, Nevada Division of Environmental Protection, Las Vegas, Nevada, hard copy and on disk
Nevada Division of Environmental Protection, c/o McGinley and Associates, Inc., 815 Maestro Drive, Reno, Nevada 89511, hard copy only
Nevada Division of Environmental Protection, c/o McGinley and Associates, Inc., 6280 South Valley View Boulevard, Suite 604, Las Vegas, Nevada 89118, hard copy and on disk
Jeff Gibson – AMPAC, by electronic mail
Mark Paris – BMI, by electronic mail
Lee Farris – BMI, by electronic mail
Ranajit Sahu – BMI, by electronic mail
Joe Kelly – Montrose, by electronic mail
Paul Sundberg – representing Montrose, by electronic mail
Jay Steinberg – NERT, by electronic mail
Allan DeLorme – NERT, by electronic mail
John Pekala – NERT, by electronic mail
Curt Richards – Olin, by electronic mail
Jay Gear – Olin, by electronic mail
Ed Modiano – OSSM GWTS, by electronic mail
Chuck Elmendorf –Stauffer, by electronic mail
Nick Pogoncheff –Stauffer, by electronic mail
George Crouse –Syngenta, by electronic mail
Enoe Marcum – WAPA, by electronic mail

Attachment A
Response to NDEP Comments Dated March 6, 2013

1. Section 1.2 - Scope of the Monitored Natural Attenuation Remedial Action, page 2, 1st paragraph of section, the Deliverable states that "All of these SRC (compounds and metals) are considered in the monitoring regimens developed in this plan irrespective of allocation and/or principal contributor. Nonetheless, evaluation of these SRC within this plan does not construe responsibility or commitment for achieving cleanup levels." The paragraph leading to the foregoing statement discusses three categories of site related chemicals (SRCs). SRCs for which TIMET is the principal contributor, co-contributor, or non-contributor. TIMET's statement would appear to indicate that they should not be construed as responsible for SRCs for which they are the principal contributor, e.g., tetrachloroethene (PCE). NDEP has not approved a deliverable outside of the Record of Decision (ROD) 2009 concerning any SRC allocation. Please revise these statements to reflect the provisions in the ROD 2009 or remove them.

TIMET Response: The referenced text has been removed.

2. Section 1.2 - Scope of the Monitored Natural Attenuation Remedial Action, page 3, 1st paragraph on page, please provide some explanation as to the rationale for the companies selected as the source for the data, e.g., OSSM is omitted from the list.

TIMET Response: TIMET selected wells in the trajectory downgradient of the plant site from the All Wells Database. Suitable wells were selected from various well maps, they were checked against the database, and the owner was identified from the database. Using these criteria, OSSM does not own any wells that were identified to support this plan.

3. Section 1.2 - Scope of the Monitored Natural Attenuation Remedial Action, page 3, TIMET notes that "TIMET will not sample wells included in this plan to fill "data gaps" for SRCs not monitored by the respective owners." Please identify what is being monitored by others and what data TIMET will need to collect to satisfy the objectives of this work plan. Also, please note that NDEP does not agree with TIMET's statement about not sampling to fill data gaps for TIMET's MNA objectives. If additional data not collected by other Companies is needed to fulfill the MNA objectives, then TIMET will be responsible for obtaining the needed data.

TIMET Response: TIMET agrees to sample select wells for select constituents to support this plan. However, the use of third-party data will allow TIMET to select existing data with minimal cost impact. The list of wells will be refined to those necessary to support this plan and TIMET will control and facilitate analyte lists and schedule accordingly. Third party data will be used to the extent it is readily available, usable, and contemporaneous with the TIMET sampling regimen.

4. Section 3.2 - Summary of ARARs and Cleanup Goals, page 5, bulleted list, the ARARs in the bulleted list employs U.S. EPA Region VI MSSLs, which were used at the time the ROD (NDEP, 2009) was prepared because U.S. EPA Region IX stopped updating the PRGs in 2004. The Region IX PRGs have since been coordinated with the risk-based screening levels used by Regions III and VI. The reference to Region VI MSSLs should be considered out of date and the reference should now be U.S. EPA Region IX RSLs. Please revise as necessary. This is a global comment as U.S. EPA Region VI MSSLs are used throughout the Deliverable.

TIMET Response: TIMET will henceforth and in this plan refer to the coordinated RSLs and not MSSLs. The text of the work plan has been revised accordingly.

5. Section 3.2 - Summary of ARARs and Cleanup Goals, page 6, NDEP provides the following comments:
   a. Please clarify the applicability of Nevada RMHQs to groundwater.

TIMET Response: RMHQs are not groundwater standards and any reference to RMHQs has been removed from the text.

   b. Please include NDEP Basic Comparison Levels (BCLs) or clarify why they are not listed as they were derived in accordance with Nevada Administrative Code for “action levels”.

TIMET Response: BCLs are ARARs and will be included as action levels. The work plan text has been revised accordingly.

6. Section 3.2 - Summary of ARARs and Cleanup Goals, page 6, bulleted list of cleanup goals, the fourth and fifth bullets are not cleanup goals. Please revise as necessary.

TIMET Response: The referenced bullet points have been removed from the text.

7. Section 4.0 - Institutional Controls, page 6, TIMET considers BCLs in this Section but they are not addressed as potential cleanup goals or RAOs. Please revise as necessary.

TIMET Response: The phrase "until BCLs are achieved" has been rephrased to state "until RAOs are achieved" in the text of the work plan.

8. Section 4.1 - Description of Land Use and Zoning, page 6, TIMET states that the downgradient areas of the site have been developed. NDEP would concur that these areas have been "mostly developed" but there is still vacant areas that are subject to future development not the least of which is the BMI Common Areas Western Hook. Please revise as necessary.

TIMET Response: Vacant lots and areas that have not been developed, and where a vested water right or actual supply well may exist, will be explored as stated in the MNA Work Plan when we state *"These concerns will be addressed and researched with the Office of State Engineer, SNWA, LVVWD and City of Henderson when the IC is formally established."* TIMET will work with NDEP and City of Henderson to ensure the institutional controls (ICs) are as complete and comprehensive in this regard as practicable. The IC plan is identified as a deliverable under the MNA Work Plan.

9. Section 4.2 - Prevention of Use of Groundwater, item 1, NDEP provides the following comments:
   a. TIMET notes that this covers "virtually all undeveloped land downgradient of the Plant Site." It is noted that a partial institutional control is not adequate. Please clarify.
   b. It is unclear if there are any exemptions to the citations that TIMET provided for commercial properties, rural properties, and/or properties over certain acreage. NDEP requests that TIMET include a discussion on any exemptions that may allow use of groundwater.

TIMET Response: These issues will be clarified in the IC plan. The answer to some of these concerns rests with the nature of any vested water rights in the domain (if any). Review of water rights in the domain that have not been revoked or retired is a task in developing the IC plan.

10. Section 5.0 - Technical Basis for Selection of MNA, pages 8 – 11, the sub-sections of this section do not discuss or present any site-specific data that has been collected to date. For example, there is a significant amount of DO, ORP, pH, TOC, etc. data that could provide context to these discussions. Please include a discussion of the data or explain why it was not included.

TIMET Response: This work plan provides the methodology for reviewing existing data, collecting new data, and analyzing data and performance. Since MNA is specified in the ROD, there is no need to support this decision at this time. This MNA plan was developed to implement the selected remedy and to establish the means to evaluate protectiveness and achievement of RAO at the time of the first five year review (FYR).

11. Section 6.3.1 - Compound Specific Isotope Analysis, page 13, NDEP provides the following comments:
    a. TIMET notes that "CSIA requires that the groundwater contain PCE at the minimum concentration threshold required for an isotopic ratio to be accurately measured for that compound." This data should be available and discussed per the NDEP's comments above. Please include this discussion or explain why it was not included.

TIMET Response: See response to Comment 10. TIMET will not predetermine sample suitability at this time. Samples will be collected and submitted to the laboratory in accordance with this plan. If the addition of a well is necessary to collect data to support this plan, it will be proposed at such time as warranted.

    b. TIMET references several wells on Figure 2 - Transect Location, Groundwater Contours, and PCE Plume, please highlight or call out these specific wells on the figure for ease of identification.

TIMET Response: Figure 2 has been revised accordingly.

12. Section 6.3.1 - Compound Specific Isotope Analysis, page 13, last paragraph, please provide the rationale for the exclusion of 1,1-DCE, which although the least prevalent intermediate of the three DCE isomers is still a potential daughter product.

TIMET Response: The linkage of PCE to TCE via reductive dechlorination using CSIA is straightforward. CSIA evaluation of daughter products of daughter products is not. Nonetheless, TIMET will pick up DCE isomers with the analysis if significant DCE concentrations exist to perform the analysis.

13. Section 6.5 - Mass Flux Demonstration of Attenuation, page 17, the Deliverable states that, "Input that will be constant will include estimates of hydraulic conductivity, which will be derived from permeability tests or other acceptable means (e.g., calibrated groundwater flow model)…" NDEP notes that TIMET does not have an acceptably calibrated groundwater model at this time. Please revise as necessary.

TIMET Response: On the flux gate aligned along northern plant boundary (Transect A), permeability values from well tests will be used. Modeling results will be used in the areas of Transects B and C using available well test data or model results from the BRC or Athens Road model. Section 6.5 is worded appropriately to accommodate identification of permeability values by "acceptable means."

14. Section 7.0 - Data Quality Objectives, page 17, the NDEP notes that Table 5 - Summary of Data Quality Objectives for MNA Implementation is neither referenced nor discussed in this section. Additionally, Table 4 - Summary of Intrinsic Bioremediation Analyses is not a statement of data quality objectives (DQOs) as referenced in this section. TIMET is referred to U.S. EPA (2006) for the preparation of DQOs. Please revise this section to address these issues.

TIMET Response: The tables will be referenced appropriately as noted in the revised text.

15. Section 9.2 - Initial Demonstration Phase, page 18, NDEP provides the following comments:

a. Based upon the schedule, it appears that the frequency selected is annual. Since no data has been discussed in this Deliverable, it is not clear that an annual frequency is sufficient. Please discuss the historic data, seasonal variations and temporal trends that support annual monitoring.

TIMET Response: The annual monitoring regimen was suggested based on the frequency of third-party monitoring in key wells; however, since TIMET has agreed to sample third-party wells (rather than relying upon their data), the schedule will be semiannual up to (at a minimum) the first FYR.

b. Please clarify how TIMET plans to demonstrate plume stability or a declining trend. (i.e. Mann-Kendall tests, or another quantitative mechanism)

TIMET Response: A Mann-Kendall analysis will be employed to evaluate trends in monitoring well data.

16. Section 9.3 - Long-Term Monitoring Phase, page 18, please clarify what the trigger is to move to the long-term monitoring phase from the initial phase.

TIMET Response: Long-term interim monitoring will commence with completion of "Initial Phase" monitoring requirements. Long term monitoring will start in year two. This is reflected in the updated schedule (Figure 7).

17. Section 9.4 - Performance Assessment and Reporting, page 18, TIMET references Performance Monitoring of MNA Remedies for VOCs in Ground Water (EPA 2004), please clarify how this guidance will be applied to the non-VOC contaminants and if there are any significant differences in approach that need to be considered.

TIMET Response: Non-VOC contaminants will be evaluated in accordance with Section 6.2 *Evaluation of Geochemical Conditions*. The EPA, 2004 reference provides protocols and methods of analysis applicable to MNA in general, as well as specifically VOCs.

18. Section 9.4 - Performance Assessment and Reporting, page 19, please clarify if calculations of plume stability or plume degradation will also be completed.

TIMET Response: Yes, and this has been clarified and reflected in revised Section 9.4

19. Section 9.4 - Performance Assessment and Reporting, page 19, the Deliverable states that, "Implementation of the institutional control described in Section 4 - Institutional Controls will ensure that Objectives 5 and 7 are met." The institutional controls discussed in Section 4.0 only included groundwater. Meeting Objective 5 -Verify no impact to receptors and Objective 7 - Demonstrate efficacy of institutional controls, depends upon the determination of whether the Las Vegas Wash would be considered a receptor or a point of compliance. Response to this issue potentially impacts Table 5 - Summary of Data Quality Objectives for MNA Implementation, Step 2 - Identify Goals of the Study, Step 3 "Can human health, drinking water supplies, and other environmental resources be adversely impacted by selecting MNA." The ROD (NDEP, 2009) directly indicates the connection between groundwater and Las Vegas Wash as follows:
    a. "In addition, downgradient groundwater represents an input to a surface water body (the Las Vegas Wash) (NDEP, 2009)."
    b. "Plumes from other facilities in and around the BMI Complex also travel through this same area and represent a completed pathway to the Las Vegas Wash (NDEP, 2009)."

    The TIMET Monitored Natural Attenuation Work Plan does not contain any discussion of groundwater discharge to surface water. Please include a discussion of groundwater discharge to surface water and how this affects the objectives.

TIMET Response: TIMET considers discharge of impacted groundwater to Las Vegas Wash not protective from the perspective of MNA implementation. From the perspective of performance assessment, for those SRC that are solely or principally TIMET's (e.g., tetrachloroethene, trichloroethene), TIMET will consider discharge to the wash a line of evidence the remedy is not working as intended. The ROD already selects MNA, so this work plan is not an alternative screening exercise. Nonetheless, TIMET will add text regarding this issue and ramifications with respect to protectiveness statement in the FYR.

20. Table 3 - Flux Transect Data Sources, NDEP provides the following comments:
    a. TIMET specifies a number of wells to be sampled by others, please reference the NDEP-approved work plans that show that these wells are sampled by others for the analytes of interest. TIMET should note that if analyte of interest are not

sampled per other work plans, then TIMET will need to arrange for the necessary sampling and data collection.

b. For clarity, please revise Table 3 by adding a column for Well Owner and indicate which analytes are collected by other Companies and which analytes will need to be collected by TIMET.

TIMET Response: Please refer to Comment 3 response. These tables will be updated with TIMET specified as collecting the data. A column of owners for third-party wells will be added when tables are updated.

21. Figure 2 - Transect Location, Groundwater Contours, and PCE Plume, please add the study boundaries listed in Table 5 - Summary of Data Quality Objectives for MNA Implementation to this Figure or another Figure.

TIMET Response: This comment incorporated into Figure 2.

22. Figure 7 - MNA Implementation Schedule, please clarify why some monitoring events are in April and others are in October. It is requested that all monitoring events be in April unless conducted multiple times per year (see comment #15.a).

TIMET Response: TIMET will sample semi-annual up to (at a minimum) the first FYR, requiring an April and October schedule.

MONITORED NATURAL ATTENUATION WORK PLAN
TITANIUM METALS CORPORATION PLANT SITE
HENDERSON, NEVADA

Prepared for:

Nevada Division of Environmental Protection

Bureau of Corrective Actions

2030 E. Flamingo Road, Suite 230

Las Vegas, Nevada 89119-0818

Prepared by:

Titanium Metals Corporation

181 North Water Street

Henderson, Nevada 89015

April 15, 2013

SIGNATURE PAGE

Monitored Natural Attenuation Work Plan

Titanium Metals Corporation

Henderson, Nevada

April 15, 2013

Kirk J. Stowers **Date**

Program Manager, Broadbent and Associates, Inc.

April 15, 2013

Victoria Tyson-Bloyd **Date**

Project Manager, Tyson Contracting, Inc.

April 15, 2013

Jay Snyder, P.G. **Date**

Hydrogeologist, EA Engineering

Approvals:

JURAT: I, Kirk Stowers, hereby certify that I am responsible for the services in this document and for the preparation of this document. The services described in this document have been provided in a manner consistent with the current standards of the profession and to the best of my knowledge comply with all applicable federal, state and local statutes, regulation and ordinances.

April 15, 2013

Kirk J. Stowers, C.E.M.
(CEM – 1549, Exp. 10/11/2014)
Broadbent & Associates, Inc.

