TETRA TECH

September 4, 2014

Mr. John Collins
Department of Environmental Quality
P.O. Box 200901
Helena, Montana 59620-0901

Subject: Draft Revised CMA, Bozeman Landfill

Dear John:

On behalf of the City of Bozeman, I am pleased to submit this Draft Revised Corrective Measures Assessment (CMA) for the Bozeman Landfill. This Revised CMA is submitted in request to your letter of June 6, 2014 to initiate an assessment of corrective measures as required in ARM 17.50.1308.

If you should have any questions regarding the Revised CMA, I would be pleased to discuss them with you.

Sincerely,

Larry Cawlfield, P.E., P.H.
Engineer/Hydrologist

Enclosures (2 copies plus CD)

C: Mr. Rick Hixson (3 copies plus CD)

Draft
Revised Corrective Measures Assessment
Bozeman Landfill
Gallatin County, Montana

Prepared for:

City of Bozeman

Mr. Rick Hixson
PO Box 1230
Bozeman MT 59771-1230

Prepared by:

Tetra Tech Inc.

303 Irene Street
Helena, MT 59601

Tetra Tech Project No. 114-560446

September 4, 2014

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

This Revised Corrective Measures Assessment has been prepared to address the off-site migration of Volatile Organic Compounds (VOCs) from the Bozeman Story Mill Landfill (Site). The Bozeman Story Mill Landfill is located between Story Mill Road and McIlhattan Road on the flanks of the Bridger Mountains. The Site is located in Section 30 of Township 1 South, Range 6 East in Gallatin County. The Site consists of historic closed or inactive cells and some active operations. One of the closed cells is an unlined cell and the other is a lined cell (see **Figure 1-1**). Both cells accepted Class II and III and IV wastes which are solid, non-hazardous, household, industrial, commercial, municipal, construction and demolition related wastes. The City disposes some of its own Class IV wastes (construction and demolition related) at a small cell north of the unlined cell. Recyclable wastes are currently accepted in containers located at the Bozeman Convenience Site. These containers are transported to the Gallatin County Landfill at Logan. The Bridger Creek Phase 3 subdivision lies to the south of the Site. Bridger Creek Phase 2 subdivision lies to the southwest of the site.

During routine sampling of groundwater in monitoring wells surrounding the landfill, concentrations of Tetrachloroethene, which is also known as PCE, were detected in one monitoring well off of the site (Tetra Tech, 2014). The particular monitoring well is named MW-20 and is located approximately 200 feet south of the Site boundary as shown on **Figure 1-1**. Concentrations of PCE in MW-20 were 10.6 micrograms per liter (µg/L) in a sample taken on March 25, 2014. Subsequent resampling of groundwater in MW-20 yielded a sample concentration of 9.4 µg/L. Montana's human health standard for groundwater is 5 µg/L (DEQ, 2012). Montana Department of Environmental Quality (DEQ) rules (ARM 17.50.1308) require the owner or operator of a facility which has detected an exceedance of ground water protection standards to initiate an assessment of corrective measures and to submit to the DEQ a report describing an assessment of corrective measures. At a minimum, the report must address the following:

a. The performance, reliability, ease of implementation, and potential impacts of appropriate potential remedies, including safety impacts, cross-media impacts, and control of exposure to residual contamination;
b. The time required to begin and complete the remedy;
c. The costs of remedy implementation; and
d. The institutional requirements such as state or local permit requirements or other environmental or public health requirements that may substantially affect implementation of the remedy(s).

On June 6, 2014, DEQ issued a letter (see **Appendix A**) requiring the City of Bozeman (City) to initiate the Corrective Measures Assessment (CMA) described above. This report is intended to meet that requirement. This report is titled a <u>Revised</u> Corrective Measures Assessment because a CMA was previously completed in 1995 (Maxim). This report relies on and revises, to the extent necessary, the 1995 CMA.

The 1995 CMA resulted in the selection of an alternative that consisted of the installation of 20 Landfill Gas (LFG) extraction wells. The LFG wells are shown on **Figure 1-2**. These wells were drilled into the waste mass of the unlined cell and withdrew LFG from the waste mass and treated it in a flare on the north side of the landfill. The selected alternative also relied on natural processes of dilution, dispersion, and biodegradation to remediate VOCs that had already migrated from the waste mass to downgradient areas. After installation of the LFG wells, concentrations of many VOCs in groundwater at many monitoring well locations showed rapid decreases. For example, at monitoring well MW-12 (see **Figure 1-2**) which is located on the site near the southwest corner of the unlined cell, concentrations of Vinyl Chloride prior to the installation of the LFG wells tended to be in the range of 50 to 100 µg/L. Within less than one year, Vinyl Chloride concentrations at MW-12 had dropped to about 20 µg/L and have stayed in the range of 5 to 30 µg/L to date. **Figure 1-3** shows the measured vinyl chloride concentrations before and after installation of the LFG wells. Not all constituents exhibited such rapid decreases at all monitoring well locations but many did. Some locations that are more remote from the waste mass and at which natural attenuation would be expected to be the dominant remediation process under this alternative, took longer to show reductions in VOC concentrations than at MW-12. Following implementation of the preferred alternative, concentrations of VOCs reached Groundwater Protection Standards (GPSs) at all off-site monitoring wells and have consistently maintained concentrations below GPSs until the PCE concentration of 10.6 µg/L at MW-20 in March of 2014.

Prior to the discovery of PCE concentrations exceeding groundwater standards at MW-20, the City proactively initiated an investigation into the potential for Vapor Intrusion (VI) into homes in the Bridger Creek Phase 2 and 3 subdivisions. Vapor Intrusion is defined by Montana DEQ as "the process by which volatile chemicals move from beneath the ground into the indoor air of overlying buildings" (DEQ 2011). The City initially collected air samples from probes along the south boundary of the landfill for VOC analysis. VOC concentrations above the EPAs Regional Screening Limits (RSL) were observed for a number of VOCs. RSLs are established by the EPA as the concentration at which further investigation is warranted. They are not cleanup levels. The presence of VOCs above RSLs at the landfill south boundary prompted the City to install soil gas probes in the Bridger Creek Phase 3 Subdivision to further define the extent of VOCs in subsurface soils. Some VOC concentrations in the Phase 3 soil gas probes were also above RSLs. The City requested permission from all 28 homeowners in the Bridger Creek Phase 3 Subdivision and four homeowners in the Phase 2 subdivision to collect air samples from inside and beneath their homes. Concentrations of some VOCs above their respective RSLs were observed in subslab samples (samples collected from beneath homes) in Phase 3. The City offered in-house mitigation systems to all residents of the Phase 3 Subdivision. It was decided by the City that the VOC results in the Phase 2 Subdivision homes did not warrant mitigation systems. The City installed in-house mitigation systems in all but one of the homes in the Bridger Creek Phase 3 subdivision. The in-house mitigation systems are similar to radon removal systems and consist of penetrations through home slabs through which a vacuum is applied and subslab gases are collected and vented to a location outside the house. While this VI investigation and resulting mitigation systems are related to this Revised CMA, its goals and objectives are separate and independent.

1.1 LANDFILL HISTORY AND PREVIOUS INVESTIGATIONS

1.1.1 Property Acquisition, Waste Cell Installation and Operation

The City of Bozeman purchased the property on which the site is located in 1969 (Mann, 1982). The property consists of approximately 200 acres and initial plans designated 150 acres for use as a landfill facility (TDH, 1972). At present, the "Snow Fill" site is a city recreational area consisting of 40 acres on the northwest corner of the property that was part of the original 200 acres. The location of the Bozeman Landfill is shown in **Figure 1-1**.

Class II, III, and IV wastes have been accepted at the landfill throughout its operational history. Waste disposal began shortly after purchase of the land and continued until 2008 in two waste cells and later, at relatively smaller Class IV cell. The majority of waste has been Class II and includes decomposable wastes such as municipal and household solid waste including food, paper, cardboard, cloth, glass metal, and plastics. Class II designation prohibits the disposal of regulated hazardous wastes.

Waste disposal was first conducted in the Unlined Waste Cell (also named the Unlined Closed Cell) between 1969 and 1995. This cell is in the southeastern corner of the landfill property. The cell is approximately 32 acres in extent and contains waste up to approximately 110 feet in thickness. Closure of this cell included approximately four feet of soil cover that was re-vegetated with a variety of grasses and forbs. Stormwater measures to collect rainfall and snowmelt from the surface of the cell and to prevent its infiltration were also constructed.

The City of Bozeman received approval from DEQ to construct a second waste cell immediately west of the unlined waste cell in 1993. This Lined Waste Cell (also named the Lined Closed Cell) was constructed with a synthetic and impermeable liner with a leachate collection system and completed by 1995. The second cell is approximately 12 acres and up to approximately 100 feet in thickness. The Lined Closed Cell is separated from the Unlined Closed Cell and has an access road between them. Waste disposal was conducted in this second waste cell between 1995 and 2008. The leachate collection system drained into a lined collection pond. Leachate accumulated in the pond and was pumped to the City municipal waste water sewer system until June 2007, when the leachate discharge pipeline was connected to the municipal waste water sewer. The leachate pond was then removed and the pond site reclaimed.

1.1.2 Early Groundwater Monitoring Activities

The City of Bozeman began monitoring the quality of surface and groundwater at the site during 1981. Initially, the City collected water samples from three monitoring wells (wells M-1, M-2, and M-3 or MW-3), several domestic wells located west or northwest of the landfill, and several springs and seeps in the area (McIlhattan Seep and Springbox, Boylan Seep). From 1981 through 1994 a total of 22 monitoring wells had been installed at the site. Of these, ten have since been abandoned or destroyed. Abandoned or destroyed wells include LF-1, LF-1A, LF-4, LF-5, LF-6, LF-6A, LF-7, LF-7A, M-1, and M-2. Since 1994, additional wells have been installed to expand the monitoring network across the site including the most recent addition of nine wells installed in February through April 2014. As of August 2014, there are a total of 31 monitoring wells installed and operating at the site. Additional monitoring sites include McIlhattan Seep, Bozeman Landfill Shop well, and the Valley View Veterinary Clinic well. The location of current and former monitoring sites is shown in **Figure 1-2**. A list of monitoring wells and their current monitoring frequency is included in **Table 1-1**.

1.1.3 Investigation and Monitoring Leading Up To CMA

According to Stiller and Associates (1985), personnel from the Montana Department of Health and Environmental Sciences (MDHES) expressed concern that landfill activities at the site were affecting groundwater conditions downgradient from the facility. The MDHES apparently based their concern on information contained in a letter report prepared by the U.S. Soil Conservation Service (SCS, 1985). In their letter, the SCS concluded there was a "leachate plume" emanating from the landfill that was characterized by elevated concentrations of total dissolved solids, chloride, and possibly, chromium. In an effort to more definitively delineate the magnitude and extent of the suspected leachate plume at the site, the City contracted Stiller and Associates to conduct additional hydrogeological investigations at the Site and review existing information.

From 1981 through 1993, the City continued to monitor the quality of surface and groundwater at the site on a periodic basis. Monitoring consisted of analyzing water samples for field parameters (pH, electrical conductivity and temperature), common ions (calcium, magnesium, sodium, etc.), dissolved metals and various inorganic parameters and organic "indicator" parameters including Chemical Oxygen Demand (COD), Total Organic Compounds (TOC), Total Organic Halogens (TOX) and others.

During the summer of 1992, the City installed an upgradient monitoring well MW-5 see **Figure 1-2**) and seven downgradient monitoring wells (wells MW-6, MW-7A&B, MW-8A&B, and MW-9A&B, **Figure 1-2**). These new wells were installed to better characterize hydrogeological conditions at the site and to provide additional groundwater sampling locations. The locations of the wells and methods used to install the wells were approved by DEQ.

In anticipation of new groundwater rules proposed by the U.S. Environmental Protection Agency (EPA), the City incorporated analyses of selected VOCs into its groundwater monitoring program during January, 1993. On November 25, 1993, the State of Montana adopted new groundwater monitoring rules for municipal solid waste landfills. These rules (formerly Administrative Rules of Montana or ARM, Title 16, Chapter 14, Subchapter 7) are in ARM Title 17, chapter 50, subchapter 13 (ARM 17.50.13). They describe specific groundwater monitoring requirements and actions that need to be taken as a result of various triggering mechanisms.

Analytical results from a sampling event in January, 1994 indicated that several VOCs listed in the newly adopted standards were present in water samples at concentrations above GPSs. Subsequent water sampling and analysis events were conducted in June 1994 and again in February 1995. Results from the February 1995 event indicated that several VOCs were present in groundwater downgradient from the closed cell at concentrations equal to or exceeding GPSs. In particular wells LF-3 and MW-7A had exceedances of tetrachloroethene and well MW-6 exceeded vinyl chloride limits. These exceedances triggered a requirement that led the City to prepare a CMA to address VOC impacts to off-site groundwater.

1.1.4 The 1995 CMA and Implementation of Remedial Alternative

The CMA was completed in August 1995 (Maxim). Various alternatives were evaluated in the CMA. Five alternatives were evaluated in detail. These included No Action, Air Sparge (AS) with Soil Vapor Extraction (SVE), Groundwater Pump and Treat, Passive Landfill Gas (LFG) Extraction, and Active LFG Extraction. Active LFG Extraction was the preferred alternative and approved by DEQ. Construction of the active LFG extraction system was conducted during 1997. The system was activated at the end of 1997 and continues to operate as of the date of this writing. Presumably the system will continue to run into the future until such time as LFGs cease to be produced in the unlined cell.

The LFG system consisted of 20 LFG extraction wells completed in the waste mass. Buried piping from each LFG well leads to a blower located on the north side of the unlined cell which evacuates LFG from the wells. Collected LFG (which includes VOCs) are thermally destroyed using a candlestick flare. The network of LFG extraction wells is shown in **Figure 1-2**. Monthly methane concentrations indicate the system collects more than 1,000 pounds of methane and other VOCs per year from the extracted LFG. The system removes approximately 150 cubic feet per minute (CFM) of landfill gas that measures approximately 24 percent methane. In 2009, one of the LFG extraction wells (MW-20) was removed from service. Historically, methane concentrations in MW-20 were lower than most other LFG extraction wells and the City planned to construct the Convenience Site that now occupies the former location of MW-20.

Seven landfill perimeter methane monitoring wells were also installed and are monitored on a regular basis. These are shown in **Figure 1-2** and designated with BLG-. These methane monitoring wells are monitored monthly with a field meter that measures methane, oxygen, carbon dioxide, and nitrogen in percent volume. The monitoring provides a field determination of the effectiveness of the operating LFG extraction system in containing LFG within the landfill property. Past monitoring results have measured methane intermittently exceeding regulatory limits (25 percent of the lower explosive limit (LEL)) in several of the perimeter gas probes during springtime when soil has the greatest amount of moisture. Methane is now rarely detected in the perimeter gas monitoring probes following repairs to the LFG extraction well-heads and operational improvements to the system. Location of the perimeter methane monitoring wells is shown in **Figure 1-2**.

1.1.5 Groundwater Monitoring Since 1997

Groundwater monitoring has continued since the completion of the LFG extraction system in 1997 and is generally performed semi-annually. Prior to 2014, groundwater monitoring was performed at 16 monitoring wells, two water supply wells, and one spring. Of these sites, only four are located off the landfill property. These include wells LF-2, LF-3 and MW-10 and a spring referred to as the McIlhattan Seep (see **Figure 1-2**). The concentration of VOCs in groundwater at these off-site wells has not exceeded GPSs since September 2003.

During 2014, the City initiated drilling and completion of ten additional groundwater monitoring wells at the site. The placement of wells were designed to identify groundwater flow paths south of the landfill and west of wells LF-2 and LF-3 in the Bridger Creek Phase 3 subdivision. These new monitoring wells are monitored on a quarterly basis to provide more information on groundwater in these areas

Well MW-20 sample results from March and May 2014 had concentrations of tetrachloroethene of approximately 10 micrograms per liter which exceeds the GPS standard of 5 micrograms per liter. Well MW-20 is located off the landfill site approximately 200 feet south of the south boundary of the landfill property on City park property, between Turnberry Court and Caddie Court roads (**Figure 1-1**). During the same time period, groundwater with concentrations of tetrachloroethene, trichloroethene, and vinyl chloride exceeding the GPS was detected on the landfill property at monitoring wells MW-17 and MW-18.

Groundwater elevations are also taken during monitoring events. Based on the groundwater elevation, a groundwater contour map can be prepared. **Figure 1-4** is such a map and is based on the groundwater elevations collected during spring sampling in 2014. Groundwater flow is generally toward the southwest under the closed cell but changes to a more westerly direction as groundwater approaches the East Gallatin River alluvium. Previously, groundwater maps had been prepared based on data collected during earlier sampling events (for example Tetra Tech, 2013) including fall/winter sampling events that exhibited similar groundwater flow direction. A monitoring event was conducted in August of 2014 and future events are scheduled to be conducted in December of 2014 and again in June of 2015.

1.2 ENVIRONMENTAL SETTING

General descriptions of several aspects of the environment at the Bozeman Sanitary Landfill are included below. More detailed explanations of site-specific features are included in Section 3.0 of this document.

1.2.1 Physiography/Demography

The landfill property lies on the southwest flank of the Bridger Mountains, immediately upslope of the East Gallatin River floodplain. The landfill property is bounded by Story Mill Road to the east; McIlhattan Road and undeveloped land to the west; agricultural land and rural residential properties to the north; and a combination of residential subdivision, golf course, and City of Bozeman park land to the south and southwest of the landfill.

Topography at the landfill property and site varies from hilly on the landfill property through Bridger Creek Phase 3 residential subdivision and adjacent golf course to flat lying ground along the East Gallatin River. Corresponding elevation above mean sea level ranges between approximately 4,900 feet at the east margin of the Unlined Closed Cell to 4,700 feet in the area of the Bridger Creek Phase 2 residential subdivision. The ground surface slopes to the west-southwest at an average grade of 5%, with much of it sloping 15 to 50%.

Two surface drainages traverse the landfill property (**Figure 1-1**). Spring Creek crosses the very northern part of the landfill property, flowing west-southwest. Churn Creek is a perennial drainage (USGS, 1960) that is located north of the Lined Closed Cell south of Spring Creek.

Historically, most of the area adjacent to the landfill was used for either farming or grazing. As previously mentioned, residential subdivisions located south and southwest of the landfill were constructed beginning during 2000.

1.2.2 Climate

The Bozeman area climate is characterized by long cold winters and short relatively cool summers. The average warmest month is in July and coolest month is in December. Average temperature highs in July and August are 83°F and the average temperature lows in December and January are 14°F.

The average annual precipitation at Bozeman is 19.74 inches. Approximately two-thirds of the annual precipitation falls between April and September and one-third occurs in May and June (Weather Channel, 2014).

1.2.3 Geology and Hydrology

The Bozeman Sanitary Landfill is situated on unconsolidated, fine- and coarse-grained sediments. Based on Tetra Tech's logging of drill cuttings and review of lithologic logs from probe and monitoring well borings drilled at the site, the sediments underlying the landfill and Bridger Creek Phase 3 residential subdivision consist of a sandy to clayey silt, thin beds of fine grained sand with silt, and gravel in a silty matrix.

At the location of the landfill property, the Montana Bureau of Mines and Geology (MBMG) has mapped sediments as an Upper Tertiary, dominantly coarse-grained facies consisting of conglomerate, sandstone, siltstone, and nearly pure volcanic ash beds (map unit Tsuc) with an approximate thickness of 1,200 feet. On MBMG's geologic map, McIlhattan Road marks the approximate western terminus of this mapped unit and the occurrence of Quaternary alluvium consisting of gravel, sand, silt, and clay deposited in stream and river channels, on floodplains, and on low terraces as much as about 20 feet above modern streams and rivers (map unit Qal, MBMG 2002).

Tetra Tech's observation of the occurrence of these sediments suggests coalescing alluvial fans that form the western flank of the Bridger Mountains and more closely correspond with MBMG's mapped Quaternary alluvial fan deposits (Qtaf, MBMG 2002). Pre-Cambrian-age crystalline metamorphic rocks underlie the alluvial fan deposits at an unknown depth.

Drilling of the groundwater monitoring wells and soil gas probes occurred in what is considered to be two hydrogeologic areas at the site. Drilling of wells MW-17 through MW-20, MW-24, and MW-25 occurred in areas where subsurface conditions are anticipated to be similar to the Bozeman Landfill. This area is interpreted to be upper Tertiary or Quaternary-age unconsolidated alluvial fan sediments. The sediments intercepted include sedimentary formations of dominantly sandy to clayey silt or silty clay that in some borings show minor gravels scattered through the section. In other cases there are gravelly intervals in a silt, clay, and/or fine sand matrix interbedded with the finer grained sediments.

A second hydrogeologic area is unconsolidated alluvial sediments of the Bridger Creek and East Gallatin River valleys. Wells MW-21 through MW-23 were drilled in this area. Well MW-26 was also drilled near the boundary or transition between the alluvial fan deposits and the stream alluvium. Sediments include silt and clay with underlying sand and gravel. Groundwater is also shallower in this area. Depth to groundwater in wells MW-21 through MW-23 was between 3.1 and 7.6 feet and in well MW-26 it was 14.1 feet in early May 2014.

Two stratigraphic cross-sections across the southern part of the site are presented on **Figure 1-5** to provide an idealized representation of the occurrence of the silt/clay and gravelly sediments across the site. The surficial silt/clay sediments can be correlated across the section. Deeper sections of silt/clay sediments appear to be discontinuous between borings. Lithologic descriptions for each borehole indicated that gravelly sediments appear to have continuity across the section. Groundwater is primarily encountered in the gravelly intervals.

Depth to groundwater in monitoring wells at the site range between approximately 1.0 feet below ground surface (bgs) in well MW-10 near the western margin of the site, 14 feet bgs in wells LF-2 and LF-3, 56 feet bgs in well MW-12, and 113 feet bgs in well MW-5 at the eastern margin of the site. Seasonal variation of groundwater elevations, since the year 2000, has been an average of 0.9 foot in well MW-10; 0.7 and 0.4 foot in wells LF-2 and LF-3, respectively; 0.3 foot in wells MW-11 and MW-12; and 0.9 foot in well MW-5.

Site monitoring indicates a southwest groundwater flow beneath the Unlined Closed Cell shifting to a west-southwest flow between the Lined Closed Cell and well MW-10, at the western margin of the site. Groundwater contours and flow directions are shown on **Figure 1-4**.

Plan or map groundwater gradients beneath the Unlined Closed Cell are a consistent 5.6% between wells MW-15 and MW-12. The groundwater gradient decreases between wells MW-12, LF-2, and into the north portion of Bridger Creek Phase 2 subdivision to approximately 1.8%. The groundwater gradient between wells MW-20 and MW-22 (and the south portion of Bridger Creek Phase 2 subdivision) is approximately 1.55%. The groundwater gradient between wells MW-25 and MW-21 is approximately 1.72%.

A distinct upward hydraulic gradient has been measured at locations on the landfill property. Two sets of paired monitoring wells were installed (MW-6/MW-6B and MW-8A/MW-8C) on the Site. MW-6B and MW-8C are completed at deeper intervals than their shallower twins MW-6 and MW-8A. The groundwater elevation in the deeper wells was ten and four feet higher (respectively) in these wells compared with their shallower well twins (MW-6 and MW-8A).

The average hydraulic conductivity of the unconsolidated sediments beneath the Bozeman Landfill is approximately 2.0 x 10^{-2} cm/sec (50 feet per day), (Huntingdon, 1994). Assuming an effective porosity of the mixed sand, gravel, and fine-grained sediments at the landfill of 0.35 (typical values for sand and gravel range from 0.28 to 0.39), (Todd, 1980) and hydraulic gradients ranging from 1.5% to 5.6%, the rate of groundwater movement in alluvial fan sediments underlying the landfill ranges from 2.4 to 9.1 feet per day.

The nearest surface water resources include Churn Creek, several ponds immediately west of McIlhattan Road, and the East Gallatin River (**Figure 1-1**). Churn Creek is a relatively small perennial stream that flows to the west and is immediately north of the Lined Closed Cell, crossing the property south of Spring Creek. Past water level and survey data indicate Churn Creek is an influent stream along the landfill reach. Past visual estimates of flow in Churn Creek have ranged from less than one cubic foot per second (cfs) to as much as five cfs during spring runoff. Several ponds have been constructed and have developed spring water flow within the East Gallatin River alluvium. Two are on the Golf Course property and the other is on vacant land west of the landfill.

The East Gallatin River, located approximately 1,000 feet west of the landfill property, is the predominant surface water feature in the area. According to historical U.S. Geological Survey records, the minimum and maximum flow in the East Gallatin River (below the confluence with Bridger Creek, approximately 2,500 feet southwest of the landfill) is 17 and 100 cfs during 12 years of record (USGS, 2014).

1.2.4 Land Use and Ownership

The landfill property is owned by the City of Bozeman and is shown in **Figure 1-1**. As mentioned above, the Site consists of approximately 100 acres consists of undisturbed ground with two creeks, a shop complex, waste disposal and recycling convenience site, an area for soil borrow, a 12-acre Lined Closed Cell and a 32-acre Unlined Closed Cell. As indicated in **Figure 1-1**, land to the east, west, and north is currently unoccupied. Land to the west is used for livestock grazing. Land use to the south and southwest consists of two residential subdivisions and a golf course. The City also owns a thin strip of property on the south side of the landfill property between the landfill and Bridger Creek Subdivision Phase 3 that is currently used a park.

2.0 REVISION GOALS AND OBJECTIVES

The primary objective of this Revised CMA is to support selection of one or more new and/or additional remedy(ies) that will mitigate PCE-containing groundwater that has migrated south of the landfill property. The new or additional remedy(ies) would act in concert with the existing LFG system. As previously noted the 1995 CMA evaluated remedial alternatives and selected an alternative that led to the installation and operation of the existing LFG system. To the extent possible, the selected remedy should also reduce or prevent the off-site migration of VOCs in soil vapor.

