

Natural Attenuation Evaluation of Volatile Organic Compounds (VOCs) in Groundwater

Natural attenuation processes such as biodegradation, hydrolysis, dispersion, dilution, sorption, and volatilization affect the fate and transport of dissolved organic contaminants in all hydrologic systems. These processes work to reduce the concentrations of contaminants dissolved in groundwater and thereby reduce their toxicity to potential receptors. Biodegradation processes are of special importance because for certain compounds these processes are the most rapid to transform toxic contaminants, through a series of intermediate products, to nontoxic byproducts. Biodegradation occurs when naturally occurring microorganisms degrade the contaminant, thereby reducing the mass of the original contaminant.

An overview of the biodegradation mechanisms that can act upon petroleum hydrocarbons and chlorinated solvents in groundwater is provided below, followed by a presentation of the natural attenuation evaluation for the AMCO Chemical Superfund Site.

G.1 Biodegradation Processes

Microbes obtain energy by breaking down organic compounds through a process called cellular respiration. During cellular respiration electrons are transferred between compounds, resulting in the transformation of the original compounds into new compounds. The original compound which loses an electron or electrons is referred to as the “electron donor”; the compound that gains an electron or electrons is called the “electron acceptor.” The electron donor compound can be considered the “primary substrate” or “food source” to the microorganism in such a reaction. The electron acceptor compound is the substrate used for respiration, such as oxygen in aerobic environments.

Microorganisms are most effective at degrading low to moderate concentrations of dissolved contaminants. Microbial activity can also slightly enhance the dissolution of contaminants adsorbed on soil. Microorganisms cannot degrade bulk contaminants in bulk non-aqueous phase liquid (NAPL), and the NAPL phase dissolution rate is too slow to effectively reduce bulk NAPL mass.

G.1.1 Mechanisms of Petroleum Hydrocarbon Biodegradation

Petroleum hydrocarbons can become completely degraded if they are utilized as the primary substrate (electron donor) for microbial metabolism (Bouwer 1992). Electron acceptors for these reactions are elements or compounds that occur in relatively oxidized states in the groundwater. Dissolved oxygen (DO) is utilized first as the preferred electron acceptor. After the DO is consumed, anaerobic microorganisms typically use additional electron acceptors as available.

In typical geochemical conditions, the order in which electron acceptors are utilized are (Wiedemeier et. al 1999; EPA 2001):

1. Dissolved oxygen (aerobic respiration) – results in depletion of oxygen
2. Nitrate (denitrification) – results in depletion of nitrate
3. Manganese (manganese reduction) – results in production of dissolved form of manganese
4. Iron (ferric iron reduction) – results in production of dissolved form of iron (ferrous iron)
5. Sulfate (sulfate reduction) – results in depletion of sulfate
6. Carbon dioxide (methanogenesis) – results in production of methane

As electron acceptors are progressively depleted, the groundwater environment becomes increasingly anaerobic and the oxidation-reduction potential (ORP) of the groundwater decreases (Figure G-1).

Because the biodegradation of petroleum hydrocarbons should deplete the concentrations of these electron acceptors and produce metabolic byproducts, construction of contour maps geographically depicting their concentrations can provide evidence of whether biodegradation is occurring, and the degree to which it is occurring.

G.1.2 Mechanisms of Chlorinated Solvent Biodegradation

Whereas petroleum hydrocarbons are biodegraded through use as a primary substrate (electron donor), chlorinated solvents may undergo biodegradation through three different pathways: through use as an electron acceptor (via reductive dechlorination), through use as an electron donor, or through co-metabolism, where degradation of the chlorinated solvents is fortuitous and therefore of no benefit to the microorganism (EPA 1998). A chlorinated solvent that was present prior to biodegradation, such as tetrachloroethene (PCE), is sometimes called a parent compound. The compounds produced by biodegradation of the parent compound, such as trichloroethene (TCE), dichloroethene (DCE), and vinyl chloride produced from PCE, are called daughter products. Note that TCE can be both a daughter compound of PCE and a parent compound by direct release of bulk TCE.

G.1.2.1 Electron Acceptor Reactions (Reductive Dechlorination)

The most important process for the natural biodegradation of the more highly chlorinated solvents is reductive dechlorination. During this process, the chlorinated hydrocarbon is used as an electron acceptor, not as a food source, and a chlorine atom is replaced with a hydrogen atom. In general, reductive dechlorination occurs by sequential dechlorination from PCE to TCE to DCE to vinyl chloride to ethene to ethane (Figure G-2). Depending on environmental conditions, this sequence may be interrupted with other processes then acting on the products. During reductive dechlorination, all three isomers of DCE theoretically can be produced; however, *cis*-1,2-DCE is the predominant intermediate, with *trans*-1,2-DCE, and 1,1-DCE being minor byproducts (Bouwer 1994; Wiedemeier et al. 1999).

Reductive dechlorination affects each of the chlorinated solvents differently. PCE and TCE are the most susceptible to reductive dechlorination because they are the most oxidized.

Conversely, vinyl chloride is the least susceptible to reductive dechlorination because it is the least oxidized of these compounds. In general, the rate of reductive dechlorination has been observed to decrease as the degree of chlorination decreases (Vogel and McCarty 1985; Bouwer 1994). Consequently, reductive dechlorination is often associated with the accumulation of daughter products (e.g., cis-1,2-DCE and vinyl chloride) as these compounds are produced at a faster rate than they are degraded.

Reductive dechlorination of PCE to TCE to DCE can proceed under all reducing conditions, even mildly reducing conditions such as denitrification or ferric iron reduction (Vogel et al. 1987; Wiedemeier et al. 1999); however, the transformation of DCE to vinyl chloride or vinyl chloride to ethene requires strongly reducing conditions such as sulfate reduction and methanogenesis (Freedman and Gossett 1989; DeStefano et al. 1991; DeBruin et al. 1992; Wiedemeier et al. 1999). Because chlorinated solvents are used as electron acceptors during reductive dechlorination, there must be an appropriate food source (electron donor) for microbial growth to occur. Potential food sources include petroleum hydrocarbons and natural organic matter.

G.1.2.2 Electron Donor Reactions

Under aerobic conditions, or even weakly reducing conditions, some chlorinated solvents can be utilized as a food source (electron donor) in microbial reactions. In contrast to reactions in which the chlorinated compound is used as an electron acceptor, only the least oxidized chlorinated solvents (e.g., vinyl chloride and, to a limited extent, DCE) may be utilized as electron donors in these reactions. This process is the same as the one by which petroleum hydrocarbons are biodegraded, and is rapid relative to reductive dechlorination. In the case of vinyl chloride, this can be an important component of plume management, in that when vinyl chloride encounters aerobic conditions, it may be quickly utilized and transformed to ethene.

G.1.2.3 Co-metabolism

When a chlorinated solvent is degraded via co-metabolism, the degradation is catalyzed by an enzyme or cofactor that is produced by the microorganisms for other purposes. The microorganism receives no known benefit from the degradation of the chlorinated solvent. All chlorinated ethenes, with exception of the highly chlorinated PCE, have been shown to be susceptible to co-metabolic degradation under aerobic conditions (Vogel 1994; McCarty and Semprini 1994). The majority of research on cometabolic degradation has focused on TCE, and found multiple strains of bacteria and substrates capable of this reaction.

During co-metabolism, the chlorinated solvent is indirectly transformed by bacteria as they use petroleum hydrocarbons or another substrate to meet their energy requirements. Therefore, the chlorinated solvent does not enhance the degradation of petroleum hydrocarbons or other hydrocarbons, nor does its co-metabolism interfere with the use of electron acceptors involved in the oxidation of those carbon sources. However, for cometabolism to occur at a significant rate, another substrate must be present to sustain microbial growth.

G.2 Natural Attenuation Evaluation for Site

The most common elements of a natural attenuation evaluation for organic compounds dissolved in groundwater include:

- 1) Evaluation of historical trends in contaminant concentrations to determine whether the plume is growing, stable, or shrinking
- 2) Evaluation of geochemical data to determine whether geochemical conditions are suitable for biodegradation and whether biodegradation has occurred (as indicated by the consumption of electron acceptors and/or the production of metabolic byproducts)

Although the first element can indicate that a contaminant plume is being attenuated, it does not necessarily show that contaminant mass is destroyed. The second element can indicate that the contaminants are biodegrading, not just diluting, volatilizing, or adsorbing to the aquifer matrix.

G.2.1 Contaminant Concentration Trends and Plume Stability

Plume stability can be assessed by examining the footprint of the plume over time, examining concentration versus time plots for individual wells, and/or statistical analysis of concentration trends.

For this evaluation, the commonly applied Mann-Kendall statistical trend analysis method was used to assess concentration trends of key VOCs over time in each well (Wiedemeier et al. 1999). This method enables the user to determine whether the concentrations over time have an upward or downward trend that is statistically significant. A confidence interval of 90 percent is considered indicative of a probable trend and a confidence interval of 95 percent is considered indicative of a definite trend. The evaluation was based on the RI groundwater data, collected from March 2005 to September 2006.

The results of the Mann-Kendall analysis are presented in Table G-1 and on Figures G-3 and G-4. Key observations are as follows:

- The compounds evaluated showed no significant trend in most wells.
- At certain wells, a trend was detected but the observed concentrations were all close to the reporting limits (i.e., less than 10 µg/L). Random variability in environmental data is relatively high, this close to the reporting limits. These results have been interpreted as artifacts of the Mann-Kendall test method rather than meaningful trends.
- At well RMW-02-13, located in the source area in the middle of the facility, DCE and vinyl chloride showed probable increasing trends. This likely reflects the occurrence of rapid reductive dechlorination of PCE and TCE being released from these compounds dissolved into the light non-aqueous phase liquid (LNAPL) and residual dense non-aqueous phase liquid (DNAPL) trapped in the soil into groundwater in this area.
- At mid-plume well RMW-12-32, located near the facility, a decreasing trend in TCE was observed.
- At shallow downgradient well RMW-05-15, an increasing trend in vinyl chloride was observed.

- At well RMW-10-15, located on the 1401 3rd Street property in the suspected separate source area, TCE showed a decreasing trend. In the deeper well at the same location, RMW-10-35, TCE and DCE showed increasing trends.

In summary, the Mann-Kendall analysis suggests the occurrence of rapid biodegradation near the source and in the middle of the plume originating from the facility. At the downgradient edges of the plume(s), south of 3rd Street, the concentrations of chlorinated solvents are generally very low, with slight increasing trends in biodegradation daughter products in some wells.

The Mann-Kendall analysis was based on a relatively short period of time (March 2005 to September 2006); additional trends would be expected to become apparent over a longer time.

G.2.2 Geochemical Indicators of Biodegradation

The biodegradation of organic compounds brings about measurable changes in the chemistry of groundwater in the affected areas. By measuring these changes, it is possible to determine the degree to which biodegradation is occurring at a site. Groundwater geochemical data that were collected to assess biodegradation at the site include electron acceptors (DO, nitrate, and sulfate); metabolic byproducts (dissolved manganese, ferrous iron [dissolved iron], carbon dioxide, methane, ethane, ethene, and chloride); and other environmental indicators (ORP). The occurrence of biodegradation would cause a decrease in the concentrations of electron acceptors and an increase in the concentration of the metabolic byproducts.

Figures G-5 through G-16 show the distributions of nitrate, dissolved manganese, dissolved iron, sulfate, methane, and ethane/ethene in shallow and mid/deep groundwater. For each sampling location, the median value from the seven RI sampling events was used. DO and ORP data are not presented graphically because they did not show any clear patterns; these are highly sensitive field parameters and the data may not be representative of actual conditions. Chloride concentrations are elevated throughout groundwater in the site vicinity due to saltwater intrusion and therefore cannot be used to evaluate the occurrence of biodegradation.

The geochemical data indicate the following:

- Nitrate, an electron acceptor, is depleted (below 1.0 mg/L) in shallow groundwater throughout most of the site area, which is consistent with nitrate being consumed through biodegradation. The elevated concentrations of nitrate in far downgradient wells RMW-09-15, RMW-10-15 and BMW-03 are higher than what would be expected from saltwater intrusion, and may indicate the presence of a source of nitrate in shallow groundwater that may inhibit reductive dechlorination downgradient of the site. In mid/deep groundwater, nitrate is depleted in and immediately downgradient of the source area in the middle of the facility, and also in far downgradient wells RMW-10-35, RMW-14-50, and RMW-13-35.
- Dissolved manganese, a metabolic byproduct of biodegradation, is elevated in shallow groundwater in and downgradient of the source area in the central portion of the facility. In mid/deep groundwater, manganese is elevated to a lesser extent in and

immediately downgradient of the source area in the central portion of the facility. It is also elevated in the far downgradient wells RMW-10-35, RMW-14-50, and RMW-13-35.