Date

Table of Contents

1.0 INTRODUCTION 1

1.1 Remedial Action Summary 1
1.2 Scope of the Monitored Natural Attenuation Remedial Action 2
1.3 Technical Basis for Selection of MNA 3
1.4 Use of Enhanced Attenuation 4

2.0 REMEDIAL ACTION OBJECTIVES 4

3.0 COMPLIANCE WITH ARAR 4

3.1 Protection of Human Health and the Environment 5
3.2 Summary of ARARs and Cleanup Goals 5

4.0 INSTITUTIONAL CONTROLS 6

4.1 Description of Land Use and Zoning 6
4.2 Prevention of Use of Groundwater 6

5.0 TECHNICAL BASIS FOR SELECTION OF MNA 8

5.1 Site Related Volatile Organic Compounds 8
5.2 Perchlorate 9
5.3 Metals 9
5.4 Encroachment Contaminants and Interferences 10

6.0 TECHNICAL ASSESSMENT OF MNA 11

6.1 Direct Evidence of Attenuation Processes 12
6.2 Evaluation of Geochemical Conditions 12
6.3 Evaluation of Biological Mechanisms for Degradation 13

6.3.1 Compound Specific Isotope Analysis 13
6.3.2 Bio-Trap® Deployment 14
6.3.3 CENSUS™ and SIP Data Evaluation 15

6.4 Evaluation of Sorption and Dispersion Mechanisms 15
6.5 Mass Flux Demonstration of Attenuation 15
6.6 Evaluation of Concentration Data 17

7.0 DATA QUALITY OBJECTIVES 17

8.0 INFRASTRUCTURE 17

9.0 MNA GROUNDWATER MONITORING OPERATIONS 17

9.1 Groundwater Monitoring Requirements and Regimen 17
9.2 Initial Demonstration Phase 18
9.3 Long-Term monitoring Phase 18
9.4 Performance Assessment and Reporting 18

10.0 WASTE MANAGEMENT 20

11.0 SCHEDULE 20

12.0 REFERENCES 20

List of Figures

1 Site Location Map
2 Transect Location, Groundwater Contours, and PCE Plume
3 Transect A – Proximal Plume Position Plan and Profile
4 Transect B – Medial Plume Position Plan and Profile
5 Transects C and C' – Distal Plume Position Plan and Profile
6 Transect Method for Flux Calculation
7 MNA Implementation Schedule

List of Tables

1 Summary of MNA Sample Methods
2 Monitoring Regimen for MNA and Flux Transect Wells
3 Flux Transect Data Sources
4 Summary of Intrinsic Bioremediation Analyses
5 Summary of Data Quality Objectives for MNA Implementation

List of Appendices

Appendix A—Reserved for NDEP Comments and TIMET Responses

Appendix B—City of Henderson Zoning, Planning, and Land Use Maps

1.0 INTRODUCTION

This work plan was prepared to initiate implementation of Monitored Natural Attenuation (MNA) for the Titanium Metals Corporation (TIMET) Plant Site in accordance with the Record of Decision (ROD) for the first water bearing zone (1st WBZ) (NDEP, 2009). The ROD specifies installation of a slurry wall and associated groundwater extraction system to prevent further migration of contaminants from the Plant Site, and MNA in downgradient groundwater in the 1st WBZ. The location of the Plant Site in Henderson, Nevada is shown on Figure 1.

The following subsections of this introduction provide a summary of the remedial action specified for Plant Site groundwater in the 1st WBZ, the scope of the MNA plan contained herein, the technical basis for selection of MNA, and the role of Enhanced Attenuation in the context of MNA that will occur as a result of the slurry wall and groundwater extraction system.

This work plan is divided into twelve sections:

- Section 1 – Introduction
- Section 2 – Remedial Action Objectives (RAO)
- Section 3 – Compliance with ARAR
- Section 4 – Institutional Controls
- Section 5 – Technical Basis for Selection of MNA
- Section 6 – Technical Assessment of MNA
- Section 7 – Data Quality Objectives
- Section 8 – Infrastructure
- Section 9 – MNA Groundwater Monitoring Operations
- Section 10 – Waste Management
- Section 11 – Schedule
- Section 12 – References
- Appendix A – Placeholder for NDEP Comments and TIMET Responses
- Appendix B – City of Henderson Zoning, Planning, and Land Use Maps

This work plan addresses MNA for groundwater in the 1st WBZ. Contaminants in the first WBZ (from the TIMET Plant Site as well as from other off-site sources) contain primarily high levels of volatile organic compounds (VOCs), metals, radionuclides, perchlorate and total dissolved solids (TDS). This combination of multiple contaminant classes, as well as commingled plume effects, must be considered when formulating the MNA regimen and performance assessment.

1.1 REMEDIAL ACTION SUMMARY

The Record of Decision for Plant Site groundwater (NDEP 2009) specifies a remedy that includes the following major components:

- *Construction of a slurry wall to facilitate containment of the plume of contaminants;*
- *Groundwater extraction in various strata of the first WBZ;*
- *Ex-Situ treatment of the contaminated groundwater;*
- *Discharge of the contaminated groundwater via a NPDES permit to the Las Vegas Wash;*
- *MNA for groundwater in the first WBZ downgradient of the TIMET Facility;*
- *Revision to and implementation of the groundwater monitoring plan; and*
- *Operation and maintenance of the above and related components of the remedy selected in this ROD by TIMET until the reasonable attainment of the performance standards, criteria, or other milestones that allow TIMET to demonstrate that the remedial activities addressing TIMET's contaminants under the existing June 28, 1996 Phase II Consent Agreement and the future Phase III Administrative Order on Consent (AOC) (of which this ROD is an attachment) and/or this ROD have been satisfactorily completed.*

Since the ROD specifies active mitigation of groundwater contaminant migration via slurry wall and groundwater recovery (active remediation) in concert with MNA for off-site 1st WBZ impacts, it is both plausible and expected that four general phases of operation exist: (1) an initial phase of MNA monitoring and testing to establish efficacy of this component; (2) a post-slurry-wall construction phase during which on-site groundwater is physically contained and extracted, and off-site (downgradient) groundwater undergoes MNA as well as Enhanced Attenuation that results from physical mass removal proximal to the source area; (3) a third phase when active remediation and EA ceases, mass loading does not exceed attenuation capacity in downgradient groundwater, and MNA is sole remedy in operation; and (4) post remediation monitoring, as applicable.

1.2 SCOPE OF THE MONITORED NATURAL ATTENUATION REMEDIAL ACTION

The scope of the MNA remedial action includes evaluation of MNA for Site Related Chemicals (SRC) identified in the Record of Decision for Plant Site groundwater in the 1st WBZ. These include SRC for which TIMET is the principal contributor (e.g., tetrachloroethene [PCE] and trichloroethene [TCE]), SRC for which TIMET is co-contributor (total dissolved solids [TDS], uranium, and arsenic), and SRC for which TIMET is considered a minimal to non-contributor (hexavalent chromium, perchlorate, chloroform).

The SRC classes specified in the ROD include volatile organic compounds, metals, radionuclides, perchlorate, and TDS. The volatiles of principal interest are PCE, TCE and the expected daughter compounds cis- and trans-1,2-dichloroethene (DCE), 1,1-DCE, and vinyl chloride (VC), and to a lesser degree, carbon tetrachloride (CT) and chloroform (CF). Metals include total chromium (since virtually all chromium in groundwater has been demonstrated to be hexavalent chromium [TIMET 2007]) and arsenic. Radionuclides present in the groundwater will be represented by uranium for the purposes of this work plan.

Data used in this plan for MNA will be sourced from a number of companies, including TIMET, the Nevada Environmental Response Trust (NERT), American Pacific Corporation (AMPAC) and Basic Remediation Company (BRC). Selected TIMET wells that are located 1) along the plume centerline

emanating from TIMET as defined by PCE, 2) along transverse flux transects defined in the proximal, medial and distal portions of the plume, and 3) on the Plant Site proper will be used as data points. Data sourced from other companies monitoring wells shall be limited to that data collected by their respective well owners. TIMET will not sample wells included in this plan to fill "data gaps" for SRC not monitored by the respective owners.

1.3 TECHNICAL BASIS FOR SELECTION OF MNA

Natural attenuation processes typically occur at all sites. However, the degree of effectiveness depends on the types and concentrations of contaminants present and the physical, chemical, and biological characteristics of the soil and groundwater. Natural attenuation processes may reduce the potential risk posed by site contaminants in three ways:

- Transformation of contaminant(s) to a less toxic form through destructive processes such as biodegradation or abiotic transformations;
- Reduction of contaminant concentrations whereby potential exposure levels may be reduced; and
- Reduction of contaminant mobility and bioavailability through sorption onto the soil or rock matrix.

MNA is appropriate where it can be demonstrated capable of achieving RAO within a reasonable timeframe when compared to other technically appropriate alternatives as stated by the Office of Solid Waste and Emergency Response (OSWER) Directive (EPA 1999). Based on the OSWER Directive, MNA appears to be appropriate as specified in the ROD since source control via slurry wall and groundwater extraction is included, and is implementable. Because of the commingled and multiple contaminant nature of solute impacts in the 1st WBZ, a focus on plume stability and protectiveness over time is key to implementing this remedy. The use of institutional controls in downgradient groundwater is important to ensure that pathways of human exposure to groundwater remain incomplete and protectiveness is maintained over the course of implementation. Further discussion of the appropriateness of MNA at the TIMET site is included in Section 6 of this work plan.

Demonstrating contaminant destruction mechanisms and sorption mechanics may prove difficult due to competing SRC and the presence of relatively conservative species (e.g., TDS, sulfate, perchlorate), particularly under ambient groundwater conditions. Nonetheless, groundwater data will be collected in general accordance with *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater* (EPA 1998) and *Site Characterization to Support Use of Monitored Natural Attenuation for Remediation of Inorganic Contaminants in Ground Water* (EPA 2008a), and more recent guidance, studies, and laboratory protocols that will be referenced throughout this work plan.

1.4 USE OF ENHANCED ATTENUATION

Enhanced Attenuation is used at sites where source mass flux reductions due to natural attenuation processes are not sufficient to meet regulatory criteria, causing MNA alone to be an unacceptable option (ITRC 2008). The use of EA can reduce the contaminant loading in the source area so that MNA may operate more effectively and sustain itself without further intervention. At the TIMET site, the goal is to increase mass removal in the source area, thereby reducing the mass flux of contaminants into the solute plume in a manner sufficient to meet regulatory requirements for using MNA as the final treatment.

Enhancements are remediation technologies falling into two broad categories that either (1) reduce the mass flux of contaminants from the source zone or (2) increase the natural attenuation capacity of the aquifer downgradient from the source. For the Plant Site, reduction of mass flux via slurry wall and groundwater extraction is the means of enhancement.

EA also has additional requirements regarding its capacity to achieve or maintain plume stability and eventual shrinkage, implementability, and sustainability for a time period sufficient to meet RAO. When implementing MNA, EPA expects that source control and long-term monitoring and performance assessment are fundamental components. The slurry wall and groundwater extraction components of the specified remedy provide source control, and the enhancement to the MNA remedy envisaged above.

2.0 REMEDIAL ACTION OBJECTIVES

Remedial action objectives for the MNA portion of the 1st WBZ are as defined in the Record of Decision (NDEP 2009).

The following RAOs are proposed for the Site:

- *Prevent off-Site migration of contaminants in the 1st WBZ;*
- *Reduce concentrations of contaminants in the first WBZ to meet cleanup goals; and*
- *Address downgradient contaminant plumes via MNA.*

Downgradient of the slurry wall (generally north and northeast of the Site) is the area where MNA is applicable. The efficacy of MNA, particularly in concert with EA for the source areas, will be determined through the development and implementation of this MNA work plan.

3.0 COMPLIANCE WITH ARAR

According to the ROD, *"The selected remedy is an interim remedial decision for downgradient groundwater within the first WBZ by addressing the potential for migration of contaminants from and/or through the TIMET Facility to downgradient receptors."*

The ROD explicitly states that the remedial action discussed therein *"is an interim remedial decision for downgradient groundwater in the first WBZ because the remedy selected in this ROD pertains only to containment and treatment of groundwater in the first WBZ at the TIMET Facility."* The MNA portion of the remedy is also interim, and this plan has been prepared to establish the efficacy of MNA during this "interim" period. At the same time, the provisions contained herein are designed to be protective of human health and the environment.

According to the ROD, NDEP established that MNA is appropriate for groundwater downgradient of the slurry wall based upon its review of available downgradient groundwater quality data that suggest concentrations of contaminants from the TIMET Site appear to disperse within 4,000 feet of the Site.

3.1 PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

The ROD states *"The selected remedy protects human health and the environment (including degradation of groundwater quality) through a combination of containment; extraction and treatment; and MNA."* A task to formalize the institutional control of restricting groundwater usage, and hence render groundwater ingestion pathways incomplete, is included as Section 4 to this plan to strengthen the protectiveness of this remedy while performance is evaluated and assessed.

The ROD contemplates protectiveness of MNA in concert with implementation of the slurry wall: *"Containment and treatment of the contaminants within the first WBZ reduces the risk to human health and the environment by halting the flow of contaminants off-Site and by reducing the mass of contaminants on-Site. This approach will also halt the degradation of the downgradient groundwater. As noted above, the groundwater in the first WBZ downgradient of the facility will initially be addressed by MNA. It is believed that once containment is achieved the downgradient plume will be dispersed and will become a minor concern."* This describes the enhanced attenuation that the slurry wall and groundwater extraction system provides.

3.2 SUMMARY OF ARARS AND CLEANUP GOALS

The selected remedy will attain and comply with all Applicable or Relevant and Appropriate Requirements (ARARs). The ARARs considered for this remedial decision are:

- National Oil and Hazardous Substances Contingency Plan (NCP);
- USEPA MCLs
- USEPA Region IX Risk Based Screening Levels (RSL);
- Nevada Administrative Code (NAC); and
- NDEP Basic Comparison Levels (BCLs).

Cleanup goals or standards that may be applicable to these RAOs include:

- USEPA MCLs;
- USEPA Region IX RSL; and

4.0 INSTITUTIONAL CONTROLS

In order for the MNA remedy specified in the ROD to be protective of human receptors, institutional controls (ICs) will be required until RAOs are achieved. For the domain encompassed downgradient of the Plant Site for which the institutional control is required, City of Henderson Ordinances, Las Vegas Valley Water Authority rules, and a Nevada State Engineer Executive Order that are already in place sufficiently provide the IC to prevent ingestion of shallow groundwater. The following subsections describe current and future land use and zoning downgradient of the Plant Site, as well as available ordinances, rules and orders to prevent groundwater ingestion.

4.1 DESCRIPTION OF LAND USE AND ZONING

Appendix B provides City of Henderson maps for (1) Future Land Use, (2) Existing Zoning, and (3) Master Plan Areas. As shown on the Existing Zoning map, the Plant Site (along with other BMI Complex industrial plants) is located in Clark County. Immediately downgradient across Warm Springs Road the properties are within the City of Henderson north to the Las Vegas Wash.

The land downgradient of the Plant Site is for the most part already developed or planned. In general, the zoning includes: (1) corridor/community mixed use (MC) along Boulder Highway; (2) public and semi-public (PS) lands consisting of the Kurt R. Segler Water Reclamation Facility and golf courses; (3) single family residential of mixed density (RS-6 and RM-10); (4) high density multifamily (RH-36); (5) neighborhood mixed use (MN); (6) industrial of various use and restriction (IG, IL, IP), and (7) planned community (PC), consisting principally of the planned Landwell Company development of the former Pabco Ponds

Other than the planned community of the Landwell Company, the domain downgradient of the Plant Site has been developed. Immediately north and west of the Plant Site is the Pitman neighborhood and the water reclamation facility. North of the Landwell planned community, are the developed Westin Hills and Tuscany Master Plan Areas (Appendix B). North of these features is the Las Vegas Wash. . Nonetheless, vacant, non-planned areas may exist in the domain and these properties will be identified and water rights searched in the process of establishing the IC to prohibit groundwater usage. Furthermore, properties that may be exempted from local ordinance, Southern Nevada Water Authority, or State Engineer rules or orders will be researched.

4.2 PREVENTION OF USE OF GROUNDWATER

Exposure to shallow groundwater within the domain will be prevented from use by the following means:

1. Henderson, Nevada Code of Ordinances, Title 14—Utility Services, Chapter 14.02—Water Commitment and Allocation Regulations

The water commitment process is facilitated through Water Commitment Procedures for Application for New Service Connections and completion of Water Commitment Information form provided by COH. Section 14.02.020.E. applies to *"all water committed to projects by the Victory Valley Land Company (VVLC), The Landwell Company, or any other subsidiary company of VVLC as determined by the city, which is under agreement with the city of Henderson, shall be governed by this chapter."* This requirement covers virtually all undeveloped land downgradient of the Plant Site.

Section 14.02.030.D. states that *"All water committed under this chapter shall be committed in a manner that is consistent with the recommendations set forth in the Southern Nevada Water Authority Resource Plan (SNWA Water Resource Plan), as approved by the city of Henderson and the Southern Nevada Water Authority, amended from time to time and on file with the state of Nevada, Division of Water Resources."* This requirement codifies by reference the provisions of Southern Nevada Water Authority and Las Vegas Valley Water District, which in turn are governed by the State Engineer.

2. Southern Nevada Water Authority (SNWA)—The SNWA was created in 1991 through a cooperative agreement among the following seven water and wastewater agencies: Big Bend Water District • City of Boulder City • City of Henderson • City of Las Vegas • City of North Las Vegas • Clark County Water Reclamation District, and Las Vegas Valley Water District (LVVWD). LVVWD and City of Henderson initiated providing water commitments circa 1991 in accordance with Office of State Engineer Amended Order 1054. LVVWD and City of Henderson have formalized the water commitment process.

   The LVVWD was formed by statutory act (NSA Chapter 167) which designates in accordance with Section 1.1.1 that *"The Las Vegas Valley Water District is hereby designated as the agency responsible for water distribution within the boundaries of the District. The Water District may exercise, in connection with its distribution functions, all of the powers granted in this act"* and by Section 1.1.2 *"The Las Vegas Valley Water District may, pursuant to an agreement with the Southern Nevada Water Authority, operate and maintain all existing and future Southern Nevada water project facilities and water treatment plants, and the money necessary to carry out these responsibilities must be provided to the Water District by the Southern Nevada Water Authority from money collected from the users of water."*

   NSA Chapter 167 establishes the authority and relationship for SNWA and LVVWD to regulate and administer water commitments within their jurisdictions.