The selected remedy must also meet the requirements of ARM 17.50.1309(2) which mandates that the preferred remedial alternative must:

- *Be protective of human health and the environment*. Tetra Tech elected to complete qualitative analyses to evaluate protectiveness for this assessment.

- *Attain the groundwater protection standards described in* ARM 17.50.1307(8 or 9). Groundwater protection standards have been established under ARM 17.50.1307(8).

- *Control the source(s) of releases so as to reduce or eliminate, to the maximum extent practicable, further releases of contaminants of concern to the environment.* In the case of the Bozeman Landfill, source control alternatives include those technologies that would potentially mitigate contaminants within the solid waste prism itself and contaminants conveyed by landfill gas or leachate that are present within the waste unit boundary.

- *Comply with standards for management of wastes specified in ARM 17.50.1310(4) which require implementation of waste administration practices that insure protection of human health and the environment and which comply with applicable federal Resource Conservation and Recovery Act (RCRA) requirements.* Evaluation of how various alternatives would achieve this objective would be most applicable to those that produce a hazardous waste as a result of implementation of a technology.

3.0 CONTAMINANT ASSESSMENT

3.1 CONSTITUENTS OF CONCERN

3.1.1 Constituents in Groundwater

The primary constituents of concern at the Site consist of the following volatile organic compounds (VOCs) measured in monitoring wells downgradient of the Unlined Closed Cell:

- Tetrachloroethene
- Trichloroethene
- Vinyl Chloride

The VOCs listed above have been measured in downgradient monitoring wells on at least one occasion at concentrations at or above GPS. However, based on statistical analysis of the data set currently available for these VOCs, tetrachloroethene and trichloroethene are not present in downgradient monitoring wells at statistically significant concentrations above GPSs. Vinyl chloride is present in two monitoring wells, within the landfill property, at statistically significant concentrations above GPS (Tetra Tech, 2014). Nitrogen as nitrite and nitrate has exceeded the GPS in well MW-8A since December 2010.

With the implementation of a selected remedial alternative to treat VOC impacts, it is anticipated that most of these VOCs will be mitigated similarly. Therefore, if there is remediation of PCE in groundwater at the Site then there will also be mitigation of the other VOCs detected at the site, to a greater or lesser magnitude.

3.1.2 Constituents in Soil Gas

Primary constituents measured in soil gas at the site consist of the following VOCs:

- Chloroform
- Vinyl Chloride
- Benzene
- Trichloroethene
- Tetrachloroethene
- Ethyl Benzene

These VOCs have been measured in soil gas probes at the south landfill property boundary and in the Bridger Creek Phase 3 Subdivision Concentrations have met or exceeded EPA Regional Screening Levels (RSLs) at times and in various soil gas probes. RSLs are levels at which additional investigation are suggested.

3.2 NATURE AND EXTENT OF CONTAMINATION

The nature and extent of impacts to groundwater and soil gas are discussed in the following sections. The previous CMA focused on impacts to groundwater from LFG. The generation of LFG also is believed to be responsible for the occurrence of VOCs in soil gas beyond the landfill property boundary.

3.2.1 Nature and Extent of Contamination in Groundwater and Surface Water

Groundwater monitoring indicates a southwesterly groundwater flow across the landfill property changing to a westerly flow direction near the west margin of the landfill and a portion of the site along the East Gallatin River. Groundwater containing VOCs exists south and west of the unlined closed cell. Table 3-1 lists the monitoring wells and the concentrations that have exceeded GPSs.

Prior to the installation of well MW-20 in 2014, three groundwater wells (wells LF-2, LF-3, and MW-10) and one spring/surface water site (McIlhattan Seep) were monitored downgradient and outside of the landfill property. Evaluation of data from these off-site monitoring stations indicate groundwater contains concentrations of VOCs including tetrachloroethene and trichloroethene. However, the concentration of these VOCs has not exceeded GPSs in groundwater outside of the landfill property since 2003. Table 3-1 lists the monitoring wells and constituent concentrations that currently exceed GPSs.

No VOCs have been detected in downgradient monitoring wells MW-21, MW-25 and MW-26. Low (and estimated) concentrations of some VOCs have been detected in downgradient monitoring wells MW-22 and MW-23. However, due to a westerly groundwater flow in the vicinity of these wells, the source of these is not believed to be the landfill (Tetra Tech, 2014). Based on this data, the downgradient extent of groundwater impacted with VOCs includes the area covered by all the monitoring wells, except the wells MW-21, MW-22, MW-23, MW-25, and MW-26. In effect, the downgradient boundary of the extent of contamination can be thought of as an arc starting on Story Mill Road between MW-24 and MW-25 then arcing southwesterly and then northwesterly through the golf course to a point south of the MW-19 then arcing northwesterly between the Bridger Creek Subdivision Phase 2 and McIlhattan Road.

3.2.2 Nature and Extent of LFG

LFG was believed to be generated by decomposition of waste in the unlined closed cell. LFG sampling at the margin of the unlined closed cell in 1995 confirmed the occurrence of LFG. During 1997, a LFG extraction system was installed in the waste mass to remove and dispose LFG. The LFG extraction system includes a candlestick flare at which collected LFG is thermally destroyed. LFG is regularly sampled prior to being destroyed. LFG is composed primarily of methane and carbon dioxide with lesser amounts of tetrachlorethene, trichlorethene, benzene, tolulene, ethylbenzene, xylenes, methylene chloride, vinyl chloride and other VOCs.

Gas sampling in 2012 in methane monitoring wells along the south side of the landfill indicated concentrations of VOCs that are likely related to migration of LFG from the Unlined Closed Cell. Subsequent installation and testing of soil gas probes in the Bridger Creek 3 Subdivision also detected VOCs that could be related to LFG or to VOC-containing groundwater underlying the subdivision. VOC concentrations measured beneath the subdivision in excess of RSLs include tetrachloroethene, trichloroethene, vinyl chloride, chloroform, benzene, ethylbenzene, toluene, and 1,2,4-trimethylbenzene (Tetra Tech, 2013).

The Unlined Closed Cell was capped starting in 1990 and completed by 1997. As the cap was completed, soil gas may have begun migrating outward from the waste mass into the surrounding soil. Initial samples were collected in 1995 from soil gas probes BLG-8 and BLG-9 (which are located in the waste of the Unlined Cell) and methane monitoring well BLG-3 which is near the southern boundary of the Unlined Cell. Analytical results from these early samples indicate concentrations of methane and VOCs were present in the waste and soil gas (Maxim, 2000).

3.3 CONTAMINANT SOURCES, TRANSPORT AND FATE

Sources of LFG including VOCs can generally come from two main sources: leachate (liquid that has migrated through the waste and into the soil and groundwater underlying the waste) or gas formed by decomposition of wastes and subsequent transport of the gas into the surrounding soil and potentially to the groundwater. In the case of the Bozeman Landfill, the source of PCE, TCE and other VOCs measured in groundwater is believed to be largely the result of gas emissions from the waste mass and not from leachate. The landfill design and construction includes many measures to prevent or minimize the infiltration of water into the waste mass to form leachate. A low permeability cap overlays the waste mass. Also, stormwater measures that collect and transmit stormwater off the cap help prevent infiltration into the waste mass. Recent groundwater sampling results (Tetra Tech, 2014) show that groundwater underlying the landfill exhibits low levels of tritium. If leachate were significantly contributing VOCs to the groundwater, elevated levels of tritium would be expected (ibid, pg. 7).

Similarly, liquid sources of pure VOCs are not believed to contribute VOCs to groundwater. In other words a discrete source of pure PCE or TCE as a liquid is not in contact with the groundwater. If it were, the concentrations of VOCs typically seen in the groundwater (for example those shown in Table 3-1) would be orders of magnitude higher.

There are three mechanisms by which VOCs can be transported by gas emissions to groundwater. These mechanisms are described below.

3.3.1 Direct Contact with Groundwater by LFG

LFG migrating from a site tends to travel the path of least resistance. Generally that path is towards the ground surface and atmosphere. Two dimensional modeling also shows that LFG tends to migrate downward from the landfill bottom before escaping to the atmosphere. As LFG reaches the capillary fringe, the VOCs in the LFG have the opportunity to be absorbed into the groundwater. Henry's Law governs the partitioning of VOCs from the LFG to groundwater. Based on recent soil gas sampling, soil gas concentrations near the groundwater agree closely with concentrations predicted by Henry's Law. This close agreement indicates that concentrations of VOCs in the soil gas are closely related to concentrations in the groundwater and vice versa.

3.3.2 Formation of LFG Condensate in the Soil Adjacent to the Landfill

LFG temperatures typically range from 80 to 110 degrees F within the landfill. At these temperatures LFG is typically 100% saturated with water. The soil surrounding a landfill is typically cooler, and in the case of the Bozeman Landfill, assumed to be 58 degrees F. The difference in these two conditions will result in the formation of condensate water outside the refuse mass (Emcon, 1982). Partitioning of VOCs from the vapor to liquid phase will typically result in concentrations of VOCs within the condensate. The liquid condensate may migrate downward to the groundwater.

3.3.3 Infiltration Water Carrying LFG Contamination in the Vadose Zone to Groundwater

As LFG migrates through the soil adjacent to the landfill, VOC mass adheres to the soil matrix in either vapor or liquid phase. As rainwater infiltrates from above, it reaches equilibrium with the VOCs present in the soil. Provided these VOCs are not consumed by bacteria or stripped from the water, they may eventually reach the groundwater. In the case of the Bozeman Landfill, groundwater is relatively close to the base of the waste and annual precipitation is approximately 19" which may be sufficient to drive vadose zone VOCs to groundwater.

Figure 3-1 shows how each of these mechanisms occurs and the exchange paths of VOCs between gases in the vadose zone and groundwater.

3.3.4 Direct VOC Contribution by Leachate

Although leachate is not believed to be a significant contributor to VOCs in the groundwater, it is possible that leachate contributes at times to VOCs in the groundwater. If regional groundwater levels rise into the waste mass or if seasonal perched springs discharge into the waste mass, VOCs in the waste mass will partition into the groundwater. The groundwater and the entrained VOCs then travel downgradient in the groundwater beyond the waste mass. If this groundwater-waste mass contact occurs, other inorganic and trace metal constituents can also be dissolved into the groundwater or partitioned into vapor in the groundwater. Inorganic and trace metal constituents have been detected in groundwater downgradient of the closed cell (Tetra Tech, 2014) at levels below GPSs. However, concentrations of these other constituents, particularly tritium, indicate that leachate is not a significant contributor to the groundwater and that VOC migration into the groundwater from the soil vapor is the dominant transport mechanism.

Figure 3-1 shows potential paths for VOC migration into the groundwater by leachate. **Figure 3-1** shows potential contact between groundwater and the waste mass. This contact, if it occurs, has not been confirmed by direct measurement of groundwater levels in the waste mass.

Once in the groundwater and regardless of whether their source is leachate or LFG, VOCs will tend to migrate with the groundwater gradient. In the case of the Bozeman Landfill, groundwater flow direction is generally to the southwest under the landfill and changes to more westerly as groundwater approaches the East Gallatin floodplain. As VOC-containing groundwater becomes more distant from the landfill, concentration of VOCs in the vadose zone, overlying the groundwater, may decrease. When this occurs VOCs will migrate out of the groundwater and into the vadose zone.

3.4 RISK TO HUMAN HEALTH AND THE ENVIRONMENT

Descriptions of potential human and environmental receptors of groundwater contaminants are presented below.

3.4.1 Potential Human Receptors and Associated Risk

South and southwest of the landfill property are two residential subdivisions, Bridger Creek Phases 2 and 3. These are within the Bozeman City limits and are supplied with municipal water and sewer services. Therefore, there is not a reliance on water wells or springs to supply domestic (drinking) water to these residences. The Valley View Veterinary Clinic near the northwest corner of the landfill property and a nearby residence at 2700 McIlhattan Road have water wells for domestic use. Groundwater monitoring has indicated that these wells have not been impacted by landfill constituents. Therefore, an initial assessment of risk to human receptors at these locations indicates a low risk.

A review of water right records from the Department of Natural Resources and Conservation (DNRC) has indicated the locations of other wells at the Site. The approximate locations of these wells and other water features are shown in **Figure 3-1**. Groundwater monitoring has indicated the following:

- Water analysis results of samples collected from the Valley View Veterinary Clinic well on indicates no VOC impacts from landfill sources. Therefore, wells in the northwestern portion of Figure 3-2 would not be impacted from the landfill.

- The landfill shop well and McIlhattan Seep is impacted with VOCs below the GPS. Therefore, the stock well identified approximately 200 feet northwest of the McIlhattan Seep has the potential to be impacted.

- The well identified for domestic use on Augusta Drive has the potential to be impacted with VOCs from the landfill due to it being in a downgradient direction from the landfill. However, initial water analysis results of samples collected from proximal monitoring wells on Augusta Drive indicate no groundwater impacts. Even though this well is identified for domestic use, the owners are known to be connected to the municipal water supply. It is likely that this well is used instead for lawn and garden watering.

- There are four lawn and garden wells in the Bridger Creek Phase 3 Subdivision proximal to monitoring wells with VOC impacts. However, the lawn and garden wells withdraw water deeper than the monitoring wells. One time sampling results have indicated that one of these four wells was impacted with several VOCs below the GPS including tetrachloroethene and trichloroethene.

3.4.2 Potential Environmental Receptors and Associated Risk

Livestock, wildlife and/or other environmental receptors could be exposed to low levels of VOC-containing groundwater expressed at the Boylan and McIlhattan Seeps. However, monitoring results have shown that only the McIlhattan Seep, contains VOCs at concentrations below the GPS. The VOC-containing groundwater proximal to the landfill property is believed to not pose a risk to livestock, wildlife and other environmental receptors.

4.0 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS

Previously (Maxim, 1995) exhaustive lists of remedial technologies were evaluated to address the off-site migration of VOCs in groundwater that were detected. The remedial technologies were screened for effectiveness, implementability and cost using screening protocols in the National Oil and Hazardous Substances Contingency Plan which is sometimes referred to as the National Contingency Plan (NCP) (EPA, 1994). The technologies remaining after the screening process were assembled into seven alternative plans that were subsequently evaluated using detailed comparisons. **Table 4-1** lists the technologies that remained after screening.

Many of the technologies that remained following screening are no longer applicable. For example, one of the processes evaluated previously was to supply municipal water to surrounding residences (of which there were few at the time). The City's municipal water supply has since been extended into the area and supplies water to both Bridger Creek Phase 2 and Phase 3 subdivisions. Those processes that were previously retained but are no longer applicable for this Revised CMA for various reasons are listed in **Table 4-1** and the reason that they are no longer retained is also shown in **Table 4-1**. Of the five alternative plans evaluated in the original CMA, one consisting of, among other things, active landfill gas extraction was selected. Subsequently, 20 landfill gas extraction wells were installed in the unlined cell and a blower and flare were installed to collect and treat landfill gas. The original CMA contemplated the exhumation of landfill solids but this technology was not carried forward for various reasons. For purposes of this Revised CMA, this remedial technology is carried forward.

For purposes of this Revised CMA, the remaining technologies shown in **Table 4-1** are combined into various alternatives and evaluated in detail in subsequent sections of this report.

5.0 DEVELOPMENT AND DESCRIPTION OF REMEDIAL ALTERNATIVES

The remaining technologies listed in **Table 4-1** are combined to create alternatives that will be evaluated in detail in the following Section of this report. Each of the alternatives are described in detail in the following sections. Some common actions or technologies are included in each alternative for various reasons. These common activities or technologies include the following:

- *Continued Groundwater and Soil Vapor Monitoring*. This activity is not only required by law but necessary to evaluate the effectiveness of existing and proposed remediation.

- *Continued Operation of the Existing Landfill Gas (LFG) System*. The existing LFG system is a fundamental and central building block upon which other remedial measures may be added.

- *Optimization of the Existing LFG System*. An evaluation of the existing LFG system is currently underway and, depending on the outcome, existing LFG system components may be replaced or enhanced.

- *Continued Operation of In-Home Vapor Intrusion (VI) Mitigation Systems.* The remedial measures contemplated for this report focus primarily on the removal of VOCs from groundwater. Removal of VOCs from groundwater should also reduce the occurrence of VOCs in soil gas. However, it is important to continue the In-Home VI Mitigation Systems until such time as the remedial measures proposed in this Revised CMA reduce concentration of VOCs in soil gas.

5.1 ALTERNATIVE A – NO ACTION

This Alternative A represents no implementation of remedial activities other than those common to all alternatives which includes those items described above. The optimization of the existing LFG system may improve removal of VOCs from groundwater and soil gas. Natural attenuation of the VOCs in the groundwater off of the landfill may occur but to what extent and over what period of time is unknown. Continued biannual groundwater and soil vapor monitoring in the existing network of groundwater and soil vapor wells, continued operation of the existing LFG blower and flare and continued monitoring and sampling of the existing in-home mitigation systems will be the primary activities performed for this alternative. It is assumed that monitoring and sampling of in-home mitigation systems will continue for ten years. Beyond this, it is assumed that vapor intrusion will be mitigated and no additional sampling and monitoring will be necessary.

5.2 ALTERNATIVE B – REMOVAL OF UNLINED CELL

In addition to those common actions described for Alternative A, this alternative consists of excavating wastes from the existing cell and transferring them to another lined repository. Options for a location for the lined repository include the existing Gallatin County Landfill near Logan, Montana, or constructing a new lined repository on City property at the existing Site or constructing a new lined repository at an as yet unknown and uninvestigated property.
If the Logan Landfill were to be selected as the site for excavated wastes, wastes would need to be trucked to the landfill. Haul routes for truck traffic to the Logan Landfill could include routes from the Site on Story Mill Road to Bridger Drive to Griffin Drive and then to Interstate 90. Another route could include a route north on McIlhattan Road to Sypes Canyon Road to the

Frontage Road and then to Interstate 90 to Logan. These routes are shown on **Figure 5-1**. Both of these routes include haul adjacent to either suburban settings for the McIlhattan/Sypes Canyon Route or through a section of the City of Bozeman. In either case, the chance for exposure of nearby residents to the odors of the putrescent wastes and possibly to other health effects is large. Also, trucking costs and tipping fees are likely to be large for any alternative that considers disposal at the Logan Landfill. The Logan Landfill charges $27.00 per ton for tipping fees. The amount and weight of wastes at the Site is not known as there are few records of the Site configuration at the time it was opened in 1970. However, the depth of wastes encountered during drilling of landfill gas extraction wells in the unlined cell is known and from this an estimate of the volume can be made (see **Appendix B**). There are approximately 3 million cubic yards (CY) of waste in the unlined cell. It is estimated that there could be anywhere from 1.0 to 2.0 million tons in the existing unlined cell depending on how dense the in-place wastes are. Tipping fees alone for this amount would range from $27 million to $54 million. Loading and hauling costs are likely to be an additional $30 million or more. It is not known if the Logan Landfill has sufficient remaining capacity for this amount of waste. For these reasons, hauling to the Logan Landfill is considered infeasible.

Locating another landfill site at an as yet unidentified property is usually a contentious and expensive process and could involve the purchase of property by the City for the new landfill site. Since the City already owns property at the existing landfill Site which is likely suitable for new landfill cells, it is most feasible to consider development of an additional cell or cells on the existing City Property at the Story Mill landfill Site. **Figure 5-2** shows the potential location of lined cells into which the waste from the existing unlined cell could be excavated and placed. No geologic or groundwater monitoring has been conducted at these sites but it is assumed due to their proximity to the existing cells that conditions at these two cells would be suitable for a landfill. Previously the City had studied the potential for adding cells on the City's property adjacent to the existing cells (Damschen-Entranco, 2000). At that time three potential cell sites were identified. One between the existing lined cell and the City Shop, another that would have filled the existing valley between the lined and unlined cells and a third located north of Churn Creek. For purposes of this Revised CMA, two relatively large cell locations north of Churn Creek have been identified as potential sites to which excavated waste from the existing unlined cell could be placed.

The proposed new cell or cells would be a lined facility similar to the existing lined cell. It would include a Flexible Membrane Liner (FML), gas collection and treatment system, leachate collection system, and surrounding gas and water monitoring wells. It is anticipated that the new cell or cells would be capped with a thick soil cap and revegetated. Roads, creek crossings, power installation and other infrastructure would be constructed to access the new cell or cells. When the new cell is ready to accept wastes, the soil cover over the existing unlined cell will be excavated and stockpiled. Underlying wastes will be loaded onto haul trucks and moved to the new cell. When the waste is exposed, it is anticipated that there will be significant odor issues and potential health impacts to both nearby residents and workers performing the excavation and haul.

On completion of removal of the wastes, the new cell or cells will be capped and closed. The old cell will be regraded and recontoured to its approximate original topography. Monitoring around the old cell will continue for some time until it is determined that residual impacts have been attenuated. Monitoring around the new lined cell will be implemented.

5.3 ALTERNATIVE C – SVE WELLS

A Soil Vapor Extraction (SVE) system would consist of wells drilled along the south side of the landfill. Each well would be screened from about 20 feet below ground surface to the groundwater level. Each well would be plumbed into a vacuum blower that would create a vacuum in soil vapor in the unsaturated vadose zone and would remove VOCs and landfill gases in that region. Collected VOCs would be treated either by filtering them through granular carbon media or by thermal destruction (a flare) or both. SVE wells by themselves do not remove VOCs from groundwater directly. However, they do remove VOCs indirectly. The mechanisms and effectiveness with which they do this are described in Section 3.3. **Figure 5-3** shows a conceptual SVE well system installation for the Site. Based on the results of a pilot test conducted during July and August of 2014, it is anticipated that 13 SVE wells would be placed along the southern boundary of the Site adjacent to the unlined cell. Each well would be spaced approximately 120 feet from adjacent wells. It is anticipated that a vacuum blower and treatment system to accompany the SVE wells would be located on the north side of the unlined cell in the vicinity of the existing LFG blower and flare. Gases collected from SVE wells are likely to be dilute. So if a flare is selected for destruction of the gases, it will likely need to be supplemented by propane. Some condensate from collected gases will occur. This will be captured in a condensate tank or tanks and periodically trucked or piped to the City's existing Publicly Owned Treatment Works (POTW).

5.4 ALTERNATIVE D – SVE WELLS WITH AIR SPARGING

This alternative builds on Alternative C by adding Air Sparging between proposed SVE wells. An air sparging well differs from an SVE well in that it injects fresh air into the groundwater at depth. A surface compressor provides fresh air that is supplied to each sparging well through a network of buried pipelines. As fresh air rises through the groundwater, VOCs dissolved in groundwater will be inducted into the air and be carried upward into the vadose zone. Adjacent SVE wells then remove the VOCs. The injected air also creates a curtain of slightly elevated air pressure along the line of sparging wells that tends to restrict the movement of VOCs away from the landfill and confine them to the north of the sparging wells.

One sparging well would replace every other SVE well described for Alternative C. SVE wells would be placed on the furthest east and west ends of the system. The compressor that supplies fresh air for sparging wells would be likely be located on the north side of the unlined cell near the existing vacuum pump and flare. Buried underground piping would supply compressed air to the to the sparging wells following approximately the same route as the buried underground piping that supplies the SVE wells. **Figure 5-4** shows a conceptual SVE-Sparging Well system.

5.5 ALTERNATIVE E – SVE WELLS WITH ADDITIONAL LFG WELLS

This alternative builds on Alternative C by adding additional LFG extraction wells within the footprint of the existing unlined cell. This provides source control by extracting VOCs from the waste mass before they have a chance to enter the soil vapor or the underlying groundwater. Six additional LFG wells would be constructed at the locations shown on **Figure 5-5**. The proposed LFG wells would be plumbed into the existing LFG collection system. Extracted LFG would be transported to and treated at the existing flare on the north side of the unlined cell. Some small adjustments to the existing flare may be necessary after additional LFG wells are constructed.

The locations shown on **Figure 5-5** were selected so as to be upgradient from MW-20 where the recent groundwater exceedance occurred and further to be as far from existing LFG wells as possible. Locating the proposed wells as far from existing LFG wells ensures a more consistent and even pattern of vacuum throughout the waste mass. Two of the additional LFG wells shown on **Figure 5-5** are located in the southeast corner of the existing unlined cell as replacements for a LFG well that was originally constructed near that location but which was later abandoned and plugged (GW-20).

5.6 ALTERNATIVE F – SVE WELLS, VZAI/AS WELLS AND ADDITIONAL LFG WELLS

This alternative builds on Alternative E by adding paired Vadose Zone Air Injection (VZAI)/Air Sparging (AS) wells between SVE wells. Paired VZAI/AS wells are constructed similarly to AS Wells except the two types of wells would be constructed side by side in the same drill hole. VZAI wells are different than AS wells in that they do not penetrate groundwater and provide a source of fresh air above the water table in the vadose zone. The VZAI/AS well pair attack VOCs dissolved in the groundwater in two ways. The first is by removal of VOCS below the groundwater surface into air injected there by the AS well and the second is by transfer of VOCs into fresh air at the groundwater boundary into air supplied by the VZAI. Adjacent SVE wells would remove the liberated VOCs and treat them at a proposed site on the north side of the existing unlined cell. One VZAI/AS well would replace every other SVE well as shown on **Figure 5-6**. The VZAI/AS wells would provide a curtain of slightly elevated pressurized air in the vadose zone on the south side of the cell. This would tend to confine VOC vapor migration in this direction.

Compressed air could be supplied to both VZAI and AS wells simultaneously or alternated between the VZAI well and the AS well. An irrigation system style timer and valve arrangement could be used to alternate air supply. This blended alternative provides clean air and resulting removal of VOCs in both the vadose zone and the groundwater plus it avoids the potential short circuiting in the vadose zone that sometimes occurs with AS wells alone.

5.7 ALTERNATIVE G – GROUNDWATER WITHDRAWAL AND TREATMENT

Alternative G involves withdrawal and treatment of VOC-containing groundwater from the uppermost portion of the aquifer along the southern boundary of the landfill. This alternative is not a source control measure in that it will prevent VOC containing groundwater from migrating off-site. Conceptually, groundwater would be withdrawn from seven wells installed along a section of the southern landfill boundary. **Figure 5-7** shows a conceptual arrangement of this system.