- Ferrous iron (Fe[II]), a metabolic byproduct of biodegradation, is elevated in shallow groundwater in the source area in the middle of the facility (i.e., in the wells with the highest VOC contamination – RMW-02-13, RMW-01-17, and MW-12). Elevated levels of ferrous iron in BMW-08 are consistent with the peaty soil in which this well is screened, and are likely a reflection of high levels of microbial activity associated with the consumption of naturally occurring organic matter. In mid/deep groundwater, ferrous iron is elevated in the source area well RMW-02-32, and in far downgradient wells RMW-10-35, RMW-14-50, and RMW-13-35.
- Sulfate, an electron acceptor, is depleted in shallow groundwater in the source area in the middle of the facility (i.e., in the wells with the highest VOC contamination – RMW-02-13, RMW-01-17, and MW-12). This depletion of sulfate is an indication of biodegradation under strong reducing conditions, within the optimal range for reductive chlorination. Sulfate is highly elevated south of 3rd Street; this is likely a reflection saltwater intrusion in this area. In mid/deep groundwater, sulfate is low in mid-level wells RMW-02-32, RMW-01-35, and RMW-12-32, located in and immediately downgradient of the source area in the middle of the facility. It is highly elevated in the far downgradient wells RMW-10-35, RMW-14-50, and RMW-13-35. The elevated levels of sulfate south of 3rd Street is likely inhibiting reductive chlorination of DCE and vinyl chloride in this area.
- Methane, a metabolic byproduct of biodegradation, is elevated in shallow groundwater in and downgradient of the source area in the middle of the facility. These elevated methane levels are an indication of biodegradation under strong reducing conditions, within the optimal range for reductive chlorination. Elevated levels of methane in BMW-08 are consistent with the peaty soil in which this well is screened, and are likely a reflection of high levels of microbial activity associated with the consumption of naturally occurring organic matter. In mid/deep groundwater, methane is highest in mid-level wells RMW-02-32, RMW-01-35, and RMW-12-32, located in and immediately downgradient of the source area in the middle of the facility.
- Ethene and ethane, the harmless final breakdown products of chlorinated ethenes (PCE, TCE, DCE, and vinyl chloride), are present at extremely high concentrations in shallow groundwater in and immediately downgradient of the source area in the middle of the facility (RMW-02-13 and MW-12). In mid/deep groundwater, ethene and ethane are present at extremely high concentrations in mid-level wells RMW-02-32, RMW-12-32, and RMW-01-35, located in and immediately downgradient of the source area in the middle of the facility. Ethene and ethane were also detected at significant concentrations in wells RMW-07-35 and RMW-14-50, where chlorinated solvents are also present. Because the only plausible source of ethene and ethane is the reductive dechlorination process, the presence of these compounds in these areas provides conclusive evidence that full reductive dechlorination of chlorinated solvents is occurring.

G.2.3 Conclusions

A wide range of evidence suggests that biodegradation is playing a key role in attenuating key VOC contaminants in site groundwater. Despite the continuing release of these compounds to groundwater from NAPL and soil, statistical analysis shows that their concentrations have remained relatively stable over time at most locations. The geochemical evidence suggests that the biodegradation of available BTEX compounds in and downgradient of the source area has created highly reducing conditions favorable for the reductive dechlorination of chlorinated solvents. The presence of high levels of ethene and ethane, the harmless final by-products of reductive dechlorination, demonstrates the occurrence of this biodegradation mechanism.

Although biodegradation is causing significant mass reduction within and immediately downgradient of the main source area, the lines of evidence do not conclusively demonstrate that biodegradation is completely controlling the extent of these contaminants in groundwater. Although concentrations of parent compounds (PCE and TCE) are below detection levels, stable, or decreasing in the main portion of the VOC plume, a few chlorinated solvents show slightly increasing trends at some far downgradient locations. This may be due to a combination of two factors: other secondary sources releasing the contaminants into groundwater outside of the main source area, and the production of biodegradation daughter products (e.g., DCE and vinyl chloride) that are not fully transforming into harmless end products. This may be due to the lack of readily available electron donor compounds (e.g., BTEX) in the downgradient area, and/or the presence of high nitrate and sulfate concentrations that are out-competing chlorinated solvents for utilization as electron acceptors. Once the final screening levels are determined for groundwater south of 3rd Street as a non-drinking water source, the need for additional evaluation, such as groundwater modeling to predict the fate and transport of these downgradient contaminants, will be determined.

G.3 References

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TABLE G-1

Mann Kendall Trend Analysis Results

Remedial Investigation Report

AMCO Chemical Superfund Site, Oakland, California

Analyte	Number of Samples			Sample Statistics			Trend Analysis		
	Total	NDs	% NDs	Min	Max	Avg	S	p-Value	Trend
BMW-01									
Benzene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Toluene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Ethylbenzene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Xylenes (total)	7	7	100	0.25	0.5	0.3	4	0.326	No Trend
Total BTEX	7	7	100	0.25	0.5	0.3	4	0.326	No Trend
Tetrachloroethene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Trichloroethene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Dichloroethenes (total)	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Vinyl chloride	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
BMW-03									
Benzene	7	0	0	0.28	1.4	1.0	8	0.147	No Trend
Toluene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Ethylbenzene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Xylenes (total)	7	7	100	0.25	0.5	0.3	4	0.326	No Trend
Total BTEX	7	0	0	0.28	1.4	1.0	8	0.147	No Trend
Tetrachloroethene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Trichloroethene	7	0	0	0.59	3.1	2.2	10	0.088	Probably Increasing
Dichloroethenes (total)	7	0	0	15.62	79.9	56.2	11	0.067	Probably Increasing
Vinyl chloride	7	0	0	2.4	19	11.5	7	0.184	No Trend
BMW-06									
Benzene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Toluene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Ethylbenzene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Xylenes (total)	7	7	100	0.25	0.5	0.3	4	0.326	No Trend
Total BTEX	7	7	100	0.25	0.5	0.3	4	0.326	No Trend
Tetrachloroethene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Trichloroethene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Dichloroethenes (total)	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Vinyl chloride	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
BMW-07									
Benzene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Toluene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Ethylbenzene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Xylenes (total)	7	7	100	0.25	0.5	0.3	4	0.326	No Trend
Total BTEX	7	7	100	0.25	0.5	0.3	4	0.326	No Trend
Tetrachloroethene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Trichloroethene	7	6	85.7	0.096	0.25	0.2	-6	0.226	No Trend
Dichloroethenes (total)	7	2	28.6	0.2	0.33	0.3	11	0.067	Probably Increasing
Vinyl chloride	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
BMW-08									
Benzene	7	6	85.7	0.25	0.5	0.3	1	0.5	No Trend
Toluene	7	7	100	0.25	0.5	0.3	4	0.326	No Trend
Ethylbenzene	7	7	100	0.25	0.5	0.3	4	0.326	No Trend
Xylenes (total)	7	7	100	0.25	1	0.4	4	0.326	No Trend
Total BTEX	7	6	85.7	0.25	1	0.4	1	0.5	No Trend
Tetrachloroethene	7	7	100	0.25	0.5	0.3	4	0.326	No Trend
Trichloroethene	7	7	100	0.25	0.5	0.3	4	0.326	No Trend
Dichloroethenes (total)	7	7	100	0.25	0.5	0.3	4	0.326	No Trend
Vinyl chloride	7	7	100	0.25	0.5	0.3	4	0.326	No Trend

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Trichloroethene	7	7	100	0.25	0.5	0.3	4	0.326	No Trend
Dichloroethenes (total)	7	6	85.7	0.25	0.5	0.3	4	0.326	No Trend
Vinyl chloride	7	7	100	0.25	0.5	0.3	4	0.326	No Trend
MW-12									
Benzene	7	1	14.3	0.2	4000	734.3	3	0.382	No Trend
Toluene	7	0	0	33	31000	14890.4	7	0.184	No Trend
Ethylbenzene	7	1	14.3	0.4	4000	720.6	-1	0.5	No Trend
Xylenes (total)	7	0	0	3	4000	1391.9	3	0.382	No Trend
Total BTEX	7	0	0	36.6	33030	17665.8	9	0.115	No Trend
Tetrachloroethene	7	3	42.9	0.25	12.5	4.7	5	0.274	No Trend
Trichloroethene	7	1	14.3	0.25	32	22.0	1	0.5	No Trend
Dichloroethenes (total)	7	0	0	37.2	91050	42559.6	5	0.274	No Trend
Vinyl chloride	7	0	0	7	8400	4643.9	-1	0.5	No Trend
RMW-01-17									
Benzene	7	2	28.6	1	5	2.1	-6	0.226	No Trend
Toluene	7	6	85.7	0.25	110	16.6	-3	0.382	No Trend
Ethylbenzene	7	1	14.3	0.28	38	6.5	-9	0.115	No Trend
Xylenes (total)	7	1	14.3	0.7	35	7.9	-11	0.067	Probably Decreasing
Total BTEX	7	0	0	2.18	110	30.4	-7	0.184	No Trend
Tetrachloroethene	7	7	100	0.25	5	1.3	-5	0.274	No Trend
Trichloroethene	7	2	28.6	0.2	5	1.3	-11	0.067	Probably Decreasing
Dichloroethenes (total)	7	1	14.3	0.5	530	76.9	-5	0.274	No Trend
Vinyl chloride	7	6	85.7	0.25	33	5.6	-3	0.382	No Trend
RMW-01-35									
Benzene	7	0	0	4.6	14	9.0	3	0.382	No Trend
Toluene	7	0	0	3.6	68	30.4	-5	0.274	No Trend
Ethylbenzene	7	1	14.3	2.5	23	10.6	5	0.274	No Trend
Xylenes (total)	7	0	0	4.4	47	20.7	-5	0.274	No Trend
Total BTEX	7	0	0	27.6	151	70.4	-9	0.115	No Trend
Tetrachloroethene	7	1	14.3	0.63	4	2.2	-6	0.226	No Trend
Trichloroethene	7	1	14.3	2.5	14	6.8	2	0.44	No Trend
Dichloroethenes (total)	7	0	0	53.4	935	335.5	3	0.382	No Trend
Vinyl chloride	7	1	14.3	2.1	170	48.9	3	0.382	No Trend
RMW-02-13									
Benzene	7	0	0	0.3	630	315.8	6	0.226	No Trend
Toluene	7	0	0	24	19000	11032.0	8	0.147	No Trend
Ethylbenzene	7	0	0	2	1200	613.1	3	0.382	No Trend
Xylenes (total)	7	0	0	14	5600	3087.7	3	0.382	No Trend
Total BTEX	7	0	0	40.3	26430	15048.6	5	0.274	No Trend
Tetrachloroethene	7	4	57.1	0.25	200	30.3	-3	0.382	No Trend
Trichloroethene	7	3	42.9	0.25	50	13.6	-2	0.44	No Trend
Dichloroethenes (total)	7	0	0	4	11076.4	6111.7	11	0.067	Probably Increasing
Vinyl chloride	7	1	14.3	2	4100	1486.0	11	0.067	Probably Increasing

TABLE G-1

Mann Kendall Trend Analysis Results

Remedial Investigation Report

AMCO Chemical Superfund Site, Oakland, California

Analyte	Number of Samples			Sample Statistics			Trend Analysis		
	Total	NDs	% NDs	Min	Max	Avg	S	p-Value	Trend
RMW-02-32									
Benzene	7	1	14.3	97	200	129.4	-6	0.226	No Trend
Toluene	7	0	0	3000	6100	4257.1	9	0.115	No Trend
Ethylbenzene	7	0	0	100	230	165.7	12	0.049	Increasing
Xylenes (total)	7	0	0	650	1810	1032.9	7	0.184	No Trend
Total BTEX	7	0	0	3900	8300	5556.6	9	0.115	No Trend
Tetrachloroethene	7	7	100	0.25	200	30.6	6	0.226	No Trend
Trichloroethene	7	5	71.4	1	200	31.2	4	0.326	No Trend
Dichloroethenes (total)	7	0	0	0.2	403	173.7	3	0.382	No Trend
Vinyl chloride	7	0	0	3500	15000	7771.4	3	0.382	No Trend
RMW-02-50									
Benzene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Toluene	7	6	85.7	0.25	7	1.2	6	0.226	No Trend
Ethylbenzene	7	6	85.7	0.25	0.59	0.3	6	0.226	No Trend
Xylenes (total)	7	6	85.7	0.25	2.83	0.7	11	0.067	No Trend
Total BTEX	7	6	85.7	0.25	10.42	1.7	11	0.067	No Trend
Tetrachloroethene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Trichloroethene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Dichloroethenes (total)	7	6	85.7	0.25	3	0.6	6	0.226	No Trend
Vinyl chloride	7	6	85.7	0.25	1.6	0.4	6	0.226	No Trend
RMW-03-15									
Benzene	7	5	71.4	0.16	0.25	0.2	3	0.382	No Trend
Toluene	7	5	71.4	0.25	1.8	0.5	7	0.184	No Trend
Ethylbenzene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Xylenes (total)	7	6	85.7	0.25	0.51	0.3	7	0.184	No Trend
Total BTEX	7	4	57.1	0.2	1.8	0.6	12	0.049	No Trend
Tetrachloroethene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Trichloroethene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Dichloroethenes (total)	7	7	100	0.25	0.31	0.3	6	0.226	No Trend
Vinyl chloride	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
RMW-04-15									
Benzene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Toluene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Ethylbenzene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Xylenes (total)	7	7	100	0.25	0.5	0.3	4	0.326	No Trend
Total BTEX	7	7	100	0.25	0.5	0.3	4	0.326	No Trend
Tetrachloroethene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Trichloroethene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Dichloroethenes (total)	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Vinyl chloride	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
RMW-05-15									
Benzene	7	2	28.6	0.25	1.1	0.6	14	0.025	Increasing
Toluene	7	6	85.7	0.074	0.25	0.2	-6	0.226	No Trend
Ethylbenzene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Xylenes (total)	7	7	100	0.25	0.5	0.3	4	0.326	No Trend
Total BTEX	7	2	28.6	0.25	1.174	0.6	14	0.025	Increasing
Tetrachloroethene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Trichloroethene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Dichloroethenes (total)	7	1	14.3	0.25	6.5	3.3	13	0.036	Increasing
Vinyl chloride	7	2	28.6	0.25	5.5	2.4	16	0.012	Increasing