3. Office of State Engineer—From the SNWA Water Resource Plan 09 *"The designated area (Las Vegas Artesian Basin) was expanded in 1944 and 1946, and a portion of the basin was closed to new irrigation rights in 1949. In 1955, the Nevada State Engineer began to issue temporary groundwater permits in the Las Vegas Valley. All permits within the designated portion of the basin and with a priority date after March 24, 1955, were issued as temporary rights subject to revocation. In the years that followed, the Nevada State Engineer issued a series of orders that systematically restricted the issuance of revocable water rights within the Las Vegas Valley."*

   The State Engineer issued Amended Order 1054 on April 15, 1992. Amended Order 1054 denies new applications for revocable water groundwater permits and requires retirement of recoverable groundwater permits with water commitment from the Colorado River.

Moreover, it encourages retirement of non-revocable groundwater permits as part of water commitment (off-set) from Colorado River. Order No. 1054 is significant because it means that, with few exceptions, all applications to appropriate groundwater in the Las Vegas Valley that are filed after March 23, 1992 will be denied.

The LVVWD, City of Henderson, and State Engineer prohibit the drilling of water supply wells in the Las Vegas Valley via these Rules, Orders and Administrative procedures. Situations that may circumvent this process include:

- Vested or non-revocable water rights associated with single-family domestic dwellings with an existing water supply well; or
- Vested or non-revocable water rights associated with new single family dwellings.

It is not known if any vested or non-revocable water rights exist in the domain of the IC, nor is it known if any private land suitably zoned for residential construction outside of planned developments still exists and that it may be suitable for single family residential development using a vested or non-recoverable right to groundwater supply. These concerns will be addressed and researched with the Office of State Engineer, SNWA, LVVWD and City of Henderson when the IC is formally established.

5.0 TECHNICAL BASIS FOR SELECTION OF MNA

The subsections below describe biological, physical and geochemical mechanisms for attenuation of site contaminants.

5.1 SITE RELATED VOLATILE ORGANIC COMPOUNDS

Concentrations of volatile organic compounds can be reduced by physical effects, such as sorption and dispersion, and biological degradation. Sorption reduces contaminant concentrations over distance by partitioning contaminants from the solute to the sorbed phase. Dispersion reduces contaminant concentrations essentially by plume spreading and dilution. Biological degradation results in destruction of contaminants, and possible biological mechanisms and degradation paths as discussed below.

Biodegradation reactions can occur under a wide range of environmental conditions. The dominant biodegradation mechanism of chlorinated solvents such as PCE and TCE in most groundwater environments is reductive dechlorination. This reductive dechlorination is evidenced by the presence of daughter products: cis-1,2-dichloroethene (DCE) and vinyl chloride (VC), as well as trichloroethene (TCE) in the case of PCE degradation.

Naturally occurring subsurface microorganisms possess the ability to biodegrade these chlorinated volatile organic compounds (CVOCs) to non-chlorinated, environmentally acceptable end products (e.g., ethene), carbon dioxide (CO_2), water, and chloride (Major *et al:.* 1991 and 1995; Edwards and Cox 1997; AFCEE 2004), which occurs as reductive dechlorination. Reductive dechlorination

occurs under anaerobic conditions and involves the sequential replacement of chlorine atoms with hydrogen atoms.

In an uncontaminated aquifer with high concentrations of dissolved oxygen (DO) (i.e., aerobic conditions), native organic carbon is used as an electron donor, and DO is used first as the prime electron acceptor. After the DO is consumed, anaerobic microorganisms typically use additional electron acceptors (as available) in the following order of preference: nitrate, manganese oxide, iron oxyhydroxide, sulfate, and carbon dioxide.

CVOCs can also act as electron acceptors under highly reducing conditions (negative oxidation-reduction potential [ORP] or Eh and very low DO concentrations, similar to iron oxyhydroxide and sulfate reduction). There must also be an appropriate source of carbon for microbial growth in order for this process to occur.

The biodegradation of chlorinated ethenes is mediated by a variety of different microorganisms. Some microorganisms cannot degrade PCE and TCE all the way to ethene, due to the decreasing favorability of dechlorination as more chlorine atoms are removed. PCE is the most susceptible to reductive dechlorination because it is the most oxidized (i.e., chlorinated), whereas VC is the least susceptible to reductive dechlorination because it is the least oxidized (i.e., chlorinated) of these compounds. Some microorganisms are capable only of converting PCE and TCE to DCE and/or VC, which can lead to the accumulation of DCE and/or VC. Specific bacteria belonging to the *Dehalococcoides* [DHC] genus can completely dechlorinate PCE, TCE, DCE, 1,1-DCE, and VC to the environmentally acceptable end-product ethene. DHC may not be present at all sites, and as such, dechlorination stalls at DCE and/or VC at many sites, despite ample electron donor availability.

5.2 PERCHLORATE

Like CVOCs, perchlorate ($ClO4^-$) can also undergo reductive chlorination, through microbially mediated processes in which it acts as an electron acceptor. The perchlorate is degraded to chlorate ($ClO3^-$), then chlorite ($ClO2^-$), and finally to chloride and molecular oxygen. MNA of perchlorate is often less costly than remediation by engineered passive and active remediation systems. Site conditions favorable to perchlorate biodegradation include mildly to strongly reducing conditions (ORP<+100 mV), the absence of strongly acidic groundwater (pH>5.5), relatively low nitrate concentrations, and the presence of TOC to supply electrons for perchlorate reduction (TOC>4 to 6 mg/L).

5.3 METALS

Unlike organic compounds, which are naturally attenuated through degradation of molecules, metals are attenuated primarily through changes in solubility, which can be associated with processes such as precipitation/dissolution, complexation (typically by anions), and adsorption to solid surfaces.

The primary metals of concern at the site are arsenic, chromium, and uranium. Generally, lower pH (increased acidity) causes increased solubility of arsenic and chromium, although there are exceptions under specific conditions. For example, increased pH can cause dissolution of iron sulfides to which arsenic adsorbs, and can also make arsenic and chromium adsorption to mineral surfaces less favorable, causing increased solubility of these metals at higher pH under certain conditions. Uranium is generally more soluble at high pH, although dissolution of iron hydroxides at low pH could also release adsorbed uranium.

One of the most important factors impacting concentrations of these metals in groundwater is the reduction-oxidation (redox) state of the aquifer, as all three can exist in multiple "redox states," each with different geochemical properties. Lower oxidation-reduction potential (ORP) and dissolved oxygen (DO) concentrations (indicating more reducing conditions) generally result in increased arsenic solubility, due to reductive dissolution of the iron oxyhydroxides oxides to which arsenic anions adsorb in soils. However, under sufficiently reducing conditions, arsenic can also adsorb to iron sulfides or precipitate in arsenic or iron-arsenic sulfides. In contrast, lower ORP and oxygen concentrations generally cause decreased chromium and uranium solubility. The more reduced form of chromium, Cr(III), forms highly insoluble oxides, whereas Cr(VI) is more soluble; therefore, chromium is generally less soluble under reducing conditions. Uranium can form precipitates under both oxidized and reduced conditions; however, the more reduced form of uranium, U(IV), generally adsorbs more strongly to soils than does the oxidized form, U(VI), decreasing effective solubility at low ORP. As with arsenic, reductive dissolution of iron oxyhydroxides with decreased ORP can also release adsorbed chromium and uranium. Monitoring concentrations of dissolved manganese, ferrous iron, and sulfide can allow assessment of the redox conditions in the aquifer and how they affect the geochemistry of and the solubility of minerals in the aquifer.

The behavior of select other species in the groundwater is closely tied to the behavior of these metals of concern. Carbonate alkalinity is an important parameter for assessing behavior of metals (especially uranium), because carbonate complexes can strongly affect effective solubilities of metals. Similarly, high concentrations of organic compounds in the groundwater can affect metal solubility through complexation. High concentrations of phosphate can allow precipitation of uranium phosphates under oxidized conditions.

5.4 ENCROACHMENT CONTAMINANTS AND INTERFERENCES

Several contaminants discussed in this plan occur as encroachment contaminants (e.g., perchlorate, chloroform, hexavalent chromium) and others as contribution contaminants to commingled plumes which migrate downgradient of the plant site. Examples of contributory impacts that may affect MNA include sulfate and TDS. The effects of these contaminants on MNA will be evaluated (if they appear to significantly affect MNA) during the performance assessment period.

6.0 TECHNICAL ASSESSMENT OF MNA

EPA expects that MNA will be most appropriate when used in conjunction with other remediation measures (e.g., source control, groundwater extraction), or as a follow-up to active remediation measures that have already been implemented. In determining whether MNA is an appropriate remedy for soil or groundwater at a given site, the following should be considered:

1. Can natural processes effectively reduce contaminants present in soil or groundwater to suitable endpoints;
2. Is the contaminant plume stable; can the plume stability change over time;
3. Can human health, drinking water supplies, and other environmental resources be adversely impacted by selecting MNA;
4. Is MNA appropriate for the entirety of the time it remains in effect;
5. Will the contamination exert a long-term detrimental impact on available water supplies or other environmental resources;
6. Is the estimated cleanup time reasonable compared to other alternatives;
7. What is the nature and extent of contaminant sources and are they adequately controlled;
8. Do resulting transformation products (e.g., PCE degrading to vinyl chloride) present a greater risk than the parent contaminants;
9. Is MNA compatible with active remediation measures; and
10. Are reliable site-specific mechanisms for institutional controls (*e.g.*, zoning ordinances) available?

Of the above factors, the most important considerations regarding the suitability of MNA as a remedy include: whether the contaminants are likely to be effectively addressed by natural attenuation processes, the stability of the groundwater contaminant plume and its potential for migration, and the potential for unacceptable risks to human health or environmental resources by the contamination.

As stated in OSWER Guidance (EPA 1999): *"MNA should not be used where such an approach would result in either plume migration or impacts to environmental resources that would be unacceptable to the overseeing regulatory authority. Therefore, sites where the contaminant plumes are no longer increasing in extent, or are shrinking, would be the most appropriate candidates for MNA remedies. An example of a situation where MNA may be appropriate is a remedy that includes source control, a pump-and-treat system to mitigate the highly-contaminated plume areas, and MNA in the lower concentration portions of the plume. In combination, these methods would maximize groundwater restored to beneficial use in a timeframe consistent with future demand on the aquifer, while utilizing natural attenuation processes to reduce the reliance on active remediation methods and reduce remedy costs."* Therefore, the use of MNA in concert with the onsite slurry wall and groundwater extraction to eliminate downgradient sourcing of solute, appears to be an appropriate use of MNA.

The subsections below and Sections 7 through 9 provide the basis for measuring and collecting data to address the questions enumerated above, evaluating and assessing the data, and determining if

MNA is appropriate as the final remedy as well as the interim remedy as stated in the ROD and considered in this plan.

6.1 DIRECT EVIDENCE OF ATTENUATION PROCESSES

Direct evidence of attenuation processes will be measured principally from MNA and transect monitoring wells. The wells which will be sampled by TIMET will be analyzed for the analytes and MNA parameters described in Table 1. Tables 2 and 3 list the MNA transect monitoring wells, as well as other BMI-wide monitoring wells. Table 3 provides a summary of data sources to support the MNA evaluation. TIMET wells will be sampled using the low flow sampling technique with sample management processes as described in the Sampling and Analysis Plan (TIMET 2010). The groundwater monitoring data will be used to evaluate stability and/or shrinkage in the aerial extent of solute plumes evaluated under this plan, as well as evidence of temporal trends at MNA wells that may indicate declining concentrations. Shrinkage of the plume in aerial extent supported by declining solute concentrations provide direct evidence that MNA processes are affecting the plume(s).

6.2 EVALUATION OF GEOCHEMICAL CONDITIONS

Inorganic parameters listed in Table 1 will be measured in groundwater from wells listed in Tables 2 and 3. The results of these measurements will be incorporated into geochemical modeling to assess the solubility of the target metals in the aquifer. Key inorganic parameters, including dissolved metals concentrations, anion concentrations including phosphate, carbonate alkalinity, pH, DO, ORP, ferrous iron, and sulfide will be incorporated into a geochemical speciation model such as Visual MINTEQ.

Visual MINTEQ allows the prediction of equilibrium speciation of the inorganic species in a complex groundwater solution. It incorporates redox- and pH-driven changes in metal solubility, sorption of dissolved species to aquifer solids, and precipitation of solid phases that may sequester metals. The model will be calibrated to observed conditions. The mineral content of the aquifer will be approximated in the model based on both the aqueous data and solids data collected from CSM (TIMET 2007), vertical delineation (TIMET 2008), and Beta Ditch (TIMET 2012) investigations. Any substantial geographical variations in groundwater geochemistry, for example changes in pH or ORP with distance from the site, will then be incorporated into the model to help interpret changes in metals concentrations.

The results of the speciation modeling will allow interpretation of the dissolved metals concentration data by indicating which processes (adsorption, precipitation, etc.) are likely dominant in determining the solubility and natural attenuation of metals in groundwater downgradient from the site.

6.3 EVALUATION OF BIOLOGICAL MECHANISMS FOR DEGRADATION

Methods for indirect and direct indication and/or measurement bioremediation, both anaerobic reductive dechlorination (RDC) and aerobic cometabolism, are described in the subsections below.

6.3.1 Compound Specific Isotope Analysis

Compound specific isotope analyses (CSIA) of ground water will be conducted to estimate the extent to which biodegradation is occurring. The traditional approach of monitoring the reduction of contaminant concentrations at a site is not always indicative of contaminant biodegradation or transformation but may reflect other processes such as dilution or dispersion. CSIA can provide evidence that contaminant reduction is due to microbial biodegradation or abiotic destruction or transformation of the contaminant (EPA, 2008b). When organic contaminants are transformed either biologically or abiotically in the environment, contaminant molecules containing the lighter carbon isotope, 12C, tend to react more rapidly than molecules containing the heavier isotope, 13C, causing a shift in the ratio of stable carbon isotopes (i. e. 13C /12C) toward the heavier 13C. Continued transformation further shifts the ratio toward the heavier 13C, and serves as an indicator of favorable intrinsic biodegradation or abiotic transformation. Hence, measuring the isotopic composition of carbon molecules making up a contaminant allows one to estimate the extent at which biodegradation or transformation is occurring.

Ground water samples will be collected for CSIA from wells located along the plume center line from five monitoring wells at increasing distances as measured from the source. CSIA requires that the groundwater contain PCE at the minimum concentration threshold required for an isotopic ratio to be accurately measured for that compound. Based on these criteria, the five wells selected for CSIA analysis are J2D2-R2, TMPZ-108, PC-067, AA-11 and AA-20 (Figure 2). Prior to the CSIA field event, the results of the MNA monitoring event will be reviewed to ensure that these five wells have sufficient mass of PCE (greater than 5 micrograms/liter). If a well is not deemed suitable for CSIA analysis, then an alternate suitable well will be chosen.

The CSIA ground water samples will be collected using the low flow sampling technique as described in the Sampling and Analysis Plan (TIMET 2010). Samples will be placed into containers provided by the laboratory. The samples will then be labeled, stored on ice, and submitted under chain of custody to Microseeps laboratory located in Pittsburg, Pennsylvania to be analyzed for CSIA and PCE daughter products (TCE, cis- and trans 1,2-DCE, 1,1-DCE, and VC).

Following receipt of ground water sampling results, the data will be evaluated and a summary report documenting the results of the CSIA evaluation according to the USEPA guidance for assessing biodegradation of organic groundwater contaminants (EPA 2008b) will be provided.

6.3.2 Bio-Trap® Deployment

Bio-Trap® samplers will be deployed in plume centerline monitoring wells to passively collect indigenous microbes over time for the purpose of identification of bacterial species and populations present in the aquifer. The Bio-Trap® samplers consist of slotted PVC containers that are "open" to groundwater flowing through the monitoring well. Contained inside the Bio-Trap® are Bio-Sep® beads, which are 2-3 mm diameter beads formulated from a composite of Nomex® and powder activated carbon (PAC).

When deployed, the Bio-Sep® beads provide an extremely large surface area to absorb contaminants and nutrients, and to facilitate colonization of indigenous bacteria. The Bio-Trap® in essence becomes an in situ microcosm of contaminants, nutrients, and bacteria. Once the Bio-Traps ® are recovered and analyzed, valuable information regarding the presence and robustness of intrinsic degradation pathways can be discerned.

Bio-trap® sampling will be conducted after the CSIA sampling to evaluate the number of degrading bacteria that may be present along the plume center line to determine if bioremediation is occurring within the plume.

Two different types of Bio-Traps® will be deployed at the site: a standard Bio-Trap® and a baited Bio-Trap®. The standard Bio-Trap® will be analyzed by Microbial Insights using the CENSUS method that uses a quantitative polymerase chain reaction (qPCR) to evaluate and quantify the specific microbial population that would aid in intrinsic biodegradation of chlorinated solvents. The baited Bio-Trap® will be baited with 13C compound to demonstrate that biodegradation is occurring. The baited Bio-Trap® will be analyzed through Microbial Insights stable isotope probing (SIP) method. The bait serves as a tracer which can be detected in the end products of biodegradation (new biomass and CO2 or dissolved inorganic carbon). Table 4 provides a summary of the analysis that will be conducted.