Treatment would likely include air stripping for removal of concentrations of VOCs from pumped groundwater. Treated water could be re-injected, land applied, placed into an infiltration gallery or potentially disposed to other local surface water features. This alternative is assumed to operate year-round for the highest degree of effectiveness.

A groundwater withdrawal pilot test would need to be conducted to determine pumping rates, radius of influence, optimal well screen, well packing material, average concentration of VOCs in the water, and confirm viability of the treatment alternative, which at present, is considered to be air stripping. Soil and infiltration testing may be needed to determine a sustained land application or infiltration rate, if reinjection is not conducted. General descriptions of the components of this alternative are presented below.

5.7.1 Groundwater Withdrawal

This technology would involve a series of wells and submersible pumps to extract groundwater. Conceptually, these wells would be located along the southern property boundary of the landfill at a distance where groundwater capture zones would be overlapping to prevent further migration of VOC impacted groundwater. Four-inch diameter wells, completed to depths of approximately 60 to 90 feet below ground surface, based on location, would provide sufficient volume for pumping and treatment based on available data. The wells would be screened across 15 to 20 feet of the saturated interval in the unconsolidated alluvial sediments. Screened sections of the well casing would be sized based on the physical characteristics of the formation material.

The estimated cost for this alternative assumes the installation of seven pumping wells spaced approximately 250 feet apart for a total treatment width of approximately 1,500 feet along the southern boundary of the landfill property. Wells would be drilled approximately 20 feet into the groundwater at approximately 60 to 90 feet below ground surface. Water pumped from these wells would be piped to an onsite treatment facility via piping buried below the frost level. Equipment would include seven submersible pumps capable of pumping up to 50 gallons per minute, power supply, an air stripping unit, piping, and valving.

5.7.2 Groundwater Treatment

It is assumed that conventional air-stripping equipment would be used to treat VOC-containing groundwater. Air stripping is a process where large volumes of air are forced through the water flowing down through a column filled with media. The media increases the surface area of the water. The air flow volatilizes VOCs in the water, which are carried to the top of the column or tower with the air stream. VOCs in the exhaust air would be removed most likely by passing VOCs in the air through activated carbon.

5.7.3 Treated Groundwater Land Application or Reinjection

Alternatives for management of treated groundwater include land application, pumping into an infiltration gallery, injection via one or more wells, and/or disposal to some local surface water. Land application may be the most cost effective alternative although it would be limited to above freezing conditions. Use of an infiltration gallery and/or injection into wells would require permits and an area for infiltration. The possibility of disposal into a local surface water feature should be evaluated during subsequent design. For purposes of this Revised CMA it is assumed that the location for discharge would be on City owned property north of Churn Creek and that the method of disposal would be either a buried infiltration gallery or a set of injection wells.

6.0 DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

6.1 ALTERNATIVE A – NO ACTION

As discussed in Section 5.0, Alternative A is the no action alternative and represents no implementation of additional corrective measures at the site. However, some common tasks are included in this alternative including continued groundwater and soil vapor monitoring, optimization and continued operation of the existing LFG extraction system, and continued operation of in-home VI mitigation systems. Natural attenuation of VOCs in the groundwater is included under this option. The performance of this alternative in meeting the criteria described in Section 2.0 is described below.

6.1.1 Ability to Meet Project Objectives

Be Protective of Human Health and the Environment – Because no specific action would be taken under this alternative to mitigate groundwater impacts near the landfill, other than remedies already implemented under the 1995 CMA, protectiveness would be provided by natural attenuating mechanisms decreasing contaminant concentration and inhibiting contaminant migration. These naturally occurring mechanisms include dilution, dispersion, biodegradation, and absorption. Protectiveness is also provided by the depth and general isolation of the groundwater from human and environmental receptors. While there are wells that withdraw water between the landfill and the East Gallatin River, they are generally used for lawn and garden watering and only incidental human contact is expected (see Section 3.4.1). The McIlhattan Seep and several groundwater fed ponds on the adjacent golf course to the west of the landfill property consists of surfacing groundwater and could provide an avenue for environmental exposures.

There is no evidence to suggest that groundwater with contaminant concentrations exceeding groundwater standards extend to the East Gallatin River. It is expected that groundwater contamination downgradient of the landfill would be significantly improved by the time it reaches the East Gallatin River through the naturally occurring mechanisms described above.

Achieve Compliance with Groundwater Protection Standards – Continued operation and optimization of the existing LFG extraction system in combination with natural attenuation could eventually lead to compliance with groundwater standards. The timeline for achieving standards is not known.

Provide for Source Control – Source control is already provided through the existing LFG extraction system. This system will be maintained and optimized as a part of this alternative.

Provide for Management of Wastes – No RCRA hazardous wastes will be generated under this alternative. Because of this, there is no need under Alternative A to provide for management of hazardous wastes.

6.1.2 Effectiveness

Performance and/or Reliability – Performance and reliability of this alternative may relate to degradation of the waste and natural attenuation. Degradation of the waste and natural attenuation is ongoing and requires no maintenance. Continued operation of the existing LFG extraction system will remove landfill gases. Some escape of VOCs has occurred from the existing system. These presumably have migrated to groundwater outside the site boundary.

Implementability – No design or construction of the alternative is needed***.***

Adverse impacts – Adverse impacts are expected to be minimal. Landfill wastes are buried and isolated. Landfill gas extracted by the existing LFG system is treated and discharged appropriately. VOC vapors in homes are being mitigated by existing in-house mitigation systems. Groundwater containing VOCs is generally deep and not readily available to human or animal exposure.

*Short- and long-term effectiveness and protectivene*ss – Although the existing system operated for many years during which time off-site groundwater did not exceed GPSs, recent results show off-site groundwater with VOC concentrations exceeding GPSs. Consequently short term effectiveness and protectiveness is not being provided. It is possible with optimization of the existing LFG system, long term effectiveness and protectiveness could be achieved but how long that might take to occur is not known.

Effectiveness of remedy in controlling source – As described in Section 3.3, the existing LFG extraction system operated many years during which off-site groundwater did not exceed GPSs. During this time, the source (LFG) was effectively controlled. Optimization of the existing system (which is ongoing) may provide additional source control but the degree of that additional source control is not known.

6.1.3 Time Required to Begin and Complete Remedy

This alternative is already mostly in place. Optimization of the existing LFG system may take a month or two beyond the date of this report. Continued monitoring of groundwater and vadose zone gas is expected to continue for at least fifteen years. Continued sampling and operation of in-house mitigation systems is expected to continue for approximately 10 years.

6.1.4 Institutional Requirements

No permits or other institutional authorizations beyond those already in effect would be required under this alternative.

6.1.5 Practical Capability of Owner/Operator

The landfill owner and operator have no practical capabilities to implement this alternative with their existing staffing. However, the landfill owner has the financial capability to implement this alternative.

6.1.6 Degree of Community Concerns

Some portion of the public may support the No Action Alternative because of its relatively low cost and effectiveness without generating wastes or creating additional infrastructure. Local residents in Bridger Creek Subdivisions and others surrounding the landfill have expressed many concerns with in-home VI. Because the VOC-containing groundwater may be a contributor to VI, it is assumed that they also would be concerned with groundwater impacts. Additional public comment on this and other alternatives will be sought at future public meetings.

6.1.7 Cost

Estimated costs for Alternative A are presented in **Appendix C-1**. The estimates include operating costs for the existing LFG system and in-home mitigation systems and continued monitoring of groundwater and soil gas. This alternative includes a small capital cost for replacing some parts on the existing LFG system to optimize its performance. It is estimated that capital cost to implement this alternative are $47,000 and annual operating costs are $176,000. Based on these costs and using a discount rate of 5%, the net present cost of this alternative over a 15-year lifespan is $1.87 million. A 15-year lifespan was selected to evaluate this and the other alternatives because gas generation in the landfill is expected to diminish to minor levels after 30 years of being buried, 15 years of which have already gone by.

6.2 ALTERNATIVE B – REMOVAL OF UNLINED CELL

As discussed in Section 5.0, this alternative consists of construction of a new lined cell or cells at a location on City property north of Churn Creek. Waste from the existing cell would be excavated, hauled and placed in the new cell or cells. The existing unlined cell location would be returned to its approximate original landform.

6.2.1 Ability to Meet Project Objectives

Be Protective of Human Health and the Environment – Lined landfill cells are generally accepted technologies that are recognized as protective of human health and the environment. During excavation and placement of the waste from the existing unlined cell may produce potential short-term human health impacts from exposure to the putrescent wastes.

Achieve Compliance with Groundwater Protection Standards – Removal and encapsulation of the wastes from the unlined cell should achieve compliance with GPSs at the location of the new lined cell. By removing the source of VOCs at the site of the existing unlined cell and through natural attenuation and dilution, residual contaminants at this site will over time meet GPSs.

Provide for Source Control – This alternative is essentially complete containment with gas and leachate collection and disposal. This could be considered as the ultimate level of source control.

Provide for Management of Wastes – Due to the age of the unlined cell and the nature of the contaminants found in groundwater and soil vapor surrounding the unlined cell, it is likely that some small amounts of hazardous wastes will be encountered during excavation and removal. If found, they will be removed and disposed of at an appropriate hazardous waste repository. No additional hazardous wastes will be generated as a result of implementation of this alternative.

6.2.2 Effectiveness

Performance and/or Reliability – Lined landfills are reliable at containing wastes and associated landfill gases.

Implementability – This alternative will involve considerable effort and time to implement. No studies have yet been done to determine if the new cell sites are suitable for landfill development. Hydrologic, geologic and other studies are necessary before the cell or cells will be ready for design. The design itself will take considerable effort to complete before the cell or cells can be constructed. Further, the cell locations are beyond the existing permit boundary so this will require an amendment of the existing permit. These necessary investigations and permitting are difficult but not insurmountable exercises.

Adverse impacts – Adverse impacts are likely to be temporary and minor. During construction, noise, dust and odors may occur.

*Short- and long-term effectiveness and protectivene*ss – Long term effectiveness of this alternative is anticipated to be very good. Due to the nature of the studies and tasks remaining until this alternative can be implemented, there is little in the short term that assures protectiveness.

Effectiveness of remedy in controlling source – Lined landfills are considered very effective at controlling landfill gases and leachate.

6.2.3 Time Required to Begin and Complete Remedy

This alternative is not quickly implemented. Between site investigations, design, permitting and construction, it is estimated that this alternative could be completed in as little as five years or it may stretch into ten years depending primarily on the amount of public opposition to the project.

6.2.4 Institutional Requirements

As noted above, the City's current permit boundary does not include the areas of the proposed new cell or cells. A permit amendment would have to be obtained. Permit amendments involve considerable public opinion and are often contentious. Additionally, a 404 permit will likely be required for constructing crossings of Churn Creek. This is obtained from the Corps of Engineers.

6.2.5 Practical Capability of Owner/Operator

The City is not practically capable of implementing this alternative with existing staffing. If implemented, it is anticipated that the City will rely heavily on contracted services to perform most of the work required for this alternative. It is doubtful that the City is financially capable of implementing this alternative.

6.2.6 Degree of Community Concerns

It is likely that there will be community concerns regarding the siting of the new cell and a permit amendment and costs for this alternative. There also will likely be community concerns regarding dust, noise and odors during construction of this alternative. Public comment regarding this and other alternatives will be taken during future public meetings.

6.2.7 Cost

Estimated costs for this alternative are presented in **Appendix C-2**. The cost for a new 40-acre cell north of Churn Creek was previously estimated in 2000 (Damschen-Entranco) as approximately $11.59M. At that time, waste would have been hauled to the cell as a normal part of garbage pickup and disposal. Consequently costs for hauling waste to the new cell were not included in the construction cost for the new cell. To adjust the previous estimate for the current situation, the 2000 estimated cost was adjusted to 2014 costs using published cost indices (Means, 2014). The result of this is that the 2014 cost for cell construction is approximately $19.3M. Additional costs for excavating, loading, hauling, placing waste from the unlined cell and engineering and administrative costs were added to the cost of cell construction. The total capital cost for cell construction and placement of the wastes there is estimated to be $57.5 Million. Annual operating costs include groundwater and soil vapor monitoring and continued operation of the in-home mitigation systems. We assumed that costs for monitoring at the proposed cell would be similar to monitoring at the existing cell ($55,000 per year). Total annual operating costs for this alternative are estimated to be approximately $219,000 per year. Using a discount rate of 5%, the present value of this alternative over a 15-year lifespan is approximately $59.8 Million.

6.3 ALTERNATIVE C – SOIL VAPOR EXTRACTION

6.3.1 Introduction to Soil Vapor Extraction

This alternative involves in-situ SVE and treatment of VOCs in the vadose zone that in turn, impact groundwater. Under this alternative, an active SVE system would be installed vertically along the southern boundary of the unlined cell. The southeast corner of the unlined cell has been identified as an area with the highest levels of PCE. Therefore, the SVE system will extend to the southeast corner of the site.

Recent soil gas testing confirms that LFG generated by the landfill contains chlorinated hydrocarbons and numerous other hydrocarbons. Field monitoring of the soil gas probes along the southern property boundary indicated that LFG has migrated beyond the waste boundary and is in contact with groundwater. There are three main mechanisms whereby LFG can cause groundwater contamination: (1) direct contact between groundwater and LFG, (2) LFG condensate formation and (3) infiltration of surface water through the vadose zone. These mechanisms are discussed in detail in Section 3.3.

The performance of an SVE system is governed by induced carrier gas flow (primarily ambient air) to extraction wells. Many complex processes occur on the micro scale; however, the three main factors that control the performance of the system are the chemical composition of the contaminants, vapor flow rates through the unsaturated zone, and the flow path of carrier gas relative to the location of the contaminants. Performance is maximized when large amounts of clean carrier gas is routed through the zone of contamination, allowing the contamination to partition from the sorbed or aqueous phases to the vapor phase (Johnson et al, 1991). VOCs in the vapor phase (LFG) would be directly captured in the extraction wells.

An active SVE system would be accompanied by treatment of the extracted gas and collection and management of condensate generated through the extraction process. The generated condensate would be collected and profiled for review and approval for disposal at a POTW. Upon acceptance, the condensate would be removed from the storage tank(s) and delivered to the POTW.

Operation of a pilot scale SVE system was necessary in order to determine feasibility and provide additional information that could be used to guide design of the full scale system. Pilot testing consisted of the installation of two SVE wells connected to a 5-hp blower and granulated activated carbon (GAC) to remove the contaminants. Results of the pilot test indicated that the subsurface soils on the southern edge of the landfill are suitable for SVE, as indicated by the propagation of vacuum in the subsurface. Based on the pilot scale flow rate and the initial concentration of PCE in the gas, one SVE pilot well removed approximately 3.33×10^{-3} lbs/day of PCE from the vadose zone.

As part of the SVE pilot test program, the gas extracted from the wells was sampled and tested. This information will help with the evaluation of treatment system options.

Figure 5-3 shows a conceptual layout of the Alternative C SVE extraction wells. The spacing between SVE wells is based on the results of the pilot test program. The Alternative C layout relies on pulling ambient air from the surface through the zone of contamination, identical to the pilot study.

6.3.2 Ability to Meet Project Objectives

In this section, the degree to which implementation of this alternative would achieve project objectives, as described in Section 2.0, is evaluated.

Protective of Human Health and the Environment – Alternative C would provide long-term protection to human health and the environment as long as the system is in operation. Groundwater containing VOCs beneath the active SVE system would see reductions in the concentration of contaminants. In addition, the potential for additional contamination caused by the vapor to groundwater mechanisms discussed in Section 3.3 would be reduced. The added protectiveness from this alternative may decrease the risk to residents living to the south of the landfill.

Achieve Compliance with Groundwater Protection Standards – This alternative may achieve compliance with GPSs for the constituents of concern at the south property boundary of the landfill. The amount of time to achieve compliance with GPSs depends on the contaminant mass removal rate achieved by the SVE system and the extent to which the SVE system remediates groundwater that has already left the property boundary.

Provide for Source Control – This alternative removes VOCs from the vadose zone before those contaminants reach the groundwater, potentially reducing the amount of VOCs entering groundwater. Therefore this alternative could be considered a form of source control as well as a remediation alternative. However, this technology primarily remediates the vadose zone and provides an environment where contaminants can partition from the aqueous phase to the vapor phase.

Provide for Management of Wastes – Hazardous wastes may be produced under this alternative if a GAC system is used to treat the gas and VOC concentrations accumulate to the point that the spent carbon meets hazardous waste criteria. The potential for generation of hazardous wastes would be significantly decreased with the use of a thermal oxidizer or flare to destroy the VOCs and other compounds extracted from the vadose zone. However, because the BTU content of the gas from the SVE system is low, the addition of propane to the gas stream may be required.

6.3.3 Effectiveness

Effectiveness criteria for this alternative are described below.

Performance and/or Reliability – Active SVE systems are proven to be effective and operationally reliable at numerous contaminated sites across the country and in a variety of environments and climates. The components of an SVE system are readily available. An important component of this alternative would be treatment of the soil gas collected by either GAC or a thermal oxidizer. Both technologies are reliable if operated correctly.

Implementability – To construct the SVE system, a local drilling contractor can be used. The SVE pilot test wells were installed with a local air rotary well driller. It is expected a total of 13 wells would be drilled and completed as 4-inch diameter SVE wells. The pilot test consisted of the installation of two wells which might be used as part of the full SVE system.

Once the SVE wells are constructed, other permanent components of the system would be installed including wellheads, lateral and header piping, valving, a condensate sump (if necessary), and the treatment facility (to be determined, thermal destruction or GAC). Operation, maintenance and monitoring of the operating SVE system is critical to ensure its effectiveness.

Adverse impacts – Workers installing the SVE wells and ancillary equipment could be exposed to physical safety hazards including fire, explosions, and potential chemical exposures to methane, carbon dioxide, and trace VOCs. During routine operation and maintenance of the system workers would have a low level of exposure to landfill gas and safety hazards. The potential for cross media impacts should be minimal because extracted gas and associated condensate would be treated by thermal destruction or GAC.

Human exposure to residual groundwater contamination is expected to be negligible because the VOC concentration is relatively low and current risk to humans is negligible. Residual VOCs in groundwater beyond the landfill property boundary may naturally attenuate.

Short- and long-term effectiveness and protectiveness – This alternative will be effective in removing VOCs that are contained primarily within the vadose zone along the southern perimeter of the landfill. Contaminants in the vadose zone are expected to rapidly decline after the SVE system is put into operation, but they may rebound after the system is turned off. Several episodes of attenuation and rebound of the VOC concentrations may be expected as a normal part of the overall cleanup process. Lower VOC concentrations in the soil gas adjacent to the groundwater surface will also result in an improvement in the quality of the groundwater south of the southern property boundary of the landfill. This improvement could occur in as little as one year.

There would be eventual long-term effectiveness as the existing off-site plume diffuses downgradient. Continued operation of the SVE system will be required to limit off-site migration of VOCs in the future. Continuous operation of this alternative would be required until compliance with groundwater protection standards is achieved. However, after compliance with groundwater protection standards is achieved, the SVE system may be operated on an intermittent basis depending upon perimeter LFG monitoring probe readings.

The active SVE system will require operational adjustments, monitoring and long-term maintenance. These requirements may decrease over time if the SVE system is operated on an intermittent basis rather than a continuous basis. The existing remedial alternative (the active LFG extraction system) should have continued and long-term effectiveness with routine maintenance.

Effectiveness of remedy in controlling source – Assuming that VOCs are primarily contained in LFG, this alternative will indirectly treat the source of groundwater impacts by controlling off site LFG migration and remediating VOC contamination in the vadose zone. All three main mechanisms causing groundwater contamination discussed in Section 3.3 will be positively affected by the removal of LFG from the vadose zone. In addition, the presence of clean ambient air in contact with groundwater will reduce the concentration of contaminants in the groundwater by allowing contaminants to partition from the sorbed or aqueous phases to the vapor phase.

Any condensate collected during the operation of the SVE system will be collected and treated in a POTW. Collected soil gas will be treated on-site through either thermal destruction or GAC.

6.3.4 Time Required to Begin and Complete Remedy

Pilot testing began on July 17, 2014, and is ongoing. Operation of the pilot SVE system is expected to result in partial remediation of the vadose zone surrounding SVE wells 1 and 2. After completion of pilot testing, the information necessary to design a full scale system will be analyzed. However, during the first phase of pilot testing, field data regarding the radius of influence of an SVE well was determined. The development of a suitable radius of influence in the vadose zone led to in a determination that SVE technology was a feasible alternative for this site. Once the most appropriate treatment system is confirmed for the extracted gas, construction of the permanent system can begin including subsurface collection system piping, the treatment system, installation of blowers, and electrical improvements. Construction of the permanent system may occur in as little as six months after completion of the pilot test. Project objectives could be met at the southern boundary of the landfill in as little as 1 year assuming VOCs are contained primarily in the soil and LFG in contact with groundwater is the primary source of PCE impacts to groundwater. The SVE system will likely operate on a continuous or intermittent basis until the landfill no longer generates significant quantities of gas, which is typically 30 years after the landfill is closed (Emcon, 1982). The unlined landfill cell was closed in 1995. LFG production could therefore continue until 2025; hence, approximately 15 years of continued LFG production is anticipated.

6.3.5 Institutional Requirements

State and local air quality permits will be needed to operate the SVE system. In addition, a modification to the landfill's closure plan may be required.

6.3.6 Practical Capability of Owner/Operator

Technically, the landfill owner and operator would have limited capability to implement the alternative. The landfill owner/operator has the financial capability to implement Alternative C.

6.3.7 Degree of Community Concerns

It is anticipated that there would not be any serious community concerns regarding implementation of this alternative. However, reaction of the public to Alternative C will be determined during a public meeting to be held in Bozeman.

6.3.8 Cost

Estimated costs for Alternative C are presented in **Appendix C-3**. The estimated cost includes the construction of the SVE system and 15 years of operations and maintenance. Alternative C capital costs are estimated to be $574,000 and ongoing operations and maintenance will cost $274,000 per year. Operation and maintenance for 15 years at an interest rate of 5% has a present worth of about $2.8 Million resulting in a total present worth cost of about $3.4 Million for this alternative.

6.4 ALTERNATIVE D – SOIL VAPOR EXTRACTION WITH AIR SPARGING

6.4.1 Introduction to Soil Vapor Extraction with Air Sparging

This alternative involves direct removal of VOCs from the groundwater through air sparging (AS). These VOCs have been measured in groundwater in monitoring wells MW-17 and MW-20. Similar to Alternative C, this alternative includes the installation of an active SVE system along the southern boundary of the unlined cell to work in concert with the AS. VOCs removed by the SVE/AS system would be treated in a flare at a location on the north side of the unlined cell.

Recent soil gas testing confirms that LFG generated by the decomposition of waste within the landfill contains chlorinated hydrocarbons and other hydrocarbons. Field monitoring of soil gas probes along the southern property boundary indicated that LFG has migrated beyond the waste boundary and is in contact with groundwater. There are three main mechanisms whereby LFG can cause groundwater contamination. These are discussed in Section 3.3.

The three main factors that control the performance of the SVE system are the chemical composition of the contaminants, vapor flow rates through the unsaturated zone, and the flow path of carrier gas relative to the location of the contaminants. Performance is maximized when large amounts of clean carrier gas is routed through the zone of contamination allowing the contamination to partition from the sorbed or aqueous phases to the vapor phase (Johnson et al, 1991).

Figure 5-4 shows a conceptual layout of the Alternative D SVE extraction wells with AS wells. The spacing between SVE wells is based on the results of the pilot test program. The Alternative D layout relies on pulling some ambient air from the surface through the zone of contamination, but primarily relies on the AS wells for a supply of carrier gas.

The function of the AS wells is to aerate the contaminated groundwater allowing contamination in the aqueous phase to partition into the vapor phase. AS wells are commonly used for this purpose. However, one drawback to this approach is the short circuiting of carrier gas (ambient air) from the AS well to the SVE well that limits the SVE well's ability to remove contaminants from the vadose zone.

The air delivery unit will consist of an oil-free air compressor capable of continuous operation supplying compressed air at pressures ranging from 5 to 25 pounds per square inch (psi) and providing a flow of compressed air ranging from 20 to 40 standard cubic feet per minute (SCFM) to each AS well. Each of the 2-inch diameter compressed air lines will be provided with a valve and flow measurement device.

An active SVE system would be accompanied by treatment of the extracted gas and collection and management of any condensate generated through the extraction process. The generated condensate would be collected and profiled for review and approval for disposal at a POTW. Upon acceptance, the condensate would be removed from the storage containers and delivered to the POTW.

Operation of a pilot scale SVE system to determine feasibility and provide additional information that could be used to guide design of the full scale system was recently completed. The pilot test did not include an AS well. However, based on lithologic information collected during the installation of groundwater monitoring wells, the site is suitable for AS. As part of the SVE pilot test program, gas extracted from the wells was sampled and tested. This information will help with the evaluation of treatment system options.

6.4.2 Ability to Meet Project Objectives

In this section, the degree to which implementation of this alternative would achieve project objectives, as described in Section 2.0, is evaluated.

Protective of Human Health and the Environment – Alternative D would provide long-term protection to human health and the environment. VOC impacted groundwater downgradient of the active SVE system may naturally attenuate. With the addition of AS wells to the active SVE system the concentration of contaminants in the groundwater may decrease more quickly than with the Alternative C system. Because the current and future risk to human health and the environment at the landfill is considered negligible, the added protectiveness under this alternative should sufficiently decrease the risk under most any future development in the vicinity.

Achieve Compliance with Groundwater Protection Standards – This alternative may achieve compliance with GPSs for the constituents of concern at the southern property boundary of the landfill. The time point at which this would occur would depend on the removal/attenuation/dispersion of VOC impacted landfill gas in the vadose zone and the movement of groundwater without VOC impacts to the south property boundary of the landfill.