TABLE G-1

Mann Kendall Trend Analysis Results

Remedial Investigation Report

AMCO Chemical Superfund Site, Oakland, California

Analyte	Number of Samples			Sample Statistics			Trend Analysis		
	Total	NDs	% NDs	Min	Max	Avg	S	p-Value	Trend
RMW-06-15									
Benzene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Toluene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Ethylbenzene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Xylenes (total)	7	7	100	0.25	0.5	0.3	4	0.326	No Trend
Total BTEX	7	7	100	0.25	0.5	0.3	4	0.326	No Trend
Tetrachloroethene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Trichloroethene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Dichloroethenes (total)	7	0	0	1.2	4	2.3	-7	0.184	No Trend
Vinyl chloride	7	4	57.1	0.2	0.6	0.3	-5	0.274	No Trend
RMW-07-15									
Benzene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Toluene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Ethylbenzene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Xylenes (total)	7	7	100	0.25	0.5	0.3	4	0.326	No Trend
Total BTEX	7	7	100	0.25	0.5	0.3	4	0.326	No Trend
Tetrachloroethene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Trichloroethene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Dichloroethenes (total)	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Vinyl chloride	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
RMW-07-35									
Benzene	5	4	80	0.25	0.39	0.3	-4	0.231	No Trend
Toluene	5	5	100	0.25	0.25	0.3	0	0.5	No Trend
Ethylbenzene	5	5	100	0.25	0.25	0.3	0	0.5	No Trend
Xylenes (total)	5	5	100	0.25	0.5	0.3	2	0.403	No Trend
Total BTEX	5	4	80	0.25	0.5	0.3	-1	0.5	No Trend
Tetrachloroethene	5	0	0	5	24	13.6	2	0.403	No Trend
Trichloroethene	5	0	0	6.1	25	15.0	4	0.231	No Trend
Dichloroethenes (total)	5	0	0	25.9	101	57.5	4	0.231	No Trend
Vinyl chloride	5	0	0	0.63	7.8	3.6	0	0.5	No Trend
RMW-08-15									
Benzene	7	1	14.3	1	5	2.5	9	0.115	No Trend
Toluene	7	4	57.1	0.25	7	1.5	8	0.147	No Trend
Ethylbenzene	7	7	100	0.25	5	1.1	9	0.115	No Trend
Xylenes (total)	7	7	100	0.25	5	1.1	13	0.036	No Trend
Total BTEX	7	1	14.3	1	7	3.1	9	0.115	No Trend
Tetrachloroethene	7	7	100	0.25	5	1.1	9	0.115	No Trend
Trichloroethene	7	3	42.9	0.25	5	1.3	6	0.226	No Trend
Dichloroethenes (total)	7	0	0	1.9	17.25	10.7	-1	0.5	No Trend
Vinyl chloride	7	0	0	5.2	16	11.2	9	0.115	No Trend
RMW-08-35									
Benzene	7	1	14.3	0.25	2	1.0	-6	0.226	No Trend
Toluene	7	5	71.4	0.2	0.45	0.3	-1	0.5	No Trend
Ethylbenzene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Xylenes (total)	7	7	100	0.25	5	1.0	5	0.274	No Trend
Total BTEX	7	1	14.3	0.25	2.45	1.1	-5	0.274	No Trend
Tetrachloroethene	7	0	0	4	83	20.5	-11	0.067	Probably Decreasing
Trichloroethene	7	0	0	11	49	24.1	-10	0.088	Probably Decreasing
Dichloroethenes (total)	7	0	0	45	141	76.0	-7	0.184	No Trend
Vinyl chloride	7	0	0	5.6	48	17.1	-11	0.067	Probably Decreasing

TABLE G-1

Mann Kendall Trend Analysis Results

Remedial Investigation Report

AMCO Chemical Superfund Site, Oakland, California

Analyte	Number of Samples			Sample Statistics			Trend Analysis		
	Total	NDs	% NDs	Min	Max	Avg	S	p-Value	Trend
RMW-09-15									
Benzene	7	3	42.9	0.2	0.37	0.3	2	0.44	No Trend
Toluene	7	6	85.7	0.17	0.25	0.2	-6	0.226	No Trend
Ethylbenzene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Xylenes (total)	7	6	85.7	0.25	0.5	0.3	9	0.115	No Trend
Total BTEX	7	2	28.6	0.2	0.55	0.3	5	0.274	No Trend
Tetrachloroethene	7	6	85.7	0.23	0.25	0.2	-6	0.226	No Trend
Trichloroethene	7	2	28.6	0.2	6.2	1.6	8	0.147	No Trend
Dichloroethenes (total)	7	2	28.6	0.25	8.4	2.3	8	0.147	No Trend
Vinyl chloride	7	3	42.9	0.2	2.8	0.8	7	0.184	No Trend
RMW-09-35									
Benzene	7	0	0	0.96	2.9	1.8	2	0.44	No Trend
Toluene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Ethylbenzene	7	7	100	0.25	0.25	0.3	0	0.5	No Trend
Xylenes (total)	7	7	100	0.25	0.5	0.3	4	0.326	No Trend
Total BTEX	7	0	0	0.96	2.9	1.8	2	0.44	No Trend
Tetrachloroethene	7	1	14.3	0.25	0.7	0.4	2	0.44	No Trend
Trichloroethene	7	0	0	5	10	7.4	-1	0.5	No Trend
Dichloroethenes (total)	7	0	0	2.5	188.1	95.6	-3	0.382	No Trend
Vinyl chloride	7	0	0	19	70	47.4	-3	0.382	No Trend
RMW-10-15									
Benzene	7	2	28.6	0.25	1	0.6	5	0.274	No Trend
Toluene	7	7	100	0.25	1	0.4	6	0.226	No Trend
Ethylbenzene	7	7	100	0.25	1	0.4	6	0.226	No Trend
Xylenes (total)	7	5	71.4	0.25	1	0.4	9	0.115	No Trend
Total BTEX	7	2	28.6	0.25	1.2	0.7	-1	0.5	No Trend
Tetrachloroethene	7	4	57.1	0.15	1	0.3	12	0.049	No Trend
Trichloroethene	7	0	0	17	34	24.7	-10	0.088	Probably Decreasing
Dichloroethenes (total)	7	0	0	319.9	431	386.3	-7	0.184	No Trend
Vinyl chloride	7	3	42.9	0.25	2	0.8	0	0.5	No Trend
RMW-10-35									
Benzene	7	2	28.6	0.93	5.4	2.3	5	0.274	No Trend
Toluene	7	2	28.6	0.61	2.5	1.4	8	0.147	No Trend
Ethylbenzene	7	2	28.6	0.75	3.3	1.7	13	0.036	Increasing
Xylenes (total)	7	2	28.6	0.21	5	1.8	9	0.115	No Trend
Total BTEX	7	2	28.6	1.5	9.44	5.4	13	0.036	Increasing
Tetrachloroethene	7	7	100	0.25	2.5	0.8	3	0.382	No Trend
Trichloroethene	7	0	0	54	160	116.6	11	0.067	Probably Increasing
Dichloroethenes (total)	7	0	0	89	425.3	242.3	15	0.018	Increasing
Vinyl chloride	7	0	0	7	25	14.7	9	0.115	No Trend
RMW-11-35									
Benzene	5	4	80	0.11	0.25	0.2	4	0.231	No Trend
Toluene	5	5	100	0.25	0.25	0.3	0	0.5	No Trend
Ethylbenzene	5	5	100	0.25	0.25	0.3	0	0.5	No Trend
Xylenes (total)	5	4	80	0.25	0.5	0.3	-1	0.5	No Trend
Total BTEX	5	4	80	0.25	0.5	0.3	-1	0.5	No Trend
Tetrachloroethene	5	5	100	0.25	0.25	0.3	0	0.5	No Trend
Trichloroethene	5	5	100	0.25	0.25	0.3	0	0.5	No Trend
Dichloroethenes (total)	5	5	100	0.25	0.25	0.3	0	0.5	No Trend
Vinyl chloride	5	5	100	0.25	0.25	0.3	0	0.5	No Trend

TABLE G-1

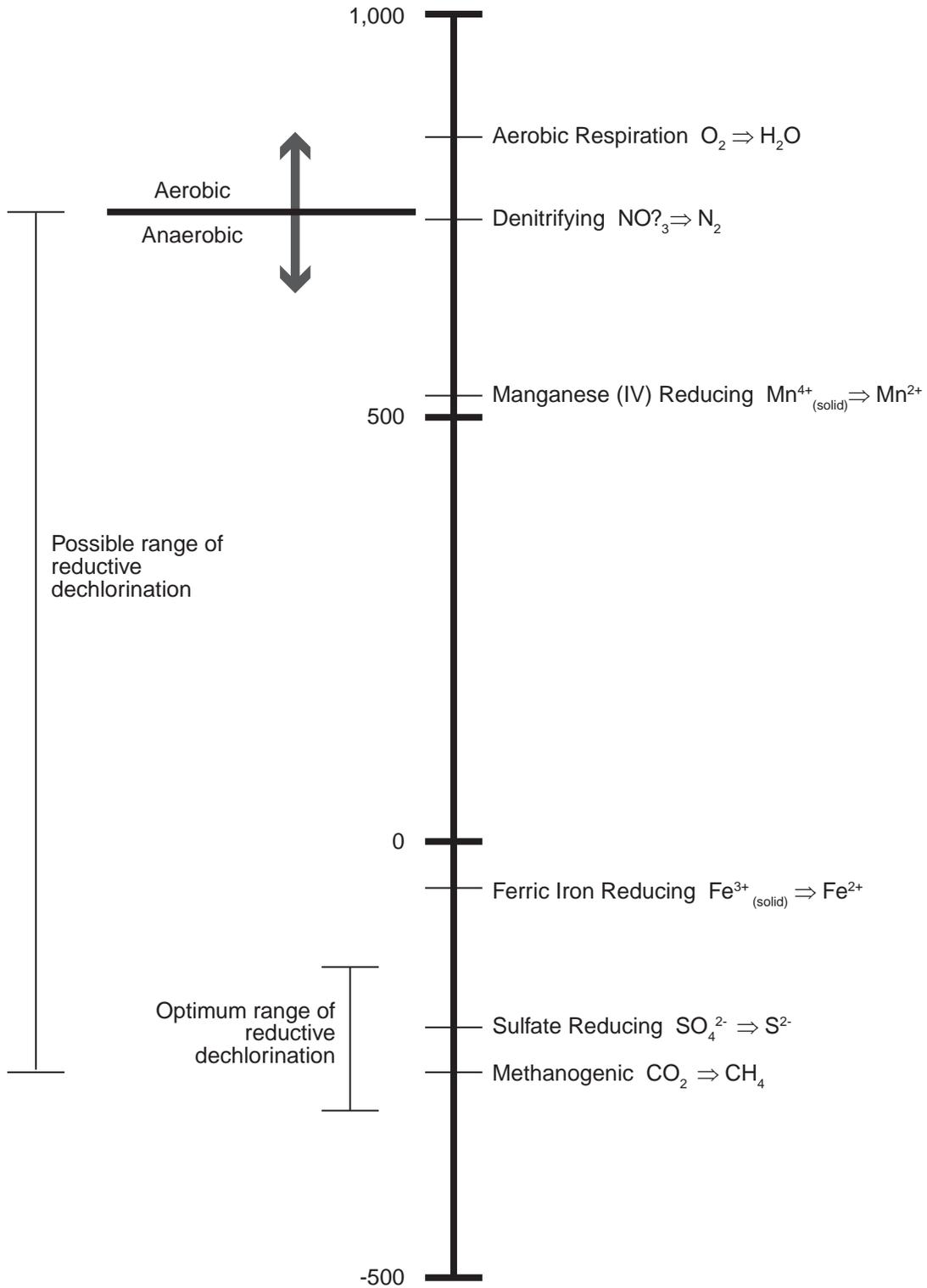
Mann Kendall Trend Analysis Results
 Remedial Investigation Report
 AMCO Chemical Superfund Site, Oakland, California

Analyte	Number of Samples			Sample Statistics			Trend Analysis		
	Total	NDs	% NDs	Min	Max	Avg	S	p-Value	Trend
RMW-12-32									
Benzene	5	0	0	43	110	84.4	6	0.11	No Trend
Toluene	5	0	0	110	200	162.0	-3	0.312	No Trend
Ethylbenzene	5	0	0	6.6	16	11.4	2	0.403	No Trend
Xylenes (total)	5	0	0	40	66	46.8	0	0.5	No Trend
Total BTEX	5	0	0	249.6	378	304.2	2	0.403	No Trend
Tetrachloroethene	5	4	80	0.1	2.5	0.7	-1	0.5	No Trend
Trichloroethene	5	0	0	34	56	42.4	-8	0.043	Decreasing
Dichloroethenes (total)	5	0	0	489	723	595.0	0	0.5	No Trend
Vinyl chloride	5	0	0	140	340	222.0	2	0.403	No Trend
RMW-12-51									
Benzene	5	3	60	0.069	1.6	0.5	-7	0.071	Probably Decreasing
Toluene	5	4	80	0.25	3.2	0.8	-4	0.231	No Trend
Ethylbenzene	5	4	80	0.25	4.6	1.1	-4	0.231	No Trend
Xylenes (total)	5	4	80	0.25	25	5.3	-4	0.231	No Trend
Total BTEX	5	3	60	0.069	34.4	7.1	-5	0.164	No Trend
Tetrachloroethene	5	1	20	0.2	1.5	0.5	-6	0.11	No Trend
Trichloroethene	5	0	0	1.3	15	4.7	-6	0.11	No Trend
Dichloroethenes (total)	5	3	60	0.25	18.93	4.2	-5	0.164	No Trend
Vinyl chloride	5	3	60	0.14	5.2	1.2	-7	0.071	Probably Decreasing
RMW-13-35									
Benzene	5	5	100	0.25	0.25	0.3	0	0.5	No Trend
Toluene	5	5	100	0.25	0.25	0.3	0	0.5	No Trend
Ethylbenzene	5	5	100	0.25	0.25	0.3	0	0.5	No Trend
Xylenes (total)	5	5	100	0.25	0.5	0.3	2	0.403	No Trend
Total BTEX	5	5	100	0.25	0.5	0.3	2	0.403	No Trend
Tetrachloroethene	5	5	100	0.25	0.25	0.3	0	0.5	No Trend
Trichloroethene	5	5	100	0.25	0.25	0.3	0	0.5	No Trend
Dichloroethenes (total)	5	5	100	0.25	0.25	0.3	0	0.5	No Trend
Vinyl chloride	5	5	100	0.25	0.25	0.3	0	0.5	No Trend
RMW-14-50									
Benzene	5	2	40	0.16	0.25	0.2	5	0.164	No Trend
Toluene	5	5	100	0.25	0.25	0.3	0	0.5	No Trend
Ethylbenzene	5	5	100	0.25	0.25	0.3	0	0.5	No Trend
Xylenes (total)	5	5	100	0.25	0.5	0.3	2	0.403	No Trend
Total BTEX	5	2	40	0.16	0.25	0.2	5	0.164	No Trend
Tetrachloroethene	5	5	100	0.25	0.25	0.3	0	0.5	No Trend
Trichloroethene	5	0	0	9.2	41	21.6	4	0.231	No Trend
Dichloroethenes (total)	5	0	0	3.3	11.8	8.3	4	0.231	No Trend
Vinyl chloride	5	0	0	0.23	0.57	0.4	8	0.043	Increasing

Notes

Minimum sample statistic is either the lowest detected result or half the lowest detection limit, whichever is less.
 Maximum sample statistic is either the highest detected result or half the highest detection limit, whichever is greater.