The two Bio-Traps® will be placed in series in wells J2D2-R2, TMPZ-108 and PC-067 (Figure 2) that are located along the center line of the PCE plume. Prior to deploying the Bio-Traps®, if the wells have not been recently purged, three well volumes will be purged from the well. Then the Bio-Traps® will be deployed on a tether separated by baffles in the wells they will be placed at a depth where significant contamination is present. The Bio-Traps® will left in place for 30 to 60 days. The Bio-Traps® are retrieved in the following manner: (1) set up a plastic lined containment pit around the monitor well area to capture fluids; (2) determine the initial depth of water below top of casing; (3) remove the tether from well until the first Bio-Trap® is visible; (4) detach the Bio-Trap® sampler from the tether; (5) place the sample into provided zippered bag with sampling information; (6) place the zippered bag with sampler into a second zippered bag; (7) place the Bio-Trap® sampler immediately on double-bagged ice; and (8) package the cooler with double bagged ice or cold packs for immediate shipping (the hold time for analysis is 24 to 48 hours). Sampling information will be recorded on a chain-of-custody form and shipped to Microbial Insights in Rockford, Tennessee, for analysis.

Following receipt of the results, the data will be evaluated and a summary report documenting the results will be provided.

6.3.3 CENSUS™ and SIP Data Evaluation

The results of the CENSUS™ method will be reviewed to evaluate the types of bacteria present within the plume. Under anaerobic conditions the following bacteria may be present and will be analyzed for: *dehalococcoides* which is a bacterium that is capable of complete dechlorination from PCE to ethene, and *deholobacter*, *desulfuromonas*, and *desulfitobacterium* which are capable of dechlorination of PCE to cis-DCE. Although not anticipated at the Site, the presence of certain bacteria under aerobic conditions can indicate that aerobic cometabolism is occurring which may indicate the potential for cometabolic oxidation of TCE. Under aerobic conditions, the following types of bacteria and chemical signatures indicating bacterial activity may be present and will be analyzed for: methane-oxidizing bacteria (*methanotrophs*), soluble methane monooxygenases, propane monooxygenases, toluene dioxygenases and ring hydroxylating toluene monooxygenases, both usually present at mixed waste sites (where both gasoline-related contaminants and TCE are present).

The SIP analysis measures the 13C compound or tracer that is present in the end product of the biodegradation of the chlorinated solvents. The SIP analysis will measure the following end products that are present in the Bio-Traps®: phospholipid fatty acids (PLFA), which are a main part of the membranes of all microbes, and dissolved inorganic carbon (DIC). The presence of 13C in the PLFA shows incorporation of the contaminant into biomass and the presence of 13C in DIC demonstrates contaminant mineralization.

6.4 EVALUATION OF SORPTION AND DISPERSION MECHANISMS

Sorption of contaminants will be estimated using data collected during the vertical delineation program (TIMET 2008) and assessment of the Beta / Northwestern Ditches and associated development of LSSLs (TIMET 2012). For organic compounds, the distribution coefficient will be estimated as the octanol-water partition coefficient (Koc) times the fraction organic carbon (foc). Distribution coefficients for inorganic species will be estimated from EPA lookup tables using existing data (EPA 1996).

6.5 MASS FLUX DEMONSTRATION OF ATTENUATION

Mass flux of select SRCs will be calculated as described in *Use of Mass Flux and Mass Discharge* (ITRC 2010). Three transects are proposed using existing monitoring wells in the 1st WBZ in proximal, medial, and distal plume positions. The wells that define these transects are listed in Table 2, and Figures 3, 4 and 5 show their locations. For the purpose of discussing the locations of these transects with respect to alignment and plume position, the PCE plume is used. The PCE plume is used because: (1) downgradient monitoring of PCE in select wells has been undertaken by TIMET for several years; (2) the PCE plume is the most defined solute plume emanating from the Plant

Site; and (3) ample monitoring wells exist with attendant water level data to allow calculation of the cross-sectional areas, hydraulic gradients, and Darcy velocities necessary for flux calculations.

Transect A, in the proximal plume position, runs along the northern property boundary of TIMET thence eastward into the former Pabco Ponds area. Transect B is in the medial plume, and strikes roughly east to west through the Pitman Neighborhood. In the distal plume, Transect C strikes east-west along Sunset Road thence east on an offset, generally upgradient of the Athens Road extraction well field. This alignment is the last feasible location prior to "natural processes" being seriously interrupted by physical removal of contaminant mass.

The unit area contaminant mass flux is calculated as:

$$Mass\ Flux = J = KiC$$

Where: K = hydraulic conductivity (L/T)

i = hydraulic gradient (L/L)

C = contaminant concentration in groundwater (M/L^3)

The mass discharge through a flux transect is computed as:

$$Mass\ Discharge = \int_A J\, dA$$

In discrete terms, the mass discharge at each flux transect will be computed as:

$$M = J \cdot A = K \cdot i \cdot C \cdot A$$

where M, J, I, and C are as defined above, and A is the area defined by the midpoint between adjacent monitoring wells (width) and distance between base of aquifer and water table (height). See Figure 6 for conceptual depiction of mass discharge. This follows the transect method as described by the Environmental Security Technology Certification Program (ESTCP 2010), EPA (2002) and ITRC (2010).

Using this discrete approach, the total mass discharge (M_T) along each transect is thus:

$$M_T = \sum_{i=1}^{n} M_i = \sum_{i=1}^{n} J_i A_i$$

An example of the mass flux and mass discharge approach, as well as how it will be implemented in this work plan, is shown in Figure 6. It is important to note that the velocity used in this analysis is Darcy velocity. It is not seepage velocity, and effective porosity is not required to perform this

analysis. Data input to calculate mass discharge each event will include (1) gauged water level, and (2) contaminant concentration from groundwater monitoring. The gauged water level will be used to calculate "height" in area calculations, and quarterly concentrations to calculate M_i. Input that will be constant will include estimates of hydraulic conductivity, which will be derived from permeability tests or other acceptable means (e.g., calibrated groundwater flow model), subcrop contours of uMCF, and widths between monitoring wells.

6.6 EVALUATION OF CONCENTRATION DATA

Current and historical groundwater analytical data will be evaluated to evaluate whether dechlorination is occurring by using molar concentrations to calculate chlorinated ethene mass. This will be accomplished by converting the concentration of each chlorinated ethene (PCE, TCE, Cis-DCE, Trans-DCE and VC) into its equivalent molar concentration. Then the total molar concentration can be evaluated by summing the concentration of each chlorinated ethene. The data will be for plotted total molar concentration versus time on graphs. If dechlorination is occurring then the total molar concentration over time should decrease.

7.0 DATA QUALITY OBJECTIVES

Data quality objectives (DQOs) for analytical chemistry data are provided in the TIMET approved Sampling and Analysis Plan (2010). Under that plan, data generated are reviewed and validated, and of suitable use for evaluating MNA and for performance assessment of MNA. DQOs for implementation of this MNA plan are provided in Table 5.

8.0 INFRASTRUCTURE

No additional infrastructure is envisioned to support this plan. The MNA monitoring wells and flux transect monitoring wells proposed herein exist, and access to and analytical results from these wells constitute adequate means to implement this plan.

9.0 MNA GROUNDWATER MONITORING OPERATIONS

MNA groundwater monitoring operations are described in the following subsections. The monitoring and data collection includes an initial demonstration phase of sampling and then the long-term phase. Performance assessment and reporting are discussed.

9.1 GROUNDWATER MONITORING REQUIREMENTS AND REGIMEN

MNA groundwater monitoring operations will consist of protocols currently employed for Plant Site groundwater monitoring with additional field measurements by either water quality meters or instruments (e.g., Hach kits for Fe^{+2}, sulfide, alkalinity) and fixed-base laboratory analyses for general water chemistry (cations-anions), phosphate, methane, ethane, and ethene. A summary of field parameters and fixed-laboratory method requirements are provided in Table 1.

9.2 INITIAL DEMONSTRATION PHASE

The first year of monitoring will constitute the initial demonstration phase. It is during this phase that implementation of the monitoring operations specified in Table 1, as well as the establishment of flux transect calculations and an evaluation of CSIA and Census™ data, will take place. At the conclusion of the initial demonstration phase, answers to the following questions regarding this plan should be available:

- Do CSIA data show a shift in stable carbon isotope ratios indicating intrinsic biodegradation?
- Do indigenous anaerobic or aerobic cometabolic bacteria exist that degrade chlorinated solvents?
- Do groundwater geochemical data indicate attenuation of site related chemicals of interest?
- Do flux transect calculations indicate declining mass flux with distance downgradient, thereby indicating attenuation of plumes?
- Are the groundwater plumes stable or declining?
- What are the effects of the slurry wall and hydraulic containment of plant site groundwater on the medial and distal plumes?

9.3 INTERIM LONG-TERM MONITORING PHASE

Interim long term monitoring will commence at the end of year one, and continue in accordance with Tables 1, 2 and 3 and provisions in the approved sampling and analysis plan (TIMET 2010). MNA sampling will be in accordance with the schedule provided in Figure 7. Flux calculations, performance assessment, and reporting will be performed in accordance with Section 9.4 (below) and Figure 7. The long-term monitoring will be synchronized with BMI-wide monitoring events to the extent practicable.

9.4 PERFORMANCE ASSESSMENT AND REPORTING

EPA (1999) provides eight specific objectives for assessing performance of MNA. These eight objectives are summarized in *Performance Monitoring of MNA Remedies for VOCs in Ground Water* (EPA 2004), and include:

1. Demonstrate natural attenuation is occurring according to expectations;

2. Detect changes in hydrogeochemical, microbial, or other groundwater characteristics that may reduce the efficacy of MNA;

3. Identify potentially toxic or mobile transformation products (e.g., undesirable daughter products);

4. Verify plume stability;

5. Evaluate monitoring well trends for stability using Mann Kendall analysis;

6. Calculate and compare trends of fluxes through flux transects;

7. Verify no impact to receptors;

8. Detect new releases of contaminants to the environment that could adversely affect remedy;

9. Demonstrate efficacy of institutional controls; and

10. Verify progress toward or attainment of RAO.

Objective 1 will be evaluated during the initial demonstration phase (Section 9.2) using data collected in Section 6. These data will be evaluated in accordance with EPA 1999, EPA 2004, and EPA 2008 a,b. Objectives 2, 3, 4, 5, 6 and 10 will be evaluated during each performance assessment period and will be based on field and fixed-laboratory data and water levels collected by TIMET and other parties as noted in Table 3. Implementation of the institutional control described in Section 4 will ensure that Objectives 7 and 9 are met. Objective 8 will be met with monitoring data specified herein as well as Plant Site groundwater monitoring under permit requirements.

The MNA performance assessment will be reported annually. The performance assessment report will include, at a minimum:

- Summary tables for select indicator contaminants being used to evaluate MNA;
- Plume maps for select contaminants showing change(s) in plume dimensions;
- Summary tables of field data for select contaminants;
- Trend plots for select contaminants;
- Flux transect calculations and change in mass discharge over time at each transect;
- Geochemical evaluation of the fate of metals using Visual-MINTEQ and hydrogeochemistry data collected from MNA wells;
- Calculations of mass reduction (or increase) over time as the result of MNA processes;
- Mann-Kendall statistics; and
- Evaluation of protectiveness of remedy.

At all times data will be reviewed and analyzed to ensure protection of the Las Vegas Wash. Within this plan, trend analysis and flux calculations along Transect C in the distal plume provides this

"sentinel" monitoring and analysis. Plume expansion and discharge to the Las Vegas Wash would challenge protectiveness of this remedy.

10.0 WASTE MANAGEMENT

Implementation of this work plan will generate solid sampling waste (coveralls, gloves, tubing, etc.) and purge water. These waste streams will be disposed in accordance with existing protocol for groundwater monitoring at the plant, and as specified in the Sampling and Analysis Plan (TIMET 2010).

11.0 SCHEDULE

Key deliverables and activities for implementing this MNA plan are provided in the schedule shown as Figure 7. The schedule spans a 5-year period, at which point the Five Year Review is due. The goal of this plan and schedule is to collect and analyze sufficient data to facilitate evaluation of the MNA remedy as specified in the ROD.

12.0 REFERENCES

Air Force Center for Environmental Excellence (AFCEE). 2004. Principles and Practices of Enhanced Anaerobic Biodegradation of Chlorinated Solvents.

Edwards, E., and E. Cox. 1997. Field and laboratory studies of sequential anaerobic-aerobic chlorinated solvent biodegradation. In: *Proceedings of Fourth International Symposium on In Situ and On-Site Bioremediation Symposium*. Volume 3. Battelle Press, Columbus, OH.

Environmental Security Technology Certification Program (ESTCP), 2010. Evaluation of Potential for Monitored Natural Attenuation of Perchlorate in Groundwater. ESTCP Project ER-200428. September.

Interstate Technology & Regulatory Council (ITRC), 2008. Enhanced Attenuation: Chlorinated Organics, Interstate Technology & Regulatory Council, 444 North Capitol Street, NW, Suite 445, Washington, DC. April.

ITRC, 2010. Use and Measurement of Mass Flux and Mass Discharge, Interstate Technology & Regulatory Council, 444 North Capitol Street, NW, Suite 445, Washington, DC. August.

Major, D., E. Cox, E. Edwards, and P. Hare. 1995. Intrinsic dechlorination of trichloroethene to ethene in a bedrock aquifer. In: Robert E. Hinchee, John T. Wilson, Douglas C. Downey (Eds.). Intrinsic Bioremediation, Battelle Press, Columbus, OH, pp. 197-204.

Major D.W., W.W. Hodgins, and B.J. Butler. 1991. Field and laboratory evidence of *in situ* biotransformation of tetrachloroethene to ethene and ethane at a chemical transfer facility in

North Toronto. In: Hinchee RE, and R.F. Olfenbuttel (Eds). On site bioreclamation. Butterworth-Heinemann, Boston, MA. pp. 147-171.

Microbial Insights, 2009. CENSUS Frequently Asked Questions. Available on-line at: http://www.microbe.com/. Accessed 8/28/09.

Nevada Division of Environmental Protection (NDEP). 2009. Record of Decision – Remediation of Groundwater in the First Water-Bearing Zone, Titanium Metals Corporation (TIMET), Clark County, Nevada, February 17, 2009.

Pirkle, Robert J. 2006. Compound Specific Isotope Analysis: The Science, Technology and Selected Examples from the Literature with Application to Fuel Oxygenates and Chlorinated Solvents. Microseeps. July.

Schumacher W., and C. Holliger. 1996. The proton/electron ratio of the menaquinone-dependent electron transport from dihydrogen to tetrachloroethene in *Dehalobacter restrictus*. *J. Bacteriol*., 178: 2328–2333.

Titanium Metals Corporation (TIMET) 2007. Conceptual Site Model. Titanium Metals Corporation, Henderson, Nevada. April 25.

TIMET. 2008 "Tasks I, II, and III Data Transmittal Report in Support of the Groundwater Remedial Alternatives Study, Titanium Metals Corporation Plant Facility, Henderson, Nevada." May 16.

TIMET. 2009. Revised Remediation Design for the First Water Bearing Zone, Titanium Metals Corporation Facility, Henderson, Nevada." October 2009.

TIMET. 2010. "Groundwater Remedial Action Operation and Maintenance Monitoring Sampling and Analysis Plan, TIMET, Henderson, Nevada" February 2010.

TIMET. 2012. Data Gap Sampling and Analysis Plan for the Beta Ditch / Northwestern Ditches Located on the Titanium Metals Corporation Plant Site, BMI Common Areas, Clark County, Nevada. March 30.

United States Environmental Protection Agency (USEPA) 1996. Soil Screening Guidance: User's Guide, April 1996. Office of Solid Waste and Emergency Response: Washington, DC, EPA/540/R-96/018. 1996.

USEPA, 1998. Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water. EPA/600/R-98/128. Office of Research and Development, Washington DC. September.

USEPA, 1999. Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites, Office of Solid Waste and Emergency Response Directive Number 9200.4-17P. (http://www.epa.gov/swerust1/directiv/d9200417.htm).

USEPA. 2002. Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies. United States Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH, EPA/540/S-02/500, November 2002.

USEPA 2004. Performance Monitoring of MNA Remedies for VOCs in Ground Water. United States Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH, EPA/600/R-04/027, April 2004.