Provide for Source Control – Like Alternative C, this alternative removes VOCs from the vadose zone before those contaminants reach the groundwater through the SVE wells. Therefore this alternative could be considered a form of source control as well as a remediation alternative. However, this technology primarily remediates VOCs in the vadose zone and in the groundwater underlying the vadose zone.

Provide for Management of Wastes – Hazardous wastes may be produced under this alternative if a GAC system is used and concentrations accumulate to the point in the spent carbon to meet hazardous waste criteria. The potential for hazardous wastes would be significantly decreased with the use of flare or thermal oxidizer to destroy the VOCs and other compounds in the extracted by the system. Condensate could potentially meet hazardous waste criteria. The condensate would be collected from the piping that would need to be sampled and likely disposed of through the existing sewer connection.

6.4.3 Effectiveness

Effectiveness criteria for Alternative D are described below.

Performance and/or Reliability – Active SVE systems are proven to be effective and operationally reliable at numerous contaminated sites across the country and in a variety of environments and climates. The components of an SVE system are readily available. The key component of the SVE system is the blower, which produces the vacuum for the system. Blowers are reliable but must be maintained. An important component of this alternative would be treatment of the soil gas collected by either GAC or a thermal oxidizer. Both technologies are reliable if operated correctly.

The AS wells will require a source of compressed air. The air compressor selected must be rated for continuous duty. Compressors are reliable but must be maintained.

Implementability – To construct the SVE system, a local drilling contractor can be used. The SVE pilot test wells were installed by a local air rotary well driller. It is expected a total of 7 wells would be drilled and completed as 4-inch diameter SVE wells. The pilot test consisted of the installation of two wells which can be used as part of the full SVE system.

AS wells would be installed between each SVE well. The AS wells would be advanced into the groundwater approximately 20 feet. It is expected a total of 6 wells would be drilled and completed as 2-inch diameter AS wells.

Once the SVE and AS wells are constructed, other permanent components of the system would be installed including wellheads, lateral and header piping, valving, a condensate sump (if necessary), and the treatment facility (to be determined, thermal destruction or GAC). Operation, maintenance and monitoring of the operating SVE system is critical to ensure its effectiveness.

Adverse impacts – Workers installing the SVE wells, AS wells and ancillary equipment could be exposed to physical safety hazards including fire, explosions, and potential chemical exposures to methane, carbon dioxide, and trace VOCs. During routine operation and maintenance of the system workers would have a low level of exposure to landfill gas and safety hazards. The potential for cross media impacts should be minimal because extracted gas and associated condensate would be treated by thermal destruction or GAC.

Human exposure to residual groundwater contamination is expected to be negligible because the VOC concentrations are relatively low. Residual VOCs in groundwater beyond the landfill property boundary may naturally attenuate.

Short- and long-term effectiveness and protectiveness – This alternative will be effective assuming that VOCs are contained within both the vadose zone and groundwater along the southern perimeter of the landfill. Contaminants in the vadose zone are expected to rapidly decline after the SVE system is put into operation, but they may rebound after the system is turned off. Several episodes of attenuation and rebound of the VOC concentrations may be expected as a normal part of the overall cleanup process.

AS wells will be effective volatilizing contaminants within the groundwater. However, AS wells “age” and short circuiting (the formation of preferential flow pathways) within the saturated formation soils may eventually occur.

Short-term effectiveness could occur when lower VOC concentrations in the soil gas adjacent to the groundwater surface decrease resulting in an improvement in the quality of the groundwater south of the southern property boundary of the landfill. This improvement could occur in as little as 1 year. Operation of AS wells in conjunction with the SVE wells may accelerate the removal of VOCs from the groundwater.

There would be eventual long-term effectiveness under this alternative as existing off-site VOCs diffuse downgradient. Continued operation of the SVE system will be required to limit future off-site migration of VOCs. Continuous operation of this alternative would be required until compliance with GPSs is achieved. However, after compliance with GPSs is achieved, the SVE system may be operated on an intermittent basis depending on perimeter LFG monitoring probe readings.

The active SVE system will require operational adjustments, monitoring and long-term maintenance. These requirements may decrease over time if the SVE system is operated on an intermittent basis rather than a continuous basis. The existing remedial alternative (active LFG extraction) should also have continued and long-term effectiveness with routine maintenance.

Effectiveness of remedy in controlling source – This alternative will indirectly treat the source of groundwater impacts by controlling off site LFG migration and remediating VOC contamination in the vadose zone and groundwater. All three main mechanisms causing groundwater contamination discussed in Section 3.3 will be positively affected by the removal of LFG from the vadose zone. In addition, the presence of clean ambient air in contact with groundwater will reduce the concentration of contaminants in the groundwater by allowing contaminants to partition from the sorbed or aqueous phases to the vapor phase.

Any condensate collected during the operation of the SVE system will be collected and treated in a POTW. Collected soil gas will be treated on-site through either thermal destruction or GAC.

6.4.4 Time Required to Begin and Complete Remedy

Pilot testing began on July 17, 2014, and is ongoing. Operation of the pilot SVE system is expected to result in partial remediation of the source area. The information necessary to design a full scale system is being acquired through the pilot test process. However, during the first phase of pilot testing field data regarding the radius of influence was obtained. The development of a suitable radius of influence in the vadose zone led to a determination that SVE technology was a feasible alternative for this site. Once the most appropriate treatment system is confirmed for the extracted gas, construction of the permanent system can begin, including subsurface collection system piping, the treatment system, installation of blowers, and electrical improvements. Construction of the permanent system may occur in as little as six months after completion of the pilot test.

Project objectives could be met at the southern boundary of the landfill in as little as 1 year, assuming VOCs are contained primarily in the soil and LFG in contact with groundwater is the primary source of the PCE in the groundwater. The SVE system will likely operate on a continuous or intermittent basis until the landfill no longer generates significant quantities of gas, which is typically 30 years after the landfill is closed. The unlined landfill cell was closed in 1995. LFG production could therefore continue until 2025; hence, approximately 15 years of continued LFG production is anticipated.

6.4.5 Institutional Requirements

State and local air quality permits will be needed to operate the SVE system. In addition, a modification to the landfill's closure plan may be required.

6.4.6 Practical Capability of Owner/Operator

Technically, the landfill owner and operator would have limited capability to implement the alternative. The landfill owner/operator has the financial capability to implement this alternative.

6.4.7 Degree of Community Concerns

It is anticipated that there would not be any serious community concerns regarding implementation of this alternative. However, reaction of the public to Alternative D will be determined during a public meeting to be held in Bozeman.

6.4.8 Cost

Estimated cost for Alternative D is presented in **Appendix C-4**. The estimated cost includes the construction of the SVE/AS system and 15 years of operations and maintenance. Alternative D capital costs are estimated to be approximately $666,000 and ongoing operations and maintenance will cost $320,000 per year. Operation and maintenance for 15 years at an interest rate of 5% has a present worth of about $3.3 Million resulting in a total present worth cost of about $4.0 Million for this alternative.

6.5 ALTERNATIVE E – SOIL VAPOR EXTRACTION AND ADDITIONAL LANDFILL GAS EXTRACTION WELLS

6.5.1 Soil Vapor Extraction with Additional Landfill Gas Extraction Wells

This alternative involves in-situ soil vapor extraction and treatment of VOCs in the vadose zone that in turn, impact groundwater. In addition, this alternative would include the installation of six new LFG extraction wells located in areas of the waste mass that would benefit from additional collection. Under this alternative an active SVE system would be installed along the southern boundary of the unlined cell as described in Alternative C. The southeast corner of the unlined cell has been identified as an area with the highest levels of PCE. Therefore, the SVE system will extend to the southeast corner of the site.

Recent soil gas testing confirms that LFG generated by the landfill contains chlorinated hydrocarbons and numerous other hydrocarbons. Field monitoring the soil gas probes along the southern property boundary indicated that LFG has migrated beyond the unlined closed cell's waste boundary and is in contact with groundwater. The migration of LFG off site is an indication that all the LFG being generated within the waste mass is not being collected and therefore the collection efficiency of the existing landfill gas extraction system needs to be increased. **Figure 5-5** depicts the six additional LFG extraction wells and their locations relative to the existing extraction wells.

Six additional LFG extraction wells will be located between existing extraction wells in the waste mass that is most likely responsible for the LFG migration to the south. Also, two of the additional LFG extraction wells would be placed near abandoned LFG extraction well GW-20 and will serve as replacements for that well. Benefits of additional LFG extraction wells include:

1. Enhanced LFG collection efficiency in the southeast corner of the waste mass where the highest concentrations of PCE have been detected.
2. Improved LFG quality and BTU content, allowing the flare to operate more reliably (continuous operation of the collection system is critical).
3. Additional LFG extraction wells will make it easier to optimize LFG collection in the southern half of the landfill because each well will be collecting from a smaller, more defined area of the waste mass; therefore each well is less likely to be "overpulled." In an overpull situation the LFG extraction well draws ambient air in to the landfill, killing the methanogenic bacteria that produce methane and carbon dioxide.

The performance of an SVE system is governed by induced carrier gas flow (primarily ambient air) to extraction wells. Many complex processes occur on the micro scale; however, the three main factors that control the performance of the system are the chemical composition of the contaminants, vapor flow rates through the unsaturated zone, and the flow path of carrier gas relative to the location of the contaminants. Performance is maximized when large amounts of clean, carrier gas is routed through the zone of contamination, allowing the contamination to partition from the sorbed or aqueous phases to the vapor phase.

An active SVE system would be accompanied by treatment of the extracted gas and collection and management of condensate generated through the extraction process. The generated condensate would be collected and profiled for review and approval for disposal at a POTW. Upon acceptance, the condensate would be removed from the storage containers and delivered to the POTW.

Alternative E would use the same SVE configuration as Alternative C. **Figure 5-5** shows a conceptual layout of the Alternative E SVE extraction wells with additional LFG extraction wells.

6.5.2 Ability to Meet Project Objectives

In this section, the degree to which implementation of this alternative would achieve project objectives, as described in Section 2.0, is evaluated.

Protective of Human Health and the Environment - Alternative E would provide long-term protection to human health and the environment as long as the system is in operation. VOC-containing groundwater beneath the active SVE system would see reductions in the concentration of contaminants. In addition, the potential for additional contamination caused by the three main contamination mechanisms discussed in Section 3.3 would be greatly reduced. Alternative E includes enhancements to the LFG collection system which would reduce the amount of LFG entering the vadose zone, reducing the mass of contamination that must be captured by the SVE system. Because the current and future risk to human health and the environment at the landfill is considered negligible, the added protectiveness under this alternative should decrease the risk to residents living in to the south of the landfill.

Achieve Compliance with Groundwater Protection Standards – This alternative may achieve compliance with groundwater protection standards for the constituents of concern at the south property boundary of the landfill. The amount of time to achieve compliance with groundwater protection standards depends on the contaminant mass removal rate achieved by the SVE system and the extent and speed at which natural processes remediate groundwater that has already left the property boundary.

Provide for Source Control – Alternative E will increase the collection efficiency of the existing LFG system, which is source control. This alternative also removes VOCs from the vadose zone before those contaminants reach the groundwater, potentially reducing the amount of VOCs entering groundwater. Both of these could be considered source control. However, SVE technology primarily remediates the vadose zone and provides an environment where contaminants can partition from the aqueous phase to the vapor phase.

Provide for Management of Wastes – Additional LFG collected can be destroyed by the existing flare. Hazardous wastes may be produced under this alternative if a GAC system is used to treat the gas and VOC concentrations accumulate to the point that the spent carbon meets hazardous waste criteria. The potential for generation of hazardous wastes would be significantly decreased with the use of a thermal oxidizer or flare to destroy the VOCs and other compounds extracted from the vadose zone. However, the addition of propane to the gas stream may be required because the BTU content of the gas from the SVE system is low.

6.5.3 Effectiveness

Effectiveness criteria for Alternative E are described below.

Performance and/or Reliability – The addition of higher BTU LFG from the six new LFG extraction wells will increase the overall BTU content of the LFG destroyed by the flare. This increase in the LFG's BTU content should increase the reliability of the collection system. Active SVE systems are proven to be effective and operationally reliable at numerous contaminated sites across the country and in a variety of environments and climates. The components of an SVE system are readily available. An important component of this alternative would be treatment of the soil gas collected by either GAC or a thermal oxidizer. Both technologies are reliable if operated correctly.

Implementability –To install additional LFG wells and construct the SVE system, a local drilling contractor can be used. The SVE pilot test wells were installed by a local air rotary well driller. It is expected that a total of 12 wells would be drilled and completed as 4-inch diameter SVE wells. The pilot test consisted of the installation of two wells which can be used as part of the full SVE system.

Once the SVE wells are constructed, other permanent components of the system would be installed including wellheads, lateral and header piping, valving, a condensate sump (if necessary), and the treatment facility (to be determined, thermal destruction or GAC). Operation, maintenance and monitoring of the operating SVE system is critical to ensure its effectiveness.

Adverse impacts – Workers installing the additional LFG wells, SVE wells and ancillary equipment could be exposed to physical safety hazards including fire, explosions, and potential chemical exposures to methane, carbon dioxide, and trace VOCs. During routine operation and maintenance of the system, workers would have a low level of exposure to landfill gas and safety hazards. The potential for cross media impacts should be minimal because extracted gas and associated condensate would be treated by thermal destruction or GAC.

Human exposure to residual groundwater contamination is expected to be negligible because the VOC concentration is relatively low and current risk to humans is negligible. Residual VOCs in groundwater beyond the landfill property boundary may naturally attenuate.

Short- and long-term effectiveness and protectiveness – Alternative E will be effective because it combines two types of groundwater contamination source control strategies: enhanced LFG collection and removal of contaminants in the vadose zone before they can impact groundwater. The effectiveness of the SVE system assumes that VOCs are contained within the vadose zone along the southern perimeter of the landfill and the soils in that area are air permeable. Contaminants in the vadose zone are expected to rapidly decline after the SVE system is put into operation, but may rebound after the system is turned off. Several episodes of attenuation and rebound of the VOC concentrations may be expected as a normal part of the overall cleanup process.

The elimination of the offsite migration of LFG by adding six new LFG extraction wells within the waste mass should be immediately effective. Short-term effectiveness could occur when VOC concentrations in the soil gas adjacent to the groundwater surface decrease resulting in an improvement in the quality of the groundwater south of the southern property boundary of the landfill. This improvement could occur in as little as one year.

There would be eventual long-term effectiveness as the existing off site VOCs diffuse downgradient or are otherwise naturally attenuated. Continued operation of the LFG collection system and SVE system will be required to limit off site migration of VOCs in the future. Continuous operation of this alternative would be required until compliance with GPSs is achieved. However, after compliance with GPSs is achieved the SVE system may be operated on an intermittent basis, depending upon perimeter LFG monitoring probe readings.

Both the LFG collection system and the active SVE system will require operational adjustments, monitoring and long-term maintenance. These requirements may decrease over time if the SVE system is operated on an intermittent basis rather than a continuous basis. The existing remedial alternative (the active LFG extraction system) should have continued and long-term effectiveness with routine maintenance.

Effectiveness of remedy in controlling source – Alternative E combines a groundwater contamination source control (enhanced LFG collection) with an active removal of contaminants in the vadose zone before they can impact groundwater. Assuming that VOCs are transported by the LFG, this alternative will indirectly treat the source of groundwater impacts by controlling off site LFG migration and remediating VOC contamination in the vadose zone. All three main mechanisms causing groundwater contamination discussed in Section 6.3.1 will be positively affected by the removal of LFG from the vadose zone. In addition, the presence of clean ambient air in contact with groundwater will reduce the concentration of contaminants in the groundwater by allowing contaminants to partition from the sorbed or aqueous phases to the vapor phase.

Any condensate collected during the operation of the SVE system will be collected and treated in a POTW. Collected soil gas will be treated on site through either thermal destruction or GAC.

6.5.4 Time Required to Begin and Complete Remedy

Pilot testing began on July 17, 2014, and is ongoing. Operation of the pilot SVE system is expected to result in partial remediation of the source area. After completion of pilot testing, the information necessary to design a full scale system will be analyzed. However, during the first phase of pilot testing field data regarding the radius of influence was obtained. The development of a suitable radius of influence in the vadose zone led to a determination that SVE technology was a feasible alternative for this site. Once the most appropriate treatment system is confirmed for the extracted gas, construction of the permanent system can begin including subsurface collection system piping, the treatment system, installation of blowers, and electrical improvements. Construction of the permanent SVE system and the enhanced LFG collection system can occur concurrently. Construction may be substantially complete in as little as six months after completion of the pilot test.

Project objectives could be met at the southern boundary of the landfill in as little as one year, assuming VOCs are contained primarily in the soil and LFG in contact with groundwater is the primary source of PCE in groundwater. The SVE system will likely operate on a continuous or intermittent basis until the landfill no longer generates significant quantities of gas, which is typically 30 years after the landfill is closed. The unlined landfill cell was closed in 1995. LFG production could therefore continue until 2025; hence, approximately 15 years of continued LFG production is anticipated.

6.5.5 Institutional Requirements

State and local air quality permits will be needed to operate the SVE system. In addition, a modification to the landfill's closure plan may be required.

6.5.6 Practical Capability of Owner/Operator

Technically, the landfill owner and operator would have limited capability to implement the alternative. The landfill owner/operator has the financial capability to implement Alternative E.

6.5.7 Degree of Community Concerns

It is anticipated that there would not be any serious community concerns regarding implementation of this alternative. However, reaction of the public to Alternative E will be determined during a public meeting to be held in Bozeman.

6.5.8 Cost

Estimated cost for Alternative E is presented in **Appendix C-5**. The estimated cost includes the construction of the SVE system and additional LFG wells and 15 years of operations and maintenance. Capital costs for Alternative E are estimated to be $661,000 and ongoing operations and maintenance will cost $264,000 per year. Operation and maintenance for 15 years at an interest rate of 5% has a present worth of about $2.7 Million resulting in a total present worth cost of about $3.4 Million for this alternative.

6.6 ALTERNATIVE F – SOIL VAPOR EXTRACTION, VADOSE ZONE AIR INJECTION/AIR SPARGING AND ADDITIONAL LANDFILL GAS EXTRACTION WELLS

6.6.1 Soil Vapor Extraction with Vadose Zone Air Injection, Air Sparging and Additional Landfill Gas Extraction Wells

This alternative involves in-situ SVE with vadose zone air injection (VZAI) and air injection into the groundwater through AS wells. In addition, this alternative would include the installation of six new LFG extraction wells located in areas of the waste mass that would benefit from additional collection. Similar to Alternative C, this alternative includes the installation of an active SVE system along the southern boundary of the unlined cell. However, Alternative F also includes the installation of vertical air injection wells between each SVE well.

The three main factors that control the performance of the system are the chemical composition of the contaminants, vapor flow rates through the unsaturated zone, and the flow path of carrier gas relative to the location of the contaminants. Performance is maximized when large amounts of clean carrier gas is routed through the zone of contamination allowing the contamination to partition from the sorbed or aqueous phases to the vapor phase.

Figure 5-6 shows a conceptual layout of the Alternative F SVE extraction wells with VZAI/AS wells. Alternative F would use the same SVE configuration as Alternative D, but the VZAI/AS wells would be installed in place of the AS wells. The spacing between SVE wells is based on the results of the pilot test program. The Alternative F layout relies on supplying ambient air directly to the vadose zone and to the groundwater so that the flow paths from supplied air sweep throughout potential zones where VOCs may be located. This alternative maximizes the amount of clean carrier gas introduced and may have the most complete coverage of the vadose zone.

The performance of an SVE system is partially governed by the volume of induced carrier gas flow (primarily ambient air) supplied to extraction wells. Many complex processes occur on the micro scale; however, the three main factors that control the performance of the system are the chemical composition of the contaminants, vapor flow rates through the unsaturated zone, and the flow path of carrier gas relative to the location of the contaminants. The function of the VZAI wells is to maximize the amount of carrier gas flow (primarily ambient air) through the contaminated soil above the groundwater, allowing contamination in the sorbed and aqueous phases to partition into the vapor phase. VZAI wells are used to control the area of influence of an SVE system. In this case, the linear installation of alternating SVE and VZAI/AS wells would limit the impact of the system on the in-place waste.

The air delivery unit will consist of an oil-free air compressor capable of continuous operation supplying compressed air at pressures ranging from 5 to 25 psig and providing a flow of compressed air ranging from 20 to 40 SCFM to each VZAI well. Each of the 2-inch diameter compressed air lines will be provided with a valve and flow measurement device.

An active SVE system would be accompanied by treatment of the extracted gas and collection and management of condensate generated through the extraction process. The generated condensate would be collected and profiled for review and approval for disposal at a POTW. Upon acceptance, the condensate would be removed from the storage containers and delivered to the POTW.

Operation of a pilot scale SVE system to determine feasibility and provide additional information that could be used to guide design of the full scale system has not been completed. The pilot test does not include a VZAI/AS well. However, based on lithologic information collected during the installation of groundwater monitoring wells, the site is suitable for air injection.

The migration of LFG off site is an indication that all the LFG being generated within the waste mass is not being collected and therefore the collection efficiency of the existing landfill gas extraction system needs to be increased. Therefore Alternative F includes enhancements to the existing LFG collection system with the addition of six additional LFG extraction wells. **Figure 5-6** depicts the six additional LFG extraction wells and their locations relative to the existing extraction wells.

Six additional LFG extraction wells will be located between existing extraction wells in the waste mass that is most likely responsible for the LFG migration to the south. Also, two of the additional LFG extraction wells will be placed near abandoned LFG extraction well GW-20 and will serve as replacements for that well. Benefits of additional LFG extraction wells include:

1. Enhanced LFG collection efficiency in the southeast corner of the waste mass where the highest concentrations of PCE have been detected at soil gas probe BSV-9.
2. Improved LFG quality and BTU content, allowing the flare to operate more reliably (continuous operation of the collection system is critical).
3. Additional LFG extraction wells will make it easier to optimize LFG collection in the southern half of the landfill because each well will be collecting from a smaller, more defined area of the waste mass; therefore each well is less likely to be “overpulled”. In an overpull situation the LFG extraction well draws ambient air in to the landfill, killing the methanogenic bacteria that produce methane and carbon dioxide.

6.6.2 Ability to Meet Project Objectives

In this section, the degree to which implementation of this alternative would achieve project objectives, as described in Section 2.0, is evaluated.

Protective of Human Health and the Environment - Alternative F would provide long-term protection to human health and the environment as long as the system is in operation. VOC-containing groundwater beneath the active SVE system would see reductions in the concentration of contaminants. In addition, the potential for additional contamination caused by the three main contamination mechanisms discussed in Section 3.3 would be greatly reduced. As with Alternative E, Alternative F's enhancements to the LFG collection system would reduce the amount of LFG entering the vadose zone, thereby reducing the mass of contamination that must be captured by the SVE system. Because the current and future risk to human health and the environment at the landfill is considered negligible, the added protectiveness under this alternative should sufficiently decrease the risk to residents living in to the south of the landfill.

Achieve Compliance with Groundwater Protection Standards – This alternative may achieve compliance with GPSs for the constituents of concern at the southern property boundary of the landfill. The amount of time to achieve compliance with GPSs depends on the contaminant mass removal rate achieved by the SVE system and the extent and rate at which natural attenuation remediates groundwater that has already left the property boundary.

Provide for Source Control – Alternative F will increase the collection efficiency of the existing LFG system, which is source control. This alternative also removes VOCs from the vadose zone before those contaminants reach the groundwater, potentially reduced the amount of VOCs entering groundwater. Therefore this alternative could be considered a form of source control as well as a remediation alternative. However, this technology primarily remediates the vadose zone but provides an environment where VOCs in the groundwater can partition from the aqueous phase to the vapor phase.

Provide for Management of Wastes – Additional LFG collected by the enhanced system can be destroyed by the existing flare. Hazardous wastes may be produced under this alternative if a GAC system is used to treat the gas and VOC concentrations accumulate to the point that the spent carbon meets hazardous waste criteria. The potential for generation of hazardous wastes would be significantly decreased with the use of a thermal oxidizer or flare to destroy the VOCs and other compounds extracted from the vadose zone. However, because the BTU content of the gas from the SVE system is low, the addition of propane to the gas stream may be required.

6.6.3 Effectiveness

Effectiveness criteria for Alternative F are described below.

Performance and/or Reliability – The addition of higher BTU LFG from the six new LFG wells will increase the overall BTU content of the LFG destroyed by the flare. This increase in the LFG's BTU content should increase the operational reliability of the collection system. Active SVE systems are proven to be effective and operationally reliable at numerous contaminated sites across the country and in a variety of environments and climates. The components of an SVE/AS/VZAI systems are readily available. An important component of this alternative would be treatment of the soil gas collected by either GAC or a thermal oxidizer. Both technologies are reliable if operated correctly.

Implementability – To install additional LFG wells and construct the SVE system, a local drilling contractor can be used. The SVE pilot test wells were installed by a local air rotary well driller. It is expected a total of 7 wells would be drilled and completed as 4-inch diameter SVE wells. The pilot test consisted of the installation of two wells which can be used as part of the full SVE system.

VZAI/AS wells would be installed between each SVE well. The VZAI wells would be advanced to the groundwater while the AS wells would be advanced into and screened in the groundwater. It is expected a total of 6 wells would be drilled and completed as 2-inch diameter VZAI/AS wells.

Once the SVE and VZAI/AS wells are constructed, other permanent components of the system would be installed including wellheads, lateral and header piping, valving, a condensate sump (if necessary), and the treatment facility (to be determined, thermal destruction or GAC). Operation, maintenance and monitoring of the operating SVE system is critical to ensure its effectiveness.

Adverse impacts – Workers installing the additional LFG wells, SVE/VZAI wells and ancillary equipment could be exposed to physical safety hazards including fire, explosions, and potential chemical exposures to methane, carbon dioxide, and trace VOCs. During routine operation and maintenance of the system, workers would have a low level of exposure to landfill gas and safety hazards. The potential for cross media impacts should be minimal because extracted gas and associated condensate would be treated by thermal destruction or GAC.