Redox Potential (ORP, Eh°)
in millivolts at pH = 7 and
temperature = 25°C

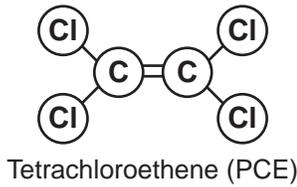


Notes:

1. Modified after Bouwer 1994, and Weidemeier et al 1999.
2. All half-reactions are simplified

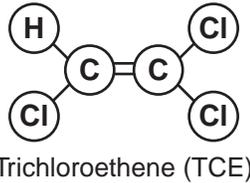
FIGURE G-1
ORP MEASUREMENTS
CORRESPONDING TO VARIOUS
ELECTRON-ACCEPTOR HALF-REACTIONS

REMEDIAL INVESTIGATION REPORT
AMCO CHEMICAL SUPERFUND SITE
OAKLAND, CALIFORNIA



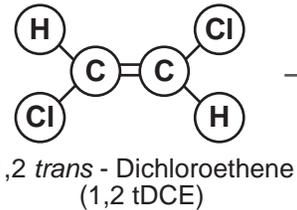
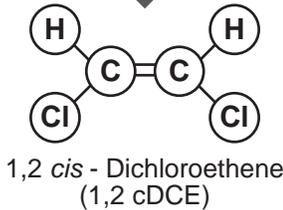
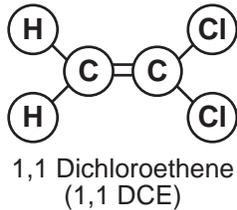
Reductive Dechlorination of PCE

- Rapid
- Occurs under all anaerobic conditions
- Most favorable under sulfate reducing or methanogenic conditions



Reductive Dechlorination of TCE

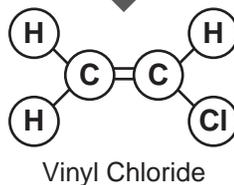
- Rapid
- Occurs under all anaerobic conditions
- Most favorable under sulfate reducing or methanogenic conditions



Biotic and abiotic aerobic oxidation (slow)

Reductive Dechlorination of DCE

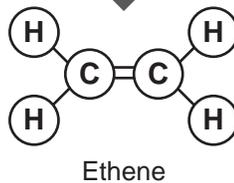
- Slower
- Only occurs under sulfate reducing or methanogenic conditions



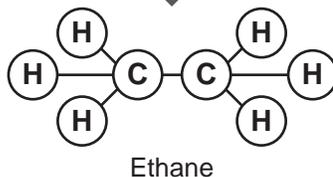
Biotic and abiotic aerobic oxidation (rapid)

Reductive Dechlorination of Vinyl Chloride

- Very slow
- Only occurs under sulfate reducing or methanogenic conditions



Aerobic oxidation



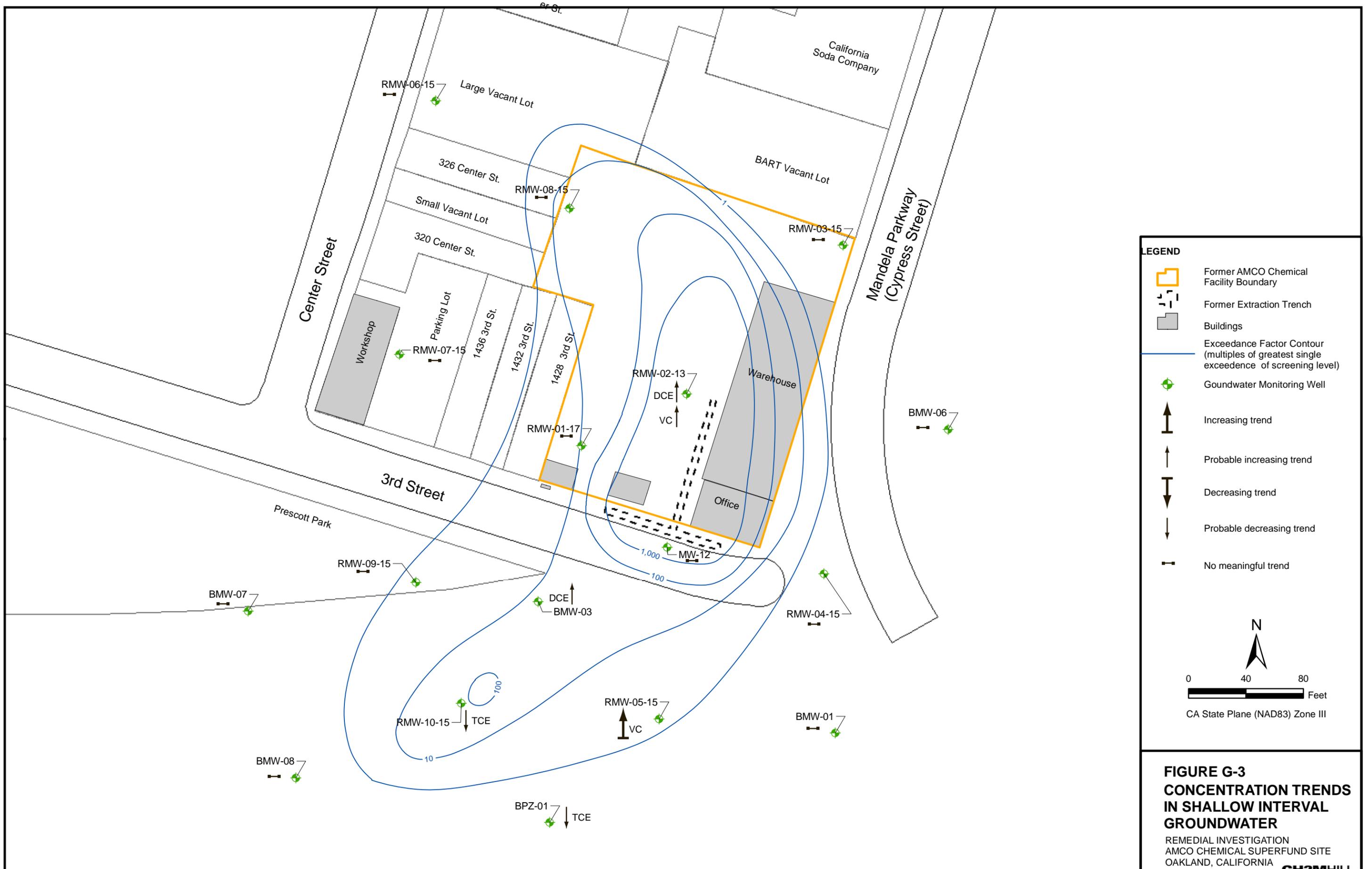
LEGEND

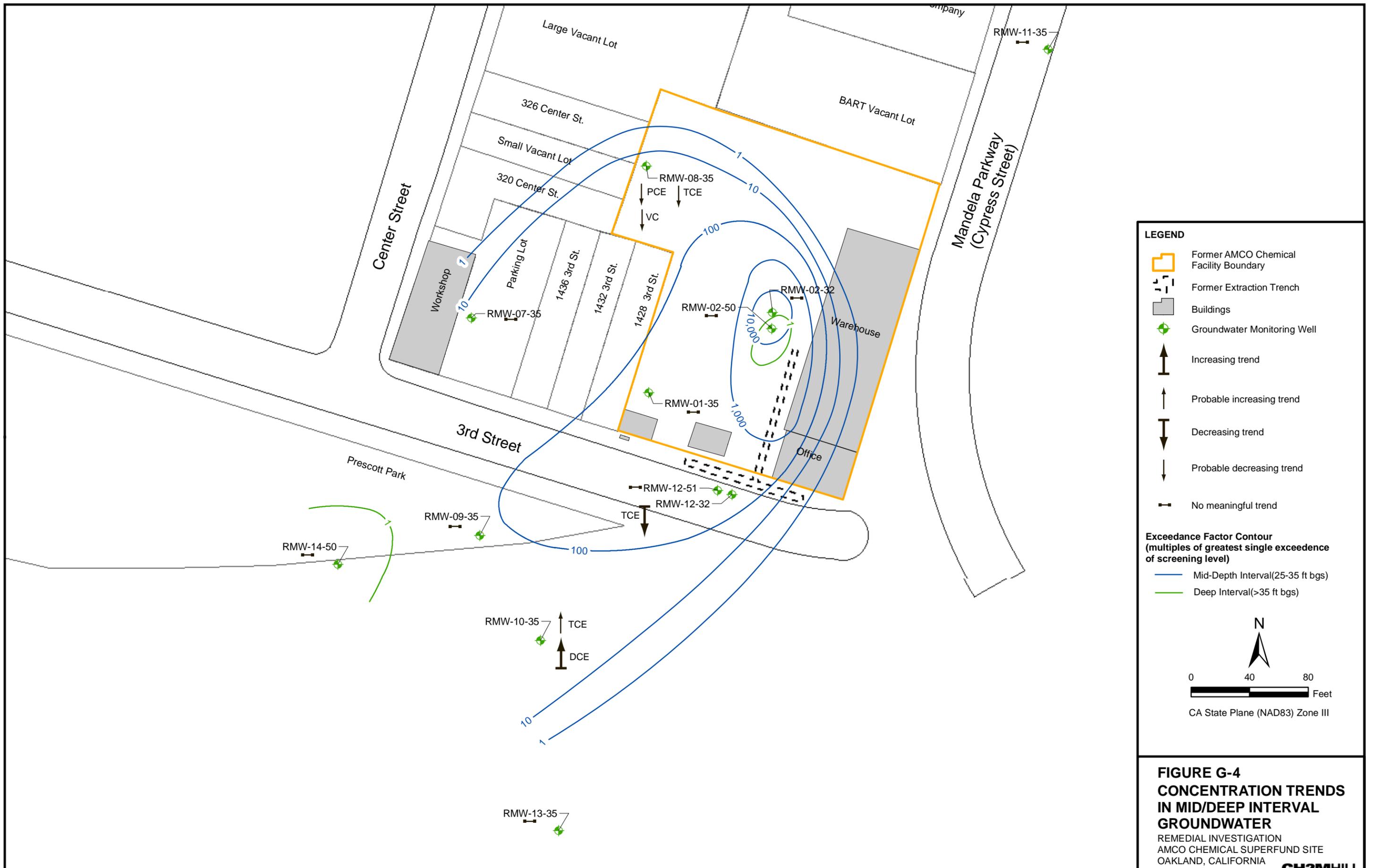
- C** Carbon atom
- Cl** Chlorine atom
- H** Hydrogen atom