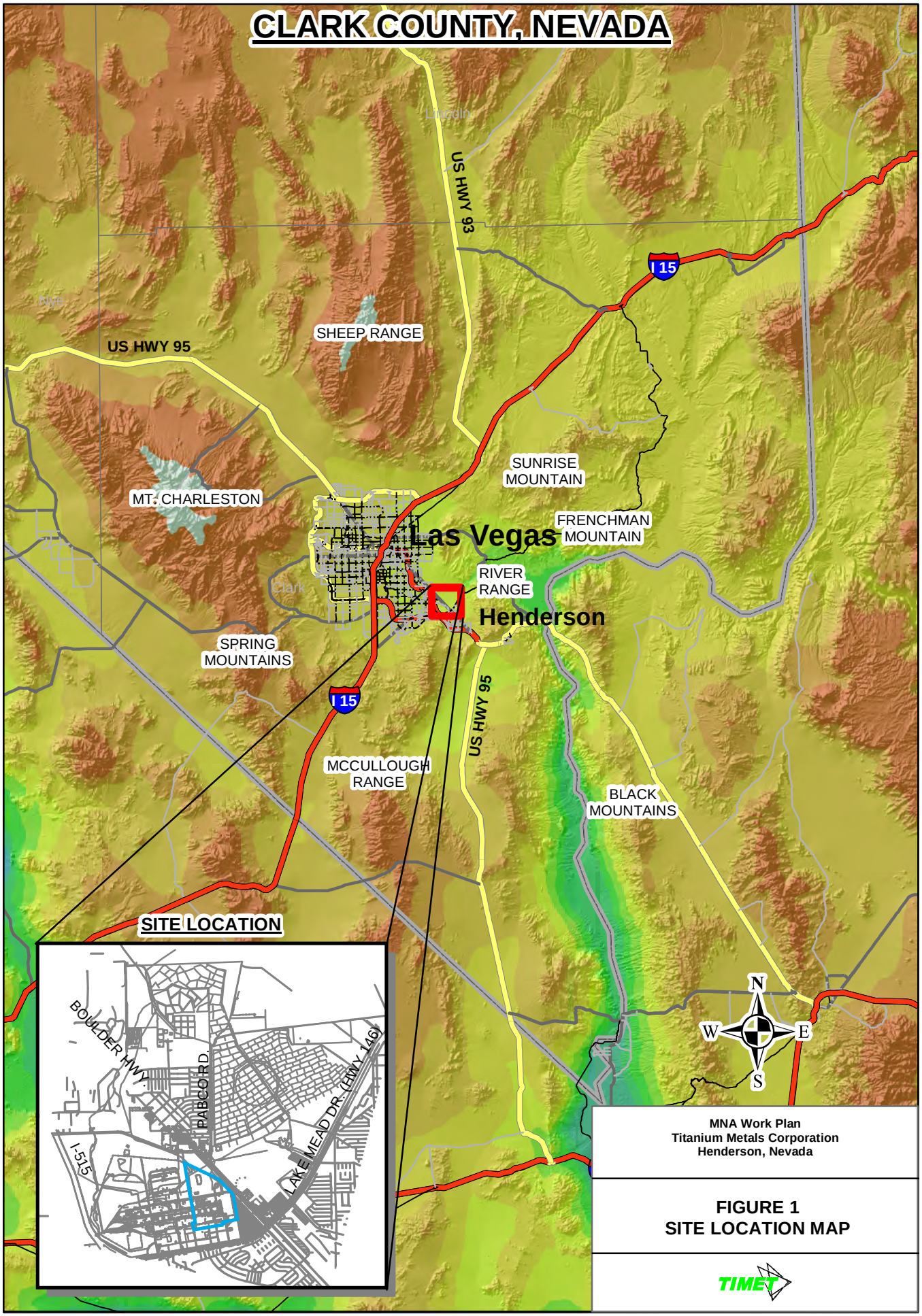
USEPA. 2008a. Site Characterization to Support Use of Monitored Natural Attenuation for Remediation of Inorganic Contaminants in Ground Water. United States Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH, EPA/600/R-08/114, November 2008.

USEPA. 2008b. *A Guide for Assessing Biodegradation and Source Identification of Organic Ground Water Contaminants Using Compound Specific Isotope Analysis (CSIA).* EPA/600/R-08/148. www.epa.gov/nrmrl/pubs/600r08148/600R08148.html.

USEPA. 2009. Regional Screening Levels (RSL) for Chemical Contaminants at Superfund Sites. Available on-line at: http://www.epa.gov/region/superfund/prg/. April.

Vogel, T.M., and McCarty, P.L. 1985. Biotransformation of tetrachloroethylene to trichloroethylene, dichloroethylene, vinyl chloride, and carbon dioxide under methanogenic conditions: *Appl. Environ. Microbiol.*, 49(5):1080-1083.

FIGURES



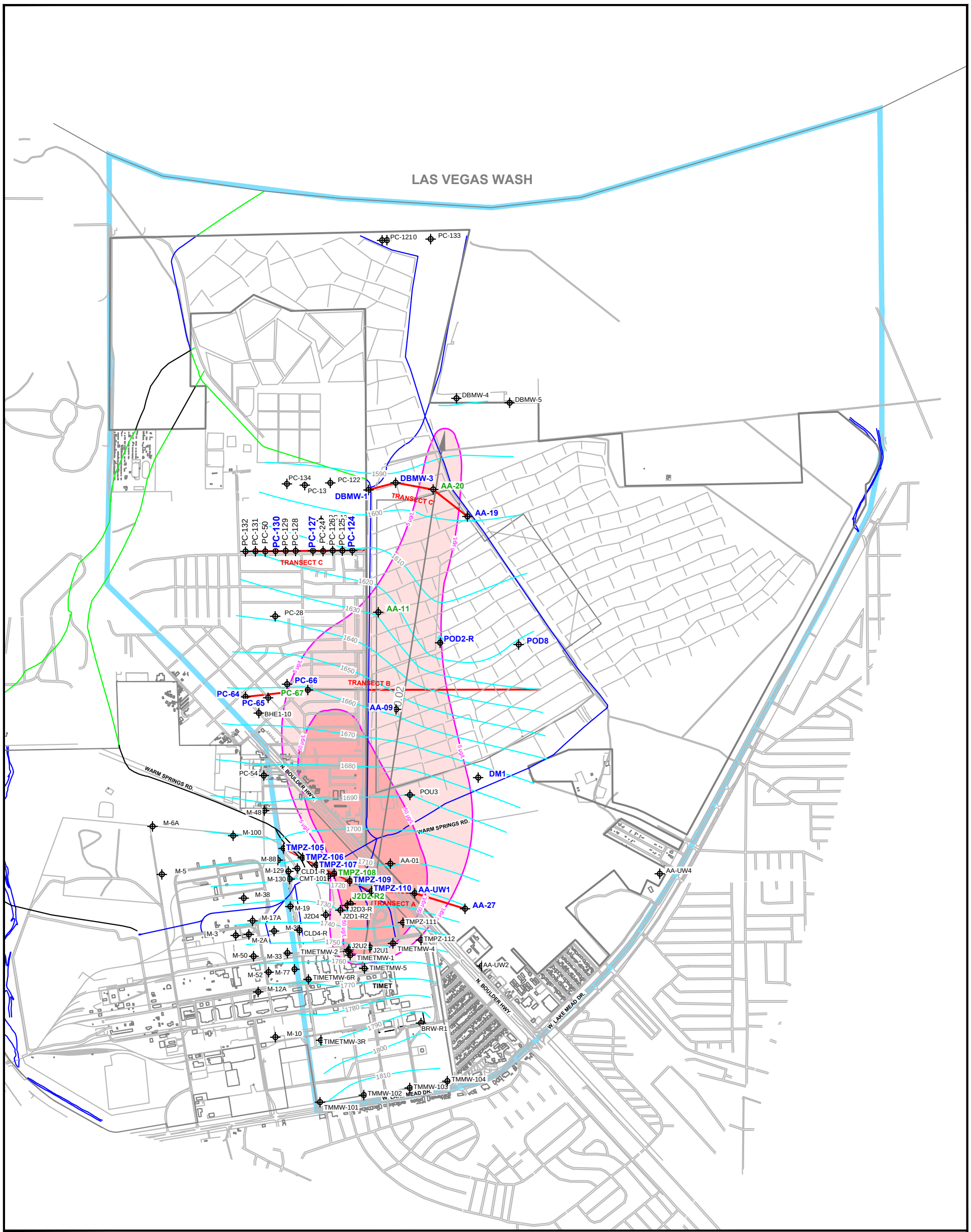
MNA Work Plan
Titanium Metals Corporation
Henderson, Nevada

FIGURE 1
SITE LOCATION MAP

TIMET

2012-09-20 C:\TIMET\1stSem2012\mxd\location_map.mxd michelle.handley

P:\Active Projects\TIMET\MNA Work Plan\Transects\Mass Flux Calcs\Figures



LEGEND

- MONITORING WELL
- TIMET BOUNDARY
- GROUNDWATER ELEVATION CONTOUR, FEET ABOVE MEAN SEA LEVEL
- DITCH OR WASH
- OFFSITE DITCH OR WASH
- TETRACHLOETHYLENE CONCENTRATION RANGE IN GROUNDWATER (MICROGRAMS PER LITER [µg/L])
- TRANSECT ALIGNMENT
- J2D2-R2 — WELLS DESIGNATED FOR COMPOUND SPECIFIC ISOTOPE ANALYSIS AND TRANSECT REGIMEN ARE DESIGNATED IN GREEN
- TMPZ-105 — WELLS INCLUDED IN TRANSECT MONITORING REGIMEN DESIGNATED IN BLUE
- STUDY DOMAIN

NOTES:
1. IMAGE SOURCE: GOOGLE EARTH.
2. IMAGE DATE: JUNE 23, 2012
3. TCE CONTOURS ARE BASED ON 1ST SEMESTER 2011 SEMIANNUAL GROUNDWATER MONITORING REPORT.

N

2,000 1,000 0 2,000

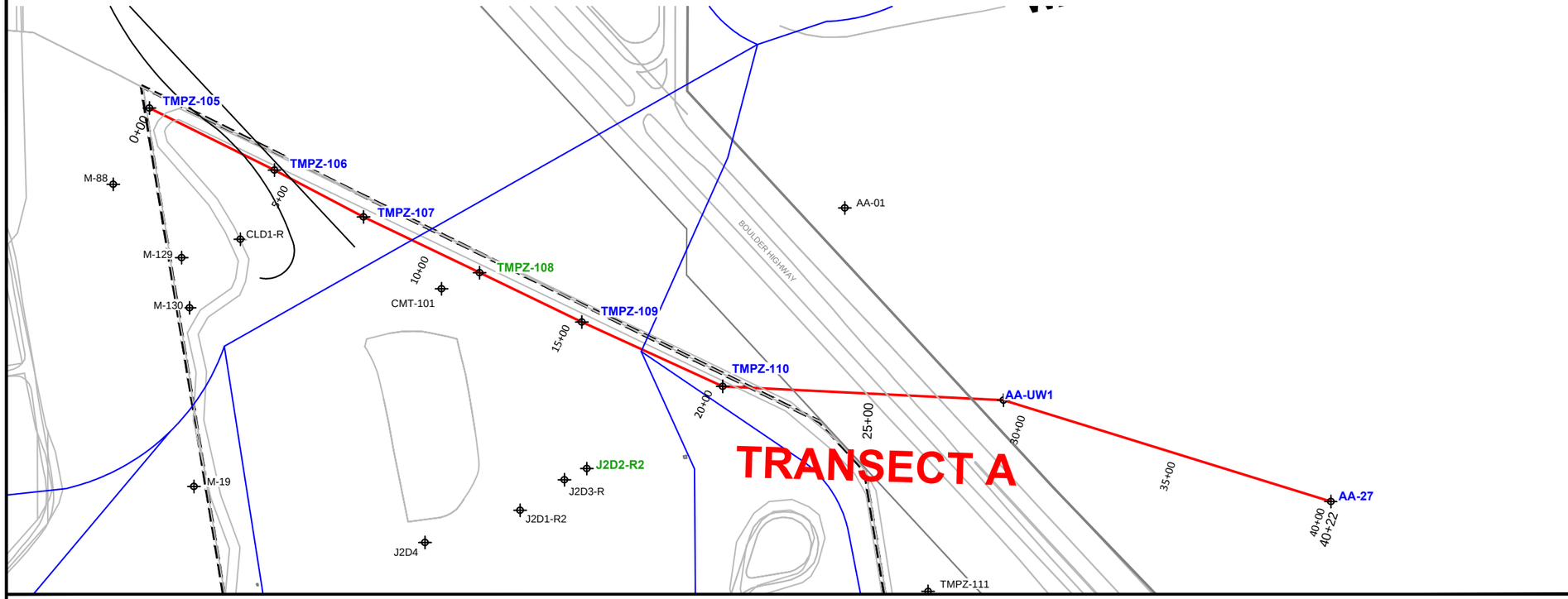
SCALE IN FEET

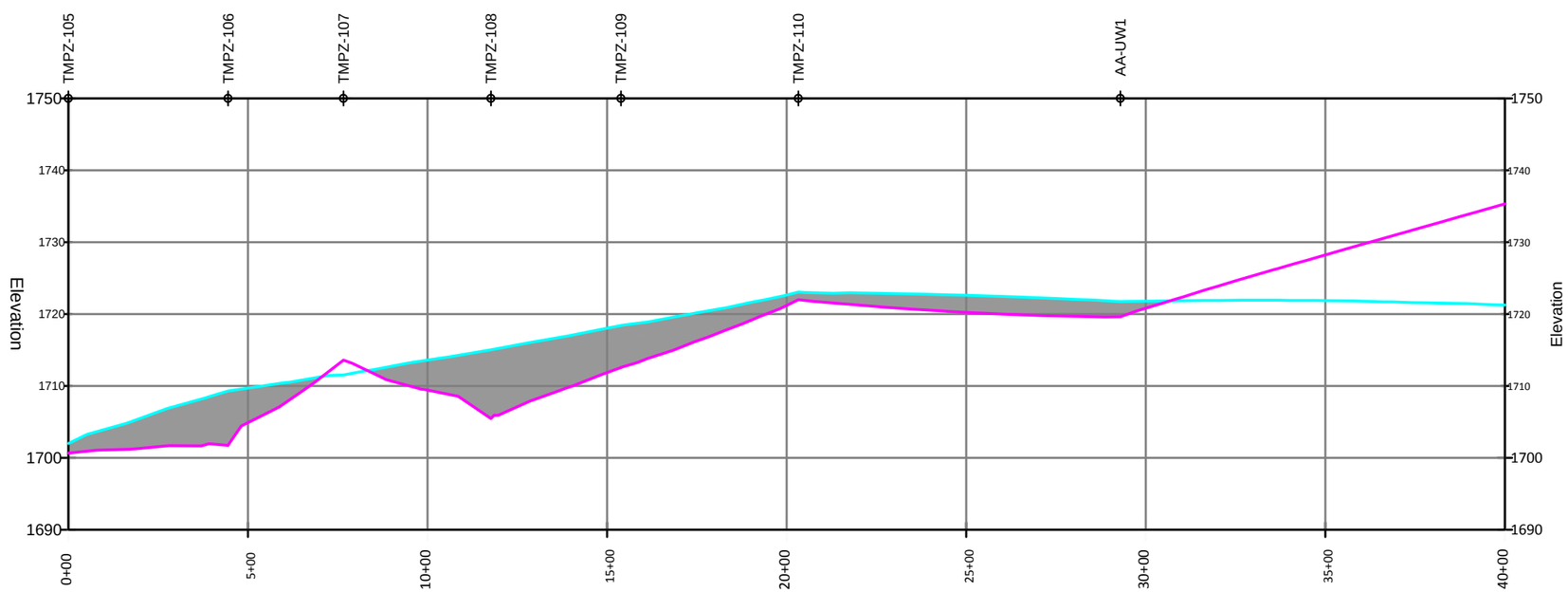
MNA Work Plan
Titanium Metals Corporation
Henderson, Nevada

FIGURE 2
TRANSECT LOCATION, GROUNDWATER CONTOURS, AND PCE PLUME

TIMET

Plan View of Transect A





Profile View of TRANSECT A

LEGEND

- MONITORING WELL
- TRANSECT ALIGNMENT
- DITCH OR WASH
- TMPZ-105 — WELL INCLUDED IN TRANSECT MONITORING REGIMEN DESIGNATED IN BLUE
- J2D2-R2 — WELLS DESIGNATED FOR COMPOUND SPECIFIC ISOTOPE ANALYSIS ARE DESIGNATED IN GREEN