Human exposure to residual groundwater contamination is expected to be negligible because the VOC concentration is relatively low and current risk to humans is negligible. Residual VOCs in groundwater beyond the landfill property boundary may naturally attenuate.

Short- and long-term effectiveness and protectiveness – Alternative F will be effective because it combines three types of groundwater contamination source/remediation control strategies: enhanced LFG collection, removal of VOCs in the vadose zone before they can impact groundwater, and direct removal from the groundwater. The effectiveness of the SVE system assumes that VOCs are contained within the vadose zone along the southern perimeter of the landfill and the soils in that area are air permeable. VOCs in the vadose zone are expected to rapidly decline after the SVE system is put into operation, but may rebound after the system is turned off. Several episodes of attenuation and rebound of the VOC concentrations may be expected as a normal part of the overall cleanup process.

The elimination of the offsite migration of LFG by adding six new LFG wells within the waste mass should be immediately effective. Short-term effectiveness could occur when lower VOC concentrations in the soil gas adjacent to the groundwater surface decrease, resulting in an improvement in the quality of the groundwater south of the southern property boundary of the landfill. This improvement could occur in as little as one year.

There would be eventual long-term effectiveness, as the existing off site VOCs diffuse downgradient or are otherwise attenuated naturally. Continued operation of the LFG collection system and SVE system will be required to limit off-site migration of VOCs in the future. Continuous operation of this alternative would be required until compliance with GPSs is achieved. However, after compliance with GPSs is achieved the SVE system may be operated on an intermittent basis depending upon perimeter LFG monitoring probe readings.

Both the LFG collection system, the active SVE system and the VZAI/AS wells will require operational adjustments, monitoring and long-term maintenance. These requirements may decrease over time if the SVE/VZAI/AS system is operated on an intermittent basis rather than a continuous basis. The existing remedial alternative (active LFG extraction system) should have continued and long-term effectiveness with routine maintenance.

Effectiveness of remedy in controlling source – Alternative F combines three types of groundwater contamination source control strategies, enhanced LFG collection and removal of contaminants in the vadose zone before they can impact groundwater. Assuming that VOCs are transported by the LFG, this alternative will indirectly treat the source of VOCs in groundwater by controlling off site LFG migration and remediating VOCs in the vadose zone. All three main mechanisms causing groundwater contamination discussed in Section 6.3.1 will be positively affected by the removal of LFG from the vadose zone. In addition, the presence of clean ambient air in contact with groundwater will reduce the concentration of VOCs in the groundwater by allowing VOCs to partition from the aqueous phase to the vapor phase.

Any condensate collected during the operation of the SVE system will be collected and treated in a POTW. Collected soil gas will be treated on-site through either thermal destruction or GAC.

6.6.4 Time Required to Begin and Complete Remedy

Pilot testing began on July 17, 2014, and is ongoing. Operation of the pilot SVE system is expected to result in partial remediation of the source area. After completion of pilot testing, the information necessary to design a full scale system will be analyzed. However, during the first phase of pilot testing field data regarding the radius of influence was obtained. The development of a suitable radius of influence in the vadose zone led to in a determination that SVE technology was a feasible alternative for this site. Once the most appropriate treatment system is confirmed for the extracted gas, construction of the permanent system can begin, including subsurface collection system piping, the treatment system, installation of blowers, and electrical improvements. Construction of the permanent SVE/VZAI/AS system and the enhanced LFG collection system can occur concurrently. Construction may be substantially complete in as little as six months after completion of the pilot test.

Project objectives could be met at the southern boundary of the landfill in as little as one year, assuming VOCs are contained primarily in the soil and LFG in contact with groundwater is the primary source of PCE impacts to groundwater. The SVE system will likely operate on a continuous or intermittent basis until the landfill no longer generates significant quantities of gas, which is typically 30 years after the landfill is closed. The unlined landfill cell was closed in 1995. LFG production could therefore continue until 2025;hence, approximately 15 years of continued LFG production is anticipated.

6.6.5 Institutional Requirements

State and local air quality permits will be needed to operate the SVE system. In addition, a modification to the landfill's closure plan may be required.

6.6.6 Practical Capability of Owner/Operator

Technically, the landfill owner and operator would have limited capability to implement the alternative. The landfill owner/operator has the financial capability to implement Alternative F.

6.6.7 Degree of Community Concerns

It is anticipated that there would not be any serious community concerns regarding implementation of this alternative. However, reaction of the public to Alternative F will be determined during a public meeting to be held in Bozeman.

6.6.8 Cost

Estimated cost for Alternative F is presented in **Appendix C-6**. The estimated cost includes the construction of the SVE system, additional LFG wells and VZAI/AS system and 15 years of operations and maintenance. Capital costs for Alternative E are estimated to be approximately

$836,000 and ongoing operations and maintenance are estimated to cost $310,000 per year. Total net present cost for this alternative for 15 years at an interest rate of 5% has a present worth cost of approximately $4.1 Million.

6.7 ALTERNATIVE G – GROUNDWATER WITHDRAWAL AND TREATMENT

Under this alternative, groundwater withdrawal and treatment (pump and treat) would be conducted. As indicated in Section 5.7 groundwater would be withdrawn from wells installed along a section on the southern landfill boundary. Treatment would include air stripping for removal of VOCs. Treated water could be re-injected, land applied, placed into an infiltration gallery, and/or potentially disposed of in other local surface waters.

6.7.1 Ability to Meet Project Objectives

In this section, the degree to which implementation of Alternative G would achieve project objectives is evaluated.

Protective of Human Health and the Environment – Alternative G would be protective of human health and the environment. Pumping wells installed along the southern boundary of the landfill property should prevent migration of VOC-containing groundwater south of the landfill property. Because the current and future risk to human health and the environment from VOC-containing groundwater is relatively small, groundwater treatment could ensure improved groundwater quality and a decrease in soil gas VOCs.

Achieve Compliance with Groundwater Protection Standards – This alternative should achieve compliance with GPSs for the constituents of concern at the south boundary of the landfill property. However, VOC-containing groundwater south of the proposed line of pumping wells may not be affected by this alternative depending on the radius of influence.

Provide for Source Control – Implementation of Alternative G would be considered as a groundwater control and treatment measure, and not controlling the source of VOC impacts which is attributed to landfill gas and leachate. The existing earthen cap, revegetation, water diversion structures and LFG Extraction System would remain in place to minimize leachate and landfill gas production and migration. These existing controls are considered, minimally, as source control measures.

Provide for Management of Wastes – Wastes would be generated in this alternative and would need to be managed. VOC-containing groundwater pumped to the surface will be routed to a treatment system. Conceptually, an air stripping system would remove VOCs from groundwater, but these VOCs would either be vented directly to the atmosphere or treated. Pilot testing will determine if air stripping (aeration) is entirely effective or if GAC is needed as a more effective or additional water treatment step. Air effluent containing VOCs generated during air stripping may need to be permitted. Spent GAC filter media would require disposal or regeneration. The spent GAC may be classified as a hazardous waste. If classified as a hazardous waste, special shipping requirements would be necessary to transport the carbon to a regeneration plant or RCRA disposal facility. The treated groundwater would, in effect, be a waste that could be used beneficially or applied to the subsurface.

6.7.2 Effectiveness

Effectiveness criteria for Alternative G is described below.

Performance and/or Reliability – The alternative would be constructed to operate year-round to maintain good performance. The operational reliability of the alternative will depend on routine maintenance and repair. Scaling and bio-fouling may occur in wells and the air stripper system which can be difficult to alleviate. Over the long-term, it may be necessary to replace or repair pumping wells, submersible pumps, and air stripper or GAC media. An effective sediment filtration system will ensure reliability of system operation and return of treated water. Routine maintenance of the air stripper and filtration system should minimize downtime and repair costs. If GAC is used, regeneration or disposal will be a routine requirement. System components can be replaced readily should the need arise.

Degradation of the landfill waste is ongoing and requires no maintenance. Natural attenuation is also ongoing and requires no maintenance. The existing landfill gas extraction system continues to operate reliably. The existing earthen capping, revegetated areas, and water diversion structures have proven reliable. These should require minimal maintenance.

Implementability – This alternative can be implemented using conventional equipment, such as water well drilling equipment and excavation equipment if an infiltration trench is constructed. Equipment and materials would likely be ordered and shipped to Bozeman. Air stripping and GAC treatment equipment can be purchased as modular assemblies shipped to the site for installation by local contractors.

Adverse impacts – This alternative, groundwater withdrawal, could potentially impact flow in nearby springs if the source of the springs is the water bearing interval in the alluvial fan deposit. Depending on the location of the return of withdrawn (and treated) groundwater, spring flow could also increase. Additional research or field investigation may need to be conducted to evaluate source formations of springs in the site vicinity if this alternative will be implemented. The alternative would, to a minor degree, impact air quality if an air stripper was used in the treatment of VOC-impacted groundwater. If VOCs are of sufficient concentration and air treatment becomes necessary, air treatment devices such as a thermal oxidizer or GAC unit could be installed to achieve acceptable emissions standards.

As with virtually all pump and treat systems, residual VOC-impacted groundwater may escape the fence of pumping wells and continue migrating to the southwest. Return of withdrawn groundwater also has the potential to alter the natural groundwater flow direction and gradient to then affect the disposition of the area of VOC-containing groundwater.

Short- and long-term effectiveness and protectiveness – Assuming placement of pumping wells along the southern property boundary of the landfill, short-term effectiveness of remediation of the entire area of impacted groundwater is not expected to occur, however, there would be short term effectiveness in the area immediately surrounding and downgradient of the extraction wells.

There would be eventual long-term effectiveness, as the existing off-site VOCs dissipate or are otherwise naturally attenuated during continued operation of the alternative. The alternative would need to be operated through the period of landfill waste decomposition with its accompanying gas and/or leachate generation to maintain long-term effectiveness. In addition, effectiveness may be compromised due to the difficulties in capturing all downgradient migrating VOCs.

Short- and long-term protectiveness would be unchanged compared with the current situation because impacted groundwater exposure potential to humans and the environment is negligible. The source of contamination with inferred VOC-impacted landfill leachate and landfill gas would not be disturbed during construction. The existing remedial alternatives consisting of earthen capping, revegetation, water diversion structures, and active landfill gas extraction system should have their continued and long-term effectiveness with routine maintenance.

Effectiveness of remedy in controlling source – The alternative is not considered effective in decreasing source concentrations of leachate or landfill gas inferred to contain VOCs that, in turn, migrate into the underlying groundwater. The alternative could be effective in controlling VOC-containing groundwater migrating away from the waste source and off of the landfill property.

The existing remedial alternatives consisting of earthen capping, revegetation, water diversion structures, and the existing LFG extraction system likely have some degree of effectiveness in controlling the source of VOCs in groundwater. However, the magnitude of reduction of leachate and landfill gas attributed to these existing remedial alternatives has not been measured.

6.7.3 Time Required to Begin and Complete Remedy

Construction of this alternative to full scale would likely take from four to six months duration. Full scale operation would likely occur for a minimum of 15 years. Eventual completion of this alternative would rely on a decline in the generation of landfill gas and/or leachates containing VOCs within the landfill waste to levels where VOC containing groundwater near the groundwater withdrawal wells would be below the GPS for COCs.

6.7.4 Institutional Requirements

A permit to withdraw groundwater may be required. A discharge permit will be required to land apply, infiltrate, or inject the treated water. Water rights and/or the need to attain a water right may need to be considered, as well. In addition, an air discharge permit may be required for air emissions from the air stripper.

6.7.5 Practical Capability of Owner/Operator

Technically, the landfill owner and operator would have limited capability to implement the alternative. The owner most likely has the financial capability to implement the alternative.

6.7.6 Degree of Community Concerns

It is anticipated there would be a community concern with regard to any potential change in flow or water quality of area springs, other surface water features, and groundwater in the site vicinity due to full scale implementation of this alternative.

6.7.7 Cost

Estimated costs for Alternative G are presented in **Appendix C-7**. There is considerable uncertainty in these costs where more pumping wells would be needed as determined by additional field testing/operation and this would translate to increased installation, operation, and maintenance costs. Also the nature and location of the treated water disposal system is a source of some uncertainty.

The estimated capital cost to conduct the pilot study, install and develop 7 wells, each capable of pumping up to 50 gpm, equipped with pumps and power, a complete air stripping unit in a heated insulated building, an infiltration gallery, and other components listed under this alternative is approximately $804,000.

Annual operation and maintenance costs for the system are estimated to be approximately $307,000. Operations and mainteenance costs include labor for maintenance and cleaning of the air stripper, power for pumps and building heat, replacement of GAC, and continued operation of in-home mitigation systems and monitoring of the existing landfill. The estimated total net present cost for this alternative's operation and maintenance activities for 15 years is approximately $3.98 million.

7.0 COMPARATIVE ANALYSIS

In this section, a comparative analysis of the seven alternatives against the previously described evaluation criteria is presented to identify the relative advantages and disadvantages of each. A score for each alternative in addressing each criterion is assigned and an overall total score is assigned. **Table 7-1** shows the scoring of each alternative. A discussion of the relative merits of each alternative in relation to the evaluation criteria follows.

7.1 ABILITY TO MEET PROJECT OBJECTIVES

The category Ability to Meet Project Objectives includes the evaluation criteria: protection to human health, protection to the environment, compliance with the GPS, source control, and management of wastes generated. Scoring indicates that Alternative F has the greatest ability to meet project objectives followed, while Alternatives B, C, D, E and G have slightly less ability to meet project objectives.

Alternative F ranked highest in general in this category largely because it provides a larger source of fresh air in the vadose zone than the other alternatives and in so doing provides faster removal of contaminants. Alternative A ranked lowest in this category because it has a smaller chance and a larger time to meet GPSs and providing protectiveness. This alternative created the need for this CMA and as a result should have a lower score for these categories. Alternative G provides strong protection and compliance in this category but was scored lower because it generates some waste (spent GAC) and provides no source control.

7.2 EFFECTIVENESS

The category Effectiveness includes the evaluation criteria: performance, reliability, implementability, adverse impacts, short- and long-term effectiveness and protectiveness, and source control effectiveness. The scoring resulted in Alternative C and E having the greatest effectiveness followed closely by Alternative D and F. Alternatives B and G make up a second tier of alternatives that were roughly scored the same in this category. Alternative A is easily implementable but scored low in performance, reliability and effectiveness categories.

In comparing potential adverse impacts between the alternatives, Alternative B has the potential for the greatest potential adverse impact. Opening up the existing landfill and moving the wastes is likely to produce significant odors and may have health effects to workers and nearby residents. Alternative G may also have adverse impacts in that it may lower groundwater levels and have adverse impacts to downgradient groundwater users. Alternatives E and F may produce some temporary adverse impacts while drilling LFG wells. These may include the potential for fires and explosions and potential exposures of well drillers to toxic chemicals or gases or biologic risks.

7.3 TIME REQUIRED TO BEGIN AND COMPLETE REMEDY

The time required to begin and complete the remedy implementing Alternatives A and C through G is considered the about the same. These Alternatives can be completed in a relatively short time frame. Alternative B on the other hand would require at least five years before all the waste in the unlined cell can be moved into a new lined cell. Residual contamination in the Unlined Cell may persist beyond that.

7.4 INSTITUTIONAL REQUIREMENTS

Institutional requirements or the requirement to secure permits to implement the remedy is about the same for Alternatives C through F. Alternative B would have the largest institutional requirement consisting of an amendment to the existing landfill permit for a new cell or cells. Alternative G also would have some significant permitting issues in water right permitting to prevent adverse impacts to downstream groundwater users.

7.5 PRACTICAL CAPABILITY OF OWNER/OPERATOR

With its existing staff, the landfill owner/operator probably does not have the technical or practical capability to operate and conduct maintenance of any of the alternatives. The landfill owner/operator probably has financial capability to implement most of the alternatives with the exception of Alternative B.

7.6 DEGREE OF COMMUNITY CONCERNS

All of the alternatives would have some degree of community concern. Community concerns are likely to be highest for Alternatives A and B. There could be as many community concerns for implementing Alternative B due to its costs and potential odor and health effects as there might be for not implementing it and implementing a less protective alternative.

Community concerns for the alternatives examined herein will be better gaged after planned public meetings and a comment period that will be conducted in the future in response to this Revised CMA.

7.7 COST

Total present worth costs over a 15-year period range from approximately $1.87 Million for the No Action Alternative (Alternative A) to $59.8 Million for the Removal of the Cell Alternative (Alternative B). All of the remaining alternatives' costs are scattered in a somewhat narrow range between $3.4 and $4.1 Million.

8.0 SELECTED REMEDY

Montana's Solid Waste Management regulations require that the landfill owner or operator present the results of the corrective measures assessment at a public meeting (ARM 17.50.1308(4). After consideration of the public comments, the owner or operator must select a remedy that meets the following requirements of ARM 17.50.1309(2):

- Be protective of human health and the environment;
- Attain the groundwater protection standard;
- Control the source of releases so as to reduce or eliminate, to the maximum extent practicable, further releases of contaminants into the environment that may pose a threat to human health or the environment; and,
- Comply with standards for management of wastes.

According to ARM 17.50.1309(3), the owner or operator shall use the evaluation factors listed in Section 6.0 of this report to determine if the selected remedy meets the above criteria.
The City has held public meetings regarding the landfill but until this CMA is published and the public has opportunity to consider it and make public comment, the City cannot select a preferred alternative. Nevertheless, based on the analysis conducted for this report, Tetra Tech is able to make a recommendation to the City as to which alternative to pursue. In our opinion, Alternative F meets the statutory criteria listed above, presents the most advantages. In particular, the advantages of Alternative F include the following:

1. Provides source control.
2. Provides a source of fresh air across both the vadose zone and in the groundwater maximizing the area through which VOCs can be removed
3. Generates no hazardous waste
4. Is easily and quickly implementable
5. Requires minimal additional permitting
6. Is likely to have minimal public concern
7. Is likely to be approved by DEQ

9.0 REFERENCES

Batterman et al, 2007. Migration of volatile organic compounds from attached garages to residences: A major exposure source. Environmental Research 104 (2007) 224-240. Batterman, Stuart; C Jia; and G Hatzivasilis.

Damschen-Entranco, 2000. City of Bozeman Solid Waste Alternative Study.

DEQ, 2011. Montana Vapor Intrusion Guide. Montana Department of Environmental Quality. Helena, MT. April 22, 2011.

DEQ, 2012. Circular WQB-7 Montana Numeric Water Quality Standards. Montana Department of Environmental Quality, Helena, MT. October, 2012.

DEQ, 2014. Solid Waste Program Laws and Rules, Administrative Rules of Montana and Montana Code Annotated. http://www.deq.mt.gov/solidwaste/LawsRules.mcpx. Montana Department of Environmental Quality, Helena, MT.

Emcon, 1982. Methane Generation and Recovery from Landfills, Second Printing. Emcon Associates, San Jose, CA.

EPA, 2001. Fact Sheet, Correcting the Henry's Law Coefficient for Soil Temperature. Environmental Protection Agency. June, 2001.

Great West, 2013. Surface Water Pollution Prevention Plan. Great West Engineering, Helena, MT. August, 2013.

Huntingdon 1994. January 1994 Groundwater Monitoring Report for the City of Bozeman Sanitary Landfill, Gallatin County, Montana. April, 1994.

Johnson et al, 1991. A Practical Approach to the Design, Operation and Monitoring of In-Situ Soil Venting Systems, in *Soil Vapor Extraction Technology*. Johnson, P.C., Kemblowski, W.M., Colthart, J.D., Byers, D.L. and Stanley, C.C.

Mann, 1982. Draft City of Bozeman Solid Waste Program Review and Recommendations. Mann, Neil, City of Bozeman. Bozeman, MT. April 13, 1982.

Maxim, 1995. Corrective Measures Assessment, City of Bozeman Sanitary Landfill, Gallatin County. Maxim Technologies Inc., Helena, MT. August, 1995.

Maxim, 2000. Effectiveness of Corrective Measures and March & June 2000 Groundwater Monitoring, Bozeman Sanitary Landfill, Bozeman, Montana. Maxim Technologies Inc., Helena, MT. August, 2000.

MBMG, 2002. Preliminary Geologic Map of the Bozeman 30' x 60' Quadrangle, Southwestern Montana, MBMG Open File Report MBMG 469. Montana Bureau of Mines and Geology, Butte, MT.

SCS, 1985. Letter from David Jones (Soil Conservation Service (SCS)) to Neil Mann (City of Bozeman. U.S. Dept. of Agriculture, Soil Conservation Service, Bozeman, MT. June 17, 1985.

Stiller and Associates, 1985. Technical Memorandum NO. 1 – Engineering and Hydrogeological Evaluation of the Bozeman Sanitary Landfill. Bozeman, Montana. December 18, 1985.

Tetra Tech, 2008. Landfill Gas Extraction System Condition Report, Bozeman Sanitary Landfill, Bozeman, Montana. Tetra Tech, Inc., Helena, MT. February 8, 2008.

Tetra Tech 2013. Progress Report on Soil Gas Probe BSV-9 to BSV-12 Installations, Second Sampling Event and Analysis of Soil Gas Samples from Soil Gas Probes BSV-1 through BSV-12, Bozeman Landfill, Bozeman, Montana. Tetra Tech Inc., Helena, MT. June 4, 2013.

Tetra Tech, 2013b. Report of Groundwater Monitoring Activities, December, 2013, Bozeman Landfill. Tetra Tech Inc., Bozeman, MT. March 31, 2014.

Tetra Tech, 2014. Draft Report of Monitoring Well Installation and Groundwater Monitoring Activities, March through May 2014. Tetra Tech Inc., Bozeman, MT. July 17, 2014.

TDH, 1972. Sanitary Landfill Development Plan for Bozeman, Montana. Thomas, Dean, and Hoskins Inc., Great Falls-Bozeman, Montana. November.

Todd, 1980. Groundwater Hydrology, Table 2.1, page 28. John Wiley and Sons, New York, New York.

USGS, 1960. Geology and Ground Water Resources of the Gallatin Valley, Gallatin County, Montana. USGS Water Supply Paper 1482, USGS, Washington, D. C.

USGS 2014. National Water Information System: Web Interface.
http://waterdata.usgs.gov/mt/nwis/uv/?site_no=06048700&PARAmeter_cd=00060,00065,00010

Weather Channel, 2014.
http://www.weather.com/weather/wxclimatology/monthly/graph/USMT0040

Tables

TABLE 1-1
Schedule of Field Measurements and Laboratory Analysis
Bozeman Landfill, Bozeman Montana

Well or Sampling Site	Monitoring Frequency	Parameters Monitored: Field pH, SC, DO & ORP	Laboratory pH & SC	VOCs	Inorganics: 'Partial List' Ba, Fe (dissolved)	'Full List' Metals (dissolved)	Chloride	Sulfate	N as NO2+NO3
LF- 2	Semi-annual monitoring	x		x			x		x
LF- 3	Semi-annual monitoring	x		x	x		x	x	x
MW- 3	No mon. requirement. Last event in 2001								
MW- 4	Semi-annual monitoring	x		x	x		x	x	x
MW- 5	Semi-annual monitoring	x	x	x	x		x	x	x
MW- 6	Semi-annual monitoring	x	x	x	x		x	x	x
MW- 6C	Four monitoring events completed								
MW- 7A	Semi-annual monitoring	x		x	x		x	x	x
MW- 7B	DEQ requests next monitoring in 2015								
MW- 8A	Semi-annual monitoring	x	x	x	x		x	x	x
MW- 8B	DEQ requests next monitoring in 2015								
MW- 8C	Four monitoring events completed								
MW- 9A	Semi-annual monitoring	x		x	x		x	x	x
MW- 9B	DEQ requests next monitoring in 2015								
MW- 10	Semi-annual monitoring	x		x		x	x	x	x
MW- 11	Semi-annual monitoring	x		x		x	x	x	x
MW- 12	Semi-annual monitoring, annual metals (1)	x		x		x	x	x	x
MW- 13	Semi-annual monitoring	x		x		x	x	x	x
MW- 14	DEQ - annual mon, next in Dec 2014								
MW- 15	Semi-annual monitoring	x	x	x		x	x	x	x
MW- 16	Four monitoring events completed								
MW- 17	Quarterly monitoring	x		x		x	x	x	
MW- 18	Quarterly monitoring	x		x		x	x	x	
MW- 19	Quarterly monitoring	x		x			x	x	
MW- 20	Quarterly monitoring	x		x		x	x	x	
MW- 21	Quarterly monitoring	x		x			x	x	
MW- 22	Quarterly monitoring	x		x			x	x	
MW- 23	Quarterly monitoring	x		x			x	x	
MW- 24	Quarterly monitoring	x		x			x	x	
MW- 25	Quarterly monitoring	x		x			x	x	
MW- 26	Quarterly monitoring	x		x			x	x	
Shop/Office Well	Semi-annual monitoring	x		x			x	x	
McIlhattan Seep	Semi-annual monitoring	x		x		x	x	x	x
Valley View Vet Wel	Semi-annual monitoring	x		x		x (1)	x	x	x
Field Duplicate	Semi-annual monitoring	x		x		x	x	x	x
Trip Blank	Semi-annual monitoring			x					
	Total Number of Samples		4	29	7	11	27	26	16

Notes :

VOCs : Volatile organic compounds

Ba, Fe : Barium, Iron

'Full List' : Analysis of 15 metals including:

arsenic	chromium	iron	selenium	vanadium
barium	cobalt	lead	silver	zinc
cadmium	copper	nickel	thallium	

(1) : Total recoverable analysis of metals

Table 3-1
Most Recent VOC Results of Groundwater Monitoring
Constituent Concentrations Exceeding the Groundwater Protection Standard
Bozeman Landfill
Bozeman, Montana

Parameter	GPS	Typical Range at Site	Wells with Concentrations Exceeding the GPS	Wells with Highest Concentrations
Tetrachloroethene	5	ND to 16	MW-17, MW-20	MW-17
Trichloroethene	5	ND to 5.8	MW-17	MW-17
Vinyl Chloride	2	ND to 19.7	MW-6, MW-7A, MW-12, MW-13, MW-17	MW-12, MW-13
Methylene Chloride	5	ND to 5.1	MW-17	MW-17

Notes: All results in micrograms per liter
GPS : Groundwater Protection Standard
ND : Not Detected (at or above the analytical minimum detection limit)

Table 4-1
Remedial Screening Technologies
Bozeman Story Mill Landfill
Revised Corrective Measures Assessment

General Response Action	Remedial Technology	Process Option	Effectiveness	Implementability	Cost	Process Retained?	Screening Comment
No Action	None	None	Does not achieve remedial action objectives.	Implementable	None	Yes	
Institutional Controls	Use Restrictions	Groundwater Development Regulations/Controlled Groundwater Areas	Effective at controlling new uses of groundwater.	Not easily implementable outside of cities for uses under 35 gpm.	Low	Yes	
		Screen Wastes Entering Landfill	Relatively effective in reducing amount of hazardous or deleterious waste entering landfill. Risk of human error in consistently judging waste types.	Human-checking relatively easy to implement. More sophisticated methods likely more difficult to implement, particularly during winter months.	Low	No	Landfill closed. Not accepting wastes.
	Access Controls	Fences	Does not address contact pathway except during remediation	Implementable	Low	No	Landfill closed. Need to minimize contact.
	Alternative Drinking Water Source	Cisterns or Tanks	Does not reduce contamination. Public not at immediate risk but would provide uncontaminated water for livestock.	Implementable but inconvenient to landowners.	Low	No	Residents on Municipal Water Supply.
		Municipal Water Supply	Protects public health but public health not a primary issue; does not reduce contamination.	Subdivision south of landfill is currently served by City of Bozeman municipal supply. Could extend to McIlhattan residence but McIlhattan well currently not a risk.	High	No	Residents on Municipal Water Supply.