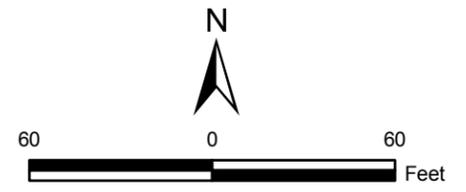
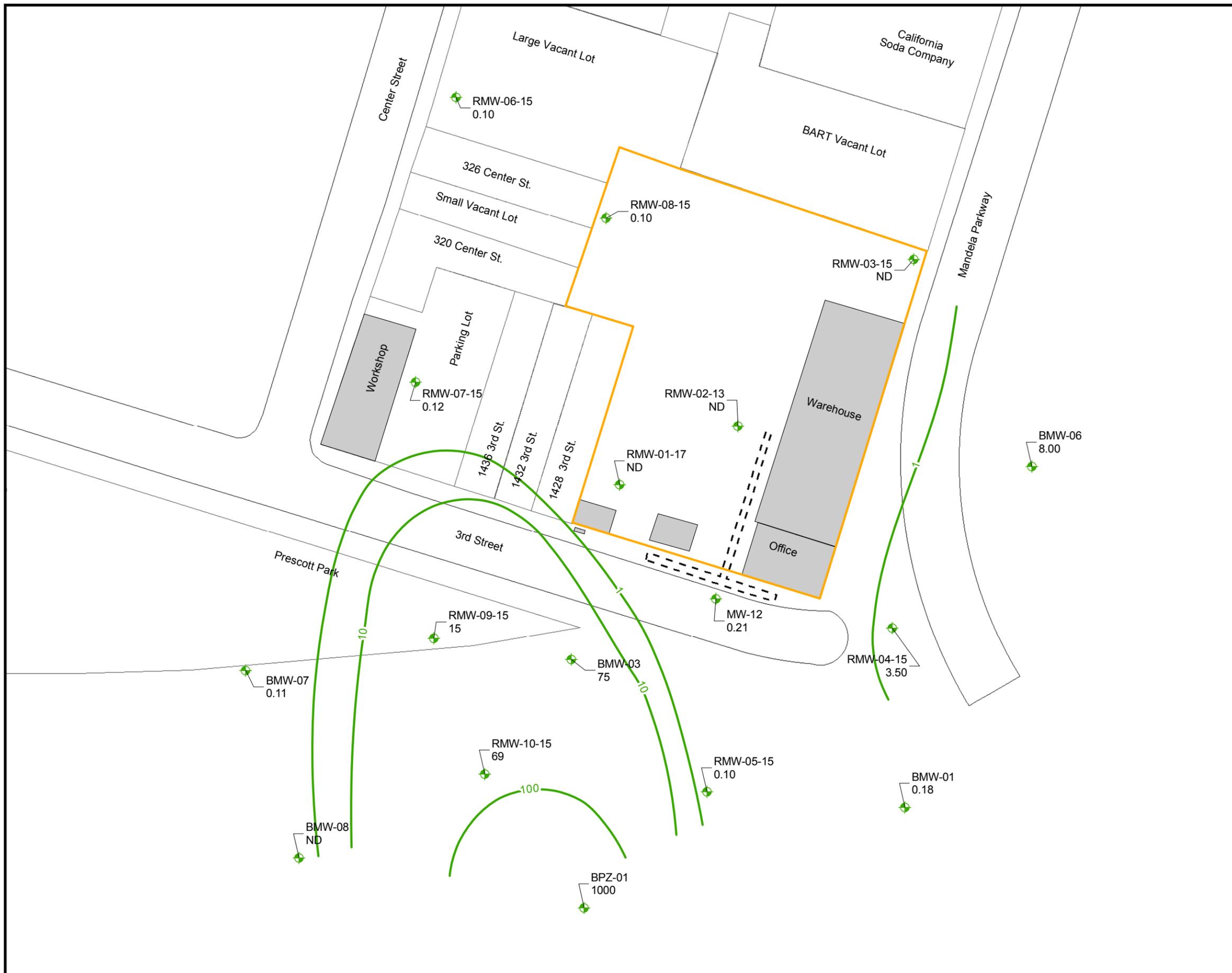
References:

1. Vogel et al. 1987
2. EPA 1998
3. Wiedemeier et al. 1999

**FIGURE G-2
NATURAL DEGRADATION OF
CHLORINATED ETHENES**
REMEDIAL INVESTIGATION REPORT
AMCO CHEMICAL SUPERFUND SITE
OAKLAND, CALIFORNIA



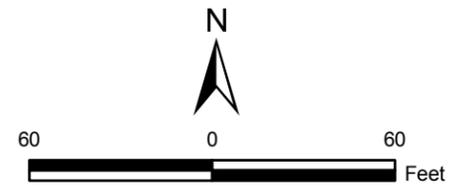
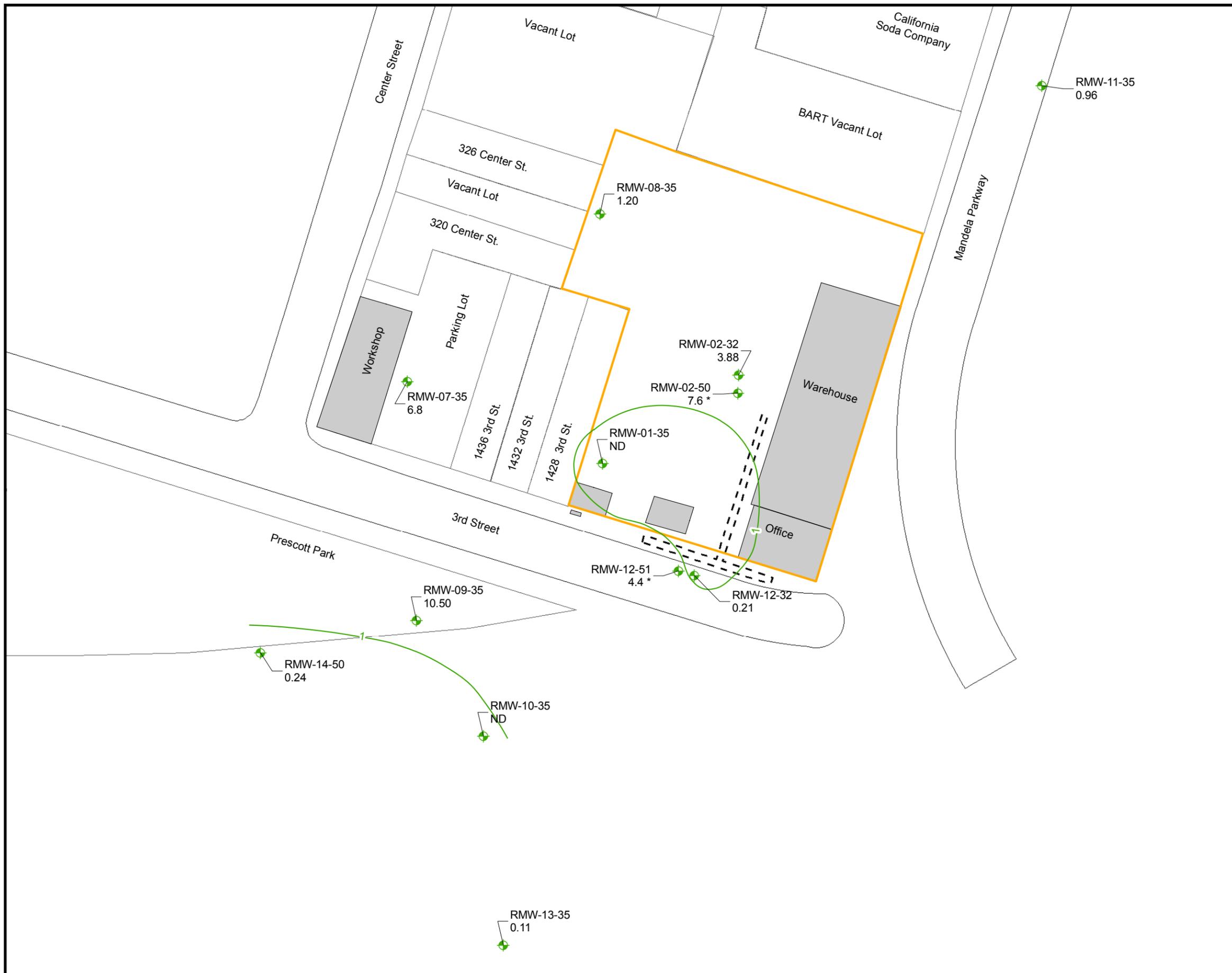




- LEGEND**
- Groundwater Monitoring Well
 - Former AMCO Chemical Facility Boundary
 - Buildings
 - Former Extraction Trench
 - Dissolved Nitrate as N Isoconcentration Contour in mg/L (dashed where inferred)

Notes:
 1) Median used as average.
 2) Nitrate mass shown as nitrogen.

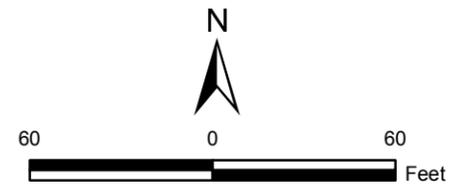
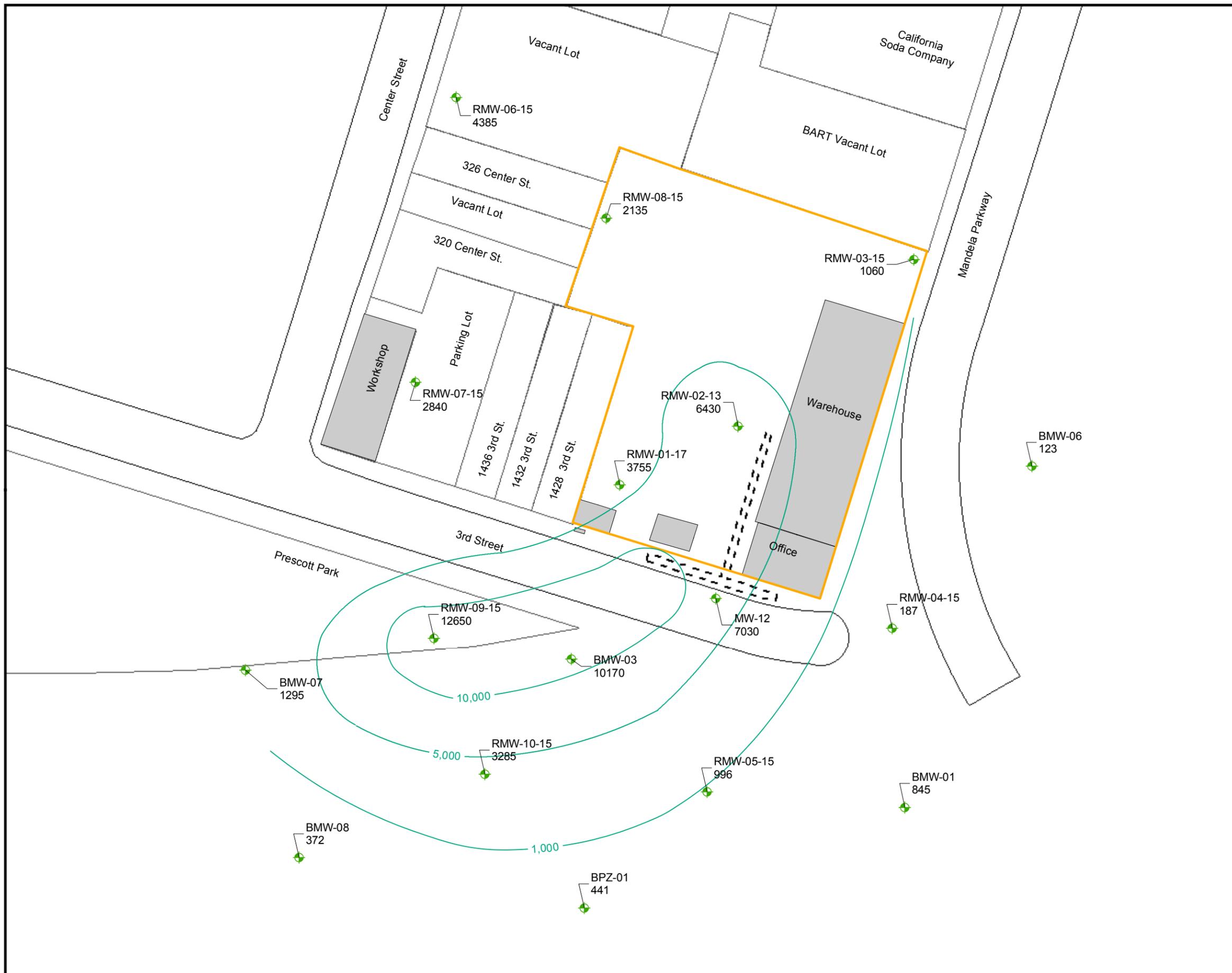
FIGURE G-5
NITRATE IN
SHALLOW GROUNDWATER
AVERAGE VALUE
1ST QUARTER 2005 TO
3RD QUARTER 2006
 REMEDIAL INVESTIGATION
 AMCO CHEMICAL SUPERFUND SITE
 OAKLAND, CALIFORNIA



- LEGEND**
- Former AMCO Chemical Facility Boundary
 - Former Extraction Trench
 - Buildings
 - Groundwater Monitoring Well
 - Dissolved Nitrate as N Isoconcentration Contour in mg/L

Notes:
 1) Median used as average.
 2) Nitrate mass shown as nitrogen.
 3) * Not used for contouring.