NOTES

SEE FIGURE 2 FOR TRANSECT LOCATION

TMPZ-108 INCLUDED IN TRANSECT MONITORING REGIMEN AS WELL

400 200 0 400

SCALE IN FEET

LEGEND

- Qal-xMCF CONTACT
- GROUNDWATER LEVEL
- SATURATED ZONE ABOVE Qal-xMCF CONTACT

20 10 0 20

VERTICAL SCALE IN FEET

400 200 0 400

HORIZONTAL SCALE IN FEET

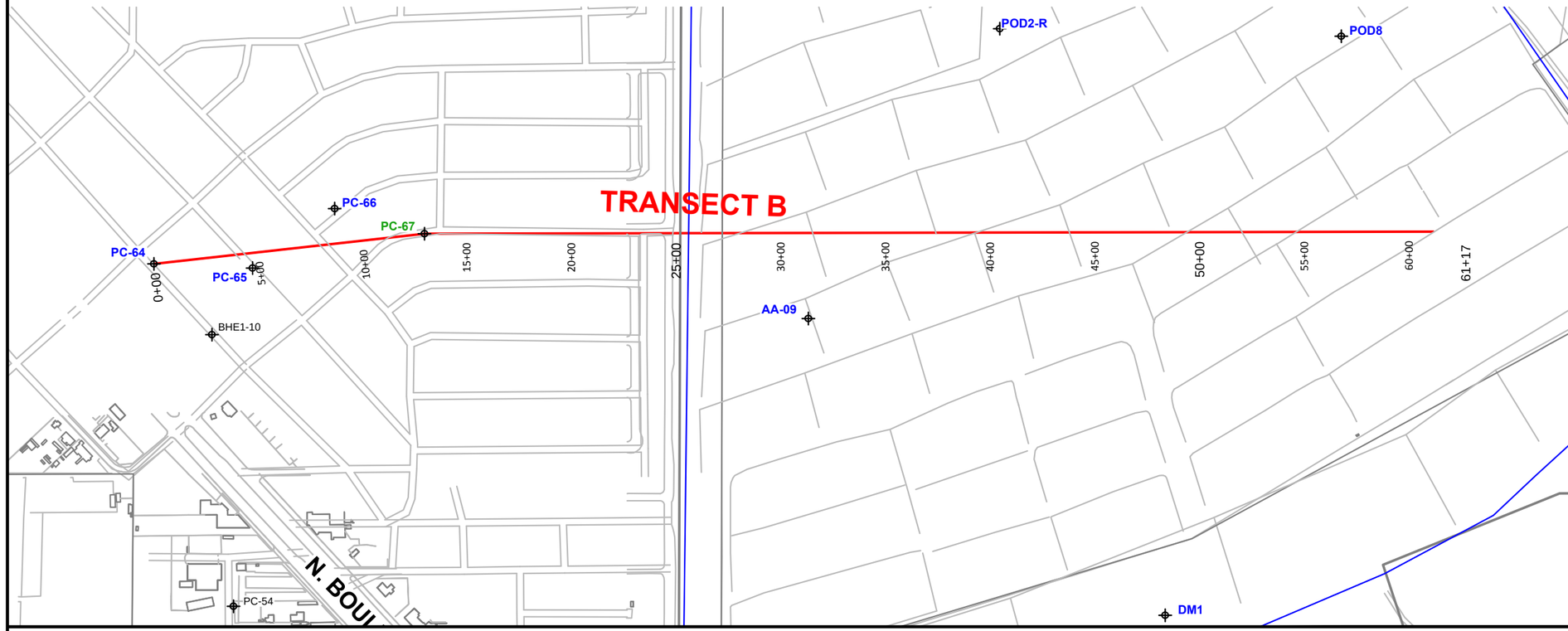
MNA Work Plan
Titanium Metals Corporation
Henderson, Nevada

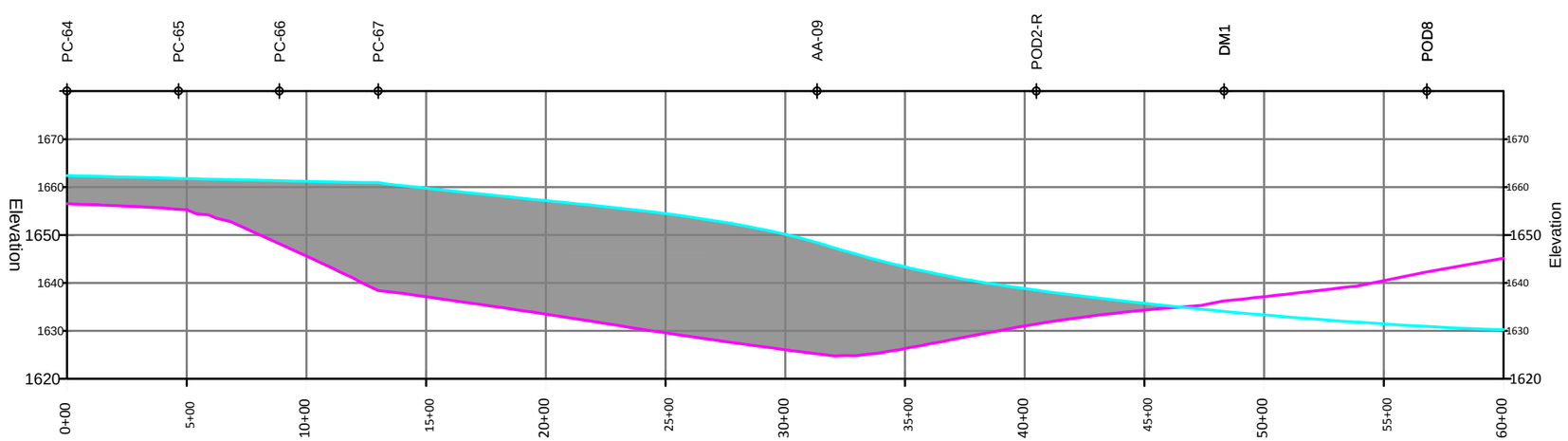
FIGURE 3
TRANSECT A - PROXIMAL PLUME POSITION PLAN AND PROFILE

TIMET

P:\Active Projects\TIMET\MNA Work Plan\Transects\Mass Flux Calcs\Figures

Plan View of Transect B





Profile View of TRANSECT B

LEGEND

- MONITORING WELL
- TRANSECT ALIGNMENT
- DITCH OR WASH
- TMPZ-105 — WELL INCLUDED IN TRANSECT MONITORING REGIMEN DESIGNATED IN BLUE
- J2D2-R2 — WELLS DESIGNATED FOR COMPOUND SPECIFIC ISOTOPE ANALYSIS ARE DESIGNATED IN GREEN

NOTES

SEE FIGURE 2 FOR TRANSECT LOCATION

PC-67 INCLUDED IN TRANSECT MONITORING REGIMEN AS WELL

600 300 0 600

SCALE IN FEET

LEGEND

- Qal-xMCF CONTACT
- GROUNDWATER LEVEL
- SATURATED ZONE ABOVE Qal-xMCF CONTACT

30 15 0 30

VERTICAL SCALE IN FEET

600 300 0 600

HORIZONTAL SCALE IN FEET

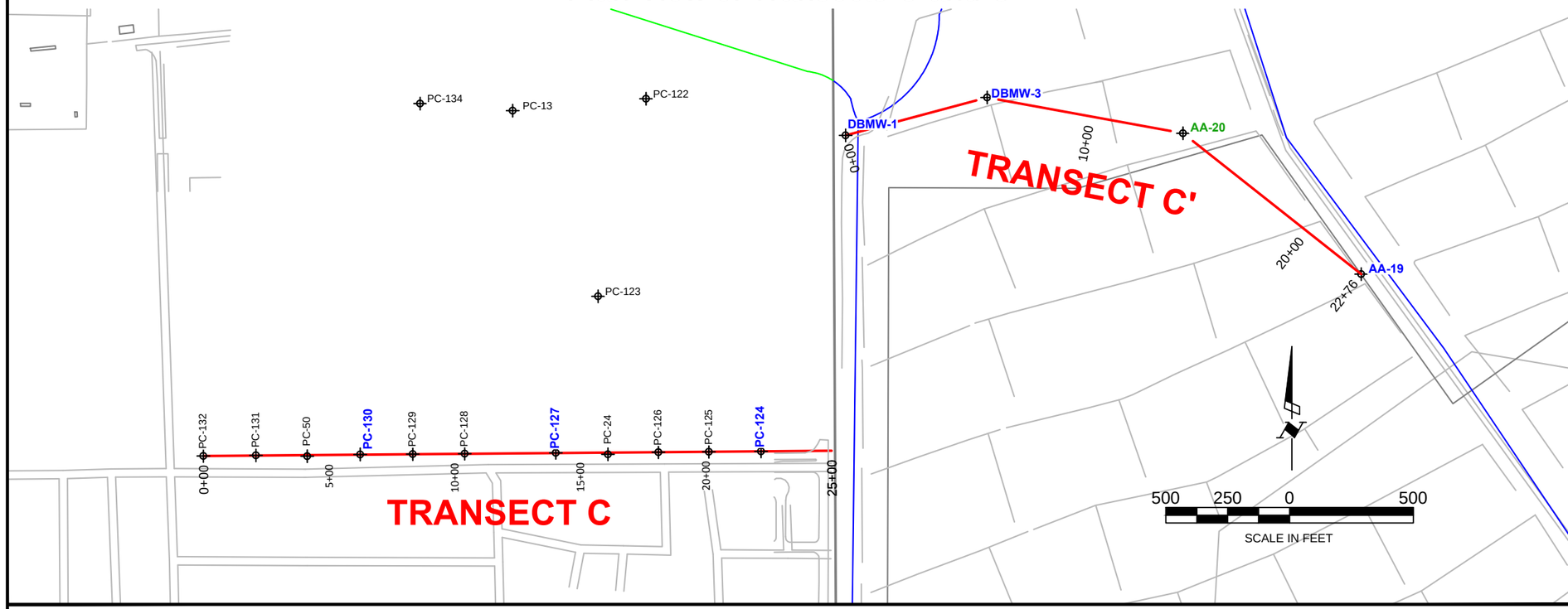
MNA Work Plan
Titanium Metals Corporation
Henderson, Nevada

FIGURE 4
TRANSECT B - MEDIAL PLUME POSITION PLAN AND PROFILE

TIMET

P:\Active Projects\TIMET\MNA Work Plan\Transects\Mass Flux Calcs\Figures

Plan View of Transects C and C'



LEGEND

- MONITORING WELL
- TRANSECT ALIGNMENT
- DITCH OR WASH
- OFFSITE DITCH OR WASH
- TMPZ-105 — WELL INCLUDED IN TRANSECT MONITORING REGIMEN DESIGNATED IN BLUE
- J2D2-R2 — WELLS DESIGNATED FOR COMPOUND SPECIFIC ISOTOPE ANALYSIS ARE DESIGNATED IN GREEN

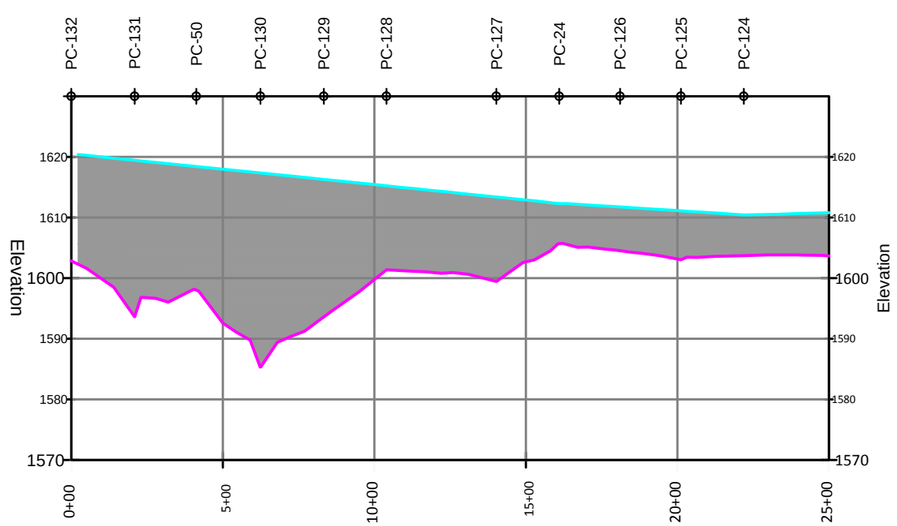
NOTES

SEE FIGURE 2 FOR TRANSECT LOCATION

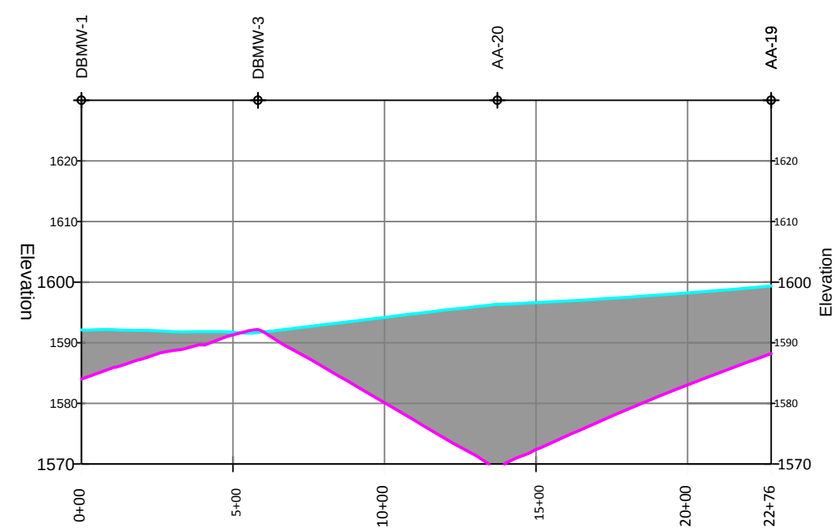
AA-20 INCLUDED IN TRANSECT MONITORING REGIMEN AS WELL

500 250 0 500

SCALE IN FEET



Profile View of TRANSECT C



Profile View of TRANSECT C'

LEGEND

- Qal-xMCF CONTACT
- GROUNDWATER LEVEL
- SATURATED ZONE ABOVE Qal-xMCF CONTACT

25 12.5 0 25

VERTICAL SCALE IN FEET

500 250 0 500

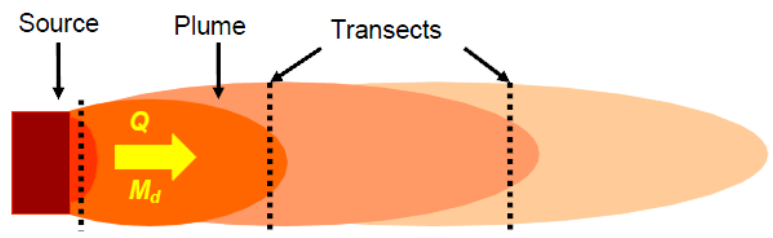
HORIZONTAL SCALE IN FEET

MNA Work Plan
Titanium Metals Corporation
Henderson, Nevada

FIGURE 5
TRANSECTS C AND C'
DISTAL PLUME POSITION
PLAN AND PROFILE

TIMET

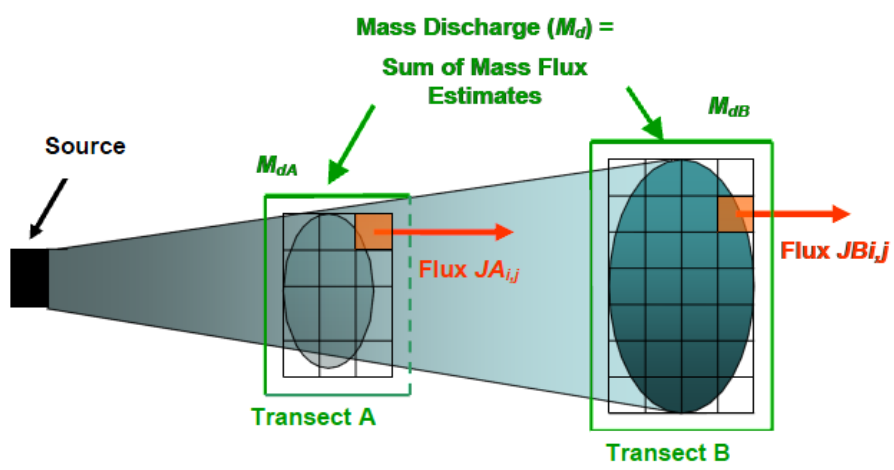
P:\Active Projects\TIMET\MNA Work Plan\Transects\Mass Flux Calcs\Figures



Across any transect, a contaminant plume conveys:

- Groundwater discharge, $Q = L^3/t$ (e.g., volume/d)
- Contaminant mass discharge, M_d = mass/time (e.g., g/d

Figure 2-1. Contaminant mass discharge in plan view. Mass discharge (M_d, the total contaminant mass moving through a transect per unit time) is conceptually similar to groundwater discharge (Q, the total volume of groundwater moving through a transect per unit time). Mass discharge is the product of groundwater discharge multiplied by the average contaminant concentration. (Graphic courtesy HydroGeoLogic, Inc.)