Table 4-1
Remedial Screening Technologies
Bozeman Story Mill Landfill
Revised Corrective Measures Assessment

General Response Action	Remedial Technology	Process Option	Effectiveness	Implementability	Cost	Process Retained?	Screening Comment
Containment	Capping	Native Soil	No surface contaminants identified; native soil historically used for daily and final cover. Effective in reducing infiltration but probably not to closure standards by itself. Would likely be part of a final closure design.	Implementable. Restricts future land use to some extent.	Low	No	Cap Complete.
		Low Permeability Soil Cap	Could reduce infiltration but some contaminants are already in contact with groundwater.	Implementable. Restricts future land use.	Low	No	Low Permeability. Cap complete.
		Synthetic Membrane	Could reduce infiltration but some contaminants are already in contact with groundwater.	Implementable. Restricts future land use.	Low	No	Cap Complete.
		Sprayed Asphalt	Could reduce infiltration but some contaminants are already in contact with groundwater.	Implementable. Restricts future land use.	Low	No	Cap Complete.
		Asphaltic Concrete	Could reduce infiltration but some contaminants are already in contact with groundwater.	Implementable. Restricts future land use.	Low	No	Cap Complete.
		Concrete Cap	Could reduce infiltration but some contaminants are already in contact with groundwater.	Implementable. Restricts future land use.	Low	No	Cap Complete.

Table 4-1
Remedial Screening Technologies
Bozeman Story Mill Landfill
Revised Corrective Measures Assessment

General Response Action	Remedial Technology	Process Option	Effectiveness	Implementability	Cost	Process Retained?	Screening Comment
		Multilayered Cap	Could reduce infiltration but some contaminants are already in contact with groundwater.	Implementable. Restricts future land use.	Low	No	Cap Complete.
		Liners	Effective in proper application.	Technically implementable.	Low to Moderate	Yes	
	Surface Controls	Surface Sealing	Effective	Technically implementable.	Low	Yes	
		Grading	Effective	Technically implementable.	Low	Yes	
		Soil Stabilization	Effective	Technically implementable.	Low	Yes	
		Revegetation	Effective	Technically implementable.	Low	No	Revegetation already complete.
		Diversion and Collection Systems	Effective	Technically implementable.	Low	No	Stormwater measures already complete.
		Settling Basins/Ponds	Effective	Technically implementable.	Low	No	Basins already complete.
	Dust Suppression	Water Spray/Flooding	Effective as a component of removal technologies.	Technically implementable.	Low	No	Landfill closed.
		Organic Agents/Polymers/Foams	Effective as a component of removal technologies.	Technically implementable.	Low	No	Landfill closed.
		Membranes/Tarps	Effective as a component of removal technologies.	Technically implementable.	Low	No	Landfill closed.
		Hygroscopic Agents	Effective as a component of removal technologies.	Technically implementable.	Low	No	Landfill closed
Removal	Groundwater Collection	Wells	Effective in suitable materials.	Technically implementable.	Moderate	Yes	

Table 4-1
Remedial Screening Technologies
Bozeman Story Mill Landfill
Revised Corrective Measures Assessment

General Response Action	Remedial Technology	Process Option	Effectiveness	Implementability	Cost	Process Retained?	Screening Comment
	Soil Vapor Extraction	Passive Vapor Extraction	Effective in suitable materials.	Technically implementable.	Low	Yes	
		Active Vapor Collection	Effective in suitable materials.	Technically implementable.	Low	Yes	
	Landfill Gas Extraction	Passive Gas Extraction	Effective in suitable materials.	Technically implementable.	Moderate	Yes	
		Active Gas Extraction	Effective in suitable materials.	Technically implementable.	High	Yes	Retained to evaluate additional wells.
	Drum & Debris Removal	Various	Only applicable if drums exists.	Technically implementable.	Low to Moderate	Yes	
	Excavation	Solids	Effective	Technically implementable.	High	Yes	
		Semi-solids	Effective for saturated sediment/garbage removal	Technically implementable.	Moderate to High	No	Wastes should be solids
		Sediments	Effective for saturated sediment/garbage removal	Technically implementable.	Moderate to High	No	Wastes should be solids
Treatment	Solids Dewatering	Sedimentation	Effective for separation of sediments.	Technically implementable.	Low	No	Landfill closed. Dewatering not an issue.
		Dewatering and Drying Beds	Effective for dewatering saturated materials.	Technically implementable.	Low	No	Landfill closed. Dewatering not an issue.
		Filtration	Effective for removing sediments from water.	Technically implementable.	Low	No	Landfill closed. Dewatering not an issue.
		Adsorption	Carbon adsorption is effective for removal of VOCs.	Technically implementable.	Moderate to high	Yes	
		Air Stripping	Effective for removal of VOCs.	Technically implementable.	Moderate	Yes	
		Evaporation	Effective, especially if volumes are not great.	Technically implementable.	Moderate to high.	Yes	
		Distillation	Effective for high concentrations of VOCs.	Technically implementable.	High	Yes	

Table 4-1 Remedial Screening Technologies Bozeman Story Mill Landfill Revised Corrective Measures Assessment							
General Response Action	**Remedial Technology**	**Process Option**	**Effectiveness**	**Implementability**	**Cost**	**Process Retained?**	**Screening Comment**
		Peroxidation	Effective at destroying chlorinated organic compounds and certain VOCs.	Proven on pilot scale; may have implementation problems at full scale.	High	Yes	
		Irradiation	Effective in stacks.	Implementable	High	Yes	
	Biological Treatment	Aerobic Processes	Effective for removing VOCs.	Implementable	Moderate	Yes	
		Anaerobic Processes	Effective for VOC removal under certain conditions.	Implementable	Moderate	Yes	
		Publicly Owned Treatment Works (POTW)	Technology proven to treat certain VOCs to achieve compliance with specific standards.	Technically implementable, especially if access to sewer is easy.	Low	Yes	
	Thermal Treatment	Incineration	Effective at high temperatures (about 1300 degrees F).	Technically implementable	Moderate to high	Yes	
		Gaseous incineration	Same as incineration after air stripping.	Technically implementable	Moderate to high	Yes	
	Air Emission Controls and Treatment	Condensation	Effective if sufficiently high concentrations in air.	Technically implementable	Moderate to high	Yes	
		Adsorption	Carbon adsorption is effective for removal of VOCs.	Technically implementable	Moderate to high	Yes	
		Catalytic Conversion	Effective	Technically implementable	Moderate to high	Yes	
		Thermal Destruction	Identical to incineration after air stripping	Technically implementable	Moderate to high	Yes	
	Liquid Treatment	Air Sparging	Effective in proper materials.	Technically implementable	Moderate	Yes	
Disposal	Resource Recovery	Energy Recovery	Effective only for flammable VOCs.	Technically implementable	Moderate	Yes	

Table 4-1
Remedial Screening Technologies
Bozeman Story Mill Landfill
Revised Corrective Measures Assessment

General Response Action	Remedial Technology	Process Option	Effectiveness	Implementability	Cost	Process Retained?	Screening Comment
		Waste Piles	Effective	May be concern with landfill regulations and emissions.	Low	Yes	
		Containers/Tanks	Effective	Must comply with hazardous waste storage regulations.	Low	Yes	
	Wastewater Discharge	Publicly Owned Treatment Works (POTW)	Effective	Distance to POTW access is not prohibitive.	Low	Yes	
Monitoring	Monitoring	Monitoring	Effective for recording site conditions.	Technically implementable	Low to Moderate	Yes	

Table 7-1
Scoring/Ranking of Proposed Alternatives
Bozeman Landfill Remediation
Bozeman, Montana

Evaluation Criteria	Score		Alternative A No Action	Alternative B Cell Removal	Alternative C SVE Wells	Alternative D SVE Wells with Air Sparging	Alternative E SVE Wells with LFG Wells	Alternative F SVE/VZAI/AS/ LFG	Alternative G Groundwater Treatment
	1	5							
Ability to Meet Project Objectives									
Protection to Human Health	Least Protective	Most Protective	3	3	5	5	5	5	5
Protection to Environment	Least Protective	Most Protective	3	5	5	5	5	5	5
Compliance with GPS	Least Compliant	Most Compliant	1	3	3	3	3	4	4
Source Control Provided	Least Source Control	Most Source Control	3	5	3	3	4	4	3
Waste Management	Most Waste Producing	Least Waste Producing	5	3	4	4	4	4	1
	Sub-Score		**15**	**19**	**20**	**20**	**21**	**22**	**18**
Effectiveness									
Performance	Worst Performance	Best Performance	2	5	4	3	5	5	5
Reliability	Least Reliable	Most Reliable	2	5	5	4	5	4	3
Implementability	More Difficult	Less Difficult	5	1	4	4	3	3	4
Adverse Impacts	Most Adverse Impacts	Least Adverse Impacts	5	1	4	4	3	3	2
Short and Long-term Effectiveness	Least Effective	Most Effective	1	3	4	4	4	4	4
Short and Long-term Protectiveness	Least Protective	Most Protective	1	3	4	4	4	4	4
Source Control Effectiveness	Least Effective	Most Effective	3	5	3	3	4	4	1
	Sub-Score		**19**	**23**	**28**	**26**	**28**	**27**	**23**
Time Required	Most Time	Least Time	5	1	3	4	3	4	3
Institutional Requirements	Most Requirements	Least Requirements	4	1	3	3	3	3	2
Technical Capability	Least Capable	Most Capable	1	1	1	1	1	1	1
Financial Capability	Least Capable	Most Capable	5	1	4	4	4	4	4
Potential Community Concerns	Most Concerns	Least Concerns	1	1	4	4	4	4	5
Cost	Most Expensive	Least Expensive	5	1	4	4	4	4	4
	Sub-Score		**21**	**6**	**19**	**20**	**19**	**20**	**19**
	Total Score		**55**	**48**	**67**	**66**	**68**	**69**	**60**

Notes: Score between 1 and 5 for Evaluation Criteria
Highest score is most favorable Alternative

Figures

NOTE:
All station locations and landfill boundary are approximate

Landfill Property Boundary
Flow Direction
Class IV Cell
Lined Landfill
Unlined Landfill

0 400 800
Feet

Datum: NAD83 StatePlane Montana

Site Plan
Revised Corrective Measures Assessment
City of Bozeman Landfill
Bozeman, Montana
FIGURE 1-1

Soil Gas Probe

Groundwater Monitoring Well

Methane Monitoring Well

Surface Water Monitoring Site

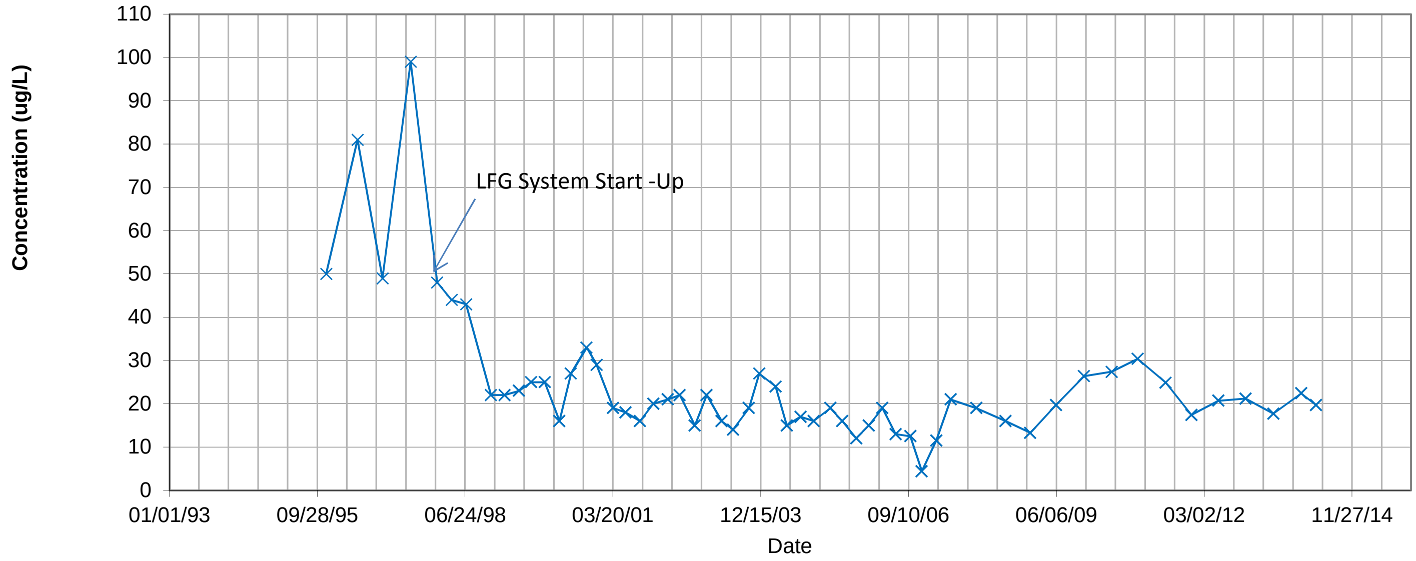
Landfill Gas Extraction Well

Stratigraphic Cross Section Line (shown in Figure 1-4)

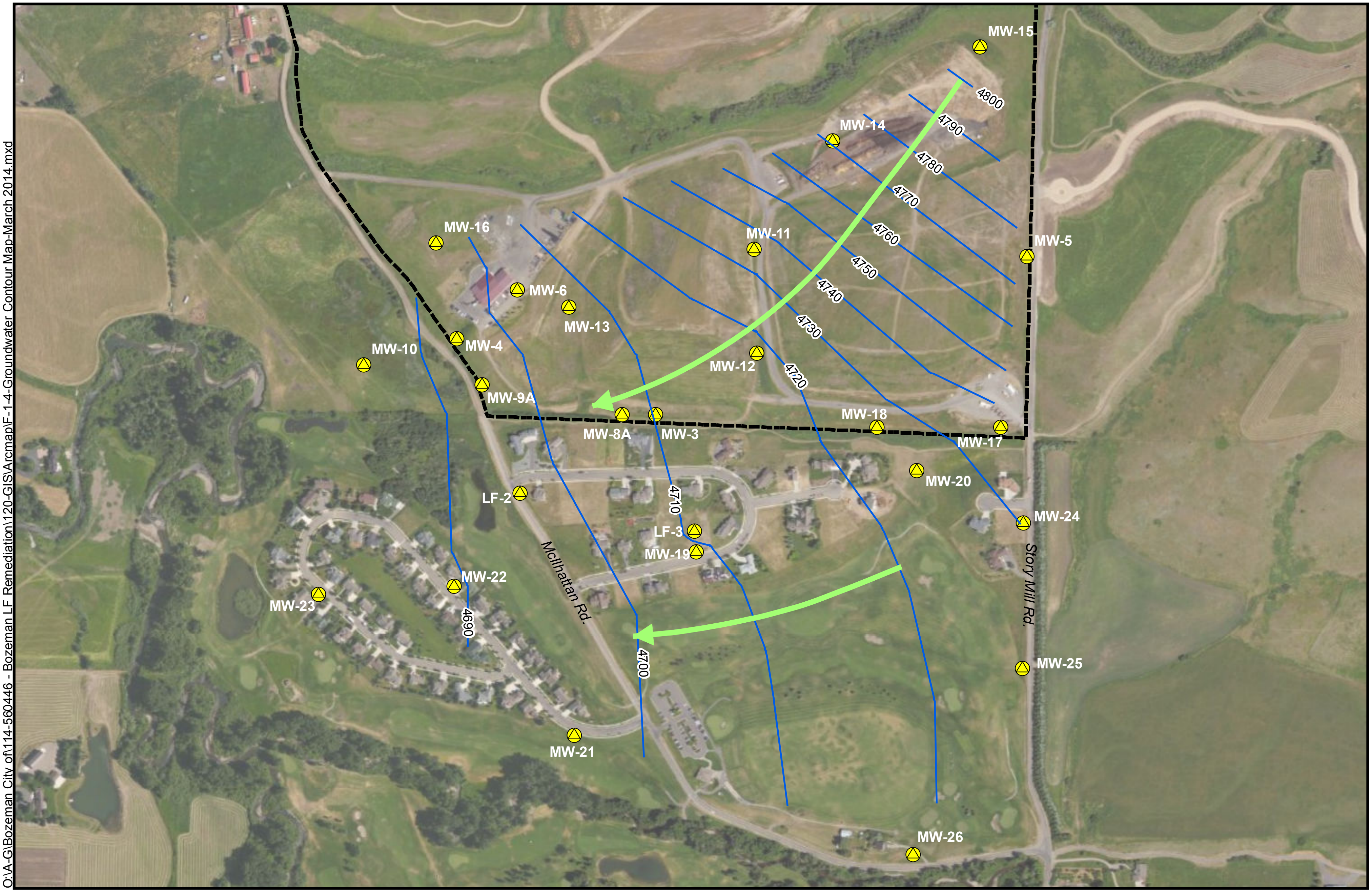
Landfill Property Boundary

Site Plan with Monitoring Stations and Extraction Wells
Bozeman Landfill
Bozeman, Montana
FIGURE 1-2

Figure 1-3
Trends in Vinyl Chloride Concentration at MW-12
Before and After LFG Extraction Start-Up



O:\A-G\Bozeman City of\114-560446 - Bozeman LF Remediation\120-GIS\Arcmap\F-1-4-Groundwater Contour Map-March 2014.mxd



114-710326.700

Feet

Datum: NAD83 StatePlane Montana

NOTE:
All well locations are approximate.
Only those wells used for preparation of groundwater contour map are shown

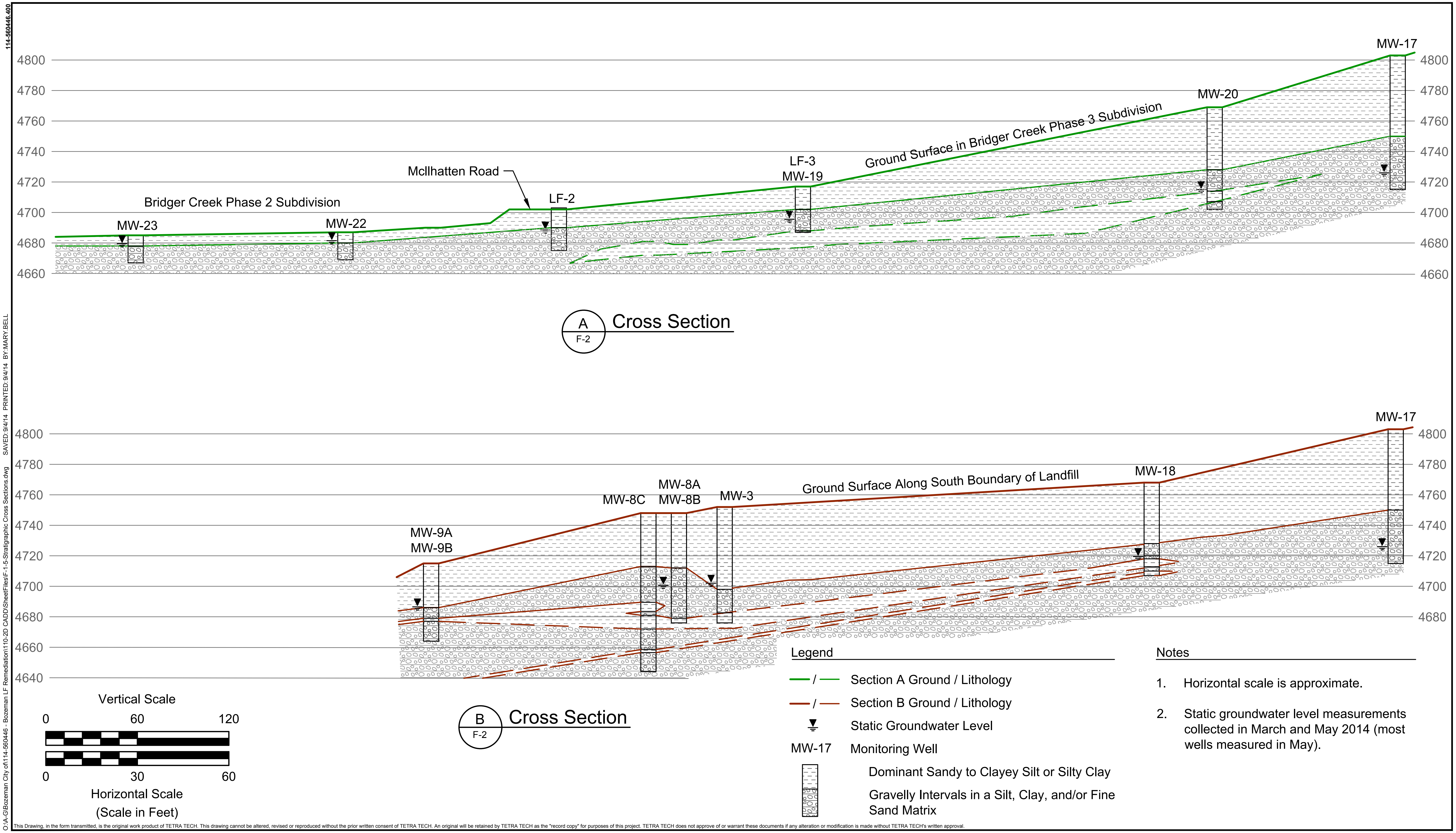
Landfill Property Boundary

4690 Groundwater Elevation in Feet (above mean sea level)

Groundwater Monitoring Well

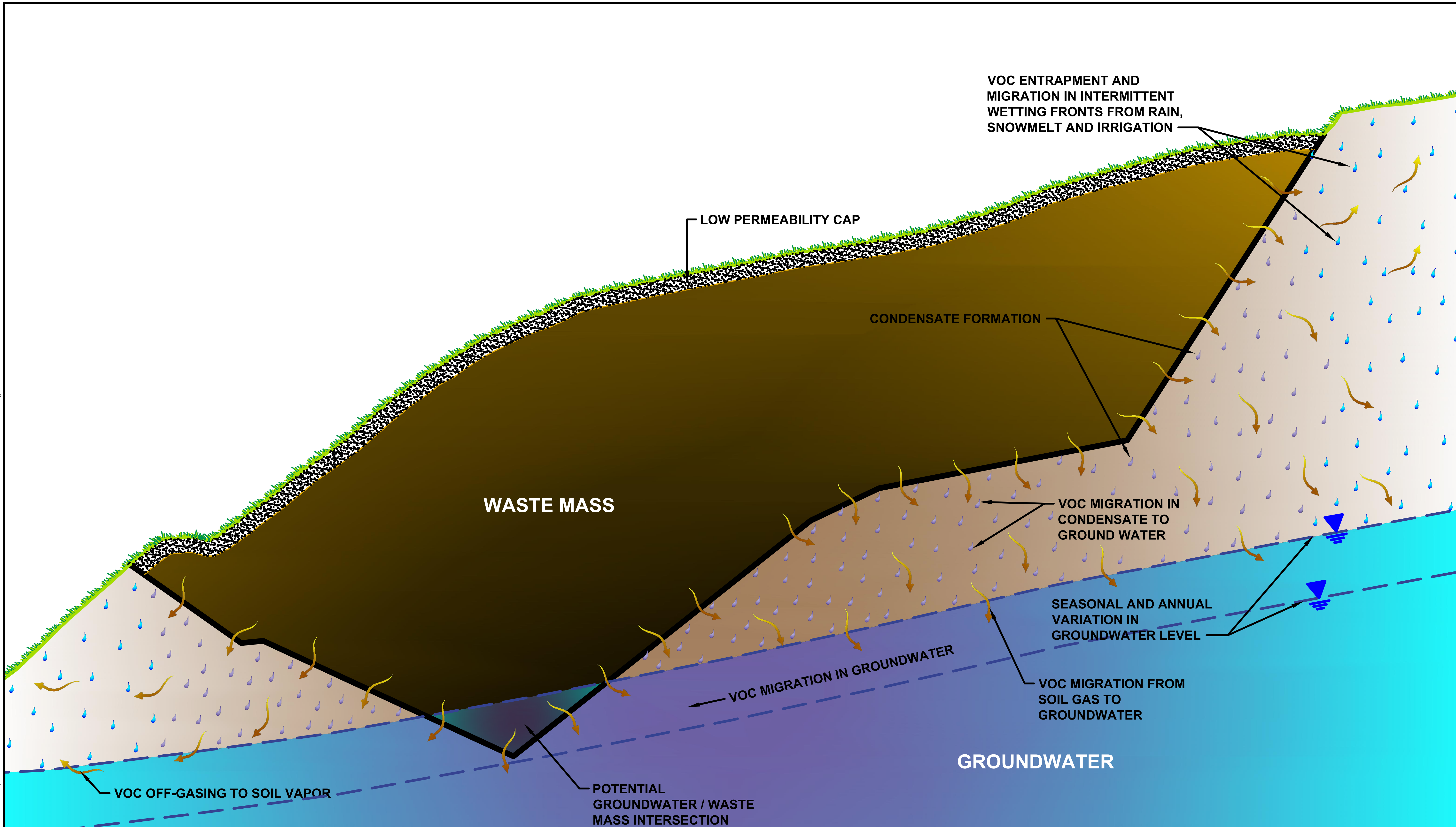
Groundwater Flow Direction

March 2014 - Groundwater Contour Map
Bozeman Landfill
Bozeman, Montana
FIGURE 1-4