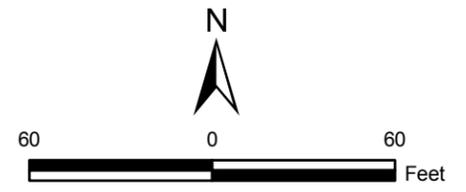
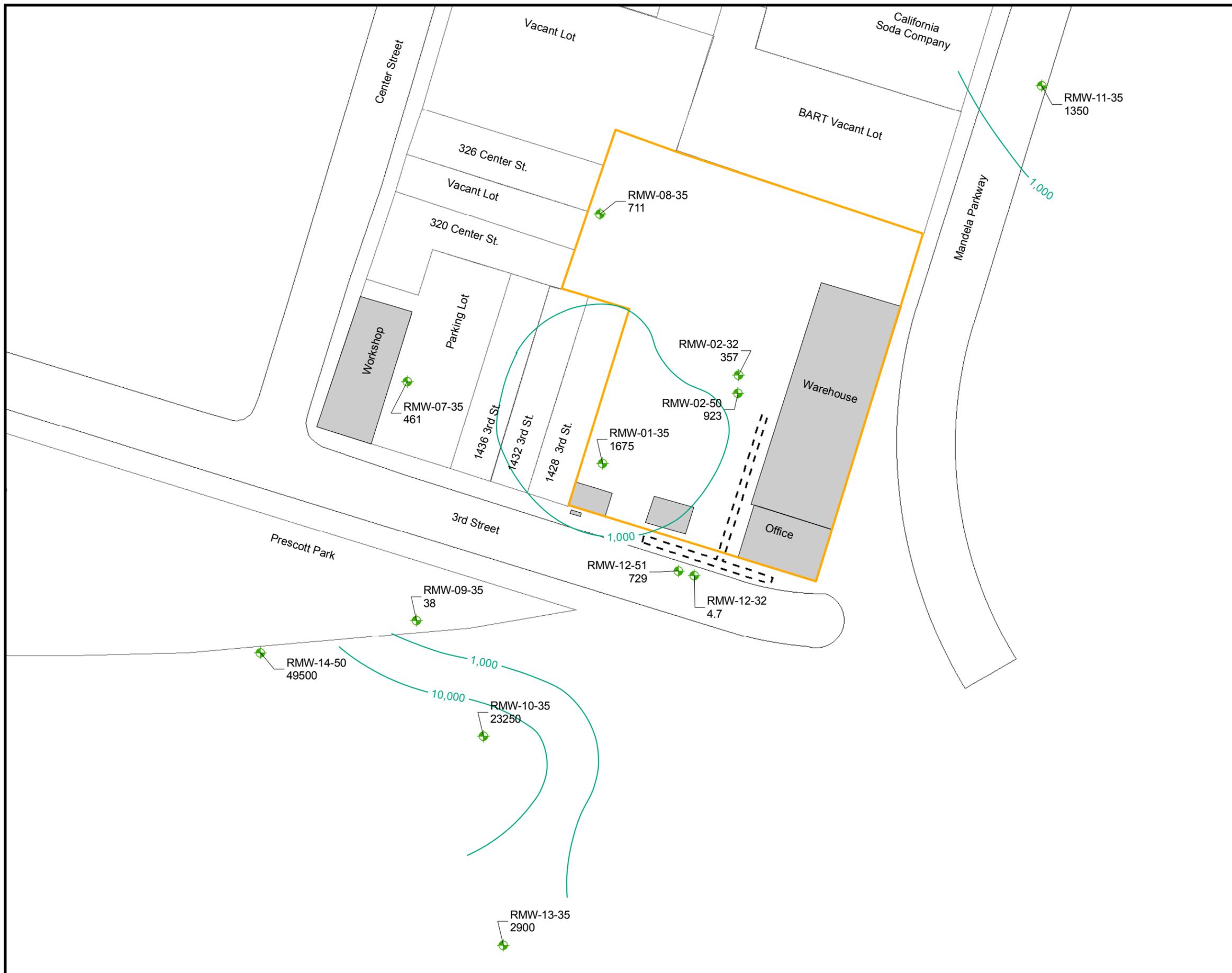
FIGURE G-6
NITRATE IN
MID/DEEP GROUNDWATER
AVERAGE VALUE
1ST QUARTER 2005 TO
3RD QUARTER 2006
 REMEDIAL INVESTIGATION
 AMCO CHEMICAL SUPERFUND SITE
 OAKLAND, CALIFORNIA



- LEGEND**
- Groundwater Monitoring Well
 - Former AMCO Chemical Facility Boundary
 - Buildings
 - Former Extraction Trench
 - Dissolved Manganese Isoconcentration Contour in mg/L

Notes:
1) Median used as average.

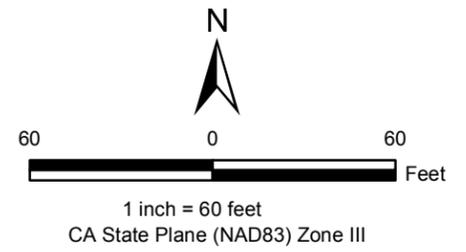
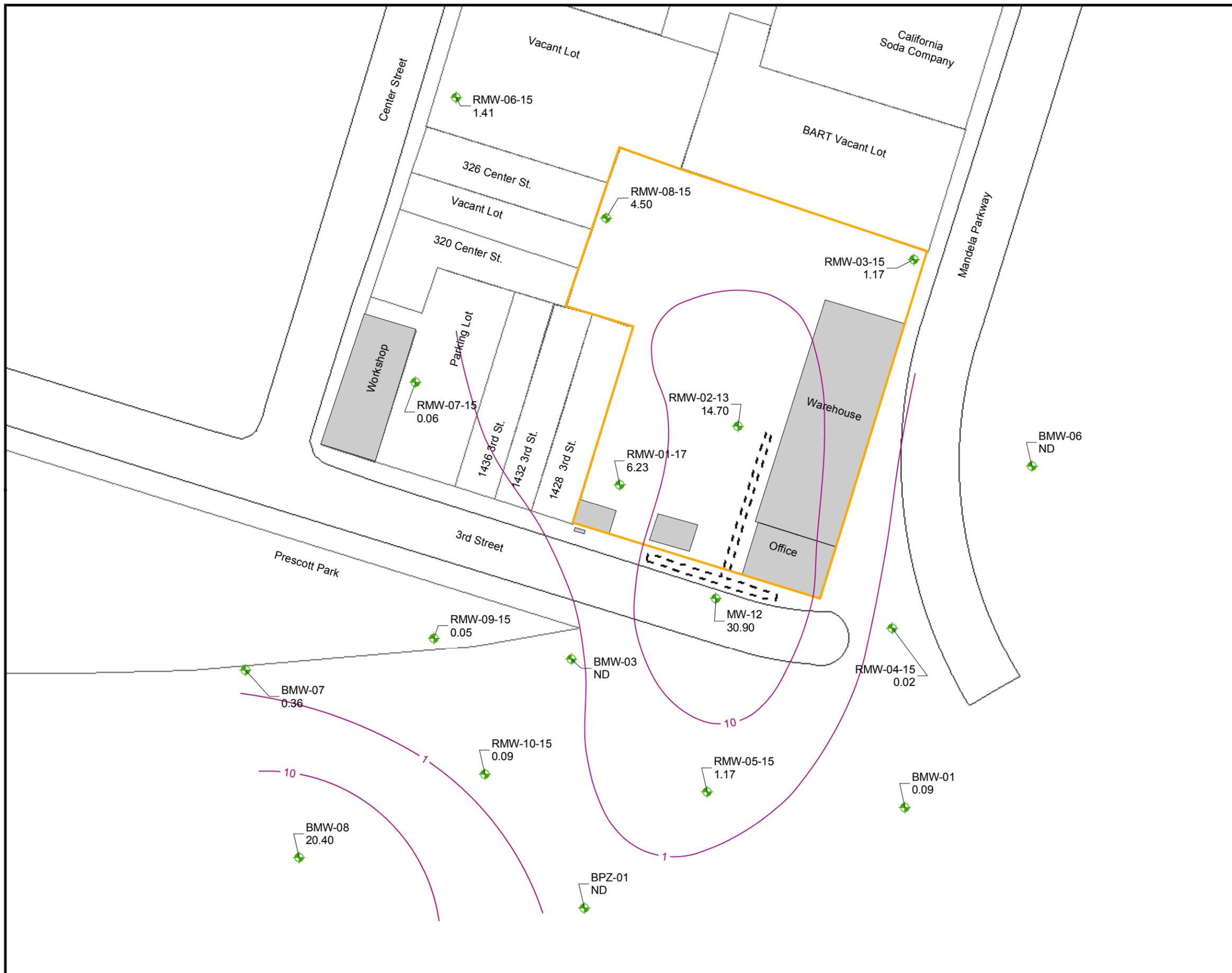
**FIGURE G-7
MANGANESE IN
SHALLOW GROUNDWATER
AVERAGE VALUE
1ST QUARTER 2005 TO
3RD QUARTER 2006**
REMEDIAL INVESTIGATION
AMCO CHEMICAL SUPERFUND SITE
OAKLAND, CALIFORNIA



- LEGEND**
- Former AMCO Chemical Facility Boundary
 - Former Extraction Trench
 - Buildings
 - Groundwater Monitoring Well
 - Dissolved Manganese Isoconcentration Contour in mg/L

Notes:
1) Median used as average.

FIGURE G-8
MANGANESE IN
MID/DEEP GROUNDWATER
AVERAGE VALUE
1ST QUARTER 2005 TO
3RD QUARTER 2006
 REMEDIAL INVESTIGATION
 AMCO CHEMICAL SUPERFUND SITE
 OAKLAND, CALIFORNIA



- LEGEND**
- Groundwater Monitoring Well
 - Former AMCO Chemical Facility Boundary
 - Buildings
 - Former Extraction Trench
 - Ferrous Iron Isoconcentration Contour in mg/L

Notes:
1) Median used as average.

FIGURE G-9
FERROUS IRON [FE(II)] IN
SHALLOW GROUNDWATER
AVERAGE VALUE
1ST QUARTER 2005 TO
3RD QUARTER 2006
 REMEDIAL INVESTIGATION
 AMCO CHEMICAL SUPERFUND SITE
 OAKLAND, CALIFORNIA

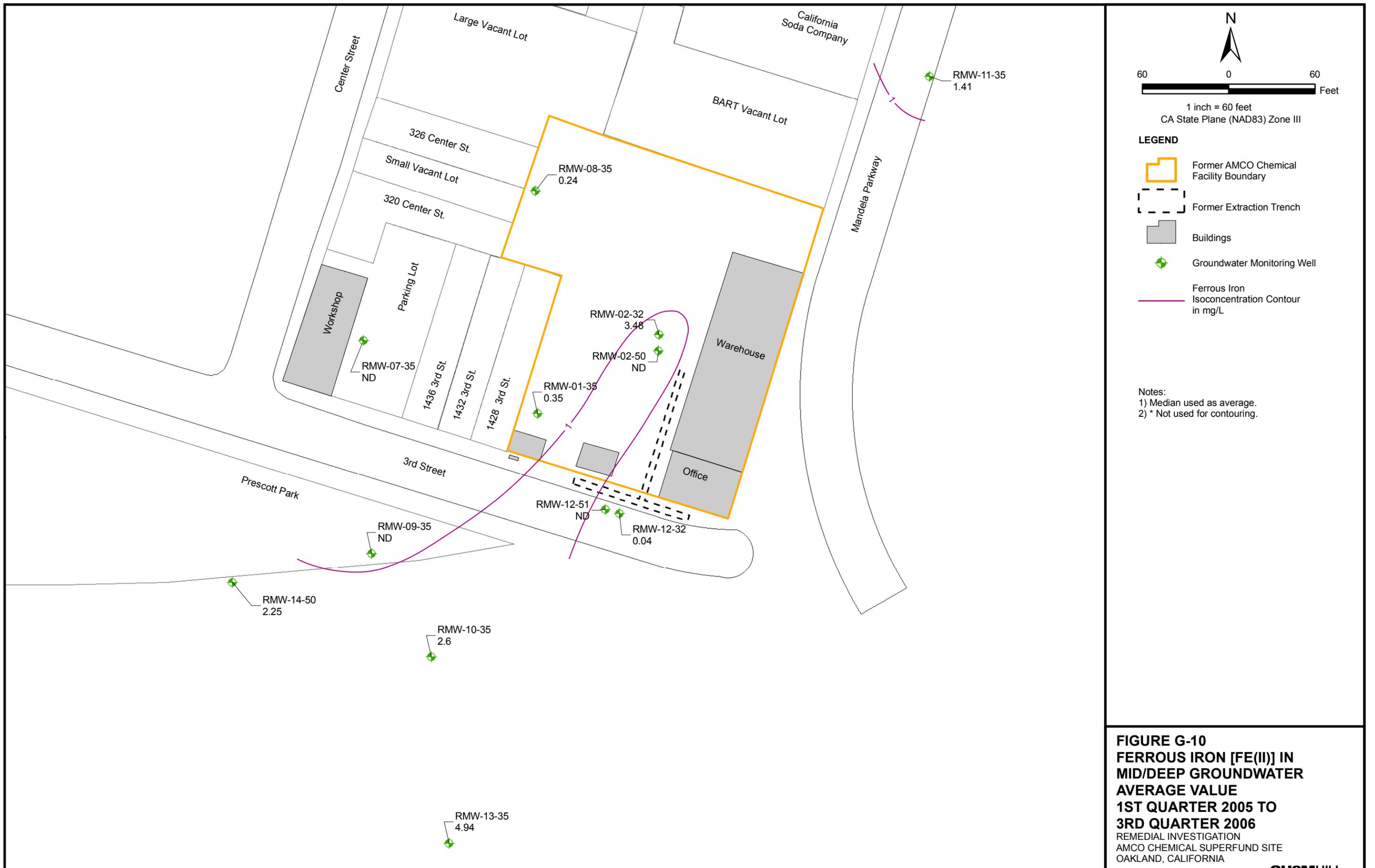
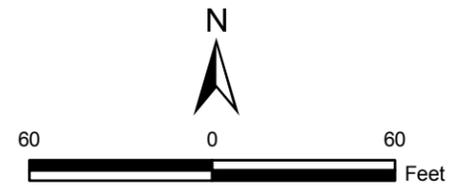
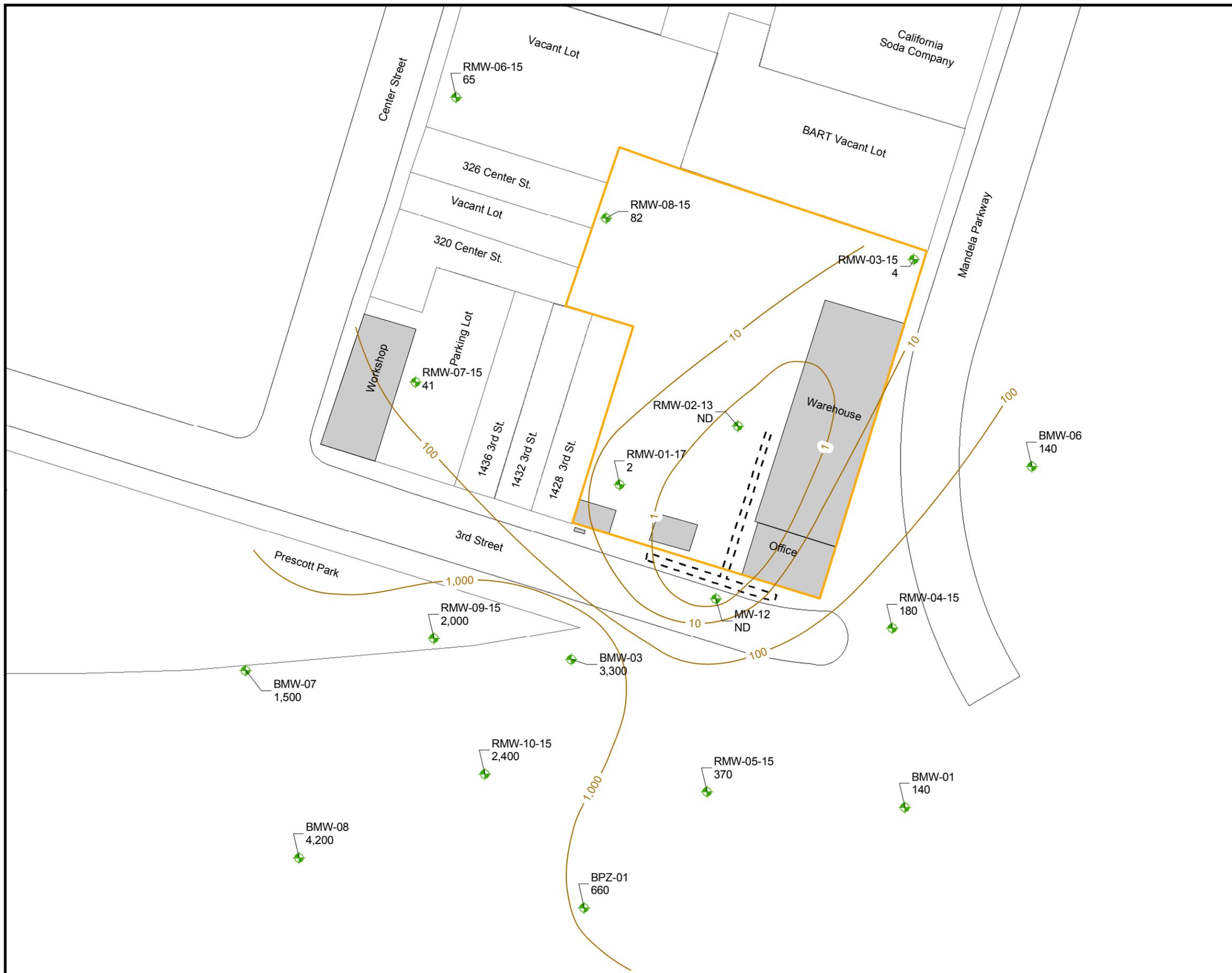