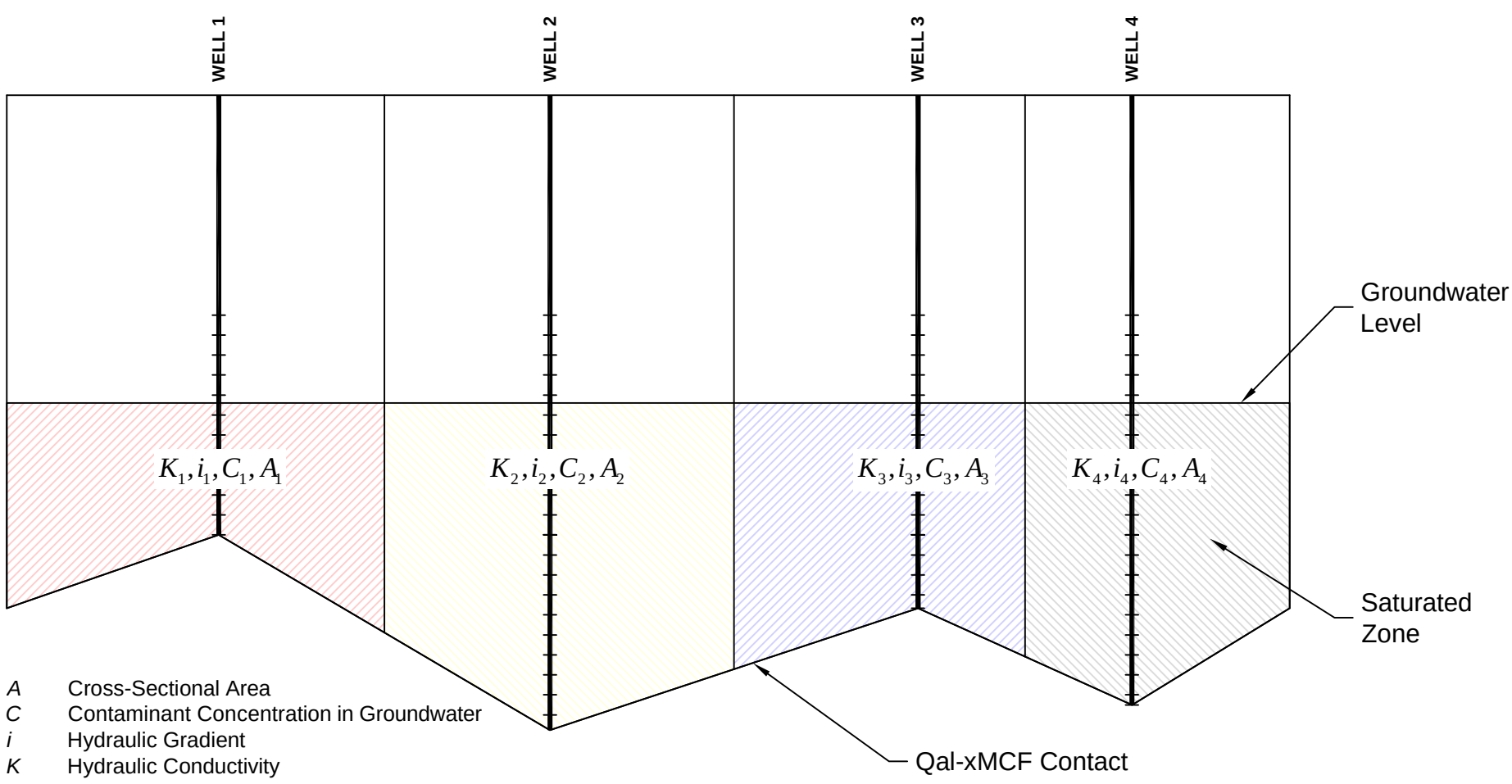
$JA_{i,j}$ = Individual mass flux measurement at Transect A

M_{dA} = Mass discharge at Transect A (total of all $JA_{i,j}$ estimates)

Figure 2-2. Concepts of mass flux (J) and mass discharge (M_d). Flux is the mass moving past a plane of given area per unit time (e.g., g/d/m^2). Each square in the transect represents the mass flux for that unit area (cell i,j) of the transect. Mass discharge is the total mass flux integrated across the entire area of a transect (e.g., g/d). It is therefore the sum of the cells in the transect. There would be two mass discharge values for this example (M_{dA} and M_{dB}) at different distances downgradient from a source. These mass discharge values can be compared to evaluate conditions at the site (e.g., the natural attenuation rate). (Graphic courtesy HydroGeoLogic, Inc.)

SOURCE: Interstate Technology and Regulatory Council (ITRC) "Use and Measurement of Mass Flux and Mass Discharge" August 2010

EXAMPLE TRANSECT



A Cross-Sectional Area
C Contaminant Concentration in Groundwater
i Hydraulic Gradient
K Hydraulic Conductivity

MNA Work Plan
Titanium Metals Corporation
Henderson, Nevada

FIGURE 6
TRANSECT METHOD FOR FLUX CALCULATIONS

TIMET

FIGURE 7
MNA IMPLEMENTATION SCHEDULE
TITANIUM METALS CORPORATION PLANT SITE, HENDERSON, NV

	2013		2014		2015		2016		2017		2018	
Activity	**April[1]**	**October**	**April**	**October**	**April**	**October**	**April**	**October**	**April**	**October**	**April**	**October**
Routine Semester Monitoring Plant Site												
Institutional Controls Technical Memo												
Formalize Flux Transects and Access												
Initial Demonstration Phase												
Interim Long-Term Monitoring												
CSIA Sampling												
Deploy Biotraps												
Analyze Biotraps												
Initial Evaluation of MNA Report												
MNA Performance Assessment Reporting												
First Five Year Review												

Notes:

MNA = Monitored Natural Attenuation

CSIA = Compound-Specific Isotope Analysis

[1] First semester 2013 sampling activities will be conducted between April and August, 2013

TABLES

TABLE 1
SUMMARY OF MNA SAMPLE METHODS
TITANIUM METALS CORPORATION PLANT SITE, HENDERSON, NV

Parameter	Analytical Method	Field or Fixed-Base Laboratory	Data Use
TAL metals (total and dissolved)	EPA Method 6010	Fixed-Base	Evaluate trends of SRC cited in ROD
Volatile organic compounds	EPA Method 8260B	Fixed-Base	Evaluate trends of SRC cited in ROD
Uranium	EPA Method 6020	Fixed-Base	Evaluate trends of SRC cited in ROD
Perchlorate	EPA Method 314	Fixed-Base	Evaluate trends of SRC cited in ROD
Total Dissolved Solids	EPA Method 160.1	Fixed-Base	Evaluate trends of SRC cited in ROD
Methane, ethane, and ethane	EPA Method 381.0- RSK-175	Fixed-Base	Evaluate occurrence and degree of RDC
Sulfate and nitrate	EPA Method 300.0	Fixed-Base	Competitive alternative electron acceptors relative to RDC
Phosphate	EPA Method 300.0	Fixed-Base	Assess likelihood of phosphate-metal complexes or precipitates affecting metal solubility
Carbonate Alkalinity	HACH	Field	Assess likelihood of carbonate-metal complexes affecting metal solubility
Dissolved Oxygen	Diaphragm galvanic battery method or optical luminescence	Field	Establish aerobic and anaerobic zones
Oxidation-Reduction Potential	Platinum Electrode Field Meter	Field	Establish aerobic and anaerobic zones
Temperature	Thermistor	Field	Establish suitable temperature range for intrinsic bioremediation
pH	Glass electrode	Field	Establish if pH is conducive to bioremediation
Specific Conductance	AC electrode	Field	General water quality parameter
Dissolved Manganese	EPA Method 6010B	Field and Fixed-Base	Indication of reducing conditions at or below "manganese reduction" Eh
Ferrous Iron	HACH	Field	Indication of reducing conditions at or below "iron reduction" Eh
Sulfide	HACH	Field	Indication of reducing conditions at or below "sulfide reduction" Eh

Notes:

EPA = United States Environmental Protection Agency

Fixed-Base = Fixed Base Analytical Laboratory

Field = Field-based measurements

ROD = Record of Decision

RDC = reductive dechlorination

SCR = site related chemcials

TAL = target analyte list

TABLE 2
MONITORING REGIMEN FOR MNA AND FLUX TRANSECT WELLS
TITANIUM METALS CORPORATION PLANT SITE, HENDERSON, NEVADA

Monitor Well ID	VOCs	Metals	Uranium	Perchlorate	Hexavalent Chromium	Sulfate/Nitrate	Methane, Ethane, Ethene	TDS	Geochemical Parameters	Gauging/Water Levels	Rationale
CLD1-R	S	S	S	S	S	S		S	S	S	Downgradient of PSA; verify stable to declining trend
CLD2-R	S	S	S	S	S	S		S	S	S	Downgradient of PSA; verify stable to declining trend
CMT-101	S	S	S	S	S	S		S	S	S	Downgradient of PSA; verify stable to declining trend
MW-3R	S	S	S	S	S	S		S	S	S	Flux from Tronox
J2D1-R2	S	S	S	S	S	S	S	S	S	S	Potential Source Area; plume centerline.
J2D2-R2	S	S	S	S	S	S	S	S	S	S	Potential Source Area; plume centerline.
TMPZ-113	S	S	S	S	S	S		S	S	S	Southeast flank of Plant Site
TMPZ-114										S	Southeast flank of Plant Site
TMPZ-115	S	S	S	S	S	S		S	S	S	Southeast flank of Plant Site
TMPZ-116										S	Southeast flank of Plant Site
TMPZ-117	S	S	S	S	S	S		S	S	S	Southeast flank of Plant Site
TMPZ-118										S	Southeast flank of Plant Site
TMPZ-119	S	S	S	S	S	S		S	S	S	Southeast flank of Plant Site
AA-11	S	S	S	S	S	S		S	S	S	Medial Plume Centerline
AA-20	S	S	S	S	S	S		S	S	S	Distal Plume Centerline

TABLE 2
MONITORING REGIMEN FOR MNA AND FLUX TRANSECT WELLS
TITANIUM METALS CORPORATION PLANT SITE, HENDERSON, NEVADA

Monitor Well ID	VOCs	Metals	Uranium	Perchlorate	Hexavalent Chromium	Sulfate/Nitrate	Methane, Ethane, Ethene	TDS	Geochemical Parameters	Gauging/Water Levels	Rationale
TPMZ-105	S	S	S	S	S			S	S	S	**Proximal Flux Gate**
TPMZ-106	S	S	S	S	S			S	S	S	
TPMZ-107	S	S	S	S	S			S	S	S	
TPMZ-108	S	S	S	S	S	S	S	S	S	S	Proximal Plume Centerline for CSIA tests
TPMZ-109	S	S	S	S	S			S	S	S	
TMPZ-110	S	S	S	S	S			S	S	S	
AA-27	S	S	S	S	S			S	S	S	
AA-UW1	S	S	S	S	S			S	S	S	
AA-09	S	S	S	S	S			S	S	S	**Medial Flux Gate**
PC-64	S	S	S	S	S			S	S	S	
PC-65	S	S	S	S	S			S	S	S	
PC-66	S	S	S	S	S			S	S	S	
PC-67	S	S	S	S	S	S	S	S	S	S	Medial Plume Centerline for CSIA tests
POD2-R	S	S	S	S	S			S	S	S	
POD8	S	S	S	S	S			S	S	S	
DM1	S	S	S	S	S			S	S	S	

TABLE 2
MONITORING REGIMEN FOR MNA AND FLUX TRANSECT WELLS
TITANIUM METALS CORPORATION PLANT SITE, HENDERSON, NEVADA

Monitor Well ID	VOCs	Metals	Uranium	Perchlorate	Hexavalent Chromium	Sulfate/Nitrate	Methane, Ethane, Ethene	TDS	Geochemical Parameters	Gauging/Water Levels	Rationale
PC-124	S	S	S	S	S			S	S	S	**Distal Flux Gate**
PC-127	S	S	S	S	S			S	S	S	
PC-130	S	S	S	S	S			S	S	S	
DBMW-1	S	S	S	S	S			S	S	S	
DBMW-3	S	S	S	S	S			S	S	S	
AA-19	S	S	S	S	S			S	S	S	
AA-20	S	S	S	S	S			S	S	S	Distal Plume Centerline for CSIA Tests

Notes:

ID = Identification

Geochemical Parameters = dissolved oxygen (DO), oxidation-reduction potential (ORP), temperature, pH, specific conductance, ferrous iron, manganese

MNA = Monitored natural attenuation

PSA = Potential source area

S = Semiannual

TDS = Total dissolved solids

VOCs = Volatile organic compounds

TABLE 3
FLUX TRANSECT DATA SOURCES
TITANIUM METALS INC. PLANT SITE, HENDERSON, NEVADA

Monitor Well ID	VOCs	Metals	Uranium	Perchlorate	TDS	Total Cr
Proximal Flux Gate						
TPMZ-105	T	T	T	T	T	T
TPMZ-106	T	T	T	T	T	T
TPMZ-107	T	T	T	T	T	T
TPMZ-108	T	T	T	T	T	T
TPMZ-109	T	T	T	T	T	T
TMPZ-110	T	T	T	T	T	T
AA-27	BRC	BRC	BRC	BRC	BRC	BRC
AA-UW1	BRC	BRC	BRC	BRC	BRC	BRC
Medial Flux Gate						
AA-09	BRC	BRC	BRC	BRC	BRC	BRC
PC-64	NERT	NERT	NERT	NERT	NERT	NERT
PC-65	NERT	NERT	NERT	NERT	NERT	NERT
PC-66	NERT	NERT	NERT	NERT	NERT	NERT
PC-67	NERT	NERT	NERT	NERT	NERT	NERT
POD2-R	BRC	BRC	BRC	BRC	BRC	BRC
POD8	BRC	BRC	BRC	BRC	BRC	BRC
DM1	BRC	BRC	BRC	BRC	BRC	BRC
Distal Flux Gate						
PC-124	NERT	NERT	NERT	NERT	NERT	NERT
PC-127	NERT	NERT	NERT	NERT	NERT	NERT
PC-130	NERT	NERT	NERT	NERT	NERT	NERT
DBMW-1	BRC	BRC	BRC	BRC	BRC	BRC
DBMW-3	BRC	BRC	BRC	BRC	BRC	BRC
AA-19	BRC	BRC	BRC	BRC	BRC	BRC
AA-20	BRC	BRC	BRC	BRC	BRC	BRC

Notes:

BRC = Basic Remediation Company owned groundwater monitoring well

Cr = Chromium

NERT = Nevada Environmental Response Trust owned groundwater monitoring well

T = TIMET owned groundwater monitoring well

TDS = Total dissolved solids

VOCs = Volatile organic compounds

TABLE 4
SUMMARY OF INTRINSIC BIOREMEDIATION ANALYSES
TITANIUM METALS CORPORATION PLANT SITE, HENDERSON, NEVADA

Method	Plume Position	Proposed Monitoring Wells	Description	Data Use
CSIA	Source, Proximal, Medial and Distal	J2D2-R2; TMPZ-108; PC-067; AA-11; AA-20	Stable isotope analysis of carbon (^{13}C and ^{12}C) along plume centerline to evaluate shift in isotopic ratios.	Enrichment of $\delta^{13}C$ along plume axis can indicate intrinsic bioremediation since ^{12}C is preferred isotope for dechlorination
Bio-Trap® Samplers	Source, Proximal, and Medial	J2D2-R2; TMPZ-108; PC-067	Passive sampling "screens" loaded with large surface area activated carbon beads that act as substrate for bacteria and sorb nutrients and contaminants.	DNA extraction for quantitative polymerase chain reaction bacterial speciation; evaluate trend in bacteria along plume axis; "spike" with labeled ^{13}C for direct observation of intrinsic biodegradation; evaluate monitored natural attenuation
Test Performed Using Bio-Trap® Samplers				
qPCR	Source, Proximal, and Medial	J2D2-R2; TMPZ-108; PC-067	Bacteria DNA tested to identify bacterial groups and species involved in remedial processes	Establish if bacterial groups and populations of suitable bacteria exist to facilitate intrinsic biodegradation.
SIP	Source, Proximal, and Medial	J2D2-R2; TMPZ-108; PC-067	Bio-traps loaded with ^{13}C labeled PCE	Direct observation of chemical, physical and microbial process activity and rates via shift in $\delta^{13}C$

Notes:
^{12}C = Carbon 12
^{13}C = Carbon 13
CSIA = Compound-specific isotope analysis
DNA = Deoxyribonucleic acid
PCE = tetrachloroethene
qPCR = Quantitative Polymerase Chain Reaction (DNA Testing)
SIP = Stable istotope probing

TABLE 5. SUMMARY OF DATA QUALITY OBJECTIVES FOR MNA IMPLEMENTATION
TITANIUM METALS CORPORATION PLANT SITE, HENDERSON, NV

STEP 1: State the Problem
Data are needed to evaluate the suitability of monitored natural attenuation (MNA) or MNA with enhanced attenuation (EA) as a remediation strategy for site related chemicals (SRC) in the first water bearing zone (1st WBZ).
STEP 2: Identify the Goals of the Study
Determine if there are indications that MNA is occurring at the Site in the 1st WBZ downgradient of the facility and if MNA is an appropriate remedy for groundwater at the site: (1) Can natural attenuation processes effectively reduce chlorinated volatile organic compounds (CVOCs) present in soil or groundwater to suitable endpoints?; (2) Is the contaminant plume stable; can the the plume stability change over time?; (3) Can human health, drinking water supplies, and other environmental resources be adversely impacted by selecting MNA?; (4) Is MNA appropriate for the entire time period that it will remain in effect?; (5) Will the contamination exert a long-term detrimental impact on available water supplies or other environmental resources?; (6) Is the estimated timeframe of remediation reasonable compared to other alternatives?; (7) Are the nature and distribution of contaminant sources such that the sources have been, or can be, adequately controlled?; (8) Do the resulting transformation products present a greater risk, due to increased toxicity and/or mobility, than the parent contaminants?; (9) Is MNA compatible with existing and proposed remediation measures and other operations in close proximity to the site?; (10) Are reliable site-specific mechanisms for implementing institutional controls available, and can an institution responsible for their monitoring and enforcement be identified? Of the above list, the most important for consideration of the suitability of MNA are (1), (2), and (3).
STEP 3: Identify Information Inputs
In order to address questions (1), (2), and (3) above, the following data will be collected: (1) Collect ground water analytical data to assess natural attenuation parameters and plume status. Analyses will include volatile organic compunds (VOCs) (EPA 8260B), target analyte list (TAL) metals - total and dissolved (EPA 6010), dissolved mangenese (EPA 6010B), uranium (EPA 6020), perchlorate (EPA 314), total dissolved solids (TDS) (EPA 160.1), methane, ethene, ethane (EPA 381.0-RSK-175), and sulfate, nitrate, and phosphate (EPA 300.0). Specific analyses required are provided in Table 1. (2) Collect ground water for field analysis of dissolved oxygen (DO), oxygen reduction potential (ORP), pH, and temperature using field probes that may be lowered down a well or used with a flow-through cell as part of standard low-flow ground water sampling. Water samples will be field tested for carbonate alkalinity, ferrous iron, and sulfide using field test kits. These parameters will be used to determine if reducing conditions exist. (3) Collect groundwater samples for compound specific isotope analyses (CSIA) to estimate the extent at which biodegradation is occurring. CSIA is a technique of measuring the shift in 13C/12C ratio that may indicate intrinsic bioremediation. (4) Collect samples for quantitative polymerase chain reaction (qPCR) testing using Bio-Traps® to determine if microbes capable of completely dechlorinating PCE, TCE, DCE, 1,1 -DCE, and VC to the environmentally acceptable end-product ethene are present. Specifically, the presence or absence of *Dehalococcoides* will be identified, along with specific genes linked to biodegradation pathways. (5) Perform stable isotope probing (SIP) to determine whether contaminants of concerns (COCs) are being degraded through biological pathways. The test will consist of deploying Bio-Traps® provided by the laboratory for an incubation period, then retrieving the Bio-Traps® for shipment to the laboratory overnight. The incubation period will range from of 30 to 60 days, depending on ground water parameters, to be determined at the time the Bio-Traps® are placed in the wells. (6) A review of land use and institutional controls in place to prevent exposure to shallow groundwater has been done to address potential effects on human health, drinking water supplies, and other environmental resources.