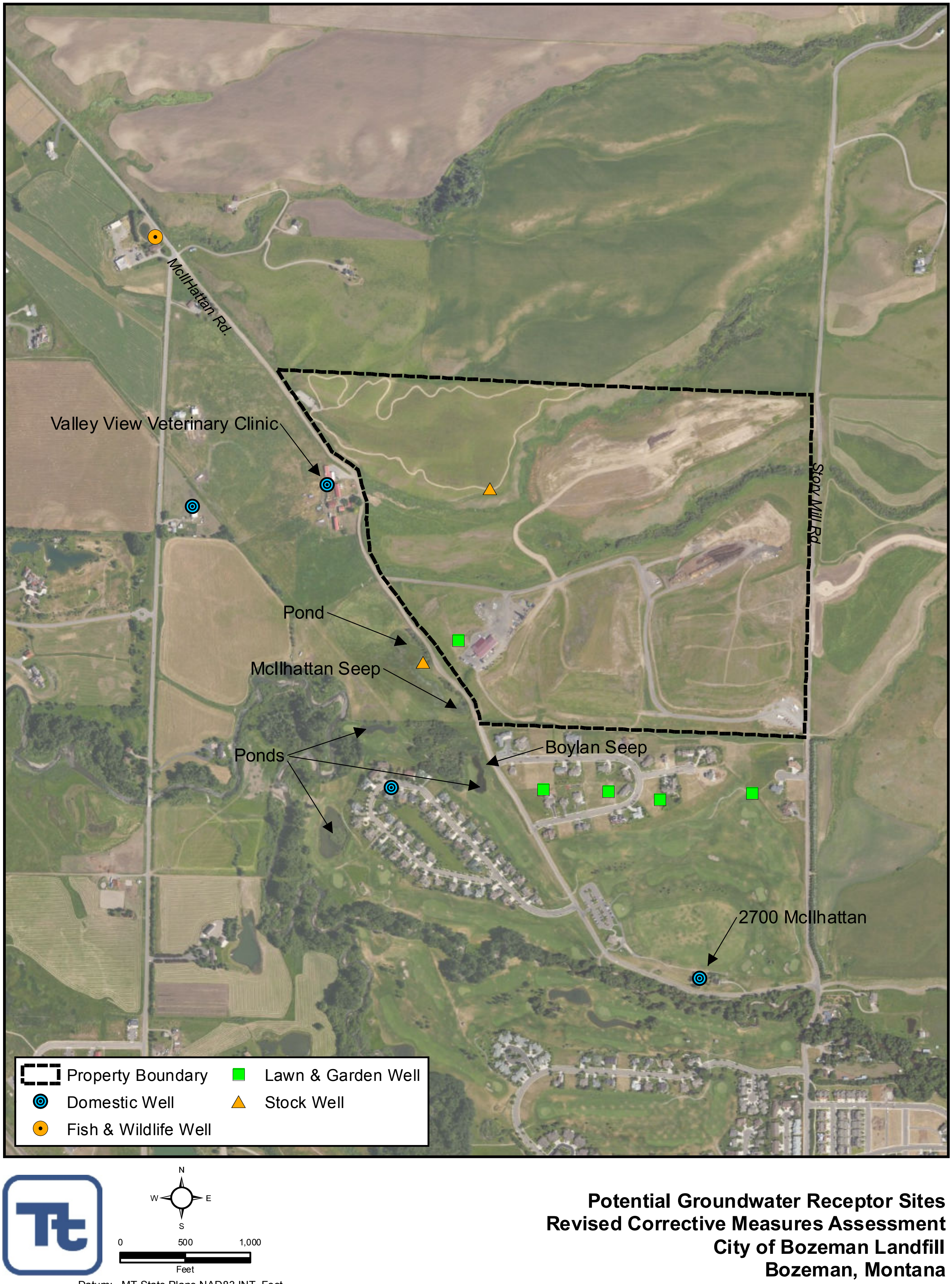


Stratigraphic Cross Sections
Bozeman Landfill
Bozeman, Montana

FIGURE 1-5

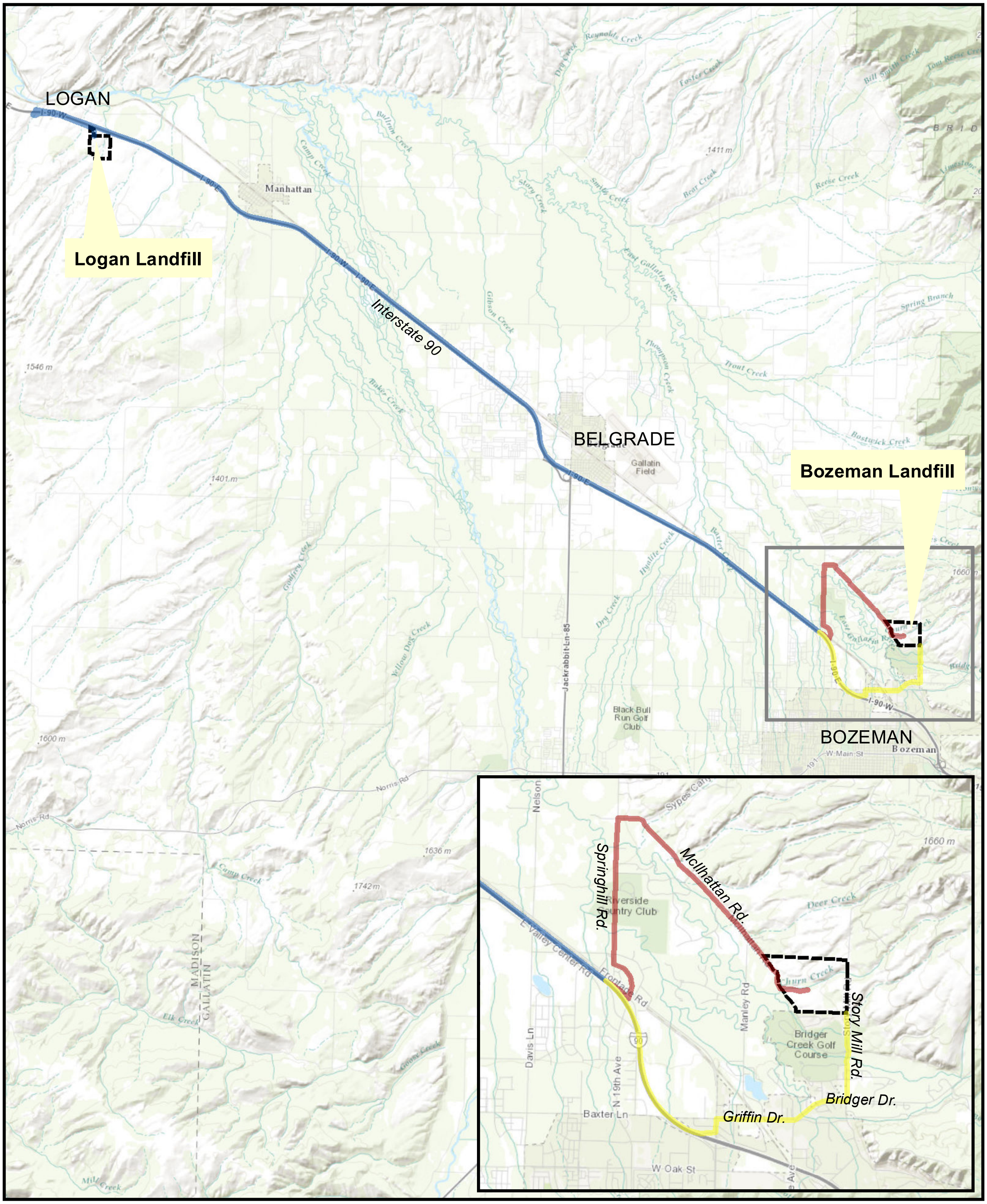


Conceptual VOC Migration Paths in the Vadose Zone and Groundwater
Revised Corrective Measures Assessment
City of Bozeman Landfill
Bozeman, Montana
FIGURE 3-1

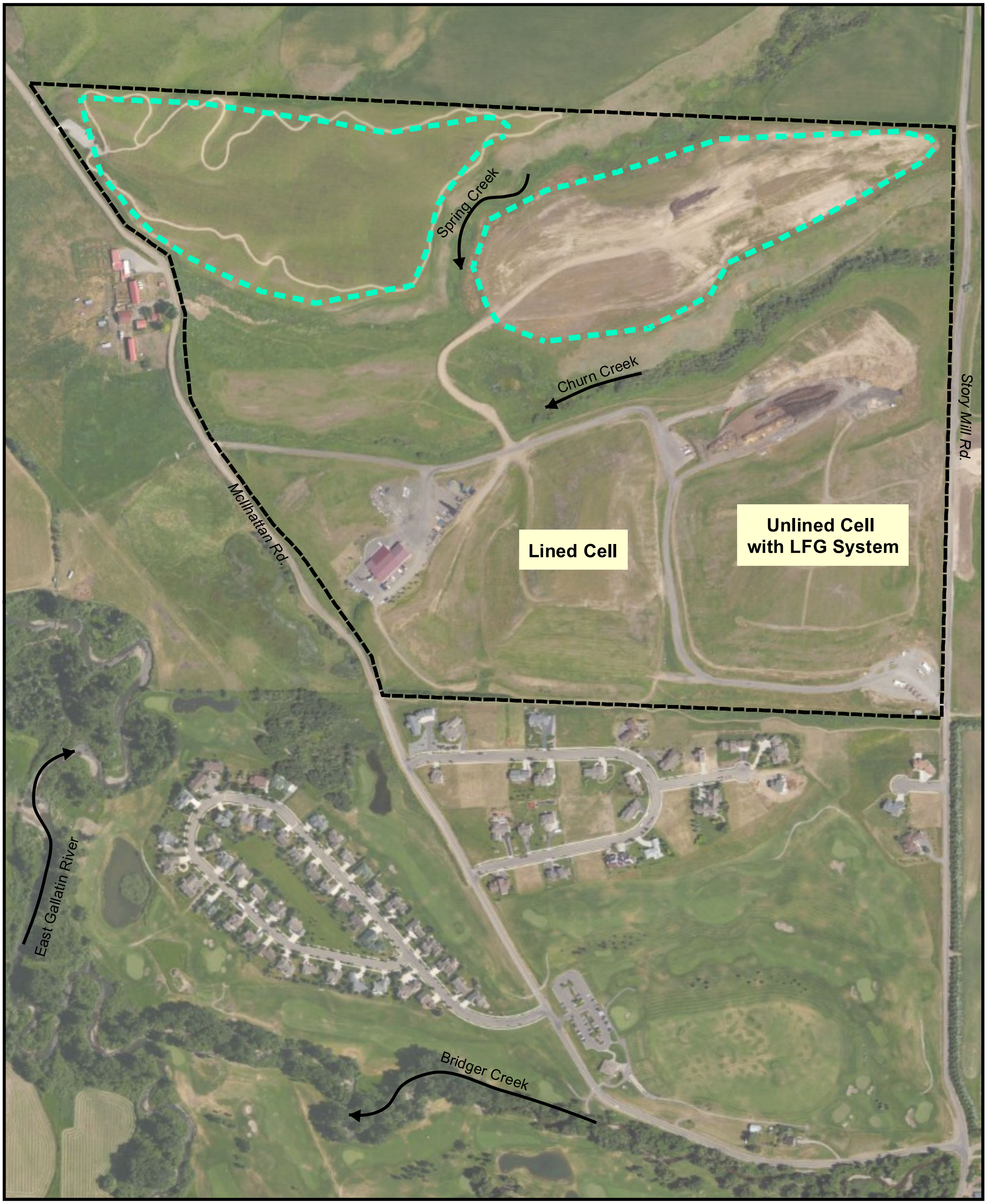


O:\A-G\Bozeman City of\114-560446 - Bozeman LF Remediation\120-GIS\Arcmap\F-3-2-Potential Groundwater Receptor Sites.mxd

Potential Groundwater Receptor Sites
Revised Corrective Measures Assessment
City of Bozeman Landfill
Bozeman, Montana
FIGURE 3-2



Potential Haul Routes to Logan Landfill
Revised Corrective Measures Assessment
City of Bozeman Landfill
Bozeman, Montana
FIGURE 5-1

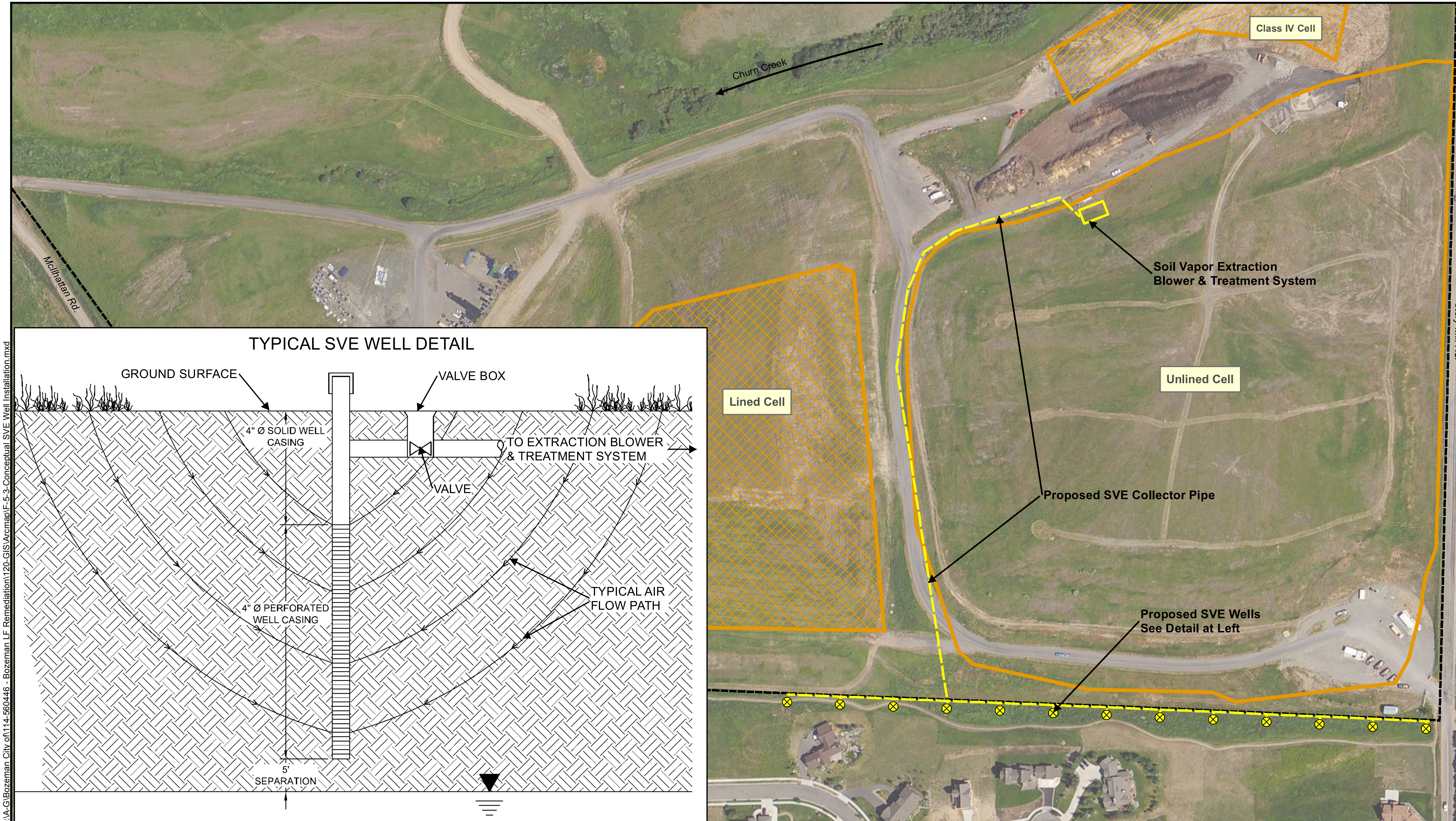


O:\A-G\Bozeman City of\114-560446 - Bozeman LF Remediation\120-GIS\Arcmap\F-5-2-Pontential New Cell Locations.mxd

N
W E
S
0 300 600
Feet
Datum: MT State Plane NAD83 INT. Feet

Potential New Cell
Property Boundary
(Approximate Only - Not Surveyed)
Flow Direction

Potential New Cell Locations
Revised Corrective Measures Assessment
City of Bozeman Landfill
Bozeman, Montana
FIGURE 5-2



O:\A-G\Bozeman City of\114-560446 - Bozeman LF Remediation\120-GIS\Arcmap\F-5-3-Conceptual SVE Well Installation.mxd

N W E S

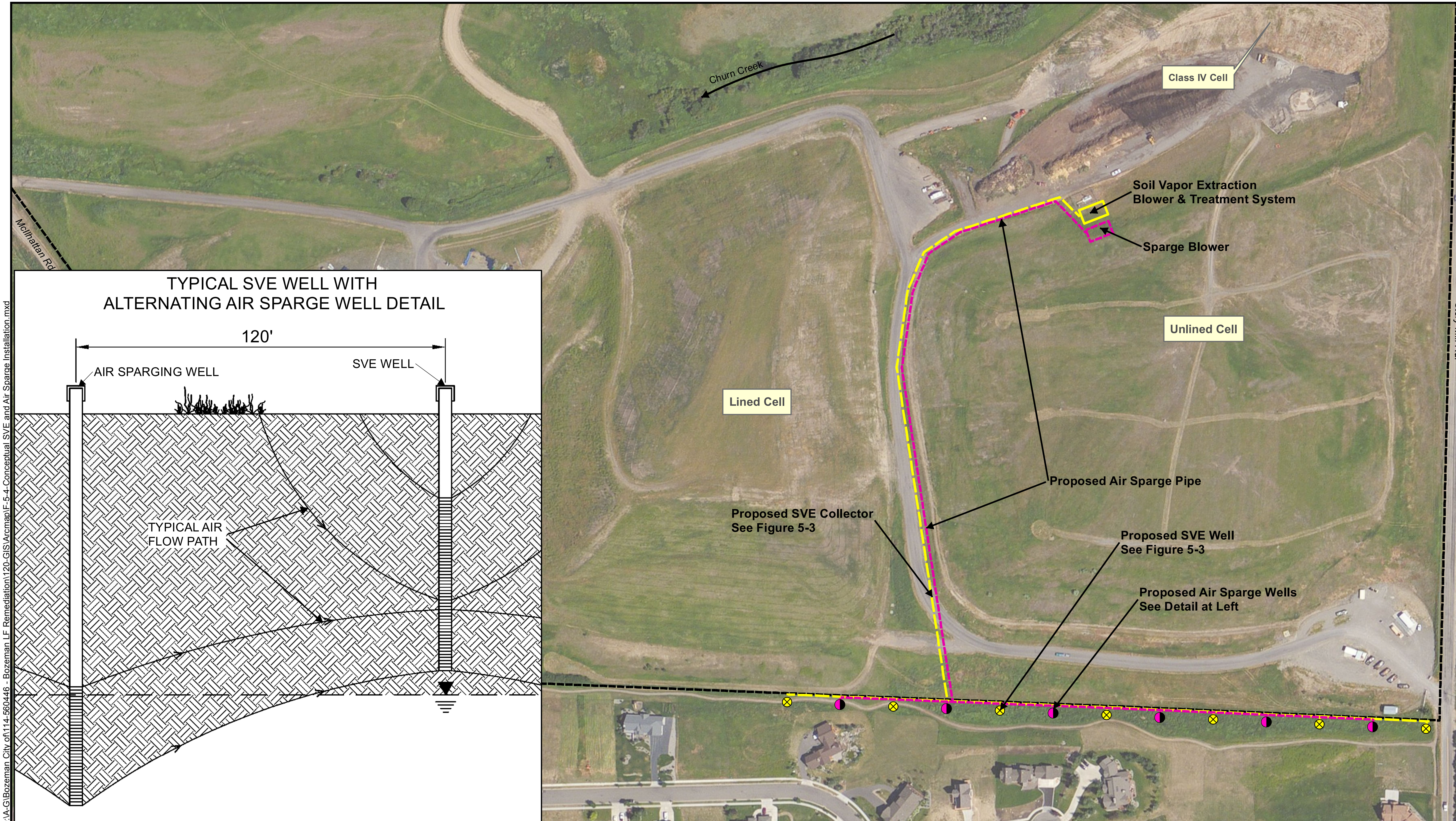
0 100 200
Feet

Datum: NAD83 StatePlane Montana

NOTE:
Landfill boundary approximate

Proposed SVE Well Location
Proposed SVE Collection Pipe
Landfill Property Boundary
Flow Direction
Class IV Cell
Lined Landfill
Unlined Landfill

Conceptual SVE Well Installation
Revised Corrective Measures Assessment
City of Bozeman Landfill
Bozeman, Montana
FIGURE 5-3



O:\A-G\Bozeman City of\114-560446 - Bozeman LF Remediation\20-GIS\Arcmap\F-5-4-Conceptual SVE and Air Sparge Installation.mxd

N W E S

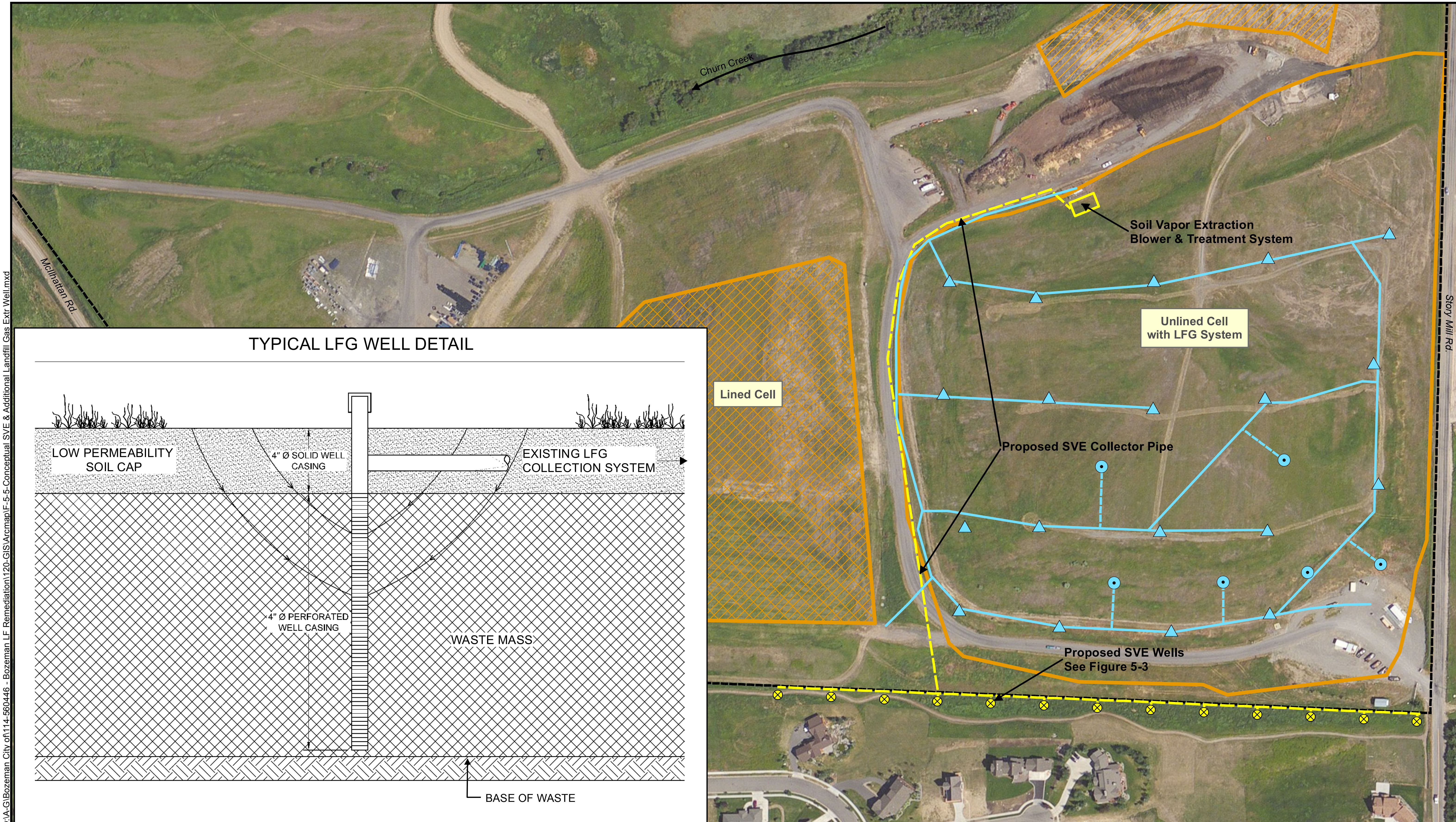
0 100 200 Feet

Datum: NAD83 StatePlane Montana

NOTE:
Landfill boundary approximate

Landfill Property Boundary
Proposed Air Sparge Well
Proposed Air Sparge Pipe
SVE Well Location
SVE Collection Pipe
Flow Direction