FIGURE G-10
FERROUS IRON [FE(II)] IN
MID/DEEP GROUNDWATER
AVERAGE VALUE
1ST QUARTER 2005 TO
3RD QUARTER 2006
 REMEDIAL INVESTIGATION
 AMCO CHEMICAL SUPERFUND SITE
 OAKLAND, CALIFORNIA



- LEGEND**
- Groundwater Monitoring Wells
 - Former AMCO Chemical Facility Boundary
 - Buildings
 - Former Extraction Trench
 - Sulfate Isoconcentration Contour in mg/L

Notes:
1) Median used as average.

FIGURE G-11
SULFATE IN
SHALLOW GROUNDWATER
AVERAGE VALUE
1ST QUARTER 2005 TO
3RD QUARTER 2006
 REMEDIAL INVESTIGATION
 AMCO CHEMICAL SUPERFUND SITE
 OAKLAND, CALIFORNIA

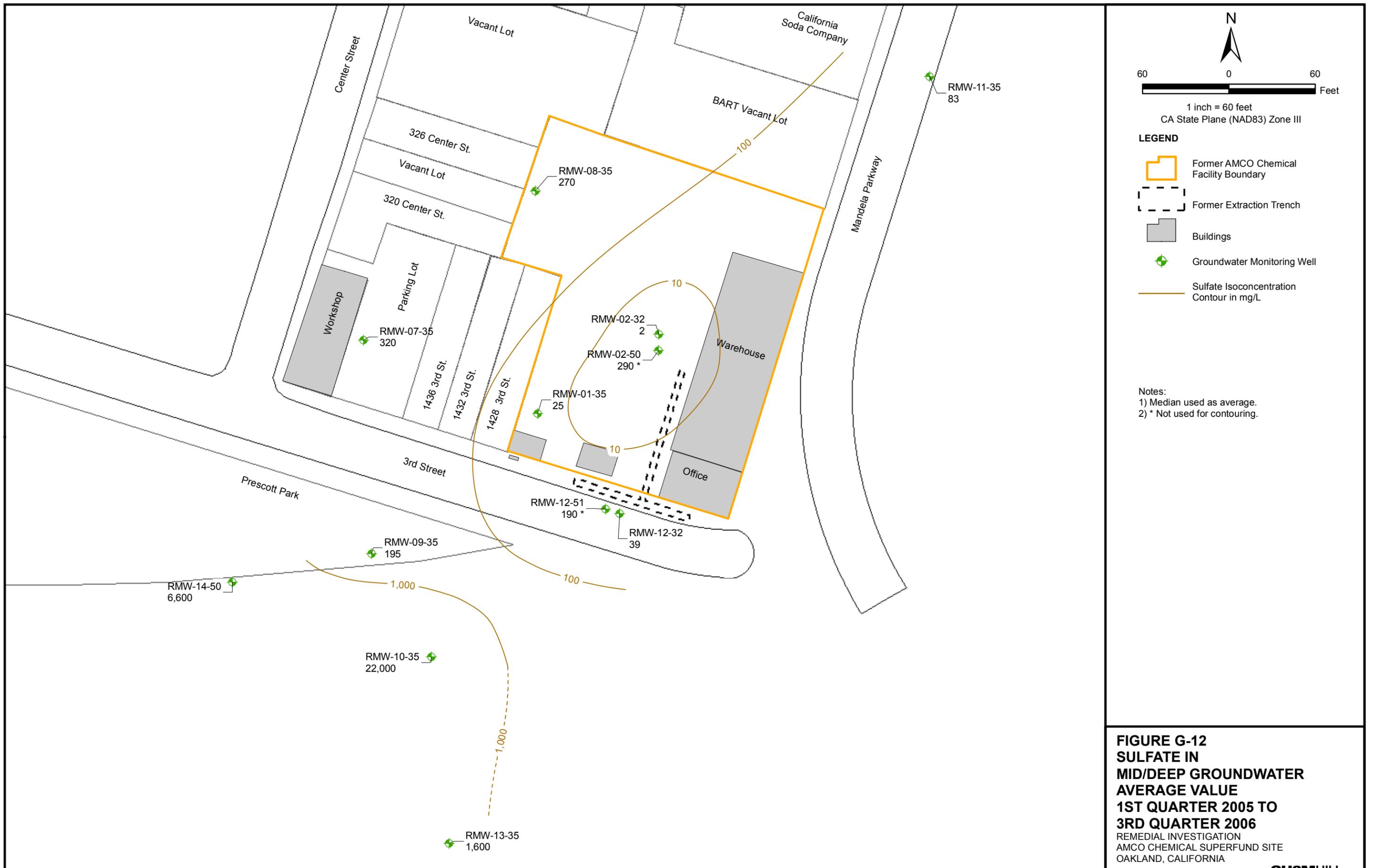
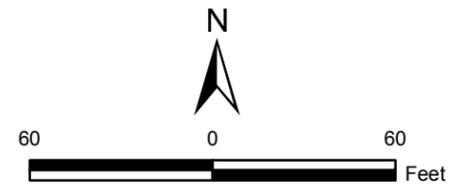
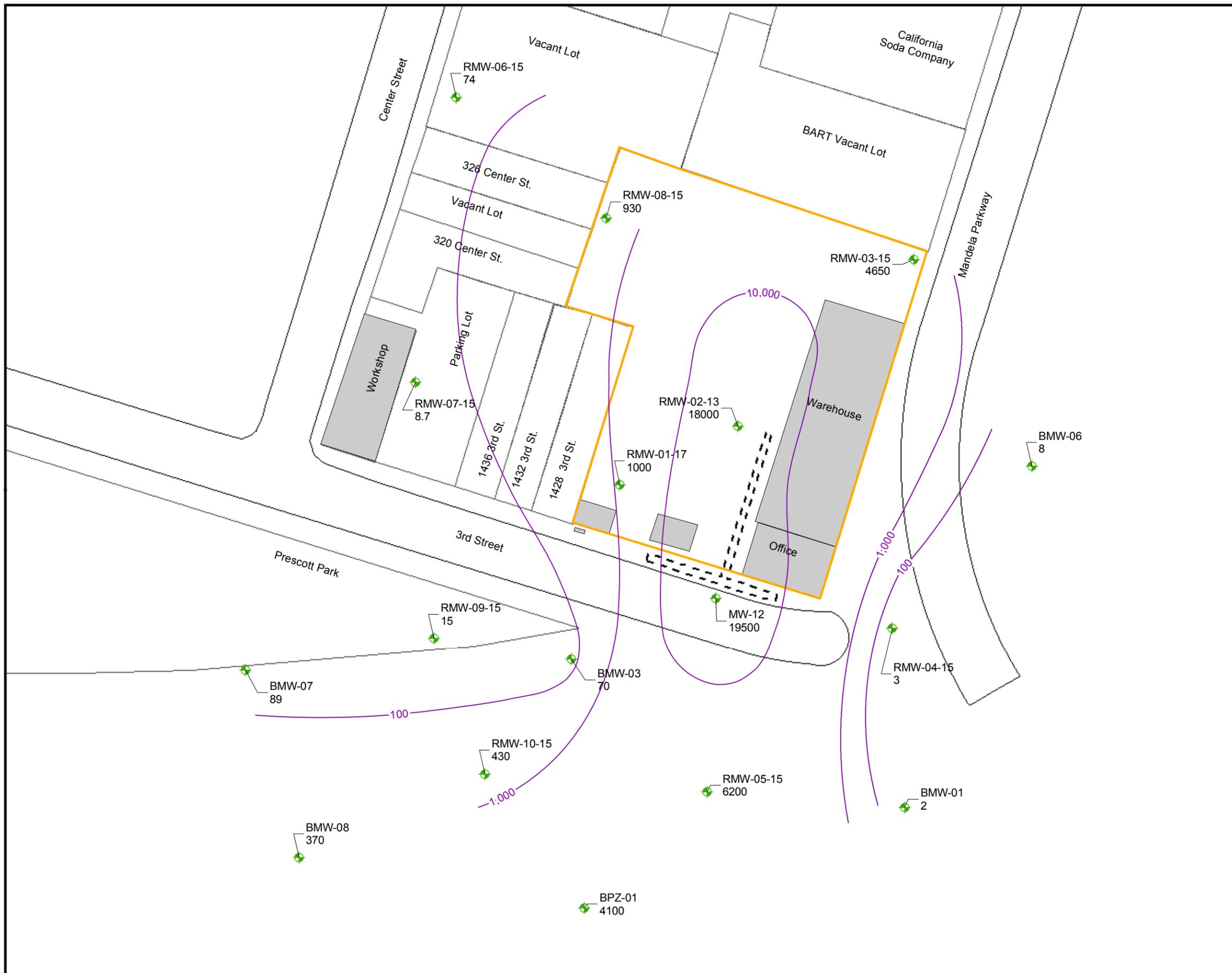