TABLE 5. SUMMARY OF DATA QUALITY OBJECTIVES FOR MNA IMPLEMENTATION
TITANIUM METALS CORPORATION PLANT SITE, HENDERSON, NV

STEP 4: Define Study Boundaries
Spatially, the study boundaries will be: Horizontally, from the south at Lake Mead Parkway to the Las Vegas Wash on the north and from the proposed developments of Landwell Corporation and Tuscany Street RD etc.. on the east to Pitman neighborhood on the west. Vertically, the study area is bound by the base of the 1st WBZ.
STEP 5: Develop a Decision Rule
Data obtained will be compiled and analyzed to identify potential breakdown products, whether the aquifer is aerobic or anaerobic, to determine if microbes capable of degrading CVOCs are present, and to identify evidence of biodegradation through isotope enrichment. If MNA or MNA with EA does not result in declining plume mass, then contingency measures may be required.
STEP 6: Specify Limits on Decision Errors
Decisions at this time are qualitative and therefore decision errors are not specified.
STEP 7: Optimize the Design for Obtaining Data
Detailed monitoring regimens for monitoring wells and flux gate wells are found in Tables 2 and 3

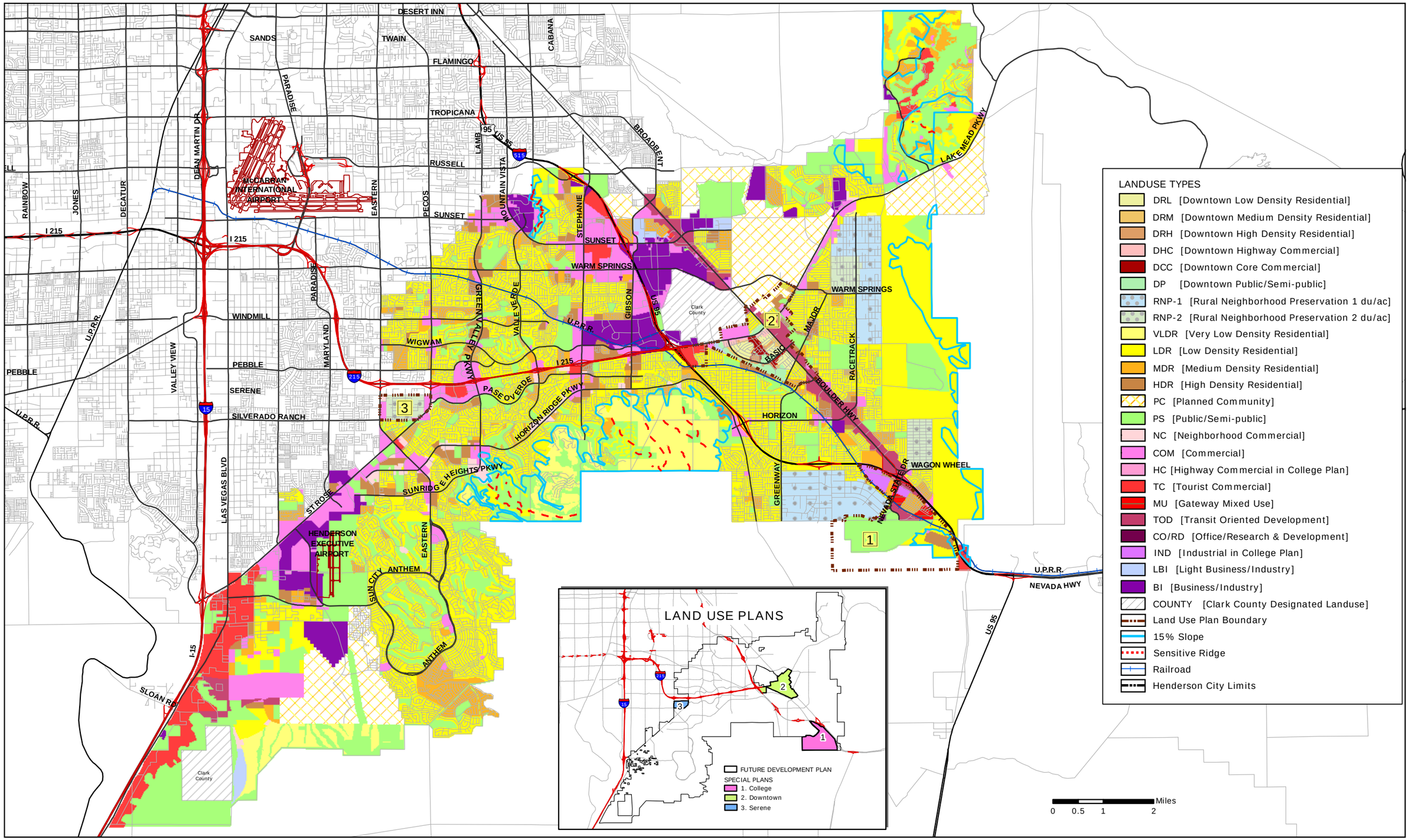
Notes:
pH = a measure of the molar concentration of hydrogen ions in the solution and as such is a measure of the acidity or basicity of the solution.
PCE = Tetrachloroethylene
TCE = Trichloroethylene
DCE = Dichloroethylene
VC = Vinyl Chloride
Acronyms:
MNA = Monitored natural attenuation
EA = Enhanced attenuation
EPA = U.S. Environmental Protection Agency
SRC = Site related chemicals
WBZ = Water bearing zone
CVOCs = Chlorinated volatile organic compounds
VOCs = Volatile organic compounds
TAL = Target analyte list
TDS = Total dissolved solids
DO = Dissolved oxygen
ORP = Oxygen reduction potential
CSIA = Compound specific isotope analyses
qPCR = Quantitative polymerase chain reaction
COCs = Contaminants of concerns
SIP = Stable isotope probing

APPENDIX A

RESERVED FOR NDEP'S COMMENTS AND TIMET RESPONSES

APPENDIX B

CITY OF HENDERSON ZONING, PLANNING, AND LAND USE MAPS

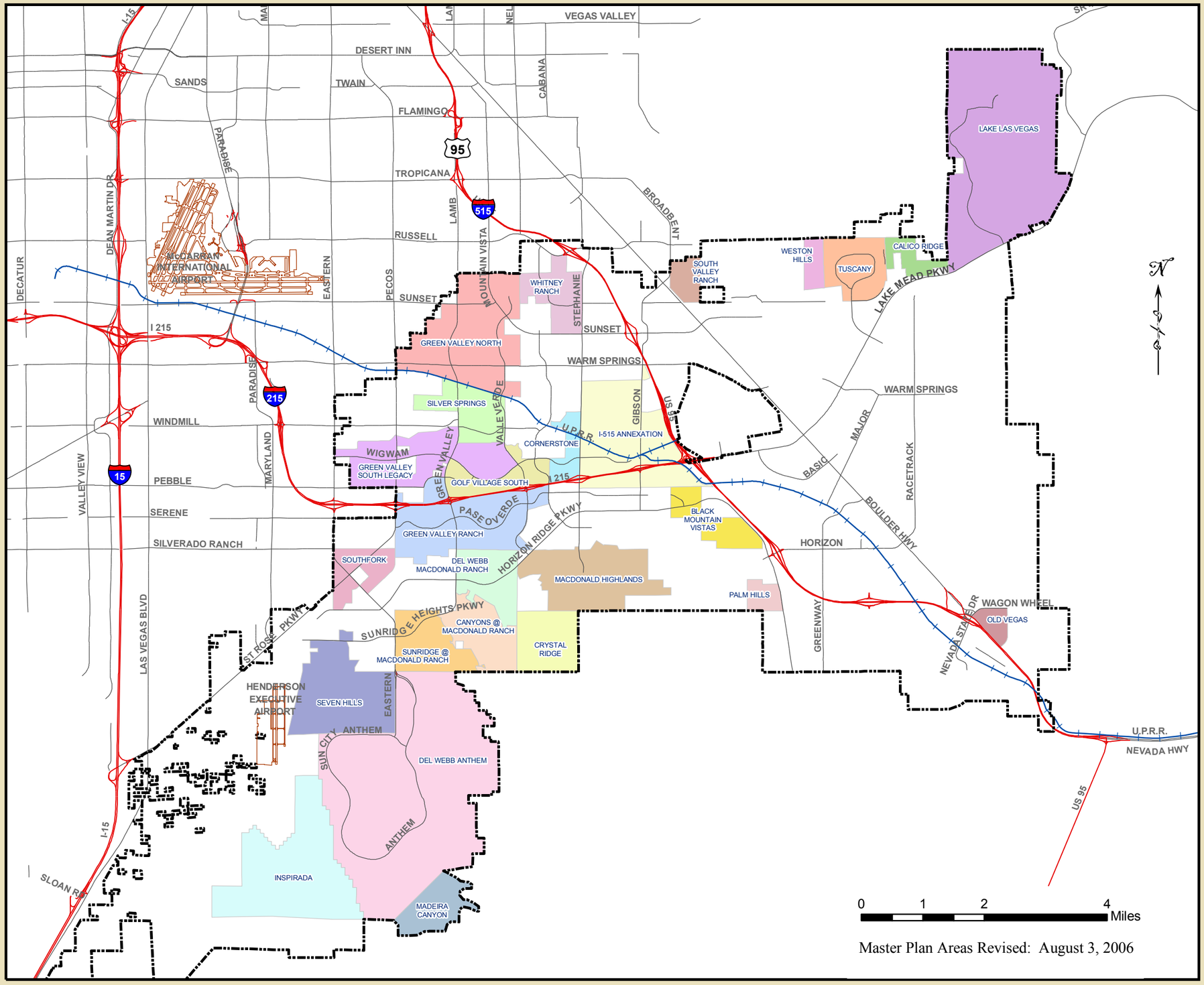


This map is offered as a general reference guide only.
Neither warranty of accuracy is intended nor should
any be assumed. Land Use data per City Council: 10/16/2012.
//gis/workareas/landuse/mxds/all_landuse_11x17

Future Land Use Plan for the City of Henderson, Nevada

NORTH

Community Development
Geographic Information Services
(702) 267 - 1500
October 2012



Master Plan Areas Revised: August 3, 2006

MASTER PLAN AREAS

- Black Mountain Vistas
- Calico Ridge
- Canyons @ MacDonald Ranch
- Cornerstone
- Crystal Ridge
- Del Webb Anthem
- Del Webb MacDonald Ranch
- Golf Village South
- Green Valley North
- Green Valley Ranch
- Green Valley South Legacy
- I-515 Annexation
- Inspirada
- Lake Las Vegas
- MacDonald Highlands
- Madeira Canyon
- Old Vegas
- Palm Hills
- Seven Hills
- Silver Springs
- Southfork
- South Valley Ranch
- Sunridge @ MacDonald Ranch
- Tuscany
- Weston Hills
- Whitney Ranch
- City Boundary
- Interstate / Ramp
- State Highway
- Major Street

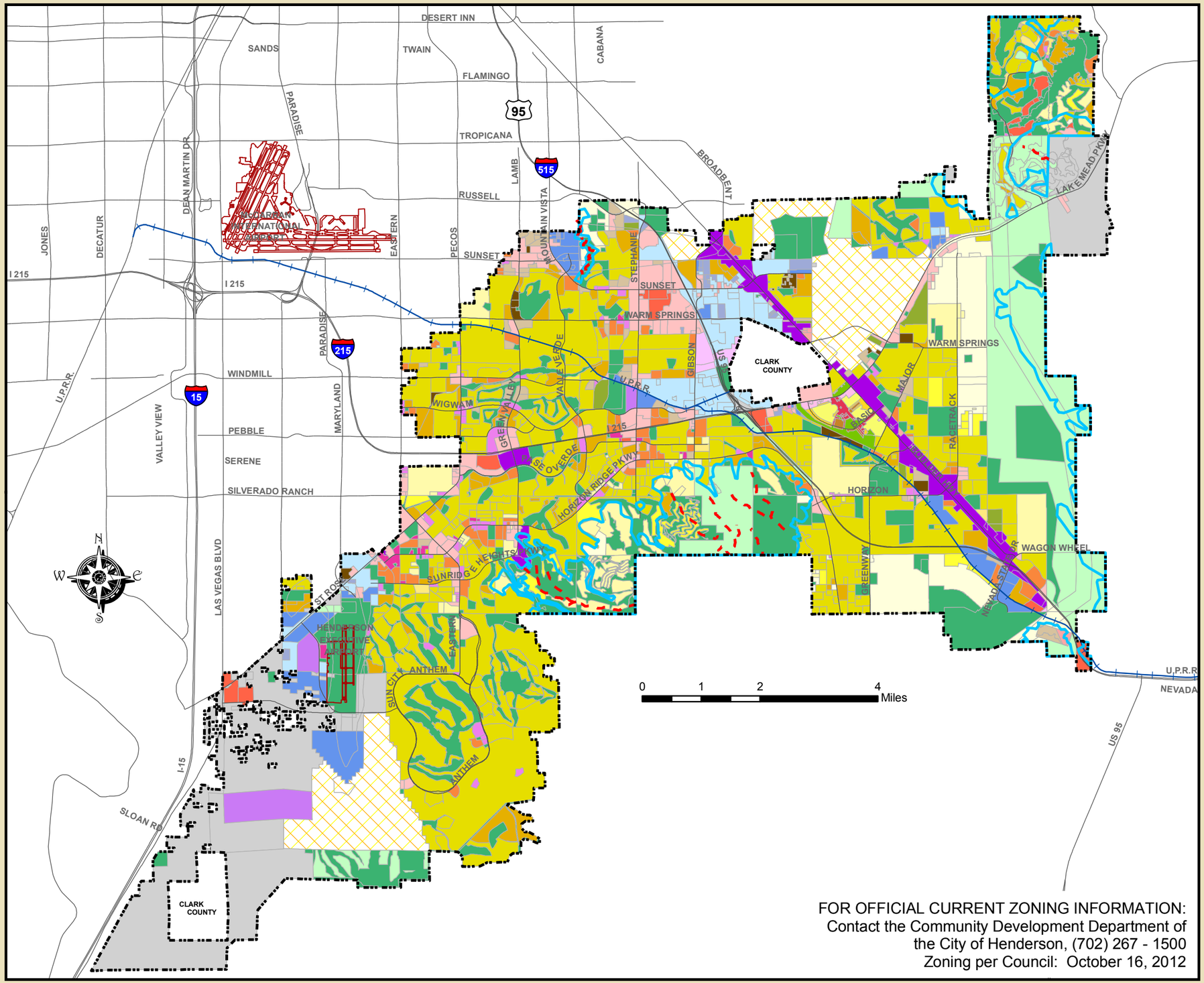
This map is offered as a general reference guide only. Neither warranty of accuracy is intended nor should any be assumed.

City of Henderson
Community Development
Geographic Information Services
January 2007

//gis/workareas/map_portfolio/mxds/masterplans

THE CITY OF HENDERSON
A Place To Call Home

HENDERSON, NEVADA



FOR OFFICIAL CURRENT ZONING INFORMATION:
Contact the Community Development Department of
the City of Henderson, (702) 267 - 1500
Zoning per Council: October 16, 2012

EXISTING ZONING

DRL	CA
DRM	CC
DRH	CH
DHC	CM
DCC	CN
DP	CO
RS-1	CT
RS-2	PC
RS-4	MC
RS-6	MN
RS-8	MR
RM-10	IG
RM-16	IL
RH-24	IP
RH-36	DH
RMH	PS
15% Slope	CNTY
Sensitive Ridge	

This map is offered as a general reference guide only. Neither warranty of accuracy is intended nor should any be assumed.

City of Henderson
Community Development
Geographic Information Services
240 Water Street MSC 115
Henderson, NV 89015
702.267.1500
October 2012

THE CITY OF HENDERSON
A Place To Call Home

//gis/workareas/map_portfolio/mxds/zoning

HENDERSON, NEVADA