Conceptual SVE and Air Sparge Installation
Revised Corrective Measures Assessment
City of Bozeman Landfill
Bozeman, Montana
FIGURE 5-4



O:\A-G\Bozeman City of\114-560446 - Bozeman LF Remediation\120-GIS\Arcmap\F-5-5-Conceptual SVE & Additional Landfill Gas Extr Well.mxd

N W E S

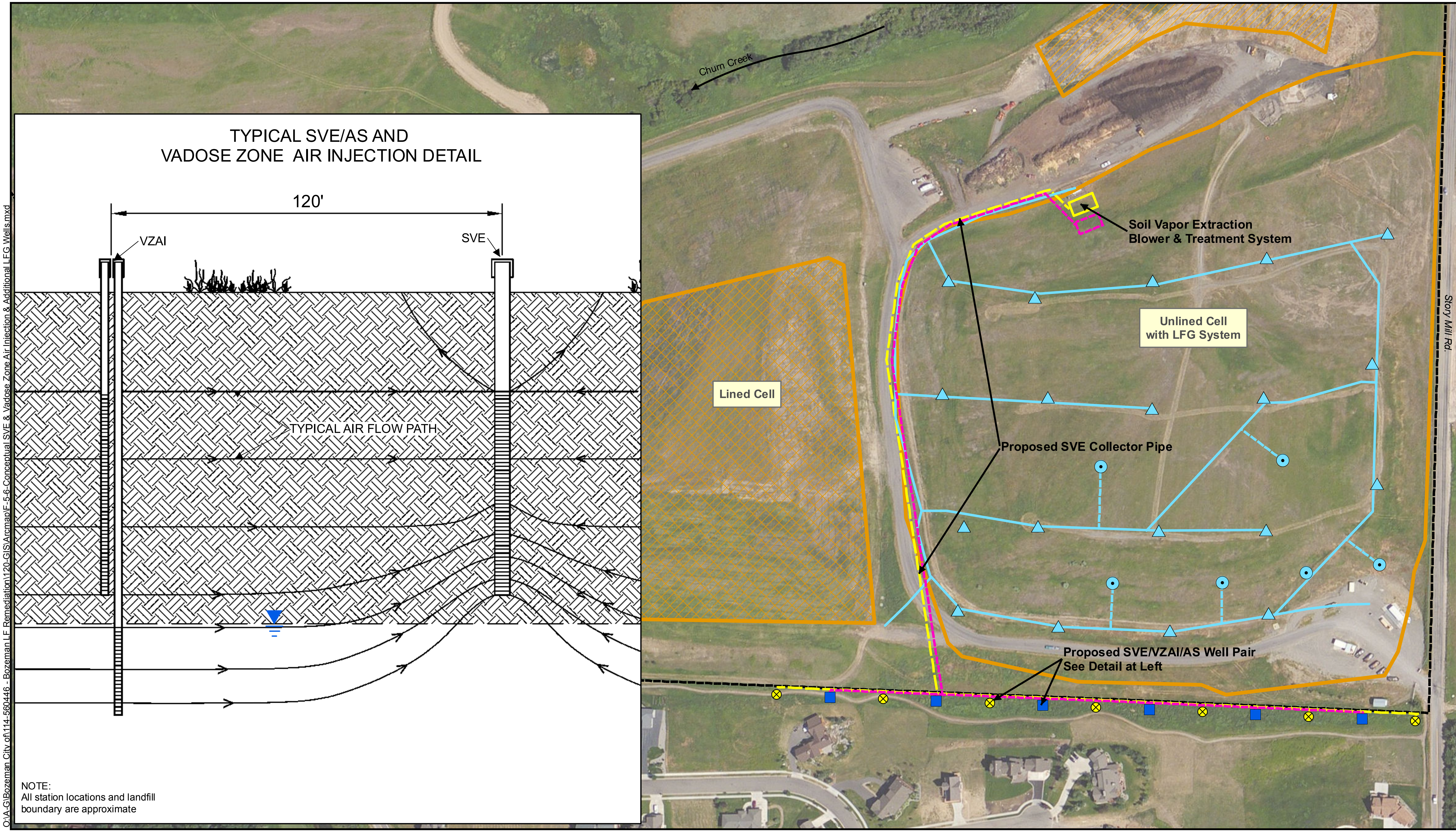
0 100 200
Feet

Datum: NAD83 StatePlane Montana

NOTE:
All station locations and landfill boundary are approximate

- Existing Landfill Gas Extraction Well
- Proposed Additional Landfill Gas Extraction Well
- Existing Landfill Gas Collection Pipe
- Proposed Landfill Gas Collection Pipe
- SVE Well Location
- SVE Collection Pipe
- Flow Direction
- Landfill Property Boundary
- Class IV Cell
- Lined Landfill
- Unlined Landfill

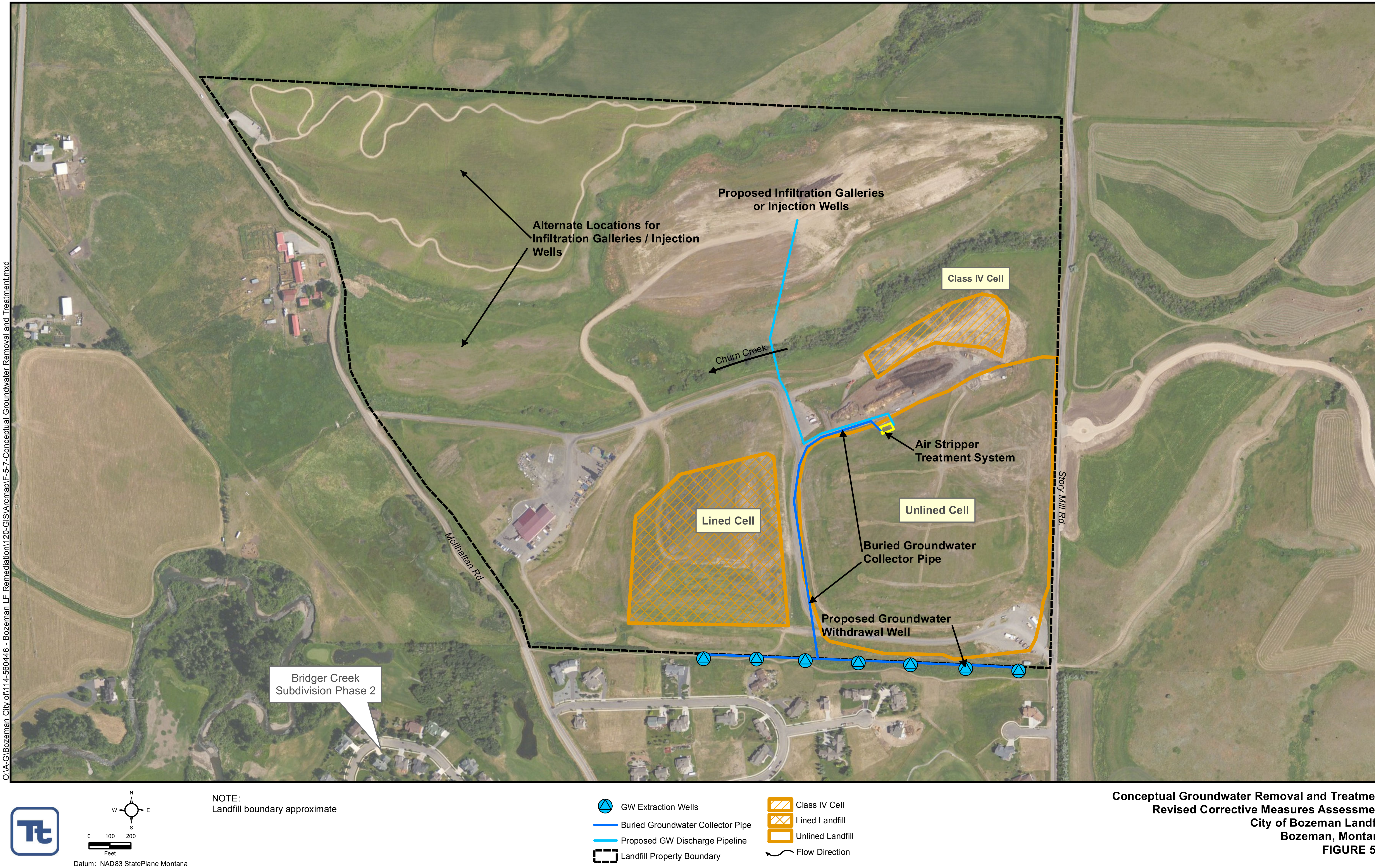
Conceptual SVE & Additional Landfill Gas Extraction Well
Revised Corrective Measures Assessment
City of Bozeman Landfill
Bozeman, Montana
FIGURE 5-5



N
W E
S
0 100 200
Feet
Datum: NAD83 StatePlane Montana

- Proposed Vadose Zone Injection/Air Sparging Wells
- Existing Landfill Gas Extraction Well
- Proposed Additional Landfill Gas Extraction Well
- SVE Well Location
- Existing Landfill Gas Collection Pipe
- Proposed Landfill Gas Collection Pipe
- Proposed Air Sparge Pipe
- SVE Collection Pipe
- Flow Direction
- Landfill Property Boundary
- Class IV Cell
- Lined Landfill
- Unlined Landfill

Conceptual SVE, Vadose Zone Air Injection/Air Sparging & Additional Landfill Gas Extraction Well
Revised Corrective Measures Assessment
City of Bozeman Landfill
Bozeman, Montana
FIGURE 5-6



NOTE:
Landfill boundary approximate

Conceptual Groundwater Removal and Treatment
Revised Corrective Measures Assessment
City of Bozeman Landfill
Bozeman, Montana
FIGURE 5-7

Appendix A
DEQ Letter Mandating Corrective Measures Assessment

Montana Department of
ENVIRONMENTAL QUALITY

Steve Bullock, Governor
Tracy Stone-Manning, Director

P. O. Box 200901 • Helena, MT 59620-0901 • (406) 444-2544 • Website: www.deq.mt.gov

June 6, 2014

RECEIVED

JUN 10 2014

TETRA TECH, INC
HELENA, MT

Mr. Craig Woolard, Ph.D., P.E.
Director of Public Works
City of Bozeman
P.O. Box 1230
Bozeman, MT 59771

RE: **CITY OF BOZEMAN LANDFILL – GALLATIN COUNTY – LICENSE #196
NOTIFICATION OF EXCEEDANCE OF GROUNDWATER PROTECTION STANDARD**

Dear Mr. Woolard:

The Solid Waste Program has reviewed the May 30, 2014, letter which serves as formal notification from the City of Bozeman, of the groundwater protection standard exceedance as defined in the Administrative Rules of Montana (ARM) 17.50.1307(8)(a). The exceedance was detected in MW-20 for Tetrachloroethene (PCE) at a concentration of 10.6 ug/l in March 2014, and in subsequent confirmation sampling in May 2014, at 9.4 ug/l. As defined in Circular DEQ-7, Montana Numeric Water Quality Standards, the groundwater standard for PCE is 5.0 ug/l. As stated in ARM 17.50.1307(7)(a)(iv), the owner or operator shall initiate an assessment of corrective measures as required by ARM 17.50.1308 within 90 days, which is August 28, 2014.

I look forward to working with you and your consultants during this process. If you have any questions or comments regarding this review, please contact me.

Sincerely,

John Collins
Environmental Science Specialist
Solid Waste Program
Phone: 406-444-2802, Fax: 406-444-1374
E-mail: jcollins3@mt.gov

cc: Mr. Kirk Miller, Tetra Tech, Inc., 303 Irene Street, Helena, MT 59601

File: Gallatin Co.\City of Bozeman Class II\License #196\Groundwater Monitoring

Appendix B
Existing Unlined Cell Waste Volume Estimate

Volume Estimate for Unlined Cell
BOZEMAN LANDFILL
BOZEMAN, MONTANA

LFG well	waste thickness in feet (1)
GW- 1	55
GW- 2	56
GW- 3	65
GW- 4	52
GW- 5	63
GW- 6	49
GW- 7	67
GW- 8	58
GW- 9	69
GW- 10	73
GW- 11	54
GW- 12	80
GW- 13	114
GW- 14	74
GW- 15	54
GW- 16	37
GW- 17	33
GW- 18	40
GW- 19	39
GW- 20	25

Mean Depth		57.85	
Landfill Area (acres)	x	32	
Square Feet per Acr	x	43560	
Cubic Feet per Cubic Yard	/	27	
Waste Volume		2,986,603	Cubic Yards

Notes:
LFG Extraction Wells installed in August 1997
(1) "Refuse Depth" from As-Built Logs

Appendix C
Alternative Cost Estimates

Appendix C-1
Alternative A Cost Estimate

Table C-1
Estimated Costs for Alternative A
No Action
Revised Corrective Measures Assessment
Bozeman Landfill

Item / Description	Duration	Units	Quantity	Unit Cost	Item Cost
Capital Costs					
Optimization of Existing LFG System	Year 1	LS	1	$ 47,000.00	$ 47,000.00
				Subtotal	$ 47,000.00
		Engineering and Design			0
		Administrative Costs			0
				Subtotal	$ 47,000.00
Annual Costs					
Monitoring of Existing Landfill	Year 1-15	YR	1	$ 55,000.00	$ 55,000.00
Continued Operation of the Existing Landfill	Year 1-15	YR	1	$ 12,058.58	$ 12,058.58
Monitoring and Operation of Mitigation Syst	Year 1-15	YR	1	$ 108,750.00	$ 108,750.00
				Subtotal	$ 175,808.58
Present Worth Analysis					
Duration 15 years					
Discount Rate 5%					$ 1,824,717.23
Total Cost					**$ 1,871,717.23**

Appendix C-2
Alternative B Cost Estimate

Table C-2
Estimated Costs for Alternative B
Cell Removal
Revised Corrective Measures Assessment
Bozeman Landfill

Item	Duration	Units	Quantitiy	Unit Cost	Item Cost
Capital Costs					
Construct New Cell(s)	Years 1-5	LS	1	$ 19,297,576.51	$ 19,297,576.51
Excavate and Stockpile Existing Cover	Years 1-5	CY	130000	$ 8.00	$ 1,040,000.00
Excavate and Load Waste	Years 1-5	CY	3000000	$ 1.40	$ 4,200,000.00
Haul	Years 1-5	LCY	3678000	$ 2.31	$ 8,496,180.00
Spread	Years 1-5	LCY	3678000	$ 2.15	$ 7,907,700.00
Compaction	Years 1-5	CY	3065000	$ 0.52	$ 1,593,800.00
Permitting	Years 1-5	LS	1	$ 50,000.00	$ 50,000.00
				Subtotal	$ 42,585,256.51
		Engineering and Design (20%)			$ 8,517,051.30
		Administrative Costs (15%)			$ 6,387,788.48
				Subtotal	$ 57,490,096.29
Annual Costs					
Monitoring of Existing Landfill	Year 1-15	YR	1	$ 55,000.00	$ 55,000.00
Monitoring of Proposed Cell	Year 1-15	YR	1	$ 55,000.00	$ 55,000.00
Monitoring and Operation of Mitigation Syst	Year 1-15	YR	1	$ 108,750.00	$ 108,750.00
Continued Operation of the Existing Landfill	Year 1-15	YR	1	$ -	$ -
				Subtotal	$ 218,750.00
Present Worth Analysis					
Duration 15 years					
Discount Rate 5%					$ 2,270,406.25
Total Cost					**$ 59,760,502.54**

Appendix C-3
Alternative C Cost Estimate

Table C-3
Estimated Costs for Alternative C
SVE Installation
Revised Corrective Measures Assessment
Bozeman Landfill

Item	Duration	Units	Quantity	Unit Cost	Item Cost
Capital Costs					
SVE well drilled and cased	Installation	EA	13	$ 7,100.00	$ 92,300.00
Buried HDPE Collection Pipe and fittings	Installation	LS	1	$ 78,650.00	$ 78,650.00
Enclosed Flare Station/ Two Blower Skid Ass	Installation	LS	1	$ 229,000.00	$ 229,000.00
Propane Tank	Installation	LS	1	$ 4,000.00	$ 4,000.00
Concrete Pad	Installation	CY	15	$ 350.00	$ 5,250.00
Electrical and Controls	Installation	LS	1	$ 10,000.00	$ 10,000.00
Revegetation	Installation	AC	2	$ 3,000.00	$ 6,000.00
			Subtotal		$ 425,200.00
		Engineering and Design (20%)			$ 85,040.00
		Administrative Costs (15%)			$ 63,780.00
			Subtotal		$ 574,020.00
Annual Costs					
Propane	Year 1-15	GAL	18250	$ 3.50	$ 63,875.00
Operation and Maintenance of Flare/Blowe	Year 1-15	LS	1	$ 34,039.86	$ 34,039.86
Monitoring of Existing Landfill	Year 1-15	YR	1	$ 55,000.00	$ 55,000.00
Continued Operation of the Existing Landfill	Year 1-15	YR	1	$ 12,058.58	$ 12,058.58
Monitoring and Operation of Mitigation Sys	Year 1-15	YR	1	$ 108,750.00	$ 108,750.00
			Subtotal		$ 273,723.44
Present Worth Analysis					
Duration 15 years					
Discount Rate 5%					$ 2,840,975.56
Total Cost					**$ 3,414,995.56**

Appendix C-4
Alternative D Cost Estimate

Table C-4
Estimated Costs for Alternative D
SVE with Sparging Wells
Revised Corrective Measures Assessment
Bozeman Landfill

Item	Duration	Units	Quantity	Unit Cost	Item Cost
Capital Costs					
AS well drilled and cased	Installation	EA	6	$ 7,100.00	$ 42,600.00
SVE well drilled and cased	Installation	EA	7	$ 7,100.00	$ 49,700.00
Buried HDPE Collection and Distribution Pip	Installation	LS	1	$ 124,222.00	$ 124,222.00
Enclosed Flare Station/ Two Blower Skid Ass	Installation	LS	1	$ 229,000.00	$ 229,000.00
Compressor Station	Installation	EA	2	$ 11,250.00	$ 22,500.00
Propane Tank	Installation	LS	1	$ 4,000.00	$ 4,000.00
Concrete Pad	Installation	CY	15	$ 350.00	$ 5,250.00
Electrical and Controls	Installation	LS	1	$ 10,000.00	$ 10,000.00
Revegetation	Installation	AC	2	$ 3,000.00	$ 6,000.00
			Subtotal		$ 493,272.00
		Engineering and Design (20%)			$ 98,654.40
		Administrative Costs (15%)			$ 73,990.80
			Subtotal		$ 665,917.20
Annual Costs					
Propane	Year 1-15	GAL	18250	$ 3.50	$ 63,875.00
Operation and Maintenance of Flare/Blowe	Year 1-15	LS	1	$ 80,772.96	$ 80,772.96
Monitoring of Existing Landfill	Year 1-15	YR	1	$ 55,000.00	$ 55,000.00
Continued Operation of the Existing Landfill	Year 1-15	YR	1	$ 12,058.58	$ 12,058.58
Monitoring and Operation of Mitigation Sys	Year 1-15	YR	1	$ 108,750.00	$ 108,750.00
			Subtotal		$ 320,456.54
Present Worth Analysis					
Duration	15 years				
Discount Rate	5%				$ 3,326,018.41
Total Cost					**$ 3,991,935.61**

Appendix C-5
Alternative E Cost Estimate

Table C-5
Estimated Costs for Alternative E
SVE with Addition LFG Wells
Revised Corrective Measures Assessment
Bozeman Landfill

Item	Duration	Units	Quantity	Unit Cost	Item Cost
Capital Costs					
SVE well drilled and cased	Installation	EA	13	$ 7,100.00	$ 92,300.00
Buried HDPE Collection Pipe and fittings	Installation	LS	1	$ 78,650.00	$ 78,650.00
LVG well drilled and cased	Installation	EA	6	$ 9,100.00	$ 54,600.00
LFG piping and plumbing	Installation	LS	1	$ 10,000.00	$ 10,000.00
Enclosed Flare Station/ Two Blower Skid Ass	Installation	LS	1	$ 229,000.00	$ 229,000.00
Propane Tank	Installation	LS	1	$ 4,000.00	$ 4,000.00
Concrete Pad	Installation	CY	15	$ 350.00	$ 5,250.00
Electrical and Controls	Installation	LS	1	$ 10,000.00	$ 10,000.00
Revegetation	Installation	AC	2	$ 3,000.00	$ 6,000.00
			Subtotal		$ 489,800.00
		Engineering and Design (20%)			$ 97,960.00
		Administrative Costs (15%)			$ 73,470.00
			Subtotal		$ 661,230.00
Annual Costs					
Propane	Year 1-15	GAL	10950	$ 3.50	$ 38,325.00
Operation and Maintenance of Flare/Blowe	Year 1-15	LS	1	$ 49,906.41	$ 49,906.41
Monitoring of Existing Landfill	Year 1-15	YR	1	$ 55,000.00	$ 55,000.00
Continued Operation of the Existing Landfill	Year 1-15	YR	1	$ 12,058.58	$ 12,058.58
Monitoring and Operation of Mitigation Sys	Year 1-15	YR	1	$ 108,750.00	$ 108,750.00
			Subtotal		$ 264,039.99

Present Worth Analysis

Duration	15 years	
Discount Rate	5%	$ 2,740,471.04
Total Cost		**$ 3,401,701.04**

Appendix C-6
Alternative F Cost Estimate

Table C-6
Estimated Costs for Alternative F
SVE with Addition LFG Wells and VZAI/AS Wells
Revised Corrective Measures Assessment
Bozeman Landfill

Item	Duration	Units	Quantity	Unit Cost	Item Cost
Capital Costs					
SVE well drilled and cased	Installation	EA	7	$ 7,100.00	$ 49,700.00
Buried HDPE Collection Pipe and fittings	Installation	LS	1	$ 78,650.00	$ 78,650.00
LFG well drilled and cased	Installation	EA	6	$ 9,100.00	$ 54,600.00
LFG piping and plumbing	Installation	LS	1	$ 10,000.00	$ 10,000.00
Enclosed Flare Station/ Two Blower Skid Ass	Installation	LS	1	$ 229,000.00	$ 229,000.00
Propane Tank	Installation	LS	1	$ 4,000.00	$ 4,000.00
Concrete Pad	Installation	CY	15	$ 350.00	$ 5,250.00
Electrical and Controls	Installation	LS	1	$ 10,000.00	$ 10,000.00
Revegetation	Installation	AC	2	$ 3,000.00	$ 6,000.00
VZAI/AS Wells drilled and cased	Installation	EA	6	$ 8,000.00	$ 48,000.00
Buried HDPE pipe and plumbing for VZAI	Installation	LS	1	$ 73,400.00	$ 73,400.00
Rotary Screw Air Compressor	Installation	LS	1	$ 51,000.00	$ 51,000.00
			Subtotal		$ 619,600.00
		Engineering and Design (20%)			$ 123,920.00
		Administrative Costs (15%)			$ 92,940.00
			Subtotal		$ 836,460.00
Annual Costs					
Propane	Year 1-15	GAL	10950	$ 3.50	$ 38,325.00
Operation and Maintenance of Flare/Blower	Year 1-15	LS	1	$ 96,639.51	$ 96,639.51
Monitoring of Existing Landfill	Year 1-15	YR	1	$ 55,000.00	$ 55,000.00
Continued Operation of the Existing Landfill	Year 1-15	YR	1	$ 12,058.58	$ 12,058.58
Monitoring and Operation of Mitigation Syst	Year 1-15	YR	1	$ 108,750.00	$ 108,750.00
			Subtotal		$ 310,773.09

Present Worth Analysis

Duration	15 years	
Discount Rate	5%	$ 3,225,513.88

Total Cost	**$ 4,061,973.88**

Appendix C-7
Alternative G Cost Estimate

Table C-7
Estimated Costs for Alternative G
Groundwater Treatment
Revised Corrective Measures Assessment
Bozeman Landfill

Item	Duration	Units	Quantitiy	Unit Cost	Item Cost
Capital Costs					
Well Drilling and Installation	Installation	EA	7	$ 6,000.00	$ 42,000.00
Submersible Pumps	Installation	EA	7	$ 2,500.00	$ 17,500.00
Buried 6" Dia. HDPE Collection Pipe	Installation	LF	2700	$ 30.00	$ 81,000.00
Buried 6" Dia. HDPE Discharge Pipe	Installation	LF	4000	$ 30.00	$ 120,000.00
Air Stripper	Installation	LS	1	$ 130,000.00	$ 130,000.00
Heated Metal Building 20x30	Installation	LS	1	$ 25,000.00	$ 25,000.00
Infiltration Well Field/Gallery	Installation	LS	1	$ 150,000.00	$ 150,000.00
Miscellaneous Controls and Electrical	Installation	LS	1	$ 30,000.00	$ 30,000.00
				Subtotal	$ 595,500.00
		Engineering and Design (20%)			$ 119,100.00
		Administrative Costs (15%)			$ 89,325.00
		Contingency (20%)			$ 119,100.00
				Total	$ 803,925.00
Annual Costs					
Monitoring of Existing Landfill	Year 1-15	YR	1	$ 55,000.00	$ 55,000.00
Operation and Maintenance of System	Year 1-15	YR	1	$ 143,079.72	$ 143,079.72
Monitoring and Operation of Mitigation Sys	Year 1-15	YR	1	$ 108,750.00	$ 108,750.00
				Total	$ 306,829.72
Present Worth Analysis					
Duration	15 years				
Discount Rate	5%				$ 3,184,585.66
Total Cost					**$ 3,988,510.66**