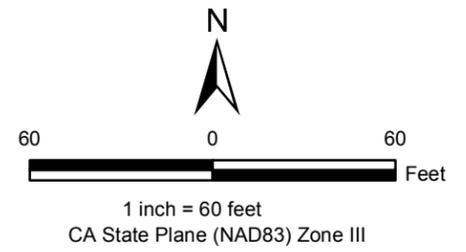
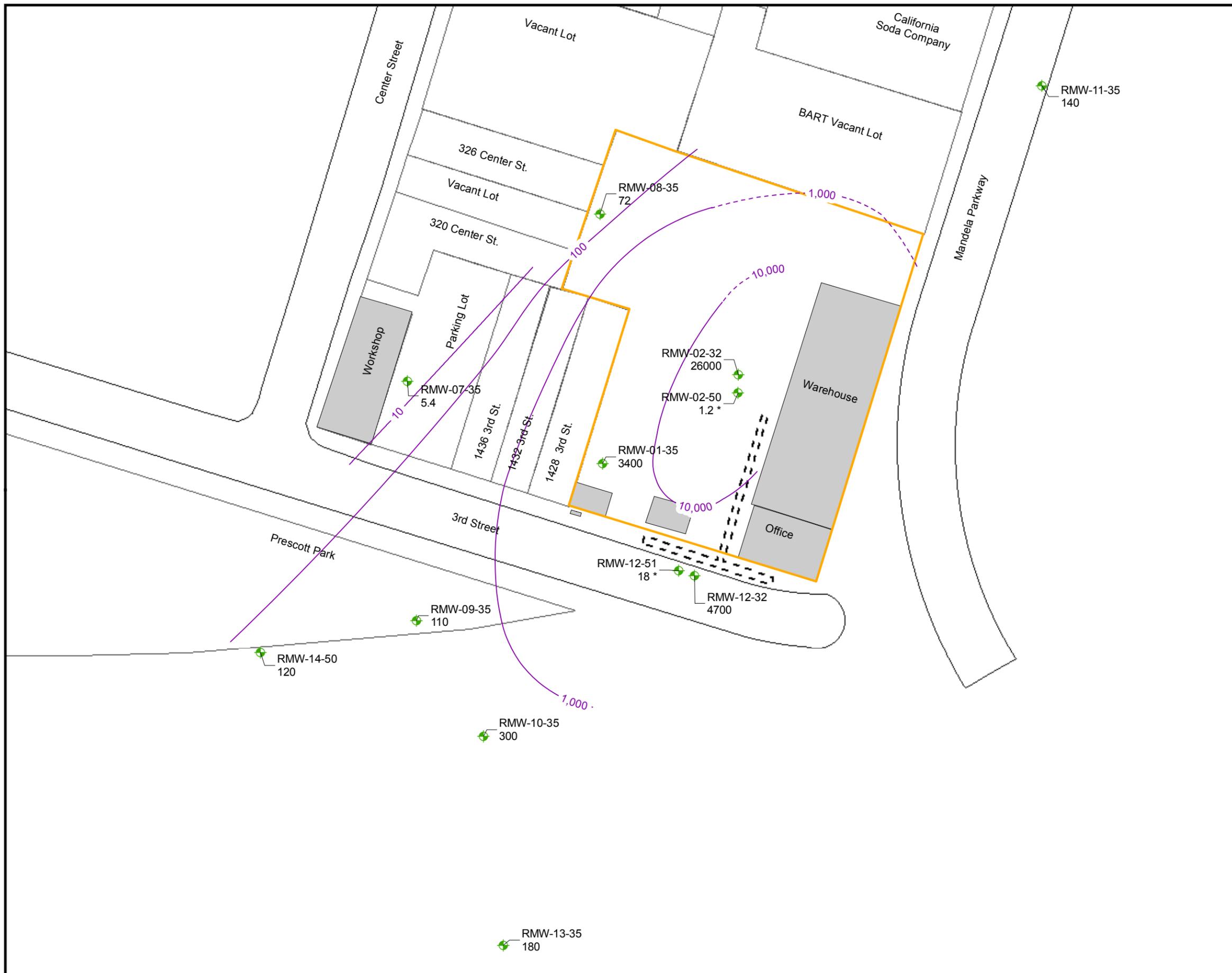
FIGURE G-12
SULFATE IN
MID/DEEP GROUNDWATER
AVERAGE VALUE
1ST QUARTER 2005 TO
3RD QUARTER 2006
 REMEDIAL INVESTIGATION
 AMCO CHEMICAL SUPERFUND SITE
 OAKLAND, CALIFORNIA



- LEGEND**
- Groundwater Monitoring Wells
 - Former AMCO Chemical Facility Boundary
 - Buildings
 - Former Extraction Trench
 - Methane Isoconcentration Contour in mg/L

Notes:
1) Median used as average.

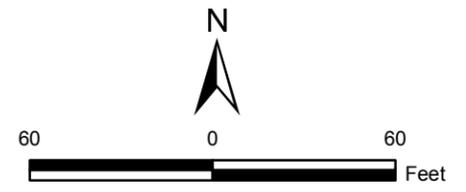
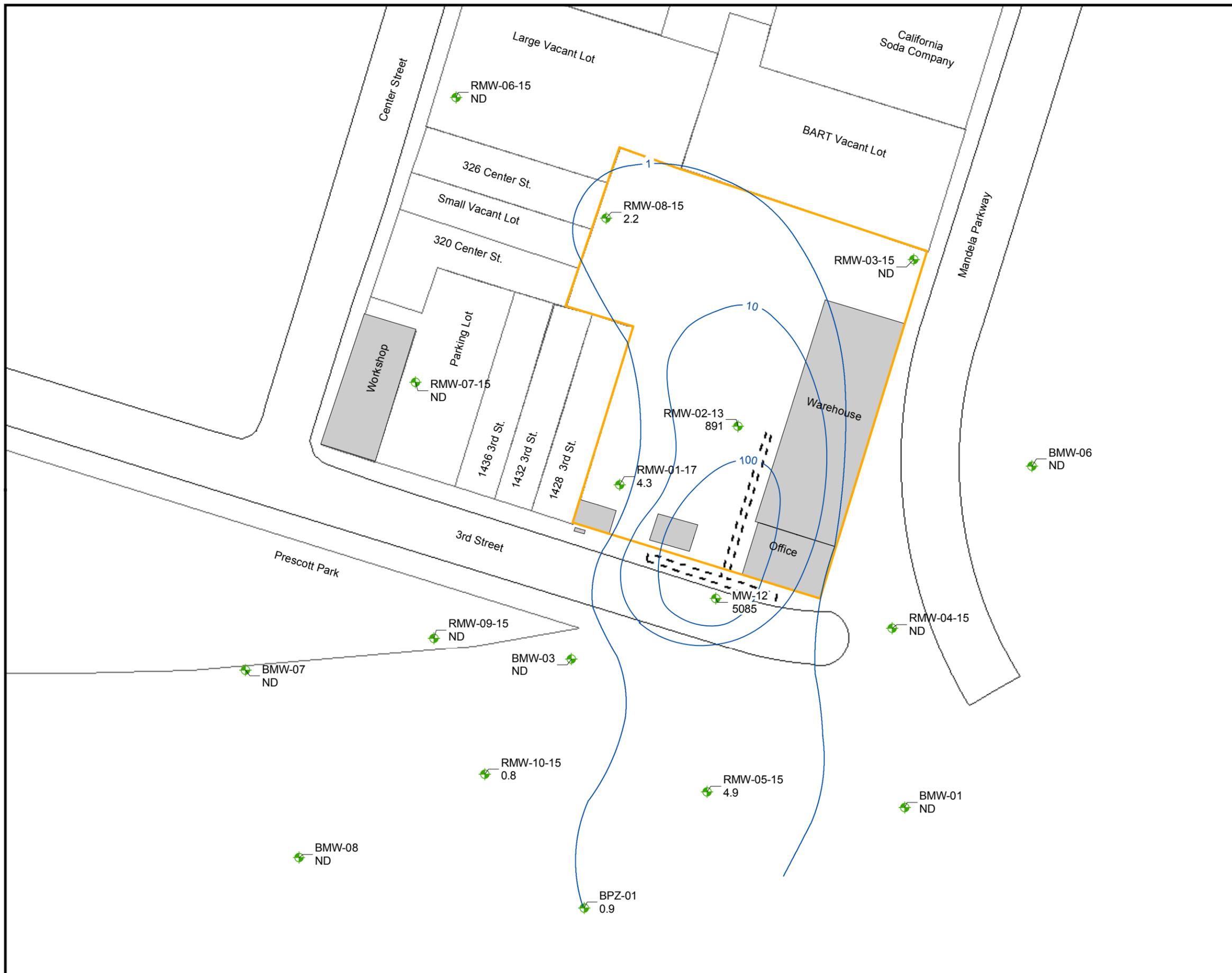
FIGURE G-13
METHANE IN
SHALLOW GROUNDWATER
AVERAGE VALUE
1ST QUARTER 2005 TO
3RD QUARTER 2006
 REMEDIAL INVESTIGATION
 AMCO CHEMICAL SUPERFUND SITE
 OAKLAND, CALIFORNIA



- LEGEND**
- Former AMCO Chemical Facility Boundary
 - Former Extraction Trench
 - Buildings
 - Groundwater Monitoring Well
 - Methane Isoconcentration Contour in mg/L

Notes:
 1) Median used as average.
 2) * Not used for contouring.

FIGURE G-14
METHANE IN
MID/DEEP GROUNDWATER
AVERAGE VALUE
1ST QUARTER 2005 TO
3RD QUARTER 2006
 REMEDIAL INVESTIGATION
 AMCO CHEMICAL SUPERFUND SITE
 OAKLAND, CALIFORNIA

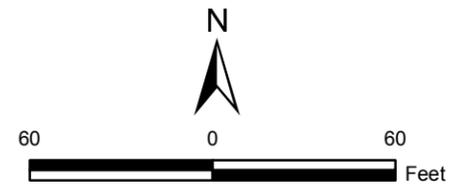
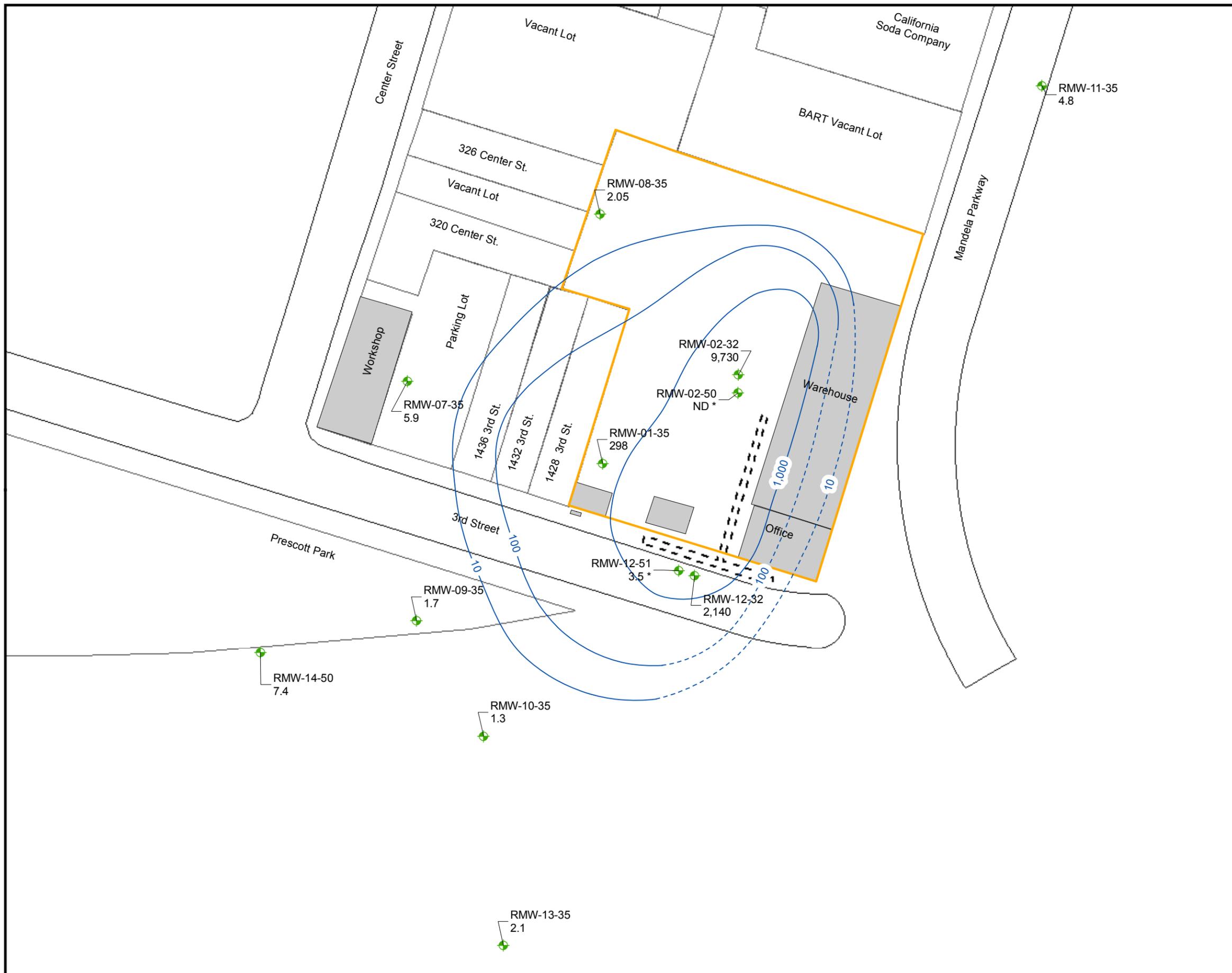


1 inch = 60 feet
 CA State Plane (NAD83) Zone III

- LEGEND**
- Groundwater Monitoring Wells
 - Former AMCO Chemical Facility Boundary
 - Buildings
 - Former Extraction Trench
 - Ethane and Ethene Isoconcentration Contours in mg/L

Notes:
 1) Median used as average.

FIGURE G-15
ETHANE AND ETHENE IN
SHALLOW GROUNDWATER
AVERAGE VALUE
1ST QUARTER 2005 TO
3RD QUARTER 2006
 REMEDIAL INVESTIGATION
 AMCO CHEMICAL SUPERFUND SITE
 OAKLAND, CALIFORNIA



- LEGEND**
- Former AMCO Chemical Facility Boundary
 - Former Extraction Trench
 - Buildings
 - Groundwater Monitoring Well
 - Ethane and Ethene Isoconcentration Contours in mg/L

Notes:
 1) Median used as average.
 2) * Not used for contouring.

FIGURE G-16
ETHANE AND ETHENE IN
MID/DEEP GROUNDWATER
AVERAGE VALUE
1ST QUARTER 2005 TO
3RD QUARTER 2006
 REMEDIAL INVESTIGATION
 AMCO CHEMICAL SUPERFUND SITE
 OAKLAND, CALIFORNIA